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ENGINEERING HISTORY PAPER #69

"Jim's Journeys – The Illustrated Travels of a Canadian Hydro Engineer"

By James L. Gordon

(updated March 2019)

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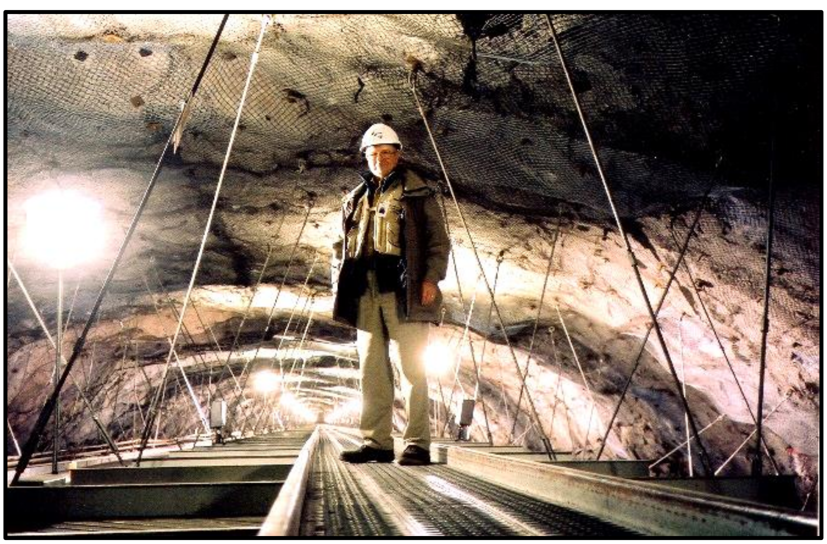
JIM'S JOURNEYS
THE ILLUSTRATED TRAVELS OF A CANADIAN HYDRO ENGINEER



Volumes 1 and 2

By

James L. Gordon

For my late wife Vera,

and

My son Howard and wife Anjana,

and

My son Graham and wife Carol,

and

My daughter Fiona,

and

My grandsons Trent and Quinn.

To the engineer falls the work of creating from the dry bones of scientific fact the living body of industry. It is he whose intellect and direction bring to the world the comforts and necessities of daily need. Unlike the doctor, his is not the constant struggle to save the weak. Unlike the soldier, destruction is not his prime function. Unlike the lawyer, quarrels are not his daily bread. Engineering is the profession of creation and of construction, of stimulation of human effort and accomplishment.

Herbert Hoover, 1909.

PRINT EDITION

VOLUME 1 of 2

VOLUME 2 of 2

VOLUME 2 of 2.

ABOUT THE AUTHOR

James (Jim) L. Gordon graduated from Aberdeen University in Scotland with a B. Sc. in Civil Engineering (First Class Honours) in 1952. He worked for Montreal Engineering Co. Ltd. from 1952 to 1990 on feasibility and detailed design of hydropower projects located in Canada and over 15 other countries, requiring extensive overseas travel, and knowledge of local construction practice. Projects ranged in size from 600 kW to over 1800MW, with heads from 5m over 800m. During the last 9 years at Monenco, he was Vice-President Hydro, responsible for all design aspects of hydropower work undertaken by Monenco.

From July 1990 to June 2011, he was a private consultant providing advice to utilities, developers and consultants on hydro project detailed design, layout and concepts, mechanical equipment selection, turbine sizing and setting, dam safety assessment, due diligence review, project design review, project cost estimate review and bid analysis for lump sum design-build contracts. Work assignments have ranged from investigating turbine foundation micro-movements to acting on review boards for major Canadian utilities

From July 2011 until his retirement in December 2017, he stopped travelling and worked as a private consultant providing internet-based consulting services to the hydro industry, consisting of project reviews, comments on concepts and advice on specifications.

PUBLICATIONS, AWARDS, SEMINARS

While working for Monenco, he was chief design engineer for 6 hydro projects which received awards for excellence in design from the Association of Consulting Engineers of Canada.

He has authored or co-authored 94 papers, and 53 “Lessons learned” articles (in HRW) on a large variety of subjects ranging from submergence at intakes to powerhouse concrete volume, cavitation in turbines, generator inertia and costing of hydropower projects.

Mr. Gordon has been the Invited speaker at 32 seminars on hydropower, discussing subjects such as penstock design, cost estimating, dam safety, detailed design, project layout and hydro mechanical equipment selection. He has produced 6 hydro design programs, available over the internet, ranging from turbine selection to pump-storage plants.

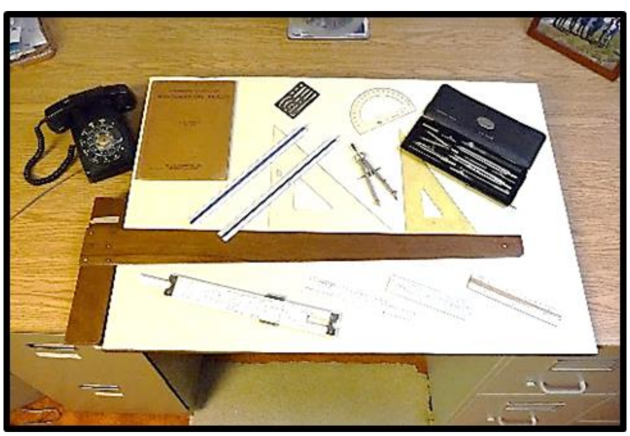
He holds a number of awards including the Rickey Gold Medal (1989) from the American Society of Civil Engineers "for outstanding contributions to the advancement of hydroelectric engineering through design of a wide range of hydropower facilities on several continents and by authoring over 50 related technical papers." In 2009, he was nominated as one of the “60 most influential people in the hydro and dam industry” that “have helped shape the course of global hydro and dam business over the last 60 years” by readers of International Water Power and Dam Construction, and decided by a panel of industry experts. In 2010 he was elected Fellow by the Canadian Society for Senior Engineers “in recognition of excellence in engineering”. He is also a life member of the Canadian Electrical Association and a Fellow of the Canadian Society for Civil Engineering and of the Canadian Dam association.

Partly by William Altimas – from an introduction prior to a presentation by the author, Nov. 2017.

FOREWORD

I have spent my entire working life of over 66 years working in the hydro industry, starting as a student on the Glen Garry surveys in Scotland in 1950, to my second retirement from consulting work in 2017, after I started to downsize my work in 2006, since my doctor advised that anyone over 70 should not be climbing ladders.

Later, I ran into a colleague who told me he was writing memoirs of his extensive travels, and suggested I should do the same. I thought about it for a while, and realized that with an extensive collection of photos, I could write an illustrated account of my career in the hydro industry. I managed to visit at least 190 developments ranging in size from a small 5kW micro-hydro plant providing power to a home in North Vancouver, to the million times larger 5,225MW Churchill Falls development in Labrador, and photos are included for most. This is not a text book, since there are only a few references to the engineering work, instead it shows how hydro developments are designed and built, providing a visual reference to the vast variety of work, since every hydro development is unique - the reason I have continued to work well past retirement age.



Old equipment. Drafting board, T-square, log tables, slide rules, rulers, drawing instruments and a black rotary dial telephone.

Where possible, I have provided Google Earth references so that the places mentioned during my travels can be seen. Many of the dates were obtained from passport stamps, but I could not find any for Yugoslavia, but did find the stamps for the Heathrow transfers, and have dated slides in my collection for Belgrade. Presumably the communist Yugoslavian immigration officials were not stamping passports of western persons, but instead stapled immigration passes to the passport, which were removed on leaving the country.

A second reason for writing my memoirs, is that I was very fortunate to work as an engineer during the transition from the old slide rule and logarithm calculation methods – used since the days when Stevenson built the first railway locomotives and Newton discovered gravity – to now when computers solve almost impossible problems within mere seconds, permitting the design of ever more complex structures such as the Bird Nest stadium in China. As the Chinese proverb goes – may you live in interesting times! – Yes; it was very interesting.

Old equipment - Zeiss camera with light meter, filters, sunshade and Kodak exposure guide.

And a third reason, is that I was fortunate to have a career in the hydro industry at a time when hydro power plants were being built around the world as nations recovered from the effects of the Second World War.

Modern equipment.
Telephone with answering device, cell phone, 2 desktop, one laptop computers, laser printers (2), slide scanner, scanner, photo copier, external hard drive backup, SLR camera and lenses, later changed to 2 digital cameras, web cam, speakers, microphone, calculator, flash drives and two emergency shut-down batteries.

My travels around half the world were always enjoyable, and at times quite exciting, something I did not expect when I joined Montreal Engineering in Canada in 1952. I managed to ride a mule through the Amazon jungle, ride a balsa wood raft down the Yolosani River rapids, trek over the high Andes at almost 16,000ft, get arrested in Colombia, sneak around the inside of the legislative building in Lima avoiding army check points during an uprising, fly in a Turkish military helicopter, burn leeches off my legs in the Sri Lanka jungle, get lost in the taiga of Labrador, survive several "hard landings" in a helicopter, stop a minor riot at the Lagos airport, visit every province and territory in Canada except the Yukon – and dine at the Petite Palace in Paris off Versailles gold painted china.

Fortunately, except for two occasions I never got sick. Once was in Lima, Peru, where I stupidly ate some strawberries and cream, with the strawberries having been washed in the local water. A few doses of Enterovioform cured it. The second time was in Joss, Nigeria, where I stopped sweating due to a lack of salt. A very salty soup cured it.

I always carried a good camera, and more than half of the text consists of almost 2,000 photographs including the occasional drawing, since I believe that a "photo is worth a thousand words". Even with cameras, the advance in technology during my working life has been astounding. I started with a folding Zeiss camera and Weston light meter. Now I have a digital camera, half the size and weight of the old Zeiss, with a 64X zoom capable of taking a hand-held full-frame photo of the moon!

I hope the photos add interest to the text.

Finally, I must thank my late wife Vera, for her patience and understanding while I travelled. And to Howard, Graham and Fiona, my apologies for missing the occasional birthday and event at school.

Hope you enjoy the narrative. And lastly, my apologies for the occasional photo of myself – this was meant to be a memoir for my family.

February 25th, 2018.

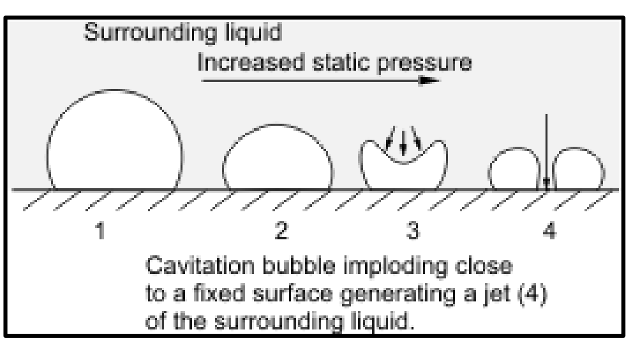
GLOSSARY.

I have used as few technical terms as possible. However, some terms have crept in; hence the following explanations are provided.

Alluvium – sediment deposited in the bed of a river, comprising boulders, gravel, sand, clay or a mixture of all.

Bentonite - Sodium bentonite expands when wet, absorbing as much as several times its dry mass in water. Because of its excellent colloidal properties, it is often used in drilling mud for oil and gas wells and boreholes for geotechnical and environmental investigations. The property of swelling also makes sodium bentonite useful as a sealant, since it provides a self-sealing, low permeability barrier.

Cavitation - is the formation of vapor cavities in a liquid, small liquid-free zones ("bubbles" or "voids"), that are the consequence of forces acting upon the liquid. It usually occurs when a liquid is subjected to rapid changes of pressure that cause the formation of cavities in the liquid where the pressure is relatively low. When subjected to higher pressure, the voids implode and can generate an intense shock wave. Cavitation is a significant cause of wear in some engineering contexts. Collapsing voids that implode near to a metal surface cause cyclic stress through repeated implosion. This results in surface fatigue of the metal causing a type of wear also called "cavitation". The most common examples of this kind of wear are to turbine and pump impellers. (Wikipedia)



Conduit – is the water conveyance structure from the intake to the powerhouse. It could be a pipe or tunnel.

Cut-off wall – a vertical trench excavated down through pervious alluvium to an impervious zone, backfilled with clay or concrete. A dam is then built on top of the wall.

Gantry crane – a type of crane used on a dam or powerhouse.

Governor – a device used to maintain a constant turbine or pump speed.

Head – the vertical difference in elevation between the reservoir level and the water immediately downstream of the powerhouse. Used to describe the water pressure acting on a turbine under no flow (static) conditions.

Net head – is the usable water pressure on the turbine obtained by subtracting the hydraulic losses in the conduit (from the reservoir to the turbine) from the head.

Penstock – is the pipe, usually steel, downstream of the surge tank or intake, extending down to the powerhouse. For small penstocks, PVC plastic pipe can be used instead.

Pipeline – a term used for the conduit down to the surge tank. If there is no surge tank, it is a penstock.

Relief valve – a valve used to discharge water when the water pressure in the turbine becomes excessive. For photo, see page 90.

Slikenslide – a very smooth surface formed on clay when the upper layer of material starts to move.

Spillway – a concrete structure with gates used to discharge excess water, or discharge a controlled flow towards the powerplant intake.

Stoploqs – wood or steel logs used to form a water barrier in a concrete channel or structure.

Surge tank – is a large water tank used to counter surges in the conduit. It could also be an excavation in sound rock.

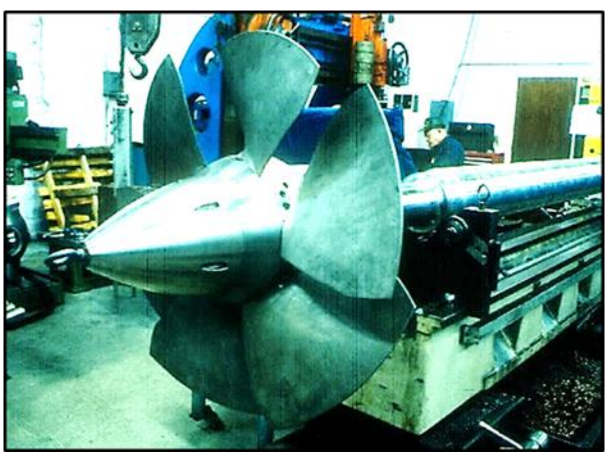
Tailrace – the water channel immediately downstream of a powerhouse.

Turbine types –

Propeller turbine – is a water turbine powered by a simple propeller, such as on a ship. There can be 3, 4, 5, or 6 blades.

Swift Rapids propeller runner.

Kaplan turbine – is similar to a propeller turbine, but with movable blades

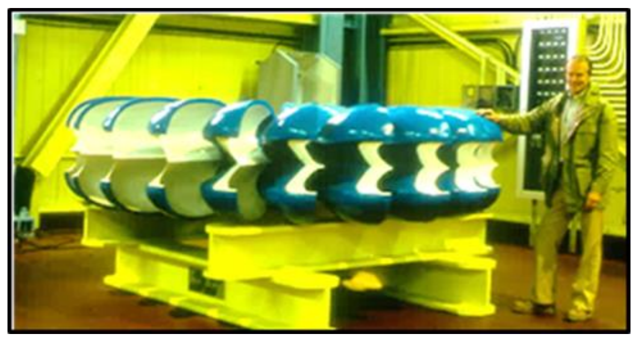


Snare Kaplan turbine runner.

Francis turbine – is again similar to a propeller turbine, but with more blades, between 11 and 19, and a steel ring around the outer periphery to add strength. The blades are more curved. It is the most common type of turbine.

Tarbella (Pakistan) Francis runner.
Source – Dominion Engineering.

Impulse or Pelton turbine – a water turbine powered by an impulse runner. A jet of water strikes the middle of the buckets.



Cat Arm impulse turbine.

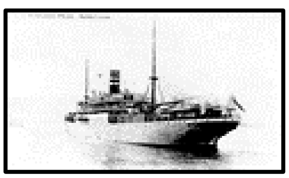
Waterhammer – the increase in pressure inside a pipe caused by a sudden reduction in flow. Can cause the pipe to burst if the pressure becomes excessive. Causes a sound similar to a hammer hitting the pipe.

1. THE ARGENTINE – 1931-47

I was born on the fifth of May 1931 in Rosario, Argentine to Margaret McKinnon who was born in Darvel, Scotland on 22 November, 1896. She was married to James Gordon, born in Keith, Scotland on 13 May 1893.

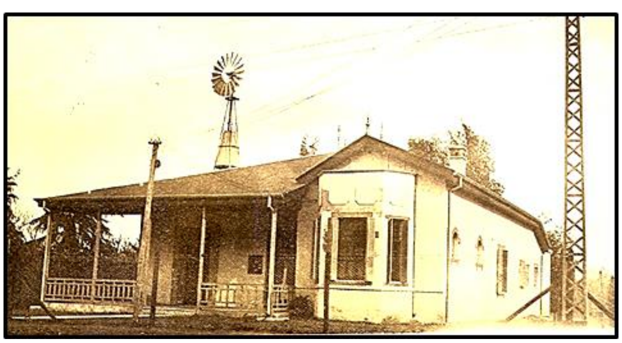
My father went to school in Keith, and later was an apprentice railway engineer working at the North of Scotland Railway engineering workshops in Keith. In 1914 he was called up and joined the Army and later transferred to the Air service as an aircraft mechanic.

In 1919, after the war, he returned to Keith and completed his apprenticeship as a mechanical engineer at the railway shops. However, he could not see any opportunities for advancement, so he joined the Central Argentine Railway and emigrated to the Argentine early in 1921, sailing on the "Highland Pride" from London to Buenos Aires.



Highland Pride, 7,469 tons.

His work contract allowed for two weeks holiday in the Argentine each year, and six months leave (including travel time) back in Scotland every five years. Since travel by boat took three weeks each way, less than five months were left to be spent on holiday in Scotland.



The house in Alberdi shortly after completion.

Arriving in Argentina, he was sent to the railway works in Rosario, and stayed in accommodation provided by the railway. He returned to Scotland in 1927, and married Margaret McKinnon at a church service in Kilmarnock.

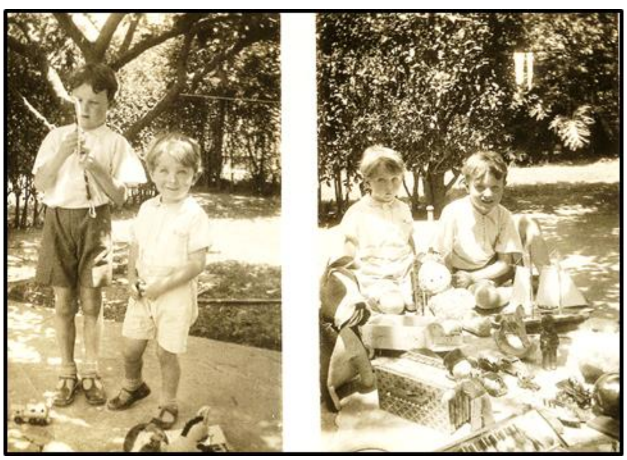
On front veranda, Rosario house, about 1929.

Dad had a house built for them at 1251 Avenida Roma (now Maza) in the suburb of Alberdi, in Rosario, with 2 water-radiator heated bedrooms. Alberdi was an easy 10-minute streetcar commute from the railway workshops. There was a good sized backyard, with a wooden shed which dad used as his workshop, since his hobby was carpentry. After I was born, about one-quarter of the back yard, adjacent to the back porch was converted to a large play area with a T-shaped concrete pavement for my brother Ian and me.

All the street names in Alberdi have been changed, but I found a street map of the area on the internet, and from what I remember of the location of a park, the tramline and a deep cut for a road down to the beach on the Parana River, about 8 streets north. The deep cut was one of the last developments I saw on our Sunday walks before leaving for Perez. In particular, I remember walking across the new road bridge over the cut with dad, (one block East and 7 blocks North) just after it had been completed.

Mom and Dad returned to Scotland in the 1932, with me in tow, bought a car and toured around their relatives for about five months before returning to the Argentine in September. Five years later in 1937, we again returned to Scotland, this time with my brother Ian as well. Ian was born on 17 May, 1935. Again, my father purchased a car and we toured around until returning to the Argentine in September.

I can remember an incident on our trip back to Buenos Aires on the Cunard liner in 1937. We had to stop at Recife on the Brazilian coast for re-fueling. There was a gale blowing at the time, so we anchored off-shore, but the ship listed severely, to such an extent that all doors to the decks were locked and nobody was allowed outside. A seaman was stationed at one of the doors used by the crew, and I persuaded him to let me out if he held on to my hand – I could hardly stand up in the gale out on the deck, even though it was only beside the door.



Xmas 1937.

I do not remember much about my early years at our home in Alberdi. I do remember attending kindergarten and part of first grade at Mrs. Anderson's school in her home next door. We sat on benches, four to a table, and being left-handed, I member being hit on the knuckles several times every time I tried to pick up my pencil with my left hand. So now I write with my right hand, used to play tennis with my left hand and attempt to golf right-handedly. One thing I do remember is that I had no playmates before Ian arrived. Nor do I remember my mother ever entertaining other expatriate families. There must have been some in the area, since there were about 10 or 12 children attending the kinder-garden to 3-year primary school run by Mrs. Anderson. Perhaps social occasions were just too difficult to organize; there were no telephones and no postal service. I think the mail was all sent and received through the railway office. Mail to Scotland took 6 weeks at least, so an answer to a letter, took over 3 months!

After I was about 5, I would travel into Rosario with my mother about once each month to shop for supplies not obtainable locally, such as clothes. It was quite an expedition. We would walk just under half a kilometer West to the tram lines, on Boulevard Rousseau, wait for the tram and then ride for about half an hour to travel about 7km into the center of Rosario, getting off when the tram crossed the main street at Cordoba, where mother would start her shopping expedition.

We always ended up going for afternoon tea in one of the stores which catered to the large expatriate British community. I think this is where I got my sweet tooth, since mother would always ply me with small sandwiches, and I remember being able to eat a whole plateful of cakes by myself, which contributed to my chubby appearance at that time. Mom only ate a couple of small triangular sandwiches and one cake, sometimes two, if I managed to persuade her.

Shortly after we returned from Scotland in 1937, my father was promoted to the assistant chief engineer position at the railway repair shop in Perez, about 15km. SW of Rosario and a half hour train ride west of Rosario. 2 years later he became the Chief Engineer. There we lived in a large two-story house provided by the railway.

It had a living room, very large dining room, morning room, half bathroom, large pantry, kitchen and servants quarters on the ground floor, plus four bedrooms and a bathroom on the second floor. The smallest bedroom had been converted to a large linen closet and was used for storage. Unfortunately, the only heating was from a fireplace in the living room. The house in Perez was surrounded by about an acre of grounds set out with lawns and gravel paths, a brick building which contained a workshop and a room which was later converted into a library, plus about another acre of undeveloped land behind the garden. There was an enclosed chicken run with a shed, and we had about 30 chickens. The house was part of a group owned by the railway company, and rented out to senior staff. It can be clearly seen on Google Earth at S 33-00-6.74 W 60-46-26.26. It was very secure, being surrounded by a 4 foot high, 2 foot thick brick wall, topped with 4 feet of chain link fence, all topped with 2 or 3 strands of barbed wire. Inside the wall there was a meter thick and over 3m high cedar hedge, obscuring the view from outside. The 3 inch thick wood doors to the sidewalk were topped with steel spikes. As an added safety measure, the house was surrounded with gravel paths, with gravel that crunched loudly when walked over. You could walk on the grass instead, but at the front and back doors the gravel opened out onto a wide area, too large to jump across. The gravel served its purpose. One of my bedroom windows looked out over the back door, and I remember being woken up by an intruder walking over the gravel to the back door. I roused dad, and he scared him away. We had a telephone on the railway phone circuit, and we could call outside through the operator. Our phone number was Perez 4, and dad's office was Perez 3. Mail was through the railway office. There was a small general store about 150m down the road toward the railway, where most food items were available. Mom would walk down the gravel sidewalk beside the dirt street with a list, buy the items, and then have Vittorio, the gardener, walk down with a wheelbarrow to pick up the purchases – usually a barrowful.

At our large house in Perez.

Across the road behind the house, wedged in a triangle between the housing and railway works, there was a large sports club divided into two sections, one for the managers and the other for the workers. The managers section included a clubhouse with bar and dining room, a lawn bowling green with a flagpole at the end opposite to the clubhouse, six tennis courts, a playground for the children which included a zip line! and a nine hole golf course. The workers section also had a clubhouse with bar and dining room, a pelota (large squash) court building, a soccer field, and a rugby/cricket field.

The club house had a veranda on three sides; with bowling green and flagpole, it was a typical colonial British club house similar to many of those built in India. Many years later, when I was working on a hydro project near Clark City, just west of Seven Islands in Quebec, I was asked out to lunch with our client at the local club, where I saw a similar clubhouse complete with veranda, bowling green and flagpole, and asked if there was any British money in their company. They replied in the affirmative, and asked how I knew.

I pointed at the clubhouse and mentioned that it was a typical design used by British expatriates all over the world.

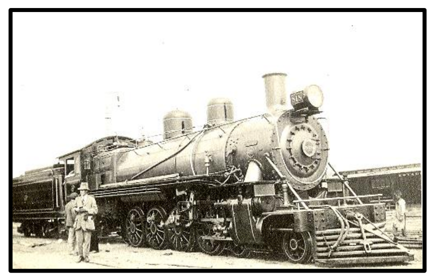
The lawn bowling green and clubhouse.

We had three sources of water. A well with a hand pump which always provided pure clear cold water – it was very welcome in summer. A pressured salty water supply from the nearby railway shops, not suitable for drinking, but was used in the kitchen and bathrooms. The third supply was rainwater from the roof, with the water stored in a large well within the enclosed back porch, and lifted out the old-fashioned way with a bucket on a rope over a pulley. It was soft, and used exclusively for washing clothes, but it also contained the occasional dead bird! Only rarely did we run out of wash water, and then we used the hand pumped water.

Vittorio – in front garden.

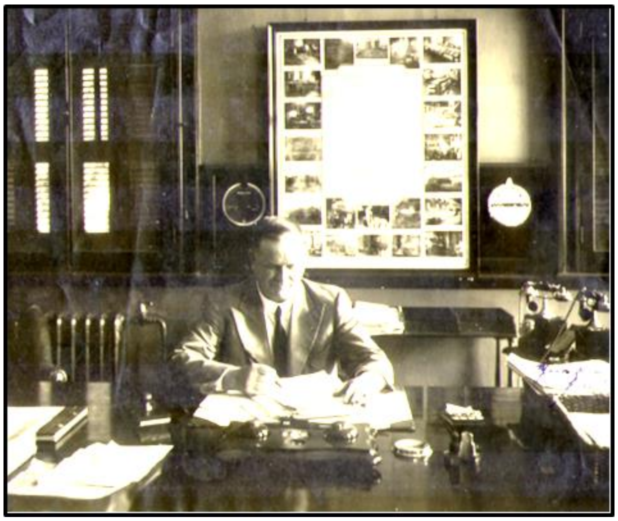
Dad bought a radio with a short wave band, and every evening would spend about a half-hour listening to BBC overseas for news on the war and kept track of the front line on a map. We also started to receive "The Buenos Aires Herald" a daily newspaper. It arrived at dad's office one day late, being delivered by train. The extensive English community in the Argentine at that time had their own clubs, schools and newspapers. Other foreign nationals such as the Germans and Italians also had similar services. In the early 40's, the Argentine government was very pro-German, and only joined the war in early 1945, when the defeat of Germany was assured.

The large railway works at Perez, had about 2,000 workers, all working on rehabilitation and repair of steam locomotives. It was the largest in all of South America, and was opened in 1917. It was adjacent to the club, and a short walk from our house. There was also a diesel workshop, and it was full of passenger cars with the diesel powered bogeys removed, having been sent back to England for repair just prior to 1939. My father later told me he had received a letter from Winston Churchill, sometime in 1938, asking him to send all diesel engines back to England "for repairs"; they would be needed to power tanks during the coming war – just shows how England at the time treated the "colonials".



Dad with a 4-8-2 locomotive in Salta.

Dad was known in the Perez village as "el ingeniero loco" (the mad engineer). After the steam locomotives were repaired, the large drive wheels needed to be re-balanced – same as car wheels are balanced. There were no facilities to balance the wheels in the shops, so dad would ride with the locomotive crew, and the engine would be driven backwards westward out of Perez on the straight main line towards Cordoba, checking speed and the mechanics and operation of the gauges. After stopping about 50km west, a chair would be strapped to the front, on the platform just above the cowcatcher, and dad would be strapped into the chair. He donned a pair of welder's goggles with clear lenses, and the engine would be driven at full speed back into and through Perez, to stop and reverse back into the locomotive works a few kilometers later – it was quite a sight to see him sitting and waving to us from above the front cowcatcher as he passed through the village. Apparently, he could detect which wheel needed balancing from the motion of the locomotive frame, magnified at his position on the front.



Dad in his office, about 1945. Note water radiator, welcome in winter.

During the war, it was impossible to obtain brass and copper for parts, so Dad spent a lot of time searching through the large scrap-yard for these metals, and managed to cut consumption considerably. He spent many Sunday mornings walking through the scrap-yard with us both tagging along, and when dad spotted some bright brass in a discarded bearing, he would have one of us climb up and mark it with a flag if it was up on a pile of rusty steel. If down near the ground, he would mark it with chalk. Many times he would suspect that a brass bearing should be attached to a piece of steel based on the shape of the part, and he would ask one of us to climb up and look for it, usually Ian since he was smaller and more nimble. Perhaps this is what encouraged us both to go into engineering. A large graph showing reducing metal use was framed behind his office desk.

On one of our tours through the railway works – 1942.

Dad never owned a car in the Argentine. He didn't need one, since he could use a private railway diesel car, a small vehicle with 3 bench seats, one for the driver at front, and 2 more for 6 passengers in back. It would meet me at the train station in Rosario when I returned from St. George's shortly after midnight. Ian also used it occasionally to commute to primary school in Rosario when the train schedule became inconvenient. I think there were only two motor cars among all the expatriate staff at the works. One was a 1935(?) SS100 (precursor to Jaguar) owned by Mr. Parker a mechanical engineer at the works. It was so long and low that it would occasionally scrape over bumps at culverts in the dirt road out front. The other was a 1936(?) Willis owned by Mr. Yves, an accountant at the works who lived across the road from our house.

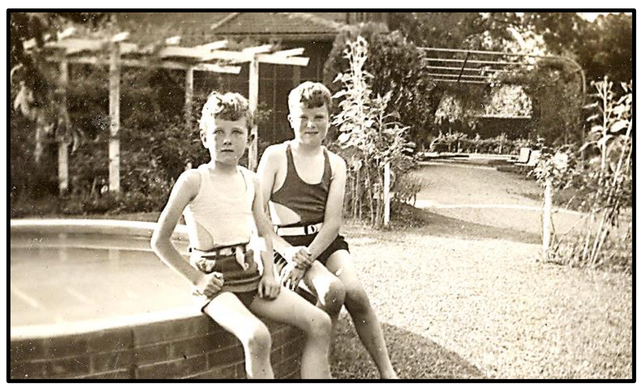
I looked at the area recently on Google Earth, it has not changed at all since we left in 1947, no new homes and no changes at the club. However, the railway works appears to be still in operation, with many cars parked in front of the office building. There have been changes in the village, with many new houses and quite a few new industrial buildings.

Apart from a full set of Popular Mechanics dating back to about 1922, we did not have many books in the house. Mom discussed this with the local ladies, and decided to set up a library in one of the rooms in the brick building at the back of the garden. Dad got a carpenter from the railway, and had shelving built around the walls. A couple of tables and a few benches completed the furniture. The families got together and donated most of their books, and the library opened. However the selection must have been very poor, since after reading a few books such as Huckleberry Finn and Robinson Crusoe, I spent most of my time pouring over dad's collection of Popular Mechanics.

I started to commute to school in Rosario, a 5 minute walk to the local train stop at the club entrance, about 25 minutes by train, and then a 10 minute walk to school. Dad provided me with a railway pass, and I still have it. When I started in 1938, there were about 8 children commuting, but I was the only one commuting when I finished in 1943. Don't know what happened to the others, some had finished grade 6 so went elsewhere. The Rosario English School was bilingual, with Spanish classes in the morning and English in the afternoon. Subjects such as geography and mathematics were taught in Spanish. It must have been a good school, since when I left for Scotland in 1947, my Spanish was better than my English! I think it is now closed since I could not find a reference on the web, but there was an old website operated by former students.

Wednesday afternoon at school was devoted to a field day, with the whole school going to a large soccer field and sports complex about halfway back to Alberdi. I don't know how the other pupils got there, but I would take the train from the railway station at midday and jump off at the railway crossing near dad's old office. The train did not stop at the crossing, instead it slowed down to about 2 miles an hour, to allow passengers to jump on and off. It did not come to a full stop since there was no platform, and the road was very busy, so trains were not allowed to stop and delay the traffic. From the railway crossing it was about a 15 or 20 minute walk to the sports complex. The afternoon was spent on calisthenics and races around a school field, and then I would walk back to the train crossing and jump on the late afternoon train back home to Perez. Mom always worried about the jumping on and off the train, but I never fell down. There was no platform, so it was quite a jump up and down.

There was a good local school with classes in Spanish only in Perez. Ian attended this school for a couple of years before going to the Rosario school. The school year started in late February and ended in mid-December, with a one-month break in July.



Beside pool – about January, 1942.

The Rosario school was operated very much along British lines, with a uniform comprising leather shoes, gray socks, gray trousers, navy blue blazer, white shirt and I think a blue tie. About half the children were from British families, the other half from local Argentine families who wanted their children to learn English. I attended the Rosario school from February 1938 until December 1943, and then I went to the boarding school at St. George's College in Quilmes, a suburb of Buenos Aires from February 1944 until December 1946.

1946. Brother Ian in his private "limo" going to school in Rosario using Dad's diesel railcar Gate ar left is entrance to railway workshops.

When I started at the Rosario school, the building was relatively new having been completed only a few years earlier. It was not overcrowded, with classes of about 20 children.

"Asado" in the back yard of the Ives house across the road – about 1945. I am on left, Ian on right.

In summer, the occasional "asado" (BBQ) would be organized. We would all chip in a few pesos, and several of the local older teenagers would order about 20 steaks from the butcher a few days ahead of the weekend, get some salad greens, and load the lot into a wheelbarrow and transport it to a barbeque pit at the worker's club. Salad dressing would be made from equal portions of red wine, olive oil and vinegar. An enjoyable time would be had by all. Since we lived closest to the grocery store, I provided and helped with the wheelbarrow.

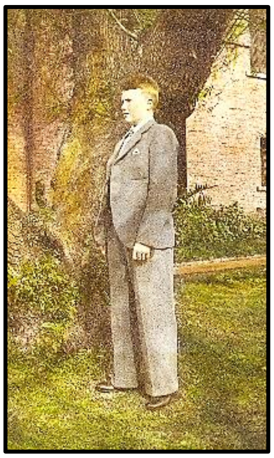
There was no garbage collection, but we had a pit about 1.5m deep excavated in the field behind the house by our gardener Vittorio. Every day Vittorio would take the garbage in a wheelbarrow and dump it in the pit. About once a week he would pour some kerosene onto the garbage and set it alight. About every four to six months Vittorio would excavate a new pit, throwing the earth onto the ashes in the old pit.

We often played tennis, always dressed in whites and in shorts until about 13 years old, and after in long trousers! Roy Ives from across the road was a keen golfer, and was often on the golf course by himself practicing. Occasionally I would go along and play with him, but I was really not in his class. We had to keep an eye out for groundskeepers since neither of us were members of the golf club. We would start at the third tee, and not play any of the holes near the clubhouse. The golf course was usually deserted during the week, and the groundskeepers always finished their work in the morning, since the afternoons were too hot to water. We always had plenty of time to play in the afternoon.

Traveling into Rosario for shopping was now more of an expedition for mom. She would take either Ian or me, walk to the local train stop, always taking the long route through the lane beside the house to the street at back, and then along the shady sidewalk. Then a half-hour train ride into the terminus in Rosario, followed by a short walk to the tram line, for a five minute ride to Cordoba Street, and then go shopping. Afternoon tea always completed the adventure.

Every year, at the end of December, after Xmas, we would spend two weeks of summer holidays in Mar del Plata, a seaside holiday resort southeast of Buenos Aires. In December of 1943, during our holidays, mother caught a severe infection, we returned quickly to Perez, but mother passed away on 14th January, 1944.

After mom died, dad had to find help to run the house. He heard of a suitable woman from a friend who was the manager at a British-owned corned beef factory further up the Parana River at Corrientes. In February, the three of us boarded a steamship at Rosario, and spent a couple of days steaming up river to land at Corrientes, to spend a few days with Dad's friend. He interviewed Cecilia Lopez, and arranged for her to come down to Perez. She proved to be very capable.



My St. Georges school uniform – Feb. 1944

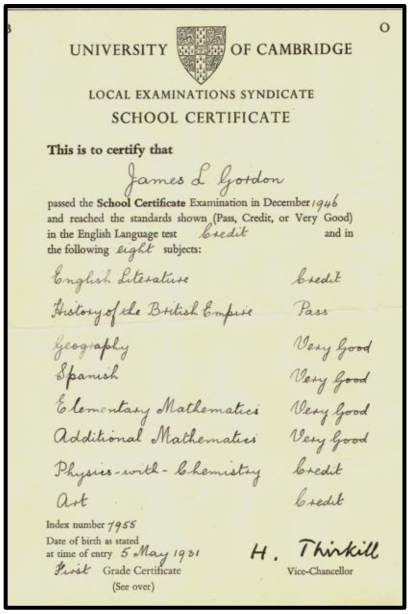
In late February 1944, I started school at St. George's College, an English boarding school for boys. The other boarding school in Buenos Aires was St. Andrew's, favored by the Scots. However dad had found out that St. George's was better, so there I went. St. George's is still going strong, has a website, and has expanded onto another campus and into a tennis club next door. Dad had the railway carpenter refurbish his 1920 steamer trunk, fixed the hinges and locks, applied a few coats of varnish and screwed on a small brass plaque with my name on it. I still have it, now as a coffee table with a round glass top in my apartment.

At St. George's we slept in dormitories, with between 15 and 40 to a room, cold showers every morning, and a warm shower once a week on a designated evening. 15 minutes of Chapel in the morning and evening every day, and an extra full service on Sunday morning! Schoolwork started at half past eight in the morning, and continued until half past two, with an hour break for lunch. Four afternoons a week we had calisthenics and sports (winter rugby or summer cricket) for about two hours, followed by Chapel, dinner and homework every evening. The concentration on sports was just what I needed, and I lost my chubby appearance. There were two 19-week terms, from the third week of February to mid-July, 3 weeks off and then from the second week in August to mid-December. We had a 4-day long weekend off in the middle of each term.

The local railway train-stop about 200m from the house.

The school had an indoor 22 mm rifle range and six outdoor tennis courts, a choir, art lessons, carpentry, and boxing classes held in a large indoor gymnasium. There was an Olympic-sized swimming pool used during the warmer weather. All were alternatives when rain interrupted outdoor sports. Fortunately, I was turned down for the choir, but participated in all the others. Wednesday afternoon was devoted to alternative pursuits – mine was carpentry. There was a well-equipped sanatorium with 4 beds, a sister and nurse resident on site, two dentist's chairs, and visiting medical doctor, dentist and orthodontist. We all had to see the dentist annually, and had a medical exam when first admitted to the school. Sunday evenings we all had to write a letter home – a compulsory assignment.

We had to have a "tuck box" a metal container suitable for storing food. Dad had a very elaborate one made for me at the railway shops – I wish I had kept it. It was an oak wood box, lined on the inside with tin, and the locking lid had a small brass plaque with my name on it.


UNIVERSITY OF CAMBRIDGE

LOCAL EXAMINATIONS SYNDICATE

SCHOOL CERTIFICATE

This is to certify that

James L Gordon

passed the **School Certificate** Examination in December 1946 and reached the standards shown (Pass, Credit, or Very Good) in the English Language test Credit and in the following eight subjects:

English Literature	Credit
History of the British Empire	Pass
Geography	Very Good
Spanish	Very Good
Elementary Mathematics	Very Good
Additional Mathematics	Very Good
Physics-with-Chemistry	Credit
Art	Credit

Index number 7955

Date of birth as stated at time of entry 5 May 1931

First Grade Certificate

(See over)

H. Thirkill

Vice-Chancellor

My certificate from St. Georges.

Saturday afternoon was family day when parents would come and visit their children. Since dad could not do this, he had asked a friend of his, Mr. Watson who lived in the Temperley suburb, in a bungalow a few railway stops from Quilmes, to visit me when possible. He would come about once every two or three weeks, occasionally bringing a cake baked by Mrs. Watson – a welcome addition to our grub. During the afternoon, the college team would play either rugby or cricket against another nearby college.

The school curriculum followed the requirements for the Cambridge School Leaving Certificate, which could be obtained after three or four years of study. The teachers were very good, but a few were elderly, having been recalled from retirement when several of the regular teachers departed for the war. I had an excellent mathematics teacher, and found that I was quite adept at the tasks, since he would assign me several problems and I would have them solved by the time I walked back to the end of the queue waiting for him to mark the assignments. After observing me do this a couple of times, he gave me the mathematics book, told me to start about halfway through and do every second problem until the end of the book, and then come to see him. I completed this in about two weeks, so he asked me if I would be interested in joining an advanced mathematics class conducted by a Mr. Roger Minor, who had a degree in mathematics from Cambridge University. I consented, and after several months with Mr. Minor, he asked me if I would think of joining another more advanced class concentrating on differential equations. This I did, so that by the time I left St. George's at age 15, I had completed all the mathematics required until about the end of the first year in university!

Travel to and from school was complex; I would take the school bus to the Quilmes railway station, catch a local commuter train from Quilmes into the Constitucion Railway station in Buenos Aires, operated by the Southern Argentine Railway, take the underground from Constitucion to the Retiro Railway station operated by the Central Argentine Railway, and catch the evening express, on which I always had a 4-person private compartment, to Rosario. At Rosario, I would be met by dad in his railcar diesel, parked on the track opposite to the platform, and I always had to persuade the train conductor to open one of the passenger car doors opposite the platform, to allow me to descend onto the rail line and climb into the diesel. We would continue on to Perez, arriving home after midnight. Fortunately, I only travelled eight times a year.

On the return journey, I would reverse the route, leaving home on the Monday morning. Mr. Watson accompanied me from the Retiro station to the Constitucion station and back to the Retiro station, to show me the route for the first two times, but after that I was on my own. I never had any luggage, since I traveled in the school uniform, and other clothes were available at home. The conductors on the express train always quizzed me about my travels, being a youth (a 12 year old kid on the first journey!)

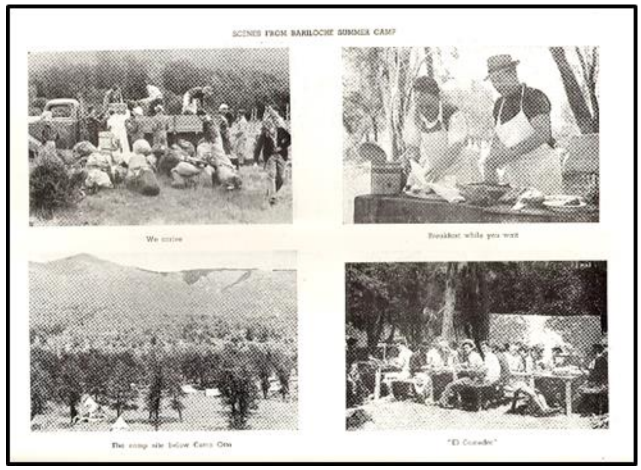
with no luggage, traveling alone with a special rail pass in a private compartment designed for 4 passengers! However, I did enjoy the freedom. Occasionally the express was overcrowded with passengers standing in the isle. Then I would invite 3 to enter and share the compartment.

School friends - John Scotland, me and Peter Goss, on last sports day. St. Georges, December 1946.

St. George's had junior and senior schools. I started in the senior school in Form III and left after completing Form V. In 1946, there were 79 pupils in the English Cambridge section and 104 in the National Certificate section where classes were mostly in Spanish, with English taught as a foreign language. There were 31 teachers, for a very low pupil-teacher ratio of 5.9. As with all English boarding schools, there were 4 "houses", and I was in Lockwood House. The houses competed against each other on the rugby and cricket sports teams. There were prefects and sub-prefects, and punishment (caning) for misdemeanors. The junior school had 97 pupils in 3 "houses" and 13 teachers, for about 7.5 pupils per teacher. With the low pupil-teacher ratio, fees must have been very high.

I found all this data in a small red book, published annually, containing the names and addresses of all pupils. On the last weekend in early December there was a sports day, with parents watching. The big event was a cross-country race through the swamp below the school grounds, up a country road and into the school field. All pupils had to participate, with time limits assigned based on age. I only managed to come within the limit on my last year, by which time I had lost all excess fat.

The school website shows a 27 hectare campus, and many other details about the school, including the fact that it is now co-ed. The school uniform has changed. The "best" uniform was a grey suit, but is now the more traditional flannels and blue blazer. Also the informal uniform is more modern, we had flannels and a blue zip-up corduroy jacket, and this is now a red ski jacket.

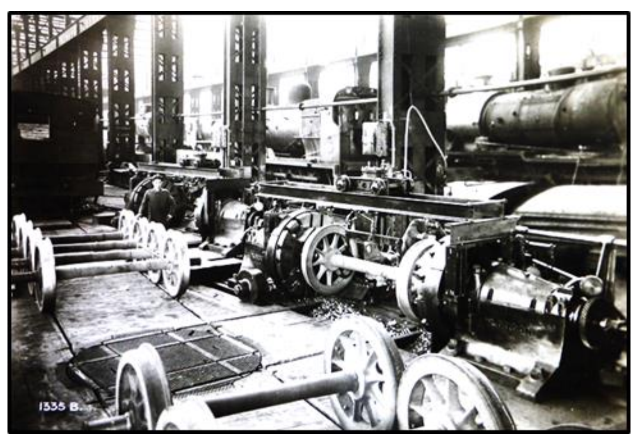


Bariloche camp scenes – from "The Georgian".

In January 1946, dad booked me into a 2-week summer holiday tent camp operated by St. George's at San Carlos de Bariloche, in Rio Negro province on the western slopes of the Andes Mountains. It was a 50 hour, 1,800km train journey south-west from Buenos Aires to Bariloche. I traveled with John Duff, a friend from school. Dad's friend Mr. Watson was supposed to meet us at the Retiro railway station, and book us into a hotel for one night, since the Bariloche train departed in the early morning from the Constitucion railway station. We waited for a couple of hours at Retiro, but no Mr. Watson, so we went over to enquiries and asked about hotels. They recommended a hotel beside the underground on the way to Constitucion, so there we went, had a difficult time persuading the hotel receptionist that we really needed a room, but eventually were allowed to book in. Fortunately, between us, we had sufficient funds. We were just on our way out to get some dinner, when we were met in the lobby by a very worried Mr. Watson. He had managed to trace our travels by talking to the enquiry clerk at the Retiro station. So he took us out to dinner, after phoning dad to advise him that he had found us.

On the train we could see the approaching mountains after we left Valcheta, but we still had a long way to go. At Bariloche we had to erect the tent camp, and were shown how to position the tent to avoid rain seeping in – no groundsheet. We dug a small ditch around the tent to direct rainwater downhill and away from the tent. We were also shown how to contour the ground to make a comfortable sleeping area by excavating a shallow dish to accommodate your rear end – no sleeping bags, just one blanket and rolled up clothes for a pillow. Cold showers out of an elevated oil drum. The food was great, since the chef from school was there to organize everything, mostly "asados" (barbeque) and salad. Ham and eggs and toast for breakfast. We hiked around the hills, saw snow for the first time, climbed a local mountain and rode on horseback to a nearby estancia. We all had a great time.

I think the incident that focused my mind on engineering occurred when one of the diesels providing electric power to Perez stopped due to a burnt bearing. The shaft was removed and brought to the locomotive shops for repairs on the only lathe large enough to accommodate the work. Unfortunately, the crane which serviced the lathe was too small to lift the heavy shaft, having a capacity about half that required. Dad knew that the crane was very conservatively designed, and though that it might still be used. He found the commissioning report with notes on the full capacity test of the crane hoist. Apparently, a piano wire was stretched across the crane girder, and a micrometer used to measure the deflection in the middle at full load. The readings were in the report. Dad reasoned that if the lift was confined to about the side quarter, the girder would not be overloaded. Also, he knew that the wire rope hoist had a safety factor of 5, so could be used with the heavier load. To test his theory, he set up a flashlight bulb on one end of the crane girder, and another on a small post at mid-span. At the other end of the girder, he mounted a steel post and attached an angle in line with the two bulbs. Another angle was attached at twice the full-load deflection distance below. The idea was that by sighting along the angle, so long as the bulb line was above the lower angle, the crane bridge would not be overloaded. He did not trust his eyesight to watch the deflection, so he asked me to climb a ladder to the crane beam, and explained what I had to do. The shaft was first lifted at each end to check the deflection, and I measured the deflection as best I could, lining up the two bulbs with my finger on a ruler, to get a reading. He was satisfied with the results, and the shaft was lifted. All went well, with the deflection well within the safety limit.



Inside the workshops, lathes on right.

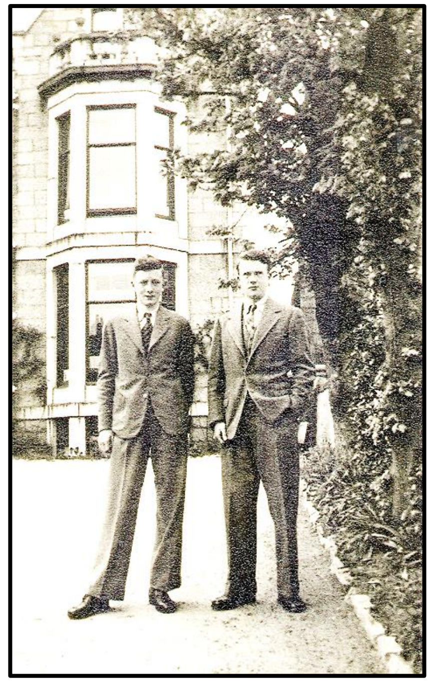
V-E day in May 1945 was celebrated with a wild party at the club. I was at St. George's at the time, but heard of it afterwards. Apparently it occurred on Monday May 7th when the club was closed as usual, with nobody present. The door to the bar was easily opened, the liquor cabinet and wine cellar forced open, and the party was on! Next day several persons were found sleeping it off on the floor.

We both finished school in December 1946, and began the wait for a ship to England. We had hoped for a ship in February, but no luck. Regular passenger sailings to Europe had not yet started, since all ships were still bringing the troops home. All we could hope for was a couple of cabins on a cargo ship. Finally a telegram arrived advising we had 2 cabins on a Liberty ship sailing out of Buenos Aires in mid-May. Just before sailing dad took us both out to dinner at a restaurant in Buenos Aires. He ordered "bife a caballo" for all – a large steak topped with a fried egg, sauce and mushrooms, with fries on the side. Dad told us to savor the treat as it would be the last red meat we would see for years, since there was still severe food rationing in Britain. He was right – I did not see steak again until I landed in Canada! We arrived at Liverpool on 23 June, 1947.

2. SCOTLAND 1947 – 52

From Liverpool, we traveled to Aberdeen by train, changing at Glasgow, and arrived at Mrs. Simpson's house at 58 Clifton Road East (N 57-09-47.94 W 2-07-06.59) where digs had been arranged for us by Uncle Paul Gordon, a police constable from Elgin.

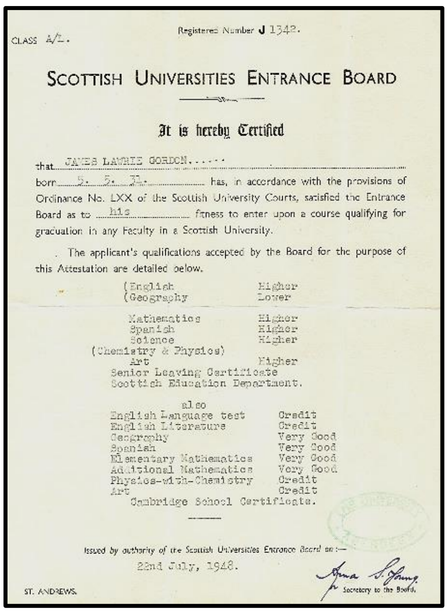
The house can be identified on Google Earth because it has an extension on the back with the roof sloping all the way down from the ridge to the garden shed where we kept our bicycles. Mrs. Simpson had a son Charlie, about my age, who showed us around Aberdeen on bicycle. Dad had bought us two new Hudson bikes, we tried to get Raleighs, but they were sold out. Hudson bikes were made by Raleigh, but to a lower standard – we found that the bolts were soft and easily stripped.



Ian and me in front of 56 Queens Road - 1949.

We shared a room, but it was far too small. Also, when dad tried to register us in school, he found that we could only be registered at the local trade school, which did not teach classes suitable for continuing on to university, so we only stayed for a month until dad found more suitable accommodation in a better part of the city, where there was a nearby grammar school. This was our first lesson in the British class system, where your opportunity to obtain an advanced education was dependent on where you lived! Maybe not surprising, since in 1947, only 1.5% of male students continued on to university, and the female ratio was insignificant

We moved to 71 Queens Road for about a year, and then across the road to 56 Queens Road (N 57-08-29.54 W 2-08-08.81) when our landlady Mrs. McArthur moved her business. Both residences were very large granite stone 4-level semi-detached homes, now converted to hotels and office buildings by joining the hallways of the two attached buildings. We both attended Aberdeen Grammar School; about 2 km down the road, and cycled there and back twice daily. Ian started in 3rd form, and I went into 6th form. Dad tried to enroll me in university, since I had the qualifications, but was rejected due to my age - 16. We had to enroll in second language classes, so of course we both took Spanish. I disconcerted the math teacher when he found out just how much mathematics I had learned at St. Georges, so he gave me an advanced math book from Aberdeen University, and told me to sit at the back of the class and work through it, only coming to see him if I had a problem understanding the logic.



CLASS A/1. Registered Number J 1342.

SCOTTISH UNIVERSITIES ENTRANCE BOARD

It is hereby Certified

that JAMES LAWRIE GORDON.....
born 5. 5. 31. has, in accordance with the provisions of Ordinance No. LXX of the Scottish University Courts, satisfied the Entrance Board as to his fitness to enter upon a course qualifying for graduation in any Faculty in a Scottish University.

The applicant's qualifications accepted by the Board for the purpose of this Attestation are detailed below.

(English	Higher
(Geography	Lower
Mathematics	Higher
Spanish	Higher
Science (Chemistry & Physics)	Higher
Art	Higher

Senior Leaving Certificate
Scottish Education Department.

also

English Language test	Credit
English Literature	Credit
Geography	Very Good
Spanish	Very Good
Elementary Mathematics	Very Good
Additional Mathematics	Very Good
Physics-with-Chemistry	Credit
Art	Credit

Cambridge School Certificate.

Issued by authority of the Scottish Universities Entrance Board on:—
22nd July, 1948.

ST. ANDREWS.

Secretary to the Board.

My school leaving certificate from the 6th form.

After we had finished school that first year in 1948, dad had arranged a summer "holiday" at Proncy farm near Dornoch north of Inverness, where we helped our cousin Gordon Rutherford with the work.

We both enjoyed the experience and returned to the Aberdeen digs at the beginning of September, but since university did not start until the second week of October, dad had arranged a short job for me as an intern at the Aberdeen Harbor engineering office. There I was attached to Rob, an engineer on trial, waiting to see if they would take him on. There were so many veterans graduating as engineers at the time, that there was a considerable surplus of engineering talent, and many graduating engineers were willing to work for nothing, just to obtain experience and perhaps a job offer after a few months of work.

Our first task was to measure the diameter and width of the wheels at the top of the jib, and the diameter of the steel wire ropes on all the harbor cranes. Apparently all the records had been lost in a fire when the harbor was bombed during the war. There were about 20 cranes, and we could do about two cranes per day. It was my task to climb the jib and take the measurements, shouting the readings down to Rob. Our work was often interrupted by the weather, since it was too slippery to climb the jib when raining. We were also asked to record how often the crane operators greased the hoist rope. This was done by Rob, but I asked the operator how he did it, and the answer was by hooking on to a bollard on the dock, backing the crane along the tracks and laying down the rope on the dock. As the rope was reeled in, the crane "greaser" painted the rope with a brush from the grease can.

Wave hitting the harbor outer groin. Source – Google Earth.

The harbor engineer had asked us to pay particular attention to crane #8, since the wire rope on this crane rusted prematurely and had to be replaced every 2 years, with the normal rate being once every 5 years. He thought it was likely due to an incorrect sizing of the pulley, possibly too small, resulting in excessive wear and flexing of the rope. At crane #8, we found nothing wrong with the pulley. However, when I asked how the rope was greased, the operator said he just lowered the hook into the harbor water, and as the rope was reeled in, the greaser would paint it from the edge of the dock! The salty water caused excessive rusting – my first lesson on problem solving – keep asking questions!

Another of our tasks was to help with a survey of the bay at the harbor mouth for a hydraulic model built at Aberdeen University. For about 2 weeks we steamed out on a tugboat, the pilot would take readings on one sextant, Rob on another and a seaman would drop a plum-line to measure the water depth. My job was to shout out "mark" when the pilot advised we were in position and all were ready for dropping the plumb-line. We had been doing this for several days, until we had a storm come through with high winds and waves. Nevertheless, the pilot decided to go out, and we worked as best we could. However, I noted that the seaman was always shouting out "6 fathoms", even with readings taken at the top of a wave, and at the bottom of a wave. Since the waves were about 10ft high, I thought this strange, so went down on deck and asked the seaman why the readings were all 6 fathoms, he replied "cause that's all the line I have" – problem solved, and another lesson learned – keep your eyes open and check all instruments. We had an extra week of work to redo all areas where the survey indicated a depth of 6 fathoms, this time with a 10 fathom line.

About a year later, when at university, our class was shown the harbor model, the wave machine, and what they were trying to model - an extension of the piers to reduce wave heights inside the harbor. However the professor mentioned that their first task was to calibrate the model to see if it could replicate existing conditions, before proceeding with changes. He indicated that they had spent many months trying to get the model to work without success; it just would not replicate the existing wave pattern within the harbor during a storm. He had eventually concluded that there must be something wrong with the survey of the harbor mouth, and had asked for a re-survey, the work we had been doing. I then mentioned my experience with the "6 fathom line" and he was astounded to learn that the re-survey could have been wrong again.

At both homes on Queens Road we had a large room facing North on the top floor. Dad gave us his short wave radio, and I set up an antenna at the second room from the north-facing window down to a post in the stone garden wall, also used for the washing line, to improve reception.

Extent of harbor model at the university.

However, we did not have any tables for homework, so dad found a couple of cantilevered bedside tables, and added a light on top of a steel rod at the side – it worked very well. We could spread out our books on the beds, and write on the desks. Both homes had large garden sheds where we kept our bikes.

I cannot remember making any friends at school; most of the students had met years before, and a last minute newcomer with a strange accent, living in digs, was likely not welcome. It did not matter, since we made many friends among the other 12 or so students at the digs – an eclectic mixture from Kenya, Malaya and India, plus a few veterans taking advantage of education subsidies offered on demobilization. In fact we were quite happy.

Aberdeen Grammar School.

We stayed in the digs over the Xmas holidays. During the first Xmas, Mrs. McArthur had a large Xmas tree in the living room, decorated with cotton wool and candles. The candles were lit, which I thought was very dangerous. We all left the living room for lunch in the adjacent dining room, and I asked Mrs. McArthur if she was going to extinguish the candles, but she thought they were OK. So we sat down and after the soup, I smelled something burning and immediately thought of the tree. Sure enough, on running into the living room it was burning, so I yelled "fire" and ran into the kitchen for water. Fortunately, Jack, an RAF vet took charge, filled a pan with water and extinguished the blaze. Mrs. McArthur then accused me of starting the fire, which I denied, but it was Jack who persuaded her that if I had indeed started the fire, it would have happened shortly after leaving the room, and not about 15 minutes later after we had finished the soup.

During the second Xmas, with nothing much to do, I joined Ian and a friend from the digs and cycled over to the Rubislaw quarry, about a kilometer west on Queens Road. This was the granite quarry which provided all the stone for the buildings in the "silver city" as Aberdeen was called. It was about 600ft deep, with a rickety wood stair down to the bottom, where there was a watchman in a small shack. It is now flooded. We climbed down and said hello to the watchman, who advised us we were trespassing, but there was nothing he could do since he did not have a phone. I don't know why he was there. Anyway, we climbed out, but it was quite a hike up and we were glad to get back on the surface since it was very cold at the bottom.

Ian and I with Dad at the boarding house in Aberdeen. 56 Queens Road, 1949.

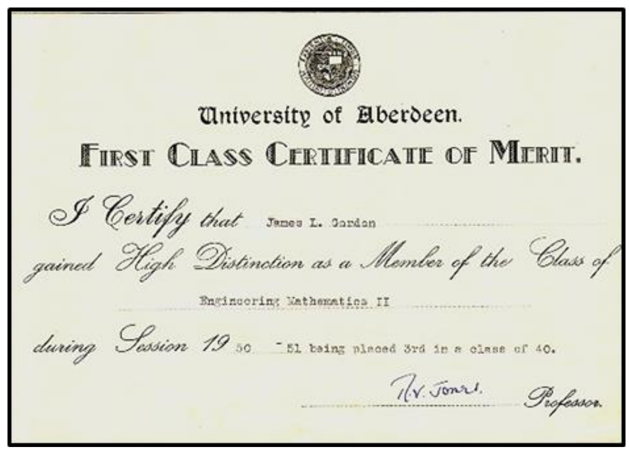
We stayed with Mrs. McArthur for just over 2 years, until she asked us to leave when I announced in early September that we would be moving out in November of 1949 to live with Dad and his new wife Betty. She quite rightly wanted tenants for the full academic year, and had a waiting list. I had to search around for temporary accommodation and found digs in a house close to the grammar school, and we moved in mid-September. However, the room was far too small, very dark and the food was terrible. Ian was quite put out, but he was consoled with the thought that it was only for about 6 weeks. We were both very happy to move to dad's home, where we each had our own room. It was further from school and the university, and up a steep hill, but still within easy cycling distance.

Aberdeen University, Marischal College.

After settling us in Aberdeen in 1947, Dad continued with his Scotland home leave and then returned to the Argentine. He continued to work for the railways until they were sold, to the Argentine government for a supply of beef, and he returned to Scotland for good, two years later in early 1949. He was too young to retire at age 56, so he looked around for work, but could not find anything suitable, since steam engines were being replaced with diesel all over the world. Eventually he found work and was employed as an inspector at a Glasgow railway steam engine factory, rented a nearby walk-up room, met and married Betty Simpson about a year later. They bought a house at 8 Woodstock Road in Aberdeen, and dad then commuted home to Aberdeen on weekends. He retired in December 1952, when his commuting schedule became too difficult to maintain for health reasons.

After completing 6^{th} form, I tried to enroll in Aberdeen University, but was rejected! Apparently my English marks from the grammar school were below 75%, the required pass mark for university, and mine were only 68%. I thought that if I showed the registrar my Cambridge Leaving Certificate from St. Georges it might make a difference. When he saw that it was issued in Buenos Aires, he said "Oh, you are a colonial, the pass mark for colonials is 67%, so you will be accepted", much to my relief, and I enrolled in engineering.

Going on to university straight from school proved easy for me and several other students from schools, but not so for the veterans which made up most of the class. They really struggled, particularly with the mathematics, having been away from classes for many years. They were always asking us for help, so four of us, Ronald Milne, John Henderson, George Mathew and I formed a group to help them. We split all the assignments in two, and two of us worked on half of them until we agreed on the answers when we met over the next few days. We then pooled our answers, copied the entire assignment, and passed the pages on to the vets to copy. This continued until we all graduated three years later.



University of Aberdeen.

FIRST CLASS CERTIFICATE OF MERIT.

I Certify that James L. Gordon

gained High Distinction as a Member of the Class of

Engineering Mathematics II

during Session 1950-51 being placed 3rd in a class of 40.

R.V. Jones. Professor.

Mathematics certificate from 1950, signed by Dr. R. V. Jones.

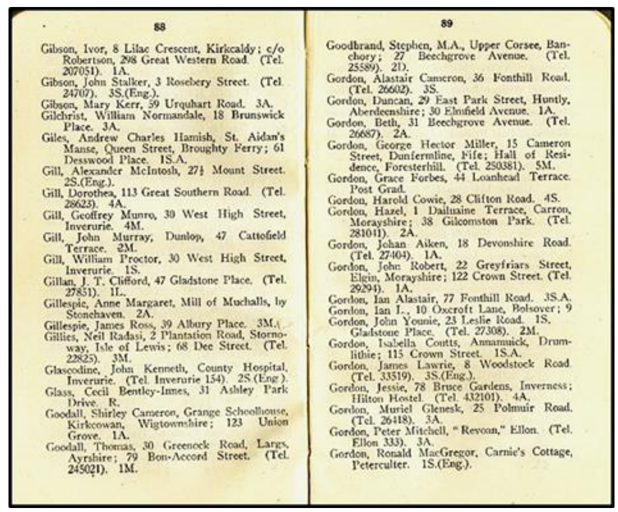
After graduation in 1951, the dean of engineering, Professor Emeritus Jack Allen, asked the four of us to meet him in his office. We did not know what to expect, and much to our surprise, he thanked us for our efforts with the vets. Of course, we asked him how he knew of our work, and he replied that it was quite easy, since we sometimes made a mistake, and then the whole class had the same mistake. They had a faculty meeting about it, and concluded that we were helping more than hindering the learning process, and in effect were acting as extra tutorial classes, so we were allowed to continue. As for the vets, they were very grateful, and occasionally would buy the odd beer for us at the Student Union bar in a building across the street from Marischal College.

Our first year "Natural Philosophy" (physics) professor was the renowned Dr. R. V. Jones. We had heard rumors of his work during the war, but it was all still very secret. Then he was head of scientific research at MI5, and an advisor to Churchill. After retiring in 1970, he wrote a book "My most secret war" which is worth reading.

I well remember one of his physics demonstrations, when he mounted a darts target on one wall of the lecture room, suspended by an electromagnet. By the opposite wall he had an ordinary bow and arrow, with the arrow pointed at the center of the target. The bow was drawn back, and held with a hook, in turn held with another electromagnet. He then asked the class if the arrow would hit the target if both were released at the same time. We all answered in the negative, since the target would drop, and the arrow would miss. When he released both by opening the electric circuit, we were all astonished to see the arrow hit the target dead center! He repeated the experiment with a compressed air gun loaded with a tennis ball, and also with a 22 caliber hand gun, when he invited a veteran to open the circuit. The target was hit dead center each time - a clear illustration of gravity acting equally on all objects.

I thoroughly enjoyed his lectures. He also taught mathematics, and I managed to come third in the second year final class exam – I still have the certificate with Professor Jones' signature.

University work was very intense. Problem solving usually occupied every evening at home and also Saturday afternoons. Often I would still be working on assignments very late at night, but set a limit that I had to be in bed no later than 2.00am. Also, absolutely no work on Sundays, just to give the brain a rest, except when faced with an exam on a Monday morning. Then I would put in a couple of hours work in the evening. Classes usually lasted from 9.00am to noon, and 1.00pm to 4.00pm, with no work on Wednesday afternoons. I found that mathematics and structures were my best subjects, and usually managed to split first and second places with George Matthew, with George coming in first more often.


88

Gibson, Ivor, 8 Lilac Crescent, Kirkcaldy; c/o Robertson, 298 Great Western Road. (Tel. 207051). 1A.
Gibson, John Stalker, 3 Rosebery Street. (Tel. 24707). 3S.(Eng.).
Gibson, Mary Kerr, 59 Urquhart Road. 3A.
Gilchrist, William Normandale, 18 Brunswick Place. 3A.
Giles, Andrew Charles Hamish, St. Aidan's Manse, Queen Street, Broughty Ferry; 61 Desswood Place. 1S.A.
Gill, Alexander McIntosh, 27½ Mount Street. 2S.(Eng.).
Gill, Dorothea, 113 Great Southern Road. (Tel. 28623). 4A.
Gill, Geoffrey Munro, 30 West High Street, Inverurie. 4M.
Gill, John Murray, Dunlop, 47 Cattofield Terrace. 2M.
Gill, William Proctor, 30 West High Street, Inverurie. 1S.
Gillan, J. T. Clifford, 47 Gladstone Place. (Tel. 27851). 1L.
Gillespie, Anne Margaret, Mill of Muchalls, by Stonehaven. 2A.
Gillespie, James Ross, 39 Albury Place. 3M.
Gillies, Neil Radasi, 2 Plantation Road, Stornoway, Isle of Lewis; 68 Dee Street. (Tel. 22825). 3M.
Glascodine, John Kenneth, County Hospital, Inverurie. (Tel. Inverurie 154). 2S.(Eng.).
Glass, Cecil Bentley-Innes, 31 Ashley Park Drive. R.
Goodall, Shirley Cameron, Grange Schoolhouse, Kirkcowan, Wigtownshire; 123 Union Grove. 1A.
Goodall, Thomas, 30 Greenock Road, Largs, Ayrshire; 79 Bon-Accord Street. (Tel. 245021). 1M.

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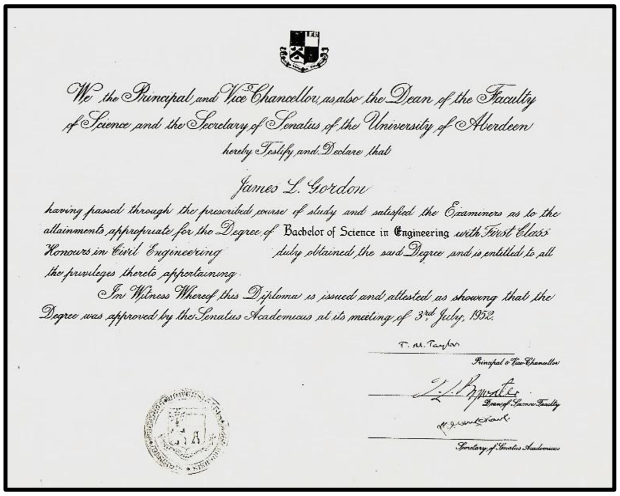
Goodbrand, Stephen, M.A., Upper Corsee, Banchory; 27 Beechgrove Avenue. (Tel. 25589). 2D.
Gordon, Alastair Cameron, 36 Fonthill Road. (Tel. 26602). 3S.
Gordon, Duncan, 29 East Park Street, Huntly, Aberdeenshire; 30 Elmfield Avenue. 1A.
Gordon, Beth, 31 Beechgrove Avenue. (Tel. 26687). 2A.
Gordon, George Hector Miller, 15 Cameron Street, Dunfermline, Fife; Hall of Residence, Foresterhill. (Tel. 250381). 5M.
Gordon, Grace Forbes, 44 Loanhead Terrace. Post Grad.
Gordon, Harold Cowie, 28 Clifton Road. 4S.
Gordon, Hazel, 1 Dailuaine Terrace, Carron, Morayshire; 38 Gilcomston Park. (Tel. 281041). 2A.
Gordon, Johan Aiken, 18 Devonshire Road. (Tel. 27404). 1A.
Gordon, John Robert, 22 Greyfriars Street, Elgin, Morayshire; 122 Crown Street. (Tel. 29294). 1A.
Gordon, Ian Alastair, 77 Fonthill Road. 3S.A.
Gordon, Ian I., 10 Oxcroft Lane, Bolsover; 9
Gordon, John Younie, 23 Leslie Road. 1S.
Gladstone Place. (Tel. 27308). 2M.
Gordon, Isabella Coutts, Annamuick, Drumlithie; 115 Crown Street. 1S.A.
Gordon, James Lawrie, 8 Woodstock Road. (Tel. 33519). 3S.(Eng.).
Gordon, Jessie, 78 Bruce Gardens, Inverness; Hilton Hostel. (Tel. 432101). 4A.
Gordon, Muriel Glenesk, 25 Polmuir Road. (Tel. 26418). 3A.
Gordon, Peter Mitchell, "Revoan," Ellon. (Tel. Ellon 333). 3A.
Gordon, Ronald MacGregor, Carnie's Cottage, Peterculter. 1S.(Eng.).

From the University Directory, lots of Gordons in Aberdeen – I am on the right page, 5 from bottom.

Each year the university published a little green or red book directory listing all student names addresses and phone numbers. A very useful document!

A certificate was awarded to the three top students in each class, and I managed to accumulate quite a few. This continued through the 4 years at university until the final exams in the fourth year, where I made a stupid mistake on each of the 5 structural assignments, and should have scored a big fat zero. However, the professor called me in to go over the paper, and later advised that after a faculty meeting, it was agreed that in view my past performance, and the type of mistakes, such as transposing a 5.92 on one page to 5.29 on the next, and the fact that the logic was all correct, they agreed to award me a 100% pass! I graduated with first class honors.



We the Principal and Vice Chancellor as also the Dean of the Faculty of Science and the Secretary of Senatus of the University of Aberdeen hereby Testify and Declare that

James L. Gordon

having passed through the prescribed course of study and satisfied the Examiners as to the attainments appropriate for the Degree of Bachelor of Science in Engineering with First Class Honours in Civil Engineering duly obtained the said Degree and is entitled to all the privileges thereto appertaining.

In Witness Whereof this Diploma is issued and attested as showing that the Degree was approved by the Senatus Academicus at its meeting of 3rd July, 1952.

T. M. Taylor
Principal & Vice-Chancellor

Dean of Science Faculty

Secretary of Senatus Academicus

My university certificate.

At university I enlisted in the Territorial Army, and was given number 22240102 – yes, I can still remember it, since we had to shout it out at every drill on Wednesday afternoon and Saturday morning. At university, we had an hour off for lunch, and I had time to cycle home for a quick bite, except on Wednesdays, when I would wear my army uniform, have lunch at the Student Union building, usually rabbit pie, since rabbit was not rationed, and then cycle out to the army barracks near the Don River. Army instruction was limited to marching, rifle drill and map reading. We also learned to drive, and on completing the course, the instructor always took the student to the steepest hill in Aberdeen, Littlejohn Lane (now Littlejohn Street, widened and re-graded with only a small hill) beside the University, asked you to stop half-way up, and failed you if the vehicle slipped back on engaging the clutch. I managed to pass on the second attempt after learning to put my heel on the brake, and toe on the accelerator, and continued on to learn how to drive large tank hauling trucks. All this was in the days when there was no synchromesh, so I had to double-declutch whenever changing gears. I tried out on a motorcycle, but found that cornering on gravel was tricky, and slid off on going too fast into a corner on a training exercise – so no more motorcycling.

On one of my instruction trips, I was hauling a small tank with a motorcycle escort ahead to warn traffic and wave it to the side of the road, since the load was very wide. We approached an arched overhead railway bridge, with right and left angled turns before and after, as the road paralleled the railway. The sergeant instructor sitting beside me advised me to take the center of the road, since the tank was high, and could hit the bridge arch. This I did, but on passing under the bridge, I found the motorcycle rider sprawled in the middle of the road, having slid off on the wet pavement. I could not stop in time with the heavy load, so I headed for the right bank and managed to stop half-way up the bank. Fortunately no injuries and no damage, but I was so shaken that the sergeant had to take over driving. Anyway, it taught me to slow down to a crawl on blind corners!

For weapon instruction, we used a 303 Lee Enfield, and after learning how to breathe and sight correctly, I achieved “marksman” status when I could consistently score a bulls-eye at 200yds. However, my eyes deteriorated from too many late nights, and I lost the ability. We also had instruction on the Sten gun, a small hand-held machine gun capable of firing off about 90 rounds in a minute. The weapon was notoriously inaccurate, and only good for close quarters, at less than 30yds. I found that it was unbalanced, and if fired continuously, the shots would tend to drift up and to the right, so you had to hold it very firmly.

After 3 years at university I had to undergo “Basic Training” at the Elgin army base, along with all the other non-veteran students. Training was mostly marching, including one overnight march of about 20 miles with full equipment, which I found very tiring. We also had a boxing competition, and with my St. George's experience, managed to win a match against a hefty dockworker, who outclassed my by several pounds. I was awarded a prize for the best performance – ten shillings, which I promptly spent at the camp NAFFI treating Ronnie and George to apple pie.

On one of our exercises, we were provided with blank ammunition, basic rations for a day, given some 1:25,000 maps and told to attack an enemy position just before dawn about 15 miles away over the moors. We had to walk to a nearby location, trying to conceal ourselves as much as possible, and then wait until it was time to attack, about 2 hours before dawn. There were about 12 in our platoon, with no designated leader. After a short while, I found that I was the only one capable of reading the maps correctly, so took over leadership. I spotted a croft on the map about 2 miles from the attack position, and thought it might be abandoned, since it was in the middle of nowhere. We slowly walked there, keeping to low lying land as much as possible and stopped nearby. We observed the croft for about an hour, noting that there was no dog, no signs of life, and concluded that it was empty. We crept down and knocked on the back door, since the front door was clearly visible from far away.

It was empty; we entered and made ourselves comfortable. The interior was spotless, so I asked the troops to take off their boots, keep the place tidy, not to light the fire, not to go near any window, and not to use the front door. This caused some murmuring and eventually I was asked what authority I had to order them around, and I told them none whatsoever. After some discussion, they agreed that I should continue as the leader since I could read maps. Next day, the sergeant asked us about the exercise, mentioning that he had managed to keep us in sight until we seemed to disappear suddenly, and he widened his search in case we had wandered off in the wrong direction. I told him about the croft, and he advised that he had not thought of it as a hiding place, and was impressed with our performance.

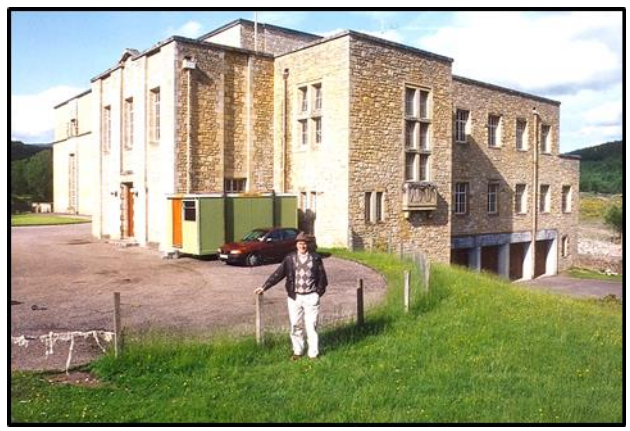
Ronald Milne, John Henderson, Me and George Matthew at university survey school – June 1951. Standing behind a "plain table" survey instrument, invented by the Romans – still used in 1950!

The night of the attack was almost pitch black with no moon. Unfortunately, the exercise did not end well. We attacked the "enemy" position, but after about a half hour of firing off the blanks, the exercise was stopped. Apparently someone had charged the enemy position and fired a blank too close to an opposing trooper with the result that the blank wadding had shot out and severely wounded a fellow engineering student, Allan Scott in the stomach. He was rushed to hospital accompanied by Ronnie Milne, and he did recover, but it took time.

We had over 3 months of summer vacation between university years, so I tried to find employment. On the first summer in 1949, I worked at the British Aluminum Company in Fort William stoking an aluminum smelter. The company hired students to replace workers on holiday, since it was shift work, and the smelting process couldn't be interrupted. The work was quite easy but very dirty, and I would be covered in soot by the time the shift ended. But the pay was good, and I often worked a second shift at double or triple time on Sundays when a worker was absent. I ended the summer with about £170 (about $8,000 today) in the bank. Considering that the average laborers' pay at the time was £4 per week, I had earned about 10 months of pay in 3 months. It certainly helped with finances, but it was costly, since I developed asthma in later life.

For the second summer in 1950, I found work with a contractor building the new Fasnakyle powerhouse, when word was passed around that the resident engineer was looking for a civil engineering student. I applied and started working for Sir William Halcrow and Partners, a London consulting engineering company working on the North of Scotland Hydro developments. I spent a week at the Fasnakyle powerhouse doing surveys and working as a rodman. I was then transferred to a very comfortable fishing lodge in Glen Garry, to take up a position allocated to an engineering student from London who had failed to appear. There, a team of six surveyors, including me, worked on a detailed survey for the Glen Garry development. I continued to work as a rodman, and spent evenings plotting the survey results and calculating positions, all very interesting. We had Saturday afternoons off, and we all went into Inverness in a Ford "woody" station wagon purchased by Halcrow from the USA army as surplus, for beers at a pub. Dinner was fish and chips in a newspaper purchased from a woman at a window in a house on the road beside the Ness River – all very "British". On Sundays we usually organized a hike into the hills, or if the weather was bad, we spent the day reading newspapers.

One weekend the "woody" wagon had to be serviced, so we had no transport and spent Saturday at the lodge. It was the cook's afternoon off, so no dinner. We looked into the cold pantry, and only found a few dozen eggs and a sack of potatoes, nothing else, since food rationing was still in force. Further searching among the cupboards revealed a box of curry powder, so we had curried eggs and mashed potatoes for dinner. Nothing for dessert until one of the engineers remembered that he had brought a bottle of liqueur back from France on his recent holiday there. He did not know what it was since he only remembered to pick one up at the last moment before boarding the ferry, had run into the bar at Calais, and bought the last bottle on the shelf. It turned out to be green Chartreuse, which nobody had heard of. It was quite pleasant, but very strong with a 55% alcohol content. We managed to finish it, my first introduction to a liqueur and I did not taste it again until much later in Canada.



Fasnakyle Powerhouse – 1995.

As a rodman, I was provided with a 16ft survey rod and an axe to cut the odd tree branch if it interfered with the sighting when working through woods. On one occasion I cut down a sapling of about 1.5-inch diameter. This caused some consternation to the chief surveyor – apparently they had to pay a duty of £2 per inch of tree diameter, for every tree cut down, and fill in a lengthy form in triplicate, all for the Scottish Forestry Commission. I remembered this much later when working in Labrador, and our survey gang would cut down any tree without thinking about it.

However, the Halcrow pay was insignificant. £3-10′ per week, with £2-10′ deducted for room and board. I ended up with just £1 per week, and after deducting expenses, I only had £9 left from the summer's work – quite a contrast to the previous summer.

The engineering course had been compressed into 3 years to accommodate the influx of veterans. So towards the end of the third year, I looked around for permanent employment. Offers of work in Britain were scarce, and the pay was abysmally poor, usually about £4-10′ per week due to the surplus of engineers. However, in March of 1951, I found employment with the Anglo Iranian Oil Company in Iran at £20 per week including room and board, and no taxes – great! However, it was not to be. On 1st May 1951, Dr. Mohammad Mosaddeq nationalized the company, and a few weeks later I received a letter cancelling the job offer.

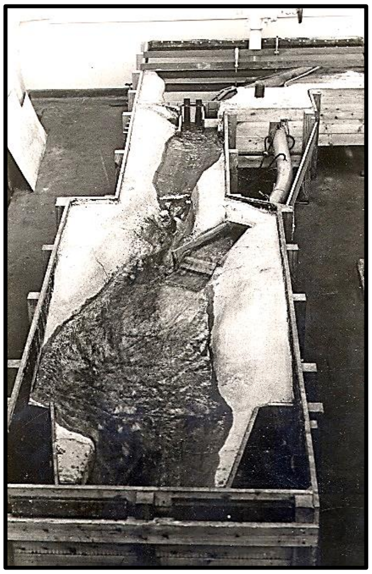
At the end of our third year at university, I attended a week-long course in surveying conducted by the professors at Hazlehead Park in Aberdeen. There I learned to use a transit and the basics of plane table surveys. Plane table surveying had been used by the Romans, and perhaps had also been used by the Egyptians when building the pyramids, so the process was several thousand years old. I used it that summer, and again in Labrador, but now surveys are a one-man task, with the surveyor equipped with a satellite receiver and a computer, quite a change!

After discussing the job situation with dad and my professors, I decided to return to university for a year to take an honors course in civil engineering, while I pondered my future. It so happened that George, Ronnie and John had also decided to continue with studies, so our quartet was still intact.

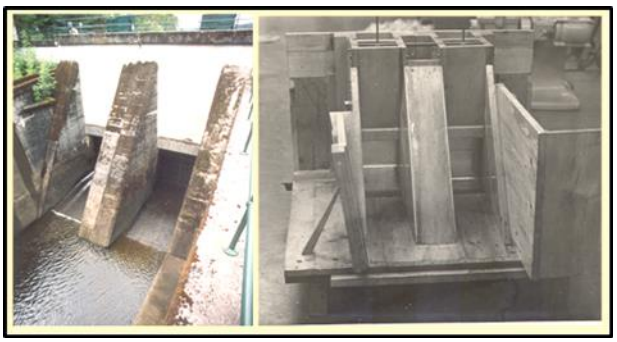
With no job, I wrote to Halcrow and asked if there was any place on the Scottish projects, and they replied in the affirmative, if I was willing to continue working as a student, but with an increase in salary to £4 with £3 deducted for room and board! I was no better off, and accepted the position; it was at the same fishing lodge in Glen Garry, but now working as a surveyor where I gained valuable experience. This time the work was on the detailed topography of the gorge in the Garry River, where the dam, spillway and intake would be built. The work was quite difficult, since the rock banks in the gorge were too steep for rodmen to climb down. The chief surveyor decided that the only practical way was to string a series of cables over the gorge at about 25ft intervals, and have a pulley system on the cable wherein a plumb-bob could be dropped to just rest on the rock. Two transits on the top of the opposite bank would then sight on the plumb-bob and with the recorded angles, we could determine its position by plane table survey, and elevation by measuring the length of line. Surveying the river bed was more difficult, and here we resorted to swinging the plum-bob and dropping it into the fast flowing water, and judging when it hit bottom, which usually required several attempts with a gradually increasing line length.

For the 4th year at university, I elected to major in hydraulics, and found myself working on the Glen Garry hydraulic model, now very interesting since I had worked on the surveys. John Reid was the engineer in charge from Halcrow, and he allowed me to undertake several of the model runs by myself, while he was off calculating the results from previous runs. I later met John in 1995 when touring the Scottish hydro plants with George – small world!

The Glen Garry hydraulic model.



Below - Actual (1995) and model sluices at Glen Garry (1952).



The water flowing off the model was retained in a sump measuring tank. The tank could easily overflow, and I was informed that each student was allowed one mistake which usually resulted in flooding of the laboratory. This was of little consequence, since the water would seep out the back door and run down Littlejohn Street into the sewer. However, the water had to be replaced, and was purchased from the city supply, so after the first incident, students had to pay a water loss cost of ten shillings. I had to pay once, and learned my lesson, always watch the sump tank very carefully, and do not try and squeeze in another model run when the sump is almost full. There was always a temptation to try another run, since it required over a half-hour of pumping to completely empty the sump tank.

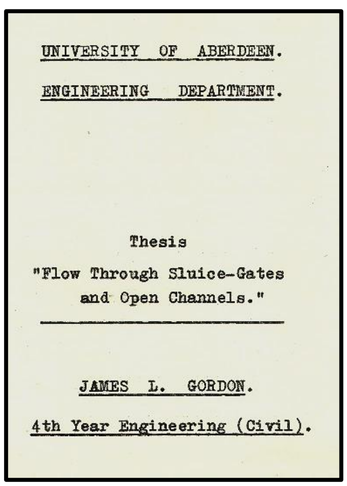
The Glen Garry dam layout was very interesting, with a long side-channel weir directing spilled water into a tunnel in the left abutment which ended in a stilling basin. On the left of the weir there was an intake, directing water into another tunnel which dropped down below the spillway tunnel and continued on to the powerhouse. To the right of the intake, there was a concrete dam with two spillway gates. My work centered on the interaction of the flows emerging from the spillway gates and tunnel, and resulted in my thesis “Flow through sluice gates and open channels”, a 95-page dissertation in leather binding which I still have. There is another copy in the university engineering library. I spent many hours working out the theoretical position of a standing wave that formed in the stilling basin or tunnel, and comparing it with the model wave position, the position being dependent on flow and tailwater level. The calculations were very complex and time consuming, a task now accomplished with a computer in a few seconds. I also worked on determining the sluice gate flow capacity, and developed a formula as a function of opening and head which I tested on the Aswan Dam sluice gates, having obtained the required data from a paper published in 1920 by the Institute of Civil Engineers.

I thoroughly enjoyed the work, and it certainly whetted my appetite for hydro engineering. I was very fortunate in arriving at the university in 1948, since Professor Allen was at the forefront of hydraulic model work on the North of Scotland hydro projects. Now, all hydro work in Scotland has been nearly completed, and the university civil engineering staff are working on North Sea oil platform and drilling projects.

I had a tour of the new laboratory with George Matthew when over at Aberdeen for the quincentenial of the founding of the university in 1995. The current hydraulic laboratory is small, with work centered on ocean waves and sediment transport

Aberdeen University Civil Engineering Graduating class – June 1951.
1. **Professor Emeritus Jack Allen. 2. Me. 3. George Matthew. 4. John Edison. 5. Ronald Milne. 6. David Hunt – met him again later in 1995.**

Cover page for my thesis.



UNIVERSITY OF ABERDEEN.

ENGINEERING DEPARTMENT.

Thesis

"Flow Through Sluice-Gates and Open Channels."

JAMES L. GORDON.

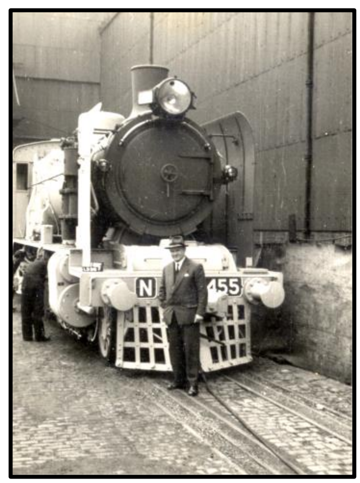
4th Year Engineering (Civil).

Professor Allen was retired, but still worked occasionally, with the title of Professor Emeritus. He always gave the first two hydraulics lectures to second year students, showing how basic hydraulic equations could all be derived from Newton's laws. This he proceeded to do for us in 1949, and after going through many lines of theoretical analysis, he paused, sensing something was wrong. I looked at the blackboard, and could see that after the next transformation, the result would be H = H, not exactly what he wanted. He must have seen the same result coming, since he said "all right boys, that's enough for today!" and walked out. He corrected it on the next lecture. Upon graduation, he provided an excellent reference for me, but I never used it. He eventually moved to Cornwall, England, and passed away at the ripe old age of 94.

In those days, we all had to take notes in class, since photocopy machines were not available, and lecture notes were not provided by the professors. Fortunately, the professors worked at a pace which allowed time for note taking, provided you could write very fast, and understood the concepts. Sometimes the vets would fall behind, or failed to understand the work, but they did not hesitate to interrupt and ask questions, which benefited us all.

During the fourth year I met John Nuttall, an Athlone scholar from Canada working towards his doctorate in hydraulic engineering, and I casually asked about the prospect of work there. He was very enthusiastic about Canada, and invited me to dinner at his flat near the university. There I met his wife Ruth. When we had apple pie for desert, she asked if I would like some ice cream on it. I demurred, since I thought it would require going out to the local shop for the ice cream. She then mentioned that there was some in the refrigerator in the kitchen, and I asked to see it, since I had never seen one. On entering the kitchen I saw several other unfamiliar appliances, and asked what they were, and she pointed to a dishwasher, clothes washer, and dryer in addition to the refrigerator. The university had a long term lease on the flat for Athlone scholars, and one of the conditions of the rental agreement with each scholar, was that they had to bring over one appliance with them and leave it in the apartment. John was the third scholar in the flat, the clothes washer having been included in the original lease. Naturally I was impressed, and decided that Canada was in my future. John then provided me with the address of Dave Duguid, a friend working as a civil engineer in the remote Yukon on the Mayo hydro development. I wrote to Dave, and received a reply shortly after. He indicated that prospects in Canada were very good, with civil engineers in high demand, and suggested that if I was ever in Montreal, to look up Montreal Engineering on St. James Street, his employer. So I departed for Canada in July 1952 and whenever I am asked why I decided to come to Canada, my reply is always that I like apple pie with ice cream!

When working as an inspector in 1951, dad had to ensure that several locomotives destined for railways in Australia were built to specification. At that time, the Australian railways had 2 gauges, standard at 4' – 8.5" and wide at 5' – 6". The locomotives were designed to work on both gauges by moving the wheels out on the axles, away from the bearings. Unfortunately, after arrival in Australia, it was found that the wheels, when on the wide track, canted inwards due to deflection of the axle. Nobody had thought of testing the wide track setting before shipping the locomotives. Dad was accused of passing defective work and threatened with dismissal. He asked for my help in calculating the deflection, to see if it was indeed a faulty design. Since the deflection was very small, at only about 1.4 degrees in total, I had to use 8 figure logarithms (obtained from a large book borrowed from the university engineering library) to calculate the deflection, and it came in at exactly what was measured, after about 8 hours of work. Today, with computers, it would only require a few minutes to write a program and obtain the answer. Dad meticulously copied my work and presented it to the plant engineer the next day. Needless to say, he was astonished at the result, and dad was able to continue working as an inspector – don't know what was done with the locomotives.



Dad with Glasgow locomotive prior to shipment.

One of the last things I did before leaving Aberdeen, was to construct a large shed at the bottom of the garden to accommodate Dad's old Austin 7 car and a work bench. It was built into a corner just outside the garden to include the two stone walls. It had a concrete floor, and cement-asbestos roof and siding. It was still there when I looked over the place in 1995, but has since been demolished and replaced with a larger 2-car garage.

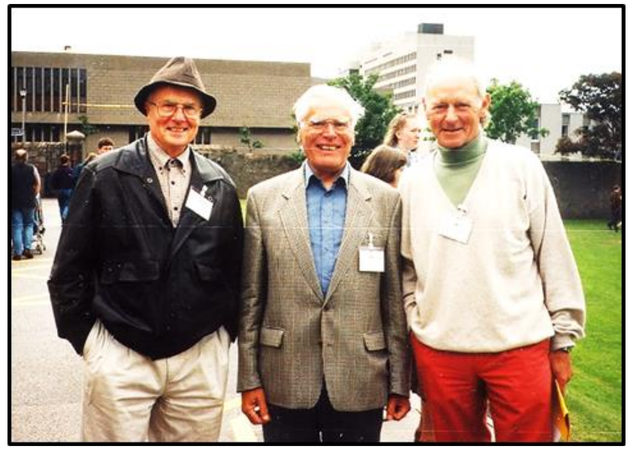
As for our foursome - George and Ronnie continued their studies and obtained their doctorates. George retired as a Reader from Aberdeen University, Ronnie as a Professor at Bristol University, and John retired as a Vice-President of the Asian Development Bank in Manila.

The garden shed at #8 Woodstock Road - 1995.

Getting to Canada was a bit of a problem. Fortunately, Mr. Robertson, my step-mother's brother-in-law in Dundee, loaned me £138 – 18´, since he had borrowed $500 from Betty's brother Mr. Jim Simpson in Montreal a few years ago, and could not return the money due to foreign exchange controls. At that time, the exchange rate was about £1=$3.60. I had to sign a promissory note to repay the money to Mr. Simpson within 6 months of arriving in Canada, which I did. This was enough to book a second class passage on a Cunard steamship, the Franconia to Quebec City, and I sailed from Liverpool on July 24 to arrive in Canada on 31 July, 1952 with my 1920 steamer trunk from St. George's, one suitcase and $20.

A few days before sailing to Canada.

When I returned for the quincentenary of the founding of the university in 1995, I had arranged to meet with George Mathew and Ronald Milne. The only other engineer from the 1951 class at the celebration was David Hunt, whom I recognized since he was one of the veterans we had helped with assignments. He had not changed in 44 years! Of course, he did not remember me.



44 years later – me, David Hunt and Ronald Milne.

Ronnie, Margaret, George, Dorothy and me, Aberdeen, King's College quadrangle, 1995.

George and Ronnie were accompanied by their wives, Margaret and Dorothy, but my wife Vera declined to come since she did not know any of my friends at university. On my last day at the celebrations, I bade a fond farewell to all. Dorothy was a doctor who had graduated from Aberdeen, and had met Ronnie at university. Margaret was a high school teacher.

Arriving in Canada in 1952, I went through customs and immigration at Quebec City, boarded a train to Montreal, where I was met by Jim Craig, stayed with him and his wife Betty for a week, and immediately started looking for work. Jim was my stepmother's nephew.

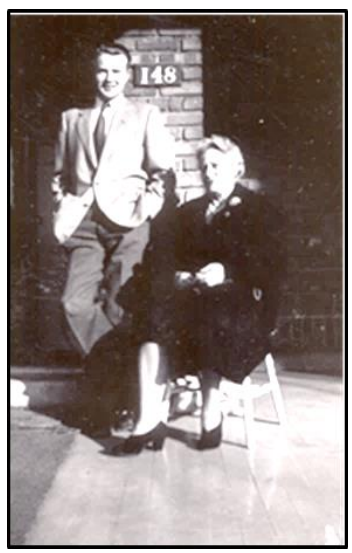
3 - MONTREAL, CANADA 1952 – 53

After going through customs and immigration in Halifax, I boarded the train for Montreal. It was very conveniently stationed near the pier, and a porter loaded my trunk onto the baggage car. At the Montreal railway station, I was met by Jim Craig and his wife Betty and driven out to his new home in Pointe Claire, a suburb of Montreal. I spent a week there until Betty's parents, Jim Simpson and his wife Janet returned from a summer holiday, and then I moved to their apartment, an upper duplex in Notre-Dame de Gras (NDG), a district in the city, and stayed for the month until I found digs in the Town of Mount Royal with Mrs. McCormick.

After a few day's rest in Pointe Claire, I started looking for work on August 4th, and soon had two job offers, one from a contractor for work on an office building under construction in Montreal, and the other from the Foundation Company of Canada, for work in the Gaspe, on a large copper mine being developed there at Murdochville. I was not enthused about working for contractors, so continued looking, and on Thursday as I was walking around town, came across St. James Street which jogged my memory of Montreal Engineering Company Limited (Monenco). I saw a phone booth, looked up the phone number and called, and was put through to 63 year old Mr. Harry Thompson, who had joined the company in 1941, he asked where I was, and I replied in a phone booth outside 276 St. James St., and he said that was their office building and to come on up to the second floor to see him.

This I did, and found that he was a senior Vice-President filling in for several department heads all away on summer holidays. After a half-hour interview during which he was not interested in my degree, but only that I had relevant hydro experience, he indicated that a job offer was very likely, and he would phone me next day. He never asked to see my degree, nor for any references – how times have changed! I was offered a job at $275 per month, accepted, and started working on Monday August 11, only a few days after arriving in Canada. In January 1953, my salary was increased by 9% to $300/month.

I arrived for work and was offered a choice of departments, civil, mechanical or electrical. This confused me, since I thought I was only qualified for civil engineering work, but Mr. Thomson indicated that degrees were just a measure of your ability, and that whatever department I selected, I would be trained accordingly. I selected civil, and was introduced to Murdo Murchison, another Scottish engineer, and started work on a hydro project being built for the Calgary Power Company, a utility in Alberta, with my first task being to calculate the quantities for a homogeneous embankment dam at the outlet of Upper Kananaskis Lake.



With Mrs. McCormick at 148 Portland Ave.

However, before this, I was introduced to Miss McCaffrey, head of the correspondence files, who had been with the company for many years. She showed how the files were arranged, and told me that they were never to be touched. If I needed a file, I would give her the file code, and she would then retrieve it for me. The code was quite simple, a number for the project work order, followed by a three digit number which was always the same 200 series for every hydro project – 210 for dams, 220 for the intake, 280 for the powerhouse and so on. It had been established about 1935, and worked very well. The thermal plants were on the 100 series, and other structures had different series.

View of Upper Kananaskis Lake Dam, built in 1954. Panoramio image.

With the help of a planimeter, the task was completed in a few hours, and I gave Murdo the results. He was rather taken aback, since he expected the work to require at least a couple of days, and asked me how I had determined the quantity. I replied that I had drawn the dam on the large scale topography, and planimetered the dam area at 5 foot intervals, and added an allowance for excavating and cleaning the foundation. Murdo then indicated that their standard method of dam quantity calculation was to draw sections of the dam at 25 ft. intervals and then planimeter the sections to obtain the area and hence the quantity. This I did, a task which, as Murdo expected, took well over a day's work. The result was within 3% of my previous quick calculation, much to Murdo's surprise.

At the office, I was provided with a drafting desk, and shared a phone with 3 other engineers. A slide rule and dad's drafting set were my only other tools. Incidentally, except for the phone, this equipment was identical to that used by all engineers since Newton, about 400 years ago! The desks were set out in groups of 4, with the phone on a pedestal in the middle. There were no draftsmen, and the first one was only hired several years later, so I had to learn how to draw and lay out the drawing in a logical way. After a quick lunch, I would return to the office, and pour over the drawings being produced by more experienced engineers. Concrete reinforcing drawings were the most difficult to follow since they used a code to indicate the bar size, shape and spacing, but after a few months, I managed to make sense of them.

My quick lunch was usually in a small Greek restaurant just off St. James Street where soup, sandwich, pie and coffee plus a tip, could be had for $0.70. I recently had the exact same meal at a local sandwich shop near the Valois railway station for $11.86, including tip. This works out at a steady inflation rate of 5.1% over 56 years, so long-term inflation is not always below the 3% that most governments like to think it is. I recently looked up the inflation rate on the StatsCan website and found that the 1953$ is worth 8.13 times the 2010$. Hence the $0.70 lunch should now cost $0.7 x 8.13 = $5.69, plus tax = $6.42. On this lunch comparison, the 1953$ should be worth 15 times the 2010$.

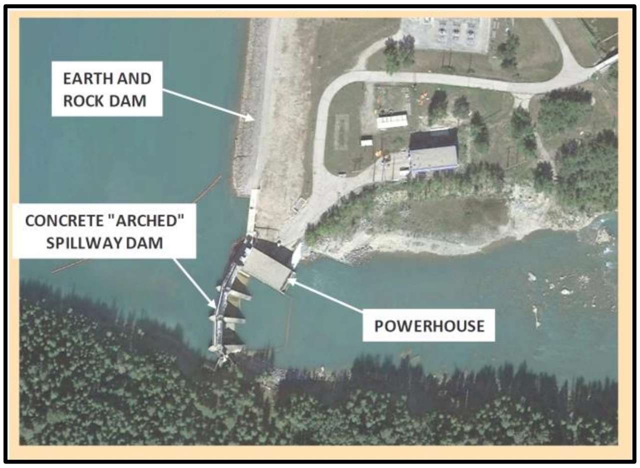
When I joined the company in 1952, there was a total of just over 60 engineers on staff. When I left in 1990, there was over 1,200, and staff had peaked at 1,969 in 1981. What I did not know when joining the company; was that it was much more than a consulting engineering company. It had been established in 1907 as the engineering and operating branch of a large financial company named Royal Securities Limited, dedicated to the purchase, establishment and operation of power utilities all over Canada and South America. They had utilities in Canada from Newfoundland Light and Power to Calgary Power, and in South America, from San Salvador Electric, to Bolivia Light and Power. There was a large purchasing department which peaked in 1965 with about 200 purchasing agents, that bought everything from rubber boots to hydro generators for the utilities, and engineers in the company had to solve operating problems such as regulating reservoirs to ensure a steady water supply, monitor equipment performance, and schedule repairs, as well as designing new projects. It provided a unique and very valuable educational experience.

The letters patent for the company, written in 1907, allowed the company to undertake just about anything, even the creation of shipping companies, building and operation of ship locks, construction companies and especially electric utilities. In fact, it was registered as a utility with the Canadian Electrical Association, while all other Canadian consultants were registered as consultants.

Up until May 1952, the company president, Mr. Gaherty, would take all the engineers out for lunch on the last Friday of the month to the nearby Montreal Club. Unfortunately, their private dining room could only accommodate about 52, so the practice was discontinued just before I joined; pity. With the large number of associated utilities, there were three senior Vice-Presidents in charge of their engineering requirements; these were Mr. Stairs for eastern Canada, Mr. Gaherty for western Canada, and Mr. Kruger for the South American overseas utilities. They certainly kept us busy.

Besides working on drawings, I had to write purchase orders for equipment on green sheets; these were sent to the purchasing department, registered with a purchase order number, mailed to the utility for signature and formal transmittal to the manufacturer, and at the same time the purchasing agent sent a copy as a "draft" to the manufacturer, with all manufacturers enquiries directed back to our engineering department. There was a large "foreign drawing" repository in the attic of an adjacent building at 244 St. James, where every drawing produced by a manufacturer for all their projects, dating back to about 1910 was available. I had to consult it many times, when spare parts were needed. It proved to be invaluable, since the utilities often lost their drawings, and the drawing from the Montreal collection was the only one still available. Sadly, the entire collection was dumped when the company was purchased by new owners in 1989, since, by that time the storage costs had become very high. The drawing store was never cleaned, resulting in a large accumulation of dust over all the large expandable envelopes in which the drawings were kept. The clerks in charge of the repository had to keep a smock just inside the door, which they donned whenever looking for a drawing.

The Chief Civil Engineer, Jack Sexton was off on holidays when I started work. About 2 months after he returned, he noticed a new name on the roster, and asked me to come into his office. He looked over my file and noted my knowledge of Spanish, whereupon he said "I see you know Spanish" to which I replied "Si señor", and then he asked me to go and work on the Santa Rosa hydro plant being built in the Zongo River valley in Bolivia, to which I replied "No gracias", and at that he asked me to get out of his office! - I learned much later that I was the first to say no to him. After he cooled down he asked be back, and why I had refused the assignment. I mentioned that I was from the Argentine, and was more interested in working in Canada, not in South America.



Google Earth image of Bearspaw dam.

Another project I worked on was the Bearspaw Hydro development on the Bow River, just west of Calgary. My first task was to check the sliding factor on the curved concrete spillway dam, a number which proved to be around 0.71. I thought this was far too high, since all references indicated it should be below 0.67 if founded on excellent granitic rock, and lower on other weaker rock. I spoke to Jack Sexton, and he asked me to make a small drawing showing the recommended sliding factor from every reference I could find, how it was calculated, and compare it to the one I had calculated for Bearspaw. When it was finished, he called our president Mr. Gaherty to arrange a meeting. Next day, I found myself describing how I had calculated the sliding factor to Mr. Gaherty, and the lower factors recommended by the references. However, Mr. Gaherty pointed out that the dam was curved and "arched", so that the methodology I had used was not correct, because the sliding factor on arched dams was not relevant, since the forces were transferred mostly into the abutments and not into the foundation. I pointed out that one of the "abutments" was the powerhouse, and that it could not take the additional thrust from the dam, since it also had a high sliding factor. Mr. Gaherty disagreed with this analysis, and there the matter ended. Much later, I realized that Jack Sexton had agreed with my analysis, but preferred to sit back and watch a very junior engineer take the flak from the company president. 25 years later, when Alberta introduced dam safety regulations, the dam was reinforced and tied down with large wire rope anchors drilled and concreted into the sandstone foundation rock.

Another task was to determine whether a tailrace excavation to increase the head would be economic. I found that a kilometer long tailrace, all in easy gravel excavation, would increase the head and be economic. However, Mr. Gaherty pointed out, quite rightly, that the first flood would wash substantial gravel from the spillway area into the tailrace and restrict flow – so no tailrace excavation.

Getting to the office was easy, a 4 minute walk to the train station in Mount Royal, a 15 minute train ride to the Central Station, followed by another 15 minute walk to the office. To encourage cooperation among staff, there was a weekly bowling tournament on Thursday evenings, so I got to know several of the other bachelor engineers, and enjoyed my first winter in Montreal.

4. NEWFOUNDLAND 1953-5

A few months later, in March, Jack Sexton called me into his office, and said that since I would not work in South America, a field job had been found for me in Newfoundland, and a refusal was not acceptable. I told him that I would be happy to work in Newfoundland. Apparently Newfoundland Light and Power, an associated company, was continuing to develop a series of hydro plants on the Avalon Peninsula, south-west of St. Johns. They had already added a third unit to Tors Cove in 1951, built Cape Broyle, in 1952 and were just completing Horsechops further upstream. The drainage area above Horsechops was being expanded by diverting the Fourth River, East Blackwoods Pond, the Crossing River and the Northwest River into the Mount Carmel reservoir above Horsechops. I arrived in St. Johns in early April 1953 and stayed until the end of October. It was my first flight, in a DC3 operated by Trans Canada Airlines.

Cape Broyle, July 1953 – last village with electricity.

The log cabin during construction.

I reported to the Resident Engineer, Al Cameron, and was provided with a 4-wheel drive Dodge Power-wagon, complete with a hefty winch on the front. I had a room in a house in Cape Broyle rented by the company and operated by Mrs. O'Brien, where I stayed on alternate weekends. However, I would be living in a genuine Canadian log cabin for most of the time.

Before leaving for Newfoundland, I had bought an excellent Zeiss camera, a small folding model, with an F3.5 lens and fully adjustable shutter, along with a Weston light meter, since I wanted to concentrate on color slides, and I was told that for slides, a light meter was essential. They both proved to be very useful.

John Cavanaugh and our cook Jerry.

Before being allowed to drive the 4x4 power wagon, Al asked if I could drive a truck with non-synchromesh gears, so the training on tank transporters in the Territorial Army was put to good use. On the test drive, I managed to double-declutch quite successfully.

In Newfoundland, I was assigned a full-time guide, John Cavanaugh, a local woodsman from Calvert, the next village south of Cape Broyle, who knew the country like the back of his hand. Apparently, there were no maps of the area, and with the low rolling hillside country, completely devoid of trees, vegetated with low alder bushes, and often covered in dense fog, one could easily get lost. Apparently, the whole peninsula had been devastated by an enormous forest fire in the 1930's. So all up-country engineers had personal guides, and it was explained that if you ever became separated from your guide, you would be immediately dismissed. This was based on an incident which had happened the previous year to Art Demers, an engineer with the company; and an extensive search and rescue effort with bush planes and guides had found him, only just in time several days later, starving, wet and suffering from hypothermia. Art had had an argument with his guide as to the direction of travel in an attempt to walk cross the peninsula from Blackwoods Pond to Gulch Riverhead, to delineate the drainage areas. A severe storm had come up, and the guide wanted to return, to the nearest eastern shore road at Aquaforte, but Art insisted on continuing, so they parted company. After this incident, the dismissal instruction was added to your warning.

The hydro plant at Cape Broyle.

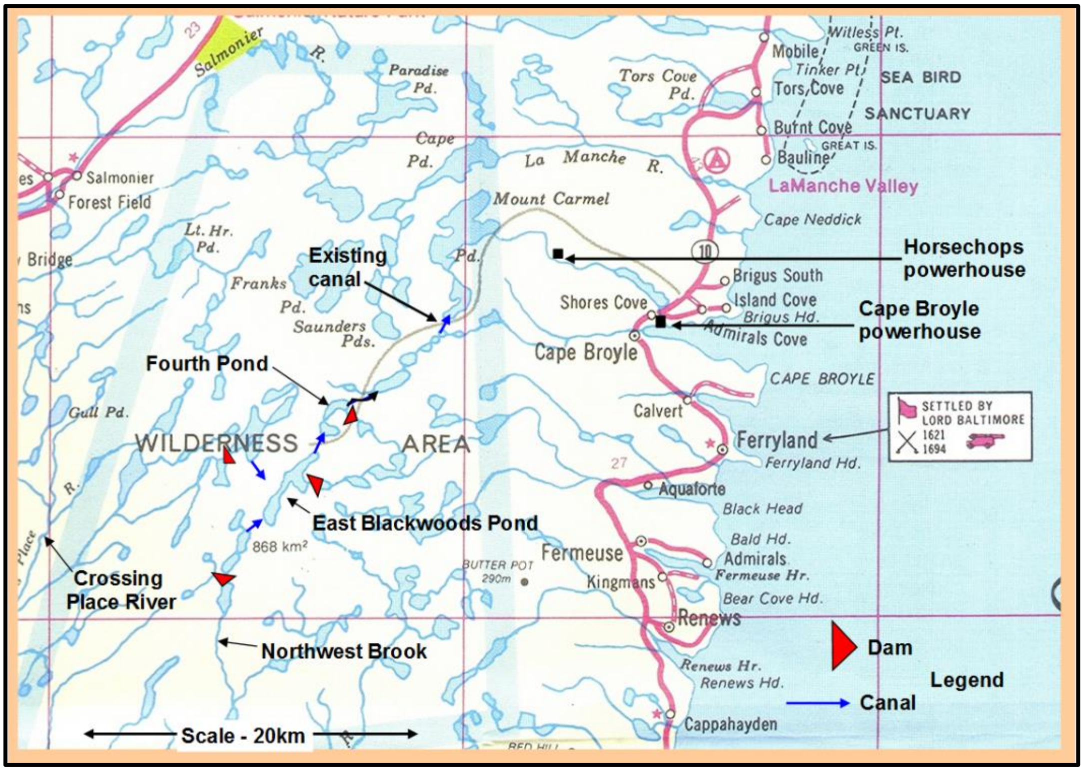
My first task was to help with commissioning of Horsechops for a few days. Then I departed on a trip up-country in the power wagon with Al Cameron, John Cavanaugh, Joel the contractor, and his foreman. We stayed 2 nights at the log cabin recently built in the only surviving copse of trees in the area.

My assignment was to set out and supervise the construction of several earth dams, two timber crib stoplog spillway dams, and a string of canals linking ponds to eventually discharge diverted waters from Blackwwods Pond, the Fourth River and Crossing Place River into the Mount Carmel reservoir upstream of Horsechops. We spent a couple of days looking over the terrain with the detailed drawings, to see where the canals and dams would be built. We then tried to start the powerwagon, only to be confronted with a flat battery. This was a problem since with the winch on the front, we could not use the crank handle, and a 30km ride out to Cape Broyle on the back of Joel's dump truck, was not relished. Fortunately, Joel had a bright idea, and suggested jacking up a back wheel, winding some rope around it, and then trying to start the engine by pulling on the rope. It worked on the third try, much to our relief.

First trip up country with the Dodge 4x4 powerwagon. Canvas covered box. Note lack of trees, Joel's dump truck.

So I moved into the log cabin, and started work. Joel built a camp after clearing an area close-by across a bog from the cabin. Meals were in the cookhouse, and we found that for foggy days, we had to mark the path through the bog with ribbons tied to alder plants. Even so, one of the rodmen sharing the cabin got lost early one morning, but had the sense to stop walking when he realized his predicament. He was found several hours later when the fog lifted slightly.

Bogged down excavating through "slime".



Map showing project layout.

Large beaver dam found on our walk to Crossing Place River. Pack-sack with rain gear and food.

The work included the diversion of the headwaters of the Crossing Place River, far to the west of our camp. There, a small timber crib dam across the river would direct flow into a short canal excavated across the height-of-land into the Blackwwods watershed. The only way to get there was by canoe, paddle for about an hour and then an hour hike over the hills to the damsite. We set up a small tent camp, and Tom Whelan, a final year engineering student from Memorial University was put in charge. He did very well, and on one occasion when I was inspecting the progress, I found Tom stripped down to his underpants holding the survey rod in the middle of a shallow pond. He was covered in slime from head to toe, but it did not bother him. All the others had refused to enter the pond. All ponds in the area had a deposit of slime, sometimes well over a meter deep, which was liquid when submerged, but dried out to a semi-hard surface capable of just supporting a person. The slime was formed from the 1930's forest fire ashes washed down by rain into the ponds. This was unexpected, so we had to re-route the canal from Fourth to Seventh ponds around the slime.

Once, on the way back from an inspection of Tom's work, dense fog descended, and I had an argument with John Cavanaugh when he veered off what I thought was the correct direction through the trackless alders. However, he insisted that he was right, so I followed, and after cresting a low hill, I saw the red canoe beached directly in front of us. I never questioned his guidance again.

Joel sent a small shovel out to excavate the canal after Tom found a route which avoided excavating rock. After about 10 days' work, the shovel broke down. The only way to reach it for repairs was to have a bulldozer go out and haul a

90lb broken part back to the welding shop. Tom volunteered to carry the part out tied to a back-pack frame if he could have two men, one on each side, helping him keep his balance. This he did, and the contractor gave him a substantial reward for his effort, as it saved considerable time and cost. Tom also carried it back! Many years later I heard that Tom was the President of St. Mary's shipyard on the Burin Peninsula in Newfoundland.

With our 4HP motorboat on Blackwoods Pond.

One of small dams on East Blackwoods Pond from the Beaver aircraft – note no trees!

Al Cameron decided that he would like to see the work at Crossing River, but did not relish the hike across the alders to get there. A de Havilland Beaver aircraft was chartered, and I drove down to Mount Carmel Reservoir to meet it. The pilot, Marsh Williams, had a new co-pilot aboard, who was being trained in bush flying.

We set off and soon approached the pond at Crossing River, with the co-pilot in charge. We descended to the pond, but a strong cross-wind caused the plane to drift off course into a rocky area, and one of the floats was punctured on landing. I was sitting in the back, and the pilot shouted that we all had to jump out into the shallow water in case the plane tipped over. However, I was concerned that my new camera would get wet, so I delayed exiting until I had tied it to a hook near the roof of the cabin. The water was not too cold, and we all stood around looking at the plane, tilted slightly, with one pontoon resting on a rock. Marsh got the bright idea of inflating the gas-charged life vests inside the punctured pontoon, after bending out the sheared aluminum in the float. This could displace enough water to float the plane. With the help of the loggers at the nearby camp, a crib was built around the rock to provide leverage for lifting the plane off the rock. This proved successful, and Marsh planed it over to a nearby sandy beach, where repairs were attempted with parts brought in by a mechanic on another Beaver, summoned to our rescue.

Almost complete Fourth River timber crib dam.

We all flew out in the late afternoon on the second Beaver, after Al had looked over the work. Work on the damaged Beaver continued next day by patching the gash with aluminum sheets, and attempting several times to lift off. However, the gap in the patch could not be sealed completely due to distortion of the aluminum float plates by the rock, and sufficient water was forced into the float to prevent take-off.

Eventually, Marsh decided to again inflate the life vests inside the damaged float, remove all unnecessary weight in the plane, including half the gas, and he managed to take off on the second attempt. The co-pilot and mechanic were rescued by another Beaver.

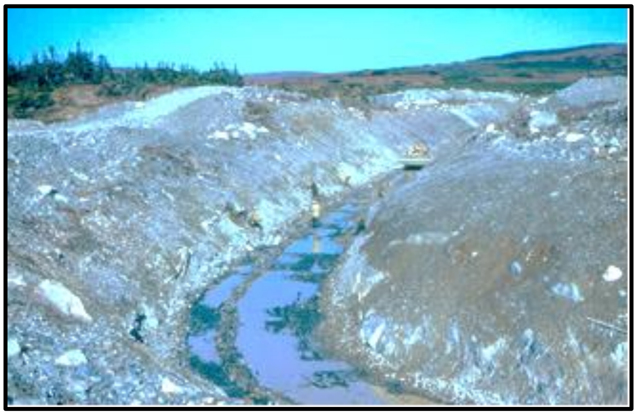
1.2m^3 dragline excavating canal from 4th pond.

The canal work progressed well, until I asked the surveyors on the third canal, how the work was coming along. The surveyor replied that it was easy, with the setting out stake level being the same as for the previous two canals. This puzzled me, since the canals should be dropping in elevation, so I looked at the drawings, and discovered that the starting level for all the canals was identical, a fact which had not been detected with each canal having its own drawing. I immediately got on the radio to Al and tried to explain the situation, difficult since Al was an electrical engineer, so he asked me to come down to his office. The next day I tried again but with no success, Al noted that all the drawings had been signed by Jack Sexton, the Chief Civil Engineer, and therefore must be correct - a junior engineer just could not challenge this experienced engineer. I asked if I could phone him or at least write a letter, all rejected. So I returned up-country and completed building the canals. However, I told Joel the contractor that we would not be surveying for final quantities but instead I would approve a progress payment based on the theoretical contract quantities. When Joel asked why, I told him that we would be re-excavating all canals below Second Pond, and would survey the work for final payment after this was completed.

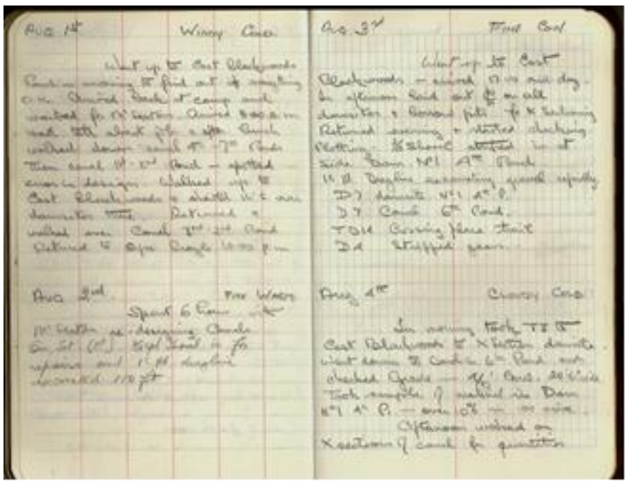
Jack Sexton arrived on 1st August to look over the almost complete work. We started on the first canal, and proceeded downstream. At the third canal, I casually mentioned that the starting level was the same on all canals. Jack immediately saw the implication, and asked why he had not been informed. I walked away and let Al answer as best he could, and Jack stormed off to cool down. When he returned, he said we would go to the engineering office in Cape Broyle, after looking over the remaining work.

We spent the next day re-designing the canals, a task I had already undertaken. Jack went over my work, pronounced it correct, and advised that a set of revised drawings would be issued from the Montreal office the next week. We completed the re-excavations in October and the project cost about doubled. Joel was very happy with all the extra work at unit prices quoted for a much smaller volume, but our client Newfoundland Light and Power was not happy at all. Fortunately, in the re-design, a way was found to increase the diversion flow, compensating somewhat for the extra cost.

I had made a fortuitous mistake in setting out the level for the Fourth River spillway. It was a foot too high. Normally, this would have required cutting down the crest level. However, when the hydrology was checked by the staff in Montreal, it was found that the higher crest allowed more flood waters to flow back upstream into the reservoir at East Blackwoods reservoir, thereby increasing the volume of captured waters, and hence the generation.



Canal nearing completion.



My log book from 1-4 August, mentioning J. K. Sexton, with a sentence in his writing on August 2.

Trepassey – could be 1930, old puffer, no hydro lines!

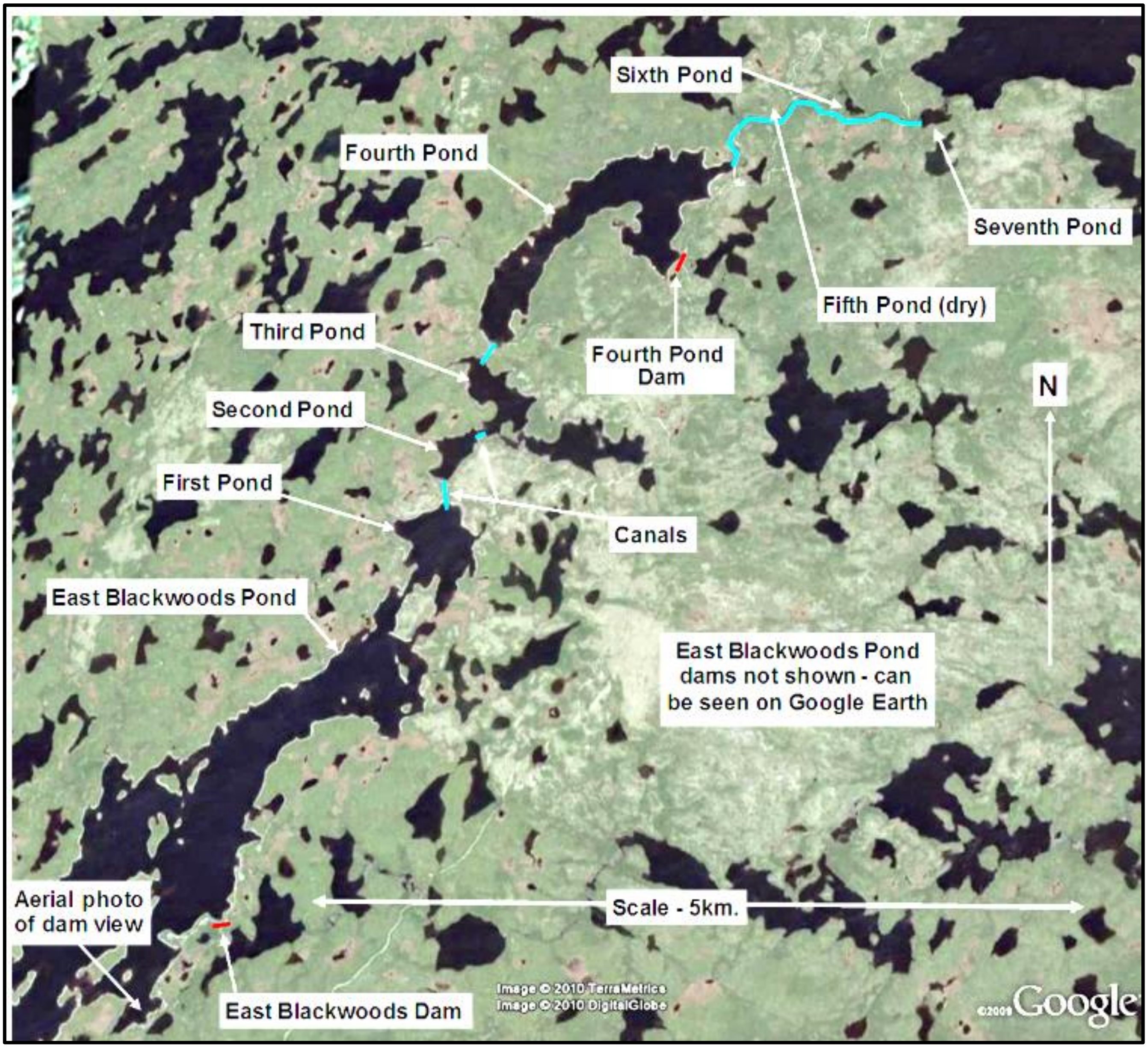
There was not much to do on the alternate weekends when I stayed in Cape Broyle. One Sunday, I persuaded Al Cameron to lend me the Land Rover, and I drove south over the single-track gravel road as far as Trepassey, stopping to take a few photos on the way. This was long before there were any services in the area, so I had to pack lunch and a thermos of coffee. Now it is a double lane paved road, and a favorite among tourists circling the peninsula.

In September, we rented a Beaver and flew camp supplies and two tents along with a small survey crew into the next watershed to survey diversion of the Northwest River. Over 2 days, we profile-surveyed all the damsites, and walked out on the third day, carrying levels to locate the best route for another series of canals.

Land Rover on road to Trepassey.

Camp at Northwest River.

Fortunately, the weather was excellent, with warm sunny days and no rain; otherwise the camp would have been quite miserable and uncomfortable. We abandoned the camp, since it proved too expensive to rent the Beaver to carry it back. The next week, John Cavanaugh and a friend hiked in to claim and recover it – everything including cots, blankets, tents and Coleman stoves a few days later. Jerry Boyle, my assistant, graduated in May 1954, and took over the work at Northwest River for the next year.



Google Earth image of dams and canals. The Crossing Place and NW River are not included since they are located in a poor resolution area.

When I returned to Montreal in November, Jack asked me to come into his office, and enquired about my previous hydro experience. When he found out about my hydraulic model work and my thesis on flow, he mentioned that all future hydraulic work in the office would have to be checked by me, and I would have to initial the drawing, a promotion for a very junior engineer which annoyed the more senior engineers in the office when they had to bring their drawings to me for signature!

I had enjoyed my work in Newfoundland, it proved to be the first of many trips to the province.

Alphonsus Heffernan (plant operator at Cape Broyle.), Jerry Boyle (student engineer), me and Cecil Vivian (Operations manager for Newfoundland Light & Power.) After finishing an inspection of the completed project in late October, 1953.

5. LABRADOR 1954-6

My next assignment was in Labrador, where I spent 3 summers on survey work and road construction. The work was for the British Newfoundland Corporation (Brinco) on the Churchill Falls project, (previously called the Hamilton River Development) where Brinco had contracted the survey work for the storage dams to Montreal Engineering (Monenco), and for the powerplant area survey around Churchill Falls, to Shawinigan Engineering. Brinco was in the process of commencing development of the enormous 5,225MW Churchill Falls project. The project was so vast, that a few words of introduction are necessary.

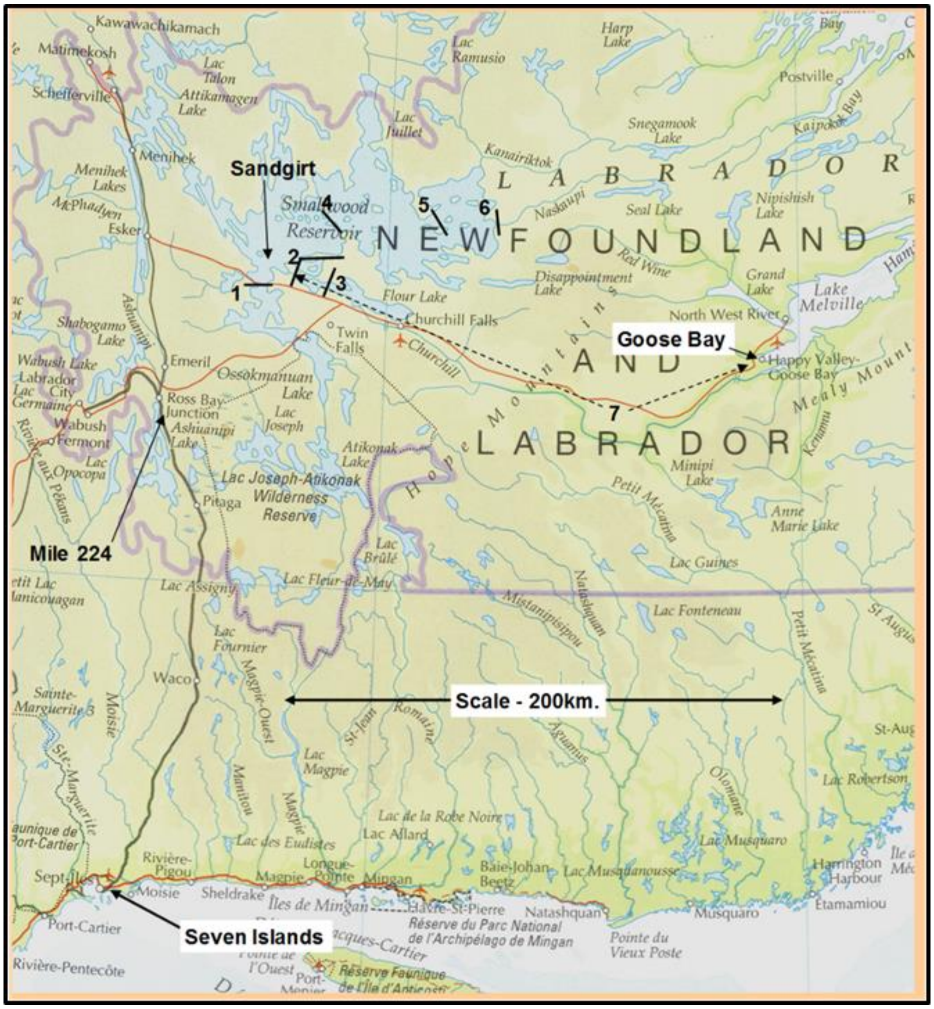
In 1952, Joey Smallwood, Premier of Newfoundland, with the assistance of the Rothschild banking company in Britain, formed the British-Newfoundland Corporation to develop the hydro and mineral potential in Labrador. Next year, they engaged the services of Denis Stairs, the president of Newfoundland Light and Power, and a vice-president of Montreal Engineering Company to undertake an initial assessment of the hydro potential at the falls. Stairs, in a 10-page report estimated that the potential was at least 4,000,000HP, but extensive surveys would be required to more accurately estimate the potential and cost.

After much discussion within Brinco, the initial estimate of $100,000 for the survey work was expanded to $3,000,000. Montreal Engineering was contracted to survey the drainage area above the falls, Shawinigan Engineering to survey the area around the channel diversion and the falls, and the underground powerplant. Both companies were to cooperate on the production of a pre-feasibility report. It was, the largest hydro survey ever undertaken in Canada.

At this time, there were no maps of the area, with the Canadian maps showing inland Labrador as a blank area described as “Unexplored territory”. So, the first task was to determine the approximate drainage area, accomplished in the winter month of March 1954 by a 10-man team based at the Menihek powerplant construction camp, and at a tent camp by Lake Mitchikamau, now called Smallwood Reservoir. Monenco engineers Art Demers and Hugh Watson were included in the team. With the help of precision barometers and Beaver aircraft, daily expeditions out over the tundra indicated that the drainage area could be about doubled by diverting the vast Michikamau Lake inflow with a canal into Lobstick Lake and a dam on the Naskaupi River.

A storage dam at the Lobstick Lake outlet would control the flow, discharging water into Flour Lake, and then Jacopie Lake where a diversion dam would direct flow into a 50km-long series of lakes and canals to the north of the river, to a forebay dam south of Sona Lake about 20km downstream of the falls.

There an intake and tunnel would convey the water down to an underground powerplant, and out to the river through a tunnel.

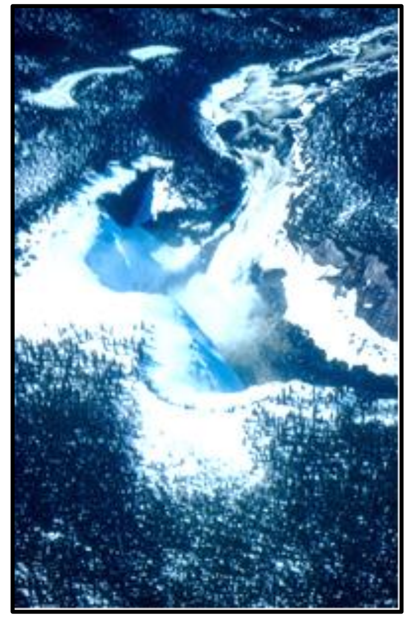


Project and survey location.

1. Gabbro Lake outlet.
2. Sandgirt Lake and Lobstick Lake outlets.
3. Flour Lake damsite.
4. Michikamau canal site.
5. Mitchikamau Lake outlet.
6. Orma Lake outlet.
7. Level transfer from Goose Bay.

The flow regime was very complicated, with Michikamau, Ossokmanuan and Sandgirt lakes all having two outlets, which flow at varying rates depending on the seasonal lake level. So the best way to describe the project hydraulics is with a schematic, shown on the next page.

On our May flight to Sandgirt, I asked to pilot to fly over the falls – very impressive.

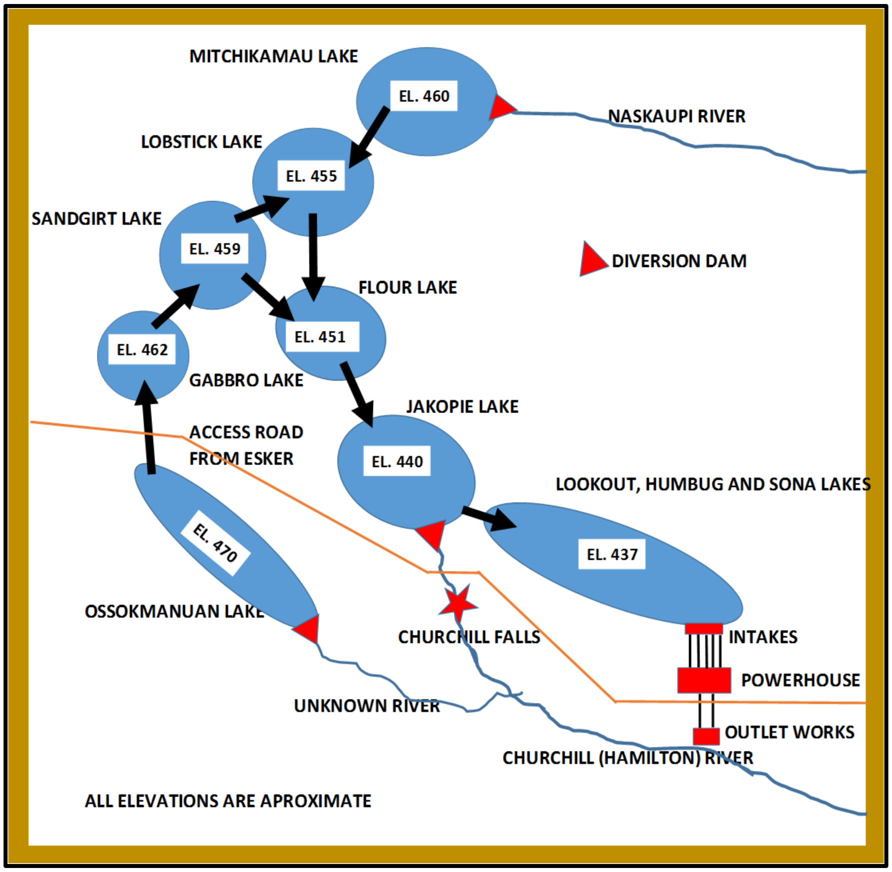


Since the potential was still unknown, the terms of reference for the report were to determine the cost and project arrangement for 4 capacities of 1 million to 4 million horsepower with interim reports each spring, and a final report in April of 1957.

With no maps, high level aerial photos were obtained from Ottawa, assembled into a mosaic, and the probable drainage area was outlined on a drawing overlaid on the photos. The potential dam sites were added, and plans made to undertake the survey work.

The site was really remote, with the only access by float plane. Access to the site was by Trans (TCA) Canada Airlines to Seven Islands on the north shore of the St. Lawrence River, then by Iron Ore Company supply train to a trans-shipment base camp at Mile 224, (the rail mileage from Seven Islands). From there we travelled by Beaver to the survey headquarter camp beside Sandgirt Lake. There was an agent in Seven

Islands called Georges Blouin equipped with a radio, who relayed all messages back to Montreal. He also ordered all our supplies and arranged transportation. He owned a general grocery store and the Seven Islands Hotel where we stayed overnight when in transit to and from Montreal.



Schematic of project flows.

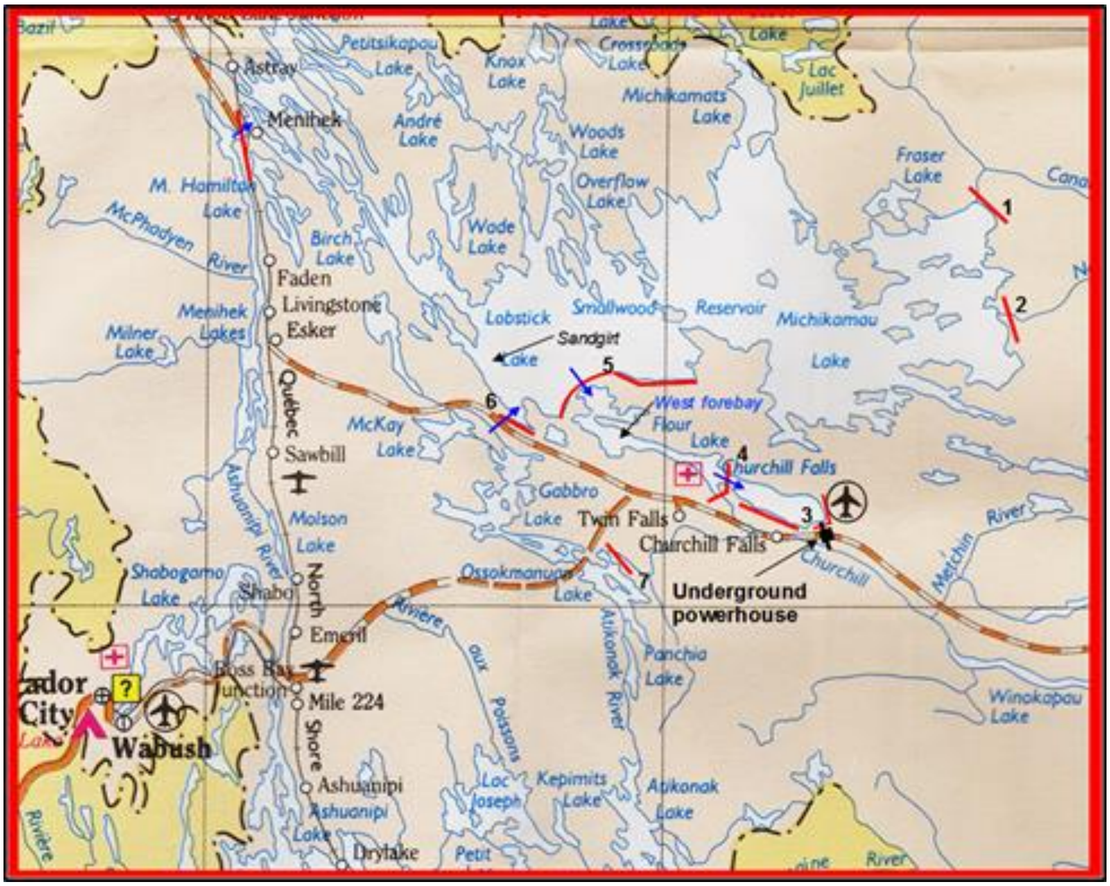
We took over an abandoned weather station at Sandgirt Lake (now flooded) as headquarters, manned by the Meco resident engineer Art Demers. There were four outlying survey tent camps, headed by Hugh Watson, Tom Myles, Hugh McDonald and myself, each with about 18 to 30 men. Another mobile team headed by Haruo Kawai, a final year engineering student from McGill University in Montreal, assisted by 3 students, 3 axemen and a cook. They were fully equipped with a portable radio, camping supplies and four large freight canoes with outboard motors and tents for the survey crew. Their assignment was to bring level data up from sea level at Goose Bay and tie all the camp levels together.

I landed on the ice at Sandgirt in May on a ski-equipped Beaver De-Havilland plane, just in time to stop dismantling of the furnace in the dug-out basement below the bungalow weather station building. It was thought that it would make an ideal cold storage room for the food. However, I reasoned that there would be no need, since all food would be in tins or sacks of non-perishables, based on how the Newfoundland contractor had operated a kitchen the previous year at Blackwoods. We managed to get the furnace working, and it was a welcome comfort. Unfortunately, I was too late to stop destruction of the bathroom, and it was converted into the radio room. The new toilet was a two-holer excavated nearby in the bush with the usual shack, and a bath could be had in the lake, once the ice melted! Later, a cold shower made from an oil drum mounted on four log posts with a valve, shower head and a canvas screen provided an alternative to the lake.

Dave Dick (Scottie) – in the radio room at Sandgirt.

Sandgirt – 2 storage sheds in middle.

At the outlying camps we had large Marconi radios powered by a car battery which had to be sent over to Sandgirt for recharging on a small Onan gas-powered generator. The generator was also used for lighting at Sandgirt. The radios were installed in all the camps by Ross, an engineer from Monenco, including the camps down by the falls, operated by Shawinigan Engineering. But we found them to be very unreliable, useless during the day, and only just acceptable in the evening.



Project structures – as finally built in 1965-70. 1. Sail Lake dykes. 2. Orma Lake dykes. 3. East Forebay dykes and spillway. 4. Whitefish control structure and Jacopie spillway. 5. Sandgirt and Lobstick dykes, Lobstick control structure. 6. Gabbro dykes and control structure. 7. Ossokmanuan dykes and spillway. The road from Wabush, the Trans-Labrador Highway, was built in 1992.

We needed some form of emergency medical help, since there were about 120 men scattered around the 6 survey crews. Brinco managed to find a third-year medical student, Joe Stipek, who was also an amateur radio operator. He arrived at Sandgirt on a Beaver at dusk, and immediately asked where to find the radio. He started to unscrew the back, over Art's protests, removed a valve and attached a small black 3cm cube. He then turned the radio around, switched it on, waited for it to warm up, and started calling "CQ, CQ, this is Joe at Victor Alpha George calling Victor Delta Harry" and immediately a woman's voice answered "This is VDH, hi Joe, all OK? over", to which he answered "Hi mom, just arrived at Sandgirt, all fine, over and out" He had spoken to his mother in Hamilton, over 1,700km away within a few minutes of arriving, while we had difficulty speaking to the camps, only a few miles away! He had certainly proved his competence to us all

The only other person hired by Brinco was ex Scots Guards Dave (Scotty) Dick, a Glasgow policeman on loan for the summer. It was his first time overseas and the Canadian bush was quite a contrast to living in Glasgow. His services were never needed, so he made himself useful on radio watch and checking the incoming supplies for alcohol. He did find a few boxes of beer, which were promptly shipped back to Mile 224. He told me he once had to dive for several boxes thrown off the Beaver into the water on the opposite side to the dock.

We had no experience working in the bush on such a large scale. In early May, a DC3 on skis had dumped all the camp supplies on the ice near the selected campsites, mine being at Flour Lake. A small group of Newfoundland loggers had stockpiled some wood, built a log platform supported on tree stumps about a meter off the ground, piled all the supplies on the platform and covered it with a large canvas tarpaulin, a few weeks before we arrived.

I arrived at the platform along with the advance camp crew on a Beaver. It was evening, and all we could do before darkness, was to burrow into the pile and wait for morning. Next day, we had to find the food supplies and tents, set up a temporary cookhouse, and start building the camp. It was expected that this would require about 2 or 3 weeks, but the Newfoundland loggers, experienced in such tasks, had the camp up and running in 3 days, with all tents on log platforms, and we were quite comfortable. The main contingent of loggers and students arrived on Beavers equipped with skis over the next few days in mid-June.

Evening departure for tent camp.

Lunch on the first day – supplies piled in background. Tom Janes, Aidan Ryan, Ray Gosine and Jim O'Brien. Bottom – Bill Harvey, John O'Brien, Pat Aylward.

My crew consisted of 3 instrument men, 4 rodmen, 4 sawmen, and 4 axemen from Newfoundland, 2 cooks from Montreal, and 1 draftsman, for a total of 19. The sawmen were equipped with reciprocating gas-powered saws, since chain-saws were considered too dangerous. We all had 4-man tents, and everyone had a summer sleeping bag made in Montreal. It proved to be far too thin, so blankets were added. I had a 2-man tent to myself, with a spare cot for visitors. Each tent had a wood stove, and it was not a question of keeping warm, but the opposite, that of trying to avoid excessive heat in the tent from the hot round and heavy cast iron stove burning green wood. There were four large tents for dining, cooking, kitchen supplies and the office. We had a cook and helper, and they soon had the kitchen operating and all well fed.

Me, ??, Scottie, Joe Stipek and Tom Myles at Sandgirt

However, I had considerable trouble with the cooks. They usually had a few lengths of copper tubing which was used to make a still hidden in the woods behind the camp. When the whole crew was out surveying, the cooks had the camp to themselves for about 8 hours, and used the time to produce some powerful home brew from potato peelings. We would often return to find the cooks high as kites, and on one occasion, swimming and laughing in the cold water around the dock. We went through 3 cooks and helpers before finding a reliable pair.

Airing out the sleeping bag, blanket, sheet and towel.

The tents proved to be quite inadequate. No fly cover, and made of untreated cotton. They leaked at all the seams, so mold soon began to appear around the floor. They were manufactured locally by sub-contractors to Pascal, a hardware store in Montreal! We had written a specification, and purchased the lowest-cost tents – a mistake. Next year we all had silk tents made by Woods, a well-known outdoor hunting equipment manufacturer.

We had about 3 weeks waiting for the ice to melt on the lake, so that we could float the canoes and get to work. I asked the loggers to set up a stockpile of wood for the stoves, since we could not spare time when surveying, and build a secure bear-proof shack for storing the food. They managed to accumulate a huge stockpile of wood, most of which likely floated off when the reservoir was flooded many years later. However, the breakup lasted about a week longer than expected and we started to run out of food. The loggers saw this and suggested that they go hunting and fishing, and within a few hours they placed about 30 large lake pike on the cook's table. Flour Lake had never been fished, and the fish were hungry after a long winter under the ice. Next day, they brought in an old caribou, tough meat, but wonderful in a stew!

Caribou stew for dinner! Cyr Couturier and Charlie Gilbert.

Brinco had set up an excellent supply chain. Orders for food and other supplies were radioed in to Sandgirt, Art's team would write up purchase orders, and these were radioed and mailed to Georges Blouin in Seven Islands. If Georges did not have the item in his store, it would be ordered and flown in on the regular Trans Canada Airlines DC3 passenger service from Montreal. Twice a week, the orders were loaded onto the North Shore and Labrador Railway passenger-cargo train and sent to Mile 224, where Brinco operated a winterized base station at an abandoned railway construction camp. It had a railway siding, electric power from 2 diesels, a paved airstrip and a seaplane base on an adjacent lake, along with accommodation and meal facilities for about 20 men. From Mile 224, the supplies would be loaded onto a Norseman and flown to Sandgirt, since the Norseman could carry about 2 Beaver-loads. At Sandgirt, the supplies would be checked and distributed to the camps by Beavers.

As soon as the ice melted, we floated the 4 large freight canoes equipped with 10HP outboard motors. Over the summer I managed to become reasonably proficient in their operation, even in quite stormy weather.

Camp at Mile 224 – runway, buildings and tents in far distance.

None of the Newfoundland loggers could swim so we distributed small plastic bags containing an inflatable life vest. Inflation was by pulling a sting to puncture the cap on a canister of compressed carbon dioxide. Very fortunately we never needed to use them. At the end of the summer, Charlie Gilbert decided to see how they worked and pulled the string – nothing happened! Of course, all the others did the same, and of the 20 packets, only one inflated! Next year we had the standard kapok floatation vests. Charlie was particularly distressed, since he couldn't swim, and had depended on the vests.

View of first camp – helicopter pad on left.

Work consisted of determining the exact elevation of three easily identified points on each aerial photo. The photos had been taken on a fly-over near the end of the breakup, and provided our reference for all the summer's work. With a 60% overlap, there were 9 points on each photo, all used to provide topographic maps of the area at the end of summer.

On the way to work – camp in background.

Top – Charley Gilbert, Roy Gilbert and Bill Harvey.

However, the photos did not arrive, so we had a few days free after the ice melted and we decided to explore the area. We had no idea where the dams would be, since the topography was relatively flat. Also, with no maps, we did not know where we were – just camped on the edge of a large lake in the middle of Labrador in a white area on all maps of Canada! There was a high hill off to the east on the other side of Flour Lake, so we decided to climb the hill for a better view of the country. We crossed the lake in 2 canoes and set off towards the hill, marking our way with blazes on the trees.

After about two hours of walking, we were surprised to encounter another crew from one of the other survey camps heading back to the lake. They appeared to be in a hurry, and were reluctant to talk. So we continued on, and soon spotted a forest fire up ahead, the reason the other crew were heading out. They must have accidentally started the fire on their brew-up.

After some discussion with the Newfoundlanders, we decided to continue in to the fire to see if we could put it out, since the season was early, the ground still wet, and the fire seemed small. On arriving at the fire, we walked around it and saw that it would be contained on three sides by swamp, and only needed extinguishing over a relatively short stretch where it could easily spread into denser forest. Without any instructions, the Newfoundland loggers immediately started to cut a fire break through the trees, and showed us how to beat out the flames with branches. After about an hour of work, it was out.

In our office – checking plan of survey line.

We decided to rest, watch the embers and have lunch. I tried to see how far we had come on our expedition to the hill, but was disappointed to find that the hill was still far away, and we would have no hope of reaching it before dark. With no overnight supplies, we had no choice but to return to camp. That evening I had a call from Art enquiring about a forest fire in our area – he had seen it from Sandgirt. I proudly told him that we had managed to put it out, but in return got a lecture on leaving fires alone! - just too dangerous to tackle with no proper equipment.

Our second camp.

It was essential to obtain very accurate elevations for the photogrammetric work, and Art devised a foolproof method we all used. Every level-man had 2 rodmen, one with a 16 foot rod, and the other with a shorter 15.5 foot rod made by cutting off 6 inches from a normal rod and re-fitting the brass end. The level was sighted on the rod, the rod was reversed, and another reading taken. The two readings had to equal the rod length, and this was checked at every point. The same procedure was undertaken with the shorter rod on another point, and totaled. The two readings for the instrument level had to be equal, and if not, the whole process was repeated. Each evening all the instruments were checked. This process proved to be so accurate, that when the Churchill Falls development was being built 15 years later, the new surveyors tried to check into the benchmarks we had set with steel rods concreted into bedrock, all over the vast project area, and could not consistently tie into the same data. I got a call from their chief surveyor Bill Steel in 1967 and was asked how we had done the survey, I told him, and he replied that they were always within a foot higher or lower than our elevation. Eventually the consultant, Acres Canadian Bechtel of Churchill Falls decided to build the development to the datum we had established in 1954-5

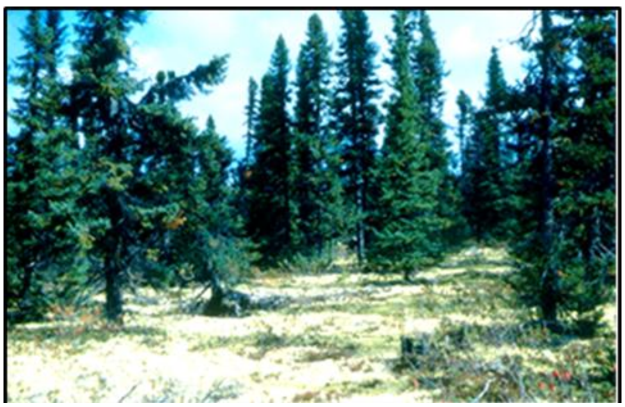
Haruo Kawai brought the level datum up from Goose Bay and tied together all the levels at the various camps. He was forever traveling around in 4 large canoes, taking readings over water to transfer levels from one side of a large lake to the other. This could only be undertaken in a dead calm, usually in early morning. Readings of the water level were repeated at 15 minute intervals for about 2 hours, and averaged. He then marked the level on an exposed nearby bedrock point, to be picked up later by the camp surveyors. Haruo's engineering students couldn't believe their good fortune at finding a summer "holiday" job, being paid to paddle around in canoes. Later Haruo joined Montreal Engineering, and after retiring is now an actor portraying a distinguished Japanese businessman. He can be seen in "The red violin" and about 20 other movies.

About a month after we started the surveys, a geologist named Ted arrived to map all the surface bedrock exposures. He shared my tent, and in the evening he spent most of the time sharpening a large axe with a whetstone. While he was doing this I told him that he would have a guide with him at all times, since nobody was allowed to work in the bush without a "buddy" for safety reasons. He objected to this, and was adamant that he should be allowed to work alone. I relented, but next day I got hold of Carl, an experienced logger, and told him to keep his distance, but to keep Ted in sight at all times. This he did, but on returning in the late afternoon, told me that Ted had acted strangely several times. When Ted started sharpening his axe again in the evening, I asked him what the axe was for, since such a large axe was not really required in the bush. He replied that "It's for the Russians", which alarmed me to no small extent. Further enquiries elicited the information that he had worked for several mining exploration companies, and knew the precise location of every uranium deposit in Canada, information he was convinced the Russians were after. So I got on the radio and told Art I needed to see him next day on a personal matter, and could he come over, or send some transport. I arrived in Sandgirt, explained the situation, and Ted was shipped out to a hospital in St. John's when he had completed his work at Flour Lake a few days later. I heard that he was there for several months, and fortunately he recovered completely.

After a severe rainstorm – drying out the office.

Early in August, we had completed our work surveying the damsite at Flour Lake, so the camp was moved to a small lake south of Lobstick Lake, where we surveyed another line eastwards to connect with a line being surveyed by Tom's crew. This would complete a 139km circuit, so we were very anxious when I called Tom Myles on the radio to find out the level of his benchmark we had tied into at the end of the line. Our level was within 0.01ft of Tom's level, demonstrating the accuracy of Art's leveling methodology.

Fortunately we only got lost once. It was on the return from our last survey down the line to intersect Tom's line. Our line had a dog-leg, and we had to walk at least 4 miles back to camp. I thought that we could save some time by cutting off the corner in the line, and walk straight across through the bush to camp, mostly easy walking through widely-spaced trees. We had aerial photos of the area, so off we set, on a wavy line avoiding lakes and swamps. After about a half hour of walking, we reached the shore of a lake which was not on our route. We realized we were lost, and everyone had a different suggestion on which direction we should proceed. However, I insisted that we sit down and identify the lake from our aerial photos. I distributed the photos among the crew, and we all looked at the lakes on the photos and at our nearby lake, looking for a match. After a short while we realized that our lake had two large rocks in the middle, which must be clearly seen on the photos, and shortly after, we saw where we were, about a quarter mile off our projected route. A new rout to camp was identified and we all set off, this time being careful to identify the lakes as we passed, and arrived at camp about an hour later.



Typical local forest cover – widely spaced spruce trees, with caribou moss on ground.

We had a small air force on the job. Two modern Beavers, an old fabric-sided Norseman, and one Bell 47G helicopter. It had a pilot plus 2-passenger bubble cockpit and an open tubework tailboom. But it was very delicately balanced. With 2 in the cockpit, the battery was mounted just in front of the engine, and with three in the cockpit, the battery was moved to a position about one-third down the tailboom. One day we had to move a canoe out to a camp at the south end of Lake Ossokmanuan, and I went along to guide the pilot. It was a long trip, so we started with a full tank of gas. About half-way there, I had to change maps, leaned over and the helicopter tilted dangerously forward, the pilot immediately grabbed me, pulled me back and said “don’t move”. Apparently sufficient gas in the tank behind the rotor had been used to disturb the balance, and the pilot had gradually been moving the rotor tilt stick back to compensate, reaching the limit without realizing his position. A landing spot on muskeg was found immediately ahead, and we descended in a shallow dive. After landing, the battery was moved to the rear position and we took off without further incident.

Every 3 or 4 weeks, I would fly into Sandgirt for a progress meeting with Art on a Sunday, sometimes staying overnight. During one of these meetings and late in the afternoon, an old Norseman aircraft landed at Sandgirt, and the pilot asked if we had any work for him. The pilot had just completed training, and only had small scale maps of the area whereas our camps were all located just inside the “Unexplored territory” white zone. The pilot mentioned that he had great difficulty finding us, and was running out of fuel when he spotted the red roof at Sandgirt. However, we had a contract for all the aircraft work and could not offer him anything. He stayed overnight and tried to take off next morning with no success. The Norseman would not lift off. I watched his attempts and one of our Beaver pilots came down to stand nearby. I asked why he could not lift off, and the pilot told me that the floats in the old plane leaked, and that they were now half full of water judging by how low in the water the floats were riding. The pilot had insufficient experience to see this and pump them out before take-off. So I asked him why he had not told the Norseman pilot, and he replied that he had to learn a lesson. After about 4 attempts at takeoff, the Norseman pilot returned to the dock, and asked if he could use the radio. He called his home base down in Seven Islands, and was advised that a mechanic would come on the next train to Mile 224, where he could get a lift to Sandgirt. However, after lunch, our pilot told him what to do, and he took off shortly thereafter.

Sandgirt meeting – Tom Myles, Art Demers & me in Art's office at Sandgirt.

Very fortunately, we had no accidents, nobody contracted any colds or other illnesses, and the weather was reasonable, with only a few days lost due to rain.

PBY Catalina at Sandgirt – September 1954.

When our work was completed in September, Brinco rented a large PBY2 Catalina flying boat from Eastern Provincial Airways to ferry the men out to Seven Islands, where it landed at the airport. The operation was very successful, since it had a seating capacity for about 42, so two flights evacuated most of the staff. After locking everything up at Sandgirt and storing all equipment in the two sheds, the remaining staff left by Beaver a week later.

Churchill was the last major survey undertaken in Canada with traditional ground surveyors in virgin unmapped territory. Now surveyors are about extinct, and surveys are aerial, using satellite electronic positioning, with radar signals, and with nobody on the ground! There is a photo of a surveyor with a satellite dish and computer in the chapter on Shikwamka dam.

6. LABRADOR 1955

Over the winter back in Montreal, I worked on the report for the Churchill project storage structures, concentrating on the design of the large canal between Michikamau and Lobstick Lakes. However, the work could not be completed, since we lacked some information, so it was back to Labrador in 1955.

In January we heard a rumor that our stores, left in the two large sheds at Sandgirt, had been broken into, so I went back in March to take an inventory. With very cold weather in Labrador, I decided to purchase wool underwear. I went to Eaton's, a large department store in Montreal, and asked for the thickest winter wool undershirts and long-johns they had. Unfortunately, at the end of the winter season, all such stock had been sent to storage, so I ordered 3 pairs and was asked to return in a week. This I did, and found I now owned some thick pure wool Stanfield's underwear, very warm, but itchy!

At the end of March, I flew to Seven Islands, stayed at the Seven Islands Hotel, dined with George Blouin, and next morning got on the Iron Ore Company train to Mile 224. It was a long freight train, with two passenger cars at the rear, one of which was converted to a dining car with a long table down the middle. With about 50 freight cars ahead, and with the rail track partially covered with snow drifts, the three diesel locomotives with a large snow plough in front, had a hard time charging through. The engineer would sound the whistle before each snow drift, speed up and hit the snow as fast as possible. At this, the couplings on the 50 freight cars behind would compress and with the passenger cars at the end, we would have to brace for a severe jolt. Not a comfortable ride. It took about six hours to reach Mile 224, so there was a lunch at mid-day consisting of a meat stew, potatoes, and apple pie. All the other passengers were French, so I had a hard time getting served, but soon learned to say “passez du pattate si vou plez”, my first words in French, hunger was a good incentive!

IOC supply train. 3 locomotives pushing snow plough.

Passenger cars at end of train.

Arriving at Mile 224, I was met by the Brinco site manager and driven over to the camp. Next day I flew out on a Beaver to Sandgirt with Jerry a cook, and a helper, settled in, and took an inventory of the stores. Fortunately all were still there, and there was no sign of a break-in.

On returning, I was held up by a winter storm at Mile 224, and while there, we received a message from the winter camp near Churchill Falls where a crew was installing a cable across the frozen river to be used in a gauging station.

At Sandgirt, and glad that the furnace in the basement is working!

Photo taken through Sandgirt window at -30C.

When the long heavy cable was being lifted up off the ice by a hand operated winch, the tooth engaging the gear wheel had not set properly so that the winch handle had rotated back and smashed the jaw of the operator. The Beaver pilot asked me to accompany him on a flight to the camp, in the middle of the snow storm. We took off across the runway, the cross wind being so fierce. My task was to look out for ice on the right wing, while the pilot watched the left wing. We landed without incident on the Churchill River and the patient was brought out on a stretcher with a friend, who accompanied him to the hospital.

The pilot asked me to stay at the camp, since he did not want to add any extra weight to the Beaver in case of ice accumulation. The camp proved to be quite comfortable despite the -20ºF (-29C) below zero weather.

Gauging station tower.

The large sleeping tent was covered with another tent, with an air space of about a foot in between to provide some insulation. The outer tent had been buried in snow to the eaves, and there were two large stoves, one at each end, which were continually stocked with wood by one of the workers on night duty. A similar tent about 30m away was used as the kitchen and dining room. The 30m separation was a fire precaution. There the two cooks slept and worked, again with two stoves continually burning. The pilot returned the next day, and I traveled back to Montreal by train and plane.

In late June, the summer work crew was ferried in on a Catalina to land at Sandgirt Lake. The aircraft required about 6ft depth of water for landing, much more than a Norseman at only 2.5ft. We had undertaken a thorough search for rocks the previous fall and found none, so we had no problems. Unfortunately, a rock was missed in the lake used at the Shawinigan camp, so when the Catalina landed, it hit the rock, slicing open the hull and it quickly sank, fortunately in relatively shallow water. All the passengers escaped to stand on the wing to await rescue, but the baggage was thoroughly soaked. The Shawinigan radio operator happened to be on air ordering food at the time, and he excitedly described the sinking. When the pilot realized he has struck a rock, he had lowered the wheels after stopping, and in the shallow water, this was sufficient to keep the wings and engines above water. The Catalina was winched to shore where the hull was repaired. The plane was flown out a month later.

This time we were well equipped with silk tents and flys, except for the cook tents, still cotton from last year. We also had excellent Woods arctic sleeping bags, a bit of overkill, since they were good to minus forty! I had designed a new square compact stove with the stove pipes and legs fitting into the stove for transport. It proved very efficient, with much better control of the draft and heat.

1955 proved to be a perfect summer, with rain the day we arrived at Sandgirt, and none again until the day we left! The previous year I had gone through 3 cooks, all had built potato mash stills back in the bush, and were often far gone when we came back from survey work. So this time I told Art that I insisted on interviewing all cooks as they came off the plane. Eventually I found Sam after rejecting 3 cooks. Sam said he was the pastry cook from the Ritz Carlton Hotel in Montreal. I was very skeptical about his claimed experience, but after asking him to describe the hotel and the location of the staff entrance, I was convinced, and asked him why he wanted to work in the bush. He just wanted to get away from his wife for a few months in the summer! He proved to be excellent, but we all put on a few extra pounds.

First task – sorting equipment for the camps.

Lunch in the bush with Sam's dessert.

Our first camp – double cook tent behind canoe.

We carried lunch with us, and Sam offered the usual choice of ham, cheese, bologna or beef sandwiches, but always asked each man what he would like for lunch dessert the next day. We were each given a package wrapped in waxed paper containing either apple, peach, strawberry or blueberry upside-down pie.

This summer, our task was to set out and survey a route from Mile 286, later named Esker, on the North Shore and Labrador Railway to Churchill Falls. The rough location of the route had been established the previous summer by Bert Kehoe, an engineer from Newfoundland working for Brinco. Upon arriving at Sandgirt, I had reconnoitered the route to select the campsites, and found a perfect location beside a sandy beach, about half-way between Gabbro and the falls.

And we are PAID for this??

We had a small tent camp consisting of 5 two-man silk tents, three 12x10ft tents for the cook, dining room and office, a fourth tent was added later for stores, a canoe and a Bell helicopter. The crew consisted of 2 student rodmen, a student surveyor, 2 loggers as axmen to clear a line through the trees, a pilot Reginald Rivard, a mechanic Hugh, Sam and myself, for a total of 9. We moved camp once to keep within easy distance of the road.

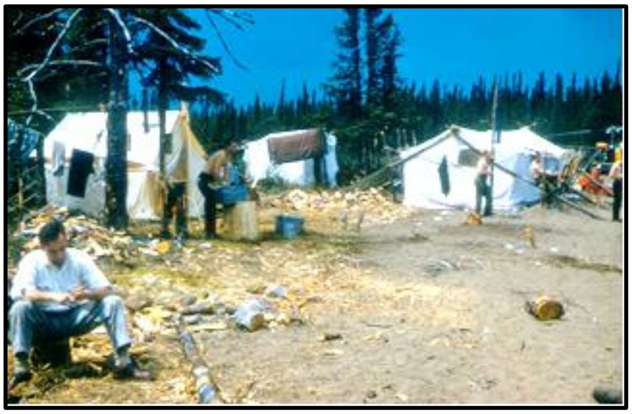
The canoes had to be ferried out to the survey camps, and we found that with a tailwind, a helicopter could carry 2 canoes if they were carefully balanced.

Hugh checking helicopter load at Sandgirt.

We were supplied by Beaver from Sandgirt, and Sam would give me a list of the required food every few days, which I forwarded by radio to Art at Sandgirt. Sam had never been in the bush, and after seeing the Beaver land with our supplies a few times, he asked what would happen if the Beaver crashed. I replied that this was very unlikely, and if so, we would get another. But he was worried, and without my knowledge increased his orders, and later asked for another 10x12ft tent for his "stores". I did not realize what was happening until we had to move camp – it took 4 beaver-loads for the camp, and another 4 for Sam's supplies! I think we lived on the stored food for the rest of the summer!

After the fire – al-fresco lunch! Clockwise – Emanon, Ken, Sam, Hugh, Reg, Cyr and Cy.

Sam could never light the Coleman pressured kerosene stove correctly. He always turned the needle valve lever the wrong way, and then threw lit matches at the cloud of vapor. Every morning we were woken with a loud bang when the vapor caught fire at about 6.00am. Eventually the inevitable happened and the cotton tent caught fire, Sam screamed and we all came running, the tent was gone, but we managed to prevent the fire spreading.



At camp on a Sunday – in perfect weather!

A few minutes later we got a radio message advising that the helicopter was grounded due to minute cracks being discovered in the tail rotors of similar helicopters.

A new rotor was on the way, but no transport for 2 days. We told Sam, and he prepared an enormous lunch feast which we enjoyed in the open, since the lunch tent was gone. A replacement tent arrived next day.

We lived high on the hog, with steak almost every night. A fact I was not aware of until Art called and asked why we had ordered a case of 48 tinned shrimp! We had been having tinned shrimp as an appetizer several times, this was the third case, and they were very expensive. Art advised that he would be keeping half the case, and that I could not order any more.

Our survey work consisted of blazing a trail on tree-trunks from Mile 286 to Churchill Falls, a total distance of about 100 miles. We had a rough route marked on aerial photos by Bert Kehoe, which we tried to follow, avoiding steep hills, muskegs and boulder fields. The boulder fields were produced by the glaciers that covered Labrador during the last ice age. I would walk ahead with one of the loggers to clear the sight line, followed by the surveyor Cyr Couturier with a transit to measure angles, the two student rodmen and the other logger. The rodmen also carried a tape to measure the distance traveled. We produced a plan of the route, with locations of rivers, streams, ponds, boulder fields and rock exposures. Often, I would use the helicopter as a sighting tool, asking Reg to hover over a known pond at a given time while Cyr took a shot, and again later when we had hiked a mile or so. In this fashion, I was able to locate the ponds relative to the road route using plane table survey principles.

On the trail – blazing trees and recording distance.

Reg would drop us all off early in the morning with 3 trips in the helicopter, usually at a nearby muskeg where there was a suitable clearing devoid of shrubs and trees. We had to reconnoiter drop-off and pick-up points in advance, since we did not have radio communication in the bush. It was difficult to estimate our progress, and often we were not at the assigned pick-up point. Reg had a duplicate photo map of our route, so he would then fly up and down the line until he found us, and then fly to the nearest open muskeg. We then had to find him! Once, when he was searching for us, flying very low, just at treetop level, he suddenly saw us directly below, pulled back on the stick to stop the helicopter, and lost some lift, so the machine dropped onto the tree-tops directly above us, we all scattered, expecting the helicopter to crash down amongst us. Fortunately, Reg regained control before any of the rotors hit a branch, managed to lift off and land nearby. When we arrived, he was still shaking, so we waited until he could fly again.

Another time, we lifted off early in the morning when the temperature was cool. Reg, Cyr and I were aboard, along with an extra 10 gallon tank of gas, which we were going to leave at our pick-up point for the day. Reg knew that we were close to being overloaded. We landed on a muskeg to review some problems with the route, where Cyr and I walking into the bush, to return over an hour later. By this time, the temperature had increased, and Reg was worried about lifting off. So he hopped over to the edge of the muskeg, to give him a longer run, we boarded, and took off.

In tent writing daily diary – large arctic sleeping bag on right.

Unfortunately, with no wind, we were overloaded for the higher temperature, and the helicopter just could not lift up over some trees on a hill at the opposite end of the swamp. We crashed into the tops, but Reg kept flying, seeing that the momentum would carry us over into a valley ahead, where he managed to get sufficient forward motion to lift up and out over the trees. We immediately returned to camp, and Hugh, the mechanic said we were quite a sight coming in with several tree branches caught on the underside skids. It took Hugh the rest of the day replacing bent oil pipes and other components, and mentioned that we were very lucky that none had ruptured.

This was not our only close call. At our second camp, the radio reception was very poor, since we had difficulty hearing Sandgirt. We decided to get some wire to extend the radio antenna from one of the abandoned construction camps beside the railway. By this time, the helicopter had fortunately been fitted with pontoons. I went with Reg, and we landed at a camp near Mile 286. Landing was difficult since the whole camp seemed to be crisscrossed with power lines and telephone cables. We found a landing spot on a road, got the wire and took off. Reg was worried about the wires, so he asked me to keep an eye on the right power line, and he would watch the left. A few seconds into our flight, Reg happened to look ahead, and saw a telephone cable directly in front, he immediately pulled back on the stick, the helicopter tilted far back, and we hit the line with the pontoons, broke it, and bounced down. Fortunately, the broken line did not recoil back into the rotor. We got out, pulled the line away, and walked far forward to see if there were any more lines across the road. Fortunately none, so we took off without further incident.

Our second camp at an abandoned mine drill site.

We had the occasional visit from senior engineers to look at our selected road route. Howard

McLean, the chief construction engineer and George Eckenfelder a senior project engineer both arrived on different days near the end of summer. Our standard procedure was to first fly over at a "high" level, some 500ft above the trees to see how we had avoided swamps, lakes and difficult ground. Then on the return journey, we would drop down to tree-top level to see the ground better. We were so low, that Reg would have to fly around the occasional taller tree! I would sit in the middle with our guest on the outside right seat. When we arrived at the end, at Mile 286 on the railroad, I would ask our guest to look right, which he would do as we passed over the rail line at a height of only a few feet. Invariably our guest would then ask why he had to look right, and my reply was always "to look out for trains!" George was not amused and told me to desist from such tom-foolery.

At the bridge site, at head of Churchill rapids

We never carried any survival gear, since the weather was always perfect. However, toward the middle of summer, when we approached Churchill Falls, the sky clouded over, and I decided that Reg should make an extra trip with a couple of tarpaulins and some food, and drop them off at our pick-up point. This he did and returned to camp to wait for the evening return flights. But the wind increased to gale force and he could not fly, stranding us for the night. However, we set up camp in the trees, and soon had a good fire going and the food heating. The tarpaulins were tied to trees for shelter, and fortunately it did not rain. Our only problem was we had forgotten some cutlery for eating the stew. This was solved by the loggers who quickly carved some sticks into flat spoons.

When we reached the end of the road at Hamilton Falls (now Churchill Falls), I had promised all the staff, including Sam, a pick-nick beside the falls. We were all dropped off by Reg on the snow bank opposite the falls and had an excellent feast with the falls roaring in the background. The snow bank was an almost permanent feature of the falls, accumulating over the long winter from spray off the water, and not melting until about September. On landing, one of the students went running down the snow-bank towards the falls, and did not return. I sent Cyr to look for him after about a half hour. Cyr returned, half dragging the poor student back. Apparently there are a series of small ledges dropping down into the gorge, and the student had run down, jumping down onto the ledge and so on until he decided to see where the next ledge was before he jumped. He was standing on the last ledge, and had almost jumped into the 400ft chasm, but fortunately had looked first. This unnerved him so much that he started shaking, sat down and could not move. Cyr had a hard time getting him to stand up and climb back. Of course, I called him a few names and gave him a lecture on safety.

Our last task at the falls; was to survey a proposed bridge site across the river about two kilometers above the falls. Fortunately there were flat bedrock outcrops on both sides, so the helicopter could land on each bank.

We completed the surveys in three days, and Reg lifted us all out. I remained for the last trip with the survey gear, and Cyr along with a student boarded the helicopter. The wind was blowing from across the river, so Reg took off over the white foaming rapids, and this time the engine decided to cough and rapidly lost power. Fortunately Reg managed to stagger back to the landing spot and bounce down, but it was touch and go.

At the falls – after I set the camera timer, I ran down, tripped and sat down to avoid sliding into the gorge. With the Churchill plant now in operation, the falls are almost dry!

Surveying the bridge site

The engine had never failed in the past, and Reg concluded that it must have been some dirt in the gas fouling the plugs. He cleaned them as best he could. He said the return trip from camp would be delayed a little, while Hugh changed the spark-plugs and checked the engine. Reg took off along the river bank in case there was another failure. Hugh was meticulous when gassing up, always filtering the gas through an old felt hat. Reg returned about 2 hours later with no further incidents. However on the first flight, on landing at camp, Cyr had to make a bee-line for the bush to throw away his underwear – it must have been a very frightening experience having a helicopter engine failure just above white water!

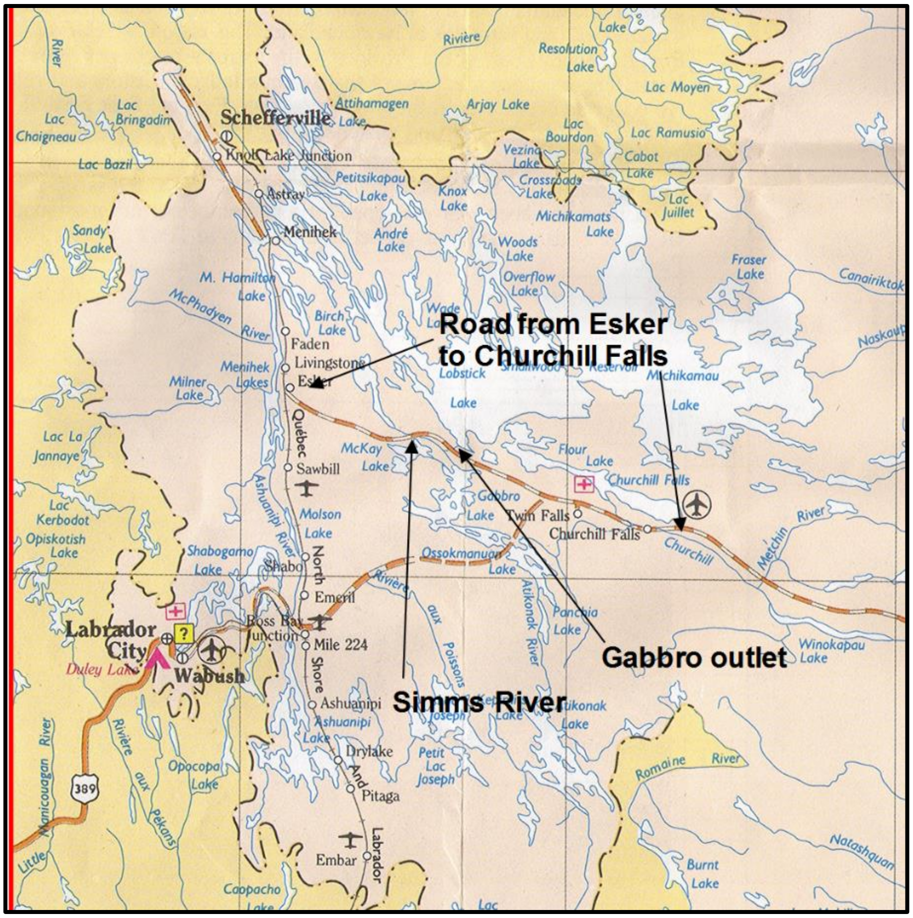
We all thoroughly enjoyed the long summer "holiday". Reg managed to survive, and I met him by coincidence at the airport restaurant in Sydney, Nova Scotia about 25 years later – he was working on the regular helicopter supply flights to the oil rigs out in the Atlantic. He was in the check-out line directly ahead, I recognized him, tapped him on the shoulder, and said "Hi Reg", needless to say he was quite surprised, and we caught up on old times.

7. ACCESS ROAD - 1956.

Next year I returned as resident engineer on the preliminary access road to Churchill Falls, in early June when there was still about a foot of snow on the ground, and three feet of ice on nearby Menihek Lake. It snowed again in mid-September, and the work was completed in early October. The task was to construct a preliminary "tote" road from Esker at Mile 286 on the railroad to the Gabbro lake outlet, and complete the road to Churchill Falls the next year. A tote road can be described as a very simple road trail through the bush, used to provide access during construction of a proper well-graded and graveled road.

June 8, Fred Clark, me and David Morgan-Grenville on Lake Menihek .

A target price contract at an overall unit price of $12,500 per mile had been negotiated with Mannix, a large earth-moving contractor from Alberta, well known to the company from work on the Calgary Power dams. The contractor's engineer was Alfred (Alf) Wright – we got along very well. He had spent a few days with us the previous year, flying over the route to get acquainted with the terrain and estimate the tote road cost.



Map showing road location.

The contractor had all his equipment off-loaded from the railroad at the new siding named Esker on the Quebec North Shore and Labrador Railway, where Brinco maintained a small camp and office.

Construction equipment included mostly D6 Caterpillar bull-dozers, some dump trucks, a couple of shovels and some Athey wagons, small wagons on caterpillar treads for pulling behind bulldozers over difficult terrain. The idea was to build a mobile camp of 2x4 timber framed, plywood-covered huts mounted on steel sleds, which could be hauled by bulldozers along the completed tote road. Camp construction took about 3 weeks while the bulldozers started to clear the route eastwards.

Alf and David at Esker. Assembling 12 ft. wide office and cook mobiles, with 20ft wide bunkhouses.

The two forward bulldozers would clear trees and remove the larger boulders. Another bulldozer would be their support, hauling a couple of tents for sleeping and cooking.

Mobile camp assembled at Esker.

The support bulldozer used the Athey wagons to haul fuel and supplies from the base camp. It was a rough life for the three bulldozer operators and their cook, but they managed, with no complaints.

Once the work got down to a routine, Alf and I, along with the surveyor, Fred Clark, an engineer just graduated from New Brunswick University, 2 rodmen and 4 axemen would take a Dodge 4x4 power wagon and drive out as far as possible and then walk to the end of the road clearing each day.

Forward bulldozers clearing trail.

My mobile office, radio in background.

I would walk ahead with Alf, with two axmen following, clearly marking the route with flags and blazes on trees. Fred would map the route with a transit and the other 2 axmen would cut a trail. We would roughly follow the previously marked trail and carefully avoid (as before) swamps, boulder fields and steep hills, even large boulders. We were told afterwards that the road looked as if it had been set out by a couple of drunken sailors!

I lived at the main camp, in a trailer on skids. It was about 12ft wide and 32ft long, with one end partitioned off into a bedroom which I shared with Louie O'Brien the accountant from Cape Broyle, who had previously worked for Al Cameron in 1953. The rest of the trailer was equipped as a field office where three summer students calculated and plotted Fred's survey work**.**

After clearing by the forward bulldozers, more bulldozers would cut a road grade, with the trucks and shovels used to place sand and gravel where needed. The contractor could build about a half-mile per day, and it took the whole season to reach the Atikonak River, at the outlet of Gabbro Lake, about half-way to the falls. After building about 10 miles of road, the camp would be hauled forward to a new site, a task taking up a whole day, since we had to dismantle power lines and re-attach them at the new site.

The survey crew.

Measuring water depth at a river crossing.

At rivers, we would build temporary bridges with timber cribs filled with boulders, and logs spanning about 10ft. The largest was at Simms River, which needed 6 cribs to cross. It was washed out in the next spring flood, after lasting less than a year, and was re-built with steel culverts. The Atikonak River was far too large to bridge, so the contractor had a steel barge made in two sections, hauled to the river and joined there to form a barge about 24ft by 40ft, equipped with a large diesel motor. When it was launched, the operator donned a new white captain's hat he had purchased for the occasion.

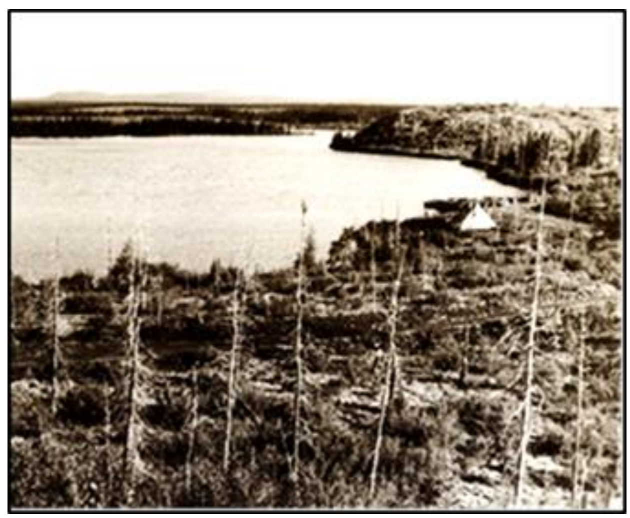
Above and below. Moving the forward camp.

Boil-up for lunch on the trail. I am standing on the right.

Moving the main camp.

The barge was used the next year to transport the equipment to the other side. Road culverts were made with logs, shorter logs being placed across with caribou moss caulking on top, and the whole nailed together. They lasted a few years until the improved access road was built with more conventional steel culverts.

Timber culvert.



Emergency dock and tent on Lake Mackay.

About half-way to the Atikonak River, we built a short side road down through a burnt out forest to Lake McKay, and installed a small tent and aviation fuel stored in barrels near the shore. This was for emergency evacuation by Beaver for any accident victims. Fortunately, it was never used. Burnt areas are common in Labrador, all caused by lightning strikes. They are very dusty, and walking through gets you covered with ash.

Hauling half of the barge across Sims River.

Timber crib bridge.

Sims River Bridge.

We showed all the adjacent lakes to approximate scale on plans of the road route. We had aerial photos of the area, and I showed Fred how to sight over to a prominent feature on the lake from the road, and then pick up the same feature from about a kilometer further along the road. The position of the lake was then established, and with the shape shown on the photos, we could add the shoreline to our drawings. The next year I had a call from the engineer building the second half of the road, asking how the lakes were added to the drawings. I explained the process, but he was not familiar with plane table surveys, so it was not followed and the lakes were omitted.

Assembling the barge at Atikonak River.

Typical boulder field – avoided if possible.

The survey crew – I am fourth from left, and Alf, fourth from right. Fred Clark third from left. Contractor superintendent on left. Terry Crow third from right.

Our supplies were brought in by train to the siding at Esker, where the railcars would be left for off-loading, and picked up again when the train returned from Shefferville, the mine site operated by the Iron Ore Company further north at the end of the railway.

The whole operation proceeded without incident, except for one occasion when the bulldozer driver hauling supplies to the forward camp lost his way at night and proceeded to bash his way out over the country, pushing down trees as he skirted muskegs driving eastwards. He was reported overdue by radio in the morning, so I borrowed a helicopter from Sandgirt and I set out to find him, a very easy task since his trail was clearly visible from miles away! We landed nearby, and provided him with breakfast, a compass and directions to re-join the trail. He wasn't worried in the least, knowing that he would either find the trail, or someone would find him!

With Alf Wright – we avoided this boulder!

The road was completed by another engineer the next year, at just below the target cost of $1,250,000.

About 3 years later, I was asked to join Alf Wright on a Mannix aircraft flight over a road route to Lac Jennine about 80 miles north of Clark City, just west of Seven Islands. Mannix were about to bid on the road construction for a new iron ore mine. We concluded that the route was more difficult than that to Churchill Falls, and would cost about $25,000 per mile. Mannix did not get the contract, and it was awarded to others who had bid lower. It was built at a cost, including extras, of exactly $25,000 per mile.

The consultant, TAMS (Tibbetts, Abbot, McCarthy and Stratton of New York) had seen the Mannix quote, and my name on the cost, so asked me to come down to New York to explain how the estimate had been made. I tried to explain over the phone without success, the TAMS engineer just would not listen; he wanted all his staff to learn from an 'expert'. I flew down for the day, and explained how the estimate was made. Naturally, they were very disappointed.

The Brinco project manager was David Morgan-Grenville, who occasionally dropped in to see how the work was progressing. I met him again, about 35 years later at an energy conference in Ottawa, where he was representing some British interests, and we caught up on old times. Small world indeed!

Crossing Sims River with the Athey wagons.

Working after first snowfall in September.

First snowfall in September.

End of the road at Lake Gabbro outlet.

In my office with Louis O'Brien, before radio installed.

I was at the Gabbro Lake outlet in 2003, and looked around to find the old road. It is now almost covered with alder bushes, and just about to disappear.

The end of the road as seen in 2003. The alders have overgrown the road, leaving only a path.

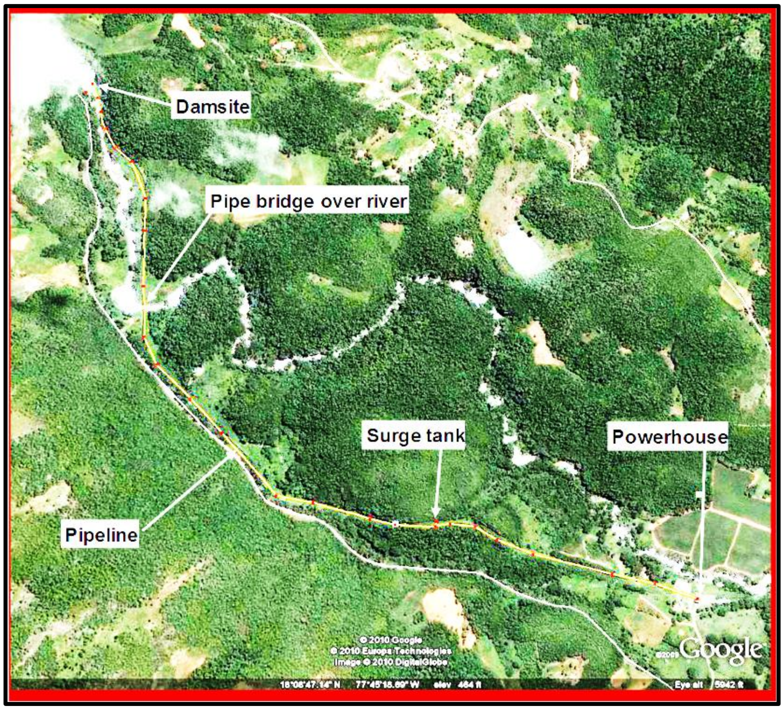
Off-loading a D6 at east bank Gabbro Lake, to be used the next year.

8. MAGGOTY – 1957-59

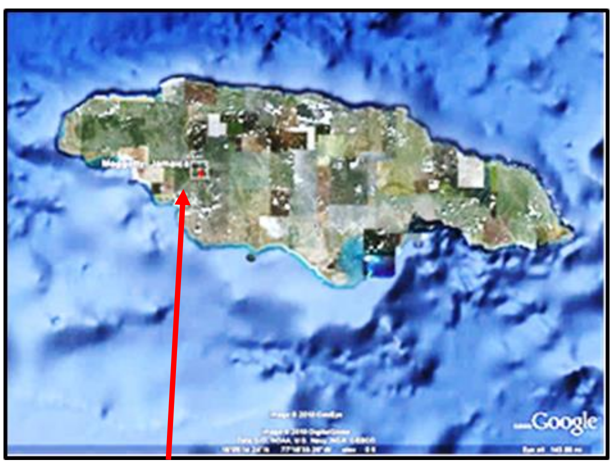
When I returned to the office in 1956, Jack Sexton told me I had been promoted to the position of Project Engineer, with my first task being design of the Maggotty small hydro project in Jamaica. So now I had a desk with a telephone and a drafting table. As assistants I had Terry Crowe (from Labrador road survey), a recent graduate, and Peter Shiskov, an excellent draftsman from Poland, in the process of upgrading his skills to become an engineer by taking night courses.

The site can be seen on Google Earth at 18-09-14.63N, 77-45-29.76W. The powerplant capacity was only 6MW, but the project was very complex. It included almost every type of structure used in a hydro plant, including a small concrete weir, a low level sluice, a low level outlet, a gathering tube intake (very rare), a concrete pipe, a steel pipe bridge over the Maggotty River, a long wood-stave pipeline, a surge tank, a surface and buried steel penstock and finally a concrete powerhouse with a vertical axis Francis turbine equipped with a relief valve.

The conduit hydraulics posed a major problem, due to the surge tank and relief valve, and I suspect this was why I was selected for the task.



Project layout – from Google Earth.



Maggotty location on map of Jamaica – from Google Earth.

Harland Engineering in Scotland had been awarded a contract for the supply of all powerhouse equipment, (turbine, relief valve, generator, controls, switchgear, crane and pumps) except for the turbine governor, to be supplied by Woodward in the U.S.A. The contracts had been awarded before I was appointed to the job, and made no mention of the hydraulic issues. I quickly found out that Harland did not know how to integrate the design of the relief valve with the turbine and governor, so I took on this task without fully realizing the implications. I designed the complex interconnection using a step-by-step process developed by George R. Rich in his book "Hydraulic Transients". The mathematics required guessing the answer first, and then working out the answer over about 15 steps, to see if your guess agreed with the answer. If not, you had to guess again and repeat the process, known as "iteration". The task required about 2 months of intensive work, and can now be accomplished in seconds with a computer. I discovered that I was the only one in the office who understood what I was trying to do, so I was on my own. The manufacturers also did not understand the process, but all was clarified when the plant was commissioned.

Steel pipe bridge over Maggotty River.

I arrived in Jamaica on March 3rd, 1958 to commission the plant, after flying up from a meeting in Peru. I changed flights at Bogota in Colombia, where I was arrested for entering the country without a visa. Many overseas flights in the late 1950's used "Super Continental" aircraft manufactured by Hughes Aircraft known as "Connies". They had 4 engines and the fuselage was curved upwards towards the rear, where there was a distinctive 3-rudder tailplane. Unfortunately, there had been several crashes where it was found that the fuselage had a week point, usually splitting about 6 seating rows from the back, and passengers in the last 4 or 5 rows often survived. Knowing this, I always booked an aisle seat in the second-last row. I had arrived in Bogota, and waited until all the passengers in front had de-planed. I gathered my belongings, and slowly walked into the terminal to the immigration desk, clearly marked. However there were no attendants, so after waiting a few minutes, I saw my suitcase on the floor about half-way to the exit, and I wandered over, grabbed my bag, walked outside and took a taxi to the Tequendama Hotel where I spent the night.

Maggotty Dam, looking upstream. 1958.

I returned to the airport the next morning, got my Pan-Am boarding pass, checked my suitcase, and walked over to the emigration desk. The attendant looked through my passport and asked when I had arrived. I replied yesterday afternoon, but he said there was no entry stamp in the passport. I then explained (all in Spanish) that there was nobody at the immigration desk, to which he replied "impossible" and had me arrested by 2 soldiers standing nearby. I then asked to speak to the Pan-Am manager who advised this was always happening, and he would speak to the police chief downtown, whom he knew. The chief asked to speak to me, and after hearing my story, he told me to go over to immigration, have my passport stamped, then go over to emigration, and then get out of his country!

Maggotty Dam, looking downstream, 1998.

When I arrived at Kingston, I was met by Mr. Ernest Mais, the operations Vice-President of Jamaica Public Service with whom I had exchanged many long letters explaining the complex hydraulics of the powerplant, since we had to install a two-speed Woodward governor, a first. Also we had to change the vent pipe to a surge tank, to reduce the pressure surges in the pipeline. I waited quite a while in the airport, and eventually I was approached by a couple of gentlemen who had been standing around, and they asked if I was Jim Gordon from Montreal Engineering. One of them was Mr. Mais, and he told me later, that he had expected a much older engineer! He was accompanied by Mr. Arundel Moody, the resident engineer with whom I drove out to the resident's bungalow on the top of a hill near the powerhouse.

Arundel Moody and Ernest Mais at site bungalow.

After settling in, Arundel asked me if I would like a swim, and thinking this would require another trip to a country club, I replied in the negative; and mentioned why. Arundel then said that the pool was behind the bungalow, and took me out to see it. Looking at its size, I asked him where the cost had been hidden in the project budget, an updated copy of which I received every month. He replied that if I looked closely, I would see an item “Fire water storage tank = £12,000”. Yes, it was there, and the fact that it had a diving board attached did not detract from its designated use.

Wood stave pipe - 1998. Photo – Hatch.

I told my arrest story to Arundel, and he later noted that I had again booked my usual seat on the flight back to New York. Several months after I returned to Montreal, I had a telegram from him saying “Am booking the same seat”. Apparently another Connie had crashed on take-off, and the only survivors were in the last 5 rows!

Steel surge tank.

When I arrived at the powerhouse, I spent the first two days just looking at the governor and reading the operating manual. The governor was a new design for the manufacturer, since it had two speeds, a rapid movement to 15% gate to obtain a quick breakaway on the thrust bearing, and afterwards a very slow opening rate of over 60 seconds to limit negative waterhammer. For closure on detection of a fault, the movement was rapid, in less than 10 seconds, while the relief valve opened at the same time.

When closing normally in 60 seconds, the relief valve did not open. The operating schematic was very complex, covering a large drawing showing how the relief valve, governor speed ball-head, pilot valves, dashpots and servomotors all interacted with one another through pipes, levers, rods and wires. I wish I had kept a copy. After becoming familiar with the governor and relief valve operation, we started dry tests to see if the relief valve opened to the calculated position on closure of the turbine wicket gates. Unfortunately, the valve did not open to the correct position at intermediate positions, despite simulation of all controls in the "wet" position, including the governor ball-head propped up to the synchronous speed position to center the pilot valve.

Control panels in powerhouse.

Powerhouse with relief valve discharging.

A review of the control schematics indicated that the shape of a stainless steel cam in the relief valve controls must be at fault. The cam rotated through about

90 degrees as the wicket gates moved to full open. As the cam rotated, a small roller lifted to move a pilot valve, which controlled the relief valve servomotor, to a position corresponding to the required maximum relief valve opening. I tried rotating the cam on the shaft, but to no avail. The shape of the roller surface on the cam had to be modified to include an indent at about the half load position. Discussing the problem with the turbine erector, it was decided to substitute a pine wood cam, to be shaped by trial and error. We then used a file to shape the cam to the required profile based on numerous dry tests. For the wet tests, a hard mahogany cam was substituted, cut to 2mm. above the pine wood profile, leaving some wood for final shaping.

Wood stave pipe – as new in 1958

The wet tests proceeded cautiously, with the pressure gauges marked with red tape at the design waterhammer pressure limits. Pressure gauges were also installed at the quarter points up the length of the penstock. They were not the recording type, so we had inspectors sitting on the pipe, carefully watching the gauges to see if the needle flipped past the red line. Load rejection tests were undertaken at 5% gate increments, and proceeded very slowly since someone had to walk up the penstock to obtain the gauge readings after every test. The mahogany cam was carefully filed down until pressures were all within design limits. The turbine erector then used the mahogany cam to shape two steel cams cut from discarded checker plating. Both were tested and finally shaped with a grinder. One was returned to the manufacturer as a model for a stainless cam, installed a few months later.

The Maggotty work was a very practical and detailed learning experience on Woodward governors, so when I returned to Montreal, I suggested that I should enroll for the one-week course at the Woodward governor school in Rockford Illinois. It proved to be very instructive, and cleared up many of the questions I had about their governors. From the extensive Woodward manual, waterhammer calculations and the problems getting the equipment to work properly, I learned a lot about relief valves, experience which proved very valuable a few years later when I had to investigate a penstock collapse on commissioning a turbine with a relief valve, all designed with the help of a computer.

8. TRAVELLING OVERSEAS – 1958-75.

Sometime around 1952, the wife of the new president for Bolivia Light and Power died from altitude sickness shortly after arriving in La Paz at an altitude of 12,000ft. The post-mortem indicated a defect in her heart. Ever since then, all staff traveling overseas to Bolivia had to have a medical. This consisted of a general examination by a doctor appointed by the company and included a rough stress test of running up and down stairs to the next floor above the doctor's office, followed by a blood pressure test and the doctor listening to your heart with a stethoscope.

The company also had a contract with Dr. S. M. Cooper at the Canadian National Railway Medical Clinic above the Montreal Central Station for administration of vaccines. He would stamp the yellow vaccination book carried by all overseas travelers, and provided a prescription for a bottle of Enterovioform obtained at large pharmacies. My first trip overseas was to the Amazon jungle in 1958, and for this, Dr. Cooper gave me a shot of every vaccine he had at his disposal, a process that took 2 months. Fortunately I had the time, since the trip was delayed.

Zongo summit at 13,800ft, Bolivia, 1958.

At over 12,000ft, Tiquimani trek, Bolivia, 1964.

Enterovioform could be used as a prophylactic to avoid dysentery. The dosage was one pill a day, and if you got the trots, then 2 every 4 hours, maximum 8 per day. They proved to be very effective, and I had to use them many times. But about 1968 it was found that they contained a carcinogen and they were discontinued in North America. They can still be purchased in other countries. On one trip to the Andes, I shared a bottle of 100 pills with Bill Matthews, putting my half in an empty aspirin bottle. After we were there for a few days, Bill asked me how my supply of Enterovioform was going, and I said OK, and forgot about it. Two days later, the same question, so I asked how many pills he was taking, and he replied, 8 per day as indicated on the instructions. So I asked if I could ask a personal question, and on his approval, asked him if he had been to the toilet, and his reply was "not since we arrived!". The pills were stopped for a while.

With Fred Clarke & Art Holroyd, Ceylon jungle, '70.

Over the years, I had over 15 injections for Cholera, Smallpox, (TABT) Typhoid (A & B) and Tetanus, Yellow fever, and gamma globulin. For the last few years, Dr. Cooper would look at my yellow books, and say that I was so full of vaccines, that he would just stamp the book, but not give me a shot. Behind his desk, Dr. Cooper had a large map of the world with notes on it showing where the latest outbreaks of yellow fever and other diseases had been found, and what type of shots were needed for each country. For most tropical countries you needed three TABT shots given at intervals of 2 weeks. When I had to travel to Ceylon now Sri Lanka, I departed before I could get my third shot. Arrangements were made to get the third shot at a hospital in Colombo, and when I turned up for the appointment, the nurse said that it would hurt. It certainly did, so I asked her why, and she replied that the needle had been used over 1,000 times, and it was getting a bit blunt!

I knew not to drink the local water, and in some countries such as Nigeria and Turkey, the water was so polluted, that it could not even be used for brushing teeth. So I always carried a 40oz bottle of scotch, usually Johnny Walker, because the square bottle fitted neatly inside the bottom of the middle pocket in my briefcase. Ice cubes, fruit and salad were always avoided. However, boiled water in coffee or tea was acceptable, along with bottled beer, wine and soft drinks. I remember one January seeing strawberries and cream on the dinner menu at a hotel in Lima, Peru, on the last night I was there, and ordered it. About an hour later I was sitting on the toilet, and remained there for the rest of the night. Fortunately, with the help of Enterovioform, Montezuma's revenge had stopped by the time I had to leave for the airport, but it was a very uncomfortable night, and I learned a lesson.

Another time, in Lagos, Nigeria, I was having lunch at the Canadian Embassy and we were served a salad, which I declined to eat. The ambassador's wife saw this, and was quite annoyed, saying that she had personally washed the salad in potassium permanganate, and showed me one of her fingers, slightly purple from seepage through a hole in her rubber gloves. So I ate the salad, fortunately with no ill effects. On that trip, I traveled north to Joss, and by the time I arrived at the hotel there, became quite ill from the effects of dehydration and the lack of salt. I recognized the symptoms, since I had stopped sweating, so asked when the restaurant would open, and was informed in about an hour. I lay down in my room until the restaurant opened, and later in the restaurant asked the waiter to immediately bring a bowl of soup and a salt shaker. I recovered completely about 20 minutes later after quaffing some very salty soup.

The only other hazard was bites from insects. Sitting in a dugout canoe in Panama, on the Bayano River, a very large spider crawled up from the bottom onto my back. Fortunately, Bob Gander, sitting behind noticed it, and one of the Panamanian engineers mentioned that it was very poisonous, and managed to flick it off into the water. I was fortunate that it did not reach my neck. On another trip to Panama, I walked across a field where there were cattle and picked up a tick infestation. They would bite at night, and were impossible to get rid of. When I arrived home, I asked Vera to bring several garbage bags to the door, I got undressed, put all my clothes, including those in my luggage into them, and one bag went straight to the dry cleaners, the others into the laundry, and I ran upstairs to have a long hot shower. It worked.

Bob Gander, ?, Alun Williams, ?, me, and Raphael Moscote, Panama, 1970.

On one trip I was traveling with Fred Clark and Frank Nickel, a geologist from the USA. We stayed for several days at a motel at Mut in south-west Turkey, a village with a restaurant, scruffy motel, gas station and several houses. It was at cross-roads where travelers would change from one bus to another. The first night at the restaurant, we did not have an interpreter, and asked for bottles of Coca-cola by mentioning the name, and making a curved sign for the bottle.

The waiter brought an empty coke bottle. We tried again, saying it should have coke inside, and the waiter brought back the bottle full of water, exactly what we wanted to avoid. This time, we said coke with a cap on top, all by making appropriate signs. He brought back a coke bottle full of water with a coke cap hammered back on. He must have thought we were nuts! We gave up and drank hot coffee in the sweltering heat. But it just shows what you have to go through when traveling off the beaten path. Incidentally, the only item on the restaurant menu was mutton and potatoes.

I stopped travelling overseas after a severe heart attack in 1975, and thereafter confined my travels to Canada. I could say that travelling for almost two decades from 1958 to 1975, was during the golden age of travel, when people dressed up for the flight, meals were included, drinks were free, seating space was adequate, and security hassles at airports were minimal.

On a Pan American flight from La Guardia to Lagos, we had stopped at Dakar to refuel, when I noticed the Concord sitting on the runway beside the terminal. I asked the guard at the gate if I could go out to have a look at it, and he said "of course" – how times have changed. At the time, in 1970, the Concord was on test flights between Heathrow and Dakar. It was much smaller than I had expected.

It was possible to arrive at the airport only a few minutes before departure if you had no checked luggage. However, security increased after the attacks at the Munich Olympics in 1972. I happened to be passing through Frankfurt shortly after the incident, and was subjected to a body pat-down by German army soldiers who appeared to have taken over the airport. The luggage was spread out on the tarmac beside the aircraft, where you had to identify your bags, and stand nearby while they were thoroughly searched. Only then were you allowed to board the plane. Needless to say, flights were delayed.

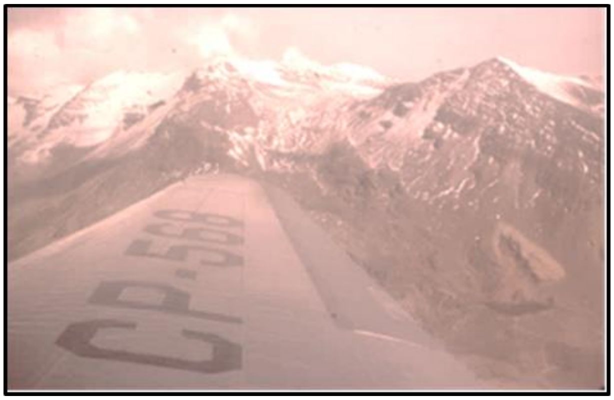
Fortunately, there were no accidents. However, I did have a few anxious moments. On the return flight from La Paz to Lima in 1958, the DC4 could not fly high enough over the Andes Mountains, so had to fly through passes. The pass was fogged in, but the captain continued to fly towards it, and we gradually approached the ground, as I could clearly see from the window. At the last minute, the plane turned around, with the wing almost scraping the mountainside. The captain came on the intercom, and announced that he had hoped that the pass would clear by the time we arrived, as it had in the past, but no such luck. So it was back to La Paz, to fly out the next day.

On a borrowed Raleigh bicycle, almost identical to the one I had in Perez. Joss airport, Nigeria, 1973.

On another occasion, in a Pan American flight from Heathrow to Colombo, we had stopped at Istanbul at about 1.00am, and on take-off, the pilot turned the aircraft around just before reaching the runway, and announced that the flight controller had just cleared an aircraft to land on the runway that we were going to use on take-off. He was going to go up to the tower to "have a few words with the controller!", and the flight was delayed for a bit.

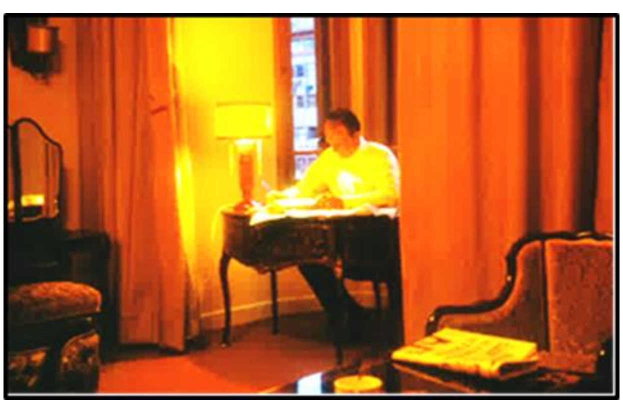
On a Fokker flight from Joss to Lagos in Nigeria, the plane flew through golf-ball sized hailstones

– I could see them bouncing off the wings. The noise in the cabin was indescribable, and when we landed, the whole nose and leading edges of the wings were pock-marked with dents from the impact of hailstones. The pilot mentioned that it would have to be completely re-skinned.



Approaching a mountain pass, Bolivia, 1958.

I knew that piston-engine aircraft had to be warmed up for at least 5-10 minutes before take-off. On a flight out of La Paz in 1958, at 13,600ft above sea level, the DC2 aircraft had sat on the tarmac all night. The pilot arrived, walked over to the plane, told us to get in, and we taxied over to the runway, and took off with no warm-up. As we reached the end of the very long runway, he merely lifted the wheels, and we continued to fly on across the level "altiplano" only a few feet above the ground, as the engines warmed up. Only then, did we climb to about 1,000ft above ground.



Intercontinental Hotel, Belgrade, 1972.

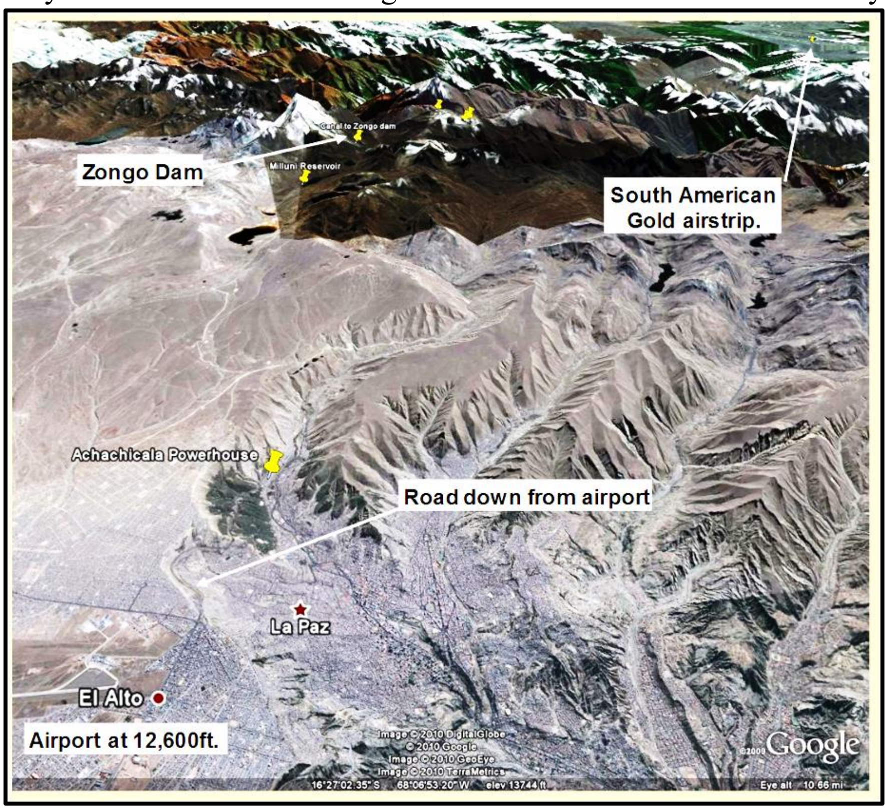
On an army DC3 flight from Bogota in Equador, to the interior, the captain announced that we would be landing on a hillside, and touch down on one wing wheel first, with the other wing wheel only touching as speed decreased. I was with Harold Hurdle, and we did not relish a return flight, so we managed to hitch a ride back to Bogota in a Toyota 4X4. The other passengers on the flight were mostly local Indians with a motley collection of chickens, piglets and lambs!

My most terrifying moment was on a Trans-Canada Airline red-eye from Edmonton to Montreal. We had taken off at about midnight, and I was sound asleep in a window seat, when I awoke with a start, as the plane was bucking and weaving around. The pilot was trying to land at Winnipeg in the dark, in a blinding snowstorm, and this was his second attempt. This was in the days before automatic radar-controlled landings. He failed, and announced that he would try one more time, fortunately with success. But I think that was about my last night flight! No more red-eye specials – work all day, get the overnight flight, and then go to work the next day – no thanks!

10. AMAZON JUNGLE – 1958.

In October of 1957, Jack Sexton asked me to go to the Amazon jungle to search for a small hydro plant to provide power for a large suction dredge working on the Yolosani River and owned by the South American Gold Company. The Chief Operating Engineer from Bolivia Light and Power, Lucio Encinas, was already there on a preliminary reconnaissance and Jack was expecting a report on his work to arrive shortly. I replied in the affirmative, but over the next few weeks, there was no report from Lucio, and all enquiries were met with silence.

Lucio's report arrived in early January, a long letter in Spanish which Jack asked me to read, and if I wanted to back out, that was fine with him. Lucio started with an apology for the long delay in sending his report, but advised that the delay was well beyond his control. Apparently, the dredge was operating in an area where there were no roads, and the only way in was to charter a DC2 from Lloyd Aero Boliviano. The flight was out of La Paz and through a very narrow mountain pass at about 17,000ft, near the upper flight limit for the aircraft, and then a long descent to a narrow grass strip paralleling the Yolosani River, about 98km to the North-East of La Paz. The abandoned airstrip is clearly visible on Google Earth at 15-48-01S, 67-38-29W. Lucio had arrived without incident, seen the proposed site, and found it attractive. However, on calling for a return flight, the aircraft had got lost, and disappeared without trace after flying through the pass.



La Paz area from Google Earth.

Another DC2 was sent out to search for the aircraft without success. The jungle in the area is so dense, and the trees so tall, that any aircraft can fall through the jungle canopy and disappear forever, unless a fire marks the spot. After searching for a few days, the DC2 flew to the airstrip and tried to land, but approached the strip from the wrong direction where there was a high hill near the end of the runway, and crashed on landing since the approach angle was too steep. Fortunately the pilots survived without injury, but the aircraft was a write-off. With only 2 aircraft, this put Lloyd Aero out of business.

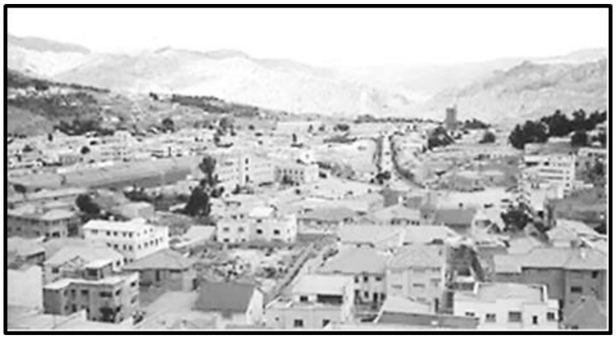
Protracted negotiations with the Bolivian Air Force followed to obtain a rescue flight, and an Air Force DC3 eventually arrived to pick up Lucio and the two pilots. Meanwhile, Lloyd Aero purchased another DC2, and was back in business. Understandably, Lucio advised that he had had enough of jungle flying, and did not want to return. However, I was still enthusiastic about going. I left Montreal on 10 February, for Miami, after being told that I would be met at La Paz by a man called Manuel, who would take care of my briefcase, now containing parts for a turbine. In Miami, I caught a Braniff flight to Lima, stayed overnight and then another Braniff flight to La Paz, arriving on February 12. I was carrying a solenoid valve and a pressure gauge needed on one of the Bolivian powerplants, given to me by one of the purchasing agents in Montreal, a common practice within the company. Manuel was waiting at the bottom of the staircase off the plane, took my briefcase from me before I went through customs, and he returned it as I left the airport, apparently a common practice to avoid customs and lengthy import regulations.

Lucio met me at the airport and guided me through immigration. We drove down to the Crillon Hotel after waiting to pass through a checkpoint set up by the army, half-way down the hill-side road into La Paz. There had recently been a major revolution, so army checkpoints were common. At the hotel, I was advised to rest for a while, to become accustomed to the 11,500ft altitude. Next day, I slowly walked over to the Bolivia Light and Power offices, and changed $100 into Bolivianos, was questioned as to the amount by the clerk, confirmed it, and was given two large wads of paper notes, so I returned half. I had not realized the extent of local currency inflation.

Switchback road down mountain – from GE

I met Lucio again, and we discussed the project. He introduced Hank, a young engineer from Montreal who would be coming with me to the jungle. This was near the end of his work in Bolivia, having completed work on some transmission lines around La Paz. A flight had been arranged for the next day to the Yolosani camp on Lloyd Aero. Hank was also staying at the Crillon Hotel, so we had dinner together, and he asked me to buy a ticket in my name for a flight from La Paz to Montreal. On enquiring why, he explained that he had become engaged to a local Bolivian girl from a very wealthy family who lived in a walled compound at a lower altitude further down the valley, on the outskirts of La Paz, with armed guards posted at the gate. However, after meeting her family several times, he realized that he would never be able to support her in a manner to which she was accustomed, so had decided to end the engagement. This the family would not accept, so he was trying to leave quietly. A few days later, I purchased the ticket, and he departed the day after I left Bolivia, and we met again in Montreal.

Next day we went up to the airport, being delayed on passing through the checkpoint and reported in at the Lloyd Aero counter. The clerk advised that the flight had been cancelled since the mountain pass was fogged in. And how did they know, by just looking out the window to the mountains on the horizon to the far North. This was to be the case over the next two weeks; the pass was always fogged in. So we had plenty of spare time, and enjoyed ourselves with the local “carnavales”, perhaps a bit too much. On one occasion we were down at the hotel entrance watching the parade go by. A couple of young girls spotted us, ran over and grabbed me by the arms, and dragged me into the parade. Seeing it was not possible to resist, I gave my camera to Hank and joined them for a few blocks, before managing to escape and return to the hotel. Unknown to me, Hank ran ahead and took some photos of me with the girls, photos which caused a lot of trouble when my fiancée saw them on my return to Montreal. I had failed to check the Kodachrome slides!



La Paz – 1958. Echtachrome slide – all turned sepia with age.

I got to know the hotel manager Pablo, since I would have to extend the room reservation daily. One day Pablo asked when I would be coming down for dinner, and I said about 6.30pm. On hearing this he asked me to wait until later, and he would phone, so I asked why. Apparently the manager of a tin mining company from Oruro was in the hotel, and he always came down to go out for dinner at precisely 6.30pm. He wanted the lobby empty at that time, as there had been a few attempts on his life, and he felt insecure coming out of a closed elevator into a space where someone could hide. So I asked if I could see him from Pablo's office which had large windows overlooking the lobby. Pablo agreed, and I waited. At exactly 6.30pm the elevator doors opened and two large Alsatian dogs emerged and ran around the lobby to return to the elevator. Then a tall thin blond man emerged with his hands on two pistols in holsters and strode out to the street, with a dog at each side. He was dressed in a well-pressed German officer's uniform, with no insignia, and wore impeccably polished brown riding boots. Just like a scene from the old American Wild West. The hotel porter on the outside door prevented anyone coming in until the mine manager had left.

Carnavales parade, La Paz.

As our enforced "holiday" continued, Lucio showed us around town one day, and proudly pointed out the white-washed cast iron light pole from which the last president had been hanged by a mob. There was a wreath at the foot. On another occasion he arranged a trip over the 12,600ft high Zongo pass and down to the powerplants on the Zongo River. It was a fascinating trip. In a red Bolivian Power van we raced past the checkpoint on the way to the airport, and I instinctively ducked down, while the driver shouted "emerjencia" as we passed. I was told not to worry. Apparently there had been an emergency at one of the Zongo powerplants late one night a few months previously, and an engineer had tried to pass the checkpoint without getting a travel pass, a process requiring several days. They would not allow him to pass, so he returned to the office and phoned the chief operating engineer in the valley, George Ebenstein.

The fogged in pass to Zongo valley at 12,600ft

He explained the situation and asked George to shut off all power to La Paz for 10 minutes at precisely 2.00am. He returned to the checkpoint, and got in line in a position where he expected to arrive at the checkpoint just before 2.00am. When questioned about the lack of a pass, he said it was an emergency, and asked to soldier to look over his shoulder at La Paz, now in complete darkness. The astonished soldier immediately let him pass, and ever since then, the red Bolivian Power vans were allowed through checkpoints if the driver shouted "emerjencia".

Zongo valley looking down at Botijlaca village. Note steep mountainside.

We drove over the pass, still fogged in, and carefully descended the steep switch-back road down into the valley. Lucio showed us the cantilevered concrete ramps built at switchback corners out over the precipice to allow a large truck used to transport the heavy generators, to go forward and backward down the switchbacks. Later, we saw the truck, a heavy 4-wheel drive vehicle with the cab cut off. The drivers had insisted on removing the cab, so at least they had a chance to leap off if the truck showed any signs of going over the edge. Apparently it had happened in the past. It was a very interesting trip. The first powerplant at Zongo had been built in 1908 with the dam at over 12,500ft in a sub-arctic climate. The ninth and last powerplant at Huaji was completed in 1998 and had a tailwater at 2,900ft, well into the tropical jungle. I was particularly interested in the intake at Botijlaca, about 7km downstream of the Zongo powerhouse, since it had been designed in 1936 by Jack Sexton. He told me it had washed out twice, before he developed a design capable of resisting the impact of large boulders rolling down the river bed.

The reason I was interested in the intake design, was that Jack had asked me to design a similar intake for the downstream Santa Rosa powerplant. I had looked at the Botijlaca drawing and thought I could improve the layout, only to have it rejected by Jack. He again emphasized that I had to use Botijlaca as a model, explained the principles in more detail, and added his on-site experience with the work in 1936. The boulder problem was so severe, that you could stand on the bank of the river and hear the large boulders rolling over and moving on downstream with a deep clunk-clunk sound. The intake design concept that Jack had developed was to use a sloping upstream face on the concrete weir, so that the boulders could roll up and over, propelled by the force of the flood waters. The intake was placed at right-angles to the flow, to avoid the boulders.

At the Botijlaca guest house.

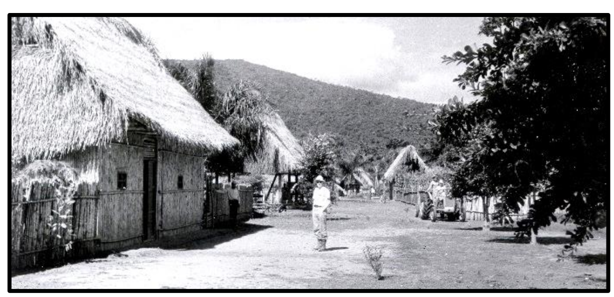
One evening I had an invitation from the local Canadian Consul to dine at the La Paz Railway Club. I had to sign in, as usual for all guests, and was enjoying a cocktail in the lounge, when a gentleman came over and asked if I was related to the James Gordon from Perez. On replying in the affirmative, he said he knew my father, and took me over to meet several other railway engineers from Rosario. Apparently they had been recruited by Bolivian Railways when the Argentine railway system was nationalized about 10 years previously. Small world!

Zongo dam today – from Panoramino #24622327

Finally the fog cleared and we flew out on February 19, landing on a grass strip so narrow that we could clearly see the monkeys in the trees on each side. Going through the pass, it looked like the wings were almost touching the mountains. Before departing, we had waited for the pilot to arrive on a war surplus Super-Fortress used to bring meat up from the Chaco, the farming area to the south-east. He jumped up into the DC2 which had been sitting on the tarmac overnight, started the engines, and we took off down the runway with no engine warm-up. He pulled the wheels up at the end of the runway, and we cruised along a few meters above the salt flats toward the pass. After about 10 minutes, when the engines had warmed, we lifted up to about 300 meters and continued along to the pass just above ground level. Quite a start to our coming adventure! Lucio's departing words had been "look for wheels", which made no sense whatsoever until after we arrived.

Abandoned South American Gold airstrip in jungle.

From the airstrip we walked over to the camp and were shown to our thatched-roof bungalow. The mining engineer, Julio, pointed out the cookhouse and his office, and asked us over for a brief meeting before lunch. At the meeting, we went over our itinerary for the next few days. Julio mentioned that it would take a couple of days to organize the 3-day hike through the jungle to the site, and that next day we would be taken over to visit an American Baptist minister a few kilometers upstream. I asked why, and Julio just said it would be good manners to visit local expatriates, and we really had nothing else to do while the mules and guide were assembled.



South American Gold jungle camp.

Next day, the few kilometers turned out to be over a 2-hour hike through the jungle, crossing the Yolosani River on a small balsa wood raft, and wading across a small stream, fortunately we were far above the piranha limit! Apparently the local Indians maintained a ferry service across rivers on the jungle paths, supplementing their income from panning gold.

Hank wading across the stream.

We arrived at a bungalow near the bank of the river, inhabited by the missionary, his wife and two young children. They invited us in for tea, and we conversed for about an hour. John, the missionary, told us how all their possessions were packed into oil drums, welded shut, transported from Kansas by ship, rail and truck to the head of the Yolosani River. There they were thrown into the river and floated down to their home-site.

Julio and Hank at the missionary's bungalow.

They only lost one drum. They had lived in tents while their bungalow was being built by the local Indians, which seemed to take forever. However, after every sentence, John giggled until he could regain his composure and continue with his story. I could see that he was completely bushed.

Me, rafting across the Yolosani River.

After we left, Julio explained why he wanted us to meet John. He had noted his giggling and concluded that he needed to go back home, but he wanted someone to get the message back to Kansas. Apparently the local Indians would not have anything to do with John, since all their religious needs were provided by a traveling catholic priest. The priest would walk from village to village, spend a few days with a local family, listen to a few confessions, marry all now living together, and say a few words over all new graves. The arrangement worked very well. After I returned to Canada, I phoned John's church and explained the situation. They were very grateful; since John's recent letters were rather strange, and they were wondering what was happening.

Starting our trip, through a banana plantation.

Next day we departed for the dam site, far up-river. Apart from me, our party included Julio, Hank, a couple of Indian helpers, and an Indian Métis guide carrying an ancient blunderbuss! Except for the guide, who walked, we were all mounted on mules. I found out that the blunderbuss was loaded, so I kept well clear of the guide. We did not seem to have any supplies, apart from coffee and a couple of tins of peaches.

Our first stop – at a jungle village, Caranavi, 1958.

Food was not needed as I was to find out. After several hours travel we arrived at Caranavi, a small village of about 15 thatched-roof dwellings. We entered one, the local restaurant for travelers, and ordered lunch. There was only one item on the menu, "arroz con pollo" - chicken with rice. We were taken out the back, and asked to choose our chickens, it was certainly fresh, and tasted delicious. I was asked if I wanted to kill it, accepted, and swung the chicken in circles until its neck snapped, a technique I had learned from Vittorio in the Argentine at Perez.

Me at our 5-star jungle motel.

Preparing to cross a river, Julio and Hank on right.

We started off after lunch, and then I realized what Lucio had meant at the airport. Since arriving, I had not seen any wheels, not even a wheel-barrow. In the tropical heat, everyone walked at a leisurely pace. The local economy was based on panning for gold in the river, and it was possible to pan enough gold in about an hour to provide all life's necessities. This was why it was so difficult to find labor; nobody was interested in working for wages. At the next village there was an overnight rest stop, in a large thatched-roof building with no walls.

We slung out hammocks from the posts, and again had our chicken meal for dinner. Our guide departed for the local bar, and came back much the worse from "chicha" the local liquor made from corn.

We were taken over to visit the local store, operated by a German Jew still hiding from the Gestapo. He told me that Colonel Percy Fawcett had traveled through the area around 1910 searching for the mythical golden city. All his transactions were in gold nuggets and dust. He had a large collection of mason jars full of gold, lining the wall behind the counter. I asked him if he was not afraid of being robbed, and he replied that there was only one path out to the end of the road, a week's journey on a mule, so any thief would not get far. He also mentioned that the jungle telegraph was very efficient, and that he had followed our progress since arriving by plane. He even knew we had visited the missionary. How the telegraph worked, I never found out. He traveled out occasionally to bank the gold. He had a "mule train shuttle" on a three-week schedule to replenish his stock. In his store, there was a long anaconda snake skin nailed to three walls just below the ceiling. It was so long that I inspected it carefully, looking for a joint, but could not find any. Anacondas can grow to over 8.5 meters, with a girth of 1.1 meters, but this one seemed much longer. Apparently the skin can be stretched considerably when drying, which could explain its length and Fawcett's claim of having seen giant anacondas.

Next morning we had a breakfast of fried eggs and bananas. The abundance of banana trees explained the lack of provisions. We could pluck bananas off the trees as we traveled on mules, and I found that there were three species, one suitable for eating, another for boiling, and another for frying. However, there was one tree we had to avoid, as explained by our guide. It had a symbiotic relationship with red fire ants, the ants being poised on the upper branches, waiting for an animal to pass below, and would descend in a cloud of ants onto the animal. Depending on the animal's size, between 50 and 100 bites were fatal. For humans, 25 bites would make you severely sick. The guide would spot the tree, and pound the ground below with his stick, a signal to the ants that there was something underneath, they would fall in a cloud, the guide would shout to the next 3 persons on the trail to gallop through before another wave of ants were ready to drop. The mules were well aware of the procedure, and this was the only time they could be persuaded to move at a gallop. We waited a few minutes, and the guide would then pound the ground again, and the process was repeated until all had passed. We met several Indians on the path, and all were naked except for a loin-cloth. They carried their possessions in a waterproof flour sack slung over their back, with a panning dish attached. At rivers, they would use the sack as a lifebelt under their chest, and swim across.

Crossing a river – the mules followed.

About 10.00am we stopped for coffee in a small clearing and I sat down on a stump. I had only been sitting for a few seconds, when the two Indian helpers ran over, grabbed my arms, and forcefully jerked me off the stump. Apparently I had sat down on a fire ant tree stump, and the ants were swarming all over my trousers. Fortunately, I was wearing "logan" boots with the tops tightly sealed to prevent insects from entering, so the ants were flicked off before any could bite, and I learned another lesson of life in the jungle. Before starting, we had been warned not to step off the trail into the jungle – too many snakes and spiders lurking about.

When I wanted to take a photo (next page) of the group in the jungle, I had to ask the Indians to first inspect the area where Hank would stand. We continued on, stopping again at a village for lunch. However, we were told that there was no village at the damsite, and we would be camping overnight in the jungle, where an abandoned pig-sty had been cleaned out. They suggested that we sling our hammocks inside – my worst ever overnight accommodation! This was declined, and we found some suitable trees, slung the US army hammocks which were equipped with a rain cover and mosquito net, and we were soon quite comfortable. Dinner was coffee, fried bananas and tinned peaches.

Coffee time - just don't sit down!

Early the next day we arrived at the river, and I had a good look at the proposed site for the dam. However, it proved quite unsuitable for a small powerplant, since the head would be created entirely by the dam, and with the flood flow being very large, the spillway would be expensive, making the site quite uneconomic.

Saddled up! – in a rare jungle clearing.

So we started back to camp, but Julio had a surprise, announcing that he had a large balsa wood raft waiting just downstream, which would take us back in about 3 hours. It had been built by the local Indians in anticipation of our return trip. Arriving at the river bank, we stripped down to our underwear, and stowed our few belongings in waterproof bags made of flour sacks impregnated with locally obtained gum from rubber treas. They proved to be completely waterproof, and the ride back was wild, especially through the rapids, where we were often completely submerged. Approaching one particularly ferocious rapid, Julio advised us to hang on tightly, since the rapids were called "Quita Calzon" – underwear stripper! The two Indian helpers were expert rafters, and managed to get us all back without overturning the raft. An unforgettable experience!

Our balsa wood (large?) raft. Hank on left, Julio sitting down in middle of raft.

Back at camp, I told Julio what we needed was a stream with a high head, instead of the low head Yolosani river site. He knew of such a stream nearby, about three hours walk through the jungle. We looked it over, it seemed suitable, and I estimated the flow by measuring the area by tape, and throwing a stick into the water to obtain the velocity. I then gave the surveyor instructions for mapping the area, expecting this to take several months of cutting survey lines through the dense jungle. After that, I flew back to Montreal. So I was surprised to receive a detailed map of the site only six weeks later. We developed a design, estimated the cost, and issued a report. Three months later we got a letter from South American Gold apologizing for the mapping, it was not correct. Apparently, the surveyor, realizing the enormity of the work involved in cutting survey lines through the dense jungle, decided to sit on a rock in the middle of the river, and make a free-hand drawing of the topography.

Julio had taken a liking to my Zeiss camera and light meter, so he offered to buy them, pointing out that I could easily get another in Montreal, and I sold it to him.

I left Bolivia on 28th February, with the mountain pass to Peru fogged in, but the DC4 flew on until the last moment before turning back to La Paz. Later, the pilot told me that the fog in the pass often lifts just sufficiently for aircraft to fly through; hence he usually continued flying until the last moment. The service ceiling for a DC4 is 22,300ft, lower than the mountain peaks on the way to Peru, so we had to fly through passes. When it turned, the plane was so low, and the valley so narrow, that we were almost down at ground level. Next day the fog had cleared and I took off again on 1st March, changed planes overnight at Lima, and flew on to Miami for a connection to Montreal.

Nick at the smaller stream.

After the topography debacle, Jack Sexton was asked to come down and look for a suitable site with the help of a very slow-flying Helio-Courier aircraft, which has a stall speed of only 28mph. Nothing suitable was found, and South American Gold decided to fill large rubber bags with diesel fuel at the road many miles upstream, throw them into the river, and have Indian rafts-men bring them down to the dredge. It proved to be very successful.

One of my more exotic trips, and quite an adventure!

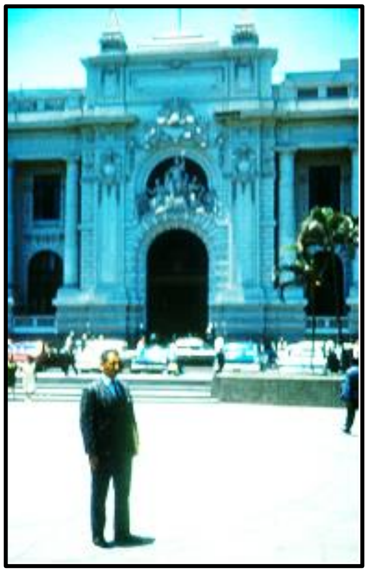
In 1958, there were no roads, no maps, just dense green jungle. Now, the area is being developed, there are roads, power lines, farms and several villages – all clearly visible on Google Earth. The thatched-roofed houses in Caranavi have been replaced with brick and concrete homes.

11. SOUTH AMERICA – 1958 – 68

The company decided to take advantage of my fluency in Spanish, and I began traveling to South America to look for business. My first trip was to Peru in 1958, and there I met our agent Hernan Estebridis, a young engineer with some experience on substation design, and an office with a telephone shared with another engineering consultant. The telephone was very valuable, as there was a 2-year long waiting list at the time. There was some talk about a call for tenders on the design of a hydro plant in the mountains east of Lima. I had a discussion with, and presented our brochure to a vice-president of Electro-Peru. However, nothing further developed from the discussion.

But I got to know Hernan, and one evening we went to a local Japanese restaurant which had recently opened. The setting was very attractive, near the mountains with a beautiful view, and tables set out for the diners among a series of small canals filled with water. Unfortunately, the architects had forgotten to include a filtration system for the water, so it quickly turned green with algae, and stank to high heaven. But we had a good dinner, and Hernan indicated that he would not return until a filtration system was installed.

My next trip was ten years later in 1968. On March 12, Wally Smith, head of the civil department came into my office about 2.00pm and asked if I could go to Peru immediately, since a call for hydro consulting services was being issued by Electro-Peru. He had just received a telex from Hernan. I though immediately meant in a few days, so I said OK. But Wally replied that passage had already been booked on a Trans-Canada Airlines (TCA) flight out of Montreal at 6.00pm to connect with a Braniff flight out of New York which would arrive in Lima at about 8.00am the next day. There was a meeting with Electro-Peru scheduled for 11.00am. So I took a taxi home, packed a bag and caught the TCA flight.



Hernan Estebridis at the Palace, Lima.

I arrived in Lima and was met by Hernan at the airport. His first question, after greeting me was "have you brought the petrochemical brochure". This threw me for a loop, and I said no. Hernan then explained that there had been some confusion at the Electro-Peru offices, and the call for consultants was for petrochemical work, not hydro. Fortunately I had grabbed our general brochure on leaving the office, and it included some data on our petrochemical work in our Calgary office, but I was unfamiliar with the work. We proceeded to Hernan's office to cobble together something on petrochemicals, only to find a message from Electro-Peru cancelling the 11.00am meeting.

The country was in some political turmoil, since there had been a coup attempt the previous week, which could perhaps explain some of the confusion. Since I was in Lima, Hernan decided that I should at least meet with Augusto, the new president of Electro-Peru.

The legislature building, Lima.

Unfortunately, he was also a member of the legislature, and conducted all his business from his safer offices in the legislature building. To add further to our difficulties, due to the recent attempted coup, the legislature building was surrounded by two rings of soldiers manning gates, where passes were required before proceeding further. Passes could only be obtained on official business from the local police station.

When Hernan described the situation, I decided that it was not worth the attempt to meet with Augusto. However, Hernan was adamant, and said he knew how to by-pass the security arrangements. So we proceeded, and easily passed the first gate with a few pesos handed to the soldier. Unfortunately, this method would not work at the second gate, since it was manned by officers. Here Hernan mentioned that he knew a route through the building which would by-pass the check-point. We ducked through a cleaner's storage room to a narrow back corridor and quietly walked along to emerge through another cleaning closet into the corridor outside Augusto's office. Needless to say, I was becoming quite nervous at all this, since the numerous soldiers and officers wandering about were fully armed. I suggested that we return, but again Hernan said he did this quite often and not to worry. We arrived at Augusto's office and fortunately he was expecting us. I had a brief discussion about our hydro experience, and gave

Augusto our brochure. On leaving, I noticed Augusto toss our brochure into a large pile of other brochures in a corner of the office!

View from hotel in Lima.

That evening we had dinner, and after dinner, Hernan asked if I would like to see the slums. I asked why, and Hernan said he had something he wanted to show me. We drove out to the slums; Herman parked the car and started to walk away without locking it. I mentioned this to him, and he asked me to look at the car, but I did not understand his request. Hernan then pointed out that there were hub-caps on the wheels and wipers on the windshield, and I understood then that cars were not vandalized. So we walked around, found a bar and sat down for a beer. About a half-hour later, near midnight, we returned to the car, and I could see that it had not been disturbed. I mentioned that this would have been impossible in New York, where Harlem was in flames almost every night. Hernan replied "los Americanos son locos, nosotros somos civilados!" – (the Americans are mad, we are civilized). Unfortunately the Peru slums are now much worse than Harlem, and I put this down to the effect of television. In 1968, television transmissions had just started in Lima, and the poor did not yet know how the other half of the world lived, but they quickly learned.

In December of 1963 we received an invitation to submit a proposal for consulting services on a 100MW hydro plant in Ecuador, so Harold Hurdle and I flew down to Quito and checked into a hotel. We had a meeting with Empresa Electrica del Ecuador (E3) and a flight for all interested consultants to the proposed site, was arranged for the next day. We arrived at the airport and found a green military DC3 waiting for us. Apparently where were no domestic airlines, so the military had taken over this service to provide access to remote areas. Inside the aircraft there were canvas seats as would be expected in a military transport. The pilot gave a brief safety talk before take-off, and told us to hang on tightly on landing, since the airport landing strip was on the side of a mountain slope, and he would be landing on one wheel!

We landed safely, but I did not relish the prospect of taking off from a side-sloping runway for our return flight. Several trucks were provided to take us to the site, so we climbed up and hung onto the sides of the box. After a short ride we arrived at the site, and I immediately saw that there must have been at least a decimal error in the size of the project.

The small hydro plant intake.

The river was only a stream, and work on the intake had already commenced. I asked the E3 staff what the capacity would be, and was told about 10MW! This was just too small to justify a proposal, particularly since they wanted all the work to be undertaken in Quito. Lunch was arranged at a local cantina, and the asado was enjoyed by all. I found a small local consulting company looking for some assistance on submitting a proposal based on us providing one or two engineers to their Quito office. But it was just not feasible, since our Canadian costs were too high compared with those for alternative Brazilian or Spain-based engineers.

Excavating the intake canal.

I asked around for anyone driving back to Quito, and found Jose, an Ecuadorian engineer with a Toyota 4x4, so asked if he had space for two, and he offered us a lift. It took about 4 hours to drive back through mountain roads at breakneck speed. I sometimes thought that it would have been far preferable to fly – but at least we got a good view of the mountainous countryside. At one point we raced past a large stone ball monument at the side of the road, I asked what it was, and Jose said that it marked the equator. I asked Jose to stop for a photo, but by then we were too far past it. Jose told us we had to reach Quito before dark, since travelling on a narrow winding and dark mountain road was just too dangerous, so we did not have time to stop for photos.

In 1970, I spent a couple of days in Bogota, Colombia, staying again at the same hotel. Our agent there had found out that there would be a call for consulting services for a large hydro plant up in the mountains.

Unfortunately, the site visit was cancelled due to a landslide on the access road, so I returned to Montreal. However, I do remember that our agent had a large open touring car built about 1934. The shocks were gone, and it could not travel at over about 40kph without getting into a long loping bounce. We were late going to the airport, so he speeded up to about 50kph, and we literally loped along until reaching the airport about 15 minutes later. Quite a ride!

Ecuador, view on the return trip.

Between 1970 and 1975, I made three trips to Caracas, Venezuela. We had an association with a local contractor-consultant who specialized in building large apartment condo blocks. Alberto was the senior partner, and if they could not clear at least 35% on a building, they were not interested. I was shown one with the garage for cars in the basement, which included a suite with no windows. It had an attached garage with a steel roll-up door marked “Servicio” and a numerical key pad. Apparently all their buildings had such a facility, used for discreet assignments!

However, I found out that they were a bit - “dodgy” is probably the best word. They were always promising a meeting with the local utility, but the meetings never took place for some reason or another. I was wined and dined, and stayed at a luxurious resort hotel overlooking Caracas. I even had dinner in their homes, where I found that they collected art, to such an extent that many of the rooms in the homes had wires stretched from floor to ceiling, on which oil paintings were mounted back to back. But I never saw their offices or any contractor’s yards with construction equipment.

At the time, Venezuela was awash with oil money, and the local utility had the practice of awarding dual feasibility contracts for consulting services on each project. They thought that they benefited from "second opinions" and development cost would be lower. I never found out how the geotechnical information was shared.

Alberto would either call us, very excited about a prospect, or send a telex at the last moment asking me to come down. When this happened for the third time, I went to see Con Mulherin, our president, and asked him if he had anything on his calendar for the next week. He looked it over, and found it was reasonably clear, so I suggested he cancel his appointments and accompany me to Caracas. He thought this was a good idea, since he had not seen Alberto recently. On the flight down to Caracas, we had dinner together, and I turned to Con and told him what would happen during our visit. I mentioned that we would be royally entertained, wined and dined, but would not see any officials from the power company, nor have any meaningful meetings. He did not believe this, and I replied that I would not mention it again.

We checked into the Eurobuilding Hotel, and events proceeded to unfold just as I had predicted. On the third day there, we were having an excellent breakfast together on the hotel patio overlooking Caracas, and I was smiling at the prospect of consuming some tasty tropical fruit. When Con saw this, he asked what was I smiling about when we did not seem to be getting anywhere with our work. I then reminded Con of our conversation on the aircraft; he frowned, and asked what we should do about it. I replied "Con, we are going to enjoy ourselves for the rest of the trip; then we will depart and never come back" – which is exactly what we did. I do remember attending a cocktail party on our last evening there, where I was persuaded to get up on a chair and tell a somewhat off-color joke (in Spanish) about a rather well-endowed male bird with short legs that an ornithologist had discovered in the Amazon jungle, which he had named a "Yui-yui-yui" bird, because this was its cry on attempting to land!

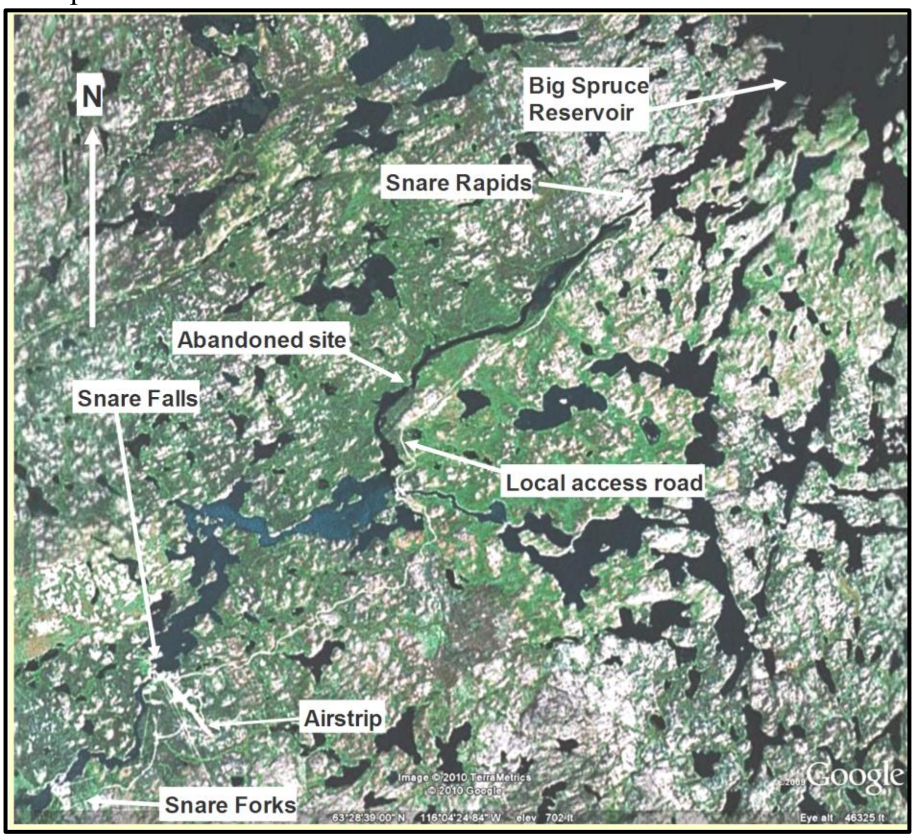
The countries in South America seemed to be divided between overseas consultants. We worked in Bolivia, and in Brazil on a large contract shared with Kaiser from San Francisco funded by the World Bank. Harza from Chicago had contracts in Venezuela. Motor-Columbus from Switzerland had contracts in Colombia. Norconsult from Norway had contracts in Ecuador, and Lahmeyer from Germany had contracts in Peru. We never got any work in Peru, Venezuela or Ecuador, but were successful on getting a water supply feasibility study contract for Medellin in Colombia, funded by the Canadian government.

12. SNARE FALLS 1960-61

The Northern Canada Power Commission (NCPC) was formed in 1946 to develop the hydro resources of the Northwest and Yukon Territories. Montreal Engineering was selected as their consultant, and their first plants were at Mayo in the Yukon and Snare Rapids in the Northwest Territories. With the development of gold mines around Yellowknife, the demand for power increased, and NCPC asked us to look at developing the next site on the Snare River downstream of the Snare Rapids powerplant with a 5MW hydro development.

So in the summer of 1960, I flew out to Yellowknife with Con Mulherin, from our construction department.

From Yellowknife, we were flown by Max Ward, owner of WardAir, in a De Havilland DHC-3 Otter to the Snare plant Big Spruce reservoir, landing near the intake. Max later expanded WardAir by starting a charter service out of Calgary to England, and was very successful, being bought out after about 15 years by Canadian Pacific Airways to lessen the competition.



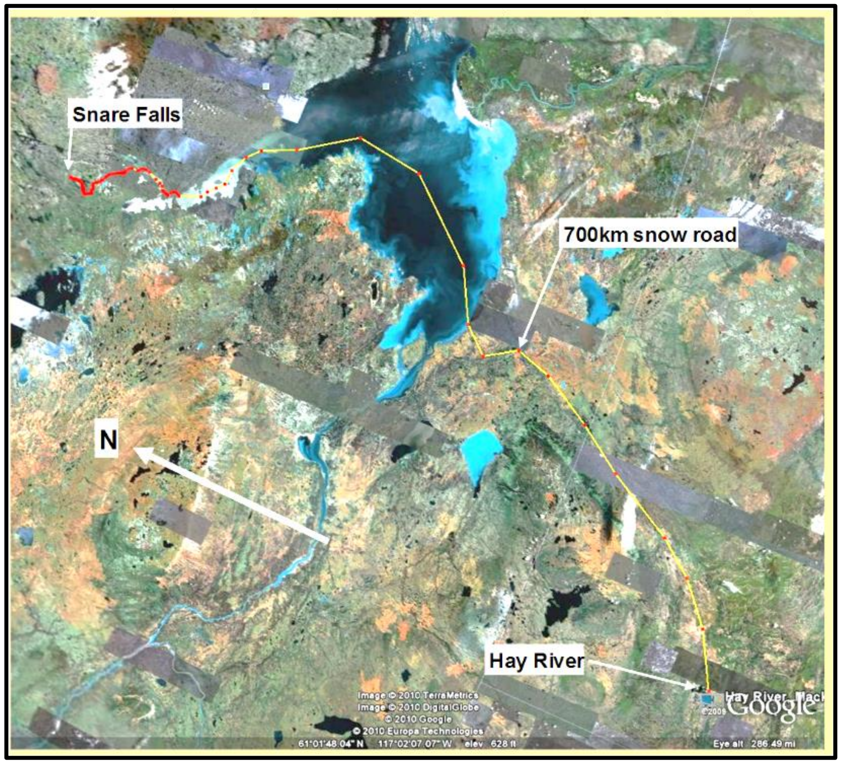
Location of Snare River powerplants. **From Google Earth.**

WardAir dock at Yellowknife - 1960.

Charlie Stollery, the president of Poole Construction (now PCL) also flew with us to Snare, since the intention was to negotiate a contract with Poole for construction of the plant. I had a set of conceptual project drawings, and after arriving at the lower site by canoe, I outlined where the various structures would be located. The development appeared to be quite easy, since there was sound rock exposed over most of the area. Poole had built the upper Snare plant, and was the only hydro contractor with experience in the remote north. Everything required was brought in over a snow road across Great Slave Lake from the railhead at Hay River.

We stayed at the Snare camp, a cluster of about 12 homes and a staff-house for visitors. This was in the days before powerplant automation, so there was a full complement of operators and their families at the remote isolated camp. The only access was by air. Apart from a small baseball diamond, there were no sports facilities for the children, and all were being home schooled. After dinner one evening, Graham Tench, the chief operator asked us over for a drink at his home. We arrived about 8.00pm, and settled down to a beer in front of a large television with nothing but snow on the screen. I asked Graham about reception, since the nearest broadcast station was in Edmonton, some 1,080km directly south. He told me to be patient, and after about an hour, a picture started to form, the sound came on and as the picture cleared up, the bungalow door burst open and about 15 parents and children crowded into the room, to watch the show, and about 40 minutes later, when the snow returned they thanked Graham and left.

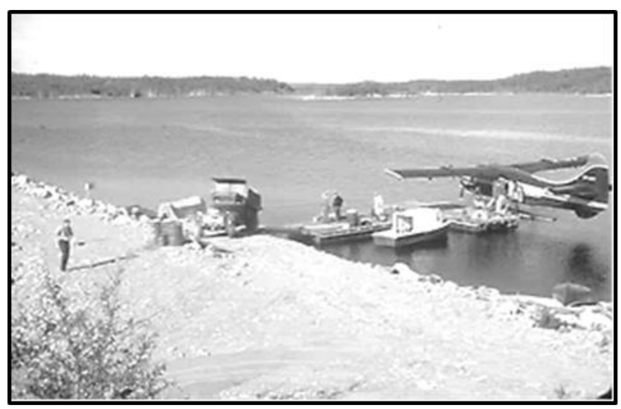
Graham then explained that there was no entertainment in the camp, so he had purchased the most powerful TV set available, set up a large antenna on a nearby hilltop and had a bell-button on the wall beside his chair. Whenever a picture appeared, he pressed the bell and it rang in all the homes, a signal to come on over if you wanted to. Graham figured that he was getting a faint signal after the second bounce off the ionosphere! Graham and his wife enjoyed the isolation, and they continued to work at Snare even after the plant was automated, and retired about 1980 to Victoria. He was awarded the Canadian Order of Merit for services in the North.



700km snow road from Hay River to site.

However, on arriving back in Montreal, Ted Humphries, the president of NCPC called to advise that their power requirements had increased, and could we find a site with about 7MW instead. So it was back to the drawing board. We just moved the site a further 9km downstream until we obtained a higher head, and found a much better site (at 63-23-28N, 116-11-12W on Google Earth) which was built and started operation in 1961, only 21 months from start to finish, a record. The site was in a very narrow canyon, so we developed an arrangement whereby a very deep and narrow trench was excavated around the damsite to two tunnels, one to the powerplant and the other to serve as the bypass for dewatering the site. All the excavated rock was used in the dam. The cost per kW was lower than for the upper site. Charlie complained that our whole site "was on wheels", and why had we wasted his time looking at the wrong site?

We had issued specifications for the equipment at the upper site, so addenda were issued simply changing the numbers for the higher head lower site.



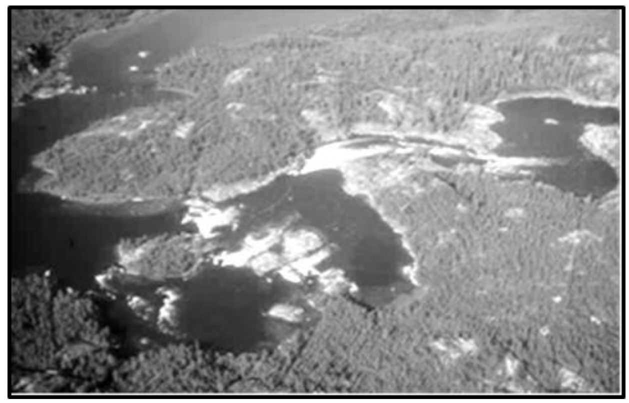
Dock on Dam at Snare Plant.

Allis Chalmers was the low bidder for the turbine, but I was suspicious of their quote since the equipment weight was much lower than in the other bids. From a close inspection of the weight distribution, I concluded that Allis had forgotten to include the steel turbine casing, since at the former lower head site, the casing was formed in concrete. Even adding an allowance for the casing cost, Allis was still the low bidder. I decided to invite Ron Passmore the Allis sales engineer for lunch, an unusual situation since manufacturers usually entertained the consultants. At lunch, we discussed the quote, and I eventually asked what would be the diameter of the turbine casing inlet, since this dimension was omitted in the bid data. This puzzled Ron, and he replied that the inlet would match the gate size, and it was our responsibility to size the gate. So I pointed out that with the higher head the specification called for a steel casing, and poor Ron turned white. After regaining his composure, he asked if they could add a casing, and I assured him that was acceptable. Then he wanted to know what would be a reasonable cost, too high and they would lose the job. So I told him to work it out and call me be back as soon as possible. A couple of days later Ron called and asked if $25,000 was acceptable, and I assured him it was, and a revised quote was received. Such an approach to contract awards would be totally unacceptable today – just too much red tape and contractual conditions.

Snare dam and powerplant.

Poole built the plant, but their quote for the unit prices was unbalanced. The cost of some timber crib work holding up the access road beside the powerhouse was more than that for concrete, so I changed the design to a concrete wing wall. Charlie called to complain, and told me that since there was no cost item in the bid document for the construction camp, he had to load the camp cost onto all early work, hence the high crib cost. I learned to add items for camps and move-in costs on future contracts.

However, a year later I was removed from the project design team to work full-time on the Brazeau development, and Gordon Atwell took over as the project engineer.



Site, about 9km below Big Spruce Reservoir.

One of our site engineers on the project was Austin Knowlton, and he called me when the powerhouse was nearing completion. The call was passed to me since Gordon was off on holiday. Austin wanted to know how the stops at the end of the crane rail were designed – a puzzling request. I told him that they could take the impact from a crane traveling at full speed into the stop, just in case control was lost. Austin then wanted to know if he could test the stops, to which I reluctantly agreed, provided there was no weight on the hook – I didn't want anything swinging into the powerhouse wall when the crane hit the stops. I later heard that when he ran the crane from the opposite end of the powerhouse at full speed into the stops. The whole powerhouse shook violently, but everything held together. Apparently everyone on site had heard about the test and had gathered to witness the event. Austin became famous for such stunts, and whenever I heard that he would be on a project, I instructed the designers to be certain that they checked that everything met the "Austin" design conditions.

The abandoned site – at the second rapids.

For commissioning the intake gate, the site engineers decided to put on a bit of a show, and invited Ted Humphries, President NCPC to press the gate lowering button. The gate was in the fully raised position, with the bottom just above the intake deck level. All went well for a few minutes, until the gate jammed on some concrete a couple of meters below deck level, that protruded about 2cm too far into the gate well – an embarrassing lesson for the site engineers.

A few months later, in January, Austin called again and asked if he could test the safety shut-off on the spillway gate electric motor hoists. I told him to go ahead, and he tried to lift a gate when it was solidly frozen into the ice. Of course, it would not budge, and the overload fuse tripped. Austin re-set the fuse and tried again, with the same result. A third attempt resulted in the motor burning out on excessive temperature, despite the outside temperature being close to 40 below. A new motor was supplied under guarantee by a very reluctant manufacturer when they heard of the circumstances. However, it was pointed out that the temperature overload solenoid was attached on the outside of the cast iron motor casing recording the outside temperature and not the motor temperature – it was changed, and on every future motor specification, the temperature sensor location was specified, all because of Austin's tests.

After this event, on the next project, at Sandy Brook, I told the engineers to check that the steelwork holding up the hoist was capable of sustaining the overload torque from the hoist, and it was found to be deficient, so it was re-designed. When Austin arrived on the site, he proceeded to test the hoist with the gate frozen in, and managed to break the lugs on the gate holding the chain from the hoist – something we had forgotten to check! Live and learn.

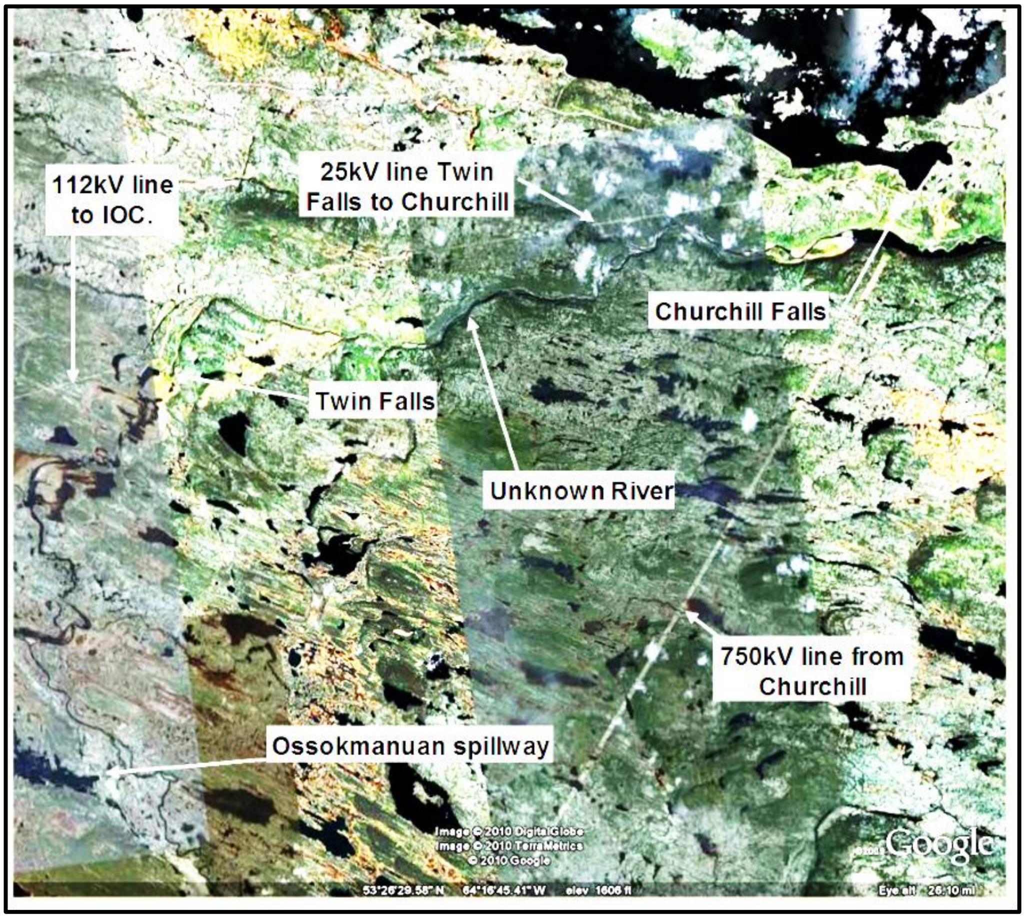
At NCPC offices in Hay River, March 1994.

NCPC's offices were on Ottawa, but all the plants were out west, so the offices were moved to Edmonton, and later to Hay River. In the process most of their project drawings were lost. I learned this about 40 years later when I was asked to see if flow through the Snare Falls plant could be increased slightly. I asked them to send a section through the powerhouse, so that I could work out the cavitation index for the turbine. Unfortunately no drawings were available. So I asked if someone could look at the large framed drawing showing a plant section which was mounted on the wall just inside the door at Snare Falls, and provide me with some dimensions. The reply was that Graham Tench had taken the drawing with him when he retired!

13 – TWIN FALLS 1963-69

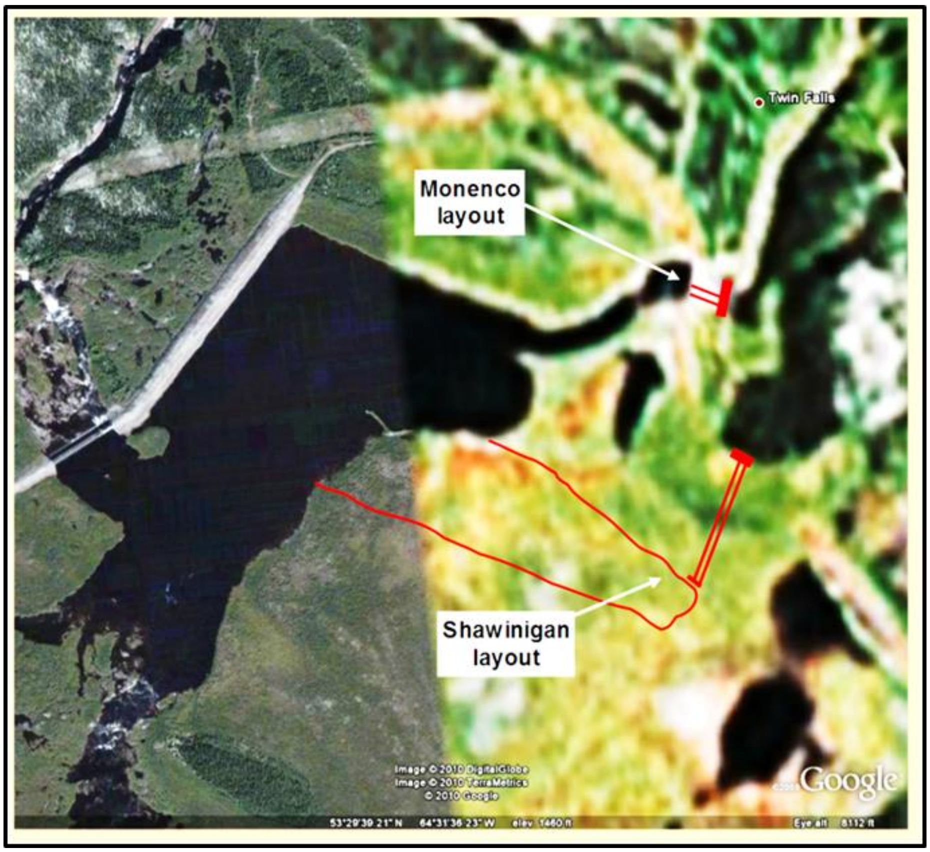
At Ossokmanuan Spillway – Oct. 1964.

In 1961, the Iron Ore Company of Canada (IOC) started construction of a large open pit mine and town at Wabush in western Labrador. Power was to be provided by a hydro development at Twin Falls, near Churchill Falls. The consultant was Shawinigan Engineering; we were retained to act as the "Owner's Engineer", and I was asked to keep an eye on the design. Shawinigan had developed a layout that included a long penstock gently dropping down into the Unknown Valley from the south. This was quite unacceptable since the frequency variations would be excessive, and Shawinigan had not thought of this. We suggested a layout with much shorter penstocks down a near-vertical rock face from the west. Shawinigan thought that construction on such a steep face was impossible, but we showed pictures of other developments where penstocks dropped down over very steep slopes, and they eventually agreed that is was possible, but still too expensive. Two estimates were produced by Shawinigan, with the west alignment costing $10 (yes, 10 dollars) more than the south alignment in a cost estimate of just over $13,000,000! The west alignment was selected due to the much improved frequency control.



Project location.

Work on the project proceeded smoothly for about 2 years. By this time, the mining consultant, who had produced the estimate for power requirements, had finalized all electric motor sizes, and realized that the 120MW capacity was going to be tight. The original power demand estimate had been for 85MW in the winter, reducing to about 55MW in the summer. The hydro plant size of two 60MW units was based on one unit being able to carry the full summer demand while the other was down for maintenance. The new demand was for 110MW in winter and about 75MW in summer. This information was communicated to the IOC, who then asked Shawinigan to determine what would happen to the power supply if one of the 60MW Francis turbines were to drop off the system due to a fault, when power demand was in the region of 110 to 120MW. A copy of the owner's letter was routinely forwarded to me.



Twin Falls - alternative layouts.

Over the preceding two years an amicable working arrangement had developed between Montreal Engineering and Shawinigan. After reading the letter, I phoned Bill Bonnell, my counterpart at Shawinigan to enquire how they would reply, since the answer appeared obvious. Bill advised that Shawinigan had just developed a sophisticated computer program which could determine the frequency variation on load changes in isolated hydro systems, based on the hydraulic characteristics of the powerplant, the generator inertia, the load inertia, motor torque and the change in load. I told Bill that this sounded very interesting, and that I would like to see their final report.

My interest resulted from an analysis of frequency variations and generator inertia requirements for isolated plants I had undertaken during commissioning problems with an isolated plant at Whitehorse. This resulted in a paper I presented to the Canadian Electrical Association in Halifax in 1961. Unfortunately, it was not accepted for publication since I had criticized a NEMA (National Electrical Manufacturers Association) standard, something just not done by a young engineer! However, it was the only paper on inertia ever presented, and the paper's subject spread around the world, so I had many requests for copies. I eventually produced an updated paper and it was accepted by a journal.

Dick Fitzmaurice at Ossokmanuan, 1964.

Based on data in the paper, the unit would stall under excessive load, and the system would fall apart as the low frequency relays cut off load. Shawinigan had used the methodology in their program, but omitted the effect of the low frequency!

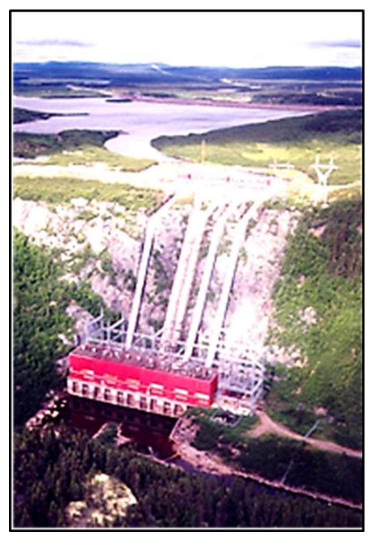
The mine consultant provided the detailed list of loads and motor characteristics to Shawinigan. Two months later I had a call from Bill advising that he had just returned from holiday, had not yet read the report but it was finished, and that a copy was being couriered to me. Next day I read the report, not getting past the executive summary which started with "We have determined that when one of the Francis units drops off the system, when load demand is at 120MW, the other 60MW turbine will be able to continue providing power at half speed". I immediately phoned Bill, and asked him if he had read the report, to which he replied in the negative.

I then asked Bill if he was sitting down, and I read the opening sentence of the short executive summary - there followed a moment of silence, and after Bill composed himself, he thanked me and said he would try to retrieve the report from the mail room, which he was fortunately able to do. The report was revised to indicate that load would have to be reduced to be within the capacity of the remaining unit. Bill later advised me that they were not charging for the report, it was being written off as an internal lesson in what could go wrong with quality control in their computer department. As for me, it was another lesson on not trusting untried engineering computer programs written by mathematical experts. With the added demand for power, another 2 units were installed, and then a fifth unit, see photo of completed development. →

At the Ossokmanuan Spillway, there were two heated gates, each equipped with a hoist for release of stored water in winter, and a long overflow spillway with timber logs, designed to be raised in the future when the Churchill Falls plant was built, by raising the piers, adding a deck and stoplog hoist.

The first two units at Twin Falls were commissioned, and I flew to the plant in early October 1964 with Dick Fitzmaurice from our electrical department, to issue a commissioning certificate required by the insurance company. We had a good look over all the facilities and issued the certificate. The plant was fully manned, and there was a village for the operators with a Hudson's Bay general store, a clinic with a nurse, and a school to grade 6. There were no recreational facilities, so the operators decided to add a "tax" to all alcoholic drinks brought in to the store, and use the money to build an indoor hockey rink. Much to their surprise, they raised the money within two years, and realized that they had a problem.

Ossokmanuan Spillway - Sept. 2000.



Aerial view of Twin Falls, taken from above penstock area in Shawinigan layout, October 1964.

Another unit was added in 1967 to serve as the power supply during construction of the much larger 5,250MW nearby Churchill Falls development. The Ossokmanuan spillway was expanded and retained as part of the Churchill Falls development, but the Twin Falls powerhouse is now abandoned, too remote to even salvage the equipment, apart from the easily dismantled smaller components such as cranes, gates and hoists. Twin Falls uses the same water as at Churchill Falls, the reason Twin was closed.

Operators housing in 1964, now moved to Churchill Falls.

Abandoned intakes, Sept. 2000, no hoist on gantry.

I was at the plant again in February of 1969, this time with Bob Provost, another engineer from the electrical department. The temperature there was about 35C below, but we were quite comfortable since all our work was indoors. At the powerhouse, five units were on line and the operator proudly showed the controls for raising the spillway gates at the remote Ossokmanuan spillway, about 40km away over a snow-covered road. The installation included a klaxon to warn anyone downstream that the gates were about to open, and a microphone inside the diesel generator house to listen to the diesel starting. We asked to listen, and heard the klaxon, but the diesel only ground on without starting – it was just too cold, and it was later converted to a propane gas unit.

In 1976, when Churchill was fully operational, the plant was shut down and mothballed with the heating on, with the idea that it could be started again for peaking duties. However, this idea was abandoned, since it would waste too much water.

In 1998, a flood study was undertaken by Acres. They found that the time required to open all the timber stoplogs and gates at Ossokmanuan during an extreme flood event was far too long. By the time operators flew into Ossokmanuan by helicopter from Churchill and spent many hours lifting the logs in 17 sluices, the flood would have arrived and overtopped the dam. The stoplog gates were then fitted with a quick-release mechanism identical (but larger) to one I had designed for the Lachute dam. I was retained to review the design, and the only major comment I had was that the logs needed to be trimmed a bit at the corners to avoid jamming when released.

Aerial view of Twin Falls powerhouse

With the earlier work in Labrador, and now at Twin Falls, we became aware of the expertise within Shawinigan Engineering, and we worked together on many projects, even forming a joint consulting company based in St. John's in

Newfoundland called Shawmont. However, Shawinigan ran into financial difficulties and asked us if we were interested in purchasing the firm. We looked over their books, but declined when we found that their pension system was severely underfunded. It was a defined benefit plan inherited from the utility Shawinigan Water and Power that used to own the company. Based on an actuarial analysis, the funding was less than 50%, and could not be integrated into our defined contribution pension plan. Shawinigan was eventually purchased by Lavalin Engineering with their pensions distributed in proportion to the funding and rolled into the Lavalin fund. Unfortunately, many of the Shawinigan senior engineers on the verge of retirement had to continue working well into their ‘70‘s.

Notched stoplogs and quick-release mechanism at Ossokmanuan.

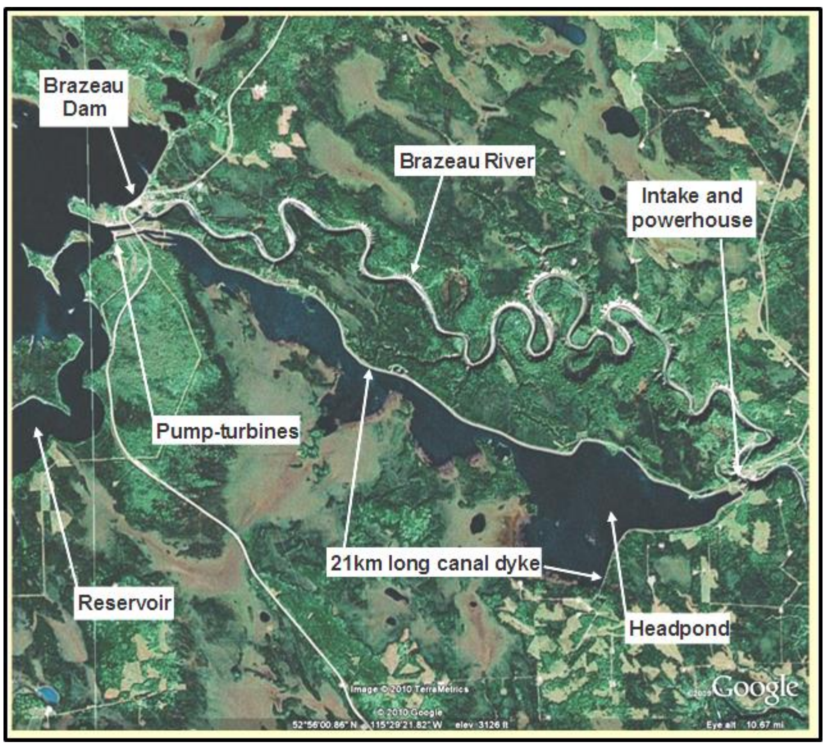
14 – BRAZEAU 1959-67

The Brazeau project is quite complex. It includes an embankment dam some 65m high across the Brazeau River, (140km SE of Edmonton) a powerplant containing two unique pump-turbines which pump water up into a long canal when the reservoir is low; and turbine water into the canal when the reservoir is high. Near the downsteam end of the 18km long canal there is a powerhouse with 2 Francis turbines having a total capacity of 343MW. There were two low-level outlets through the dam that were used as a temporary spillway, until the main spillway was built several years later between the pump-turbines and the dam.

Equipment starting to build the dam.

After about a week spent looking over the preliminary concepts for the project, Mr. Gaherty invited me over to the Montreal Club for lunch along with his assistant Harold Hurdle, to talk about the project. This was in the days of the 3-martini lunch, and Mr. Gaherty mentioned that he liked to drink martinis, and hoped I would join him. The drinks were served, Mr. Gaherty started to expound his ideas on the project, and I took out a pad and pen to record the discussion. Mr. Gaherty noted this and said “Jim, the club has a rule, no paper and pencils are allowed to be seen in the club. Also I would like to add another rule of my own, please remember what I say after the first martini, question what I say after the second martini, and forget what I say after the third martini!” We got along famously. Many times we were the last to leave the club, and after quaffing 3 martinis, I would have to phone Vera and say I was coming home early – in no condition to return to the office. We met regularly for lunch about every fortnight on a Friday, for almost 3 years. A wonderful learning experience!

Brazeau was by far the largest hydro plant ever built by Calgary Power. In fact, for about 4 months after it started in 1965, it had the largest powered hydro turbines in the world at 210,000HP and 250,000HP. I remember showing a couple of Russian engineers around the plant in 1968, and when they saw the nameplate on the turbine giving the horsepower, they asked me to come over, and made motions of scratching out one of the zeros. Unfortunately, we did not have an interpreter. I eventually managed to convince them of the capacity by working out the horsepower on a piece of paper from the size of the pipe carrying the water, the water velocity, and the height of the intake above the powerhouse. Currently, the record for turbine size is just over 1,000,000HP.



Project layout.

We pushed the design envelope in many areas. The working stress in the penstocks was very high since we used high-strength T1 steel. This required careful control of the welding process and tensile testing of run-off tabs at the end of every weld, from each penstock can. One tab showed under-strength welds, and this was traced to an open window admitting 30 degree below Celsius cold air adjacent to the welding machine!

We checked with the railway companies to find out the largest pipe that could be transported from Levis in Quebec, where the penstock can sections were being welded, to the site. It was 18.0ft. So the penstock for Unit#1 had this diameter. However, we wanted to install a larger pipe on the second unit, and realized that before the steel "spiders" holding the pipe in a round configuration were installed, the pipe sagged into an oval shape, losing about 18inches in the vertical diameter. So the second unit has a pipe diameter of 19.5ft. Unfortunately, the pipe dimensions were so tight when travelling under bridges, that one pipe contacted formwork on a bridge being repaired, and was knocked sideways, almost falling off the railcar. It was hauled back to the rail yards at Westmount, where I examined it, found the damage to be minor, and told them to proceed with shipment

There were gates on two concrete conduits under the dam, designed to close under a head of about 40m. However, Mr. Gaherty wanted to use the gates as temporary low-level outlets, regulating flows under heads of 64m. This was a 60% increase in design load on the gate wheels, so we commissioned Mr. Stan Pappius, Chief engineer at the Vickers plant in Montreal, where the gates were being manufactured, to undertake full-scale tests on a wheel and bearing riding on a rail, to determine if bearing and rail could withstand the added load. Fortunately, the test was successful, but you could see the deflection of the rail contact surface at full load – not very reassuring!

The concrete conduits through the dam were oval, 12ft. wide by 15ft high. We engaged Dr. Stein, professor of structures at McGill University to undertake a finite element analysis of the oval, to determine concrete stresses. The oval shape was found to be much more efficient than a circular shape when resisting earth loads from the dam. Both Dr. Stein and Dr. Hardy, dean of geotechnical engineering at the University of Edmonton, cooperated to produce an estimate of settlement and deflection in the conduit under the dam load. Unfortunately, they agreed to disagree, with Dr. Stein calculating settlement at over 12 inches, and Dr. Hardy at less than 4 inches. Dr. Hardy was correct, and the difference was found to be in Dr. Stein assuming that the modulus of elasticity of the rock was the same as determined from shallow samples, whereas Dr. Hardy had assumed that the modulus increased with depth due to the effects of surface weathering.

Measuring clearances on pipe in Westmount railway yard.

Standing in front of turbine stay vane ring, 1962.

The Francis turbine for Unit #1 was a duplicate of the Hydro Quebec turbine recently installed at Bersimis, but operating at a higher head, producing more power. This was in the days when turbine manufacturers always built the unit slightly larger than required, with something like 8% to 12% of spare capacity in case their calculations were too optimistic, or in case the castings shrank more than estimated on cooling. After casting the first components for the first unit at Brazeau, Mr. Gaherty asked Mr. Bob Sproule, Chief engineer at Dominion Engineering, the turbine manufacturer, what the capacity would be if no allowance for shrinkage and optimism were included.

A few days later, Bob replied that the capacity could be increased from 210,000HP to 250,000HP, a 19% increase in power! This incident shows what can be done with a "hands-on engineer-owner" capable of making quick decisions, permitting a last-minute change in design. Nowadays, with computer designs and finite element analysis of flows, turbines rarely have more than 3% of spare capacity, and owners would require months of study to make such a decision.

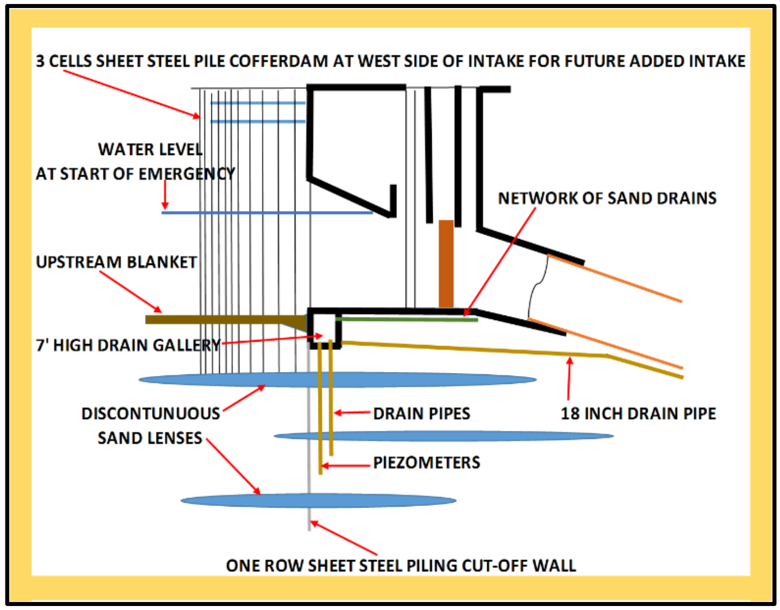
Unfortunately in one case, we pushed the design envelope a bit too far. Our geotechnical consultant was Dr. Hardy, who had undertaken many design assignments for Calgary Power and was deemed infallible. He had presented his design concept for the intake at a meeting in Montreal attended by Mr. Gaherty, Mr. Stairs a senior Vice-President, Howard McLean our Chief Construction Engineer, and myself, and later sent us his report.

However, when I saw the report and details of the design for the intake foundation, I was so worried about the complexity to such an extent, that I wrote a 2-page memorandum to our Chief Civil Engineer Walter Smith, my superior, expressing my concerns. I could not put my finger on exactly what was troubling about the design, but my instinct said something was definitely wrong. In my memo, which I still have, I discussed the risks in the design and ended by requesting another meeting with Dr. Hardy. Walter said I could not question Dr. Hardy's designs, so no meeting, and he discarded my memo into the waste paper basket, but I told him I was keeping my copy. However, I was so worried that I requested the site resident engineer, Frank Vassallo, to carefully monitor the water pressure under the intake, a simple task, since there was a drainage gallery below the intake, accessible by a vertical 100ft ladder. I also provided Frank with a chart showing safe, unsafe and disaster water pressures, with a note saying that I had to be advised of the measured pressure on a daily basis.

View of intake – headpond half full. Vertical inspection shaft is in square box in corner nearest to camera.

As the work progressed, all went well. I had been inspecting the construction work about every three months, flying out to Edmonton, renting a car, and driving to the site. The daily pressure readings at the intake showed no change, and all seemed well.

In November 1964, I went to site to commission the first unit, and was met at the airport by a very worried Frank. He told me that over the past few hours, the water pressure under the intake had started to increase, was now over the safe level, and if it continued at the same rate, it would reach the disaster pressure in just 19 hours! We had to do something immediately to avoid a disaster.



Schematic of intake.

The reservoir in front of the intake was only at half level, a precaution very fortunately proposed by Frank months previously, when he understood my concerns. However, there was no way to evacuate the water except through the turbine, unfortunately not ready to operate, since the thrust bearing would require a few more days to install.

Looking at compressors on powerhouse turbine floor.

During our discussions on the 90 minute drive back to the site we arrived at a plan to pass water through the turbine by tying down the generator, preventing the unit from rotating, something never done in the past.

At site we had a meeting with the contractor, and the turbine erector Hans Jensen from Dominion Engineering, and phoned Dr. Hardy. We initiated the plan after Frank and I had signed letters taking over control of the project and absolving the contractor and the turbine manufacturer of any damages. The construction camp at the powerhouse was evacuated, and because of the danger, the only staff remaining on site was the contractor's superintendent, Frank and one of his engineers, Grover McTavish, Bill Steele, a volunteer from the survey crew to read the pressure gauges, Bill Maxwell, the plant chief operator, Bill Muzillo operator, Hans and myself.

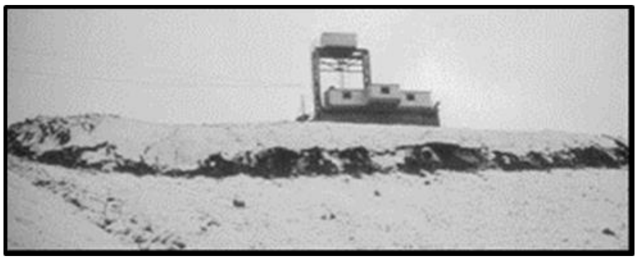
Hans, was instructed to stop bearing installation and tie down the 157MW generator by attaching wire ropes from the generator spider to any fixed point in the powerhouse. Within two hours the generator was laced with rope and secure. You almost had to crawl through the ropes to access the turbine pit, and I didn't think the generator would rotate under any circumstances, since Hans had done such a good job. The wicket gates were opened to 6% and Grover kept a close watch was kept on water level in the gallery and flow in the drain was recorded by Bill Steele at a measuring station between the two penstocks about 80m down the slope from the intake. After about three hours, it became evident that the battle was being lost, and that the wicket gates would have to be opened further.

After some discussion, and over the vociferous objections of Hans, the wicket gates were opened to 11%. By this time the noise and vibration within the powerhouse was indescribable - expected, since something like 20,000 horsepower of energy was being dissipated through the stationary turbine! The effect on the rate of water level rise in the gallery was immediate; it peaked within 0.3m of the gallery roof before subsiding. Within a few more hours the headpond was empty, and the crisis was over much to our relief.

But what had gone wrong? A detailed examination of the headpond upstream of the intake revealed a watertight blanket. However, the rate of water inflow to the gallery indicated that there must have been a direct connection to horizontal sand lenses within the foundation till adjacent to the intake. Eventually, the investigation concentrated on the sheet steel piles beside the intake, where it was found that there was just enough flow area within the interlocks to conduct water down to the sand lenses, through and below the perimeter sheet steel piling and then up the drains into the gallery. Water could flow into the sheet steel pile interlocks through the vertical steel slots where the steel to steel contact was discontinuous.

Powerhouse interior, generator floor.

The remedial work included welding closed all the vertical interlock slots from 3m below grade to 1m above maximum flood water level, the addition of a bentonite-beneficiated blanket contact with the sheet steel piling to 3m below grade to improve impermeability, and a float operated alarm in the drainage gallery. The repairs, undertaken in mid-winter, proved successful and operated without incident. Of course, the incident had to happen in the late afternoon when the office in Montreal was closed. We phoned the next day to advise what had happened and I spoke to Chris Ritchie, the senior Vice-President who advised me to take a few deep breaths to calm down before I continued, I was speaking far too rapidly! He was quite astounded at the events, but did not comment.



View of earth starting to slide off, below intake.

Dr. Hardy arrived on site in the next morning, just in time to see the second disaster begin to unfold, as the earth dyke behind and downstream of the intake started to slide down the hill towards the powerhouse. The earth was moving relatively fast, at about 1ft per hour, and we had avoided walking on the moving earth in case it suddenly accelerated. However, Dr. Hardy walked confidently out over it, and we followed. The dyke was founded on about 30 meters of over-consolidated glacial till over horizontally stratified sandstone and shale. The slope of an erosion gulley traversed by the dyke varied between 3 and 3.5 horizontal to one vertical.

A geotechnical investigation of the till in the gulley indicated that the till could easily support a 25m high dam with a downstream slope of 2.5:1. Construction of the dyke commenced at the upstream end of the canal, about 18km away, and 2 years later reached the gulley, after winter breaks of several months. The dyke section consisted of a central core of glacial till, with flanks of either till at a downstream slope of 3:1 in the sections below 8m high or sandy gravel in higher sections, where the downstream slope was 2.5:1.

When the dyke was being built across the gulley at the intake, the downstream slope failed in a shallow slide when the dyke was only 15m high. After consultations with Dr. Hardy, the failure was attributed to the use of excessively silty and wet rounded sandy gravel obtained from a riverbed deposit. The material was removed, and the design changed to include sand filters and drains on the downstream face of the central till core, and the use of clean gravel at a slope of 2.25 in 1. This design was successful, and the dyke construction crew proceeded on downstream.

View of earth slide downstream of intake.

View from river level – powerhouse on right. Much of the slide material ended up sliding down the gulley.

However, after about 2 months in place, a crack appeared, to arch in a curve across the downstream face, reaching to within about 3 meters of the crest, extending across most of the width of the gulley.

Hans Jensen and Bill Maxwell at powerhouse bridge. Note sheet steel piling protecting the powerhouse.

Completed powerhouse.

Dr. Hardy had arrived during a mild snowstorm, and the crack, which was now several centimeters wide, was clearly visible as a black line in the snow. By late afternoon it was possible to climb down into the open crack to the sliding surface near the edge of the gulley, where the height of the gravel fill was less than 2m. There, a perfectly smooth slikenslide could be observed, with the gravel sliding on the slick surface of the glacial till foundation. The contractor was instructed to remove the slide material. This required bulldozing most of the material off the slope, and catching the material which had slid into the gulley beside the powerhouse with a dragline shovel placed at the entrance to the powerhouse, and depositing the material in the river. Sheet steel piling was also placed on the back and side wall of the powerhouse as protection from material falling down the gully. After this work was completed we left the site and Dr. Hardy asked me to come to his home in Edmonton for dinner before I caught the midnight "red-eye" flight to Montreal. This was a surprise, since I did not know Dr. Hardy that well, but I was soon to find out the reason for the invitation.

I arrived at Dr. Hardy's home overlooking the North Saskatchewan River and he asked me to join him for a drink, saying that he had heard that I liked scotch, and he had found a new brand "Cutty Sark". After getting three-quarters through a 25oz bottle, Dr. Hardy, by now called Bob, approached me and put his arm over my shoulder and said "Jim, I hear you like to write papers", to which I replied yes, and he continued "you won't write anything about Brazeau, will you", I promised not to, and I kept the promise until long after he passed away.

As for the slippery slope, we found during further testing of the till foundation, that the surface of the over-consolidated glacial till had lost considerable strength down to about one meter, due to being exposed to the effects of freeze-thaw over two winters and now had insufficient shear strength to support the dam, something very difficult to anticipate. I continued to work with Bob Hardy on many developments, the next one being at Duncan Lake in British Columbia, and I certainly respected Bob's opinion.

When I returned to Montreal, I walked into Walter's office with my memo. He said to forget about it, and that was the last of the matter, but it certainly was my baptism of fire in the hydro business.

A month later Dr. Hardy produced a design for the repairs at the intake, I was dubious about the details, and refused to sign the drawing, the only drawing I ever refused to sign in all my 38 years with the company. I was concerned about the seepage path under the dam near the intake, which I thought was far too short. The drawing was signed by several company vice-presidents, including Chris Ritchie, after considerable argument and discussion.

Part of the 21km of dykes.

Some forty years later, in September 2006, I got a phone call from Andrew Szojka the Lead Engineer, Hydrotechnology Technical Services for TransAlta, the successor to Calgary Power. He mentioned that a sinkhole had been discovered at Brazeau, and I interrupted him to say "don't tell me anything more. Facing downstream, the sinkhole is on the right side of the intake, about 4 meters out from the upstream corner". There was a few seconds silence on the phone, and then he asked me "who told you, we are trying to keep this quiet!" I answered and explained my concerns about the old design, saying I had been waiting for such a phone call.

Next day I was on a flight to Calgary where a helicopter had been chartered to fly us to Brazeau the following morning. We took off, in wintry weather, and had to land temporarily in a farmer's field during a snow squall. Taking off again we managed to reach Rocky Mountain House, but had to land at the small airport due to fog. We rented a Yukon 4x4 from the local GM dealer and drove to Brazeau. We looked at the sinkhole and discussed remedial work with the consultant retained for the repairs. We also looked at several of the drawings of the intake and dams, all containing my signature. Eventually the 1965 repair drawing was produced, and Andrew asked me to look at the signatures. I had completely forgotten my refusal to sign it, so I searched for my signature, and told Andrew I did not know why my signature was not on the drawing, to which he replied "we heard that you refused to sign it". This completely blew me away. Andrew was the third operating manager since Tom Stanley, the Vice President for operations in 1966 had retired, and I had thought that nobody outside our office knew about the controversy over the intake design!

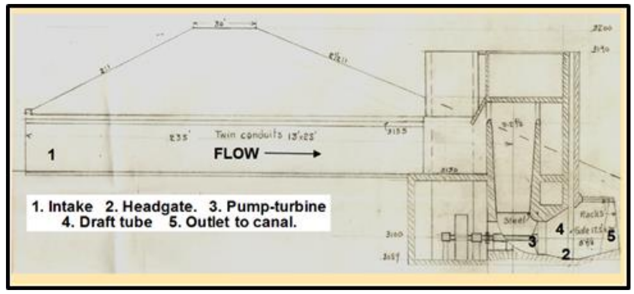
Upstream face, Brazeau Dyke.

Looking for slide cracks, none found. September 2006.

A few years ago I was asked to participate in a panel discussion on emergency actions during a dam failure. All the other panel members spoke about committees and action approvals, consultations with the head office and so forth. I asked the chairman if I could speak last, and when I spoke, I summarized the measures taken during the Brazeau failures, without identifying the project, noting the need for immediate actions, sufficient authority to command resources, the ability to take responsibility for the work and someone willing to step in front to direct work without having to refer back to any other offices. This was possible at Brazeau due to the close relationship between consultant and client. It is certainly not possible today with numerous agencies responsible for various safety issues, overlapping jurisdictions, and the inability to assume unquestioned command. This explains the failure of FEMA at New Orleans. Who would be foolish enough today to say to Hans, the turbine erector, "we just have to do it. I will type out a paper absolving Dominion Engineering of all responsibility, you can read it over the phone to Percy Soicher (his superior in Montreal) and we can both sign it".

Pumphouse, adjacent to Brazeau Dam.

But this was not the last surprise at Brazeau. The development has two powerplants, with a pump-turbine some 18km upstream, adjacent to the 65m high Brazeau Dam. It is a unique structure, with only one other in the world approximately similar, in Brazil at Traicao. It was so unique, that Mr. Gaherty brought in Mr. J. H. McLaren, who had retired in 1949 after 14 years as chief engineer, to work on it. Mr. McLaren had joined the company in 1923, was now 80 years old and still had an office next door to Mr. Gaherty's. I started to work with him in 1959, and spent almost a year trying to arrive at the best layout for the pump-turbine structure. We went through 15 different layouts before arriving at something suitable, again an interesting learning experience.

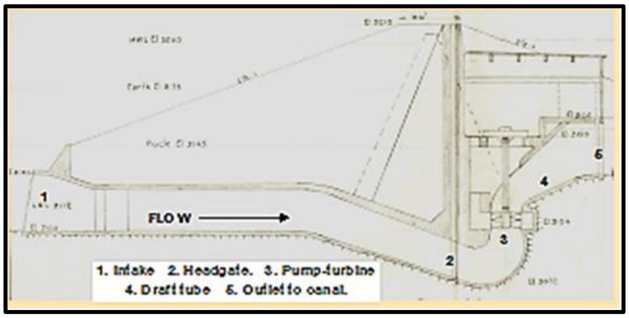


A first layout with two horizontal units.

The pump-turbine was to be supplied by Dominion Engineering, and they also went through several iterations of the pump-turbine setting. Dominion started with air models built with transparent plastic, using smoke to show the air flow, since they were far less expensive than water models. Many shapes were modeled before we reached an arrangement that looked reasonable.

Mr. McLaren drew all his work on tracing paper overlying metric graph paper at a scale of 1cm = 10ft, and calculated approximate quantities for each layout. When I asked him why he used such a strange scale, his reply was "these are conceptual drawings, with no attention to details, you need to develop the design, and I don't want you tracing them!"

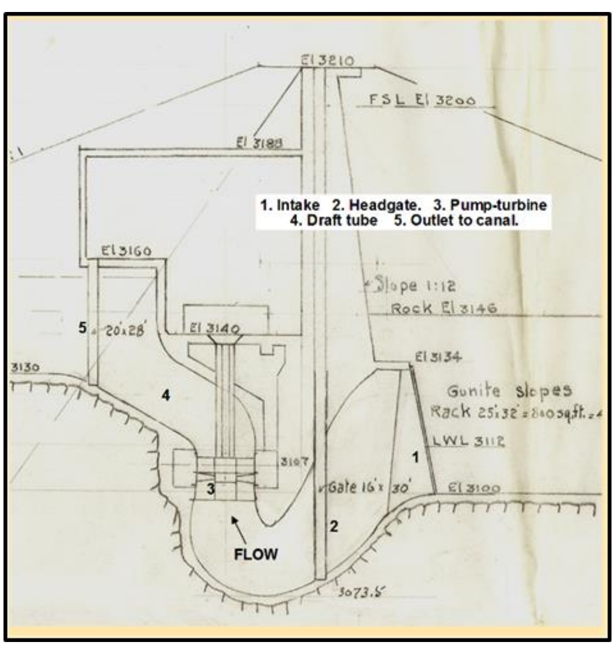
I retained until recently all of his original drawings - a most remarkable man. After working for about a year, Mr. McLaren arrived at an arrangement using two vertical shaft propeller turbines, which I refined and it was built in 1962-4. The section is shown on Page 113.



Another early layout with an earth dam.

The first unit was installed and worked as expected. The second duplicate unit was added two years later, but did not operate at all well. It vibrated, did not produce the expected power, and needed more power when pumping. Also, it was considerably noisier, an indication of cavitation. The manufacturer Dominion Engineering, conducted many tests, checked the alignment, looked at the bearing clearances, but could not find anything amiss. So the unit continued to operate while we all tried to puzzle out what was wrong.

The plant operator was Bill Muzillo, and his hobby was building working scale models of railway steam locomotives, and he had shown me several of his prize-winning models.



Another layout with a concrete dam.

He was so fascinated with the plant; that he decided to build an exact scale model, including the turbine and generator from the detailed construction and manufacturer's drawings, a task which lasted about a year. In March 1968, I was attending a conference of the Canadian Electrical Association, and one evening was in Tom Stanley's hotel room along with Bob Sproule, the chief hydraulic engineer at Dominion Engineering and a few other engineers enjoying some refreshments. The phone rang, and Tom answered. After listening for a few minutes, he replied "could you repeat that to Jim" and handed the phone to me.

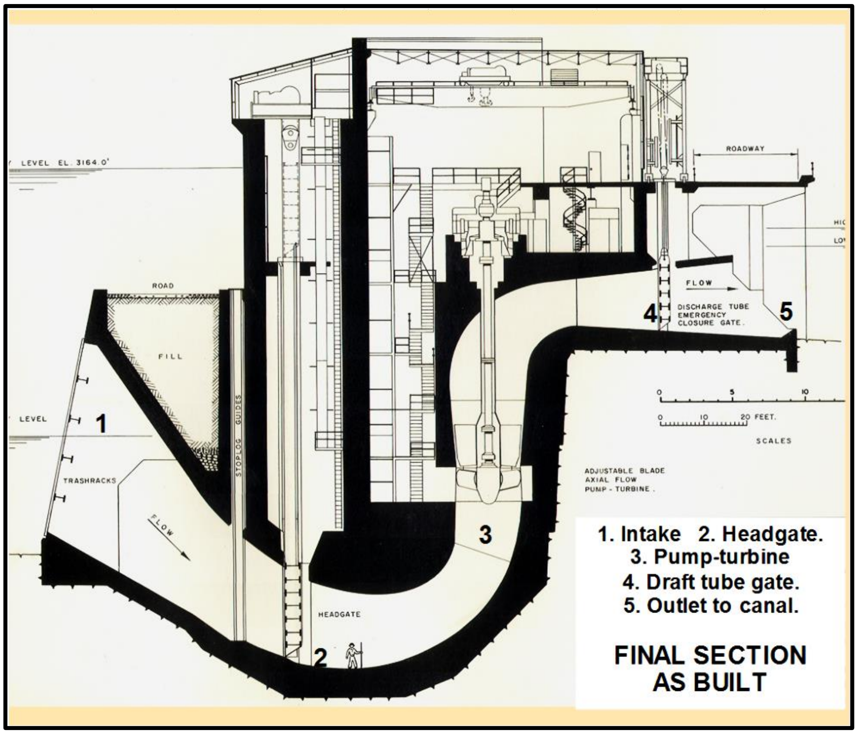
Bill was at the other end, and told me that he had about completed his model of the pumphouse, and that this morning he was inside the pump-turbine doing some maintenance work, and had looked up at the turbine blades. They did not seem to be the same shape as those on his model. Thinking he had made a mistake, he returned home to get the model, and took it with him into the turbine to compare the blade shapes. They were slightly different. He then looked at a set of turbine detailed drawings filed at the pumphouse control room to see where he had made the mistake. Instead, he found his model blades to be correct, and the turbine blades in error, and the error was that they had been installed upside-down! The blades had an airfoil shape similar to a very elongated "S", and it was just possible to install them upside-down without noticing the error. I then told Bob Sproule, and he was adamant that such an error was impossible, but on looking at the factory turbine assembly photos over the next week, he found where the error had been made – the machinists had inverted the runner hub when assembling the second unit, since it was more stable resting on the flange than on the nose cone, before installing the blades. It was an expensive lesson for Dominion, since they had to dismantle the turbine and re-assemble it at their own cost. Fortunately, there were provisions in the pumphouse to remove the runner from below, without having to remove the generator.

After correcting the blades, the turbine was re-tested and operated as expected. It remains the only hydro turbine in the world where the turbine was installed upside-down, and due to the unique shape of the powerhouse, I suspect it will retain this somewhat dubious record.

In 1929, Calgary Power had just completed building the Ghost Dam. It included three Westinghouse generators, each with a capacity of 13MW. Unfortunately, the depression started and the utility found that there was no market for the power, resulting in a severe cash flow problem, and insufficient funds to make payments on the generators.

Pumphouse interior.

An agreement was reached with Westinghouse to delay payments with no interest charged, on the understanding that all future generators would be purchased from Westinghouse. Brazeau was the last generator purchased under this agreement, and Mr. Gaherty asked us to see if the price quoted was reasonable. Fortunately, we found the price quite comparable with recently purchased generators for other clients in Canada, much to his relief!



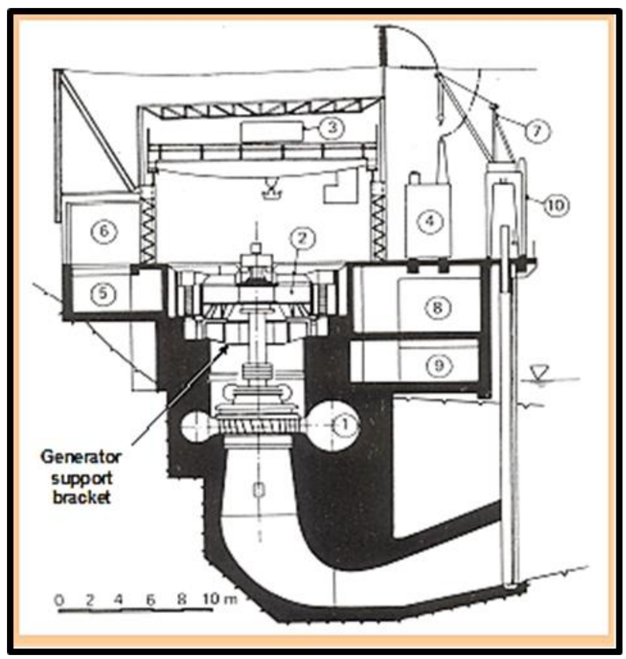
At last – the final pump-turbine layout. Note size of man at bottom, beside #2.

However, it was our practice to check the stresses in all critical components of manufactured equipment, and this included the lower bracket supporting the generator thrust bearing. At Brazeau, the load on the bearing was just under 2,000tons. The bracket consisted of a cylinder with 6 radial arms out to the mass concrete below the generator. I had a brilliant structural engineer, Karl Raethe working with me, and he found that the stresses in the steel cylinder were far over the yield strength, resulting in failure. I told Karl that this was a Westinghouse generator, and they had been manufacturing generators since Edison invented the light bulb, and he must have a decimal error in the calculations.

He re-calculated, with the same result. I went over the calculations, and to my surprise, found them to be correct. I immediately phoned Ed Neville, the electrical project engineer on Brazeau, and his reaction was the same as mine, so I had great difficulty in persuading him to allow me to address the Westinghouse engineers at their next meeting. At the meeting I also had difficulty persuading Westinghouse to at least check the stresses, and finally they reluctantly agreed. Nothing was heard from Westinghouse for 6 months, and the reply to our enquiries was always that they were working on it. Finally, a new drawing of the bracket arrived, with larger components and the thickness of the steel increased by a factor of 3! Karl checked the stresses and found them to be acceptable.

I then asked Ed to let me informally talk to Westinghouse at their next meeting, preferable quietly during a coffee break. This I did, and in response to my question of what happened, was informed that they were astounded to find that the bracket was never designed, merely drawn by a draftsman to "look right" based on previous brackets! Apparently the same draftsman had been doing this for all brackets since he had started working there in 1938. Westinghouse had no senior structural engineers, so they had engaged the services of a local consultant to 'back-engineer' all the brackets built by Westinghouse, a task requiring over a year of computations. Fortunately, they found only one other bracket needing reinforcement. Just goes to show what you might uncover on digging deeply! Westinghouse ceased manufacturing large generators in 1968, when competitors from Japan and Europe managed to consistently undercut their prices.

Construction at Brazeau started in 1960, and was completed in 1967 with commissioning of the second unit. In 1961 there was a recession in Canada, and Calgary Power stopped construction at their Spray and Rundle developments, further south near Calgary. At a mid-day in the middle of June, our design staff on the projects was told to wrap up their work, write short summaries and place all work in files by the end of the day. No further man-hours could be charged to the projects. This presented us with a temporary staff surplus, so I suddenly found that I had extra engineers available to work on Brazeau – a welcome addition. The same happened in the field, all site staff at Spray and Rundle were told to move to Brazeau, an arrangement that had been approved by Calgary Power – they did not want us to loose valuable experienced engineers, only to be short of staff a couple of years later when the projects were resumed. Just goes to show the changes in the profession that have occurred since then – now surplus staff would be immediately dismissed.



Section through Brazeau powerhouse.

1. Turbine; 2. Generator; 3. Crane; 4. Transformer; 5. Piping gallery; 6. Control room; 7. Service derrick. 8. Switchgear room; 9. Excitation room; 10. Gantry crane.

In the end, Brazeau was built for about $36,000,000. (About $475,000,000 in $CAN

2018) including the cost of repairs at the intake, well under the budget of $44,000,000. This was a remarkable achievement, no doubt helped by the fact of the recession, and the stable prices during the 1960's. Equipment and construction costs were all under the estimate. Unfortunately, Mr. Gaherty passed away in 1963, so did not live to see completion of the development.

15. NITCHEQUON – 1963

In 1963 we had a call from the Canadian Department of Transport to have someone undertake a very brief pre-feasibility study of a micro-hydro installation for the remote weather station at Nitchequon, in Northern Quebec, some 280km west of Labrador City in western Labrador. The local radio operators had found a small stream with a low waterfall about 20km from the weather station, which they thought could be developed. The weather station was supplied by air, with Beaver flights from the seaplane base at Labrador City, so access was a problem, because flying in would still require a 20km hike to the site, a difficult undertaking since there was no trail. The site had been found by a local Indian as he was working on his trap-line with sled-dogs in winter. The only practical solution was to use a helicopter, but the location was too far from a road where fuel would be available.

Below - Map showing Nitchequon location.

The Canadian Government came to the rescue with an offer of a large twin-rotor Piasecki H-21A helicopter with a range of 550km, operated by Dominion Helicopters Ltd. on contract to work at the Mid-Canada Line of radar stations. However, this was still not enough to fly to the site, have a look around and then fly back, so a fuel cache was established on a hill-top about 200km west from Labrador City. They had some difficulty finding a suitable bare hill-top, and this one was a little off the direct route from the Lab City airport to Nichequon. Once everything was ready, I flew out to Lab city in early May and checked into the Wabush Hotel, where I met the 3-man flight crew, "Blackie" the pilot, a co-pilot and the mechanic. Based on the Labrador experience, I had ordered a set of 1:10,000 high-level aerial photos of the route from Lab City to the site, and the area surrounding the Nitchequon weather station. We took off early in the morning, and I followed the route on my photos, marking the flight line as we flew, and the fuel cache location when we arrived.

It took almost an hour to fuel the helicopter, since the fuel had to be pumped in by hand from 40-gallon drums rolled over to the helicopter. I took the opportunity to ask Blackie how he liked flying in the bush, to which he replied that he did not like it at all, no radio signals, no direction instructions, and that this was his first experience of bush-flying. In view of this, I decided to maintain a careful record of our flight on the photos. We continued on to the weather station and set down on their heli-pad, had lunch, and discussed the hydro site requirements with the radio operators. They were looking for something very small, at least 20kW for their own needs, mostly heating and electricity for the radio, and up to about 200kW if electricity was to be supplied to the nearby Cree village. After lunch we took off with one of the radio operators who knew where the site was located, and had a good look around with me in the co-pilot's seat. Unfortunately, we could not land, since there were no clear patches in the sparse tree cover, and they had not thought of cutting a clearing. I took several photos, tried to visualize what a development would look like, and returned to the camp, where we left the operator.

Fuel cache on a snowy hilltop.

It was a lonely existence for the 3 operators. They worked an 8-hour shift with four weeks on, next four off, and were supplied by float plane in summer, ski-plane in winter about every 2 weeks, depending on the weather. During spring and fall, there was often a 6-week interval between flights, so they had a large 2-month supply of food and fuel at all times. Now there is a gravel strip airfield nearby.

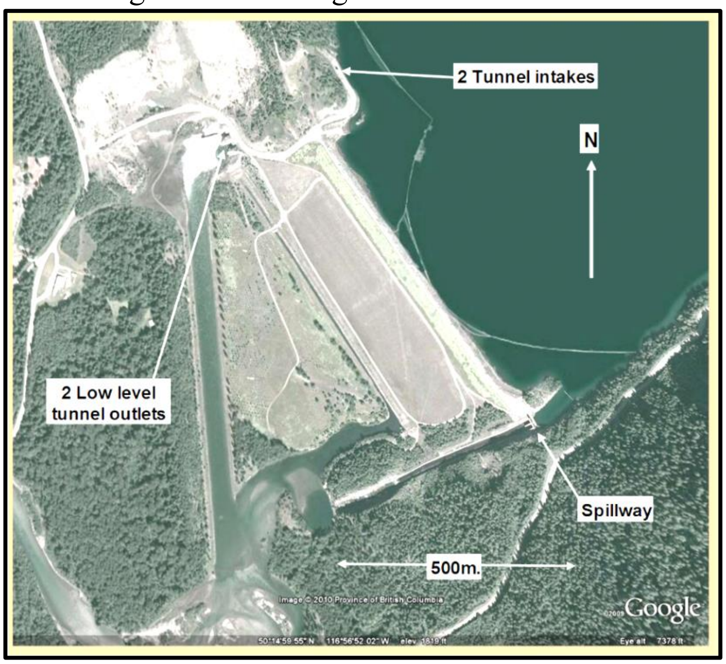
We took off from the helipad and from the direction Blackie was flying, which seemed to be going directly to Lab City, based on the photos, I thought we must have enough fuel, and were by-passing the cache. However, after about 45 minutes, the helicopter started to circle, and I surmised Blackie was looking for the fuel cache. I walked up to the cockpit and asked Blackie if he needed fuel, and he replied that there was only about 15 minutes left, and did I know where the fuel was. I told him directly south, he said "are you absolutely certain" and I showed him where we were on the photos, and where the fuel was, so he turned south, and we landed with about 3 minutes left in the tanks! Blackie was very relieved at finding the cache, since they would have been severely reprimanded for getting lost and having another helicopter sent out to find us.

Our report indicated that the site could be developed, but the cost would be excessive, since everything would have to be hauled in over snow roads in winter. It was not developed, and after a few years the weather station was automated, and later was abandoned, when another weather station was established at the Brisay hydroplant owned by Hydro Quebec on the western shore of the Caniapiscau Reservoir, about 100km further north. It was a lesson on bush flying with an inexperienced pilot.

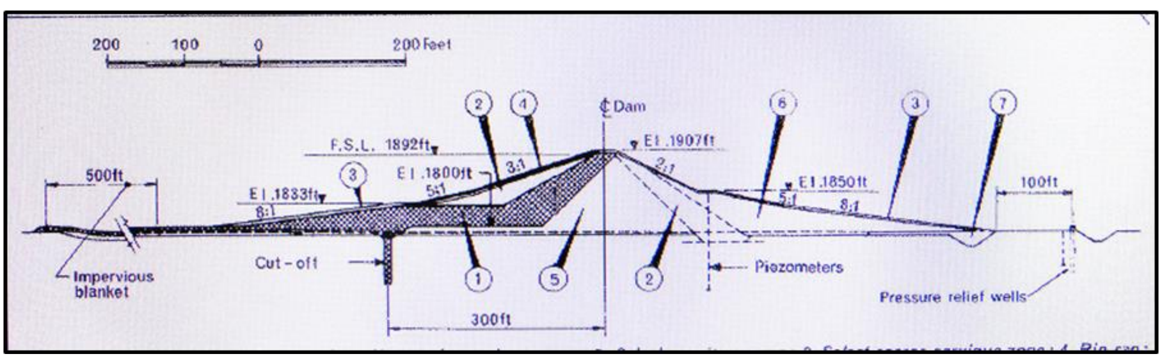
16. DUNCAN DAM 1964 – 67

Towards the end of Brazeau design work, I was asked to work on the Duncan Dam project for British Columbia Hydro (BCH). Duncan was one of the three storage dams built under the Columbia Water Treaty with the United States. It comprised a 36m high dam built on a very soft silt deposit at the lower end of Duncan Lake.

About 10 years earlier, I was part of a 4-man team, headed by Jack Randle, our chief hydrologist, working on the power benefits on the Columbia River due to the construction of three storage dams, one being Duncan, in British Columbia. The Americans had a similar team working on the same problem. Our task was to calculate the incremental energy derived from the stored water flowing through 4 powerplants in BC and about 6 more in the USA. We had 48 years of flow records and it was a monumental task, so large in fact that Jack decided to use only one year, the next lower below the average year, and using only 34 flow periods of 10 days each, and one 15 day period for the year. Our only tools were slide rules and one adding machine. The American General at the USA Corps of Engineers would devise a flow scenario, and both teams would then work out the benefits and compare the results. On the first scenario, we found that we could complete the task in 6 days, and we then sent our results to the general by telegram. A month later, an answer was received advising that they agreed with our calculation, theirs being about 1.5% higher.



Duncan Dam project layout.



Dam section. 1. Impervious. 2. Select pervious. 3. Coarse gravel. 4. Rip-Rap. 5. Semi-pervious. 6. Common pervious. 7. Filter.

A second scenario was received, and we sent out the answer a week later. Again a delay of a month, but this time the telegram advised that the general would like to phone our chief hydrologist at 2.00pm the next day, and indicated their result was again about 1% higher than ours. Next day Jack answered the phone, and after a few preliminaries, the general said “we have a complement of 54 engineers and 12 technicians working on the power scenarios feeding data into two UNIVAC computers, and it takes us over a month to get an answer. Our numbers agree with yours within less than 1.5%, yet you are producing answers within about a week. We would like to know how many engineers and technicians are working for you, and in particular, the manufacturer of your computer!!” When Jack told him of our capabilities, he was somewhat discombobulated.

On Duncan Dam, BCH insisted that they only wanted to communicate with one engineer at the consultant’s offices, and that the engineer should be called the “Project Coordinating Engineer” (PCE). I was appointed to the position. However, the appointment started some thinking within our management, and it was decided to set up divisions for lines of business such as hydro, thermal, airports, and industrial, and still retain the departments such as civil, mechanical, electrical, transmission, construction, purchasing and so forth. As the Duncan PCE, I would report to George Eckenfelder, the new Vice President Hydro, and also to Ran Howard, the Chief Civil Engineer. Reporting consisted of forwarding a copy of all my correspondence to George and

Ran. This functioned very well, but I never got any comments from either on anything at all. Many years later, when Ran retired, I attended his retirement party and asked him why he had never commented on my work. His reply "well, I knew George was reading your stuff, so why should I; my copy went straight into the garbage!" And when George retired years later, his response to the same question was "well, Ray Sandham is reading it, so I didn't think I should duplicate his work" (Ray was then the chief civil). So much for quality control within a matrix management system! With no comments, I had suspected that was what was happening, so kept quiet and had a great deal of freedom. However, I did keep George abreast of developments with occasional meetings.

Looking down the spillway chute.

Duncan was a very difficult assignment from a technical standpoint. The dam holds the world record for settlement during construction at over 5 meters, and is continuing to settle at a slower rate, exactly as predicted by Bob Hardy, one of our geotechnical consultants. The other consultant was Bob Peterson, retired chief engineer from the Prairie Farm Rehabilitation Association, and they were collectively known as "the two Bobs". BCH appointed a very distinguished review board consisting of Barry Cook (ex-Chief Engineer for Kaiser Engineers in San Francisco), Calvin Davis (President of Harza Engineering in Chicago), Gordon Watson (Chief Engineer for the Canadian Prairie Farm Rehabilitation Association) and Lt. General Raymond Wheeler (retired Chief of the USA Corps of Engineers). We would meet every 3 months in Vancouver to report on design and progress of the work. During our first meeting in 1965, General Wheeler asked a few questions on the design, and during the coffee break, came over to me and said "you seem to be a bright young lad, and have it all under control, so I won't be asking any more questions" He was 76 at the time and full of vigor.

We had prepared a feasibility report on the project, with a design having no spillway and only one outlet tunnel. The lack of a spillway was justified by the requirements of the Columbia River Treaty, wherein the reservoir had to be emptied by March every year prior to the spring flood. Also, the reservoir was so large, that the maximum flood could be retained in the reservoir if the water level was allowed to rise to near the dam crest, with absolutely no discharge through the tunnel. However, this concept did not satisfy the review board, and we had to add a spillway and another tunnel just in case the single tunnel failed or the trash-racks were blocked by debris. We calculated that if all water discharge features were operating, the dam was capable of passing the 1 in 600,000,000 flood! Normally, we would design for the 1 in 10,000 flood at most. Construction commenced with the new design.

As design work progressed, Bob Peterson became worried about the potential for foundation liquefaction, a characteristic of fine silt soils when disturbed by an earthquake. This is exactly what we had at Duncan. So, at the next meeting of the review board, Bob prepared a demonstration of the effect. He obtained a large low bowl from the hotel, and placed it in the middle of the conference table at the hydro offices. He then filled it with Ottawa sand, a fine even sized white sand, and then filled the bowl with water to just below the sand surface. In the middle of the bowl he carefully placed an ordinary lead fishing weight of about 2cm. diameter, and then covered it all with a towel. When the meeting started, fortunately nobody referred to the object in the middle of the table.

When the meeting resumed after the morning coffee break, Bob announced he had a small demonstration. He started with a short lecture on the properties of the Duncan foundation silts and how liquefaction occurs, and then removed the towel covering the bowl. He asked us all to imagine that Duncan Dam was represented by the fishing weight built on the valley silt. He then leaned over and flicked a finger against the side of the bowl simulating an earthquake; the sand immediately liquefied, and the fishing weight disappeared below the sand, much to the astonishment of all present! The room was quiet for several minutes, and then Barry Cook asked if there were any countermeasures. Bob replied that liquefaction would only occur under a strong earthquake, and perhaps the risk was acceptable. At the time, Duncan was in a low earthquake zone, so the risk was accepted.

Looking up the spillway chute.

Unfortunately, the earthquake map of British Columbia has now been revised, and Duncan is in a higher earthquake zone. Liquefaction is a risk; nothing can be done other than remove the dam. However, Kootenay Lake downstream of Duncan is large enough to contain a dam break flood, and warning sirens have been installed around the lake shore.

Inspecting the test pit with the review board.

On my first trip to Duncan in March 1967, I was shown a huge test pit excavated through the surface gravels down to the silt. There was a shovel standing nearby at the bottom, and I was invited to dig out some silt, and watch what happened. I did so, and was astonished to see the silt ooze back into the excavated area – a dramatic demonstration of the foundation softness!

At bottom of test pit. Right – Barry, Gordon, Bob Hardy above.

The dam design included a bentonite-beneficiated 18m deep cut-off wall down through the very pervious surface gravels to the silt deposit. At the time, the design of cut-off walls had only recently been developed by Dr. Morgenstern, (From Edmonton University) and the temporary factor of safety against collapse, when the wall was being excavated, was only just above unity, in the region of 1.06 to 1.2. The density of the slurry in the excavation, and the height of the slurry above groundwater were crucial, so much so that careful operation of the slurry mixing plant was essential.

Dragline excavating the slurry trench.

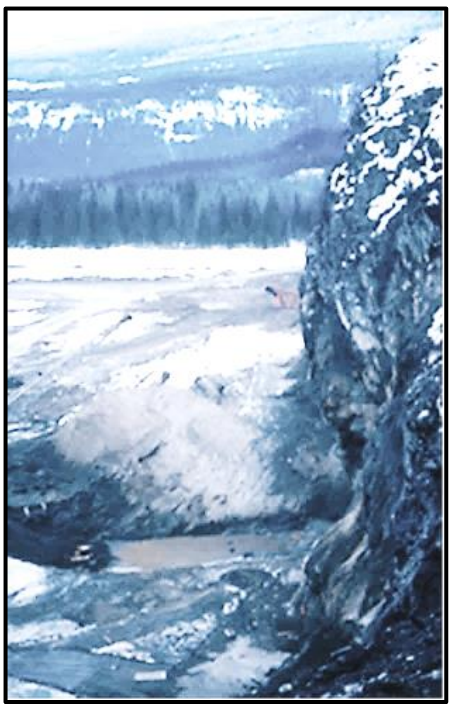
The technology was new to the Duncan contractor, so we were fortunate to obtain the services of Charlie Toll, a construction superintendent from Oklahoma, who had experience with several cut-off walls. All went well until over a long week-end the river level increased, and the trench wall failed after a heavy rainstorm. It was re-excavated and completed as designed. But it was a lesson on the critical stability, the calculation of which was quite complicated. Later, I managed to produce a stability design nomograph which Charlie appreciated, after consulting a paper titled "A Short Monograph on Nomography" by F. M. Wood, and published in the Canadian Engineering Journal in August 1930, not very short at 25 pages of small 6-point text, charts and La-Place mathematical transforms.

However, after a few months of placing material on the dam, it was settling as expected, but a portion of the left side got hung up on the rock abutment. The rest of the dam continued to settle, and a series of large vertical cracks developed right through the dam. They slowly widened to a maximum of about 8cm. Of course, we could not leave cracks in the dam, so something had to be done, and quickly. Unfortunately, the cracks developed about 10 days before our next review board meeting. So with our two consultants, the "two Bobs", Orly Simmons our site resident engineer, Dave Duguid our Vancouver office liaison engineer and I met at site to look at the cracks and decide what should be done about them. We could not agree, so we all flew down to Vancouver for the review board meeting and checked into the Vancouver Hotel. Dave had reserved a small conference room for our own meetings on the third floor, and there we continued to argue all next day on the method of crack repair. Coffees and lunch were brought in, but no resolution.

Start of transverse crack across the dam.

About 6.00pm, Bob Hardy mentioned that he would like some refreshments, and would get a bottle of Cutty Sark from his room. I brought in my bottle of Johnny Walker. We continued to argue, and by 8.00pm I realized that we had not had dinner, so Dave booked a table up in the hotel's prestigious Panorama Room for 9.00pm. We arrived for dinner, and continued to argue. By then the effects of the scotch and wine at dinner were showing, we got too loud for the diners around us, and the Maître asked us to quiet down. To no effect, and eventually we were asked to leave. We returned to the conference room, and by about midnight had agreed on a course of action. I wrote it down and booked a hotel secretary for 7.00am to type it all out. We agreed to meet again at 8.00am after breakfast to read our report, and walk over to the BCH building for our 9.00am review board meeting.

As we came out of the conference room the next day at about 8.45am, Gordon Watson walked out of the room on the left, and Barry Cook from the room on the right. They mentioned that our discussions were "very interesting" and jokingly said that we did not need to present our report, since they had already heard it!



Upstream tunnel portal in right abutment. Note vertical face, had to be re-shaped to accept fill.

However, when we did present the report on the remedial work, it was rejected as being too risky. They wanted a more conservative approach, and fortunately we had developed a more conservative "Design B", but it was very costly, and this was the reason for all our arguments. We outlined the concept to the board, and it was tentatively accepted, and we were requested to return with a completed design. We revised our report, presented it the next day, and it was accepted. It required a complete re-design of the left portion of the dam by pre-loading the area with a weight equivalent to the completed dam, to induce settlement, let it settle for a few months, and then remove the material to continue building a new core in the same area immediately upstream of the original alignment. The work had to start immediately, so there was no time for a return to the Montreal office to re-draw the dam. After discussions with BCH, I was flown in the BCH Grumman Goose to land at Duncan Lake to re-draw the dam at the site construction office.

It was a spectacular flight through the mountains at a leisurely 170mph, on a beautiful clear day. The pilot asked me to sit in the co-pilot's seat for a better view, and I thoroughly enjoyed it. On landing at Duncan, it was straight to work. All our drawings for the project were in ink on Mylar plastic paper with lettering done on a special typewriter with a carriage wider than the drawing. However, I could not replicate such a standard, all I could accomplish was ordinary tracing paper and pencil lettering. I had the drawing completed by early evening, Orly signed it as approved for construction, I signed it for the design, and Dave signed it as approved for construction. It was given to the contractor the next morning, and copies were sent down to the BCH offices, and others were posted to the two Bob's. A traced copy in ink with typed lettering was eventually issued from our Montreal office about 2 months later. BCH's comment was that my pencil drawing was more understandable, with clearer instructions in the expected places. So my time looking over drawings by others about 12 years previously was well spent.

The Duncan dam was commissioned ahead of schedule and well within budget, despite the design changes, and was the only Columbia River treaty dam built within time and estimated cost.

There were a few amusing incidents during construction. BCH had developed a set of standard contract conditions applicable to all contracts. It was a large document, about 3 inches thick contained in a three ring binder. The contract for the intake trashracks was awarded to a local small steel shop in Vancouver, and the contract supervision staff of about 10 engineers from BCH assembled in the board room for the usual signing ceremony and publicity photos. The steel shop owner, attired in well-worn dungarees had trouble getting past the secretary, but eventually entered the board room, and without waiting for introductions asked for the page to be signed, signed it and started to leave. He was then asked if he was going to wait and take a copy of the document, but replied that "no, you can mail it, I have work to do", and out he went. So much for the signing ceremony and publicity photos!

Gantry crane at tunnel intake.

The right abutment of the dam adjacent to the tunnels was very steep and needed re-shaping to accommodate the dam core contact. We produced a drawing showing a very complex excavation, and it was difficult to visualize the end result. So we built a cardboard model, clearly showing the re-shaping work. Bob Peterson wanted to see it, and told us he had a few hours spare time between flights when passing through Dorval airport near Montreal. So I decided to rent a room at the Dorval Hilton Airport hotel for a half-day where I could assemble the model in one of the rooms. When I arrived at the hotel, I asked the reservation clerk about renting for a few hours. He wanted to know why I needed a room for such a short time in the middle of the day, so I unwittingly replied "to show a model". He then answered with "Oh, we don't rent on an hourly basis; try a hotel near St. Lawrence Boulevard", a seedy part of Montreal. This stumped me until I realized what he thought I was going to do, so I explained that the "model" was a cardboard structure showing some engineering work. However, he did come to the room with the waiter when I ordered some coffee for Bob and myself – just to see what was going on!

Tunnel outlets with Tainter gates.

About half-way through the project, the BCH decided to introduce a new drawing numbering procedure. It was very complex, with about 25 alpha-numeric digits designed to indicate drawing contents, size and so forth. This allowed a search for the drawing to be undertaken by computer. I was asked how long it would take to add their drawing number to our drawings, and after some thought, indicated that the task could be completed in a few weeks. What I had failed to realize, was that every drawing contained references to other drawings, and these had to include the new number. Also, the reference drawing numbers could not be added until all drawings were numbered! It required over 7 months changing the numbers. I heard that BCH were having similar problems.

Looking at near-vertical right abutment.

Final stages of dam construction.

Our drawing number was very simple. One letter to indicate drawing size, followed by a number sequentially issued and obtained from our drawing registry clerk. Retrieval was simple, get the drawing number from the register maintained for each project, then go to the correct cabinet based on drawing size. All drawings were filed in the cabinets sequentially by number. Most drawings could be found in less than 2 minutes. Towards the end of the project I heard that BCH were having great difficulties in finding drawings, with the task often taking many hours and sometimes a day. At one of the meetings with BCH, I was asked how our system was working, and I mentioned that we could retrieve drawings within 2 minutes, which they clearly did not believe.

Their lawyer was Bill Noble, whom I got to know from the Vancouver meetings. He was on holiday in Montreal about a year later, and dropped unannounced into my office. After some pleasantries, he asked if he could test our drawing system. So I asked him to name a drawing on Duncan, and he suggested the dam. However, I knew the dam drawing number, since we had to refer to it frequently, and suggested something more difficult. After some prompting, since he was not an engineer, we agreed on the reinforcing drawing for the intake deck slab at Duncan. He started his watch; I left for the drawing storage room, and returned within 90 seconds with the drawing. He was quite astounded, and enquired how the system worked. A remarkable demonstration of the “KISS” principle - “keep it simple stupid”.

BCH was a very conservative client, in stark contrast to Calgary Power. I would often fly out to Brazeau, and then continue on to Duncan. As I crossed the Rocky Mountains into BC, I often thought that I now had to take off my “bold hat” and put on my “conservative hat”! It was my first experience of working with a Review Board, and it proved to be very instructive. The dam was completed in May 1967, and the reservoir was filled a few months later.

17. THE HIGH ANDES – 1965

In early 1965, I was working, along with Bill Matthews on the Chururaqui hydro project for Bolivia Light and Power. We had never seen the site, and worked from topography restricted to the immediate area of the structures. Construction was almost finished, when we received a telex from Lucio Encinas, the project manager stating - “Access road to powerhouse blocked with massive landslide from spillway discharge. Your presence at site required immediately. Encinas." Neither of us could understand the telex since the project's spillway was on one side of the steep river valley, while the access road was on the opposite side. Also, the small-scale aerial photos, our only other reference, showed a wide separation between spillway location and access road

La Paz, 1965.

The layout of the hydro facility was typical for a high-head development on a steep mountain river. A sloping concrete weir was built across the river following Jack Sexton's design, with a low-level sluice gate to discharge bed load. This gate is adjacent to a stoplog-controlled intake parallel to the flow, followed by a gravel trap and sand trap. Both traps contain low-level sluices and weir spillways to discharge excess flows back to the river. At the end of the sand trap, there was another intake equipped with trashracks and a gate leading to an unpressurised 2.5-kilometer-long tunnel. The tunnel ended at a small pond with daily storage perched some 250 meters above river level, high up on the right side of the valley.

The pond had a small spillway for use on occasions when flows entering the tunnel were not shut off in time and the pond overflowed. After the pond, there was an intake leading to a steep penstock pipe down to the powerhouse about 20 meters above river level. There did not appear to be anything in the design that could result in the landslide as described by Lucio.

On the road over the high Altiplano to Zongo.

A few days later, we both flew down to Bolivia, arriving on October 13, to be met at the La Paz airport by Lucio. We drove over the mountain pass at 15,600 ft., past the Zongo Reservoir and down into the Zongo valley to the staff house near the Santa Rosa powerhouse at a more pleasant 10,300 ft. where I had stayed in 1956.

Next day we drove down the road to the slide, where we could look up the opposite slope to the spillway, which appeared as a small masonry wall. Below the spillway, there was an extensive scar on the mountain where all of the overburden had been washed away down to the river, blocking the river and also the road.

At the pass, looking down the Zongo valley.

A bulldozer was at work, cutting a notch in the slide debris to clear a way through the blockage before the access road was flooded. Another bulldozer was removing debris from the road. Fortunately, no lives had been lost, and with the downstream river valley uninhabited, there was no danger from the expected flood when the slide washed out. The road was anticipated to open in about two days, but the river would remain blocked for a further month.

We all looked at the topographic drawings, and realized that the "creek" shown on the drawing below the spillway was only an intermittent stream that flowed in the wet season - far too small to receive the spillway flow; hence the washout. The accidental spillway overflow occurred when the pond was being filled for the first time. The water volume in the tunnel had not been taken into account when the intake gate was closed when the pond filled, and the remaining water in the tunnel continued to flow down into the pond.

We had a lengthy discussion at the site and decided to leave the design as originally conceived, since any future spill at the pond would not result in any more material being washed down the now cleared and bare rock mountainside. However, we realized that it is very difficult for a design engineer to envision site conditions without ever visiting the site, especially where topography is steep and limited to the immediate vicinity of the structures. In an effort to keep design costs to a minimum, expensive site visits were restricted to construction engineers. Fortunately, this attitude within the company changed after the accident, and regular site visits by design engineers were encouraged for all future hydro developments.

At one of the tunnel adits, at about 600m intervals.

One thing I noticed was the lack of a workers camp. I asked Lucio about it and was informed that all the workers built their own temporary homes from local trees and other vegetation, similar to their homes in the villages. Several had their families with them. The company provided corrugated steel roofing and a day off with pay for time to build their homes. All seemed satisfied with the arrangement. The construction supervisors and engineers stayed in rooms built adjacent to the powerhouse, later converted into homes for the operators.

In the valley I again met George Ebenstein, an engineer who had emigrated from Germany in the mid-thirties. Once ensconced in the valley, he never left, not even to visit La Paz, until he retired to Florida about 1975. He was a brilliant engineer and was in charge of all operations in the Zongo valley. There were now 6 impulse powerplants in series down the valley, all relying on the Zongo Reservoir for water, and George’s task was to operate the plants in such a manner that the varying daily load demand from La Paz could be met without spilling any water. This he managed to do with a large spreadsheet on which he calculated flows, power and when units could be shut down with enough temporary storage in the head-ponds and even in the tunnels. Quite a complicated task, now easily accomplished with computers.

George and his wife lived in a bungalow built behind a huge boulder on the mountainside. The house was half buried into the mountain below the rock, and the front was cantilevered out over the road down the valley, with the floor about 6 or 7 meters above the road. It was built with hardwood and had a corrugated steel roof. His office was at the back, below the rock, and there were massive timbers supporting the rock to prevent it crushing the house. But, he had an excellent 270-degree view from his living room at the front. I had to ask him why he had selected what appeared to be such a precarious location, and his explanation made a lot of sense.

His house was in a part of the valley where there were no trees on the mountainside. The valley slopes were very steep, close to the natural angle of repose, with the rock and earth on the verge of sliding down into the valley. Also, the mountainside was strewn with boulders, and these would come rolling down during rainstorms or shortly thereafter when their support was eroded out from under. Boulders at higher levels could hit others and in a billiard-ball effect, cause a rolling avalanche of rocks and boulders known locally as a "massamora". George reasoned that the best protection would be another enormous boulder above his house, to absorb the impact of smaller rocks, and deflect others away to the side. He had lived there for about 30 years, and the house had never been hit, but many boulders had rolled down nearby and into his boulder to continue bouncing down and across the road into the river.

Bill Matthews at pipe bridge over the "ski jump"

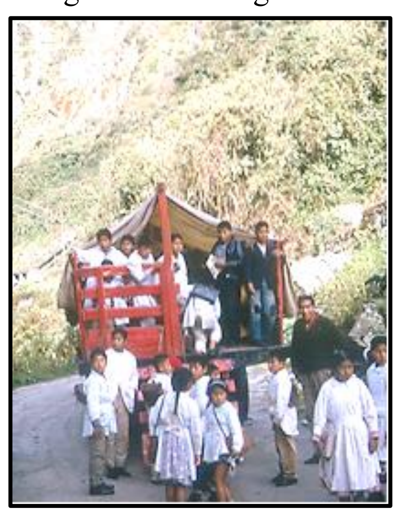
The problem of rolling boulders was well known, since they would occasionally hit a pipe providing water to a turbine, or destroy a steel transmission tower. There was a storage area half-way down the valley, where parts for towers and spare pipes were kept for all the powerplants, and they were needed quite often. The danger to the operator's houses was reduced with masonry deflection walls on the mountain-side above the houses, and gravel around the homes where boulders stopped rolling. I did not hear of any homes being hit.

Remains of Santa Rosa powerhouse after landslide.

Nevertheless, the danger was real, and in 1962, a substation adjacent to a powerhouse was completely destroyed by a massamora (landslide), and only a few years ago, the powerhouse at Santa Rosa was completely demolished when the mountainside above the plant failed. Very fortunately, there had been no injuries to staff when we were there in 1965.

However, Fred Clark, the resident engineer in the Tiquimani project, had a very close call one day when driving up the valley. He noticed a boulder rolling down toward him, and thought that by speeding up he could get ahead of the boulder. Unfortunately, it bounced forward and landed on the hood of his jeep, crashed through, took the engine out and brought the jeep to a sudden halt. Fred told me he could not walk for about a half-hour afterwards; his legs were shaking so much.

The school bus.



There had been another close call in 1956, when a small earthquake dislodged many boulders on the mountainside. It happened in the evening when a group of engineers were playing cards in the staff house at Santa Rosa. One of them was Con Mulherin on a site inspection and he remarked "I did not think you had a railway line in the valley" on hearing the rumbling boulders. The others recognized the sound, and all ran out to wait below the staff house. Boulders rolled down and slightly damaged the nearby substation, but fortunately no injuries.

The plant operators were well looked after by the power company, with a school, and transport to the school for the children. There was also a soccer field, but it sloped somewhat, since there were no level areas in the valley. I was told that some of our engineers tried to play, teaming up with the operators, but found they could easily run downhill on the field, only to collapse on trying to run uphill. The playing field was at Botijlaca, at over 11,900ft above sea level!

Chururaqui powerhouse set well above flood level.

The problem with rolling boulders was clearly illustrated when we had arrived at the Chururaqui powerhouse. Just upstream, at the bottom of a gully adjacent to the pipe down the mountainside, there was a large concrete structure resembling a ski jump. This had never been shown on our drawings, so we asked Lucio what it was for. He explained that, in his extensive experience supervising construction in the valley, that excavation for the pipe grade usually weakened the rock locally and resulted in boulders rolling down for a few years until the mountainside stabilized. Anticipating this, he had designed the ski-jump so that the boulders would continue rolling and flip over the road to fall in the river. Several boulders had already rolled into the river, and on one occasion, a massamora had flipped through.

We had already started on the design of the next hydro plant further down the valley at Harca, so we took the opportunity to hike down to the site, roughly following the tunnel and pipe route to the powerhouse.

The steep mountainside and the jungle vegetation made the hike very difficult. Workmen had spent about 3 months cutting a path of sorts with the occasional ladder, shaky scaffolding built around steep rock faces, and log bridges placed over streams.

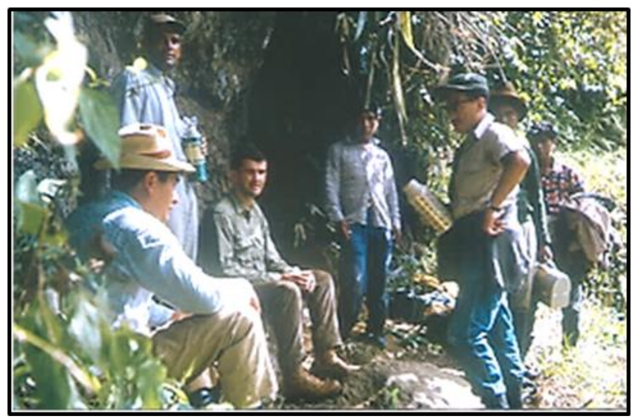
The bridge at Chururaqui, at start of hike to Harca.

Bill on one of the scaffolds.

Sometimes we were crawling on hands and knees under overhanging rocks. We needed several hours to hike about 3 kilometers down the valley and we then realized why Lucio was always vague when answering our questions on when the road for the next hydro plant would reach the powerhouse site. He always answered - "when it arrives" with no fixed date. Road construction on the side of the steep valley was so difficult that there was a permanent road crew blasting and bulldozing the rock down to reach the next plant, advancing at a rate of about one kilometer per year! Lucio explained that with the river dropping at an average grade of about 13%, and with an average road grade of about 5%, it was necessary to construct about 3km of road, including switchbacks for every kilometer of river, something we had not thought of.

Looking back at Chururaqui – Lucio Encinas, Fred Clark and Bill. Washout scar in background.

A few days later, we split up, with Bill looking over the work near the Chururaqui powerhouse, while Lucio took me to see the site of a side-stream intake for Chururaqui. We climbed a few hundred meters up and walked along a path in the mountainside being built to accommodate mules used to carry cement for the intake concrete. However, the path was only half-completed, and terminated at a near-vertical cliff. Two hawsers, each about two inches thick were strung over the 30 meter gap across the cliff face to the path on the other side. The idea was to walk across holding on to the upper hawser, with the notch in the heel of your boot sliding along on the lower hawser, suspended about 4ft below. As a precaution, you could don a crude harness fashioned from rope, with safety ropes held by workers on each side. Both hawsers were lying on the sloping cliff face. Lucio went over first to show how it was done, and I followed. We continued to hike along the trail, but Lucio stopped when it began to rain, turned round and said we must return immediately. I asked why, and he said that it was too dangerous to walk in the rain because the path became too slippery, and at the cliff face, mud from above would be trickling down, covering the hawsers. Also, the workers would be leaving to return to camp.



Resting on treck to Harca, Lucio Encinas, Fred Clark, Bill Matthews and others.

We walked back as quickly as possible, only to find the cliff face abandoned. Also, the safety harness was on the other side after being used by the last worker. We had a short discussion, the upset being that we could wait in the rain, hoping that we would be missed, and a rescue party dispatched to find us, or we could walk across without the harness. We decided to continue. Lucio mentioned that I should not worry about getting covered in mud, it was easily washed off. He again went first, showing how to loop one arm over the upper hawser and hang onto your belt, then slowly slide your boots along the lower hawser carefully pulling yourself across with your other arm. Easy, but very dangerous, since you had to keep your boots on the lower hawser and not slip off, with the drop below being over 200 meters. I can honestly say that this was the most dangerous maneuver I have ever undertaken. We arrived back at camp covered in mud, but safe and sound.

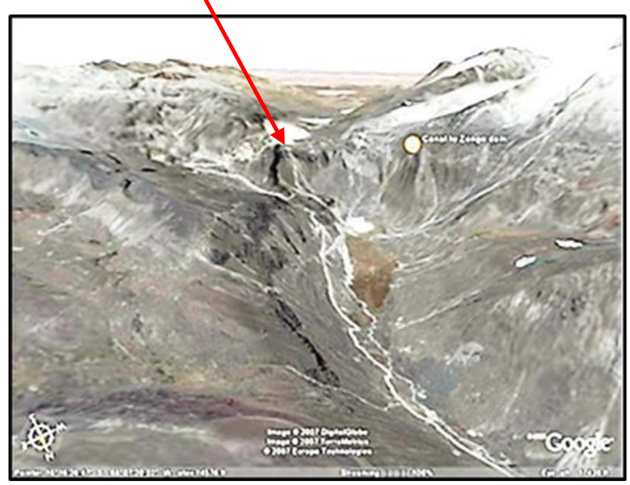
Next day we set out to inspect the Chururaqui tunnel. We started at the upper end, walking downstream in the dark towards the intake pond, with the only illumination being our flashlights. Nearing the lower end, we were surprised by a blast, and Lucio immediately started to run toward the headpond where the blast had taken place, while I turned round and started to run back. He called me to come with him, since the next blast would be much more powerful, and we had to reach the headpond before it was detonated. We arrived in time, but it was a lesson in safety – next time I will ask when blasting is scheduled.

View up the valley to the Botijlaka headpond dam.

We slowly became acclimatized to the high altitude, and after about a week in the lower Zongo valley, we embarked on a trek across the high Andes to look at damsites and a diversion route to bring more water into the Zongo from the adjacent Tiquimani watershed. Fred Clark, Bill Matthews, Manuel Contreras (Lucio's assistant), two guides and I climbed over the eastern slopes of the Cordillera Real just north of La Paz, Bolivia, at an altitude mostly over 4,600m. In this area, the climate is sub-arctic, with no vegetation. The weather was excellent with clear cool mornings and gradual clouding over in the afternoons due to moisture drifting up from the Lower Amazon basin. The scenery was absolutely spectacular.

Bill took a photo of me with the Zongo dam far in the background. Imagine my surprise 40 years later to find the same view on Google Earth, below.

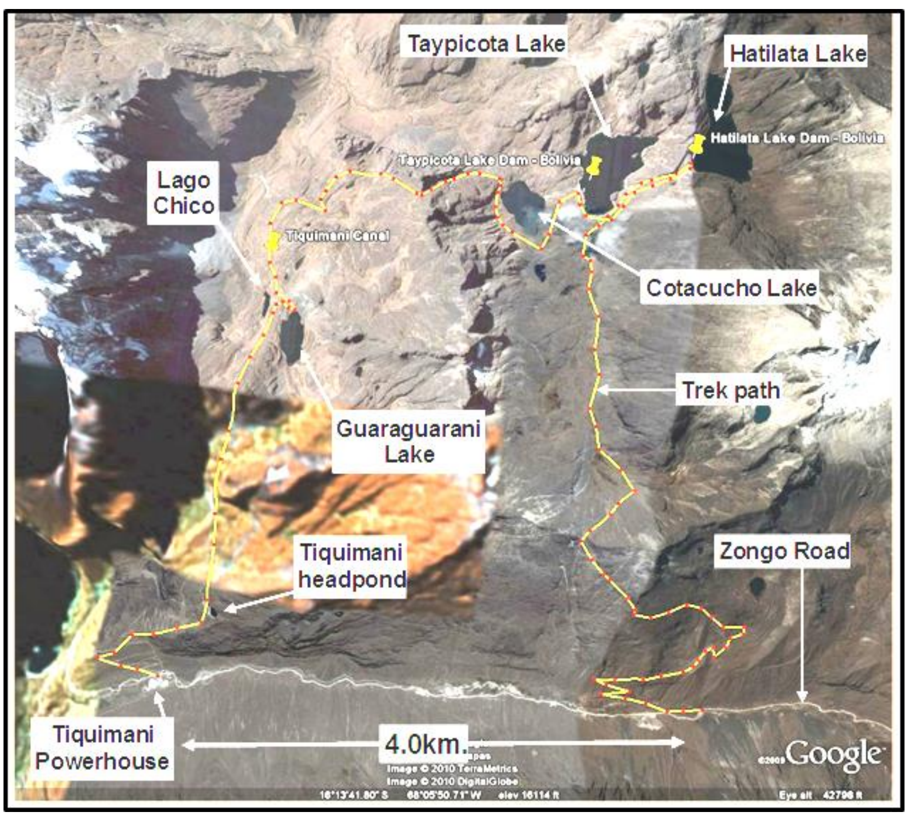
At start of trek. See next image.



Same image from Google – note fork in road down to the Zongo powerhouse (in center of image), and dam, red arrow.

When we first looked at the sites, our only reference were high-level aerial photos, since there were no maps of the area.

Drainage areas were unknown until recently. With so many developments in cascade, upstream storage for the Zongo powerplants is extremely valuable. With steep mountains this is difficult and expensive to develop. It was only with the availability of high level aerial photographs around 1958, that Lucio and Manuel Contreras were able to identify possible storage sites in the adjacent Tiquimani valley, where the outflow could be diverted into the Zongo. Stream gauges were installed, and monitored for a few years. All the lakes depended on inflow from the glaciers. However, one lake did not have sufficient outflow, so it was named by Manuel "Canada Dry" since it was discovered on Canada day. Aneroid barometers were used to outline possible diversion routes following contours, for canals and tunnels through the heights of land. By 1965, it was evident that storages on Hatilata, Taypicota and Guaraguarani Lakes could be economically developed.



19km trek route marked in yellow.

Bill and Fred with Huayana-Potosi glacier behind.

Climbing to our first pass into the Tiquimani valley.

Our ascent to the site began in the early morning, from the road about 6 kilometers above the Botijlaca village, and after reaching a point high up on the mountainside, we paused to admire the view of Huayna-Potosi, a 6,100m mountain in the Cordillera Real. The same view on Google Earth. How times have changed! We climbed over the pass at 15,930ft and walked on to Lake Taypicota, continued on to Lake Hatilata, and then down to a 2-tent camp set up on the shore of Lake Cotacucho.

I found it difficult to sleep at such an altitude, since I would wake up about every hour gasping for breath. You had to force yourself to take deeper breaths than you would take at lower altitudes, so when asleep, your breathing would slow down, and eventually you woke up gasping.

One of our guides climbed a local peak.

However, the Bolivians with us were used to the altitude, and some could even run up the mountainsides, while Bill and I were walking slowly and often pausing for breath. The camp had been manned for several summers by the survey crew, who were also charged with the task of recording outflows from the lakes.

Getting higher, near 15,800ft, towards first pass.

The camp at Lake Cotacucho.

The camp was kept supplied by a weekly mule train climbing up from the road near Botijlaca. Next morning I asked Fred how he had slept since he seemed more alert than the rest of us. He replied that he had slept at the camp many times, and found a sleeping pill very effective, something that gave me pause, since you could asphyxiate from lack of oxygen.

Fred looking at our route over scree to the second pass – top left.

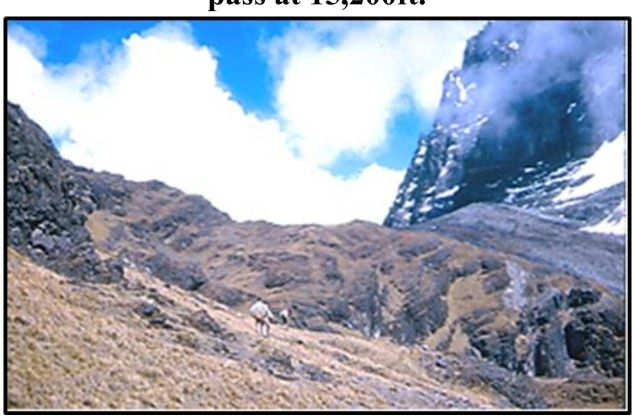
Next morning we skirted Lake Cotacucho and started a long slow climb up the flank of a rocky mountain towards our second pass at 15,560ft, into a high valley where the Tiquimani canal would follow the contour towards Lago Chico. This part was a difficult traverse of a scree slope, but it eased toward the upper part of the climb.

After we passed through the pass, our trek eased as we followed the contour approximately on the canal route towards Lago Chico. I took a photo of the scenery with Fred in the foreground, and again I was able to find the same image on Google! – next page.

We climbed over to the Guaraguarani Lake outlet, and then it was a long walk out over the tunnel route into the Zongo valley and on to about the headpond area at the Tuiquimani intake. This required climbing again to a pass at about 15,200ft; then across a plain where we encountered some llamas. From the headpond area we climbed down the mountainside to arrive at the Botijlaca village in the evening. By plotting our route on Google, I was able to determine the trek length at just over 19km.

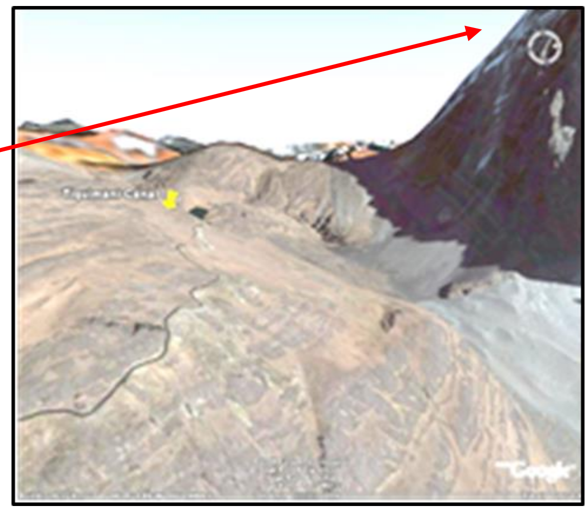
Up to the second pass – small white dot top center is our guide. Fred at bottom.

Above and below - Following canal route – Lago Chico on center right. Fred with Bill in front and Manuel ahead of Bill.
Below climbing towards our third mountain pass at 15,200ft.



Fred stayed on to supervise construction of the three dams, two tunnels and canals over the next two years. The development has the highest altitude hydro dams in the world, all built by hand with supplies, including fuel oil, carried in by mules and llamas.

The compressors used for drilling in the tunnel, were all dismantled down to parts weighing less than 25kg, the maximum load carried by the animals. The three outlet gates, each about 300kg, could not be cut down and were slowly carried on a timber frame by four men up to the dam sites. Quite an achievement!



Same view from Google Earth showing canal.

After the trek, we returned to Chururaqui to look over the construction work. The weir across the Zongo river and adjacent intake with gravel and sand traps was still being built, since it was quite complex. The generating equipment was being installed, and a small penstock up to the Mono Coscapa side stream intake on the opposite side of the valley was inspected. The 2-unit 26MW plant was started about four months later.

We then returned to La Paz and spent a couple of days there, looking over the project drawings with Lucio. On a weekend, he drove us around town to see the sights, a welcome respite from climbing around in the Andes.

A small herd of llamas on our walk out.

Canal to intake.

Intake stoplog structure.

On our last evening in La Paz, Lucio invited us to an "asado" (barbecue) at his new home down the valley. His family had just moved in, but the electricity was just being connected that day. Lucio picked us up at the Crillon Hotel and drove for about 40 minutes down the valley, and we arrived at his new Spanish style bungalow only to see Lucio stop the car and start to swear, something he had never done since we met. There, in front of the car was the bungalow with a recently asphalted driveway, and right in the middle of the driveway stood a distribution pole with the transformer on top! Lucio drove around it and we entered the house. After he calmed down, he mentioned that the power company distribution crew was having some issues with management, and were doing everything to make their lives uncomfortable. We had a hard time containing our laughter, and eventually Lucio saw the humorous side, and we had a pleasant evening there.

Pipe to side-stream intake at the end of the canal from the Mono Coscapa stream.

The local Indian market.

Narrow gauge locomotive in La Paz.

We had spent nearly three weeks in Bolivia, hiked through the upper reaches of the Amazon forest, trekked over the high Andes, and met some very interesting people for quite an enjoyable holiday?!

There are now 10 powerplants down the valley, terminating at Huaji at El. 935m, completed in 1999. Over a short road distance of about 75km from the Zongo reservoir it is possible to drop down from a sub-arctic climate into dense tropical jungle, one of the few places on Earth where this is possible.

View of modern La Paz (1965).

Trekker standing in the Tiquimani canal. Panoramio photo.

George Eckenfelder used to have a similar photo of him at this location, taken in 1967 and mounted on his office wall.

Development in the Zongo valley started in 1908 with construction of the dam and startup of a small 820kW turbine in 1909, with glacier water stored in the Zongo Reservoir. Now, there is a hiking hostel beside the reservoir, and conducted treks, including some along the Tiquimani canals in the summer when the canal is dry and glacier melt-water is being stored. Late last century, the capacity in most of the plants was doubled and they are now used for peaking power with the La Paz and Cochabamba systems interconnected. The distribution system has recently been nationalized.

Hostel beside the Zongo reservoir. Panoramio photo.

18. CORANI 1965-67

Based on our work for Bolivia Light and Power, we were successful in obtaining a contract for consulting services on the Corani Hydro plant being developed for the city of Cochabamba and the Catavi mine, at that time the largest tin mine in the world. It was funded by the World Bank, with all designs to be undertaken in Cochabamba using Bolivian engineers as much as possible. Cochabamba lies at an altitude of 8,400ft, has an ideal climate, and my stays at the Cochabamba Hotel were always very pleasant.

I was asked to go down to help solve a dam design problem in 1965, when I was at Santa Rosa in the Zongo Valley, so I flew over, and only stayed overnight. Apparently the rock quarry selected for the material in the dam was producing gravel instead of larger rock particles, due to the large number of faults and shear zones in the quarry. This was easily solved by flattening the slopes in the dam, which added to the volume and pleased the contractor. Later, there was a party in the Cochabamba hotel bar with all our staff and a few of the contractor's engineers.

After being there for about 2 hours, I mentioned that I had a dinner invitation from Lou Winnicki, our Chief Civil on the project, at his rented house nearby.

Courtyard in the Cochabamba hotel.

Typical homes in Cochabamba.

I went over to the bar and asked for the bill for all the drinks and the barman gave me the total in Bolivianos. I asked for the bill in $US, and he changed it over and asked for about $22.00. I told him this must be wrong, since I was expecting something over $100, he checked the conversion twice, told me it was correct, so I gave him $40 and to keep the change. It was the best bargain for a party I ever had.

I walked over to Lou's, had dinner, and returned to the hotel about 10.00pm. Lou insisted that he escort me back, intimating that the streets were dangerous, which I knew to be incorrect, since at the time Cochabamba was very peaceful. We returned, and I realized why Lou wanted to come with me – the party was still in full swing, so we joined the festivities.

However, the area had seen a revolution recently, and the door to the house rented by our electrical project engineer, Frank Roger, had a bullet hole in it. It was owned by the former mayor of Cochabamba.

At a restaurant in Cochabamba. Joe Clark our Resident Engineer, Mario Zenteno ENDE engineer, ?,? and Art Murphy, our Construction Manager.

Dam and intake house at Corani.

I returned to Cochabamba a couple of years later in May 1967 for the inauguration ceremony. It was quite a spectacle, with the Bolivian President pressing the button to start the units, lights coming on a minute later, and banquet tables set up in the powerhouse among the machinery. Our client, Empresa Nacional de Electricidad (ENDE) were quite satisfied with our work. However, when it came to adding the next powerplant downstream at Santa Isabel, they selected another consultant from Europe. Apparently the new management at ENDE thought that our staff was too inexperienced, most being under 40 years old, and wanted more mature engineers.

Corani Powerhouse.

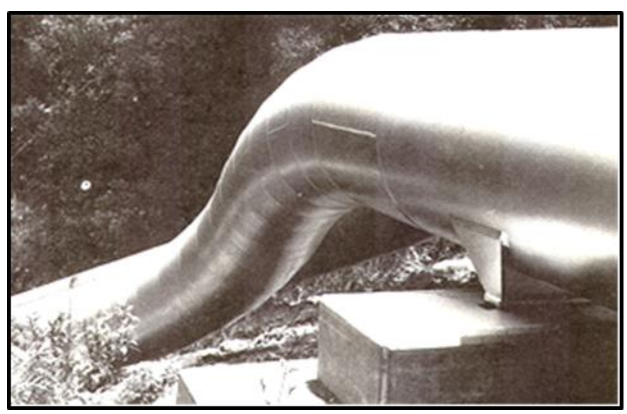
Unfortunately, the high altitude and the very rugged nature of the terrain meant that young engineers had to be used, with older engineers being incapable of undertaking the difficult climbs to inspect pipe anchors and to scramble through tunnels. However, we did make a mistake with one engineer, a recent graduate.

Penstock pipe at Corani.

He arrived at the Corani dam with an ENDE engineer, and was standing beside the long low overflow weir spillway. He turned to the engineer and said "I can see the dam and intake, but where is the spillway!" My mistake, I should have briefed him a bit better – he was expecting to see a large gated spillway.

Inauguration ceremony at the powerhouse, with Bolivia President Rene Barrientos at microphone.

The new consultant for Santa Isabel provided more senior staff, and we heard that they wanted a helicopter to facilitate access to the steep portions of the penstock! However, the thin air at high altitudes was unsuitable for the helicopters at that time. Unfortunately, they made a mistake in the penstock design, and it burst on first filling at about 70% of the design static pressure. So we were called back to analyze the problem and devise a solution. They had elected to use a very sophisticated design, which could only be analyzed with a complicated computer program called AdlePipe, developed by A. D. Little, with free-standing bends at every second bend to allow for contraction and expansion. The pipe burst at the free-standing bend with the largest change in direction.



Repaired free-standing pipe bend at Santa Isabel – note, pipe is free to move around on the concrete pedestal.

Our review indicated that they had not allowed for an adequate safety factor for the secondary bend stresses in their computer program. The paper we wrote on the problem was awarded a prestigious prize by the Association of Consulting Engineers of Canada. As a result of our work on the failure, we managed to obtain the second expansion work, adding two more units at Corani and one at Santa Isabel, along with a large side channel intake to bring in more water to Santa Isabel, all undertaken from an office in Cochabamba.

The side channel intake was a very interesting design being located at a sharp bend in a steep mountain stream called Rio Vinto. A hydraulic model of the intake complete with a rock trap, gravel trap and sand trap was built at the San Andres University in La Paz, and proved very useful since several alternatives had to be modeled before we managed to arrive at an acceptable design. The resulting structure has about three times the concrete volume in the powerhouse, and illustrated the high added cost of removing sand from mountain stream waters

Bolivia proved to be the most fascinating country I have had the privilege to visit, and the design problems posed by the mountainous terrain were demanding.

19. PARENT 1968

About 1960, Canada started to construct the mid-Canada Pinetree radar line. One of the installations was near the village of Parent, in central Quebec, which was only accessible by rail, and by a snow road in winter. The village council thought that it would be a good idea to build a small hydro plant on the nearby Bazin River where there was a small set of rapids about 12km from the village. They searched for a suitable consultant, and found Anton, an elderly retired structural engineer with no hydro experience that would work for a minimal fee. His mandate was to build a small plant with about 10MW of capacity to power the village and the radar installation at minimum cost.

The village issued $1,500,000 of government guaranteed bonds to finance construction. Anton found a complete turbine, generator and controls being dismantled from another plant and installed them in the Bazin powerhouse. Unfortunately, at this point Anton passed away, so the local car mechanic and electrician attempted to complete the works. The turbine was started and connected to the village electrical system and all the lights blew out. A second attempt was made after some adjustments to the controls, and again the lights blew out. The village council then sought help, but could not find anyone willing to take on the assignment. The plant remained shut down, and the village eventually defaulted on the bonds.

The Quebec Municipal Council stepped in, an agency set up to administer the affairs of any town in financial difficulties. They called us to see if we could look at the site and suggest what should be done. So a few days later, I took the overnight train from Montreal to Cochrane, getting off early in the morning at Parent. There I was greeted by Jean, the village mayor and the station porter. His wife Annie operated the local guest house, and we drove there after the train departed. After breakfast, when Annie found out I was to look at the powerplant, she asked me to look at her freezer, which had stopped working. I asked her when this had happened, and Annie said when the new plant started. I then asked her if the lights had been very bright before the freezer stopped, and she confirmed this. I continued and asked her if it had happened any time previously, which Annie confirmed, saying that the freezer was new, only a few weeks old, since the previous freezer had been replaced by Eatons under warranty!

So I now knew that the governor or voltage controls were not working at the hydro plant. Jean drove to the powerhouse and there I met Mark the operator. He started the turbine, ran over to the control board and closed a large switch, and hung a short steel rail on it. After a few minutes, the powerplant lights came on. I looked at the control board, and noted the propeller turbine was now operating at half power, so thought that it was connected to the village system. Mark kept looking at the turbine speed dial gauge, making small adjustments to the speed, keeping it at 300rpm. I asked Mark how much power was being sent to the village, and he replied none, since connection to the village system was prohibited in view of the previous problems – all the power was being used to heat and light the powerhouse!

Abandoned powerplant. Panoramio image.

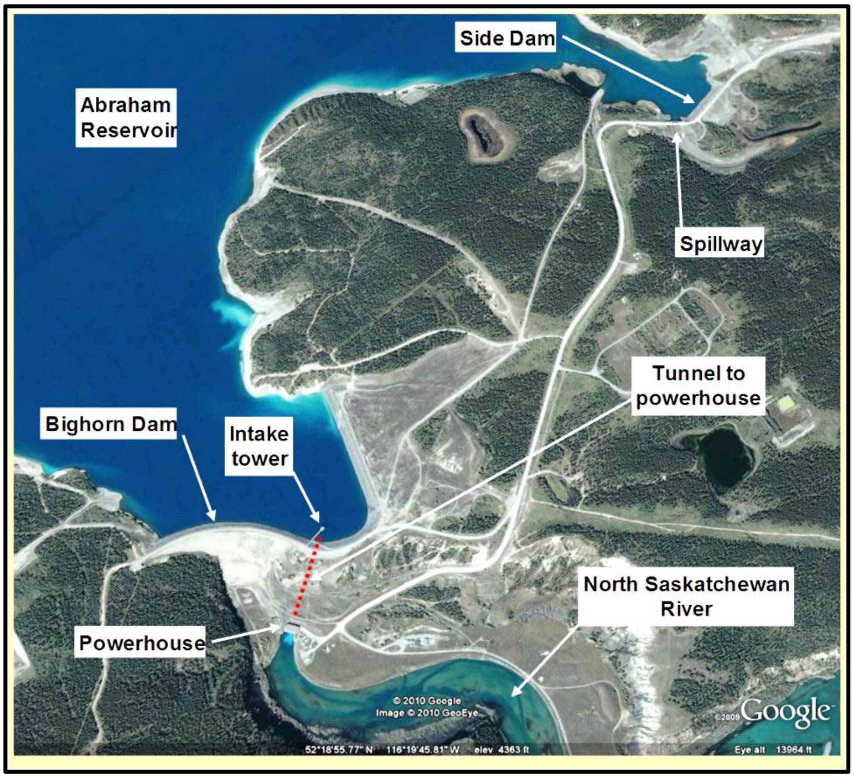
I asked Mark why there was a weight on the control board switch, and he replied that it was there to prevent the safety controls from opening the switch! I had now seen enough of the operation, and asked Mark to shut down the turbine. Normally there is a brake on the generator which stops rotation, but here Mark picked up a long 8-inch square timber beam and jammed one end in a slot in the concrete below the generator, and pushed it against the rotating shaft, and the generator slowly stopped. I told Mark I would like to see the turbine, so he closed the intake gates by levering down the rack and pinion supported timber gate, a type of mechanism which had been used in 1910, and opened a manhole in the floor. He then probed for a valve wheel with a long steel fork, found it, opened the valve, and the water around the turbine slowly drained out.

With the help of a wood ladder, I climbed down and looked at the propeller turbine, only to find it was loose on the shaft – it could be jiggled around by pushing on a blade – and that the blade clearance was over an inch, where it should have been about 0.02 inches. I climbed out, and asked Mark to close up. He shut the valve and hastily climbed out, since the water started to rise rapidly, and he then closed the manhole, tightening down the bolts. I had seen enough, and returned to Montreal on the next train.

Our report was quite discouraging, advising that the old equipment was not serviceable; should be cut out of the concrete and replaced with a new modern turbine-generator. Unfortunately the cost was too high to provide economic power, so the site was abandoned. About 2 years later, Hydro Quebec brought in a transmission line from the grid to power the town and nearby radar station. And so ended the Parent saga – an expensive lesson for the village in how not to undertake a hydro development.

20. BIGHORN 1968-72

In 1969 we started work on the Bighorn development in Alberta, on the North Saskatchewan River. It had a very difficult foundation condition with a deep buried valley in-filled with pervious gravel. It was only due to the recent development of specialized excavation equipment by an Italian contractor that construction of the dam was possible. The special equipment would be used to construct a narrow vertical concrete wall in the valley floor, down to impervious rock, with the earth dam built on top. Again, the “two Bob’s” (Dr. Hardy and Mr. Peterson) were our geotechnical consultants.



Project layout – Google Earth image.

Unfortunately, Bob Peterson passed away shortly after we began work, a great loss. He was replaced with the eminent Dr. Arthur Casagrande, of Harvard University, whom I got to know very well. Dr. Casagrande would fly from Boston to Montreal, stay overnight, and then we would fly out in the early morning to Calgary, rent a car, and drive past Banff to the site, a very picturesque journey along the Trans-Canada and David Thompson Highways.

Dr. Casagrande made a fundamental change to the dam design, joining the main impervious core to the cofferdam core with a horizontal layer of clay, to engage a short upstream blanket to increase the seepage path by a considerable margin. It proved to be the detail which saved the dam from a possible disastrous washout. When the dam was filled, seepage was much larger than expected, and we had to add a large gravel toe and drains to the downstream side to contain the seepage. From a study of the foundation pressures, we found that the concrete wall in the pervious foundation gravels, constructed with the specialized equipment must have flaws, resulting in the increased seepage. The wall was the deepest ever built at the time, so we were pushing the design envelope. However, the seepage was contained and now is decreasing due to fine glacial rock flour silt being slowly deposited in the reservoir, providing an impervious coating to the river bed.

View of Bow Glacier from the highway.

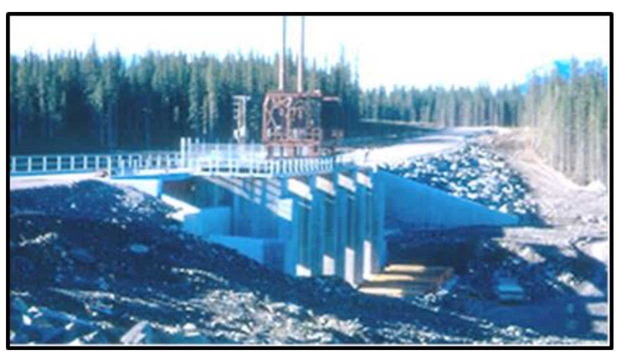
Construction work at Bighorn proceeded without any incident, except during closure of the diversion tunnel gate. The gate, was designed by Les Bakar, the senior structural engineer on the project in our Montreal office. Fortunately he was on holiday in Alberta and decided to observe the closure. He had designed the gate for the full reservoir head of 250 feet, and with difficult access, it was decided to construct the gate in place using the steel support structure to hold it during construction. The completed concrete and steel gate weighed 200 tons. The gate was closed by slowly lowering it by means of cables connected to two dozer mounted winches. The dozers were anchored on the slope above the intake. The tension in each cable was monitored by a tensometer to ensure that the pull did not exceed 5,000 lbs. thus reducing the risk of collapsing the gate support structure. When closing, the gate stopped 3 inches from the bottom sill and Dave Forbes, our Resident Engineer, told Les that the gate had jammed. Les figuring that the steel structure was designed with a factor of safety of about 1.33 to 1.5, and if the cable tension was increased by 10% it would still have a factor of safety of approximately 1.2. Les told Dave to take it up to 5500 lbs, whereupon the gate lifted to about 6 inches, and it was dropped from there. Fortunately, and much to the relief of everyone, including Les, it closed.

Diversion tunnel intake and gate hoist.

Dr. Casagrande was such an eminent engineer that his opinions were never questioned on consulting assignments. He mentioned this to me when returning from a trip to the site. He opened the conversation with the remark that he enjoyed working with the Montreal Engineering team at site, I thanked him for the compliment and then I asked why. He replied that we always questioned his opinions, and often the resulting discussion improved the design by some change in details. Apparently on all other projects – and he was involved in many – his remarks were never questioned, and implemented without further discussion, so he had to be very cautious before expressing any opinion, and act as his own critic! On Bighorn, he was not afraid to express an opinion he had not thoroughly investigated, knowing that we would look at it from all angles to see if it would work as expected. I was heartened to hear that our approach to consultants was vindicated - always question their opinions!

View inside cut-off wall enclosure.

Heated cut-off wall enclosure (hoarding) stretching across river bed.



Upstream view of stoplog spillway structure.

Work on the cut-off wall was undertaken by a specialist contractor, and the low bidder was from Italy. The wall was constructed inside a gigantic plastic-covered temporary enclosure (hoarding) during winter, with heat provided by propane burners. In fact it was so warm inside the building that the Italian workers joked that they should have brought over some grape vines.

View out at diversion tunnel outlet.

Quality control of the concrete being poured into the wall proved to be difficult. The problem was the fragile stability of the trench wall. Small local gravel sloughs would fall down during concreting onto the rising top of the poured concrete, causing gaps in the concrete wall. The gaps would be filled with the pervious wall material. The volume of concrete in each wall panel was carefully calculated, but this was of no use, since the volume of a slough into the wall would match the volume of concrete replacing the sloughed material. The end result was a leaky wall, just what we were trying to avoid.

Current construction methods call for grouting of the foundation adjacent to a deep cut-off wall, prior to wall trench excavation to improve wall stability and eliminate sloughing. However, the cost about doubles with this technique, but seepage through the wall is almost eliminated. When Bighorn was constructed, grouting to such depths was not possible, so we had no choice. In hindsight, we should have used a longer blanket.

I did make one mistake in the powerhouse layout. We could not obtain a permit for a sewer and instead installed an "Incinolet" electric toilet in the powerhouse for the occasional infrequent use by an operator, even though the plant was unmanned and fully automated.

Dr. Casagrande, Steve Chrumka Geotechnical Engineer, (?), Jack Reid Alberta Water Controller and Stan Rutledge, Construction Manager. Concrete structure is diversion tunnel outlet. PH on right.

Inspecting downstream toe of dam for seepage. Note large toe berm.

Downstream view of stoplog structure.

On the drawings, I did not notice that the toilet chimney terminated just below the powerhouse air inlet louvers. After the toilet was installed, it had to be commissioned, so someone volunteered to use it. A few minutes after starting the electric furnace in the toilet, the smell within the powerhouse was overpowering and all the workers rushed out, to return about a half-hour later. When I went out to inspect the plant after it was commissioned, I was asked to look at the toilet – there was a plasticised image of a man hanging from a noose with a tag saying "Jim" on the seat! Since then, Incinolet has updated the toilet, and new models have no odor after use.

View of completed powerhouse.

The reservoir has a distinctive aquamarine color from the glacier silt in the headwaters of the North Saskatchewan River, and is frequently visited by tourists, judging by the number of Panoramio photos posted in Google Earth. The powerhouse exterior was designed by our architect Allister McLean, and is quite attractive; showing what can be accomplished with the use of color.

Aerial view of dam and powerhouse. Note large toe berm on dam to counter seepage.

The plant was commissioned in 1972, and was the last hydro plant built for Calgary Power. After this, the utility concentrated on developing large mine-mouth coal-fired plants around Lake Wabamun, west of Edmonton.

Aerial view of intake tower and reservoir.

21. TURKEY 1969

In 1969 we obtained an assignment in Turkey from Cukurova Electric based in Adana near the Mediterranean coast. Jack Randle went to Adana with Fred Clark to look over their data, and they selected 4 sites. It took some time to get organized since we had to find a helicopter, and the only source was from the Turkish army. We managed to reach an agreement with them, and Wally Smith, then the chief civil engineer, suggested I book a flight for the next week. However, I asked if the company insurance would cover flights in a Turkish military helicopter, and Wally said "of course". But on leaving his office, I noted he reached for the phone, and a few minutes later came out to my desk and told me to postpone the trip.

Insurance coverage was arranged, with an agreement that all such flights would be recorded, and on return from an assignment, a list of the flights would be provided to the insurance company; we would be billed an added cost for the insurance. So I booked a flight on BOAC and Pan-Am through Heathrow and Frankfurt to

Ankara, and a local flight down to Adana. I arrived in Ankara on 20th October, and departed on 6th November. I had arranged to meet our Turkish partner Massun, Dr. Frank Nickel and Fred Clark in Ankara for a meeting on the work before we all met the client in Adana. Frank was an experienced geologist from the USA, and we needed his input since there was an abundance of karst limestone deposits in the project area, and with karst limestone there would likely be solution cavities and water passages in the foundation, not favorable for a dam site.

The survey area in southern Turkey.

Also while in Ankara, I had arranged to interview Dave Cass for a design position in Montreal, since he was then working nearby on a water supply project in Egypt, but he didn't arrive. The next day, we flew down to Adana, and spent a couple of days going over the work done by Cukurova. On the second night there, I was surprised at dinner when Dave Cass showed up. I hired him on the spot, and when he asked what had influenced my decision, I told him that anyone who could trace my movements in a foreign country had the type of intelligence and gumption we needed. He only stayed with us for a few years before moving on to a small consulting company in Victoria where he is now a partner.

Our saviour.

In Adana, Massun arranged for transport and our helicopter flights over the sites. We then drove to Mersin, now called Icel, and spent a few days looking at the accessible sites on the Mersin River. On our drive west from Adana we raced past a sign on the side of the road with "Tarsus" on it, and I asked Massun if it was the same village that St. Paul was born in, and he confirmed it was. Next day we drove up the Mersin river valley just west of Mersin in our jeep, and got stuck in the mud.

Fred and I were about to hop out to push, when Massun held us back, saying "you don't want to get your boots muddy", apparently engineers in Turkey prefer to work in an office. So we waited, and eventually a farmer came along with two bullocks, and he pulled us out.

Mersin River valley.

One evening I was walking along the boardwalk at Icel with Fred and Frank taking advantage of the cool evening, when we met Massun and his wife. We exchanged pleasantries, and I expected Massun to introduce his wife who was waiting patiently a few steps behind him, but it never happened. Afterwards, Fred explained that in Turkey, wives are just not introduced to strangers.

Typical solution cavities in karst limestone rock.

Mut – restaurant beside utility pole.

Mut – now! (2010) Panoramio photo.

We traveled inland and stayed at Mut, at that time a small village, and now a large modern town. We could only find accommodation in a Turkish motel with minimal facilities, an eastern bathroom with a hole in the middle of the floor and broken windows. We had our meals at a nearby restaurant with only one item on the menu, mutton and potatoes. No water, and no beer in the Muslim country.

On our first night there, Massun was delayed and could not join us until the next day, when he arrived with a good supply of Coca-Cola, very welcome since the water was undrinkable. One evening after dinner, Fred, Frank and I were sitting in my room at the motel with Fred drinking Ouzo, Frank his Jack Daniels and me with my Johnny Walker. Frank suggested we spice up the party by exchanging bottles, which we did, just shows what you have to do for entertainment in difficult circumstances.

Lunchtime – Massun, Fred, Frank and driver.

We spent several days looking at dam-sites near Mut. The country was very arid with no trees. At one site, there was a beautiful Roman arch bridge across the river, at the exact spot we would like to build a dam. Frank suggested it would be an ideal spot for a rig to drill an exploration hole down in the middle of the river! I suggested we could instead use an angled hole from one of the banks, thinking that we should at least leave a 2,000 year old bridge undamaged by drilling.

Finally, the helicopter flight was arranged and we took off from a local airport in a camouflaged Bell OH-58 Jet Ranger and flew over the 4 dam-sites. We landed at some of the sites, and whenever we did so, always attracted an audience of the local farmers, surprising since the land seemed arid and unpopulated. I was told afterward that many were many shepherds living in the limestone caves, unnoticed from the air.

Boarding the helicopter.

I noted that there seemed to be many more Roman ruins along the Mediterranean coast in Turkey than in Italy. Massun confirmed this, and mentioned that it was due to the fact that the area had been by-passed and remained undeveloped after the Romans left, however the irrigation canals were clearly visible, and some were still being used.

Corycos Roman castle on an island.

Corycos Castle – Panoramio photo

We flew past Corycos, a large Roman castle in remarkably good condition covering a whole island just off the coast, North-East of Silifke. Massun said it was the home of a Roman general and that his wife was never allowed to leave the island. Now the entire coast has been developed with 4-lane highways, condos and resorts, and is completely unrecognizable from our 1969 expedition to the area.

No Frank, we cannot drill through the bridge!

Frank always traveled first class, so on the return journey, I booked first class on Pan-Am from Ankara to Heathrow, so we could travel together to discuss work.

During our excellent dinner, I noticed the stewardess bringing drinks to John, one of the passengers, and then John would ask her to take them back to someone in the economy section. John got off at Frankfurt, and during the stop, I asked the stewardess why she was taking the drinks back, and she said it was for a woman, but the amusing thing is that she told me John had wanted to go to the bathroom, and the one in first class was occupied, so he went back to the rear, and it was also occupied, so he sat down on the nearest empty chair, which happened to be the one occupied by the stewardess, and she had left her lunch tray on it while attending to a passenger. John was quite a mess, but they cleaned him up as much as possible.

I noticed John had one suitcase very similar to one of mine when we were in the first class lounge at Ankara, and when I reached Heathrow, I got my small case along with John's case! I flew on to Aberdeen and my suitcase caught up with me there, having been brought up on the Queen's Daimler limousine from the Edinburgh airport on its way back to Balmoral. It caused quite a sensation on the street in front of the house. I did not envy John arriving in Frankfurt with dirty pants and no luggage!

Damsite on the Goksu River, from a cave.

Suspension bridge over Goksu River near damsite.

During dinner on the flight to Heathrow, I kept copious notes of Frank's comments on the dam foundations, and how the expected seepage could be reduced. However, when I looked at my scribbling back in Montreal, it was quite indecipherable; a clear lesson in the dangers of flying first class with a bounteous supply of alcohol!

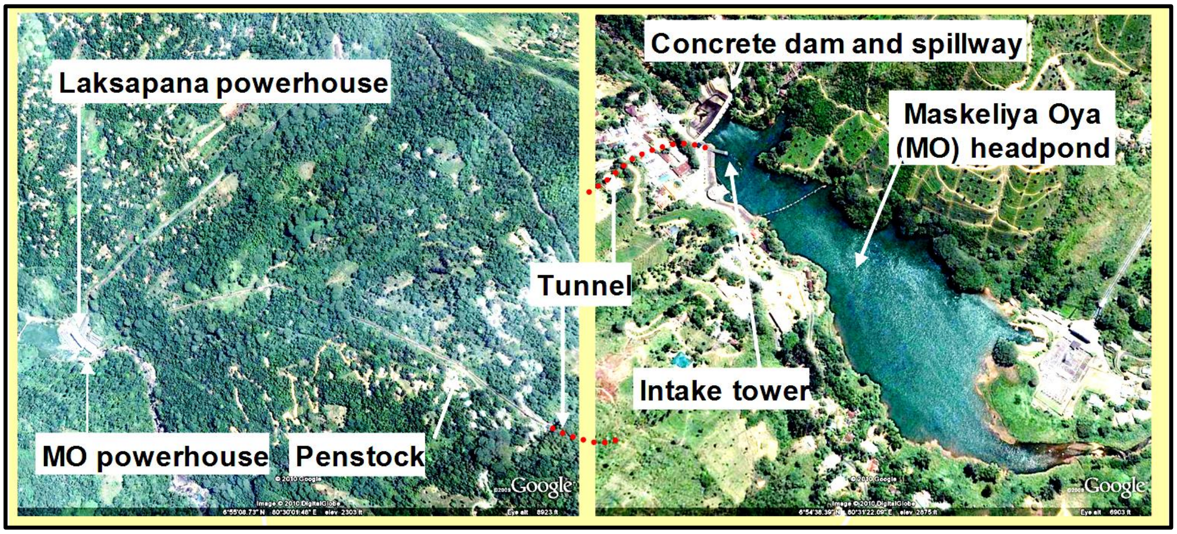
Driver, Massoun, Fred and Frank.

Dr. Frank Nickel at Mersin damsite.

Unfortunately, the area was riddled with karstic limestone and solution cavities, so nothing developed from our work; the project costs were just too high; but it was an interesting experience. However, two low water supply and irrigation storage dams have since been built on both rivers.

22. SRI LANKA 1970

In 1970 we obtained a contract to engineer a 100MW addition to the Laksapana powerhouse by developing the Maskeliya Oya (river) in Ceylon, now Sri Lanka. The feasibility report and contract documents had been prepared by a British consultant, Ingledow-Kidd. The project included a small headpond, a concrete dam and spillway, a 5,500m long tunnel, two 1,800m long penstocks to a powerhouse containing two units operating under 578m of head.



Maskeliya Oya project layout.

Our review of the project work indicated that the penstocks were oversized for the design flow. The pipes were sized to operate continuously at full flow, whereas the flow would vary with demand. A detailed cost/benefit analysis indicated that the diameter could be reduced by about 5%, at a significant cost saving. The contract documents were revised, issued and bids received for two major contracts, one for construction, and the other for the manufacture and installation of penstocks and all the electromechanical equipment.

Colombo oceanfront near Galle Face Hotel.

In August I booked flights to Heathrow and from there down to Ceylon, now Sri Lanka, through Istanbul and Bombay, to arrive at about 8.00am on 29 August, 1970. I had three tasks to accomplish, one was to select the contractor for all the electrical and mechanical equipment, another was to inspect the site, and finally, I had to assist Art Holroyd in selecting the general contractor. I was met at the airport by our agent, who informed me that the Ceylon Electricity Board (CEB) chairman, Mr. Mendez wanted to see me at 10.00am. I was not too happy with this, since I had just spent two nights flying east.

Galle Face Hotel – Panoramio photo.

I checked into the old renowned Galle Face Hotel on the ocean front, showered and accompanied by our agent, took a taxi over to the CEB offices on Sir Chittenapalam A. Gardiner Mawatha Road, only a mile from the hotel. There I was confronted with open moving elevators on a continuous loop. You had to jump on and off at the right moment, which took some practice. The floor of the elevator was wet, since the sump pumps in the well at the bottom were not functioning. I met Mr. Mendez in his office sitting at a large table with three telephones, none of which worked. He kept two messengers squatting on the floor just outside his door, which he could summon with a bell on his desk.

View from CEB office window, parliament building on right.

Our agent had warned me not to look below the table, and I found out why. Mr. Mendez wore sandals, and he would often take them off and twiddle his toes, quite a sight when you were trying to carry on a serious conversation. His staff had named him "twinkletoes".

View from agent's office window. Colombo harbour.

He wanted to know how I would be assessing the bids for the equipment, and I demurred since I had not seen the proposals, so I mentioned something about looking at the equipment quality and the unit efficiencies. This seemed to satisfy him and I left to look at the bids. There were six, and when I opened them, I found that all were within 0.5% of each other! Our agent saw my surprise and mentioned that all the bidders were working through local agents, all known to each other, so some collusion was expected, but not within 0.5%. So I had a problem!

After the meeting, I went with our agent over to his offices in the old Gafoor building near the harbor, and had lunch in a nearby restaurant.

Colonnade at entrance to Agent's office.

I spent the next three days working through the bids with Nadi, a CEB engineer assigned to assist with the work. About every two hours Nadi would disappear for about 15 minutes, and return. I assumed he was keeping Mr. Mendez informed, and found this to be correct the next day. The bidder who most closely met the specifications was from Yugoslavia, and it was becoming apparent that they could be the winner. Nadi returned from one of his absences and advised me that Mr. Mendez wanted to know what I thought of the Cegelex bid from France. I replied that some of their equipment did not meet the specification requirements, so I thought it was not acceptable. I continued to work on the bid comparison, bringing in a value for the unit efficiency, even though all the efficiencies were very close. The Yugoslavian bid still remained on top. Nadi again asked what my opinion was of the Cegelex bid, and I told him it had not changed. He then told me that Mr. Mendez would like to see me.

Up in his office, Mr. Mendez wanted to know the criteria I was using to assess the bids, and I told him, quality and efficiency. Then he asked what was wrong with the Cegelex bid, and I told him, but he was not too happy.

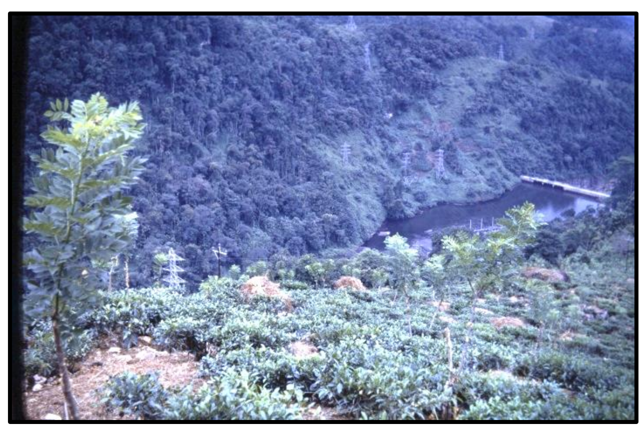
A back lane in Colombo.

Next day I continued to work on the assessment, until Nadi mentioned that Mr. Mendez said he would REALLY like me to look at the Cegelex bid. So the light bulb goes on, and I realize that I have to do something about it, but what. By fiddling around with the efficiency evaluation, I found that it was possible to put Cegelex on top. As soon as Nadi saw what was developing, he disappeared and on returning he said that Mr. Mendez would like to see me again. In his office he was now very affable, asked how the evaluation was going and when I mentioned that Cegelex might be the winner, he smiled and invited me to join him for lunch at the local Masonic Club, a formal occasion. I said sorry, since I did not have a dinner jacket, and he said by formal it meant you have to wear a tie!

I had been working in their board room and the two window air conditioners were not up to the task, only blowing out a feeble stream of cool air. I looked at one, took off the face plate and found that the filter was completely blocked with dust. I asked Nadi to get someone to look at it, and he said that would be difficult since the air conditioners had been borrowed from the nearby hospital. On hearing this, I took both filters to the bathroom and washed them, put them back, and found that the air conditioners now worked fine. Nadi was surprised at this, and thought that I should show one of the building maintenance workers how to clean the filters, which I did. This incident, the useless telephones on the desk beside Mr. Mendez, and the broken elevator sump pumps gave me an indication of what to expect for equipment maintenance.

Since time was short, I worked over a Saturday, and in the afternoon, was surprised to hear some fire crackers go off nearby. Nadi immediately ducked under the table, and when I asked him why, he replied that there was some talk about a demonstration or insurrection at the nearby parliament buildings – a foretaste of what was to come! It was only the celebration of the opening of a local taxi stand.

On road to site – past tea estates.



View of Laksapana tailpond

I completed the evaluation, recommending an award to Cegelex, provided they revise the quality of some equipment to meet our specifications. Mr. Mendez was quite happy with this result, and I departed to inspect the site, a 5-hour, 70-mile drive east from Colombo on a winding single-lane road past many tea estates, arriving at the staff house and met Art Holroyd the resident engineer and his assistant Fred Clark.

I spent a couple of days looking over the dam and powerhouse sites, and asked if I could walk down the penstock route where a narrow trail had been cut through the tropical jungle. Apparently this was a bit of a problem, and I was told that I would be covered in leeches when I emerged from the trail. I was also told that the movie “Bridge on the river Kawai” had been filmed in the adjacent valley, and the jungle was the same one that William Holden had crawled through in the movie. We set off, and on completing the trek, after about 2 hours, I had to borrow a cigarette to burn off the leeches as expected. Fortunately, none had crawled into my socks. Art was not so lucky, and found several inside his socks and his feet bleeding profusely where leeches had bitten into veins.

Fred Clark, Art Holroyd, a CEB engineer, and an agent from the World Bank.

I returned to Colombo with Art and again stayed at the Galle Face Hotel. We had one final task to accomplish before I left for Canada. Art had received copies of two bids from contractors for the construction work, and was doubtful about the low bid. The work included the construction of a diversion tunnel to dewater the site for the concrete dam, and the tunnel diameter seemed to be on the small side, resulting in a lower price. We arranged a meeting and asked the contractor to outline the basis for design of the tunnel.

The contractor proudly informed us that he had discovered a formula developed by a brilliant scientist named Manning, and by placing sand on the bottom of the rough rock excavation in the tunnel, he was able to smooth out the floor, so that the water velocity would increase, and he could then use a smaller tunnel based on applying the Manning hydraulic formula and sand friction factor! We refrained from pointing out that the velocity in the tunnel would be so high, that all sand would be washed out within a few minutes. But we now had a sound basis for rejecting the bid.

Damsite.

With Fred and Art at his site bungalow.

The Galle Face hotel had an excellent English bookstore next to the lobby. One day I went in to see if there were any books on the history of Ceylon, but nothing was suitable. The clerk was an Oxford graduate, and had his diploma mounted on the wall of his small office. I asked why an Oxford graduate would be working in a bookstore, and he replied that apart from there being no suitable jobs in Colombo, he now had the opportunity to read all the latest English books, which he enjoyed. Such a wasted education!

One incident at the hotel deserves to be mentioned. On a Sunday evening, Art and I were having dinner in the hotel dining room when an elderly couple, both tall and slim, arrived all dressed in tropical whites, with the man even carrying a white pith helmet. The waiters made quite a fuss over them and they were seated at an excellent table beside a window looking out over the ocean. I asked our waiter about them and was told that they were British tea planters now living in the hotel, and had been there for about 6 years, enjoying their retirement.

Existing upstream reservoir on Maskeleya Oya.

Colombo zoo.

On the day before we left, we toured the famous Colombo zoo with some CEB engineers. Very large, but also smelly.

I returned to Montreal, and work continued on the project, but we had to reject some of the equipment proposed by Cegelec when we received the detailed designs, since it did not meet the specified standards. Mr. Mendez suggested that we all meet in Paris to resolve the impasse. This was accepted, so Alun Davies and I flew over and checked into the George V Hotel, where we met George Efstathiou who had arrived from Colombo. When I reached my room, I found it was a large suite with two bedrooms and two bathrooms. I returned to the desk to ask for a smaller room, but was advised that I could not change it, since the reservation was made by Cegelex, one of their best customers.

Interior of existing Laksapana powerhouse.

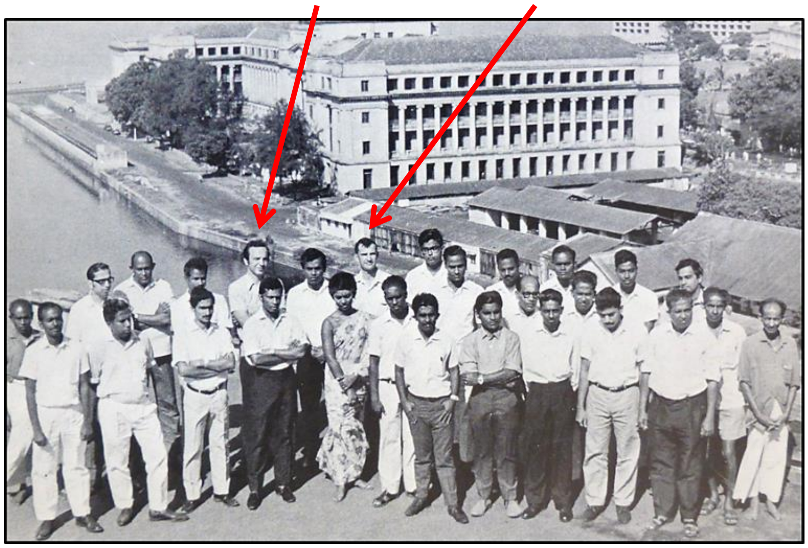
Next morning, a Cegelex representative arrived and drove us over to their offices. Mr. Mendez was taken to meet the president, and he never joined us for the technical discussions, which continued all day until precisely 5.00pm. Then the Cegelex engineers departed, and were replaced by three others who arrived with Mr. Mendez. They mentioned that they had reservations at a famous restaurant and for the Follies Berger. So we had a leisurely dinner, saw the show, and arrived back at the hotel at about 1.00am, with the news that we would be picked up in the morning at 7.30am.

Next day, the same routine, with technical discussions all day, out to dinner and on to the Crazy Horse Saloon later in the evening, and back to the hotel at about 1.30am. On the third day, I was so punchy with lack of sleep, that I declined to go out for dinner, and went straight to bed for 12 hours. Alun told me later that they went for dinner and on to a night club where they all had to kiss a pig in order to get in! However, on the fourth day I was thinking more clearly, and it was apparent that Cegelex were just not going to meet the precise terms of the technical specifications. So we had a quiet meeting with Mr. Mendez and explained the situation. We could relax the specifications to meet the lower standards, but the powerplant would need more staff to monitor the gauges during operation and the equipment installation would take longer. Mr. Mendez readily agreed to this and we decided to accept the Cegelex equipment as proposed.

To celebrate the occasion, Cegelex had reserved a large room at the Petit Palais and we all went there for lunch. This was the setting used by the French government to entertain visiting Kings and dignitaries, so it was quite an occasion. There were about 30 in the party, and we sat at a long table set out with the finest Versailles gold painted Limoges china available, and with a waiter for each diner dressed in Louis XIV costumes standing quietly behind against the wall. The Limoges china was removed before we started the meal. Needless to say, the lunch went on for over 3 hours, and was the most sumptuous meal I have ever consumed!

As for the project, it was built without any problems, and commissioned in 1973. Bill Matthews spent two years in Colombo along with our electrical engineer John Efstathiou directing a large design team provided by the CEB. Cegelex later awarded six four-cylinder Pugeot cars to the senior engineers at the CEB, and a six-cylinder Pugeot car to Mr. Mendez for their cooperation during construction, something I had been expecting - just the way business is conducted in Asia.

The Colombo design team on roof of office. Parliament building in background. John Efstathiou. Bill Matthews.



23. PANAMA 1970

In October 1970, I had a call from our receptionist saying that two gentlemen had arrived and were asking about hydro consultants, but their command of English was very poor, and their business cards indicated they were from Panama. So I went to the reception area to meet Raphael Moscote and Manuel Estrada, engineers from the Instituto de Recursos Hydraulicos y Electrificacion (IRHE). They were looking for consultants to help them build a 300MW hydro plant on the Bayano River. Well, prospective clients just do not walk into a consulting office without an appointment, particularly when the project is likely to cost well over $100 million. So I asked who had referred them to us, and they mentioned an acquaintance Robert at the World Bank, whom I knew from work on other overseas projects such as Maskeliya Oya funded by the bank.

The company president and all vice-presidents were off traveling on business, so I took them to our board room, asked a secretary to provide coffee, excused myself for a couple of minutes, and phoned Robert, who confirmed that they had been in his office negotiating a loan for the project, and that he had recommended Montreal Engineering for their knowledge of Spanish and work experience in South America. I grabbed Bob Gander, our contracts negotiator who had some knowledge of Spanish and returned to the board room. They had some preliminary drawings of the project, so we looked them over, and said we were interested in negotiating a contract. The upshot was an invitation to present a proposal, inspect the site and negotiate a contract down in Panama in December.

With Bob Gander at the Catedral Nuestra Senora de la Assuncion in old Panama.

The project included a large concrete dam, and we had no recent experience in concrete dam design, the last one being Ghost in Alberta in 1929. At a meeting with the company management, I suggested we join forces with Shawinigan Engineering since they had relatively recent concrete dam experience in Quebec. Also, we were currently working with Shawinigan on several projects in Newfoundland. This was very reluctantly agreed, and Shawinigan joined our team, providing about half of the engineering staff.

Since all the contract negotiation would be conducted in Spanish, I traveled to Panama with Bob Gander in December.

We were given a tour of the local sights by an IRHE engineer, and later we drove to the site past farmers' fields and I noted that due to the fertility of the soil, combined with frequent rains that fence posts at the side of the road developed roots, and soon sprouted into trees! We inspected the site, traveling up the Bayano River in several long dug-out canoes. On boarding the canoe, I noted that it was made from mahogany, and very heavy, likely to sink if swamped, since it had a large outboard motor mounted at the back. No life jackets were provided, so I unlaced my shoes as a precaution. Bob was sitting in front of me, and we both turned round to see who was on the next canoe, when Bob quietly mentioned that a large spider was crawling up my back, so I asked him to flip it off, but Raphael saw it first and swept it off with a rolled drawing he was carrying, saying that it was very poisonous.

In dug-out canoe with Bob Gander.

After about a half-hour of swift travel up-river we arrived at the site and had a look around. At the site some work was being done on access roads and there was a small camp cleared in the jungle. Due to the proximity of the Atlantic and Pacific oceans, there was an almost permanent cloud cover, so aerial photos of the site were not available. Also, the site was on the edge of the "Darien Gap" in the Pan-American Highway. I would tell everybody that to get to the site, just take the Pan-American Highway south to the end, turn right, and drive for 2 km!

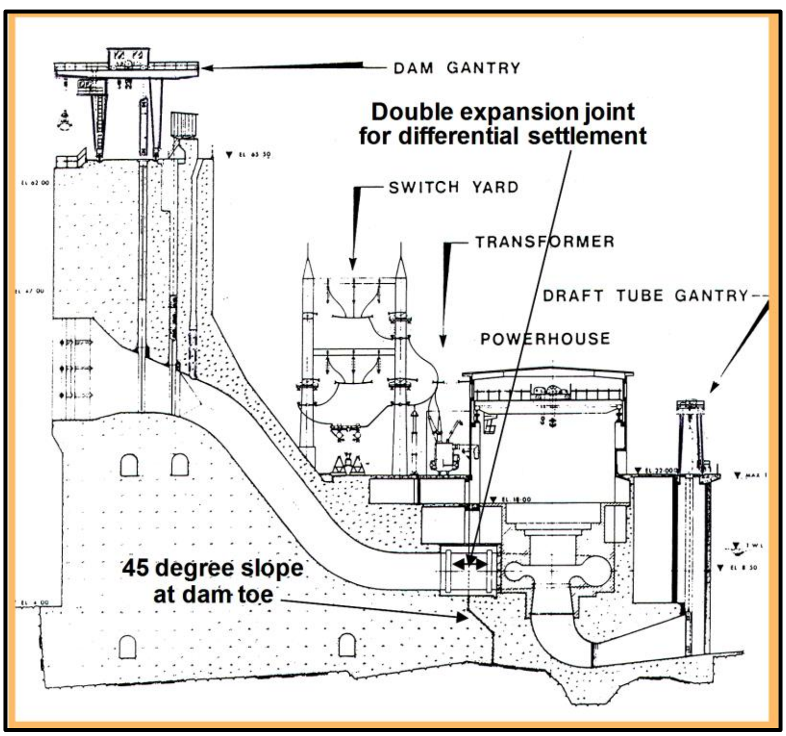
Canoe with local Darien Indians and produce travelling downstream.

At the campsite. Alun Williams, Bob Gander, ?, ?, Manuel Estrada, me and Raphael Moscote.

We were eager to start work, so Alun Williams, recently returned from site work in Bolivia, and now fully fluent in Spanish was sent to the site shortly after our Montreal meeting to supervise surveys and drilling. He commuted to the site from a rented home in Panama City.

After seeing the site, we returned to the IRHE office and successfully negotiated a contract, with all work to be done from an office in Panama provided by IRHE. Normally Bob would take the lead in this task, but I persuaded him to let me do the talking, since I was more fluent in Spanish. He consented, and outlined the contract requirements, simply a 25% salary increase for our staff in Panama, with no local taxes, and an allowance for schooling. This was readily agreed, but I added that site staff had to have a 12.5% salary increase over this, since they would have extra expenses for their family living in Panama City, while they were working at site. Bob kicked me under the table at this suggestion, but I ignored him. Some more discussion and they agreed, much to Bob's surprise. Later events proved that the higher site pay was needed, but I had a hard time explaining to our accounting department why site staff had a 37.5% salary increase!

Uncleared damsite.



Section through intake and powerhouse.

After signing the contract, a delegation of IRHE engineers arrived in Montreal in early March 1971 for training when we assured them that by then, winter would be almost over. We provided them with overshoes and heavy winter coats. Unfortunately, in mid-March we had a record 80cm of snow which shut the city down for 3 days, with snowmobiles and skis the only method of travel. They never let us forget our forecast, and always joked about the weather in Montreal. We eventually assembled quite a large team of engineers for the work in Panama City.

The site had a very difficult foundation comprising soft volcanic tuff. When Don McKenzie, a geologist from Shawinigan Engineering inspected the site early in 1971, he tossed a discarded rock core sample into the river, only to see it float away downstream!

In January of 1972 I started work in Vancouver assisting Jack Sexton on a report outlining the power potential in British Columbia. I had taken the family after Vera thought it would be a nice change from spending the winter in Montreal. We had just settled in when Jack had a call from George Eckenfelder asking me to go down to Panama immediately to settle some problems. I could not understand the request, since all design issues had been resolved before I left Montreal. George was no help when I phoned him, only saying that I was needed there. I arrived in Panama on 4 February, 1972 and checked into the Panama Hotel in the evening. I got a phone call from John Clark, the site resident engineer, asking me to order a box lunch from the hotel, and he would pick me up at 8.00am the next day. We drove to the site in about 2 hours, with no further news on the problem from John, despite my repeated questions. We toured the site until noon, and everything seemed to be progressing satisfactorily with no engineering problems whatsoever!

Pet baby monkey at cookhouse.

At lunchtime, John asked me if I had by box lunch, and I said yes, whereupon he said, “give me your box, and take my ticket for lunch at the contractor’s mess hall”, and I immediately knew where the problem was. I was directed to the mess hall, an open-sided hut with a corrugated steel roof and a table in the middle with benches on each side. On presenting my ticket, the waitress walked over to the kitchen hut nearby and returned with my lunch, a roasted small hairless monkey fully intact from toes to eyes. I nearly threw up, thanked her, and walked back to John who was by now smiling and said that he had saved half of the box lunch for me.

New site staff accommodation, later used by operators.

John also took me to see the site staff quarters, small huts with communal washing facilities infested with every imaginable tropical bug.

Later that afternoon I had a meeting on site with the contractor, and asked why the food was so poor and the accommodation was not as specified in the contract. The contractor advised that he was being paid in Panamanian dollars for the food and accommodation as part of the contract with IRHE, and that he needed payment in US$ to improve the standards. I then asked him what would he need in US$ to upgrade meals and accommodation to the standards specified, and he answered about $200 per person per month. On my return to Panama City, I met with Alberto Moscote to discuss the situation. Apparently they could not pay the contractor in US$ due to currency restrictions, even though the Panamanian dollar was pegged as equal to the US$. I then suggested that we increase the pay of all site staff by a $200 site monthly living allowance, to be transferred directly by site staff to the contractor. We in turn would bill IRHE with no markup, and IRHE would pass the invoice on to the World Bank for payment in $US. This was readily agreed and I departed back to Vancouver next day. I asked John why he could not have done this himself, and the answer was that Moscote wanted to deal with me only, since my fluency in Spanish would help to clarify any contract discussions.

I returned to Bayano twice, in July 1972, to discuss the difficult foundation design with Dr. Norbert Morgenstern from the University of Edmonton, and again in February 1974 to see how the work was progressing. Norbert developed a 3-dimensional computer model of the dam, powerhouse and foundation, to predict differential movements and provide some data for the design.

He described the model as based on using "iso-parametric hexahedrons with eight nodes and 24 degrees of freedom". I had to ask him what this meant, and his reply – "Jim, just think of rubber cubes". His advice on the work was very valuable, but I was puzzled about the differing standards for earthquake and flood design. The dam was being designed for the 1 in 10,000 flood, but only for the 1 in 200 earthquake. So I took the opportunity to discuss the design standard when we were standing at the top of a hill near the dam, and asked Norbert why we were not designing for the 1 in 10,000 earthquake. His reply – "look around, if we designed for the 1 in 10,000 earthquake, this land would be as flat as Saskatchewan and there would be no dam!"

Alun, Norbert, me, and John Martin, at site.

Me, Nick Karnick, John Marica, Don McKenzie, Lou Winnicki, Norbert Morgenstern, John Martin in Panama office.

The Panama office provided by IRHE.

The construction contract had been awarded to EnergoProject of Yugoslavia, the low bidder, since they also had experience working with similar soft volcanic tuff foundation rock at Bajina Basta in Yugoslavia.

Earlier I had travelled to Bajina to look at how the dam was designed. Norbert suggested that a flexible joint be provided between dam and powerhouse, and that the powerhouse be designed as a nearly solid concrete block, with shafts down to areas where access was needed for equipment maintenance, instead of stairs and open floors. This was done, and the resulting structural rigidity avoided the problems being experienced at Bajina Basta.

View of downstream toe of concrete dam showing 45 degree slope.

EnergoProject staffed the work with a large number of Yugoslavian workers who were not allowed to wander off the site. The workers were paid a pittance and soon revolted, refusing to work. This was quickly solved by the contractor with help from the Panamanian army. A machine gun was borrowed and brought to the site. The workers were lined up in front of a wall in groups of about 6, and asked if they would continue working. Naturally, all agreed. The work was completed without further incident in 1975.

We never found out just how much of the jungle upstream would be inundated by the reservoir. There were radar images taken through the cloud cover, but they were not accurate enough to define the reservoir shoreline. Also, it was not possible to undertake a ground survey, since cutting survey lines in the dense vegetation was not practical, and there were rumors that the native Indians living in the jungle were not at all friendly, probably one of the reasons the Darien Gap still exists 45 years later, and there is no road link from Panama to Colombia.

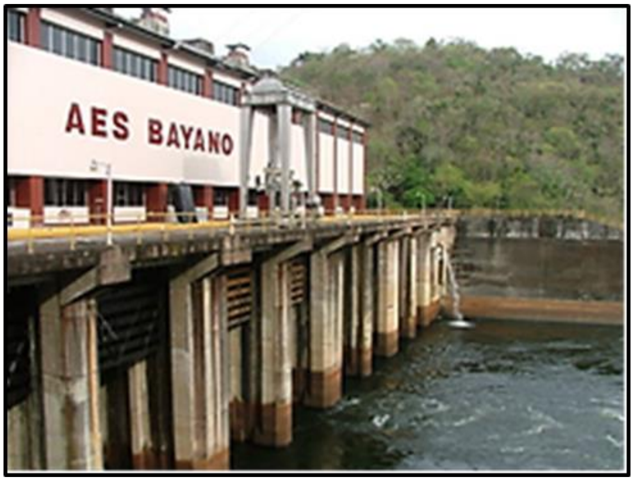
Inspecting penstock pipes fabricated locally in Panama.

Dam and powerhouse construction.

On filling the reservoir, a large area of tropical jungle was inundated. The resulting decomposition of the forest under water produced large volumes of hydrogen-sulfide gas which drifted down the valley to the powerhouse. This produced sulphuric acid on contact with water which dissolved any exposed copper, requiring a complete replacement of all exposed wiring several years later. Also, the operators had to wear gas masks for the first few years, until the gas concentration declined to acceptable levels.

This was one of the first demonstrations of what happens when dense jungle is inundated, was totally unexpected and indicated that for future hydro plants in the tropics; the jungle would have to be completely cleared. The dam is located at

9-10-31.13N, 78-53-3.92W, unfortunately in a poor resolution zone due to cloud cover.



View of downstream face of powerhouse. Panoramio image.

24. NIGERIA 1971

KAINJI

In 1971 we were awarded the contract to add two hydro turbine units to the Kainji powerhouse on the Niger River in Nigeria. I few to Lagos from New York, and the Pan-Am flight stopped in Dakar to refuel late at night. Dakar was the southern terminal for test flights of the new supersonic Concord, and one was parked on the tarmac when we landed. I asked the guard at the gate to the terminal if I could go out and have a look at the plane, and he consented. It was far smaller than I expected, not much larger than a DC3. I landed at Lagos on May 26.

On road into Lagos.

I was accompanied by George Cuthbertson, head of our construction department and Bob Provost, the electrical project engineer. After landing at Lagos, we had been told to get a taxi and to go to an apartment rented by the company for visiting staff. This we did, with Bob sitting in front with the driver, who drove somewhat fast into the city and soon arrived at our destination. George and I got out of the taxi and proceeded to unload our luggage from the trunk, but Bob stayed put in his seat. I walked round to the front to see why Bob had not appeared, only to find him sitting and trembling with fright. I asked him what the matter was, and he said "did you see how he drove – up on sidewalks, chickens scattering, kids running aside, over a football, back out on the wrong side of the road against traffic coming toward us, it was terrifying!" It was our first lesson on Lagos traffic, and there would be many more. A few years later, a dual highway was built from Lagos to the airport, and spiked chains, anchored into the ground had to be placed on the median to prevent cars from racing down the middle.

We arrive at the Lagos apartment. George on right.

Next day we flew to the airstrip at Kainji, and were driven to a bungalow in the "expatriate quarters" where engineers from Ontario Hydro were also accommodated. They had a 5-year contract to help operate the plant. We spent most of our time obtaining data for the engineering work, and one morning, when I was in the control room copying some of the operating records, I noted several red lights on the control board. I walked over and saw that some indicated fires at three of the turbine governors.

George, plant operator, Bob and plant manager.

I asked the operator sitting at the control desk why he had not taken any action, and he replied that the red lights were always on. So I walked down to the governors to see what the problem was, and found that the cooling air duct above each governor had been blocked with rags, so the temperature sensor on the governor was above the upper limit, signaling a fire. I then traced the route of the cooling duct back to the upper floor, and found that another vent was in the glass-sided cubicle beside the generator, where the unit operator was stationed. The operator was lying on a mattress on the floor, fast asleep, with his head beside the vent! I found the same scene in the other three cubicles. I made a note to add some redundancy to the automatic controls for the new units.

Control room.

We also inspected all bridges on the road from the railhead to Kainji, and some obviously needed repairs if heavy equipment had to be carried across. Some were so badly damaged that they would have to be rebuilt and all steelwork replaced. However, it was decided to build temporary fords instead, to be used during the long dry season. We also inspected the large road "transporter" used to carry very heavy components from the railhead to Kainji. Unfortunately, it had been stored out in the open, and all control wiring insulation had been devoured by rats, and all piping stolen. It would require considerable repairs.

George looking at bridge support piers.

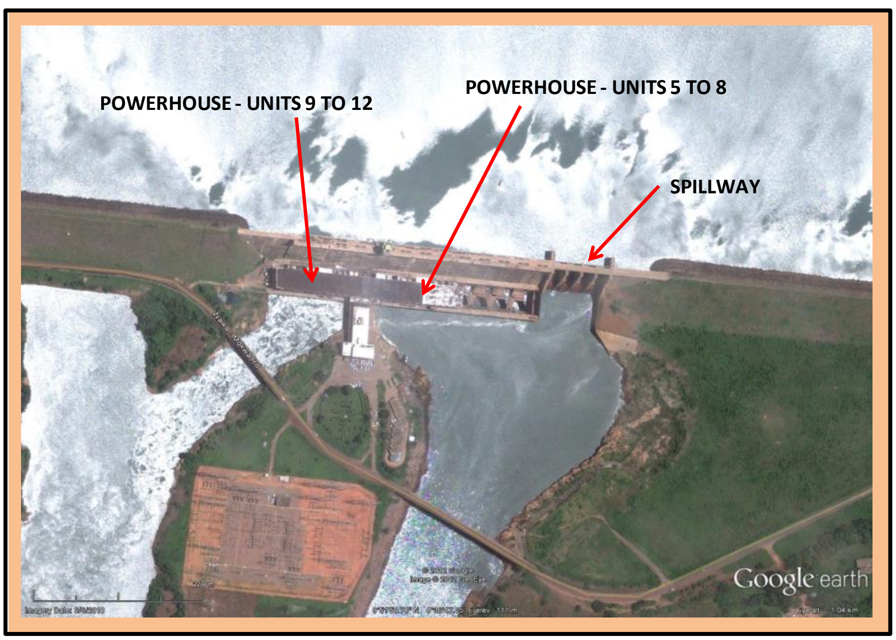
George inspecting bridge – note bent and broken truss steelwork.

There was a swimming pool at the local Kainji Club, and we were all invited there for dinner one evening by the Ontario Hydro staff, and told to bring our swimming trunks.

Unfortunately, George had not brought any, so arrangements were made with the local tailor to make some. He arrived at noon when we were having lunch in the bungalow to measure George, and said that the shorts would be ready at his home in the old village by 5.00pm. About 5.30, just before dusk, we drove down to the village and stopped at the surrounding mud-straw wall.

African village. Reed and post fences between huts to keep livestock inside.

Me with the transporter.



Google Earth image of Kainji. Substation, on island in middle of river. Ship lock not shown.

It was a typical African village with round thatched roof huts, drums were beating a melody, and in the middle of the village there was a large cast iron pot over a fire, where something very aromatic was cooking. The sun was setting, and there was a smoky haze over the village - the exact scene pictured in many Tarzan movies, the only thing missing was a white missionary in the cast iron pot!

Lunch time at local food court.

George did not appear for some time, and I was becoming worried that perhaps he was destined for the pot. He eventually appeared and I asked him why he was delayed. He replied that the shorts were far too wide, so wide that two persons could easily fit into them, one in each leg. He got the tailor to cut out a few inches, but they were still so large that the shorts ended up being pinned to the wall of his family room as a conversation piece.

We returned to Lagos, and Bob flew back home. We got an invitation to dine at the expatriate Lagos Club, and we borrowed Harold Hurdle’s car for the evening, an old Austin with running boards. Harold was our representative in Lagos. We were warned about “ladies” hanging around the entrance to the club, and were advised not to stop the car under any circumstances. After a pleasant dinner, we departed with George driving and me navigating, car doors locked. At the club gates, there were about eight women waiting, and when we drove slowly out, three of them jumped on the car and hung on, one on each side, and one was across the hood trying to obstruct the view. George wanted to stop since he couldn't see. I told him to keep driving slowly, and put one hand on the wheel since I could see out of a corner of the windshield. We continued, fortunately the street was deserted, so we drove down the middle and after several blocks the women dropped off.

We had to return the car to Harold, and he had warned us about his "guard", an ex-Nigerian army soldier with a Lee Enfield rifle keeping night watch on the house. This was shortly after the Nigerian civil war ended, and there were a lot of jobless soldiers around, hence the guard. We approached the house cautiously, but no signs of the soldier. We drove right up to the front porch and parked the car. Getting out of the car, George (ex-British commando) noticed the soldier fast asleep on the front steps; ran over and grabbed his rifle. The soldier woke with a start, and lunged for the rifle, but George kept it away, walked over to the front door and rang the bell. Harold appeared, told us not to worry since the rifle was not loaded; George returned the rifle to the now awake soldier. Harold called for a taxi, and we returned to the apartment – enough excitement for one night.

Next day George flew back to Canada, while I stayed on to find some missing drawings of the Kainji plant that we needed from the Nigerian Electric Power Authority (NEPA) offices in Lagos. I took a taxi over to their offices, got caught in a traffic jam in downtown Lagos and the taxi stopped. A few minutes later, some soldiers came running down the street, banging on car roofs and shouting. On arriving at the taxi, a soldier banged his truncheon on the roof and shouted to the driver to get off the road, and with no room to maneuver, the driver drove up onto the sidewalk. There we stayed until a truck pulling a tank on a trailer drove past. The traffic jam then sorted out and we continued to the NEPA offices. I found out that this was a common occurrence, with the army frequently conducting an "exercise" to see how long it took to pass through congested traffic in downtown Lagos.

Walter Smith had arrived to discuss contractual matters with NEPA, and we were invited by Gerald, head of our local agent Panalpina, to a cocktail party. Panalpina was a travel agency and was very helpful in getting staff in and out of Lagos at the airport. After about an hour at the party, Gerald came over, and said he would like to discuss our contract, which Walter was somewhat reluctant to do, since he had heard that they wanted a hefty percentage of our contract with NEPA, funded by the World Bank. So we walked over to Gerald's office.

Before the traffic jam.

On arriving at the office, Gerald made a point of showing us the double doors, with seals and padding on both sides, preventing transmission of any sounds from within the office. After a few preliminary discussions, Gerald excused himself, saying he had to make a phone call, and on leaving, reminded us about the double doors, both of which he closed on leaving. Walter immediately started to speak, starting to outline what Gerald wanted in the contract, so I punched him on his arm, and he was so surprised that he shut up. I mouthed "microphone", but he could not understand, so I wrote "mike" on a piece of paper and pointed to the underside of the desk overhang. Walter smiled, and we discussed the weather. A few minutes later Gerald returned, looking somewhat disappointed.

One bit of advice Gerald gave us, was to keep a few Pounds, the local currency, (£N – later, the name was changed to Niaras), for use at the airport on departure. I left the next day, with about £20N in my pocket. I passed through all the visa controls, aided by the Panalpina agent who would put some Nigerian Pounds folded into my passport whenever handing it to an agent. I thanked him for his help, and started to walk alone down the passage to the departure lounge. There were three soldiers at a desk near the end of the passage, one was standing, an officer in a smart uniform similar to those worn by British officers, the other standing was a soldier with a Sten gun pointing down, and another was sitting crouched down over the desk. I stopped at the desk, and the officer asked me if I had any Nigerian Pounds, and I replied yes, whereupon he said "put them there", pointing down at the desk, the soldier at the desk smiled and brought out a black garbage bag from under the desk, and the other soldier pointed the Sten gun at me. Naturally, I complied with their request, and understood Gerald's instructions. They would have been very unhappy if I did not have any Nigerian Pounds, and could have easily delayed my departure.

Work on the units proceeded as expected until they were nearly completed. One of the final tasks was to join the turbine and the generator shafts with very large bolts, and to tighten the bolts an enormous five foot long wrench or spanner was provided as part of the turbine equipment. Tightening the bolts requires several days' work, since they all had to be tightened equally and in unison to avoid distorting the flanges. The work started, and next day, the large wrench could not be found. The plant manager said not to worry perhaps another could be purchased in the local market. When we arrived at the Kainji market, there was an identical wrench, nicely polished and on sale for £100N. They managed to bargain the cost down to £50N and continued with the work. Next day, the wrench was again missing, so back to the market to buy it back, and this process continued until the bolts were finally tightened, despite trying to hide the wrench and lock it in the plant manager's office.

The Kainji market – special today on wrenches!

The two generating units were commissioned about two months later without further incident, and we were successful in obtaining a contract to install another two, also funded by the World Bank.

There we did have an incident which illustrates the difficulties of working in Africa. There was a large gantry crane stationed on top of the dam, running on rails and powered from a thick 52 meter long electric cable which could be plugged into receptacles placed at 100 meter centers on the dam. Fred Clark was the resident engineer, and he asked the crane operator to move the crane over to the intakes for the new units. The crane operator returned an hour later to advise that the crane would not work, so Fred asked the plant chief operator to look into it and find out what was wrong. Again, no definite answer, only that it would not work. This situation continued for several months until I sent Fred a telex asking him to go up onto the dam with the crane operator, and see exactly what was wrong. Next day I had his reply “Crane operational – WAWA – report coming”.

Fred’s report was amusing. Apparently on reaching the crane, the operator proceeded to pull out the rolled-up cable towards the power plug, and stopped a few meters short of the plug on reaching the end of the cable. So Fred told him to pull the cable over to the plug in the opposite direction, and the problem was solved. Yes, WAWA means West Africa Wins Again, and is used to describe any situation where common sense is lacking.

The dam can be seen on Google Earth at 9-51-51.77N and 4-36-44.65E.

But we were not successful in designing an absolutely foolproof control system. About 25 years later, in 1998, I saw a news item that a turbine unit had “blown up” at Kainji. Water turbines just do not explode, so I was curious as to what had happened, and called some of the engineers in Canada and Europe who had worked on the project. Also, I happened to attend an international conference shortly after, and there was a paper on the incident by an engineer from the United States Bureau of Reclamation who had offered to undertake a free inspection. As is common, the official published report did not fully describe the accident, and I managed to pull together a more accurate description of the event based on the report and my phone calls.

Apparently, the plant operators had great difficulty keeping the equipment operating due to a lack of spare parts, exacerbated by non-convertibility of the local Nigerian currency and their inability to obtain import permits. Even governor oil was impossible to obtain, and it tended to “disappear” as the operators siphoned off small quantities to be sold in discarded glass perfume vials at the local market as a “personal” lubricant. The result was predictable, low oil in the governor caused an alarm in the control room, and further loss of oil caused a unit to stop operating. All the safety controls, and there were many, were by-passed, allowing the unit to continue operating with no safeguards.

Eventually the inevitable happened. With insufficient oil in the governor, control was lost during a system disturbance, and the unit went to over-speed at almost twice normal speed. Flow through the unit increased. Unfortunately, the emergency head-gate closure switch in the control room was also out of order. The head-gates were operated with a hydraulic cylinder hoist, and over the years the seals had worn causing the gate to drift down. The limit switch used to keep the gate open had also failed, and was not operational. To prevent the gates closing, they had been propped open with steel beams. When the alarm sounded, the chief operator tried to shut down the unit, could not, so he had to close the gates from the top of the dam. He could not take the lift to the dam deck since it had long ago ceased working, and there was no lighting in the stairs, all the light bulbs having been stolen leaving the dark stairway populated by bats and snakes. So he jumped into his car and drove around onto the dam crest, and about 15 minutes after the unit went to over-speed the head gate was successfully closed, but damage to the turbine was severe.

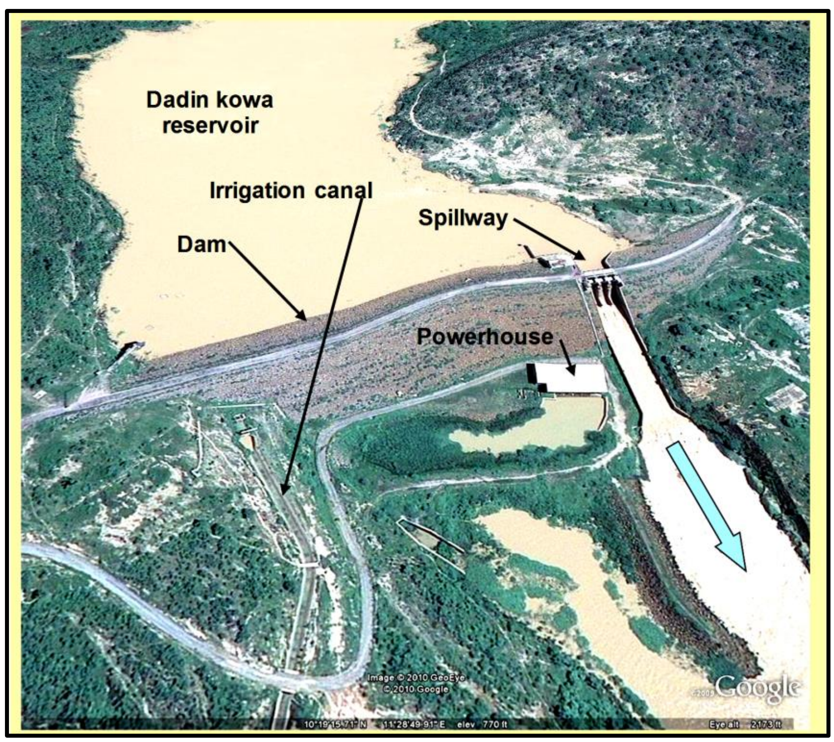
On accelerating to run-away, the propeller unit speeded up and rode up on the water column in the unit, causing the unit to lift and hit the steel cover on the turbine. The cover received the full impact from the runner, after which the runner bounced down, and rose to hit the cover again. This motion continued until eventually the bolts holding the cover failed, the cover lifted by about a foot, and the turbine pit flooded. Also, the harmonic waterhammer in the water passage below the turbine ruptured the draft tube steel casing. The whole powerhouse flooded to just below generator level, and all eight units were stopped. The turbine bearing was destroyed, and consequently the generator rotor, spinning at about 200rpm tilted and hit the stator, destroying the generator. The entire generating unit was a write-off, and is still not repaired. WAWA once more!

DADIN KOWA

In 1973 I returned to Nigeria and landed at Lagos on March 27, staying at the Ikoyi Hotel. This trip was to inspect a new site for a proposed hydro and irrigation development on the Dadin Kowa River in northern Nigeria. We had obtained the contract in association with Shawinigan Engineering, and it was funded by the local irrigation authority with money from the new oil fields near Port Harcourt. The trip proved as eventful as the last one.

My first task was to obtain maps of the area, so I went down to the local map office and ordered copies of four maps at a cost of £1N each. I was told to return after lunch, and the maps would be ready. Back I went after lunch, and paid for the maps with a £5N note. The clerk gave me the maps, I asked for a receipt, got it, and asked for my change, saying I had given him five Pounds, when the maps cost £4N. He looked me straight in the eye and said "No master, all you gave me was four Pounds". Just one small example of Nigerian "dash", you had to add some "dash" to every transaction in order to get anything done. Later, I had to explain to our accountant what "dash" meant when submitting my expense account.

By now, the whole Nigerian economy was awash with oil money. While staying at the Ikoyi, there was a national budget conference going on in the conference room in the top floor of the hotel, and all the provincial chiefs were in attendance. I was in an elevator going back up to my room after breakfast, when two chiefs entered, dressed in their flowing white robes. One was talking, saying in a cultivated Oxford accent "You know Nigel, I have been attending these meetings for five years, and I have always asked for twice what I needed, knowing that I would be given half of what I asked. This time I did the same, and Obo said surely that wasn't enough, and gave me twice what I had asked, and I now have four times what I need. What am I going to do with it?" To which his partner replied "Well I know what I am going to do with mine, I have a friend in Switzerland and I'll give you his number".



Google Earth image of Dadin Kowa damsite.

At the Joss airport. I borrowed a Raleigh bicycle for a short ride.

Next day I departed for Joss with Hans Kolle from Shawinigan Engineering, leaving most of my luggage at our office and carrying only a small canvas pack-sack and a brief case. Nigerian Air managed to lose my pack-sack, but I had to wait overnight in Joss for transport, and hoped it would be on the next flight. At Joss we were joined by a six-man survey team from Canadian Aero Surveys, who were going to map the site. My bag was lost. Next day we were met by a driver from the irrigation office in Gombe and we started off in a Toyota jeep with the survey crew following in their own large van. The day was very hot as usual, and there was no air conditioning in the jeep. As we drove along, the driver dozed off and we hit a mound of earth at the side of the road, almost tipping over, I grabbed the wheel and held on tight, preventing the driver from making any sudden turn, and we righted and stopped. I asked the driver if he wanted me to drive, but he said no, so we continued with me keeping a close eye in him. We all stopped for lunch at the Bauchi Club, and were told that there was a severe drought in the area, so food was difficult to obtain. When they heard that we were going on to Gombe, the club manager said we would not find any food there, and would have to return. As a precaution, we asked if he could provide some sandwiches for dinner, and he obliged. We continued on, our target being a cotton ginnery where we had reserved a couple of houses occasionally rented to passing travelers. We arrived in late afternoon, and were informed by the Scottish manager of the cotton ginnery, that he was sorry, but the last group had made such a mess in the houses, that he was not renting them anymore. I told him that we had a very quiet civilized group, and would take good care of the houses. But he was adamant, no houses, even when I offered double the going rate. His broad Glasgow accent triggered a thought and I said “I have an unopened 40 ounce Johnny Walker in my briefcase, if ---” He interjected “The houses are yours, and come over for a drink when you’ve cleaned up!” My practice of always carrying a bottle of Scotch was paying off.

Next day we went over to the Gombe Club for a breakfast of eggs and toast, but we could not get anything to take out for lunch. So we filled our water bottles with boiled water and set off, driving as far up the Dadin Kowa river valley as possible, to within about 5 miles of the dam site. We walked the rest of the way, had a good look around, told the surveyors what we needed, and walked back to the cars to return to our rented houses, very hungry. After showering, we all drove over to the Gombe Club for dinner, and were informed that there was only two items to choose from, more fried eggs and toast or some pork left over from the previous evening’s barbeque. I asked if it had been kept refrigerated, and was told that power went off at midnight and had not returned. There were candles all over the place, hence my question. I chose the eggs, but some of the surveyors went for the pork and later were very sick.

There was plenty of warm beer, so after dinner I wandered out onto the patio and spotted a man lying down on the low stone wall, sipping beer. We had a conversation, and I found out he was the mechanic from the nearby cotton ginnery, and again a Scot from Glasgow. He said “this is the best place on earth", so I had to ask him why, and he replied "because the natives talk to you in English!"

Next day Hans and I returned to Joss to catch the 3.00pm flight back to Lagos. At the airport I wandered out onto the runway where the pilot was looking at a violent thunderstorm approaching from the south. I asked him if he was going to fly around it, since it was directly in our path to Lagos. He said no, that he would try to fly over it. We took off, in a high-wing Fokker 27, and started climbing towards the storm. I was busy filling in a lost baggage form I got at the flight counter, and did not notice the commotion until much later. The long form asked for a list of all baggage contents, and after completing it, I suddenly realized that the isle was filled with men bowing and praying, and that golf-ball sized hail was hitting the aircraft causing a huge racket. However we arrived at Lagos intact, but not the aircraft. On disembarking, I walked over to the pilot on the tarmac at the front of the aircraft, looking at the pock-marked wings and fuselage; he turned to me and said that it would not fly again until it was re-skinned.

Hydraulic model of Dadin Kowa spillway.

Hans went into the airport to pick up his bag, so I asked him to get a taxi, while I found someone to take my lost baggage form. The Nigerian airways office was closed, so I went back looking for Hans. I found him out on the parking lot in the midst of a melee of about 50 porters all fighting one another. He was looking quite bewildered. I walked out and waded through to Hans, occasionally dodging a punch, and asked him what the hell was going on. He replied that a porter had brought his very large bag over to a taxi, he had tipped him, but the taxi would not start. They were now all arguing over who should pick up the bag and take it over to the next taxi. I looked around for the largest porter; saw a 6 foot tall man standing nearby, with his arm around the neck of another smaller man. I tapped him on the shoulder and said "You, pick up that bag and take it there!" He turned around, let go of his assailant, saluted and said "Yes master" and immediately all the fighting stopped, and the porters returned to the terminal. Quite an experience, but I would not try to do it again in today's climate.

A few days later I left Lagos, but before doing so, I found the Nigerian Air office and asked for the manager. A pleasant man came out and I explained about my lost green canvas pack-sack tied up with string (the leather straps had broken) and that it contained a Zeiss camera, an Abney level, a steel tape and some clothes, as he would see from the claim form. He said he would look for it and I gave him by business card. But I thought that was the end of it, lost bags in Nigeria are just not found. So imagine my surprise to get a call from the customs at Dorval airport about 3 months later informing me that they had a bag with my name on it, and could I come out and open it. I asked them to describe it, confirmed it was my bag, told them they could open it for inspection, and to put it on a taxi. This they refused to do, so out to Dorval I went after dinner at home. The knots on the string holding the bag together had never been untied! I was very surprised, and wrote a letter to the Lagos Nigerian Air manager thanking him for returning it. Don't know if he got it.

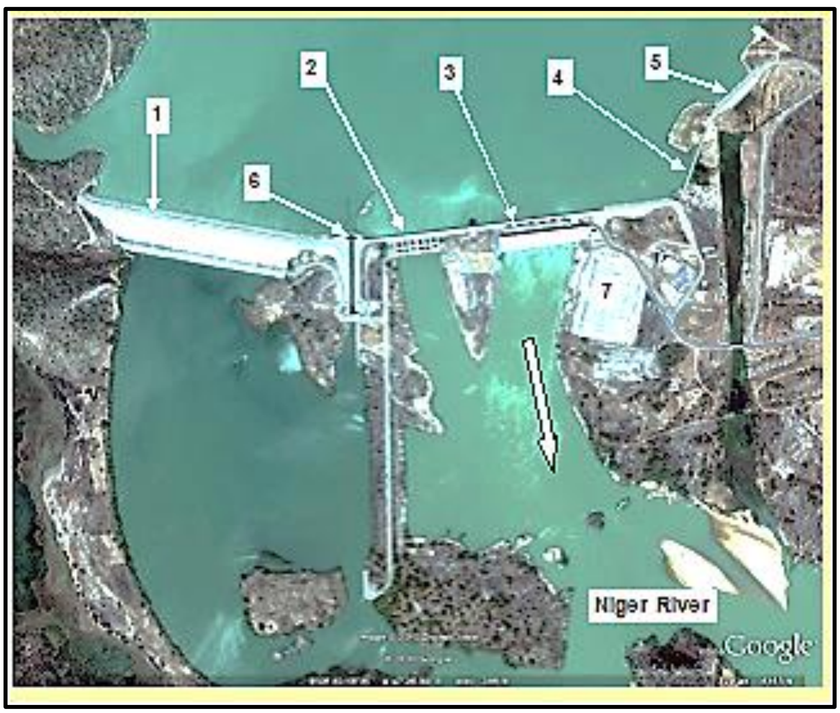
The survey team had to abandon Gombe due to the lack of food, and retreated to the provincial capital at Bauchi, staying at the Bauchi club. Work on Dadin Kowa proceeded for about 3 years until the client ran out of money and work stopped. The earth dam and spillway span across the valley, and there are two buried penstock pipes down to an empty powerhouse. The spillway gates were not installed, and remained in Europe, along with all the rest of the electro-mechanical equipment, until other buyers were found. Chinese contractors are reportedly installing all new equipment manufactured in China, and the plant was expected to start producing electricity in 2008. The Chinese are paid in oil to be delivered over the next 20 years, a barter arrangement very beneficial to China.

The dam can be clearly seen on Google Earth, in a high resolution area, well worth a look. It is at 10-19-19.52N and 11-28-54.38E. There is the earth dam across the river, a spillway with water flowing through, and a white-roofed powerhouse with an earth dyke around it, still not operating (2016). The irrigation canal on the west bank is clearly visible, snaking down to a large water treatment plant and beyond to fields. So at least the irrigation part is used.

JEBBA

NEPA were so pleased with our performance on Kainji, that in 1974 we were awarded a contract to undertake a feasibility study and detailed engineering of the large Jebba hydro development downstream of Kainji. It proved to be both a blessing and a curse for the company. The large project, costing well over $1Billion (1982$US) taxed our resources, and limited our ability to undertake other hydro work. Our entire civil and hydro-mechanical staff worked on the project, and I had to appoint a "Project engineer" for each structure due to the magnitude of the development.

Model showing section through dam and powerhouse, to be placed in the Jebba office lobby



Jebba development. 1. Dam. 2. Spillway. 3. Powerhouse. 4. Emergency weir spillway. 5. Side dam. 6. Navigation lock. 7. Substation.

The staff under my supervision totaled about 40, and to maintain quality control, I had to drive to the office about an hour early to do a "walkabout", looking over the drawings as they developed, noting items that needed review with the engineers, and then later asking them to come into my office for a discussion. Now, with all drawings produced on computers, such reviews are not possible. Years later, I asked consultants, in my role as a member of review boards, how they undertook quality control, and have never received a satisfactory answer. Unfortunately, I never visited the site.

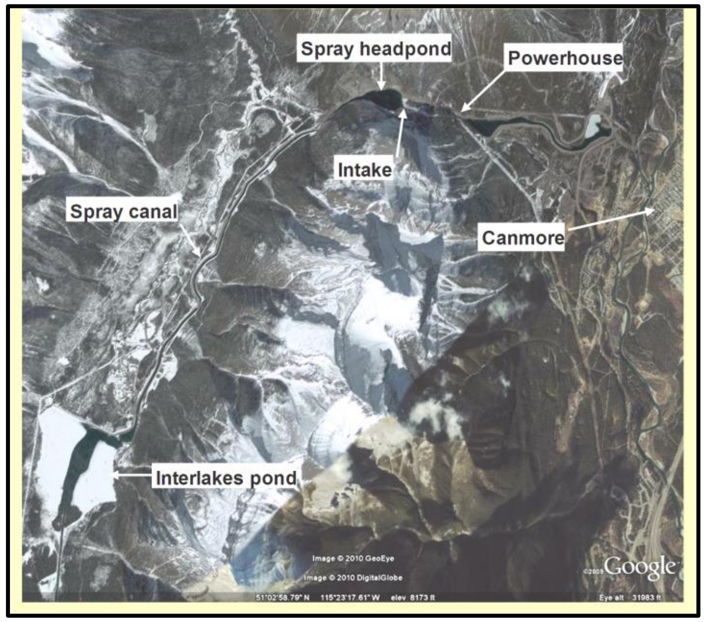
Reviewing Jebba drawings.

Project model for lobby in Jebba office building

Jebba was the last major hydro project undertaken by the company, before it was purchased by another consultant in 1990. Unfortunately, we had to dismiss most of the very experienced Jebba design and site construction supervision staff due to a downturn in business, when a recession commenced about 1980. Jebba was commissioned in 1986.

25. SPRAY CANAL – 1973

Spray canal has a long history. The 4.6km long canal was built in 1950 to supply water to the Calgary Power Spray Lakes development just above Canmore, Alberta. It traverses several talus slopes, and failed on first filling in 1951 due to the development of sinkholes. It was repaired and operated until it failed again in 1973.

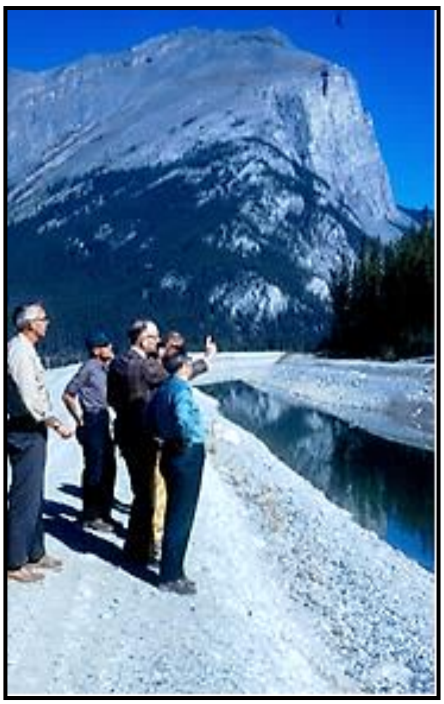


Canal layout.

MS Spray inspection barge.

The second failure happened 2 years after the operator who witnessed the 1950 failure had retired – a simple case of not passing on the canal maintenance procedures to the next generation. Apparently, the original operator was instructed by Dr. Hardy on how to look for sinkholes in the canal bottom, and how to fill the hole with sand and silt to staunch the leak. Having witnessed the failure and the disastrous consequences, the operator was very diligent, maintaining records of sinkhole locations, dates and approximate volume of silt required to fill the sinkhole.

He even built a boat which eventually evolved from a simple canoe into a 2-pontoon barge with a central cabin with a glass floor, storage boxes for sand and silt and a canvas elephant trunk for exact placement of material. With this apparatus, he inspected the canal bottom regularly, about once a week, even in winter, since ice rarely formed. Unfortunately this practice ceased when the new operator took over.



Bill Maxwell, Steve Chrumka, Dr. Casagrande and Dr. Hardy, inspecting the canal. Oct. '73.

The second failure occurred in the spring of 1973, shutting down about 130MW of capacity, so a quick fix was necessary. I had recently hired David, a civil engineer with a doctorate, and he told me that he could develop a program to compute the optimum location of the canal on the side-slope of the mountain, where the cut volume would match the fill volume, so I told him to go ahead. We had detailed topography, and the canal was set out according to David's calculations. A contract for the earthworks was awarded, and work proceeded as planned. However, the site staff encountered considerable difficulty in following the layout, since the drawings called for several abrupt changes in direction, and these had to be smoothed out.

View of completed canal.

The end result was a much straighter canal, with fill quantities about three times what had been calculated by the computer. It was the first time we had used a computer to estimate quantities, so I was somewhat disappointed with the outcome. I inspected the work three times, in October and December of 1973, and again in November of 1974. To date, 2018, the canal has continued to operate successfully.

26. VANCOUVER – 1972

In October of 1971, George Eckenfelder asked if I could go to Vancouver for a few months to help Jack Sexton with a study of the hydro potential of the province, to identify at least 25,000MW of hydro sites. Jack was the project head, on loan to BC Hydro, with all the technical work being undertaken by BC Hydro staff. Since Jack was writing and editing the massive report, he did not have time to check the BCH technical work, so had asked for my help.

Vera was enthusiastic, and relished spending a winter away from the snow in Montreal, so I accepted. We rented a bungalow in Vancouver from a retired couple wanting to spent 3 months in Hawaii, flew out on the first of January, and returned on March 31st.

At Stanley Park, with Howard, Graham and Fiona.

My contract for the assignment included payments for the bungalow and rental of a car. I had reserved an Avis car at Vancouver airport, drove to the bungalow, and next day went shopping with the family for supplies. The car sat in the carport for the rest of the week, so after using it over the next weekend, I drove it back to Avis. At the BCH offices, I enquired if there was a car rental agency nearby, and was informed that a Ford dealer, one block from the office rented out their demos at a very low rate, but required a hefty cash deposit. So on the Friday I walked over to the dealer, and explained that I would like to rent a car from Friday evening to Monday morning, and would be doing so until the end of March. The rate was $10 for the weekend, plus re-filling the tank, plus a refundable deposit of $100, if there was no damage. This was far lower than the Avis rate, so I drove out with a car, my choice of several on the lot. Next weekend I was back and this time the dealer said to forget about the deposit, but would have to pay it if there was any damage. I later found that I could rent a car overnight for only $2, and did so on several occasions – quite a change from current rental costs!

We did the usual tourist routine, visiting a different park every weekend, having lunch at the top of Grouse Mountain and going over on the ferry to Vancouver Island.

In February, I had a call from Vera after lunch; apparently the oven would not work. During the day, there had been rumors in the office that BCH was having trouble with the system. I asked her to turn on a light, it was dim, so I told her I would call back. Our office in the BCH building was on the second floor, the same floor as their central control, so I walked over and looked through the window in the door. The control room was in absolute chaos; red lights on all the annunciator boards, and the staff running around. I asked an emerging engineer what was the problem, and he told me that a severe ice storm in the North-East of the province was collapsing many of their transmission towers. I called back, and told Vera that the power could go off soon, and there was nothing to be done about it, just be patient.

Later I learned that all transmission lines from the North, except one, had tower collapses, that in the morning BCH was exporting 2,000MW to Bonneville Power, and that an hour later, Bonneville was sending 2,000MW back to BCH! Also, Bonneville advised that this would have to be cut off shortly as evening approached and their load increased.

On the beach – English Bay, Vancouver.

The situation was so critical, that BCH asked (over the local radio stations) for all street lights and store window lights to be turned off, for homes to only use one light bulb and one stove element, and to shut off all electric heaters. Stores were asked to cut floor lighting by at least half, switch off window displays and all industrial loads to shut down. Fortunately everyone cooperated, and the Vancouver area load was cut to about 20% of normal.

On the beach – English Bay, Vancouver.

Hiking through a park.

It took several days for the situation to return to normal. The downed towers were in deep snow, and access was extremely difficult. BCH had to resort to renting large mobile cranes to suspend individual insulator strings at a few locations. It was an expensive lesson for BCH, and resulted in the addition of new transmission lines in different valleys to reduce the ice risk.

Lighthouse Park.

Capilano suspension bridge.

The other notable incident was not as serious. Our report was nearing completion, and one of the illustrations was a color map of the flood inundation zones in the Frazer River delta adjacent to Vancouver, from a series of large floods. The delta contained the towns of Delta and Richmond, and the map showed that under an extreme flood, several of the outlying housing developments would be under water. The map was produced by a series of overlays (before digital printers) with a different color for each flood risk, and the illustration was many days late. Phone calls to the printers only elucidated an excuse that they were having difficulty aligning the different colored overlays, a common problem. Eventually Jack asked me to go out to the printer's office and find out just what was wrong.

Capilano suspension bridge.

The real delay was caused by the president of the company. Apparently he owned one of the homes within the flood zone, and he was in the final process of selling the property. He did not want the map to become public until the deal had closed, expected in a few days. I told him we could wait for a few more days, but that was final. The sale was completed, and we got the map the next day, much to our relief! Delta and Richmond are protected by a series of dykes as at New Orleans. But continual siltation in the river means that the dykes eventually need higher crests, and this work is often delayed.

View from back deck, on a rare sunny day.

During our stay in Vancouver, the weather was typically terrible, cool and damp, with almost constant rain and fog with very few sunny days; but we enjoyed our "holiday". Many years later I learned that the children hated it – no friends at their new schools, reinforcing my conviction to never move the family when asked to work in Brazil or other countries.

27. CAPE BRETON – 1972-74

Two heavy water plants were built in Cape Breton, Nova Scotia, one near Port Hawkesbury, and the other near Glace Bay. The heavy water was used as a moderator in the CANDU type of nuclear power plant used in Canada and a few countries in Asia. The plants were owned by the Atomic Energy of Canada (AEC).

Heavy water plant at Port Hawkesbury.

In July 1972, we had a call from AEC asking for someone to look at a problem with a channel providing raw water for the heavy water plant at the town of Port Hawkesbury. So I flew to Halifax, rented a car and drove out to Port Hawkesbury. The plant was built on the north shore of Canso Strait about 2 miles from the town. Arriving at the plant, I was given a 20-minute instruction on use of their safety equipment, and introduced to Bob, the plant engineer. The plant heavy water process used highly toxic hydrogen sulphide gas, which is invisible, tasteless and has no odor at high concentrations. The process piping and the high cracking towers covered about two acres. About 6 meters above ground, there were numerous natural gas burners, set to fire whenever sensors detected a sulphide leak. The idea was that the burners would heat the atmosphere, the air would rise and bring fresh air in from below, thus lifting any hydrogen sulphide gas up off the ground. Also, when a leak was detected, several loud sirens around the plant would sound the alarm. At the same time, sirens in the nearby town would alert the local population.

The safety equipment consisted of a gas mask, a bottle of compressed air, sufficient for about 15 minutes, and a walkie-talkie radio. You had to walk with your "buddy" and keep about 7 meters between you. If the siren went off, signaling a gas leak, you had to put on your gas mask, and if your buddy was overcome, you put his gas mask on his face, opened the air valve and you then informed the emergency center by radio, and waited for the stretcher crew to arrive. I had to show that I could put on the gas mask, open the air valve and call on the radio. After passing this test, I walked with Bob, keeping apart by the regulation 7 meters through the plant to where the water channel problem was located.

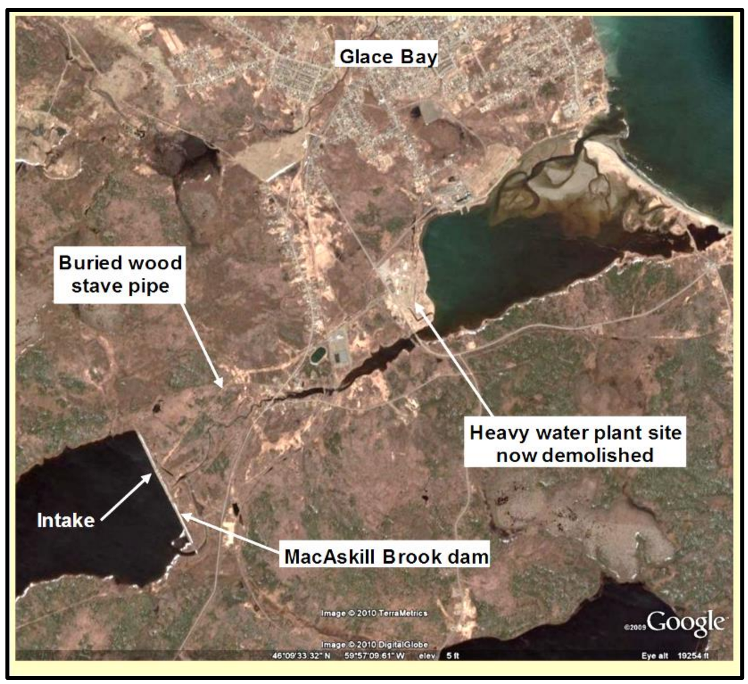
The problem turned out to be excessive erosion at the outlet of a culvert discharging the processed water back to the ocean. This was easily remedied with a small stilling basin which we later designed and sent the drawing to them for construction.

Excessive erosion at process water outlet.

So I asked Bob if I could have a look around the facility, and we walked about, eventually coming to a high fence enclosing the plant, where several people were walking past on the other side. I asked Bob why the fence was so close to the plant, only a few meters from the elevated piping and gas burners, providing minimal protection for passing pedestrians. Bob replied that the plant owners, AEC, had tried to purchase the adjacent land to provide added separation, but were prevented from doing so by the town. A young boy passing by saw us with our gas masks and shouted “are you going to the moon!”

The plant was very near the town, so the local population had been thoroughly instructed on what to do when the siren sounded. High school students had been recruited to go door to door with instruction pamphlets advising all residents to immediately go indoors and to close all windows, all vehicle drivers were advised to stop and enter the nearest building, all pedestrians to enter the nearest shop or public building and all school children on recess to go back inside the school. Gas stations were provided with instruction pamphlets to give to all customers. The plant manager told the town that he would like to test the warning system, and it was agreed to sound the sirens on a Friday afternoon at 2.30pm. Everyone was made aware of the test, the sirens went off, and all precautions worked exactly as planned.

However, the plant manager thought that it had worked too well. So about 2 months later, without telling anyone, except one of the plant engineers, who was asked to go out to the plant with a buddy a few minutes before he sounded the alarm, wait for the siren and then to fall down as a “victim”. The siren went off on a Wednesday morning about 10.30am. All hell broke loose, the school children were on recess and all ran home. Shopkeepers closed their doors and would not let anyone in. Drivers in cars stopped and unsuccessfully tried to enter the shops. Most truck drivers decided to get out of town as fast as possible. Wives with husbands working at the plant phoned to see what the problem was, jammed the phone lines, and not getting through, they jumped in their cars and raced to the plant causing a traffic jam and several minor fender-bender accidents.



Glace Bay site.

The plant engineer fell down as instructed, his buddy called for help and the emergency center phoned for an ambulance. The local newspaper reporter heard the siren, witnessed the chaos, saw an ambulance depart for the plant and called in a report on an emergency and accident at the plant to his editor. The editor tried to verify the story by phoning the plant, could not get through, assumed the worst and alerted the radio station. The local radio announcement of the now "serious accidents" caused more ambulances to be dispatched from as far away as Antigonish and even Sidney. It took about two hours to get everyone calmed down and believe that it was only another test of the system. For me, it was a remarkable lesson on the difference between a test of an emergency action plan and an actual event. Before I left, I did see the heavy water dripping from a tap into a 40 gallon stainless steel oil drum. It looked just like ordinary water!

MacAskill Brook dam and intake tower during early stages of construction.

The other plant at Glace Bay had a water supply from the nearby MacAskill Brook, where the company obtained a contract to design and supervise construction of a small dam, spillway, intake and buried wood stave penstock. The water intake structure was in a remote area, and the development operated without any staff, other than the occasional inspection by the plant engineer.

Installing wood stave pipe.

Unfortunately, there was considerable local opposition to the Glace Bay heavy water plant, due to the safety drill incident at Port Hawkesbury.

Heavy water plant scrapped.

After completion, all went well, until raw water flow suddenly ceased. The plant engineer drove out to the dam, and found that the intake house door had been forced open, and the gate dropped. A new stronger door was installed, but again the flow ceased.

This time, the aluminum roof had been ripped open to gain access. It was replaced with a quarter inch steel plate solidly attached to the concrete walls. Again the flow ceased, when the vandals gained access by shooting out the door lock. What to do. After some discussion with the Project Engineer, who was from Nova Scotia, he suggested phoning the Navy in Halifax, and asking if they had a surplus heavy steel door from a destroyer. They had, it was installed, and no more problems. Just goes to show what has to be done on occasion to "fortify" remote facilities.

Both plants operated for a few years without further incident, until the demand for heavy water was fulfilled, and were then demolished.

28. YUGOSLAVIA – 1972-3

In November of 1972, I traveled to Yugoslavia to inspect the Bajina Basta hydro plant about 130km south-west of Belgrade. It was founded on a soft volcanic tuff, similar to that at Bayano in Panama. I needed to see how the foundation had distorted under the load from the dam, and how the powerhouse foundation was designed to counter the deflections. A couple of days were needed to arrange the trip, and we set off squeezed into an ancient car. The trip took far longer than I expected, due to the poor roads with many twists and turns in the mountainous terrain. After about 4 hours, we arrived at the plant and had a sandwich lunch. After lunch, we were conducted around the powerhouse and dam. A contractor was working on something, and I suspect it was reinforcing the foundation, but we were not told. No photos were allowed, but I managed to take a few, unnoticed by the local soldiers.

On road to Bajina Basta.

We tried to descend down to the lower floor of the powerhouse, but there was a rope across the stairway, just the area I wanted to see. I asked to go down, but was told it was too dangerous. I managed to walk away from our guide and was about to go down the stairs when a soldier grabbed me, and took me back to the guide.

We had an interpreter, but his knowledge of technical terms was minimal, so we did not find out what was being done. But I now knew that despite the contractor's assurances that all was well, there were problems with the foundation. After a couple of drinks of slivovitz we departed for the long drive back to Belgrade.

It was soon dark, there were no lights on the road, not even in the towns we passed through, and with the conditions in the car, the drive was becoming very uncomfortable, so I asked our interpreter if we could stop for a meal, or at least a rest. After some discussion with the driver, I was told that there was a perfect stop up ahead in a town, I think it was Valjevo.

Bajina Basta Dam and spillway.

From hotel window – a foggy day in Belgrade.

On arriving at the town we drove around some streets in complete darkness and stopped in front of what appeared to be the town hall opposite a park. On opening the huge carved wood door, we were greeted by a band playing and a woman up on the stage belting out all the old Marlene Dietrich songs in English!

The whole town seemed to be there having a whale of a time, occasionally joining in the singing. So we stopped for a couple of hours, had dinner and an excellent time. I just could not get over the fact that such entertainment was available at a small town in the middle of Yugoslavia.

Hydraulic model – third sluice from left too large!

The next trip was in April of 1973, to inspect the hydraulic model of the Bayano dam and sluices being built and operated at the Yaroslav Cerni Hydraulic Laboratory in Belgrade. The hotel was booked by the laboratory, and I arrived in the late afternoon after a sleepless night spent on the plane to Heathrow, for connections to Belgrade via Frankfurt, where I met John Marica, our project manager in the Panama office. After a short nap, I went down for dinner, and then to an early bed. About midnight, I was woken up by a persistent knocking on the door. I could not understand where I was, but eventually opened the door, not a recommended action in a foreign country so late at night, but I was too groggy to think clearly. Nobody was there, so back to bed. Then the phone rang, and on answering, a woman's voice jabbered away in Croatian, and after collecting my thoughts, I replied over and over again, "no understand, get hotel manager, speak English". Eventually a man answered and said "Mr. Gordon, do you want woman for night", I said no thanks, and again went to bed, not thinking anything more of the incident.

Next morning after breakfast, I was met by Vladimir, the head of the laboratory and driven to the lab on the outskirts of Belgrade. Apparently the model was not yet ready for inspection, so Vladimir suggested some slivovitz to warm us up, since it was cold, and there was no heating in the building. This was followed by more slivovitz, and a third was proposed, but I objected and asked to see the model. I had a good look at the dry model, before it was filled with water to simulate flow through the sluice gates. I took some photos, but failed to notice that there was a mistake in the dimensions of one of the sluice gates – no doubt due to the effects of the slivovitz. At lunch with all the staff in the laboratory, there was more slivovitz, and after a few drinks, Vladimir said "Mr. Gordon, did you enjoy your sleep last night?" to which I replied, without thinking "Of course, I slept very well thank you", and everybody smiled. This bothered me, why would everyone smile? It was not until days later, on board the plane home that it occurred to me that Vladimir must have paid for the woman at my door! But one thing did impress me; all the staff in the laboratory could speak excellent English.

John Marica looking at model.

Manuel Estrada, Vladimir and John Marica looking at low level outlet flow.

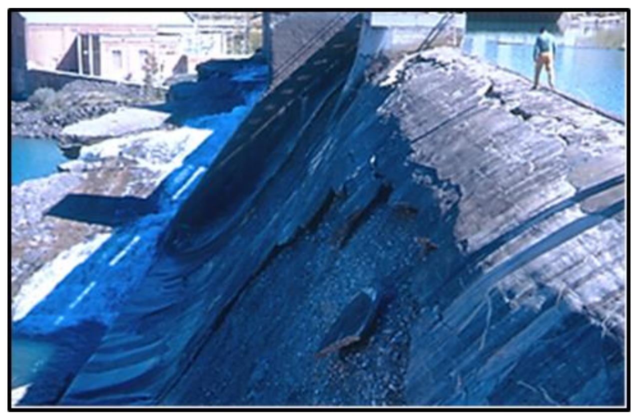
Vladimir figured that I now owed him a favor. He had a son who had left home a couple of years ago to study engineering at MIT in Boston, and he wanted to see him. This was in the middle of the cold war and he could not get a visa to the USA, but could to Canada. So he asked me if I could write a letter to him a couple of months after arriving back in Canada, saying that there was a problem with the design of the spillway, and could he come to our offices for discussions. This I did, Vladimir arrived, we had a short meeting, and he left to meet his son who had traveled up from Boston to Montreal. Happy ending. Yes, he brought a bottle of slivovitz.

In hotel room working on report.

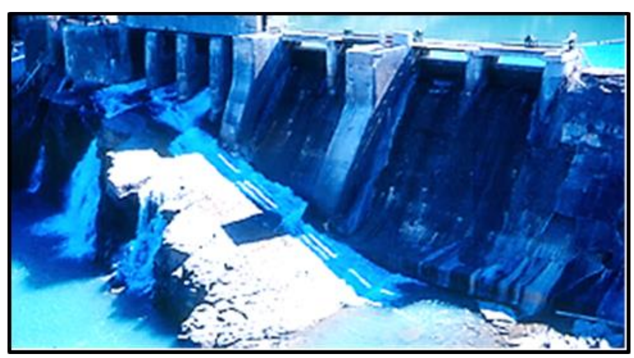
When I had the photos of the model developed, I saw the error in the spillway gate section, wrote to Vladimir, and asked if it had been corrected. He replied that they knew about the mistake, and had hoped that I would not notice it, and that it was now corrected. He included some photos to show the changes. Just shows what a few glasses of slivovitz can do!

29. HORSESHOE DAM 1973-5

The first hydro plant built in Alberta was at Horseshoe Falls on the Bow River, about 72km upstream of Calgary. The plant started operating in 1911; has been in continuous service since then and still has the original units, four Francis turbines. Apart from installing new runners and controls, all the other components are original. The question is often asked – why not install new modern units? The answer is the low cost of incremental energy when compared with coal-fired generators, at less than one cent per kilowatt-hour. The installation has a log sluice, a 4-gated spillway, a stoplog spillway with 4 openings, and a weir spillway.



Downstream face, prior to repair.

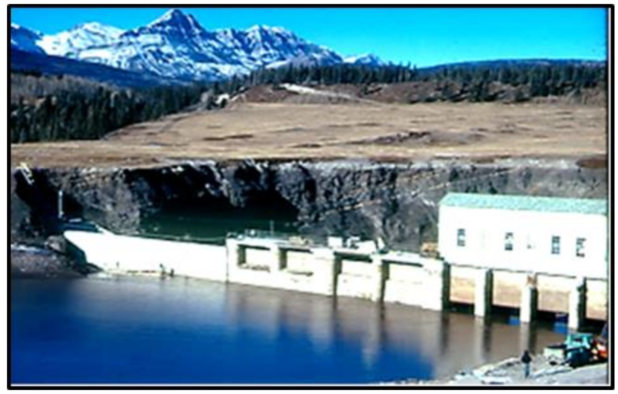


Weir spillway, prior to repair.

The original concrete was of very poor quality, due to a lack of understanding of the effect of excessive water in the mix. This required frequent concrete repairs, usually by spraying the downstream faces with gunnite or shotcrete. This did not prove to be very effective, other than providing some temporary cosmetic enhancement. The problem was always inadequate bonding to the old concrete surface, and seepage through the more pervious old concrete encountering the more impervious gunnite or shotcrete, where water collected at the interface, resulting in freeze-thaw de-bonding and deterioration, which resulted in slabs of the repaired surface falling off.

Two views of downstream face, repaired concrete.

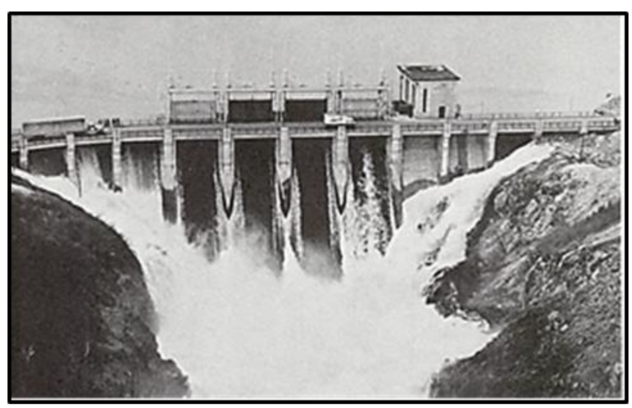
By 1973, the situation had become serious, so that an effort was made to provide a more permanent solution. This consisted of removing all deteriorated surface concrete down to "sound" concrete, a task which required some interpretation of "sound". The site engineers commented that in places, excavation of the surface could have proceeded indefinitely! The new concrete was anchored to the old, and included surface reinforcing. The work was accomplished in 2 summer seasons, and hopefully will last many more years.



View of upstream face of repaired dam.

30. St. MARGUERITE – 1973-83

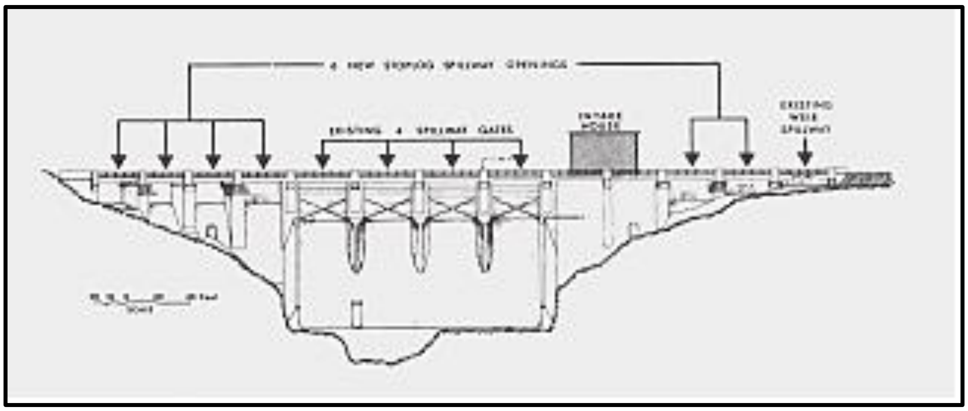
In March of 1973, we had a call from Peter Payne, Chief Engineer for the Iron Ore Company of Canada (IOC) in Seven Islands. Apparently the spring flood at the nearby St. Marguerite dam was extremely large, and had nearly overtopped the embankment dams on each side of the concrete spillway structure. The short concrete flanking dams on each side of the spillway were equipped with overflow weirs, but the flood indicated that total spill capacity was insufficient. The IOC wanted the ogees cut out and replaced with removable stoplogs.



Spring flood – 1973.

This concept while viable, was difficult to develop since the dam crest served as the main highway to the town of Seven Islands, hence it was not possible to use a stoplog hoist for log removal. Some other means had to be devised. After much thought, we developed a quick release mechanism, whereby the bottom of a wide flange column in the middle of the stoplog opening was held by a reinforced steel angle on top of the ogee, and the column top was retained by a removable pin. When the pin was jacked out, the column would rotate about the bottom, and the logs would be instantly released and lost downstream, along with the steel column.

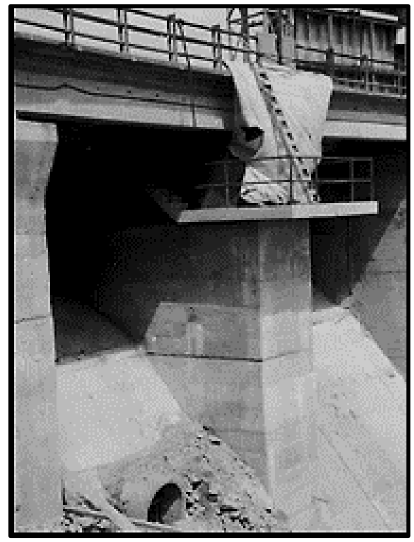
At St. Marguerite, the only problem was getting access to the top of the column. This was solved by a portable ladder, (for security) down from the road, to a concrete platform on every second pier, cantilevered out from the pier just below the deck.



Downstream view showing stoplog locations.

View of concrete platforms on every second pier.

It was considered too awkward to release the pin from below the deck, so a hydraulic pipe was routed from the jack up to a pumping nipple in a locked box on the deck railing. It worked very well, and has been used several times by the plant operators.



Access platform construction.

A heavy steel beam spanning the opening just below the road bridge holds the central column and the jacking-pin mechanism. Another steel platform was built upstream of the piers for stoplog placement, since it would be too difficult to place stoplogs from the downstream platform on only one pier in each bay.

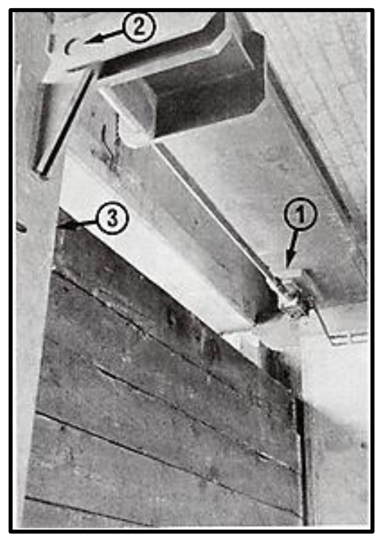


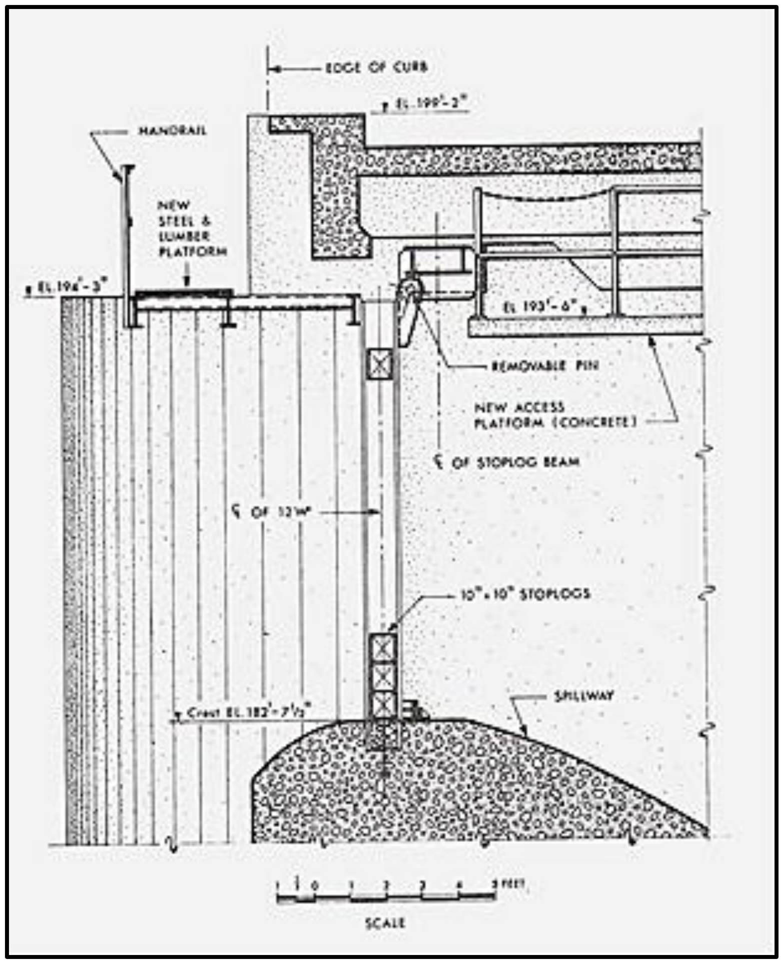
Photo showing quick-release concept. – 1. Hydraulic jack. 2. Pin at top of column. 3. Steel column in center of ogee.

The concrete ogees were cut down by about 10ft., to accommodate the stoplogs.

Since all the construction work comprising some concrete demolition, pouring of new concrete and installation of the stoplog system was clearly visible, we called for lump sum bids from contractors. The low bid was well below our estimate, and was accepted.

View of access to hydraulic jack just below deck.

Drawing showing quick release mechanism



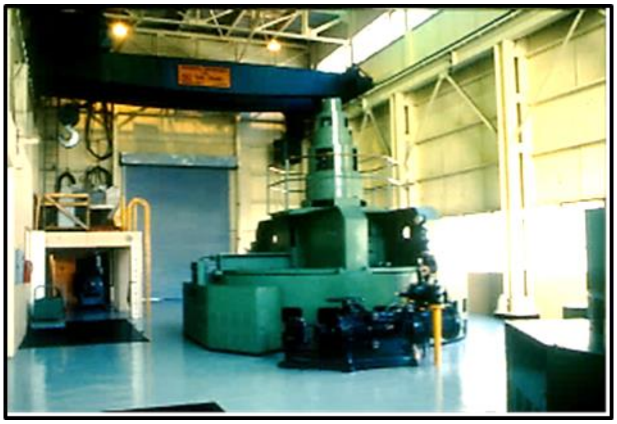
When the contract was signed, we gave the contractor a full set of “Approved for construction” drawings, and told him to commence work. He was flabbergasted by this, and we could see his discomfiture. He then informed us that he knew his bid was low, and had relied on drawing changes for profits, a common scenario used by contractors to produce a profit from an underbid project. There were no drawing changes, and the work was completed on schedule by an unhappy contractor!

No explosives were allowed for concrete demolition, since traffic across the bridge had to be maintained. Instead, the contractor used a hoe-ram to break out the concrete along with expanding chemical wedging. The concrete proved to be much harder than expected, with crushing strengths in the region of 45 to 50MPa.

It proved to be an interesting assignment, and resulted in the development of a quick-release facility for stoplogs, which is now used by many utilities. By 2010, the stoplogs had been successfully released several times.

One modification that was made by the IOC, was to connect the lower end of the column to the steel stop with a heavy chain, so as not to lose the column. The wood stoplogs were always lost in the flood waters.

Peter Payne called again in 1983, and I returned, this time to look at the two St. Marguerite turbines. One turbine casing was dewatered, and I had a good look at the Francis runner. It had some cavitation on the underside of one bucket, and by stretching my hand further into the runner, I could feel a wavy shape on the bucket, where sand in the mold had been displaced. The cavitation was immediately downstream. The runner was too small to repair, so the only course was to continue using the runner until the cavitation became more severe, requiring a new runner.



View of vertical axis Francis unit at St. Marguerite.

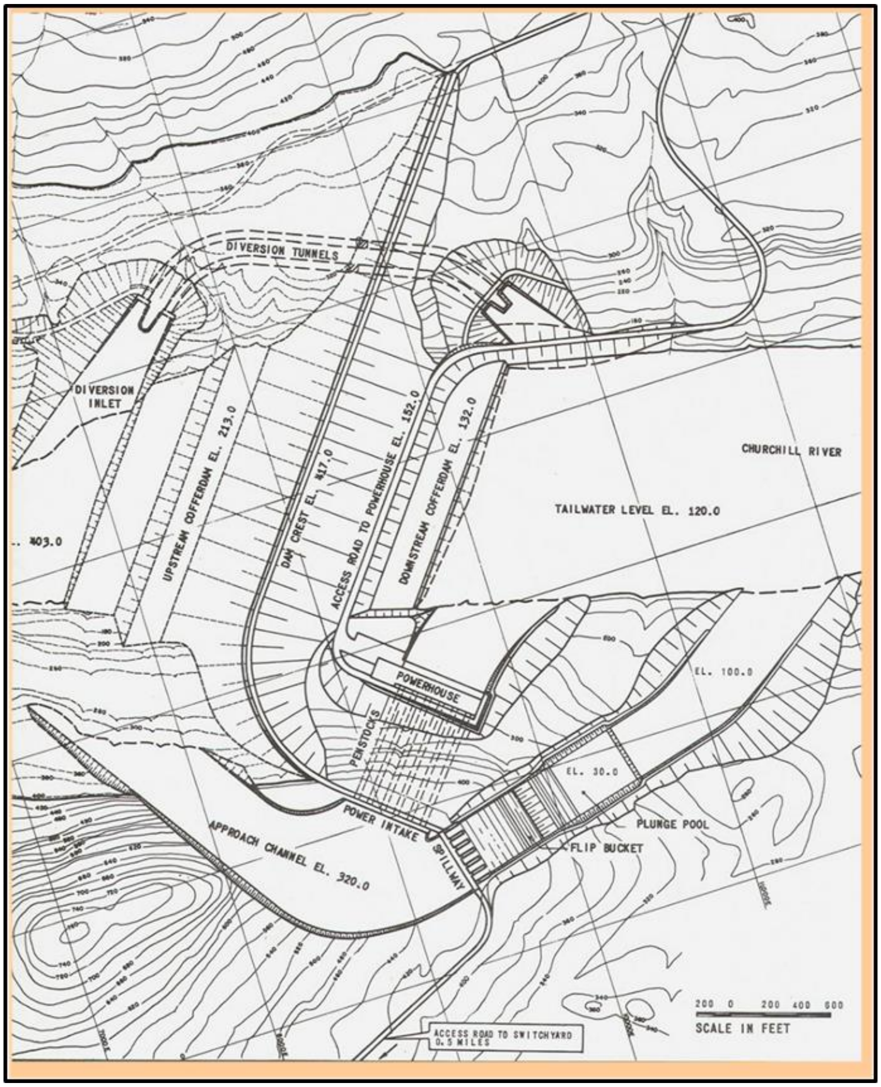
However, the downstream powerplant was being abandoned, and stoplogs were to be removed from the spillway, thus lowering the tailwater at St. Marguerite, resulting in severe cavitation on the runners. I told Peter that this could be countered by building a submerged rock weir across the tailrace channel, and this was done during the next month.

31. GULL ISLAND 1974-5

In 1974, we were asked by Newfoundland Hydro to form a consortium with two of our rival consultants Shawinigan Engineering and Acres International Ltd. to provide consulting services for the 1,800MW Gull Island project on the Churchill River, near Goose Bay, Labrador. The project was being developed by the British Newfoundland Corporation (BRINCO). It was by far the largest hydro project any of us had worked on, except for Acres, who had designed Churchill Falls, so it was a difficult assignment. A well-appointed office was set up in the Westmount Square Building, about 3km from our office in the Bonaventure Building. An organization chart was developed, and the positions were assigned equally among the three consulting companies. I was given the position of engineering manager, at the same level as Stan Peppler from Shawinigan, the construction manager, and Dick Stuchbury from Acres, the project services manager. It was a disaster from the beginning, due to a combination of circumstances.

The rival consulting companies would not assign their best engineers full time to the project, instead they provided less experienced engineers with instructions to consult their chief engineers back in head office on any difficulties. I could only work there half time, at the Gull office in the morning, and travel back by taxi to the Montreal Engineering office in the afternoon, or vice-versa. Perhaps the best illustration of the mess was a meeting called to start writing the turbine specification. Normally, this should take about three engineers some 10 days to complete, with most of the time spent waiting for the specification to be typed, corrected and finally approved. The actual words were cobbled together by cutting and pasting from previous specifications. At the Gull meeting, I entered the room last, as the meeting chairman, only to find about 22 engineers gathered expectantly around a large table. I asked who they all were, and found that about half were the chief engineers and assistants from the parent companies, called in to help their more junior engineers assigned to the project. I immediately cancelled the meeting and told all the engineers from the head offices to go home. Of course, this caused an uproar, but I insisted that the specification would be developed by the Gull staff, and forwarded after completion to the parent companies for comments. I suspect that our engineering man-hours were about 40% above the normal expected for such work, due to the added references back to the consultant's head office.

The other complicating circumstance was our client. The only market for the large amount of energy to be produced by the project was Hydro Quebec (HQ), and Newfoundland Hydro (NH) would not enter into any discussions with HQ, due to the perceived unfairness of their previous contract with HQ for the Churchill Falls energy. The Churchill Falls contract was signed in 1964, at the time when electricity costs had been reducing everywhere in North America down to below 2 mills per kilowatt hour. The Canadian Electricity Association published annual statistics on electricity cost, and their charts showed a continual reduction since about 1920.



Gull project plan as of 1976.

Also, nuclear energy was being developed, and the cost was projected to be so low, that it would not be economic to install light switches, just leave the lights on all the time! The Churchill contract had been signed unfortunately without an escalation clause, and with a fixed rate for the energy for the first 30 years, and a slightly lower rate for the following 30. Now, HQ is purchasing the Churchill energy and selling it at a price more than 10 times the cost, so no wonder NH thinks they have been swindled. With no client for the energy from Gull, there would be no development, a major problem for NH, and one that they would not address.

Drill rig on river at dam centerline.

Unloading equipment at Goose Bay.

The president for NH did not help either. Mr. Reginald Groom was an accountant with no previous experience in hydro development, brought over from England by BRINCO. Every month, we would have a two-day progress meeting with senior staff from NH at our Gull office in Montreal. The meetings followed a regular format, wherein I would discuss the engineering work, Stan would cover the site investigations, mainly foundation drilling and searching for materials for the large dam, and Dick would discuss progress on developing the specifications and contractual conditions.

View of site. Drill rig in middle of river.

Allan Graves and Bill Thompson on drill rig.

We would then have a working lunch, with sandwiches brought in. On the third or fourth meeting, Reginald came over to me during the morning coffee break, and asked if we could have a quiet discussion over lunch, and I readily agreed. After a few pleasantries, he said he wanted to ask me a technical question; it was "what is the difference between a kilowatt and a kilowatt-hour?" Right then I realized that the project was going nowhere!

However, I did not know what to do about it, since the project momentum seemed to be such that Gull could not be stopped. About a month later, I decided to speak to Wally Read, the Vice-President of operations at NH. I had known Wally for many years, so felt that I could confide in him.

Survey camp at site.

During a private discussion of Gull, I diverted the conversation by asking him "what is your plan B?" Of course, he did not know what I was referring to, so I told him that nothing would come of Gull, and wanted to know if there was an alternative. Wally insisted that Gull was going ahead, and there was no "plan B". However, I said to assume that Gull work was stopped, what would NH do about future energy supply on the Island. Wally then said that they had not considered this scenario, and what would I suggest. I told him to concentrate on developing all the remaining hydro sites in Newfoundland. About 15 years later I met Wally at the Canadian Electricity Association annual convention, and he pulled me over, saying "let's go and have a drink, I owe you one". I asked him why, and he replied that he was following my advice on hydro development on the island, and just wanted to thank me – I had forgotten all about it.

I inspected the site in September of 1974 with Bill Thompson, our geotechnical department head. I had hired him only a few months previously, and did not know him well. So after dinner, I walked over to his room at the camp with a 25oz. bottle of Johnnie Walker, knocked on his door, and asked if he would like a drink.

We managed to finish the bottle by about 11.00pm, and we were both still reasonably sober. Bill left after a few years to teach geotechnical work at Ottawa University. When he was leaving, he came into my office and after some talk on his work, he asked if I remembered our evening at Gull. I assured him I did, and then he said "were you trying to get me drunk", and I told him that was exactly my intention. He didn't smile, and I never did get to know him well.

Bridge construction on road to site.

At Gull, the momentum increased, with construction camp trailers from Churchill Falls being hauled down to the damsite, and upgrading of the roads from Churchill and Goose to the site. Gull work continued for just over 2 years, and was eventually stopped in 1976 when NH at last realized that there was no client for the energy. HQ would compare the cost of the Gull energy with the alternative of energy from Quebec-based hydro developments. Although Gull energy was relatively inexpensive, it could not compete against Quebec energy from the James Bay area hydro plants, when the moneys returned to the Quebec government in the form of Quebec workers income taxes and Quebec-based manufacturing taxes were subtracted from the James Bay hydro cost. NH has continued working intermittently on the project for the past 35 years, and now a new NH president has started the work again, with a major effort to review costs and energy client alternatives. However, it is unlikely that Gull will be developed until the HQ cost of new hydro, less Quebec taxes, is higher than the Gull energy cost.

Fuelling the Huey helicopter.

One constraint on Gull development is the foundation condition in the river, which has a deep gravel-filled canyon similar to that at Bighorn. When I was working on Gull, we could never agree on the dam design, with Montreal Engineering staff favoring a concrete cut-off wall as at Bighorn, and Acres favoring a full foundation excavation as at their recently completed Lower Notch dam in Ontario. The Gull report, issued in 1976, did not arrive at a firm recommendation for the dam design, instead suggested further foundation investigation work.

The current consultants, SNC-Lavalin have discovered that there is insufficient clay at the site for the impervious core in a dam, hence are favoring first grouting the foundation in the area of the foundation cut-off wall, then building a plastic concrete wall through the grout, similar to that at Peribonka, topped with a concrete-faced rock fill dam – a difficult and very expensive design, adding to cost and further unfavorable comparisons with HQ hydro costs from new projects on the North Shore of the St. Lawrence River on the Romaine and Mecatina Rivers.

The Gull work has now ceased due to cost and no client for the energy.

But one important lesson we learned from the experience, was to never enter into a consortium of rival engineering consultants – it does not produce an efficient organization or a satisfactory consulting group for the client. Hydro Quebec was aware of the experience, and now distributes all their large hydro work between several consultants, one on the dam, diversion and spillway, another on the power facilities, intake, conduit and powerhouse, and another on the infrastructure - camp, access roads and bridges.

There is another hydro site downstream of Gull at Muskrat Falls. However, the head is lower than at Gull, hence the energy cost is much higher. It is now being built, with major cost over-runs and a schedule delay of over two years, see Chapter 163 for details.

Looking over at drill rig. Bill Thompson and Allan Graves

View of Muskrat Falls site – looking downstream.

Unfortunately, I did not complete the Gull assignment – I suffered a major heart attack in June of the following year due high stress from excessive work, and Bill Matthews took over my position on the project.

32. LAKESHORE GENERAL HOSPITAL 1975

Looking back on May 1975, I was clearly overworked, with two offices, one in the Westmount Building for the Gull Island project, and the other in the Bonaventure Building about 3km away for the rest of our projects. Also, I was on three committees, the Technical Advisory Board for the Engineering Institute of Canada, which met about every 6 months to provide advice on future conventions. Another was the TC4 sub-committee on hydraulic turbines for the International Electrotechnical Commission based in Geneva, where we provided Canadian input to the development of standards on turbine design.

For the third, I was the sub-chairman on the Hydraulic Program Papers committee for the Canadian Electrical Association. This required a fair amount of work since all papers were invited from authors selected for their association or direction of hydro developments currently under construction. We would meet during the annual March convention, where about 12 papers were presented, and again during the September site visit, when about 4 papers would be presented on the project being inspected.

We also produced a report on the work undertaken by hydro consulting engineers during the previous year. Furthermore, on the Gull project, I was under considerable stress, knowing that the project was doomed.

The upshot was that on 6th June, I was rushed by ambulance to the Lakeshore General Hospital with a massive heart attack! I spent a week in intensive care, and another 3 weeks recuperating before being allowed home, where I rested for about 4 months, returned to work part-time , and gradually worked up to full time.

Before – with Howard, May 1975.

The cardiologist, Dr. Marcotte, later told me it was touch and go as to whether I would survive, since blood tests indicated that I had lost 30% of the muscle mass in the left ventricle. Apparently, most heart attack patients can survive a 25% loss, but none survive with a loss of over 35%. In between, there is a grey area, where survival depends on fitness and such factors as obesity and smoking. Fortunately, I was fit and a non-smoker, so I managed to survive.

In hospital, June 1975 – note garbage can.

When recovering in hospital, I would get brown envelopes full of work, fortunately discarded by Vera into the waste paper basket! I was off work until November, and then only worked part-time for some 3 hours, gradually and slowly increasing to full time over about 18 months.

Many years later, I was told by a colleague that when I returned to the office, I looked so terrible, having lost about 20lbs. dropping down to my college weight of 140lbs, that a committee was formed to alleviate my work load. Any engineer with a question for me had to have it reviewed first by the committee, and if they could not provide an answer, only then would the engineer be allowed into my office. It worked very well, and I noted a marked decrease in work.

After, Xmas, 1975 with my brother Ian and families.

When I returned, I resigned from all committee work, and advised the company that I could no longer travel overseas, but was willing to continue travelling in North America, once my energy recovered. Fortunately the company was very understanding and I gradually worked up to my previous hectic pace.

33. MACLAREN 1978-2010

In 1978, we had a call from McLaren Power in Masson, Quebec, where they had discovered that the vertical pipes to a couple of very large surge tanks on the Masson powerplant had corroded severely and needed replacement. However, the value of the power being generated was such that they were very reluctant to take the tanks out of service for the repairs. We looked at several alternatives, such as adding steel bands around the pipes, or installing a slightly larger pipe around the existing pipe, but all were discarded as unsuitable.

View of completed tanks.

The tanks were so large, that McLaren had installed an elevator between the two tanks, to carry the operators up to the top to facilitate inspection of the infra-red and hot air heaters used to keep the water clear of ice in winter – an excellent idea, so we were able to inspect the tanks quite comfortably.

View of concrete liner about 1/3 up the riser.

After some discussion we decided to install a post-tensioned concrete liner around the pipe, after welding steel studs to the pipe to hold the deteriorating steel to the concrete. The whole process worked remarkably well until the very last bit of concrete at the top, just below the bottom of the tank. Here the tank was found to be "breathing", slowly moving as the water level fluctuated within the tank. Any concrete placed there just crumbled due to the movement, and there was a slow leak from a pinhole in the steel pipe which had to be staunched.

This is where Stan Livingstone came to our rescue. He had been employed for most of his life with a chemical company which specialized in additives for concrete, to change its characteristics, to set more quickly, or to become more fluid. We had retained his services as a consultant when he retired. Stan thought that by some modification of the chemicals, he could produce a concrete that would set within minutes instead of hours. He experimented at the plant and eventually found a mix that set in 12 minutes. So we asked for the plant to be shut down for an hour, and Stan went to work mixing and pounding a small ring of concrete into place just under the tank. It worked like a charm, the leak was stopped and the concrete was at full strength by the time the turbine was re-started.

McLaren was a new client, and they were so pleased with our work on the tanks that they called us again in 1987 to look into the low efficiency on a new turbine runner at their High Falls plant, just upstream of Masson. They had tested the old runner before removal, and then tested the new runner using the same procedure, and found that it was less powerful and less efficient than the old runner. I had a good look at the test procedure and concluded that there were a couple of questionable procedures, so the test was repeated with the manufacturer present, and the results were the same as before. I asked the manufacturer for the runner design data and found that it had been based on another runner, but the manufacturer had failed to take into account the different speed of the new runner. This was such a basic mistake, that I found it difficult to accept, since the manufacturer was well-known and competent. Later, I found out that many of the manufacturers senior engineers had retired and the remaining staff was relatively inexperienced.

Array used to measure tailwater level. The instantaneous level for all 9 probes was averaged.

Piezometers and recorder for spiral case pressure.

Part of computers used in efficiency test.

However, the manufacturer would still not accept the test results, so a specialized turbine testing team was called in from Hydro Quebec, and the turbine was tested again using a more accurate and much more expensive procedure which satisfied the codes issued by the International Electrotechnical Commission based in Geneva. There were so many readings to be taken, that I helped record the fluctuating tailwater level along with several others.

Measuring current in busbars.

However, I was surprised at the extent of instrumentation required to undertake the efficiency test, but it helped to explain why it was so expensive, at over $100,000 and why small hydro plants cannot afford such tests.

In 2010, I was asked to join a Review Board to again look at the Masson tank. By this time, the corrosion had proceeded to such an extent, that the riser pipe inside the tank was severely corroded, and needed reinforcing. To add more steel struts to the bottom of the riser, the plant had to be shut down, so McLaren were planning for the event scheduled for some time in 2013. We were taken up to the top of the tanks in the rack-climbing elevator to inspect the interior, at the same time getting a spectacular view of the surrounding countryside. Did not hear anything more, so I assumed the repair was successful.

More computers – current meter measuring station.

Inside tank top. Note small crane and Zodiac boat.

View of top of internal riser.

Rack-climbing elevator at top of tank.

34. GRAND FALLS – 1979

View of 3 old penstocks.

The Grand Falls powerplant in Newfoundland started operating with 4 turbine units in 1908. It had two long penstocks down to the powerhouse. They were built too close to the hydraulic gradient, so that pressure in the pipes was not sufficient to keep them round, and they sagged. The problem was so serious, that the pipes "breathed" with the top slowly rising and falling by about 6 inches every minute. Each penstock supplied two Francis turbines, each equipped with pressure relief valves.

Over the years, the powerhouse was extended, first with another 2 generating sets on another penstock, and later about 1948, with another vertical axis Francis turbine on a new penstock. The extensions had surge tanks to relieve pressure surges, but at full flow, the water level in the tanks was just above the bottom.

By 1950, fatigue cracks began to appear on the two oldest penstocks at the horizontal diameter, requiring patching plates to stop the leakage. At some locations, the movement was severe enough to crack off the tops of the unreinforced concrete saddles supporting the pipes.

View of cracked concrete saddle.

View looking down to surge tanks.

The engineering manager for the facility was Bert Budgell, whom I had met at several CEA meetings. He asked me if I could come down and look over the problem, to see if there was a solution. I flew to Gander, drove to Windsor, and stayed at their guest house, a luxuriously furnished abode dating from about 1910, and maintained in excellent condition. There I had dinner with Bert, and he outlined the problem. The powerhouse extensions had resulted in very uneven flows in the four penstocks, and he thought that by connecting two that had the highest and lowest velocity, the breathing could be decreased.

I found that this was possible where the two pipes were close together just upstream of the surge tanks. With this in mind, I reasoned that joining two pipes with a smaller pipe all encased in concrete, with no provision for expansion would be possible. This was done the next year, and the cracking rate decreased, but was not eliminated.

Penstock cross-over at surge tanks. Note bellows expansion joint.

I then had a look around the plant, and noted a large rusty steel structure which looked abandoned and dangerous. I asked Bert if it was to be demolished, but he answered that quotes from local contractors were ridiculously high. I mentioned a Montreal contractor that specialized in demolition work, and they managed to remove the structure for a much lower cost.

View of patched penstock at saddles.

Now, the old penstocks have been demolished and replaced with a canal. The 3 original units have been replaced with modern turbines, as described in Chapter 74.

35. ALMONTE 1981-2010

In 1981, hydro consulting work was very scarce, so the company decided to work on design-build projects in partnership with a contractor, but we were never successful, probably just as well, since most design-build hydro projects either cost more than expected, or are built to lower standards to cut costs. Our standards were just too high, and hence costs were above those for other bidders. We worked on a feasibility study for adding a couple of new units to a very old powerplant in the town of Almonte, just west of Ottawa. The project appeared to be economic, so bids were called for a design-build contract, and we submitted one, but it was far too high, about 25% above the low bid. The successful bidder was a small Ontario consultant in partnership with a new turbine manufacturer. I was leery of the success of the bid, so my parting words to Brian Gallagher, the Almonte operations manager was to give me a call if he ever needed any help, and perhaps something could be worked out. I had got to know him very well from our feasibility work.

View looking upstream, powerhouse on left.

About two years later, Brian called and said "Jim, say it", which I did not understand, so he repeated the request, and I caught on, so I said "I told you so". After that we worked together until the powerplant was commissioned, providing advice to the owner, consultant and contractor. But it was a difficult task, made more so by the turbine contractor's owner arriving at the site one day in a large brand new Mercedes 500, when he should have been driving a Chevrolet! His new turbine company only had one contract, so it looked as if all the progress payments were spent on the car – not a good impression to make before his only client. To add insult to injury, he opened the trunk and handed out truckers caps with the name of his company "Turbex" on them. They went bankrupt after nearly completing the work, with their bonding company having to take over during the last few months.

Working on the powerhouse.

The powerhouse interior was gutted, and the exterior reinforced with a layer of concrete.

When it came to starting the turbines, I found that the governor was controlled by a computer, and the software for the computer was faulty. The software engineer, Larry Polanski, based in the USA would not come to the site until he had been fully paid for previous work, and had a retainer deposited in his account to cover the site work. It took two years to resolve the issue with the bonding company, and during that time, the units were operated manually.

Powerhouse and waterfalls.

Powerhouse interior.

It was an early lesson on the difficulties associated with design-build work, now so prevalent in the industry. Fixed price hydro contracts are a significant restraint on the quality of work, and invariably result in lower standards, but are preferred by investors since the cost of the project is defined before work starts.

View of falls in winter

Our first work in the project started in 1981, and the new units were commissioned 9 years later in March of 1990; a very long time from feasibility study to energy for such a small plant.

Larry Polanski on left, commissioning the 2 units.

New powerhouse interior – quite crowded.

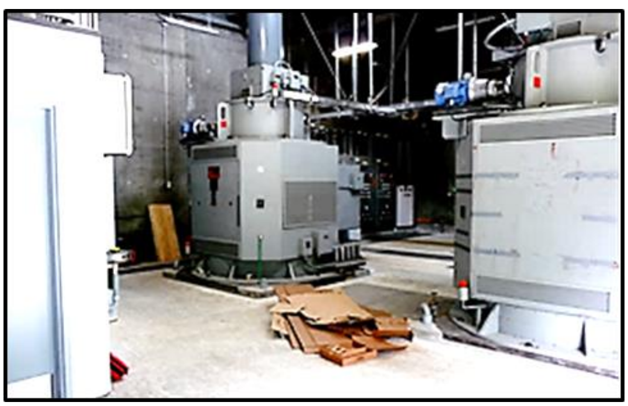
About 25 years later, the powerhouse was converted to an intake and a new powerhouse was built further downstream, where the higher head more than doubled the capacity. I had nothing to do with the new work, but visited the site several times, just to see how the work was progressing, since it was close to Howard's home in Kanata, west of Ottawa.

View of flooded site – April 2009

The penstock to the powerplant was buried below the river and out of sight, a brilliant idea since the site was in a park. It has a large manhole where a surge tank could be added if necessary.

On my last visit, I arrived when the plant operator was inspecting the powerhouse, so had the opportunity to look inside.

Completed powerhouse – June 2010.



Above - Powerhouse interior - Generator floor.

New powerhouse interior - Turbine floor.

36. CAT ARM 1982-6

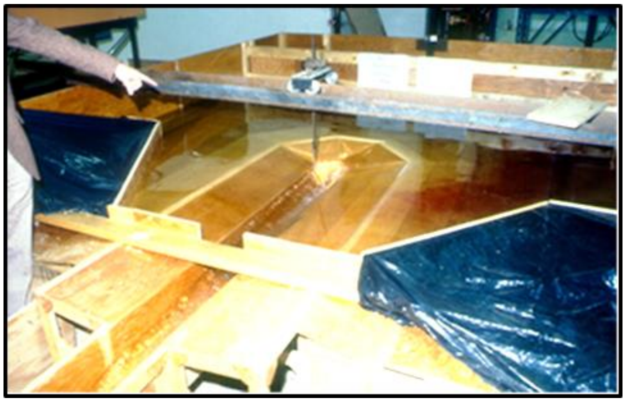
The Cat Arm development is located on the east coast of the Northern Peninsula in Newfoundland. The project was a miniature version of Churchill Falls, with 9 side dams scattered around the countryside.

Construction camp.

A feasibility study had been undertaken a few years previously which recommended a development with two high head Francis units and a three-gated spillway. However, when I had a look at the project with Phil Helwig, the Shawmont project engineer, we thought that there were some attractive alternatives which had not been analyzed in the report.

At a head of almost 400m, it was possible to install impulse units, and they could be operated without a surge tank, allowing a constant slope in the tunnel from the intake to powerhouse, instead of a more classical high-level tunnel, vertical bore and low level tunnel layout, at a considerable cost saving. The spillway was far from the powerhouse, requiring an expensive transmission line to power the gate hoists. With rock exposed everywhere and with many small side dams, Phil thought that a weir spillway was an alternative, and we eventually selected an area adjacent to the main dam as a perfect location for the weir. Phil produced a design which folded the weir around a deep central excavation and called the structure a “bathtub spillway”, and apt name. It was modeled by Memorial University engineering students as a final year class project.

All the rock excavated from the cut in the middle of the spillway was used in the main dam, again at a major cost saving.



Bathtub spillway model at Memorial University.

It took some time to convince our client, Newfoundland Hydro (NH) that the changes were for the better, particularly since they were not familiar with impulse units. However, they accepted our recommendations, and years later we were thanked for suggesting impulse turbines since they found that with the flat high efficiency curve in an impulse unit, the turbines could be used as load-followers without loss of efficiency

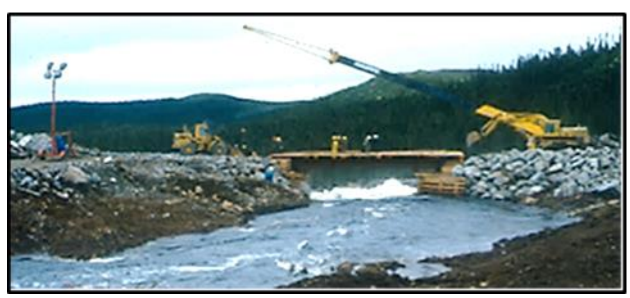
Diversion tunnel intake.

I asked Charles Szoo, one of our senior and very experienced hydro project engineers to head up the civil design team, and he readily accepted, provided we agreed to send all his files with him. I agreed, only to find that his "files" consisted of 17 banker's boxes filled with a copy of every drawing he had worked on since joining the company in 1957! This was his last assignment before retiring, and Shawmont, the consultant on the project, asked to keep the files when he left in 1985

Adit to main tunnel.

Construction started in 1983 at a time when there was high inflation in Canada, and costs rapidly escalated far beyond the initial estimate, and there was even a risk that the project could be cancelled.

The first task was to build a 30km long access road along the steep rocky shore to the powerhouse site, and the contractor soon became bogged down with deep rock excavations, with the projected cost escalating to well over twice the estimate, very worrisome for NH, since this was the first contract on the project.



Building bridge in a hurry.

We decided to send Austin Knowlton out to assist the contractor, and his first words on arriving at the site were "I am the ultimate weapon in

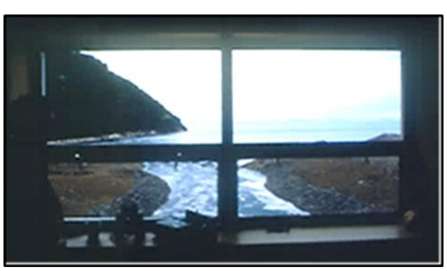
Montreal Engineering's arsenal – so here I am, and you have been warned!" He toured the work by helicopter and soon found a better route for the road, getting the contractor back on schedule.

Low-body mining ore truck in main tunnel.

Powerhouse in early stage of construction.

All the engineering design was being done out of an office in St. John's, so I had to spend many weeks there at the beginning (about 2 weeks per month) to help with the powerhouse design and to ensure that drawings were being issued in time. None of the engineers had worked on an impulse unit powerhouse, so most of my time was spent arranging the equipment layout within the powerhouse.

View from operator's desk in control room.



Dave Besaw, Richard Humphries and Charles Szoo at penstock bifurcation.

The powerhouse was located in a beautiful cove, with a view out over the Atlantic Ocean where there was an occasional spectacular sunrise. So I insisted on placing a window just above the operator's desk in the control room, with a view of the Atlantic. When I inspected the powerhouse in 2004, I mentioned the window to the operator at the desk, and he stood up and thanked me – he certainly enjoyed the view.

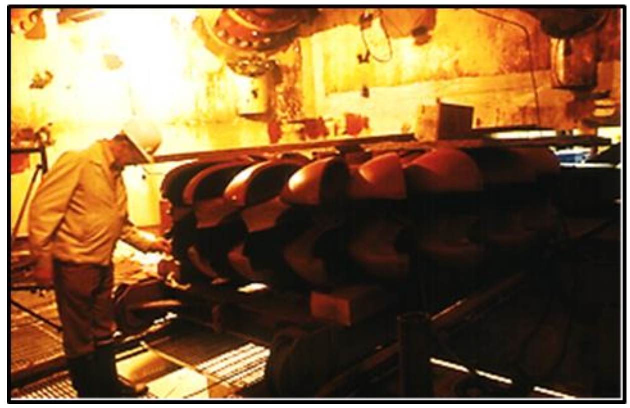
I would occasionally visit the site, and when I arrived just after the dam cofferdam was closed, Austin mentioned that the contractor was working feverishly to complete the deck on a timber bridge to an island where his equipment had been parked. The water was rising rapidly, so I grabbed a hammer and started to pound some nails into the beams, securing the deck timbers. Austin put his hand on my shoulder, and asked me to look around. All the workers had dropped their tools, and were looking at me! I asked him why the stoppage, and he told me to put down the hammer, and work re-started – my mistake, no carpenter union card! But I did make one other mistake. Sulzer Inc., the turbine manufacturer, had developed a close-coupled design for the turbine and generator which substantially reduced the powerhouse height, and after perusing their drawings, I accepted the layout. What I forgot to check, was access to the turbine bearing – it was down through a manhole just inside the generator casing, so access was only possible when the turbine was not operating. To compound the problem, Sulzer had provided only one seal on the turbine bearing, whereas we had specified two. This was questioned prior to contract award, but Sulzer provided a precedent for the design, at a powerplant in South America, and it was accepted.

The units were commissioned, and all appeared well. They were monitored by two operators, Bert and Joe, and only operated in daytime to meet the higher peak loads at that time, but every morning when Bert entered the control room, he found a yellow warning light on, indicating low oil in the turbine bearing. So he crawled down through the manhole and added about 3 liters to the bearing oil well.

Powerhouse piping gallery during installation work.

View of completed intake.

This happened every day, and Bert could not find where the leak was, despite looking very carefully for oil stains around the bearing. A week later, after Bert had added the oil, he went to the control room before the units were started, to see Joe gazing out the window at the rising sun, so he looked out and saw an oil sheen on the tailrace canal reflecting in the sunlight, and exclaimed "so that's where it's going"; a bit embarrassing, since there were beluga whales swimming by offshore. They called me later to explain what happened, and after some reluctance, Sulzer added a second seal to the bearing and the leakage stopped.



Charles inspecting runner in pit below generator.

Formwork for concrete plug in diversion tunnel.

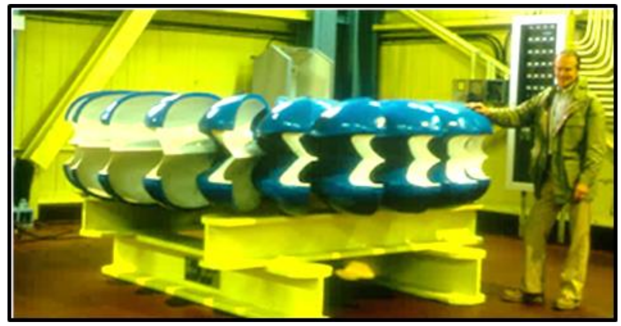
But what about the precedent? It was at a powerplant in Peru, so I obtained the powerhouse phone number from Sulzer and called the operator. I spoke in Spanish, and after some preliminary discussion, I asked him how the turbine bearings were working, and he replied "muy bueno, solo usan un barril de aceite por semana!" – very well, they only use a barrel of oil each week – lesson learned – always check references! Apparently they thought that oil use was normal, and had never questioned Sulzer about the loss.

View of runner nozzles and jet deflectors.

Bathtub spillway excavation.

With a head of almost 400 meters, the Cat plant was an ideal candidate for the addition of a third peaking unit, and I eventually persuaded NH to ask Shawmont to prepare a feasibility report, pointing out that the access tunnel to the lower end of the water tunnel adjacent to the powerhouse had been located in a position such that it could be used as the penstock for a third unit, after lining it with steel.

Finished powerhouse on a typical foggy day.



With spare runner – one of last by Fischer Castings.

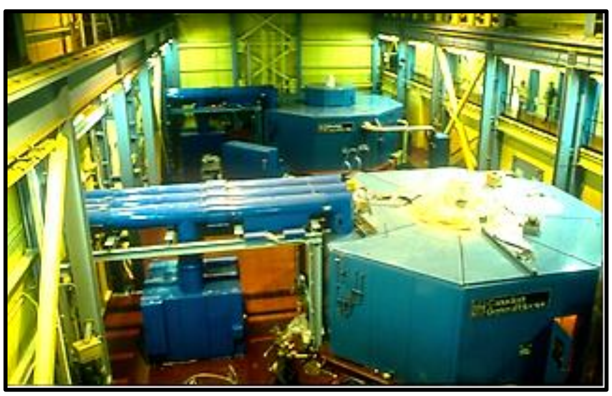
Placing fill near top of dam – a crowded area.

Mass concrete re-shaping rock for core contact.

Hence the cost of the addition was likely to be very reasonable. NH agreed, and a report was duly issued. Years later, when their next hydro project at Granite Canal was being optimized, the incremental energy cost provided by NH appeared to be excessive. So I asked NH where the cost had been derived, and they replied from their proposed next development at Round Pond – a low head, high-cost powerplant. I pointed out that the incremental cost should come from the third unit at Cat Arm, and I found that their staff was totally unaware of this alternative. Apparently the Cat Arm #3 report had been filed and forgotten! With the lower incremental energy cost derived from Cat Arm, the Granite optimization appeared much more reasonable.

Completed bathtub spillway.

Concrete core wall in a small side dam.



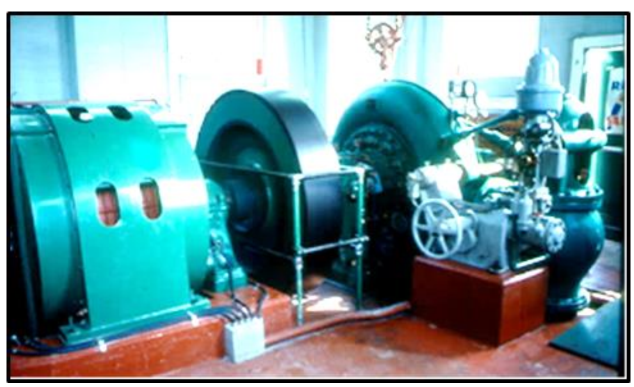
Completed powerhouse – gen. floor.

Piping gallery.

SF6 switchgear – an indoor substation.

37. TOPSAIL 1982-4

In 1982 we were providing help to Newfoundland Light and Power (NLP) on adding capacity to the Topsail powerhouse. The previous year NLP had installed a larger penstock pipe after determining that the volume of water spilled annually could justify a larger turbine. The Gilbert, Gilkes and Gordon turbine, generator and inlet pipe plus relief valves from Scotland, and the Woodward governor were easily sold, despite being 60 years old. We issued a specification for new equipment, and after my experience at Maggotty, I decided that all the hydraulic analysis was to be undertaken by the equipment manufacturer.

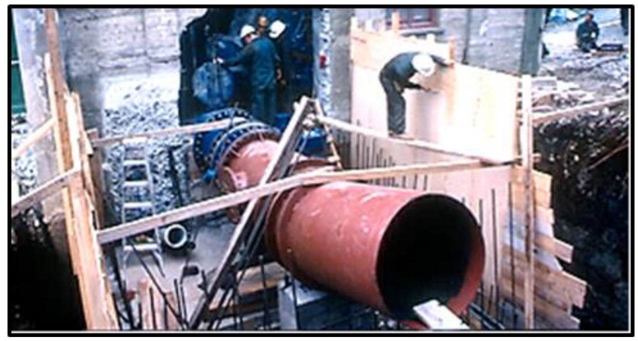


The old unit – note excellent quality, massive flywheel and condition.

I briefed Bob, the Topsail project engineer on the Maggotty troubles, and warned him to keep an eye on the hydraulic analysis. The low bidder was Barber, a small turbine manufacturer with no known hydraulic analysis capability, but they had manufactured relief valves. They proposed using a computer program called SURNAL to integrate the valve with the turbine. I was aware that the analysis could now be undertaken on computers in a few minutes, compared with the months required in a manual calculation, so was relieved to hear of this development. All went well, and Bob showed me the computer print-out of the waterhammer wave, with transient pressures well within the design parameters.

Excavating foundation in powerhouse for larger unit.

About a year later, I was surprised to get a phone call from a very angry John Evans, the operations manager for NLP, informing me that the penstock pipe to the turbine had just collapsed when the new turbine was undergoing commissioning tests, and to come down to the plant immediately. I flew out to St. John's, and was driven to Topsail the next day. There I found that the wood stave penstock had collapsed on the first test, so I inspected the unit, and noted that all controls were electronic, using programmable logic controllers, a major change from my previous experience with the mechanical governor at Maggoty. Nevertheless, there had to be a servomotor and pressure tank with valves to move the wicket gates and relief valve, and here I was in familiar territory. A detailed inspection of the controls revealed that there was no position sensor on the relief valve, nor any means of limiting the extent of relief valve opening on load rejection at small turbine gate openings. Something was seriously wrong! The relief valve had fully opened on a load rejection from only 20% load, and the penstock had collapsed from negative pressures induced by the sudden increase in flow.



Installing new pipe to turbine.

Waterhammer was to be limited to +/- 25%, but with the SURNAL computer program, Barber advised that more precise control of waterhammer could be attained, and would be within +/- 15%. Calculations of waterhammer at other flows all showed on a graphical trace of pressure versus time, that waterhammer was indeed within the range claimed by the manufacturer. When I looked at the output for full load rejection I noted that the relief valve discharge was about 80% of the turbine flow, the expected valve size based on the waterhammer criteria. After the accident, discussions with the Barber revealed that the hydraulics of the relief valve had been subcontracted to a graduate in mathematics who had written the SURNAL program. I obtained a copy of the computer program and input-output. I perused it in detail, and could not find any instructions in the program for valve or turbine characteristics. A meeting with the program developer was arranged in Toronto.

Completing repairs on the wood stave pipe.

The new unit.

At the meeting the programmer sat down at the computer, entered the data, and produced the waterhammer-time profile for a full load rejection. I asked for the exercise to be repeated with a 50% load rejection. The graphical output was identical in shape to the previous calculation! And I knew from Maggotty, that this was a physical impossibility, since the flow characteristics of turbine and valve were different. I then asked the programmer how the relief valve knew that with a 50% load rejection, the valve should only open about half-way, a question which puzzled the programmer.

Further discussion elicited the response "Oh, with a half load you must use a half sized relief valve!" - end of discussion and problem solved. The programmer, with a degree in mathematics, had no concept of the engineering involved, and Barber was not aware of this, hence the lack of a valve position sensor and a means of limiting relief valve opening.

Tailrace flow from new unit.

Topsail powerhouse with old unit flow.

The repair was expensive and included a positioner to physically limit relief valve opening based on the extent of wicket gate opening at start of load rejection, all at Barber's cost. Commissioning was delayed by several months. As for the collapsed wood stave penstock, it was repaired with the original staves and some spares at minimal cost. Further investigation revealed that when Barber had shopped around for a computer program, they purchased the least expensive program, without determining whether the program was correct and had been used with success on other projects.

Also Barber had no senior engineers within the organization who could have spotted the defects on the equipment drawings, namely the lack of a position sensor on the relief valve, and the lack of a limit on opening at part load rejection. Barber's previous experience with relief valves was found to be many years in the past, and none of the present staff had the relevant experience. The cost to Barber was so high that the company declared bankruptcy and ceased to operate the next year. It was a very expensive lesson with untested computer programs, and unfortunate for Barber, since they were very good at producing small hydro turbines, and at that time, they were the only local source of such equipment in Canada.

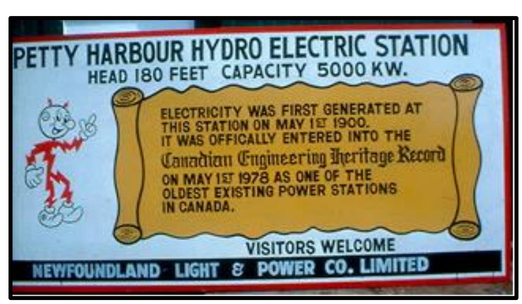
Relief valve controller. A complex combination of slider, pipes, valves, solenoids and pistons.

I asked the programmer for a list of the companies that had purchased the program, and he provided a tabulation of 12 companies with addresses and contacts. I knew a few of the names, so I sent a telex warning them of the program deficiencies. They replied that they had doubts about the program, and had not used it on any detailed design work, but one had used it on feasibility studies.

38. AVALON PENINSULA HYDRO 1983-6

Newfoundland Light and Power (NLP) has developed a series of small hydro plants on the Avalon Peninsula, south of St. John's. The first was Petty Harbor which commenced operation in 1900 to provide power for trams and lighting St. John's. It burnt down in 1926, and was re-built with larger units on a new route for the penstock. Some of the units were upgraded again between 1983 and 1986 with a new runner, valve, governor and a generator. NLP is meticulous in plant maintenance and cleanliness, a policy which has helped to keeping the units working.

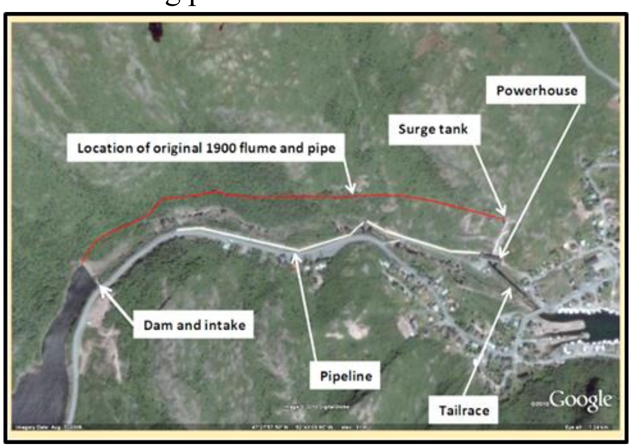
Map of Avalon Peninsula showing hydro facilities. 1. Topsail. 2. Petty Harbor. 3. Gull Pond dam. 4. Mobile. 5. Tors Cove. 6. Cape Broyle. 7. Horsechops.



Notice board at Petty Harbour powerhouse entrance.

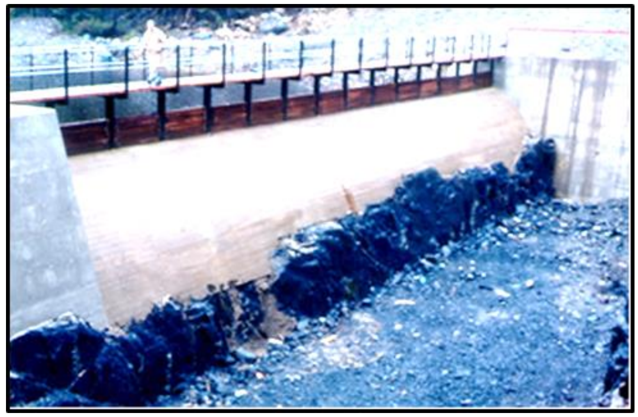
The Petty Harbor dam and intake were also renovated. All the design was by Hydro staff, but we were asked to keep an eye on the work, with an occasional site inspection. One other dam which was renovated, was at Gull Pond, which diverts waters south to Mobile Big Pond, for generation at the Mobile powerhouse. At Gull Pond, there is a small weir with a stoplog spillway.

A few years ago, most of the Petty Harbor wood stave pipe was replaced with a steel pipe painted white. During my 1986 inspection, I also looked at the Tors Cove plant, where the retiring operator was in the process of painting the whole powerhouse interior; since he knew that the plant had just been automated and would be unattended. NLP had an excellent policy of waiting until the local operator was about to retire before adding plant automation.



Petty Harbor layout – Google Earth image.

Renovated dam and intake at Petty Harbor.



Gull Pond dam with stoplog control.

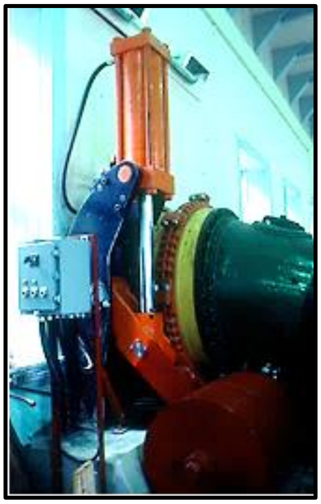
Discharge channel back to river.

Two views of Petty Harbor units 1, 2 and larger 3rd unit. Note excellent condition of equipment and powerhouse.

In 1986, the equipment at Petty Harbor was upgraded. The Francis runner on the larger 3rd unit had severe cavitation erosion, and was replaced, along with the turbine intake valve. The generator and governor on Unit #2 were also replaced. I inspected the sites before work commenced in 1983, and again when most of the work had been completed in 1986. I found that the Hydro staff had done excellent work.

The old surge tank was retained. It is at end of the original flume and pipe which supplied water to the first development in 1900, high up on the hillside above the powerhouse.

Old surge tank.



Inlet valve with servomotor on top, horizontal axis – unusual.

Governor and pressure tank.

New generator and exciter.

Cavitation erosion on old runner.

If properly maintained, hydro plants have an indefinite life.

39. BISHOPS FALLS 1983

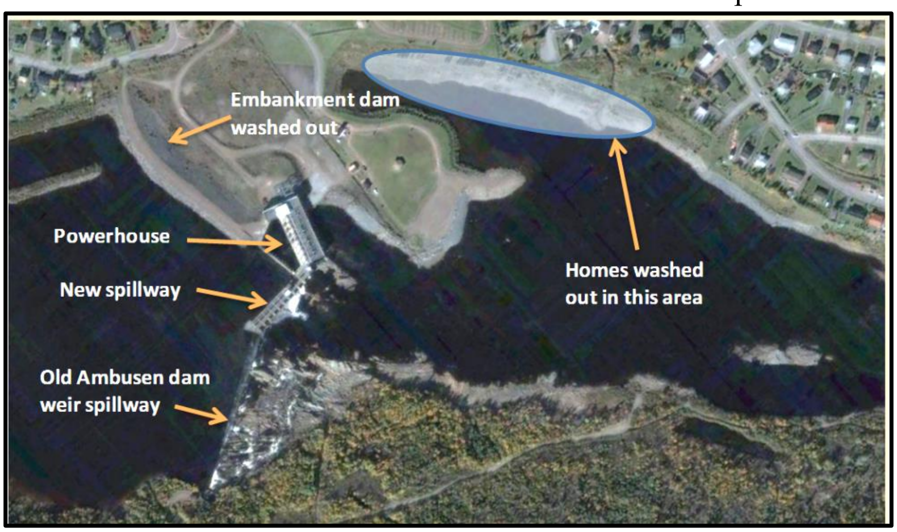
In January of 1983, there was a severe flood on the Exploits River in Newfoundland. It washed out the embankment dam at the Bishops Falls powerplant, flooded over the powerhouse roof and caused extensive damage downstream. Later analysis indicated that the magnitude of the flood corresponded to a return frequency of about 1 in 5,000 years – certainly an enormous flow.

View of washed out wood room and no dam.

Downstream view – washed out wood room.

Upstream view – Ambursen dam on right.

The Trans-Canada highway crossed the river downstream of the plant, and we were asked by the Newfoundland Department of Highways to inspect the bridge for damage. I flew down the next day, met two engineers from our St. John's office and we drove over to the bridge. Fortunately, there was no damage, it had not been moved off the bearings despite considerable pressure from the flood waters, and the erosion around the abutments could be easily repaired.



Google view of Bishops Falls development.

With some spare time on our hands, I called Bert Budgell the operating engineer for the Bishops plant, whom I had known for several years, and asked if we could have a look at the damages. He readily consented, and told us to meet him at the right abutment.

Unfortunately, there was no prospect for work on the repairs, since Acres had some engineers in the area, working on another hydro facility, and they had done some successful "ambulance chasing" by driving to the plant on the day of the flood, to provide advice to Bert on safety measures and recommendations on evacuating several homes adjacent to the river bank.

Home at edge of cliff.

Bert conducted the tour of the plant. Dusk was approaching, so my photos are subdued with little contrast, and it was too late to photograph inside the powerhouse. We had to walk across the top of the Ambursen Dam weir spillway to the powerhouse.

The powerhouse was a sorry sight; it had been completely overtopped by the flood, with water pouring across the roof. The flood had deposited gravel on the downstream side to the height of some windows, and this is where we gained access to the interior.

Inside, everything was covered in mud, and gravel had poured through the windows, to cover the floor to a depth of over a meter. It was not possible to descend to the lower floor, since all the stairways were blocked with sand and silt. Bert told us that when the plant was built in 1928, it was part of the Bowaters wood pulp facility, and that most of the turbines had been connected to grinders. In 1930, a large flood almost washed out the dam, but in this case all the workers turned out to fill sandbags and placed them on the dam, and prevented an overtopping.

In this flood, all the turbines were connected to generators, all on automatic remote control. There was only one operator in the plant, and when the magnitude of the flood became apparent, he shut down the generators, fully opened all sluice gates, and left the facility. Later, Bert showed us a movie taken by the Canadian Broadcasting Company from a helicopter during the flood. It was almost impossible to see the powerhouse, with the muddy waters completely engulfing the plant – all that could be seen was a riffle where the water flowed over and off the roof.

On crest of weir spillway, walking across to Powerhouse.

Near the left bank, there were the remains of an old wood room, recently used to store some recreation boats. It was completely destroyed.

Lights on at dusk, somebody is still inside!

The earth dam at the left abutment had washed out, and the resulting flood had scoured the left bank for over a kilometer downstream, with several homes on the verge of toppling into the river. A park adjacent to the dam also washed out along with some park buildings. Fortunately, no lives were lost.

View of restored powerplant. New spillway in center.

The repairs were completed some two years later, with about double the spillway capacity. It was a very instructive lesson on the extent of damage which could be caused by large floods.

In 1998, I returned as part of a team assessing the value of the powerplants owned by Abitibi-Price. The Bishops plant had been restored with a new much larger spillway, and the powerhouse was operating, with all units on line. The opportunity was taken to increase the capacity with new runners and re-wound generators.

View of weir from new spillway.

View inside restored powerhouse.

View of intake headpond control structure from new spillway.

40. MORRIS 1983

A series of hydro developments were built by Newfoundland Light and Power (NLP) on the South Shore of the Avalon Peninsula near St. John's. Petty Harbor had been in operation since 1905, but upstream of the dam, there remained about 30 meters of undeveloped head, and in 1983, NLP decided to add a small 1,100kW horizontal axis Francis unit in a new powerhouse.

Intake house – Access Bridge behind.

The design was undertaken by NLP staff, mainly by Peter Halliday, a bright young civil engineer. However, with their lack of design experience, they asked me to look over their drawings. All went well until I was asked to have a look at the construction work, so I flew to St. John's, checked into the Newfoundland hotel, where Peter met me the next day. We drove out to the site, less than an hour from St. Johns and I had a good look over their work.

Morris Powerhouse during construction.

The powerhouse was well advanced, and a 4ft diameter fiberglass penstock was about half installed. However, when I saw the intake, I noted that a seepage collar was missing on the short steel pipe through the intake earth dam out to the fiberglass penstock. The contractor was about to place fill over the pipe, so I suggested to Peter that the work should be halted until a seepage collar was added.

Completed powerhouse.

We then walked down to Peter's office in a small trailer, and a few minutes later I produced a small sketch of a reinforced concrete collar with sufficient dimensions on it so that the contractor could build the required formwork. This was accomplished in a few hours, and the concrete collar was poured the next day.

View from intake, short steel pipe to fiberglass pipe.

Looking over the intake drawings, I noted that I had seen the detailed drawings for the concrete, but the short steel pipe section downstream of the intake, through the earth dam was not included, so I had missed the lack of a seepage collar. It was a fortunate coincidence that I had arrived at the site just in time to see the intake before the steel pipe was buried. The plant was started a few months later, and has been operating without any further problems.

New Barber unit, induction generator.

Turbine inlet valve.

41. GLENMORE DAM 1984-8

In 1984, the City of Calgary asked Monenco to undertake an analysis of dam safety at the Glenmore reservoir, the storage reservoir for the drinking water supply to the City. It proved to be quite a lesson in the diverging priorities of the local residents.

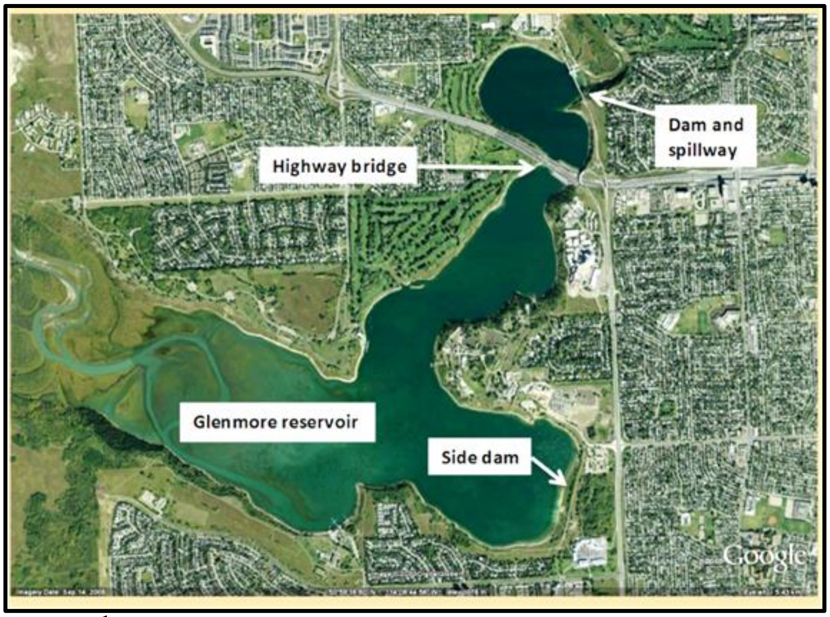
The reservoir is located within the city boundaries, and surrounded by many expensive properties. We found that while the spillway was adequate, the old stoplog operating mechanism was too slow to open the logs in time to pass an extreme flood. Also, there is a highway across the reservoir, and the bridge imposed a considerable hydraulic restriction when passing flood waters.

Glenmore dam before modifications.

Downstream view of spillway. Note stoplogs on crest and difficult operation.

View of road restriction in reservoir.

A previous flood had indicated that the spillway bucket design was deficient, and would probably need enlarging.



Glenmore development layout – Google Earth image.

A hydraulic model was constructed in Calgary, and various modifications to the bucket were modeled and tested. It was eventually decided to re-build the bucket with a much larger stilling basin, and add a few meters to the height of the right abutment downstream training wall.

As for the stoplogs, they were modified to wood gates with cables at each end, up through a pocket in the dam deck where they could be attached to a propane gas-powered gate hoist.

Spillway passing possible maximum flood.

Right abutment training wall overtopped.

The earth fill side dam was increased in height by about 2m, when it was found that the highway road bridge restricted flood flows.

Detail showing new gate guide attached to pier.

However, the local residents downstream of the dam started a lawsuit claiming that their spectacular view of the distant Rocky Mountains had been obscured by the raised dyke, resulting in a considerable loss in property value. Rather than contesting the lawsuit, the City instructed us to remove the offending dyke. An appeal to the resident's community spirit was of no use. We pointed out that a breach at the dyke would cause extensive damage downstream, probably wiping out many homes as the flood waters flowed down to the Bow River, but this argument was not given any consideration.

Detailed view of wood gate guides.

View of dam with new wood gates.

Concreting new spillway stilling basin.

View towards left abutment – new stilling basin. Two pipes are low level outlets.

View of right abutment and raising top of training wall.

Yes, a hard lesson in civics where local interests are valued more than those of the larger community! The work was completed in 1988.

42. THELWOOD PENSTOCK – 1984-5

In May 1984, we had a call from the Tahsis Company, a small paper company operating at Gold River on the North-West of Vancouver Island. They had an 8MW hydro plant and were building another with 10MW capacity. They needed some help with the penstock design, so accompanied by Martin Benham and Frank Vassallo from our Vancouver office, we drove through the Strathcona Provincial Park to Gold River. The penstock would follow a logging road currently under construction to Donner Lake. Fortunately, the outlet of Donner Lake was just outside the park, and the company managed to obtain a license to build a small storage dam there along with the penstock intake.

All the penstock design was undertaken at our Vancouver office, with me keeping an eye on the work. It proved to be a simple assignment, with a buried penstock and only a few concrete anchors at abrupt bends. However, it was a lesson on the way small hydro work was going. Tahsis had placed a water-to-wire contract for all the powerhouse equipment, which left only a small portion of the engineering for the consultant. Another lesson was the construction quality expected for a paper company.

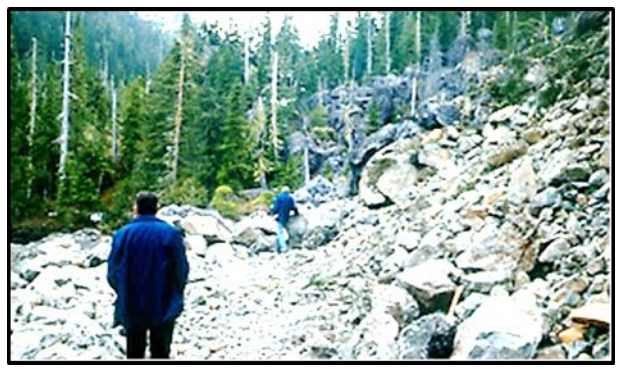
Left – view towards Donner Lake. Right, Donner Lake outlet.

Frank Vassallo inspecting a logging road bridge.

Penstock route on logging road.

Above - on penstock route.

During a preliminary site inspection, we managed to look at the existing small hydro plant, and were astounded to find the surface penstock tied to trees at bends, and piers made of timber cribs! At the new plant, the powerhouse "was on wheels" until a suitable site was found at the last minute, long after all contracts had been awarded. Unfortunately, the paper company closed in 1998 due to a drop in demand for paper.



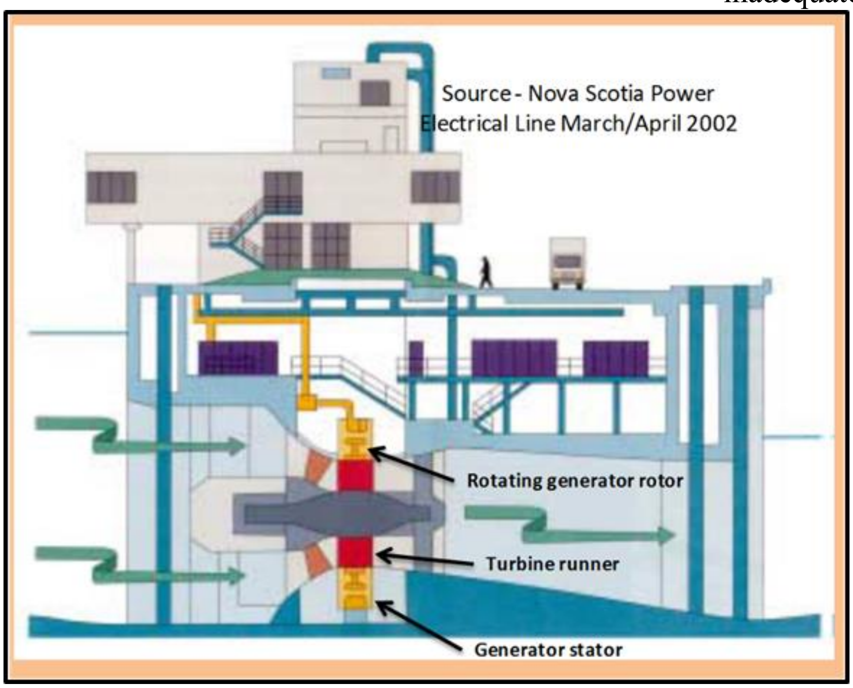
Frank Vassallo and Martin Benham at road's end.

43. ANNAPOLIS – 1984.

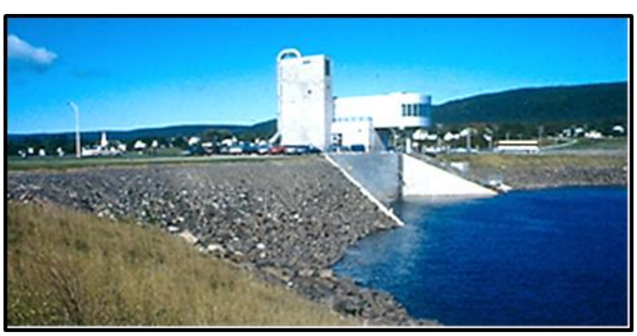
Montreal Engineering being both a consultant and operator of hydro plants, was listed as a "utility" by the Canadian Electricity Association (CEA), an association composed of most utilities, consultants and electric equipment manufacturers in Canada. The annual fee was based on total capacity in kilowatts, and allowed the member company to send a delegation to the annual convention. Our allowance was 6. I attended my first convention in Halifax in 1961 and continued to attend whenever possible. By 1970, the association was well organized with spring meetings for presentation of papers, and fall meetings to visit a hydro plant under construction.

In September of 1984, I was at the 20MW Annapolis Royal tidal power plant, the first tidal plant with a rim generator, where the generator is attached to the outside of the turbine runner, known as a "Straflo" unit for "straight flow". It was built as an experimental prototype with partial funding from the Federal Government.

Looking down at turbine and generator (yellow).



Section through powerplant



View of Annapolis Royal tidal power plant.

When it started, the seals between the stationary parts and the rotating generator proved inadequate and had to be revised. But this was the only problem, and the plant has operated successfully, apart from a minor incident.

Since the head is low and flow is straight through, the rotational speed is slow, and there are no trash racks. One day, about 5 years after the plant started, the operators heard two loud crunching sounds from the turbine, they ran upstairs to the deck, to see three sections of a wood row-boat floating off downstream! They then ran across to the upstream side and were relieved to see two fishermen swimming to the bank just upstream of the log boom. Apparently they had got too close to the powerplant, and fortunately realized that they could not row upstream against the current, so had abandoned the boat and swam to the shore. It certainly gave the operators a fright!

The experimental plant was, built to see what measures were needed to keep operating in salty sea water, and to verify the seal design for a much larger development across the Bay of Fundy, never built due to environment issues.

Right – view of underside of generator and turbine governor. Left – switchgear and compressors.

44. HOOVER DAM – 1984.

Hoover Dam – Google Earth image. 1. Four intake towers. 2. Two side channel spillways. 3. Arizona side powerhouse.

In 1983 I was asked by Charles (Chuck) Sullivan at the Electric Power Research Institute (EPRI), based in San Francisco, California, to join a committee they were forming to provide advice to a small publishing company in Boston, to assist in the expansion of a magazine called Hydro Review. The magazine concentrated on micro-hydro work in the North-East states, and EPRI wanted to enlarge their scope to cover all hydro in the North American continent.

There were about eight engineers on the committee, and I knew most of them from discussions at conferences. Our first meeting was to be at Boulder City in Nevada, so I asked our travel agent to book a flight. She called back about an hour later to advise that there was no Boulder City anywhere in the USA. I called Chuck, and was told that Boulder City was their name for Las Vegas, derived from the name for the construction camp built for the workers on the nearby Hoover Dam during the depression. Chuck did not want any publicity about a meeting in Las Vegas for obvious reasons. It was selected as the most central location for the committee members.

At Las Vegas, I checked into a hotel on the strip along with all the others in January, 1984. We had meetings over two days and devised a strategy for improving circulation of the magazine. It is still going strong, and has spread across the world with another publication HRW for Hydro Review Worldwide.

Gaudy entrance to hotel on strip.

On our second evening in Las Vegas, we all decided to take advantage of the free $10 worth of tokens we had been provided with on checking into the hotel. They could be used on any $0.25 slot machine at any of the casinos. We all walked to one of the larger casinos, and agreed to meet in the bar after about a half hour.

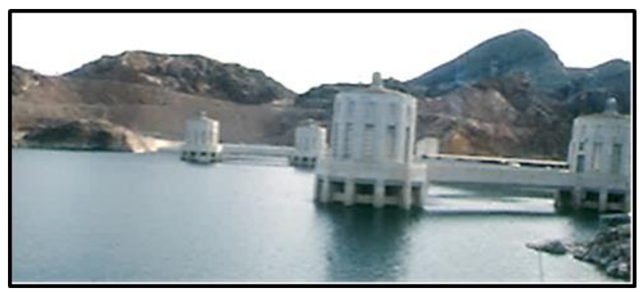
I found a suitable machine, and was standing a few feet back to see how it worked, when a man shuffled up to it carrying a tin pail. He crouched down and looked up through the glass window into the workings, nodded, inserted $0.25, jammed his bucket below the spout where winnings emerged, and pulled the lever. Much to my surprise, the spout discharged somewhere between 50 and 100 quarters, the man smiled, grabbed his bucket, and shuffled on down the line of slot machines, so I followed.

Interior of Arizona powerhouse – generator floor.

Looking down onto the powerplants. Source – Las Vegas website.

He would stop at some machines, and again peer up into the workings, but continued on until he found something in the workings that was acceptable, jammed in his bucket as before, and pulled the lever, this time with no success. He continued, and at the next machine, he was again successful.

I left him to his wanderings, and tried my luck with no success, quickly losing $10, so walked over to the bar to join the others there. I related my story of the shuffling man, and was told that on some of the older slot machines, there is a counter hidden above the window, which counts the number of times the lever has been pulled since the last payout. The higher the number, the more likely the next pull will be successful. Unfortunately, the casino management was aware of the counter, and was replacing the old machines, so very few were left.



Intake towers in Lake Mead.

Hoover Dam turbine floor.

After the two days of meetings, EPRI had arranged for a detailed tour of Hoover dam and powerhouse, which I thoroughly enjoyed. The tour guide, an employee of the US Corps of Engineers started us off with the standard "tourist" tour, walking across the dam crest to descend to the powerhouse in the Arizona elevator and ascend later in the Nevada elevator. However, we explained that we were all hydro engineers and would appreciate a more comprehensive tour. This was quickly arranged, and we were then guided around by the plant manager.

There are two powerhouses, one on each side of the gorge, each with 8 Francis turbine-generators. As we walked around, I noted that many of the generators were operating at only about 60% of capacity, so I asked the plant manager why, since this was very inefficient. It would be far more efficient to operate fewer generators all on their peak efficiency point, at about 85% of capacity. He replied that he was aware of this, but the generators were owned by different utilities, and each operated according to the utility requirements. The two we were standing beside were owned by the city of Los Angeles.

The "gold" room – copper-enclosed switchgear

This was quite a revelation, and I realized that we were far more advanced in Canada when it came to hydro operations. Fortunately, the operating procedure has now changed at Hoover, with the utilities cooperating to improve efficiency.

The tour included a look at the "gold room", a large room containing some switchgear all enclosed in copper cubicles. Apparently, during the depression, copper was selling for $0.03 per pound, and it was less expensive to use ¼ inch copper sheets than thinner steel for the cubicles. With copper now selling at around $4 per pound, the salvage value could probably pay for new switchgear!

Nevada powerhouse exterior.

One of two side channel spillways.

A USA consulting company had been retained by EPRI to direct the expansion of Hydro Review, and Carl Vansant was their project engineer working out of Kansas City. When their work was completed two years later, Carl resigned from the consulting company, bought the magazine and moved their office from Boston to Kansas City. The magazine prospered, added an international edition and took over the operation of WaterPower, a bi-annual hydro convention, for the American Society of Civil Engineers. Carl added another bi-annual conference called HydroVision for the years in between WaterPower, and both conferences now have increased attendance from less than 1,000 to over 3,000 – quite an achievement. During this time I provided advice to Carl, suggesting the addition of low tech papers (reject anything with a differential equation) and even wrote a few.

45. BEARSPAW SPILLWAY – 1984-6.

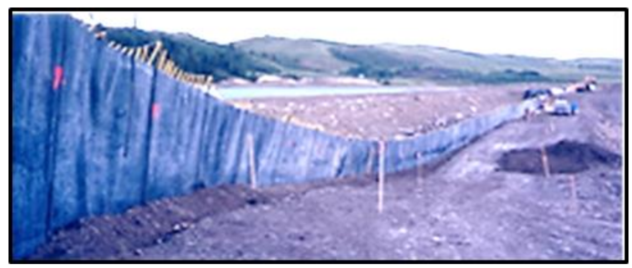
The Canadian Dam Association had developed some dam safety guidelines in 1981, and the province of Alberta was the first to adopt the new guidelines. Montreal Engineering had undertaken a survey of all their hydro facilities to see how they complied with the guidelines, and found that at several of the plants, there was insufficient spillway capacity. At Bearspaw, just upstream of Calgary, the spill capacity had to be about doubled.

Project layout – Google image.

Our Calgary office staff had developed two layouts, one with a conventional gated spillway, and the other with a long side-channel weir spillway, requiring a significant increase in dam height to provide the necessary spill depth over the weir. Cost of the two layouts was about the same, well within estimating error, and the Calgary staff could not decide which was the most attractive.

Existing spillway and powerhouse.

I flew to Calgary along with Jack Randle, our Chief Hydrological Engineer. At meetings with the Calgary staff I found that Jack favored the weir layout, and I favored the gated spillway because the weir was partially founded on sands and gravels, where foundation design could be a problem. The discussion went back and forth for several days, and we could not reach a consensus.



Geotextile impervious earth-concrete joint.

Concreting of weir spillway.

On the third day, Jack appeared at the meeting with a smile on his face. The discussions started, and Jack waited until there was a pause, whereupon he said we should give some consideration to the operation of the spillways. He asked if we had thought of what the operator would be thinking when he had to open the new spillway gates, knowing that this would cause severe flooding throughout downtown Calgary, where much of the development was in the flood plain. We were all aware of this, but had not thought much about it, since the Calgary municipal engineers knew the likely extent of the inundation, but the residents were not so fully aware.

Jack went on to say that the plant operator, faced with a requirement to open the new spillway gates, and knowing that this would cause extensive flooding and severe damage to property in Calgary, would hesitate to press the open button, perhaps delaying this until it was too late, and the dam would be in danger of overtopping, causing a disaster.

Completed huge weir spillway.

On the other hand, with a weir spillway, the headpond would continue to rise when the flood flow exceeded the capacity of the existing gates, the flow over the weir would gradually increase, and it would be "an act of God" that caused the flood, and not the powerplant operator. I had to admit that this was an obvious reason to select the weir alternative, and it was built over the next 2 years. However, it did require some innovative engineering including the use of geotextile fabric and bentonite to obtain a waterproof joint from the earth dam to the concrete weir.

The "arched" spillway dam was anchored to the sandstone foundation with several long post-tensioned anchors to improve safety.

46. BAY d'ESPOIR SURGE TANKS – 1988.

The highest (371ft.) surge tanks in the world are at Bay d'Espoir on the south shore of Newfoundland. They were built in 1963, and 25 years later we had a call from Newfoundland Hydro that one was leaking, and could we have a look at it. I flew to Deer Lake, rented a car and drove south to Bay d'Espoir where I met Tom Vatcher, the powerplant manager. Apparently, a rust spot had been detected on the outside cladding covering the insulation around the pipe leading up to the tank, at a couple of meters below the tank bottom. The local cladding and insulation had been removed, to reveal some seepage at a weld joint.

Surge Tanks.

6-unit Bay d'Espoir powerhouse and surge tanks.

The only access to the inside of the vertical pipe was by a 'bosons' chair from a manhole at the bottom. I got suited up in a safety harness, and climbed into the pipe through a manhole. There, the harness was attached to a safety rope, the other end being attached to a small electric winch in the bottom of the tank, some 50 meters above. Bill, a technician sat on one side of the boson's chair (a 12 inch wide wood plank) and I sat on the other. We were slowly hauled up by the winch in utter darkness, except for the glow from our miner's head-lamps. Perhaps just as well, because it was not reassuring to look down at your feet dangling in the abyss. We arrived at the suspect area, and all that could be seen, was some erosion of the weld metal joining the steel plates. I took some photos, and we were lowered back down.

Typical rust nodules

There was no apparent reason for the weld to be eroded, so samples were cut out and sent to a laboratory operated by the Ontario Research Council. Their report indicated that the weld metal chemistry was within the specified range, but at the limit for trace elements of copper and magnesium, so that in the presence of the slightly acidic muskeg water at the Bay, the weld had acted as a sacrificial anode, slowly eroding over the years and depositing metal on the adjacent steel plate. During the next summer, the vertical pipe was replaced at considerable cost.

While I was at the plant, Tom asked me to look at one other small problem. One of the turbines had been removed for weld repair to eroded areas on the runner blades, and the throat ring around the turbine had been measured to check the circularity. Unfortunately, it was found to be slightly oval, only by a few thousands of an inch, but sufficient to cause concern.

After wire brushing, erosion at weld joint.

A check with previous readings had shown that the out-of-roundness was continuing to increase – but why? The longitudinal diameter, as measured along a line through the other unit centerlines, indicated a slowly decreasing diameter. I looked all over the concrete in the powerhouse structure for clues based on any hairline crack pattern; but could not find any. I then asked Tom if there was any difference in the operation of the six units in the plant, and he told me that the ovalling unit was started and stopped twice per day, to follow the power demand pattern, while the other units were kept operating. This provided the needed clue, the adjacent units were kept pressurized, and the oval unit was not, so the concrete could creep over the years, and cause the ovalling. I suggested he change the operation procedure to rotate dewatering between the units, this was done, and a measure several years later, indicated that the turbine was slowly returning to circularity.

However, the powerhouse concrete was later found to have AA (alkali-aggregate reactivity) – causing a slow expansion, and this likely also contributed to the change in circularity.

47. GRAND LAKE DAM – 1985

In 1985, our associated company Shawmont Newfoundland was asked to undertake a dam safety inspection of the Grand Lake Ambursen dam. The Ambursen dam is a patented design for a reinforced concrete dam with narrow piers and a 45 degree sloping upstream face. Many have been built around the world. The main attraction is that due to the modular construction, the dam can be built mostly without a cofferdam, since water can flow between the piers as the dam is constructed. In Canada, the main problem with the dam, is that due to the thin upstream face, exposed to freezing on the downstream side, there is usually rapid deterioration of the concrete. In several cases, the dam had been enclosed and heated during winter, adding considerably to maintenance costs.

In September, I flew to Deer Lake, checked into the Deer Lake Motel, and accompanied by Dave Brown from Shawmont, we drove to the damsite.

Two views of dam interior, at overflow section. The curved face is the underside of the spillway ogee.

The dam was used by Newfoundland Rail for their only line across the island from Port aux Basques, the ferry terminal, to St. Johns. It ceased operating shortly after our inspection. I stood inside the dam as a heavy train was passing over, and the whole structure vibrated, not a very pleasant experience.

Closer view of downstream face.

View of downstream face with train passing.

View from dam crest showing narrow gauge railway.

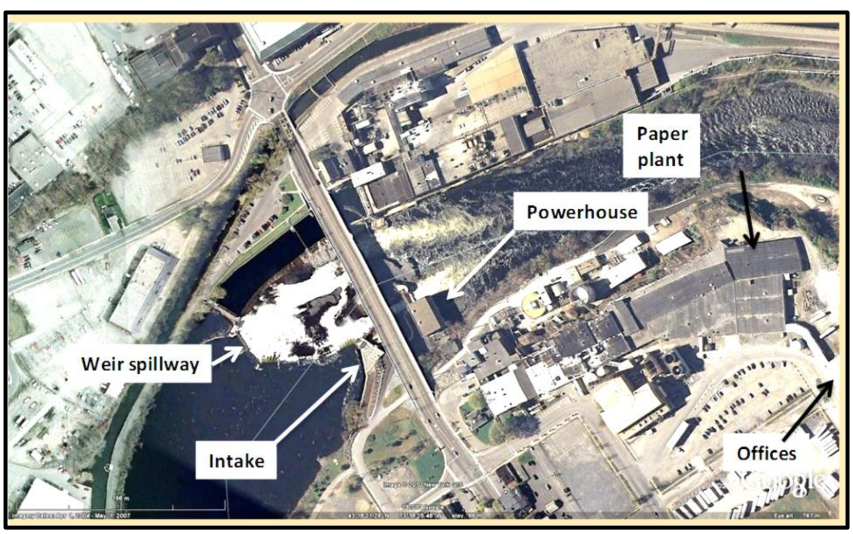
The dam interior was found to be acceptable in the overflow sections, but severely deteriorated in the open sections exposed to frost. As a result of the inspection, Shawmont obtained a contract to rehabilitate the dam by adding a supporting concrete slab to the upstream face inside the dam, and some facing to a few piers. The stilling basin was reinforced, and a larger flip was added at the end. The interior of the exposed sections now has a heating system to prevent further deterioration of some sections, where a timber-framed wall was used to retain the heat.

The dam is used for storage by the Deer Lake Power Company, and is essential for continued operation of the hydro plant.

Due to their light weight, and open construction, the dams are particularly susceptible to considerable damage during an earthquake. In British Columbia, BC Hydro has infilled an Ambursen dam with mass concrete, in effect, converting the structure into a standard concrete dam. This solution was found to be much more attractive than trying to reinforce the structure.

48. OLD TOWNE – 1985-6

About 1978 we purchased a small New York consultant named Carlson & Sweat who specialized in work for paper companies. They managed to obtain a contract for the installation of three small 3.3MW generators at the Old Towne hydro plant on the Hudson River in Glens Falls, used to power the paper mills.



Site plan from Google Earth.

View of intakes.

View of governors and pumping units in room upstream of turbines→

The assignment was quite easy, since there were three empty bays ready for the addition of horizontal axis "S" type turbines, gearboxes and generators. I would drive down to the site early in the morning, and return in the evening after spending about 4 hours at the plant and having lunch with the plant engineers. This went on for three years until I appeared too frequently on the USA border computer, and on my last trip I was informed that I would have to get a green card – so no more site visits, but fortunately by then, the work was completed.

Below - Unit #3

installed. Unit #2 waiting for generator.

The time was at the start of CAD (computer aided design) drawings, so the drawings were sent from New York by post on diskette, printed in the office, and then I would have a look at them. Changes would be returned by FAX – all very efficient. The main problem was getting the equipment through the old paper plant adjacent to the powerhouse.

View of stoplog-controlled weir at the hydro plant.

Installing switchgear and controls.

49. NIPAWIN – 1985

By 1985, the company was suffering financially due to some unfortunate purchases of overvalued assets. It was so bad, that all staff were asked to take a 10% cut in salary, to be refunded when business improved. The refund was obtained about 20 years later, but only after the employees sued the new owners. I refused to participate in the salary reduction, instead offering to work part time, and never charge unworked hours to the overhead account. This was accepted. However, attendance at meetings and conventions was stopped, and the only way I could continue to attend the 2 annual meetings of the Canadian Electricity Association (CEA spring convention with paper presentations, fall meeting, one day of papers on the project followed by a one day site visit) was to charge the time to my holidays, use my Aeroplan points for travel, while the company agreed to pay for other expenses such as hotels.

This was the arrangement when I travelled to the fall CEA meeting at Regina and to the hydro plant at Nipawin in north-central Saskatchewan. It worked well, and allowed me to attend meetings until I resigned from the company in 1990.

5-gated spillway, passing diversion flow.

View of spillway. Blue powerhouse structure.

Fuse plug spillway dyke – reservoir not yet filled.

Nipawin was designed by Acres, and the meeting, along with the site inspection, proved to be very instructive, since excellent papers were presented on the measures required to allow for differential settlement due to the soft clay foundation.

Many years later, Acres provided me with a large three-ring binder full of all the papers on the project, much appreciated since they had used several innovative designs to counter the effects of settlement.

Left – spillway hoist structure.
Right – interior of hoist house, hoists still being installed.

Kaplan turbine and shaft awaiting installation.

Powerhouse interior.

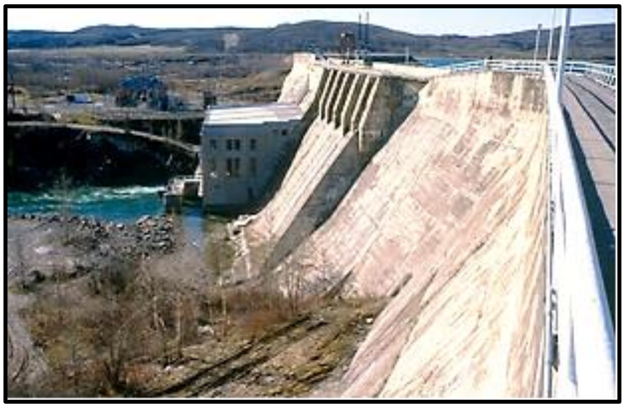
50. GHOST SPILLWAYS – 1985-9

View of ghost powerhouse and main spillway.

The Ghost Dam is located about 50km west of Calgary, on the Bow River. It was built just before the depression, and the first three units came on line in 1929. It almost bankrupted the owner, Calgary Power, and they could not make the final payments for the Westinghouse generators. Fortunately, they reached an agreement with Westinghouse to postpone payments until commercial conditions improved, in return for a promise to purchase all future generators from Westinghouse, a promise which was kept until Brazeau was commissioned in 1964.

Upstream view showing lower dam crest section.

Wave wall at intake.



View of downstream face of dam and spillway.

The facility includes a concrete dam and integral main spillway with 6 gates, and another spillway on a side channel with 10 stoplog openings. All were operated by mobile hoists. The designers had to reduce costs to an absolute minimum, and elected to make the dam crest about one meter lower across the powerhouse intake and spillways. The thought was that in an extreme flood, the lower dam could act as an emergency weir spillway! However, no thought was given to the effect of the water landing on the roof.

Another deficiency was the lack of an adequate flip bucket on the main spillway. Hence, the operators preferred to use the secondary spillway before opening the main spillway gates.

Stoplog auxiliary spillway in side channel.

Unfortunately, the designers had not thought of what could happen during a high wind from the west, a frequent occurrence in the valley. A few months after the plant was started, such an event occurred, and the wave spray overtopped the low section of the dam and landed on the powerhouse roof. There the tar and gravel roof soon disintegrated under the onslaught, and gravel blocked the roof drains. A 1m parapet wall around the roof contained the water, and the roof soon collapsed due to the weight of the water. Fortunately, insurance covered the damage, but it was a costly lesson for Calgary Power.

The parapet on the downstream side was removed and the roof repaired. Eventually, a wave wall was built across the intake section upstream of the powerhouse.

As at Bearspaw, a dam safety analysis was made in 1984, and it was soon found that the spill capacity had to be increased substantially, some of the concrete dam sections needed added weight for stability, and the slow flood response time with the old hoists needed improvement. For any upgrading, both the spillway and powerhouse had to be maintained in an operating condition, imposing severe restrictions on options available for design, schedule and construction.

Model of main spillway. Note level of powerhouse draft tube deck.

This posed quite a challenge to the staff in our Calgary office headed by John Nunn. After looking at many alternatives, they selected a design with 8 spillway gates at the main spillway, with the two center ones being larger than the others. It was model tested at the Western Canada

Hydraulic laboratory in Vancouver. The secondary spillway would be converted to a simple weir.

Extreme flood – note water level at powerhouse over draft tube deck.

At maximum flood, the flow past the spillway was quite spectacular, and the powerhouse would be inundated to above the generators. However, the chance of this happening is extremely remote, and the risk was accepted. Also, the draft tubes would likely be blocked with rock eroded from the spillway plunge pool.

Measuring erosion depth after flood.

Construction of the new spillway commenced at the far end, opposite to the powerhouse, with both the old spillway and powerhouse kept in operation. Also, concrete was added to the downstream face of the dam for added stability, and the crest level was increased to match the embankment dam level.

Adding concrete to downstream face of dam.

Adding downstream concrete was not sufficient for all sections, hence concrete was also added upstream, cantilevered off the deck. This task could only be accomplished in the late winter after the reservoir had been drawn down to near the low supply level.

Downstream face – note new spillway piers.

View of gate and guides and stoplog guides on spillway.

Getting access to the main spillway was difficult, and the contractor had to build a long access ramp up to the level of the ogee, while still keeping the generating units operating.

Lloyd Courage, upstream face extra concrete.

It proved to be an excellent assignment for the Calgary office staff, providing experience in detailed design of hydro spillways, experience which was useful when the office was downsized, and most staff moved on to other hydro consultants or utilities.

Work on main spillway section, access ramp on right.

View of downstream face, during construction.

Due to the scheduling constraints, the work was undertaken over a 5 year period, from 1985 to 1989. Normally, it would have been accomplished in about 2 years. The last task was converting the auxiliary spillway to a weir. The end result is a safe facility, with a quick response time.

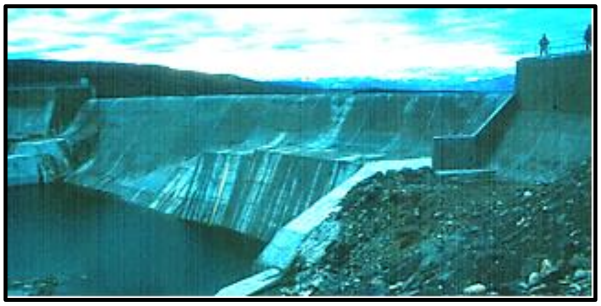
View of hoist house interior.

I visited the Calgary office 6 times to discuss the work, and inspect the construction activities. However, I could have relaxed and stayed in Montreal, since the Calgary staff did such an excellent job!

Reinforcing for flip bucket – main spillway.

Completed main spillway.

Working on auxiliary spillway.



Completed auxiliary spillway weir.

51. ISLE MALIGNE – 1987

In October, I returned to the 402MW Isle Maligne powerhouse where Alcan wanted to investigate movement in the concrete near the intake. Many years previously, I had looked at concrete creep in the powerplant when they were having trouble aligning units. The powerhouse is built on top of the downstream toe of a triangular concrete dam.

View of powerhouse, showing location on top of dam.

Generator floor.

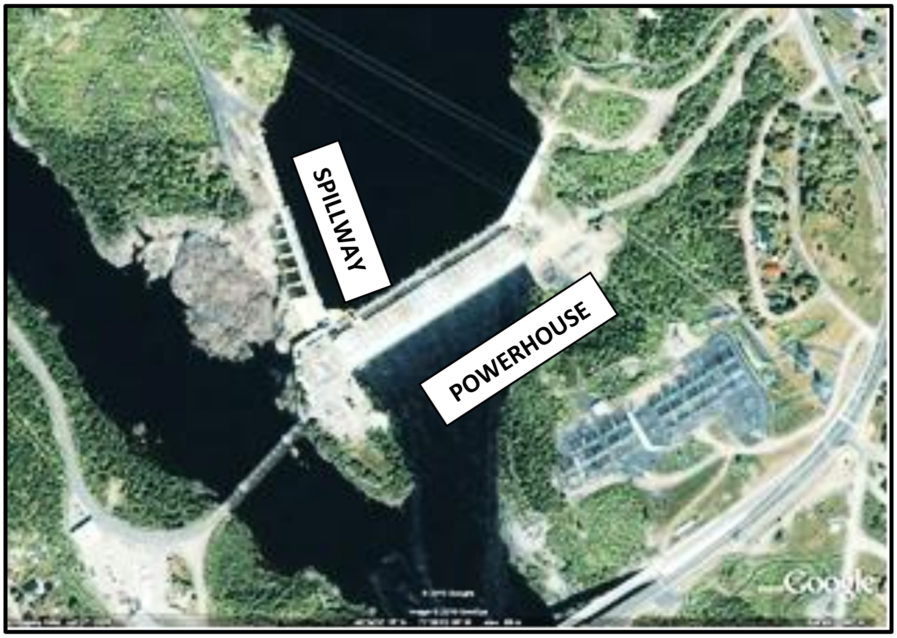
After looking closely at the cracking pattern in the concrete, I found that all the arches supporting the concrete below the generators had 45 degree shear cracks at the top, indicating that there was excessive thrust in the downstream direction at the generator floor level. However, on looking at the drawings, I noted that the designers had anticipated this, and had included an open 1-inch contraction joint between dam and powerhouse, filled with cork.

Crack detail.

View of arch below generator floor.

In view of this, I could not see how any force from the dam could be transmitted through to the powerhouse.

The floors upstream of the generators were tiled, and they showed no cracks. After more searching, I found several cable trenches across the cork joint location, and had the steel checker-plate covers removed. However, the trench walls were covered in thick dust, and any cracks were obliterated. We asked that the dust be removed, and departed for lunch.



Google Earth image of powerplant.

We returned after lunch, to find that the cork-filled expansion joint was completely closed, indicating that dam creep forces would now be transmitted to the powerhouse, causing the miss-alignment of the bearings in the vertical axis Francis units.

View of downstream wall of powerhouse.

The concrete movement near the intake was halted by adding mass concrete weight above the penstocks, when it was found that the unreinforced penstock pipes through the mass concrete dam de-stabilized the area, and weight was needed to counter uplift.

When the powerplant was built in 1926, it was the largest in the world, and provides power to the Alcan aluminum smelters in Arvida. For many years the only access to the powerplant and operator's village was by rail.

52. VANCOUVER MICRO-HYDRO – 1987

In March of 1987, I was asked by CANMET, a division of Canadian Energy Mines and Resources to present a paper at their seminar "Small hydro Canada 87" in Vancouver. The seminar included a visit to a 5kW plant at the toe of Grouse Mountain in North Vancouver.

There, a homeowner had asked BC Hydro for service, only to be told that the 6km transmission line would cost over $50,000, to be paid up front. Since there was a small creek running through his property, he applied for a license, and installed a small impulse unit with an induction generator and some fancy electronics which converted the power to 3-phase at 220/110 volts. The generating package was provided by Thompson & Howe, from nearby Burnaby, and the homeowner built the dam, penstock and powerhouse for the unit.

The "dam" was a simple log structure across the creek. The intake consisted of a plastic milk crate, covered with mosquito netting connected to a short length of flexible pipe, so that the crate could be lifted out of the water to stop the flow. Quite ingenious! The 8-inch PVC pipe down the mountain was tied to trees. The "powerhouse" was a small shed with a valve and the generating unit. Cables to the nearby house completed the plant. A rope had been provided so that we could scramble up the steep mountainside to look at the intake.

Intake to penstock.

Log weir dam across the creek.

Left – penstock on steep mountainside. Right – powerhouse.

There was no governor on the unit, so that it was always running at full load. The surplus power was dumped into a large water tank heater in the house, and used for both heating and washing. Excluding the owners "sweat equity" building the plant, the total cost was less than $10,000, and the owner had free electricity for the life of the plant!

Left – valve and power unit. Right – house, 3 bedrooms.

Just shows what can be done with a little bit of ingenuity. The 5kW is more than enough for the home. Maintenance consists of a weekly cleaning of the netting at the intake, and annual oiling of the generator bearings.

53. MOORE DAM – 1987

Moore Dam beside highway.

In 1987, I was motoring through Vermont with Vera on a summer holiday. We had booked into the Rabbit Hill Inn for a few days. On the second day, we decided to motor over into New Hampshire, and we passed the Moore Dam on the Connecticut River, at the border between the two states. I quickly looked over, and noted that the spillway did not appear to have any hoists on the gates.

View of Moore Dam from highway.

I asked Vera if she minded a diversion for a few minutes while I had a closer look at the dam, and with no objection, we drove over to the powerhouse, where we happened to encounter the operator about to leave. I told him I was a hydro engineer, and could I have a closer look at the spillway. He readily agreed, and we drove up to the dam, and walked over to the gates. They were equipped with vertical steel beams called "needles" holding timber logs against the water. The 36 needles could be released by hitting a trigger mechanism with a heavy mall. Apparently it had never been used; however I liked the idea of a simple quick release mechanism that did not require electric power. It was very similar in concept to the jacked-pin mechanism we had developed for the St. Marguerite spillway in 1973.

The design was by Harza in Chicago, and the dam was completed in 1957 with an installation of 192MW units. It has three Tainter gates in the middle of the spillway, and vertical "needles" on each side. To prevent accidental operation, a bolt kept in place with a cotter pin, along with a bolted-down wood stop at the top of the needle was added when it was discovered that waves impacting the needles caused vibration and the U-bolt retainer to slowly migrate upwards leading to an accidental release of the needles. Removing the safety measures requires time.

The trigger mechanism.

However, access to the retaining hook area is very difficult, and the only way I could photograph the mechanism was to climb over the safety railing on top of the dam, crawl out onto the concrete end pier, and take a photo. As would be expected, the operator was not at all comfortable with this. Also, as discovered on other similar mechanisms, the steel walkway at the top, holding the needles, will vibrate severely when a needle is released, disconcerting the operator, resulting in a reluctance to release the needles when required.

The needles are relatively slender, and one could deform when an adjacent needle was released, due to the loss of support and the sideways upstream water force, something to be investigated on any future application. It could result in accidental release of all the needles. The Tainter gate sills are well below the sill of the needles, so that needles can be replaced in the dry after a flood has passed. On the whole, I prefer the concept we developed for St. Marguerite.

54. ONTARIO HYDRO – 1987

In September, the CEA fall meeting was in Niagara Falls, with a site visit to 3 Ontario Hydro plants. The first was to the old 5-unit DeCue plant, now decommissioned. It is being converted into a museum for hydro power.

23MW DeCue powerhouse, started in 1898.

The next was to the 174MW pump-turbine installation where there are Derriaz units wherein the wicket gates are in a cone at 45 degrees to the axis, a very difficult arrangement, and extremely difficult to maintain.

DeCue old riveted steel penstocks.

Intake gantry crane

The intake is serviced by a gantry crane. The pump-turb powerhouse is of the semi-outdoor type, with a large gantry crane having doors on all 4 sides so that the opening below into the powerhouse can be enclosed during inclement weather, not really suitable for Canadian conditions.

Motor-generator for pump-turbines.

One of the hatches in the powerhouse roof had been opened, so that it was possible to look down into the disassembled unit. The generator rotor poles were being checked in the repair bay at the end of the powerhouse. The turbine had not been removed, and the machinists advised that due to the 45-degree turbine wicket gate configuration, fitting of wicket gates and alignment of bearings was extremely difficult.

View of pump-turbine "draft tube" deck and powerhouse roof. Intake gantry at top.

The Adam Beck #1 powerhouse, commissioned in 1920, was also briefly inspected. The units were due to be renovated within the next few years, with output increased from 400 to 498MW.

400 MW Sir Adam Back powerhouse #1 interior.

55. LACHUTE DAM – 1986-7

In 1986, I had a call from Jim Hayman of Ayers Group in Lachute, 80km north-west of Montreal. Ayers used to have a large woolen mill, and their blankets were sold throughout Canada, but it had ceased operating when fleece became far less expensive. Their remaining assets were two small hydro plants on the Riviere du Nord, previously used to power the mill, and a large property suitable for re-development within the town. Apparently a small local engineering company had been engaged to see if they were operating the plants as efficiently as possible. Their report indicated that they should be producing about 20% more energy. Jim wanted a review of their report, and I asked him to mail it to me. A quick perusal of the document indicated that the consultant had forgotten to include the turbine, generator and transformer efficiencies, and if this was included, the present output was correct and could not be improved.

I phoned Jim with the answer, and he asked me to drive up to their offices to discuss it. I arrived the next day, and explained to the consultants their error, for which they were grateful.

After the meeting I had a tour of the two plants with Jim, and told him that there would be no charges for our work, since it only involved a few hours. Jim was insistent on us sending an invoice, but I had seen that there was the possibility of some future plant upgrading work, since the equipment was nearing the end of its service life, having been installed in 1928. So we did not issue an invoice.

Dam and powerhouse before flood.

PH interior before flood.

About a month later, at 11.10pm, my daughter Fiona, came running up to my bedroom and woke me with "Dad, that dam you were looking at in Lachute has just washed out, it is on TV!" so I rushed downstairs, but the news had changed. Next morning, a Sunday, I got up early to watch the 6.00am news, and there was the same broadcast. After a quick breakfast, I drove out to the dam, to be greeted by a disconsolate Jim, looking at the disaster and wondering what to do. I asked him if he was open to some advice, which he readily welcomed. The first task was to make the site safe, and close it off to the public, since there were children on tricycles riding across an unreinforced concrete wall, devoid of handrails and spanning the washout, which appeared to be on the point of collapse!

Unreinforced wall over river after washout.

Concrete wall over river.

Debris on dam crest after 0.6m overflow.

I then enquired if they had thought of repairs or just demolishing the remaining plant, the powerhouse being flooded with the equipment coated in mud. Jim advised that they had insurance, and of course they would be rehabilitating everything, since the energy agreement they had with Hydro Quebec was too valuable to abandon. So we agreed on a contract with Montreal Engineering, and I undertook a more detailed inspection of the disaster. The powerhouse door had been forced open by the flood waters, and equipped with a flashlight I had a good look around. The first thing I noticed missing, was a beautiful mahogany wood cabinet holding all the original drawings of the powerplant which had been adjacent to the door. It had floated away downstream and was never found.

Muddy powerhouse interior.

During my tour of the powerhouse a month earlier, I had seen the cabinet, and looked into a few of the wide shallow drawers. They all contained detailed drawings made with black India ink on linen paper, the more intricate ones being worth over $1,000 to collectors. I had commended the operator on having a set of the original powerplant drawings, something rarely found on old hydro developments.

Powerhouse flooded from debris in river bed.

After a good look around, I was about to depart when an engineer from Lavalin Engineering, a local competitor arrived, and spoke to me briefly. I outlined what had happened, a consequence of some vandalism. The dam was used as a short-cut by students at a nearby high school, and someone had chopped off the electrical plug on the power cable to the spillway gate hoist, so when a thunderstorm passed over the watershed, the spillway gates could not be opened, and the water rose to 0.6m above the dam crest, causing the washout. The plant included 8 sluices controlled by stoplogs lifted by an ancient but still serviceable electric hoist, two low level outlets and three horizontal axis double-runner Francis turbines of 1.5MW capacity at 12.2m head. The powerhouse was flooded to just above the horizontal generating unit shaft level, due to backwater from dam washout material in the river bed.

Jim Code, Geotechnical Deptment Head, looking at washout.

Drying out a generator

After the flood, Jim Hayman contracted an electrical company to restore the powerhouse equipment. Two days later I returned with Bob Gander to sign a contract for the civil work. We were told afterwards that the Lavalin engineer had complained to Jim Hayman that “Quebec was Lavalin territory, and they should have been awarded the contract” – just goes to show what a bit of “ambulance chasing” can do.

We decided to cut out two of the ogees, and with the low level outlets fully open, we had sufficient diversion capacity to pass summer flows.

Cut-down ogees and low level outlets discharging.

A cofferdam was constructed upstream of the washout, and the washout area was cleaned out. We decided to re-build the abutment embankment to about the same dimensions. The first task was to excavate a core trench down to impervious material, and this work was easily accomplished with a large backhoe.

View of cofferdam – almost as high as the dam!

The dam core material was obtained from a local quarry, and the shell materials from the tailrace washout excavation. Heavy gravel was used as rip-rap, since the fetch was short. Some concrete was placed against the powerhouse wall to improve core contact, and the presence of a contractor was used to undertake some other repairs to the old powerhouse.

Excavating core trench and placing forms for core contact.

The work was completed about a year later, and I included a "quick release" mechanism in one of the spillway gates, whereby an ordinary 5-ton hydraulic car jack could be used to lift pins holding the top of a central column, to release the stoplogs in an emergency.

The contractor placed the jack inside a cubby-hole below the dam deck, hidden from view, but easily accessible.

Dam nearing completion.

Standing on cofferdam beside nearly completed dam.

It disappeared overnight, so when I arrived to inspect the completed work, I asked the operator if he had a jack, and he advised that he now had three, one in his truck, one in the powerhouse, and another in his office!

Restored dam and powerplant.

View of quick-release stoplogs, middle sluice.

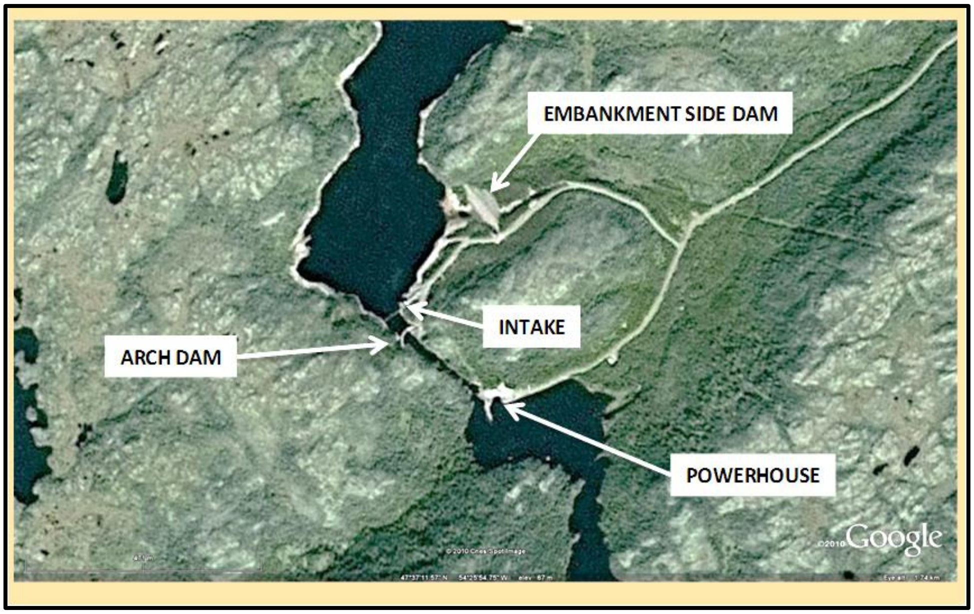
The quick release mechanism was an interesting development. It had been developed for use on the St. Marguerite Spillway in 1973, and has since been used by several Canadian utilities on spillways where an unpowered emergency release is required.

Quick release mechanism.

The largest is on the Grand Mere development owned by Hydro Quebec, near Shawinigan. There they even undertook a test with a gate immediately upstream of the stoplogs, water in between, and filmed the release when the pin was jacked up. Quite spectacular.

56. PARADISE – 1986-88

Project layout – Google Earth image.



The Paradise Dam has the third double curved arch dam in Canada, and the only one in Newfoundland. It is located in a very narrow gorge on the Paradise River at the head of Paradise Sound on the East side of the Burin Peninsula.

In fact, the gorge is so narrow, that it is not possible to take a row boat upstream; instead you had to haul the boat up by a rope conveniently attached to the rock wall.

With near-vertical and sound rock walls, the topography favored a concrete arch dam near the upstream end of the gorge, with a tunnel to the powerhouse, which could also serve as the bypass tunnel. The cofferdam would be located just before the gorge, allowing the contractor space to build a road down to the damsite. In addition, a small earth side dam on the left bank would complete the project.

When we started work on the design we had no prior experience in arch dam design, so we engaged a consultant, Howard Boggs from Denver, who had taken early retirement from the Bureau of Reclamation. Howard was an expert in arch dam design, and had developed a program to determine stresses within the concrete arch.

Howard provided a copy of his program to the Shawmont engineers in Newfoundland, and they attempted to run the program. I was working for a short time in their St. John's office ensuring that the project design was progressing on time. However, Phil Helwig, one of their engineers, had insisted that with the arch dam program, we did not need Howard to design the dam. Phil struggled for weeks with the program, always producing a design with excessive stresses within the concrete. Time was running short, with the contractor asking for the rock excavation drawings which could not be produced until the dam was designed. Eventually, I had to tell Phil that if he did not produce the design within the next few days, I would call Howard. No design, so I called Howard who told me that he was waiting for my call, and would be on a plane that evening. He arrived the next day and got down to work.

Upstream cofferdam, canal to diversion intake.

Construction camp.

Pulling upstream to the damsite in the gorge.

Two weeks later, Howard had the design completed and the excavation drawing was produced the next day. I asked Howard why Phil had been unable to produce a design, and he told me that the arch stresses are mainly due to temperature differences, and are a maximum near the abutments, where the "flexible" arch meets the rigid rock abutment. They are usually too high in the initial trial shape, and the program operator then increases the thickness of the concrete near the abutment, thinking that more concrete will lower the stress. But instead the stress increases because there is less flexibility at the abutment due to the thicker arch concrete. The secret to the program operation is counter-intuitive – decrease the thickness near the abutments, the arch will flex more moving the high stress away from the abutment, decreasing the stress near the abutment, and increasing the center stresses. Howard was well aware of this quirk, and hence had no fear of providing a copy of the program, knowing that he alone could find the optimum shape for the arch.

Diversion tunnel outlet back to Paradise River.

Howard spent only three weeks in the office, and left behind a detailed design brief on the arch dam. I worked in the cubicle next to him, and often heard him exclaim "got you sucker" when the program eventually arrived at a point where he could proceed to the next step.

Damsite – scaling off loose rock.

Setting out the dam shape in the field was a challenge due to the very complex double-curve configuration of the dam. Every corner of each concrete lift had to be established within a few centimeters. The problem was overcome when a Shawmont engineer with an aptitude for mathematics wrote a computer program to set out each corner (vertical and horizontal angles) from several theodolite stations on the abutments. I don't think the dam could have been built without the help of computers.

Removing overburden with water jet.

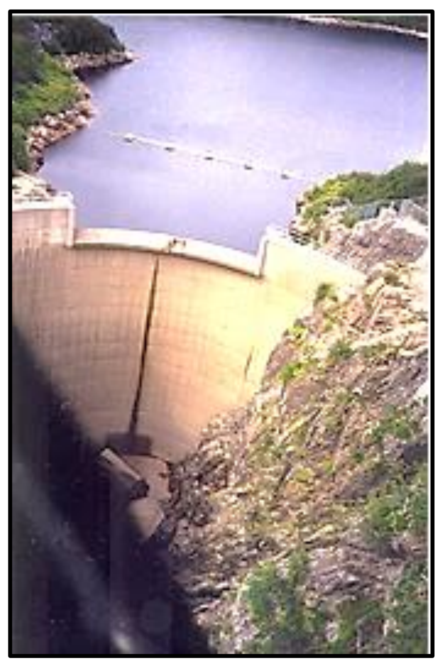
Two views of dam during construction.

Power intake during construction.

Two views of upstream face.

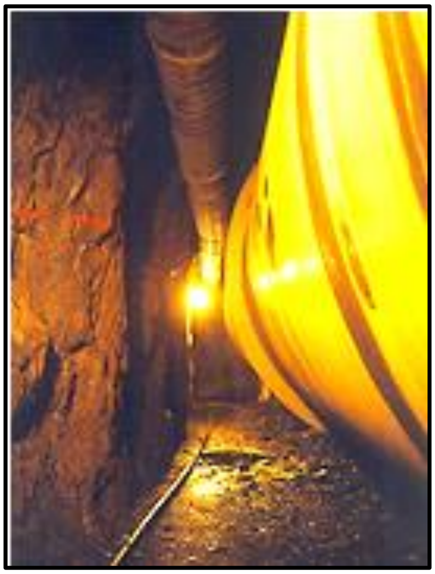
Completed dam in winter.

Aerial view of dam.



The power intake is located above the diversion tunnel and feeds water into the tunnel a few meters downstream of the diversion intake. The intake house completely encloses all the equipment.

Start of penstock installation within tunnel.



View of penstock within the tunnel.

There is a short steel penstock within the tunnel near the powerhouse. This design was found to be more economic than embedding the penstock in concrete. There is easy access to the tunnel from the lower level of the powerhouse.

Access door to penstock.

Powerhouse foundation – steel elbow for draft tube.

Diversion tunnel intake with concrete-steel gate above.

I spent some time on the powerhouse layout. The turbine was very small, with a runner diameter of only 1.2m, so headroom within the powerhouse was at a premium. This was solved when I suggested using a split level design, with the repair bay floor level with the bottom of the generator, the control room floor on the other side at the back and at a level near the top of the generator, and a lower floor below the control room with sufficient headroom.

Powerhouse during construction.

Spiral casing for turbine. Tunnel access door top left.

Power intake, with reservoir near low drawdown.

I suggested adding a concrete roof to the control room, at a level only 2m below the crane, where spare parts could be stored. It all worked out very well. At the bottom floor, there is access to the penstock and tunnel for inspection.

Powerhouse nearing completion.

Completed powerhouse.

The project was built without any problems, no fatal accidents and started on time. The gorge is so spectacular, that Newfoundland Hydro have installed stairs up to the top of the gorge and down to near river level for tourists. 14 years later I returned to inspect the project with the Newfoundland Hydro Dyke Board, and was astonished to find faint micro-cracks in a map-work pattern, in the downstream powerhouse wall concrete, indicating the possible presence of alkali-aggregate reactivity. It is being watched, and hopefully will not affect unit operation. We had diligently tested the aggregate for possible reactivity, and all was well, but the tests at that time were later found to be inaccurate, and only suitable for detecting severe reactivity. Fortunately, there is no cracking evident in the arch dam.

View of dam after Igor hurricane had passed over.

Side dam with Dyke Board helicopters.

During the design work, we had several discussions as to the powerplant level, to avoid flooding, since there was no tailwater data. From the next photo, it looks like Shawmont got the powerplant level right, just above flood level as shown by Newfoundland Hydro photos.

View of project just after the Igor hurricane had passed over – caused 1/5,000 flood. Sept. 2010. Note powerhouse level.

New Tainter gates.

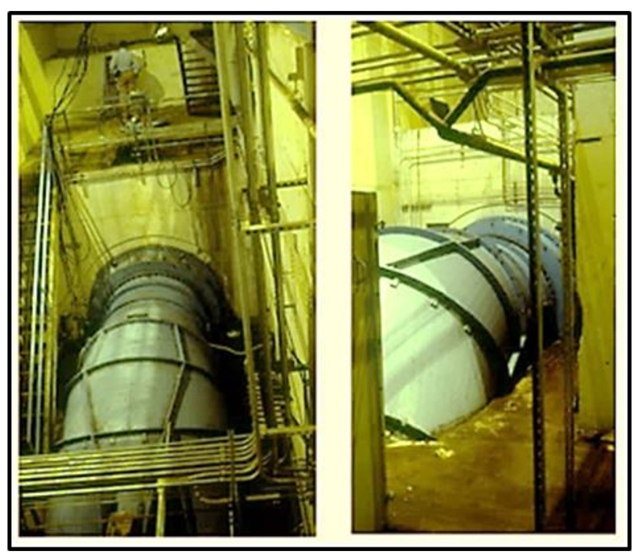
57. RAPIDAN DAM – 1986

The committee that advised Hydro Review included Professor John Gulliver from the University of Minnesota. I got to know him, and in 1985, he invited me to present two lectures at a week-long short hydro course he was teaching at the university. The following year, the class spent an afternoon visiting the Rapidan Hydro plant on the Blue Earth River near Mankato. It had been rehabilitated with new tainter gates and the installation of a 5MW tube turbine operating under 18m of head.

View of spillway.

Generator end of unit.

It proved to be quite interesting, since the new powerhouse was designed by a consultant with little hydro experience. One aspect was the proliferation of high-pressure oil tubing, which seemed to wander around the powerhouse from the governor tank to the turbine wicket gates.



Two views of tube turbine. Note oil piping.

Controls and switchgear.

High pressure governor oil pumps and tanks.

The pumps were not located close to the turbine, but instead were behind the electrical controls. Also, the wicket gates were paired, each pair with its own servomotor – very unusual.

58. BONNEVILLE – 1987

View of upstream face of powerplant #2.

In August of 1987, I attended the Waterpower Conference in Seattle, Washington.

On the last day, there was a tour of the nearby Bonneville powerplant, and I took the opportunity to book a seat on the bus. Construction started in 1933-7 at a cost of $88.4M, it was completed after 9 years. Later, in 1974-8, at a cost of $664M, a second powerhouse was added.

Interior of powerplant #2.

The second powerhouse contains 8 Kaplan units of 66.5MW- 76.5MW (overload) at 18.3m gross head. The old operating room was equipped with analogue gauges and controls. There was an excellent "tourist tour" with very simple signs available explaining the operation. The turbine was called "a giant mixmaster".

Powerhouse #2, analogue control room panel.

Construction of the second powerhouse commenced in 1974. The spillway is located between the two powerplants, and is opened to pass the full flow when the juvenile salmon migrate downstream to minimize losses. During this time, there is no power generation! The log sluices beside the powerplants are also opened to pass fish that were attracted into the powerhouse forebays.

Generator floor, powerhouse #1.

The first powerplant has recently been rehabilitated, with new windings on the generators, and all deteriorated parts, such as bearings on the turbines replaced.

Tailrace, powerhouse #2.

New draft tube gate hoist.

Powerhouse interior.

The first powerhouse also has Kaplan turbines, the first 2 having a capacity of 43MW, and the remaining 8 at 54MW. On our tour, we found that housekeeping was outstanding with floors polished to a high sheen. However, other parts were not so well maintained, and I noticed that draft tube gate wheels were severely rusted. Their website has many photographs.

We were fortunate to visit the plant in 1987. Since 9/11, the tours have been severely curtailed; all drawings of the power facilities and other technical details have been removed from their websites.

Google Earth image of the Bonneville facilities. Powerhouse #1 at top, spillway in middle, and powerhouse #2 beside two ship locks at bottom.

I returned to Bonneville in 1995 when attending the WaterPower convention in Seattle. The second tour was through the newer second powerhouse.

View of powerhouse interior from top of a generator.

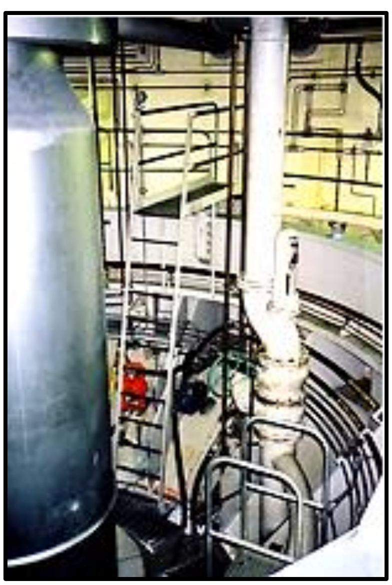
This time, there was a gate partially lifted above the deck, and it was possible to assess the condition of the wheels. I tried to rotate the wheel, an easy test of the bearing, and found that it was frozen onto the axle. They were in the process of rehabilitating all the gates.

Intake gantry crane.

This is a common problem with maintenance at hydro plants. The powerhouse equipment is well maintained, but gates seem to be neglected, since they do not directly contribute to the production of energy.

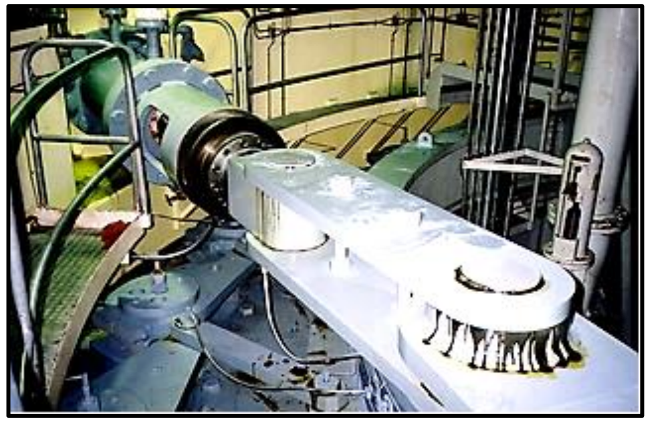
View of rusty wheel.

One of the turbines was shut down for some maintenance, so we were allowed to enter the turbine pit to have a look at the underside of the generator and the turbine servomotor. The turbine had a large hollow shaft, one of the first that I had encountered. However, the coupling to the generator shaft was only slightly larger than the shaft, requiring a taper down at the top – most unusual.



Turbine pit.

Another unusual revelation; was that the plant manager was a biologist! Apparently there are major problems with the fish passing downstream despite large fish ladders on the powerplants. When we were there, the spillway was open, and generation was minimal, resulting in a large loss of energy. Evidently, fish are more important than energy.



Turbine servomotor link to operating ring.

At one point, there was a pause in the proceedings just before lunch, so I asked the guide if I could relate a story about the Columbia River, and on his approval, I related our experience calculating the energy benefits from the Columbia River treaty. When I finished, several of the local Bureau engineers mentioned that I had captured the essence of their organization!

Spillway open to pass fish. Fish ladder in foreground.

It was a very interesting trip.

59. MOUNT HOOD – 1987

Before attending the August of 1987 Waterpower Conference, I had a tour of several small powerplants on the Farmers and Middle Fork irrigation systems north of Mt. Hood. They were in the final stages of construction, and known simply as Plant 3 and Plant 2. The first plant had been decommissioned.

Our trip started in the town of Parkdale, at Farmers plant #3, then we drove upstream to plant #2, paralleling the Hood River. Then across to the Middle Fork starting at the upstream powerhouse #1, continuing back downstream to powerplants #2 and #3, and back to Parkdale.

Powerhouse for Plant 3.

Plant 3 had one small Pelton unit of 1.8MW capacity, housed in a building far too large for the unit – presumably it would also be used for other purposes.

1.8MW unit in Plant 3.

Another view of 1.8MW unit.

Note excessive repair bay space, unless it is being used for storage of other irrigation equipment.

Further upstream, Plant 2 housed two small Francis units, of 1.0MW and 2.0MW capacity. Again, the powerhouse was oversized.

Powerhouse for Plant 2.

Francis turbines of 1.0 and 2.0MW capacity.

Wicket gate servomotor.

Governor and pumping units.

Their website mentions that maintenance on the units is very onerous due to annual instrumentation adjustments.

First powerhouse, 2MW unit.

Spherical valve at first 2MW powerplant.

The first plant had a 2MW impulse unit, and the second powerhouse had a small 500kW Francis turbine with a very loud high-pitched whine coming from the turbine.

The second powerhouse.

I suspect it could be due to severe cavitation since there did not appear to be any tailrace vent downstream, with the draft tube connected directly to the penstock to the third powerhouse in the series.

Impulse turbine at first powerhouse.

Small Francis turbine in second powerhouse.

I was particularly struck by the ductwork in the third powerhouse. It would interfere with access to the generator. Also, there were no provisions for maintenance on the equipment, no cranes and no roof hatches. Since the architectural features of the buildings were similar, I suspect that one consultant had designed all three plants.

Third powerhouse.

Impulse unit in third powerhouse.

It was an interesting trip, showing how some small utilities approach hydro development, with no appreciation for previous hydro experience and use of completely inexperienced consultants.

Cooling air ductwork above generator.

60. St. JOVITE MINI HYDRO – 1987

In July of 1987, a couple of monks arrived at the office asking for me. They had been given my name by an associate Dave de-Montmorency, who was a turbine designer and manufacturer. They caused quite a stir when walking through the office in brown robes and sandals to my office. They started to talk about building an 800kW hydro plant and mentioned that they had just completed building a 300kW plant. Father Joseph was leading the conversation, but he paused when my face showed utter disbelief. So he pulled out some photos.

Father Joseph crossing the dam.

I was astonished to see a powerplant with a Kaplan unit and a small concrete dam. I expected such a development to cost around a million dollars, so I asked where he had obtained the financing. He told me that financing, amounting to only $30,000 was obtained from contributions to their monastery.

Concrete powerhouse.

This was my second surprise, how could someone build such a plant for so little! The moneys had gone to the purchase of a computer and some controls to automate the plant. Everything else, including the turbine had been built by their brothers or been contributed by companies for a tax receipt.

The dam and powerhouse were built with donated cement, the penstock was fashioned from several discarded railway tank cars; they had built the turbine with help from Dave who provided the runner blade shape; and they rehabilitated an old governor and generator found in a scrap yard. I just had to see the plant, so I drove to their monastery near St. Jovite, north of Montreal.

Kaplan turbine and 300kW generator.

Window in draft tube to observe flow angle.

I was quite impressed with their achievement. The only difficulty they had was to obtain the correct turbine runner blade angle corresponding to the wicket gate opening. Dave did not know how this would be found, but their solution was remarkably simple. Dave had told them that the best combination of opening and angle was when the flow was coming off the runner blades at an angle of 32 degrees. They simply cut an opening in the draft tube just downstream of the runner, closed it with Plexiglas, after tying a red thread to a screw on the inside. Then they drew a line on the glass at 32 degrees to the shaft axis from the screw, varied the blade angle until the thread was on the line for several wicket gate openings, and they had their solution. A cam was then cut so that the governor could follow the correct combination of blade angle and gate opening.

I had to turn down their request for help, since they had no money, and we could not take on such a responsibility.

Mechanical governor and tank.

61. BIG CHUTE – 1987-93

View of old powerhouse adjacent to the marine railway.

In December, Ontario Hydro called for proposals to undertake the design and construction supervision of the re-development of the 4.2MW

Big Chute hydro plant built in 1911. Water was being spilled most of the time; hence the intention was to install a single 10MW unit.

Powerhouse containing 4 horizontal axis Francis units.

Two views of old powerhouse interior

The development was in the middle of a recreation area, with over 100,000 tourists passing through every summer, a factor affecting both the design and construction schedule. I inspected the site prior to working on the proposal. The powerhouse contained three horizontal axis, double-runner Francis units, and one small station service exciter unit.

The work required enlarging the short intake canal, demolition of the intake, penstocks and powerhouse and construction of new facilities. Meanwhile, the boat transporter and tailrace pond had to be kept operational since they were part of the Trent-Severn water system. Unfortunately, we were not successful and the contract was awarded to a consortium of small Ontario consultants.

Rail transporter used to ferry boats over the dam.

Google Earth view of new development.

In 1993, the CEA fall meeting was at Orillia, with all the papers on the Big Chute re-development.

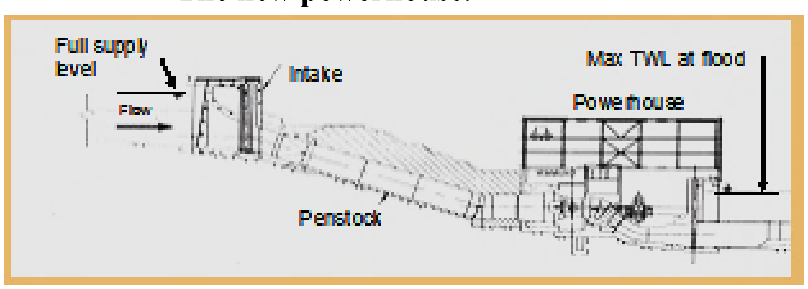
After a day of papers, we inspected the completed project, and I had a good detailed look at the work. The right half of the powerhouse had been

demolished to make way for the new unit foundation.

View looking down at runner throat ring and wicket gate operating ring.

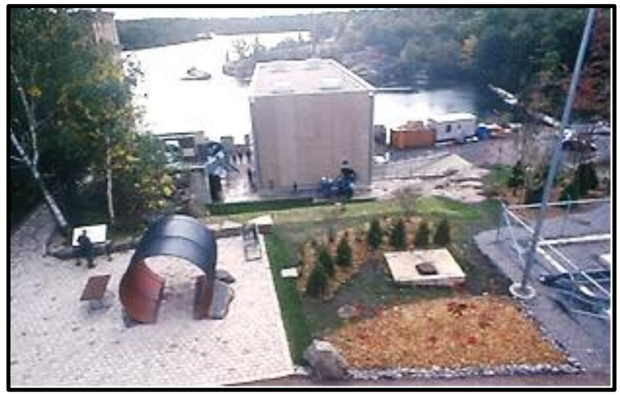
View of old surge tower, retained as part of museum.

The new powerhouse.



Section through Big Chute new powerplant.

The new unit is a horizontal axis "S"-type 9.8MW Kaplan turbine-generator. A 40Ton overhead crane and small repair bay are included in the plant. The left half of the old powerhouse was retained and one of the unit casings was removed to show the runners and shaft as part of a small "hydro museum". Also, large windows were built into the new powerhouse left wall, so that museum visitors could look into the interior.



View looking down at new powerhouse.

View from generator floor. I am at left.

The tailrace includes a 93m long concrete conduit with adjustable openings in the sides to distribute the flow evenly over the tailrace pond, so as not to disturb recreation boats approaching the marine railway. It works very well.

View of "hydro museum" at old powerhouse.

Total cost of the facility was higher than expected at $40M. Part of the reason was due to a “large hydro” approach to the engineering and construction, with many meetings with Ontario Hydro staff, and considerable documentation of the work, as opposed to minimal meetings and token documentation on small hydro work.

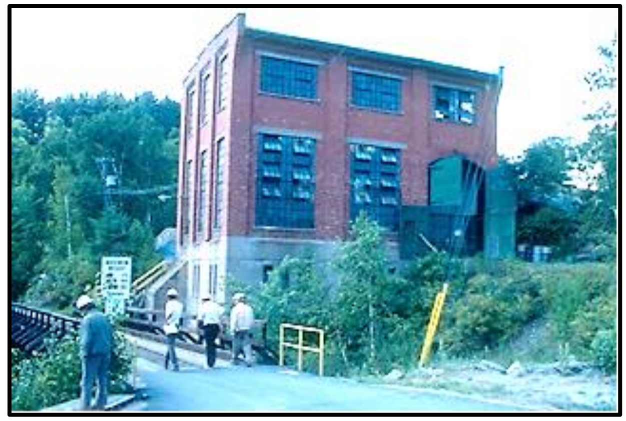
New intake with trash rake.

The powerhouse concrete was placed during winter within a large propane-heated plastic and wood enclosure.

The cost contrasts with that at Ragged Chute, described in Chapter 80. There the turbine is identical, and the generator almost identical with an output of 9.0MW, built at a cost of only $12M. There is the added cost of a canal and tailrace conduit at Big Chute, but this is not sufficient to justify the higher cost, entirely due to the “large hydro” approach at Big Chute.

62. HIGH FALLS INCO – 1988

In September, we had a call from INCO in Sudbury, asking us to submit a proposal to install a new runner and make some other modifications to their High Falls #4 unit. I had a good look at the plant along with several of our staff from the Toronto office.



High Falls powerhouse, commissioned in 1928.

The turbine was installed in 1928, had a cast iron Francis runner with the spiral casing 19.2ft above tailwater, an extremely high setting. Normally the casing is below tailwater. I casually mentioned that with this setting, there must be severe cavitation on the runner, and I was told that it had the original runner, and there was no evidence of cavitation.

Powerhouse generator floor.

This was very surprising, since all the turbine formulae at the time, indicated that the runner should cavitate. Since this was not the case, I undertook a detailed review of the literature and found an old unpublished 1948 paper by E. B. Stowger in our library vertical files that related setting to tailwater elevation and velocity through the runner instead of the usual Sigma.

View of intake house and headpond.

With the Stowger formula, the runner would not cavitate, and this discovery resulted in a series of papers on turbine cavitation, the first of which I presented at the Waterpower conference in 1989.

View of intake gate screw stem hoist.

We inspected the intake, where I found that the air vent was far too small and located in a downstream corner where it could easily freeze. I was about to mention that the vent would have to be enlarged, when I remembered my remark about cavitation, and decided to shut up, since it had been operating successfully for 60 years. Unfortunately, the air vent froze the next year, and the penstock collapsed. It was simply filled with water, and the riveted steel pipe rounded out.

This time we were fortunate to obtain the assignment and the work was completed without incident. The turbine setting was so high, that there was no access to the underside of the runner for inspection. This was remedied by cutting a horizontal hole through the concrete substructure to the draft tube cone, and adding a manhole.

Riveted steel penstock at intake.

63. MANIC 5 – 1988

In September, the CEA fall meeting was in Baie Comeau, with a site visit to the Manic 5 Dam and the 1,064MW (Manic 5-PA) powerplant being added for peaking capacity.

East bank, note surge tanks and initial powerhouse.

The main arch in the dam had extensive cracking, which had been instrumented to determine the cause. A huge slab of concrete had recently fallen off the main arch and hit the ground with such force that it started all the seismic instruments.

Fortunately there were no injuries. After much analysis, it was determined that the cracking was due to the lack of tensile strength in the concrete. To prevent freeze-thaw deterioration of the main arch, the lower half of the arch was temporarily enclosed and heated.

Cracks and seepage, main arch.

Crack instruments all wired to a recorder.

View of drainage gallery.

We had an opportunity to walk through the lower drainage gallery in the main arch. The intake is quite unique with a large red hoist enclosure. The middle "column" encloses the hoist cables, and can be dismantled to allow lifting the gate to well above water level for maintenance.

Intake and red hoist housing.

There are two large 24m diameter concrete surge tanks. The part below full reservoir level is insulated. The initial 1,592MW powerhouse is outside, on the east bank.

Turbine inlet valve gallery.

Hydro Quebec had found that it was more economic to add peaking capacity to existing dams instead of constructing pump-storage facilities.

View of underground main powerhouse.

It was an interesting meeting. I had just finished my paper on cavitation, so I checked the setting of the turbines, and surprisingly found that there would be severe cavitation. So I questioned the author of the turbine paper presented at the conference, and got into quite an argument. We agreed to continue the discussion during the coffee break, and a few engineers from HQ joined us. Eventually we could not agree, but one of the HQ engineers asked for my phone number, and two years later he called to confirm my analysis. The new powerplant can only be operated at the same time as the first powerplant, when the tailwater is high. There must have been some confusion in the specification for such an occurrence, since the 328.5MW, turbine was subjected to very detailed hydraulic model testing.

View looking down into generator stator frame, no poles attached. Machinists working on turbine shaft.

As for the main arch, when the large slab of concrete fell off, the reservoir was lowered as fast as possible down to the low supply level to reduce the load on the dam. HQ then assembled a small team of arch dam consultants to help determine the cause

One of the members was Dr. J. L. Seraphim, head of COBA in Portugal, whom I had met at conferences. He would call me when in Montreal, and we would meet for dinner at a downtown hotel. The team met regularly, about twice annually for several years reviewing the work of the teams assembled to re-design the dam and undertake testing and analysis of the cracking pattern. They could not arrive at a consensus, and I think Dr. Seraphim was using me as a sounding board for his ideas on the failure before discussing them with the team.

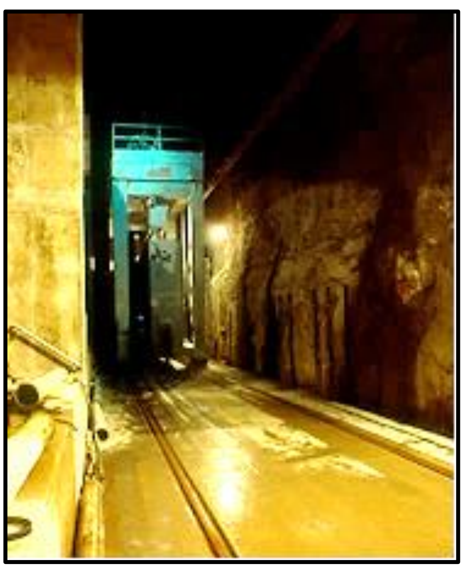
At first, it was thought that frost had penetrated about 2m into the concrete and when water slowly seeping through the concrete encountered the frost, the water would freeze causing a watertight barrier behind which the pressure would gradually build up until it was sufficient to crack off the large slab. However, this was discredited since there was no evidence of similar effects in the other arches.

View of repair bay during unit assembly.

Eventually an engineer from Harza in Chicago, Dr. C. H. Yeh found the answer with a detailed finite element analysis of the structure. Later, I worked with him on the "panel of experts" assembled by Hydro Quebec to review their work.

View of transformers in draft tube gallery.

With no tensile strength, the concrete in the main arch, on the downstream face would contract more than the concrete further inside the dam due to low surface temperatures penetrating into the concrete. The surface layer would then tend to pull away, and the first section to fail would be at the crown where there was no support. Sections at the side would be retained by gravity. As mentioned, the quick solution was to erect a large heated enclosure under the lower part of main arch. This structure was removed after new concrete and anchors were installed to maintain the integrity of the arch.



View of draft tube gate gantry in gallery.

Yes, a very interesting experience and a lesson on how meeting networking can increase your knowledge of hydro work. Unfortunately, the CEA has discontinued such meetings due to the cost.

64. JOLIETTE MICRO HYDRO – 1988

In 1983, the Canadian Government started to sponsor development of small hydro, and I was asked to join a "Technical Advisory Board" to review applications for funding research and development. By 1988, Professor Netch at the University of Laval in Quebec, had developed and tested a simple propeller turbine with no wicket gates, intended for micro hydro applications. The first application was at a remote hunting lodge near Joliette. I was asked to inspect the installation and comment on the project.

Upstream and downstream views of weir and intake screen. There is an uncontrolled low level outlet for compensation water.

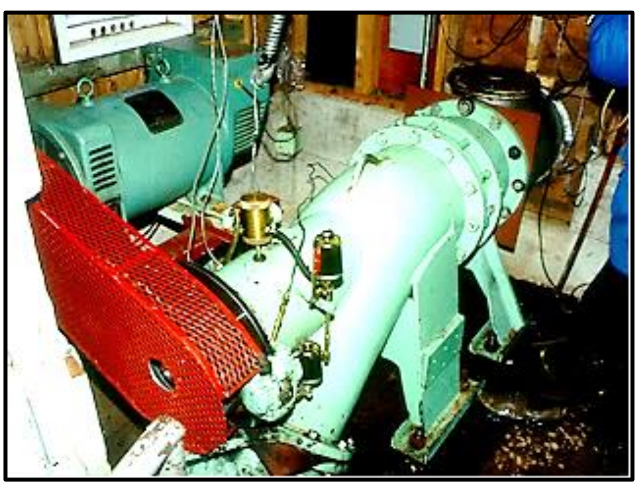
The propeller turbine was in an L-shaped pipe, with the shaft emerging downstream to a V-belt pulley powering the 3-phase generator. There was no regulation on the turbine; it just ran flat out all the time. Surplus power was dumped into resistance heaters through an electronic system which followed the power demand, maintained constant frequency with surplus to the heaters. The surplus heat was dissipated to air, but there were plans for a swimming pool alternative.

Penstock and shut-off valve.

The electricity was used in the small lodge and a few cottages, which we did not see, since they were a few kilometers away over a snow-bound road. The time was early in December, and the only way to reach the plant was on an ATV provided by the operator over about 1km of snow.

Powerhouse – an un-insulated wood shed.

On the return journey, I sat too far back on the on the ATV and it tipped up – fortunately without overturning! Just indicates the hazards of hydro site inspections in winter! See photo - I am about to fall off the 4x4!



View of L-turbine and 30kW generator.

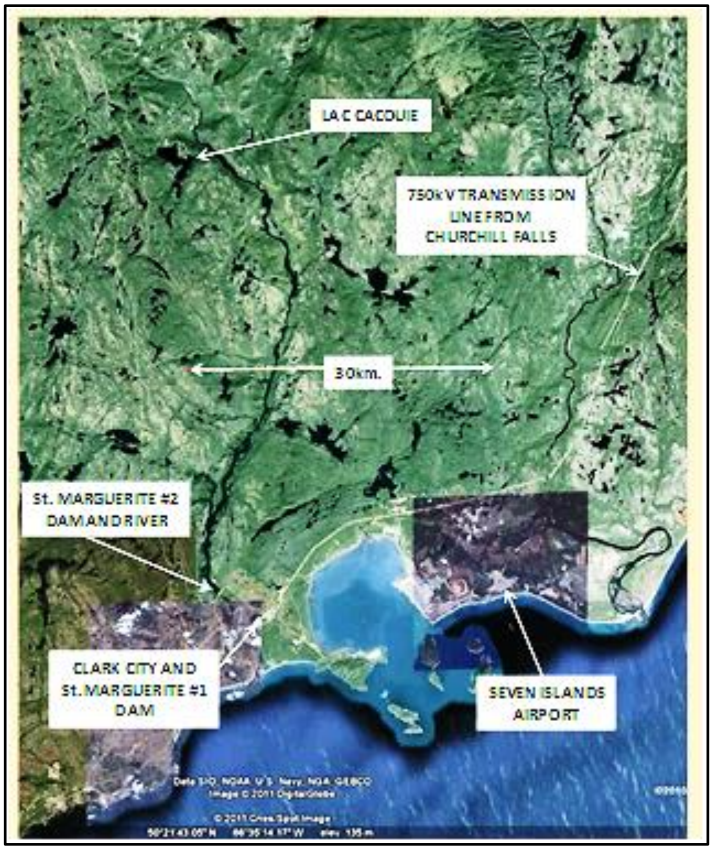
Photo by Bruce Pratt, from the National Research Council. Upended 4X4 with me hanging on back – hat in snow!

65. LAC CACOUIE – 1989

In April I had another call from Peter Payne. He had been going through the Gulf Pulp Company files in Clark City after they had purchased the company assets in 1968, and found our 1955 feasibility report on adding storage to the Lac Cacouie dam, some 60km north on a tributary of the St. Marguerite River. The lake was relatively large and could store some water to be released during the low winter flow season. He was thinking of re-activating the facility, since they needed more storage for their St. Marguerite #2 plant.

Peter Payne at Seven Islands airport with helicopter.

The Gulf Pulp Co. was based in Clark City, about 12km west of Seven Islands. It had been founded in 1918 to exploit the local timber resources, with a barking mill and hydro plant added in 1922 at the lower falls below St. Marguerite. Our 1955 report indicated that the storage was economic, so they asked us to stamp the preliminary drawings, and a year later called to complain that the dam was leaking. The drawings were never intended to be used for construction, so the foundation details were not shown. Fortunately, some silty sand and muskeg dumped upstream of the timbers sealed the leaks



Location of Lac Cacouie.

Poor condition of timber crib facing timbers.

Initially, Clark City was so isolated that the company paid their workers in script, only accepted in the company store – an illegal practice at the time, discovered when Peter opened the company safe and found several boxes of "Canadian" coins with the company name on the back. Since they fitted any coin slot machine such as parking meters, he had to call in the local police to take over the find. They were quite astonished, having never heard of the local coinage. Gulf Pulp ceased operations in 1968 when transport of the logs to their mill at Clark City became uneconomic, and the Iron Ore Company purchased their assets, including the old hydro plant which controlled the St. Marguerite tailwater.

Timber sluice gates and part of timber crib dam.

I tried to tell Peter that late winter was no time to look at the dam, but he insisted, so we flew out of the Seven Islands airport in a Bell Ranger helicopter for a quick look.

Walking on the spillway crest.

The entire storage facility had been built by the loggers in 1956 using untreated local wood harvested from the surrounding trees. Naturally, 33 years later it had rotted, and was now quite useless. The entire dam would have to be re-built using treated wood, an expensive and quite uneconomic exercise.

Of course, Peter was disappointed, and that was the end of the idea – but interesting, since I had never seen the dam. It was a fascinating look at how logging operations worked many years ago. Living in such an isolated cabin would have been challenging to say the least. Inside there was an old cast iron stove used for both cooking and heating.

Dam operators quarters.

Locomotive used to haul timber to port at Seven Islands. Source - Panoramio photo.

When we left Seven Islands airport, the helicopter pilot was flying with skids, but inflated the pontoons as soon as he saw the landing area on melting ice beside the dam.

After inspecting the remains of the dams, we took off and dropped in to look at the old abandoned powerplant on the St. Marguerite River. It was quite dangerous, since the roof of the powerhouse had caved in from excessive snow loads due to the absence of heat melting the snow.

We then flew back to Seven Islands, and the pilot noted that the right pontoon had partially deflated from a small puncture, probably incurred at the St. Marguerite plant where there was lots of debris lying around in the grass. This presented a dilemma, since if he landed with a deflated pontoon, the helicopter would tilt and the rotors would strike the ground. He discussed the situation with the mechanic at the airport, who suggested that he could build a short timber stage to support the partially deflated pontoon. However, he did not know how high the stage must be, since the pontoon was only partially deflated.

We flew around considering the situation, until I suggested to the pilot that he land on a muskeg just north of the airport with the deflated pontoon beside a strip of soil, I could get out with a pump and try to pump up the pontoon while he kept the rotors going to level the helicopter. After some thought he decided to give it a try, landed, I hopped out with the pump, and after some hard pumping for about 20 minutes, managed to inflate the pontoon sufficiently to attempt a landing. We then flew over to the airport where the mechanic was waiting with another pump, and landed without incident.

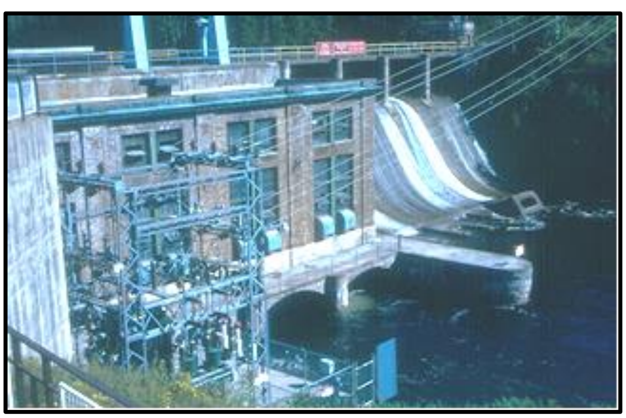
Now, Hydro Quebec has built the St. Marguerite #3 powerplant with a large reservoir upstream, completely changing the winter flow in the river, to such an extent that HQ is considering purchasing both of the lower powerplants and constructing a new large powerplant to take advantage of the head difference between the gulf and the St. Marguerite #2 headpond.

St. Marguerite #2 dam. Source - Panoramio photo. Quick-release stoplogs top left.

66. SWIFT RAPIDS – 1989

I had met John Mattinson at a CEA meeting, and he called me early in the year. He was the operations manager for Orillia Water Light and Power, (OWLP) and they wanted to install a new runner in Unit #1 at their Swift Rapids powerhouse on the Trent-Severn waterway.

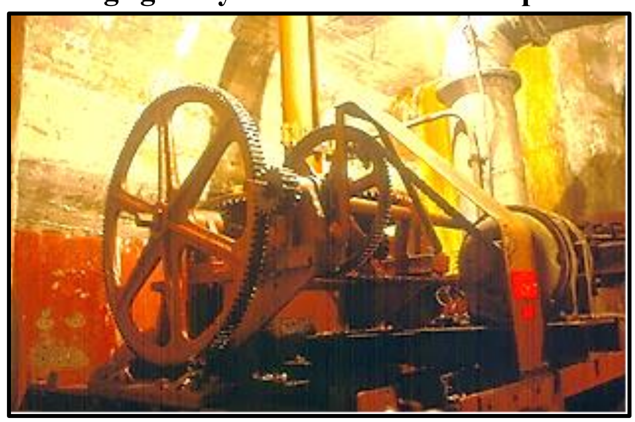
View of lock and dam at Swift Rapids.



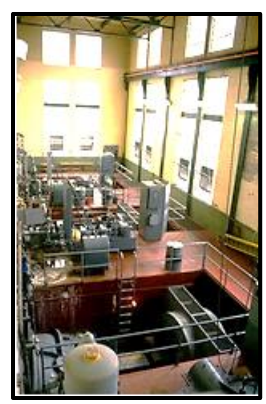
Swift Rapids powerplant.

The 1920 dam and powerhouse contained 2 small horizontal axis "tube" Kaplan units with no wicket gates, and one propeller unit with wicket gate control, all installed in 1965, after removing the original units which I suspect were the common horizontal (tin can) double-runner Francis type. There was a low level outlet in the spillway and 4 spillways with stoplogs operated with a small log lifter.

Drainage gallery and low level outlet operator.



1920 operating mechanism for low level outlet.



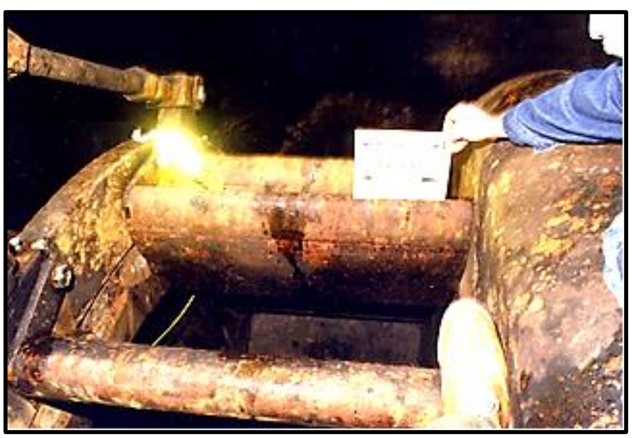
View of powerhouse interior. Propeller unit in foreground.

The Kaplan unit blades could be almost closed, requiring notches in the blades, and were used to synchronize the units onto the system, very unusual.

When I arrived at the plant in February, the cover was on at the Francis Unit #1, but was off at the two Kaplan units which were undergoing repairs to some cavitation.

Unit #1. Note wicket gate servomotor above unit.

The manhole on the cover was removed, and I lowered myself in to straddle the shaft, and with a safety rope around my waist, I inched forward to look at the old rusty runner. Water was still in the draft tube, to a level just below my legs. It still looked serviceable, but they wanted a new higher efficiency runner.



Wicket gates – note, stay vanes inside wicket gates.

Another unusual feature was the location of the stay vanes inside the wicket gate ring. The old runner and vanes were removed, and the throat ring cavitation was repaired.

Old runner.

A new runner was installed, the cover closed, and the unit was tested and commissioned without any difficulties. I had inspected the new runner when it was being machined on a 5-axis milling machine at a factory near Montreal. When I was there, I noticed other very large runners with tarpaulins over them, and asked why they were covered. I was told that they were new experimental "silent" propellers for nuclear submarines for the USA navy!

Welding and grinding out cavitated areas.

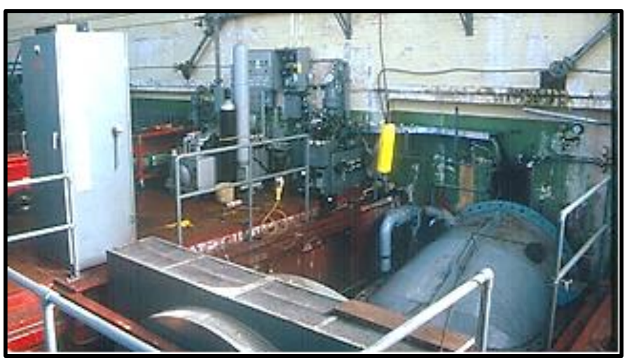
🡐 Dewatered Unit #3 – note notched blades.

Meanwhile, OWLP were working on the two Kaplan units. A new gate and hydraulic hoist was being installed, on Unit #3 since the old 1920 gate had difficulty closing.

When the Kaplan units were commissioned, I was advised that synchronization took a long time, with the governor hunting around the synchronous speed. It certainly was an interesting assignment, particularly the unusual synchronization process.

Unit #1 tailrace flow at full load.

The new runner in machine shop near Montreal.



Unit #3. New hydraulic unit for gate, top left center.

New gate hydraulic cylinder.

A year later, John asked me to look at their Minden Francis runner and provide a report, which I did. I then asked him why me, since there were several other much more qualified turbine engineers, and I was told that I was the only one who could fit through a 17-inch manhole! A fitting (pun intended) blow to my ego!

17-inch manhole at Minden turbine casing – too tight to wear a hard hat.

67. SAUNDERS – 1989-90

I had regularly been attending both the spring paper sessions and the fall site visit meetings of the CEA. At these meetings, I had become acquainted with Jack Mainprize, an engineer in the operations group at Ontario Hydro, and we often discussed issues common to our hydro work, mostly during the evening breaks.

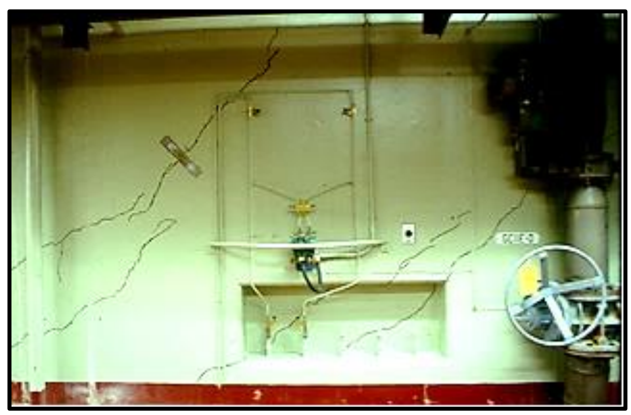
View of powerhouse roof with generator hatches.

By 1988, Ontario Hydro was encountering serious difficulties in operation of the large propeller turbines at their Saunders hydro plant near Cornwall in Ontario, straddling the St. Lawrence River. The vertical axis propeller turbine runner blades were rubbing against the throat ring which, from accurate measurements taken annually, seemed to be changing from circular to a slightly oval shape. Also, numerous cracks were slowly appearing throughout the concrete powerhouse. The staff was at a loss to explain the cracking, which seemed to be random, and even local foundation settlement was suspected. A survey company had been called in, and tried to look for differential foundation settlements in the order of 1/1,000 inch, but the technology was not sufficiently accurate, since they found that their base levels on rocks far removed from the powerplant seemed to be moving seasonally. Ontario Hydro then asked us to look into the problem.

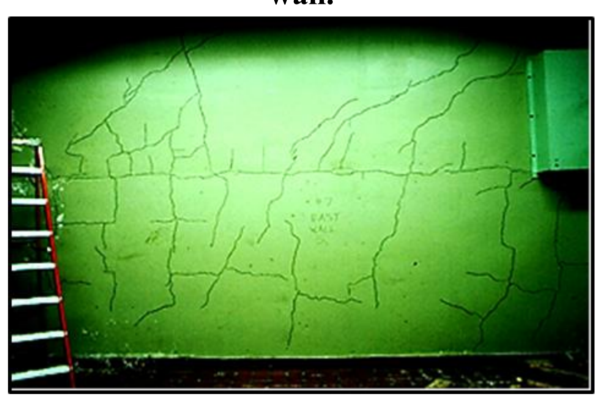
View of downstream face.

I drove out to Cornwall and met Jack Mainprize, now the Ontario Hydro project engineer for the Saunders investigation. We walked through the plant, with Jack pointing out all the cracks and mentioned that their latest theory was concrete cracking due to differential winter-summer temperatures, since the concrete powerhouse was not similar to other Canadian hydro powerplants, but instead was based on a design developed by the United States Bureau of Reclamation for southern USA weather conditions. At Saunders, there was no steel superstructure enclosing a space above the generators, instead there was a concrete roof with hatches for a large gantry crane to access the units. With this design, the concrete structure was exposed to severe temperature fluctuations on top and at the downstream side, perhaps resulting in the cracks. I was dubious about this theory, since the cracks seemed to have a pattern. So I stayed for a few days to record the crack pattern on photos by outlining the cracks on concrete walls with black felt marking pens, and by white spray paint inside the semi-spiral concrete turbine casing. Returning to Montreal, I had a draftsman draw the cracks on a set of large powerhouse drawings, and indeed a pattern emerged.

The pattern was particularly evident in the concrete casing. There, the cracks all sloped down from the left and right sides towards the upstream-downstream unit axis. This pattern appeared to indicate that there was no shear resistance in the concrete, with the cracks all following a pattern attributable to a shear failure from the water pressure on the upstream face of the powerhouse. I did check the shear stress, and found it to be well within allowable values, so the cracks were not attributable to shear stress.



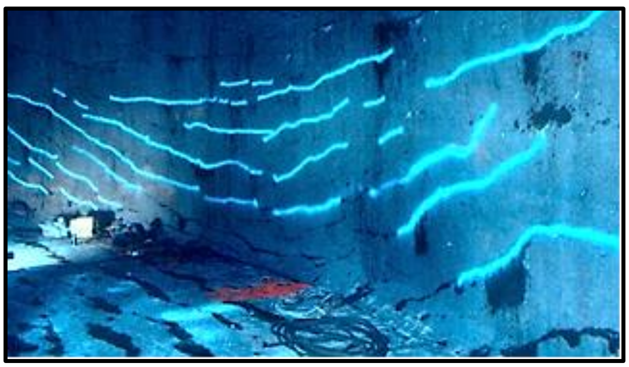
View of sloped 45° cracks on generator casing wall.



Mapwork cracking on a wall.

Cracks sloping down to middle in casing.

But Ontario Hydro wanted us to look into the temperature theory. I had a long discussion with Dr. Ken Moore, our computer expert and he agreed that perhaps there was some merit to the temperature theory. So we undertook a dual approach with me looking at the cracking to see if I could find an answer, and Ken looking at the temperature theory.

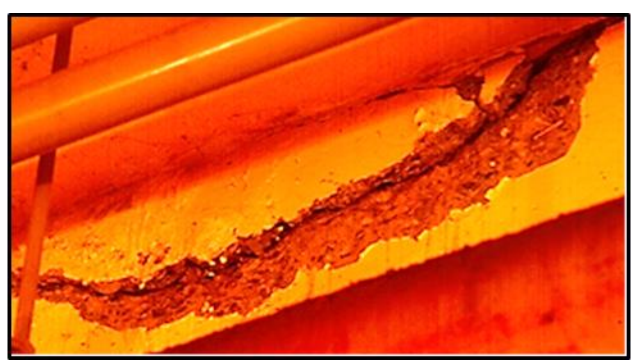


Cracks sloping down to middle in semi-spiral casing.

Me, pointing to painted crack pattern on casing wall.

Ken worked diligently, eventually requesting the purchase of a new computer with a much larger memory at a cost of over $70,000, since he found that the finite element grid he was using in the company computer was too coarse, and he needed more nodes for a finer grid. After a few months with no success, I arranged a visit to the powerhouse with Ken and Jack. The three of us were walking slowly along the generator floor, just below the cold concrete roof, with me pointing out the cracks to Ken. About half-way along, Ken stopped and said “This structure is in a condition of slow collapse!” With Jack, on one side, and me on the other, we both jumped away from Ken and turned to question him in more detail. But all he could say was - look at the evidence. However, the structure is still standing, with no evidence of collapse. For me, it was an unambiguous lesson in keeping the back room “boffins” in the back room, and away from clients!

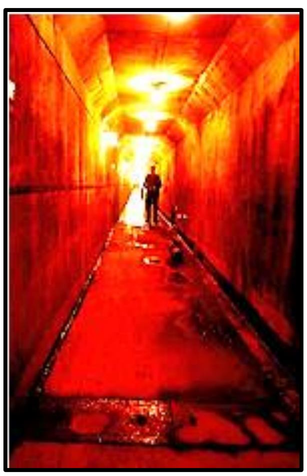
Floor at El. 174. Grey tiles replaced old cracked tiles.



Large crack in concrete beam.

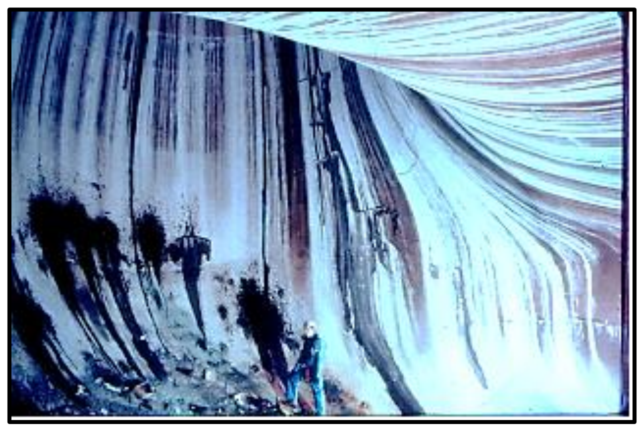
Cracking on casing El. 143, outside wall.

The work took about 18 months, with Ken eventually producing a cracking pattern on the computer which mimicked that on the structure. I was puzzled by this sudden success, and needed to see just how it was done; so I sat down with the engineer to have him explain the process. It turned out that in order to mimic the pattern; the properties of the concrete in parts of the structure were changed, by changing the Young's Modulus for the concrete at some of the 18,000 nodes in the finite element program – certainly not an acceptable analysis.



Wet drain gallery from seepage through cracks.

Meanwhile, I was struggling with the crack problem, and wrote a paper on the issue, which was presented at a CEA meeting. The paper included many photos of the crack pattern, and admitted that the solution was still unknown. By good fortune, I mailed a copy of the paper to Dan Strickland at Bello Horizonte in Brazil. Dan had worked for us about 20 years previously, and I held him in high regard; he was a deep thinker on problems, not letting them go until he had found a solution. A week later, I was woken up about 2.00am by the phone, with an excited Dan at the other end. Apparently he had read my paper and immediately realized that the crack pattern was identical to that on a similar-shaped powerplant at Moxoto in Brazil which he had worked on. He told me that at Moxoto the cracking was found to be entirely due to aggregate-alkali reactivity (AAR) in the concrete; the "concrete cancer" which causes concrete to expand very slowly over about 60 years until the chemical reaction between aggregate and alkali in the cement stops. Dan mailed drawings of the Brazilian plant showing the cracks, and papers on the problem, all in Portuguese, which is very similar to Spanish, so I could read them.

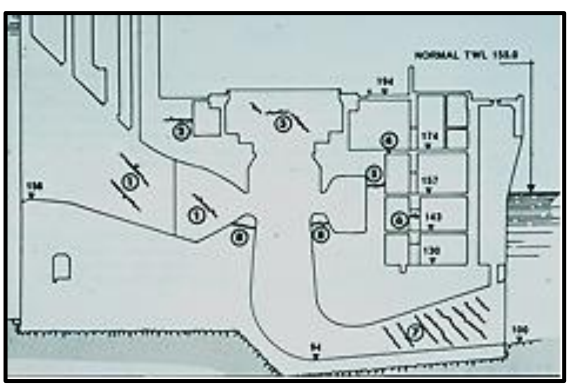


Me in draft tube, at about 94ft. level, looking for cracks – see powerhouse section →

Now, AAR is well known, but in 1990 it was a relatively new phenomenon, only just beginning to appear in many concrete structures built after the war, at a time when testing of aggregates for reactivity was still too crude to detect very low levels of potential reactivity.

My report was produced, mentioning that the problem was AAR, and perhaps there was some contribution from the temperature fluctuations. However, this was just at the time after I had resigned from Montreal Engineering and was now working as an independent consultant, having agreed to complete any outstanding work. Unfortunately, 70% of our fees had been spent on the temperature analysis, so the engineer who had taken my place insisted that the conclusions should be reversed, cracking was due to the temperature with perhaps some contribution from AAR. I resisted this conclusion, but eventually capitulated provided I was allowed to present the report to the Ontario Hydro Engineers.

In the presentation, I followed the report, but at the end I told the 20-odd Ontario Hydro engineers assembled to hear the report, that I had left Montreal Engineering, (then AGRA) and that I was now taking off my MECO hat and donning my consulting hat. I then mentioned that my own conclusions were the reverse, with the cracking entirely due to AAR, pointing out the similarity to Moxoto. At this revelation, Jack Mainprize spoke and told me that OH had also come to that conclusion, having engaged an expert on AAR to look at the structure. After this, AGRA, the successor to Montreal Engineering, was never asked to bid on Ontario Hydro work, so it just shows that honesty is the best approach.



Crack pattern on powerplant section. Levels in ft.

About 2 weeks after presenting the report, I called Jack and left a message on his phone. Another engineer called back to inform me that Jack had retired at the compulsory age of 65; had come into the office to clean out his desk a few days ago, and on leaving the building had collapsed inside the outside revolving door and died – a very unfortunate occurrence. Jack had told me that he was instrumental in getting the contract awarded to Montreal Engineering, since the mechanical group at Ontario Hydro wanted to award the contract to Acres, one of our rivals – another clear example of the value of networking at conventions.

68. ONTARIO MICRO HYDRO – 1989-90

In February of 1990, Tony Tung asked me to have a look at two micro hydro plants where CANMET had contributed to the development. They were near Almonte, and owned by local farmers. Both had identical turbine-generators with 630mm 4-blade propeller runners built by Canadian Hydro Components (CHC) of Almonte, just south-west of Ottawa.

The first plant was at Stewart where a 225kW unit operating at 12.8m head was used to provide electricity for the farming operation. All we could see was the small powerhouse, since the dam and intake were buried in snow.

4-inch Rodney Hunt 102mm diameter Francis runner. 12Hp at 18.3m head flow 0.0613m3/s. Estimated efficiency at full flow about 81%.

Bob Sproule (left) at the Stewart plant.

Both powerhouses were timber-framed insulated sheds still under construction. The windows were not yet installed, and at Barrie, the aluminum cladding still needed to be placed. The foundations were reinforced concrete. Both developments had been well executed with no frills, at a bare minimum cost.

Interior of the Stewart powerplant.

The only comment I could make, was that the snow load on the back of the sheds appeared to be high, and that some bracing might be needed if there was any signs of deflection. CANMET was partially funding such developments in the hope of promoting micro-hydro. However, it is unlikely that they will be economic within an area provided by utility power, due to the low kWh cost of electricity, unless the utility pays a premium for "green" power, as is currently the case. They will only be economic in areas where there is no utility energy, or in remote areas where the cost of diesel generation is high.

View of Barrie mini powerplant.

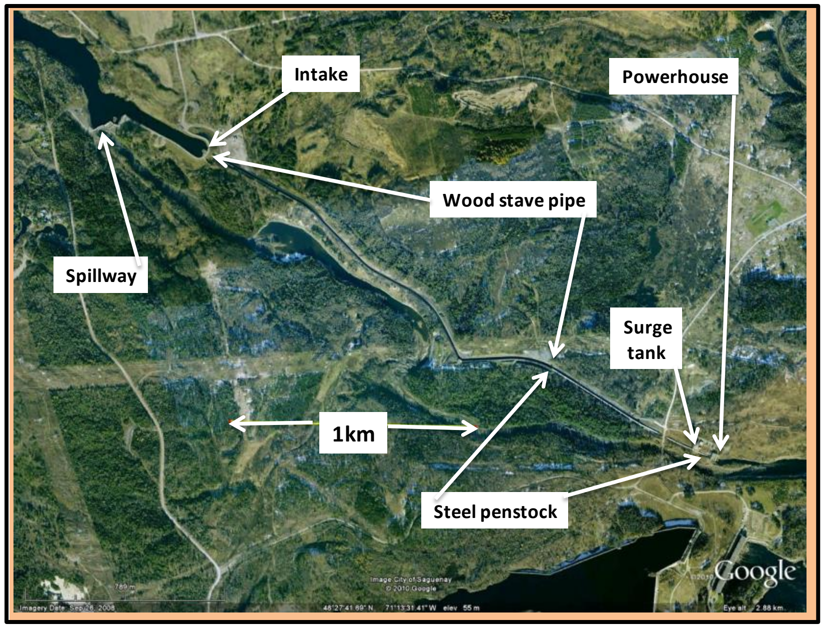
View of generator and turbine. Lever controls wicket gates. Turbines are identical in both plants

Mike Dupuis, the entrepreneur owner of CHC had a very small micro-micro turbine on his desk as a paperweight. I took a photo of it, (previous page) and have used the photo many times to illustrate the similarity between large and small Francis turbines.

69. CHUTE WILLSON – 1989-90

By 1989, there had been a complete change in operators and plant managers at the Abitibi-Price plants at Chute Willson and Jim Grey designed by the company in the 50's, and the original staff had retired. The new staff asked for someone to look over their operations, provide an opinion on their maintenance procedures and look at some suspected AAR, so off I went.

Sluice piers with AAR.



Chute Willson project location and layout.

I inspected their facilities at Chute Willson three times, mainly to see how the AAR cracking was progressing.

Spillway at Chute Willson. Note flap doors on sluices.

They were interesting trips since they had some unusual design details on their structures. The spillway had downstream wood flap doors on the sluices, so that they could be heated in winter. They worked very well, and were not even lifted clear of the water when the sluices were discharging!

One structure I wanted to see was the wood stave penstock. At 18ft in diameter it is the largest in the world. It was built with treated western knot-free pine, now unobtainable. It was in remarkably good condition, but will pose a problem when it needs to be replaced in about 20 years, since wood is now too expensive; steel will have to be used instead.

Wood penstock.

The 33-year old stoplog hoist on the spillway was still in good condition, and only needed some paint to counter the rust.

Stoplog hoist.

The surge tank had been recently painted, and was in excellent condition. However, I had a close look at the bracing, which tends to slap together at the cross-overs and cause wear notches in the rods. I could just see some wear notches beginning to form, but nothing to be concerned about. Another concern was the tank design, which was undertaken when building and earthquake codes were not as severe as they are now. Designing the tank for current earthquake condition would be difficult and expensive to retrofit, so the risk will have to be accepted

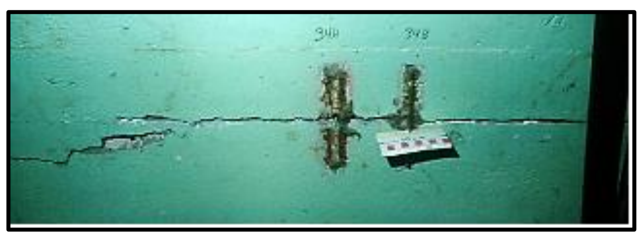
Surge tank

The lower portion of the penstock is steel, where the pressure is too high for wood stave. It has ring girders for support, but without the normal rockers at the bottom, to allow for expansion and contraction. Instead, there are simple flat steel plates with no anchors. This design saves cost, but the danger is that during an earthquake, the pipe could conceivably slide off the concrete pier. The plant is in a relatively high earthquake zone, and since there have been a few earthquakes, a few of the supports indicated that the girders had moved sideways. Restraining steel angles had been added to restrain the movement.

Mapwork cracking on generator casing.

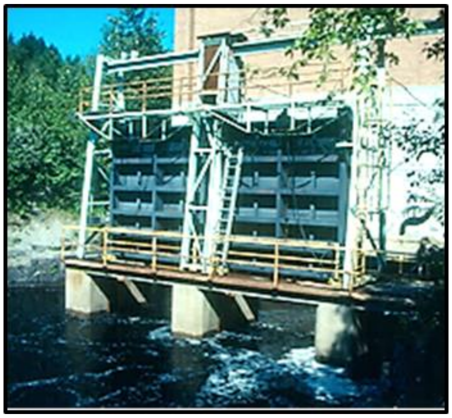
Ring-girder supported steel penstock.

There is only one unit in the powerhouse, so the concrete is free to expand in all directions; hence the unit is still on center. However, the cracking pattern around the unit was such that the operator described the effect "*as if a giant hand was trying to twist the unit out of the concrete!*" This effectively ties in with the Saunders crack pattern, since there is a twisting force in the powerhouse from the torque reaction from the generator stator. Hence shear stresses, magnified by the tension in the concrete from AAR will result in a cracking pattern imitating excessive shear.



Large crack in generator support concrete.

The plant operators had glued glass slides across the larger cracks, but they soon broke. I advised them to continue to replace the slides, and record the break dates, to see if the movement was due to AAR or seasonal expansion and contraction. There was nothing more to be done, other than monitor the cracking, since there is no cure for AAR.



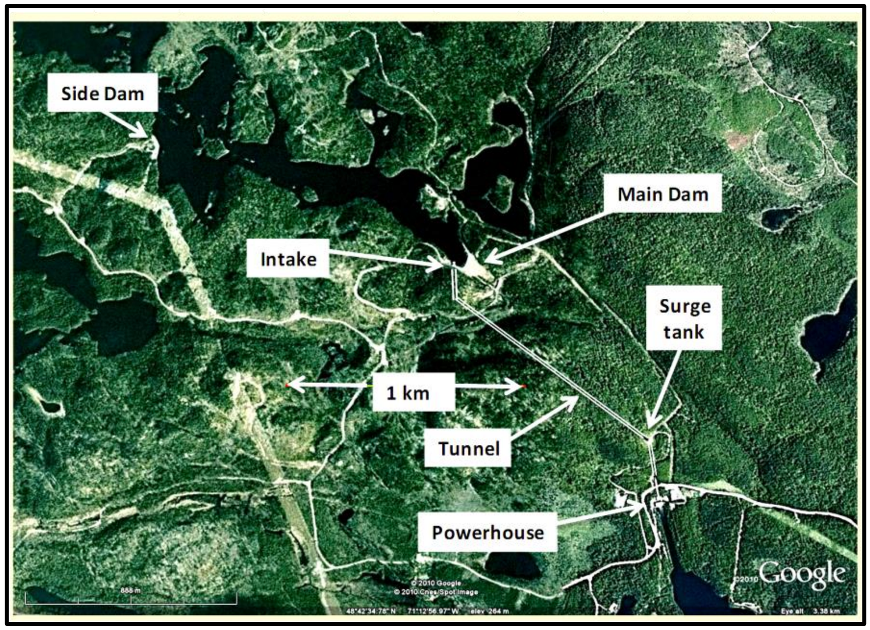
Downstream face of powerhouse and draft tube gates.

On the whole, another interesting trip. I told the staff that maintenance was excellent, and to just keep monitoring the glass slides, to see if there is a decrease in the rate of breaks, indicating decreasing reactivity as the chemical process concludes. AAR usually lasts about 60 years before the reaction stops.

Powerhouse interior

70. JIM GREY – 1990

I also inspected the Jim Grey development on the Shipshaw River at Lac Lamothe. It had been commissioned in 1952, the year I joined Montreal Engineering.



Jim Grey location and project layout.

The river was so well regulated, that there was only a small spillway which I did not see. There was a small side dam reached by boat from a launching area about a half-kilometer north of the intake on Lac Lamothe. The side dam was covered in vegetation and obviously was rarely inspected.

We reach the side dam.

Downstream slope of side dam.

I told the operator that the vegetation needed to be removed, so that any seepage or slope instability could be detected, and this was done the next year.

Side dam crest – mostly hidden among the treas.

View of intake from north side.

View of intake from south side.

The intake was a neat structure with the hoist fully enclosed within an insulated house. There was an air vent on each side – very conservative.

The main dam is at Chute Georges and the intake dam is really another side dam. It was also covered with bush, but no trees. Again, I told the operator that the vegetation needed to be removed. The spillway is at Betsy Dam just west of Lac Lamothe village, and the main dam at Chute Georges is further west; I did not see them.

Downstream face of the main dam.

There is a 1.2km long tunnel to the heated surge tank which has a wood casing for frost protection. It was so dry that it now constituted a fire hazard should there be any vandalism. Again, I had a close look at the bracing, and could see evidence of notching just beginning to form. After the tank, the tunnel continues to an exposed steel penstock.

Welded steel penstock.

← Surge tank with wood casing.

The saddle supported steel penstock was interesting. The sliding expansion joint was at the top, but the upper three saddles had ring girders tack welded to the pipe. Presumably, there was some leakage at the expansion joint if the pipe sagged if there was insufficient pressure, and the rings had been added to maintain circularity.

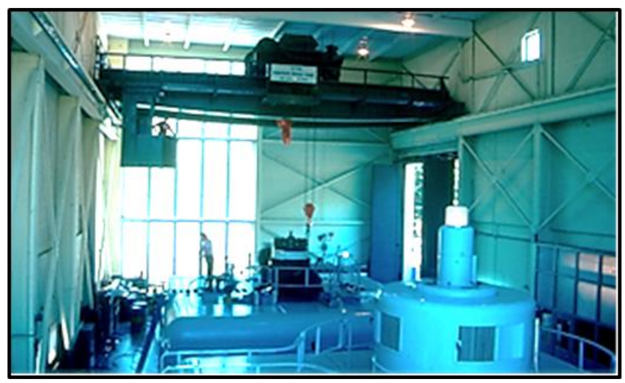
Saddles with rings.

Penstock saddle – no ring.

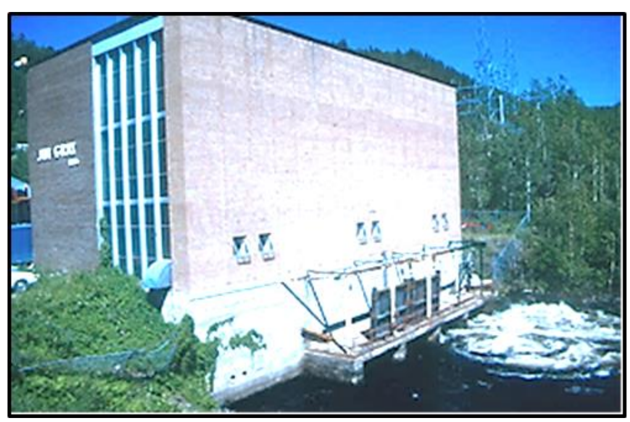
Inside the powerhouse, I found one of the last riveted joints to be made in Canada, at the butterfly valve. Just shows that welding was a new technique at the time.

Butterfly valve.

The powerhouse was quite conventional with two vertical axis Francis units. About the only unusual feature was the main door, a bi-folding affair instead of the more usual roll-up door. Again, a most interesting trip, and the only serious deficiency, the surge tank casing; there have been fires at similar wood-cased tanks.



Views of powerhouse interior and exterior.



Views of powerhouse interior and exterior.

71. RETIREMENT? 1990

Ezra Cohen, Bill Matthews, me and Bob Thicke, in my office, 1983.

In April of 1990, a company called AGRA purchased Montreal Engineering from Perini USA. The company had been in financial difficulties since about 1980 due to purchase of overvalues assets, and a turndown in hydro work, and had looked around for an investor. The Perini construction company in the United States had purchased a controlling interest about 1984, with the objective of starting a design-construction business, but nothing developed, and they remained a silent partner. Then Perini themselves got into difficulties when Trump paid for the construction of the Trump Casino in Atlantic City with shares instead of cash. Perini then decided to sell MECO to raise cash.

The first action by AGRA was to cut costs, and they started by throwing out all our foreign drawings to save on rental space. I only found out when I was told to have a look at the docking bay in the basement of the building, where they were being loaded onto a truck. I had relied on the foreign drawings when replying to technical questions from old clients. They dated back to 1913, and in many cases they were the only record of the equipment since the utilities had lost their own set. I immediately asked John Feeney, the office manager to halt the shipments, pointing out that at least we should offer our clients the option of purchasing them, to no avail.

Then in May, Jim Watson from the office next door asked me if I had seen the latest organization chart. I replied negatively, since there had been a steady stream of new charts over the previous years as the company tried to downsize, and so long as I remained in my position as Vice-President Hydro, I was not too interested in the changes. About a week later Jim asked me again at lunch in a local restaurant which we often frequented, and again I said no. Two weeks later Jim was passing my door, came in and said I really needed to look at the chart.

So I decided to have a look. I searched for my name in vain, and my blood pressure slowly increased to the point where I just had to go home and think. Vera was surprised to see me home so early, so we had some tea out on the patio, and I mentioned that I had lost my position as VP hydro. Vera thought about it for a while, and then suggested that perhaps the time had come to retire, something I had been vaguely thinking about.

Next day I asked personnel to let me know what was in my retirement fund, called a financial advisor and asked about annuities, and was told that since interests rates were over 12%, an annuity could be purchased for very little cash. By purchasing an annuity with half of my money in the fund, and investing the other half, I found we had more than sufficient to live off the income. So on Vera's old manual typewriter I slowly typed out a resignation letter.

I left the letter on the desk of the Montreal office manager the next morning, giving the company a month notice. I returned to my office to wait for John's phone call which arrived about an hour later. Of course, when we met, John wanted to know why, and I asked him to look at the organization chart for my name. A minute later he stated that there must be a mistake, to which I replied that mistakes like that are just not made, and I was leaving.

My first home office – no computers or fax, 1990.

Basement office 2008.

However, I did have several unfinished projects, so I told John that I was willing to return on an hourly basis, until the work was completed. John readily agreed to this until I told him my rate would be three times my current take-home pay, which he vociferously declined. Three weeks later, he called and told me the rate was acceptable, and to come on in. I worked intermittently for the next three years until all the projects were completed.

My first home office was in an upstairs bedroom until we had the painters in to do the dining room below. The painter looked at the ceiling, and asked what was causing all the cracks. I immediately realized that my heavy filing cabinets were overloading the floor, so I moved the office down to the basement where there was much more space.

I found that my retirement decision was correct. At the end of 1990, AGRA decided to close our large technical library. Some of the books were moved to the small AGRA head office library in Oakville, most of the journals were donated to McGill University, some to the National library in Ottawa, and the staff were invited to take anything that remained. I managed to obtain several old hydro handbooks and all the hydro "vertical files"; eight large drawers full of technical papers and brochures accumulated since about 1930, a real treasure trove of hydro information.

The "vertical files" were unique. Any engineer could open a new file on any subject and place any useful material into the file. The file name was registered by the librarian, but not the contents. If you needed information on say gates, you could go to the gate files and peruse the contents. The librarian later told me I was the only one to use any of the hydro vertical files, so when the library closed, she called me to come in and pick up the contents. They required two trips in my car to get them all home. At home, I threw out all the old obsolete brochures, cutting the volume to about half. They now occupy 4 extra-long file drawers, with additions I have made over the last 25 years. They contain many old technical papers now difficult to find.

I continued to attend conferences, and passed the word around that I was accepting assignments, but no detailed design work, as I put it "don't ask me to design reinforcing!" Much to my surprise, the work started to come in, and I was soon turning down half the requests.

For my home office, my first purchase was an electric typewriter; the second being a telephone with a built-in answering device with a 1 hour tape and FAX machine. I used a local secretarial service for the first 8 years until computers took over the task, and I obtained one.

Another view of basement office, 2008.

My computer experience was interesting. I was wary of the devices, since my experience had not been too positive, with the disasters at Topsail and Saunders. However, our eldest son Howard was working for Hewlett Packard, and was provided with a new computer every three months, since the technology was changing so fast. In 1998, he presented me with an old computer, and told me to play with it, and if it was destroyed, he could always get another. I read the manual, and decided to try out the "Write" program. It proved to be very easy to master, so I gradually took over the secretarial work, since I was wasting time going back and forth with changes to the text on reports.

In 1999, with the "Millennium bug" scare in full swing, the Federal government offered a 1-year write-off on any new computer equipment, so I purchased a laptop, scanner and printer. I was working with an Ottawa engineer Kearon Bennett on several projects, and we often met to discuss the work. He showed me his laptop and how he was developing EXCEL programs to simplify the tasks. I had looked at EXCEL, but had not done anything with the program. Kearon admonished me for this, and showed me how to enter formulae. From some books on Windows programs, I soon found that EXCEL was simple to use, so I started to write programs and eventually developed several hydro design-cost programs with funding from CANMET. They can now be purchased at www.hydrohelp.ca

Courier delivery - overloaded with work, 2002!

Now, I have an array of equipment, including 2 desktops and 2 laser printers with Windows 7, a hard drive for backups, a slide scanner and a regular scanner, 2 digital cameras, also an old laptop with Windows XP for PowerPoint presentations. Two large backup batteries for emergency shut-down when the power is off, and lastly, a photocopier. Also an HDMI cable connection to a 48 inch high definition TV with remote keyboard and mouse for looking at large areas of an excel program, which I rarely use.

Quite a change in 25 years!

Office in my apartment in a retirement home, 2016.

72. CRAZY CONCEPTS.

Time to add some humor to these memoirs.

When I was with Montreal Engineering, we would get the occasional phone call from a muddled inventor. They invariably asked for the president to attend a secret conference where they would describe their latest invention to produce hydro power at a remarkably low cost. Con Mulherin, our president would call and ask me to attend in his place. We received two such calls, one about 1965, and the second about 20 years later. Also, I had a conversation with a dentist on his hydro concept while attending a conference at the University of Minneapolis.

The first meeting was at the Windsor Hotel in Montreal, where a conference room had been reserved by the Hamilton Valve Company. At the door I had to sign a secrecy agreement form drafted by a local lawyer. At the podium there was a Mr. Hamilton, and the audience consisted of about 20 engineers representing all the local consulting companies.

Mr. Hamilton started off by admitting that he was not an engineer, but had extensive technical experience in the instrumentation field. At the time, we were working on a pre-feasibility report on development of tidal power in the Bay of Fundy, in conjunction with Shawinigan Engineering, Acres International and a professor from Bristol University in England with experience in modeling the tidal effect of the proposed Severn barrage. The professor was modeling the effect of the project on the tides around the eastern seaboard as far south as Boston – quite a complicated task, which was a function of the Coriolis Effect, gravity, the moon and mass energy in the flowing water. Unfortunately, the model predicted an increase of about 6 inches in the tide at Boston, not at all acceptable due to the low airport runways at Logan, just above sea level which flooded at high tides when the atmospheric pressure is low.

Mr. Hamilton had heard of this, since there had been a few articles in the popular press. The articles mentioned that the power would be produced by low-head reversible Kaplan turbines as later installed at the experimental plant at Annapolis Royal.

Anyway, Mr. Hamilton, after a few preliminaries on how tidal energy was developed, proceeded to inform us that we had selected the wrong type of turbine, only suitable for low heads. He stated that the correct type was a high head impulse unit, located 1,000ft below the dam, where the energy produced from each cubic foot of water would be about 30 times that obtainable by the Kaplan units at the dam. He then went on to describe the new “Hamilton valve” that would be used to divert the waters down the vertical pipe to the underground impulse units.

The valve can be described as two large cubes, one on top of the other, raised and lowered by a cable hoist. The top cube would be open on the ocean and reservoir sides. The bottom cube would be open on the reservoir side and the bottom. With the valve lowered, the top cube would be in position, and the water would flow through to fill the tidal reservoir. After the reservoir was full, the cubes would be lifted to put the lower cube in position, and the reservoir water would then flow down to the impulse turbines.

Of course everybody wanted to know how the water would then get back to the surface. Mr. Hamilton said he had anticipated such a question, and produced about 15 large detailed drawings of two alternatives.

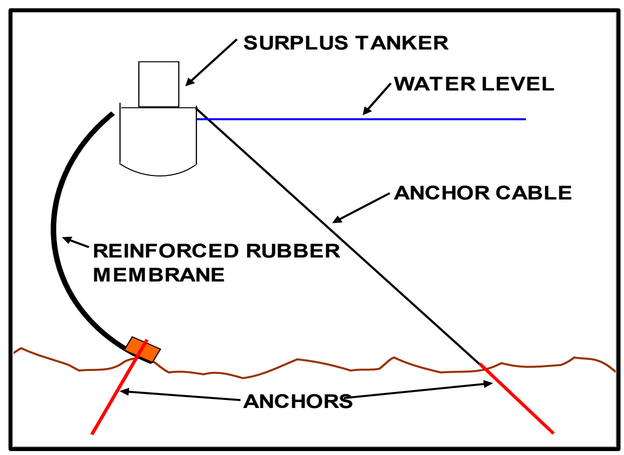
Where the land was lower (? what! the Dead Sea?) than the tidal water; the discharge from the impulse units would simply flow out to the lower land. Now, Israel is looking at the concept.

Where the land was higher, the water would be pumped up using part of the surplus energy developed by the impulse units, remembering that they produced 30 times the power obtained from the surface Kaplan units.

An engineer sitting next to me started to mention something about the conservation of energy, but I told him that any argument would be useless since it was obvious that Mr. Hamilton did not have any concept of the physics involved with the idea. We all left, and on walking out the door past the lawyers, I mentioned to one of them that they should ask for a certified payment check before leaving.

I don't know where Mr. Hamilton obtained his financing, since a considerable sum had been spent on renting the conference room, producing the detailed drawings, and on lawyer fees. But what astonished me, was the extent of work undertaken without involving an engineer at an early stage!

The second invention was by an elderly retired McGill professor of civil engineering. He had rented a small theatre in Montreal for his lecture, and had the usual lawyer at the door with a secrecy agreement form. Again, there were about 20 engineers present, and I knew most of them. However, this time, I thought the professor was onto something until I spotted the flaw in his reasoning.



Concept – one-inch dam.

The professor started the lecture by describing a normal embankment dam, with upstream and downstream slopes of about 2.5 in 1. The base width of a 100ft high dam, would then be about 500ft. His invention allowed the development of a 100ft high dam only 1 inch thick! Of course, this got our attention.

The dam would consist of a rubber membrane reinforced with steel cables, anchored to the rock at the bottom, and held up by surplus oil tankers floating in the deep water formed by the dam. The tankers would be held in place by their anchors set into the rock foundation. The professor had a concept sketch showing the arrangement, and I thought that this was so simple, why it had not been thought of before – there must be a flaw in the concept.

To counter this, the professor mentioned that he had already built a model of the concept in his bathtub, and it worked! He passed around a photograph of a black plastic sheet dam taped to the bottom of the bath, and held up by strings across the tub and to the sides, with the ends retained by duct tape. Height of the dam was about 8 inches.

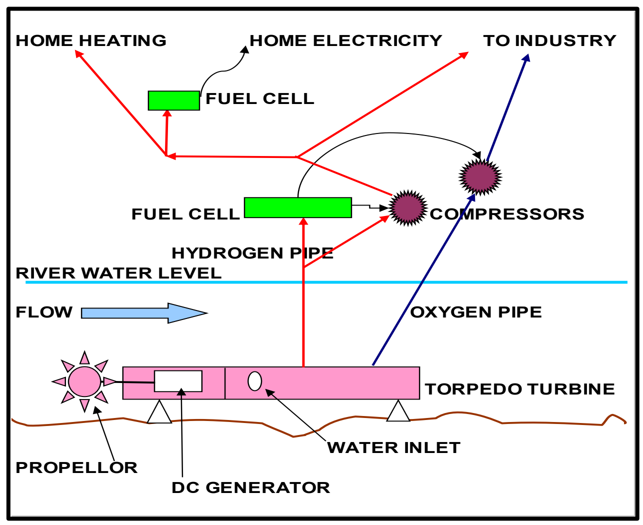
While the professor droned on about the benefits of the concept, I made my own sketch, added the force lines, and saw that the forces could easily be calculated based on the anchor line being at 45 degrees to the horizontal. After a few minutes of calculations, I found that the displacement of the tanker could be calculated, and from this, the size of the tanker. The result indicated that the tanker displacement would be equal to the depth of the water!

I then waited for a pause in the professor's dissertation and politely asked if he was open to questions, and he readily agreed. I then went through my analysis, presenting the conclusion on the tanker displacement whereupon the professor asked what principle had I used to calculate the displacement, and I replied "the Archimedes principle", and then the professor said – "who was Archimedes?"

At this, everyone got up to leave.

However, there were some professors from McGill in the audience, and they pointed out that if the tankers were anchored instead with horizontal cables to the shore, the result could be different. I agreed, but reasoned that the forces involved would be so large as to make the concept quite uneconomic. Nevertheless, they applied to CANMET for a $10,000 grant to undertake some computer simulations, and despite my objections, (I was on the CANMET advisory committee) they were awarded a contract. Their report indicated that the cable size would be well beyond anything currently available, and number of cables required would make the concept uneconomic when compared with an embankment dam, as I had anticipated.

Later, I found out that the professor was in the early stages of dementia, but being so renowned, nobody had the courage or inclination to question his ideas.



Torpedo turbine hydro concept.

My third experience with crazy concepts occurred when I was helping John Gulliver with an annual hydro seminar at the University of Minneapolis. I would have lunch at the Faculty Club, where there was a table set out with instructions that all present had to introduce themselves, and participate in any discussions. I always sat there since the people I met were invariably interesting.

On one of the lunches, there was only one other diner, a dentist from Ohio, upgrading his skills at the dental school. On hearing that I was a hydro engineer, he started to describe his idea of completely transforming the hydro industry through the use of "torpedo turbines". These devices would sit on the bottom of rivers, and would consist of a long tube with a propeller at the upstream end powering a direct current generator, so that there was no need for speed control. Downstream of the generator there would be a watertight bulkhead. Small fins on the outside would direct water through a screen into the tube, downstream of the bulkhead where direct current from the generator would produce oxygen and hydrogen from the water. The gasses would be collected in separate chambers at the top of the tube, and piped to the shore.

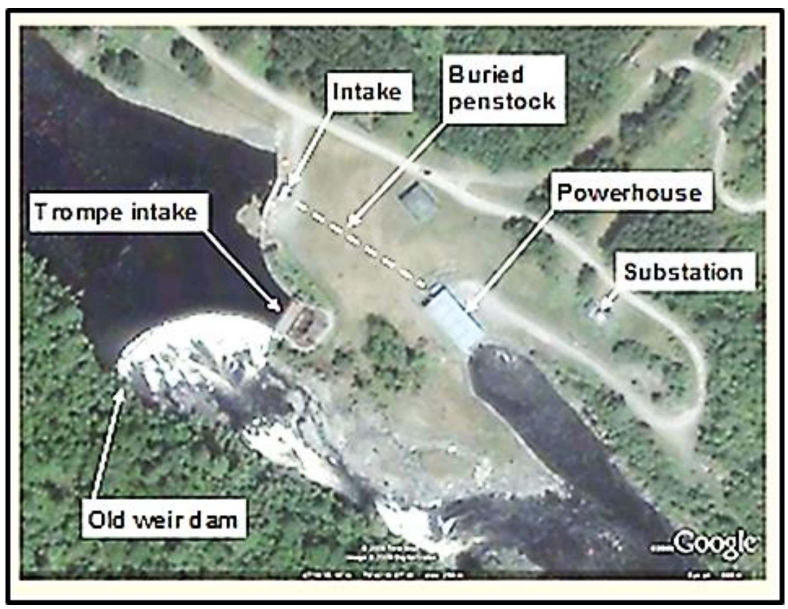
On shore, some of the hydrogen would be used in fuel cells to generate electricity to power compressors for the gasses. The oxygen would be compressed into standard oxygen cylinders and sold to hospitals and welding suppliers. The remaining hydrogen would also be compressed and piped through small-bore gas pipe to homes and industrial plants, thus eliminating the requirement for unsightly and expensive transmission lines.

At the homes, the hydrogen would be used for heating and in small fuel cells to generate electricity to power appliances and for lighting.

The dentist was convinced that the whole system will be much more energy efficient than having to use transformers and transmission lines, and the cost would be a fraction of conventional hydro due to the elimination of dams and reservoirs! I still don't know whether the doctor was pulling my leg, or whether he seriously believed in the concept!

73. RAGGED CHUTE – 1991

The first significant work that I undertook as an independent consultant was for Clary Gatien, a retired powerline contractor in Northern Ontario, who had decided to develop a small hydro plant at Ragged Chute near Cobalt. He negotiated for the supply and installation of all the equipment with Sulzer, asked a friend Bob Cumming, a retired consultant to do the civil design with help from a retired draftsman, and asked Sulzer where he could find a hydro consultant, since Bob had only worked on industrial buildings. Sulzer gave him my phone number, and he called me, the start of an interesting 2-year contract.



Google Earth image of site with structures named. Photo taken when no flow through turbine.

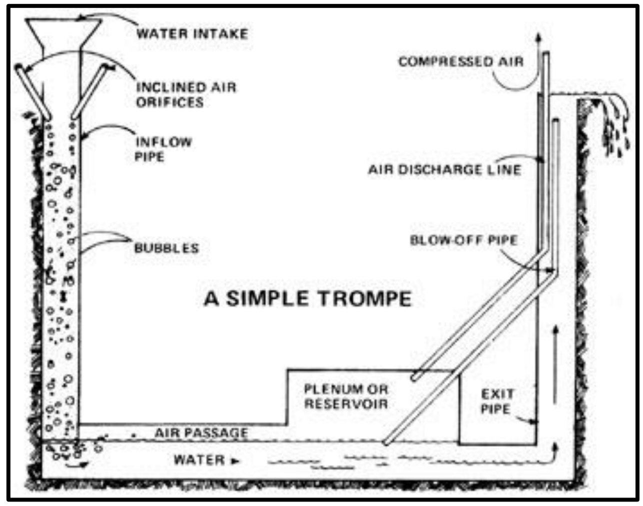
I flew to North Bay, rented a car and drove to the project site, meeting Clary at a house he had purchased about 3km from the powerplant, where he had converted the living room into an office. Clary undertook all the project management, placing orders and contracts, and exerted control over site supervision, where his skills as a contractor ensured a very efficient operation.

Downstream view, powerhouse and tailrace.

I was very impressed with his approach to the work. He had spent the previous year drilling numerous holes to find the rock level at the intake and powerhouse, so he knew where the foundation was located. The site was at an abandoned air compressing plant, (known as a Trompe) where the fall of water had been used to provide compressed air for a nearby underground cobalt mining operation. Just enter “Ragged Chute air compressor” into Google and a description of the plant will appear – one of only 4 built world-wide. The compressor is unique in that it has no moving parts.

Trompe blow-off.

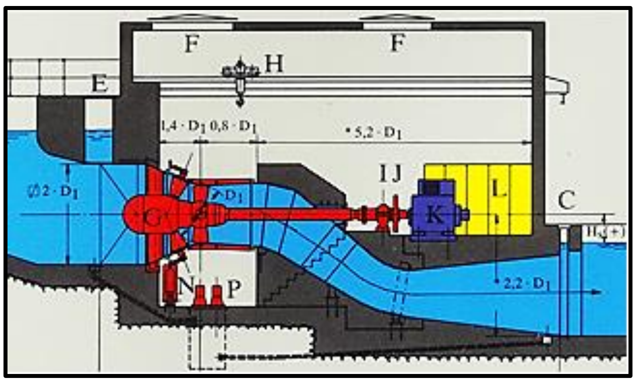
Clary had come to the conclusion that the only profitable way to develop small hydro was to keep the consulting work and the engineering staff to a bare minimum, a decision with which I thoroughly agreed.



Trompe section.

He had Sulzer, a turbine contractor, develop a basic layout for the powerhouse, and I reviewed it, suggesting some minor changes to facilitate equipment access. Clary added space for an office complete with a full bathroom, something rarely included in a small powerhouse – but it proved very useful during construction. I prepared a layout for the intake, and Bob undertook the detailed design. I also designed the penstock, and had the Agra staff at my old office prepare drawings and basic specifications, which was accomplished in a few days.

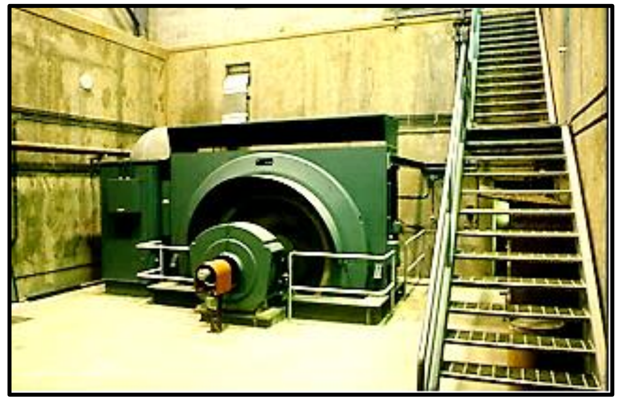
The powerhouse contained a horizontal axis Kaplan turbine and 9MW generator, and the entire project was built at a cost of less than $12M. For comparison, Ontario Hydro re-developed the Big Chute plant near Orillia, only a few kilometers away with exactly the same equipment, a slightly smaller and longer penstock and a similar intake, at a cost of $44M! The higher cost at Big Chute was partly due to the "large project" approach used by Ontario Hydro. I was told by Sulzer that when they had to discuss the work on Ragged Chute, Clary was the other only person contacted, and Clary would call me to discuss any changes. But for Big Chute, there were usually 22 or more Ontario Hydro and consulting staff at the meeting! A change in the elevation of the Ragged Chute powerplant illustrates the more simple approach used by Clary.



Schematic section through turbine-generator. Source – Bell brochure # 21.04.30 KB 84-60e

Intake house, powerhouse roof middle left.

When the foundation rock was exposed at Ragged, Clary found that by removing a few more cubic meters in one corner, the powerhouse could be lowered by 0.6m. He knew that this would improve cavitation performance, and this meant that a few more kilowatts of power could be produced without changing the equipment. He called me in the morning, I worked out the extra power for the same cavitation coefficient and the benefits, discussed the higher output with Sulzer, and called Clary back just after lunch, indicating that it was a good idea.



View of generator floor.

Work started immediately to remove the rock, and this was accomplished by the evening. The whole change had been made within one day. If it had been an Ontario Hydro project, there would have been meetings, detailed assessments of costs and benefits, more meetings, change orders and so forth, and the whole adjustment process would have taken several months, far too long to be of any use, since the contractor was on site, excavating.

The only other professional required was a geotechnical engineer to provide advice on slope stability problems encountered during excavation for the pipe.

I visited the site several times to provide some advice, and for a last time when severe vortices were discovered at the intake when the plant started operation. This was particularly puzzling, since I had derived the hydraulic formula for vortex prevention in 1970, and had it published in a paper in Water Power. However, when I arrived at the intake, I found that the trash-rack bars were mostly blocked with a large sheet of geo-textile fabric which had drifted off the cofferdam when it was being demolished, interfering with the flow and producing the vortices. The fabric was removed, and the vortices disappeared, much to my relief.

After the success of Ragged Chute, Clary continued to search for small hydro sites in Ontario, finding several, but when I worked out the cost, they unfortunately proved to be only marginally economic. He eventually found one, the re-development of a powerplant within a small town, but the numerous permits required by many jurisdictions and other environmental concerns proved to be insuperable.

The site and design staff. Jim Gordon, Dean Gatien, Frank Kirwan, Claire young, Clary Gatien, Bob Cumming, ? and Kearon Bennett.

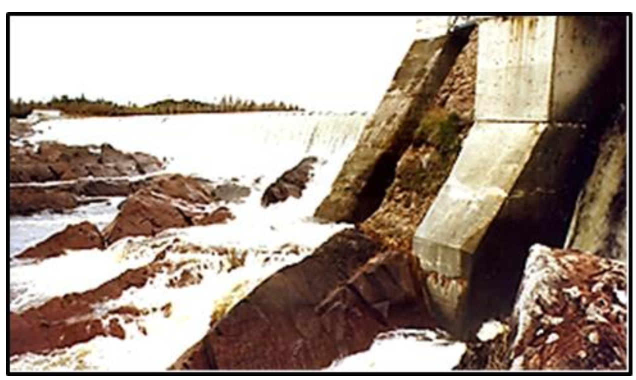
Funding for the work was provided by a bank, and they appointed Kearon Bennett, a small hydro consultant and owner of a micro-hydro plant, to visit the site each quarter to check on progress and costs. I got to know him, and later we worked together on many projects. A few years later, I used the Ragged Chute experience in several papers on how to approach small hydro development. Now, with use of the internet, many such developments are being built with the engineering undertaken by independent engineers and draftsmen working from their homes.

74. GRAND FALLS – 1991

In May, I had a call from Dave Johnson, the head of the management department at AGRA, asking if I could help in the evaluation of the Abitibi hydro facilities in Newfoundland, and I advised that I could. Apparently, Abitibi-Price, a large Canadian paper company was in financial difficulties due to the decreasing demand for newspaper, and they were considering selling their hydro plants in Ontario and Newfoundland.

When the 40MW Grand Falls started operating in 1911, the nearby mill produced paper which was transported by rail to Botwood and exported to England. At Bishops Falls, the output was 22MW from 9 units, mostly used to power grinders to produce pulpwood which was pumped through a 14km pipeline to the mill at Grand Falls.

View of Grand Falls weir dam and two sluices.



Weir dam and sluices.

In Newfoundland, they had three plants at Grand Falls, Bishops Falls and at Badger, all in central

Newfoundland. The task would be to evaluate the facilities based on the average annual energy, assuming it was sold to a company with a contract to sell the energy to Newfoundland Hydro. From this value, the present worth of the estimated cost of repairs and upgrades over the next 30 years would be deducted to arrive at a fair market value.

Another hydro consulting company, Acres International, had been contracted to undertake the same exercise for an interested purchaser, and after this work had been completed, the two consulting companies would compare their results – quite an interesting assignment.

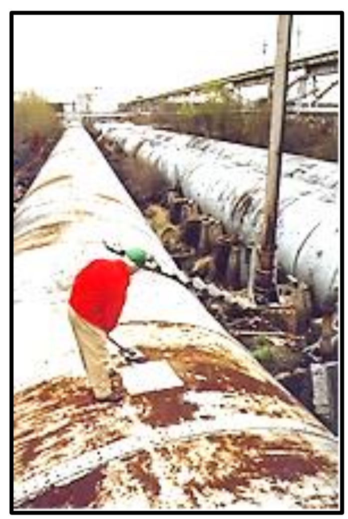
My task was to evaluate the structures and the mechanical equipment, along with producing the estimate for upgrading and repairs.

Grand Falls was the largest and most complex of the three facilities. Construction started in 1909 with first power in 1911 from a dam, intake, long steel penstock, and three horizontal axis single-runner Francis turbines equipped with relief valves. This was followed in about 1922 with another penstock with a surge tank to two horizontal axis double-runner Francis turbines housed in a powerhouse connected to the original powerhouse. Still later, in 1948, a third penstock and surge tank were added, providing water to a single vertical axis Francis turbine, again in a powerhouse connected to the other side of the original powerplant.

View of intake forebay.

The dam was a mass concrete weir with flashboards on the crest to add about 2ft of head. The intake was very interesting, in that it had a small forebay with 8 gantry-controlled gates at right angles to the river flow admitting water into the forebay. The designers had seen the large volume of frazil ice in the Exploits River during winter, and had reasoned that this had to be controlled by gates, lifted to allow only the lower "cleaner" waters to enter the forebay. Unfortunately, it did not work quite as expected, since the volume of frazil was just too large and it still entered the forebay.

Intake forebay. Note steel rope for rake on left.



Bert Budgell inspecting penstocks

The partial solution was to install a "sledge rake" on a rope across the front of the trashracks. When frazil ice started to block the racks, the rake would be pulled across the front of the racks in an attempt to clear them, but it was an almost continuous battle throughout the winter, adding considerably to operating costs.

The top 6ft of the racks were covered with steel plate to prevent ingress of cold air. The gates were operated by ancient rack and pinion hoists. As mentioned in Chapter 34, the penstocks were placed too close to the hydraulic gradient, and "breathed" as the internal pressure changed. It was quite an experience to stand on a penstock and see the other structures slowly rise and fall.

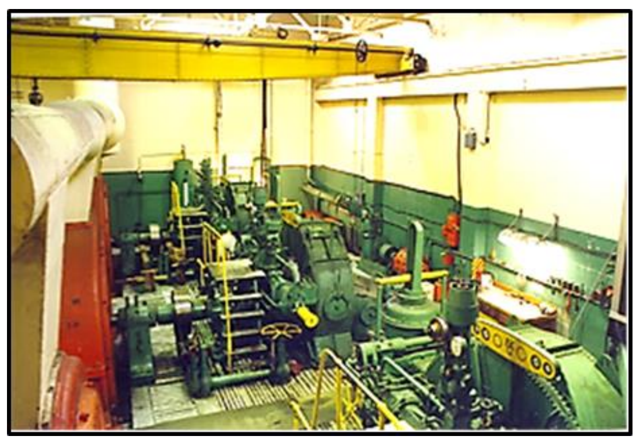
The work was in early June, when the largest seagulls I have ever seen were nesting in the grass between the pipes and the Exploits river shoreline. In fact, there were so many nests that one had to be careful when walking, in order not to tramp on one. Meanwhile, the screaming seagulls were angrily wheeling around trying to chase you away. The eggs were almost as large as chicken eggs, and I was told quite tasty if you liked fish! Fresh eggs were obtained by throwing out all eggs in a nest, and waiting for new ones to be produced.

Penstocks going everywhere below surge tanks.

The first powerhouse was absolutely fascinating. The atmosphere was full of a fine oily mist and all surfaces were covered in oil. Apparently it was leaking from the relief valve servomotors, and could not be stopped. Standing on the turbine floor, I had the impression of being inside a Jules Verne submarine in "20,000 leagues under the sea!"

The oil was so pervasive; that there were paper towels at all doors into the powerhouse, along with a detergent tray and brushes so that you could wipe your boots on departing. In 2004, the powerhouse was demolished, and a new single vertical axis Francis unit installed

First powerhouse with 1906 turbines.



View of first powerhouse from door to control room.

The second powerhouse was also very interesting since it contained two of the largest horizontal axis double-runner Francis turbines I have seen. Quite an achievement for 1922! By this time, the hydraulics of surge tanks had been developed, so there was a surge tank on the penstocks instead of relief valves on each turbine.

Jack Randle looking at a relief valve on left.

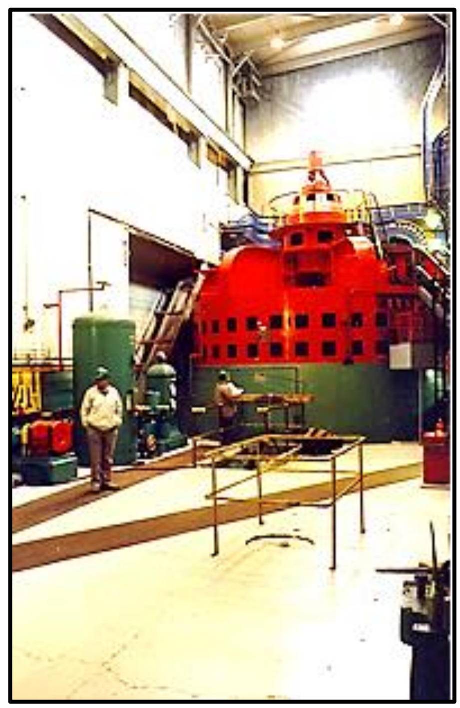
Ancient slate panel mounted instruments in control room.

By 1948, when the third powerplant was built, the design of turbines was quite advanced, so a vertical axis unit was installed in a conventional layout. It was tightly squeezed between the powerhouse walls, so that there was barely room to walk by, and on one side, the generator casing almost touches the access door. Maintenance must be difficult due to lack of space.

Two generators in second powerhouse.

We spent a full week looking over the structures, which also included a storage dam at the outlet of Red Indian Lake further upstream. After about a month of work estimating the value of all the facilities, we had a long meeting with the other consultant Acres, and much to my surprise, our valuations were within 10% on a total of over several hundreds of millions of dollars. I had thought that we would not be within even 30%.

Double runner Francis units in second powerhouse.



Third power house with single Francis turbine and generator.

However, Abitibi began to realize that the hydro assets were much more valuable as a stream of cash flow instead of as a lump sum payment and loss of the facilities. Consequently, they were not sold, and instead Abitibi negotiated contracts for the sale of the surplus power to the local utility, and embarked on much-needed repair and rehabilitation of all the equipment.

The penstock breathing problem was permanently solved by removing the old penstocks and building a long canal and new intakes near the powerhouse.

The three original generating units were still producing power at 25Hz (cycles), and since there was no longer any demand for such power, there was a 25MW frequency converter near the powerhouse, simply a 25Hz motor turning a 60Hz generator. It was sold after the new powerhouse was built in 2004.

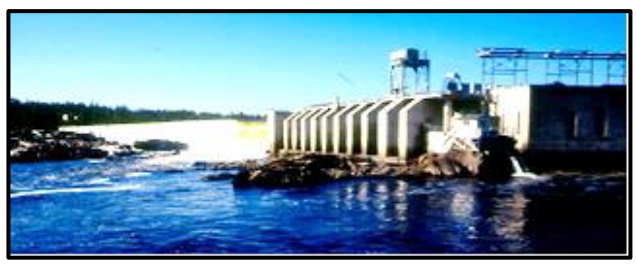
Previously, the paper company had not undertaken any repair or upgrade unless the cost could show a return of well over 20%, as expected from all their other assets. However, hydro cannot meet such onerous conditions, since, due to the high up-front capital cost, and low operating cost, the return is more in the region of 10% to 15%. However, the plants were nationalized by the Newfoundland government in 2009, when Abitibi ceased paper production on the island. This action is currently being contested in the courts.

On the whole, a most interesting exercise!

75. BISHOPS FALLS – 1991

After Grand falls, we evaluated Bishops Falls further downstream on the Expolits River. There was a long Ambursen Dam spillway, and with the structure being fully enclosed, it was in remarkably good condition. A new gated spillway section, added after the disastrous 1983 flood, is in excellent condition.

Grand Falls. Current layout showing canal, new intakes and powerhouse at location of the original powerhouse. Log boom across canal. Forebay gate structure retained to dewater canal if necessary.



Bishops Falls. Looking upstream at powerplant. New spillway in middle.

The powerhouse contains 7 horizontal axis propeller units, still operating with the original but re-wound generators. The runners are relatively new with more power from extended blades.

The plant was built in 1911, and shows how the life can be extended if properly maintained. Most of the generators were used to power grinders producing pulp for the mill at Grand Falls. Pulp production ceased in 1952, and then the power was transmitted to the paper mill at Grand Falls.

Interior of Ambursen dam spillway. Sloping face is upstream concrete face on dam. Dark portion is seepage at joints.

Bert Budgell inspecting turbine shaft bearing.

Forebay – intake on left, control structure on right.

Old Woodward HR (mechanical-hydraulic) governor, still functioning.

Powerhouse interior.

Left- powerhouse interior. Right - Turbine distributor being removed for repairs.

New mixed-flow propeller runner.

Our inspection indicated that the old Woodward governor needed new controls and instrumentation, and parts of the old concrete structures needed repairs.

With an increased spill capacity, and new turbine runners, the powerplant should be capable of many more years of production.

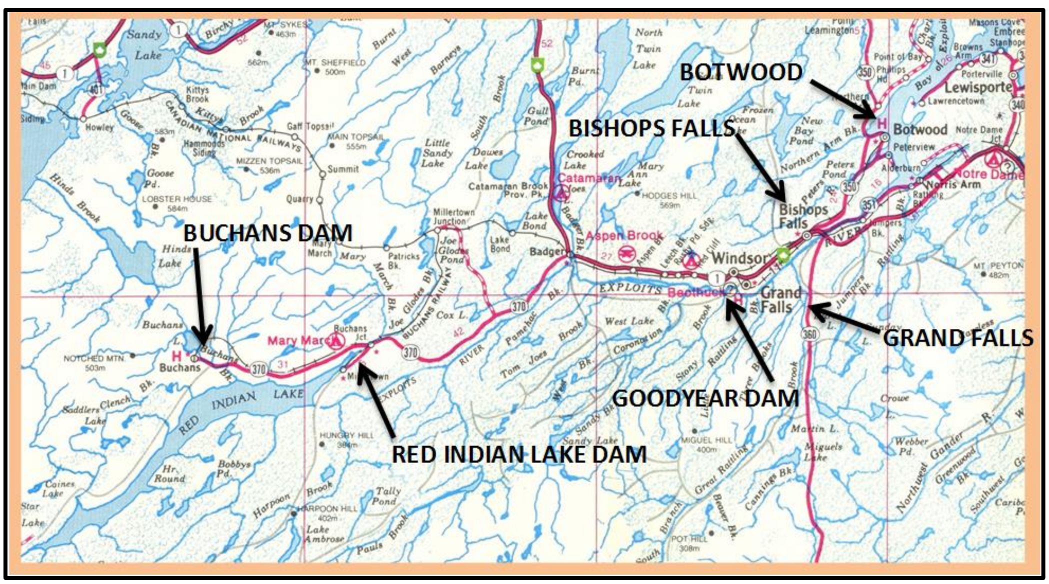
76. RED INDIAN LAKE DAM – 1991

By 1928, the demand for energy at Grand Falls and Bishops Falls had increased to such an extent, that storage had to be added to the watershed. This was accomplished by a dam at the outlet of Red Indian Lake, about 72km west of Grand Falls. Our inspection continued, and we had a quick look at the low Goodyear Dam weir on the way. The Goodyear weir was also built in 1928 to mitigate the problems with frazil ice at Grand Falls. It is located some 2.6km upstream of the Grand Falls dam.

Downstream view of Goodyear weir on Exploits River.

Upstream view of Red Indian Lake dam.

Below - Map of project area – central Newfoundland.



Also, there are about 10 low level sluices with gates operated by an electric travelling hoist, which appeared to be a relatively recent acquisition. The low level sluice gates appeared to be in very poor condition, probably due to the difficulty of lifting the gates out for painting and greasing the wheel bearings.

At Red Indian Lake there are 4 large sluice gates each having a standard lifting screw stem hoist on steel towers.

The spillway gates were all in excellent condition, probably due to the fact that they can be easily lifted to above deck level for maintenance.

Added emergency spill capacity was provided by 14 weir spillway openings below the deck on the right bank concrete dam. The weir was used to pass debris and driftwood on downstream by occasionally letting the reservoir rise to above the weir crest.

Well-maintained spillway gate.

Low level sluices and 4 spillway gates.

View of main spillway. Fish pass in middle left.

On the right bank there was an embankment dam with some seepage which had been partially staunched with some sheet steel piling. The whole dam had timber spray walls on the upstream side to prevent ice accumulating on the equipment. The side dam timber wall on top of the sheet steel piling had been damaged by ice.

Travelling hoist for low level sluices.

Rusty low level sluice gate.

Weir spillway, downstream view.

Downstream view of weir spillway.

There is a side embankment dam on the left bank known as the South Twin Dam. It had been converted to a fuse plug spillway by means of a trench excavated across the crest designed to trigger a washout when the reservoir increases to a dangerous level.

Right bank embankment dam.

South Twin Dam with trench on crest.

Our sojourn in the Windsor area was quite pleasant. However, we were unable to stay at the old staff house where I stayed in 1979 since it was closed and being converted into a bed and breakfast.

79. BUCHANS – 1991

Our next inspection was the old 1.85MW power plant at Buchan's, built in 1927 to provide power to a zinc-copper-gold-silver mine and adjacent village. The mine closed and the powerplant was sold to Abitibi in 1976. A narrow-gauge railroad was built from the mine to connect with the railroad at Grand Falls, so that the ore could be shipped out through Botwood. The development is close to the village of Buchans,

When we were in the area, we took the opportunity to look at the new fish ladders built to allow salmon access past Bishops, Grand Falls and Red Indian dams. They have been remarkably successful.

Downstream view of new spillway.

Upstream view of spillway

At Buchans we found a new dam, built after the old dam was washed out during the 1983 flood. The dam was an odd mixture including a concrete spillway with 5 gates, a creosoted timber crib weir dam, an untreated timber crib section, an embankment dam on the left flank, and even an untreated timber crib emergency spillway.

The concrete intake had a manually operated screw stem intake gate leading to a 1,760m pipeline to the powerhouse. The pipe was in poor condition, and looked as if it had never been re-painted. The concrete saddles were also in poor condition, some having fallen over and others were missing altogether.

Right abutment embankment dam.

Intake with timber crib flanking dams.

Presumably, the creosoted section was still in place after the flood, and the new timbers could not be creosoted.

The pipeline had several old-fashioned bellows expansion joints, common in penstocks installed before about 1950. There had been no maintenance on the pipe, and vegetation had been allowed to flourish around and below the pipe, increasing dampness, resulting in further rusting.

Penstock along the side of the access road to powerhouse

Intake and penstock. Embankment dam at top.

Props on timber crib weir dam at intake.

Bellows expansion joint.

However, there was no seepage, and while there was some surface rust on the pipe, it was not excessive, perhaps due to the fact that steel manufactured before about 1940 had a relatively high carbon content which seems to inhibit rusting.

Timber crib emergency spillway.

Powerhouse and generator, governor on right. Operator with Bert Budgell.

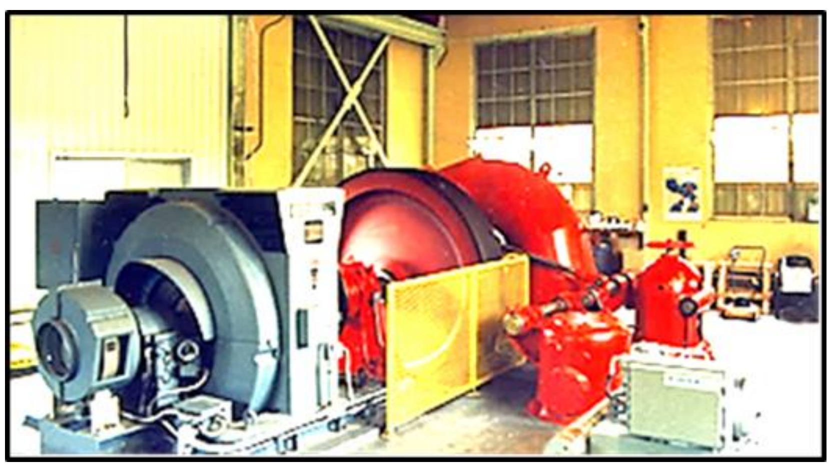
The powerhouse contained a single horizontal axis Francis turbine with a relief valve and a massive flywheel. Since the plant operated in the isolated mode for many years until connected to the Grand Falls grid, a heavy flywheel was required to smooth out the frequency fluctuations. I noted that the relief valve and wicket gates were operated through the same servomotor, an arrangement similar to that at Maggoty. Now, there is a tendency to use separate servomotors or even an electrical connection to the relief valve, an invitation to a disaster when the connection malfunctions.

The powerhouse included a manually operated crane, adequate for servicing the small unit. There was a short tailrace wall to keep out the debris and gravel being washed down the Buchans River. The upstream powerhouse windows had been covered with sheet metal as protection against vandalism. The windows on the river and downstream side, were not covered and could be opened for ventilation.

View of another expansion joint and bend near powerhouse.

One surprise was the turbine governor, which had recently been replaced with a new digital unit.

The operator had kept the powerhouse interior in immaculate condition, but mentioned that budget restrictions prevented any work on the other structures. This is a common experience with industrial owners; all generating equipment is well maintained, and other equipment is allowed to deteriorate.



Turbine and relief valve. Governor at lower right. Note large flywheel for speed regulation.

Powerhouse with upstream windows covered as protection from vandalism.

Unfortunately, such high quality generating equipment is no longer available.

77. TWIN FALLS ONTARIO 1991

In August, I had a call from Frank, an engineer at a large private utility. They were interested in bidding on the Abitibi Consolidated hydro plants in Ontario. I told him I could have a conflict of interest, having worked for Abitibi on the evaluation of the Newfoundland facilities, and I would have to check first with Abitibi. I called Bert Budgell at the Abitibi Toronto offices, and he told me to go ahead – the more companies interested in the facilities, the better. In September, I flew to Iroquois Falls and met Frank to start inspecting the three plants at Twin Falls, Iroquois Falls and Island Falls.

The Twin Falls facility was completed in 1922 and contains 5 vertical axis Francis turbines, each producing 4.8MW at 16m of head. When we inspected the plant, it was in poor condition, but new switchgear was installed in 1999, and new controls in 2009.

Downstream view of spillway weir.

Two spillway gates. Note missing downstream panels.

Old switchgear.

Intake hoisthouse.

Log chute at end of Twin Falls powerhouse.

Powerhouse interior.

Turbine servomotor.

The intake gates are held in the open position by a trigger mechanism, and can be quickly closed. An overhead crane is used to open the gates.

My client was not impressed with the facility, and after a quick look around, suggested we return to the town for some lunch before looking at the nearby Iroquois Falls development.

78. IROQUOIS FALLS ONTARIO –1991

The upstream Twin falls facility controls the water level in the large Abitibi Lake. Iroquois falls is a run-of-river plant adjacent to the paper mill. When we visited Iroquois Falls, it contained 14 horizontal axis double-runner Francis turbines which had been operating since 1914 under 13m of head. Initially, 10 of the units were attached to grinders, and were later converted to generators in 1946.

View of forebay. Top of trashracks covered with aluminum sheets to reduce heat loss in winter.

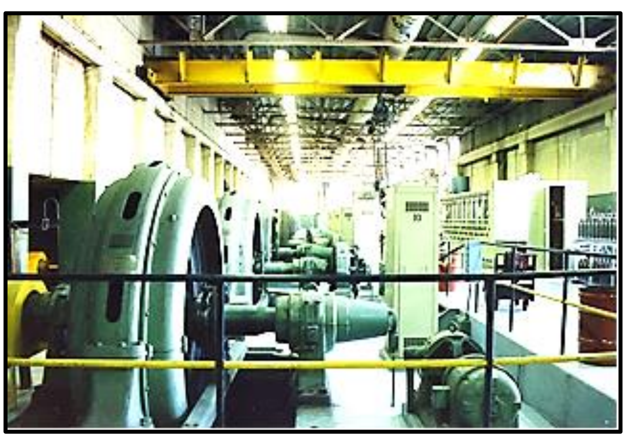
Ancient stoplog hoist – still working.

There are 4 spillway gates, one with an old screw stem hoist, and the other three have recently been equipped with modern hydraulic hoists. Also, there are 14 stoplog bays serviced by an ancient stoplog hoist.

In 2002-4 nine of the old turbines were removed and replaced with Kaplans, bringing the plant output up to 30MW. Two turbine units were decommissioned, and the three newer units were refurbished.

Stoplogs for spillway gates.

Downstream face of powerhouse.



Powerhouse interior. Three newer units in foreground.

Old Woodward governor with open belt drive – still working.

Three-phase transformers.

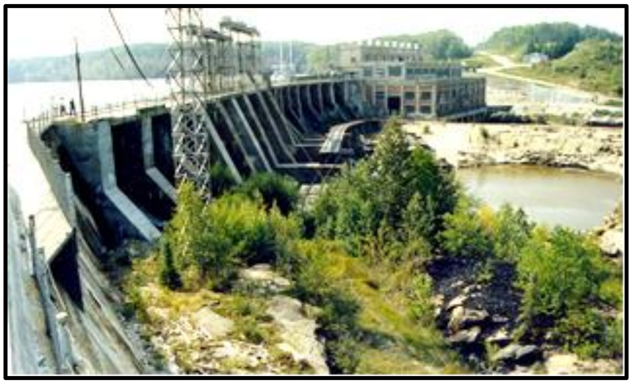
The concrete structures were in reasonable condition, and any repairs would be mostly cosmetic improvements. Again, my client was not at all impressed with the facility, and I was getting the impression that they would be reluctant to make an offer for the projects. All they could see was a very large expenditure to bring the facility up to modern standards.

80. ISLAND FALLS ONTARIO – 1991

Upstream view of Island Falls Powerplant.

Our last inspection was at the Island Falls plant built in 1925, when the only access was by rail. It had several interesting features, one of which was operating with no safety freeboard on the dam, the first I have ever seen. The headpond water was at the dam crest!

The other was an inverse arch on the powerhouse crane beam, again a very unusual design. The plant has 4 vertical axis Francis turbine units producing 40MW at 20.5m head.



View of spillways. Note partially demolished railway bridge.

Stoplog hoist. Note spray wall near powerhouse.

Oops – no freeboard! Fence to prevent driftwood flowing over dam during a storm.

Headgate hoist house. Gates - trigger close, crane open.

Powerhouse.

Pumps and compressors.

Each turbine is equipped with an "ejector" to increase flow past the facility during floods.

After we saw an electric motor mounted on a column, with an open belt drive to the governor pump, my client told me that most of the equipment belonged in a museum, and they were not going to bid on the facilities. They did not have any hydro facilities in their portfolio of investments, so were unaccustomed to seeing such ancient plants. They had been looking for a modern plant, or at least one where the plant had been updated regularly.

Powerhouse interior.

81. NOVA SCOTIA – 1991

Testing concrete at Lumsden spillway.

In the summer, between the Abitibi assignments, I was asked to help AGRA assess the condition of several old small hydro plants operated by Nova Scotia Power (NSP). AGRA had an office in Halifax headed by Jim McCrea, and the NSP chief hydro engineer was Eric Brown, both of whom had worked for Montreal Engineering. It was an interesting assignment seeing how old developments had survived for well over half a century.

M. Afif at Black Lake embankment dam.

White Rock stoplog weir spillway, upstream view.

White Rock spillway, downstream view.

At many sites, the vegetation had been allowed to flourish, to such an extent that at the Lumsden dam, the downstream slope was completely forested, and it was difficult to see the extent of the slope. Jim struggled down through the undergrowth and trees to find a seepage pool at the bottom. We returned a couple of months later to view the cleared downstream slope.

Cleared downstream slope at Lumsden Dam.

Eric Brown viewing tainter gate at White Rock spillway.

At the White Rock Dam there is an old abandoned powerhouse substructure which encased a very rare vertical axis double-runner Francis Turbine. Also, there was a Tainter gate with a timber face, still serviceable after about 80 years. However, there was no gate hoist. Apparently, the gate is lifted manually by a small winch.

Very rare double-runner, smaller runner on top, vertical axis Francis unit, on display at the Hells Gate Dam.

NSP had a large number of old wood stave pipes, and replacement with steel proved to be very expensive

Hells Gate dam spillway.

Two alternatives were used. For the larger pipes, bell and spigot fiberglass pipes were installed, buried up to the three-quarter diameter. The exposed portion of the pipe was painted white to counter deterioration from ultraviolet light. The bell and spigot joints were found to have sufficient flexibility to allow the pipe to follow the gentle curves originally used by the wood stave pipe. The installation proved to be quite successful, and to date, no problems have been encountered.

The fiberglass pipe was manufactured at a plant in Mahone Bay, about 70km west of Halifax, so transport cost was not excessive. I was surprised to see the relatively rough inside of the pipe, since fiberglass is usually assigned a friction factor equal to that for steel. It would be interesting to find out if any friction coefficient tests have been undertaken on the installation.

Fiberglass pipe arriving at site.

Normally fiberglass pipe is buried, since the coefficient of expansion for fiberglass is much higher than that for steel, and hence exposed fiberglass pipe would require frequent expansion joints.

Concrete spillway with stoplog control at Paradise Dam.

Concrete weir and low level outlet at Paradise Reservoir.

Tainter gate and stoplogs at Nictaux. Note hand crank hoists at each pier and timber strut a center of stoplogs to prevent lifting.

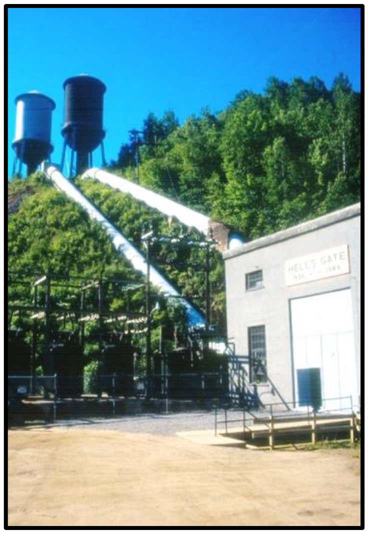
It is interesting to note that between 1924 and about 1950, Montreal Engineering designed all the powerplants owned by the Nova Scotia Light and Power Company, purchased by Mr. Killam in 1924. The power company was later purchased by NSP in 1972.

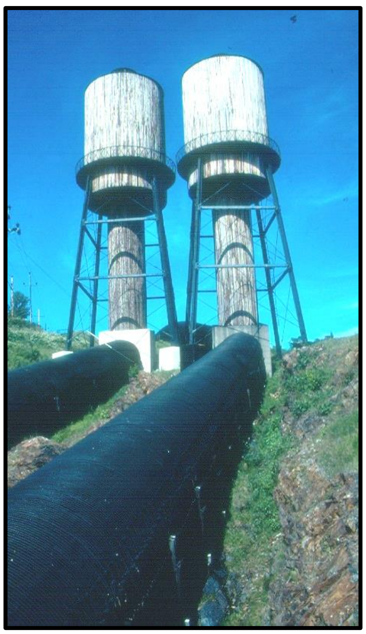
Our inspection was part of a program to rehabilitate all the NSP hydro facilities. Over the next decade, timber frost casings on surge tanks, by now mostly rotten and a fire hazard, were removed, and replaced with a bubbler system to prevent freezing. Rusted penstocks and old wood stave pipes were replaced, anchor blocks were checked and reinforced where necessary, the foundations for surge tanks were checked for stability and anchored if necessary, and even old rivets were either replaced with high strength bolts or ring welded. The program added considerable life to the plants.

World's highest wood fish ladder at White Rock.

Penstock at the Gulch 6MW powerplant built in 1952.

Rocker support for ring girder on Gulch penstock.





Surge tanks at Hells Gate and Weymouth. Hells Gate #1, 3.4MW in 1930, #2, 3.4 MW in 1949. Weymouth #1, 9Mw in 1959, #2, 9MW in 1961.

Part way through the rehabilitation program, I had a call from NSP, asking if I knew how to design riveted steel penstocks. I told them that the last lecture in my 1951 structures class at university was on riveted steel penstocks, and that I still had my class notes. I was then asked to check an old rusted penstock where extensive thickness tested had been undertaken. My analysis indicated that the penstock needed to be replaced.

I was surprised by the request, since I thought that the design procedure was well documented in textbooks. However, when I consulted my references, I could not find any mention of rivet design other than in the 1941 edition of Marks Mechanical Engineers Handbook! Now the procedure is well documented in a penstock design manual issued by the American Society of Civil Engineers.

Quick-release stoplog spillway at Weymouth Reservoir.

Eric Brown, M. Afif and Jim McCrea inspecting penstock at the Hells Gate Dam.

Yes, another interesting assignment, and a lesson on how to keep old structures functioning.

82. LA GRANDE 2A – 1991

In September, the CEA fall meeting was at the Airport Hilton in Montreal with a full day inspection of the Quebec Hydro plants at La Grande 2A and La Grande 1. Five papers were presented on the projects on Thursday, and the next day there was an early departure at 7.00am for the 2.4hour flight to the La Grande 2 airport.

It was a long day, and we returned to Montreal after 9.30pm.

Construction camp at La Grande 2.

A few years earlier, Hydro Quebec had undertaken a study to add pump-storage to the system, but found that it was more economical to add peaking capacity to existing plants; hence the new powerhouse at La Grande 2. The two powerplants now (as of 2011) comprise the largest underground hydro facility in the world.

Headpond and intakes for La Grande 2A.

There was some concern when the spillway was being designed, that the rock steps would deteriorate with time, due freeze-thaw jacking within the rock cracks. This has happened, but not to a serious extent. Fortunately, with the addition of the new powerplant, the spillway is rarely used.

The La Grande 2A powerplant contains 6 vertical axis Francis turbines and generators, each with an output of 339MW at 138.5m of head. The rating is identical to the La Grande 2 turbines, but the units are set 4.46m lower, hence the 2A runner is smaller at 5.235m compared with 5.600m for La Grande 2.

The famous stepped spillway at La Grande 2.

The powerhouse is a 3-chamber design, with chambers for the transformers, the generating equipment and for the draft tube gates, collector gallery and surge chamber. There are 2 tailrace tunnels each 15m by 20m high, 1,300m long.

View of powerhouse generator floor.

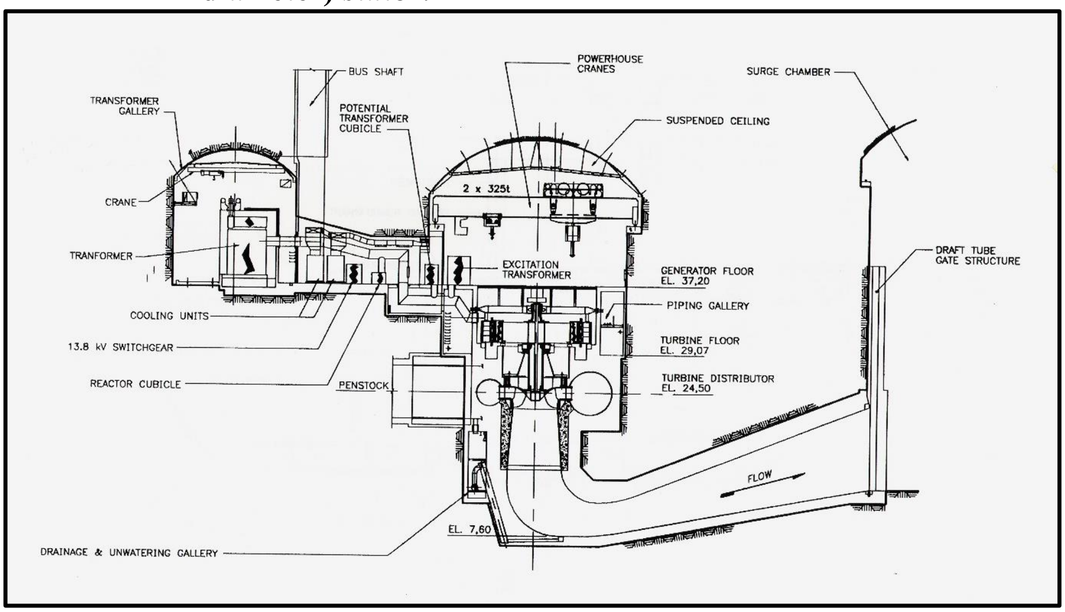
We had an excellent tour through the plant, even walking into the turbine steel spiral casing, so large that a staircase had been built from the manhole down to the curved steel floor.

Hydro Quebec had made excellent facilities available for the tour. In fact, so many tourists arrived at the plants by car during the summer, that permanent viewing platforms had to be installed, and these were used by our group. A large highway bus was stationed at the La Grande

2 administration building to transport both tourists and our group.

Assembly of generator 12.75m (outer diameter) stator.

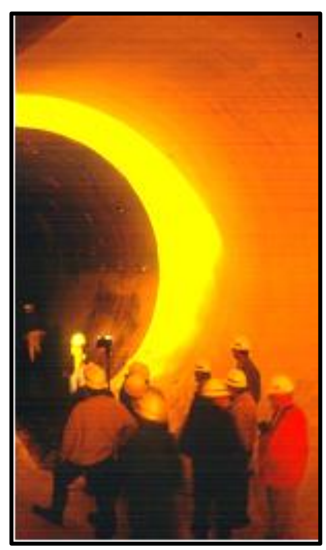
Junction of 6.25m penstock to turbine spiral casing.



Section through powerhouse to surge chamber.

When the projects were being built, there was some negative publicity about lack of recreation facilities at the camps. So some sand was deposited on the banks of a nearby stream, flowers were planted, and beach chairs were placed on the sand.

Assembly of the generator 10.4m diameter rotor.

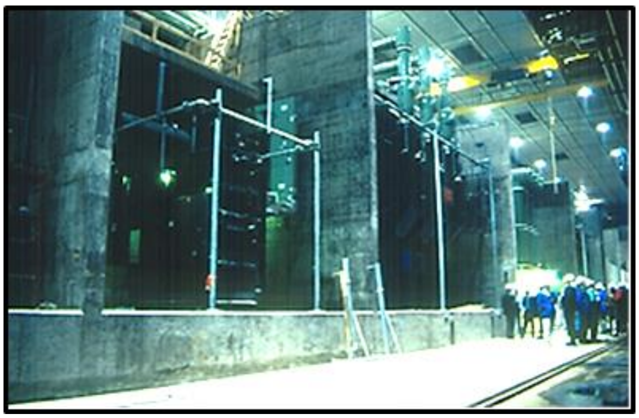


Near end of turbine steel spiral casing.

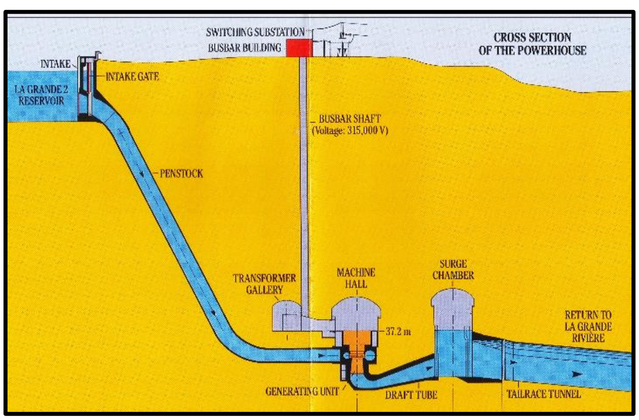
The far north "beach" at La Grande 2.

Next, models in bikinis were photographed cavorting around with careful framing of the photos to avoid too much background. This produced more workers, but now there are bars, sporting facilities, internet, and a swimming pool at all the construction camps.

Tour bus in powerhouse access tunnel.



Transformer gallery.



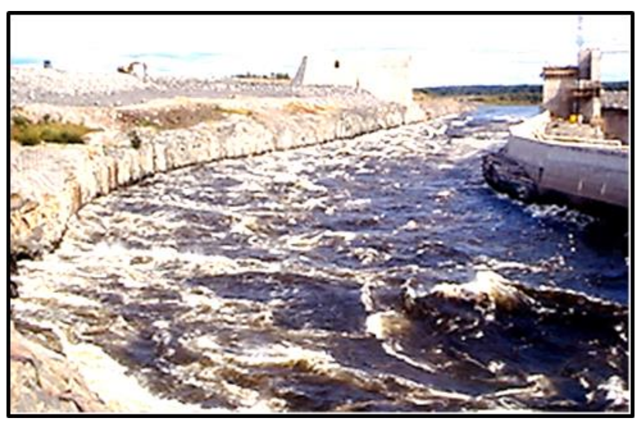
Section through powerplant from intake to tailrace tunnel. Note inclined penstock – preferred by Hydro Quebec to a vertical shaft. Source – HQ brochure.

83. LA GRANDE 1 – 1991

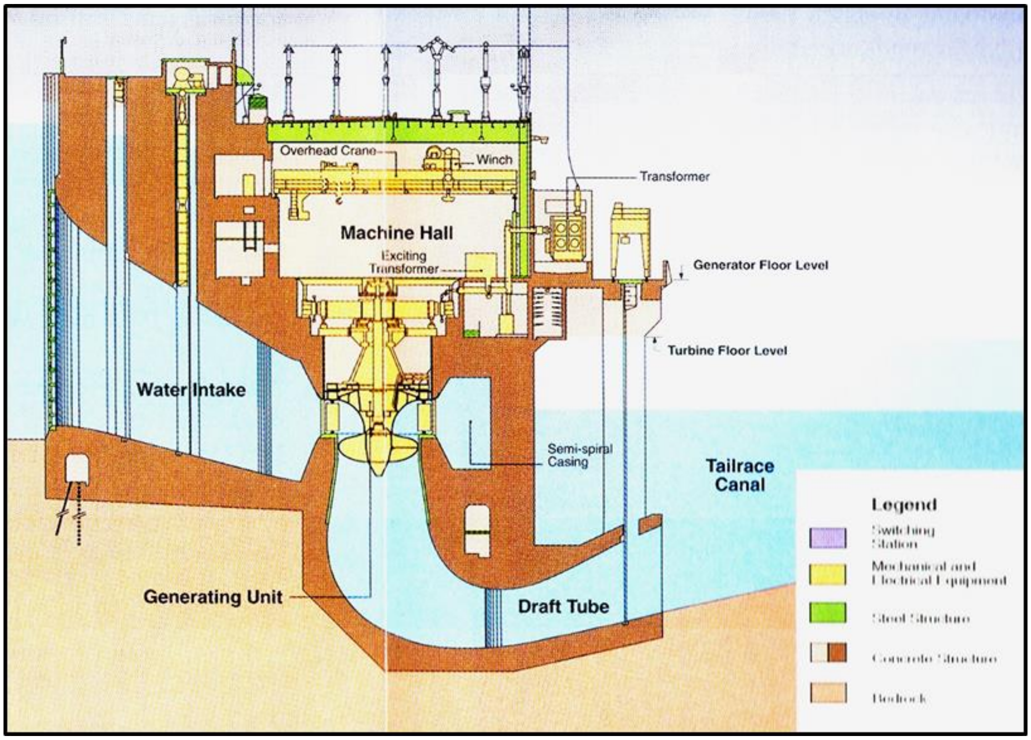
Our tour continued in the afternoon, after an excellent steak lunch at the cafeteria at La Grande 2. The group inspected construction of the downstream La Grande 1 powerplant, a relatively low head surface facility where 12 Kaplan turbine-generators were being installed, each with a capacity of 116MW at 27.5m head.

Diversion channel around structures, spillway in center.

We also had a look at the turbine semi-spiral concrete casing. It was so large, with a runner diameter of 8.0m, that I was unable to take a photo of the interior. I was the last one to leave the casing, and only emerged when one of the tour guides took me by the elbow and gently guided me out! They needed to abide by their tour schedule.



View of diversion channel.



Section through powerhouse. Source – HQ brochure.

We were left with a distinct impression that Hydro Quebec certainly knows how to build very large generating facilities. They have benefitted from their practice of retaining control of all site work and project management.

The construction was well organized, and our only complaint was that the trip was about a year too soon!

Powerhouse intake, spillway top right.

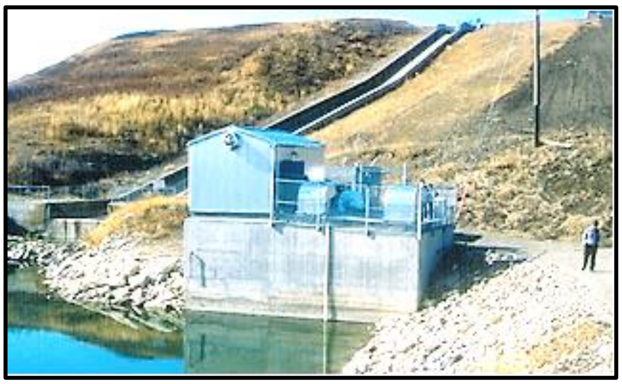
Wider view of structures.

84. BELLY RIVER – 1992

In March, CANMET organized a seminar on small hydro at Pincher Creek in Alberta. They asked me to present a paper on equipment selection, which I did. I knew that Art Holroyd, the retired resident engineer from Maskeliya Oya in Sri Lanka was living there, so I called him and asked if he would be attending, and he advised me that he was already registered. I looked forward to seeing him again, after some 20 years.

Intake channel, drop structure on right.

Before I presented my paper, I asked the audience of about 50 which measures they preferred, either imperial or metric units. The answer was metric, so I started my dissertation, and told them they could interrupt at any time if something needed further explanation. After about 5 minutes, a hand went up at the back, and a large gentleman stood up and asked “what is a megapascal?” to which I replied that a megapascal was equal to 145.07 pounds per square inch! He said “Oh” and sat down. I don’t think I was very helpful.



Powerhouse and drop structure.

820mm, 720rpm Francis turbine.

As with such seminars, there was a site inspection included to the nearby Belly River hydro facility, where a single unit, horizontal axis 3MW Francis turbine, operating under 45m of head had been added to the adjacent irrigation drop structure. It proved to be quite an interesting development with some unique features. Total cost was about $3 million in 1992.

The development was in the arid south-west corner of Alberta, and only operated in the summer during the irrigation season. The intake was at the end of a short canal off the irrigation canal, and functioned as expected until the trashracks became blocked with weeds. What had been forgotten, was that tumbleweeds rolled across the prairies and eventually dropped into the long irrigation canal, floated down to the intake and soon blocked flow. Something I would not have thought of! The solution was temporary manual racking, for 24 hours per day, until automatic racking equipment was installed.

Generator.

The powerhouse was extremely compact, with just enough room to walk around the equipment. There was no repair bay. If major repairs were required, the entire roof could be easily removed by a mobile crane and the equipment lifted out, and moved to a repair facility.

A most innovative solution to the electrical assembly was to mount all the control and switchgear panels, and everything electrical, all fully wired and tested, inside a steel building, transported it to the powerhouse and slid it into place. This proved to be a very efficient and site labor-reducing solution, and very impressive.

I had lunch and later dinner with Art. I found out he was quite a history buff, and had presented a few papers to the local historical society. Altogether a pleasant trip.

With Art Holroyd at the Belly River drop structure inlet.

85. CARMICHAEL FALLS – 1992

Sulzer (now ANDRITZ) is a large turbine manufacturer and they had a contract to install all the electrical and mechanical equipment at a small 20MW hydro plant at Carmichael Falls in northern Ontario. Their mechanic was having difficulty aligning the long horizontal shaft turbine, and suspected that the upstream powerhouse wall was moving. The upstream thrust bearing on the turbine was anchored to the intake wall, which was also the upstream powerhouse wall, and this seemed to be moving since he was getting different readings on his very precise machinist level at the bearing. So Pierre Cloot from Sulzer called me and asked if I could have a look at the problem.

The developer was a company owned by three lawyers, and the president was called Peter. By coincidence, I had met Peter the previous year at a small hydro convention, where he mentioned he was looking for a consultant to help with the development of a 600MW site in Northern Ontario. I was somewhat skeptical of the claim, but he did say that they were currently developing a 20MW site north of Timmins. I asked him for some more data on his company, but he only revealed that he had two partners. I told him that the northern area he was considering had been subjected to several studies by Ontario Hydro, and they had abandoned the investigation when they discovered deep deposits of unstable marine clays, making the sites quite uneconomic. I told him I was just not interested, much to his annoyance.

View of "S" turbine casing and governor. Intake wall on left.

Upstream view of dam and iced-in gates.

A few days after my conversation with Pierre, I flew to Kapuskasing, rented a 4x4 GMC truck;

drove east on an icy road to Faquier and then south beside the Groundhog River to the plant.

Powerhouse attached to dam.

Brackets attached to intake wall for plumb-bobs.

The development was being constructed by a private company, and I could see that there were several design issues with the layout, but my assignment was limited to the turbine. On entering the powerhouse, I was greeted by the operator with "and who are you?", so I introduced myself, giving him a business card, and he immediately went over to the office phone to call someone. A few minutes later, he emerged and said "Peter told me about you; we know who you are, and you have to leave immediately, and if not, I will have you arrested for trespassing!" the first time I have been threatened with arrest. I then spoke to Pierre, and he told me to forget about it, the operator was just being difficult and could not interfere with their work. So I had a good look around, but was interrupted by the operator who again asked me to leave, but provided an option "if you don't leave, let me know if you prefer to be arrested by the Royal Canadian Mounted Police, or the Ontario Provincial Police!

So I again spoke to Pierre, and he said perhaps it would be wise to go back to the motel and wait while the lawyers work out the problem. I drove back to Kapuskasing, had lunch and waited for about 2 hours until the phone rang, and I returned to the plant. There I was told that I could not look at anything other than the turbine, which I tried to do without too much success.

Dial gauges attached to underside of distributor ring.

There were two identical "S"-type horizontal Kaplan turbines in the plant, (identical to the one at Ragged Chute) and from the preliminary movement readings taken by Pierre, I could see that the upstream wall was deflecting and bending as would be expected from the water pressure. A buttress wall between the units to prevent deflection was missing. The bearing had been aligned when there was no water in the reservoir, and was now out of alignment with the reservoir filled and pressure on the wall. It was not possible to take the water pressure off the wall, so some other method was needed to show that the wall was deflecting. I reasoned that the wall was likely to deflect further from the weight of water in the turbine casings, and this could be measured at floor level by hanging plumb-bobs off the wall from a fixed points just above the turbines. I discussed the concept with Pierre and he agreed to set up the plumb-bobs and complete work on the bearings so that the turbine could be filled with water.

Two views of measuring movements at plumb-bobs.

I returned a few of weeks later, only to be confronted again by the operator and left until the lawyers could agree on my presence. When I returned about 4 hours later, I watched as very precise readings, to within 0.0005 inches were taken on the plumb-bobs using a micrometer fitted with an electrical contact buzzer, as the turbine casing was slowly filled with water. The movements were just as I had expected, downwards and out from the centerline on each turbine. Meanwhile, the plant owner had retained a retired engineer from Ontario Hydro to measure deflections on other parts of the powerhouse. Unfortunately he used a simple Invar tape measure, so could not detect any movements. My report showed that the structural design was deficient, and Sulzer's claim for the extra alignment work was paid by the owner.

View looking upstream at generator and 40 Ton overhead crane.

On both trips to the plant, I had a good look around, and was astonished at the poor design and lack of an understanding of hydro requirements.

Attempting to melt ice at stoplogs with small propane torch.

Apparently the owner had accepted a lump sum design fee from the low bidder, a consulting company with no previous hydro experience. Moreover, the general contractor had no experience working in a river.

The project became an example of what not to do when building a small hydro facility, and I used it in several lectures I was asked to present at conferences. The list of deficiencies was extensive, and included – the first contractor declaring bankruptcy after the powerhouse was flooded twice when the cofferdam failed; a new general contractor was retained, again with no hydro experience and the powerhouse was flooded a third time when the sump pump failed on a long weekend; the generator for the second unit was dropped 2 meters onto the powerhouse floor when the mobile crane started to tip due to settlement of the earth pad on which the crane was standing; the powerhouse concrete was so porous that it had to be grouted, using a grout volume equal to half the concrete volume; the spillway had timber-steel-frame gates which froze into the slots in winter and could not be removed in time for the spring flood, since the river flowed northward and flood waters flowed over the ice from melting in the southern parts of the watershed; the hoist for the gates was a mobile crane parked away from the dam with flat tires; the buttress dam was so thin, that it vibrated when the single hydraulic hoist sluice gate was opened; there was no emergency exit from the powerhouse; and finally, the powerhouse structure was not sufficiently rigid, as we had discovered.

Downstream view of iced-in gates.

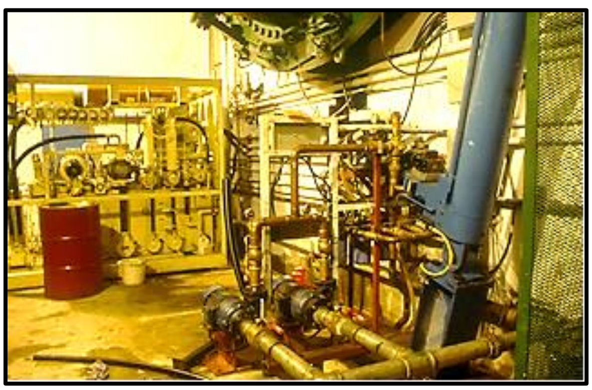
Lifting intake gate with mobile crane.

I think the owner was aware of the deficiencies since he sold the plant to an insurance company in Chicago. During my second visit, I saw two persons walking around taking copious notes, and later, when I was up on the roof having a box lunch, I noticed them sitting nearby. So I walked over, introduced myself, and asked if they would mind answering some questions, prefacing the request with an acknowledgement that I had no authority to ask the questions, and did not mind if they declined to answer. They were quite friendly, and I found that they were two engineers from Chicago undertaking a due diligence inspection for an insurance company. I knew all the hydro consulting companies based in Chicago, and I had not heard of theirs. I found that they were heating, ventilating and air conditioning engineers, and had no hydro experience whatsoever. So I asked them what they thought of the plant, and their reply - “it’s fascinating, the first we have ever seen, and by the way, we don’t think the air ventilation system will work”.

As for the moving bearing, it was reasoned that if re-aligned with the reservoir full, it should stay aligned, but wear might be slightly higher due to very small movements as the reservoir fluctuates over about a meter between full and empty. It just goes to show the difference between allowable deflections in structures as compared with mechanical equipment. Now, Sulzer adds a clause to all their quotations that require an immovable foundation.

Later I heard that over $1,500,000 was spent on upgrades to the plant and the insurance company was surprised to learn that the income from energy sales fluctuated annually, as flow in the river varied, something they had not expected! Despite the upgrades, which included hydraulic hoists for several of the gates, and a bubbler system to keep ice off the gates, the dam overtopped during a spring flood when the power supply to the hoists failed. Fortunately, the dam did not fail and damage was minor. After a few years, the insurance company sold the plant to a private utility.

The draft tube gates can be closed against flow, in case the governor fails. Hence there are no hoists on the intake gates, an acceptable design.



Pumps and piping for operating ring servomotor. Governor at middle left.

View of two 10MW generators.

86. KICKING HORSE - 1992

In the early spring, CANMET asked me to prepare a pre-feasibility report on installing a small 500kW hydro plant on the Kicking Horse Creek adjacent to the Trans-Canada Highway just west of Lake Louise, where a head of 204m could be obtained. The power was to be used by the village of Field, currently supplied by diesels. The entire area was within the Yoho National Park, and the Canadian Pacific Railway and the Trans-Canada highway crossed the site, adding to structure location problems. A previous report had been prepared by another consultant, but the structure locations interfered with both the railway and the road. A gauging station had been maintained on the creek for a few years.

Gauging station.

I had a good look around the site, and relocated the small weir and intake further downstream, still beside the highway, but in an area where the contractor could gain access without interfering with the traffic. The small buried penstock could be located alongside the creek and pass under both the highway and road at existing bridges, again in areas where access was possible. The powerhouse would be in the middle of a ski development, but also off to one side and not interfering with the facilities.

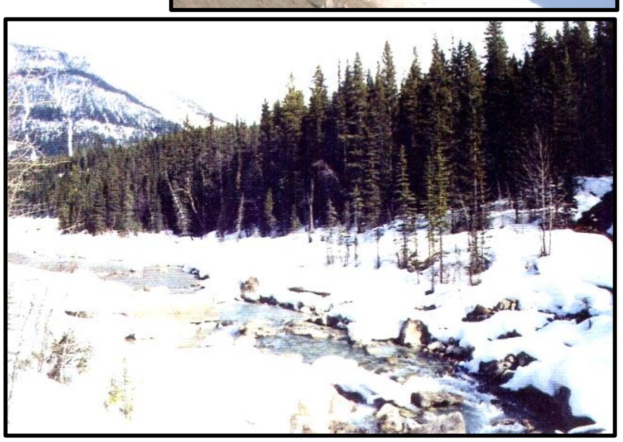
The suggested alternative would be a buried power line cable from Lake Louise alongside the highway which would cause considerable traffic disruption during construction. I sketched out the layout, estimated the cost and submitted the report. However, the cost proved to be quite high, mainly due to restrictions imposed on the contractor, such as no blasting, due to the proximity of highway and railroad. A few years later a transmission line from Golden to Field was constructed.

Original damsite beside highway.

New intake and weir site.

I managed to look around the village of Field. It proved to be a bedroom community for workers at Lake Louise, since accommodation there was far too expensive. However, they did complain about electricity rates in Field which were so high, that use of clothes dryers was very limited.

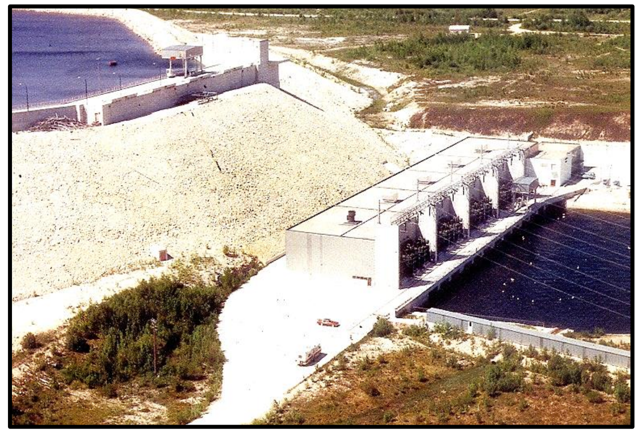
Pipeline route along the creek side. Main road on left.



Powerhouse site.

87. GRAND RAPIDS – 1992

Hydro-electric turbines do not explode, but in the last two decades it has happened three times, one was at Kainji in Nigeria, the second was at Sayano Shushenskaya in Russia, and the third was at Grand Rapids in Manitoba.

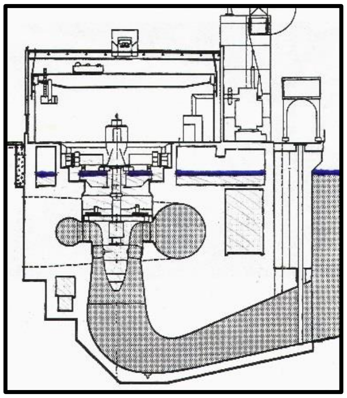


Grand Rapids. Source – Manitoba Hydro brochure 97-03.

The 4-unit Grand Rapids development started operating in 1965-8, and in 1991 new digital governors were ordered for installation the next year. At the same time, the opportunity was taken to replace some rusty piping. Work on governor wiring and piping was underway on Unit #2 in March, on a double shift basis. At 8.00pm on March 20, the night shift workers had stopped for a coffee break, and were up on the main floor when there was a loud explosion followed by rumbling and the sound of rushing water. Two of the workers looked down the stairway to the lower floor at Unit #1, and all they could see was white water, so they ran up to the control room, and advised the operator who immediately shut the 4 intake gates bringing all units to a standstill.

Back on the main floor, they realized that with the lower floors flooded, electric power had to be shut off, and this was done. Next day, the draft tube gates were placed in Unit #1, and fire pumps were installed to pump out the powerhouse, a task completed by the evening. Engineers then inspected the damage, and found that governor piping at Unit #1 had been ruptured spreading oil over all surfaces, making floors very slippery.

Section through powerhouse showing flood level - up to blue water line. Source – W. L Pawlikewich "Grand Rapids Generating station Unit #1 headcover failure"



Unit #2 being checked after the accident.

The head-cover on the turbine was found to be ruptured, angling up at about 30 degrees, and the upward movement was only stopped when the headcover came into contact with the heavy generator support bracket. The turbine bearing had been destroyed, but very fortunately, the generator rotor had not impacted the stator. The propeller turbine blades had remained intact, acting as a rough bearing, allowing the generator to stop without scoring the stator. Most of the turbine wicket gates had been destroyed, and the remaining wickets were hanging like icicles from the tilted headcover.

Same view Unit #1. Damaged. Note angled turbine cover and angled ruptured red turbine servomotor, which was full of oil.

But what had caused the failure? Manitoba Hydro (MH) then asked Don Coulson and me to come and help in the investigation as independent consultants.

Inspecting damaged turbine.

Don Coulson was the chief mechanical engineer at RSW, a large hydro consulting company, and was near retirement. I had known him for a long time, so we worked together very amicably. We flew to Winnipeg, attended a presentation on the accident, and the next day flew to Gillam, the village established by MH for the Grand Rapids plant operators. Donning white hazmat disposable overalls, we descended into the lower floors to look at the turbine. Very fortunately, the emergency generator was located just above tailwater level, so power had been restored. We had to walk very carefully, since the floors were still slippery with oil. On the floor just above the headcover, the force of water had carried all loose cabinets and everything else on the floor and slammed them in a crumpled heap against the far wall. The turbine was a mess, with extensive damage to the oil piping above the head-cover and not much left of the wicket gates inside the turbine. The failure appeared to originate at the bolts holding down the headcover, with many appearing to be cracked with a fatigue type stress failure.

View of turbine pit, Unit #2. No damage.

Same view Unit #1. Turbine operating ring in contact with generator bracket.

We returned to the MH head office in Winnipeg to discuss the failure. We all agreed that it appeared to be due to fatigue, but why, and what had been the final cause. I kept insisting that there must have been some action just prior to the rupture, but the MH staff could not think of any occurrence. I kept asking what had happened, and did they have a record of the events just prior to the rupture? At this, one of the MH engineers recalled that about 2 years previously, an automatic data-logger had been installed in the central control room in Winnipeg to record the position of every instrument in all their powerplants every 10 seconds, and must therefore have a record of the event. It had never been consulted in the past, so we asked for the data-logger record starting 5 minutes prior to the rupture until 2 minutes after.

Turbine wicket gates lifted out of lower bearings.

All spare parts lifted off racks and smashed against end wall.

Pressure washing walls and floors to remove oil.

Next day the record was obtained, but proved useless since it was in code and needed translation. This took another day, because translation of the code required reference to the data-logger manual for every number, and there were thousands. Eventually, we found that a few seconds prior to the rupture, the unit had been instructed to open up to full power, putting added pressure on the headcover, the proverbial "straw that broke the camel's back," causing the unit to burst.

Emergency Francis turbine-generator.

Further investigations found that the head-cover was held down by 120 bolts and all except 2 were found. Analysis showed that 64% of the bolts had already failed or had large cracks through them at the time of the rupture, based on the extent of rust in the cracks. The remaining bolts just could not hold the head cover any longer. If inspected prior to the rupture, the failed bolts could have easily been turned or lifted out.

Don Coulson in control room.

Fortunately, MH had kept the detailed records of the turbine installation from 1965, and they showed that the head cover bolts on Unit #1 had not been tightened to the correct torque, hence had failed due to repeated stress fluctuations over the previous 20-odd years. Also, Don discovered that the nuts were non-standard, too small and overstressed to beyond the yield point! The bolts on the other units had been properly sized and installed, hence had not failed. MH realized that the failure occurred at a very opportune time – if it had happened in the morning, there would have been about 30 workers in the lower floors of the powerhouse, and many would have been killed. Of course, everybody in the Canadian hydro industry heard about the explosion, so when a paper on the incident was presented at a CEA conference in March of 1993, by Walter Pawlikewich, the room was packed. However, half of the audience ran out to the phones (before cell phones) when the cause was revealed, to instruct their operators to immediately check all the head-cover bolts on all their turbines!

MH instituted a lawsuit against the turbine manufacturer claiming improper installation. I was very skeptical of the success of the lawsuit, since the manufacturer had long ago ceased operation. However, the assets of the company had been purchased by another turbine manufacturer, and a few years later, their assets had in turn been purchased by another company. So I was astonished to receive a phone call about 12 years later from Walter at MH advising that their lawsuit had been successful! Just goes to show how long liability can last, even though the manufacturer's guarantee only covers the first year after commencing operation.

It is interesting to note that I have worked on all three exploding turbines, on the design for Kainji, on the cause analysis for Grand Rapids, and as a paper peer reviewer on Sayano. The Sayano case is compelling reading, so I have included a couple of photos.

From security camera video.

(Source Eugenio Kolesnikov "Reflections on Russian accident on Aug. 17th 2009). Showing the turbine and generator being ejected from pit on column of high pressure water – difficult to believe without photo!

The destruction at Sayano was extensive and many lives were lost. The cause is still being debated as either a fatigue rupture of the headcoved bolts as at Grand Rapids, or a break in the draft tube water column due to too rapid wicket gate closure, causing a collapse of the vacuum and resulting explosive upward force on the turbine head cover. New digital governors had recently been installed with a fast close time.

Complete destruction of Sayano unit.

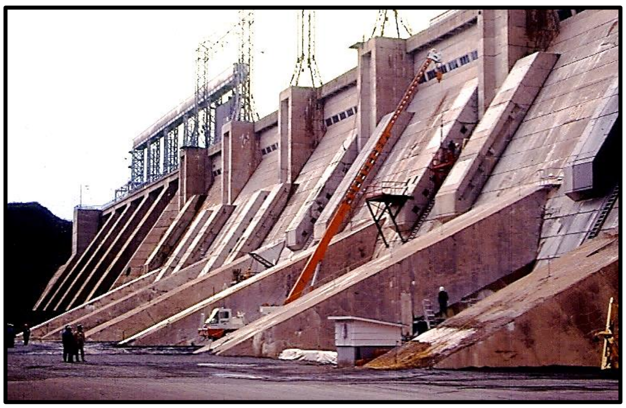
Manitoba was a most interesting assignment, with several lessons – locate the emergency generator well above tailwater, and use a separate electrical circuit for all power to floors below tailwater. At Grand Rapids, this was not done, so restoring power to the upper floors and control room required time to modify circuits, and yes, check headcover bolts!

88. MACTAQUAC – 1992

In view of the new interest in alkali-aggregate reactivity, or "concrete cancer", the September CEA fall meeting was an extended affair at Fredericton with a site inspection of the nearby Mactaquac powerplant followed by a flight to Montreal, and an inspection of the Beauharnois powerplant, both of which exhibited extensive concrete cracking due to aggregate-alkali reactivity (AAR).

At Mactaquac, the owner, New Brunswick Power was in the process of cutting large vertical slots with a diamond-impregnated endless wire rope. The slots extended in the upstream-downstream direction and were closed with a rubber waterstop at the water face. The compression force from the expanding concrete was so large, that many slots closed shortly after cutting, and had to be re-cut.

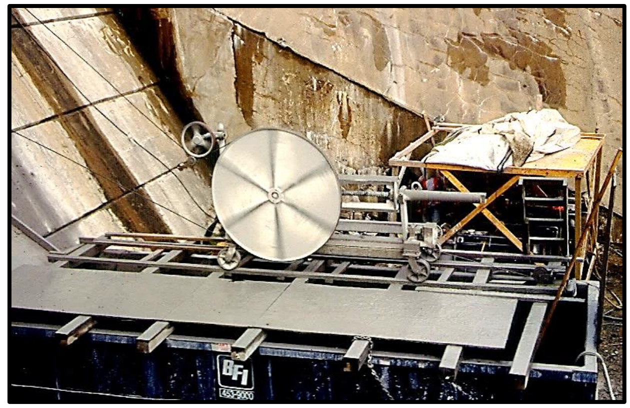
View of Mactaquac powerhouse draft tube deck.



View of downstream face of dam.

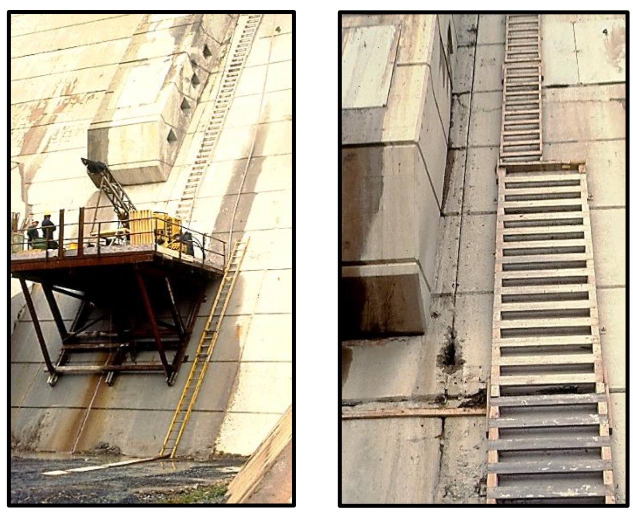
Typical mapwork cracking in penstock concrete.

The wire rope cutting was an interesting operation. There was a large wheel powering the rope, with smaller guide wheels. As the rope cut into the concrete, the gap closed behind and the tension had to be maintained by pulling on the rope loop. The process was very dusty and slow, with several machines in operation



Slot cutting machine.

Slot cutter on wheels to maintain tension on rope.

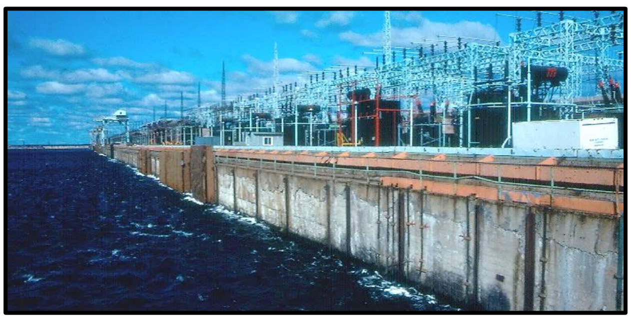


Slot cutter on left, finished slot on right.

Recently, New Brunswick Power has concluded that the concrete will continue to deteriorate to such an extent, that the dam and powerplant will have to be re-built.

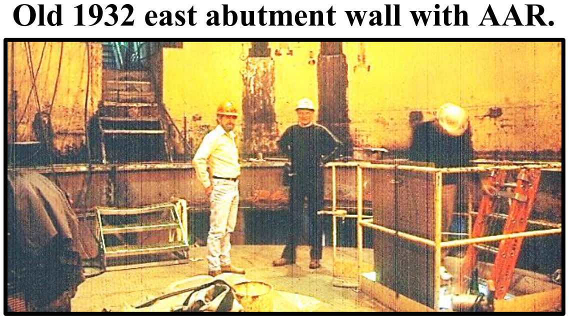
89. BEAUHARNOIS – 1992

When the flight from Fredericton landed, there was a bus waiting to take the group to Beuharnois, a low-head powerplant just west of Montreal. There the owner, Hydro Quebec, was in the process of rehabilitating the facility, since concrete expansion had caused significant problems. At almost one kilometer, Beauharnois is the longest powerhouse in the world. It contains 27 Francis turbines and 11 propeller turbines with a total capacity of 1,666MW plus 2 station service Francis units, all at 24m net head.

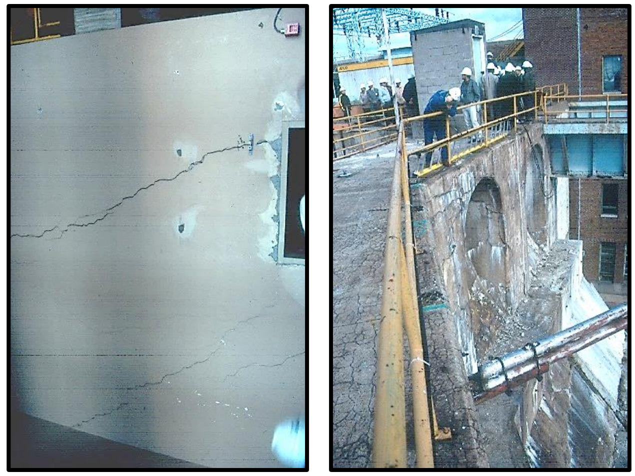


View of intakes.

Old 1932 east abutment wall with AAR.

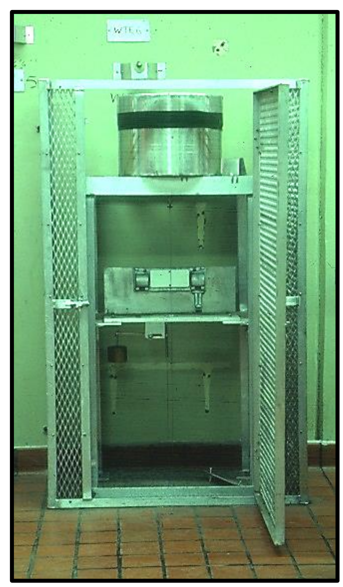


With HQ staff inside turbine distributor ring.



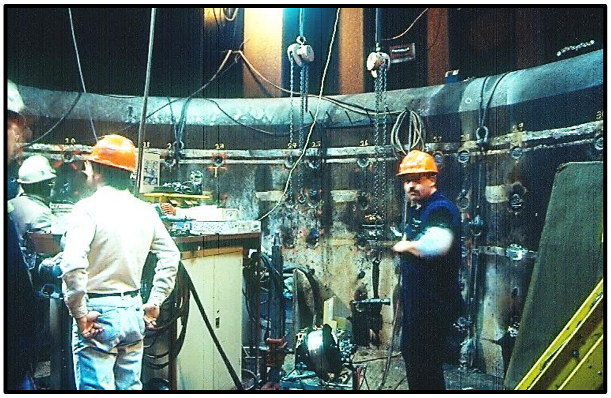
Cracks from AAR in abutment and an inside wall.

Monitoring 45 degree cracks inside powerhouse.



Inverted plumb-bob to measure dam tilting.

At the time of our inspection, HQ had just started an eleven year, $1.5 billion complete rehabilitation program to replace old runners, re-align all units, up-grade controls and instrumentation, along with anchoring and re-centering all turbine throat rings that had become slightly oval due to concrete expansion from AAR.



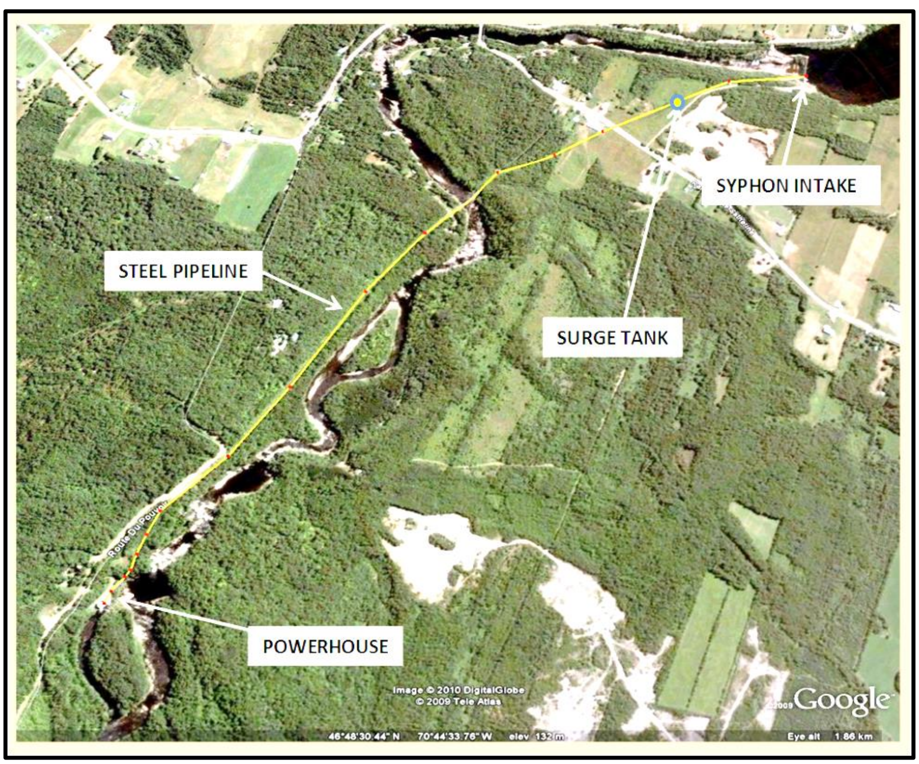
Anchoring turbine throat ring.

90. St. RAPHAEL – 1993

In the summer of 1993, I had a call from Serge Proulx the president of a small consulting company in Sherbrooke which specialized in the rehabilitation of old small hydro plants. They had purchased the rights from Hydro Quebec (HQ) to rehabilitate the three turbines at the mothballed 3.5Mw St. Raphael powerhouse and install a 2,280m long new penstock from the dam, which remained the property of HQ. The plant hydraulics proved to be a challenge.

St. Raphael Dam – before intake added.

The facility, about 260km North-West of Montreal, had been built in 1921 with 1,400kW Francis turbines operating under a head of 68.2m. There was no surge tank on the long wood stave penstock, but each turbine had a relief valve, and six small spring-loaded pressure relief valves had been added at the end of the penstock, presumably due to the relief valve capacity being insufficient.



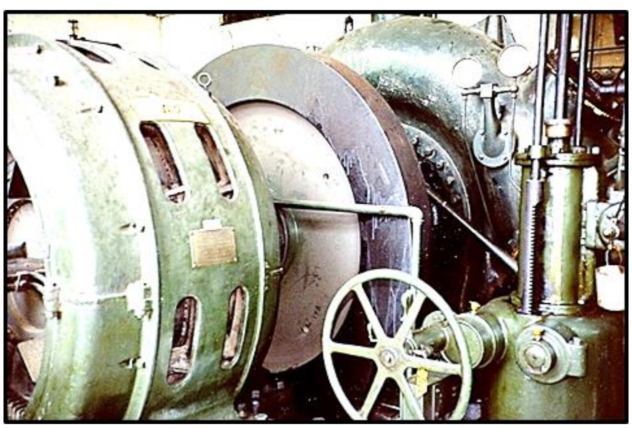
Project layout.

Serge was installing a 2.13m diameter steel penstock with a siphon intake over the concrete dam. We drove up to the site and had a good look around.

HQ had retained one of the operators as a watchman for the powerhouse, and he provided much useful information on the old plant. Apparently, they had managed to collapse the penstock twice, but with wood staves, it was easily repaired. The operation of the relief valves had been changed by removing the operating bar linking the wicket gates to the relief valve, and an electrical motor had been substituted, a major mistake, indicating that whoever made the change, did not understand the system hydraulics.

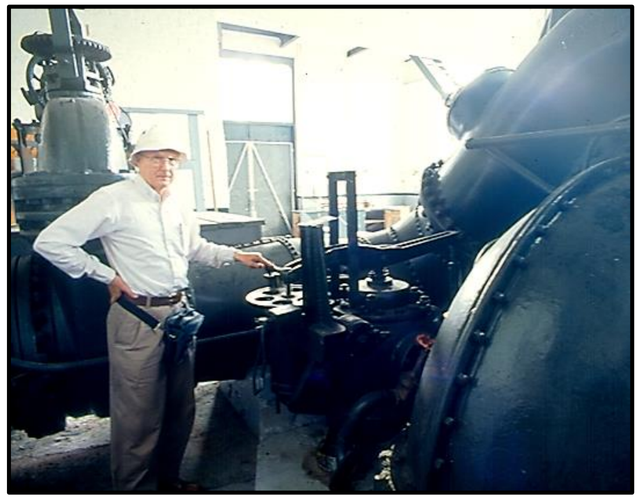
When the electric motor operator was added to the relief valve, they must have removed the valve position cable to the governor, and I could not see how the valve would open to about the half-way position on a half load rejection, the same problem as at Topsail.

Powerhouse interior with three horizontal turbines.



Old horizontal axis turbines – note flywheel.

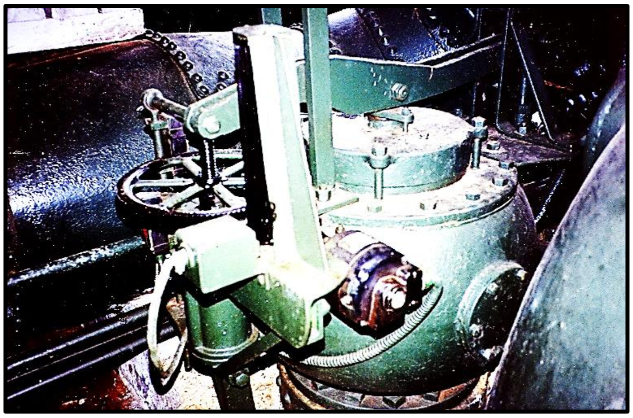
Also, there was no data on the turbine or relief valve characteristics, so I was at a loss as to how I could undertake the hydraulic calculations. To compound the problem, Serge was an electrical engineer, and had no concept of the difficulties. However, with the penstock grade close to the hydraulic grade, the reason for the previous collapses, it was essential to add a surge tank to the pipe, particularly since there was no vent at the siphon intake. I tried to explain this to Serge, but he just could not understand the problem, he even said "why is it so easy to talk to you, but you keep sending me these terrible letters!"



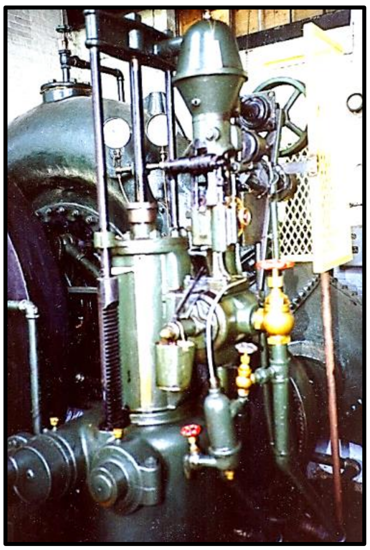
Hand on relief valve.

I asked him what would he do if the penstock collapsed, to which he answered "I will sue you", so I decided it was best to stop working on the project, and I returned the fees he had paid. But I did recommend that he engage the LaSalle Hydraulic Group to continue the work.

Several months later, I called Fred Parkinson, the chief engineer at LaSalle, and asked him how the work at St. Raphael was going. He was surprised at my knowledge of the site, so I told him that I had recommended the company after I found that I could not make Serge understand the need for a surge tank. Fred told me that they had the same difficulty, but eventually Serge understood when Fred said "no tank, no project!" The plant is now operating, but I would still be very wary of the relief valves causing problems

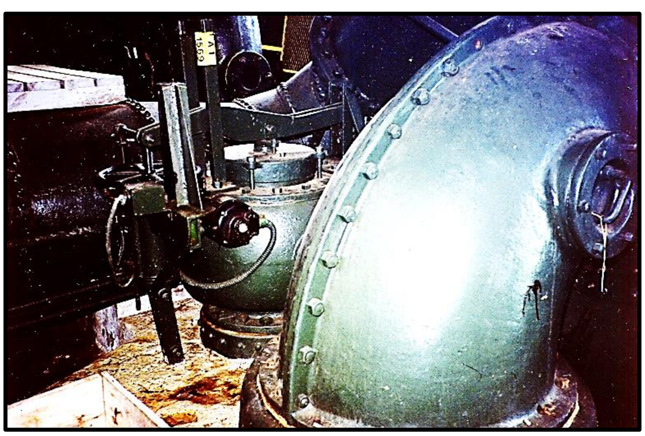


Relief valve with retro-fitted electric motor operator.



Ancient Woodward governor.

The project was commissioned, and a couple of problems were encountered. One was a build-up of an organic moss-like growth inside the penstock causing increased friction and reducing power output by about 3%. The growth was caused by excessive fertilizer run-off in the predominantly agricultural watershed, and there is no solution.



Relief valve beside draft tube elbow.

View of new syphon intake. Source – BPR brochure.

The second was an accumulation of air at the top of the syphon, causing a reduced flow. This was solved by having a small suction pipe from the top of the syphon running constantly and discharging the small aerated flow back to the river near the anchor block at the dam toe.

91. NATIVE PEOPLES – 1993-2000

1 – Snare Cascade.

In 1993, I received a call from Phil Helwig who was working for the Northern Canada Power Commission (NCPC) in Hay River. He was working on specifications for a design-build contract for a small 4.3MW hydro plant at Snare Cascade on the Snare River in the Northwest Territories. So I flew up to Hay River, and spent a week helping to write the specifications. It was early in March, and the severe winter weather was over, but it was still quite cold.

The only place in the town for lunch was a small restaurant a short distance from the NCPC offices, where you had to line up to get in. I remember standing in line behind a young Cree Indian dressed in a T-shirt when the temperature was about -10ºC, while I had on a thick goose down parka! I asked him if he was cold, and he replied that it was spring and warm with no wind – he must have been immune to the cold.

The NCPC had negotiated an agreement with the local Cree Indians for the Cree to own the powerplant, while the NCPC would operate it and purchase the energy. Work on the design-build specifications continued for about a year, and they were issued with a generous 6 months allowed for bidding.

Snare Cascade hydro plant.

Tenders for the project were received and meetings were held with the two lowest bidders at a hotel in Yellowknife in August. The meetings were quite large, with a lawyer representing the Cree, eight Cree chiefs, four engineers including Phil from NCPC and myself. The contractor had about six staff there discussing how the work would be undertaken and his consultant had about another four engineers present to answer questions on the design. We spent about a day questioning each contractor, and throughout the meetings, the Cree would request a "smoke break" about every two hours. After these smoke breaks, the Cree lawyer would always have a list of new questions for the contractor, so it was also used as an opportunity for a private discussion.

At lunch, we would all go down to a room reserved in the nearby hotel, and there I would arrange to sit beside one of the Cree Chiefs. At one of the lunches, I told the Cree Chief that their questions were very pointed and indicated a sound knowledge of business, so I was curious as to their educational background. He proudly told me that he had a university degree in business, and also a degree from the Banff School of Fine Arts, and invited me to come and see his paintings at his shop in Yellowknife! Unfortunately, I never found the time. He also told me that most of the other chiefs had degrees. This was quite a revelation, since the common perception of native peoples was quite the opposite, so when I later had dinner with the Cree lawyer, (a Hindu from India) I asked him about the Cree.

Apparently about 20 years previously, the band chiefs had met to discuss the sorry state of affairs among the Cree and Inuit, with drugs and drunkenness being rampant in all their villages. They resolved to improve the situation, and encourage children to continue their education, while banning drugs and alcohol from their communities. Adults were encouraged to go to a trade school, and since there being none in the territory, a large contractor, Kiewit, was asked to start one in Yellowknife. Kiewit now are able to undertake a construction contract with 95% Cree and Inuit, and that on recent government contracts to construct new airfields in the far north, there was only a white foreman and another white accountant on the job. Kiewit were awarded the contract for the hydro plant, and it was built with over 65% of the workers were Cree and Inuit, quite an achievement. Consequently, living conditions in the villages slowly improved, and the trade school graduates found jobs with local contractors.

The new 4.5 MW Kaplan was added to the small, remote 50 MW power system, where about two-thirds of the power was being supplied by five small hydro plants, and one-third by diesels fueled with high-cost oil. With the recent addition to the system and a drop in load due to the closure of a mine, the system operators were now in a position to shut down the diesels and lower the cost of power. They were shut down and for the first time in about 20 years the plant was silent. Shortly after the diesel shut-down, the operator in the system control center noticed that the system frequency was starting to wander up to about 61 cycles and then down to 59 cycles. Slowly the frequency deviation widened to plus or minus two cycles, the wander assumed a cyclic pattern and it became apparent that the system was hunting between 58 and 62 cycles. Concerned that the frequency deviation might increase, the system operator started a diesel, placed it on line, and shortly thereafter the frequency deviations ironed out to the normal half cycle. He then called the utility engineers to look into the problem.

Next day, in the presence of the utility engineers, the diesel was again shut down, and the same frequency wander was observed. The hydro plants had not operated on frequency control since the diesel units had started up, twenty years ago, and as a consequence, the hydro plant operators had damped down the dashpot return times on the mechanical hydro governors, and changed the governor droop settings, all in an effort to keep the hydro plants on the base load, leaving the quick-response diesels to control the frequency - as a result, the system was far from an optimum setting, particularly when the diesels were off line, hence a wander around 60 cycles could be expected. A governor expert was brought in, the system was analyzed with the aid of a computer program, and all hydro governor droop settings and dashpot return times readjusted to the optimum for frequency control. After this effort, all were surprised to observe that the hunting persisted whenever the diesels were off, particularly since the system was stable with the same hydro plants operating 20 years ago, prior to bringing the diesels onto the system.

To try and isolate the cause of the hunting, the hydro plants were each in turn shut down over a low load period at night, and to everyone's surprise, the new 5MW hydro plant equipped with an electronic governor was found to be the cause of the problem. With the new plant off line, the system was stable, even without the diesels. The turbine and governor manufacturers for the new plant were called in, the turbine and governor were checked, but nothing could be found to explain the hunting. The new unit was started up and the manufacturer's engineers observed the unit's operation as the system began to hunt - and after some time, it became apparent that when system frequency fell below 60 cycles, the governor would open the wicket gates by a small amount, and shortly thereafter the gates would close slightly and the reverse would occur on higher frequencies. The new unit appeared to be hunting at a frequency which apparently matched a natural hunting frequency in the system - in other words, a small kick from the unit at the right instant was all that was required to start the whole system hunting.

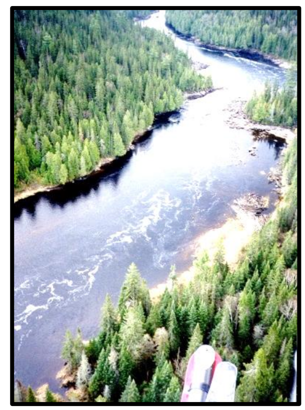
I had a call from the system operator whom I had met during the bid analysis meetings. After he explained the problem, I asked him to check the wicket gate opening time and the blade opening time. About a month later, he called back to say that both were set at 4 seconds. This immediately identified the problem. The hunting was caused by the Kaplan blades on an opening stroke, moving to a higher efficiency angle, which then called for the governor to slightly close the wicket gates. I advised him to re-set the Kaplan blade opening/closing time at 20 seconds, or 4 times the wicket gate opening time. This was done, and the unit placed on line. Much to everyone's relief, the system operated as expected with only minor frequency deviations.

I knew the manufacturer from previous work on the Carmichael plant which had an identical turbine. I called them and asked why the blade time had been set so fast. Their reply was that this was the timing set on three identical units, and there were no problem, however the others were connected to large systems, so frequency was stable. They were not aware of the different timing requirements for isolated systems.

2 – Algonquin hydro survey.

A few years later, I was asked by the Canadian Department of Indian Affairs to look at a report on hydro possibilities in the Algonquin reserve, about 100km north-west of Ottawa. The report had been prepared by a small consultant, and they had identified 12 sites, recommending development of about 8. A meeting was arranged with the Cree at their village in the reserve to discuss the work, but access to the sites was not possible. Unfortunately, all the sites except one, had capacities of less than 4MW, and heads of less than 3m. All were remote with no road access, and hence quite uneconomic. One attractive larger site at about 20MW was on a river bordering the reserve which was used by kayakers, but the Cree opposed its development and it was excluded from consideration. My report in essence advised the department to forget about any hydro development. However, it was forwarded to the consultant for comment, and they vigorously disputed the conclusions, questioning how I could reach such conclusions without inspecting the sites, a reasonable argument.

The Travers "damsite"



Poigan "damsite"

I told the Department that if they could arrange for a helicopter, I could inspect the three most favorable sites with an associate Kearon Bennett, with whom I had worked in the past, and we could issue a more detailed report. Kearon would run the data through RETScreen, a computer program we had developed for CANMET to facilitate cost estimating small hydro sites. It can be downloaded free over the internet, and now has over 200,000 users worldwide. This was agreed, and the department arranged for a meeting with the Algonquin Indians to discuss the work, at their village at Lac Rapide in the middle of the reservation. A few days later we drove up to a gas station at Le Domaine in the western end of their reservation where we had agreed to meet the Eurocopter AS 350 helicopter at 9.30am. We spent the day flying and landing at the three sites in deteriorating weather, with the last flight dodging several severe thunderstorms before landing safely back at Le Domain. We issued a report, but the conclusions were the same as previously. Again it was forwarded to the consultant, but they still disputed the conclusions. A meeting with the Algonquin lawyer in Ottawa and the consultant was arranged, but nothing was resolved. We found that the consultant was using costs derived from the construction of a small hydro plant in the city of Hull, which had no relation to costs in a remote location. None of the sites were developed.

However, my first meeting with the Algonquin at Lac Rapide was in distinct contrast to the meetings in Yellowknife. We were advised that the meeting would convene at 10.00am "Indian time", and I knew what that implied. I arrived at the agreed time accompanied by three engineers from the department of Indian Affairs. We met the white Band administrator and the local Indian police chief, and had coffee. With no sign of the eight band council members by 11.30am, when the administrator told the police chief to arrest the band council, on "the usual charges, drunk and disorderly". We had a short meeting, with no interest whatsoever being displayed by the council, half of them being asleep. They were more interested in the free lunch than anything else!

Travers "damsite"

After the meeting, I asked if I could have a quick drive around the village, and the administrator readily consented. The village had about 700 occupants, the homes looked as if they had been built within the last few years, and I was told that all were about 6 years old. But the aluminum flashing was falling off on several of the homes, and had not been nailed back in place. Some had broken windows, and several of the doors were askew. A couple of diesel generators were thumping away on the outskirts of the village. Near the entrance to the village there was an enormous pile of firewood, sufficient for several years of heating, but it was untouched. I was told that an agreement had been signed with a Quebec logging company to log within the reservation, on the provision that they would provide free firewood for the village. However, the homes also had electric heating, so it was more convenient to turn up the thermostat than to use the firewood in the stoves provided in the homes. Also, the thermostats were always turned fully on, with heat regulation obtained by opening windows.

Bois Franc 20MW site – undeveloped due to kayaking.

The village was provided with free electricity by the Department of Indian Affairs, so there was no incentive to conserve power. The power cost from the diesels was very expensive, and the Department had hoped that this could be alleviated with a hydro development. And the band had hoped that hydro development would provide both free power and that the surplus could be sold to Hydro Quebec to add to their income without working for it. So both parties were disappointed with our report. The lawyer in Ottawa was a member of the band who had managed to get a good education. He told me that the band's problems were the usual drugs and alcohol, no incentive to work since the Department provided for all the basic necessities, and a total lack of leadership within the band. There is no solution to such a situation until government support is withdrawn; some "tough love" is needed. The contrast with the Yellowknife band could not be greater.

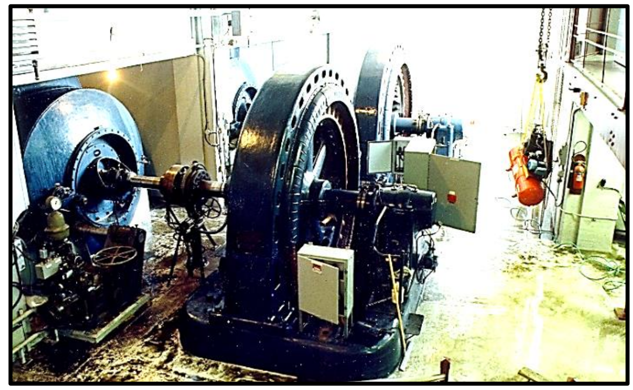
92. RIDEAU FALLS – 1993

In the spring I was asked by Gananoque Power to have a look at the inundation of their Rideau Falls powerplant.

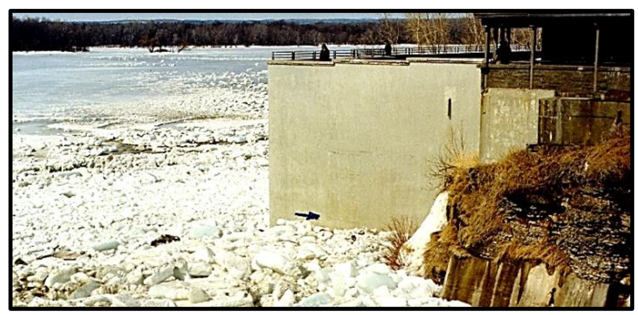
Arched ice dam and powerhouse, top right.

It is located beside the Rideau Falls in Ottawa. Sometimes, during the spring floods, an ice arch forms below the falls and when it breaks, the ice causes a high backwater at the powerhouse, flooding the plant. In this flood, the water level reached the shaft centerline!

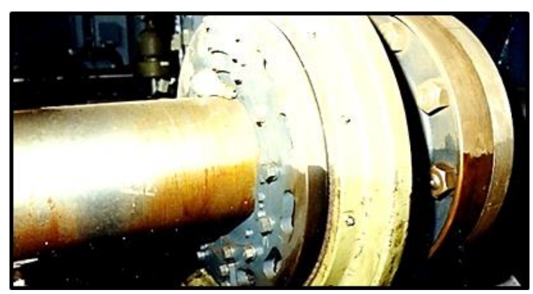
I drove to the plant and looked around. The flood had deposited silt all over the floors and equipment. My assignment was to estimate the cost of the cleanup, somewhat difficult since it can be influenced by any restrictions on disposal of contaminated silt. However, by comparing the task with the cost of the same cleanup at the Ayers powerhouse, I was able to provide an approximate cost.



Powerhouse interior after flood.

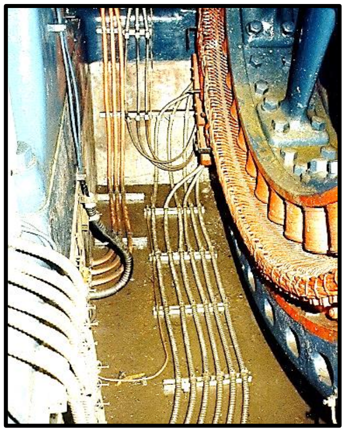


Flood level at powerhouse – see arrow.



Flood level in power house – mid shaft.

Years later, Gananoque decided to upgrade the controls and solicited lump sum bids for a SCADA (**S**ystem **C**ontrol **A**nd **D**ata **A**cquisition) system to provide control of the plant from their operating center in Gananoque. We submitted a bid, and (in hindsight) were fortunate to fail to obtain the contract. Another consulting company



was successful, completed the work, but their cost was far over their bid price, hence they lost a substantial sum.

Silt deposited inside generator.

The problem was in the instruments installed at Rideau, they could not communicate reliably with the older equipment at Gananoque. The contractor spent a large sum trying to make the system work, but to no avail. This was my first experience with SCADA, and ever since I have warned all my clients to beware of new SCADA installations at control centers. Without fail, they all experienced problems. Later, I found out that this was due to the rapid advances in SCADA, where the equipment changed so frequently, that consulting engineers could not keep up with the new developments.

Pointing out flood level on the compressors.

93. MATTHIAS – 1993

In September, I had a call from John Mattinson, generation manager at the Orillia Water Light and Power Company, now the Orillia Power Generation Corporation, to have a look at the concrete deterioration on the Matthias intake. Matthias was built in 1948-50 and had a single vertical axis Kaplan unit providing 2.8MW of power. I had met John at CEA conventions.

Matthias dam and spillway.

I flew to Toronto, rented a car and drove to Orillia where I was met by John. We then drove over to the Matthias dam and had a good look at the concrete. I found that where the concrete was shaded, the deterioration was not too severe, but anywhere in the winter sun, deterioration was extensive, all due to freeze-thaw from water seeping through the concrete.

View of deteriorated concrete.

Normally, I did not accept “concrete reinforcing” assignments, but in this case I made an exception, mainly because the work was so simple, and because Orillia was an excellent client. All I did, was to produce a series of sketches on four pages of standard letter paper, and described the repair work in a short report.

View of deteriorated concrete at penstock junction.

View of deterioration at junction of intake with dam.

Floating muskeg island in headpond.

This was sufficient for the contractor to produce detailed reinforcing drawings. The repair followed the same principles as those used on the Horseshoe Dam in Alberta.

The work was completed the next summer without any complications.

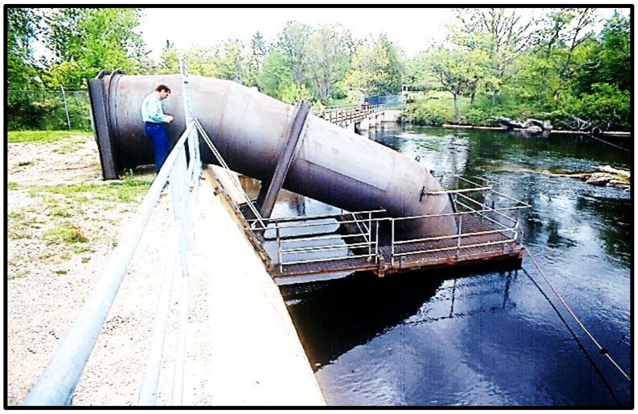
I am convinced that this was the way to undertake small repairs – engage an experienced consultant to produce sketches of the work, and then leave the rest to the contractor. If a consulting company had been retained, they would have produced a series of drawings detailing the concrete and reinforcing, at a far higher cost.

One intriguing fact was the presence of floating muskeg islands in the headpond. Some even had small trees growing on them.

94. WASDELL – 1993

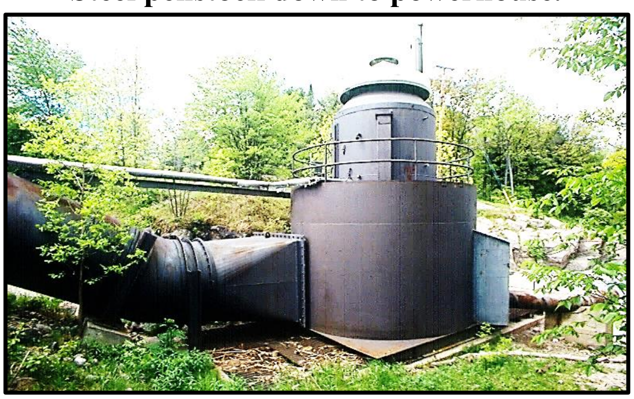
During one of my site inspections at Swift Rapids, John Mattinson asked me to have a quick look at the abandoned mini-hydro plant at Wasdell Falls. After the oil shock in the '70's, both the Federal Government and the province of Ontario introduced incentives for hydro in the form of tax write-offs and grants for innovative solutions. Ontario Hydro took advantage of the opportunity and commissioned the development of a packaged mini-hydro plant for the dam at Wasdell Falls.

To minimize costs, there was a syphon intake and short steel penstock down to the powerhouse. Since most of the penstock was above the hydraulic gradient, the dissolved air in the water came out of solution and accumulated at the top of the pipe, where it traveled downstream to a small tank, and was sucked out in a pipe through the powerhouse.



John Mattinson at abandoned syphon intake.

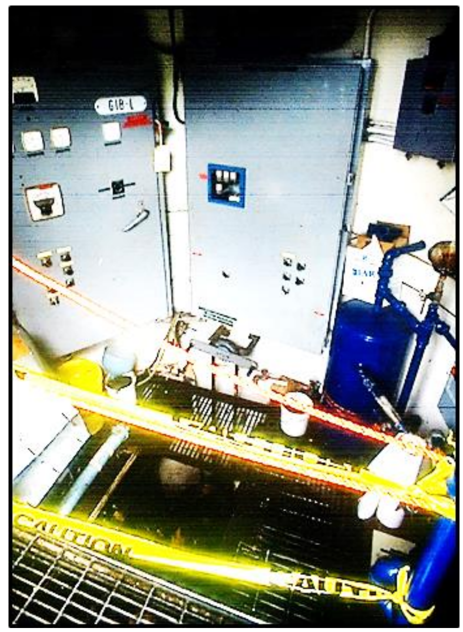
Steel penstock down to powerhouse.



Packaged powerplant – transported to site intact.

The powerhouse was in a circular steel shell, and no consideration had been given to access to the equipment for maintenance. There was a vertical shaft propeller turbine where the powerhouse shell was the outer wall of the semi-spiral casing. There were many problems with the equipment, and the plant only operated intermittently for about 2 years and was then abandoned. The exact nature of the problems was never divulged.

Another view of powerhouse.



Very tight powerhouse interior.

I had a look inside the powerhouse, and quickly concluded that any attempt to reactivate the facility was going to be just too expensive. Turbine access was down a short ladder into a confined space, so that safety rules would require several men at the plant for even minor repairs.

Recently, a new attempt is being made to develop the site with a canal replacing the penstock and a small concrete powerhouse with 2 Kaplan turbines. But with only 3.3m of head, the attempt failed due to the high estimated cost, unless a very generous purchase price for the energy can be obtained, far above the average cost. I advised John to forget about it.

95. COULONGE – 1994

In June I was invited by a contractor to have a look at their design-build small hydro project on the Coulonge River west of Ottawa.

Intake with headgate dogged open.

The turbines were being commissioned, so it was an opportune time to have a look around. The intake was in the middle of a small park, so it did not have a building over the gate, which was operated by a rented mobile crane. There was a long tunnel to the powerhouse which contained two units.

Long narrow powerhouse.

The powerhouse was long and narrow housing two horizontal axis double runner Francis units. The runners were back to back with the draft tubes on each side of the spiral casing. Each generator could produce 8.5MW at 41.5m head. The inlet valves were operated by a hydraulic servomotor to open, gravity weight close. An overhead crane serviced all equipment.

Overhead crane.

The project was built by an entrepreneur, so costs were kept to an absolute minimum. There was no hoist on the intake gate, and the air vent terminated at a grating on the intake deck. I would have preferred at least a small building over the vent to lift the air outlet to above snow level.

Two views of powerhouse interior.

Control room with switchgear.

The draft tube gates were operated by a small monorail hoist suspended at roof level, the ideal location. There was no surge tank, so I enquired about speed regulation, since there were no relief valves on the units. Apparently, the tunnel size was increased to facilitate excavation, and the velocity was slow enough to allow reasonable governor closing times without adding generator inertia. On the whole, I was quite impressed with the work.

Coulonge Falls.

96. APPLETON – 1995

In January, I attended a meeting of the CANMET Technical Advisory Board in Ottawa, and the next day, we all drove to Appleton, a short ride west of Ottawa, to inspect the new small hydro plant.

Intake structure.

The plant is low head with three inclined axis Kaplan turbine connected to induction generators through speed increasing gear boxes.

Distributor and wicket gates.

Inclined shaft generators and gearboxes.

Inclined axis turbine units.

The equipment was supplied by a local small turbine manufacturer where most of the components were cast using the lost wax process. They had a standard range of turbines in various sizes, and could produce components at a very low cost. For example, cast wicket gates cost less than $20 each, quite an achievement.

The layout was quite simple, with a horizontal intake passage transitioning from square to round, followed by a 45 degree elbow to an inclined turbine-generator, followed by another 45 degree elbow to a horizontal draft tube. My only concern would be with the inclined gears where lubrication may be inadequate due to the oil accumulating in a corner of the sump.

Similar unit with 90^0 elbow.

After looking at the powerplant we all went over to inspect the factory where a smaller 800kW unit destined for the Snare powerhouse near Yellowknife in the Northwest Territories, was in the final stages of assembly.

6-blade Kaplan turbine. Manufacturer – Canadian Hydro Components in Almonte.

97. RUSKIN – 1995

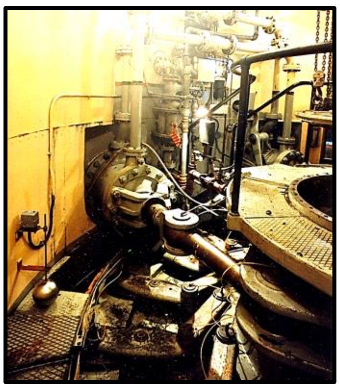
In March, the CEA meeting was at Vancouver and the opportunity was taken to visit the Western Canada Hydraulics laboratory in Port Coquitlam, and then on to the Ruskin hydro plant in the Frazer valley. The laboratory had several hydro models, one for a large Tainter-gated spillway on an overseas project. The Ruskin hydro plant was next, but we only paused briefly, since the most time was to be spent at the Stave Falls development.

Hydraulic model of a spillway.

Ruskin spillway.

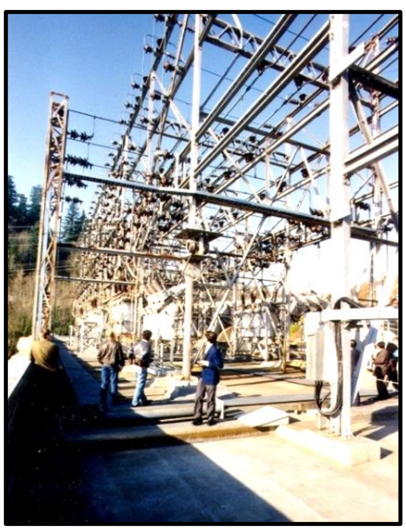
The plant is located about 6km downstream from Stave Falls. The first two units at Ruskin were installed in 1930. Power output was a total of 70MW. A third unit was added in 1952.

View of powerhouse and spillway.



Servomotor and operating ring on turbine.

The dam is 59m high and contains Hayward Lake. It includes seven Tainter spillway gates with a discharge capacity of 3,700 cubic meters per second. The powerplant was fully automated in 1970 and connected to the central control room on the second floor of the Vancouver BC Hydro downtown office building, now moved to Burnaby.



Substation behind powerhouse.

During the CEA meetings I heard that the association may be discontinued due to the high cost, and this proved to be the case, with the last spring meeting occurring in 1999.

Powerhouse – glass building is visitor entrance.

98. STAVE FALLS – 1995

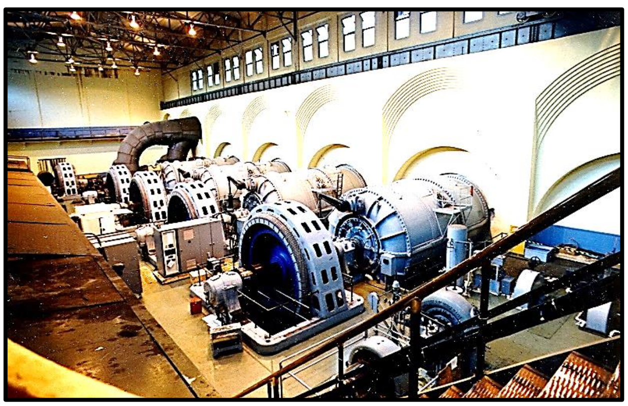
The Stave Falls development proved to be particularly interesting since the powerhouse was to be decommissioned and converted into what became the best hydro museum in Canada. I had the opportunity to visit the plant again after the museum was operating in 2004 and found that the effort had been well worth-while. It is certain to be popular for high school trips.

Err – which way should the penstock pipe go??

The lighting had been improved, there were pamphlets available explaining how all the equipment worked; toilets had been installed;

guides were available to show visitors around and answer questions, a 50-seat theatre was added and on the whole, an excellent effort by all concerned.

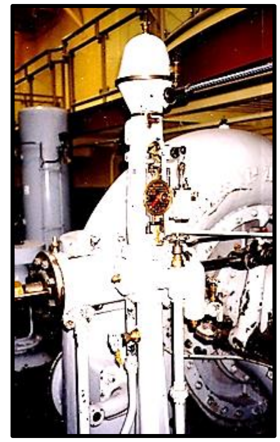
OK – we'll swing those two small ones over to the left, and that large one up and over to the right.



Powerhouse floor before conversion to museum.

Powerhouse floor after change to a museum.

Right – Old Woodward HR governor.

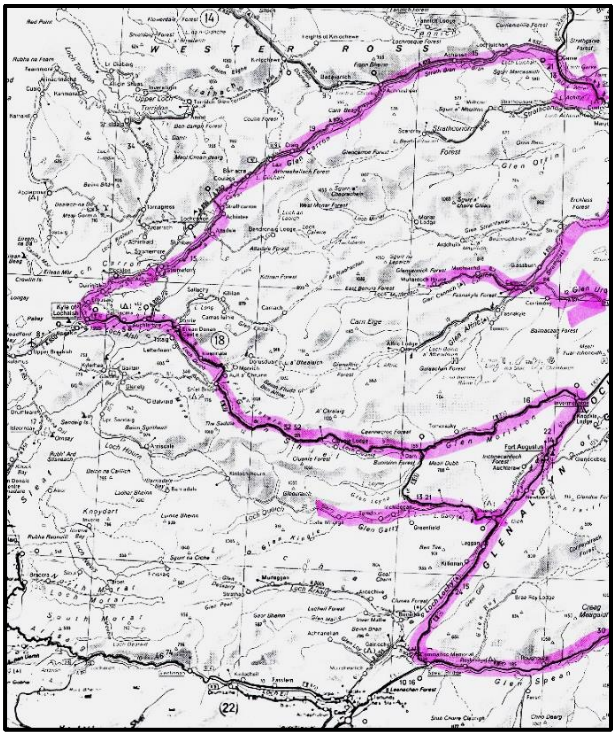


Penstock to horizontal axis double-runner Francis turbine.

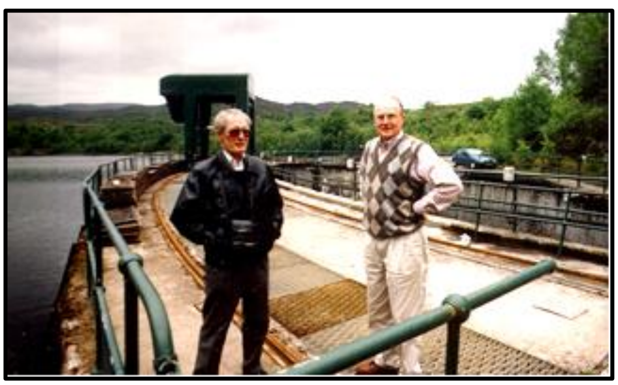
99. SCOTLAND – 1995

In June, I traveled over to Scotland through Amsterdam since KLM had a connecting flight to Dyce Airport at Aberdeen. I stayed with George Matthew and his wife Margaret. After attending the quincenntennial (500) celebrations of the founding of Aberdeen University, I toured the Scottish hydro plants with George.

Left – looking down the Glen Garry gorge from the spillway dam. Right – the side channel spillway at Glen Garry.

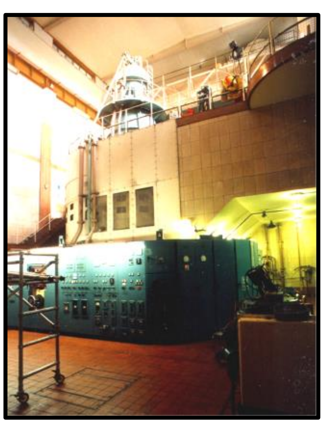


Our route through the highlands.



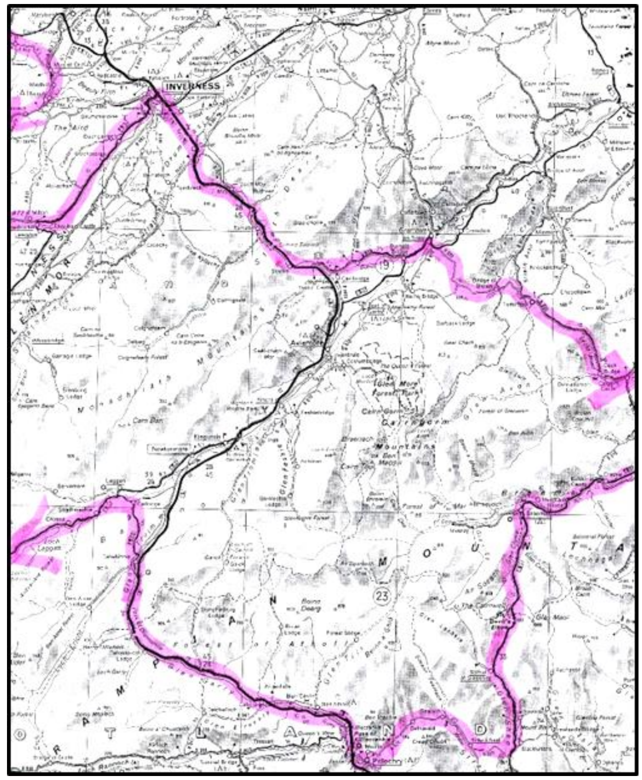
With George on the Glengarry Dam.

We had both worked on some of them, with George having been more involved with the detailed design of Ceannacroc and Dundreggan.



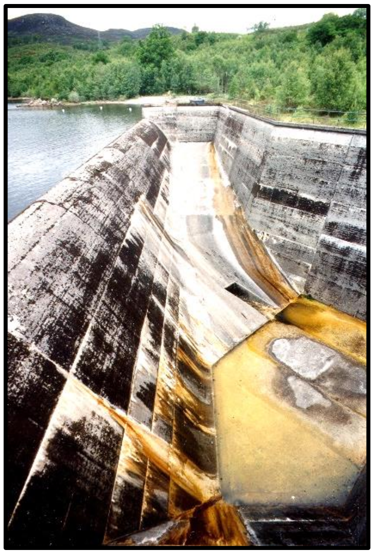
View of the Glen Garry single unit powerhouse interior.

Our route through the highlands.



We stayed at local bed and breakfasts and were quite comfortable. The only place we had trouble finding accommodation was at Glen Garry, where there was a large hiking group meeting in the area for a walk through the glen. There we happened to meet John Reid, the Halcrow engineer who worked on the Glen Garry model at Aberdeen University in 1951-2. He was semi-retired providing consulting services to water boards, mostly in the former colonies of the British Empire. We all had dinner in the Glen Garry Hotel, where we met his wife, both in formal dinner dress – yes, they still dress for dinner in hotels, quite a revelation. And yes, the class system was still functioning – George and I, both in flannels and blazers, did not receive the same attention from the hotel waiter!

We found that there was no security at any of the developments. No gates to open, and even the powerhouse doors were unlocked, so we simply walked in!



View of the Glen Garry side channel spillway.

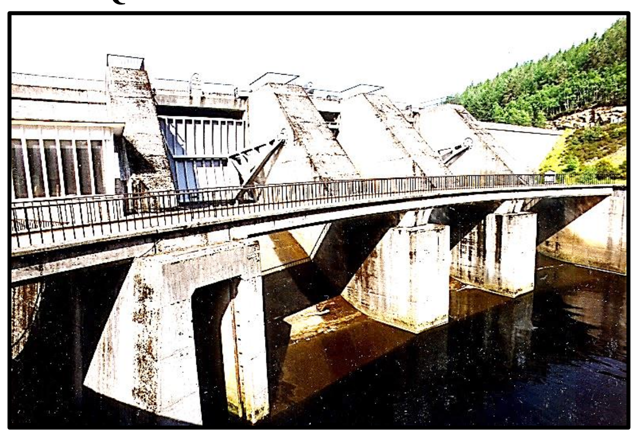
I had worked on the Glen Garry hydraulic model in my final year at Aberdeen University, so I was very interested in how the facility had survived. One item I noted was the excessively large trashrack area, it must have been at least 4 or 5 times larger than what I would have used in Canada.

Enormous trashracks at the power intake.

After Glen Garry, we drove up the valley to the storage reservoir at Loch Quoich, where I had also undertaken some survey work in the summer of 1951. To reach the dam area, we had to ford the Quoich River by car, and I remember we always had to watch the weather, since a sudden thunderstorm in the upper valley would quickly make the ford quite impassable. On two occasions we had to leave our survey work and retreat downstream! Now there is a bridge.

The Quoich side channel spillway.

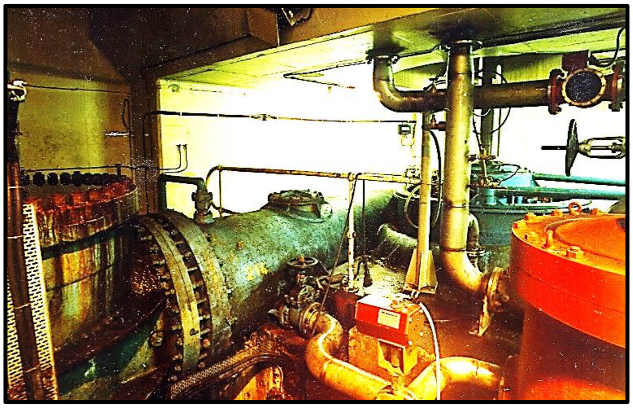
The Quoich concrete faced rock fill dam.



The Dundreggan dam, designed by George.

George in the Ceannacroc underground powerhouse, also designed by George.

George also worked on the Ceannacroc underground powerhouse, so he was quite eager to see the plant, having been denied the chance when he was a junior engineer with the consulting company.



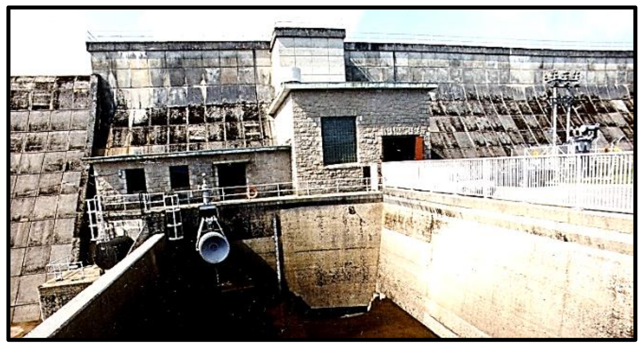
Turbine pit at Ceanncaroc.

We then drove over to the Loyne dam through Fort Augustus and Inver Moriston – I just wanted to have another look at the road we had travelled many a Saturday from the glen up to Inverness, when surveying at Glen Garry. Apart from new surfacing, it had not changed.

From Loyne, we became tourists for a short while, and drove west to the Kyle of Lochalsh on the west coast, stopping to photograph the Eilean Donan castle, the most photographed castle in Scotland. We had lunch at the Kyle of Lochalsh Hotel, in the dining room with large windows facing south, and with a weak sun streaming in; it was the only time I was warm in my trip to Scotland, the heating having been turned off for summer! We then drove over to Plockton when George mentioned that there were palm trees there – I just had to see them. Apparently an arm of the Gulf stream flows over to the west coast past the inner and outer Hebrides keeping the area relatively warm.

We then drove through Glen Carron, past Loch Luichart to Garve and Beauly, turning south-west to Glen Affric where we stopped to look at the Fasnakyle powerhouse where my career in hydro had started in July 1950.

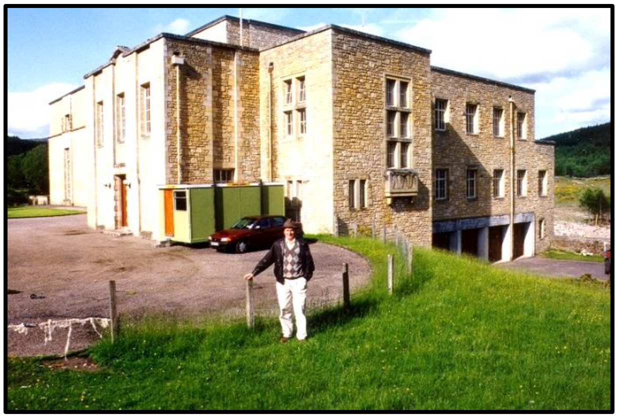
The Loyne Dam.



The small powerhouse at the Loyne Dam.

Plockton village – yes, there are palm trees in Scotland!

When Fasnakyle was built, it included a large office complex which was intended to function as the control and engineering center for all the western Scotland hydro plants. However, it was now mostly empty, with the control center having been transferred to Dundee. The transfer took place in 1975, shortly after the plants had been automated.

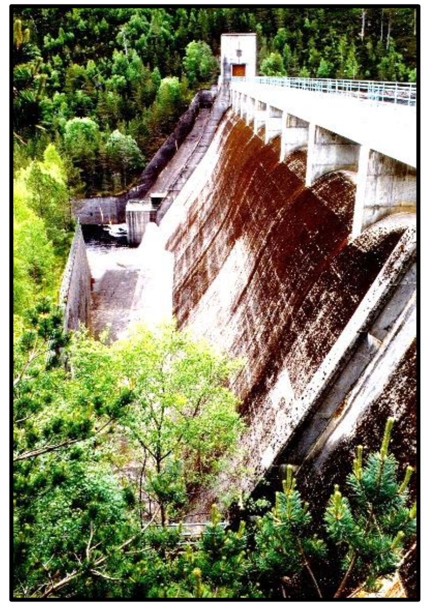


At the Fasnakyle powerhouse.

About a week after the transfer, a telephone technician at Dundee was checking the lines when he found a red light on one of the circuits. He plugged into the circuit and heard one voice saying over and over "the turbine bearing on unit #2 at Fasnakyle is overheating", and another voice was repeating "the number you have just called has been changed to 55 4126"! This incident was reported in the Water Power magazine as a reminder to check all automated circuits when moving control centers.

Fasnakyle powerhouse interior.

I was eager to see the turbine outlets since the turbines had relief valves discharging well above tailwater, with the jet directed across the river. My very first task as a student rodman was to help with the survey of the bank opposite the turbines. Apparently it had to be graded to a certain profile and covered with gravel to absorb the impact of the water jet.



Benevean Dam and intake for the Fasnakyle powerhouse.

Even as a student, I was very skeptical of the design, thinking that the large water jet would tear up the gravel and completely destroy the relatively smooth surface. I saw that the gravel was no longer there, and the bank was now covered with grass with sheep wandering about. But who would listen to a second year engineering student, so I kept my mouth shut!

From Fasnakyle, we drove up to the remote Loch Mullardoch Dam and had coffee at the Mullardoch Hotel. The hotel was almost empty, so the large windows in the dining room were wide open despite the outside temperature being just above freezing. The waitress asked if we would like the heating to be put on, but we declined since we were only staying for coffee, and it would take hours to heat the dining room.

On the road up Glen Cannich to Mullardoch Dam.

I noted the furniture in the dining room; most of it looked remarkably like my father's furniture that was sold to a large fishing lodge! But I could not be certain.

George on Mullardoch Dam.

The Mullardoch Hotel was being advertised as a retreat, with no TV, no entertainment, no electricity, only peace and quiet, only some hill walking and perhaps some fishing. Apparently they were quite busy in the summer.

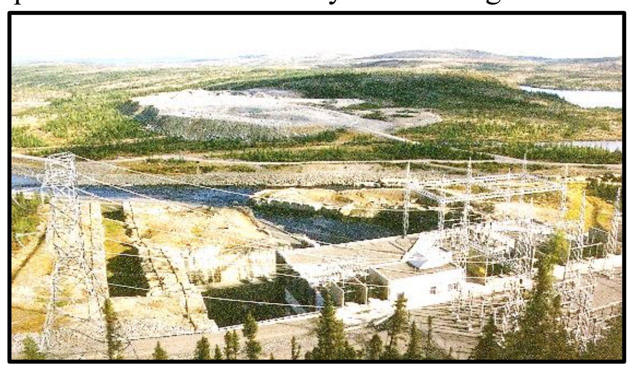
Finally, back at George's home in Aberdeen.

From Mullardoch, we drove back to Aberdeen through Inverness. It was an enjoyable trip around the highlands; and very interesting to see the hydro facilities. Also, great to meet Ronnie and George again after 43 years!

100. BRISAY – 1995

In September, the CEA/CANCOLD fall meeting was held in Montreal at the Dorval Hilton with a site meeting to the Hydro Quebec developments of Brisay and La Forge in the far north of Quebec, some 940km north of Montreal. Brisay was operating when we arrived.

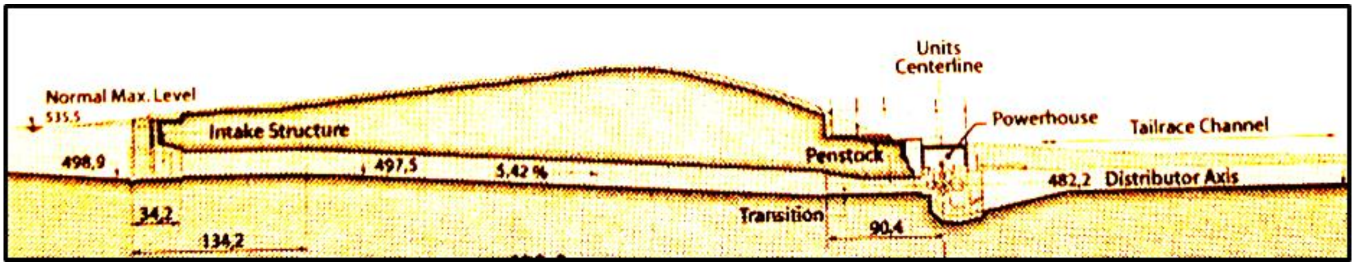
The facility had many provisions for the inclement weather, since temperatures would often drop to -50C. For example, the draft tube hoist was within a heated enclosure, and included a concrete wall to well below ice level. The operators were quartered in a large hotel-recreation complex with such facilities as a swimming pool, library, internet, squash court and a south-facing sun-room. Each operator had his own permanent room, and worked on a 12-hour shift, 3-week cycle, and flying back home from a nearby airfield on a Thursday. The quarters were also used by the La Forge staff.



Powerhouse and substation.

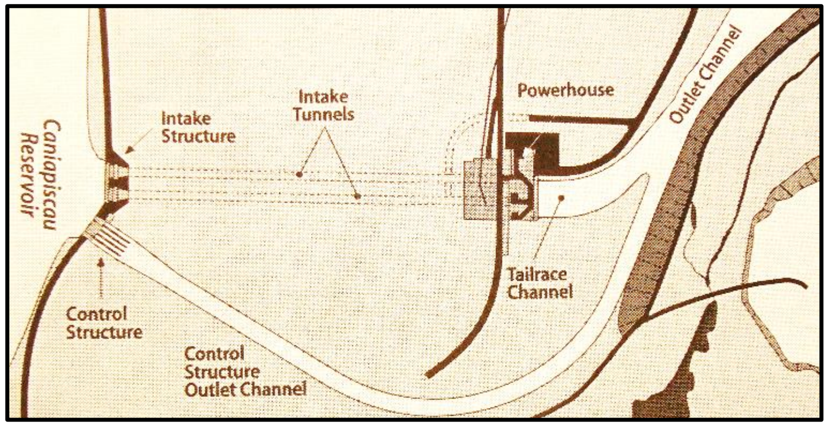
Powerhouse with granite tiled generator floor

I asked an operator about the granite-tiled generator floor, he was not at all impressed; they had to cover it with plywood whenever it was used!



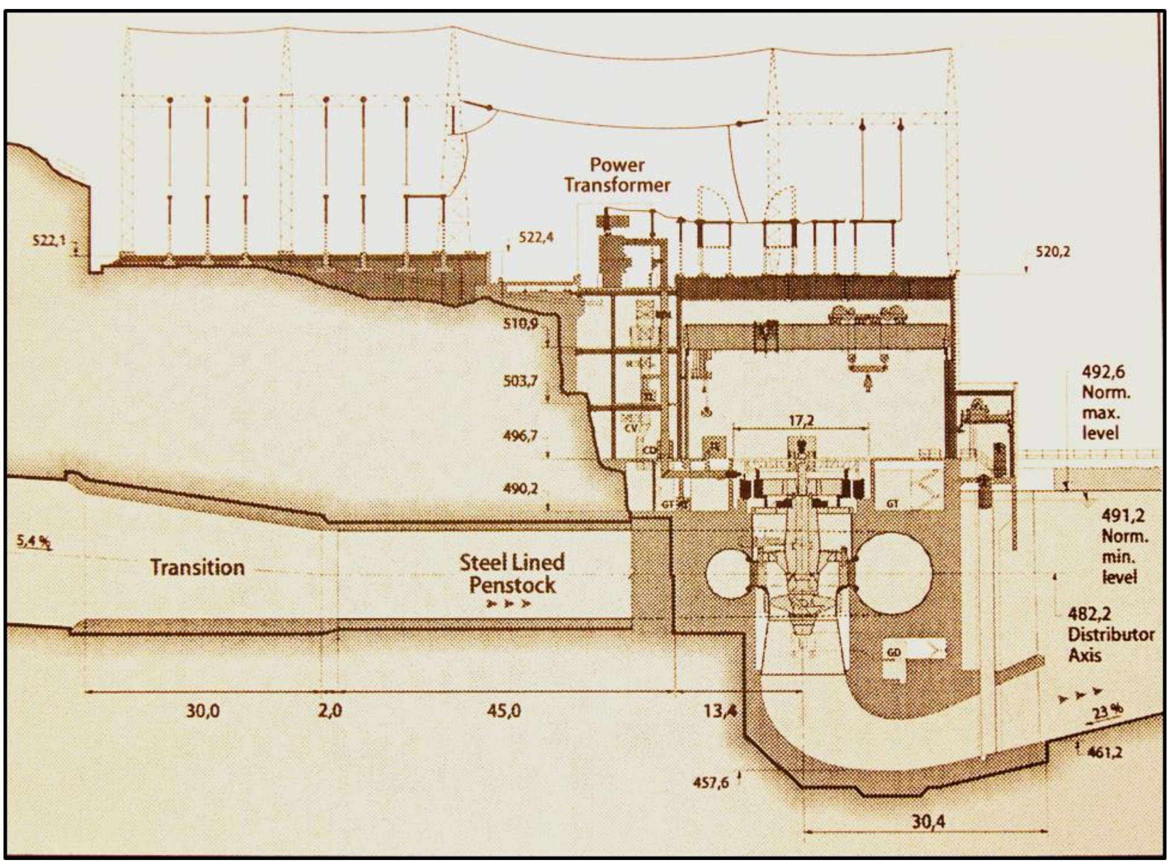
Section through development.

Plan of development.



Left – turbine pit. **Right – Enclosed draft tube deck**

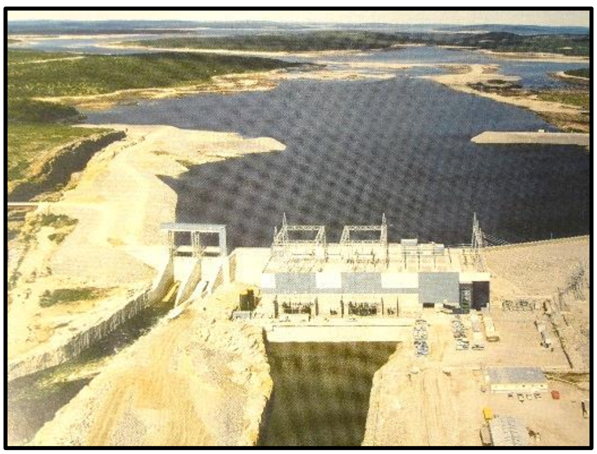
Below - Section through powerhouse. Figure source – "the Brisay Hydropower Development" Verville and Bouchard. CEA/CANCOLD conference, Sept. 1995.



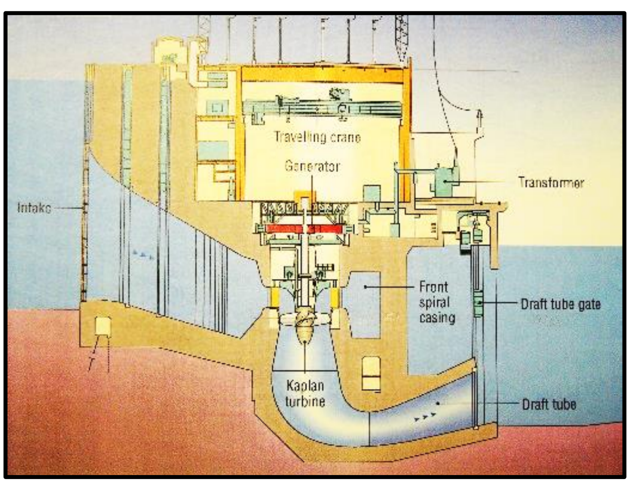
Staff dining room.

101. LA FORGE – 1995

After looking over Brisay, the group proceeded on downstream to La Forge #2.



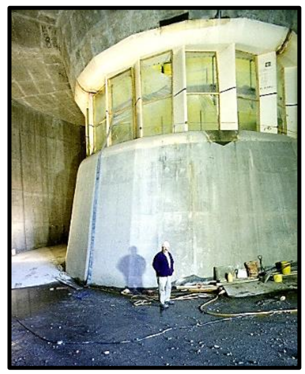
Aerial view.

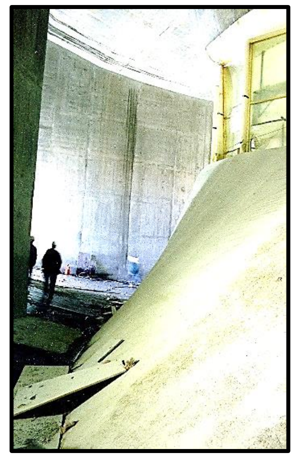


Powerhouse section. Source – HQ brochures.

Three-gated intake for one unit.

It was a gigantic facility, still under construction and equipped with two Kaplan turbine runners of 8.45m diameter – the largest I have ever seen!

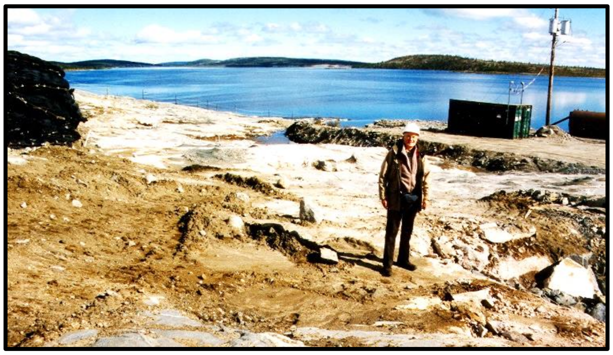




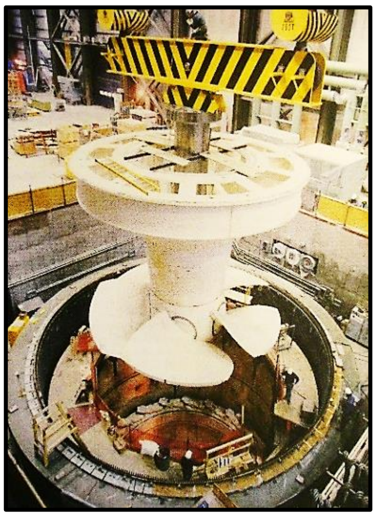
Tour guide in turbine semi-spiral casing.

Diversion channel.

As at Brisay, all operations are within heated buildings. There is even access to the intake hoists from inside the powerhouse, and as at Brisay, the draft tube hoists are enclosed with a deep downstream wall to below ice level. The operators are housed at the same complex as the Brisay staff. The two plants are the most northern of Hydro Quebec facilities.



At the site, with La Forge 1 reservoir in background.



Placing runner.

We had a good look at the concrete semi-spiral casing, and I was impressed by the size, and had the same reaction when looking at the draft tube! Intake gates are 6.1m wide by 17.75m high. Each turbine produces 155MW at a net head of 28.8m. Flow per unit is 1,200m^3/s

Draft tube hoist gallery – hoist capacity = 25 tons.

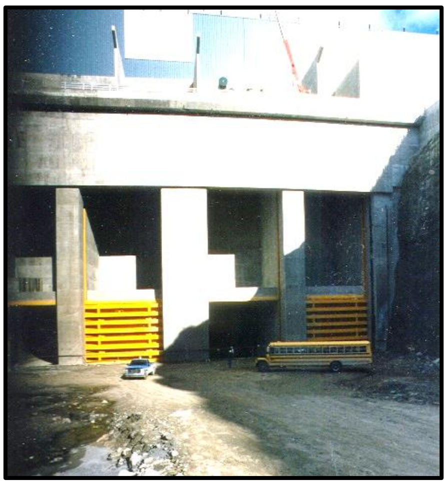
Each draft tube has two gates, 9.0m high by 11.2m wide. The transformers are on top of the draft tube deck, and the plant substation is on the powerhouse roof.

View of powerhouse generator floor. Lower distributor ring on repair bay floor.

However, there was an interesting "incident" during commissioning of the units. The "watering up" process was started wherein the water passages are slowly filled with water through by-pass valves. Due to the large size of the units, this process took many hours, so the commissioning staff decided to let the water run into the units during the night, expecting to return the next day to continue the commissioning. Next morning they were surprised to hear water running within the powerhouse, and a red light on in the control room indicating an overflow in the sump. They ran downstairs to the turbine floor and were astonished to see several centimeters of water covering the floor and flooded turbine pits. Closer inspection revealed spouts of water emanating from long cracks in the concrete near the end wall of Unit #2. The by-pass valves were immediately closed, and pumps installed to remove the water. But what had happened?

A few days later I had a call from Dr. Ken Moore (the Saunders boffin) who asked me a simple question "what is the maximum stress in reinforcing steel where concrete will not crack under the tension?" and I replied that everyone knew the answer – about 83MPa (12,000psi.). Of course, I had to ask why he wanted to know.

So he told me about the incident, and that he had photos of the spouting water. I immediately told him that I wanted to see them, since I knew the engineers who had designed the powerhouse, and could not imagine they could make such a mistake in the design. So I immediately drove to the Montreal AGRA office to have a look. Ken had been engaged to review the design and find the cause of the cracking.



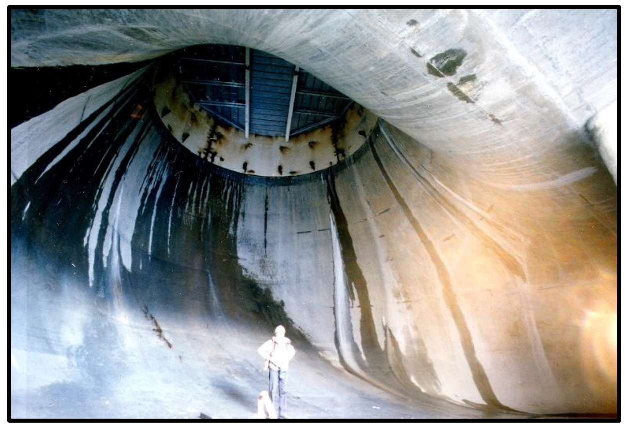
Draft tube outlets.

The concrete structure was so complex, that a finite element computer program had been used to calculate stresses. The concrete beam across the top of the semi-spiral casing was over 6m thick, so there was more than sufficient concrete to take the forces. Ken looked over the program, the modeling shape, and all seemed well.

If the program data was correct, the only other source of error was in the boundary conditions. The computer had modeled the surrounding rock with strength parameters for sound granite rock, about 8 times stronger than concrete. The computer output indicated that the rigid rock would contain the structure and prevent any movement, resulting in only minimum reinforcing steel in the 6m thick concrete slab above the semi-spiral casing.

In fact, the rock had been severely cracked when blasting out the excavation for the powerhouse, and was no longer supporting the side walls. The result was cracking due to the water pressure within the casing pushing out the end wall and compressing the cracked rock. By assuming minimum support from the rock, Ken was able to duplicate the crack pattern.

Nineteen post-tensioned anchors were required to stich the structure together and stop the leaks.



At bottom of draft tube elbow.

It was an expensive lesson for Hydro Quebec, and resulted in a decision to use Review Boards (a group of about 4 very senior and experienced hydro engineers who could look at the designs and ask many "what if" questions) to monitor designs in the future.

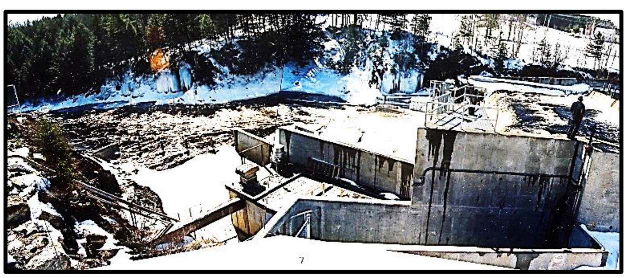
Looking into half of draft tube. Note enormous size!

Yes, a very interesting development, made more so by the "incident", kept quiet and now forgotten.

102. MORGAN FALLS – 1996

In March, I had a call from Tony Tung at CANMET asking me to go down to Nova Scotia and look at the Morgan Falls plant, where the 600kw turbine was only producing about 400kW at full load. The plant was on the LaHave River near the town of New Germany.

It was another example of how not to undertake a small hydro development. The owner had contracted the design to a young engineer with only a few years of hydro experience, and unfortunately he had developed a layout with several major flaws in the design.



Panorama – powerhouse, by-pass sluice and tailrace.

View of intake channel and dam.

The water dropped down a concrete shaft from the intake and turned through a right angle immediately upstream of the turbine, resulting in very uneven flow onto the turbine runner. Turbine specifications require a straight approach to the turbine, and any bend upstream has to be gradual and not abrupt.

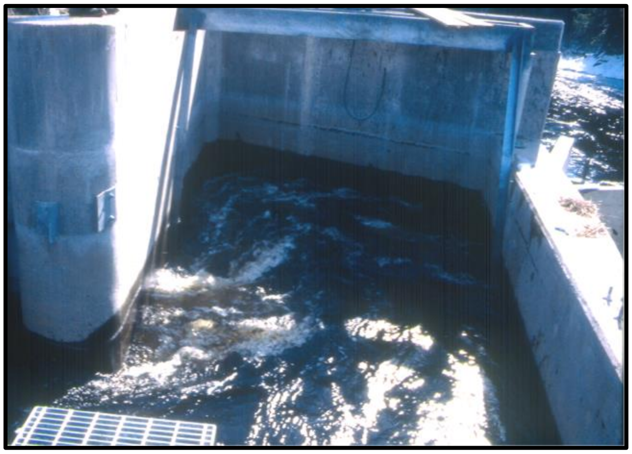
There was another problem at the intake. The intake gate was too close to the surface, so that when the power exceeded about 250kW, large vortices formed on the water surface, becoming so severe that air was drawn down resulting in less water and of course, a lower power output.

View of powerhouse and intake shaft. The two men are standing on the intake deck.

Another, although relatively minor problem; was in the powerhouse. There was no emergency exit in case of fire in the control cabinets located beside the entry.

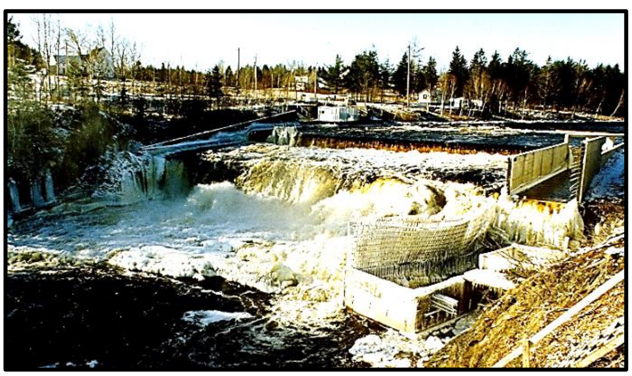
View of turbine. Note abrupt right-angle bend immediately upstream of turbine.

The turbine had several issues, the servomotor was too small, the Kaplan blade angle was not correctly set for the optimum position relative to the wicket gate opening, and the turbine runner starts cavitating at only 250kW output.



Large vortex beside pier at maximum power output.

Some of the deficiencies were corrected, but eventually, the runner was removed and another installed designed for a slightly lower output.



During construction, March 1995.

An unfortunate learning experience for the owner!

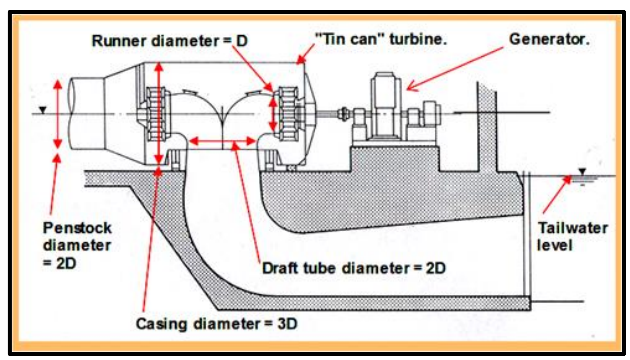
I have seen this situation on most small hydro developments. Owners engage inexperienced consultants. The solution is to add an experienced hydro engineer as Clary Getien did at the Ragged Chute development near Cobalt, Ontario.

103. MERRICKVILLE – 1996

In the spring, I had a call from Ontario Hydro requesting my assistance in solving an argument between the consultant and equipment contractor at the small 1,700kW Merrickville hydro plant.

The first 500kW unit at Merrickville was started in 1915, and the second followed in 1919. The turbines were horizontal "tin can" double runner Francis units providing power to local industries around the village.

The facility was acquired by Ontario Hydro about 1970, and continued to operate until 1993, when a decision was made to upgrade the units. They wanted to encourage small hydro equipment manufacturers in Ontario, and persuaded Barber, who had a machine shop still working, to manufacture the turbines. Barber made some preliminary calculations, and found that they could easily increase the capacity to the 850kW required by Ontario Hydro with a slightly larger "tin can" turbine.



Section through "tin can" turbine and generator.

The Merrickville plant had been declared a "heritage" building, hence every effort was made to preserve as much as possible of the old building. The Barber calculations indicated that the larger turbine could be easily fitted within the footprint of the existing building. However, the Barber turbine engineers had all left the company when it had ceased production of turbines a few years previously, so Sulzer was brought in to review and update the turbine design. They immediately found that Barber had seriously underestimated the required turbine size, and consequently the unit could not fit within the building. Ontario Hydro decided to proceed with the rehabilitation, but only preserve the front wall of the building.

The new units were installed and when started, all the bearings registered excessive temperatures. An analysis discovered that the shaft in each unit was no longer horizontal, and had moved out of alignment by a few thou. Further work indicated that both the footings and the turbine "tin can" had deflected. At this juncture, the consultant blamed the contractor and vice-versa.

Sulzer remembered my work at Carmichael Falls, and suggested to Ontario Hydro that I should be retained as an independent consultant to resolve the impasse. I motored over to Merrickville and stayed at the renowned Sam Jakes Inn close to the plant, now demolished. Ontario Hydro had asked me to determine the extent of movement attributable to the foundation and also to the turbine.

An inspection of the plant indicated nothing amiss, since deflections of a few thousandths of an inch could not be detected by eye. I reasoned that accurately measuring deflection of the four footings supporting the "tin can", the movement of the inlet pipe at the upstream end of the "tin can" and at the shaft where it emerged from the "tin can", when the unit was filled with water, as compared with the unit empty, would indicate the source of the deflections – the same procedure as used at Carmichael Falls.

There was some difficulty finding a reliable rigid bench mark for the foundation movements, and after some discussion, a spot on a rock immediately downstream was selected. Measurements were taken with all units empty, with one filled, with the other filled, and finally with both full of water.

Since the tin cans were much larger, the water pipe to each unit had a slight bend just upstream of the units with a slip joint. This introduced a lateral force into the tin cans, which added to the complexity of the movements. I found that parts of the unit were moving up, other parts down and the shaft also had a lateral movement. After much analysis, I found that the upward movement at the inside footings was caused by the lateral force from the inlet pipe.

Foundation supports moved up to 20thou, but averaged 4thou. Shaft movement was up to 16 thou, but averaged 7thou. Detailed analysis indicated that on Unit #1, the movement was 9% attributable to the foundation, and the rest to the turbine. For Unit #2, foundation movement was 28%, and the rest due to the turbine. I could not determine the reason for the different ratios. The report was accepted; the units strengthened, and are now operating successfully.

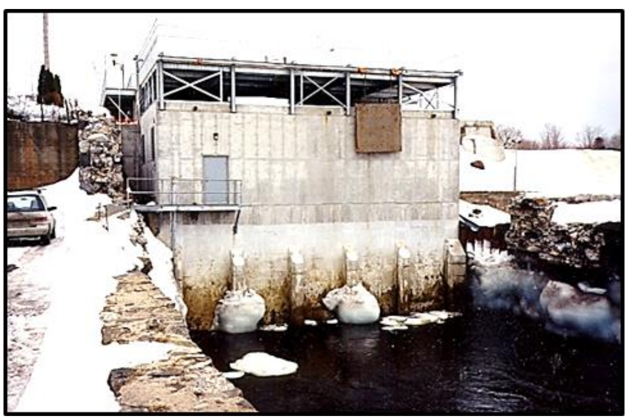
A few years later, Tony Tung asked me to join a group of Swedish and Norwegian hydro engineers touring Canadian hydro plants. They had meetings with CANMET to discuss hydro policies, and had requested a tour of Merrickville since it had recently been in the news.

At the plant, they had a good look over the shiny new units, both operating at near full load. They were very impressed with the facility, and congratulated the Ontario Hydro operator on the excellent condition of the equipment.

However, the head of the delegation spoke to me, and asked how it was possible to maintain an 85 year old plant in such excellent condition. I had to inform him that it was brand new, whereupon he remarked "why have you installed new turbines based on 1910 technology?" – To which I had no answer. I later told Tony never to show the facility to any foreign hydro engineer!

104. MONTMAGNY – 1997

One of my projects as an independent consultant, was the investigation of poor performance of a mini hydro plant at Montmagny just north-west of Quebec City.



View of downstream wall of powerhouse.

There an entrepreneur, Pierre, a lawyer from Quebec City, had built a 5-unit powerhouse containing inclined axis propeller turbines each producing about 440kW at 9.5m head. The turbines were not producing the expected power at full load, being about 6% lower than expected.

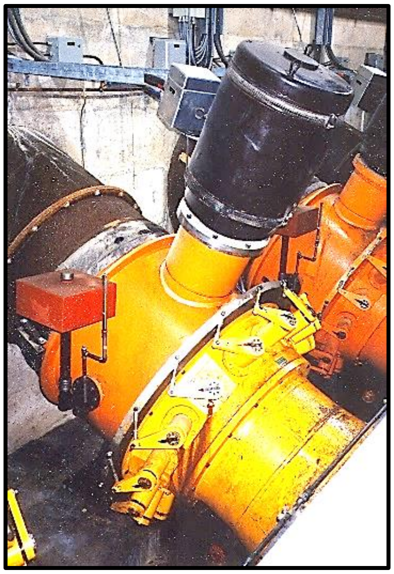
I had a good look at the installation, and it appeared to be well built. Unfortunately, the turbine manufacturer had just entered the business, and was not aware of the importance of the draft tube in a low-head installation. The construction drawings showed the draft tube shape, and I immediately noted that the cone angle was too wide, and the tube too short, resulting in a loss in efficiency.

View of intake area.

I looked through my set of "vertical files" for draft tube information, and came across an old paper on draft tube design, where a draft tube with a similar shape to that at Montmagny had been tested. With this information, I was able to calculate the efficiency and found that the output was correct for the draft tube shape used at the plant.

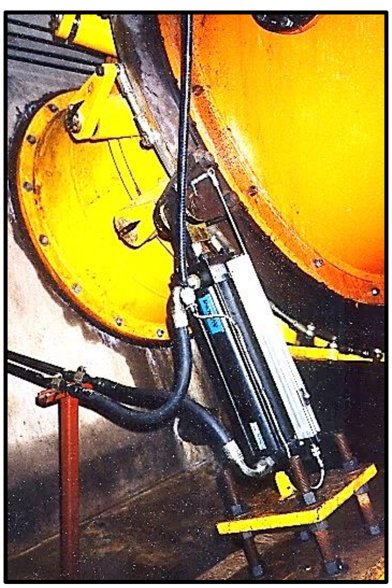
Powerhouse interior.

Changing the configuration of the draft tube proved to be too expensive, so it remained in operation at the lower maximum output.



Right-angle gears to generator above turbine.

However, this was not the end of problems. About 2 years later, Pierre called me, asking for advice on the right-angled gears which were overheating in all the turbines. I did not know anything about gearboxes, so I referred Pierre to a mechanical engineer Bill that I knew who had extensive turbine experience. Pierre called me back about an hour later, and said "who in hell did you recommend!" In all my experiences with Pierre, I had never heard him swear, he was invariably polite and a real gentleman. After calming him down, I managed to find out what had happened. Apparently Bill, on finding out that Pierre was a lawyer, had berated him for almost an hour, stating that lawyers should not own hydro plants.



View of turbine servomotor.

Pierre was too polite to terminate the conversation, so just let Bill talk until he ran out of steam.

I told Pierre I would call him back with another suggestion, which I did, after speaking to Jack, a machinist I knew in Ontario. Jack had worked on gearboxes in ships, and managed to solve the problem; insufficient oil flow from the sump, remedied by extending the suction pipe down to the corner of the inclined sump.

However, that was the end of recommending Bill as far as I was concerned.

105. JONQUIERE – 1997

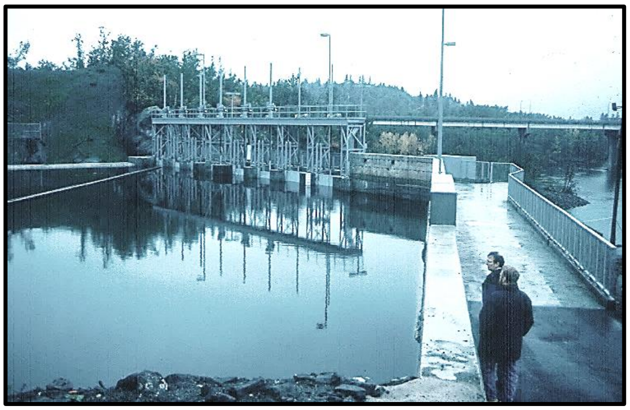
I had joined the Canadian Dam Association a few years ago, and this year they had their annual October meeting in Chicoutimi, with a tour of the repairs being made to dams and spillways that had been damaged by the 20th July 1996 flood, which was estimated to have had a return frequency of 1/5,000. It was a mostly foggy and cloudy day.

View of dam breach. New weir added downstream.

The Hydro-Jonquiere Dam was interesting, in that this was the second washout within a few years, both repaired with insurance moneys. The first failure had something to do with the design, but I never found out the exact cause.

There were several hydro plants in the watershed, and the flood was a major disaster, with many of the spillways failing due to blockage with driftwood and other debris swept down in the flood waters. In some cases, the debris was so dense, that the gates could not be opened, with debris piled up on top of the gates.

New spill weir downstream of dam breach.



Repaired Hydro Jonquiere dam – upstream view.

Repaired Hydro Jonquiere dam, downstream view.

It was an excellent lesson on how much damage can be caused by debris blocking spillways. In most hydro facilities, Owners rarely survey the upstream watershed for debris, hence the risk is unknown.

New spillway gates and monorail hoist.

Repairs to dam breach.

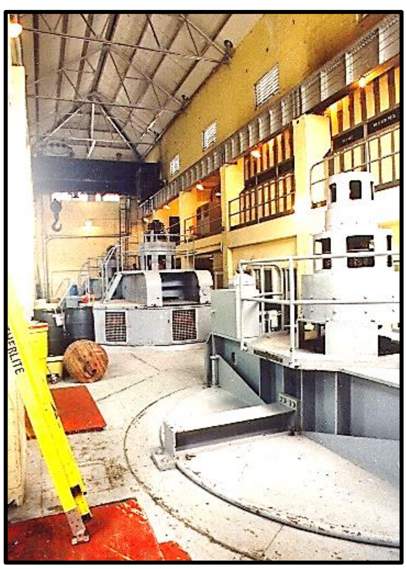
Repaired dam breach.

106. HIGH FALLS – 1998-2002

I had known Colin Clark since he graduated and started working for Gananoque Light and Power in the mid-seventies, so I was not surprised when he called me and asked if I could provide some advice on their planned refurbishment of the High Falls powerplant near Wawa, Ontario.

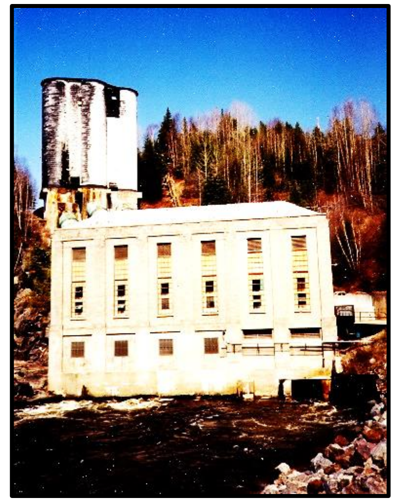
Colin was now the Vice-President Production for Great Lakes Power (GLP), the owner of 13 hydro plants west of Sault Ste. Marie. High Falls is the second of four powerplants on the Michipicoten River with a capacity of 27MW in 3 units. The first 2 units were installed in 1929, and another was added in 1950. However, it had reached the end of its service life, with insufficient spillway capacity, AAR problems in the powerhouse, asbestos insulation in the surge tank, and three old leaky wood stave penstocks. Also, the small capacity was now a bottleneck in the system. GLP had decided it was now time to demolish the old plant and build a new one with about twice the capacity at 45MW under a head of 45m.

Old powerplant. Dam at head of dry river bed.



Powerhouse interior.

A consultant had been retained to undertake a feasibility study, and had produced a detailed report recommending construction of a new dam immediately downstream of the existing dam, two intakes, two penstocks and a powerhouse with 2 Francis units on the right bank. I was provided with the report for review, but my comments were not favorable, and I suggested changing the penstock layout and type of units.



Powerhouse, surge tanks behind.

View of old intake house and spillway dam.

New spillway pier.

The dam concept was acceptable, but the penstocks were located down in the river valley, close to the river and subjected to flooding when the spillway operated. The powerhouse was also too close to the river, and likely to flood on a large spillway flow. The choice of Francis units was not sound, since there was a requirement for fish compensation flows, and the Francis units could not operate at such low flows, so Kaplan units would be a better choice. The consultant vigorously defended their layout, and pointed out that Kaplan units would be more expensive, and that flooding would be a very rare occurrence.

View of new spillway structure.

Quick-release stoplogs were used in 3 openings.

However, GLP had decided to issue specifications for a "design-build" contract, so I insisted that a clause stating that alternative layouts would be considered, and there was no insistence on following the recommended layout shown in the feasibility report.

A separate specification for the water-to-wire generating equipment was issued well before the general contract specification, with the turbine operating requirements clearly stipulated. All bidders provided prices for Kaplan units, with the successful low bidder at a cost just below the estimated cost for Francis units. The low cost was a result of the Kaplan turbines being duplicates of a recent design for another project.

View of intake hoist structure. New spillway hoist structure and old intake in background.

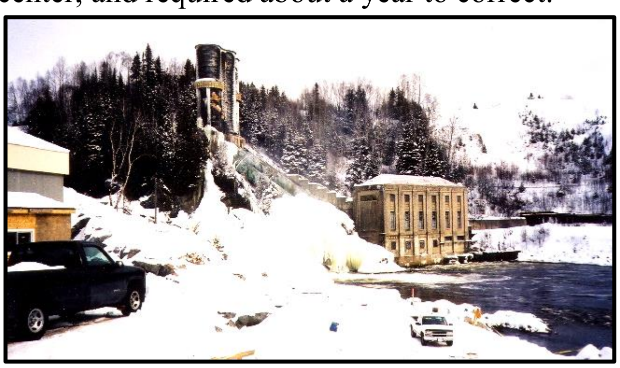
Steel spiral casing for new turbine.

The civil work specifications were issued, including the drawings of the report layout. A few days later, I received a phone call from Agra-Monenco (AM) indicating that they were unhappy with the contract arrangements, wherein the original consultant was allowed to bid and hence they must have the inside track from their prior knowledge of the site. I was reluctant to discuss anything since I was speaking to a former associate at Monenco, and pointed out that they should not be talking to me, but only to GLP. However, I did point out the relevant clause in the specification on alternative layouts, and then terminated the conversation.

Three bids were received, with Agra-Kiewit being the low bidder. They had an alternative layout with a short canal to intakes on the right bank, and penstocks down to the powerhouse well away from the river. All my concerns with the former layout had been addressed.

New powerhouse.

My only other comment was much later when I was shown the drawings for the powerhouse. Access to the lower floors appeared deficient with only a small hatchway. I asked if the hatchway size had been checked against the size of equipment to be installed in the lower floors, and was assured that it had been. However, I later learned that a larger hole had to be cut into the concrete floor. The project was successfully commissioned a few years later, with the only problem being the SCADA – it would not communicate with the existing GLP control center, and required about a year to correct.



Old powerhouse and tanks still to be demolished.

I had mentioned that, although I was not an electrical engineer, they should expect problems with the SCADA. GLP pointed out that the SCADA had been clearly specified, even down to the instrument numbers and models. Unfortunately, progress in SCADA at that time was so rapid, that the specified equipment was no longer being manufactured, hence the problems. Despite the SCADA problems, the project was completed on schedule and well within the contractor's budget.

107. COMPUTERS – 1998

When my brother Ian arrived in Montreal in 1956, he found a job with Adalia Ltd., a computer company owned by Sir Robertson (Rob) Watson-Watt the co-inventor of radar. Rob thought that by installing one of the first commercial computer services in Montreal that clients would be pounding at the door. Unfortunately, this was not the case, and the company closed a few years later.

However, in 1957 Ian persuaded me to bring over a few engineers and he would show how a computer could easily generate reinforcing bar lists needed by contractors to bend steel for concrete structures. Unfortunately, this was still too early for the technology, since the programming took far more time than an experienced draftsman needed to produce the same results. Ever since that early introduction, I was always skeptical about the benefits of a computer, even as the speed and capacity increased. About 1970, we made another attempt to use computers in our design work, since their number-crunching capacity had been demonstrated in hydrology and financial work.

I had a small team working in their spare time developing a cost and design program called

"POWDAC" – six letters being the file name capacity at that time. The acronym stood for "POWerplant Design And Cost". After a considerable amount of programming time, we managed to get it working, at a cost to the company of around $70,000. Hydro Quebec heard about the program, and asked to meet us, since they were developing something similar. We ran a comparative test, and found that our program was far more advanced, whereupon the hydro engineers wanted to know where we had obtained our "database". Apparently their program ran on statistics from their projects, whereas our program ran on first principles, calculating all parameters from scratch. About two years later, when I tried to use it for the first time on a new project, I was told that the POWDAC program had to be re-written into a format acceptable to our new computer, so I gave up until computers evolved further.

After I started working as an independent consultant, I had thought of trying to use a computer, but was intimidated by the technology. In 1991 I had taken a course in DOS, but the intricate commands were not intuitive, so I dropped it. However, Howard (my son) later came to my rescue. He was working for Hewlett Packard, and they gave him a new computer about every 6 months as the computer technology was advancing very rapidly in 1997. He told me "Dad, just read the manual, play with it, and if it breaks, we can get another". By this time the windows operating system was available, and I found it much simpler, so I started typing my own reports. Then I discovered Excel when Kearon Bennett showed me how he was using it, and I started to play with it, even buying a book "A guide to Microsoft Excel for Scientists and Engineers" and I was hooked. I started writing simple programs, and eventually thought of re-programming POWDAC, but decided instead to start again from the basics.

Meanwhile, Natural Resources Canada decided to develop a small hydro screening program called RETScreen for Renewable Energy Technology Screening. I partnered with Ottawa Engineering and we got the contract to write the hydro design-costing section. There were other sections for wind and solar energy. I developed the design and cost equations, and Kearon Bennett, president of Ottawa Engineering did the programming. The program was an outstanding success, and is available free over the internet at www.retscreen.net. It has been downloaded by over 260,000 persons, but how many use it is questionable. It has now been re-written without the hydro option, instead having a reference to the HydroHelp programs.

Top shelf – laser printer, computer. Bottom shelf – phone/fax, mouse, screen, keyboard, external hard drive (above scanner) and scanner.

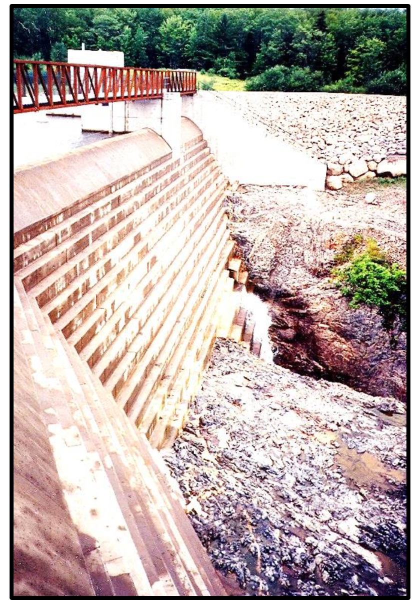
It required several years of work between assignments, but I eventually developed a series of hydro design and cost programs covering an entire hydro project, from access road to the transmission line and substation. There are now six programs, for turbine selection, Francis, impulse and Kaplan powered projects.

I tested them on all sizes of developments ranging from Three Gorges in China to large and small hydro plants here in Canada. The program produces quantities, generic drawings of all structures and costs. I sold the marketing rights to CANMET, a branch of Natural Resources, and they have sub-contracted the sales work to OEL-Hydrosys, a small hydro company here in Montreal, where Kearon is a partner.

After this success, I developed a pump-turbine program with a more sophisticated output, including a drawing to scale of all the underground excavation work, and including a surface profile obtained from Google Earth. With the increasing interest in pump-turbine projects in North America, the program has now been purchased by several consultants. I have used the program on over 40 possible sites, using three computers simultaneously, a laptop to run the program, my desktop to look at the site on Google Earth, and another laptop to write my report while observing the site and the program results, much more efficient that using the same computer for all three programs, and switching screens. I am now always astonished at the capabilities of computers – a remarkable tool for engineers!

108. FALLS DAM – 1998

I was passing through Halifax in the spring, on returning from an assignment in Newfoundland, and dropped in to see Eric Brown, now the Chief Hydro Engineer at Nova Scotia Power. We had worked together many years ago at Monenco. He asked me if I was interested in accompanying a team to look at their recently completed roller compacted concrete (RCC) Falls Dam. I was certainly interested, so we set off to the dam.

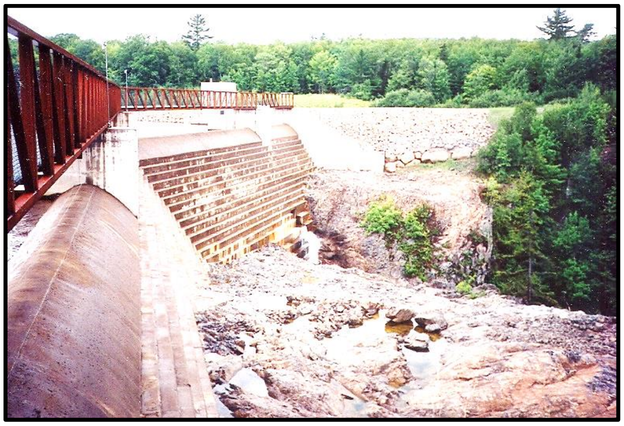


View of left abutment, low level outlet and embankment dam tie to abutment.

The dam included four free-overflow sections, each about 24m long, with an adjacent short embankment dam and low-level outlet to complete the structure. The low level outlet was located upstream of the dam face, so as to allow room for the concrete placing equipment and roller compactors free access along the dam. The RCC dam was topped with a conventional concrete ogee so as to obtain a high discharge coefficient for the weir, and a durable overflow surface.

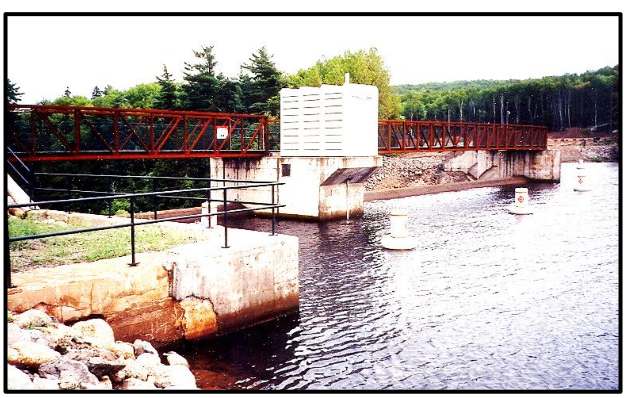
View from right abutment.

The RCC mix included fly ash to reduce the heat of hydration. The upstream face was formed with plywood sheets, but the downstream face was constructed of pre-fabricated square concrete blocks 1.2m high, for a more durable overflow facing. The new dam was constructed downstream of an old dam where there was insufficient spillway capacity. After the site had been prepared and foundations cleaned, the RCC dam was constructed in a record 7 days! – one of the major benefits of RCC work.



View towards left abutment.

View from left abutment.



Upstream view of low level outlet hoist house.

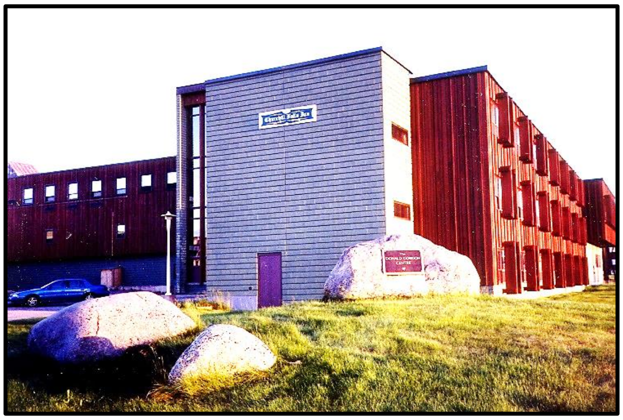
The dam has performed as expected, and the spillway was fully tested by recent hurricanes over the area, with the spillway flowing at near rated capacity.

109. CHURCHILL FALLS – 1999

In July, I had a call from Wallace Smith, the engineering manager at Churchill Falls. He asked me to look at their design for quick-release stoplogs at the Ossokmanuan Dam, as discussed in Chapter 30. I flew to Wabush by Quebec Air and was picked up by the Churchill helicopter and flown to the Churchill airstrip where I met Wallace, whom I knew from Cat Arm work.

Roadside sign at entrance to Churchill village.

I checked into the Churchill Falls Inn, the former staff house for the owners' engineers working on the original development in 1964-72. It had not changed at all. The rooms were still equipped with the original beds and a desk by the window. The inn was part of a complex housing a library, primary school, swimming pool, gymnasium, some administration offices and a general store. It all worked quite well. The town-site had been designed by an architect, but unfortunately, little attention had been paid to the environment. It would have been better to arrange all homes to be facing south to capture the low winter sun. Also, the exterior siding was treated wood with vertical wood strips to complement the spruce trees.



The Churchill Falls Inn.

A local pond had been developed as a swimming pool with a sandy beach, but with only a few days of summer weather, combined with voracious mosquitoes, there was little demand for the facility. There was a bar in the inn, and another somewhere in the town, which I never saw.

Town and inn.

A typical room at the inn.

The only other enterprise was a souvenir shop near the inn where I purchased a Churchill Falls coffee mug. After looking at the Ossokmanuan drawings, and making some comments, I had a quick tour of the development, concentrating on the nearby structures. The structures will be shown in more detail in later chapters.

Wood sided housing.

Almost 30 years after commissioning, the powerhouse is still the largest single underground powerhouse in the world. La Grande 2 has 2 underground powerplants.

Homes moved over from Twin Falls.

Churchill Falls office and control center located 1,000ft above the powerhouse.

We drove over to the office building, and I was shown the control room with all instruments dating back to the original development. It will require a major updating when money can be found since the cost will be significant.

We took the elevator 1,000ft down to the powerhouse where I was shown the vault containing copies of all drawings from the original surveys and construction. I looked for and found a profile drawing of one of the dams I had made in 1954 on graph paper. An impressive achievement, since there are many utilities where all the original drawings have been lost.

Control room with analogue gauges.

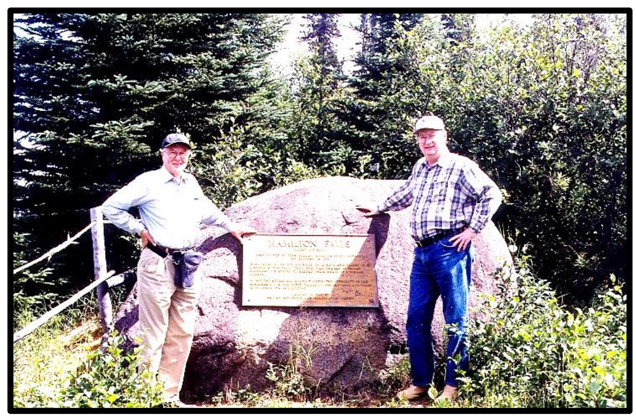
Drawing vault. My 1954 drawings were rolled up, top left.

We drove over to the falls where a trail had been cut for tourists to look at the falls and canyon. I took a photo from about the same location as in 1955 (see Chapter 6 for photo) where the survey crew had a picnic. Of course, this time the falls were almost dry.

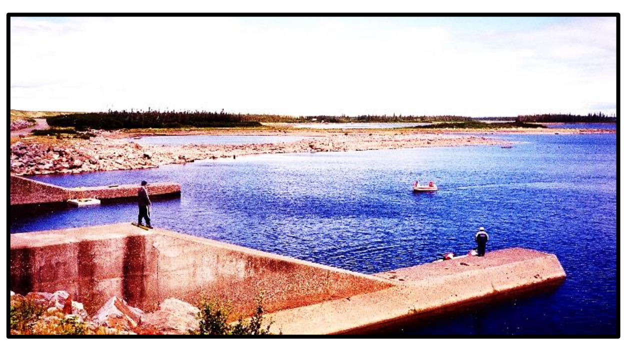
With Wallace Smith on powerhouse generator floor – plant capacity = 5,428,500kW.

The only recreation available to the staff is fishing in summer and snowmobiling in winter. There are several cottages built by the operating staff around the area, all near service roads and by the side of lakes. The most popular beach was our old campground used when surveying the road in 1955, where there are three or four cottages.

The by-passed falls, now almost dry.



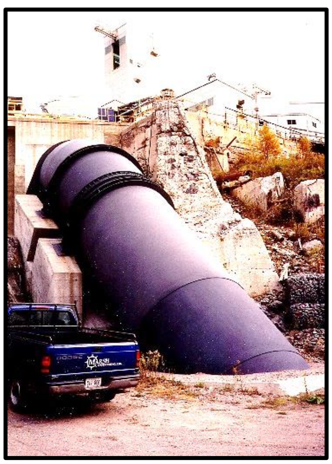
Plaque near falls.



Fishing near the Lobstick Control Structure.

110. ESPANOLA – 1999

The last Canadian Electrical Association spring meeting was in March, 1999. A few months later, the association announced that it was ceasing operations, and converting to a small lobby group based in Ottawa. The engineering side was purchased by three of the staff and re-named CEATI for Canadian Electrical Association Technical Institute. The CEA was shut down due to the very high cost of continuing operations, with highly subsidized meetings in the spring and fall. The annual cost of membership to the utilities, based on installed capacity, was relatively high, and in the new competitive deregulated market, the utilities decided that since membership was not compulsory, they just could not justify the expense. This was unfortunate, since the CEA was the only Canadian association where general papers on hydro subjects could be presented.



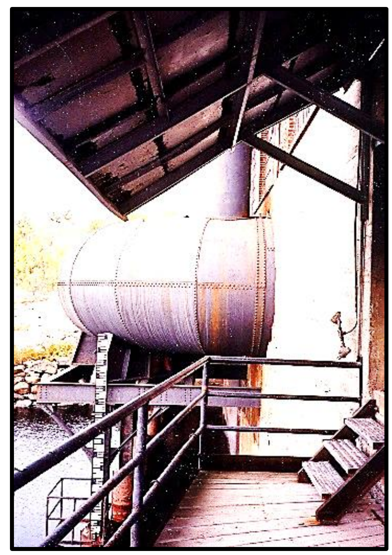
Penstock #1 from dam.

Rumors of the demise of the CEA began to circulate in 1995, so I decided to join the Canadian Dam Association (CDA), and started to attend their meetings in the fall, which always included a site tour of a nearby dam. In September of 1999, the tour was to the Espanola hydro plant operated by the E. B. Eddy paper company. It proved to be very interesting.

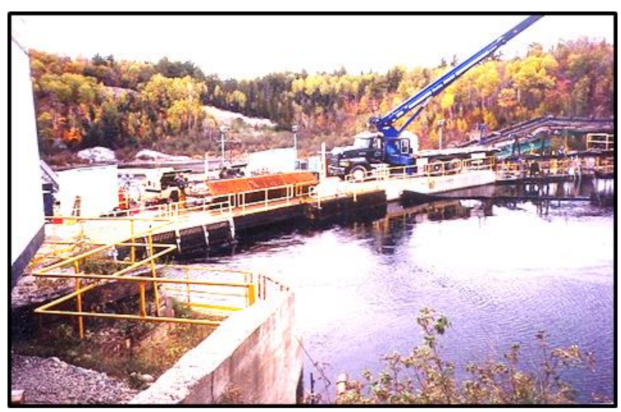
The facility had been built in 1904, and expanded with a second penstock. The first penstock approached the powerhouse from below where it split into 2 pipes for the 2 units, both horizontal axis, double runner tin can Francis units.

View of both penstocks

Instead of excavating down into rock beside the powerhouse, the second penstock was wound around the end of the powerhouse and entered through the downstream wall, a very unusual arrangement – but not unexpected since it would have been the most economical alternative for the paper company.



Penstock #2 behind powerhouse.



View of repair work on dam.

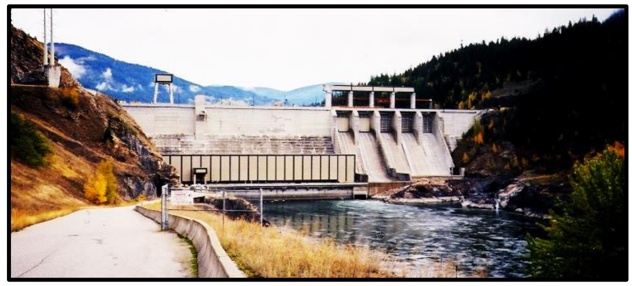
Espanola powerhouse interior.

Work was being undertaken on the dam, but unfortunately the tour group was not allowed to approach the area since we were not equipped with safety boots.

111. SEVEN MILE DAM – 2000-4

Plan of Seven Mile dam.

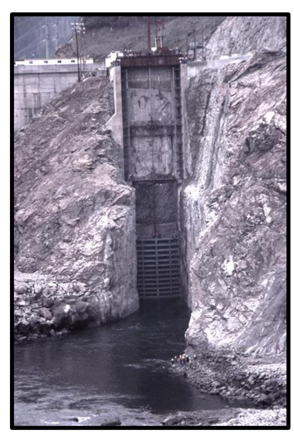
In March of 2000 I had a call from Ray Stewart, Director of Dam Safety at BC Hydro asking if I could join a review board looking at the design of the Seven Mile Dam. I replied in the affirmative, and soon was meeting with Len McDonald the chairman of the board and the other member, Don Coulson whom I had known for many years. At the time Len was Chairman of the New South Wales Dam Safety Committee in Australia, and Don was a Vice-President of RSW, a consulting company in Montreal, with his specialty being hydro mechanical equipment.



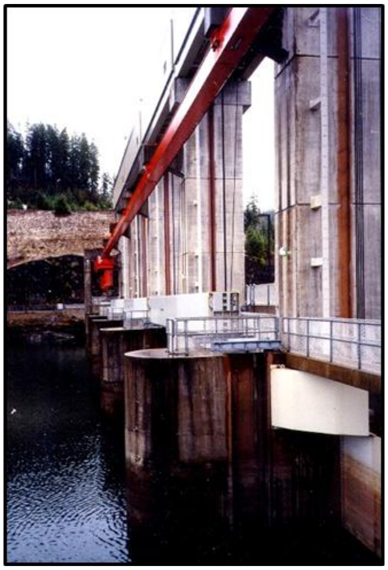
Seven Mile dam, 2002. One spillway gate hoist removed.

The facility is located on the Pend d'Oreille River, near Trail, and just above the USA border. It is downstream of the Boundary Dam in the USA, and just upstream of the Waneta Dam in Canada. It has 3 Francis units of 198MW capacity at 66.4m head, and a fourth unit was installed in 2003. The spillway has 5 gates.

Below - Diversion tunnel gate (1974). Source – www.virtualmuseum.ca

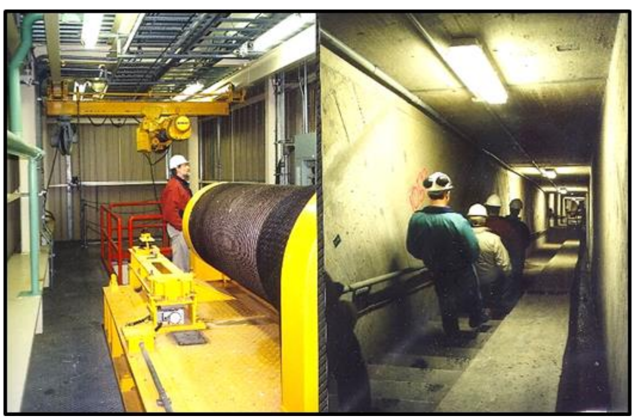


The Board meetings usually lasted about a week, with the first two days being spent on listening to several presentations made by BC Hydro engineers, the next day on a site inspection, and the last two days on preparing and presenting our report.



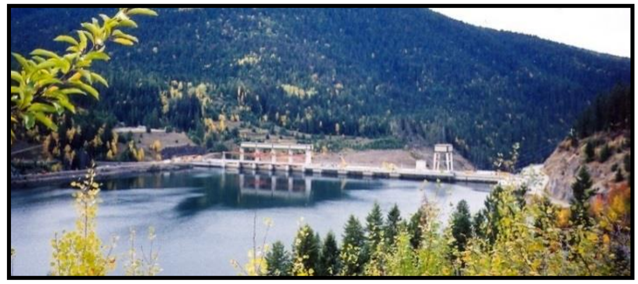
Spillway gates.

The problem at Seven Mile Dam was that it did not have sufficient spillway capacity and an adequate margin of safety against sliding and overturning. Since the dam was designed in 1972, the earthquake, flood and stability standards had all been upgraded, and the reservoir level had been increased by 4m, resulting in an inadequate dam. The BC Hydro staff had spent several years trying to arrive at an acceptable and economic method of stabilizing the dam and adding spill capacity without success.

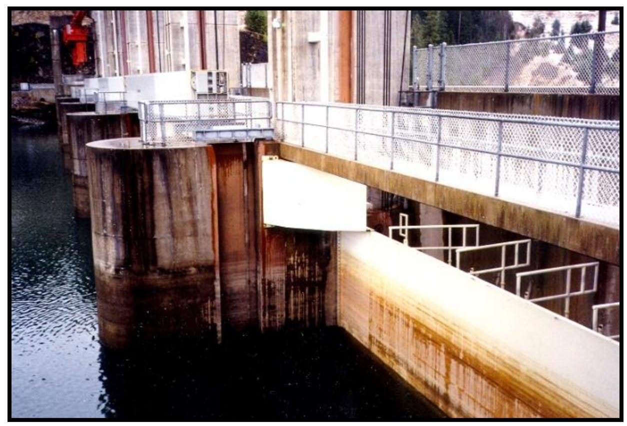


Left – spillway gate hoist. Right – drain gallery access.

The problem was too many options without a clear choice between the options. The stability could be easily increased by adding anchors. The question was how many, and to what standard. The dam had internal penstock pipes and drainage galleries which had to be avoided by the anchors, limiting the amount of anchors to about 95, more than sufficient for added stability.



View from upstream. Note concrete towers.



Spillway gate with wave boards on top.

Adding spill capacity was more complicated. There were many options such as allowing the reservoir to rise above the current flood level, reactivating the diversion tunnel by installing a large low-level outlet gate at either the upstream end or at the outlet, or by adding a side channel spillway on the left abutment with either a weir or gate control. In all, there were more than about 16 options, each with a different cost and safety factor.

Another complication was that the work was being based on a risk assessment analysis, a relatively new method wherein you had to assign a mathematical probability of failure to a series of events, all multiplied together to obtain the result. BC Hydro was at the forefront of this process, and their staff had published several papers on the methodology. The major problem with the analysis was that the probability numbers assigned to each event were at best just guesses, so that unless there was a large difference in the resulting number, it was impossible to decide which option was the best or most attractive.

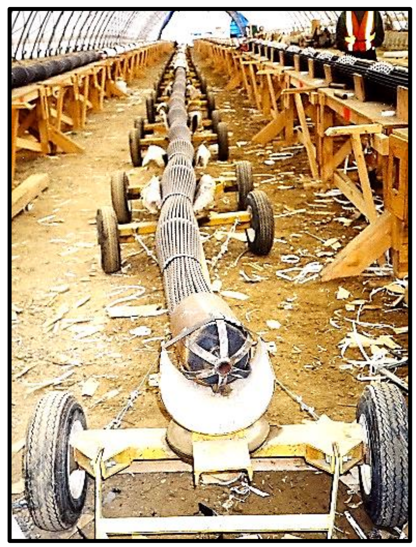
Drill for anchors.

400mm drill head.

At the first board meeting, I spent the two days listening to the presentations with mounting concern that there were just too many options, and no clear path to a decision. After the site inspection the next day, I decided to confront Len with my concerns, and told him that I could not see how a decision could be reached based on a risk analysis. Instead, I suggested that the traditional method of analyzing the forces on the dam be used, as outlined by the Canadian Dam Safety Guidelines, which always resulted in a clear undisputable safety factor.

Assembling anchors.

Anchor dolly train.



I was concerned that I would be over-ruled since Len had many more years of experience in dam safety analysis than I had, and BC Hydro staff had spent many months working on the risk analysis method. Much to my surprise, Len agreed with my conclusions, and later thanked me for being so outspoken. He had been coming to the same conclusion, but had hesitated to voice his opinions due to the expense and disruption involved in discarding the previous work undertaken by BCH over about 2 years. We drafted a report recommending the changed methodology, and it was accepted by Hydro after considerable discussion.

Anchor train arriving on dam.

The next meeting was in the fall, when we were presented with the new analysis. However, the spillway options were still numerous; the design level for the reservoir at flood was still unclear; and costs were within the margin of error, again resulting in no clear preferred design. I suggested that instead of continuing the analysis with more detailed designs, we should look at practical solutions, and the first would be to anchor the dam to be safe with the reservoir water at the dam crest. With the water level now fixed, the spill capacity with the existing gates could be determined, and then we could look at the options needed to provide adequate spill capacity.

Roller jig used to turn anchors to vertical.

It turned out that this change in water level just provided the required added capacity, and from there it was easy to determine the number of anchors to stabilize the dam against both earthquake and water forces. The number of anchors was reduced to 57, but they proved to be, at that time, a world record in capacity at 23,972kN. Each anchor was assembled from 92 strands, each having 6 wires. 460km of strands were delivered to the assembly area 1.6km from the dam.

Roller jig placing cables into anchor holes.

Completed anchors with covers.

Anchor, box cover removed.

One problem remained with the design. The earthquake analysis undertaken by a couple of professors at the University of

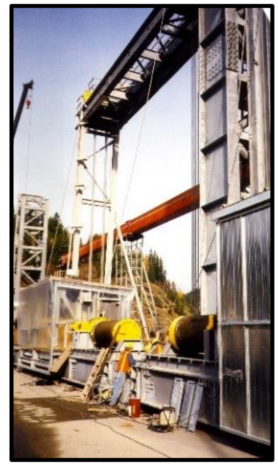
British Columbia, indicated that the horizontal acceleration of 0.27g at the top of the spillway hoist towers could be magnified by 3 due to the shape of the dam and towers.

Jannox 550ton jack used to test anchor strands.

2,000ton tensioning jack.

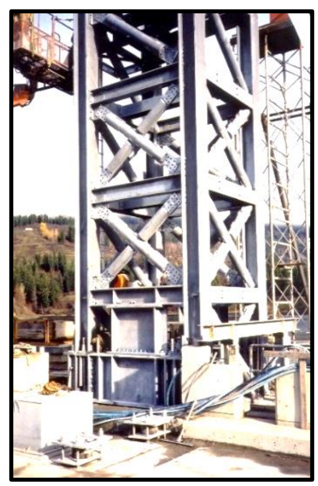
When asked how accurate their analysis was, their answer was within a factor of about +/-3! This meant that anything on top of the tower should be designed for an acceleration of 9 times that expected from the earthquake. Further work indicated that the concrete towers could not withstand the earthquake forces, and would have to be replaced with steel towers. Moreover, any heavy equipment on top of the towers such as the spillway gate hoists would have to be relocated down onto the concrete deck of the dam. Don managed to develop a concept for the relocation, and it was worked into a suitable design by the hydro staff.

Left – concrete towers being removed.



Steel towers being installed, hoists now on deck.

Hydro then found that there was no electrical equipment designed for a 2.43g acceleration, and even contacted NASA to see if they had a source for their space shuttles, to no avail. Eventually, Hydro designed the equipment, and had fully powered prototypes tested on a shaking table at the university. I saw a video of the tests, with the shaking gradually increasing from 1g, to 3g, to 6g, to 10g, and at the maximum acceleration I could not see how anything could survive the shaking – but the solenoids just kept on working!



Heavily braced steel tower.

We inspected the site twice during the anchoring work. It proved to be very instructive. The anchors were up to 126m long and could only be bent through a gentle radius, so that a dolly train was needed to transport the anchors from the fabrication shed, about 1.6km down to the dam. There a gently curved jig roller apparatus was used to turn the horizontal anchors to the vertical for feeding down the 400mm drilled holes. The work was completed in 2004 at a cost of about $100M, substantially below the initial cost estimates.

In August 2002, BC Hydro published a short report titled "Seven Mile Dam safety improvements" stating –

"The project design has been reviewed by internal and external specialists and an external Advisory Board comprising three internationally recognized experts."

Heavily braced steel housing for hoists.

Steel towers being installed. Red beam is monorail for stoplog hoist.

A most interesting and very challenging assignment; and an eye-opener on the extent of earthquake bracing!

Hoist drum on deck, before installing housing with a slit in roof for the cable.

112. ELSIE DAM – 2000-4

In July, I had another call from Ray Stewart. This time he asked me to join a 2-man review board looking at Elsie Dam on Vancouver Island. The other board member was Dr. Norbert Morgenstern, whom I had not seen since working on the Bayano Dam in Panama.

The free-standing gate tower.

Geotechnical investigations had found that the dam was in danger of slumping during an earthquake due to inadequate compaction of the impervious material in the dam. Also, the low level outlet with a free-standing intake gate tower was in danger of collapsing during an earthquake, and the Howell-Bunger valve at the end of the conduit through the dam needed major repairs. My task was to provide advice on the tower, conduit and valve.

Embankment dam – slope to be flattened. Tower on left of Ray Stewart, outlet on right.

We flew to the Elsie Reservoir in a float plane from the sea airport in Vancouver harbor, and had a good look over the dam and outlet. The weather was poor, and BC Hydro had erected a large canopy at the end of the dam for our lunch. Norbert, on seeing the canopy remarked that it looked like a scene from a Fellini movie!

The "Fellini" lunch tent.

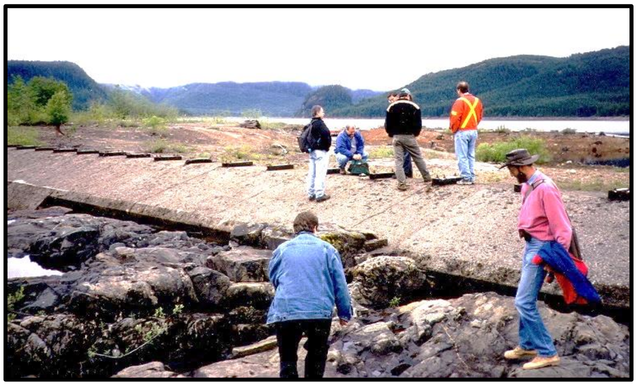
Outlet structure, Dr. Morgenstern in red jacket.

The hydro engineers had envisioned strengthening the tower with a well-braced steel cage, and installing a hoist on top. My problem with the concept was the lack of access to the tower. The operator had to row out, grab the ladder and climb up, a difficult and dangerous task in inclement weather. I suggested instead that the concrete tower be demolished and replaced with a low steel frame to hold the hoist upper pulleys; then bring the hoist rope down to a pulley on the concrete intake structure and then up the dam face within a steel pipe to a hoist house on the dam crest. The steel frame would be just high enough to lift the gate above low water level for inspection. The concept would be similar to the diversion gate at Brazeau, so there was a precedent. The concept was accepted by Hydro.

Howell-Bunger valve discharging.

Opening dial gauge.

The other problem was the old valve. Hydro wanted to rehabilitate the valve instead of purchasing a new one. Also, there was no second line of flow control in case the valve operator failed. The sliding intake gate could not close against flow. This was resolved by adding a butterfly valve capable of closing against flow. A new outlet structure was constructed to house the two valves, since it had to be moved downstream to accommodate a flatter downstream dam slope as recommended by Dr. Morgenstern.



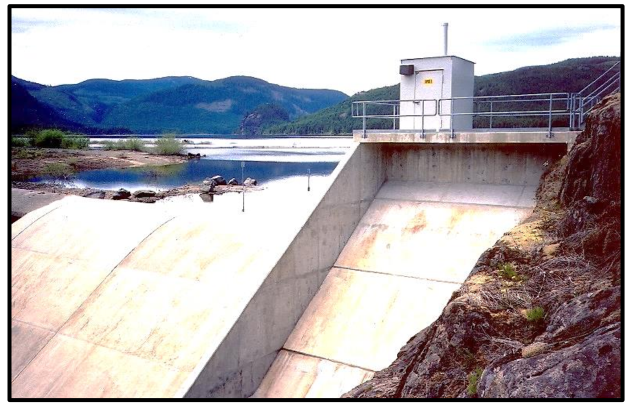
Weir spillway – to be replaced.

I returned to the site in 2004, to look at the progress. The new spillway weir was completed, with the rock immediately downstream having been removed to provide rock fill for the flatter dam slopes. Also, the channel was continued up the left bank to provide a temporary diversion channel during construction of the new outlet works, thus allowing for continued use of the reservoir.

Departing for Vancouver.

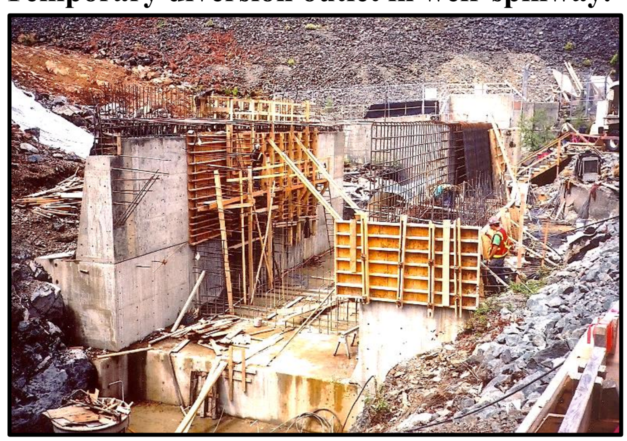
The foundation for the new Howell-Bunger valve house was completed, and the pipe extension had been installed. The extension included anchors to bond the steel pipe to the surrounding concrete, so I thought that the pipe would be well anchored.

The renovated Howell-Bunger valve was on site awaiting installation, and everything was on schedule.



New weir spillway.

Temporary diversion outlet in weir spillway.



New outlet structure.

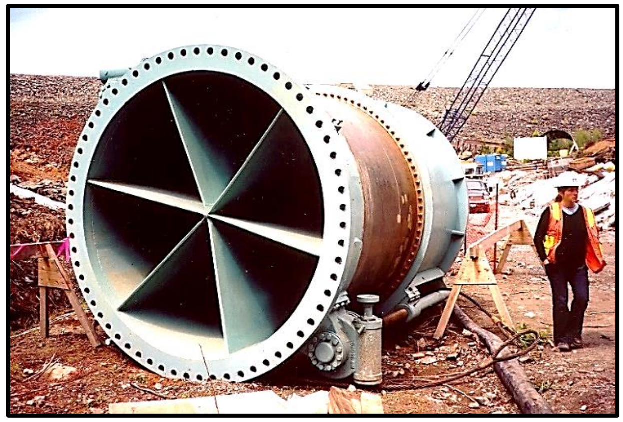
Eric and Pentti were also at the site, so instead of flying back to Vancouver, they had offered a drive back to Qualicum Beach, stopping en route to look at the high head small hydro plant at

Doran-Taylor, west of Albernie. My brother was retired in Qualicum, so I welcomed the opportunity to see him, and also look at the hydro plant. The slow drive down from the site was over the unimproved access road, a surprise, since I expected some minimal upgrading for the Elsie work.

Outlet structure view from dam crest.

Pipe extension for flatter dam slope.

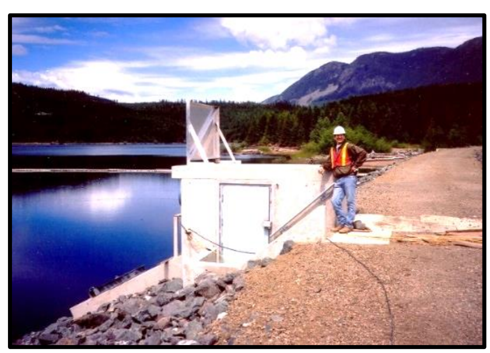
When the valves were commissioned, tests were performed to check that the butterfly valve could close at full Howell-Bunger valve flow. Unfortunately, there was a short free-standing section of pipe upstream of the butterfly valve, and it started to vibrate violently with the vibrations induced by the almost closed butterfly valve. The butterfly valve did not have adequate mass, and there was insufficient anchoring to prevent the vibrations. The solution would have been to encase the upstream pipe in concrete, but by this time, the contractor had left the site, and consequently the concrete would be extremely expensive.



Restored Howell-Bunger valve.

Valve building placed further downstream.

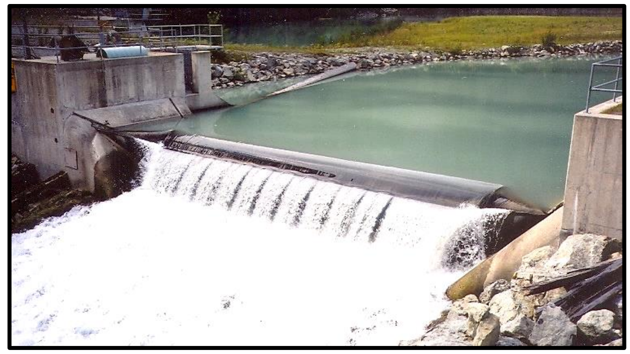
Ring girder support just before HB valve.



New intake gate hoist house.

Eventually, it was decided to accept the situation when a risk analysis indicated that the chance of a Howell-Bunger valve failure at full flow was extremely unlikely, and even if it did occur, the butterfly valve could be closed until vibrations became excessive, flow would then be small, and the intake gate would probably close, or if not, the Howell-Bunger valve could be closed at a lower flow. I had seen the outlet structure detailed drawings, and the lack of support at the upstream pipe and I had reasoned that if the pipe vibrated, concrete could easily be added, but I had not thought that the contractor would have left the site before all equipment was tested! A difficult lesson for me! Also, the valve was purchased from the low bidder, with components manufactured in several countries. The valve design was inadequate, with severe vibration at the near-closed position. Another lesson in purchasing the low bidder manufacturing equipment from an inexperienced supplier.

The outlet was commissioned in 2004, with the leisurely schedule due to having to keep the reservoir and an outlet operational during the repairs.



Rubber dam weir.

Intake with trash rake.

Automatic low level sluice – opens when units are closed.

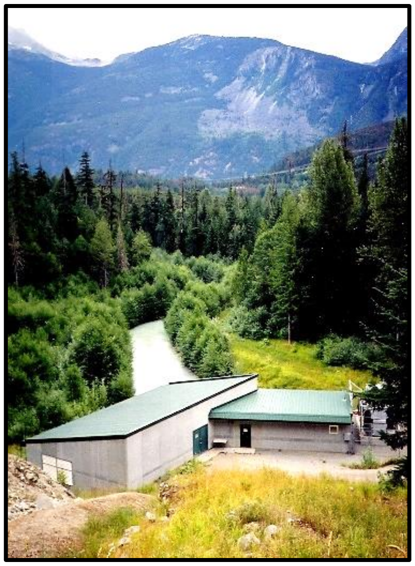
113. SOO HYDRO – 2000

Two of the engineers on Elsie were Eric Johnston and Pentti Schoman. I had corresponded with Pentti for a few years, working with him on some penstock designs, but we had never met. Pentti suggested that we should take the opportunity on the weekend to visit a small high head hydro plant near Whistler. On Saturday, after our first visit to Elsie, the three of us drove to the Soo plant, some 15km north of Whistler and had a look over the facilities.

Buried penstock.

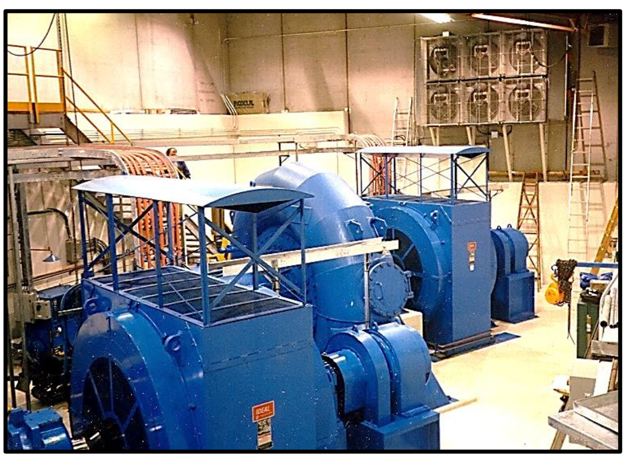
It was an interesting development, with two 6.75MW horizontal axis Francis turbines and generators.

The intake, off to one side of the spillway is serviced by a trashrack cleaner. The spillway is controlled by a 2m high rubber dam, 20m long. There is a 940m, 3.75m horseshoe tunnel followed by a 214m steel penstock of about 2m diameter.



Powerhouse.

The only problem encountered is in the forebay, which silts up about every few years and has to be cleaned out with a dragline and bulldozer during the dry season.



Powerhouse interior - generators.

One innovation was the use of soil-cement to cover the buried penstock since gravel and sand backfill could not be retained on the steep slope.

Don't know how the equipment will be serviced. At least roof hatches should have been included in the design.

Powerhouse interior, turbines – note no crane.

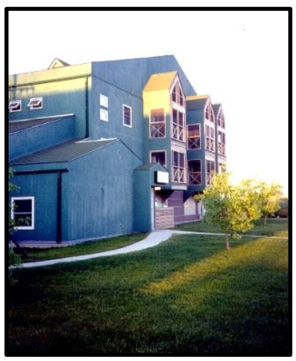
114. KETTLE DAM – 2000

In late June I had a call from Lloyd Courage. He was the geotechnical engineer on Bay d'Espoir and now had his own consulting practice based in Calgary. He wanted to know if I was interested in helping Agra-Monenco undertake a dam safety analysis of the Kettle Dam owned by Manitoba Hydro (MH). I replied in the affirmative.

The old Gillam Hotel, 5km from the dam.

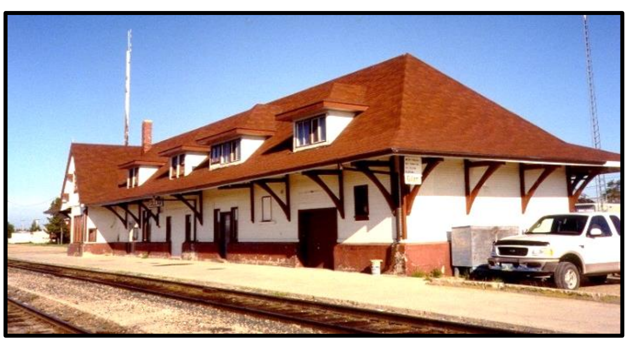
The plant is located 700km north of Winnipeg, near the town of Gillam, a railway station only 270km south of Churchill on Hudson Bay. The powerhouse has 12 propeller units producing a total of 1,272MW and was built in 1966-73. We flew to Gillam, checked into the old Gillam Hotel, and had a quick meeting with the Manitoba Hydro staff at their modern offices.

Manitoba Hydro offices at Gillam.



MH single staff quarters.

Later that evening, I walked around Gillam just to see what a company town looked like after about 35 years. Then, the only access was by rail and air. Now there is a gravel highway to Thomson and from there to Winnipeg. However, it still looks like a frontier town.



The railway station at Gillam.

I took so many photos, that instead of describing our work, I will comment on the photos, since many illustrate what can be seen during a dam safety inspection.

After the meeting, we had a quick tour of the powerhouse. However, our task was to look at the structures and not the equipment, except for the spillway, where the operation could affect safety of the dams. The powerhouse concrete was still in pristine condition, with absolutely no signs of AAR, and the only cracks were found in transverse walls where the elastic deflection of the concrete structure under the water load from the reservoir, had produced some minor 45-degree hairline cracking, which I marked with a red felt pen so that they could be seen in photographs.

Powerhouse tailrace deck with 12 transformers.

Powerhouse generator floor.

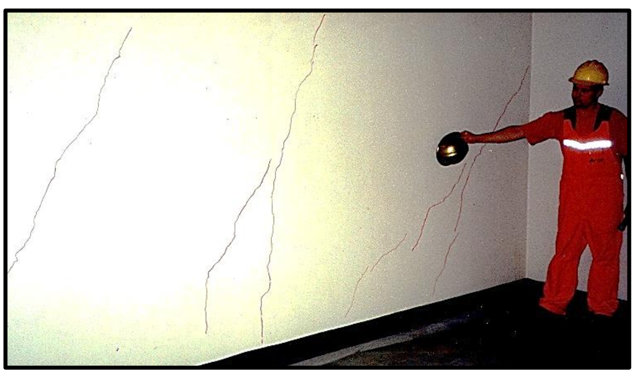
These walls were never intended to take the shear forces resulting from normal deflection of the powerhouse-intake structure. If cracking is to be avoided, then the walls will have to be isolated from the shear force by expansion joints.

However, this solution is not practical, since the walls support the upper floors in the powerhouse.

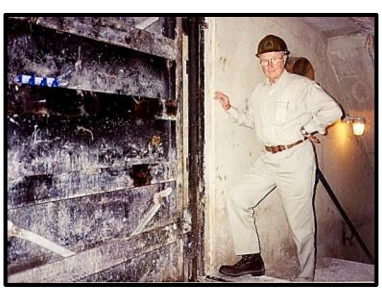
Transformers.

Air vent pipe in turbine pit.

Below - Red-marked 45-degree cracks in transverse walls.



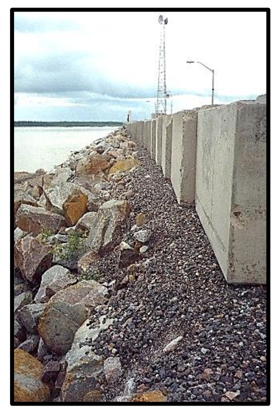
At an automatic flood closing door within powerhouse. Swings to right. I am beside the hinge.



In case there is an equipment failure in the powerhouse, causing a flood, there are several automatic flood doors which close to prevent flooding of the lower drainage system below the powerhouse and intake structures, a wise precaution. Note that the door has a positive seal to prevent water from above flowing down – the reverse of what one would expect.

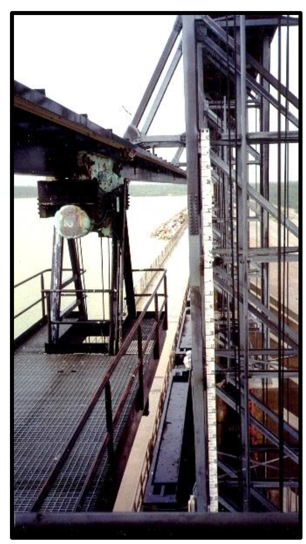
A well-graded downstream slope.

A smooth slope indicates close attention to construction details, and well-supervised construction.



Two views of concrete block wave wall on dam crest.

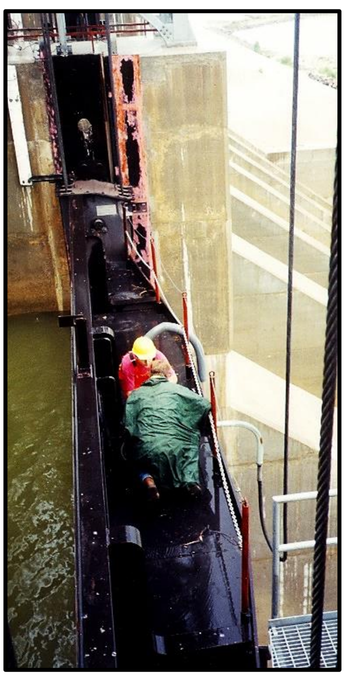
View of spillway stoplog monorail hoist.



Waves can be contained by adding either a row of rip-rap about 1m high, or by adding concrete blocks. The rip-rap requires a wider crest, but is less expensive than concrete blocks. In this case, with the blocks resting on gravel, it appears that waves are not frequent, since the gravel would have been washed out.

Spillway hoist house interior.

As we were inspecting the dam near the spillway, we noticed a severe thunderstorm approaching from the west. We all ran over to the spillway and climbed up the stairs to the hoist housing, where we expected to shelter from the storm and also inspect the hoists. As it happened, the gale force winds lifted some loose corrugated steel panels on the roof, allowing the intense rain to enter the housing at a point just above the power entrance panel. There were long blue sparks emanating from the power box over to a steel column.



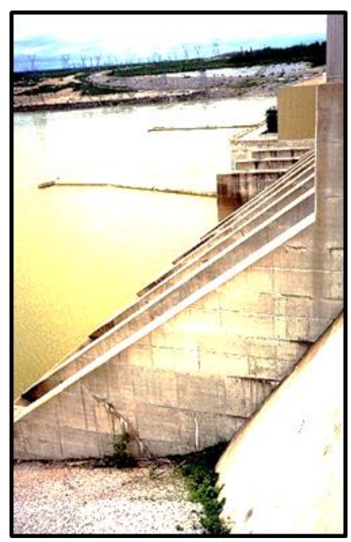
Preparing to inspect spillway gate interior.

Fortunately, one of the plant operators was our guide, and he picked up a nearby phone and asked the operator at the powerhouse control desk to immediately cut all power to the spillway. An inspection revealed that several bolts holding the roof panels had either worked loose or were never installed. For us, it was a lesson that inspections should preferably be undertaken during inclement weather. We would never have noticed the missing bolts during dry weather!

After the storm passed, we inspected the gate interiors which are rarely inspected. They contain hot air heaters and fans used to keep the exterior ice-free when operation in winter is required. Also, they should be inspected for rust.

Seepage at downstream toe.

Seepage at dam toes is often discolored if flowing through cracks in the foundation rock. If flowing through the dam it is only serious if there is fine silt eroded from the core in the seep deposit. In this case, the flow is so minor, that it dissipates through evaporation, and only needs to be monitored occasionally.



View of 45-degree cracks in spillway piers.

Almost every pier and wing wall has this type of cracking; must be due to arrangement of reinforcing steel.

View of 45-degree cracks in spillway piers.

Piles of driftwood indicate that the dam crest at this location is too low, and needs to be raised by about 1m.

Driftwood on dam crest.

Below – Wavy dam crest on discontinuous permafrost foundation.

Ring dykes around southern rim of the reservoir are founded on permafrost. We found that they needed to be raised as the permafrost melted.

Again, an interesting assignment – and a lesson on the value of inspections during inclement weather!

Rain erosion of crest in low area.

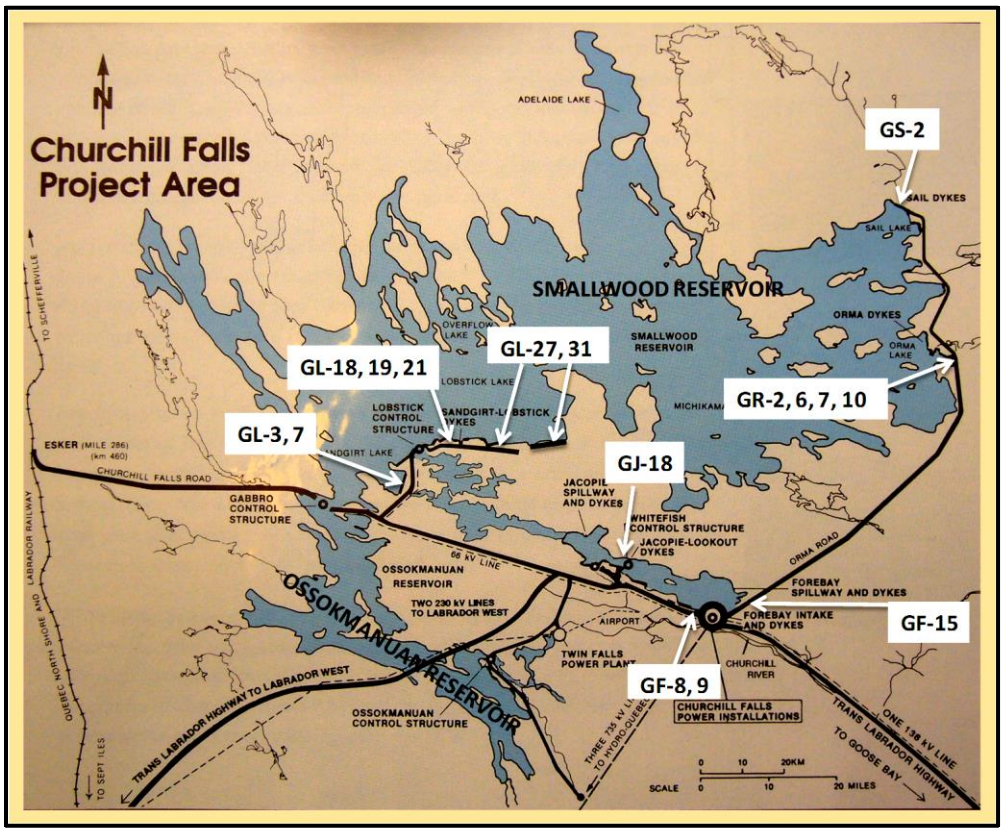
115. CHURCHILL DYKES – 2000-5

In 2000, I was asked to join the "Dyke Board" a group of four engineers contracted by Newfoundland and Labrador Hydro to provide annual safety inspections at Churchill Falls (CF) and several other hydro developments on the island of Newfoundland.

Entrance to Churchill Falls town site.

The board is the longest-running hydro dam safety board in the world, having been established shortly after the 5,250MW Churchill plant was completed in 1975, when unexpected seepage appeared at several dykes and concrete-wall-earth contacts on structures. Over time, the participants have changed, and currently the other members included Ray Benson, an independent consulting geologist from Vancouver, Tony Tawil, a retired chief geotechnical engineer from Acres, and Kent Murphy, a retired chief geotechnical engineer from Hydro Quebec. My task was to look at all the concrete structures. When I retired from the Board five years later in 2005, my place was taken by Dave Brown, retired chief civil engineer from ShawMont Engineering in Newfoundland.

The Huey helicopter.



Dyke locations.

The inspections always took place on the first two weeks in September, immediately after the labor-day holiday. Also, the routine was always the same, fly to Wabush on the Tuesday on Quebec Air, transfer to a King Air aircraft operated by CF, land at Churchill, check into the Churchill Falls Inn, and start the inspections after lunch. Wednesday and Thursday would be spent flying around on a large "Huey" Bell UH – 1H helicopter capable of carrying 17 persons.

Churchill Falls is such a vast project, that I have decided to break the work into six chapters, beginning with the dykes, followed by the three spillways at Ossokmanuan, Jacopie and the East Forebay, the three control structures at Gabbro, Lobstick and Whitefish, the intake, the tailrace structures and finally the powerhouse.

The aerial inspection included looking at all the rip-rap and downstream slopes on the dykes, and landing at some locations to view seepage, slips and other problems. Friday was spent looking at dykes near the powerplant by truck, and on Saturday morning we were conducted through the large underground powerhouse, looking at seepages, and inspecting the bare rock tunnels. We would be accompanied by Wallace Smith, the site manager, his assistant Gordon Hynes and three or four members of the dyke inspection staff. Saturday afternoon and Sunday was spent working on the report, presented on Monday morning.

During my 6 years on the Board, I managed to accumulate so many photos of the effect of weathering and slope stability; that I decided to include several with this memoir. The dykes have a rather complex numbering system, which takes time to learn. It is supposed to designate the dyke location and type of section, there being different sections used for the varying foundation conditions and materials available locally.

The work was very interesting, since the project included 88 dykes with a total length of 65km, a volume of over 20Mm^3 and covering a vast area, with the distance from the southernmost dyke to the most northern being almost 200km, and with the east-west distance being about 150km. Despite the fact that the project had been in operation for 25 years, there was always something to look at. The project had been designed for a private developer, Brinco, (British Newfoundland Corporation) and every effort had been made to cut costs. Hence, the dykes had steep slopes, and in some cases these were found to be only marginally stable, and needed to be flattened slightly. The Dyke Board had been assembled to provide advice on the dyke repairs and maintenance as weather eroded the slopes.

On my first inspection, I found that a considerable amount of time was spent on determining the downstream slope on the dykes. An Abney level could not be used since many of the slopes had shallow concave depressions, and to obtain an accurate measure of the slope, a survey crew had to set up a level, and this took time.

Measuring overly steep slope at GF-8, at 1.76:1.

Steepest slope at 1.3:1 on GR-2.

For the second year, I suggested that a simple instrument could be made with a piece of 8-foot long 1 x 2 inch oak wood lumber with two hinged arms on which carpenters levels with a metric tape could be attached. The next year it was produced, and proved an immediate success, with the slope determined accurately in a few minutes – it became known as the “Gordon slope meter”.

Due to the steep slopes, there was continual work on adding material to flatten the slopes, thus improving stability. The steeper slopes, as determined with the new instrument, were tackled first.

Our inspections occurred during the best weather in the fall, when the first frost had killed most of the mosquitoes and before the snow arrived. However, in 2004, the tail end of a hurricane passed over, and when the Huey arrived to pick us up at the powerhouse helicopter pad, the pilot Dave Hussey mentioned that the wind was just below the limit for flying. We flew north inspecting the dykes and when we approached the northern-most dykes at Orma, we could see spray flying over one of the dykes. We landed, transferred to the trucks which had been left for us the previous day, and drove to the dyke. When I got out, the wind whipped open the pick-up door which I was holding onto, and I was almost thrown into the rock rip-rap. It was blowing a gale, and it was difficult to stand, but I managed to take a couple of photos from inside the pickup showing the spray and waves washing up onto and over the dam crest.

Waves on GR-2.

Wave and spray washing over GR-2.

This was a major concern, since the reservoir water level was 1 meter below full, and the wind speed was not at the maximum expected in a hurricane. The dam crest would have to be raised, but by how much? We needed to know the present wind speed, so when we returned to the helicopter, I persuaded Dave to fly to the dam, land on the crest for a minute, and record the wind speed on his anemometer – it was 54km/hour, gusting to 63km/h, only half the design wind speed. Even so, the wind buffeted the helicopter, and Dave had a difficult time keeping it steady. We were all relieved when we became airborne again.

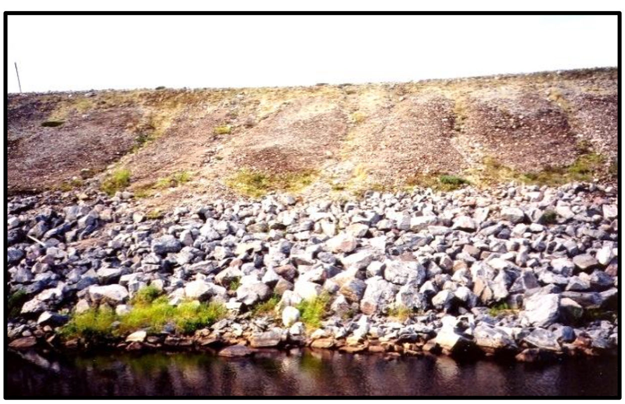
GR-2, next day, same location, calm and no waves.

I then used this data in a rip-rap sizing and wave run-up Excel program I developed, to calculate the wave height run-up on a full reservoir with the design wind of 107km/h, and found that the dyke rip-rap top would have to be raised by 2.0m. This has now been done by raising the earth crest 1.0m and adding a rip-rap mound 1.0m higher. N&LH now have a copy of the program.

Next year, adding fill to increase height of GR-2 by 1m.

However, the lesson we learned in this case, as at Kettle, was that dam inspections should preferably be undertaken during severe storms, when deficiencies will likely be revealed. We returned the next day to the same location, with the sun shining and only a faint breeze blowing. The reservoir water level was far below the dyke crest, and it was impossible to imagine waves reaching the crest as we had witnessed the previous day. Looking west, we could see that waves would have a clear run for about 70km, more than adequate to build up heavy waves. Also, looking at the configuration of the reservoir shoreline upstream of the dyke, it was just possible to imagine a concentration of waves being funneled towards the dyke, adding to the height and run-up on the dyke, a phenomenon not allowed for in present dam freeboard design calculations. Perhaps this accounted for the high run-up.

Reading piezometers at GF-8.



Erosion gulleys on GF-15.

Inspecting rip-rap on Dyke GS-2 at Sail Lake.

Steep slope at GF-8.

Flattened slope at GF-8.

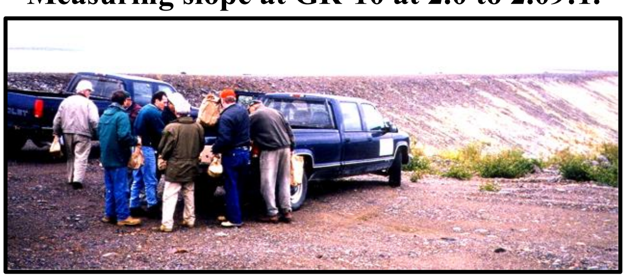
Seepage measuring weir at 12+25 north-east of intake structure.

Adding fill to downstream slope at GF-8. Note smoothness of finished slope – excellent work!

Adding drains and toe berm at GL-21.

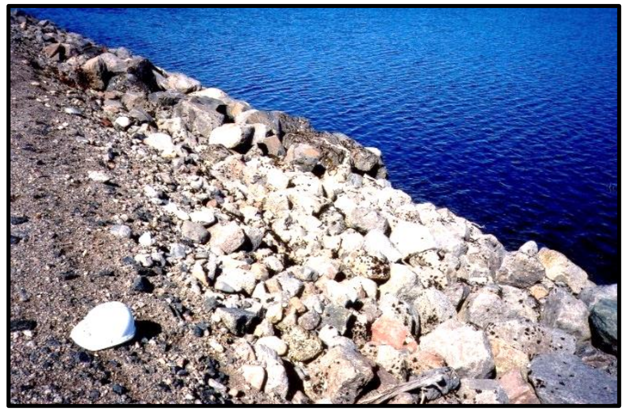
GL-21 work. Dark green vegetation could indicate seepage.

Measuring slope at GR-10 at 2.0 to 2.09:1.

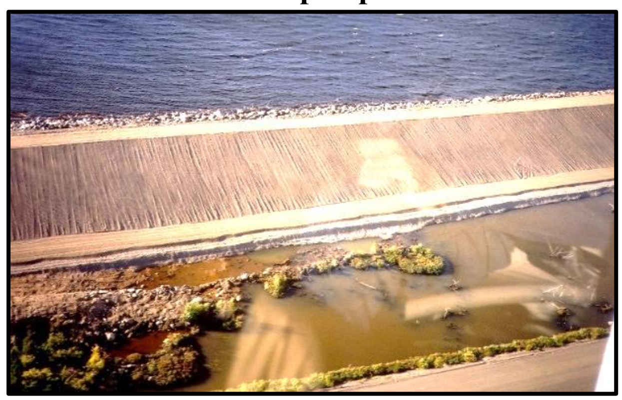


Tailgate lunch at Dyke GL-8 west of Churchill.

At GR-10, even with a downstream slope at a relatively flat 2.09:1, the surface material tended to slide down. Test pits indicated that the surface slide was only 0.3m deep.



Undersized rip-rap at GJ-18.



Erosion with even "corduroy runnels" on GL-19.

Surface cracking and slipping at GR-10

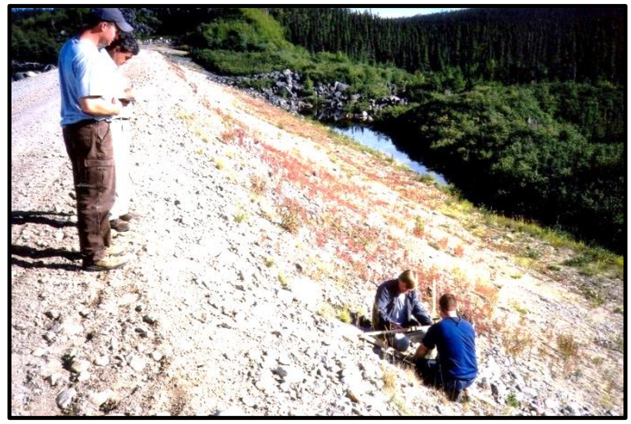
When out inspecting the dykes west of Churchill Falls, we would always have a "tailgate lunch" prepared by staff at the inn. On trips up to the top end of the reservoir, looking at the Orma and Sail Lake dykes, we would lunch at a shed near the Orma Dykes, maintained as a refuge in case dyke staff was caught out in poor weather.

Sheltered area, no rip-rap on GL-3.

Looking at erosion gullies on GL-27.

In the Huey helicopter, sitting side-saddle for better photos.

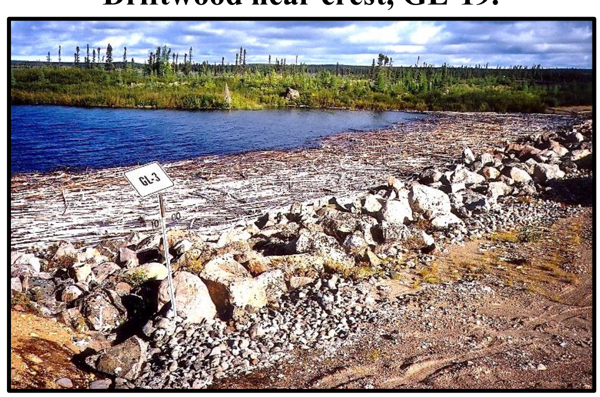
Slope measuring, at 1.8:1 on 5.6km long Dyke GL-31.



1.6:1 slope on GL-8 near left abutment. The reddish vegetation is “Labrador tea”.

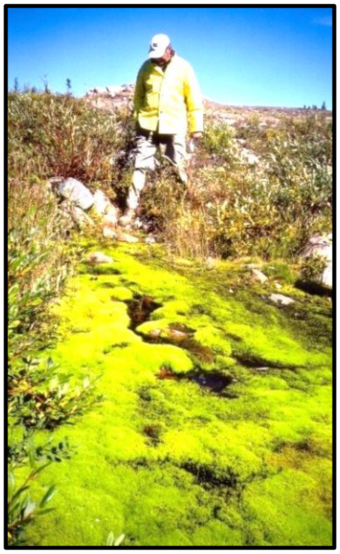
Reading piezometers at GR-6.

Driftwood near crest, GL-19.



Driftwood floating in reservoir, GL-3.

We looked at this spring every year. Over time, the moss appeared to grow and cover more ground.



Ray Benson looking at strange moss in spring downstream of GR-7.

My time on the board was very instructive, and I learned a lot about dyke stability, mostly from Dr. Benson, who advised: **-** **"*The approach used at Churchill was based on site observations. This meant that the dyke inspections must continue for the entire life of the project. The 'design as you go' approach allowed the project to proceed expeditiously into construction and then to operation. Design change decisions made in the field regarding dyke foundations and slopes, allowed the structures to be built safely and economically for the conditions that were revealed during construction but could not be anticipated in detail in the designs, as the investigations had to be limited due to the great expanse of the dykes. During operations for the first few decades, there was readjustment by some dykes to the underseepage and climatic conditions that resulted in slope creep with some cracking and downstream sloughing of dykes. So a remedial process was developed that took a few years to finalize, and was then utilized to remediate and stabilize the affected dykes. This has been on-going for a good number of years and still continues. It has resulted in stabilization of a significant number of the dykes, especially the large ones, resulting in benefits that will reach decades into the future and perhaps beyond the design life of the project. The benefits to the project were, and are, immense".*** Unfortunately, the Dyke Board has now (2017) been dissolved, but Dave Brown occasionally undertakes an inspection.

With so many dykes, differing orientations and designs, and changes in the proportions of gravel, sand and silt within the dykes, analysis of their slope stability would make an excellent subject for a thesis, and perhaps someone will undertake this task.

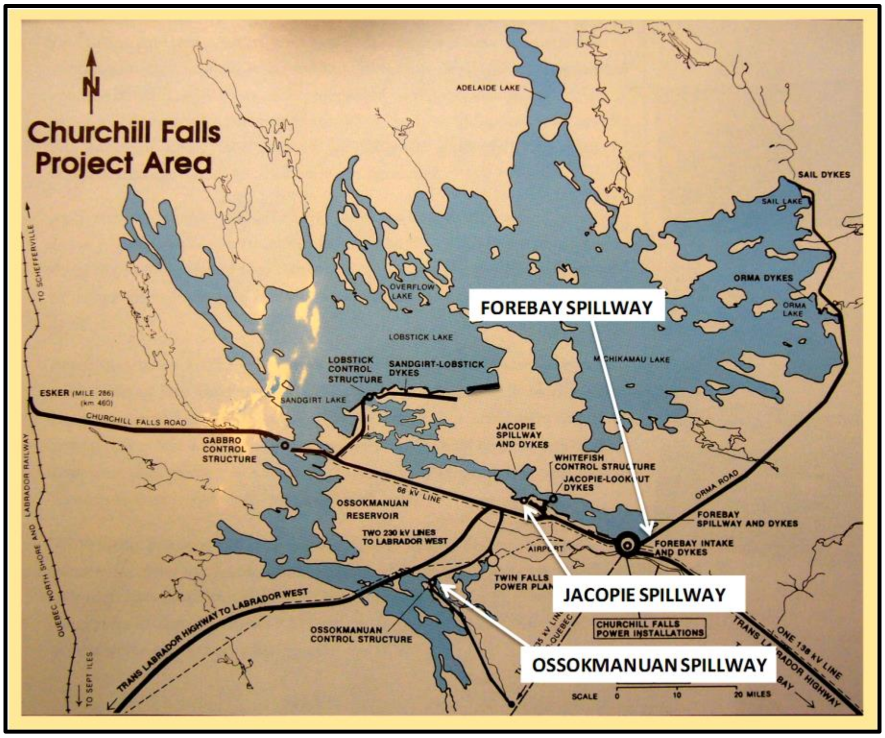
Dyke board in 2000. Ray Benson, Guy Larocque, Rick Seemel, Zak Erzinglioglu and Jim Gordon.

2003 - Dyke Board, hydro staff and survey crew.
Jim Gordon, Wallace Smith, Kent Murphy, Gordon Hynes, Tony Tawil, Justin Hardy, Ray Benson. Kneeling - Tony McEachren and Garry Tucker (with Gordon meter!).

116. CHURCHILL SPILLWAYS – 2000-2005

There are three spillways at Churchill. Their locations are shown in the following map.

Upstream view of spillway



Spillway locations.

When the Ossokmanuan reservoir was filled shortly after Churchill commenced operating in 1970, it started to spill around the south end of the spillway dyke. I had a call from the Churchill powerplant operator asking if I knew anything about the area. I told him that the survey had been undertaken by Hugh Watson, and that he had to continue far to the south before he found any ground above the reservoir full supply level, and that a copy of the survey profile should be in their files. This was found, and three very small freeboard dykes had to be built to close the reservoir rim.

Ossokmanuan spillway.

2 screw stem hoist gates on left, stoplog hoist on right.

Gordon Hynes with open stoplog quick-release jacking box.

The Ossokmanuan Spillway was originally built for the Twin Falls powerplant in 1964, and increased in height for Churchill Falls in 1969. It diverts the Ossokmanuan River flow into Gabbro Lake, and then on down to Churchill. It has two spillway gates and 17 quick-release stoplog bays.

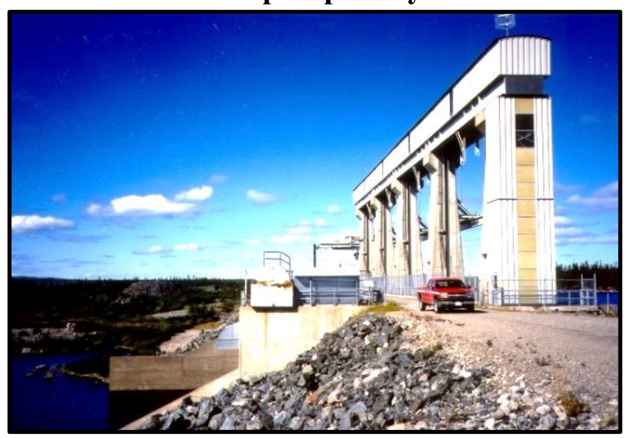
Stoplog hoist deck with locked jacking boxes.

A 50-ton jack is placed between the two pins to lift them free of the top of the steel column holding the stoplogs. The column is retained at the bottom with a robust steel angle anchored into the base slab concrete. When released, the logs are lost, but the column can usually be retrieved. The spillway has never been opened, since all the water can be used at Churchill. The access road is long and rough, so that the operators now prefer to use a helicopter to reach the structure. I expect that eventually, a shorter access road will be built from the nearby Trans-Labrador highway shown in the preceding map.

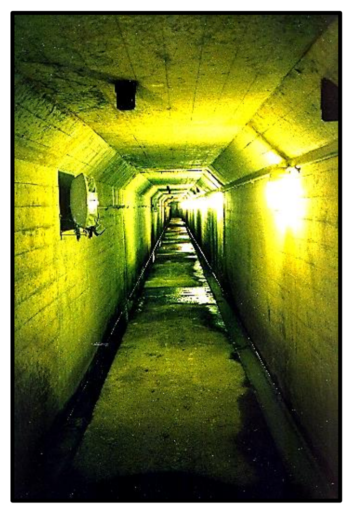
Stoplog bay with center steel column. Leakage expected to reduce when the new timber stoplogs swell.

The Jacopie spillway is the main spillway for the development, releasing flood waters from the very large Smallwood Reservoir. It has 4 wire rope hoist gates.

Jacopie spillway.

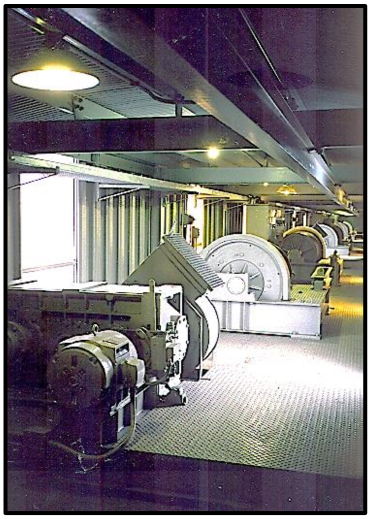


Jacopie spillway from north dyke.



Drainage gallery.

The spillway is rarely used. The last time was during the severe winter ice storm in 1996, when many transmission lines collapsed around Montreal and power was lost throughout most of Quebec. Consequently, Churchill had to immediately reduce power production.



Hoist house interior.

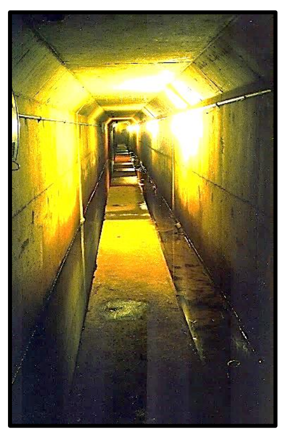
For my inspections I had to climb down ladders to reach the drainage gallery where there were several drains from the foundation. All were usually just seeping as would be expected. I also looked at the heaters to see if they were still operating and watched the operator test the sump pumps by lifting the float control. The longest ladder was almost 100ft, and when I had my usual annual medical in 2004, I proudly told the doctor that I was still working, and even climbing 100ft ladders. She put down her pen, looked me straight in the eye and said "Mr. Gordon, anyone over 70 should not step on a ladder, period". It was the danger of losing your balance on a ladder, wherein the small bone in the inner ear slowly becomes calcified as one ages, and results in gradual loss of balance. So I had to advise my client that the next year, 2005, would be my last on the board – pity, because I really enjoyed the work.

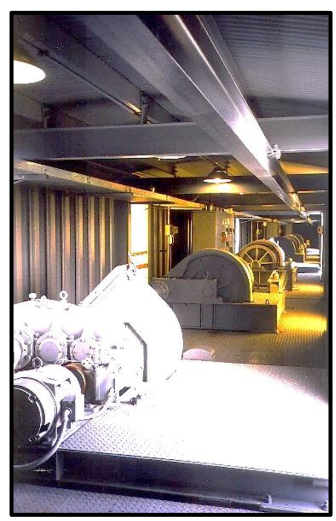
Forebay spillway.

The third spillway was at the East Forebay. It is only used when there is a full shut-down at the Churchill powerhouse, and waters already released from the reservoir cannot be stopped before the forebay overflows.

This was the only spillway structure where there was some seepage. However it was well within normal standards, but it was being monitored with sump alarms linked to the control room at Churchill Falls.

Spillway. Shed is diesel air vent, yellow fuel tank.





Drainage gallery. Hoist house interior.

In all the spillways and control structures, lights were left on all night. The result was an influx of mosquitos and hence birds. We often found birds flying around inside the hoist houses, and of course, they left quite a mess. I suggested turning off the lights, but found that there was no circuit for this. So they are left on. The houses are cleaned out annually by university students hired for such casual labor. I suspect it provides a valuable lesson on continuing with their education!

Seepage into sump.

Sump alarms.

All spillways and control structures, except for Whitefish, have the same gate width, so that one set of stoplogs can service all structures. The logs are used to dewater the gates for inspections. An excellent idea which saves a considerable sum of money.

Mosquito carcasses on hoist drum.

Access to top of gate and heating element, white can.

117. CHURCHILL CONTROL STRUCTURES – 2000-5

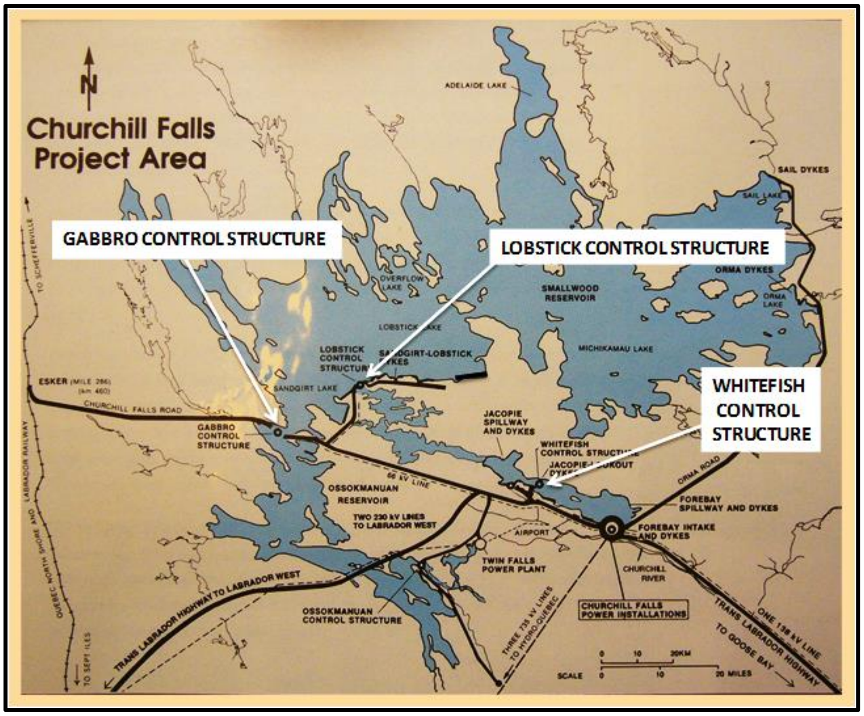
There are three control structures at Churchill. From upstream to downstream, they are at Gabbro which discharges flow from the Ossokmanuan reservoir into the Smallwood reservoir, at Lobstick which discharges flows from the Smallwood reservoir into the West Forebay, and at Whitefish, which discharges flows from the West Forebay into the East Forebay. Their locations are shown in the map on the next page.

The Gabbro Control Structure was constructed behind a cofferdam built to divert the flows south to Ossokmanuan for use at Twin Falls. It has 4 gates, and is usually always discharging water.

Aerial view of Gabbro Control Structure.

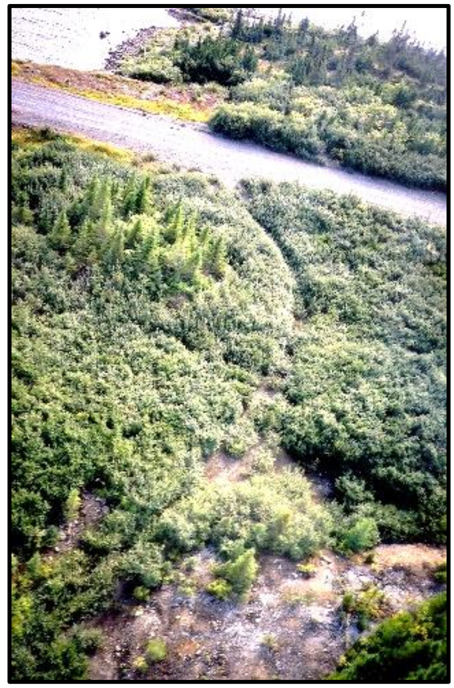
At Gabbro, I found the remains of the tote road I had worked on in 1956. It was almost completely overgrown with alder bushes. As with the other spillways, the steel rail for a stoplog monorail hoist was in place, but the hoist was being used at Lobstick.

One issue not fully addressed in the design of the flow control structures was the fact that water would be constantly flowing through the sluices at a high velocity, and over time, this would erode the concrete surfaces immediately downstream of the sluice gates.

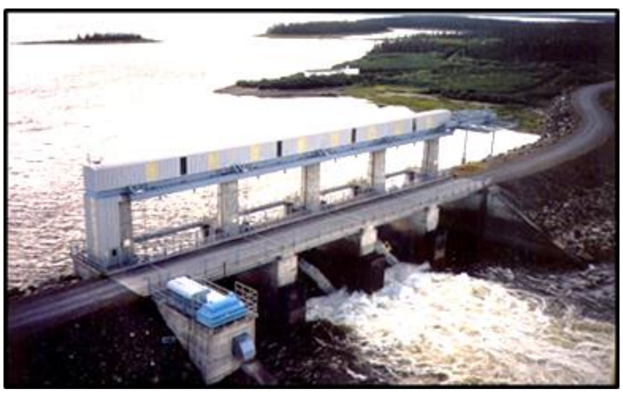


Control structure locations.

Remains of ’56 tote road.



Below - View from left abutment. Note stoplog hoist monorail, but no monorail hoist.

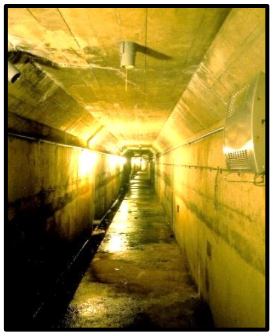


Aerial view of Gabbro control structure. Emergency diesel generator in concrete pier below blue oil tank.

Remains of old 1956 tote road to Gabbro.

This is not a problem with spillway gates, since they are rarely used, and then only for a short time during a flood. All the Churchill control structures have stoplog guides well downstream of the gates, but no means of access to the guides. Consequently, temporary bridges and hoists had to be installed to undertake repairs. It would have been far preferable to have placed the downstream stoplog guides at the end of the stilling basin and provide some means of access to the guides in the original design. However, this would have added cost and hence was debatable.

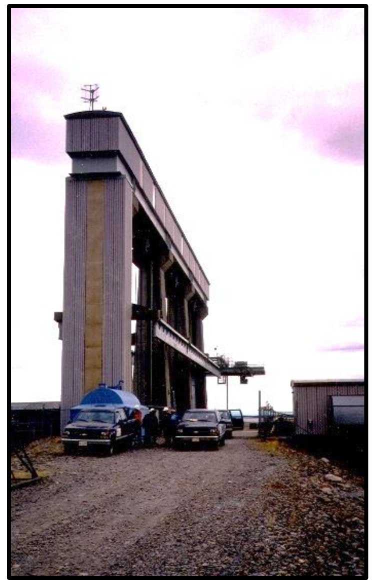
Drainage gallery.



The concrete erosion problem had to be addressed at Lobstick, where divers had conducted underwater inspections of the concrete and found, as expected, concrete erosion immediately downstream of the gates. Two bridges were installed across the sluiceways to gain access, and a stoplog hoist was fabricated, riding on rails placed on the piers.

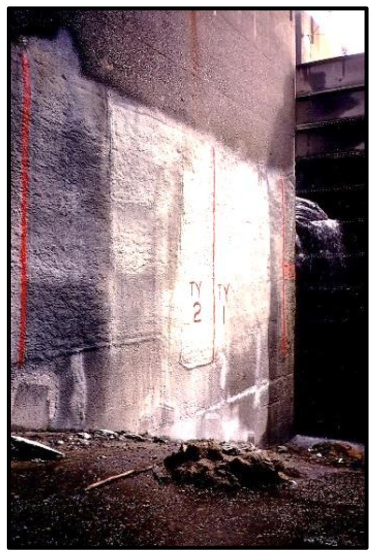
Gabbro hoist house interior.

Lobstick Gate #2 channel repaired. Other gates will be closed to permit removal of middle gate stoplogs in calm water.



Left – hoist structure.

When we looked at the repairs in September 2000, the work was almost complete. Steel panels had been added to cover the concrete immediately downstream of the stoplog guides, and after that, shotcrete of varying mixes had been sprayed on the concrete in several test panels, to determine which mix stood up best to erosion.

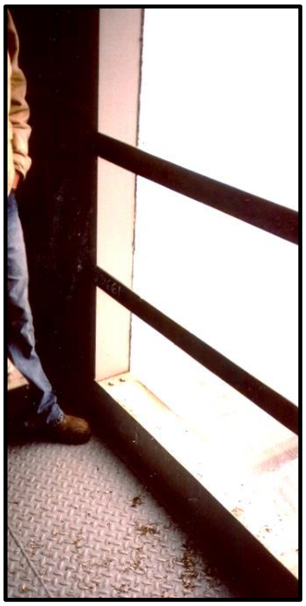


View of repairs to sluice concrete, 2000.

Access bridge.

One point I learned from the inspections is that the quality of maintenance will be a function of the ease of access. If it is difficult, it will be imperfect, but if access is easy, maintenance will be much improved.

A simple illustration of this was the problem of replacing broken window glass in spillway hoist houses perched high above the dam crest. The panes were broken by Canada geese flying into them. A large mobile crane was needed to reach the windows, to lower the large (about 4ft by 8ft high) cracked heavy glass window, and lift a new one into the opening.



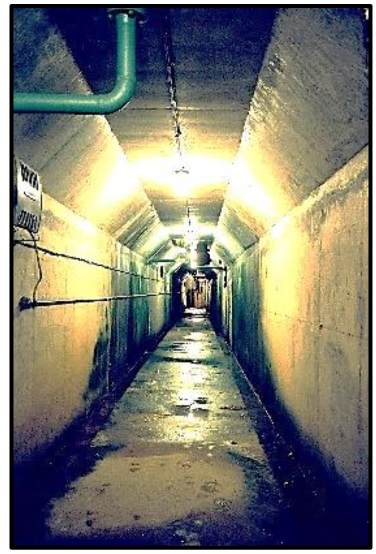
New (right) and old window frame designs.

I found that several of the windows had temporary Plexiglas panels over the broken glass, simply because it was too expensive to bring up a mobile crane from Churchill for the repairs. I suggested that the window frame be re-designed so that the glass panes could be removed from inside the hoist house, and that the glass panes be reduced in size to a weight easily carried up the hoist stairway by hand.

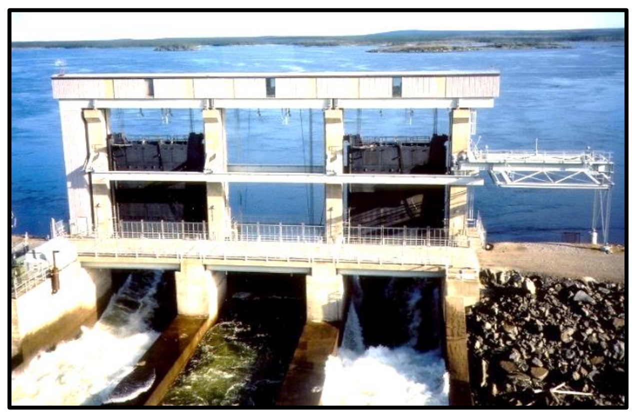
Lobstick hoist house interior.

The third control structure is at Whitefish.

Lobstick drainage gallery.



Design of the project had severely taxed the ability of the consultant, Acres. Their offices were just overloaded with the work. To solve the problem, they prepared specifications for the design of the three control structures, requested bids, and Montreal Engineering was successful in obtaining the design of Whitefish. However, I was too busy on other projects, so did not work on the detailed design.

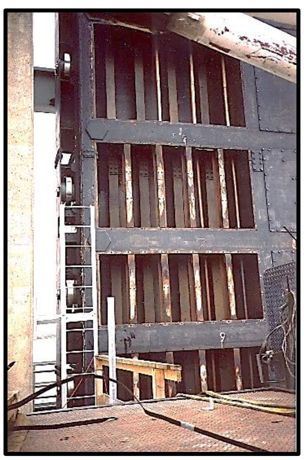


Whitefish – view from downstream.

I had visited the site in 1968 along with George Eckenfelder our VP Hydro to prepare the proposal. At the time, Mannix was working on the road from Churchill to Orma, and I met their resident engineer Joe on the flight back to Montreal, and enquired about Alf Wright from the tote road days. Alf had retired, but had worked on their Orma road proposal. Joe was returning to Calgary to discuss the Orma work because it was seriously behind schedule. Apparently he had run out of gravel fill for the road about half-way to Orma, and there appeared to be no suitable sources near the end of the road. Don't know how the problem was solved.

Whitefish hoist superstructure.

Replacing wheels.



Gate back panels removed for access.

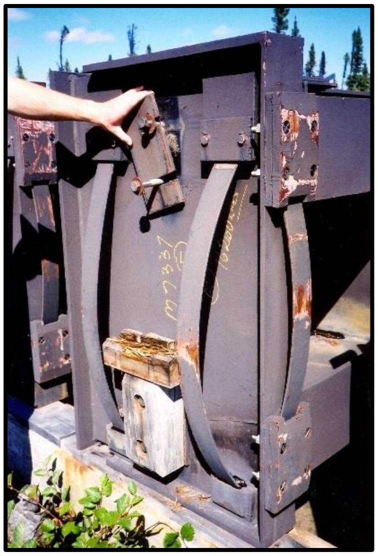
Another issue we discovered with all the control and spillway structures was the lubrication of the bronze bushings in the wheels on the gates. This was particularly serious on the spillways. The bronze bushings were made by Lubrite and had a patented greasing arrangement whereby the axle bushing had felt pad inserts impregnated with grease. The idea was that the outer bronze bushing, attached to the wheel, would rotate over the greased pads and distribute the grease around the bearing.

The problem was that many of the gates were rarely moved and remained in place for several years. Over time, the higher aromatics in the grease would evaporate, the grease would harden and lubrication would be lost. Sometimes the wheel would freeze, and would not rotate. In fact, there had been a recent incident at Folsom Dam in the USA where a gate had failed due to frozen bearings.

Interior of hoist house.

The solution was to institute a program of gate bearing inspections and regular operation. This was easy to accomplish on the control structures, but difficult on the spillways, since any opening of a gate would release valuable stored water. But it just had to be done, so on spillways, the stoplogs are placed upstream of a gate, and the gate is lifted until the wheels have rotated through 1.5 revolutions. There are so many gates on the development; that this task proved to be almost a full-time job for a new maintenance crew. Of course, the work could only be undertaken during the ice-free months.

Whitefish stoplogs in storage.



The side wood panel guides showed weathering.

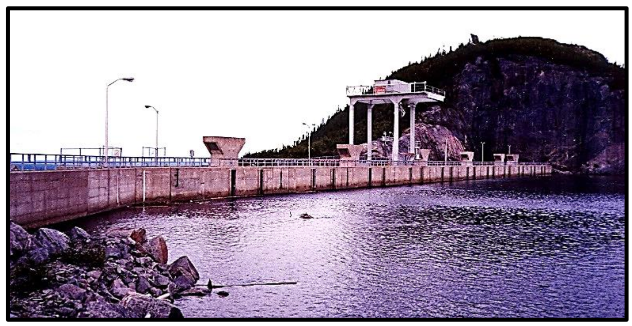
For some reason, the Whitefish gate width is only 35ft, as compared to all other gates at 45ft, hence there is an extra set of stoplogs stored nearby. Also, the gates are subjected to back-slap from waves, and over time, the steel panels on the back of the gate distorted and had to be reinforced. A hydraulic model study would have detected this condition, but I don't know if such a study was undertaken.

118. CHURCHILL INTAKE – 2000-5

On my first Churchill inspection in 2000, there were so many dykes and structures to look at, that I only realized after leaving, that I had not seen the intake gate hoists. So on returning in 2001, I asked to see the hoists, only to be told that the Dyke Board had never looked at them. However, I repeated the request, and was advised that such an inspection would need organizing, since access was through a manhole in the intake deck, the hoists being on a steel platform just below.

As we approached the intake, I noted heavy rock rip-rap on the downstream side of the dyke beside the intake, an unusual feature. So I asked why, only to be told that it was because the "intake burped". Apparently the "burping" occurred in winter due to a malfunction of the intake gate controls, resulting in water spouting out, lifting a 15-ton concrete slab over the hoist, and pouring out onto the dyke to run down both dyke faces, hence the rock protection.

Churchill intakes. Inverted triangular structures are air vents, each one servicing 2 units.



Intake structure from left bank dyke.

Rip-rap on downstream slope of dyke.

When I looked at the hoist, I could see that maintenance was minimal, no doubt due to the difficult access, and that the heaters were not effective since the hoist area was open to the outside cold air, with air vent flaps missing in the vents. The malfunction occurred due to freezing of the gate hoist controls. When opening a gate on an empty penstock, the gate is normally stopped after opening about 10cm. With the controls frozen, the gate continues to lift, allowing a large volume of water to enter the steep penstock, trapping a large air bubble at the bottom. When flow slows on filling, the pressurized bubble rises to emerge with enough explosive force at the hoist to lift the concrete slabs.

This is not an uncommon event, as I found out when collecting data for a paper on "burping intakes". It has also occurred at Bay d'Espoir as will be described in a following chapter.

Intake gate hoist on steel beams just below deck.

I suggested installing flaps in the air vents to contain the warm air around the hoist, but only one flap was installed, leaving the vent on the other side open, rendering the modification ineffective. It is difficult to change the mind-set of operators when they have been working on equipment for over 30 years! But what I found surprising was that nobody had thought of investigating the root cause of the control failures.

Intake deck with gantry crane. Grab for trash removal. Hoist can lift trashracks and gates to above deck. Each air vent has 2 openings.

119. CHURCHILL OUTLETS – 2000-5

View of tailrace tunnel outlets – note stored stoplogs.

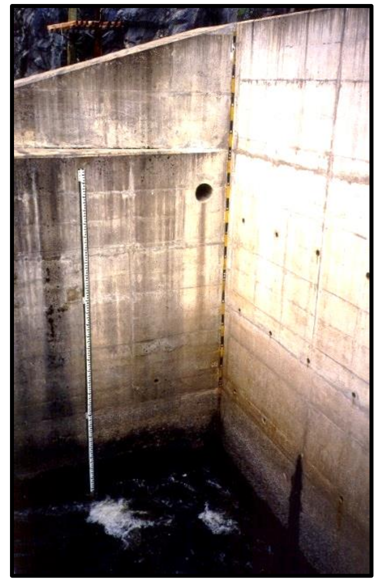
There are two tunnels at Churchill from the tailrace surge chamber. They exit at the Churchill River in two outlet structures equipped with stoplog guides to allow unwatering of one tunnel at a time. This was undertaken in 1998-9 to inspect the tunnels and clear out any fallen rock. Access to each tunnel is down the space between the stoplogs and the concrete face on the rock wall.

Outlets, looking upstream. Stoplog guides are below the steel grating.

Access to the outlet is along a dog-leg road from the town which passes Garry Tucker's small farm, the only registered farm in all of Labrador. Garry (now retired) had been a resident of Churchill since the construction, and experimented with several varieties of potatoes in a quest to find a species that will flourish in the local soil and climate. He always provided the best of his latest species for our dinner at McParland House on the Thursday before we left, and they were certainly appreciated.

Outlets looking downstream.

The concrete was in remarkably good condition. In fact, all the concrete at Churchill was in excellent condition, with absolutely no signs of AAR.



Space for access down to tunnel.

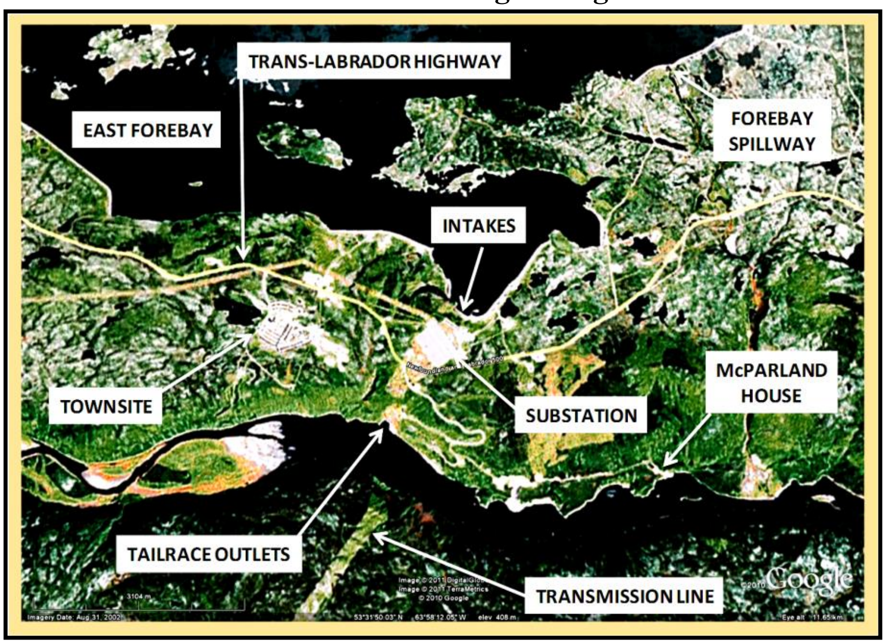
The tailwater level at the outlet is about 1m higher than expected. This is due to siltation in the river downstream of the outlet which occurred when the Forebay Spillway was tested during commissioning in 1973. It discharges into a small stream, and the large discharge severely eroded the stream bed, depositing the sand and gravel in a large delta about 6km downstream of the outlets. (Remember Harca!) It now remains mostly in place since there are no major floods in the river with a seven-year filling cycle in the upstream Smallwood Reservoir to wash it out. However, one benefit is reduced cavitation on the turbines, which permitted an increased output of 4% when new runners were installed in 1985. The optimum relationship between submergence and output could not be determined in 1965 when the turbines were designed, but this can now be accomplished with computers.

Stoplogs in storage.

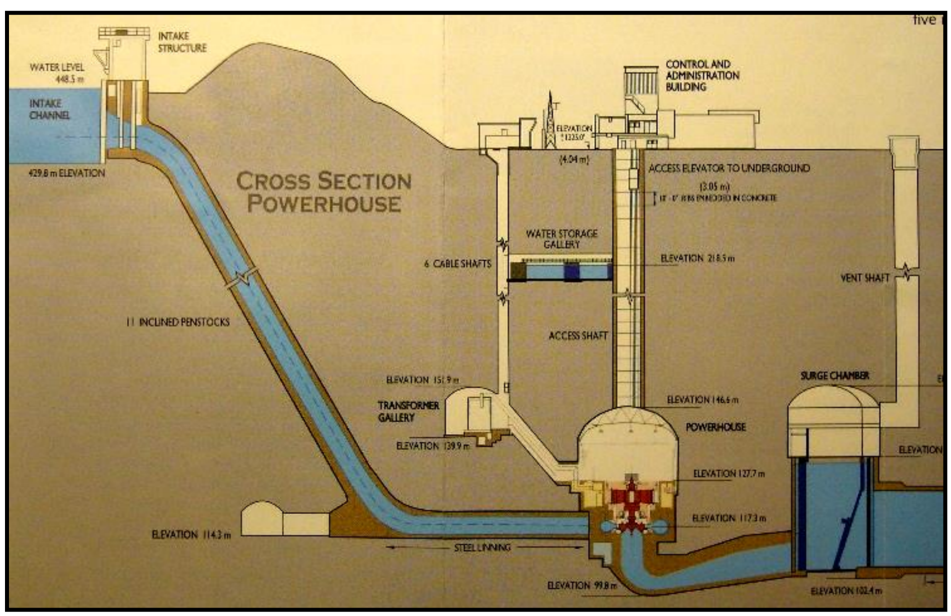
120. CHURCHILL POWERHOUSE – 2000-5

At 5,428MW capacity, the Churchill Falls powerhouse is the largest single underground powerhouse in the world. It contains 11 vertical shaft Francis turbines, operating under a net head of 312.4m.

Churchill Falls Google image.



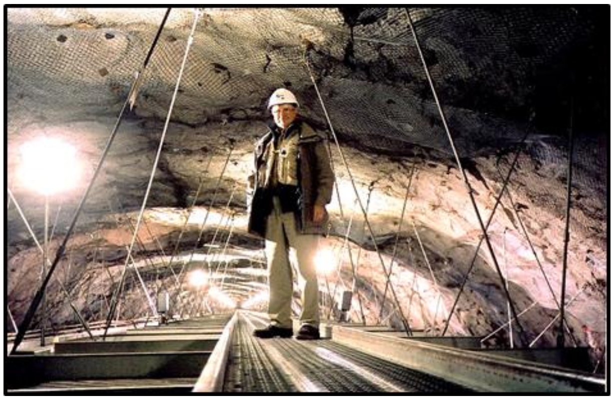
Section through powerplant. Source – N&LH brochure.



Until the Trans-Labrador Highway was built in 1997, the town was isolated, with the only access by air or by train to Esker. Construction of the development in 1968-75 was a remarkable achievement. It had several firsts – the largest powered turbines in the world by a significant margin, the largest underground caverns, and the first use of finite element analysis of rock stresses around the caverns. The powerhouse cavern is 296m long, 25m wide and 47m high. The tailrace surge chamber is 233m long, 12 to 20m wide and 45m high.

Our inspections of the powerplant concentrated on the exposed rock and observations of seeps into the galleries. We started by walking the length of the suspended roof above the generators, looking at the condition of the wire mesh holding up rock fragments that had fallen off the roof arch, and then through the powerhouse.

The area had been equipped with excellent mercury arc lighting, which took a few moments to warm up, and then clearly illuminated the entire roof arch. The suspended roof was strong enough to support workers engaged on removing fallen rock from the wire mesh, a task which was undertaken every few years.



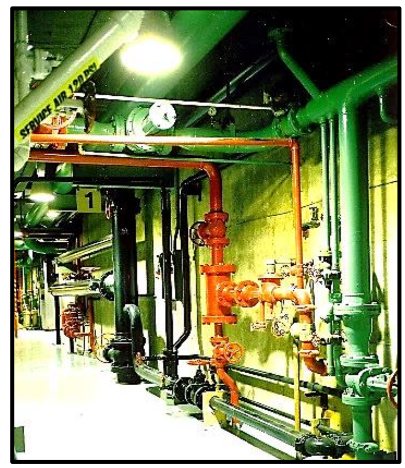
Looking down roof arch.

With Zak Erzinglioglu at powerhouse crane rail.

View of generator floor from crane rail.

After walking under the roof arch, we climbed down several ladders to emerge at the crane rail level in the powerhouse, and then walked along a catwalk beside the rail looking at the exposed rock, and then down a ladder to the powerhouse generator floor

Unit below crane undergoing maintenance. Generator floor.

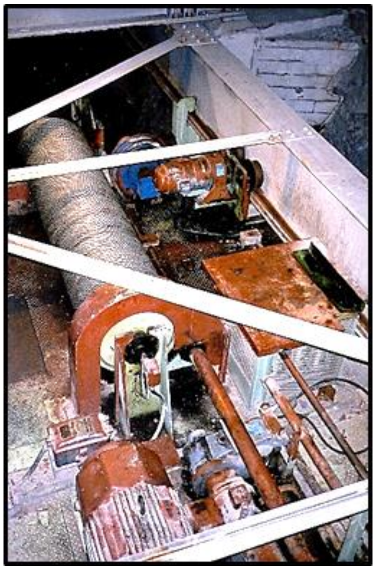


Piping gallery.

We then took the elevator up to a passage leading to the draft tube surge chamber; always a spectacular sight. There was one problem with the chamber design. There was no access to the arched roof over the water for maintenance. This resulted in the wire mesh holding the rock spalls falling off the roof becoming engorged, and eventually failing, letting the rock fall down into the water below. The point I learned from this, was that access must be provided for anything that might need repair, even something many years in the future. You have to think of what will need to be done in 30 or even 50 years ahead, something very few designers even contemplate.

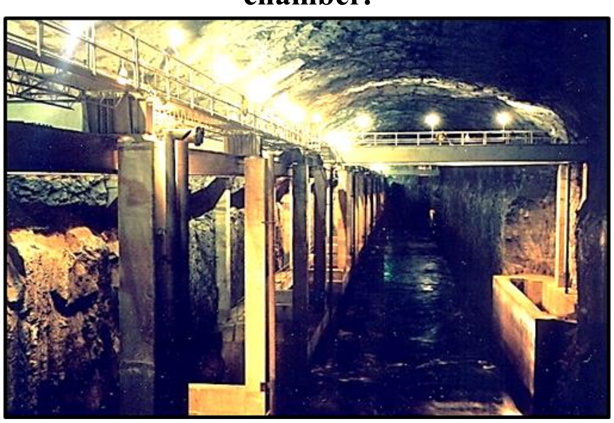
In the chamber, it is just too dangerous to work suspended from rock anchors in the roof over the surging water below. A work platform running on rails along each wall is needed, and can be built at a very high cost, probably in the range of a few million dollars, but it would have been a very simple addition to the structure if included in the initial construction.

With difficult access, the draft tube gate hoist needed some painting to counter rusting.



Draft tube gate hoist in surge chamber

West end of surge chamber showing access chamber.



View of surge chamber from access chamber.

After looking at the surge chamber, we would walk down to the gallery below the penstocks to look at seepage into the lowest level of the structure. Since it was only an open passage left over from the construction, only half of the roof arch had been covered with mesh, so we had to be careful to only walk below the meshed half.

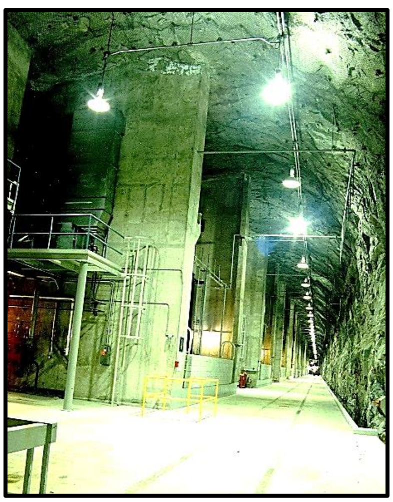
At east end of chamber, overhead I-beam rails for draft tube hoist on bottom right.

Occasionally we managed to look inside a turbine spiral casing and the steel penstock. In order to cut costs, the turbines did not have shut-off valves at the inlet, despite the fact that valves are required whenever the head is above about 120m. The valves are needed to avoid very high velocity water seeping out through minute spaces between the wicket gates. Over time, this results in what is called "wire drawing" erosion of the wickets. The erosion looks as if a wire has been rubbed across the edge of the gate causing a small groove. Eventually, the leakage past the gates becomes excessive, and it is difficult to stop a unit rotating. To overcome this problem, the Churchill penstocks are emptied whenever the turbines are stopped for more than 20 minutes. This has contributed to the intake "burping" problems.

Stainless steel turbine wicket gates.

Looking into horizontal section of a penstock.

After looking at the seepage gallery, we would walk through the transformer gallery looking at the exposed rock and several minor seepages.

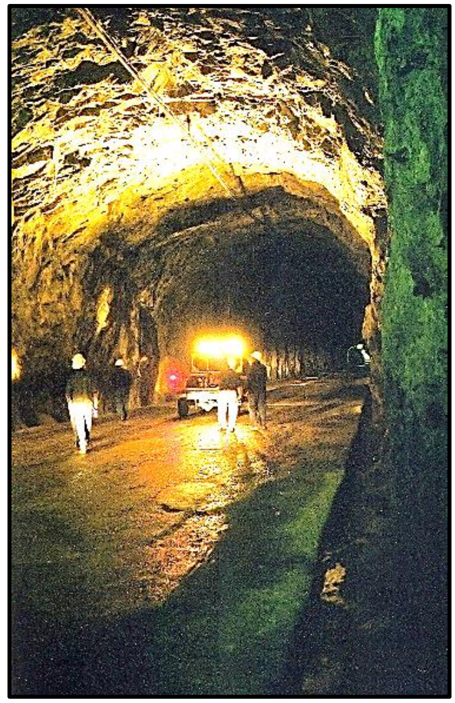


Transformer gallery.

Below - drain gallery.

Our last inspection was to slowly walk down the powerhouse access tunnel behind a pick-up equipped with powerful lights directed upwards towards the arched roof.

The tunnel entrance was equipped with an air lock with two sets of doors, and enough space between the doors for a large truck. On our first inspection, we noticed that silt washing off the steep slope above the doors had accumulated on the access road into the tunnel, to such an extent that it was being washed down into the tunnel and eventually into the powerhouse sumps. We suggested re-grading the road to slope back towards the river.

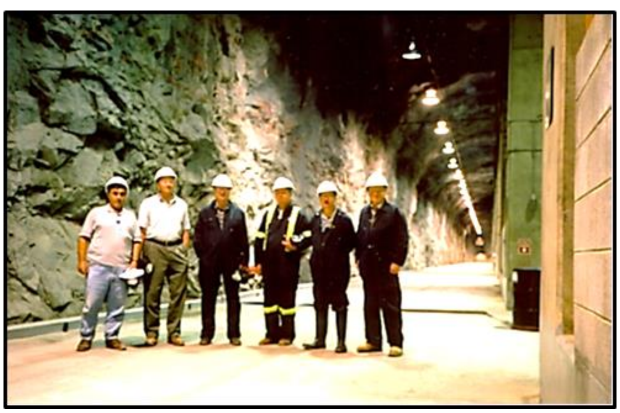


Above and left - access tunnel inspection.

After the road inspection, it was down to work preparing a report in a room adjacent to the library, reserved for us in the large building housing the inn and other facilities. Time was tight, since we started on Saturday afternoon, and it had to be presented on the following Monday morning.

Access tunnel entrance.

Working on report using the same desk as used during construction by the Bechtel engineers.



Tony Tawil, Ray Benson, Wallace Smith, Kent Murphy, Gordon Hynes and Jim Gordon in transformer gallery.

Before leaving Churchill, I should mention McParland House. It was built as a VIP center to Don McParland's designs. Unfortunately, he was killed in an accident in 1969 during construction of the facility. The executive jet aircraft transporting several senior staff from Churchill to Wabush and Montreal, crashed into a hill at Wabush during a landing at night, and all 6 passengers, including Don McParland and the two pilots were killed.

CHURCHILL FALLS POWERHOUSE TECHNICAL INFORMATION

RATED CAPACITY	
Original	5 ,225,000 kw
Uprated (1985)	5,428,500 kw
GENERATING UNITS	
Number of Turbines	11
Type	Francis
Rated Capacity	648,000 HP 680,000 HP
Rated Net Head	312.4 m
Synchronous Speed	200 r.p.m.
Scroll Case Inlet Diameter	4.45 m
Runner Inlet Diameter	5.82 m
Runner Weight	77.13 t
Long Term Plant Mean Flow	1 387.52 m^3/s
Generators	
Rated Voltage	15 kv
Rated Capacity	
(7 units)	526,315 kva
(3 units)	500,000 kva
(1 unit)	530,000 kva
Rated Power Factor	0.95
Rotor Diameter	9.11 m
Rotor Weight	576 t
Strator Core Depth	2.99 m
PENSTOCKS	
Number	11
Length	426,72 m
Diameter- Concrete Lined Section	6.10 m
Diameter- Steel Lined Section	4.45 m
MACHINE HALL	
Length	296.27 m
Width	24.70 m
Height	46.94 m
Overhead Travelling Crane	2x 400 t

SURGE CHAMBER	
Length	232.56 m
Bottom Width	12.19 m
Top Width	19.50 m
Height	45.11 m
VENT SHAFT	
Diameter	6.10 m
Depth	252.68 m
TAILRACE TUNNELS (UNLINED)	
Number	2
Width	13.71 m
Height	18.29 m
Length	1691.64 m
TRANSFORMER GALLERY	
Length	260.91 m
Width	15.24 m
Height	11.89 m
CABLE SHAFTS	
Number	6
Diameter	2.13 m
depth	263.65 m
RESERVOIRS	
Smallwood	
Maximum Normal Water Level	1,551 ft
Minimum Water Level	1,522 ft
Reservoir Area	5698 km^2
Active Storage	28.97 x 10^9 m^3
Ossokmanuan	
Maximum Normal Water Level	1,572 ft
Active Storage	2.83 x 10^9 m^3
DYKES	
Number	88
Total Crest Length	64.4 km

Churchill data. Source – N&LH brochure.

The VIP center was re-named to McParland House in his honor. It has a spectacular setting on the North rim of the Churchill gorge. On the

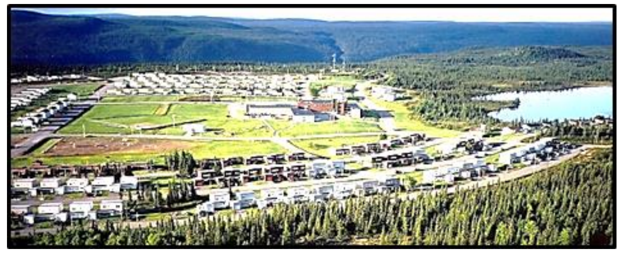
Thursday evening, N&LH would host a dinner at the House for the Board and staff associated with the dyke inspections. It was a welcome occasion to get to know the Churchill staff and enjoy some refreshments, including Garry's potatoes.

At McParland House terrace overlooking the Churchill River valley. 750kV transmission line in background.
Jim Gordon, Kent Murphy, Ray Benson, and Wallace Smith
View from McParland House terrace.

At McParland House dinner.
Tony McEachren, Justin Hardy, Garry Tucker, Gordon Hynes, Wallace Smith, Tony Tawil, Jim Gordon.
Seated – Ray Benson and Kent Murphy.

I had enjoyed my Churchill work, and was reluctant to leave. But the risk associated with climbing down and up the 100ft ladder to the Lobstick drainage gallery and in the other structures was just too much!

When I left, I was presented with a picture of the falls before diversion and 2 numbered prints, one signed by the inspection team and consultants – much appreciated!

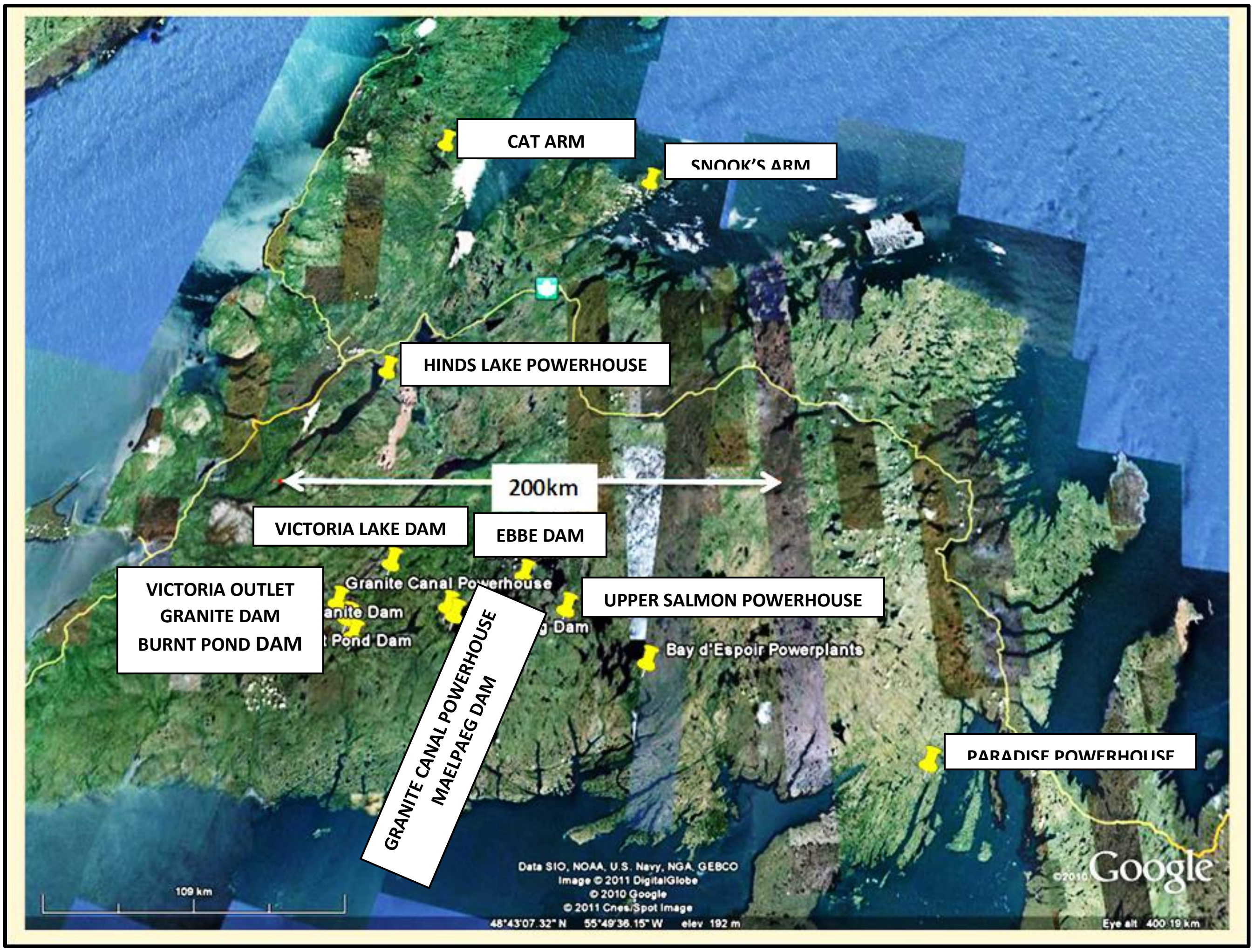


Churchill town. Town complex in center.

121. NEWFOUNDLAND HYDRO - 2000-5

Late last century, the Dyke Board started to look at the hydro plants in Newfoundland owned by Newfoundland Hydro. They included the small isolated plant at Snooks Arm, and other larger plants at Cat Arm, Hinds Lake, the large storage reservoirs at Victoria Lake, Maelpaeg Lake and Burnt Pond, all in the Bay d'Espoir watershed and locally known as the "Up country dams". Also, Bay d'Espoir, and the upstream powerplants in the Bay'dEspoir watershed at Upper Salmon, Granite Canal, and finally the Paradise plant over on the Burin Peninsula.

On Monday morning, after report presentation, we would fly from Churchill Falls in the King Air aircraft operated by Churchill Falls to Dear Lake in central Newfoundland. There we would be met by a delegation of hydro staff, usually in shorts since the temperature was much warmer than at Churchill, due to the lower elevation and maritime climate, and driven to a camp near the Hinds Lake powerhouse.



Powerplant locations in Newfoundland.

2004 inspection team.
Trevor Arbuckle, Bob Barnes, Garry Poole, Jim Gordon, Tony Tawil, Madan Rana, Kent Murphy and Ray Benson.

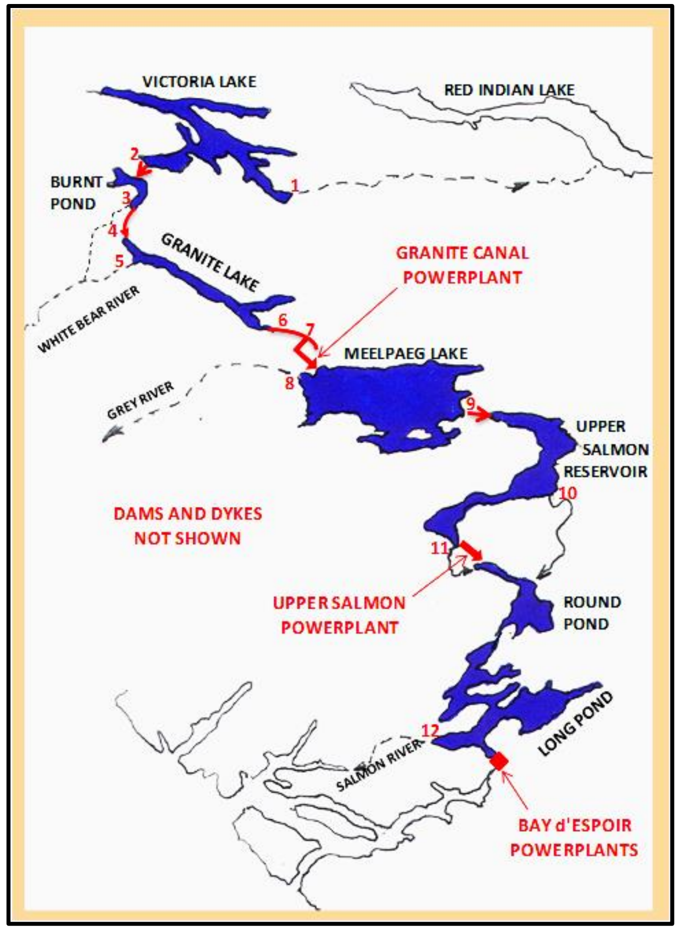
Except for the last day, we would be flown around the plants in two Eurocopter 350 helicopters. On the last day, the next Friday, we spent driving around the Bay d'Espoir dams near the powerplant, before working on the report all Saturday, to be presented on the Sunday morning before departing for home.

We were well looked after, with hydro having engaged the services of an excellent chef, Colin Kendell, who followed us by truck from the camp at Hinds Lake, to Camp Boggy (yes, it is shown on the road map of Newfoundland) adjacent to the Bay d'Espoir powerhouse. There, Hydro maintained a training center with a large kitchen, dining room, lounge, meeting rooms and about 12 bedrooms. It was our comfortable quarters for work around the area.

2000 farewell dinner at Camp Boggy. Jim Gordon, Zak Erzinclioglu, Rick Seemel, Garry Poole, Gunter Dlugosh, Colin Kendell the Chef, Trevor Arbuckle, Guy Larocque and Ray Benson.

Eurocopter 350 helicopters on landing pad at Camp Boggy. Training center in background.

I got to know Colin, our chef. One day he asked me how old I was, and when I told him he just shook his head. I asked what was wrong, and he said he just did not understand why anyone wanted to work well past their retirement age. He said he was now partly retired at 40. He only worked for about 14 weeks every year to obtain sufficient hours to qualify for 36 weeks of unemployment insurance. He had no debts, owned his house, which he had built with the help of some friends in a small fishing village with a view of the Atlantic. He had a pickup, an ATV, a chain saw and logging license to cut deadfall for his wood stove. A potato patch behind the house, a woods camp for the annual moose hunt and some occasional jigging for cod provided food. So why work any longer than necessary?



Map showing structures in the Bay d'Espoir watershed.

The Bay d'Espoir watershed contains so many structures, dams and dykes; that it very easy to become confused, hence a map of the development has been included. The dams and dykes containing the reservoirs are not shown.

The upper reservoir is Victoria Lake, with flow diverted by the spillway (1) to discharge through a control structure (2) into Burnt Pond. At Burnt Pond, there is a manned camp to operate the Burnt Pond Spillway (3) which diverts waters from the White Bear River into Granite Lake through the long Burnt Canal (4).

At Granite Lake there is a spillway, again diverting waters from the White Bear River eastwards to the long Granite Canal (6). Near the downstream end of the canal, there is the Granite Canal Diversion Structure (7) which directs water over to the recently constructed Granite Canal Powerplant, with the tailrace discharging into the very large Maelpaeg Lake.

With Garry Poole and Trevor Arbuckle.

At Maelpaeg Lake there is a dam across the outlet locally known as Pudops Dam (8), diverting waters from the Grey River eastwards. At the east end of the lake, there is the Ebbegunbeg Control Structure (9) directing waters into the Upper Salmon Reservoir. The northern portion of the upper Salmon Reservoir floods out Crooked Lake and Great Burnt Lake and the waters used to flow out past the North Salmon Spillway (10) into the Upper Salmon River which discharges into Round Pond. The lower end of the reservoir floods out Cold Spring Pond, which also used to discharge into Round Pond.

The Upper Salmon Powerplant was developed by diverting the Cold Spring Pond with the West Salmon Spillway (11) and a canal to Round Pond. Between Round pond and Long Pond, there is a small drop which remains to be developed. The Long Pond Reservoir was formed by flooding Jeddore Lake with the Salmon Spillway dam (12) at the outlet to the Salmon River. The two powerplants at Bay d'Espoir take advantage of the large head drop between Long Pond and near tidewater at the head of Bay d'Espoir.

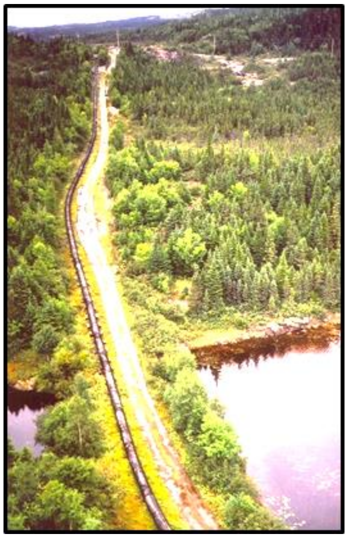
Yes, a complex system of diversions, spillways, control structures and powerplants. It must have taken many years to survey and develop the concept. A remarkable achievement undertaken in the days when there was no satellite imagery!

The project was investigated by Brinco with field work starting in 1954, just after the start of work on the Churchill project. The consultant was Shawinigan Engineering. However, with no market in sight, the rights were sold to the Newfoundland government in 1964, and work started on the detailed design and construction with the consultant being a joint venture between Shawinigan Enginering and Montreal Engineering. It was the start of Shawmont Engineering.

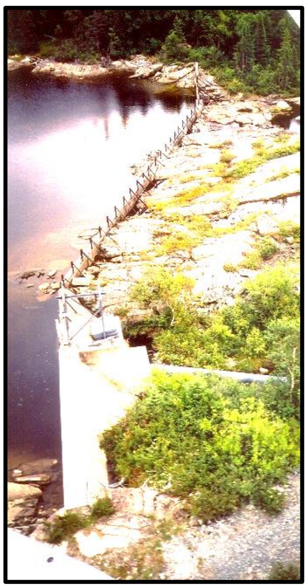
122. SNOOKS ARM – 2000-5

Snooks Arm is a small fishing village on the North-East corner of the Baie Verte peninsula in Newfoundland. There are only 17 homes, but it has a small hydro plant built in 1955 by the Maritime Mining Corporation, to provide power for a copper mine at Tilt Cove, about 6km north. The mine closed in 1967.

Several of the homeowners in the village have tapped into the wood stave pipe for their pressurized water supply. The pipe was nearing the end if its service life, and was replaced with a steel pipe in 2006. Developed head is about 53m. We flew over the facility in 2005, and inspected it on the ground once in 2002.



Wood stave penstock wandering through the village.



Aerial view showing weir dam with flashboards.

Aerial view of pipe through village.

The small powerhouse and equipment were in excellent condition. One feature I noted; was the large flywheel on the generating unit, a requirement for isolated operation during load changes at the mine.

Newfoundland Hydro acquired the facility, along with another at Venam's Bight. Total capacity of the two plants is only 1MW.

Left – Ray Benson looking at pipe and hose taps to nearby homes.

Below – leaky pipe near powerhouse.

Horizontal shaft Francis turbine, with large flywheel in middle for isolated operation.

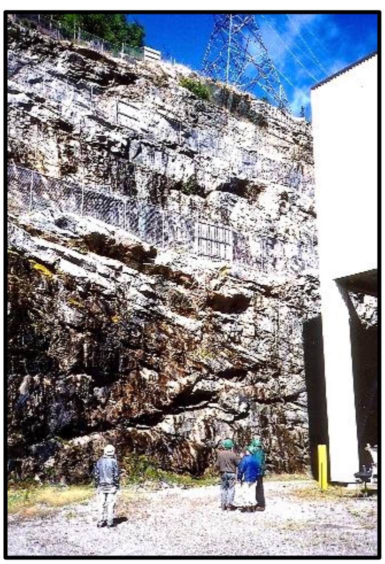
123. CAT ARM – 2000-5

When we left Churchill, the weather was usually very cool, with signs of winter approaching, but on landing at Deer Lake, the contrast could not be greater. Summer in Newfoundland usually lasts until late September, and often we would be greeted by the Newfoundland staff in shorts, having just come off a golf game. Due to the large number of plants, we split the work in two, covering the larger plants annually and the smaller plants every two years.

After landing at Deer Lake, we would drive to a camp near the Hinds Lake powerhouse, with sufficient time for a meeting outlining the work, dinner, and after we would walk over to the powerhouse for an inspection.

Early the next day, two Eurocopter 350 helicopters would pick us up and we would all fly to Cat Arm on the Northern Peninsula, spending the day inspecting the dams and structures.

Cat Arm powerhouse.



Rock wall behind powerhouse.

We always had a good look over the rock wall behind the powerhouse, to see how it was weathering. Apart from a few rock spalls falling onto the rock shelves, it posed no problems.

Intake structure

We were there in 2001, when the news of the 9/11 disaster in New York occurred. As we came in to land at the powerhouse, several of the operators came running out with the news. We could not believe the scenes broadcast on television.

When we departed, the helicopter pilot told us that he had just got a message from Dear Lake airport, asking him to return immediately since all aircraft were grounded. He told us we had two options, either return as instructed, or he could drop down below radar cover and continue flying. We suggested continuing with our work, but we lost the helicopter for a couple of days after we returned to camp.

The “bathtub spillway”

After looking over Cat Arm, we would continue the inspections with a look at Hinds Lake. The facility had been built in 1966 and has a single vertical shaft Francis unit.

Downstream slope on side dam west of the bathtub spillway.

Rip-rap at side dam just west of bathtub spillway.

124. HINDS LAKE – 2000-5

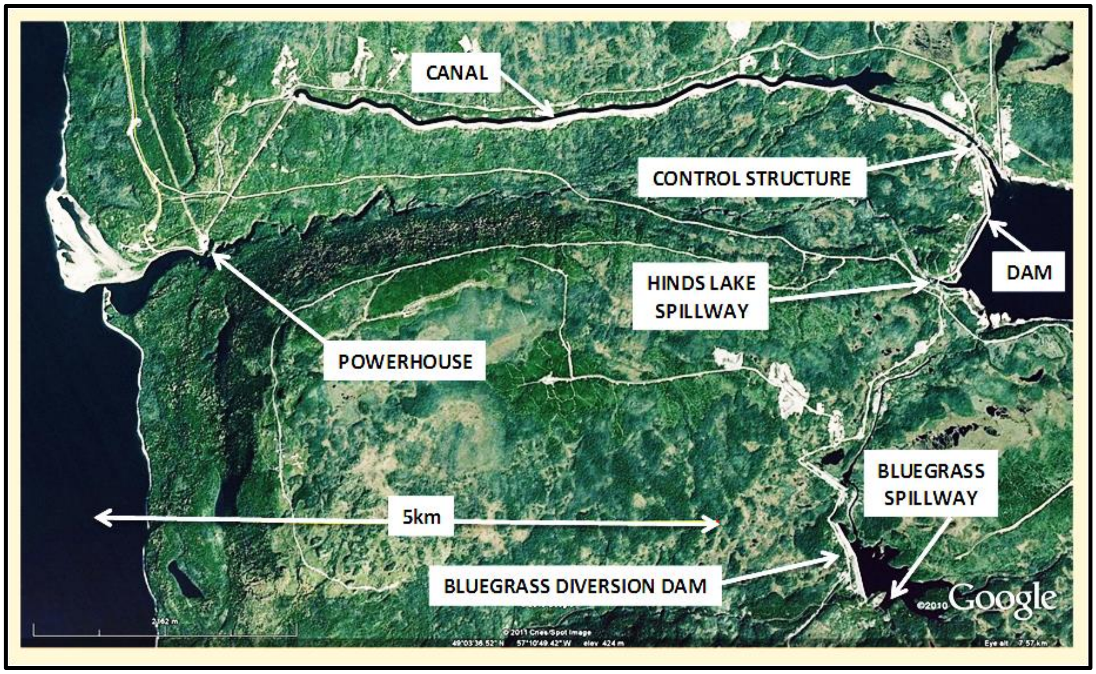
The development had been designed by Shawinigan Engineering, and for some unknown reason, all the exterior faces of the concrete structures had been "parged" with a thin coating of sand and cement. Over time, freeze-thaw action had destroyed the bond, and the parging had fallen off in many areas, resulting in a structure that looked old before its time. However, it was only cosmetic, so no attempt was made to repair the parging. All concrete was in excellent condition, with no evidence of AAR.

The layout was quite conventional with a dam and spillway on Hinds Lake, followed by a control structure at the inlet to a canal, a 6km long side hill canal, intake, and buried penstock to the powerhouse on the south shore of Grand Lake in central Newfoundland. Also, there was a diversion dam on Bluegrass Brook to the West, and another diversion from Goose Pond to the East.

Two views of screw stem hoists on spillway gates.

Ray Benson at Hinds Lake spillway.

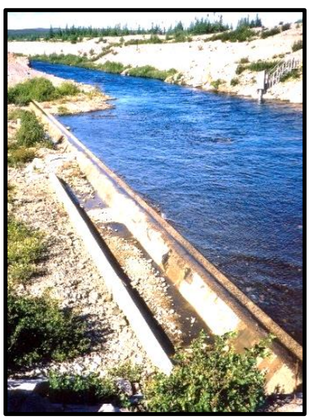
Screw stem hoists were very popular, now replaced with wire rope hoists, at a significant cost saving. Also, they had problems with wear on the hoist crown gears engaging the vertical screw stems.



Hinds project layout.

allowing the level to vary with the reservoir would have required a deeper canal, at a much higher cost. It had two wire rope hoist gates and was in excellent condition; in fact it was the cleanest building of all the buildings I looked into on the island.

Rock cut below spillway.



Canal spillway.

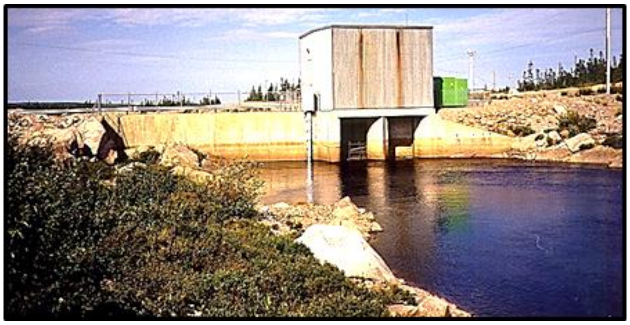
Bluegrass Diversion spillway.

Bluegrass Diversion Dam.

Besides the main gated spillway, there are two small weir spillways, one on the canal, and the other on the Bluegrass Diversion, with the latter being equipped with stoplogs. Being remote, weir spillways are preferred, since they do not require any operation, and spill capacity increases rapidly with increasing head.

The canal control structure was required to maintain a constant level in the canal, since

The powerhouse was built in a sandstone rock excavation, which required constant monitoring. It was deteriorating from freeze-thaw, and the slopes had to be covered with wire mesh to prevent the larger rocks from falling down onto the powerhouse siding.



Control structure at canal entrance.

The long side hill canal has an interesting history. It was built over pervious alluvium, and has several side streams entering on the uphill side. The canal was built using the classical cut and fill technique, with a clay liner covered with sand providing a watertight membrane.

Very clean interior of control structure.

During a severe storm in February 1982, the canal embankment washed out across from a creek entrance. The failure was due to high velocity water entering the canal from the creek, eroding the sand and clay blanket resulting in a piping failure through the embankment.

The creek entrance was revised to limit velocities and the canal repaired with much of the work being undertaken during winter, a remarkable achievement. Since then, the canal has been inspected annually by a team of divers, looking for sinkholes and any erosion of the blanket.

Aerial view of side hill canal.

Inspecting seeps on canal bank.

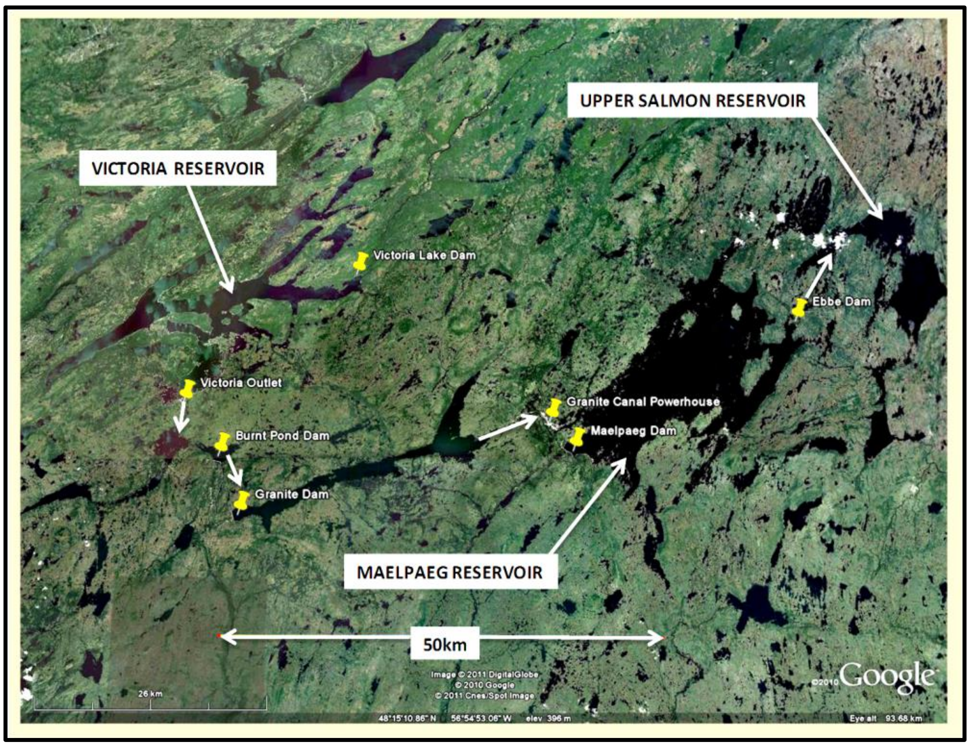
Hinds lake powerhouse.

Rock slope behind powerhouse – sandstone.

125. UP-COUNTRY STRUCTURES 2000-5

The up-country structures are all located in the upper regions of the Bay d'Espoir watershed. After looking over Hinds Lake, we would fly over to these structures while Colin took our baggage by truck over to Camp Boggy at the Bay. There were so many structures, that it was easy to become confused, so they will be described from upstream to downstream, beginning at Victoria Dam.

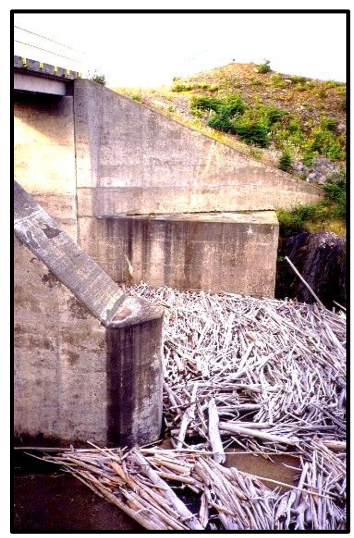
Victoria Dam on Victoria Lake.



Project locations with flow directions.

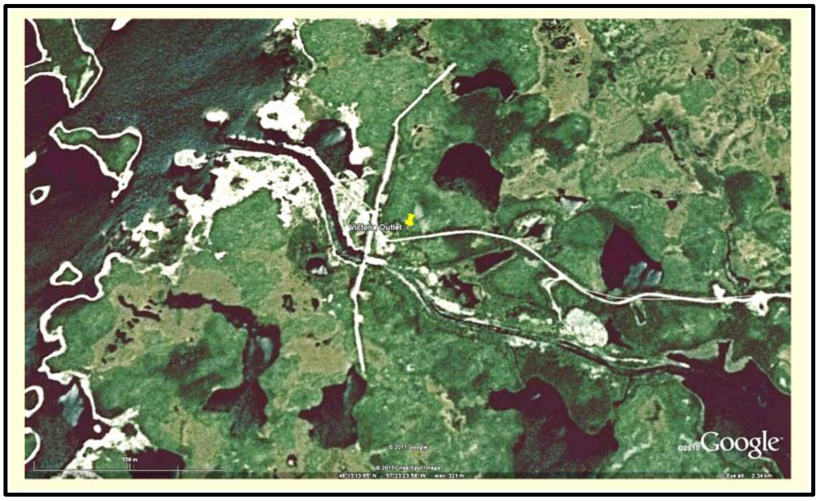
Victoria Lake used to drain northwards into Red Indian Lake. It was diverted south with the Victoria Dam at the eastern end. There is a 2-gated spillway, but more detailed flood analysis indicated that it is not required, and it has now been converted to a weir, with water flowing over the gates.

The tops of the gates have been modified with the addition of flow splitters and pipe vents at one corner. Since there is no freeboard on the gates, driftwood is blown over to accumulate downstream. It constitutes a fire hazard, and is removed when the pile becomes too large. The screw stem hoist superstructure could be removed, but due to the remote location, removal costs exceed salvage value. It is still in remarkably good condition.



Spillway, downstream showing structure and driftwood.

At the south end of the lake, there is the Victoria Control Structure, with 2 gates controlling waters discharging into Burnt Pond.



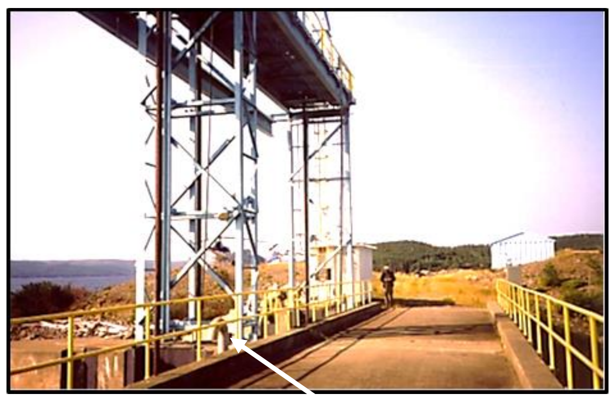
Inlet channel, control structure, flanking dykes and discharge channel at Victoria Reservoir.

Victoria Dam on Victoria Lake.

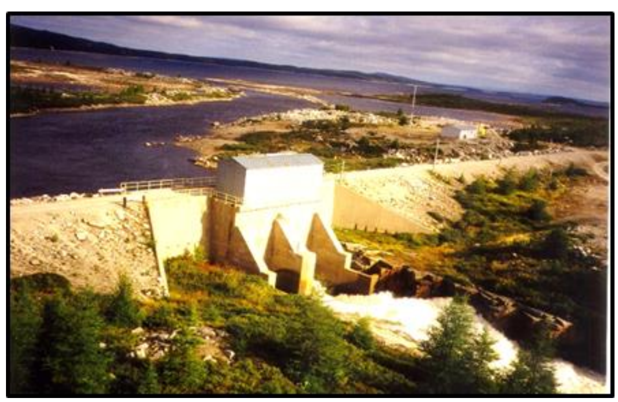
Victoria Spillway at Victoria Dam.

At Burnt Pond there is a spillway and a small camp for two operators who operate the up-country gates at the Victoria Control Structure, and Burnt Spillway. They also monitor the structures. The only access was by a road from Millertown on Red Indian Lake, far to the north. It was not plowed in winter, so the only access was by snowmobile or helicopter. But now, with the recent construction of the Granite plant, there is a road from the Granite powerplant, however it is not maintained in winter, so winter access is by snowmobile.

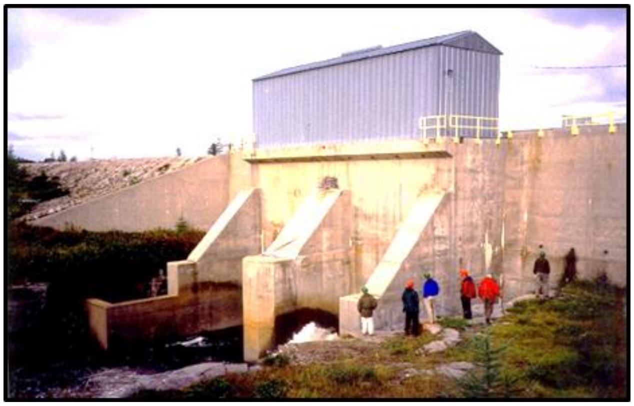
Looking down back of gates – note flow splitters.



Spillway deck. Note vent pipe, bottom left.

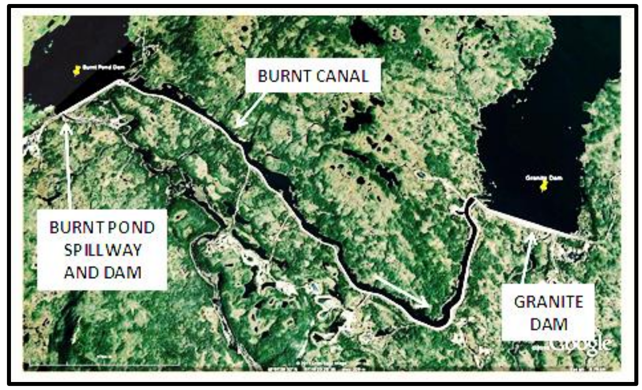


Victoria Control Structure.



Downstream view of Victoria Control Structure.

We would drop in for lunch at the camp, excellent soup, sandwiches and pies plus coffee, all prepared by the operators. There I had an interesting conversation with one of the helicopter pilots, “Scotty”. Scotty spoke with a broad Scottish accent, so I asked him where he was from, and he replied that he had been recruited by the last ship chartered by the Hudson Bay Company in 1973 to sail with new recruits from Orkney to Hudson’s Bay to work as clerks to their store managers. Almost all the Hudson’s Bay staff was recruited there since 1750 due to their knowledge of arithmetic and familiarity with severe weather. He had signed on for 5 years at the age of 18, and was apprenticed to a factor at Moose Factory in Northern Ontario. He had plenty of time on his hands, so offered to help a helicopter pilot with loading his supplies for nearby mining camps. On his second summer, he helped again, and the pilot offered to show him the basics on how to fly the helicopter. Scotty liked this far more than clerking at the store, so he saved all his money, and on finishing his 5-year stint, successfully enrolled in a helicopter school in Newfoundland, based on a strong recommendation from the pilot, obtaining his license a year later, and a job in Newfoundland with Canadian Helicopters - quite a story.



Burnt Pond structures.

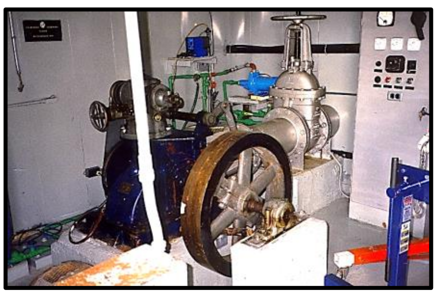
View of Burnt camp from spillway superstructure.

Two views of Burnt pond spillway.

Compensation flows have to be passed by the spillway. A mini hydro plant with a horizontal axis Banki (cross-flow) turbine was installed to power and heat the camp using the compensation water when it was built in 1966. However, it proved difficult to maintain, so it was abandoned in favor of two diesels. I tried to interest Hydro in installing a modern mini-hydro plant, since there are now so many options for the equipment, but don't know if the idea is being pursued.

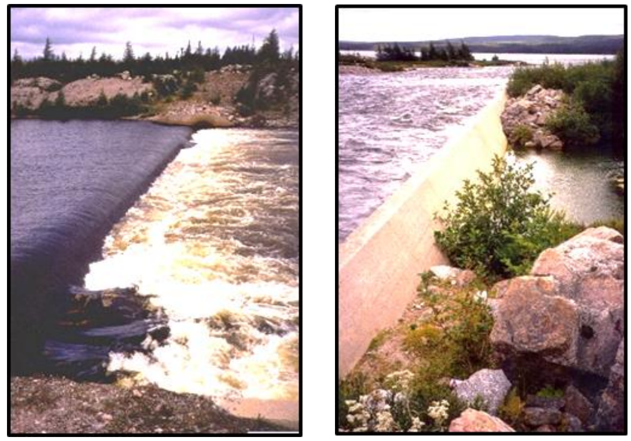
Diesel house and fuel tanks at Burnt Camp.

Abandoned micro-hydro plant.



At the eastern end of Burnt Pond, there is a long canal to Granite Lake. There is a small weir at the end of the canal to maintain flow depth to promote an ice cover and eliminate the formation of frazil ice. The canal discharges at the northern end of the diversion dam at Granite Lake, which directs the flow eastwards towards the Granite Canal which discharges into Meelpaeg Reservoir. The canal is excavated through sandstone rock, which weathers and falls into the canal resulting in considerable maintenance to remove the rock.

There are several small dykes around Granite Lake, but we only flew over them to check their general condition. Most were freeboard dykes, but one was a small spillway where we would occasionally land to inspect the structure.



Burnt canal weir and wing wall.

Stoplogs stored at Burnt spillway.

Granite Dam.

Aerial view of side dam on Granite Lake.

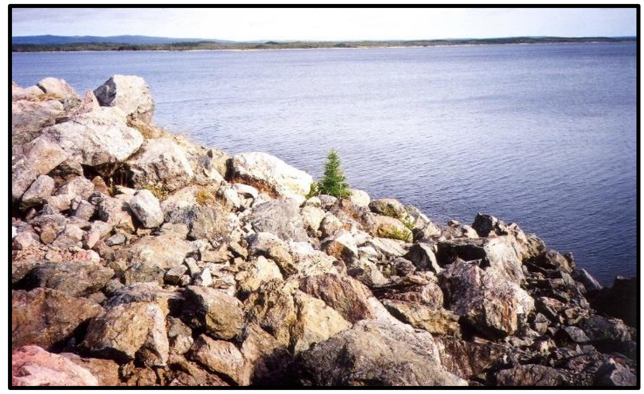
Inspecting weir spillway on Granite Lake.

Fisheries structure before renovation.

Fisheries structure after renovation.

Maelpaeg Lake originally discharged down the Grey River southwards to emerge at the village of Grey River on the south coast of Newfoundland. The flow is diverted eastwards by the Grey River Dam, locally known at Pudops Dam. It is a large dam with a crest length of 1.6km, and a long exposure to winds from the north-east across Maelpaeg Reservoir. This has resulted in some deterioration of the rip-rap.

There is a nearby fish compensation structure to pass flows downstream on Grey River. It was being renovated during our inspections, by Newfoundland Hydro.

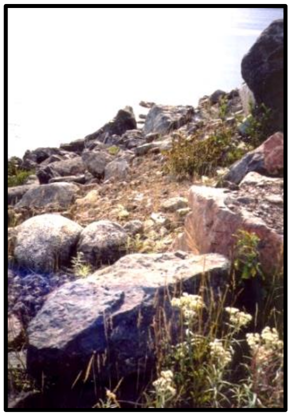


Large rocks and large fetch on Pudops Dam.

Pudops Dam was so large, that it was given a thorough inspection. I would walk along the crest inspecting the rip-rap, while the rest of the team walked along the toe looking for seepage, and flow at a measuring weir. On the eastern end of Meelpaeg Reservoir there is the Ebbegunbaeg flow control structure releasing water into the Upper Salmon Reservoir. During one inspection, some roof panels were being replaced, so I managed to photograph the interior.

Downstream face of Pudops Dam.

During our inspection in 2000, I mentioned to the operators at the Burnt camp, that they should be on the lookout for driftwood blown onto the crest or over a dam after a severe windstorm. A couple of years later, I found some large logs on the crest of the Victoria Spillway dam, and started to look for more on the downstream face, since the size of the logs indicated that smaller branches would have been blown further over. But I could not find any, so I asked the operators if they had cleared off the driftwood. They were grinning from ear to ear, having placed the logs on the crest to see my reaction.



Gap-graded rip-rap on dam.

Pudops dam from left abutment. Note driftwood level.

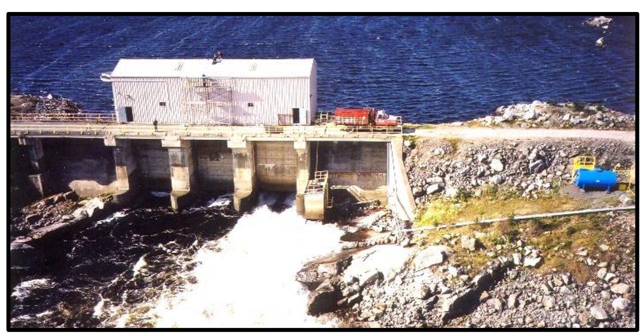
They had played the same trick on one of the Hydro engineers when he dropped in during a routine inspection, and decided to leave the logs in place for some more fun. Just goes to show what you have to do when working in such an isolated environment!

Based on our experience with the Orma Lake dykes at Churchill, I suspect that the rip-rap needs some upgrading. However, there is no evidence of driftwood overtopping the dam, hence the freeboard appears to be adequate.

I was surprised at the extent of channel excavations at almost all the control structures. These are clearly seen on the satellite images. There is even some excavation within the Upper Salmon reservoir, as shown in the Google image on the next page.

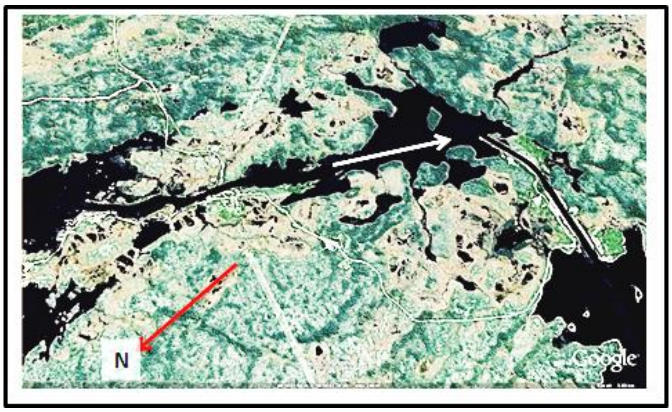
View of missing rip-rap at nose on Pudops Dam.

The interior walls of the flow control structure were covered with a fabric water vapor barrier over the insulation. However, it was easy to accidentally rip or punch holes. The damage was patched with duct tape, and looked quite unsightly. I have recently seen similar installations where a powerhouse has the same type of fabric covered walls, more economic, but requiring more upkeep. I suspect the incremental cost of a good aluminum or galvanized steel sheeting would be minimal and well worth the extra expense.



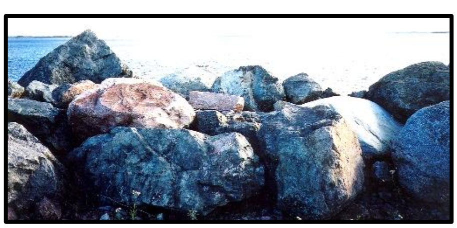
Flow control structure.

Ebbegunbaeg dykes, flow control structure and discharge channel.



Channel excavations between Great Burnt Pond and Coldspring Pond, now part of Salmon Reservoir.

The facility has three gates 3.66m high by 6.1m wide, an unusual size, being wider than high. The normal ratio is to have a gate about 50% higher than wide to avoid jamming when one side is lifted more than the other. However, this must have been anticipated, since the hoists are screw stem all enclosed within a heated building, with a single shaft powering both screws on each gate, thus avoiding gate jamming.



Very large rip-rap on Pudops dam

Flow control structure from right abutment. Note monorail for hoist turning around outside building.

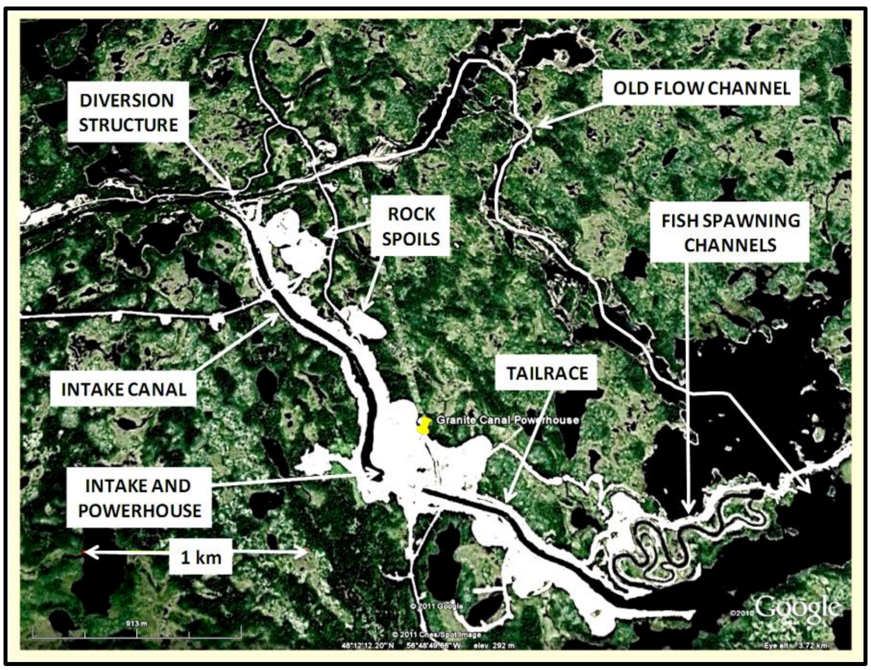
Flow control structure interior. Some roof panels removed for maintenance access.

In this description of the "up country" structures, the new development at Granite Canal has been passed by. The facility will be described in the next chapter.

Discharge channel from control structure.

126. GRANITE CANAL 2000-5

In 1999, I was asked by Shawmont to be an advisor on their Granite design work, undertaken in association with SNC. I accepted and worked on the project layout. The intake at Granite Canal was an interesting experience. The structure was being built on a design-build contract. Unfortunately, they would not follow my advice, and the new immigrant engineer from southern Europe, with no Canadian cold climate experience thought he knew better. The design he developed was not functional, but the contractor would not change it, so I resigned from the assignment, without submitting an invoice.

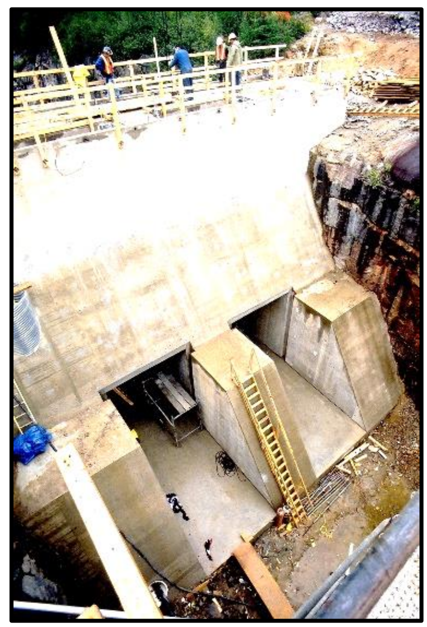


Granite Canal layout.

When I was asked by Newfoundland Hydro to join the Dyke Board and review the designs being proposed for Granite Canal, I had to inform them of my previous involvement. I was told that they had heard of my intake suggestions, and that was one of the reasons for wanting me on the board. However, due to the nature of the contract, Hydro decided that it would be better to accept the deficient design rather than provide the contractor with an opportunity to claim extras.

Old Granite canal.

Below - Canal diversion structure.



On our first inspection of the structures at Granite, during construction, I pointed out the intake deficiencies and included the comments in our report. However, Hydro asked us to remove the intake comments after they had read them, and I agreed, reasoning that they now knew what needed fixing. Imagine my surprise to arrive at the site a year later to find the completed intake, with no changes. I asked the hydro vice-president of operations who was with us at the time to come into the intake, and I pointed out all the deficiencies, such as electric heaters around the walls, with fixed open louvers above, rendering the heaters totally ineffective, and an open air vent to the penstock which allowed someone to throw a rock into the pipe, likely damaging the turbine. After the contract work was completed, Hydro revised the intake by changing the louvers to flaps and enclosing the air vent to prevent rocks entering the penstock.

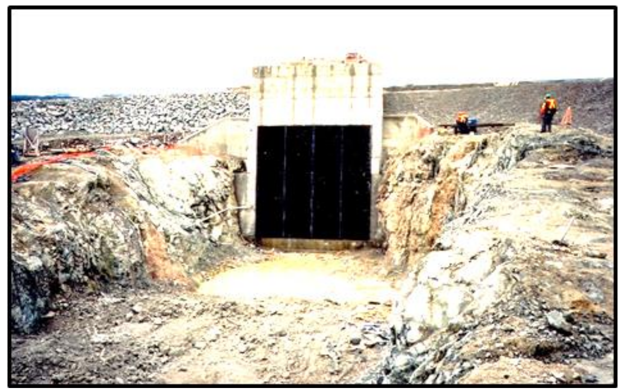
Completed diversion structure. Gates 3m wide, 4m high.

1.9km long, 16m wide intake canal.

5.7m Penstock down to the powerhouse.

The powerhouse is within a deep rock excavation, so deep that the roof is only a couple of meters above the surrounding rock. In my review for the contractor, I had suggested a much higher structure with the repair bay floor at about the surrounding rock level, with the single generator down in a deep silo, to reduce rock excavation and move the powerhouse access road out of a deep excavation beside the tailrace, which will be engulfed in snow blowing off the rock above during winter.

However, it was not accepted, and I suspect the reason was a slightly higher cost. It was an excellent illustration of the deficiencies associated with design-build contracts wherein only the construction cost is analyzed, instead of the total life-cycle cost.

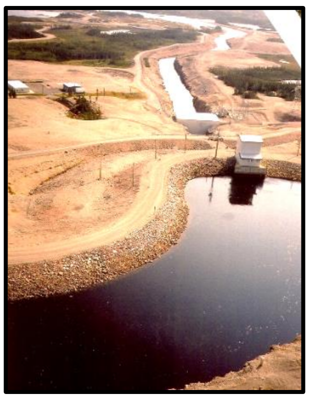


Intake structure has polyethylene trashracks.

Penstock pipe from intake.

With the powerhouse roof only about 2m above ground level, it is routinely used by snowmobilers in winter as a ski jump, by driving over the surrounding fence and roof!

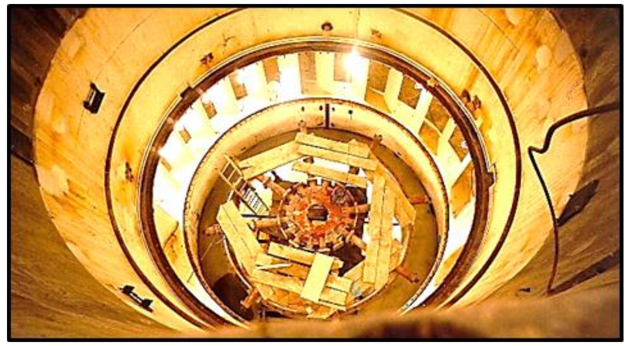
Powerhouse, upstream view. Note roof level.



Aerial view of intake, powerhouse and tailrace channel.

Aerial view of 45,000m² fish spawning channel.

Installing 45MVA, 13.8kV generator. Speed 180rpm.



Looking down at 41.5MW Kaplan turbine pit at guide vanes.

Powerhouse generator floor.

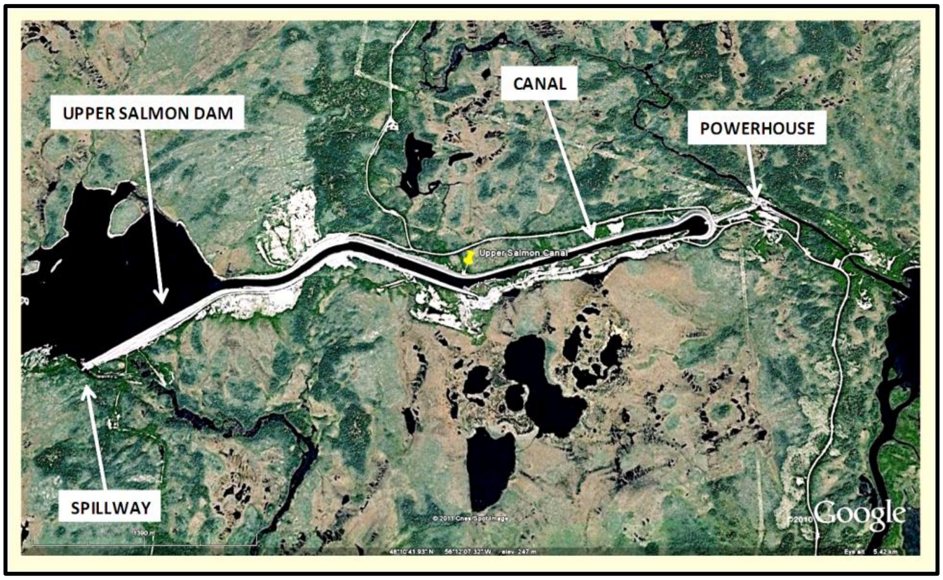
There is a large fish spawning area near the tailrace outlet. Fishing is allowed, and the channel is extremely productive. Altogether, a very successful development.

127. UPPER SALMON – 2000-5

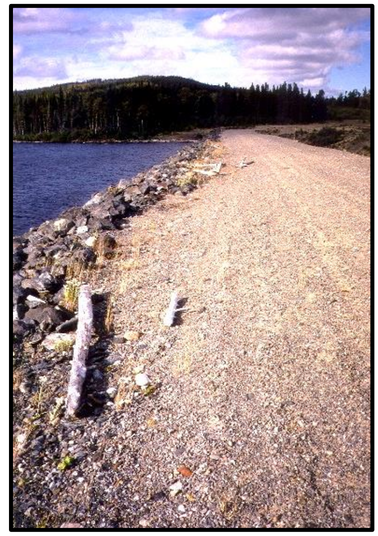
The Upper Salmon development started operating in January, 1983 with a single vertical axis Francis turbine producing 84MW under 51m of head.

At the north end of the Upper Salmon Reservoir there is a spillway constructed on Great Burnt Lake, and at the south end of the lake, the outlet was closed with the Upper Salmon Dam as part of the Bay d'Espoir development in 1968.

Layout showing canal and powerhouse.



Below - West Salmon Dam. Note driftwood on crest and slope.



Aerial view of West Salmon Spillway.

The 3km long canal ends in a small forebay at the intake. There is a short buried penstock to the powerhouse, and a tailrace to Godaleich Pond which discharges into Round Pond.

The project was well executed, but in an attempt to save excavation around a hill on the canal route, the canal side slope was increased by ¼:1. This was just a fraction too steep, and over about 20 years, the hillside slowly slipped and caused cracks in the road beside the canal at the bottom of the hillside. They were being monitored, but the Dyke Board eventually suggested stabilizing the slope before a landslide blocked the canal.

Note mapwork cracking on concrete anchor indicating AAR. View towards intake.

The Dyke Board solution was to flatten the slope below the hillside to the same grade as the slopes in the rest of the canal. This was accomplished by cutting into the top half and placing gravel covered with rip-rap on the lower half. This reduced the flow area slightly, but hydraulic calculations indicated that the increased friction loss would be negligible. The work was quite demanding, since the material had to be placed below water in a very precise area. This was solved by the contractor using a backhoe equipped with a computer and a GPS system which showed the exact position of the bucket on a screen in relation to the canal section.

North Salmon Spillway.

Salmon Canal – slope by hill being flattened.

Loading rock onto barge.

Dumping rock rip-rap to flatten slope. Backhoe equipped with GPS bucket positioning system.

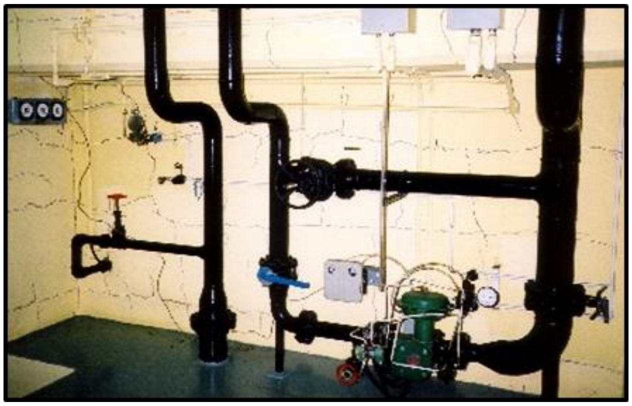
Aerial view intake area.

Intake structure

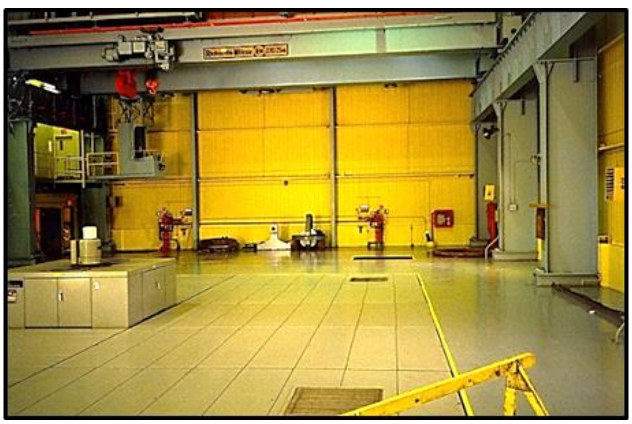
Unfortunately, there is "concrete cancer" or AAR present in the powerhouse structure. This is now affecting the unit alignment, but with only one unit, it is hoped that there is adequate room for expansion around the unit.

With Trevor Arbuckle at intake hoist house. Note – hoists for intake gate (right) and bulkhead gate, left. Birds fly inn through the hoist rope opening.

Birds can enter the heated intake hoist structure through the gap provided for the hoist rope. They cause quite a mess with their droppings, which have to be cleaned out regularly. While we were there, there was on bird flying around trying to escape.



Powerhouse turbine floor, mapwork cracking outlined with pen.



Upper Salmon powerhouse. Generator floor. Note size of generator casing outlined with steel angle painted yellow.

Upper Salmon powerhouse.

128. CHAUDIERE – 2000

Tony Tung from CANMET convened a meeting of the Technical Advisory Board in Ottawa, and the next day we all toured the Chaudiere plant near Quebec City in the afternoon, and then we motored on to Riviere du Loup where we inspected two more small hydro plants.

View of Chaudiere Falls.

The 24MW Chaudiere plant includes two horizontal axis Kaplan turbines with the generators tucked under the penstocks to minimize the footprint. The intake includes hydraulic hoists on the gates, to minimize the external visual effect within the park. A small trashrack cleaner travels on the deck. There was no bird problem at the intake, since, with hydraulic hoists at deck level, there are no openings for bird access.

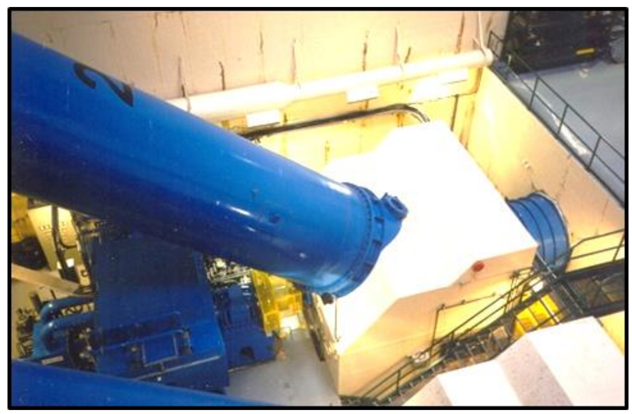
The powerhouse has two large skylights above the units and access to the flat powerhouse concrete roof. Visitors to the park can look down through the skylights to see all the equipment within the powerhouse. A nearby electronic notice board shows current power production and other data. It is a popular destination for local school trips.

View of weir from intake deck.

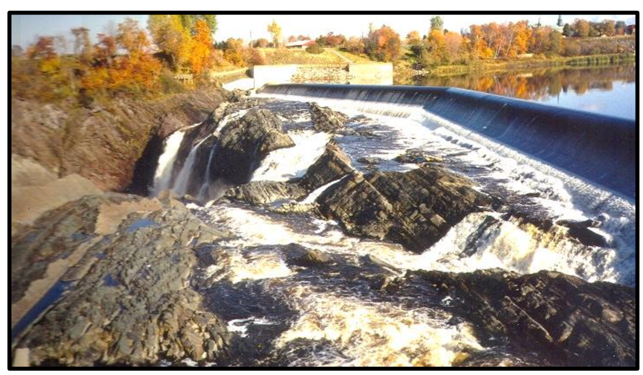
View of intake.

Intake trashrack cleaner.

View of intake hoist house interior.



Below - Powerhouse interior. Note location of generators below penstock. However, access for repairs is difficult.



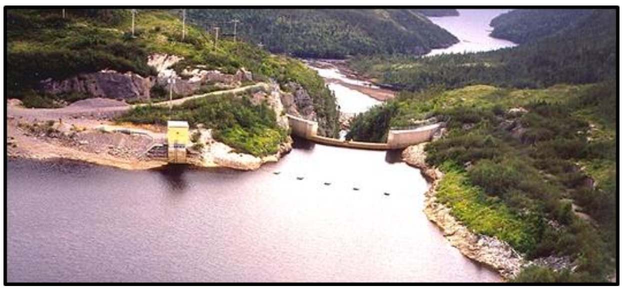
Chaudiere Falls.

The developed head is 35m, and the total cost was $45M in 1999.

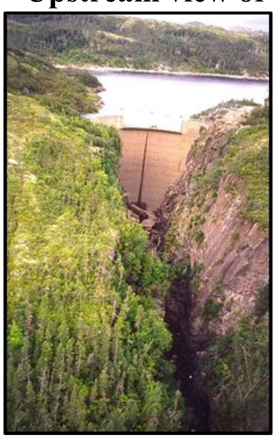
I was quite impressed with the attention to minimizing the visual details, which included buried penstocks and a partly buried powerhouse.

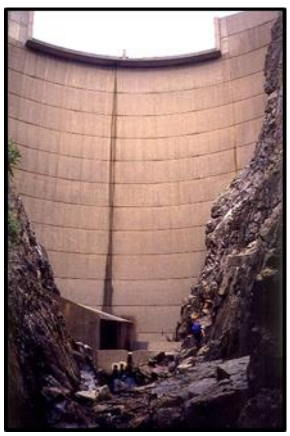
129. PARADISE – 2000-5

Every second year, the Dyke Board would inspect the Paradise Dam. It was difficult work since when climbing over the very slippery rocks in the canyon, it was very easy to fall. Fortunately, on our first inspection in 2000, the operators had installed a taut wire rope about 2m above the rocks which greatly eased part of the rock traverse.

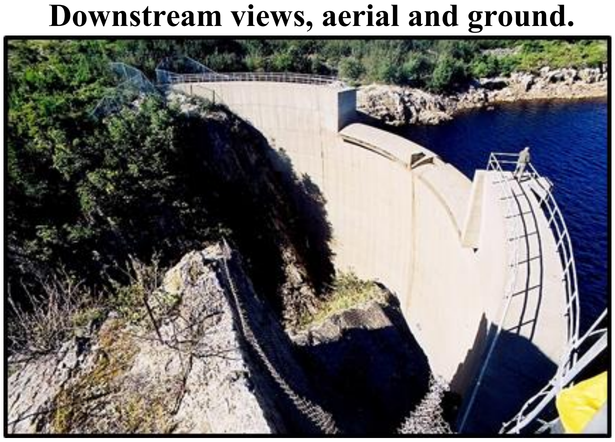


Upstream view of dam and intake on left.



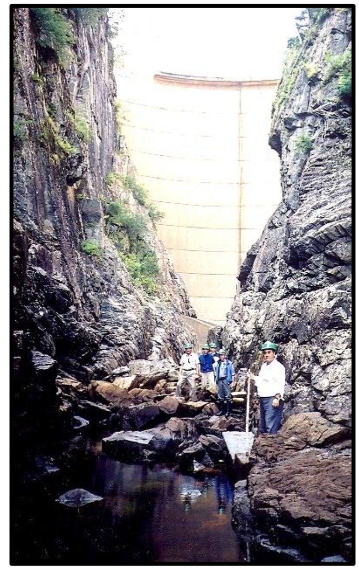


Downstream views, aerial and ground.



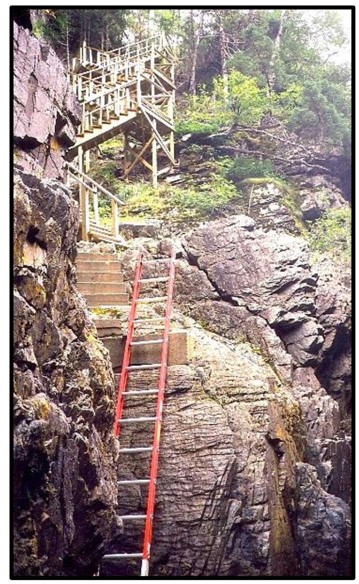
View from left abutment.

Inspection team in canyon.



The flight to Paradise was long, over an hour in the helicopters, so we would have a contest as to which helicopter crew could spot the most moose. All sightings had to be confirmed by another passenger.

Stairs and ladder down into canyon.



One time we were caught by fog on the return trip. Scotty, one of the pilots elected to travel north along the coast which seemed more clear and then overland to Camp Boggy hoping he could find a way around the fog. However, he had to land and wait for it to clear. Our young and bolder pilot elected to fly slowly just above ground level through the fog, using satellite navigation to reach Camp Boggy, which he managed to do in about 90 minutes. I was sitting in the front with the pilot, so had a clear view of the terrain – the occasional stunted tree and mostly muskeg looming out of the fog – but the pilot remembered the route from previous flights and would often change direction on recognizing a brook or larger tree – quite an experience! About two hours after we arrived at Boggy, Scotty landed. What is the saying about pilots – many old pilots, but no old bold pilots!

2004. Left – Board on stairway out of canyon.

Jim Gordon, Ray Benson, Tony Tawil and Kent Murphy.

130. GARDINER DAM – 2000

The CDA fall meeting was held at the end of September in Regina, Saskatchewan. I arrived a day late due to a meeting with a client, so I missed the conducted tour of the Gardiner Dam and Coteau Creek Powerhouse. I reasoned that if I met an engineer from SaskPower, I would ask if I could visit the plant after the conference ended, since the plant had a couple of unique features – a "vernier stabilizer" on the turbine, and a couple of "alignment tanks" in the powerhouse substructure. This was arranged, and I saw that Bruce Clarida from Great Lakes Power was in the same predicament, so we joined forces.

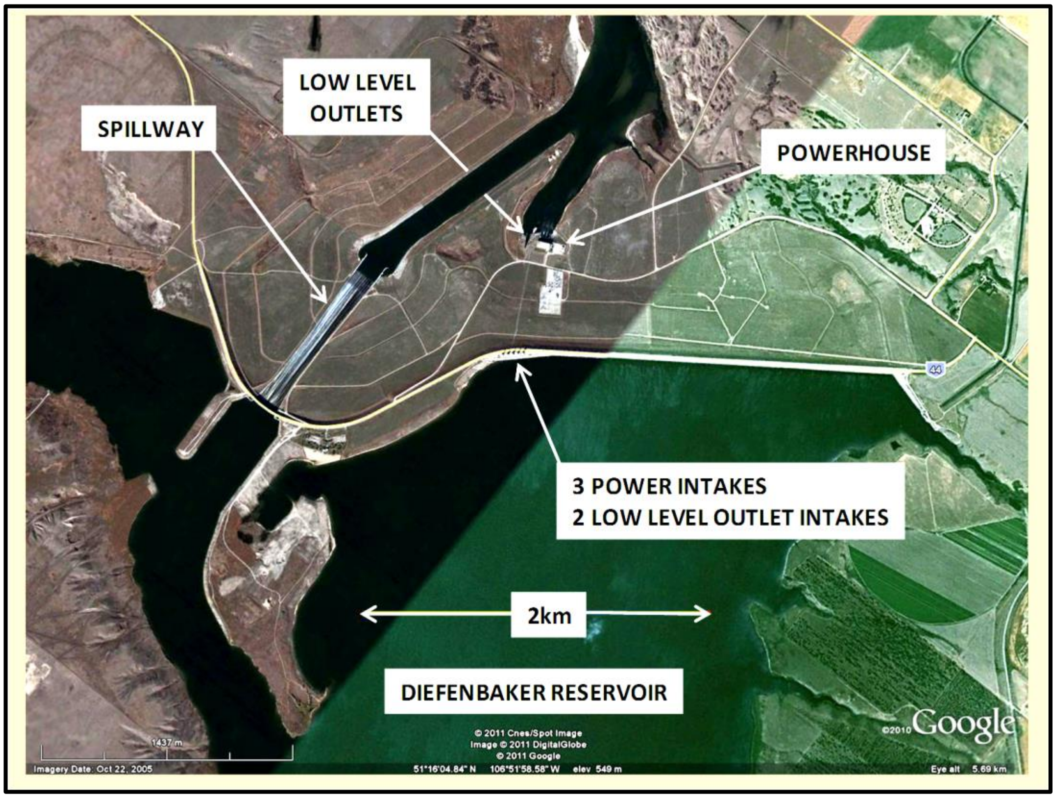
We rented a car and drove out in the early morning, having previously asked directions for the quickest route to the plant. We were told to drive out on the Trans-Canada as far as Davidson, and then take highway 44 west to the dam. It proved to be a very interesting trip!

A lonely farm on the horizon.

We reached Davidson, which proved to be a lone gas station beside the highway. We turned onto a wide gravel road, but within about 200m it narrowed down to two lanes barely adequate for two passing cars. The road undulated gently, so we could not see far ahead. After a short while, we noticed that there were no hydro lines, no gates to farms, no farm houses and no cell phone reception! The country was absolutely deserted, and we were witnessing the effect of depopulation.

Abandoned sheds in a field.

The government could no longer maintain the paved side roads, so they had been ground up and turned to gravel. Family farms were no longer viable, so they were being sold to large agri-businesses. The fields were now being cultivated by extremely large machines and combines, all operated automatically (no driver, just on cruise control!) with satellite navigation. If they needed repair, a mechanic was flown out by helicopter, who then called back to home base by radio when he finished work!



Gardiner Dam layout.

Every so often we would see an abandoned farm on the horizon. The farm houses can now be purchased for a pittance as duck hunting retreats, and many Americans have done so. Occasionally we would pass an agribusiness base, surrounded with large silos for storage. We were told all this by an engineer when we arrived at the powerplant.

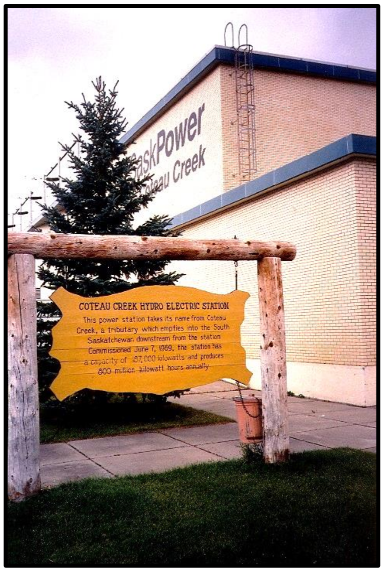
Ducks and more ducks in slews.

We had a good tour of the powerhouse, but found that the operators had no knowledge of either the stabilizer or the tanks! The stabilizer was simply a small relief valve with a capacity equal to only 10% of the full turbine flow, used to assist in synchronizing since the governor times were very slow due to the long penstocks.

The powerplant has three units, each producing 62 MW. As for the tanks, they had been used to maintain the powerhouse in a shaft-vertical position as the ground settled under the load from the adjacent dam, but are no longer needed as settlement had now ceased. The Gardiner Dam took 11 year to build between 1959 and 1967. When it was built, it was the largest dam by volume in the world, with 65,000,000m^3 of fill. It is founded on relatively soft clay-till which rebounds when material is excavated and settles under load. This required very flat slopes on the dam, which range up to 32:1 at the bottom, making the dam look more like a natural topographic feature instead of a dam.

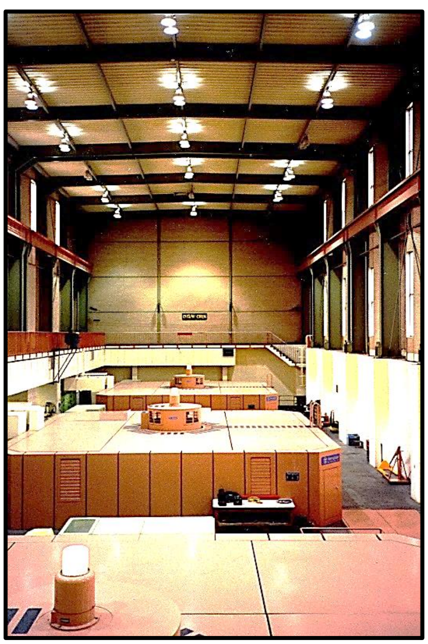
Agribusiness compound.

View of Coteau Creek powerhouse from dam crest.



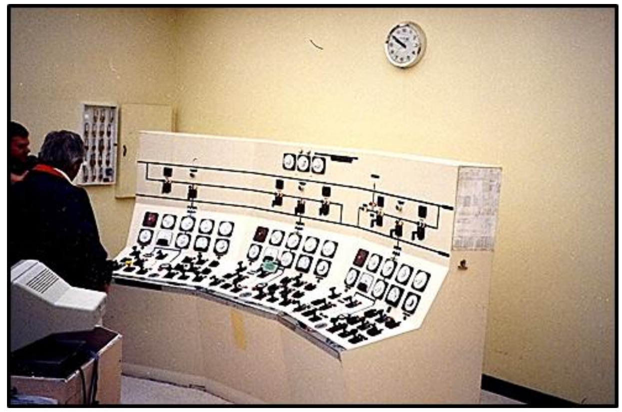
Powerplant entrance.

We then went up to the intake and had a look at the towers housing the gates. They were quite unique, and a structure, designed more for visual impact than practical use. I asked the operator if they had replaced the wire ropes on the hoists, since they were over 30 years old.

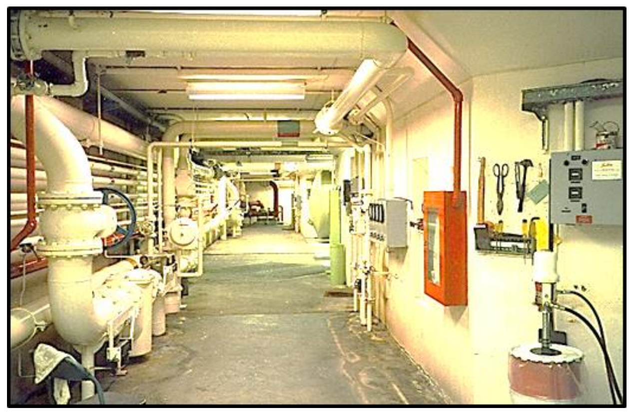


View of powerhouse generator floor.

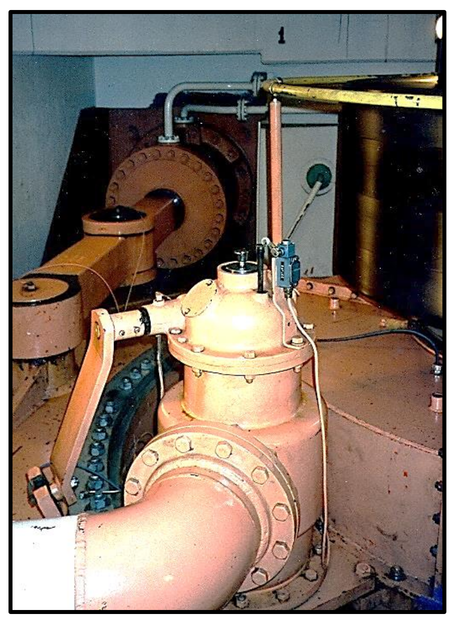
He replied that they had just been replaced. The technician came out to look at the towers with the gates about 65m down below, to see what equipment was required. When he returned the next day, he was surprised to see that the wire rope had broken overnight, and was now lying in a tangle on top of the gate!



Analogue control center for three units.



Piping gallery at turbine floor level.



Turbine pit with servomotor and vernier stabilizer operated by turbine wicket gate ring.

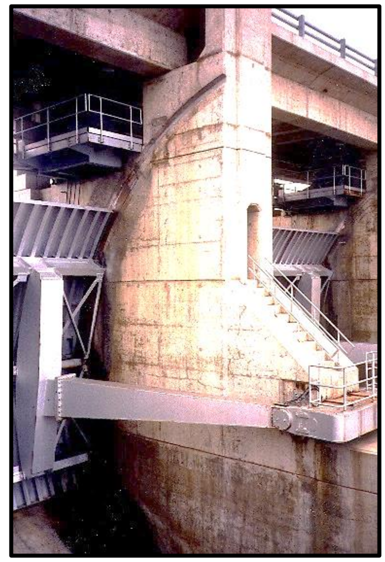
We had a look down the low level outlet gate shaft and enquired whether they had ever been operated. They had not, and were only expected to be used when the reservoir was below the Tainter gate sills and the powerplant was not operational. This situation had never occurred.

Turbine draft tube door with penstock dewatering by-pass pipe above.

After the intakes, we went over to the spillway. It has the largest number of Tainter gates on any dam in Canada. I advised the operator of the failure of the Folsom Dam Tainter gate due to freezing of the bearings, and asked if the gates were ever used. He said that he had never seen them open. I suggested that they should have the design checked and their operating procedure reviewed. About 2 years later I met an engineer from Acres, and he thanked me for the Gardiner suggestion, but I did not know what he was referring to. He then told me that SaskWater had asked them to check the design, and they found one gate member that needed some strengthening.

Intake gate towers.

Before departing, we invited the operator for lunch, but he declined. However he told us about a good coffee shop in Lorburn, and warned us to fill up with gas, since gas stations were scarce. We left the plant and drove over to Lorburn for a late lunch, but forgot about the gas. We then decided to drive back on highway 42 through Moose Jaw to Regina to see a bit more of the countryside.

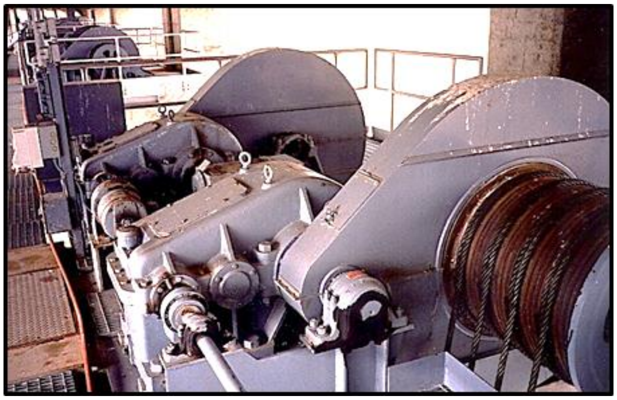


Tainter gate pier. Note stairs within pier.

Spillway with Tainter gates.

Monorail hoist for Tainter gate stoplogs.

We passed the small hamlets of Elbow and Eyebrow, all with signs on the side of the road saying “No services”. We noticed that our gas tank was now near empty, so we were worried about finding an open gas station, and resolved to drive into the next hamlet without the "No services" sign.



Tainter gate wire rope hoist. In excellent condition.

Tainter gate and arm to bearing support.

View of long spillway chute.

We found this at Brownlee, and turned off the gravel road, and drove down the street past mostly shuttered and abandoned homes, becoming more worried that there would be no service station. Turning a corner, we found a small store with a couple of cars parked outside. We entered bought a couple of soft drinks, and asked about a gas station. The clerk said "I think old Mary round the corner may still be open". We thanked him, and drove round to find an ancient gas station with one old hand pump tilted well off vertical. It had the two glass tanks on top, must have been at least 80 years old!

View looking down dam slope at spillway chute. Note extremely flat downstream slope on dam.

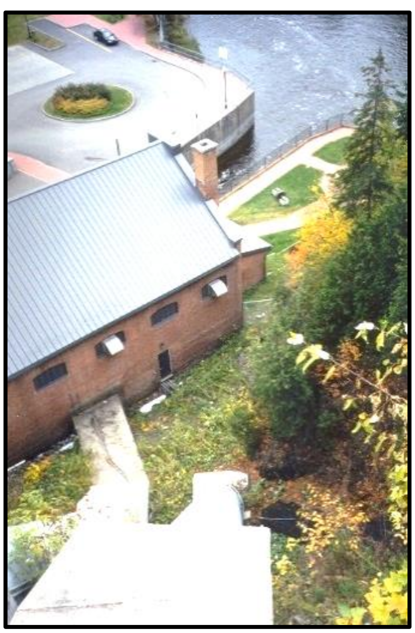
However, there were no signs of any attendant. We entered the log building and found Mary sound asleep in a rocking chair. Bruce tapped on the counter, and Mary woke up. We asked about gas, and she replied "I think I have one tankful left, you will be my last customers. After this I am closing down!" We pumped the gas, paid and left, as we saw Mary check the gas tank with a dipstick and then attach a "No gas" sign to the pump. It was just another nail in the coffin for Brownlee; and when the little general store closes, another sign will be placed by the road.

The excursion was quite a dramatic lesson on the depopulation problem, and the effect of agribusiness on the province. Yes, a very interesting trip!

131. RIVIERE du LOUP - 2000

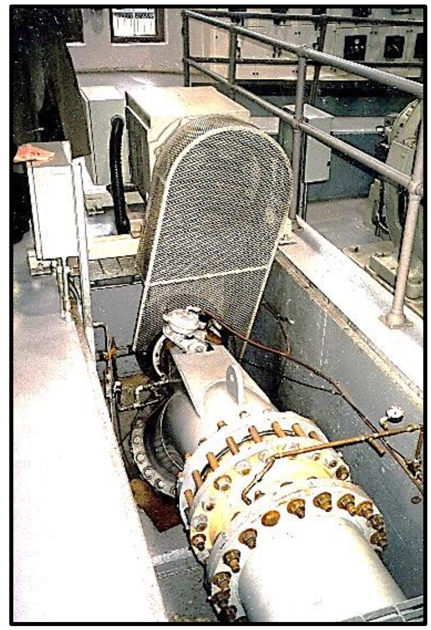
After looking at Chaudiere,(Chapter 128) we all drove up to look at two small plants in Riveire du Loup. Both were within the town and had been built early last century. We checked into the Hotel Universal near the highway and next day we drove over to the first plant at Riviere du Loup (RdL) and then the second plant, Hydro-Fraser (HF).

Riviere du Loupe powerplant locations



Looking down from dam onto RdL powerhouse.

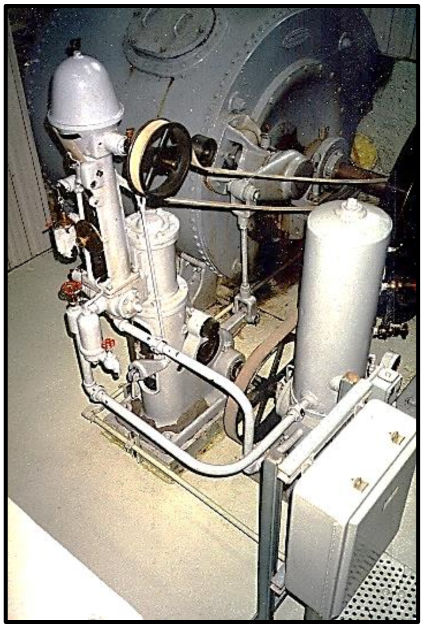
The RdL powerplant capacity is 2,400kW at 31m head in two horizontal Francis units and a micro-hydro propeller unit designed by Dr. Netch, a professor at Laval University in Quebec City. He had developed a tube turbine, and a prototype was installed in the powerhouse as a demonstration project partially funded by CANMET. It was a simple propeller installation with guide vanes but no wicket gates, intended to operate at full load all the time. The main attraction was the simplicity, and the small diameter of the runner, which was the same diameter as the inlet pipe.



Netch turbine.

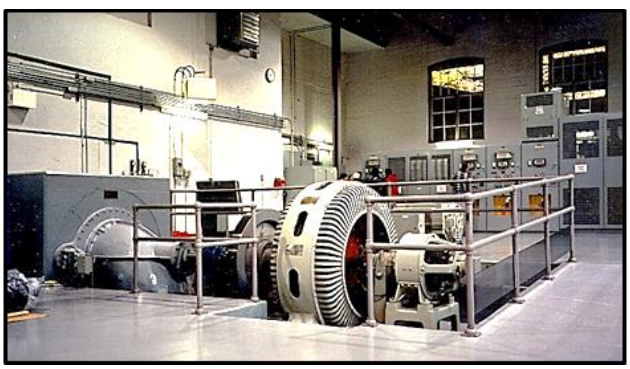
Concrete dam and spillway, Riviere du Loup.

The Riviere du Loup plant was refurbished in 1995 with new controls, re-wound generators and new runners. Every effort was made to preserve the scenic beauty of the area, with a park-like setting around the powerhouse.

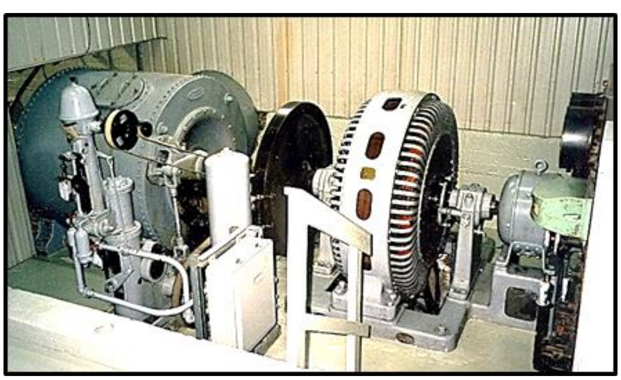


Governor for unit #2.

We then drove downstream to the Hydro-Fraser powerhouse where there are two units of 1,062kW capacity at 22.2m head and an ancient intake structure still equipped with rack and pinion gate hoists.

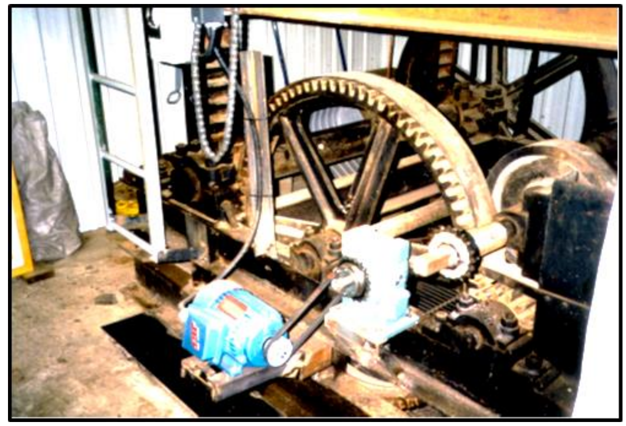


Horizontal Francis unit #1 at Riviere du Loup.



Horizontal Francis unit #2 at Riviere du Loup.

The dam was concrete structure with a canal off the left bank. The canal had a timber trashrack structure at the inlet. The plant started operation in 1917 It was refurbished in 1992 with new controls, runners and rewound generators.

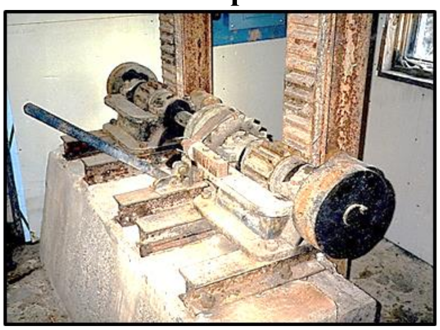


Motorized rack and pinion hoist at Riviere du Loup.

Hydro-Fraser spillway and canal intake structure.

Timber trachracks at entrance to intake channel.

Wood stave pipe to Hydro-Fraser powerhouse.



Ancient 1917 but still serviceable rack and pinion intake gate hoist.

Intake channel – intake gates open.

Hydro-Fraser powerhouse with 2-1,062kW units.

132. DORAN-TAYLOR - 2000

On my second visit to Elsie Dam, Pentti Sjoman was at the site, and suggested I ride back with him instead of flying back to Vancouver. We could then look at the Doran-Taylor plant beside Highway 4, about 40km west of Port Alberni. He could then drive over to Qualicum Beach where my brother is retired in a condo.

View of buried penstock grade – very rugged.

The plant commenced operating in 1996, has a capacity of 5.3Mw in a single horizontal shaft, 2-nozzle impulse turbine operating under a gross head of 652m. The intake is on Doran Lake which I did not see since the road was closed. The 24 inch steel penstock is buried on a very rugged grade notched into the mountainside. When I saw the 1.9km long penstock grade, I realized that they must have had considerable difficulty excavating and placing the pipe.

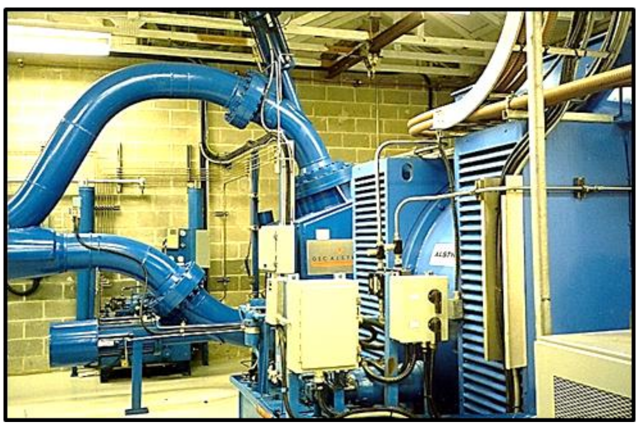
Doran-Taylor powerhouse.

There was no overhead powerhouse crane and no removable roof hatches, making normal servicing of the unit somewhat difficult.

However, due to the small size of the equipment, I suspect that it could be easily removed if major repairs were required. The plant is remote controlled and operates unattended. The turbine inlet valve has an unusual position with a vertical axis.

Spherical turbine inlet valve.

2-jet impulse unit. Design flow is $1.155m^3$ s. Alsthom generator, 5,900kW.

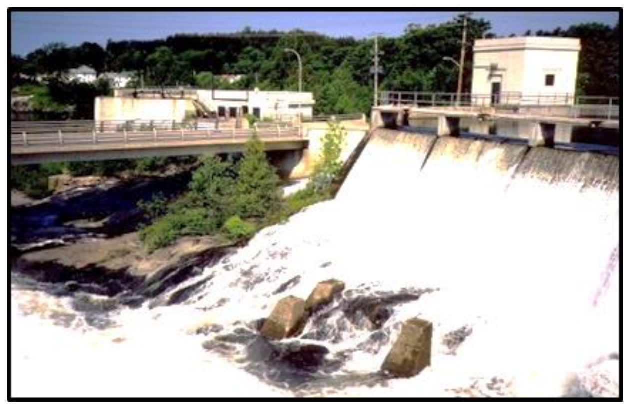


Unit control panels.

133. PARRY SOUND – 2001

In spring, I had a call from Clary Gatien, (see Chapter 73) asking me to help with an assessment of the cost of installing a new unit at the Parry Sound development in central Ontario. The development had been built in 1920, and the two old turbines had now reached the end of their service life.

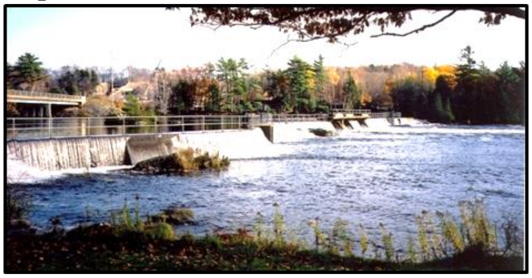
There were two concepts, either rehabilitate the intake, and build a new penstock to a new powerhouse located besides the old building, which could be converted into a museum. The other option was to build a new intake, slightly longer penstock and a new powerhouse.



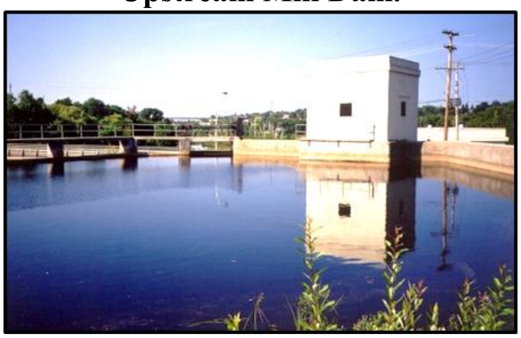
Existing intake on right and powerhouse. Spring flood.

Old intake gate and air vent.

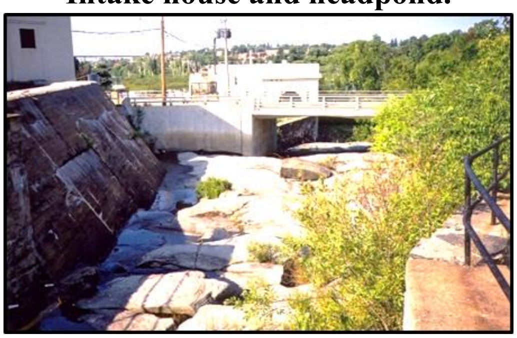
However, the project proved to be too difficult. It was in the middle of the town, and there were too many environmental issues such as noise and dust during construction, and interruption of local traffic, since the penstock would cross underneath a busy street. It was just another lesson on the difficulties of rehabilitating old developments.



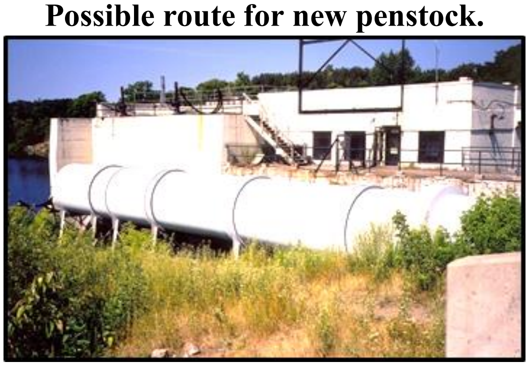
Upstream Mill Dam.



Intake house and headpond.



Possible route for new penstock.



Penstock to powerhouse.

However, the 1.2MW old plant was demolished and a new 3.2MW powerplant built by Bracebridge Generation was commissioned in 2018 at a cost of $17M, or $5.3M/kW.

View of new powerhouse.

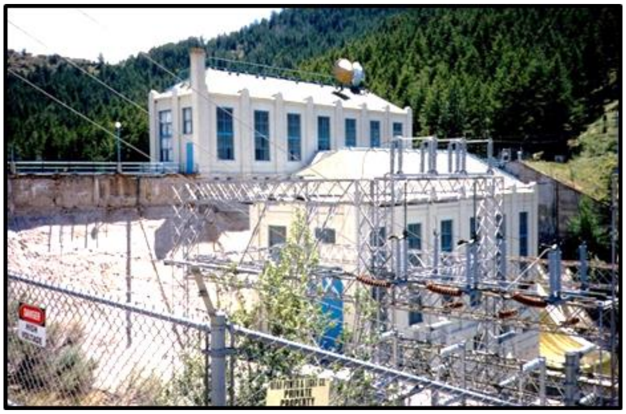
Source – Water Canada.

134. BEAR RIVER PLANTS 2001

The 2001 the HydroVision conference was held in Salt Lake City. The organizers had managed to reserve the new convention center and the adjacent Grand America Hotel for the event. The hotel had been built, at a cost of over $1B, specifically for the 2002 winter Olympics. It was by far the most luxurious hotel I have ever seen.

Grand America Hotel room – Source, hotel website.

After the convention there was a tour of the old hydro plants on the nearby Bear River. I went on the tour more for the scenery than the plants. The plants had not been renovated and I suspect that the low power rates from western coal mine-mouth thermal plants made hydro renovations uneconomic.



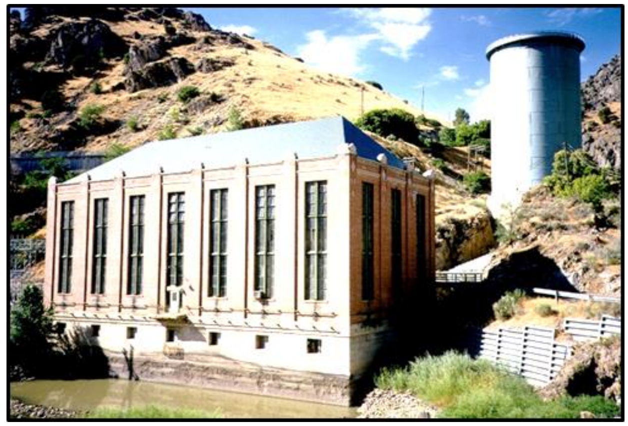
Soda – 14MW, 31m head built in 1925.

Old Soda units, never renovated.

Not much to see in the plants, but the scenery made the whole trip worthwhile!

Cutler powerhouse interior.

The developments indicated the difficulty of arranging tours of modern powerplants in the USA. None have been built recently, hence tours always visit old plants, not very informative for young hydro engineers.



Cutler, 30MW, 33m head, built in 1927.

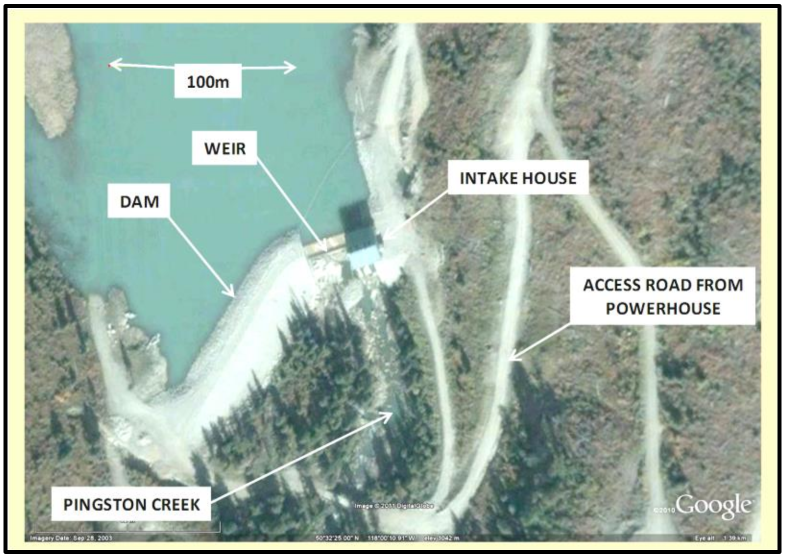
135. PINGSTON CREEK – 2001

In July, I had a call from Colin Clark, President of Great Lakes Power. They were interested in the Pingston Creek development being built about 55km south of Revelstoke in British Columbia. However, they did not want to alert the developer of their interest and were looking for some way to quietly undertake a due diligence inspection. I told Colin that I knew the consultant and could probably obtain an invitation to look at the project if I was passing through the area as a tourist. This was done, and I flew out to Kamloops, rented a car and drove over to Revelstoke.

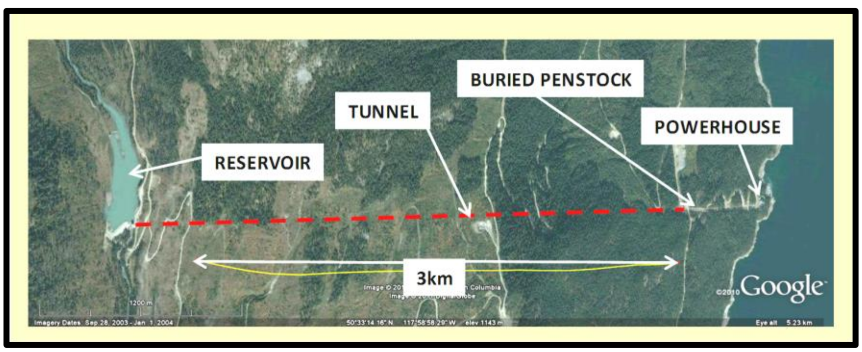
From the hotel in Revelstoke, I phoned the site and spoke to Jeff Drain, their Project Manager. Jeff was very helpful, and mentioned that he lived in Revelstoke and could drive me to the site the next day. I asked if he could provide some project drawings so that I could familiarize myself with the project before looking at the work in progress, and Jeff brought a full set of half-size drawings to the hotel in the evening.

The project was a classic high head development with a small reservoir, an embankment dam, weir spillway and fully enclosed intake structure to a

2.13km long low-pressure tunnel to a vertical bore down to the 1.43km long high pressure tunnel leading to about 640m of buried penstock to the powerhouse on the shore of Upper Arrow Lake, just South of the Shelter Bay ferry crossing. Developed head is a good 591m. Capacity is 30MW.



Pingston Creek project layout.



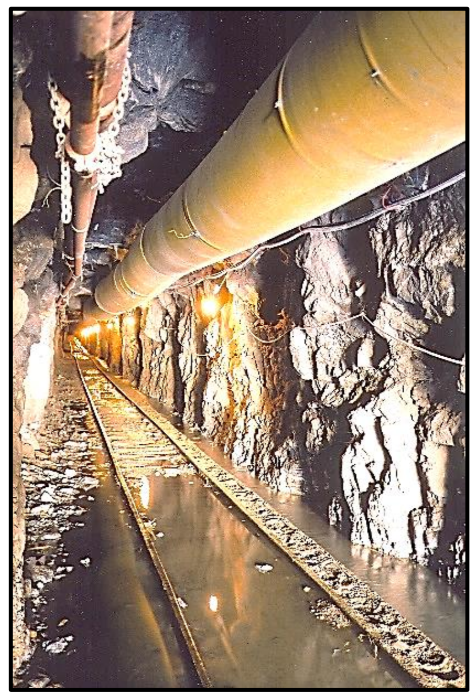
Pingston Creek Dam area layout.

← Battery locomotive hauling rock out of tunnel.

I spent a few hours going over the construction drawings, and found an error in the reinforcing of the wing walls at the spillway. This presented me with a bit of a dilemma, since Colin's instructions were not to take any notes and to just act as a casual tourist!

Next day we had an early start, and Jeff gave me an excellent tour of the site. We started at the lower tunnel where the contractor was struggling through a fault zone filled with soft "gouge" (grey clay) material which could be plucked from the rock wall by hand!

Inside tunnel.



The tunnels are about the smallest possible being only 2.4m wide by 2.7m high. The lower tunnel was excavated using rail equipment and Haaglund ore cars which just fit into the tunnel below the ventilation duct. The tunnel was being excavated through very poor rock, in fact for the first 200m the rock is slowly moving down-hill, "sagging" at a rate of a few mm per year as recorded on the surface. It would have been preferable to have used a surface “hyperstatic” penstock pipe in this area. A steel pipe was to be installed in the tunnel through this area. However, I could see that the contractor was in difficulties so I decided to recommend that Dr. Benson, a geotechnical engineer tunnel expert from Vancouver, should be engaged to assist the design team by reviewing their work.

Rail mounted drill jumbo.

After the tunnel, Jeff drove over the height of land to the dam area. It was a spectacular trip over a slightly improved abandoned logging road, where it was possible to obtain cell phone reception for a short distance at the summit.

View from summit, looking north.

At the At the damsite we were joined by Paul Kemp, President of the consulting company working on the project. I knew Paul since he had worked briefly for Montreal Engineering. He knew more about the design details than Jeff, who was not an engineer, but had a degree in project management.

With Paul Kemp, President of Canadian Hydro Developers, the consultant, at the damsite.

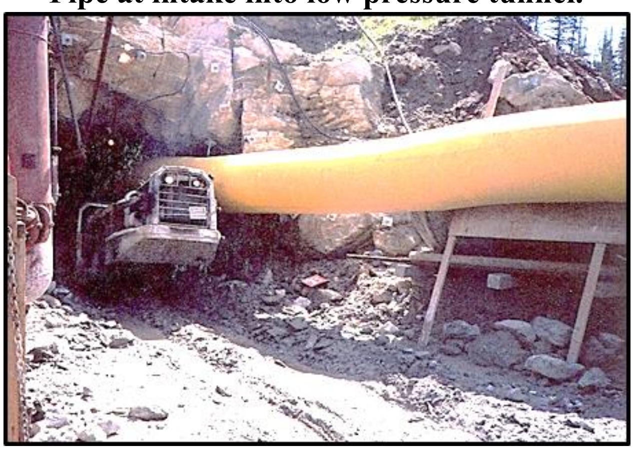
Intake and pipe to low pressure tunnel.

I asked Paul about the intake design, which was very unusual. It had a back-flush facility for the trashracks, added when the future plant operator, with experience in municipal water works had insisted on the requirement. However, it has never been used. But one feature also attributed to the operator, was his insistence that all intake operations had to be conducted from inside a building. Due to the high snow accumulation over winter, this proved to be a remarkably useful and sound suggestion, facilitating gate operation.

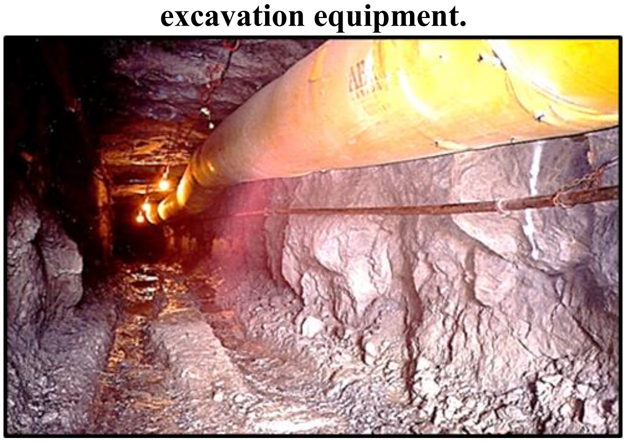
The upper tunnel was being excavated by small diesel-powered mining equipment and the progress was faster due to better rock. There was a side adit sloping down at 14% to the tunnel, and then the grade flattened to 2% to the vertical bore.

There was no surge tank, hence the plant cannot operate isolated from the system. This is now an issue on other similar projects in BC, where the developers promote isolated operation to supply local villages during a utility system disturbances, without attention to the plant hydraulics.

Pipe at intake into low pressure tunnel.



Very tight fit for low pressure tunnel excavation equipment.



Inside the low pressure tunnel.

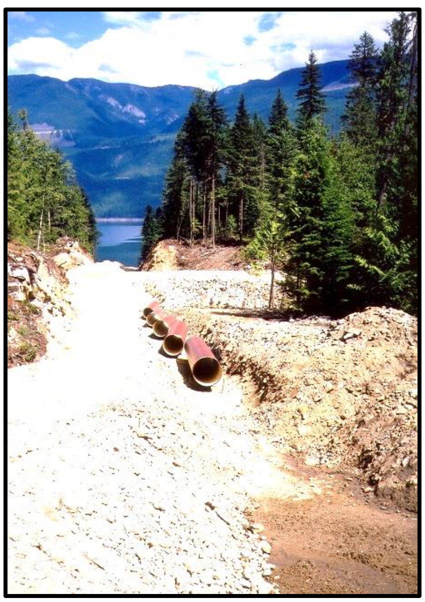
Tunnel adit near intake structure.

The suspect wing wall in foreground, at the dam.

Penstock pipes down to powerhouse.

We then had a look at the damsite and the suspect wing walls. However, I had been looking at so much detail without taking notes that I thought the wing wall concrete had already been poured, so refrained from mentioning the error with the reinforcing.

Colin had asked for a quick report, so when I got back home, I had the photos developed within an hour, and proceeded to write the report in the evening. I had a good look over the photos, and realized that the wing wall concrete had not been poured. By this time it was nearly midnight, and I knew that Jeff returned from looking over the damsite work at about 9.00pm, midnight my time, so I took a chance and phoned his cell, and to my relief he answered immediately. He was driving over the top of the ridge so I told him to stop the truck, I needed to talk. I then told him of my concerns with the wing walls, asked him to write down the drawing number and the section letters which he was somewhat reluctant to do since he had no knowledge of the engineering details, and he had never heard of an old "tourist" commenting on the work.



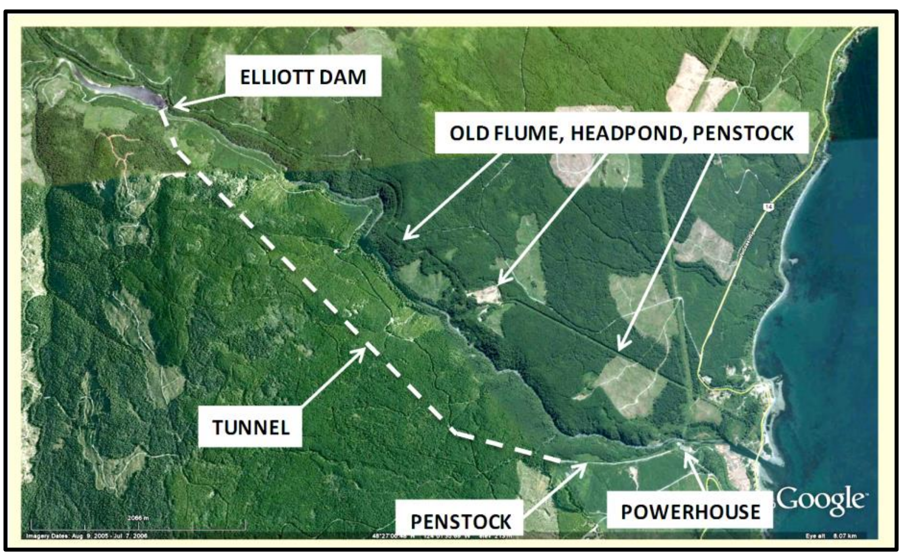
Spiral gas (penstock) pipe to be welded and buried.

However, I managed to convince him to immediately call Paul in Calgary and convey my concerns. I was still working on the report at 2.00am, when the phone rings, and Paul says – "Jim thanks, I owe you one. The concrete will be poured tomorrow and I have asked our draftsman to come in as soon as possible to revise the drawings!"

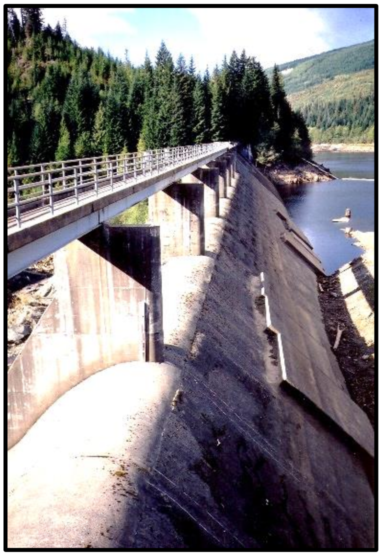
The powerhouse had not been started, with the area only cleared. It was correctly set well above the maximum water level on Arrow Lake, with a short tailrace excavation to the lakeshore. I was impressed by the design. There are roof hatches to remove the equipment for maintenance, with all the controls and switchgear housed in a container transported to the site fully wired and tested, as at Belly River. The only problem they had was installing the heavy generators through the roof hatches. They had to rent a 200ton mobile crane and wait for calm weather. A second penstock and third unit has now been added to the powerhouse, bringing the capacity up to 45MW. Altogether a very successful development.

136. JORDAN RIVER - 2002

Jordan River project layout



In September, the CDA fall meeting was in Victoria with a site visit to the Jordan River hydro power facility operated by BC Hydro. The river was developed in 1911 with the Elliott Dam and an 8.5km long timber flume to a headpond and then a steel penstock to the 26MW powerhouse.



Elliott Ambursen Dam

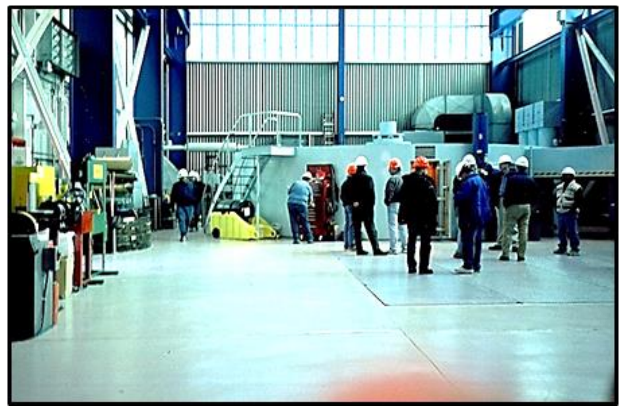
It was the main source of power for the town of Victoria. In 1971, the site was re-developed with a 7.2km long tunnel and penstock to a new powerhouse on the opposite side of the river, with a single vertical axis Francis unit of 175MW capacity, equipped with a direct-coupled relief valve.

Valve operating.

Elliott Dam has a Howell-Bunger low level outlet which was operated for our benefit. We were then driven over to the right abutment to look at the intake and weir spillway, still part of the Ambursen Dam.

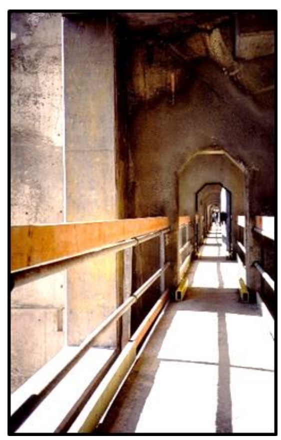
Ambursen Dam spillway structure.

Intake structure and weir spillway.



New powerhouse with single unit.

Cam on return motion lever.



Internal inspection passage in Ambursen dam.

I was able to photograph the cam on the return motion levers on the relief valve, but was unable to see the valve since it was embedded in the foundation concrete.

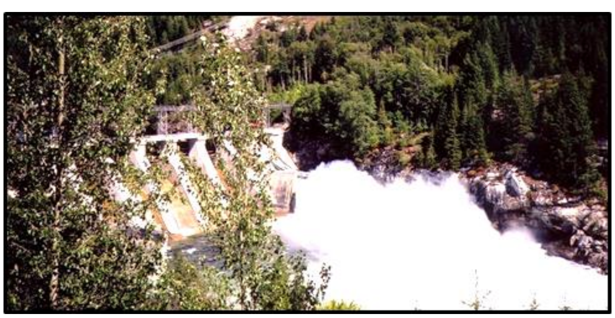
Another very interesting site inspection.

137. BRILLIANT – 2002

I had a call from the Columbia Power Corporation asking if I could join a panel to assess the bids on a design-build hydro plant addition to the Brilliant development on the Kootenay River in British Columbia.

Existing development.

The plant was built in 1944, has 4 units and 8 sluice gates. Considerable water was being spilled, hence the expansion. There were eight engineers on the assessment team faced with a large bookcase of three-ring binders, about 12 from each of the two bidders. Fortunately, the binders were divided into several subjects such as civil work, mechanical equipment, electrical equipment, construction, quality control and so forth. Each of us had about 4 binders to peruse and assess the proposals.

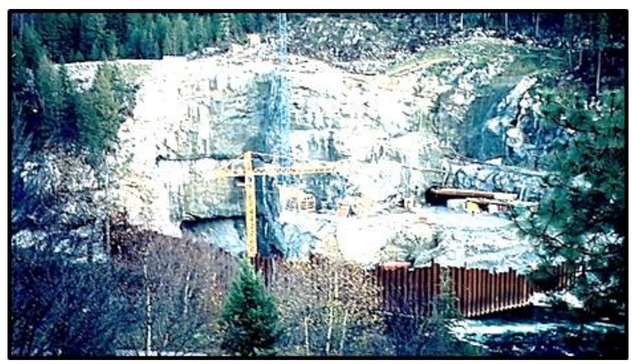


Site of new intake on left bank.

The process was quite complex, since we did not have access to the cost, this being assessed by the corporation. We had to give each aspect of the work a number out of a given total, such as 8 out of 10 for the concept. There were about 20 different categories, and at the end we had a meeting to agree on each evaluation.

Future left abutment tunnel route to powerhouse at end of rapids.

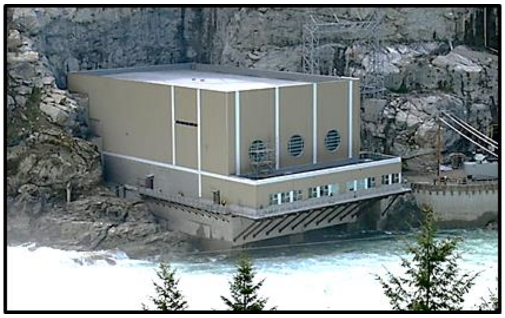
After this we met the two bidders separately and asked questions on the proposal where we wanted more information or clarification. The bidders each had about 12 persons present, made a pitch on their proposal and then replied to our questions.



Powerhouse site showing excavation and tunnel adit. Sheet pile cofferdam in foreground.

One of my tasks was to assess the quality control. So I asked each bidder how they would undertake this work. One provided a very unique answer. Their quality control engineer had retired near the site, and said "Oh, I will walk around the job every morning for a couple of hours, and then retire to my golf club which is only a few miles from the site. If there are any problems, I can easily be reached on my cell phone and be there in half an hour!" Needless to say, that reply scored very low. The proposals were for a

120MW single unit installation operating under a head of 32m. Tunnel length is 150m.



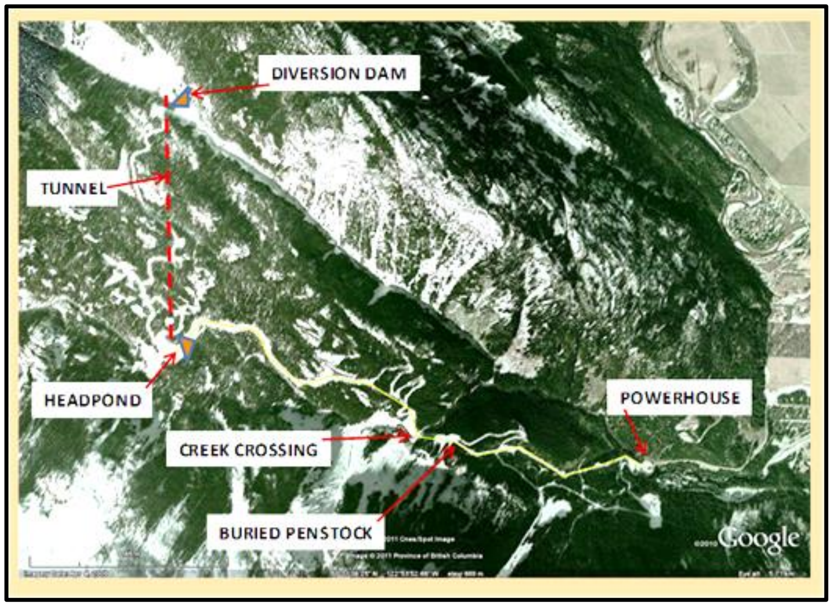
Completed powerhouse. Source – virtual museum.ca.

The project concept was to excavate a short intake canal on the left bank, to a new intake in line with the existing dam, then a short tunnel to a powerhouse in a deep excavation beside the left bank. Operation of the existing plant could not be interrupted, and access to the site was not possible over the dam to the left bank due to all the spillway equipment on the dam crest.

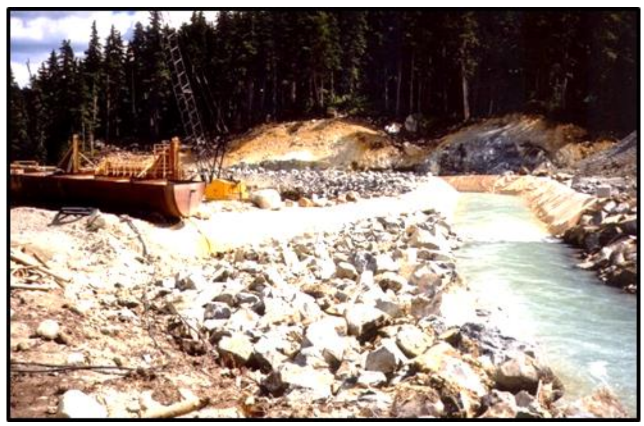
The access problem was solved by using the highway bridge downstream, and then cutting a new access road into the left bank up to the powerhouse. A long sheet steel pile cofferdam was built to dewater the powerhouse site. The successful bidder was a consortium of a Swedish contractor allied with a large Canadian consultant. Work started in August 2004, and the opening ceremony was on 23 June, 2008.

138. MILLER CREEK - 2002

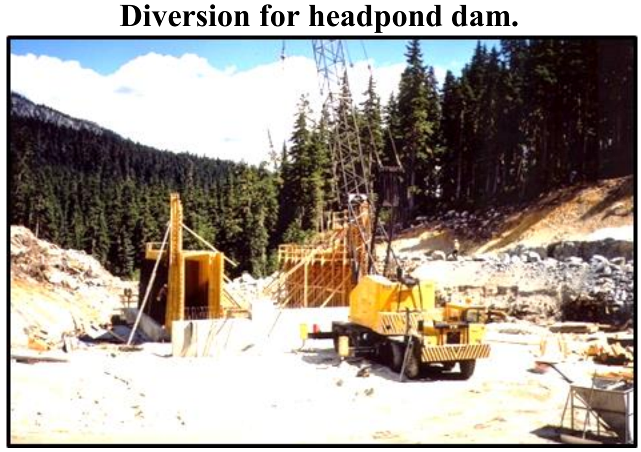
After completing our work on Brilliant, I met Pentti Sjoman on the Saturday, and accompanied by Eric Johnston and Niko Kozobolidis, we drove up to Miller Creek, where Pentti had arranged a visit to the 30MW, 5-jet impulse unit powerplant then under construction. It is located about 4km NW of Pemberton, BC.



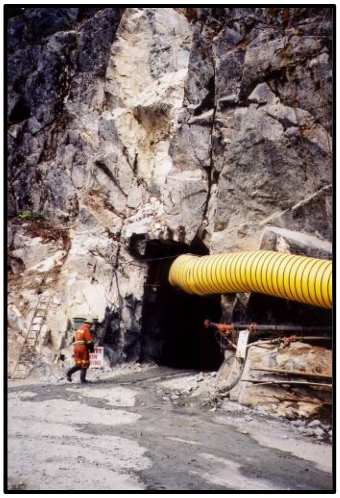
Project layout.



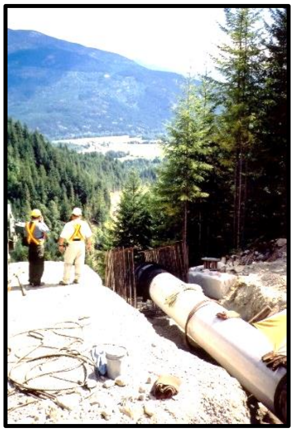
Diversion for headpond dam.



Headpond dam, formwork for spillway.

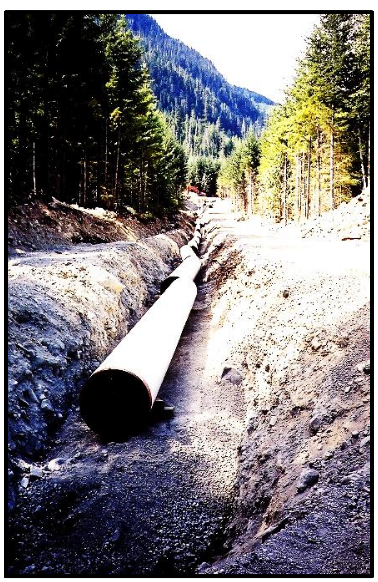


Tunnel adit at headpond.



Pipe at end of road.

Pipe aligned and ready for welding.



Pipe in trench prior to welding.

The layout includes a small diversion dam directing waters into a 2.2km long tunnel from the creek north of the 2 hectare headpond, where there is a spillway with rubber dam control and another intake directing waters into a 4.2km long buried steel pipe down to the powerhouse located near the Lillooet River.

We could see the progression of pipe construction with parts completed and others ready for welding. There was a spectacular pipe crossing at one of the side streams.

Buried pipe on right, at side of road.

Spectacular side stream crossing.

Radiator coolers for generator cooling water located in draft tube below turbine.

The powerhouse also included a small horizontal axis, 2-jet impulse unit of 3.3MW capacity which operates only during the low flow season, and during floods when water is spilling at the headpond.

Miller Creek powerhouse.

Distributor for 5-jet impulse unit.

5-jet impulse units are relatively rare, since it is not possible to balance the flow when fewer jets are operating. It is preferable to use units with either 2, 4 or 6 jets.

Runner casing for 2-jet impulse unit. Only operates during low flow season.

There are no sediment exclusion facilities at the intake, so I was not surprised to get a call from the plant operator after it had been working for about 5 years, asking what I knew about entrainment at impulse units. I started to explain about air entrainment in the water falling off the runner, but he interrupted to say that it was gravel being "entrained!" Apparently the headpond had filled with sediment, sand and gravel, and this material was now rolling down the penstock and eroding the runner. Unfortunately, the only solution is an expensive sand trap at the intake.

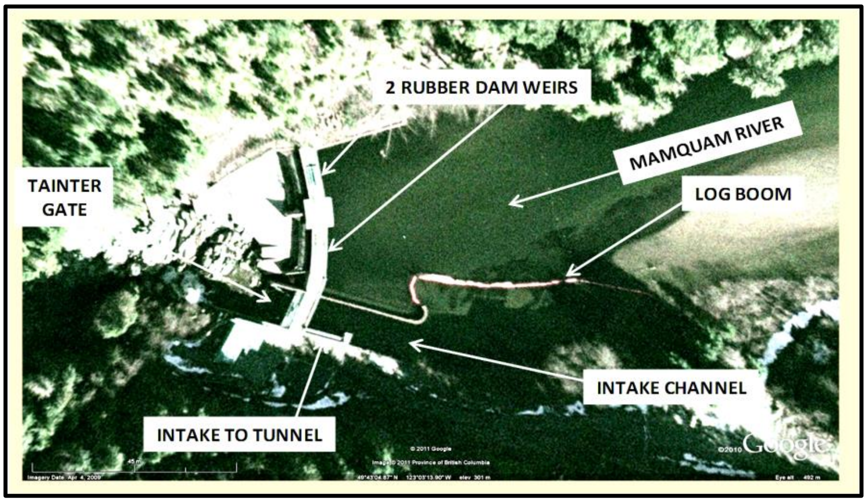
With Eric Johnston and Pentti Sjoman (in middle). In borrowed wellies, and lunch by Mrs. Sjoman.

139. MAMQUAM – 2002

After looking at Miller Creek, we took the opportunity to look at the Mamquam intake near Squamish, north of Vancouver. Pentti Sjoman had also arranged this trip, and we were accompanied by Eric and Nikko Cosobolides.

I was very interested in the intake, since I had been asked by a Vancouver consultant to review the layout for a similar intake in Indonesia, being built for the Ok Teddy gold mine in 1985. It was located on a steep river with a huge bed load, and a hydraulic regime whereby it rained torrents during every night, bringing down boulders, gravel and sands. By day, the river was almost dry. To determine the extent of the boulder load, the boulders in the river were spray painted different colors during the day, photographed to fix their position, and then photographed again for the next few days as they rolled downstream every night. They had a drawing of the intake area, showing tracks of the boulders as they passed by.

View of Mamquam headpond.



Intake layout – note sand bar in river.

The Mamquam intake had the same problem, since the Mamquam River has the highest bed load per unit of flow of any river in Canada. In fact, the Canadian Hydrographic Service had tried to maintain a flow gauging station on the river at Squamish, but abandoned the effort after a few years since the river kept changing shape as boulders and sediment passed by.

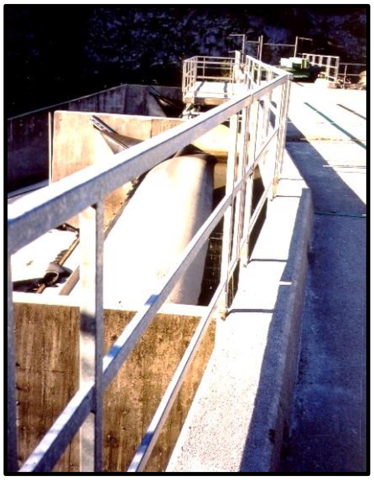
Mamquam weir and low level Tainter sluice gate.

The consultant was trying to design a weir and intake which would let boulders, gravel and sand pass on downstream, while still entraining clean water – an almost impossible task.

Looking upstream at log boom and headpond.

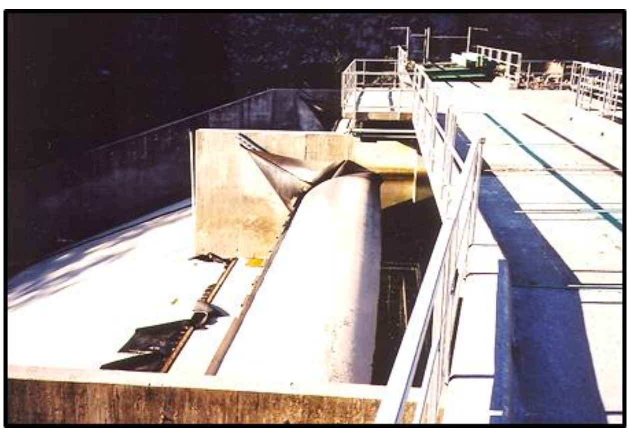
The Mamquam intake and weir had been model tested in a hydraulic laboratory in Vancouver, and after many modifications, was being built based on the model results.

I looked at the layout for Ok Teddy, and told the consultant that it would not work. The intake trashracks were too low down, and the by-pass sluice in front of the racks was at the same level as the bottom of the racks, so sediment would flow directly into and past the racks.

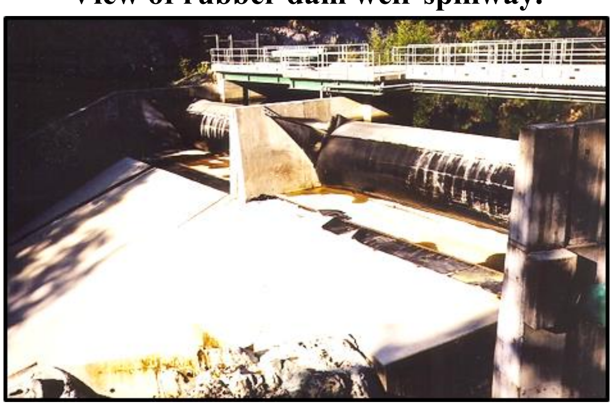


View of weir deck.

I was then informed of the model studies, but I still maintained that the design was deficient, and was invited to look at the model. I found that the material being used in the model did not replicate the properties of the sand and boulders in the river, hence the results were suspect.



View of rubber dam weir spillway.



View of the two rubber dam weirs.

This was a blow to the consultant, since the Ok Teddy intake was under construction, and they were very reluctant to make any changes. It was built to the original design. However, I persuaded them to at least include space for a large dragline to be positioned so that it could reach out in front of the trashracks to scoop out any material accumulating there and dump it on downstream. About two years later, I had a call from the operating Ok Teddy engineer on holidays back in the USA. He told me that the dragline was in constant use and the intake was occasionally overwhelmed with sediment.

Hence my interest in the Mamquam intake, I wanted to see how it was performing.

My concerns were verified. The headpond was full of sand and silt. When we arrived, the unit was shut down, hence it was possible to look down at the bottom of the trashracks and see gravel above the rack sill, ready to flow past.

The high head Francis units must be eroding fast from the gravel sandblast! The design mistake was a low level sluice just downstream of the racks with a sill at about the same level as the racks. To be effective, the top of the sluice gate must be at least one or preferably two meters below the bottom of the trashracks.

View of Tainter gate low level outlet.

I had tried several times to visit the powerhouse, but could not get permission from the plant owner. I suspected that they were undertaking frequent repairs on the runners, so visitors were discouraged.

Many years later, the plant was offered for sale, and I was asked by a bidder to undertake a due diligence inspection. I told them that it was not necessary, since I knew the plant, and not to touch it with a barge pole! They were rather taken aback at this comment, so I suggested that they look at the costs of runner repairs and plant generation continuity. The repair costs would be extraordinarily high, and the continuity of power output would vary more than normal due to removing runners for repairs. They found this to be correct and declined to bid on the plant.

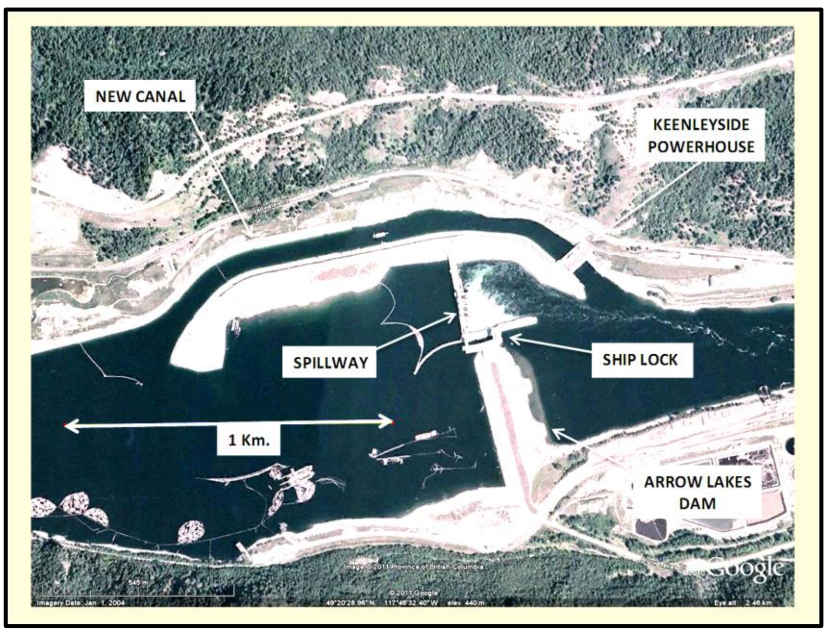
In fact, they found a copy of the tunnel inspection report after one year of operation. The tunnel has two rock traps, one just before a shaft down to the high pressure tunnel, and another just upstream of the tunnel steel lining near the powerhouse. The upstream trap was full, and could not be emptied since there was no convenient access. The second trap was half full of heavy gravel, and could have been emptied since there was access from the powerhouse, but this would be a difficult task since the access was only possible through a small manhole.

About six months later, I had a call from the new operating engineer at the plant. He wanted to know what could be done to prevent sand erosion of the runners! I told him that the only solution was either a major re-build of the intake and weir, or a sand trap downstream of the intake, neither being feasible due to the cost.

A large number of small high head hydro plants are being built in BC. All the creeks have a high silt and bed load, and very few have adequate intakes with sand-exclusion facilities, hence more problems similar to those at Mamquam can be expected. In fact, just this week I was advised that a small impulse runner on a new high head plant had worn out after only six months of service!

Turbine manufacturers assure utilities that new ceramic coatings can eliminate erosion – not entirely correct – they reduce the rate of erosion, but eventually new runners are required.

140. KEENLEYSIDE – 2002



Keenleyside development layout.

During our analysis of the Brilliant bids, we were flown over to Castlegar to look at the site on the Kootenay River. We were also given a tour of the recently completed Keenleyside project, the addition of a powerplant to the Arrow Lakes

Dam. The Keenleyside plant was owned by Columbia Power, and was their first development, having been constructed on a design-build contract.

I was very interested in the development, since it was the first major design-build contract for a hydro development in Canada, at a value of around $209M. I am very dubious about such contracts, being of the opinion that they are acceptable for small plants of about less than 50MW capacity, but not advisable for large developments, since the designers were always under pressure to reduce cost, sometimes to the detriment of quality, as will be noted from my observations. My opinion on this has not changed as of 2018. For a large development, no reduced quality should be contemplated, since it will add to the maintenance cost.

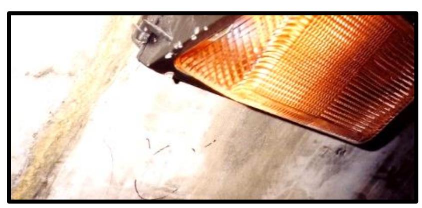
Keenleyside powerhouse.

Powerhouse generator floor.

On a thorough look around the plant, my fears were realized. The concrete was cracked in many places, and there were numerous seeps where water was running down the walls. Calcite, leeched out of the concrete was visible on many walls, and incredibly, there was water dripping out of light fixtures in the turbine pit!

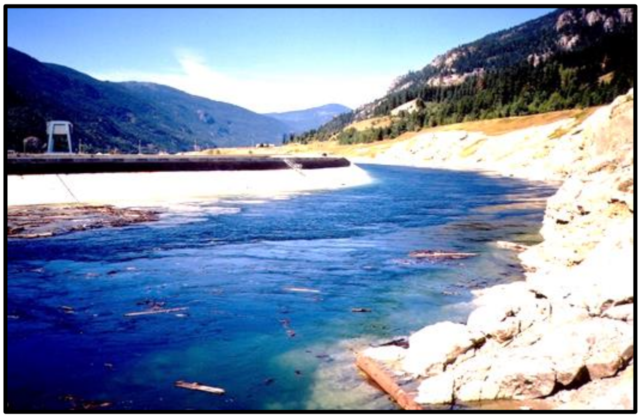
Talking to the operators, I found that they had to purchase new hydraulic hoists for the intake gates, and that some of the controls such as the limit switches to halt motion, were installed inside the high pressure hydraulic cylinders where they were quite inaccessible for maintenance.

Piping gallery – note water pooled on floor.



Water dripping off a light fixture in turbine pit.

The plant has two vertical shaft Kaplan units of 85MW capacity, operating under a head which varies from 13m to about 18m. Each is equipped with 3 intake gates and 3 draft tube gates for the very large runners. There is an intake channel 1.5 km long lined with concrete panels to prevent erosion of the underlying materials. There is an elaborate drain system below the panels to prevent uplift from artesian pressures from nearby mountain streams, equipped with sensors to indicate excessive flow.



Looking up intake channel.

Intake (left) and channel.

The concrete panels failed a few years ago. They lifted due to excessive uplift when the reservoir was near the low supply level. The plant operators had suddenly increased load on the turbines from almost nothing up to almost full load. The sudden demand for more water caused a sharp drop in the canal water level and when the water pressure down on the panels was less than the weight of the panels and the artesian uplift pressure, the panels lifted, an alarm went off in the powerhouse when it detected excessive flow through the drain system, and the units were shut down.

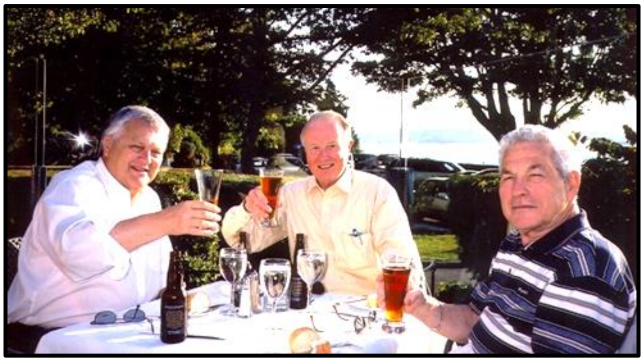
Everyone got into the argument as to whom was responsible – the contractor, the contractor's consultant, the owner's consultant, and the operators. All four entities called me for assistance in the coming lawsuits, but after asking a few questions, I realized that the issue was so complex, that a court would have great difficulty in assigning blame, so I declined.

Spillway built in 1969.

Meanwhile revenues were being lost as the plant remained shut down. Eventually sanity prevailed, and an agreement was reached on no lawsuits, with everyone contributing to the repair costs. A few months later, the plant was back in operation much to the relief of Columbia Power.

But Columbia Power had "loss of business" insurance, and collected some tens of millions on the policy. This sum was several times the repair cost. The insurance company then sued the two consultants and the contractor! The cases were settled out of court for a fraction of the claim, and all involved learned a valuable lesson – liability for a failure will not just disappear.

The liability confusion was due to an obscure warning in the operating manual. The warning was buried in some back pages in the voluminous manual, and briefly mentioned that the rate of increasing load on the units was limited to a slow gradual rate – don't know the value – when the water level in the reservoir was low. But this restriction on the "ramping rate", as it is known in the industry, was never mentioned to the operators during the commissioning tests – so who is to blame? I learned this from my questions to the entities asking for help. All had asked me how prominent should a warning on the ramping rate be? – something I could not easily answer.



With Bill Freeman (left, VP Planning, Columbia Power) and Jim Sinclair (right, mechanical consultant) at a restaurant in Stanley Park, Vancouver – enjoying consulting!

The owner's consultant benefitted from the Keenleyside experience, and the contract documents for the Brilliant plant limited all stresses to 90% of the allowable stress as defined by international codes and specifications.

141. KOKISH – 2002

In October, I had another call from Colin Clark, President of Great Lakes Power, asking if I could look over some reports on developing the Kokish River on Vancouver Island. The river discharges into Johnstone Strait east of Port McNeill at Beaver Cove. It has the large Bonanza Lake about 14km inland suitable for storage, a rare occurrence on the mountainous island.

BC Hydro had looked at the possibilities of developing up to 200MW of peaking power using several meters of storage on Bonanza, but Colin was thinking of something much more modest. I suggested that since I would be in Vancouver at the end of October, on another project, I could look at the site by prolonging my trip by a couple of days, and this was accepted. I flew to Campbell River, rented a 4x4 Jeep Cherokee and drove over to the site.

Signs posted at start of logging road.

To reach the damsite, I had to drive over an active logging road, and from my past experience on such roads, I had found that they were extremely dangerous during the week, when large logging trucks hogged the road driving at ridiculous speeds, since the drivers all had radio communication, were familiar with the road, and knew when and where they would be passing other trucks. On weekends, the roads were open to the public at their own risk, so I arranged to look at the site on a Saturday.

It was a warm sunny fall day, and I had a pleasant drive to Kokish and along the gravel road to the damsite. I did not need a 4x4, since the road was reasonably wide and well graded. At the site, there was a small park, developed and maintained by the logging company. With several picnic tables to choose from, I should have brought a lunch.

Part of the damsite, a small creek with rock on the left bank.

The concept was to build a dam at Ida Lake, and a long pipe buried in the logging road down to a powerhouse near Beaver Cove. Since it would take at least 2 years to install the pipe, traffic on the road would have to be re-routed to another logging road on the other side of the river. However, the other road was in poor condition and would have to be upgraded at considerable expense.

View of Ida Lake, just downstream of Bonanza Lake.

The logging road.

I wrote a long 216 page report, optimizing capacity at 34MW, a task which would have required several months of work without the software, if undertaken by Montreal Engineering. The software was an early development of HydroHelp. Cost was estimated at $73.3M.

After I arrived home, I read the environmental report by BC Hydro, which indicated that there were at least 200 bears in the watershed! I was aware of the danger when I wandered around the damsite, making a lot of noise, but I would have insisted on a companion from Great Lakes had I read the report before visiting the site. After looking at the site, I drove to Port McNeil for a late lunch, then back to Campbell River, exchanged the Jeep for an Altima, and drove down to visit my brother and his wife Lynn at Qualicum Beach, stayed for a day, then back to Campbell River for a flight to Vancouver and Montreal. A most interesting trip – next time I will look at the environmental report first!

In 2015 the site was developed with a 45MW plant at a cost of about $175M, due to the rapid inflation of costs, at around 60%, comparable with $155M from the pre-feasibility report.

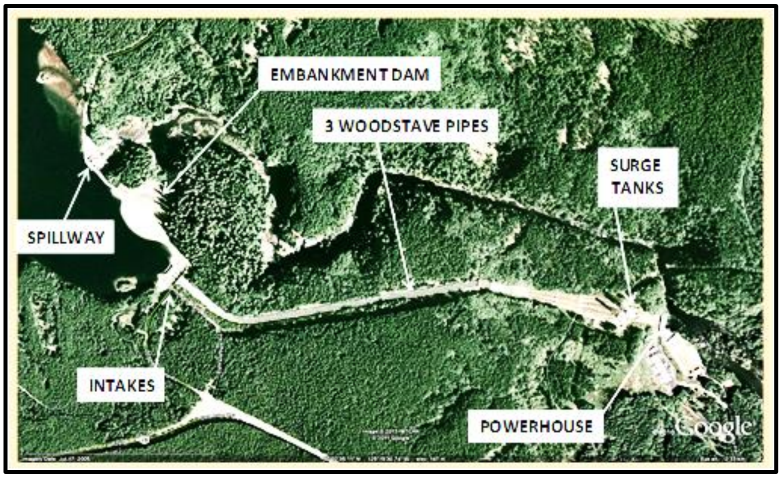
Ida Lake dam. – Brookfield Renewable.

142. JOHN HART – 2002

In October, I had a call from BC Hydro asking if I could have a look at their plans for adding spill capacity to the John Hart spillway near Campbell River. I combined the trip with the nearby Kokish work, further north.

There were several options such as building a spillway into the embankment dam, or cutting out space for a weir in the concrete dam. They had already added faster closing gates on the intake by installing hydraulic hoists, in case the woodstave penstocks ruptured during an earthquake. But adding full earthquake bracing to the surge tanks proved to be far too expensive, and the risk was deemed acceptable. At the powerhouse, bracing was added to all equipment. It was an easy trip, since a report was not required – only comments at the site.

The three surge tanks. Partially braced and retrofitted for earthquake forces.

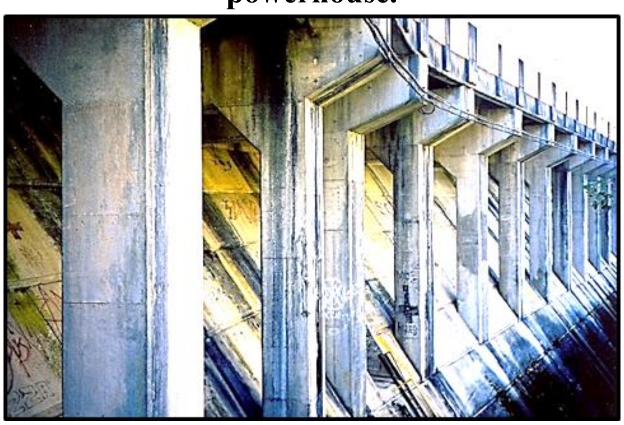


← John Hart project layout.

On top of spillway hoist structure at JH. Note large crown gear.

Earthquake bracing at John Hart powerhouse.

Years later, the plant was renovated by BC Hydro with a new spillway, intake and tunnel to a new 138MW powerhouse at a cost of $1.35B.

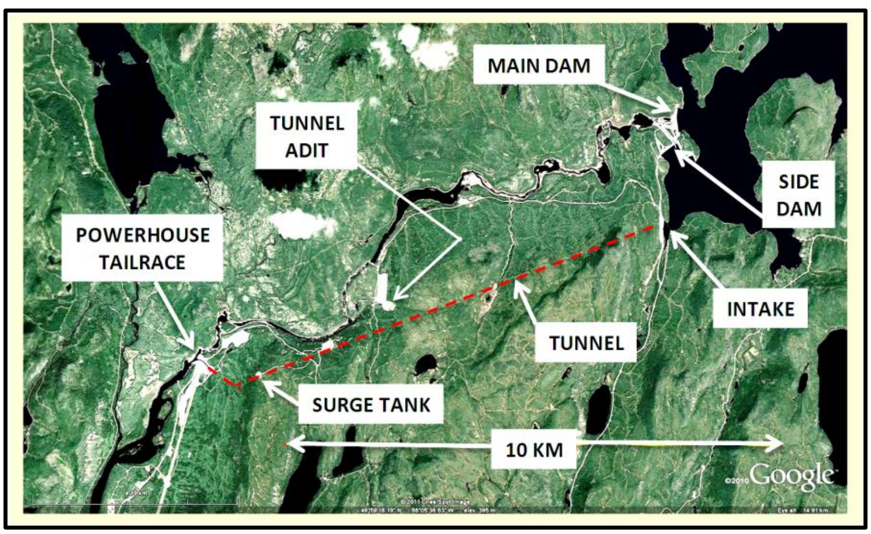


Concrete dam at right of spillway.

Intake gantry.

143. TOULNUSTOUC – 2003-5

In 2003, I had a call from Dr. Jean-Pierre Tournier, head of hydro plants at Hydro Quebec asking if I could join their "panel of experts" to provide advice on the design and construction of their hydro projects. I initially declined since I thought that all the discussion would be in French, it wasn't; that I was no longer a member of the "Order of Engineers of Quebec", neither were the other panel members; nor because I did not have liability insurance. HQ advised they would cover this aspect. So I joined a panel which included Alberto Marulanda from Colombia, president of a large Colombian consulting company, Dave Kleiner, retired chief geotechnical engineer from Harza, and Dr. C. H. (CH) Yeh, retired chief structural engineer, also from Harza Engineering in Chicago. We formed a good team, with Alberto looking at underground and surface rock excavations, Dave at embankment dams, CH at finite element designs, and I looked at the structures – powerhouses, intakes and spillways.



Toulnustouc project layout.

HQ had four projects for our review, Toulnustouc and Peribonka in North-East Quebec; Eastmain and Rupert at the lower end of James Bay. All were large multi-billion dollar developments. We arrived too late to make much of an impact on Toulnustouc, a little on Eastmain, but were effective on Peribonka and Rupert, which were still in the early design stages.

The panel usually spent about a week on each project, meeting about twice annually around May and October. Sometimes the project meetings were combined and lasted two weeks. All panel discussions would start with a Monday meeting at the site where there would be a short presentation of progress on the work, followed by a site inspection for one or two days, depending on the extent of the work, and return to Montreal in the late afternoon. There we would have more formal presentations on the design progress and discussion of many technical issues. Finally, we would present a report on our recommendations before leaving late on a Friday afternoon, all very efficient. We would stay at the Gouverneur Hotel in downtown Montreal, conveniently connected to their offices.

The first project, Toulnustouc is on the Toulnustouc River, a tributary of the Manicouagan River in north-west of Quebec. It has two concrete-faced rock-fill dams (CFRD), a first for Hydro Quebec and a learning experience for them. There is a smaller CFRD side dam, built first to familiarize the workers with the construction process before starting on the larger main dam – a wise decision. There is an intake to an 11 km long tunnel with an adit at about the middle, and a large simple surge tank near the downstream end, preferable to a restricted orifice tank This leads to the powerhouse tucked into a large rock excavation, with a short tailrace excavated through rock and soft alluvium back to the river.

I wondered why the surge tank was a simple design with no throttle, since the latter reduces tank diameter. It was not until I worked on Athmuquam (Page 509), that I realized why. At Athmuquam, there is a long 17km tunnel, and the surge has to be added to the waterhammer to determine maximum penstock pressure. With a throttling tank, the surge pressure is equal to the level at the top of the tank, and this may be far too high to avoid restricting the wicket gate close time on the turbines, to be within the maximum allowable waterhammer plus surge of 50% of gross head, and without adding inertia on the generator. Instead, with a simple tank, the maximum surge at the end of the wicket gate closing time is only half the turbine flow volume multiplied by the gate close time, to obtain the water volume flowing into the tank, and this, divided by the tank area, will determine the surge height to be added to the waterhammer. It will be far lower than with an orifice tank, hence the advantage of the simple tank. I have outlined this in more detail than usual, since I have never seen it mentioned in papers or textbooks.

Building the concrete-faced dam was quite difficult, and is described with the help of following photos.

Forms for the concrete toe plinth.

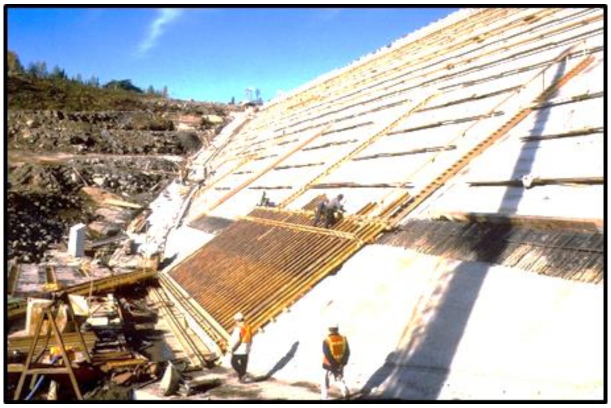
The rock fill in the dam is built before the face and allowed to settle. Space must be left at the foundation rock contact for the kerb (working slab) placing machine. A large concrete foundation called the plinth is poured first to connect the face concrete to the foundation rock along the upstream toe of the dam.

Machine placing kerb in horizontal strips at top, along face of the rock fill.

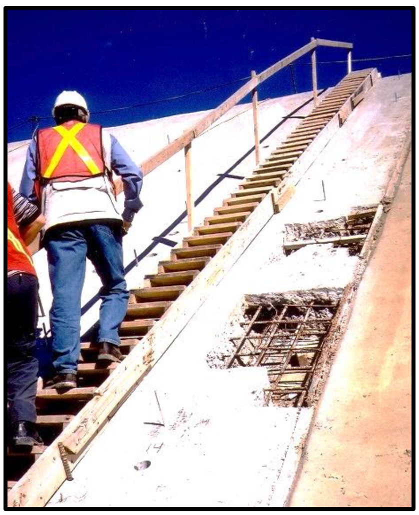
Next comes the concrete kerb, this is the working platform on which the concrete face is poured. The kerb is a series of strips of concrete poured on the upstream rock face. There are small gaps left in the bottom of each strip to allow for some settlement during construction, and these have to be filled in by hand.

Copper waterstops between concrete face panels.

The dam is built with a series of panels joined together with copper waterstops and for safety, a second rubber waterstop on the surface bolted to the concrete. In the above photo, the waterstop is too close to the kerb concrete. Debris falling from above is a constant problem.

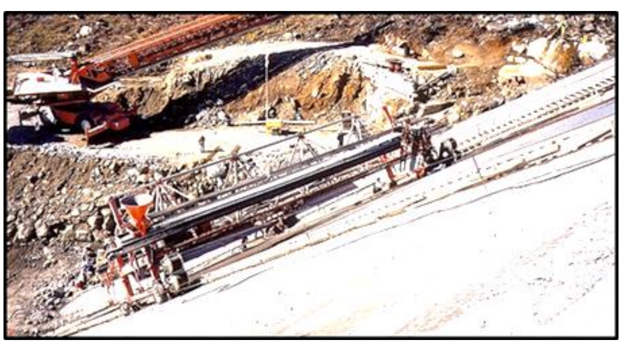


Horizontal planks are work platforms for filling kerb gaps with concrete. Workers are placing horizontal re-bars.



Any porous concrete has to be cut out and re-poured.

The concrete slabs are poured in one continuous lift using a form which slowly travels up the face of the dam.



Slip-form for concrete face.

Black paint is a bond breaker on working kerb.

Kerb gaps filled in except near bottom.

Slip form for the concrete on dam crest.

Before the facing slab is poured, the kerb concrete is painted with a bond breaker. Most of face slabs have already been poured in the photos

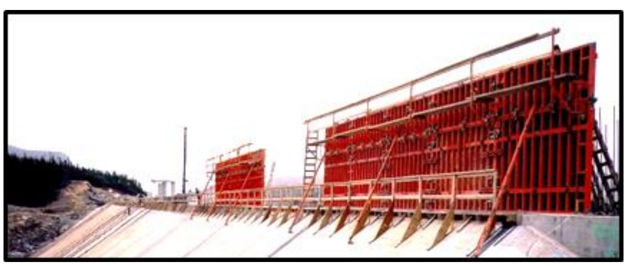
Concrete being poured into parapet wall base slab

Note reinforcing in middle of face slab. Usually 25mm bars at about 20cm to 25cm centers. At the top of the dam, there is a wave wall - a concrete "L" shaped wall, since there can be a large wave run-up on the smooth concrete face.

Rubber membrane surface waterstop.

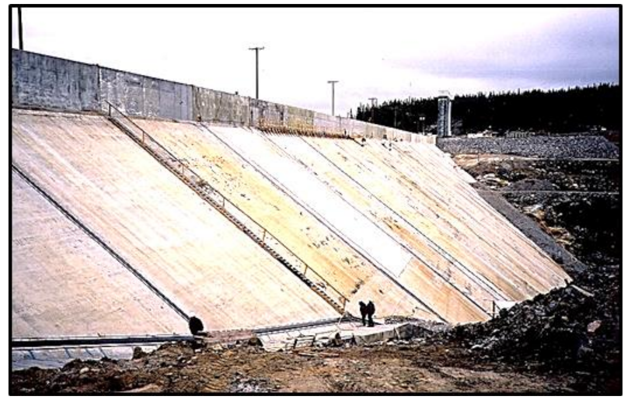
The waterstop is secured with stainless steel angles bolted to the concrete. This photo shows the intersection between surface panels and toe plinth concrete. Complicated details such as this have to be designed in the field. Note debris – this is a constant problem. The debris rolls down the dam face from work being undertaken above.

Diversion tunnel closure gate.



Formwork for high parapet wall on main dam crest. Note spillway gate hoist structure at far left on side dam.

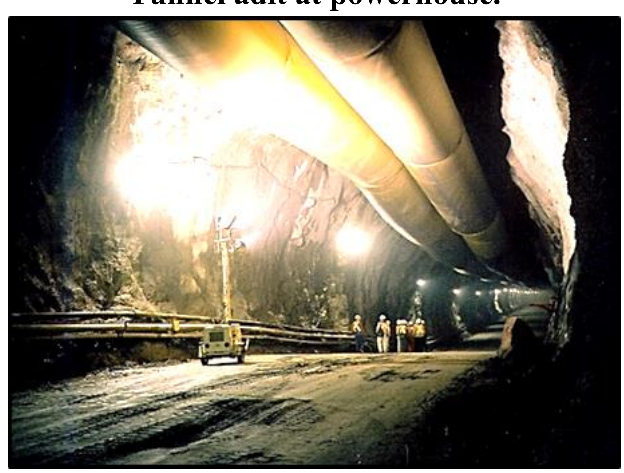
The wood ladder in the next photo is for workers installing the rubber surface waterstops. The white carpet in the middle of the dam is a test section of Carpi geomembrane. The geomembrane was installed to determine wear performance under Canadian winter conditions. For safety, workers on dam face wear harnesses.



Completed main dam. Note rubber waterstops.

The diversion tunnel gate is a simple steel gate with wheels on axles designed to fail when head on the gate reaches low supply level. The gate is suspended on a hoist structure with a fan brake for lowering. The structure will be removed before reservoir is filled. The gate is partially filled with concrete for added weight to ensure complete closure.

Tunnel adit at powerhouse.



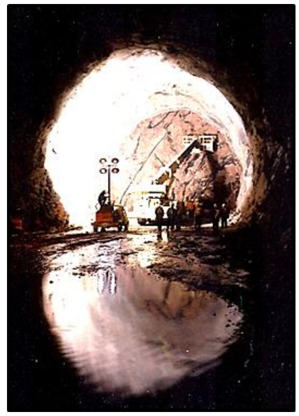
Power tunnel near the intake.

Power tunnel between adit and surge tank.

We did not see much of the powerhouse since the structure had been fully designed and equipment purchased by the time we were engaged to review the project work. It was tucked into a large rock excavation, with the location based on an analysis of tunnel versus open cut excavation.

Power tunnel at powerhouse bifurcation.

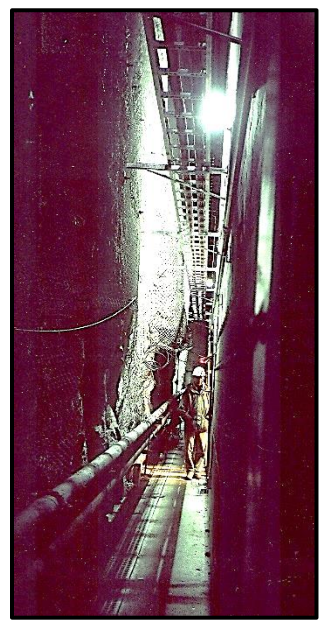
About midway between the middle adit and the surge tank, the tunnel passed too close to the river valley. There was a chance that there could be some "hydrojacking" of the rock, and many tests were undertaken to measure the water pressure in the rock that would cause rupture at fault planes. If this pressure was less than the water pressure in the tunnel, a blow-out could theoretically occur. A few tests showed that this was possible, so an elaborate drainage system was installed on the rock slope between the tunnel and the river bank. It is being monitored, but has not indicated any danger. The survey work in this area was found to be incorrect, with the rock level lower than expected and the surface closer to the tunnel.



Power tunnel near powerhouse.

Powerhouse deep rock excavation.

With a high pressure tunnel and short steel penstocks lining the tunnel, some seepage was expected. Rather than leave exposed damp rock walls in the powerhouse, concrete block walls were built to close off the exposed rock. Trenches at the bottom channeled any seepage over to the powerhouse sump. In retrospect, this design was found to be superfluous, with seepage being minimal.

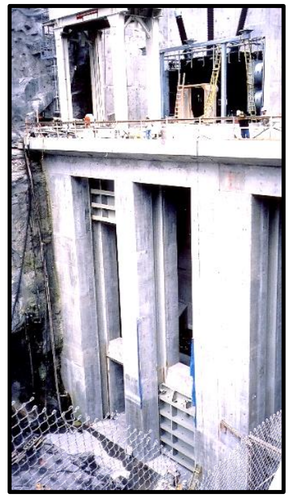


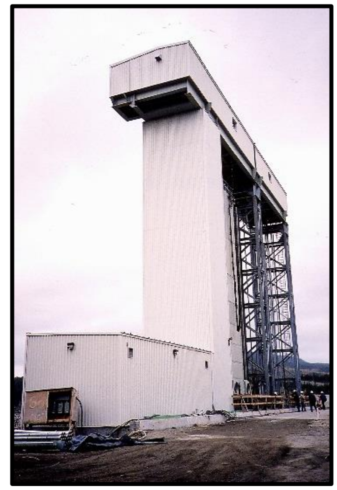
Space left between rock wall and powerhouse wall to monitor seepage.

Low level valves in gate bottom.

Draft tube form at powerhouse, tailrace rock cut.

Spillway gate superstructure.



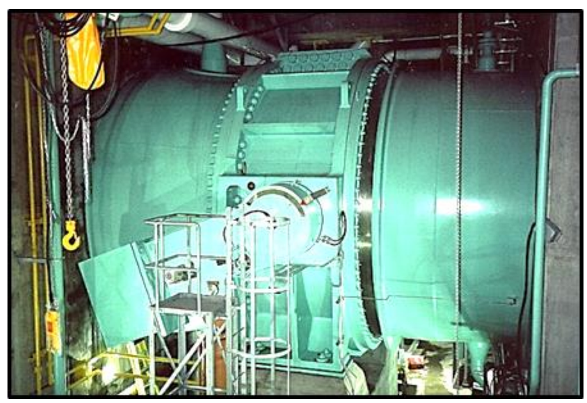


View looking down at draft tube outlet.

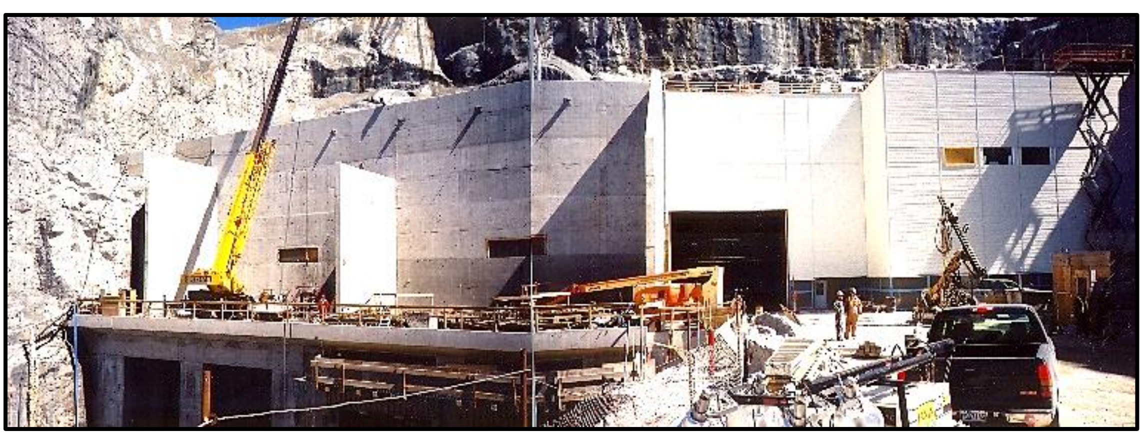
Testing one of the gate valves.

One of the two spillway gates has three low level outlet valves built into the bottom. There was some concern that the valves could vibrate, but tests indicated that there was no vibration. Each valve was opened with a technician inside the gate listening and looking for any signs of vibration, but nothing was detected other than noise.

Hydro found that the cost of the concrete wall on the dam was about twice what was expected due to the high labor input. However, there was no alternative due to the paucity of impervious till for a dam core. It was another successful development for Hydro Quebec.



Above - Butterfly turbine inlet valve.



Downstream wall of powerhouse.

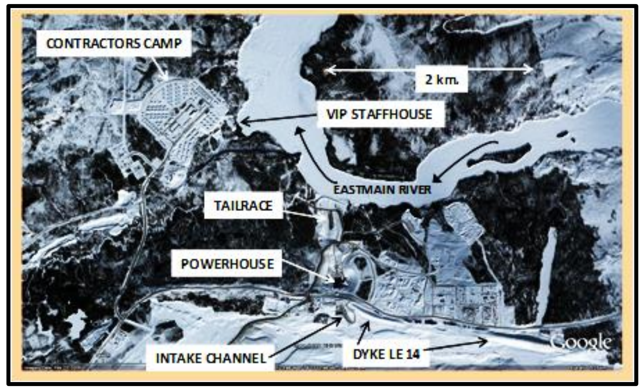
Toulnustouc construction camp.

Hydro Quebec staff and "Panel of experts*". Dave Kleiner*, Jean-Paul Rigg, Alain Grenon, C-H Yeh*, Jean-Pierre Tournier, Alberto Marulanda*, Jim Gordon*.

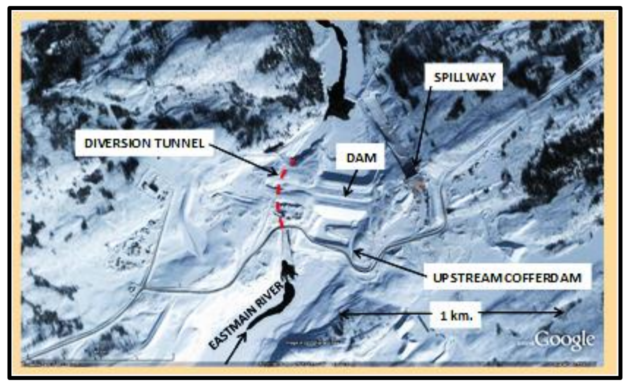
144. EASTMAIN – 2003-6

After looking over Tolnustouc we were flown across Quebec to the Eastmain project where construction had just started. It is located on the Eastmain River, some 300km south of the La Grand River. Diversion dams had already been constructed during 1976-9 on the Eastmain and Opinaca Rivers as part of the James Bay projects, to direct the flow northwards into the vast La Grande 2 reservoir.

The project involved the creation of a 603km^2 reservoir by damming the river with a main dam beside the spillway, 19 dykes around the northern rim and a further 14 dykes around the south-west rim to prevent the water from overflowing into the Pontax River watershed. Total crest length is over 13.6km. The watershed area is 25,800km^2, or slightly larger than the State of Vermont, and slightly less than the area of Belgium.



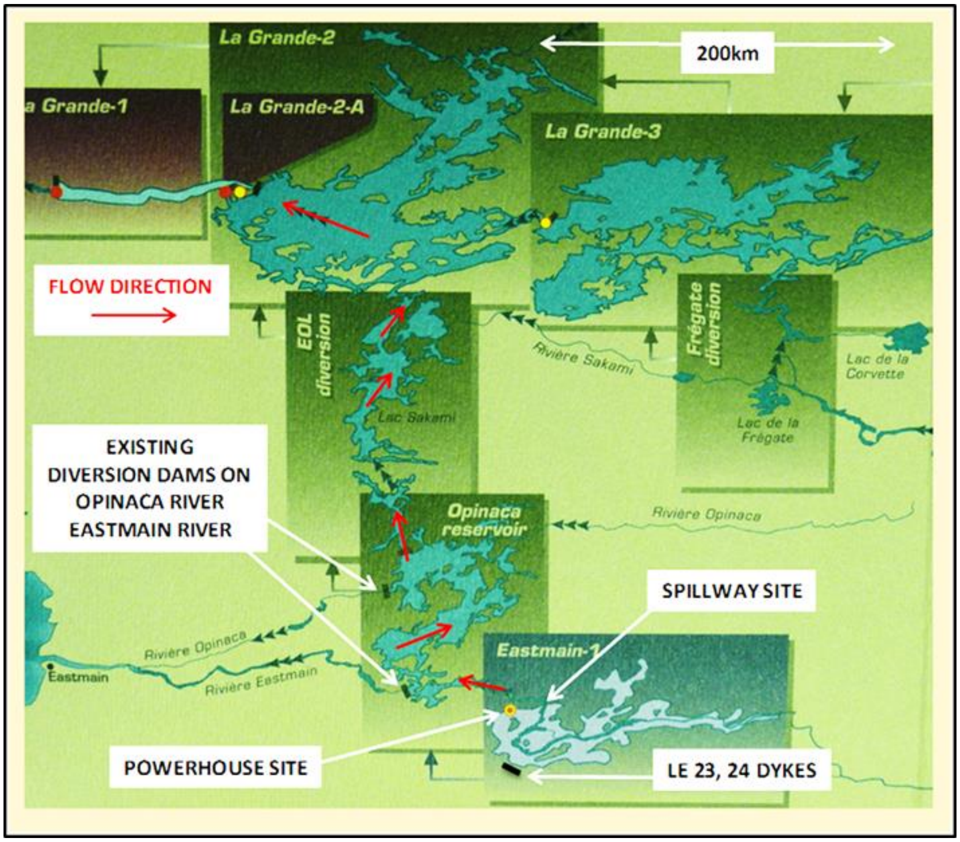
Eastmain powerhouse site layout. Winter 2003-4.



Eastmain damsite layout. Winter 2003-4.

The main dam is 69m height, has a crest length of 860m, a volume of 2.8Mm^3, and is founded on sound rock. The damsite was dewatered with cofferdams and a large tunnel in the left abutment.

The powerhouse site is some 20km east of the dam in a deep rock excavation with a tailrace cut through soft marine clays. There are 3 intakes into short tunnels to the 3 turbines, each producing 160MW at 63m net head. On our first visit in June 2003, we stayed in trailer rooms equipped with a kitchenette, small dining table, bedroom and bathroom. We dined at the camp "club" and were quite comfortable. The VIP quarters were being built, later to be used by the plant operators as their permanent residence.



Eastmain development – Source HQ ISBN 2-921077-06-X.

Our site visits were very well organized. We were provided with a map of the site showing our inspection route and were driven around in a 24 passenger mini bus, with a guide in a 4x4 ahead, usually accompanied by about 6 to 8 Hydro Quebec staff to answer any questions.

Air vents at

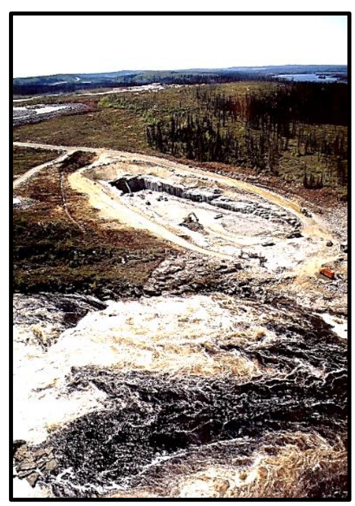
diversion tunnel intake.

Construction camp – still being built.

Aerial view of diversion tunnel outlet channel.

Aerial view of diversion tunnel intlet excavation.

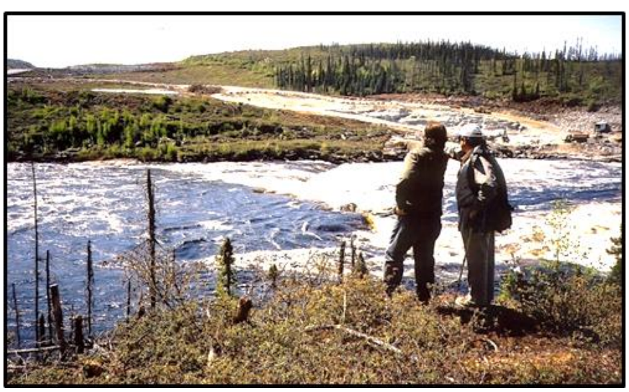
We had strict instructions to stay with our guides, since wandering around the busy site was very dangerous with many dozers and trucks working on the dam.



Diversion tunnel inlet channel.

The 325m long diversion tunnel was large, being 14m wide by 18.4m high, inverted "D" section, excavated in two lifts. Design flow was 3,100m^3/s.

First lift excavation for diversion tunnel.



Our first view of the damsite.

The diversion tunnel intake had three air vent pipes which spouted a mixture of air and water every few minutes since the shallow intake entrained air, and as this accumulated in the top of the tunnel, it eventually reached a volume large enough to vent upstream at the intake.

Upstream cofferdam.

On our second visit to the dam, the foundation was dewatered ready for an inspection. The contractor was very concerned about safety and when he heard that 4 "senior" engineers would be looking over the rock, he asked about their mobility and was informed that one walked with a cane, and another was over 70!

The contractor then decided to be safe, and ordered the construction of a plywood sidewalk with stairs from the access road down over to the center of the rock foundation. It was quite a site to witness carpenters hurriedly hammering in the plywood as we arrived, and literally pulling it up behind us as we left.

Carpenters building sidewalk down to dam foundation.

View of main dam construction.

Enormous diversion tunnel – note size of men.

Above – Construction of Dyke LE-14. Below, boulders removed by a rock rake.

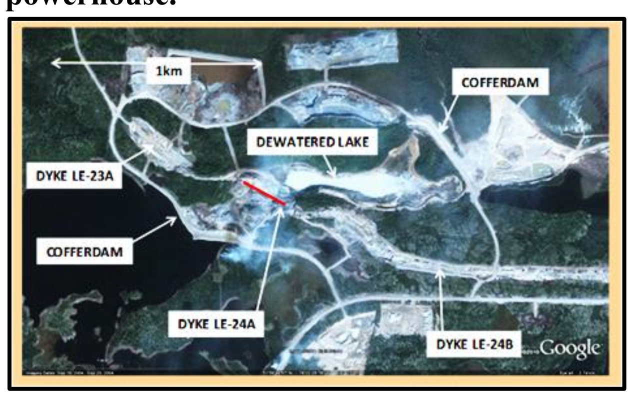
25 Ton Bomag vibrating octagonal roller compactor.

Hydro Quebec was always keen to try out new equipment and construction methods. We saw a Bomag octagonal roller compactor on site, but did not hear of any results.

Around the south-west rim of the reservoir there were several dykes. Dyke LE-24A proved to be particularly difficult since it crossed a small lake with 2m of quick clay mud on the bottom, overlying about 10m of sand and silt. The lake had to be drained, and the foundation excavated down to rock. A further problem was the orientation of the right abutment rock, which had to be excavated to obtain a positive angle for the core contact.

Completed Eastmain Dam.

← Placing fill on Dyke LE-14, east of powerhouse.



Dyke LE-24A construction.

The Google Earth view (previous page) illustrates the extent of work Hydro Quebec will undertake to avoid building a dyke on sensitive clay, as opposed to the approach at Muskrat – see Chapter 166.

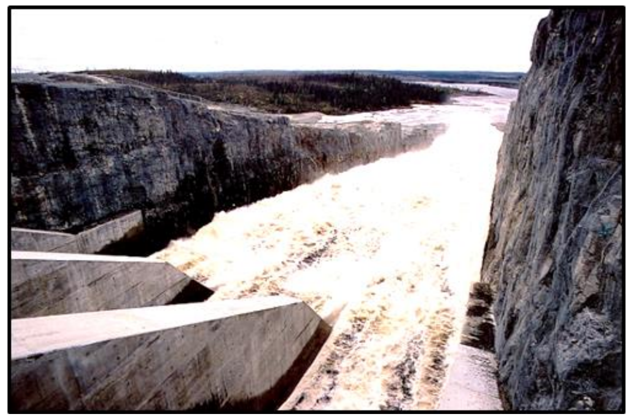
Abutment notch excavation, drained lake. Dyke LE-24A.

The spillway has three gates 11.4m wide by 9.2m high. There have wire rope hoists in a housing well above deck level with the usual stairs at one end and a cantilever out at the other end with a small crane and hatch in the floor to lift equipment up into the housing, and a monorail hoist for the stoplog gates on the upstream side. The road across the spillway is on the upstream side, a far better location for access to the gates and stoplogs.

Completed spillway hoist structure. Note driftwood upstream of gates.

On most spillways the road is located downstream of the gates. Spill capacity is 4,880m^3/s. The spillway chute terminates in a plunge pool before joining the Eastmain River. When the reservoir was flooded, a large volume of driftwood descended on the spillway. It was lifted out and burned.

Looking upstream in spillway chute excavation.



Completed spillway chute rock cut.

Intake excavation completed, tunnel liner form in right penstock excavation.

Standing on main dam as it is being built.

Intake excavation completed. Tunnel form on left.

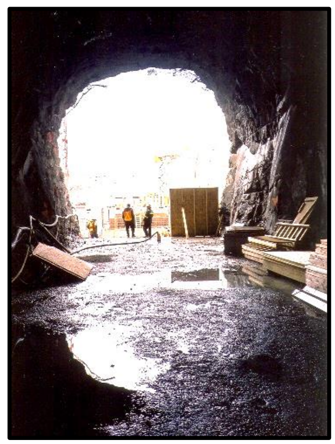
Giant hoarding for winter intake construction.

Concreting inside hoarding.

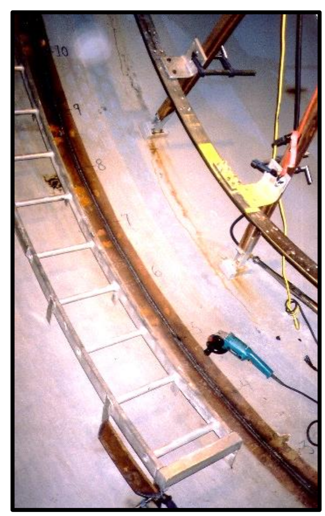
Completed intakes, air vent housing above deck

Installing intake stoplogs and gate guides.

The intake hoists are located below deck, a Hydro Quebec "standard design concept". I tried to warn hydro that the hoists could flood on a full load rejection, but my objections were overruled. Perhaps it was too late to introduce such a change. However, shortly after the plant started, the hoists flooded as I had predicted. Now the design has been changed to hoists above deck level for future plants!

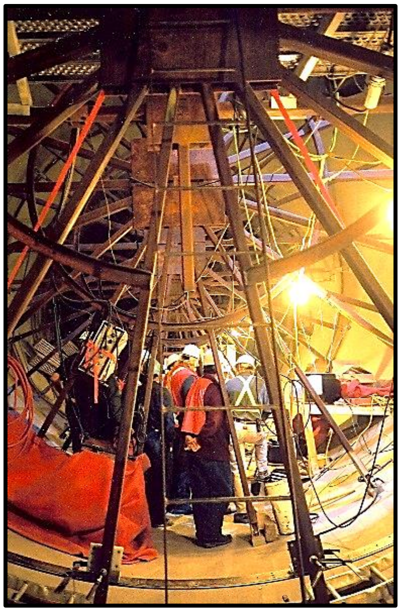


View of penstock tunnel at powerhouse.



View of automatic welding machine setup and track inside penstock.

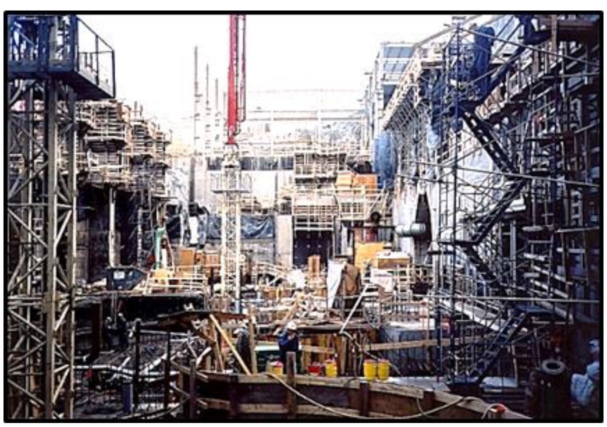
The welding of the penstock pipes proved to be very interesting. It was all done by an automatic welding machine working from inside the penstock. The pipes were aligned and held in a precise circular shape by many spider supports; the penstock weld area was closed off with tarpaulins and the interior heated to about 25^0C to dispel any humidity.



It was a very pleasant working environment for the welders, particularly in winter!

Penstock welding from inside – note spider spacing.

At access cross-tunnel junction, for penstock excavation near powerhouse.

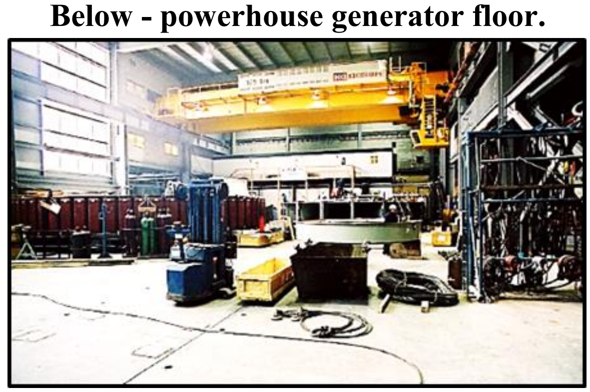


View across powerhouse – penstock tunnels on right.

The powerhouse is located within a very deep excavation with the roof level still well below the surrounding rock level. This will result in a very large snow loading on the roof, and it has been designed for such an eventuality. Also, the draft tube gantry crane is on the deck exposed to the weather, and very difficult to operate in the winter. I would have preferred a monorail hoist within an extension of the powerhouse, with a downstream wall extending down to well below tailwater level as at Brisay, so that there would be no icing problems when operating the gates.

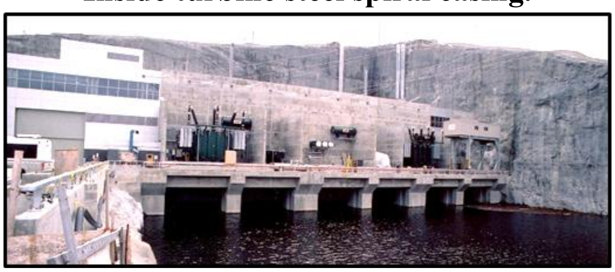
Draft tube formwork and reinforcing.

Assembling generator rotors.
Below - powerhouse generator floor.



Generator casing assembly.

Inside turbine steel spiral casing.



View of powerhouse draft tube deck.

The 950m long tailrace excavation was partly through soft sensitive clays which required dewatering with pumped wells and very flat side slopes.

Powerhouse.

Looking upstream at large tailrace excavation.

Looking downstream at large tailrace excavation.

As I mentioned, unfortunately we arrived on the project too late to make any significant changes. I would have liked to see the intake hoists above deck, and the draft tube gantry replaced by a monorail hoist inside an extension of the powerhouse. One discussion I had with their turbine engineer was on cavitation. I insisted the turbine would cavitate based on the data provided and a run through my turbine program. However it had been model tested with no cavitation evident. Eventually the problem was solved when they found that there was a mistake in the runner diameter listed on the data sheet, and a re-run on my software indicated no cavitation.

145. GRAND MERE – 2006

In September, the CDA fall meeting was at Shawinigan in Quebec, with a visit to the Grand Mere powerplant operated by Hydro Quebec. There was a full day of excellent papers on the project, the addition of a new powerhouse and spillway to an existing development. The site tour was a bitter disappointment since we were not allowed into the powerhouse, no photos were permitted and we only saw the deck of the spillway.

Our group on the plant tour – I am at right.

A couple of years previously, well after 9/11, Hydro had been criticized for the lack of security in their plants when a reporter and cameraman from a television station had walked into one of their large underground powerhouses. As a result, they had clamped down on visits and had new security in place equal to that at airports. We had to leave cell phones, cameras and a photo identification with security staff before entering the grounds, and pick them up on leaving.

My only photo, taken from a road.

The large spillway Tainter gates are operated by high pressure hydraulic cylinders. One was missing, and when I asked the Hydro engineer why, he informed me that they were having considerable trouble with the seals constantly leaking oil into the water, confirming my suspicions that such an operating mechanism required considerable maintenance when compared with wire rope hoists.

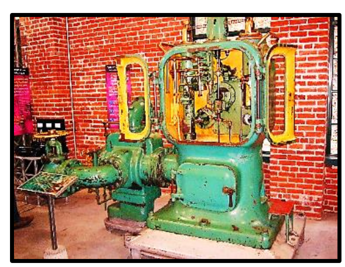
The spillway has 5 quick-release gates based on the design developed for St. Marguerite and also used at Ossokmanuan. With their usual attention to detail and conservatism, Hydro engineers had inspected these spillways and also the single gate at Lachute. In addition, to verify the design, they had conducted a full test on one of the gates, operating the jack to release a gate while filming the episode with a high speed camera. I was shown the film during one of the Peribonka meetings – quite impressive!

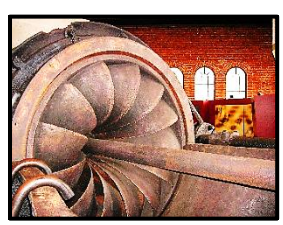
The new facility has three vertical shaft Kaplan turbines connected to 84MVA generators rotating at 112.5rpm. The spillway has three Tainter gates 10m wide by 20m high, another three 10m wide by 15m high and the 5 quick release fuse gates 10m wide by 10m high.

To compensate for the poor site inspection, we had a tour of a hydro museum built at the next powerplant about 10km downstream. It had a viewing tower where one could see the development of the sites and both powerplants. The museum had some old turbines and governors with cut-outs to show their mechanisms. Quite interesting, and very popular with the local schools.

View from tower.

Old mechanical governor cut-out.

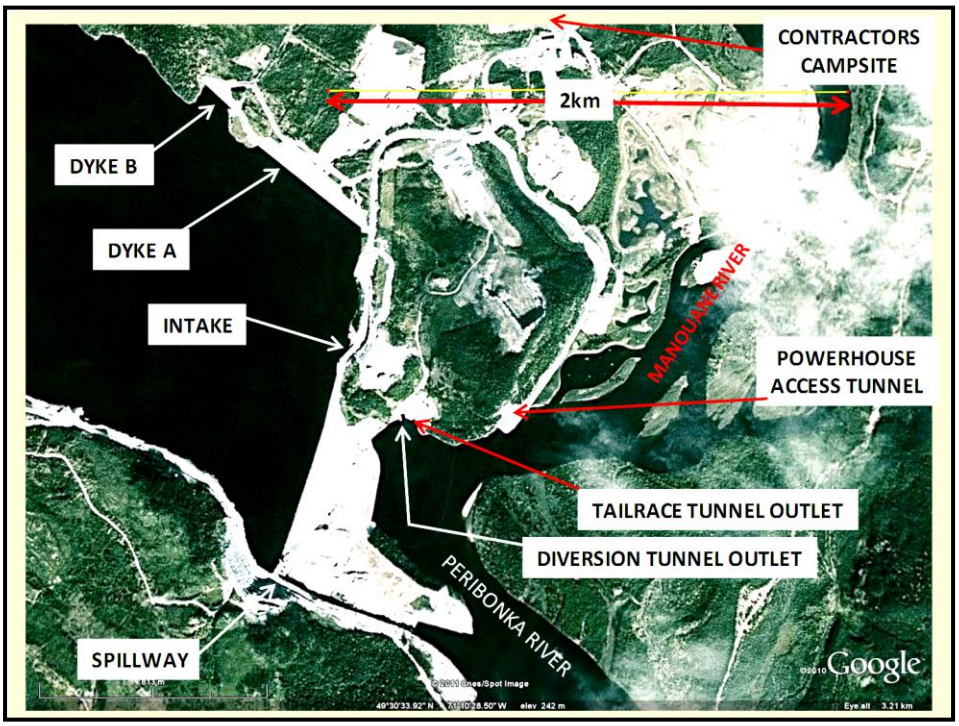




Francis turbine.

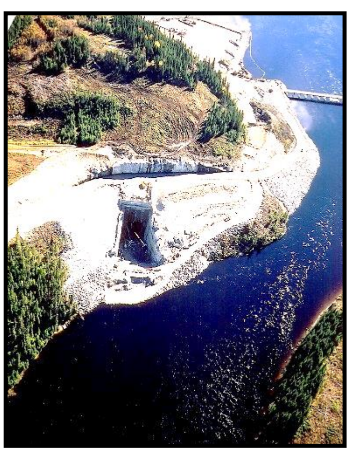
146. PERIBONKA – 2004-6

In March of 2004, we had our first inspection of the Peribonka Project. The Aluminum Company of Canada had already developed powerplants on the river, both upstream and downstream of the site, which had remained undeveloped due to the deep infilled canyon, too deep to construct a cut-off wall until new excavation equipment had recently been developed. Hydro-Quebec accepted the challenge.



Peribonka project layout.

Diversion tunnel inlet



The project included a 22km access road, a 90m high embankment dam on top of a 121m deep cut-off wall, two side dykes, a 3-gated spillway, and an underground powerhouse with three Francis units producing a total of 385MW. Construction cost was $1.2B. (HQ Feb. 11, 2014)

Start of construction of temporary bridge over river.

On our first two trips we flew in by helicopter since the access road was still being built. We saw the inlet to the 13.5m wide by 16m high diversion tunnel, the start of a temporary bridge over the river, and the damsite. We stayed at accommodation provided for the contractor's foremen, and dined at the worker's camp, since not all contractors had started work. Once the road was finished, we stayed at the 4-star "hotel" built for the operators.

Contractor's camp.

Inlet channel for diversion tunnel.

Placing cofferdam at diversion tunnel outlet.

Diversion tunnel plug.

When the dam was finished, a cofferdam was built at the outlet, and the diversion tunnel was closed off with a concrete plug in May of 2008, and the units were commissioned shortly thereafter, right on schedule. It was a remarkable achievement, bearing in mind that records were set with the depth of the cut-off and a new contractor had to be engaged when the first one could not excavate to the depth required on the cut-off. We were impressed by the quick response to the problem by Hydro, when they quickly engaged the second contractor.

Spillway abutment excavation – crane installing wire mesh for safety.

The spillway is located on the right abutment where a large excavation was made to form a notch for the spillway and the spillway chute. Fortunately all the excavated rock was used to build the dam. There was some concern about the safety of the workers below when they were constructing the spillway. Would rock spalls fall down onto the workers, or end up on the benches. To resolve the issue, Hydro undertook an experiment, with a bulldozer pushing rocks off the top of the cut and watching to see where they ended. They even had a video crew out recording the event.

Rock cut into abutment, now covered with wire mesh.

The result was quite spectacular. Some rocks bounced down all the way to the bottom, ending up in the spillway chute. In view of this, the entire cut was covered with 3mm wire mesh, requiring the use of a very large crane to hoist the rolls of wire mesh for rock anchoring to the face.

Looking upstream at spillway structure.

Looking down completed spillway chute.

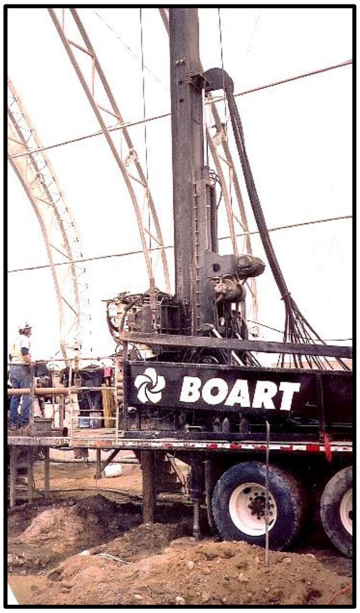
30m drop into spillway chute plunge pool excavation.

The spillway has three gates 11.5m wide by 18.5m high, with a capacity of 5,300m^3/s. They discharge into a partially concrete lined chute to a drop into a 20m deep plunge pool before flowing back into the Peribonka River. When the headpond was filled, timber debris floated down to the spillway where it was removed with a dragline and burnt.

Spillway hoist structure. Full headpond. Note debris.

Bauer rig on panel excavation at Dyke A.

Dyke A and the main dam were both built on pervious alluvium deposits, and required cut-offs to the rock below. The alluvium around the cut-off was grouted to both stabilize the alluvium and provide a second line of defense in case there were holes in the cut-off. This proved to be a challenge, since alluvium had not been successfully grouted to such depths. However, a new drill rig had been developed to undertake such work. It was very sophisticated, with a computer system recording and monitoring the rate of grout injection, the volume and the pressure on six nozzles simultaneously.



Boart grouting rig on cut-off wall.

It proved to be very successful, and the question arose as to why build the wall if the grouting was accomplishing the same task. The answer was easy – it was not possible to test the continuity of the grouting, hence the wall was necessary for a conservative design.

Technician watching grouting progress on 6 vents, using a computer.

Hoarding over cut-off wall grouting work on main dam during winter.

The vertical cut-off wall, only 1.0m wide was excavated with a clamshell as at Shikwamkwa, and tied into the foundation rock by using a newly developed "hydromill" to cut about 0.5m down into the hard granite rock foundation, to provide a positive seal.

View of hydromill cutter teeth.

Hydromill rock cutter. Note boulder caught in teeth.

One problem encountered by the hydromill was excavation of the abutment rock on the very steep sides of the in-filled valley, which were nearly vertical in places. This was solved by first pouring the concrete panel nearest to the abutment, and then lowering the cutter with one wheel stationary, rolling down the concrete panel providing side thrust for the other wheel cutting into the rock. This proved to be a very slow but successful operation.

Interlocking panel excavation at Dyke A.

After this, construction of the dykes and dam became a relatively simple task, with the usual careful attention to quality and choreography of the large number of machines working on the dam – I counted over 20 on one occasion.

Main dam core placement and upstream filter.

On Peribonka dam.

View of excellent "pine-tree" contact filter to core.

Dyke B piezometer shed with telemetry.

View of dam with nearly full headpond. Note trash and debris in headpond.

Upstream face of Dyke A. Rip-rap placed with long-arm shovel, not bulldozed, to achieve a smooth face.

Completed main dam upstream face.

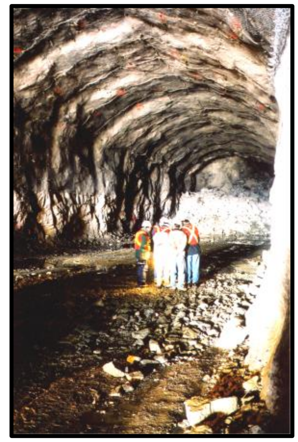
Downstream face, main dam.

The panel of experts. Dr. C. H. Yeh, Alberto Marulanda, Dave Kleiner and Jim Gordon.

Penstock formwork installation.

The three intakes are cut into a vertical rock face at the end of a short channel. The gates are 6.4m wide by 8.3m high operated with wire rope hoists located below the deck, contrary to my recommendations. It was a Hydro "standard", now discarded after a similar intake at Eastmain flooded as I had anticipated.

Upstream face of intakes.



Powerhouse access tunnel.

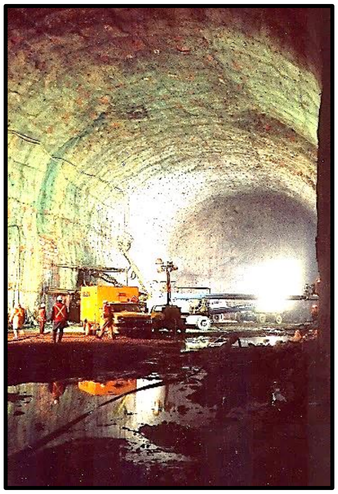
Access to the underground powerhouse is through a 477m long tunnel 11m wide by 10.3m high. The width was dictated by the space required for two rock spoil haul trucks passing inside the tunnel. The roof arch was fully wire meshed for safety. There is an 8m square door at the entrance, smaller than the tunnel since excavation work is completed.

Intake deck with air vent housings.

Powerhouse access tunnel portal.

Completed access tunnel portal.

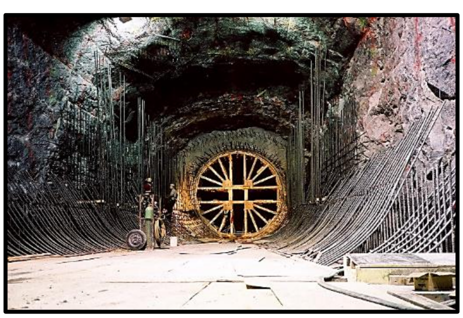
The 115m long underground powerhouse has three vertical shaft Francis units within a 37m high cavern. At the East end there is a large repair bay and control building, with the building being constructed after the units had been assembled. This provided extra floor space, so that two generator rotors could be assembled at the same time.



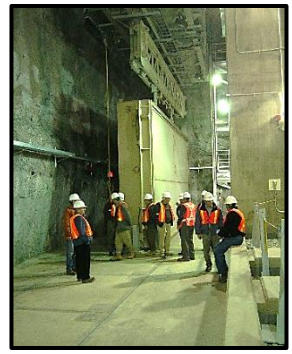
Powerhouse cavern.

Another construction feature which contributed to an early powerhouse completion was the installation of long steel columns from the lowest rock excavated level to support the crane rail, instead of starting the columns at the generator floor level, after most of the concrete had been poured. This allowed the early installation of a temporary construction crane and later the two powerhouse cranes, which were then used to install the turbine casings and help with the concreting. Both cranes are used to lift the 385 ton 8.9m diameter generator rotor.

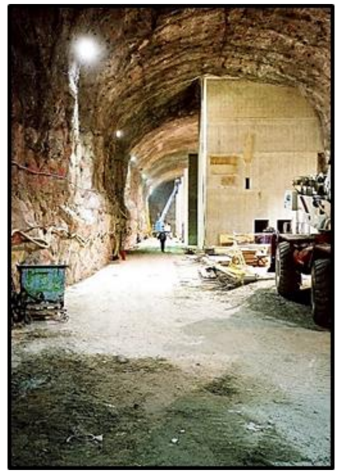
Penstock access tunnel at powerhouse.



Concrete form and re-bar in draft tube.



Half of 9.3m wide by 4.5m high draft tube gate.

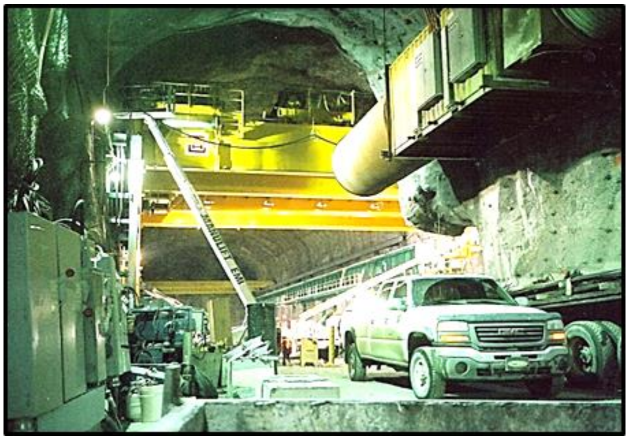


Transformer and draft tube gallery completed. Repair bay area in foreground.

Transformer and draft tube gallery.

Left - Installing steel spiral casings. Note steel columns from lowest concrete level.

The turbine runner weighs 35 tons and rotates at 128.6 rpm.



Powerhouse gallery entrance, two 205 ton crane installation.

Powerhouse gallery upstream wall – note steel columns and man in center platform directing crane.

Two cranes installing generator rotor. Source – Hydro Quebec.

There was an amusing incident during one of the early presentations to the Panel. One of the consultant's engineers was describing the generator and mentioned that he had found an old 1961 paper by a Mr. Gordon on inertia, and had used the data to determine the required inertia for the Peribonka generator. The engineer behind him quietly mentioned that the author of the paper was sitting behind him, at the head of the U-shaped table!

Completed generator floor and two 205 ton cranes.

Cooling water piping gallery.

Cable tray corridor.

The "panel of experts*" with HQ engineers. Dave Kleiner*, Jean-Pierre Tournier, Jim Gordon*, Alberto Marulanda*, Alain Grenon, Jean Maniez, Remi Dussault, Dr. C. H. Yeh*, and Bernard Turgeon.

It was another very successful development for Hydro Quebec, on time, and below budget.

147. RUPERT RIVER – 2004-6

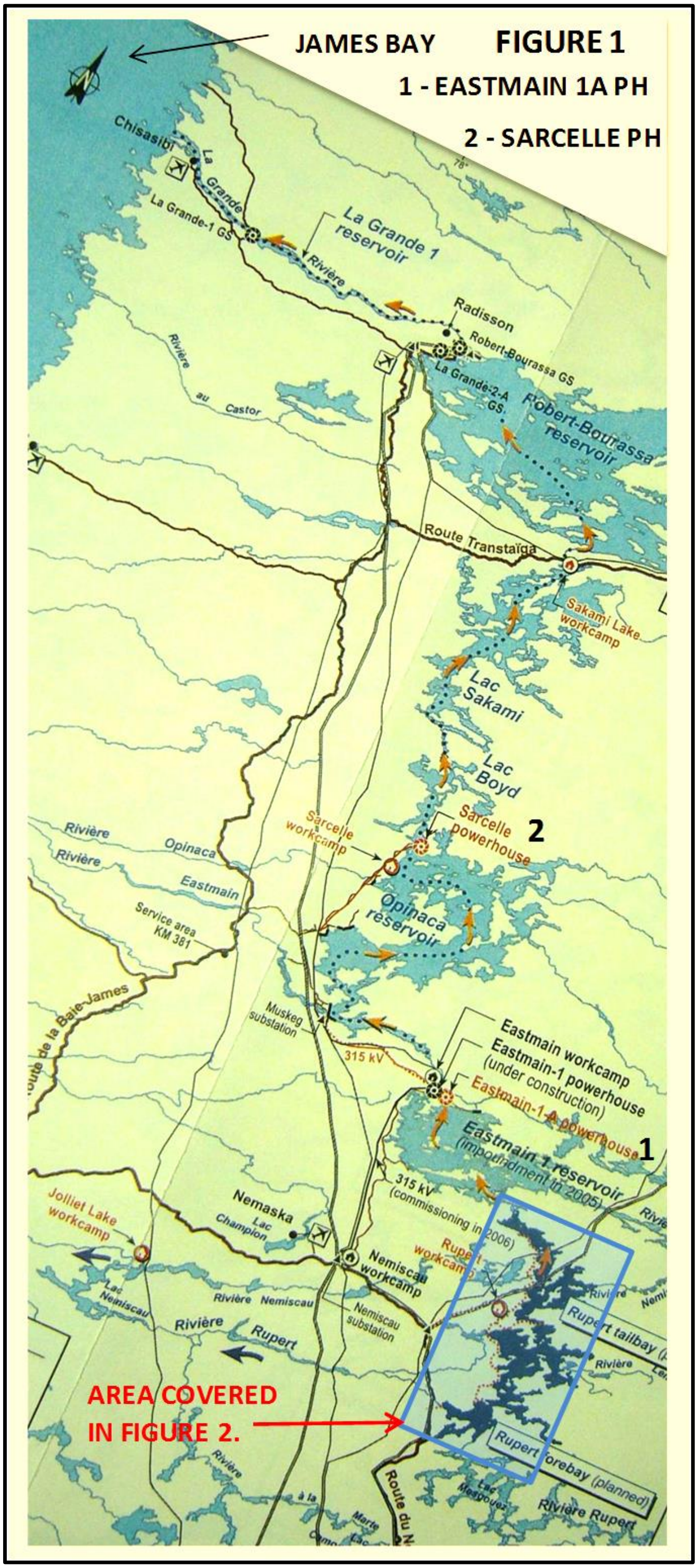
The last project I worked on for Hydro Quebec, was the Rupert River diversion. However, in 2006 HQ decided to divide the "Panel of Experts" into two, with one group looking over the reservoir structures, and another group looking over the power structures. Also, they wanted a younger panel, capable of working through to the completion of the Romaine River projects to about 2015. Consequently, both Dr. Yeh and I were retired after our fall 2006 meeting. Just as well, since I had already decided that it was time to retire for a second time. Don Coulson took over my position on the "Power Panel".

Unfortunately, I never got to see the Rupert site, since for the first 2 years, all the work was on concept and development of designs. All figures in this chapter are obtained from Hydro Quebec reports.

It was another vast project, the partial diversion of the flow from a drainage area of over 48,000km^2, about equal to the combined area of Vermont and New Hampshire. Net diversion flow will be 452.6m^3/s. The work will require the construction of 4 dams and 65 dykes with a total volume of 5,600,000m^3 around the Rupert Forebay and Tailbay. Also, the construction of 9 canals, a 2,910m long transfer tunnel, a new powerhouse at Eastmain 1A, and a low head Sarcelle powerhouse at the outlet of the existing Opinaca Reservoir, at a cost of $5B.

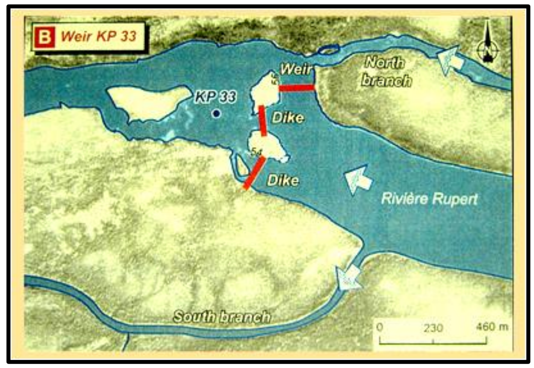
The flow will be diverted north across the Lemare and Nemiscau Rivers. Flow from these rivers will be passed on at the spillways by means of gated outlet structures, with controlled releases mimicking the variations in natural flows. Flow will pass into the large Eastmain Reservoir and on into the even larger Opinaca Reservoir, and then on down into the La Grande River Robert-Bourassa Reservoir, as shown in Figure 1. There are no powerplants on the watersheds, since the reservoir level at Rupert, will be only 23m above the reservoir level at Eastmain, with about a third of the difference being lost at the inlet weir and transfer tunnel. However, a large powerhouse will be built just east of the existing Eastmain Powerhouse to satisfy the treaty terms with the Native Peoples.

Rupert Rapids at km33 – Source – Panoramio photo.



Rupert River diversion.

Since there are some recreation and fishing activities on the Rupert River, there will be 8 weirs to maintain the normal flow depth, all designed to allow fish passage. They will be located at existing rapids and low waterfalls such as at Weir KP 33, (33km from river mouth) where there will be 2 dykes and an overflow weir, with a south branch stream left open to act as a fish bypass.



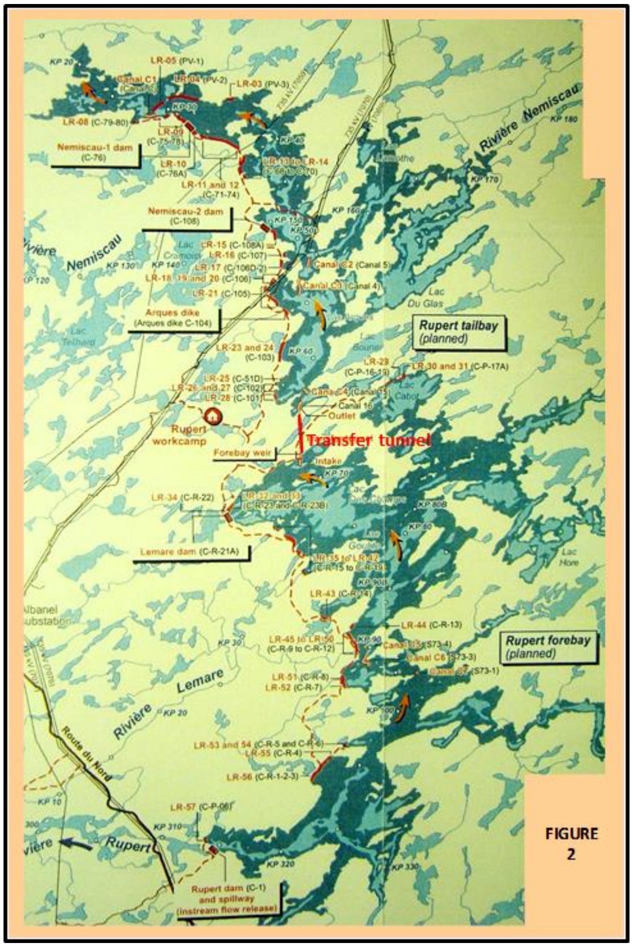
Dyke and weir concept for km33 rapids.

Most work will be concentrated around the Rupert Forebay and Tailbay as shown in Figure 2. The 2.9km long transfer tunnel is between the forebay and tailbay.

Unfortunately, due to the low head of only 10.8m at Sarcelle and low cost of energy in Quebec, the Sarcelle powerhouse is not economic, but is being built as required by the treaty with the First Nations. It will include three of the largest bulb-turbine units in the world, with a diameter of 7.1m, about the same as a WW2 submarine.

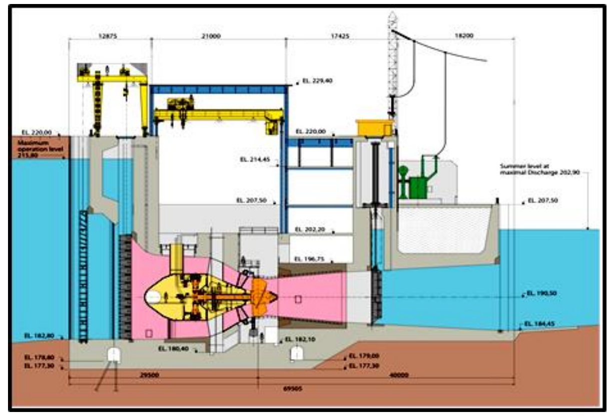
Rupert River at KP 223, 223km from outlet.

Site of a weir.



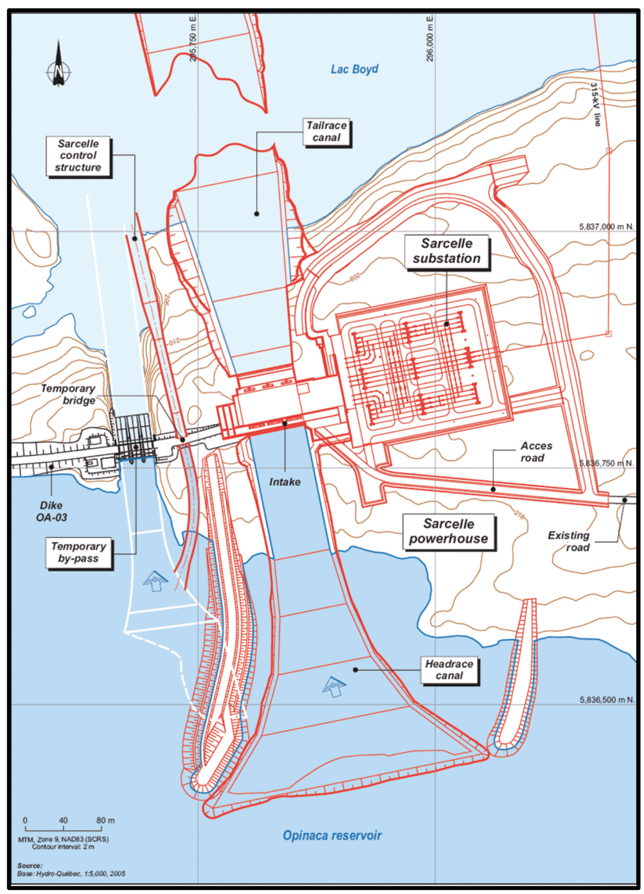
Rupert Forebay and Tailbay dams and dykes.

During our discussions on the layout, I tried to convince the HQ engineers that a horizontal access to the submerged bulb would be beneficial, since it would avoid the restrictions imposed by the "enclosed space" access requirements, and I gather Don Coulson also tried, but with no success. The horizontal access would be through two horizontal vanes at the upstream end of the bulb, and has been successfully used on other plants. HQ had looked at this alternative, but found that it would theoretically decrease the efficiency by a fraction of 1%. Unfortunately, they did not look at the possibility of angling the vanes to even out flow reaching the turbine, and I believe that this would have more than compensated for the efficiency loss.



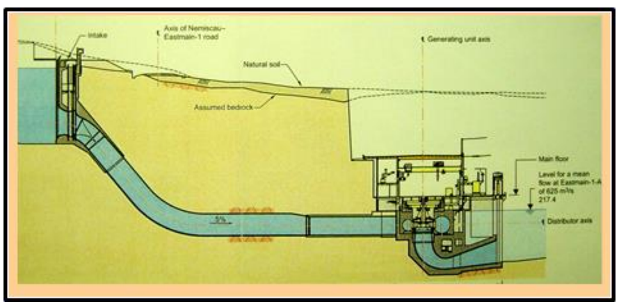
Near-final section through Sarcelle Powerhouse.

The other powerplant is at Eastmain 1A, where there will be three vertical axis Francis units with a runner diameter of 6.7m operating under a head of 63m to produce a total output of 768MW. The powerhouse will be very similar to the adjacent Eastmain 1 powerhouse, but about 50% larger due to the larger turbines.



Sarcelle Powerhouse site plan. Source – HQ.

HQ wanted to "fast track" the construction work, and asked for ideas. They were very keen to try using pre-cast concrete panels for part of the exterior powerhouse walls, so that the building could be enclosed at an earlier date. This was approved, and I understand has been an outstanding success. I suggested that they also add a short tunnel from the penstock access tunnel to the other side of the powerhouse generator floor, to provide access for small parts and construction materials when the repair bay was full of the generator components. A loading bay, only accessible with the small auxiliary crane hook could be used to transfer components to their required location. However, I do not know if the idea survived the change in the "Panel of Experts".



Section Eastmain 1A intake to powerhouse.

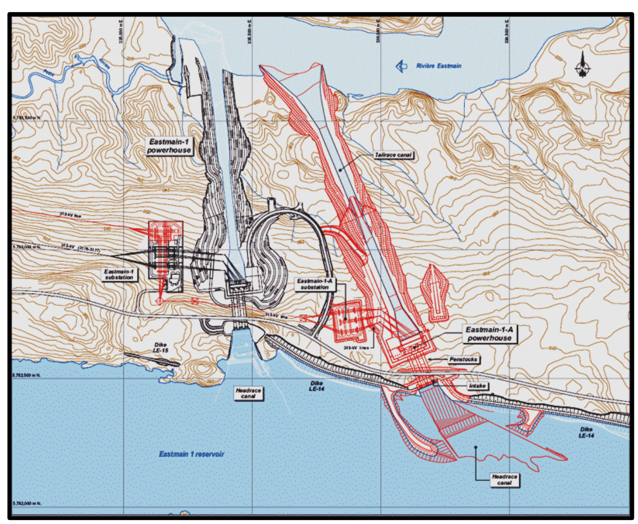
Rupert hydraulic model of intake channels.

A major issue at the new Eastmain powerhouse was the flow pattern approaching the powerhouse. It had to be smooth enough so that all three intakes received the same volume of water, and there had to be no effect on flow to the existing Eastmain 1 powerhouse, just downstream. The issue was solved with the help of a hydraulic model by shaping the intake channel and adding a groin.

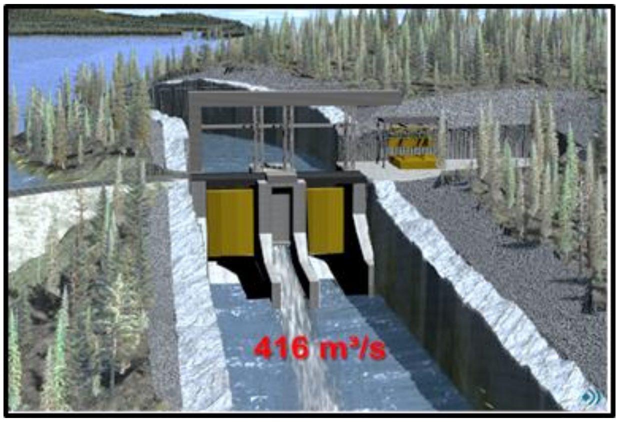
Eastmain 1 intake on left, 1A on right.

By this time, the staff working for the consultants on the project had acquired an enviable experience on hydro design. To borrow an analogy from boxing, they could have undertaken the work with "one hand tied behind their back!" This prompted HQ to add another consultant to their roster of acceptable Quebec-based consultants. They were awarded the design of the Rupert River weirs, and as their experience improves, no doubt they will be awarded more complex assignments.

Also, by this time, the computer-aided-design (CAD) programs now available to facilitate design and construction optimization were so sophisticated that it was possible to closely investigate the benefits of different layouts for the generator components on the repair bay floor, and the effect on other floors.

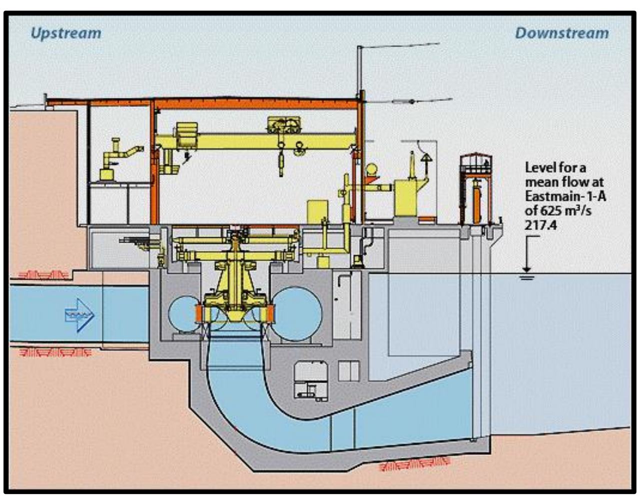


Plan Eastmain 1A Powerhouse. Source HQ.



CAD Rupert Spillway concept. Note similarity to actual spillway - below.

View of Rupert Spillway, completed. Hoist access to gate hoist moved to opposite end. Source – CBC News.



Section through Eastmain 1A powerhouse. Source – Hydro Quebec. Total turbine flow 1,344m^3/s.

Another very interesting project, but unfortunately I left long before it was completed.

148. HYDRO QUEBEC – 2004

Before leaving Hydro Quebec, I should mention that they are by far the best utility in Canada, if not the world, and are equal to or better than other superior utilities such as Vattenfall in Norway. Their approach to hydro development is quite unique. They have looked at all the major rivers in Quebec, prepared pre-feasibility studies and determined the cost of development. From this list, they have selected the most attractive and developed more reliable estimates to rank the sites in order of economic viability, and now have a program of development stretching far into the future.

They have an experienced and dedicated staff, and they maintain extensive statistical data on costs and equipment parameters from all their projects.

When we were preparing our reports, we were accommodated in their meeting rooms in Montreal, and were surrounded by filing cabinets and piles of reports, and drawings for future developments on Quebec Rivers which I had never heard of.

On return flight from Peribonka. Jim Gordon, Jean-Pierre Tournier, Alberto Marulanda and Remi Dussault.

Site accommodation - the VIP lounge, a 4-star hotel.

After meeting our "POWDAC" team (Chapter 107), HQ went on to develop their own program in much more detail and kept it up-to-date as needed. It is now used on all their studies at a considerable saving in engineering costs.

Also, HQ makes extensive use of "Panels of Experts" on all their projects. They look at possible alternatives not envisioned by HQ staff, and possible unintended consequences of their designs – added assurance for HQ.

VIP dining room table set for dinner. Note bar. Dave Kleiner and Jean-Pierre Tournier.

HQ also has a unique approach to hydro site development. They continue the feasibility study of a site selected for development further than is normal to optimize the design, and define all the structures in more detail, based on extensive use of their detailed knowledge of remote site construction costs.

Crème de champigons

\++++++

Petites salade automnale et
sa vinaigrette

\++++++

Médaillon de veau sauce crème
Ou
Poitrine de poulet Cordon Bleu

Servi avec
Pommes de terre du château
légumes du marché
Riz pilaf

\++++++

Gâteau mousse d'abricots
Ou
Bavarois à l'orange sanguine

Thé, café et infusion

Bon appétit

Typical 4-course dinner menu. Construction camp food was never like this!

A set of drawings are produced showing the concept for all structures, and this document is turned over to three consultants selected to undertake the detailed design. One works on the access road, bridges and construction camp, another on the dam, dykes, spillway and diversion structures, while another works on the power structures, the intake, penstocks, tunnels and powerplant including all the associated equipment. The consultants do not have access to costs, and we were rarely advised of the cost breakdown. Site management, construction supervision, safety, quality control, scheduling and cost reporting was all undertaken by Hydro staff. The consultants only had a liaison engineer on site to clarify any difficulties with the drawings.

At the site, the camp included a "VIP" set of trailers or a building with about 20 rooms, dining, bar and lounge facilities. It was later expanded to accommodate all the operators on the project, while the rest of the camp was dismantled and moved on to the next project. The VIP accommodation was equivalent to at least a 4-star hotel!

Typical VIP room at site camp, later to be used by construction foremen.

We were always very comfortable, and were provided with hard hats, safety vests and yellow raincoats if needed. The hard hats were inscribed with our names and stored in lockers until our next visit – all very efficient.

About to board plane at site. C. H. Yeh, Alberto Marulanda and me.

The only drawback to this approach is that the consultant's staff never obtain valuable site construction experience. The only way to obtain such experience is to work for Hydro Quebec and then move to consulting. However, their salary scale for site engineers is far higher than for consulting work due to the remote locations of sites, and no accommodation for families, hence engineers find it difficult to return to consulting.

Finally, HQ has wisely decided to isolate their transmission system from the rest of North America by using DC links to both Ontario hydro and the North-East US power pool. This prevents any system disturbances from cascading through into Quebec. The value of this decision was demonstrated when relays on an overloaded transmission line near Chicago opened on August 14, 2003 and the resulting imbalance in the North American Electrical Power Grid shut down all power in Ohio and eastwards into Ontario for many hours. It took about 4 days for power to be restored to normal at some locations. Such a decision on DC links would likely not have been made by a private utility due to the cost!

On a late winter visit to Toulnustouc.

May 2007, in the Peribonka powerhouse

149. SHIKWAMKWA – 2004-6

The Shikwamkwa embankment dam is part of the Hollingsworth development owned by Great Lakes Power. It was built in 1958-9 with a crest length of 436m and a height of 29m. It is founded on pervious alluvium extending down to a depth of up to 60m below the dam and had severe seepage from the start. Unfortunately, the original design assumed that the dam would be founded on bedrock or impervious rock flour, but the contractor had difficulty with the dewatering and the foundation conditions were never verified. Seepage was being carefully monitored with weirs instrumented to transmit levels to the control center where alarms notified operators of any sudden level increase. However, by 2003, seepage, downstream boils and deep sinkholes in the upstream face had reached such an extent that the risk of a failure was deemed to be too high.

Seepage at monitoring weir below old dam.

Cut-off wall during construction.Old dam at top of photo.

Panorama of old dam and downstream valley.

A decision was made to replace the dam with a new dam about 250m further downstream. Construction started in the summer of 2004. The new dam would have a plastic concrete cut-off wall down to bedrock topped by an embankment dam with a central core tied to the cut-off wall. I was asked to be part of a 5-member review board assembled to advise Great Lakes Power on the design and construction. Our first meeting was in November 2004.

Cut-off wall during construction.

Clamshell used to excavate alluvium.

Chisel used to cut through boulders and into rock foundation.

Excavation of a panel. Note similarity to Peribonka.

Oversized rocks removed from excavation.

The construction contract was innovative – a partnership between the contractor, consultant and owner with an agreed target price and schedule, with the partners sharing in savings and cost over-runs. It worked very well.

Left – surveyor with GPS and computer on staff. Knapsack full of stakes to place at intersection of material sections.

The days of large survey crews are long gone. Now just one person equipped with a GPS, computer and some stakes can easily set out the entire dam within an accuracy of a few centimeters. All they do is pound in a stake at the intersection of dam materials on every lift as the dam increases in height. Unfortunately, this new technology now excludes summer engineering students from a valuable learning experience. However there still are opportunities for students at the site laboratory, if they are interested in geotechnical engineering.

Plastic concrete being poured into cut-off trench.

Compacting core material on dam. Cut-off completed.

Tri-axial testing machine in site laboratory.

The seepage through the old dam was so severe that a stream and ponds with fish had developed downstream. The Department of Fisheries insisted that the "seepage" flow should be maintained with the new dam, and this required the construction of an intake at the upstream toe of the dam, a long pipe to an outlet structure below the new dam with two valves, each capable of maintaining the required "seepage" flow!

Placing embankment material.

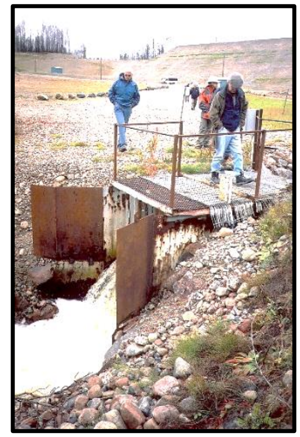
This added considerable expense to the project. Just shows the unintended consequences of a faulty design. The pipe was also used as a temporary by-pass for seepage flows and foundation pumped flows during construction of the new dam. Controlling groundwater during excavation of the cut-off wall was difficult due to the extensive seepage from the dam through the foundation gravels.

Panorama of partially completed dam.

Carefully placed rip-rap on upstream face.

A deep pumping well system had to be installed upstream of the new dam with the water pumped over the dam to be discharged downstream. Even with careful control of the upstream water level, there was one incident where there was a local failure in the trench excavation which required repairs. Grouting of the alluvium as at Peribonka would have prevented such failures, but this solution was a far too expensive, about doubling the cost of the cut-off.

The completed dam, November 2005.



Seepage monitoring weir below new dam.

The bedrock was grouted in the area of the wall contact, but a secure notch into the rock was not possible, since the only equipment available for notch excavation was a chisel. The Hydromill machine used at Peribonka was only in the final development stage and not available until a few months later. Consequently, when the dam was finished, there was still some seepage and this caused a boil in the pond downstream of the new dam which will have to be monitored. Still, a much safer dam, built within budget and in record time – only 30 months!

The “seepage” flow outlet structure.

The review Board with client consultants. Dr. Sean Hinchberger, Dr. Ray Benson, Dr. Norbert Morgenstern, Mr. Rick Donnelly, Mr. Jim Gordon and Mr. Al Whitcomb.

Pond downstream of new dam. Green spot in middle right, below gull is a boil.

Dr. Benson inspecting downstream face, October 2006 →

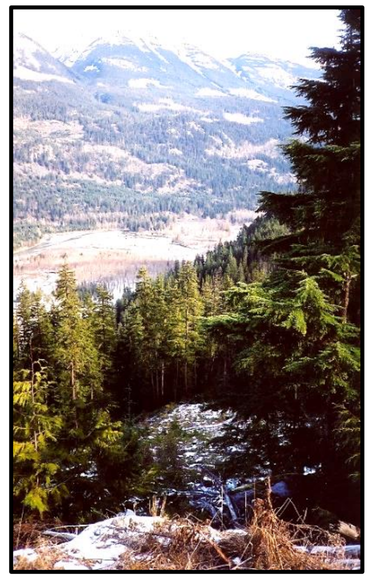
150. SOUTH CREEK – 2005

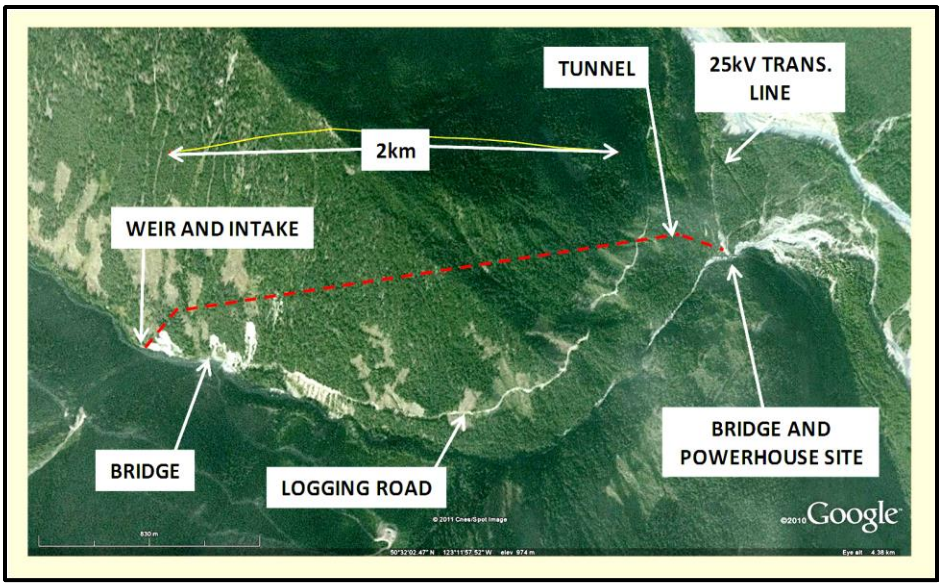
The next site visit for Brookfield Renewable Energy was to South Creek, an excellent example of how high head small hydro plants in BC are currently being found and evaluated.

When BC Hydro announced that they would be purchasing energy from small high head run-of-river plants, a rush ensued to discover suitable sites. Many companies started the search for creeks with substantial drainage area and steep slopes within 25km of transmission lines and 10km of logging roads.

Our transport – a Norwegian army snow cat!

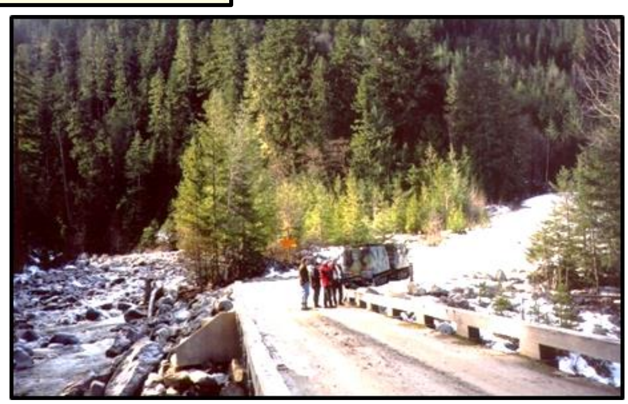
View from road looking down possible penstock route.





Proposed South Creek layout.

Below - We arrive at lower bridge – powerhouse site on right.



On road zigzagging up to the damsite.

Once they found a possible site, they filed a claim and installed a digital water level recorder capable of storing 40,000 readings with a battery lasting about three months. The recorder was hidden among the boulders and someone hiked into the site about every two months to change the battery and download the readings. The main problem was calibrating the records and I don't know how this was done. After they had about 18 months of flow records, they tried to co-relate the flows with nearby creeks or rivers with longer records. This was also difficult, since there is a wide variation in creek flows due to watershed orientation, land type and elevation.

Frequent stops to remove boulders from road.

Passing a steep rock cut.

With a rough estimate of the flow and topographic data from maps and Google Earth, a small consultant would be engaged to prepare a very preliminary cost estimate. Armed with a cost, the site owner would then look around for a developer to purchase the rights, and this is when Brookfield came in. Mike Walsh was Brookfield's financial number cruncher, and decided that the site had possibilities, so he called Jean Pellerin, Brookfield's Director of Hydro Development, who called me, and we all met in Vancouver, where Mike had engaged the services of John, the owner of a wilderness adventure company with a snow cat.

Looking up creek towards intake site.

At the upper bridge site.

Mike rented a large Dodge Durango 4X4truck and we then met the site owner, Melinda Straight in Pemberton and drove on to meet John with the Norwegian Army surplus snow cat on the Lillooet River west bank road, north of Pemberton. The snow cat had a trailer partly filled with extra gas tanks and survival gear. Fortunately the weather was excellent, and our only fear was being stuck on the road if it was blocked behind us by boulders or a landslide, a common occurrence in the springtime, we would have had to walk out. Luckily, this never happened.

We had to make several stops to remove boulders from the road, but fortunately none fell behind us. The snow cat was indeed an army vehicle with only basic amenities. We all managed to squeeze into the cabin and set off along the steep road zigzagging up the mountain, and after about a kilometer reached the relatively flat section curving around the mountain to the upper bridge. We stopped at the bridge where Melinda retrieved the latest flow data from the hidden recorder. We could not reach the damsite about 350m further up the creek, since the path over the boulders was too slippery, covered with ice.

However, I had seen enough to prepare a pre-feasibility estimate using HydroHelp. Melinda had an excellent GPS and had provided data on road levels and distances from the lower bridge. The previous consultant had suggested a long penstock buried in the logging road, and this was possible if the road could be closed for a couple of summers. Another alternative was a 3km long tunnel, and this was selected since the road closure was debatable. With HydroHelp it was easy to optimize the project structures and estimate energy and costs for alternative capacities. An 11 page report with 5 appendices was produced, but costs were on the high side, and there was insufficient flow data to justify further work for the time being. An interesting assignment and a trip in a Norwegian snow cat!

The site inspection team. Mike Walsh, Melinda Straight, Jean Pellerin and Jim.

151. MILL CREEK – 2005

In March, I had another call from Mike Walsh of Brookfield Renewable Energy in Vancouver, asking if I could look over a couple of small hydro prospects. The first was at Mill Creek, just west of Squamish, where a pulp mill was closing down and they were looking for someone to purchase their hydro plants. We took a ferry from Squamish over to the plant, returning by water taxi later in the afternoon.

Ferry approaching pulp mill near Squamish.

Intake with sloping bottom trashracks.

Their small hydro plant had been built in 1947 and had a small weir across a creek with close-spaced trashracks on the bottom just downstream of the weir. Of course, the intake captured all the fine silt and sand, but this was filtered out at a screening room where fine stainless steel mesh screens removed everything over about 1.5mm. However, the screens had to be flushed down frequently by hand with a pump and hose. Upstream of screens, there was a bottom sluice built into the wood flume which was used to discharge gravel, and a balancing tank where surplus water flowed back into the creek. All very labor intensive, but quite acceptable for a pulp mill where the older workers welcomed an easier job in the heated screening building.

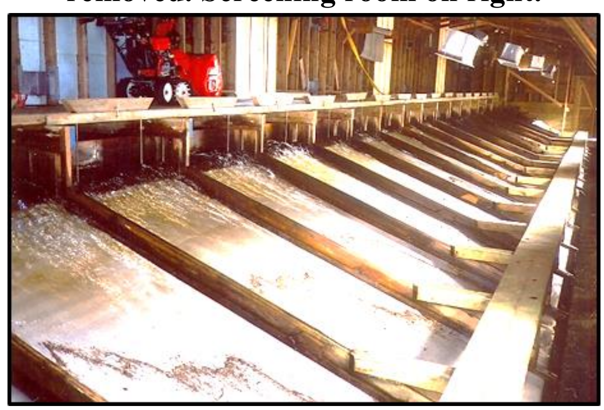
Intake sill and start of wood flume.

Wood flume from intake to balancing tank.

We took the opportunity to look at a boulder avalanche that had recently destroyed one of their logging roads past Scott Creek. With the mountain slopes at close to the angle of repose, this is a frequent occurrence. There was nothing left of the road, and my photos do not show just how destructive such an avalanche can be. An aerial view would have been required. Looking up the creek from where the road bridge used to be, all I could see was a vast boulder field ready to descend during the next severe rainstorm.

Flume, with bottom gravel sluice.

Mill Creek tank where surplus waters removed. Screening room on right.



Screening room – water flows over fine stainless steel wire mesh.

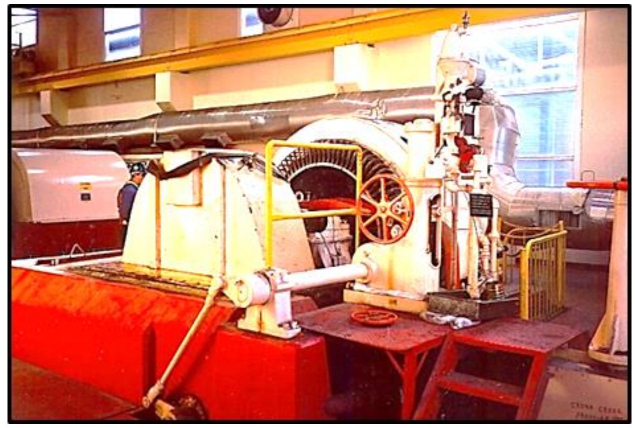
Boulder avalanche at Scott Creek.

The powerhouse contained a single impulse unit meticulously maintained, since it was their only source of power when the transmission line was down. The turbine had been manufactured under license in Vancouver. However, the labor required for operating the plant detracted from its value, and nothing was developed.

Horizontal axis 2-jet impulse unit, installed in 1947.

Cedar Creek screen house and tank – note penstock.

Cedar Creek is also on the property, where a similar intake, flume and balancing tank have been installed. There is a small pond at the head of the creek, with a concrete dam and sluice gate, only accessible on foot. Another small hydro plant could be connected to the existing intake after the screen house, and near the end of the penstock, but again, due to the high labor required for operation, it proved to be uneconomic.



515rpm, 3,234kVA, 920 ft. head Pelton Water Wheel.

An informative trip – learned more about screen houses and wood flumes.

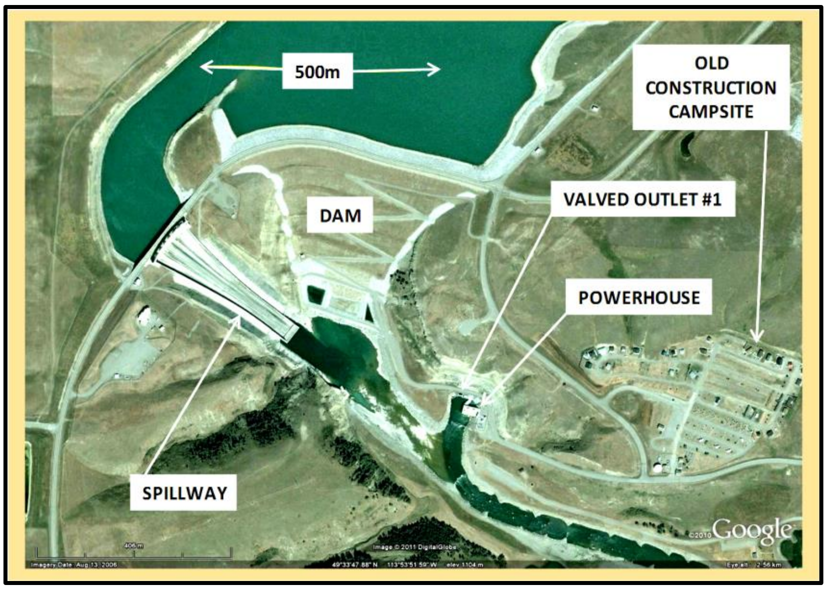
152. OLDMAN DAM POWERHOUSE – 2005

During my work with Montreal engineering, I had produced the occasional "expert opinion" for legal cases, but fortunately none had gone to trial, being settled in our client's favor at the last minute. In the following case, I was asked by Claude O'Neil, the President of VA Tech-Bouvier, (VAT) the successor to Sulzer, (now Andritz) to help defend an arbitration case where they were being assessed $2.5 million in liquidated damages for late delivery and poor performance of the turbine-generators at the Oldman Dam. It was a very interesting experience, but unfortunately we lost the case.

My task was to prepare a report on when the powerhouse was ready to accept equipment, since Claude had been of the opinion that it was no use delivering equipment to a site with no secure heated storage facilities well ahead of the actual required time. I thought this would be an easy task, requiring a quick look through the project documents. However, I found the files to be in such disarray, that I could not see how I could produce a reliable document. This is when Lorna Tardiff entered the conference room where I was working. Lorna was the daughter of George Cuthbertson, and had obtained a degree in civil engineering from McGill University. After graduation she worked for about 10 years in the field with a large contractor on hydro projects at James Bay. She then resigned and formed a company with an associate that specialized in document retrieval, control and expert testimony on scheduling at arbitration and engineering legal cases. I remembered meeting her when she was a student and was having lunch with her father about 30 years previously at a restaurant near our offices.

When Lorna was brought in by Claude, the first thing she had asked was where the files were. Very fortunately, all the project files and drawings were electronic and stored in the VAT computer in St. Catherines, Ontario. A call to St. Catherines revealed that a new computer had just been installed, and the old computer was on their loading dock, waiting for transport to a re-cycling depot, and that they had not bothered to retain a backup file. Lorna was aghast at this, and told the technician in St. Catherines to immediately go down to the loading dock to retrieve the computer, and that she would have a van there by evening to transport the computer to her offices in Montreal.

Back in the conference room, Lorna asked me what I needed, and I told her anything to do with the powerhouse crane up to the time the equipment arrived on site, and she replied that a copy of all the files would be brought in within 30 minutes. I could not see how this would be accomplished, but a half-hour later, she brought in a one-inch thick file with all the data I needed. Of course, I had to ask how she had done this, and she told me that her company had developed software for document retrieval based on key words, and that she had brought in a high speed printer, so after entering the key words in her program, the printer had immediately started to print out all the emails and letters in chronological order. So I could see how her company was very successful, with a staff of over 40 engineers and technicians.



Oldman Dam layout.

Oldman Dam – two low level outlets on right.

The project should have been very easy to construct. It involved the addition of a powerhouse to one of the existing two low level outlets at the large Oldman Dam in Southern Alberta, constructed to provide summer irrigation water. Each outlet works included an intake with a gate capable of flow control, and a long tunnel terminating in a hollow cone valve. High flows had to be maintained throughout the 6-month irrigation season, at a lower rate thereafter, and during construction of the power facility. The feasibility study had envisioned removal of one valve, the addition of a short steel penstock with a bifurcation, one leg leading to the re-installed hollow cone valve, and the other to a silo type powerhouse, with the powerhouse door and repair bay well above the generator.

The powerhouse would contain an inlet valve followed by one 25MW vertical axis Kaplan turbine, with an interconnection to the relocated hollow cone valve, retained to act both as a by-pass and relief valve for the turbine, allowing fast closure of the wicket gates. As is common in arid areas, the design flood was large, resulting in a 10m rise in tailwater at the powerhouse, hence the selection of a vertical axis unit. Since the project was marginal, the feasibility study envisioned the use of a mobile crane to install the unit, and no powerhouse superstructure.

Looking down at the two low level outlets.

Tenders were called for "water to wire" equipment, and proposals were received for a wide variety of turbines, ranging from a vertical Kaplan to 3 horizontal shaft Francis units. Due to the large variety of equipment, almost a year was needed to decide on the optimum proposal, and eventually a contract was awarded for 2 horizontal axis Francis turbines, with the turbine shaft set 3m below low tailwater! The contract included liquidated damages for late delivery tied to specified delivery dates. The low turbine setting and the large rise in tailwater, resulted in a flood tailwater 13m above the turbine shaft. The powerhouse was completely re-designed to become a concrete-walled structure with flood tailwater only 0.4m below roof level. Installation of the equipment now required the use of a mobile crane to lower the equipment through a roof hatch, and an 85 ton powerhouse overhead crane to move the equipment to its permanent location. Unfortunately, the equipment assessment had not included the powerhouse cost, and this cost was substantially higher due to the large volume of concrete required to counter floatation in a structure with a very much larger footprint.

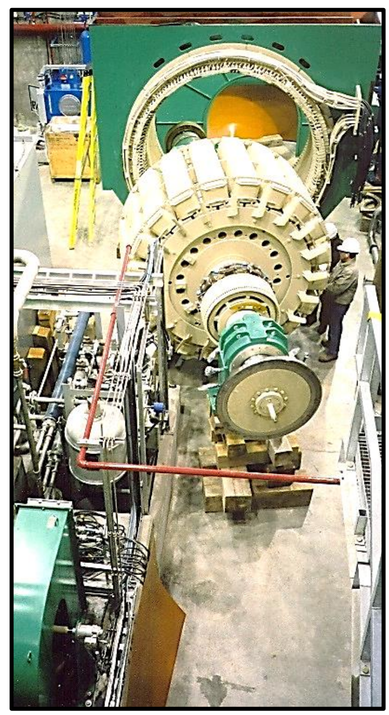
Another complication was the contract document, which had not been fully revised to incorporate the changed concept. The addition of the powerhouse overhead crane was not addressed, the change from a custom assemble-in-place generator to the use of a standard pre-engineered motor as a generator was not addressed, and the difficulty of interconnecting the hollow cone valve with 2 turbine units to allow for rapid wicket gate closure was not addressed. Also, the civil work drawings had to be completely revised, resulting in delays to contract awards for the work. The owners of the facility ATCO (for Alberta Trailer Company) now a large conglomerate, decided to act as the project manager, even though they had no previous hydro experience. They awarded separate contracts for the penstock and bifurcation, dewatering and excavation, and construction of the concrete powerhouse. Delays were experienced in all three contracts, with the result that the powerhouse was not ready for the equipment contractor until many months after the original scheduled date.

The new powerhouse. Crane about to lift out generator for repairs. Large hole in wall is relief valve outlet.

The project schedule was never updated to reflect the delays, causing considerable confusion. Lorna found that the original construction schedule was flawed, apparently showing ample time for all activities. In fact, due to a lack of "links" (example - powerhouse excavation must be completed before concreting starts) the original schedule was short by several months. This flawed schedule resulted in the owner still believing that the project could be completed on time, even after delays in the excavation work. Hence no measures were implemented to accelerate the schedule. Unfortunately the flaw in the schedule was not discovered until Lorna received the complete CD file for the computer-developed schedule just before the arbitration hearing was to commence, and this evidence could not be included in her testimony due to the arbitration rules (no prior notification of testimony) – very unfortunate.

During the arbitration testimony, it became evident that the owner did not understand the implications of the change in powerhouse concept, and believed that the equipment could still be installed with a mobile crane. In the original concept, with a single vertical axis unit, a mobile crane sitting on a concrete pad adjacent to the silo powerhouse, could easily reach over to all areas of the powerhouse. However, with two horizontal axis units, the large footprint meant the crane could only reach one corner of the building. Moving the crane to another location down in the river bed meant that it had to lift the heavy equipment over 20m high walls, an impossibility for a medium-sized crane.

The owner also believed that the equipment contractor could have used a mobile crane and commenced equipment installation at the same time as the powerhouse contractor was still working on completion of the powerhouse, to make up for time lost by previous contractors. The cost implications of working in a dusty open floor, trying to install equipment in a small powerhouse with the contractor still building the walls and roof, were never discussed.



Powerhouse with very tight repair bay floor.

VAT had considerable difficulty completing the contract. Claude was used to dealing with small entrepreneurs, whose only concern was delivery of the equipment, and was not prepared to deal with the large volume of documents required by the contract, such as schedules, layout drawings, single line diagrams, progress reports and equipment tests, and Claude had neglected to provide most of such data. In addition three incidents had delayed deliveries. One was due to an accident on the railroad during transport, damaging the full-length steel draft tube liners, one of which required extensive repairs. This delayed the powerhouse contractor, since concreting of the draft tubes and concrete above the tubes had to be delayed. Another incident was at the generator manufacturing plant. The sub-contractor for the coated stator coil wires had recently been changed, and the manufacturing process for applying the coating insulation was not functioning consistently. The result was a burn-through failure during the stator insulation test on both stators. The burns were repaired and the stators installed, but the repairs delayed commissioning by several months.

The third incident was the bankruptcy of the sub-contractor manufacturing the control panels and switchgear, just before the work was due for delivery. When another contractor took over the work, it was discovered that the owner's specification was flawed (incorrect standards) and that the controls would not function as needed (incorrect logic) and were not integrated with the hollow cone valve. All this took considerable time to rectify. In fact, the valve controls were still not functioning a year after the plant was commissioned.

Both parties had used "experts" to provide opinions on several issues during the arbitration hearings, and the total testimony documentation amounted to a large number of 3-ring binders, enough to fill a bookcase 2m wide by 2m high. All this had to be perused by the arbitration panel prior to rendering a decision. The arbitration panel comprised two senior lawyers and an experienced hydro engineer. After several months of deliberations, the arbitration panel decided in favor of the owner, since the contractor had not abided by the terms of the contract, having neglected to reply to the Owner's requests for information, and prompt production of plant layouts and work schedules. All the engineering testimony counted for naught, since the panel based their decision entirely on whether the terms of the contract were observed.

The whole process was a great learning experience, and I concluded that one should never resort to arbitration. The cost is usually very high, in this case about one-third of the liquidated damages. Always try to reach an acceptable solution. Another conclusion was to read the contract! And read it again! In this case, the contract was very clear on the extensive documentation and information required from the equipment contactor, and the dates for data submission, most if which was completely ignored by VAT. Although I felt that some responsibility for the delays was the fault of the owner, the arbitration decision had to be based on the terms of the signed contract. There were many mitigating circumstances, but none could be taken into account.

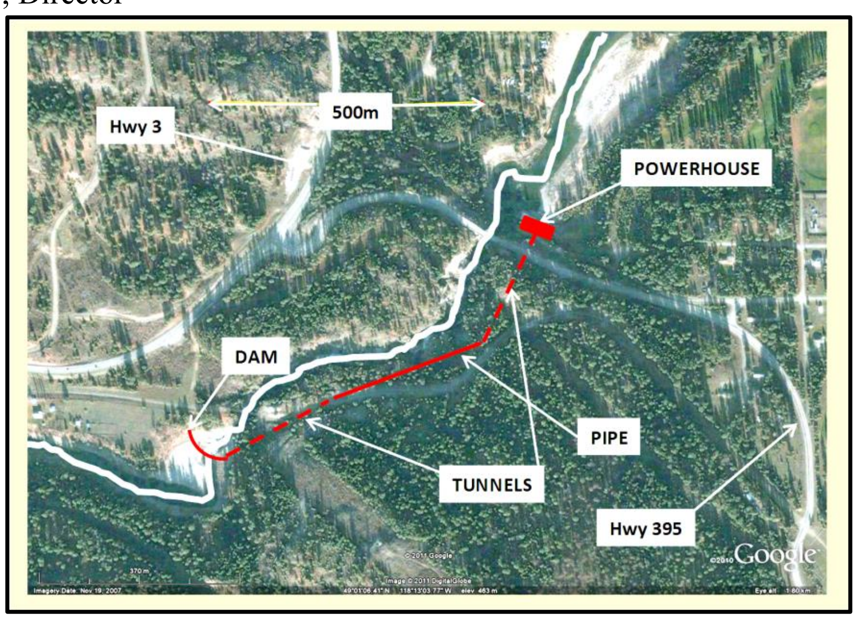
During the arbitration hearings, it became evident that although there was an extensive exchange of e-mails and the occasional meeting during execution of the work, there was a lack of understanding of the complexity of the work by both parties, and a misunderstanding of the role of a "project manager". The liquidated damages were tied to dates established prior to award of the three civil work contracts. The dates did not reflect the site conditions, and were not revised due to delays in completion of the three civil work contracts. In the request for equipment bids, the type of turbine was not specified and turbine selection was based on equipment price including an analysis of the energy produced from a defined flow pattern, without considering the effect of varying powerhouse cost.

When the change in the project concept was made, no time was taken to review the new concept and ensure that it was appropriate to the site. Turbine hydraulics were not considered in the concept change, for example, the hollow cone valve could easily be connected to one turbine to act as a relief valve, but connection to two turbines becomes very complex, and was eventually abandoned. This results in the generators going to full runaway over-speed on full load rejection faults, due to a very slow wicket gate closing time required by the long tunnel and waterhammer restrictions, not a desirable situation.

When difficulties arose on the project, no attempt was made by the owner to work with the contractors to arrive at an amicable solution. During the testimony it became apparent that there was no "meeting of the minds" at many of the discussions, and instead it became more of "it's your problem, what are you going to do about it?" The whole assignment turned into another lesson on how NOT to develop a hydro site.

152. CASCADE – 2007

In April I had a call from Chris Oakley, Director of Business Development for Brookfield in Western Canada. He wanted me to look at a possible re-development of the Cascade Falls site just East of Grand Forks in BC.

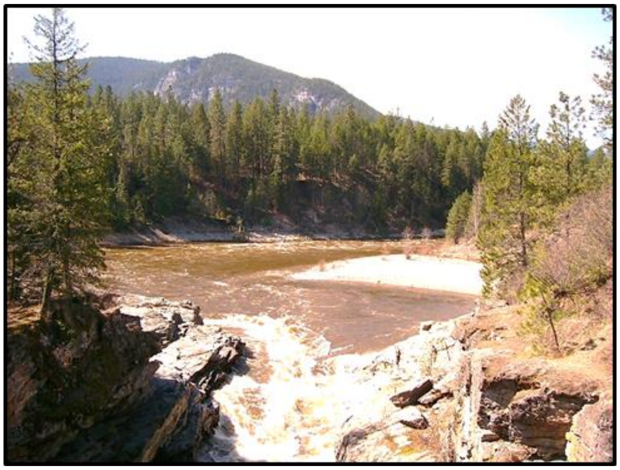


Cascade site layout.

The site had been developed with a small plant in 1897, completed in 1901, and dismantled in 1919. There was a 400ft long timber crib dam across the river with intake, canal and penstock to a powerplant further downstream. Power was transmitted to Grand Forks over one of the first 60Hz transmission lines in Canada. It had severe frazil ice problems in winter, requiring a backup transmission line to the Lower Bonnington Plant on the Kootenay River.

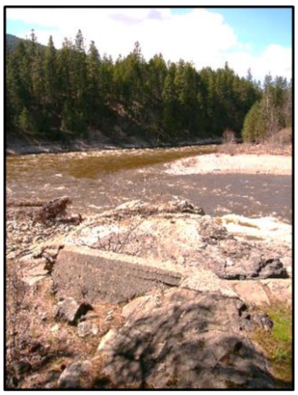
The old timber crib dam – Source - Virtualmuseum.ca

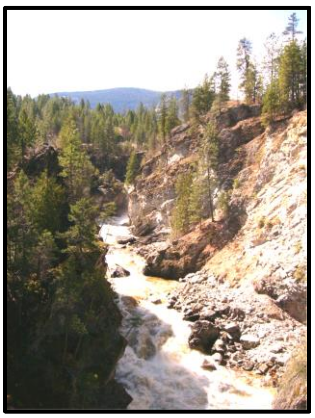
The re-development would follow the same layout used in the original plan, but with a gravity arch RCC concrete dam across the river, an intake with an adjacent low level sluice, tunnel, pipeline and another tunnel down to the powerhouse at the previous plant location. In fact, the old powerhouse substructure is still visible at the site, and would have to be demolished for the new plant.



View of damsite from lookout on abutment

View of canyon from road bridge.





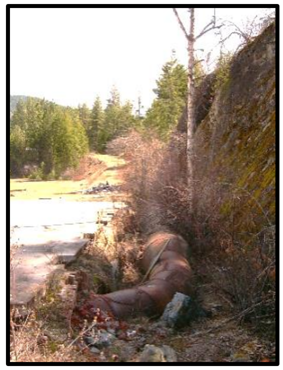
Remains of old intake.

Unfortunately, there was considerable local opposition to the re-development. However, the cost was somewhat high, and the frazil ice problem would still be evident at the new plant, since it was not possible to increase the forebay level sufficiently to eliminate the problem.

Old canal and penstock route past canyon.

The old plant must have required considerable staff to operate. But it was pioneering the development of hydro in Canada.

Remains of tunnel.



Remains of pipe into powerhouse.

Opposition sign on trail past canyon.

Powerhouse site with remains of substructure.

Remains of intake gate at tunnel – Note small filling gate. Source – Virtual Museum.

Below - Old dam sluices – Source Virtualmuseum.ca

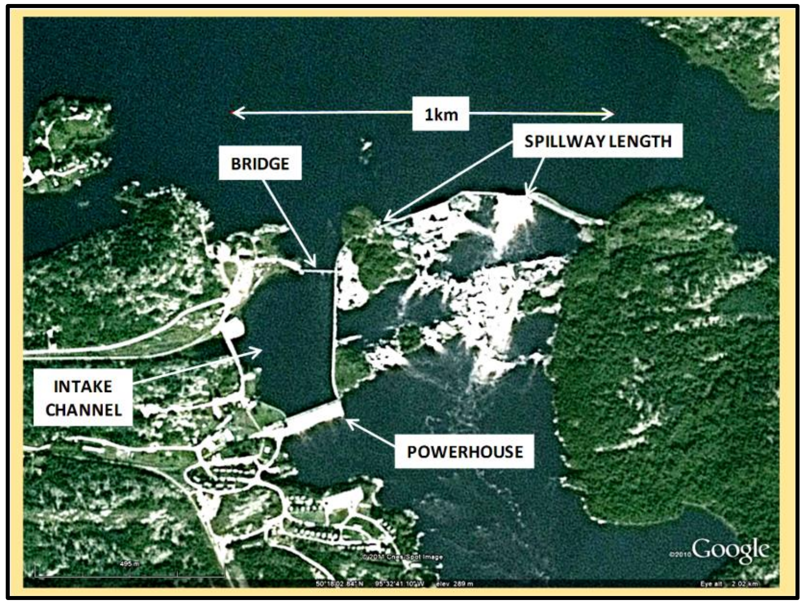
April – spring in BC, enjoyed lunch at local golf club with Chris Oakley.

View of tailwaters. Old powerhouse concrete floor substructure on right.

It was an interesting inspection, but unfortunately it did not lead to a development. The local opposition and the frazil ice problems were just too difficult to overcome.

155. POINTE DU BOIS - 2008

During the summer, I had a call from Manitoba Hydro (MH) asking me to join a Review Board looking at the redevelopment of their old Pointe du Bois hydro facility. It is located 160km NE of Winnipeg and was built during 1908-11 when the only access was by rail until a road was built in 1950. It is a low head site with a gross head of only 14m. 5 units of 3MW capacity were operating by 1911, another 3 at 4MW were added in 1914, and finally another 8 at 5.2MW were added between 1922 and 1925. All are horizontal axis double runner Francis units.

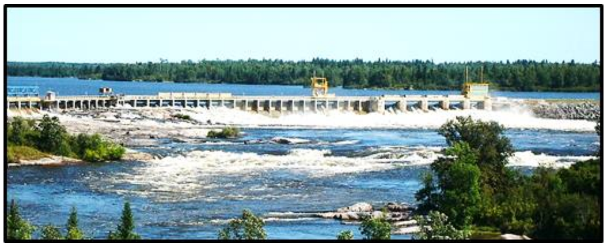


Project layout.

Being so old, the units are difficult to maintain, particularly since the powerhouse concrete shows signs of AAR, throwing the units out of alignment. The facility holds the record for the largest number of spillway bays in Canada at 68, now reduced to 64 when four were decommissioned. All spillways are stoplog-controlled with the stoplogs operated by three different hoists, all powered with electricity, requiring considerable labor.

Abandoned old stoplog hoist.

Spillway operation is difficult since there is no proper access to the structures, and no roadway on the spillway structure. Access to the west end is over a light capacity bridge, and to the east end by barge. Winter operation must be an absolute nightmare, and walking across the structure in a blizzard particularly dangerous!



Eastern end of spillways.

Near western end of spillways.

View of upstream flow at eastern spillways.

A "Straflo" unit was added in 1999 having a capacity of 8.4MW with a 3.2m runner diameter.

MH was finding that the cost of rehabilitation was very high, and uneconomic when compared to other new undeveloped hydro plants. This was due to the very low head combined with the necessity to re-build both the powerhouse and all the spillways to modern standards.

The other two members of the Hydrotechnical Review Board were Duncan Hay and Graham holder, both recently retired consulting engineers from hydraulic laboratory companies.

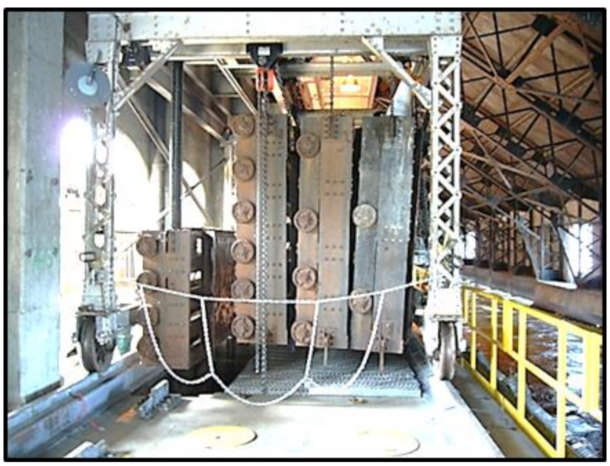
The largest stoplog hoist I have seen!

Downstream flow at eastern end of spillways.

View of spillways from near east abutment.

The best option would have been to decommission the whole facility and return the site to original conditions. But this was not considered since the reservoir now had many cottages around the shoreline, and their owners had raised vociferous objections to losing the headpond where the water level was maintained at an almost constant level.

Access Bridge to spillways, with micro-hydro turbines on barges being tested by engineering students from the University of Manitoba.

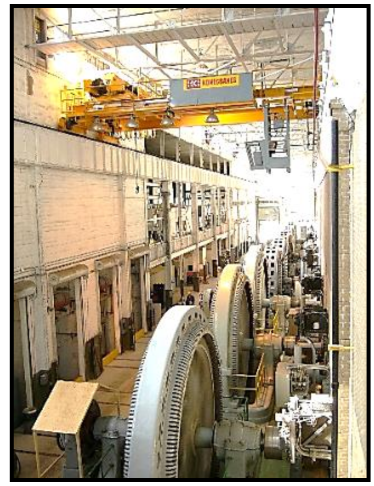


Intake stoplogs.

Intake housing.

Construction of a new facility proved to be an equally difficult task since the cottagers raised objections to large trucks and the ensuing dust, particularly on weekends.

Inside powerhouse.



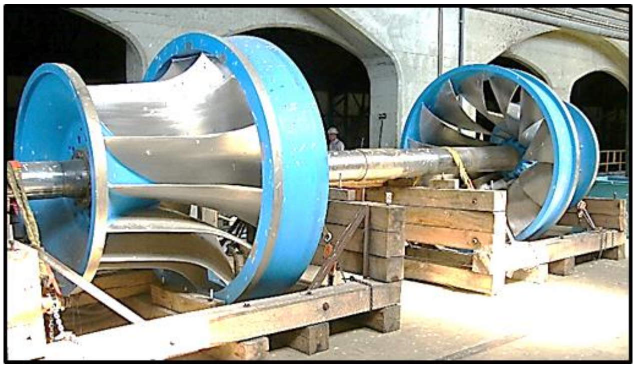
The low head and the large flood flow meant that cofferdams were larger than the final structures, and access to the cofferdams was difficult to say the least. Eventually, MH decided to decommission the powerplant, and only rebuild the spillway.

"Tin can" station service unit – operating since 1911.

Spiral stairs up to roof lookout.

There was an excellent lookout on the powerhouse roof where it was possible to see the intake channel, bridge and all the spillways.

Perhaps, an alternative to scrapping the powerhouse would be to convert it into a hydro museum similar to the one at Ruskin in BC.



New runner for one of the units.

Powerplant office and microwave communication tower.

View of dogging device on a stoplog gate.

This was to be my last extended business field trip, since approaching my 80th birthday; I had decided that the time for my second retirement was near. However, it was, as always, an interesting assignment, and a significant lesson on the costs of rehabilitation – sometimes with very old low head sites, the rehabilitation costs are just too high, and decommissioning is the best option. The facility was developed by the city of Winnipeg as their second hydro plant in the days when labor was relatively inexpensive and difficult working conditions an accepted norm. MH purchased the plant in 2002.

Likely site for new powerhouse.

Site inspection team on powerhouse roof lookout. Duncan Hay, Ryan Penner, Jim Gordon, Don Murray, Graham Holder, Kevin Sydor, Halina Zbigneiwicz, Joe Groen. Kneeling – Dennis Lemke, Barry Nazar, Garth Ferguson, and Dave Brown.

Nowadays, only a cursory look at the site by an experienced hydro engineer would indicate that development would not be economic due to the combined effects of the low head and a very wide river with a large flood flow.

155. DU LIEVRE POWERHOUSE – 2008

In April, I asked Brookfield if I could look at their recently completed Du Lievre powerhouse addition to a storage dam. I was interested in the project since I had seen the concept drawings a few years previously. My comments at the time were that they would have problems with both the syphon intake and the inclined axis unit.

View of steel box syphon intake.

The intake is a steel box, and suction is difficult to maintain due to air seepage at the concrete-steel seal where the box is bolted to the concrete. The other problem is with the gearboxes on the units. As with all other inclined shaft units, the gearboxes overheated and had to be returned to the manufacturer several times. Since there was no powerhouse crane, rental of a large mobile crane became so expensive, that two cranes were retrofitted to the powerhouse roof, capable of lifting the equipment through roof hatches onto the dam deck for transport to the factory.

There are no draft tube gates since the turbine runners are set just above normal tailwater. Unfortunately, they cannot be serviced when the tailwater is higher.

Emergency generator and intake gate hoists.

View of powerhouse downstream of concrete dam.

Cranes retrofitted to powerhouse.

Inclined axis Kaplan turbine.

It was an expensive lesson for Brookfield, but they now have complete control of the river, a major advantage, since other entrepreneurs were interested in the site.

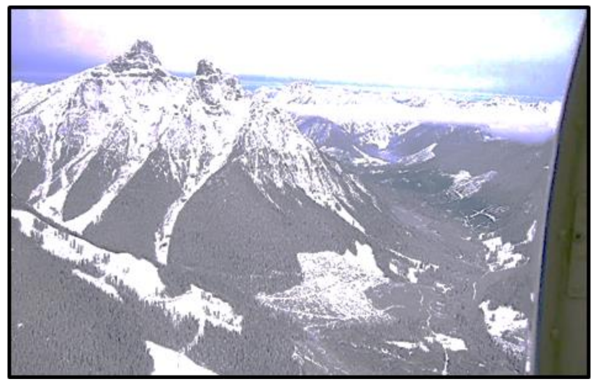
156. VANCOUVER ISLAND HYDRO – 2008

I had been sending my memoirs to the family, when I had a comment from Fiona at about Chapter 45 saying “what, no more crazy helicopter trips?”, so I will have to describe my last “crazy helicopter” trip. It was in the middle of winter and started with a call from an entrepreneur wanting a quick assessment of several small high head hydro sites on the northern half of Vancouver Island. I pointed out that they would all be covered with deep snow, so that very little would be visible, and it would be preferable to postpone the trip until about May. However, he was adamant, so off we went.

We met in Vancouver, where we boarded a local flight to Qualicum Beach, rented a truck and drove to a small logging town where we checked into the local motel. It was famous for the rooms, each of which had a different theme – mine was a jungle.

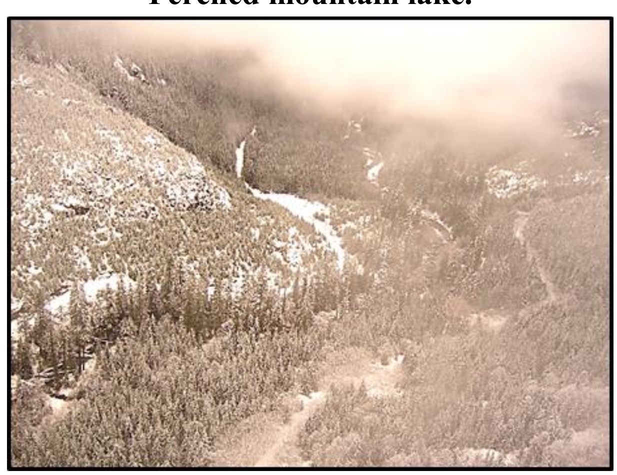
Jungle room in motel.

The weather was reasonable to start, with clear visibility and high cloud. We flew west past Victoria Peak, and looked at the first site, a perched mountain lake where some storage could be developed. Then it was off to the second site, but after looking it over, the weather deteriorated, and the pilot had to descend to tree-top level for the flight back to the airport. Fortunately, he had stopped to refuel at a logging camp, since he had to fly very slowly through the fog, avoiding the occasional larger tree. Fog is a particular hazard for helicopter pilots, and they are not allowed to fly in fog since the pilot can easily become disoriented with no visual references.



Flying past Victoria Peak, 2,163m.

Perched mountain lake.

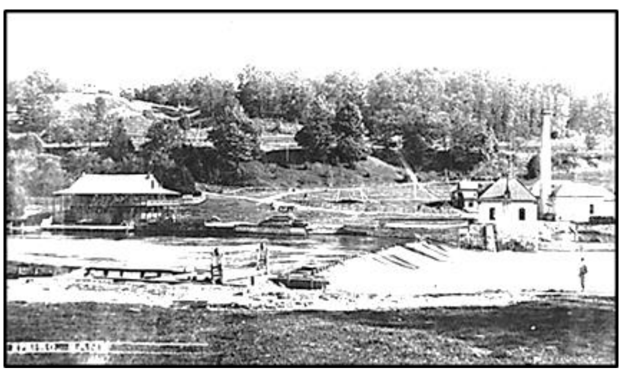


Descending down to tree-top level.

Checking with the airport tower, the pilot found that there were no other flights in the area, and we still had about 30km to travel. We could not land due to the forest cover, but since the pilot was familiar with the area, he was confident that with the help of his GPS, we would soon see the airport. As we approached the coast, the fog lifted, and we could see the airport as we emerged from the fog near the end of the runway. After my experience flying through fog in Newfoundland, I was not at all worried, but my companions were very silent during the foggy portion of the trip! Another helicopter adventure!

None of the sites were developed – just too difficult to access and too expensive.

157. SPRINGBANK DAM – 2008



Springbank Dam in 1880. Source – Waterworks Dam and Pumphouse at Springbank Park. www.imagesontario.ca

One of my last assignments was on the Springbank Dam in London, Ontario. The dam was originally built in 1878 as a small weir to provide a headpond for the city water pumping plant. It washed out several times, was replaced, and eventually abandoned in 1917. In 1929 a new dam was built with some 5.5m of storage to provide a much larger headpond, as a recreation facility (swimming and canoeing) for the residents in London. It had 5 sluices, four controlled by stoplogs and one by a steel vertical lift gate, operated with a wire rope hoist.

As re-built in 1929. Stoplogs being removed.Source – www.thamesriver.on.ca

Downstream view, 1929 dam.

The stoplogs are installed in May and removed in November to allow fish migration past the dam. On July 9th 2000 a large flood occurred, and the operators were unable to lift the stoplogs in time, resulting in the water overtopping the left abutment, causing a washout as seen in the next photo taken just after the flood.

Flood damage, July 11, 2000. Source www.thamesriver.on.ca/July 2000 flood.

A decision was then made to replace the dam with a new structure with improved gates and easier operation. Funding for the $6.8M new structure was provided by the Province, the Federal Government and the city in equal proportions. Construction started in September 2006, and the work was mostly completed by the spring of 2008.

On June 19th 2008, before the structure had been released for operation by the owner, the gate was operated by conservation officials when the contractor was off the site for lunch, and the safety controls were not yet commissioned and inoperable. The gate hoist safety controls are crucial to gate operation, since the gates are operated by 2 hydraulic hoists, which must be closely monitored to avoid gate wracking (twisting) if one hoist moves more than the other or if the gate encounters an obstruction. The right hand gate encountered silt accumulations below the gate when nearly fully lowered, the silt acted as a fulcrum to prevent further lowering, but without the safety controls, the gate wracked and one of the two hinges on the bottom of the gate ruptured, causing the gate to lodge against the right abutment pier when the operators tried to lift the gate. Repair costs have been estimated at around $5M, and the city is now suing the contractor, gate manufacturer and the consultant.

Downstream view of four new gates with hydraulic hoists – note jammed gate at left. Source – Google Panoramio photo.

Another complication is fish. Studies of fish passage, comparing pre-2006 and post-2008 gate installation have shown that fish passage has reduced from around a 90% success rate to around 50% with the new gates in the fully open position – not a positive outlook – the open gate sill may be too high, impeding fish passage.

All of the foregoing facts have been obtained from documents posted on the web.

10 Oct., 2008. Upstream view of new gates.

In September of 2008, the Montreal consulting company OEL-Hydrosys was asked to prepare a report on the cause of the gate failure, and I was asked to join the team. Knowing that it would likely result in a court case, and based on my Oldman experience, I stipulated that I was willing to work with them, provided that the client knew that I would not testify in any court proceedings.

Gate seal jammed against right pier.

Gate seal pulled away from left pier.

We inspected the site on October 10, and produced a report about 2 months later. At the site, we found the gate adjacent to the right abutment jammed against the right pier due to the broken hinge, hidden underwater.

Control panel with computer readouts from sensors.

Hhydraulic hoists on dam deck.

It was not possible to inspect the damaged hinge, since there were no provisions to unwater the gate sill. Also, there was no easy access for trucks onto the dam deck, but it may be possible to build a road down from Riverside Drive through a forested area on the right abutment.

The inspection team – me, Sebastien Vittecoq (Partner, OEL-Hydrosys) and Simon Rousseau (President Rousseau and Dupere Engineering).

Simon was asked to join the team due to his expertise in detailed gate design. Analyzing the failure mode was quite easy, since all parties had already agreed on the cause. We were then asked to produce a report on the appropriateness of the gate design. The lawsuit was eventually settled seven years later in 2015 - ***The City of London says an out-of-court settlement has been reached in connection with the Springbank Dam Rehabilitation Project. As part of the settlement, the city will receive nearly $3.8 million and all lawsuits will be dropped. Still, no party admitted liability in the case.*** Source – CTV London, Dec 17, 2015.

Since the operators had no training, no experience in gate operation, and no permission to operate the gates, the fault was entirely theirs – something the city would not admit due to the cost of repair. The gates are still not repaired, and there is opposition to any repair since a scientist proclaimed – ***"A dam-free decade has "allowed for a more natural flow of water," creating a safer habitat for several species, Gillingwater said."*** Source – London free Press 2017/04/03.

Another interesting assignment!

158. ASHLU – 2009

One of my last site visits organized by Pentti Sjoman, was to the Ashlu 50MW powerplant 24km NW of Squamish in BC. I was eager to see the facility since it had a long tunnel excavated with a boring machine. We were very fortunate to be accompanied by the site owner's resident engineer and the turbine engineer from Andritz. At the time I was in Vancouver at a conference. We drove over a slightly improved forestry road to the damsite. There we found a low rock dam with a set of bottom-hinged crest gates adjacent to the left abutment, a pre-fabricated steel fish ladder, a spillway gate with another small gate built in to pass compensation water, and an intake to the long tunnel.

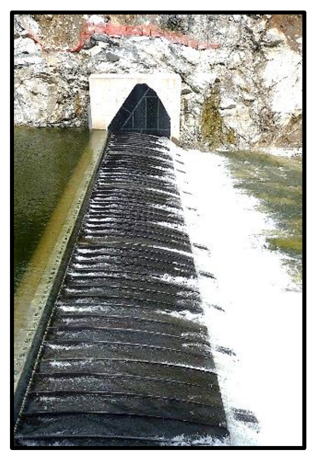
Schematic of project layout.

View of steel fish ladder.

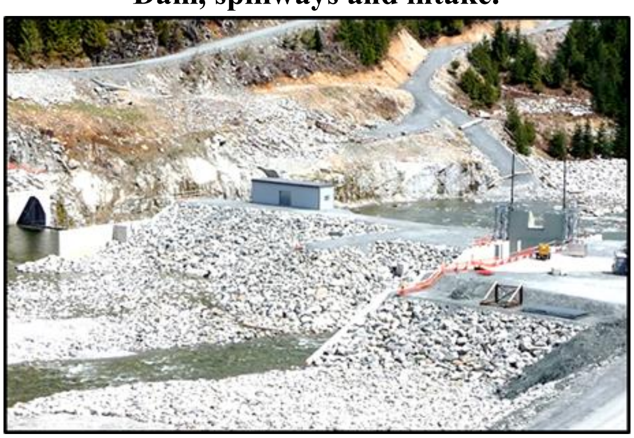
View of steel fish ladder. Mr. R. Blanchette on left.

Dam, spillways and intake.

The fish ladder was built off-site in about 9 sections and simply bolted together at site. A very low-cost solution if it works!



Bottom-hinged Obermayer gated weir.



Spillway, dam and intake. Building has hydraulic hoist servo pumps for spillway.

The contractor was still working on a 120m vertical bore down from the intake to the tunnel, a long slow process where a cutter wheel starting down in the tunnel, grinds the rock to fall as gravel particles into the tunnel, where it is loaded and removed. There is a long shaft up to the surface, where a motor powers the grinding wheel.

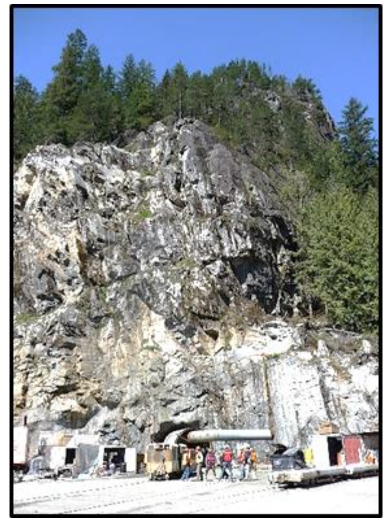
Trashracks with temporary cover to preserve heat inside intake.

The grinding wheel motor slowly turning the shaft down to the tunnel.

Another innovation was to build a small sluice gate into the main spillway gate to pass the compensation flows so as to maintain some water in the river bed throughout the year. The intake trashracks are located just upstream of the spillway gate and hopefully above the bed load when it is being passed.

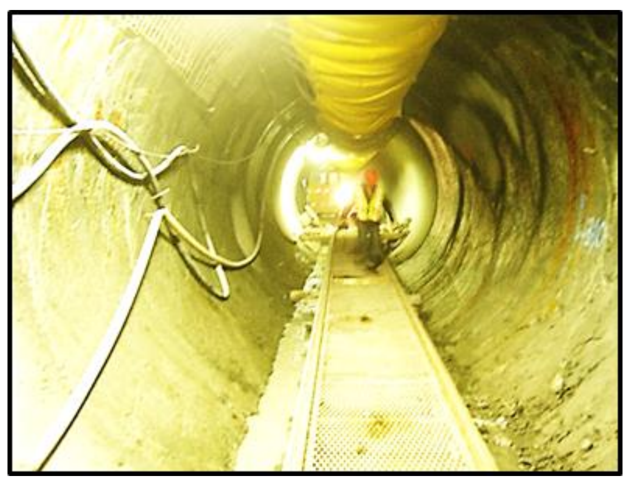
Spillway gate with small compensation flow gate.

The 4.4km long tunnel was excavated from a single adit with a reconditioned old boring machine having a diameter of 4.08m. Very hard rock was encountered resulting in about a 6-month delay in the tunnel construction. The tunnel wall is very smooth, almost resembling a concrete pipe surface.



Tunnel adit.

Diesel locomotive with 8-person car.



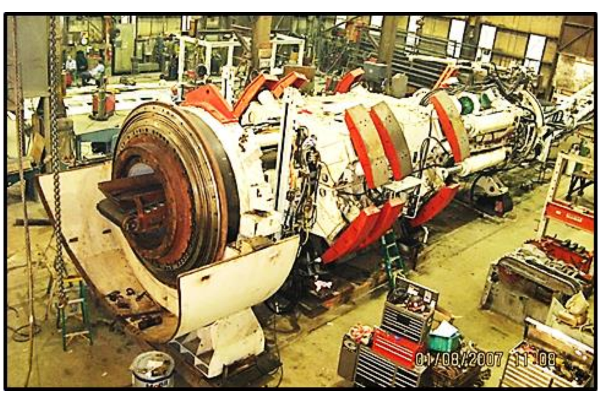
Tunnel interior – note relatively smooth wall.

The tunnel was bored through rock with a strength varying from 160 to 330MPa, at an overall average rate of 7.1m per day from May 2007 to February 2009.

Inside 8-person tunnel passenger car.

Pentti Sjoman inside tunnel – a very tight fit.

The powerhouse has three horizontal shaft Francis units operating under a gross head of 225m. There are three relief valves electronically connected to the turbines capable of continuous operation for a slow flow ramp-down rate.



23 year old boring machine rehabilitation. Source – TunnelTalk April 2009.

The relief valves are a new design since flows cannot be rapidly shut off after a power load rejection, due to concerns about stranding fish in pools.

At only car by-pass in tunnel.

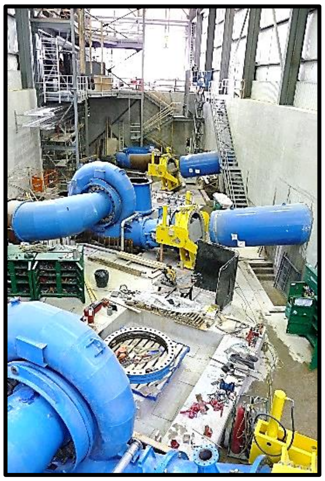
Substation and powerhouse.

Relief valve room.

Powerhouse beside creek.

It was a very instructive trip, and due to the easy access from Vancouver, the site has become a favorite hydro facility tour destination during conferences, along with the fish spawning channel which has been developed just downstream of the powerhouse.

Transmission line connection.



Two views of powerhouse interior.

Right - Note control room location beside repair bay, below crane. Should have been at side of powerhouse, not intruding into repair bay space.

Richard Blanchette (RE), Pierre Duflon (Andritz), with consultants Jim Gordon and Pentti Sjoman.

159. THOMAS LOWE – 2012

I was intending to retire in 2012, but was not successful. I had a call from Renfrew Power in September of 2012, asking for some help in the selection of turbines for a small hydro facility they were about to build. It consisted of a new penstock and a single powerhouse taking water from an existing intake and by-passing two old powerplants built in the 1920's.

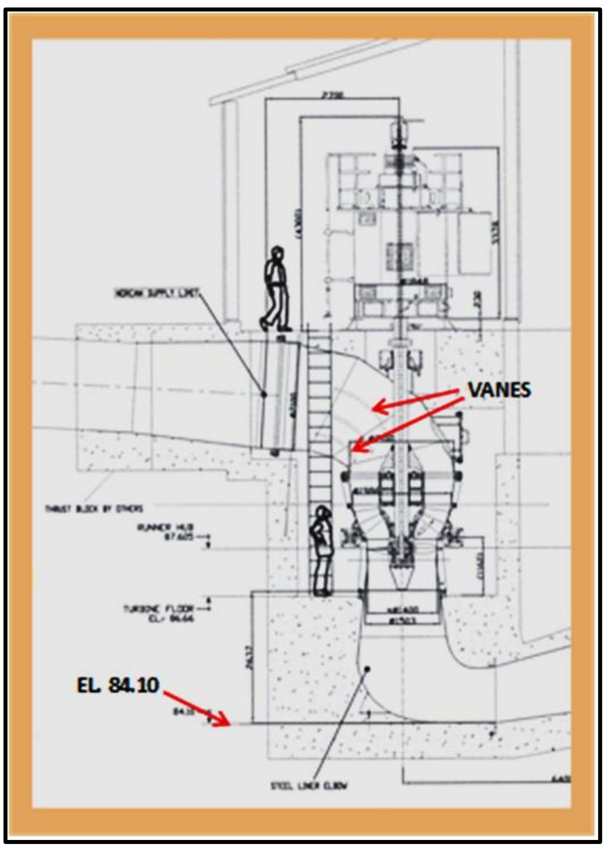
I took the train to Fallowfield just west of Ottawa, was met by one of Renfrew Power's engineers and driven to the site. Had a good look at the site, took a few photos and discussed the project with a couple of their staff.

Upstream intake and powerhouse on the Mississippi River, just west of Ottawa.

Their main problem was assessing the bids from two turbine manufacturers. The quoted prices were very similar, but there was a small difference in the estimated turbine efficiencies, favoring the higher bidder. Also, there was a right- angled bend in the pipe leading into the vertical axis unit, which was significantly different in the two quotations.

I produced a report favoring the high bidder due to improved bend and turbine efficiencies which more than compensated for the higher cost. I was then asked to present my report to the town council at an evening meeting.

View of second old powerhouse with surge tanks upstream. New powerhouse to be built at side, on grass slope.



Section through turbine and inlet pipe.

I had to speak in non-technical language to make the assessment understandable to the councilors. Fortunately all went well. It was supposed to be my last project, but again I took on another assignment.

Penstock route, to be buried below the road.

160. WORLD BANK PROJECTS 2013-16

TRISHULI – NEPAL
SUPER TRISHULI - NEPAL
KARNALI – NEPAL
MARSYANGDI - NEPAL
NATCHIGAL – CAMEROON
PANAL - INDIA

In January of 2013, I had a call from a Mr. Ragu Sharma asking me to become a consultant to the bank. I was reluctant, since I wanted to retire. However, he mentioned that he had been reading some of my papers, and agreed with many of my views, and it was this reason that he wanted me to join their team.

They were in the middle of considering financing three large hydro projects in Nepal, and needed assistance in reviewing the feasibility reports.

My contract was with the International Finance Corporation (IFC), a branch of the World Bank. The contract was quite extensive and included a long questionnaire on my morals and behavior such as accepting bribes and so forth. I told Ragu that I could no longer travel, and that I did not have insurance – no problem, all work would be over the internet and the IFC would provide the insurance.

Meeting with IFC staff and Korean consultant in Montreal. Raghu on my right. The young woman was their presenter, since many could not speak English.

I had just moved into a retirement home, and fortunately had brought my office which fitted well into my small apartment of 775 square feet.

So I accepted, and started reviewing the three massive feasibility reports. The number of pages was over several thousand each since they included all the detailed calculations based on every formula the consultant could find in papers, codes and textbooks. Also the number of drawings in each report was over 600, since they used computer aided design to produce very detailed drawings of all the structures.

However, the consultant from Korea was inexperienced, hence there were many changes required to improve the design.

In all, there were three projects, Trishuli, Marsyangdi and Karnali, two at about $600M and one at $1B. They kept me busy for about 4 years, and then I had to recommend the addition of an experienced “Owner’s Engineer” to the design group, and a large consulting company from England was awarded the contract. Also, I recommended adding a Review Board, and 5 experts from various countries were selected.

TRISHULI

This project was located in the foothills of the Himalaya Mountains. It had the usual layout of a concrete dam in a narrow V-shaped valley followed by a long tunnel with pressurized sand traps to a surface powerhouse. I recommended many changes, particularly to the intake.

Drawing showing the Trishuli access road and project layout, in my apartment office.

One of the main problems was excluding sediment from the tunnel. This was partially accomplished by designing an intake parallel to the river, with a gravel trap included. All optimized with hydraulic models built in Kathmandu, Nepal and in Grenoble, France.

Google image of Trishuli valley.

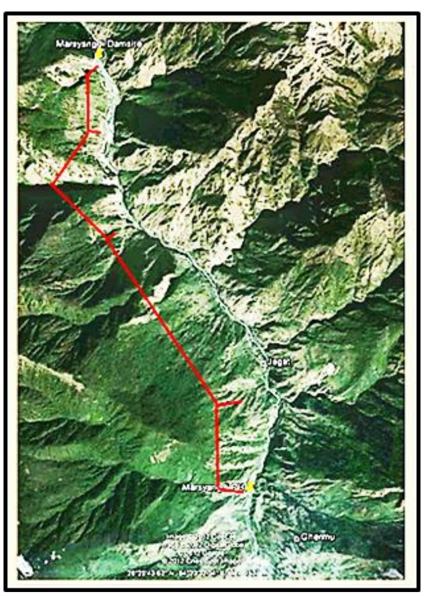
We would have meetings using computers to show PowerPoint presentations and sound with cameras to show all involved. The main problem was selecting a time suitable to most, since we had participants from Australia, Korea, Nepal, France, England, Puerto Rico, Washington and Canada. The setup worked well for most, but the signal from Nepal was intermittent, hence they had to use the phone, with no PowerPoint presentations. I downloaded massive files using Drop Box.

Just shows what can be achieved with modern technology! We had one kick-off meeting in Montreal, with a young lady interpreter, with no engineering knowledge, hence communication was difficult. I was given the feasibility report and a full set of the drawings.

Construction started, but all work was destroyed in the 2013 earthquake. Construction did not re-start until after 2016, when I was asked to review the detailed specifications – a document of about 4,000 pages. This required too much time, so when finished, I told the Bank that I was no longer interested in continuing work past the end of 2016.

MARSYANGDI - 2

Also located in Nepal and similar in layout to Trishuli, except the powerhouse was located underground.



Google Earth view of site.

However, my work did not progress beyond a review of the feasibility report, which included a cost analysis with HydroHelp 6.1

UPPER KARNALI

This was a lower head development in Nepal, harnessing the head in a bend in the Karnali River, which was considered to be a prime hydro site.

However, access was difficult, requiring a long road tunnel paralleling the power tunnel. Again, my work did not proceed past a review of the feasibility report.

Google Earth view of site. Triangle is concrete dam, red oblong the powerhouse. Access tunnel and power tunnel between.

SUPER TRISHULI

This proved to be a very short assignment. All the Bank wanted was a rough cost estimate based on my “Ballpark Cost” program.

NATCHIGAL

Again, another short assignment, where the Bank wanted a Ballpark cost and an estimate of the design cost which they were considering financing.

PANAL

A considerable sum of money had been spent on the geotechnical work and a feasibility report for this development. Unfortunately it was located in the upper reaches of the Natchigal River where the river slope was steep, and consequently there was a considerable bed load of boulders. No attention had been paid to the problems associated with passage of the boulders past the dam. My review indicated that the project, as designed, was just not feasible. The dam storage would quickly fill with boulders!

I advised that "all work on this project should cease immediately", but the Bank asked me to tone it down.

After submitting my report, I heard nothing from the bank for several months, so I sent an email asking about the status of the project, and their reply was ***"The Bank has decided not to fund this project based on the comments in your report".*** So, no Bank funding, no project.

The following month, Ragu called me to ask if I was interested in helping the proponent develop a revised and acceptable design. I declined. However, Ragu again called and mentioned that the proponent would like to talk to me to arrange a contract for my services. Again I declined, but eventually agreed to the phone call.

View of damsite facing upstream. Note numerous boulders, rolled down during the monsoon.

When the call arrived, the Indian proponent spoke so fast that I could not understand a word he said, despite asking him to speak slowly several times. I agreed to issue a short explanation of why the project was not possible without major changes to the dam concept, and that was the last I heard of the project.

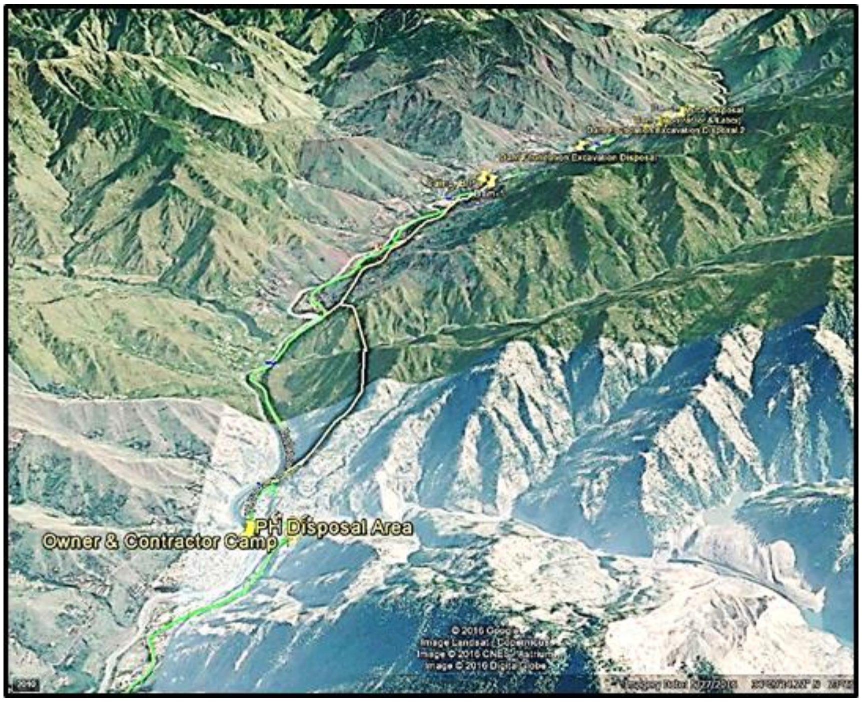
161. CHAKOTHI-HATTIAN – 2017

My plans for retirement were tested in January, when I had an email from Jang Ock-jae, an engineer with the Daelim Industrial Company in Korea, asking me to review the feasibility report for Chacothi. I replied that I had closed my consulting business, hence was not interested. Daelim was one of the developer partners at Trishuli, and their senior executives had met me at the Trishuli Montreal meeting, where they became acquainted with my work.

A second email arrived asking me to reconsider, but again I declined. Then one evening at 9.00pm when I was sitting by the fireside enjoying a single malt, a phone call arrives from Jang. He asked me to again reconsider, but I advised him that the office was closed. However, after some further discussion, I agreed that I could produce a 2-3 page comment on the report at no cost. If they were satisfied, then they could send a couple of bottles of a good 18-year single malt as a gift.

I received pertinent extracts from the report, including the principal drawings. It had been prepared by the Indian office of a Montreal based hydro consultant. However, on reading the report, I realised that nobody from the Montreal office had read the report. The project was in Pakistan in the foothills of the Himalayas, where the rock was faulted with severely folded beds of sandstone and shale – very difficult for underground construction work.

The design engineers had concluded that the rock was sound and strong, similar to granite, hence many changes were required to produce a functional project. There were outlined in my 3-page report.



Google image of site – facing east.
Powerhouse site at bottom, tunnel in yellow.

Folded and interbedded sandstone and shale at site.

A few days after sending my report, another email arrived advising the Jang would be arriving in Montreal to discuss the report. He arrived in mid-February, and we spent a pleasant 3 days discussing the project in my apartment office. I had to tell him that in the afternoon of the first day I needed a 15 minute break to photograph a St. Valentine's Day concert by an Elvis entertainer for our monthly newspaper "The Bridge", for which I am the editor. We both went down to the concert venue, I found him a seat and proceeded to take photos. After about 15 minutes, I returned to his seat and suggested we go back up to my apartment. I was surprised when he said, "I am enjoying the concert and would like to stay!"

After we had finished work, I asked Jang if he would like a beer at our "Happy hour". He declined, too tired from the long flight and 14 hour time change.

We met again on Thursday, continued our discussions and we ran the project through HydroHelp, resulting in a significant cost increase due to measures required for supporting the poor rock in the tunnels.

Again I asked him to the "Happy hour" and this time he accepted and stayed for dinner at our table.

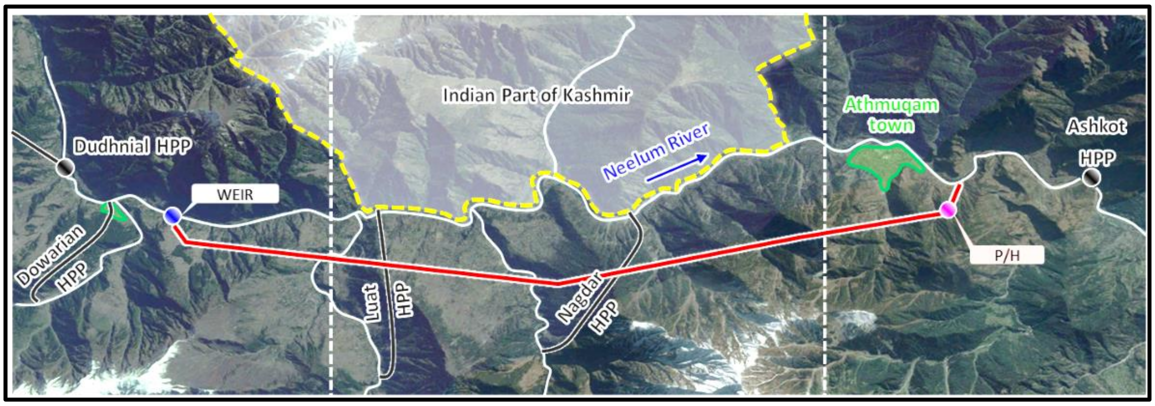
The happy hour was themed – with all participants requested to dress in black and white, and most participated. Later, he enquired as to what type of retirement residence I was occupying! – Elvis concerts and themed happy hours!

Before he departed, he again asked me to sign a contract, the first being based on the standard FIDIC consulting services contract, and the second on a brief 8 page contract, both of which included liability. I tried to explain that a sole consultant could not obtain liability insurance if working on either nuclear projects, environmental reports, or dams. The risk was just too high. I hope he understood.

However, I agreed to answer any questions at no cost, provided there was no calculation involved.

162. ATHMUQUAM – 2018

Jang Ock-jae, the engineer with the Daelim Industrial Company in Korea, emailed again in April 2018, asking me to review the pre-feasibility report for Athmuquam, a 436MW, 227m head hydro project Pakistan on the Kashmir border with India. After issuing my report, which required many changes, he advised that he would come to Canada in August to discuss the new concept. I told him this was definitely my last assignment.



Project Layout.

Damsite.

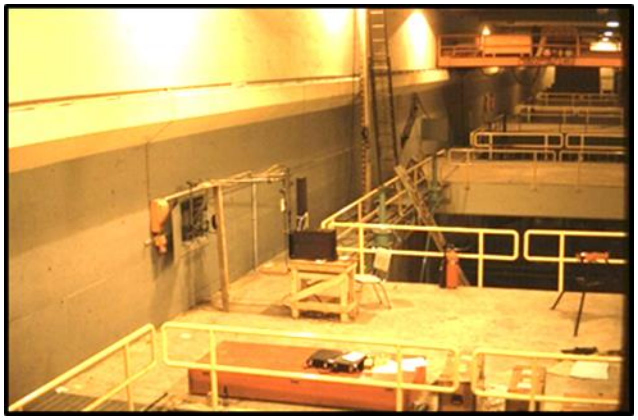
The principal comment was that the intake silt flushing facilities were inadequate and would have to be studied with a hydraulic model. Also, the project hydraulics were incorrect with a far too small surge tank, and an inadequate underground powerhouse with no downstream vent for the turbines, requiring an extra chamber.

162. UNMENTIONED PROJECTS

I have not included any mention of feasibility studies and other work which did not reach the construction stage. This is because either I have no records of the work, only some distant memories, or the work was minimal. My camera was my record medium, and looking over my register of slides, I found a few not mentioned. Also, all my early work records and photo negatives were shredded when I moved here, hence I cannot provide more details. Also, all the diskettes (floppies) are no longer readable since I do not have the program.

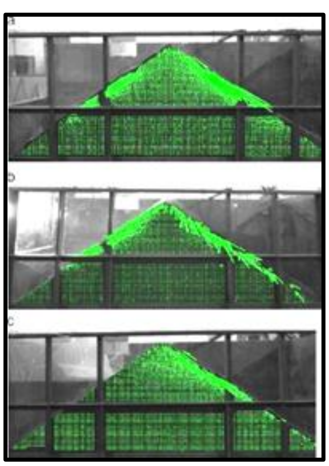
Woodward Governor Company – In September 1960, **a**fter my work on Maggotty, I persuaded the company to send me to a one week course run by the company, mainly for powerplant operators. It was very instructive, and I left with several of their manuals and design records. At the time, Woodward had a monopoly on governors in North America, hence were very generous with employee benefits – in-factory dental care, haircuts and meals. The annual course was an occasion for their entire staff to mingle with the students at an outdoor lunch.

Gibson turbine efficiency testing. In October 1960, we were asked if we would be interested in purchasing the rights to the Gibson pressure-time method of measuring turbine efficiencies. This was a difficult test requiring several days of work and many technicians. I traveled to the Bersimis underground powerplant operated by Hydro Quebec to help with and witness the tests. I recommended turning down the offer since the cost of a test would be so high, that few would ever be undertaken. It has now been superseded by the more accurate ultrasonic method.



Bersimis #2. – Underground powerhouse.

CALTEC – Berkeley campus – In March of 1968, I attended a short course on dam design. This was still in the days when most dam designs was based on precedent. We had lectures on core thickness and guidelines for slope stability with various materials and foundation conditions. One of the highlights was to observe a dam shaking table test for earthquake resistance. A dam section was modeled between 2 glass walls mounted on a table which could be shaken back and forth to simulate an earthquake. Very instructive. The earthquake lectures were presented by Professor Harry Bolton Seed.

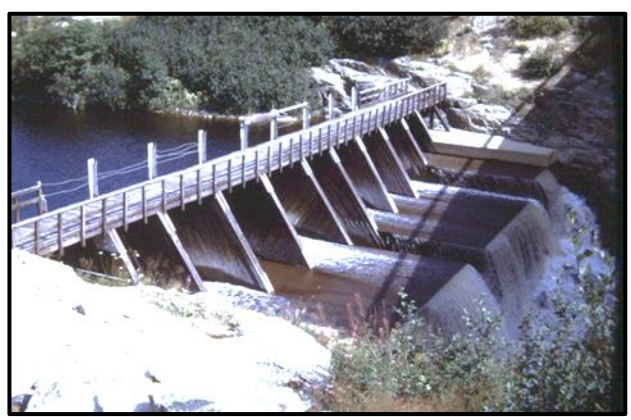


Model dam on shaking table to test earthquake resistance.

Bob Petersen and Steve Chrumka at Berkeley.

Lynn Lake – In August 1972, I traveled with Steve Chrumka to Lynn Lake in northern Manitoba to investigate the failure of a side dam belonging to a mining company. The only access was by canoe, and the downstream slide was found to be caused by too steep a slope on a soft clay foundation. Repaired by flattening the slope. Fortunately the slide was local and the reservoir containment was not affected.

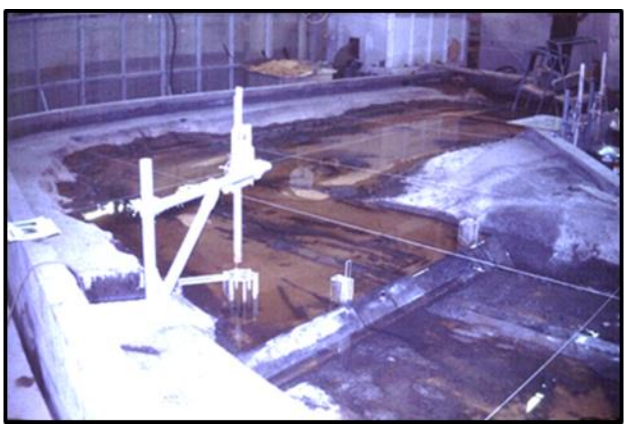
View of failed side dam.



View of wood spillway dam.

Cargill Grain Dam – Also in August of 1972, I inspected the wooden dam operated by Cargill Grain in the North Shore of the St. Lawrence River. They wanted to know if the life could be extended. I suggested that it would be preferable to build a new concrete dam immediately downstream.

Andekaleka, Madagascar – In 1978 our associated company Cartier Engineering was designing the high head hydro development in Madagascar on the Andekaleka River. It carried a high silt load and their engineers were having difficulty eliminating the silt from the water diverted to the turbine. I was requested to provide some advice. The "cleaner" water was at mid-height of the flow, with the lower level carrying silt, and the upper level carrying forest debris. I suggested a gathering tube type of intake, as at Maggotty, built into the concrete dam. A hydraulic model was built at the nearby LaSalle Hydraulic laboratory, and after several trial runs, an acceptable layout was developed.



Andekaleka hydraulic model.

Kingston Mills – In 1987 we were commissioned to install a new generator in the Kingston Mills powerhouse. It had a capacity of only 500kW, and was so small that it could be lifted by about 6 men. A new generator was installed after removing the roof.

Slave Lake – a preliminary study of a dam and small powerplant at the outlet to prevent flooding in the town of Slave Lake.

Athabaska River – a preliminary study of several dams and generating facilities to provide energy to the oil sands developments.

Chicoutimi – a preliminary study of a small powerplant near Chicoutimi.

Brazeau Pump-Storage – a preliminary study to add several reversible pump-turbines to Brazeau.

Pembina Dam – a feasibility study to add a storage dam on the Pembina River in Alberta. The Alberta government contracted Canadian Aero Surveys to undertake the study, they surveyed the site, and asked Dr. Hardy to complete the study. Hardy undertook the geological work and sub-contracted the report to Montreal Engineering. I wrote the report, with all drawings on Canadian Aero Surveys letterhead. The completed report was given to the Alberta Water Resources Commission for review. The head of the commission was Jack Reid, he read the report and phoned me to ask if I had written it. I knew Jack from the Brazeau work, so I asked him why he had called, since there was no mention of me or Montreal Engineering in the report. He replied that he had recognised my writing!

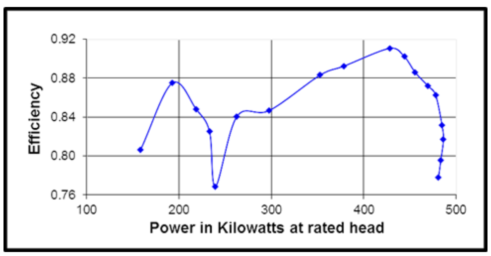
Kagawong – my very first assignment as an independent consultant was to determine the reason for unexplained friction losses in the penstock at a small hydro plant on Manitoulin Island. I never met the Owner. After some analysis, I concluded that the spiral welds in the long steel pipe caused the water to rotate, increasing the velocity and hence the friction loss. Now I realize it could also be moss in the penstock as at St. Raphael.

Wiwilli – a small hydro project in Nicaragua, built by an environmental group with a minimum of funds. I provided advice at no cost on layout and the dam design.

Petite High Falls – a 600kw hydro plant near Casselman, Ontario, built by the local dentist. Along with Kearon Bennett we undertook some index tests on the turbine, which was not performing as expected.

Horizontal axis, double runner Francis turbine at Petite High Falls. 500kW, 15m head, 720rpm. Note draft tube on each side of turbine.

Results from the index test.



South River – another small hydro project working with Kearon Bennett. There was an abandoned hydro plant, and the local municipality wanted to reactivate the facility.

Old South River powerhouse.

Below - old anchor block for surge tank T, penstock route.

We surveyed the site (I was the rodman!) and produced a report on a complete re-build with new equipment, but still using the old brick powerhouse. It was commissioned about 18 months later.

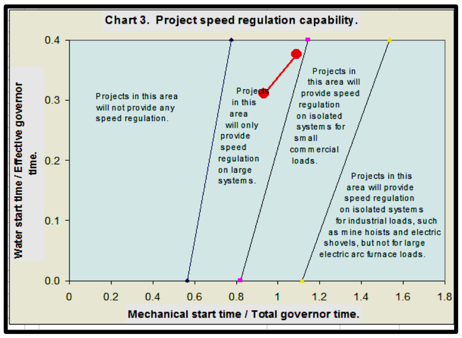
View of monsoon flood passing over the Baglihar dam.

Baglihar – Peter Rae used to work for Montreal Engineering. He moved to a suburb in Chicago and opened his own office. He managed to get a contract to provide advice on the Baglihar intake at a dam in India for a legal case between India and Pakistan, with Peter on the Pakistan side. I helped him with an analysis of the intake hydraulics. By the time the case wound its way through the courts, the dam was half built, but changes could still be made to the intake.

Intake racks almost covered with silt!

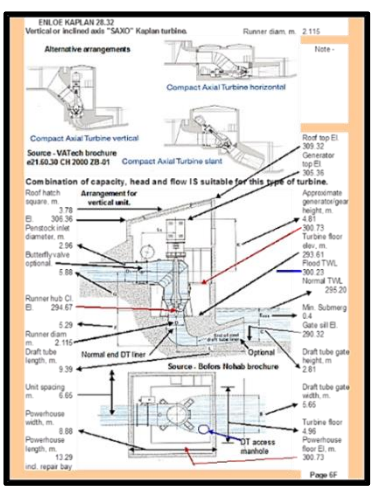
The case was in arbitration with Professor Lafitte from France as the arbitrator. He eventually ruled in favor of India. However, I was provided with several photos of the concrete dam showing it overflowing during a monsoon flood, the usual practice in India for construction of concrete dams, design the by-pass for the non-monsoon flood. Also photos of the intake hydraulic model where silt poured into the intake since the sill of the adjacent sluices was too high.

Waneta – I had a call from the Columbia Power Corporation requesting an analysis of the required inertia for a Francis turbine unit to be added to the existing development. Again, I simply ran the parameters through HydroHelp and provided the answer.

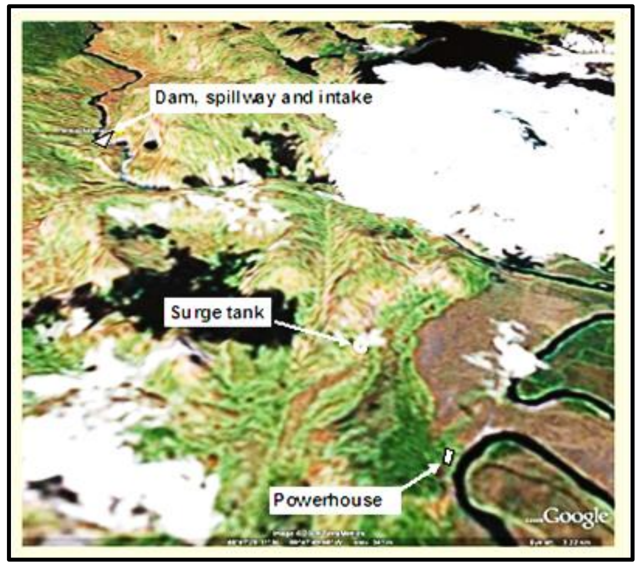


Hydrohelp inertia chart

Enloe – John Christensen also used to work for Montreal Engineering, but moved to California and opened an office. He asked for help in the design of a 5.5MW plant to be attached to an existing dam. I ran the parameters through HydroHelp and developed the basic dimensions for the powerhouse. As with all hydro projects in the USA, the project was delayed for many years over environmental and permit issues. It has not yet been built (2018).



HydroHelp output for Enloe powerhouse turbine.



Essipit project layout.

Essipit – I had a call from HydroMega Services to review the project and estimate the probable cost. It included a dam, long tunnel, surge tank and powerhouse. It proved to be uneconomic, hence abandoned.

Forrest Kerr – This proved to be an interesting assignment. AltaGas wanted to develop the 195MW site on the Iskut River in North-Western BC. Unfortunately, the river has a high bed load, and there is a large volume of sediment just waiting to be transported downstream during a large flood in a lake immediately upstream of the intake. Also, there is insufficient space at the intake site to include sand traps.

At the lab in Burnaby, BC.

Spillway and 4-bay intake layout.

I was engaged by SNC to provide advice on the intake design. Prepared a concept, and traveled to the Western Canada Hydraulic laboratory to view the model operating with crushed walnut shells simulating the silt. Despite many revisions to the layout, it was just not possible to exclude the silt from entering the intake, and SNC so advised AltaGas, and withdrew from the work.

Below - Powerhouse interior.

The design work was picked up by Hatch, and after many attempts, they managed to find a workable (?) layout with a set of wide racks leading into a short basin, where the bottom had 4 channels to capture the sediment and direct it towards a low level sluice into pipes back to the river. I looked at the design and concluded that the weak link was the pipe and sluice with no access for cleaning.

Intake, looking upstream. Note sand trap pipes.

After the plant began operation, it was found that the intake was not performing as expected, and an excessive volume of sand was passing through the turbine. Fortunately, Hatch had decided to change the 3 vertical axis Francis units to 9 horizontal axis impulse units to gain easy access to the runners, and jet nozzles.

However, after a few years operation, with runner and jet maintenance costs increasing, it was recently decided to install a set of Sedicon desander pipes to replace the sand trap pipes in 2 of the 4 bays as an experiment.

Sedicon sluice pipes in one of the bays at the Forrest Kerr intake. Two bays have the pipes.

Highgate Dam, Saskatchewan – I obtained an assignment from Golder Associates to assist in the design of the powerhouse on the North Saskatchewan River for three alternative capacities. Again, all I did was run the project parameters through HydroHelp.

Miel Hydro, Columbia – An underground powerplant with severe turbine vibration problems due to harmonic interaction between the draft tube rope, upstream conduit and discharge conduit. I concluded that – "The shaft run-out, shaft vibrations and power surges are all caused by the effect of the draft tube rope, magnified slightly by resonance of the rope and sound wave return frequencies at higher harmonics when conditions are right" after running the data through my turbine design program.

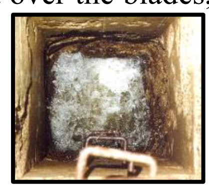
Peace Site C – I undertook a small amount of work on the project, concentrating on the spillway layout. The main issue was the soft rock foundation which required a massive stilling basin with a thick concrete slab. The first meeting was in May 2011, just as I had turned 80. I saw that the assignment would last many years, so I informed BC Hydro that they should look for someone else.

Site C project layout. Spillway on left.

Mill Creek mini hydro - This was an interesting short assignment. A retired jet engine design engineer had designed a series of hydro mini-turbines using the same fluid dynamics equations used for jet engines, but with water as the fluid. The propeller turbine had 14 blades instead of the normal 3 to 5. The designs included estimates for the turbine efficiency, all in the +90% range, far too high for a mini turbine, where the efficiency should be in the low '80's. The first turbine was installed at a site in Northern New York State at an abandoned mill. The 260kW output was far below the contract output at 410kW, and I was asked to look into the cause.

Mill Creek power house.

I found that the intake concrete conduit restricted the flow, to such an extent that on looking down the air vent, all I could see was white water, indicating that the flow was near the spouting velocity. Also, grass was folded over the blades, reducing output to 240kW.



White water in air vent.

A few calculations indicated that after subtracting the hydraulic losses in the intake pipe, and using a more reasonable assumption for the turbine efficiency, the output was about what was being produced.

Tailrace flow. White foam indicates excessive air in the water due to the high intake velocity.

Unfortunately, there was no solution to the problem. A new turbine would have to be purchased, and the cost would be too high resulting in having to abandon the site.

I never found out what was done.

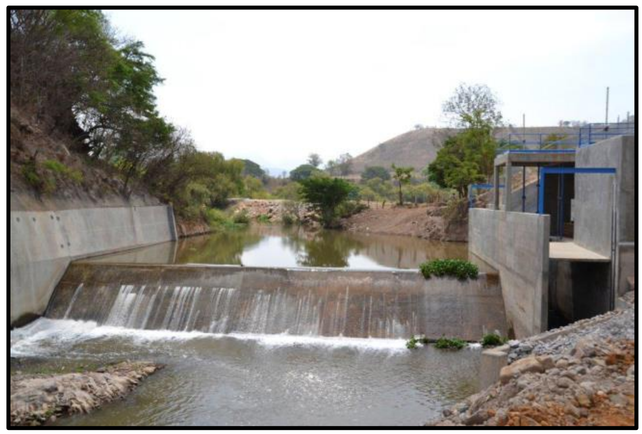
Arcoiris, Mexico. In 2009 about a month after attending a conference in Vancouver, I had an email from Jose Ayala, an engineer in Mexico, developing a small hydro site, seeking some advice. He was at the conference, but we never met. I told him that I no longer travelled oversees, but could work in cooperation with a former associate Jeremy Gilbert-Green. He accepted, and we worked intermittently on the project for 3 years providing the occasional advice.

The river was steep and carried gravel, boulders and forest debris requiring a sloped weir intake as used in Bolivia. There is space for a future sand trap just downstream of the intake. The project was quite complex, requiring a weir and gravel trap before the intake, across the Mascota river, followed by an intake, pipe, a free-flow tunnel to a small head pond, a low-pressure 500m long fiber-reinforced plastic pipe and 440m long steel penstock down a steep slope to a powerhouse containing 2 vertical axis, 5-jet impulse turbines each producing an output of 4MW at 212m head, with provisions for a third.

Jeremy inspected the site in September 2009, and again in April 2012. The project was built without any difficulties, apart from problems with constructing the penstock down a steep ravine to the powerhouse. In all, our contribution was minor, comments and two site visit reports.

Two years after the project was commissioned, a hurricane passed over the site. I email Jose, asking about the project, and was advised that it was the only one in the area which had survived the hurricane without damage, no doubt due to the sloping weir intake design.

Powerhouse interior.

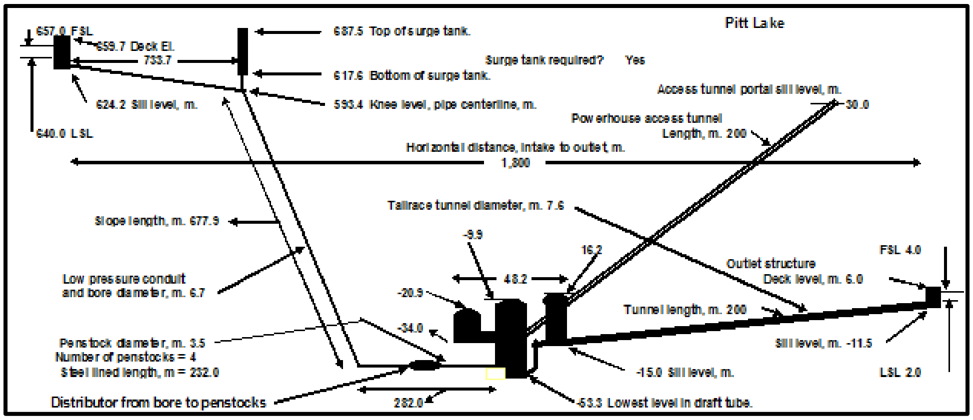


Weir and intake.

Intake.

Floating forest debris in river. Note boulders on bank. Photos from Jose Ayala.

Pump Storage Survey. A search for pump storage sites in BC, Ontario and Nova Scotia for a developer using HydroHelp and Google Earth.



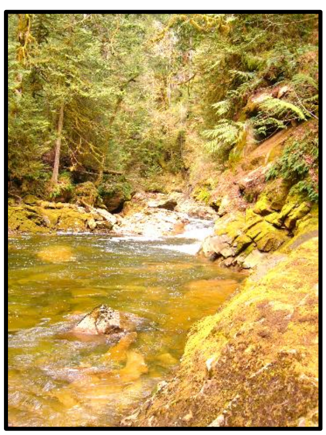
Project schematic.

Report included a computer-generated schematic of a section from the reservoir to the tail-pond. A total of 10 sites were identified and some were overflown by helicopter. Capacities ranged from about 300MW up to a nominal 1,000MW.

A site in Ontario.

Tsable. Work on a small hydro site in BC. Environmental issues were severe, and site was abandoned. No report, inspection only.

Tsable Creek →



Burps pump-turbine development. A quick estimate of the 2,000MW development for another consultant, using an early version of HydroHelp.

El Carmen. Estimates for 6 project capacities ranging from 11MW to 45MW for another consultant using HydroHelp.

El Consuelo. Estimate for a capacity of 3MW, again using HydroHelp for another consultant.

Highgate Dam, Saskatchewan. Cost estimates for the powerhouse and equipment for another consultant. Costed using HydroHelp for three capacities for outputs from 133MW to 166MW. Report included powerhouse sections generated by HydroHelp.

Big Beaver Falls. Review of a report and costing for a small hydro site for a developer. Capacity was just under 3MW.

Capilano. Advice to another consultant on the expansion of the Vancouver water supply. The project was complex with tunnels, break pressure tanks, pumps and turbines.

Clint Creek. Cost estimate using HydroHelp and Google Earth of a small hydro site for a developer. Capacity 6MW. Access to a perched lake proved to be too difficult.

Roaring River. Inspection of site on Vancouver Island. Access difficult, making the site too expensive and it was abandoned.

Ksi Gwinahatal, Ksi Sgasginist and Anudol Hydro Projects. A preliminary assessment of three hydro sites in BC for a developer using Google Earth and HydroHelp. Capacities of 5MW, 7MW and 5MW. Cost proved to be excessive.

Lower Lake. A cost estimate for a small hydro site for a developer using HydroHelp. Capacity 10MW.

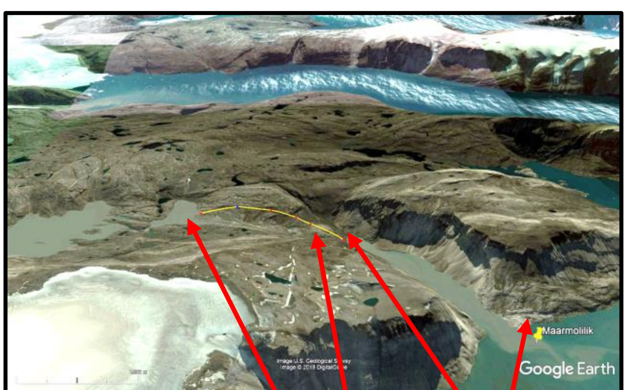
Red Rock Falls. Assessment of the effects of AAR at a hydro development in BC.

Black Angel Mine, Maarmolrilik, Greenland.

In 1970, we had a request from the Black Angel Mine company to investigate the possibility of constructing a small hydro plant of about 12MW capacity to power a zink mine in northern Greenland.

The project would tap a glacier lake with an underwater intake, construct a 3.5km long tunnel through frozen rock to a powerhouse at the ocean.

Due to the location, well north of the arctic circle at 77’ 09’N and 52’ 45’W, the project posed several problems. One was the obvious, would the cold water off the glacier lake freeze when flowing through the frozen rock tunnel?



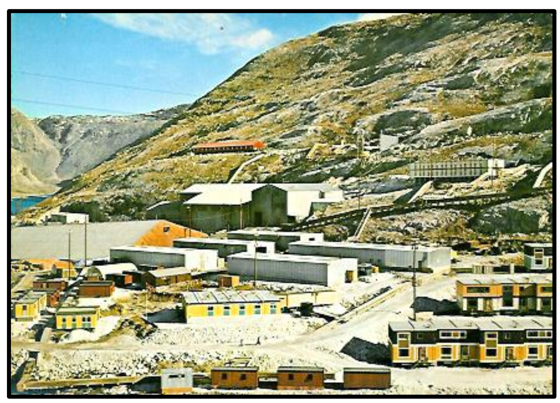
Project layout. Lake. Tunnel. Powerhouse. Underwater cable to minesite.

We undertook several calculations trying to determine the calories generated by the friction loss in the unlined tunnel, and asked a physics professor at McGill University to undertake the same calculations. The results indicated that the water would not freeze, but flow could not be stopped for more than about an hour.

Stan Rutledge visited the site for three days, discussed power requirements and looked for suitable glacier-fed lakes.

The other was how could a powerplant be constructed in such a harsh environment? The answer was to build the powerhouse on a large barge, float it to the site and jack it up onto a concrete pad above wave level. The powerhouse would contain two horizontal axis 2-jet impulse units operating under a head of about 480m, with a pressure relief valve to empty the tunnel during a shut-down longer than one hour.

The financial aspects were very onerous. The plant payback could not exceed about 12 years since the life of the mine was estimated to be about 15 years. Unfortunately, the hydro cost was too high, and the project was abandoned.



Minesite – 1983. Now abandoned.

The mine was high up on the mountain face looking down on the campsite. It was reached by cable car, a MONENCO suggestion. The mine operated from 1973 until 1990 producing zinc ore. Tailings from the concentrator were discharged to the ocean in an underwater pipe! It is now being reactivated due to the high value of Zinc.

163. MUSKRAT FALLS – 2014-8

These memoirs would not be complete without mentioning Muskrat Falls, currently being built in Labrador, just upstream of Goose Bay on the Churchill River. Cost is now estimated at around $13B. I undertook some work, all on a bro bono basis for the Committee of 2041, (the year Nfld. regains control over Churchill energy), it comprises a group of Newfoundland citizens all concerned about the "boondoggle" as the project has been described by the new president of NALCOR, the owner and developer. It is a classic lesson in how a multi-billion hydro project should NOT be developed. The original budget has increased by 140%, and the commissioning date is now over 2 years late.

The plant characteristics are as follows -

Optimal plant capacity:	**824 MW (at the HV bus)**
Average annual energy:	**5.53 TWh (at the HV bus)**
Plant flow capacity:	**2,667 m3/s**
Average plant flow:	**1,980 m3/s**
Average spill:	**46 m3/s**

CAPITAL COST ESTIMATE

Description	**June 1998 $M. CAN**
Permanent Support Facilities	6.1
Reservoir, Diversion, Dam, Spiliway	188.6
Powerhouse and Related Facilities	445.5
Communications	2.0
Construction Facilities and Support	111.7
Management, Engineering and Others	734.0
GRAND TOTAL	**$ 965.226**

Cost estimate source – Final feasibility Study. Vol. 1. Engineering report. January, 1999. SNC-AGRA. Table 1-1. Page 46.

My interest was piqued when I read a short book by Cabot Martin titled "Muskrat Madness". It concentrated on the questionable stability of a natural side dam called the North Spur which contained layers of sandy silt and sensitive clay. I emailed Cabot, a member of the 2041 committee, on August 27th 2014 commenting on his book, and remained involved until my last concerns on the North Spur instability were published in a blog in July 2018.

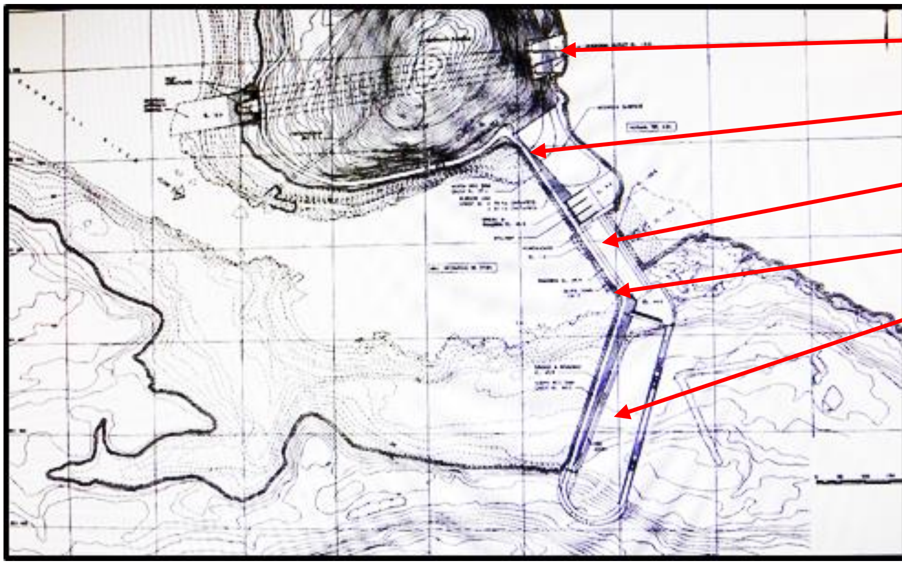
Muskrat Falls – Spirit mountain in middle, south end of North Spur on left.

The project is located about 30km upstream of Goose Bay and Happy Valley on the Churchill River, where a head of 39m can be obtained by a dam across the river. The site has been investigated many times, with work commencing about 1970. The difficulties associated with the North Spur have been known from the start, emphasised by a massive slide on the downstream face in 1978, which required stabilization with a series of pump wells to lower the piezometric pressures within the spur.

Diversion would be through two tunnels 600m long, 14m wide by 17m high.

The estimated cost was just over $965M, for the power project, excluding all transmission and financing. A partial breakdown of the estimate was as shown in the previous table extracted from the SNC-Agra report. The first comprehensive work started with a 662 page extensive feasibility report by SNC-Agra issued in 1999. The project layout required construction of 2 large diversion tunnels and a spillway, powerhouse and concrete dam across the river as shown in the following drawing;-

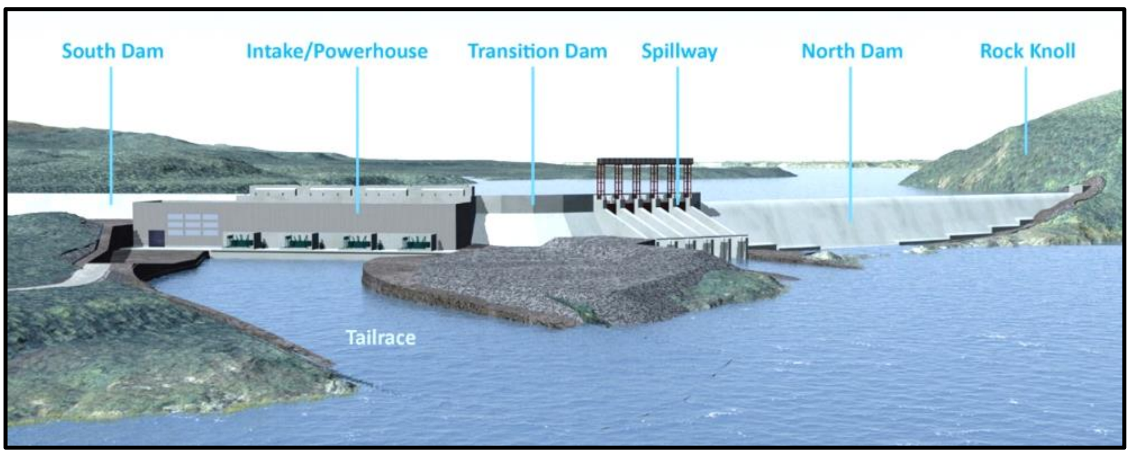
Below - Muskrat general layout, excluding the North Spur. Source – SNC-Agra report – 1999.



The cost turned out to be gross underestimate, and can be compared with the Ballpark cost derived from a simple computer program wherein only 6 parameters are required, namely the developed gross head, the installed capacity, the number of frost days at the site, an inflation cost index, the design standard and powerplant type. The 1998 cost derived from this simple program was $1,623 million. Bearing in mind that the site is remote, and the climate is sub-arctic, this cost should be regarded as a bare minimum.

A detailed review of the project layout in 2010 resulted in a new feasibility report with a new layout. The diversion tunnels were eliminated in favor of diversion through the spillway, with the spillway and powerhouse built further into the rock exposure on the right bank. The river would be dammed with an Roller Compacted Concrete weir called The North Dam.

This report was never made public, hence I do not have any drawings, only an artist's impression of the development as shown in the following illustration. The North Spur would be stabilized by flattening the side slopes. Cost would be about $3.372B, not including transmission and financing.



Muskrat Falls development pictorial representation. Source NALCOR Energy.

Again, this turned out to be an underestimate, with the cost escalating to $3.7B in 2015, and to $5.6B in 2017.

The total cost, including transmission and financing increased from $6.0B in 2010, to $6.2B in 2012, to $6.5B in 2013, to $7.0B in 2014 and to $12.7B in 2017.

Allowing for cost escalation, the cost of the power facilities, excluding transmission and financing, increased as follows –

Year	Estimate	Inf. Fact.	2017 cost
1999	0.97	2.403	2.33
2010	3.37	1.103	3.72
2015	3.70	1.021	3.77
2017	5.50	1.015	5.58

Cost estimate excluding transmission and financing.

From the original estimate, the cost has more than doubled. There are many factors leading up to such a debacle, including – gross underestimate of the construction difficulties in a harsh sub-arctic environment; senior management staff with absolutely no hydro experience; acceptance of a low bid for the civil work from an Italian contractor (Astaldi) with no cold climate experience, and no experience working in Canada; no independent quality control, resulting in several incidents causing significant cost increases; the lack of an independent Project Review Panel; no oversight by any government department, and a powerhouse construction design unsuitable for a sub-arctic cold climate.

This latter comment deserves some explanation. In harsh environments it is customary to undertake all concrete work within a large heated and insulated hoarding, as shown in the photos of Hydro Quebec work. For a large structure such as the powerhouse, the structure would be designed with the superstructure steel commencing at the lowest possible level, to be embedded in the concrete substructure up to the repair bay floor level. The outside walls would be closed off with pre-cast concrete panels up to the repair bay level and above with the powerhouse siding, so that the entire building could be heated at the earliest possible date for easy concrete placement. Interior access would be facilitated by an overhead warehouse high speed crane with a capacity of about 10-15 tons, running on the main crane rails, for transporting concrete and re-bar.

Astaldi finally recognised the advantage of a hoarding and started to install the building (known locally as the "dome"), only to demolish it when half built – why? – Because they had forgotten to include an overhead crane, so interior access was not possible with the site tower cranes. An excellent illustration of the lack of experience. Decisions such as this resulted in Astaldi being on the verge of bankruptcy in 2015, requiring a major renegotiation of the contract at a substantial increased cost.

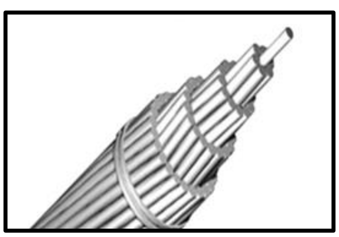
Dome being installed.

Scrap steel from demolished dome. Source – Uncle Gnarley blog, May 2015.

Currently there is a forensic cost review being undertaken by an independent commission appointed by the government. Results are not expected until the end of 2019.

There are three other incidents that demonstrate the lack of construction experience resulting in increased costs. All contractors were required to undertake their own quality supervision, a fatal mistake. This is clearly illustrated by the acceptance of several hundred kilometers of defective transmission wire with a popped-out strand. The defective wire passed all inspections (by contractors?) to arrive at the site. On seeing the defect, the transmission contractor advised NALCOR, only to be told to string it anyway! And approximately 170 km (total 340 km of conductor) of the DC transmission line had been strung before the work was halted. After removal, the conductor was sold as scrap'.

Defective transmission cable conductor with popped-out strand.

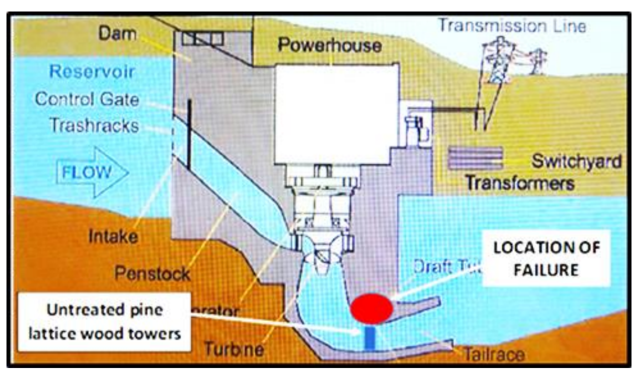


Transmission line conductor strand layout.

To quote Joe Schell, a transmission line expert - ***"The only logical place for this to happen is in the factory during the stranding procedure. Each strand comes off its reel or spool, is fed into the stranding machine where it is preformed and coiled around the layer below it, layer after layer, until the final layer is completed. As the first conductor is formed, all the procedures are [presumably] checked, measured and corrected as necessary until the output from the stranding machine meets the specification. Then the production run can commence, after which, to a great extent, automation takes over. Obviously, sometime during the stranding procedure, something must have occurred that caused this one strand to be incorrectly coiled and it continued, reel after reel, without stopping until at least 340 km of conductor had been fabricated."***

The other far more serious incident was the collapse of a concrete form during a concrete pour in the lower part of the powerhouse. As reported by the CBC on May 30, 2016, (the collapse occurred on the 29th) ***"Concrete was being poured to construct the lower draft tube, essentially a large pipe that will return water to the Churchill River".***

Concrete forms do not collapse. During my 67 year career in the hydro industry, I have never encountered such an incident. Their collapse is so serious, that formwork design is rigorously verified, since a collapse will endanger worker safety, and if a worker is submerged in the heavy wet concrete, retrieval is impossible. NALCOR was very fortunate that no lives were lost, and only 6 workers were injured.



Schematic showing location of draft tube formwork failure. Source – NALCOR.

The forms were supported with untreated southern pine softwood timber lattice towers as shown in the photos obtained from the Independent Engineer's report dated July 2016.

From the photographic evidence it is obvious to any observer that the timber lattice towers were rotten, weathered and hence deficient and should never have been used to support a heavy load of concrete.

Photo showing lattice timber supports

At the time of the collapse, there were 6 workers at the site. All fell into the concrete mix during the collapse, and one was submerged up to his shoulders, but luckily was instantly pulled out by a fellow worker.

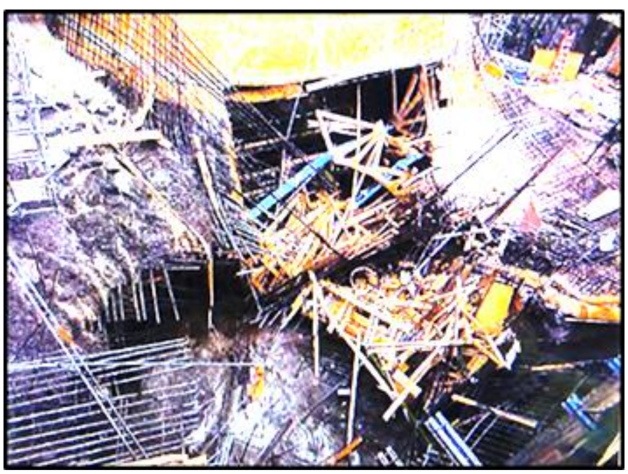


Photo of collapsed formwork.

There were 6 towers supporting the forms, and all collapsed. The failure destroyed all evidence, hence the report was based on observations of the condition of the lattice towers in the other units. The collapse was attributed to - Flooding up to about 3 feet above the timber tower foundation; Fungus and decayed wood in towers with mushroom growth; Exposure of the untreated wood to rain and snow; Severe weathering, with some weathering occurring during storage at site, and several other factors. From the foregoing, it is obvious that there was no quality control at the fabrication plant and on site, and no NALCOR staff with sufficient experience to realize that the towers were inadequate. This is astonishing, since any carpenter looking at the towers would conclude that something was seriously wrong.

Fungus growth and weathering of timber.

Silty water spout downstream of cofferdam, in center of red circle. Photo by worker on site.

The third incident was excessive seepage through the dam cofferdam.

Hydraulic model studies had indicated that the water in the rapids was too fast to allow the use of only one rock groin advancing into the river. Two were required. This resulted in a cofferdam design as illustrated below. The impervious material was to be placed between the two groins. However, there was no upstream temporary seal allowing dewatering of the impervious material foundation. This resulted in the sandy, silty clay being dumped into the water between the groins, and no assurance of a tight seal between clay and rock. Moreover, the extensive seepage through the upstream rock groin meant that the fines in the sandy clay were washed out near rock level.

On November 18th, 2016, the CBC reported – *"There was "increased water seepage" from a temporary cofferdam at the Muskrat Falls reservoir early Friday morning, according to a statement from Nalcor Energy. An engineering team inspected the cofferdam and recommended the reservoir levels be reduced to "mitigate risk associated with increased flow and to maintain the integrity of the cofferdam," according to a statement from Nalcor. The Crown Corporation opened the spillway gates, causing increased water flow downstream of the Muskrat Falls hydroelectric project. Nalcor CEO Stan Marshall said Nalcor made the decision to bring down the water after noticing increased flow and discoloration of the water".*

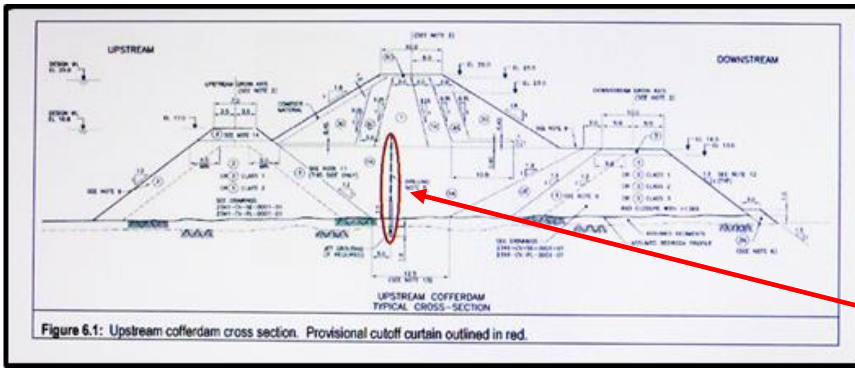


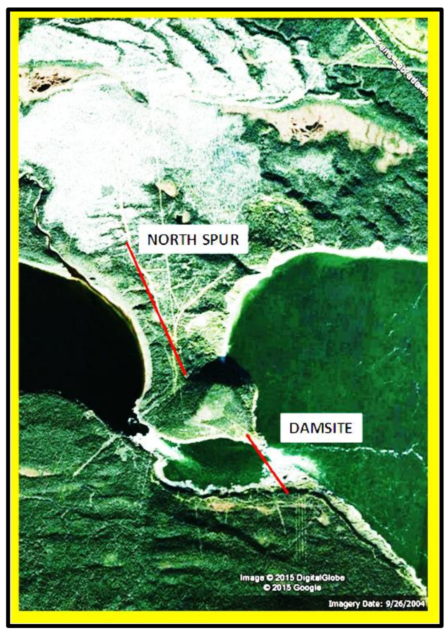
Figure 6.1: Upstream cofferdam cross section. Provisional cutoff curtain outlined in red.

Drawing showing cofferdam section. Source – NALCOR. Note cut-off wall was not built.

Another issue was extensive large cracks in the cofferdam rock foundation which were never grouted. Also, the provisional cut-off curtain was never installed. The result was as expected, excessive seepage through the cofferdam, to such an extent that the small downstream cofferdam was breached. After a few days, the seepage became large as fines were being washed out, and a spout developed on the downstream face of the downstream cofferdam.

View of Muskrat spillway and cofferdam.

Google view of the North Spur at Muskrat



After lowering the headpond, NALCOR started a grouting program to grout the foundation of the upstream cofferdam, since there was the very real danger of a washout. The grouting continued for several months over the winter until the seepage was reduced sufficiently to be handled by pumps, contributing to a substantial increase in cost.

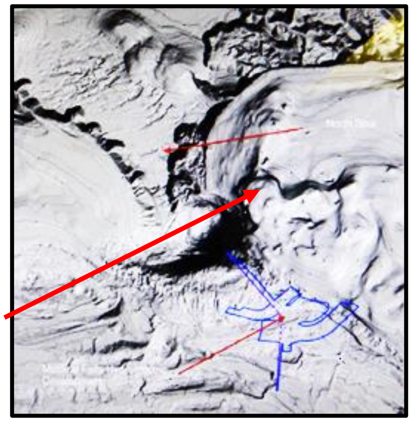
But enough about costs, so turning now to the issues associated with the North Spur.

The north spur forms a natural earthfill dam, with a crest elevation of about 60 m, and about one km long, which connects the rock knoll to the north bank of the valley……. The crest width varies from about 1,000 m at its north end to about 70m at its south end where it has been narrowed by erosion and landslide activity in the past. The head across the spur is presently 16 m from river level upstream to downstream. The impounding of the reservoir to El. 39 m will increase the hydraulic head across the spur to 36 m and stabilization measures are then necessary to ensure its long-term stability under both normal and extreme water levels. The soils forming the spur consist of a complex interbedded sequence of relatively low permeability silty sands and sands, and sensitive marine clays. Source – NALCOR.

Also, there is a history of landslides in the valley, with several occurring on the upstream and downstream banks of the Spur. A very large landslide occurred at Edwards Island, some 65km upstream of Goose Bay about the end of February 2010. It involved about 2,000,000m^3 of material. Source – AMEC Geotechnical investigation: Edwards Island Landslide, August 2011. There are many other landslides both upstream and downstream of Muskrat Rapids.

1978 landslide scars. Other scars.

Google Earth view of right river bank downstream of Muskrat Rapids.



Lidar image of area around North Spur, showing numerous landslide scars, even in river bed. Source – Stabilization of the North Spur at Muskrat Falls: an overview. CDA paper presented at annual conference – October 2014 by Greg Snyder.

In November 1978 a large landslide occurred on the downstream side of the North Spur. The slide removed about 1,000,000m^3 of soil from the neck of the Spur and reduced the width of the crest by almost 100m. (Source Snyder paper).

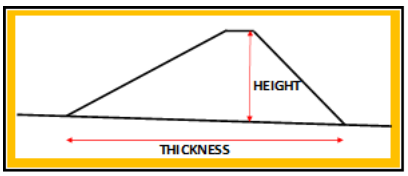
Edward Island landslide.

All dams built on sensitive clays have very flat side slopes to achieve stability. The flatness can be judged from the base thickness to dam height ratio. For example a 50m high dam with a base thickness of 300m would have a ratio of 300/50 = 6. (See schematic) The North Spur side slopes are stepped to give an overall ratio of about 10. (Source Snyder paper Figure 6). A comparison with four other dams on sensitive clays is shown below. Fortunately, few dams are built on sensitive clays, hence the lack of more data.

Name	Height-(meters)	Thickness (meters)	Thickness/height ratio
Gardiner Dam, Saskatchewan.	**64**	1,500	**23.4**
Rafferty Dam, Saskatchewan.	20	278	13.9
Waba Dam, Ontario.	11	200	18.2
North Spur, Labrador.	**64**	570 – 950**	**8.9 – 14.8**
Dyke D-14, Quebec (SEBJ).	**7**	65	9.3

* *thickness below creek outlet from the Kettle Lakes. Note, Gardiner Dam has same height as the North Spur.

Schematic – Thickness-height ratio.



NALCOR has maintained that the SNC design for the North Spur, which required re-shaping of the slopes and the installation of a cut-off wall had been reviewed by four independent experts. These included – MWH, Hatch, Professor Idris and Dr. Leroueil. Not exactly in accordance with the facts, as I found out -

Professor I. M. Idriss, Professor Emeritus of geotechnical engineering, is a retired earthquake expert from the University of California at Davis (UC Davis). He attended a NALCOR workshop in December 2013. ***"In his presentation at the end of the workshop, Professor Idriss concluded that if the stabilization measures of the North Spur are built as currently designed, they will have a satisfactory performance during future earthquakes".*** Source – NALCOR 2016 report, page 198. Note that Professor Idriss has not commented on the slope stability safety aspects of the North Spur dam.

Dr. Serge Leroueil from the University of Laval in Quebec. In 2012 he co-authored a paper with Dr. A. Locat titled "Progressive failure in natural and engineered slopes". Hence he knows the properties of quick clay. However, in his review of the NALCOR 2014 report, (not released by NALCOR) he was very cautious in his comments. He surprisingly starts with ***"my knowledge on the dynamic behaviour of soils and its analysis is rather limited".*** His brief comments contained in 1.5 pages, are only based on Section 2 of the report, without reviewing the extensive appendices. He described the report as "satisfactory". However, he did mention that "***the stabilization works increase the factor of safety from about 1.0 to about 1.6, which is very significant ……. eliminating the possibility of progressive failure in the sensitive clays".*** And ***"the conclusions however (on dynamic analysis) look very interesting".*** (A higher safety factor is preferable). This is certainly not an unequivocal endorsement of the SNC work.

Hatch has stated in a personal communication that they have not checked the stability of the spur, only providing a hydro-geological computer program to determine the peizometric pressures within the spur due to changing reservoir levels.

MWH were adamant that they had not reviewed any of the documents provided by NALCOR with the statement that – ***"MWH have never at any stage been involved in the design of the North Spur. We act as Lender's Engineer to the Federal Government and have never at any point been actively involved in the design of any of the project components. I think you should correct this as I believe some of this ends up in the Newfoundland Press."*** Source personal email dated 9th December 2016. This lack of a design review is the main reason I have been calling for an independent Review Board.

Reshaping work on the upstream face. Note slips on face.

Re-shaping work on the downstream face. August 2016.

Then there is the pro-bono work undertaken by **Dr. Stig Bernander** at the request of the Grand Riverkeepers Association in Happy valley. His expenses to visit the site and river valley were paid by concerned citizens, and later he issued three extensive reports. A remarkable achievement, since he has just turned 90!

Dr. Bernander is eminently qualified to analyse the North Spur safety issues. He is-

A recognized international expert in sensitive clays. He studied civil engineering and became Head the Design Department of Sanska, one of the world's leading project development and construction groups. After a 40 year distinguished career, he started his own consulting company. After a large landslide in Tuve, Sweden in 1977, he began developing an engineering model for slope stability analysis on 'sensitive' clays. He developed software for the model during the 1980s and, in 2000, summarized his findings in a PhD thesis at Luleå University. An unpublished Paper by a Professional Engineer familiar with Bernander writes: "the thesis conveys his experiences of slide modeling focusing on the nature of triggering agents and the different phases that a slope may undergo before its stability becomes truly critical." Source – Uncle Gnarley, 27th October 2014'

Dr. Bernander reviewed the SNC report titled "North Spur–Stabilization–Works–Progressive–Failure-Study", dated December 2015. After reading it, I become more concerned than previously, since Dr. Bernander had effectively demonstrated that the SNC analysis was flawed, being based on inapplicable methodology. In fact my concern had escalated to the point where I thought it may not be possible to prove that either the North Spur is safe beyond any reasonable doubt, or that it is shown to be unsafe.

Aerial view completed Spur downstream face re-shaping.

Aerial view of completed re-shaping work on the North Spur. Source of above 4 photos – NALCOR Energy.

Dr. Bernander is not convinced that the Spur will fail, only that the stability has not been proven beyond any doubt, a situation which requires further geotechnical work. Dr. Bernander's report is far too technical to explain. It is filled with geotechnical engineering terms and equations, to such an extent that only someone with a doctorate in geotechnical engineering and extensive experience will be able to follow the reasoning. His conclusions are as follows –

1. The SNC methodology is incorrect.
2. Insufficient analysis of failure planes.
3. The use of FLAK analysis is not justified.
4. The applicability of the "elastic-plastic" (FLAC) methodology is not proven.
5. The safety factors determined by the SNC methodology are not correct.
6. Finger drains are not effective.

Eventually, NALCOR convened a Geotechnical Peer Review Panel (GPRP) at the end of 2017. The members included –

Prof. Bipul C. Hawlader. Geotechnical Professor at Memorial University, St. John's.

Prof. Serge Leroueil. Retired professor at Université Laval, Québec City, Canada.

Dr. Jean-Sébastien L'Heureux. Technical Lead, Norwegian Geotechnical Institute, Norway

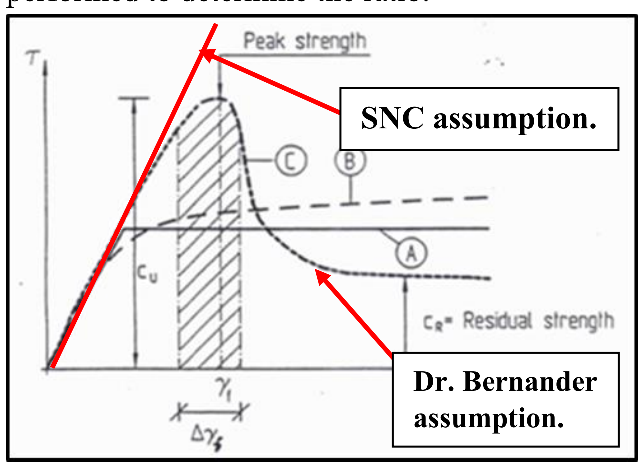
Prof. Ariane Locat. Professor at Université Laval, Québec City, Canada.

They issued a report titled Geotechnical Peer Review Panel of Dr. S. Bernander's Reports and Analysis of the North Spur, dated 2nd February, 2018. The 30 page report concluded that –

1. The Muskrat landslides are similar to others in Eastern Canada in sensitive clays.
2. The clays in the North Spur are comparable to others in Eastern Canada and Norway.
3. The analysis methodology used by SNC corresponds to state of the art current practice.
4. The "Progressive Failure Anaylis" performed by SNC is conceptually acceptable.
5. SNC used State of the Art methodology in their earthquake analysis.
6. The Bernander-Drury analysis of the cut-off wall is not correct, and there is no lateral force.
7. Finger drains will be effective and enhance local stability.
8. The tests recommended by Dr. Bernander could undermine the slope stability.
9. Dam Breach flood wave has been investigated and attended to.

This report did not convince me that the Spur is stable since there was no new calculations and no further geotechnical testing. Hence I have several concerns with the report -

The first concern is that apparently stress-strain tests have not been undertaken on the Spur soils, instead results from other soils were used. Dr. Bernander believes that the stress-strain relationship will not be linear at higher strains, whereas the SNC analysis assumes a linear relationship at all strains. A test should be performed to determine the ratio.



Typical stress-strain relationship. Source – Bernander Report 21st Dec. 2015.

The second concern is the impermeability of the cut-off wall. Based on the experience at Bighorn, pervious pockets may well remain in the wall due to collapse of the pervious sides during placement of the clay barrier. Unfortunately there is no method to test the impermeability of the wall until after the reservoir is filled.

The third concern, as first mentioned by Phil Helwig, is the use of safety factors developed for dams constructed with known homogeneous materials such as rock, gravel, and silt, all within a determined size, placed and compacted under strict code requirements, and tested throughout construction. On the other hand, the North Spur contains a mixture of sand, silt and clay, resting naturally, and not compacted nor tested as frequently as in an engineered dam. The safety factor for such a natural dam should be higher.

And the last concern is the use of an average strength for the materials in the dam, whereas, Dr. Bernander used strengths determined from the areas with minimum strength. What is that old saying – a chain is only as strong as its weakest link! I doubt if sufficient borehole testing has been undertaken to justify the use of an average strength. The extent of soft and low-strength materials is unknown at this time.

I wrote an article published in the Uncle Gnarley blog on July 9, 2018 titled – The North Spur, My Final Comments - outlying all my concerns. I was astonished that the GPRP dismissed the effect of the horizontal force (Item 6) from the reservoir on the spur, it is there and cannot be ignored.

Dr. Bernander issued a comprehensive rebuttal of the GPRP report pointing out the lack of further geotechnical analysis, and all of the issues I had with the report. The rebuttal was endorsed by two other Geotechnical Professors stating –

The stability of the dam at North Spur in the Muskrat Falls hydro power plant in Churchill River in Labrador, Canada, is a geotechnical challenge with strain-softening soils that may lose their stability when being deformed. There is a risk that a forward progressive failure may be initiated. The concern from Stig Bernander, that a proper analysis of such a progressive failure ought to be carried out, should be taken seriously. Such an analysis must use the deformation properties of the soils in question and has, as far as we can see, not been undertaken by the Muskrat Falls Corporation or its contractors.
Luleå in July 2018
Jan Laue Chair Professor, Dr.Ing.
Sven Knutson Senior Professor, Tekn. Dr.
Division of Soil Mechanics and Foundation Engineering
Luleå University of Technology

NALCOR has yet to reply to the rebuttal, and I sincerely hope that further geotechnical work and analysis will be undertake.

And finally on the financial side – the bond interest and operating cost will double the kilowatt-hour rate to 23.3cents (Source, Vardy, The Independent, February 23, 2018) to become the most expensive electrical power rate in Canada. This will persuade customers to find other sources of energy such as wood for heating, resulting in a reduction in electrical demand. The end result will be – ***"It is essential to the survival of the Province that a financial restructuring of the Muskrat project take place as early as possible. The Federal Loan Guarantees must result in the debt being fully taken on by Ottawa."*** Source PlanetNL. 26 Feb. 2018 in Uncle Gnarley blog.

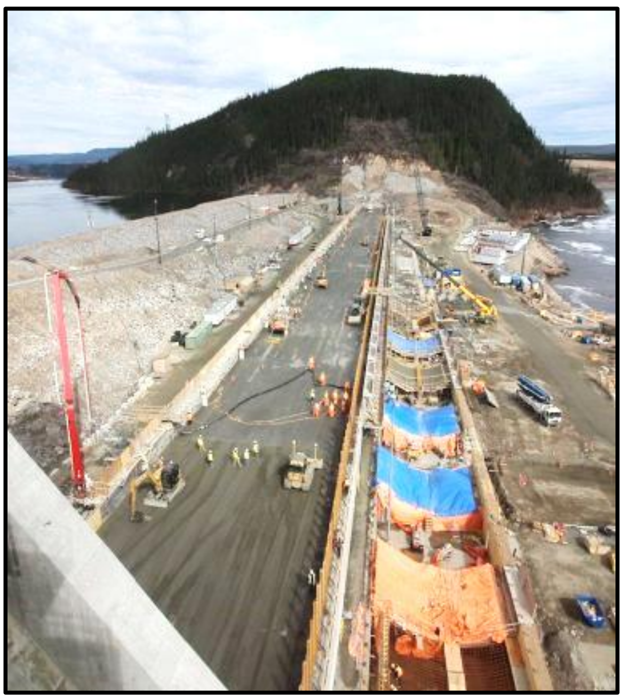
To illustrate the dilemma faced by Newfoundland, the cost of the project at $12.7B (including transmission and financing) is equivalent to Ontario, with a population 26 times larger, embarking on a development costing

$12.7B times 26 = $330B, just not financially feasible, and totally beyond the comprehension of any economist.

Even The Economist magazine has written an article on the project, titled – ***"A dodgy dam in Canada's East – The moral of Muskrat"***. August 19, 2017.

And lastly, the question remains – is the North spur absolutely safe? It can withstand a 1/10,000 flood and a 1/10,000 earthquake. Is the risk of a slope or slide failure at the North Spur also assessed at 1/10,000? - I doubt it – then how risky? – Nobody knows, until a risk analysis has been undertaken.

Site photos follow, all from Nalcor construction photo website.



RCC dam construction across river.

Spillway to North Spur – downstream view.

Downstream view, spillway and cofferdam.

Powerhouse cofferdam.

RCC dam construction.

RETIREMENT AT LAST – 2017

Sitting here in my office in July 2018, it is now 67 years since first graduating in June 1951. During that period I have witnessed remarkable changes in the engineering profession. Engineering tools which had remained static for centuries, suddenly evolved with the introduction of computers and thousands of time-saving programs permitting the construction of very complex structures such as the "birds nest" Olympic stadium in China, and the Guggenheim museum in New York.

Similarly in the hydro energy industry, there are programs for determining waterhammer and surges in conduits, slope stability of dams, foundation seepage, and dam breach flood wave propagation, to name only a few. Now engineers can complete a complex analysis in a few hours instead of weeks or months.

The hydro consulting industry has changed completely. Previously there were many independent large consulting companies, all working on a fee for services based on an hourly charge for the work. The award of consulting contracts was based mainly on experience and knowledge, with only a secondary glance at the estimated engineering cost. For example, all World Bank financed developments were awarded on a 2-envelope system, whereby the "A" envelopes containing project methodology and experience were opened first, the best consultant selected, and after this only the one "B" envelope for the selected consultant containing cost was opened, and the contract awarded. The remaining "B" envelopes were returned to the consultants unopened.

Now, most large independent hydro consultants have been purchased by international contractors so that they can participate in the new contracting method for hydro plants. This requires the preliminary design of the facility and the submission of a single price for the entire work. With between 3 and 5 contractors bidding for the work, this means that between 67% and 80% of the bidding cost is wasted. Also, the bid cost is very high since the entire project has to be designed and firm prices obtained for all the equipment. I do not entirely agree with this form of contract. It leads to contractors cutting corners in both the design and construction.

For the engineering staff, the changes have been difficult. Previously, an engineer worked with experienced engineers directing the work, looked at alternatives, and designed the structure with little regard to the engineering time spent, since the hourly cost was always billable, within limits. Now, many engineers are given a fixed time for the design, and if more time is required, there is no further remuneration. Senior experienced engineers have only a limited time for advising and training junior engineers, since they also are working within a defined time budget. One recently remarked ***"I don't even have time to think!"*** This is due to the new type of contract with one fixed price for the project. Engineering costs (and all other costs) just have to be kept within budget, or the contractor will incur a loss.

This lack of training and passing on knowledge by senior engineers explains the increase in errors and omissions in feasibility reports and construction. It has resulted in hydro engineers working on projects when they do not have the required extensive experience, exacerbated by minimal discussions with their peers in other companies due to the absence of technical papers and attendance at conventions. Every feasibility report I have reviewed in about the last 15 years has at least one serious error, and there have been enormous cost over-runs during construction of recent hydro projects. Consequently, there are now three major hydro projects being built in Canada, all with estimated costs of $7B to $13B, and all are over budget and behind schedule.

I presented two lectures to senior engineering students at the University of Toronto for three years. I always mentioned that "you have to train your successor". And always someone would ask **"why? This will endanger my job security".** The answer is simple – no successor, no possibilities of promotion. I cannot see how this can now be accomplished with limited man-hours, again helping to explain the current hydro debacles.

Staff motivation and loyalty has also changed, with instant dismissal when the project is completed and there is no prospect for a new assignment. Whereas, previously, there was sufficient retained earnings within the consulting company to carry over staff for a few months until the next project appeared, as was done by Montreal Engineering when Spray and Rundle were postponed in 1961 due to a downturn in energy demand from the recession.

There have also been peripheral changes. Up until about 1980, engineers had time to prepare and publish papers on their projects. There were many journals available for papers such as the American Society of Civil Engineers Energy Journal and the Canadian Electrical Association Transactions, both of which have ceased publication.

Between 1980 and 2000 there was a significant decrease in hydro papers since engineers no longer had time for paper preparation, and attendance at conventions was limited due to lower budgets imposed by the recession and account managers, their impression being that such work does not contribute to the bottom line. Instead, I found that attendance at conventions was very important, since networking revealed many new clients, and one which I worked for was at a convention in Vancouver, where I presented a paper. About a month later, he email asking me to provide advice on his hydro project.

Now, hydro papers are even discouraged by utilities and drawings of structures prohibited due to a fear of providing information for sabotage or terrorist attacks. Permission for site visits by hydro convention delegates is difficult to obtain, with restrictions on photos and tours through the powerhouse, for the same reasons. Just look at the tour facilities for La Forge in 1995, as compared with the tour of Grand Mere in 2006, both large Hydro Quebec plants. Hence, it is no wonder that young engineers are not attracted to careers in the hydro industry.

Looking back, I can see that I was often in the right place at the right time, and that unrelated actions by others influenced the direction of my career. A London (England) engineering student does not report for work, and I take his place, to start a career in hydro; Dr. Mosaddeq nationalizes an oil company in Iran, I return to university and meet John Nuttall, who suggests I go to Canada, and through his friend Dave Duguid, I find Montreal Engineering; Jack Sexton (Chief Civil) makes a simple mistake, and I am suddenly in charge of all hydraulics.

In the early years, I started with a drafting board (important) and I had an excellent mentor in the form of Geoffrey Gaherty, president of both Montreal Engineering and Calgary Power.

Even my work for the Aberdeen Harbour Board prior to starting university proved to be a learning experience – always question the data – and don't be afraid to speak up if something appears to be questionable.

From this, it is easy to conclude that I was indeed fortunate to work on hydro plants during their golden years, when they were perceived as being entirely beneficial, with all nations wanting and encouraging their development. Yes, there were a few unexpected disasters such as the degradation of the Nile delta due to the change in annual flow pattern caused by the Aswan Dam. Another is the changed flow regime at Wood Buffalo National Park in Canada caused by the dam at Peace Canyon in British Columbia. But the industry has learned from such mistakes.

Now, the hydro industry is over-regulated with the cost of permits and environmental assessments often being larger than the cost of site investigations and engineering, a prime example being Enloe in California. This has resulted in few new developments on the North American continent, except in remote areas of Labrador, Quebec, Manitoba and British Columbia, where there are still many undeveloped and attractive hydro sites, with minimal environmental concerns.

So, time to take down the shingle and retire. Let someone else solve hydro problems, and I wish them luck. It has been a blast!

On a personal note, my dear Vera was diagnosed with dementia in January 2012 and I moved her into the nearby Vivalis nursing home where she stayed until passing away from a massive stroke in May 2014. She told me twice that she was happy there, knew that her **“*head did not work*”** and that **“*all my needs are taken care of here”.*** Miss her!

With an empty 4-bedroom house, I looked around for a retirement home and selected this one now called Le Selection West Island in May 2012, located in Pointe Claire, and near the Vivalis. I moved into an apartment on the 6th floor in June 2012. At 775 square feet, it has enough space for my home office.

My retirement home.

My home office.

In 2013, my old heart started to misbehave, so I was fitted with a 3-wire synchronizing pacemaker, with strict instructions to – never enter a factory or powerhouse with electrical generators, do not stand near a large loudspeaker, do not walk under a high-voltage transmission line, and do not walk through an airport scanner!

And now my balance is off, along with my hearing, so I walk with a cane and wear hearing aids!

These restrictions obviously affected my ability to function as a consultant. On my last site inspection at Thomas Lowe, both powerplants were shut down due to work on the intake. Also, I had a cane which prompted the local engineer to offer a pickup for my transport, which I rejected, since walking was then not difficult. I could still see what was required to upgrade the facility.

So, no more site inspections!

After reading over this memoir, I was left with the impression that the photos may prove to be the most valuable contribution, since they cover a wide range of facilities including old and new developments, both large and small, along with my odd comment on the project.

So what do I do now? Well, I am the editor of our quarterly newsletter. Paper copies are distributed to the approximately 300 residents here and another 200 relatives receive a digital copy over the internet. I take all the photos.

Also, there are over 30 activities here at the residence, and I participate in several including the daily exercise classes, the fortnightly excursions to a restaurant for lunch, the occasional excursion to a museum, attend conferences on various subjects by invited speakers, watch the occasional movie (screened every evening), watch the occasional "TED" talk on Sunday afternoons, and of course, I always attend the "Happy Hours" on Tuesdays and Thursdays in the residence pub, one of the reasons I selected this residence! There are no other retirement residences in Quebec with a liquor license.

Yes, I am still busy; should have come here far sooner.

AND THIS TIME I DID MANAGE TO RETIRE.

I HOPE THESE MEMOIRS WILL TO BE OF INTEREST TO OTHER HYDRO ENGINEERS.

19th July, 2018.

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