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### **ENGINEERING HISTORY PAPER #99**

## **“Manicouagan 3 Main Dam – History of the Board of Consultants”**

**by Richard Gervais**

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# Overview of the Manicouagan 3 Main Dam – History of the Board of Consultants

## Aperçu du barrage principal de Manicouagan 3 – Histoire du Comité des experts

Richard Gervais

### ABSTRACT

The Manicouagan 3 Project was built by Hydro-Québec between 1971 and 1975. Early references in the technical literature date back to 1965, but an official Board of Consultants was established by the owner in 1967. This paper covers information about this board and its members as we near the 45th anniversary of this successful project resting on difficult foundations.

### RÉSUMÉ

L'aménagement Manicouagan 3 a été construit par Hydro-Québec entre 1971 et 1975. Les premières références dans la littérature technique remontent à 1965, mais un Comité d'experts a été formé par le propriétaire en 1967. Vous trouverez dans ce document des informations sur ce comité et ses membres alors que nous approchons du 45e anniversaire de ce projet reposant sur des fondations difficiles.

### MANICOUAGAN RIVER

The Manicouagan River flows towards the St. Lawrence River through a vertical drop of 358 m from the Manicouagan Reservoir, filling an ancient meteoritic crater, to Baie-Comeau on the North Shore of the Province of Quebec. Figure 1 shows the extent of the river drainage basin.

From downstream to upstream, six power stations are located on the

river: McCormick (235 MW), Manic-1 (185 MW), Manic-2 (1229 MW), Manic-3 (1326 MW), Manic-5 (1596 MW) and Manic-5-PA (1064 MW). Two other stations, Toulnostouc (526 MW) and Hart-Jaune (51 MW), are located on tributaries of the same name. Electricity from these stations is delivered to large population centres through a 735 kV transmission grid, which was a technical breakthrough in the mid 1960s.

### MANICOUAGAN 3 PROJECT

The Hydro-Québec Manicouagan 3 Project consists of three main structures built between 1971 and 1975:

- Underground power station with 6 turbines for a total of 1326 MW
- Secondary dam, a 71 m high concrete gravity structure with the spillway gates
- Main dam, a 106.68 m high sand and gravel embankment with a till core



Figure 1. Manicouagan River Drainage Basin (Hydro-Québec).

Figure 1. Bassin versant de la rivière Manicouagan (Hydro-Québec).

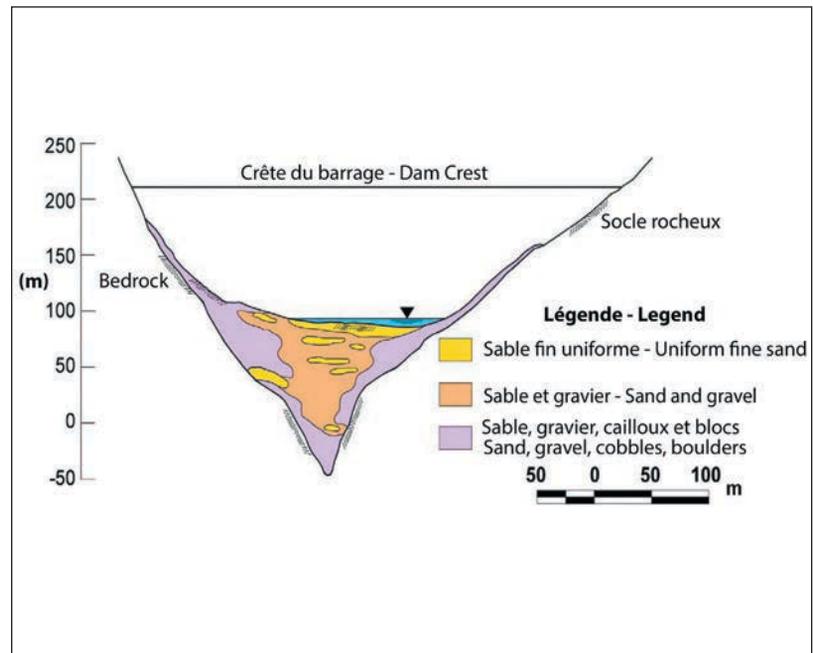


Figure 2. Manicouagan-3 Stratigraphic Profile.

Figure 2. Profil stratigraphique à Manicouagan-3.

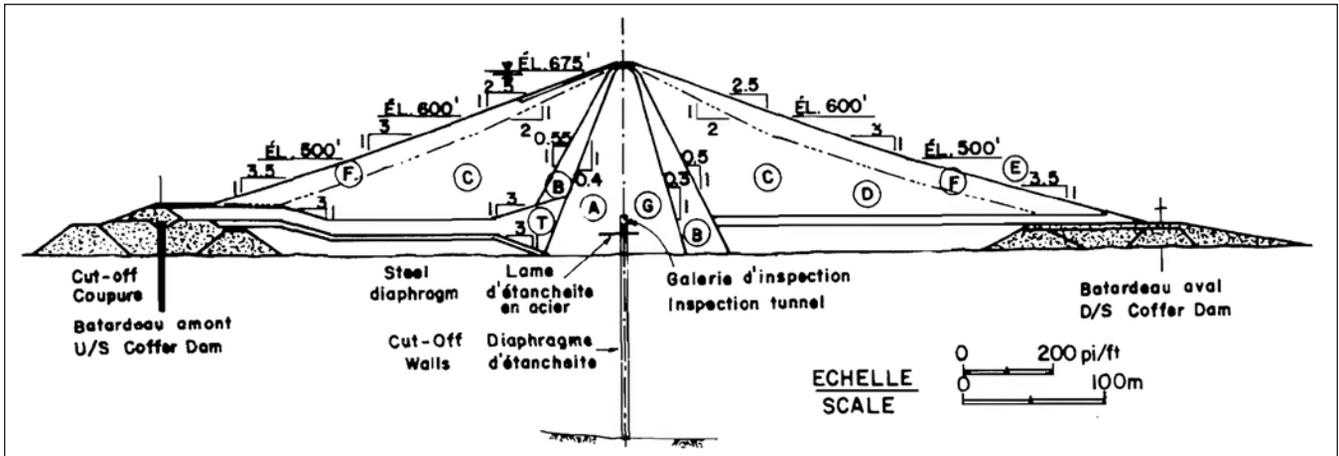


Figure 3. Manicouagan-3 Main Dam Typical Cross Section (Dascal 1979).

Figure 3. Coupe-type du barrage principal Manicouagan-3 (Dascal 1979).

| Legend  |                                                                                                              |
|---------|--------------------------------------------------------------------------------------------------------------|
| Légende |                                                                                                              |
| A       | Till Core<br><i>Noyau de till</i>                                                                            |
| B       | Gravelly Sand Transition<br><i>Transition en sable graveleux</i>                                             |
| C       | Coarse Granular Shell<br><i>Recharge en sol pulvérulent grossier</i>                                         |
| D       | Selected Gravel Drain<br><i>Drain de gravier sélectionné</i>                                                 |
| E       | Rockfill Downstream Slope Protection<br><i>Protection du parement aval en enrochement</i>                    |
| F       | Cobble, Boulder and Rockfill External Zones<br><i>Zones extérieures avec cailloux, blocs et enrochements</i> |
| G       | Bentonite Cushion Above Inspection Tunnel<br><i>Zone de bentonite au-dessus du tunnel d'inspection</i>       |
| T       | Till Blanket<br><i>Tapis en till</i>                                                                         |



Figure 4. Manicouagan-3 Main Dam Aerial View (Hydro-Québec).

Figure 4. Vue aérienne du barrage principal de Manicouagan-3 (Hydro-Québec).

of interlocking piles bored to bedrock through the alluvium.

When these piles were bored, computer-controlled drilling equipment did not exist. Great care was necessary to maintain the verticality of the piles to the required depths. Inclinoimeters were embedded in these piles during concreting.

The Peribonka Dam was built by Hydro-Québec from 2005 to 2007 on alluvial foundations like those of the Manicouagan 3 Main Dam. However, foundation treatment technology has made great progress over the last decades, and the solutions used at Peribonka are quite different (Morency *et al.* 2012).

The cutoff walls were capped with an inspection gallery that also allowed access for a small drill rig, if grouting between the concrete cutoff walls was deemed necessary. This injection was never required.

Since the cutoff and the gallery are rigid inclusions within a large volume of compressible foundation materials overlain by a large dam, a bentonite layer is present above the gallery to act as a soft transition to the till core. The cutoff walls and the gallery were instrumented to measure stresses and displacements.

Numerous open pipe and vibrating wire piezometers are located in the dam core and in the foundation.

Figure 4 shows an aerial view of the Manicouagan 3 Main Dam downstream slope and both abutments.

## BOARD OF CONSULTANTS 1967-1983

The first meeting of the Board of Consultants was held in August 1967 with Arthur Casagrande, Frank A. Nickell (Bureau of Reclamation), Robert Peterson (Prairie Farm



From l. to r. (Taken from Hydro-Presse, June 1973)

De g. à dr. (Extrait d'Hydro-Presse, juin 1973)  
Leo Casagrande, Francis B. Slichter, Arthur Casagrande, Oscar Dascal, Frank A. Nickell.

## MAIN DAM

The main dam rests on a thick foundation of alluvial materials, up to 126 m deep. It consists mostly of sand and gravel, with coarser elements present near the steep faces of the valley. Figure 2 shows the heterogeneous nature of the soils within the deep canyon.

Figure 3 shows the cross section of the embankment dam with a central till core and sand and gravel shoulders. The positive cutoff consists of two 600 mm thick concrete walls made

Rehabilitation Administration) and Francis B. Slichter (U.S. Army Corps of Engineers).

Mr. Peterson died suddenly in 1969. Mr. Frank A. Nickell also died in 1975. They were not replaced on the board.

Acting as secretary for Hydro-Québec until 1972 was Guy S. Larocque. After he was transferred to *Société d'énergie de la Baie James* for the construction of the La Grande Hydroelectric Complex, Oscar Dascal took on his role.

When Arthur Casagrande passed away in 1981, he was replaced by his brother, Leo Casagrande. The 22<sup>nd</sup> and last meeting of Board was held in September 1976, but correspondence with the remaining experts can be traced until 1983.

### ARTHUR CASAGRANDE

Board of Consultants 1967-1980



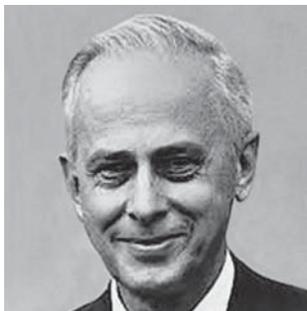
Arthur Casagrande was born in 1902 in Haidenschaft, Austria. He graduated from the *Technische Hochschule* in Vienna in 1924. He moved to the United States where he became a research assistant to Karl Terzaghi at the Massachusetts Institute of Technology (MIT) from 1926 to 1932. He instituted the soil mechanics

program at Harvard University in 1932, where he was a professor for more than forty years. Among his contributions were soil classification, water flow in soils, and shear strength.

He organized the first international conference on soil mechanics and foundation engineering in 1936. He was president of the International Society of Soil Mechanics and Foundation Engineering (ISSMFE) from 1961 to 1965. He gave both a Rankine and a Terzaghi lecture before he passed away in 1981.

### LEO CASAGRANDE

Board of Consultants 1981-1983



Leo Casagrande was born in 1903 in Haidenschaft, Austria. He graduated from the *Technische Hochschule* in Vienna. He started work as a structural engineer in Bavaria, then moved to the United States from 1930 to 1932 as a research assistant to Karl Terzaghi at the MIT. He returned to Vienna with Dr. Terzaghi in 1932. He organized a technical institute for soil mechanics at the University of Berlin in 1933. In 1934, he was appointed head of the division of soil mechanics for German motorways, the *Autobahn*. He worked in this field

for more than ten years, developing the principles of electro-osmosis. He spent the period of the Second World War in Berlin.

After this conflict, he was invited in Great Britain to join the Building Research Station in Watford, where he worked from 1946 to 1950. His brother, Arthur Casagrande, brought him to the United States in 1950. He became a professor at Harvard University in 1956. He developed a practice as a geotechnical consultant with his son, Dirk Casagrande. He died in 1990.

### FRANK A. NICKELL

Board of Consultants 1967-1973



Frank A. Nickell was born in 1906. He graduated as a geologist in 1927 from the California Institute of Technology (Caltech). He obtained a master's degree in 1928 and a Ph.D. in geology and civil engineering from Caltech in 1931. He was a geologist for the U.S. Bureau of Reclamation (USBR) from 1931 to 1942 in Denver, Colorado. He was the resident geologist during the construction of Hoover Dam and he became chief geologist at USBR from 1938 to 1942. He worked for Shell and Standard Oil from 1943 to 1944.

Mr. Nickell was a consultant from 1945 until his retirement in 1973. He worked in forty countries, notably as an expert to determine the causes of the Malpasset Dam failure in France. He was an expert geologist for Hydro-Québec during the construction of the dams at Première-Chute, Rapides-des-Îles, Manicouagan 3 and Manicouagan 5. He also worked for the underground power stations at Outardes 2 and Outardes 3. He died in 1975.

## ROBERT PETERSON

Board of Consultants 1967-1969

Robert Peterson was born in Eston, Saskatchewan in 1918. He graduated *magna cum laude* from the University of Saskatchewan in 1939. He began his career at the Prairie Farm Rehabilitation Agency (PFRA). He pursued graduate studies at Harvard University under the supervision of Dr. Karl Terzaghi and Dr. Arthur Casagrande. He obtained his master's degree in civil engineering in 1941. He was chief engineer for soil mechanics at the PFRA from 1941 to 1969.

He contributed to the construction of the Pothole, St. Mary and Travers dams in southern Alberta. He was a pioneer in the study of the Bearpaw Shale and of high plasticity clays. He worked on Seven Sisters Dam in Manitoba and Duncan Dam in British Columbia. His career crowning achievement was the successful impoundment in 1967 of Gardiner Dam in Saskatchewan. He died in 1969 at the age of 50. He posthumously received the Leggett Award in 1970.

## FRANCIS B. SLICHTER

Board of Consultants 1967-1983

Francis B. Slichter was born in 1904 in Kansas City, Montana. He was a graduate of the University of Kansas.

He began working for the United States Army Corps of Engineers (USACE) in the Kansas City District. He then moved to the Missouri Division in Omaha, Nebraska, when large dams were being designed and built on the Missouri River. He was head of the engineering division for the Corps of Engineers where he worked from 1949 to 1980 in Washington, D.C. He returned to Kansas City in 1980 and moved to Salt Lake City in 1994. After his retirement, he was a worldwide consultant for hydroelectric projects, notably for the final location of the Manicouagan 5 underground power station. He died in 2000.

## GUY S. LAROCQUE

Secretary for the Board of Consultants 1967-1971

Guy S. Larocque was born in 1933. He graduated in 1957 as a geologist from the University of Montréal. He then graduated as an engineer from École Polytechnique in 1960. He completed in 1963 a master's degree in Soil Mechanics from Harvard University. He started to work for Hydro-Québec in 1960 where he became deputy head of the Geology and Soil Mechanics Division.

He worked on several major projects as well as the Manicouagan-Outardes Hydroelectric Complex. In 1972, he went to *Société d'énergie de la Baie James (SEBJ)* for Phases I and II of the La Grande Project where he stayed until 1986. When he returned to Hydro-Québec, he became head of Dam Safety from 1986 to 1990. He then retired but continued to act as a consultant around the world.

He was president of CANGOLD from 1992 to 1994. He was chairman from 1990 to 1996 of the Technical Committee for embankment dam materials for the

International Commission on Large Dams (ICOLD). He became general reporter for Question 66 on difficult foundations at the Vienna Congress in 1991. He was the Quebec representative for the Tunnelling Association of Canada (TAC), where he was appointed vice-president in 1995. He received the Inge Anderson Award of Merit in 1999. He is also a CDA Life Member. He died in 2018.

## OSCAR DASCAL

Secretary for the Board of Consultants 1972-1976

Oscar Dascal was born in 1926 in Romania. He graduated from the Institute of Mines and Metallurgy of the Politehnica University of Bucharest. He worked in Romania from 1950 to 1962 as well as in Israel from 1963 to 1966.

He moved to Canada in 1966 where he started to work for Hydro-Québec. He became head of the Soil Mechanics Division in 1973. He became an internal consultant with Hydro-Québec in 1978 until he transferred to the Dam Safety division in 1986. He served as an Associate Editor of the Canadian Geotechnical Journal. He received the G. Geoffrey Meyerhof award from the Canadian Geotechnical Society (CGS) in 1999. He became a Fellow of the Engineering Institute of Canada (EIC) in 2001. He retired from Hydro-Québec in 2005. He was a CDA Life Member. He died in 2008. ■

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