DBHD 1.4.1 Canada – Nuclear Repository in Deep Rocksalt, New Brunswick, Nova Scotia

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Abstract

Currently, there are several alternative approaches that have been considered by the various entities that comprise the nuclear industry in Canada for repositories that can accommodate different waste. Ontario Power Generation (OPG) operates multiple nuclear power plants that generate over 50% of the province's electricity. OPG is proposing a storage facility near Kincardine and Lake Huron to inter low and intermediate wastes that is referred to as the Deep Geologic Repository (DGR). However, it is not intended to store high-level radioactive waste. Atomic Energy Canada Limited (AECL) has plans for geological disposal of research and operating waste at a location near to the Ottawa River beneath the Chalk River National Laboratory beside the Ottawa River. The Nuclear Waste Management Organization (NWMO), operating on behalf of Canadian utilities, is reviewing the viability of multiple sites to bury all of Canada's highly radioactive fuel waste. Currently, the NWMO is the only organization in Canada that is studying long-term solutions to the problems posed by high-level radioactive waste. What initiatives are being taken in other countries with regard to the long-term storage of high-level radioactive waste? One example is the Deep Big Hole Repository (DBHD) - for High Level Waste (HLW) that has been developed by engineers in Germany (https://www.dbhd-hlw.de/). DBHB has evolved to the point where there are comprehensive designs and cost estimates to allow for construction. The technology relies upon the availability of Shaft Boring Machines (SBM) of 12 m diameter that can drill down through soil and rock to depths of many thousands of metres. The preferred ground geology is rocksalt which can be found in the Maritime region of Canada. As such, DBHD is thought to be a suitable technology to introduce to Canada for consideration to help dispose of approximately 83,200 tonnes of spent fuel from CANDU reactors.

1. Introduction

For decades the nuclear industry in Canada has studied the question of what to do with the radioactive waste products that result from nuclear power generation. The favoured approaches include proposals to bury the waste products at great depths below ground as a form of geological disposal. There are challenges associated with such proposals including the risks during transportation to a site, validation of the long-term stability of a site, and the life expectancy of containment vessels for the waste.

2. Description of Radioactive Waste

The nuclear industry in Canada operates under the regulatory auspices of the Canadian Nuclear Safety Commission (CNSC) that defines radioactive waste as follows [1]: "Radioactive waste is any material ((liquid, gas or solid)) that contains a radioactive nuclear substance ((as defined in section 2 off the Nuclear Safety and Control Act)) and which the owner has determined to be waste ((as per regulatory policy PP--229900, Managing Radioactive Waste)).. Radioactive waste produced in Canada is managed safely in specially designed facilities. The [CNSC] regulates and licenses these facilities, to protect the health, safety and security of Canadians and the environment."

The CNSC classifies nuclear waste as follows:

Low-level Radioactive Waste: "Low-level radioactive waste contains material that is more radioactive than clearance levels and exemption quantities allow. This type of waste loses most or all its radioactivity within 300 years. It includes contaminated equipment from the operation of nuclear power plants (like protective shoe covers and clothing, rags, mops, equipment and tools). The owners of low-level radioactive waste are responsible for managing the waste they produce. This usually takes place onsite, within its own facility."

Intermediate-level Radioactive Waste: "Waste that has been exposed to alpha radiation, or that contains long-lived radionuclides in concentrations that require isolation and containment for periods beyond several hundred years, is classified as intermediate-level radioactive waste. It typically requires shielding during handling and interim storage. This type of waste includes refurbishment waste, ion-exchange resins and some radioactive sources used in radiation therapy. The owners of intermediate-level radioactive waste are responsible for managing the waste they produce. This usually takes place onsite, within its own facility."

High-level Radioactive Waste: "High-level radioactive waste (HLW) in Canada is used (irradiated) nuclear fuel that has been declared as radioactive waste. This type of waste also includes small amounts of radioactive waste from medical isotope production and other applications that generate significant heat via radioactive decay. Used nuclear fuel produces ionizing radiation. This type of radiation has a strong ability to penetrate matter, so shielding against the radiation is required. Since used nuclear fuel contains significant quantities of radionuclides with long half-lives, it requires long-term management and isolation."

Currently, there are several alternative approaches that have been considered by the various entities that comprise the nuclear industry in Canada for repositories that can accommodate different waste. Ontario Power Generation (OPG) operates multiple nuclear power plants that generate over 50% of the province's electricity. OPG is proposing a storage facility near Kincardine and Lake Huron to inter low and intermediate wastes that is referred to as the Deep Geologic Repository (DGR). However, it is not intended to store high-level radioactive waste. Atomic Energy Canada Limited (AECL) has plans for geological disposal of research and operating waste at a location near to the Ottawa River beneath the Chalk River National Laboratory beside the Ottawa River. The Nuclear Waste Management Organization (NWMO), operating on behalf of Canadian utilities, is reviewing the viability of multiple sites to bury all of Canada's highly radioactive fuel waste. Currently, the NWMO is the only organization in Canada that is studying long-term solutions to the problems posed by high-level radioactive waste.

3. Description of DBHB

What initiatives are being taken in other countries with regard to the long-term storage of high-level radioactive waste? One example is the Deep Big Hole Repository (DBHD) - for High Level Waste (HLW) that has been developed by engineers in Germany (https://www.dbhd-hlw.de/). DBHB has evolved to the point where there are comprehensive designs and cost estimates to allow for construction. The technology relies upon the availability of Shaft Boring Machines (SBM) of 12 m diameter that can drill down through soil and rock to depths of many thousands of metres. The preferred ground geology is rocksalt which can be found in the Maritime region of Canada. As such, DBHD is thought to be a suitable technology to introduce to Canada for consideration to help dispose of approximately 83,200 tonnes of spent fuel from CANDU reactors.

The underlying success of such an advancement of repository technology (see Figure 1) is the placement of the site in an area with so-called rocksalt geology, also called Halit, where the gamma radiation is rendered safe after travelling only 30 cm through the surrounding rocksalt. Gamma rays (https://en.wikipedia.org/wiki/Gamma_ray) are a form of ionizing radiation that is biologically hazardous and are a product of nuclear fission and fusion processes. They have a high penetration power and will damage bone marrow and internal organs. Unlike alpha and beta rays, they pass readily through the human body and are a challenge when it comes to protection from this radiation. Due to their penetrating power, gamma rays require extensive amounts of shielding mass to attenuate them to levels which are not harmful to living cells, in contrast to alpha particles, which can be stopped by paper or skin, and beta particles, which can be shielded by thin aluminum.

The DBHD process begins with the use of a shaft boring machine (SBM) from Herrenknecht AG / DE that is 12 m in diameter to drill down to depths on the order of 3,350 m. This deep shaft is then subject to further construction to install multiple layers, essentially a series of floors, each of which can support containers that encapsulate the HLW. A single DBHD can store up to eight (8) “Castor” containers per floor with a total of up to 360 per site. The 12 m diameter allows for a 113 sqm surface for all the ventilation pipes, Castor on steel cable, a staircase, a lift and a concrete tubbing ring to keep the hole open. Each Castor can take 10,5 tons of heavy metal (spent fuel).

The maximum temperature from waste heat from HLW after 25 years is 160 K - plus deep environmental temperatures of 105 °C ranging up to a maximum of 265 °C on the edge of shaft concrete to the surrounding rocksalt. As it turns out, the Castor container sealings are able to take up to +600 °C. As such, the DBHD does not infringe on the limits of the Castor containers. Recent estimates from July 23, 2018 suggest that seven such repositories to accommodate 2520 Castor containers at sites in Germany would cost on the order of 5.65 billion Euros ($CAD 8.7 billion).

Why Canada? As it turns out, as shown in Figure 2 (https://www.dbhd-hlw.de/dbhd---geology), there are rocksalt formations in the Maritime provinces of Canada, including New Brunswick, Nova Scotia, and Prince Edward Island that are suitable candidates for the advanced repository performance offered by the DBHD technology. As a geologically viable region, it should be subject to consideration for the long-term storage problems associated with HLW. The authors also believe it to be a more cost-effective solution than those currently under consideration by the NWMO and believe its advancements offer improved performance and safety. Figure 3 shows a more detailed survey result for a location in New Brunswick with rocksalt.

4. Review of Engineered Cost Estimates

Figure 4 provides a line item breakdown for the cost of ten DBHB installations which can accommodate 83,200 tonnes of nuclear waste. The total cost estimate being $CAD 12.5 billion. The following point-form presentation reviews the top ten costs evidenced from the various line items.

- The staffing for eighty years assumes 50 people would be employed with a cost of $CAD 3.1 billion over this time frame.
- A total of 832 concrete pellets are assumed with a life cycle cost of $CAD 1.501 billion.
- A total of ten cable-drum houses containing cranes to lower of raise Dry Storage Containers (DSC) has a cost estimate of $CAD 1.350 billion.
- A total of ten material storage ring installations comprising the floors of each subterranean level and walls made of concrete has a cost estimate of $CAD 945 million.
- A total of ten drilling platforms has a cost estimate of $645 million.
- Cash compensation for people near the facilities has been envisaged with an estimate on the order of $CAD 600 million.
- A total of 832 portions of Magnetit powder would be purchased at an estimated cost of $CAD 582 million.
- A total of ten shaft drills would be purchased at an estimated cost of $CAD 530 million.
- A total of ten land purchases of 110,000 square metres each is estimated to cost $CAD 396 million.
- A total of four SBM would be needed at an estimated cost of $CAD 360 million.
- Lastly, a contingency of $CAD 471 million has been assumed.

Conclusion

DBHB offers a technology that is in line with that favoured in Canada in the form of geological disposal. DBHB offers a progressive technology that addresses concerns over long-term stability of a site and the life expectancy of containment vessels for the waste. Plans are underway to create a DBHB facility in Germany based substantially on the approaches described herein which are also suitable when considered for installation in rocksalt formations in the Maritime provinces of Canada, notably New Brunswick.

References

[1] R.H. Brown, “A method to make reference to literature”, Journal of Citation, Vol. 11, No. 2, 1988, pp. 195-204.

[2] J.D. Irish and S.R. Douglas, “Validation of WIMS-IST”, Proceedings of the 23rd Annual Conference of the Canadian Nuclear Society, Toronto, Ontario, Canada, 2002 June 2-5.

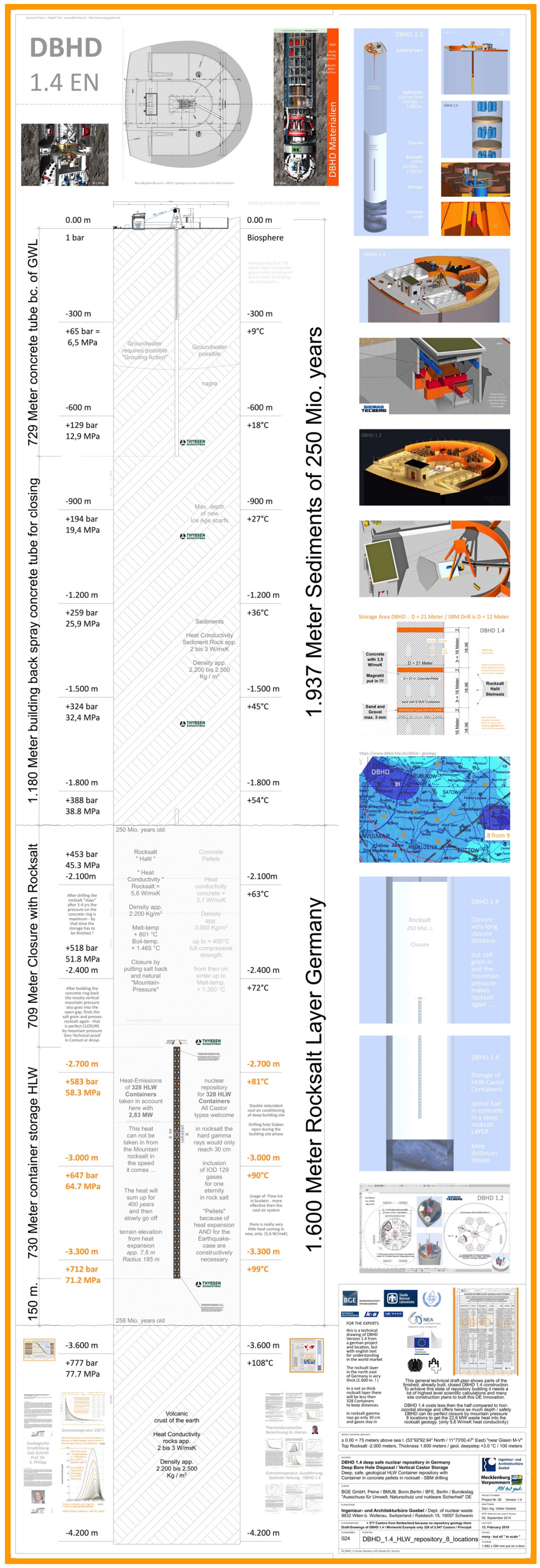
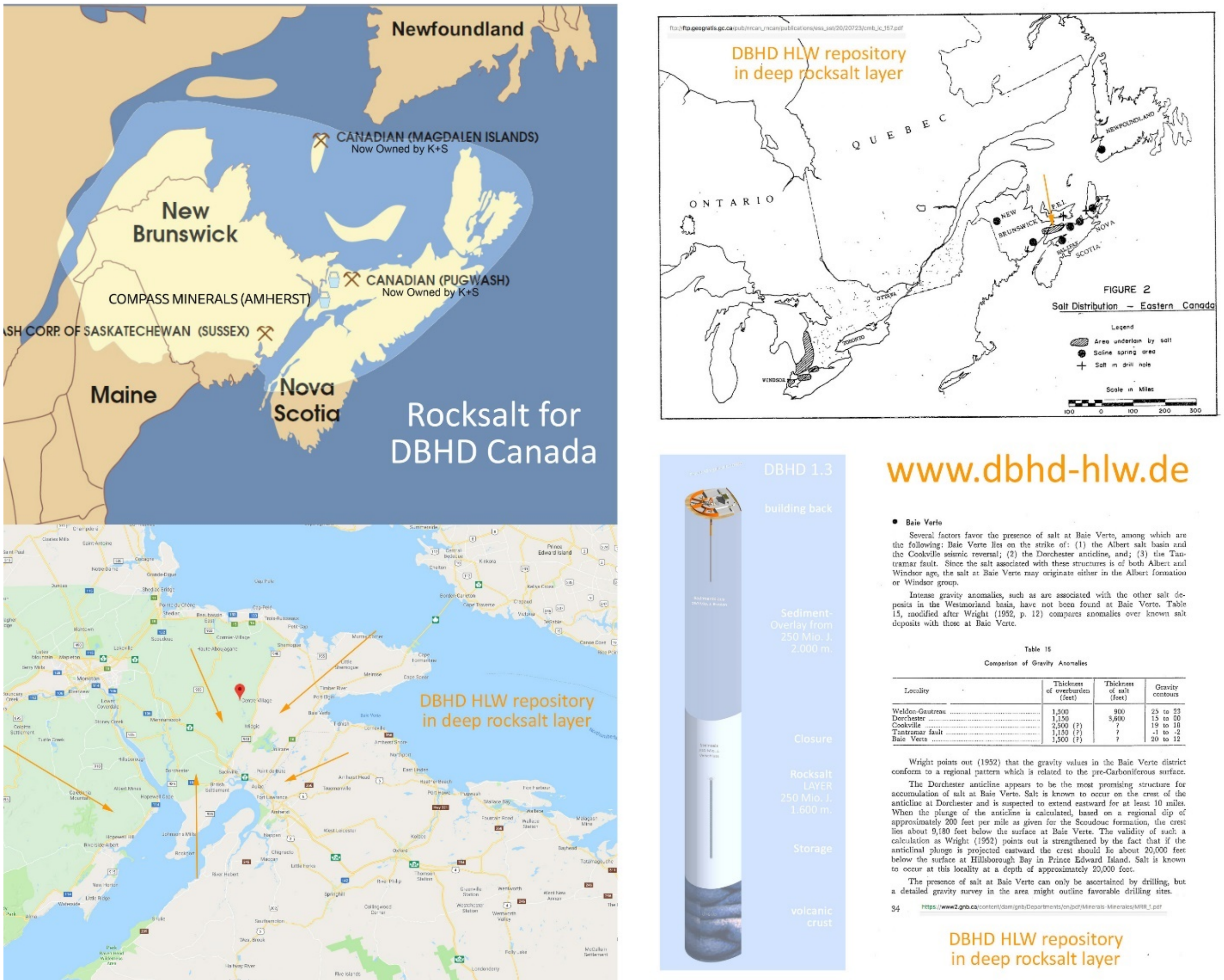


Figure 1: DBHD 1.4 EN Soil Stratification Profile for a Proposed Site in Germany



• Baie Verte

Several factors favor the presence of salt at Baie Verte, among which are the following: Baie Verte lies on the strike of: (1) the Albert salt basin and the Cookville seismic reversal; (2) the Dorchester anticline, and; (3) the Tantramar fault. Since the salt associated with these structures is of both Albert and Windsor age, the salt at Baie Verte may originate either in the Albert formation or Windsor group.

Intense gravity anomalies, such as are associated with the other salt deposits in the Westmorland basin, have not been found at Baie Verte. Table 15, modified after Wright (1952, p. 12) compares anomalies over known salt deposits with those at Baie Verte.

Table 15

Comparison of Gravity Anomalies

Locality	Thickness of overburden (feet)	Thickness of salt (feet)	Gravity contours
Weldon-Gautreau	1,500	900	25 to 23
Dorchester	1,150	3,600	15 to 00
Cookville	2,500 (?)	?	19 to 18
Tantramar fault	1,150 (?)	?	-1 to -2
Baie Verte	1,500 (?)	?	20 to 12

Wright points out (1952) that the gravity values in the Baie Verte district conform to a regional pattern which is related to the pre-Carboniferous surface.

The Dorchester anticline appears to be the most promising structure for accumulation of salt at Baie Verte. Salt is known to occur on the crest of the anticline at Dorchester and is suspected to extend eastward for at least 10 miles. When the plunge of the anticline is calculated, based on a regional dip of approximately 200 feet per mile as given for the Scoudouc formation, the crest lies about 9,180 feet below the surface at Baie Verte. The validity of such a calculation as Wright (1952) points out is strengthened by the fact that if the anticlinal plunge is projected eastward the crest should lie about 20,000 feet below the surface at Hillsborough Bay in Prince Edward Island. Salt is known to occur at this locality at a depth of approximately 20,000 feet.

The presence of salt at Baie Verte can only be ascertained by drilling, but a detailed gravity survey in the area might outline favorable drilling sites.

34 https://www2.gnb.ca/content/dam/gnb/Departments/en/pdf/Minerals-Minerales/MRR_1.pdf

Figure 2: DBHD Deep Repository in a Canada Rocksalt Formation near New Brunswick

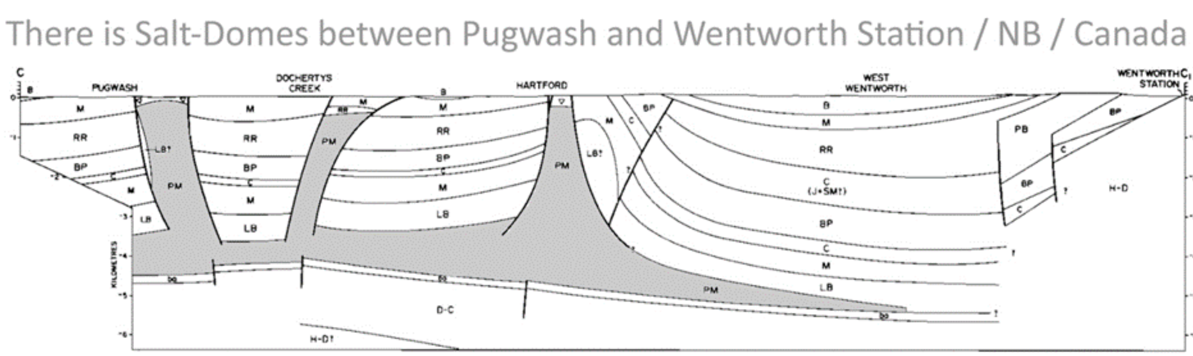


Figure 3: Other Rocksalt Formations in New Brunswick

Version 0.2.4

http://www.dbhd-hlw.de + http://www.ing-goebel.de

Calculation 10 x DBHD 1.4.1 Canada nuclear repository

Last edit: 18. March 2019 / Dipl.-Ing. Volker Goebel Switzerland / Nuclear Repository Planner ww

Capacity : 8.320 DSC's Canada (white 60 tons concrete **D**ry **S**torage **C**ontainer with +10 tons net spent fuel)

Repository-Storage-Depth in DBHD 1.4.1 Canada : from -1.350 Meters down to -2.100 Meters

Based on : Draft-Planning from 2014 - 2019 actually in Version **1.4.1** - Final for NWMDER

ONTARIO POWER GENERATION | Bruce Power | Énergie NB Power | nwmo

Type of invest	Amount	Offer / Quote	Factor	Total	Comment	dwg
		or hint from :				
Repository Plans	2014-2019 (5,25 yrs)	Ing. V. Goebel + T.	562'000 CAD	2'950'000 CAD	Draft-Plans, B-Plans	yes
Probe-Drillings	20 x	Prof. Dr. M. Reich	9'500'000 CAD	190'000'000 CAD	Cores > -2.250 m	
24x Land Purchase	1,1 km2	from local owners		396'000'000 CAD	10 x 110.000 m2	
Shaft-Boring-Ma.	4 x SBM / SBR	Herrenknecht AG	90'000'000 CAD	360'000'000 CAD	2 yrs. delivery time	yes
External streets	70 km	make-over		30'000'000 CAD	new / enhance	
E-powerconnection	10 x	local NB Power		38'000'000 CAD	10 kV med. voltage	
Water-connection	10 x	incl. water		45'000'000 CAD	10 bar with DN 200	
Internal Logistics		anticipation		75'000'000 CAD	10 building sites	
Drilling platforms	10 x	43.000 m3	1500 CAD/m3	645'000'000 CAD	floors and walls	yes
Mat. storage ring	10 x	70.000 m3	1350 CAD/m3	945'000'000 CAD	floors and walls	yes
Conveyor Belts	5 x			150'000'000 CAD	diverse types	
Heavy load trucks				22'500'000 CAD	Dump trucks	
Compensationes	20.000 Shares	direct local people	45'000 CAD	600'000'000 CAD	payment not bribe	yes
Planning Offices	Scientific expertise	many disciplines		308'000'000 CAD	over 80 years	
Approval Fees		many agencies		124'000'000 CAD	to Gov. Agencies	
Start-Setting SBM	10 x	Thyssen Schachtbau	4'500'000 CAD	45'000'000 CAD	temp. Structures	
Shaft Drills D=12 m	10 x	Thyssen Schachtbau	53'000'000 CAD	530'000'000 CAD	autom. Maschine	
Spray-concr.-wall	9,3 m2 x 1.315 m	12.230 m3 x 10	900 CAD/m3	110'070'000 CAD	steel-fibre-amored	yes
Shaft completition	6 sets	Siemag Tecberg	45'000'000 CAD	270'000'000 CAD	Vent., Transport	
Air-Conditioning	5 x	Siemag Tecberg	10'500'000 CAD	52'500'000 CAD	cold dry air IN	
Flow-Ice Piping	5 x	Siemag Tecberg	9'000'000 CAD	45'000'000 CAD	50 Liters / Sec.	
Cable-Drum-Houses	10 x	90.000 m3 S.T.	1'500 CAD	1'350'000'000 CAD	House with crane	yes
Cabledrum&Motor	5 x	Siemag Tecberg	6'000'000 CAD	30'000'000 CAD	Drum-Diam.=14 m	
Work-Over Rigs	3 x	Steelbuilders	4'800'000 CAD	14'400'000 CAD	with return pulley	yes
Dyneema Ropes	16 x	Gleistein DE	4'400'000 CAD	70'400'000 CAD	D=60 mm 2.100 m	
Transition Cone	10 x	concrete constr.	1'100'000 CAD	11'000'000 CAD	12 m. to 16,18 m.	yes
Hole-opening	10 x	to Diam. = 16,2 m.	2'700'000 CAD	27'000'000 CAD	with chain-saws	
Staff 80 years	50 Man&Woman	4 h. shifts down t.		3'100'000'000 CAD	Work & Safety	
Rocksalt-Salt-Sale	10 x 310.000 m3	rough quality	75 CAD/m3	- 232'500'000 CAD	Salt many uses	K+S
Concrete-Pellets	832 Pellets	1.203 m3 x 832 x 10	150 CAD/m3	1'501'344'000 CAD	Quality-Concrete	yes
Sand/fine gravel	832 Layers 1m	206 m3 x 832 x 10	105 CAD/m3	179'961'600 CAD	D = max. 3 mm	
Magnetit powder	832 Portions	70 m3 x 832 x 10	1020 CAD/m3	582'400'000 CAD	Rio Tinto, Billiton	yes
Closure works	10 x	own Salt grain		134'000'000 CAD	Salt + M. Pressure	
building back	10 x			30'000'000 CAD	farmland again	
Unforseeables	4%			471'281'024 CAD	the un-expected	
Total	**March 2019**	**Version 24**		**12'253'306'624 CAD**		

plus **street - ship - street** transports, plus law cases — **12,5 Bio. CAD**

Ingenieur- und Architekturbüro Goebel GmbH

DBHD 1.4.1 Canada Final

capacity 8.320 DSC container

83.200 tons spent Candu fuel

deep rocksalt New Brunswick & Nova Scotia

EN_010_Calculation_DBHD_1.4.1_Canada_nuclear_repository_Invest_Ing_Goebel_for_NWMO_832_DSC.xlsx

FIGURE 4: Cost Estimate for Nuclear Waste Repositories for Canada