Making Conceptual Design Choices For A Long-Term Waste Management Facility – Environmental Impact vs. Environmental Performance - 8166

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ABSTRACT

In 1982 the Government of Canada established the Low-Level Radioactive Waste Management Office (LLRWMO) with a mandate that includes resolving historic low-level radioactive waste (LLRW) problems across the country. Historic wastes are defined as those wastes for which the original producer can no longer reasonably be held responsible and which the federal government has accepted responsibility. A variety of sites contaminated with LLRW materials have been identified across Canada. Many of these sites, associated with former radium and uranium refining and processing operations, are located in urbanized areas of Southern Ontario. However, other sites have also been discovered at more remote locations in Canada, including northern Alberta and the Northwest Territories. The diversity of waste forms, ranging from pitchblende ore and residual processing wastes, to mixed contaminated soils and construction debris, present ongoing challenges for the LLRWMO to overcome in meeting its mandate to resolve these historic waste problems.

INTRODUCTION

In 2002 July, the LLRWMO was appointed to act as Proponent, on behalf of the Canadian government, for two distinct long-term LLRW management projects carried out jointly under a program identified as the Port Hope Area Initiative (PHAI). Both projects are based upon community-initiated solutions for the cleanup and appropriate, safe, local long-term management of historic low-level radioactive waste and contaminated soils present in the adjacent Ontario municipalities of Port Hope and Clarington.

This paper presents a discussion of a number of design choices that were made during the various stages in the development of the conceptual plans for the individual long-term waste management facilities and during the environmental assessments carried out on the respective projects. Both projects are based upon the general concept of long-term surface mound engineered management systems and were selected by the communities as their waste management technology of choice. As such, the conceptual design aspects for both projects started out much the same. However, the evaluation of the potential design choices, which involved consideration of potential environmental impacts as well as required on-going refinement of environmental performance specifications, resulted in some divergence of certain detailed design aspects for the individual local settings in which the facilities would be constructed. In addition, as conceptual design developments were refined for one project, these often led to similar refinements for the other project. The conceptual design process to date therefore has been one involving both separate (diverging) development as well as common refinement or convergence. These diverging and converging factors have influenced the design process and resulted in optimized designs for the respective projects, which, though only separated by about 15 kilometres, are located in differing physical and socio-economic environments. It will be seen that similar facilities can have different design solutions reflecting local variations to achieve comparable environmental performance.

HISTORIC LLRW AND THE LLRWMO

In Canada, LLRW has generally been defined by exclusion. If a waste is radioactive, but is neither nuclear fuel waste (also called high-level waste) nor uranium mine and mill tailings, then it is classed as LLRW. Most of Canada's LLRW accumulated to date is historic waste consisting of contaminated soil generated over the past 70 years. LLRW today arises from activities associated with nuclear electricity generation, from nuclear research and development, and from the production and use of radioisotopes in medicine, education, research, agriculture and industry.

Historic waste is defined as LLRW that was managed in the past in a manner that is no longer considered acceptable, for which the current owner cannot reasonably be held responsible, and for which the federal government has assumed responsibility. Most historic waste consists of contaminated soil, process residues and contaminated materials associated with radium and uranium refining operations that started in the 1930s when radium was refined for medical applications at a refinery in Port Hope, Ontario.

The LLRWMO is the agent of the federal government with the mandate to resolve historic LLRW problems. The LLRWMO is administered as a division of Atomic Energy of Canada Limited (AECL), taking policy and priority direction from the federal department of Natural Resources Canada (NRCan). NRCan also provides funding for LLRWMO activities. All activities of the LLRWMO are carried out in accordance with the requirements of the Canadian Nuclear Safety Commission (CNSC), the federal nuclear regulatory agency.

ELDORADO AND LLRW WASTE MANAGEMENT IN THE PORT HOPE AREA

In 1932/33, Eldorado Gold Mines Limited (the predecessor of the crown corporation Eldorado Nuclear Limited) constructed a refinery in the Town of Port Hope, Ontario, (approximately 100 km east of Toronto), for the processing of pitchblende ores from their Port Radium mine on the eastern shore of Great Bear Lake in the Northwest Territories. Initially the focus of the refinery was on the recovery of radium-226, with a secondary focus directed towards the recovery of uranium oxide and silver. The radium produced by the Port Hope refinery was used for a variety of uses including medical treatments and luminous dial applications.

Starting in 1942, the emphasis of operations at the Port Hope plant began to shift towards the refining of uranium, and in 1953 radium refining ceased. Because the pitchblende was delivered to the refinery as an ore, (i.e., no prior removal of the naturally occurring radioactive decay products from the ore) the refining process generated a substantial inventory of low-level radioactive residues and wastes. Initially these processing wastes and residues were retained on the refinery plant site or taken to designated sites within the Town of Port Hope for storage and/or disposal. Many of the chemical residues contained substantial quantities of other metals (e.g., nickel, silver, copper and cobalt) that were considered amenable to secondary recovery.

Commencing in 1948, the process residues and wastes were taken to a new site (the Welcome Waste Management Facility) in the adjoining Township of Hope, approximately 3 kilometres northwest of the refinery plant site. Use of this site continued until 1955 when problems with contaminated runoff from the site forced Eldorado to relocate its waste management activities to a new site – the Port Granby Waste Management Facility (WM) - in Clarke Township (now the Municipality of Clarington), some 12 kilometres due west of Port Hope. Waste management operations continued at the Port Granby site until 1988.

In the mid-1980s, conceptual plans were developed by Eldorado to address the concerns at each WMF that would have involved the removal of wastes and contaminated soils from both the Port Granby and

Welcome sites and their transfer to a new single disposal facility. Residents in the area of the potential sites voiced their opposition to Eldorado's proposed plans to construct a low-level radioactive waste disposal site near their community and the project was put on hold pending the outcome of a province-wide search for a willing host community that would accept the wastes from the Welcome and Port Granby WMFs.

PORT HOPE AND THE HISTORIC WASTE LEGACY

During the early years of operations at the Eldorado refinery, wastes and residues from the operation were deposited in a variety of locations within the Town of Port Hope. The potential extent of low-level radioactive contamination of properties in the community came to light in the mid-1970s during an assessment and radiation reduction program carried out by the 1976 Federal-Provincial Task Force on Radioactivity. Within the Town of Port Hope over 3,500 individual homes and properties were investigated for levels of radioactivity that exceeded the Task Force's cleanup criteria for gamma radiation and radon gas.

As a result of these investigations, cleanup work was conducted on over 400 private properties. By the end of 1980, more than 100,000 m^3 of historic waste had been transported 350 kilometres to a designated waste management area at AECL's Chalk River Laboratories in northeast Ontario. Because the designated area at the Chalk River site only had a limiting capacity of 100,000 m^3, the remaining 235,000 m^3 of contaminated waste that had been found in undeveloped areas, various ravines, the municipal landfill site, and sediments within the harbour turning basin could not be shipped to the Chalk River Laboratories site.

TASK FORCE SEARCH FOR A NEW WASTE MANAGEMENT SITE

Commencing in 1986, a federal Siting Task Force set out to find a willing host municipality in the Province of Ontario for the historic wastes situated at the Welcome and Port Granby WMFs, as well as within the Town of Port Hope. By 1996 the Siting Task Force had identified a potential host municipality; however, negotiations on the terms and conditions of a legal agreement between the federal government and the municipality on which to base the project were not successful.

PORT HOPE AREA INITIATIVE

In 1997, each of the three source municipalities in the Port Hope area (Town of Port Hope, Township of Hope and Municipality of Clarington) in response to the unsuccessful outcome of the Siting Task Force process, each passed resolutions of their respective councils to investigate the possibility of becoming hosts for the wastes currently existing in their respective municipality. With financial and technical support from the federal government each was able to put forward a community-based proposal for the local long-term management of the historic LLRW in their municipality. Negotiations on the terms and conditions of a legal agreement between the federal government and the three municipalities on which to base the project were successful, and in late 2000/early 2001 an *Agreement for the Cleanup and Long-Term Safe Management of Low-Level Radioactive Waste Situate in the Town of Port Hope, the Township of Hope and the Municipality of Clarington* [1] was signed by the municipalities and the Minister of Natural Resources Canada.

In June 2001, the federal government announced the start of the Port Hope Area Initiative to complete the cleanup and provide appropriate, safe, local long-term management for historic low-level radioactive waste and contaminated soils in Port Hope, Hope Township and Clarington, and leave an honourable legacy for future generations of Canadians.

COMMUNITY CONCEPTUAL DESIGN PREFERENCES

For the Port Hope and Hope Township long-term management sites [2,3], the wastes would be encapsulated within locally sited new long-term engineered management facilities developed using a single composite base liner system (comprising a sand drainage layer and HDPE geomembrane and compacted clay layer) and multi-component cover system (comprising topsoil, general fill, intrusion barrier/drainage layer, sand cushion, geosynthetic clay liner and sand grading layer).

In contrast to the Port Hope and Hope Township concepts, the Port Granby design [4] was based upon in situ management of the waste that utilized a multi-component cover system and groundwater diversion system to isolate the waste from the environment.

EA INFLUENCE ON CONCEPTUAL DESIGNS

The conceptual designs put forward by each municipality served as the initial basis for the federally mandated environmental assessment (EA) of the respective projects [5,6]. By the time the EA was started, the Town of Port Hope and the Township of Hope had amalgamated to form the Municipality of Port Hope. As a result, a single "project" with two long-term waste management proposals was carried forward into the EA. As part of the EA process "investigations of alternative means" of carrying out the project were required and conducted. This resulted in the identification of technically and economically feasible preferred designs for the Port Hope and Port Granby Projects.

The final Port Hope preferred (proposed) design was based upon the consolidation of all historic wastes (estimated at 1.2 million cubic metres) located within the former Town of Port Hope and the former Township of Hope into a single new long-term waste management facility that would be located at the site initially proposed by Hope Township for its wastes.

For the Port Granby Project the "investigations of alternative means" identified a preferred design based upon relocation of the 500,000 cubic metres of historic waste from the existing Port Granby Waste Management Facility to a new engineered long-term management facility (LTWMF) that would be located approximately 500 metres further inland just north of the existing WMF, and 700 metres away from the Lake Ontario shoreline.

The overall designs for the two projects would subsequently be enhanced to reflect the individual physical and socio-economic environments in which the proposed projects would be developed. Some of the more substantial of these enhancements are described below for each of the projects.

PORT HOPE LONG-TERM WASTE MANAGEMENT FACILITY

The new Port Hope LTWMF will be developed near the urban area of Port Hope within the 48-hectare property currently owned by Cameco Corporation (the successor company to Eldorado) that comprises the existing 36-hectare Welcome Waste Management Facility and adjacent 12-hectare parcel of land currently occupied by a tenant auto recycling operation. The LTWMF will comprise an above ground engineered containment mound with a double composite base liner system (vs. the originally proposed single composite) and a low-permeability final cover.

Fig. 1. Conceptual Layout – Port Hope LTWMF

The above ground mound will be trapezoidal in shape, will occupy a 15-hectare footprint and will be constructed with three containment cells. The waste volume capacity would total approximately 1.2 million m^3, including 500,000 m^3 of on-site waste from the existing Welcome WMF and 700,000 m^3 of offsite arrivals from locations within the former Town of Port Hope. The maximum height will be in the order of 22 metres above the existing surface, with excavations 0.5 to 7 metres below the existing surface. Side slopes of the mound will be at a 25% grade (14^o angle) and the top cover slope will be at a grade of 5% (3^o angle). Over the anticipated seven-year construction period approximately 373,000 m^3 of clay, soils and aggregates and 1,730,000 m^2 of geomembrane and geotextile products will be transported to the new facility for use as backfill and in the construction of the base and cap.

COMPOSITE BASE LINER DESIGN

The proposed base liner concept consists of a double composite liner system of both natural and synthetic materials to enhance the protection of the specific near surface groundwater conditions present at the site. The double composite liner system also enhances the engineering properties required for the design service life of at least several hundred years. The double composite base liner system is composed of a primary or upper liner and a secondary or lower liner, which together with associated drain layers and protective materials, form the composite liner system. The secondary liner serves as a backup to the primary liner by providing a fully redundant liner below the primary liner. The double composite liner system facilitates direct monitoring of the primary liner performance. The proposed final cover and base liner design for the Port Hope LTWMF has considered the characteristics and limitations of each of the various components. For instance, a compacted clay layer (CCL) is not proposed for use in the final cover due to potential desiccation concerns and instead a geosynthetic clay liner (GCL) is proposed (a CCL is installed at a high moisture content and therefore can "dry out", whereas a GCL is installed dry). A CCL is proposed for the base liner of the secondary liner system as it is not subject to the same desiccation concerns being below grade and the additional thickness provides a higher ability to adsorb some contaminants.

The proposed design for the double composite base liner (thickness of approximately 1.38 metre) consists of the following elements, from top to bottom:

- Geotextile fabric layer – to provide physical separation and protection for upper granular drainage layer during initial waste placement;
- Granular drainage layer (leachate collection layer) - 0.3 metre thick to collect and drain leachate from the overlying waste to a sump for collection and subsequent removal;

- Geocomposite layer – to provide protection (act as a cushion) for the geomembrane underlying the granular drainage layer and to provide higher leachate transmissivity during the waste placement stage;
- Geomembrane liner – 80 mil thick high-density polyethylene (HDPE), to provide an impermeable barrier to the leachate;
- Geosynthetic clay liner – to provide additional low permeable layer below the geomembrane that has the properties of hydrating and self-healing any defects in the overlying geomembrane that may be present from manufacture or that may occur during installation, generally having a hydraulic conductivity of 1.0×10^{-11} m/s to 5.0×10^{-11} m/s;
- Geotextile fabric layer – to provide additional protection (act as a cushion) for the geosynthetic clay liner overlying the lower granular drainage layer;
- Granular drainage layer (leak detection layer) - 0.3 metre thick, to collect and drain any liquid that may migrate through the upper liner system to a sump for collection and subsequent removal. Also provides for monitoring of primary liner performance;
- Geotextile fabric layer – to provide protection (act as a cushion) for the geomembrane underlying the lower granular drainage layer;
- Geomembrane liner – 80 mil HDPE, to provide an impermeable barrier to any liquid that may migrate into the secondary liner system; and
- Compacted clay layer - 0.75 metre thick, to provide a natural material barrier to downward migration of any leachate should a breach of the lower geomembrane occur (and assuming a breach of the primary liner has occurred), generally having a hydraulic conductivity of less than 1.0×10^{-9} m/s.

FINAL COVER DESIGN

A multi-component final cover system is proposed over the entire surface area of the completed mound, to minimize moisture infiltration into the waste and leachate generation. The cover system concept has also been designed to provide shielding for gamma radiation from the waste and yield background levels of radioactivity on the surface of the mound. The design to achieve background levels of radioactivity is in accordance with the conditions of the legal agreement and the original concept that would allow passive recreational use on the top of the completed mound.

The proposed engineered 2.1 metre thick final cover consists of the following elements, from top to bottom:

- Vegetated topsoil layer– to support cover vegetation and control erosion of the final cover soil;
- General uncontaminated fill– minimum 1.0 metre thick, to fulfill several purposes including to provide shielding of gamma radiation from the LLRW within the engineered mound, to protect the underlying layers from freeze/thaw effects, to provide additional storage capacity for precipitation infiltration and to provide additional surcharge on the underlying geomembrane and GCL layers;
- Geotextile fabric layer– to control migration of fines from the overlying soil layer into the fine stone layer;
- Fine stone layer– 0.2 metre thick, to provide grading transition (in conjunction with the geotextile fabric) between the fine-grained general fill layer above and the coarse stone barrier layer below;
- Coarse stone intrusion barrier/drainage layer – 0.5 metre thick, to prevent burrowing animals and/or root penetration from reaching the geomembrane, and to provide for lateral drainage of percolation from the overlying layers. The stone layer may also act as a capillary break, further reducing percolation from the overlying layers;
- Geotextile fabric layer– to provide separation and control penetration of the stone layer into the underlying sand cushion layer;
- Sand cushion layer– 0.2 metre thick, to provide protection of the underlying geomembrane against penetration from the overlying stone layer;

- Geomembrane liner– 80 mil thick HDPE to provide an impermeable barrier against percolation from the overlying layers, and;
- Geosynthetic clay liner– to provide an additional low permeable layer below the geomembrane that has the properties of hydrating and self-healing any defects in the overlying geomembrane that may be present from manufacturing or that may occur during installation, generally having a hydraulic conductivity of 1.0×10^{-11} m/s to 5.0×10^{-11} m/s.

METHANE GAS VENTING SYSTEM

The composite base and final cover systems are designed to form a sealed "envelope" around the waste placed into the containment mound. However, certain wastes unique to the Port Hope Project (e.g., co-mingled LLRW/soil/municipal refuse from the Highland Drive Landfill) to be placed into the containment mound will contain organic materials, which, through biological decomposition, have the potential to generate gases such as carbon dioxide and methane. The generation of these gases could lead to a build-up of pressure within the cells which could eventually cause a rupture of the cell envelope (base liner and/or final cover) if not relieved. To relieve any gas pressure within the cells of the containment mound in a controlled manner, gas collection and venting systems have been incorporated into the design. These higher organic content wastes will be placed into Cell 3. Other wastes that may also contain organics will include the harbour sediment, grubbed vegetation, and soil from areas of impacted surficial soil at the various remediation sites, which will be placed into Cells 1 and 2.

Assessments of the gas generation potential were performed for the various waste sources and based on the results of the assessments, it is not anticipated that gases would be generated in sufficient quantities to require treatment to meet air quality criteria. As a result, the gas collection and venting systems will vent directly to the atmosphere (Cell 3) or to the subsurface around the perimeter outside of the cells (Cells 1 and 2). The gas collection and venting system for Cell 3 will consist of a granular material layer, 300 mm thick, over the waste immediately beneath the final cover in Cell 3. A network of perforated high-density polyethylene pipes within the granular layer and spread across the cells on 40-metre spacing will exit the cell envelope and vent to the atmosphere through two vertical vent pipes on the north side of Cell 3.

The gas generation potential for the waste in Cells 1 and 2 will be much lower than for Cell 3 due to the much lower quantity of organic waste to be placed in to these cells. As such, the gas collection and venting system for Cells 1 and 2 will consist of a synthetic geocomposite layer installed directly beneath the final cover, which will exit the cells in a series of "finger extensions" and terminate below grade outside the cell perimeter.

WASTE HAULAGE ROUTES

The examination of alternative means was not limited to only the structural aspects of the mound design. For example, the technical team compared numerous routes for trucks carrying waste to the proposed LTWMF. The waste areas containing the wastes were grouped into centroid regions (e.g., South - 500,000 m^3, Central - 100,000 m^3, and North - 180,000 m^3). Factors such as the number of trucks, potential for accidents, railway level crossings, number and type of schools, environmental effects, disturbance to residents, and cost of roadway improvements were considered. The routes identified through this alternative means process will use the Municipality of Port Hope's existing truck routes wherever possible. Trucks carrying the waste and construction materials will enter the proposed facility along a to-be-constructed dedicated internal access road. Waste will be hauled in covered trucks to minimize dust.

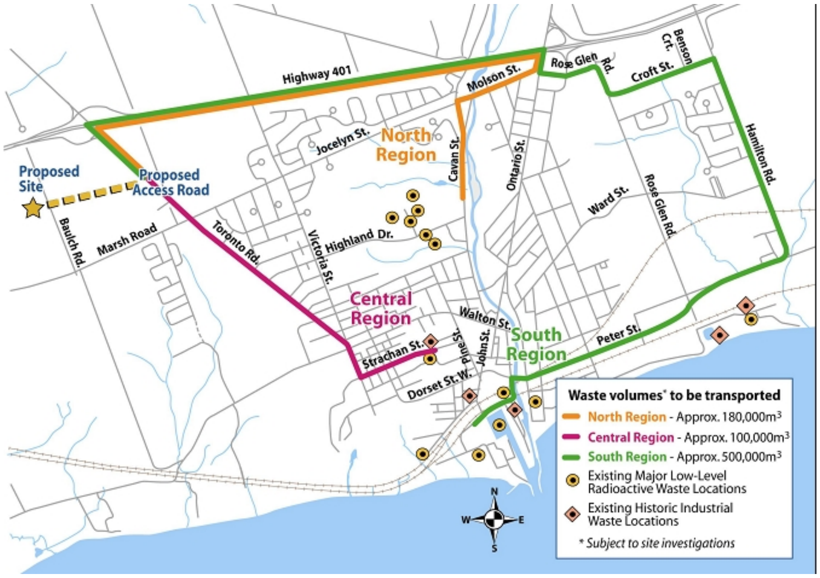

Fig. 2. Preferred Transportation Routes – Port Hope Project

TRADEOFFS AND CHOICES –PORT HOPE PROJECT

Consideration of potential environmental impacts as well as required on-going refinement of environmental and engineering performance specifications resulted in a number of opportunities to make refinements to the design and operation of the facility. Table I presents some of the more important considerations incorporated into the currently proposed design for the Port Hope Project.

Table I. Port Hope Project Tradeoffs and Choices

Trade-off / Choice	Basis	Description	Outcomes
One LTWMF versus the original concept of two within the same municipality	Alternative Means Process	Consolidation of all historic waste within Port Hope into one engineered facility	• Consolidation of efforts • Only one site to monitor • Effective use of lands
Double composite base liner rather than original single composite liner	Engineering refinement and Environmental improvement	Original conceptual design enhanced with addition of second composite liner system	• Enhanced performance for near surface groundwater conditions • Greater protection of downstream groundwater environment
Use of GCL vs. CCL in double composite liner system	Environmental improvement	Substitution of one of the CCL units with a GCL in the double liner system	• Reduction in amount of clay required for project • Reduction in number of truck trips • Reduction in liner profile

Trade-off / Choice	Basis	Description	Outcomes
Lowering of base of mound	Environmental improvement	Anticipated reduction in groundwater profile beneath new LTWMF allowed for base of mound to be developed deeper than originally proposed.	• Reduced profile of mound • Reduced amount of construction material • Reduction in number of truck trips to the site
Reduced travel of construction vehicles on placed waste within the LTWMF	Environmental improvement	Travel distances reduced from 200 metres to 50 metres for construction equipment spreading and compacting waste material within placement cells.	• Reduction in dust emissions from placement operation • Reduced exposure to critical receptor • Reduced environmental impacts
Designated haul routes within Municipality of Port Hope	Alternative Means Process	Specific haul routes were identified for the transportation of the wastes from the specific source sites within Port Hope to the LTWMF site.	• Higher costs due to longer haulage distances • Reduced impacts of dust and noise on residential and downtown areas • Reduced potential for traffic accidents

Port Granby Long-Term Waste Management Facility

The proposed new Port Granby LTWMF will be developed in a rural setting, within the 600 ha vacant agricultural property currently owned by Cameco Corporation (the successor company to Eldorado) north of the existing Port Granby Waste Management Facility. The LTWMF will comprise an above ground engineered containment mound with a single composite base liner and an enhanced low-permeability final cover that includes a capillary barrier system beneath the geosynthetic clay liner. (The use of a single composite base liner is possible at this site because on the on-site geological conditions described below.) This design was identified through the alternative means process to be a better long-term solution than the in situ design originally proposed by the community.

The above ground mound will be rectangular in shape, will occupy a 10-hectare footprint, and will constructed with two containment cells of equal area, referred to as Cells 1 and 2. The maximum height will be in the order of 9 metres above existing surface, with excavation to about 5 to 8 metres below existing grade. Side slopes of the mound will be at a 25% grade (14^{o}angle) and the top cover slope will be at a grade of 5% (3^{o}angle). Over the anticipated five-year construction period approximately 294,000 m^3 of soils and aggregates and 761,000 m^2 of geosynthetic products will be transported to the new facility for use as backfill and in the construction of the base and cap.

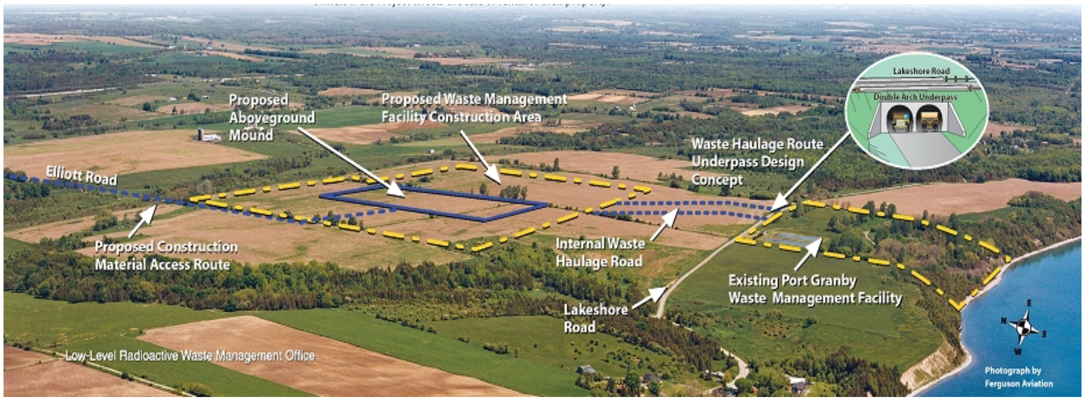

Fig. 3. Port Granby LTWMF Conceptual Layout

LTWMF LOCAL AREA SITE SELECTION

The initial selection of the site for the proposed new LTWMF was based upon previous geotechnical investigations conducted on the property to the north of the existing waste management facility. These investigations showed that the site-specific geology at the proposed LTWMF is comprised of a complex succession of glacial till sheets and interstadial glacio-lacustrine deposits. A layer of low permeability silty sand to clayey silt till containing a trace to some clay and gravel (the Upper Till) was encountered directly beneath the topsoil and/or the surficial sand layer. The mound will be constructed within a relatively low permeability silty sand till deposit referred to as the Upper Till. For planning purposes, it has been assumed that the thickness of the Upper Till Unit separating the base of the mound from the Upper Sand Complex ranges from 20 metres at the north end of Cell 1 to 4 metres at the south end of Cell 2. This remaining Upper Till material beneath the mound represents a natural diffusion barrier and adsorption media, which can contribute towards minimizing impacts on the Upper Sands Complex in the unexpected event that the base liner system deteriorates. Most of the groundwater flow across the site towards Port Granby Creek occurs within this Upper Sands Complex and therefore it is the primary layer that needs to be protected from potential long-term contaminant impacts from the mound.

BASE LINER AND LEACHATE COLLECTION SYSTEM

The single composite design components for the proposed 1.25 metre thick base liner and leachate collection system for the mound comprise the following layers from bottom to top:

- Compacted Clay Liner - Design hydraulic conductivity of $<1 \times 10^{-7}$ cm/s, to seal any undetected defects (i.e., pin holes and/or seam defects) in the overlying geomembrane and provides a backup hydraulic and diffusion barrier in the unexpected event of geomembrane failure. The clay liner also provides an adsorption media for attenuation of contaminant migration;
- Geomembrane Liner - 80 mil HDPE geomembrane, to serve as the primary hydraulic and diffusion barrier;
- Geocomposite Drainage Layer - Biplaner geonet core with non-woven geotextile filter fabric on one side for the base area and on both sides for the side slope areas;
- Granular Drainage Layer – 0.5 metre thick layer of concrete sand to prevent intrusion of fines, while provide adequate permeability to effectively convey leachate to the central and intermediate drains;
- Central and Intermediate Stone Drains – 5 metre wide by 0.8 metre thick drains leading to the sump locations, constructed with 6.2 mm coarse sand and gravel (chip stone);
- Sump Areas – 20 m x 20 m x 0.8 m thick, comprising 0.6 metre thick layer of 13.2 mm concrete stone overlain by 0.2 m thick layer of 6.2 mm coarse sand and gravel (chip stone) filter layer, and;

- Leachate Extraction Pipes - non-perforated, corrugated riser pipe with smooth inside wall.

FINAL COVER DESIGN AND GRADES

A multi-component final cover system is proposed over the entire surface area of the completed mound, to minimize moisture infiltration into the waste and leachate generation. The cover system concept has also been designed to provide shielding for gamma radiation from the waste and yield background levels of radioactivity on the surface of the mound. The components of the final cover system proposed are as follows (from top to bottom):

- Vegetated Topsoil Layer- stripped from the cell excavation areas, with vegetation consisting of a drought resistant indigenous grass mixture having a robust root structure to provide aesthetically pleasing finished surface for the mound, to enhance evapo-transpiration and reduce the potential for erosion of the cover soils;
- Fill Layer - 1.2 m thick layer of silty sand till to provide gamma radiation shielding, additional root zone media for grass vegetation, freeze-thaw protection and confining pressure for the geosynthetic clay liner;
- Geotextile Filter Fabric – to minimizing migration of fines from of the fill layer into the intrusion barrier;
- Intrusion Barrier Layer - 0.5 metre thick layer of coarse gravel and cobbles obtained by on-site screening of the silty sand till from the cell excavation to prevent burrowing animals and/or plant roots from reaching and potentially damaging the geo-composite drainage layer and geomembrane liner;
- Sand Cushion/Drainage Layer - 0.3 metre thick layer of concrete sand to protect the geomembrane liner from puncture by angular gravel/cobbles in the overlying intrusion barrier and provide lateral drainage above the geomembrane;
- Geocomposite Drainage Layer - Biplaner geonet core with non-woven geotextile filter fabric on both sides to facilitate vertical and lateral drainage above the cover geomembrane;
- Above Liner Outlet Drains - 0.3 m thick by 3.0 m wide layer of 6.2 mm coarse sand and gravel (Chip Stone) placed above geomembrane liner;
- Geomembrane Liner – 60 mil thick HDPE geomembrane, which together with geosynthetic clay liner described below, together form an impermeable barrier that minimizes moisture infiltration into the waste. The geomembrane represents the primary infiltration barrier;
- Geosynthetic Clay Liner- Sodium bentonite layer contained between a non-woven geotextile and a scrim reinforced woven geotextile by needle punching between the two geotextiles;
- Capillary Drainage Layer - 0.3 metre thick layer of Granular “A” gravel;
- Capillary Break Layer - 0.3 metre thick layer of 9.5 mm to 26.5 mm stone. The capillary drainage and capillary break layers together form the capillary barrier system, which provides an additional level of protection against moisture infiltration into the waste in the event of deterioration of the overlying geomembrane liner;
- Capillary Barrier Outlet Drains - Uniformly spaced drains (approximately 30 metre spacing) consisting of 6.2 mm coarse sand and gravel (chip stone), and;
- Interim Cover - 0.3 metre thick (minimum) interim cover layer consisting of silty sand till (Upper Till) placed over exposed waste.

PORT GRANBY WASTE HAULAGE ROUTES

The alternative means process for the Port Granby Project compared various available routes for trucks carrying construction materials to the proposed LTWMF site. Although the adjacent alignment of the existing waste management facility and proposed the site for the new LTWMF did not require the transport of contaminated wastes along pubic roadways, local area residents were concerned about the impact of increased truck traffic through their rural community. The process identified a less obvious route that would involve the upgrade of an existing but closed municipal roadway and upgrades to railway level crossing thereby avoiding travel through the hamlet of Port Granby on the available road network.

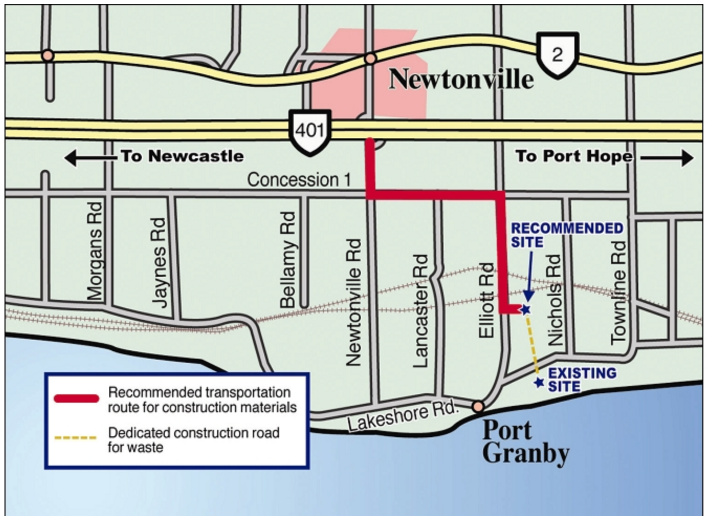

Fig. 4. Preferred Transportation Routes – Port Granby Project

TRADEOFFS AND CHOICES –PORT GRANBY PROJECT (CLARINGTON)

Consideration of potential environmental impacts as well as required on-going refinement of environmental and engineering performance specifications resulted in a number of opportunities to make refinements to the design and operation of the facility. Table II presents some of the more important considerations incorporated into the currently proposed design for the Port Granby Project.

Table II. Port Granby Project Tradeoffs and Choices

Trade-off / Choice	Basis	Description	Outcomes
Relocation of wastes versus original concept of in-situ stabilization	Alternative Means Process	Placement of wastes into engineered full containment system	• Complete encapsulation of wastes • Reduced maintenance program • No groundwater diversion • Improvement in terrestrial environment
Enhancement of cap versus addition of second composite liner system	Environmental improvement	Municipal request for enhance performance addressed by inclusion of capillary drainage system in cap rather than requested addition of double composite liner system	• Enhanced public confidence in performance of system • Reduced truck traffic compared to requirements for construction of double liner system
Use of dedicated underpass to connect	Community Preference	Construction of new underpass beneath	• Enables use of on-site dedicated haulage vehicles

Trade-off / Choice	Basis	Description	Outcomes
waste site and LTWMF	Environmental Improvement	Lakeshore Road to allow construction vehicles to travel between the waste site and LTWMF without travelling on municipal roadways	and roadways • Reduction in travel times • Reduced accident potential • No interaction with public roadways • Increased cost for tunnel construction
Identification of designated haulage route	Alternative Means Process	A specific haulage route was identified for the transportation of construction materials to the new LTWMF, to avoid travelling through Port Granby	• Higher costs due to requirement for significant road upgrades • Reduced impacts on Port Granby community • Reduced potential for accidents

CONCLUSIONS

During the environmental assessment process, opportunities for design choices became evident for both Projects. For each Project, this occurred at the initial stage of the assessment involving the evaluation of Alternative Means and at the subsequent detailed environmental effects assessment of the preferred alternative. At the Alternative Means evaluation stage, design choices tended to be more large scale, affecting the overall Long-term Waste Management concept. For example, in the case of the Port Hope Project, the movement from two separate LTWMFs (that would have been located about 3 kilometres apart from each other) in the initial municipal concepts to a single consolidated facility for the Municipality of Port Hope. Similarly, at the Port Granby Project, the movement from an in situ management concept to a relocation to a fully engineered facility resulted as the evaluation of Alternative Means was completed.

During the environmental effects assessment stage for the preferred concepts, design choices were presented at a more detailed, specific level of consideration. As can be expected, site-specific considerations (e.g., bio-physical environmental differences and socio-economic environmental differences) resulted in design choices that were unique to the particular Project and hence resulted in some divergence from initially comparable conceptual design features. For example, the incorporation of a double composite base liner in the Port Hope facility but the retention of a single composite base liner for the Port Granby facility.

General on-going engineering design refinements were also applicable for each project and continued throughout the EA process. These often resulted in enhancements that were subsequently incorporated into both projects, keeping them comparable (similar) while they were diverging on other areas. For example, the recommendation by the Port Granby Project engineering team to adopt a bi-planar geo-composite drainage membrane into the base liner of the Port Granby facility was forwarded to the Port Hope Project design team for similar utilization.

The examples of design choices made during, and as a result of the environmental assessment process for the Port Hope and Port Granby projects presented in this paper indicate that in both these projects, the EA process was truly a beneficial planning tool. Not only did the EA demonstrate that the projects could be carried out with no significant adverse environmental effects, it helped the design process by identifying areas where alternate approaches could be adopted that would result in improved performance. The iterations of design, assessment and refinement of design clearly resulted in improvements to each project, which may not have become apparent otherwise.

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