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BC Ministry of Environment
Environmental Protection Division
2080 Labieux Road
Nanaimo, BC V9T 6J9

Attn: AJ Downie, Regional Director - Authorizations South

Dear Mr. Downie,

Re: Independent Review of Final Closure Plan for the Shawnigan Lake Landfill, 460 Stebbings Road.

Hemmera Envirochem Inc. was retained by the BC Ministry of Environment (BC MoE) Regional Operations Branch in Nanaimo to complete two phases of document review pertaining to the Shawnigan Lake Landfill. The Shawnigan Lake Landfill is owned by Cobble Hill Holdings Ltd. (CHH) and is located at 460 Stebbings Road, near Shawnigan Lake, BC (Site). Contaminated soil and ash were placed in the Permanent Encapsulation Area landfill facility (the "PEA") as part of a reclamation plan for a quarry site. This letter provides the findings of the second phase of the document review, which includes review of the Final Closure Plan prepared by Sperling Hansen Associates (SHA) and recent documents provided by local residents.

For this second phase of the project, Mr. Paul Webb, P.Geo., CSAP and Mr. Chuck Jochems, P.Eng., CSAP of Hemmera have reviewed the Final Closure Plan for the Shawnigan Lake Landfill prepared by SHA on behalf of Cobble Hill Holdings Ltd. dated May 31st, 2017. The Closure Plan was reviewed relative to its conformance with current BC MoE guidance for landfill closure, the 2016 2nd Edition Landfill Criteria for Municipal Solid Waste (LCMSW) and for its completeness with the Amended Spill Prevention Order (SPO), Section 4 requirements.

Concerns documented by local residents provided as part of the information package were reviewed in order to guide and focus the technical document review, and were taken into consideration when preparing the conclusions and recommendations of this report. Preparation of written responses to concerns were considered outside of the work scope.

The findings of the initial phase of the document review were presented in a letter dated May 26, 2017 and included review and comment on background documents that were submitted to the BC MoE further to the Amended SPO for the landfill issued on March 15, 2017. The documentation package included as-built reports and drawings by qualified professionals, QA/QC documentation, submissions from local residents, and other technical documentation and correspondence, and the review was completed to assess, where possible, the level of representation of "As-Built" documentation.

The scope of both review phases was to provide comments, conclusions and recommendations focusing on the engineering design, construction and stability of the landfill to assist BC MoE in making a determination of the adequacy of the landfill, leachate collection and storage works, and the post-closure inspection, operation, and maintenance and environmental monitoring program, to prevent an escape or spill of leachate into the environment during the post-closure period.

This Work was performed under contract between Hemmera Envirochem Inc. (Hemmera) and BC Ministry of Environment (Client), dated May 3, 2017 (Contract). This Report has been prepared by Hemmera, based on work conducted by Hemmera, for sole benefit and use by BC Ministry of Environment. In performing this Work, Hemmera has relied in good faith on information provided by others, and has assumed that the information provided by those individuals is both complete and accurate. This Work was performed to current industry standard practice for similar environmental work, within the relevant jurisdiction and same locale. The findings presented herein should be considered within the context of the scope of work and project terms of reference; further, the findings are time sensitive and are considered valid only at the time the Report was produced. The conclusions and recommendations contained in this Report are based upon the applicable criteria, guidelines, regulations, and legislation existing at the time the Report was produced; any changes in the regulatory regime may alter the conclusions and/or recommendations.

1.0 BACKGROUND

BC MoE issued Permit PR- 105809 to Cobble Hill Holdings Ltd. (CHH) for the Shawnigan Lake Landfill at 460 Stebbings Road on August 21, 2013, authorizing discharge of refuse from contaminated soil treatment facility to the landfill. The Permit PR-105809 was canceled on February 23, 2017.

The permit allowed for soil treatment on site; however, in accordance with CVRD municipal bylaws no soil treatment was conducted on site. A covered soil management area (SMA) was used as a staging area for incoming soils.

The permit allowed for discharge of non-Hazardous Waste contaminated soils and ash into engineered lined landfill cells. Contaminants permitted included hydrocarbons, styrene, methyl tertiary butyl ether (MTBE), volatile petroleum hydrocarbons, light and heavy extractable petroleum hydrocarbons, polycyclic aromatic hydrocarbons, chlorinated hydrocarbons, phenolic substances, chloride, sodium, glycols, metals, dioxins, and furans. The permit also allowed for effluent to be discharged from the site.

On March 15, 2017, Amended Spill Prevention Order MO1701 was issued after the Permit PR-105809 was cancelled.

2.0 REVIEW OF LANDFILL CLOSURE PLAN

In accordance with the 2016 2nd Edition LCMSW, a Closure Plan must document how the facility will be operated and maintained post-closure to ensure that all required environmental control systems will continue to function and all performance criteria will be met.

The post-closure operation and maintenance program shall include:

- Maintenance of the final cover including vegetation and the repair of damage due to erosion, leachate breakouts, slope failures, settlement and burrowing animals.
- Where applicable, operation and maintenance of surface water management works, including repairs required due to settlement.
- General site maintenance including maintenance of access roads and fencing.
- Where applicable, operation and maintenance of leachate collection and on-site leachate treatment facility or leachate haulage program.
- Where applicable, operation and maintenance of landfill gas management facilities, including repairs to infrastructure damaged by settlement.
- An environmental monitoring program to be carried out during the contaminating lifespan.
- Practical and implementable contingency measures to address any failure of the works or non-compliance with the performance criteria.

The Landfill Closure Plan prepared by SHA appears to address these documentation requirements in a well prepared and comprehensive document. In addition to providing the information pertinent to the design and performance objectives of the LCMSW, SHA indicate that the closure plan includes information on the following at the request of the MoE in Section 4 of the Amended Spill Prevention Order (SPO) MO1701 dated March 15, 2017:

- Assessment of the adequacy of the existing facility,
- Landfill Stability assessment and Hydrologic modelling that demonstrates the final cover and ditching will be stable and adequate for worst case conditions including 1 in 200-year storm event, plus snowmelt and multi-day precipitation events,
- Leachate collection and storage works assessment – ability to prevent an escape or spill of leachate into the environment,
- Leachate collection and storage plan – including hydrologic modelling that demonstrates the infrastructure is adequate for the worst-case conditions including 1 in 200-year storm events, plus snowmelt plus precipitation,

- Leachate removal and transport plan,
- A plan for the management of contaminated soil stored in the Soil Management Area,
- Post closure inspection, operation and maintenance and environmental monitoring program,
- Implementation schedule for commencement and completion of closure activities.

The SPO also requested that the closure plan include contingency measures to address any failure of the works or the escape or spill of Leachate or Contaminated Soil into the environment. These contingency measures do not appear to have been included in the Final Closure Plan.

2.1 ASSESSMENT OF THE ADEQUACY OF THE EXISTING FACILITY

It is noted that Design criteria in LCMSW Sections 5.2 (Site Layout), 5.3 (Landfill Base Design), 5.4 (Landfill Base Liner), and 5.5 (Leachate Collection System) do not apply to Existing Landfills. Discussion of aspects of these sections is included in the SHA Closure Plan which provides responses to the MoE request for assessment of the adequacy of the existing facility and assessment of leachate collection and storage works.

Existing Landfill Facility	SHA Closure Plan	LCMSW Compliant?	Reviewer Comments
Basal Seepage Layer	SHA was not involved in the detailed design nor construction QA/QC of the basal systems. They are assured that a continuous layer of shot rock was achieved by overblasting the rock quarry.	Yes	The submitted as-builts show this layer to be present. Photographs taken during test pitting to test bedrock quality in the landfill footprint also appear to support this.
Clay Secondary Liner	The PEA is indicated to be lined with a 1 m thick brown marine clay impermeable barrier sourced from the Victoria area. SHA has apparently used similar brown marine clay from the Victoria area on other projects on Vancouver Island and the permeability of that clay was 2.8×10^{-8} cm/s.	Yes	The reviewers agree that the clay layer appears to meet minimum requirements of the landfill criteria - a 1 m thick clay barrier with a hydraulic conductivity (K) less than 1×10^{-7} cm/s or an equivalent geomembrane.
40 mil LLDPE Primary Liner	<p>The CHHL PEA is lined with a 40 mil geomembrane which serves as the primary liner.</p> <p>In SHA's opinion, the double liner is equivalent to the liner requirements of the 2016 LCMSW (thicker clay liner and thinner geomembrane liner).</p> <p>The report explains that the 2016 LCMSW recommendation of a 60 mil HDPE liner for the primary geomembrane was in recognition of research that revealed that geomembrane liners tend to deteriorate rapidly when subject to elevated temperatures. As the soils placed into PEA are biologically inert, the primary geomembrane is expected to be subject to far less thermal stress and a 40 mil thickness will be adequate to provide the desired long term performance.</p> <p>SHA offer a professional opinion that given that the geomembrane will not be subject to elevated temperatures and that it is well cushioned top and bottom by 200 mm thick sand layers, a service life in excess of 100 years is anticipated.</p>	Yes	The reviewers agree with the SHA rationale and professional opinion provided regarding the adequacy of the 40 mil primary liner.

Existing Landfill Facility	SHA Closure Plan	LCMSW Compliant?	Reviewer Comments
Texturing of Liner	<p>The existing smooth materials are indicated to achieve the desired level of stability on the base and crest areas of the fill because the smooth sheet is encapsulated in sand friction layers top and bottom. The report indicates that smooth membrane cannot be used on capping of the 3H:1V side slopes of the PEA. SHA has required that the smooth membrane be replaced with a double textured 40 mil LLDPE liner to achieve the necessary slope stability factors of safety</p>	Yes	<p>The reviewers agree with the SHA rationale provided regarding the use of double textured 40 mil LLDPE liner on the sloped portions of the cover.</p>
Leachate Collection Layer	<p>The report expects no new precipitation to enter the lined and fully encapsulated PEA, other than minimal quantities of water through any undetected liner defects.</p> <p>Upon closure of the landfill, the 300 mm thick sand drainage layer built at 2% grade is considered more than adequate to capture and convey any future leachate seepage that will exit the waste fill. The seepage rate is expected to continue to decline with time.</p>	Yes	<p>The reviewers agree with the SHA rationale provided regarding the adequacy of the sand layer to provide the required conveyance capacity for the anticipated leachate seepage rate.</p>
Soil Filter	<p>A geotextile filter was not installed above the sand drainage layer in the PEA. The 2016 LCMSW guidance is for installation of a geotextile filter layer above the drainage blanket, or installation of an engineered graded soil filter. The 300 mm sand layer is expected to provide a high degree of filtration capacity and should be effective in preventing migration of fines toward the leachate collector.</p>	Yes	<p>The reviewers agree with the SHA rationale provided regarding their experience with geotextile filter layers and the adequacy of the sand layer to provide the required filtration capacity.</p>
Leachate Collection Piping	<p>As part of the closure works, SHA has designed two new leachate collectors, one for the primary leachate collection layer above the liner and a second for the leak detection layer below the liner. Both collectors will be 100 mm HDPE DR-17 perforated pipes that will withstand anticipated loads.</p> <p>The leachate collection piping has not been installed in a herringbone fashion within the drainage layer (not required in the 1993 Landfill Criteria). As the PEA is fully encapsulated and expected to have negligible leachate flow, the 300 mm sand drainage layer has more than enough hydraulic capacity to convey any collected leachate to the landfill toe.</p>	Yes	<p>The Closure Report describes the installation of the leak detection piping such that it is notched into the basal clay layer which is expected to be adequate to collect any water that may accumulate on the clay liner surface. The reviewers agree that this should address a potential shortcoming of the current system.</p>
Grading of Permanent Encapsulation Area	<p>The report discusses the reconfiguration of the facility to meet final design criteria. Following the transfer of soil from the SMA to the PEA and regrading of the existing PEA geometry on the east and north slopes, the final contours for the landfill will be established at the desired 3H:1V grade.</p> <p>The existing settling pond will manage onsite non-contact run-off from closed areas and quarry floor to settle out any suspended sediments prior to discharge.</p>	Yes	<p>The reconfiguration appears to be achievable and the extension of the basal layer will facilitate the modifications to the leachate and leak detection systems.</p>

2.2 CLOSURE PLAN COMPLIANCE WITH 2016 LANDFILL CRITERIA

The Landfill Closure Plan was reviewed in the context of compliance with the 2016 BC MoE Landfill Criteria. It is noted that this information also includes the responses to the additional information requested in Section 4 of the SPO.

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
SITING CRITERIA			
Section 2 of the LCMSW indicates that existing approved landfill footprints are not subject to the siting requirements.	The Closure Plan does not address Siting Criteria with the exception of a discussion of depth to water table.	Yes	Siting Criteria, such as the buffer zone, are not applicable to existing landfills, and lack of discussion in the Closure Plan is not considered deficient.
Buffer Zone	Closure Plan report does not discuss buffer zone compliance	Yes	See above comment
Depth to Water Table - The landfill base shall be a minimum 1.5 m above groundwater surface.	SHA indicates in its assessment of the adequacy of the existing facility that monitoring of the water table is consistently several metres below the landfill base.	Yes	Landfill is not at base of quarry and appears to be located a minimum of 1.5m above the groundwater surface in the footprint area.
LANDFILL BASE DESIGN			
The landfill base shall be placed in stable soils or rock, with a minimum distance of 1.5 m above groundwater at all times.	SHA indicates that monitoring of the water table is consistently several metres below the landfill base.	Yes	Landfill is not at base of quarry and appears to be located a minimum of 1.5m above the groundwater surface in this area.
The landfill base soils shall not be subject to consolidation that could result in differential settlement under the applied waste and cover soil loading.	Closure Plan report does not discuss landfill base compliance since SHA was not involved in the detailed design nor construction QA/QC of the basal systems.	Yes	Compacted to appropriate specifications.
The landfill base shall be graded to provide a minimum 2 % grade for the primary drainage path (leachate collection piping) and minimum 0.5 % for the secondary drainage path (drainage blanket).	As-built cross sections were completed by SIRM and included in Appendix B of the report. The shot rock seepage layer, the 1,000 mm thick compacted clay secondary liner, the lower sand leak detection layer, and the 40 mil LLDPE geomembrane will be extended prior to the regrading of the encapsulation cell.	Yes	Seepage layer and clay base graded 2% to north.

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
The maximum drainage path in the drainage blanket to a leachate collection pipe shall be 50 m.	Upon closure of the landfill, the 300 mm thick sand drainage layer built at 2% grade is considered more than adequate to capture and convey any future leachate seepage that will exit the waste fill.	Yes	The reviewers agree with the SHA rationale provided regarding the adequacy of the sand layer to provide the required conveyance capacity for the anticipated leachate seepage rate.
Geologic inspection of the landfill base by a Qualified Professional.	SHA was not involved in the detailed design nor construction QA/QC of the basal systems.	Yes	AEE and Brimmell completed bedrock integrity assessments of the landfill base.
LANDFILL BASE LINER			
The landfill base liner shall comprise a primary High Density Polyethylene (HDPE) geomembrane liner and a secondary compacted clay liner or Geosynthetic Clay Liner (GCL).	In SHA's opinion, the existing double (primary/secondary) liner is equivalent to the liner requirements of the 2016 LCMSW (thicker clay liner and thinner geomembrane liner). The 2016 LCMSW recommendation of a 60 mil HDPE liner for the primary geomembrane was in recognition of research that revealed that geomembrane liners tend to deteriorate rapidly when subject to elevated temperatures. As the soils placed into PEA are biologically inert, the primary geomembrane is expected to be subject to far less thermal stress and a 40 mil thickness will be adequate to provide the desired long term performance.	Yes	The reviewers agree with the SHA rationale and professional opinion provided regarding the equivalency of the existing double (primary geomembrane / secondary clay) liner to the liner requirements of the 2016 LCMSW.
Continuous QA/QC inspection by a Qualified Professional during geomembrane installation and subsequent coverage is required to limit occurrence of undetected defects.	The report acknowledges the requirement for continuous QP inspection and documentation of all work completed on the PEA closure. Periodic QA/QC testing was conducted by SHA during installation of the geomembrane system.	Yes	There is a line item in the SHA closure cost estimate for QA/QC that suggests continuous QP inspection and documentation of all work.
Each seam should be individually tested using non-destructive methods.	SHA indicates that a thorough review and inspection program will be undertaken of the existing crest area 40 mil LLDPE geomembrane during closure construction works to ensure that all seams, boots and minor holes identified during the last inspection have been properly sealed up.	Yes	Seam testing has passed inspection to date.
Leak detection survey should be performed on HDPE geomembrane after it has been backfilled to locate areas that may have been damaged during material placement.	Leak detection survey not previously completed, survey on liner extension not discussed in the closure plan.	No	Leak detection survey not completed to date.

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
The minimum specifications for the primary HDPE geomembrane liner are:			
<ul style="list-style-type: none"> • HDPE geomembrane thickness of 1.5 mm (60 mil). 	<p>LLDPE liner is 40 mil</p> <p>The liner extension will utilize 40 mil double-textured LLDPE to provide additional shear resistance at the landfill toe.</p>	Yes	The reviewers agree with the SHA rationale and professional opinion provided regarding the suitability of the liner material for this landfill.
<ul style="list-style-type: none"> • Service life of 100 years at expected operating temperatures 	<p>SHA offer a professional opinion that given that the geomembrane will not be subject to elevated temperatures and that it is well cushioned top and bottom by 200 mm thick sand cushion layers, a service life in excess of 100 years is anticipated.</p>	Yes	The reviewers agree with the SHA rationale and professional opinion provided.
<ul style="list-style-type: none"> • HDPE geomembrane should be installed to meet or exceed industry standard QA/QC programs for material manufacture and installation. 	<p>The new liner extension will be double wedge or extrusion welded to the existing 40 mil LLDPE liner and detailed QA/QC will be undertaken that this critical seam is free of defects and leaks.</p> <p>SHA indicates that a thorough review and inspection program will be undertaken of the existing crest area 40mil LLDPE geomembrane during closure construction works to ensure that all seams, boots and minor holes identified during the last inspection have been properly sealed up.</p>	Yes	<p>Manufacturer seam and material testing to date has passed inspection.</p> <p>The reviewers agree with the SHA QA/QC program.</p>
<ul style="list-style-type: none"> • Consideration is to be given to the requirement for texturing and asperity size of the primary geomembrane to ensure stability of the fill in all circumstances, including earthquake loading. 	<p>The basal liner extension will utilize 40 mil double textured LLDPE to provide additional shear resistance at the landfill toe.</p> <p>SHA has required that on the 3H:1V side slopes the smooth membrane be replaced with a double textured 40 mil LLDPE liner to achieve the necessary slope stability factors of safety.</p>	Yes	<p>The reviewers agree with the SHA rationale provided for use of texturing.</p> <p>No current texturing of the membrane observed.</p>

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
The specifications for the secondary compacted clay liner are:			
<ul style="list-style-type: none"> Soil containing minimum 25 percent clay and minimum 60 percent silt and clay by weight. 	The clay contains about 70% fines passing the No. 200 sieve (0.074 mm) with 20 to 30% clay content.	Yes	Grain size analysis completed on basal layer.
<ul style="list-style-type: none"> A minimum compacted thickness of 750 mm. Thickness is to be measured perpendicular to the slope. 	The PEA is lined with a minimum 1 m thick impervious brown marine clay barrier.	Yes	Clay has 1.0 to 3.0 m nominal thickness.
<ul style="list-style-type: none"> Compacted hydraulic conductivity of 1×10^{-7} cm/sec or less. 	The PEA is indicated to be lined with a 1 m thick brown marine clay impermeable barrier sourced from the Victoria area. SHA has apparently used similar brown marine clay from the Victoria area on other projects on Vancouver Island and the permeability of that clay was 2.8×10^{-8} cm/s.	Yes	The clay has been shown to be compacted to 90% Proctor, however the hydraulic conductivity of the clay layer was not measured.
<ul style="list-style-type: none"> Organic carbon content of at least 0.1 %. 	Not specified in plan.	Unknown	Not specified.
<ul style="list-style-type: none"> Clay structure and permeability to remain stable when exposed to leachate. 	Not specified in plan.	Unknown	Not specified in as-built package or discussed in Final Closure Plan.
LEACHATE COLLECTION SYSTEM			
A leachate collection system is to be constructed above the landfill base liner. The leachate collection system is to provide a free draining layer that allows for collection of leachate and eliminates the buildup of a leachate head on the landfill base liner.	<p>SHA to install new leak detection collection piping at north end of cell as well as a 5-25 mm clear crush drainage layer above the geomembrane liner.</p> <p>The leak detection collection piping will be notched into the secondary clay barrier layer and surrounded by free-draining gravel and geotextile to maximize conveyance of leachate and minimize potential clogging.</p> <p>A new double lined leachate storage facility with additional storage capacity will be constructed.</p>	Yes	<p>Currently 0.3m of free draining sand installed above geomembrane liner.</p> <p>The reviewers agree with the notching of the leak detection piping into the clay layer to improve the functioning to the system.</p> <p>The reviewers also agree with the changes to the leachate storage facility and the additional storage capacity.</p>

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
The leachate collection system is to be designed to minimize clogging and allow for maintenance of the leachate collector pipes.	The collection piping will be surrounded by free-draining gravel and geotextile to minimize potential clogging. Leachate system clean outs will be installed to provide an opportunity for flushing of the collection system in the future, if necessary.	Yes	Agreed that clean outs be installed at the ends and T- connectors.
Minimum design requirements for a leachate collection system are:			
<ul style="list-style-type: none"> The leachate collection system shall be constructed of a continuous 0.3 m thick stone drainage blanket with perforated or slotted collector pipes with protective geotextile layers. Composite solutions which provide a proven equivalent hydraulic conductivity and mechanical protection are acceptable alternatives. 	Upon closure of the landfill, the 300 mm thick sand drainage layer built at 2% grade is considered more than adequate to capture and convey any future leachate seepage that will exit the waste fill.	Yes	<p>The reviewers agree with the SHA rationale provided regarding the adequacy of the sand layer to provide the required conveyance capacity for the anticipated leachate seepage rate.</p> <p>Sand drainage layer performance is expected to be similar to stone drainage blanket.</p>
<ul style="list-style-type: none"> The stone drainage blanket shall be constructed of 50 mm diameter clear stone with minimal fines or equivalent. The stone shall be chemically stable and inert rock. 	New leachate collector will be installed at the furthest extent of the sand drainage layer will consist of a 25-50 mm clear round drain rock surround, protected by a geotextile separation layer above the gravel.	Yes	Sand drainage layer installed rather than stone drainage blanket. Sand and clear stone is expected to be chemically stable.
<ul style="list-style-type: none"> A non-woven geotextile shall be placed on top of the geomembrane liner prior to placement of the stone drainage blanket to protect the geomembrane liner against puncture. 	Not discussed in Closure Plan.	Yes	Sand drainage layer installed rather than stone drainage blanket, sand provides protection. In the landfill north edge toe extension, this geotextile is incorporated into the design.

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
<ul style="list-style-type: none"> An engineered filter layer shall be placed above the clear stone drainage blanket to maintain separation of the waste from the clear stone and to minimize the potential for ingress of fines into the stone drainage blanket. 	<p>25-50 mm clear round drain rock is protected by a geotextile separation layer above the gravel.</p>	<p>Yes</p>	<p>Sand layer is also expected to meet criteria.</p>
<ul style="list-style-type: none"> Perforated or slotted HDPE leachate collector pipes shall be placed within the stone drainage blanket. Steps should be taken to prevent entry of air into drainage pipes. 	<p>The perforated collection piping will be surrounded by free-draining gravel and geotextile to minimize potential clogging. Leachate system clean outs will be installed to provide an opportunity for flushing of the collection system in the future, if necessary.</p>	<p>Yes</p>	<p>Leachate collector pipes tied into header to tank.</p>
<ul style="list-style-type: none"> Leachate collector pipes are to be installed at a lateral spacing that provides a maximum spacing of 15 m and maximum drainage path of 50 m. 	<p>The 300 mm thick sand drainage layer built at 2% grade is considered more than adequate to capture and convey any future leachate seepage that will exit the waste fill.</p>	<p>Yes</p>	<p>The reviewers agree with the SHA rationale provided regarding the adequacy of the sand layer to provide the required conveyance capacity for the anticipated leachate seepage rate.</p>
<ul style="list-style-type: none"> The collector pipes shall be sized to handle leachate flows based on site-specific leachate generation calculations but shall be a minimum 150-mm-diameter in all cases. 	<p>The 300 mm thick sand drainage layer built at 2% grade is considered more than adequate to capture and convey any future leachate seepage that will exit the waste fill.</p>	<p>Yes</p>	<p>The reviewers agree with the SHA rationale provided regarding the adequacy of the sand layer to provide the required conveyance capacity for the anticipated leachate seepage rate.</p>
<ul style="list-style-type: none"> The pipe wall thickness shall be designed based on the site-specific loadings from the mass of the waste and final cover soils. 	<p>Both collectors will be 100 mm HDPE DR-17 perforated pipes that will withstand anticipated loads</p>	<p>Yes</p>	<p>Leachate collector pipes tied into header not installed. The 100 mm HDPE DR 17 header pipe wall thickness is approximately 6.86 mm. Pressure rating is 690 kPa (100 psi). The reviewers accept the SHA opinion on the adequacy of the material.</p>

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
<ul style="list-style-type: none"> The collector pipes shall be installed at a minimum slope of 2 % along primary leachate flow paths. 	<p>The 300 mm thick sand drainage layer built at 2% grade is considered more than adequate to capture and convey any future leachate seepage that will exit the waste fill.</p>	<p>Yes</p>	<p>Leachate collector pipes tied into header not installed. The reviewers agree with the SHA rationale provided regarding the adequacy of the sand layer to provide the required conveyance capacity for the anticipated leachate seepage rate.</p>
<ul style="list-style-type: none"> Clean outs are to be provided at each end of the leachate collector pipes. 	<p>Leachate system clean outs will be installed to provide an opportunity for flushing of the collection system in the future, if necessary.</p>	<p>Yes</p>	<p>Clean outs on leachate and leak detection collector pipe header to be installed, meets design criteria</p>
<ul style="list-style-type: none"> The collector pipes shall drain to a collection header and sump to allow for the removal of collected leachate. Leachate shall be removed to maintain a leachate head of less than 0.3 m at any point on the landfill base liner. 	<p>Sand drainage layer installed. The existing leachate and leak detection system will be extended and discharge piping tied-in to piping extending north to proposed leachate storage facility.</p>	<p>Yes</p>	<p>Extra leachate collector pipes installed. Leachate may be present at a head of >0.3m in some areas of landfill. Construction photos show accumulations of water in Cell 1C that appear to suggest that some portions of the liner may build up leachate head. It is noted however that this water head would not be expected on top of the clay basal liner.</p>
<ul style="list-style-type: none"> Continuous QA/QC inspection shall be carried out during installation by a Qualified Professional during the construction of the leachate collection system. 	<p>SHA anticipates continuous QP inspection and documentation of all work completed on the PEA closure.</p>	<p>Yes</p>	<p>The reviewers agree that this QA/QC is important and recommend that QP sign-off of this important milestone in the plan be completed prior to regrading of the landfill material in this area.</p>
<ul style="list-style-type: none"> The collected leachate shall be managed in accordance with the approved Leachate Management Plan. 	<p>Leachate to be pumped from tank on regular basis for off-site disposal Leachate and leak detection tank quantity will be recorded during each leachate removal and/or leachate tank monitoring event. This will be correlated to precipitation data to assess and confirm cover integrity and demonstrate there is no correlation between rainfall events and leachate production due to cover liner leaks.</p>	<p>Yes</p>	<p>The reviewers agree with this approach; however it is suggested that the Closure Plan stipulate a maximum volume that the tank may hold before the contents are removed. This would be expected to provide sufficient capacity to handle any short term unforeseen increases in leachate volume.</p>

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
SURFACE WATER MANAGEMENT WORKS			
Surface water management works are to:			
<ul style="list-style-type: none"> Convey and direct surface water runoff away from the active operation area within the landfill footprint to minimize surface water contact with waste. 	No additional waste will be added to the PEA. Existing waste soil will need to be relocated to prepare slopes to meet final grading requirements. SHA indicates any contact water / leachate from the SMA and PEA will continue to be managed using the existing leachate collection system and contact water storage pond.	Yes	Meets Criteria. Ditching around PEA to divert surface run-off.
<ul style="list-style-type: none"> Minimize potential for on-site erosion and sediment loading to downstream water courses. 	A crest ditch and riprap lined downchutes are planned to direct storm water runoff from the crest of the PEA. Runoff will be directed towards the Western Settlement Pond.	Yes	Discharge to rock quarry and settlement pond.
<ul style="list-style-type: none"> Control peak flows from the landfill to minimize the downstream flood risk. 	Storm water management works were designed to meet a 1 in 200 year storm event.	Yes	Meets storm intensity requirements requested by MoE.
<ul style="list-style-type: none"> Prevent surface water run-on onto the landfill footprint. 	Based on topography surrounding the Site, all surface water which accumulates due to precipitation that does not fall on the landfill portion will be directed to Shawnigan Creek to the east and south, plus the ephemeral tributary of Shawnigan Creek to the north.	Yes	Meets Criteria. Ditching around PEA to divert surface run-off away. Final cover design should contemplate construction methods to divert run-on away from not only landfill footprint but also from the leak detection system.
Surface water management works shall be designed in accordance with the following criteria.			
<ul style="list-style-type: none"> All components of a surface water management system, including stormwater retention ponds, are to be designed to promote settling of sediment and infiltration of retained storm water for groundwater recharge where possible. 	Not included in Closure Plan given it was built prior to the landfill accepting waste.	N/A	Outside of review scope.

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
<ul style="list-style-type: none"> • Ponds are to be designed with low flow control structures and high flow overflow spillways. 	<p>Not included in Closure Plan given it was built prior to the landfill accepting waste.</p>	<p>N/A</p>	<p>Outside of review scope.</p>
<ul style="list-style-type: none"> • Surface water ditches and retention ponds shall be designed for the control and retention of a 1:100-year, 24-hour storm event. 	<p>All storm water ditches and downchutes are designed to accommodate for a 1 in 200-year rainfall event.</p>	<p>Yes</p>	<p>Exceeds design criteria requirements. Closure Plan Design to capture all surface water and route it to local streams.</p>
<ul style="list-style-type: none"> • The design shall make allowances for additional water that may result from snow melt and from prolonged multi-day precipitation events. 	<p>Allowances in the design have been made for snowmelt and multi-day precipitation events</p>	<p>Yes</p>	<p>Meets additional requirements requested by MoE.</p>
<ul style="list-style-type: none"> • Surface water runoff generated from active areas of the landfill (i.e., areas that are not capped with final or interim cover but containing waste) shall be managed as leachate. Run-on diversion ditches and other control structures are to be used where required to minimize clean surface water contact with active waste disposal areas. 	<p>Landfill no longer active, no additional waste will be added to the PEA. Existing waste soil will need to be relocated to prepare slopes to meet final grading requirements. SHA indicates any contact water / leachate from the SMA and PEA will continue to be managed using the existing leachate collection system. The storm water management plan is designed to keep clean water clean.</p>	<p>N/A</p>	<p>Landfill is capped and permit revoked. No more waste accepted. Soils currently in SMA area are proposed to be placed in the landfill during final closure, and contact water management is addressed in the Final Closure Plan.</p>
<ul style="list-style-type: none"> • All ditch surfaces are to be armoured with appropriate protection for expected flow velocities (i.e., rip rap, erosion control matting, or vegetative cover) to prevent erosion of ditch bottom and side slopes 	<p>Downchutes are to be armoured with riprap and other ditching includes erosion control matting.</p>	<p>Yes</p>	<p>Current ditching adjacent to landfill meets criteria.</p>

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
<ul style="list-style-type: none"> All ditches are to maintain a minimum 1 % grade to prevent sedimentation and maintain hydraulic design capacity. Ditches shall be designed to accommodate localized settlement (no grade reversals). 	<p>SHA recommends ditches with a triangular cross section, 0.75 m depth and 2H:1V side slopes lined with a 300 mm layer of 150 mm to 300 mm rip rap. The sizing of this ditch exceeds the requirements for a 1 in 200-year storm event, including snowmelt and multi-day precipitation.</p>	<p>Yes</p>	<p>Proposed ditching exceeds design requirements.</p>
<ul style="list-style-type: none"> Erosion control measures are to be used to prevent active erosion of channel slopes and surfaces that contribute to run-off. Common erosion control measures include loose straw, hydro-seed, erosion control blankets and straw wattles, amongst others. 	<p>Erosion Control Plan includes hydroseeding, straw wattle ditch protection, straw slope protection and erosion control in ditches.</p>	<p>Yes</p>	<p>Final Closure Plan meets design requirements.</p>
<ul style="list-style-type: none"> Mid slope drainage ditches/swales shall be constructed on the final cover surface as required to intercept run-off and prevent erosion of final cover soils. The recommended spacing of such ditches is every 15 m (vertical separation). 	<p>The Closure Plan includes installation of a crest ditch to direct storm water runoff to downchutes which drain to the toe surface water ditches. The vertical separation from the crest of the PEA to the toe surface ditches is less than 15 m elevation.</p>	<p>Yes</p>	<p>Rip rap lined downchutes allow for storm water drainage from the landfill crest and side slopes are less than 15 m vertical difference in geodetic elevation.</p>

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
LANDFILL GAS MANAGEMENT WORKS			
As per the requirements of the Landfill Gas Management Regulation, landfill owners must design, construct, and operate landfill gas management facilities in accordance with the BC Landfill Gas Management Facilities Design Guideline.	Based on the landfilled material, generation of landfill gas is not anticipated.	N/A	Closure Plan design has considered LFG, but since no municipal waste is present no LFG will be generated. A VOC monitoring program is included in the Closure Plan.
FINAL COVER DESIGN			
The final cover is to achieve the following objectives:			
<ul style="list-style-type: none"> Prevent exposure of humans and/or wildlife to MSW. 	Both a low permeability soil barrier layer with a K (hydraulic conductivity) less than 1×10^{-7} cm/s and a geomembrane barrier are specified to provide maximum environmental protection.	Yes	The reviewers agree with the final cover design.
<ul style="list-style-type: none"> Control infiltration of precipitation. 	To ensure minimal leachate generation, a geomembrane cap rather than a clay cap, a drainage layer to prevent head build up on the cover barrier layer and a subsoil layer that will have the functionality of a secondary liner will be installed.	Yes	The reviewers agree with the final cover design. Design exceeds criteria.
<ul style="list-style-type: none"> Minimize the uncontrolled release of methane to the atmosphere. 	As the landfill is not a Municipal Waste Landfill and the gas generation rate for the types of waste being landfilled is extremely slow if at all, Landfill Gas is not deemed to be of great concern at the site.	Yes	Minimal odour generation expected due to landfilled material.
<ul style="list-style-type: none"> Limit erosion and release of sediment to surrounding surface waters. 	Erosion control measures that are proposed are hydroseeding immediately after placing the final cover layer, straw wattles, erosion control blanket on the slopes, and rip rap.	Yes	The reviewers agree with the final cover design.
<ul style="list-style-type: none"> Control the release of odours. 	Release of volatile organic compounds through the barrier layer is a minor concern. This should be verified with a one-time monitoring run of VOCs emissions from the landfill. A VOC instrument will be used to sample from a minimum of 10 locations.	Yes	Minimal odour generation expected due to landfilled material. The reviewers agree with monitoring of VOC emissions.

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
<ul style="list-style-type: none"> Minimize oxygen infiltration and fire risk. 	Not discussed in Closure Plan.	Yes	Minimal fire risk expected due to composition of landfilled material.
<ul style="list-style-type: none"> The final cover shall be compatible with the end use planned for the landfill site. 	<p>If a vegetated end use is planned, an erosion control layer comprised of topsoil at least 150 mm thick will be installed. If industrial end use, the erosion control layer can be substituted by a pavement or gravel layer.</p>	Yes	No specific end-use stated in document.
<p>The minimum final cover shall consist of a barrier layer, providing a maximum hydraulic conductivity of 1×10^{-5} cm/sec for landfill sites located in arid and semi-arid regions and 1×10^{-7} cm/sec for landfill sites located in non-arid regions</p>	<p>Both a low permeability soil barrier layer with a K (hydraulic conductivity) less than 1×10^{-7} cm/s and a geomembrane barrier are specified to provide maximum environmental protection and to minimize future leachate disposal costs.</p>	Yes	The reviewers agree with the final cover design. Design exceeds criteria.
<p>The final cover barrier layer shall have a minimum compacted thickness of 0.6 m measured perpendicular to the slope with a minimum 0.15 m topsoil layer capable of establishment and sustained growth of the vegetative cover.</p>	<p>A 300 mm thick top soil layer is planned to provide flexibility in the type of vegetation implemented long term. A 500 mm secondary low permeability barrier is being installed on the crest areas as a design contingency to provide very long term security for the future.</p>	Yes	The reviewers agree with the final cover design. Design exceeds criteria.
<p>The final cover system is to be designed to ensure the maximum allowable leachate generation rate is not exceeded but will allow for waste stabilization during the post-closure period.</p>	<p>A drainage layer is specified in the cover system above the barrier layer to prevent head build up and saturation of the top soil.</p>	Yes	The reviewers agree with the final cover design. Proposed design exceeds minimum requirements.

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
<p>Hydrologic modeling of the “final cover” performance using the applicable climatic setting for the landfill site shall be completed to demonstrate the final cover stability under design storm conditions and consistency with the Leachate Management Plan.</p>	<p>The leachate generation estimation was performed using the Hydrologic Evaluation of Landfill Performance (HELP) model.</p> <p>The forecast is based on a 200-year wet winter weather with monthly rainfall intensity of 1.5 times the average and including snow melt and multi-day precipitation.</p>	<p>Yes</p>	<p>The reviewers agree that final cover design meets additional requirements requested by MoE.</p>
<p>A lower permeability barrier layer or the addition of a textured geomembrane or geo-composite equivalent may be required to control leachate generation rates.</p>	<p>Both a low permeability soil barrier layer with a K (hydraulic conductivity) less than 1×10^{-7} cm/s and a geomembrane barrier are specified to provide maximum environmental protection and to minimize future leachate.</p>	<p>Yes</p>	<p>Final Closure Plan proposed final cover design meets design requirements.</p>
FINAL CONTOURS			
<p>Final contours of the landfill shall be constructed at grades not steeper than 3H:1V (33 %).</p>	<p>Regrading of the waste soil on the north and east slopes will be completed to 3H:1V slope.</p>	<p>Yes</p>	<p>Final Closure Plan contours meets design requirements.</p>
<p>The recommended design criteria for the top plateau of the landfill is a slope not less than 10H:1V (10 %) for cover systems using a soil barrier layer. The grade for the top plateau can be reduced up to 25H:1V (4%) for cover systems using a durable geomembrane or composite barrier layer with an overlying drainage layer above the final landfill side slope.</p>	<p>Final cover to be sloped at a minimum of 4%, to promote surface water runoff, to a maximum slope of 33%.</p>	<p>Yes</p>	<p>Final Closure Plan contours meets design requirements.</p>

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
Surface water control benches to intercept surface water run-off shall be provided on the landfill final contours every 15 m vertical or less. Benches shall be graded in a way that will effectively convey surface water run-off from the landfill refuse via ramps, down-chutes, or spillways and shall account for anticipated settlement.	The crest run-off containment ditch will be reshaped further to the south beneath liner.	Yes	Final Closure Plan contours meets design requirements.
Site Security and Fencing	Not discussed in Closure Plan.	No	West, southwest and south perimeter fence absent.
Access Roads	An 8m wide access road along the northern toe of the PEA has been included providing access to the leachate and leak detection storage tanks as well as the western portion of the cell.	Yes	The access road meets design requirements.
Vector and Wildlife Management and Nuisance Controls	Not discussed in Closure Plan as the landfill no longer operating.	N/A	Controls not anticipated to be required after final closure.
CLOSURE AND POST-CLOSURE CRITERIA			
Closure Plan	Closure Plan does not specify a proposed post-closure land use for the landfill site.	No	The criteria state that a Closure Plan shall be prepared identifying a specific post-closure land use proposed for the landfill site.
Progressive Closure	Not applicable to this landfill closure.	N/A	
Post-Closure Operation and Maintenance	Each year a Qualified Professional will collect the required monitoring data and compile an Annual Report outlining the closure performance of the landfill. An annual inspection of all infrastructure will be completed by a Qualified Professional prior to compilation of the annual report.	Yes	The reviewers agree with the Post-Closure Operation and Maintenance plan.
Contaminating Lifespan	It is SHA's opinion that the characteristics of soil disposed at CHL will not pose a risk to human health or the environment beyond the 50-year post closure period and that aquatic life water quality objectives will be achieved at the property line after the post closure maintenance period has ended.	Yes	The reviewers agree with the SHA rationale and professional opinion provided regarding the expected contaminating lifespan of this landfill.

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
Contaminated Sites Regulation and Landfill Closure	Not discussed in Closure Plan.	No	The EMA requires at the time of decommissioning (10 days prior to final deposit of waste), that a landfill property owner complete and submit a site profile
FINANCIAL SECURITY			
Amount of Financial Security	Closure costs and post closure period bonding / security posting reflect the current conditions at the site and the potential risk posed to the environment based on final closure to the PEA.	N/A	Outside of review scope. However as noted below, the costs for disposal of leachate appear to be lower than expected based on the current annual leachate accumulations.
Calculating Financial Security	The amount of financial security was calculated and included closure of the permanent encapsulation area, annual Post Closure sampling, monitoring, analysis and reporting costs over the 50-year Post Closure Period.	Yes	The reviewers note that the costs for disposal of leachate appear to be lower than expected. Leachate disposal costs of \$3,065 are accounted for in the post closure monitoring costs. While it is acknowledged that the leachate volume will decline over time, based on the current annual leachate accumulations of 182 m ³ (182,000 L) and a disposal cost of \$0.25 /L, the disposal of leachate would be expected to be closer to \$45,000. The cost for the lower volume (58 m ³) expected in the future would still be in the order of \$14,500 per year.
Post-closure Period	Landfill subject to a 50-year contaminating lifespan post closure period, no calculations were made to support this. There is a question whether the facility should be grandfathered to a 25-year post closure period. SHA provides an opinion that the characteristics of soil disposed at CHL will not pose a risk to human health or the environment beyond the 50-year post closure period and that aquatic life water quality objectives will be achieved at the property line after the post closure maintenance period has ended.	Yes	The reviewers agree with the SHA rationale and professional opinion provided regarding the expected contaminating lifespan of this landfill post closure.
Cost to be presented in Current Dollars	The net costs were adjusted for inflation and interest.	N/A	Outside of review scope.
Review Period	The closure plan and security posting will be reviewed every five years.	Yes	The reviewers agree with the review period.
Types of Financial Security	The type of financial security is a Post Closure Bond.	N/A	Outside of review scope.

2016 Landfill Criteria	SHA Closure Plan	Compliant?	Reviewer Comments
MONITORING CRITERIA			
Leachate Monitoring	<p>Leachate Chemistry is required to assist with determining the contaminating lifespan of the landfill.</p> <p>Leachate and leak detection tank quantity will be recorded and will be correlated to precipitation data to assess and confirm cover integrity and demonstrate there is no correlation between rainfall events and leachate production due to cover liner leaks.</p> <p>SHA anticipate that leachate currently being generated at approximately 0.5 m³/day should reduce to approximately 0.16 m³/day or 58 m³/year, post closure.</p>	Yes	The reviewers agree with the Post-Closure Leachate Monitoring plan.
Groundwater and Surface Water Monitoring	<p>SHA proposes a groundwater monitoring program consisting of three wells, one background (MW-6) and two downgradient at the property boundary (MW-2 & MW-3). Sampled quarterly, changing to semi annual Spring / Fall after 10 years and annual in Fall after 25 years.</p> <p>Surface water monitoring program to include sampling of two stations at spring and fall.</p> <p>A groundwater monitoring program is to be installed in the seepage blanket, down-gradient of the PEA. The seepage blanket monitoring will be conducted from two standpipe monitoring wells excavated approximately 3.0 m into the seepage blanket at the landfill toe.</p>	Yes	<p>In general, the reviewers agree with the Post-Closure Groundwater and Surface Water Monitoring plan.</p> <p>Regarding the monitoring of the seepage blanket, the reviewers have two recommendations:</p> <ol style="list-style-type: none"> 1. The number of monitoring wells be increased to at least 3, with the western most well relocated further to the west (east well spacing may also require adjusting to provide representative coverage) and an additional well installed adjacent to the subsurface leachate collection system piping near to the storage tanks to monitor any potential leaks in the piping. A 4th well may be required on the west portion of the seepage blanket to provide representative coverage. 2. That the seepage blanket monitoring well screens be extended to the competent bedrock surface (regardless of depth) to ensure all water within the seepage layer is captured in the wells.
Landfill Gas Monitoring	<p>Release of volatile organic compounds through the barrier layer is a minor concern.</p> <p>This should be verified with a one time monitoring run of VOC's emissions from the landfill. A VOC instrument will be used to sample from a minimum of 10 locations.</p>	Yes	The reviewers agree with the Post-Closure Landfill Gas Monitoring plan.

The Final Closure Plan included geotechnical considerations with regard to the stability of the landfill for both static and seismic conditions. There are no geotechnical design criteria for comparison within the 2016 Landfill Criteria. However, SHA concluded the deep seated factor of safety (FOS) for static and seismic conditions were more than 1.5 and 1.0, respectively, indicating that the landfill will be globally stable. Further recommendations are made for erosion control measures and closure construction considerations. The information presented in the Final Closure Plan appears reasonable, however the reviewers are not qualified to review geotechnical issues.

2.3 LOCAL RESIDENT CONCERNS

The information package contained documents received by the BC MoE from local residents documenting concerns they have raised regarding the landfill construction. The documents provided from local residents are listed in Appendix A along with a brief summary of the content.

3.0 DISCUSSION

Overall, the Final Closure Plan document was comprehensive and provided details with respect to the Landfill closure and post-closure maintenance and monitoring. Many aspects of the landfill closure design exceed the minimum requirements of the Landfill Criteria.

Section 4 of the SPO requested that the closure plan include contingency measures to address any failure of the works or the escape or spill of Leachate or Contaminated Soil into the environment. Contingency measures are provided for potential spills in the leachate storage tank area, such as a secondary geomembrane liner and gravel cushion layer surrounding the storage tank, as well as a roof structure to prevent infiltration of precipitation. The extra contingency afforded by the improvements to the cover design is also discussed. Additional contingency measures to address any failure of the works or the escape or spill of leachate, for example a plan for collection of leachate from the seepage blanket should the basal liner system be found to be compromised, do not appear to have been included in the Final Closure Plan.

3.1 2016 BC LANDFILL CRITERIA FOR MUNICIPAL SOLID WASTE

The focus of our work centered on conformance with the 2016 BC Landfill Criteria for Municipal Solid Waste (LCMSW – a ministry guidance document). We have noted for discussion various aspects of the LCMSW with respect to the landfill closure plan as follows:

3.1.1 Landfill Base Extension and Design

SHA provide cross-sections and figures that show the details of the landfill basal liner extension along the north toe of the landfill to accommodate the final cover contours. Leachate collection and leak detection systems and piping will be upgraded to address concerns with the current configuration of these systems. As the landfill is not located at the base of the quarry, it is agreed that the landfill base can be expected to be a minimum of 1.5 m above the groundwater surface.

As-built cross-sections of the landfill base provided by SIRM continue to not show details of clay berms between the three landfill cells that are apparent in photographs taken during the cell construction. Details of the current leachate and leak detection piping that are expected to intersect the liner in the vicinity of these berms are also not provided. It is anticipated that system modifications further to the landfill extension will mitigate any apparent shortcomings with the construction in these areas.

3.1.2 Landfill Base Liner

SHA provide sufficient rationale for the equivalent use of a Linear Low Density Polyethylene (LLDPE, 40 mil) geomembrane rather than a High Density Polyethylene (HDPE, 60 mil) geomembrane in accordance with the LCMSW. While not specifically stated in the closure plan document, they appear to account for continuous Qualified Professional (QP) inspection during geomembrane installation in the costing for the extension of the basal liner system.

No leak detection survey is proposed after the modifications to the liner system. The LCMSW states the organic carbon content and leachate stability of the compacted clay liner. No information for these was provided, and no discussion of the potential issues related to the absence of this information was included.

3.1.3 Leachate Collection System and Leakage Detection System

The new double lined leachate storage facility will be constructed north of the landfill footprint after extension. The discussion of the management of leachate during the basal layer extension works indicates that the new collection system will be established prior to the basal liner extension, however it is expected that a temporary system for collecting leachate will be required due to the extent of the system modifications. The modification of keying the leakage detection system collector pipe into a notch in the clay layer appears to be properly located to intercept leakage liquids.

Currently, precipitation that collects along the upper portions of Cell 1 is expected to infiltrate between the clay berm and the geomembrane, and accumulate within the leak detection sand layer. There is no discussion of any mitigation of this to reduce or eliminate surface water ingress into the leakage detection system included in the final cover design.

Removal of leachate from the storage tanks should be completed before levels exceed the capacity of the system to accommodate any unforeseen fluctuations in the leachate flow volume, as may be expected following extreme weather events. A remote telemetry level monitoring system may facilitate the ability to remove leachate in a timely manner, and more closely spaced inspections may be required in the absence of such a system until a clear trend in leachate accumulations in the new system is established.

3.1.4 Seepage Blanket Monitoring

SHA have designed a groundwater monitoring program in the seepage blanket down-gradient of the landfill footprint that will remain intact following final cover completion. The number, depth, and locations of monitoring wells to be installed should be reviewed to ensure adequate capture and detection of any leakage below the landfill. An additional well appears warranted adjacent to the subsurface leachate collection system piping near to the new storage tanks to monitor any potential leaks in the piping. As well, the seepage blanket monitoring well screens should be extended to the competent bedrock surface (regardless of depth) to ensure all water within the seepage layer is captured in the wells.

3.1.5 End Use of Property and Security

Our review of the Final Closure Plan for the landfill identified that there was no end use explicitly stated for the site. The western and southern fence were absent, which would allow trespassers and wildlife to freely roam on to the closed landfill area.

3.2 LOCAL RESIDENT CONCERNS AND PHOTOS

The review of documents provided regarding the local residents concerns identified that the concerns included issues such as:

- questions regarding the basal liner integrity further to apparent wrinkles or folding of the geomembrane;
- questions regarding the representativeness of the as-builts;
- extent of buffer zones and PEA contours;
- chemical sample data that suggests a leachate source for chemical parameters that are present in the ephemeral stream downgradient of the site; and,
- concerns with wrinkles forming in the upper liner due to shrinkage of the soils.

Our review of local resident's concerns revealed that some of their observations differed with respect to as-built documents provided by CHH. We have considered this information during the course of our work. Some issues raised, such as the presence of buffer zones for the landfill, are noted to not apply to existing landfills in the LCMSW. The issues raised regarding the wrinkles or folds in the liner are noted, and agreed to not be optimal, however the geomembrane exceeds the design criteria in place at the time of construction, and it has been shown that the leakage through composite liners is only a very small fraction of that expected for either a geomembrane or clay liner alone.

Due to the location of the landfill within a rock quarry, there are multiple potential sources of contamination in the vicinity of the landfill. The modifications to the facility, such as to the landfill basal liner, leachate and leak detection collection systems, and cover as presented in the Landfill Closure Plan, are expected to facilitate the direct monitoring of site conditions to more accurately confirm if the landfill

closure is protective of the environment. Until the modifications are complete and the proposed monitoring plan initiated, it is the reviewers' opinion that it is not possible to draw conclusions regarding the source of chemical parameters in the ephemeral stream down-gradient of the site.

4.0 CONCLUSIONS

Based on the information provided and reviewed, the Landfill Closure Plan appears to be a comprehensive document that substantially addresses the requirements of Section 4 of the SPO as well as input from Ministry of Environment staff contained in letters dated March 17, April 13, and May 18, 2017. The Closure Report appears to provide sufficient technical justification to demonstrate that proposed site-specific alternatives provide an equivalent or better level of environmental protection relative to LCMSW, including for worst case conditions, such as, 200-year design storm event(s), plus snowmelt and multi-day precipitation events.

While many aspects of the Landfill Closure exceed minimum criteria requirements, some details require further clarification to ensure the facility is designed, constructed and operated to minimize any risks to the environment. Contingency measures to address any failure of the works or the escape or spill of leachate or contaminated soil into the environment were not fully addressed in the report. Section 10.3.4 of the LCMSW indicates that a closure plan must include practical and implementable contingency measures to address any failure of the works or non-compliance with the performance criteria. Updated as-builts of the PEA were provided separately by SIRM that included east-west cross-sections, however these continue to lack details of the construction between cells, such as, liner completion/sealing around leachate piping extensions and apparent soil berms. The recommendations from the May 26, 2017 Hemmera report were also in general adequately addressed, however there was no discussion of provisions to eliminate non-contact water from entering the leakage detection system.

5.0 RECOMMENDATIONS

In the context of avoiding any leaks or spills of leachate to the environment, and for the landfill closure to more closely conform with the 2016 LCMSW (a ministry guidance document), in our professional opinion the following items must be completed:

1. Ensure that the leachate collection and storage system is adequately maintained such that it continues to operate effectively throughout reconstruction of the landfill toe area during modifications being made to accommodate the final cover slopes. During final closure construction, the current contact water treatment system will be decommissioned. Please confirm if a temporary leachate collection system will be needed to manage leachate accumulations during the transition to the newly installed leachate storage facility.
2. Final cover design should contemplate construction methods to divert surface water and precipitation away from the leak detection system. Confirm that there are provisions in the Final Closure Plan cover design to minimize non-contact water from entering the leakage detection system.

3. Confirm and discuss any potential issues that may arise further to unknowns regarding clay organic carbon content and stability of compacted clay liner (structure and permeability) when exposed to leachate.
4. Confirm that the frequency of the storage tank inspections will be sufficient to identify water levels in the tanks, or meter leachate flow into the leachate collection tank, such that leachate accumulations can be removed with sufficient remaining capacity to accommodate unforeseen increases in leachate volume. The required capacity should be determined and the maximum tank volumes specified in the monitoring and maintenance plans. Remote monitoring (telemetry) of the tank levels should be considered, possibly as part of the proposed leachate metering, to ensure that sufficient tank capacity is maintained regardless of tank inspection frequency.
5. Have continuous QP inspection and documentation of all work completed on the landfill closure. Inspection and QP approval of the modifications to the Basal liner system and the Leachate Collection and Leak Detection systems to be completed prior to regrading of landfill material.
6. The number of seepage blanket monitoring wells should be increased to at least three, with the western most well relocated further to the west (east well spacing may also require adjusting to provide representative coverage) and an additional well installed adjacent to the subsurface leachate collection system piping near to the storage tanks to monitor any potential leaks in the piping. A fourth well may be required on the west portion of the seepage blanket to provide representative coverage for groundwater capture.
7. The seepage blanket monitoring well screens should be extended to the competent bedrock surface (regardless of depth) to ensure all groundwater within the seepage layer is captured in the wells.
8. Provide contingency measures to address any failure of the works or the escape or spill of Leachate or Contaminated Soil into the environment.

Implementing the preceding recommendations is expected to increase adequacy of the works to prevent the escape of leachate into the environment during the post-closure period and minimize the potential for environmental risk.

We have appreciated the opportunity to work with you on this project and trust that this report meets to your requirements. Please feel free to contact the undersigned regarding any questions or further information that you may require.

Report prepared by:
Hemmera Envirochem Inc.

Report peer reviewed by:
Hemmera Envirochem Inc.

**ORIGINAL SIGNED
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This document represents an electronic version of the original hard copy document, sealed, signed and dated by Paul Webb, P.Geo., CSAP and Chuck Jochems, P.Eng., CSAP and retained on file. The content of the electronically transmitted document can be confirmed by referring to the original hard copy and file. This document is provided in electronic format for convenience only. Hemmera Envirochem Inc. shall not be liable in any way for errors or omissions in any electronic version of its report document.

APPENDIX A

Files Containing Local Resident Concerns

Files Containing Local Resident Concerns

File Name	Format	Summary of Information
SRG Summary of SHA Final Closure Plan – Juurlink June 8, 2017	Word	Any consideration of final closure as an option must assume a 2018 implementation.
Review – SHA Final Closure Plan Brent Beach June 8, 2017	Word	Review of previous closure plan for landfill.
Evidence that Cell-1C is Compromised Dave Hutchinson June 8, 2017	PowerPoint	The file contains images that show wrinkles in a portion of the base liner
Recent Insights regarding the Design and Construction of Modern MSW Landfills EurAsia Waste Management Symposium May 2-4, 2016	PDF	This document makes recommendations further to the design and construction of landfills. Many of these have been incorporated into the Final Closure Plan.
Missing From Any of the Reports: The Evidence that the Liner is Leaking – Juurlink	Word	The footprint of contaminants in the leachate is essentially the same footprint as the contaminants in the Settling Pond outflow and the Ephemeral stream
Review – CHH As Built Documents Brent Beach May 31, 2017	Word	This project has been characterized by false, misleading and incomplete information from the first Open House in May of 2012.
CHH-SIRM Photos Dave Hutchinson	PowerPoint	Additional photos taken during PEA construction.
Review – Landfill Closure under Landfill Criteria for Municipal Solid Waste Brent Beach May 31, 2017	Word	This review considers the contaminated waste pile in the context of the Spill Prevention Order issued March 15, 2017. The review notes that the SPO introduces a new set of restrictions on the contaminated waste site and analyses the footprint relative to buffer zone criteria and slope criteria.
The Contaminated Soil Waste Landfill Site is Leaking Dr. Bernie Juurlink May 31, 2017	Word	Before the Ministry of Environment considers a closure plan for the contaminated soil dumpsite at 460 Stebbings Road, the Ministry must determine whether the site is leaking or not.
SRG Additional Documents – 2017-06-13.docx	Word	Shawnigan Research Group (SRG) submitted five additional documents to the Ministry of Environment with regard to the Amended Spill Prevention Order
Leachate and Water Quality Data Analysis-Juurlink.docx	Word	Letter presents laboratory data that apparently shows that the contaminated soil waste landfill site at 460 Stebbings Road is leaking contaminants into the watershed
Maxxam WQ Data 2017-06-12.pdf	PDF	Results of water quality samples collected on June 2, 2017, analyzed by Maxxam Laboratories

File Name	Format	Summary of Information
Maxxam WQ Data 2017-06-12.xls	Excel	Results of water quality samples collected on June 2, 2017, analyzed by Maxxam Laboratories
SHA Final Closure Plan-Addendum-Beach.docx	Word	The CVRD Zoning Case – with pending lawsuit, it would be improper for MoE to move ahead with a landfill closure Cover Folding – Shrinkage of the pile is creating folds. Contact Water Management – photos of hoses in leachate tank and contact water pond