Reasons for Decision
Conditional Approval of 2019 Final Closure Plan for Cobble Hill Holdings Landfill

Decision at Issue

The decision before me as the designated statutory decision-maker under the *Environmental Management Act* (EMA), is whether to approve, with or without conditions, the 2019 Updated Final Closure Plan, as amended, submitted under the Second Amended Spill Prevention Order MO1701 (SPO), by the parties named to that order (the Named Parties). The first amended spill prevention order required the Named Parties to either permanently close the landfill or remove the soil. The Named Parties chose to permanently close the landfill and submit a closure plan, so the order was amended a second time to reflect this choice.

For the reasons outlined below, I have decided to approve the 2019 Updated Final Closure Plan, as amended, with conditions as outlined in my conditional approval letter.

Background

This matter concerns a landfill facility for contaminated soil and ash located at 460 Stebbings Road near Shawnigan Lake, British Columbia on land legally described as Lot 23 Blocks 156, 201 and 323 Malahat District Plan VIP78459 owned by Cobble Hill Holdings Ltd. (CHH).

Permit PR-105809 (the Permit) was issued to CHH under EMA, authorizing the discharge of contaminated soil and effluent in connection with the facility. The Permit was cancelled by the Minister on February 23, 2017 for non-compliance with the terms of the Permit for the failure to provide updated financial security intended to support closure and post-closure activities.

Currently, there are approximately 100,000 tonnes of soil in the landfill, but the landfill has not yet been permanently closed with appropriate final cover layers to provide long-term protection from the elements. There are also approximately 3,360 tonnes of contaminated soil located in a soil management area, which has not yet been relocated to the landfill.

In addition, leachate continues to be generated from the contaminated soil in the landfill. As there is currently no valid and subsisting permit which would authorize the discharge of leachate to the environment, all leachate must be collected and actively managed in accordance with the spill prevention order such that there is no release into the environment.

Spill Prevention Order History

January 27, 2017: The first spill prevention order was issued under the authority of section 79 of EMA at the time the Permit was suspended, and required CHH and other named parties to prevent the discharge of leachate and waste to the environment. The order required the collection of all leachate and its transportation off-site for disposal, and the maintenance of all leachate collection and management works.

March 15, 2017: Following cancellation of the Permit, the spill prevention order was amended to require the parties named to the order to either remove the soil from the site or to permanently close the landfill. The parties elected to close the landfill and, in accordance with the terms of the amended spill prevention order, they submitted a Final Closure Plan to the ministry for review and approval.

Spring 2017: The ministry retained Hemmera Envirochem Inc. (Hemmera) as an independent Qualified Professional (QP) to assist in the ministry's review of the Final Closure Plan. Ministry staff agreed with Hemmera's conclusions and recommendations, which informed a decision to further amend the spill prevention order.

June 29, 2017: The Minister amended the spill prevention order a second time (the Second Amended Spill Prevention Order, or SPO) to require the Named Parties to submit an update to the Final Closure Plan, to address minor additions and changes in accordance with Hemmera's recommendations.

July 21, 2017: An Updated Final Closure Plan was submitted by the Named Parties as required by the SPO. The plan proposed significant re-engineering of some aspects of the landfill as well as installation of monitoring wells to address uncertainties with the design, and confirm the effectiveness of works in preventing a release of contaminants into the environment. The plan proposed completion of "minor closure works" in 2017, with the major closure works delayed until the 2018 construction season.

August 11, 2017: The Minister responded to the Named Parties indicating that the totality of the Updated Final Closure Plan was still under review by the ministry. However, to lessen the risk of an escape or spill of the polluting substances identified in the SPO during the fall and winter, the Minister approved the minor construction works proposed for 2017 and the proposed environmental monitoring program, with additional conditions including further testing and enhanced monitoring. The additional requirements were set in part to address concerns raised by community members who have engaged extensively with the ministry regarding this file.

September to October 2017: The Named Parties completed the minor construction works and the ministry hired its own QP, GHD, to oversee all construction activities on site. GHD did not raise any significant concerns with respect to the overall quality of work performed on the site, or the proposed Updated Final Closure Plan.

September 20, 2018: The ministry review of the Updated Final Closure Plan was completed and the ministry provided notice that the Minister was contemplating a conditional approval of the plan. A draft set of conditions were shared with the Named Parties, and they were invited to provide comments.

October 9, 2018: The ministry received two letters from the Named Parties and subsequently met with CHH on October 12, 2018. Further to the letters and meeting, the Named Parties requested that the ministry consider revisions to the Updated Final Closure Plan. The ministry subsequently agreed to consider revisions submitted by December 14, 2018.

November 30, 2018: Ministry staff met with the Named Parties to receive an update on efforts to revise the Updated Final Closure Plan. At the meeting the Named Parties requested an extension to January 31, 2019 to submit the revised Updated Final Closure Plan, and the ministry agreed to the extension.

December 2018 to January 2019: Ministry staff met with the Named Parties and their QPs who were preparing the revisions, and provided direction and feedback on proposals. The QP who prepared the revisions, Sperling Hansen Associates Inc. (SHA), is an experienced landfill consultant in the province and is the same QP who authored the original closure plan.

January 4, 2019: Ministry staff hosted an information-sharing meeting between SHA and the local community as represented by two local community members and the Cowichan Valley Regional District (CVRD) Area Director. The community representatives asked questions and provided comments to the QPs to inform the drafting of the revisions.

January 31, 2019: A revised Updated Final Closure Plan (the 2019 Updated Final Closure Plan) was submitted to the ministry by the Named Parties. It was posted to the ministry’s website to ensure transparency with the community and other stakeholders, and a copy was shared with the Ministry of Energy, Mines and Petroleum Resources (EMPR) for their review.

February to March 2019: The ministry hired GHD again as an independent QP to assist in the review of the 2019 Updated Final Closure Plan. GHD’s QPs included an engineer, geotechnical engineer and a hydrogeologist. Reports were provided to ministry staff to inform the ministry’s technical review.

April 10, 2019: Ministry staff and GHD met with the Named Parties and their QP to discuss some concerns identified in the ministry’s technical review. The Named Parties agreed to address these concerns in an amendment to the 2019 Updated Final Closure Plan.

April 16, 2019: A subsequent meeting was hosted by the ministry with SHA in attendance to answer questions from the community and to inform the ministry’s review of the plan. In attendance were the local MLA, the CVRD Area Director, community representatives from the Shawnigan Research Group (SRG), and the Malahat First Nation.

April 23, 2019: An amendment to the 2019 Updated Final Closure Plan was submitted to the ministry by the Named Parties.

June 7, 2019: Ministry review of the 2019 Updated Final Closure Plan, with amendment, was completed and the ministry provided notice that the Minister was contemplating a conditional approval of the plan. A draft set of conditions was shared with the Named Parties, and they were invited to provide comments.

June 17, 2019: The Named Parties responded to the draft conditional approval letter, indicating general agreement with the proposed conditions, with the exception of certain requirements regarding the appropriate level of QP supervision during closure activities.

Considerations

The first amended spill prevention order required the Named Parties to either permanently close the landfill or remove the soil. The Named Parties chose to permanently close the landfill and submit a closure plan, so the order was amended a second time to reflect this choice.

In considering whether to approve the 2019 Updated Final Closure Plan (dated January 31, 2019), as amended on April 23, 2019, with or without conditions, I am guided by factors related to environmental protection, including whether the plan, either on its own or with reasonable additional conditions, provides sufficient protection to prevent or reduce the risk of an escape or spill of contaminating substances from the landfill to the environment.

In making my decision, my consideration of reports and other documentation have included those referred to in the Appendix to these reasons.

Technical Review

Ministry staff have conducted a detailed technical review of the 2019 Updated Final Closure Plan. The review was performed primarily by Regional Operations Branch engineers and a hydrogeologist, with significant input from a contracted independent third-party consulting company (GHD) that provided landfill engineering, geotechnical engineering and hydrogeologist QPs to work on the file. Additional review and input was received from EMPR, the ministry's Land Remediation Branch, the local community, and earlier advice on the file was also provided through two independent QPs contracted to support the ministry in 2017 (Hemmera and GHD).

The technical review focused on the ability of the proposed 2019 Updated Final Closure Plan to protect the environment. The review relied on the ministry's published Landfill Criteria for Municipal Solid Waste, June 2016 (the Landfill Criteria) for guidance. The conclusions and recommendations of the ministry's review are based on the premise that, because the Landfill Criteria provide ministry guidance and recommended practices for other landfills within the province, a closure plan in this case would be expected to be consistent with the Landfill Criteria. The Landfill Criteria does not contemplate removal and re-location of waste as way of closing landfills.

The ministry's review findings concluded that:

- There is a robust water quality monitoring dataset that generally indicates the landfill does not pose a risk to the surrounding environment; however, there are opportunities to improve monitoring by focussing additional efforts on monitoring shallow groundwater.
- The quality and quantity of leachate being generated is as expected, and does not suggest there are any issues with the existing infrastructure.

- The 2019 Updated Final Closure Plan includes some deviations from the Landfill Criteria, however, the Landfill Criteria allows for some deviation to occur. In particular, the Named Parties' QP has provided technical justification to demonstrate that proposed site-specific alternatives generally provide equivalent or better environmental protection, and the ministry's QPs (GHD and/or staff), have generally agreed with the conclusions.
- Steeper internal slopes are being managed to ensure slope stability by adding extra layers of materials and through construction of a stabilizing soil wedge. Construction of this soil wedge will, however, require importation of a substantial volume of new soil to the site that would need to comply with provisions of EMA and the Contaminated Sites Regulation (CSR) for soil relocation, as applicable. As such, additional soil testing and environmental monitoring should be considered.
- If done correctly, the soil wedge should result in improved stability, reduced vulnerability to erosion, and opportunity to have native topography and vegetation.

The Named Parties and their QP have acknowledged that the 2019 Updated Final Closure Plan sometimes deviates from the Landfill Criteria because this is an existing landfill that is already constructed. They indicate they have sought to find a practical and pragmatic solution that is financially viable and reflects what is currently on-site, but still provides adequate protection of the environment. I am aware that the 2019 Updated Final Closure Plan proposes a stabilizing soil wedge that will require additional soil to be brought onto the site. Acceptance of this type of fill at this type of site is something that is not unique, and is currently allowed to occur in the province if done in accordance with soil relocation provisions of EMA and the CSR. I have therefore determined that this is a reasonable aspect of the proposal, provided that a robust testing program is in place to confirm the quality of this fill material, oversight is provided by QPs, and monitoring is conducted in the receiving environment. I do not consider it reasonable to add further requirements to restrict the sources of this fill.

I accept the detailed technical review prepared by ministry staff, with the assistance of GHD, and in making my decision I put significant weight on the findings of the review.

Community Concerns

I am aware that there remains considerable opposition in the community regarding closure of the landfill on the site, and representatives from the community and the local government continue to advocate for removal of the contaminated soil from the property rather than the final closure of the landfill. Ministry staff have met local community representatives on numerous occasions over the last few years, including as recently as April 2019.

All information and submissions from the community have been reviewed and considered by ministry staff. Many issues have been investigated and addressed, with responses posted on the ministry's website in a Frequently Asked Questions document. As appropriate, comments and concerns have informed the process up to and including development of the amendment to the 2019 Updated Final Closure Plan that was prepared in April, 2019.

I have considered the concerns raised by the Shawnigan Residents Association (SRA) including, in particular, the concerns outlined in the materials submitted by SRA and/or SRG listed in these reasons for decision.

I am satisfied that the technical concerns identified by the SRA/SRG have been adequately vetted by the ministry and its QPs in its detailed technical review of the 2019 Updated Final Closure Plan and amendment. I would, however, like to specifically address key technical concerns raised by SRA/SRG in their letter to me dated May 8, 2019.

The first technical concern is that the 2019 Updated Final Closure Plan is based on flawed as-built plans and ought to be rejected. I am satisfied that any uncertainties associated with the as-built plans can be managed through rigorous monitoring. The ministry has placed considerable effort into reviewing the proposed post-closure monitoring program to ensure a multi-barrier approach is in place to evaluate the performance of the landfill works in preventing the escape of leachate into the environment. Enhancements have been made to the monitoring program as detailed in the April 23, 2019 amendment to the closure plan, and I have made further enhancements in the conditions of my approval. In the event that new information or monitoring results reveal that the landfill engineering is not sufficient to protect the environment, decision-makers under EMA may exercise authorities, as appropriate, to ensure remedial measures are implemented as needed, up to and including consideration of requiring the removal of soil, if the grounds to do so exist.

Second, regarding concerns about elemental sulfur in the landfill, the ministry is aware that soils with elevated levels of sulfur were accepted at the site. This has been considered by the QPs who drafted the plan, as well as in the ministry's technical review. I accept the ministry's conclusion that because the soil was treated and subsequently isolated from exposure to water in the engineered landfill, the proposed closure plan and associated monitoring program are adequate to protect the environment from pollution originating from this source.

Third, the SRA/SRG has alleged that the site is leaking, and in particular points to changes in chloride and sodium in monitoring well 3S. This evidence has been carefully considered by the ministry's hydrogeologist, along with significant additional data and information collected from the site. I am not persuaded that the technical information before me indicates that any leakage from the landfill, if occurring, presents a risk to the environment. However, out of an abundance of caution, adjustments have been made to the monitoring program so it will provide better early detection of any potential issues and allow for corrective actions to be taken before pollution occurs in the environment.

Finally, concerns are raised that the landfill was built as a temporary structure and a proper landfill foundation was not prepared. As indicated above regarding the landfill engineering and as-built plans, I am satisfied that the proposed additional engineering works to be implemented as part of the landfill closure, combined with the proposed monitoring program, will protect the environment.

Other Considerations

Compliance history

In making my decision, I have considered the compliance history associated with the SPO and its previous versions. Since the original spill prevention order was issued in 2017, the site has been subject to ten formal inspections. The first four inspections, which occurred in 2017, resulted in one advisory, two warnings and one referral to the Conservation Officer Service for investigation which did not ultimately result in a penalty or sanction. The last six inspections, up to April 2019, have all resulted in notices of compliance, with no significant issues identified. I do not consider that the compliance history provides grounds for refusal of the 2019 Updated Final Closure Plan; however, I have considered compliance history as a factor which has informed the appropriate level of oversight required for implementation of the closure plan, as well as post-closure monitoring requirements.

Conflicts of interest and bias

I am aware of concerns that have been raised in materials submitted to the ministry by the SRA/SRG regarding certain allegations of conflict of interest and bias associated with the final closure plan. Any risks in this regard have been mitigated by obtaining signed Conflict of Interest Declarations from QPs working for both the ministry and the Named Parties, and furthermore I have sought information and advice from multiple QPs as well as ministry staff.

Financial security

I have considered whether to include a requirement for financial security to be provided by the Named Parties in the conditions to my approval, however, I am not satisfied that I have the authority to do so under EMA and the SPO. The ministry intends, however, to continue to retain the existing financial security which was provided by CHH under the Permit.

Soil removal

I have considered the alternative of not approving the 2019 Updated Closure Plan and instead requiring that the contaminated soil be removed from the landfill. However, I am not persuaded that this is a reasonable option at this time for the following reasons:

- It is not normal practice for landfills in the province to be authorized to accept waste, and then once that authorization ceases, for the waste be removed from the landfill. This would be an exceptional remedy which would call for an exceptional justification, and I am not satisfied that justification exists at this time.
- The 2019 Updated Final Closure Plan, as amended, has been thoroughly reviewed by ministry staff and other technical experts as explained earlier in these reasons. There is no technical rationale for me to conclude that the closure plan, properly implemented, would not be capable of providing an acceptable level of environmental protection.
- I am not persuaded, based on the technical information, that there is leakage occurring at the landfill that is presenting a current risk to the environment.

Conditions

In reviewing the 2019 Updated Final Closure Plan and in consideration of some of the concerns raised by the local community as well as the various QPs who have reviewed this file, there are a number of opportunities to enhance the robustness of the closure plan that have been incorporated in the approval letter as conditions:

- Approval for SHA to perform the work required to fulfill the conditions and supervise works on site, with any additional or different QPs requiring prior approval by the ministry to ensure appropriate qualifications and the absence of any conflict of interest.
- Before construction begins, submission of additional testing results and analyses to address questions and concerns raised by GHD in their technical review of the closure plan.
- Authorization to relocate the existing non-hazardous contaminated soil in the soil management area and discharge it into the landfill.
- Before construction begins, submission of a quality management plan for the continued use, and the cutting, removal and re-installation, of the existing geomembrane cover liner.
- Before construction begins, submission of a construction activities workplan and implementation schedule to ensure adequate planning and assist with facilitating ministry oversight of closure activities.
- Confirmation that the relocation of soil to the Land for use as final cover is governed by the EMA and the CSR; the soil must also be characterized/classified by a QP in accordance with ministry technical guidance and by an approved QP.
- Requirements for the installation of the two new shallow groundwater monitoring wells using appropriate drilling and well installation methods to ensure their adequacy.
- Construction end date of October 31, 2019 in order to avoid construction during the rainy season.
- Additional semi-monthly reporting during closure activities to assist with ministry oversight and compliance assessment.
- Submission of a revised standalone environmental monitoring program by December 31, 2019 to improve clarity regarding ongoing activities that will occur during the post-closure period.
- The duration of the post closure period is subject to further review and approval, based on monitoring results during the post closure period.

I have also considered the Named Parties' feedback on a draft version of my conditional approval letter where they indicate that the *"attendance of two professionals [QPs] to monitor the same closure activities appears to be excessive and imposes significant unwarranted costs given such costs would most likely equate to $1000/day."* The responsibilities of these two QPs are different; and therefore, it is important that each party pay separately for appropriate oversight.

I am further aware that in the absence of an approved final closure plan, there are very few requirements currently in place to protect the environment at the site. The existing infrastructure was not intended to provide long-term protection and control of the soil and leachate without additional measures (e.g. additional cover layers over the landfill), and the longer that the site remains in its current state, the greater the risk of damage or failure of the works.

Conclusions

After careful consideration of the 2019 Updated Final Closure Plan, as amended, and a substantial body of technical and other information provided to me by my staff, independent qualified professionals hired by both the Named Parties and the ministry, other agencies, and the community, I have determined that approving the plan, as amended and with conditions, would be a reasonable and necessary action to ensure protection of the environment. I intend to provide close ministry oversight to ensure compliance with all conditions and commitments in the approval letter and plan. I also reserve the right to take any further actions as necessary to ensure protection of the environment in the vicinity of the site.

G Heyman

George Heyman

Minister of Environment and Climate Change Strategy

Signed on June 26, 2019

Supporting Documentation

Supporting documentation I have been provided include the following:

- A chronological history of the site.
- A comprehensive ministry assessment report summarizing the detailed technical review by staff, including as appendices:
  - APPENDIX A. SHA Cobble Hill Landfill Updated Final Closure Plan 2019, dated January 31, 2019 (2019 Final Closure Plan)
  - APPENDIX B. SHA Amendment to Cobble Hill Landfill Updated Final Closure Plan 2019, dated April 23, 2019 (Amendment to 2019 Final Closure Plan)
  - APPENDIX C. 2018-11-19 Islander Eng Winter Liner Inspection
  - APPENDIX D. GHD Leachate Generation Review – Task 4 dated March 28, 2019
  - APPENDIX E. Ministry Review of Water Quality Collected from the Cobble Hill Landfill, dated April 29, 2019
  - APPENDIX F. Ministry Review of Groundwater Information in the Cobble Hill Landfill Closure Plan, dated April 25, 2019
  - APPENDIX G. GHD Slope Stability Detailed Engineering Review – Task 1 dated March 28, 2019
  - APPENDIX H. GHD Cover System Detailed Engineering Review – Task 2 dated March 28, 2019
  - APPENDIX I. GHD Hydrogeological QP Review – Task 3 dated April 2, 2019
  - APPENDIX J. GHD General Review and Comments – Task 5 dated March 28, 2019
  - APPENDIX K. Ministry Land Remediation Section Comments dated May 15, 2019
  - APPENDIX L. SRG Critique of the 2019 Final Closure Plan, dated March 29, 2019
  - APPENDIX M. Ministry Frequently Asked Questions (FAQ), April 15, 2019, posted on Ministry website: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/site-permitting-and-compliance/sia/cobblehill_faq-april15-2019.pdf
  - APPENDIX N. Ministry Addendum to Review of Groundwater Information in the Cobble Hill Landfill Closure Plan, dated April 29, 2019
- Other submissions from the local community, including:
  - Questions for SHA and the Ministry of Environment & Climate Action (submitted by SRG at January 4, 2019 meeting)
  - Ministry SIA Notes (submitted by MLA Furstenau at a January 17, 2019 meeting)
  - Questions the Shawnigan Research Group have for the Ministry of Environment and Climate Change to Address (dated March 29, 2019 and submitted for discussion at the April 16 meeting)
  - Letter to the Minister of Environment and Climate Change Strategy from Shawnigan Residents Association (dated May 8, 2019)
- Signed QP Declaration forms (Declaration of Competency and Conflict of Interest Disclosure Statement) from all QPs who worked on the file from both SHA and GHD, submitted in accordance with the ministry's new Professional Accountability Policy.

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Photos

Photo 1 – PEA North Face Liner Folds

Photo 2 – PEA East-West Surface Ditch System

Photo 3 – PEA North-South Surface Ditch System

Photo 4 – PEA East Face- Evidence of Wildlife is devoid on the liner system

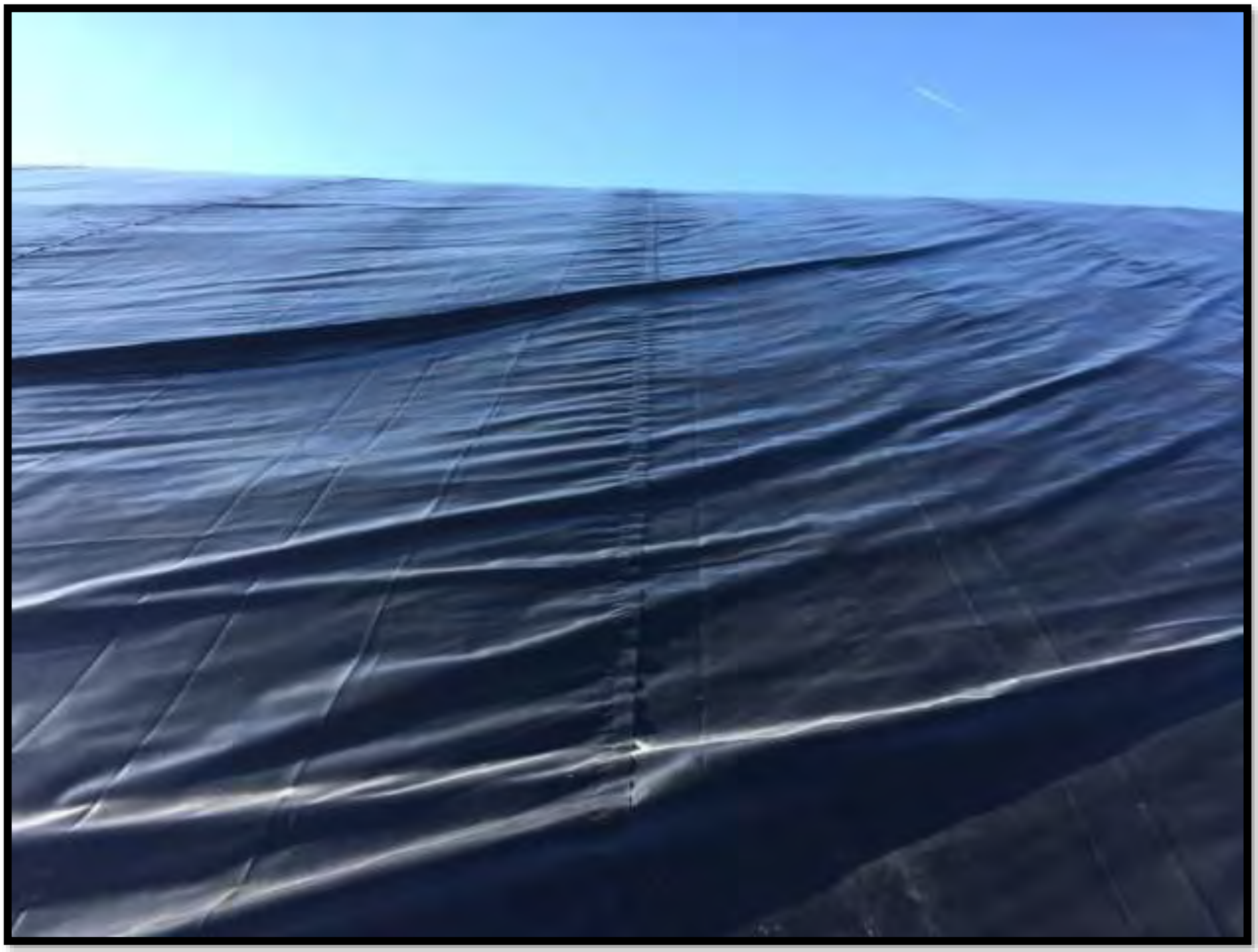

Photo 5 – PEA North Face- Evidence of Wildlife is devoid on the liner system

Photo 6 – PEA South-East Surface- Evidence of Wildlife is devoid on the liner system

Photo 7 – Wildlife track marks outside of the PEA-Base of north toe

Photo 8 – Minimal ponding of surface waters is observed

Photo 9 – South ditch erosion is not present

Photo 10 – Slight erosion of the quarry is noted at the NW toe-the liner is fully sealed at this location

Photo 11 – Grasses, weeds, small shrubs are present along the PEA perimeter-SE crest

Photo 12 – Grasses, weeds, small shrubs are present along the PEA perimeter

Photo 13 – Grasses, weeds, small shrubs are present along the PEA perimeter

Photo 14 – Liner seams show no signs of deterioration

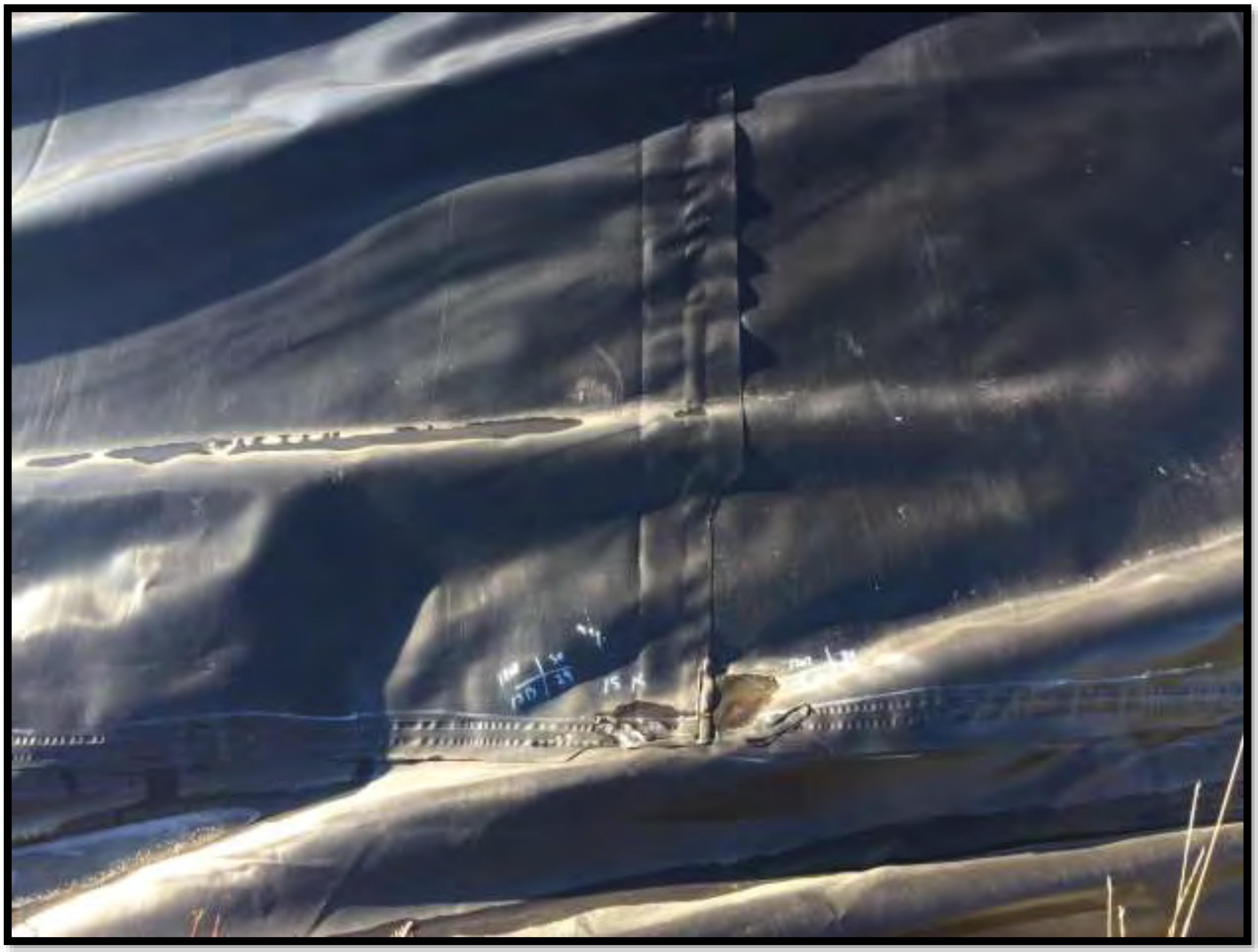

Photo 15 – Liner seams show no signs of deterioration

Photo 16 – Liner seams show no signs of deterioration

Photo 17 – Liner seams show no signs of deterioration

Photo 18 – Liner seams show no signs of deterioration

Photo 19 – Monitoring site SHA-SW-2

Photo 20 – Monitoring site SHA-SW-1

Photo 21 – Monitoring site Leachate and Leak Detention piping and enclosure

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Memorandum Date: November 19, 2018

To: ALLTERRA Construction Ltd.
2158 Millstream Road
Victoria, BC V9B 6H4

Project: 2087

Attention: Todd Mizuik

RE: Cobble Hill Holdings Ltd. 460 Stebbings Road-Winter Liner Inspection November 19, 2018

1.0 INTRODUCTION

Islander Engineering Ltd. (IEL) has been retained by ALLTERRA Construction Ltd. to provide a pre-winter liner inspection for the 2018 season for Cobble Hill Holding Ltd. 460 Stebbings Road (the "Site"). IEL staff conducted a thorough inspection of the Site's Permanent Encapsulation Area (PEA) on November 19, 2018.

Specifically, the winter liner inspection was conducted to verify the status of the liner as exposed to direct sunlight from Oct 2016 to the present date (approximately 2 years), inspect pollution control works, and inspect monitoring sites.

Previously, Qualified Professional (QP) reports made by Sperling Hansen Associates on January 30, 2017 and GHD on Dec 31, 2017 indicate that "*The liner system will provide an adequate closure system for the cell for up to approximately five years, with direct exposure to ultra-violet radiation*" and that "*Concentrations of leachate indicators in the on-Site groundwater monitoring wells have remained relatively stable since landfilling began indicating that progressive deterioration of water quality from a leachate source has not occurred,*" respectively.

A QP water quality report made April 2018 by ALLTERRA Construction Ltd. is attached and concludes that the liner system of the Site's PEA is functioning as designed with no degradation of surrounding water quality observed.

Consideration was taken by IEL staff to fully inspect the PEA liner for any possible liner degradation presumably caused by the effects of UV radiation, and additionally, wildlife, and surface water erosion. The presence of odours and any signs of vegetation toxicity or stress were also documented. IEL inspected liner seams for tearing and robustness.

2.0 Potential Causes for Liner Degradation

2.1 UV Radiation

The entire liner system, including the surface and faces, were inspected for signs of stretching and heat degradation caused by UV radiation. The liner system appeared smooth throughout showing no signs of warping or stretching on all faces. Small folds were noted to exist on North and East faces that have likely accommodated small movements of the liner during its installation (Photo 1). To investigate the likelihood of stretching as a cause of these small folds, IEL removed tires and geotextile membranes that lay overtop the liner system in the surface water ditch systems. This is the most likely area where stretching would occur as ditches are weighted down by tires and sand bags.

Ditches were observed as lined with tires and sand bags placed upon geotextile fabric followed by the PEA liner underneath. Tires, sandbags, and fabric were removed to show no signs of tearing, stretching, or warping (Photos 2 and 3).

2.2 Wildlife

Evidence of wildlife in the forms of hoof prints, feces, bird nesting, burrowing, were devoid on the entire PEA including surface and faces (Photo 4, 5, 6). There were no signs of wildlife markings including punctures or nesting on the liner itself, however, wildlife marking can be shown to track along the North and South toes in the ditch systems located outside the PEA's footprint (Photo 7).

2.3 Surface Water Erosion

The surface contours and ditch systems of the PEA appear to promote adequate drainage of surface waters from the PEA with minimal surface pooling observed (Photo 8). Signs of abrasion are devoid on the liner itself including PEA surface ditch works. Erosion caused by PEA surface water to ditch works designed to transfer water from the south east corner to the southwest corner and onto the surrounding property is not evident (Photo 9), however, there are small signs of minimal erosion to the quarry most noticeably at the toe of the NW corner (Photo 10).

2.4 Odours

There were no odours perceived at the time of inspection.

2.5 Vegetative Toxicity or Stress

Signs of vegetative toxicity or stress including soil discoloration were devoid along the outer perimeter of the PEA indicating that it is functioning as designed. Vegetation in the form of grasses, small weeds, small shrubs appear within surface water ditch works along the outer quarry perimeter of the PEA (Photo 11, 12, 13).

2.6 Liner Seam Robustness

Seams were inspected throughout the PEA including those welded during the minor construction works during the fall of 2017. Original seams welded by the liner manufacturer were also inspected including others that could be visually detected. Seams show no sign of degradation (Photo 14, 15, 16, 17, 18). Extrusion welds were observed to hold strong with no observable deterioration. Additionally, water was devoid within the liner system itself i.e. there was no pooling within the liner system at all toes along the perimeter.

2.7 Pollution Control Works and Monitoring Sites

The site's PEA design contains redundancy in pollution control i.e. the liner system is primary pollution control and a clay basal liner poses as redundant secondary control. Detailed liner inspection is presented above in this report. The clay basal liner is discussed in the GHD Dec 11, 2017 report entitled Clay Basal Liner Evaluation who report "*GHD does not have any fundamental concerns regarding the adequacy of the basal clay liner in relation to the protection of human health and the environment based on the information reviewed and data obtained during the clay liner investigation.*" A QP water quality report made in April 2018 by ALLTERRA Construction Ltd. is also attached and concludes that the liner system of the Site's PEA is functioning as designed with no degradation of surrounding water quality observed.

Monitoring sites are maintained well. Surface water stations SHA-SW-2 and SHA-SW-1 are shown in Photo's 19 and 20 respectively and show natural foliage. The leachate/leak detection enclosure and piping system is shown in Photo 21. IEL did not observe any soil discoloration or vegetative stress surrounding the closure. Monitoring wells are encased in metal housing and show no signs of deterioration.

3.0 Conclusion

The PEA liner system and monitoring stations at Cobble Hill Holding Ltd. 460 Stebbings Road appear to be in very good condition and well maintained. The liner system shows no signs of UV radiation deterioration. Liner seams are intact and show no signs of degradation. Surface contours and ditches are observed to promote adequate drainage of surface waters to limit storm water ponding and minimize quarry erosion. The liner system appears to be functioning as designed in controlling pollution to the surrounding environment.

During this inspection, it was noted that there were no perceivable effects on the liner caused by UV radiation including stretching, warping, tearing, or puncturing of any kind. Additionally, contours of the PEA seem to be a sufficient deterrent to wildlife encroachment as wildlife track marks were devoid on the PEA itself and concentrated within the perimeter quarry ditch works.

Odours were not present on the PEA at the time of inspection nor observed throughout semi-monthly inspections from September 2017 to the present. Further, vegetative stress or discoloration of soil was not observed directly outside the PEA footprint and including leachate piping and secondary containment indicating the CHH PEA system is functioning as designed.

Please contact the undersigned with any questions.

ISLANDER ENGINEERING LTD.

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March 28, 2019 Reference No. 11191916-04

AJ Downie
Director, Authorizations South
Environmental Protection Division
Ministry of Environment and Climate Change Strategy
2080a Labieux Road
Nanaimo, BC V9T 6J9

Original Sent Via Email

Dear Mr. Downie:

Re: Leachate Generation Review – Task 4
Review of the Cobble Hill Landfill Updated Final Closure Plan 2019
460 Stebbings Road Near Shawnigan Lake, British Columbia

GHD was retained by Ministry of Environment and Climate Change Strategy (ENV) to review leachate generation data provided in the Cobble Hill Landfill Updated Final Closure Plan 2019 (Closure Plan) dated January 31, 2019 prepared by Sperling Hansen Associates (SHA) for the Cobble Hill Landfill located at 460 Stebbings Road near Shawnigan Lake, British Columbia (Site). This review was conducted primarily to determine if there is evidence that indicates that water is entering the landfill since the geomembrane cover installation (Fall 2016), and the significance of leakage, if any, into the landfill.

1. Leachate Monitoring Program

Scope Item

Review the monitoring program for leachate and make recommendations if/where deficiencies are identified.

Review

Section 9.1 of the 2016 Landfill Criteria states:

- *Leachate monitoring is required to establish site specific leachate chemistry and contaminants and to ensure these contaminants are included in the groundwater and surface water monitoring. Monitoring of leachate levels within the landfill shall be conducted to ensure that landfill gas extraction wells (or horizontals) are not flooding, the waste is not becoming saturated and excessive pore pressures are not developing to trigger slope instability.*
- *Leachate chemistry is also required to assist with determining the contaminating lifespan of the landfill at the time of closure.*

There are no leachate monitoring requirements in the 1993 Landfill Criteria.

Section 7.8 of the Closure Plan describes the post-closure leachate monitoring program. This section states that leachate volumes in the storage tanks will be monitored prior to removal, leachate tanks will be inspected quarterly and leachate levels will be documented quarterly; and the leachate collection/storage system will be inspected after major (1:10 year) precipitation events. The section also states that leachate volumes will be monitored daily during construction to monitor whether leachate collection and conveyance piping has been compromised. Section 10.2 of the Closure Plan provides the leachate analyses frequency prior to preparation for off-site transportation and/or prior to treatment.

Post closure, the leachate generation rate may increase as a result of the consolidation of the waste soil following placement of the cover material, although GHD expects this increase to be insignificant due to the already compact physical characteristics of the waste soil. Consequently, GHD's opinion is that increased monitoring frequency of the leachate storage tanks is not warranted.

The proposed quality monitoring program includes parameters that will assist in monitoring for a potential release to the environment and evaluating potential impacts. The leachate quality and quantity monitoring programs generally meet the requirements of the Landfill Criteria. The list of parameters identified in Section 10.0 appears appropriate based on historical analytical data for leachate.

A closure period (and, therefore, monitoring period) of 30 years is deemed in the report to be appropriate because of the "nature of the waste received (non-leachable contaminated soils) and the nature of the double encapsulation system" (geomembrane and low permeable soils covering the PEA, and the basal liner comprised of the primary geomembrane and secondary clay layer beneath the PEA). While GHD agrees that the nature of the waste indicates that the contaminating lifespan would not necessarily be the same as that of a municipal soil waste (MSW) landfill, Section 7.5 notes that leachate from the PEA exhibits elevated levels of chloride, which is often used as an indicator for MSW landfill contaminating lifespan since it is not readily found naturally in the environment (other than coastal areas), it does not degrade, and is only removed through dissolution from waste to leachate and subsequent removal of the leachate. With lower volumes of leachate generation, the chloride mass in the waste will take longer to decrease resulting in a longer contaminating lifespan than a landfill that permits a higher volume of precipitation to infiltrate. No evaluation has been done to assess the actual contaminating lifespan as it relates to contaminants at the Site and the service life of the geomembrane system(s).

Regardless, as stated in Section 10.1, a Qualified Professional (QP) will provide guidance on whether more or less time is required as supported by monitoring data 30 years after closure. GHD recommends that the recommendation for cessation or continuation of the post-closure monitoring be signed-off by a QP (i.e., not just provide 'guidance') and also considering the overall condition of the landfill, its various systems and components, and its contaminating lifespan beyond the 30-year period.

Regarding leachate pre-treatment mentioned in Section 10.3, the Ministry may request that the triggers for leachate pre-treatment, treatment objectives, and methodology be provided.

2. Volume Measurement Methodology

Scope Item

Review the leachate volume measurement methodology and, if necessary, provide recommendations to improve accuracy and usefulness of the data.

Review

Section 7.6 references that the leachate storage tank is equipped with a "solar panel, control panel, transducer, floats and fully automated high and low-level alarm system for leachate tanks. With the smartphone system, levels in the tanks can be monitored and floats and alarms adjusted. The smartphone application has been downloaded by CHH and will be used to manage leachate levels with the storage facility." During the 2017 Minor Works, GHD observed and confirmed its operation.

Assuming this system is maintained, transducers can generally measure liquid levels to within a centimetre and due to the smartphone connectivity, be monitored throughout the year, not only during the quarterly inspections. It is thus both accurate and useful. Another standard measurement method is using a water level meter, although this necessitates access to the tanks, whereas, the transducer data can be accessed remotely. The system calibration should be periodically checked (e.g., based on manufacturer's instructions) to confirm that the transducer is accurately measuring the liquid level.

Insofar, as Section 7.6 references the transducers and smartphone application, Section 7.8, which discusses leachate generation monitoring, does not. It is thus unclear if the leachate level monitoring referenced in Section 7.8 is also using the transducer data and can be recorded remotely (in addition to the on-site tank inspections) on whatever basis is warranted.

Improved usefulness of leachate level data could include recording the transducer data on a more frequent basis such that leachate generation during or following heavy precipitation events could be monitored more closely.

3. Leachate Generation

Scope Item

Analyze data prepared and provided by the Ministry including the review of leachate generation rates in conjunction with monthly precipitation data, to evaluate leachate generation after capping of the landfill, following changes to the monitoring system in October 2017, and provide interpretation based on estimated potential leachate generation under existing *load and following closure (additional compaction due to final soil cover placement).* Provide comments, conclusions and recommendations with regards to whether or not the cumulative leachate volume since geomembrane cover installation is reasonable.

Review

HELP modeling

Section 7.4 of the Closure Plan describes the leachate generation modeling. Inputs include Lake Cowichan weather station (1981-2010) data, including an evaluation of average and maximum monthly precipitation. The final precipitation input to the leachate generation estimate is based on 1.5 times the annual worst case (200-year) precipitation. This precipitation value is then evaluated with runoff, evapotranspiration, and storage values from HELP modeling to determine the resulting leachate generation rate. This methodology is consistent with industry practice for forecasting leachate generation rates, particularly for encapsulated sites where the monthly variation in generation rates is low and therefore monthly rates are not necessary for evaluating peak leachate generation. GHD notes that the Executive Summary states that the post-closure leachate generation rate is estimated at 12 m^3/year, however, Section 7 provides the estimated leachate generation rate as 0.12 m^3/year. Based on the results of the HELP modeling, the 0.12 m^3/year value appears correct and the value in the Executive Summary is assumed to be a typographical error.

GHD reviewed the remaining inputs listed for the various final cover layers for the crest and side slope models. The material properties appear to be within a range that GHD would find acceptable. GHD notes that some of the inputs are open to interpretation and some variation could be expected depending on the assumptions from the modeler.

GHD reviewed the inputs to the HELP model and noted that, for a geomembrane-lined cover system the infiltration rate is heavily influenced by the assumed number of holes per hectare. The HELP model was set up with four holes per hectare, which generally represents poorer quality and, thus, generally would represent a conservative assumption based on GHD's experience. Typically, this is input based on the assumed quality of the geomembrane installation. The number of holes would increase the amount of leachate generated. This is exacerbated when hydraulic pressure is allowed to increase above the holes due to poor drainage. The use of a geocomposite drainage layout or draintube and gravel drainage layer on the top slope and side slope, respectively, will assist in limiting this pressure if any defects are present. Furthermore, GHD reviewed quality control documentation from the geocomposite installation; the data suggests that the geocomposite was installed in accordance with manufacturer's instructions.

Based on GHD's opinion, the forecasted post-closure leachate generation rate that is referenced in the Closure Plan (0.12 m^3/yr) is commensurate with a rate that would be expected for a final cover system constructed with an LLDPE geomembrane. Additional holes could be expected as a result of the folding/rolling, relocation, storing, relocating, and reinstalling the liner in the area of the SMA relocation activities, although a comprehensive quality monitoring program should mitigate this.

Leachate generation due to precipitation

GHD reviewed the available leachate collection, storage, and transfer data obtained from bi-weekly reports and summarized for GHD by ENV. GHD notes that prior to the installation of the current leachate storage system in late September 2017, leachate was stored in an exposed lagoon.

During this time, leachate generation and storage data shows reductions in total leachate storage volume while no leachate was removed for off-site disposal. This may have been a result of evaporation since no leaks of leachate through the pond liner was observed by GHD during the 2017 Minor Works. Since this leachate storage data may not be representative of the quantity of leachate generation, data that was used for the leachate generation evaluation below included that available from October 2017 through February 2019 during which storage in tanks was implemented.

As reported in the Closure Plan, the leachate generation rate since placement of the geomembrane is decreasing, although, it has not decreased to the rate of 0.12 m^3/year forecasted through the use of the HELP model. SHA notes that they expect the leachate generation rate to continue to decrease until it reaches the rate forecasted by the HELP model. GHD agrees that the rate of leachate collection will gradually decrease, rather than instantaneously decrease, due to the hydraulic conductivity of the waste (roughly equivalent to that of a silty fine sand or loam), the degree of saturation of the waste, and the field hydraulic capacity of the waste. The waste material is not expected to be uniform and these values will, therefore, likely vary throughout the waste. Moisture present in the waste pore space prior to installation of LLDPE cover will migrate through the waste mound to the leachate collection system until such time that the waste reaches field capacity. It would not be unexpected for this process to take several years.

An estimate of how much excess moisture was in the waste soil greater than the field capacity at the time of the geomembrane placement is challenging to estimate due to the number of assumptions that need to be made, range of variable values, and lack of data such as the quantity of leachate collected during waste soil placement.

There is reportedly 94,235 tonnes (approximately 52,000 m^3 based on 1.8 tonnes/m^3) of contaminated soil in the waste mound as reported in the Closure Plan. Based on a porosity of 0.5 and field capacity of 0.284 for the waste soil (used in the HELP model calculations representative of an organic silts and very fine sand – USCS ML soil type – as used by SHA), the resulting pore volume is approximately 26,000 m^3 and the field capacity is approximately 15,000 m^3. (The use of HELP modeling values associated with ML soil is reasonable. If SHA had used instead a silty sand “SM” soil type, the volumes would be approximately 10 to 20 percent less, but regardless in the same order of magnitude.)

For the purpose of this estimate, assuming that the moisture content of the waste soil being transported to the site was between 10-15 percent (moist but not near field capacity), that would constitute approximately 5,000-8,000 m^3 of interstitial leachate, which would infer that approximately 7,000-10,000 m^3 of pore space was remaining prior to the waste soil reaching field capacity, after which additional leachate would flow to the base of the PEA to be collected.

To determine the volume of precipitation that would have contributed to the quantity of leachate within the waste soil once deposited in the PEA, GHD used the dates of each cell’s as-built submittal letter submitted to ENV to estimate the construction and soil deposition timeline for Cells 1A through 1C. Based on the Closure Plan’s “Fall of 2016” reference for the geomembrane installation, GHD assumed for the purpose of the calculation that the cells were covered by December 15, 2016.

Table 3.1 – Estimated Cumulative Leachate Generation

Cell	Cell 1A	Cell 1B	Cell 1C	TOTAL
Date Operated (assumed)	July 30, 2015 - December 15, 2016	November 1, 2015 - December 15, 2016	July 4, 2016 - December 15, 2016	
Open Area (m^2) (approx.)	2,600	2,600	2,600	
Total Precipitation into cell (mm) (based on Lake Cowichan data)	3,581	3,288	1,173	
Precipitation collected within each Cell (m^3)	9,310	8,549	3,051	20,910

As shown in Table 3.1, approximately 21,000 m^3 of precipitation fell into the PEA prior to the placement of the geomembrane; however, the data isn't available to subtract how much was collected in the leachate storage tanks and thus determine the quantity that infiltrated into the waste soil (also accounting for evaporation). From the 21,000 m^3 of precipitation, it is certainly plausible that the amount that infiltrated the waste soil and wasn't collected by the leachate collection system or evaporated was greater than the 7,000-10,000 of remaining field capacity, which would result in leachate being generated and collected in the leachate storage tanks. Without any additional data, leachate generation trending should be evaluated based on on-going collection data, as recommended below.

Leachate generation compared to precipitation

GHD compared the precipitation from the Lake Cowichan Station to the leachate collection rates measured at the leachate storage facility. Figure 1 shows the comparison of the average daily leachate collection rates (a rolling average over 6 measurements/3 months) and average daily precipitation from October 2017 through February 2019.

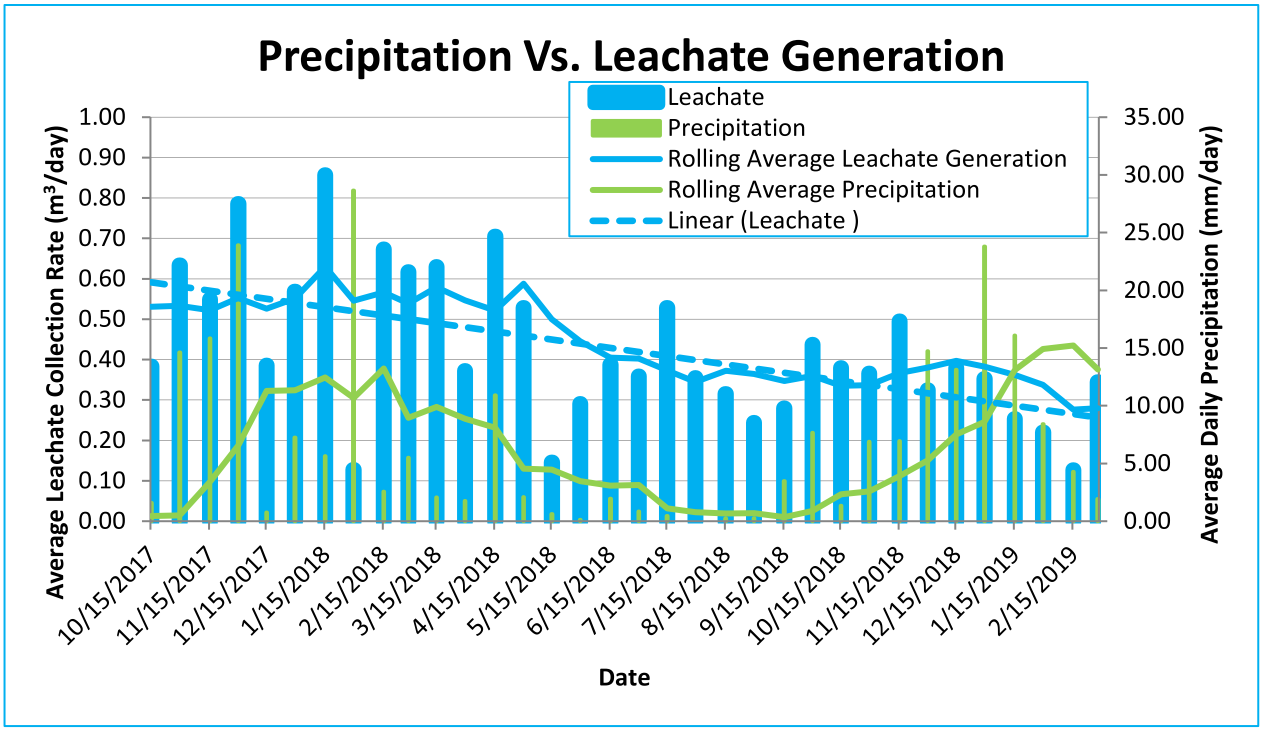

Figure 3.1 – Precipitation vs. Leachate Generation

As shown in Figure 3.1 and in the Closure Plan, the leachate generation rate is trending downwards. In general, spikes in the precipitation do not appear to have a strong correlation with increases in leachate generation. There is a period between February 2018 and September 2018 where both the precipitation and leachate generation rates are decreasing. However, the leachate generation rate is expected to decrease following closure and precipitation decreases for the summer months. From October 2018 through December 2017, the precipitation increases without a significant increase in leachate generation. Note, also, that the leachate generation rate falls from November 2018 through February 2019, which is the wettest season. This timeframe is also beyond the chart shown in Figure 7-3 in the Closure Report and would support the continuation of the downward trend line presented on that figure. From the data available, there does not appear to be a strong correlation between precipitation and leachate generation. GHD does note that this assessment is based on approximately 16 months of data. The fluctuations in leachate generation illustrated in the graph may be due to the heterogeneity of the waste soil matrix rather than influences from water ingress. A larger data set would facilitate additional trend comparisons between precipitation and leachate generation over multiple seasons. Also note that precipitation that infiltrates into the waste soil mass would need to flow through what is reported to be silty soil, so regardless, any effect of a leak on leachate generation would be muted and likely take months to reach the leachate collection system.

Regarding an increased in leachate generation from a consolidation effect when the soil cover material is placed on the geomembrane, GHD's opinion is that this increase is expected to be nominal since the waste soil was already compacted during placement by equipment and is already up to 13 m thick. Leachate generation during the consolidation would not be expected to overwhelm the leachate storage system based on leachate generation rates and storage capacity.

GHD recommends that a trending evaluation be included in each annual report to confirm that the downward trend is continuing, compare leachate generation with precipitation, monitor the overall leachate generation rate versus what is expected based on the modeling, and assess any deviations or irregularities in the results.

Cumulative leachate volume since geomembrane cover installation

As discussed above, estimating the volume of leachate generation that would be expected following the installation of the geomembrane is challenging without more historical or future data. Regardless, the downward trend based on GHD's evaluation of existing data and the current generation rates is within reason.

4. Conclusions and Recommendations

1. The monitoring frequency of the leachate storage tanks provided in the Closure Plan is adequate.
2. GHD recommends that the recommendation for cessation or continuation of the post-closure monitoring after the 30-proposed closure period be signed-off by a QP (i.e., not just provide 'guidance') considering the overall condition of the landfill, its various systems and components, and its contaminating lifespan beyond the 30-year period.
3. Regarding leachate pre-treatment mentioned in Section 10.3 of the Closure Report, the Ministry may request that the triggers for leachate pre-treatment, treatment objectives, and methodology be provided.
4. Section 7.8 of the Closure Report, which discusses leachate generation monitoring, does not refer to the transducers and smartphone application referenced in Section 7.6. It is thus unclear if the leachate level monitoring referenced in Section 7.8 is also using the transducer data and can be recorded remotely (in addition to the on-site tank inspections) on whatever basis is warranted.
5. Improved usefulness of leachate level data as discussed in Section 7.8 could include recording the transducer data on a more frequent basis such that leachate generation during or following heavy precipitation events could be monitored more closely.
6. Based on GHD's opinion, the forecasted post-closure leachate generation rate that is referenced in the Closure Plan (0.12 m^3/yr) is commensurate with a rate that would be expected for a final cover system constructed with an LLDPE geomembrane. Additional holes could be expected as a result of the folding/rolling, relocation, storing, relocating, and reinstalling the liner in the area of the SMA relocation activities, although a comprehensive quality monitoring program should mitigate this.

GHD recommends that a trending evaluation be included in each annual report to confirm that the downward trend is continuing, compare leachate generation with precipitation, monitor the overall leachate generation rate vs. what is expected based on the modeling, and assess any deviations or irregularities in the results.

7. The downward trend based on GHD's evaluation of existing data and the current generation rates is within reason.

5. Closing

We trust the above meets your present requirements. Should you have any questions or need clarifications, please do not hesitate to contact James Reid at 604-248-3669.

Sincerely,

GHD

2019-03-28

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cc: Kirsten White (ENV)
David Barton (GHD)

File: Cobble Hill Holdings Ltd.
Date: April 29, 2019

RE: Review of Water Quality Data Collected from the Cobble Hill Landfill

1 SUMMARY

This document reviews data from water quality samples collected from the Cobble Hill Landfill, which is a contaminated soil landfill located at a rock quarry in Shawinigan Lake, BC. Graphical representation is used to interpret the groundwater and surface water samples. The objective of this review is to evaluate the samples and determine if there is evidence of water quality impacts from the landfill.

The landfill leachate has high concentrations of water quality parameters, such as chloride, hardness, sodium, sulphate, and electrical conductivity. These parameters are used as potential leachate indicators in the groundwater and surface water data. Time-series graphs of the indicator parameters and trilinear diagrams of major ions are used to evaluate whether changes or evolution of those parameters are occurring.

Some historical influence on water quality at the quarry is evident in the data, such as the surface water effects related to the 2016 slump of the soil cover and hydrocarbons found sporadically in groundwater. Since the landfill encapsulation in the fall of 2016, the data indicates that there is no direct evidence of water quality impacts. However, there are small increases in some indicator parameters at a single monitoring well (MW3S). The increases are minor and they pose no risk to the environment at this time. Although the landfill may be a likely source, the increases may not be attributed to the landfill alone or at all. Continued monitoring at this site is recommended for the landfill closure.

Shallow groundwater quality below the landfill is unknown because all groundwater monitoring wells are installed excessively deep. Installation of shallow monitoring wells near the water table and their monitoring is prudent for the landfill closure.

The following sections describe and visualize the water quality results and provide interpretations and conclusions about the water quality near the landfill site.

2 GROUNDWATER QUALITY REVIEW

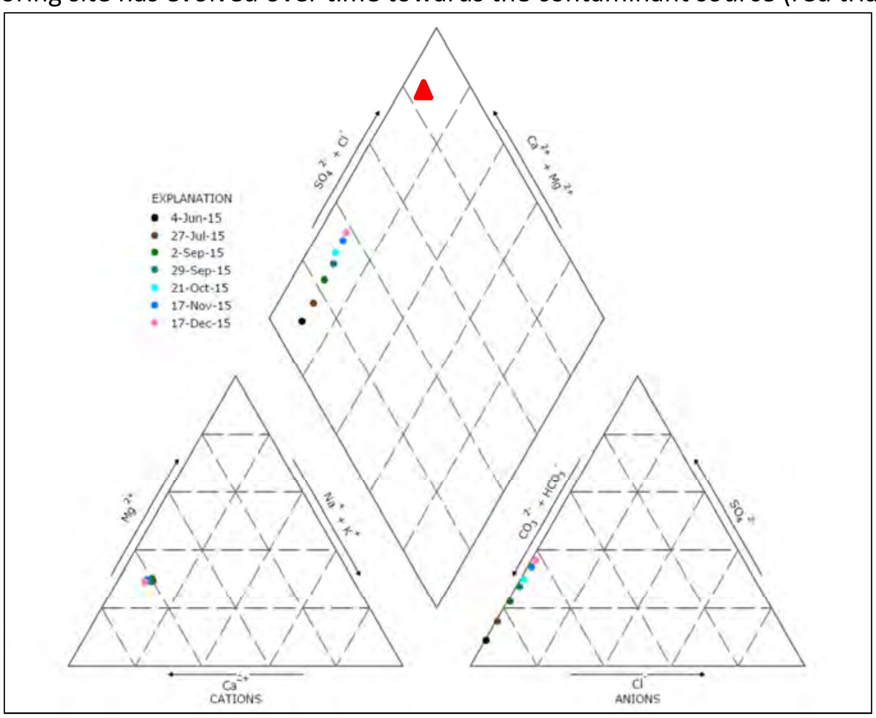
This review is focused on analysis and interpretations of groundwater and surface water samples that were collected at the landfill between 2011 and 2018. The following sections describe the relevant history and physical characteristics of each monitoring site and its water quality. Adequacy of the monitoring network is also evaluated.

The key objective of this review is to evaluate the water quality and comment on whether there is evidence of impacts. This is achieved by graphing the water quality data in the following two ways: 1) time-series graphs that depict concentrations of the indicator parameters over time intervals, and 2) trilinear diagrams that graphically represent the ionic species found in the water samples.

Since the landfill leachate is high a number of water quality parameters, such as chloride, hardness, sodium, sulphate, and electrical conductivity, these parameters are used as indicators of potential leakage from the landfill into nearby water sources. The time-series graphs of the indicator parameters are used to evaluate whether changes or evolution of those parameters are occurring. Although the leachate is also high in sulphur, graphical evaluations of sulphur concentrations in the water samples have been intentionally omitted. This is because monitoring of sulphur was initiated late in 2016 and so there is no baseline information. However, since sulphur typically occurs in water as an ion, either as sulphate or bisulfide, evaluation of sulphate is deemed sufficient. Finally, hydrocarbons found sporadically in groundwater are also considered as potential indicators of leakage from the landfill.

This review uses trilinear diagrams to evaluate the geochemical character of the water samples. These diagrams are useful for detecting similarities or differences in the geochemical character between leachate and the water samples. The diagrams are also commonly used to track mixing and geochemical evolution of water quality. The example plot below illustrates this concept. As shown in Plot 1, the geochemical character of water samples from a monitoring site evolved over time from the left portion of the diamond towards the contaminant source (red triangle) at the top of the diamond. This demonstrates how a contamination source can change water quality at a receiving environment monitoring site.

Plot 1 shows an example of a trilinear diagram in which the geochemical character of water from a monitoring site has evolved over time towards the contaminant source (red triangle).



2.1 Water Monitoring Network and Program

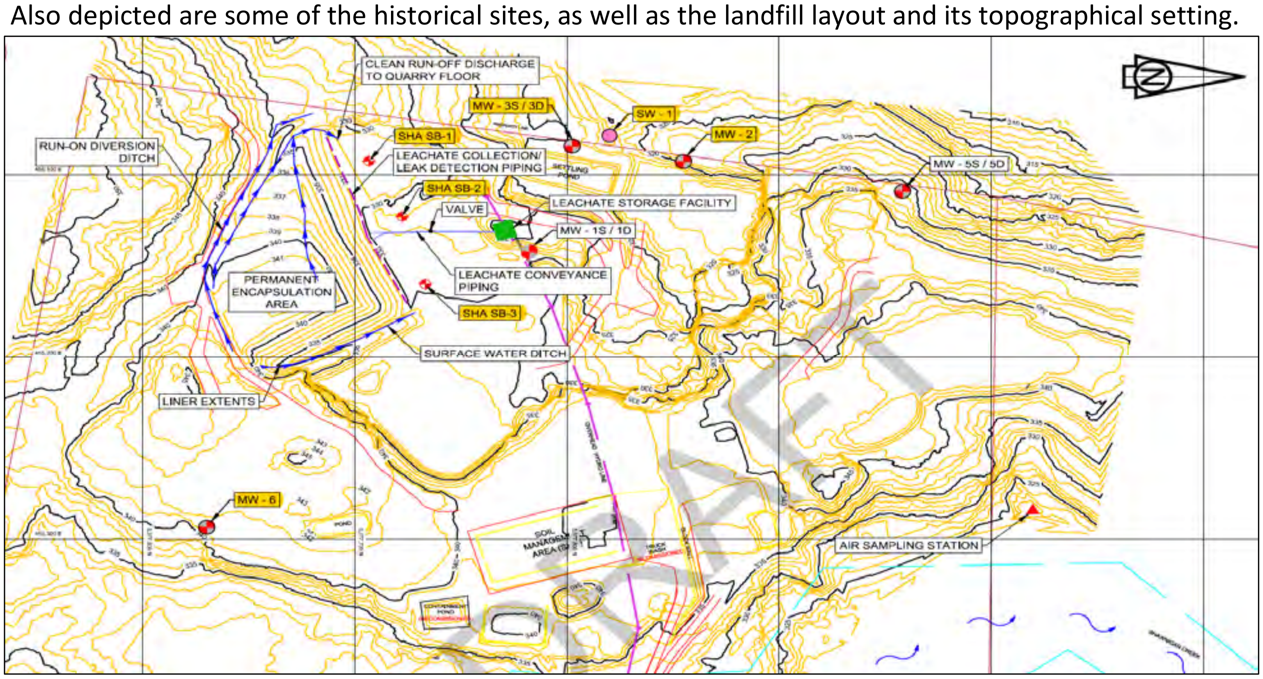
The groundwater monitoring network at the landfill targets the following two groundwater flow components: 1) interflow and 2) deep water-bearing bedrock. The interflow wells are installed at the contact between the loose quarry rock and the bedrock surface. The bedrock wells are deep and their well intakes are installed tens of metres below the water table. This is a key deficiency, since the deep wells are unable to adequately monitor the water table where groundwater is most susceptible to potential impacts from surface activities such as the landfill.

The surface water monitoring network initially included one background and three downstream monitoring sites situated along a creek located downhill from the landfill. However, long-term monitoring of many of those sites indicated impacts from other sources and therefore their monitoring was discontinued. The recent monitoring efforts have focussed on a single surface water site (SW1) situated at the west property boundary. The creek at SW1 is hydraulically connected to the bedrock water table and hence SW1 receives all water from the landfill, including surface runoff, interflow and groundwater.

The current water monitoring network and program at the landfill have changed substantially since the initial baseline characterization. Initially the monitoring frequency ranged from bi-annually to quarterly. Then in 2017, the frequency increased to monthly. As a result, the water quality data includes a long baseline period prior to any waste deposition into the landfill, as well as a robust data set that was collected in the recent years.

This water quality review is focussed on the current monitoring sites, which are highlighted yellow under Figure 1 below.

Figure 1 shows the current groundwater and surface water monitoring sites that are highlighted yellow. Also depicted are some of the historical sites, as well as the landfill layout and its topographical setting.



The following subsections describe the individual or grouped monitoring sites and interpret their respective water quality data. Further discussion about the interpretations and conclusions is provided at the end of this document.

2.2 Monitoring Wells MW1S&D

The monitoring well pair MW1S&D was installed in 2010 hydraulically downgradient from the landfill. The depth of the shallow well is 52 m from surface; the depth of the deep well is about 84 m. Both wells are installed excessively deep in reference to the water table, which is found within 10 metres below the surface. MW1S&D cannot track potential changes at the water table, which is most susceptible to potential impacts from the landfill.

Water samples were collected from MW1S&D for only a short time and the quality of the samples is low. The operator has made claims that the wells have been tampered with. This argument was based on detectable concentrations of hydrocarbons in both wells and high pH reported in the shallow well. Hydrocarbons have been and continue to be detected in most of the wells at the landfill and the source is still poorly understood. The operator claims that the hydrocarbons are naturally occurring, but no evidence is provided to support that conclusion. In terms of the high pH, this may be attributed to improper well installation and contamination of the well screen from the overlaying bentonite grout.

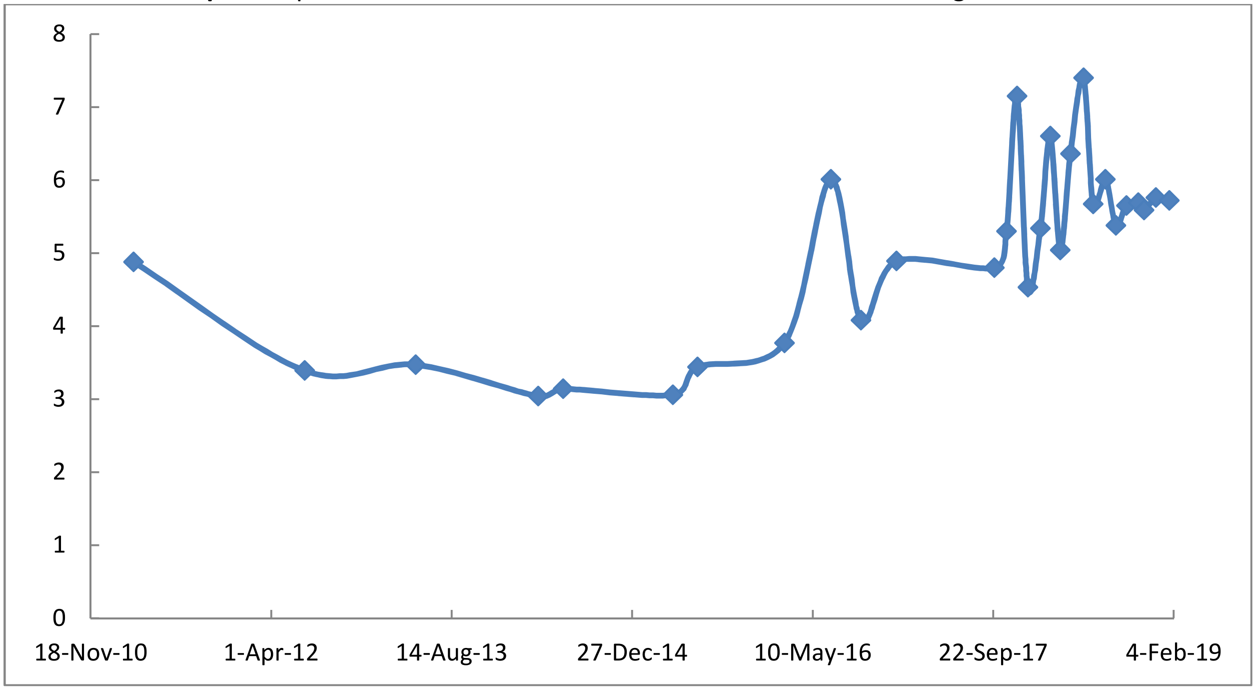
The combination of limited and low quality data collected from MW1S&D does not allow for a meaningful assessment.

2.3 Monitoring Wells MW2

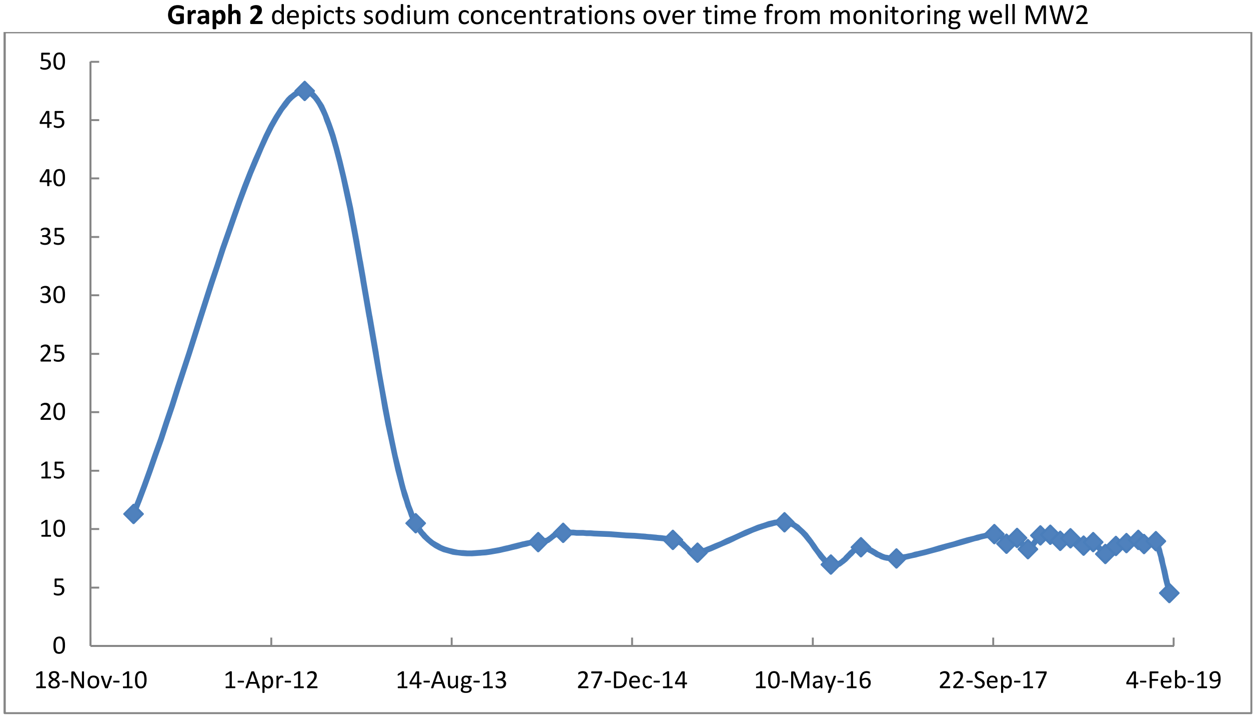
The monitoring well MW2 was installed in 2010 hydraulically downgradient from the landfill at the western property boundary and near the creek. Groundwater in MW2 is hydraulically connected to the creek. The depth of MW2 is 43 m from surface. Again, this is notably deeper than the depth of the water table, which is near the surface. Hence, MW2 is considered inadequate to track potential changes at the water table. Further, since MW2 is located on the north side of the creek, it is unlikely to intercept groundwater that originates from the landfill, which is located on south side of the creek.

The following time-series graphs depict the indicator concentrations found in water collected from MW2. Data interpretations are provided below the graphs.

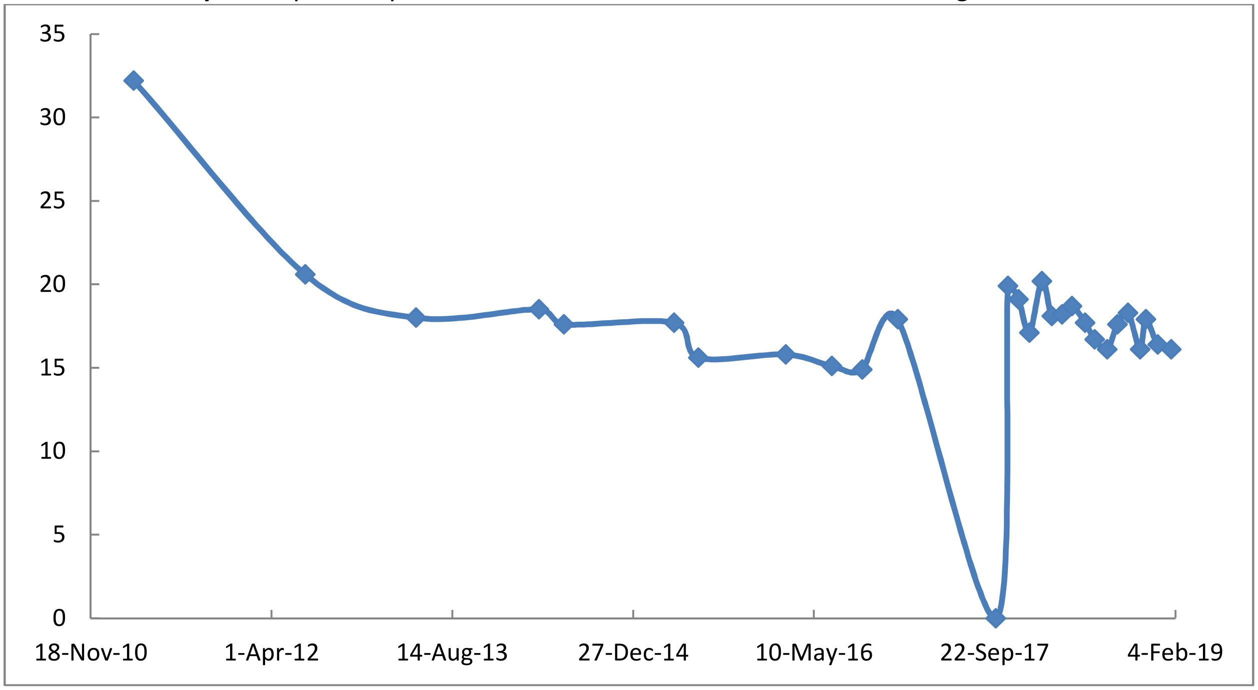
Graph 1 depicts chloride concentrations over time from monitoring well MW2



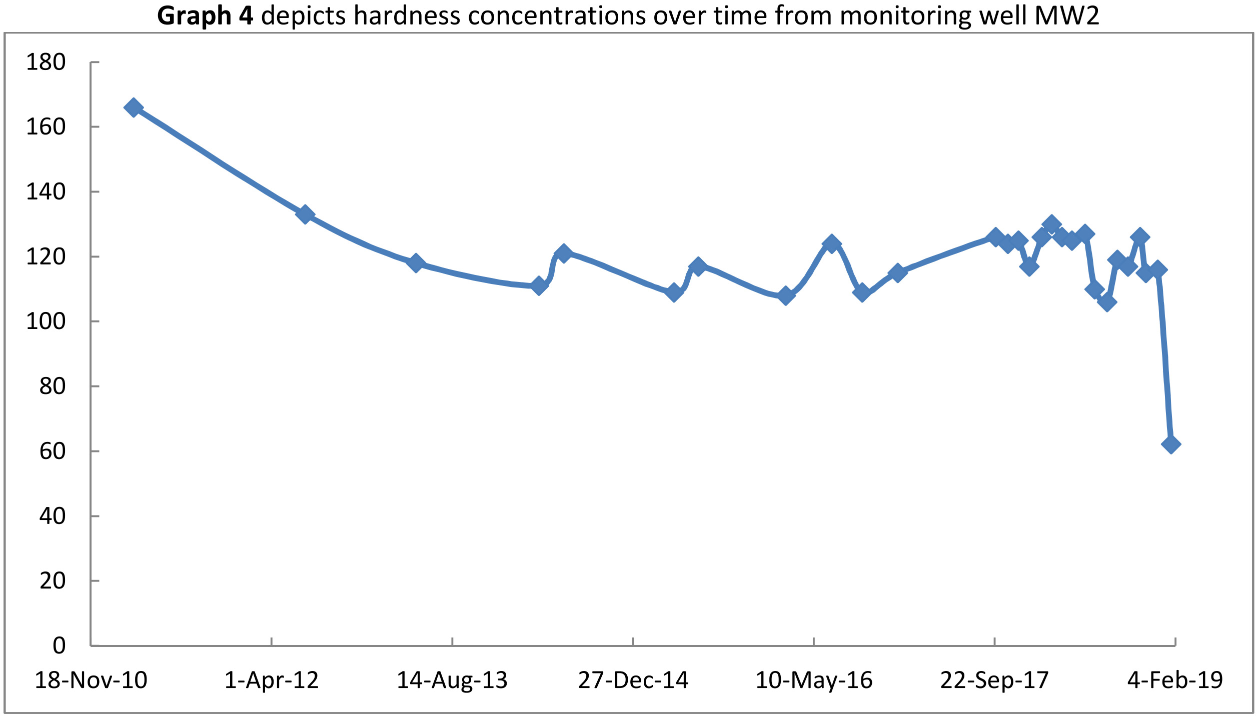
Graph 2 depicts sodium concentrations over time from monitoring well MW2



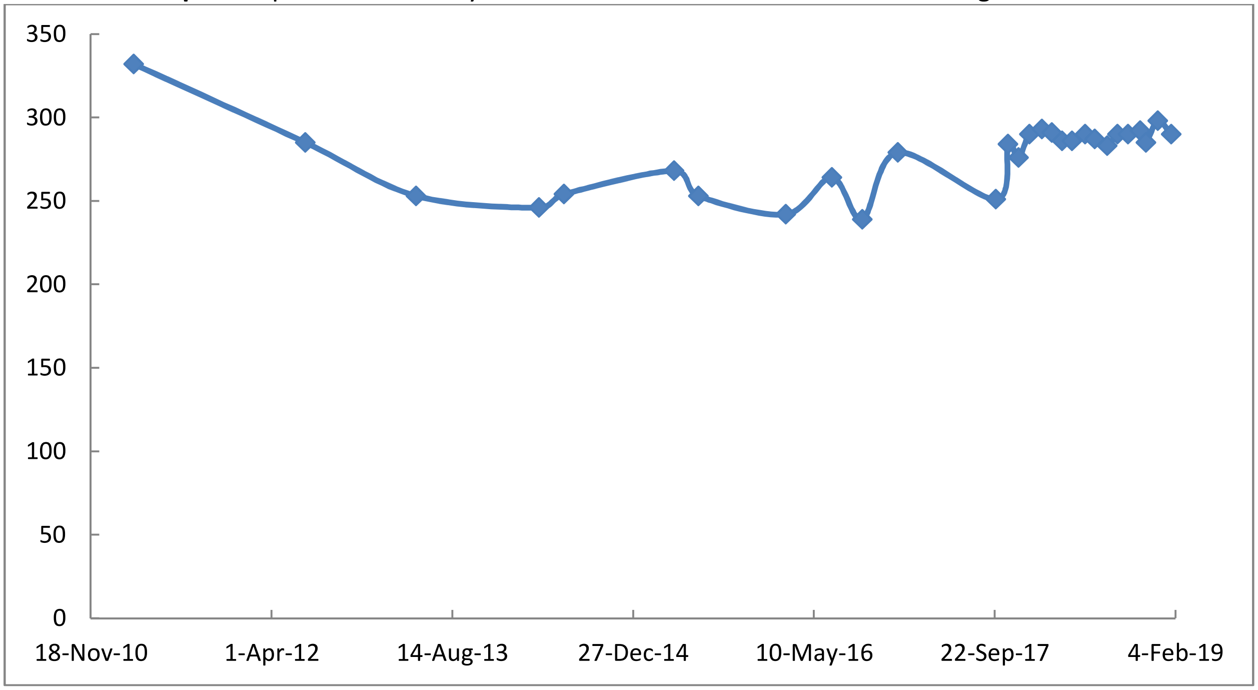
Graph 3 depicts sulphate concentrations over time from monitoring well MW2



Graph 4 depicts hardness concentrations over time from monitoring well MW2



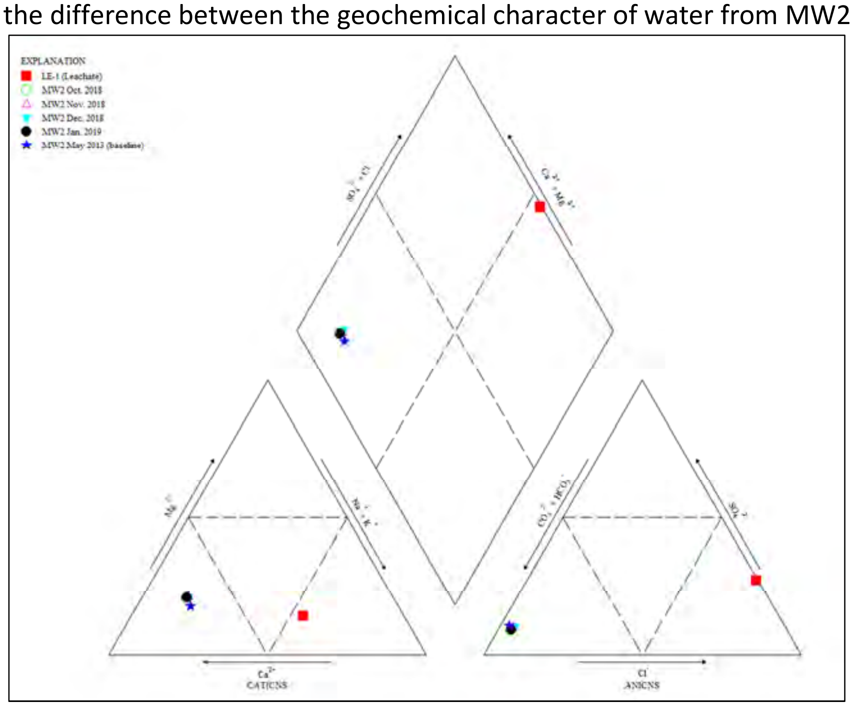
Graph 5 depicts conductivity concentrations over time from monitoring well MW2



All water quality indicators graphed above are generally stable. The chloride graph may show a minimal upward trend, but additional monitoring is required to confirm this interpretation.

The trilinear diagram presented below indicates that the geochemical character of the recent water quality collected from MW2 is stable and unaffected by leachate. As such, there is no evidence that water quality in monitoring well MW2 is impacted by the landfill.

Plot 2 shows the difference between the geochemical character of water from MW2 and leachate

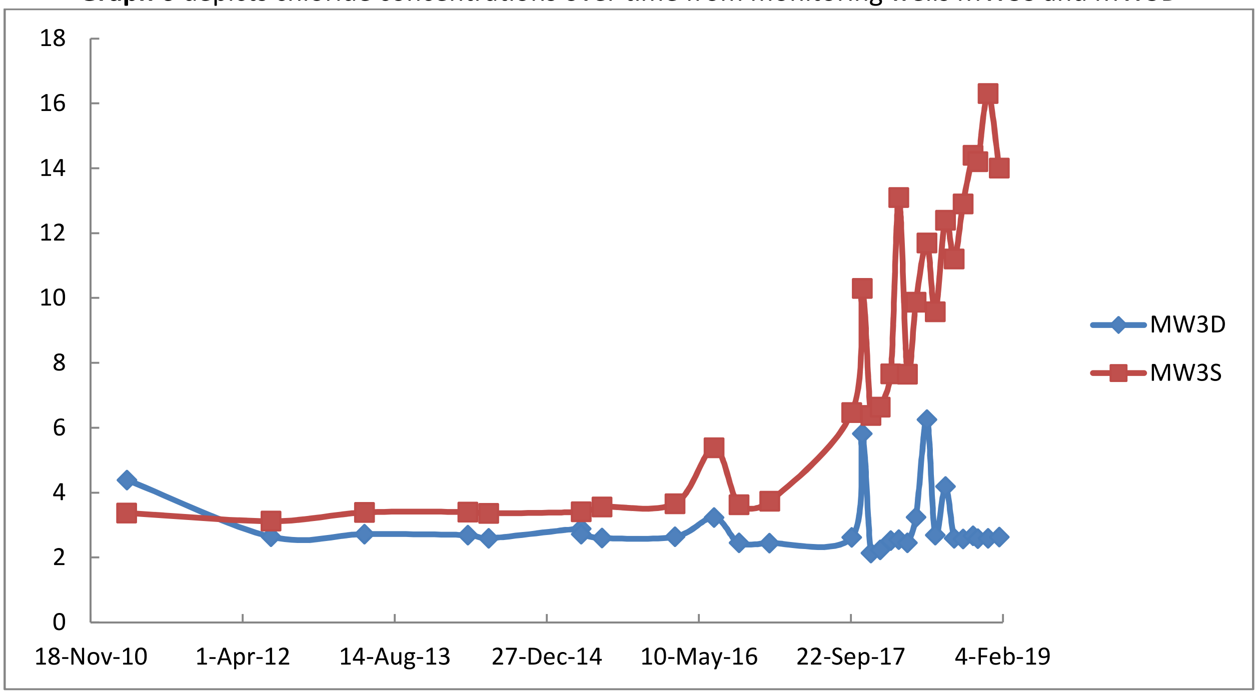


2.4 Monitoring Wells MW3S&D

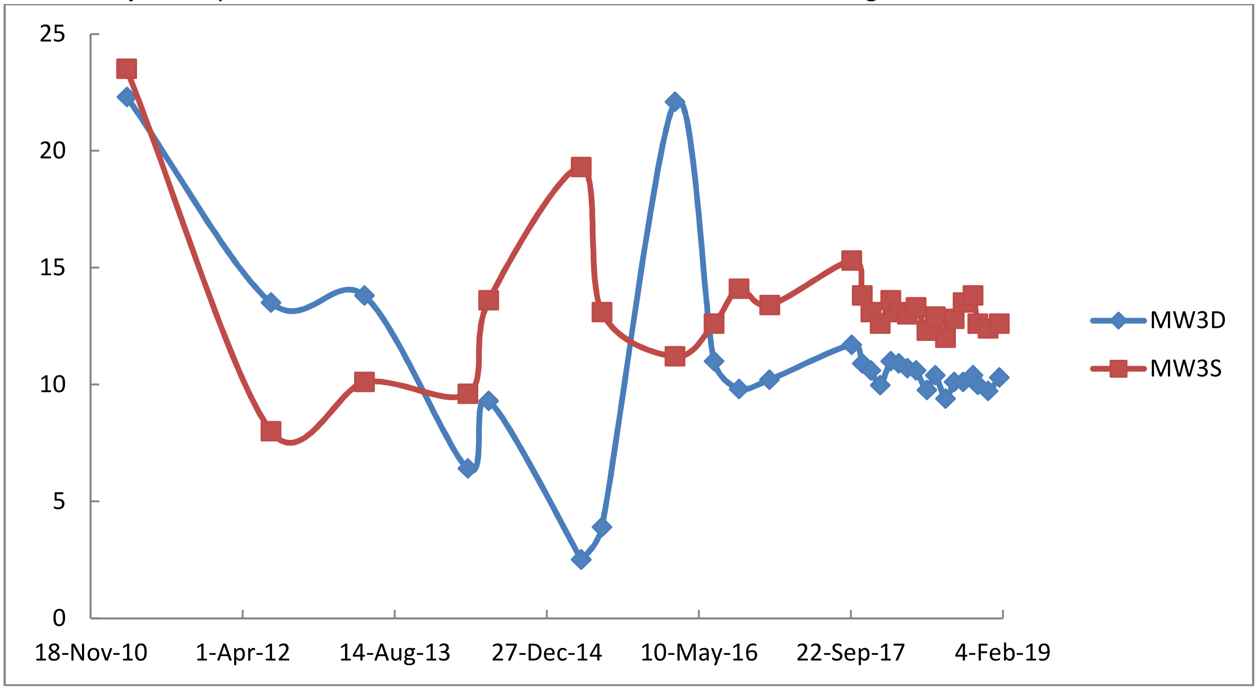
The groundwater monitoring pair MW3S&D was installed in 2010 hydraulically downgradient from the landfill, near its western property boundary and next to the creek. Similar to MW2, water levels from the MW3 wells indicate that groundwater in the area is hydraulically connected to the creek. The depth of the shallow well is 23 m from surface; the depth of the deep well is about 46 m. While both wells are notably shallower than the other wells in the area, they are still notably deeper than the water table, which is found near the surface.

The following time-series graphs depict concentrations of the indicator parameters found in water collected from the MW3 wells. Data interpretations are provided below the graphs.

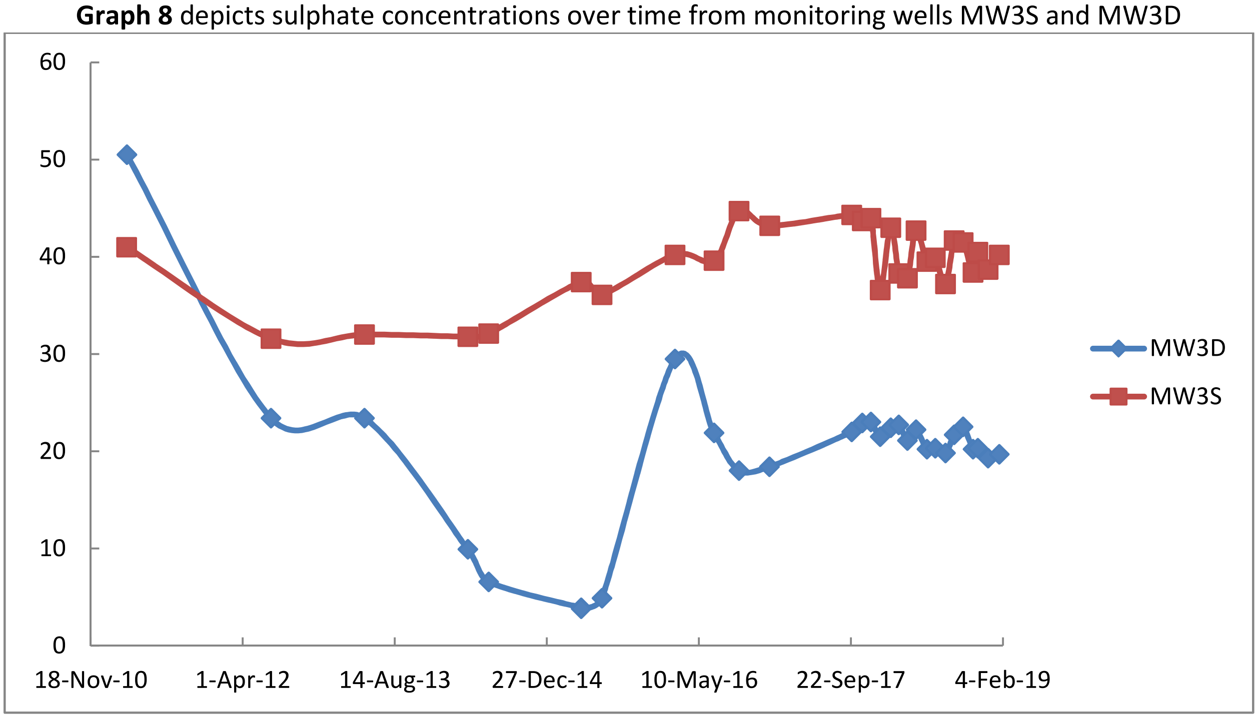
Graph 6 depicts chloride concentrations over time from monitoring wells MW3S and MW3D



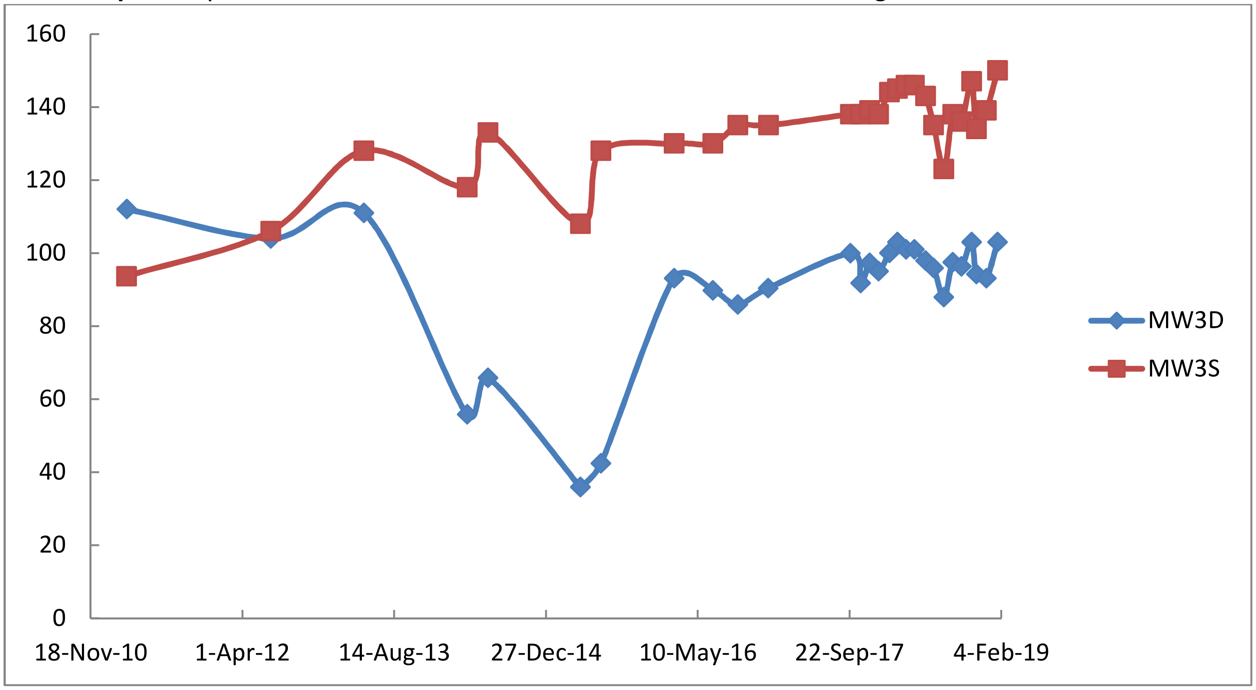
Graph 7 depicts sodium concentrations over time from monitoring wells MW3S and MW3D



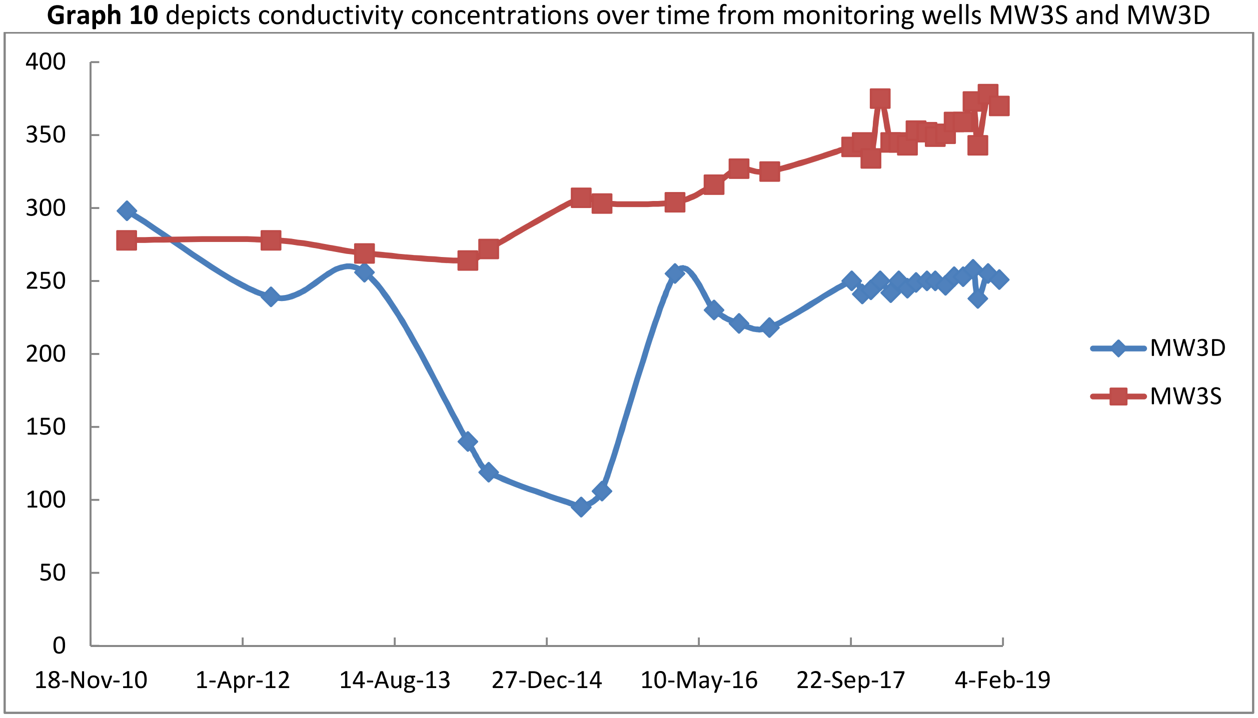
Graph 8 depicts sulphate concentrations over time from monitoring wells MW3S and MW3D



Graph 9 depicts hardness concentrations over time from monitoring wells MW3S and MW3D



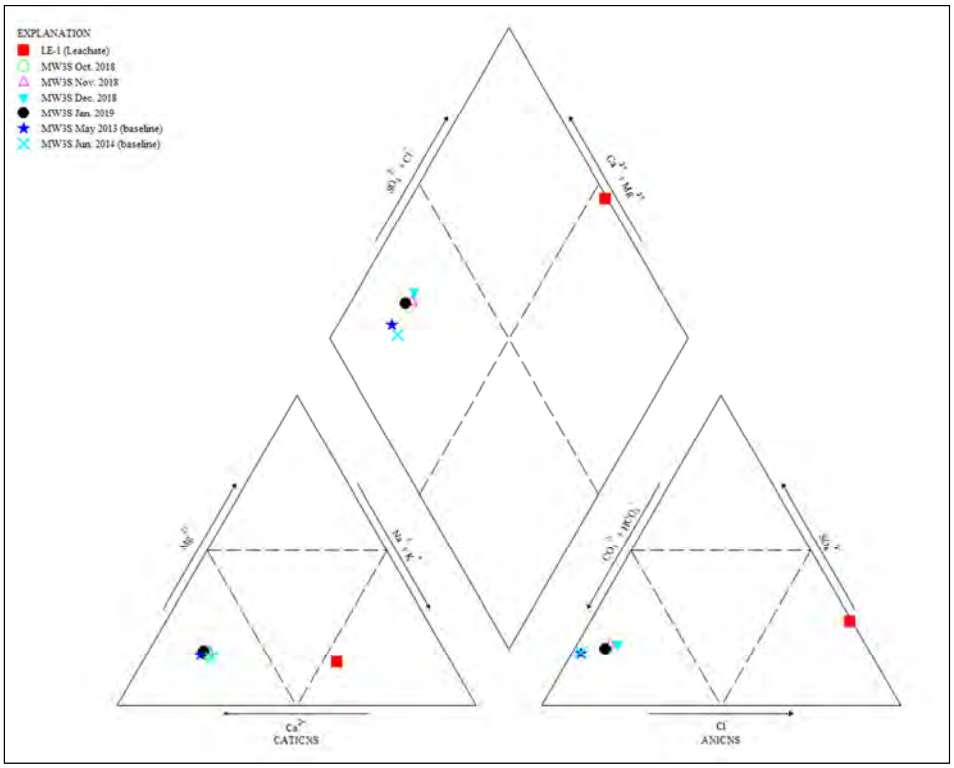
Graph 10 depicts conductivity concentrations over time from monitoring wells MW3S and MW3D



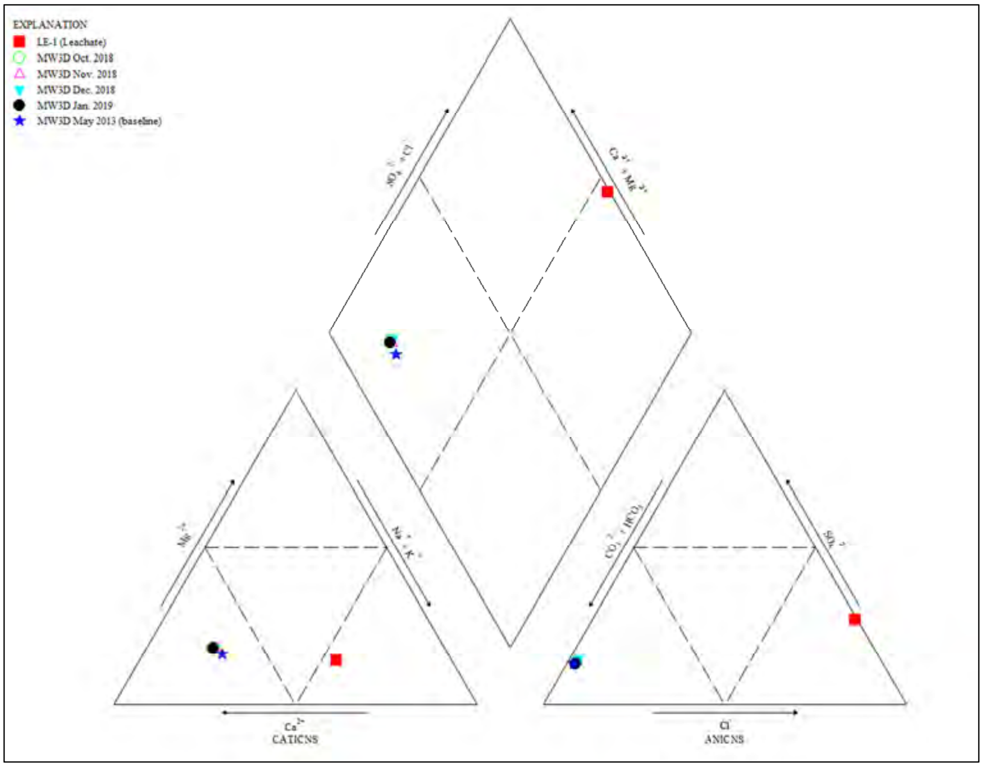
An increasing trend in chloride concentrations is evident in the shallow monitoring well MW3S (Graph 6). Similar but less pronounced trends are observed at MW3S in the electric conductivity and hardness graphs (Graphs 9 and 10). These small increases pose no risk to the environment at this time, since the water quality guideline for chloride is 250 mg/L. The reason for the upward trends is unknown, but the landfill may be a likely source. However, the trends may not be attributed to the landfill alone or at all. A detailed discussion regarding the small changes in water quality at MW3S is described later in this review. All other indicators at MW3S and all indicators at MW3D are generally stable.

The trilinear plots shown below indicate that there is no obvious connection between the geochemical character of leachate and the groundwater samples collected from MW3S and MW3D. However, while the data from MW3D is plotted within the same cluster, the data from MW3S (Plot 3) shows a slight change or potential evolution between the recent and baseline results. This interpretation is consistent with the minor increases in some indicator parameters noted above.

Plot 3 shows the difference between the geochemical character of water from MW3S and leachate



Plot 4 shows the difference between the geochemical character of water from MW3D and leachate

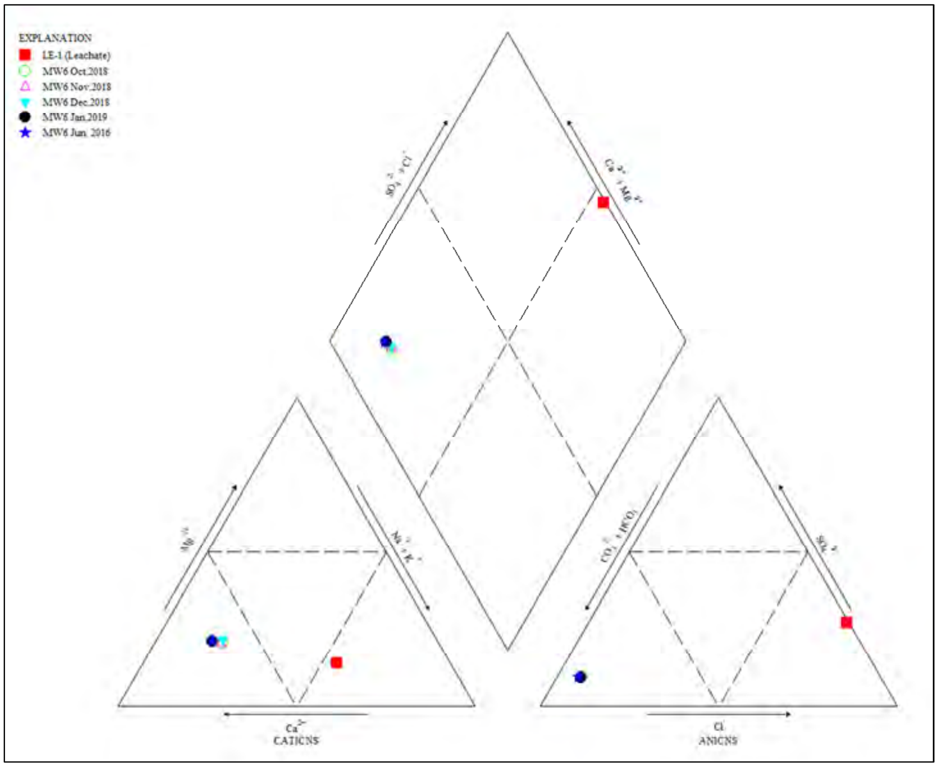


2.5 Monitoring Wells MW4 and MW6

The background monitoring well MW4 was monitored for a short period of time before it was decommissioned in 2016. The decommissioning occurred because MW4 was located within the landfill footprint. It is my understanding that the well decommissioning was completed by a qualified contractor in a manner that was consistent with the Groundwater Protection Regulation.

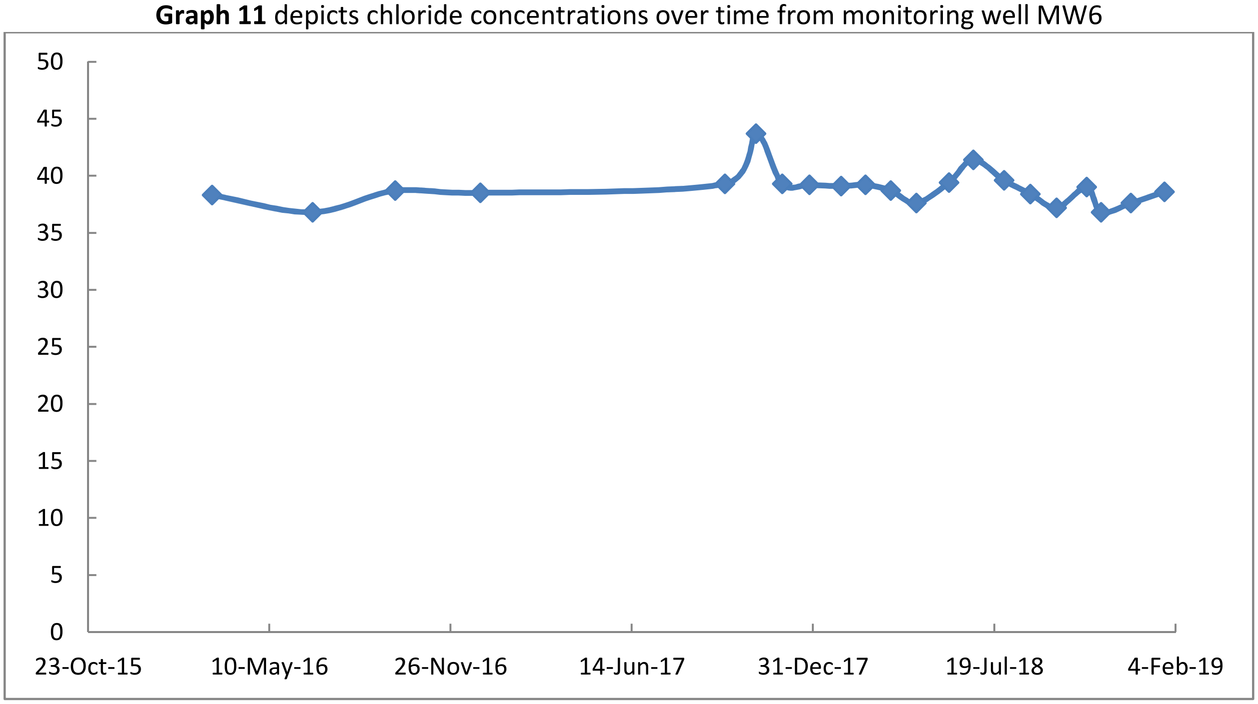
A new background monitoring well MW6 was installed in 2016. Similar to MW4, water collected from MW6 is very hard, which is reflected in higher ion concentrations compared to the downhill wells. This difference raised concerns about the suitability of MW6 as a background well and whether the higher concentrations of ions in that well are due to leakage from the landfill. The Ministry initially retained a third-party hydrogeologist to review those concerns. That assessment concluded that MW6 is located hydraulically uphill from the landfill and that the geochemical character of water from MW6 does not contain any evidence of leachate. I have conducted a similar assessment and came to the same conclusions. Water in MW6 cannot be impacted by the landfill because MW6 is located hydraulically uphill from the landfill. This is supported by the February 2016 water level data, which reported that the water level at MW6 were nearly four metres higher than below the landfill (at MW4). In terms of the geochemistry, water collected from MW6 does not plot anywhere near the landfill leachate, as shown in the trilinear diagram below. All of this supports the conclusion that water from MW6 is unaffected by the landfill.

Plot 5 shows the difference between the geochemical character of water from MW6 and leachate

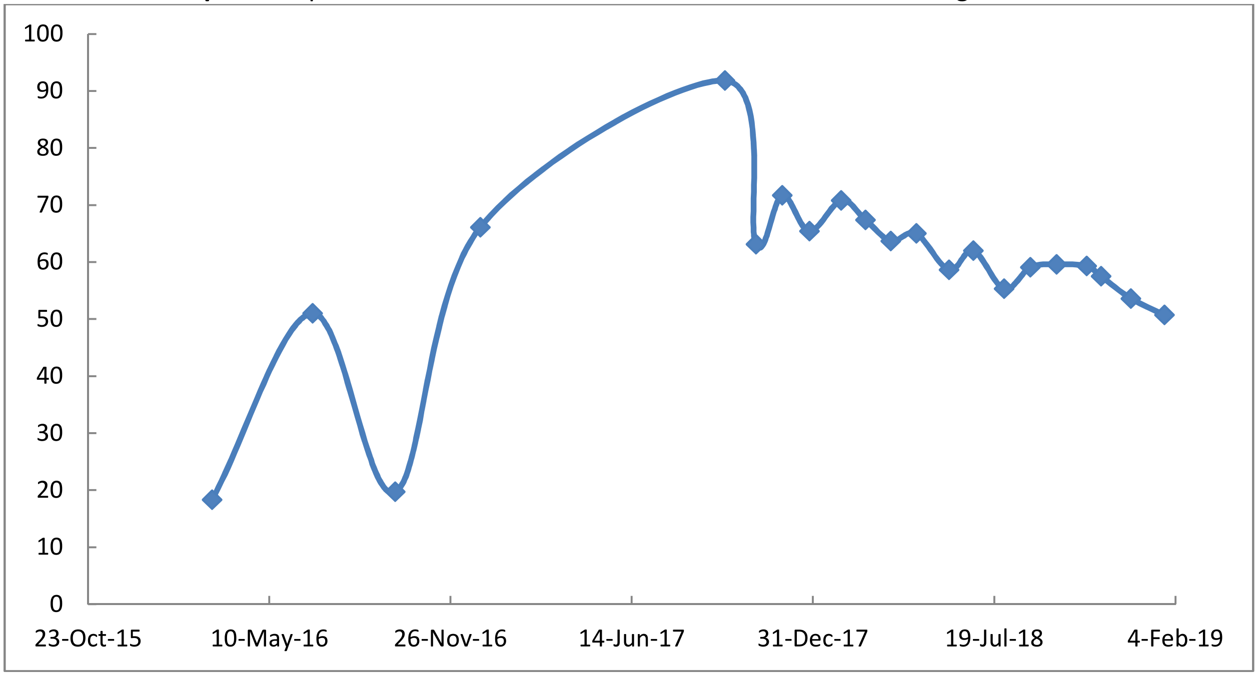


The water quality indicators at MW6 remain generally stable, as is shown in the following time-series graphs.

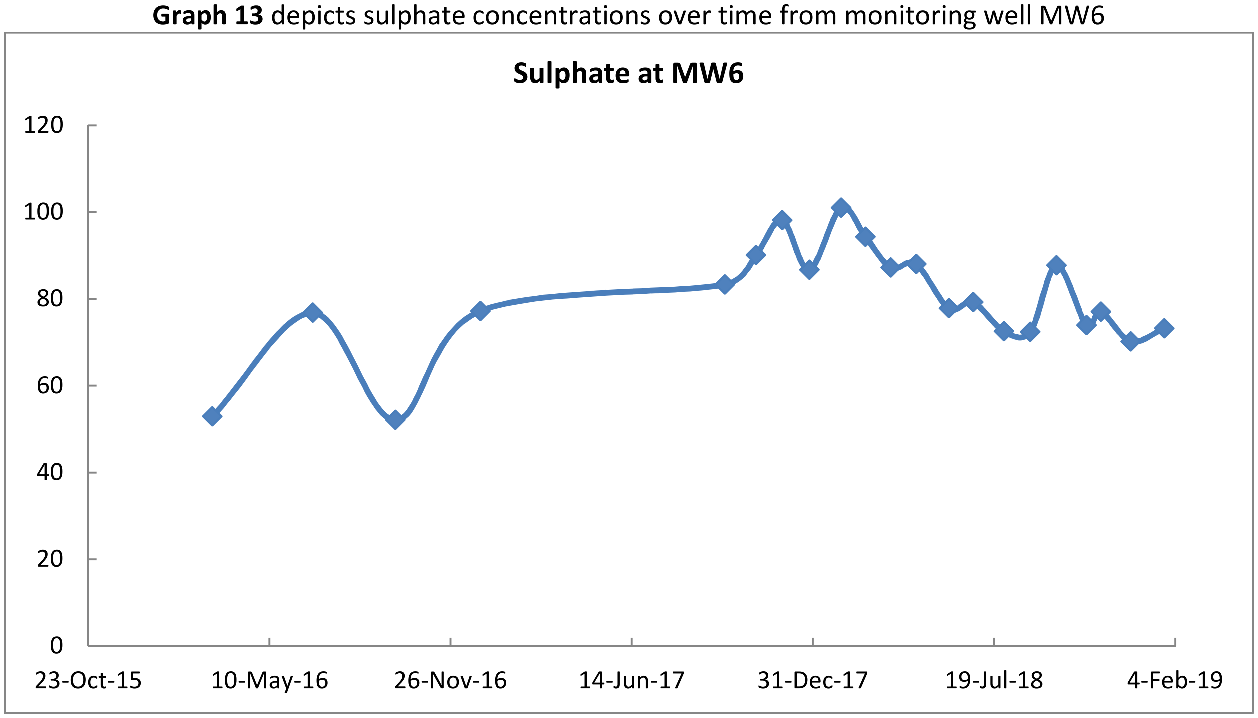
Graph 11 depicts chloride concentrations over time from monitoring well MW6



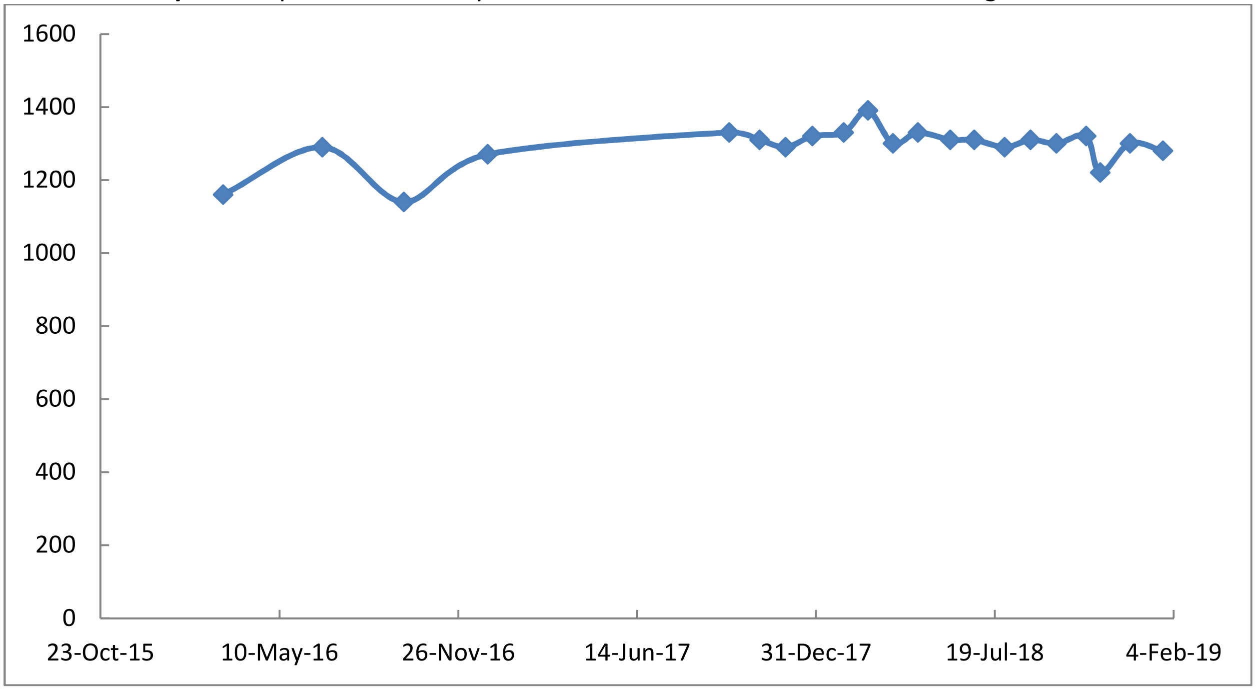
Graph 12 depicts sodium concentrations over time from monitoring well MW6



Graph 13 depicts sulphate concentrations over time from monitoring well MW6



Graph 14 depicts conductivity concentrations over time from monitoring well MW6



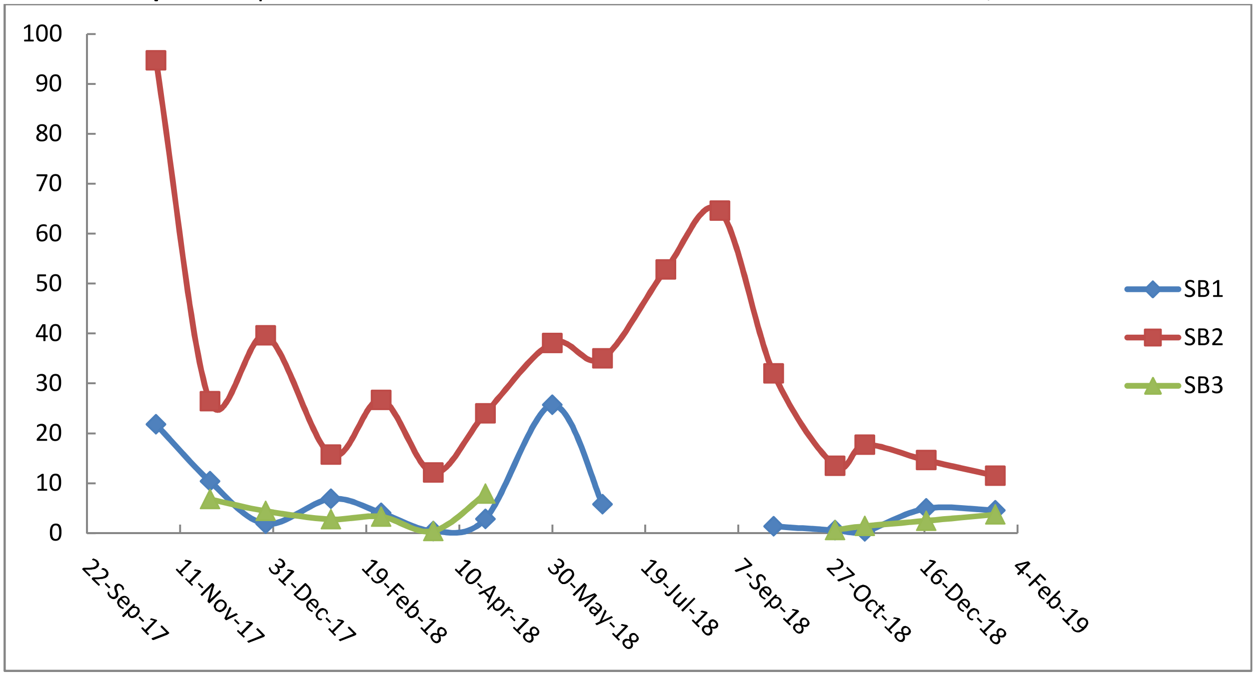
2.5 Monitoring Wells MW5S&D

The groundwater monitoring pair MW5S&D was drilled cross slope from the landfill in 2013 for the initial site characterization. Due to their location, monitoring of those wells was not included into the routine monitoring program and water quality from those wells is not assessed in this review.

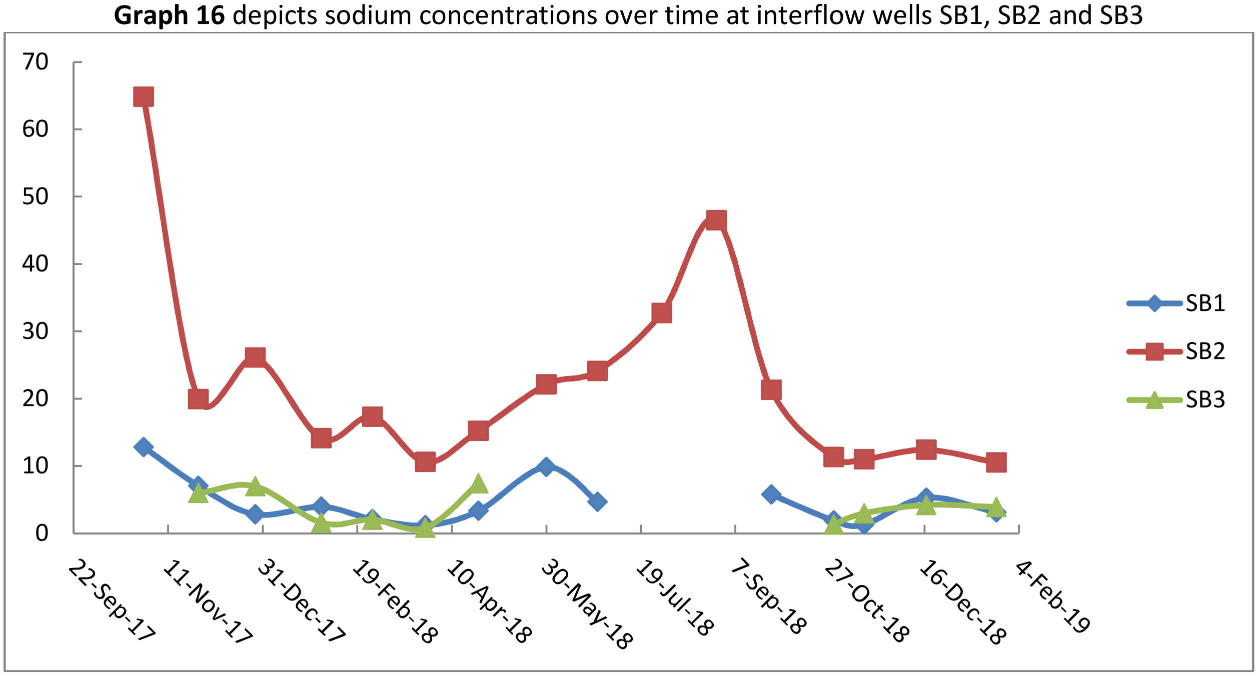
2.6 Seepage Blanket/Interflow Wells SB1, SB2 and SB3

In 2017 three wells were excavated directly downhill from the landfill into the loose quarry rock (i.e. the seepage blanket). The wells targeted the interflow that occurs below the landfill at the contact between the quarry rock and the bedrock surface. The interflow is controlled by precipitation, which can lead to high dilution in winter and absence of water in summer. This is supported by the water quality data collected from the three wells. As shown below, water quality from the interflow wells report lower concentrations of the water quality indicators in the winter season due to high dilution. In the summer season, if water is present in the wells, the indicators are found at higher concentrations due to water stagnation. These fluctuations make water quality interpretations challenging and can erroneously suggest results that are false positive.

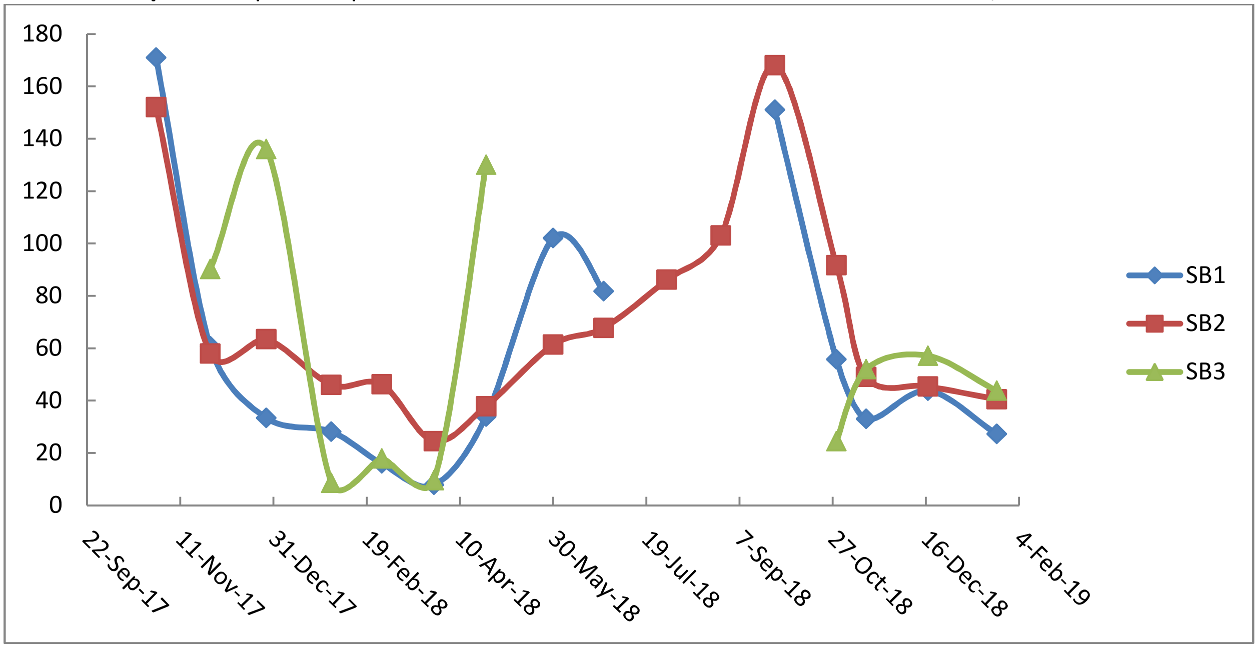
Graph 15 depicts chloride concentrations over time at interflow wells SB1, SB2 and SB3



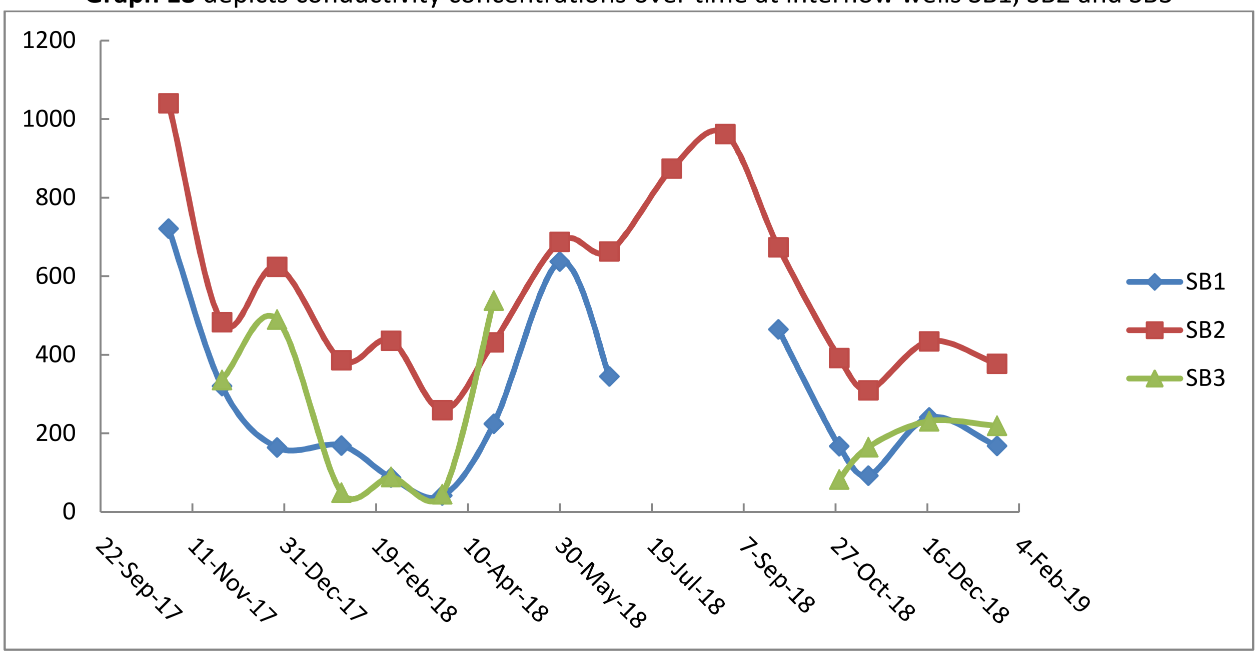
Graph 16 depicts sodium concentrations over time at interflow wells SB1, SB2 and SB3



Graph 17 depicts sulphate concentrations over time at interflow wells SB1, SB2 and SB3

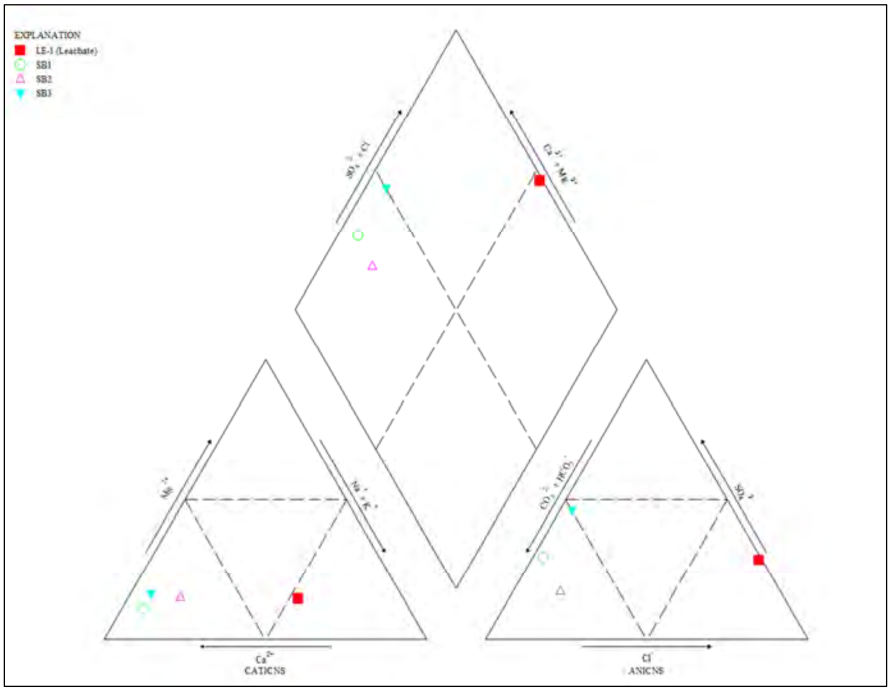


Graph 18 depicts conductivity concentrations over time at interflow wells SB1, SB2 and SB3

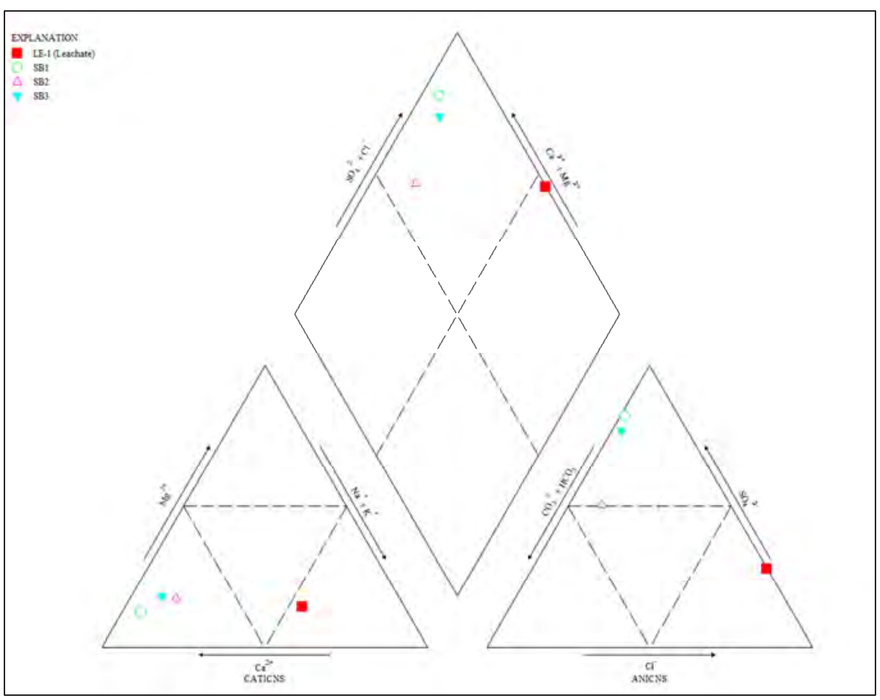


The following trilinear plots depict the geochemical character of water collected from the three interflow wells. The plots indicate that the geochemical character differs between the seasons. Plots 6, 7 and 8 indicate notable seasonal fluctuations in the water chemistry in the interflow wells. The fluctuations are influenced by precipitation such that the chemistry is elevated at the beginning of the rainy season (October and November) as a result of the fall flush, which washes out accumulated dust and oxidized materials within the quarry. This interpretation is supported by the sulphate enriched water shown in Plot 7, which corresponds to the beginning of the rainy season. Plot 8 depicts the geochemical character from the later part of the rainy season (January), in which the water character is similar to the character from the previous spring (Plot 6).

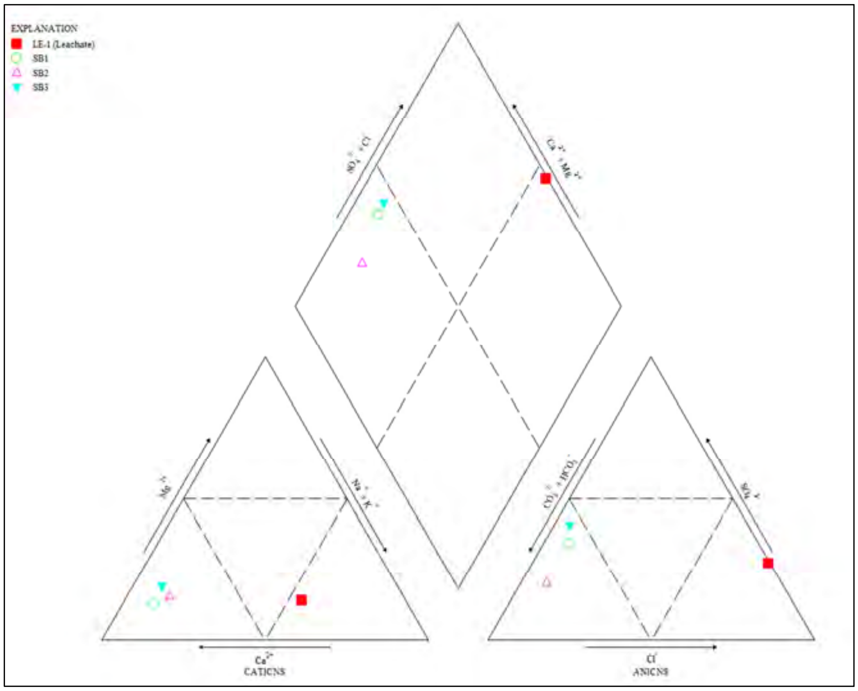
Plot 6 shows the difference between the geochemical character of leachate and water from SB1, SB2 and SB3 in April 2018.



Plot 7 shows the difference between the geochemical character of leachate and water from SB1, SB2 and SB3 in October 2018.



Plot 8 shows the difference between the geochemical character of leachate and water from SB1, SB2 and SB3 in January 2019.



The geochemical interpretations of the interflow water described above are consistent with the water quality conclusions from the time-series graphs. In summary, the interflow is influenced by precipitation, which leads to elevated concentrations of the indicators during the fall flush, followed by reduction of the indicators during the winter season and, finally, increasing concentrations of the indicators during the summer season due to absence of flow and water stagnation. These seasonal fluctuations can obscure early detection of potential leakage, which is the key limitation of the interflow wells.

2.7 Hydrocarbons in Groundwater

Detectable concentrations of hydrocarbons were measured in some monitoring wells at the landfill prior to any waste deposition. Hydrocarbons (mostly polycyclic aromatics) continue to be detected in the interflow and bedrock wells as recently as 2018. The landfill operator maintains that the hydrocarbon detections are naturally occurring, but no evidence is provided to support that conclusion. The hydrocarbon distribution reports from 2014 indicate that the groundwater samples contained both light and heavier hydrocarbon compounds associated with gasoline and diesel/oil, respectively.

There are a number of potential sources of hydrocarbons, including the historical blasting activities, leaks, spills and other accidental releases form the quarry machinery and equipment. Given that the hydrocarbon concentrations in the raw leachate itself range from non-detectable to low, the landfill is an unlikely source. Also, given that hydrocarbons are found in wells that are located hydraulically upslope (MW6) and cross slope (MW2 and MW5) from the landfill, this further suggests that the source of hydrocarbons may not be attributed to the landfill. Nonetheless, hydrocarbons in groundwater need to be characterized by additional investigations, analysis and forensics to identify and, if still present, to eliminate the source(s).

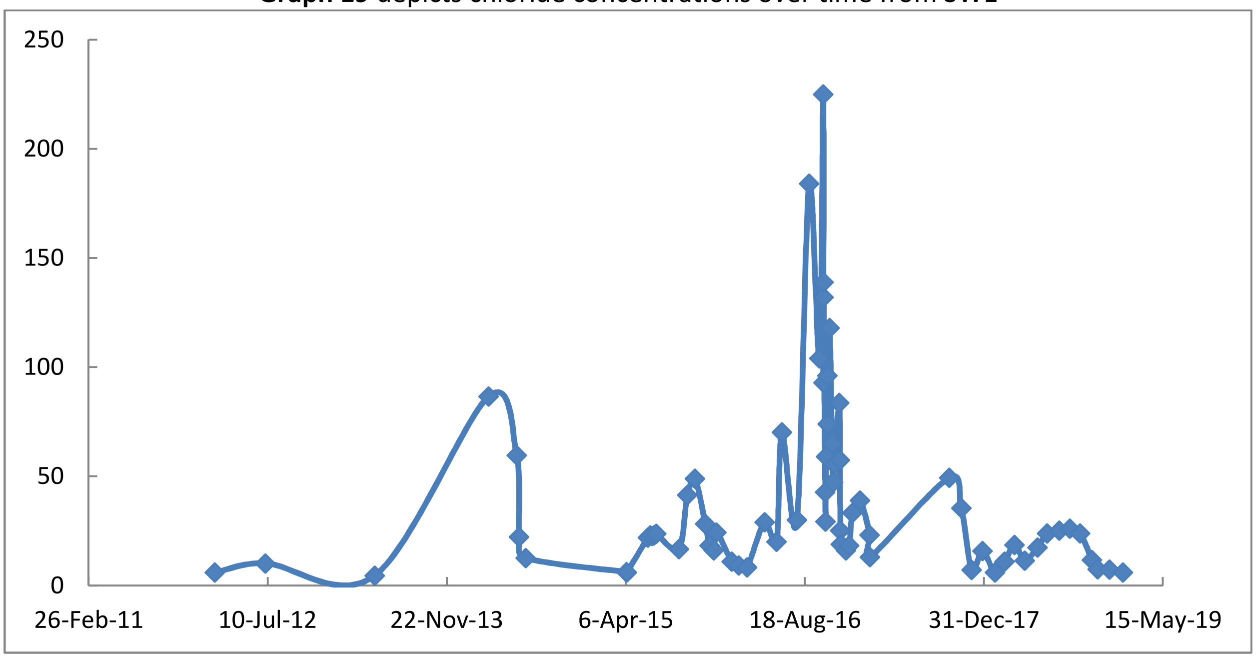
2.8 Surface Water Location SW1

This section is focussed on evaluation of water quality collected from the creek (SW1) located next to the quarry's western boundary. Water quality from SW1 is shown in Graphs 19 to 22 below.

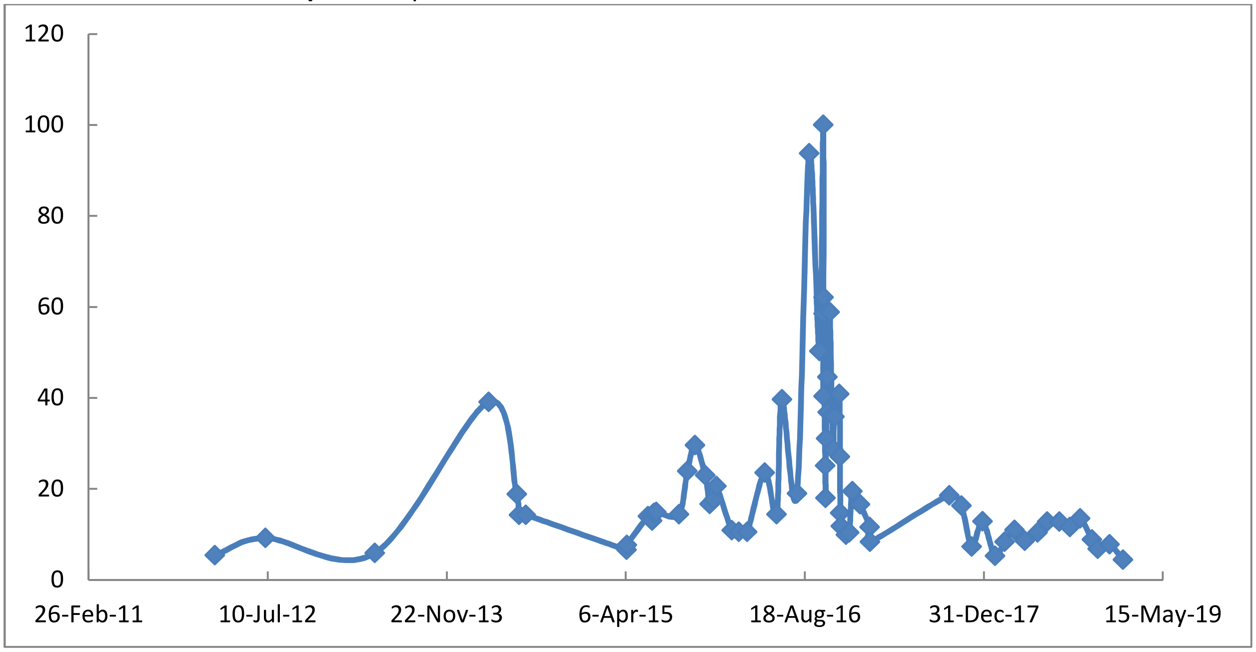
The highest concentrations of the indicators at SW1 were measured in fall of 2016 after slumping of the soil cover during rainstorm events. Other than that event, the water quality graphs indicate the following three distinct annual components of the hydrologic system. In fall the concentrations of indicators increase as a result of the fall flush. This is followed by decrease in the indicators due to the winter rain that inundates the system. Finally, the indicators begin to increase during the summer season when surface runoff is minimal or absent and the flow in the creek is dominated by the groundwater contribution.

With the exception of the 2016 soil cover event, the SW1 water quality shows no evidence of impacts from the landfill.

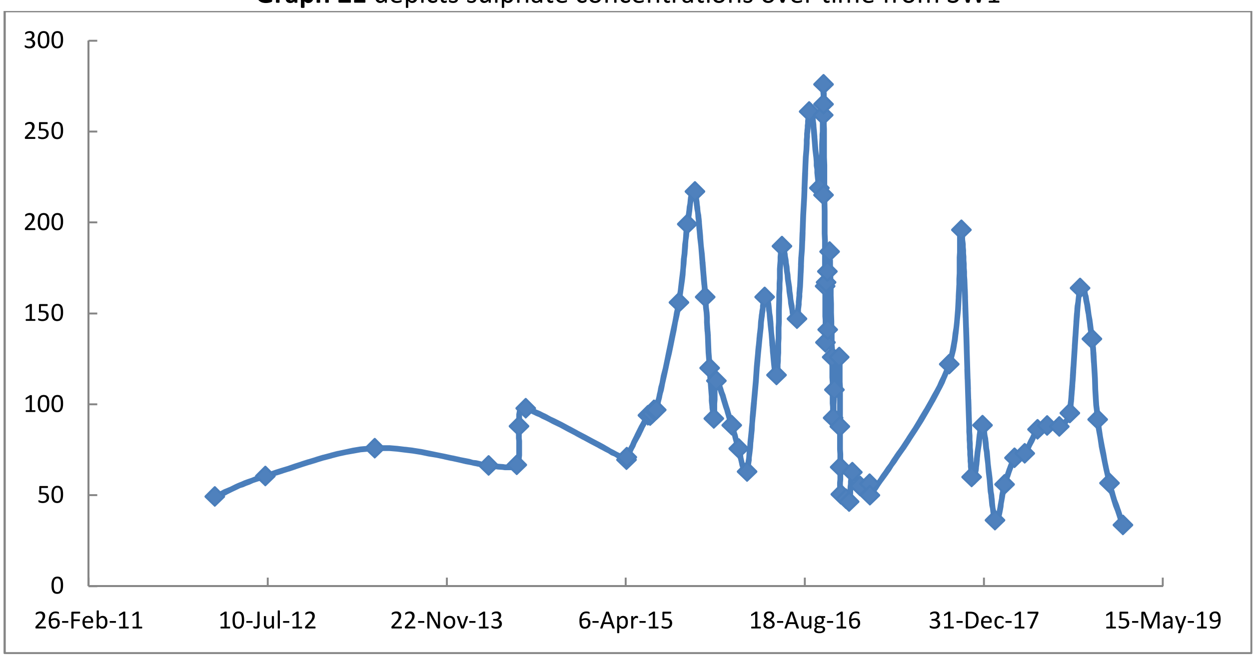
Graph 19 depicts chloride concentrations over time from SW1



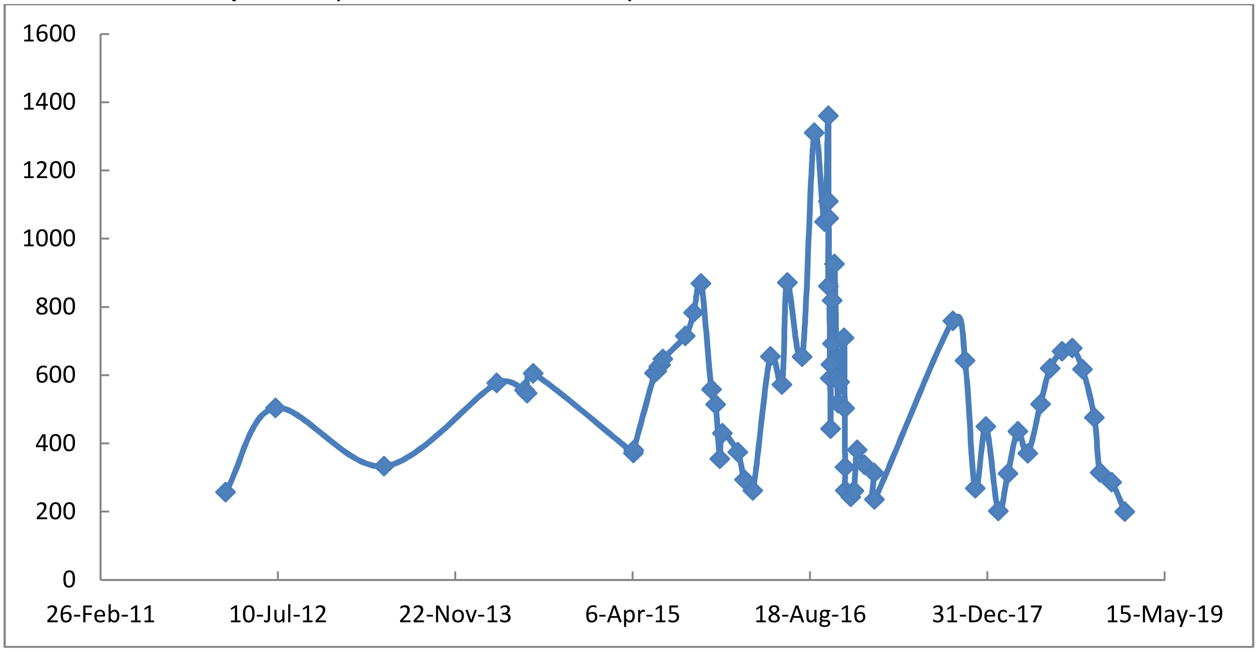
Graph 20 depicts sodium concentrations over time from SW1



Graph 21 depicts sulphate concentrations over time from SW1



Graph 22 depicts electric conductivity concentrations over time from SW1



Chloride and conductivity are two parameters used to assess the relationship between surface water and groundwater. The graphed concentrations of those parameters support the interpretation that during dry or low flow conditions water at SW1 is predominantly daylighting groundwater. This is illustrated in Graphs 19 to 22 that show generally lower concentrations of the indicators during winter when the system is inundated and water at SW1 is a mixture of runoff, interflow and groundwater, compared to the increasing summer concentrations when runoff and interflow are absent and the system is dominated by the groundwater discharge.

3 DISCUSSION

This discussion section summarizes the key findings identified in this review and introduces a number of recommendations. The recommendations are further described in the next section.

This review found that water quality at the landfill is controlled by three hydrologic components. First is the interflow that occurs at the contact between the quarry rock and the bedrock surface. The interflow quality is influenced seasonally by precipitation such that the parameter concentrations are elevated at the beginning of the rainy season as a result of the fall flush, which rinses dust and oxidized material that accumulated during summer within the quarry. This is followed by a decrease in the concentrations due to the winter rain that inundates and dilutes the interflow. Finally, the concentrations increase again during the summer season due to reduced flow and water stagnation, which increases the concentrations due to the residence time of water to react with the bedrock.

The second hydrologic component is the bedrock groundwater system. Its parameter concentrations are generally stable throughout the year but they may be elevated in some wells. The difference in chemistry between the wells is a result of the local geology and the residence time of the water to react with that geology.

The third hydrologic component represents the water contribution from the landfill to the ephemeral creek. This contribution includes surface runoff, the interflow and discharge of groundwater from the bedrock. The three stages described under the interflow resemble the water quality fluctuations observed at the creek. The first stage is the fall flush characterized by elevated concentrations, followed by the high-flow low-concentrations winter season. Lastly, the concentrations in the creek increase again during the summer season due to the increased groundwater contribution, which contains higher concentrations of the water quality indicators due to their interaction with the bedrock.

The existing groundwater monitoring network at the landfill has two key limitations. The first relates to the excessively deep monitoring wells that are unable to monitor the water table where the potential impacts from the landfill would most likely be observed. The second limitation relates to the "flashy" behaviour of the interflow and surface water monitoring sites, which can obscure early detection of potential leakage. Installations of additional shallow monitoring wells are recommended to address these limitations.

As shown in Section 2.4 above, the water quality data from MW3S indicates minor changes in water quality. Although the changes are minor and pose no risk to the environment, they warrant ongoing monitoring. The geochemical character of water from MW3S also shows a slight change or potential evolution from baseline to the more recent conditions. This observation is consistent with the water quality changes noted above. Although the landfill may be a likely source, those changes cannot be attributed to the landfill alone or at all. Forensic investigations (e.g. isotope analysis) would be required to further characterize those changes and potential source(s). Given that the changes are minor, recent and limited to only a few parameters, such investigations may not be warranted at this time. However, ongoing groundwater monitoring at MW3S is recommended. Additionally, the installation of new monitoring wells should provide further information about the shallow groundwater quality downhill from the landfill.

The ongoing detections of hydrocarbons in the bedrock and interflow wells is concerning. Forensic fingerprinting is recommended to characterize and, if present, to eliminate the source(s).

4 CONCLUSIONS and RECOMMENDATIONS

The following conclusions and recommendations are made about the water quality and closure monitoring at the landfill:

- With the exception of the 2016 soil slump event, there is no evidence that the landfill has impacted water quality in the neighbouring creek. Continued monitoring of the creek (SW1) is recommended for the landfill closure.

- A single monitoring well (MW3S) indicates recent water quality changes in some of the indicator parameters. These changes are small and pose no risk to the receiving environment, but ongoing monitoring of MW3S is recommended. Water quality from the other groundwater wells shows no impacts from the landfill.

- Groundwater quality near the water table cannot be monitored with the existing monitoring network of deep monitoring wells. It is recommended that new bedrock monitoring wells are installed near the water table and as close as practical to and downgradient from the landfill.

- Water quality results indicate that the bedrock groundwater below the landfill is vulnerable to impacts from surface sources. This is supported by hydrocarbons that are found sporadically in the bedrock and seepage wells. Forensic fingerprinting is recommended to characterize and, if present, to eliminate the hydrocarbon source(s).

5 CLOSURE

I hope this document is useful for your decision making on this file. Should you have any questions please contact Rusto.Martinka@gov.bc.ca.

Sincerely,

Rusto Martinka
Hydrogeologist
Mining Authorizations

BRITISH COLUMBIA | Ministry of Environment and Climate Change Strategy

File: Cobble Hill Holdings Ltd.
Date: April 25, 2019

RE: Review of Groundwater Information in the Cobble Hill Landfill Closure Plan

1 SUMMARY

This document reviews groundwater information that is presented in the 2019 Cobble Hill Landfill Closure Plan (Closure Plan). The plan is prepared by Sperling Hansen Associates for a contaminated soil landfill that is located at a rock quarry in Shawinigan Lake, BC. The objective of this review is to evaluate the groundwater information presented in the plan and provide advice on the landfill closure.

Based on my review, I conclude that some of the groundwater information presented in the Closure Plan lacks conceptualization, information or rationale. Specifically, I found deficiencies in the conceptual model and the proposed groundwater monitoring plan. The model is incomplete and inconsistent with data collected from the landfill. The proposed monitoring plan abandons groundwater and focuses on interflow and surface water monitoring only. Improvements to these groundwater components in the Closure Plan are necessary for the groundwater monitoring at the landfill.

This review also suggests two closure conditions that would improve the monitoring efforts at the landfill. This includes characterization of hydrocarbons found in groundwater and development of a stand-alone document that specifies the environmental monitoring program at the landfill.

The following sections of this review describe the deficiencies introduced above and provide recommendations and potential approval conditions for the landfill closure, if the Closure Plan is approved by the Minister.

2 BACKGROUND

The rock quarry in Shawnigan Lake has an interesting history. In 2013, the quarry was authorized to landfill contaminated soil. Nearly 100,000 tonnes of soil was landfilled by 2016 within the landfill cell, which consists of a double basal liner and leachate collection and leak detection systems. The authorization was cancelled due to financial security issues and a Pollution Prevention Order followed by a Spill Prevention Order were issued in 2016 and 2017, respectively. Since then, the landfill has been capped and routine environmental monitoring continues while the Closure Plan is being reviewed by the Ministry. This portion of that review is focussed on the groundwater components presented in the plan.

3 GROUNDWATER REVIEW

The information provided below describes two key groundwater deficiencies identified in the Closure Plan. The first deficiency relates to the conceptual hydrogeological model, which is inconsistent with the monitoring data. The second deficiency pertains to the proposed groundwater monitoring program, which suspends the groundwater monitoring. Both of these deficiencies were also reviewed by a third-party consulting hydrogeologist, whom concurred with my conclusions.

This review also concludes that the following two closure conditions would improve the monitoring efforts at the landfill. First is development of a stand-alone document that specifies the environmental monitoring program, which should be used to guide the monitoring efforts after the landfill closure. Second, further characterization of hydrocarbons that are found sporadically in groundwater at the quarry is deemed necessary to isolate and eliminate the source(s).

Recommendations to remedy the deficiencies and satisfy the conditions are further described below and then summarized under the Recommendations section of this document.

3.1 Conceptual Hydrogeological Model

A conceptual hydrogeological model was requested by the Ministry so that the model can guide the environmental monitoring and management efforts at the landfill. The following two subsections summarize and critique the conceptual model presented in the Closure Plan.

3.1.1 Groundwater Flow

The conceptual hydrological model presented in the Closure Plan describes the top 75 meters of the bedrock below the landfill as very component (not fractured) and not readily able to transmit water. The plan also describes strong upward hydraulic gradients that are assumed to further restrict the flow of water. As shown below, these two concepts are inconsistent with the field observations and monitoring data.

The two groundwater concepts introduced above mischaracterize the landfill setting as being protective of groundwater. Those concepts are not supported by the field observations and the groundwater monitoring data. The quarry walls are visibly fractured and those fractures are expected to extend down into the rock mass. This is supported by the packer test results, which report hydraulic conductivities that are well within the range of fractured crystalline bedrock (10^{-7} to 10^{-8} m/s). Groundwater levels also provide evidence that the bedrock is fractured, because the levels respond rapidly to recharge during the winter season. Groundwater quality also supports the interpretation that the bedrock below the landfill is fractured. As described below, hydrocarbons and some key water quality indicators are found in groundwater at concentrations that are indicative of impacts from surface sources.

The strong and upward vertical hydraulic gradients described in the Closure Plan are mischaracterized. The groundwater levels collected from the paired monitoring wells indicate low to moderate gradients and those gradients exist in both upward and downward directions. This means that groundwater flow is not restricted and it can occur in all directions.

In addition to the above, the conceptual model fails to mention the interflow that occurs below the landfill at the contact between the loose quarry rock and the bedrock. Also missing from the model is the creek that is located at the northwest property boundary. Based on the groundwater levels, the creek is hydraulically connected to the bedrock water table, hence the creek is a groundwater discharge zone. Both of these components are critical to the groundwater conceptualization and the post-closure monitoring of the landfill.

3.1.2 Groundwater Quality

Groundwater monitoring at the landfill started in 2011. Since then the monitoring frequency ranged from bi-annually to quarterly. Then in 2017, the frequency increased to monthly. As a result, the water quality data includes a long baseline period prior to any waste deposition, as well as a robust data set that was collected in the recent years.

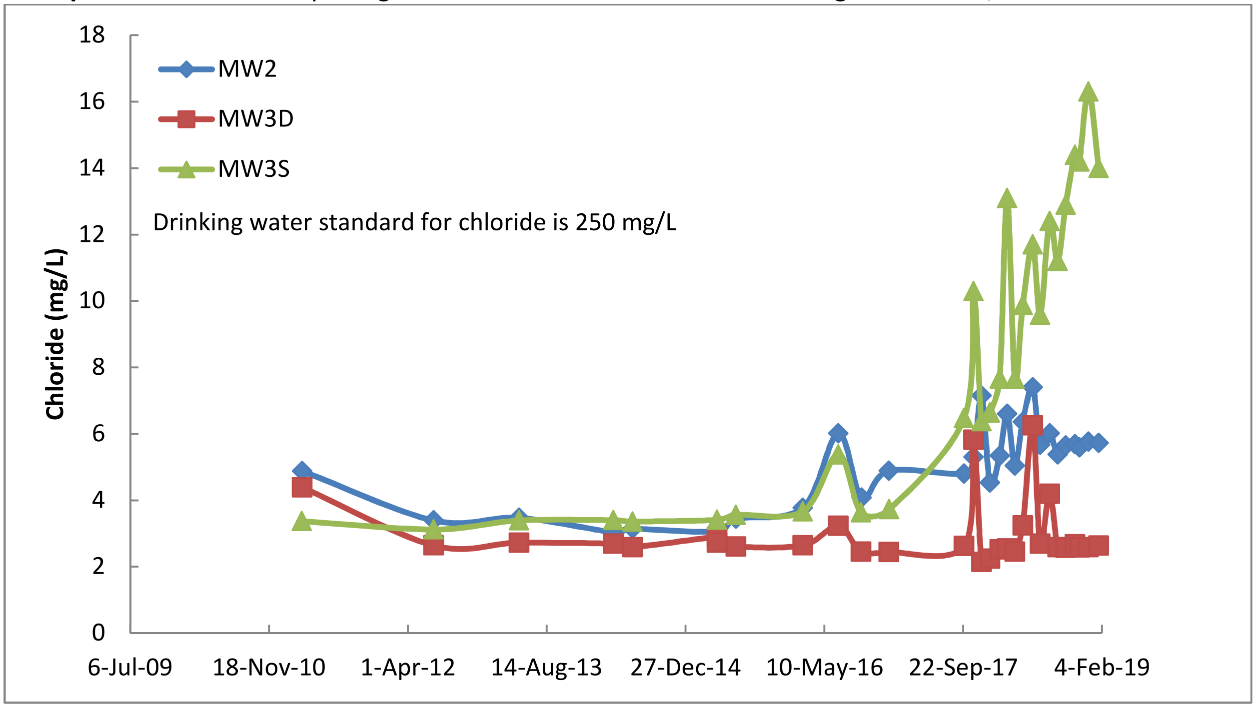
The groundwater system below the landfill consists of two key elements. First is the interflow that occurs at the contact between the loose quarry rock and the bedrock. The interflow is controlled by precipitation, which can lead to high dilution in winter and absence of water or flow in summer. This interpretation is supported by the water quality data collected from three interflow wells, which report lower concentrations of the water quality indicators (e.g. chloride, sulphate and specific conductivity) in the winter season due to high dilution. In the summer season, if water is present in the wells, the indicators are found at higher concentrations due to water stagnation. These fluctuations can obscure potential water quality impacts from the landfill. Therefore focused monitoring of the interflow wells, which is proposed in the Closure Plan, is considered insufficient for the long-term groundwater monitoring.

The second element of the groundwater system below the landfill consists of the fractured bedrock. Water quality in the bedrock shows signs of impacts from surface sources. Detectable concentrations of hydrocarbons were measured in some wells prior to any waste deposition. Hydrocarbons continue to be detected in the interflow and bedrock wells as recently as 2018.

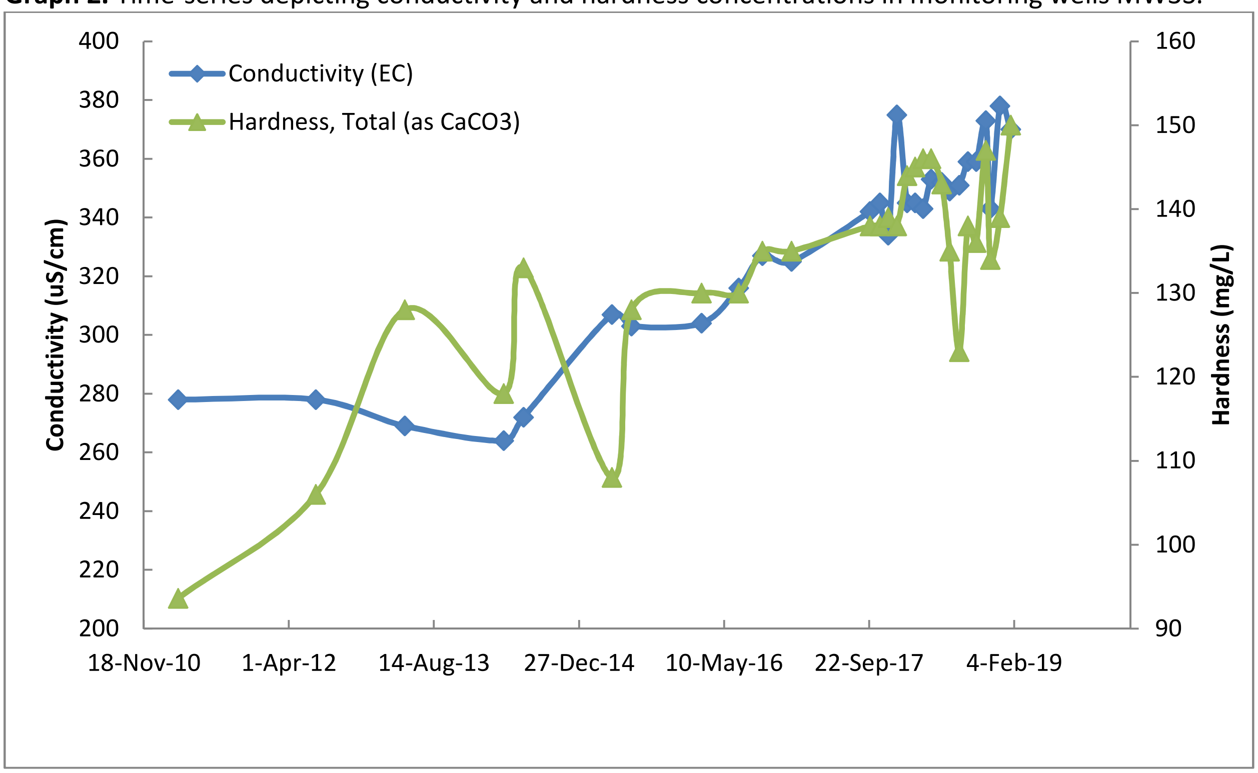
In addition to hydrocarbons, concentrations of some indicator parameters suggest that small changes in groundwater quality below the landfill are occurring. As shown below in Graph 1, the baseline chloride concentrations in groundwater are stable until 2016. Since then, chloride has been gradually increasing with the most notable increase in the monitoring well MW3S. A similar but less pronounced increase in MW3S is also depicted by the conductivity and hardness time-series graph (Graph 2). These small changes pose no risk to the receiving environment, because they are well within their respective environmental benchmarks. Other indicator parameters in groundwater, such as sodium and sulphate, are generally stable.

The source of the increasing water quality indicators in groundwater is unknown, but the landfill is a likely source. However, it is important to note that the small water quality changes may not be attributed to the landfill alone or at all, and that a forensic investigation would be required to further characterize the changes. Given that the changes are small, recent and limited to only a few parameters, such investigation may not be warranted at this time. However, installation of new shallow monitoring wells downslope from the landfill, as recommended below, should provide further information about the groundwater quality.

Graph 1. Time-series depicting chloride concentrations in monitoring wells MW2, MW3S and MW3D.



Graph 2. Time-series depicting conductivity and hardness concentrations in monitoring wells MW3S.



3.1.3 Conclusion

The conceptual hydrogeological model presented in the Closure Plan is incomplete and inconsistent with the available information. The model is therefore unlikely to effectively guide the monitoring efforts at the landfill. **I recommend that the conceptual model is revised as a condition of the landfill closure.**

3.2 Groundwater Monitoring Plan

Eight monitoring wells were initially installed at the landfill between 2010 and 2013. A new background monitoring well (MW6) was installed in 2016 to replace the original background well (MW4), which was destroyed during landfilling. Then in 2017, three interflow wells were dug into the bedrock surface downslope from the landfill.

As shown in the cross section presented in the Closure Plan, all groundwater monitoring wells are excessively deep. This restricts their ability to monitor groundwater quality near the water table, which is most susceptible to potential impacts from the landfill. **I therefore recommend that new shallow monitoring wells are installed as a condition of the landfill closure.** The new wells should target the water table downslope from the landfill and they should be advanced using a drilling method that allows for logging of borehole core.

The Closure Plan proposes to discontinue sampling of the groundwater wells based on the conceptualization that is reviewed above. The proposed monitoring program focusses on the interflow wells and surface water monitoring only. The plan describes a phased approach to install new monitoring wells only if the monitoring data indicates leakage from the landfill. In my opinion this proposal is insufficient for the following reasons. The interflow is controlled by precipitation and therefore its monitoring results can be obscured by seasonal fluctuations in precipitation. The recent increase in some indicator concentrations in the monitoring wells is indicative of impacts from surface sources and therefore continued monitoring of those wells is considered necessary. Finally, since the bedrock water table is most susceptible to impacts but it is not currently monitored, installation and monitoring of shallow wells is recommended.

Finally, the Closure plan provides locations of new monitoring wells in the event that the monitoring data indicates leakage from the landfill. One of the proposed wells (MW19-01) is located hydraulically cross gradient from the landfill and therefore unlikely to track potential water quality changes from the landfill. The other well is located at the property boundary and near the creek. Both of these locations should be reconsidered such that the wells are located as close as practical to and downgradient from the landfill so that they can provide early detection of potential changes in water quality.

Given the importance of environmental monitoring after the landfill closure, it is recommended that the Named Parties develop and submit a standalone document that details the environmental monitoring program. A list of necessary components of that program is provided under the Recommendations section.

3.3 Hydrocarbons in Groundwater

Detectable concentrations of hydrocarbons were measured in some monitoring wells at the landfill prior to any waste deposition. Hydrocarbons (mostly polycyclic aromatics) continue to be detected in in the interflow and bedrock wells as recently as 2018. The landfill operator maintains that the hydrocarbon detections are naturally occurring, but no evidence is provided to support that conclusion. The hydrocarbon distribution reports, which are commonly used for "fingerprinting", indicated that the 2014 groundwater samples contained both light and heavier hydrocarbon compounds associated with gasoline and diesel/oil, respectively. There are a number of potential sources of hydrocarbons such as the historical blasting activities, leaks, spills and other accidental releases from the quarry machinery and equipment.

Given that the hydrocarbon concentrations in leachate range from non-detectable to low, the landfill may be an unlikely source of hydrocarbons in groundwater. Also, given that hydrocarbons are found in wells that are located hydraulically upslope (MW6) and cross slope (MW2 and MW5) from the landfill, this may further suggest that the source of hydrocarbons may not be attributed to the landfill. However, it is important to note that this ongoing water quality issue remains inadequately characterized and that **additional investigations, analysis and forensics are recommended to identify the source(s) of hydrocarbons at the landfill**.

3.5 Water Quality Benchmarks

Water quality in the landfill's background groundwater well (MW6) is very hard and the concentrations of its key water quality indicators are notably higher than in the downgradient bedrock wells. Hence, MW6 is considered unsuitable for background monitoring. Rather than requiring another background well, the Ministry suggested that the Named Parties develop background benchmarks through statistical determination of water quality. The background benchmarks were developed and submitted in the Closure Plan, however, those benchmarks were unlikely representative of background conditions.

The earlier version of this review recommended that the proposed water quality benchmarks are revised. This recommendation is being retracted because the bedrock water quality is quite variable, which makes development of meaning groundwater quality benchmarks impractical. Rather, the routine water quality monitoring at the landfill should focus on other tools and assessment measures, such as the baseline data, trilinear diagrams and time-series graphs, and groundwater standards and surface water guidelines.

4 RECOMMENDATIONS

The following recommendations are provided for the landfill closure:

- The conceptual groundwater model is incomplete and inconsistent with the available data, and therefore unlikely to effectively guide the monitoring efforts at the landfill. The model should be revised so that it better reflects the hydrologic conditions at the landfill.

- The existing groundwater monitoring network consists of deep wells installed tens of metres below the water table. The network should be expanded to include monitoring near the water table where groundwater is most susceptible to potential impacts.

  The Closure Plan proposes to discontinue sampling of the existing monitoring wells and install new shallow wells only if leachate breakthrough is reported. Based on the information summarized in this review, the shallow monitoring wells should be installed and monitored prior to the landfill closure. Also, changing water quality in MW3S should continue to be monitored.

  The elevations of all new monitoring wells and the existing wells that may be altered during the landfill closure should be surveyed so that water level monitoring can be referenced to a geodetic datum.

In the event that the Closure Plan is approved, the following draft landfill closure conditions are provided:

- A separate document is required to specify and guide the groundwater and surface water monitoring program, environmental triggers and responses, and related reporting.

  Condition 1: By XX DATE, the Named Parties must develop an environmental monitoring program and submit it to the Ministry for approval. The program must be submitted as an independent document and it must include the following components:

  i. Summary of the conceptual hydrogeological model.
  ii. A well installation details table for the existing and new monitoring wells. The table must detail geographical coordinates of all wells, installation depth, screen interval and geology, and water levels.
  iii. A site plan depicting all monitoring locations.
  iv. Description of monitoring frequencies and parameters.
  v. Description of field methods.
  vi. Quality assurance and quality control measures.
  vii. Description of water quality benchmarks, limits and triggers, and a summary of linkages between triggers and responses.
  viii. Description of all reporting objectives and deliverables.

- The ongoing detection of hydrocarbons in the bedrock and interflow wells need to be further investigated. Forensic fingerprinting is recommended to characterize and eliminate the hydrocarbon source(s).

  Condition 2: The Named Parties must complete additional forensic investigations on future water samples that report detectable concentrations of hydrocarbons. The forensic investigations must address the following key queries:

i. Characterize the product.
ii. Determine the source(s).
iii. Evaluate the product age and degradation, if any.
iv. Describe mitigations to eliminate the source(s).

5 CLOSURE

I hope this document is useful to inform a decision on this file. Should you have any questions please contact me at 250-751-7056 or Rusto.Martinka@gov.bc.ca.

Sincerely,

Rusto Martinka
Hydrogeologist
Mining Authorizations
Ministry of Environment and Climate Change Strategy

March 28, 2019 Reference No. 11191916-01

AJ Downie
Director, Authorizations South
Environmental Protection Division
Ministry of Environment and Climate Change Strategy
2080a Labieux Road
Nanaimo, BC V9T 6J9

Original Sent Via Email

Dear Mr. Downie:

Re: Slope Stability Detailed Engineering Review – Task 1
Review of the Cobble Hill Landfill Updated Final Closure Plan 2019
460 Stebbings Road Near Shawnigan Lake, British Columbia

GHD was retained by the Ministry of Environment and Climate Change Strategy (ENV) to provide a third party opinion of the 'soil wedge' and related static and seismic stability calculations that are discussed in the Cobble Hill Landfill Updated Final Closure Plan 2019 (Closure Plan) dated January 31, 2019 prepared by Sperling Hansen Associates (SHA) for the Cobble Hill Landfill located at 460 Stebbings Road near Shawnigan Lake, British Columbia (Site).

1. Soil Wedge Detailed Engineering Review

Scope Item

i. *Review technical rationale and justification provided by SHA in the Closure Plan regarding the Soil Wedge, and provide comments based on personal professional opinion.*

    a. *State whether or not you are in agreement with the benefits and justifications that are listed in the Closure Plan. If not, indicate why.*

Review

Unless otherwise approved by ENV with sufficient technical justification provided, the British Columbia (BC) Ministry of Environment and Climate Change Strategy (ENV) requires[1] the above- grade landfill slopes to be:

- At a gradient of 3 Horizontal to 1 Vertical (3H:1V)
- Must contain a 150 mm thick vegetated topsoil and 450 mm thick soil barrier layer placed over geotextile over textured geomembrane placed over waster material

[1] BC ENV (2016): 'Landfill Criteria for Municipal Solid Waste' 2nd Edition, p20-23.

The existing landfill slope is 2.5H:1V (slope of 21.8 degrees to the horizontal). In order to address the ENV criteria and utilize the existing smooth LLPDPE, SHA has proposed to incorporate the soil wedge. Soil wedge at 5H:1V is proposed to buttress the existing 2.5H:1V slope increasing its stability and also providing increased cover on the LLDPE protecting it from the environment. In GHD's opinion, the soil wedge at 5H:1V over the existing slope of 2.5H:1V in general is beneficial in terms of erosion protection and improving slope stability.

SHA has stated in Section 4.7.1 that "…*with the stabilizing wedge approach the existing smooth membrane can be left in place while realizing an improved level of global slope stability*." However, in GHD's opinion there remain risks related to its construction and seismic stability, which are discussed in the following section.

Scope Item

ii. *Based on professional expertise and/or past experience, identify any additional risks or benefits associated with the proposed soil wedge (e.g. risks to existing leachate and leak detection pipes including access to leachate and leak detection pipes for post-closure inspection, maintenance and repair, etc.).*

Review

There is a risk of the wedge sliding off the smooth LLDPE at 2.5H:1V slope. This could affect infrastructure within and down gradient of the wedge, including the seepage blanket wells. Please see comments under slope stability.

Scope Item

iii. *For any risks identified, suggest possible design considerations or mitigation measures that could be enacted to minimize the risks.*

Review

Refer to the following section discussing smooth versus textured geomembrane. A mitigation for the slope stability, especially for the construction and seismic conditions, includes replacing the smooth LLDPE with a double-sided textured LLDPE or a double-sided textured HDPE. The extra cost may be offset by eliminating the friction sand layer and crushed drainage gravel depending on further slope stability and veneer type stability analysis.

2. Static and Seismic Stability Calculation Review

Scope Item

i. *Review inputs, variables, assumptions and results (to the extent that this information is available in the Closure Plan or otherwise) and provide comment on whether the calculations appear reasonable and correct, and/or identify shortcomings or deficiencies and their implications in terms of landfill slope stability for static and seismic conditions and environmental protection.*

ii. *Review interpretations and conclusions made by SHA and identify any areas of disagreement based on professional opinion/experience.*
iii. Provide interpretation, conclusions and recommendations.

Review

The Closure Plan states "The results indicate that the revised buttressing wedge design is stable for all static and seismic loading conditions." (Section 9.2.5). As discussed below, GHD recommends further evaluation to confirm this statement.

SHA has carried out stability analyses utilizing Rocscience's SLIDE 4.0© using the Bishop Simplified method, a limit equilibrium analysis method. The Bishop's Simplified method is an established method of stability analysis, however, it does not satisfy all equilibrium conditions, e.g., it does not satisfy horizontal force equilibrium and does not take into account interslice shear. These factors typically effect the computed factors of safety values to some degree, with Bishop's Simplified method sometimes providing slightly higher factors of safety compared to methods that satisfy all conditions of equilibrium such as Spencer and Morgenstern-Price. It is, therefore, recommended that the analyses should be verified by using either Spencer or Morgenstern-Price methods of limit equilibrium.

SHA has analyzed one cross-section 3-3' as shown on Figure 9-1 of the Closure Plan. Although GHD does not have significant concerns regarding this location, the Closure Report should provide a rationale for selecting this location.

SHA has used target factors of safety of 1.5 for static conditions and 1.0 for seismic conditions. A factor of safety (FS) in slope stability analysis can be defined as the ratio of the available shear strength to that of the applied stresses along a potential failure plane. A FS of 1.0, therefore, indicates equilibrium conditions wherein available shear strength and applied stresses are in perfect equilibrium. As such a FS typically greater than 1.0, even for short term condition such as pseudo-static (seismic) analysis are considered acceptable.

The U.S. Department of Interior, Bureau of Reclamation (USBR) Design Standard No. 13 titled 'Embankment Dams' dated October 2011 recommends that the FS should be selected based on a number of factors a few of which relevant to this study are listed below:

- the design condition being analyzed and the consequences of failure,
- estimated reliability of shear strength parameters, pore pressure predictions, and other soil parameters,
- judgment based on past experience.

SHA have referenced Hynes-Griffin and Franklin (1984)[2] to reduce the horizontal peak ground acceleration (PGA) by 50 percent. This reduction is in combination with the use of 80 percent of shear strength parameters used in static analyses and is justified subject to the following:

- The material is not subject to severe strength loss
- The Hynes-Griffin and Franklin (1984) and Franklin method assumes that 1 m of permanent displacement is acceptable.

One (1) m of permanent displacement may not be acceptable in this case, therefore, it is recommended that the seismic coefficient k should be more accurately determined by methods such as Bray and Travasarou (2009)[3] for an acceptable level of permanent displacement, and determine if seismic coefficient as a fraction of the PGA value should be used for the magnitude of acceptable deformation. It is further recommended that a minimum target FS of 1.1 should be used for the seismic analyses.

In GHD's opinion, the FS of 1.5 for static condition is adequate subject to completion of material property sensitivity analyses recommended below.

The soil parameters used by SHA are tabulated in Table 9-1 of the Closure Plan (CP), and the stability analyses are shown on Figures 9-2 and 9-3. The soil parameters used are reported to be based on assumptions made by SHA and SHA's experience. Specific references for these soil parameters should be provided. No laboratory testing was carried out, although the CP identified that laboratory testing would be required to confirm friction angle once the sand for the interface is selected. The soil parameters can have some variation with some change in particle size distribution, degree of (or lack of) cohesiveness, short term versus long term conditions. GHD notes that the parameters listed in Table 9-1 may not be conservative depending on the reference cited. The saturated unit weights for the waste soil seem high, and the unsaturated unit weight seems to be low. All parameters, unit weight and strength components, should mimic the same material. The bedrock is not modeled as impenetrable indicating that it could be highly or completely weathered (soil like). If this is the case, the highly/completely weathered and sound bedrock zones should be identified on the graphical outputs and strength values backed with discussion should be provided. In a summary, more discussion with references needs to be provided as to how the material strength parameters and unit weights were selected for the soil and bedrock material involved. Due to the lack of Site-specific laboratory testing at present and possible variation in literature based values, it is recommended that SHA should conduct a sensitivity analyses with a range of soil parameters.

In Section 2.4 and 9.2.2 the Closure Report mentions addition of cement to the waste soil. In Section 9.2.2, the Closure Plan states that "It is suspected that the addition of large volumes of cement has increased the shear strength of the waste materials above normal values, but as the material was not tested, the strength contribution of the cement was not factored in our analysis." Based on GHD's review

[2] Hynes-Griffin, M.E. and Franklin A.G. (1984): 'Rationalizing the Seismic Coefficient Method', Report No. GL-84-13, U.S. Army Engineers Waterways Experiment Station, Vicksburg, Mississippi

[3] Bray J.D. and Travasarou, T. (2009): 'Pseudostatic Coefficient for use in Simplified Seismic Slope Stability Evaluation', Journal of Geotechnical and Geoenvironmental Engineering, Vol. 135, No. 9, p1336-1340.

of Section 2.4 of the CP, the cement was added to soil from a specific project rather than all soil deposited in the PEA. Without knowledge of where and how this specific soil was placed, its effect on increasing the shear strength of soil in the PEA may be limited and, thus, the statement above should be clarified or removed.

The Closure Plan Figures 9-2 and 9-3 also show that the critical slip circle passes along the geomembrane along the 2.5H:1V slope. According to Koerner[4] the efficiency between concrete sand and smooth geomembrane can be as low as 60 percent. A 32° shear strength (assumed by SHA) sand placed along the smooth LLDPE geomembrane/sand interface could provide an interface shear strength of only 19.2° (2.87H:1V), which means that the factor of safety against sliding of the sand on 2.5H:1V (21.8°) slope could be only ~~1.1~~ for dry construction conditions, and the sand might not stay on the 2.5H:1V slope even when placed using manual labour or stone slinger. Material-specific testing should be done to confirm the interface shear strength and mitigate concerns.

0.9

April 4, 2019

It is also noted that in Section 4.7.2 of the Closure Plan, SHA has indicated that the placement of the sand friction layer over the smooth LLDPE geomembrane will increase the interface friction angle to about 23 degrees. However, as noted above, the interface friction angle can be as low as 19 degrees. The reduced interface friction angle should also be used into the stability analyses to complete the sensitivity analyses.

On Page 9-2, 1st paragraph, SHA mentions National Building Code of Canada (NBC) 2012. This warrants correction as possibly the report was referring to the BCBC 2012 or NBC 2015, which was adopted by BC in 2018. Regardless, GHD confirmed that the Victoria BC area peak horizontal ground acceleration value and exceedance probability used in SHA modeling are as published in the current 2015 NBC and, thus, the 2018 BCBC.

In Section 9.2.1 of the Closure Plan SHA states that "It is noted that a more accurate peak ground acceleration may be obtained by performing site specific response analysis. This is typically done when a site is very high risk, or foundations are known to be problematic. It is our opinion that neither is the case at CHL." GHD agrees with this statement. GHD also agrees with the SHA approach of using 50 percent of PGA value in the pseudo-static analysis, provided up to 1 m displacement is acceptable. However, in GHD's opinion, SHA should have calculated the amplified value at the crest of the landfill using any simplified procedures such as Rathje and Bray[5], using the average of NBC bedrock value and the amplified value and then applied the 50 percent factor to the average value. Alternatively seismic coefficient for the acceptable deformation limit should be determined using Bray and Travasarou (2009)[3] or similar methods.

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[4] Koerner R.M. (2012): Designing with Geosynthetics; 6th Edition, Vol. I and Vol. II, Rev. 2016.

[5] Rathje E.M. Bray J.D. (1998): An Examination of Simplified Earthquake induced Displacement Procedures for Earth Structures, Canadian Journal of Geotechnical Engineering Issue 36, p72-87

3. Conclusions and Recommendations

1. General comment: As suggested in the following bullets, a better understanding of the level of risk, notably under seismic conditions and incorporating sensitivity analysis, will provide a greater degree of certainly as to how close the design is to the minimal appropriate factor of safety. As an alternative, using a textured geomembrane is expected to provide additional stability under seismic conditions.
2. There remain risks related to the construction of 5H:1V wedge over 2.5H:1V slope due to the anticipated low interface shear strength available along the smooth geomembrane and sand interface especially during seismic conditions.
3. A mitigation particularly for the seismic slope stability includes replacing the smooth LLDPE with a double-sided textured LLDPE or a double-sided textured HDPE. The extra cost may be offset by eliminating the friction sand layer and crushed drainage gravel depending on further slope stability and veneer type stability analysis

   Stability analyses should also be carried out using Spencer or Morgenstern-Price methods of limit equilibrium
4. SHA should provide a discussion on the rationale for selecting the location of the cross-section 3-3’ for stability analyses
5. Instead of using Hynes-Griffin and Franklin (1984) method of reducing the seismic coefficient to 50 percent of the PGA value with the implicit assumption that up to 1 m of permanent displacement would be acceptable, it is recommended that the seismic coefficient should be determined for the Site-specific acceptable permanent deformation using Bray and Travasarou (2009) or similar methods
6. A minimum target factor of safety of 1.1 should be used for pseudo-static stability analysis
7. Soil parameters used may not be conservative. Due to the absence of any Site-specific lab testing it is recommended that a sensitivity analyses should be carried to determine the effect of soil strength parameters on the factor of safety
8. Material-specific testing should be carried out to remove uncertainties in the analyses and to mitigate concerns especially about interface shear strength parameters
9. Use of cement for stabilizing the waste soil is not well documented; the reference that it may have increased the shear strength of the waste soil should be clarified or removed
10. Soil-membrane interface efficiency should be accounted for and used in the slope stability analyses
11. SHA should calculate the amplified PGA value at the crest of the landfill using any simplified procedure and the NBCC bedrock value and then use 50% of the average of the values in the pseudo-static analyses

4. Closing

We trust the above meets your present requirements. Should you have any questions or need clarifications, please do not hesitate to contact James Reid at 604-248-3669.

Sincerely,

GHD

Hassan Gilani, M.Sc., P. Eng.

HG/vk/01

cc: Kirsten White (ENV)
James Reid (GHD)
Chris Trumbull (GHD)

March 28, 2019 Reference No. 11191916-02

Mr. AJ Downie **Original Sent Via Email**
Director, Authorizations South
Environmental Protection Division
Ministry of Environment and Climate Change Strategy
2080a Labieux Road
Nanaimo, BC V9T 6J9

Dear Mr. Downie:

Re: Cover System Detailed Engineering Review - Task 2
Review of the Cobble Hill Landfill Updated Final Closure Plan 2019
460 Stebbings Road Near Shawnigan Lake, British Columbia

GHD was retained by Ministry of Environment and Climate Change Strategy (ENV) to provide a third party opinion on the proposed landfill cover system that is discussed in the Cobble Hill Landfill Updated Final Closure Plan 2019 (Closure Plan) dated January 31, 2019 prepared by Sperling Hansen Associates (SHA) for the Cobble Hill Landfill located at 460 Stebbings Road near Shawnigan Lake, British Columbia (Site).

1. Geomembrane Review

Scope Item

Determine whether a smooth geomembrane can be expected to adequately protect the environment in this circumstance.

a. Based on review of site specific circumstances, results of stability analysis, and the proposed soil wedge, provide comments and professional opinion (based on expertise and/or past experience) on whether or not the proposed smooth geomembrane adequately protects the environment. If appropriate, recommend additions/changes to the engineering that would be needed to reduce any risks identified.

b. Provide a professional opinion (based on expertise and/or past experience) as to whether or not it is reasonable to expect that the smooth liner, deployed as proposed, would be considered equivalent to the Landfill Criteria.

Review

The requirements of the Landfill Criteria for final cover are described in Section 4 of this letter. The continued use of the smooth 40 mil LLDPE geomembrane in itself can be reasonably expected to protect the environment (through minimization of infiltration) when properly installed, with a stable slope.

GHD
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Textured geomembranes, as illustrated in the 2016 Landfill Criteria, are generally required to enable final cover systems to meet slope stability factors of safety. The review provided under separate cover for Task 1 of the Engineering Review and within Section 3 of this document indicate concerns related to the slope stability during construction and under a seismic loading scenario with the presence of the soil wedge. Recommendations for additional slope stability assessment and alternate cover construction, such as using a textured geomembrane, are provided in the Task 1 letter provided under separate cover.

2. Functionality of Existing Geomembrane

Scope Item

Based on professional expertise and/or past experience, provide your opinion as to whether or not the existing geomembrane remains fully functional and suitable for its intended use, and/or if necessary, identify what additional information would be required to inform this determination.

a. *Review Closure Plan including information, data and references to determine areas of agreement/disagreement in opinion regarding suitability of continued use of the existing geomembrane.*

b. *Based on professional expertise and/or past experience, comment on whether or not the existing geomembrane which has been exposed to UV and the elements since late 2016 is acceptable to use at this site, for its intended purpose.*

Review

In a letter to Mr. A. J. Downie dated January 30, 2017 re: Cobble Hill Holdings Ltd. Pollution Prevention Order File 108608, from SHA, SHA notes that the geomembrane can be exposed to UV for five years and still perform as required. If the landfill closure is completed in 2019, the existing geomembrane, which was placed in Fall 2016, will have been exposed for less than three years.

UV degradation is a primary concern for impacts to service life on exposed LLDPE. UV degradation can break polymer chemical bonds and cause the polymer to become more brittle and prone to stress cracking thereby reducing its effectiveness as a low permeability barrier. Generally, the end of a geomembrane service life is deemed when the material strength has reached 50 percent of its initial strength (the half-life). Although research into the UV exposure effects on HDPE and LLDPE is limited, the available findings indicate that exposed service life of LLDPE is at least five years (Islam, 2011). The Geosynthetics Institute (GSI) developed a predicted service life for exposed LLDPE of 36 years in a dry and arid climate based on laboratory UV exposure per ASTM D7238 (GSI, 2011).

The geomembrane cover installed at the Site is 40 Mil LLDPE BB 140-7000 manufactured by Solmax. GHD contacted Solmax to discuss the effects of UV exposure. Solmax indicated that the antioxidants in the geomembrane would be slowly depleted with UV exposure before the physical properties are affected and after three years, Solmax would expect antioxidants to still be present and the geomembrane would exhibit physical property performance commensurate with new material. It is Solmax's experience that

LLDPE material exposed for 10 years still contains antioxidants and exhibits sufficient physical properties to function adequately. Solmax commented that deployed material would likely have minor scratches that would affect the elongation at break test results, but not significantly affect other aspects of the geomembrane's performance.

Testing of the existing geomembrane will be necessary to confirm these assumptions, especially the geomembrane that is being cut, handled and reused during the soil relocation activities. Minor scratches could be exacerbated when the section of the geomembrane is handled during the SMA soil relocation activities and result in unacceptable geomembrane performance that could include crack development. Solmax indicated that they can perform an Oxidation Induction Time (OIT) test on a piece of 25 mm x 25 mm material cut from the edge flap of an existing weld. The OIT test would indicate whether the material contains antioxidants that would protect it from UV exposure and maintain its physical properties. Solmax would expect an OIT time of approximately 80 minutes but noted the actual result could be lower. The OIT test would determine if the material would be considered likely to perform as desired. Additionally, a strip of material approximately 1,000 mm by 25 mm could be tested for tensile strength to evaluate the existing material's modulus of elasticity (degradation would increase the modulus of elasticity). Solmax could then comment on the status of the geomembrane's performance due to the UV exposure.

Further to the testing discussed above, GHD recommends that Solmax be contacted to discuss the status of their manufacturer warranty against defects for the existing geomembrane that is proposed to be left in place and the geomembrane that is to be cut, handled and reused during the SMA soil relocation activities. A quality management plan should be prepared with input from Solmax that helps maintain performance of the material. Any reduction in the geomembrane characteristics will need to be reviewed and assessed.

Regarding the existing geomembrane in its present condition, based on GHD's review of as-built information, the geomembrane cover was installed in pre-fabricated panels that were delivered to the Site, unfolded in place, and welded to the basal geomembrane system. In a letter dated January 30, 2017 from SHA to Mr. A.J. Downie re: Cobble Hill Holdings Ltd. Pollution Prevention Order File 108608, SHA notes that the contractor, SIRM, and their subcontractors, were completing quality control testing, including pre-weld tensometer shear and peel tests. The manufacturer quality assurance testing, observations by SHA, and observations by GHD during the 2017 Minor Works suggest that the cover geomembrane was properly installed.

An exposed geomembrane may also be damaged by animal or human activity. The Closure Plan appropriately notes that inspection of the geomembrane will be completed prior to the placement of the remaining cover system. The ENV may opt to have a representative on-Site during this inspection and/or after all repairs have been completed to corroborate the inspection and repair activities prior to the remaining cover materials being placed.

The existing material may exhibit physical properties that could be protective of the environment, provided the aforementioned testing is completed to verify the protective properties of the existing geoemembrane. GHD recommends that the geomembrane manufacturer be contacted to confirm what testing would be necessary to verify geomembrane performance. The performance of the geomembrane that was placed on the PEA is first and foremost dependent on the methodology of geomembrane installation, of the placement of the remaining cover materials above the geomembrane, and respective QA/QC. The subsequent concern is the degradation of the geomembrane due to UV exposure and other potential damage.

Although GHD's preference is replacement of any geomembrane that is removed with new material, if a thorough inspection and testing of the existing geomembrane is completed prior to construction activities and in accordance with manufacturer instructions, repairs are made in accordance with manufacturer instructions, and construction practices are implemented in accordance with manufacturer instructions to consider protection of the geomembrane, the material should continue to perform as designed.

3. Final Cover Construction Methodology

Scope Item

Assess the appropriateness and risks associated with the proposal to cut, remove and re-use (and add to) the existing geomembrane liner on the landfill crest.

a. Provide a professional opinion (based on expertise and/or past experience) regarding whether or not the proposed approach seems reasonable:

1. If so, has sufficient information been provided to have confidence that the relocation activities themselves do not pose a risk to the environment? If not, identify any additional measures that would need to be incorporated into the construction plan.

2. Does working around, cutting and welding of the existing liner pose unique technical or logistical difficulties or limitations due to previous exposure of the liner to sunlight for a prolonged period of time (approximately three years)?

3. Overall, does the proposal compromise the long-term integrity of the landfill?

4. What changes or additional measures if any should be incorporated to reduce any risks identified?

Review

Relocation activities posing a risk to the environment

The relocations activities themselves as described in Section 3.2 of the Closure Plan, if completed with appropriate controls and verifications, should not pose a risk to the environment; however, additional procedures details, such as the following, could be considered:

- Specify that after each truck is loaded with soil in the SMA, the area be inspected and, if necessary, swept of soil that fell onto the concrete during loading that could be tracked away.
- Specify that the access roads be inspected on at least a daily basis for soil that may have spilled from the truck during transport.
- Provide more detail on how trucks and construction equipment will get to open area of PEA without potentially damaging the geomembrane. Section 3.2 references metal ramps to allow crossing the ditch; however, there is at least 3 m of distance beyond the ditch to the open area.
- Provide some detail as to the procedure to prevent surface flow during a precipitation event from flowing onto the geomembrane out of relocation area.
- Provide some detail on dust control measures for the period when the PEA cover will be partially removed and contaminated soil will be relocated to the PEA, especially given that the material is proposed to be conducted in the dry season.

Working around, cutting and welding of the existing geomembrane

As mentioned previously, minor scratches that exist in the geomembrane are not a concern as mentioned by the Solmax representative; however, movement of the geomembrane could exacerbate the condition during the SMA soil relocation activities and result in unacceptable geomembrane performance that could include crack development. GHD's concern is whether there is an acceptable method to verify material performance after it's been folded, rolled, and potentially creased or bent, and re-attached. This is not to say it's infeasible; but rather the quality of the work by the geomembrane installation contractor and verification of the reinstallation will require strict adherence to quality controls consistent with manufacturer's direction.

The Closure Plan should reference the necessity of additional geomembrane material that will be needed due to the addition of the SMA soils. This additional material required to join the cut material to the material left in place should be constructed such the seams are outside of 1.5 metres from the crest of slope.

Cutting of the upper portion of the existing geomembrane to open an area of the PEA poses some concerns for the integrity of the geomembrane. The geomembrane on the side slopes is currently in tension on either side of the PEA. By cutting the top portion, there is no longer any force anchoring the material in place aside from the friction between the smooth geomembrane and the underlying material. Table 4.2 of the Closure Plan indicates that the final cover layers, including the sand friction layer, the gravel drainage layer, and the common fill soil wedge will commence in March and be completed in October. The crest geomembrane is proposed to be cut in June. There is not sufficient detail as to what stage of cover soil placement will be complete at this time and there has not been an evaluation of the interface shear tension or potential for veneer slope failure without the support of the upper portion of the geomembrane during this construction period. At a minimum, GHD recommends that the wedge be constructed prior to cutting the geomembrane on the top slope for to preclude potential slippage of the geomembrane down the side slopes during the wedge's construction.

GHD discussed the proposed construction methodology with the geomembrane manufacturer, Solmax. Solmax noted that if the existing material is to be cut and welded to new material, the new material should be placed beneath the old material. Since the surface of the material may have some oxidation, wedge welding can occasionally fail to adequately seam the exposed material. However, in the event of a wedge weld failure, extrusion welding has been shown to perform adequately as long as welds are at least 1.5 metres from the toe or crest of a slope, since a grinder is first used to smooth out the surface of the geomembrane along the seam.

In GHD's experience, typical geomembrane installation requirements do not permit seaming within 1.5 metres of the crest or toe of slope. Based on the geomembrane cutting locations being 3 m from the top slope crest as illustrated on Figures 3-1 and 3-2, and assuming no geomembrane slippage (refer to recommendation regarding wedge construction prior to geomembrane cutting above), there are no concerns with respect to the location of the geomembrane cut.

Soil Relocation Procedure compromising long-term integrity of the landfill

As discussed above, GHD has some concerns regarding the overall methodology, feasibility, and quality controls related to the cutting, handling, and replacing of the existing geomembrane. Documented geomembrane manufacturer buy-in of this process is preferred. However, if the geomembrane is cut, handled, replaced and rewelded with appropriate quality controls, and the geomembrane manufacturer supports the quality control measures and the geomembrane's reuse, the long-term integrity of the landfill should be unaffected. The addition of the new welds, as long as they are at least 1.5 metres from the crest of the top slope, is not a concern.

4. Final Cover Design Review

Scope Item

Determine the adequacy of final cover system design and layers on landfill crest and slopes (including draintubes, gravel drainage layer, and toe drainage soak away trench).

- *a. Review the Closure Plan and identify if the cover system layers and design generally meets Landfill Criteria and provide a professional opinion on whether the proposal can reasonably be expected to adequately protect the environment:*

1. Identify risks associated with the proposed design, and where possible, suggest possible mitigation measures that could be enacted to minimize the risks.

Review

The 2016 Landfill Criteria requires the following layers in a geomembrane final cover system from top to bottom:

- Vegetative cover
- Minimum 150 mm of topsoil
- Minimum 450 mm of common fill
- Non-woven geotextile or sand layer equivalent
- Textured geomembrane and geocomposite equivalent to a 600 mm barrier layer with a hydraulic conductivity of less than or equal to $1x10^{-7}$ cm/sec

The Closure Plan final cover design has the following layers on the PEA top slope, from top to bottom:

- 500 mm topsoil
- Minimum 1,500 mm subsoil, with a hydraulic conductivity of $1x10^{-7}$ cm/s or less
- Draintube 606 ST4 D25
- 40 mil smooth LLDPE geomembrane
- 12 oz non-woven geotextile

The Closure Plan final cover design has the following layers on the PEA side slope, from top to bottom:

- 500 mm topsoil
- Minimum 1,500 mm subsoil, with a hydraulic conductivity of $1x10^{-5}$ cm/s or less
- 8 oz non-woven geotextile
- 5-25 clear crushed drainage gravel
- 12 oz non-woven geotextile
- 50 coarse sand friction layer
- 40 mil smooth LLDPE geomembrane
- Sand cushion layer

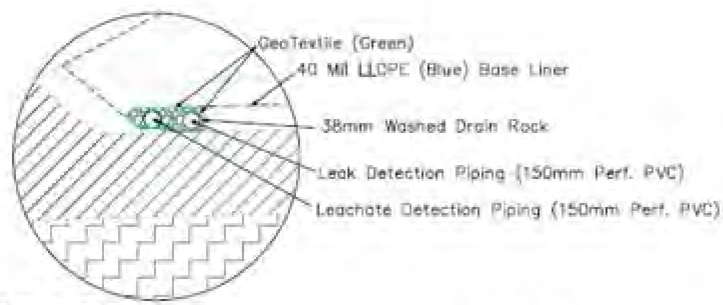
Both the top slope and side slope final cover systems exceed the required topsoil and general fill layer thicknesses. The draintube material proposed for the top slope consists of two non-woven, needle punched geotextiles surrounding a series of small perforated pipes. Therefore, both the top slope and side slope meet the requirement to have a non-woven geotextile between the common fill and the geomembrane.

In terms of the ability to prevent infiltration of precipitation, the smooth geomembrane can be expected to provide equivalent or better performance to a 600 mm barrier layer with a hydraulic conductivity of less than or equal to $1x10^{-7}$ cm/sec. Geomembrane covers offer very low permeability, to the point that their performance is generally dictated by the number and location of holes/defects in the geomembrane material/installation. The rate of leakage through such holes is also dictated by the pressure head above the geomembrane. The provision of a drainage layer, such as the drain tubes and gravel drainage layer, will minimize the amount of head that can accumulate on the geomembrane. Based on a review of QA/QC procedures documented in Section 2, the installed material can be reasonably expected to perform in accordance with the Landfill Criteria. However, the Landfill Criteria indicates that the geomembrane in final cover should be textured. Although no rationale is provided in the Landfill Criteria, textured geomembrane is generally used to provide additional friction between the geomembrane and underlying/overlying materials to increase slope stability. Textured geomembrane also facilitates construction as it is easier to walk on the material when installing on a side slope. From an environmental protection perspective, the smooth geomembrane would be considered equivalent to a textured geomembrane. However, there may be concerns with slope stability, which is discussed under separate cover in Task 1 of the Engineering Review.

The addition, the 1,500 mm of common fill with a maximum hydraulic conductivity of $1x10^{-7}$ cm/s on the top slope and at least 1,500 mm of common fill with a maximum hydraulic conductivity of $1x10^{-5}$ cm/s on the side slopes will be very beneficial in reducing the rate of infiltration of precipitation through the soil to the geomembrane. This exceeds the requirements of the Landfill Criteria and, as mentioned in the Closure Plan, contributes to the modeled expectation of 0.12 m^3/year of leachate generation. (GHD notes that $1x10^{-7}$ cm/s for the top slope is referenced in Section 4.2 and in Table 7-1, but Section 4.6.3 mentions $1x10^{-6}$ cm/s. This latter reference should be corrected.)

GHD reviewed the HELP model output files to evaluate the capability of the subsurface drainage layers to manage the anticipated infiltration. The HELP model indicates the draintube layer must be capable of managing an average of 300 cubic meters per year per hectare and the gravel drainage layer must be capable of managing an average of 11,740 cubic metres per year per hectare, plus the drainage from the draintube. Assuming the side slope gravel drainage layer accounts for the majority of the PEA surface area, the gravel drainage layer would need to manage a conservative 14,000 cubic metres per year or 39 cubic metres per day. With an assumed hydraulic conductivity of $1x10^{-3}$ m/s and a thickness of 200 mm, the gravel drainage layer would be capable to manage this flow.

GHD reviewed the figures in Section 4 for additional details related to the final cover system and drainage features. GHD notes that the PEA Toe Drainage Soak Away Trench appears to be constructed with minimal clay basal liner between the primary basal geomembrane and the toe drain as depicted in Figure 4-6. The 1.0-m thick secondary clay basal liner should be maintained between the primary basal geomembrane and the PEA Toe Drainage Soak Away Trench to contain a potential leak from the secondary clay basal liner system as depicted in the as-built drawings provided in Appendix B of the Cobble Hill Landfill Final Closure Plan Report (Sperling Hansen Associates, May 31, 2017):



Maintaining a full thickness of the secondary clay basal liner between the geomembrane and the PEA Toe Drainage Soak Away Trench will reduce the potential for migration of leachate beyond the secondary clay basal liner and into the PEA Toe Drainage Soak Away Trench. ENV may consider requesting that the details of the piping layout in the Closure Plan be revised to be consistent with the layout in the as-built drawings referenced above.

The side slope gravel drainage layer drains into a clear crush shot rock trench. This trench is to be hydraulically connected to the existing seepage blanket layer (fractured bedrock) underneath. Based on this construction and the minimal volume of water expected to reach the drainage layer, GHD does not have concerns regarding the capacity of the shot rock trench.

The Closure Plan, Section 4.3, references that the 2 metre total thickness of the topsoil and common fill layers will "*support a broader diversity of vegetation which will reduce the risk of long-term erosion damage and root penetration*" and references a document with supporting data. GHD agrees that the 1.5-metre thick fine-grained soil will inhibit the downward intrusion of plant roots, and that most plants' roots will remain within this 2 metre thickness; however documents such as CSAP Technical Guidance for Soil Sampling Depth to Characterize Ecological Exposure (Azimuth, 2013) reference deeper rooting depths. GHD recommends that this opinion be provided by a Registered Biologist (R.P.Bio). Although unlikely, GHD recommends that the biologist opine on borrowing and soil disturbance depths for vertebrates as it relates to the 2-m soil cover thickness.

5. Conclusions and Recommendations

Geomembrane Review

1. The continued use of the smooth 40 mil LLDPE geomembrane in itself can be reasonably expected to protect the environment (through minimization of infiltration) when properly installed and inspected, with a stable slope.

Recommendations for additional slope stability assessment and alternate cover construction, such as using a double sided textured geomembrane, are provided in the Task 1 letter provided under separate cover.

Functionality of Existing Geomembrane

2. It is Solmax's (the geomembrane's manufacturer) experience that LLDPE material exposed for 10 years still contains antioxidants and exhibits sufficient physical properties to function adequately. However, testing of the existing geomembrane will be necessary to confirm these assumptions, especially the geomembrane that is being cut, handled and reused during the soil relocation activities. Testing in accordance with a quality management plan and in accordance with manufacturer recommendations will confirm the status of the geomembrane's performance.
3. GHD recommends that Solmax be contacted to discuss the status of their manufacturer warranty against defects for the existing geomembrane that is proposed to be left in place and the geomembrane that is to be cut, handled and reused during the SMA soil relocation activities.
4. A quality management plan should be prepared with input from Solmax that helps maintain performance of the material. Any reduction in the geomembrane characteristics will need to be reviewed and assessed.
5. The manufacturer's quality assurance testing, observations by SHA, and observations by GHD during the 2017 Minor Works suggest that the cover geomembrane was properly installed.
6. The Closure Plan appropriately notes that inspection of the geomembrane will be completed prior to the placement of the remaining cover system. The ENV may want to consider having a representative on-Site during this inspection and/or after all repairs have been completed to corroborate the inspection and repair activities prior to the remaining cover materials being placed.
7. If a thorough inspection and testing of the existing geomembrane is completed prior to construction activities and in accordance with a quality management plan and manufacturer instructions, repairs are made in accordance with manufacturer instructions, and construction practices are implemented in accordance with manufacturer instructions to consider protection of the geomembrane, the material should continue to perform as designed.

Final Cover Construction Methodology

8. The relocations activities themselves as described in Section 3.2 of the Closure Plan, if completed with appropriate controls and verifications, should not pose a risk to the environment. However, additional procedures and details, which are described in Section 3 above, could be considered.
9. A concern is whether there is an acceptable method to verify material performance after it's been folded, rolled, and potentially creased or bent, and re-attached. This is not to say it's infeasible, rather the quality of the work by the geomembrane installation contractor and verification of the reinstallation will require strict adherence to quality controls consistent with the quality management plan and manufacturer's direction.

10. The Closure Plan should reference the necessity of additional geomembrane material that will be needed due to the addition of the SMA soils.

11. GHD recommends that the wedge be constructed prior to cutting the geomembrane on the top slope for to preclude potential slippage of the geomembrane down the side slopes during the wedge's construction.

12. Solmax noted that if the existing material is to be cut and welded to new material, the new material should be placed beneath the old material. Since the surface of the material may have some oxidation, wedge welding can occasionally fail to adequately seam the exposed material; extrusion welding has been shown to perform adequately as discussed in Section 3 of this letter.

13. Based on the geomembrane cutting locations being 3 m from the top slope crest as illustrated on Figures 3-1 and 3-2, and assuming no geomembrane slippage, there are no concerns with respect to the location of the geomembrane cut as it relates to the soil relocation activities.

14. GHD has some concerns regarding the overall methodology, feasibility, and quality controls related to the cutting, handling, and replacing of the existing geomembrane. However, if this work is completed with appropriate quality management plan and controls, and the geomembrane manufacturer supports the quality control measures and the geomembrane's reuse, the long-term integrity of the landfill should be unaffected.

Final Cover Design Review

15. From an environmental protection perspective, the smooth geomembrane would be considered equivalent to a textured geomembrane. However, there may be concerns with slope stability, which is discussed under separate cover in Task 1 of the Engineering Review. The use of the other cover materials, such as the Draintube, geotextiles, gravel and sand layers, is reasonable.

16. The 1,500 mm of common fill with a maximum hydraulic conductivity of $1x10^{-7}$ cm/s on the top slope and at least 1,500 mm of common fill with a maximum hydraulic conductivity of $1x10^{-5}$ cm/s on the side slopes will be very beneficial in reducing the rate of infiltration of precipitation through the soil to the geomembrane. This exceeds the requirements of the Landfill Criteria and, as mentioned in the Closure Plan, contributes to the modeled expectation of 0.12 m^3/year of leachate generation.

17. A conductivity of $1x10^{-7}$ cm/s for the top slope is referenced in Section 4.2 and in Table 7-1, but Section 4.6.3 mentions $1x10^{-6}$ cm/s. This latter reference should be corrected.

18. The PEA Toe Drainage Soak Away Trench appears to be constructed with minimal secondary clay basal liner between the primary basal geomembrane and the PEA Toe Drainage Soak Away Trench. The 1.0-m thick secondary clay basal liner should be maintained between the primary basal geomembrane and the PEA Toe Drainage Soak Away Trench to contain a potential leak from the secondary clay basal liner system.

19. Based on the proposed construction and the minimal volume of water expected to reach the drainage layer, GHD does not have concerns regarding the capacity of the shot rock trench.

20. GHD agrees that the 1.5 m thick fine-grained soil above the geomembrane will inhibit the downward intrusion of plant roots, and that most plants' roots will remain within this 2 metre thickness. However, GHD recommends that this opinion be provided from a Registered Biologist (R.P.Bio).

21. Although unlikely, the R.P.Bio. should also provide an opinion on borrowing and soil disturbance depths for vertebrates as related to the 2-m soil cover thickness.

Professional opinion on whether the proposal can reasonably be expected to adequately protect the environment

When considering the proposed materials of construction, GHD believes that the proposed materials can adequately protect the environment provided a detailed quality management plan be developed, and implemented prior to and during any construction activities associated with this project. (ENV may consider requesting that this quality management plan be submitted for review.) A detailed quality management plan will ensure that the original gemembrane properties are maintained throughout the construction process and ensure adequate protection of the environment. That said, the proposed materials will only adequately protect the environment if the final cover system integrity is maintained and GHD's concerns with respect to the Slope Stability Detailed Engineering Review – Task 1 are adequately addressed.

6. References

1. Azimuth Consulting Group. CSAP Technical Guidance for Soil Sampling Depth to Characterize Ecological Exposure, MOE Policy Decision Summary Issue 11. July 2013.

2. Geosynthetic Institute, Geomembrane Lifetime Prediction: Unexposed and Exposed Conditions, Updated February 8, 2011.

3. Islam, M. Zahirul, Gross, Beth A., Rowe, R. Kerry, Degradation of Exposed LLDPE and HDPE Geomembranes: A Review, Geo-Frontiers, 2011.

4. Nosko V., Andrezal T., Gregor T., Ganier P., SENSOR Damage Detection System (DDS) – The Unique Geomembrane Testing Method, Geosynthetics Applications Design and Construction, De Groot, Den Hoedt & Termaat, 1996.

5. Ossa, Mauricio. "Re: Solmax LLDPE UV Exposure Discussion". Email to Daniel Turner and James Reid. March 24, 2019.

7. Closing

We trust the above meets your present requirements. Should you have any questions or need clarifications, please do not hesitate to contact James Reid at 604-248-3669.

Sincerely,

GHD

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cc: Kirsten White (ENV)

April 2, 2019 Reference No. 11191916-03

Mr. AJ Downie
Director, Authorizations South
Environmental Protection Division
Ministry of Environment and Climate Change Strategy
2080a Labieux Road
Nanaimo, BC V9T 6J9

Original Sent Via Email

Dear Mr. Downie:

Re: Hydrogeological QP Review - Task 3
Review of the Cobble Hill Landfill Updated Final Closure Plan 2019
460 Stebbings Road Near Shawnigan Lake, British Columbia

GHD was retained by Ministry of Environment and Climate Change Strategy (ENV) to provide third party comments on hydrogeologic components that are discussed in the Cobble Hill Landfill Updated Final Closure Plan 2019 (Closure Plan) dated January 31, 2019 prepared by Sperling Hansen Associates (SHA) for the Cobble Hill Landfill located at 460 Stebbings Road near Shawnigan Lake, British Columbia (Site). Specifically, GHD reviewed the hydrogeologic conceptual model, the monitoring program and the trigger response plan included in the Closure Plan.

In addition, GHD reviewed a memorandum prepared by the ENV hydrogeologist, which provides the hydrogeologist's opinion regarding the above-referenced sections of the Closure Plan, supplemented by a telephone discussion.

1. Conceptual Site Model

Section 6 of the Closure Plan includes a hydrogeological conceptual model. The conceptual model includes a description of the regional and local bedrock geology and presents a conceptual understanding of the hydrogeologic features at the Site.

The discussion of the Site hydrogeology presented in the Closure Plan is summarized in the following points:

- A thin veneer of overburden (less than 2 m in thickness) overlies bedrock.
- The underlying bedrock is very competent and hard from surface to approximately 75 m below ground surface (bgs).
- The shallow bedrock does not readily transmit the flow of groundwater. This statement is reportedly based on a conclusion made by Active Earth Engineering Ltd. (Active Earth) [assumed by GHD to be from the "Technical Assessment for Authorization to Discharge Waste for the Site" (Active Earth, 2012)].

- Below 75 m bgs the bedrock is more highly fractured and groundwater yield from this zone is higher. The on-Site water supply well is completed within this zone and is capable of supplying 20 gallons per minute.

Packer testing of fractures observed in boreholes drilled within the competent mass of bedrock reported hydraulic conductivities of 1.1×10^{-7} m/s (at 19 m bgs) and 8.1×10^{-8} m/s (at 34 m bgs).

The Closure Plan states that there is very little risk to the underlying deeper bedrock flow system, given the lack of fractures within the upper 75 m of bedrock and upward gradients between deeper bedrock wells and shallower bedrock wells. Based on the lack of risk, the Closure Plan proposes elimination of all bedrock groundwater monitoring.

Although the above-described features are beneficial for protecting the deeper bedrock flow system, the data being relied upon to support the presence of these features is insufficiently robust to warrant elimination of all bedrock groundwater monitoring at this time. There are several reasons for GHD's position on this matter, as described in the following points:

- Static groundwater elevations within the shallower bedrock well installations experience wide fluctuations (up to approximately 5 m within a single year) indicating that the water levels within bedrock may be sensitive to recharge from surface. The fluctuations appear to be seasonally-related, based on the data presented on Figure 6.3 of the Closure Plan.
- Although upward gradients are more commonly observed, there are numerous occasions throughout the monitoring data set where the downward vertical hydraulic gradients were reported. This reversal has been observed at every monitoring well nest on several occasions, with no obviously seasonal correlation, as summarized in Table 1 below.
- The borehole logs for the monitoring wells installed at the Site do not generally indicate the presence of fractures, however, the boreholes were drilled with rotary drilling (no bedrock core available for identifying fractures) and contain very little detail regarding the bedrock characteristics and condition.
- The recurrence of hydrocarbon detections at MW6 and to a lesser extent at MW1, MW3S and MW3D could be indicative of impacts to bedrock groundwater quality from a surface source. This evidence further supports the interpretation that bedrock groundwater is sensitive to surface recharge.
- The variability of groundwater quality (at MW6 and to a lesser extent at MW4) supports the interpretation that groundwater within the bedrock could be affected by variable sources of recharge. This variability does not support the interpretation that all bedrock within the upper 75 m is competent.

Table 1.1 Summary of Vertical Gradient Measurements

Monitoring Well Nest	Number of Events with Upward Vertical Gradient Observed	Number of Events with Downward Vertical Gradient Observed
MW-01S/01D	18	3
MW-03S/03D	26	8
MW-05S-05D	8	11

2. Groundwater Monitoring Program

Section 10 of the Closure Plan outlines the proposed Environmental Monitoring Plan for leachate, groundwater, surface water and landfill gas. This review considers the groundwater monitoring portion of the monitoring plan only. Section 10.2 of the Closure Plan states that the objectives of the Environmental Monitoring Plan are as follows:

- "*Demonstrate compliance with the performance criteria.*
- *Demonstrate that monitoring results are consistent with the applicable plans and reports, including the groundwater and surface water impact assessment.*
- *Address the need for monitoring within 1 km of the landfill footprint.*
- *Given favorable results over time, the monitoring regime may be reduced upon review by a qualified professional."*

The groundwater monitoring plan includes monitoring at the three seepage blanket monitoring wells (SB- 1, SB-2 and SB-3). Monitoring frequency is to be dependent on precipitation with a minimum of two events annually. The analyte list includes 15 general chemistry and dissolved metals parameters. Although seepage blanket monitoring is an important component of the long-term groundwater monitoring strategy, it is GHD's opinion that this monitoring, on its own, is insufficient for the following reasons:

- The Site characterizations that have been completed to date have not adequately addressed the possibility of a water table aquifer within shallow fractured bedrock. Although it may be that such a shallow bedrock groundwater flow zone does not exist, there is insufficient information to verify this. If there is a shallow fractured bedrock water table, this groundwater would be the most susceptible natural flow zone to leachate leakage.
- It is not clear from the information provided in the Closure Plan that monitoring data from the three seepage blanket wells would necessarily detect leakage from the liner no matter where the leakage occurred. The effectiveness of this component of the monitoring program is based on the assumption that a release will be detected in those wells; however, the basis for this assumption is not clearly explained. This uncertainty further supports the interpretation that a better understanding of the potential for groundwater in shallow bedrock is warranted.

- The locations of the seepage blanket wells illustrated on Figures 6-1 and 6-4, which appear to be the locations of the wells as installed, are different than the proposed locations. In particular, SB-1 is located a considerable distance to the east of the originally proposed location. Because of this, there isn't a seepage blanket well located downgradient of landfill Cell 1C. The lack of a monitoring point downgradient of Cell 1C represents an important gap in the monitoring network, particularly considering the emphasis that is being put on the seepage blanket wells for early detection of leachate leakage from the landfill.
- It is not understood how the monitoring plan will satisfy the stated objectives if bedrock groundwater monitoring is eliminated.

The Closer Plan states that the chances of detecting landfill-related water quality impacts in the deep bedrock groundwater wells is extremely remote. Based on the information provided in the Closure Plan this statement is likely correct. The Closure Plan further states that the primary leachate migration path is through the seepage blanket and through surface water flow. Based on the conceptual understanding of the Site presented, this is also likely correct.

Notwithstanding these interpretations, the conceptual site model is based on an understanding of the Site which relies on relatively limited information concerning the Site hydrogeologic conditions. It is GHD's opinion that there are insufficient data to eliminate shallow groundwater within the bedrock as a potential receptor of landfill related water quality impacts at this time. The Closure Plan includes a contingency plan which involves the installation of two shallow bedrock wells (MW19-01 and MW19-02) downgradient of the landfill footprint. GHD concurs that shallow bedrock monitoring wells downgradient of the landfill area are prudent; however, GHD recommends that these monitoring wells be installed and monitored quarterly as part of the long-term monitoring program, and not reserved as a contingency response only. A rationale should be included as to the location and number of the wells.

3. Trigger Response Plan

Section 10.12 of the Closure Plan outlines the Trigger Response Plan portion of the Environmental Monitoring Plan. This section outlines a five-step approach that will reportedly be used in responding to an incident. The five steps included in the approach are:

1. Routine Monitoring
2. Confirmatory Monitoring
3. Additional Investigation to establish magnitude of problem
4. Mitigation Strategy to fix problem
5. Follow up monitoring to confirm mitigation strategy was successful

The five steps represent, in concept, a suitable strategy for identifying and responding to potential landfill- related impacts to environmental media. The Trigger Response Plan could be strengthened by defining a more precise method by which identification of impacts may be triggered. Although it may be adequate to rely on the professional judgment of a Qualified Person to interpret the results of routine and confirmatory monitoring, it would provide more confidence in the plan if the means of identification were more clearly defined (trigger parameters, trigger levels, statistics methodology, etc.).

It is noted that Section 2.3.3 states that the groundwater benchmarks developed based on the monitoring data are "a conservative estimate of trigger concentrations that would warrant potential initiation of the site's trigger and response plan". It is not clear from either section how these benchmarks will be used in the context of the Trigger Response Plan. The groundwater benchmarks are discussed in the following section.

4. Groundwater Quality Benchmarks

Section 2.3.3 describes the development of groundwater benchmarks for the Site's groundwater quality database. The benchmarks were reportedly created using the BC Ministry of Water, Land and Air Protection Protocol 9 *Determining Background Groundwater Quality* and Technical Guidance 12 *Statistics for Contaminated Sites*.

The benchmarks reportedly represent the 95^{th} percentile of the available data from 2011 to 2018 for monitoring wells MW-1S/D, MW-2, MW-3S/D, MW-4, MW-5S/D and MW-6. Early data from MW-1S was not included in the calculations due to suspected tampering of the well in May 2014. The calculated benchmarks are presented along with their respective interquartile ranges in Table 2.5 of the Closure Plan.

In general the approach for establishing groundwater benchmarks is suitable, however it is not considered appropriate to use water quality from the deep bedrock for establishing groundwater benchmarks for the purpose of comparing groundwater quality at shallow monitoring wells. It is GHD's opinion that it would be more appropriate to establish one or more background monitoring wells that are more representative of un-impacted water quality likely to be encountered in the seepage blanket monitoring wells or proposed (contingency) shallow bedrock groundwater monitoring wells.

In addition, as noted above, the water quality observed in MW-6 (and to a lesser extent MW-4) differs from the water quality observed in other monitoring wells on Site. Because of this difference in water quality it may not be appropriate to be using water quality from all sources for defining groundwater benchmarks for the deeper bedrock. A more thorough understanding of deeper bedrock water quality should be accounted for in establishing these benchmarks, if they are to be used for evaluating deeper bedrock groundwater quality moving forward.

5. ENV Groundwater Review

GHD conducted a review of a memorandum prepared by the ENV hydrogeologist (Mr. Rusto Martinka) dated March 27, 2019 (ENV memorandum). The ENV memorandum provides Mr. Martinka's opinion regarding the sections of the Closure Plan discussed above. Based on GHD's review of the ENV memorandum, GHD is in general concurrence with Mr. Martinka's assessment of the Closure Plan. The following points summarize important points of concurrence:

Conceptual Hydrogeological Model

- The competency of the bedrock is overestimated. The ENV memorandum provides several reasons for this opinion including visibly fractured quarry walls, packer test data, groundwater quality and the response of water levels to seasonal changes. GHD concurs with Mr. Martinka's opinion regarding the competency of the bedrock.
- Vertical gradients are not consistently in the upward direction. As described in Section 1 of this letter, there is sufficient evidence from field data that vertical gradients at nested monitoring wells fluctuate between upward and downward.
- The ENV memorandum recommends that the conceptual model is revised in light of the inconsistencies identified. GHD concurs with this recommendation.

Groundwater Monitoring Plan

- All monitoring wells at the landfill are too deep to effectively monitor groundwater near the upper water-bearing bedrock (i.e. water table).
- The proposed monitoring well locations aren't ideally positioned to identify potential leakage from the landfill.
- Mr. Martinka recommends that new shallow monitoring wells be installed prior to the landfill closure. Mr. Martinka further recommends that an independent document describing the environmental monitoring program is provided. GHD concurs with these recommendations.

Groundwater Quality Benchmarks

- The water quality from well MW-6 is considered unsuitable for background water quality monitoring. Based on a comparison of water quality at MW-6 compared to other monitoring wells on-Site, GHD concurs with this opinion.
- Mr. Martinka states that the proposed benchmarks appear high and recommends that they should be revised before their approval. In consideration of the discussion provided in Section 4 of this letter, GHD concurs with this recommendation.

6. Summary of Review Comments

1. The data being relied upon to support the presence of competent bedrock that protects the underlying lower aquifer is insufficiently robust to warrant elimination of all deeper bedrock groundwater monitoring at this time.

2. Although seepage blanket monitoring is an important component of the long-term groundwater monitoring strategy, this monitoring, on its own, is insufficient. There are insufficient data to eliminate shallow groundwater within the bedrock as a potential receptor of landfill related water quality impacts.

3. The Closure Plan includes a contingency plan which involves the installation of two shallow bedrock wells downgradient of the landfill footprint. GHD concurs that shallow bedrock monitoring wells downgradient of the landfill area are prudent; however, GHD recommends that these monitoring wells be installed and monitored quarterly as part of the long-term monitoring program, and not reserved as a contingency response only.

4. Based on GHD's review of the ENV memorandum, GHD is in general concurrence with Mr. Martinka's assessment of the Closure Plan.

7. Closing

We trust the above meets your present requirements. Should you have any questions or need clarifications, please do not hesitate to contact James Reid at 604-248-3669.

Sincerely,

GHD

PROFESSIONAL GEOSCIENTIST
LIMITED MEMBER
BENJAMIN KEMPEL
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4/02/2019

Ben Kempel, P.Geo. (Limited)

BK/vk/03

cc: Kirsten White (ENV)
James Reid (GHD)

March 28, 2019 Reference No. 11191916-05

AJ Downie **Original Sent Via Email**
Director, Authorizations South
Environmental Protection Division
Ministry of Environment and Climate Change Strategy
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Dear Mr. Downie:

Re: General Review and Comments – Task 5
Review of the Cobble Hill Landfill Updated Final Closure Plan 2019
460 Stebbings Road Near Shawnigan Lake, British Columbia

GHD was retained by Ministry of Environment and Climate Change Strategy (ENV) to provide any comments and recommendations resulting from general review of the Cobble Hill Landfill Updated Final Closure Plan 2019 (Closure Plan) dated January 31, 2019 prepared by Sperling Hansen Associates (SHA) for the Cobble Hill Landfill located at 460 Stebbings Road near Shawnigan Lake, British Columbia (Site) to supplement those provided in the other four submissions.

1. General Review and Comments

Scope Item

To inform the review being conducted by the ENV Engineer Scope of Review:

i. Provide any additional comments and recommendations resulting from general review of the Closure Plan in its entirety. Include identification of any areas of disagreement with SHA.

ii. Provide any additional comments and recommendations resulting from general review of the Covering Letter. Include identification of any areas of disagreement with SHA.

iii. Review the contingency plans and proposed contingency actions for each of the aspects discussed in the Closure Plan. Identify any gaps, deficiencies and proposed recommendations to improve contingency planning and proposed contingency actions.

iv. Provide comments regarding typical mechanism or scenarios of landfill closure failure, and identify whether or not these mechanisms are mitigated in the proposed SHA closure and post closure approach.

Review

1. Although not specifically referenced in the Closure Plan itself, the cover letter (page 9) references that record drawings will be signed by a Qualified Professional (QP).

2. The cover letter states "*Clay exceeds the requirements of the 1993 and 2016 LCMSW as per GHD*". This is correct, although, the clay permeability sampling was conducted in only one test pit completed in cell 1B. No testing was completed in Cells 1A or 1C. Refer to the comments in Section 3 of the GHD's December 11, 2017 letter, Clay Basal Liner Evaluation.
3. Regarding Sperling Hansen Associates' (SHA's) response on page 10, bullet 2, related to continuous oversight during the 2017 Minor Works, the following bullet was provided in GHD's December 11, 2017 "Final Report following Completion of the 2017 Minor Works": "*A QP was not continuously present on Site to supervise all minor construction works, as required by the SPO, from September 18 to 26, 2017, inclusive; however, as of the September 27, 2017 on-Site meeting with Ministry personnel, a QP was present continuously during the remaining minor construction works from September 27 to 29 and on October 5, 2017, inclusive, based on GHD's observations*."
4. The Closure Plan does not include a provision for inspecting the clay layer at the toe of Cell 1C. As recommended in GHD's December 11, 2017 letter, the Cell 1C clay basal liner thickness was not investigated during the 2017 Minor Works and could be investigated, similar to how Cells 1A and 1B were investigated, during the next phase of construction.
5. The seepage bed monitoring wells are not located on the figures in the correct locations other than Figures 6-1 and 6-4. GHD did not identify in the Closure Plan a rationale on whether the new locations would satisfy the objectives of the original locations, notably SB-1, which is not downgradient of Cell 1C as illustrated on the other Closure Plan figures. In addition, as a result, the third paragraph of Section 7.7 needs to account for the vertical extension of SB-1.
6. The Closure Plan should mention the need to extend the leachate conveyance valve stem as it is within the area of the soil wedge.
7. During installation of the new cleanouts, the QP can conduct an inspection of the leak detection layer where the pipe connections are made to support the conclusion provided in Section 7.2 that the primary basal geomembrane liner is operating as designed.
8. The eastern proposed cleanout should extend to the top of PEA on Figure 7-4 to be consistent with the details provided on Figure 7-6. An access road will likely be needed to access this cleanout with equipment, especially due to the already long length of the cleanout piping.
9. The references in Section 4.4 to needing additional geomembrane when reattaching the existing liner following the soil relocation, and tarping exposed areas should there be a risk of a rain event, should also be mentioned in the main soil relocation section, Section 3.
10. Section 4.8 references that the common fill will be placed in 300 mm lifts at 95 percent standard Proctor, whereas, the accompanying figures reference 600 mm lifts at 95 percent modified Proctor. This discrepancy should be corrected. GHD recommends that, if 600 mm lifts are to be used, justification should be provided as 300 mm lifts are more generally used.

11. Bi-weekly inspections by the QP are referenced in Section 4.11. A prior requirement from ENV for the 2017 Minor Works was continuous on-Site presence. ENV may want to consider the requirement for more frequent inspections, or at a minimum, identification by the QP of the activities on site that will trigger the “critical inspections”.

12. GHD notes that the schedule provided in the Closure Plan began in March 2019. A revised schedule should be provided.

13. The effectiveness of the contingency leachate collection trench discussed in Section 7.3 is dependent on further evaluation of the shallow bedrock being fractured as discussed in GHD’s Task 3 letter report related to an evaluation of the site’s hydrogeology. Additional discussion on trigger levels could be provided.

14. Understanding that detail may be provided in the detailed design, Figure 7-4 should conceptually illustrate how the surface water ditches and leachate contingency trench will interact. Similarly, reference should be made regarding the intersection of the storm water ditching and the leachate conveyance piping at the toe of the proposed wedge.

15. Please note that GHD did not complete ditch/stormwater modelling to provide specific comment on the ditch erosion protection measures discussed in Section 5.4, specifically which materials are proposed for specific slopes and capacities. The materials themselves appear reasonable.

16. Section 2.4 references that the settling pond will manage on-site stormwater to “*knock out any suspended sediments prior to discharge*”. Section 10.12.2 states “*In the event that run-off from the capped area exceeds some water quality parameters, run-off shall be stored in the settling pond until water quality is acceptable for discharge*.” GHD is unaware of whether an evaluation has been completed to confirm the stormwater settling pond’s capacity and ability to meet these objectives. ENV may consider requesting clarification on this aspect of the Closure Plan.

17. Section 10.4 references quarterly surface water monitoring frequency. Depending on how the above concern is addressed, ENV may consider requiring sampling during heavy rainfall events, when parameters such as turbidity could be elevated, to document stormwater quality.

18. ENV may consider whether the final inspection of the PEA cover geomembrane following all final repairs and prior to soil placement should be accompanied by ENV representative.

19. In general, geotextiles and liners terminate in anchor trenches or run-outs. ENV may consider requesting clarification on how the 12-oz and 8-oz non-woven geotextiles will be terminated at the crest of the PEA where they meet the draintube. Neither an anchor trench (which may not be feasible due to the presence of the existing geomembrane) nor a run-out is illustrated on Figure 4-3.

20. Regarding typical mechanism or scenarios of landfill closure failure, these include, but are not limited to:

    i) During closure works: puncturing the liner, pipe fusing or liner welding failure, poor distribution of vegetation, slope failure/erosion or other unintended material movement.

ii) Clogging of leachate collection system

iii) Liner leakage or other failure due to, for example, erosion from weather, intrusion of plant roots, borrowing animals, settling, human-caused damage, damage from the generation of landfill gas

iv) Failure of leak detection system or leak monitoring network (e.g., monitoring wells)

v) Slope failure

vi) Leachate treatment failure

In general, the closure works meet or exceed the 2016 Landfill Criteria requirements, are an improvement over the Cobble Hill Landfill Final Closure Plan Report (Sperling Hansen Associates, May 31, 2017), and appear to be protective of the environment. However, GHD has identified in this Task 5 letter and the other letters related to Tasks 1 through 4, comments and questions for ENV consideration to further help address concerns regarding potential failure mechanisms at the Site.

2. Conclusions and Recommendations

Section 1 of this letter provides a list of GHD's comments on the Closure Plan and its cover letter, and recommendations for ENV consideration.

In general, GHD agrees that the closure works meet or exceed the 2016 Landfill Criteria requirements and are an improvement over the 2017 Cobble Hill Landfill Final Closure Plan Report, subject to comments and considerations provided herein and the four separate GHD letter submissions related to Tasks 1 through 4.

3. Closing

We trust the above meets your present requirements. Should you have any questions or need clarifications, please do not hesitate to contact James Reid at 604-248-3669.

Sincerely,

GHD

James A. Reid, P.Eng., P.E.

JAR/vk/05

cc: Kirsten White (ENV)
David Barton (GHD)

Memorandum

Ministry of Environment and Climate Change Strategy
Environmental Emergencies and Land Remediation Branch

May 15, 2019

<u>Land Remediation Section Review of Cobble Hill Landfill - Updated Final Closure Plan</u>

This memo summarizes Land Remediation Section (LRS) comments on those aspects of the January 31, 2019 Updated Final Closure Plan (Plan) prepared by Sperling Hansen Associates (SHA) that pertain to proposed future land use, the proposed methodology for characterization/classification of soils proposed to be accepted at the site to construct the stabilizing soil wedge, and an issue that has recently come to the attention of the ministry regarding Contaminated Sites Regulation (CSR) environmental soil quality standards and their application to sites receiving large volumes of imported soil such as what is being proposed in the Plan.

Proposed future land use

According to the Plan, the local CVRD land use zoning definition (“Primary Forestry (F-1)”) has significant breadth and would appear to be inclusive of several CSR land use categories including residential (“single family residential”, “bed and breakfasts”), agricultural (“agriculture, horticulture, silviculture”), industrial (“extraction, crushing and milling of aggregate material”) and likely even commercial. It is LRS’ understanding that local government has primary responsibility and authority regarding land use within their areal jurisdiction.

LRS considers CSR industrial land use (IL) applicable to quarry use as well as a landfill such as the Cobble Hill Landfill when it is in operation and until such time as closure activities (e.g., engineering controls, institutional controls, etc.) have been designed, implemented and confirmed in such a way as to potentially allow higher land use(s).

The Plan also indicates that “Section 2 of the site’s Quarry Permit Q-8-094 amended October 28, 2015 states that the surface of the land and watercourses shall be reclaimed to the following land use: Forestry/Industrial”, a zoning category that is not specifically defined in the Plan but which appears to be encompassed by CVRD’s zoning definition, inclusive of industrial land use. Nearby land (as close as 200m to the landfill site according to the Plan) is zoned by the CVRD as “Community Land Stewardship”, which falls into both the residential and commercial CSR land use categories.

As a general comment in situations where land may be used for more than one different use, the most stringent/conservative CSR standards are typically chosen to ensure appropriate human health and environmental protection across the range of possible site uses.

In summary, the Plan proposes ongoing industrial land use at the site; therefore, IL is the applicable generic/numerical CSR land use category and associated standards that apply.

Should changes to the proposed industrial land use be contemplated in the future, a number of implications would likely arise for the land/landfill owner including the possible need for additional site investigation/assessment, engineering/institutional controls, etc. A proposed future land use change may also require applying for local government authorizations such as a development and/or building permit, which may in turn trigger requirements under Part 4 of the *Environmental Management Act* (EMA) and Contaminated Sites Regulation (e.g., preparation and implementation of a site-specific risk assessment and risk management plan to ensure adequate ongoing protection of human and environmental health).

Proposed methodology for soil characterization/classification

Qualified professionals providing expertise and advice under EMA Part 4 and the CSR follow to characterize both in-situ and ex-situ soil at sites. Although we understand from our discussions with ROB that there may be some misunderstanding on the part of the Plan authors regarding authorization to move soil from the SMA to the PEA, it is assumed that any necessary approvals for this (and the importation of cover fill materials) would be provided alongside any approval of the Plan.

Section 4.8 of the Plan addresses proposed importation of “common fill” for the purpose of construction of a stabilizing soil wedge and the final facility cover. The Plan further proposes that the imported soil be demonstrated to meet CSR industrial quality standards. To this end, it is recommended that a licensed, qualified professional (ideally an Approved Professional under Part 4 of EMA) be required to characterize all soil – prior to shipment to the Cobble Hill Landfill – in accordance with “Technical Guidance 1 - Site Characterization and Confirmation Testing” (TG1) and to provide a signed statement of assurance confirming soil quality.

It should also be pointed out to Plan authors that a twelfth stage of amendment was made to the CSR in January 2019, so it must always be the most current version of that regulation that is referenced and used.

The Plan correctly identifies TG1 as appropriate technical guidance for characterization and classification of any soil proposed for importation to the site and further provides that a “Waste Approval Application” (see Appendix E to Plan) will document imported soil quality. Since it is unclear (and potentially variable) who the “Authorized Representative of Generator” will be on the Appendix E form, the accompanying certification is not as focused as it should be. It is therefore recommended that the form be amended to ensure that a licensed qualified professional is a mandatory signatory certifying that all incoming soil has been characterized and classified in accordance with ministry expectations.

It is further recommended that the Plan include a requirement to document the specific deposit locations of each shipment of imported and classified soil for potential future reference.

Potential concern regarding imported soil volume

As part of Land Remediation's Soil Relocation Legislative Review Project, an issue regarding potential limitations (in terms of ensuring adequate environmental protection at receiving sites) to the generic/numerical CSR soil standards has been identified. Proposed legislative/regulatory changes – although not yet fully researched and developed – would be intended to establish any additional protective measures (e.g., site/facility management practices) that may be necessary to adequately protect environmental and human health arising from high volumes of imported soil (typically > 20,000 m^3).

Due to the present absence of any special guidance or recommendations for the above circumstances, LRS recommends that the landfill closure design, implementation and monitoring programs be carried out to ensure that any changes in water quality arising from the deposition of large volumes of industrial quality soil (wedge and final cover materials) will be detectable. In tandem with the earlier recommendation to require documentation of soil deposit locations, the land/landfill owner and the ministry should be in a better position to develop any future response that may be necessary in connection with the proposed soil deposition.

Additional comment

As high-level comment which is beyond the soil importation matters addressed above, the Plan is fundamentally a proposed engineering solution for ongoing encapsulation of contaminated soil to protect the environment and human health. As such, the primary professional expertise needed to design, implement and verify the solution must come from civil/geotechnical engineers and hydrogeologists; however, should unacceptable concentrations of contaminants ever escape, then the professional expertise of a human health and ecological toxicologist and risk assessor may be required. Regarding the latter expertise, the Plan should recognize – perhaps through the development of supporting contingency plans – the potential need for additional assessments.

LRS recommends that appropriately licensed and qualified professionals be required to provide clear, explicit statements of assurance for any design, implementation (including monitoring), assessment and verification work they carry out in connection with closure of the Cobble Hill Landfill.

Shawnigan Research Group (SRG) Critique of Sperling Hansen Associates (SHA) Updated Final Closure Plan Dated January 31, 2019

March 29, 2019

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MAJOR PROBLEMS IN THE UPDATED CLOSURE PLAN

1) *<u>P. 2-13, Acid Rock Drainage Problem:</u>* "To limit the potential for acid rock drainage (ARD) and to stabilize the soil Portland cement was added at a rate of 200 Kg/m3 at the PCT site prior to shipment. An additional 100 Kg/m3 of cement were added prior to compaction in the landfill."

Shawnigan Research Group Response: In the January 4, 2019 meeting with the Ministry and SHA we were astonished that SHA was not informed of the significant elemental sulfur deposited in the PEA – somewhere between 2.5 and 5 thousand tonnes, likely the latter. We note that some soil samples tested as high as 24.9% elemental sulfur. The Ministry was aware of this problem especially since it had been specifically brought up by a Contaminated Sites Specialist, Gary Hamilton in a prior meeting on June 8, 2018 with Ministry officials. <u>We find it very problematical that the Ministry did not inform SHA of this sulfur problem and question why</u>. We see that SHA now has attempted to address this problem of high elemental sulfur-containing soils.

The problem we have with the above statements concerning Portland cement addition is whether they are true. We note that the Quarterly and Annual Reports state that no Fly-Ash was deposited on site. Despite these statements we have documented tankers clearly labelled FLYASH depositing a dusty material (we assume fly-ash) onto the PEA (see Appendix 1). Thus, we have little trust in any after-the-fact statements made by the Named Parties. There was nothing in the Quarterly Reports that indicated the PCT soils had previously been treated with Portland cement. Indeed, during the Community Protest in December of 2015 we noted that the soils coming from Port Moody were saturated, dripping water onto the road. It is difficult to understand how this would be possible if 200 Kg of cement had been added to each cubic metre of soil. We must keep in mind that according to Hemmera the As-Builts presented to Hemmera usually were not correct and often contradicted what Hemmera observed. Also, we note that the Quarterly Reports stated that no Fly-Ash was added to the soils dumped onto the PEA while we documented the unloading onto the PEA of a very dusty material from a tanker clearly labelled FLYASH – see Appendix 1 of this Critique. If materials from a tanker labelled FLYASH was added to the PEA and according to the Quarterly and Annual Reports no fly-ash was added, why was the tanker labelled FLYASH? One can see why we do not trust any statements from the Named Parties. We need to independently verify that 200 Kg Portland cement was added prior to shipment. We also note that the leachate is becoming progressively acidic which is not congruent with Portland cement being added in the amounts stated.

Our Contaminated Sites Specialist Gary Hamilton pointed out to the Ministry in the June 8, 2018 meeting that no landfill site in BC would accept sulfur-rich soils. The reason for this is clear if we examine the Alberta Ministry of Environment regulations concerning sulfur disposal in landfill sites. This fact about the Pacific Terminals soil being rich in elemental sulfur appeared to be a surprise to Ministry staff in the June, 2018 meeting. If this be the case, then it is clear that Ministry staff were not properly monitoring the Waste Disposal Permit.

In the Alberta Sulfur regulations it is stated that any soil containing more 0.04% elemental sulfur (and some of the Port Moody soils had up to 24.9% elemental sulfur) must be deposited in landfills according to the following conditions (emphasis added for critical aspects of the regulations):

"**6.1 Small Quantities of Sulphur Waste**

When disposing of small quantities of S-waste at approved Class I or Class II landfills, the person responsible for the S-waste and the person responsible for the landfill receiving the S-waste must jointly ensure that the S-waste is mixed stoichiometrically with alkaline product prior to or upon disposal. This is critical when the small quantity of S-waste is disposed of into a cell/trench that has not been specifically designed to receive industrial waste or S-waste only.

Exceptions to mixing may apply when the small quantities of S-waste is

- pyrophoric S-waste such as spent iron sponge being disposed of at Class I landfills; or
- industrial equipment such as containers, vessels, heat exchangers, piping, or similar units not suitable for mixing with alkaline products; or
- disposed of into a cell or trench dedicated to S-wastes only.

In these cases, the S-waste must be disposed of as per the encapsulation *alternating method* described in 6.2.2. Persons responsible for pyrophoric S-waste should take special precautions when handling, transporting, storing and disposing of this waste by keeping it moist to prevent the fire hazard. Pyrophoric waste can not be disposed of into approved Class II landfills unless the waste is previously treated to a non- hazardous condition.

Certain S-waste spent slurries or sludges from gas sweetening processes must be dewatered to a solid condition prior to landfill disposal of the solids. The liquid phase has to be further treated and/or disposed of at approved facilities.

The following applies to landfill disposal of small quantities of solid S-waste (from https://open.alberta.ca/dataset/3cf0451d-9f44-45e6-a798-c6878a7b107a/resource/5ca6d33c-bd23-4df8-99f9-b6e56b458b91/download/2011-guidelines-landfill-disposal-sulphur-waste-remediation-sulphur-september-12-2011.pdf):

(a) **an area should be designated for the disposal of S-waste within a landfill cell/trench where incompatible wastes (municipal solid organic wastes and other wastes prone to generate acidic leachates) must not be co-disposed of with the S-waste.**

(b) **the designated area shall be at least 1.5 m above the water table;**

Co-disposal of S-waste with municipal solid waste is not an acceptable waste management practice.

(c) **the bottom and sides of the designated area should be lined with a 0.30 m thick layer of finely ground alkaline product applied in consecutive compacted lifts 0.10-0.15 m (4-5 inches) thick;**

(d) at the generating site or immediately upon arrival at the landfill, the S-waste should be mixed with alkaline product prior to or after placement in the cell/trench at the ratios described in section 4.1. (Note the exceptions mentioned above for pyrophoric S-waste, industrial heterogeneous equipment, or multi-loads of small quantities of S-waste going to the same dedicated cell/trench described in section 6.2.2.)

(e) **after mixing and/or layering, the S-waste should be immediately covered with a uniform layer of alkaline material in an amount and thickness equal to 10-15 % of the amount used to line the cell; and**

(f) an intermediate or final cover, as applicable, shall be applied over the S- waste plus alkaline material to prevent water percolation.

Limestone, lime or other alkaline products used as neutralizing agents in landfills should be no coarser than the commercially available product known as "3/8th minus". A laboratory investigation which involved leaching a solution of sulphuric acid through columns of this limestone product indicated a considerable margin of safety is provided as long as a significant content of fine particles is present. Removing the particles which pass a 60 mesh sieve significantly increased the percolation rate and jeopardized pH control. The limestone grain size has to be balanced with site stability, erosion and dust formation.

Alkaline materials, other than those identified in section 4.2, have to be assessed on a case by case basis with respect to their ANC (expressed as calcium carbonate equivalent) and other constituents/contaminants that might be present.

The objective in lining the disposal cell with alkaline material is to provide additional safety against the formation of acidic leachate. When disposing of small quantities of S-waste into cells/trenches that are not dedicated to S-wastes only, a layer of limestone/lime about 0.3 m thick should provide such a margin of safety. Between active disposal periods, an intermediate cover, preferably an alkaline product or buffer should be placed on top of the S-waste to minimize dust, erosion and leachate.”

In addition, the Alberta guidelines provide the following information for stoichiometric addition of neutralizing agents:

“STOICHIEOMETRIC (sic!) MIXING and encapsulation with alkaline products apply to the disposal of small quantities of S-waste. The weight of alkaline product in the mixture per each kilogram of sulphur is (detail in section 4.1)

3.2 kg for limestone (calcium carbonate)
2.4 kg for hydrated lime (calcium hydroxide)
1.8 kg for quick lime (calcium oxide)”

Shawnigan Research Group Comments: The Alberta Government is not as blasé as SHA in the disposal of sulfur-containing soils. Why should the BC Ministry of Environment and Climate Change be so blasé?

SHA states that the permanent cover will prevent oxygen and water from penetrating the elemental sulfur in the PEA. The problem with this is that no one knows exactly where in the PEA the sulfur-laden soils are, And, if one examines Figure 1 of this critique and Figure 2 of the Appendices of the Updated Final Closure Plan one can readily see that rain water and groundwater can enter the PEA bringing not only moisture but also oxygen. <u>Why is SHA not concerned about rain water entering the PEA containing sulfur-laden soils?</u>

<u>Does SHA know much sulfur-containing soils from PCT has been brought on site and what the tonnage of elemental sulfur was in all the soils dumped into the PEA?</u>

<u>2)</u> <u>*In addressing the Ministry's point #3 (p. 11 of the Plan):*</u> "Four test pits were completed during the 2017 Minor Construction Works by CHH with oversight from GHD (Ministry consultant) to assess the presence and integrity of the basal clay liner, and soil samples were collected (by GHD); the results of the investigation are documented in GHD's December 11th 2017 Clay Basal Liner Evaluation Report. Four (4) test pits were completed with three of the four locations showing a minimum 1.0m thick clay liner was in place. Although GHD found that the clay at one of the test pits was less than 1 metre thick (as per the 1993 Landfill Criteria), GHD indicated that the dual liner system is considered to "exceed the 1993 Landfill Criteria Requirements. Additionally, GHD indicates that existing secondary liner generally meetings (sic!) the requirements of the 2016 LCMSW. It should be noted that the basal clay liner test pits were completed outside (north toe) of the PEA basal liner area and all indications show that the clay basal liner is in fact 1.0m thick under the PEA base."

Shawnigan Research Group Response: What the GHD Report dated December 11, 2017 actually states is: "The clay liner thickness observed in TP-1, TP-2 and TP-3 was generally 1 metre, athough several locations were observed to be between 0.7 and 1 metres as illustrated in the photographs. The clay liner thickness in TP-4 was not confirmed as it was excavated only to identify the clay liner; a clay liner thickness of 0.5-m was observed prior to backfilling the test pit but the clay liner thickness was not confirmed." <u>SHA appears to have a selective interpretation of the GHD report.</u>

<u>3)</u> <u>*GHD Request/Comment #2 (p. 11 of the Plan):*</u> "As outlined previously, SHA does not recommend that Cell 1C base liner be exposed during construction of the final cover system. It is SHA's opinion that at this point ensuring the final cover layer provides an effective cap to reduce infiltration and leachate generation, as well as re-confirming the monitoring program is sufficient through completion of an updated conceptual model, is the most appropriate strategy for closure and for environmental protection."

Shawnigan Research Group Response: What this ignores is that there is no anchor trench that would prevent rain (and other) water from permeating the clay liner that forms the base liner. See Hemmera's May, 2017 Report (Section 5.3.3, p. 25 that states: "The leakage detection system collector pipe does not appear to be properly located to intercept leakage liquids. Since approximately November 2016 when the cover liner was installed and welded to the basal geomembrane, any precipitation that collects along the upper portions of Cell 1 is expected to infiltrate between the bedrock and the geomembrane, and accumulate within the leak detection sand layer." This was pointed out to SHA by the SRG members during the January 4, 2019 meeting. <u>We are surprised that SHA would ignore this part of Hemmera's Report.</u>

Figure 1 illustrates how rain water and ground water can penetrate the base of the PEA.

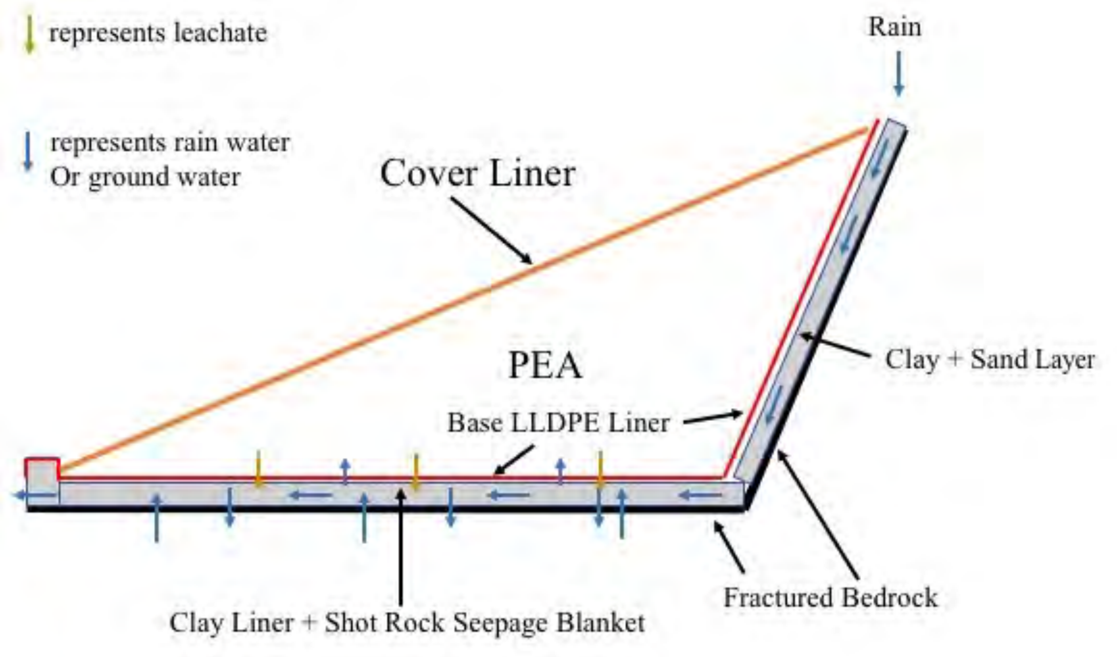


Figure 1. Diagram shows how leachate can pass through failed seams and ruptures in the base LLDPE liner to enter the ground water and if the area of the seepage blanket is saturated with water, then water can penetrate the PEA itself. The diagram also shows how rainfall at the edge of the PEA where it abuts the south-easterly and south-westerly walls can enter the space between the LLDPE base liner and the fractured bedrock.

Further, from GHD's report we know that the clay has a high concentration of smectite (>30% weight) according to the December 11, 2017 GHD Report. The presence of smectite increases the permeability of the clay liner due to several factors and, thus, is undesired as an impermeable clay liner – see peer-reviewed paper by J.B. Joseph et al. 2001. Variation in clay mineral performance in the presence of leachate. *Proc of Sardinia 2001, 8th International Landfill Symposium. Oct 2001*, S. Margherita di Pula, Cagliari, Italy. Edited by: Christensen, T. H., Cossu, R. and Stegmann, R. Vol. III, pp.255–264. Cagliari: CISA.

See also Section #11 of this Critique for additional information about the problematical aspects of high smectite clay.

<u>We find the failure to acknowledge that smectite is problematical very troublesome; indeed, the Updated Closure Plan seems to suggest that high smectite clay is desirable.</u>

<u>4)</u> <u>*GHD Report/Request #3 (p. 13 of the Plan):*</u> "As above, no new liner extension is planned in the new design. SHA has provided technical justification in the 2019 Closure Plan which supports leaving the existing smooth 40 mil LLDPE liner in place and providing additional stabilizing and environmental protection measures, as outlined in Chapter 4. The black geomembrane liner contains carbon black UV protection which allows the liner to maintain its functionality even when exposed to sunlight for many years. A service life of at least 20 years is expected geomembrane lined ponds (sic!)."

<u>*And from p. 4-2 of the Plan (p. 4-2, second last paragraph):*</u> "SHA has also determined through literature, industry examples, and observations from the CHH 2018 pre-winter liner inspection produced by Islander Engineering Ltd., that there have been no adverse effects of UV radiation or other forces to the existing PEA liner."

<u>*And from p. 4-2 of the Plan (p. 4-2, last paragraph):*</u> "SHA has determined there will be no adverse effects of loading caused by the increase in final cover thickness on existing infrastructure including PVC SDR 28 leachate/leak detection piping,…"

Shawnigan Research Group Response: It should be noted that a possible service life of 20 years in lined ponds is irrelevant to considering the cover liner degradation on Lot #23 since water and especially organisms growing in water absorb a significant amount of the UV light and this is not the case in liners directly exposed to the atmosphere. The superficial visual inspection by Islander Engineering could not determine changes in the chemical and mechanical properties of the liner; hence, the Islander Engineering report has little credibility. We note that in the paper by Ojeda *et al.* (see below) it is stated that within 1 year of sunlight exposure the structural integrity of an LLDPE liner, even laden with anti-oxidants, is markedly diminished. So how has SHA determined that there will be no adverse effect of increased loading on the cover liner?

We are surprised that SHA, a company that boasts on its website about designing better landfills, is relying upon CHH businessmen for expert advice about landfill liners. On p. 18 of the Plan SHA writes: "SHA acknowledges the existing liner has been exposed to sunlight since Fall 2016. CHH provided literature to the MOE which indicates liner exposure, similar to that of the PEA, is not a longterm issue. Service life of exposed HDPE and LLDPE liners is generally considered to be 20 plus years."

Also surprising to us is the unfamiliarity of SHA with research on the effect of sun exposure on LLDPE liners, even those that contain anti-oxidants. Note the paper by T. Ojeda *et al.* 2011. Degradability of linear polyolefins under natural weathering. *Polymer Degradation & Stability*, **96:** 703-707.

The abstract of this paper states (note emphasis in bold added):
"High density polyethylene (HDPE), linear low density polyethylene (LLDPE), and isotactic polypropylene (PP) containing antioxidant additives at low or zero levels were extruded and blown moulded as films. An HDPE/LLDPE commercial blend containing a pro-oxidant additive (i.e., an oxo-biodegradable blend) was taken from the market as supermarket bag. These four polyolefin samples were exposed to natural weathering for one year during which their structure and thermal and mechanical properties were monitored. This study shows that the real durability of olefin polymers may be much shorter than centuries, **as in less than one year the mechanical properties of all samples decreased virtually to zero, as a consequence of severe oxidative degradation**, that resulted in substantial reduction in molar mass accompanied by a significant increase in content of carbonyl groups. **PP and the oxo-bio HDPE/LLDPE blend degraded very rapidly, whereas HDPE and LLDPE degraded more slowly, but significantly in a few months**. The main factors influencing the degradability were the frequency of tertiary carbon atoms in the chain and the presence of a pro-oxidant additive. **The primary (sterically hindered phenol) and secondary (phosphite) antioxidant additives added to PP slowed but did not prevent rapid photooxidative degradation, and in HDPE and LLDPE the secondary antioxidant additive had little influence on the rate of abiotic degradation at the concentrations used here.**"

<u>We find it surprising that SHA is not cognizant of the scientific literature that actually examines the response of polyethylene liners to sun exposure.</u> Would SHA please list the peer-reviewed journal articles on which they base their assessment of the service life of the LLDPE liner used on the site, under the conditions to which the liner has been exposed.

<u>5)</u> *<u>David Morel's Request for Comments 3 d. (p. 17 of Plan):</u>* "iii) SHA's primary strategy to address environmental concerns is to ensure the landfill is closed with a properly designed final cover system; this will reduce the amount of infiltration into the waste and reduce leachate generation. The suitability and chemical stability of the Victoria clays is discussed in Section 2.4 of the 2019 Closure Plan. In addition, the EMP that is in place is designed to monitor the effectiveness of the basal liner. As outlined Chapter 7, the predicted leachate generation is very low. If the monitoring results indicate the liner is failing, contingency measures have been included, such as: a Leachate cut-off trench at the North toe of the facility which can be implemented under QP recommendation"

Shawnigan Research Group Response: The problem with a cut-off trench at the North toe of the facility is that this will not capture leachate penetrating fissures that can move the leachate in different directions. We note that on occasions polyaromatic hydrocarbons are found in Monitoring Well #6 (and on occasion in the leachate). Such polyaromatic hydrocarbons are products of incomplete combustion and cannot be explained away as being normal groundwater constituents.

Nothing is known about the surface of the bedrock under the seepage layer (the blast rock on top of the bedrock). If leachate is moving through the basal liner and the clay, it will move immediately to the bedrock surface since the seepage blanket layer has high conductivity. The leachate will pool in the craters on the surface of the bedrock. SHA has pointed out that overblasting has resulted in the development of many fractures within the bedrock – see Section #5. No one has any idea in which directions the leachate could move, although the presence of polyaromatic hydrocarbons in Monitoring Well #6 and Seepage Blanket Wells 2 & 3 strongly supports the idea that the leachate can move in many directions through the fractures in the bedrock.

As for the suitability of Victoria clays please go to Section #11 below.

6) *Obfuscation on p. 2-12 of the Final Plan. On p. 18, SHA writes:* "Previous analysis of deep monitoring wells has shown that the potentiometric surface in groundwater wells developed in the deep competent bedrock is near the quarry floor (see Active Earth drawing Figure 6, Detailed Cross Section B at Quarry) 2012-02-21. It is important not to confuse this piezometric surface in the competent bedrock with the water table. The water table has consistently been observed several metres below the pit floor when drilling blast holes, according to CHH representatives, providing clear evidence that an upward gradient exists beneath the landfill site."

Shawnigan Research Group Response: Relying upon CHH representatives on where the water table lies is problematical since CHH provided As-Builts that Hemmera had deemed incorrect and often contradictory to what Hemmera has observed. Further, from the perspective of whether there is a chance of ground water contaminating the PEA, the distinction between the potentiometric surface and the water table becomes irrelevant when the bedrock is fractured. In SHA's own words: "Overblasting of the competent Wark Gneiss bedrock has opened up fractures that now allow groundwater to permeate more freely than was the case in the past."

As can be seen even SHA acknowledges the possibility that fractures in the bedrock allow water to upwell into the PEA because of hydrostatic pressure. The distinction between the water table and piezometric levels is irrelevant in this situation. So why is this brought up?

7) *Executive Summary p. vii (Conceptual Hydrogeologic Model):* "Groundwater within the region of the encapsulation area will travel in a north easterly direction, in addition to groundwater north of the encapsulation area."

And P. 6.3 of the Plan, third last paragraph: "Figure 6-4 illustrates the groundwater flow conceptual flow map for the Landfill and Figure 6-2 illustrates a hydrogeologic cross section showing the groundwater elevations and predominant flow directions. There is a groundwater flow divide located east of the Landfill and separates groundwater flowing into Shawnigan Creek and its tributaries and groundwater flowing to the Landfill."

Shawnigan Research Group Response: There is no evidentiary basis for this conclusion by SHA. We have no idea about the fractures within the bedrock and the direction water travels in these fractures. We note that on occasion polyaromatic hydrocarbons are noted in Monitoring Well #6. These products of incomplete combustion are also in the PEA and do not form a natural constituent of the local groundwater, thus it is likely that they came from the PEA and migrated in a south-easterly direction to MW#6.

Further, SHA's Figure 6.2 represents a very selective use of data. It uses data from the rainy months when rain water influences the levels of the wells. One notes at the bottom of the graph shown in the Updated Final Closure Plans's Figure 6.2 that in the summer and early fall period of 2018, the wells are at essentially the same metres above sea levels. This is also seen in the Groundwater levels figure in the Quarter 3 Report of 2016 (Page 7 of the Report (p. 13 of pdf) and shown as Figure 2 in this Critique. Here there is essentially no difference between MW#1S and MW#3D and wells in between. Using winter well level data to argue the direction water will travel we consider to be deceptive.

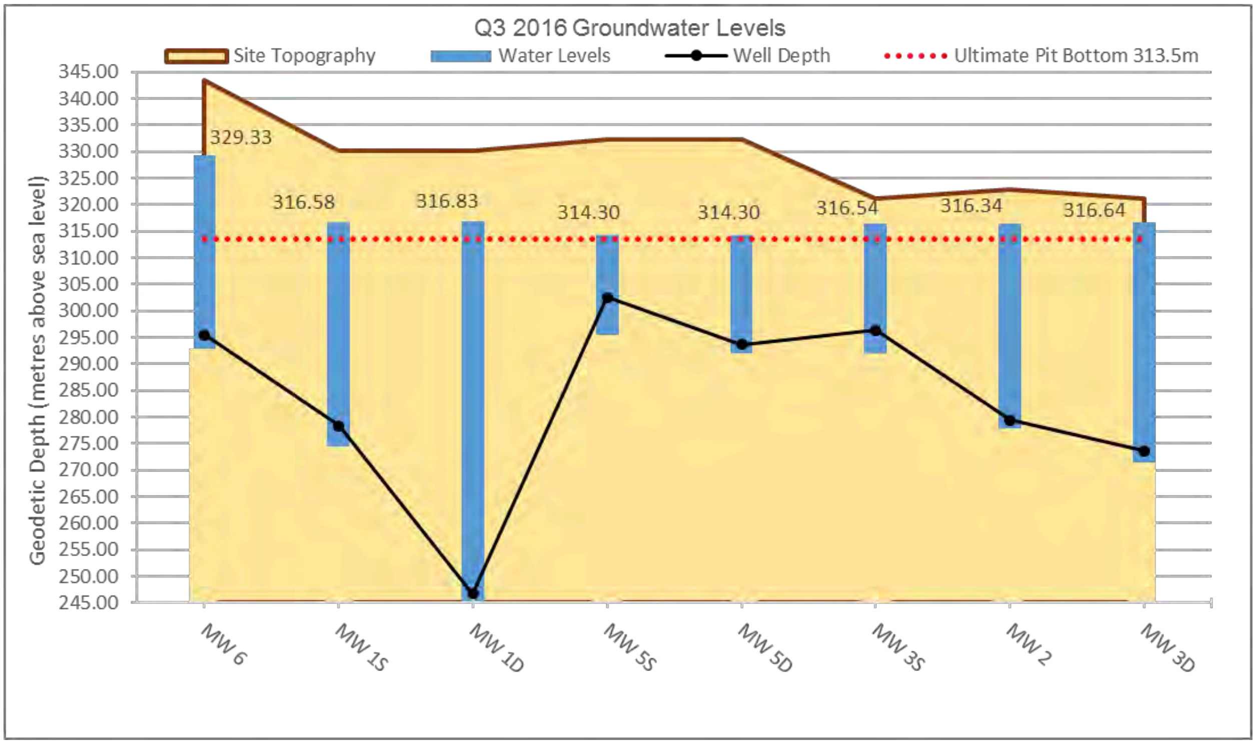


Figure 2. Water levels in the monitoring wells shown taken from the Quarter 3, 2016 Report by the Named Parties.

Also we point out that SHA's hydrogeological model is based upon Active Earth Engineering Technical Assessment Report. We note that Justice Sewell's decision was based, at least in part, on "Active earth or some entity representing its principals to perform the engineering work required for the Facility in exchange for a 50% interest in the business operating the Facility", an arrangement not disclosed to the Environmental Appeal Board. Active Earth's business interest in the outcomes of the Permitting process renders all of its analyses suspect.

8) *P. 2-7 of the Plan: 2.3 Environmental Conditions:* "CHH completes water quality monitoring and reporting for the CHL for groundwater monitoring wells, seepage blanket

monitoring wells (SB), surface water and leachate. Based on the most recent reporting period available to SHA (September 2017 to April 2018), the results indicate the works are functional and are working as intended in accordance with the SPO."

And Leachate Management Strategy, p. 7.2: "Of note, since the construction of this collection and storage system, no leachate has been generated by way of the leak detection system, proving the existing leachate collection system below the primary basal liner of the PEA is operating as designed."

Shawnigan Research Group Response: These statements are not correct since we know from both observations by SRG and Hemmera that the leak detection system is not working. From Hemmera's May 26, 2017 Report (Section 5.3.3, p. 25):

> "The leakage detection system collector pipe does not appear to be properly located to intercept leakage liquids. Since approximately November 2016 when the cover liner was installed and welded to the basal geomembrane, any 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. However, the leak detection system has not identified any flow from the sand layer to date."

We did point the problem with the Leak Detection/Collection System to SHA in the January 4, 2019 meeting. The problem pointed out by Hemmera is illustrated in Figure 1 of this Critique. Why is SHA ignoring yet again information provided by the SRG?

9) *P. 2-7 of the Plan: 2.3.1 Hydrocarbons in Groundwater:* "Inconsistent hydrocarbon concentrations at low levels have been historically observed at MW-05 and MW-06, within 5 times respective detection limits, as shown in Table 2-3 and Table 2-4."

Shawnigan Research Group Response: This statement is rather disingenuous. Of course, there are low levels hydrocarbons resulting from degradation of plant materials in the ground water. ***What should not be present are polyaromatic hydrocarbons such as benzo(a)pyrene that are products of incomplete combustion.*** Such hydrocarbons are not naturally present in the local ground water but have been found on occasion in the leachate, in MW#6 as well as in the Seepage Blanket Wells 2 & 3. How does SHA account for the presence of these products of incomplete combustion?

10) *Page 2-11 of the Plan: Post Closure Monitoring Locations and Key Parameters:* "To provide insight on changes in groundwater chemistry, SHA recommends that a Piper Plot analysis be undertaken to interpret the quarterly sampling data."

Shawnigan Research Group Response: Tri-Linear Piper Plot analysis is an inappropriate tool to determine whether the site is leaking. These plots are only suitable for comparing the ionic composition of a set of water samples to another. Piper plots cannot tell anything about whether one site is influencing another in ionic composition. But if SHA insists on this then we point out that SB2 nestles close to the leachate in the Piper plot represented in Figure 2-4 of the Plan. <u>How does SHA interpret this?</u>

> <u>*11) Basal Seepage Layer:* From p. 2-11 of the Plan</u> "Basal Seepage Layer: SHA was not involved in the detailed design nor construction QA/QC of those systems. However, the base of the landfill is being developed in a rock quarry. We have been assured by representatives of CHH that a continuous layer of shot rock was achieved by overblasting the rock quarry a minimum depth of 2.0 m below design grade prior to placement of the clay barrier. During SHA's presence onsite during the '2017 Minor Construction Works' several test pits were completed during leachate conveyance piping construction as well as the installation of the Seepage Blanket Wells where it was confirmed that the Seepage Blanket Layer seemed to be a minimum of 2.0m in depth. Overblasting of the competent Wark Gneiss bedrock has opened up fractures that now allow groundwater to permeate more freely than was the case in the past. This shallow layer is referenced as the seepage blanket"

Shawnigan Research Group Response: Being reassured about facts by CHH which has provided As-Builts that contradicted what Hemmera observed is not reassuring to the SRG. Note, we directed the attention of SHA (and the Ministry) in the January 4, 2019 meeting, to the Hemmera Report of May 26, 2017. On p. 23 of this Report Hemmera that the As-builts were different from what was observed in the field and often contradicted what was observed. From the Report:

> "**5.1. As-Builts**
> The as-built plans were significantly different from what was observed in the field and **often contradicted information presented in provided reports***. The As-Built package does not appear to be complete, up to date, and accurately reflect current conditions at the existing facility."

*Emphasis added.

The fact that overblasting of the competent Gneiss bedrock has opened up fractures that now allow groundwater to permeate freely completely contradicts the previous statement by SHA in the executive Summary (p. 7): "Only a few fractures have been observed in the bedrock during drilling, rendering the deep rockmass nearly impervious." <u>Why does SHA appear to selectively grab 'information' supplied by CHH that supports whatever argument is currently being made?</u>

We point out that the LLDPE base liner at the northern toe of the PEA is at 329.44 metres above sea level (masl). With the seepage blanket layer comprised of shot rock being a minimum of 2 metres below the LLDPE liner, this means the fractured quarry floor below the PEA is at 327.44 masl or even lower, we have a problem of potential ground water upwelling into the PEA as well as rain water potentially entering the PEA as shown in Figure 1 of our Critique. Note from the

Quarterly Reports issued by the named Parties, the water levels of monitoring wells #4 and #6 can be as high as 333.31 masl (December 2015) and 327.61 masl (Feb 2016), respectively, that is well above the fractured bedrock below the PEA. The upwelling of groundwater as well as rainwater coming down along the sides of the PEA should be of concern since this can bring partially oxygenated water up into the PEA itself. Why is SHA ignoring these data?

12) *P. 2-12, last paragraph:* "Clays with an ilitie, chlorite and smectite mineralogy are generally considered relatively stable and in case of reactions typically convert to minerals that have higher cation exchange capacity."

Shawnigan Research Group Response: This statement is not true.

From M.K. Widomski et al. 2016. Sustainability of compacted clays as materials for municipal waste landfill liner. *Middle Pomeranian Society of the Environment Protection*, **18:** 439-454: "Our research showed that if the sustainability of compacted clay liner is considered, high plasticity clays, of significant content of clay and fine (clay + silt) particles, clay minerals and swelling clay minerals (il- lites and smectites), as well as the low content of coarse fraction should be avoided."

And from A. Allen. 2001. Containment landfills: The myth of sustainability. *Engineering Geology*, **60:** 3-19: "Clay liners also pose problems as the smectite components of bentonite liners are subject to chemical interaction with landfill leachate, leading to a reduction in their swelling capacity and increase in hydraulic conductivity."

And from Austin *et al.* 1986. The role of clay minerals in disposal and storage of hazardous materials. *New Mexico Geology*, **November Issue**, pp 79-82: "If engineered disposal sites are developed, they commonly are constructed principally of locally occurring smectitic clay bearing rocks or artificially emplaced clay barriers of Wyoming bentonite containing sodium smectite However, these clay minerals expand in water and can undergo relative expansion or collapse due to replacement of water by other solvents, cation exchange, or increasing ionic strength at the clay-solvent interface (Griffin et al., 1985). If relative collapse and flocculation of the clay structures occur the result will be cracks and much higher permeability."

It is clear that the scientific literature states that smectite minerals are not desired as landfill liners even if they convert to minerals with a higher cation exchange capacity since this also introduces problems. We are surprised that in a company that prides itself as having expertise in landfills the QPs are not aware of the literature, and if they are, this is even more worrisome.

13) P. 2-13 & 2-14, Acid Rock Drainage Problem: "In the worst case scenario that the capping system allowed some infiltration and the cement neutralization potential was not sufficient to neutralize acid produced, ARD would potentially be generated, leading to dissolution of some metals such as iron and manganese. The resulting leachate would still be effectively contained by the liner system and would then be neutralized on site and hauled off site for disposal."

SRG Response: SHA is ignoring our data that show the base LLDPE liner for Part B of the PEA was laid down in the rainy November of 2015 and the liner sections could not have been welded together in the rain thus leaving large areas that allow leachate to pass through. SHA is also ignoring the data we presented with all the problems in laying down the liner of the Part C of the PEA. A liner that had gouges, tears and other marks indicating the excavator (spreading a thin layer of sand onto the LLDPE liner of Part C of the PEA) tracks directly contacted the LLDPE. Why is SHA ignoring the documentation presented by the SRG?

SHA is also ignoring the presence of polyaromatic hydrocarbons in Monitoring Well #6 and the Seepage Blanket wells as well as the very different ionic compositions of these wells compared to other monitoring wells on site and nearby residential wells.

14) P. 2-14, 40 mil LLDPE Liner: "The CHL PEA is lined with a 40-mil geomembrane which serves as the primary liner. The double liner approach adopted by CHL makes the PEA much more secure than most MSW landfills in B.C. that contain far more hazardous wastes."

Shawnigan Research Group Response: Imperfectly sealed LLDPE liner together with a high smectite-containing clay liner that often does not meet the 1.0 metre requirement does not give rise to assurances of great security. GHD's report on the clay liner integrity points out this smectite problem as well as some of the clay liner is much less than the 1.0 metre required and in areas may be as little as 0.5 metres.

As far as the 'far more hazardous waste' in other landfills, the Contaminated Sites Specialist Gary Hamilton has informed us, as well as the Ministry, that there is no other landfill site in BC that accepts sulfur-laden soils. Unlike SHA, Contaminated Sites Specialists consider elemental sulfur to be hazardous. We also note, the extensive efforts that are required by Alberta landfills in dealing with elemental sulfur indicating that Alberta considers elemental sulfur to be extremely hazardous. We ask why SHA's conclusion regarding the handling of elemental sulfur is so different from CSAP's that deal with elemental sulfur.

15) P. 2-14, 40 mil LLDPE Liner: "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. However, as SHA has not had any involvement in the construction of this liner, we cannot warrant the liner integrity or service life, but only offer a professional opinion that a long service life is expected."

Shawnigan Research Group Response: SHA clearly has ignored our photographs demonstrating that the sand cushion on top of the liner clearly was not 200 mm and ignored the many defects in liner placement. We also wonder why, if true, a service life of 100 years is satisfactory to SHA and the Ministry since the PEA will be there for an eternity. This ridiculous 100-year service life is a number that SHA and other landfill companies simply pull out of the air. There is no experimental evidence supporting such statements. When landfills lined with clay and a geomembrane are actually examined over time, we see that some landfills start leaking within 1 or 2 years and the majority are leaking within 30 years. We have previously sent the Ministry peer-reviewed papers on this topic but did present any such papers to SHA because we assumed that a professional landfill company would be cognizant of what science says about landfill liners. For example, a paper by Pivato shows that some liners begin leaking within a year or two and that more than 60% of landfills double-lined with a geomembrane plus >1 metre clay liner leak within 30 years: A. Pivato. 2011. Landfill liner failure: An open question for landfill risk analysis. *Journal of Environmental Protection* **2:** 287-297.

> *16) P. 2-14, Leachate Collection System:* "The leachate collection layer was constructed of a 300 mm thick sand layer built at 2% grade and with perforated leachate collection pipes. As the PEA has been fully encapsulated and will remain fully encapsulated once the new final cover"

Shawnigan Research Group Response: In a previous paragraph SHA states the leachate collection sand layer was 200 mm, now it is 300 mm. As pointed out earlier, there was no 200 mm sand layer and certainly no 300 mm sand layer. Further, the leachate collection system was not comprised of a sand layer with perforated pipes. There are no perforated pipes in the sand layer. This ignorance on the part of SHA reinforces our thinking that the Final Closure is completely unreliable.

> *17) P. 2-14, Soil Filter:* "A geotextile filter was not installed in the PEA above the sand drainage layer. Hemmera has raised concerns about this alleged omission. There is no requirement for a filter layer in the 1993 Landfill Criteria."

Shawnigan Research Group Response: We point out that a geotextile filter was present in the Technical Assessment Report, a report that the Permit was based upon. We also note that a possible reason for the decrease in leachate collection is that the sand layer of the leachate collection sand layer is being clogged by fines. This seems a reasonable explanation for the use of hydronix filters by the Named Parties this past January. If the leachate is silted up, then we have a problem with the leachate collection system.

18) *P. 6.2 of the Plan, second last paragraph:* "It has been concluded by Active Earth that the geology and hydrogeology of the Landfill indicate that the shallow bedrock does not readily transmit the flow of water."

Shawnigan Research Group Response: This conflicts with the previous statement by SHA: "Overblasting of the competent Wark Gneiss bedrock has opened up fractures that now allow groundwater to permeate more freely than was the case in the past." Also, why is SHA dealing with conclusions by Active Earth or CHH for that matter. These are the people who provided misleading As-Builts and/or misled the Environmental Appeal Board.

We find it strange that SHA's Updated Final Closure Plan contains contradictory statements: one moment stating that the shallow bedrock does not readily transmit water and the next that overblasting has created many fractures within the bedrock? How does SHA explain such contradictions?

We bring forth for your attention the Judgement comments in the Decision rendered by Justice Sewell in:

> **Shawnigan Residents Association,** Petitioner
> And
> **Director, *Environmental Management Act*, Cobble Hill Holdings Ltd. and Environmental Appeal Board**, Respondents
>
> Justice Sewell has written:
> "[175] I am satisfied that the Board was misled about the true nature of the relationship between Active Earth and CHH and the fact that Active Earth's principals were partners in the proposed Facility. That is information that ought to have been disclosed to the Board. I am also satisfied that Mr. Block deliberately concealed that information from the Board in his testimony on behalf of CHH."
> "[179] I also find that CHH filed misleading evidence in this Court."

The Shawnigan Research Group believes that the work of Active Earth CANNOT be used by SHA until that work has been reviewed by the Environmental Appeal Board, as directed by Justice Sewell.

19) *Leachate Management Design Contingency, p. 7.3:* "If the seepage blanket monitoring wells and/or leak detection system indicate the basal liner is failing and leachate is being released into the environment, SHA has conceptualized a Leachate Contingency Ditch / Trench at the downgradient toe of the landfill as shown in Figure 7-4."

Shawnigan Research Group Response: The problem with this is that there is no evidence that leachate will only flow into the toe of the PEA; indeed, the Seepage Blanket Well number 1 is usually dry in summer whereas Seepage Blanket Wells 2 & 3 contain water in the summer, indicating there is flow from the area of the PEA via fractures into SB2 and SB3 but not into SB1(situated at the toe).

Further, we note that on occasion SB2, SB3 and Monitoring Well #6 have polyaromatic hydrocarbons that are products of incomplete combustion:

a. MW6 January 31, 2018: Benzo(a)anthracene: 0.084 µg/L; Benzo(a)pyrene: 0.074 µg/L; Benzo(b+j)fluoranthene: 0.307 µg/L; Benzo(g,h,i)perylene: 0.167 µg/L; benzo(k)fluranthene: 0.167 µg/L
b. SB3 January 31, 2018: Benzo(a)anthracene: 0.024 µg/L; Benzo(a)pyrene: 0.038 µg/L; Benzo(b+j)fluoranthene: 0.085 µg/L; Benzo(g,h,i)perylene: 0.084 µg/L
c. Benzo(a)pyrene on April 24, 2018 also seen in SB2 and SB3

The simplest explanation for these hydrocarbons is that they are derived from the PEA. Such hydrocarbons are also at times present in the leachate (e.g., the December 17, 2018 test of leachate). We know that the PEA has soil that contains such polyaromatic hydrocarbons. From the 2015 Annual Report, Revised April 27, 2016, p. 10:

Table 4. Imported Soil Quality 2015 - Polycyclic Aromatic Hydrocarbons

Polycyclic Aromatic Hydrocarbons (ug/g)	Weighting Factor	MAX	Mean (n=20)	MIN	ST. DEV.	MAX PAHTEQ SUM
Benz(a)anthracene (0.1 MRL)	1	2.46	0.47	< MRL	0.7	4.2066
Benzo(a)pyrene (0.1 MRL)	0.1	3.08	0.54	< MRL	0.9	
Benzo(b)fluoranthene (0.1 MRL)	0.1	4.30	0.66	< MRL	1.3	
Benzo(k)fluoranthene (0.1 MRL)	0.1	1.69	0.34	< MRL	0.5	
Dibenz(a,h)anthracene (0.1 MRL)	1.1	0.42	0.09	< MRL	0.1	
Indeno(1,2,3-c,d)pyrene (0.1 MRL)	0.2	1.91	0.33	< MRL	0.6	
					PAHTEQ HWR Guideline =100	

We also know that such polyaromatic hydrocarbons are present in fly-ash. These products of incomplete combustion are not naturally found in groundwater.

Also, as we have pointed out to the Ministry, the ionic composition of Monitoring Well #6 and Seepage Blanket Wells 2 & 3 is very different from those of the other monitoring wells as well as nearby household wells – see Appendix 2. The Ministry claims that MW#6 has a different ionic composition because this well penetrates deeper into the aquifer. If one goes to the Annual and Quarterly Reports by the named Parties it clearly can be seen that MW#6 is a relatively shallow well and is certainly not deeper than most of the other monitoring wells.

As for SHA's Seepage Blanket Well comment on p. 2-7: "Leachate that is generated from the Landfill is collected and sampled before being transferred to an off-site treatment facility. The leachate is observed to be high in chloride and sodium, and illustrates conductivity of between 5,680 – 13,000 µS/cm. In contrast, samples collected from the seepage blanket wells show conductivities of 41 – 1,310 µS/cm." If the latter statement is meant to imply that the Seepage Blanket Wells do not contain leachate because the conductivity is lower than the leachate, this shows a surprising naiveté on the part of SHA with respect to the hydrogeological conditions at the site. Any leachate leaking from the site would be diluted by the ground water coming either through fractures in the bedrock (mentioned by SHA as pointed out elsewhere) or by rain water that has penetrated between the liner and surrounding walls (southern and western walls) around the PEA (Figure 1 of this Critique). ***Keep in mind that although the As-Builts showed anchor trenches, there are no anchor trenches holding the base LLDPE liner in place and that would prevent such rain water from penetrating below the base LLDPE liner***.

We ask what is the purpose of pointing out that the conductivities of the Seepage Blanket Wells are lower than the conductivity of the leachate.

<u>*20) Onsite treatment of leachate, p. 7.5:*</u> "The amount of leachate generated is very small. Leachate is treated onsite, post sampling, to reduce certain constituents, for offsite licensed discharge on Vancouver Island."

Shawnigan Research Group Response: According to the Spill Prevention Order leachate can be treated only at a site that is authorized to treat and/or dispose of leachate: "The Named Parties must ensure that all Leachate generated at the Facility, including from the landfill, soil management area and wheel wash area, is collected, stored temporarily pending removal from the Facility, and transported from the Facility to an off-site facility that is authorized to treat and/or dispose of the Leachate." CHH is not authorized to treat leachate. Why is it currently allowed to treat leachate?

Another question concerns what treatment is the leachate subjected to? We note that often the analytical results of leachate composition is post-treatment. We need to know what is present in the leachate prior to treatment. The public has a right to know to know this since the contaminated soil landfill is in a public watershed. We need to know which filters were used, the nature of the filters and what the filters were filtering out.

We point out that the treatment in January, 2019 used Hydronix filters. Hydronix filters can only filter sediment and/or hydrocarbons. If hydrocarbons are being filtered out then we need to know the hydrocarbon content of the leachate prior to filtration. If sediment is being filtered out then this indicates there is a problem with the leachate collecting sand blanket. The likely problem is that fines have clogged up the sand blanket and leachate is running through sand-free channels bringing fines to the leachate collection tank. And if this be the case then we have additional pressure pushing leachate through openings in the base LLDPE liner and from there through the sides of the clay berms surrounding the base of the PEA. <u>What are SHA's comments regarding the use of Hydronix filters?</u>

<u>*21) SHA is mistaken to claim that clean fill needs to be brought in to fulfill their updated final closure plan.*</u>

Shawnigan Research Group Comments: What SHA seems not to be aware of is that clean fill to reclaim the quarry has already been brought onto the adjacent Lot #21. This fill has been brought in to specifically reclaim the quarry on Lot #23. Lot #21 is owned by SIA (which initially held the quarrying Permit for Lot #23), a sister company to CHH with the same owners. We bring your attention to the July 16, 2015 Ministry of Energy and Mines Information sheet (See Appendix 3) that states (on p. 2):

"Mines Act Permit Q-8-331; Lot 21

- Mines Act permit issued to South Island Aggregates Ltd. in June, 2010
- Under this permit, SIA authorized to operate an aggregate quarry at the site. Annual production shall not exceed 200,000 tonnes.
- Soil importation is permitted; soil imported must meet the Ministry of Environment guidelines for the intended end land use (residential; zoned F-1, Primary Forestry)
- The purpose of the imported soil is to back-fill the quarry under Mines Act permit Q-8-094
- To date no mining extraction has taken place under this permit "

Permit Q-8-094 is the permit allowing quarrying activities on Lot #23.

The Shawnigan Lake residents want the contaminated soil in the PEA to be removed from their watershed. Interestingly, SHA appears to be concerned about the environmental impact of moving the soil from the PEA to elsewhere: "Furthermore, relocating nearly 100,000 tonnes of soil to an alternate facility would introduce another level of environmental impacts including traffic risks associated with 8,000 round trip movements, GHG emissions, dust release, etc." Yet they do not have similar concerns to bringing 70,000 or so tonnes of soil from elsewhere to cover the PEA on Lot #23. <u>We are sure that SHA will be pleased to learn the soil on Lot #21 can be used in the final cover, thereby minimizing the impact on the environment.</u>

Shawnigan Research Group Final Conclusions: The Updated Final Closure Plan is as badly flawed as the previous versions. The Ministry of Environment and Climate Change should not recommend approval of this Closure Plan to the Minister.

APPENDIX 1

Figure A-1. Tanker on site clearly labelled FLYASH.

Figure A-2. Material from the tanker labelled FLYASH being dumped onto the PEA.

APPENDIX 2

Comparison of Nearby Private Wells to MW6, SB2 and MW3D

(Unless otherwise indicated, the units are µg/L)

Item Measured	Private well (360 m SSE of the PEA) Feb 16, 2018	MW6 Dec 27, 2017	MW6 Sept 26, 2018	SB2 Dec 27, 2017	SB2 Sept 26, 2018	MW3D Dec 27, 2017	MW3D Sept 26, 2018	Private well (1,850 m NNE of the PEA) Jan 23, 2017	Leachate Collected Dec 27, 2017	Leachate Collected Aug 28, 2018
Conductivity uS/cm	Not done	1,320	1,300	624	674	250	253	Not done	11,100,000	11,500,000
Hardness (as $CaCO_3$)	122,000	560,000	530,000	237,000	262,000	95,000	117,000	82,100	2,700,000	3,050,000
Total Chloride	Not done	39,200	37,200	39,200	32,000	2,240	5,650	Not done	2,610,000	2,820,000
Total Sulfate	8,340 (calculated from total S)	86,700	87,700	63,400	168,000	21,500	22,500	Not done	1,390,000	1,560,000
Total Barium	2.96	88.5	82.3	32.9	29.1	20.5	21	<9	59.4	64
Total Boron	20	86.1	75.2	29.5	52.5	27	23.3	<50	288	293
Total Calcium	38,200	192,000	167,000	91,500	90,100	33,300	32,400	24,000	881,000	882,000
Total Copper	0.98	3.21	2.33	17	14.6	<0.4	0.58	<8	3.5	6.2
Total Iron	<10	1,950	3,170	6,600	4,440	135	270	<10	94[1]	87[1]
Total Lead	0.219	0.96	1.02	1.77	1.48	<0.2	<0.2	0.5	<0.2[2]	<0.2[2]
Total Lithium	<1.0	12.7	11.6	2.06	1.63	0.16	0.25	Not done	0.5	0.6
Magnesium	5,930	37,100	35,400	13,200	15,300	5,470	5,760	5,400	244,000	241,000
Total Manganese	106	2,230	2,060	264	179	279	361	<4	29,400	28,100
Total Potassium	253	4,380	3,270	2,510	1,950	680	590	214	20,900	21,400
Total Sodium	8,560	73,600	64,200	30,000	23,000	11,500	11,200	5,790	1,560,000	1,590,000
Total Strontium	157	619	583	285	298	193	196	59	4,320	4,550
Total Uranium	0.28	8.27	6.91	1.55	1.18	0.69	0.792	Not done	0.6	0.3
Zinc	<3.0	7.2	13.7	15.5	12.9	<4.0	4.6	34	14.6	52.6

[1]Iron can fluctuate, e.g., on the May 4, 2017 the iron content was 1,180 micrograms/L leachate and on Oct 8, 2016 it was 369,000 micrograms/L; [2]Lead can also fluctuate, e.g., on Oct 8, 2016 the lead content was 266 micrograms/L leachate

APPENDIX 3

July 16, 2015

BRITISH COLUMBIA

Ministry of Energy and Mines

Information Sheet

on

South Island Aggregates Ltd.

Legislation governing mining in British Columbia

- Mines Act
- Health, Safety and Reclamation Code for Mines in British Columbia
- Other Provincial legislation as applicable

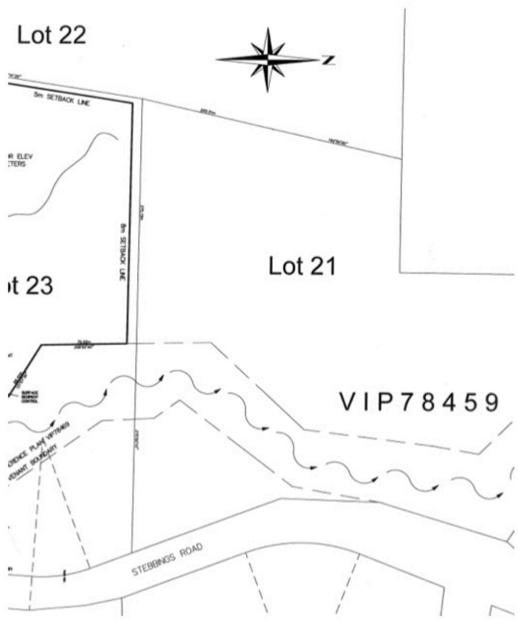
Mines Act Permit Q-8-094; Lot 23

- Mines Act permit issued to South Island Aggregates Ltd. (SIA) in October,2006, amended 2009, 2012
- Under this permit, SIA authorized to operate an aggregate quarry at the site.
- Annual production shall not exceed 240,000 tonnes.

- Permit 105809 issued under the Environmental Management Act by the Ministry of Environment lies within the footprint of Mines Permit Q-8-094.
- As all activity within the mine footprint needs to be authorized under the Mines Act permit, an amendment is required before SIA can bring in material under the EMA permit
- All decisions regarding amendments to Mines Act permits are made by statutory decision makers in the Ministry of Energy and Mines.

Inspections and Compliance

- Inspections occur at intervals that are determined by a risk matrix that takes into account the type of mine, the size, the compliance history and other factors
- Inspections are also made in response to public complaints and specific incidents
- Inspectors make site visits unannounced
- The last inspection of this mine was made on July 9, 2015; one minor non-compliance was found
- An inspection on June 16, 2015 resulting from a production blast that encroached upon the 5-metre buffer zone resulted in an order to prepare and implement an engineered design to restore the damaged area of the buffer zone as well as prepare a blasting procedure, by a blasting consultant, that will include recommendations to prevent future encroachment into the buffer zone from blasting
- The company has submitted the above plans but they have not yet been approved by the Ministry



Mines Act Permit Q-8-331; Lot 21

- Mines Act permit issued to South Island Aggregates Ltd. in June, 2010
- Under this permit, SIA authorized to operate an aggregate quarry at the site. Annual production shall not exceed 200,000 tonnes.
- Soil importation is permitted; soil imported must meet the Ministry of Environment guidelines for the intended end land use (residential; zoned F-1, Primary Forestry)
- The purpose of the imported soil is to back-fill the quarry under Mines Act permit Q-8-094
- To date no mining extraction has taken place under this permit

Inspections and Compliance

- The last inspection of this mine was made on July 9, 2015; no non-compliance was found
- On May 13, 2015 staff from the Ministry of Environment sampled imported soils to determine if they met the objectives set out in the Mines Act permit. Results can be obtained through MOE
- On May 1, 2015 a Stop Work Order was issued with respect to the importation of soils onto the mine site; to date, this order has not been rescinded

File: Cobble Hill Holdings Ltd.
Date: April 29, 2019

RE: Addendum to Review of Groundwater Information in the Cobble Hill Landfill Closure Plan

This is an addendum to my previous review of groundwater information presented in the 2019 Cobble Hill Landfill Closure Plan. The objective of this addendum is to review the groundwater information presented in the Amendment to Cobble Hill Landfill Update Final Closure Plan 2019 document (Amendment), which was prepared by Sperling Hansen Associates on April 23, 2019 for a contaminated soil landfill that is located at a rock quarry in Shawinigan Lake, BC.

The Amendment proposes to install two new shallow groundwater monitoring wells next to and downslope from the landfill. This proposal satisfies my recommendation provided in the previous review. While this is a positive step to improve the monitoring network at the landfill, specifically as it relates to monitoring of the water table, I have the following comments and suggestions on the proposed installations:

- Indicate when the new monitoring wells will be installed and developed.
- The proposed monitoring well MW19-02 is located on the downslope east edge of the encapsulated landfill. In order to have MW19-02 more centrally located, it should be moved (10-15 metres) in the southwest direction towards MW19-01.
- The new wells should be installed as close as practical to the toe of the landfill.
- Rather than targeting a specific depth (e.g. 10 m), the drilling should focus to locate the water table. Then, the wells should be installed such that the screens straddle the water table. The ultimate depth of the new wells should be determined by the water table at the time of drilling and water levels and their seasonal fluctuations at the neighbouring wells.
- The well screens lengths should not exceed 3 metres to avoid dilution during sampling.
- The new wells should be surveyed to allow for geodetic water level monitoring.
- During drilling the bedrock should be logged by an experienced hydrogeologist. The core logging should include:
  - Label fractures and mark core
  - Calculate core recovery and rock quality designation
  - Describe core samples, including formation and rock type, field strength, colour, structure, decomposition, disintegration, fracture density, depth, and type, dip angle, aperture, healing, infilling, and moisture conditions
  - The drill logs should be stored at the quarry for future inspection

I hope that the information provided in this addendum is useful for the upcoming drilling program. Should you have any questions please contact me at 250-751-7056 or Rusto.Martinka@gov.bc.ca.

Sincerely,

Rusto Martinka
Hydrogeologist
Mining Authorizations
Ministry of Environment and Climate Change Strategy

Provided to ENV by SRG in meeting Jan 4/19

Questions for SHA and the Ministry of Environment & Climate Action

1) How has Sperling Hansen addressed the acid drainage problem in the Final Closure Plan?

CHH/SIA claim the contaminated soil dumpsite is part of mine reclamation. We note that mine reclamation must have mitigation measures for the potential production of acid drainage. We also note that a large fraction (at least 30,000 tonnes and possibly 60,000 tonnes) of the contaminated soil in the PEA contains Port Moody Pacific Coast Terminals-derived soils that contain elemental sulfur in amounts up to 24.9% dry weight? Of 18 sample data that we examined in some detail, the average elemental sulfur content was 10.48%. Assuming that the average dry weight of the soils brought onto site was 75%, this means that anywhere from 2,350 tonnes to 4,700 tonnes of elemental sulfur was placed into the PEA.

It is also known that bacteria can oxidize elemental sulfur to sulfuric acid; hence, there is a need to neutralize any potential sulfuric acid that can be formed.

As noted above, we do not know exactly how much of this elemental sulfur-laden soil was deposited on site but a Pacific Coast Terminals Contaminated Soil Relocation Agreement Application (p. 522 onwards of the Binder E pdf of the FOI) states that there were 60,000 tonnes of this contaminated soil. The last time that the Cobble Hill Quarterly Reports showed the original location and amount of soil deposited was when Active Earth Engineering was preparing the Quarterly Reports. The Quarter 4, 2015 Report states that 29,597 tonnes was deposited (p. 11 of the Report pdf) up to the end of 2015. It is likely that the remainder of the 60,000 tonnes from the Pacific Coast Terminals was deposited on site in 2016.

According to the Report (March 18, 2015, Binder E, pp 222-223) written by Kevin Morin PhD, P Geo., L. Hydrogeo., for every 1% of Sulfur, 6.25% calcium carbonate must be added to neutralize the sulfuric acid that could be formed by bacterial actions on elemental Sulfur. As noted above, the sulfur contents of the Port Moody soils up to 24.9% (p. 657 of Binder H Pt 1 obtained through the FOI) and likely averaged somewhere around 10.5% resulting in the deposition of anywhere from 23,500 to 47,000 tonnes of elemental sulfur that would require anywhere from 146,875 tonnes to 293,750 tonnes of limestone for neutralization. Clearly from the observations of the SRG this was not done. Nor has the specialized alkali-lined landfill cells (required for depositing sulfur-laden soils in Alberta) been constructed for the sulfur contaminated soils.

Not surprisingly, a contaminated-sites specialist (Gary Hamilton) has informed the Shawnigan Research Group that there is no landfill in BC or Alberta that would accept such sulfur-laden soils.

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ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1559893-1	L1559893-2	L1559893-3	L1559893-4	L1559893-5
	Description	Soil	Soil	Soil	Soil	Soil
	Sampled Date	17-DEC-14	17-DEC-14	17-DEC-14	17-DEC-14	17-DEC-14
	Sampled Time					
	Client ID	W14	W15	W16	W17	W18
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)	20.8	23.2	28.5	32.0	21.6
	pH (1:2 soil:water) (pH)	9.63	9.94	8.49	10.30	9.76
Leachable Anions & Nutrients	Sulphide as S (mg/kg)	7.1	<5.9 DLM	6.8	7.6	6.0
Plant Available Nutrients	Available Ammonium-N (mg/kg)					
	Available Nitrate-N (mg/kg)					
	Available Phosphate-P (mg/kg)					
	Available Potassium (mg/kg)					
	Available Sulfate-S (mg/kg)	1320	1140	3530	1430	1090
Saturated Paste Extractables	Chloride (Cl) (mg/kg)	1380	1480	1810		1520
	% Saturation (%)	38.0	44.5	51.9		39.2
	Sodium (Na) (mg/kg)	130	188	205		180
Metals	Antimony (Sb) (mg/kg)	1.27	1.42	0.61	2.61	1.33
	Arsenic (As) (mg/kg)	4.53	4.46	6.70	6.02	4.19
	Barium (Ba) (mg/kg)	59.4	56.8	48.8	59.6	53.3
	Beryllium (Be) (mg/kg)	<0.20	<0.20	0.22	<0.20	<0.20
	Cadmium (Cd) (mg/kg)	0.442	0.417	0.842	0.478	0.422
	Chromium (Cr) (mg/kg)	16.7	16.1	26.4	21.3	15.3
	Cobalt (Co) (mg/kg)	4.94	5.08	6.88	6.03	4.87
	Copper (Cu) (mg/kg)	33.9	30.1	33.0	47.3	28.0
	Lead (Pb) (mg/kg)	21.5	22.4	24.7	16.0	17.4
	Mercury (Hg) (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	Molybdenum (Mo) (mg/kg)	1.78	1.68	3.66	2.23	1.78
	Nickel (Ni) (mg/kg)	11.8	10.8	17.9	14.5	10.2
	Selenium (Se) (mg/kg)	0.26	0.22	0.58	0.30	0.23
	Silver (Ag) (mg/kg)	<0.10	<0.10	0.11	0.12	<0.10
	Sulfur (S)-Total (mg/kg)	87000	95900	178000	162000	107000
	Thallium (Tl) (mg/kg)	0.073	0.068	0.117	0.085	0.067
	Tin (Sn) (mg/kg)	<2.0	2.1	<2.0	3.4	<2.0
	Uranium (U) (mg/kg)	0.787	0.729	1.41	0.951	0.751
	Vanadium (V) (mg/kg)	37.9	38.9	56.2	40.9	36.0
	Zinc (Zn) (mg/kg)	125	138	109	157	115
TCLP Metals	1st Preliminary pH (pH)					
	2nd Preliminary pH (pH)					
	Final pH (pH)					
	Extraction Solution Initial pH (pH)					
	Antimony (Sb)-Leachable (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

p 656 Binder H PVJ

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1559893-6	L1559893-7	L1559893-8	L1559893-9	L1559893-10
	Description	Soil	Soil	Soil	Soil	Soil
	Sampled Date	17-DEC-14	17-DEC-14	17-DEC-14	17-DEC-14	17-DEC-14
	Sampled Time					
	Client ID	W19	W20	W21	W22	W23
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)	35.0	32.2	26.9	30.2	27.6
	pH (1:2 soil:water) (pH)	10.34	10.15	10.01	10.18	10.26
Leachable Anions & Nutrients	Sulphide as S (mg/kg)	10.6	5.5	6.3	7.1	6.3
Plant Available Nutrients	Available Ammonium-N (mg/kg)					
	Available Nitrate-N (mg/kg)					
	Available Phosphate-P (mg/kg)					
	Available Potassium (mg/kg)					
	Available Sulfate-S (mg/kg)	1250	1370	2430	1720	1450
Saturated Paste Extractables	Chloride (Cl) (mg/kg)		1800			
	% Saturation (%)		46.5			
	Sodium (Na) (mg/kg)		222			
Metals	Antimony (Sb) (mg/kg)	2.87	1.95	1.96	2.74	2.50
	Arsenic (As) (mg/kg)	6.36	7.37	5.74	7.14	5.93
	Barium (Ba) (mg/kg)	56.6	68.1	55.9	60.2	63.7
	Beryllium (Be) (mg/kg)	<0.20	0.23	<0.20	<0.20	<0.20
	Cadmium (Cd) (mg/kg)	0.483	0.553	0.467	0.526	0.486
	Chromium (Cr) (mg/kg)	22.1	24.5	20.9	21.7	20.4
	Cobalt (Co) (mg/kg)	6.15	7.13	5.49	6.46	6.19
	Copper (Cu) (mg/kg)	51.6	40.6	47.6	46.4	45.2
	Lead (Pb) (mg/kg)	17.8	18.1	18.1	13.8	16.1
	Mercury (Hg) (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	Molybdenum (Mo) (mg/kg)	2.58	2.99	2.13	2.62	2.20
	Nickel (Ni) (mg/kg)	14.1	17.1	13.0	16.0	13.9
	Selenium (Se) (mg/kg)	0.31	0.47	0.26	0.36	0.27
	Silver (Ag) (mg/kg)	0.15	0.14	0.11	0.13	0.11
	Sulfur (S)-Total (mg/kg)	103000	81400	161000	164000	148000
	Thallium (Tl) (mg/kg)	0.083	0.117	0.079	0.083	0.075
	Tin (Sn) (mg/kg)	4.1	2.7	2.6	3.5	3.2
	Uranium (U) (mg/kg)	1.01	1.40	0.871	1.00	0.866
	Vanadium (V) (mg/kg)	42.8	48.0	42.8	40.1	40.5
	Zinc (Zn) (mg/kg)	174	122	165	141	158
TCLP Metals	1st Preliminary pH (pH)					
	2nd Preliminary pH (pH)					
	Final pH (pH)					
	Extraction Solution Initial pH (pH)					
	Antimony (Sb)-Leachable (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

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ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1559893-11	L1559893-12	L1559893-13	L1559893-14	L1559893-15
	Description	Soil	Soil	Soil	Soil	Soil
	Sampled Date	17-DEC-14	17-DEC-14	17-DEC-14	17-DEC-14	17-DEC-14
	Sampled Time					
	Client ID	W24	W25	W26	W27	W28
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)	24.0	28.3	29.7	28.1	22.2
	pH (1:2 soil:water) (pH)	10.29	10.43	10.21	10.46	10.17
Leachable Anions & Nutrients	Sulphide as S (mg/kg)	6.0	5.4	7.1	13.8	5.9
Plant Available Nutrients	Available Ammonium-N (mg/kg)					
	Available Nitrate-N (mg/kg)					
	Available Phosphate-P (mg/kg)					
	Available Potassium (mg/kg)					
	Available Sulfate-S (mg/kg)	1590	1610	1780	1790	1490
Saturated Paste Extractables	Chloride (Cl) (mg/kg)		2950		1790	2370
	% Saturation (%)		41.3		42.3	61.5
	Sodium (Na) (mg/kg)		198		204	271
Metals	Antimony (Sb) (mg/kg)	2.50	3.12	2.16	2.99	2.65
	Arsenic (As) (mg/kg)	6.33	6.36	5.97	6.24	7.88
	Barium (Ba) (mg/kg)	62.8	64.9	57.2	63.7	65.3
	Beryllium (Be) (mg/kg)	<0.20	<0.20	<0.20	<0.20	0.22
	Cadmium (Cd) (mg/kg)	0.493	0.520	0.521	0.489	0.776
	Chromium (Cr) (mg/kg)	20.7	21.6	22.2	22.5	28.2
	Cobalt (Co) (mg/kg)	6.20	6.42	5.89	6.13	7.76
	Copper (Cu) (mg/kg)	44.6	54.4	48.6	54.2	49.6
	Lead (Pb) (mg/kg)	17.2	17.1	17.9	17.1	15.0
	Mercury (Hg) (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	Molybdenum (Mo) (mg/kg)	2.31	2.55	2.41	2.45	3.27
	Nickel (Ni) (mg/kg)	14.4	14.8	14.7	15.0	19.1
	Selenium (Se) (mg/kg)	0.30	0.30	0.31	0.29	0.58
	Silver (Ag) (mg/kg)	0.12	0.15	0.13	0.13	0.15
	Sulfur (S)-Total (mg/kg)	151000	142000	192000	249000	113000
	Thallium (Tl) (mg/kg)	0.077	0.081	0.075	0.076	0.115
	Tin (Sn) (mg/kg)	3.3	4.3	2.9	3.7	3.6
	Uranium (U) (mg/kg)	0.958	0.945	0.940	0.942	1.44
	Vanadium (V) (mg/kg)	41.8	42.3	42.2	40.5	50.0
	Zinc (Zn) (mg/kg)	153	178	165	178	138
TCLP Metals	1st Preliminary pH (pH)					
	2nd Preliminary pH (pH)					
	Final pH (pH)					
	Extraction Solution Initial pH (pH)					
	Antimony (Sb)-Leachable (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Is there acid production in the PEA? We note that at times the leachate has a pH well into the low 6's; thus, indicating some acid production on site:

Leachate pH (from MoE's Named Parties Reports):

September 7, 2017:	7.7
October 29, 2017:	6.28
November 27, 2017:	7.49
December 27, 2017:	7.38
January 31, 2018:	7.29
February 27, 2018:	7.28
March 27, 2018:	7.18
April 24, 2018:	7.15
May 30, 2018:	7.14
June 26, 2018:	7.03
June 26, 2018:	7.14
July 30, 2018:	6.54
August 30, 2018:	7.55
September 5, 2018:	7.28

2) Is SHA relying upon the As-builts? If so, note the Hemme ra Report to MoE of May 26, 2017, p. 23:

> **"5.1. As-Builts**
> The as-built plans were significantly different from what was observed in the field and often contradicted information presented in provided reports. The As-Built package does not appear to be complete, up to date, and accurately reflect current conditions at the existing facility."

If SHA is relying upon the As-Builts, how valid is the final closure plan?

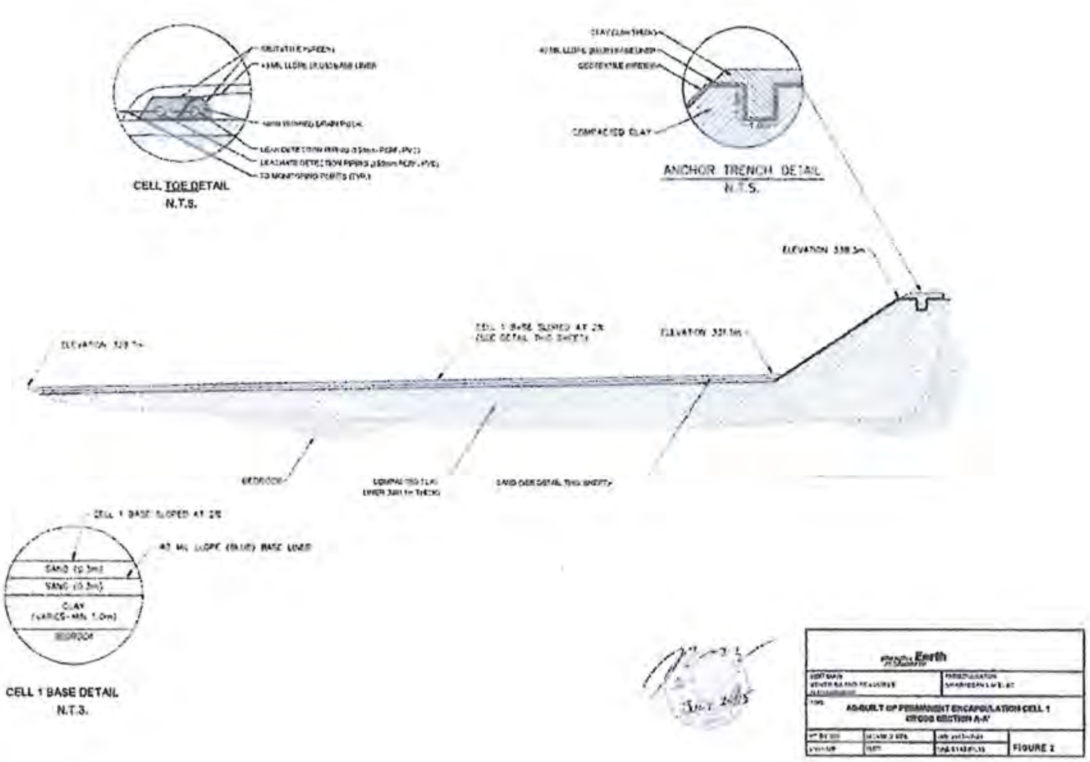
N.B.: We have seen that all of the as-built documentation for parts of the landfill that are visible are in error. In fact, SHA has determined that all the work done on the project that **can** be redone without removing the waste from the site **must** in fact be redone. Given the total failure of all visible parts of the landfill, it makes no sense to accept the as-builts for the invisible parts of the landfill.

Looking at the pictures of sections B & C of the waste pile, it is clear that many mistakes were made. From mishandling of the wrong thickness of liner to insufficient sand above the liner (the claim that there is 30 cm above the liner is shown to be false in many pictures) to folds in the liner (pictures) and heavy equipment operating on that liner (pictures), a completely failed base installation. See Figures 1-7.

3) How does the Final Closure Plan deal with the fact that the Leak Collection System is non-functioning? This is based upon SRG's detailed documentation of the building of Part C of the PEA (see May and June, 2017's SRG submission on the Ministry's website) and Hemmera's May 26, 2017 Report (Section 5.3.3, p. 25):

> "The leakage detection system collector pipe does not appear to be properly located to intercept leakage liquids. Since approximately November 2016 when the cover liner was installed and welded to the basal geomembrane, any 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. However, the leak detection system has not identified any flow from the sand layer to date."

The Hemmera Report can be found on the Ministry of Environment's website. The reason for the non-functional status of the Leak Collection System is evident in the Cell Toe Diagram submitted by Active Earth Engineering for the amended Mining Permit – see below.



N.B.: We also note that the leak collection system if it were to function can only detect leakage that goes through the LLDPE liner and is transported by the sand to the toe. Leakage through the underlying clay will not be detected by a functioning leak collection system.

4) How does Sperling Hansen account for the evidence that the site is leaking.

a) The fact that MW#6 and several of the Seepage Blanket wells have much higher levels of contaminants than a nearby private well as well as other monitoring wells on site (see The Site Is Leaking Table).

b) The occasional appearance of polyaromatic hydrocarbons such as benzo(a)pyrene in MW6 and SB2.
   a. MW6 January 31, 2018: Benzo(a)anthracene: 0.084 mg/L; Benzo(a)pyrene: 0.074 mg/L; Benzo(b+j)fluoranthene: 0.307 mg/L; Benzo(g,h,i)perylene: 0.167 mg/L; benzo(k)fluranthene: 0.167 mg/L
   b. SB3 January 31, 2018: Benzo(a)anthracene: 0.024 mg/L; Benzo(a)pyrene: 0.038 mg/L; Benzo(b+j)fluoranthene: 0.085 mg/L; Benzo(g,h,i)perylene: 0.084 mg/L
   c. Benzo(a)pyrene on April 24, 2018 also seen in SB2 and SB3

5) How does the Final Closure Plan meet the 2016 Landfill Criteria for Municipal Solid Waste? For example, both the 2016 and 1993 criteria call for a 50 metre buffer zone. In addition, we note that the 2016 criteria calls for a 100 metre buffer if it lies adjacent to a regional park. The regional park immediately to the west of the PEA is where the Shawnigan Research Group members viewed the violations of the Permit by CHH/SIA and its operators.

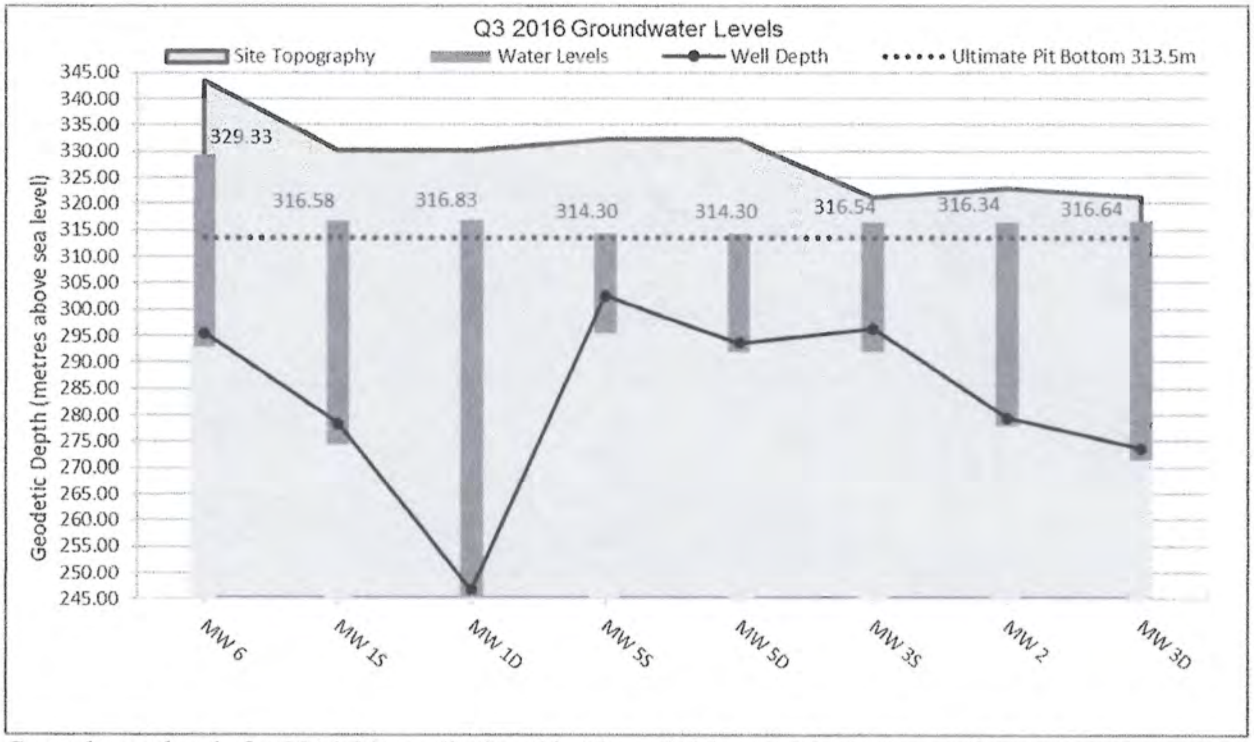
N.B.: While the LCMSW grandfathered existing landfills when it was promulgated, the SPO which said the landfill closure plan would meet or exceed the 2016 LCMSW made no mention of grandfathering. The minister could have said that certain sections of the 2016 LCMSW did not apply under the SPO. She did not.

The 2016 LCMSW specifies a 100 metre buffer to the boundary. That is the rule that the final closure plan must satisfy. Even if one ignores this specification, then the 1993 still requires a 50 metre buffer zone. Currently, the western edge of the PEA is 15 metres from the adjacent CVRD parkland.

The Site Is Leaking: Comparison of a Private Well ~360 Metres SSE of the PEA to MW6, SB2 and MW3D. Both MW3D and the Private Well Are Very Different in Composition from MW6 & SB2

(Unless otherwise indicated, the units are µg/L)

Item Measured	Private well Feb 16, 2018	MW6 Dec 27, 2017	MW6 Sept 26, 2018	SB2 Dec 27, 2017	SB2 Sept 26, 2018	MW3D Dec 27, 2017	MW3D Sept 26, 2018		
Conductivity uS/cm	Not done	1,320	1,300	624	674	250	253		
Hardness (as $CaCO_3$)	122,000	560,000	530,000	237,000	262,000	95,000	117,000		
Total Chloride	Not done	39,200	37,200	39,200	32,000	2,240	5,650		
Total Sulfate	8,340 (calculated from total S)	86,700	87,700	63,400	168,000	21,500	22,500		
Total Barium	2.96	88.5	82.3	32.9	29.1	20.5	21		
Total Boron	20	86.1	75.2	29.5	52.5	27	23.3		
Total Calcium	38,200	192,000	167,000	91,500	90,100	33,300	32,400		
Total Copper	0.98	3.21	2.33	17	14.6	<0.4	0.58		
Total Iron	<10	1,950	3,170	6,600	4,440	135	270		
Total Lead	0.219	0.96	1.02	1.77	1.48	<0.2	<0.2		
Total Lithium	<1.0	12.7	11.6	2.06	1.63	0.16	0.25		
Magnesium	5,930	37,100	35,400	13,200	15,300	5,470	5,760		
Total Manganese	106	2,230	2,060	264	179	279	361		
Total Potassium	253	4,380	3,270	2,510	1,950	680	590		
Total Sodium	8,560	73,600	64,200	30,000	23,000	11,500	11,200		
Total Strontium	157	619	583	285	298	193	196		
Total Uranium	0.28	8.27	6.91	1.55	1.18	0.69	0.792		
Total Vanadium	2.59	1.1	<1.0	14	10.4	<1.0	<1.0		
Zinc	<3.0	7.2	13.7	15.5	12.9	<4.0	4.6		



Groundwater levels for 2016 Q3 are displayed in Figure 3 (above). Monitoring well water levels remain above the ultimate pit bottom elevation of 313.5 m (geodetic).

From the Quarter 3 Report of 2016. (Page 7 of the Report but Page 13 of pdf).

Provided to ENV by ~~[illegible]~~ ~~[illegible]~~ SRG in mtg. Jan 4/19

Figure 1: Photo taken November 17, 2015 during the installation of the base liner of PEA 1B.

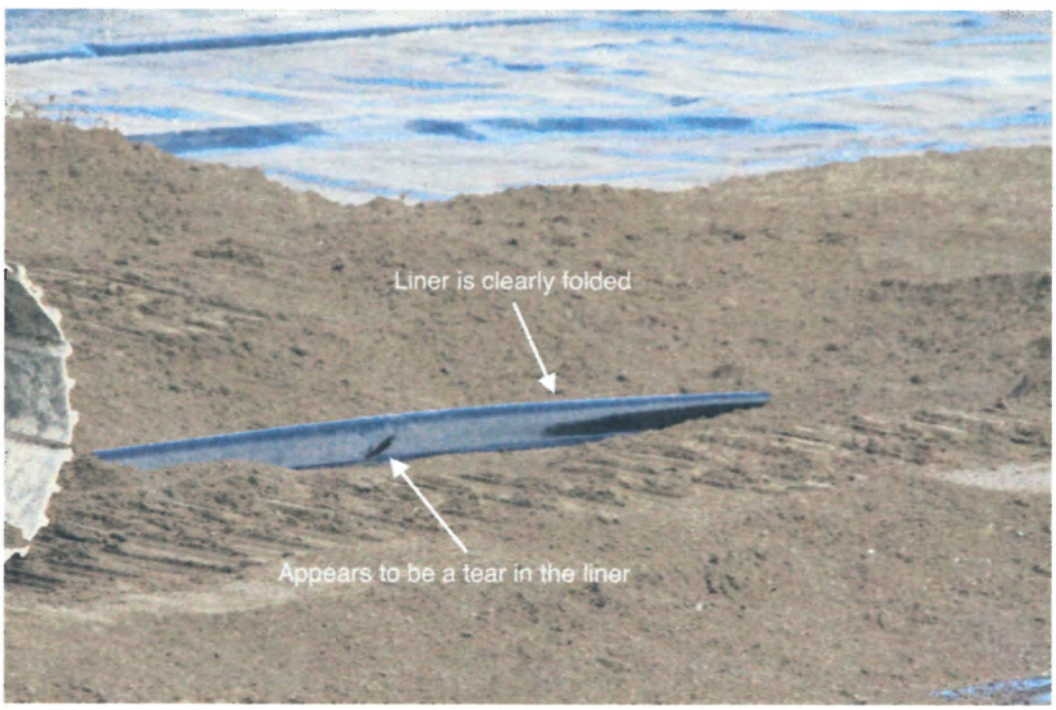


Figure 2: Note the base liner fold and an apparent gouge possibly formed by excavator track – see Figures 5 & 6.

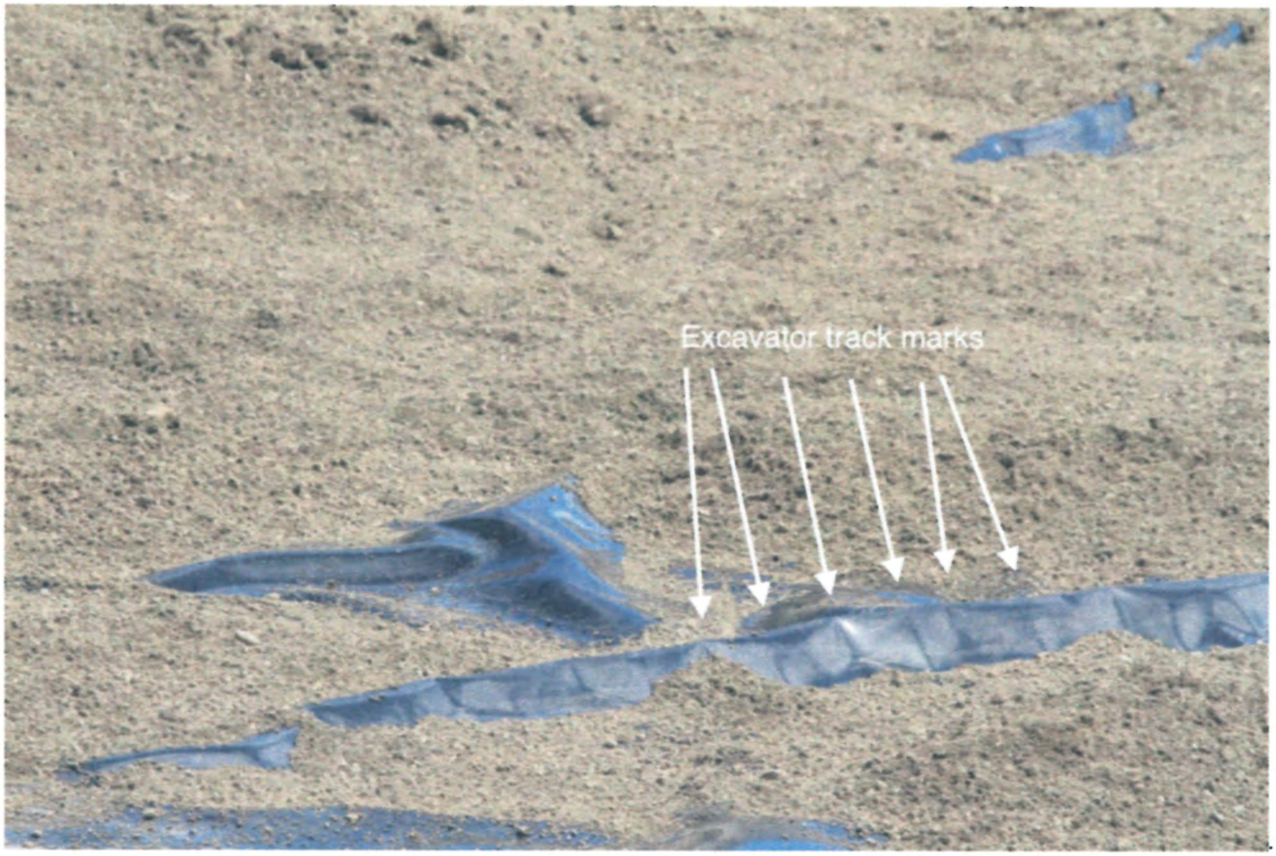


Figure 3: Excavator track marks on base liner of PEA 1C.

Figure 4: Note how close this excavator track is to the base liner of PEA 1C.

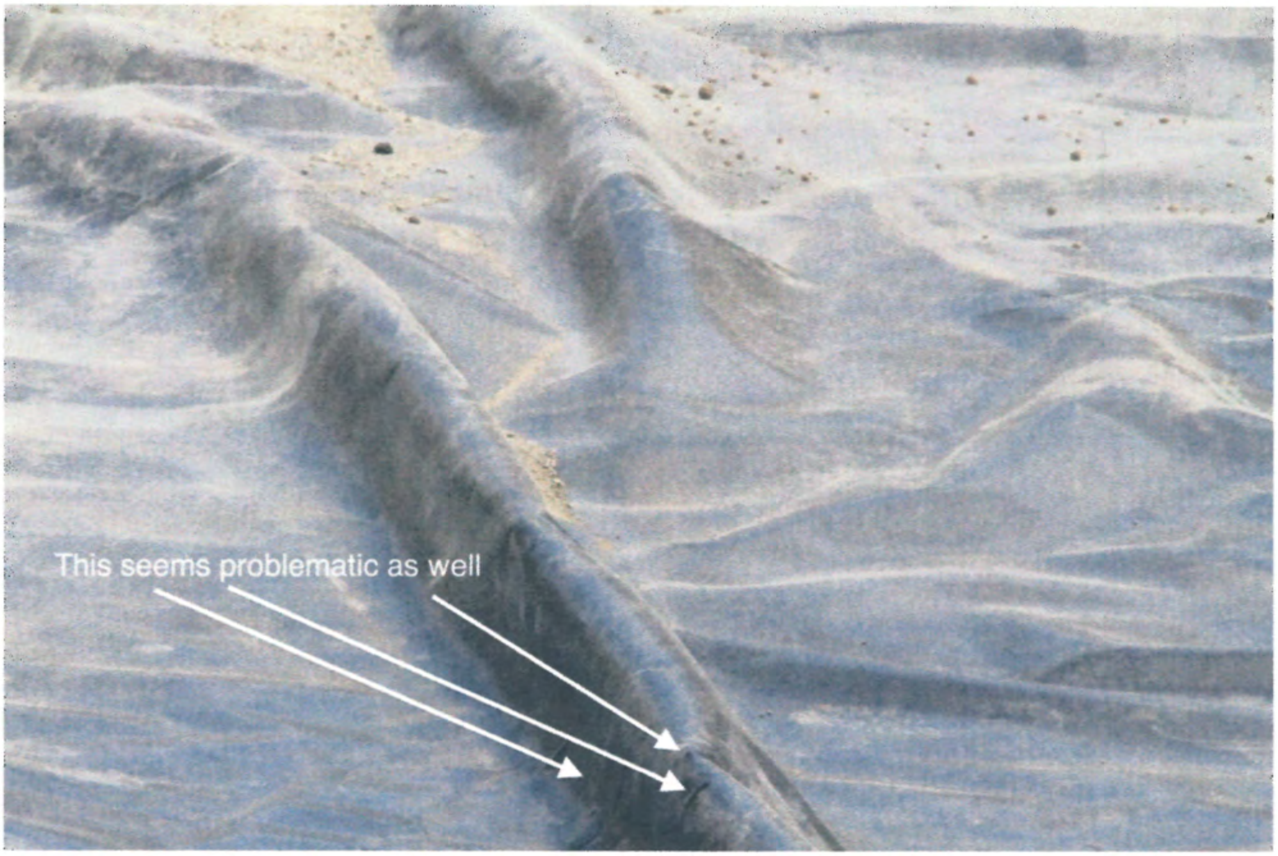


Figure 5: Cracks in base liner fold of PEA 1C.

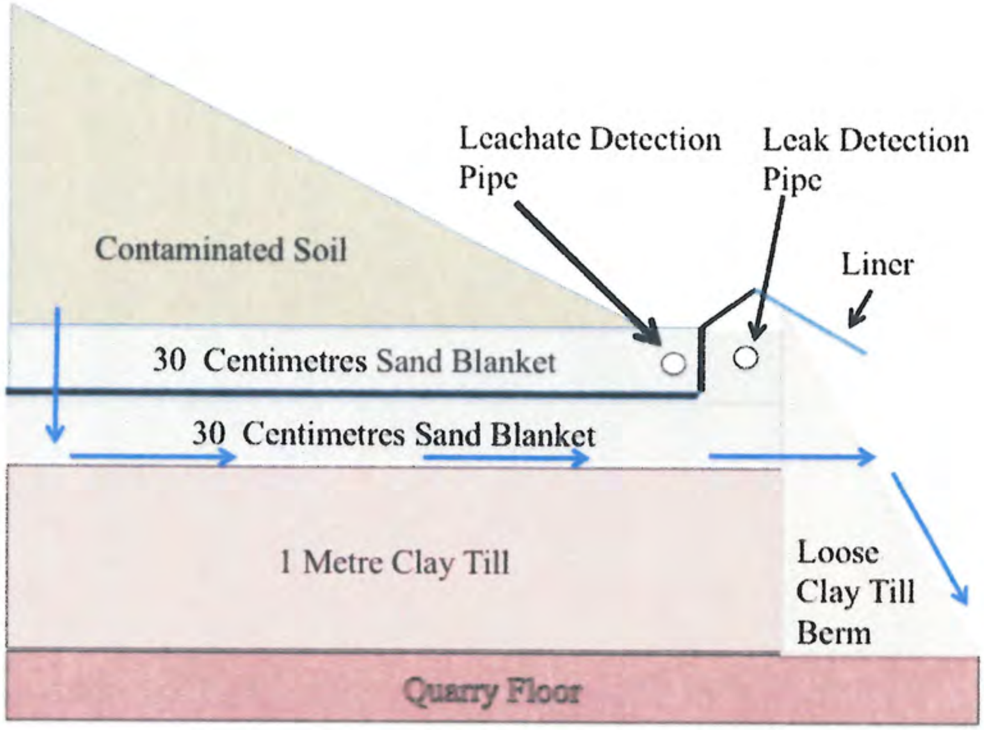


Figure 6: The so-called "leak detection system" designed by SIRM. The leaks would have to go **uphill** through sand and course crushed rock to enter the leak detection pipe. The simplest route for leaks is to flow through the sand blanket below the liner and through the loose clay till berm and from there the leak makes its way ultimately to the Ephemeral Stream. This is the source of the wet patches seen in Figure 4.

Figure 7: Early stage of installation of the leak collection and leachate collection pipes in PEA 1C. The worker on the right is standing on the PEA 1C floor. It can be seen that the leak collection pipe is well above the floor of PEA 1C.

The Questions The Shawnigan Research Group Have For The Ministry of Environment and Climate Change To Address

March 29, 2019

#1: Reliability of the Named Parties in their Quarterly and Annual Reports
From the 2015 Annual Report, p. 8, line 6: "No ash was accepted during the 2015 reporting period." Yet we have documented the presence of a tanker clearly labelled FLYASH unloading a dusty material onto the PEA during December 2015, a time when the Pacific Coast Terminals soil was transported to Lot #23.

Figure 1. Tanker on site clearly labelled FLYASH.

Figure 2. Material from the tanker labelled FLYASH being dumped onto the PEA.

Shawnigan Research Group Question: How does the Ministry plan to deal with this contradiction? The reason we ask this question will become clear in Item #2 below. Parenthetically, this contradiction between the named Parties Quarterly & Annual Reports and what was observed had been pointed out to the Ministry before.

#2: Documentation of the Addition of Portland Cement to the Pacific Coast Terminals Soil Prior to Shipment to Lot #23

Until the January 4, 2019 meeting with the Shawnigan Research Group members SHA appeared completely unaware that the Pacific Coast Terminals (PCT) soil dumped into the PEA had high levels of elemental sulfur (some assays measuring 24.5% sulfur. In the most recent Final Closure Plan SHA states that 200 kg of Portland cement was added per cubic metre of PCT soil before being transported onto Lot #23 and then an additional 100 kg of Portland cement was added/cubic metre of soil as the soil was added to the PEA. During the Community protests of December 2015, we noted that the soil being brought onto the site was saturated with water such that the trucks were dripping leachate onto the road. If 200 kg of Portland cement had been added prior to shipping the soils from PCT then the soils should have been quite dry. The Shawnigan Research Group has great difficulty believing that 200 kg of Portland cement was added to the PCT soils prior to shipment.

Shawnigan Research Group Question: Can the Ministry provide documentation that 200 kg of Portland cement was actually added to the PCT soils prior to transport onto Lot #23?

#3: The Issue of High Levels of Sulfur in the PCT Soils Brought onto Lot #23

The Contaminated Sites Specialist, Gary Hamilton, in the June 8, 2018 meeting with the Ministry pointed out that sulfur-laden soils are very problematical in a landfill. He also stated that no other landfill site in BC would accept such sulfur-laden soils. In a January 4, 2019 meeting with SHA Dr Tony Sperling informed the SRG members present that he was not aware of the presence of sulfur-rich soils.

Shawnigan Research Group Questions:

1) Was the Ministry aware that high sulfur soils were being brought onto Lot #23 prior to this being pointed out by Gary Hamilton?
2) Why has the Ministry not paid attention to what the Contaminated Sites Specialist stated about the problems with high-sulfur soils?
3) Why did the Ministry not inform SHA of the presence of sulfur-rich soils?

#4: The High Ionic Content of Monitoring Well #6 and Seepage Blanket Wells 2 and 3

The Ministry previously informed the SRG that its hydrogeologist stated that the high ionic content of Monitoring Well #6 is due to the fact that this is a much deeper well than all the other monitoring wells. This clearly is incorrect as can be seen in Figure 3.

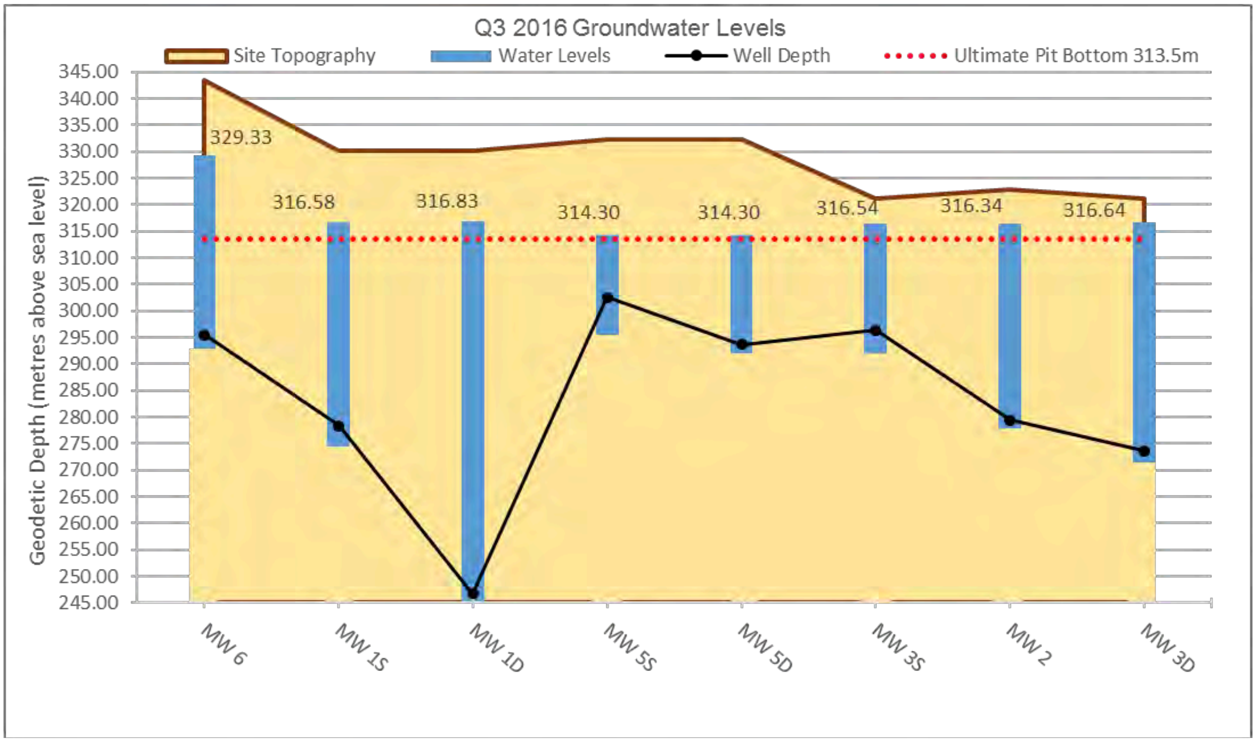


Figure 3. Water levels in the monitoring wells shown taken from the Quarter 3, 2016 Report by the Named Parties.

The Table below illustrates the ionic composition and other measurements of Monitoring Wells 6 and Seepage Blanket Wells 2 and 3 compared to Monitoring Well 3D and two nearby private wells. Monitoring Well #3D is very similar in composition to all the monitoring wells except for #6.

Comparison of Nearby Private Wells to MW6, SB2 and MW3D

(Unless otherwise indicated, the units are µg/L)

Item Measured	Private well (360 m SSE of the PEA) Feb 16, 2018	MW6 Dec 27, 2017	MW6 Sept 26, 2018	SB2 Dec 27, 2017	SB2 Sept 26, 2018	MW3D Dec 27, 2017	MW3D Sept 26, 2018	Private well (1,850 m NNE of the PEA) Jan 23, 2017	Leachate Collected Dec 27, 2017	Leachate Collected Aug 28, 2018
Conductivity uS/cm	Not done	1,320	1,300	624	674	250	253	Not done	11,100,000	11,500,000
Hardness (as $CaCO_3$)	122,000	560,000	530,000	237,000	262,000	95,000	117,000	82,100	2,700,000	3,050,000
Total Chloride	Not done	39,200	37,200	39,200	32,000	2,240	5,650	Not done	2,610,000	2,820,000
Total Sulfate	8,340 (calculated from total S)	86,700	87,700	63,400	168,000	21,500	22,500	Not done	1,390,000	1,560,000
Total Barium	2.96	88.5	82.3	32.9	29.1	20.5	21	<9	59.4	64
Total Boron	20	86.1	75.2	29.5	52.5	27	23.3	<50	288	293
Total Calcium	38,200	192,000	167,000	91,500	90,100	33,300	32,400	24,000	881,000	882,000
Total Copper	0.98	3.21	2.33	17	14.6	<0.4	0.58	<8	3.5	6.2
Total Iron	<10	1,950	3,170	6,600	4,440	135	270	<10	94[1]	87[1]
Total Lead	0.219	0.96	1.02	1.77	1.48	<0.2	<0.2	0.5	<0.2[2]	<0.2[2]
Total Lithium	<1.0	12.7	11.6	2.06	1.63	0.16	0.25	Not done	0.5	0.6
Magnesium	5,930	37,100	35,400	13,200	15,300	5,470	5,760	5,400	244,000	241,000
Total Manganese	106	2,230	2,060	264	179	279	361	<4	29,400	28,100
Total Potassium	253	4,380	3,270	2,510	1,950	680	590	214	20,900	21,400
Total Sodium	8,560	73,600	64,200	30,000	23,000	11,500	11,200	5,790	1,560,000	1,590,000
Total Strontium	157	619	583	285	298	193	196	59	4,320	4,550
Total Uranium	0.28	8.27	6.91	1.55	1.18	0.69	0.792	Not done	0.6	0.3
Zinc	<3.0	7.2	13.7	15.5	12.9	<4.0	4.6	34	14.6	52.6

[1]Iron can fluctuate, e.g., on the May 4, 2017 the iron content was 1,180 micrograms/L leachate and on Oct 8, 2016 it was 369,000 micrograms/L; [2]Lead can also fluctuate, e.g., on Oct 8, 2016 the lead content was 266 micrograms/L leachate

Shawnigan Research Group Question: How does the Ministry's hydrogeologist account for the differences in composition of the waters drawn from Monitoring Well #6 and Seepage Blanket Wells 2 and 3 compared to all the other wells?

#5: The Polyaromatic Hydrocarbons Seen on Occasion in Monitoring Well #6 and Seepage Blanket Wells 2 & 3

We note that on occasion SB2, SB3 and Monitoring Well #6 contain polyaromatic hydrocarbons (PAHs). For example:

a. MW6 January 31, 2018: Benzo(a)anthracene: 0.084 µg/L; Benzo(a)pyrene: 0.074 µg/L; Benzo(b+j)fluoranthene: 0.307 µg/L; Benzo(g,h,i)perylene: 0.167 µg/L; benzo(k)fluranthene: 0.167 µg/L
b. SB3 January 31, 2018: Benzo(a)anthracene: 0.024 µg/L; Benzo(a)pyrene: 0.038 µg/L; Benzo(b+j)fluoranthene: 0.085 µg/L; Benzo(g,h,i)perylene: 0.084 µg/L
c. Benzo(a)pyrene on April 24, 2018 also seen in SB2 and SB3

Such PAHs are also, at times, present in the leachate (e.g., the December 17, 2018 test of leachate). We know that such PAHs are products of incomplete combustion and are not natural constituents of ground water. The source of PAHs in the PEA are soil brought onto the site. From the 2015 Annual Report, Revised April 27, 2016, p. 10:

Table 4. Imported Soil Quality 2015 - Polycyclic Aromatic Hydrocarbons

Polycyclic Aromatic Hydrocarbons (ug/g)	Weighting Factor	MAX	Mean (n=20)	MIN	ST. DEV.	MAX PAHTEQ SUM
Benz(a)anthracene (0.1 MRL)	1	2.46	0.47	< MRL	0.7	4.2066
Benzo(a)pyrene (0.1 MRL)	0.1	3.08	0.54	< MRL	0.9	
Benzo(b)fluoranthene (0.1 MRL)	0.1	4.30	0.66	< MRL	1.3	
Benzo(k)fluoranthene (0.1 MRL)	0.1	1.69	0.34	< MRL	0.5	
Dibenz(a,h)anthracene (0.1 MRL)	1.1	0.42	0.09	< MRL	0.1	
Indeno(1,2,3-c,d)pyrene (0.1 MRL)	0.2	1.91	0.33	< MRL	0.6	
					PAHTEQ HWR Guideline =100	

Another potential source of PAHs is fly-ash – see Section #1 above.

Shawnigan Research Group Question: How does the Ministry's hydrogeologist explain the occasional presence of these PAHs in Monitoring Well #6 and Seepage Blanket Wells 2 and 3?

#6: Filtering of Leachate Prior to Analysis

The October 29, 2018 results in the Named Parties November 30, 2018 report gives leachate analysis post-treatment. Previously the Ministry had informed Sierra Acton that Allterra initially stated that they were filtering out hydrocarbons and then corrected this by stating that they were filtering out manganese. The Shawnigan Research Group is very interested in what filter Allterra was using to filter out manganese. We mention this since this past January the leachate was being filtered using Hydronix filters. Hydronix filters can only filter out sediment and/or hydrocarbons. The only way to use Hydronix filters to remove manganese is to make the leachate alkaline (above pH of 8) resulting in the manganese to precipitate out and this precipitate can then be filtered out using Hydronix filter cartridges. However, the pH of the leachate of October 29, 2018 sampling was 6.85 and not the expected alkaline pH.

The Shawnigan lake Community is concerned that the Named Parties maybe hiding data of interest to the Community.

Shawnigan Research Group Questions:

1) Will the Ministry provide us with details of what filter was used last fall as well as of what was being filtered and the mechanisms that allowed the component(s) to be filtered?
2) Will the Ministry provide us with details which Hydronix filter was used this past January and what was being filtered?

#7: The Fill Present on Lot #21

The Ministry is aware that fill has been brought onto Lot #21 in the past. The purpose of this fill was to reclaim the quarry on Lot # 23. This is clearly stated in the July 16, 2015 Ministry of Energy and Mines Information sheet that states (on p. 2).

"Mines Act Permit Q-8-331; Lot 21

- Mines Act permit issued to South Island Aggregates Ltd. in June, 2010
- Under this permit, SIA authorized to operate an aggregate quarry at the site. Annual production shall not exceed 200,000 tonnes.
- Soil importation is permitted; soil imported must meet the Ministry of Environment guidelines for the intended end land use (residential; zoned F-1, Primary Forestry)
- The purpose of the imported soil is to back-fill the quarry under Mines Act permit Q-8-094
- To date no mining extraction has taken place under this permit "

This Information sheet forms Appendix 1. We remind the Ministry that Permit Q-8-094 is the Waste Discharge permit that has been suspended.

Shawnigan Research Group Questions: If the Updated final Closure Plan submitted January 31, 2019 is approved, will the Ministry insist that the fill on Lot #21 be used for the Final Closure?

SHAWNIGAN RESEARCH GROUP FINAL CONCLUSIONS: The Updated Final Closure Plan is as badly flawed as the previous versions. The Ministry of Environment and Climate Change should not recommend approval of this Closure Plan to the Minister.

We agree with the Report by Gary Hamilton (P. Geo), a BC Registered Contaminated Sites Specialist who stated (p. 2 of the Report):

"Based on the chemical characteristics of the material, disposal options were assessed. The most practical, feasible options were disposal at permitted solid waste landfills in the United States, specifically in Washington and Oregon states. Both Waste Connections, Inc. and Waste Management Inc. have facilities in the USA that are permitted to accept this material. Disposal options in British Columbia and Alberta were also assessed; however, due to the heavy metals and sulfur content in the waste, it is unlikely that this material would meet the landfill waste permit requirements."

This Report is found in Appendix 2.

Appendix 1

July 16, 2015

BRITISH COLUMBIA

Ministry of Energy and Mines

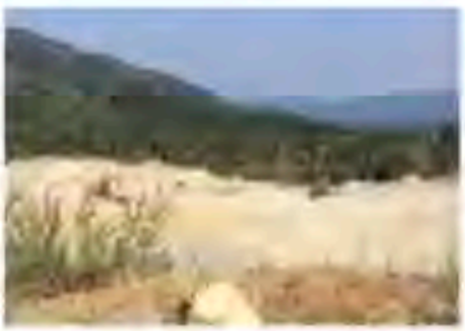
Information Sheet

on

South Island Aggregates Ltd.

Legislation governing mining in British Columbia

- Mines Act
- Health, Safety and Reclamation Code for Mines in British Columbia
- Other Provincial legislation as applicable



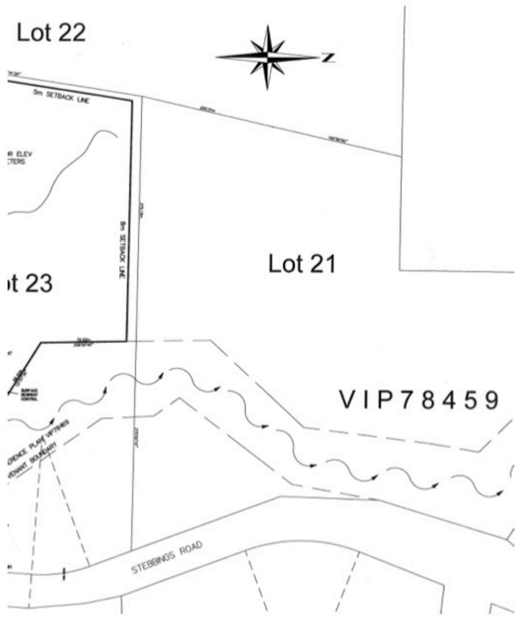
Mines Act Permit Q-8-094; Lot 23

- Mines Act permit issued to South Island Aggregates Ltd. (SIA) in October,2006, amended 2009, 2012
- Under this permit: SIA authorized to operate an aggregate quarry at the site.
- Annual production shall not exceed 240,000 tonnes.

- Permit 105809 issued under the Environmental Management Act by the Ministry of Environment lies within the footprint of Mines Permit Q-8-094.
- As all activity within the mine footprint needs to be authorized under the Mines Act permit, an amendment is required before SIA can bring in material under the EMA permit
- All decisions regarding amendments to Mines Act permits are made by statutory decision makers in the Ministry of Energy and Mines.

Inspections and Compliance

- Inspections occur at intervals that are determined by a risk matrix that takes into account the type of mine, the size, the compliance history and other factors
- Inspections are also made in response to public complaints and specific incidents
- Inspectors make site visits unannounced
- The last inspection of this mine was made on July 9, 2015; one minor non-compliance was found
- An inspection on June 16, 2015 resulting from a production blast that encroached upon the 5-metre buffer zone resulted in an order to prepare and implement an engineered design to restore the damaged area of the buffer zone as well as prepare a blasting procedure, by a blasting consultant, that will include recommendations to prevent future encroachment into the buffer zone from blasting
- The company has submitted the above plans but they have not yet been approved by the Ministry



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- The purpose of the imported soil is to back-fill the quarry under Mines Act permit Q-8-094
- To date no mining extraction has taken place under this permit

Inspections and Compliance

- The last inspection of this mine was made on July 9, 2015; no non-compliance was found
- On May 13, 2015 staff from the Ministry of Environment sampled imported soils to determine if they met the objectives set out in the Mines Act permit. Results can be obtained through MOE
- On May 1, 2015 a Stop Work Order was issued with respect to the importation of soils onto the mine site; to date, this order has not been rescinded

Appendix 2

5 July 2018

Patrick Consulting Inc.
PO Box 581, Stn Ganges
Salt Spring Island, BC
V8K 2W2
(Phone: 250-538-0215)

Shawnigan Research Group,
A division of the Shawnigan Residents Association
2268 Renfrew Road
Shawnigan Lake BC V0R 2W1

Attn: David Munday

RE: Draft Estimated Costs to Remove Contaminated Soil at Lot 23 – Stebbings Road, Shawnigan Lake, BC to a Permitted Facility

Dear David,

Further to our proposal dated 12 June 2018, Patrick Consulting Inc. (PCI) is pleased to provide Shawnigan Research Group (SRG) and Shawnigan Residents Association (SRA) with the results of our estimate of the costs and approach for the removal of contaminated soil at the contaminated soils landfill at Lot 23 – Stebbings Road Shawnigan Lake, BC. (the "Site").

Background

Information on the source and chemical characteristics of the material placed at the Site was obtained by SRG from the Province of British Columbia through a freedom of information request. We understand that this information consisted mainly of 20 large PDF files of laboratory certificates, summary data tables and environmental site assessment reports. Based on the information presented in the Updated Final Closure Plan for the Site that was prepared by Sperling Hansen Associates Inc. dated 21 July 2017, it is estimated that 98,000 tonnes of contaminated soil (waste) is present that could potentially be relocated.

The scope of work comprised a) a review of the existing data to develop an understanding of the source and chemical characteristics of the contaminated soil, and then b) an estimate of the potential costs to remove and dispose of the material. The estimated costs include professional and contractor fees to characterize, load, transport, broker, and dispose of the material at a permitted facility.

Review of Available Data

A representative number of the documents provided was reviewed, with a focus on identifying the source and source characteristics of the soils. PCI also contacted waste disposal companies familiar with the waste material to corroborate the findings of the document review.

Results of our document review concluded that the material at the Site originated from the following three primary sources:

- Fleet Maintenance Facility, Cape Breton at CFB Esquimalt, BC;
- Pacific Coast Terminal, Port Moody, BC; and
- Industrial and commercial sites in BC.

The primary contaminants of concern were identified to be heavy metals, petroleum hydrocarbons and sulfur. The heavy metals primarily consisted of antimony, arsenic, cadmium, chromium, copper, lead, nickel, and zinc. Concentrations of heavy metals and petroleum hydrocarbons are regulated under the BC Environmental Management Act and its regulations (i.e., Contaminated Sites Regulation); however, sulfur has only limited restrictions that mainly relate to its disposal to agricultural land. Based on the data reviewed, it appears that concentrations of contaminants exceed the provincial Industrial/Commercial land use standards but are less that the Hazardous Waste Regulation standards.

Due to the format of the data provided to PCI, we were unable to establish a comprehensive listing of all contaminants of concern and the reported concentrations of each contaminant. As an alternative approach, we evaluated a statistically representative sub-set of the data.

Results of Review of Disposal Options

Based on the chemical characteristics of the material, disposal options were assessed. The most practical, feasible options were disposal at permitted solid waste landfills in the United States, specifically in Washington and Oregon states. Both Waste Connections, Inc. and Waste Management Inc. have facilities in the USA that are permitted to accept this material. Disposal options in British Columbia and Alberta were also assessed; however, due to the heavy metals and sulfur content in the waste, it is unlikely that this material would meet the landfill waste permit requirements.

The logistics of removing the material from the Site and final disposal at a permitted landfill in the United Sates are somewhat complex. As a first step, it is necessary to ensure that the material is adequately characterized so that the receiving facility can confirm acceptance. Typically, one composite sample (composed of 3 to 5 aliquots of the material) is required for each 100 tons (US) of material. One US ton equals 0.907 tonnes; therefore, 98,000 tonnes would equal approximately 108,000 US tons. A total of at least 1,080 soil chemical analyses would be needed to meet typical US landfill permit disposal requirements.

Extensive sampling of the waste material was conducted prior to acceptance at the Site. Therefore, we have assumed that a limited amount of additional sampling would be required to meet the requirements of the disposal sites.

Once the waste is adequately characterized and a landfill has been identified, a waste customs broker would need to be retained to facilitate preparing the documentation required to move the material into the United States.

The removal process would begin with loading the material onto dump trucks and transporting the material by land to the Bamberton barge loading facility. Once the material is loaded onto the barge, it would be transported to a barge unloading facility located closest to the receiving landfill. The material would then be unloaded and transported by either truck or rail to the permitted facility.

Cost Estimate

As the final destination of the material is assumed to be the United States, the mass of material was converted from 98,000 tonnes to 108,000 US tons. Waste transportation costs from the Site to the barge unloading facility in the United States were estimated in Canadian dollars, and the waste transport and disposal cost from the barge unloading facility to the landfill in the US were provided in US dollars and converted to Canadian Dollars at an exchange rate of 0.75.

A breakdown of the costs in Canadian dollars for each step of the removal process is as follows:

Task	**Estimated Cost ($CAN)**
Waste characterization and brokerage fee:	$250,000
Waste loading and transportation to Bamberton barge facility ($10 per ton):	$1,080,000
Transportation by barge to unloading facility in United States (10,000 ton per barge; 11 loads @ $250,000 per load):	$2,750,000
Barge unloading and transportation to permitted landfill ($15 per ton)	$1,620,000
Landfill tipping fee ($50 per ton):	$5,400,000
Landfill closure sampling and reporting	$100,000
Total Estimated Cost:	***$11,200,000***

Estimated transportation and disposal costs were provided by Waste Connections, Inc. and QM Environmental (Quantum Murray LP). Barge loading fees were provided by the Malahat Nation. Actual costs could be determined through a competitive bidding process.

Limitations

This review was conducted for the exclusive use of the Shawnigan Residents Association. The report is intended to provide a technical review and opinion of information provided in the documents referenced above respecting the quality of material at the subject Site adequacy of the environmental Site investigations and remediation conducted at the subject Site, and an opinion of costs. This report is not meant to represent a warranty, or a legal opinion regarding compliance with applicable laws. The reviewer makes no other representation or warranty as to the accuracy or completeness of the information provided.

This review followed the standard of care expected of professionals undertaking similar work in British Columbia under similar conditions. The reviewer's conclusions and opinions are entirely based on the information provided by the client and by contractors as noted in this report. The reviewer has relied on the accuracy and completeness of the background materials upon which the reported information was based, and is not responsible for errors or omissions in such background materials.

Any use by which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. The reviewer accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Closure

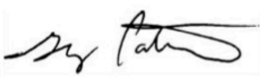
We trust that the estimated costs to remove the waste material from the Site to a permitted facility, as presented in this letter, is sufficiently detailed for your current needs. Should you have any questions or require additional information, please contact the undersigned at your convenience.

Sincerely,

Patrick Consulting Inc.

Gary Hamilton, P.Geo.
Contaminated Sites Approved Professional

Reviewed by:



Guy Patrick, P.Eng.
Director

Letter to the Minister of Environment and Climate Change Strategy

Shawnigan Residents Association

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Letter to the Minister of Environment and Climate Change Strategy

May 8, 2019

From: The Shawnigan Research Group

To: The Honourable George Heyman,
Minister of Environment and Climate Change Strategy

Dear Minister Heyman,

Your staff will shortly give their opinion on the final closure plan for the contaminated soil landfill site established under Permit # 105809. Although your staff have met with us, the Shawnigan Research Group, many times they have never taken our concerns seriously. Our concerns fall into two categories: perceived conflicts of interest/biases and flaws in the final closure plan.

Conflicts of Interest and Biases Associated with the Final Closure Plan:
According to Tony Sperling in a January 4, 2019 meeting, it was the Ministry that reached out to Sperling Hansen Associates (SHA) to develop a final closure plan on behalf of the Named Parties. We find this very problematical. Why did the Ministry do this? Your Ministry seems determined to have a final closure solution that involves the contaminated soils being kept in the Shawnigan Lake watershed. This does not seem like an unbiased approach to determining the fate of the contaminated soil landfill in the Shawnigan Lake watershed.

Tony Sperling in the January 4, 2019 meeting did point out that Cobble Hill Holdings (CHH) owes SHA a considerable sum of monies from previous work. In the April 16 meeting Mr. Sperling pointed out that the amount owed was over $100,000. We note that the final closure plan developed by SHA enables the Named Parties to make money by bringing in an additional 70,000 tonnes of fill, thus increasing the probability that SHA will receive the monies previously owing. We wonder how the monies owed influenced the final closure plan? Note also the complete contrast between the first closure plan developed by SHA and the final closure plan delivered January 31, 2019 – see Appendix 3.

We were informed by your Ministry staff at the April 16, 2019 meeting that the Ministry has hired GHD to review SHA's final closure plan. We note that GHD is the company that has done the analysis as to the suitability of the gravel quarry in Campbell River for a contaminated soil landfill site. Contrary to the QPs hired by the City of Campbell River and the QPs hired by the Campbell River Environmental Committee, GHD stated that there was no possibility of this contaminated soil landfill contaminating the local watershed. We do not think that GHD has an unbiased perspective with respect to the final closure plan for the contaminated soil landfill in the Shawnigan Lake watershed. We were surprised that Hemmera was not contracted to review SHA's final closure plan as they had been contracted to review a previous version of SHA's closure plan. In this review Hemmera pointed out that most of the As-builts provided by the Named Parties were incorrect and often contradicted what could be observed on the site. Hemmera also pointed out that the Leak Collection System was non-functional.

Flaws in The Final Closure Plan:

The Final Closure Plan Is Based on Flawed As-Builts: The Final Closure Plan is very dependent upon the As-Builts and other information supplied by the Named Parties. Regarding these As-Builts Hemmera, hired by the Ministry to review SHA's first Closure Plan, wrote in their May 26, 2017 Report:

"**5.1. As-Builts**
The as-built plans were significantly different from what was observed in the field and **often contradicted information presented in provided reports***. The As-Built package does not appear to be complete, up to date, and accurately reflect current conditions at the existing facility."

*Emphasis added.

We also note that in Justice Sewell's Decision he wrote:

"[179] I also find that CHH filed misleading evidence in this Court."

If CHH filed misleading evidence to the Court, then how trustworthy is information given by CHH to SHA, information that SHA relied upon for their final closure plan.

A reasonable person would conclude that a Final Closure Plan dependent upon disinformation and incorrect As-Builts ought to be rejected.

Problem of Elemental Sulfur: There are approximately 5,000 tonnes of elemental sulfur in the landfill. Elemental sulfur is a problem since it can be oxidized to sulfuric acid which in turn can cause release into the environment metals present in the contaminated soil. Gary Hamilton, a BC Registered Contaminated Sites Approved Professional, wrote that elemental sulfur is so problematical that no other landfill site in BC would have accepted the PCT sulfur-laden soils – see Appendix 1. Some samples tested as high as 24.9% elemental sulfur. In the January 4, 2019 meeting when we asked Tony Sperling how his final closure plan deals with the many thousands of tonnes of elemental sulfur in the landfill, he had a surprised expression since he was unaware of up to 5,000 tonnes of elemental sulfur being in the landfill. Your Ministry staff did not point this out to Mr. Sperling when requesting him to do a final closure plan. Nor, surprisingly, did Mr. Sperling deem it worthwhile to find out which contaminants were present in the landfill site before designing the final closure plan. In final closure plan dated January 31, 2019 prepared by SHA it was reported that 200 kg of Portland cement was added to each cubic metre of PCT soil before the soil left Port Moody. The purpose of the cement addition was to neutralize any sulfuric acid being formed. We have asked your Ministry staff for documentation of this. We do not believe that 200 kg cement/cubic metre of soil was added since if it had been then the soil should not have arrived at Lot 23 dripping water onto the road. Indeed, the only documentation we could find through an FOI was that 10 kg of cement was added/tonne of soil, i.e., approximately 15 kg/cubic metre and in this documentation it stated that the cement was added to stabilize the PCT soil, not to neutralize potential sulfuric acid formation. However, suspiciously, the analytical results of this stabilization have been redacted from the FOI we obtained from the Ministry.

Also problematical is that Tony Sperling In the April 16 meeting told us that there was only about 1% elemental sulfur in the soils from PCT. This is incorrect since although a few batches did test about 1% elemental sulfur, many batches of soil tested from 10 to 24.9% elemental sulfur; indeed, a random sampling of the data showed an average of 10.5% elemental sulfur in the PCT soils.

The contaminated soil must be removed from the watershed. Your Ministry staff did not consider the possibility of moving the sulfur-laden soil to a suitable landfill site. The Shawnigan Residents Association hired Gary Hamilton, CSAP, to explore possible costs of such a final closure plan. His report forms Appendix 2.

Evidence the Landfill Site Is Leaking:

There are several lines of evidence that the site is leaking but we will only point out one. The Ministry hydrogeologist informed us at the April 16 meeting that the best evidence that a site is leaking is if the monitoring wells show increases in contaminant levels, although he said this was not ideal since any contaminants leaking into the monitoring wells would be diluted by groundwater. Most of the soil in the landfill comes from the PCT at Port Moody. This soil is very high in chloride and sodium. Since soils and rocks have an overall negative charge one would expect that the negatively-charged chloride would migrate through soils/rocks faster than the positively-charged sodium. We examined changes in chloride and sodium in Monitoring Well 3S. This well is located north of the landfill site and is adjacent to the settling pond. As can be seen in the graph on the next page there are large increases in chloride and smaller increases in sodium between the summer of 2015 and the summer of 2018 in MW3S. According to the Ministry hydrogeologist this would indicate that the contaminated soil landfill is leaking.

Changes In Chloride and Sodium Concentrations In Monitoring Well 3S

Data were taken from the June readings of each year. We do not have access for 2017.

Ignored by your Staff is that the Contaminated Soil Landfill was built as a Temporary Structure:

The Final Closure Plan is premised on the idea that the base of the landfill was properly constructed. The present contaminated soil landfill, called the Permanent Encapsulation Area (PEA), was originally built as a Temporary Encapsulation Area (TEA). Because it was a temporary structure a proper landfill foundation was not prepared. As an example of a problem with the base of the landfill site is the non-functional state of the Leak Collection System. Hemmera in the May 2017 Report pointed out problems with the Leak Collection System:

"The leakage detection system collector pipe does not appear to be properly located to intercept leakage liquids. Since approximately November 2016 when the cover liner was installed and welded to the basal geomembrane, any precipitation that collects along the upper portions of Cell 1 is expected to infiltrate between the bedrock and the geomembrane and accumulate within the leak detection sand layer."

How can SHA develop a final closure plan with no true knowledge of what the floor of the quarry looks like beneath the contaminated soil landfill? Details of the problematical aspect of the base of the TEA transformed into the PEA has been outlined by Brent Beach and forms Appendix 3.

Appendix 1: Letter from Gary Hamilton, BC Contaminated Sites Association Professional, Pointing Out That Sulfur-Laden Soils Do Not Meet The 2016 Municipal Landfill Criteria for Solid Wastes, Contrary to What Your Ministry Staff States

8 April 2019

G Hamilton Consulting Inc.
2636 Templeton Drive
Vancouver, BC
V5N 4W3
(Phone: 604-816-3854)

Shawnigan Research Group,
Shawnigan Residents Association
2268 Renfrew Road
Shawnigan Lake BC V0R 2W1

Attn: David Munday

RE: Sulfur Contaminated Soil at Lot 23 – Stebbings Road, Shawnigan Lake, BC

Dear Dave,

Further to your request, G Hamilton Consulting Inc. is pleased to provide Shawnigan Research Group (SRG) and Shawnigan Residents Association (SRA) with this letter regarding the closure of the South Island Aggregates (SIA) site at Lot 23 – Stebbings Road Shawnigan Lake, BC. (the "Site"). This letter specifically addresses potential concerns with sulfur soils from the Pacific Coast Terminals (PCT) in Port Moody that was sent to the Site.

Sulfur Soils for Pacific Coast Terminals in Port Moody

From 2001 until 2006, PCT sent more than 50,000 metric tonnes of sulphur soils to the Envirogreen Technologies Ltd. facility at the Similco Mine (now Copper Mountain Mine) site near Princeton BC1. According to PCT, this location was selected because the only other option at that time was to send the material to an Alberta landfill. Based on my direct experience with this type of material, sulfur content in the material that was sent to the Similco Mine may be up to 100 percent and the pH as low as 1.0.
1 http://pct.ca/wp-content/uploads/2014/12/Summer-2006.pdf

In 2015 PTC began sending similar sulfur soils to the South Island Aggregates (SIA) site near Shawinigan Lake, BC. Up to approximately 60,000 metric tonnes of sulfur contaminated soil from PTC's Port Moody facility was reportedly sent to SIA site.

Hazard Associated with Sulfur Soil

The Transportation of Dangerous Goods Regulation (TDGR) identifies solid sulphur as Class 4.1 dangerous goods when transported as a solid. Due to the presence of high percentages of sulfur, some

sulfur soil may be flammable and as such also regulated as a controlled product under the Hazardous Products Act (Canada) as it relates to workers' occupational health and safety. Despite the TDGR classification, sulfur soil is not classified as hazardous waste regardless of the sulfur content, provided that it is managed in accordance applicable guidelines, is the only contaminant of concern in the soil and is not liable to spontaneous combustion when it is being handled or disposed of.

Landfill Closure Design

It is our understanding that Sperling Hansen Associates prepared a Final Closure Plan for the facility using BC Environment and Climate Change Strategy (BC ENV) guidance for landfill closure 2016 2nd Edition *Landfill Criteria for Municipal Solid Waste*. Guidance on the disposal of elemental sulfur contaminated soil in Canada is presented in Government of Alberta Environment document entitled "Guidelines for the Remediation and Disposal of Sulphur Contaminated Solid Wastes" dated 12 September 2011.

Typically, sulfur soil is conditioned with alkaline products prior to landfilling. When managing sulfur-containing soil the objective is to add a sufficient amount of alkaline material is to prevent sulfur oxidation, neutralize the sulphuric acid eventually formed and prevent migration of acidic leachate from the landfill cell/trench. Landfill operators typically adopt a cell/trench landfill design that optimize landfill space, minimize liability, and protect the environment. The bottom and sides of the cell/trench would typically be lined with a 0.60 m thick layer of fine-grained alkaline product (for example, 3/8th-inch minus limestone, lime, or equivalent alkaline product) applied in consecutive compacted lifts 0.10-0.15 m thick.

There are no permitted landfills that may accept sulfur contaminated soil in British Columbia. In Alberta, landfill disposal of sulfur soil is limited to Class I or Class II landfills. These facilities are typically located at sulfur production or recovery plants, within mined out areas at coal and oil sands plants or off-site as stand-alone or components of specific waste management facilities. A Class II registered landfill is a landfill where not more than 10 000 tonnes per year of waste is disposed of. Regardless of the approval, the class and design of the landfill, and the quantity of sulfur soil being disposed of, the applicable disposal procedures must be described in the landfill operations plan.

Professional Opinion

In our opinion, the use of BC ENV guidance for landfill closure 2016 2nd Edition *Landfill Criteria for Municipal Solid Waste* to design the closure of a facility that contains sulfur soils may not be appropriate. Government of Alberta Environment document entitled "*Guidelines for the Remediation and Disposal of Sulphur Contaminated Solid Wastes*" dated 12 September 2011 could have been used to design the closure of the cells within the facility that contain the sulfur soil.

The potential for specific micro-organisms to oxidize the sulfur in the sulfur soil or water under aerobic conditions is concerning with the current closure design that does not include the addition of a sufficient amount of alkaline material is to prevent sulfur oxidation, neutralize the sulphuric acid eventually formed and prevent migration of acidic leachate from the landfill. Sulphuric acid increases soil acidity, solubilizes sulphates, mobilizes trace metals from soil, reduces the concentration of basic ions, decreases soil availability of nutrients, and ultimately reduces microbial activity. In our opinion, the closure design should have incorporated acid neutralizing agents.

Limitations

This review was conducted for the exclusive use of the Shawnigan Residents Association. The letter is intended to provide a technical review and opinion of information provided in the documents referenced above respecting the quality of material at the subject Site. This letter is not meant to represent a warranty, or a legal opinion regarding compliance with applicable laws. The reviewer makes no other representation or warranty as to the accuracy or completeness of the information provided.
This review followed the standard of care expected of professionals undertaking similar work in British Columbia under similar conditions. The reviewer's conclusions and opinions are entirely based on the information provided by the client and by contractors as noted in this report. The reviewer has relied on the accuracy and completeness of the background materials upon which the reported information was based and is not responsible for errors or omissions in such background materials.

Any use by which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. The reviewer accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Closure

We trust that this review is adequate for your current needs. Should you have any questions or require additional information please contact he undersigned.

Sincerely,

G Hamilton Consulting Inc.

Gary Hamilton

Gary Hamilton, P.Geo.
Contaminated Sites Approved Professional

Appendix 2: Estimated Cost of Removing the Contaminated Soil by Gary Hamilton, BC Contaminated Sites Association Professional

5 July 2018

Patrick Consulting Inc.
PO Box 581, Stn Ganges
Salt Spring Island, BC
V8K 2W2
(Phone: 250-538-0215)

Shawnigan Research Group,
A division of the Shawnigan Residents Association
2268 Renfrew Road
Shawnigan Lake BC V0R 2W1

Attn: David Munday

RE: Draft Estimated Costs to Remove Contaminated Soil at Lot 23 – Stebbings Road, Shawnigan Lake, BC to a Permitted Facility

Dear David,

Further to our proposal dated 12 June 2018, Patrick Consulting Inc. (PCI) is pleased to provide Shawnigan Research Group (SRG) and Shawnigan Residents Association (SRA) with the results of our estimate of the costs and approach for the removal of contaminated soil at the contaminated soils landfill at Lot 23 – Stebbings Road Shawnigan Lake, BC. (the "Site").

Background

Information on the source and chemical characteristics of the material placed at the Site was obtained by SRG from the Province of British Columbia through a freedom of information request. We understand that this information consisted mainly of 20 large PDF files of laboratory certificates, summary data tables and environmental site assessment reports. Based on the information presented in the Updated Final Closure Plan for the Site that was prepared by Sperling Hansen Associates Inc. dated 21 July 2017, it is estimated that 98,000 tonnes of contaminated soil (waste) is present that could potentially be relocated.

The scope of work comprised a) a review of the existing data to develop an understanding of the source and chemical characteristics of the contaminated soil, and then b) an estimate of the potential costs to remove and dispose of the material. The estimated costs include professional and contractor fees to characterize, load, transport, broker, and dispose of the material at a permitted facility.

Review of Available Data

A representative number of the documents provided was reviewed, with a focus on identifying the source and source characteristics of the soils. PCI also contacted waste disposal companies familiar with the waste material to corroborate the findings of the document review.

Results of our document review concluded that the material at the Site originated from the following three primary sources:

- Fleet Maintenance Facility, Cape Breton at CFB Esquimalt, BC;
- Pacific Coast Terminal, Port Moody, BC; and
- Industrial and commercial sites in BC.

The primary contaminants of concern were identified to be heavy metals, petroleum hydrocarbons and sulfur. The heavy metals primarily consisted of antimony, arsenic, cadmium, chromium, copper, lead, nickel, and zinc. Concentrations of heavy metals and petroleum hydrocarbons are regulated under the BC Environmental Management Act and its regulations (i.e., Contaminated Sites Regulation); however, sulfur has only limited restrictions that mainly relate to its disposal to agricultural land. Based on the data reviewed, it appears that concentrations of contaminants exceed the provincial Industrial/Commercial land use standards but are less that the Hazardous Waste Regulation standards.

Due to the format of the data provided to PCI, we were unable to establish a comprehensive listing of all contaminants of concern and the reported concentrations of each contaminant. As an alternative approach, we evaluated a statistically representative sub-set of the data.

Results of Review of Disposal Options

Based on the chemical characteristics of the material, disposal options were assessed. The most practical, feasible options were disposal at permitted solid waste landfills in the United States, specifically in Washington and Oregon states. Both Waste Connections, Inc. and Waste Management Inc. have facilities in the USA that are permitted to accept this material. Disposal options in British Columbia and Alberta were also assessed; however, due to the heavy metals and sulfur content in the waste, it is unlikely that this material would meet the landfill waste permit requirements.

The logistics of removing the material from the Site and final disposal at a permitted landfill in the United Sates are somewhat complex. As a first step, it is necessary to ensure that the material is adequately characterized so that the receiving facility can confirm acceptance. Typically, one composite sample (composed of 3 to 5 aliquots of the material) is required for each 100 tons (US) of material. One US ton equals 0.907 tonnes; therefore, 98,000 tonnes would equal approximately 108,000 US tons. A total of at least 1,080 soil chemical analyses would be needed to meet typical US landfill permit disposal requirements.

Extensive sampling of the waste material was conducted prior to acceptance at the Site. Therefore, we have assumed that a limited amount of additional sampling would be required to meet the requirements of the disposal sites.

Once the waste is adequately characterized and a landfill has been identified, a waste customs broker would need to be retained to facilitate preparing the documentation required to move the material into the United States.

The removal process would begin with loading the material onto dump trucks and transporting the material by land to the Bamberton barge loading facility. Once the material is loaded onto the barge, it would be transported to a barge unloading facility located closest to the receiving landfill. The material would then be unloaded and transported by either truck or rail to the permitted facility.

Cost Estimate

As the final destination of the material is assumed to be the United States, the mass of material was converted from 98,000 tonnes to 108,000 US tons. Waste transportation costs from the Site to the barge unloading facility in the United States were estimated in Canadian dollars, and the waste transport and disposal cost from the barge unloading facility to the landfill in the US were provided in US dollars and converted to Canadian Dollars at an exchange rate of 0.75.

A breakdown of the costs in Canadian dollars for each step of the removal process is as follows:

Task	**Estimated Cost ($CAN)**
Waste characterization and brokerage fee:	$250,000
Waste loading and transportation to Bamberton barge facility ($10 per ton):	$1,080,000
Transportation by barge to unloading facility in United States (10,000 ton per barge; 11 loads @ $250,000 per load):	$2,750,000
Barge unloading and transportation to permitted landfill ($15 per ton)	$1,620,000
Landfill tipping fee ($50 per ton):	$5,400,000
Landfill closure sampling and reporting	$100,000
Total Estimated Cost:	***$11,200,000***

Estimated transportation and disposal costs were provided by Waste Connections, Inc. and QM Environmental (Quantum Murray LP). Barge loading fees were provided by the Malahat Nation. Actual costs could be determined through a competitive bidding process.

Limitations

This review was conducted for the exclusive use of the Shawnigan Residents Association. The report is intended to provide a technical review and opinion of information provided in the documents referenced above respecting the quality of material at the subject Site adequacy of the environmental Site investigations and remediation conducted at the subject Site, and an opinion of costs. This report is not meant to represent a warranty, or a legal opinion regarding compliance with applicable laws. The reviewer makes no other representation or warranty as to the accuracy or completeness of the information provided.

This review followed the standard of care expected of professionals undertaking similar work in British Columbia under similar conditions. The reviewer's conclusions and opinions are entirely based on the information provided by the client and by contractors as noted in this report. The reviewer has relied on the accuracy and completeness of the background materials upon which the reported information was based, and is not responsible for errors or omissions in such background materials.

Any use by which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. The reviewer accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Closure

We trust that the estimated costs to remove the waste material from the Site to a permitted facility, as presented in this letter, is sufficiently detailed for your current needs. Should you have any questions or require additional information, please contact the undersigned at your convenience.

Sincerely,

Patrick Consulting Inc.

Gary Hamilton, P.Geo.
Contaminated Sites Approved Professional

Reviewed by:

Guy Patrick, P.Eng.
Director

Appendix 3: Why Does the Final Closure Plan Developed by Sperling Hansen Associates Completely Contradict the First Closure Plan Developed by Sperling Hansen?

Introduction

The Shawnigan Research Group has been given the specification for a landfill in a bedrock quarry, prepared in 2016 by a leading British Columbia Engineering firm. That specification is called **16Spec** in this article.

We also have the **As Built** drawing supplied by the companies. An As Built drawing is an exact engineering drawing of the landfill. It is made as part of the Quality Control during construction. The As Built is stamped by an engineer, showing that the engineer and his firm stands behind the drawing as being a truthful depiction of the landfill.

This article compares **16Spec** to the **As Built** for the SIA landfill.

We look at the 6 parts of the landfill base, from the bedrock, the lowest level, to the sand leachate collection layer, the highest layer and immediately under the waste itself. The article explains the functions of each layer in turn.

As a whole, the 6 layers must collect all leachate coming out of the waste and move it to a leachate collection system. Leachate is water plus contaminants leaving the waste. If there were no water in the waste, there would be no leachate - no contamination leaving the site. Since the waste brought to the site was at times supersaturated - of 45% water by weight - and since the waste was uncovered through an entire Shawnigan Lake rainy season during which 2,000 mm of precipitation landed on the waste, the waste contains many thousands of cubic meters of water and thus will produce many thousands of cubic meters of leachate.

Leachate capture is crucial to the landfill not contaminating the watershed.
The As Built Model
This model shows the 6 parts of the landfill on which the contaminated waste rests.

This model is to scale. The height on the wall on the left is about 10 m (meters) and the length of the base is about 65 m.

As Built Landfill Model

First, naming the parts.

As Built Landfill Layers Named

1. Bedrock

Beginning at the bottom, the bedrock. While there has been considerable debate on how permeable - the rate at which water can flow through it - it is now generally conceded that water can permeate the bedrock over time. The length of time water sits on the bedrock determines how much water moves though the bedrock and into the groundwater.

The **As Builts** do not address the shape of the surface of the bedrock. It is simply whatever shape the bedrock had after blasting to mine the rock in the quarry. We do not know whether water landing on the bedrock will simply sit in a depression or will flow over smooth areas in any some direction. We know nothing. We can only assume that some water sill sit in pools and some water will flow in each possible direction.

16Spec defines the surface of the bedrock in its landfill specification:
The base of the quarry will carry a 2% grade, draining to the west towards the existing settling pond. The base of the quarry will be blasted and excavated to a smooth surface, as much as possible, to ensure minimal ponding of water.

There are two separate aspects of this specification:
The base of the quarry - the bedrock - will carry a 2% grade, draining to the west towards a collection point.

The base of the quarry - the bedrock - will be blasted and excavated to a smooth surface, as much as possible, to ensure minimal ponding of water.
16Spec makes it clear that knowing that the surface of the bedrock is smooth and that its slope ensures that any water on the bedrock will move to a collection point is an essential part of the construction of a landfill in a bedrock quarry.

When SIA began construction of its landfill, it had a permit to deposit 5,000,000 tonnes of contaminated waste in the quarry. At the time, it chose to start landfilling before the quarry had been mined to the maximum depth. Instead, it placed the landfill in a temporary location, 10 m above the eventual pit bottom. Because this was a temporary location, SIA used the bedrock as it was. That is, the unknown surface left by quarrying long before a landfill was permitted.

This level of the landfill base - the bedrock - therefore fails completely to meet **16Spec**.

Bedrock Layer surface unknown
The bedrock layer is exposed, the bottom layer of the model is pulled out, here to show one possible surface - sloping down to the left and right. This is just one possibility, and perhaps not the most likely possibility. The bedrock surface could be dome shaped, high in the middle and sloping down in all directions. It could be cup shaped - low in the middle, with all slopes into the middle. It could be any **more-or-less-flat** surface imaginable. It is more-or-less-flat because blast holes would be drilled to more or less the same depth and would be filled with more or less the same amount of explosive rock would be more or less the same hardness and the blast would more or less have the same effect across this bedrock surface.

When the permit was suspended in January 2017, the temporary location suddenly became a permanent location. Since the temporary location already contained 100,000 tonnes of contaminated waste, they could not go back and properly prepare the bedrock under the landfill.

The engineering firm writing the current Final Closure Plan has expressed no concern about the failure to prepare the bedrock layer.

2. Blast Rock Seepage Layer

On top of the bedrock is a layer of blast rock. That is, after blasting had reduced this part of the quarry to broken rock, much of that broken rock was moved to a crusher and reduced to gravel for various purposes.

Some of the blast rock was left in place so that the area was a suitable surface for mining equipment.

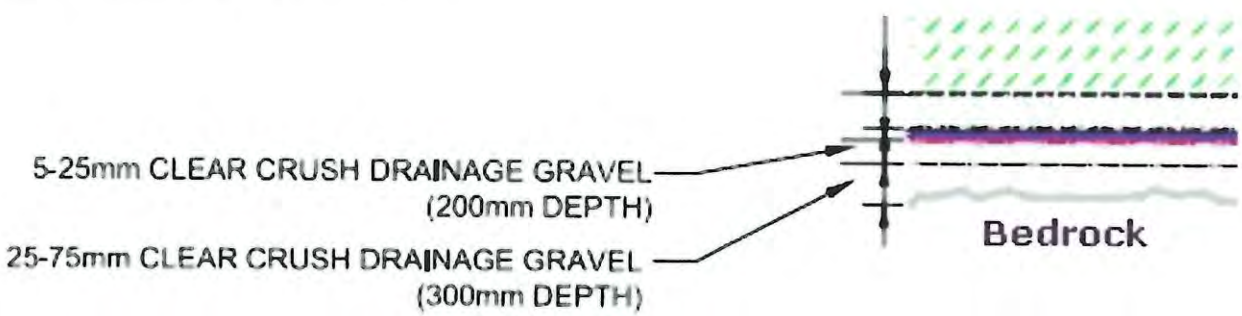
As Built Seepage Layer

The seepage layer here is shown with a texture taken from a picture of blast rock in the quarry.

It is called the seepage layer because it is a high permeability layer. Any water entering this layer falls almost immediately to the bedrock. There is either pools if it happens to land in a depression, or flows downhill along the bedrock, if it lands on a dome.

The seepage layer is there to allow water to flow down to the bedrock.

Here is the seepage layer in **16Spec**:



16Spec Seepage Layer

Here the seepage layer has two types of gravel. The lower gravel is 1" to 3", while the upper gravel is .2" to 1".

None of the rock in the **As Built** seepage layer meets either specification. Much is 4" or larger. It is simply what was left after blasting. It is not sized gravel.

Why is this a problem? The seepage layer has a second function - supporting the layers above it, the very low permeability layers. The layer immediately above the seepage layer is the very low permeability clay layer. When placed on fine gravel, the clay layer is stable. When placed on coarse gravel, the clay layer will wash into the coarse gravel if it is saturated with water. The second phase of the SIA landfill, Cell 1B, was built during October 2015 when an estimated 150mm rain fell on the quarry. The potential for the clay to wash into the seepage layer either before the base liner was added, or after, increases with increased gravel size.

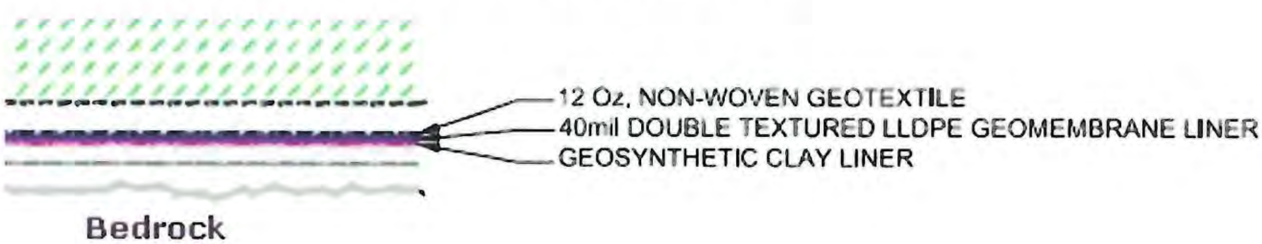
The **As Built** seepage layer does not provide an adequate base for the clay liner. It certainly does not meet the **16Spec**.

3. Clay Liner

The clay liner is the main protection from leachate leaving the landfill and entering the seepage layer.

As Built Clay liner

What does **16Spec** say about clay liners? Here is their model:



16Spec Impermeable Layers

The clay liner, from **16Spec**:

a double lined system composed of a geosynthetic clay liner (GCL) overlain by a 40mil HPDE geomembrane liner. The GCL material has become the secondary liner of choice in landfill applications as the bentonite clay has a hydraulic conductivity that is typically 3 to 5 orders of magnitude less permeable than low permeability silts and clays available on Vancouver Island, consistent engineering properties and much simpler installation.

16Spec continues:
experience working with numerous clay liners that they are prone to desiccation cracking and dust generation during the summer months and stockpiles are prone to erosion, absorption of water and tracking of mud during the winter months, increasing the potential for contamination of the gravel drainage layers during construction of the basal liner system.
What they are saying is that the clay used in the SIA landfill is unacceptable. They also say that with even with the GCL which is 1000 to 100,000 times less permeable than the clay used, the landfill should still have a plastic liner on top of the clay layer.

The **As Built** clay liner does not meet the **16Spec**. In fact, it is 1,000 to 100,000 times more permeable than what is required.

4. Sand Leak Detection Layer

The **As Built** landfill has a layer of sand on top of the clay.

As Built Sand Leak Detection Layer

The next layer in the **As Built** landfill is the Leak Detection Layer. There is no corresponding layer in **16Spec**. More on that later.

This is a relatively high permeability layer that lies between the low permeability clay below and the plastic liner above. Should the plastic liner leak, the leachate would enter the sand and flow down to the clay. Because the clay is much less permeable than the sand, the leachate would flow downhill on the clay to the leak detection piping. The addition of this layer in the SIA landfill is perhaps to make up for the substandard clay they used. Rather than the correct low permeability clay, they hoped that permeable sand on so-so clay would carry leaked leachate to a collection point.

This sand layer is 300 mm thick. This sand layer exposed at the top runs around the landfill - a distance of 170 m. The total exposed area of this layer is then 51 m2 (square meters). Rain falling on this exposed area should appear in the leak collection system. There is about 2 m of rainfall on the site a year. That means the leak detection system should collect 102 m3 (cubic meters) a year, even if the landfill is not leaking.

No water has ever been collected by the leak detection system. The only possible conclusion is that the leak detection system is entirely non-functional. This problem was first pointed out by engineers of Hemmera in their review of an earlier Final Closure Plan.

In the meeting with ENV on 19 04 16, Sperling of Sperling Hansen, authors of all four Closure Plans, drew a diagram to explain why the leak detection system did not collect any rainwater. His diagram was wrong. It omitted the clay between the quarry wall and the landfill. He said water entering the sand layer would disperse into the quarry wall.

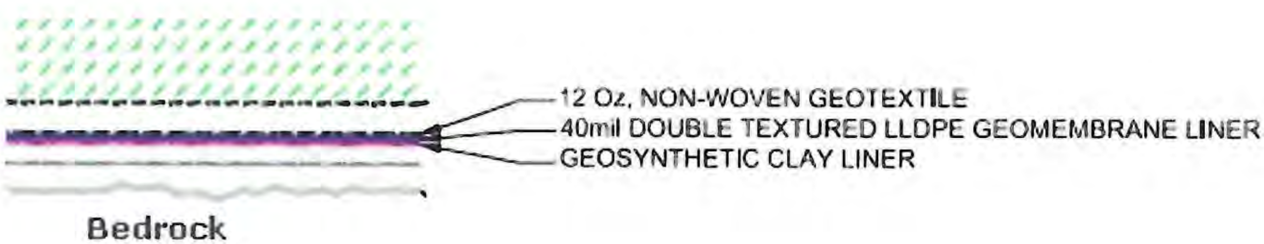
Sperling demonstrated a profound misunderstanding of the construction of the layers supporting the landfill.

We are faced with the following facts:
102 m3 rainwater enters the leak detection system each year;
no rainwater is collected by the leak detection system.

Conclusions include:
the sand seepage layer is non-functional;
the clay liner is allowing this water to pass through into the blast rock seepage layer;
the leak detection system is entirely non-functional.

Impossible conclusions:
the landfill is not leaking through to the leak collection layer.

It is interesting that the **16Spec** does not include a leak detection layer. Again, their base layers are:



16Spec Impermeable Layers

There three leak prevention layers - the geosynthetic clay liner, the LLDPE liner and the geotextile. These leak prevention layers are far superior (1,000 to 100,000 times less permeable, with two plastic layers) to the **As Built** landfill.

With this set of 3 layers, leaks in any one layer move along the next lower layer to the leachate collection piping. It far superior leachate collection layer above the impermeable layers also helps.

5. Plastic Liner

The plastic liner both prevents movement of water into the lower layers and prevent movement of the layers themselves.

As Built - Plastic Liner

The existing landfill has a single 40 mil LLDPE liner that was installed during the rainy season.

2015:10:29 14:50:51

The next day 29 mm of rain fell at the Shawnigan Lake Environment Canada weather station. Typically, rainfall at the landfill is 133% of the rainfall at lake level. The liner was installed and welded in the rain.

In their current Final Closure Plan, the consultant for the companies insists that closure must take place during the dry season. And yet, they approve of this landfill constructed during the rainy season.

Perhaps the **As Builts** did not include the fact that the base liner was laid down and welded during the rainy season. However, in several meetings with them, the SRG has repeatedly made this point. To no avail.

6. Sand Leachate Collection

Sand - Leachate Collection

The **As Built** drawings for the site show the sand layer for leachate collection as an even 30 cm (about 1 foot) layer on top of the base liner.

2015-11-13 11-47-36 -sand missing and disturbed

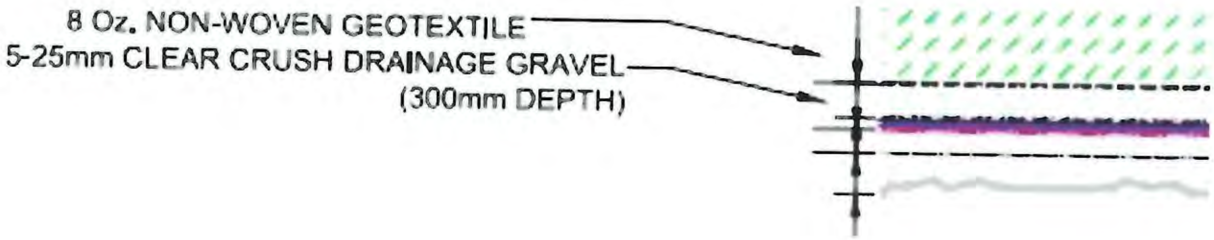
The reality is quite different. The above picture was taken after they started moving waste onto cell 1B. It is clear in the picture that the sand layer is missing in many places.

2015-11-19 11-47-29 sand washed off liner

A few days later, after more heavy rain and water leaching from the waste (the waste from Pacific Coast Terminals was being delivered with over 45% water content), sand has been washed from the base liner.

It is clear from these pictures that this sand layer is no more than 15 mm (about 6 inches), where there is any sand at all.

What is the **16Spec** recommended leachate collection system?



16Spec Leachate collection

16Spec requires 300 mm (1 foot) of clear crush drainage gravel, covered by 8 Oz. non-woven geotextile. The **As Built**, evident in the above pictures, is 0 to 15 mm of sand.

16Spec uses gravel instead of sand for several reasons. First, gravel is much more permeable. Any water entering this gravel layer moves much more quickly to the collection pipes and so has less chance of leaking. Second, gravel is much less likely to be disturbed by rainfall during installation. (See what happened to the sand layer during the October rains in pictures below). Finally, by requiring geotextile on top of the gravel, **16Spec** prevents fines from the waste (which is mostly clay with very fine particles) from entering the leachate collection layer and reducing its permeability.

Lest you think they repaired the sand layer before placing the waste on top:

2015-11-19 11-48-10 waste on sand layer

The waste being delivered during this time period, the first waste deposited in cell 1B, was the high sulphur waste from Pacific Coast Terminals. To be clear: this high sulphur waste with moisture content over 45% is being placed directly on the base liner in those many areas in which the sand layer is now missing.

It should be no surprise that leachate collection amounts have dropped so precipitously. The leachate collection system, which is primarily this sand layer, was hopelessly compromised during construction of the landfill. What we have in place of a permeable sand layer is the waste itself - often dredgeate made up of various clays.

The Sulphur Complication

We see, in the above pictures, that high sulphur waste from Pacific Coast Terminals was deposited directly on the base liner.

Sulphur, water and bacteria combine to produce sulphuric acid. The plastic base liner is not designed to withstand sulphuric acid.

When a previous consignment of PCT sulphur waste had to be moved from a site in Princeton, no landfill in BC was able to accept the waste. Let me repeat that. No existing landfill in BC, all of which presumably can comply with the 2016 Landfill Criteria for Municipal Solid Waste (the requirement for the SIA landfill), could accept this high sulphur waste, even when dry.

High sulphur waste requires a specifically designed landfill. In particular, the entire receiving area has to be lined with cement powder which is there to neutralize any sulphur bearing leachate escaping the landfilled waste. The high sulphur content waste must be dry when it is delivered. The high sulphur content waste must be delivered during the dry season and covered before any rain can fall on the waste.

The current Sperling Final Closure Plan continues to gloss over the complete failure of this site to be suitable to accept high sulphur waste.

Conclusion

The lowest 6 layers of the landfill, the layers that prevent contamination from the waste from entering the environment, do not meet the **16Spec** requirements for a landfill in a bedrock quarry.

Let me repeat, **NOT A SINGLE LAYER OF THE LOWEST 6 LAYERS OF THE LANDFILL** meets **16Spec**.

16Spec makes it clear that the SIA landfill is not acceptable as a contaminated waste landfill, let alone a landfill receiving high sulphur waste.

16Spec was written in December 2016 by a BC Engineering company called Sperling Hansen Associates. It was written as a proposal for the SIA quarry landfill design before Permit 105809 was cancelled.

Now it is a surprise to me that there are two engineering firms in BC, both called Sperling Hansen.

However, that must be the case. It is clearly impossible that the authors of **16Spec** could be the same people who looked at the **As Built**s for the SIA landfill and decided that it meets or even exceeds the requirements for a contaminated waste landfill in a bedrock quarry in BC. Let alone one with high sulphur content waste deposited directly on the plastic base liner.

While we do not necessarily agree that a landfill built to the **16Spec** would not contaminate the Shawnigan Lake Community watershed, we are absolutely certain that a landfill which fails to meet the **16Spec** on every single layer, and which contains 50,000 tonnes of waste that is unacceptable in any landfill in BC, cannot possibly be allowed to remain in the watershed.

It is now up to ENV to decide which of the consulting firms, both named Sperling Hansen, is right and which is catastrophically wrong about this landfill.

We are not asking that you take the word of the Shawnigan Research Group. Rather we ask you to compare the work of two respected BC Engineering firms and decide which is right.

BRITISH COLUMBIA | Ministry of Environment and Climate Change Strategy

Declaration

I, Ben Kempel as a member of Association of Professional Geoscientists of Ontario declare

Select one of the following:

☒ Absence from conflict of interest

Other than the standard fee I will receive for my professional services, I have no financial or other interest in the outcome of this project.
I further declare that should a conflict of interest arise in the future during the course of this work, I will fully disclose the circumstances in writing and without delay to AJ Downie, Director, Authorizations South, erring on the side of caution.

☐ Real or perceived conflict of interest

Description and nature of conflict(s):

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____

I will maintain my objectivity, conducting my work in accordance with my Code of Ethics and standards of practice.

In addition, I will take the following steps to mitigate the real or perceived conflict(s) I have disclosed, to ensure the public interest remains paramount:

____

____

____

Further, I acknowledge that this disclosure may be interpreted as a threat to my independence and will be considered by the statutory decision maker accordingly.

Signature:

X [signature]

Print name: Ben Kempel

Date: May 22/19

Witnessed by:

X [signature]

Print name: Madison Mantha

Ministry of
Environment and
Climate Change Strategy

Declaration

I, Hassan Gilani as a member of Engineers and Geoscientists BC declare

Select one of the following:

☒ Absence from conflict of interest

Other than the standard fee I will receive for my professional services, I have no financial or other interest in the outcome of this project. I further declare that should a conflict of interest arise in the future during the course of this work, I will fully disclose the circumstances in writing and without delay to AJ Downie, Director, Authorizations South, erring on the side of caution.

☐ Real or perceived conflict of interest

Description and nature of conflict(s):

I will maintain my objectivity, conducting my work in accordance with my Code of Ethics and standards of practice.

In addition, I will take the following steps to mitigate the real or perceived conflict(s) I have disclosed, to ensure the public interest remains paramount:

Further, I acknowledge that this disclosure may be interpreted as a threat to my independence and will be considered by the statutory decision maker accordingly.

Signature:

X

Print name: HASSAN GILANI

Date: MAY 22, 2019

Witnessed by:

X

Print name: Konstantinos Paliouras

BRITISH COLUMBIA

Ministry of Environment and Climate Change Strategy

Declaration

I, David Barton as a member of Engineers and Geoscientists BC declare

Select one of the following:

☒ Absence from conflict of interest

Other than the standard fee I will receive for my professional services, I have no financial or other interest in the outcome of this project.
I further declare that should a conflict of interest arise in the future during the course of this work, I will fully disclose the circumstances in writing and without delay to AJ Downie, Director, Authorizations South, erring on the side of caution.

☐ Real or perceived conflict of interest

Description and nature of conflict(s):

I will maintain my objectivity, conducting my work in accordance with my Code of Ethics and standards of practice.

In addition, I will take the following steps to mitigate the real or perceived conflict(s) I have disclosed, to ensure the public interest remains paramount:

Further, I acknowledge that this disclosure may be interpreted as a threat to my independence and will be considered by the statutory decision maker accordingly.

Signature:

X

Print name: DAVID BARTON

Date: May 22/2019

Witnessed by:

X

Print name: RON GEPERKUSKI, P.ENG (BC/ON)

Ministry of Environment and Climate Change Strategy

BRITISH COLUMBIA

Declaration

I, Dr. Iqbal Hossain Bhuiyan as a member of Engineers and Geoscientists BC declare

Select one of the following:

☒ Absence from conflict of interest

Other than the standard fee I will receive for my professional services, I have no financial or other interest in the outcome of this Cobble Hill Landfill closure Plan. I further declare that should a conflict of interest arise in the future during the course of this work, I will fully disclose the circumstances in writing and without delay to AJ DOWNIE, erring on the side of caution.

☐ Real or perceived conflict of interest

Description and nature of conflict(s):

____

____

____

I will maintain my objectivity, conducting my work in accordance with my Code of Ethics and standards of practice.

In addition, I will take the following steps to mitigate the real or perceived conflict(s) I have disclosed, to ensure the public interest remains paramount:

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____

____

Further, I acknowledge that this disclosure may be interpreted as a threat to my independence and will be considered by the statutory decision maker accordingly.

Signature:

X ________________

Print name: DR. IQBAL HOSSAIN BHUIYAN

Date: May 27th, 2019

Witnessed by:

X ________________

Print name: ANNE GALLANTREE

BRITISH COLUMBIA | Ministry of Environment and Climate Change Strategy

Declaration

I, James Reid as a member of Engineers and Geoscientists BC declare

Select one of the following:

☒ Absence from conflict of interest

Other than the standard fee I will receive for my professional services, I have no financial or other interest in the outcome of this project. I further declare that should a conflict of interest arise in the future during the course of this work, I will fully disclose the circumstances in writing and without delay to AJ Downie, Director, Authorizations South, erring on the side of caution.

☐ Real or perceived conflict of interest

Description and nature of conflict(s):

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____

____

I will maintain my objectivity, conducting my work in accordance with my Code of Ethics and standards of practice.

In addition, I will take the following steps to mitigate the real or perceived conflict(s) I have disclosed, to ensure the public interest remains paramount:

____

____

____

Further, I acknowledge that this disclosure may be interpreted as a threat to my independence and will be considered by the statutory decision maker accordingly.

Signature:

X James Reid

Print name: JAMES REID

Date: MAY 22 2019

Witnessed by:

X

Print name: Stephen Bishop

BRITISH COLUMBIA | Ministry of Environment and Climate Change Strategy

Declaration

I, Scott Garthwaite as a member of ASTTBC declare

Select one of the following:

☑ Absence from conflict of interest

Other than the standard fee I will receive for my professional services, I have no financial or other interest in the outcome of this Cobble Hill Closure Plan.. I further declare that should a conflict of interest arise in the future during the course of this work, I will fully disclose the circumstances in writing and without delay to AJ Downie / Luc Lachance, erring on the side of caution.

☐ Real or perceived conflict of interest

Description and nature of conflict(s):

I will maintain my objectivity, conducting my work in accordance with my Code of Ethics and standards of practice.

In addition, I will take the following steps to mitigate the real or perceived conflict(s) I have disclosed, to ensure the public interest remains paramount:

Further, I acknowledge that this disclosure may be interpreted as a threat to my independence and will be considered by the statutory decision maker accordingly.

Signature:

X [signature]

Print name: Scott Garthwaite

Date: 27/05/2019

Witnessed by:

X Megan Gardner

Print name: Megan Gardner

BRITISH COLUMBIA

Ministry of Environment and Climate Change Strategy

Declaration

I, DR. TONY SPERLING as a member of APEG BC declare

Select one of the following:

☒ Absence from conflict of interest

Other than the standard fee I will receive for my professional services, I have no financial or other interest in the outcome of this COBBLE HILL CLOSURE PLAN. I further declare that should a conflict of interest arise in the future during the course of this work, I will fully disclose the circumstances in writing and without delay to LUC LACHANCE & A.J. DOWNIE erring on the side of caution.

☒ Real or perceived conflict of interest

Description and nature of conflict(s):
NEW CLOSURE PLAN RESULTS IN MORE STABLE SLOPES THAT WILL REQUIRE ADDITIONAL FILL SOIL. REVENUE FROM SOIL RECEIVED WILL CONTRIBUTE TO PAYING FOR SOME OUTSTANDING WORK BY ALTERRA CONSTRUCTION AND SHA ON THIS PROJECT.

I will maintain my objectivity, conducting my work in accordance with my Code of Ethics and standards of practice.

In addition, I will take the following steps to mitigate the real or perceived conflict(s) I have disclosed, to ensure the public interest remains paramount:
NO FURTHER ACTION REQUIRED AS I BELIEVE SOLUTION IS A WIN-WIN IDEA THAT RESULTS IN A SAFER CLOSURE PLAN THAN PREVIOUS DESIGN.

Further, I acknowledge that this disclosure may be interpreted as a threat to my independence and will be considered by the statutory decision maker accordingly.

Signature:
X [signature]

Print name: DR. TONY SPERLING

Date: MAY 27, 2019

Witnessed by:
X Anne Gallantree

Print name: ANNE GALLANTREE