MEMO

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Date:	Project No.:
May 26, 2017	351312

Subject:

Groundwater/Surface Water Assessment Review of Walker Environmental Group Southwestern Landfill Environmental Assessment Submissions

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1.0 Introduction

We have been retained by the Town of Ingersoll as experts on hydrogeology (groundwater) and surface water issues in connection with the Southwestern Landfill Proposal (the Walker Environmental Group (WEG) landfill). In preparation of this letter, we have reviewed the following reports:

- Southwestern Landfill Proposal Environmental Assessment: Groundwater/Surface Water Assessment Work Plan (revised report dated Feb. 8, 2017);
- Alternative Methods Interim Report (draft report dated Jan. 3, 2017);
- Facility Characteristics Assumptions (draft report dated Jan. 3, 2017);
- Work Plan: Cumulative Effects Assessment in the Southwestern Landfill EA (draft for Discussion dated Jan. 12, 2017).

Collectively, these reports are hereinafter referred to as the “Work Plans”. We have limited our review and commentary to the hydrogeological and surface water aspects of the Work Plans which are closely linked.

2.0 Background

In Ontario, O.Reg. 232/98 provides a standard approach to characterizing the hydrogeology and hydrology, designing, and predicting the performance of a new landfill. However, due to the multitude of potential issues with the site-specific hydrogeological setting of a landfill, O.Reg. 232/98 cannot provide full consideration of and guidance for all aspects of siting, designing, predicting and mitigating the potential environmental impact of a proposed landfill. As a result, we recommend that O.Reg. 232/98 should be understood as only a minimum standard, and, in our opinion, should be used only as guidance.

From a hydrogeological perspective, O.Reg. 232/98 imposes requirements on landfill proposals to reliably monitor the effects on quantity and quality of groundwater and other media (surface water, landfill gas). At the proposed WEG landfill, this is a very challenging task and we would like to emphasize that the site in which the proposed landfill is planned is not a “typical” site. Instead, it is a complex hydrogeologic setting requiring significant amounts of studies to adequately characterize, monitor, and plan for any failures that could occur (e.g., leakage of leachate leading to contamination of surface water/groundwater resources or leakage of landfill gas creating explosion hazards). Even with detailed studies, it is very difficult to reliably predict the changes in groundwater flow and the development of a potential contaminant plume in groundwater in fracture rock settings. We acknowledge that it can be done, but it is ultimately more complicated and comes with much greater uncertainties than what would be the case for other hydrogeological settings. This consequently requires more effort on the part of hydrogeological characterization and on-going monitoring.

The unique features of the WEG landfill proposal include:

- The landfill is proposed to be located within a fractured rock hydrogeological setting. It is commonly accepted that fractured rock sites are highly complex and therefore significantly more complicated to characterize, monitor, and predict than porous media sites. In addition, in fractured rock media, groundwater and gas flow and contaminant transport occur at much faster rates than in porous media, and contaminant attenuation (e.g. by adsorption to soil particles) is minimal to non-existent in fractured rock. These commonly accepted complexities are unique to fractured rock settings and therefore require a more detailed hydrogeological investigation than for simpler sites. It is more difficult to predict and monitor the long-term performance of a landfill in this setting, and to mitigate any impacts, should this be required.
- WEG proposes to construct the landfill within a deep quarry on top of several metres of backfill. Differential settlement of the backfill material beneath the engineered systems (liners, leachate collection pipes) will be a significant concern for the gradual degradation or even the potentially sudden breakage of the liner and leachate collections systems which would result in a sudden escape of landfill leachate into the groundwater system. Such a failure could also release landfill gas into the unsaturated soil zone. Once an escape of landfill leachate or gas has occurred, the natural system would have to provide sufficient attenuation capacity to reduce any potential impacts to acceptable levels. However, due to the fractured rock setting, natural attenuation may be very limited or not be available at all.
- Proximity of the landfill to the Thames River and the Ingersoll water supply wells. Once landfill leachate or landfill gas escape from the landfill’s containment system (i.e. liner and leachate collections system), the contaminants will migrate with the groundwater (landfill leachate) or unsaturated soil zone (landfill gas). Natural attenuation with the fractured rock setting will be limited

and the prevention of impacts will depend on the early detection of impacts and the successful implementation of contingency (mitigation) systems. Due to the nature of a fractured rock setting, this is a very difficult task with an uncertain outcome. The Thames River is immediately downgradient from the proposed landfill, and the water supply wells for Ingersoll are nearby (and future water supply requirements could increase which may result in an increase in the area of the groundwater protection zones).

Compared to other hydrogeological settings, the complexities of a fractured rock setting typically require a substantially increased effort in order to achieve a sufficiently detailed characterization of the hydrogeology. A detailed understanding of the fractured rock system(s), heterogeneities of the various geological deposits, and interaction of groundwater and surface water is required to successfully design a new landfill, to predict the potential migration of landfill-related contaminants, and to monitor (and potentially mitigate) the effects of the landfill on the quantity and quality of groundwater, surface water, and landfill gas.

The Work Plans must clearly acknowledge and provide a more detailed scope of work to address the complexities of this difficult task. In the following sections, we provide our high level concerns, and also provide a more detailed summary of our comments on what we perceive to be gaps in the Work Plans. In particular, many important details to the plans for site characterization, monitoring, numerical modeling, uncertainty analyses, and contingency planning are missing.

In addition, as a matter of record, we would like to point out that the Work Plans have not addressed many of Dr. Illman’s comments from his previous reports. It appears that these comments will be addressed during the EA process and we reserve the right to examine and follow up on any responses by WEG to all of Dr. Illman’s comments from this and previous reports.

3.0 General Observations and Comments

The Work Plans do not provide sufficient information to address the following overall concerns:

1) The fractured rock setting is complex and results in uncertainties for monitoring, predicting, and mitigating potential impacts from landfill leachate and landfill gas

The landfill is proposed to be sited in a fractured rock setting. It is commonly known that fractured rock sites are highly complex due to the presence of discrete fractures, fracture networks, weathering, secondary porosity, and generally, heterogeneities (e.g. due to layered stratigraphy) in the rock. Therefore, fractured rock systems are generally considered to be the most complicated hydrogeological settings to characterize, and it is also much more difficult to predict, monitor and mitigate potential contaminant impacts from landfill leachate and landfill gas than for landfills in porous media settings. Consequently, the complexities inherent in fracture rock settings always leave a significant degree of uncertainty for the prediction, monitoring, and mitigation of potential impacts due to leachate and landfill gas migration.

In addition to the complexities of groundwater flow and gas migration through fractured rock media, groundwater and gas flow and contaminant transport occur at much faster velocities than in porous media, and contaminant attenuation (e.g. by adsorption to soil particles) is minimal to non-existent in fractured rock.

2) Differential settlement of the material beneath the proposed landfill could cause failures of the liner and leachate collection systems

It is proposed to set the landfill into a deep quarry and to build the base of the landfill on top of several metres of backfill. Our concern is that differential settling of the underlying backfill could potentially cause a gradual deterioration or even a sudden failure of the performance of the liner and leachate collection systems. If the liner and/or leachate collection systems fail before their design lifespan is reached, there will be a potential for the escape of landfill leachate and/or landfill gas and the only mitigation available would then be due to natural attenuation (which is limited in a fractured rock setting).

3) We are concerned about the impacts of the proposed landfill on the quantity and quality of the drinking water supply for the Town of Ingersoll

The proposed landfill is near the drinking water wells for the Town of Ingersoll. The proposed groundwater studies must address the long-term changes to the water resource in terms of quantity and quality due to future changing demands on the Ingersoll water supply, location of new water supply wells, water management at the landfill during and after the operation of the landfill, and the potential of a landfill leachate plume on the water resource in the area. We wish to point out that, by design, landfills allow for the escape of contaminants at some point after the landfill operation ceases, and the degree of an impact at a receptor (e.g. a water well or surface water body) depends on the contaminant concentrations that are still present within the landfill at that time and the natural attenuation capacity of the natural groundwater system. As pointed out above, fractured rock settings are highly complex, and predicting the movement of groundwater and contaminants dissolved in groundwater, and the monitoring and mitigation of a contaminant plume in groundwater is difficult and subject to uncertainties, and the natural attenuation of contaminants within a fractured rock system is likely to be minimal. Therefore, appropriate consideration of long-term water supply needs of the Town of Ingersoll and the potential effect of the landfill on the water resource is required.

4) We are concerned about potential contaminant impacts of the proposed landfill on the Thames River

The proposed landfill is in very close proximity and immediately upgradient of the Thames River. The proposed groundwater studies must address the impact of the landfill on the river and surface water quality. Again, as pointed out previously, landfill engineering systems cannot contain landfill-related contaminants (leachate) in perpetuity, and contaminants will, in the long term, escape from the liner system. The impact on the Thames River (and other, smaller surface water bodies) requires careful consideration in general, but also due to the complexities of the fractured rock setting in particular.

4.0 Specific Comments on Sections of the Groundwater/Surface Water Assessment Work Plan

The following sections provide comments on groundwater/surface water pertaining to each of the Work Plans reviewed.

<u>Comments on Southwestern Landfill Proposal Environmental Assessment Groundwater/Surface Water Assessment Work Plan (revised report dated February 8, 2017)</u>

1. p. 1: Title page: revised report
   Comment: This is a revised report and not a final work plan. A final work plan should include details to the study that will be conducted at the site. It should be noted that many of the comments on Dr. Illman's previous submissions as part of Town of Ingersoll's submissions are not incorporated into the revised report. Please provide a detailed response to Dr. Illman's previous comments.

2. p. 4: Study Durations, Operational Period
   Comment: How long is the operation period expected to last? What are some issues that could affect the operational period?

3. p. 4: Study Durations, Post-Closure Period
   Comment: How long is this period estimated to be? The timeframe should be specified.

4. p. 4: Study Durations, EA Criteria, Effects due to contact with contaminated groundwater or surface water
   Comment: How about the effect on the natural groundwater flow path when the landfill is constructed? Would this change the flow direction? Will this focus groundwater flows into certain areas and create stagnant zones where contaminants can accumulate over long periods?

5. p. 5: Study Durations, EA Criteria, Loss/displacement of surface water resources
   Comment: If the groundwater flow path is altered with the construction of the landfill, how will this affect stream flows and flow into/out of wetlands?

6. p. 5, "Post closure Period"
   Comment: the comment "and thus have a more limited range of potential effects" is not appropriate, because the most significant effects or impacts, especially in groundwater and surface water may potentially occur in the post closure period.

7. p. 5:
   Comment: statement "These contaminants have the potential to seep into the groundwater or surface water and could pose a public health concern" should be re-phrased to include environmental health concerns.

8. p. 6: 5.0 Study Areas
   Comment: The study area may need to be examined to consider the impacts of regional groundwater flow. How will current and future municipal wells be affected by activities at the proposed landfill?

9. p. 6: 5.0 Study Areas, "These study areas are not intended to be fixed"
   Comment: Study areas may not be intended to be fixed, but they should be defined in greater detail. Also, the rationale for selecting the study area should be better explained.

10. p. 6: 5.0 Study Areas, "These study areas are not intended to be fixed."
    Comment: The areal extent is mentioned, but what about the vertical extent? Would deeper units be affected by the proposed landfill if leaks develop? Would the leachate be dense and sink causing the plume to migrate downwards? One would also need to know what the expected leachate chemicals will consist of and their concentrations.

11. p. 6: 5.0 Study Areas, "…initial estimate of the study areas based on experience with the existing Carmeuse Lime (Canada) Limited site, and other landfills."
    Comment: Is the extent of the study site based on aggregate operations? The area may be too small considering that the impacts from the landfill are anticipated to be potentially more severe (leakage of contaminants and migration of landfill gases).

12. p. 6: 5.0 Study Areas, "…and other landfills".
    Comment: What other landfills are considered to base the experience upon? Are these landfills built in unconsolidated deposits, fractured rocks, and/or karst terrains?

13. p. 6: 5.0 Study Areas, "The boundaries of the study areas will reflect the limits of the groundwater flow domain…"
    Comment: It is not clear how the limits of the groundwater flow domain will be established. How will the impacts of the proposed landfill be anticipated?

14. p. 7: 5.0 Study Areas, EA criteria, Explosive hazard due to combustible gas accumulation in confined spaces
    Comment: What criteria are used to determine the distance of "500 m" for examining explosive hazard due to combustible gas accumulation in confined spaces? What infrastructure is present (e.g., water mains, sewer lines, tile drains, cables, gas lines, etc.) in the area that could cause the migration and storage of landfill gases that could lead to explosion hazards? The radial focal point is not indicated in the Work Plan (i.e., 500 metres from the limit of waste, or property boundary). The assessment of LFG migration potential does not specifically include the identification all potential receptors within the study area, or evaluation of theoretical gas migration potential within the study area in the event of failure of landfill environmental controls.

15. p.7: 5.0 Study Areas, Loss/Displacement of surface water resources
    Comment: there are several external watercourses north of the site that will need to be diverted or incorporated into the on-site drainage collection system and controls. Given the potential for increased snowmelt and peak flow runoff over time, this volume will need to addressed in the site drainage plan and not adversely impact downstream water users or aquatic systems due to lower flows, if any, to the confluence point of the Thames River.

16. p. 8: 5.0 Study Areas, EA criteria, impact on the availability of groundwater supply to wells.
    Comment: The study site to assess this appears to be too small and needs to be rigorously justified. There are municipal wells in surrounding areas (and new wells could also be installed in the future for groundwater extraction for drinking water purposes).

17. p. 8: 5.0 Study Areas, EA criteria, impact on the availability of groundwater supply to wells, "…due to the existing and proposed activities at the Site"
    Comment: Will quarrying be permitted as a proposed activity alongside the construction and operation of the proposed landfill?

18. p. 9: 6.0 Indicators/Measures, "Effects due to contact with contaminated groundwater or surface water"
    Comment: What is it meant by effects due to contact with contaminated groundwater or surface water? It would be better to specify the potential receptors.

19. pgs. 7, 8, 9: study area,
    Comment: The study area for groundwater should not be constrained to the study area shown in Figure 1. The study area should be extended to natural boundaries of groundwater flow, e.g. groundwater divides, in order avoid that artificial boundary effects are created due to the setting of arbitrary boundaries (e.g. in the modelling). In order to properly define hydrogeological conditions (e.g. to infer groundwater flow directions and natural groundwater flow boundaries), interpretations and interpolations of data from outside of natural boundaries are typically required, and therefore, the area for data collection and monitoring should include areas far outside what is shown in Figure 1, and must be flexible as described in the TOR. A minimum starting point would be the natural surface water divides that are further assessed based on underlying strata and direction.

20. p. 10: Indicators/Measures:
    Comment: Reg. 153/04 (as amended) together with its "Rationale" document (including updates) should be included in the table showing the Proposed Indicators/Measures for "Effects due to contact with contaminated groundwater or surface water". Reg. 153/04 and its underlying "Rationale" document are currently the most complete compendium of human health and environmental standards in groundwater and surface water.

21. p. 11: 7.0 Assumption, 7.1 Facility Characteristics, Groundwater
    Comment: Why is the buffer variable from 30 to 150 m? According to EPA ON reg 232-98, s. 7(2), the buffer area should be at least 100 m wide at every point. Note the exceptions (30 m buffer) in s.7(3), however, WEG needs to demonstrate that a 30 m buffer is sufficient.

22. p. 11: 7.0 Assumption, 7.1 Facility Characteristics, Groundwater, "The waste fill area will average approximately 32.85 m thick; depth below grade will range between 30 and 40 m and depth below the bedrock/overburden interface will range between 10 and 20 m."
    Comment: Landfill will encompass both the overburden and bedrock, hence the site is heterogeneous which will make groundwater flow more complex. This will cause the design and operation of the proposed landfill to be more technically complex.

23. p. 12: 7.0 Assumption, 7.1 Facility Characteristics, Landfill gas
    Comment: Will gas pressure be monitored to eliminate positive gas pressure? How will this be accomplished?

24. p. 12: “Groundwater”
    Comment: states “compacted engineered backfill” – the nature of the material and compaction criteria are unknown and need to be specified. Backfill type and its compaction have a significant effect on differential settlement of the material which can cause deformation of the liner(s) and leachate collections system pipes, and can even cause failure (breaking) of these systems.

25. p. 12: “Groundwater” and “Surface Water”
    Comment: it is unclear if dewatering and water management in general will be conducted during the operational life only, or if these activities will be continued in perpetuity. The hydrogeological and hydrological assessments and any modelling of effects and impacts on local groundwater and surface water resources and receptors (including groundwater / surface water flow and contaminant transport) must take this into account.

26. p.11 “Surface Water”
    Comment: it is stated that the landfill, stormwater and groundwater seepage on the undeveloped portion of the quarry will be managed separately. As the new landfill would be constructed on fill, its base may be significantly higher than the unused and adjacent future quarry floor elevation resulting in a significant groundwater and surface water gradient. It will be important to detail how this will be controlled so that potentially impacted runoff does not affect groundwater quality beneath the site. The monitoring well network will need to be oriented to detect any early issues.

    Similarly, it will need to be clear how the elevation of the existing waterbody south of the proposed landfill site relates to the landfill area and the potential for contaminants to migrate towards the waterbody and further to the Thames River or groundwater system.

27. P. 11: “Surface Water”
    Comment: spills management during operations not mentioned. While waste coming to the site will be classified as non-hazardous, there is the possibility of hazardous materials being present at site and vehicle spills/fuel leaks entering the “undeveloped area” drainage system and contaminating a large volume of site runoff. This will need to be addressed in the drainage system design as it could impact water quality for discharge and treatment requirements. The site operations plan should also address the potential for the site runoff to become impacted by operations and include viable contingencies.

28. p. 12: 7.3 Climate Change
    Comment: Section 7.3 of the draft Work Plan outlines anticipated average annual and seasonal changes in temperature and precipitation from recent climate change projections for Ontario. (McDermid and Hogg, 2015). While these data show changes suitable for long-term water balance calculations, they do not show possible changes due to discrete extreme precipitation events. For example, reductions in summer precipitation could vary from 2.5 to 4.5% over the next 80 years but the intensity of individual short-term events could increase significantly from present levels (e.g. 4 hr, 6 hr or 24 hr precipitation amounts). This will factor greatly in the design and costs for on-site stormwater management infrastructure and facilities within the base area of the landfill to isolate non-contact water.

A similar issue exists with high flow changes in the upper Thames River basin. This extreme flow condition may be compounded by the anticipated higher winter precipitation (snowpack) and higher resultant runoff that could combine with higher short duration rainfall events to create higher peak flows. The resultant flows from higher spring runoff should be assessed in conjunction with the 1:250 year storm event for design purposes for peak flows expected in the Thames River to address potential overflow onto the site.

29. p.12: 7.3 Climate Change
Comment: higher summer temperatures and evaporation have the potential to worsen low flow conditions in the Thames River which already has historically poor assimilative capacity for dilution of treated leachate discharged to the river. This could further affect water quality and associated aquatic health.

30. p.15: 8.2 Field Data Collection
Comment: Because the quarry is currently being dewatered, and during the construction and operation of the landfill, this dewatering will continue, a deep unsaturated zone is/will be present. Therefore, the unsaturated zone should also be characterized, but this is not apparent in the work plan. Also, what will WEG do to characterize surface water/groundwater interaction? How will WEG characterize the fluxes of groundwater into and out of the Thames River and other surface water bodies? The work plan should also include some language of the characterization of the engineered barrier system (e.g., lab tests on cover and backfill material, clay liner, etc.).

31. p.15: 8.2 Field Data Collection
Comment: Will parameters necessary for conducting contaminant transport simulations obtained during the field studies? This was not apparent in the work plan. For example, parameters such as the diffusion coefficient, longitudinal and transverse dispersivity, degradation and reaction parameters, etc. should be obtained for the overburden, fractured bedrock, backfill, clay liner, and any other material used as part of the engineered barrier system.

32. p.16: 8.2 Field Data Collection
Comment: Will the MOECC or other parties such as the Town of Ingersoll be consulted to make sure that the characterization and sampling plan is adequate? Such language is included for the surface water characterization and monitoring below.

33. p. 16: states "Drill boreholes in the bedrock and overburden at representative locations on the site to characterize site geological and hydrogeological conditions…"
Comment: this should say to "characterize in great detail".

34. p. 16: states "Obtain and review available site specific studies previously undertaken to determine hydraulic conductivity in the bedrock aquifer(s) and assess groundwater flow directions".
Comment: This statement is somewhat unclear, as the groundwater flow and contaminant transport would occur through fractured rock. It should be re-phrased to indicate that appropriate hydrogeological studies will be undertaken to appropriately characterize flow through discrete fractures (e.g. vertical fractures) and through more frequently and randomly fractured media (horizontal and vertical).

35. p. 16 states “Carry out an inventory of private and public water wells in the vicinity of the site, based on MOE water well records, augmented with door-to-door inventories of selected receptor points.”
Comment: It is unclear what will be done with this information. It should be clear that this information will be used cautiously, as the drillers’ logs of these wells are not always reliable, but it should also be noted that selected wells from this database should be used for groundwater quality monitoring.

36. p. 16: states “Retain an expert in Karst geology provide input into, and participate in data collection and interpretation regarding Karst features”.
Comment: This work should also include an evaluation of the effect on the development of Karst due the potential presence of more aggressive landfill leachate within the fractured bedrock.

37. p. 17: states “Groundwater samples will be collected using dedicated sampling equipment and analyzed by an independent accredited laboratory for the parameters listed in Section 10 of O. Reg. 232/98, as well as for a suite of groundwater quality indicator parameters.”
Comment: The list of parameters contained in O.Reg. 232/98 is a good starting point, but it is necessary to consider additional chemical parameters in the groundwater quality characterization in order to establish pre-construction (pre-operation) conditions, and during on-going monitoring in order to detect effects.

38. p.18: 9.0 Data Analysis, Groundwater
Comment: What scenarios will be considered in the groundwater modeling? What conceptual model will be utilized and how will this be decided? Will a 2D or 3D model be constructed? How large will the model be and what features will be built into the model (e.g., 3D extent of the landfill and the buffer materials)? Will surface water/groundwater flow and transport be jointly considered or will they be treated separately? If surface water and groundwater are treated separately, what is the rationale for this? What is the extent of the groundwater model? It should at the minimum consider the critical receptors (municipal wells, etc.) in the area. How will the landfill be treated in the groundwater model and how will the leakage be simulated? How will the groundwater model account for the contaminant attenuation zone? Will biodegradation, sorption, etc. be considered?

39. p.18: 9.0 Data Analysis, Groundwater
Comment: The length of the simulation period should also be discussed. How long is the operational period and the closure period? How long would potential hazards need to be considered? Would changes in material properties be considered in the assessment if the closure period is excessively long (e.g., > 1000 years)?

40. p.18: 9.0 Data Analysis, Groundwater
Comment: What model will be used to conduct the groundwater flow and contaminant transport studies? For the surface water assessment, a model is specified.

41. p.18: 9.0 Data Analysis, Groundwater, “The degree of potential effects will be compared using the criteria and indicators”
Comment: This is quite vague. What kinds of potential effects do WEG anticipate and how will this be simulated and assessed?

42. p.18: 9.0 Data Analysis, Groundwater, "A groundwater monitoring program will be developed and proposed trigger mechanisms will be set for the implementation of a contingency plan"
Comment: The groundwater monitoring program will be very critical. Because the tear in the liner may be small, the release of contaminants may be very narrow causing a narrow plume. How will the planned monitoring system detect a narrow plume?

43. p.18: 9.0 Data Analysis, Groundwater, "The potential for leachate from the landfill impacting adjacent properties will be assessed"
Comment: Presumably, the monitoring will only take at some horizontal distance away from the landfill. What if there is leakage beneath the landfill? Will there be monitoring systems placed below the engineered barrier system, to what depth, and at what density?

44. p.18: 9.0 Data Analysis, Groundwater, "Prediction of future environmental conditions will be completed using modeling and other methods. This will specifically identify, recognize and determine any potential effects upon the Wellhead Protection Areas (WHPA) associated with the municipal drinking water wells, Highly Vulnerable Aquifers (HVA) and Significant Groundwater Recharge Areas (SGRA) identified in the source water protection studies. Further, the County of Oxford will be consulted with to identify any pre-existing plans for municipal well field expansion, and incorporate those into the evaluation."
Comment: If the impacts of the proposed landfill are to be identified, recognized, and determined, then the field studies and groundwater models have to encompass these areas. Therefore, the current study areas may be too small.

45. p. 18: states "During each sampling event, surface water quantity, in the form of discharge rates, will be established measured at each sampling station using an industry standard flow meter. A cross-section will be measured at of each station, (if not previously determined), will be taken and flow measurements will be collected following standard Provincial flow measurement protocols".
Comment: The use of weirs should be considered in smaller streams in order to allow a more accurate measurement of stream flows.

46. p. 19: 9.0 Data Analysis, Groundwater, "The Geology and Hydrogeology discipline, in consultation with the EA Management Team and the Design & Operations Team, will provide input…"
Comment: Would input be obtained and considered from outside experts including MOECC, JMCC, the Town of Ingersoll and other parties? This section implies that the input will only come from the proponent's side.

47. p. 19: states "A predictive model of landfill performance (contaminant transport model and/or flow model) will be conducted. Requirements to meet groundwater quality criteria will be assessed at the On-Site site property boundary using the results of the contaminant transport model."
Comment: It is noted here that a combination of one- and three-dimensional models will likely be required to achieve this goal. Models will need to be calibrated and then will need to appropriately represent the fate and transport of leachate through the liner system, backfill, and natural (fractured rock) groundwater system, and this will need to be done under various plausible scenarios (base case operation and failure modes). The models have to be capable of predicting groundwater flow and contaminant transport to private and municipal wells and surface water features, and they have to be able to do this during and after the operational phase of the waste disposal site.

In general, the Work Plan lacks details on the groundwater modeling given the complexity of the heterogeneous overburden and fractured rock terrain. The groundwater modelling should be used to evaluate the migration of landfill leachate and landfill gas with the fracture rock system. The modelling should consider the lifespan of engineered systems and the strength of the contamination potential of the landfill based on when a potential release of leachate would occur (e.g. due to breach in the liner).

Modelling should be conducted for the performance and operation of the engineering systems, taking into account:

a. Contaminating lifespan of the waste;
   i. Design lifespans of the engineering systems (liners, covers, leachate collection systems, etc.)
   ii. Groundwater management by dewatering (it is unclear if dewatering is intended to continue during only the operating life of the waste disposal site or is it will continue beyond this time frame)
   iii. Effect of landfill operation on stream baseflow, including dewatering (and potential discontinuation of dewatering).
b. Potential failure scenarios, including, but not limited to:
   i. Differential settlement of material beneath the liner system(s) in order to evaluate the effects of abrupt failure of liner and/or leachate collection system on releases of contaminants into the groundwater flow system;
   ii. Failure of the leachate collection systems, including timing of such failures which may affect changes in leachate chemistry migrating within the fracture rock system (i.e. the earlier leachate can escape from the landfill, the higher will be the leachate concentrations), and
   iii. Failure of dewatering pumping wells, e.g. to predict effects on contaminant migration on drinking water supplies and streams.
c. Potential development scenarios, including, but not limited to:
   i. Increased pumping from municipal wells;
   ii. Establishment of new municipal wells;
   iii. Continued extraction of rock from existing and future quarries.

48. p. 19: 9.0 Data Analysis, Landfill gas
    Comment: Will a model for landfill gas migration be developed for this undertaking? If so, what model will be used?

49. p. 19: 9.0 Data Analysis, Landfill gas
    Comment: There is no mention of the unsaturated zone. Will the unsaturated zone be characterized during the EA studies? The extent of the unsaturated zone is unclear. What is the depth to the water table under current conditions, under operational conditions, and during the closure period? The pathway for gas migration may be different depending on the extent of the unsaturated zone (e.g., depending on the amount of dewatering, the extent of the unsaturated zone could be deeper exposing more units and pathways in both the overburden and fractured bedrock to landfill gas migration).

50. p. 24, Figure 1: Location Plan
Comment: The Wellhead Protection Area designated by the source water protection plan should be included on this figure. The study area may have to be made larger to consider the Wellhead Protection Areas of the Town of Ingersoll. While WEG states that the current Wellhead Protection Areas do not intersect the current quarry and the potential landfill, the Wellhead Protection Areas could change with the construction of the landfill and future quarrying operations. In addition, all environmentally sensitive features designated by various agencies should be included in the groundwater/surface water study areas.

51. p. 24, Figure 1: Location Plan
Comment: Will all of these surface water bodies be sampled and monitored during the investigation?

52. p. 24, Figure 1: Location Plan
Comment: The boundary of the study area should be extended beyond the current one and include all the nearby municipal wells and the Carmeuse property as aggregate resources may be extracted in the future. Cumulative impacts from both the proposed landfill and future quarry operations on adjacent Carmeuse lands need to be considered.

53. p. 24, Figure 1: Location Plan
Comment: The figure also includes breaks in the study area with arrows indicating that the study area will also include "contributing drainage area". While this is good, the contributing area should also include that for the groundwater. The contributing areas for the surface water and groundwater regimes may be different.

<u>Comments on Alternative Methods Interim Report dated January 3, 2017</u>

1. p.9: 4.1.4 Landfill Footprint Alternative 3: Active Quarry & Lime Plant
Comment: While the choice of the active quarry area for the construction of the landfill may be beneficial to the company, is it beneficial to the Town of Ingersoll? This option is closest to the town which gives rise to increased risks of contamination of municipal wells. Shouldn't WEG consider other options where the landfill is situated further from the Town of Ingersoll on Carmeuse property?

2. p. 20: 5.1.2 Regulatory & Design Requirements
Comment: How is a 30-m buffer deemed sufficient? What studies have been done to show this? Given the proximity of the Town of Ingersoll and the municipal wells, perhaps a much wider buffer (especially on the west side) should be planned for added safety.

3. p. 21: 5.1.3 Alternative Landfill Design Configurations, Deep Design
Comment: While the deep landfill design may be more desirable because it may keep the landfill out of sight, this design appears to have considerably less backfill than the conventional design. In addition, based on the schematic diagram (Figure 7), the liner system is more extensive for the deep design. This means that the engineered barrier system (landfill liner, leachate collection system) becomes more important. How does this increase the risk of leakage if the liner is more extensive (i.e., it occupies a larger area of the subsurface)?

4. p. 21, 5.1.3 Alternative Landfill Design Configurations, Deep design
Comment: The slope is not as steep so more infiltration should take place with everything else being the same in comparison to the conventional approach. Therefore, a landfill cap with a lower permeability should be considered to minimize infiltration.

5. p. 21: 5.1.3 Alternative Landfill Design Configurations, Conventional design
Comment: A steeper slope of the landfill cap for the conventional design should lead to more runoff. Thus, there should be less infiltration into the underlying waste resulting in less gas generation, less leachate production, and less potential for groundwater contamination. Perhaps WEG should consider this design further.

6. p. 22, 5.1.6 Deep Design Alternative
Comment: One way to minimize the production of leachate is to minimize the infiltration through it. Limiting the amount of water in the waste (i.e., moisture content) will also generate less landfill gas. There are different cover designs that the WEG should consider that would utilize the “capillary barrier effect” to shed the infiltrating water from reaching the waste.

7. p. 26: 5.3.3 Mitigation
Comment: How will infiltration and emission of landfill gas be minimized with a small working face and how large will this be?

8. p. 29, 6.1.1 General Design Considerations
Comment: Will infiltration of leachate from the ponds into the underlying groundwater take place? If a liner is present, what sort of design will be used to prevent any leakage?

9. p. 53: Appendix A, Glossary of Selected Terms, Landfill Gas
Comment: All anticipated landfill gas constituents and their anticipated concentrations should be listed in the glossary. Currently, only the major constituents are listed.

10. p. 53: Appendix A, Glossary of Selected Terms, Leachate
Comment: All anticipated leachate constituents and their anticipated concentrations should be listed in the glossary.

11. p. 56: Table B-1: Alternative Landfill Design Evaluation – Criteria Screening, Indicators & Data Sources, Criteria 1, Explosive hazard due to combustible gas accumulation in confined spaces
Comment: It is stated that there are no significant differences between alternatives for explosive hazard due to combustible gas accumulation in confined spaces. The amount of moisture that will be present in the landfill may be different depending on the alternative selected.

12. p. 56: Table B-1: Alternative Landfill Design Evaluation – Criteria Screening, Indicators & Data Sources, Criteria 4, Effects due to contact with contaminated groundwater or surface water
Comment: It is stated that there are no significant differences between the alternatives on effects due to contact with contaminated groundwater or surface water. However, the thickness of the backfill will be different. Therefore, the travel time if a subsurface leakage occurs will be different, hence the effects due to contact with contaminated groundwater will be different among the various alternatives. The alternative designs should have impacts on landfill gas generation and migration,

as well as have impacts on both the surface water and groundwater regimes. For example, a steeper landfill cover will generate more runoff. Perhaps a more detailed analysis of alternatives is necessary.

13. p. 56: Table B-1: Alternative Landfill Design Evaluation – Criteria Screening, Indicators & Data Sources, Criteria 5, Flood hazards
    Comment: Again, in terms of flood hazard, no significant differences between the alternatives are projected. The area of the landfill cover should be provided for the alternative designs. This means that the cover may be more exposed to rainfall and frost heaving that could cause fractures to develop in the landfill cover. Induced fractures within the landfill cover will result in higher infiltration rates and larger amounts of leachate generated, landfill gas seepage, and potentially the failure (i.e., mass wasting) of the cover. The latter possibility should be examined more closely by a geotechnical engineer.

14. p.58: Table B-1: Alternative Landfill Design Evaluation – Criteria Screening, Indicators & Data Sources, Criteria 32, Loss/displacement of surface water resources
    Comment: It may be premature to declare that there are no significant differences between the alternatives because the presence of the proposed landfill may affect both the surface water/groundwater regimes.

15. p.59: Table B-1: Alternative Landfill Design Evaluation – Criteria Screening, Indicators & Data Sources, Criteria 33, Impact on the availability of groundwater supply to wells
    Comment: It may be premature to declare that there are no significant differences between the alternatives because the presence of the proposed landfill may affect both the surface water/groundwater regimes. Therefore, there is potential for an impact on the availability of groundwater supply to wells.

16. p.59: Table B-1: Alternative Landfill Design Evaluation – Criteria Screening, Indicators & Data Sources, Criteria 34, Effects on stream baseflow quantity/quality
    Comment: It may be premature to declare that there are no significant differences between the alternatives because the presence of the proposed landfill may affect both the surface water/groundwater regimes. Therefore, there is potential for an impact on stream baseflow/quality.

Comments on Facility Characteristics Assumptions report dated January 3, 2017

1. p.1: 1. Design, 1.1.3 Buffer Area
   Comment: How will WEG justify that a 30 m buffer zone is sufficient and what methods will be used? It is stated in the footnotes that, "A 30 m buffer area was determined adequate for a landfill of similar size and conditions (e.g. South Landfill). The impact assessment will evaluate if 30 m buffer for this EA is adequate as described in O. Reg. 232/98." If there is a leak from the landfill, this does not seem like enough space to detect, contain, and remediate the contaminated groundwater as well as the escaped landfill gas. Without considering the impact assessment, how can one determine that this 30 m buffer is adequate? It would be more prudent to assume a larger buffer area as part of the facility characteristics assumptions given that the west side of the landfill closest to the Town of Ingersoll is where the 30 m buffer is assumed.

2. p.2: 1. Design, 1.1.6 Height & Depth: "For a generic double liner design landfill, the maximum waste loading is 328,500 m^3/ha (or a maximum average waste thickness of 32.85 m) for an assumed background groundwater chloride concentration of 100 mg/L using preliminary groundwater quality data."
   Comment: This preliminary groundwater quality data has not been made available for review. Where, how many and how were those values obtained, and what do the data indicate?

3. p.2: 1.2 Site Development Stages
   Comment: If the liner is constructed in stages, then what about the protection of groundwater during the intermediate stages? How does one assess leakage during this intermediate phase when landfill is being filled (prior to final closure)?

4. p.4: 1.4 Surface & Ground Water Management, 1.4.1 Quarry Floor
   Comment: The undeveloped portions of the existing quarry floor will continue to be dewatered. What will happen to the portion of the quarry where the landfill has been already been filled. Will dewatering continue in these areas?

5. p.4: 1.5 Liner System
   Comment: How long is the anticipated full contaminating lifespan of leachate? What are the assumptions used for this?

6. p.4: 1.5 Liner System
   Comment: The assumption is that the liner is fully protective of groundwater. What is the basis of this assumption?

7. p.4: 1.5 Liner System
   Comment: The geotextile will be added and welded as the landfill cell becomes completed. How will the welding be done and how can one ensure that no leaks will develop through the welds upon installation and after the waste has been placed?

8. p.4: 1.5 Liner System
   Comment: What is the density of the HDPE pipes and how was this determined?

9. p.5: 1.5 Liner System
   Comment: There is no thickness specified for the secondary (lower) compacted clay liner. This should be added.

10. p.5: 1.6 Final Cover
    Comment: What soil type will be used for the top cover? This is quite ambiguous and more details to the type of material used should be provided for further review. Same for the top soil. Are the thicknesses sufficient?

11. p.7: 1.7.3 Leachate Treatment
    Comment: Figure 8 has no scale attached so it is impossible to gauge how the leachate collection system will be used. What is a 0.3 m clear stone as indicated on Figure 8? 0.3 m thick stone layer? Leachate is designed to flow down and along the liner layer via gravity drainage. If so, the leachate could bypass the leachate collection pipe because the pipe is 0.15 m thick. Bypassing could occur because if the collection pipes are placed in the middle of the layer as indicated on Figure 8, the leachate could flow beneath the pipe. This applies to both the primary and secondary leachate collection systems. Also, where will the leachate collection system be placed? Uniformly along the bottom?

12. p. 8: 1.8.2 Subsurface Landfill Gas Migration Controls: "A series of horizontal and vertical wells, along with pumps, are proposed to provide a vacuum to the landfill to collect the landfill gas generated by the site."
    Comment: It is not clear where, how deep, and at what intervals these wells will be placed.

13. p. 12: 3.8 Monitoring
    Comment: Very little details are provided here. Where and how often?

14. p.14: Figure 1
    Comment: In this report, there are no details provided on the monitoring system. Only the construction and operational details are provided. Assuming groundwater flows from north to south, where should monitoring take place during the closure period? Where will landfill gas be monitored?

15. p.14: Figure 1
    Comment: The monitoring requirements could change from during the operational and closure periods. If there is a leak underneath the landfill, how will this be detected? If there is a leak on the side, it will flow along the barrier (depending on the hydraulic gradient) thus a monitoring system installed in the buffer zone may not detect this (depending on where it is installed). The contaminant plumes that will develop are anticipated to be narrow. How will a narrow plume be detected?

Comments on Work Plan: Cumulative Effects Assessment in the Southwestern Landfill EA, Draft for Discussion, dated January 12, 2017

1. p.2: 3. Regulatory Requirements & Guidance
   Comment: It is stated that "Cumulative effects assessment is neither explicitly required nor defined under the Ontario Environmental Assessment Act, nor is there any specific procedural guidance provided in the associated Code of Practice" by WEG. While not required, the "Ministry will consider

cumulative effects on the environment in making decisions (p.15) and, therefore, proponents are encouraged to provide such information to the Ministry when preparing an EA (p.16)." It will be very good for WEG to consider cumulative impacts. It is hoped that this assessment is done in a quantitatively rigorous manner.

2. p.7: 5.3. Step 3: Mitigation
   Comment: In order to minimize cumulative effects, one must have a very good understanding of the past, current, and future conditions of the site and the processes involved. Some of the individual effects could synergistically act. For example, surface water contamination can result in groundwater contamination if the contaminated surface water enters the subsurface and results in a groundwater plume. Also, a plume that develops from the landfill can enter the surface water and contaminate downstream.

3. p.7: 5.3. Step 3: Mitigation, "Here, Walker, in conjunction with its technical experts, will carry out a review of the potential effects (which in this case are the cumulative effects, as discussed above) to see if any adverse effects can be further mitigated."
   Comment: It is very good that WEG will consider adverse effects that can be mitigated. However, what if the effects cannot be minimized? For example, what if there is a catastrophic leak from the liner, enters a karst feature, and rapidly is transported away from the landfill? How will this cumulatively impact the environment? Obviously, all potential scenarios may not be considered, but the most likely ones should be considered in the cumulative impact assessment.

4. p.8: 5.4. Step 4: Significance, "The determination of the significance of an adverse environmental effect is a fundamental component of the overall federal EA process. Determining significance as undertaken in the federal EA process is neither explicitly required nor defined under the Ontario Environmental Assessment Act, nor is there any specific procedural guidance provided in the associated Code of Practice."
   Comment: How does WEG propose to quantitatively calculate the significance of cumulative effects? This needs to be made clearer in future reports.

5. p.8: 5.4. Step 4: Significance
   Comment: WEG proposes to use indicators and it is stated that indicators have been reviewed and commented by various parties. As an example, WEG states that "…one of the indicators proposed for EA criterion #35 *Loss or disturbance to terrestrial ecosystems* is the loss of the (lesser of 10 ha or 5% of habitat for area-sensitive species as defined as the Ecological Land Classification System for Southern Ontario." For groundwater and surface water, how will the impacts be *quantitatively* defined? For example, EA criterion #33 Impact on the availability of groundwater supply to wells can potentially occur due to the construction of the landfill as groundwater may be pumped from the aquifer or if recharge is reduced. What level of reduction in groundwater level induced by pumping required for landfill construction be considered an acceptable impact? How will the reduction in recharge be calculated and how will this impact the availability of groundwater? In future EA submissions, WEG should provide more details to how impacts could be defined quantitatively. Are there any trigger mechanisms that will be proposed that would require WEG to supply water to the Town of Ingersoll?

5.0 Appendices

In Appendix 1 of this report, we provide Dr. Illman's responses to WEG's reply to the Town's comments dated April 2, 2014 (7m – GRT Comment Table – Town of Ingersoll – Final.pdf). This is provided in a tabular format.

In Appendix 2 of this report, we provide a table that includes Dr. Illman's comments that the Town of Ingersoll submitted on May 12, 2014.

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APPENDIX 1

Responses by Dr. Illman to WEG's table provided in (7m – GRT Comment Table – Town of Ingersoll – Final.pdf)

Appendix 1: Responses by Dr. Illman to WEG's table provided in (7m – GRT Comment Table – Town of Ingersoll – Final.pdf)

Terms of Reference Comments submitted by	Walter A. Illman, Ph.D., P. Geo. Original Comment	Walker Environmental Group Response	Walter A. Illman, Ph.D., P. Geo. Response
Town of Ingersoll October, 15, 2013	**s.5.7: Groundwater/Surface Water Assessment** The Town retained Walter A. Illman, PhD, PGeo, a contaminant hydrogeology expert to peer review the Draft ToR focussing primarily on contaminant hydrogeology, fractured rock hydrogeology, and unsaturated (below ground areas not filled with water) zone hydrology. Dr. Illman's review dated June 7, 2013 formed part of Ingersoll's comments on the Draft ToR. Dr. Illman has provided an update to his review dated September 24, 2013 for the purposes of assessing how the ToR has been modified to address his comments of June 7, 2013.	We appreciate the further technical input from Dr. Illman. We have also reviewed Dr. Illman's attached letter and tables containing further details regarding his comments, and believe that the following responses address his main points of concern. We note, though, that many of Dr. Illman's comments deal with detailed technical matters that cannot be addressed or resolved until actual studies are carried out during the EA. Dr. Illman notes this himself in his letter:" This may be due to the fact that the project is still at the proposal stage and that the details to the studies on groundwater flow, contaminant transport, and subsurface gas migration are forthcoming in the Environmental Assessment (EA) process" (p.81). Consequently, we have indicated in numerous places in the following responses where the requested information is deferred to the EA.	I appreciate the response to my comments from WEG. While the comments may deal with technical issues and additional descriptions are forthcoming, I hope that reviewer comments from all parties are incorporated sooner than later in the work plans.

Terms of Reference Comments submitted by	Walter A. Illman, Ph.D., P. Geo. Original Comment	Walker Environmental Group Response	Walter A. Illman, Ph.D., P. Geo. Response
Town of Ingersoll October, 15, 2013	The following is a summary of Dr. Illman's comments on the ToR: 1. The Draft ToR is unclear with respect to whether there is groundwater flowing into the quarry from the sideslopes and bottom. The ToR acknowledges that water on the quarry floor originates from both surface water and groundwater.	The ToR represents plan to study the potential effects of the proposed landfill, not the results of such a study. Therefore, the specific answer to this question not yet known, aside from the general observation in the ToR that both groundwater and surface water are collected in the quarry. Note that the scope of the EA studies proposed in Appendix B, Section 5.7 to the ToR includes geological mapping, water monitoring and other activities that will further characterize the existing environment.	The Final ToR indicates (on p. 18) that "Carmeuse actively dewaters groundwater from its quarries (under permits issued by the Province of Ontario), thereby intercepting and collecting some of the bedrock groundwater flow (along with precipitation captured in the quarry)." Therefore, WEG acknowledges that water found in the quarry floor originates from both surface water and groundwater.
Town of Ingersoll October, 15, 2013	2. The description of the site geology and the cross-section provided in Figure 3 of the Draft ToR ("Figure 3") is inconsistent. The ToR, and in particular Figure 4, is still unclear on site geology. For instance, the cross-section shows limestone "cap rock" and "chemical stone". However, this distinction is not explained in the ToR.	The cross section was provided for illustrative purposes to show the relative location of the quarry wall and the Thames River. It was not intended to be used for geological or hydrogeological references and should not be used for this purpose. Detailed borehole logs providing detailed site profiles will be generated by the technical experts during the EA process. "Cap rock" and "chemical stone" are simply terms used in the lime quarrying industry that will be familiar to many in the	The cross-section (now Figure 4) has been modified and is more consistent with the description in the Approved Amended Final ToR. However, additional details to the site geology should be provided during the EA.

Terms of Reference Comments submitted by	Walter A. Illman, Ph.D., P. Geo. Original Comment	Walker Environmental Group Response	Walter A. Illman, Ph.D., P. Geo. Response
		local community, with the “chemical stone” being the rock suitable for lime production. The terms are not important to the ToR, though, and can be disregarded at the present time.	
Town of Ingersoll October, 15, 2013	3. The depth of the landfill is unclear based on the Draft ToR. The depth of the landfill as well as the extent of the proposed landfilling area has not been delineated in the ToR.	[We presume the reference here is meant to be the final ToR, not the draft.] The depth of the landfill has not yet been determined. It will be defined through the evaluation of alternative methods during the EA process (see ToR, Section 7.2 and Section 8.1).	This is now better described in the Facilities Characteristics Assumptions report dated January 3, 2017.
Town of Ingersoll October, 15, 2013	4. The source of the water in the lake shown in Figure 3 needs to be identified. The ToR does not identify the source of the water in the quarry pond.	The ToR represents a plan to study the potential effects of the proposed landfill, not the results of such a study. As a result, the hydrogeology of the area, including the lake referenced here, has not yet been investigated. As we noted in our responses on the draft ToR, based on a general understanding, the water in the former Global Stone quarry south of the railway tracks presumably comes from a combination of groundwater and surface water sources.	It is understood that the source of the water in the quarry pond (former Global Stone quarry south of the railway tracks as described by WEG) will be investigated during the EA process.
Town of Ingersoll October, 15, 2013	5. The groundwater level in the area should be illustrated in Figure 3. The ToR	As noted above, the studies have not yet been undertaken to adequately represent the	It is now understood that the current quarry floor is estimated to be about 40 to 45 m below ground

Terms of Reference Comments submitted by	Walter A. Illman, Ph.D., P. Geo. Original Comment	Walker Environmental Group Response	Walter A. Illman, Ph.D., P. Geo. Response
	states that the natural groundwater table is estimated to be 40-45m below the ground surface. The source of the water in the quarry pond is uncertain if the description of the groundwater levels is accurate.	groundwater levels at the site. These will be completed as part of the EA. The specific sentence referenced in the ToR may be somewhat confusing, though in that it is meant to convey that the current quarry floor is estimated to be about 40 to 45 m below ground surface, which is below the original, natural groundwater table. This will be noted as an erratum to the ToR.	surface, which is below the natural groundwater table. This has been noted as an erratum in the Amended, Approved, ToR. It is indicated in the Amended Approved ToR that the natural groundwater table level in the area is estimated to be 40-45 m below the ground surface, which suggests that an extensive unsaturated zone exists at the site. Therefore, the unsaturated zone needs to be characterized in addition to the saturated zone.
Town of Ingersoll October, 15, 2013	6. Figure 3 indicates substantial aggregate reserves at the site and the Draft ToR is unclear as to whether the establishment of a landfill at this site would sterilize licenced aggregate reserves at the site. Figure 4 continues to indicate substantial aggregate reserves at the site. There is no indication in the figure as to the extent of the suitable limestone reserves.	The initial business opportunity that WEG identified is to place the landfill in a mined-out portion of the Carmeuse property, as noted in Section 4.2 of the ToR. In this case, Carmeuse will have extracted all of the economically viable limestone suitable for lime production from the quarry prior to the landfill construction. Therefore, no aggregates will be sterilized. In order to fulfill the Environmental Assessment Act requirement to consider "alternative methods",	It is understood that the proposed landfill will occupy only the area/volume where all aggregate resources have been extracted.

Terms of Reference Comments submitted by	Walter A. Illman, Ph.D., P. Geo. Original Comment	Walker Environmental Group Response	Walter A. Illman, Ph.D., P. Geo. Response
		WEG will include in its EA an assessment of other possible landfill footprints on the Carmeuse property. That work has not yet been completed, but it is conceivable that some of the possible alternative footprints on the Carmeuse property could potentially sterilize aggregate reserves or resources, and may be screened out from further consideration on that basis.	
Town of Ingersoll October, 15, 2013	7. The ToR is not clear on how the prohibition against establishment of a landfill site in a lake does not apply to the site. The nature and extent of the water in the quarry pond raises concerns that the quarry pit shown in Figure 4 was a lake prior to dewatering activities.	The active portion of the Carmeuse quarry currently being mined does not meet the criteria for a lake under the Environmental Protection Act and would not be prohibited from landfilling under the provisions of Section 27(3). However, when other possible "footprint" alternatives on the Carmeuse property are examined during the EA it is possible that some options may have to be screened out and excluded under this regulation.	The active portion of the quarry may not be a lake because dewatering is currently taking place. A former employee of the quarry noted that, groundwater flowing into the quarry is substantial Studies are necessary to substantiate this claim. The presence of a reservoir next to the active quarry is another indication that the lake could be present without dewatering. The forthcoming technical studies should estimate the volume of groundwater and surface water flowing into the quarry as well as its spatial and temporal variability.
Town of Ingersoll October, 15, 2013	8. The impacts of global climate change must be considered in the EA. The	Acknowledged. WEG is continuing to work with the MOE and other	It is understood that during the EA, WEG will consider climate change

Terms of Reference Comments submitted by	Walter A. Illman, Ph.D., P. Geo. Original Comment	Walker Environmental Group Response	Walter A. Illman, Ph.D., P. Geo. Response
	ToR must include provisions that the EA will address the impacts of catastrophic rain, wind, tornadic and drought events on groundwater, surface water and the unsaturated zones.	regulators to develop an acceptable and practical protocol for accounting for climate change.	impacts of the proposed landfill.
Town of Ingersoll October, 15, 2013	The following is a summary of Dr. Illman's comments on the Study Methods for Groundwater/Surface Water Assessment contained in section 5.7 of Appendix B, EA Criteria and Studies of the ToR. It is noted that Dr. Illman's June 7, 2013 comments, to the extent that they are not addressed in the ToR remain outstanding: 9. Background data collection techniques, study areas and durations, including for historical data should be described in more detail.	Noted. The suggested clarifications will be considered by the groundwater technical experts as part of the development of the final technical work plan during the EA. The work plan will be developed in consultation with JMPRCC review team and other agency experts.	It is good that the clarifications will be considered by the groundwater technical experts during the development of the final technical work plan. Presumably, the current version available on the WEG website is not a final version. It is hoped that my comments and suggestions (not just the JMPRCC review team and other agency experts) are considered in the final work plan to better characterize the site and to plan for any potential impacts in order to ensure the safety of the Town of Ingersoll.
Town of Ingersoll October, 15, 2013	10. The study area in Figure 5 is too small for a groundwater assessment as the affected area could be substantially larger. The groundwater study should include all wells in the Town of Ingersoll, including the municipal well. Ideally, the study area should be made larger to coincide with major groundwater boundaries/divides. At a minimum, the groundwater	All of the study areas mentioned and illustrated in the ToR are noted as being preliminary. Section 6.2 of the ToR clearly states that the study areas will remain flexible and adaptable to ensure that the full extent of the potential effects are addressed. We disagree with Dr. Illman's opinion that	It is acknowledged that the study area is preliminary. The disagreement of my comment by WEG is noted. While the source water assessment report may show a well head protection zone that does not intersect the proposed landfill, it is premature to exclude the

Terms of Reference	Walter A. Illman, Ph.D., P. Geo.	Walker Environmental Group	Walter A. Illman, Ph.D., P. Geo.
Comments submitted by	Original Comment	Response	Response
	study area should encompass the areas impacted by the existing and future quarrying activities at the Carmeuse site.	the initial study area is too small, or that it will necessarily need to extent to all of the municipal water wells servicing the Town of Ingersoll. We have examined the source water assessment report for this area, and discussed it with the UTRCA. None of the well head protection zones intersect the area of the proposed landfill site.	municipal wells especially considering how this is an important drinking water supply for the Town of Ingersoll. The groundwater modeling was likely completed without the presence of the proposed landfill. Therefore, the following points should be considered: 1) A detailed review of the groundwater model used to prepare the Wellhead Protection Area should be conducted. This includes the groundwater model and its input files, how the model was set up (initial and boundary conditions, source/sink terms, etc), data utilized to conduct model calibration, and any validation efforts conducted by the consultants who built the model. The groundwater model utilized to conduct the analysis likely considered the presence of the existing quarry and the dewatering that is taking place, but this should be verified. Based on this initial review of the groundwater model and the Wellhead Protection Area, an initial study area may be delineated where

Terms of Reference	Walter A. Illman, Ph.D., P. Geo.	Walker Environmental Group	Walter A. Illman, Ph.D., P. Geo.
Comments submitted by	Original Comment	Response	Response
			the EA studies are conducted. 2) It should be noted that the assessment results of the Wellhead Protection Area could be affected by the construction of the proposed landfill. In addition, during the EA process for the proposed landfill, new data collected by WEG will become available. While the delineation of the Wellhead Protection Area may have been done correctly based on existing data, new site conditions (i.e., construction of the proposed landfill), availability of new characterization data collected by WEG may materially change the Wellhead Protection Area and therefore any conclusions derived from the study may change. 3) The assessment of the Wellhead Protection Area should be repeated with new data collected during the EA process of the proposed landfill. Given the uncertainties present (lack of characterization data, modeling approaches utilized, lack of consideration for a potential landfill), it would be prudent for WEG's EA

Terms of Reference Comments submitted by	Walter A. Illman, Ph.D., P. Geo. Original Comment	Walker Environmental Group Response	Walter A. Illman, Ph.D., P. Geo. Response
			study area for groundwater to consider the Town's municipal wells.
Town of Ingersoll October, 15, 2013	11. The study area for surface water needs to be justified and reviewed by a qualified hydrologist.	The initial surface water study area was recommended by a qualified hydrologist based on his experience and expertise, and reviewed by similarly qualified experts within the Ministry of the Environment and the joint municipal peer review team representing (among others) the Town of Ingersoll. The study areas will be refined in the EA once the work plans are finalized.	It is acknowledged that the study area for surface water is preliminary and will be refined during the EA once the work plans are finalized.
Town of Ingersoll October, 15, 2013	12. Detailed well completion data, driller's logs, information on stratigraphy and available well yield tests should be obtained.	Agreed, background data collection is part of the proposed scope of studies for the groundwater/surface water assessment (see Appendix B, Section 5.7).	It is acknowledged that the background data collection will be completed during the EA process.
Town of Ingersoll October, 15, 2013	13. Characterization of the following should occur: (a) Shallow groundwater flow and contaminant transport which could affect wetlands and other surface water features; (b) The degree to which surface water interacts with groundwater at the site;	Characterization of the groundwater and surface water environment is a key task in the proposed scope of the studies outlined in Appendix B, Section 5.7 to the ToR, and described in further detail in the preliminary work plan contained in the supporting documents.	It is acknowledged that the characterization of the groundwater and surface water environment will take place in the preliminary work plan. However, in the final work plan, additional details should be provided. For example, the work plan should specify all surface water features within the study area.

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	(c) How the Thames River interacts with the underlying and adjoining aquifer; (d) The quarry pond and other surface water features; (e) The effects of climate change, including catastrophic rain, wind, tornadic and drought events; (f) The extent and nature of the unsaturated zone; (g) Subsurface heterogeneity must be characterized to properly assess groundwater flow and potential for contaminant transport; (h) Multiple groundwater flow and contaminant transport (including subsurface gas migration) scenarios should be developed, which scenarios should serve as part of the consideration in the human health risk assessment.		The characterization of subsurface heterogeneity will be critical in building more defensible groundwater flow and contaminant transport (and subsurface gas migration) models. The work plan should clarify how subsurface heterogeneity will be characterized and how the complexity of fractured rocks will be translated to a numerical model.
Town of Ingersoll October, 15, 2013	14. A water balance study should be conducted for the surface water hydrologic basin and the groundwater hydrologic basin that will be affected by the placement of the landfill involving: (a) Meteorological records;	A water balance assessment has been proposed for inclusion in this EA. Please refer to Section 8.0 (p.16) in the preliminary Groundwater/Surface Water Assessment Work Plan (Golder Associates), contained in the Supporting Documents to the ToR.	It is acknowledged that a water balance assessment will be completed during the EA process. Such studies should be conducted for both surface water/groundwater study areas.

Terms of Reference	Walter A. Illman, Ph.D., P. Geo.	Walker Environmental Group	Walter A. Illman, Ph.D., P. Geo.
Comments submitted by	Original Comment	Response	Response
	(b) Estimates of groundwater flow into and out of the subject basin; (c) Estimates of surface water flow into and out of the subject basin, evapotranspiration estimates, and other sources/sinks.		
Town of Ingersoll October, 15, 2013	15. The Human Health Risk Assessment Work Plan notes that the study area will be for on site and in the vicinity. The study area needs to be justified based on the surface water and groundwater assessment. In addition, the study needs to consider the potential effects of subsurface gas migration. In addition to methane, other more toxic volatile organic compounds may also be present.	Section 5.0 of the preliminary HHRA work plan (Intrinsik; Supporting Documents to the ToR) describes the study area for the HHRA as being specifically linked to the air quality, groundwater and surface water study areas. Subsurface gas is not typically included as a component of off-site air quality since in modern sites, landfill gas is contained and managed on-site via liners, gas collection systems, perimeter venting, etc. (backed up with confirmatory monitoring programs). Should the assessment in this EA identify a potential for off-site migration, then further mitigation would have to be put in place to contain the gas regardless, since it would represent a potential explosive hazard.	It is acknowledged that the study area for the HHRA will be specifically linked to the air quality, groundwater and surface water areas. More details on how the linkage will be established should be provided in the work plans. It is noted that subsurface gas is not typically included as part of the assessment, WEG should consider the possibility of a tear in the liner that could lead to subsurface gas migration through the unsaturated zone. Another consideration is that the double barrier liner system is only present at the bottom of the proposed landfill. Presumably, the sides of the landfill are only protected by the liner and the backfill.

Terms of Reference Comments submitted by	Walter A. Illman, Ph.D., P. Geo. Original Comment	Walker Environmental Group Response	Walter A. Illman, Ph.D., P. Geo. Response
Town of Ingersoll October, 15, 2013	16. The Human Health Risk Assessment does not specify how predicted groundwater contamination concentrations will be obtained. The ToR must indicate how the predictions will be established.	Section 7.0 of the preliminary HHRA work plan (Intrinsik; Supporting Documents to the ToR) states: "Groundwater and surface water concentrations for the relevant COPC's will be provided by the Groundwater/Surface Water Assessment Study." Please refer to the preliminary Groundwater/Surface Water Assessment Work Plan (Golder Associates), also contained in the Supporting Documents to the ToR.	It is acknowledged that the groundwater and surface water concentrations will be obtained from the Groundwater/Surface Water Assessment Study. What was not clear was how the values obtained from the technical study will be used in the Human Health Risk Assessment.
Town of Ingersoll October, 15, 2013	17. The ToR should clarify that subsurface gas transport modeling will be undertaken.	As noted above, in modern sites, landfill gas is contained and managed on-site via liners, gas collection systems, perimeter venting, etc. (backed up with confirmatory monitoring programs). Should the assessment in this EA identify a potential for off-site migration, then further mitigation would have to be put in place to contain the gas regardless, since it would represent a potential explosive hazard. As a result, off-site subsurface gas transport modeling is not expected to be required for this EA.	While the engineering plans may indicate that landfill gas will be contained, what if there is leakage from the liner? As pointed out earlier, differential settlement of the backfill could potentially induce failures to the engineered barrier system that could then cause leakage of leachate and landfill gas into the environment. As liners could fail, it is suggested that subsurface gas transport modeling be conducted to assess how far the gas is expected to migrate and at what concentration. Modeling studies should be conducted to ensure that gases that escape

Terms of Reference Comments submitted by	Walter A. Illman, Ph.D., P. Geo. Original Comment	Walker Environmental Group Response	Walter A. Illman, Ph.D., P. Geo. Response
			could be captured with gas collection systems. In order to design a mitigation plan, one should know the expected migration pathways to avoid the unexpected situation.
Town of Ingersoll October, 15, 2013	18. The ToR should provide detailed information on how the uncertainty analysis will be conducted. Note: See Appendix “C” for Dr. Illman’s review of the Draft ToR and his proposed redline for Groundwater/Surface Water Assessment in the Draft ToRm and see Appendix “C1” containing Dr. Illman’s review of the final ToR, dated September 26, 2013.	The modeling for the groundwater and surface water assessments will follow normal industry protocols for QA/QC and uncertainty analyses. These can be further described during the finalization of the work plans during the EA, if necessary.	It is good that the modeling for the groundwater and surface water assessments will follow normal protocols for QA/QC and uncertainty analyses. While this is good, WEG should keep in mind that the proposed landfill will be placed next to a Town, a municipal wellfield utilized for drinking water purposes, in a complex hydrogeological setting (heterogeneous sediments overlying fractured rocks that may be karstified) and next to the Thames River. Therefore, it is expected that significant precautions are taken in conducting the modeling and examining various scenarios, as well as conducting detailed uncertainty analyses beyond what is expected from a normal modeling study for a typical landfill in unconsolidated media.

APPENDIX 2

Reiteration of Walter A. Illman, Ph.D, P.Geo. comments submitted by the Town of Ingersoll on May 12, 2014

Appendix 2: Reiteration of Walter A. Illman, Ph.D, P.Geo. comments submitted by the Town of Ingersoll on May 12, 2014

Comments on the file, "Amendment to the ToR – April 2, 2014.pdf"	Walter A. Illman, Ph.D., P. Geo.
Comments submitted by	**Original Comment**
Town of Ingersoll May 12, 2014	WEG states in point 1f (Amendment to the ToR – April 2, 2014. pdf) that meetings will be arranged "between WEG technical experts and the respective technical experts of the TRT, MNR, UTRCA, and the JMCC PRT to review the revised draft work plans and seek resolution of any outstanding technical issues." Similar statements regarding alternative methods evaluation are made in point 2. While this is good, it should also state that other experts deemed necessary by the Town of Ingersoll or other parties should be included in these meetings. This point is important because the technical experts of TRT, MNR, UTRCA, and the JMCC PRT may not have expertise in some important areas related to the application. The lack of expertise can lead to studies that are not properly designed and not adequately reviewed.
Town of Ingersoll May 12, 2014	WEG states in point 3 that, "WEG will extend its characterization of conceptual hydrogeologic model and potential net effects of the proposed landfill on groundwater, surface water and related ecology to the Thames River basin scale." This is desirable, but contradicts with WEG's comment made in bullet 10 (see p.22 of 30 of 7m – GRT Comment Table – Town of Ingersoll – Final.pdf) of responses to my comments with regards to the extent of the study area. In addition, it is not clear what "the characterization of the conceptual model" means. If this means to update the conceptual model, then WEG should state how will this be done and on what basis will the model be updated? In particular, how will decisions be made on what physical, chemical, and biological processes will be considered in the conceptual model? A rigorous framework on what processes will be included and excluded should be provided.
Town of Ingersoll May 12, 2014	WEG states in point 4 that, "WEG will make available any data it collects related to the Thames River to regulatory agencies that request the data to support their ongoing programs." It would be advisable if WEG can make all data collected on- and off-site available to technical experts as they are collected so that they can be reviewed and if necessary, conduct independent analyses to verify WEG's findings and conclusions.
Town of Ingersoll May 12, 2014	WEG states in point 5 that "the forecast of future baseline considerations for the proposed undertaking, set out in Section 8.2, p.32, Item 2 of the ToR, will include specific consideration of the ongoing dewatering and rehabilitation of the quarries operated by Carmeuse Lime (Canada) Ltd." This is desirable and WEG should also consider changes in operations by Carmeuse Lime in establishing the baseline. In addition, it is recommended that all relevant data should be obtained from Carmeuse to establish credible baseline conditions and to build defensible groundwater models that considers changes in the operations (e.g. changes in surface water and groundwater extraction rates, extraction footprint, etc.).

Comments on the file, “Amendment to the ToR – April 2, 2014.pdf”	Walter A. Illman, Ph.D., P. Geo.
Comments submitted by	**Original Comment**
Town of Ingersoll May 12, 2014	WEG states in point 6 that the evaluation of the proposed undertaking set out in Section 8.2, p.31-34 of the ToR, will specifically identify, recognize and determine any potential effects upon the Wellhead Protection Areas (WHPA) associated with the Town of Ingersoll municipal drinking water wells, Highly Vulnerable Aquifers (HVA) and Significant Recharge Areas (SGRA) identified in the source water protection studies.” However, WEG (bullet 10; see p. 22 of 30 of 7m – GRT Comment Table – Town of Ingersoll – Final.pdf) “disagrees with my opinion that the initial study area is too small, or that it will necessarily need to extend to all of the municipal water wells servicing the Town of Ingersoll.” The statements made by WEG are contradictory and need to be made clear.
Town of Ingersoll May 12, 2014	WEG states in point 7 that, “WEG will consult with the County of Oxford during the EA to identify any pre-existing plans for municipal well field expansion, and incorporate those into the evaluation of the proposed undertaking set out in Section 8.2, p.31-34 of the ToR.” WEG should also consider the Town of Ingersoll’s and individual residents’ expansion plans for the need of additional water supplies and wells.
Town of Ingersoll May 12, 2014	WEG states in point 8 that, “the Groundwater/Surface Water Assessment set out in Appendix B, Section 5.7 of the ToR will specifically include: mapping of geological exposures in the existing quarry, along with borehole investigations and testing to determine the presence and significance of fractures and Karst features within the bedrock, in consultation with an expert in Karst geology.” It is desirable that karst studies are included here, but there were additional recommended studies in my previous letter report that should be included in this section. In particular, WEG mentions in bullet 15 (see p. 23-24 of 30 of 7m – GRT Comment Table – Town of Ingersoll – Final.pdf) that “Subsurface gas is not typically included as a component of off-site air quality since in modern sites, landfill gas is contained and managed on site via liners, gas collection systems, perimeter venting, etc. (backed up with confirmatory monitoring programs). Should the assessment in this EA identify a potential for off-site migration, then further mitigation would have to be put in place to contain the gas regardless, since it would represent a potential explosive hazard.” While engineered barriers and measures may be designed to prevent subsurface gas migration, there is the potential for leakage, hence all pathways should be adequately characterized and numerical modeling should be performed for risk assessment. Finally, the site consists of both unconsolidated materials and fractured rocks. I do not consider this site to be a typical landfill site completed in unconsolidated deposits (i.e., sands, gravels, clays, etc.). Instead, the geology is quite complex. Therefore, studies need to be carefully planned, diligently performed and rigorously reviewed by recognized experts to ensure safety.

APPENDIX A

Curriculum Vitae

Thomas Franz

Brian Adeney

Walter A. Illman

Thomas Franz, M.Sc., P.Geo.

President, Senior Hydrogeologist

Education

M.Sc. (1989), Earth Sciences, University of Waterloo, Ontario

Diplom-Ingenieur (M.A.Sc.) (1987), Civil Engineering, Universitaet Stuttgart, Germany

Years of Experience

Total – 26 yrs

With ARCADIS – 2 yrs

Professional Registrations

Qualified Person for Environmental Site Assessments (QP-ESA) in Ontario

Qualified Person for Risk Assessments (QP-RA) in Ontario

Member, Association of Professional Geoscientists Ontario (APGO)

Member, Association of Professional Engineers and Geoscientists in BC (APEG)

Member, Association of Professional Geoscientists in Newfoundland & Labrador (PEGNL)

Member of the Roster of Contaminated Sites Approved Professionals (CSAP) in BC

Mr. Thomas Franz is the President of ARCADIS Canada Inc. (ARCADIS), a global natural and built asset consultancy with over 28,000 staff worldwide and approximately 270 staff in Canada specializing in environmental consulting and engineering. Mr. Franz is registered as a Professional Geoscientist (P.Geo.) in Ontario, British Columbia, and Newfoundland & Labrador. Since 1989, he has been providing consulting services with a specialization as a hydrogeologist and contaminated sites specialist. His expertise as it pertains to this report is in the evaluation and remediation of contaminated sites, with contamination present in soils and/or ground water. He is the founder of Franz Environmental Inc. and a co-founder of Waterloo Hydrogeologic, Inc. He holds the degrees of M.A.Sc. in Civil Engineering from the University of Stuttgart, Germany, and M.Sc. in Earth Sciences from the University of Waterloo, Ontario, Canada; both degrees focused on contamination issues in the subsurface.

Mr. Franz is a Qualified Person for Environmental Site Assessments (QPESA) and for Risk Assessments (QPRA) in Ontario and has been appointed to the Roster of Contaminated Sites Approved Professionals in BC (CSAP) since 2006. As an expert advisor to regulatory agencies, he is often involved in consultation with the Ontario MOE and other Canadian regulatory agencies in regards to the development of regulatory amendments; he was selected as a panel expert to provide a peer-review of the amendments to Ontario's brownfields regulation (O.Reg. 153/04), assisted in the production of the MOE's Phase One and Phase Two ESA plain language guides, and under a MOE contract he developed a new computer model for the simulation of contaminant transport. Recently, he developed a guidance document for the evaluation and modelling of PFOS contamination in soil, on behalf of Health Canada and Environment Canada.

Mr. Franz has conducted numerous environmental site assessment and remediation projects on behalf of private and government clients involving petroleum hydrocarbon compounds, chlorinated solvents, metals, and other regulated chemicals. He works as an external reviewer on behalf of the Ontario Ministry of Environment and has completed over 75 projects where he reviewed environmental site assessments and remediation plans. He has made submissions to the BC and Ontario Ministries of Environment under their respective regulatory frameworks for various instruments pertaining to contaminated sites. He has also provided expert opinions in numerous litigation matters involving the contamination of soils and groundwater.

Mr. Franz has special expertise in the development and application of groundwater flow and multi-species contaminant transport models. He is the principal developer of various industry-standard groundwater flow and contaminant transport models such as FLOWPATH and Visual MODFLOW. He has taught professional short courses in Canada, the US, Germany, Portugal, Japan, Brazil and Chile on the application of computer models in hydrogeology, risk assessment, and natural attenuation of contaminants in the subsurface.

Expert Reviews and Expert Opinions

Provided expert testimony on behalf of the Attorney General of Canada and the Department of National Defence in a contamination case involving non-aqueous phase petroleum hydrocarbon liquids at a property adjacent to 5 Wing Goose Bay in Goose Bay, Labrador. 10565 Nfld Inc v. Attorney General of Canada (AGC) (2016)

Prepared an expert opinion report on an alleged violation of the Fisheries Act due to petroleum hydrocarbon impacts on a pond and wetland area in Mount Pearl, Newfoundland. (2013)

Expert witness on behalf of the U.S. Department of Justice on hydrogeological issues of groundwater contamination by chlorinated solvents and remediation at Areas I&J Superfund Site at US Navy Base, Lakehurst, NJ. Primary contaminants of concern: TCE, 111-TCA, PCE and breakdown products. Heritage Minerals Inc. vs. United States of America, Civil Action No. 99-CV-83 (MLC). (2002-2003)

Expert witness in three civil litigation cases on behalf of The Boeing Company on groundwater contamination at an industrial facility in Wichita, KS. Primary contaminants of concern: PCE, TCE, and breakdown products, petroleum hydrocarbons, chromium. (Novinger et al. vs. The Boeing Company; Certain Interested Underwriters at Lloyd's et al. vs. The Boeing Company; The Boeing Company vs. Lloyd's et al.). Sedwick County, Kansas, Dist. Ct. No. 99 C 536. (1998-2000)

Prepared several expert opinion reports on heating oil releases and remediation at residential properties throughout Ontario. Court File No's.: CV-07-0385, CV-09-0172-00A1, 04-CV-277424CM2, 10-47859A1 (2011-2013)

Prepared two expert opinion reports on creosote contamination of soils, groundwater, and marine sediments at Vancouver Shipyards, North Vancouver, BC. Conducted expert review of hydrogeological issues, modelling, and proposed remediation plans by Domtar and Seaspan. Project was under Remediation Order issued in February 2010. Primary contaminants of concern: wood treatment chemicals (creosote, naphthalene, petroleum hydrocarbons). BC Ministry of Environment (2011-2012)

Prepared expert opinion report on soil and groundwater contamination due to drycleaning chemicals in Woodstock, ON. Primary contaminants of concern: PCE and breakdown products, petroleum hydrocarbons. Ontario Superior Court of Justice, Court File No. CV-11-420029, Makzmum (Woodstock) vs. Schwartz and Trow Associated Ltd. (2010-2013). Attended successful mediation in 2016.

Prepared expert opinion report on origin of petroleum hydrocarbon contamination at two gas stations in Etobicoke, ON. Primary contaminants of concern: petroleum hydrocarbons. Ontario Superior Court of Justice, Court File No. 61754-01, Advance Service Centre Ltd. vs. Imperial Oil Limited. (2010-2011)

Prepared expert opinion report in contamination case in Langley, BC, involving petroleum hydrocarbon migration through a clay layer at a retail gas station; Happy Face Enterprises (1981) Ltd. vs. Imperial Oil Limited et al., Superior Court of B.C., Vancouver Registry S027058. (2008)

Prepared expert opinion report on origin of petroleum hydrocarbon contamination and allocation of remediation cost case at a retail gas station in Chilliwack, BC; 450855 B.C. Ltd. vs. S2S Enterprises et al. (Federated Co-Operatives Ltd.) Superior Court of B.C., Vancouver Registry L032882; Primary contaminants of concern: petroleum hydrocarbons, MTBE. (2008)

Provided expert review services in sale of United Keno Hills Mine by the federal government to Alexco. Reviewed hydrogeological characterization and long-term care and maintenance plan by Alexco. Primary contaminants of concern: zinc and other heavy metals. On behalf of INAC.

Approved Professional review of environmental investigation of former auto repair shop for residential redevelopment in Burnaby, BC. Obtained Determination. (2010)

Approved Professional review of environmental investigation of former pre-cast concrete industrial facility for commercial/industrial redevelopment in Langley, BC. Obtained Determination. (2010)

Approved Professional review of environmental investigations and remediation of operational areas on Fort Nelson Airport. Obtained Certificate of Compliance. (2009-2010). Client: Ian Chatwell, Transport Canada (Tel. 604-666-6750)

Approved Professional review of environmental investigations and remediation of hydrocarbon and metals contamination at provincial correctional facility in Maple Ridge, BC. Obtained Certificate of Compliance (2008)

Environmental Site Assessment (ESA) Projects

Senior scientist, QP-ESA and QP-RA for five Phase One and Two ESAs, risk assessments, and construction oversight projects for the redevelopment of the Toronto Waterfront. Contaminants of concern include metals, petroleum hydrocarbons, PAHs, VOCs, PCBs, and salt. 2011-ongoing.

Project Director, QP-ESA, QP-RA for Phase One and Two ESAs for former chemical manufacturing plant in Mississauga, Ontario. Contaminants of concern include metals, petroleum hydrocarbons, PAHs, VOCs. (2009-2014)

Project Director, QP-ESA, QP-RA for Phase Two ESA for former munitions plant in Alton, Ontario. Contaminants of concern include metals, petroleum hydrocarbons, PAHs, and VOCs. (2011-ongoing)

Principal scientist for the investigation of petroleum hydrocarbon contamination in soil and groundwater at a former retail service station in the Region of Waterloo and at two operating retail service stations in Guelph and Oakville, Ontario. Contaminants of concern include petroleum hydrocarbons, PAHs, and metals. (2008-ongoing)

Project director and QP-ESA for Phase 1 and 2 ESAs of commercial property in Mississauga, Ontario, for institutional redevelopment. Contaminants of concern include metals, petroleum hydrocarbons. Obtained Record of Site Condition (RSC) (2011)

Project Director for the investigation and regulatory issues in relation to on-site and off-site environmental impacts at a former gas station at a shopping mall in Salmon Arm, BC. Liaised between oil company, property owner, buyer, tenants, municipality, and Ministry of Environment. Contaminants of concern include metals, petroleum hydrocarbons, PAHs, VOCs. (2010-2012)

Project Director for environmental issues relating to the redevelopment of several properties along the lakeshore of Lake Ontario, on behalf of Waterfront Toronto. Involved in Phase 1 and 2 ESAs, risk assessments, remediation, construction of risk management systems, and geotechnical projects (2011-ongoing).

Project director for due diligence Phase 2 ESA of municipal works yard in Caledon, Ontario. Contaminants of concern include metals, petroleum hydrocarbons, PAHs, VOCs, and salt. (2011)

Principal scientist for determination of NAPL (free product) mobility at the Heavy Bomber Hydrant Area, CFB Goose Bay. Contaminants of concern include petroleum hydrocarbons, PAHs. (2010-2011)

Senior hydrogeologist and project director for environmental investigations, historical reviews, and analysis of soil, groundwater, and sediment contamination at a tank farms, soil treatment and waste storage facilities, and former construction camps at an aluminum smelter site in Kitimat and Kemano, BC. Contaminants of concern include metals, petroleum hydrocarbons, PAHs, VOCs, and PCBs. (2007-ongoing)

Project Manager and contaminant hydrogeologist for delineation and remediation optimization of 4-Million litre diesel plume at Upper Tank Farm at CFB Goose Bay, Labrador (1994-2000, 2005)

Project Manager and hydrogeologist for characterization of impacts from 11 landfill sites to groundwater along South Escarpment at CFB Goose Bay, Labrador (2005)

Project Manager and contaminant hydrogeologist for ESA of bunker C contamination at Bushell Public Wharf, Uranium City, SK (2002/03)

Project Manager for detailed environmental site assessments and site-specific risk assessments of contaminated sites in correctional institutions at Bowden, AB, Leclerc, QC, and William Head, BC (2003)

Senior reviewer and contaminant hydrogeologist of hydrocarbon impacts in soil and groundwater at former industrial facility in North Vancouver, BC (2003-on-going)

Project Manager and contaminant hydrogeologist for ESA of site impacted by waste oil and diesel at Coal Harbour Public Wharf, BC (2002-2004)

Project Manager and contaminant hydrogeologist for petroleum hydrocarbon and coal-tar impacted site at former bulk marine fuel terminal, Belleville, ON (2002/03)

Senior reviewer and contaminant hydrogeologist for chlorinated solvent impacts at an active industrial facility in Calgary, AB (1997-2007)

Senior reviewer of Phase III ESA of landfills and petroleum hydrocarbon spill sites at Watson Lake airport, Yukon (2001)

Senior reviewer and contaminant hydrogeologist for Detailed Site Assessment and quantitative human health and ecological risk assessment of chlorinated solvent, hydrocarbon, and metals impacts at former railway facility in Vancouver, BC (2001-2010)

Project Manager and contaminant hydrogeologist for metals and hydrocarbon impacts of 2000 acre property at former cement plant in Bamberton, BC (1998-2004)

Project Manager and contaminant hydrogeologist for detailed site investigation for property divesture in Victoria Harbour, Lots 3, 8, 9a,16 and 17 (1997-2005)

Project Manager and contaminant hydrogeologist for coal-tar impacted site in Rock Bay, BC (2000-2004)

Senior Reviewer of environmental baseline study of Civil Aviation Area at Canadian Forces Base Goose Bay for Department of National Defence (1999)

Project Manager and contaminant hydrogeologist for environmental baseline study at Wabush Airport, Labrador, on behalf of Transport Canada (1998)

Project Manager and contaminant hydrogeologist for environmental baseline studies, numerous ESAs and remediation projects at airports in Fort Nelson, Tofino, Prince Rupert, Port Hardy, and Smithers, British Columbia, on behalf of Transport Canada and Public Works & Government Services Canada (PWGSC). Issues included impacts to soil, groundwater, surface water, and sediments due to historical leaks and spills from underground and above ground storage tanks, tank farms, fuelling systems, fire training areas, and dump sites. (since 1996)

Project Manager and contaminant hydrogeologist for environmental baseline studies at Timmins Airport, Ontario, and North Bay Airport, Ontario on behalf of PWGSC and Transport Canada (1995-1998)

Project Manager and contaminant hydrogeologist for soil, groundwater, surface water, and sediment impacts at two fire training areas, two former dump sites, a hazardous materials compound, and a 4,000,000 litre diesel and avgas spill site at CFB Goose Bay, Labrador. (1995-2000)

Project Manager for environmental assessment and remedial planning at Summerland Rifle Range near Penticton, British Columbia, on behalf of Agriculture Canada (1996)

Project Manager for environmental assessment of outdoor small arms range at Pussey's Hill Rifle Range, CFS St. John's, Newfoundland (1995)

Project Manager for Phase II environmental assessment of Cornwall Harbour on behalf of PWGSC and Canadian Coast Guard (1994)

Project Manager for environmental site assessment of 5 airport beacon/radar sites for PWGSC and Transport Canada. (1993)

Project Manager for Department of National Defence's Environmental Assessment of 17 fire fighter training areas at Canadian Forces Bases across Canada. The project included an extensive field program, risk assessment and screening of remedial alternatives for organic contamination (dissolved and liquid phase). (1992-1993)

Project Manager for Department of National Defence's field investigations and environmental assessment of heavy metal contamination at 6 outdoor small arms ranges at Canadian Forces Bases across Canada. (1992-1993)

Project Manager for environmental baseline studies, risk assessments and remediation plans for five Canadian Forces facilities and airfields in Germany ($1.5 million). (1991-1993)

Hydrogeological study in connection with environmental compliance review of fertilizer manufacturing plant near Kingston, Ontario, for financial backer. (1990)

Environmental assessment and evaluation of management practices pertaining to herbicide application to rights-of-way. (1990)

Risk Assessments

- 2012-2014. Senior risk assessor (QP-RA) for 5 ESAs and risk assessments for a variety of contaminants in soil and groundwater at Toronto Waterfront, Toronto, ON. Risk assessment for park development at Portland Slip accepted by MOE, 4 RAs in review process. Negotiated CPUs. Contaminants of concern include metals, petroleum hydrocarbons, PAHs, VOCs, PCBs, and salt.

- 2012-2014. Senior risk assessor (QP-RA) for streamlined Tier 3 RA of metals and PAHs contamination in soil and groundwater at a former munitions plant. Alton, ON. Risk assessment in final stages of acceptance by MOE. Contaminants of concern include metals, petroleum hydrocarbons, PAHs, VOCs.

- 2012-2013. QP-RA for certifying completion of Certificate of Property Use (CPU) at Jarvis Street slip. Contaminants of concern include metals, petroleum hydrocarbons, PAHs.

- 2012. Developed Soil Quality Guideline for Perfluorooctane sulfonate (PFOS) for potable water pathway for Health Canada.

- 2012. Senior risk assessor (QP-RA) for Tier 3 RA of chlorinated organic chemicals in soil, groundwater, and vapour contamination at a former chemical manufacturing plant. Mississauga, ON. Negotiated CPU and is responsible for implementation of risk management plan. Risk assessment accepted by MOE. Contaminants of concern include metals, petroleum hydrocarbons, PAHs, VOCs.

- 2008-2014. Expert reviewer (QP-RA) of approximately 75 risk assessments of contaminated sites for Ontario MOE dealing with a multitude of issues involving soil, groundwater, surface water, sediment, and vapour impacts, and a variety of chemicals (petroleum hydrocarbons, halogenated and non-halogenated volatile and semi-volatile organics, PCBs, metals, phthalates, pesticides, herbicides, wood treatment chemicals, coal tar).

- 2009-2010. Senior risk assessor (QP-RA) for Tier 3 quantitative Human Health & Ecological Risk Assessment of a retail gas station, with endangered fish species and in a wider area of abatement (includes off-site consultation and risk evaluation), for land dedication to the municipality, and site redevelopment. Oakville, ON. Contaminants of concern include metals, petroleum hydrocarbons, PAHs, VOCs.
- 2007-2009. Senior risk assessor (QP-RA) for Tier 3 quantitative Human Health & Ecological Risk Assessment of a former printing plant for redevelopment as multi-tenant housing complex. Contaminants were chlorinated organic chemicals, PAH, metals, within a wellhead protection area. RA was accepted by MOE, filed Record of Site Condition. Contaminants of concern include metals, petroleum hydrocarbons, PAHs, VOCs.
- 2007. Member of expert review panel of proposed Ontario MOE's Site Conditions Standards on behalf of MOE.
- 2005. Prepared "Guidance document for review of risk assessment reports under O.Reg. 153/04" which is a review the MOE's "Procedures for the Use of Risk Assessment under Part XV.1 of the Environmental Protection Act" to facilitate the consistent review of RAs in Ontario, on behalf of the MOE.
- 2005. "Guidance on Risk Assessment of Microbial Contamination". This document provides guidance and discusses the similarities and differences of risk assessment approaches for chemical RAs and microbial RAs, on behalf of Health Canada.
- 2004. Prepared screening level Ecological Risk Assessment for PHCs, PCBs and metals in a salmon bearing stream at Tofino Airport powerhouse and dump site. Developed risk management plan.
- 2001-2005. Project manager and principal investigator for Detailed Site Investigation and quantitative human health and ecological risk assessment of a site contaminated by PCE, TCE, DCE, and vinyl chloride due to a railcar spill in mid-1980s in downtown Vancouver. Obtained AIP from BC MOE.
- As Senior risk assessor, prepared quantitative human health risk assessment (including a detailed hydrogeological investigation and a 3-D groundwater flow model) for hydrocarbon contamination in Port Hope, Ontario (2004-2005)
- Prepared screening level ecological risk assessment for petroleum hydrocarbon, PCBs and metals contamination in a salmon bearing stream at Tofino Airport, Tofino, BC. Contamination originated from a former powerhouse and dump site. Developed risk management plan. (2004)

- 2000. Conducted human health risk assessment for petroleum hydrocarbon contamination in soils and groundwater at a former Avgas bulk fuel storage tank farm at Fort Nelson airport. Calculated site-specific target levels for risk-based cleanup. Transport Canada

- 1994-2012. Project manager, senior environmental scientist, senior risk assessor for ESAs, modelling, RAs at 2 FFTAs, 13 landfills, 10 free product plumes (up to 4 million L), CFB Goose Bay, Labrador. Developed interim remediation criteria based on Goose Bay specific quantitative RA. Completed quantitative HHERA of a drum dump (DDT, oils, PCBs) using US EPA RAGS (1994/95), ecological risk assessment for hydrocarbon contamination and landfill-related contaminants of a wetland area (1994/95), HHRA for lead in water supply piping in housing on the base (1997), and HHRA using risk-based remedial action (RBCA) methodology for diesel contamination at Upper Tank Farm (1994, 1995, 2001).

- 2001. Conducted detailed natural attenuation study and monitoring programs for groundwater and surface water at Upper Tank Farm and Spring Gulch wetland after implementation of remediation systems. (2001)

- 1998-2003. Managed and conducted quantitative ecological risk assessment of marine sediment impacts at a former cement plant at Bamberton, B.C., for metals, PAHs and various petroleum hydrocarbons. Biological studies of marine sediments included studies of benthic communities and tissue analysis of shellfish. Microtox testing and bioassay testing were conducted to assess marine sediment toxicity. (1998-2003)

- 1996-2004. Project Manager and contaminant hydrogeologist for detailed site investigations for property divestiture in Victoria Harbour, Lots 3, 9a, 16 and 17. All projects included quantitative and/or qualitative human health and ecological risk assessments (1996-2004

Remediation Projects

- Project Manager or Senior Reviewer for remediation of petroleum hydrocarbon contamination at Fort Nelson, Tofino, Port Hardy, Prince Rupert, and Smithers airports in British Columbia. Systems included soil vapour extraction, in-situ air sparging, pump-and-treat, site-specific risk assessment, monitored natural attenuation, excavation and ex-situ soil treatment in engineered biological soil treatment facility (up to 20,000 m3), and dig-and-dump. Project values up to $22,000,000.

- Senior Reviewer and contaminant hydrogeologist for reactive wall, in-situ air sparging, vapour extraction system and groundwater pump-and-treat system for chlorinated solvent impacts in groundwater at a railway facility in Calgary, AB (since 1997)

- Project Manager for remediation of petroleum hydrocarbon impacts in soils and groundwater at a former bulk fuel terminal in Belleville, Ontario (Brownfield redevelopment project) (2001/02)

- Project Manager for design and installation of a physical barrier and pumping system at a petroleum contaminated site at CFB Goose Bay, Labrador (1995)

- Project Manager for installation of a physical barrier and horizontal drain at a solvent impacted industrial site in Toronto, Ontario (1994)

Groundwater Flow and Contaminant Transport Modelling

- Developed and modelled remedial strategies in 2-D and 3-D for 8.5 billion gallons of chlorinated VOC plume at the US Navy's Air Warfare Centre (now Navy Air Engineering Centre) in Lakehurst, New Jersey, Superfund site using FLOWPATH, MODFLOW, MODPATH, MT3D

- Senior hydrogeologist and reviewer for the dewatering feasibility model for the Diavik mine.

- Principal scientist for the review and gap analysis of environmental data for the development of a 3-D groundwater flow and contaminant transport model for an inorganic contaminant plume at an aluminum smelter in Kitimat BC

- Senior hydrogeologist and modeler for groundwater flow and contaminant transport at an underground mine site at Koenigstein, various waste rock dumps (Pirna, Aue), and an open pit mine near Gera, former East Germany, for Wismuth GmBH, Germany

- Senior hydrogeologist and modeler for uranium mine McClean Lake project in Saskatchewan. Conducted 3-D modelling of GW flow and contaminant transport due to waste rock backfill.

- Senior modeller for groundwater flow and contaminant transport analysis involving PCE, TCE (and breakdown products) and carbon tetrachloride, at an aircraft manufacturing facility in Wichita, Kansas, using MODFLOW, MODPATH and MT3D/RT3D

- Senior modeller for simulating fate and transport of dissolved phase hydrocarbons at CFB Goose Bay using MODFLOW and RT3D

- Senior modeller of remediation strategies for Coke Ovens Brook at Sydney Tar Ponds, Sydney, NS, using MODFLOW, MODPATH and MT3D

- Senior modeller for simulation of pump-and-treat scenarios at TCE contaminated industrial site in Calgary, AB using MODFLOW, MODPATH and RT3D
- Senior modeller for simulation of funnel-and-gate system at a former coal gasification plant in Glens Falls, New York
- Senior risk assessor and modeller for quantitative RA of hydrocarbon impacts at Moose Factory hospital.
- Senior reviewer of contaminant transport model for a nitrate plume in groundwater at CFB Bagotville, Quebec
- Senior review and guidance for a 3-D groundwater flow modelling effort for TCE-contamination at Florida Petroleum Re-Processing plant in Ft. Lauderdale, Florida (Superfund site) on behalf of the U.S. Army Corps of Engineers
- Development of a numerical model for the evaluation of co-metabolic bioventing systems for the remediation of chlorinated solvents in the vadose zone (for ICI Chemicals, U.K.)
- Review of a groundwater flow model for First Chemical Corporation for remediation of TCE and PCE contaminated groundwater in New Albany, TN, and Pascagoula, MS
- Implementation of a 3-D groundwater flow and contaminant transport model for a waste oil recovery site in Breslau, Ontario for evaluation of remedial alternatives using MODFLOW, MODPATH, MT3D
- Provided expert review for landfill modelling at municipal landfill site near Cobourg, Ontario, using POLLUTE and U.S. EPA HELP
- Supported landfill design at L.B. Pearson International Airport using FLONET flow and transport model.
- Modelled 1 million gallon free hydrocarbon product plume at CFB Goose Bay using ARMOS
- Implementation of a 3-D groundwater flow model for CFB Goose Bay for the assessment of off-site contaminant migration and evaluation of remedial alternatives using MODFLOW
- Review of 2-D and 3-D groundwater flow modelling for wellhead protection area delineation for wellfields in the Regional Municipality of Waterloo using MODFLOW

- Predicted impact on water quality and supported engineering design by modelling groundwater flow and transport of inorganic contaminants (phosphorus, fluoride, cyanide) at Albright & Wilson America's plant site in Long Harbour, Newfoundland, using USGS MOC

- Provided numerical modelling for delineation of well head protection areas of 32 municipal wells in the Regional Municipality of Peel, Ontario, using FLOWPATH and MODFLOW

- Modelled the transport of a heat plume from a proposed quarry pit to a cold water stream in the Regional Municipality of Waterloo, Ontario

- 2-D flow and transport modeling to support RI/FS for a TCE/PCE plume on ARMCO Superfund site in Traverse City, Michigan, using FLOWPATH and USGS MOC.

- Implementation of a 3-D regional groundwater flow and contaminant transport model for the Uniroyal plant site in Elmira, Ontario, for NDMA, chlorobenzene, herbicides using TARGET

- EPA-level groundwater flow and transport modelling for Innisfil landfill expansion

- EPA-level hydrogeological analysis and impact assessment modelling for municipal landfill in Township of Iroquois Falls

- Hydrogeological characterization and analytical modelling for impact prediction for two 45 ha landfill sites in Lagos State, Nigeria

- Modelled dewatering scenarios for clean-up operation at Husky Oil's oil loadout facility in Hardisty, Alberta

- Hydrogeological mapping and numerical groundwater flow modelling for a regional aquifer in the Region of Peel as part of an impact assessment for contingency landfill site

- Model calibration for wellhead protection area delineation in Sioux Falls, South Dakota, for the South Dakota Geological Survey.

- Numerical modelling of radionuclide diffusion through high level nuclear waste repository buffer materials.

- Experimental determination and numerical modelling of permeability distribution of excavation disturbed zone in deep nuclear waste disposal site at the Underground Research Laboratory, Lac-du-Bonnet, Manitoba (Ontario Hydro, AECL).

- Opponent review for Municipality of Littleton, Massachusetts of environmental impact assessment for major coal-fire generating station.

- Modelled regional and local groundwater flow system for environmental assessment of LNAPL spill at chemical manufacturing facility in Red Deer, Alberta, under contract for Hardy BBT, Calgary.

- 2-D and 3-D numerical modelling pertaining to U.S. EPA's wellhead protection effort and monitoring network design in Littleton, Massachusetts, under contract for Lockheed Engineering and Sciences Company, Las Vegas

- Modelled aquifer clean-up scenarios for Superfund site in Vega Alta, Puerto Rico

Landfill-Related Studies and Waste Management

- Project Director and Contaminated Sites Approved Professional (CSAP) for waste management of bottom ash and fly ash from Burnaby incinerator on behalf of Metro Vancouver. (since 2013)

- Review of the overburden and fractured rock hydrogeology, leachate plume characterization, and groundwater modelling in the context of closure planning for the Canadian Waste Nepean Landfill on behalf of the Ontario Ministry of Environment (2010).

- Hydrogeological study of the South Escarpment area at CFB Goose Bay, includes the assessment and development of monitoring and/or remediation and closure programs for 11 landfill sites (2004/05)

- Review of Adams Mine landfill proposal and Permit-to-Take-Water application on behalf of Ontario Ministry of Environment (2004)

- Review of modelling concept for open-pit uranium mine decommissioning at Ronneburg, Germany (1997/98)

- Calculation of waste rock pile water balance using U.S. EPA HELP at former open-pit uranium mine, Aue, Germany (1997)

- Conducted hydrogeological characterization study and modelled landfill design alternatives for relocating a landfill for a new runway at L.B. Pearson International Airport, Toronto, using FLONET groundwater flow and transport model. (1997)

- Project Manager for Innisfil landfill site monitoring program and remedial investigation for Price Waterhouse Ltd. (1996)
- Project Manager and senior hydrogeologist for drum dump risk assessment and remedial options evaluation at CFB Goose Bay, Labrador (1996)
- Hydrogeological expert for landfill hearing for Northumberland County (1996)
- Project Manager for hydrogeological study, environmental assessment and remediation of groundwater, surface water, sediment, and soil contamination at CFB Goose Bay, Labrador at the Central & Eastern Landfill Site (1994/95)
- Project Manager for characterization of abandoned construction landfill site at CFB Petawawa, Ontario. (1995)
- Project Manager for environmental assessment of Confined Disposal Facility in Lake St. Clair for dredged sediment management, on behalf of PWGSC and Coast Guard (1995)
- Provided groundwater model review for a valuation hearing on a landfill expansion in Brantford, West Gwillimbury, Ontario. (1993)
- Hydrogeological mapping and numerical groundwater flow modelling for a regional aquifer in the Region of Peel as part of an impact assessment for contingency landfill site. (1993)
- Groundwater flow and transport modelling for Innisfil landfill expansion. (1993, 1995)
- Geological and hydrogeological inventory and constraint analysis for a Greater Toronto area contingency landfill site search in the Regional Municipality of York. (1991-92)
- Stage 2B hydrogeological analysis for Waste Management Master Plan landfill site selections for South Simcoe County and Port Colborne - Fort Erie. (1991/92)
- Hydrogeological analysis and impact assessment modelling for municipal landfill in Township of Iroquois Falls. (1992)
- Hydrogeological characterization and analytical modelling for impact prediction for two 45 ha landfill sites in Lagos State, Nigeria. (1991/92)
- Numerical modelling of radionuclide diffusion through high level nuclear waste repository buffer materials. (1990)

Mining / Hydrogeology Projects

- Senior reviewer of hydrogeological effects study for copper mine in Panama on behalf of Inmet Mining (2010)
- Senior reviewer of well construction and failure modes for groundwater monitoring wells in deep permafrost (well depths over 200 m) at Meadowbank Mine in Baker Lake, Nunavut on behalf of Agnico Eagle (2009/2010)
- Senior hydrogeologist for the review of pump-and-treat groundwater remediation plan for Faro Mine, Yukon, on behalf of Environment Canada
- Member of an expert panel for the review of a fixed-cost remediation and long-term care & maintenance proposal for the UKHM mine in Yukon. Reviewed hydrogeological and engineering aspects of the project on behalf of PriceWaterhouse and INAC (2006/2007)
- Senior reviewer of the dewatering feasibility study of the Diavik diamond mine in Lac de Gras, NWT, on behalf of Diavik (2006/2007)
- Expert, senior hydrogeologist and project manager for the review of the hydrogeology and engineering of a proposed landfill development and dewatering application in the former Adams Mine in Kirkland Lake, Ontario, on behalf of the Ministry of Environment. (2005/2006)
- Expert reviewer of hydrogeological and groundwater modelling aspects of permit documents for the decommissioning of an underground uranium leach mine in Koenigstein (near Dresden), Germany, on behalf of the Saxony Department of Environment and Geology in Germany (2004-2006)
- Senior hydrogeologist for the assessment of groundwater flow and contaminant transport models for application of permit for uranium mine development at Sue C and Jeb pits, Saskatchewan (Cogema/Areva) (1999-2003)
- Senior hydrogeologist and project manager of evaluation of the groundwater flow system and flooding of an underground uranium mine in fractured rock aquifer in Koenigstein (former East Germany, Wismut GmbH) (1995-1998)
- Senior hydrogeologist and project manager for the evaluation of contaminant transport (via leaching) at various mine tailings and waste rock piles using U.S. EPA HELP and BOWAM at former uranium mines in Germany (Wismut GmbH) (1995-1998)

- Senior hydrogeologist and project manager for the review of modelling concept for open-pit uranium mine decommissioning at Ronneburg, Germany (Wismut GmbH) (1996)
- Senior Reviewer of 3-D groundwater flow models at uranium mines in Northern Saskatchewan (Cominco) (1996)

Model Development

- Lead scientist in the development of a groundwater fate and transport model for the Ontario MOE to replace the Domenico model in the MOE's effort of setting new soil and groundwater standards in Ontario (2008 – 2011)
- Principal author of several commercially available numerical models: Visual MODFLOW, FLOWPATH, FLONET and AIRFLOW.
- Principal author of a model for evaluation of co-metabolic bioventing systems for remediation of chlorinated solvents in unsaturated soil zone.

Publications/Papers/Conference Presentations

Franz, T.J., A. Dawe, L. McDonald, C. Lessard, and J. Miller, 2014. Fate and Transport Modelling of PFOS in Groundwater. Presented at Federal Contaminated Sites National Workshop, Real Property Institute of Canada, Ottawa, 2014

Franz, T.J., 2012. Characterization of Non-Aqueous Phase Liquid Mobility at CFB Goose Bay. Presented at Federal Contaminated Sites National Workshop, Real Property Institute of Canada, Toronto, 2012.

Franz, T.J., 2008. Problems with the Domenico Solution. Presented at Federal Contaminated Sites Workshop, Real Property Institute of Canada, Vancouver, 2008.

Franz, T.J., 2006. Use and Limitation of Groundwater Flow and Contaminant Transport Models in Contaminated Site Assessment and Remediation. Presented at Federal Contaminated Sites Workshop, RPIC, Ottawa, 2006.

Franz, T.J., I. Chatwell, R. Birk, I. Lambrecht, R. Sisler, S. Hamilton. Remediation of Salmon Bearing Stream at Tofino Airport. Presented at Federal Contaminated Sites Workshop, RPIC, Ottawa, 2006.

Franz, T.J., Mason, A., Harkness, M., Tsentas, C., Becker, M., and Figura, M., 2000. Natural Restoration of an Chlorinated Solvents Contaminated Aquifer at NAES Lakehhurst, NJ. Presented at Batelle Conference, Monterey, CA.

Mason, A., Franz, T., and Harkness, M., 2000. Modeling of Multi-Species Reactive Transport of Chlorinated Solvents Contaminated Aquifer at NAES Lakehhurst, NJ. Presented at Batelle Conference, Monterey, CA.

Sayles, G., Moser, L., Franz, T., Mason, A., Morgan, P., 2000. Co-metabolic Bioventing at Dover Airforce Base. Presented at Batelle Conference, Monterey, CA.

Franz, T., Mason, A., Morgan, P., 1999. Development of a Co-metabolic Bioventing Model. Presented at Batelle Conference, San Diego, CA.

Akindunni, F., Gillham, R. W., Conant, B. and Franz, T. J., 1995. Modelling of Contaminant Movement Near Pumping Wells: Saturated-Unsaturated Flow with Particle Tracking. Ground Water, Vol. 33, No. 2, March-April, 1995.

Franz, T.J., 1993. Hydrogeological Computer Models Used in Evaluating Contaminant Transport. In Geotechnical News, Vol. 11, No. 4.

Franz, T. J. and Rowe, R. K., 1992. Simulation of Groundwater Flow and Contaminant Transport at a Landfill Site Using Models. Invited paper by Int. Journal of Numerical Methods in Geomechanics.

Jakubick, A. T. and Franz, T. J., 1991. Vacuum Testing of the Permeability of the Excavation Damaged Zone: Assessment of Hydrogen Leakage from an Underground Repository. Presented at Int. Conference for Nuclear Waste Repositories, Aix-En-Provence, France.

Guiguer, N. and Franz, T. J., 1991. Development and Application of a Well Head Protection Area Delineation Computer Program. In Wat. Sci. Tec., Vol. 24, No. 11, pp 51-62

Franz, T. J., 1989. Optimal Purging Schemes for Aquifer Remediation Using the Particle Tracking Method. M.Sc. Thesis, University of Waterloo.

Akindunni, F., Gillham, R. W. and Franz, T. J., 1989. Movement of Contaminants Near Pumping Wells Installed in Shallow Unconfined Aquifer: Numerical Simulations. Conference Proceedings to 28th International Geological Congress, Washington, DC.

Franz, T. J., Kinzelbach, W. and Frind, E. O., 1989. Calculation of Capture Zones in Transient Flow Fields. Presented at 28th Int. Geol. Congress, Washington, DC.

Franz, T. J., Sudicky, E. A. and Frind, E. O., 1989. Mathematical Modelling of the Effects of Septic Systems on Groundwater, Interaction Between Septic Systems and Water Supply Wells. University of Waterloo, WRI Report 1291201.

Franz, T. J., 1987. Calculation of Capture Zones under Transient Hydrological Conditions. M.A.Sc. Thesis, University of Stuttgart, Stuttgart, Germany.

TETRA TECH

Brian C. Adeney, P.Eng.
Senior Project Director - Environment

EXPERIENCE SUMMARY

Mr. Adeney is the Senior Project Director and a Senior Environmental Engineer with the Environment practice. He has over 30 years of consulting experience and has managed and contributed water resources input to a range of multidisciplinary environment and stormwater management projects throughout Alberta, British Columbia, the Yukon Territory, and Ontario. Mr. Adeney oversees and is a senior reviewer of environment projects in Alberta, and coordinates water resources projects at other offices in western Canada. He is registered as a Professional Engineer in Alberta and the Northwest Territories/Nunavut.

RELEVANT EXPERIENCE

Mr. Adeney has managed a wide range of drainage studies and watershed plans that have involved the investigation of basin hydrology, surface flooding, water quality, erosion potential, and drainage mitigation opportunities. These projects have involved the integration of engineering and biological services with the objective of achieving a comprehensive solution within approval guidelines. Recent projects have been completed for proposed road widenings/twinnings, logging road and well access crossings, pipeline crossings, site remediation, industrial and oil sands plants and urban lakes. Water quality data assessment and inventories have recently been completed for stormwater ponds in St. Albert, Edmonton and Lethbridge as well as the Qu'Appelle River near Regina and Cold Lake region of Alberta. Projects in British Columbia include numerous flood frequency analyses for flooding flow calculations, a hydrologic study of the Taku River basin in northwest British Columbia, constructed wetland design in Chemainus for water quality management and hydrologic studies in the Okanagan Valley. Mr. Adeney has also been Project Manager for land use and water treatment studies at Alexander, O'Chiese and Tallcree First Nations in Alberta.

Mr. Adeney has led or participated in over 50 stream crossing capacity studies for linear corridors involving road culverts, bridges, and pipelines. These projects have involved determining the crossing hydrology and hydraulic characteristics to safely accommodate extreme flow conditions. Northern projects have been conducted in Carcross, Yukon, Colomac Mine in the Northwest Territories, Ekati Mine NWT, and near Atlin, in northern British Columbia, and have involved an understanding of northern climate issues. Further to this, erosion and sediment control plans have been prepared to address sensitive fisheries habitat and downstream water quality for a wide range of development projects.

In addition to preparing and senior reviewing technical studies, Mr. Adeney has presented expert testimony on water resources issues on over 10 occasions. This involvement has included disputes over site drainage issues in rural areas, existing oil and gas facilities, proposed land development,

EDUCATION

B.E.S., Geography (Geomorphology), University of Waterloo

B.Sc. (Eng), Water Resources Engineering, University of Guelph

AREA OF EXPERTISE

Project management

Environment assessments

Site drainage

Soil and groundwater remediation

Groundwater monitoring programs

Water quality assessments

Sediment and erosion control designs

REGISTRATIONS/ AFFILIATIONS

Member, Association of Professional Engineers and Geoscientists of Alberta (APEGA)

Member, Northwest Territories Association of Professional Engineers and Geoscientists, (NAPEG)

Member, Environment Council for Transportation Association of Canada (TAC)

OFFICE

Edmonton, AB

YEARS OF EXPERIENCE

30

CONTACT

Brian.Adeney@tetratech.com

landfill sites, sediment spills, and the modification of Approval Certificates for operating stormwater pond releases at industrial facilities. Brian has been the Project Manager for five 3PC Oil Sands EIA expert reviews on behalf of Alberta Environmental Sustainable Resource Development (ESRD) with focus on surface hydrology, hydrogeology, terrestrial resources and air impacts.

Walter A. Illman, PhD, PGeo

Department of Earth & Environmental Sciences, University of Waterloo, Waterloo, Ontario, Canada
Phone: 519-888-4567 ext. 38341; E-mail: willman@uwaterloo.ca

Education

Ph.D., Hydrology (minor in Applied Mathematics), University of Arizona, 1999

B.Sc. (with Distinction), Geological Sciences, University of Washington, 1994

Appointments

Professor, Department of Earth & Environmental Sciences, University of Waterloo, 2014 - present

Associate Professor, Department of Earth & Environmental Sciences, University of Waterloo, 2007 – 2014

Associate Professor, Department of Geosciences, University of Iowa, 2006 – 2007

Assistant Professor, Department of Geosciences, University of Iowa, 2001 – 2006

Professional Focus and Accomplishments

Professor Illman has over 20 years of academic and consulting experience in a wide range of hydrogeological problems worldwide, particularly in applying advanced computational models and high-resolution subsurface characterization techniques, as well as conducting innovative laboratory and field investigations to solve complex environmental and hydrologic problems. His current research interests include field and laboratory investigations of subsurface heterogeneity in both porous and fractured geologic media, hydraulic fracturing and its impacts on groundwater, DNAPL source zone characterization and investigations of abiotic and biotic degradation mechanisms in heterogeneous media, and unsaturated zone hydrology including gas flow in fractured rocks. He is considered one of the pioneers in developing hydraulic tomography, a new subsurface characterization method to image heterogeneities of hydraulic conductivity and specific storage. Prof. Illman is the author of over 55 publications in peer-reviewed journals and has served as an Associate Editor for Water Resources Research and Groundwater. Other notable published work includes a book on Bioremediation and Natural Attenuation: Process Fundamentals and Mathematical Models, published by John Wiley & Sons, Inc. of which he is a coauthor.

Refereed Journal Publications

1. Zhuang, C., Z. Zhou, W. A. Illman, Q. Guo (2017), Estimating hydraulic parameters of a heterogeneous aquitard using long-term multi-extensometer and groundwater level data, Hydrogeology Journal, in press.
2. Zhuang, C., Z. Zhou, and W. A. Illman (2017), A joint analytic method for estimating aquitard hydraulic parameters, *Groundwater*, DOI: 10.1111/gwat.12494, in press.
3. Zha, Y., T.-C. J. Yeh, W. A. Illman, H. Onoe, C. M. W. Mok, J.-C. Wen, S.-Y. Huang, and W. Wang (2017), Incorporating geologic information into hydraulic tomography: A general framework based on geostatistical approach, Water Resour. Res., 53, doi:10.1002/2016WR019185.
4. Clark, J., R. L. Stotler, S. K. Frape, and W. A. Illman (2017), Compound specific isotope analyses to assess TCE biodegradation in a fractured dolomitic aquifer, *Groundwater*, 55(1), 88-99, DOI: 10.1111/gwat.12440.
5. Zhao, Z, and W. A. Illman (2017), On the importance of geological data for three-dimensional steady state hydraulic tomography at a highly heterogeneous aquifer-aquitard system, Journal of Hydrology, 544, 640-657.
6. Zha, Y., T.-C. J. Yeh, W. A. Illman, T. Tanaka, P. Bruines, H. Onoe, H. Saegusa, D. Mao (2016), An application of hydraulic tomography to a large-scale fractured granite site, Mizunami, Japan, *Groundwater*, 54(6), 793-804, DOI: 10.1111/gwat.12421.
7. Zhao, Z., W. A. Illman, and S. J. Berg (2016), On the importance of geological data for hydraulic tomography analysis: Laboratory sandbox study, *Journal of Hydrology*, 542, 156-171, http://dx.doi.org/10.1016/j.jhydrol.2016.08.061.
8. Luo, N. and W. A. Illman (2016), Automatic estimation of aquifer properties using long-term water supply pumping records, *Hydrogeology Journal*, 24(6), 1443-1461. doi:10.1007/s10040-016-1407-x.

9. Schöniger, A., W. A. Illman, T. Wohling, and W. Nowak (2015), Finding the right balance between groundwater model complexity and calibration effort via Bayesian Model Averaging, *Journal of Hydrology*, 531, 96-110, http://dx.doi.org/10.1016/j.jhydrol.2015.07.047.
10. Zha, Y., T.-C. J. Yeh, W. A. Illman, T. Tanaka, P. Bruines, H. Onoe, H. Saegusa (2015), What does hydraulic tomography tell us about fractured geological media? A field study and synthetic experiments, *Journal of Hydrology*, 531, 17-30, http://dx.doi.org/10.1016/j.jhydrol.2015.06.013.
11. Zhao, Z., W. A. Illman, T.-C. J. Yeh, S. J. Berg, and D. Mao (2015), Validation of hydraulic tomography in an unconfined aquifer: A controlled sandbox study, *Water Resources Research*, 51, 4137–4155, doi:10.1002/2015WR016910.
12. Illman, W. A. (2015), Lessons learned from hydraulic and pneumatic tomography in fractured rocks, 7th Groundwater Symposium of the Int. Association for Hydraulic Research (IAHR), *Procedia of Environmental Sciences*, 25, 127-134.
13. Illman, W. A., S. J. Berg, Z. Zhao (2015) Should hydraulic tomography be interpreted using geostatistical inverse modeling? A laboratory sandbox investigation, *Water Resources Research*, Vol: 51, Pages: 3219–3237, DOI: 10.1002/2014WR016552.
14. Hwang, H.-T., S.-W. Jeen, E. A. Sudicky, and W. A. Illman (2015), Determination of rate constants and branching ratios for TCE degradation by zero-valent iron using a chain decay multispecies model, *Journal of Contaminant Hydrology*, 177-178, 43-53. http://dx.doi.org/10.1016/j.jconhyd.2015.03.001.
15. Berg, S. J., W. A. Illman, and C. M. W. Mok (2015), Joint estimation of hydraulic and poroelastic parameters from a pumping test, *Groundwater*, published online, doi: 10.1111/gwat.12271.
16. Berg, S. J. and W. A. Illman (2015), Comparison of hydraulic tomography with traditional methods at a highly heterogeneous site, *Groundwater*, 53(1), 71-89, doi: 10.1111/gwat.12159.
17. Illman, W. A. (2014), Hydraulic tomography offers improved imaging of heterogeneity in fractured rocks, *Groundwater*, 52(5), 659-684, doi: 10.1111/gwat.12119.
18. Liu, X., Q. Zhou, J. Birkholzer, and W. A. Illman (2013), Geostatistical reduced-order models in under-determined inverse problems, *Water Resources Research*, doi:10.1002/wrcr.20489.
19. Hwang, H.-T., Park, Y.-J., Sudicky, E.A., Unger, A.J.A., Illman, W.A., Frape, S., and Shouakar-Stash, O. (2013), Use of a multiphase flow and multiphase transport model for DNAPL-involved compound specific isotope analysis, *Advances in Water Resources*, 59, 111-122, http://dx.doi.org/10.1016/j.advwatres.2013.05.009.
20. Berg, S. J. and W. A. Illman (2013), Field study of subsurface heterogeneity with steady state hydraulic tomography, *Groundwater*, 51(1), 29-40, DOI: 10.1111/j.1745-6584.2012.00914.x.
21. Sudicky, E. A., H.-T. Hwang, W. A. Illman, Y.-S. Wu, J. B. Kool, P. Huyakorn (2013), A semi-analytical computer model for simulating groundwater fate and transport of contaminants subject to chain decay reactions, *Journal of Contaminant Hydrology*, 144(1), 20-45.
22. Sharmeen, R., W. A. Illman, S. J. Berg, T.-C. J. Yeh, Y.-J. Park, E. A. Sudicky, and K. Ando (2012), Transient hydraulic tomography in a fractured dolostone: Laboratory rock block experiments, *Water Resour. Res.*, 48, W10532, doi:10.1029/2012WR012216.
23. Berg S. J. and W. A. Illman (2012), Improved predictions of saturated and unsaturated zone drawdowns in a heterogeneous unconfined aquifer via transient hydraulic tomography: Laboratory sandbox experiments, *Journal of Hydrology*, 470-471, 172-183, http://dx.doi.org/10.1016/j.jhydrol.2012.08.044.
24. McLaren, R., E. A. Sudicky, Y.-J. Park, and W. A. Illman (2012), Numerical simulation of DNAPL emissions and remediation in a fractured dolomitic aquifer, *Journal of Contaminant Hydrology*, 136-137, 56-71. http://dx.doi.org/10.1016/j.jconhyd.2012.05.002.
25. Illman, W. A., S. J. Berg, and M. Alexander (2012), Cost comparisons of aquifer heterogeneity characterization methods, *Ground Water Monitoring & Remediation*, 32(2), 57-65, DOI: 10.1111/j.1745-6592.2011.01376.x.

26. Illman, W. A., S. J. Berg, and T.-C. J. Yeh (2012), Comparison of approaches for predicting solute transport: Sandbox experiments, *Ground Water*, 50(3), 421-431, DOI: 10.1111/j.1745-6584.2011.00859.x.
27. Berg, S. J., P. A. Hsieh, and W. A. Illman (2011), Estimating hydraulic parameters when poroelastic effects are significant, *Ground Water*, 49(6), 815-829, | DOI: 10.1111/j.1745-6584.2010.00781.x.
28. Berg, S. J. and W. A. Illman (2011b), Three-dimensional transient hydraulic tomography in a highly heterogeneous glaciofluvial aquifer-aquitard system, *Water Resour. Res.,* 47, W10507, doi:10.1029/2011WR010616.
29. Berg, S. J. and W. A. Illman (2011a), Capturing aquifer heterogeneity: Comparison of approaches through controlled sandbox experiments, *Water Resour. Res.,* 47, W09514, doi:10.1029/2011WR010429
30. Sudicky, E. A. and W. A. Illman (2011), Lessons learned from the suite of CFB Borden experiments, *Ground Water*, 49(5), 630-648, DOI: 10.1111/j.1745-6584.2011.00843.x
31. Alexander, M., S. J. Berg, and W. A. Illman (2011), Field study of hydrogeologic characterization methods in a heterogeneous aquifer, *Ground Water,* 49(3), 365-383, doi: 10.1111/j.1745-6584.2010.00729.x.
32. Illman, W. A., S. J. Berg, X. Liu, and A. Massi (2010), Hydraulic/partitioning tracer tomography for trichloroethene source zone characterization: Small-scale sandbox experiments, *Environ. Sci. Technol*., 44(22), pp. 8609-8614, doi: 10.1021/es101654j.
33. Illman, W. A., J. Zhu, A. J. Craig, and D. Yin (2010), Comparison of aquifer characterization approaches through steady-state groundwater model validation: A controlled laboratory sandbox study, *Water Resour. Res., 46,* W04502, doi:10.1029/2009WR007745.
34. Sudicky, E. A., W. A. Illman, I. K. Goltz, J. J. Adams, and R. G. McLaren (2010), Heterogeneity in hydraulic conductivity and its role on the macroscale transport of a solute plume: From measurements to a practical application of stochastic flow and transport theory, *Water Resour. Res*., 46, W01508, doi:10.1029/2008WR007558.
35. Illman, W. A. and P. J. Alvarez (2009), Performance assessment of bioremediation and natural attenuation, *Critical Reviews in Environmental Science and Technology*, 39(4), 209-270, doi: 10.1080/10643380701413385.
36. Yin, D., and W. A. Illman (2009), Hydraulic tomography using temporal moments of drawdown recovery data: A laboratory sandbox study, *Water Resour. Res*., 45, W01502, doi: 10.1029/2007WR006623.
37. Illman, W. A., X. Liu, S. Takeuchi, T. J. Yeh, K. Ando, and H. Saegusa (2009), Hydraulic tomography in fractured granite: Mizunami Underground Research site, Japan, *Water Resour. Res*., 45, W01406, doi: 10.1029/2007WR006715.
38. Illman, W. A., X. Liu, and A. Craig (2008), Evaluation of transient hydraulic tomography and common hydraulic characterization approaches through laboratory sandbox experiments, *Journal of Environmental Engineering and Management*, 18(4), 249-256.
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