MINISTRY OF THE ENVIRONMENT

Municipality: Town of Greater Napanee

Re: Site Conceptual Model Report
Richmond Landfill
Lots 1, 2 and 3, Concession 4
Geographic Township of Richmond
Town of Greater Napanee
Provisional Certificate of Approval A371203

Date: February 22, 2010 **Report by:** K. Stephenson

Purpose

I have reviewed the report entitled "Site Conceptual Model Report, WM Richmond Landfill" (Report) dated October 2009 and completed by B. Kueper and Associates Ltd. (BKA) and Water and Earth Science Associates Inc. (WESA) on behalf of Waste Management (WM). I have also reviewed the results of additional groundwater modeling completed by WM / BKA at the request of the Ministry (memorandum dated February 12, 2010). I reviewed the report and memorandum to evaluate the proposed conceptual hydrogeological model and to determine if the model can reliably form the basis for development of a site Environmental Monitoring Program (EMP). The EMP is required for incorporation in the closure plan for the Richmond Landfill.

I have further reviewed and considered comments from Franz Environmental Inc. (Franz) who provided an independent third party review of the conceptual model report under contract with the Ministry. I have also reviewed and considered third party review comments from XCG Consultants Ltd. (XCG) and Neegan – Burnside Ltd. (NBL) submitted on behalf of the Mohawks of the Bay of Quinte. Significant peer review comments related to the conceptual model are discussed below.

I have provided a discussion, conclusions and recommendations related to the Report and peer review comments.

Background

The status of the Richmond Landfill with respect to Guideline B-7 conformance has not been determined. Additional information is required in order to develop an acceptable monitoring program so that conformance with Guideline B-7 can be assessed. The information required to determine conformance is as follows:

Step 1. Determination of the hydrogeological conceptual model for the site (groundwater flow direction / pathways, rate of groundwater flow etc.);

Step 2. Identification of suitable background and downgradient groundwater quality monitoring locations to support an Environmental Monitoring Program (EMP); and

Step 3. Completion of a Guideline B-7 assessment based on the EMP.

In order to support the development of a conceptual model for the site (Step 1), WM completed additional investigations in spring 2009. These investigations included the installation of additional test wells, multiple pumping tests and geophysics investigations. This work was considered along with the results of all other historical investigations at the site and ongoing monitoring data to develop the conceptual model. Once a reliable conceptual model is determined, Steps 2 and 3 can be completed.

Site Conceptual Model

The site conceptual model presented by WM is summarized on pages 36 through 40 of the Report as follows:

- the active groundwater flow zone at the site extends to a depth of approximately 30 metres below the top of bedrock;

- the shallow groundwater flow zone is conceptualized as the overburden, overburden – bedrock contact and the upper one to two metres of bedrock;

- the direction of groundwater flow in the shallow flow zone is strongly influenced by topography;

- there is a flow divide west of the landfill associated with Empey Hill directing groundwater to the north and south;

- the shallow groundwater flowing to the north discharges to Marysville Creek and the water flowing to the south moves toward Beechwood Ditch;

- the intermediate flow zone extends from one to two metres below top of bedrock to a depth of approximately 30 metres below top of bedrock;

- groundwater flows through a well-connected network of fractures in the upper 30 metres of bedrock;

- the dominant fracture orientation is horizontal to sub-horizontal however vertical to sub-vertical fractures are present providing hydraulic connection between horizontal fractures;

- the rate of groundwater flow is expected to be relatively lower to the north of the site based on the results of hydraulic testing;

- fracture apertures are relatively uniformly distributed with the possible exception of a zone of larger apertures between approximately 5 metres and 15 metres below top of bedrock;

- the spring 2009 pumping test program revealed continuity of hydraulically connected fractures in the intermediate flow zone to the west, south and east of the site (horizontal and vertical connections);

- intermediate flow nets show that groundwater generally flows to the west from the western edge of the landfill, to the south-southeast from the southern edge of the landfill, to the southwest from the southwest corner of the landfill and north to northwest from the northwest portion of the landfill;

- flow directions in the intermediate zone are variable with season; and

- impacts from the landfill are likely to be detected in the shallow zone monitoring network prior to being detected in the intermediate zone monitoring network.

Screening level mathematical modeling completed by WM has indicated that contaminant concentrations should increase gradually over time in downgradient intermediate bedrock monitoring wells. This suggests that trend analysis of ongoing monitoring data should be adequate to detect the movement of a contaminant plume in bedrock.

WM has provided estimates of groundwater velocity for the shallow and intermediate flow zones of 1.44 metres per year and 1120 metres per year, respectively. Contaminant migration will occur at lower rates due to attenuation processes.

Some preliminary work to assess groundwater chemistry conditions was also presented by WM in the Report. It is expected that further analysis of groundwater chemistry will be required to support development of the EMP (Step 2 above).

Based on the conceptual model, WM has concluded that the directions of groundwater flow are understood and that a monitoring well network can be relied upon to detect the presence of landfill impact to groundwater.

Peer Review Comments

I have provided a summary of the main significant comments from peer reviewers in the following three sections. I have not detailed every comment provided by the peer reviewers however; I expect that peer review comments will be provided to WM and that WM will provide an acceptable response to all comments prior to final acceptance of the site conceptual model. Many comments from the peer reviewers relate to the need for additional assessment of geochemistry at the site so that a monitoring program can be established. The development of the monitoring program (EMP) is the planned next stage of work to be completed by WM. MOE will ensure that relevant comments from peer reviewers related to the development of the monitoring program will be considered during the next stage of work.

Peer Review - Franz Environmental Inc.

I have separated conclusions and recommendations from Franz into those that relate to the conceptual model (the Report) and those that relate to the development of an Environmental Monitoring Program (the next step).

Comments on the Site Conceptual Model

The main conclusions and recommendations from Franz were as follows:

1. The work completed to-date represents a solid basis for the development of a long-term monitoring plan; however, additional work is required to assess / consider the potential presence of preferential pathways to the south and west of the landfill that may allow for faster contaminant migration.

2. Additional interpretation of information / data supporting flow nets should be undertaken to consider the presence of preferential pathways (zones of higher hydraulic conductivity) and to consider additional wells which may have responded to pumping tests (in particular the test at well M82-2).

3. The mathematical modeling completed by WM does not account for the worst-case-scenario and is therefore not conservative. Mathematical modeling should be completed to simulate the landfill as part of the development of the EMP. This modeling should be capable of modeling preferential pathways (high hydraulic conductivity zones) and landfill systems (liners and leachate collection system) over time.

Comments Related to Development of the EMP

In summary, Franz has indicated that the conceptual model presented by WM can be used as the basis for the EMP provided that the following recommendations are addressed:

1. The effects of the landfill in its current state and in the future (i.e. after eventual failure of the liner and leachate collection system) should be considered in the development of the EMP.

2. There are leachate impacts in downgradient monitoring wells (particularly south of the landfill) that should be further assessed.

3. The observation of increasing trends of leachate indicator parameter concentrations in downgradient monitoring wells (including those located to the south of the landfill) should be considered as part of the EMP.

Peer Review – XCG Consultants Ltd.

XCG provided numerous general comments on the Report. Similar to above, I have separated specific comments from XCG into those comments that relate to the site conceptual model (the Report) and those that relate to the development of an Environmental Monitoring Program.

Overall, XCG has indicated that the site conceptual model is not satisfactory to form the basis of a reliable monitoring program.

Comments on the Site Conceptual Model

1. XCG has indicated that additional angled drilling is required to identify the presence of vertical to sub vertical fracture features.

2. Contrary to statements from WM, XCG has indicated that leachate impacts may be detected in the intermediate zone bedrock prior to detection in shallow monitoring wells due to downward groundwater flow and vertical connectivity in the system.

3. XCG has indicated that there are horizontal and vertical gaps in shallow and intermediate zone monitoring which should be addressed through installation of additional monitoring wells (for example in the southeastern end of the site between monitoring wells at location M70 and location PW3 there is a separation distance of approximately 275 metres).

4. XCG has indicated that more information is needed on water levels in the intermediate aquifer to the north and northeast of the site and to the southeast of the site.

Comments Related to Development of the EMP

XCG provided the following contaminants related to the development of the EMP:

1. Monitoring wells chosen as representing upgradient groundwater chemistry should be reviewed and potentially revised (M60-1 was noted in particular as a location to be reviewed).

2. There is a need for more reliable leachate indicator parameters which are not naturally elevated in background groundwater. Tritium has been proposed by XCG as a potentially valuable leachate indicator parameter.

3. Additional leachate impact assessment is required based on reliable leachate indicator parameters particularly to the south of the waste mound.

4. The computer (mathematical) modeling completed by WM is not conservative and there is potential for contaminants to migrate quickly in the bedrock groundwater flow system.

<u>Peer Review – Neegan Burnside Ltd.</u>

Similar to above, conclusions and recommendations from Neegan Burnside have been separated into two groups. Overall, Neegan Burnside has indicated that the site conceptual model is not satisfactory to form the basis of a reliable monitoring program.

Comments on the Site Conceptual Model

The main conclusions and recommendations from Neegan Burnside were as follows:

1. NB has indicated that groundwater flow at the site is complex and this increases the difficulty of establishing a reliable monitoring network. Neegan Burnside questions the overall reliability of the groundwater flow mapping and indicates that the accuracy of groundwater flow mapping in the intermediate bedrock zone must be improved.

2. NB has indicated that additional information and analysis is required to understand the fill area, leachate collection system and liner in relation to the bedrock surface and the water table.

3. NB has indicated that further information is required on the leachate production, collection and attenuation capacity of the site.

4. NB has indicated that additional assessment of the extent of discharge to surface water features and potential off-site flow is required.

5. NB has indicated that additional assessment of vertical gradients at the site is required.

Comments Related to Development of the EMP

Neegan Burnside recommended the following with respect to the site monitoring program and Guideline B-7 assessment:

1. Long term trend analysis is required for leachate quality, surface water quality and groundwater quality.

2. A determination of leachate indicator parameters and a Guideline B-7 assessment is required. Identification of boundary wells to be used in the assessment is required and it must be shown that boundary wells are of an adequate number, spacing and location to detect a plume.

<u>Discussion</u>

Site Conceptual Model

Overall, I am in general agreement with the conceptual model presented in the Report. However, based on my review of all information, the site conceptual model requires further work from WM prior to forming the basis for a site Environmental Monitoring Program. The site conceptual model presented in the Report represents a significant change in comparison to the historical conceptual model which has significant implications to contaminant migration at the site. The following issues must be addressed prior to acceptance of the model:

1. I am in agreement with comments from Franz that there appears to have been a hydraulic response at several wells situated to the north of the landfill to the pumping test at monitoring well M82-2. WM has indicated the response at this group of wells (wells M67-2, M74, M75, M6-3, M5-3, M3A3, OW1, M4-3 and M46-2) to be "inconclusive" in the Report. While the response at these wells appears to be different than the response at other wells observed during the test (e.g. monitoring wells M95-1, M58-3, M73 and M72), WM should further assess the response at wells north of the landfill and determine the effect of this apparent response to groundwater flow direction (flow nets) and contaminant migration. Wells to the north appear to exhibit a delayed response to pumping based on the shape of the response curve and the magnitude of response which may be related to generally lower hydraulic conductivity in this area (refer to Figure 3.14 in the Report).

2. The conceptual model indicates that contaminant migration in fractured rock should result in gradual increases in leachate indicator parameters at site monitoring wells. This is based on the assumption that an "average" fracture aperture can be used to characterize the fractured rock at the site. While this treatment of fractures is generally reasonable, there is the potential for zones of higher aperture fracture features to be present (in certain areas of the site) that would result in more rapid (and potentially less predictable) contaminant migration.

   Wells that clearly and significantly responded to pumping tests are likely located in zones of higher hydraulic conductivity relative to areas / zones where there was no response or where there was an apparent delayed response (e.g. wells to the north of the site). Further work to identify areas where there was almost immediate response to pumping in wells at varying distances from the pumped well should be completed to identify areas of higher hydraulic conductivity. The results of pumping tests should be considered alongside the results of other hydraulic testing (Figure 3.14 of the report) to identify zones across the site where higher hydraulic conductivity are present (generally to the south and west of the landfill). While it may be difficult to separate rapid response observed during pumping tests caused by high hydraulic conductivity from the effects of limited storage in bedrock, further effort should be made to consider the presence of zones where higher hydraulic conductivity may be present and contaminant transport may occur more quickly.

   Based on my review of the pumping test response data, the following wells appear to be located in areas of higher hydraulic conductivity relative to other areas / well locations: M71, M9-3, PW3, PW1, M49-1, M10-1, M80-1, M56-2, PW5, M72, M73, M58-3, M95-1 and M82-2. This conclusion is based on rapid and significant response at these wells to pumping relative to responses at other locations and based on results of other hydraulic tests (single well slug tests). Contaminant transport may occur faster in these areas and this should be considered in the development of the groundwater quality monitoring program. Further interpretation of water quality conditions at these locations is also required and this is discussed below.

   Additional discussion of potential higher hydraulic conductivity zones and their impact on contaminant migration should be completed by WM. This discussion should consider both groundwater flow conditions and groundwater chemistry. Where higher hydraulic

conductivity zones are identified, more frequent monitoring may be required to ensure that potentially faster contaminant migration in these areas can be appropriately monitored (in other words, monitoring must be frequent enough that the "breakthrough" of contaminants can be monitored).

Concerns related to the rate of contaminant migration in fractured bedrock were expressed to WM by MOE and additional modeling was completed to explore these concerns (memorandum from BKA dated February 12, 2010). The modeling completed by WM / BKA is useful as a screening level tool and sensitivity analysis using the model has provided insight into the possible behaviour of contaminant migration at the site. The modeling has shown that the rate of contaminant migration is highly sensitive to fracture aperture. The fracture aperture incorporated into the model is based on an average of fracture apertures present at the site. It has been assumed that fracture apertures in intermediate bedrock can be described using an average value and that larger aperture fractures measured at the site do not represent the characteristics of the connected fracture network over a significant distance. Some averaging of fracture apertures is acceptable given that smaller fracture apertures can limit groundwater flow in the system. However, additional modeling completed by WM has indicated that relatively moderate increases in fracture aperture can significantly increase the rate of contaminant transport. Sensitivity analysis also showed that a reduction in the width of the source of contaminants and consideration of a finite source of contaminants significantly reduce impact at the property boundary. It is important to understand that the screening level modeling simulations can only provide broad estimates of likely / potential contaminant transport. Ongoing monitoring at the site must be conducted to validate model predictions and to determine overall site conformance.

Development of the Environmental Monitoring Program

Once the issues discussed above are addressed and the conceptual model is accepted, the focus will shift to further assessment of groundwater chemistry conditions to support development of the EMP. The assessment should primarily be based on chemistry in wells which were determined to be part of the active groundwater flow system based on pumping test investigations (responsive wells) although monitoring of other wells should also be included. As part of this assessment, the following issues should be addressed:

3. Further interpretation of on-site groundwater quality is required to support the EMP. Part of the review completed by Franz included a preliminary concentration trend analysis at wells along the flow path in intermediate bedrock to the south of the site. Further trend analysis should be undertaken to determine the variation in water quality at site monitoring wells over time. Tri-linear plots should also be used to improve the understanding of groundwater quality across the site. This work should be used to clearly delineate the extent of leachate impact at the site and the extent of leachate impacts should be indicated on a site plan.

   In particular, further analysis of apparent trends of increasing leachate indicator parameter levels at the following monitoring wells should be undertaken: M10-1, PW1 (limited data), M49-1, M49-2, M9-2, M9-3, M71, M53-2, M6-3 and M5-2. It appears that increasing levels of some (or a combination of the following parameters) over time at these wells is related to

leachate impact as opposed to natural background water quality: alkalinity, ammonia, DOC, chloride, hardness, COD, iron, potassium, sodium, sulphate and manganese. Parameters at each well which exhibit an increasing concentration trend are as follows:

- M10-1 – alkalinity, ammonia, COD, chloride, DOC, hardness, iron, manganese and sodium;
- M49-1 – ammonia, COD, chloride and sodium;
- M49-2 – alkalinity, COD, chloride and sodium;
- M9-2 – COD, ammonia, chloride, potassium and sodium;
- M9-3 – alkalinity, COD, hardness, DOC, chloride, iron and sodium;
- M71 – alkalinity, COD, chloride, DOC, hardness, potassium, sulphate and sodium;
- M53-2 – alkalinity, ammonia, COD, iron and sodium;
- PW1 (limited data) – alkalinity, ammonia, COD, chloride, DOC, iron and sodium;
- M6-3 – ammonia, COD, chloride, DOC, hardness and sulphate; and
- M5-2 – alkalinity, COD, chloride, potassium, sodium and sulphate.

In general, leachate impacts appear to be present to the south and north / northwest of the waste fill area. It appears that pH and likely reducing conditions associated with the landfill may be influencing contaminant solubility and mobility of redox sensitive / active parameters in these areas (e.g. iron). Trends are also apparent for other parameters which are not sensitive to redox reactions (e.g. chloride). Further information regarding redox chemistry conditions in downgradient groundwater would improve the understanding of landfill leachate impact.

Apparent leachate impacts to the south and north / northwest of the waste mound are consistent with, and confirm, the groundwater flow directions presented in the conceptual model.

It also appears that there is some correlation between wells which were most responsive to pumping tests (high hydraulic conductivity zones discussed above) and increasing leachate parameter concentration trends (e.g. wells M71, M9-3, M10-1 and M49-1). This suggests that these wells are located in zones which may be key pathways for contaminant migration.

I have also reviewed the locations of site monitoring wells where Volatile Organic Compounds have been detected historically. VOC impacts have occurred to the south and north / northwest of the landfill in the same general locations as impacts discussed above. Based on the conceptual model, the historical presence of VOC impacts occur near the toe of the landfill and further downgradient indicating that the landfill is a likely historical source of these contaminants.

It is recognized that the nature of background / natural groundwater chemistry makes detection of leachate impacts difficult at this site. The Ministry will consider multiple lines of evidence to determine the presence of leachate impact however the Ministry will always take a conservative approach and will employ the precautionary principle in terms of determining potential adverse effect / offsite impact. This approach should be implemented in the development of the EMP and in determination of site conformance with Guideline B-7.

4. The EMP should include ongoing monitoring to determine potential impacts to offsite groundwater (compliance monitoring locations) and to determine the quality of groundwater discharging to surface water (groundwater – surface water interaction monitoring program). Potential impacts to offsite groundwater resources should be assessed using Guideline B-7 and potential impacts to surface water should be assessed using Provincial Water Quality Objectives (PWQO).

   The EMP should include remedial action / contingency plans and trigger mechanisms that would initiate the implementation of these plans under specific circumstances (i.e. exceedence of Guideline B-7 limits at a compliance monitoring well or exceedence of specific PWQO limits at a groundwater – surface water interaction monitoring well / location).

   If potential impact is indicated by exceedences of PWQO, additional surface water assessment work would be required to determine if exceedences in groundwater may cause adverse impact to surface water. The MOE Surface Water Unit should be consulted during development of the groundwater – surface water interaction monitoring program.

5. I am in agreement with comments from peer reviewers that the EMP should consider both the effect of the current landfill and the effect of the landfill when liners and leachate collection systems fail. Monitoring locations should be selected to ensure that downgradient groundwater (including locations within zones of higher hydraulic conductivity at the "responsive" wells) is monitored on an ongoing basis and beyond the time that landfill systems fail. Peer reviewers have noted that leachate mounding in a landfill can cause significant downward groundwater flow and radial groundwater flow away from the landfill. The conceptual model has indicated that there is hydraulic connection in fractured bedrock from surface through the intermediate bedrock zone. Given that leachate mounding may result in a significant downwards driving force, leachate impacts could occur within intermediate bedrock prior to impact in shallower zones. This concept should be incorporated into the EMP by including appropriate monitoring at downgradient monitoring wells completed in intermediate bedrock in addition to monitoring at shallower locations.

6. WM has indicated that additional monitoring locations will be installed to address gaps in the monitoring network to improve the EMP. This work will include installation of monitoring wells to the southeast of the waste fill area.

7. It is my opinion that the need for further modeling should be evaluated once further interpretation of groundwater quality is completed (refer to point 3 of this section). Some preliminary work to assess trends suggests that leachate impacts are present in groundwater to the south and north / northwest of the landfill. Once the leachate plume has been delineated, additional model simulations could be completed to validate the model using field results.

Whether or not additional modeling is required, the results of modeling sensitivity analyses (particularly those simulations that consider contaminant transport in larger aperture fractures) should be considered in the selection of monitoring locations and in the determination of the frequency of monitoring incorporated in the EMP.

Volatile Organic Compounds

WM has indicated that Volatile Organic Compound (VOC) impacts in intermediate bedrock may be associated with historical site activities at ground surface south of the landfill while others may be associated with the former operation of a nearby meat processing facility. It is difficult to determine the source of VOC impacts however, the landfill cannot be ruled out as another potential source. The concentrations of VOCs in groundwater have been significantly reduced relative to historical levels and currently do not exceed Ontario Drinking Water Standards in recently monitored on-site and off-site wells.

The concentrations of benzene, toluene, ethylbenzene and xylenes (BTEX) are naturally elevated in certain portions of bedrock at the site. These natural conditions make it difficult to determine the origin of these compounds at this site. WM has indicated that most BTEX detected at the site can likely be attributed to natural conditions however the possibility of contribution from site operations is also discussed. Due to their elevated concentrations in background, these parameters are not ideal for leachate identification.

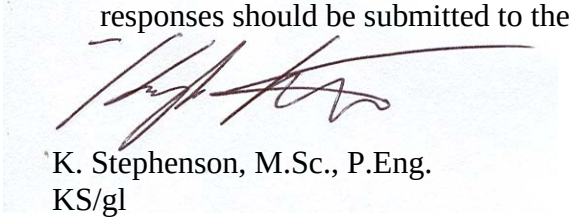
<u>Conclusions and Recommendations</u>

1. Overall, I am in general agreement with the conceptual model presented in the Report. However, based on my review of all information, the site conceptual model requires further work from WM prior to forming the basis for a site Environmental Monitoring Program. Comments presented in the "Discussion" section must be addressed prior to final acceptance of the conceptual model (comments 1 and 2). I expect that WM will submit an updated report or memorandum to MOE to address these issues.

2. The development of the EMP should address comments presented in the "Discussion" section (comments 3 through 7).

3. Once the EMP has been established and specific compliance monitoring wells have been determined, a Guideline B-7 assessment should be completed.

4. As indicated above, several concerns have been pointed out by peer reviewers related to the site conceptual model. I expect that WM will respond to all of the concerns outlined by Franz, XCG and Neegan Burnside prior to final acceptance of the conceptual model. These responses should be submitted to the concerned parties and this Ministry for review.



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