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## Supplier Document

# Technical Memo – Whiteshell Reactor 1 (WR-1) Groundwater Flow and Solute Transport Modelling – Additional Sensitivity Simulations (Consolidated)

**WLDP-26000-041-000**

**Revision 0**

Accepted by:

A handwritten signature in black ink, appearing to read 'J. Miller', written over a horizontal line.

Jeff Miller  
Manager, Regulatory Approval

2024-11-25

Date

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## TECHNICAL MEMORANDUM

**DATE** November 2024

**Reference No.** 20145046-31000

**TO** Jeffrey Miller  
Canadian Nuclear Laboratories

**FROM** Cameron Toy, Jennifer Levenick

**EMAIL** Cameron.Toy@wsp.com;  
Jennifer.Levenick@wsp.com

### **WHITESHELL REACTOR 1 (WR-1): GROUNDWATER FLOW AND SOLUTE TRANSPORT MODELLING – ADDITIONAL SENSITIVITY SIMULATIONS COMPLETED TO ADDRESS INFORMATION REQUESTS FROM THE FEDERAL, PROVINCIAL AND INDIGENOUS REVIEW TEAM – CONSOLIDATION OF INITIAL AND EXTENDED SIMULATIONS**

Canadian Nuclear Laboratories (CNL) is in the process of decommissioning the Whiteshell Laboratories (WL) facilities, located near Pinawa, Manitoba. Part of this work will involve the decommissioning of Whiteshell Reactor 1 (WR-1), where the reactor is proposed to be disposed in-situ through below-grade macro-encapsulation with grout. An engineered cover and concrete cap will then be installed on top of the grout, extending above-ground surface. A groundwater flow and solute transport model (GWFSTM, Golder 2021) was developed and used to simulate the current and future (post-closure) conditions of the WL facilities, to support a Decommissioning Safety Assessment Report (DSAR) and an Environmental Impact Statement (EIS) for the in-situ disposal of WR-1.

The submissions in support of the WR-1 decommissioning plan have undergone a series of reviews from the Federal, Provincial and Indigenous Review Team (FPIRT), leading to a number of Information Requests (IRs) to help clarify the assessment. In the second round of the IRs (R2 IRs), the FPIRT requested additional information from the groundwater flow and solute transport assessment to address uncertainties in the model inputs and assumptions.

Attachment 1 of this memorandum (WSP 2024a) provides the methodology and results for additional groundwater flow and solute transport modelling undertaken to address concerns identified in the R2 IRs. Attachment 1 includes the following:

- Overview and consolidation of the R2 IRs relevant to the groundwater flow and solute transport assessment.
- Description of 11 new sensitivity scenarios (i.e., Scenarios 19 through 29) designed to address concerns raised within the R2 IRs.
- Explanation of the modelling approach and documentation of the modifications to the existing groundwater flow and solute transport models required to assess the 11 new scenarios.
- Presentation of the results from the 11 new sensitivity scenarios and discussion of key observations.

After finalization of Attachment 1, it was identified that the 500,000-year simulation period was not long enough to capture the peak mass loading rate for all of the solutes analyzed. The model simulations presented in WSP (2024a) were completed for a simulation period of 500,000 years and the reported peak mass loading rates are representative of the highest mass loading rates simulated during that 500,000-year simulation period. This observation is consistent with what was observed during the original GWFSTM assessment (Golder 2021), with select scenarios also requiring a longer simulation period to effectively assess predicted peak loading rates. Attachment 2 of this memorandum (WSP 2024b) presents the results of similar extended model simulations for the scenarios presented by WSP (2024a) to appropriately capture the predicted peak mass loading rates.

Review of the expanded model simulation time results identified that the new peak loading rates predicted for the extended scenario simulations are either equivalent to or lower than the maximum peak mass loading rates previously reported for each solute. As such, extending the simulation periods to capture the peak mass loading rates for all solutes for all scenarios resulted in no changes to the overall maximum peak mass loading rates previously reported by WSP (2024a), and the new peak loadings presented in WSP (2024a) are still the appropriate values to consider in the site receptor model to determine the potential impact of these results on the overall assessment.

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This report was prepared for the exclusive use of Canadian Nuclear Laboratories Ltd. Any use of this report and its content by a third party is the responsibility of such third party. WSP shall not be held responsible for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

The services performed as described in this report were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and geoscience professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

The findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in future work, including excavations, borings, or other studies, WSP should be requested to re-evaluate the findings of this report, and to provide amendments as required.

This report provides a professional opinion in light of the information available at the time of this report and therefore no warranty is either expressed, implied, or made as to the conclusions, advice or recommendations offered in this report.

## REFERENCES

Golder, Member of WSP (2021). In-Situ Decommissioning of WR-1 at the Whiteshell Laboratories Site: WR-1 Groundwater Flow and Solute Transport Modelling – Revision 4. Submitted to Canadian Nuclear Laboratories, Whiteshell, Laboratories, Pinawa, MB. December 2021.

WSP (2024a). Whiteshell Reactor 1 (WR-1): Groundwater Flow and Solute Transport Modelling – Additional Sensitivity Simulations Completed to Address Information Requests from the Federal, Provincial and Indigenous Review Team. July 16, 2024.

WSP (2024b). Whiteshell Reactor (WR-1): Groundwater Flow and Solute Transport Modelling – Extended Model Simulation Time Results to Assess Peak Mass Loading Rates. November 20, 2024.

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## LISTS OF ATTACHMENTS

Attachment 1 – Whiteshell Reactor 1 (WR-1): Groundwater Flow and Solute Transport Modelling – Additional Sensitivity Simulations Completed to Address Information Requests from the Federal, Provincial and Indigenous Review Team

Attachment 2 – Whiteshell Reactor (WR-1): Groundwater Flow and Solute Transport Modelling – Extended Model Simulation Time Results to Assess Peak Mass Loading Rates

**ATTACHMENT 1**

**Whiteshell Reactor 1 (WR-1):  
Groundwater Flow and Solute Transport  
Modelling – Additional Sensitivity  
Simulations Completed to Address  
Information Requests from the Federal,  
Provincial and Indigenous Review Team**



## TECHNICAL MEMORANDUM

**DATE** July 16, 2024

**Project No.** 20145046-31000

**TO** Jeffrey Miller  
Canadian Nuclear Laboratories

**FROM** Cameron Toy, Scott Donald

**EMAIL** cameron.toy@wsp.com;  
scott.donald@wsp.com

### **WHITESHELL REACTOR 1 (WR-1): GROUNDWATER FLOW AND SOLUTE TRANSPORT MODELLING – ADDITIONAL SENSITIVITY SIMULATIONS COMPLETED TO ADDRESS INFORMATION REQUESTS FROM THE FEDERAL, PROVINCIAL AND INDIGENOUS REVIEW TEAM**

## **1.0 INTRODUCTION**

Canadian Nuclear Laboratories (CNL) is in the process of decommissioning the Whiteshell Laboratories (WL) facilities, located near Pinawa, Manitoba as shown on Figure 1. Part of this work will involve the decommissioning of Whiteshell Reactor 1 (WR-1), where the reactor is proposed to be disposed in situ through below-grade macro-encapsulation with grout. An engineered cover and concrete cap will then be installed on top of the grout, extending above-ground surface. The completed facility will be referred to as the Whiteshell Reactor Disposal facility (WRDF). A groundwater flow and solute transport model (GWFSTM, Golder 2021a) has been developed and used to simulate the current and future (post-closure) conditions of the WL facilities, to support a Decommissioning Safety Assessment Report – DSAR (Golder 2021b) and an Environmental Impact Statement (EIS [WSP Golder et al. 2022]) for the in situ disposal (ISD) of WR-1. In addition, the output from the model was fed into an Environmental Risk Assessment (ERA [EcoMetrix 2021]), which underpins the analysis in the DSAR and EIS.

The above submissions in support of the WR-1 decommissioning plan have undergone a series of reviews from the Federal, Provincial and Indigenous Review Team (FPIRT), leading to a number of Information Requests (IRs) to help clarify the assessment. In the second round of the IRs, the FPIRT requested additional information from the groundwater flow and solute transport assessment to address uncertainties in the model inputs and assumptions. These requests were distributed amongst a number of separate IRs, though were under the same general theme of assessing the sensitivity of the groundwater flow and solute transport modelling results under expanded parameter ranges compared to those assessed in the DSAR and EIS. The following provides a general consolidation of the IRs that fall under this category:

- **Expanded Parameter Range for the Geological Pathways:** A number of the IRs requested consideration of an expanded parameter range for the hydraulic conductivity of the bedrock pathway, including consideration of flow and transport in a fractured bedrock environment as well as conditions of higher recharge into the geological pathways outside the footprint of the WRDF (IR 50\_R2, IR 201\_R2, IR207\_R2 and IR220\_R2).

- **Expanded Parameter Range for the Whiteshell Reactor Disposal Facility Components:** Similarly, a number of IRs requested consideration of an expanded parameter range for various components of the WRDF itself, including: the hydraulic conductivity of the grout / foundation (ECCC-04, IR 39\_R2, IR 40\_R2, IR 48\_R2, IR 205\_R2, IR 206\_R2, IR 214\_R2, IR 218\_R2 and IR 264\_R2); recharge through the cap (IR 215\_R2); and solute transport parameters (IR 211\_R2, IR 214\_R2 and IR 218\_R2).
- **Alternative Assessment Assumptions:** Lastly, several IRs requested consideration of alternative assumptions for the placement of the “Well-in-Plume” in the DSAR (IR 191\_R2) and the performance (rate of degradation) of the engineered cap for the WRDF (IR 264\_R2).

In order to address the specific IRs noted above, which relate to the outputs of the groundwater flow and transport modelling, the following scope of work was completed:

- Development of a set of sensitivity simulations founded on the existing groundwater flow and transport model that covers an expanded range of parameter inputs and/or WRDF assumptions designed to address the specific IRs included in the Round 2 FPIRT review.
- Where necessary, update and re-calibrate the groundwater flow model in order to complete the forecast groundwater flow and solute transport sensitivity simulation.
- Extract the peak loadings from the groundwater flow and solute transport model for comparison to those estimated for the Normal Evolution Scenario in the EIS.

This groundwater flow and solute transport modelling memorandum is organized as follows: Section 2.0 summarizes the series of additional sensitivity scenarios completed in response to the FPIRT Round 2 IRs; Section 3.0 presents the results of the simulations, while Section 4.0 provides a summary and discussion of the findings. Section 5.0 provides general limitations associated with WSP’s services. This work is considered an extension to the original groundwater flow and solute transport modelling (Golder 2021a). Combined with the original work, the forecast simulations now include a total of 29 Sensitivity Scenarios in addition to the Normal Evolution Scenario (or Base Case) in the EIS.

## 2.0 ADDITIONAL SENSITIVITY SIMULATIONS

In addition to the Base Case assessment (i.e., the “Normal Evolution Scenario”), a total of 18 sensitivity simulations were completed with the WR-1 groundwater flow and solute transport model to support the DSAR and EIS submissions. The results of these simulations in terms of the peak loading estimate to the Winnipeg River are provided in Table 1 of this memorandum. Table 1 indicates which of the collective set of sensitivity runs at the time of the original submission produced the highest peak loading for each constituent of potential concern (COPC). Depending on the COPC, this was usually a result of one of the following simulations: Scenario 1 (a preferential pathway between WR-1 and the Winnipeg River); Scenario 5 (use of a lower bound estimate or the adsorption co-efficient of the geological pathway; or Scenario 17 (an upper bound estimate of the radionuclide inventory at WR-1). The maximum peak loading rates from this initial set of sensitivity runs range from 100% less to over 10,000% greater than the Normal Evolution Scenario assessed in the DSAR and EIS. The findings from the Environmental Risk Assessment by Ecometrix, which considered the outputs from the Sensitivity Scenarios as well as the Normal Evolution Scenario, are provided in the EIS (WSP Golder et. al. 2022).

In order to address the FPIRT Round 2 IRs, 11 additional sensitivity simulations were completed with the WR-1 groundwater flow and solute transport models, largely to consider an expanded range for the input parameters used in the assessment. The following provides an overview of the 11 additional simulations completed:

- **Scenarios 19 and 20 – “Well-in-Plume” Location Relative to WRDF:** A “Well-in-Plume” event was included in the Disruptive Events assessment (DSAR Section 5.4.3.2.5), considering the placement of a well halfway between the WRDF and the Winnipeg River (~ 250 metres downgradient of the WRDF). CNL’s understanding of the reviewer’s concern (expressed in IR191\_R2, Parts A and B) was that this does not adequately cover the potential for a well location closer to the WRDF leading to an under-representation of the potential impacts to a future groundwater receptor in the area. To address this concern, two additional sensitivity scenarios were completed giving consideration to a potential future well 100 metres (Scenario 19) and 10 metres (Scenario 20) downgradient of the WRDF. The groundwater flow model and solute transport model set-up for these Scenarios remained the same as considered in the Normal Evolution Scenario, with the exception that results are extracted at distances of 100 m and 10 m from the WRDF for Scenarios 19 and 20, respectively. Appendix A illustrates conceptually the condition assessed in Scenarios 19 and 20.
- **Scenarios 21 and 22 – Fractured GeoPathway:** The geo-pathway in the EIS and DSAR assessments was based on Equivalent Porous Media (EPM) assumptions with a mean hydraulic conductivity ( $5 \times 10^{-7}$  m/s) derived from model calibration to measured groundwater elevations in the project area and inflows to the WR-1 Building sump. This value lies towards the upper end of the range noted within the RSA of  $6.5 \times 10^{-7}$  m/s (Stevenson et. al. 1996) and within the range of the three measurements from single well response tests in the LSA ( $< 1 \times 10^{-7}$  m/s to  $2 \times 10^{-6}$  m/s; Dillon, 2016). Several sensitivity scenarios were completed in the original assessment that considered faster transport through the geo-pathway: Scenario 1 (Preferential Pathway) considered a flow rate 10 times greater than the Normal Evolution Scenario; Scenario 11 (Increased Hydraulic Conductivity of the Upper Bedrock) considered an increase of the bedrock hydraulic conductivity to  $1 \times 10^{-6}$  m/s; and Scenario 16 (Half Pathway Length) in which the distance to the Winnipeg River along the geo-pathway was cut in half (essentially cutting the travel time to this receptor in half compared to the Normal Evolution Scenario). Overall, the model results were shown to be sensitive to the rate of travel between the WRDF and the Winnipeg River, with the impacts on loadings and dose discussed in Section 6.5 of the DSAR (Golder 2021). CNL’s understanding of the reviewer’s concern (expressed in IR50\_R2, IR201\_R2, IR207\_R2 and IR220\_R2) was that the geo-pathway condition could be more permeable than assessed in the Normal Evolution Scenario or the above Sensitivity Scenarios (including the potential for fracture flow), leading to shorter travel times to the Winnipeg River and higher impacts in groundwater downgradient of the facility than assessed to date. To address this concern, two additional sensitivity scenarios were completed giving consideration to a fractured flow condition in the bedrock pathway ranging from a parallel set of 5 fractures (Scenario 21) to a parallel set of 10 fractures (Scenario 22). The groundwater flow model and solute transport model set-up for these Scenarios remained the same as considered in the Normal Evolution Scenario, with the exception that the geo-pathway is represented as a fracture flow within the bedrock. Appendix B illustrates the condition assessed in Scenarios 21 and 22, including the assumptions developed to characterize the fracture conditions in the transport model.
- **Scenarios 23 through 26 – Alternate Bounds on Solute Transport Properties:** Diffusivity and adsorption values applied in the model, and their source, are summarized in Table 4-6 of the original assessment (Golder 2021). In addition to incorporating these values in the Normal Evolution Scenario, two sensitivity scenarios were originally completed for these parameters: Sensitivity Scenarios 5 and 6 assessed lower-

bound and upper-bound  $K_d$  values, respectively, while Sensitivity Scenario 18 assessed an increase in the diffusivity by a factor of 2. In addition, conservative assumptions were adopted for Normal Evolution Scenario in that adsorption was only applied for the geologic (bedrock) pathway (i.e., it was not applied for either the grout or the foundation materials; see Table 3-1, Golder 2021). Lastly, diffusion was not simulated for the grout in the transport model. It is assumed the mass is fully mixed across the grout. Overall, the model results indicated some sensitivity to the  $K_d$  and diffusivity values applied (Section 5.2 of Golder, 2021) with the impacts on loadings for the above Scenarios discussed in Section 5.2 of the GWFSTMR (Golder, 2021). CNL's understanding of the reviewer's concern (expressed in IR211\_R2, IR214\_R2 and IR218\_R2) was that there was insufficient justification for some of the solute transport input parameters and that the selection of values for these inputs was not necessarily conservative; leading to potentially higher impacts in groundwater downgradient of the WRDF. To address this concern, four additional sensitivity scenarios were completed giving consideration to: updated lower bound (Scenario 23) and upper bound (Scenario 24) adsorption co-efficients for the bedrock geo-pathway (based on additional literature review); and increased diffusivity for the WRDF foundation (Scenarios 25 and 26). The groundwater flow model and solute transport model set-up for these Scenarios remained the same as considered in the Normal Evolution Scenario, with the exception of the adjustments to the solute transport models for the respective sensitivity scenario. Appendix C illustrates the parameter assignment for revised upper and lower bound adsorption co-efficient assignments (Scenarios 23 and 24) while Appendix D illustrates the assumptions developed for an increased diffusivity through the WRDF foundation (Scenarios 25 and 26).

- **Scenarios 27 and 28 – Hydraulic Conductivity of the Grout:** The hydraulic conductivity ( $K$ ) of the grout assigned for the Normal Evolution Scenario ( $5 \times 10^{-8}$  m/s) was selected based on a conservative estimate from review of technical literature, degrading to a  $K$  of  $5 \times 10^{-7}$  m/s after 2000 years (degradation rate assigned based on general information from the technical literature (Section 4.1.4 of Golder, 2021)). In addition to incorporating this into the Normal Evolution Scenario, two additional sensitivity scenarios were originally completed in the EIS: Sensitivity Scenario 8 considered a faster degradation rate than the Normal Evolution Scenario, assuming that the grout degraded to  $5 \times 10^{-7}$  m/s after 1000 years; and Sensitivity Scenario 14 considered an even faster degradation rate, assuming that the grout degraded to  $5 \times 10^{-7}$  m/s after 100 years. In Scenario 14, parallel changes were also made to the Foundation  $K$  and recharge through the cover to bring those values to the long-term (degraded) estimates after 100 years (i.e., Foundation  $K$  of  $5 \times 10^{-7}$  m/s and cover recharge of 8 mm/yr). Overall, "the mass loading rate for solutes was not significantly affected by the increases in the degradation rate of the building foundation, the grout, or the concrete cap" (Section 5.2, Scenario 14, Golder, 2021). CNL's understanding of the reviewer's concern (expressed in ECCC-04, IR39\_R2, IR40\_R2, IR48\_R2, IR205\_R2, IR206\_R2, IR214\_R2, IR218\_R2 and IR264\_R2) was that there was insufficient studies and/or analogs to support the parameter assignments in the Normal Evolution or Sensitivity Scenarios originally assessed, and that the grout  $K$  may lie outside (above) the bounds of the assessed condition in the DSAR and EIS leading to potentially higher impacts in groundwater downgradient of the WRDF. To address this concern, two additional sensitivity scenarios were completed giving consideration to: a grout hydraulic conductivity at the maximum value from the scale-up testing (i.e.,  $1.5 \times 10^{-6}$  m/s in Scenario 27; WSP 2023); as well as an extreme upper bound assumption of  $1 \times 10^{-4}$  m/s for the grout in Scenario 28 (note: this extreme upper bound assumption lies at the upper end of the range of hydraulic conductivities noted for cracked grout in core samples from a recent CNSC research project (Androuet, 2024)). In both Scenarios 27 and 28, the higher grout  $K$ 's were applied at the beginning of the simulation; essentially assuming immediate degradation of the grout to a long-term higher permeability condition. The

groundwater flow model and solute transport model set-up for these Scenarios remained the same as considered in the Normal Evolution Scenario, with the exception of the adjustments to the models for the respective sensitivity scenario. Appendix E illustrates the parameter assignments for a revised hydraulic conductivity condition in Scenarios 27 and 28).

- **Scenario 29 –Recharge Rates in the Till:** The recharge rates applied in the Normal Evolution Scenario to the till materials across the LSA (0.8 mm/yr) were based on calibration of the groundwater flow model to groundwater elevations and inflows to the WR-1 Building sump. Recharge rates into the Cap/Cover were assigned at 0.8 mm/yr initially, increasing over time to a maximum value of 8 mm/yr in the Normal Evolution Scenario. Sensitivity Scenario 2 considered an increase in the infiltration rate through the Cap/Cover to 135 mm/yr. Recharge rates into the backfill surrounding the WRDF was set at 2 mm/yr in the Normal Evolution Scenario, while Sensitivity Scenario 10 considered an increase in the infiltration rate through the backfill to 20 mm/yr. Overall, the model results were found to be sensitive to the rate of infiltration applied (in particular for Sensitivity Scenario 2 where the flow through the WRDF increased by a factor of 40). The impacts on loadings and dose for this Scenario were discussed in Section 6.6 of the DSAR (Golder 2021). CNL’s understanding of the reviewer’s concern (expressed in IR201\_R2) was that the recharge rates applied to the native till materials surrounding the WRDF may be less than actual conditions in the field, leading to an under-representation of peak loadings to the Winnipeg River compared to those assessed in the DSAR and EIS. To address this concern, an additional sensitivity scenario was completed giving consideration to higher recharge rates into the native tills (11 mm/yr; Scenario 29). The groundwater flow model and solute transport model set-up for these Scenarios remained the same as considered in the Normal Evolution Scenario, with the exception of the adjustments to the models to represent this scenario. Appendix F illustrates the model set-up for Scenario 29, including the results of recalibration of the groundwater flow model to represent a higher recharge condition into the native tills.

## 3.0 RESULTS OF SENSITIVITY SIMULATIONS

### 3.1 Approach

The overall approach to the simulations remains the same as that applied in the original assessment, where groundwater flow conditions are established by the MODFLOW groundwater model, while the solute transport calculations are completed within GoldSim. For each sensitivity scenario, the parameter adjustments for that scenario are made with respect to the Base Case model presented in the original assessment. This could involve changes to the MODFLOW groundwater model, changes to the GoldSim solute transport model, or both (as noted earlier in Section 2.0). The model simulations are completed for a simulation period of 500,000 years, with the peak loading of each COPC extracted from the results. The peak loadings are extracted at the Winnipeg River, with the exception of the “Well-in-Plume” scenarios (19 and 20) where the peaks are extracted at the well location.

### 3.2 Results of Additional Sensitivity Scenarios

The results of Sensitivity Scenarios 19 and 20 (the “Well-in-Plume” scenarios) are presented in Table 2, while Table 3 summarizes the results for Sensitivity Scenarios 21 through 29. In addition to the peaks for each individual scenario, a summary of the maximum peak from the set of additional Sensitivity Scenarios considered in the response to R2 FPIRT IRs is presented in Table 1, in parallel with the peak assessed in the original submission. A review of the results in Tables 1 through 3 allows the following observations:

- For most solutes, the “Well-in-Plume” scenario where a hypothetical well is placed 10 metres from the edge of the WRDF (Scenario 20) results in the highest peak loading of the three scenarios where the “Well-in-Plume” receptor is considered (ranging from a few percent higher to > 10000% higher than the peak for the assessed case in the DSAR, where the “Well-in-Plume” was placed at a distance of 250 metres; see Table 2). The cells highlighted in Table 2 indicate the highest peak loading rates of the three scenarios. As shown in Table 2, for some solutes the peak loading is lower for locations closer to the WR-1 (e.g., H3). This results from the screening criteria where the results within the first 100 years following decommissioning are excluded from the assessment; recognizing that the area will be under institutional control during this time period.
- For the remaining sensitivity scenarios, which assess the peak loadings to the Winnipeg River, the simulated peak loadings for a number of the solutes exceed the peak loading of that assessed previously in the DSAR and/or EIS. These are denoted by the cells highlighted in yellow in Table 1. As shown in Table 1, the highest peak loadings simulated were generally a result of considering the bedrock geological pathways as a series of 5 parallel fractures (Scenario 21; Ag108m, Am241, Am243, Ba, Ca41, Cd, Co60, Cs137, Cu, Eu152, Eu154, Fe55, Hg, Mn, Nb94, Ni63, Np237, Np239, Pa233, Pd, Pu238, Pu239, Pu240, Pu241, Sm, Sm148, Sr90, Th231, Th234, U237, Y90 and Zr), although for a few solutes the overall peak loading was highest under a case of increased recharge to the till (Scenario 29; B, HB40, Pb), a lower Kd within the geo-pathway (Scenario 23; Cr, Ni, Ni59, Tc99, U234, U235, U236 and U238) and increased diffusivity for the foundation (Scenario 25, Gd).

## 4.0 SUMMARY

The groundwater flow and solute transport modelling results presented in this technical memorandum were developed in response to FPIRT Round 2 IRs provided to CNL in May 2023 (CNSC 2023). They were intended to explore the sensitivity of the modelling results to an expanded set of parameter inputs and assumptions made in the original assessment. The results are presented as peak loadings for the full suite of radiological and non-radiological solutes considered in the original assessment. The results indicate that the expanded set of parameter inputs results in increased mass loading estimates to the environment for some scenarios relative to those assessed in the Draft EIS submitted December 2022 (WSP Golder et. al. 2022). The overall impact of the mass loadings estimated herein should be evaluated in the context of the site receptor model to determine the potential impact of these results on the overall assessment in the DSAR.

## 5.0 LIMITATIONS

This report was prepared for the exclusive use of Canadian Nuclear Laboratories Ltd. The report, which specifically includes all tables, figures and appendices, is based on data gathered by WSP, and information provided to WSP by others. The information provided by others has not been independently verified or otherwise examined by WSP to determine the accuracy or completeness. WSP has relied on this information in good faith and does not accept responsibility for any deficiency, misstatements, or inaccuracies contained in the information as a result of omissions, misinterpretation or fraudulent acts of the persons who provided the information. WSP shall not be held responsible for damages resulting from unpredictable or unknown underground conditions, from erroneous information provided by and/or obtained from sources other than WSP, and from ulterior changes in the site conditions unless WSP has been notified by Canadian Nuclear Laboratories Ltd. of any occurrence, activity, information or discovery, past or future, which would modify the underground conditions described herein, and have had the opportunity of revising its interpretations and comments. WSP shall not be held responsible for damages resulting from any future modification to the applicable regulations, standards and criteria. Any use of this report and its content by a third party is the responsibility of such third party. WSP shall not be held responsible for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

Hydrogeological investigations and groundwater modelling are dynamic and inexact sciences. They are dynamic in the sense that the state of any hydrological system is changing with time, and in the sense that the science is continually developing new techniques to evaluate these systems. They are inexact in the sense that groundwater systems are complex, and invariably limited data are available for the purposes of hydrogeological evaluation. A groundwater model uses the laws of science and mathematics to draw together the available data into a mathematical or computer-based representation of the essential features of an existing hydrogeological system. While the model itself obviously lacks the detailed reality of the existing hydrogeological system, the behaviour of a valid groundwater model reasonably approximates that of the real system. The validity and accuracy of the model depends on the amount of data available relative to the degree of complexity of the geologic formations and on the quality and degree of accuracy of the data entered. Therefore, every groundwater model is a simplification of reality and the model described herein is not an exception.

The services performed as described in this report were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and geoscience professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

The findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in future work, including excavations, borings, or other studies, WSP should be requested to re-evaluate the findings of this report, and to provide amendments as required.

This report provides a professional opinion in light of the information available at the time of this report and therefore no warranty is either expressed, implied, or made as to the conclusions, advice or recommendations offered in this report.

## 6.0 REFERENCES

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## List of Tables

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Appendix A – Well-in-Plume Configurations (Sensitivity Simulations 19 and 20)

Appendix B – Fractured Geo-Pathway (Sensitivity Simulations 21 and 22)

Appendix C – Adsorption Co-efficient Ranges (Sensitivity Simulations 23 and 24)

Appendix D – Diffusivity Assumptions (Sensitivity Simulations 25 and 26)

Appendix E – Hydraulic Conductivity Assignments for Grout (Sensitivity Simulations 27 and 28)

Appendix F – Model Configuration with Higher Recharge Rates (Sensitivity Simulation 29)

Jeffrey Miller  
Canadian Nuclear Laboratories

Project No. 20145046-31000  
July 16, 2024

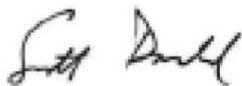
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WSP Canada Inc.

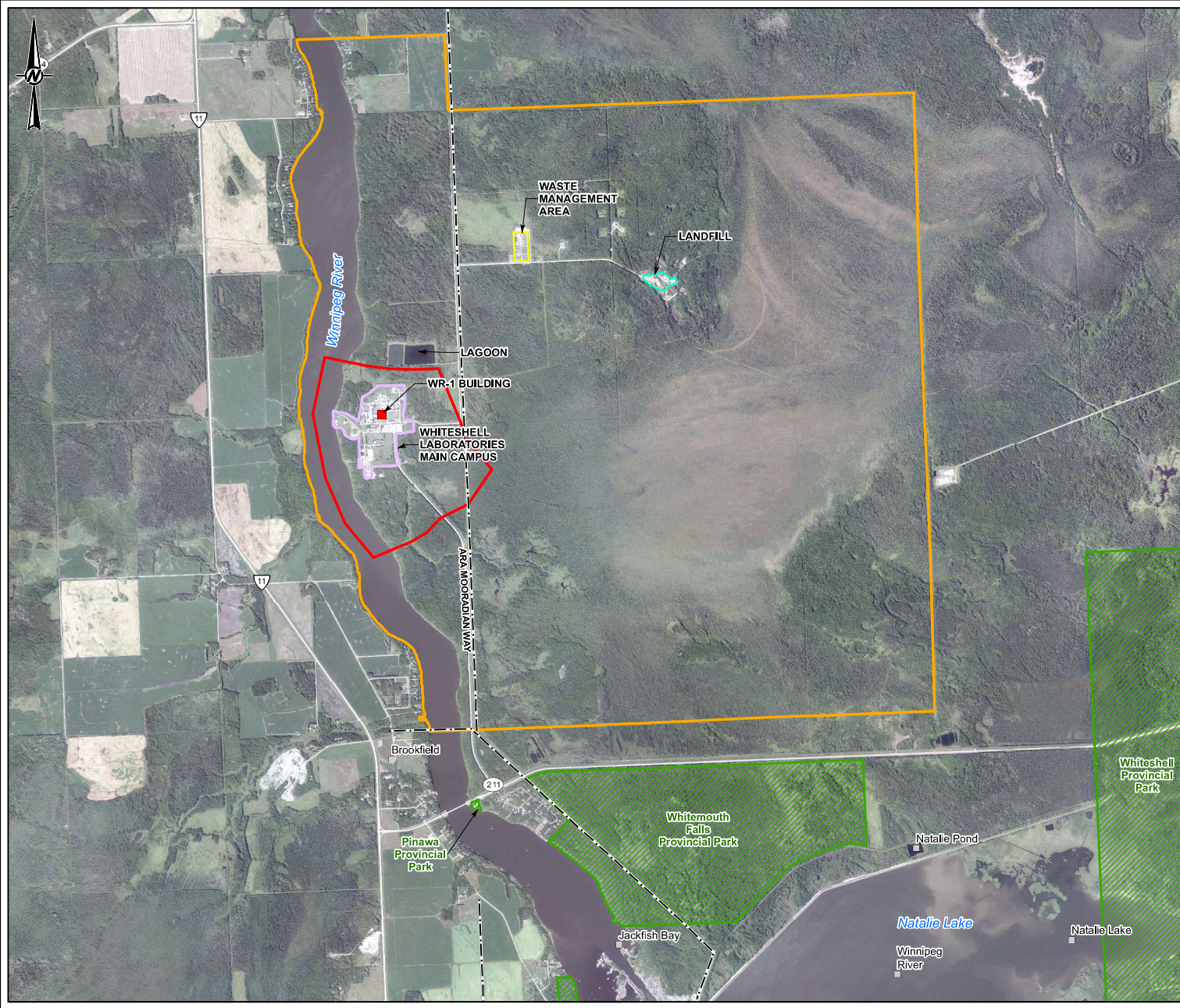


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*Hydrogeologist*

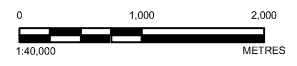
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Scott Donald, M.A.Sc.  
*Principal Hydrogeologist*



- LEGEND**
- WR-1 BUILDING (SITE STUDY AREA)
  - LOCAL STUDY AREA
  - REGIONAL STUDY AREA (WHITESHELL LABORATORIES SITE)
  - WASTE MANAGEMENT AREA
  - WHITESHELL LABORATORIES MAIN CAMPUS
  - LANDFILL
- BASE FEATURES**
- CITY/TOWN
  - TRANSMISSION LINE
  - PROVINCIAL PARK



NOTE(S)

- REFERENCE(S)**
1. BASE DATA - CANVEC AND MLI, 2016
  2. PROJECT DATA - CNL, 2016
  3. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 14N

CLIENT  
CANADIAN NUCLEAR LABORATORIES

PROJECT  
WR-1 GROUNDWATER FLOW AND SOLUTE TRANSPORT  
MODELLING REPORT

TITLE  
**WHITESHELL LABORATORIES SITE**

YYYY/MM-DD	MARCH 2021
DESIGNED	CGE
PREPARED	CGE/PR/RRD
REVIEWED	NB
APPROVED	MM

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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SCALE HAS BEEN MODIFIED FROM THE ORIGINAL SOURCE.

Table 1: Peak Mass Loadings to Winnipeg River: Summary of Each Sensitivity Scenario

Solute	Normal Evolution Scenario (Base Case)	Summary of Original Sensitivity Scenarios (Scenario 1 through 18)			Summary of New Sensitivity Scenarios (Scenario 21 through 29)			Percent Change in Peak Mass Loading from Sensitivity Runs 21 through 29 relative to Previously Assessed Peak Mass Loading
	Peak Mass Loading (g/yr)	Minimum Peak Mass Loading (g/yr)	Maximum Peak Mass Loading (g/yr)	Scenario with Maximum Peak Mass Loading	Minimum Peak Mass Loading (g/yr)	Maximum Peak Mass Loading (g/yr)	Scenario with Maximum Peak Mass Loading	
Ac225	1.7E-17	2.8E-18	1.7E-16	Scenario 17 - Radionuclide Inventory	0.0E+00	1.7E-17	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	1%
Ac227	1.4E-14	1.7E-15	1.4E-13	Scenario 17 - Radionuclide Inventory	0.0E+00	4.4E-14	Scenario 21 - Fractured GeoPathway (5 Fractures)	215%
Ag108m	8.0E-13	0.0E+00	1.2E-08	Scenario 1 - Preferential Pathway	0.0E+00	4.7E-08	Scenario 21 - Fractured GeoPathway (5 Fractures)	>10000%
Am241	0.0E+00	0.0E+00	0.0E+00	Scenario 1 - Preferential Pathway	0.0E+00	1.1E-11	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Am243	0.0E+00	0.0E+00	0.0E+00	Scenario 1 - Preferential Pathway	0.0E+00	8.0E-12	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Ar	6.9E-12	5.5E-12	6.0E-11	Scenario 17 - Radionuclide Inventory	4.2E-12	1.2E-11	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	74%
B	1.9E-04	2.8E-05	1.9E-03	Scenario 7 - Upperbound Mass Inventory	2.8E-05	2.4E-03	Scenario 29 - Increases to Recharge (11 mm/yr) and Bedrock K (4.1 x 10 <sup>-6</sup> m/s)	1211%
Ba	1.5E-23	0.0E+00	1.1E-07	Scenario 1 - Preferential Pathway	0.0E+00	9.1E-07	Scenario 21 - Fractured GeoPathway (5 Fractures)	>10000%
Be	0.0E+00	0.0E+00	0.0E+00	N/A	0.0E+00	0.0E+00	N/A	N/A
Bi	1.1E-08	4.8E-10	1.1E-07	Scenario 17 - Radionuclide Inventory	1.1E-23	1.1E-08	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	1%
Bi210	2.3E-14	3.0E-16	6.5E-13	Scenario 5 - Lowerbound Kd	0.0E+00	2.3E-14	Scenario 26 - Maximum Diffusivity through Foundation (tort = 1.0, n = 1.0)	0%
C14	5.6E-04	1.4E-14	5.6E-03	Scenario 17 - Radionuclide Inventory	1.4E-14	6.0E-04	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	8%
Ca41	1.6E-06	0.0E+00	2.1E-05	Scenario 1 - Preferential Pathway	0.0E+00	5.5E-05	Scenario 21 - Fractured GeoPathway (5 Fractures)	3421%
Cd	3.7E-01	3.9E-05	4.8E+00	Scenario 1 - Preferential Pathway	7.6E-19	1.8E+01	Scenario 21 - Fractured GeoPathway (5 Fractures)	4827%
Ce	0.0E+00	0.0E+00	0.0E+00	N/A	0.0E+00	0.0E+00	N/A	N/A
Cl36	1.2E-08	2.2E-09	1.2E-07	Scenario 17 - Radionuclide Inventory	9.9E-09	2.8E-08	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	146%
Cm244	0.0E+00	0.0E+00	0.0E+00	N/A	0.0E+00	0.0E+00	N/A	N/A
Co	2.1E-02	1.6E-02	2.1E-01	Scenario 17 - Radionuclide Inventory	0.0E+00	2.7E-02	Scenario 23 - Lower Kd in GeoPathway	27%
Co60	0.0E+00	0.0E+00	0.0E+00	Scenario 1 - Preferential Pathway	0.0E+00	9.2E-12	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Cr	5.0E-27	0.0E+00	1.2E-04	Scenario 5 - Lowerbound Kd	0.0E+00	3.5E-00	Scenario 23 - Lower Kd in GeoPathway	>10000%
Cs137	0.0E+00	0.0E+00	2.0E-19	Scenario 1 - Preferential Pathway	0.0E+00	2.0E-07	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Cu	2.0E-04	1.2E-06	4.9E-03	Scenario 1 - Preferential Pathway	1.2E-06	1.3E-02	Scenario 21 - Fractured GeoPathway (5 Fractures)	6504%
Eu152	0.0E+00	0.0E+00	0.0E+00	N/A	0.0E+00	2.2E-25	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Eu154	0.0E+00	0.0E+00	0.0E+00	N/A	0.0E+00	2.2E-27	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Eu155	0.0E+00	0.0E+00	0.0E+00	N/A	0.0E+00	0.0E+00	N/A	N/A
Fe55	0.0E+00	0.0E+00	0.0E+00	N/A	0.0E+00	4.5E-19	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Gd	6.5E-06	1.3E-08	2.4E-05	Scenario 2 - Cover	1.3E-08	2.6E-05	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	307%
Gd152	1.7E-07	3.5E-10	1.7E-06	Scenario 17 - Radionuclide Inventory	3.5E-10	7.2E-07	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	322%
H3	6.4E-05	0.0E+00	2.6E-02	Scenario 1 - Preferential Pathway	0.0E+00	1.7E-02	Scenario 29 - Increases to Recharge (11 mm/yr) and Bedrock K (4.1 x 10 <sup>-6</sup> m/s)	>10000%
HB40	4.1E+01	3.8E+01	8.2E+01	Scenario 2 - Cover	3.7E+01	1.3E+02	Scenario 29 - Increases to Recharge (11 mm/yr) and Bedrock K (4.1 x 10 <sup>-6</sup> m/s)	218%
He	1.1E-02	1.9E-03	1.3E-01	Scenario 7 - Upperbound Mass Inventory	9.0E-03	2.6E-02	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	139%
Hg	1.4E-18	1.8E-21	5.4E-04	Scenario 1 - Preferential Pathway	1.8E-21	2.1E-03	Scenario 21 - Fractured GeoPathway (5 Fractures)	>10000%
I129	1.4E-04	2.8E-05	1.4E-03	Scenario 17 - Radionuclide Inventory	2.0E-10	3.5E-04	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	146%
K	3.3E-07	2.6E-07	3.3E-06	Scenario 17 - Radionuclide Inventory	1.5E-11	3.7E-07	Scenario 29 - Increases to Recharge (11 mm/yr) and Bedrock K (4.1 x 10 <sup>-6</sup> m/s)	13%
KOH	4.8E-02	1.9E-02	4.8E-01	Scenario 7 - Upperbound Mass Inventory	3.4E-02	2.2E-01	Scenario 29 - Increases to Recharge (11 mm/yr) and Bedrock K (4.1 x 10 <sup>-6</sup> m/s)	365%
Mn	8.3E-05	3.0E-05	5.8E-04	Scenario 1 - Preferential Pathway	0.0E+00	1.1E-03	Scenario 21 - Fractured GeoPathway (5 Fractures)	1264%
Mo	1.2E-02	6.9E-04	1.2E-01	Scenario 17 - Radionuclide Inventory	4.5E-05	1.2E-02	Scenario 29 - Increases to Recharge (11 mm/yr) and Bedrock K (4.1 x 10 <sup>-6</sup> m/s)	1%
N	5.4E-04	5.4E-04	5.4E-03	Scenario 17 - Radionuclide Inventory	5.4E-04	7.0E-04	Scenario 24 - Higher Kd in GeoPathway	28%
Nb94	1.5E-21	0.0E+00	2.7E-07	Scenario 1 - Preferential Pathway	0.0E+00	3.0E-03	Scenario 21 - Fractured GeoPathway (5 Fractures)	>10000%
Nd144	0.0E+00	0.0E+00	0.0E+00	N/A	0.0E+00	0.0E+00	N/A	N/A
Ni	2.0E-05	9.0E-26	9.8E-04	Scenario 5 - Lowerbound Kd	0.0E+00	1.1E-03	Scenario 23 - Lower Kd in GeoPathway	5459%
Ni59	5.5E-05	0.0E+00	6.6E-02	Scenario 5 - Lowerbound Kd	0.0E+00	7.7E-02	Scenario 23 - Lower Kd in GeoPathway	>10000%
Ni63	0.0E+00	0.0E+00	4.9E-21	Scenario 5 - Lowerbound Kd	0.0E+00	1.1E-06	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Np237	5.2E-06	4.6E-07	6.2E-05	Scenario 1 - Preferential Pathway	1.1E-22	1.6E-04	Scenario 21 - Fractured GeoPathway (5 Fractures)	3032%
Np239	0.0E+00	0.0E+00	0.0E+00	N/A	0.0E+00	2.5E-14	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Pa231	2.2E-11	9.0E-13	2.2E-10	Scenario 17 - Radionuclide Inventory	0.0E+00	6.8E-11	Scenario 21 - Fractured GeoPathway (5 Fractures)	215%
Pa233	2.3E-16	1.3E-17	3.5E-15	Scenario 5 - Lowerbound Kd	0.0E+00	1.0E-14	Scenario 21 - Fractured GeoPathway (5 Fractures)	4230%
Pb	2.5E-01	5.0E-10	5.9E+00	Scenario 1 - Preferential Pathway	1.3E-25	1.6E+01	Scenario 29 - Increases to Recharge (11 mm/yr) and Bedrock K (4.1 x 10 <sup>-6</sup> m/s)	6273%
Pb210	9.3E-13	4.9E-14	9.3E-12	Scenario 17 - Radionuclide Inventory	0.0E+00	9.3E-13	Scenario 26 - Maximum Diffusivity through Foundation (tort = 1.0, n = 1.0)	0%
Pd	1.0E-01	1.9E-02	1.3E+00	Scenario 1 - Preferential Pathway	2.8E-17	5.3E+00	Scenario 21 - Fractured GeoPathway (5 Fractures)	4949%
Po210	1.6E-10	2.1E-15	1.6E-09	Scenario 17 - Radionuclide Inventory	0.0E+00	1.6E-10	Scenario 26 - Maximum Diffusivity through Foundation (tort = 1.0, n = 1.0)	0%
Pu238	0.0E+00	0.0E+00	9.9E-22	Scenario 1 - Preferential Pathway	0.0E+00	5.5E-08	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Pu239	2.4E-07	3.1E-15	1.0E-04	Scenario 1 - Preferential Pathway	0.0E+00	7.0E-04	Scenario 21 - Fractured GeoPathway (5 Fractures)	>10000%
Pu240	1.6E-10	9.0E-26	1.5E-05	Scenario 1 - Preferential Pathway	0.0E+00	2.6E-04	Scenario 21 - Fractured GeoPathway (5 Fractures)	>10000%
Pu241	0.0E+00	0.0E+00	0.0E+00	N/A	0.0E+00	3.1E-09	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Ra223	3.4E-16	7.1E-17	3.4E-15	Scenario 17 - Radionuclide Inventory	0.0E+00	1.1E-15	Scenario 29 - Increases to Recharge (11 mm/yr) and Bedrock K (4.1 x 10 <sup>-6</sup> m/s)	215%
Ra224	6.7E-22	1.1E-22	6.7E-21	Scenario 17 - Radionuclide Inventory	0.0E+00	6.7E-22	Several Scenarios	0%
Ra225	2.2E-16	5.8E-17	2.2E-15	Scenario 17 - Radionuclide Inventory	0.0E+00	2.2E-16	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	1%
Ra226	1.6E-11	5.7E-12	1.6E-10	Scenario 17 - Radionuclide Inventory	0.0E+00	1.6E-11	Scenario 26 - Maximum Diffusivity through Foundation (tort = 1.0, n = 1.0)	0%
Ra228	3.9E-19	6.2E-20	3.9E-18	Scenario 17 - Radionuclide Inventory	0.0E+00	3.9E-19	Several Scenarios	0%

Table 1: Peak Mass Loadings to Winnipeg River: Summary of Each Sensitivity Scenario

Solute	Normal Evolution Scenario (Base Case)	Summary of Original Sensitivity Scenarios (Scenario 1 through 18)			Summary of New Sensitivity Scenarios (Scenario 21 through 29)			Percent Change in Peak Mass Loading from Sensitivity Runs 21 through 29 relative to Previously Assessed Peak Mass Loading
	Peak Mass Loading (g/yr)	Minimum Peak Mass Loading (g/yr)	Maximum Peak Mass Loading (g/yr)	Scenario with Maximum Peak Mass Loading	Minimum Peak Mass Loading (g/yr)	Maximum Peak Mass Loading (g/yr)	Scenario with Maximum Peak Mass Loading	
Rn222	4.8E-12	5.3E-13	4.8E-11	Scenario 17 - Radionuclide Inventory	0.0E+00	4.8E-12	Scenario 26 - Maximum Diffusivity through Foundation (tort = 1.0, n = 1.0)	0%
Ru	6.2E-09	6.1E-09	8.7E-08	Scenario 5 - Lowerbound Kd	5.7E-09	3.3E-08	Scenario 23 - Lower Kd in GeoPathway	430%
S	2.4E-12	4.9E-13	2.4E-11	Scenario 17 - Radionuclide Inventory	5.4E-14	5.4E-12	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	129%
Sm	0.0E+00	0.0E+00	1.8E-13	Scenario 5 - Lowerbound Kd	0.0E+00	4.0E-10	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Sm148	1.4E-24	1.4E-24	2.1E-22	Scenario 6 - Upperbound Kd	1.4E-24	4.0E-22	Scenario 21 - Fractured GeoPathway (5 Fractures)	>10000%
Sr90	0.0E+00	0.0E+00	2.2E-13	Scenario 1 - Preferential Pathway	0.0E+00	1.4E-06	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Tc99	1.6E-05	1.2E-06	1.8E-04	Scenario 1 - Preferential Pathway	1.9E-07	3.7E-04	Scenario 23 - Lower Kd in GeoPathway	2221%
Th227	6.1E-17	2.7E-18	6.1E-16	Scenario 17 - Radionuclide Inventory	0.0E+00	1.9E-16	Scenario 21 - Fractured GeoPathway (5 Fractures)	214%
Th228	2.8E-20	9.4E-22	2.8E-19	Scenario 17 - Radionuclide Inventory	0.0E+00	2.8E-20	Several Scenarios	0%
Th229	8.7E-12	2.2E-12	8.7E-11	Scenario 17 - Radionuclide Inventory	6.4E-28	8.8E-12	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	1%
Th230	1.7E-10	1.5E-11	1.7E-09	Scenario 17 - Radionuclide Inventory	0.0E+00	1.7E-10	Scenario 26 - Maximum Diffusivity through Foundation (tort = 1.0, n = 1.0)	0%
Th231	4.6E-18	2.0E-19	7.0E-17	Scenario 5 - Lowerbound Kd	0.0E+00	5.8E-16	Scenario 21 - Fractured GeoPathway (5 Fractures)	>10000%
Th232	2.1E-10	7.0E-12	2.1E-09	Scenario 17 - Radionuclide Inventory	0.0E+00	2.1E-10	Several Scenarios	0%
Th234	7.3E-16	3.2E-17	1.2E-14	Scenario 5 - Lowerbound Kd	0.0E+00	5.1E-14	Scenario 21 - Fractured GeoPathway (5 Fractures)	6781%
Tl	0.0E+00	0.0E+00	0.0E+00	N/A	0.0E+00	0.0E+00	N/A	N/A
U233	2.8E-08	1.6E-08	2.8E-07	Scenario 17 - Radionuclide Inventory	9.9E-25	9.1E-08	Scenario 23 - Lower Kd in GeoPathway	227%
U234	1.4E-07	3.1E-08	1.4E-06	Scenario 17 - Radionuclide Inventory	0.0E+00	3.8E-06	Scenario 23 - Lower Kd in GeoPathway	2675%
U235	1.6E-04	1.7E-05	1.9E-03	Scenario 1 - Preferential Pathway	0.0E+00	1.6E-02	Scenario 23 - Lower Kd in GeoPathway	9925%
U236	7.2E-06	7.3E-07	7.2E-05	Scenario 17 - Radionuclide Inventory	0.0E+00	1.1E-04	Scenario 23 - Lower Kd in GeoPathway	1419%
U237	0.0E+00	0.0E+00	0.0E+00	N/A	0.0E+00	1.5E-13	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
U238	7.1E-03	7.5E-04	9.1E-02	Scenario 1 - Preferential Pathway	0.0E+00	8.0E-01	Scenario 23 - Lower Kd in GeoPathway	>10000%
Xe	1.4E-09	7.1E-10	1.2E-08	Scenario 17 - Radionuclide Inventory	7.5E-10	3.6E-09	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	157%
Xylene	4.3E+00	1.2E+16	4.3E+01	Scenario 7 - Upperbound Mass Inventory	7.7E-03	1.5E+01	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	253%
Y90	0.0E+00	0.0E+00	3.3E-19	Scenario 1 - Preferential Pathway	0.0E+00	5.5E-12	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A
Zr	0.0E+00	0.0E+00	8.5E-14	Scenario 1 - Preferential Pathway	0.0E+00	1.3E-07	Scenario 21 - Fractured GeoPathway (5 Fractures)	N/A

Table 2: Peak Mass Loadings: Well-in-Plume Scenarios

Solute	Normal Evolution Scenario (Base Case) - Supply Well at 250 m	Scenario 19 - Supply Well at 100 m		Scenario 20 - Supply Well at 10 m	
	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Percent Change in Peak Mass Loading	Peak Mass Loading (g/yr)	Percent Change in Peak Mass Loading
Ac225	1.7E-17	1.5E-17	-14%	4.6E-18	-74%
Ac227	2.1E-14	3.1E-14	44%	4.4E-14	108%
Ag108m	3.9E-11	1.2E-09	2834%	4.7E-08	> 10000 %
Am241	0.0E+00	0.0E+00	N/A	6.2E-28	N/A
Am243	0.0E+00	0.0E+00	N/A	0.0E+00	N/A
Ar	5.8E-12	4.9E-12	-15%	4.5E-12	-23%
B	3.6E-04	7.9E-04	118%	2.4E-03	575%
Ba	3.6E-08	9.1E-08	150%	9.1E-07	2399%
Be	0.0E+00	0.0E+00	N/A	0.0E+00	N/A
Bi	5.5E-09	1.8E-09	-67%	6.0E-11	-99%
Bi210	2.0E-14	1.7E-14	-19%	1.2E-14	-41%
C14	5.6E-04	5.6E-04	0%	5.6E-04	1%
Ca41	3.3E-06	8.6E-06	159%	5.5E-05	1556%
Cd	7.4E-01	1.9E+00	150%	1.8E+01	2364%
Ce	0.0E+00	0.0E+00	N/A	0.0E+00	N/A
Cl36	1.4E-08	1.3E-08	-2%	1.2E-08	-11%
Cm244	0.0E+00	0.0E+00	N/A	0.0E+00	N/A
Co	2.6E-02	2.8E-02	7%	2.5E-02	-2%
Co60	0.0E+00	0.0E+00	N/A	1.5E-23	N/A
Cr	8.0E-03	2.0E-02	150%	2.0E-01	2399%
Cs137	0.0E+00	0.0E+00	N/A	1.6E-11	N/A
Cu	1.1E-03	2.6E-03	142%	1.4E-02	1156%
Eu152	0.0E+00	0.0E+00	N/A	0.0E+00	N/A
Eu154	0.0E+00	0.0E+00	N/A	0.0E+00	N/A
Eu155	0.0E+00	0.0E+00	N/A	0.0E+00	N/A
Fe55	0.0E+00	0.0E+00	N/A	0.0E+00	N/A
Gd	7.1E-06	7.4E-06	4%	7.3E-06	3%
Gd152	1.9E-07	2.0E-07	5%	1.9E-07	2%
H3	5.0E-05	4.2E-05	-15%	3.5E-05	-29%
HB40	4.1E+01	4.1E+01	0%	4.1E+01	0%
He	1.3E-02	1.1E-02	-16%	9.6E-03	-26%
Hg	8.3E-05	2.1E-04	150%	2.1E-03	2399%
I129	1.7E-04	1.7E-04	-2%	1.5E-04	-11%
K	3.4E-07	3.5E-07	4%	3.5E-07	2%
KOH	5.8E-02	4.7E-02	-19%	3.9E-02	-33%

Table 2: Peak Mass Loadings: Well-in-Plume Scenarios

Solute	Normal Evolution Scenario (Base Case) - Supply Well at 250 m	Scenario 19 - Supply Well at 100 m		Scenario 20 - Supply Well at 10 m	
	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Percent Change in Peak Mass Loading	Peak Mass Loading (g/yr)	Percent Change in Peak Mass Loading
Mn	1.7E-04	3.6E-04	110%	1.1E-03	562%
Mo	1.1E-02	1.1E-02	0%	1.1E-02	0%
N	5.1E-04	5.2E-04	0%	5.1E-04	0%
Nb94	3.1E-15	3.3E-10	> 10000 %	2.0E-04	> 10000 %
Nd144	0.0E+00	0.0E+00	N/A	0.0E+00	N/A
Ni	9.6E-05	2.3E-04	142%	1.2E-03	1124%
Ni59	6.9E-04	6.0E-03	768%	8.1E-02	> 10000 %
Ni63	0.0E+00	0.0E+00	N/A	5.2E-19	N/A
Np237	1.0E-05	2.6E-05	149%	1.6E-04	1462%
Np239	0.0E+00	0.0E+00	N/A	0.0E+00	N/A
Pa231	3.3E-11	4.7E-11	44%	6.8E-11	108%
Pa233	4.7E-16	1.2E-15	149%	7.3E-15	1462%
Pb	5.0E+00	5.0E+00	0%	5.0E+00	0%
Pb210	8.3E-13	6.7E-13	-19%	4.9E-13	-41%
Pd	2.1E-01	5.2E-01	150%	4.9E+00	2252%
Po210	1.5E-10	1.2E-10	-20%	8.2E-11	-44%
Pu238	0.0E+00	0.0E+00	N/A	1.6E-13	N/A
Pu239	2.6E-06	2.2E-05	752%	5.2E-04	> 10000 %
Pu240	1.7E-08	1.1E-06	5979%	1.5E-04	> 10000 %
Pu241	0.0E+00	0.0E+00	N/A	8.1E-26	N/A
Ra223	5.1E-16	7.3E-16	44%	1.1E-15	108%
Ra224	6.7E-22	6.5E-22	-2%	2.8E-22	-58%
Ra225	2.2E-16	1.9E-16	-14%	5.9E-17	-74%
Ra226	1.5E-11	1.2E-11	-19%	8.7E-12	-41%
Ra228	3.9E-19	3.8E-19	-2%	1.6E-19	-58%
Rn222	4.3E-12	3.5E-12	-19%	2.5E-12	-41%
Ru	6.3E-09	6.5E-09	3%	1.3E-08	109%
S	1.5E-12	6.2E-13	-57%	9.2E-14	-94%
Sm	1.2E-11	3.0E-11	150%	3.0E-10	2399%
Sm148	1.3E-23	3.0E-23	139%	2.9E-22	2219%
Sr90	0.0E+00	1.3E-19	N/A	7.9E-09	N/A
Tc99	3.2E-05	7.8E-05	143%	3.7E-04	1048%
Th227	9.3E-17	1.3E-16	44%	1.9E-16	108%
Th228	2.8E-20	2.8E-20	-2%	1.2E-20	-58%
Th229	8.9E-12	7.7E-12	-14%	2.4E-12	-74%

Table 2: Peak Mass Loadings: Well-in-Plume Scenarios

Solute	Normal Evolution Scenario (Base Case) - Supply Well at 250 m	Scenario 19 - Supply Well at 100 m		Scenario 20 - Supply Well at 10 m	
	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Percent Change in Peak Mass Loading	Peak Mass Loading (g/yr)	Percent Change in Peak Mass Loading
Th230	1.5E-10	1.3E-10	-19%	9.4E-11	-39%
Th231	9.1E-18	2.2E-17	140%	1.9E-16	2049%
Th232	2.1E-10	2.1E-10	-2%	8.8E-11	-58%
Th234	1.5E-15	3.7E-15	149%	3.4E-14	2237%
Tl	0.0E+00	0.0E+00	N/A	0.0E+00	N/A
U233	3.1E-08	3.3E-08	7%	3.4E-08	9%
U234	1.8E-07	2.8E-07	57%	1.6E-06	823%
U235	3.1E-04	7.5E-04	140%	6.7E-03	2049%
U236	1.4E-05	3.3E-05	131%	1.0E-04	626%
U237	0.0E+00	0.0E+00	N/A	0.0E+00	N/A
U238	1.4E-02	3.5E-02	149%	3.3E-01	2237%
Xe	1.2E-09	8.3E-10	-29%	7.4E-10	-36%
Xylene	4.8E+00	5.0E+00	5%	4.8E+00	1%
Y90	0.0E+00	1.9E-25	N/A	1.2E-14	N/A
Zr	3.4E-09	8.6E-09	150%	8.6E-08	2397%

Notes:

1. Peak mass loadings exclude results within first 100 years post-closure (assumes no potential for supply well to be installed due to institutional control).

Table 3: Peak Mass Loadings to Winnipeg River: Peak from All Sensitivity Scenarios

Solute	Normal Evolution Scenario (Base Case)	Scenario 21 - Fractured GeoPathway (5 Fractures)	Scenario 22 - Fractured GeoPathway (10 Fractures)	Scenario 23 - Lower Kd in GeoPathway	Scenario 24 - Higher Kd in GeoPathway	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	Scenario 26 - Maximum Diffusivity through Foundation (tort = 1.0, n = 1.0)	Scenario 27 - Upper Bound K for Grout and Foundation (1.5 x 10 <sup>-6</sup> m/s)	Scenario 28 - Maximum K for Grout, Foundation and Backfill (1.0 x 10 <sup>-4</sup> m/s)	Scenario 29 - Increases to Recharge (11 mm/yr) and Bedrock K (4.1 x 10 <sup>-6</sup> m/s)
	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)
Ac225	1.7E-17	2.6E-18	3.5E-18	2.4E-18	0.0E+00	1.7E-17	1.7E-17	1.7E-17	1.7E-17	8.8E-18
Ac227	1.4E-14	4.0E-14	2.6E-14	6.2E-15	0.0E+00	1.4E-14	1.4E-14	1.4E-14	1.4E-14	4.0E-14
Ag108m	8.0E-13	2.2E-08	7.8E-09	8.0E-13	0.0E+00	1.0E-12	7.8E-13	9.4E-13	9.7E-13	1.7E-08
Am241	0.0E+00	1.1E-11	1.8E-13	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Am243	0.0E+00	8.0E-12	3.4E-14	1.7E-12	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ar	6.9E-12	4.3E-12	4.2E-12	6.9E-12	6.9E-12	1.2E-11	6.3E-12	9.1E-12	9.8E-12	5.4E-12
B	1.9E-04	1.2E-03	7.0E-04	1.9E-04	2.8E-05	1.9E-04	1.9E-04	1.9E-04	1.9E-04	2.0E-03
Ba	1.5E-23	8.6E-07	2.2E-07	4.5E-17	0.0E+00	1.5E-23	1.5E-23	1.5E-23	1.5E-23	2.5E-07
Be	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Bi	1.1E-08	1.2E-09	2.4E-09	6.4E-11	1.1E-23	1.1E-08	1.1E-08	1.1E-08	1.1E-08	3.2E-10
Bi210	2.3E-14	1.8E-14	1.6E-14	1.8E-14	0.0E+00	2.3E-14	2.3E-14	2.3E-14	2.3E-14	1.3E-14
C14	5.6E-04	5.5E-04	5.4E-04	5.6E-04	1.4E-14	6.0E-04	5.4E-04	5.7E-04	5.7E-04	5.8E-04
Ca41	1.6E-06	3.2E-05	1.5E-05	1.8E-06	0.0E+00	1.6E-06	1.6E-06	1.6E-06	1.6E-06	2.7E-05
Cd	3.7E-01	1.7E+01	5.2E+00	3.7E+00	7.6E-19	3.7E-01	3.7E-01	3.7E-01	3.7E-01	6.1E+00
Ce	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cl36	1.2E-08	1.2E-08	9.9E-09	1.2E-08	1.2E-08	2.8E-08	1.1E-08	1.8E-08	2.1E-08	2.6E-08
Cm244	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Co	2.1E-02	1.8E-02	1.7E-02	2.7E-02	0.0E+00	2.1E-02	2.1E-02	2.1E-02	2.1E-02	2.6E-02
Co60	0.0E+00	9.2E-12	1.3E-13	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Cr	5.0E-27	2.7E-01	6.8E-02	3.5E+00	0.0E+00	5.0E-27	5.0E-27	5.0E-27	5.0E-27	2.1E-04
Cs137	0.0E+00	2.0E-07	3.8E-09	1.1E-18	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.5E-17
Cu	2.0E-04	9.6E-03	4.6E-03	1.0E-03	1.2E-06	2.0E-04	2.0E-04	2.0E-04	2.0E-04	6.2E-03
Eu152	0.0E+00	2.2E-25	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu154	0.0E+00	2.2E-27	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Eu155	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Fe55	0.0E+00	4.5E-19	8.3E-23	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Gd	6.5E-06	6.7E-06	6.1E-06	6.5E-06	1.3E-08	2.6E-05	6.9E-06	1.7E-05	1.9E-05	1.2E-05
Gd152	1.7E-07	1.8E-07	1.6E-07	1.7E-07	3.5E-10	7.2E-07	1.8E-07	4.6E-07	5.2E-07	3.2E-07
H3	6.4E-05	2.4E-03	8.1E-04	6.4E-05	0.0E+00	2.1E-04	5.1E-05	8.4E-05	1.3E-04	1.7E-02
HB40	4.1E+01	4.1E+01	4.1E+01	4.1E+01	3.8E+01	3.7E+01	4.4E+01	4.3E+01	5.2E+01	1.3E+02
He	1.1E-02	1.1E-02	9.0E-03	1.1E-02	1.1E-02	2.6E-02	9.4E-03	1.6E-02	1.9E-02	2.3E-02
Hg	1.4E-18	1.9E-03	4.7E-04	4.8E-11	1.8E-21	1.4E-18	1.4E-18	1.4E-18	1.4E-18	6.9E-04
I129	1.4E-04	1.5E-04	1.2E-04	1.4E-04	2.0E-10	3.5E-04	1.3E-04	2.3E-04	2.6E-04	3.3E-04
K	3.3E-07	1.4E-07	1.2E-07	3.3E-07	1.5E-11	3.3E-07	3.3E-07	3.3E-07	3.3E-07	3.7E-07
KOH	4.8E-02	4.3E-02	3.4E-02	4.8E-02	4.8E-02	9.3E-02	3.7E-02	5.4E-02	6.8E-02	2.2E-01
Mn	8.3E-05	8.0E-04	5.1E-04	2.0E-04	0.0E+00	8.3E-05	8.3E-05	8.3E-05	8.3E-05	7.5E-04
Mo	1.2E-02	1.1E-02	1.1E-02	1.2E-02	4.5E-05	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
N	5.4E-04	5.4E-04	5.4E-04	5.4E-04	7.0E-04	5.4E-04	5.4E-04	5.4E-04	5.4E-04	5.4E-04
Nb94	1.5E-21	3.0E-03	9.6E-04	2.8E-08	0.0E+00	1.6E-21	1.5E-21	1.6E-21	1.6E-21	2.2E-06
Nd144	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ni	2.0E-05	8.4E-04	4.2E-04	9.8E-04	0.0E+00	2.0E-05	2.0E-05	2.0E-05	2.0E-05	5.4E-04
Ni59	5.5E-05	6.2E-02	3.1E-02	6.6E-02	0.0E+00	5.5E-05	5.5E-05	5.5E-05	5.5E-05	2.9E-02
Ni63	0.0E+00	1.1E-06	1.6E-08	4.9E-21	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

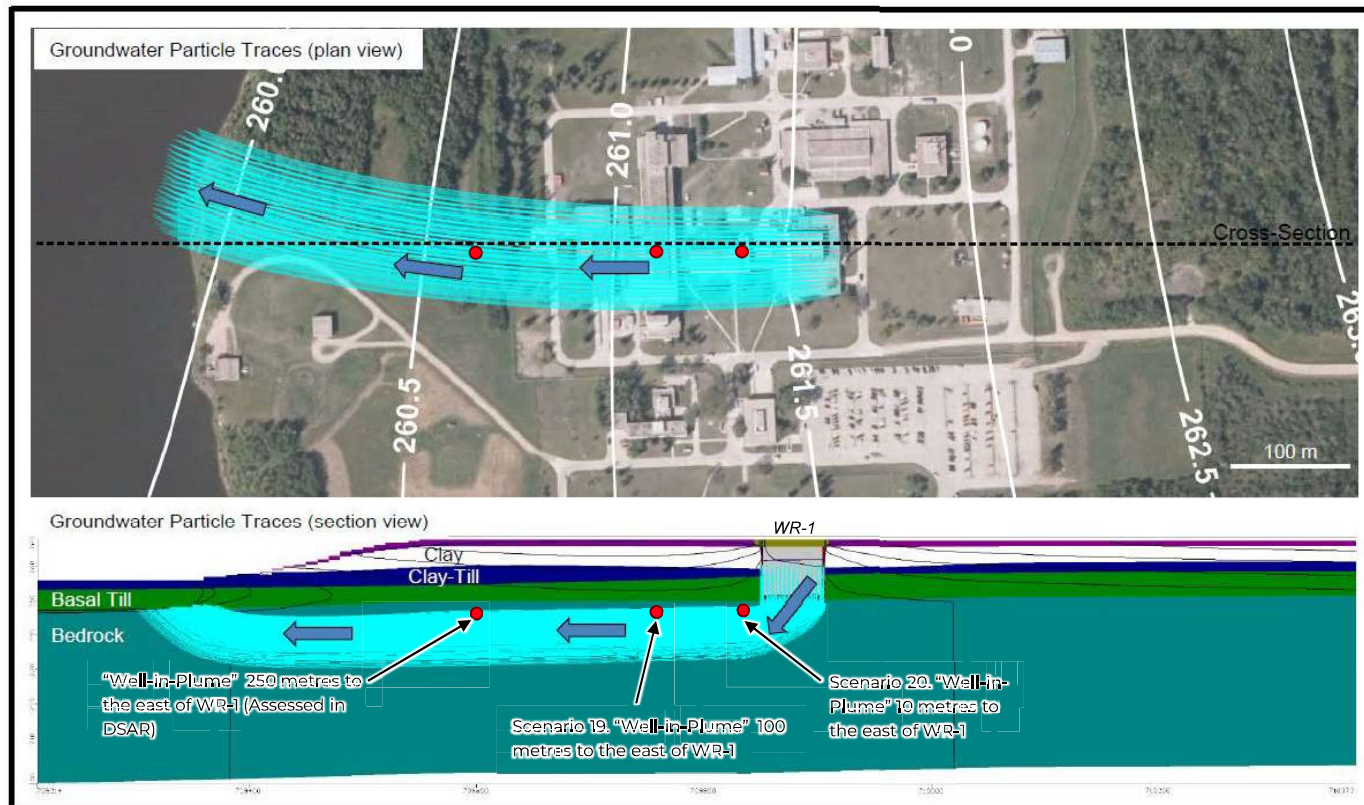
Table 3: Peak Mass Loadings to Winnipeg River: Peak from All Sensitivity Scenarios

Solute	Normal Evolution Scenario (Base Case)	Scenario 21 - Fractured GeoPathway (5 Fractures)	Scenario 22 - Fractured GeoPathway (10 Fractures)	Scenario 23 - Lower Kd in GeoPathway	Scenario 24 - Higher Kd in GeoPathway	Scenario 25 - Adjust Diffusivity for Foundation (tort = 1.0, n = 0.01)	Scenario 26 - Maximum Diffusivity through Foundation (tort = 1.0, n = 1.0)	Scenario 27 - Upper Bound K for Grout and Foundation (1.5 x 10 <sup>-6</sup> m/s)	Scenario 28 - Maximum K for Grout, Foundation and Backfill (1.0 x 10 <sup>-4</sup> m/s)	Scenario 29 - Increases to Recharge (11 mm/yr) and Bedrock K (4.1 x 10 <sup>-6</sup> m/s)
	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)	Peak Mass Loading (g/yr)
Np237	5.2E-06	1.2E-04	6.6E-05	4.9E-05	1.1E-22	5.2E-06	5.2E-06	5.2E-06	5.2E-06	7.7E-05
Np239	0.0E+00	2.5E-14	1.1E-16	6.1E-17	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Pa231	2.2E-11	6.1E-11	4.0E-11	7.8E-12	0.0E+00	2.2E-11	2.2E-11	2.2E-11	2.2E-11	6.1E-11
Pa233	2.3E-16	1.0E-14	5.5E-15	4.2E-15	0.0E+00	2.4E-16	2.3E-16	2.3E-16	2.4E-16	3.5E-15
Pb	2.5E-01	4.5E+00	3.9E+00	5.0E+00	1.3E-25	2.3E-01	2.8E-01	2.8E-01	3.3E-01	1.6E+01
Pb210	9.3E-13	8.8E-13	7.4E-13	1.1E-13	0.0E+00	9.3E-13	9.3E-13	9.3E-13	9.3E-13	5.4E-13
Pd	1.0E-01	5.3E+00	2.1E+00	6.3E-01	2.8E-17	1.0E-01	1.0E-01	1.0E-01	1.0E-01	1.7E+00
Po210	1.6E-10	4.2E-11	4.6E-11	4.8E-13	0.0E+00	1.6E-10	1.6E-10	1.6E-10	1.6E-10	9.4E-11
Pu238	0.0E+00	5.5E-08	4.1E-09	3.4E-24	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E-19
Pu239	2.4E-07	7.0E-04	2.5E-04	7.1E-05	0.0E+00	2.4E-07	2.4E-07	2.4E-07	2.4E-07	1.4E-04
Pu240	1.6E-10	2.6E-04	8.7E-05	8.2E-06	0.0E+00	1.6E-10	1.6E-10	1.6E-10	1.6E-10	2.6E-05
Pu241	0.0E+00	3.1E-09	4.4E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ra223	3.4E-16	4.9E-16	3.1E-16	2.1E-17	0.0E+00	3.4E-16	3.4E-16	3.4E-16	3.4E-16	9.5E-16
Ra224	6.7E-22	1.5E-22	2.4E-22	1.1E-23	0.0E+00	6.7E-22	6.7E-22	6.7E-22	6.7E-22	5.0E-22
Ra225	2.2E-16	3.2E-17	4.4E-17	4.3E-18	0.0E+00	2.2E-16	2.2E-16	2.2E-16	2.2E-16	1.1E-16
Ra226	1.6E-11	8.3E-12	6.7E-12	1.5E-13	0.0E+00	1.6E-11	1.6E-11	1.6E-11	1.6E-11	9.6E-12
Ra228	3.9E-19	8.8E-20	1.4E-19	6.5E-21	0.0E+00	3.9E-19	3.9E-19	3.9E-19	3.9E-19	2.9E-19
Rn222	4.8E-12	1.1E-12	9.3E-13	1.4E-14	0.0E+00	4.8E-12	4.8E-12	4.8E-12	4.8E-12	2.8E-12
Ru	6.2E-09	1.2E-08	6.7E-09	3.3E-08	5.7E-09	6.1E-09	6.2E-09	6.2E-09	6.2E-09	7.1E-09
S	2.4E-12	5.4E-14	5.8E-14	2.4E-12	2.4E-12	5.4E-12	2.2E-12	6.2E-12	4.1E-12	3.7E-13
Sm	0.0E+00	4.0E-10	1.0E-10	1.5E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.2E-13
Sm148	1.4E-24	4.0E-22	1.0E-22	2.0E-22	2.1E-22	1.4E-24	1.4E-24	1.4E-24	1.4E-24	1.6E-24
Sr90	0.0E+00	1.4E-06	1.5E-07	5.7E-12	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.2E-12
Tc99	1.6E-05	2.0E-04	1.0E-04	3.2E-04	1.9E-07	1.6E-05	1.6E-05	1.6E-05	1.6E-05	2.3E-04
Th227	6.1E-17	1.8E-16	1.1E-16	1.9E-17	0.0E+00	6.1E-17	6.1E-17	6.1E-17	6.1E-17	1.7E-16
Th228	2.8E-20	6.4E-21	1.0E-20	2.4E-21	0.0E+00	2.8E-20	2.8E-20	2.8E-20	2.8E-20	2.1E-20
Th229	8.7E-12	1.3E-12	1.8E-12	8.6E-13	6.4E-28	8.8E-12	8.7E-12	8.7E-12	8.7E-12	4.5E-12
Th230	1.7E-10	1.3E-10	7.8E-11	8.6E-12	0.0E+00	1.7E-10	1.7E-10	1.7E-10	1.7E-10	1.0E-10
Th231	4.6E-18	5.8E-16	2.4E-16	4.4E-17	0.0E+00	4.6E-18	4.6E-18	4.6E-18	4.6E-18	7.0E-17
Th232	2.1E-10	4.6E-11	7.6E-11	1.8E-11	0.0E+00	2.1E-10	2.1E-10	2.1E-10	2.1E-10	1.6E-10
Th234	7.3E-16	5.1E-14	2.1E-14	7.8E-15	0.0E+00	7.3E-16	7.3E-16	7.3E-16	7.3E-16	1.2E-14
Tl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U233	2.8E-08	1.3E-08	1.1E-08	9.1E-08	9.9E-25	2.8E-08	2.8E-08	2.8E-08	2.8E-08	3.4E-08
U234	1.4E-07	1.6E-06	6.7E-07	3.8E-06	0.0E+00	1.4E-07	1.4E-07	1.4E-07	1.4E-07	6.5E-07
U235	1.6E-04	7.0E-03	2.9E-03	1.6E-02	0.0E+00	1.6E-04	1.6E-04	1.6E-04	1.6E-04	2.4E-03
U236	7.2E-06	3.8E-05	2.6E-05	1.1E-04	0.0E+00	7.2E-06	7.2E-06	7.2E-06	7.2E-06	7.1E-05
U237	0.0E+00	1.5E-13	2.1E-15	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
U238	7.1E-03	3.5E-01	1.4E-01	8.0E-01	0.0E+00	7.1E-03	7.1E-03	7.1E-03	7.1E-03	1.2E-01
Xe	1.4E-09	7.5E-10	7.7E-10	1.4E-09	2.3E-09	3.6E-09	1.3E-09	2.4E-09	2.7E-09	8.2E-10
Xylene	4.3E+00	4.5E+00	4.0E+00	4.3E+00	7.7E-03	1.5E+01	4.5E+00	9.8E+00	1.1E+01	7.9E+00
Y90	0.0E+00	5.5E-12	5.9E-13	3.1E-18	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.8E-18
Zr	0.0E+00	1.3E-07	3.2E-08	1.7E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-12

**APPENDIX A**

**Well-in-Plume Configurations  
(Sensitivity Simulations 19 and 20)**

The "Well-in-Plume" configurations considered in the response to FPIRT R2 IRs include a water supply well 100 metres to the east of WR-1 (Scenario 19) as well as a water supply well 10 metres to the east of WR-1 (Scenario 20). These locations are illustrated conceptually in the images below. Note that the "Well-in-Plume" configuration assessed in the DSAR (Golder, Member of WSP, 2021b) was at 250 metres to the east of the WR-1 building. All other input parameters for these sensitivity scenarios remain the same as that applied in the Normal Evolution Scenario (Base Case).



Base image above taken from inset image in Figure 4.3A of Original Groundwater Flow and Solute Transport Modelling Assessment (Golder, Member of WSP, 2021a)

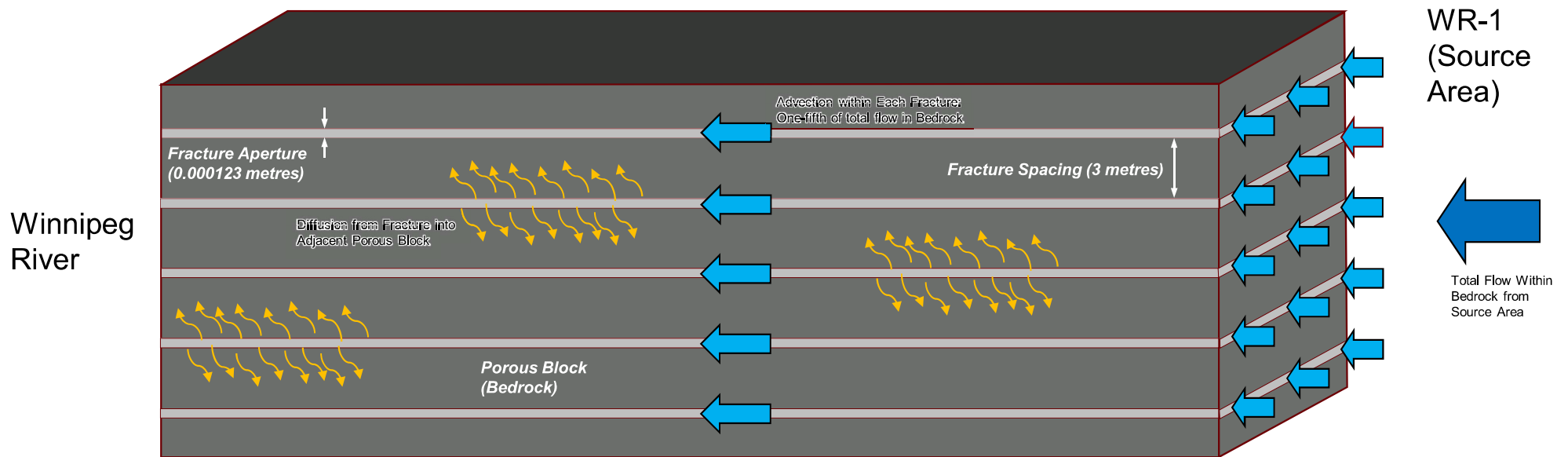
**APPENDIX B**

**Fractured Geo-Pathway (Sensitivity  
Simulations 21 and 22)**

Two sensitivity scenarios were completed to assess a wider range of assumptions for the hydraulic properties for the geo-pathway between WR-1 and the Winnipeg River to the west. In the Normal Evolution Scenario (provided in the original assessment; Golder, Member of WSP, 2021a), the geo-pathway between WR-1 and the Winnipeg River was simulated using equivalent porous media assumptions and properties associated with the bedrock at the site. In responding to FPIRT Round 2 IRs, two additional sensitivity scenarios were completed, both of which consider transport within the bedrock based on fracture flow assumptions. This appendix summarizes the model configuration for Sensitivity Scenario 21 (flow and transport within a set of 5 parallel fractures) and Sensitivity Scenario 22 (flow and transport within a set of 10 parallel fractures). The following summarizes the general framework for these simulations, while schematics of the model set-up are provided on page 2 of Appendix B for Scenario 21, and page 3 of Appendix B for Scenario 22:

- The release of mass from the WR-1 Source is that same as that calculated for the Normal Evolution Scenario.
- Total groundwater flow in the bedrock established from MODFLOW (EPM) model is routed through a set of 5 (Scenario 21) or 10 (Scenario 22) continuous fractures extending from WR-1 to the Winnipeg River. The rationale for the selection of this number of parallel fracture sets was based on a review of geological information from the site, which indicated on the order of 7 to 8 fractures in the upper 6 to 22 metres of bedrock at locations to the north of WR-1 (presented on page 4 of Appendix B).
- The width of the fracture pathway was assigned to be equal to the width of the WR-1 Source Area. This was considered a conservative approach as it does not account for potential lateral dispersion of solutes within the fractured bedrock pathway.
- The fracture aperture was assigned at 0.000123 m based on a review of information from fractured bedrock observed at boreholes just north of the WR-1 area (Davison, 1980).
- The fracture spacing for each Scenario was assigned at 3 metres based on a review of geological information from the site (presented on page 4 of Appendix B).
- Advective flow and transport occurs within the fractures only. There is no adsorption applied within the fracture itself, or on the fracture surface (a conservative assumption).
- Diffusion occurs from the fracture into the adjacent porous blocks of the bedrock. The properties of the porous blocks between the fractures are based on those applied for the bedrock in the Normal Evolution Scenario. Diffusion, adsorption and radioactive decay occur within the porous blocks between the fractures; however, there is no advection.

## Schematic Representation of Fracture Flow – Sensitivity Scenario 21



## Schematic Representation of Fracture Flow – Sensitivity Scenario 22



## Notes on Fracture Spacing

The logs below are from borehole televiewer survey's from locations near WR-1, describing the condition of fractures within the boreholes (Davison, 1980). The summaries below (in red text) are based on an interpretation of the logs for the current assessment. Based on Boreholes WN2 and WN3, the fracture spacing in the upper part of the bedrock ranges from ~ 0.8 metres to 3.1 metres (No open fractures were observed in WN4). Based on mapping of outcrops for the Lac du Bonnet Batholith, the average spacing (based on limited data) was estimated at 3.5 metres (CNL, 2021). For the purposes of the additional sensitivity scenarios, a fracture spacing estimate of 3.0 metres was applied.

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BOREHOLE TELEVISION SURVEY PAGE 1

PINAWA BOREHOLE WN2						
DEPTH (METRE)	DISCONTINUITY	WIDTH (MM)	INFILLING	WIDTH OF INFILLING (MM)	STRIKE (DEGREE)	DIP (DEGREE)
31.331	OPEN FRACTURE	.2			91	6
36.594	OPEN FRACTURE	.2			294	17
39.726	CLOSED FRACTURE	.2		.20	215	80
40.675	CLOSED FRACTURE	.2		.20	208	4
40.910	CLOSED FRACTURE	.3		.30	30	85
43.565	CLOSED FRACTURE	.1		.10	327	80
44.946	CLOSED FRACTURE	.2		.20	163	16
46.315	CLOSED FRACTURE	.2		.30	298	5
46.650	CONTACT				234	35
47.444	VEIN				144	48
49.752	OPEN FRACTURE	.4			148	53
49.815	OPEN FRACTURE	.3			321	34
49.842	OPEN FRACTURE	.4			134	53
50.022	OPEN FRACTURE	.3			137	62
50.212	CLOSED FRACTURE	.4		.40	163	16
53.226	OPEN FRACTURE	.4			0	6
54.262	VEIN	8.0			244	51
67.591	CLOSED FRACTURE	.3		.30	251	7
69.373	CLOSED FRACTURE	.2		.20	173	3
69.395	CLOSED FRACTURE	.2		.20	209	11
71.425	VEIN	24.0			280	82
73.273	VEIN	10.0			266	54
75.068	VEIN	9.0			205	48
75.456	CLOSED FRACTURE	.3		.30	324	8
77.135	CLOSED FRACTURE	.3		.30	340	13
77.491	CLOSED FRACTURE	.3		.30	318	14
79.608	CLOSED FRACTURE	.3		.30	201	4
82.324	CLOSED FRACTURE	.5		.50	73	11
87.045	CLOSED FRACTURE	.3		.30	256	43
90.316	CLOSED FRACTURE	.3		.30	275	6
90.414	VEIN	28.0			249	52
91.137	CLOSED FRACTURE	.2		.20	164	9
91.712	CLOSED FRACTURE	.2		.20	350	10
91.716	CLOSED FRACTURE	.2		.20	350	10
92.101	CLOSED FRACTURE	.2		.20	216	8
92.326	CLOSED FRACTURE	.2		.20	169	11
100.362	CLOSED FRACTURE	.2		.20	337	89
100.393	CLOSED FRACTURE	.2		.20	337	89
100.749	CLOSED FRACTURE	.2		.20	159	60
108.082	PARTLY OPEN FRACTURE	2.0		1.00	362	89

7 open fractures in the upper ~ 22 metres of bedrock

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BOREHOLE TELEVISION SURVEY PAGE 1

PINAWA BOREHOLE WN3						
DEPTH (METRE)	DISCONTINUITY	WIDTH (MM)	INFILLING	WIDTH OF INFILLING (MM)	STRIKE (DEGREE)	DIP (DEGREE)
32.335	CLOSED FRACTURE	.5		.50	322	9
32.774	CLOSED FRACTURE	.5		.50	357	14
35.156	CLOSED FRACTURE	.5		.50	237	74
35.358	CLOSED FRACTURE	.5		.50	217	84
35.996	CLOSED FRACTURE	.4		.40	77	81
36.293	CLOSED FRACTURE	.3		.30	237	59
36.795	CLOSED FRACTURE	.3		.30	262	74
36.725	PARTLY OPEN FRACTURE	.6		.20	57	24
36.805	PARTLY OPEN FRACTURE	.6		.20	57	29
36.832	SHEAR ZONE				57	29
36.878	OPEN FRACTURE	12.0		.10	57	39
36.891	OPEN FRACTURE	11.0		.10	57	39
37.127	OPEN FRACTURE	20.0		.10	42	44
37.133	OPEN FRACTURE	25.0		.10	42	44
37.550	OPEN FRACTURE	10.0		.30	32	34
37.572	SHEAR ZONE				32	34
38.147	PARTLY OPEN FRACTURE	.5		.25	317	14
38.149	CLOSED FRACTURE	.5		.50	7	29
38.269	CLOSED FRACTURE	.3		.30	7	24
38.270	CLOSED FRACTURE	.3		.30	7	14
38.302	CLOSED FRACTURE	.4		.40	57	84
39.297	CLOSED FRACTURE	.4		.40	30	69
39.354	CLOSED FRACTURE	.4		.40	187	69
39.377	CLOSED FRACTURE	.4		.40	177	69
39.430	CLOSED FRACTURE	.3		.30	27	74
41.205	CLOSED FRACTURE	1.0		1.00	32	77
47.884	CLOSED FRACTURE	.5		.50	252	9
47.932	CLOSED FRACTURE	.7		.70	247	11
53.384	CLOSED FRACTURE	.5		.50	247	29
57.247	CLOSED FRACTURE	.4		.40	222	9
57.257	CLOSED FRACTURE	.5		.50	222	19
72.200	CLOSED FRACTURE	.5		.50	192	29
72.213	CLOSED FRACTURE	.5		.50	197	34
73.238	CLOSED FRACTURE	.5		.50	172	14
73.558	CLOSED FRACTURE	.5		.50	162	9
87.871	CLOSED FRACTURE	.3		.30	47	69

8 open fractures in the upper ~ 6 metres of bedrock

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BOREHOLE TELEVISION SURVEY PAGE 1

PINAWA BOREHOLE WN4						
DEPTH (METRE)	DISCONTINUITY	WIDTH (MM)	INFILLING	WIDTH OF INFILLING (MM)	STRIKE (DEGREE)	DIP (DEGREE)
21.770	CLOSED FRACTURE	.6	CN	.60	139	81
27.499	CLOSED FRACTURE	1.0	CN	1.00	281	78
30.856	CLOSED FRACTURE	.8	CL	.80	272	5
30.902	CLOSED FRACTURE	.8	CN	.80	10	4
31.001	CLOSED FRACTURE	.6	NC	.60	107	3
31.782	CLOSED FRACTURE	.3	NC	.30	201	77
31.934	CLOSED FRACTURE	.6	NC	.60	222	85
32.320	CLOSED FRACTURE	.3	CN	.30	133	85
32.414	CLOSED FRACTURE	.4	CN	.40	202	85
33.005	CLOSED FRACTURE	.2	CL	.20	134	79
37.162	CLOSED FRACTURE	.2	CL	.20	317	88
37.861	CLOSED FRACTURE	.8	NC	.80	107	8
38.356	CLOSED FRACTURE	.3	CL	.30	182	70
39.938	CLOSED FRACTURE	2.0	NC	2.00	187	9
42.210	CLOSED FRACTURE	.3	CL	.30	48	3
49.863	CLOSED FRACTURE	.3	CL	.30	264	10
51.216	CLOSED FRACTURE	.5	CL	.50	9	3
53.912	CLOSED FRACTURE	.6	NC	.60	163	10
55.249	CONTACT				113	85
55.551	BAND	95.0			70	75
55.932	CONTACT				25	72
56.963	CONTACT				66	39
56.963	VEIN				68	39
59.098	VEIN	16.0			246	65
60.252	BAND	10.0			144	81
63.707	CLOSED FRACTURE	.4	CL	.40	213	12
65.184	CLOSED FRACTURE	1.0	CN	1.00	9	3
65.314	CLOSED FRACTURE	.7	CN	.70	168	9
68.938	CLOSED FRACTURE	.2	CL	.20	16	01
69.343	CLOSED FRACTURE	.2	CN	.20	53	13
71.184	CONTACT				316	31
71.123	BAND	28.0			317	32
71.142	CONTACT				318	35
80.384	CLOSED FRACTURE	.6	NC	.60	291	5
80.496	PARTLY OPEN FRACTURE	1.0	CL	.60	260	18
80.643	CLOSED FRACTURE	.8	CN	.80	259	19
80.721	CLOSED FRACTURE	.3	CN	.30	296	39
80.954	CLOSED FRACTURE	.2	CL	.20	179	15
83.002	CONTACT				297	49
83.042	BAND	40.5			297	49

0 open fractures in the upper ~ 30 metres of bedrock

**APPENDIX C**

**Adsorption Co-efficient Ranges  
(Sensitivity Simulations 23 and 24)**

The table below summarizes the Kd values considered in the original assessment, alongside revised estimates of the lower bound Kd (Scenario 23) and upper bound Kd.(Scenario 24) for the current assessment. All other parameter inputs for Sensitivity Scenario 23 and 24 remain the same as those applied for the Normal Evolution Scenario. The footnotes to the table describe the rationale followed for the selection of the upper and lower bound estimates.

Parameter	Kd Estimates Used in Original Assessment (mL/g)				Kd values from Sheppard & Thibault (1990) - Table A-1 (Sand Soil) <sup>(2)</sup>			Revised Lower Bound - Scenario 23 <sup>(3)</sup>	Revised Upper Bound - Scenario 24 <sup>(4)</sup>
	Normal Evolution Scenario (Base Case)	Lower Bound	Upper Bound	Data Source <sup>(1)</sup>	Mean	Lower Bound	Upper Bound		
Ac	1500	750	8100	3	450	67	2980	67	8100
Ag	0.4	0.4	40	4	90	2.7	1000	0.4	1000
Am	8000	2000	31000	1	1900	8.2	300000	8.2	300000
Ar	0	0	0	1	n/a	n/a	n/a	0	0
B	0.19	0.19	1.3	4	n/a	n/a	n/a	0.19	1.3
Ba	530	265	1060	4	n/a	n/a	n/a	265	1060
Be	1	1	1000	3	250	37	1640	1	1640
Bi	1	0	100	3	100	15	665	0	665
C	0	0	22	3	5	1.7	7.1	0	22
Ca	1	1	1000	3	5	0.9	40	0.9	1000
Cd	10	1	100	1	80	2.7	625	1	625
Ce	1500	750	8100	3	500	40	3968	40	8100
Cl	0	0	0	3	n/a	n/a	n/a	0	0
Cm	4000	2000	31000	2	4000	780	22970	780	31000
Co	1.94	0.97	3.88	4	60	0.07	9000	0.07	9000
Cr	1500	95	24000	1	70	1.7	1729	1.7	24000
Cs	3	2	5	1	280	0.2	10000	0.2	10000
Cu	41.9	20.95	83.8	4	n/a	n/a	n/a	20.95	83.8
Eu	1500	750	8100	3	n/a	n/a	n/a	750	8100
Fe	15	1.5	15	4	220	5	6000	1.5	6000
Gd	0	0	10	5	n/a	n/a	n/a	0	10
H	0	0	1	1	0.06	0.04	0.1	0	1
HB 40	0	0	10	5	n/a	n/a	n/a	0	10
He	0	0	0	5	n/a	n/a	n/a	0	0
Hg	322	161	644	4	n/a	n/a	n/a	161	644
I	0	0	0	1	1	0.04	81	0	81
K	0.3	0.2	0.4	1	15	2	90	0.2	90
KOH	0	0	0	4	n/a	n/a	n/a	0	0
Mn	16.5	8.25	33	4	50	6.4	5000	6.4	5000
Mo	0	0	25	1	10	1	52	0	52

Parameter	Kd Estimates Used in Original Assessment (mL/g)				Kd values from Sheppard & Thibault (1990) - Table A-1 (Sand Soil) <sup>(2)</sup>			Revised Lower Bound - Scenario 23 <sup>(3)</sup>	Revised Upper Bound - Scenario 24 <sup>(4)</sup>
	Normal Evolution Scenario (Base Case)	Lower Bound	Upper Bound	Data Source <sup>(1)</sup>	Mean	Lower Bound	Upper Bound		
N	0	0	0	4	n/a	n/a	n/a	0	0
Nb	210	84	530	1	160	25	1100	25	1100
Nd	1500	750	8100	3	n/a	n/a	n/a	750	8100
Ni	40	1	1000	3	400	60	3600	1	3600
Np	2	0.2	20	1	5	0.5	390	0.2	390
Pa	1500	95	24000	1	550	81	3640	81	24000
Pb	40	1	1000	3	270	19	1405	1	1405
Pd	6	1	30	1	55	8.2	365	1	365
Po	0	0	400	1	150	9	7020	0	7020
Pu	9	0.9	90	1	550	27	36000	0.9	36000
Ra	175	55	550	1	500	57	21000	55	21000
Rn	0	0	0	1	n/a	n/a	n/a	0	0
Ru	55	0.5	274	2	55	5	490	0.5	490
S	0	0	0	4	n/a	n/a	n/a	0	0
Sm	1500	95	24000	1	245	37	1640	37	24000
Sr	1	1	1000	3	15	0.05	190	0.05	1000
Tc	0.5	0.05	5	1	0.1	0.01	16	0.01	16
Th	800	50	12000	1	3200	207	150000	50	150000
Tl	0	0	0	4	n/a	n/a	n/a	0	0
U	5.7	0.9	36	3	35	0.03	2200	0.03	2200
Xe	0	0	0	5	n/a	n/a	n/a	0	0
Xylene	0	0	10	5	n/a	n/a	n/a	0	10
Y	170	85	720	2	170	25	1100	25	1100
Zr	2400	1000	6000	1	600	90	4000	90	6000

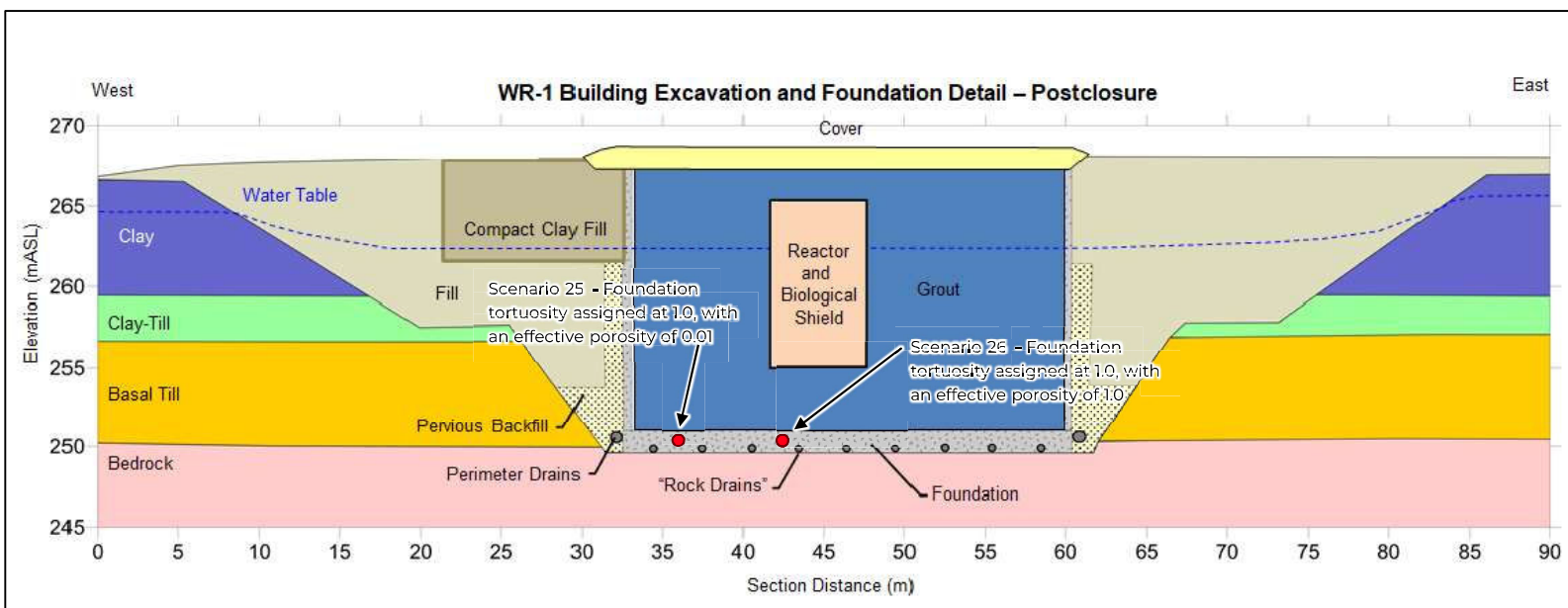
Notes:

1. Data Source; established from original assessment (Golder, Member of WSP, 2021a):
  - 1) Vandergraaf and Ticknor 1994, Table 2.
  - 2) Vandergraaf and Ticknor 1994, Table 3 value for Sand.
  - 3) Ticknor and Vandergraaf 1996.
  - 4) Stenge and Peterson 1989, Table 4.1. The value was selected based on less than 10% clay and a pH of 5.9.
  - 5) No data, assumed zero.
2. Mean estimate is the geometric mean of data, where lower bound and upper bound derived from range provided in Sheppard & Thibault
3. The lower bound Kd for Scenario 23 is the lowest of the lower bound estimates from the original assessment or Sheppard & Thibault (1990).
4. The upper bound Kd for Scenario 23 is the largest of the upper bound estimates from the original assessment or Sheppard & Thibault (1990).

**APPENDIX D**

**Diffusivity Assumptions (Sensitivity  
Simulations 25 and 26)**

Two sensitivity scenarios were completed to assess a wider range of assumptions for the diffusivity of (i.e., rate of diffusion through) the foundation relative to that considered in the Normal Evolution Scenario of the Original Assessment (Golder, Member of WSP). In both simulations, the tortuosity of the foundation was assigned at 1.0 (i.e., essentially a direct, minimum, pathway distance from the grout through the foundation), while the effective porosity of the foundation was varied from a minimum of 0.01 (Scenario 25) to a maximum of 1.0 (Scenario 26). This is illustrated in the schematic below. With respect to Scenario 26, the diffusion co-efficient across the foundation is essentially equal to the free solution diffusion co-efficient in water, which is noted as the upper bound of the diffusion co-efficient for a cracked foundation (Androuet, 2024). Note that in the Normal Evolution Scenario, the tortuosity of the foundation was assigned at 0.65, while its effective porosity was assigned at 0.6. The free-solution diffusion co-efficients for the sensitivity runs remain the same as those defined for the Normal Evolution Scenario (Golder, Member of WSP, 2021a; Table 4-6).



Base image above taken from inset image in Figure 4-1 of Original Groundwater Flow and Solute Transport Modelling Assessment (Golder, Member of WSP, 2021a)

**APPENDIX E**

**Hydraulic Conductivity  
Assignments for Grout (Sensitivity  
Simulations 27 and 28)**

Two sensitivity scenarios were completed to assess a wider range of assumptions for the hydraulic conductivity of the grout, cover and foundation materials relative to that considered in the Normal Evolution Scenario of the Original Assessment. In Sensitivity Scenario 27, the hydraulic conductivity was assigned at  $1.5 \times 10^{-6}$  m/s, consistent with the maximum value from the scale-up testing (WSP, 2023). For Sensitivity Scenario 28, an extreme upper bound estimate of  $1 \times 10^{-4}$  m/s was considered for these materials. In both cases, the higher hydraulic conductivities were applied at the beginning of the simulation. The results from these simulations with respect to flow rates used in the solute transport model assessment are provided in the table below.

**PARAMETERIZATION AND SIMULATED FLOW THROUGH WRDF COMPONENTS – BASE CASE NORMAL EVOLUTION SCENARIO:**

Time Following Decommissioning (Years)	Model Input Parameters					Simulated Flow (m <sup>3</sup> /day)		
	K (m/s)			Recharge (mm/year)		Grout	Foundation	Backfill
	Grout and Cover	Foundation	Backfill	Cover	Backfill			
0	5.0E-08	5.0E-10	1.0E-07	0.8	2.0	0.0062	0.011	0.167
500	1.0E-07	1.0E-09	1.0E-07	1.6	2.0	0.012	0.022	0.169
1,000	2.0E-07	2.0E-09	1.0E-07	3.2	2.0	0.024	0.043	0.173
2,000	5.0E-07	5.0E-09	1.0E-07	8.0	2.0	0.053	0.093	0.180
5,000	5.0E-07	5.0E-08	1.0E-07	8.0	2.0	0.12	0.24	0.186
10,000	5.0E-07	5.0E-07	1.0E-07	8.0	2.0	0.13	0.28	0.193

Above parameters and results are as presented on Table 4-4 of Golder, Member of WSP (2021a)

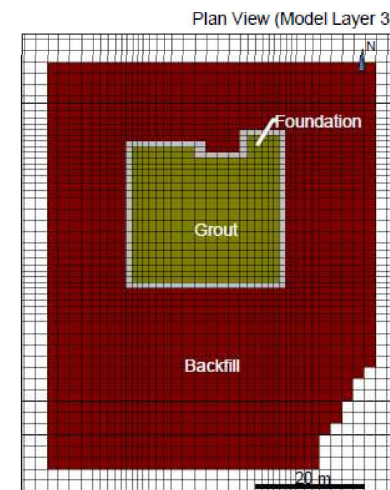
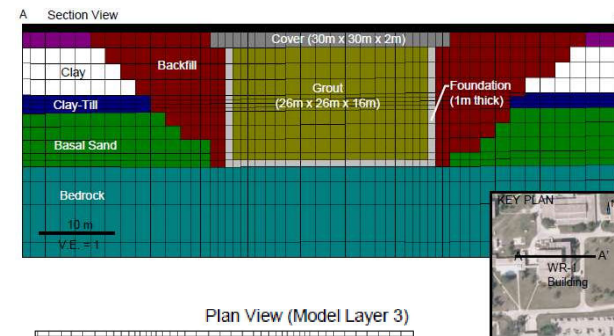
**PARAMETERIZATION AND SIMULATED FLOW THROUGH WRDF COMPONENTS – SENSITIVITY SCENARIO 27:**

Time Following Decommissioning (Years)	Model Input Parameters					Simulated Flow (m <sup>3</sup> /day)		
	K (m/s)			Recharge (mm/year)		Grout	Foundation	Backfill
	Grout and Cover	Foundation	Backfill	Cover	Backfill			
All Time Steps	1.5E-06	1.5E-06	1.0E-07	8.0	2.0	0.14	0.30	0.197

**PARAMETERIZATION AND SIMULATED FLOW THROUGH WRDF COMPONENTS – SENSITIVITY SCENARIO 28:**

Time Following Decommissioning (Years)	Model Input Parameters					Simulated Flow (m <sup>3</sup> /day)		
	K (m/s)			Recharge (mm/year)		Grout	Foundation	Backfill
	Grout and Cover	Foundation	Backfill	Cover	Backfill			
All Time Steps	1.0E-04	1.0E-04	1.0E-04	8.0	8.0	0.16	0.35	0.340

**GROUNDWATER FLOW MODEL REPRESENTATION OF POST-CLOSURE WRDF COMPONENTS:**



Images are based on those provided in Figure 4-2 of Golder, Member of WSP (2021a)

**APPENDIX F**

**Model Configuration with Higher  
Recharge Rates (Sensitivity  
Simulation 29)**

Sensitivity Simulation 29 was completed to give consideration to higher recharge rates into the native tills relative to that considered in the Normal Evolution Scenario (i.e., 11 mm/yr compared to the 0.8 mm/yr applied for the Normal Evolution Scenario). Recalibration of the hydraulic conductivity parameters assigned to the hydrostratigraphic units was required to accommodate the additional recharge. The "PEST" automated parameter estimation approach (Doherty and Hunt, 2010) was used to estimate the hydraulic conductivity of the hydrostratigraphic units required to provide the best match between the calibration targets and the simulated data for a scenario where the recharge across the entire model domain was set to 11 mm/year. The parameter values resulting from the PEST analysis are presented below along with the parameters for the Normal Evolution Scenario. A comparison of the quality of calibration between the Normal Evolution Scenario and Sensitivity Scenario 29 is provided on the next page of this appendix. As shown below, the hydraulic conductivity of the bedrock pathway is increased for Sensitivity Scenario 29 (from  $5 \times 10^{-7}$  m/s to  $4.1 \times 10^{-6}$  m/s) in order to accommodate the additional recharge. The resulting change in groundwater flow components based on this alternate calibration are summarized on the third page of this Appendix.

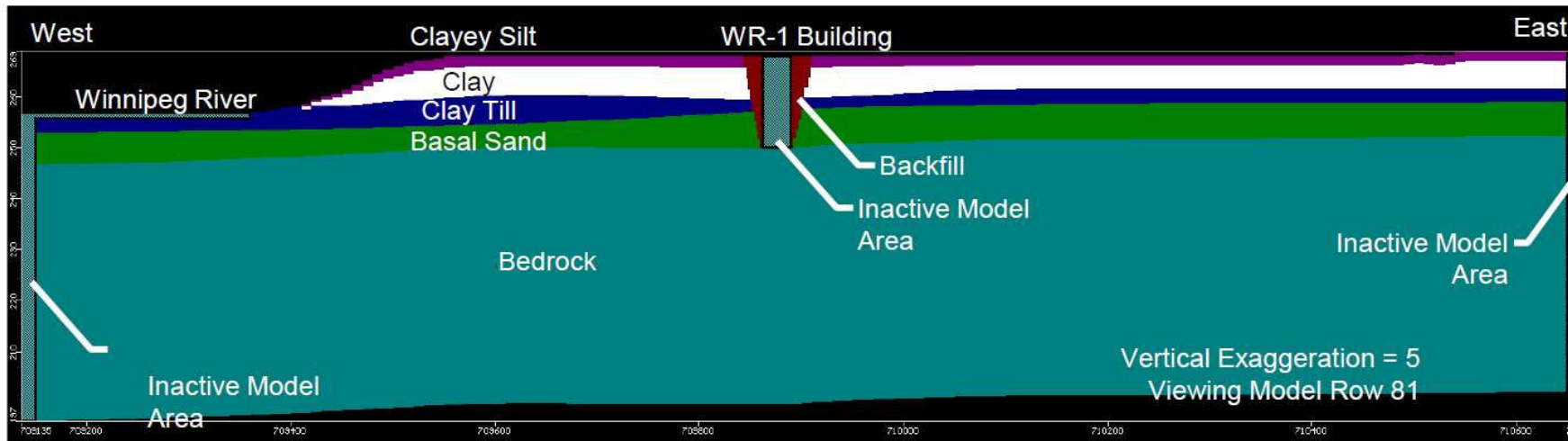
**PARAMETERIZATION OF HYDROSTRATIGRAPHIC UNITS  
 BASE CASE NORMAL EVOLUTION SCENARIO:**

Material	Hydraulic Conductivity (m/s)		$K_h:K_v$	Recharge (mm/year)
	Horizontal ( $K_h$ )	Vertical ( $K_v$ )		
Silty Clay	4.0E-08	4.0E-09	10	0.8
Clay	5.0E-09	4.0E-11	125	
Clay Till	1.0E-08	5.0E-11	200	
Basal Sand	1.7E-08	5.0E-11	340	
Bedrock	5.0E-07	5.0E-07	1	

**PARAMETERIZATION OF HYDROSTRATIGRAPHIC UNITS  
 SENSITIVITY SCENARIO 29:**

Material	Hydraulic Conductivity (m/s)		$K_h:K_v$	Recharge (mm/year)
	Horizontal ( $K_h$ )	Vertical ( $K_v$ )		
Silty Clay	1.4E-08	1.3E-07	0.1	11
Clay	4.1E-08	4.8E-10	85	
Clay Till	1.1E-10	4.6E-10	0.2	
Basal Sand	5.4E-07	1.4E-09	386	
Bedrock	4.1E-06	5.9E-06	0.7	

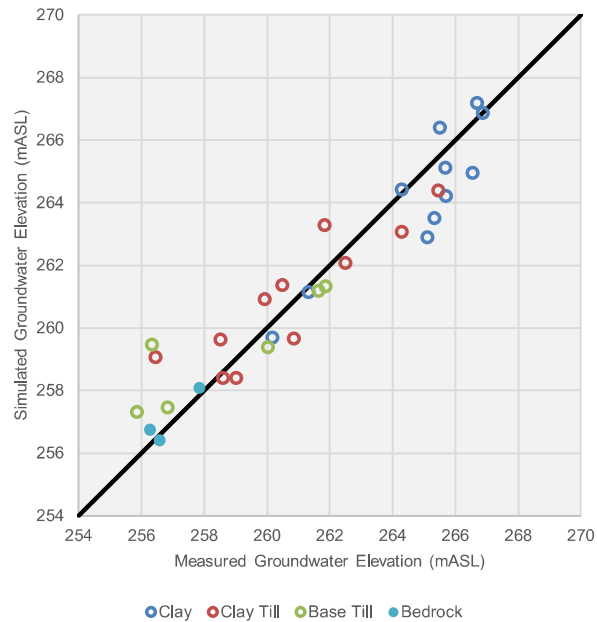
**CROSS-SECTION THROUGH GROUNDWATER FLOW MODEL ILLUSTRATING HYDROSTRATIGRAPHIC UNITS (CURRENT CONDITIONS):**



Based on an image provided in Figure 3-2 of Golder, Member of WSP (2021a)

Comparison of Calibration Quality

Base Case Normal Evolution Scenario  
 (as presented in Golder, Member of WSP, 2021)

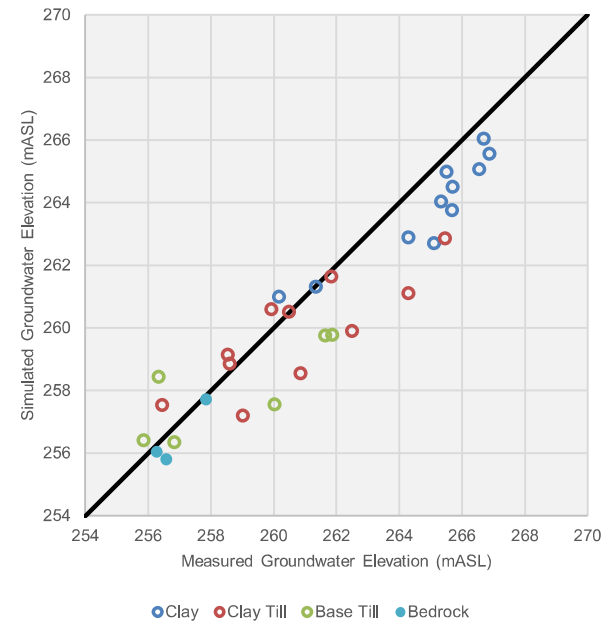


Calibration Statistics

Number of Data Points: 31  
 Normalized RMSE: 10.9%  
 Residual Mean Error: -0.008 m  
 Abs. Residual Mean Error: 0.95 m  
 Correlation Coefficient: 0.95

**Simulated Groundwater Inflow to Sump:** 24 m<sup>3</sup>/day

Sensitivity Scenario 29



Calibration Statistics

Number of Data Points: 31  
 Normalized RMSE: 13.9%  
 Residual Mean Error: -0.85 m  
 Abs. Residual Mean Error: 1.3 m  
 Correlation Coefficient: 0.94

**Simulated Groundwater Inflow to Sump:** 201 m<sup>3</sup>/day

Note: Measured inflow to sump: 24 m<sup>3</sup>/day to 31 m<sup>3</sup>/day (Golder, Member of WSP, 2021)

**PARAMETERIZATION AND SIMULATED FLOW THROUGH WRDF COMPONENTS – BASE CASE NORMAL EVOLUTION SCENARIO:**

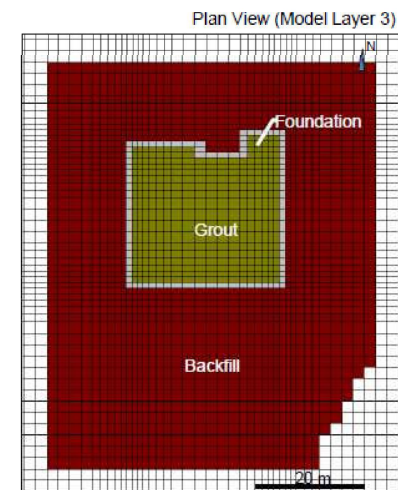
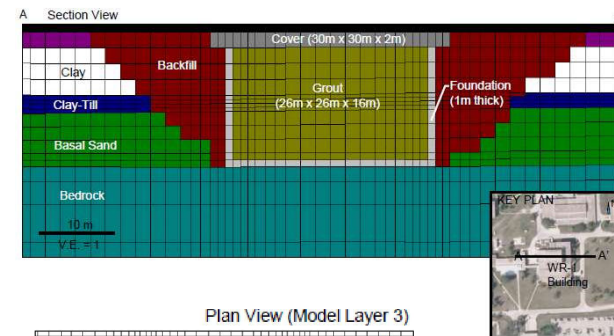
Time Following Decommissioning (Years)	Model Input Parameters					Simulated Flow (m <sup>3</sup> /day)		
	K (m/s)			Recharge (mm/year)				
	Grout and Cover	Foundation	Backfill	Cover	Backfill	Grout	Foundation	Backfill
0	5.0E-08	5.0E-10	1.0E-07	0.8	2.0	0.0062	0.011	0.167
500	1.0E-07	1.0E-09	1.0E-07	1.6	2.0	0.012	0.022	0.169
1,000	2.0E-07	2.0E-09	1.0E-07	3.2	2.0	0.024	0.043	0.173
2,000	5.0E-07	5.0E-09	1.0E-07	8.0	2.0	0.053	0.093	0.180
5,000	5.0E-07	5.0E-08	1.0E-07	8.0	2.0	0.12	0.24	0.186
10,000	5.0E-07	5.0E-07	1.0E-07	8.0	2.0	0.13	0.28	0.193

Above parameters and results are as presented on Table 4-4 of Golder, Member of WSP (2021a)

**PARAMETERIZATION AND SIMULATED FLOW THROUGH WRDF COMPONENTS – SENSITIVITY SCENARIO 29:**

Time Following Decommissioning (Years)	Model Input Parameters					Simulated Flow (m <sup>3</sup> /day)		
	K (m/s)			Recharge (mm/year)				
	Grout and Cover	Foundation	Backfill	Cover	Backfill	Grout	Foundation	Backfill
0	5.0E-08	5.0E-10	1.0E-07	11.0	2.0	0.023	0.028	0.608
500	1.0E-07	1.0E-09	1.0E-07	11.0	2.0	0.033	0.047	0.611
1,000	2.0E-07	2.0E-09	1.0E-07	11.0	2.0	0.052	0.086	0.618
2,000	5.0E-07	5.0E-09	1.0E-07	11.0	2.0	0.10	0.19	0.640
5,000	5.0E-07	5.0E-08	1.0E-07	11.0	2.0	0.34	0.69	0.748
10,000	5.0E-07	5.0E-07	1.0E-07	11.0	2.0	0.42	0.97	0.827

**GROUNDWATER FLOW MODEL REPRESENTATION OF POST-CLOSURE WRDF COMPONENTS:**



Images are based on those provided in Figure 4-2 of Golder, Member of WSP (2021a)

**ATTACHMENT 2**

**Whiteshell Reactor (WR-1):  
Groundwater Flow and Solute  
Transport Modelling – Extended  
Model Simulation Time Results to  
Assess Peak Mass Loading Rates**



## TECHNICAL MEMORANDUM

**DATE** November 2024

**Project No.** 20145046-31000

**TO** Jeffrey Miller  
Canadian Nuclear Laboratories

**FROM** Cameron Toy, Jennifer Levenick

**EMAIL** Cameron.Toy@wsp.com;  
Jennifer.Levenick@wsp.com

### **WHITESHELL REACTOR (WR-1): GROUNDWATER FLOW AND SOLUTE TRANSPORT MODELLING – EXTENDED MODEL SIMULATION TIME RESULTS TO ASSESS PEAK MASS LOADING RATES**

#### **1.0 INTRODUCTION**

Canadian Nuclear Laboratories (CNL) is in the process of decommissioning the Whiteshell Laboratories (WL) facilities, located near Pinawa, Manitoba. Part of this work will involve the decommissioning of Whiteshell Reactor 1 (WR-1), where the reactor is proposed to be disposed in-situ through below-grade macro-encapsulation with grout. An engineered cover and concrete cap will then be installed on top of the grout, extending above-ground surface. A groundwater flow and solute transport model (GWFSTM, Golder 2021) was developed and used to simulate the current and future (post-closure) conditions of the WL facilities, to support a Decommissioning Safety Assessment Report (DSAR) and an Environmental Impact Statement (EIS) for the in-situ disposal of WR-1. Golder (2021) documents the results of the base case assessment (i.e., the “Normal Evolution Scenario”) and 18 sensitivity simulations completed with the WR-1 groundwater flow and solute transport model to support the DSAR and EIS submissions.

The submissions in support of the WR-1 decommissioning plan have undergone a series of reviews from the Federal, Provincial and Indigenous Review Team (FPIRT), leading to a number of Information Requests (IRs) to help clarify the assessment. In the second round of the IRs, the FPIRT requested additional information from the groundwater flow and solute transport assessment to address uncertainties in the model inputs and assumptions. To address the FPIRT Round 2 IRs, 11 additional sensitivity simulations were completed with the GWFSTM, largely to consider an expanded range of model input parameters. These additional sensitivity simulations were documented in WSP (2024).

Subsequent to WSP (2024) being issued, it was identified that some solutes may not have reached their peak mass loading rate at the receptor and that an extended model simulation time (beyond the applied 500,000-year time period) may be required to effectively assess maximum predicted mass loading rates at the receptor. This memorandum presents the model results from these extended model simulations and compares these results to predicted peak loading rates from past assessments (Golder 2021, WSP 2024) to evaluate if new inputs to the site receptor model need to be considered. A similar process of extended simulation time needed to be completed in the original 2021 GWFSTM assessment (Golder 2021).

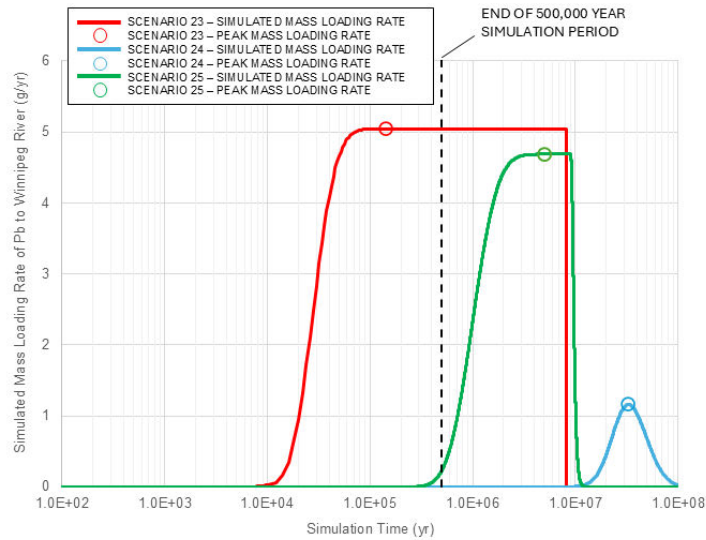
The model simulations were initially completed for a simulation period of 500,000 years, with the peak mass loading rate of each solute extracted from the results. The peak mass loading rates were extracted at the Winnipeg River, with the exception of the “Well-in-Plume” scenarios (i.e., Scenarios 19 and 20) where the peaks were extracted at the well location. Several solutes did not reach their peak mass loading rates within the 500,000-year simulation period. For the solutes identified to not reach their peak, either the peak mass loading rate was recorded at year 500,000 of the simulation (i.e., indicating that the rate may still be increasing at the time the simulation period ended) or the recorded peak mass loading rate was 0 grams per year (i.e., indicating that the solute had not begun discharging to the receiver by the end of the simulation period). This observation was attributed to a number of factors, including: the solute partition coefficient applied to the bedrock pathway; the time associated with ingrowth of these parameters from parent isotopes; and the release function applied to the reactor component to account for corrosion (Golder 2021).

## 2.0 EXTENDED SIMULATION MODELLING RESULTS AND CONCLUSIONS

Table 1 (scenarios simulating loading to the Winnipeg River) and Table 2 (scenarios simulating loading to a well) provide lists of the solutes requiring an extended simulation period to capture the peak mass loading rate for at least one of the 11 additional scenarios presented in WSP (2024). In general, with the exception of Scenario 24 which had a broader list of parameters that did not reach their peak, the solutes requiring extended simulation were consistent with those identified in the 2021 assessment. Scenario 24 involved the application of higher soil partition coefficients than previously assessed, which would be associated with slower solute migration through the bedrock pathway and higher likelihood that the peak loading rate would be slower to reach.

Figure 1 illustrates three typical situations where extending the simulation period was required to assess the peak mass loading rates. These situations are as follows:

- Simulated mass loading rates of a solute plateaued during the 500,000-year simulation period; however, since the loading rate did not begin decreasing during the 500,000-year simulation period, an extended simulation period was required to assess if the plateaued loading rate was representative of the peak value. This situation is illustrated on Figure 1 by the predicted mass loading of lead (Pb) to the Winnipeg River for Scenario 23.
- Simulated mass loading rates of a solute were zero grams per year throughout the 500,000-year simulation period; as such, an extended simulation period was required to assess whether the solute would begin to discharge to the receptor at a later time and at what peak loading rate. This situation is illustrated on Figure 1 by the predicted mass loading of Pb to the Winnipeg River for Scenario 24.
- Simulated mass loading rates for a solute were increasing at the end of the 500,000-year simulation period; as such, an extended simulation period was required to assess the peak mass loading rate. This situation is illustrated by the predicted mass loading of Pb to the Winnipeg River for Scenario 25.



**Figure 1 : Illustration of typical situations requiring extension of the simulation period to assess peak mass loading rates.**

Capturing the peak mass loading rates for each of the analyzed solutes generally required extending the simulation period to 50,000,000 years; however, for Scenario 24, some solutes required extending the simulation period to 2,000,000,000 years. No other changes were made to the groundwater flow or solute transport model previously documented by WSP (2024). Tables 1 and 2 present the time of peak mass loading occurrence for each solute requiring an extended run time for each sensitivity scenario.

The following observations are provided:

- Table 1 presents the results of the extended simulations (i.e., simulated peak mass loading rates to the Winnipeg River and time of peak occurrence) for solutes requiring an extended simulation period. Peak mass loading rates from the Normal Evolution Scenario, the maximum peak mass loading rates from the 18 sensitivity runs presented in the original GWFSTM (i.e., Scenarios 1 through 18), the maximum peak mass loading rates of the additional 11 sensitivity scenarios at the end of the previous 500,000-year simulation period (i.e., Scenarios 21 through 29) and the overall maximum peak mass loading rates from each of these previously reported results are provided on Table 1 for comparison. Inspection of Table 1 indicates that none of the peak mass loading rates from the extended simulation period simulations exceeded the previously reported maximum peak mass loading rates.
- Table 2 presents the results of the extended “Well-in-Plume” scenario simulations (i.e., simulated peak mass loading rates to the well and time of peak occurrence) for solutes requiring an extended simulation period. Peak mass loading rates from the Normal Evolution Scenario, Scenario 19 (limited to the 500,000-year simulation period), Scenario 20 (limited to the 500,000-year simulation period), and the overall maximum peak mass loading rates from each of these previously reported results are provided on Table 2 for comparison. Inspection of Table 2 indicates that none of the peak mass loading rates from the extended simulation period simulations exceeded the previously reported maximum peak mass loading rates.

Review of Table 1 and Table 2 identifies that the new peak loading rates predicted for the extended scenario simulations are either equivalent to or lower than peak mass loadings rates previously identified for the simulated solutes. As such, extending the simulation periods to capture the peak mass loading rates for all solutes for all scenarios resulted in no changes to the overall maximum peak mass loading rates previously reported by WSP (2024), and the peak loadings presented in WSP (2024) are still the appropriate values to consider in the site receptor model to determine the potential impact of these results on the overall assessment.

### 3.0 LIMITATIONS

This report was prepared for the exclusive use of Canadian Nuclear Laboratories Ltd. The report, which specifically includes all tables, figures and appendices, is based on data gathered by WSP, and information provided to WSP by others. The information provided by others has not been independently verified or otherwise examined by WSP to determine the accuracy or completeness. WSP has relied on this information in good faith and does not accept responsibility for any deficiency, misstatements, or inaccuracies contained in the information as a result of omissions, misinterpretation or fraudulent acts of the persons who provided the information. WSP shall not be held responsible for damages resulting from unpredictable or unknown underground conditions, from erroneous information provided by and/or obtained from sources other than WSP, and from ulterior changes in the site conditions unless WSP has been notified by Canadian Nuclear Laboratories Ltd. of any occurrence, activity, information or discovery, past or future, which would modify the underground conditions described herein, and have had the opportunity of revising its interpretations and comments. WSP shall not be held responsible for damages resulting from any future modification to the applicable regulations, standards and criteria. Any use of this report and its content by a third party is the responsibility of such third party. WSP shall not be held responsible for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

Hydrogeological investigations and groundwater modelling are dynamic and inexact sciences. They are dynamic in the sense that the state of any hydrological system is changing with time, and in the sense that the science is continually developing new techniques to evaluate these systems. They are inexact in the sense that groundwater systems are complex, and invariably limited data are available for the purposes of hydrogeological evaluation. A groundwater model uses the laws of science and mathematics to draw together the available data into a mathematical or computer-based representation of the essential features of an existing hydrogeological system. While the model itself obviously lacks the detailed reality of the existing hydrogeological system, the behaviour of a valid groundwater model reasonably approximates that of the real system. The validity and accuracy of the model depends on the amount of data available relative to the degree of complexity of the geologic formations and on the quality and degree of accuracy of the data entered. Therefore, every groundwater model is a simplification of reality and the model described herein is not an exception.

The services performed as described in this report were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and geoscience professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

The findings and conclusions of this report are valid only as of the date of this report. If new information is discovered in future work, including excavations, borings, or other studies, WSP should be requested to re-evaluate the findings of this report, and to provide amendments as required.

This report provides a professional opinion in light of the information available at the time of this report and therefore no warranty is either expressed, implied, or made as to the conclusions, advice or recommendations offered in this report.

## 4.0 REFERENCES

Golder, Member of WSP (2021). In-Situ Decommissioning of WR-1 at the Whiteshell Laboratories Site: WR-1 Groundwater Flow and Solute Transport Modelling – Revision 4. Submitted to Canadian Nuclear Laboratories, Whiteshell, Laboratories, Pinawa, MB. December 2021.

WSP (2024). Whiteshell Reactor 1 (WR-1): Groundwater Flow and Solute Transport Modelling – Additional Sensitivity Simulations Completed to Address Information Requests from the Federal, Provincial and Indigenous Review Team. July 16, 2024.

### WSP Canada Inc.



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CWT/JL



Jennifer Levenick, M.Sc.  
*Mine Water Group*

### LISTS OF TABLES

Table 1 – Peak Mass Loading Rates to Winnipeg River and Time of Peak Occurrence for Solutes Requiring Extended Simulation Period

Table 2 – Peak Mass Loading Rates to Well (Well-in-Plume Scenarios) and Time of Peak Occurrence for Solutes Requiring Extended Simulation Period

**TABLES**

**Table 1 – Peak Mass Loading Rates to Winnipeg River  
and Time of Peak Occurrence for Solutes Requiring  
Extended Simulation Period**

**Table 2 – Peak Mass Loading Rates to  
Well (Well-in-Plume Scenarios) and Time  
of Peak Occurrence for Solutes Requiring  
Extended Simulation Period**

TABLE 1 – Peak Mass Loading Rates to Winnipeg River and Time of Peak Occurrence for Solutes Requiring Extended Simulation Period

Solute	Previously Reported Simulated Peak Mass Loading Rates (g/yr)				Scenario 21 - Fractured GeoPathway (5 Fractures) Extended Simulation Period		Scenario 22 - Fractured GeoPathway (10 Fractures) Extended Simulation Period		Scenario 23 - Lower Kd in GeoPathway Extended Simulation Period		Scenario 24 - Higher Kd in GeoPathway Extended Simulation Period		Scenario 25 - Adjust Diffusivity for Foundation (fort = 1.0, n = 0.01) Extended Simulation Period		Scenario 26 - Maximum Diffusivity through Foundation (fort = 1.0, n = 1.0) Extended Simulation Period		Scenario 27 - Upper Bound K for Grout and Foundation (1.5 x 10 <sup>-6</sup> m/s) Extended Simulation Period		Scenario 28 - Maximum K for Grout, Foundation and Backfill (1.0 x 10 <sup>-4</sup> m/s) Extended Simulation Period		Scenario 29 - Increases to Recharge (11 mm/yr) and Bedrock K (4.1 x 10 <sup>-6</sup> m/s) Extended Simulation Period				
	Normal Evolution Scenario (Base Case) <sup>1</sup>	Maximum from Sensitivity Scenarios 1 through 10 <sup>1</sup>	Maximum from Sensitivity Scenarios 21 through 29 (Standard Simulation Period) <sup>2</sup>	Maximum Previously Reported	Time of Peak Mass Loading (yr)	Peak Mass Loading (g/yr)	Time of Peak Mass Loading (yr)	Peak Mass Loading (g/yr)	Time of Peak Mass Loading (yr)	Peak Mass Loading (g/yr)	Time of Peak Mass Loading (yr)	Peak Mass Loading (g/yr)	Time of Peak Mass Loading (yr)	Peak Mass Loading (g/yr)	Time of Peak Mass Loading (yr)	Peak Mass Loading (g/yr)	Time of Peak Mass Loading (yr)	Peak Mass Loading (g/yr)	Time of Peak Mass Loading (yr)	Peak Mass Loading (g/yr)	Time of Peak Mass Loading (yr)	Peak Mass Loading (g/yr)			
	Ac225	1.7E-17	1.7E-16	1.7E-17	1.7E-16	--	--	--	--	--	5.9E+06	1.8E-18	--	--	--	--	--	--	--	--	--	--	--		
Ac227	1.4E-14	1.4E-13	4.4E-14	1.4E-13	--	--	--	--	--	4.5E+07	3.2E-15	--	--	--	--	--	--	--	--	--	--	--			
Ba	1.5E-23	1.1E-07	9.1E-07	9.1E-07	--	--	--	--	5.4E+06	3.6E-08	2.2E+07	9.1E-09	1.1E+07	1.8E-08	1.1E+07	1.8E-08	1.1E+07	1.8E-08	1.1E+07	1.8E-08	6.5E+05	3.0E-07			
Bi210	2.3E-14	6.5E-13	2.3E-14	6.5E-13	--	--	--	--	--	4.5E+07	1.6E-16	--	--	--	--	--	--	--	--	--	--	--			
Ca41	1.6E-06	2.1E-05	5.5E-05	5.5E-05	--	--	--	--	--	3.1E+06	7.3E-25	--	--	--	--	--	--	--	--	--	--	--			
Cd	3.7E-01	4.8E+00	1.8E+01	1.8E+01	--	--	--	--	--	1.3E+07	5.9E-03	--	--	--	--	--	--	--	--	--	--	--			
Co	2.1E-02	2.1E-01	2.7E-02	2.1E-01	--	--	--	--	--	1.8E+08	1.7E-05	--	--	--	--	--	--	--	--	--	--	--			
Cr	5.0E-27	1.2E-04	3.5E+00	3.5E+00	--	--	--	--	--	4.9E+08	2.5E-04	3.1E+07	4.0E-03	3.1E+07	4.0E-03	3.1E+07	4.0E-03	3.1E+07	4.0E-03	3.1E+07	4.0E-03	1.9E+06	6.6E-02		
Cu	2.0E-04	4.9E-03	1.3E-02	1.3E-02	--	--	--	--	--	1.7E+06	2.6E-04	8.8E+05	5.5E-04	8.8E+05	5.5E-04	8.8E+05	5.5E-04	8.8E+05	5.5E-04	8.8E+05	5.5E-04	--	--		
HB40	4.1E+01	8.2E+01	1.3E+02	1.3E+02	--	--	--	--	--	2.2E+06	4.1E+01	--	--	--	--	--	--	--	--	--	--	--			
Hg	1.4E-18	5.4E-04	2.1E-03	2.1E-03	--	--	--	--	3.3E+06	8.3E-05	1.3E+07	2.1E-05	6.6E+06	4.2E-05	6.6E+06	4.2E-05	6.6E+06	4.2E-05	6.6E+06	4.2E-05	6.6E+06	4.2E-05	--	--	
I129	1.4E-04	1.4E-03	3.5E-04	1.4E-03	--	--	--	--	--	1.6E+06	2.0E-08	--	--	--	--	--	--	--	--	--	--	--			
K	3.3E-07	3.3E-06	3.7E-07	3.3E-06	--	--	--	--	--	2.0E+06	1.9E-08	--	--	--	--	--	--	--	--	--	--	--			
Mn	8.3E-05	5.8E-04	1.1E-03	1.1E-03	--	--	--	--	--	1.0E+08	2.8E-07	--	--	--	--	--	--	--	--	--	--	--			
Mo	1.2E-02	1.2E-01	1.2E-02	1.2E-01	--	--	--	--	--	1.1E+06	3.5E-04	--	--	--	--	--	--	--	--	--	--	--			
Nb94	1.5E-21	2.7E-07	3.0E-03	3.0E-03	--	--	--	--	--	--	--	6.2E+05	6.6E-21	6.3E+05	6.6E-21	6.2E+05	6.6E-21	6.2E+05	6.6E-21	6.2E+05	6.6E-21	--	--		
Ni	2.0E-05	9.8E-04	1.1E-03	1.1E-03	--	--	--	--	--	7.4E+07	5.0E-07	8.4E+05	4.8E-05	8.4E+05	4.8E-05	8.4E+05	4.8E-05	8.4E+05	4.8E-05	8.4E+05	4.8E-05	8.4E+05	4.8E-05	--	--
Np237	5.2E-06	6.2E-05	1.6E-04	1.6E-04	--	--	--	--	--	5.7E+06	3.1E-09	--	--	--	--	--	--	--	--	--	--	--			
Pa231	2.2E-11	2.2E-10	6.8E-11	2.2E-10	--	--	--	--	--	4.5E+07	1.7E-12	--	--	--	--	--	--	--	--	--	--	--			
Pa233	2.3E-16	3.5E-15	1.0E-14	1.0E-14	--	--	--	--	--	5.7E+06	1.7E-18	--	--	--	--	--	--	--	--	--	--	--			
Pb	2.5E-01	5.9E+00	1.6E+01	1.6E+01	8.1E+06	4.9E+00	8.1E+06	4.8E+00	--	3.3E+07	1.2E+00	8.8E+06	4.7E+00	7.5E+06	5.5E+00	7.7E+06	5.4E+00	6.5E+06	6.5E+00	5.9E+05	1.6E+01	--	--		
Pb210	9.3E-13	9.3E-12	9.3E-13	9.3E-12	--	--	--	--	--	4.5E+07	1.3E-13	--	--	--	--	--	--	--	--	--	--	--			
Pd	1.0E-01	1.3E+00	5.3E+00	5.3E+00	--	--	--	--	--	7.5E+06	1.7E-03	--	--	--	--	--	--	--	--	--	--	--			
Po210	1.6E-10	1.6E-09	1.6E-10	1.6E-09	--	--	--	--	--	4.5E+07	4.3E-16	--	--	--	--	--	--	--	--	--	--	--			
Ra223	3.4E-16	3.4E-15	1.1E-15	3.4E-15	--	--	--	--	--	4.5E+07	3.5E-18	--	--	--	--	--	--	--	--	--	--	--			
Ra224	6.7E-22	6.7E-21	6.7E-22	6.7E-21	--	--	--	--	--	2.0E+09	8.3E-22	2.6E+06	6.7E-22	2.6E+06	6.7E-22	2.6E+06	6.7E-22	2.6E+06	6.7E-22	2.6E+06	6.7E-22	--	--		
Ra225	2.2E-16	2.2E-15	2.2E-16	2.2E-15	--	--	--	--	--	5.9E+06	1.1E-18	--	--	--	--	--	--	--	--	--	--	--			
Ra226	1.6E-11	1.6E-10	1.6E-11	1.6E-10	--	--	--	--	--	4.5E+07	6.5E-13	--	--	--	--	--	--	--	--	--	--	--			
Ra228	3.9E-19	3.9E-18	3.9E-19	3.9E-18	--	--	--	--	--	--	--	2.6E+06	3.9E-19	2.6E+06	3.9E-19	2.6E+06	3.9E-19	2.6E+06	3.9E-19	2.6E+06	3.9E-19	2.6E+06	3.9E-19	--	--
Rn222	4.8E-12	4.8E-11	4.8E-12	4.8E-11	--	--	--	--	--	4.5E+07	2.3E-11	--	--	--	--	--	--	--	--	--	--	--			
Ru	6.2E-09	8.7E-08	3.3E-08	8.7E-08	--	--	--	--	--	6.7E+06	1.1E-08	--	--	--	--	--	--	--	--	--	--	--			
Sm	0.0E+00	1.8E-13	4.0E-10	4.0E-10	--	--	--	--	7.6E+05	2.4E-10	4.9E+08	3.8E-13	3.1E+07	6.3E-12	3.1E+07	6.0E-12	3.1E+07	6.1E-12	3.1E+07	6.2E-12	1.9E+06	1.0E-10	--	--	
Sm148	1.4E-24	2.1E-22	4.0E-22	4.0E-22	--	--	--	--	7.3E+05	2.8E-22	5.0E+06	2.3E-22	--	--	--	--	--	--	--	--	--	1.8E+06	6.7E-23	--	--
Th227	6.1E-17	6.1E-16	1.9E-16	6.1E-16	--	--	--	--	--	4.5E+07	4.1E-19	--	--	--	--	--	--	--	--	--	--	--			
Th228	2.8E-20	2.8E-19	2.8E-20	2.8E-19	--	--	--	--	--	2.0E+09	2.3E-20	2.6E+06	2.8E-20	2.6E+06	2.8E-20	2.6E+06	2.8E-20	2.6E+06	2.8E-20	2.6E+06	2.8E-20	2.6E+06	2.8E-20	--	--
Th229	8.7E-12	8.7E-11	8.8E-12	8.7E-11	--	--	--	--	--	5.9E+06	2.7E-14	--	--	--	--	--	--	--	--	--	--	--			
Th230	1.7E-10	1.7E-09	1.7E-10	1.7E-09	--	--	--	--	--	4.5E+07	4.4E-12	--	--	--	--	--	--	--	--	--	--	--			
Th231	4.6E-18	7.0E-17	5.8E-16	5.8E-16	--	--	--	--	--	4.5E+07	2.4E-20	--	--	--	--	--	--	--	--	--	--	--			
Th232	2.1E-10	2.1E-09	2.1E-10	2.1E-09	--	--	--	--	--	2.0E+09	1.7E-10	2.6E+06	2.1E-10	2.6E+06	2.1E-10	2.6E+06	2.1E-10	2.6E+06	2.1E-10	2.6E+06	2.1E-10	2.6E+06	2.1E-10	--	--
Th234	7.3E-16	1.2E-14	5.1E-14	5.1E-14	--	--	--	--	--	4.5E+07	3.9E-18	--	--	--	--	--	--	--	--	--	--	--			
U233	2.8E-08	2.8E-07	9.1E-08	2.8E-07	--	--	--	--	--	5.9E+06	4.1E-11	--	--	--	--	--	--	--	--	--	--	--			
U234	1.4E-07	1.4E-06	3.8E-06	3.8E-06	--	--	--	--	--	4.5E+07	9.9E-10	--	--	--	--	--	--	--	--	--	--	--			
U235	1.6E-04	1.9E-03	1.6E-02	1.6E-02	--	--	--	--	--	4.5E+07	4.0E-07	--	--	--	--	--	--	--	--	--	--	--			
U236	7.2E-06	7.2E-05	1.1E-04	1.1E-04	--	--	--	--	--	3.7E+07	5.7E-09	--	--	--	--	--	--	--	--	--	--	--			
U238	7.1E-03	9.1E-02	8.0E-01	8.0E-01	--	--	--	--	--	4.5E+07	1.8E-05	--	--	--	--	--	--	--	--	--	--	--			
Zr	0.0E+00	8.5E-14	1.3E-07	1.3E-07	--	--	--	--	1.8E+06	4.6E-08	1.2E+08	6.9E-10	4.9E+07	1.7E-09	4.9E+07	1.7E-09	4.9E+07	1.7E-09	4.9E+07	1.7E-09	4.9E+07	1.7E-09	3.0E+06	2.8E-08	

Notes:

<sup>1</sup> Golder, 2021

<sup>2</sup> WSP, 2024

Standard Simulation Period is 500,000 years

Extended Simulation Period length varied as required to capture peak mass loading rates for all solutes

"--" in the Extended Simulation Period results indicates that the peak occurred during the Standard Simulation Period and are reported in WSP (2024)

This table contains only the solutes that required an Extended Simulation Period to capture the peak mass loading rate for at least one of Scenario 21 through 29. Results for all solutes for these scenarios are presented in WSP (2024).

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**TABLE 2 – Peak Mass Loading Rates to Well (Well-in-Plume Scenarios) and Time of Peak Occurrence for Solutes Requiring Extended Simulation Period**

Solute	Previously Reported Simulated Peak Mass Loading Rates (g/yr)				Scenario 19 - Supply Well at 100 m Extended Simulation Period		Scenario 20 - Supply Well at 10 m Extended Simulation Period	
	Normal Evolution Scenario (Base Case) <sup>1</sup>	Scenario 19 (Standard Simulation Period) <sup>2</sup>	Scenario 20 (Standard Simulation Period) <sup>2</sup>	Maximum Previously Reported	Time of Peak Mass Loading (yr)	Peak Mass Loading (g/yr)	Time of Peak Mass Loading (yr)	Peak Mass Loading (g/yr)
<b>Ba</b>	3.6E-08	9.1E-08	9.1E-07	9.1E-07	2.2E+06	9.1E-08	--	--
<b>Cr</b>	8.0E-03	2.0E-02	2.0E-01	2.0E-01	6.1E+06	2.0E-02	6.1E+05	2.0E-01
<b>Hg</b>	8.3E-05	2.1E-04	2.1E-03	2.1E-03	1.3E+06	2.1E-04	--	--
<b>Pb</b>	5.0E+00	5.0E+00	5.0E+00	5.0E+00	5.7E+06	5.0E+00	--	--
<b>Sm</b>	1.2E-11	3.0E-11	3.0E-10	3.0E-10	6.1E+06	3.0E-11	6.1E+05	3.0E-10
<b>Sm148</b>	1.3E-23	3.0E-23	2.9E-22	2.9E-22	--	--	6.1E+05	2.9E-22
<b>Zr</b>	3.4E-09	8.6E-09	8.6E-08	8.6E-08	9.8E+06	8.6E-09	9.8E+05	8.6E-08

**Notes:**

<sup>1</sup> Golder, 2021

<sup>2</sup> WSP, 2024

Standard Simulation Period is 500,000 years

Extended Simulation Period length varied as required to capture peak mass loading rates for all solutes

"--" in the Extended Simulation Period results indicates that the peak occurred during the Standard Simulation Period and are reported in WSP (2024)

This table contains only the solutes that required an Extended Simulation Period to capture the peak mass loading rate for at least one of Scenario 19 or 20.

Results for all solutes for these scenarios are presented in WSP (2024).