Title:
2024 NUCLEAR SUSTAINABILITY SERVICE – WESTERN GROUNDWATER PROGRAM RESULTS

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Table of Contents

List of Figures, Graphs and Tables

Page

Revision Summary

Revision Number	Date	Comments
000	2025-11-07	Initial issue.

Land Acknowledgement

Ontario Power Generation acknowledges that the Western Waste Management Facility is located on the traditional territory of the Chippewas of Saugeen First Nation and the Chippewas of Nawash Unceded First Nation, collectively known as the Saugeen Ojibway Nation, and are the traditional keepers of the land. The area is also home to many diverse First Nations, Inuit and Métis peoples and as a company, we remain committed to fostering positive and mutually beneficial relationships with Indigenous people and communities across Ontario.

Executive Summary

The Western Waste Management Facility (WWMF) and the Radioactive Waste Operations Site 1 (RWOS1) have a mature and robust groundwater protection program. The groundwater monitoring aspect of the program is in place to address the following primary goals:

- Monitor changes to on-site groundwater quality to ensure timely detection of inadvertent releases to groundwater;
- Confirm predominant on-site groundwater flow characteristics at both sites; and
- Ensure no adverse off-site impacts from groundwater beneath the WWMF and RWOS1.

The findings in 2024 with respect to the monitoring program include the following:

- The groundwater data collected from the systems, structures and components indicate tritium concentrations are:
    - consistent with results for previous years and expected fluctuations associated with ongoing operations;
    - where tritium concentrations have been elevated above background conditions historically, they are generally showing improvement (decreased concentrations); or
    - in a small number of wells where tritium concentrations in groundwater were showing an increasing trend, the increases are understood to be associated with historical conditions.
- The predominant groundwater flow patterns in 2024 remain unchanged from interpretations in recent years.
- Tritium concentrations within the site perimeter wells are at background levels and do not indicate potential risks to off-site water quality and use beneath the WWMF or RWOS1.

1.0 INTRODUCTION

The Western Waste Management Facility (WWMF) and Radioactive Waste Operations Site 1 (RWOS1) are located at the Bruce Nuclear site, within the municipality of Kincardine in the County of Bruce. The WWMF and RWOS1 are each situated about 1.1 km from the east shore of Lake Huron, near the Village of Tiverton. The WWMF is licensed by the Canadian Nuclear Safety Commission (CNSC) as a class 1B Nuclear Facility to manage and store radioactive waste from Ontario Power Generation's (OPG's) and Bruce Power's nuclear generating station. The RWOS1 is located approximately 660 m southwest relative to the WWMF and operates under a Waste Nuclear Substance Licence.

For the purposes of this groundwater program results report, when referring to both WWMF and RWOS1, they are collectively identified as "the Site". The Site has a mature and robust annual groundwater monitoring program in place. The program examines the chemical, radiological, and physical characteristics of the groundwater beneath the Site.

The following objectives for the groundwater monitoring program are documented in the CSA N288.7-compliant WWMF and RWOS1 Groundwater Protection Monitoring Program (GWPMP) (Ecometrix, 2022a):

- Objective 1:
    - monitor tritium concentrations in groundwater near Low-Level Storage Buildings (LLSBs), Steam Generator Storage Building (SGSB), and the Retube Component Storage Building (RCSB) within the WWMF to ensure timely detection of inadvertent releases to groundwater;
    - monitor tritium concentrations in groundwater beneath the RWOS1 to ensure timely detection of inadvertent releases to groundwater;
    - establish and monitor background tritium concentrations in groundwater at the WWMF;
- Objective 2: confirm the predominant on-site groundwater flow characteristics beneath the WWMF and RWOS1; and
- Objective 3: monitor tritium concentrations in groundwater on the perimeter of the WWMF and RWOS1 in the direction of groundwater flow ("Downgradient Perimeter") to confirm no adverse off-site impacts to groundwater quality.

The location of the WWMF and RWOS1 are shown in Figure 1. Within the WWMF, the LLSBs, SGSB and RWCB are shown in Figure 2, along with other infrastructure including the Used Fuel Dry Storage building. Stages 1, 3 and 3E are discussed as well in this report, which pertains to the trenches, tile hole inground container and Quadricell area, which are shown in Figure 2.

The groundwater sampling and monitoring program conducted in 2024 followed the Sampling and Analysis Plan (SAP) for 2024 (Ecometrix, 2024). This report presents groundwater data collected at WWMF and RWOS1 for the period from January 1 to December 31, 2024.

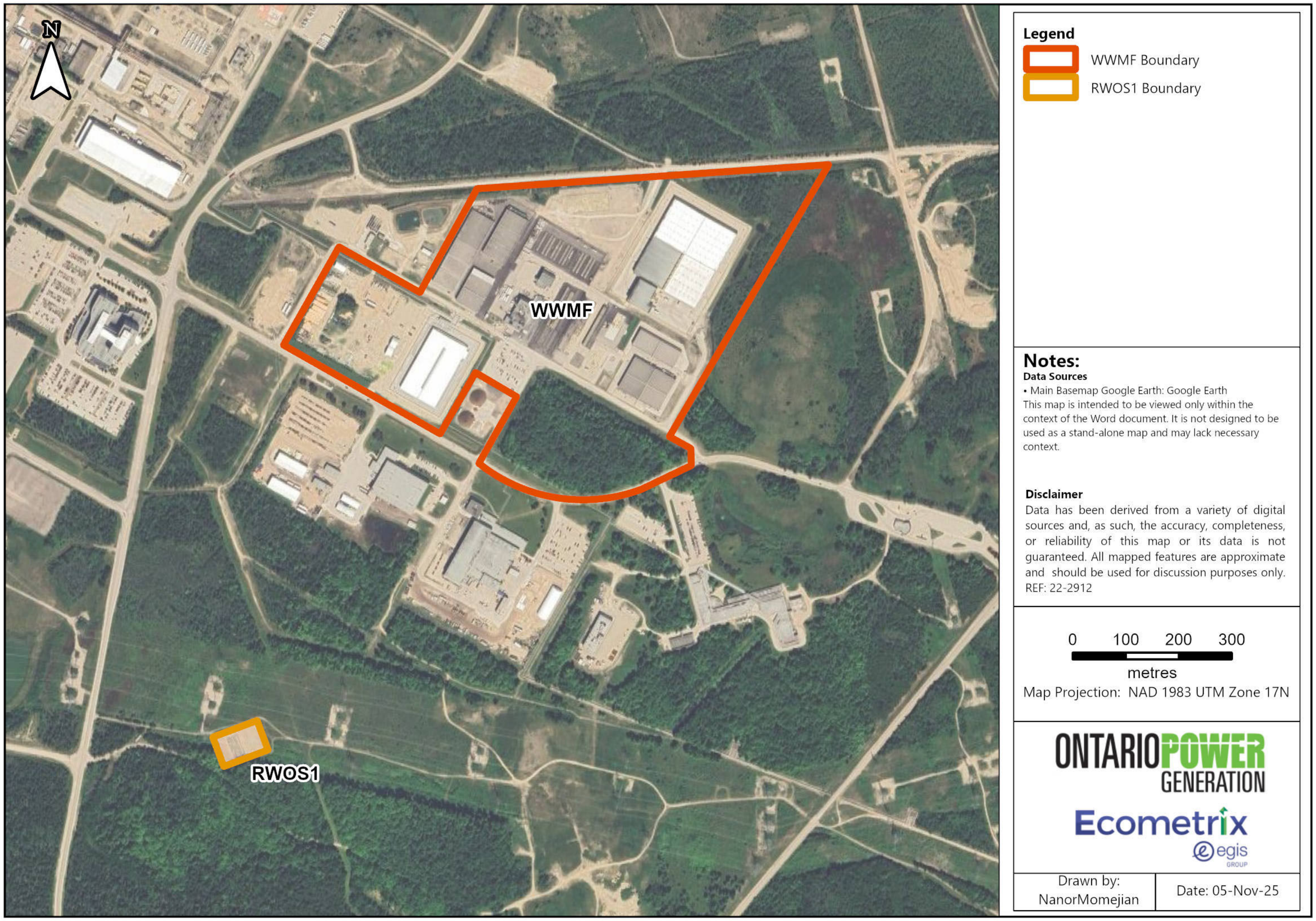


Figure 1: WWMF & RWOS1 Location and Boundaries

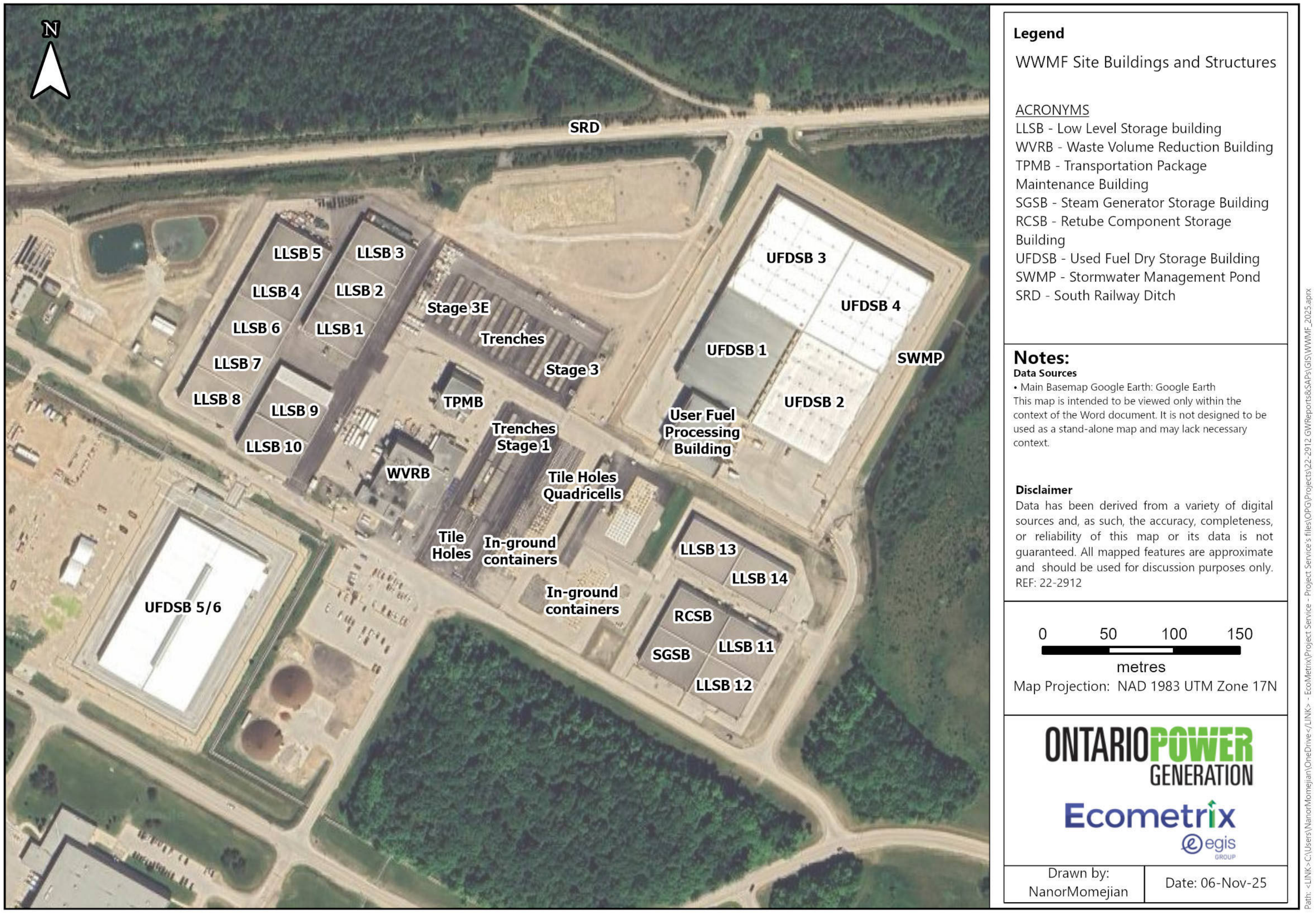


Figure 2: WWMF Site Buildings and Structures

1.1 Summary of Hydrogeological Characteristics at the WWMF and RWOS1

Historical assessments identified 7 hydrostratigraphic units (HUs) beneath the WWMF and RWOS1. Of the 7 HUs, 3 main groundwater flow systems (comprised of 5 HUs) have been identified for the Site:

- HU1-3: Perched/Shallow Water Table, comprised of fill, native sand, and silt till;
- HU4: Middle Sands Aquifer (MSA);
- HU5: Unweathered Till, comprised of Lower Silt Till;
- HU6: The basal sand unit; and
- HU7: Limestone/Dolostone Bedrock.

Surficial fill materials at the Site (HU1) are unsaturated and lie above the water table. The underlying sands (HU2) are silty and frequently contain gravel, and are unsaturated or saturated, depending on the location. Underlying HU2 is a weathered till unit of clayey to sandy dense subglacial silt till with interbeds of fine to coarse sand, and fine to coarse gravel (HU3). The HU4 consists of beds of silty fine sand to well-sorted sand with occasional gravel layers and some silt till interbeds and represents an aquifer. The HU5 shares similar characteristics to HU3 but this deeper till is less weathered and more competent. HU5 with HU3, which is treated as a single unit where HU4 is absent, reaches thicknesses of up to 15 m. The basal sand unit (HU6) is discontinuous as well and where it occurs, HU6 and HU7 are treated as a single aquifer unit in this report.

Groundwater flow is generally vertical downwards across the fine-grained till units, and horizontal within the aquifer units (Ecometrix, 2022b).

At the RWOS1, overburden beneath the western portion of the Site consists of till overlying dolostone bedrock, and overburden beneath the eastern portion of the Site consists of sand and lesser till overlying bedrock. The monitoring wells in the eastern portion of the Site are installed within the native sands, which are found to extend approximately 4 to 6 m from the ground surface to bedrock. Groundwater is encountered at the sand-bedrock interface. The groundwater monitored is considered to represent a single unconfined HU and best aligns with HU2 at the WWMF.

1.2 Subsurface Drainage System at the WWMF and Discharge Infrastructure

Inside the WWMF fenced area, groundwater and surface water are collected by several engineered drainage systems. The surface drainage system captures runoff from precipitation and discharges collected water to the South Railway Ditch (SRD).

The subsurface drainage system at the WWMF includes drains and sumps associated with building foundations, tile holes or trenches. Buildings with subsurface drainage systems include the LLSBs (#2 to 10, #11 to 14), SGSB, RCSB and the Used Fuel Dry Storage building. The LLSB #1 does not have a subsurface drainage system.

Water collected by the subsurface drainage systems is directed to either the SRD or the Stormwater Management Pond (SWMP or "grassed swale"). The SRD and SWMP are shown in Figure 2**.** Monitoring of the groundwater quality collected by the subsurface drainage is part of the GWPMP for the WWMF, Objective 1.

2.0 2024 PROGRAM DESIGN

The groundwater monitoring program design is detailed in the WWMF GWPMP (Ecometrix, 2022a). The CSA N288.7-compliant 2024 SAP (Ecometrix, 2022c) was developed to meet the relevant components of the objectives listed above.

In 2024, groundwater samples were collected from 57 sampling locations, including groundwater monitoring wells and subsurface drainage structures. Earlier in 2023, 3 new wells were installed and will be sampled beginning 2025. Sample results of the groundwater quality monitoring are provided in Appendix A: Tables A-1 to A-7.

The 2024 SAP specified the sampling locations and the frequency of sampling tritium concentrations in groundwater at each location (e.g., semi-annually or annually) (Ecometrix, 2024).

Groundwater monitoring activities specified in the GWPMP and SAP include:

- water level measurements before the collection of groundwater samples;
- purging to remove standing water from the wells prior to sample collection to collect groundwater representative of the conditions in the HUs sampled; and
- analysis for tritium concentrations by the Bruce Power Health Physics Laboratory.

The field program was completed by OPG personnel. The groundwater data generated from the sampling program and the associated interpretations are described in Section 3. Refer to Section 6.0 of this report for details on the sampling naming/location nomenclature used in the groundwater program. The frequency of sampling of the subsurface drainage is monthly. The frequency of sampling of the groundwater monitoring wells has been specified based on groundwater conditions at the locations being sampled and ranges from semi-annual to biennial.

2.1 Objective 1 Methodology

2.1.1 Tritium near LLSBs, SGSB and RCSB within the WWMF

In 2024, groundwater quality was monitored at monitoring wells at the Site near the following systems, structures and components (SSCs), at the locations shown in Figure 3:

- LLSBs #1 to #10;
- LLSBs #11 to #14, SGSB and RCSB; and
- Trenches, Tile Holes, Quadricells and Inground Containers (ICs).

Sample results for tritium concentrations related to this objective are presented in Appendix A (Table A-1a, Table A-1b, Table A-2a, Table A-2b, Table A-3a and Table A-3b).

2.1.2 RWOS1

In 2024, groundwater quality was monitored in 5 groundwater monitoring wells at the RWOS1. Figure 4 shows the locations of the wells monitored for this objective. Sample results for tritium concentrations in groundwater related to this objective are presented in Appendix A (Table A-4).

2.1.3 Background Tritium Concentrations at WWMF

In 2024, 6 locations were monitored to establish background tritium concentrations in groundwater at the WWMF. Figure 5 shows the groundwater wells monitored for this objective. Sample results for tritium concentrations in groundwater related to this objective are presented in Appendix A (Table A-5).

2.2 Objective 2 Methodology

The groundwater flow interpretations for the WWMF and RWOS1 were developed in the WWMF GWPMP (Ecometrix, 2022c). On an annual basis, the GWPMP requires that a set of hydraulic head measurements to be collected from all wells at RWOS1 and a subset of the wells in the groundwater well network at the WWMF over a short period of time (days). This “snapshot” program intends to verify that groundwater flow conditions, which are the basis for interpreting the migration of constituents in groundwater, have not changed and that OPG continues to have a sound understanding of groundwater flow patterns at the Site.

The water level readings collected on April 17, 2024, were used to calculate the groundwater elevation at each monitoring well and generate water elevation contours, from which groundwater flow directions are inferred. Groundwater flow directions are interpreted to be perpendicular to and downgradient across the contour lines.

2.3 Objective 3 Methodology

In 2024, downgradient groundwater quality was monitored in 7 groundwater wells located on the perimeter of the WWMF Locations monitored for this objective are shown in Figure 6. Sample results of groundwater tritium concentrations for Objective 3 are presented in Appendix A (Table A-6).

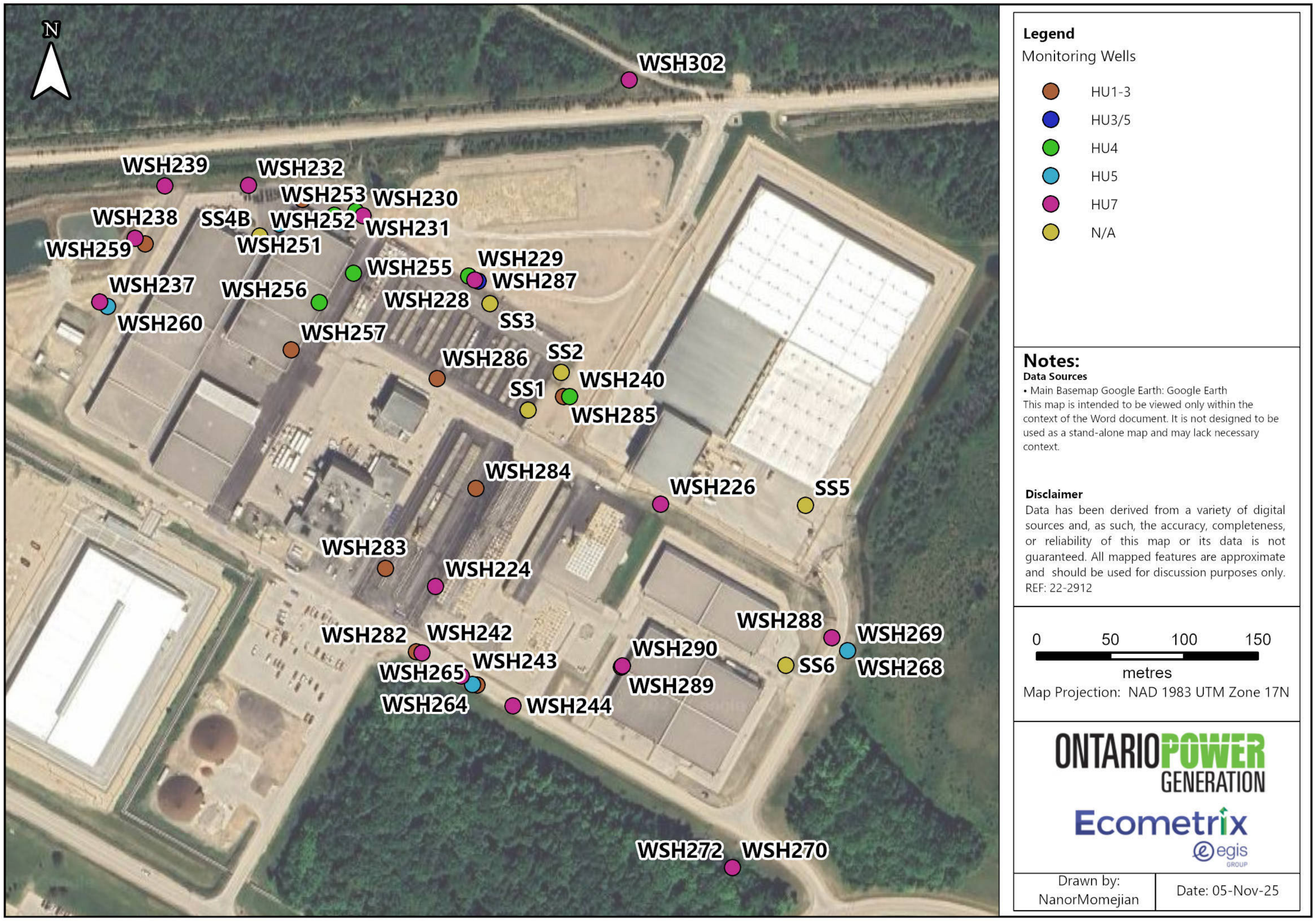


Figure 3: 2024 Monitoring Locations – Objective 1, WMMF

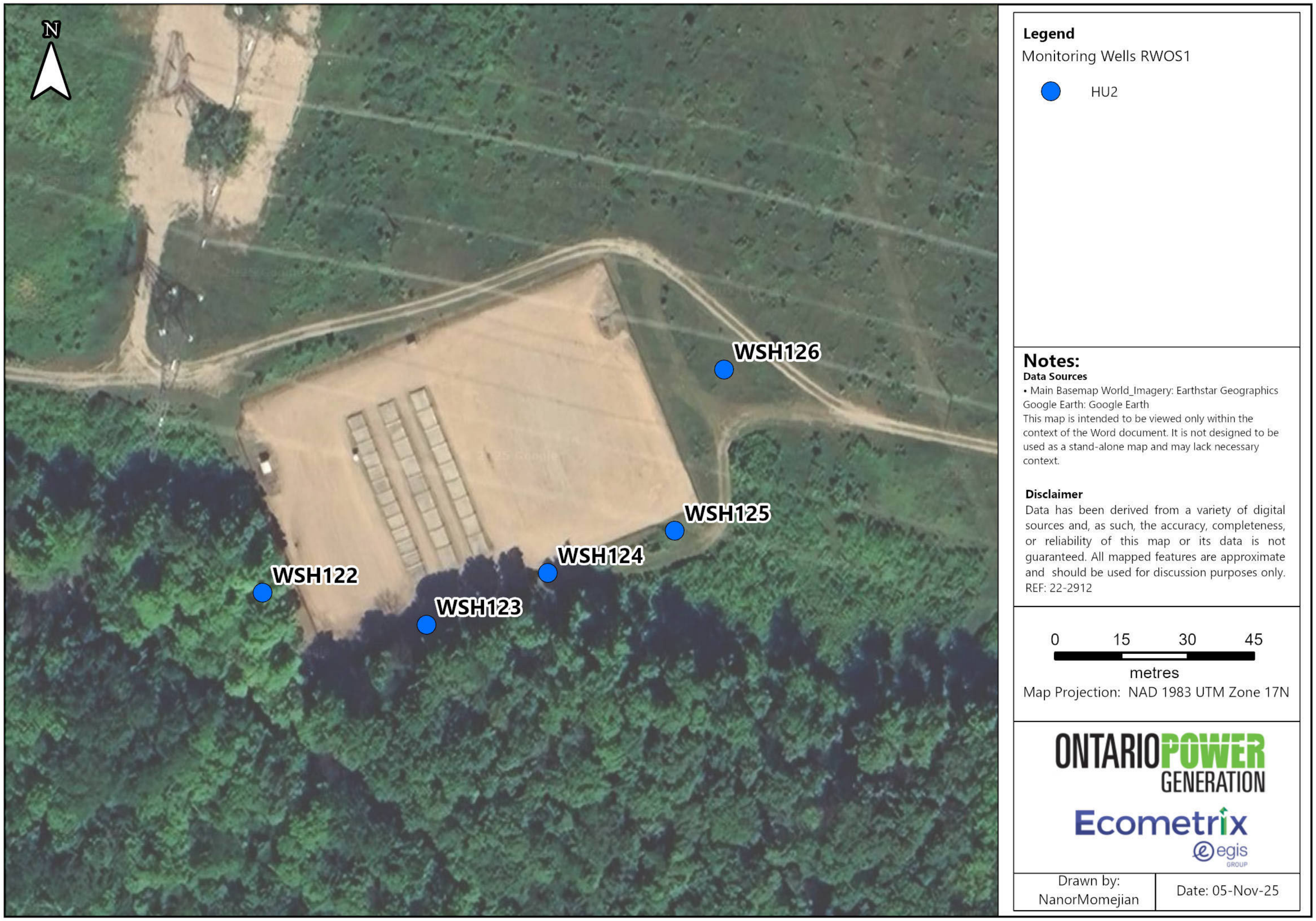


Figure 4: 2024 Monitoring Locations – Objective 1, RWOS1

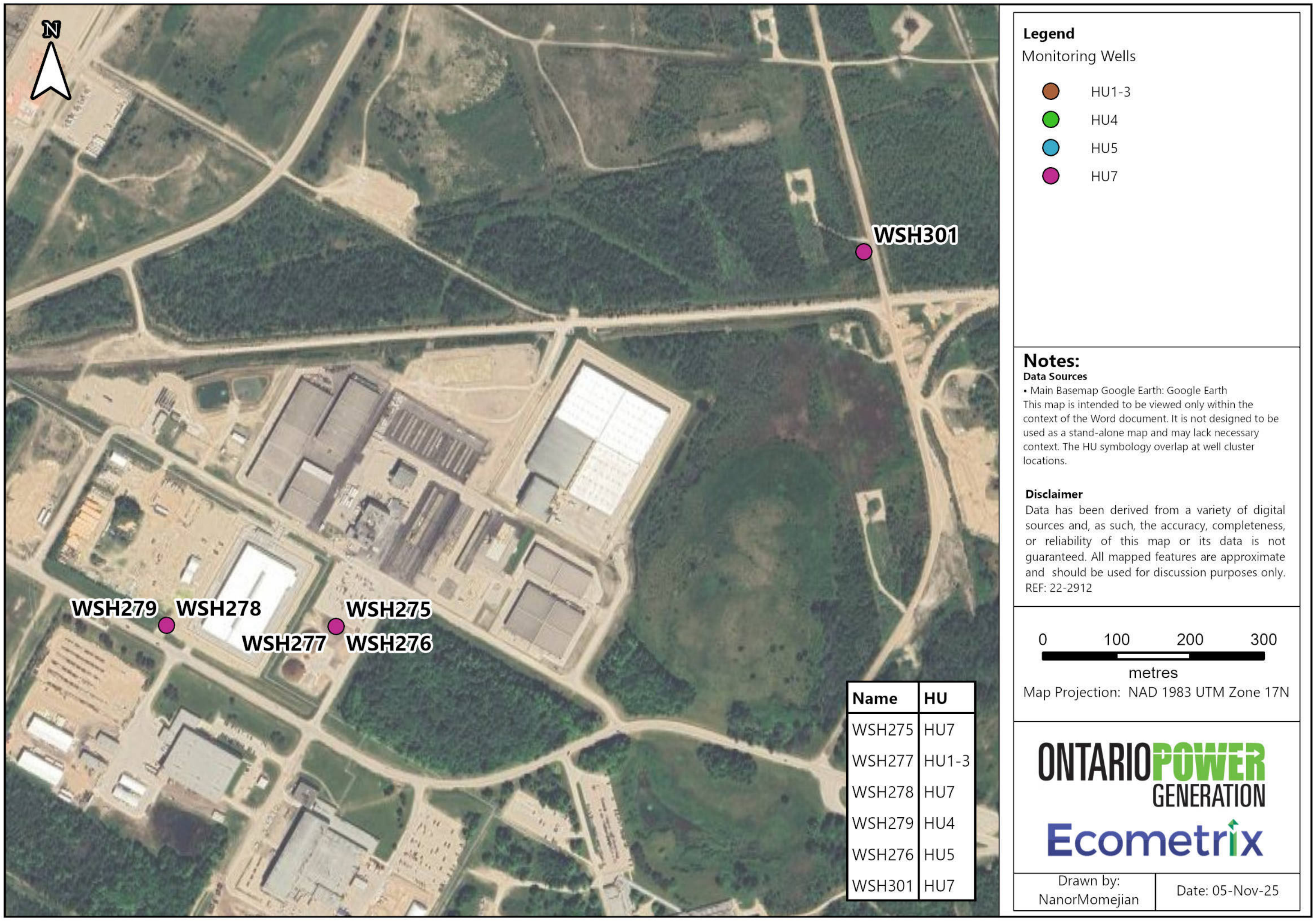


Figure 5: 2024 Monitoring Locations – Objective 1, Background Monitoring Wells

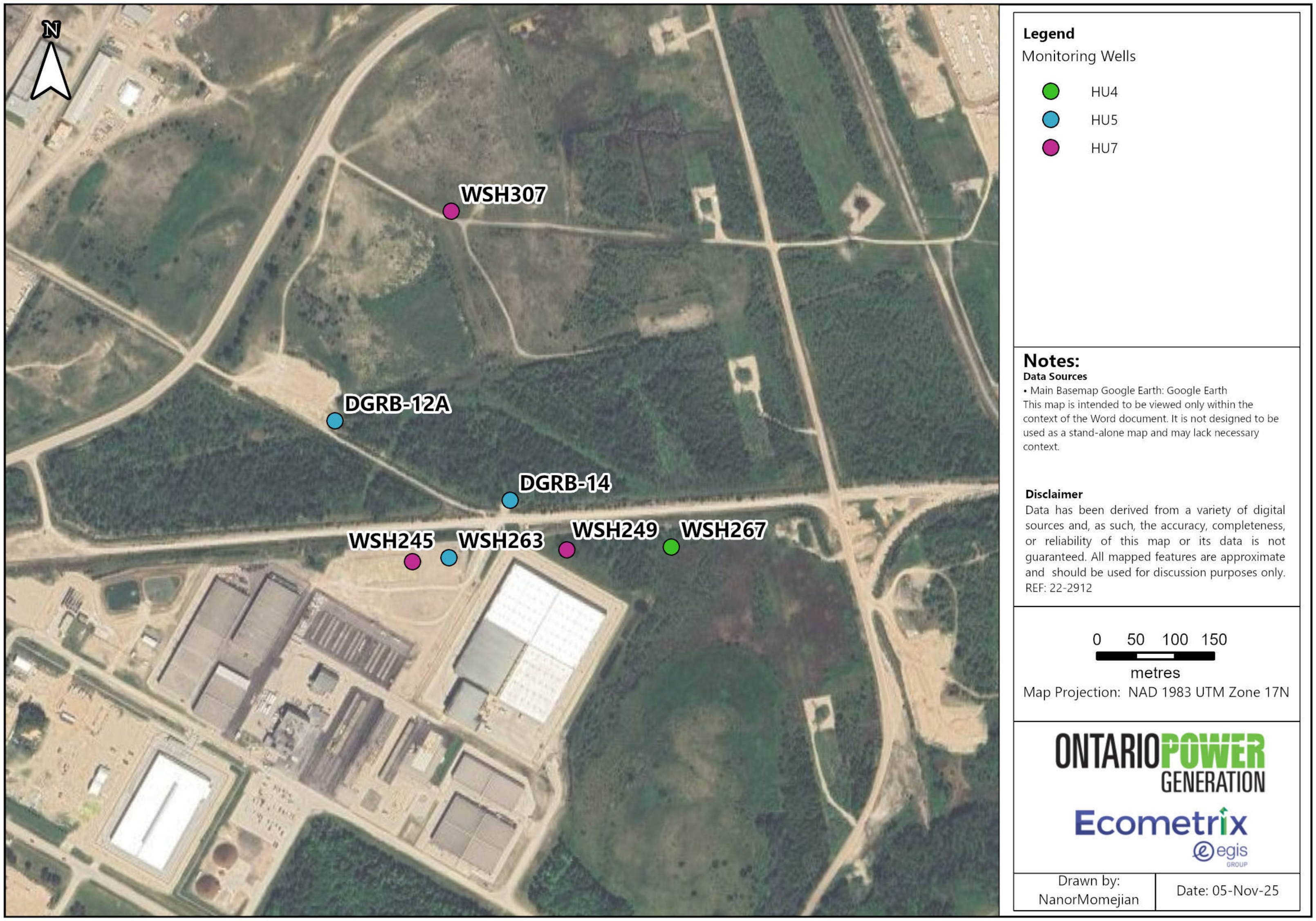


Figure 6: 2024 Monitoring Locations – Objective 3, Downgradient Perimeter Wells at the WWMF

3.0 2024 PROGRAM RESULTS

3.1 Objective 1 Results

3.1.1 Tritium Concentrations near SSCs at the WWMF

In 2024, the groundwater data collected from the areas surrounding SSCs at the WWMF indicate that tritium concentrations in groundwater have remained, overall, consistent with results for previous years. The concentrations observed in 2024 are within the ranges of expected fluctuations represent the expected movement of well-characterized and understood tritium releases to groundwater. Further discussion is provided in the sections below for the specific SSCs at the WWMF.

3.1.1.1 LLSBs #1 to #10

Within the LLSB #1 to #10 area, the primary point source of tritium to groundwater is tritiated water vapour that originates from the stored waste within the LLSBs. Tritium vapours that condense on the internal and external surfaces of the LLSBs and surrounding asphalt surfaces have the potential to migrate to the subsurface via sumps or pervious surfaces. In recent years, including 2024, tritium concentrations in groundwater in this area are, for the most part, decreasing over time or are stable, and are not showing changes over time.

The maximum tritium concentrations in the groundwater samples collected in 2024 from the HUs beneath the LLSB #1 to #10 area are illustrated in Figure 7. The tritium concentrations are highest to the north of LLSBs #3, specifically in the monitoring well WSH253, and in the subsurface drainage, SS4B.

The tritium concentrations in groundwater to the west of the LLSBs #1 to #10, in monitoring wells WSH237, WSH238 and WSH239 (all in HU7), are stable, decreasing or demonstrate no trend, as represented in Graph 1 for WSH237. These wells are located in the inferred upgradient groundwater flow direction to the LLSBs #1 to #10 (see Objective 2, Section 2.2) and tritium concentrations in these wells represent background conditions in those HUs within this area of the Site.

North and east of LLSBs #1 to #5, maximum concentrations of tritium in the groundwater are measured in the subsurface drainage, monitored at SS4B. The tritium concentrations in SS4B have decreased over time and have stabilized to values between approximately 10,000-20,000 Bq/L in the past 5 years, as shown in Graph 3. In 2024, the tritium concentrations in SS4B were more variable, ranging from 9,860 Bq/L (February) to 41,600 Bq/L (August), with an annual average concentration of about 19,900 Bq/L (Graph 3 and Table A-1b). The range of concentrations falls within the historical range and can be attributed to drier weather conditions in 2024 and sump repairs carried out during the summer months.

The maximum tritium concentrations in groundwater within HU1-3 were 2,810 Bq/L in 2024 (WSH252). These concentrations are within the background concentrations observed in this HU.

The tritium concentrations above background values are observed in HU4. The maximum tritium concentrations in HU4 were observed at WSH253 (22,300 Bq/L) in 2024. This is consistent with the findings from previous years; tritium concentrations in this well have been stable in recent years (Graph 2). Further downgradient, tritium concentrations in WSH231 are decreasing steadily (Graph 4). Tritium concentrations west of the LLSBs are approximately 3,000 Bq/L at monitoring wells WSH255, WSH256, and WSH257, as shown in Graph 5. For WSH257, the background value is 1,325 Bq/L. These concentrations do not suggest an increased risk to groundwater end-uses.

The tritium concentrations in the underlying unweathered till (HU5) and bedrock aquifer (HU7) to the northeast of LLSBs #1 to #5 are above background levels, reflecting natural downward vertical gradients between the MSA and the deeper groundwater units across the WWMF (Ecometrix, 2022b). In the bedrock (HU7), monitoring well WSH230 is clustered with MSA well WSH231 (HU4). The tritium concentrations in the bedrock HU at WSH230 are steadily increasing, as shown in Graph 6, with a maximum concentration of 859 Bq/L in 2024 which is approximately an order of magnitude lower than the concentrations in the overlying MSA at WSH231 (maximum concentration in 2024 of 11,500 Bq/L; Figure 7). Low levels of tritium are migrating to the northwest in the groundwater in bedrock (HU7). This increase is expected as part of the migration of tritium in groundwater originating from beneath the LLSBs #1 to #5, primarily, and migrating downwards from the MSA into deeper till and the bedrock aquifer.

The extent of tritium migration further downgradient in HU7 is being monitored in wells WSH302 and DGRB-12. The tritium concentrations in well WSH302 in 2024 are below detection limits (Graph 7). The tritium concentrations in DGRB-12 measured since 2022 show no trend, with a 2024 value of 108 Bq/L (Graph 8).

The data in 2024 confirms that groundwater conditions continue to decrease or are stable, with respect to tritium concentrations north and east of LLSBs #1 and #5. Tritium continues to migrate downwards from shallow groundwater to the bedrock. The extent of tritium migration in HU7 will continue to be monitored. Monitoring of additional downgradient perimeter wells as part of Objective 3 (Section 2.3) demonstrates that tritium concentrations in the perimeter wells remain substantively below the groundwater evaluation criteria.

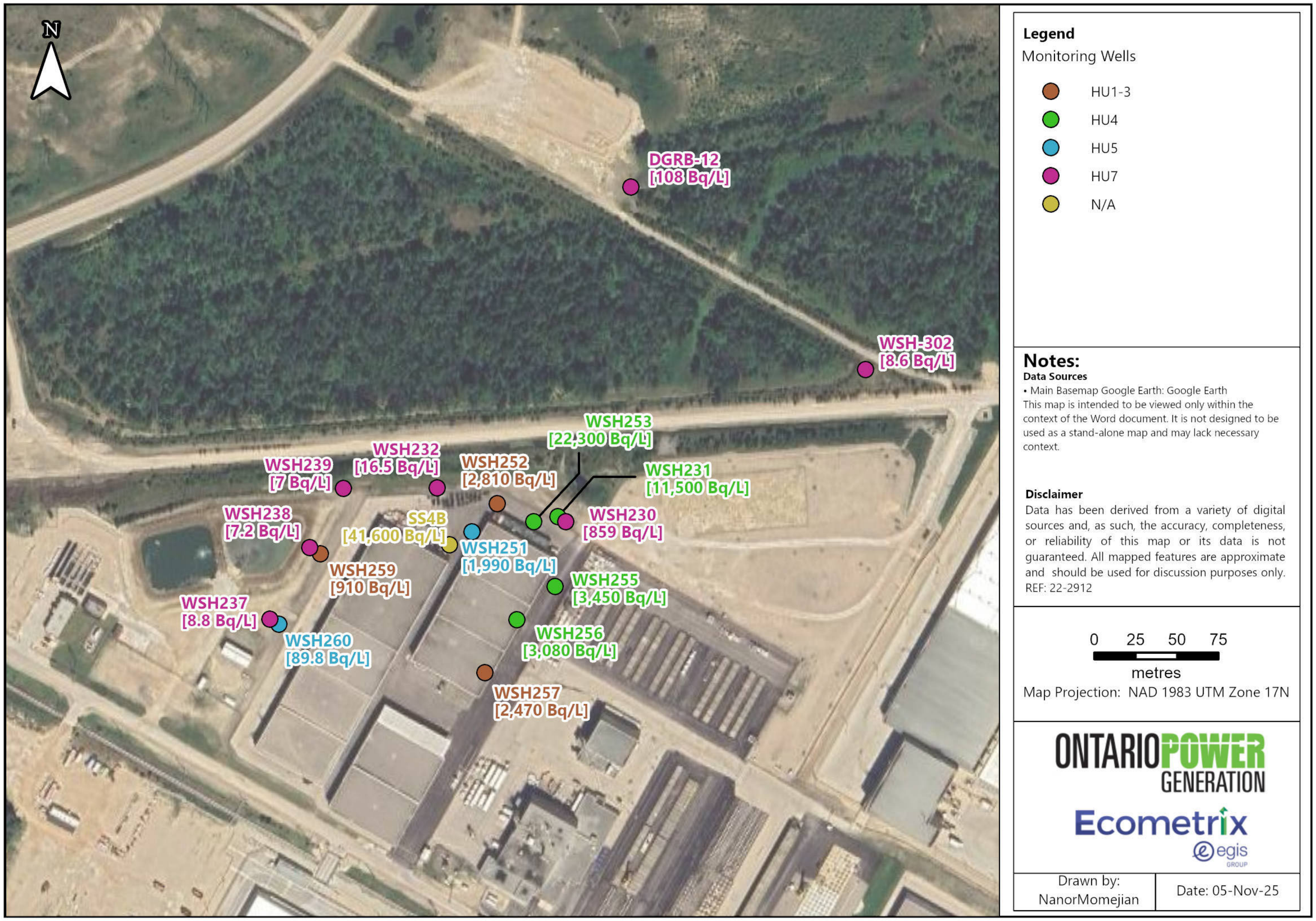
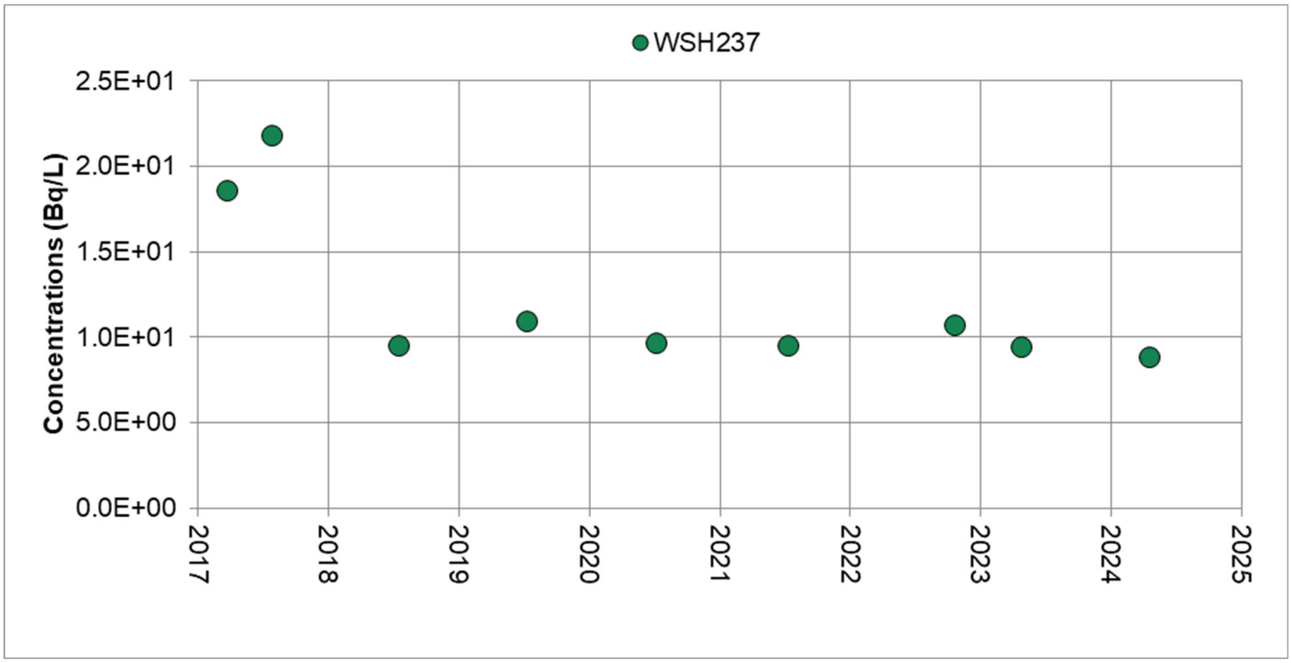
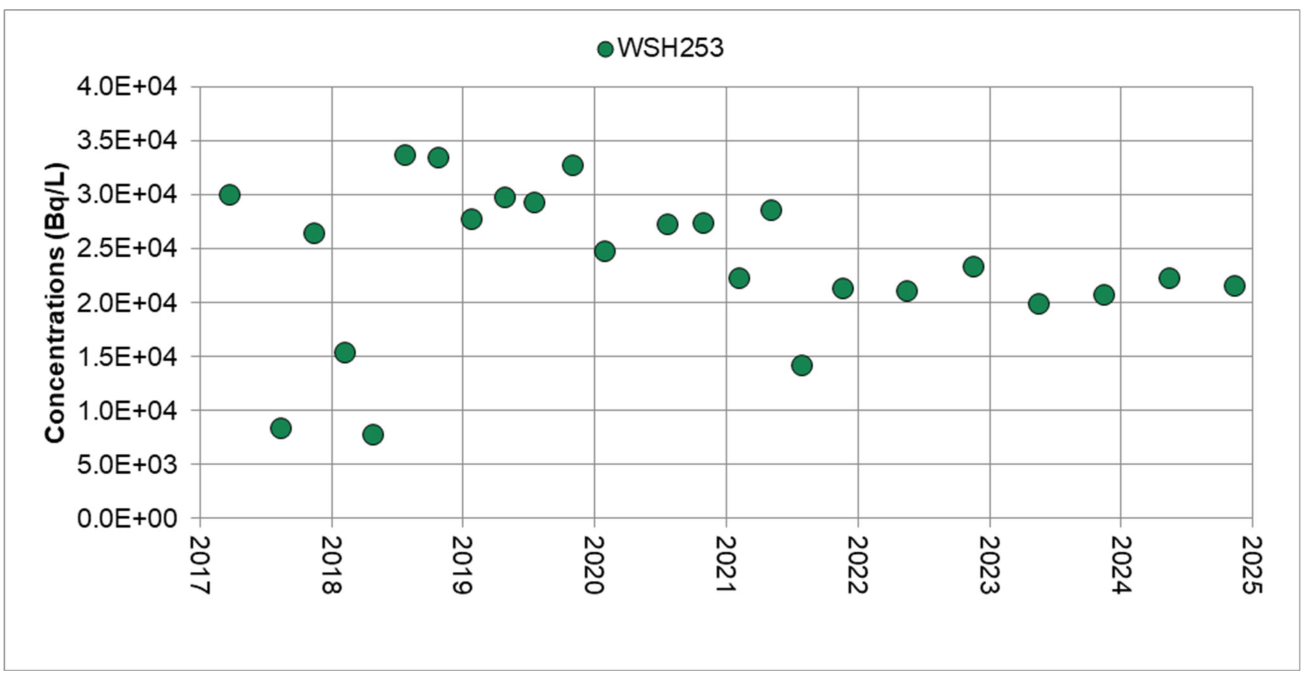


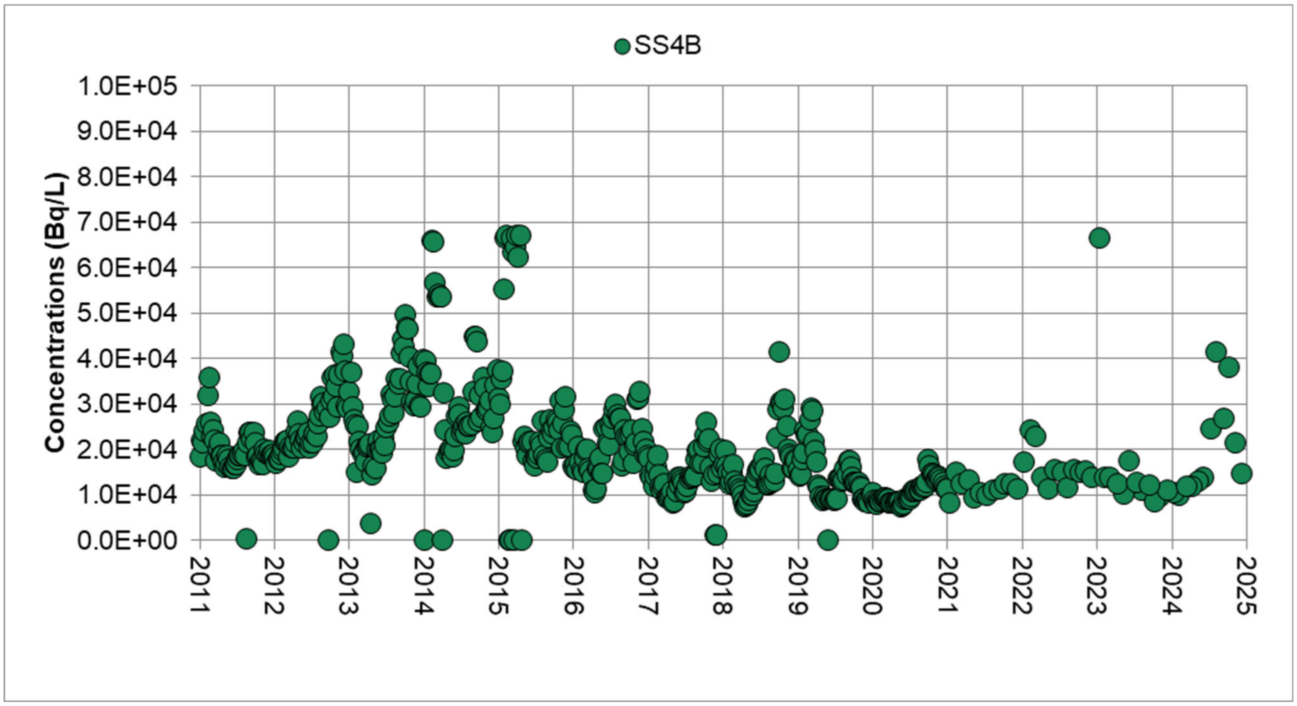
Figure 7: 2024 Maximum Tritium Concentrations – Objective 1 (A), LLSB #1 to #10



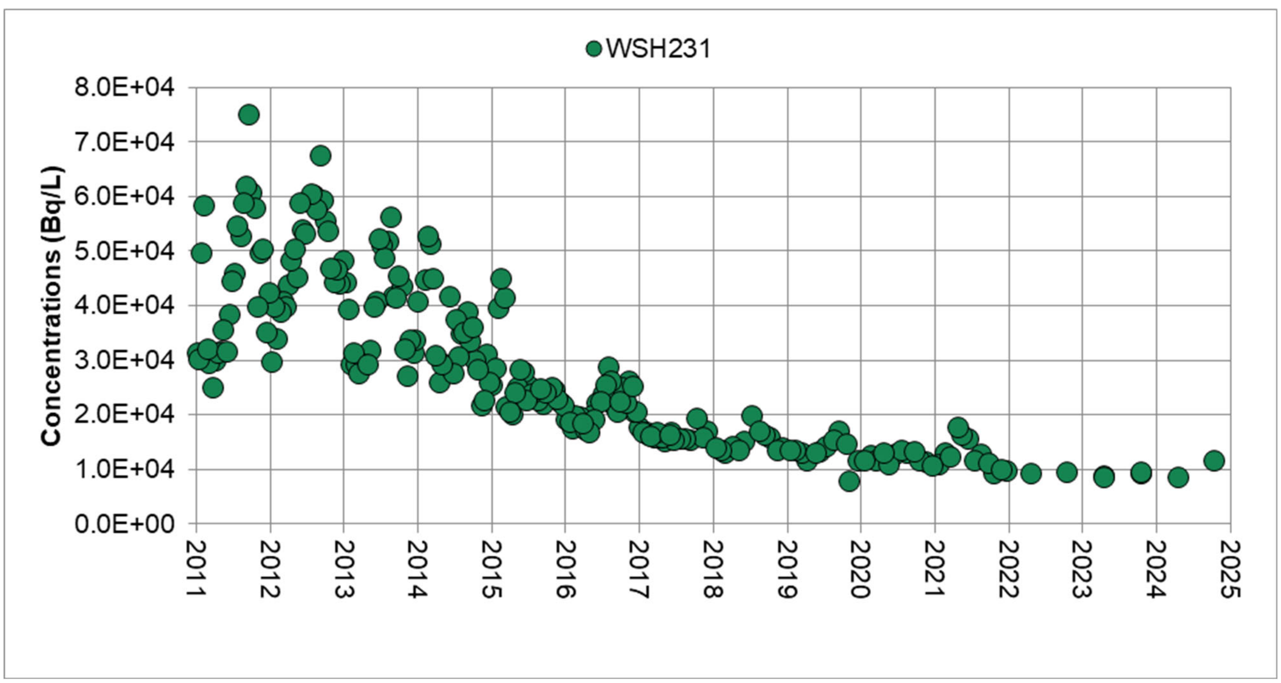
Graph 1: Tritium Concentrations at WSH237



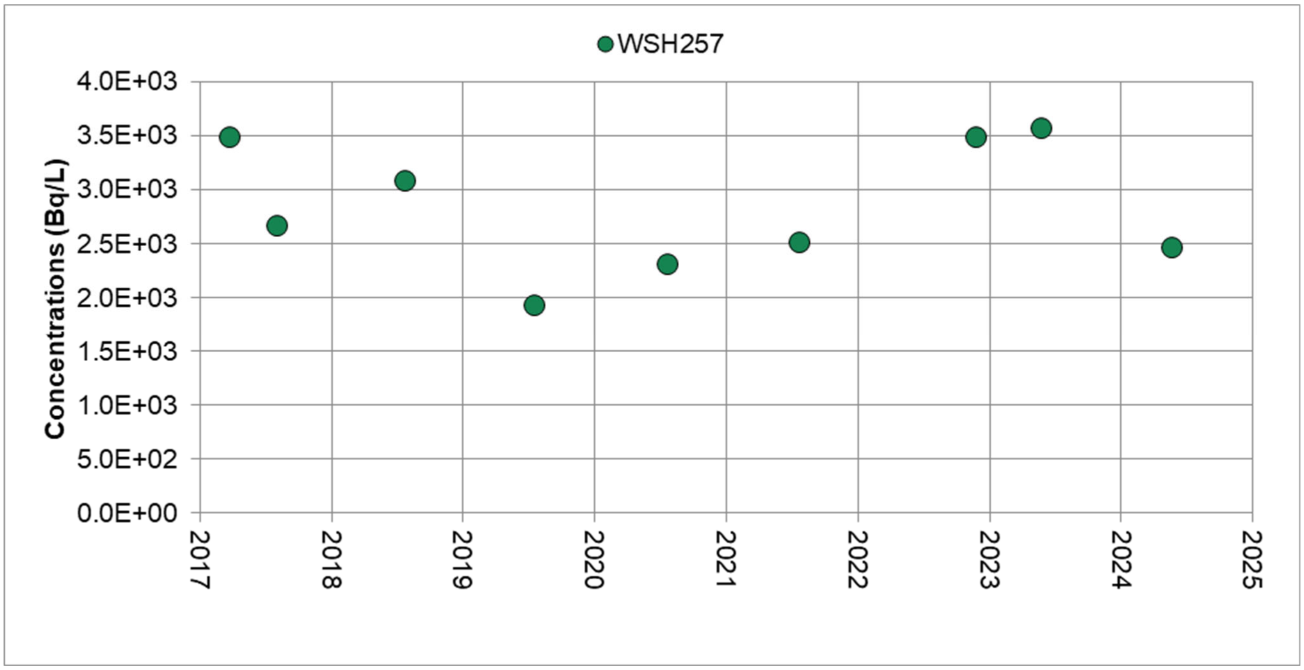
Graph 2: Tritium Concentrations at WSH253



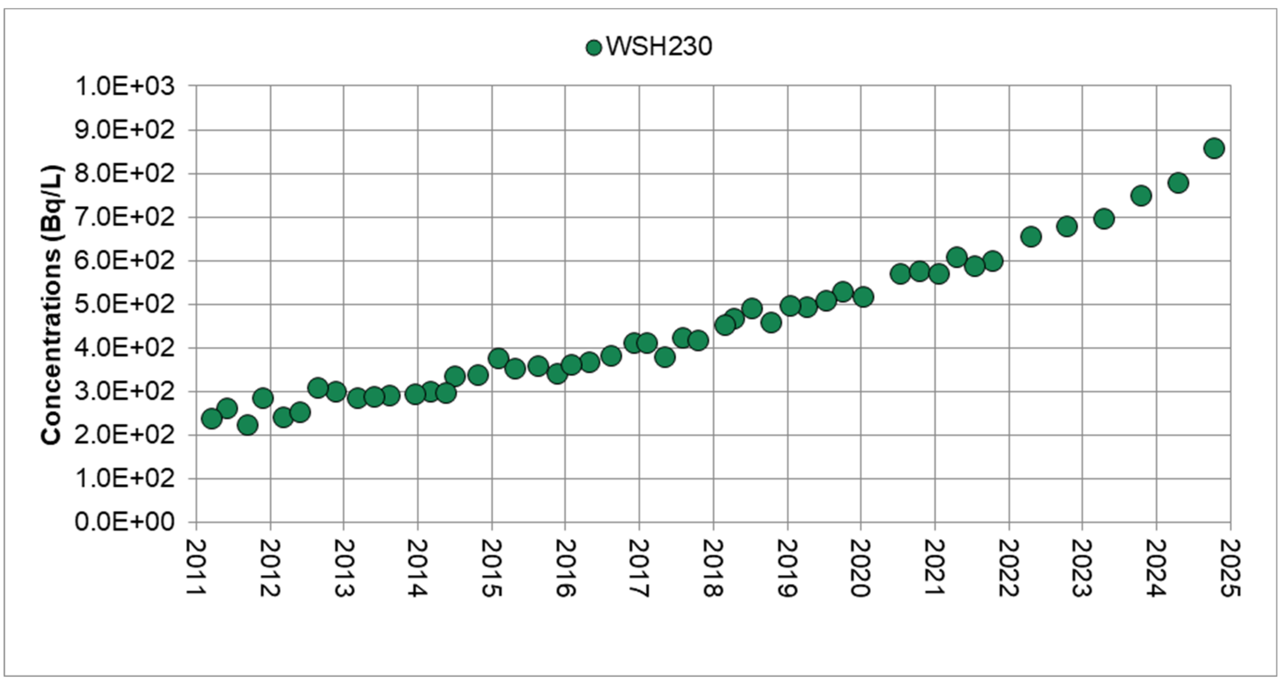
Graph 3: Tritium Concentrations at SS4B



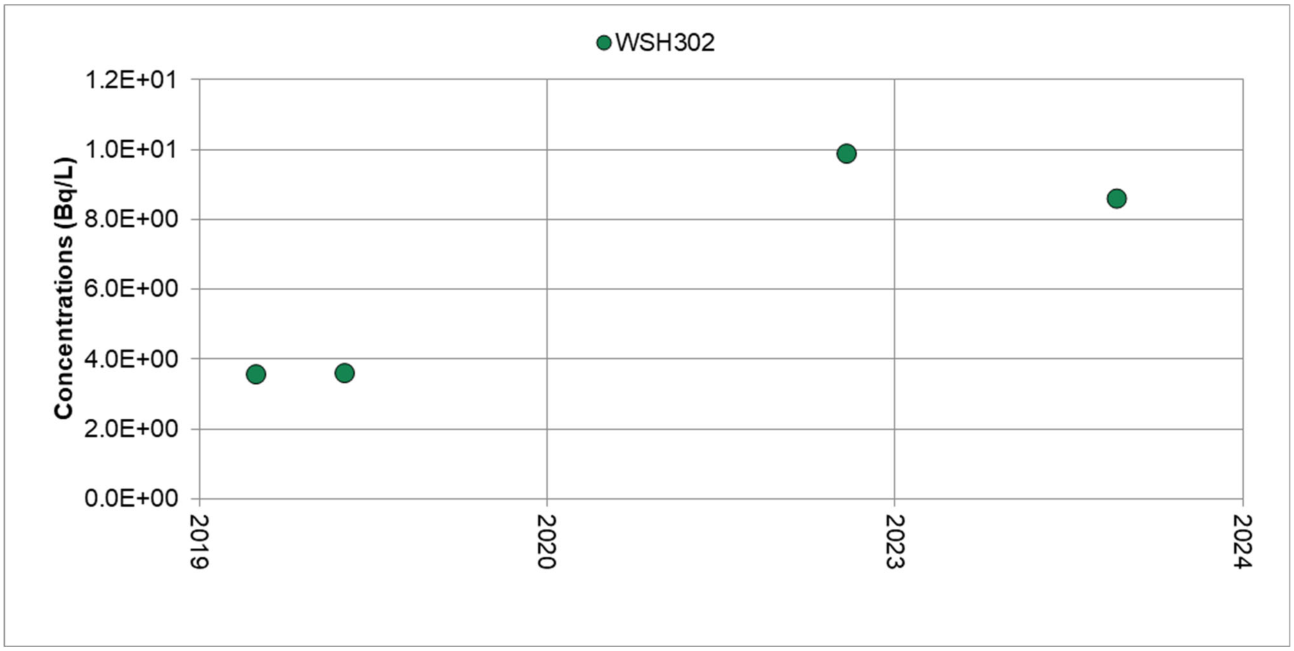
Graph 4: Tritium Concentrations at WSH231



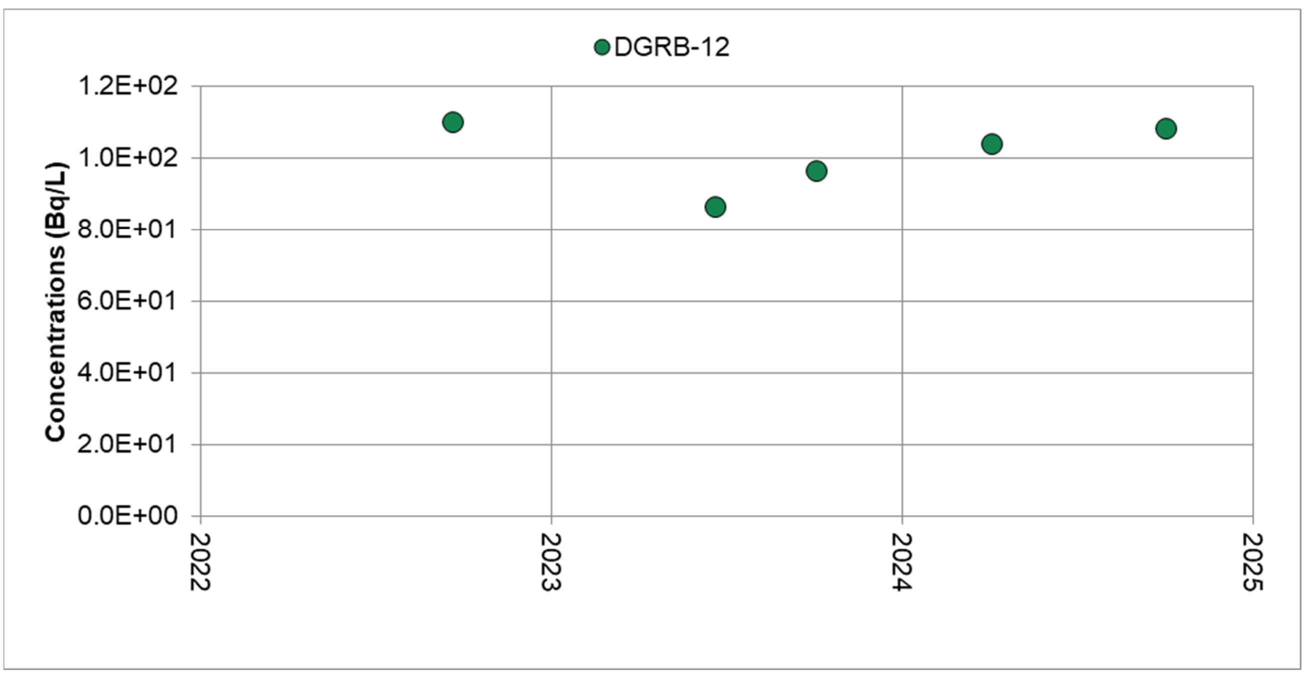
Graph 5: Tritium Concentrations at WSH257



Graph 6: Tritium Concentrations at WSH230



Graph 7: Tritium Concentrations at WSH302



Graph 8: Tritium Concentrations at DGRB-12

3.1.1.2 LLSBs #11 to #14, SGSB and RCSB

Tritium that condenses on the internal and external surfaces of the LLSBs and surrounding asphalt surfaces has the potential to migrate to the subsurface via sumps or pervious surfaces. LLSBs #11 to #14, SGBS and RCSB are located in the southeast corner of the

WWMF. The maximum tritium concentrations observed in 2024 in this area are shown spatially in Figure 8. The MSA is not present beneath this portion of the WWMF. The groundwater monitoring network includes monitoring wells installed in shallow groundwater (HU1-3), and bedrock (HU7). Subsurface drainage collected in this area is monitored at SS6. Historical results in this area suggest that uncontrolled releases of tritium from the LLSBs #11 to #14, the SGSB or the RCSB to groundwater have not occurred (Ecometrix, 2022b).

Tritium concentrations in groundwater and subsurface drainage in this area in 2024 are summarized in Tables A-2a and A-2b, respectively.

Tritium concentrations in the subsurface drainage, measured at SS6, have fluctuated since the LLSBs were put into service in 2010, and are considered to result from operational activities (e.g., waste loadings, sump pump outs, etc.). Maximum tritium concentrations in subsurface drainage at SS6 were observed in December 2024, with concentrations remaining stable (Graph 9). Tritium concentrations at SS6 in 2024 ranged from 2,320 Bq/L (September) to 4,910 Bq/L (December) with an average annual value of 3,600 Bq/L (Appendix A, Table A-2b).

In 2024, groundwater flow conditions (Section 2.2) were consistent with historical conditions, from south to north in HU7. Tritium concentrations are at background levels upgradient of the SSCs in HU7 (WSH270); however, the tritium concentration is elevated above background levels in HU1-3 (WSH272), with a maximum tritium concentration in 2024 of 422 Bq/L (Graph 10) and an increasing trend, as indicated by the Mann-Kendall statistical test; however, the concentrations are significantly lower than the administrative levels. Tritium concentrations in groundwater near the SSCs are measured in HU1-3 at WSH269. Tritium concentrations indicate an increasing trend according to the Mann-Kendall statistical test; however, when plotted over time, the data demonstrate fluctuations of tritium concentrations over time (Graph 11), which reflects normal routine operations. Furthermore, the concentrations are below the background levels; therefore, these trends do not pose any risk. Groundwater quality in this area will continue to be monitored.

The temporal behaviour of tritium in WSH269 and WSH272 indicates that routine operational activities associated with the LLSBs #11 to #14 are influencing water quality near the SSCs to a limited extent, but an uncontrolled release has not occurred. Groundwater quality in the deeper groundwater is not influenced by operational activities.

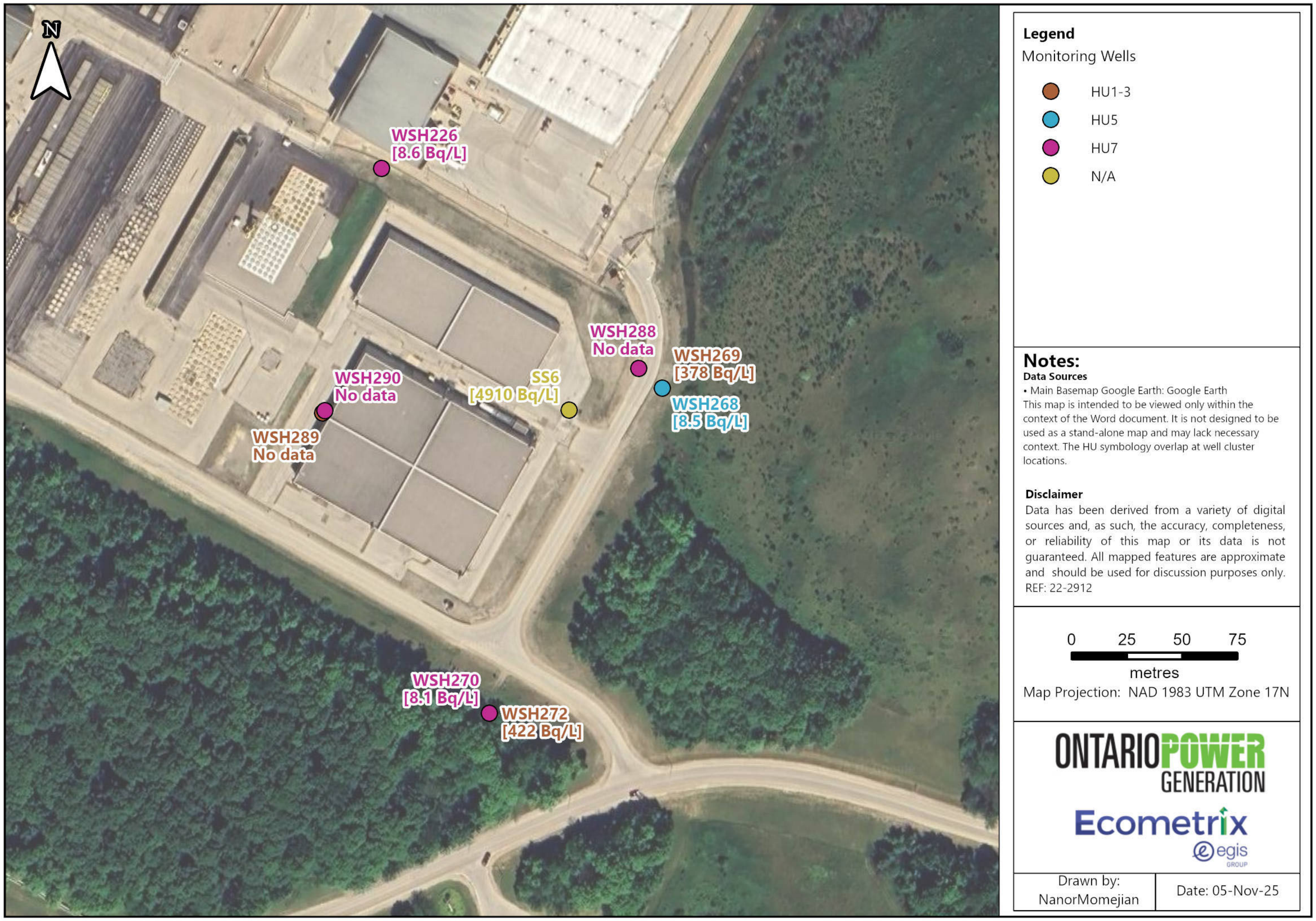
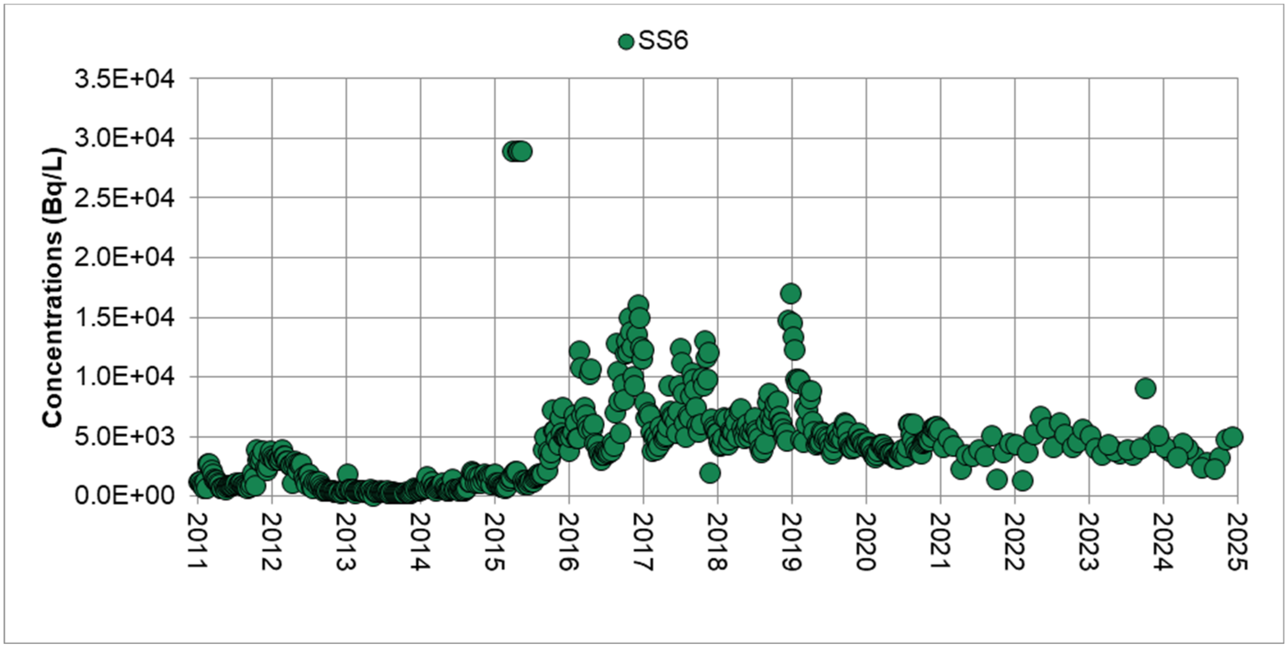
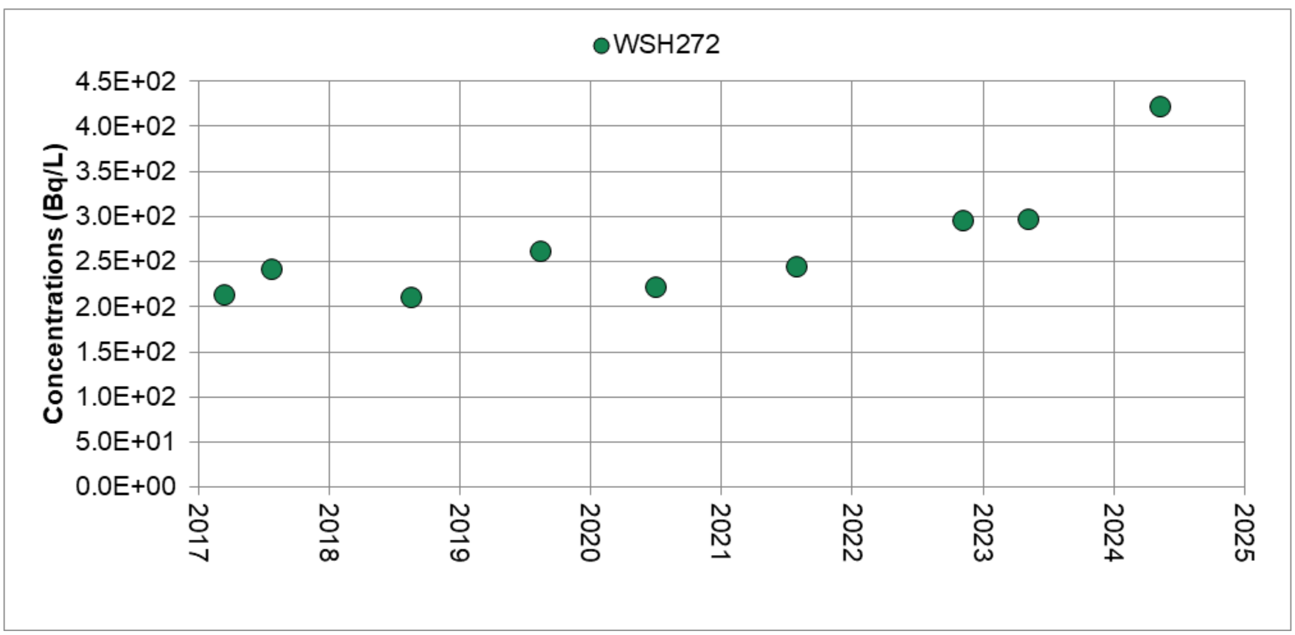


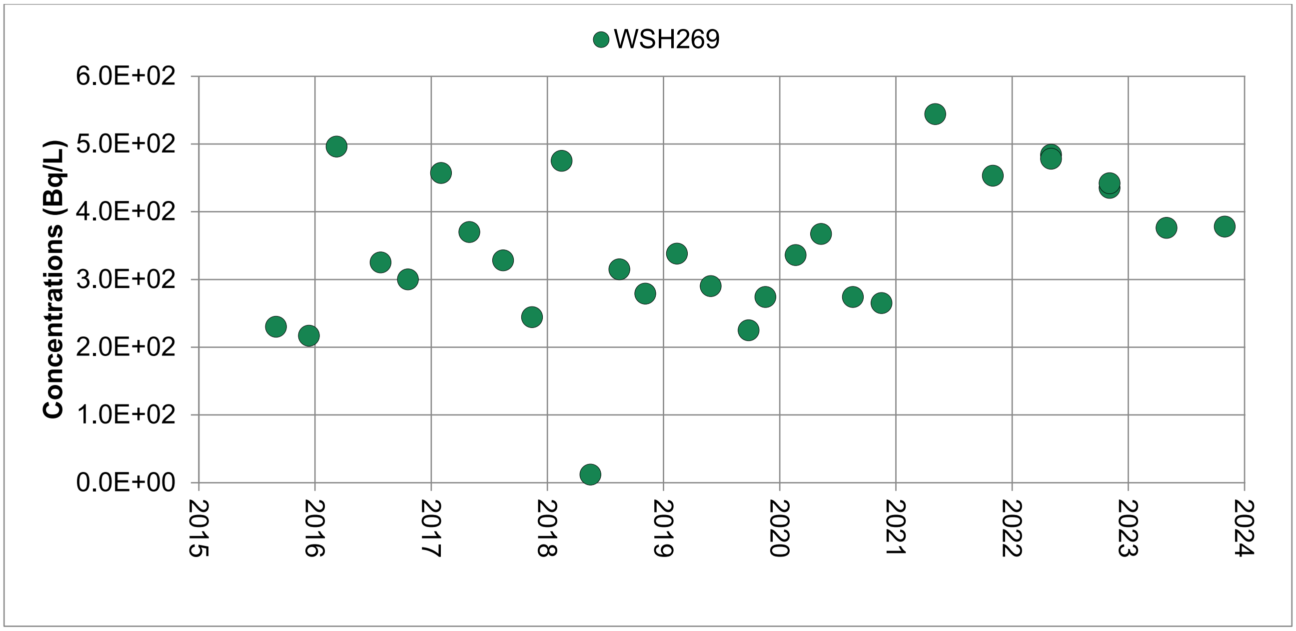
Figure 8: 2024 Maximum Tritium Concentrations – Objective 1, LLSB #11 to #14, SGSB and RCSB



Graph 9: Tritium Concentrations at SS6



Graph 10: Tritium Concentrations at WSH272



Graph 11: Tritium Concentrations at WSH269

3.1.1.3 Trenches, Tile Holes, ICs and Quadricells

The area containing the trenches, tiles holes, in-ground containers (ICs) and Quadricells is in the central portion of the WWMF. In this area, tritium concentrations in the groundwater and the subsurface drainage are influenced by the movement of groundwater out of waste structures, primarily from the tile holes and trenches in Stages 1 and 3 (Ecometrix, 2022b).

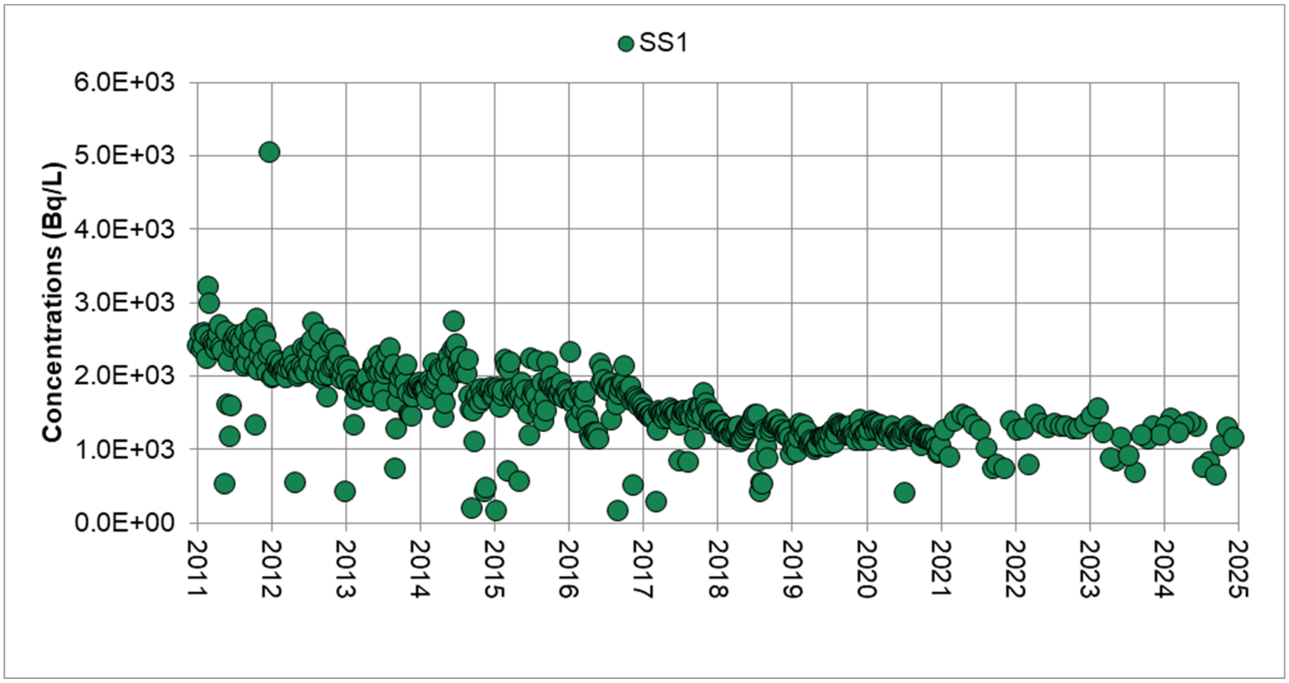
The subsurface drainage in the central part of the WWMF is collected around the:

- Stage 1 tile holes (TH101 to TH180) and trenches (TRH3 to TRH6), sampled at SS1;
- Remaining tile holes and trenches (TRH7 to TRH10), sampled at SS2; and
- Stage 3 and 3E trenches, sampled at SS3.

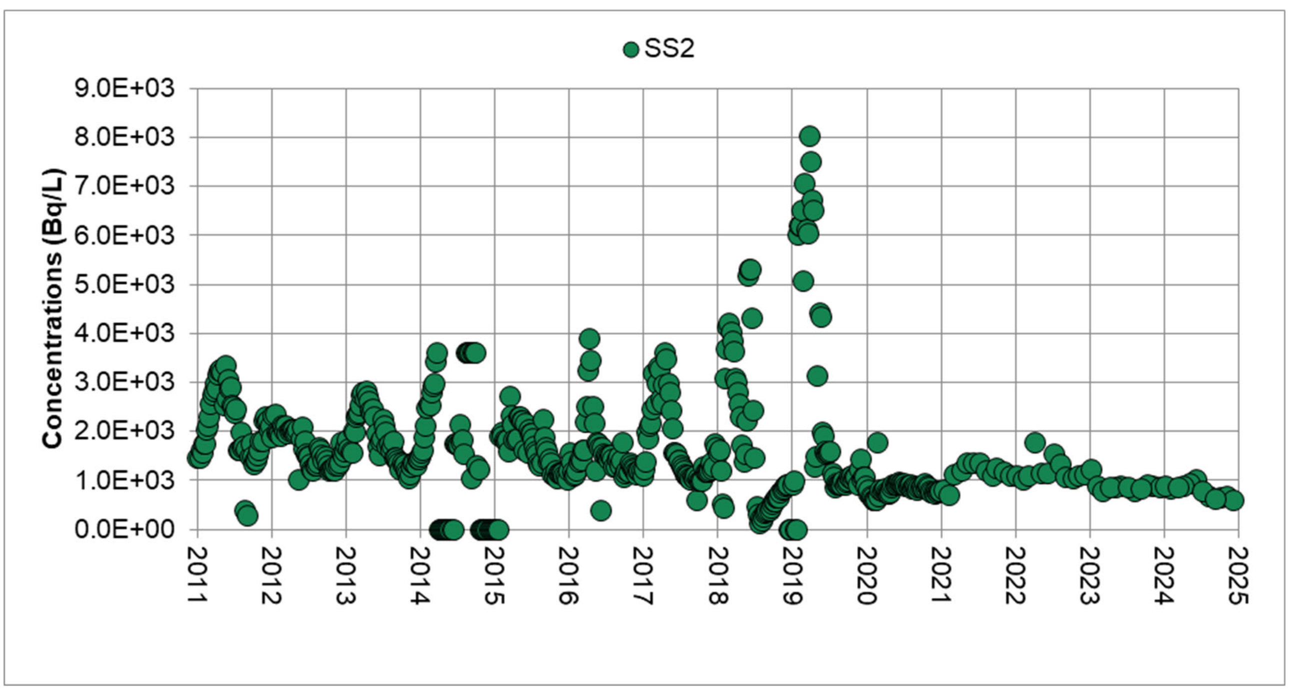
Tritium concentrations in groundwater and subsurface drainage in this area in 2024 are summarized in Appendix A, Tables A3-a and A3-b, respectively. Maximum tritium concentrations in 2024 are illustrated in Figure 9.

Tritium concentrations in subsurface drainage since 2011 are shown in Graph 12 for SS1, Graph 13 for SS2 and Graph 14 for SS3. Tritium concentrations have fluctuated over time but show no trend at SS1 and a decreasing trend at SS2 and SS3. The maximum tritium concentrations measured at SS1, SS2, and SS3 in 2024 were 1,430 Bq/L, 1,020 Bq/L and 3,850 Bq/L, respectively. Meanwhile, the annual average tritium concentrations measured at

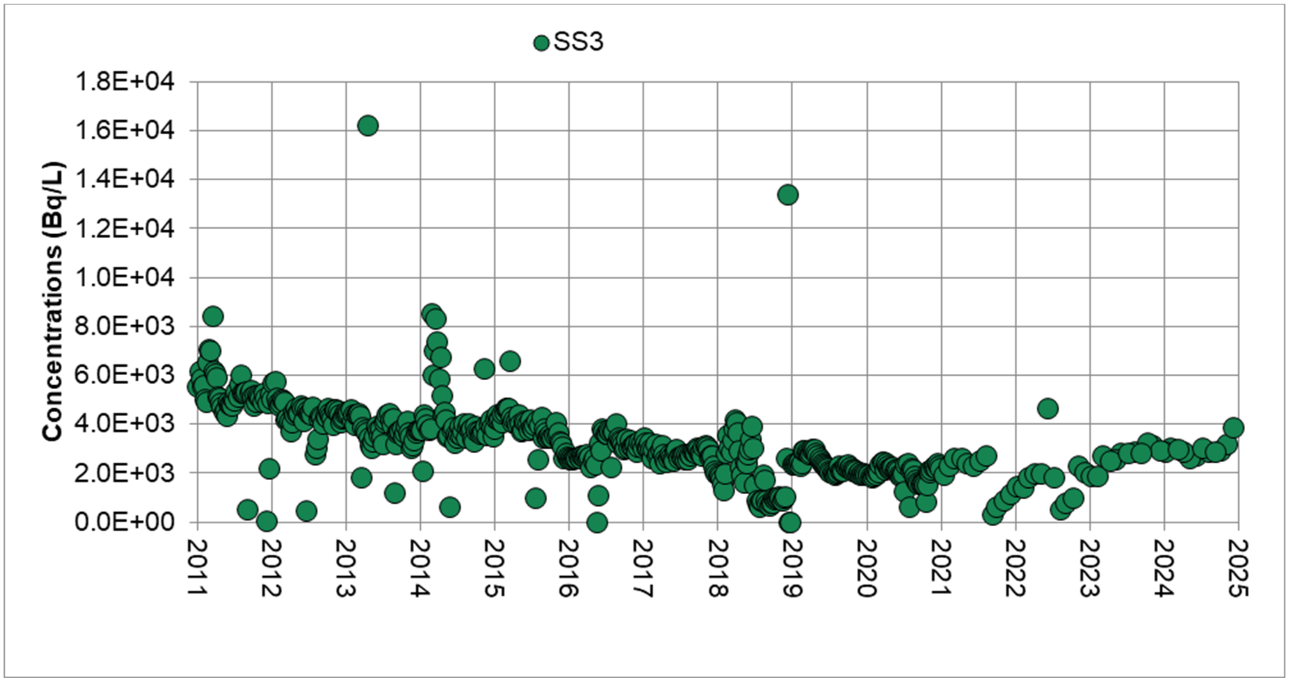
SS1, SS2, and SS3 in 2024 were 1,148 Bq/L, 781 Bq/L and 2,965 Bq/L, respectively (Graph 12 to Graph 14 and Table A-3b).



Graph 12: Tritium Concentrations at SS1



Graph 13: Tritium Concentrations at SS2



Graph 14: Tritium Concentrations at SS3

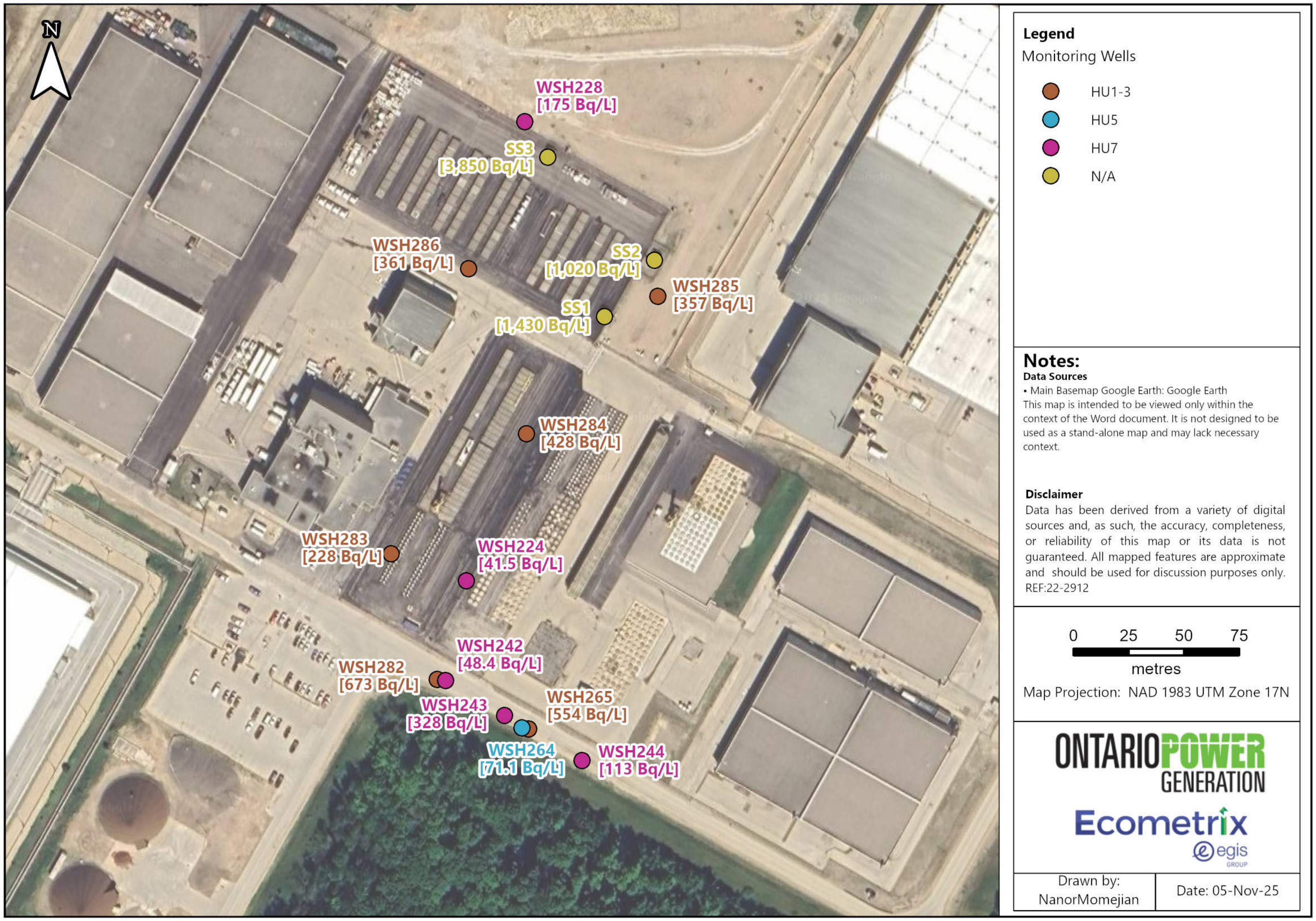
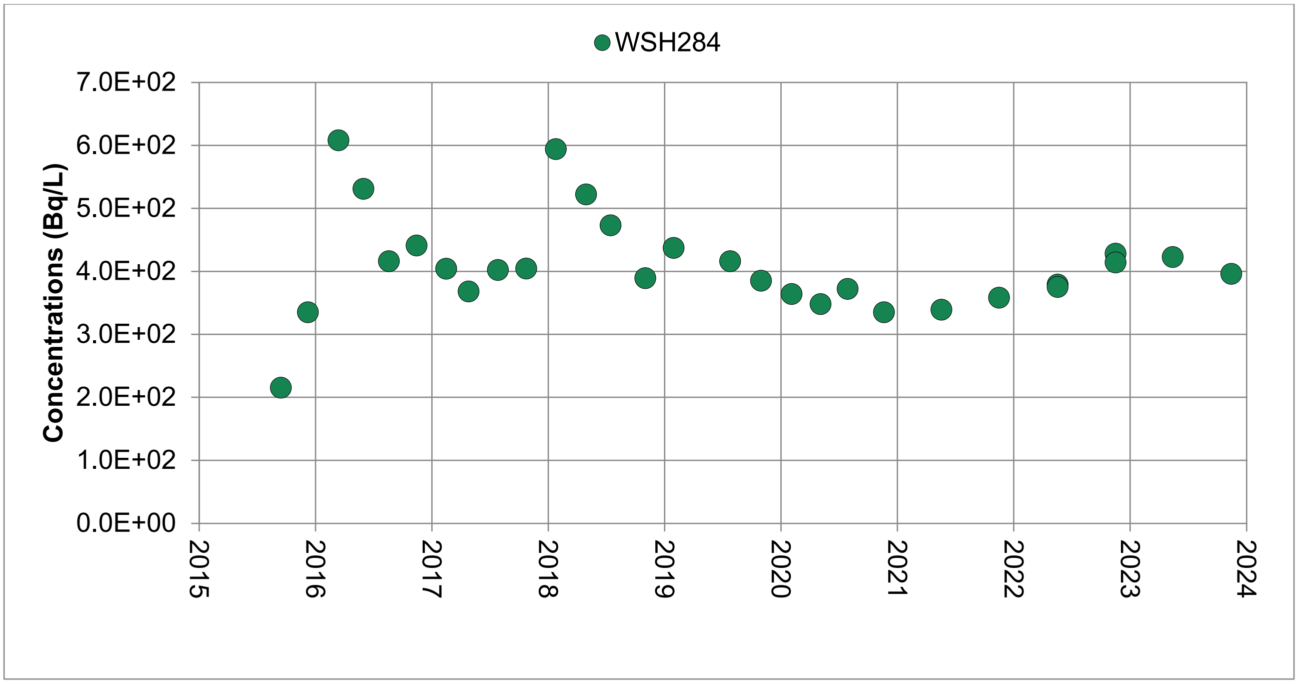


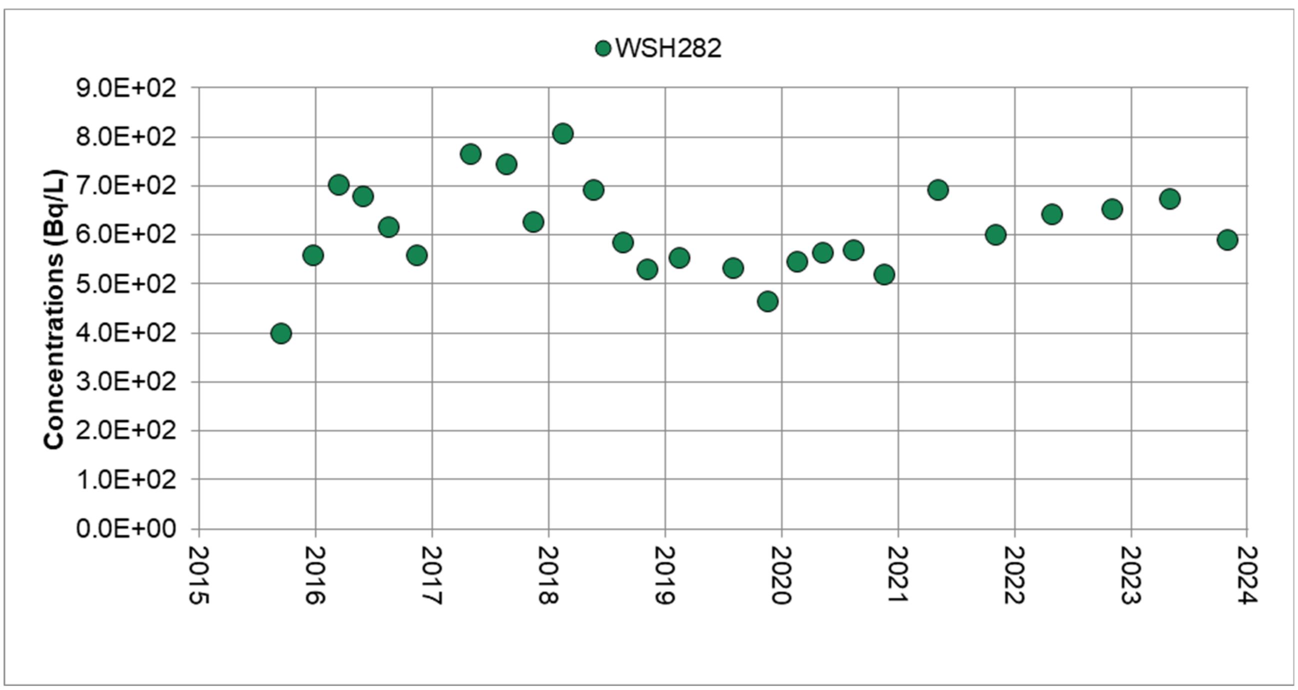
Figure 9: 2024 Maximum Tritium Concentrations – Objective 1, Trenches Tile Holes, Inground Containers and Quadricells

Over this central portion of the WWMF, groundwater is inferred to flow generally from south of the ICs, tile holes and Quadricells to the north, in both HU1-3 and HU7 (Section 2.2). However, the groundwater flow directions are understood to be more complex in the southeastern portion of this area, where mounding of groundwater in the area around WSH224 has been noted (Jensen, 1996). There is also a groundwater divide in the HU1-3 south of the ICs, tile holes, and Quadricells. The MSA is interpreted to be present beneath the majority of this area and is, for the most part, overlain by several metres of fill/till material (Ecometrix, 2022b). Groundwater flow in the MSA is interpreted to be to the east (Section 2.2).

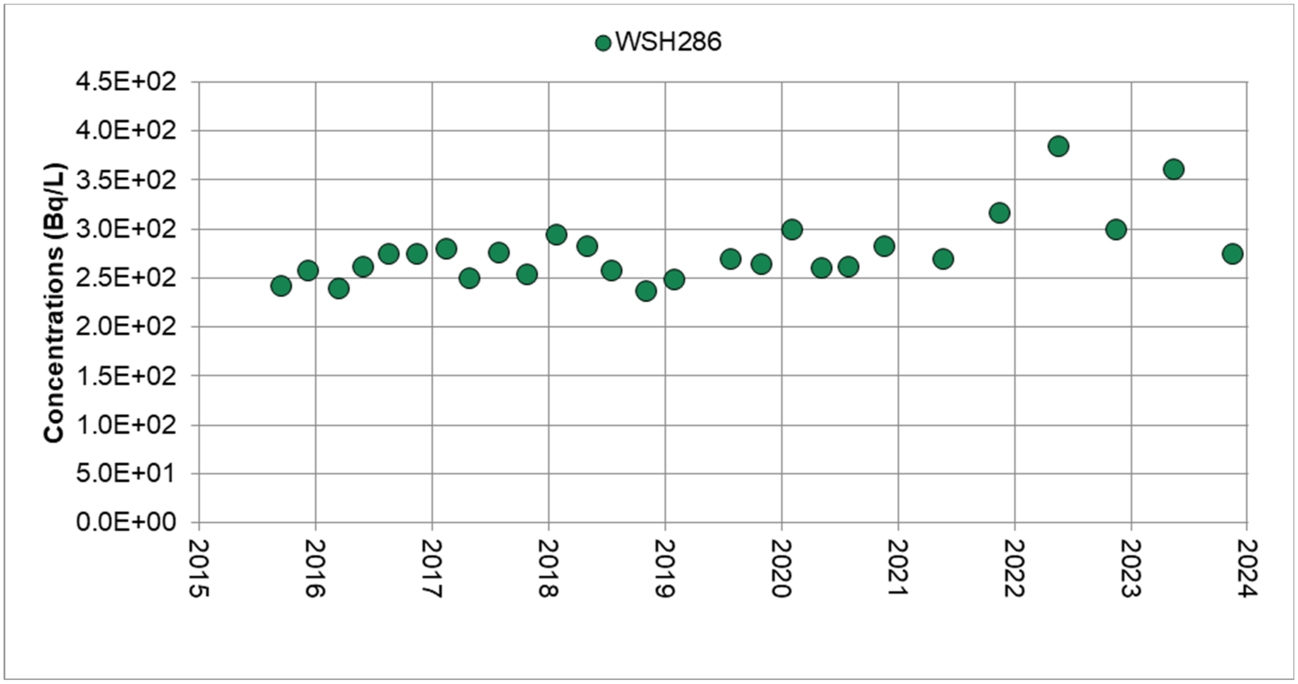
Across this entire central portion of the Site, tritium concentrations in HU1-3 are lower than the background conditions. Wells monitoring tritium concentrations in HU1-3 include: WSH265, WSH282, WSH283, WSH284, WSH285, and WSH286. Monitoring well WSH287 is screened deeper in the till (HU3/5). Tritium concentrations in WSH282, WSH283, and WSH284 are stable, as represented by WSH284 shown in Graph 15. The maximum concentrations increased temporarily at WSH282 in February 2019 (807 Bq/L) and May 2022 (693 Bq/L) with concentrations decreasing to background levels between these times (Graph 16). For monitoring wells WSH285 and WSH286 (Graph 17), despite the Mann-Kendall statistical test of the tritium concentration data indicating an increasing trend, these concentrations are two times lower than the background value and approximately 3,000 times lower than the administrative limits. The recorded trend is likely due to low groundwater tritium concentration fluctuations as a result of the groundwater conditions. Monitoring will continue at these locations to observe the fluctuations in tritium within the groundwater.



Graph 15: Tritium Concentrations at WSH284

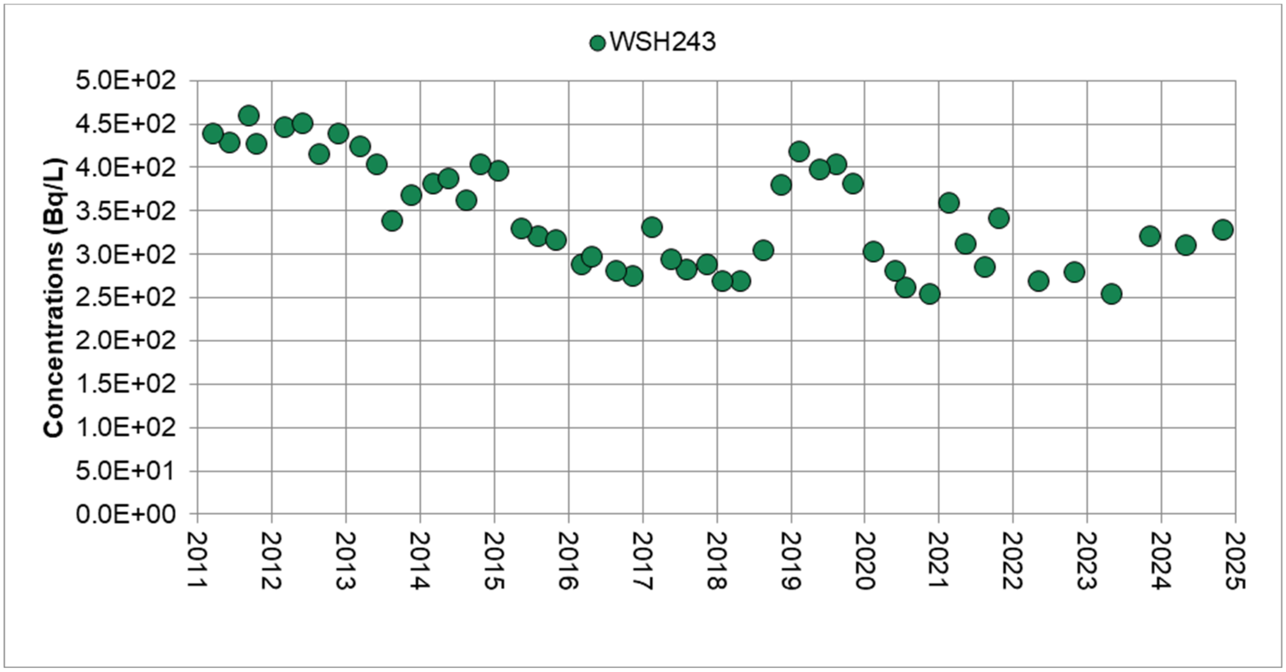


Graph 16: Tritium Concentrations at WSH282



Graph 17: Tritium Concentrations at WSH286

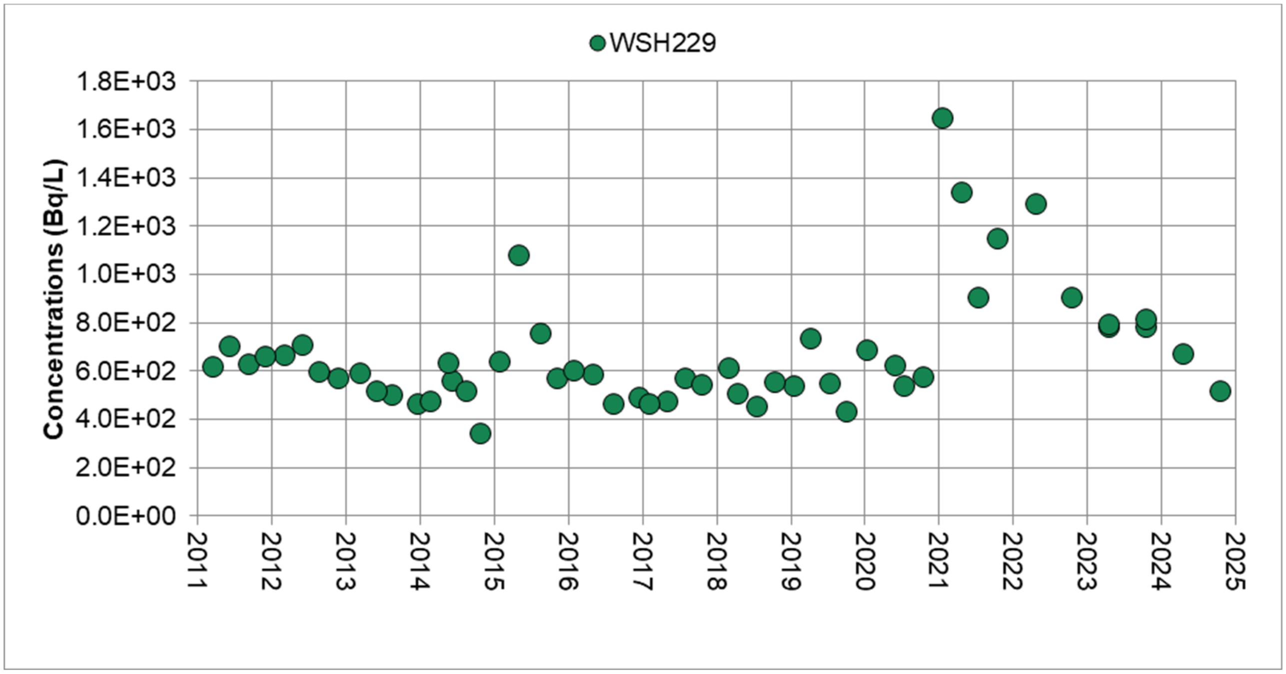
In deeper groundwater, tritium concentrations in the central part of the Site are discussed for wells to the south, close to the Stage 1 trenches, tile holes, ICs, and Quadricells separately from conditions to the north, within the Stage 3 and 3E trenches. South of the ICs, tile holes and Quadricells and nested with wells in HU1-3, there are monitoring wells in the deep till and bedrock, including WSH242 (HU7), WSH243 (HU7) and WSH244 (HU7). Tritium concentrations in bedrock at WSH242 and WSH244 are below background levels. Tritium concentrations at WSH243 have been decreasing since 2013 (Graph 18). The maximum concentration at WSH243 in 2024 was 328 Bq/L.



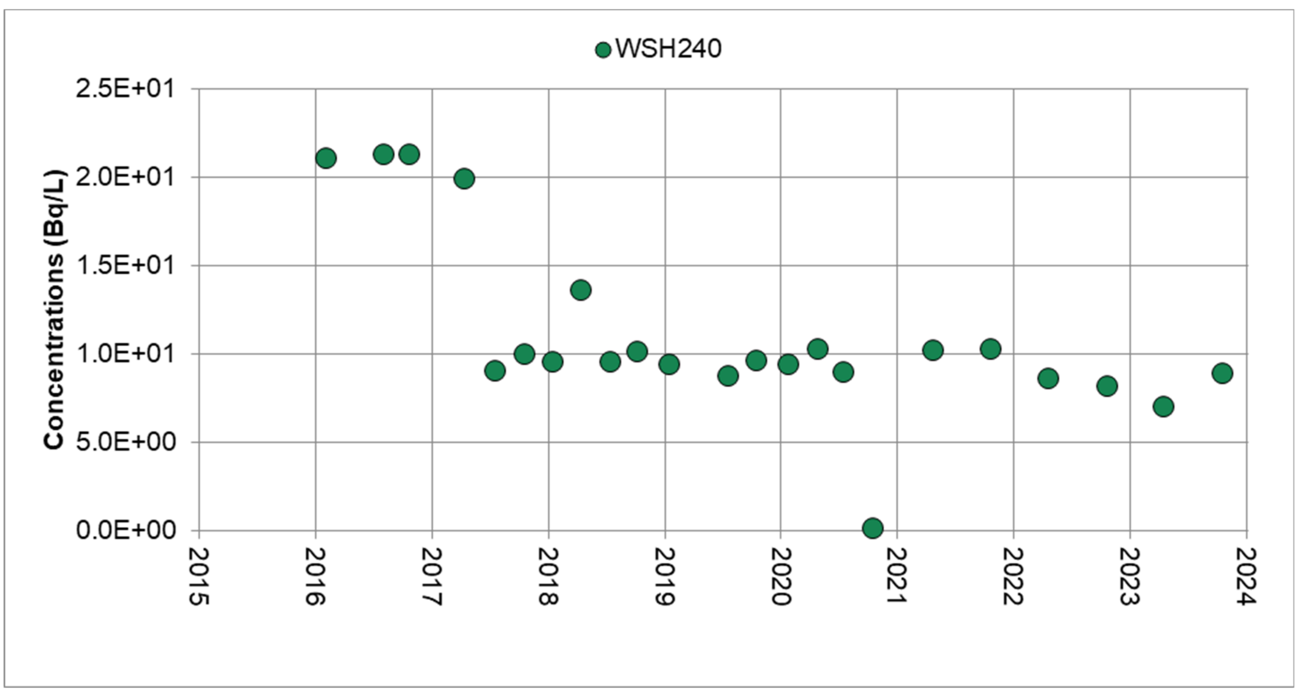
Graph 18: Tritium Concentrations at WSH243

North of the Stage 3E trenches, tritium concentrations in the MSA and bedrock HUs are monitored at locations WSH229 (HU4) and WSH228 (H7). East of the Stage 3 trenches, the MSA is monitored at location WSH240 (HU4). Tritium concentrations in WSH229 fluctuated with the highest concentration of 1,650 Bq/L observed in 2021 (Graph 19). Because tritium concentrations in shallow groundwater in the overlying till (monitored at WSH287) are at background values, it is considered possible that tritium concentrations in the MSA at WSH229 reflect tritium migration from beneath the LLSBs #1 to #10, consistent with the inferred groundwater flow direction in the MSA to the east (Section 2.2). Further to the east in WSH240 (HU4), tritium concentrations remain at background levels (Graph 20).

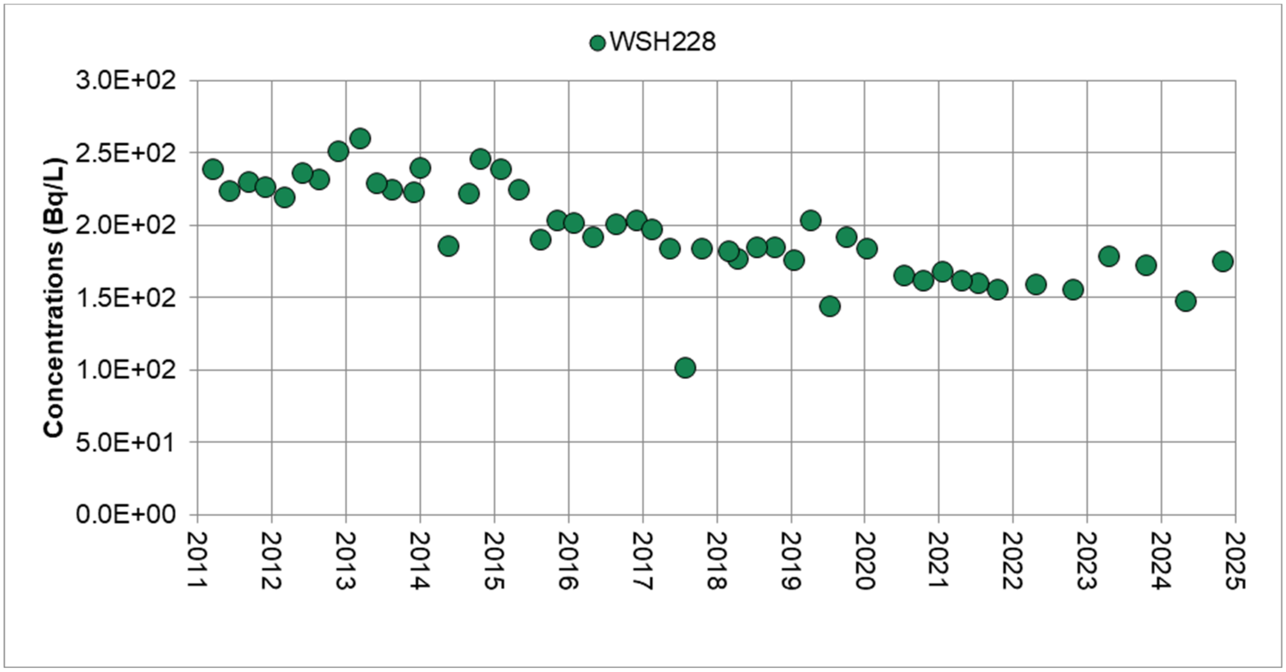
Tritium concentrations in the bedrock well in this area, at WSH228, show a decreasing trend, as shown in Graph 21. The persistence of low concentrations of tritium in groundwater in this well may indicate influence from the interconnectedness of the upper bedrock with the MSA. Groundwater quality in this area will continue to be monitored.



Graph 19: Tritium Concentrations at WSH229



Graph 20: Tritium Concentrations at WSH240



Graph 21: Tritium Concentrations at WSH228

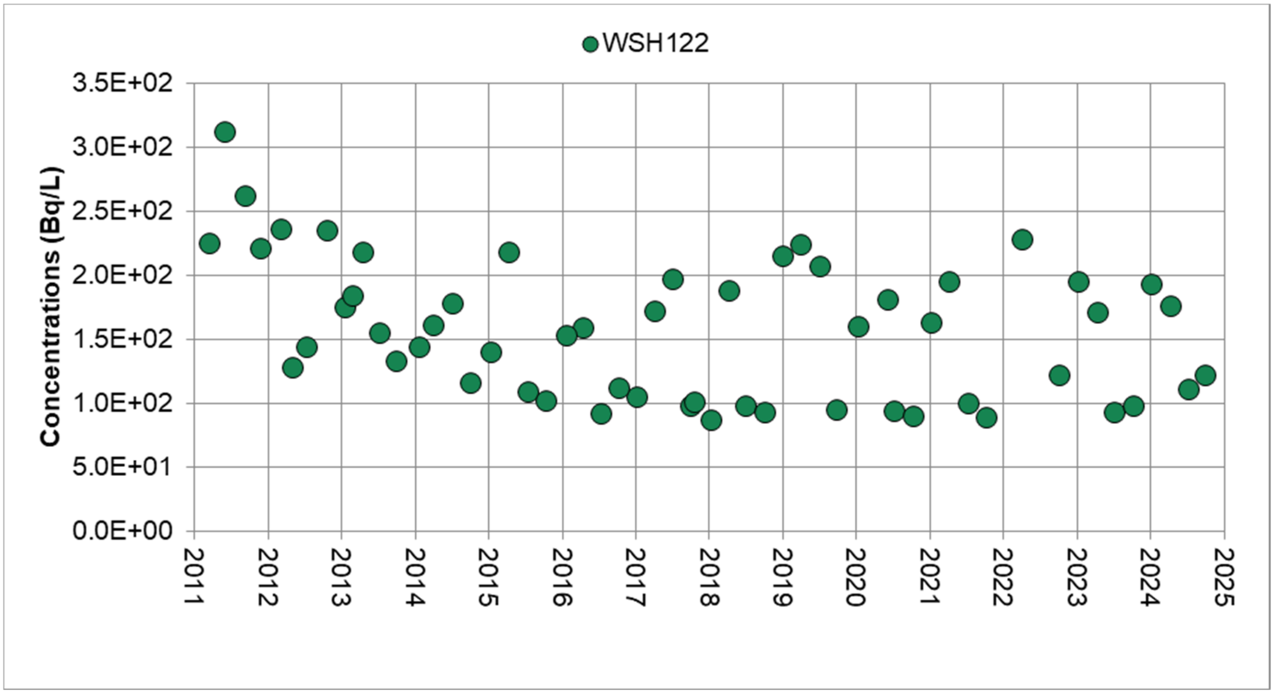
3.1.2 RWOS1

In developing the GWPMP for RWOS1, tritium concentrations in groundwater beneath the RWOS1 were determined to be comparable to those measured in precipitation (wet deposition) and no localized tritium sources were identified (Ecometrix, 2022b). The potential for the influence of SSCs on groundwater at RWOS1 is considered low; new wastes have not been received at RWOS1 since the 1970s and some wastes were relocated in the 1990s and 2000s.

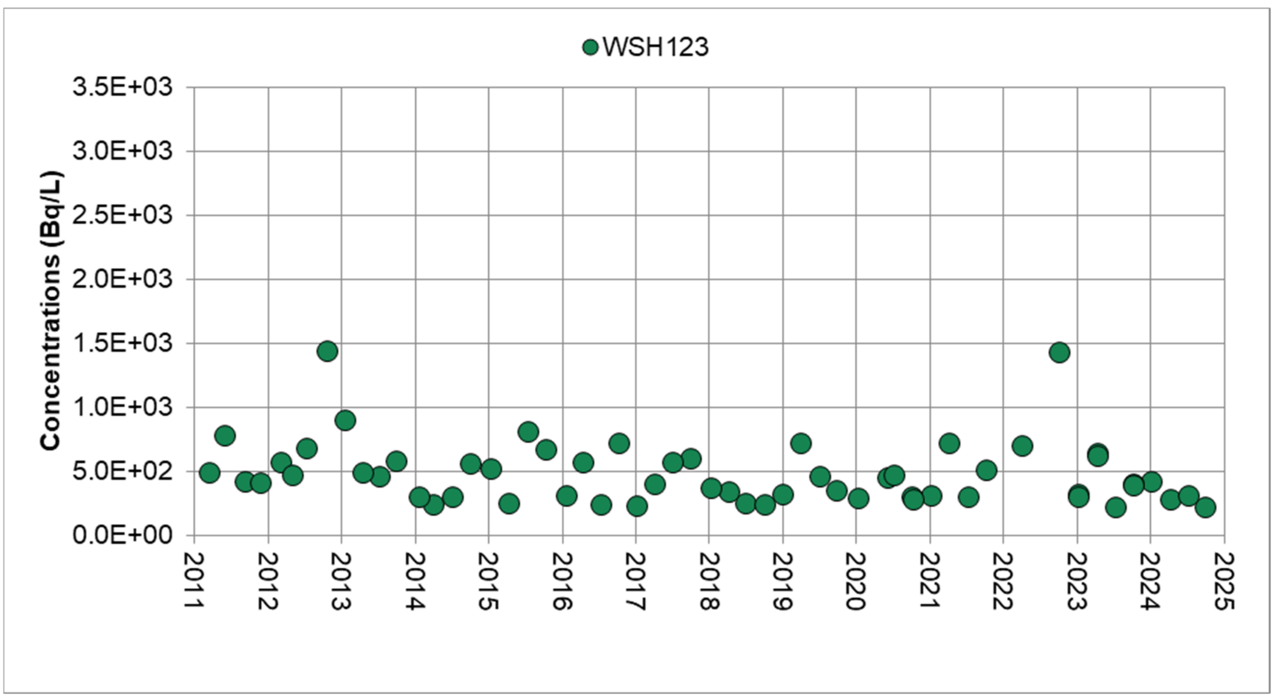
The frequency of sampling of groundwater monitoring wells in the RWOS1 wells is semi-annual. Maximum tritium concentrations in groundwater beneath the RWOS1 are shown in Figure 10.

Tritium concentrations in 2024 were within historical ranges within the RWOS1. Fluctuations in tritium concentrations in RWOS1 wells are observed, as represented by wells WSH122 and WSH123 in Graph 22 and Graph 23, respectively; however, the concentrations observed over time were stable. Fluctuations in tritium concentrations reflect fluctuations in tritium concentrations in precipitation (Ecometrix, 2022b).

As was concluded in the GWPMP, there is no evidence of the influence of the SSCs on groundwater tritium concentrations at RWOS1. Groundwater will continue to be monitored in this area.



Graph 22: Tritium Concentrations at WSH122



Graph 23: Tritium Concentrations at WSH123

Figure 10: 2024 Maximum Tritium Concentrations – Objective 1, RWOS1

3.1.3 Background Tritium

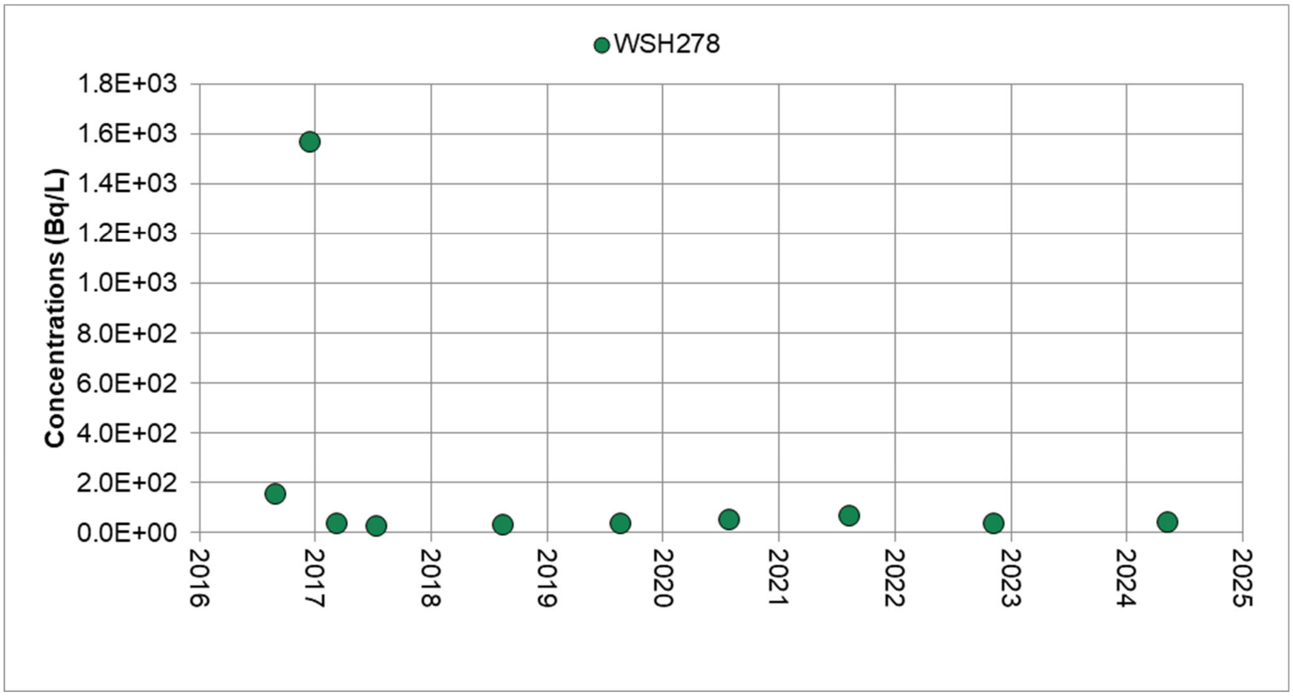
This objective was included as part of the GWPMP to monitor tritium concentrations at well locations uninfluenced by SSCs. Tritium concentrations in wells meeting these criteria provide the means of identifying changes in background concentrations related to air emissions around the WWMF, to be considered in interpreting data downgradient of SSCs.

Background concentrations of tritium in groundwater for the WWMF are measured in groundwater monitoring wells located in the southwest portion of the Site, in 2 wells clusters:

- WSH277(HU1-3), WSH276 (HU5) and WSH275 (HU7); and
- WSH279 (HU4) and WSH278 (HU7).

Background tritium concentrations are additionally monitored in WSH301, on OPG property north of the WWMF.

Tritium concentrations in background wells are provided in Appendix A, Table A-5. The spatial distribution of the maximum tritium concentrations observed in background monitoring wells in 2024 is shown in Figure 11. Tritium concentrations in the background wells are stable over time, indicating that they are not being influenced by SSCs. The temporal behaviour of tritium in background monitoring wells over time is represented by WSH278 in Graph 24. Tritium concentrations in groundwater have fluctuated since 2017 in the upper fill/till (WSH277), the MSA (WSH279), and in the unweathered till (WSH276); (Appendix A, Table A-5) and are at or below detection in the bedrock wells at WSH275 and WSH301; (Table A-5).



Graph 24:Tritium Concentrations at WSH278

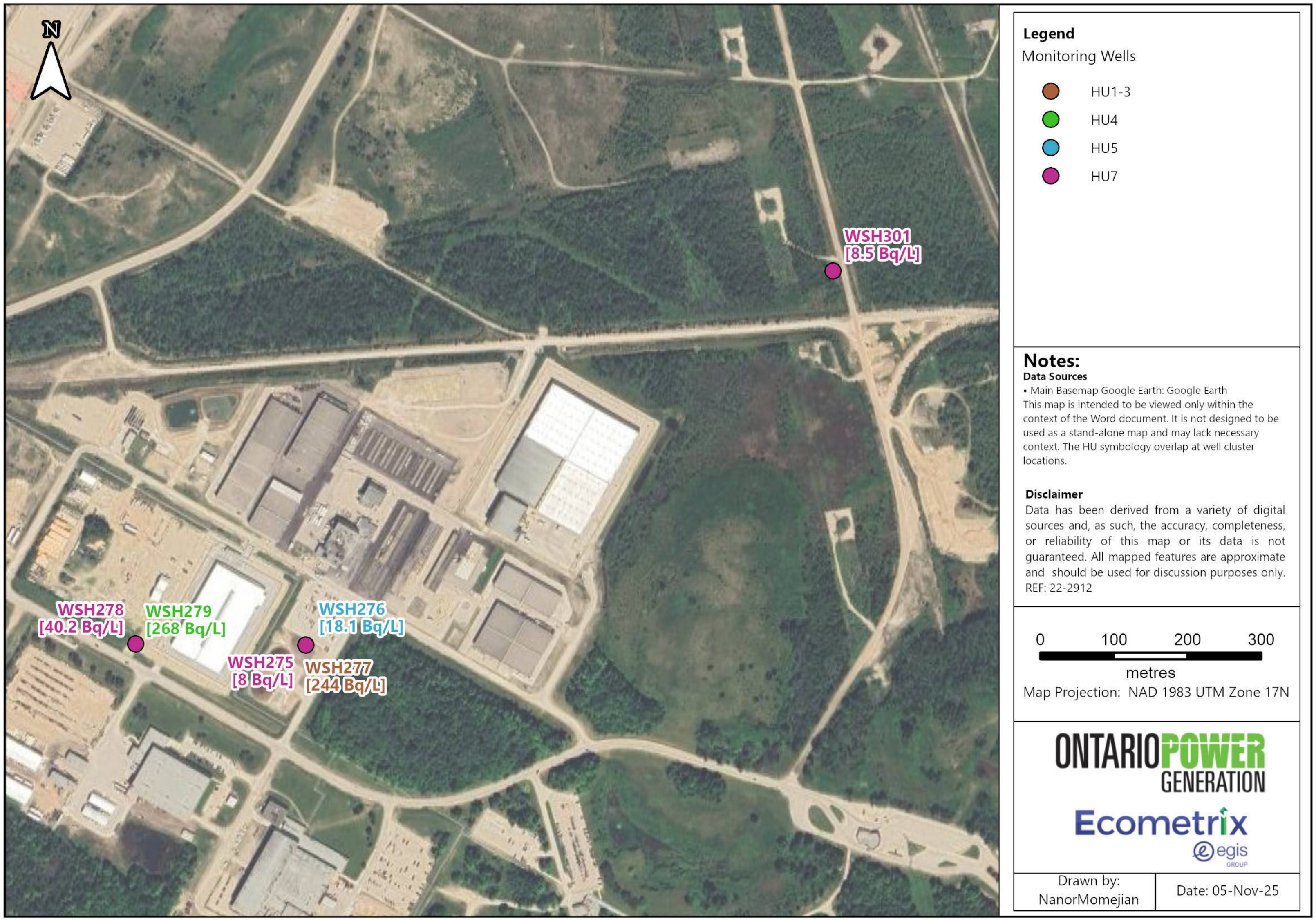


Figure 11: 2024 Maximum Tritium Concentrations – Objective 1, Background Monitoring Wells

3.2 Objective 2 Results

The groundwater flow directions inferred for HUs beneath the WWMF and the RWOS1 from hydraulic head data reported in metre above sea level (m asl) collected in 2024 are consistent with historical interpretations.

The interpreted groundwater elevation contours and inferred groundwater flow directions in HU1-3 are shown in Figure 12. The interpreted contours are based on the measured elevations, and the inferred contours are extrapolated based on conclusions drawn from analyzing the interpreted results. The flow directions are complex in this HU, which is considered to reflect influences from the subsurface drainage infrastructure and the heterogeneous nature of the till/fill material. Groundwater in HU1-3 is inferred to discharge to the SRD and other drainage ditches on the WWMF (e.g., perimeter ditches in the laydown area), which ultimately discharge to Lake Huron (Ecometrix, 2022b).

Groundwater flow in HU4 is directed towards the east (Figure 13). Groundwater in HU4 also flows downward into the bedrock. Once in the bedrock, groundwater is inferred to flow to Lake Huron (Ecometrix, 2022b). In the bedrock aquifer, groundwater is inferred to flow north towards Lake Huron, as shown in Figure 14.

Contours for the water table at RWOS1 are presented in Figure 15. Groundwater flow beneath the RWOS1 is inferred to flow towards WSH124. Ultimately, groundwater from beneath the RWOS1 is inferred, based on regional groundwater elevations in bedrock, to flow to the south towards Lake Huron (Ecometrix, 2022b).

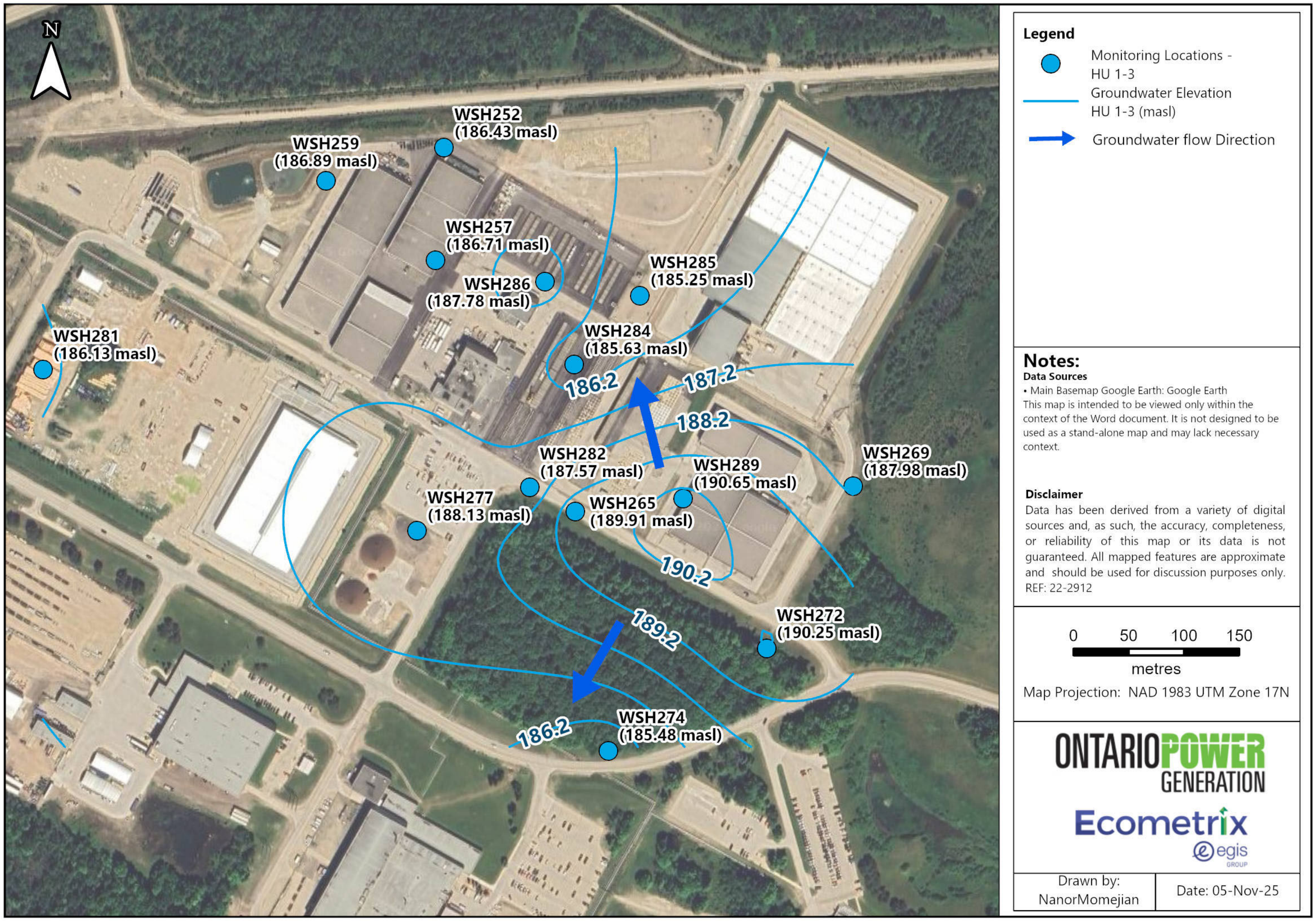


Figure 12: 2024 Shallow (HU1-3) Groundwater Contours based on April 17, 2024, measurements

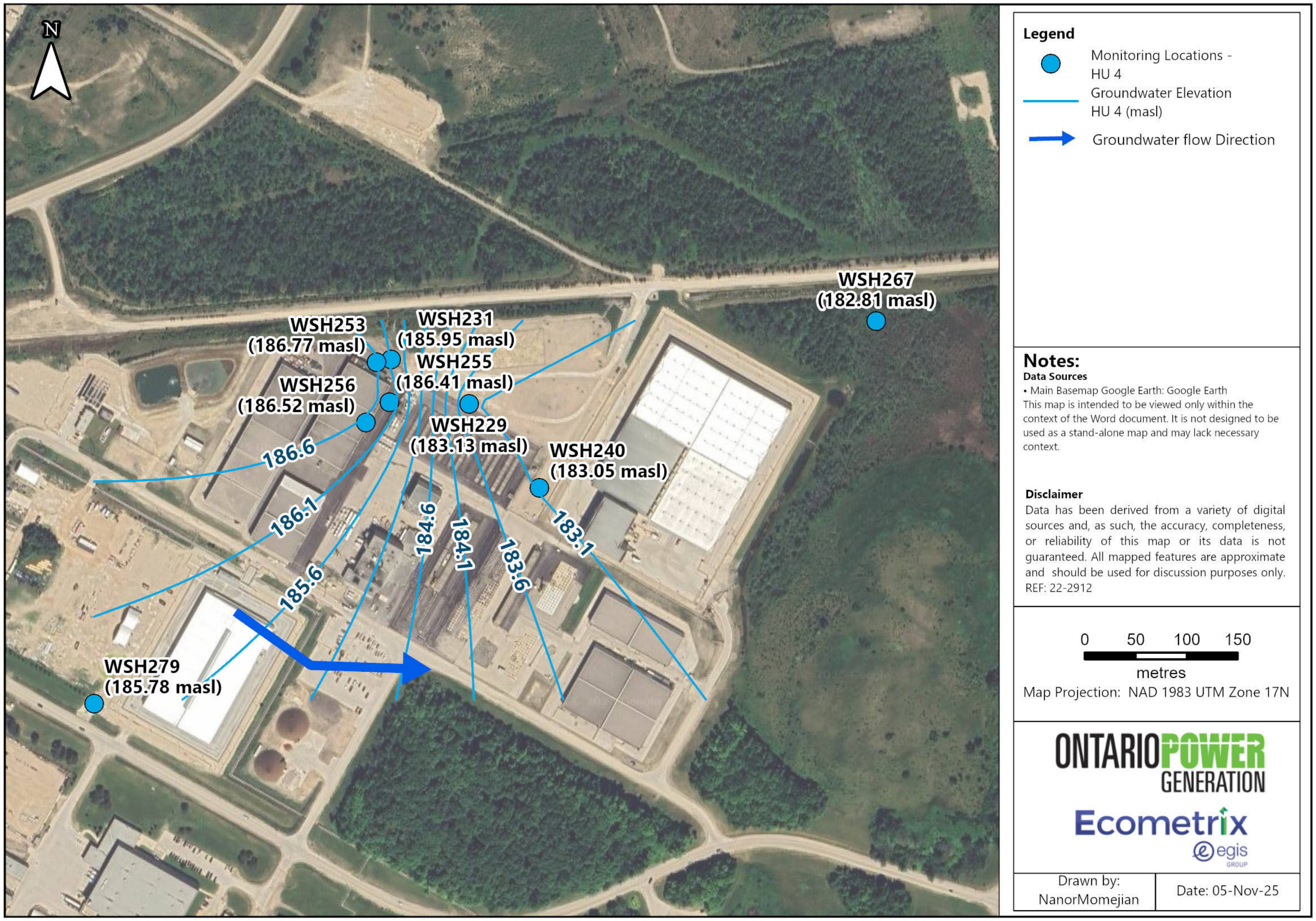


Figure 13: 2024 MSA (HU4) Groundwater Contours based on April 17, 2024, measurements

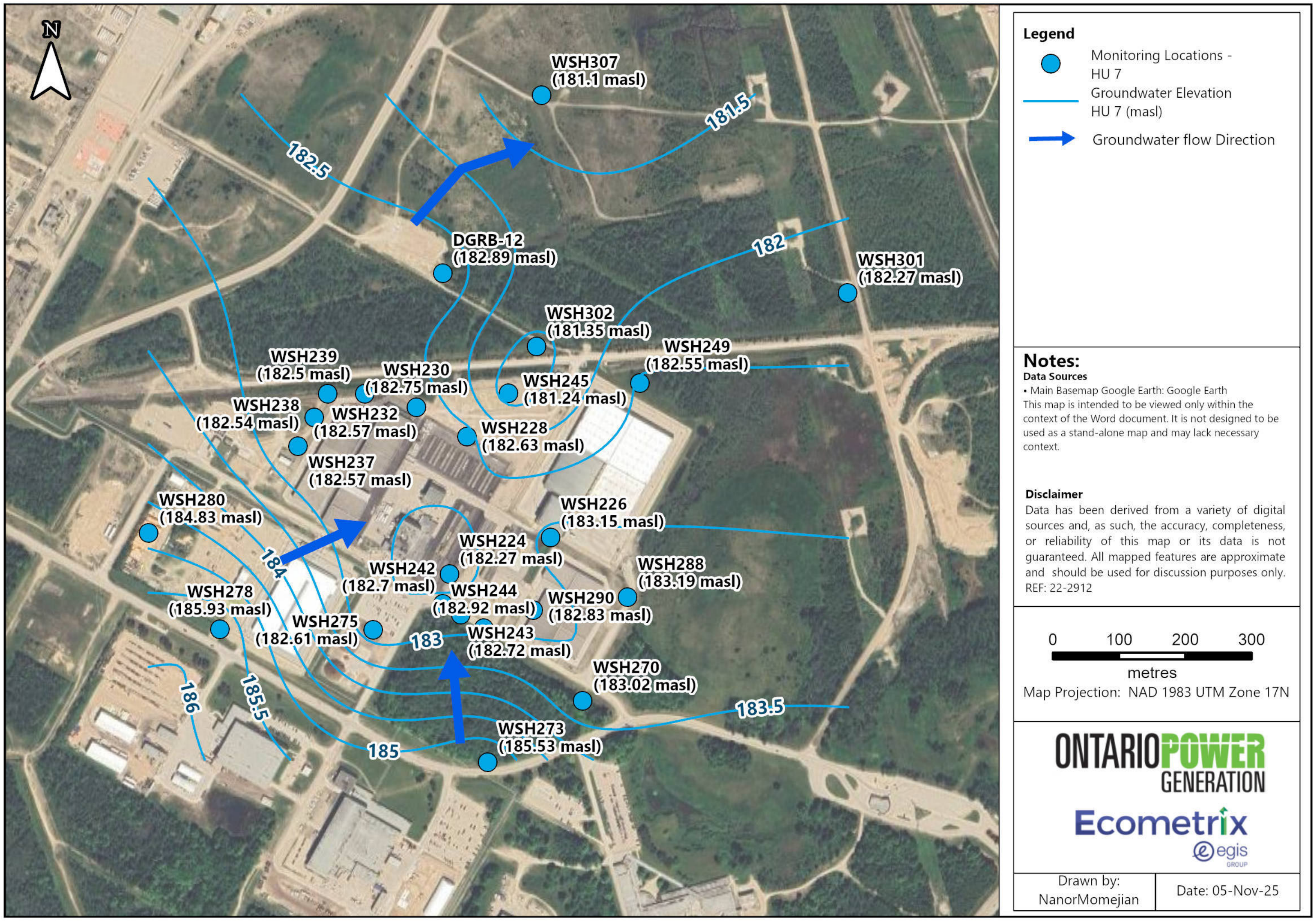


Figure 14: 2024 Bedrock (HU7) Groundwater Contours based on April 17, 2024, measurements

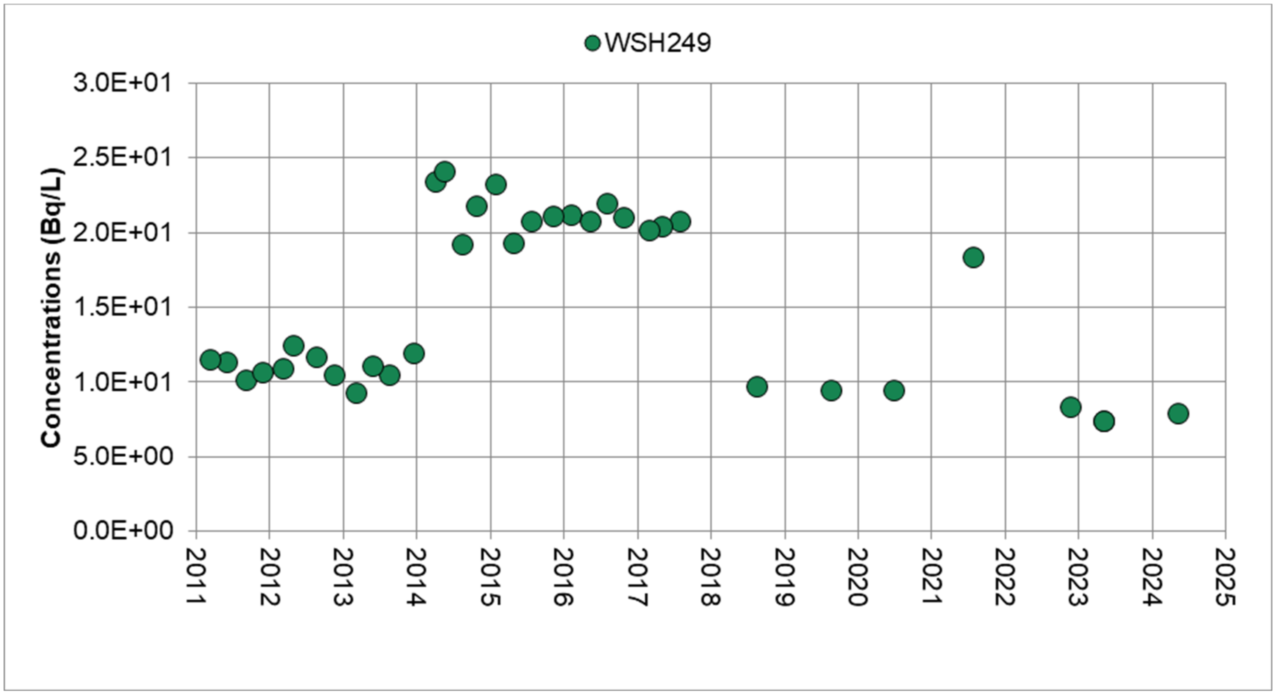
Figure 15: 2024 Native Sand (HU2) Groundwater Contours at RWOS1 based on April 17, 2024, measurements

3.3 Objective 3 Results

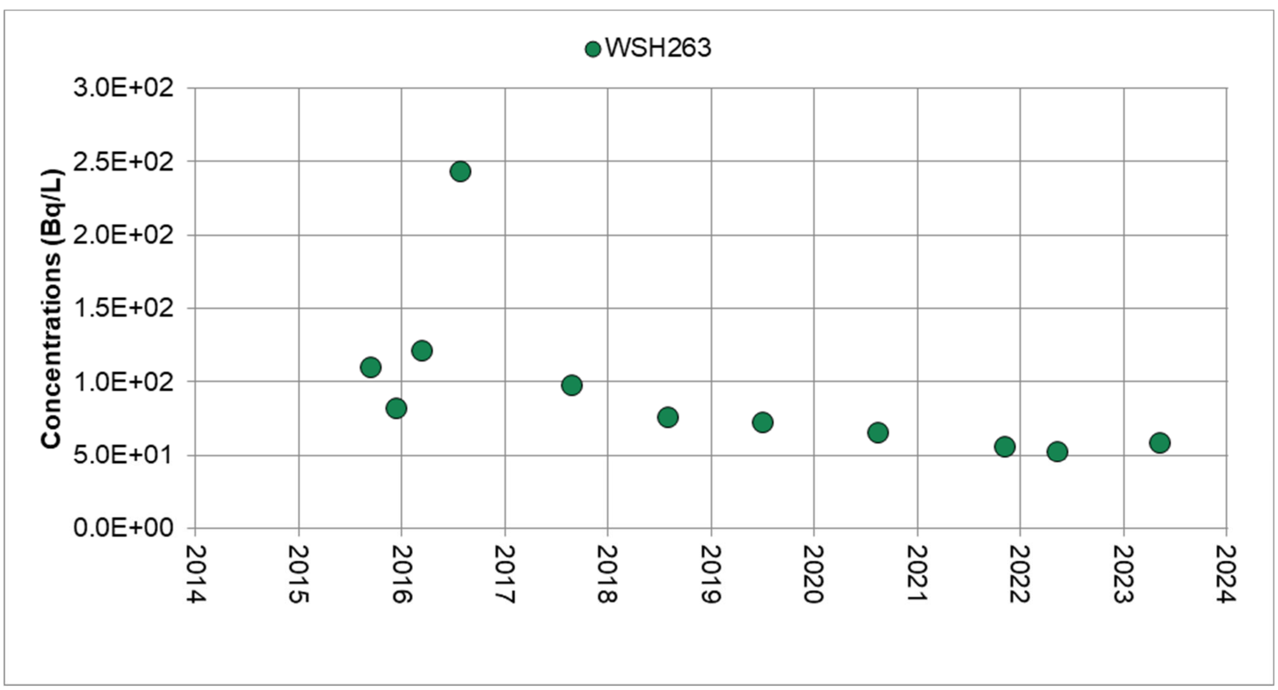
Groundwater quality along the perimeter of the WWMF in the inferred downgradient direction of groundwater flow in the middle sand (HU4) and bedrock (HU7) HUs is monitored to provide timely data to evaluate whether human and ecological receptors associated with the groundwater end-uses are protected. Tritium concentrations in these wells are compared to numeric groundwater evaluation criteria to identify the potential impact for off-site groundwater end-uses. Groundwater end-uses are off-site potable water wells and the discharge of groundwater from beneath the Site to Lake Huron.

Tritium concentrations in perimeter wells WSH245 (HU7), WSH249 (HU7), WSH263 (HU5), WSH267 (HU4), WSH307 (HU7), DGRB-12A (HU5) and DGRB-14 (HU5) are provided in Table A-6. Monitoring wells WSH307, DGRB-12A and DGRB-14 are located north of the WWMF site boundary on OPG lands. The maximum tritium concentrations observed in 2024 at background monitoring wells are illustrated in Figure 16.

Tritium concentrations in the perimeter wells are stable as shown in Graph 25 for WSH249 or decreasing as shown in Graph 26 for WSH263. The results for the perimeter wells remain below groundwater evaluation criteria and do not indicate the potential for adverse effects on water quality off-site beyond the WWMF site boundaries.



Graph 25: Tritium Concentrations at WSH249



Graph 26: Tritium Concentrations at WSH263

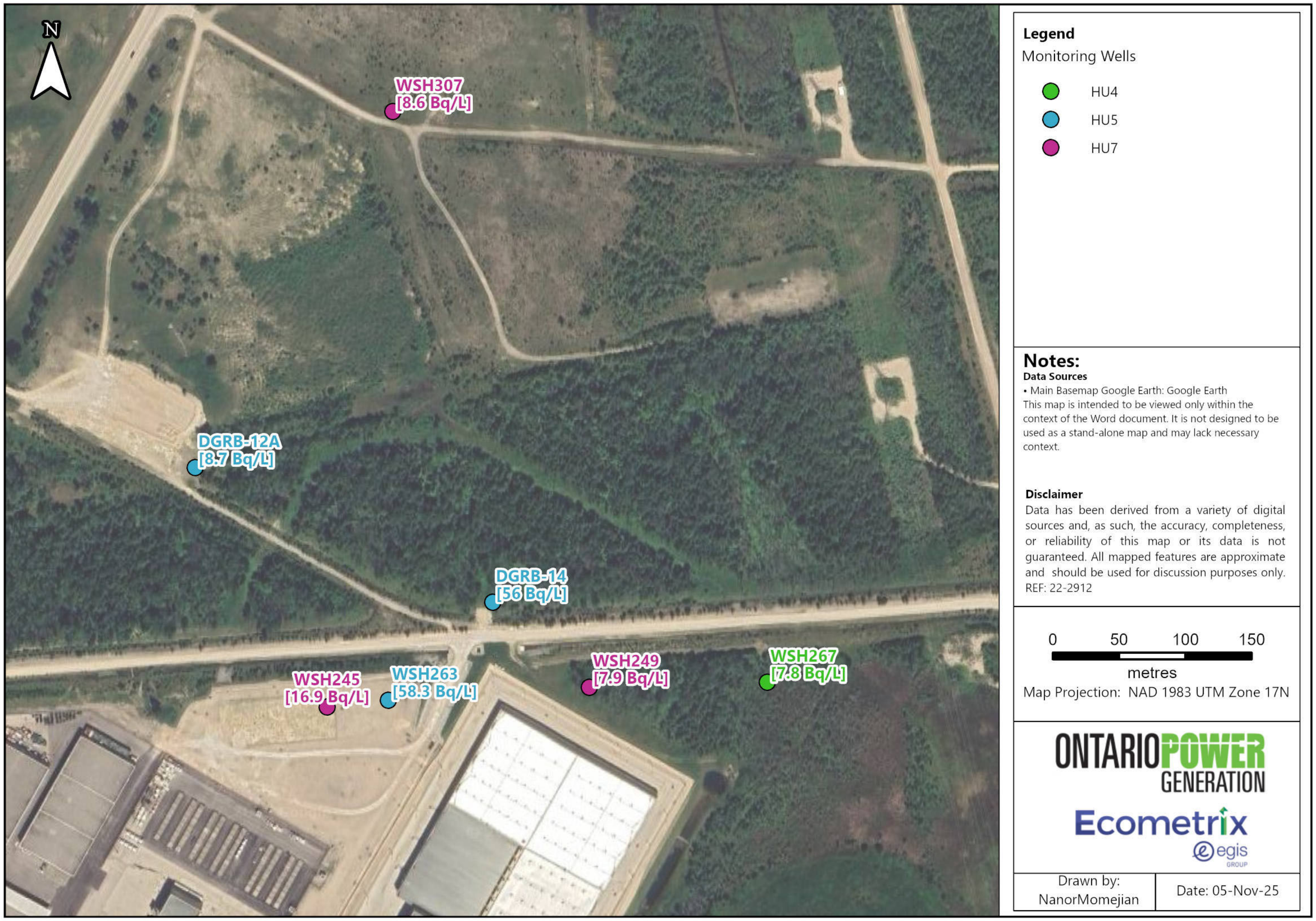


Figure 16: 2024 Maximum Tritium Concentrations – Objective 3, Downgradient Perimeter Monitoring Wells

4.0 2024 PROGRAM QUALITY ASSURANCE/QUALITY CONTROL

The Quality Assurance and Quality Control for the groundwater monitoring program encompasses the field sample collection, laboratory analysis and laboratory quality control activities. The objective is to provide confidence in the interpretation of the WWMF and RWOS1 groundwater monitoring data through a systematic and documented process.

4.1 Quality Assurance Program for Laboratories

In 2024, water samples were submitted to the Bruce Power Health Physics Lab, which performs laboratory activities according to a documented quality assurance program.

4.2 Quality Control Results

Field duplicates were collected at a frequency prescribed in the GWPMP to measure sampling and analytical performance. The GWPMP defined 2 data quality objectives to verify the precision and accuracy of the sampling program. The first objective is applied where concentrations of tritium being evaluated are greater than or equal to 5 times the detection limit and it is to achieve a relative percent difference of 20% or less between the original and duplicate samples. The second objective is applied when the tritium concentrations being evaluated are less than 5 times the detection limit, and an absolute difference between the original and duplicate samples of less than 2 times the detection limit is to be achieved.

In 2024, 16 field duplicate samples of tritium in groundwater were collected. The sample and field duplicate pairs met the data quality objectives outlined above. The field techniques and the laboratory’s analytical methods employed were determined to be reproducible and reliable.

5.0 SUPPLEMENTARY STUDIES AND AUDITS

There were no supplementary studies related to the groundwater monitoring program at WWMF or RWOS1 initiated in 2024.

6.0 NOMENCLATURE OF SAMPLING LOCATIONS

Sampling Location Type	Identifier	Explanation of Nomenclature
Groundwater Monitoring Well (“Water Sampling Hole”)	WSHXXX or DGRB-XX	*XXX* or *XX* represents a unique identifier

7.0 ACRONYMS

Bq/L	Becquerel per Litre
CNSC	Canadian Nuclear Safety Commission

GWPMP	Groundwater Monitoring Protection Plan
HU	Hydrostratigraphic Unit
IC	Inground Containers
km	kilometre
LLSB	Low Level Storage Building
MSA	Middle Sands Aquifer
m	metre
masl	metres above sea level
OPG	Ontario Power Generation Inc.
RWOS1	Radioactive Waste Operations Site 1
RCSB	Retube Component Storage Building
SAP	Sampling and Analysis Plan
SSC	Systems, Structures and Components
SGSB	Steam Generator Storage Building
SRD	South Railway Ditch
WWMF	Western Waste Management Facility

8.0 REFERENCES

Ecometrix (Ecometrix Incorporated), 2022a. Groundwater Protection and Monitoring Programs – CSA N288.7 Implementation at WWMF AND RWOS1. Report No. W-REP-07294-00002. October.

Ecometrix (Ecometrix Incorporated), 2022b. Conceptual Site Model – CSA N288.7 Implementation at WWMF and RWOS1. Report No. W-REP-07294-00001. October.

Ecometrix (Ecometrix Incorporated), 2022c. 2022 Sampling and Analysis Plan, Western Waste Management Facility and RWOS1. July.

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Jensen, M.R. (Ontario Hydro), 1996. BNPD RWO Site 2: Ground Water Monitoring Well Network Assessment. Report No. NK37- 03480–96006.

OPG (Ontario Power Generation), 2023. Groundwater Protection and Monitoring Programs for Pickering Nuclear - CSA N288.7 Implementation. Prepared by: Ecometrix Inc. Report No. P-REP-07294-00002. September.

Appendix A: Tables A-1 to A-7

Table A-1a: 2024 Groundwater Results near LLSBs #1 to #10

Monitoring Location	Analysis Parameter	HU	Frequency	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
WSH230	Tritium	HU7	Semi-Annual	--	778	--	859
WSH231	Tritium	HU4	Semi-Annual	--	8,540	--	11,500
WSH232	Tritium	HU7	Annual	--	16.5	--	--
WSH237	Tritium	HU7	Annual	--	<8.81	--	--
WSH238	Tritium	HU7	Annual	--	<7.17	--	--
WSH239	Tritium	HU7	Annual	--	<7.01	--	--
WSH251	Tritium	HU5	Annual	--	1,990	--	--
WSH252	Tritium	HU1-3	Annual	--	2,810	--	--
WSH253	Tritium	HU4	Semi-Annual	--	22,300	--	21,600
WSH255	Tritium	HU4	Semi-Annual	--	3,450	--	2,490
WSH256	Tritium	HU4	Annual	--	3,080	--	--
WSH257	Tritium	HU1-3	Annual	--	2,470	--	--
WSH259	Tritium	HU1-3	Annual	--	910	--	--
WSH260	Tritium	HU5	Annual	--	89.8	--	--
WSH302	Tritium	HU7	Annual	--	<8.61	--	--
DGRB-12	Tritium	HU7	Annual	--	104	--	108

Notes:
"--": Not required as per the WWMF GWPMP.
"N/A": Sample was not collected.

Table A-1b: 2024 Subsurface Drainage Results near LLSBs #1 to #10

Drainage ID	Analysis Parameter	Frequency	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SS4B Subsurface	Tritium (Bq/L)	Monthly	10,600	9,860	12,000	11,900	13,000	14,000	24,600	41,600	26,900	38,100	21,400	14,800

Note:
Administrative Limit: 98,000 Bq/L.

Table A-2a: 2024 Groundwater Results near LLSBs #11 to #14, SGSB and RCSB

Monitoring Location	Analysis Parameter	HU	Frequency	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
WSH226	Tritium	HU7	Semi-Annual	--	8.34	--	8.57
WSH268	Tritium	HU5	Annual		<8.48		--
WSH269	Tritium	HU1-3	Semi-Annual	--	376	--	378
WSH270	Tritium	HU7	Annual	--	8.06	--	--
WSH272	Tritium	HU1-3	Annual	--	422	--	--
WSH288	Tritium	HU7	Semi-Annual	--	N/A	--	N/A
WSH289	Tritium	HU1-3	Semi-Annual	--	N/A	--	N/A
WSH290	Tritium	HU1-3	Semi-Annual	--	N/A	--	N/A

Notes:
"--": Not required as per the WWMF GWPMP.
"N/A": Sample was not collected.

Table A-2b: 2024 Subsurface Drainage near LLSBs #11 to #14, SGSB and RCSB

Drainage ID	Analysis Parameter	Frequency	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SS6 Subsurface	Tritium (Bq/L)	Monthly	4,080	3,810	3,230	4,470	3,970	3,390	2,410	2,770	2,320	3,290	4,750	4,910

Note:
Administrative Limit: 98,000 Bq/L

Table A-3a: 2024 Groundwater Results near Trenches, Tile Holes, ICs and Quadricells

Monitoring Location	Analysis Parameter	HU	Frequency	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
WSH224	Tritium	HU7	Annual	--	41.5	--	--
WSH228	Tritium	HU7	Semi-Annual	--	148	--	175
WSH229	Tritium	HU4	Semi-Annual	--	673	--	516
WSH240	Tritium	HU4	Semi-Annual	--	<7.03	--	<8.88
WSH242	Tritium	HU7	Semi-Annual	--	48.4	--	45.7
WSH243	Tritium	HU7	Semi-Annual	--	311	--	328
WSH244	Tritium	HU7	Annual	--	113	--	--
WSH264	Tritium	HU5	Annual	--	71.1	--	--
WSH265	Tritium	HU1-3	Semi-Annual	--	554	--	372
WSH282	Tritium	HU1-3	Semi-Annual	--	673	--	591
WSH283	Tritium	HU1-3	Semi-Annual	--	228	--	219
WSH284	Tritium	HU1-3	Semi-Annual	--	428	--	395
WSH285	Tritium	HU1-3	Semi-Annual	--	357	--	340
WSH286	Tritium	HU1-3	Semi-Annual	--	361	--	275
WSH287	Tritium	HU3/5	Semi-Annual	--	358	--	329

Note:
"--": Not required as per the WWMF GWPMP.

Table A-3b: 2024 Subsurface Drainage near Trenches, Tile Holes, ICs and Quadricells

Drainage ID	Analysis Parameter	Frequency	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SS1 Subsurface	Tritium (Bq/L)	Monthly	1,310	1,430	1,240	1,340	1,370	1,320	756	829	664	1,060	1,300	1,160
SS2 Subsurface	Tritium (Bq/L)	Monthly	880	819	861	889	930	1,020	770	680	617	641	666	602
SS3 Subsurface	Tritium (Bq/L)	Monthly	2,850	3,000	2,950	2,840	2,570	2,710	3,010	2,860	2,860	2,920	3,160	3,850

Note:
Administrative Limit: 98,000 Bq/L

Table A-4: 2024 Groundwater Results near RWOS1

Monitoring Location	Analysis Parameter	HU	Frequency	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
WSH122	Tritium	HU2	Semi-Annual	193	176	111	122
WSH123	Tritium	HU2	Semi-Annual	416	279	308	215
WSH124	Tritium	HU2	Semi-Annual	159	188	205	179
WSH125	Tritium	HU2	Semi-Annual	186	179	183	146
WSH126	Tritium	HU2	Semi-Annual	173	164	182	163

Table A-5: 2024 Groundwater Results to Establish Background Concentrations at WWMF

Monitoring Location	Analysis Parameter	HU	Frequency	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
WSH275	Tritium	HU7	Annual	--	<8	--	--
WSH276	Tritium	HU5	Semi-Annual	--	18.1	--	9.8
WSH277	Tritium	HU1-3	Semi-Annual	--	244	--	226
WSH278	Tritium	HU7	Annual	--	40.2	--	--
WSH279	Tritium	HU4	Semi-Annual	--	268	--	233
WSH301	Tritium	HU7	Annual	--	<8.48	--	--

Note:
"--": Not required as per the WWMF GWPMP.

Table A-6: 2024 Groundwater Results in Downgradient Perimeter Wells at WWMF

Monitoring Location	Analysis Parameter	HU	Frequency	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
WSH245	Regular	HU7	Annual	--	16.9	--	--
WSH249	Regular	HU7	Annual	--	<7.88	--	--
WSH263	Regular	HU5	Annual	--	58.3	--	--
WSH267	Regular	HU4	Annual	--	<7.84	--	--
WSH307	Regular	HU7	Annual	--	<8.57	--	--
DGRB-12A	Regular	HU5	Annual	--	<8.7	--	--
DGRB-14	Regular	HU5	Annual	--	56	--	--

Note:
"--": Not required as per the WWMF GWPMP.

Table A-7a: 2024 Groundwater Results in Downgradient Perimeter Wells at WWMF

Date	Monitoring Location	Water Level (m below top of pipe)	Top of Pipe Elevation (m asl)	Water Level Elevation (m asl)	Difference between Q2 and Q4 2024 (m)	Hydrostratigraphic Unit
29-Apr-2024	WSH265	1.64	191.595	189.955	-0.55	HU1-3
29-Oct-2024		2.19	191.595	189.405		
29-Apr-2024	WSH269	2.7	190.720	188.020	-0.25	HU1-3
30-Oct-2024		2.95	190.720	187.770		
29-Apr-2024	WSH276	6.04	190.694	184.654	-0.26	HU5
30-Oct-2024		6.3	190.694	184.394		
30-Apr-2024	WSH277	2.6	190.749	188.149	-0.01	HU1-3
30-Oct-2024		2.61	190.749	188.139		
30-Apr-2024	WSH279	3.38	189.176	185.796	-0.1	HU4
30-Oct-2024		3.48	189.176	185.696		
30-Apr-2024	WSH282	2.61	190.284	187.674	-0.81	HU1-3
30-Oct-2024		3.42	190.284	186.864		
13-May-2024	WSH283	2.52	188.800	186.280	0.46	HU1-3
13-Nov-2024		2.06	188.800	186.740		
13-May-2024	WSH284	3.07	188.983	185.913	0.96	HU1-3
13-Nov-2024		2.11	188.983	186.873		
18-Apr-2024	WSH285	5.04	190.300	185.260	-0.03	HU1-3
15-Oct-2024		5.07	190.300	185.230		
13-May-2024	WSH286	1.6	189.420	187.820	-0.68	HU1-3
13-Nov-2024		2.28	189.420	187.140		
18-Apr-2024	WSH287	7.6	190.125	182.525	NC	HU3/5
15-Oct-2024		0	190.125	190.125		
3-Apr-2024	DGRB-12	3.07	186.580	183.510	-1.17	HU5
2-Oct-2024		4.24	186.580	182.340		
25-Apr-2024	WSH226	6.82	168.759	161.939	-2.88	HU7
29-Oct-2024		9.76	168.759	159.059		
15-Apr-2024	WSH228	7.46	189.976	182.516	-0.86	HU7
15-Oct-2024		8.32	189.976	181.656		

Date	Monitoring Location	Water Level (m below top of pipe)	Top of Pipe Elevation (m asl)	Water Level Elevation (m asl)	Difference between Q2 and Q4 2024 (m)	Hydrostratigraphic Unit
15-Apr-2024	WSH229	6.97	190.089	183.119	-0.71	HU4
15-Oct-2024		7.68	190.089	182.409		
18-Apr-2024	WSH230	6.78	189.555	182.775	-1.01	HU7
16-Oct-2024		7.79	189.555	181.765		
18-Apr-2024	WSH231	3.44	189.445	186.005	-0.30	HU3
16-Oct-2024		3.74	189.445	185.705		
25-Apr-2024	WSH242	7.5	190.195	182.695	-1.10	HU7
29-Oct-2024		8.6	190.195	181.595		
29-Apr-2024	WSH243	8.11	191.015	182.905	-1.21	HU7
29-Oct-2024		9.32	191.015	181.695		
15-Apr-2024	WSH240	7.11	190.290	183.180	-0.66	HU4
15-Oct-2024		7.77	190.290	182.520		
10-May-2024	WSH253	2.17	188.920	186.750	-0.73	HU4
13-Nov-2024		2.9	188.920	186.020		
15-May-2024	WSH255	2.4	188.780	186.380	-0.30	HU4
13-Nov-2024		2.7	188.780	186.080		

Table A-7b: Quality Control Results, Trip and Field Blank Sample Results

Sample Type	Parameter	Sample Result (Bq/L) by Date						
		03-Oct-2024	02-Oct-2024	15-Oct-2024	16-Oct-2024	29-Oct-2024	30-Oct-2024	13-Nov-2024
Field Blank	Tritium	7.04	9.5	14	12.9	19.5	13	-1.66
Trip Blank	Tritium	--	--	--	--	11.2	16.1	-11.2

Note:
"--": no sample collected
"###": <LC below critical level or decision threshold (using 95% confidence level). If the net signal is less than Lc, the signal is considered not to be detected. If the net signal is greater than Lc, the signal is considered to be detected.

Table A-7c: Tritium Quality Control Results, Duplicate Samples and Relative Percent Differences

Location	Sample Date	Sample Values (Bq/L)		Relative Percent Difference (%)	Absolute Difference
		Duplicate	Primary		
WSH123	09-Jan-2024	419	416	0.7	--
	12-Apr-2024	299	279	6.9	--
WSH229	15-Apr-2024	650	673	3.5	--
	15-Oct-2024	521	516	1.0	--
WSH231	18-Apr-2024	8,520	8,540	0.2	--
WSH269	30-Apr-2024	397	376	5.4	--
WSH276	30-Apr-2024	12.9	18.1	--	5.2
WSH249	09-May-2024	<7.86	<7.88	N/A	--
WSH284	13-May-2024	417	428	2.6	--
WSH252	23-May-2024	2,800	2,810	0.4	--
WSH123	12-Jul-2024	321	308	4.1	--
	03-Oct-2024	214	215	0.5	--
WSH231	16-Oct-2024	11,500	11,500	0.0	--
WSH269	30-Oct-2024	382	378	1.1	--
WSH276	30-Oct-2024	<9.22	9.8	N/A	--
WSH284	13-Nov-2024	397	395	0.5	--

Note:
"--": where calculation is not necessary
N/A: where not applicable