2022 Pickering Nuclear Groundwater Monitoring Program Results

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Revision Summary

Revision Number	Date	Comments
000	2023-03-29	Initial Issue
001	2023-11-24	Revised Figure 21 to include the elevation of contour lines of 75 masl.

Land Acknowledgement

The lands and waters on which the Pickering Nuclear Generating Station (PNGS) is situated are within the traditional and treaty territory of the Williams Treaties First Nations, which includes Curve Lake First Nation, Hiawatha First Nation, Alderville First Nation, Chippewas of Beausoleil First Nation, Chippewas of Georgina Island First Nation, Chippewas of Rama First Nation, and the Mississaugas of Scugog Island First Nation.

The PNGS is within the territory of the Gunshot Treaty and the Williams Treaties of 1923. The Gunshot Treaty Rights were reaffirmed in 2018 in a settlement with Canada and the Province of Ontario.

To acknowledge the treaty and traditional territory, is to recognize the rights of the First Nations. It is to recognize the history of the land, predating the establishment of the earliest European colonies. It is also to acknowledge the significance for the Indigenous peoples who lived and continue to live upon it, to acknowledge the people whose practices and spiritualties are tied to the land and water and continue to develop in relation to the territory and its other inhabitants today.

ALDERVILLE FIRST NATION | BEAUSOLEIL FIRST NATION | CURVE LAKE FIRST NATION | GEORGINA ISLAND FIRST NATION | HIAWATHA FIRST NATION | SCUGOG ISLAND FIRST NATION | RAMA FIRST NATION

Executive Summary

Pickering Nuclear Generating Station (PNGS) has a mature and robust groundwater monitoring program in place to address the following three primary objectives:

- Objective 1: Monitor changes to on-site groundwater quality to ensure timely detection of inadvertent releases to groundwater;
- Objective 2: Ensure there are no adverse off-site impacts from PNGS groundwater; and
- Objective 3: Confirm predominant on-site groundwater flow characteristics at the PNGS site.

The findings in 2022 with respect to the above objectives are:

- Objective 1:
  - The groundwater data collected from the system structures and components indicate tritium concentrations are consistent with results for previous years and expected fluctuations associated with ongoing operations or represent increases that occur because of the expected migration of tritium associated with historical releases to groundwater and that are limited over time and space.
  - Dissolved iron concentrations in 2022 associated with the East and West Landfill do not present off-site adverse effects.
  - The results for the remediation approach of natural attenuation of petroleum hydrocarbons present in Units 1 to 4 Standby Generators (SG-A), SG-A Overflow area, Units 5 to 8 Standby Generators (SG-B), Emergency Power Generators (EPG), and EPG3 areas are consistent with historical results.
  - The results of hydrocarbons and dissolved iron associated with the Fukushima Diesel Generators do not present off-site adverse effects.
- Objective 2: Tritium concentrations within the site boundary wells and shoreline wells are stable and are within historical ranges. Off-site effects of tritium in groundwater to Lake Ontario are not observed.
- Objective 3: The predominant groundwater flow patterns remain unchanged in 2022 from the recent years' interpretations.

1.0 INTRODUCTION

Ontario Power Generation (OPG), Pickering Nuclear Generating Station (PNGS), 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 three primary objectives are addressed by specific objectives detailed in the N288.7-compliant PNGS Groundwater Protection Plan (GWPP) and Groundwater Monitoring Program (GWMP) (Ecometrix, 2020a):

- Monitor changes to on-site groundwater quality to ensure timely detection of inadvertent releases to groundwater; which include Objectives 1 to 4 of the PNGS GWMP (Ecometrix, 2020a):
    - PNGS GWMP Objective 1: Tritium concentrations in groundwater near system structures and components (SSCs).
    - PNGS GWMP Objective 2: Dissolved iron concentrations in groundwater at East and West Landfills.
    - PNGS GWMP Objective 3: Petroleum hydrocarbon (PHC) concentrations in groundwater at SG-A, SG-A Overflow area, SG-B, EPG, and EPG3.
    - PNGS GWMP Objective 4: PHC concentrations in groundwater at Fukushima Diesel Generators.
- Ensure there are no adverse off-site impacts from PNGS groundwater, as described by Objective 5 of the PNGS GWMP:
    - Tritium concentrations in groundwater in Perimeter Wells - monitor tritium in site perimeter wells to establish tritium concentrations at the PNGS site boundaries and to confirm no adverse off-site impacts.
- Confirm predominant on-site groundwater flow characteristics at the PNGS site, as described by Objective 6 of the PNGS GWMP:
    - Hydraulic Head Measurements - provide head measurements in selected monitoring wells to confirm the groundwater flow conditions across the PNGS site and to support the interpretation of constituent migration in groundwater.

The groundwater sampling and monitoring program conducted in 2022 followed the Sampling and Analysis Plan (SAP) for 2022 (OPG, 2022). This report presents groundwater data collected at PNGS for the period from January 1st to December 31st, 2022.

1.1 Summary of Hydrogeological Characteristics at the PNGS

Eight hydrostratigraphic units (HUs) have been identified beneath PNGS through historical assessments. Of the eight HUs, four main groundwater flow systems have been identified for the site:

- Shallow/Water Table (HU 1-3);
- Intermediate Overburden (HU 6);
- Deep Overburden (HU 7); and
- Deep Bedrock (HU 8).

HUs 4 and 5 are not always observed, and where they are observed, are generally thin and are grouped into the shallow groundwater system. The shallow groundwater system is an aquifer, and the intermediate overburden and bedrock groundwater flow systems are considered to be aquitards. The deep overburden groundwater system may represent an aquifer. Groundwater migration into this HU from overlying HUs is considered to be limited due to the low permeability of the till materials in HU 6.

2.0 2022 PROGRAM DESIGN

The groundwater monitoring program design is detailed in the PNGS GWPP and GWMP (Ecometrix, 2020a). The N288.7-compliant 2022 SAP was developed to meet the relevant components of the objectives listed above.

Groundwater quality results are provided in Appendix A.

2.1 Objective 1 Methodology

2.1.1 Tritium Concentrations in Groundwater Near SSCs

In 2022, as per the SAP, groundwater samples were collected from various locations, including monitoring wells, foundation drains, sumps, and groundtubes (91 sampling locations in total). Figure 1 shows these locations. Most of the locations sampled are near the operating reactors. Refer to Section 6.0 of this report for details on the sampling nomenclature used in the groundwater program.

The 2022 SAP specified the sampling locations and frequency (e.g., quarterly, annually) of sampling tritium concentrations in groundwater at each location.

Groundwater samples analyzed for tritium were collected from the following key areas in 2022:

- Unit 1 to 4 Reactor Buildings (RBs);
- Unit 5 to 8 RBs;
- Irradiated Fuel Bays (IFBs) for Units 1 to 4 and Units 5 to 8; and
- Upgrading Plant Pickering (UPP).

Water levels were collected in each monitoring well prior to the collection of samples by OPG technicians. Following measurement of the water level and prior to sample collection, each monitoring well was purged to remove standing water, ensuring that the groundwater collected had a quality representative of subsurface conditions. Collected samples were analyzed for tritium concentrations by the OPG PNGS Chemistry Laboratory.

The groundwater data generated from the sampling program was subsequently analyzed to either support previous conclusions, identify changes in groundwater quality (trends) including improvements, or demonstrate no significant change. Sample results of groundwater tritium concentrations for Objective 1 are presented in Appendix A (Table A-1, Table A-2, Table A-3 and Table A-4).

2.1.2 Dissolved iron concentrations at East and West Landfills

In 2022, one groundwater sample was collected downgradient of both the East and West Landfills, respectively, along the shoreline. Samples were collected by Pottinger Gaherty Environmental Consultants Ltd. (PGL). Samples analyzed for dissolved iron were submitted to Bureau Veritas, a laboratory accredited to ISO/IEC 17025. Sample results at these locations are presented in Appendix A (Table A-5). Figure 2 shows the locations of the two wells that were monitored in 2022.

2.1.3 PHC concentrations in groundwater at Units 1 to 4 SGs, Units 5 to 8 SGs, EPG and EPG3

A monitored natural attenuation program (MNA) was implemented in the SG-A, SG-A Overflow area and SG-B areas in 2011, following remedial activities. MNA programs are long-term because hydrocarbon mass attenuation occurs through volatilization, dissolution and natural microbial degradation processes. Groundwater monitoring results in these three areas have, in the past, been reported under separate cover. The MNA program for these areas was incorporated into the GWMP developed for the site in 2019. Since that time, the results of the MNA programs in these areas are discussed in the annual report (this report) for PNGS.

In 2022, as per the SAP and the GWMP (Ecometrix, 2020a), eighteen groundwater wells were monitored for water levels and petroleum hydrocarbon free-phase product thickness near the U1–4 SGs. If free-phase product was present in the wells, the thickness of the product and depth to water were the only measurements taken. If free-phase product was not present, groundwater samples were collected for analysis of PHCs including benzene, toluene, ethylbenzene, and xylenes (BTEX), PHC Fractions 1-4 (PHC F1 to PHC F4), and dissolved iron. In addition, sixteen wells were sampled for the analysis of one or more of the following parameters: PHCs, BTEX, and dissolved iron. Groundwater was sampled using low-flow methodology. Samples analyzed for PHCs, BTEX, and dissolved iron were submitted to Bureau Veritas, a laboratory accredited to ISO/IEC 17025. Figure 3 shows the locations of the wells that were monitored in 2022.

Product thicknesses and water quality analytical results for Units 1 to 4 SGs, Units 5 to 8 SGs, EPG, and EPG3 are presented in Appendix A (Table A-6a and Table A-6b, respectively).

2.1.4 PHCs at Fukushima Diesel Generators

Four groundwater samples were collected in association with the Fukushima diesel generators in 2022. Samples were collected by PGL. Three samples were analyzed for PHCs and BTEX and one sample was analyzed for dissolved iron. All samples were submitted to Bureau Veritas, a laboratory accredited to ISO/IEC 17025, for analysis. Analytical results for groundwater quality within the area of the Fukushima Diesel Generators are presented in Appendix A (Table A-7). Figure 4 shows the locations of the wells that were monitored in 2022.

2.2 Objective 2 Methodology

The 2022 SAP included the sampling of monitoring well clusters at the site boundary to confirm that there are no adverse off-site impacts from PNGS groundwater. Boundary wells are located across the entire site in directions upgradient or cross-gradient to the SSCs and provide spatial information on background groundwater quality conditions. Shoreline wells are also monitored downgradient to the SSCs to assess off-site impacts to groundwater quality. Figure 5 shows the locations of the site perimeter wells. Analytical results for monitoring wells sampled at the PNGS perimeter are presented in Appendix A (Table A-8)

The methodology for groundwater collection, analysis, and data evaluation in the perimeter wells was the same as what is described above for the tritium samples collected under Objective 1.

2.3 Objective 3 Methodology

Groundwater flow interpretations for PNGS were first established in 2002. On an annual basis, the GWMP requires that a set of water levels be collected from several groundwater monitoring wells at the site over a short period of time (days). The intent of the program is 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. In Q4, water level readings were collected from monitoring well locations across the site over a period of eleven days (October 3 to October 14, 2022). The data was subsequently used to calculate the groundwater elevation at each monitoring well. The resulting groundwater elevations and the average daily mean Lake Ontario water levels between October 3 and October 14, 2022 (IJC, 2023) were used to generate groundwater elevation contours, from which groundwater flow directions are inferred.

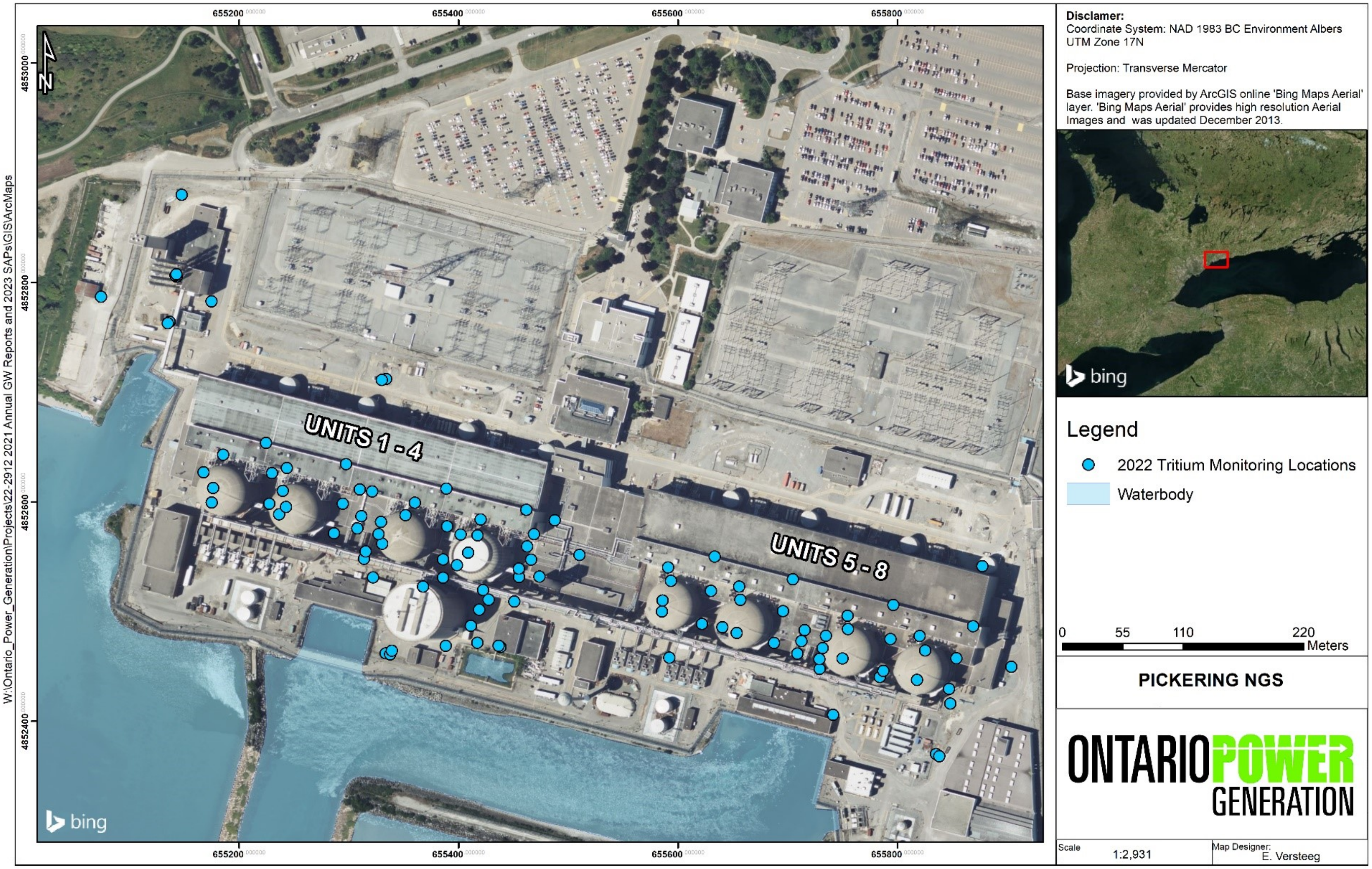


Figure 1: 2022 Tritium Monitoring Locations for Objective 1

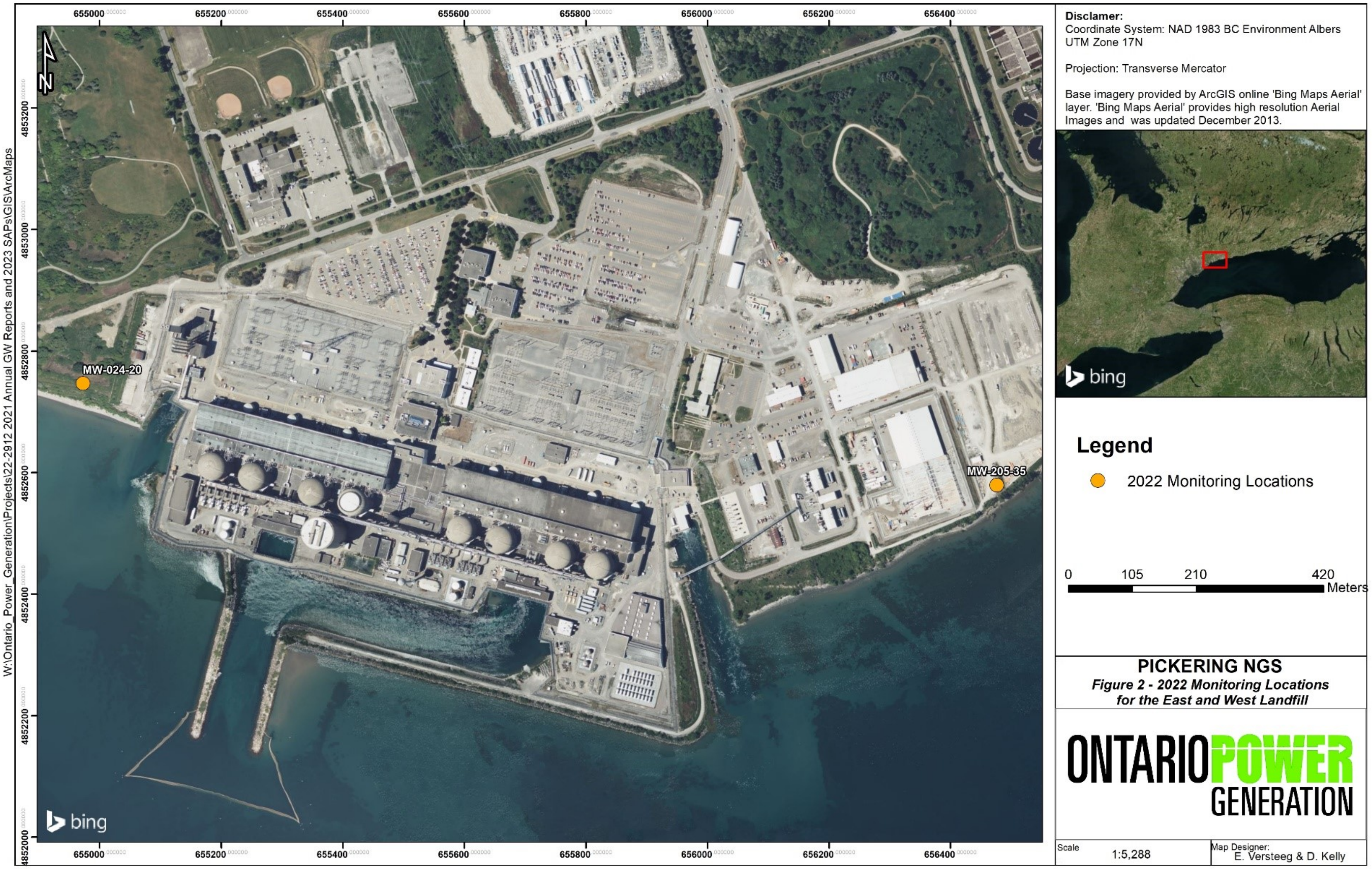


Figure 2: 2022 Dissolved Iron Monitoring Locations for Objective 1 – East and West Landfill

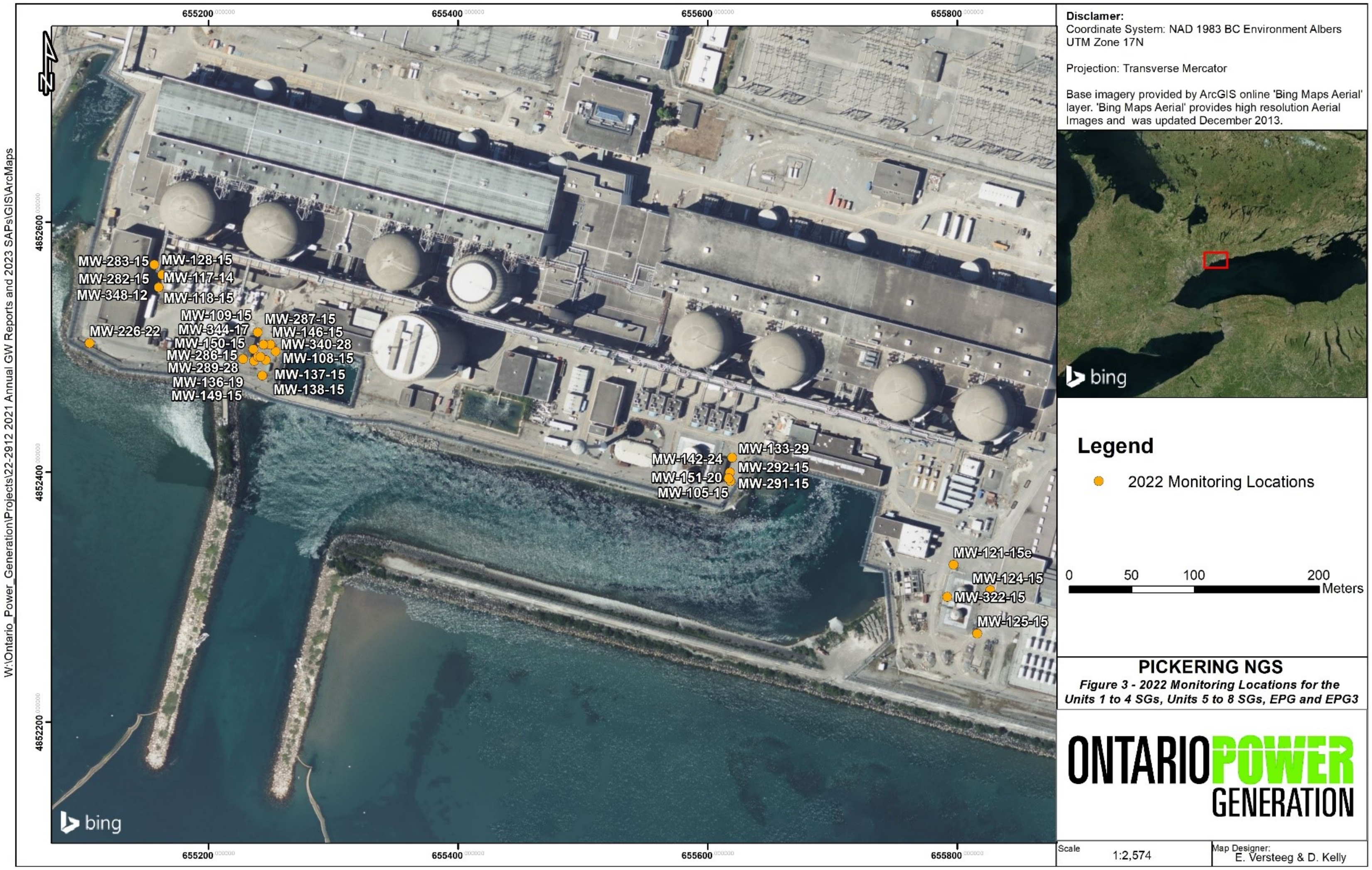


Figure 3: 2022 PHC, BTEX and Dissolved Iron Monitoring Locations for Objective 1 - SG-A, SG-B and SG-A overflow tank area, EPG and EPG3

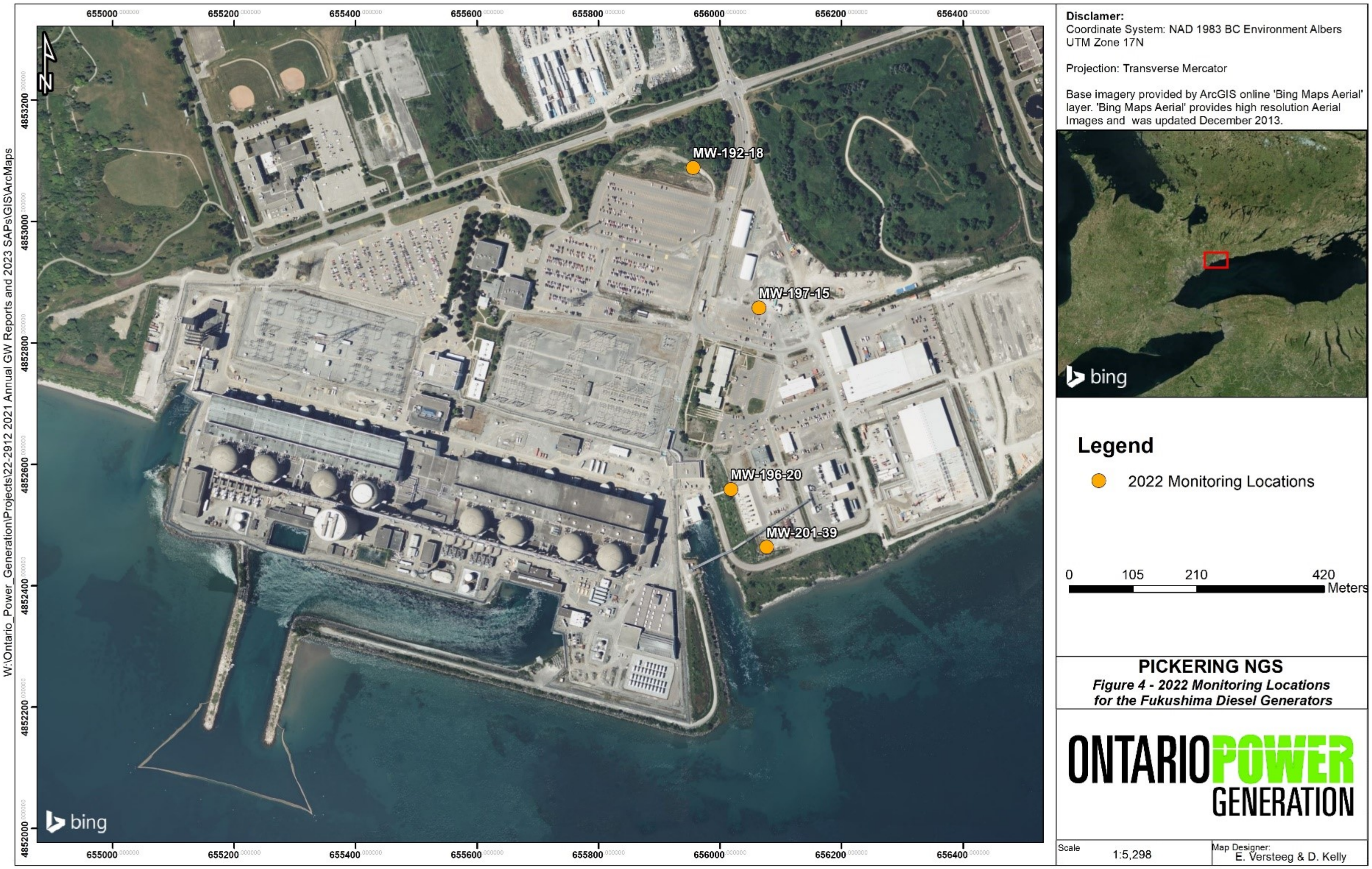


Figure 4: 2022 PHC, BTEX and Dissolved Iron Monitoring Locations for Objective 1 – Fukushima Diesel Generators

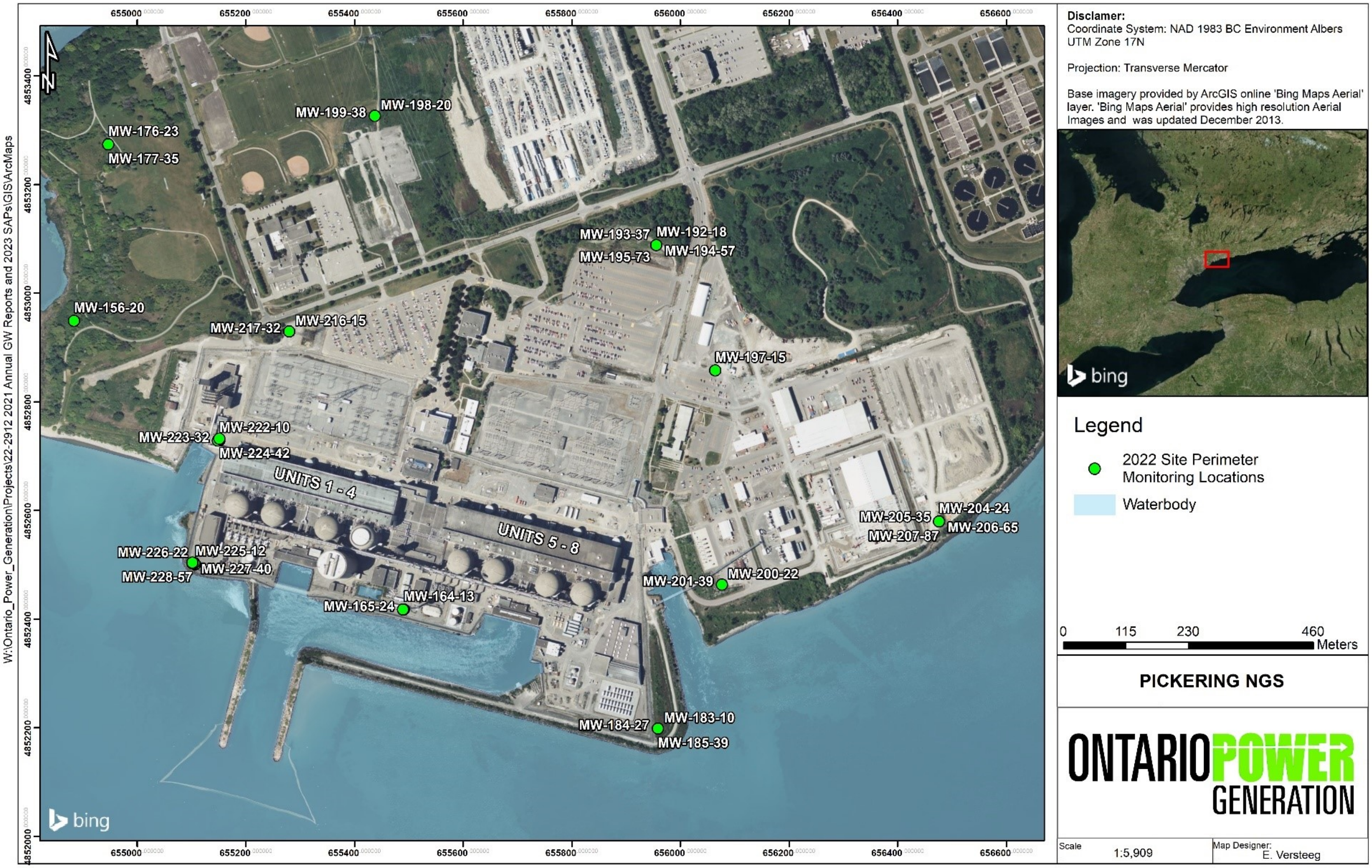


Figure 5: 2022 Monitoring Locations for Objective 2

3.0 2022 PROGRAM RESULTS

3.1 Objective 1 Results

3.1.1 Tritium Concentrations in Groundwater Near SSCs

In 2022, the groundwater data collected from the areas surrounding SSCs at PNGS indicate that tritium concentrations in groundwater have remained, overall, consistent with results for previous years and within the range of expected fluctuations resulting from ongoing operations, or represent the expected movement of historical tritium releases to groundwater. Further discussion is provided in the sections below.

3.1.1.1 Unit 1 to 4 Reactor Building Area Overview

The 2022 groundwater sampling results within the area of Units 1 to 4 are presented in Table A-1 (Appendix A). The majority of the monitoring wells in this area are sampled quarterly. Figure 6 to Figure 8 display the distributions of maximum annual tritium concentrations within the vicinity of Units 1 to 4 area and Units 1 to 4 IFBs in HU 1-3, HU 6 and HU 7.

Key sampling locations are discussed in further detail below, by specific area.

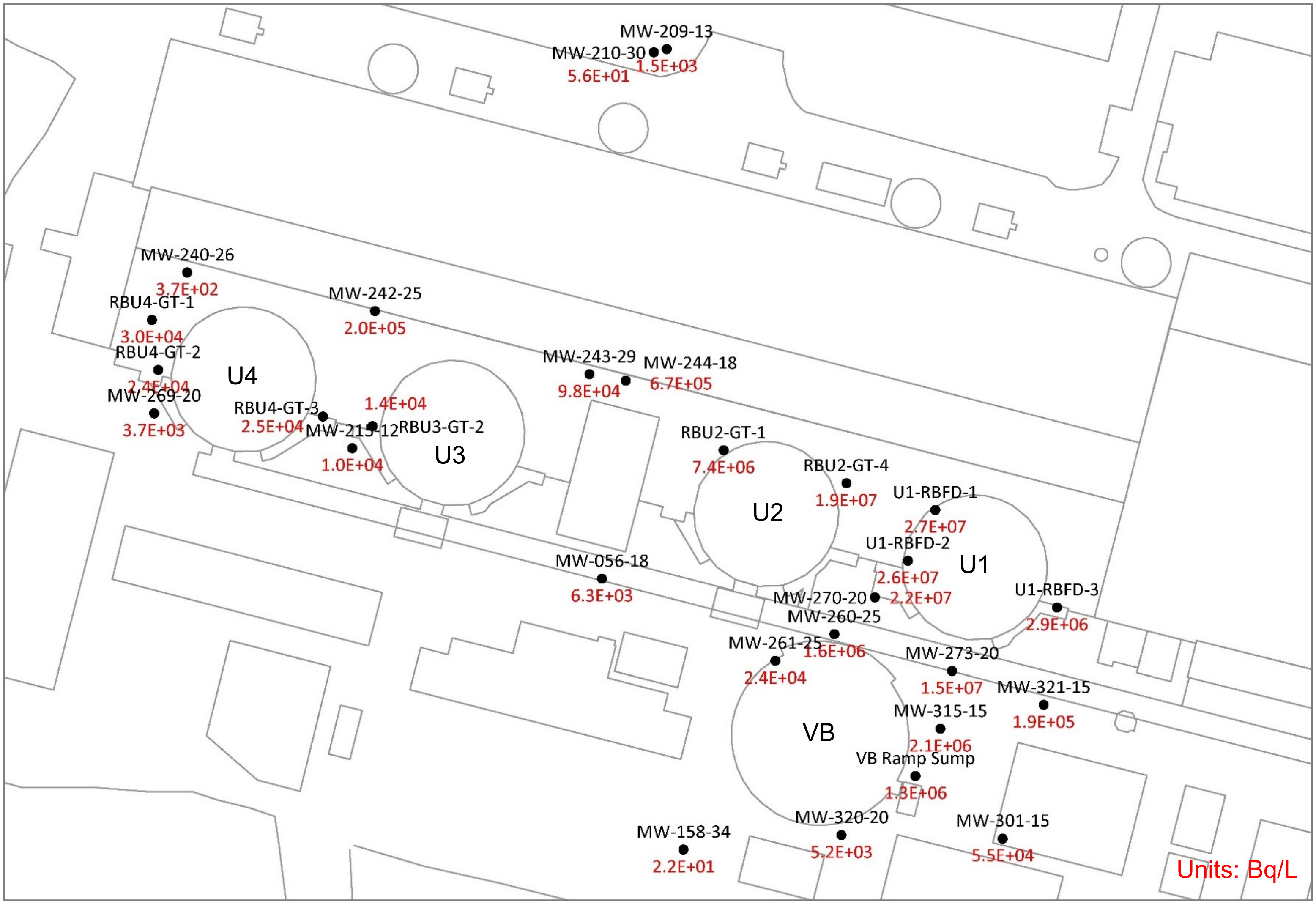


Figure 6: 2022 Annual Maximum Tritium Concentrations within HU 1-3, Units 1 to 4 and IFB-A

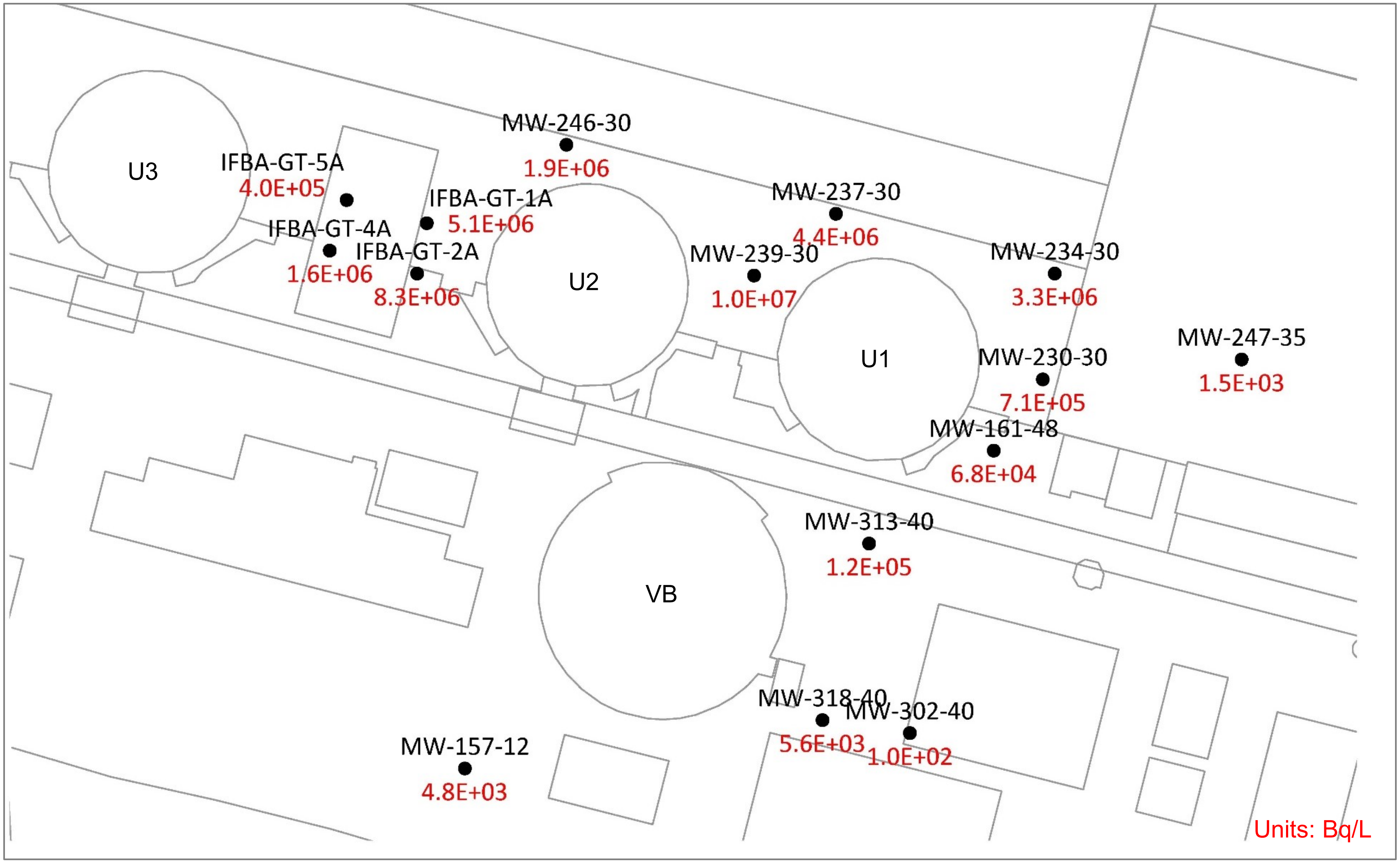


Figure 7: 2022 Annual Maximum Tritium Concentrations within HU 6, Units 1 to 4 and IFB-A

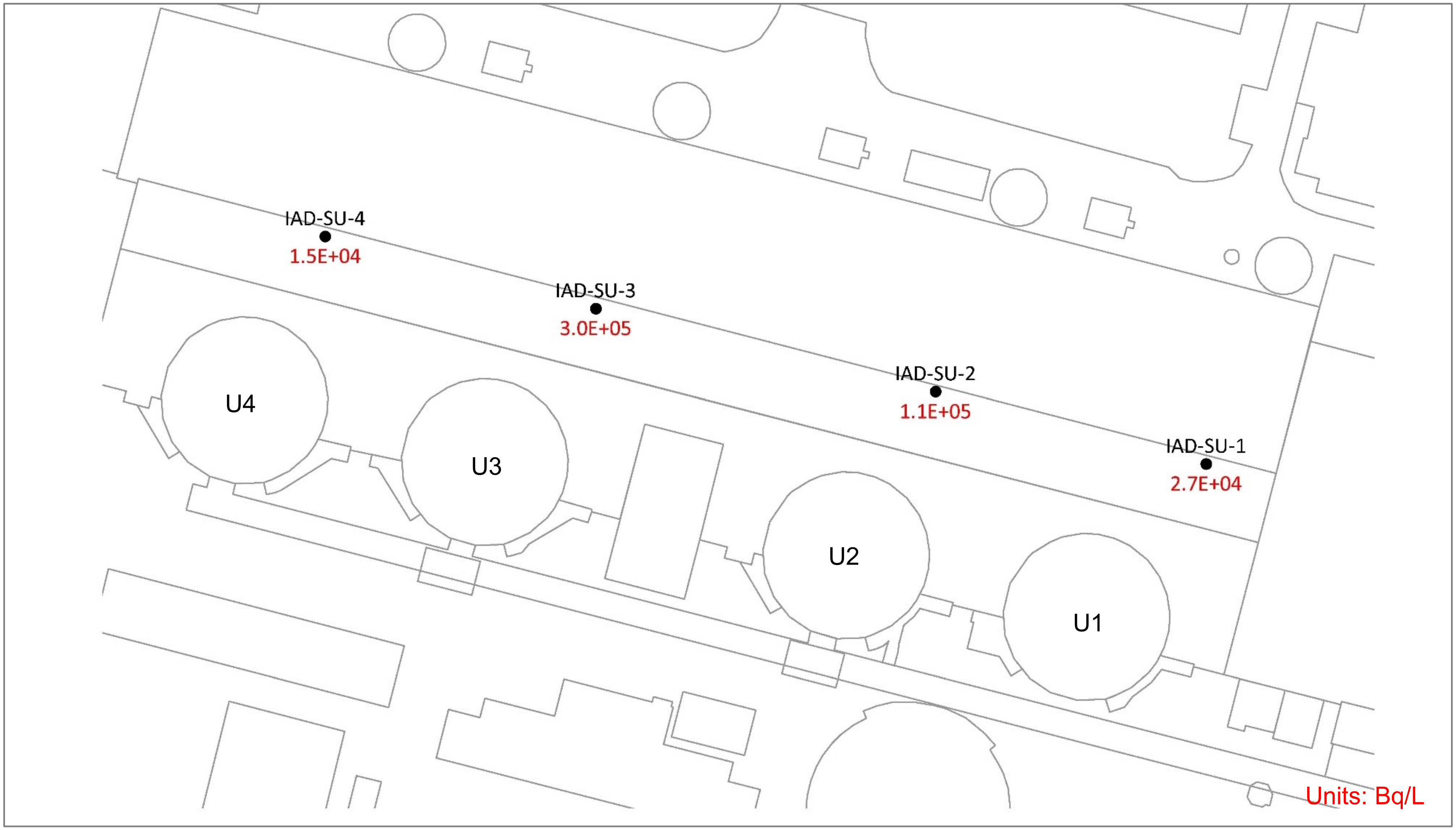


Figure 8: 2022 Annual Maximum Tritium Concentrations within HU 7, Units 1 to 4 and IFB-A

Unit 1 and 2 Area

Tritium concentrations within groundtubes (U1-RBFD-1 to U1-RBFD-3), monitoring wells towards the south-southeast (MW261-25, MW-270-20, MW-273-20, MW-313-40, MW-315-15, MW-320-20 and MW-313-40) and the Vacuum Building Ramp Sump (VBRS) were generally steady during 2022 and consistent with concentrations measured during previous years (excluding those time periods impacted by leaks). A component of the historically identified tritiated plume in groundwater in this area migrates south towards the VBRS, located east of the Vacuum Building (VB), which acts as a hydraulic sink and collects a portion of groundwater in Unit 1 and 2 areas (Ecometrix, 2020b). The tritium plume within shallow groundwater is shown in Figure 9. Tritium concentrations at MW-321-15, located east of the VBRS were within historical range in 2022.

Tritium concentrations decreased from Q4 2021 and Q1 2022 to Q2 2022 at monitoring well MW-234-30, which is located to the northeast of Unit 1 and remained within historical ranges. Groundwater in the area of Unit 1 is also known to migrate north towards the actively pumped Turbine Axillary Bay (TAB) foundation drains and west towards Units 1-4 IFBs (Ecometrix, 2020b).

Graphs 1 to 12 display tritium concentrations over time at groundtubes and select monitoring wells mentioned above, and the VBRS.

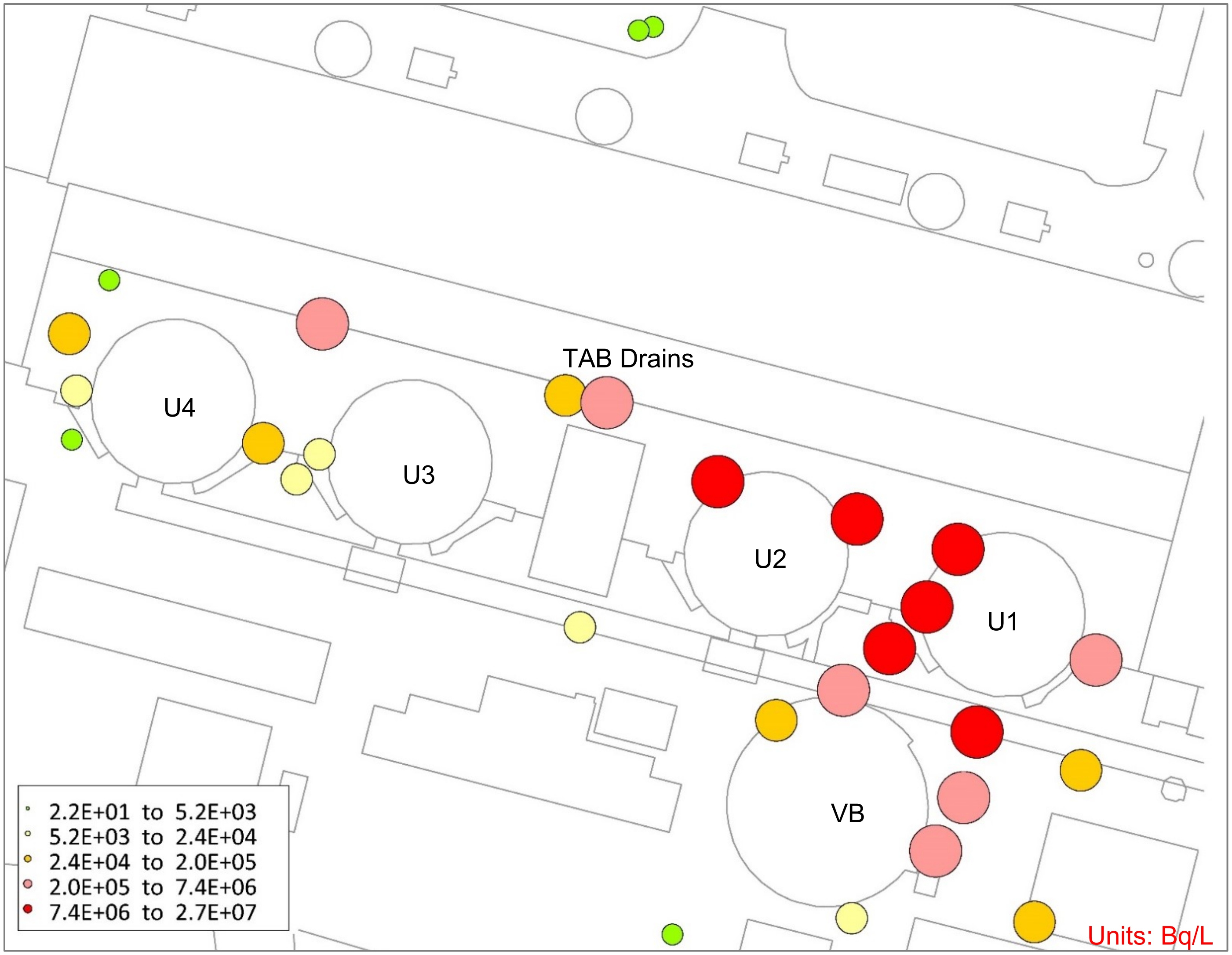
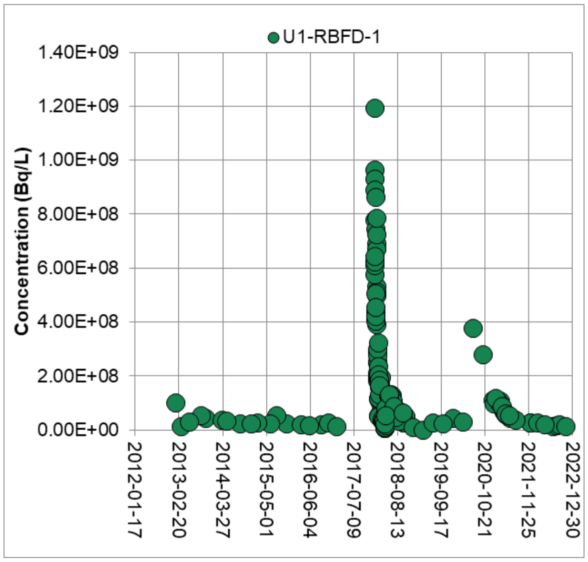
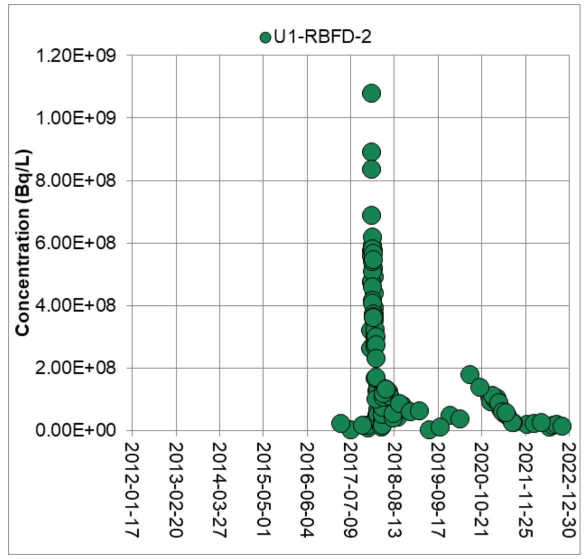


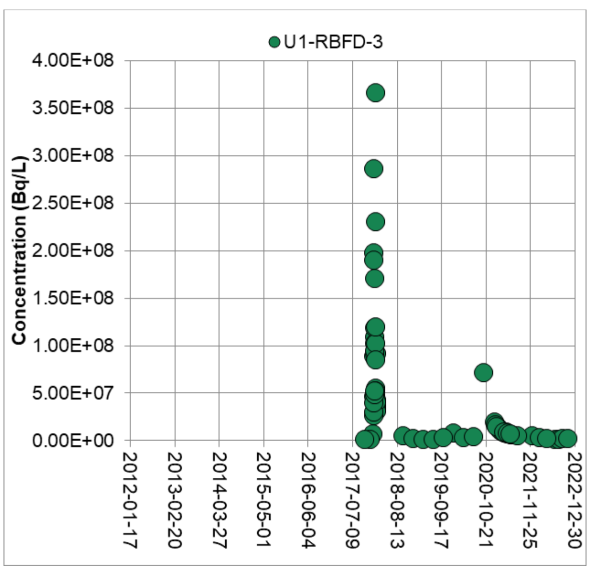
Figure 9: Maximum Tritium Concentrations in 2022 Showing Tritiated Groundwater Migration to TAB Drains and VBRS



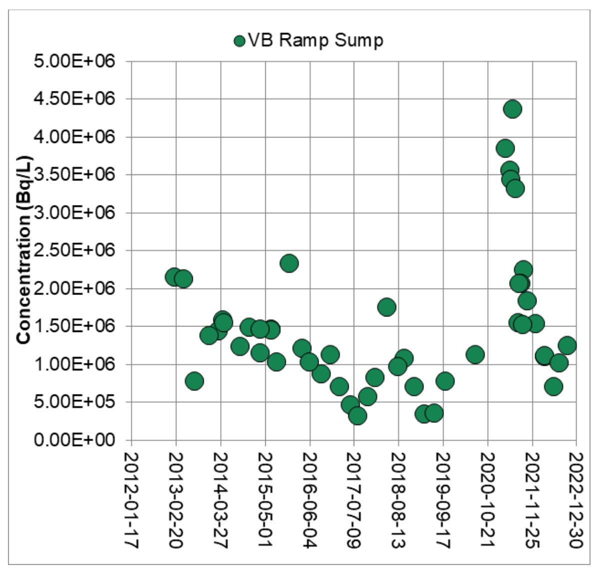
Graph 1: U1-RBFD-1 Tritium Data



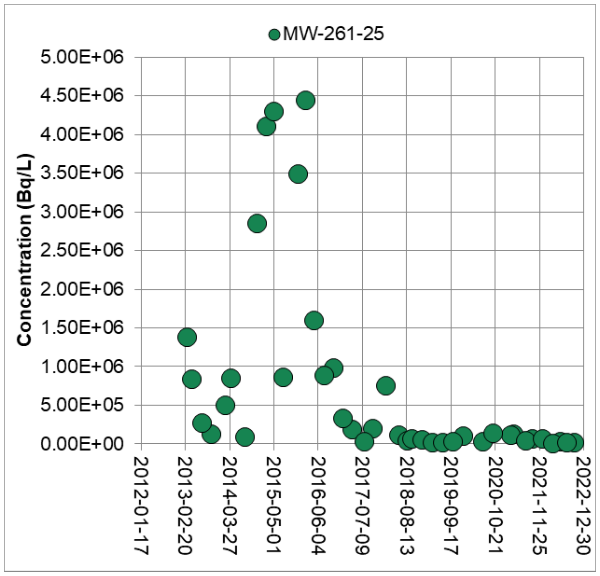
Graph 2: U1-RBFD-2 Tritium Data



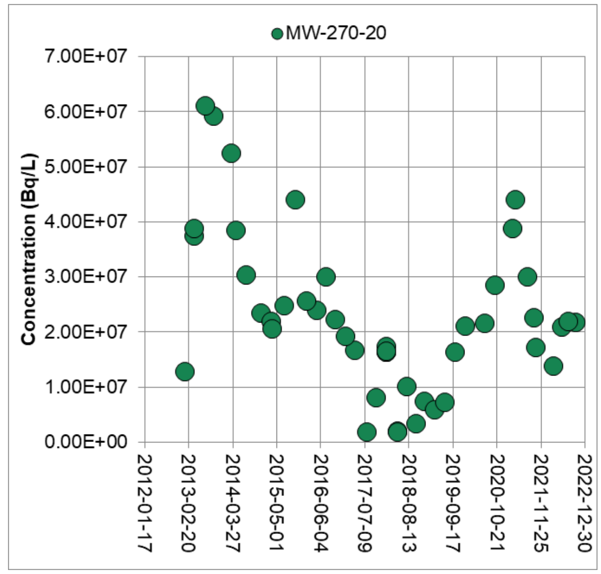
Graph 3: U1-RBFD-3 Tritium Data



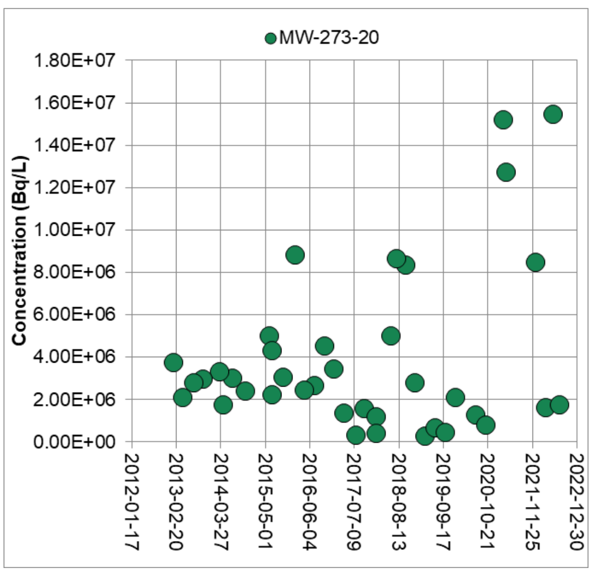
Graph 4: VBRS Tritium Data



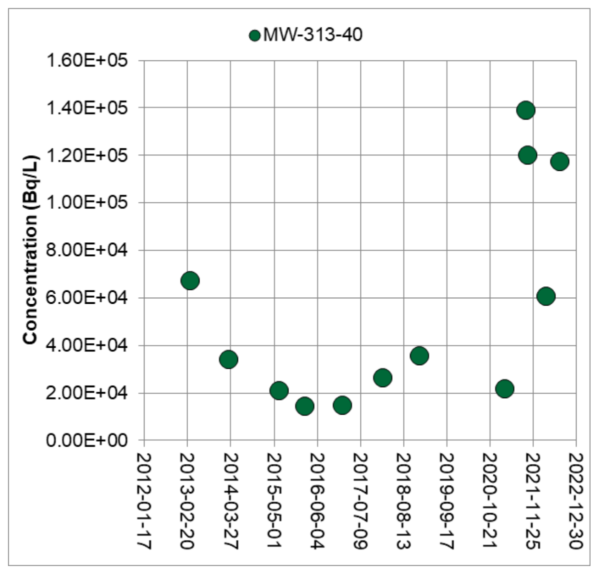
Graph 5: MW-261-25 Tritium Data



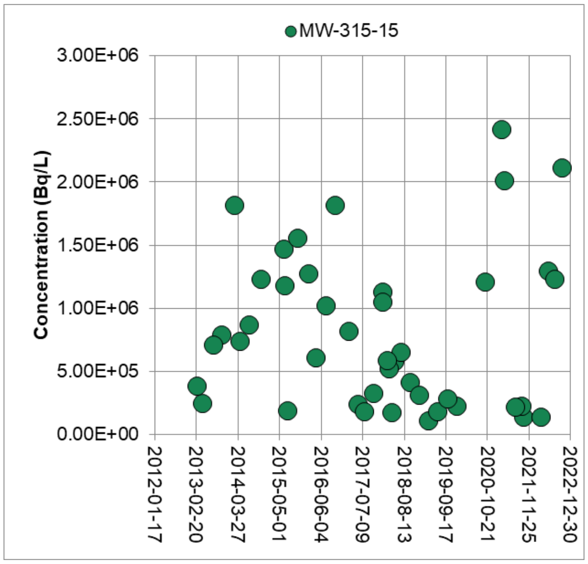
Graph 6: MW-270-20 Tritium Data



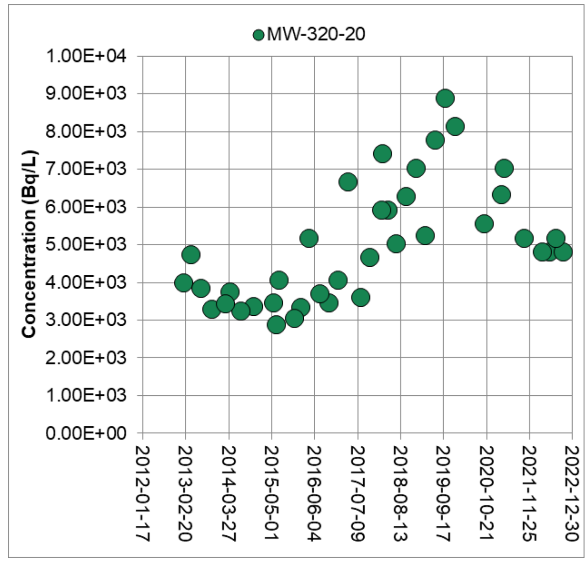
Graph 7: MW-273-20 Tritium Data



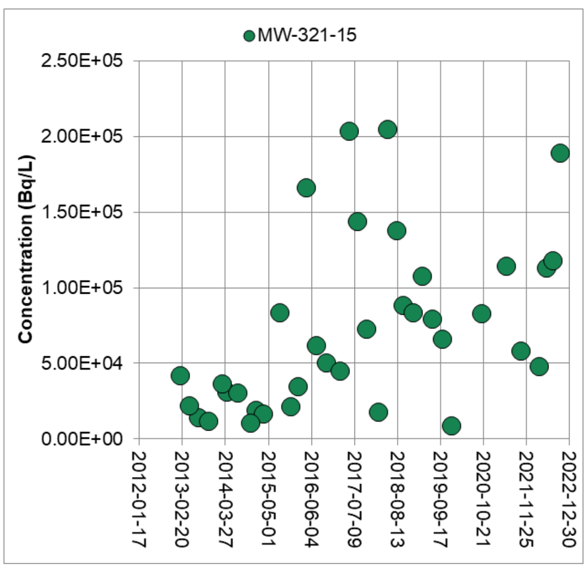
Graph 8: MW-313-40 Tritium Data



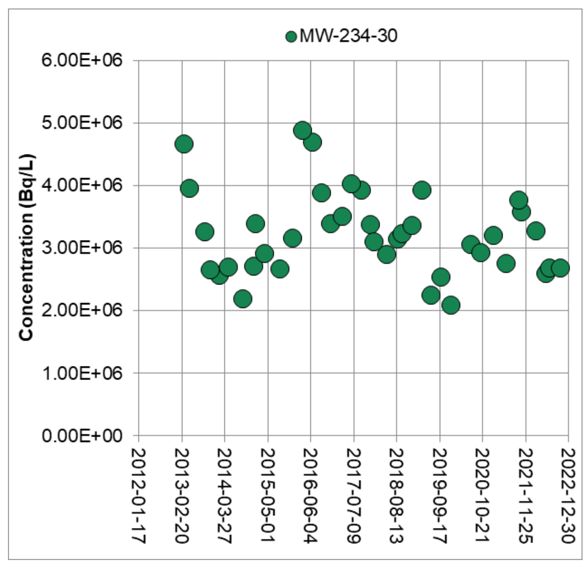
Graph 9: MW-315-15 Tritium Data



Graph 10: MW-320-20 Tritium Data



Graph 11: MW-321-15 Tritium Data

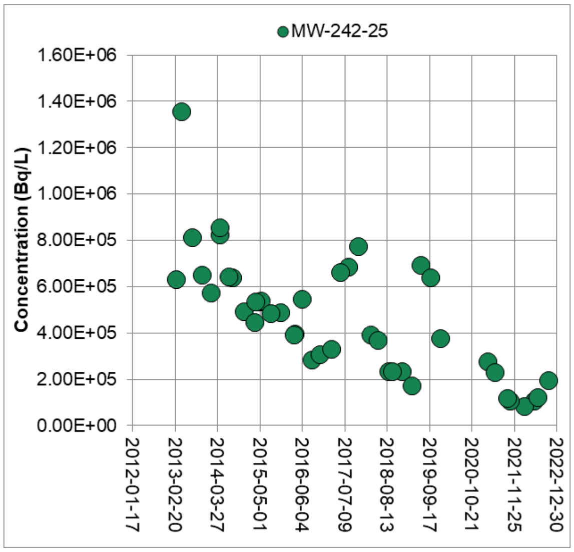


Graph 12: MW-234-30 Tritium Data

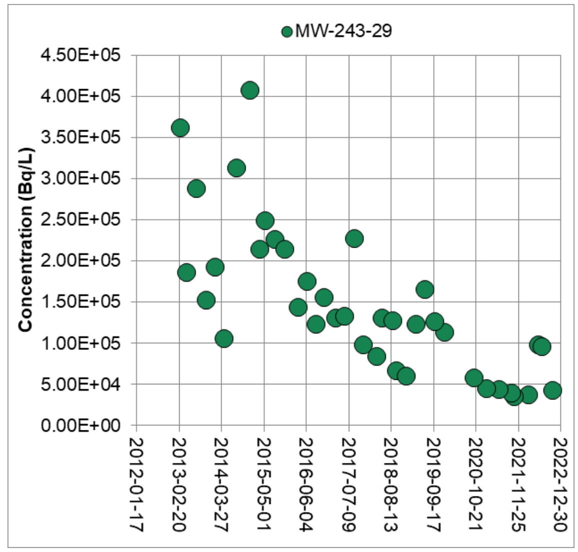
Unit 3 and 4 Area

In the Unit 3 and 4 areas, tritium concentrations measured in RB groundtubes, as well as in the monitoring wells located within the Reactor Auxiliary Bay (RAB), were generally stable, or no trends were observed. Tritium concentrations at downgradient monitoring well MW-243-29 located in the RAB fluctuated in 2022, but show an overall decreasing trend.

Graphs 13 to 14 illustrate the results for selected monitoring wells within the vicinity of Unit 3 and Unit 4.



Graph 13: MW-242-25 Tritium Data



Graph 14: MW-243-29 Tritium Data

3.1.1.2 Unit 5 to 8 Reactor Building Area Overview

The 2022 groundwater sampling results in the area of Units 5 to 8 are presented in Table A-2 (Appendix A). Distributions of the annual maximum tritium concentrations in the area of Units 5 to 8 within HU1-3, HU 6, and HU 7 are presented in Figure 10 to Figure 12, respectively.

Key sampling locations are discussed in further detail below by specific area.

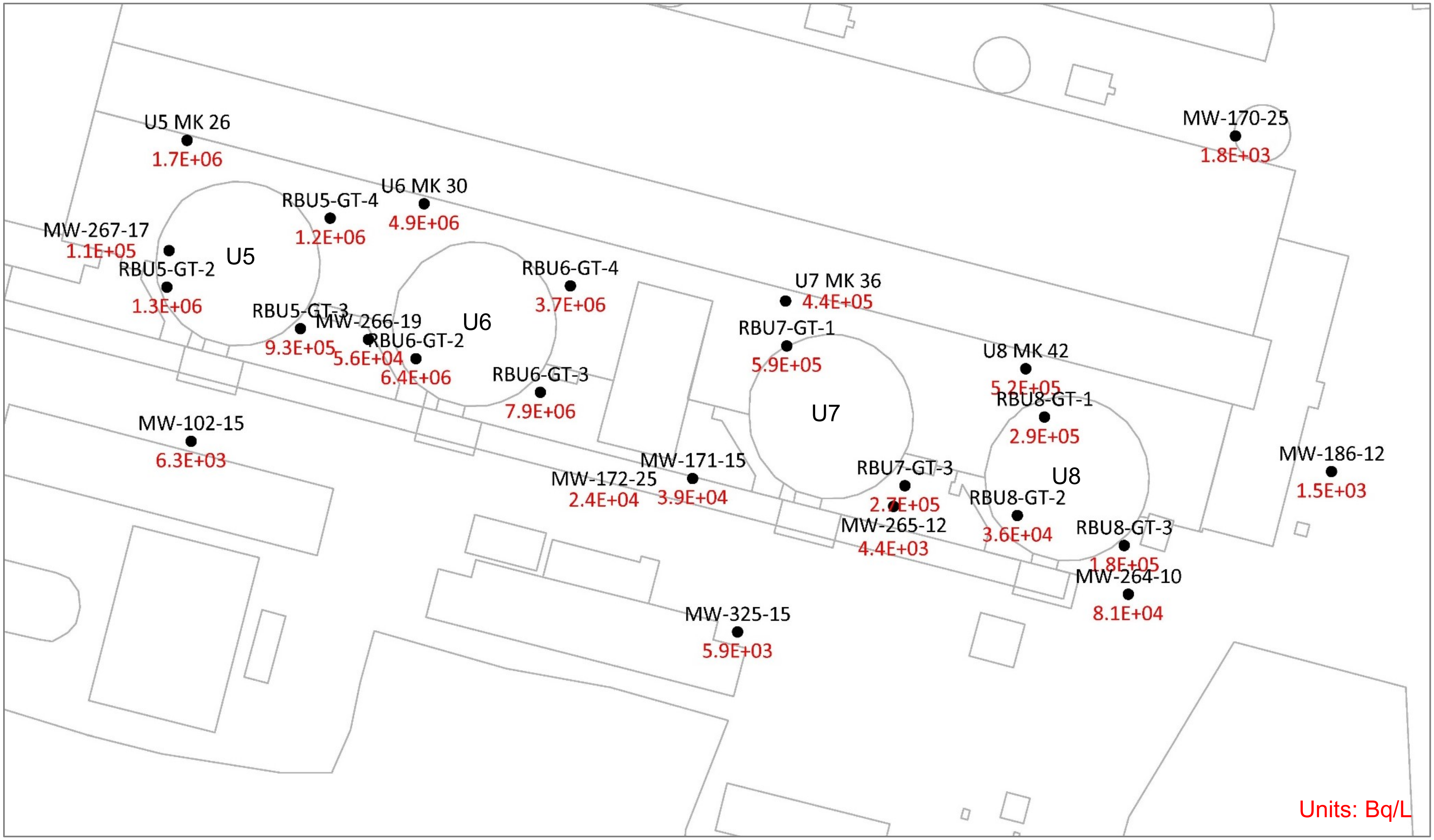


Figure 10: 2022 Annual Maximum Tritium Concentrations in HU 1-3, Unit 5 to 8 and IFB-B

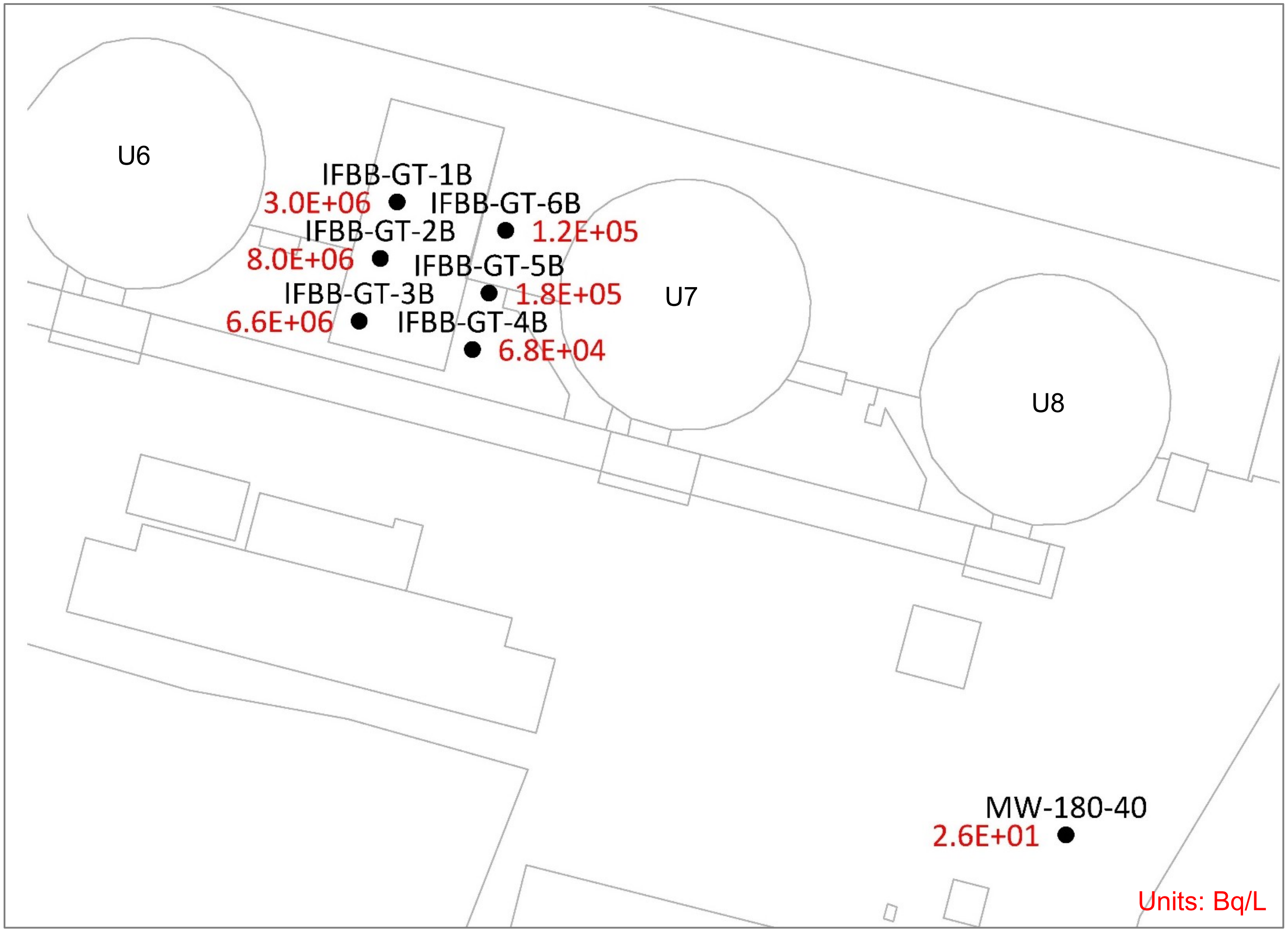


Figure 11: 2022 Annual Maximum Tritium Concentrations in HU 6, Unit 5 to 8 and IFB-B

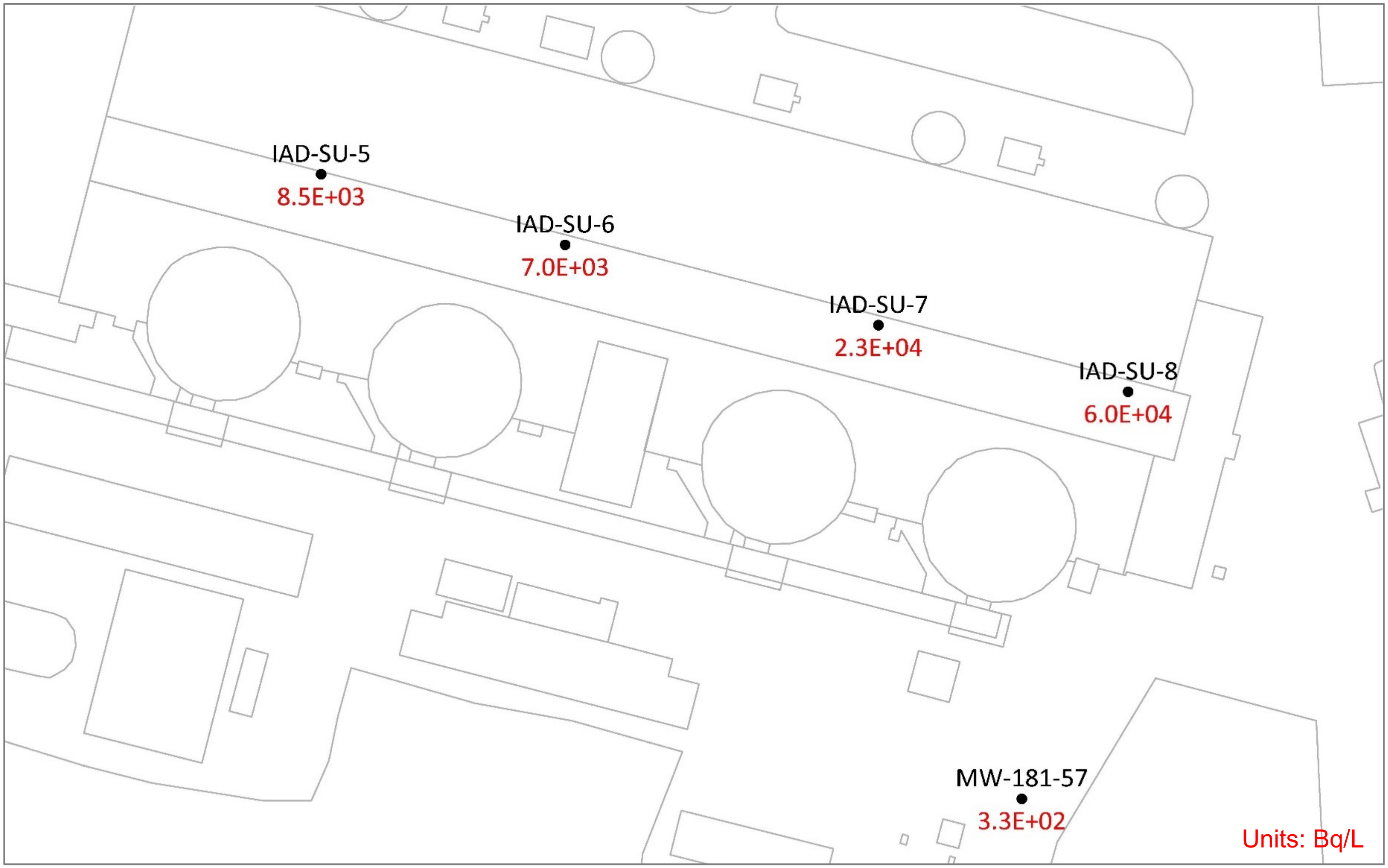
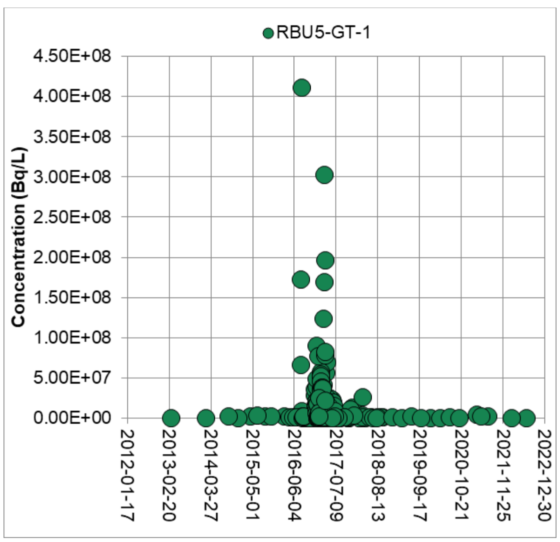


Figure 12: 2022 Annual Maximum Tritium Concentrations in HU 7, Unit 5 to 8

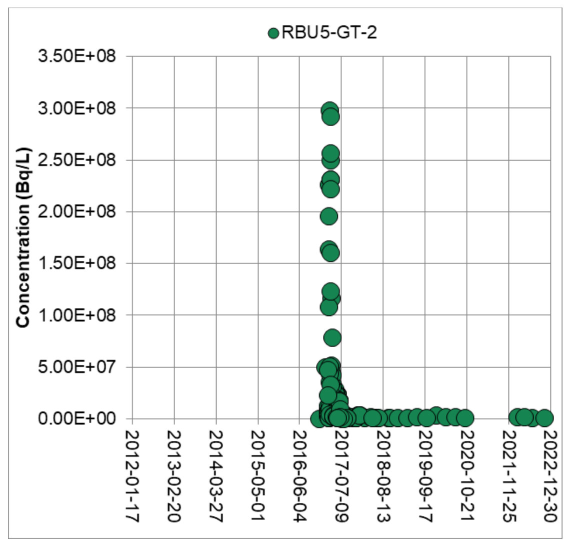
Unit 5 Area

The samples collected from the Unit 5 RB foundation drainage groundtubes in 2022 indicate that tritium concentrations in groundwater have been generally steady. No overall increasing trend in tritium concentrations was observed over the last two years for MW-267-17. The tritium concentrations in groundwater at IAD-SU-5 demonstrate an increasing trend however the values remain within a range considered to reflect fluctuations associated with routine operations. Any changes in groundwater quality are adequately observed with the existing monitoring schedule. Groundwater in these locations will continue to be monitored.

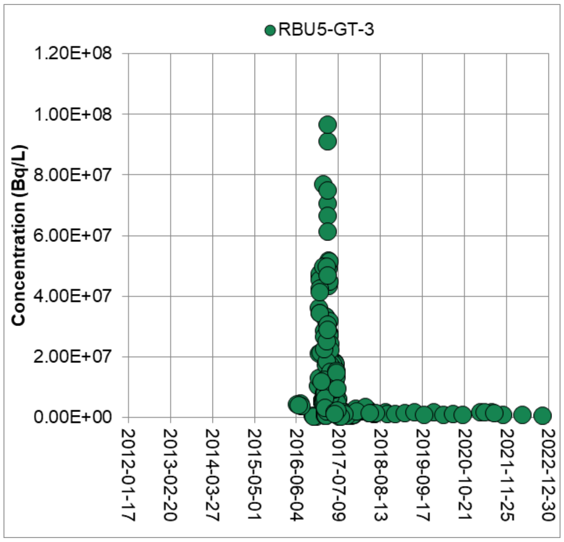
Graphs 15 to 21 present data from the Unit 5 RB foundation drainage groundtubes (RBU5-GT-1 to RBU5-GT-4), the U5 MK26 sump, and MW-267-17, respectively.



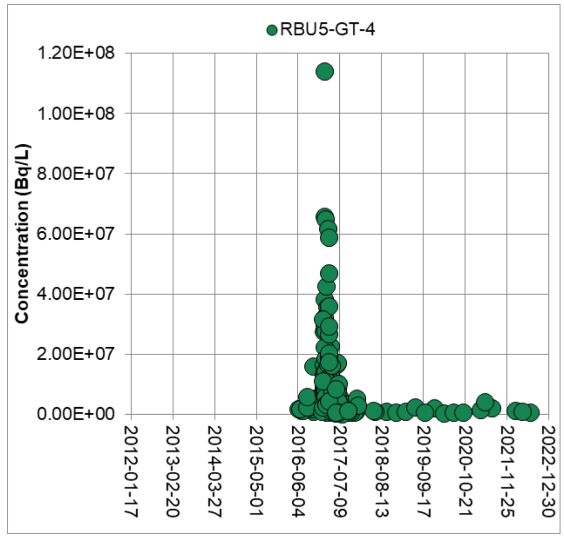
Graph 15: RBU5-GT-1 Tritium Data



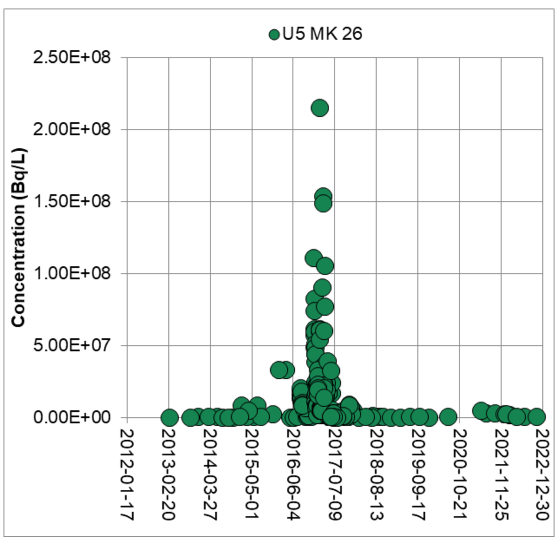
Graph 16: RBU5-GT-2 Tritium Data



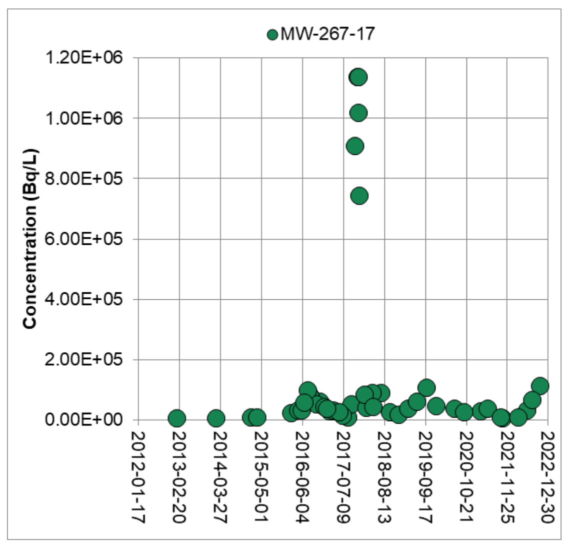
Graph 17: RBU5-GT-3 Tritium Data



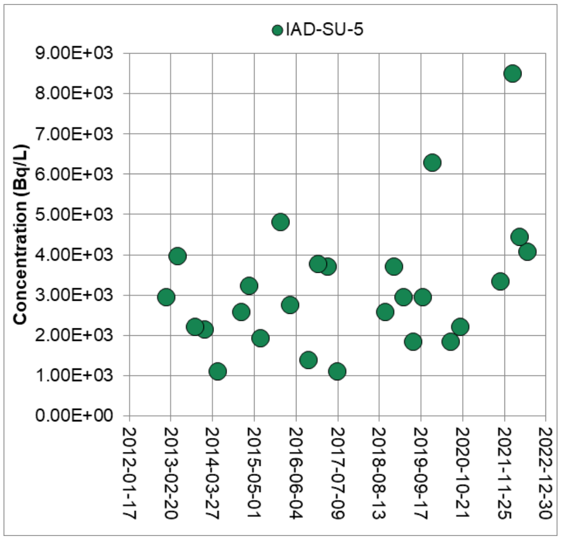
Graph 18: RBU5-GT-4 Tritium Data



Graph 19: U5 MK26 Tritium Data



Graph 20: MW-267-17 Tritium Data

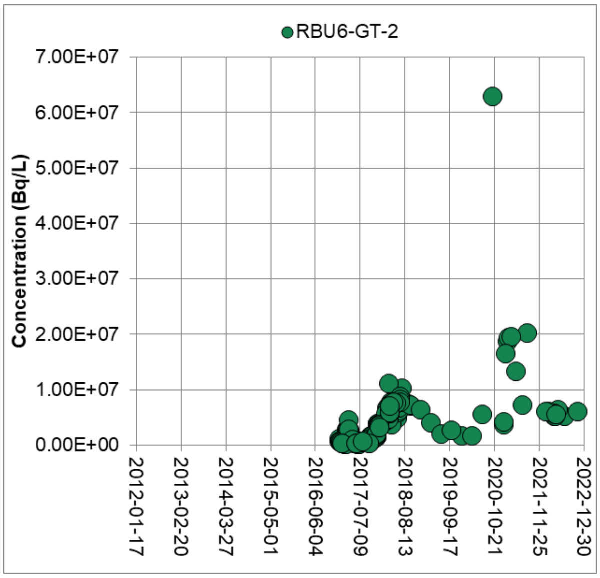


Graph 21: IAD-SU-5 Tritium Data

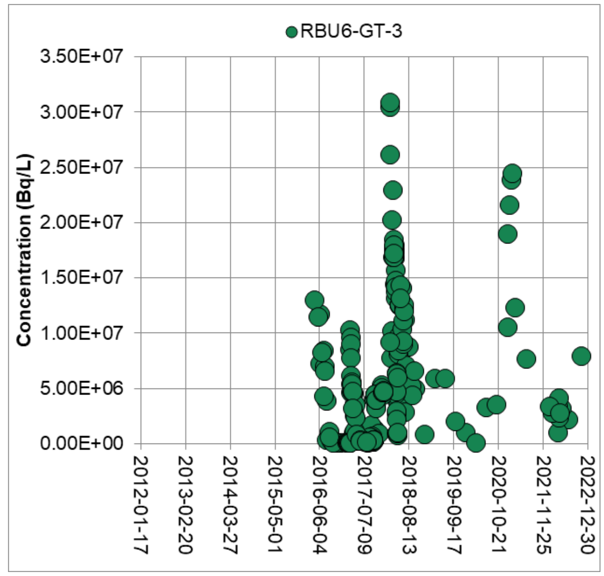
Unit 6 Area

Tritium concentrations in groundwater in the Unit 6 RB foundation drainage groundtubes, monitoring well and sump were generally steady during 2022, and within the range of historical concentrations. The tritium concentrations in groundwater at IAD-SU-6 generally demonstrate a slightly increasing trend, however, the values remain within a range considered to reflect fluctuations associated with routine operations. Any changes in groundwater quality are adequately observed with the existing monitoring schedule.

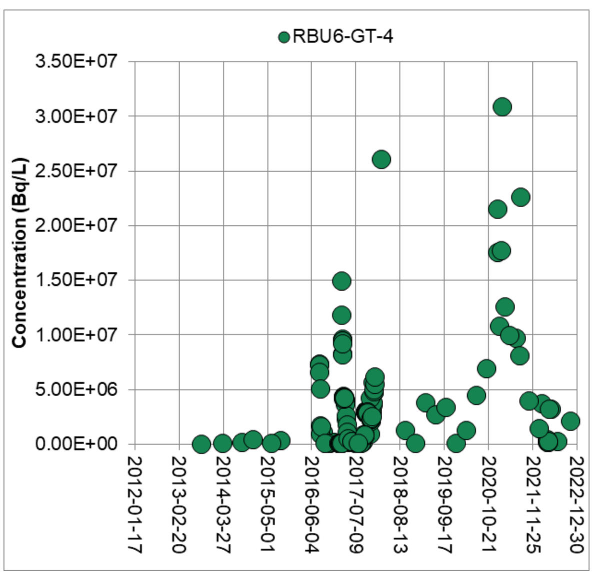
Graphs 22 to 27 present the data from the Unit 6 RB foundation drainage groundtubes (RBU6-GT-2 to RBU6-GT-4), the U6 MK30 sump, and monitoring well MW-266-19.



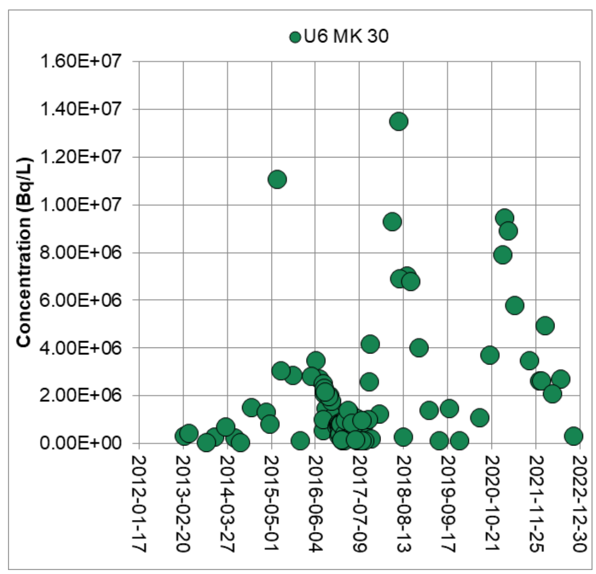
Graph 22: RBU6-GT-2 Tritium Data



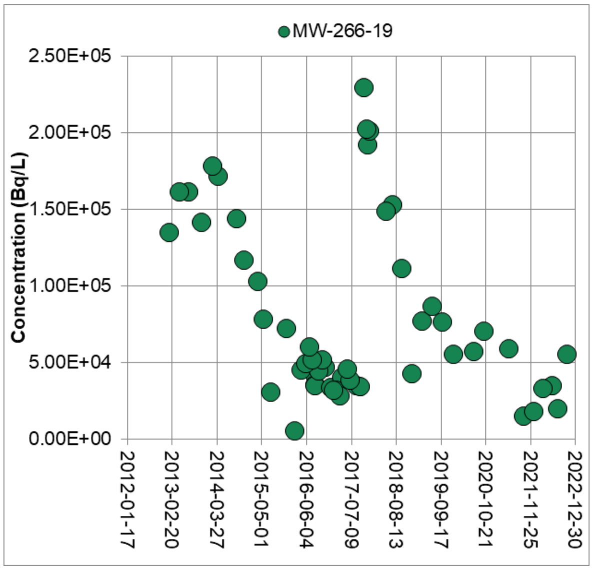
Graph 23: RBU6-GT-3 Tritium Data



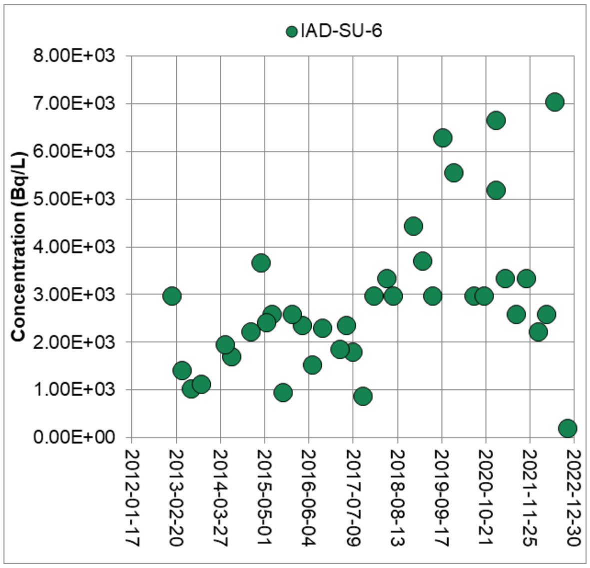
Graph 24: RBU6-GT-4 Tritium Data



Graph 25: U6 MK30 Tritium Data



Graph 26: MW-266-19 Tritium Data

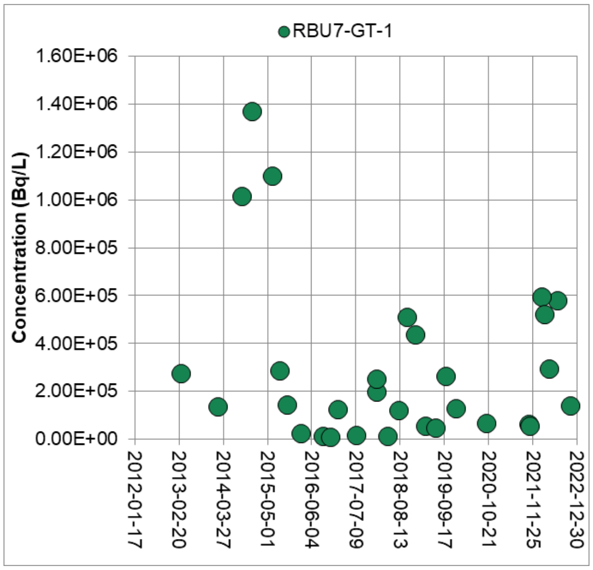


Graph 27: IAD-SU-6 Tritium Data

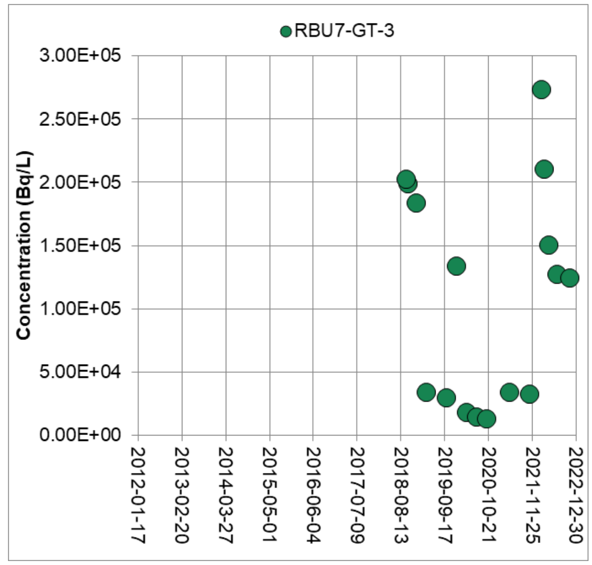
Unit 7 Area

At RBU7-GT-1, tritium concentrations in groundwater in February 2022 were the highest since 2015, however, concentrations declined over the year and were consistent with the historical average by October 2022. No trend in groundwater tritium concentrations was identified in RBU7-GT-1. Tritium concentrations in groundwater at RBU7-GT-3 are generally stable overall. Tritium concentrations in groundwater at U7-MK-36 and MW-265-12 were within historical ranges and no increasing trends were identified visually. Tritium concentrations at IAD-SU-7 were among the highest measured to date in February 2022, and tritium concentrations in water sampled at this location overall demonstrate an increasing trend, however, the values remain within a range considered to reflect fluctuations associated with routine operations. Any changes in groundwater quality are adequately observed with the existing monitoring schedule. Groundwater in the Unit 7 area will continue to be monitored.

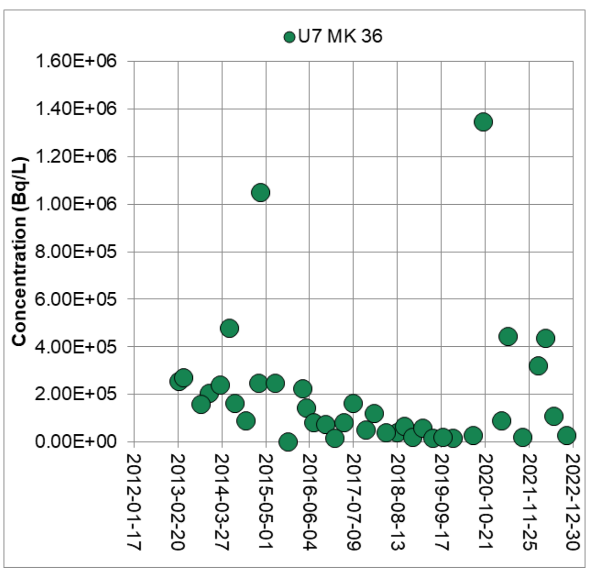
Graphs 28 to 33 illustrate the data for RBU7-GT-1, RBU7-GT-3, U7 MK36, MW-265-12, and MW-325-15.



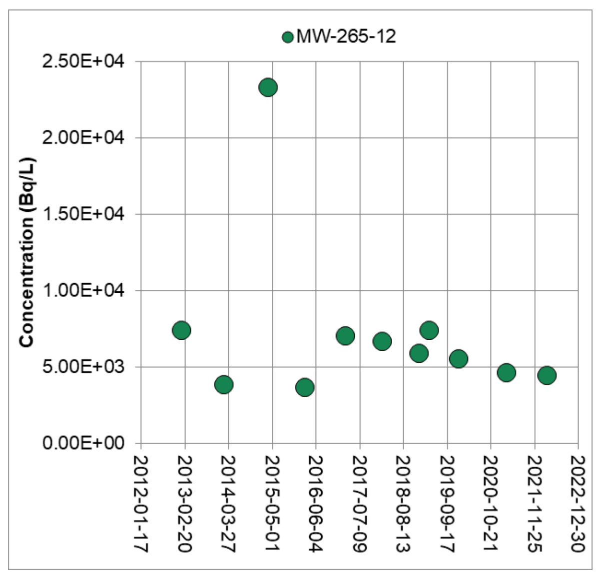
Graph 28: RBU7-GT-1 Tritium Data



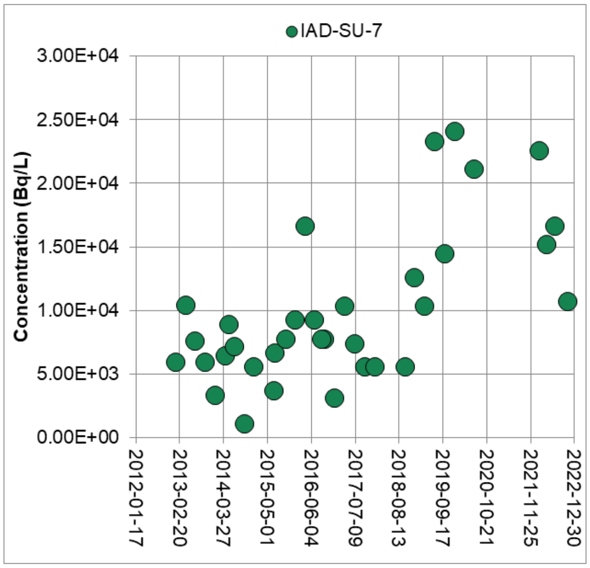
Graph 29: RBU7-GT-3 Tritium Data



Graph 30: U7 MK36 Tritium Data



Graph 31: MW-265-12 Tritium Data

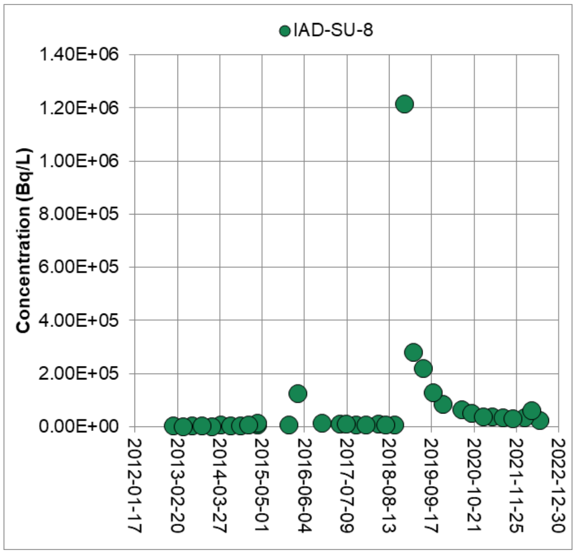


Graph 32: IAD-SU-7 Tritium Data

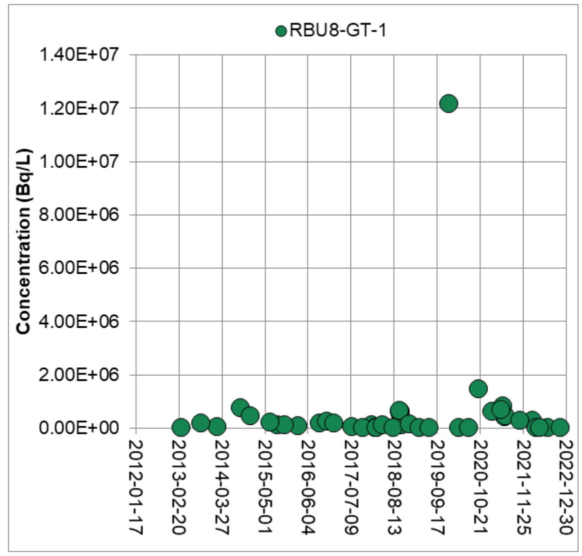
Unit 8 Area

In 2022, tritium concentrations in the Unit 8 TAB Inactive Drainage (IAD) (IAD-SU-8) sump and Unit 8 RB foundation drainage groundtubes were consistent with historical levels and did not indicate any increasing trends. Tritium concentrations at U8 MK42 were similar to previous years. At MW-264-10, tritium concentrations are measured annually. The concentrations at this well overall demonstrate a probable increasing trend, however, concentrations remain within the range of other monitoring wells close to the RBs in this area. Groundwater will continue to be monitored at this well.

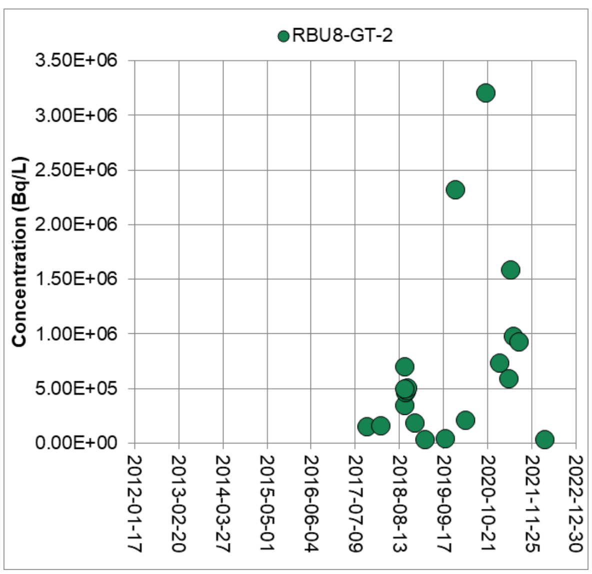
Graphs 34 to 39 illustrate the tritium data for IAD-SU-8, the Unit 8 RB foundation drainage groundtubes, U8 MK42, and monitoring well MW-264-10.



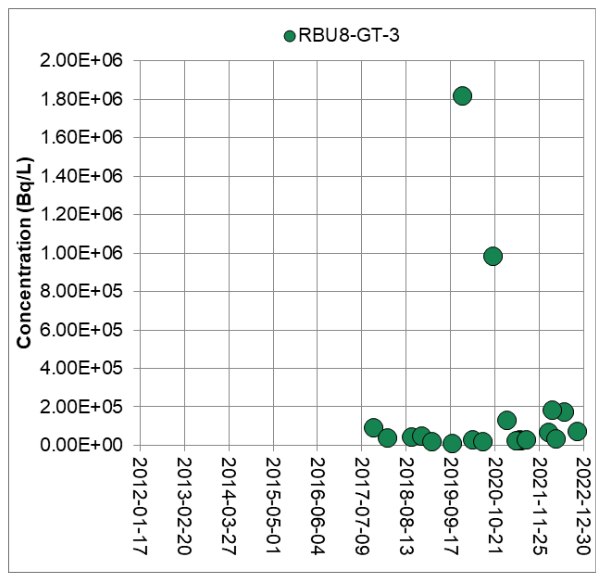
Graph 33: IAD-SU-8 Tritium Data



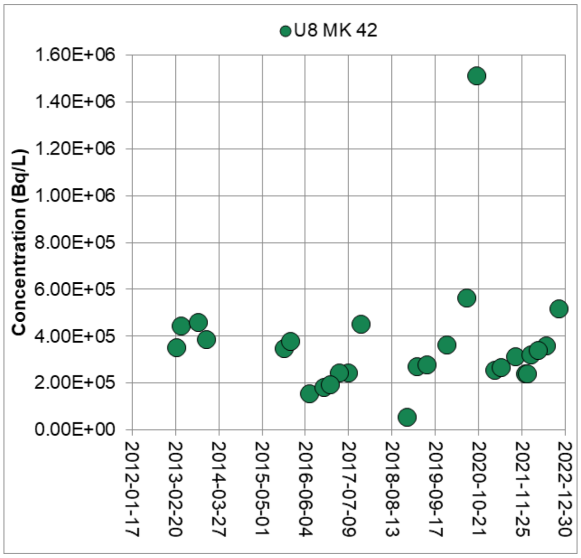
Graph 34: RBU8-GT-1 Tritium Data



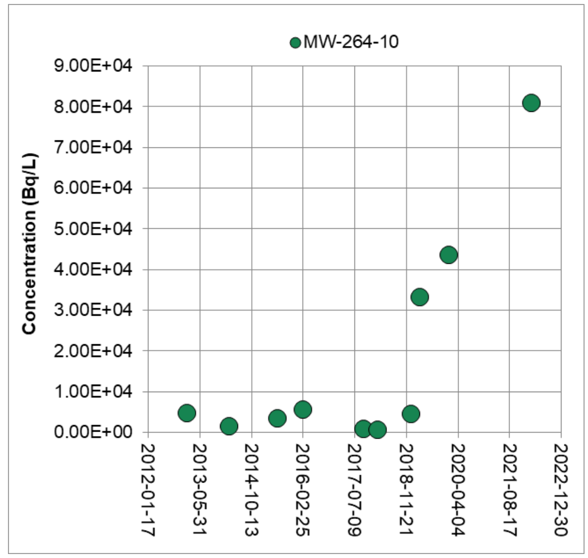
Graph 35: RBU8-GT-2 Tritium Data



Graph 36: RBU8-GT-3 Tritium Data



Graph 37: U8 MK42 Tritium Data



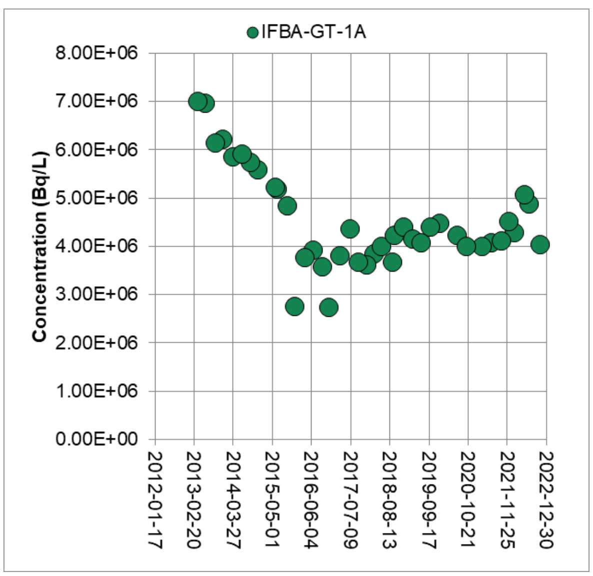
Graph 38: MW-264-10 Tritium Data

3.1.1.3 Irradiated Fuel Bay Areas

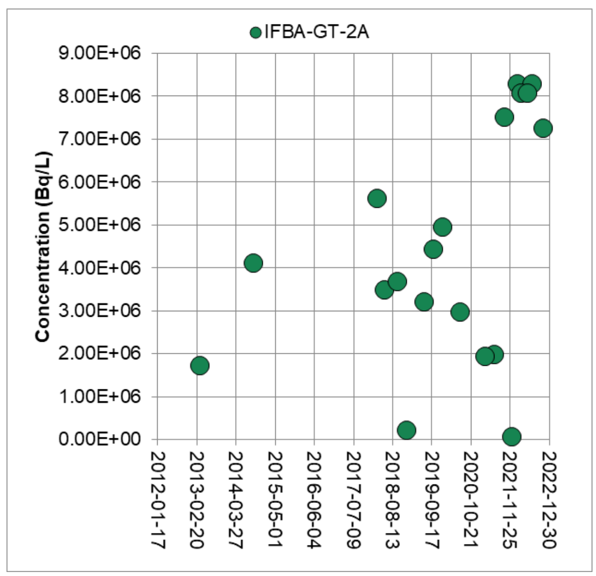
IFB-A

In 2022, the eastern groundtubes (IFBA-GT-1A and IFBA-GT-2A) showed higher tritium concentrations than IFBA-GT-5A to the west. Concentrations in IFBA-GT-2A are increasing. Monitoring well MW-244-18 in the vicinity of the IFBs displayed an increased concentration in 2022 compared to the concentration measured in 2021 and demonstrates a probable increasing trend. The tritium concentrations within IFBA-GT-2A and MW-244-18 are expected as groundwater in the Unit 1 area migrates towards the Units 1 to 4 IFB-A and TAB foundation drains in addition to the VBRS. The increased tritium concentrations are interpreted as the western edge of the tritium plume associated with the 2020 heavy water release originating in the Unit 1 area, extending towards the IFB-A. Groundwater in the protected area eventually flows north towards the low-lying TAB sumps which are eventually discharged via a monitored pathway.

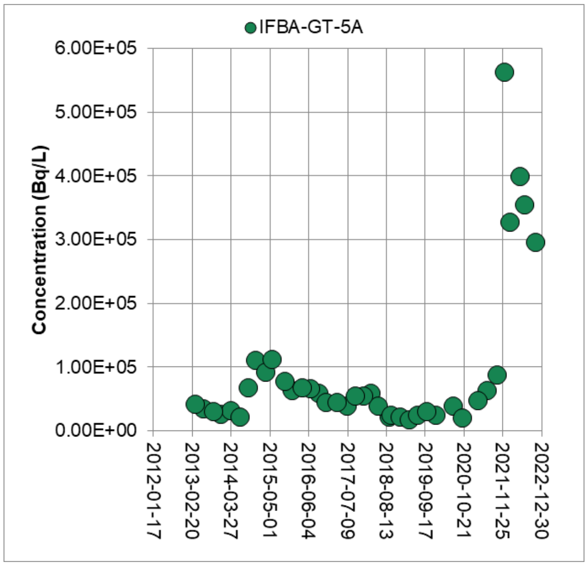
Tritium concentrations over time for the IFB-A groundtubes and MW-244-18 are presented in Graph 39 to 43. The 2022 tritium sample results are presented in Table A-3. (Appendix A). Figure 13 and Figure 14 also display the annual maximum tritium distributions of Unit 1 to 4 IFBs in HU 1-3 and HU 6, respectively.



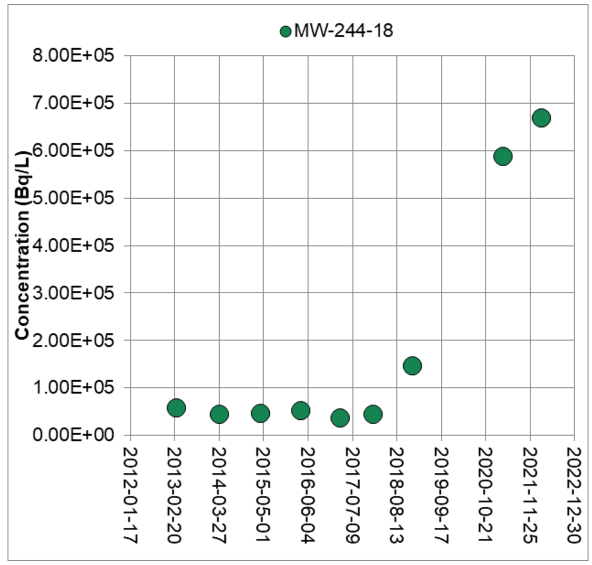
Graph 39: IFBA-GT-1A Tritium Data



Graph 40: IFBA-GT-2A Tritium Data



Graph 41: IFBA-GT-5A Tritium Data



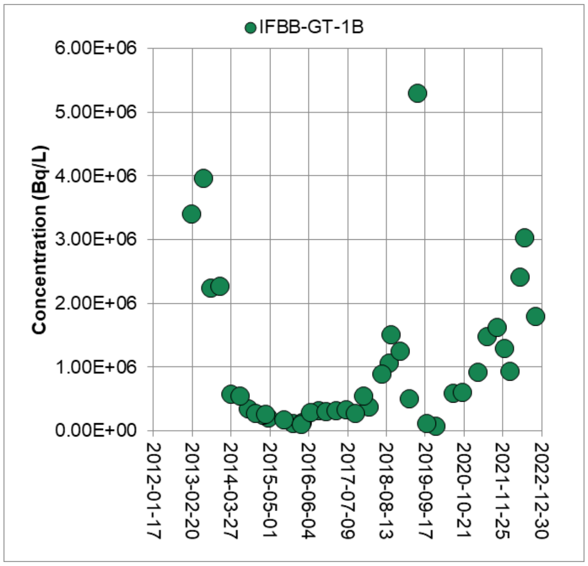
Graph 42: MW-244-18 Tritium Data

IFB-B

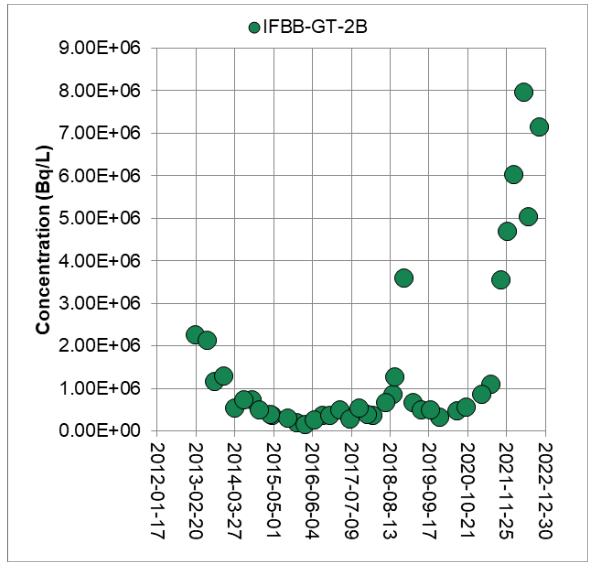
The groundwater results collected from sampling locations in the Irradiated Fuel Bay area located between Units 6 and 7 (IFB-B) are described below.

In 2022, tritium concentrations in the western groundtubes (IFBB-GT-1B, IFBB-GT-2B, and IFBB-GT-3B) increased relative to 2021 and tritium concentrations at all three locations show an upward trend since 2019. Monitoring wells MW-171-15 and MW-172-25 located further south of Units 5-8 continued to show tritium concentrations within historical ranges. In addition, tritium concentrations in each of the eastern groundtubes (IFBB-GT-4B, IFBB-GT-5B, and IFBB-GT-6B) demonstrate decreasing trends. A review of the available groundwater flow conditions suggests groundwater moves from Unit 6, beneath the IFB-B area and ultimately towards the TAB IAD sumps. As such, the recent increases in tritium concentrations in the western groundtubes within the IFB-B area are likely related to the elevated concentrations observed in Unit 5 and 6 groundtubes since 2021. Groundwater quality in this area will continue to be monitored.

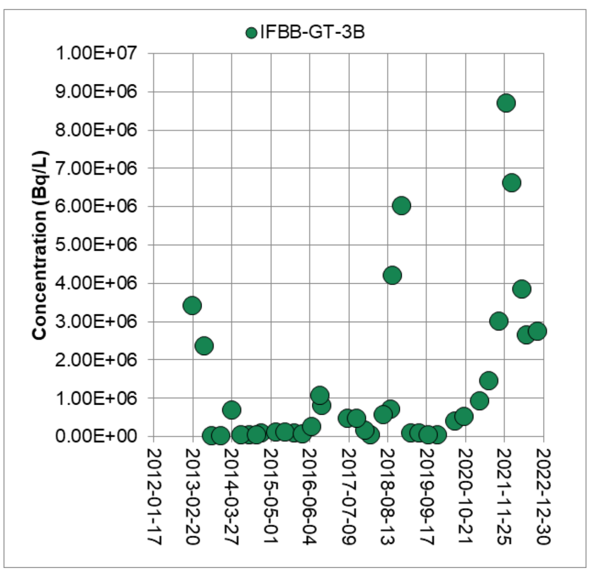
Tritium concentrations over time for the IFB-B groundtubes and monitoring wells are presented in Graphs 44 to 51. The 2022 tritium sample results are presented in Table A-3 (Appendix A). Figure 15 also displays tritium distributions of the Unit 5 to 8 IFBs in HU 6



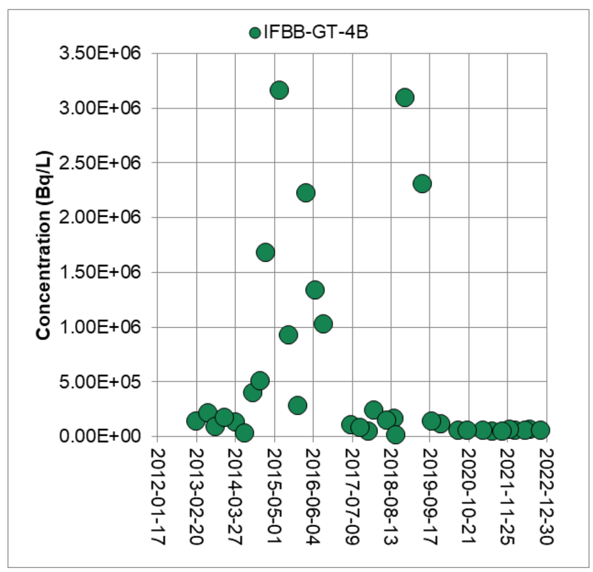
Graph 43: IFBB-GT-1B Tritium Data



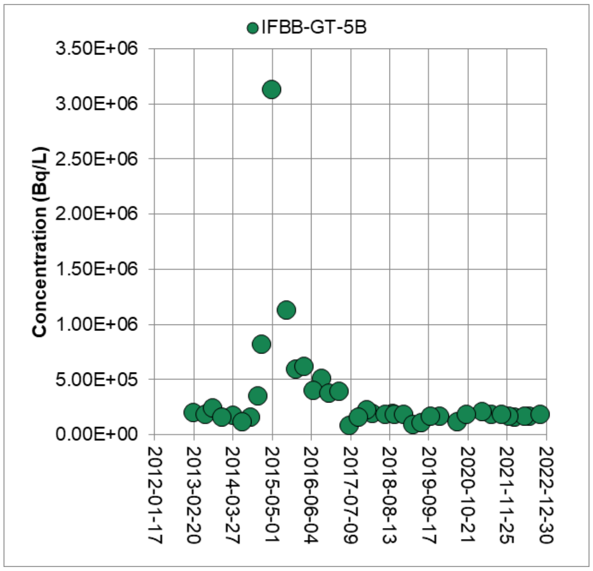
Graph 44: IFBB-GT-2B Tritium Data



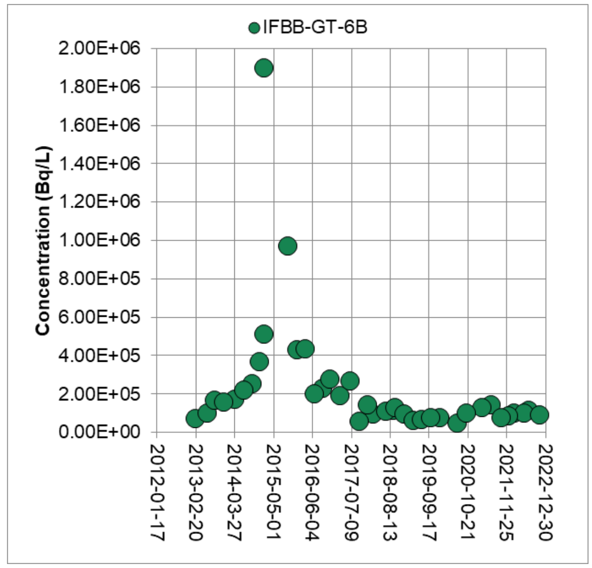
Graph 45: IFBB-GT-3B Tritium Data



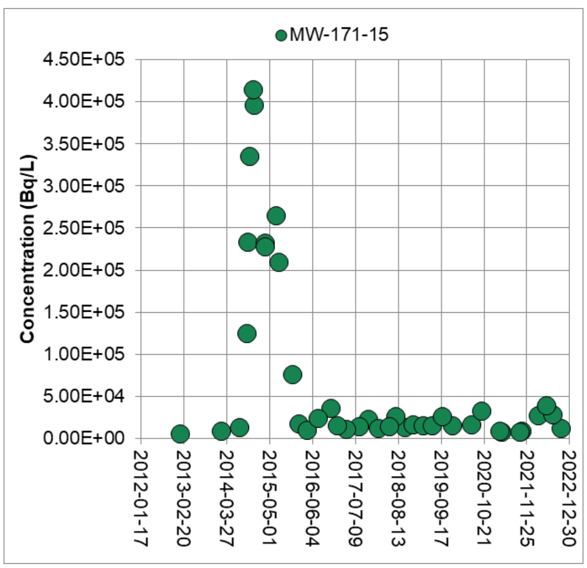
Graph 46: IFBB-GT-4B Tritium Data



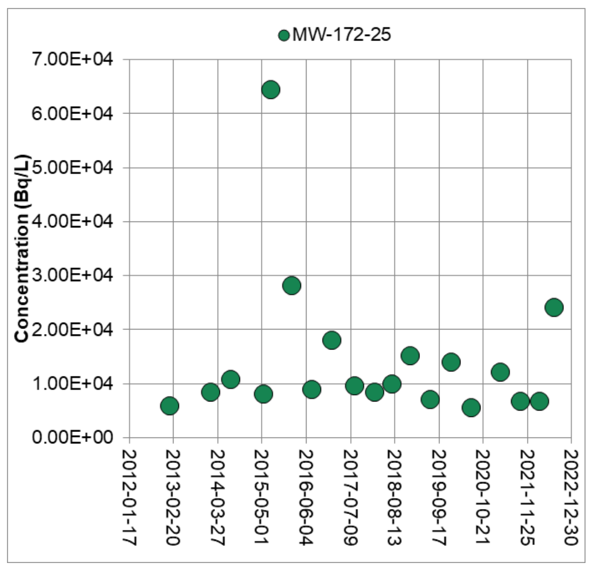
Graph 47: IFBB-GT-5B Tritium Data



Graph 48: IFBB-GT-6B Tritium Data



Graph 49: MW-171-15 Tritium Data



Graph 50: MW-172-25 Tritium Data

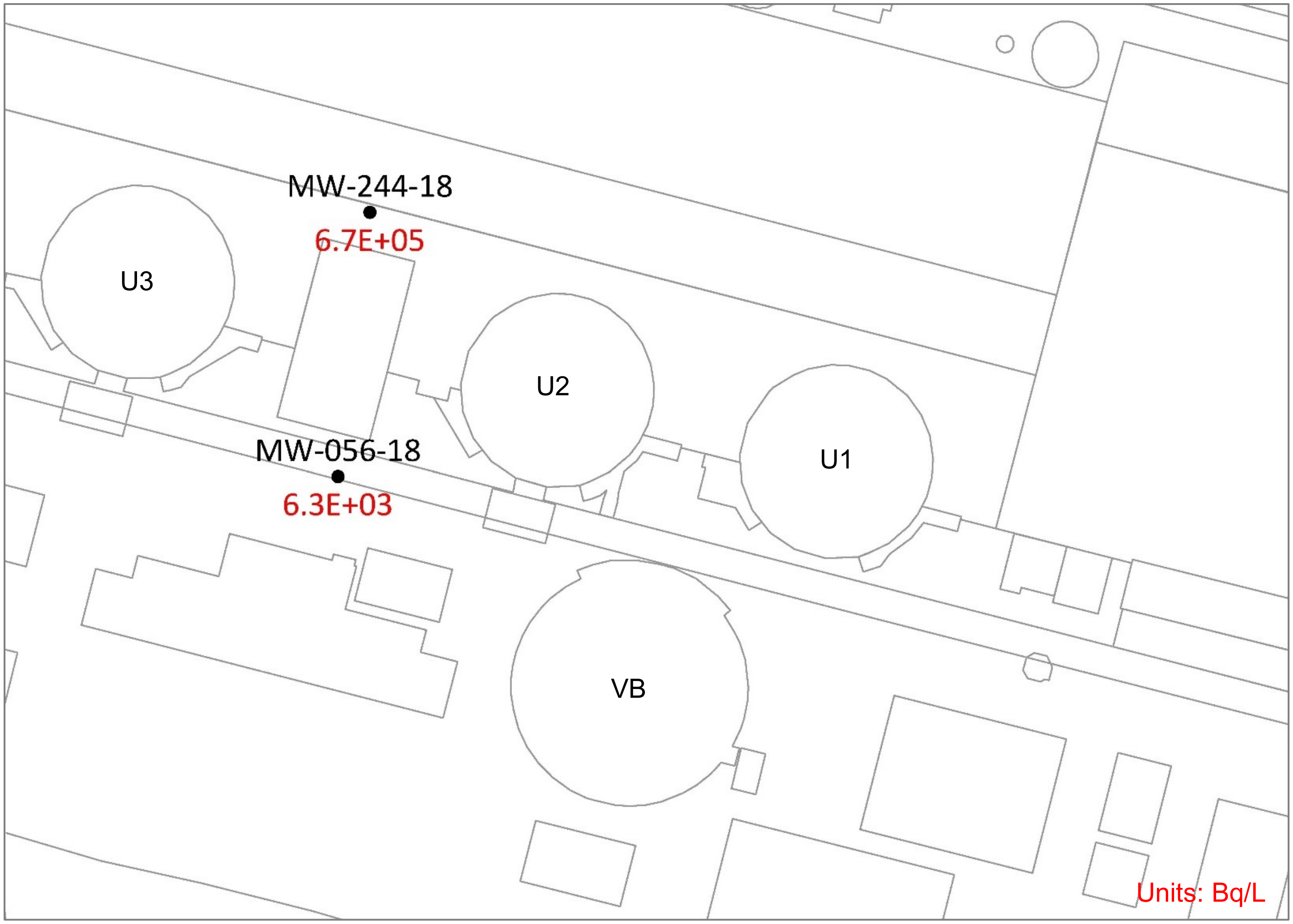


Figure 13: 2022 Annual Maximum Tritium Concentrations at IFB-A in HU 1-3

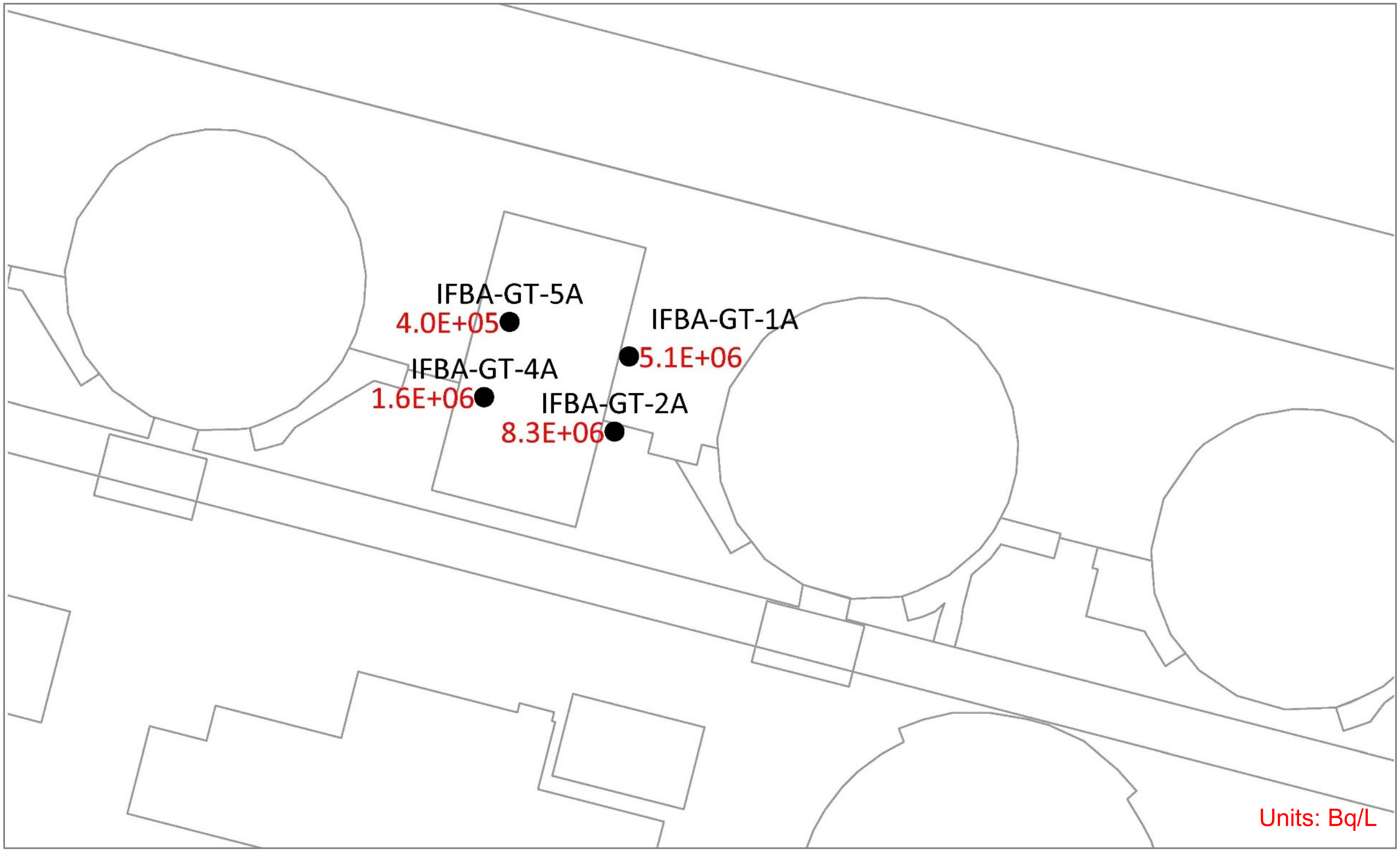


Figure 14: 2022 Annual Maximum Tritium Concentrations at IFB-A in HU 6

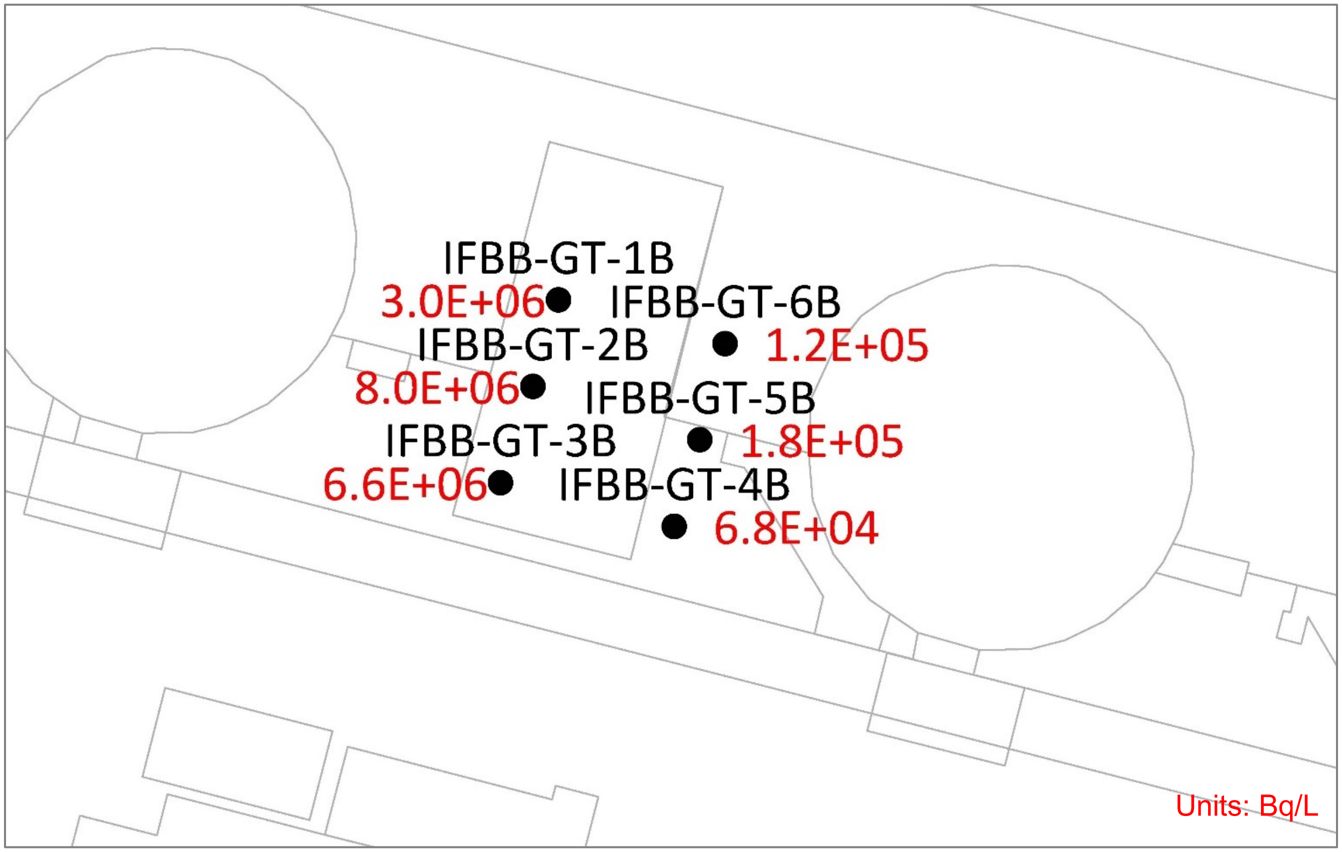
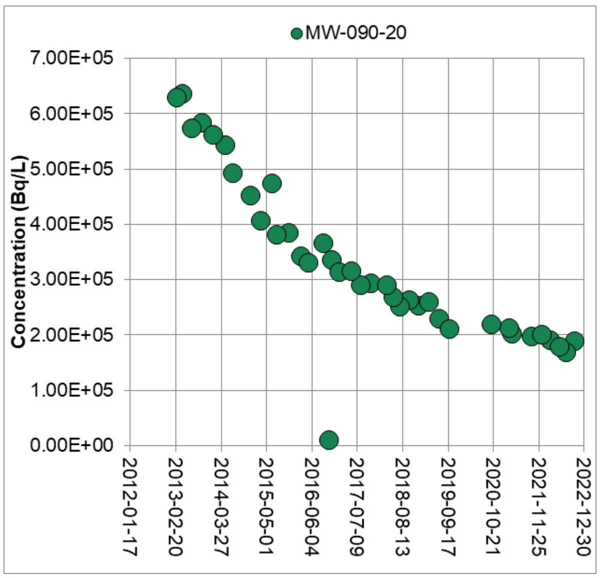


Figure 15: 2022 Annual Maximum Tritium Concentrations at IFB-B in HU 6

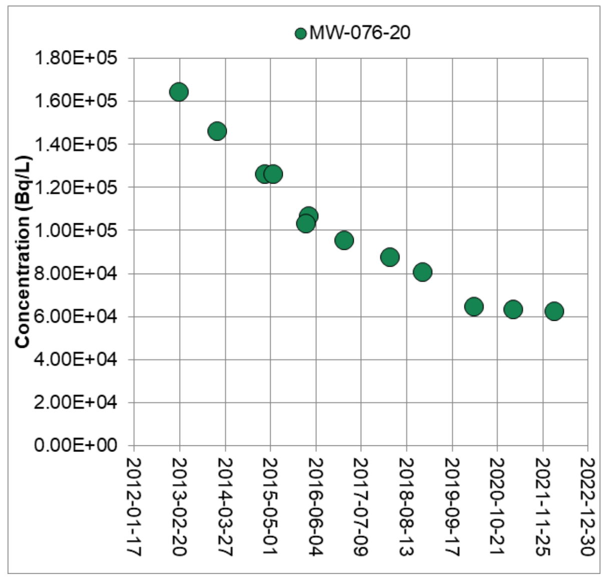
3.1.1.4 Upgrading Plant Pickering Area

In 2022, tritium concentrations in this area continue to decrease or appear to be stable.

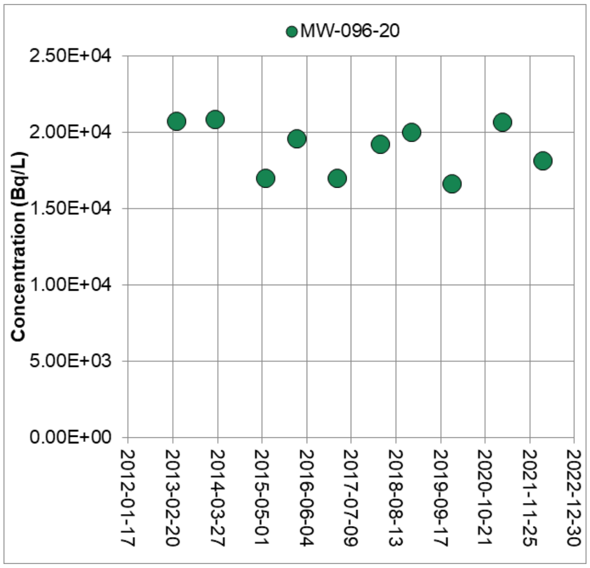
Tritium concentrations in groundwater over time for the UPP area are presented in Graph 51 to 54. The 2022 sample results for tritium concentrations in groundwater at the locations sampled in the UPP area are presented in Table A-4 (Appendix A). Figure 16 and Figure 17 display the annual maximum tritium concentration distributions within HU 1-3 and HU 6 in the UPP area.



Graph 51: MW-090-20 Tritium Data



Graph 52: MW-076-20 Tritium Data



Graph 53: MW-096-20 Tritium Data

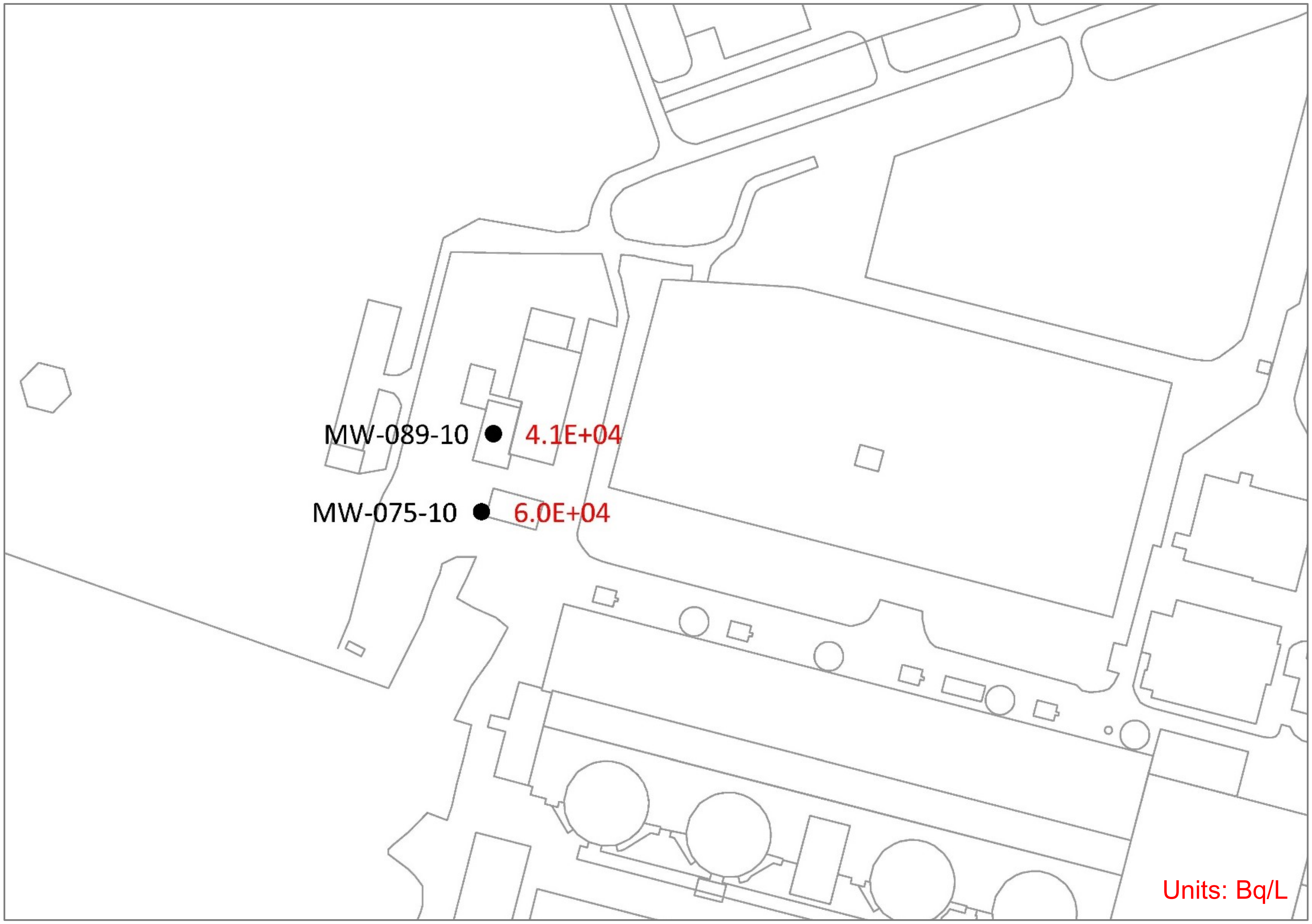
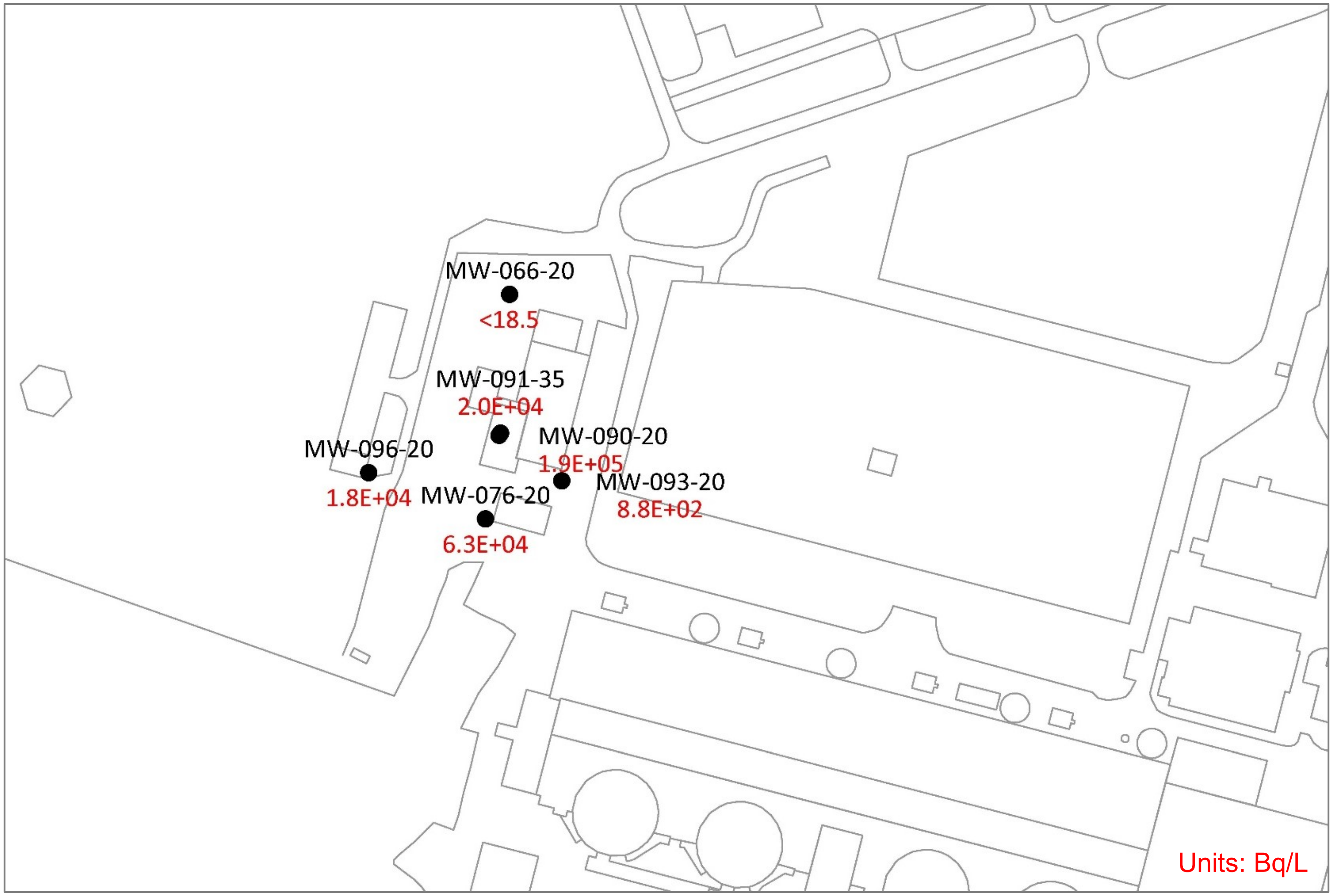


Figure 16: 2022 Annual Maximum Tritium Concentrations in HU 1-3, UPP



Note: MW-093-20 is installed within HU 5.

Figure 17: 2022 Annual Maximum Tritium Concentrations in HU 6, UPP

3.1.2 Dissolved iron concentrations downgradient of East and West Landfills

In 2022, one monitoring well associated with each of the East and West Landfills was sampled for the analysis of dissolved iron (MW-024-20 and MW-205-35). Concentrations of iron are 1,000 µg/L and 1,900 µg/L and remained within the historical range. Concentrations were below the groundwater numeric evaluation criteria of 3,000 µg/L developed in the PN GWPP and GWMP (Ecometrix, 2020a).

Table A-5 (Appendix A) summarizes the dissolved iron concentrations at the wells associated with the East and West Landfill.

3.1.3 PHC concentrations in groundwater at Units 1 to 4 SG, Units 5 to 8 SG, EPG and EPG3

In 2022, eighteen wells were monitored within the vicinity of Unit 1 to 4 SG (SG-A), SG-A overflow area, and Unit 5 to 8 SG (SG-B). The monitoring wells were monitored for groundwater/fuel oil product levels and sampled for PHC F1 to F4, BTEX, and dissolved iron, where free-phase hydrocarbon product was not present. Monitoring well MW-287-15 was sampled and analyzed for PHC F1 to F4, BTEX, and dissolved iron in Q3. Product was present in that well and the remaining wells in Q1, Q2, and Q4. The 2022 results for PHC product thickness and hydrocarbons in groundwater in these areas were within the historical ranges for each well in recent years.

In 2022, sixteen monitoring wells were sampled for PHC and BTEX within the vicinity of the SG-A, SG-A overflow area, SG-B, EPG, and EPG3. All samples collected met the MECP Table 9 Site Condition Standard (SCS) for non-potable groundwater within 30 m of a water body and industrial/commercial/community land use except for three locations sampled. PHC F2 concentrations exceeded the MECP SCS at MW-146-15, MW-287-15, and MW-282-15. PHC F3 concentrations exceeded MECP SCS at MW-287-15. In 2022, three monitoring wells were sampled for dissolved iron. Iron concentrations exceeded the numerical evaluation criteria at MW-226-22, in the SG-A overflow area.

However, concentrations of PHC F2 from MW-146-15 have decreased compared to historical samples collected as summarized in the MNA report for 2022 (PGL, 2022, tbl. 2). Concentrations of PHC F2 and F3 at MW-287-15 demonstrate a decreasing trend since 2008 and concentrations of PHC F2 at MW-282-15 does not demonstrate a trend using data from 2010 (PGL, 2022, tbl. 2). The localized presence of PHCs and iron at concentrations above the groundwater evaluation criteria are expected in these areas, where remediation using a natural monitored attenuation approach is ongoing.

Table A-6a (Appendix A) summarizes the product thickness and Table A-6b summarizes the PHC, BTEX, and dissolved iron concentrations at the wells associated with the SG-A, SG-A overflow area, SG-B, EPG, and EPG3.

3.1.4 PHC and dissolved iron concentrations in groundwater at Fukushima Diesel Generators

In 2022, three monitoring wells associated with the Fukushima diesel generators were sampled for the analysis of PHCs and BTEX and one monitoring well was sampled for the analysis of dissolved iron. PHC and BTEX concentrations remained below detection. The dissolved iron concentration remained below the groundwater numeric evaluation criteria of 3,000 µg/L developed in the PN GWPP and GWMP (Ecometrix, 2020a).

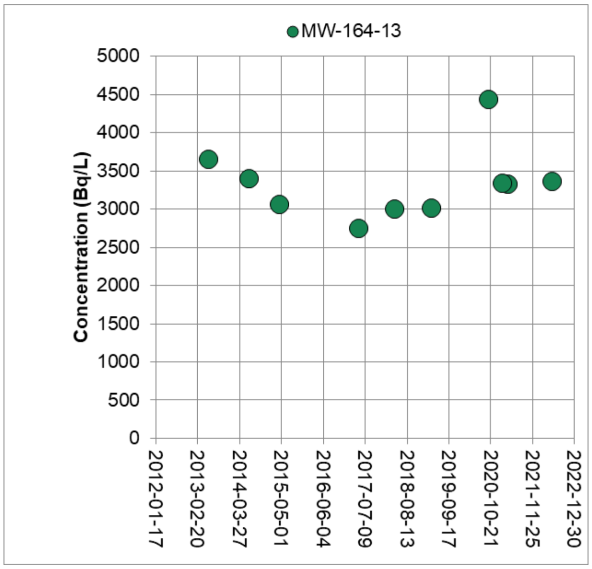
Table A-7 (Appendix A) summarizes the PHC, BTEX, and dissolved iron concentrations at the wells associated with the Fukushima Diesel Generators.

3.3 Objective 2 Results

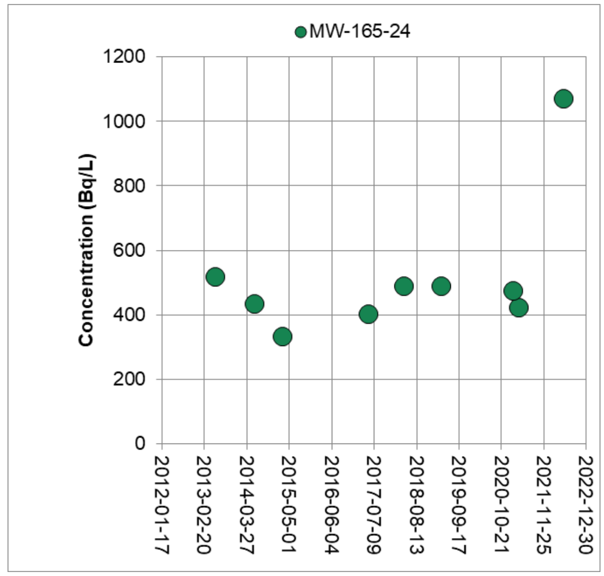
3.3.1 Site Perimeter Overview

In 2022, concentrations of tritium in groundwater within the boundary perimeter wells were low (less than 900 Bq/L) and are considered to reflect background conditions. Shoreline wells MW-164-13 and MW-165-24 are located southeast of Unit 1 and 2 reactor buildings. Shoreline wells MW-225-12 and MW-226-22 are located southwest of Unit 3 and 4 reactor buildings. Shoreline wells MW-183-10 and MW-184-27 are located southeast of Unit 5-8 reactor buildings and the overall site. Shoreline wells MW-222-10 and MW-223-32 are located south of the UPP area. Tritium concentrations from 2022 in these shoreline wells are within historical ranges and are stable. Tritium concentrations in all shoreline wells remain substantively below groundwater evaluation criteria, demonstrating no potential for off-site impacts from tritium in groundwater at PNGS.

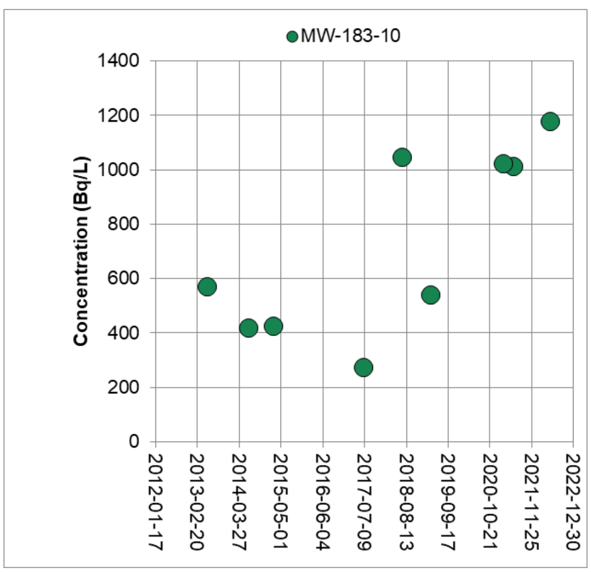
Table A-8 (Appendix A) summarizes the tritium concentrations at each of the perimeter wells, and the annual maximum tritium concentrations within HU1-3, HU 6, and HU 7 are in Figure 18 to Figure 20 respectively. Tritium results within the shoreline wells are shown below in Graphs 55 to 62.



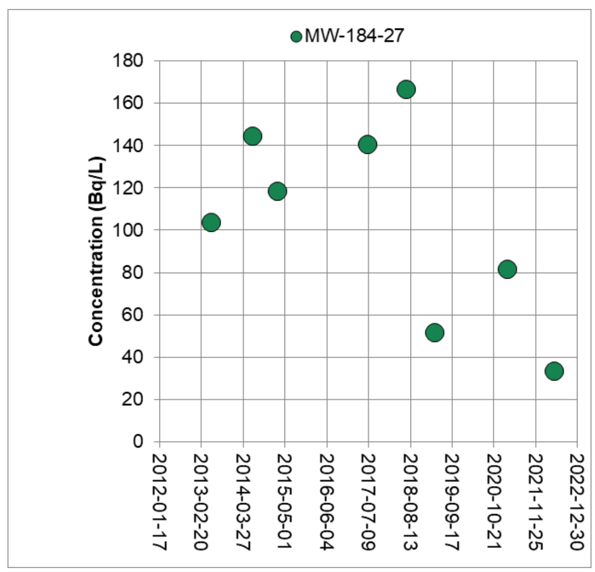
Graph 54: MW-164-13 Tritium Data



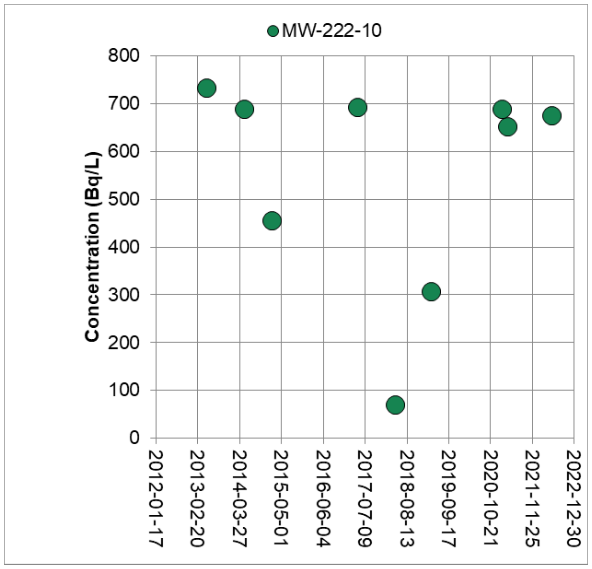
Graph 55: MW-165-24 Tritium Data



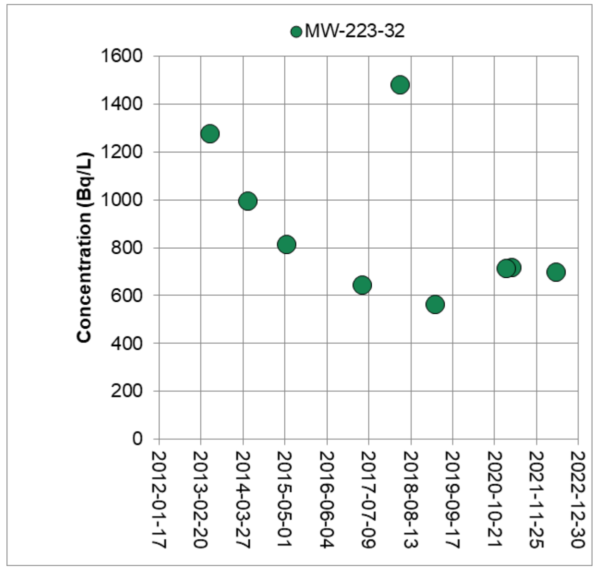
Graph 56: MW-183-10 Tritium Data



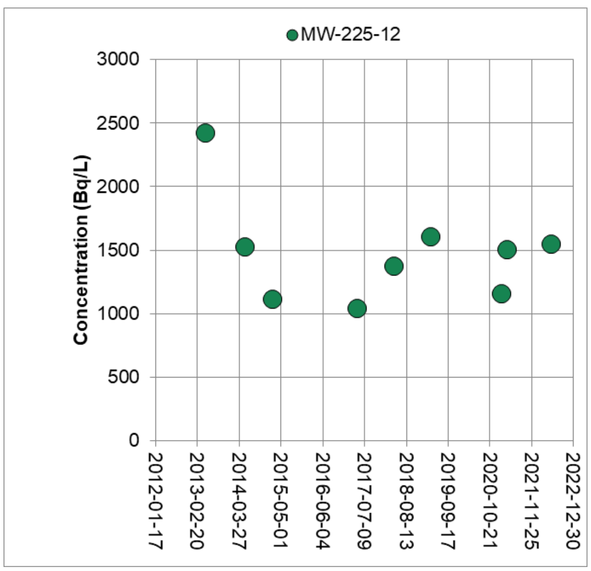
Graph 57: MW-184-27 Tritium Data



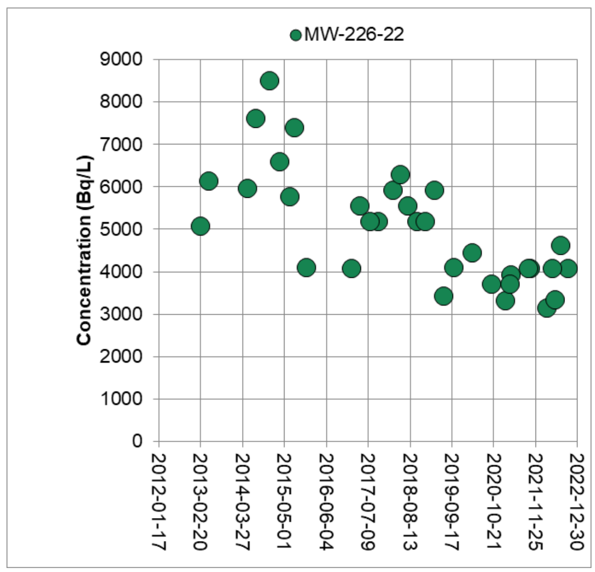
Graph 58: MW-222-10 Tritium Data



Graph 59: MW-223-32 Tritium Data



Graph 60: MW-225-12 Tritium Data



Graph 61: MW-226-22 Tritium Data

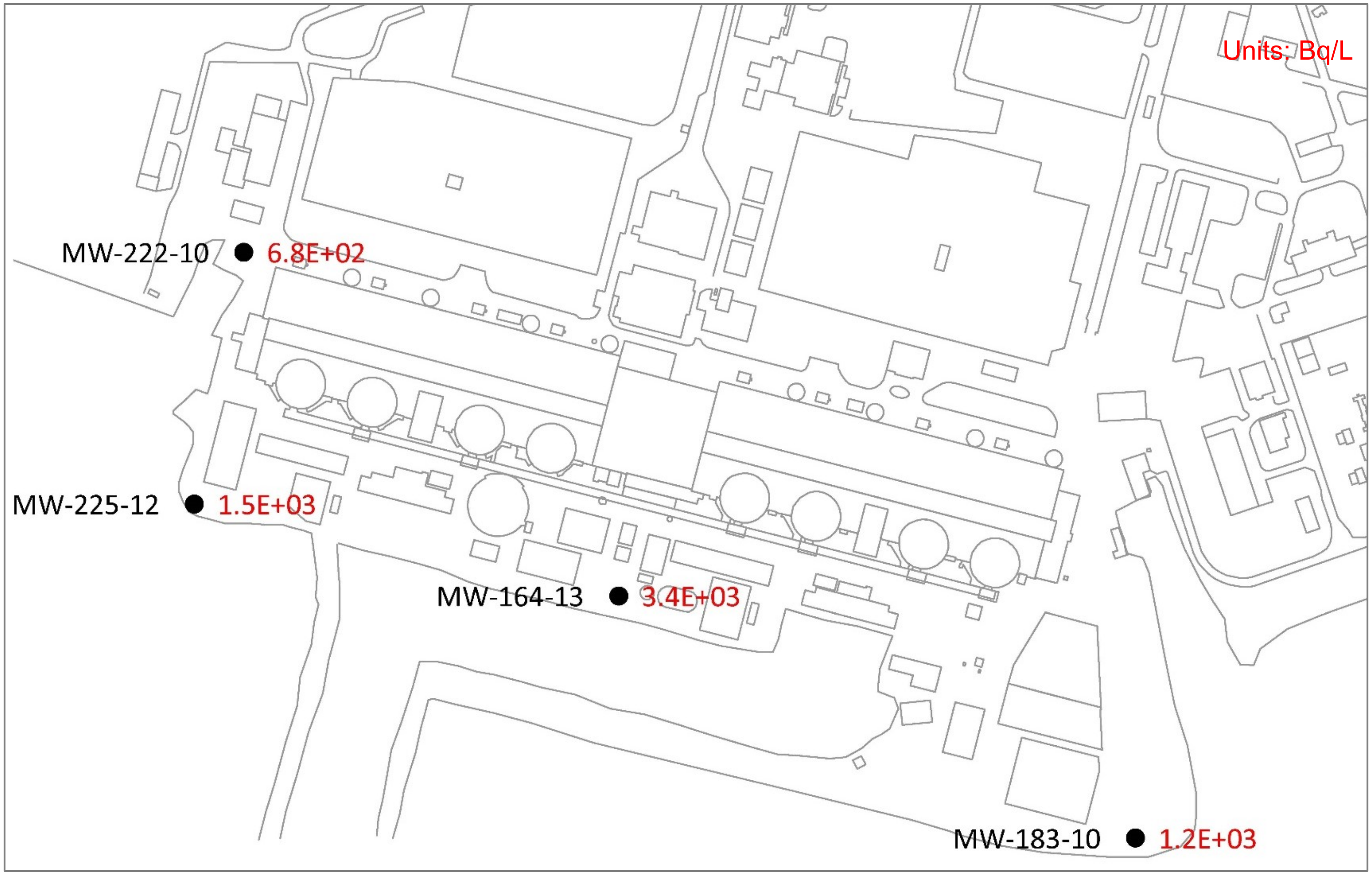


Figure 18: 2022 Annual Maximum Tritium Concentrations in HU 1-3, Site Perimeter

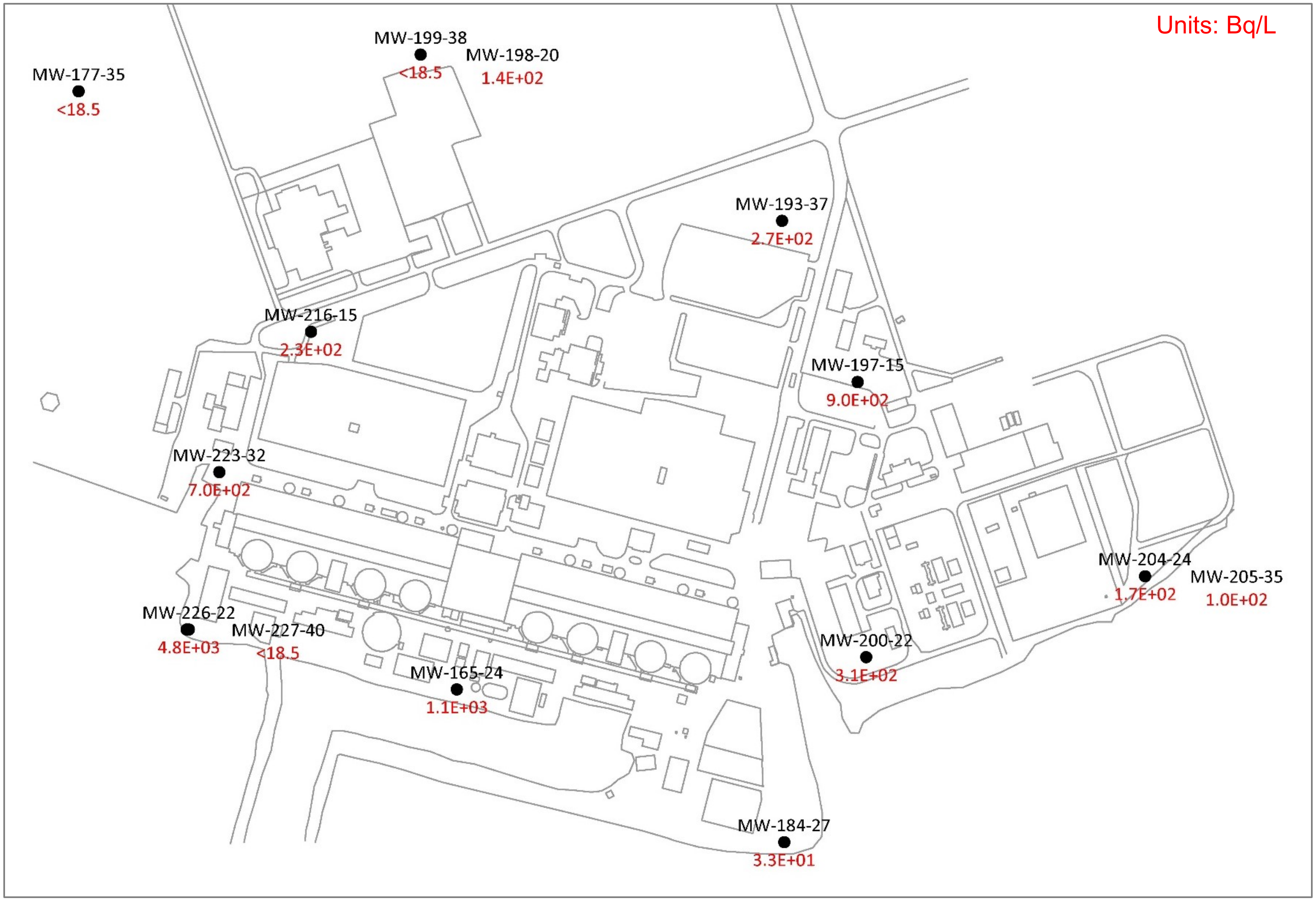


Figure 19: 2022 Annual Maximum Tritium Concentrations in HU 6, Site Perimeter

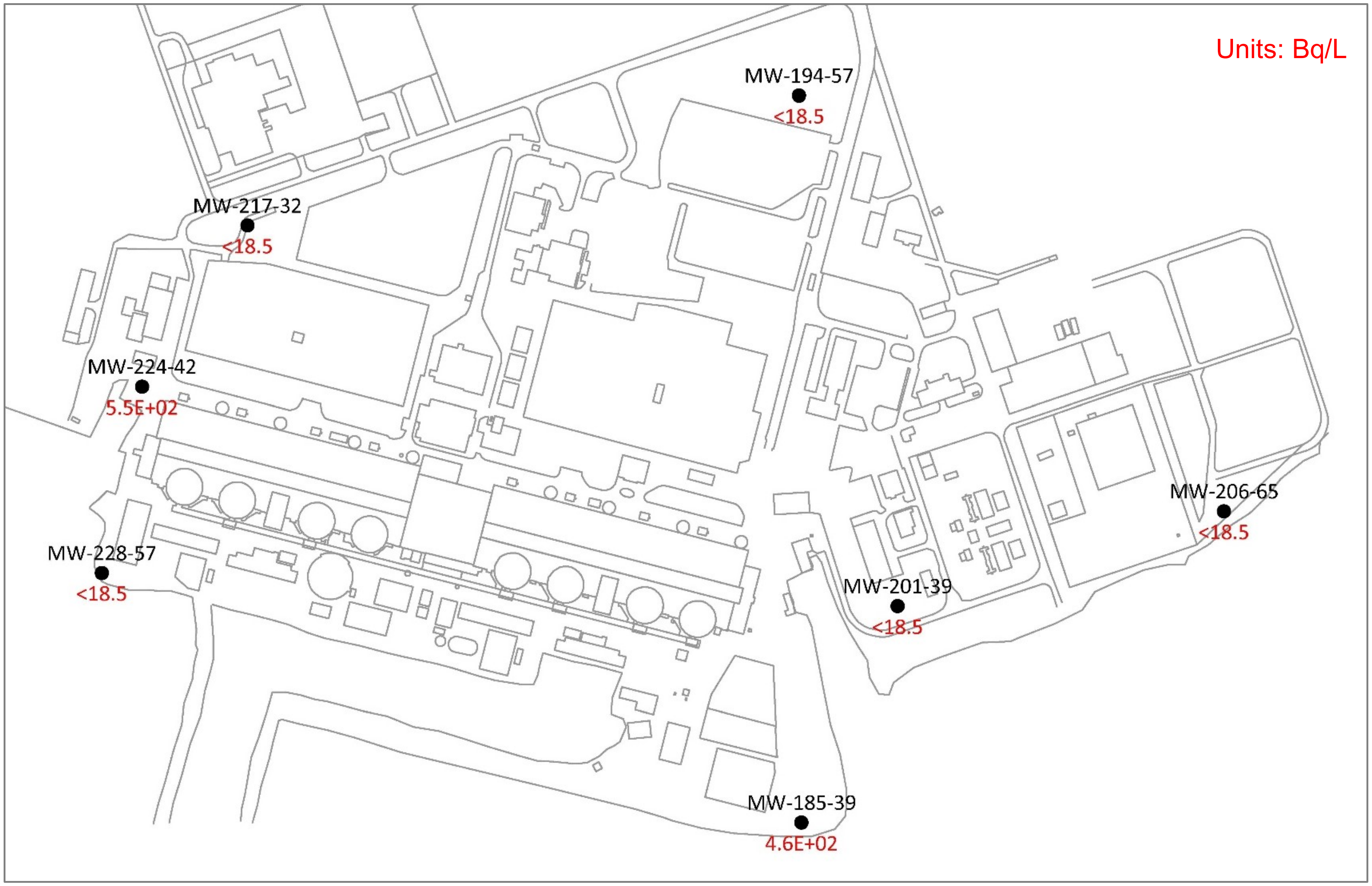


Figure 20: 2022 Annual Maximum Tritium Concentrations in HU 7, Site Perimeter

3.4 Objective 3 Results

3.1.5 Overview of Groundwater Flow Direction

The groundwater flow directions inferred for HUs beneath the PNGS from hydraulic head data collected in 2022 are consistent with historical interpretations.

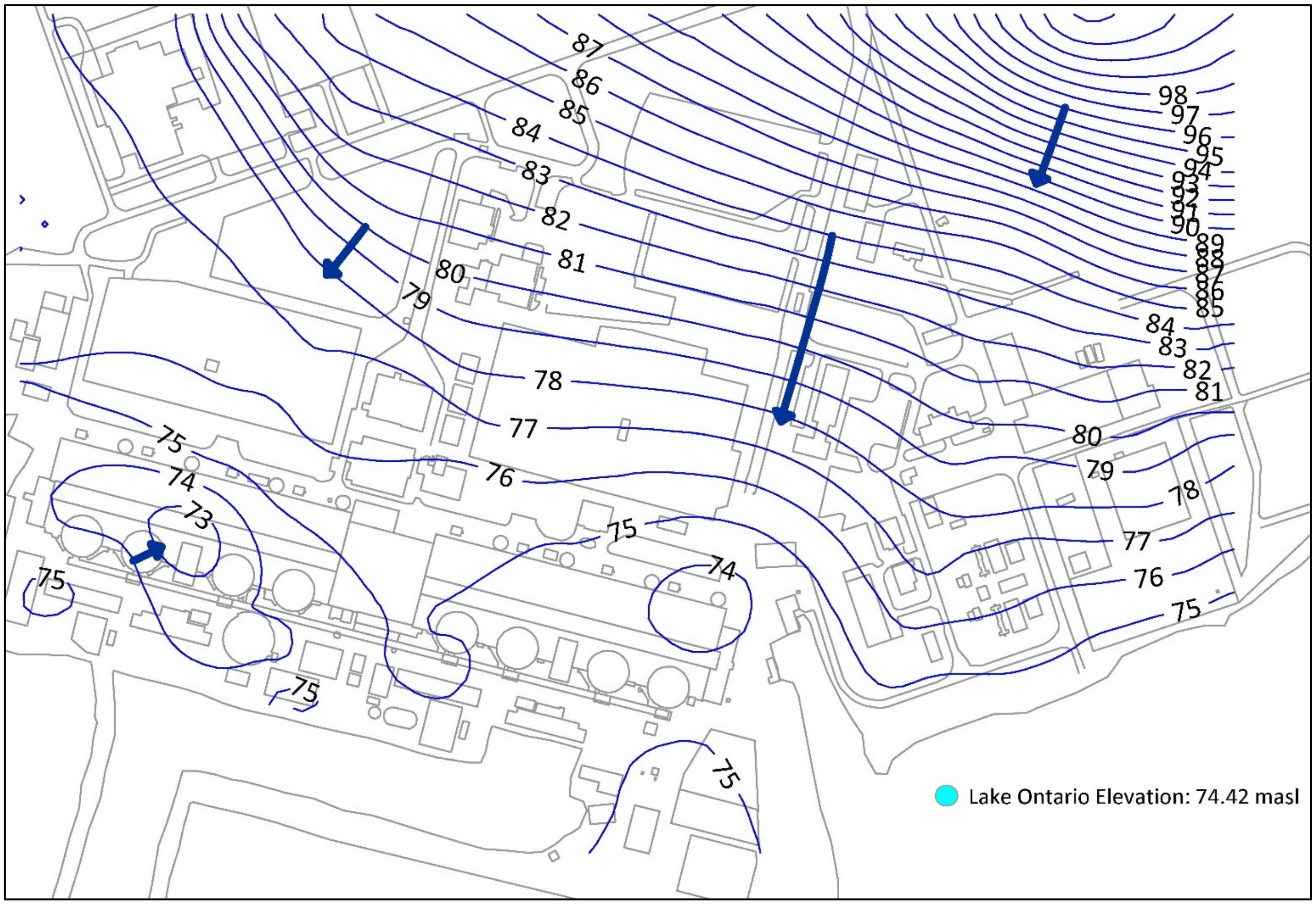
In the shallower groundwater table (HU 1-3; Figure 21), the East Landfill (northeast of the PNGS) remains the major local recharge area with groundwater flowing generally from the landfill towards the station buildings to the southwest, and towards the Lake Ontario in the south.

Closer to the reactor units, groundwater flow directions are more complex due to subsurface structures and active pumping in the TAB foundation drains and VBRS. The general groundwater flow direction is interpreted to be south towards the lake, with influence from the pumping activities around the reactors. Groundwater within the vicinity of Units 1 to 4 is inferred to migrate towards the TAB and IFB-A. In the Units 5 to 8 area, groundwater is generally inferred to migrate towards the TAB. The TAB foundation drains collect groundwater and terminate in the TAB IAD sumps associated with each reactor unit. These sumps also collect other station process water. The water collected in the IAD sumps is eventually discharged via a monitored pathway.

Groundwater within the area of Units 1 and 2 in HU 1-3 is interpreted to migrate towards the VBRS. As mentioned above, the VBRS acts as a hydraulic sink, diverting a portion of groundwater in Unit 1 and 2 areas towards the VBRS.

Water levels collected from wells installed within HU 6 and HU 7 are generally consistent with historical values. Thus, no change in the historically inferred groundwater flow directions in these units, towards Lake Ontario, is suggested.

Overall, the groundwater monitoring completed in 2022 was sufficient to determine groundwater flow conditions at the site and support the understanding of the migration of chemical and radiological constituents in groundwater throughout the site.



Note: Groundwater contours were developed using water level measurements collected between October 3 to 14, 2022. The Lake Ontario elevation used to determine groundwater contours were determined from an average of daily mean water elevations between October 3 to 14, 2022 (IJC, 2023).

Figure 21: 2022 Q4 Shallow (HU 1-3) Groundwater Elevation Contours

4.0 2022 PROGRAM QUALITY ASSURANCE/QUALITY CONTROL

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

4.1 Quality Assurance Programs for Laboratories

In 2022, samples analyzed for PHC, BTEX, and dissolved iron were submitted to BV, which is accredited to ISO 17025 by the Standards Council of Canada for environmental tests. Many of the conventional contaminants are governed by criteria established in MECP's (formerly Ministry of Environment or MOE) 'Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario' (MECP, 2009). BV has developed its analytical protocols to meet the recommended analytical protocols documented in this publication.

The PNGS Chemistry Lab performs laboratory activities according to a documented quality assurance program.

4.2 Quality Control Results

Duplicates, field blanks, and trip blanks were collected at a prescribed frequency to measure sampling and analytical performance.

Over the 2022 sampling programs, 42 field duplicate samples were collected. The results and calculated relative percent differences (RPD), to understand the sampling precision, are presented in Table A-9a and Table A-9b (Appendix A). All calculated RPDs were below 20 percent as recommended in the PNGS GWMP. All duplicate samples were deemed of acceptable quality, demonstrating that the field techniques and the analytical methods employed by the laboratories were reproducible and reliable. Quality Control results summarizing Field and Trip Blank samples are presented in Table A-9c (Appendix A).

5.0 SUPPLEMENTARY STUDIES AND AUDITS

There were no supplementary studies initiated or completed in 2022.

6.0 NOMENCLATURE OF SAMPLING LOCATIONS

Sampling Location Type	Identifier	Explanation of Nomenclature
Monitoring Well	MW-*XXX*-*YY*	*XXX* represents a unique identifier *YY* represents the depth of the monitoring well in feet

Reactor Building Foundation Drainage Groundtube	RBU*X*-GT-*Y*	*X* represents the unit associated with the groundtube *Y* represents the position (1 is northwest, 2 is southwest, 3 is southeast, 4 is northeast)
Reactor Building Foundation Drainage Sump	U*X* MK *YY*	*X* represents the unit associated with the sump *Y* is a unique identifier
Irradiated Fuel Bay Groundtube	IFBA-GT-*X*A IFBB-GT-*X*B	*X* is a unique identifier
TAB Foundation Drainage	IAD-SU-*X*-*Y*	*X* represents the unit associated with the foundation drainage *Y* represents the orientation of the drainage line (1 is north and 2 west)
TAB Inactive Drainage Sump	IAD-SU-*X*	*X* represents the unit associated with the sump

7.0 ACRONYMS

Bq/L	Becquerel per Litre
BTEX	Benzene / Toluene / Ethylbenzene / Xylene
CNSC	Canadian Nuclear Safety Commission
CSA	Canadian Standards Association
EMP	Environmental Monitoring Program
EPG	Emergency Power Generator
HU	Hydrostratigraphic Unit
IAD	Inactive Drainage
IFB	Irradiated Fuel Bay
ISO	International Organization for Standardization
MDL	Method Detection Limit
MECP	Ministry of Environment, Conservation and Parks
OPG	Ontario Power Generation Inc.
PHC	Petroleum Hydrocarbon
PNGS	Pickering Nuclear Generating Station
RAB	Reactor Auxiliary Bay
RB	Reactor Building
RLWMS	Radioactive Liquid Waste Management System

RPD	Relative Percentage Difference
SAP	Sampling and Analysis Plan
SRST	Spent Resin Storage Tank
TAB	Turbine Auxiliary Bay
UPP	Upgrading Plant Pickering
VB	Vacuum Building
VBRS	Vacuum Building Ramp Sump
VOC	Volatile Organic Compound
WSP	Water Supply Plant

8.0 REFERENCES

Ecometrix (Ecometrix Incorporated), 2020a. Groundwater Protection and Monitoring Programs for Pickering Nuclear - CSA N288.7 Implementation. Report No. P-REP-07294-00002. December.

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IJC, 2023. International Lake Ontario-St. Lawrence River Board- Lake Ontario Daily Mean Water Levels 2021-20223 [WWW Document]. Int. Jt. Comm. Int. Lake Ont.-St Lawrence River Board. February. URL https://ijc.org/en/loslrb/watershed/water-levels

MECP (Ministry of Environment, Conservation and Parks), 2009. Guidance on Sampling and Analytical Methods for Use at Contaminated Sites in Ontario. March.

OPG (Ontario Power Generation), 2022. Pickering Nuclear Groundwater Sampling and Analysis Plan. July.

PGL (PGL Environmental Consultants), 2022. 2022 Biennial Report: Monitored Natural Attenuation. P-REP-10120-1080594. December.

Appendix A: Tables A-1 to A-9

Table A-1: Units 1 to 4, Vacuum Building Areas and Units 1 to 4 Turbine Auxillary Bays

Monitoring Location	Frequency	Analysis Parameter	HU	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
IAD-SU-1	Quarterly	Tritium	HU 7	19980	27010	19610	7400
IAD-SU-1-1	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-1-2	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-2	Quarterly	Tritium	HU 7	111370	N/A	N/A	N/A
IAD-SU-2-1	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-2-2	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-3	Quarterly	Tritium	HU 7	269730	198320	296740	17020
IAD-SU-3-1	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-3-2	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-4	Quarterly	Tritium	HU 7	15170	4440	4810	2960
IAD-SU-4-1	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-4-2	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
MW-064-21	Annual	Tritium	HU 1-3	N/A	--	--	--
MW-157-12	Annual	Tritium	HU 6	4810	--	--	--
MW-158-34	Annual	Tritium	HU 1-3	22.2	--	--	--
MW-161-48	Quarterly	Tritium	HU 6	65120	65490	67710	65490
MW-209-13	Annually	Tritium	HU 1-3	1480	--	--	--
MW-210-30	Annually	Tritium	HU 1-3	55.5	--	--	--
MW-215-12	Quarterly	Tritium	HU 1-3	6660	8140	8880	10360
MW-230-30	Quarterly	Tritium	HU 6	710400	666000	710400	677100
MW-234-30	Quarterly	Tritium	HU 6	3274500	2597400	2682500	2678800
MW-237-30	Quarterly	Tritium	HU 6	4403000	4181000	4292000	3959000
MW-239-30	Quarterly	Tritium	HU 6	10064000	9583000	9324000	8954000
MW-240-26	Annual	Tritium	HU 1-3	366.3	--	--	--
MW-242-25	Quarterly	Tritium	HU 1-3	84175	107670	121730	196470
MW-243-29	Quarterly	Tritium	HU 1-3	37740	97680	96200	43290
MW-246-30	Quarterly	Tritium	HU 6	1946200	1820400	1887000	1820400
MW-247-35	Annual	Tritium	HU 6	1480	--	--	--
MW-251-5	Quarterly	Tritium	HU 1-3	N/A	N/A	N/A	N/A
MW-257-5	Quarterly	Tritium	HU 1-3	N/A	N/A	N/A	N/A
MW-260-25	Quarterly	Tritium	HU 1-3	1642800	1050800	1232100	980500
MW-261-25	Quarterly	Tritium	HU 1-3	11100	24420	20350	20350
MW-269-20	Quarterly	Tritium	HU 1-3	2960	2960	3700	3330
MW-270-20	Quarterly	Tritium	HU 1-3	13875000	20979000	21941000	21682000
MW-273-20	Quarterly	Tritium	HU 1-3	1602100	15466000	1735300	N/A
MW-301-15	Quarterly	Tritium	HU 1-3	15355	55130	10730	10360
MW-302-40	Annual	Tritium	HU 6	99.9	--	--	--
MW-313-40	Semi-Annual	Tritium	HU 6	60680	--	117290	--
MW-315-15	Quarterly	Tritium	HU 1-3	137640	1291300	1232100	2112700
MW-318-40	Quarterly	Tritium	HU 6	4070	5550	4810	4440
MW-320-20	Quarterly	Tritium	HU 1-3	4810	4810	5180	4810
MW-321-15	Quarterly	Tritium	HU 1-3	47730	112850	117660	188700
RBU2-GT-1 or GT-2	Quarterly	Tritium	HU 1-3	1742700	490250	N/A	7363000
RBU2-GT-3 or GT-4	Quarterly	Tritium	HU 1-3	6327000	1409700	1021200	18611000
RBU3-GT-1 or GT-2	Quarterly	Tritium	HU 1-3	11470	12580	12580	14060
RBU3-GT-3 or GT-4	Quarterly	Tritium	HU 1-3	N/A	N/A	N/A	N/A
RBU4-GT-1 or GT-2	Quarterly	Tritium	HU 1-3	N/A	30340	16280	N/A
RBU4-GT-3 or GT-4	Quarterly	Tritium	HU 1-3	N/A	24790	N/A	N/A
U1-RBFD-1	Quarterly	Tritium	HU 1-3	26529000	20720000	13653000	12691000
U1-RBFD-2	Quarterly	Tritium	HU 1-3	24235000	26196000	12173000	14430000
U1-RBFD-3	Quarterly	Tritium	HU 1-3	2867500	2164500	1443000	2512300
U1-RBFD-4	Quarterly	Tritium	HU 1-3	N/A	N/A	N/A	N/A
VB Ramp Sump	Quarterly	Tritium	HU 1-3	1098900	706700	1021200	1250600

Note:
"--" - Sample not required
N/A - Sample was not collected

Table A-2: Units 5 to 8 and Units 5 to 8 Turbine Auxillary Bays

Monitoring Location	Frequency	Analysis Parameters	HU	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
IAD-SU-5	Quarterly	Tritium	HU 7	8510	4440	4070	N/A
IAD-SU-5-1	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-5-2	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-6	Quarterly	Tritium	HU 7	2220	2590	7030	196.1
IAD-SU-6-1	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-6-2	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-7	Quarterly	Tritium	HU 7	22570	15170	16650	10730
IAD-SU-7-1	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-7-2	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-8	Quarterly	Tritium	HU 7	33670	60310	24050	N/A
IAD-SU-8-1	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
IAD-SU-8-2	Quarterly	Tritium	HU 7	N/A	N/A	N/A	N/A
MW-102-15	Annual	Tritium	HU 1-3	6290	--	--	--
MW-170-25	Annual	Tritium	HU 1-3	1850	--	--	--
MW-180-40	Annual	Tritium	HU 6	25.9	--	--	--
MW-181-57	Annual	Tritium	HU 7	333	--	--	--
MW-186-12	Annual	Tritium	HU 1-3	1480	--	--	--
MW-264-10	Annual	Tritium	HU 1-3	81030	--	--	--
MW-265-12	Annual	Tritium	HU 1-3	4440	--	--	--
MW-266-19	Quarterly	Tritium	HU 1-3	32930	35150	19610	55500
MW-267-17	Quarterly	Tritium	HU 1-3	7770	30340	65860	113590
MW-325-15	Annual	Tritium	HU 1-3	5920	--	--	--
RBU5-GT-1	Quarterly	Tritium	HU 1-3	219040	N/A	403300	N/A
RBU5-GT-2	Quarterly	Tritium	HU 1-3	1246900	1291300	1191400	1069300
RBU5-GT-3	Quarterly	Tritium	HU 1-3	N/A	928700	N/A	592000
RBU5-GT-4	Quarterly	Tritium	HU 1-3	1217300	721500	514300	N/A
RBU6-GT-1	Quarterly	Tritium	HU 1-3	N/A	N/A	N/A	N/A
RBU6-GT-2	Quarterly	Tritium	HU 1-3	6068000	6401000	5180000	6031000
RBU6-GT-3	Quarterly	Tritium	HU 1-3	3374400	2575200	2186700	7918000
RBU6-GT-4	Quarterly	Tritium	HU 1-3	3696300	3211600	285640	2116400
RBU7-GT-1 or GT-2	Quarterly	Tritium	HU 1-3	592000	291190	577200	136900
RBU7-GT-3 or GT-4	Quarterly	Tritium	HU 1-3	273430	150220	126910	124690
RBU8-GT-1 or GT-2	Quarterly	Tritium	HU 1-3	291560	32560	30710	23680
RBU8-GT-3 or GT-4	Quarterly	Tritium	HU 1-3	183890	35520	173160	71410
U5 MK 26	Quarterly	Tritium	HU 1-3	1709400	361120	758500	421800
U6 MK 30	Quarterly	Tritium	HU 1-3	4921000	2083100	2701000	309320
U7 MK 36	Quarterly	Tritium	HU 1-3	320420	436600	109520	25160
U8 MK 42	Quarterly	Tritium	HU 1-3	321900	338920	358530	518000

Note:
"--" - Sample not required
N/A - Sample was not collected

Table A-3: Units 1 to 8 Irradiated Fuel Bays

Monitoring Location	Frequency	Analysis Parameters	HU	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
Unit 1-4 IFB							
MW-056-18	Semi-Annual	Tritium	HU 1-3	N/A	--	6290	--
MW-057-30	Quarterly	Tritium	HU 1-3	N/A	N/A	N/A	N/A
MW-062-42	Quarterly	Tritium	HU 7	N/A	--	--	--
MW-244-18	Annual	Tritium	HU 1-3	669700	--	--	--
IFBA-GT-1A	Quarterly	Tritium	HU 6	4292000	5069000	4884000	4033000
IFBA-GT-2A	Quarterly	Tritium	HU 6	8288000	8066000	8288000	7252000
IFBA-GT-4A	Quarterly	Tritium	HU 6	1576200	21830	21830	N/A
IFBA-GT-5A	Quarterly	Tritium	HU 6	327820	399600	354460	296000
Unit 5-8 IFB							
MW-171-15	Quarterly	Tritium	HU 1-3	27010	39220	27750	12210
MW-172-25	Semi-Annual	Tritium	HU 1-3	6660	--	24050	--
IFBB-GT-1B	Quarterly	Tritium	HU 6	932400	2408700	3022900	1790800
IFBB-GT-2B	Quarterly	Tritium	HU 6	6031000	7955000	5032000	7141000
IFBB-GT-3B	Quarterly	Tritium	HU 6	6623000	3848000	2649200	2745400
IFBB-GT-4B	Quarterly	Tritium	HU 6	59940	60310	68080	59940
IFBB-GT-5B	Quarterly	Tritium	HU 6	159100	170570	169830	183150
IFBB-GT-6B	Quarterly	Tritium	HU 6	99530	102120	115810	89910

Note:
"--" - Sample not required
N/A - Sample was not collected

Table A-4: Upgrading Plant Pickering

Monitoring Well	Frequency	Analysis Parameters	HU	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
MW-066-20	Annual	Tritium	HU 5/HU 6	<18.5	--	--	--
MW-075-10	Annual	Tritium	HU 1-3	59940	--	--	--
MW-076-20	Annual	Tritium	HU 6	62530	--	--	--
MW-089-10	Annual	Tritium	HU 1-3	40700	--	--	--
MW-090-20	Quarterly	Tritium	HU 6	190365	178710	168165	188330
MW-091-35	Annual	Tritium	HU6/HU 7	20350	--	--	--
MW-093-20	Annual	Tritium	HU 5	884.3	--	--	--
MW-096-20	Annual	Tritium	HU 6	18130	--	--	--

Note:
"--" - Sample not required

Table A-5: East and West Landfill

Location	Quarter	HU	Dissolved Iron
MW-024-20	Q3	HU 6	1000
MW-205-35	Q3	HU 6	1900

Table A-6a: Units 1 to 4 SG, Units 5 to 8 SG, EPG and EPG3

Year	Quarter	Standby Generator A									SG A Overflow Area						Standby Generator B		
		MW-136-19	MW-137-15	MW-138-15	MW-146-15	MW-286-15	MW-287-15	MW-289-28	MW-340-28	MW-344-17	MW-117-14	MW-118-15	MW-128-15	MW-282-15	MW-283-15	MW-348-12	MW-142-24	MW-291-15	MW-292-15
2011	Q1	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	0.170	0.070	ND	ND	-	ND	ND	ND
	Q2	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	0.180	0.080	ND	ND	-	ND	ND	ND
	Q3	0.017	ND	0.051	ND	ND	-	ND	ND	ND	0.001	ND	0.215	ND	0.060	-	ND	ND	ND
	Q4	ND	0.082	0.002	ND	0.120	-	ND	0.028	0.019	ND	0.040	ND	ND	0.010	-	0.010	0.053	ND
2012	Q1	0.001	0.003	ND	ND	0.001	-	ND	0.035	ND	ND	0.015	ND	ND	0.080	-	ND	0.030	ND
	Q2	ND	0.180	0.005	ND	0.105	-	0.006	0.010	0.070	ND	0.002	0.059	ND	0.057	-	ND	0.055	ND
	Q3	ND	0.100	0.030	ND	0.002	-	ND	0.021	ND	ND	ND	0.030	ND	0.030	-	ND	0.166	0.011
	Q4	ND	0.005	0.050	ND	0.033	-	ND	0.022	ND	ND	ND	0.080	ND	0.035	-	ND	0.060	0.030
2013	Q1	ND	0.002	0.001	ND	0.037	-	ND	0.002	ND	ND	ND	0.002	ND	ND	-	0.01	0.015	ND
	Q2	ND	0.004	ND	ND	0.068	-	ND	ND	ND	ND	ND	0.075	ND	ND	-	ND	ND	ND
	Q3	ND	ND	ND	ND	0.225	-	ND	ND	ND	ND	ND	0.121	ND	0.075	-	0.05	ND	ND
2014	Q2	ND	0.130	0.007	ND	0.095	-	ND	ND	0.002	ND	ND	0.035	ND	0.13	-	ND	ND	0.01
	Q3	ND	0.100	0.001	0.002	0.1	-	ND	0.001	0.001	ND	ND	0.001	ND	0.100	-	ND	ND	0.001
	Q4	ND	0.145	0.020	ND	0.103	-	ND	ND	0.008	ND	ND	0.025	ND	0.240	-	ND	ND	0.007
2015	Q2	ND	0.135	ND	ND	0.023	-	0.002	ND	0.012	ND	ND	0.05	ND	ND	-	ND	ND	0.002
	Q3	ND	ND	ND	ND	ND	-	ND	ND	ND	ND	0.005	0.253	ND	ND	-	ND	ND	ND
	Q4	ND	0.2	ND	ND	0.137	-	ND	ND	0.047	ND	ND	0.218	ND	0.115	-	ND	ND	ND
2016	Q2	ND	0.193	ND	ND	0.194	-	ND	ND	ND	ND	0.003	ND	ND	0.12	-	ND	ND	ND
2018	Q2	ND	0.249	0.053	ND	0.372	-	ND	0.492	0.009	ND	ND	0.023	ND	0.013	-	0.016	ND	ND
	Q3	ND	0.311	ND	ND	ND	-	ND	0.404	ND	ND	0.001	ND	ND	ND	-	ND	ND	ND
	Q4	ND	0.001	0.807	ND	ND	-	ND	0.19	ND	ND	ND	ND	ND	ND	-	ND	ND	ND
2020	Q3	ND	ND	0.078	ND	ND	-	ND	ND	ND	ND	ND	0.298	0.222	ND	-	0.004	ND	ND
	Q4	ND	0.195	0.38	ND	ND	-	ND	0.060	ND	ND	0.001	0.032	ND	0.071	-	ND	ND	ND
2021	Q1	-	0.256	0.086	-	0.208	0.084	-	0.114	0.08	-	-	-	-	-	-	-	-	-
	Q2	-	0.168	0.268	-	0.082	ND	-	0.012	0.058	-	-	-	-	-	-	-	-	-
	Q3	-	0.028	0.001	-	0.084	0.001	-	0.102	0.005	-	-	-	-	-	-	-	-	-
	Q4	-	0.104	0.017	-	0.180	ND	-	0.002	0.002	-	-	-	-	-	-	-	-	-
2022	Q1	-	0.15	0.003	-	0.224	0.001	-	0.008	0.003	-	0.001	0.001	-	0.067	-	0.001	-	-
	Q1 Supplementary	-	0.12	-	-	0.11	-	-	-	-	-	-	-	-	-	-	-	-	-
	Q2	-	0.068	0.005	-	0.117	0.001	-	0.084	0.059	-	0.005	0.181	-	0.073	-	0.001	-	-
	Q3	0.069	0.121	0.042	ND	0.125	ND	0.006	0.074	0.086	ND	-	-	ND	-	0.001	-	0.011	0.01
	Q4	-	0.132	0.322	-	0.088	0.001	-	0.073	0.049	-	-	-	-	-	-	-	-	-

Notes:
"--": product thickness was not measured
"ND" : No detectable product

Table A-6b: Units 1 to 4 Standby Generators Analytical Results

Location	Quarter	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Xylene Total (µg/L)	PHC F1-BTEX (µg/L)	PHC F2 (µg/L)	PHC F3 (µg/L)	PHC F4 (µg/L)	Dissolved Iron (µg/L)
Standby Generator A										
MW-108-15	Q3	-	-	-	-	-	<100	<200	-	-
MW-109-15	Q3	-	-	-	-	-	<100	<200	-	-
MW-146-15	Q3	-	-	-	-	-	670	410	-	-
MW-149-15	Q3	-	-	-	-	-	<100	<200	-	-
MW-150-15	Q3	-	-	-	-	-	<100	<200	-	-
MW-287-15	Q3	0.24	<0.2	<0.2	<0.4	<25	2000	950	<200	1000
Standby Generator A Overflow Area										
MW-117-14	Q3	-	-	-	-	-	<100	<200	-	-
MW-282-15	Q3	-	-	-	-	-	240	<200	-	-
MW-226-22	Q3	-	-	-	-	-	-	-	-	18,000
Standby Generator B										
MW-105-15	Q3	-	-	-	-	-	<100	<200	-	-
MW-133-29	Q3	-	-	-	-	-	<100	<200	-	-
MW-151-20	Q3	-	-	-	-	-	<100	<200	-	-
Emergency Power Generator										
MW-121-15	Q3	<0.2	<0.2	<0.2	<0.4	<25	<100	<200	<200	-
MW-124-15	Q3	<0.2	<0.2	<0.2	<0.4	<25	<100	<200	<200	-
MW-125-15	Q3	<0.2	<0.2	<0.2	<0.4	<25	<100	<200	<200	-
MW-322-15	Q3	<0.2	<0.2	<0.2	<0.4	<25	<100	<200	<200	-
East and West Landfills										
MW-024-20	Q3	-	-	-	-	-	-	-	-	1000
MW-205-35	Q3	-	-	-	-	-	-	-	-	1900
Fukushima Diesel Generators										
MW192-18	Q3	<0.2	<0.2	<0.2	<0.4	<25	<100	<200	<200	-
MW196-20	Q3	<0.2	<0.2	<0.2	<0.4	<25	<100	<200	<200	-
MW197-15	Q3	<0.2	<0.2	<0.2	<0.4	<25	<100	<200	<200	-
MW-201-39	Q3	-	-	-	-	-	-	-	-	670

Note:
"--" - Sample not required

Table A-7: Fukushima Diesel Generators

Location	Quarter	Benzene	Toluene	Ethylbenzene	Xylene Total	PHC F1-BTEX	PHC F2	PHC F3	PHC F4	Dissolved Iron
MW192-18	Q3	<0.2	<0.2	<0.2	<0.4	<25	<100	<200	<200	-
MW196-20	Q3	<0.2	<0.2	<0.2	<0.4	<25	<100	<200	<200	-
MW197-15	Q3	<0.2	<0.2	<0.2	<0.4	<25	<100	<200	<200	-
MW-201-39	Q3	-	-	-	-	-	-	-	-	670
MW-326-10	Q3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-

Notes:
"--" - Sample not required
N/A - Sample was not collected

Table A-8: Site Perimeter Wells

Monitoring Well	Frequency	Analysis Parameters	HU	Q1 (Bq/L)	Q2 (Bq/L)	Q3 (Bq/L)	Q4 (Bq/L)
Boundary Wells							
MW-156-20	Annual	Tritium	HU 4-6	--	N/A	--	--
MW-176-23	Annual	Tritium	HU 5	--	< 18.5	--	--
MW-177-35	Annual	Tritium	HU 6	--	< 18.5	--	--
MW-185-39	Annual	Tritium	HU 7	--	462.5	--	--
MW-192-18	Annual	Tritium	HU 5	--	344.1	--	--
MW-193-37	Annual	Tritium	HU 6	--	266.4	--	--
MW-194-57	Annual	Tritium	HU 7	--	< 18.5	--	--
MW-195-73	Annual	Tritium	HU 8	--	< 18.5	--	--
MW-197-15	Annual	Tritium	HU 5 / HU 6	--	895.4	--	--
MW-198-20	Annual	Tritium	HU 5 / HU 6	--	144.3	--	--
MW-199-38	Annual	Tritium	HU 6	--	< 18.5	--	--
MW-200-22	Annual	Tritium	HU 6	--	310.8	--	--
MW-201-39	Annual	Tritium	HU 7	--	< 18.5	--	--
MW-204-24	Annual	Tritium	HU 6	--	166.5	--	--
MW-205-35	Annual	Tritium	HU 6	--	103.6	--	--
MW-206-65	Annual	Tritium	HU 7	--	< 18.5	--	--
MW-207-87	Annual	Tritium	HU 8	--	< 18.5	--	--
MW-216-15	Annual	Tritium	HU 5 / HU 6	--	229.4	--	--
MW-217-32	Annual	Tritium	HU 7	--	< 18.5	--	--
MW-224-42	Annual	Tritium	HU 7	--	547.6	--	--
MW-227-40	Annual	Tritium	HU 6	--	< 18.5	--	--
MW-228-57	Annual	Tritium	HU 7	--	< 18.5	--	--
MW-229-70	Annual	Tritium	HU 8	--	N/A	--	--
Shoreline Wells							
MW-164-13	Annual	Tritium	HU 1-3	--	3363.3	--	--
MW-165-24	Annual	Tritium	HU 6	--	1069.3	--	--
MW-225-12	Annual	Tritium	HU 1-3	--	1546.6	--	--
MW-226-22	Quarterly	Tritium	HU 6	3145	4070	4810	4070
MW-183-10	Annual	Tritium	HU 1-3	--	1176.6	--	--
MW-184-27	Annual	Tritium	HU 5 / HU 6	--	33.3	--	--
MW-222-10	Annual	Tritium	HU 1-3	--	675.25	--	--
MW-223-32	Annual	Tritium	HU 6 / HU 7	--	699.3	--	--

Notes:
"--" - Sample not required
N/A - Sample was not collected

Table A-9a: Tritium Quality Control Results, Duplicate Samples and Relative Percent Differences (RPD)

Location	Sample Date	Units	Sample Values		RPD (%)
			Duplicate	Primary	
IAD-SU-1	21-Apr-2022	Bq/L	27380	26640	2.7
IFBB-GT-1B	04-Feb-2022	Bq/L	939800	932400	0.8
	17-May-2022	Bq/L	2419800	2408700	0.5
	06-Jul-2022	Bq/L	3030300	3022900	0.2
	26-Oct-2022	Bq/L	1813000	1790800	1.2
MW-090-20	09-Mar-2022	Bq/L	190550	190180	0.2
	31-May-2022	Bq/L	178710	178710	0.0
	21-Jul-2022	Bq/L	167980	168350	0.2
	03-Oct-2022	Bq/L	187960	188700	0.4
MW-161-48	16-Mar-2022	Bq/L	64010	66230	3.4
	02-Jun-2022	Bq/L	64750.00	65490.000	1.1
	27-Jul-2022	Bq/L	68820	67710	1.6
	05-Oct-2022	Bq/L	61420	65490	6.4
MW-170-25	15-Mar-2022	Bq/L	1850	1850	0.0
MW-222-10	31-May-2022	Bq/L	688.2	662.3	3.8
MW-226-22	16-Mar-2022	Bq/L	2960	3330	11.8
	31-May-2022	Bq/L	3330	3330	0.0
	21-Jul-2022	Bq/L	4440	4810	8.0
	03-Oct-2022	Bq/L	4070	4070	0.0
MW-242-25	02-Mar-2022	Bq/L	83250	85100	2.2
	01-Jun-2022	Bq/L	107670	107670	0.0
	07-Jul-2022	Bq/L	123210	121730	1.2
	12-Oct-2022	Bq/L	207200	196470	5.3
MW-301-15	22-Mar-2022	Bq/L	14800	15910	7.2
	02-Jun-2022	Bq/L	54020	55130	2.0
	27-Jul-2022	Bq/L	11100	10730	3.4
	05-Oct-2022	Bq/L	10730	10360	3.5
U7 MK 36	28-Jan-2022	Bq/L	316350	320420	1.3
	20-Apr-2022	Bq/L	418100	436600	4.3
	05-Jul-2022	Bq/L	108040	109520	1.4
	27-Oct-2022	Bq/L	27010	25160	7.1
VB Ramp Sump	15-Mar-2022	Bq/L	1113700	1098900	1.3
	02-Jun-2022	Bq/L	717800	706700	1.6
	27-Jul-2022	Bq/L	1021200	1021200	0.0
	05-Oct-2022	Bq/L	1243200	1250600	0.6

Table A-9b: PHC, BTEX and Iron Quality Control Results, Duplicate Samples and Relative Percent Differences (RPD)

Sample Type	Sample ID	Sample Date	Benzene		Toluene		Ethylbenzer		Xylene Tota		F1 -BTEX		F2 (C10-C16		F3 (C16-C34		F4 (C34-C50		Iron (Filtere	
			µg/L	RPD(%)	µg/L	RPD(%)	µg/L	RPD(%)	µg/L	RPD(%)	µg/L	RPD(%)	µg/L	RPD(%)	µg/L	RPD(%)	µg/L	RPD(%)	µg/L	RPD(%)
Primary	MW-108-15	02-Sep-22	-	-	-	-	-	-	-	-	-	-	<100	N/A	<200	N/A	-	-	-	-
Duplicate	Z004 (MW-108-15)	02-Sep-22	-		-		-		-		-		<100		<200		-		-	
Primary	MW-109-15	01-Sep-22	-	-	-	-	-	-	-	-	-	-	<100	N/A	<200	N/A	-	-	-	-
Duplicate	MW-109-15_LabDup	01-Sep-22	-		-		-		-		-		<100		<200		-		-	
Primary	MW-287-15	01-Sep-22	0.24	11.8	<0.2	N/A	<0.2	N/A	<0.4	N/A	<25	N/A	2000	N/A	950	-	<200	N/A	1000	N/A
Duplicate	MW-287-15_LabDup	01-Sep-22	0.27		<0.2		<0.2		<0.4		<25		-		-		-		-	
Primary	MW-226-22	31-Aug-22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18,000	0.0
Duplicate	Z002 (MW-226-22)	31-Aug-22	-		-		-		-		-		-		-		-		18,000	
Primary	MW-151-20	30-Aug-22	-	-	-	-	-	-	-	-	-	-	<100	N/A	<200	N/A	-	-	-	-
Duplicate	Z001 (MW-151-20)	30-Aug-22	-		-		-		-		-		<100		<200		-		-	
Primary	MW-121-15	31-Aug-22	<0.2	N/A	<0.2	N/A	<0.2	N/A	<0.4	N/A	<25	N/A	<100	-	<200	-	<200	N/A	-	-
Duplicate	MW-121-15_LabDup	31-Aug-22	<0.2		<0.2		<0.2		<0.4		<25		-		-		-		-	
Primary	MW-124-15	31-Aug-22	<0.2	N/A	<0.2	N/A	<0.2	N/A	<0.4	N/A	<25	N/A	<100	N/A	<200	N/A	<200	N/A	-	-
Duplicate	Z003 (MW-124-15)	31-Aug-22	<0.2		<0.2		<0.2		<0.4		<25		<100		<200		<200		-	
Primary	MW-205-35	07-Sep-22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1900	0.0
Duplicate	Z002 (MW-205-35)	07-Sep-22	-		-		-		-		-		-		-		-		1900	
Primary	MW192-18	07-Sep-22	<0.2	N/A	<0.2	N/A	<0.2	N/A	<0.4	N/A	<25	N/A	<100	N/A	<200	N/A	<200	N/A	-	-
Duplicate	Z001 (MW-192-18)	07-Sep-22	<0.2		<0.2		<0.2		<0.4		<25		<100		<200		<200		-	
Primary	MW196-20	07-Sep-22	<0.2	N/A	<0.2	N/A	<0.2	N/A	<0.4	N/A	<25	N/A	<100	N/A	<200	-	<200	N/A	-	-
Duplicate	MW196-20_LabDup	07-Sep-22	<0.2		<0.2		<0.2		<0.4		<25		-		-		-		-	
Primary	MW-201-39	07-Sep-22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	670	1.5
Duplicate	Z003 (MW-201-39)	07-Sep-22	-		-		-		-		-		-		-		-		680	

Notes:

N/A : RPDs could not be calculated as at least one sample value was below detection or the lab duplicate was not analyzed for that parameter.

Table A-9c: Quality Control Results, Trip and Field Blank

Sample Type	Sample Date	Benzene	Toluene	Ethylbenzene	Xylene Total	F1 -BTEX	F2 (C10-C16)	F3 (C16-C34)	F4 (C34-C50)
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
FIELD BLANK	02-Sep-22	<0.2	<0.2	<0.2	<0.4	<25	<100	<200	<200
TRIP BLANK	02-Sep-22	<0.2	<0.2	<0.2	<0.4	<25	<100	<200	<200