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Project ref:
60628556

Date:
December 8, 2022

Re: 2022 Foreshore Passive Treatment System Monitoring and Maintenance Plan – Foreshore Area of Burrard Inlet Located Down Slope from the Eastern Impounding Basin, Area 2, Parkland Burnaby Refinery, Burnaby, B.C.

AECOM has prepared this 2022 Monitoring and Maintenance Plan (MMP) for the Foreshore Passive Treatment System (FPTS) to maintain and assess the performance of the FPTS along the Foreshore area of Burrard Inlet located down slope from the Eastern Impounding Basin, Area 2 of the Parkland Burnaby Refinery (hereafter referred to as “the Foreshore Site”) (**Figure 1**).

The initial FPTS MMP dated December 21, 2017 (AECOM, 2017) was prepared to maintain and assess the performance of the FPTS and was based on the Ministry of Environment and Climate Change Strategy’s (ENV) supported Remedial Action Plan (RAP) prepared in 2016 (AECOM, 2016). The FPTS 2022 MMP is considered as equivalent to a Performance Verification Plan as defined by ENV.

Monitoring and sampling of the Foreshore Site is performed in accordance with the MMP and is completed under the oversight of ENV.

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APPENDICES

1. 2022 MONITORING AND MAINTENANCE PLAN FOR THE FORESHORE PASSIVE TREATMENT SYSTEM

This 2022 Monitoring and Maintenance Plan (FPTS 2022 MMP) has been prepared to maintain and assess the performance of the Foreshore Passive Treatment System (FPTS) along the Foreshore area of Burrard Inlet located down slope from the Eastern Impounding Basin, Area 2 of the Parkland Burnaby Refinery (hereafter referred to as "the Foreshore Site").

2. SUMMARY OF THE FORESHORE PASSIVE TREATMENT SYSTEM

The FPTS was designed and constructed to be the final remedial action to address any free-phase and dissolved phase hydrocarbon and sheens at the Foreshore Site. The FPTS, installed between July and October 2017, consists of a larger Eastern section (60 m) and a smaller Western section (20 m). The multicomponent FPTS is comprised of permeable subsurface treatment cells for the mitigation of light non-aqueous phase liquids (LNAPL) and dissolved phase hydrocarbons impacted porewater. The FPTS also contains an oleophilic biobarrier (OBB) surface layer for the prevention of sheens.

To assess the performance of the FPTS, thirty-three (33) monitoring wells (PW17-1 through PW17-33), divided into four types Up Gradient Wells, Performance Wells, Sentry Wells and Compliance Wells were installed at the Site during construction of the FPTS and will be monitored and sampled under this MMP (refer to **Table 1**). Generally, all wells were screened between 0.45 and 1.2 metres (m) below ground surface (bgs) with a 0.3 m length screened interval and in some instances a 0.36 m length screen (stainless steel prepacked screens), as presented in the FPTS Construction report (AECOM 2017).

3. OBJECTIVES

The FPTS 2022 MMP is considered as equivalent to a Performance Verification Plan as defined by ENV, the objectives of the FPTS 2022 MMP are as follows:

- Assess the presence/absence of NAPL and the concentrations of dissolved phase contaminants of concern (COCs) in porewater at the Site;
- Assess the performance of the remedial treatment cells and OBB; and
- Maintain the integrity of the FPTS by checking and, where needed, replacing the protective rip-rap, cobbles, repairing or replacing monitoring wells, and by managing vegetation as required.

4. SCOPE OF WORK

The scope of work for the FPTS MMP is as follows:

- Ensure all required authorizations are obtained and followed;
- Inspect and gauge monitoring wells on the Foreshore Site and coordinate repairs or replacements for damaged wells;
- Monitor porewater wells and collect porewater samples from monitoring wells associated with the FPTS per the schedule provided below. Porewater samples will be submitted to a Canadian Association for Laboratory Accreditation (CALA) certified laboratory on a standard turn-around-time basis for analysis of the following COCs: benzene, toluene, ethylbenzene, xylenes (BTEX), volatile petroleum hydrocarbons in water (VPHw), light extractable petroleum hydrocarbons in water (LEPHw), benzo(a)pyrene, naphthalene, dissolved copper and dissolved zinc;
- Screen water samples for color, clarity, temperature, pH, dissolved oxygen (DO), salinity, electrical conductivity, oxidation reduction potential (ORP), turbidity, and total dissolved solids (TDS);

- Complete trend analysis of COC concentrations and compare analytical results to their respective Risk-Based Management Target (RBMTs) (refer to **Appendix A**);
- Maintain the integrity of the treatment cells and the OBB surface layer, which will include inspection and maintenance of the rip-rap, cobbles, vegetation and monitoring wells;
- Provide analysis and science-based recommendations that address the well monitoring and sampling frequency after eight years (i.e. 2031);
- Reporting; and,
- Notification to ENV (if required).

5. MONITORING COMPONENTS OF THE FPTS MMP

5.1 Well Network

To assess the performance of the FPTS, thirty-three (33) monitoring wells (PW17-1 through PW17-33) (refer to Table 1) were installed at the Site during construction of the FPTS. Generally, all wells were screened between 0.45 and 1.2 metres (m) below ground surface (bgs) with a 0.3 m length screened interval and in some instances a 0.36 m length screen (stainless steel prepacked screens), as presented in the FPTS Construction report (AECOM 2017).

Table 1. Monitoring Wells Associated with The FTPS

Well Type	Rationale	Well Name
Up Gradient Wells (8)	Monitoring wells installed up gradient of the treatment cells. These wells will be used to monitor porewater concentrations entering the Site.	PW17-1, PW17-4, PW17-9, PW17-13, PW17-16, PW17-21, PW17-26, and PW17-31
Performance Wells (8)	Monitoring wells installed within the treatment cells. These wells will be used to evaluate the ability of the treatment cells to reduce petroleum hydrocarbon concentrations through adsorption and degradation.	PW17-5, PW17-6, PW17-17, PW17-18, PW17-22, PW17-23, PW17-27 and PW17-28
Sentry Wells (8)	Monitoring wells located down slope of the treatment cells, but still within the FPTS. These wells will be used to evaluate the performance of the treatment cells, but also provide an early warning if elevated concentrations of dissolved COCs have migrated past the treatment cells.	PW17-2, PW17-7, PW17-10, PW17-14, PW17-19, PW17-24, PW17-29, and PW17-32
Compliance Wells (9)	Monitoring wells installed twelve meters north of the toe of the slope and beyond the limit of the FPTS.	PW17-3, PW17-8, PW17-11, PW17-12, PW17-15, PW17-20, PW17-25, PW17-30, and PW17-33

5.2 Analytical Program

Porewater samples collected from the monitoring wells will be submitted to a Canadian Association for Laboratory Accreditation (CALA) certified laboratory on a standard turn-around-time basis, for the following laboratory analyses:

- BTEX and VPHw
- LEPHw
- Benzo(a)pyrene and naphthalene
- Dissolved copper and dissolved zinc

5.3 Porewater Sampling Schedule

The sampling schedule for years 2023 through 2030 is summarized in **Table 2** below. Porewater samples will be collected on a biennial basis (every two years), in 2023 and 2025. After 2025 the sampling frequency will be reduced to quinquennial (every five years).

Table 2. Monitoring Well Designation and Sampling Schedule

Well / Location	Designation	Frequency	
		2023-2025	2030
Western Seep Area			
PW17-1	Up Gradient Well	Biennial	Quinquennial
PW17-2	Sentry Well	Biennial	Quinquennial
PW17-3	Compliance Well	Biennial	Quinquennial
PW17-4	Up Gradient Well	Biennial	Quinquennial
PW17-5	Performance Well	Biennial	Quinquennial
PW17-6	Performance Well	Biennial	Quinquennial
PW17-7	Sentry Well	Biennial	Quinquennial
PW17-8	Compliance Well	Biennial	Quinquennial
PW17-9	Up Gradient Well	Biennial	Quinquennial
PW17-10	Sentry Well	Biennial	Quinquennial
PW17-11	Compliance Well	Biennial	Quinquennial
In-between Area			
PW17-12	Compliance Well	Biennial	Quinquennial
Eastern Seep Area			
PW17-13	Up Gradient Well	Biennial	Quinquennial
PW17-14	Sentry Well	Biennial	Quinquennial
PW17-15	Compliance Well	Biennial	Quinquennial
PW17-16	Up Gradient Well	Biennial	Quinquennial
PW17-17	Performance Well	Biennial	Quinquennial
PW17-18	Performance Well	Biennial	Quinquennial
PW17-19	Sentry Well	Biennial	Quinquennial
PW17-20	Compliance Well	Biennial	Quinquennial
PW17-21	Up Gradient Well	Biennial	Quinquennial
PW17-22	Performance Well	Biennial	Quinquennial
PW17-23	Performance Well	Biennial	Quinquennial
PW17-24	Sentry Well	Biennial	Quinquennial
PW17-25	Compliance Well	Biennial	Quinquennial
PW17-26	Up Gradient Well	Biennial	Quinquennial
PW17-27	Performance Well	Biennial	Quinquennial
PW17-28	Performance Well	Biennial	Quinquennial
PW17-29	Sentry Well	Biennial	Quinquennial
PW17-30	Compliance Well	Biennial	Quinquennial
PW17-31	Up Gradient Well	Biennial	Quinquennial
PW17-32	Sentry Well	Biennial	Quinquennial
PW17-33	Compliance Well	Biennial	Quinquennial

6. FPTS INSPECTION AND MAINTENANCE

To ensure acceptable performance of the FPTS and maintain integrity of the system, inspections were completed on a quarterly basis in 2022. The frequency of inspections will be reduced to a semi-annual basis between 2023 through 2030, during which time inspections will be completed in March and September.

The inspections and actions will include:

- Monitoring for the presence of LNAPL in 12 select monitoring wells (including eight Up Gradient Wells [PW17-01, PW17-04, PW17-09, PW17-13, PW17-16, PW17-21, PW17-26, and PW17-31] and four Organoclay Performance Wells [PW17-05, PW17-17, PW17-22, and PW17-27]). Wells will be monitored using an oil/water interface probe along with a flame ionization detector (e.g. Eagle RKI) for the collection of combustible headspace vapours,
- Visual inspection of the system to check that two layers of rip-rap are above the treatment cells (i.e., maintaining a thickness of approximately 1.4 m) and two layers of cobbles are above the OBB surface layer (i.e., maintaining a thickness of 0.4 m).
  - If necessary, replacing and adding rip-rap and/or cobbles as required to maintain the required thickness.
- Visual inspection of the FPTS to make sure vegetation is not growing above the treatment cells or the OBB surface layer. The roots of the vegetation may puncture the liner, reducing the system effectiveness.
  - If necessary, removing any vegetation that may affect the treatment cells or the OBB surface layer.
- Inspection of the monitoring well network for damage.
  - If necessary, replacing/repairing any wells that are destroyed or damaged.

7. PROGRAM REVIEW

The RBMTs (refer to **Appendix A**), will be used as screening levels for Compliance and Sentry Wells. Action will be taken if any of the following conditions occur:

- If there is an exceedance above a RBMT in porewater collected from a Compliance or Sentry Well, the well will be re-sampled twice immediately (e.g., twice within the month following the exceedance).
- If there are two consecutive exceedances in a Compliance or Sentry Well above an RBMT, data from adjacent Compliance, Sentry, Performance and Up Gradient Wells will be assessed to determine if this exceedance is indicative of a wider issue and what further action is required, if any. This will occur in consultation with ENV.
- If LNAPL is detected in any of the Compliance or Sentry Wells, porewater samples will be collected from adjacent Compliance, Sentry, Performance and Up Gradient Wells to determine what further action is required. This will occur in consultation with ENV.

The FPTS includes contingency piping into which bioremediation enhancements (e.g., nutrients, sulphate and nitrate) may be applied as appropriate to further aid the breakdown of petroleum hydrocarbons. If bioremediation enhancements are applied, they would be done in consultation with ENV and other stakeholders and be recorded in the Annual FPTS Monitoring Report.

In 2030, the data collected between 2022 and 2030 will be reviewed to assess if the Site monitoring and sampling frequency change to every 5 years is still appropriate. The frequency of future Site monitoring and sampling will be assessed based on the absence, decrease, stabilization, or increase of concentrations of COCs in porewater, primarily in Compliance and Sentry Wells.

8. REPORT

Annual FPTS Monitoring Reports will be prepared and will contain the following key elements:

- Summary
- Statement of Objectives
- Description of Monitoring and/or Sampling
- Presentation of Data
- Presentation of any monitoring and maintenance of the FPTS

- Interpretation and Evaluations
- Recommendations

The Annual FPTS Monitoring Reports will be prepared under the direction of a Contaminated Sites Approved Professional (CSAP) and submitted for ENV's review on an annual basis on or before July 31 of each year.

9. ENV NOTIFICATIONS

In the event exceedances of COCs are observed in Compliance Wells and the following Up Gradient and Sentry Wells (PW17-1, PW17-2, PW17-9, PW17-10, PW17-13, PW17-14, PW17-31 and PW17-32) above the applicable RBMTs, written notification to ENV will be reported within 30 (thirty) days from the date of observation. The wells specified by ENV for notification in the event of an exceedance are highlighted in Figure 1 attached.

In the event exceedances of Upper Cap Concentrations (Protocol 11) are observed in any porewater wells ENV will be notified immediately through verbal and written notifications.

Yours very truly,
AECOM

per:

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STATEMENT OF QUALIFICATIONS AND LIMITATIONS

The attached Report (the "Report") has been prepared by AECOM Canada Ltd. ("AECOM") for the benefit of the Parkland Refining (B.C.) Ltd. (Client) in accordance with the agreement between AECOM and Client, including the scope of work detailed therein (the "Agreement").

The information, data, recommendations and conclusions contained in the Report (collectively, the "Information"):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the "Limitations");
- represents AECOM's professional judgement in light of the Limitations and industry standards for the preparation of similar reports;
- may be based on information provided to AECOM which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the Report and the Agreement; and
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time.

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This Statement of Qualifications and Limitations is attached to and forms part of the Report and any use of the Report is subject to the terms hereof.

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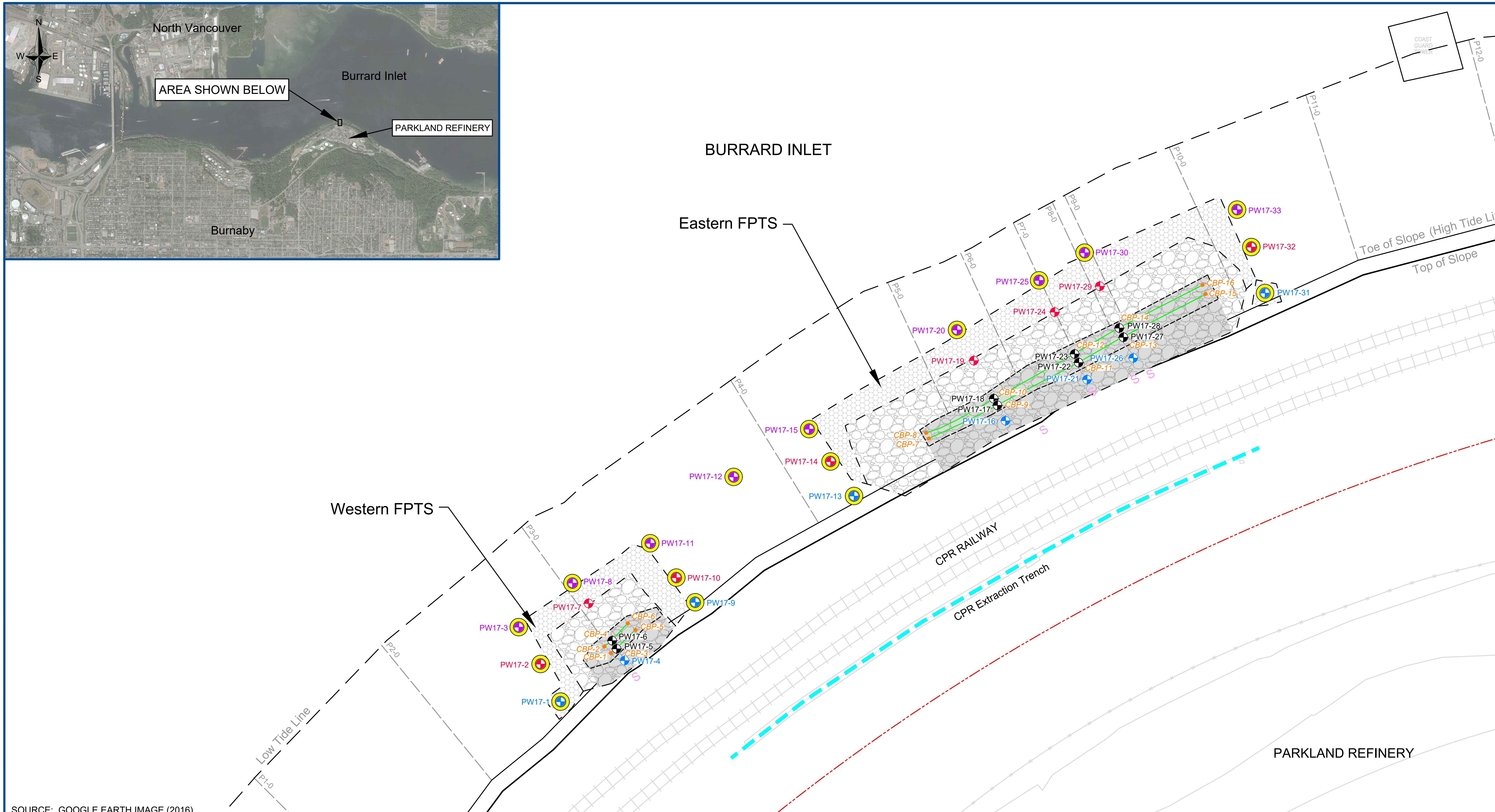
FIGURES



LEGEND:

Property Line		Impermeable Sheet	
Fence Line		Cobble Mat	
Foreshore Sampling Transect		Rip Rap Embankment	
CPR Extraction Trench		French Drain	
		NAPL Seep Observed in 2010	S
		Contingency Biodegradational Piping	

POREWATER SAMPLES

- Compliance Well
- Sentry Well
- Performance Well
- Up Gradient Well
- ENV Requires Notifications²

ABBREVIATIONS:

COC	Contaminants of Concern
CPR	Canadian Pacific Railway
ENV	BC Ministry of Environment & Climate Change Strategy
NAPL	Non-Aqueous Phase Liquid
RBMT	Risk-Based Management Targets

NOTES:

1. The Foreshore Passive Treatment System (FPTS) was installed between July 12 and October 21, 2017.
2. The FPTS was upgraded with additional material on September 27, 2021.
3. BC ENV requires written notification within 30 days of exceedances of COCs above RBMTs in select wells.
4. BC ENV requires immediate verbal and written notification of COCs above Upper Cap Concentrations (Protocol 11) in all wells.

GRID NORTH

metres: 0 10 20

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SITE MAP AND FORESHORE SAMPLING LOCATIONS
2022 Foreshore Passive Treatment System
Monitoring and Maintenance Plan
Foreshore Area of Burrard Inlet Down Slope from the Eastern Impounding Basin, Area 2, Parkland Refinery, Burnaby, B.C.

PARKLAND REFINING (B.C.) LTD.

DATE:	PROJECT NO.:	DRAWN BY:	REVISION NO.:	DRAWING NO.:
January 2022	60628556	SGC	0	FIGURE 1

FILE NAME: C:\Users\georgiana.stegaru\AECOM Directory\Parkland Burnaby Refinery - CAD Support - General\2021 Foreshore Upgrade\Figures\Figures 11.25.2021\F03 - Site Map and Foreshore Sampling Locations (Post-Maintenance) 2021-11-25 - 60653584.dwg

APPENDIX A
REGULATORY CONTEXT

The British Columbia Ministry of Environment and Climate Change Strategy (ENV) approved the Stage 13 Amendment to the Contaminated Sites Regulation (CSR) on February 1, 2021. Pursuant to the CSR, standards for aquatic life water use apply to groundwater located within 500 metres of a surface water body containing aquatic life. Standards for aquatic life water use also apply where there is the potential for contaminated groundwater to flow through preferential corridors that discharge directly to a surface water body containing aquatic life.

In 2014, SLR Consulting (Canada) Ltd (SLR) derived Risk Based Management Targets (RBMTs) for the Site and completed a Human Health and Ecological Risk Assessment (HHERA) for the contaminants associated with the seeps (SLR 2014). The HHERA was submitted to ENV, Port of Vancouver (POV – formerly Port Metro Vancouver) and Fraser Health. The RBMTs are intended to be used as a risk management tool to assess the performance of the FPTS. The RBMTs were developed to be protective of aquatic plants and invertebrates at the community level and fish at the population level. The HHERA did not find any significant risk to human health; therefore, RBMTs were not needed for human receptors.

These RBMTs were established and accepted by the ENV in 2014 (ENV, 2014).

RBMTs for Site porewater were developed for benzene, ethylbenzene, toluene, xylenes, benzo(a)pyrene, naphthalene, VPHw, LEPHw, dissolved copper, and dissolved zinc. The results of SLR's HHERA indicated that all other previously identified COCs were no longer considered to be a concern to humans or marine aquatic life. Concentrations of COCs reported in porewater samples will be screened against the RBMTs, present in **Table A-1** below.

TABLE A-1 FORESHORE RISK BASED MANAGEMENT TARGETS

Parameter	**RBMT micrograms per litre (µg/L)**
LEPHw	300
VPHw	1,500
Benzene	2,100
Toluene	770
Ethylbenzene	320
Xylenes	330
Naphthalene	44
Benzo(a)pyrene	0.28
Dissolved copper	6.2
Dissolved zinc	90

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APPENDIX B

FORESHORE MONITORING WELLS CONSTRUCTION DETAILS

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TABLE B-1 FORESHORE MONITORING WELLS CONSTRUCTION DETAILS

Monitoring Well	Well Type	Total Depth (m bgs)	Top of Well Screen (m bgs)	Bottom of Well Screen (m bgs)	Screen type
PW17-1	Up Gradient	1.20	0.85	1.15	PVC
PW17-2	Sentry	1.20	0.85	1.15	PVC
PW17-3	Compliance	1.20	0.85	1.15	PVC
PW17-4	Up Gradient	0.80	0.45	0.75	PVC
PW17-5	Performance	1.10	0.64	1.00	SS
PW17-6	Performance	1.30	0.84	1.20	SS
PW17-7	Sentry	1.05	0.7	1.00	PVC
PW17-8	Compliance	1.30	0.84	1.20	SS
PW17-9	Up Gradient	1.20	0.85	1.15	PVC
PW17-10	Sentry	1.25	0.85	1.15	PVC
PW17-11	Compliance	1.20	0.74	1.10	SS
PW17-12	Compliance	1.20	0.85	1.15	PVC
PW17-13	Up Gradient	1.20	0.85	1.15	PVC
PW17-14	Sentry	1.20	0.85	1.15	PVC
PW17-15	Compliance	1.30	0.84	1.20	SS
PW17-16	Up Gradient	0.80	0.45	0.75	PVC
PW17-17	Performance	1.10	0.64	1.00	SS
PW17-18	Performance	1.30	0.84	1.20	SS
PW17-19	Sentry	1.20	0.87	1.15	PVC
PW17-20	Compliance	1.10	0.64	1.00	SS
PW17-21	Up Gradient	0.80	0.45	0.75	PVC
PW17-22	Performance	1.10	0.64	1.00	SS
PW17-23	Performance	1.30	0.84	1.20	SS
PW17-24	Sentry	1.20	0.85	1.15	PVC
PW17-25	Compliance	1.25	0.85	1.15	PVC [1]
PW17-26	Up Gradient	0.80	0.45	0.75	PVC
PW17-27	Performance	1.10	0.64	1.00	SS
PW17-28	Performance	1.30	0.84	1.20	SS
PW17-29	Sentry	1.20	0.85	1.15	PVC
PW17-30	Compliance	1.30	0.84	1.20	SS
PW17-31	Up Gradient	1.20	0.85	1.15	PVC
PW17-32	Sentry	1.20	0.85	1.15	PVC
PW17-33	Compliance	1.20	0.85	1.15	PVC

Notes:
m bgs - metres below ground surface
SS - Stainless steel wrapped screen prepacked with 20/40 sand
PVC - Schedule 40 - 10 slot screen
1 - Screen consisted of a 3" - 10 slot screen surrounding a 2" - 10 slot screen prepacked with 20/40 filter sand (manufactured by Bluemax Drilling)

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APPENDIX C

POREWATER SAMPLE COLLECTION METHODOLOGIES

MONITORING, WELL PURGING AND WATER SAMPLING METHODOLOGY

There are 33 monitoring wells at the Site (Figure 1 and Table B-1).

Porewater monitoring will include recording the time of day, depth to water (DTW), depth to product (DTP) and total depth of the well (TD). The DTW and DTP will be measured using an oil/water interface probe which will be decontaminated between monitoring wells to prevent cross contamination. Combustible headspace vapours will be collected from porewater monitoring wells using a flame ionization detector (e.g. Eagle RKI).

Porewater samples will be collected from each monitoring well using dedicated high-density polyethylene and silicone tubing attached to a peristaltic pump, to ensure minimal entrainment of silt in the sample as well as minimal losses of volatile constituents. Prior to sample collection, water will be purged from the well for approximately 5 to 10 seconds until clear. During purging, field parameters including pH, temperature, electrical conductivity, salinity, TDS, ORP, DO, and turbidity will be monitored and documented. During purging and sample collection, care will be taken to remove water from near the top of the water column to minimize any disturbance and subsequent entrainment of solids near the base of the well. Samples will be placed into a cooler containing blue or wet ice and kept under chain-of-custody procedures until delivery to a CALA certified laboratory on a standard turnaround time.

DECONTAMINATION

All non-disposable water monitoring and sampling equipment (i.e., interface probes and YSI multimeters) will be decontaminated between sample locations as follows:

- Washing external and internal surfaces of the sampling equipment with amended water2; scrubbing as necessary to remove dirt, grime, grease, and oil;
- Rinsing with de-ionized water; and
- Double rinsing wit de-ionized water.

[2] Amended water is a 0.5% solution of an environmentally friendly cleaner labelled Liquinox and de-ionized water.

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APPENDIX D

QUALITY ASSURANCE AND QUALITY CONTROL PROCEDURES

DATA QUALITY ASSURANCE/QUALITY CONTROL

In order to assure the integrity and defensibility of the data collected, rigorous QA/QC protocols will be observed. These protocols ensure that all samples are properly collected, identified, stored, shipped, and documented. Standard operating procedures (SOPs) for sample collection and storage, equipment decontamination, and sample chain of custody protocols will be followed. Porewater samples will be collected using sampling techniques discussed above. The use of these methods ensures the quality, soundness, and defensibility of the data obtained. The laboratory analytical data, once generated, will be proofed for inconsistencies and anomalies. Field duplicates, trip blanks, and rinsate blanks will be collected for QA/QC purposes.

Field Duplicate Samples

Field duplicate samples are two identical samples that are submitted to the laboratory with no indication that they are the same. The analysis of field duplicate samples provides an indication of the total precision of the sampling and analysis process. Field duplicate samples will be collected and analyzed at a rate of approximately 10% of samples for a given analytical suite.

Trip Blanks

Trip blanks are samples of clean deionized, distilled (Reagent Grade Type II) water that are prepared in the laboratory, taken to the field, retained on site throughout sample collection, returned to the laboratory, and analyzed with the environmental samples. The QA/QC review will identify trip blanks with detections of target analytes and evaluates the effect of the detections on associated sample results for possible cross-contamination during transport. One trip blank will be included for analysis in every cooler submitted to the laboratory.

Rinsate Blanks

Rinsate blanks are samples of deionized and distilled analyte free (Reagent Grade Type II) water that are prepared in the field by pouring water over or through decontaminated field sampling equipment[3], prior to the collection of the environmental samples. The QA/QC review identifies rinsate blank detections of target analytes and evaluates the effect of the detections on associated sample results for possible cross-contamination during sample collection. Rinsate blank samples will be collected and analyzed at a rate of approximately 5% of samples for petroleum hydrocarbon parameters (BTEX, VPH_w, and $LEPH_w$).

Precision

Precision measures the reproducibility of repetitive measurements and is usually expressed in terms of imprecision. It is strictly defined as the degree of mutual agreement among multiple independent measurements as the result of repeated application of the same process under similar conditions.

Analytical precision is a measurement of the variability associated with the duplicate (*i.e.,* two) or replicate (*i.e.,* more than two) analyses of the same sample in the laboratory, and is determined by the analysis of matrix spike duplicate or laboratory duplicate samples.

Total precision is a measurement of the variability associated with the entire sampling and analysis process. It is determined by the analysis of duplicate or replicate field samples and incorporates any variability introduced by the analytical procedure, sample collection and handling procedures, and matrix factors. Precision data must be interpreted by taking into consideration these possible sources of variability.

Duplicate field samples will be collected, and duplicate spiked or unspiked samples will be analyzed to assess analytical precision. The results will be assessed using the relative percent difference (RPD) between duplicate measurements. The equation used to calculate RPD for duplicate samples is:

[3] Throughout the 2020 and 2021 sampling programs, the decontaminated equipment used for the collection of the rinsate blanks included the oil/water interface meter.

$$RPD = \frac{(A-B)}{((A+B)/2)} \times 100$$

where:

A = analytical result
B = duplicate result.

Note that for RPDs the result can be a positive or a negative value. RPDs are often presented as absolute RPDs, in which case the absolute value of the RPD is reported, always resulting in a positive number. Reporting the absolute RPD results in a reduction in information, since, for instance, if a duplicate sample consistently returned higher results than the original sample, all RPD values would be negative and it may be an indication of a precision problem. In this case, if absolute RPD was reported, no indication would be forthcoming.

Total precision will be determined by collecting field duplicate samples. These samples were collected and analyzed at a rate of approximately 10% of total samples for each analytical suite.

Analytical precision will be determined in the laboratory by running matrix spike/matrix spike duplicate (MS/MSD) pairs, or by running laboratory duplicate analyses. These samples will be analyzed at a rate of approximately 5% for each analytical suite.

Accuracy

Accuracy is a statistical measurement of correctness and includes components of random error (e.g., variability due to imprecision) and systematic error (e.g., bias). Therefore, accuracy reflects the total error associated with a measurement. A measurement is accurate when the value reported does not differ beyond acceptable limits from the true value or known concentration of the spike or standard. Acceptance criteria are indicated in the individual standardized analytical methods.

Analytical accuracy is typically measured by determining the percent recovery of known target analytes that are spiked into a field sample (i.e., a surrogate or matrix spike), or reagent water (i.e., laboratory control sample [LCS] or blank spike) before extraction at known concentrations. Percent recovery is calculated as:

$$\%REC = \frac{A}{B} \times 100$$

where:

A = obtained value
B = true value.

Analytical accuracy was determined in the laboratory by the running of MS samples or laboratory control samples. These samples will be analyzed at a minimum rate of 5% for each analytical suite.

Completeness

Completeness for this investigation was defined as the percentage of valid analytical results. Results made uncertain due to missed hold times, improper calibration, blank contamination, or poor calibration verification results would be deemed invalid. Results that may be flagged due to matrix effects are not considered invalid. Completeness for projects should exceed 90%. Completeness is calculated by:

$$completeness = \frac{A}{B} \times 100$$

where:

A = number of valid analytical results
B = total number of analytical results.