Kearl Directive 085 Measurement System Plan

Prepared by: Imperial Oil Resources Limited
Submitted to: Alberta Energy Regulator

Date: January 2024

Table of Contents

List of Figures

List of Tables

1.0 Introduction

Imperial received Oil Sand Conservation Act (OSCA) Approval No. 10829H, and the accompanying Decision 20180716A, in response to Imperial's Application for Kearl's Tailings Management Plan, on July 16, 2018.

Imperial submitted the first version of the Kearl Directive 085 Measurement System Plan in January 2019 in accordance with Section 5 of Directive 085 (AER 2017) and Measurement System Plan Requirements letter (AER 2018) dated July 16, 2018. This updated version of the Measurement System Plan is being submitted to account for the placement of tailings within In Pit Tailings Area 1 (ITA1) and provide updated quality assurance and quality control (QA/QC) document due to a change in the 3rd party used for laboratory analysis.

1.1 Background

Imperial's Kearl Oil Sands Mine and Processing Plant is located north of Fort McMurray, Alberta. The Application for the approval of the Kearl Tailings Management Plan (TMP) was submitted to the Alberta Energy Regulator (AER) in November 2016 and was approved in July 2018 under the Oil Sands Conservation Act (OSCA) Commercial Scheme Approval No. 10829H. Following an administrative proceeding to update Imperial's legal name in their registry, the AER issued the latest Oil Sand Conservation Act (OSCA) Approval No. 10829I for Kearl on September 6, 2018. In response to a subsequent application (No 1915674), related to Kearl's mine plan, the AER issued OSCA Approval No. 10829J on January 15, 2019. All the clauses in OSCA Scheme Approval No. 10829H that relate to tailings management remained in the latest OSCA Approval No. 10829M. On March 31, 2022, Imperial submitted a Mine Plan Amendment and Tailings Management Plan application (integrated application) to the AER, requesting amendment of the Scheme Approval issued under Oil Sands Conservation Act and other enactments. The integrated application was still being reviewed by the AER at the time of submission of this measurement plan.

Imperial's current tailings deposition areas at Kearl include the West External Tailings Area (WETA), East External Tailings Area (EETA) and In-Pit Tailings Area 1 (ITA1). The WETA also serves as the source of recycled water (RCW) to the plant. The EETA includes the thickened tailings (TT) deposition area where the TT produced from the Kearl Fine Tailings Treatment (KFTT) facility and treated tailings from supplemental fines treatment pilot (ILF, eILF) are deposited on the south side of the EETA. Coarse sand tailings (CST) deposition from Plant 1 (K1) was relocated in September 2023 to ITA1 from the WETA.The EETA continues to receive CST from Plant 2 (K2). The tailings solvent recovery (TSRU) tailings from both K1 and K2 are now deposited to ITA1 (since April 2023), but previously were deposited into the WETA.

Imperial will estimate annually the volume of fluid tailings (FT) that are present in tailings ponds and tailings deposits and the estimated volume of treated tailings that met Ready to Reclaim (RTR) sub-objective 1 as defined by the volume of TT having 65% solids content by weight (w/w) (Imperial Approval No. 10829J Appendix C). TT placed within the EETA that meets both RTR sub-objective 1 and sub-objective 2 (as defined by Approval No. 10829M, as amended) will not be included in the annual inventory of fluid tailings at Kearl. Currently, all ILF and eILF treated tailings are still included in the fluid tailings inventory since the technology at Kearl has not yet been commercialized and no RTR criteria have been applied for or approved by the AER.

This report describes Imperial's approach to meet the measurement plan requirements, as outlined in section 5 of Directive 085, Appendix 6 (Measurement System Plan) of AER's Decision 20180716A, OSCA Approval No. 10829M, and the June 29, 2022 Directive 085 Reporting Requirement Clarification – Water Quality Characterization letter.

1.2 Measurement System Plan Annual Cycle

Imperial conducts annual field investigation and sampling campaigns to assess and measure the performance of the thickened tailings deposit and to estimate the volumes of FT and RTR tailings. This program includes the following activities:

- Development of sampling program

- Field execution
- Data interpretation and modelling
- Quality assurance and quality control (QA/QC)
- Fluid tailings regulatory reporting

To support the Directive 085 annual fluid tailings management reports, required by April 30th in the year following the reporting year, Imperial targets completion of the field execution of the annual sampling program by early Q4 of the reporting year. This is to allow for ease of access to the fluid tailings deposits while also allowing sufficient time for data collection, analysis and model integration. Figure 1-1 demonstrates the approximate timelines associated with the measurement plan activities for a given year.

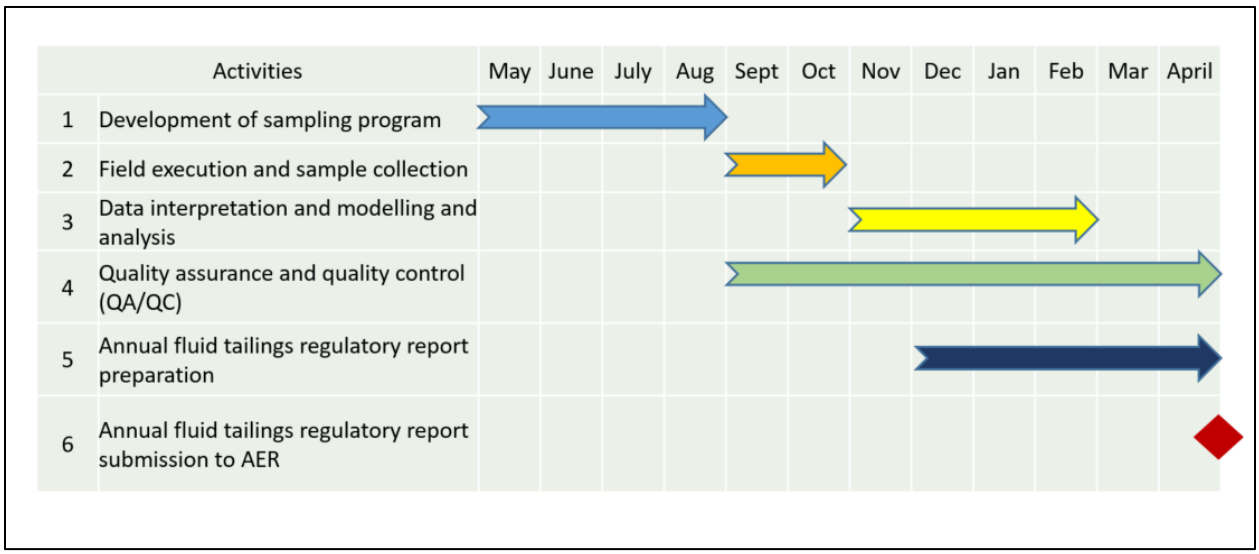


Figure 1-1: The Measurement System Plan Annual Cycle

1.3 Concordance and Reporting Requirements

The purpose of this Measurement System Plan (MSP) is to provide the planned measurement methodologies in accordance with the following requirements:

- Directive 085 (AER 2017)
  - Section 5 (conditions 17 to 20)
- "Measurement System Plan Requirement" letter (AER 2018)
- OSCA Approval No. 10829M
  - Condition 29 and 30
  - Appendix C (RTR criteria)
- "Directive 085 Reporting Requirement Clarification – Water Quality Characterization" letter (AER 2022)

To identify the sections within this MSP that satisfy specific requirements as outlined above, concordance tables are provided in Appendix A, Appendix B, Appendix C and Appendix D

2.0 Determination of Fluid Tailings

The Tailings Management Framework (TMF) defines fluid tailings as any fluid discard from bitumen extraction facilities containing more than 5 mass per cent suspended solids and having less than an undrained shear strength of 5 kilopascals. Canada's Oil Sands Innovation Alliance's (COSIA) Guidelines for Determining Oil Sands Fluid Tailings Volumes (COSIA 2015a), provides a standard set of practices for defining and determining fluid tailings volume. Directive 085 indicates that these guidelines provide a FT volume that the AER considers comparable to the TMF definition.

For Imperial's annual assessment of tailings deposits, fluid tailings are determined using COSIA's set of measurement techniques in accordance with this guidance in Directive 085.

2.1 Fluid and Non-Fluid Tailings

Fluid Tailings (FT) volume estimation in the West External Tailings Area (WETA), East External Tailings Area (EETA), including the Thickened Tailings (TT) deposit area , will be based on the interpreted mudline (top of FT, using sonar surveys) and pond bottom (based on sounding data, using CT09™ to define the bottom of the FT) as outlined in the COSIA Guidelines (COSIA 2015a).

The mudline, and consequently the top of fluid tailings, is monitored more frequently over the course of the year through the use of commercial fish finder tool. A more comprehensive sonar survey with less than 100 m spacing, is completed concurrently with the annual field investigation program to provide comparable data set for estimation of the fluid tailings inventory.

The CT09™ probe (Appendix E.1) is a drop sounding tool consisting of an integrated piezocone penetrometer, a data acquisition system, a weight and a data logger. The test is conducted by allowing the tool to fall on a winch line from the water surface until it stops. During the fall, CPTu parameters (tip stress, pore pressure and probe inclination) are recorded and cable payout is recorded at the surface. Material below the measured pond bottom will be considered as non-fluid tailings and this material volume will not be part of the fluid tailings inventory. CT09™ tests are currently completed on approximately a 100 m -200 m grid pattern. This spacing will be increased or decreased depending on the variability of the pond bottom observed over time. The testing frequency and locations will be finalized prior to the execution of the tailings measurement field program based on site conditions, historical CT09™ data and trends, and safety considerations.

The undrained shear strength of the FT will be evaluated using Cone Penetration Tests (CPTu), Ball Penetration Tests (BPT) and Vane Shear Tests (VST), as appropriate, depending on conditions encountered. Details of these tests are in Appendix E.1. BPTs are full-flow penetrometers that are used to assess the consistency and strength of soft to very soft sediments. During penetration of full-flow penetrometers, the soil is forced to flow around the penetrometers in a viscous, fluid-like manner. The accuracy of the BPT is improved over the CPTu for very soft sediments since a larger volume of material is engaged during penetration.

VSTs will accompany selected BPT and/or CPTu to calibrate the undrained shear strength interpreted from this equipment to vane shear test results. Field vane shear tests will be used to measure the peak and residual undrained shear strength.

Samples of FT will be extracted using a piston type sampler that uses compressed nitrogen gas to collect samples through passive suction. Samples of FT will be collected on a similar pattern as the solids samples and be finalized in the field program development to ensure sufficient representative samples are collected to characterize the deposit. FT samples will continue to be retrieved down to the pond bottom, as identified by CT09™ soundings. Laboratory testing (Appendix E.2) of the FT samples will include Dean Stark, percent solids, particle size distribution (PSD) and Atterberg limits, where appropriate.

The depth, location and frequency of testing and sampling will be based on field observations and technical analysis to enable sufficient characterization of the deposition. Once completed the fluid tailings volume will be calculated by determining the volume of material situated between the mudline and pond bottom for each deposit (WETA and EETA) in accordance with COSIA guidelines (COSIA 2015a).

3.0 Key Measurement Methods and Parameters

3.1 Deposit Measurements

The volume of FT within a tailings deposit is determined (illustrated in Figure 3-1) according to the methodology outlined in the *Guidelines for Determining Oil Sands Fluid Tailings Volumes* (COSIA 2015a) and included as Appendix 4 of Directive 085 (AER 2017).The testing methods are referenced in Table 3-1.

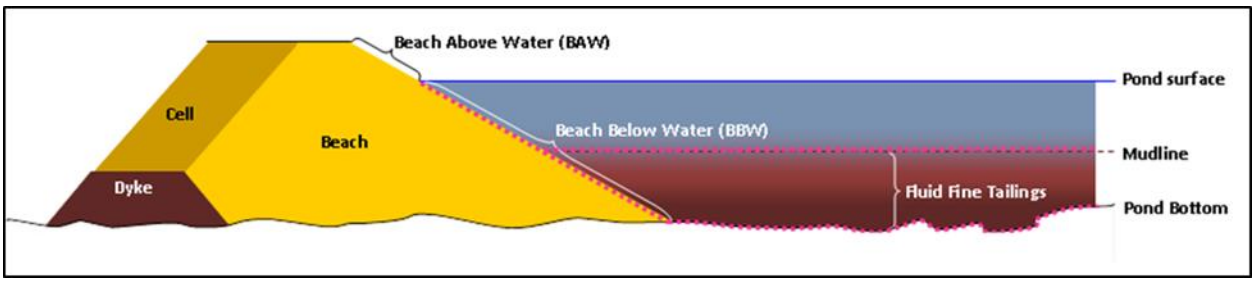


Figure 3-1: Tailings Deposits Volumetric

3.1.1 Field Testing

3.1.1.1 Volumetric Surveys

Figure 3-1 above illustrates the transitional boundaries between Water, FT and Non-fluid tailings as per the COSIA Guidelines. FT is defined as the volume of material between the mudline and the pond bottom. Whereas water cap volume is defined as the fluid between the mudline and the top of water or pond surface. Any material below the pond bottom is considered non-fluid. The methods and procedures used to determine pond bottom, mudline and water surface are accordance to Guideline for Tailings Deposit Sampling and Measuring Tools (COSIA 2015b) and are briefly described in the following sections.

3.1.1.1.1 Measurement of Pond Bottom

With a drop sounding tool, the bottom of the fluid tailings is determined by dropping a weighted probe from a boat and recording the depth to the hard bottom when the probe stops.

Drop sounding measurements are validated with selective CPTu measurements. When dense bitumen mats or debris cause difficulties with drop sounding, the CPTu tool is used in conjunction with drop soundings to interpret the hard bottom interface. Appendix E.1 provide further details on the two methods. Reference details are provided in Table 3-1.

3.1.1.1.2 Measurement of Mudline

The pond mudline (Figure 3-1) is surveyed to locate the fluid fine tailings upper boundary. A bathymetric survey will be completed using a sonar unit mounted on a workboat supplied with a GPS unit to provide positional information. A travel path that provides sufficient coverage will be selected. Measurements will be recorded and used to develop a mudline surface.

3.1.1.1.3 Measurement of Water Cap and Water Volume

Measurement of the water cap for each deposit is calculated using satellite or aerial imagery to determine the pond surface in conjunction with the mudline measurements from sonar to estimate clear water volumes (water volume between mudline and pond surface). Concurrent satellite images, or alternately surveyed data obtained at about the same time as the program execution, provides survey data consistent with the annual sampling program Table 3-1.

Table 3-1: Fluid Tailings Testing Methods

Indicator	Measurement requirement	Methods Employed
Top of Water Surface	Total contained water	Water surface survey, Satellite Image
Mudline (for water capped pond)	Determination of FT volume	Sonar
Pond bottom	Determination of FT volume	CT09™ TM / CPTu

3.1.2 Material Properties

Tailings deposit material properties play a significant role for deposition planning and managing the deposit safely. To determine material properties Imperial conducts several laboratory tests and analysis on samples collected from the field along with relevant in-situ tests on the field for additional verification. The following sections provide brief descriptions of tests Imperial uses to determine material properties at Kearl. A summary of the material property testing methods is provided in Table 3-2. These tests and procedures follows the Guideline for Tailings Deposit Sampling and Measuring Tools COSIA 2015b.

3.1.2.1 Fluid Sampler and Procedures

Fluid sampling tool is used collect water and or fluid tailings samples at different depths in the tailings ponds. Those samples are analyzed in the laboratory to understand the material properties (e.g.; solids content). Reference details are provided in Appendix E.1.

3.1.2.2 Sonic Sampler

Sonic sampling is conducted using a sonic piston sampler and a drill rig that has been fitted with a sonic drill head to collect samples for laboratory testing. The stainless steel sampler is designed to collect a 50 mm diameter sample in one or two meter lengths. The sampler has a free piston that moves up and down the barrel, which is kept in place by a column of water. The sonic drill head uses mechanically induced vibration that is transferred directly to the drill rods and sampler. The vibrations induce a layer of liquefaction surrounding the rods which reduces both rod friction and tip resistance. The sonic sampler procedure is provided in Appendix E.1.

3.1.2.3 Sharky Sampler

The Sharky Sampler™ is designed to sample soils that are sensitive to sampling disturbance as the sample tube has a very low wall thickness to sample area ratio. The sampler comprises a Shelby tube attached to a piston. The Shelby tube is a 30 inch thin-walled hollow aluminum tube with a three inch diameter with an open bottom that is chamfered to form a cutting edge for insertion into the deposit. Collected samples are sent to the laboratory for material property testing. The sonic sampler procedure is provided in Appendix E.1.

3.1.2.4 Gamma and Gamma Ball CPT

The electric piezocone penetrometer (CPTu) is used for geotechnical and geo-environmental soil characterization. The CPTu tool measures tip resistance, dynamic pore pressure, and sleeve friction continuously during penetration. The instrument provides discrete, semi-continuous soil measurement data that can be used to develop design parameters. The Standard Operating Procedure (SOP) for the CPTu tool is found in Appendix E.1.

As the CPTu is advanced into the material being investigated, various measurements are collected such as tip and sleeve resistance, pore water pressure and gamma counts per second. The data is analyzed and compared with a database of known tailings characteristics to develop traces of material properties and classifications, which includes:

- % solids by weight
- fines content

- in-situ strength
- pore pressure characteristics
- soil classification (Tailings Behavior Type)

Naturally occurring radioactive materials (NORMs)occur within tailings deposits. Gamma ray detectors can determine the presence of higher concentrations of NORMs within a deposit. A gamma ray probe is used in conjunction with penetration testing. The SOP for the gamma ray probe is found in Appendix E.1.

3.1.2.5 Vane Shear Testing

The vane shear test is a widely used an in situ method to assess the undrained shear strength of saturated cohesive soils. It is sometimes used to validate the undrained shear strength values of the CPTu instrumentation.

The calibrated instrument is pushed into the deposit and turned at a specified rate. The force required to turn the instrument is recorded as the strength of the deposit; this is then compared to the CPTu results. The SOP for VST Testing is found in Appendix E.1.

3.2 Laboratory Tests

Laboratory tests and analysis are conducted on samples collected from the field to improve both understanding of the material properties and their processability and quality assurance. Many of the tests have since become industry standard and oil sands operations routinely use them to predict the behavior of the material and improve performance of the thickened tailings facility. These tests are integral in collecting data for Imperial's tailings management and Kearl Fine Tailings Treatment operation.

These tests include:

- bitumen, mineral and water (see Section 3.2.1)
- particle size distribution (see Section 3.2.2)
- methylene blue index (see Section 3.2.3)
- water chemistry (see Section 3.2.4)

3.2.1 Bitumen, Mineral and Water

The Dean Stark test is used to determine and characterize the bitumen, mineral and water content of oil sand, petroleum products or other bituminous materials. Dean Stark SOPs are provided in Appendix E.2.

3.2.2 Particle Size Distribution

The wet sieve test is commonly used to determine the PSD of a tailings sample. In the oil sands industry, "fines" is generally defined by the minus 44 micron fraction (COSIA 2016). This fine material can either be sand or clay. In general, clay particles that are not caught in the beach when the tailings are deposited end up in the wet portion of the pond and will form FT. Details in Appendix E.2.

3.2.3 Methylene Blue Index Test

The methylene blue test is a commonly used test to provide reasonable quantitative evaluation of the clay content. Understanding the clay content of the material, is a leading indicator for treatment of the fines for the KFTT facility as higher clay contents will influence operational parameters such as chemical requirements and solids loading rates. Details in Appendix E.2.

Table 3-2: Material Property Testing Methods Summary

Measures	Analysis Supported	Methods Employed
Solids content (%)	Dewatering /Consolidation	Dean Stark, G-CPTu
Fines content (%)	SFR and fines in FT and TT	G-CPTu, laboratory sample PSD
Clay content (%)	Treatment effectiveness	MBI
In-situ strength	TT strength	G-CPTu, vane shear test
NORMs concentration	Potential SOPCs	G-CPTu

3.2.4 Water Chemistry Testing

A water quality monitoring program is in place for the WETA. Parameters analyzed include pH and soluble ions. Detailed chemical analyses for inorganics, metals, volatile organics, and polycyclic aromatic hydrocarbons (PAH) are conducted and reported in accordance with the National Pollutant Release Inventory Program (NPRI Program) and also reported annually as per *Environmental Protection and Enhancement Act* (EPEA) Approval No. 46586-01-00, as amended or renewed, reporting requirement.

Clear water (water volume between mudline and pond surface) quality sampling is completed as part of the WETA sampling program. The key parameters (Table 3-3) which provide an average clear water quality characterization will be included in Directive 085 annual report.

3.2.4.1 Sample Collection Methodology

Tailings samples are collected, preserved, stored, and handled in accordance with procedures outline in the Protocols Manual for Water Quality Sampling in Canada (Canadian Council of Ministers of the Environment {CCME} 2011) and Stadard Methods for the Examination of Water and Wastewater (American Public Health Association 2017). Samples are analyzed by a fully accredited laboratory, Bureau Veritas.

Field variables (temperature, pH, dissolved oxygen, and electrical conductivity) are measured using a YSI Pro Plus multi-probe meter calibrated according to the manufacturer's manual.

Tailings water from the WETA is collected from the boat launch using a long sampling pole and clean glass bottle. Samples are collected approximately 0.3m below the surface and decanted into laboratory supplied containers. Tailings water from the EETA is collected from the barge dock using the same methodology. The samples are collected once per year during the open-water season.

Samples containers are labeled with unique sample identification names and date of collection. The samples are cooled to approximately 4 degrees Celsius. The chilled sample containers are packed in coolers with ice. The coolers have a signed custody seal placed over the lid and are shipped via courier to Bureau Veritas Laboratories for analysis with an accompanying Chain of Custody document.

3.2.4.2 Quality Assurance and Quality Control

Tailings samples are collected by a field crew from an on-site environmental consulting company who employ a quality assurance system designed to meet defined standards of quality for Kearl's surface water sampling across site. The quality assurance system includes procedures related to planning, documentation, training, consistency in collection and handling samples, protocols to avoid cross contamination, analysis, data validation, and reporting.

Quality control is conducted in accordance with Imperial's preferred operating practices on quality review of environmental data (Imperial 2004). The tailings samples are evaluated as a component of the site-wide surface water sampling program which includes the collection of field duplicates, field blanks, trip blanks

and equipment blanks on a pre-determined frequency. Laboratory quality control includes method blanks, matrix spikes, reference samples, and laboratory duplicates. Quality control sample results are used to evaluate the reliability of reported results and identify potential issues with sample integrity.

Table 3-3: Water quality testing key parameters

Parameter Group
Major ions
Conventional parameters
Total and dissolved metals
Nutrients
F1-F4 hydrocarbons
Benzene, toluene, ethylbenzene, and xylene (BTEX)
Volatile Organic Compounds
Phenols
Total Naphthenic acids
PAHs and alkylated PAHs
Additional Parameters - Acrylic acid, Acrylamide, Polyacrylamide.

3.3 Tailings Measurement in Process Streams

Imperial has installed flow meters, densitometers and sampling points to monitor tailings process performance. At the thickener plant, the flow and density of the thickened tailings underflow is measured as well as the clarity of the overflow. Further downstream on the thickened tailings lines, after the second chemical injection, samples are collected to measure solids content, capillary suction time and dewatering. A simplified process diagram indicating the location of the instrumentation is shown in Figure 3-2.

For sample collection, auto-samplers and manual samplers have been selected to provide representative samples by automatically retrieving material from the process line at a predefined time interval. The collected samples are then analyzed as described in Section 5.0. This information is only used to provide leading indicators of deposit performance and influences operational parameters of the fines treatment facility.

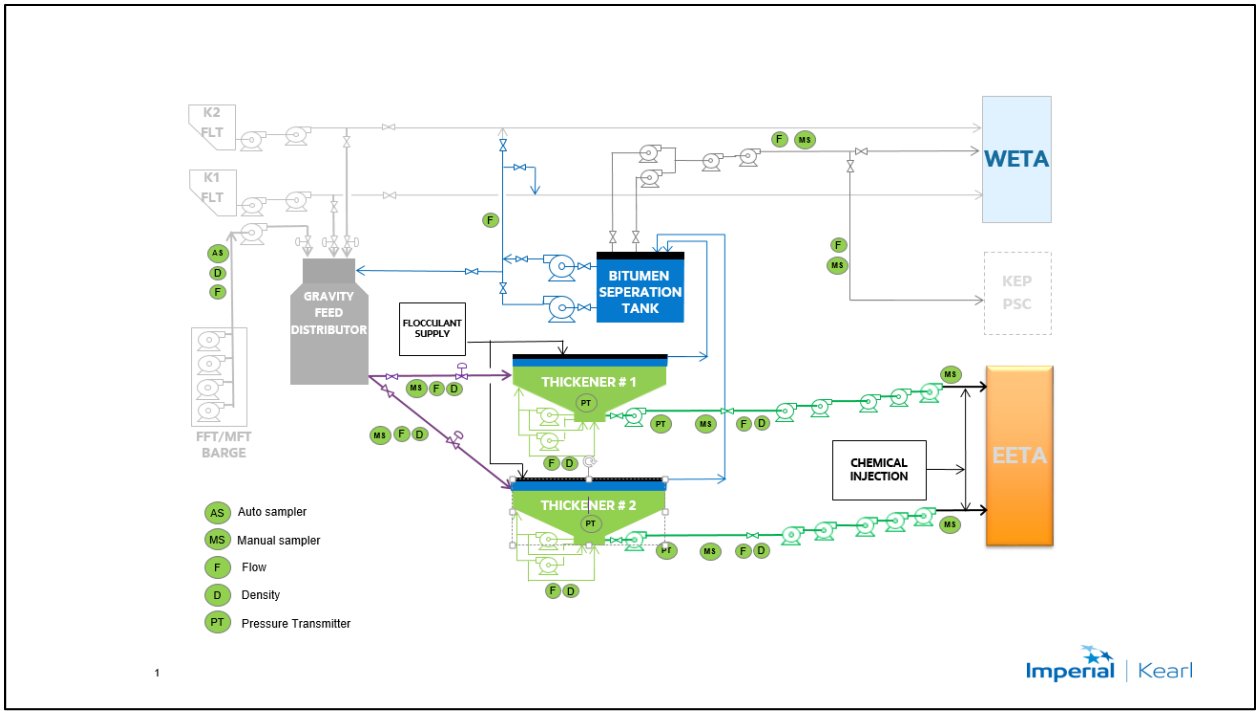


Figure 3-2: Location of Instrumentation

3.4 Site Wide Water Balance

Imperial and other oil sands mining operators have worked collaboratively to develop a common template to be used by each operation to report their water balance. The intent of the template was to provide consistent information. Imperial will provide the annual values for the points A through M on Figure 3-3 for its reporting. These values, which will be provided in D085 Annual Report in the form of Table 3-4, are based on annual averages of measured volumes, which include flow meters at specific locations and annual calculations (e.g. for precipitation and connate water).

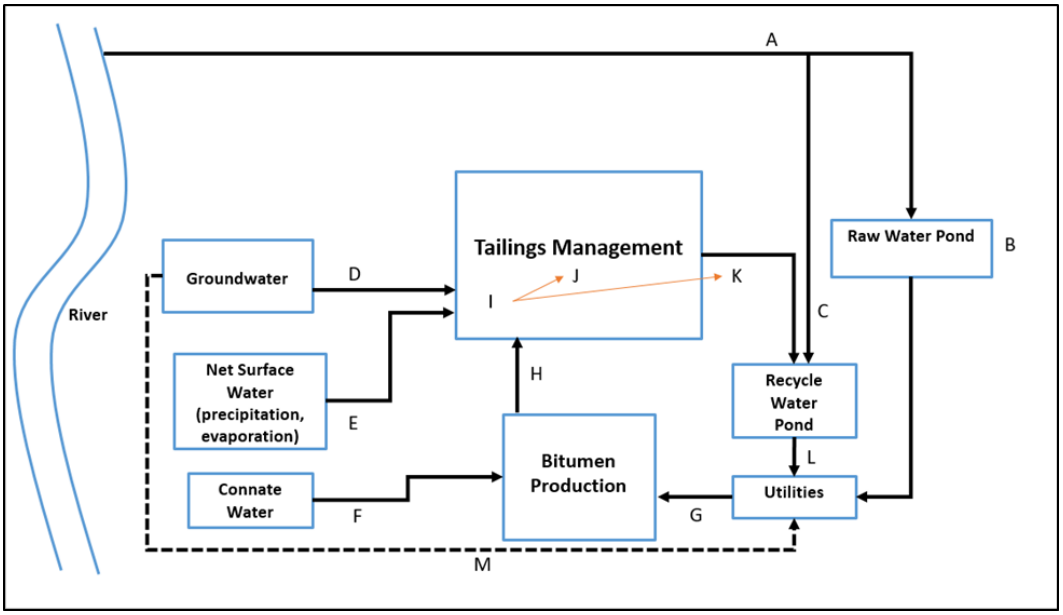


Figure 3-3: Site Wide Water Balance Schematic

Table 3-4: Site Wide Water Balance Reporting Table

	Activity	Annual Volume (Mm^3)
A)	River water taken from the Athabasca River to raw and recycle water pond	
B)	River Water to Raw Water Ponds and to Utilities	
C)	River Water to Recycle Water Pond	
D)	Overburden, Basal, and Devonian groundwater to Tailings Management	
E)	Surface water runoff (net precipitation including rain, snow, and evaporation) to tailings management	
F)	Connate water from within ore body to bitumen production	
G)	Utilities to bitumen production	
H)	Bitumen Production to Tailings Management	
I)	Water into Tailings Management (D + E + H)	
J)	Storage in Tailings Management (I - K)	
K)	Tailings Management to Recycle Water Pond	
L)	Recycle Water to Bitumen Production via Utilities (heat added)	
M)	Basal Well Groundwater to Bitumen Production via Utilities (heat added)	

Water Balance Notes:

- The Precipitation and site surface water runoff to Tailings Management are all directed to perimeter ponds and then pumped to the WETA.
- Groundwater from the pumping wells is currently directed to the perimeter ponds, or through Bitumen Production (Basal water), and pumped to the WETA, however, in the future may be discharged to the environment per Imperial's approved Kearl Groundwater Release Monitoring and Response Plan (depending on the quality).
- Values for domestic water use (such as potable water use and sanitary water use) are considered minimal for the site and included with the volumes from Utilities to Bitumen Production.
- The majority of the water on Kearl is stored within the WETA and contributes to Tailings Management which includes: saturated tailings, water within the beach deposits and the dyke, slurry steam losses, and seepage to site groundwater.
- Values submitted for this balance do not include small water volumes (such as process steam losses) in the overall water balance.

4.0 Treatment Effectiveness

Fines treatment effectiveness considers both thickener and inline flocculation performance.

4.1 Thickener Performance

The purpose of a thickener is to recover water and produce concentrated slurry. Thus, the overflow clarity and underflow density/solids content are key process indicators to measure the success of thickening processes. Additionally, other process variables that are monitored include feed solids rate, bed level, rake torque reading, flocculant dosage and concentration. All process parameter measurements are used for operational performance monitoring of the thickeners.

4.2 Inline Flocculation Performance

The floc size and structure of reflocculated thickened tailings are the primary key process indicators for inline flocculation performance. Capillary suction time tests are used to provide estimated measurement of

the dewaterability of these flocculated material. As such the following key process variables are monitored to ensure flocculation performance:

- Capillary suction time
- Solids content gain in 24 hours and 7 days

Additional parameters, such as the thickened tailings density, flow and floc dosage are also monitored to evaluate treated tailings performance.

5.0 Thickened Tailings Deposit Surveillance

Imperial conducts annual sampling programs of the TT deposit to monitor deposit performance. The annual investigation program includes in-situ measurement of deposit properties and sample collection for laboratory testing. Detailed spacing and frequency for sampling locations and frequency are given in Table 5-1.The in-situ and laboratory measurements are in accordance with the requirements of Section 5 of Directive 085 (AER 2017). In-situ measurements include sonar bathymetric surveys, CT09 pond bottom surveys, Ball Gamma Cone Penetration Test with Pore Pressure Measrement (BGCPTu) and vane shear tests. Laboratory tests of collected samples include dean stark, particle size distribution, MBI, specific gravity and some limited consolidation tests. Both in-situ and laboratory test data will be used to estimate RTR satisfied material and FT in the treated tailings deposit and form the basis of Imperial's TT deposit modelling.

Table 5-1: Measurement of Fluid Tailings Properties for Determination of RTR Status

Parameter	Tool	Density	Frequency
Solids content / fines content / clay content	Sonic / Piston sampling	• 100 m-200 m grid • Vertical intervals 1 test per 1-5 m	Annually
In-situ Strength	G-CPTu	• 100 m-200 m grid	Annually
In-situ Strength	Vane shear	• As needed for QA/QC G-CPTu results	Annually

5.1 Deposit Assessment and Modelling

Once the in-situ and laboratory data is received, data is statistically analyzed to evaluate deposit property variables such as solids content, clay content, SFR, undrained shear strength, pore pressure and consolidation parameters (if measured). Correlations between different properties are also developed for future prediction and identification of improvements for the deposit performance. In addition, data will be used to develop a 3D block model to produce a representative 3 dimensional geo spatial representation of the deposit. The block model will illustrate spatial distribution of major properties of the deposit such as solids content, clay content and SFR. The model also helps to estimate quantity of material which satisfies the RTR criteria based on solids content. The material which does not satisfy RTR solids content criteria will contribute to site wide FT inventory. The 3D block model is also used to separate out other tailings types (such as CST) within the treated tailings deposit.

The 3D block model will be developed annually and compared with the previous year's model to estimate spatial and temporal variation of properties. Satellite data, consolidation prediction and engineering analysis will be used to delineate the deposit by solids content and age (model years) to estimate volumes and locations of material that satisfies the RTR criteria of obtaining 65% solids by weight within a one year timeframe. Figure 5.1 illustrate such comparison between two block models.

In addition to comparing the two models it is also important to consider the impact of consolidation on the prior year's data. As such it is expected that the prior year's original surface level will be lower due to the consolidation of the material (Figure 5-1). This difference will be estimated using Imperial's consolidation modelling of the TT deposit, as physical measurement is not possible. This analysis will be applied to TT deposit achieving solids content of ~40% and higher. Material having less than 40% solids content is more fluid and therefore challenging to identify exact age as it may be displaced due to the deposition of subsequent higher solids content material. Approximations will be developed using operational data and sampling campaigns.

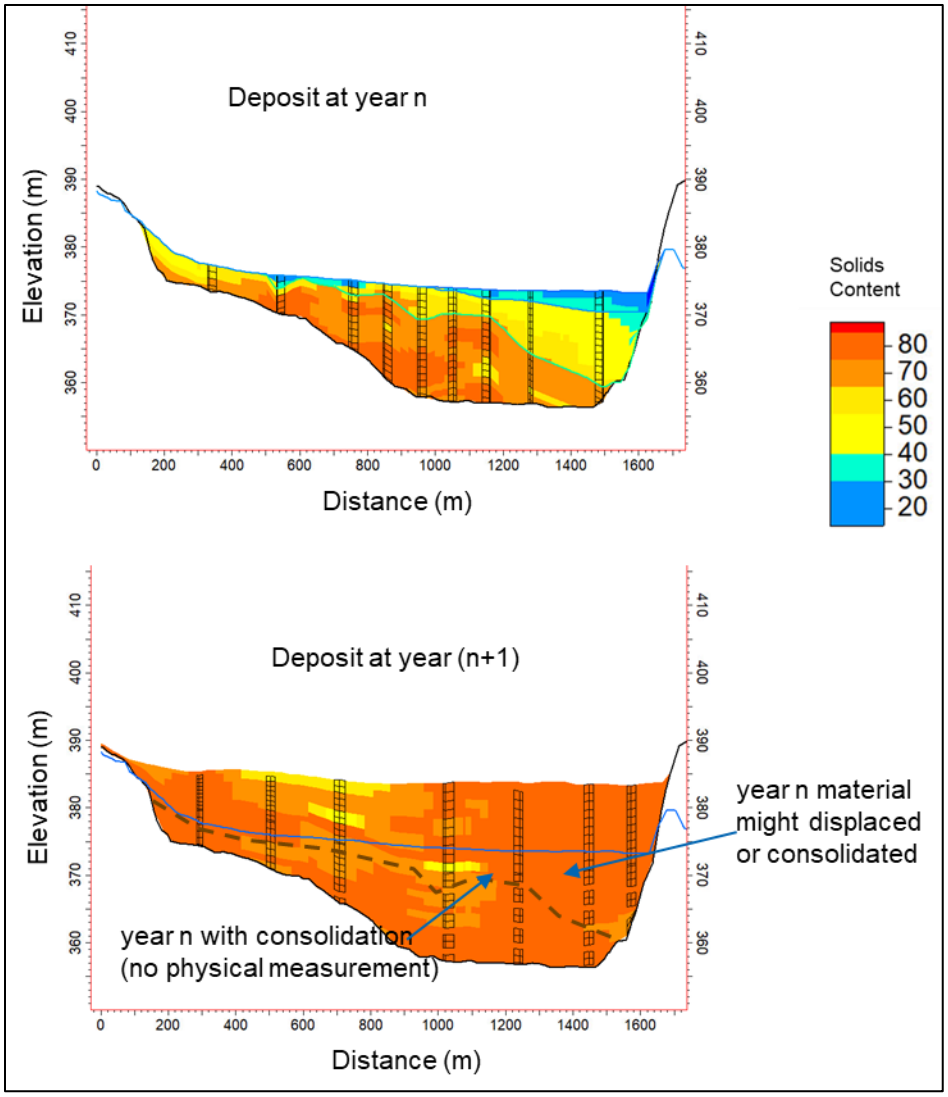


Figure 5-1: Representative cross section of TT panel showing TT deposition and consolidation year over year

5.1.1 RTR Criteria, Measurement and Inventory

RTR performance criteria for the East ETA TT deposit is provided in Appendix C of OSCA approval No. 10829M and shown in the following Table 5-2 .

Table 5-2: RTR Criteria

Deposit	Subobjective	RTR criteria
EETA TT Panels	Sub-objective 1	65 percent solids by weight within one year of treated fluid tailings placement, based upon deposit sampling
	Sub-objective 2	Groundwater is monitored as required by *Environmental Protection and Enhancement Act* (EPEA) Approval No. 46586-01-00, as amended or renewed

As described within Section 3.1, Imperial will provide total estimated fluid tailings levels and identify volumes of material which meet the RTR criteria. Due to the challenges of clearly defining temporal measurements (identifying exact flow paths, build up and deposition locations within the panels), Imperial will provide estimates of the age of the deposit per Section 5.1. Fluid tailings inventory which has not met the current RTR criteria, will be identified as fluid tailings in the current time until consolidation modelling and final reclamation closure plans identify otherwise.

Material which meets RTR criteria will be reported on an annual basis and be removed from the fluid tailings profiles as per Directive 085.

5.1.2 Statistical Analysis of Field Data

Imperial conducts statistical analysis of the deposit properties to identify overall performance of the material. The deposit will be split into several zones of commonality, such as beach above / beach below, to allow for more meaningful correlations. A summary of the statistical analysis is outlined below:

- Summary statistics
  - Univariate statistics for each of the following including comparison with depth:
    - % solids by weight
    - MBI / % clay
    - SFR
- Outlier investigation
  - Examine each dataset for outliers and determine refine data set appropriately
- Comparisons of current summary statistics to previous year's data
  - Current summary is compared with previous years TT data to evaluate potential densification / consolidation of material with time

5.1.3 Justification of Sampling and Spacing Intervals

Imperial uses industry standard spacing, Kearl specific experience and engineering judgment to determine the current sampling spacing for the TT panels (100m-200m grid spacing with 1m – 5m vertical spacing). In addition decimation study of block model is used to evaluate applicability of sampling intervals.

The block model is capable of interpreting the distribution of properties within the deposit. Measured properties of the deposit samples are used in the model preparation. The properties between measured

sample locations are calculated from surrounding known data, using the “inverse distance squared” geostatistical prediction method.
Reduced data sets are prepared to conduct decimation study and results are compared with the full data set prediction to estimate level of accuracy of the block model predictions. Every other sampling location is removed from full data set while maintaining proper distribution of sample locations to recreate two reduced data sets, which are then used to develop two additional block models. Solids content distributions for the two reduced data sets are then developed and the volume which meets the RTR criteria is determined.

The following procedure is carried out to determine accuracy of the volume estimation of treated fluid tailings that achieve Sub Objective 1 RTR status. For comparison purposes, locations where samples are extracted are considered as unit cross section columns of treated tailings deposits. At each sample location, RTR volume (height multiplied by unit cross section) is estimated using measured solids content data (measured RTR volume). Then, solids content predictions at each of the removed data locations are extracted using reduced data models. The extracted data is used to calculate predicted RTR satisfied volumes at each removed sample data location (predicted RTR volume). The measured RTR volume, at sample locations, and predicted RTR volume, after removing each sampled location, is compared to calculate the error of RTR volume estimation at each sample location.

Volumes estimated at individual sample locations are combined to calculate error between measured and predicted total RTR volume.

Removed data locations are the farthest locations from known data points and hence the highest error is expected to occur at those locations. Based on the used data propagation technique, the model makes more accurate predictions closer to known data locations. Therefore, if RTR volume is calculated considering all blocks of the model, the total error is expected to be less than the error estimated from above method.

This type of analysis coupled with engineering judgment and operational history, will provide input into deciding an appropriate spacing in the field sampling program.

6.0 Froth Treatment Tailings

6.1 Tailings Solvent Recovery Unit

In the froth treatment plant, paraffinic solvent is added to froth to help separate bitumen from water and solids. The water and solids (i.e., tailings) from the froth treatment plant are sent to the tailings solvent recovery unit (TSRU) to recover the paraffinic solvent. Once the tailings are processed by the TSRU, they are known as TSRU tailings. When introduced to the tailings pond TSRU tailings forms a non-fluid deposit with most water being recycled for plant use and stored in the WETA.

The composition of TSRU tailings stems from the original minerals within the oil sands being extracted. The hydrocarbon composition comprises primarily of the bitumen that was not recovered within the froth settling units, primarily the heavier asphaltenes, and the residual solvent not recovered in the TSRUs; both of which are measured and reported as per regulatory requirements. Furthermore, NORMs and substances of potential concern (SOPCs) exist in both the original oil sand as well as the residual TSRU streams, the difference being the potential concentration of these NORMs and/or SOPCs. Therefore, Imperial's measurement plan is setup such that the concentrations of different types of SOPCs (e.g. NORMs) will be assessed in terms of operational, environmental, reclamation and closure impacts.

6.2 Measurement of TSRU Placement and SOPCs Identification

In accordance with OSCA approval 10829M, Imperial was placing all TSRU tailings in the WETA until April 2023. The deposition and pipeline layouts are clearly identifiable within satellite imagery. After receiving authorization from AER in January 2023, Imperial relocated TSRU tailings deposition from WETA to in-pit tailings area 1 (ITA1) in April 2023.

The presence of NORMs in tailings is expected and as such alpha, beta and gamma survey meters are used to determine potential areas of higher concentration within the deposits. To date NORMs have not been found to be abundant in Kearl's TSRU deposit with readings at background levels. As such, testing of the TSRU deposit has largely been investigative to support industry initiatives through COSIA.

The TSRU Tailings were analyzed through COSIA regional assessment of challenges to Froth Treatment Tailings (FTT, also referred to as TSRU Tailings and Naptha Recovery Unit [NRU] tailings) in 2017 and 2018 and Imperial's 2019 TSRU characterization program. The results of the assessment were summarized in the recent Mine Plan Amendment and Tailings Management Plan Integrated Application submitted to AER in March 2022.

The assessment characterized the TSRU tailings geotechnically and biogeochemically. No significant concerns related to shear strength or consolidation behavior were identified through the geotechnical characterization of the TSRU tailings from the WETA that would limit the feasibility of a closure concept involving future capping and reclamation of the TSRU deposit. The biogeochemical assessment identified the following potential conceptual risks:

- Total metals and organics in pore water: Elevated total metal concentrations in the pore water suggests that colloidal (i.e., not dissolved) transport is a likely transport mechanism. Organic parameters that were elevated in pore water include F2 hydrocarbons and naphthenic acids.

- Sulphide Oxidation: Pyrite (FeS2) is present in all the depositional environments, is considered to be reactive, and the neutralizing potential of TSRU tailings is limited.

- Radioactivity in solids: The overall source of radioactivity at the site is the presence of uranium and thorium-bearing minerals. The radioactivity measurements from the tailings varies between depositional environments but are generally higher at the beach and transition locations.

The Application also recognized that additional studies and monitoring will be required to support potential mitigation strategies for the above potential biogeochemistry risks. The strategies are intended to address risks to human and ecological receptors at closure and include:

- reducing oxygen ingress into TSRU tailings;
- seepage mitigations; and
- capping.

As these strategies are evaluated, Imperial will provide the updates through related deliverables i.e. Life of Mine Closure Plan and Groundwater Management Plan.

7.0 Data Quality Assurance

7.1 Validation of Field Data and Laboratory Results

To maintain quality assurance and quality control of the data, Imperial relies on several overlapping processes. These processes range from contractor quality assurance and quality control (QA/QC) programs through engineering assessment and analysis using historical data sets or trends and supplementing with alternate measurement or estimation methodologies to validate newly acquired field data.

Imperial's contract management plans require detailed QA/QC plans are adhered to with supporting written documentation asserting compliance. Written documentation from contractors are requested as required. This requires that both field and laboratory analysis follow industry standards to achieve repeatable and accurate results. Imperial may perform, as necessary, blind or duplicate sample tests as additional verification and quality assurance. Imperial representatives may also be present to review and/or attend the physical extraction or testing of samples to provide independent verification of procedures.

Additional quality assurance of the field and laboratory data is achieved through engineering analysis, comparison with historical trends and with internally modelled expectations. The majority of the fluid tailings volumes, including thickened tailings deposits, are modelled throughout the year using operational data cross referenced with geolocational data (primarily satellite imagery). As such using operational data, physical measurements and historical modelling Imperial we are able to estimate the relative compositions of the deposits for both fluid tailings and thickened tailings. Supplementing these estimates with ongoing bathymetric studies, in-situ instrumentation (where applicable) and/or field survey data Imperial can develop relatively accurate models. Comparison of these models with the annual sampling campaign provides another method for QA/QC as deviations between field/lab data and modelled expectations will indicate areas for additional investigation.

7.2 Validation of Modelling Results

Once the modelling is completed it requires that engineering judgement and historical correlations are applied to identify deviations from expectations. The physical samples represent the foundation of the model and as such strong correlation between both data sets should exist. Furthermore extrapolation between sampling locations should include statistical analysis to determine levels of confidence based off the natural variation expected of the data. This validation would typically be supported through graphical representations and cold eyes model evaluation by internal subject matter experts.

8.0 Data Management System

An AcQuire database is used to store most of the pond sampling data and geotechnical investigation data. First, QA/QC of the data is conducted to determine accuracy. Once the subject matter expert approves accuracy, data is moved to a permanent location in the database. Different interface tools are developed to visualize data for other uses without accessing original data in the data base not to compromise integrity of data.

Imperial's Operations Integrity Management System (OIMS) is an integrated management framework required across all of Imperial to guide operational performance and improve its safety, health and environmental performance. OIMS meets the standards outlined in the International Organization for Standardization's ISO 14001: Environmental Management Systems. OIMS is implemented over the complete life cycle of a project — from exploration and development to production and reclamation and closure.

Data management is integrated into the existing systems of Imperial's OIMS framework, which Includes internal information and records management protocols for the retention of data and external correspondence. These protocols are consistent with regulatory approvals. Imperial's information management protocols apply to all monitoring data collected for Kearl, including that for tailings. External regulatory correspondence including approvals, authorizations, letters, reports, and associated data are tracked by a document management process and retained in a database as required.

9.0 Summary

Imperial's Measurement System Plan is based on comprehensive and representative data collection, and analyses. The Measurement System Plan incorporates the requirements of Section 5 of Directive 085 and information contained in the TMP Decision Report 20180716A (AER 2018), the Measurement System Plan Letter (Appendix 6 of the Decision Report) and the Directive 085 Reporting Requirement Clarification – Water Quality Characterization" letter (AER 2022).

The Measurement System Plan uses both standardized industry testing and best practices supplemented with Imperial specific learnings from the last 10 years of operations at Kearl. Additional learnings will be incorporated as the deposits mature allowing for refinement of the models created and improve future operation.

The measurement procedures and methodologies included in this Measurement System Plan are reaffirmed through completion of the annual field surveys. Imperial will continue to refine its methods of measurement and treatment performance through continuous learnings and applying them to the current and future plans.

Imperial is focused on the reduction of FT generation, as well as process optimization and continuous improvement to enable mining, tailings and reclamation practices are integrated and sustainable. This Measurement System Plan will form the basis for reporting both fluid tailings inventories and material which has met the RTR criteria pursuant to Imperial's Directive 085 requirements.

10.0 Acronyms

Acronym	Definition
AER	Alberta Energy Regulator
BGCPTu	Ball Gamma Cone Penetration Test with Pore Pressure Measurement
BPT	Ball Penetration Tests
BMW	Bitumen, Mineral and Water
COSIA	Canadian Oil Sands Innovation Alliance
CPT	Cone Penetration Tests
CPTu	Cone Penetration Tests (using electric piezocone penetrometer)
CT09™	Conetec 2009
Directive 085	Fluid Tailings Management for Oil Sands Mining Projects
EETA	East External Tailings Area
EPEA	Environmental Protection and Enhancement Act
FT	Fluid Tailings
G-CPT	Gamma – Cone Penetration Test
GPS	Global Positioning System
ITA	In-pit Tailings Area
Imperial	Imperial Oil Resources Limited
Kearl	Kearl Oil Sands Mine
MBI	Methylene Blue Index
mm	millimeter
MSP	Measurement System Plan
NORM	Naturally Occurring Radioactive Material
OIMS	Operations Integrity Management System
OSCA	Oil Sands Conservation Act
PSD	Particle Size Distribution
QA/QC	Quality Assurance and Quality Control
RTR	Ready to Reclaim
SFR	Sand to Fines Ratio
SOP	Standard Operating Procedure
SOPC	Substances of Potential Concern
TMF	Tailings Management Framework
TMP	Tailings Management Plan
TSRU	Tailings Solvent Recovery Unit
TT	Thickened Tailings
VST	Vane Shear Test
WETA	West External Tailings Area

11.0 References

AER 2015 *Lower Athabasca Region Tailings Management Framework for the Mineable Athabasca Oil Sands*. March 2015:

http://aep.alberta.ca/land/programs-and-services/land-and-resource-planning/regional-planning/lower-athabasca/documents/LARP-TailingsMgtAthabascaOilsands-Mar2015.pdf

AER 2017 *Directive 085 Fluid Tailings Management for Oil Sands Mining Projects. October 2017:*

https://www.aer.ca/documents/directives/Directive085.pdf

AER 2018 *Decision 20180716A: Imperial Oil Resources Limited; Application for Kearl Mine's Tailings Management Plan:*

https://www.aer.ca/documents/decisions/2018/20180716A.pdf

COSIA 2015a *Guidelines for Determining Oil Sands Fluid Tailings Volumes*, June 2015:

https://www.cosia.ca/uploads/documents/id19/FT%20Volume%20Measurement%20%20June%202015%20b.pdf

COSIA 2015b *Guideline for Tailings Deposit Sampling and Measuring Tools.* Prepared by COSIA Geostatistical and Deposit Sampling Working Group. April 27, 2015:

http://cosia.ca/uploads/documents/id21/Guidelines%20for%20Tailings%20Deposit.pdf

COSIA 2016 *Unified Fines Method for minus 44 micron material and for Particle Size Distribution; issued for use for COSIA Inter-Laboratory Study Round 2*. Revised February 2016:

https://cosia.ca/uploads/documents/id18/COSIA%20FMWG%20Fines%20Method%20February%202016.pdf

CCME(Canadian Council of Ministers of the Environment) 2001: *Water Quality Sampling in Canada. PN 1461. ISBN 978-1-896997-0 PDF. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.*

APHA (American Public Health Association) 2017: *Standard Methods for the Examination of Water and Wastewater, 23rd edition. American Public Health Association, Washington, D.C.*

12.0 Appendices

Appendix A Concordance to OSCA Approval No. 10829J

Regulatory Requirements	Section Number within Measurement Plan
29. The Operator shall monitor: *(a) on a quarterly basis, or such other basis as the AER may stipulate in writing, the solids content and sands to fine ratio of the thickened tailings after secondary chemical treatment;* *(b) on an annual basis, or such other basis as the AER may stipulate in writing, the sands to fine ratio, effective stress, deposit consolidation, pore water pressure, and particle size distribution in each treated tailings deposit; and* *(c) any other parameter on the basis as specified in writing by the AER*	Sections 3.3 and 4 Sections 5 NA
30. The Operator shall, in addition to any reporting requirements under Directive 085, provide in the annual fluid tailings management report: *(a) for each treated tailings deposit, monitoring data including representative cross-sections to illustrate the variation of the following:* *i) sands to fine ratio;* *ii) effective stress;* *iii) deposit consolidation;* *iv) pore water pressure;* *v) particle size distribution plot;* *vi) any other parameter considered relevant by the Operator; and* *vii) any other parameter specified by the AER.* *(b) a summary of quarterly monitoring results for the solids content and sands to fine ratio of thickened tailings after secondary chemical treatment;* *(c) the available storage capacity of each tailings deposit or tailings pond that contains water or tailings at the end of the reporting period;* *(d) annual storage capacity and volume requirements for the five years following the end of the reporting period; and*	Sections 3, 4 and 5 Sections 3.3 and 4 Sections 3 and 5 NA

Appendix B Concordance to Directive 085

Regulatory Requirements	Section Number within Measurement Plan
17) Operators must provide quality information and ensure that the measurement system used for fluid tailings management achieves the following outcomes to the satisfaction of the AER:	
a) Accuracy: the degree to which the measurement matches the correct value.	Sections 7 and 8
b) Precision: the measure of agreement among repeated among repeated measurements of an indicator.	Sections 7 and 8
c) Sensitivity: the degree of ability to discriminate differences in performance of indicators.	Sections 7 and 8
d) Representativeness: the degree that the data is a suitable measure of the condition being examined.	Sections 7 and 8
e) Comparability: a qualitative expression of the confidence that the quality of data is sufficient to contribute to analysis, even when measurement methods differ.	Sections 5, 7 and 8
f) Completeness: the measure of the amount of valid data not omitted.	Sections 7 and 8
g) Bias: the measure of systematic distortion of measurements.	Sections 7 and 8
18) Operators must maintain a data management system that supports the following outcomes to the satisfaction of the AER:	Section 8
a) Verification: the process to ensure that data are evaluated for accuracy, errors and inconsistencies after data migration is done.	Section 7 and 8
b) Validation: follows verification; a process to compare data to documented acceptance criteria.	Section 7
c) Integrity: maintaining and assuring the accuracy and consistency of data over its entire life cycle.	Section 7 and 8
19) Operators must submit their measurement system plan to the AER within six months following approval of the tailings management plan.	This document

Appendix C Concordance to "Measurement System Plan" Later dated July 16, 2018

Decision Report Letter: Measurement System Plan Requirements	
1) Key definition of parameters for fluid tailings and RTR criteria measurements.	Section 2, 3 and 5.1.1
2) Reference of standards and procedures used to measure fluid tailings, treated tailings, and RTR criteria.	Section 2, 3 and 5.1.1
3) An explanation of and justification for measurement procedures that are unique to Imperial and this plan.	NA
4) Evidence that the plan will address the measurement outcomes as per section 5 of Directive 085, as amended.	Sections 3, 4 and 5
5) An explanation of how each of the tailings deposit's RTR criteria will be measured calculated and reported.	Sections 3, 4 and 5
6) A description of the tailings deposit survey program.	Sections 3 and 4
7) Justification of how measurement, sampling and spacing intervals will show the variation of the deposit properties and verify that the tailings deposit is achieving RTR criteria.	Section 5
8) Identify if any material in the deposit is not achieving RTR criteria.	Sections 3 and 5
9) Any other information the AER may require.	NA
10) Where measurement plans exist for either sub-objective, Imperial may incorporate references to other plans, such as the groundwater monitoring program.	Table 5-2
11) Imperial must also ensure the measurement system plan developed aligns with the Groundwater Monitoring Program authorized under its EPEA approval.	Table 5-2
Decision Report Requirements	
[158] Volume of treated tailings that meets the RTR criteria based on deposit sampling and cannot use annual average solids content for the entire deposit. Treated tailings can only be removed from the fluid tailings inventory if the RTR criteria are achieved.	Sections 3 and 5
[111] Describe how Imperial will measure the volume of treated tailings that do not meet RTR criteria.	Sections 3 and 5
[113] Measure the volume of fluid tailings and treated tailings that meets the RTR criteria based on deposit sampling and may not use an annual average for the entire deposit.	Sections 3 and 5
[64] Imperial is not permitted to place TSRU tailings in any deposit except the West ETA at this time. Because the location of TSRU tailings is restricted, Imperial's measurement system plan is required to include identification of substances of concern in TSRU tailings, and measurement location and measurement methodology for the substances of concern.	Section 6
[123] Imperial is required, for each treated tailings deposit, to monitor and report, on an annual basis, solids content, sand-to-fines ratio, effective stress, deposit consolidation, pore water pressure, and any other parameters considered relevant by the AER or Imperial. The results of this monitoring could result in modifications or new subobjective 1 RTR criteria.	Sections 3 and 5

Appendix D Concordance to "Directive 085 Reporting Requirement Clarification – Water Quality Characterization" letter (AER 2022)

Directive 085 Reporting Requirement Clarification: Measurement System Plan Requirements	
Measurement System Plan for water quality sampling methods, locations and sampling freequency	Section 3.2.4

Appendix E Pond Assessment Field Techniques (QA/QC Processes)

E.1 QA/QC and SOP Document from Mikisew ConeTec

Mikisew ConeTec Limited Partnership
2820 Ellwood Drive SW, Edmonton, AB, T6X 0A9
+1 780-485-1095 (Office) | +1 780-485-1097 (Fax)
mikisew-conetec@conetec.com | conetec.com/mikisew

Manoj Biswas, M.Eng., P.Eng.
Sidantha Weerakone, Ph.D., P.Eng.
Mining & Tailings Engineering
Imperial Oil Resources Ltd.
505 Quarry Park Boulevard SE,
Calgary, AB, T2C 5N1

December 10, 2022

Re: **Discussion Memo: Outline of ConeTec quality assurance and control programs for TMF and D.085 pond assessments**

Dear Mr. Biswas & Weerakone,

Mikisew-ConeTec Limited Partnership (Mikisew-ConeTec) is a partnership between the Mikisew Group of Companies (Mikisew) and ConeTec Investigations Ltd. (ConeTec). Mikisew-ConeTec is proud to offer site investigation services to the Oil Sands industry, while also providing direct economic benefit to the Mikisew-Cree First Nation (MCFN), and employment opportunities with ConeTec to MCFN members. ConeTec retains ownership of all equipment, intellectual property, and employment relationships while working through Mikisew-ConeTec to execute projects in the region. Mikisew-ConeTec is the contracted entity, ConeTec in its capacity as the Operating Partner maintains responsibility for the execution of all services and provision of Professional Work Products (PWP's) as defined by the Association of Professional Engineers and Geoscientists of Alberta (APEGA).

In response to the Alberta Energy Regulator's (AER) requirement for error quantification in annual Directive 85 reporting, Mikisew-ConeTec has outlined Directive 85 specific and standardized field testing and quality assurance and control processes to meet this objective.

Quality control is defined as a series of procedures put in place to ensure the performed services adheres to a defined set of quality criteria, such as:

- Quality criteria
  - the data must be correct and complete
- Control procedures
  - Ensure equipment is working properly through instrument calibration, field checks (including instrument baseline verification and monitoring, depth verification, data quality checks)
  - Non-conformance tags attached to equipment not functioning properly and sent for assessment and repair
  - Data analysis team performs checks and verification on data collected using specialized software and standardized processes
  - Senior review of data and data reports
  - Post processing checklists for data review process

Mikisew ConeTec Limited Partnership
2820 Ellwood Drive SW, Edmonton, AB, T6X 0A9
+1 780-485-1095 (Office) | +1 780-485-1097 (Fax)
mikisew-conetec@conetec.com | conetec.com/mikisew

- Quality memos generated and communicated to all personnel

Quality assurance is defined as a process or protocols to maintain a desired level of quality, such as:

- Training conducted with all personnel on procedures and protocols
  - Yearly company training
  - New hire training
  - On the job training
- On site field visits by project managers for verification of field procedures and quality checks
- Manuals and protocol documents generated, maintained and available to all personnel for reference and review

ConeTec is committed to meeting the APEGA standard for Authenticating Professional Work Products. ConeTec is a Permit Holder with APEGA. After comprehensive analysis and review, each report is authenticated by an APEGA registered Professional Engineer or Professional Geoscientist and validated by a Responsible Member. ConeTec has quality assurance documentation, and a Professional Practice Management Plan (PPMP) as required by APEGA.

Contents

Mikisew ConeTec Limited Partnership
2820 Ellwood Drive SW, Edmonton, AB, T6X 0A9
+1 780-485-1095 (Office) | +1 780-485-1097 (Fax)
mikisew-conetec@conetec.com | conetec.com/mikisew

CT09™

Objective of a CT09 survey: Define the bottom bounding surface (termed "hard bottom") for modelling fluid volume. AER Directive 85 specific quality assurance activities that could be used to quantify or minimize measurement errors:

- Provide individual cone penetrometer calibration records used on the project.
    - Provides the appropriate data to show that the penetrometer has been properly calibrated within a timely manner in general accordance with ASTM standard D5778.
- On a per-sounding basis, highlight hard bottom selection criteria, manual or automated, hard bottom achieved or not.
- Conduct multiple CT09s in a cluster to assess repeatability in each pond in multiple areas (shallow, deep, hard refusal areas, frictional refusal areas). Recommended 8 in a cluster (small offsets), multiple clusters in pond centered about a cone penetration test profile, ideally paired with sample data. Use the data to determine the repeatability of CT09 hard bottom measurement versus GCPTu or BGCPTu and sample results. Where this is done, generate a statistical analysis on a per-pond basis that evaluates the accuracy and precision of CT09 measurements in the facility.
- In tailings facilities where hard bottom is not achieved with the CT09 due to a frictional refusal, suggest using GCPTu or BGCPTu as a more representative test.
- When the boat is not fixed (dynamic positioning), suggest collecting high quality coordinates throughout the test sounding. Guidelines for tailings deposit sampling and measuring tools (2015) report to COSIA recommends that horizontal deviation does not exceed 5% of sounding depth. Currently this is not always possible due to weather conditions and the depth to mudline. In ponds where the mudline is deeper than 8m, efficient anchoring is not possible with the current equipment. Suggest measuring and reporting deviations. Opportunities for equipment improvement include:
    - Longer (telescopic) anchoring spuds
    - RTK GNSS system on workboat (centimeter accuracy) for positioning and coordinate measurement pre/post/during sounding

Standardized quality activities

- Cone calibration date is within 1 year of testing date
- When dynamically positioned, collect pre and post sounding coordinates, report horizontal deviation, it should never exceed 5% of sounding depth.
- Up/down difference does not exceed 0.4m for soundings where depth is greater than 10 meters.
- Up/down difference does not exceed 0.2m for soundings where depth is less than 10 meters.
- Cone penetrometer cleaned at the end of each day
- Cone penetrometer saturated prior to each sounding

Mikisew ConeTec Limited Partnership
2820 Ellwood Drive SW, Edmonton, AB, T6X 0A9
+1 780-485-1095 (Office) | +1 780-485-1097 (Fax)
mikisew-conetec@conetec.com | conetec.com/mikisew

GCPTu

Objective of Gamma Cone Penetration Test with Pore Pressure Measurement (GCPTu): Provide detailed stratigraphic log of tailings deposit with direct measurements of tip resistance, sleeve friction, pore pressure and passive gamma. Use measured data to calculate geotechnical parameters such as shear strength and tailings constituents using a Tailings Behaviour Type (TBT) model. AER Directive 85 specific quality assurance activities that could be used to quantify or minimize measurement errors:

- Provide individual cone penetrometer calibration records used on the project.
    - Provides the appropriate data to show that the penetrometer has been properly calibrated within a timely manner in general accordance with ASTM standard D5778
- Provide dimension verifications for CPTu wear parts. This procedure is common in natural soils and compacted soils but will provide limited value in fluid tailings besides operational transparency.
- Provide zero load readings for each sounding.
    - Zero load readings between soundings should be similar for the same cone
    - Provide the cone calibration check record for instruments that have undergone a shift in zero load readings.
- Provide a table summarizing the point reading resolution for each capacity of penetrometer used on the project.
- Assess the variance between paired adjacent GCPTu soundings in beach and fluid tailings to assess the repeatability and implicit spatial variability of the deposit in the measurements.
- TBT interpretations to be compared with sample results collected adjacent to the sounding. A statistical analysis of TBT variance from lab data will be presented with each report.
- Recommend twinning a minimum of one sounding or approximately 1/10 of GCPTu holes with electric downhole vane shear testing to confirm assumptions in undrained shear strength interpretations in each tailings facility. Provided basis for N_{kt} factor used in calculating the data.
- Report on methodology of unit weight assumptions and method of determination. Unit weights are determined from either from PPD tests (in fluid slurries) and SBT zones (in materials generating effective stress), or from the lab data with the following assumptions; SGfines=2.62, SGsand=2.57, SGoil/water=1 and unit UWwater=9.81kN/m3 or TBT.
    - $G_{S\ total\ sample} = \left[\frac{\frac{Total\ Sample\ Percent}{100\%}}{\left(\frac{(sand\ wt\%)}{G_{S\ sand}\ x\ 100\%} + \frac{(fines\ wt\%)}{G_{S\ fines}\ x\ 100\%} + \frac{(Oil\ wt\% + water\ wt\%)}{G_{S\ oil+water}\ x\ 100\%} \right)} \right]$
    - $\gamma_{material} = \gamma_{water}\ x\ G_{S\ total\ sample}$

Standardized quality activities:

- Testing procedures generally meet or exceeds ASTM D5778
- Cone calibration date is within 1 year of testing date
- Each filter is saturated in silicone oil under vacuum pressure prior to use

MIKISEW CONETEC

Mikisew ConeTec Limited Partnership
2820 Ellwood Drive SW, Edmonton, AB, T6X 0A9
+1 780-485-1095 (Office) | +1 780-485-1097 (Fax)
mikisew-conetec@conetec.com | conetec.com/mikisew

- Recorded cone penetrometer zero load measurements are checked with an independent multi-meter (applicable to analog systems only)
- Baseline readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final zero load measurements are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards
- Cone penetrometer is cleaned between soundings
- Before and after each sounding, gamma modules are verified against reference values from materials having consistent output. These values are recorded for inspection during data processing. Data scaling may be conducted using pre and post calibration values.
- There are certain geotechnical properties or physical laws that cannot be violated and as such are used for detailed quality control checks. The review procedure identifies any such violations and recommends small adjustments to the data or a re-collection of field data.
    - $f_s >= 0$, $q_t >= 0$
        - Sleeve friction cannot be negative (because of the design, a ConeTec cone sleeve load cell cannot go into tension) nor should the tip resistance.
    - $q_t >= u_d$
        - Because the tip is a total stress sensing device the tip resistance (q_t) cannot be less than the total overburden stress. In typical geotechnical testing the unit weight of the material must be estimated to determine the total overburden stress, however, in fluid tailings the total stress is a result of the fluid pressure which is directly measured by the dynamic pore pressure (u_d) channel.
    - $\sigma_v' >= 0.0$
        - Effective vertical stress must not be negative. ConeTec software independently calculates the total stress and the fluid pressure, slightly negative effective stresses may be computed.

BGCPTu

Objective of Ball Gamma Cone Penetration Test with Pore Pressure Measurement (BGCPTu): Assess the undrained shear strength (Su) of tailings that flow around the penetrometer. BGCPTu testing collects direct measurements of ball tip resistance, pore pressure and passive gamma. The calculated undrained shear strength and passive gamma data is used to provide tailings constituents (TBT). AER Directive 85 specific quality assurance activities that could be used to quantify or minimize measurement errors:

- Provide individual cone penetrometer calibration records used on the project.
    - Provides the appropriate data to show that the penetrometer has been properly calibrated within a timely manner in general accordance with ASTM standard D5778
- Provide dimension verifications for BGCPTu wear parts. This procedure is common in natural soils and compacted soils but will provide limited value in fluid tailings besides operational transparency.

MIKISEW CONETEC

Mikisew ConeTec Limited Partnership
2820 Ellwood Drive SW, Edmonton, AB, T6X 0A9
+1 780-485-1095 (Office) | +1 780-485-1097 (Fax)
mikisew-conetec@conetec.com | conetec.com/mikisew

- Provide zero load readings for each sounding.
    - Zero load readings between soundings should be similar for the same instrument
    - Provide the cone calibration check record for cones that have undergone a shift in zero load measurements.
- Provide a table summarizing the point reading resolution for each capacity of penetrometer used on the project.
- Assess the variance between paired adjacent BGCPTu soundings in fluid tailings to assess the repeatability and implicit spatial variability of the deposit in the measurements.
- TBT interpretations to be compared with sample results collected adjacent to the sounding. A statistical analysis of TBT variance from lab data will be presented with each report.
- Recommend twinning a minimum of one sounding or approximately 1/10 of BGCPTu holes with electric downhole vane shear testing to confirm assumptions in undrained shear strength interpretations in each tailings facility. Provided basis for N_{ball} factor used in calculating undrained shear strength.

Standardized quality activities:

- Cone calibration date is within 1 year of testing date
- Testing procedures generally meet or exceeds ASTM D5778
- Each filter is saturated in silicone oil under vacuum pressure prior to use
- Recorded cone penetrometer baselines are checked with an independent multi-meter (applicable to analog systems only)
- Zero load readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final baselines are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards
- Cone penetrometer is cleaned between soundings
- Before and after each sounding, gamma modules are verified against reference values from materials having consistent output. These values are recorded for inspection during data processing. Data scaling may be conducted using pre and post calibration values.

Mikisew ConeTec Limited Partnership
2820 Ellwood Drive SW, Edmonton, AB, T6X 0A9
+1 780-485-1095 (Office) | +1 780-485-1097 (Fax)
mikisew-conetec@conetec.com | conetec.com/mikisew

Sampling

Objective of tailings sampling: Collect profiles of physical samples for analysis, providing solids content, fines content, bitumen content, and Methylene Blue Index (MBI) testing by lab or HyperScan.

Sample Collection & Laboratory Analysis

AER Directive 85 specific quality assurance activities that could be used to quantify or minimize measurement errors:

- Collect one duplicate sample per fifty. Analyze duplicate pairs for repeatability and provide summary statistics per deposit. Duplicate sampling density may need to be increased in smaller tailings facilities to get a statistically meaningful dataset for each deposit. This error analysis will contain components of field collection error, spatial variability error and laboratory analysis error.
    - Lab services provider to select certain samples to duplicate testing for their own QA/QC
    - Utilize blind splits to assess lab measurement error
    - ConeTec can include lab duplicate testing with our duplicate samples for statistical analysis
    - Industry could commission a study to determine the repeatability and reproducibility of lab reported tailings constituents
- Assess the variance between paired adjacent fluid, Fixed Interval Sampler (FIS) and sonic soundings in fluid and/or beach tailings to assess the repeatability and implicit spatial variability of the deposit in the measurements.
- Instruct the lab to split occasional samples and report the laboratory split data. Analyze laboratory duplicate pairs for repeatability and provide summary statistics per deposit. Duplicate lab sampling density will need to provide a statistically meaningful set of data pairs. The error analysis will contain components of sub-sampling error and laboratory process error.
- Compare laboratory splits to field duplicates to approximate field error versus laboratory error.

Standardized quality activities:

- Record gas pressure during deployment of gas actuated piston samplers (verify that gas pressure exceeds deposit pressure)
- Collect photographs of all samples
- Mudline from sonar reading is within 10cm of the mudline from FIS samples
- Locations with paired sampling/GCPT/CT09:
    - Mudlines should be within 10cm
    - Fluid sampler refusal is within 1m of CT09 refusal

HyperScan (Hyperspectral Sensing Technology for Oil Sands Tailings Constituent Analysis)

Proposed AER Directive 85 specific quality assurance activities that could be used to quantify or minimize measurement errors:

- Utilize HyperScan and Tailings Behaviour Type results to identify potential poor quality laboratory results for retesting.

MIKISEW CONETEC

Mikisew ConeTec Limited Partnership
2820 Ellwood Drive SW, Edmonton, AB, T6X 0A9
+1 780-485-1095 (Office) | +1 780-485-1097 (Fax)
mikisew-conetec@conetec.com | conetec.com/mikisew

- Report the sum of total mass percent bitumen, total mass percent solids, and total mass percent water predictions produced by HyperScan models.
- Report the homogenization methodology, such as no homogenization (point scans on core), mechanically mixed, manual, or sand suspending polymer utilized.
- Report a tabular summary of samples that required polymer amendments to homogenize the sample for HyperScan testing, including the mass used and name of product.
- Report the confidence interval of model predictions
- Conduct a third-party validation using data collected during the 2023 tailings assessment

Standardized quality activities:

- Perform confirmatory laboratory testing on a subset of HyperScan tested samples
- Conduct baseline scans on the Spectralon white reference discs every 15 minutes
- Conduct daily reference tests on a mylar card for wavelength verification of the instrument
- Conduct weekly inspection of fiber optic cables
- Conduct daily tests on control samples to verify model performance is within control limits

Vane Shear Testing

Objective of vane shear testing (VST): Provide a direct measurement of undrained shear strength in-situ. Proposed Oil Sands Directive 85 specific quality assurance activities that could be used to quantify or minimize measurement errors:

- Provide calibration records for each vane load cell used on project. Calibrations comply with ASTM D2573/D2573M.
- Provide zero load readings for each sounding (baseline counts)
- Provide a table of point reading resolution for each capacity of downhole load cell used on the project.
- Provide proof or record of elapsed time from insertion to rotation. From remolding to remold testing.
- In sand/fine mixtures (CT, high SFR MFT) evaluate drained versus undrained behaviour to assure VST is representative of an undrained shear strength. This is achieved by performing an adjacent CPT pore pressure dissipation test to obtain the coefficient of consolidation (c_{vh}). A non-dimensional vane test time factor is then calculated based on the time elapsed between vane insertion and failure (t_f) and the vane diameter (D) such that $T = c_{vh} * t_f / D^2$. If T is less than 1.3 we can assume undrained conditions. A recent paper by Reid (2016) evaluated T from VST in silty Australian mine tailings and showed the need to perform faster VST to avoid partially drained vane strength measurements.

Standardized quality activities:

- Torque is measured downhole, negating the need for rod string friction measurements. In the case of uphole torque measurement, rod friction must be recorded for each test.
- Testing procedures generally meet or exceeds ASTM D2573. Variances from standard:
    - Extra-large vane for profiling fluid tailings (150x300mm)

Mikisew ConeTec Limited Partnership
2820 Ellwood Drive SW, Edmonton, AB, T6X 0A9
+1 780-485-1095 (Office) | +1 780-485-1097 (Fax)
mikisew-conetec@conetec.com | conetec.com/mikisew

  - Depths referenced to the middle of the vane blade, not to the vane tip
  - Rate of remolding is not recorded
  - We do not plot torque versus rotation we plot shear stress versus rotation
- Appropriate vane selected for testing based on adjacent GCPTu or BGCPTu calculated undrained shear strength assuming an N_{kt} factor of 15 or N_{ball} factor of 11.
- Vane load cell calibration date is within 1 year of testing date
- Zero load readings between soundings are similar (within 1% of the measured Su value)
- Peak test starts within 5 minutes of reaching the required test depth
- Remold test starts within 1 minute after remolding process
- Vane is inspected for damage before use. Vane blade thickness and stem diameter are measured and recorded.

Acoustic Mudline Measurements

Objective of testing: Delineate the upper boundary surface (mudline) for fluid tailings volume and constituent modelling.

Single Beam Sonar

Proposed Oil Sands Directive 85 specific quality assurance activities that could be used to quantify or minimize measurement errors:

- Provide measurement uncertainty value for each reported elevation
- Provide a table in the report that outlines equipment precision, equipment uncertainty and offset measurements

Standardized quality activities:

- Measure and document the transducer depth below water and verify keel offset settings in software
- Verify sonar depth measurement versus an area with physically verified depth each day to verify setup
- Sonar transducer mounted to an outrigger barge for dynamic surveying, verifies that transducer elevation does not change as boat pitch and draft change due to travel velocity and turning
- Static sonar readings at sampling locations should agree within 10cm of collected FIS mudline

Mikisew ConeTec Limited Partnership
2820 Ellwood Drive SW, Edmonton, AB, T6X 0A9
+1 780-485-1095 (Office) | +1 780-485-1097 (Fax)
mikisew-conetec@conetec.com | conetec.com/mikisew

Swath Bathymetry (3DSS)

Proposed Oil Sands Directive 85 specific quality assurance activities that could be used to quantify or minimize measurement errors:

- Provide measurement uncertainty value for each reported elevation
- Provide a table in the report that outlines equipment precision, GNSS uncertainty and equipment offset measurements (transducer depth, offset from GNSS antenna)
- Provide any equipment calibration reports (Sound Velocity Probe)

Standardized quality activities:

- Compare sonar mudline measurements with Fixed Interval Sampler mudline measurements to ensure they agree within the measurement uncertainties
- Perform 'Patch Test' calibration for 3DSS equipment each time the equipment is deployed on a vessel.
- Ensure 3DSS Sound Velocity Probe is calibrated yearly
- Sound velocity profiles are used to transform time series data to distance
- Data is compensated for pitch, roll, and vector of the survey vessel

GNSS Survey

Objective of testing: Define a pond surface datum to reference tests against.

Standardized quality activities:

- Fixed versus float solutions
- Provide detailed error report
- Verification of rod length used (staff length + deck to ground from CPT)
- Verify against independently surveyed elevations or monuments

Planned and Proposed Deliverables

1. Field Data Report (within 2 weeks of completing each field project)
    - Factual report of field data
    - Authenticated by a Professional Engineer or Geoscientist
2. Field Data Error Analysis (within 2 weeks of receipt of lab data)
    - Statistical summary of repeatability and variance observed
    - Reported for each tailings deposit
3. Pond Assessment Quality Report (Q1 of the following year, after receiving all laboratory data)
    - Comprehensive report outlining the QA processes used

Mikisew ConeTec Limited Partnership
2820 Ellwood Drive SW, Edmonton, AB, T6X 0A9
+1 780-485-1095 (Office) | +1 780-485-1097 (Fax)
mikisew-conetec@conetec.com | conetec.com/mikisew

References

Ansah-Sam, M., Binczyk, T., Dobek, C., Geremew, A., Mimura, W., Weerakone, S., (COSIA geostatical and deposit sampling working group), 2015, “Guidelines for Tailings Deposit Sampling and Measuring Tools”, retrieved from http://www.cosia.ca/uploads/documents/id21/Guidelines%20for%20Tailings%20Deposit.pdf, COSIA Geostatistical and deposit sampling working group

ASTM D2573 / D2573M-15, 2018, “Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils”, ASTM International, West Conshohocken, PA.

ASTM D5778-12, 2020, "Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils", ASTM, West Conshohocken, US.

Entezari, I., McGowan, D., and Glavina, J., 2022, ”Hyperspectral imaging (HSI) technology for oil sands tailings characterization: practical aspects”, Proceedings of Tailings and Mine Waste 2022; Denver, CO, USA.

Entezari, I., McGowan, D., Glavina, J., and Sharp, J., 2022, ”Tailings behaviour type to predict oil sands tailings constituents from the gamma cone penetration test”, Proceedings of International Oil Sands Tailings Conference; Edmonton, AB, Canada.

Styler, M.A., McGowan, D., and Sharp J., 2018, ”Characterizing soft oil sand tailings by gamma cone penetration testing”, Proceedings of the 6th International Oil Sands Tailings Conference, Edmonton, Alberta.

Contributors

Alexis Maddaloni, Training and QA/QC Manager, ConeTec Investigations Ltd.
Chris Hermiston, Geophysics Project Manager, ConeTec Investigations Ltd.
David Parkinson, P.Eng., Project Manager, ConeTec Investigations Ltd.
Iman Entezari, PhD, Research Engineer, ConeTec Investigations Ltd.
Mary Nguyen, Data Analyst, ConeTec Investigations Ltd.

Mikisew ConeTec Limited Partnership
2820 Ellwood Drive SW, Edmonton, AB, T6X 0A9
+1 780-485-1095 (Office) | +1 780-485-1097 (Fax)
mikisew-conetec@conetec.com | conetec.com/mikisew

Closing

Mikisew-ConeTec has robust quality assurance and control processes involving all aspects of data collection, analysis, release, and archiving – the data must be right! The summarized additional reporting will quantify the degree of accuracy, representativeness, bias, and precision of the collected field data. This information will enable Imperial Oil Resources Ltd. to determine the accuracy of inputs to modelling and regulatory reports.

This memo is provided for discussion and is intended to give an overview of options available to improve statistical analysis of accuracy, reliability, representativeness and precision of testing tools and methods used to characterize Imperial Oil's tailings facilities. This additional data will help modelling experts in quantifying error in their reports.

If you have any questions, please contact the undersigned.

Sincerely,

Dallas McGowan, P.Eng.
Vice President, Mikisew-ConeTec Limited Partnership
Vice President - Oil Sands, ConeTec Investigations Ltd.
(780)-381-9753
dmcgowan@conetec.com

E.2 QA/QC and SOP Document from Tarcore

Loring Tarcore Labs Ltd.

Particle Size Distribution of Oil Sands Sample

by Laser

INTRODUCTION

This procedure is used for the determination of particle size distribution of oil sands samples through Coulter LS13 320.

PRINCIPLE OF THE METHOD

Dry mineral samples are disaggregated physically and dispersed chemically. The aqueous sample is then circulated through the lens of LS13 320, where a laser beam measures the particle size using the principle of diffraction. Coulter LS13 320 particle size analyzer can measure grain sizes between 0.04 µm and 2000 µm.

PROCEDURE

1. **SAMPLE PREPARATION**
   - 1.1 Put the sample into the mortar and grind it using a wooden pestle to avoid crushing the sand grains, then pass sample through No.10 testing sieve (2000µm). If there is some gravel that cannot pass through the sieve, weigh and record it.
   - 1.2 Weigh 0.7-5 grams (depends on the natural of sample, 0.7g for clay sample, 5g for sandy sample). Put it in the test tube.
   - 1.3 Wet the sample with just enough iso-propanol, and then add carbonate/ bicarbonate buffer solution. Let samples stand for overnight
   - 1.4 Boil samples for 15 minutes.

2. PARTICLE SIZE MEASUREMENT

- 2.1 Turn on the Coulter, water, and computer. Warm up the Coulter for 20 minutes before starting the LS13 320 program.
- 2.2 Run a test sample to verify the instrument's performance before testing any sample.
- 2.3 Load proper SOP (pre-created according sample and client's requirement) and run sample testing.

LASER DIFFRACTION CALIBRATION PROCEDURE

1. SAMPLE DESCRIPTION

Two Control samples are used for instrument calibration. They are Coulter LS Control G15 and GB500.

2. CALIBRATION PRECEDURE

2.1 Select Cycle in the Run Menu and select all options except sonication. Align should be in Auto mode. Measure Offsets should be set for 60 seconds and Measure Background must be set for 60 seconds.

2.2 Load contents during the Measure Loading phase of the cycle. Wait until the obscuration value stabilizes before selecting “Done”. Obscuration should be 10%+/- 3%.

2.3 In Run info set the run length to 60 seconds and select Compute Sizes and Save File. In Optical Model select GARNET for Coulter LS Control G15; In Optical Model, select Fraunhofer for Coulter LS Control GB500.

3. CALIBRATION RESULTS

Select Statistics in the Analyze Menu and Verify that the values you obtain are within the limits in the tables below.

3.1 For Coulter LS Control G15

Sample Name	LS Control G15
Mean	14.4+/-1.8 micron
Standard Deviation	6.20+/-2.25 micron

3.2 For Coulter LS Control GB500

Sample Name	LS Control GB500
Mean	582+/-34.5micron
Standard Deviation	49.5+/-22.5micron

Standard Operating Procedure LT-SOP-160

DEAN STARK FOR TAILING SAMPLES

Author: Hudson Sun _____

Approved by: Serena Li, Vice President/QA/QC _____

Revision Record

Revision	Date	Responsible Person	Description of Change
0	May 5, 2023	Hudson Sun	Initial Release
1	May 30, 2023	Hudson Sun	Edited according to Brad Komishke suggestion/requirement

Contents

1 SCOPE AND APPLICATION

This standard operating procedure (SOP) covers the Dean Stark analysis for tailing samples. Tailing samples' preparation is based on Dean Stark analysis for BEU tailings (Bradley Komishke and Louxiang Wang).

2 METHOD SUMMARY

2.1 A weighed sample is separated into bitumen, water, and solids by refluxing toluene in a Dean & Stark Soxhlet extraction apparatus. Condensed solvent and co-distilled water are continuously separated in a trap designed to recycle the toluene through the extraction thimble, dissolving the bitumen present in the sample, while the water is retained in the trap for determination. This determination is done volumetrically. When all the bitumen has been extracted, the washed solids that are retained in the thimble are dried and weighed. The bitumen can be calculated by difference.

2.2 The resulting bitumen/solvent extract transferred into a volumetric flask (500mL) and made up to volume with clean toluene. An aliquot is taken and dispersed on a glass microfiber filter paper allowing evaporation of the solvent and gravimetric determination of the bitumen content (by closure).

3 DEFINITIONS

3.1 Tailings: tailings slurry is a mixture of sand particles, dispersed fines, water and residual bitumen

3.2 MFT: Mature Fine Tailings

4 HEALTH AND SAFETY WARNINGS 

4.1 Toluene is extremely flammable, and maybe fatal by inhalation or ingestion.

4.2 Toluene is a known teratogen. Individuals who are pregnant must inform their supervisor and be assigned alternate duties.

4.3 A half mask respirator with organic vapor cartridges is mandatory when loading and unloading thimbles.

4.4 Toluene drums must be always grounded.

4.5 Use Extreme caution: when opening the door of an oven, wear oven mitts, distance yourself from the oven (stand behind the oven door) and open it slowly (let the heat escape for a few seconds). The heat, especially if there is potential toluene vapor, can cause burns to your face and irritate eyes!

4.6 In case of the following emergency situations DO NOT PANIC:

4.6.1 A flask is broken while toluene is refluxing: this may cause fire. If a fire is present, locate the sand bucket and put out the fire using sands. Turn off the power supply to this flask by pulling the plug. If a fire is not present, shut off the power supply and use

Solusorb absorbent to soak up the spill. Inform staff in the immediate area and your supervisor.

4.6.2 Refluxing with the water circulation pump off may cause serious leaking. Shut off power supply immediately; shut off cooling water inlet valve (this section only); turn on circulation pump; fix leaking area and open the inlet valve; replace wet heating mantles; turn power supply back on

4.7 Safety data sheets (SDSs) should be available to all personnel involved in this analysis.

5 INTERFERENCES

5.1 NA

6 SAMPLE REQUIREMENTS

6.1 NA

7 EQUIPMENT, SUPPLIES, CHEMICALS AND STANDARD

7.1 Equipment and Supplies

7.1.1 Refer to LT-SOP-010

7.1.2 Propeller and drills for homoginization

7.1.3 Ladle

7.1.4 Aluminum Foil Pie Pans

7.2 Chemicals

7.2.1 Toluene, ACS grade

8 QUALITY CONTROL

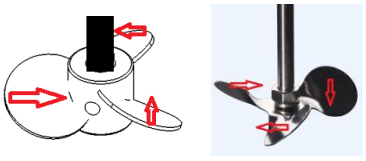
8.1 Duplicate is measured 1 of every 20 sample. The bitumen value between duplicates should be within ±0.3% absolute (if the bitumen less than 2%) or ±0.5% absolute (if bitumen more than 2%). Water and solids ±1% absolute

9 PROCEDURES

9.1 <u>SUBSAMPLING OF TAILINGS SLURRY AND MFT SAMPLES</u>

9.1.1 Receive & sort the field samples and label them with RC# and lab ID

9.1.2 Set-up the homogenization equipment, check the drill propeller to make sure in good shape and turning in the direction as indicated



9.1.3 Take one tailing sample (5L pails), remove the lid using a lid removal tool, and place it into the homogenization bucket

9.1.4 Submerge impeller into the sample and start the drill or stirrer on low speed. If the material has compacted, may have to start/stop the drill repeatedly in order to get the material moving (or use special propeller)

9.1.5 Increase the speed gradually until you reach a stage where the material is lifting off of the bottom of the pail, yet no so fast that you are losing material over the sides

9.1.6 Move the rotating impeller head throughout the entire sample volume (top to bottom and side to side motion), placing special emphasis on lifting material that has settled and compacted on the floor and corners of the pail

9.1.7 Blend for approximately one minute, until a consistently homogenous appearance is attained

9.1.8 While continuing to blend the sample, collect a portion of material (at least 2 scoops) using a long-handled sauce ladle and transfer to one of the pre-weighed aluminum foil pie pan with 3 pieces of coffee filters. It may need more than 2 scoops to collect enough solids (about 70g of dry solids) if the solids content is low.

9.1.9 For high solids content, non-flowing samples: mix the sample using a spatula, transfer portions of the sample into a large shallow pan; mix the sample in the shallow until completely homogenous; flatten sample and form a rectangular shape, remove several sections and placed in pre-weighed aluminum foil pie pan with 3 pieces of coffee filters

9.2 SAMPLE WATER PARTIAL REMOVING BEFORE DS EXTRACTION

9.2.1 Leave above sub-samples in a fume hood or drying room or in an oven (80 °C) for several hours. Meanwhile, check the status of sediments every two hours till sediments almost dry.

9.2.2 Weigh the samples and calculate the water evaporated

9.3 DEAN STARK EXTRACTION

9.3.1 Setup ready for extraction system

9.3.2 Prepare thimbles by clipping the label on. Arrange the thimbles row by row from left to right into a thimble tray and dry 2 hours at 100 ± 5°C. Record the dry weight of the thimbles.

9.3.3 Pack sediments in a pre-weighed thimble the same way as oil sands samples

9.3.4 Weigh the thimble with sample and record its weight into the computer

9.3.5 Place the pre-weighed sample thimbles into the extraction flasks, and double check all is ready for extraction

9.3.6 Check the completeness of the extraction after 5 hours by looking the color of drippings and thimbles.

9.3.7 When the extraction determined completed, wash down the condenser with toluene to dislodge any water droplets that may have adhered to the glassware

9.3.8 Read the water volume in each water trap and record the data into computer
9.3.9 Continue the extraction process for another half hour
9.3.10 Read and record the water volume again by second technician
9.3.11 Shut down extraction system after cooled down
9.3.12 Remove extracted thimbles from flasks and left in fume hood for one hour, and then dried in oven (100 ±5°C) for 4 hours
9.3.13 Weigh the thimbles containing dried solids, recorded to computer

10 DATA ANALYSIS AND CALCULATIONS

Use the following formulas to calculate the contents of water, bitumen and solids:

Mineral, wt % = Wt. Mineral (g) / Sample Weight (g) * 100

Water, wt % = Wt. Water (g) / Sample Weight (g) * 100

Wt. Water = Evaporated water (from sample drying) + DS Water (reading portion from extraction)

Bitumen, wt % = 100 - Mineral, wt % - Water, wt %

11 WASTE MANAGEMENT

Spent toluene is collected and stored in the marked drum with MSDS label for exterior waste management.

12 REFERENCE METHOD DEVIATION

Tailing samples are pre-treated to prevent wet clay samples solidified and form hard shell during extraction process. If hard shell formed, it is extremely difficult to complete the bitumen extraction. This deviation come from Teck BEU talings treatment for Dean Stark analysis (Bradley Komishke and Louxiang Wang)

13 REFERENCES

13.1 ASTM D95 - 05(2010) Standard Test Method for Water in Petroleum Products and Bituminous Materials by Distillation
13.2 ASTM D4006 - 07 Standard Test Method for Water in Crude Oil by Distillation
13.3 OSRD Method 1.05 Determination of the bitumen, water and solids in oil sand

Loring Tarcore Labs Ltd.

Determination of Methylene Blue Index (MBI) of Oil Sands Samples

PRINCIPLE

Methylene blue dye is added to a sample that retained in the thimble after Dean Stark analysis. The dye is absorbed onto the clay mineral surface by a cation exchange reaction. Because non-clay minerals have a low cation exchange capacity, the dye absorbed by a sample is an indication of the clay content of that sample.

PROCEDURE

1. Sample preparation

1.1 Disaggregate the sample properly. Weight certain amount of samples into centrifugal tubes.
1.2 Add NaHCO3+NaOH (pH=9.7) solution to the sample. Heat the tube in 80°C water bath for 20 minutes. Take out and stay at room temperature for overnight.
1.3 Sonicate the sample for 20 minutes in ultrasonic cleaner.
1.4 Transfer sample into beaker, add more NaHCO3 solution to get total volume of 100ml. Adjust pH to 2.5-3.8

2. Sample Analysis

2.1 Label a Whatman #2 filter paper with well name, sample ID, date and the analyst's initial.
2.2 While stirring the sample slurry, add 0.5 mL-2mL of MB solution from a burette. Stir for 1-2 minutes on the magnetic stir plate. Record this amount of MB on the filter paper.
2.3 Using a Pasteur pipette, place a drop of the slurry on the surface of the filter paper.
2.4 Observe the appearance of the drop. The endpoint is indicated when a blue halo forms around the drop. If no halo appears, continue adding MB solution to the slurry in 0.5mL or 1mL or 2-mL, with 1-2 minutes of stirring after each addition. Write the volume of MB added for each addition on the filter paper. When the endpoint is near, reduce the titrant volume to 0.5 mL and continue until the endpoint is reached. **Make sure that the halo persists after one minute of additional stirring.**
2.5 Let the filter paper dry, turn it on its backside and determine the point at which a halo exists surrounding the inner dark blue. This is the endpoint of the titration. Continue adding 0.5mL MB solution two or three times to confirm.
2.6 Once the endpoint is determined, record the total amount of MB titrant (mL) used to reach the endpoint in the MBI Logbook.

2.7 Input sample weight and total amount of MB titrant (mL) used into MBI data process program.

3. Calculation

Use following formula to calculate MBI

$$\mathbf{MBI = 0.006 \times V \times 100/W}$$

Where:

MBI = Methylene Blue Index in **meq/100g** sample

V = volume (mL) of Methylene Blue solution (0.006 N) used

W = weight (g) of dry sample used

QUALITY CONTROL

1. Methylene Blue titrant must be checked with dry Bentonite before the test.
2. Perform duplicate analysis on one sample for every ten samples analyzed. Duplicate results should agree within +/- 10% RPD of the average value

Loring Tarcore Labs Ltd.

PARTICLE SIZE DETERMINATION BY SIEVE (WET/DRY SIEVE)

PRINCIPLE

The bitumen and water in an oil sands sample are extracted by Dean Stark leaving clean dry solids. The solids are wetted and dispersed before being passed over a 325 mesh US standard sieve. The washed liquid (< 44µm) collected below the sieve is sent for laser diffraction measurement. The retained sample not passing through the sieve (>44µm) is collected and dried in the oven. The dried sample (> 44µm) is then passed over a sieve stack fractionating the sample into its respective size distribution.

The overall particle size distribution is obtained by combining the wet-dry sieve and laser diffraction data.

PROCEDURE

1. Disaggregation

1.1 Pour the solids over a 3.35 mm (No. 6 mesh) sieve with a receiving pan below.
1.2 Disaggregate pieces of unconsolidated sandstone (easily reduced) that do not pass through the sieve with a mortar and *rubber* pestle.
1.3 Pour the contents of the mortar back over the 3.35mm sieve
1.4 Split the sample using a chute riffle to obtain one representative sample
1.5 Add 300 mL of sodium hexametaphosphate solution to the sample in a beaker
1.6 Place the beaker on a hot plate and boiling for 15 minutes
1.7 Turn the hot plate off and allow the beaker to sit for 30 minutes until cool. Cover the beaker and allow it to sit for at least 12 hours

2. Wet Sieve

2.1 Stir the sample thoroughly using a glass rod with rubber policeman and then sonicate for 15 seconds
2.2 Quantitatively transfer the slurry from the beaker to the sieve. Wash beaker and police man/glass rod with DI water to ensure complete transfer of solids.
2.3 Shower the sample with DI water, gently move the samples around in the sieve.
2.4 Continue washing in this manner until the water flowing into the receiving pan is clear
2.5 The slurry portion for laser PSD, the above portion for dry sieve after drying

3. Dry Sieve

3.1 Inspect standard sieves (mesh 10, 18, 35, 45, 60, 80, 120, 200, 325) and receiving pan to ensure that they are not damaged or punctured.
3.2 Stack the pre-weighed sieves on top of each other with the largest mesh size 10 at the top and progressively smaller down to mesh 325 below, with the receiving pan at the bottom of the sieve stack.
3.3 Add pre-weighed samples to the sieve stack, place the sieve stack on the shaker, active the shaker for 5 minutes.
3.4 Remove the sieve stack from the shaker, weigh each sieve (with retains).
3.5 Clean the sieves

4. Data Analysis and Calculation

The wet/dry sieving results will be combined with results from laser diffraction for fines and fed into particle size distribution reporting template for final reporting.

5. Quality Control

5.1 Calibrations are completed and recorded regularly
5.2 A duplicate analysis is performed on 1 in 20 samples analyzed
5.3 Blind and/or reference samples may be provided by the client for each well.