SUNCOR ENERGY INC.

BASE PLANT

DIRECTIVE 085

MEASUREMENT SYSTEM PLAN

December 2022

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EXECUTIVE SUMMARY

The purpose of this Measurement System Plan (Plan) is to meet the requirements of Section 5 of Directive 085 (AER 2017a) and the *Measurement System Plan Requirements* letter dated October 25, 2017 (AER 2017b) for Base Plant operations. The Plan will be updated as needed to reflect changes to tailings management operations and revisions to date are outlined in the table below.

According to Suncor's Mission, Vision and Values (www.suncor.com), Suncor values safety above all else. With this in mind, the *Measurement System Plan* (Plan) proposed herein will and may be modified as required to ensure that all field activities are carried out in a safe manner.

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1. INTRODUCTION

The purpose of this Measurement System plan (Plan) is to meet the requirements of Section 5 of Directive 085 (AER 2017a) and the *Measurement System Plan Requirements* letter dated October 25, 2017 (AER 2017b) for Base Plant operations. Additional requirements are summarized in Section 1.3 and Appendix 10.3. This Plan is consistent with the *Pond 5 Monitoring Plan* (Suncor 2017b) and the Mine Dump 9 (*MD9) Settlement Monitoring Plan* (Suncor 2018a) which are included in Appendix 10.8.

This Plan is a living document and is updated as needed to reflect current best practices and changes to tailings management operations and plans. Revisions of the Plan to date are outlined in the table below.

Version	Date	Comment
3	December 16, 2022	Updated to reflect DDA3 RTR Criteria as per OSCA Approval 8535R Appendix C
		Updated to reflect requirement of AER letter dated February 23, 2022 requiring water quality characterization and reporting. (AER2022)
		Updated Figure 1-1: Standardized Site Wide Water Balance Report Template to align with Suncor 2021 D085 Fluid Tailings Management Report. (Suncor2022b)
		Updated Tailings Asset Management Data Sheets to reflect operational changes • Improved methodology for light hydrocarbon measurement (Suncor 2021b) • Removal of Pond 5 – Phase 1 as Pond 5 completed Phase 1 • Removal of DDA1 information as DDA1 has ceased operations • Removal of MD9 Co-disposal Phase 1 information due to completion of co-disposal operations and transition into Phase 2 settlement monitoring. • Removal of Asset Measurement Plan and Calculation and Modelling Methods from all asset sheets. These details are not required as part of the Plan.
2	February 10, 2020	Updated to align with the MD9 South Co-disposal Amendment Application
1	April 27, 2018	Original

This Plan will support the requirements of the *Annual Fluid Tailings Management Report* for the processing plant and associated mines which are collectively referred to as Base Plant.

According to Suncor's Mission, Vision and Values (www.suncor.com), Suncor values *safety above all else*. With this in mind, the Plan proposed herein will and may be modified if conditions are considered unsafe. Potential changes or modifications may include variations in procedures and methods, delay of field testing and/or sample collection for the affected area or time period.

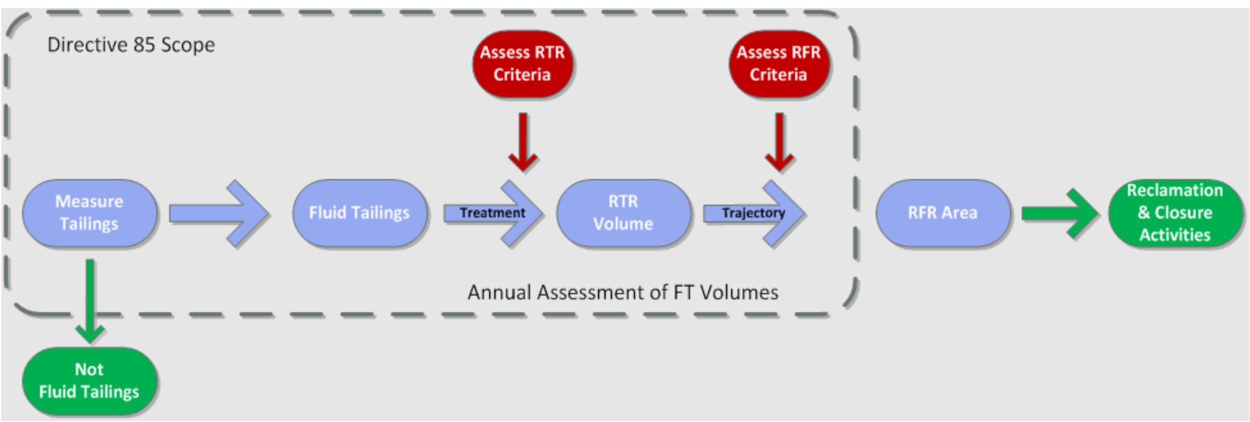
1.1. Background

The relationship of tailings management and reclamation activities and how the terminology described is used is provided in Figure 1-2. The following points summarize these relationships:

- Oil sands mine tailings volumes will be assessed annually, as per Directive 085 (AER 2017a) requirements;
- The majority of the tailings material produced will not be fluid tailings (FT) and will continue to be monitored through other regulatory mechanisms (i.e., EPEA and OSCA approvals);
- The FT that have been treated through an approved technology and placed in their final landscape position (except for specified exceptions) are assessed to determine if ready to reclaim (RTR) performance criteria has been met;
  - RTR performance criteria are a measure that is assessed annually to determine whether a volume of material has been treated effectively and are progressing on a trajectory to support future planned reclamation activities;
- Tailings areas that have finished receiving treated FT are further assessed to determine if these areas have met ready for reclamation (RFR) criteria and are capable of supporting planned reclamation activities;
  - The RFR criteria is a final measure that is assessed to determine whether a treated FT deposit is ready for reclamation activities and the trajectory is monitored through other regulatory mechanisms (i.e., EPEA and OSCA approvals).

This Plan has been developed in accordance with the approach outlined above and has been aligned with relevant regulatory approvals.

Figure 1-2: Summary of Directive 085 Scope



The Plan does not differentiate between legacy and new FT. The measurement techniques described in this *Measurement System Plan* apply to all FT. The distinction between legacy and new FT profiles will be made at the time of reporting.

1.2. Measurement System Plan Annual Cycle

The Plan is an annual cycle with 5 key activities, including:

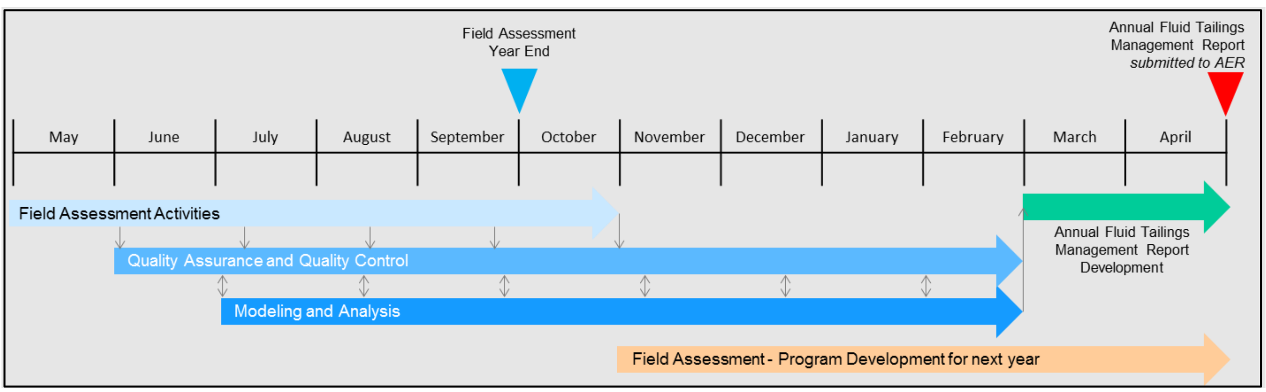
- Field program development;
- Field assessment activities;
- Modelling and analysis;
- Quality assurance and quality control (QA/QC); and
- *Annual Fluid Tailings Management Report* construction.

Field assessments are primarily completed during the summer months when access to the deposits is safest (Figure 1-3). In order to ensure that the requirements of Section 5 of Directive 085 (AER 2017a) are met, data collection in the field must be completed with sufficient time to allow for modelling, analysis and QA/QC to occur prior to report submission.

To ensure the accuracy of reported FT volumes and to meet the requirement that all reported volumes are to be measured volumes, October 1st has been selected as the target '*year-end*' (i.e., annual cycle from October 1st to September 31st as illustrated in Figure 1-3). To achieve this, specific assets that have the largest influence on the overall FT inventory (i.e., assets that either contain the most FT or assets that are subject to higher annual FT volumes fluctuations) will be scheduled to have field assessments completed as close to this date as practicable (i.e., targeting within a month). This minimizes the variation in the reported FT inventory due to time gaps between assessments.

The reporting cycle (as illustrated in Figure 1-3) is consistent with the definition of "*Fluid Tailings Inventory*" that states "*total volume of fluid tailings measured in treated tailings deposits or fluid tailings ponds, excluding any volume that meets specific RTR criteria at time of measurement*" (Appendix 3 of Directive 085 [AER 2017a]) and AER's clarification on Directive 85 – Fluid Tailings Management Reporting Requirements by letter dated January 27, 2020 (AER 2020).

Figure 1-3: Measurement System Plan annual cycle



The annual cycle incorporates an ongoing continuous improvement process, and includes:

- Analysis and modelling of data from the previous year's program;
- Assessment of improvements to program to ensure quality information is provided as per Section 5 of Directive 085 (AER 2017a); and
- Definition of upcoming assessment scope based on learnings.

This may result in increases or decreases to scope, including:

- field measurements;
- samples;
- modelling; and
- analysis procedures.

Reporting will continue to be improved and revised as dialogue continues over tailings management and reporting to help ensure transparency in how the outcomes specified in Directive 085 (AER 2017) are being met. This may result in changes to the reporting methodologies as described within this plan.

1.3. Concordance and Reporting Requirements

The purpose of this Plan is to provide the planned measurement methodologies in accordance with the following requirements:

- Directive 085 (AER 2017a)
  - Section 5 (Requirements 17 to 20)
- “Measurement System Plan Requirements” letter (AER 2017b)

To identify the sections within this Measurement System Plan that satisfy specific requirements as outlined above, concordance tables are provided in Appendix 10.3.

This Plan also provides the measurement methodologies required to support the *Annual Fluid Tailings Management Report*. A concordance for the requirements of the annual report is provided in Appendix 10.3, including:

- Directive 085 (AER 2017a) (section 6.2);
  - Fluid Tailings Volume Reporting Requirements, and
  - Monitoring Reporting Data Requirements.
- OSCA Approval No. 8535S, Condition 45 and Appendix C

2. JUSTIFICATION OF MEASUREMENT, SAMPLING AND SPACING INTERVALS

The basis of this Plan has been refined over more than 50 years of operations and has provided consistent and reliable inventories. Measurement, sampling and spacing intervals are based on historical work as described below and will continue to be improved as the information collected is reviewed.

Since 2006, geological block modelling processes has been used to build representative 3-dimensional models of the tailings deposits. For most of the pond deposits, vertical settlement of FT is the primary influence on the deposit's behaviour, which results in a gradual increase in material density with depth and lateral continuity within the deposit. This behaviour allows for an assumption that the samples within each test site are more related to samples at similar depths elsewhere in the deposit, and that the relationship could be based on the linear distances between them. This estimation method is known as "*inverse distance*". In order to determine the spacing and number of test sites, a model would be run with all the available data and mass total estimates of the FT compositions. One of the sample sites would then be removed at random, and the model would be rerun, producing comparable totals. This would continue until the estimated totals deviated significantly from the full data runs. This was assumed to be the minimum number of test sites required for the asset, and has proven to result in robust annual assessments that show acceptable variation over time. Typical spacing for this analysis is shown in Table 2-1 in the 2017 area per test site. As shown in the *Asset Description Sheets* provided in Appendix 10.9, each test site location will have samples taken at pre-determined depth intervals. These values range from as low as 13 hectares per site for Pond 5 to as high as 80 hectares per site for Pond 7.

This Plan embeds continuous improvement initiatives to ensure ongoing quality analyses. Prior to producing the block model, data from the test sites will be analysed geostatistically to determine how they relate to each other. Physical considerations such as structural controls, deposition and withdrawal conditions, and pond bottom slopes are included, with the sample relationships determining how the various sample datasets will be combined in the block model. This geostatistical analysis also provides clear estimates of likely error, and informs the number of sites and spacing requirements for the asset. This methodology is an important component of the measurement plan, as not all of the tailings assets conform to the previous assumption of vertical settlement as the dominant control on material properties.

Table 2-1: Planned Test Sites for Tailings Pond Assets

Pond Name	2017 Test Sites	2022 Plan Test Sites	2022 Pond Area	2017 Area per Test Site	2022 Area per Test Site
	(number of)	*(number of)*	*(ha)*	*(ha/site)*	*(ha/site)*
Pond 1A(1)	2	N/A	N/A	25.0	N/A
Pond 2/3(1)	8	N/A	N/A	28.8	N/A
Pond 5	17	17	220	12.9	12.9
Pond 6	5	5	279	55.8	55.8
Pond 7(2)	6	14	461	80.5	32.9
Pond 8B	11	10	175	64.8	21.9
STP	10	3	869	83.7	86.9
SD8(3)	3	3	100	33.3	8
DDA3	-	11	361	-	32.8
Total/Average	**62**	**68**	**2389**	**47.0**	**35.1**

Notes:

(1) No assessment for Pond 1A and Pond 2/3 in 2022

(2) Pond 7 assessment requirements may change once sand infilling begins.

(3)Sand Dump 9 and 10 will have similar assessment requirements as SD8.

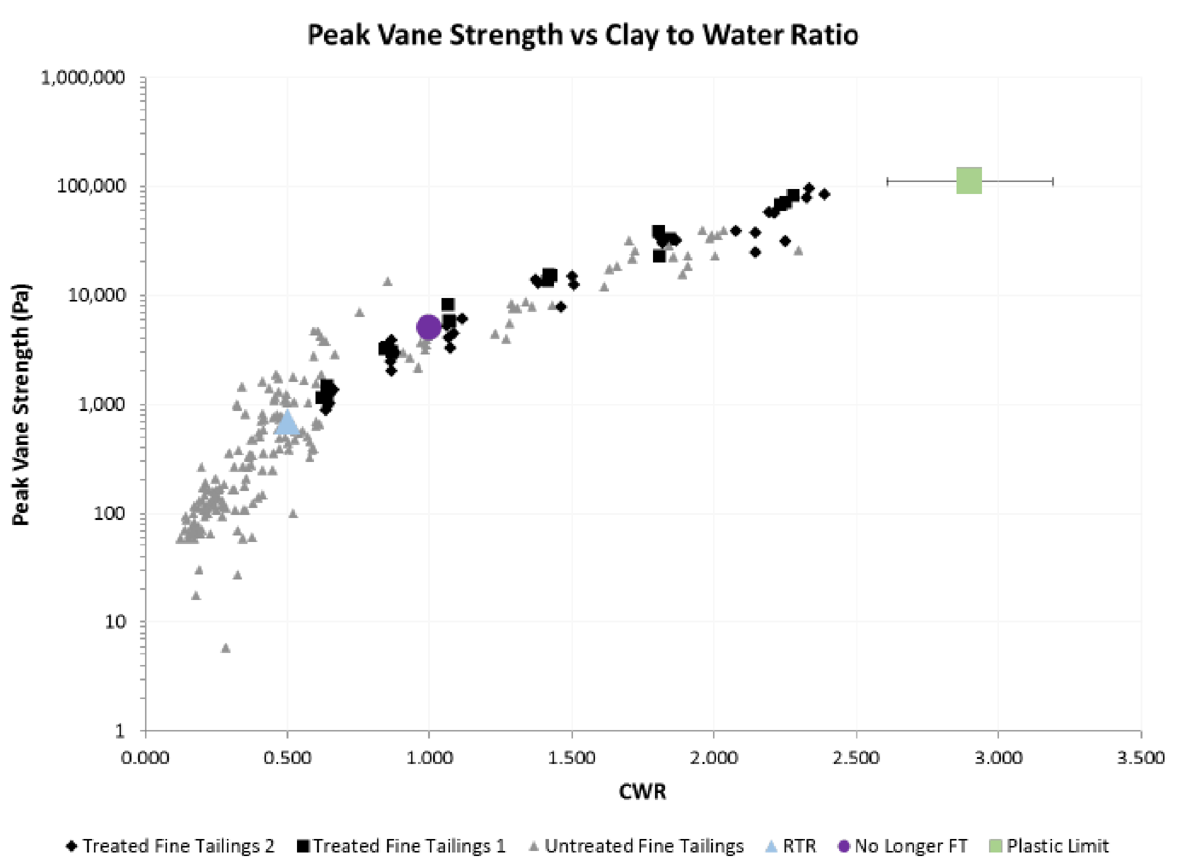
3. DETERMINATION OF FLUID TAILINGS

Annual assessments of tailings deposits are undertaken to measure the total site inventory of FT. This assessment measures the volume of FT in accordance to Directive 085 (AER 2017a), which defines FT as "*any fluid discard from bitumen extraction facilities containing more than 5 mass percent suspended solids and having less than an undrained shear strength of 5 kilopascals*".

3.1. Fluid and Non-Fluid Tailings

A key classification for tailings as defined by the AER is the measure of undrained shear strength. The measurement of this parameter in tailings deposits has refined over several decades and 2 primary field measurement tools are utilized, vane shear and ball cone penetration tests (B-CPT). The correlation of the undrained peak shear strength to clay to water ratio (CWR) is provided in Figure 3-1 (originally provided in Suncor 2016b).

Figure 3-1: Relationship between Undrained Peak Shear Strength and CWR



Vane shear and B-CPT are the standard in measuring in-situ strengths of materials with a peak undrained shear strength less than 10 kPa (e.g. clay dominated deposits). ASTM standards are applied in the use of these tools and the results are considered reliable. In order to increase the confidence, both methods are used in combination; with the vane shears providing validation of the data provided by the B-CPT tests.

Based on the correlations developed with vane shears and B-CPT to CWR, CWR can be used to determine when fines dominated deposits are no longer FT (i.e., CWR correlates to undrained shear strength). When the CWR is greater than or equal to 1.0, the correlated undrained shear strength is greater than or equal to 5 kPa, and the material is no longer classified as FT.

This is an important consideration in several situations. When assessing the effectiveness of a tailings treatment and deposition system, CWR provides a method of evaluating and predicting the transition from fluid to non-fluid tailings. This method is also insensitive to changing sand and silt contents (i.e., changing sand to fines ratios [SFR]), which can impact other measurements, such as solids content, in providing predictions of behaviour and evaluations of dewatering performance from the tailings treatment stage through to the final placed deposit. In addition, deposits containing ice can be sampled and tested to produce a reliable measure of the strength of the material once thawed, aiding in determining whether or not this material is FT.

3.2. RTR Status

Approved RTR criteria are included in Appendix C of the Base Plant OSCA Approval No. 8535S. Section 6 of this Plan summarizes how the measurements, calculations and reporting on RTR status will be completed as part of the *Annual Fluid Tailings Management Report*. Additional details are provided in the tailings asset description sheets provided in Appendix 10.9 for Pond 5, Pond 6, Pond 7, Dedicated Disposal Area 3 (DDA3), Dedicated Disposal Area 1 (DDA1), MD9 Co-disposal, and MD9 South Co-disposal.

4. KEY MEASUREMENT METHODS & PARAMETERS

4.1. Deposit Measurements

Consistent with, or in addition to the methodology outlined in the *Guidelines for Determining Oil Sands Fluid Tailings Volumes* (COSIA 2015c) and included as Appendix 4 of Directive 085 (AER 2017a), the volume of FT within a tailings asset is determined (illustrated in Figure 4-1) following the standards referenced in Table 4-1.

Figure 4-1: Tailings Asset Inventories

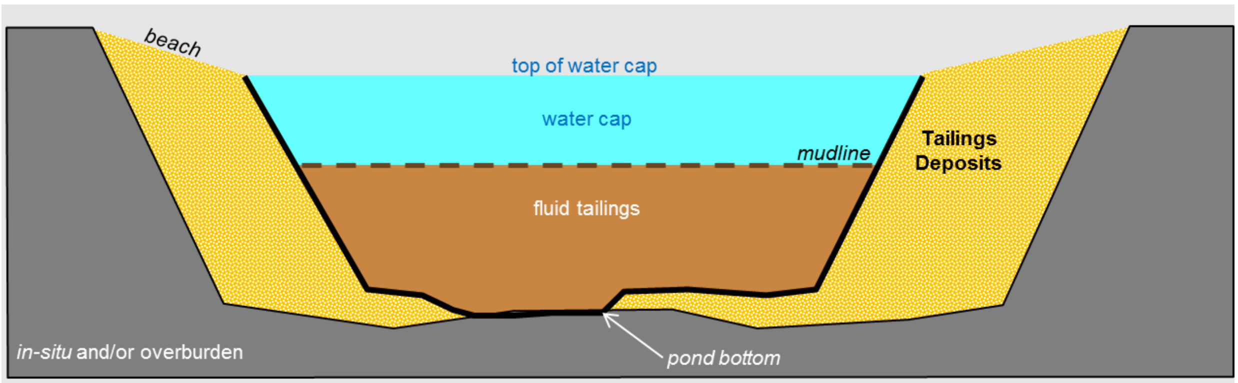


Table 4-1: Tailings Testing References

Test Name	Reference
Clay to water ratio	*Laboratory Test – Methylene Blue Procedure dried solids* OR *Laboratory Test – Methylene Blue Procedure sludges and slurries*
	Appendix 10.5- Methylene Blue Testing Procedures
Bitumen/Mineral/ Water content (Dean and Stark)	*Unified Fines Method for minus 44 micron material and for Particle Size Distribution*
	refer to COSIA (2016); Dean and Stark methodology is described in Appendix A of this document
Particle Size Distribution	*Unified Fines Method for minus 44 micron material and for Particle Size Distribution*
	refer to COSIA (2016)
Top of water cap	*Guideline for Tailings Deposit Sampling and Measuring Tools*
	refer to COSIA (2015a)
Top of FT	*Guideline for Tailings Deposit Sampling and Measuring Tools*
	refer to COSIA (2015a)
Pond Bottom	*Guideline for Tailings Deposit Sampling and Measuring Tools*
	refer to COSIA (2015a)
NORMs concentration	Gamma CPT Indicator Mineral Identification
	Appendix 10.6- Gamma-CPT Identification of NORM Potential in Tailings Deposits
Deposit Strength	*Measuring Undrained Shear Strength of Oil Sands Tailings Deposits*

Table 4-1: Tailings Testing References

Test Name	Reference
	refer to COSIA (2015b)
CPT Testing	*Guideline for Tailings Deposit Sampling and Measuring Tools*
	refer to COSIA (2015a)
Tailings Behaviour Type	*Guideline for Tailings Deposit Sampling and Measuring Tools*
	refer to COSIA (2015a)
Water Chemistry	Water Quality Testing Guide
	Appendix 10.6- Water Quality Testing Guide

4.1.1. Base Plant Testing Methodology

4.1.1.1. Site Specific Testing Methodologies

Site specific testing methodologies utilized include the two methylene blue laboratory tests (testing procedures are summarized in Appendix 10.5) and the gamma cone penetration tests (G-CPT) and gamma-ball CPT (GB-CPT) tests to determine CWR. These tests have been developed over several decades, and have been used to consistently and reliably describe the behaviour of tailings materials. Gama cone penetration test (G-CPT) and gamma ball CPT (GB-CPT) test methodologies have either been developed by research facilities or by independent organizations to measure CWR, however Base Plant does not use these methods to determine the properties of FT for reporting purpose at this time. These methods are further described, including appropriate justification, in the proceeding sections.

4.1.2. Field Testing

4.1.2.1. Volumetric Surveys

The volume of FT is defined as the materials above the pond bottom and below the mudline, as illustrated in Figure 4-1. The total volume of water cap is defined as all fluids located above the mudline. The methodology used to survey the pond bottom (or hard bottom), mudline and water cap are summarised in the following sections.

Pond Bottom Measurement

The pond bottom surface (Figure 4-1) is measured through the use of drop weights (or drop soundings) in water capped tailings ponds using the CT09™ sounding tool (or similar), and CPT strength testing in areas where drop weights are not practicable. Reference details are provided in Table 4-1.

Mudline Measurement

The top of FT, referred to as the mudline (Figure 4-1), is most often measured using a sonar survey on deposits with a water cap, or by an aerial survey such as LiDAR or air photo or satellite image interpretation where there is no water cap. Reference details are provided in Table 4-1.

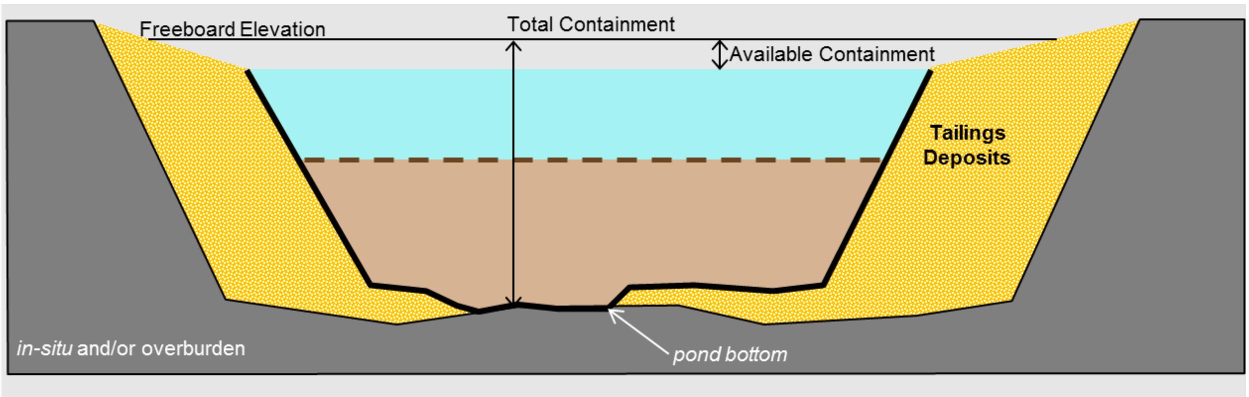
Water Cap Measurement

In areas where water volume needs to be measured, the water surface elevation is measured using surface survey techniques or can be determined from LiDAR or air photos. Reference details are provided in Table 4-1.

Total Containment

Total containment is defined as the total available containment of fluids (e.g. FT and water) in a tailings asset maintained below the allowable freeboard elevation (i.e., maximum allowable fluid elevation within a tailings asset) and above the pond bottom. The freeboard elevation is dictated by the geotechnical design and performance of the containment structure and meeting dam safety regulations, as illustrated in Figure 4-2.

Figure 4-2: Tailings Asset Containment



Available Containment

Available containment is defined as the unused portion of the total containment this is available for fluid containment by the operations. This volume is calculated as the volume beneath the freeboard elevation and above the used containment (i.e., typically top of watercap or top of FT if no watercap is present).

4.1.2.2. Material Properties

In order to understand material properties of the various deposits contained within a tailings asset, samples are collected for laboratory analysis, as well as several downhole tools are used to obtain material properties of in-situ materials.

4.1.2.3. Fluid Sampler

The Fluid Sampler tool is capable of obtaining samples of both water and FT material at depth, which are then analyzed in the lab. Reference details are provided in Table 4-1.

4.1.2.4. Sonic Sampler

This system uses a sonic piston sampler and a drill rig that has been fitted with a sonic drill head. It is designed to collect a 50 mm diameter sample in one or two meter lengths. This system is best used to sample competent tailings materials with higher yield strengths than FT. Once samples are collected, they are then sent to the lab for analysis. Reference details are provided in Table 4-1.

4.1.2.5. Settlement Marker Plates

Settlement plates are used to measure elevation changes as a controlled survey point either on the surface of or at depth in a deposit. In the case of capped tailings, plates are located at the interface between the mitigation cap and the FT. A fixed rod is attached to the plate, and the cap is placed on and around the instrument. Surveys taken of the elevation of the top of the rod accurately reflect the elevation of the plate below the cap and are insensitive to changes in the cap thickness.

4.1.2.6. Gamma CPT and Gamma Ball CPT

In recent years, work on downhole tools, such as the CPT; have enabled field measurement of tailings properties which had previously only been available from laboratory analysis of collected samples. The use of these tools allows for a larger dataset which can be assessed for the deposit and which allow for a more representative sampling program.

The G-CPT and GB-CPT uses a receiver to determine the amount of gamma rays being emitted by the surrounding material. In conjunction with additional measures taken by the tool, including tip and sleeve resistance and pore pressure measurements, a series of correlations can be made to material properties.

Once this data is collected, the various readings can be correlated to the specific material types and physical characteristics in the deposit. Through examining readings such as tip resistance, sleeve friction, pore water pressure and gamma counts per second (cps), a correlation algorithm known as the Tailings Behaviour Type (TBT) analysis is capable of producing reliable assessments of tailings deposits which includes solids content, fines content, in-situ strength, and clay-to-water ratios. In addition, the tool provides an almost continuous trace within the deposit, increasing the number of analysis points when compared with interval point samples. Statistical validity of the continuous traces is compared to laboratory sample profiles to validate the TBT analysis, and is also used to refine and improve TBT results. As data is collected and correlations improved, reliance on laboratory sampling may be reduced in future.

Due to the presence of naturally occurring radioactive materials (NORMs) within any tailings deposits, gamma ray detectors can determine the presence of higher concentrations of NORMs within a deposit. The conventional gamma probe used in conjunction with penetration testing is the standard industry practice. More information is provided in Section 6.9.1.

Reference details for both the G-CPT and TBT aspects of this method were provided in Table 4-1.

4.1.2.7. Vane Shear Testing

This test is conducted to understand the in-situ undrained shear strength of a deposit. The test involves the use of a calibrated vane, inserted into the tailings deposit to be tested, and turned at a specific rate of rotation. Measurements are taken as to how much force is required to start and maintain this rotation, and those values are recorded as strengths of the deposit. In general use, this test is done on a few of the sites as a validation of strength measurements taken with the G-CPT and GB-CPT tests only.

Reference details for this test are provided in were provided in Table 4-1.

4.2. Laboratory Tests

Testing of oil sands tailings materials have been conducted for several decades through the collection of samples, followed by analysis in the laboratory. Several tests have become standard, and are used to predict the behaviour of the material both in the field and during processing.

4.2.1. Bitumen, Mineral and Water

The Dean and Stark test, also known as a Bitumen Mineral Water (BMW) test, is the standard in measuring weight percent values of bitumen, mineral, and water in a sample.

4.2.2. Particle Size Distribution

A common determination of material behaviour is the size of the mineral particles in the sample (i.e., particle size distribution [PSD]). The use of the wet sieve test is common, with the oil sands industry selecting a particle size of 44 microns as the differentiator between sand and fines (see Table 4-2).

Table 4-2: Particle Size Distribution Classifications

Material	Parameter	Measurement Method
Sand	> 0.044 mm particle site	weight percent retained by 325 mesh sieve
Fines	< 0.044 mm particle site	weight percent passing 325 mesh sieve

Sands and fines contents are reported as the weight percent of the total dry mineral or as weight ratios (e.g. SFR). The use of SFR is an important component in evaluating tailings deposits, as the material deposit behaviour varies based on the sand content. Due to this classification for deposit types uses SFR as a primary differentiator.

4.2.3. Methylene Blue Test and Clay to Water Ratio

In order to determine clay content, and the CWR, industry standard BMW tests are combined with those designed to quantify the clay activity in a sample. The standard for measuring clay characteristics is x-ray diffraction (XRD). This provides both mineralogy and available surface area (based on the specific surface area contribution by each clay mineral). While detailed XRD can be considered the standard, it is an expensive and time consuming test.

Work done by the Advanced Separation Technology group at CANMET in Devon, Alberta, has compared several measurement methods with XRD, and determined that the methylene blue test provides the most consistent results that correlate well with detailed XRD results.

The methylene blue test is used to obtain CWR for all tailings streams and deposits. Testing procedures for methylene blue test are located in Appendix 10.5.

CWR can then be used to correlate with deposit dewatering behaviour, strength of the deposit and hydraulic conductivity.

4.2.4. Water Chemistry Testing

Routine water chemistry analysis is conducted on samples from various locations throughout the year. Details on the sampling program, including test methodologies are located in Appendix 10.6. The water quality characterization and reporting has been updated per AER letter dated February 23, 2022. (AER2022). Suncor notes in Appendix 10.7 that the measurement method for Naphthenic acids commercially performed is similar to the method stated in AER Letter (AER2022) which specifies a three step extraction similar to the method developed by Syncrude Research. Three step extraction method is not commercially available at this time. Base Plant's current vendor offers two testing methods which both use FTIR measurement but vary the extraction method used prior to the FTIR measurement. One is based on the USEPA 3510 Standard or a second modified version of the Syncrude Method that also uses a single extraction step. Suncor's historical measurements of Naphthenic acids has been to USEPA 3510 extraction method and the Measurement System Plan reflects this to maintain historical data integrity. Asset specific testing requirements are provided in the asset description sheets in Appendix 10.9.

4.3. Key Measurement Parameter Summary

Overall, performance of tailings is assessed using the parameters summarized in Table 4-3 and described in the previous sections.

Table 4-3: Measurement Method Summary

Key Parameter	Analysis Supported	Measurement Methods Employed
CWR	primary dewatering and strength indicator for FT	G-CPT, laboratory sample analysis (BMW, methylene blue and PSD)
solids content (% solids)	dewatering indicator	G-CPT, laboratory sample analysis (BMW)
fines content (% fines)	SFR and fines in FT	G-CPT, laboratory sample PSD
in-situ strength	FT inventory determination	G-CPT, vane shear
% bitumen	composition requirement	laboratory sample analysis (BMW)
water volume	total contained water	water surface survey, sonar
mudline (for water capped pond)	FT volume determination	sonar
pond bottom	FT volume determination	CT09™ / CPT
NORMs concentration	indicator of other COPCs	G-CPT
water quality	water chemistry changes with time	laboratory sample methods (See Appendix 10.7)

(1) Where NORMs are naturally occurring radioactive minerals

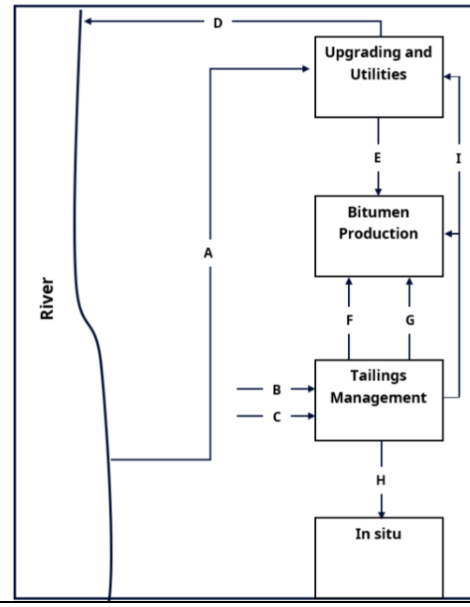
4.4. Process Measurements

4.4.1. Site wide water balance

Base Plant and the other operations have worked collaboratively to develop a common template to be used by each operation to report water balance information that accounts for the differences in the operations. The intent of the template was to provide consistent information. The template (Figure 4-3) is utilized in the Annual Fluid Tailings Management Report (Suncor2021b). Annual values for the points labeled A through H on Figure 4-3 will be provided, for its reporting. These values will be and are based on annual averages of measured volumes (composite and grab samples).

Figure 4-3: Standardized Site Wide Water Balance Report Template

Identifier	**Description**	**(Mm³)**
A	Gross River Water Intake	13.9
B	Ground Water – Fresh	0.9
C	Surface Water Runoff – Fresh	13.3
D	Water Returned to the Athabasca – via outfall	1.5
E	Utilities and Upgrading to Bitumen Production	8.2
F	Bitumen Production to Tailings Management	165.7
G	Tailings Management to Bitumen Production	121.9
H	Regional Water to In Situ Facilities	1.5
I	Hot Process Water to Utilities from Tailings	38.7



4.4.2. Permanent Aquatic Storage Structure Treatment Process

Volumes and quality of source FT transferred from source tailings assets, treated by the Permanent Aquatic Storage Structure (PASS) process (described further in Section 6.2), and deposited in DDA3 will be measured and reported as annual volumes. An average CWR and solids content of the total volume will be provided, along with the distribution of CWR values transported to the treatment system.

5. ASSESSMENT AND MODELING

Several phases of analysis of field and laboratory data are conducted in order to understand and report on FT performance. These activities meet the requirements of Section 5 of Directive 085 (AER 2017a). This effort can be divided into several steps including the statistical analysis of field data, geospatial analysis of field data and pond material changes and validation, as described in the following sections. Most of the discussion provided in this section is focussed on depositional data and not water quality.

5.1. Statistical Analysis of Field Data

Once datasets have been collected, statistical analysis is conducted from a number of perspectives. Each dataset is analysed with the following:

1. All Asset data – summary statistics
   a) Univariate and covariate statistics for each of the following, including comparisons with depth:
      i. % solids by weight
      ii. MBi / % clay
      iii. % fines
      iv. % bitumen
2. Specific Asset Data – summary statistics
   b) Univariate and covariate statistics for each of the following, including comparisons with depth:
      i. % solids by weight
      ii. MBi / % clay
      iii. % fines
      iv. % bitumen
3. Outlier investigation
   a) Examine each dataset for outliers
   b) Determine whether each outlier is justified or requires investigation or reruns
   c) Flag any uncertain or incorrect data points as "*Not for Use*"
4. Comparison of current summary statistics to previous year's data
   a) Can the changes observed be explained by evolution of the asset (i.e., FT densification with time, dredge withdrawal impacts, sand placement, etc.)?
   b) Determine if changes in summary statistics are appropriate (If not, investigate data sets and results and correct where needed.
5. Examine distributions within individual material classifications

5.2. Geospatial Analysis of Field Data

Once the base datasets have been statistically validated, the next step is to conduct preliminary spatial analysis. This includes:

- Plot location maps of average values per hole
- Create maps of above values to look for spatial trends in X-Y plane
- Examine data for trends with depth
- Examine data for potential spatial sampling biases i.e., conduct declustering analysis.
- Estimate and model variograms in horizontal and vertical directions. Look for anisotropy in horizontal directions
- Krige models and perform cross-validation analysis
    - Check for unbiased errors and conditional unbiasedness. To aid in identifying potential errors and problem datum
- Conduct multi-variate and multi-variate spatial analyses:
- Calculate correlations between variables of interest
- Assuming multi-variate correlations exist, perform stochastic modeling:
    - Perform Project Pursuit Multivariate Transform (PPMT), to transform to a de-correlated multi-Gaussian space
    - Use sequential Gaussian simulation to model each property of interest in Gaussian units.
    - Perform PPMT back transform to get back to original unit space
- Perform simulated model validation:
    - Check for accuracy and precision in the simulated results using accuracy plots
    - Check for histogram, variogram and multi-variate correlation reproduction
- Calculate post-modeling products:
    - Average of all realizations (E-Type model)
    - Field-wide average parameters with uncertainty distribution

Once this analysis is complete, the univariate and multi-variate spatial analysis will be used for:

- Determining tailings area average values (such as CWR) with confidence intervals
- Determining material totals for each asset
    - Mass of fines/sand/water/bitumen
    - Volumes of contained material
- To identify strong and weak portions of the tailings area
- To identify areas of varying water quality and how it changes over time
- Characterizing how much (proportion) of a tailings area meets criteria (e.g. RTR) and mapping the volumetric locations of each.

Note that these validation and analytical procedures may also be used to determine geochemical distributions within a tailings asset where necessary, but is conducted only in tailings assets requiring this level of detail and analysis.

5.3. Pond Material Changes and Validation

In alignment with Section 5 of Directive 085 (AER 2017a), requirements for verification and validation, several checks to historical information are conducted to help verify and validate volume estimates. Once all spatial models are complete, a comparison of the new results and the previous year's block models is completed, when available. This comparison includes determination of the changes in the pond deposit's volume and tonnage, where applicable.

The intent of this check is to determine how the various deposits within the tailings asset have changed since the last assessment was completed. With current and prior year modelled values, differences can be compared to the process records, mass balance, operational events and impacts data for the same time period. This allows for a degree of validation as the datasets are independent. Where differences occur, further investigation will be conducted to determine the causes. If required, pending further investigation, the data provided through this validation may be used to adjust the assessment.

It is not intended that this information will be reported upon. It may be shared if it helps to identify any issues with the current year's assessment and is required to help explain what has occurred and why the assessment has been adjusted.

6. ASSET DESCRIPTIONS AND TAILINGS DEPOSITS

Tailings assets at Base Plant hold a variety of deposit types. These deposits are classified according to their behaviour within these assets, with the behaviours correlated to specific laboratory and field testing techniques utilized and refined over the greater than 50 years of operations.

6.1. DDA1

In-line flocculation (ILF) is used to describe the process by which FT are treated with flocculant and deposited in a DDA where FT expresses water. At Base Plant, flocculated FT is deposited in thin lifts in DDA1 and then left exposed to the atmosphere to dewater further (e.g. evaporation). The treated FT are excavated in the winter and approved for placement in MD9 and/or MD9 South where they are co-disposed with overburden.

Since DDA1 operations and ILF is no longer active, the details provided in previous Plans for effectiveness of this treatment has been archived and the removed from this plan . This information will be keep as archived in the event that Suncor should need to use this technology in the future at which time the Plan will be updated.

6.2. DDA3

Consistent with the MOA, TD Submission and the 2018 EPEA Renewal Application (Suncor 2016a and b, 2018b), PASS process includes treatment of FT with both ILF and coagulation and deposited in a DDA where it expresses water. Suncor will be using this technology in DDA3 where the treated FT are deposited in-pit. As per Appendix C of OSCA Approval No. 8535R, the approved RTR performance criteria for DDA3 is that treated FT achieves a CWR greater than 0.3 threshold based on deposition sampling and modeling and the annual average total suspended solids (TSS) in the release water is less than or equal to 500 ppm.

The DDA3 Phase 1 and 2 Asset Sheet has been updated to reflect the approved DDA3 RTR criteria, see Appendix 10.9 for additional information.

6.2.1. Representative Deposit Sampling and Calculation

6.2.1.1. Clay to Water Ratio

The treated FT in DDA3 will be measured using the same standards and procedures as other assets that contain FT. Test sites will be selected based on a starting basis of 35 hectares per site (as described in Section 2), with each test profile covering the entire deposit depth from the measured mudline to the pond bottom. Once this data is collected, total volume calculations and standard geospatial analysis and block modelling will be completed, to determine the deposit CWR.

The full depth of treated FT in DDA3 will be sampled, and this will represent more than one year's deposition.

6.2.1.2. Total Suspended Solids

Total suspended solids will be managed from samples taken from DDA3 recycle water barge. Annual average will be calculated based on this sampling.

6.2.2. DDA3 Reporting

Once all the data analysis is complete, reporting tables and maps will be produced for the annual report. This report will contain:

- Map showing the location of all test sites
- Representative cross sections of block model showing CWR
- Histogram of CWR data
- Comparison of CWR based on deposit sampling to RTR criteria
- Comparison of annual average TSS to RTR criteria

Suncor will report both the CWR and TSS as described above. If the situation arises where the CWR in some areas of the deposit are less than 0.3, but the TSS RTR criteria is achieved, Suncor will not report the treated material with CWR of less than 0.3 as RTR.

If during a given year the average TSS is greater than the RTR criteria, Suncor will report that year's treatment as not RTR until the appropriate mitigations can be applied. Previous year's RTR FT inventory status will not be changed.

6.3. Pond 5, Pond 6 and Pond 7

Pond 6 and Pond 7 will be RTR when the planned mitigation is complete. A map for each of the areas requiring mitigation will be provided and will include a comparison of the extent of the mitigation with cap design to demonstrate completion of the mitigation and that the FT within the deposit is now RTR.

Mitigation for Pond 5 is complete and therefore its status is RTR and as such asset data sheets for Pond 5 have been removed and archived.

6.4. Closed-Circuit Water Management Systems

All treated tailings deposits (Pond 5, Pond 6, Pond 7, MD9 Co-disposal, MD9 South Co-disposal and DDA3) have a subobjective 2 RTR criteria for "Surface water and seepage" that must demonstrate that "the closed circuit water management system is operating as designed".

This will be demonstrated in the *Annual Fluid Tailings Management Report* by reporting the frequency of system inspections, summary of loss of containment incidents with mitigations, and notated annual air photo inspection documents.

6.5. MD4 and Wapisiw Lookout (Pond 1)

Two additional deposits contain minor volumes of FT, those being Mine Dump 4 (MD4) and a small area within Wapisiw Lookout. These areas are considered RFR as described in Section 1.1. Any volume of FT within these deposits is not part of the approved FT inventory. Based on this, there are no measurement requirements under Directive 085 (AER 2017a) for these assets.

6.6. MD9

Placement of co-disposal material within MD9 has ceased as of 2020, including DDA1 treated tailings and overburden, the MD9 Co-disposal area will be capped with overburden to begin progressing the reclamation of the structure.

6.6.1. MD9 Co-disposal - Phase 1

The status of MD9 is currently settlement monitoring. As such, asset data sheets have been removed from the Plan for MD9 – Phase 1 and archived.

6.6.2. MD9 Settlement – Phase 2

Active dumping is complete in MD9 and Phase 2 is settlement monitoring of the structure. This is descried in the MD9 Phase 2 Asset Sheet.

6.7. MD9 South Co-Disposal

Pond 8B remnant FT and DDA1 treated FT will be transported to MD9 South and be co-disposed with overburden.

As per Appendix C of OSCA Approval No. 8535R, the approved Subobjective 1 RTR performance criteria for MD9 South Co-Disposal is Clay to water ratio > 0.5 in DDA1 based on deposit sampling and Annual overburden to tailings volume ratio > 1.

6.7.1. Overburden to tailings ratio and MD9 South Co-Disposal Area – Phase 1

Volumes and quality of source FT (treated or remnant) transferred from Pond 8B and DDA1, and co--deposited in MD9 South will be measured. MD9 South will be assessed following the same procedures as those used in MD9. Volumes of overburden will be validated monthly through load counts. The co-deposited volumes will be surveyed and/or modelled to determine total inventory. Additional details are provided in the MD9 South Asset Sheet.

6.7.2. MD9 South RTR Reporting – Phase 1

Once all the data is collected and analysis complete, reporting tables and maps will be produced for the annual report. This report will contain:

- Ratios of overburden to transported FT (remnant and treated) as annual volumes
- Range of CWR for treated FT and corresponding co-deposited volumes in MD9 South based on co-disposal area sampling
- Cross-section and plan view maps showing MD9 South co-disposal areas and deposit characteristics

Additional details are provided in the MD9 South Co-disposal Asset Sheet.

6.7.3. MD9 South Settlement – Phase 2

MD9 South settlement monitoring is proposed for Phase 2 only, once active dumping in the co-disposal areas is complete. This is described in the MD9 South Co-disposal Asset Sheet.

6.8. Mixed Deposits

Any particular column of material within a tailings asset will consist of layers of varying thicknesses and material properties, some of which may meet the physical definitions of FT and some of which may not. This produces a challenging environment for the determination of a single FT volume and can pose problems in developing a single overarching procedure that applies to all deposits under all conditions. Due to this, the 5 kPa FT definition, RTR criteria for a particular deposit, and reasonable technical assumptions are used to determine the specific volumes of FT within each tailings asset on a case-by-case basis. These assumptions and data interpretations are provided in each *Annual Fluid Tailings Management Report*.

6.9. Froth Treatment Tailings

Froth Treatment Tailings (FTT) are the water, mineral and hydrocarbon remaining after froth from primary extraction is processed to produce diluted bitumen in froth treatment. FTT is a tailings stream transported by a pipeline from the Naphtha Recovery Unit to a tailings area. This stream contains approximately 2% of the total mineral from the oil sands that are processed. When placed in a tailings pond this stream forms primarily a non-fluid deposit and the majority of the water in the stream is collected and recycled.

The minerals within the FTT come from the naturally occurring oil sands. All of the oil sands and tailings deposits will contain these minerals and have varying concentrations of the minerals from the oil sands. The water based flotation process utilized in extraction can result in an increase in hydrophobic (or oleophilic) minerals concentration due to the air used in flotation and the bitumen that is recovered. While there is a wide variety of mineral types found within the deposits, a series of naturally occurring radioactive minerals (NORMs) are common.

The hydrocarbons within the FTT come from residual diluted bitumen that was not recovered in the Froth Treatment process. The diluted bitumen is a mixture of bitumen from the oil sands and naphtha (i.e., light hydrocarbon separated from the bitumen during the upgrading process). All of the oil sands deposits and therefore all of the tailings deposits will contain varying compositions of hydrocarbons.

As a result, it is recognized that it is not the origin of the tailings (i.e., primary extraction or froth treatment), but the concentrations of COPCs in the tailings that dictates mitigation requirements. Therefore, The Plan is setup such that different types of COPCs (e.g. NORMs) are assessed in terms of operational, environmental, reclamation and closure impacts.

6.9.1. Measurement of FTT Placement and COPCs Identification

To meet OSCA Approval 8535S, condition 49 FTT (the stream in the pipeline exiting the Naphtha Recovery Unit) can only be placed in Ponds 2/3, 7 and 9. This will be measured by providing pipeline location data each year, showing discharge locations of specific tailings lines, pipeline diagrams showing routes of these lines, and notated air photos identifying line relocations with time. Fluids are transferred from Pond 2/3 and Pond 7 to manage fluid inventory on site and treat FT. Water is transferred to various locations on site via the utilities systems.

Due to the presence of NORMs within any tailings deposits, gamma ray detectors can determine the presence of higher concentrations of NORMs within a deposit with confidence. The conventional gamma probe used in conjunction with penetration testing is the standard industry practice. When the presence of elevated NORMs is detected, typically characterised by gamma readings in excess of 60 cps (see Appendix 10.6), the area will be identified for follow-up. NORMs are used as an indicator of other COPCs, and if the area has not been previously identified, the follow-up investigation will be conducted with the objectives to confirm the presence of COPCs; to determine the location, concentration and form of the COPCs; and to identify the make-up of the deposit including mineralogy, hydrocarbon content and density as necessary. The detailed scope of the investigation will be determined based on the conditions in the field, and will be reported as part of the *Annual Fluid Tailings Management Report*.

Another COPC is light hydrocarbons; the presence of this material may impact the performance of some of the treated FT materials, and as such is measured and modelled through the use of the modified Dean and Stark test (Appendix A of COSIA 2016).

7. DATA QUALITY ASSURANCE

7.1. Validation of Laboratory Data

As part of the scope of work, the service providers will provide on an annual basis written documentation of the results of internal QA/QC activities as they apply to the program. This documentation is to include, as a minimum, an outline of the provider's QA/QC philosophy (i.e., the methodology used to confirm the validity of the measurements, e.g. in terms of repeatability, accuracy, potential for measurement bias, conformance to analytical procedures), as well as a summary report of quality control statistics for the analytical program (e.g. by showing variability in blind duplicates for a representative number of samples within the total program). To further ensure best QC practices are being followed, sample blanks and/or duplicates will be sent to an additional service provider. A comparison of these data will be assessed prior to data being used in the *Annual Fluid Tailings Management Report*.

7.2. Validation of Field Data

Volumetric testing focuses on pond bottom measurements with the CT09™ tool, mudline soundings with sonic equipment, and strength testing with vane shears or G-CPT.

In general, QA/QC efforts focus on equipment maintenance and calibration (using ASTM standards where available), collection and evaluation of repeat soundings, cross validation with different tools or field samples, and monitoring and control of equipment positions during testing as described in Appendix 10.4. Ensuring proper training and adherence to procedures is important, and the service provider provides verification records on these efforts.

7.3. Validation of Gamma and Gamma-Ball CPT

Similar to validation work of volumetric data, geo-physical QA/QC focuses on equipment maintenance and calibration (using ASTM standards), as well as the collection and evaluation of repeat site profiles. In addition, equipment components, like the gamma detection module, are calibrated against known source materials to ensure proper responses.

Further details on this validation are provided in Appendix 10.4.

7.4. Validation of Spatial Model Data

Once the spatial models have been completed, a series of statistical analysis are produced to determine confidence intervals in the values, correlations between variables, accuracy in the simulated results using accuracy plots, and a check that the histogram, variogram, and multi-variate correlations are comparable to the original sample values.

8. DATA MANAGEMENT SYSTEM

As per Section 5, Condition 18 of Directive 085 (AER 2017a), an existing database systems and processes are utilized, including (but not limited to) geological data. This system meets the requirements of this condition in the following manner:

- Verification: the process to ensure that data are evaluated for accuracy, errors and inconsistencies after data migration is done.
  - A database is used to store geoscience data. Upon import, data is validated against strict import rules, native to the software. Custom data is used for verification on import, ensuring issues with data are captured early in the process. These processes are flexible, allowing for data validation and improvement over time, and thus reducing errors and inconsistencies prior to importing.
- Validation: follows verification; a process to compare data to documented acceptance criteria.
  - Following import to the database, new data can be analysed and compared to existing data. Statistics and graphs can then be run from the database system itself, or exported for analysis via other platforms, to assess trends and identify outliers. Several tools are available for storing and analysing QA/QC sampling data, such as duplicate samples, inter-laboratory samples, blind samples, standards, blanks etc.
- Integrity: maintaining and assuring the accuracy and consistency of data over its entire life cycle.
  - A database record tracking is used as a live audit trail of data updates over time. Record tracking captures all changes to data (what was updated, who updated it and when). Data can also be locked down, to prevent any updates.

A stringent database backup process is in place for disaster recovery.

9. SUMMARY

The Plan, achieves the measurement outcomes as outlined in Section 5 of Directive 085 (AER 2017a), by utilizing the following:

- An annual assessment cycle structured to provide accurate and representative data,
- A robust system based on standardized industry testing that has been refined through years of operation,
- A sampling program based on continuous improvement that provides a representative and complete data set,
- A system with checks and balances which ensures comparability of data
- A suite of assessment techniques focused on providing the ability to discriminate differences in performance
- A data management system which verifies, validates and ensures the long term integrity of data.

Methods for FT measurement and treatment performance will be continuously reviewed to improve them. An annual review of its *Measurement System Plan* will be undertaken to ensure that it continues to meet the measurement outcomes as defined in Section 5 of Directive 085 (AER 2017a).

A summary of measurement tools and frequency for the measurement of water and FT volume for Directive 085 reporting is attached as Appendix 10.10. A summary of measurement tools and frequency for the measurement properties of fluid tailings for determination of RTR status is attached as Appendix 10.11.

10. APPENDICES

Appendix 10.1 Acronyms and Definitions

Appendix 10.2 – References

Appendix 10.3 – Concordance Tables

- *Concordance to Directive 085*
- *Concordance to Measurement System Plan Requirements Letter*
- *Concordance to OSCA Approval No. 8535S*

Appendix 10.4 – Pond Assessment Field Techniques (QA/QC Processes)

Appendix 10.5 – Methylene Blue Testing Procedures

Appendix 10.6 – Gamma CPT Identification of NORM Potential in Tailings Deposits

Appendix 10.7 – Water Quality Testing Guide

Appendix 10.8 – MD9 Settlement and Pond 5 Monitoring Plan

Appendix 10.9 – Tailings Asset Description Sheets

Appendix 10.10 - Summary of Measurement of Water and Fluid Tailings Volume – Tools and Frequency

Appendix 10.11 - Summary of Measurement of Fluid Tailings Properties for Determination of RTR Status

10.1. Acronyms

Acronym	Definition
AER	Alberta Energy Regulator
AD Test	Anderson Darling Test
ASTM	America Society for Testing and Materials
B-CPT	Ball – Cone Penetration Test
BMW	Bitumen Mineral Water
cm	Centimetre
COPC	Constituents of Potential Concern
COSIA	Canadian Oil Sand Innovation Alliance
cps	Counts per second
CPT	Cone Penetration Test
CT	Consolidated Tailings
CT09™	Conetec 2009
CvM Test	Cramer-Von Mises Test
CWR	Clay to Water Ratio
DDA	Dedicated Disposal Area
DDA1	Dedicated Disposal Area 1
DDA3	Dedicated Disposal Area 3
EPA	Environmental Priority Area
EPEA	Environmental Protection and Enhancement Act
ERP	Enhanced Review Process
FT	Fluid Tailings
FTT	Froth Treatment Tailings
G-CPT	Gamma - Cone Penetration Test
GB-CPT	Gamma Ball - Cone Penetration Test
ha	Hectare
hr/hrs	Hour/hours
ILF	In-Line Flocculation
kPa	Kilo-pascals
KS Test	Kolmogorov-Smirnov Test
m	Meter
MBi	Methylene Blue Index
mm	Millimeter
MD4	Mine Dump 4
MD9	Mine Dump 9
MD9 South	Mine Dump 9 South
MOA	Millennium Operational Amendment

Acronym	Definition
NORM	Normally Occurring Radioactive Minerals
NSE	North Steepbank Mine Extension
OSCA	Oil Sands Conservation Act
PASS	Permanent Aquatic Storage Structure
ppm	parts per million
PPMT	Project Pursuit Multivariate Transform
PSD	Particle Size Distribution
QA/QC	Quality Assurance/Quality Control
RFR	Ready for Reclamation
RTK GNSS	Real Time Kinematic – Global Navigation Satellite System
RTR	Ready to Reclaim
SD8	Sand Dump 8
SD9	Sand Dump 9
SD10	Sand Dump 10
SFR	Sand to Fines Ratio
SIR	Supplemental Information Request
STP	South Tailings Pond
TBT	Tailings Behaviour Type
TD	Tailings Directive (referring to Directive 085)
TFT	Thin Fine Tailings
TSS	Total Suspended Solids
VSD	Vertical Strip Drain
WBDA	West Bank Development Area
wt/wt	Weight to weight ratio
XRD	X-Ray Diffraction

10.2. References

Alberta Energy Regulatory (AER). 2015. Lower Athabasca Region Tailings Management Framework for the Mineable Athabasca Oil Sands. March 2015.

AER. 2017a. Directive 085. Fluid Tailings Management for Oil Sands Mining Projects. October 12, 2017.

AER. 2017b. "Measurement System Plan Requirements" Letter to Suncor dated October 25, 2017.

AER. 2020. "Notice of Reporting Requirement Clarification Directive 85 – Fluid Tailings Management Reporting Requirements" letter to Oil Sands Mine Operators dated January 27, 2020.

AER. 2022. "Notice of Reporting Requirement Clarification Directive 085 – Fluid Tailings Management Reporting Requirements. Water Quality Characterization and Reporting" letter to Oil Sands Mine Operators dated February 23, 2022.

Canadian Oil Sand Innovation Alliance (COSIA). 2015a. Guideline for Tailings Deposit Sampling and Measuring Tools. Prepared by COSIA Geostatistical and Deposit Sampling Working Group. April 27, 2015.

COSIA. 2015b. Measuring Undrained Shear Strength of Oil Sands Tailings Deposits. Prepared by COSIA Deposit Characterization Committee. April 2015.

COSIA. 2015c. Guidelines for Determining Oil Sands Fluid Tailings Volumes. June 2015

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.

CanmetEnergy. 2008a. Methylene Blue Procedure : Dean-Stark Solids. Natural Resources Canada, CanmetENERGY-Devon Extraction and Tailings, January 6, 2008.

CanmetEnergy. 2008b. Methylene Blue Procedure : Sludges and Slurries. Natural Resources Canada, CanmetENERGY-Devon Extraction and Tailings, January 6, 2008.

Kolmogorov-Smirnov test. Encyclopedia of Mathematics. URL: http://www.encyclopediaofmath.org/index.php?title=Kolmogorov-Smirnov_test&oldid=22659

Suncor Energy Inc. (Suncor). 2016a. Millennium Operational Amendment (MOA) Application, submitted to Alberta Energy Regulator; April 14, 2016

Suncor. 2016b. Suncor Base Plant Application for the Draft Tailings Directive, submitted to Alberta Energy Regulator; April 14, 2016.

Suncor. 2016c. Base Plant Millennium Operational Amendment Fluid Tailings Management Plan Supplemental Information Request Responses, submitted to Alberta Energy Regulator; September 20, 2017.

Suncor 2016d. Base Plant Millennium Operational Amendment Fluid Tailings Management Plan Supplemental Information Request Response Addendum, submitted to AER on December 23, 2016.

Suncor. 2017a. Suncor Base Plant Enhanced Review Process Clarification Request – Reference Guide, submitted to Alberta Energy Regulator; June 2, 2017.

Suncor. 2017b. Pond 5 Monitoring Plan, submitted to AER in compliance with AER Approval 8535N, Clause 34(a); November 30, 2017.

Suncor. 2018a. MD9 Settlement Monitoring Plan, submitted to AER in compliance with AER Approval 8535N, clause 43(a); February 28, 2018

Suncor. 2018b. Suncor Base Plant Environmental and Protection Act (EPEA) Renewal Application, submitted to the AER on April 17, 2018.

Suncor. 2019. Proposed Ready to Reclaim Criteria for Mine Dump 9 C0-Disposal Area, submitted to AER in compliance with AER Approval 8535N, Conditions 27 & 32 on September 27, 2019.

Suncor. 2020a. SIR – Suncor Base Plant. Request to Alter Tailings Management System Plan submitted to the AER on July 23, 2020.

Suncor. 2020b. Mine Dump 9 South (MD9 South) Co-Disposal Amendment Application submitted to AER on February 28, 2020.

Suncor. 2020c. Base Plant 2019 Annual Tailings Management Report Supplemental Information Request submitted to the AER on July 23, 2020.

Suncor. 2020d. Notification of Change to Tailings Operations, in response to COVID-19 submitted to AER on March 24, 2020.

Suncor. 2021a. Request for Modification of DDA3 RTR Criteria submitted to AER on May 14, 2021.

Suncor. 2021b. 2020 Annual Fluid Tailings Management Report Supplemental Information Request submitted to AER on August 20, 2021.

Suncor. 2022a. Suncor Mine Dump 9 South Expansion Amendment Application submitted to AER on February 11, 2022.

Suncor. 2022b. 2021 Base Plant Fluid Tailings Management Report (Directive 085 – Fluid Tailings Management for Oil Sands Mining Projects) – Supplemental Information Request 1 – Response Number 9 submitted to AER on August 2, 2022.

Water Environment Federation (WEF). 2017. Standard Methods for the Examination of Water and Wastewater, 23rd Edition. American Public Health Association, American Water Works Association and Environment Federation. 2017.

10.3. Concordance Tables

10.3.1. Concordance to Directive 085

		Requirement	"Project Title" Section
Section 5: Measurement Outcomes			
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:	Section 9
	a)	Accuracy: the degree to which the measurement matches the correct value.	*all sections*
	b)	Precision: the measure of agreement among repeated measurements of an indicator.	*all sections*
	c)	Sensitivity: the degree of ability to discriminate differences in performance of indicators	*all sections*
	d)	Representativeness: the degree that the data is a suitable measure of the condition being examined.	*all sections*
	e)	Comparability: a qualitative expression of the confidence that the quality of data is sufficient to contribute to analysis, even when measurement methods differ.	*all sections*
	f)	Completeness: the measure of the amount of valid data not omitted.	*all sections*
	g)	Bias: the measure of systematic distortion of measurements.	*all sections*
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 8
	b)	Validation: follows verification; a process to compare data to documented acceptance criteria.	Section 8
	c)	Integrity: maintaining and assuring the accuracy and consistency of data over its entire life cycle.	Section 8
19)		Operators must submit their measurement system plan to the AER within six months following approval of the tailings management plan.	*This document*
20)		Operators must address deficiencies in their measurement system plan identified by the AER.	-
Section 6: Fluid Tailings Management Reporting **Section 6.2: Fluid Tailings Management Report Requirements**			
Fluid Tailings Volume Reporting Requirements			
Include a project site summary of all annual fluid tailings volumes, as per the accounting table in appendix 3.			Sections 1.1, 6.1, 6.2, 6.3, 6.5, 6.6 and 6.7
		• Previous year inventory of new and legacy FT • FT inventory • Change in new and legacy FT inventory • New and legacy FT inventory • Approved profile new and legacy FT inventory • rolling profile deviation for new and legacy FT	

Requirement	"Project Title" Section
Show in a figure the approved new and legacy profiles with the actual fluid tailings volume and the three thresholds (profile deviation, total volume, and total volume limit).	Section **Error! Reference source not found.**, 6.2.2, 6.3, 6.5, 6.6 and 6.7
Describe if and how activities have deviated from the fluid tailings management plan and any modifications made to improve performance	*not a measurement*
Identify the management level (as described in the TMF) that the operation's performance falls within.	*not a measurement*
If the operation is deemed level 2 or higher, describe the circumstances that led to the increased fluid accumulation and any actions that are being taken to improve fluid tailings management performance.	*not a measurement*
Provide a site-wide water balance or provide the reference to another AER report and location where this information can be obtained.	Section 4.4.1
Provide a water volume (in tabular form) or provide the reference to another AER report and location where this information can be obtained. The table must include, for each treated tailings deposit and fluid tailings pond	Sections 4, 5 and 6
• total volume of water at the beginning of the reporting period, • total volume of water at the end of the reporting period, • characterization of the quality of water, and • the volume and quality of water recovered from fluid tailings and runoff from RTR tailings.	Section 4.1, 4.2, 4.4, 5, 6
Provide information about fines that were not captured, which form fluid tailings, including: • quantity of fines in the ore processed during the reporting period, and • quantity of fines in fluid tailings.	*not a measurement*
Estimate the change in fluid tailings volume inventory as a result of settling and consolidation and provide an explanation if inconsistent with the predictions.	Section 5
Provide a status map of the current locations and sizes of all fluid tailings ponds and treated deposits for the project.	*not a measurement*
Provide tables indicating the volume and composition of each deposit containing fluid tailings (including the volume of fluid tailings, of treated and placed fluid tailings meeting RTR status, and of water).	Sections 3, 4, 5 and 6
Provide tonnage of ore processed and average composition (bitumen, water, solids) or provide the reference to another AER report and location where this information can be obtained.	*not a measurement*
For each fluid tailings treatment technology, • provide volume of fluid tailings treated and where they were placed; • provide chemical and physical properties of the treated fluid tailings and the water recovered from treatment; and • if the technology is not performing as predicted, provide mitigation measures to rectify performance (address any impacts on the deposit performance).	Section 4 and 6

Requirement		"Project Title" Section
Monitoring Reporting Data Requirements		
For each monitoring dataset required in the annual fluid tailings management report,		Section 5 and 7
	• identify any uncertainties and • explain the dataset adequacy.	
For each treated tailings deposit and fluid tailings ponds and their surrounding environment provide monitoring results, including the following:		Sections 4, 5 and 6; Appendix 10.9
	• a map and tabular data showing the survey locations of tailings deposits; • representative cross-sections to illustrate the variation of tailings characteristics; • for each deposit containing treated and placed fluid tailings, • the measured data on the chosen indicators and confirm performance against the chosen performance criteria; • for those fluid tailings deposits that have met RTR status, data to support that it is trending appropriately; and • confirmation that indicator and performance criteria are still appropriate or justify the need to modify them; and • verification that the tailings deposit is meeting the milestones in the fluid tailings management plan.	

10.3.2. Concordance to "Measurement System Plan Requirements" Letter dated October 25, 2017.

Requirement		"Project Title" Section
The measurement plan must include the following:		-
	Key definition of parameters for fluid tailings and RTR criteria measurements.	Section 3 and 4
	Reference of standards and procedures used to measure fluid tailings, treated tailings and RTR criteria.	Section 4; Table 4-1
	An explanation of and justification for measurement procedures that are unique to Suncor and its plan.	Section 4.1
	Evidence that the plan will address the measurement outcomes as per section 5 of Directive 085, as amended.	Section 2, 3, 4, 5, 6 and 9
	An explanation of how each of the tailings deposit's RTR criteria will be measured, calculated and reported.	Section 4, 5 and 6; Appendix 10.9
	A description of the tailings deposit survey program.	Section 4 and Appendix 10.4
	Justification of how measurement, sampling, and spacing intervals will show the variation of the deposit properties, verify that the tailings deposit is achieving RTR criteria and	Sections 2, 5, and 6.2.1
	Identify if any material in the deposit is not achieving RTR criteria.	Sections 3, 4.1, 4.2, 4.4, 5 and 6
Froth treatment tailings: the measurement plan must also include:		-
	identification of substances of concern from froth treatment tailings,	Section 6.9
	measurement locations, and	Section 6.9
	measurement methodology for the substances of concern.	Section 4 and 6.9

10.3.3. Concordance to OSCA Approval No. 8535S

Requirement				"Project Title" Section
45	The Operator shall, in addition to any reporting required by Directive 085, provide in the annual fluid tailings management report:			-
	(a)	The available storage capacity of each tailings deposit or pond that contains water or tailings at the end of the reporting period;		Sections 4.1.2.1 and 6; Appendix 10.9
	(b)	Annual storage capacity and volume requirements for the five years following the end of the reporting period;		*not a measurement*
	(c)	An assessment of PASS technology operation for the reporting period, including		-
		(i)	the number of days the technology was not operating as intended;	*operational records*
		(ii)	a description of why the technology was not operating as intended; and	*not a measurement*
		(iii)	the variation of properties of the treated tailings and the released water ;	Section 6.2
		(iv)	the characterization of water recovered from treated tailings and runoff from ready to reclaim tailings required by Directive 085, including bitumen, hydrocarbons and ultrafines;	Section 4.1 and 4.2
		(v)	an evaluation of whether or not the treatment performance met the objectives stated in Application No. 1890348;	*not a measurement*

Requirement				"Project Title" Section
		(vi)	an assessment of consolidation, based on sampling and drilling data, of treated tailings within DDA3; and	Section 5
		(vii)	any other information the AER may require.	*not a measurement*
	(d)	A summary of research results and technology improvements supporting reduced Mine Dump 9 (MD9) reclamation timelines;		*not a measurement*
	(e)	Report on Pond 5 settlement, strength and dewatering; and		Section 6.3; Appendix 10.9
	(f)	Confirm the rate of Pond 5 settlement will support proposed commencement of reclamation prior to May 1, 2024 and will support the achievement of targeted final landforms, unless otherwise specified in writing by the AER		*not a measurement*
Appendix C - RTR criteria for Suncor Pond 5, Pond 6, Pond 7, MD9, MD9 South and DDA3				
Pond 5	Subobjective 1		capping with coke and vertical strip drains (VSDs) installation is complete in 2019	Section 6.3
	Subobjective 2		Surface water and seepage: The closed-circuit water management system is operating as designed. Groundwater is monitored as required by *Environmental Protection and Enhancement Act (EPEA)* Approval. 94-03-00, as amended on renewed	Section 6.4
Pond 6	Subobjective 1		Pond 6 mitigation is complete by December 31, 2028	Section 6.3
	Subobjective 2		Surface water and seepage: The closed-circuit water management system is operating as designed. Groundwater is monitored as required by *Environmental Protection and Enhancement Act (EPEA*) Approval. 94-03-00, as amended on renewed	Section 6.4
Pond 7	Subobjective 1		Pond 7 mitigation is complete by December 31, 2033	Section 6.3
	Subobjective 2		Surface water and seepage: The closed-circuit water management system is operating as designed. Groundwater is monitored as required by *Environmental Protection and Enhancement Act (EPEA*) Approval. 94-03-00, as amended on renewed	Section 6.4
MD9 Co-disposal	Subobjective 1		Clay to water ratio > 0.5 in DDA1 based on deposit sampling Annual overburden to tailings volume ratio > 1	Section 6.1 and 6.6
	Subobjective 2		Surface water and seepage: The closed-circuit water management system is operating as designed. Groundwater is monitored as required by *Environmental Protection and Enhancement Act (EPEA*) Approval. 94-03-00, as amended on renewed	Section 6.4
MD9 South Co-disposal	Subobjective 1		Clay to water ratio > 0.5 in DDA1 based on deposit sampling Annual overburden to tailings volume ratio > 1	Section 6.7
	Subobjective 2		Surface water and seepage: The closed-circuit water management system is operating as designed. Groundwater is monitored as required by *Environmental Protection and Enhancement Act (EPEA*) Approval. 94-03-00, as amended on renewed	Section 6.4
DDA3	Subobjective 1		Clay to water ratio > 0.3 threshold based on deposit sampling Expressed water from DDA3 treated tailings annual average total suspended solids ≤ 500 parts per million	Section 6.2

Requirement			"Project Title" Section
	Subobjective 2	Surface water and seepage: The closed-circuit water management system is operating as designed. Groundwater is monitored as required by *Environmental Protection and Enhancement Act (EPEA)* Approval. 94-03-00, as amended on renewed	Section 6.4

10.4. Pond Assessment Field Techniques (QA/QC Processes)

1. Introduction

3rd party expertise is relied upon to conduct pond assessments, field sample collection and laboratory analysis. Where available, 3rd parties follow ASTM or industry standards for the work completed. For activities not included in industry standard documentation, these 3rd parties are required to develop and execute QA/QC programs for the work planned, which results in reasonable assurances that the data provided is of sufficient quality to base technical and business decisions.

2. General Field Testing QA/QC

Quality Control (QC) procedures are put in place to ensure the performed services adhere to a defined set of quality criteria.

- Quality criteria:
  - 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)
  - 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
  - quality memos generated and communicated to all personnel

Quality Assurance (QA) procedures are put in place to ensure that the maintenance of a desired level of quality is maintained.

- Training conducted with all personnel on procedures and protocols, in
  - annual 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 Investigations Ltd. (Conetec) has been employed as the primary contractor for assessing tailings assets. The equipment and quality checks provided here are those used by Conetec. Alternative contractors executing this works will be required to meet or exceed the QA/QC standards described here.

Industry standard tools and techniques for assessing tailings deposits are utilized. Table 1 provides an index of the techniques used for each of the primary tailings material classes.

Table 1: Tailings Asset Field Assessment Techniques

Tailings Material	Technique	Primary Measures
Fluid Tailings	Gamma Ball CPT (GB-CPT)	Strength, TBT, temperature
	CT09 Pond Bottom Sounding	Pond bottom
	Fluid Sampling	FT Laboratory Material Properties
	Vane Shear	Strength validation
Mudline	Sonar Mudline	Mudline
	Fixed Interval Sampling	Mudline validation by sampling
Non-Fluid Tailings	Gamma CPT (GCPT)	Strength, TBT, temperature
	Sonic Sampling	Laboratory Material Properties
	Vane Shear	Strength validation

2.1 CT09 – Pond Bottom Soundings

The primary tool used by Conetec to determine pond bottom is known as the CT09™.

The objective of a CT09 survey is to define the bottom bounding surface (termed "pond bottom" or "hard bottom") for modelling fluid constituents and volume.

QA/QC activities

- 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 per cluster (with small offsets), multiple clusters in pond centered on a G-CPT or BG-CPT profile, ideally paired with sample data. ConeTec to assess the repeatability of CT09 hard bottom measurement versus G-CPT or BG-CPT and sample results and to provide a statistical analysis on a per-pond basis that evaluates the accuracy and precision of CT09 measurements in the facility.
- In ponds where hard bottom is not achieved with the CT09 due to a frictional refusal, suggest using G-CPT or BG-CPT as a more representative test.
- When the boat is not in a fixed location (dynamic positioning), collect high quality coordinates throughout the test sounding. *Guidelines for Tailings Deposit sampling and Measuring Tools* (COSIA 2015) 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 (i.e., in ponds where the mudline is deeper than 8 m, efficient anchoring is not possible with the current equipment). Opportunities for equipment improvement include:
  - longer (telescopic) anchoring spuds
  - RTK GNSS system (Real Time Kinematic – Global Navigation Satellite System) on workboat (centimeter accuracy) for positioning and coordinate measurement pre/post/during sounding

Quality Activities

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

2.1.1 Mudline Measurements – Acoustic Techniques

In water capped tailings deposits, determining the top of the FT material is required to obtain inventory volumes. Acoustic measurements are relied upon, as the FT mudlines tend to occur as sharp increases in % solids by weight and form a clear surface off of which acoustic signals readily reflect.

The objective of testing is to delineate the upper boundary surface (mudline) for fluid tailings (FT) volume and constituent modelling.

2.1.1.1 Single Beam Sonar

QA/QC Activities

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

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 a 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 10 cm of collected mudline from sampling

2.1.1.2 Swath Bathymetry

QA/QC Activities

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

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 equipment each time the equipment is deployed on a vessel.

- Ensure 3DSS Sound Velocity Probe is calibrated yearly

2.1.2 Field Sampling – Fluid, Sonic and Fixed Interval Sampling

Samples of FT are typically taken within a tailings deposit as vertical profiles from the mudline surface to pond bottom. The distance between samples varies depending on the variability within the deposit, the total thickness of the deposit, and the degree of confidence provided by previous assessments and geostatistical modelling. Samples have provided the basis for most historical assessments of Base Plant assets, and will continue to form a key component in the evaluation of the facilities as technology advances allows for migration to in-situ based material assessments.

Objective of tailings sampling: Collect profiles of physical samples for laboratory analysis, providing solids content, fines content, bitumen content, and clay reactivity testing.

QA/QC Activities

- Collect duplicate samples for every 50th sample.
  - analyze duplicate pairs for repeatability and provide summary statistics per deposit.
  - duplicate sampling density may need to be increased in smaller tailings facilities in order to get a statistically meaningful set of data pairs for the deposit
  - this error analysis will contain components of field collection error, spatial variability error and laboratory analysis error
- Laboratory subcontractor to select certain samples to duplicate for their own QA/QC
  - laboratory duplicate samples can be combined with duplicate samples for statistical analysis
- Instruct the laboratory to split occasional samples and report the laboratory split data
  - analyze laboratory duplicate pairs for repeatability and provide summary statistics per deposit
  - duplicate laboratory 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 get an approximation of field error versus laboratory error

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 10 cm of the mudline from FIS samples
- Locations with paired sampling/G-CPT/CT09:
  - mudlines should be within 10 cm
  - fluid sampler refusal is within 1 m of CT09 refusal
- YSI (environmental multi-meter to measure pH, ORP, Conductivity, temperature) calibrations performed daily in non-expired solutions
  - calibration readings are recorded after each sample profile
  - if the calibration readings are not within acceptable limits then the probe is recalibrated (currently deciding what the quantitative value of these limits is)

- it should be noted that this tool provides a qualitative assessment of pH, ORP, and conductivity. It is designed and intended for water samples.

2.2 Gamma (Ball) CPT - In-Situ Material Testing

2.2.1 Fluid Tailings

The primary tool used by Conetec to assess in-situ material properties for FT material is known as the Gamma-Ball Cone Penetrometer (BG-CPT). The strength of FT is presented as the primary defining characteristic of FT by the AER. As such, BG-CPT has been selected as the primary measure of undrained shear strength.

The objective of BG-CPT testing is to assess the undrained shear strength of tailings that flow around the penetrometer. BG-CPT 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 (i.e., TBT).

QA/QC activities

- 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 GB-CPT wear parts. This procedure is common in natural soils and compacted soils, however will provide limited value in FT besides operational transparency.
- Provide zero load readings for each sounding.
- Baselines between soundings should be similar for the same cone
- Provide the cone calibration check record for cones that have undergone a load-cell shift.
- Provide a table highlighting the point reading resolution for each capacity of penetrometer used on the project.
- TBT interpretations to be compared with sample results collected adjacent to the sounding. A statistical analysis of TBT variance from laboratory data will be presented with each report.
- Twinning a minimum of one sounding or approximately 1/10 of G-CPT holes with electric downhole vane shear testing to confirm assumptions in undrained shear strength interpretations in each tailings facility. Provided basis for Nball factor used in calculating the data.

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 or glycerine under vacuum pressure prior to use
- Recorded cone penetrometer baselines 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 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.

2.2.2 G-CPT for Non-Fluid Tailings

The primary tool used by Conetec to assess in-situ material properties for non-FT material is known as the Gamma Cone Penetrometer, or G-CPT test.

The objective of G-CPT testing is to provide detailed stratigraphic log of tailings deposit with direct measurements of tip resistance, sleeve friction, pore pressure and passive gamma. This measured data is used to calculate geotechnical parameters such as shear strength and tailings constituents (TBT).

QA/QC activities

- 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 CPT wear parts. This procedure is common in natural soils and compacted soils, however will provide limited value in FT besides operational transparency.
- Provide zero load readings for each sounding.
- Baselines between soundings should be similar for the same cone
- Provide the cone calibration check record for cones that have undergone a load-cell shift.
- Provide a table highlighting the point reading resolution for each capacity of penetrometer used on the project.
- TBT interpretations to be compared with sample results collected adjacent to the sounding. A statistical analysis of TBT variance from laboratory data will be presented with each report.
- Recommend twinning a minimum of one sounding or approximately 1/10 of G-CPT holes with electric downhole vane shear testing to confirm assumptions in undrained shear strength interpretations in each tailings facility. Provided basis for Nkt factor used in calculating the data.
- Report on methodology 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 laboratory data with the following assumptions; SG_{fines}=2.62, SG_{sand}=2.57, SG_{oil}/water=1 and unit Unit $Weight_{water}$=9.8 1 kN/m^3 or TBT.

$$G_{S\ total\ Sample} = \left[\frac{\frac{Total\ Sample\ Percent}{100\%}}{\left(\frac{(sand\ wt\%)}{G_{s\ sand}\ x\ 100\%} + \frac{(fines\ wt\%)}{G_{s\ fines}\ x\ 100\%} + \frac{(Oil\ wt\% + water\ wt\%)}{G_{s\ oil+water}\ x\ 100\%} \right)} \right]$$

$$\gamma_{material} = \gamma_{water}\ x\ G_{S\ total\ sample}$$

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 or glycerine under vacuum pressure prior to use
- Recorded cone penetrometer baselines 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 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.
- 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.
- fs >= 0, qt >= 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.
- qt >= ud
  - Because the tip is a total stress sensing device the tip resistance (qt) 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 FT the total stress is a result of the fluid pressure which is directly measured by the dynamic pore pressure (ud) channel.
- σv' >= 0.0
  - Effective vertical stress must not be negative. Due to the fact that in ConeTec software the total stress and the fluid pressure are independently calculated, slightly negative values may be computed.

2.2.3 Tailings Strength Validation - Vane Shear Testing

The strength of FT is presented as the primary defining characteristic of FT by the AER. As such, multiple measurement methods have been selected to employ in the field to build comparative datasets. The vane shear test is conducted in the field but is subject to differing error conditions than the primary GB-CPT method.

Objective of vane shear testing: Provide a direct measurement of undrained shear strength in-situ.

<u>**QA/QC Activities**</u>

- 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 FT) 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 (cvh)
  - A non-dimensional vane test time factor is then calculated based on the time elapsed between vane insertion and failure (tf) and the vane diameter (D) such that T = cvh*tf/D2
  - If T is less than 1.3 then 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.

<u>**Quality Activities**</u>

- Testing procedures generally meet or exceeds ASTM D2573. Variances from standard:
  - Extra-large vane for profiling FT (150x300mm)
  - Depths referenced to the middle of the vane blade, not to the vane tip
  - Rate of remolding is not recorded
  - Instead of plotting torque vs rotation, plot shear stress and rotation
- Appropriate vane selected for testing based on adjacent G-CPT or BG-CPT calculated undrained shear strength assuming an Nkt factor of 15 or Nball 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.

10.5. Methylene Blue Testing Procedures

This Appendix includes copies of the following:

- Methylene Blue Procedure : Dean-Stark Solids (CanmetENERGY 2008)
- Methylene Blue Procedure : Sludges and Slurries (CanmetENERGY 2008)

METHYLENE BLUE PROCEDURE:

DEAN-STARK SOLIDS

Revised by:
Dr. Oladipo Omotoso &
Michelle Morin

Revision date:
January 6, 2008

Natural Resources Canada
CanmetENERGY-Devon
Extractions and Tailings

1. OBJECTIVE AND SCOPE OF THE PROCEDURE

The Methylene Blue Procedure is intended to address dispersion of oil sands process solids prior to methylene blue adsorption described in general by the ASTM Standard Test Method for Methylene Blue Clay (C 837-99 (Re-approved 2003).

A mature fine tailings (MFT) analog is used as a calibration standard, to monitor the level of dispersion provided by the dispersion equipment used for sample preparation. The MFT analog is comprised of sand, montmorillonite, de-ionized water and bitumen. Bitumen and water are removed using Dean Stark extraction, the same procedure used for extracting bitumen and water from test samples.

2. PURPOSE

This procedure was developed specifically for oil sands process solids but could be used for oil-free minerals as well.

3. APPARATUS

- 250ml beakers
- 1l volumetric flasks
- analytical balance, accurate to 0.001g
- hotplate/magnetic stirrer and stir bars
- methylene blue powder
- mortar & pestle
- top-loading balance, accurate to 0.01 g
- disposable pipettes
- ultrasonic bath (Cole Parmer 1 ½ gallon with 40kHZ transducers & built in seep frequency)
- room temperature water bath
- hand held pH meter
- burette stand
- 50ml burette with teflon stopcock
- whatman 42 ashless filter paper
- watchglasses
- dean-stark extraction apparatus – for preparation of mft-analog calibration standard.

4. REAGENTS

- Analytical grade reagents shall be used in all tests.
- De-ionized water shall be used unless otherwise indicated in the procedure
- Methylene Blue trihydrate (M.W. 373.9) (1 ml = 0.006 meq). Dissolve 2.2436 g of Methylene blue powder in 1L de-ionized water (or 1.1218 g in 500 ml). Wrap volumetric flask in aluminium foil to keep the solution from degrading. A fresh batch should be used within a day.

- 10% w/w NaOH (sodium hydroxide). Dissolve 10g of NaOH pellets in 90g of de-ionized water.
- 10% v/v H_2SO_4 (sulfuric acid). Add 10 ml of concentrated H_2SO_4 to 90 ml de-ionized water.
- 0.015M $NaHCO_3$ (sodium bicarbonate). Add 1.26 g of dry $NaHCO_3$ to 1 L de-ionized water.
- pH 4,7 & 10 buffer solution (calibrating pH meter)
- Coarse Ottawa sand, retained on 200-mesh sieve
- Na-montmorillonite, marketed as Bentonite by Fisher Scientific.
- Solids-free oil sands bitumen

5. SAFETY PRECAUTIONS

Wear gloves and protective eyewear when handling methylene blue, caustic and acidic agents.

It is particularly painful if it enters the eyes and will stain skin a very dark blue. If you get Methylene blue on your clothes or skin apply Sunlight Dish-soap immediately to the area (without water).

6. MFT-ANALOG STANDARD PREPARATION

1. Add Ottawa sand (35 g), water (55 g), bitumen (5 g) and bentonite (5 g) into a clean glass jar.
2. Mix the 100-g mixture thoroughly.
3. Run the entire mixture through standard Dean Stark extraction. Sub-sampling without adequate homogenization may cause the bentonite to preferentially pass through the Dean-Stark thimble.
4. Once bitumen and water have been extracted, the dried solid serves as a bulk standard sample containing 12.5-wt% bentonite. This gives a methylene blue adsorption capacity similar to MFT.
5. The bitumen free standard is referred to as an MFT-analog.
6. Gently shatter the MFT-analog to remove clumps of materials
7. Store as bulk standard.

7. PROCEDURE FOR STANDARDS

1. Prepare 500 ml of 0.006 N Methylene Blue solution. Stir solution at 400 rpm for a minimum of 10 minutes to ensure that all the dye is dissolved. Prepare this solution fresh daily.
2. The MFT-analog must have gone through the Dean Stark extraction process or equivalent bitumen removal process.
3. Bentonite is used as received.
4. Gently shatter the MFT-analog sample with a mortar and pestle to ensure that the particles will disperse during the titration.
5. Measure out in a clean beaker, approximately 1 g of MFT-analog on a top loading balance and record the weight.

6. In a second clean beaker, measure approximately 0. 2 g bentonite on a top loading balance and record the weight.
7. Add 50 ml of 0.015 M $NaHCO_3$ to each sample. Add $NaHCO_3$ carefully so that the solids don't get spread all over the inside of the beaker. Use a disposable pipette to rinse the sides of the beaker with the $NaHCO_3$ solution.
8. Add 2 ml of 10% w/w NaOH solution to each sample with a disposable pipette. Place a clean dry stir bar in the mixture. Cover the beaker with a watchglass to keep the sample from evaporating.
9. Place the two beakers (containing Bentonite and MFT-analog) on a hotplate/stirrer set to 120° C (the sample should not heat above 60° C with the hotplate set at this temperature – monitor temperature as different hotplates heat at different rates). Set the stirrer to a minimum of 250 rpm. Adjust the mixing speed as required. *Make sure the sample is mixing completely and that all solids are in suspension*.
10. The samples shall be stirred and heated for a minimum of 20 minutes. If the solids have not completely dispersed after this time (note: small clay balls floating on solution surface) the sample can be transferred to an ultrasonic bath for 20 minutes. Continue this cycle of heating/stirring and ultrasonication until the sample is completely dispersed. **NOTE: DISPERSION IS THE MOST IMPORTANT PART OF THIS METHOD**. If the sample is not dispersed completely the titration results will be inaccurate.

For MFT-analog, 20 minutes stirring followed by 20 minutes sonication is often adequate for complete dispersion.

11. Place the beakers in a room temperature water bath and let them cool for 3-5 minutes.

The following steps are carried out for the Bentonite first, followed by the MFT-analog.

12. Place the beaker on a stirring plate located underneath the burette and start stirring the sample (no heat).
13. Place the handheld pH meter in the solution of the sample. Add 10% v/v H_2SO_4 until the pH drops to 2.5-3.8.
14. Titrate the sample with 0.006 N Methylene Blue while the sample is stirring. Add the methylene blue solution in 1 ml increments. Switch to 0.5 ml increments when the sample is close to reaching the endpoint.

From prior experience with pure bentonite, depending on the batch, the endpoint can range between 28 and 34 mls.

15. With a transfer pipette, remove an aliquot of the sample (after each titrant addition) and place one droplet on a piece of Whatman 42 ashless filter paper. Continue placing drops of sample on the filter paper after each addition of titrant until the endpoint is reached. .The endpoint is observed when there is excess of methylene blue in the water phase of the sample indicating. A blue halo will form around the sample droplet on the filter paper.

8. PROCEDURE FOR TEST SAMPLES

1. Prepare 500 ml of 0.006 N Methylene Blue solution. Stir solution at 400 rpm for a minimum of 10 minutes to ensure that all the dye is dissolved. Prepare this solution fresh daily.
2. All test solids are assumed to have gone through the Dean Stark extraction process or equivalent bitumen removal process.
3. Gently shatter the solids with a mortar and pestle to ensure that the particles will disperse during the titration.
4. Place a clean dry beaker on the top-loading balance and tare the weight. Before adding the sample please take the following into consideration:

   i. Is the sample very sandy? If so, use 5 g of sample.

   ii. Does the sample contain large proportions of clay? If so, use 1-2 g of sample.

5. Add the sample to the beaker and record the weight of the sample used.
6. Add 50 ml of 0.015 M $NaHCO_3$ to the sample. Add $NaHCO_3$ carefully so that the solids don't get spread all over the inside of the beaker. Use a disposable pipette to rinse the sides of the beaker with the $NaHCO_3$ solution.
7. Add 2 ml of 10% w/w NaOH solution to the sample with a disposable pipette. Place a clean dry stir bar in the mixture. Cover the beaker with a watchglass to keep the sample from evaporating.
8. Place the beaker (containing the sample) on a hotplate/stirrer set to 120° C (the sample should not heat above 60° C with the hotplate set at this temperature – monitor temperature as different hotplates heat at different rates). Set the stirrer to a minimum of 250 rpm. Adjust the mixing speed as required.

Make sure the sample is mixing completely and that all solids are in suspension.

9. The sample shall be stirred and heated for a minimum of 20 minutes. If the solids have not completely dispersed after this time (note: small clay balls floating on solution surface) the sample can be transferred to an ultrasonic bath for 20 minutes. Continue this cycle of heating/stirring and ultrasonication until the sample is completely dispersed. **NOTE: DISPERSION IS THE MOST IMPORTANT PART OF THIS METHOD.** If the sample is not dispersed completely the titration results will be inaccurate.

For MFT, 20 minutes stirring followed by 20 minutes sonication is often adequate for complete dispersion. For froth solids, longer dispersion time may be required.

10. Place the beaker in a room temperature water bath and let it cool for 3-5 minutes.
11. Place the beaker on a stirring plate located underneath the burette and start stirring the sample (no heat).

12. Place the handheld pH meter in the solution of the sample. Add 10% v/v H_2SO_4 until the pH drops to 2.5-3.8.
13. Titrate the sample with 0.006 N Methylene Blue while the sample is stirring. Add the methylene blue solution in 1 ml increments. Switch to 0.5 ml increments when the sample is close to reaching the endpoint.
14. With a transfer pipette, remove an aliquot of the sample (after each titrant addition) and place one droplet on a piece of Whatman 42 ashless filter paper. Continue placing drops of sample on the filter paper after each addition of titrant until the endpoint is reached.

The endpoint will be evident when a light blue halo spreads out from the sample droplet on the paper. Record the ml's required to reach this endpoint.

9. CALCULATIONS

METHYLENE BLUE INDEX (MBI)

$$MBI(meq/100g) = \frac{\text{mls of MB} \times \text{Normality of MB}}{\text{mass of sample (g)}} \times 100$$

METHYLENE BLUE NUMBER (MB#)

$$MB\#(mls\ of\ 0.006\ N\ MB/100g) = \frac{\text{mls of 0.006 N MB}}{\text{mass of sample (g)}} \times 100$$

WEIGHT PERCENT CLAY (BASED ON REFERENCE 2)

$$Wt\%\ Clay = \frac{\text{MBI} + 0.04}{14} \times 100$$

10. STANDARDIZATION

$$\text{MBI}_{\text{MFT-Analog}}\ (\pm\ 0.25\ \text{meq/100g}) = \frac{\text{MBI}_{\text{Bentonite}} \times \text{Wt\%}_{\text{Bentonite in MFT-analog}}}{100}$$

The precision is taken from the ASTM Standard: C837-99.

$$\text{Wt\% Bentonite in MFT-analog} = \frac{\text{Mass of B}}{\text{Mass of B} + \text{mass of S}} \times 100$$

Mass of B is the mass of bentonite added to MFT-analog

Mass of S is the mass Ottawa sand added to the MFT analog

IF THE MFT-ANALOG MBI IS OUTSIDE THE SPECIFIED RANGE, THE DISPERSION EQUIPMENT SHOULD BE CHECKED AND TEST SAMPLES REPEATED.

11. REFERENCES

1. ASTM Standard: C 837 – 99 (Re-approved 2003)
2. Sethi, Amar. January 23, 1995. *Methylene Blue Test for Clay Activity Determination in Fine Tails.* MRRT Procedures.

METHYLENE BLUE PROCEDURE:

SLUDGES AND SLURRIES

Revised by:
Dr. Oladipo Omotoso &
Michelle Morin

Revision date:
January 6, 2008

Natural Resources Canada
CanmetENERGY-Devon
Extractions and Tailings

Canada

1. OBJECTIVE AND SCOPE OF THE AST PROCEDURE

The AST methylene blue procedure is intended to address dispersion of oil sands process solids prior to methylene blue adsorption described in general by the ASTM Standard Test Method for Methylene Blue Clay (C 837-99 (Re-approved 2003).

A mature fine tailings (MFT) analog is used as a calibration standard, to monitor the level of dispersion provided by the dispersion equipment used for sample preparation. The MFT analog is comprised of sand, montmorillonite, de-ionized water and bitumen. Bitumen and water are removed using Dean Stark extraction, the same procedure used for extracting bitumen and water from test samples.

2. PURPOSE

This procedure was developed specifically for oil sands process solids but could be used for oil-free minerals as well.

3. APPARATUS

- 250ml beakers
- 1l volumetric flasks
- analytical balance, accurate to 0.001g
- hotplate/magnetic stirrer and stir bars
- methylene blue powder
- mortar & pestle
- top-loading balance, accurate to 0.01 g
- disposable pipettes
- ultrasonic bath (Cole Parmer 1 ½ gallon with 40kHZ transducers & built in seep frequency)
- room temperature water bath
- hand held pH meter
- burette stand
- 50ml burette with teflon stopcock
- whatman 42 ashless filter paper
- watchglasses
- dean-stark extraction apparatus – for preparation of mft-analog calibration standard.

4. REAGENTS

- Analytical grade reagents shall be used in all tests.
- De-ionized water shall be used unless otherwise indicated in the procedure
- Methylene Blue trihydrate (M.W. 373.9) (1 ml = 0.006 meq). Dissolve 2.2436 g of Methylene blue powder in 1L de-ionized water (or 1.1218 g in 500 ml). Wrap volumetric flask in aluminium foil to keep the solution from degrading. A fresh batch should be used within a day.
- 10% w/w NaOH (sodium hydroxide). Dissolve 10g of NaOH pellets in 90g of de-ionized water.
- 10% v/v H_2SO_4 (sulfuric acid). Add 10 ml of concentrated H_2SO_4 to 90 ml de-ionized water.

- 0.015M $NaHCO_3$ (sodium bicarbonate). Add 1.26 g of dry $NaHCO_3$ to 1 L de-ionized water.
- pH 4,7 & 10 buffer solution (calibrating pH meter)
- Coarse Ottawa sand, retained on 200-mesh sieve
- Na-montmorillonite, marketed as Bentonite by Fisher Scientific.
- Solids-free oil sands bitumen

5. SAFETY PRECAUTIONS

Wear gloves and protective eyewear when handling caustic and acidic agents.Wear gloves and protective eyewear when handling methylene blue.

It is particularly painful if it enters the eyes and will stain skin a very dark blue. If you get Methylene blue on your clothes or skin apply Sunlight Dish-soap immediately to the area (without water).

6. MFT-ANALOG STANDARD PREPARATION

1. Add Ottawa sand (35 g), water (55 g), bitumen (5 g) and bentonite (5 g) into a clean glass jar.
2. Mix the 100-g mixture thoroughly.
3. Run the entire mixture through standard Dean Stark extraction. Sub-sampling without adequate homogenization may cause the bentonite to preferentially pass through the Dean-Stark thimble.
4. Once bitumen and water have been extracted, the dried solid serves as a bulk standard sample containing 12.5-wt% bentonite. This gives a methylene blue adsorption capacity similar to MFT.
5. The bitumen free standard is referred to as an MFT-analog.
6. Gently shatter the MFT-analog to remove clumps of materials
7. Store as bulk standard.

7. PROCEDURE FOR STANDARDS

1. Prepare 500 ml of 0.006 N Methylene Blue solution. Stir solution at 400 rpm for a minimum of 10 minutes to ensure that all the dye is dissolved. Prepare this solution fresh daily.
2. The MFT-analog must have gone through the Dean Stark extraction process or equivalent bitumen removal process.
3. Bentonite is used as received.
4. Gently shatter the MFT-analog sample with a mortar and pestle to ensure that the particles will disperse during the titration.
5. Measure out in a clean beaker, approximately 1 g of MFT-analog on a top loading balance and record the weight.
6. In a second clean beaker, measure approximately 0. 2 g bentonite on a top loading balance and record the weight.
7. Add 50 ml of 0.015 M $NaHCO_3$ to each sample. Add $NaHCO_3$ carefully so that the solids don't get spread all over the inside of the beaker. Use a disposable pipette to rinse the sides of the beaker with the $NaHCO_3$ solution.

8. Add 2 ml of 10% w/w NaOH solution to each sample with a disposable pipette. Place a clean dry stir bar in the mixture. Cover the beaker with a watchglass to keep the sample from evaporating.
9. Place the two beakers (containing Bentonite and MFT-analog) on a hotplate/stirrer set to 120° C (the sample should not heat above 60° C with the hotplate set at this temperature – monitor temperature as different hotplates heat at different rates). Set the stirrer to a minimum of 250 rpm. Adjust the mixing speed as required. *Make sure the sample is mixing completely and that all solids are in suspension*.
10. The samples shall be stirred and heated for a minimum of 20 minutes. If the solids have not completely dispersed after this time (note: small clay balls floating on solution surface) the sample can be transferred to an ultrasonic bath for 20 minutes. Continue this cycle of heating/stirring and ultrasonication until the sample is completely dispersed. **NOTE: DISPERSION IS THE MOST IMPORTANT PART OF THIS METHOD**. If the sample is not dispersed completely the titration results will be inaccurate.

For MFT-analog, 20 minutes stirring followed by 20 minutes sonication is often adequate for complete dispersion.

11. Place the beakers in a room temperature water bath and let them cool for 3-5 minutes.

The following steps are carried out for the Bentonite first, followed by the MFT-analog.

12. Place the beaker on a stirring plate located underneath the burette and start stirring the sample (no heat).
13. Place the handheld pH meter in the solution of the sample. Add 10% v/v H_2SO_4 until the pH drops to 2.5-3.8.
14. Titrate the sample with 0.006 N Methylene Blue while the sample is stirring. Add the methylene blue solution in 1 ml increments. Switch to 0.5 ml increments when the sample is close to reaching the endpoint.

From prior experience with pure bentonite, depending on the batch, the endpoint can range between 28 and 34 mls.

15. With a transfer pipette, remove an aliquot of the sample (after each titrant addition) and place one droplet on a piece of Whatman 42 ashless filter paper. Continue placing drops of sample on the filter paper after each addition of titrant until the endpoint is reached. The endpoint is observed when there is excess of methylene blue in the water phase of the sample indicating. A blue halo will form around the sample droplet on the filter paper.

8. PROCEDURE FOR TEST SAMPLES

1. Prepare 500ml of 0.006 N Methylene Blue solution. Stir solution at 400 rpm for a minimum of 10 minutes to ensure that all the dye is dissolved. Prepare this solution fresh daily.
2. Acquire % solids data (in duplicate) for the sample prior to Methylene Blue analysis. Assess the sample and make sure that it has a low amount of bitumen contamination.
3. Place a clean dry beaker on the top-loading balance and tare the weight. Before adding the sample please take the following into consideration:

   i. Is the sample very sandy? If so, use 20g of sample.

   ii. Does the sample contain large proportions of clay? If so, use 10g of sample.

4. Shake the sample extremely well before adding to the beaker. It is very important to acquire a representative homogenous sample for this analysis.
5. If the sample has less than 5% solids it is difficult to get enough solids in suspension for an accurate titration. Samples with low amounts of solids will have very low endpoints (typically less then 5mls). Modify the procedure by adding 50 ml of sample ONLY to the beaker. Do not add any additional water. Continue sample preparation as described below in steps 10-19.
6. Add the sample to the beaker and record the weight of the sample used.
7. Determine the amount of solids in the sample weighed out.
8. Example:

   Percent Solids = 35%

   Sample Wt. = 10.01g

   Amount of solids in sample= 10.01 x 0.35

   There are 3.5035g of solids in the sample.

9. From this we can assume that the remaining weight of the sample is water:

   Therefore: 10.01g – 3.5035g = 6.5065 g. there are 6.5065g of water

10. If 10g of sample was used **ADD 40ml of de-ionized water** to the sample.
11. If 20g of sample was used **ADD 80ml of de-ionized water** to the sample.
12. Add 2ml of 10% w/w NaOH solution to the sample with a disposable pipette. Place a clean dry stir bar in the mixture. Cover the beaker with a watchglass (this will keep the sample from evaporating)
13. Determine the total amount of water in the sample (g water + 40g water added = 46.5065g)
14. Calculate the amount of 1.0M $NaHCO_3$ that needs to be added to the slurry. We want the concentration of $NaHCO_3$ to be 0.015M in the solution.
15. $C_1V_1 = C_2V_2$ where (46.5065g H_2O)(0.015M $NaHCO_3$) = (1M $NaHCO_3$)(X) making X = the volume of 1M $NaHCO_3$ in ml that should be added to the sample.
16. Place the beaker (containing the sample) on a hotplate/stirrer that has the temperature set to 120°C (the sample should not heat above 60°C with the hotplate set at this temperature – monitor temperature as different hotplates heat at different rates. Set the stirrer to a minimum of 250RPM. Adjust the mixing speed as required. **MAKE sure the sample is mixing completely and that all solids are in suspension**.

17. The samples should stir and heat for a minimum of 20 minutes. If the solids have not completely dispersed after this time (note: small clay balls floating on solution surface) the sample can be transferred to the sonicator for 20 minutes. Continue this cycle of heating/stirring and sonication until the sample is completely dispersed. **NOTE: DISPERSION IS THE MOST IMPORTANT PART OF THIS METHOD**. If the sample is not dispersed completely the titration results will be inaccurate.
18. Evaluate the sample for dispersion. *Is there hydrophobic mineral floating on the surface? Are there clay balls present? Does the suspension settle rapidly after stirring has stopped? Do the mineral particles start to flocculate after stirring has stopped?* If any of these qualitative questions can be answered with a 'YES' the sample is not fully dispersed. Repeat step 14 until dispersion is complete.
19. Place the beaker in a room temperature water bath and let it cool for 3-5 minutes.
20. Place the beaker on a stirring plate located underneath the burette and start stirring the sample (no heat).
21. Place the handheld pH meter in the solution of the sample. Add 10% v/v H_2SO_4 until the pH drops to 2.5-3.8.
22. Titrate the sample with 0.006 N Methylene Blue while the sample is stirring. Add the methylene blue solution in 1 ml increments. Switch to 0.5 ml increments when the sample is close to reaching the endpoint.
23. With a transfer pipette, remove an aliquot of the sample (after each titrant addition) and place one droplet on a piece of Whatman 42 ashless filter paper. Continue placing drops of sample on the filter paper after each addition of titrant until the endpoint is reached.

The endpoint will be evident when a light blue halo spreads out from the sample droplet on the paper. Record the ml's required to reach this endpoint.

9. CALCULATIONS

METHYLENE BLUE INDEX (MBI)

$$MBI(meq/100g) = \frac{\text{mls of MB} \times \text{Normality of MB}}{\text{mass of solids in sample (g)}} \times 100$$

METHYLENE BLUE NUMBER (MB#)

$$MB\#(mls\ of\ 0.006\ N\ MB/100g) = \frac{\text{mls of 0.006 N MB}}{\text{mass of solids in sample (g)}} \times 100$$

WEIGHT PERCENT CLAY (BASED ON REFERENCE 2)

$$Wt\%\ Clay = \frac{\text{MBI} + 0.04}{14} \times 100$$

10. STANDARDIZATION

$$\text{MBI}_{\text{MFT-Analog}}\ (\pm\ 0.25\ \text{meq/100g}) = \frac{\text{MBI}_{\text{Bentonite}} \times \text{Wt\%}_{\text{Bentonite in MFT-analog}}}{100}$$

The precision is taken from the ASTM Standard: C837-99.

$$\text{Wt\% Bentonite in MFT - analog} = \frac{\text{Mass of B}}{\text{Mass of B} + \text{mass of S}} \times 100$$

Mass of B is the mass of bentonite added to MFT-analog

Mass of S is the mass Ottawa sand added to the MFT analog

IF THE MFT-ANALOG MBI IS OUTSIDE THE SPECIFIED RANGE, THE DISPERSION EQUIPMENT SHOULD BE CHECKED AND TEST SAMPLES REPEATED.

11. REFERENCES

1. ASTM Standard: C 837 – 99 (Re-approved 2003)
2. Sethi, Amar. January 23, 1995. *Methylene Blue Test for Clay Activity Determination in Fine Tails.* MRRT Procedures.

10.6. Gamma CPT Identification of NORM Potential in Tailings Deposits

The G-CPT (Gamma Cone Penetration Test) and GB-CPT (Gamma Ball Penetration Test) are performed by advancing instrumented probes into the tailings at 2 cm/sec. The probe sensors are sampled and recorded every 2.5 cm of penetration. Both probes are attached in front of a passive-gamma module. The module housing contains a scintillating crystal that glows when it is struck by gamma rays. The observed gamma-ray incidents are counted and used to calculate the gamma counts-per-second (cps), which is reported in the G-CPT and GB-CPT soundings every 10 cm of penetration.

There are three main naturally occurring radioisotopes: Potassium 40, Thorium 232, and Uranium 238. These radioisotopes exist naturally because their very long half-life times are a similar magnitude to the age of the earth. A small fraction of all of the potassium in the world is this natural radioisotope Potassium 40. Some clay minerals in the oil sand tailings, such as illite and mica, contain potassium atoms. When the passive-gamma module is in the presence of clay-minerals it will start to glow and will be recorded as an increased rate of gamma rays, as it does in the presence of other NORMs. In the tailings deposit, gamma rays will interact with the tailings material and lose energy as it travels from the source mineral, until it is completely absorbed. For the typical densities of tailings, gamma rays may travel 20 to 30 cm, which means that the passive gamma measurements respond to the local material adjacent to the probe.

When the passive-gamma module is above the mudline there are almost no gamma rays observed. A value of 6 cps can be used as a threshold to profile the depth to the mudline using the passive-gamma readings. Typical passive-gamma rates of 20 to 50 cps are found when in fluid FT, where the rate of gamma rays depend on the quantity of suspended fines. In contrast, when the gamma module is in sand beach tailings, passive-gamma rates of 10 to 20 cps are measured.

Fluid tailings typically do not produce passive gamma rates in excess of 60 cps. When this cps point is exceeded, it is indicative of potential presence of froth treatment tailings.

10.7. Water Quality Testing Guide

Testing of water quality within the recirculating process water systems includes a standard set of analyses, shown in Table 1. Testing is conducted on a minimum annual basis, with reporting conducted as annual averages for each area. Samples are taken from specific sample locations, analysed in the laboratory, and entered into the process database.

Table 1: Water Quality Testing Analyses

<table>
<tr><th colspan="4">Conventional Parameters</th></tr>
<tr><th>Analyte</th><th>Unit</th><th>BV Laboratory Method</th><th>Analytical Method</th></tr>
<tr><td>Conductivity</td><td>uS/cm</td><td rowspan="2">AB SOP-00005</td><td rowspan="2">Alkalinity Acidity Conductivity Fluoride and pH by PC-Titrate (Modified SM 2510 B, SM 4500 H+B, SM 2320 B, SM 4500-F C, SM 2310 B) - Soil & Waters PC Titrate Conductivity (25 °C)
Alkalinity
Fluoride
pH
Acidity</td></tr>
<tr><td>pH</td><td>pH</td></tr>
<tr><td>Anion Sum</td><td>meq/L</td><td rowspan="4">Auto Calculated</td><td rowspan="4">Auto Calculated</td></tr>
<tr><td>Cation Sum</td><td>meq/L</td></tr>
<tr><td>Ion Balance (% Difference)</td><td>%</td></tr>
<tr><td>Hardness (CaCO3)</td><td>mg/L</td></tr>
<tr><td>Alkalinity (PP as CaCO3)</td><td>mg/L</td><td rowspan="2">AB SOP-00005</td><td rowspan="2">Alkalinity Acidity Conductivity Fluoride and pH by PC-Titrate (Modified SM 2510 B, SM 4500 H+B, SM 2320 B, SM 4500-F C, SM 2310 B) - Soil & Waters PC Titrate Conductivity (25 °C)
Alkalinity
Fluoride
pH
Acidity</td></tr>
<tr><td>Alkalinity (Total as CaCO3)</td><td>mg/L</td></tr>
<tr><td>Total Dissolved Solids (Calculated)</td><td>mg/L</td><td>Auto Calculated</td><td>Auto Calculated</td></tr>
<tr><td>Total Suspended Solids</td><td>mg/L</td><td>AB SOP-00061</td><td>Total Suspended Solids, Total Fixed Solids, Total Volatile Solids (Modified SM 2540 D, E) Gravimetric
Total Suspended Solids
Total Suspended Solids Fixed
Total Suspended Solids Volatile</td></tr>
</table>

Major Ions			
Analyte	Unit	BV Laboratory Method	Analytical Method
Bicarbonate (HCO3)	mg/L	AB SOP - 00005	Alkalinity Acidity Conductivity Fluoride and pH by PC-Titrate (Modified SM 2510 B, SM 4500 H+B, SM 2320 B, SM 4500-F C, SM 2310 B) - Soil & Waters PC Titrate Conductivity (25 °C) Alkalinity Fluoride pH Acidity
Carbonate (CO3)	mg/L		
Hydroxide (OH)	mg/L		
Chloride (Cl)	mg/L	AB SOP-00020	Chloride and Sulfate Analysis by Discrete Autoanalyzer (Modified SM 4500 Cl E & SM 4500 SO4 E) – Soils and Waters Chloride *Sulfate
Sulphate (SO4)	mg/L		

Total and Dissolved Metals			
Analyte	**Units**	**BV Laboratory Method**	**Analytical Method**
Aluminum (Al)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Antimony (Sb)	mg/L		
Arsenic (As)	mg/L		
Barium (Ba)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters ICP/OES
Beryllium (Be)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Boron (B)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters ICP/OES
Cadmium (Cd)	ug/L		
Calcium (Ca)	mg/L		
Chromium (Cr)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Cobalt (Co)	mg/L		
Copper (Cu)	mg/L		
Iron (Fe)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters

			ICP/OES
Lead (Pb)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Lithium (Li)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters ICP/OES
Magnesium (Mg)	mg/L		
Manganese (Mn)	mg/L		
Mercury (Hg)	ug/L	AB SOP-00084	Mercury in Waters, Leachates and Liquids by Bromination and Cold Vapour [Modified BC MOE LABORATORY MANUAL SECTION C and EPA 245.7] Mercury
Molybdenum (Mo)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Nickel (Ni)	mg/L		
Phosphorus (P)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters ICP/OES
Potassium (K)	mg/L		
Selenium (Se)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Silicon (Si)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters ICP/OES
Silver (Ag)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Sodium (Na)	mg/L	AB SOP-00042	Metals on Liquids and Solids by ICPOES (Modified EPA 6010 D) - Soils and Waters ICP/OES
Strontium (Sr)	mg/L		
Sulphur (S)	mg/L		
Thallium (Tl)	mg/L	AB SOP-00043	Metals Analysis on Soils and Waters Using ICPMS (Modified EPA 6020 B) - Soils and Waters [TCLP: EPA 1311] ICP/MS
Total Tin (Sn)	mg/L		
Titanium (Ti)	mg/L		

Uranium (U)	mg/L		
Vanadium (V)	mg/L		
Zinc (Zn)	mg/L		
Nutrients			
Analyte	**Units**	**BV Laboratory Method**	**Analytical Method**
Nitrate (N)	mg/L	AB SOP-00091	NO2 and TON by Gallery Plus (Modified SM 4500-NO3-H and 4500-NO2)
Nitrate plus Nitrite (N)	mg/L		
Total Nitrogen (N)	mg/L	AB SOP-00093	Total Nitrogen by Konelab (Modified SM 4500-N C) – Soil and Water Colorimetric
Total Total Kjeldahl Nitrogen (Calc)	mg/L	BBY WI-00033	Auto Calculated
Ammonium	mg/L		
Hydrocarbons - BTEX			
Analyte	**Units**	**BV Laboratory Method**	**Analytical Method**
F1 (C6-C10) - BTEX	ug/L	AB SOP-00039	Extraction and Analysis of BTEX/F1 and select Volatiles by HS/GC/MS/FID Water, Soil and Oil (BTEX: Modified EPA 8260D, GC/MS – HEADSPACE) (F1/PHC: Modified CCME Petroleum Hydrocarbons - Tier 1 Method and EPA5021A) – Soils and Waters (BTEX TCLP: EPA 1311) GC/MS - HEADSPACE
F1 (C6-C10)	ug/L		
F2 (C10-C16 Hydrocarbons)	mg/L	AB SOP-00040	Analysis of Extractable Hydrocarbons in Water and Soils by GC/FID (Modified Reference Method for the Canada-Wide Standard for Petroleum Hydrocarbons in Soil – Tier 1 Method) Modified EPA 1617)- Sheen
F3 (C16-C34 Hydrocarbons)	mg/L		
F4 (C34-C50 Hydrocarbons)	mg/L		
Benzene	ug/L	AB SOP-00039	Extraction and Analysis of BTEX/F1 and select Volatiles by HS/GC/MS/FID Water, Soil and Oil (BTEX: Modified EPA 8260D, GC/MS – HEADSPACE) (F1/PHC: Modified CCME Petroleum Hydrocarbons - Tier 1 Method and EPA5021A) – Soils and Waters (BTEX TCLP: EPA 1311) GC/MS - HEADSPACE
Toluene	ug/L		
Ethylbenzene	ug/L		
m & p-Xylene	ug/L		
o-Xylene	ug/L		
Xylenes (Total)	ug/L		

Volatile Organic Compounds			
Analyte	**Units**	**BV Laboratory Method**	**Analytical Method**
Total Trihalomethanes	ug/L	AB SOP-00056	Preparation and Analysis VOC -Water and Soil by HS/GC/MS (Modified from EPA8260D and EPA5021A) (VOC TCLP: EPA 1311) - Soils and Waters
Bromodichloromethane	ug/L		
Bromoform	ug/L		
Bromomethane	ug/L		
Carbon tetrachloride	ug/L		
Chlorobenzene	ug/L		
Dibromochloromethane	ug/L		
Chloroethane	ug/L		
Chloroform	ug/L		
Chloromethane	ug/L		
1,2-dibromoethane	ug/L		
1,2-dichlorobenzene	ug/L		
1,3-dichlorobenzene	ug/L		
1,4-dichlorobenzene	ug/L		
1,1-dichloroethane	ug/L		
1,2-dichloroethane	ug/L		
1,1-dichloroethene	ug/L		
cis-1,2-dichloroethene	ug/L		
trans-1,2-dichloroethene	ug/L		
Dichloromethane	ug/L		
1,2-dichloropropane	ug/L		
cis-1,3-dichloropropene	ug/L		
trans-1,3-dichloropropene	ug/L		

Methyl methacrylate	ug/L		
Methyl-tert-butylether (MTBE)	ug/L		
Styrene	ug/L		
1,1,1,2-tetrachloroethane	ug/L		
1,1,2,2-tetrachloroethane	ug/L		
Tetrachloroethene	ug/L		
1,2,3-trichlorobenzene	ug/L		
1,2,4-trichlorobenzene	ug/L		
1,3,5-trichlorobenzene	ug/L		
1,1,1-trichloroethane	ug/L		
1,1,2-trichloroethane	ug/L		
Trichloroethene	ug/L		
Trichlorofluoromethane	ug/L		
1,2,4-trimethylbenzene	ug/L		
1,3,5-trimethylbenzene	ug/L		
Vinyl chloride	ug/L		
Phenols			
Analyte	**Units**	**BV Laboratory Method**	**Analytical Method**
Phenols	mg/L	AB SOP-00088	Phenol Phenolics-Automated 4--Aminoantipyrine Colorimetry (Modified SSMA Chapter 40 & EPA 9066) - Water Colorimetric – Distillation Extraction
Naphthenic Acids			
Analyte	**Units**	**BV Laboratory Method**	**Analytical Method**
Naphthenic Acids	mg/L	AB SOP-00060	Naphthenic Acids in water by FTIR (Modified EPA 3510C R3/FTIR) IR
Naphthenic Acids	mg/L	AB SOP-00070	Extraction and Analysis of Naphthenic Acids in Water (DCM Extraction) [Modified from Syncrude 1995 m] IR DCM Extraction Naphthenic Acids

PAH’s and Alkylated PAH’s			
Analyte	**Units**	**BV Laboratory Method**	**Analytical Method**
B[a]P TPE Total Potency Equivalents	ug/L	AB SOP-00037 CAL SOP-00250	Preparation and analysis of Alkylated PAH in soils and water (Modified SM 8270 E and ESTD-OR-20) – Soils and Waters GC/MS – Extraction
Acenaphthene	ug/L		
Acenaphthylene	ug/L		
Acridine	ug/L		
Anthracene	ug/L		
Benzo(a)anthracene	ug/L		
Benzo(b&j)fluoranthene	ug/L		
Benzo(k)fluoranthene	ug/L		
Benzo(g,h,i)perylene	ug/L		
Benzo(c)phenanthrene	ug/L		
Benzo(a)pyrene	ug/L		
Benzo(e)pyrene	ug/L		
Chrysene	ug/L		
Dibenz(a,h)anthracene	ug/L		
Fluoranthene	ug/L		
Fluorene	ug/L		
Indeno(1,2,3-cd)pyrene	ug/L		
Indeno(1,2,3-cd)fluoranthene	ug/L		
2-Methylnaphthalene	ug/L		
Naphthalene	ug/L		
Phenanthrene	ug/L		
Perylene	ug/L		

Pyrene	ug/L		
Quinoline	ug/L		
Retene	ug/L		
C1-Naphthalene	ug/L		
C3-Naphthalene	ug/L		
C4-Naphthalene	ug/L		
C2-Naphthalene	ug/L		
Biphenyl	ug/L		
C1-biphenyl	ug/L		
C2-biphenyl	ug/L		
C1-fluorene	ug/L		
C2-fluorene	ug/L		
C3-fluorene	ug/L		
Dibenzothiophene	ug/L		
C1-dibenzothiophene	ug/L		
C2-dibenzothiophene	ug/L		
C3-dibenzothiophene	ug/L		
C4-dibenzothiophene	ug/L		
C1 phenanthrene/anthracene	ug/L		
C2 phenanthrene/anthracene	ug/L		
C3 phenanthrene/anthracene	ug/L		
C4 phenanthrene/anthracene	ug/L		
C1 fluoranthene/pyrene	ug/L		
C2 fluoranthene/pyrene	ug/L		

C3 fluoranthene/pyrene	ug/L		
C4 fluoranthene/pyrene	ug/L		
C1 benzo(a)anthracene/chrysene	ug/L		
C2 benzo(a)anthracene/chrysene	ug/L		
C3 benzo(a)anthracene/chrysene	ug/L		
C4 benzo(a)anthracene/chrysene	ug/L		
C1benzobjkfluoranthene/ benzoapyrene	ug/L		
C2benzobjkfluoranthene/ benzoapyrene	ug/L		
C1-Acenaphthene	ug/L		
1-Methylnaphthalene	ug/L		
NORM's (Radiological Parameter)			
Analyte	**Units**	**BV Laboratory Method**	**Analytical Method**
Lead-210	Bq/l	BQL SOP-00007	Gamma Spectrometry
Potassium-40	Bq/l		
Radium 226	Bq/l		
Radium-223	Bq/l		
Radium-228	Bq/l		
Thorium-227	Bq/l		
Thorium-228	Bq/l		
Thorium-230	Bq/l		
Thorium-234	Bq/l		
Uranium-235	Bq/l		

10.8. MD9, MD9 South Settlement and Pond 5 Monitoring Plan

The following appendix is included here for completeness.

The Pond 5 Monitoring Plan, required to satisfy the requirement of Clause 34(a) of OSCA Approval No. 8535N, was submitted on November 17, 2017.

The MD9 Settlement Monitoring Plan, required as a condition of OSCA Approval 8535N, Clause 43(a), was submitted to the AER on February 28, 2018.

MD9 South settlement monitoring is proposed for Phase 2 only, once active dumping in the co-disposal area is complete. This is described in the MD9 South Co-disposal Asset Sheet, and as such no separate stand-alone monitoring plan is necessary.

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November 30, 2017

Mr. Rob Cruickshank
Manager, Oil Sands Mining East, Authorizations
Alberta Energy Regulator
Suite 1000, 205 – 5th Street SW
Calgary, AB T2P 0R4

Submitted electronically to: OSminingreportsplans@aer.ca

RE: Pond 5 Monitoring Plan
Suncor Energy Inc. Oil Sands Processing Plant and Mine
AER Approval 8535N, Clause 34(a)

Dear Mr. Cruickshank,

Please find attached Suncor's Pond 5 Monitoring Plan to satisfy the requirement of Clause 34(a) of AER Approval 8535N.

If you have any questions regarding this document or if additional information is required, please do not hesitate to contact me at (403) 296-4335.

Regards,

S. Chernys

Sheila Chernys
Director, EHS, Oil Sands,
Environment & Industrial Hygiene

cc Jason Heisler, Suncor Energy Inc.

SUNCOR ENERGY INC.

OIL SANDS

Pond 5 Monitoring Plan

In compliance with AER Approval 8535N, Clause 34(a)

Submitted to:
Alberta Energy Regulator (AER)
November 30, 2017

This monitoring plan is submitted in accordance with Clause 34(a) of Energy Resources Conservation Board Approval No. 8535N:

The Operator shall confirm the monitoring plan for Pond 5 by November 30, 2017.

The Pond 5 monitoring plan is being submitted in accordance with Approval 8535N. Monitoring results will be provided to the Alberta Energy Regulator in the Directive 085 Annual Fluid Tailings Management Report, submitted in April of each year and with groundwater monitoring results submitted through the EPEA biennial groundwater monitoring reports. This monitoring plan is for the purpose of meeting Clause 45 (e) and (f) and is not intended to duplicate requirements in Section 6 of Directive 085. The monitoring plan (summarized in Table 1) is designed to track progress to Ready to Reclaim (RTR) criteria outlined in Appendix C within Approval 8535N and Ready for Reclamation (RFR) criteria.

Table 1- Summary of Proposed Monitoring Types and Frequency

Primary Monitoring Result	Monitoring Type	Measurement Frequency	Supported Monitoring Results
Settlement	Surface Light Imaging, Detection, Ranging (LiDAR)	Annual	-Settlement with time -Expressed water quantity
	Settlement Markers	Annual	-Settlement with time -Cell 9 settlement progression to start additional activities
Strength	Cone Penetration Test	Annual	-Fluid tailings strength profiles -Fluid tailings quantity
Expressed Water Quantity	Pumped volumes from cap drainage system	Monthly	-Expressed water quantity -Surface water quantity
Groundwater	Groundwater program	As per EPEA Operating Approval 94-02, Clause 4.6.14	-Groundwater monitoring as per EPEA Operating Approval 94-02, Clause 4.6.9

Long, Marlyss

From: Long, Marlyss
Sent: Wednesday, February 28, 2018 5:10 PM
To: OSminingreportsplans@aer.ca
Cc: 'Chernys, Sheila'; Heisler, Jason; Angie Taksas (Angie.Taksas@aer.ca)
Subject: Suncor - OSCA Approval 8535N, Clause 43(a), MD9 Settlement Monitoring Plan

Good afternoon,

Please find attached the MD9 Settlement Monitoring Plan, required as a condition of OSCA Approval 8535N, Clause 43(a).

If there are any further questions, please contact me at 403-296-4335.

Marlyss Long
Senior Environmental Advisor
Environmental Compliance & Reporting
Suncor Energy Services Inc.
Tel 403 296 4335
Cell 403 510 8125
mlong@suncor.com

AER OSCA 8535N MD9 Settlement...

Long, Marlyss

From: OSMining Reports Plans <OSminingreportsplans@aer.ca>
Sent: Wednesday, February 28, 2018 5:10 PM
To: Long, Marlyss
Subject: Submission Received

The Report/Plan submission was received.

Thanks,

Alberta Energy Regulator
inquiries 1-855-297-8311 24-hour emergency 1-800-222-6514 www.aer.ca

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February 28, 2018

Ms. Angie Taksas
Manager, Oil Sands Mining East, Authorizations
Alberta Energy Regulator
Suite 1000, 205 – 5th Street SW
Calgary, AB T2P 0R4

Submitted electronically to: OSminingreportsplans@aer.ca

RE: MD9 Settlement Monitoring Plan
Suncor Energy Inc. Oil Sands Processing Plant and Mine
AER Approval 8535N, Clause 43(a)

Dear Ms. Taksas,

Please find attached Suncor's MD9 Settlement Monitoring Plan to satisfy the requirement of Clause 43(a) of AER Approval 8535N.

If you have any questions regarding this document or if additional information is required, please do not hesitate to contact me at (403) 296-3193.

Regards,

Marlyss Long
Marlyss Long
for

Sheila Chernys
Director, EHS, Oil Sands,
Environment & Industrial Hygiene

cc Jason Heisler, Suncor Energy Inc.

SUNCOR ENERGY INC.

OIL SANDS

MD9 Settlement Monitoring Plan

In compliance with AER Approval 8535N, Clause 43(a)

Submitted to:

Alberta Energy Regulator (AER)

February 28, 2018

This monitoring plan is submitted in accordance with Clause 43(a) of Commercial Scheme Approval No 8535N:

The operator shall submit for MD9:

(a) By February 28, 2018 a settlement monitoring plan;

This Settlement Monitoring Plan is specific to the co-disposal area of the Mine Dump 9 (MD9) facility. Information related to other measurements required in DDA1-MD9 will be provided with the Measurement System Plan which will be submitted on or before by April 27, 2018 as per Directive 085.

MD9 Co-Disposal Area Deposit Description

The MD9 Co-Disposal Area deposit is described in the Enhanced Review Process Clarification Request – Additional Information provided on June 2nd, 2017, pages 87-88.

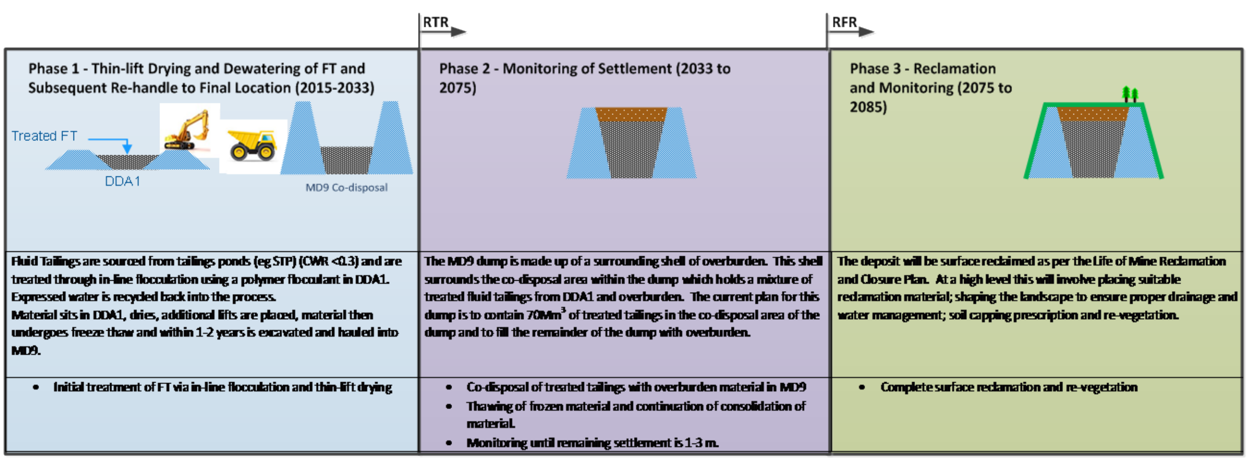

Figure 1 – Recreated from June 2nd ERP Clarification Request Page 88, Figure 24

MD9 Co-Disposal Area Settlement Monitoring Plan

In Phase 1, Suncor will monitor settlement and report via the Directive 085 Fluid Tailings Management report as follows:

1) Annual surface surveys of the deposit surface
2) Elevation and isopach maps from each survey will be provided and show the change in surface elevation from the last reported survey

In Phase 2, Suncor will monitor settlement and report via the Directive 085 Fluid Tailings Management Report as follows:

1) Annual surface surveys of the deposit surface
2) Settlement monuments will be installed on the surface
3) Slope movement indicators will be installed to determine settlement amounts at various depths
4) Elevation and isopach maps and cross sections will be provided and show the change in elevation from the last reported survey and back to the start of Phase 2.

MD9 Co-Disposal Area Settlement Measurements – Phase 1 - Annual Survey		
Characteristic	**Measurement Method**	**Key Measured Value**
Settlement and Deposit Depth	Surface Surveys (LiDAR or Air Photo)	Surface elevation change with time
MD9 Co-Disposal Area Settlement Measurements – Phase 2 - Annual Survey		
Settlement	Surface Surveys (LiDAR or Air Photo)	Surface elevation change with time
	Settlement monuments	Site specific elevation change with time
	Slope movement indicators	Settlement with Depth in deposit

The settlement analysis will be provided as part of the annual Fluid Tailings Management Report submitted on or before April 30 of each year beginning in 2019, as required by Directive 085, Requirement 21.

10.9. Tailings Asset Description Sheets

Note: A set of detailed descriptions is provided in order to measure, analyze and report on required parameters for each tailings asset, including:

- Pond 1A
- Pond 2/3
- Pond 5 (Phase 2)
- Pond 6 (Phase 1 and 2)
- Pond 7 (Phase 1 and 2)
- MD9 Co-disposal (Phase 2)
- MD9 South Co-disposal (Phase 1 and 2)
- DDA3
- STP
- SD8, SD9 and SD10
- Pond 8B.

Each sheet is broken up into two sections:

- Deposit Description – this section describes the FT materials stored or placed within the asset
- Measurement Reporting Requirements – this section describes the items reported in the *Annual Fluid Tailings Management Report*

Within the sheets, references are made to "Phases". These represent the status of the asset related to RTR and RFR, as described in Section 1.1.

Tailings Asset	Pond 1A		
Deposit Descriptions			
Asset contains FT Asset has an operational watercap			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Watercap volume	Volume	n/a	
Watercap quality	Routine Water Chemistry	n/a	Water sample collected from dock on the pond. Refer to *Appendix 10.7 "Water Quality Testing Guide"*
Total containment	Volume from Pond Bottom	n/a	
FT volume	Volume	n/a	
FT composition	CWR, BMW(1), NORMs	n/a	

Tailings Asset	Pond 2/3		
Deposit Descriptions			
Asset receives froth treatment tailings (FTT) Asset contains FT Asset has an operational watercap			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Watercap Volume	Volume	n/a	
Watercap Quality	Routine Water Chemistry	n/a	Water sample collected from dock on the pond, during winter months, and from a syphon drain, outside of winter months. Refer to *Appendix 10.7 "Water Quality Testing Guide"*
Total Containment	Volume	n/a	
FTT Deposition Location	GPS survey	n/a	
FT Volume	Volume	n/a	
FT Volume Transferred	Volume and Destination	n/a	
FT Composition	BMW[1], NORMs	n/a	
Notes:			
[1] Suncor utilizes Dean Stark method to determine BMW, and Analytical Protocol for Naphtha Content in Tailings by Coanda Research & Development Corporation.			

Tailings Asset	Pond 5 - Phase 2		
Deposit Descriptions			
Asset contains RTR FT Asset contains RTR FT (soft CT)			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Expressed Water Quality	Routine Water Chemistry	n/a	Water sample collected from sump pump system. Expressed water mixed with precipitation; Refer to Appendix 10.7 "*Water Quality Testing Guide*"
Expressed Water Volume	Line flow volumes	n/a	Expressed water mixed with precipitation
FT Volume	Volume	n/a	
FT Composition	CWR, BMW[1], PSD and NORMs	n/a	
Mitigation Coke Cap / FT Interface Elevation	Elevation survey for Cell 9	*1087 ft*	RFR achieved when the base of the Cell 9 coke cap reaches 1087 ft elevation
Settlement, Strength and Dewatering	Annual Settlement vs. Predicted Curve	*settlement follows model*	Confirm the rate of Pond 5 settlement will support proposed commencement of reclamation prior to May 1, 2024 and will support the achievement of targeted final closure landforms
	Pond 5 Settlement Monitoring Plan	*plan is followed*	*Pond 5 Settlement Monitoring Plan* (Suncor 2017b)
Closed Circuit Water System	Inspection Records	*operating as designed*	To be reported in "*Fluid Tailngs Management Report*" submitted annually to AER.
Groundwater	Refer to Groundwater Monitoring Program		

Tailings Asset	Pond 6 - Phase 1		
Deposit Descriptions			
Asset contains FT Asset has an operational watercap			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Watercap Volume	Volume	n/a	
Watercap Quality	Routine Water Chemistry	n/a	Water sample collected from drain at pump (81G-339A/B) discharge. Refer to *Appendix 10.7 "Water Quality Testing Guide"*
FT Volume	Volume	n/a	
FT Composition	CWR, BMW[1], PSD and NORMs	n/a	
Mitigation Installed[3]	Air photo showing mitigation installation map	*Complete Dec 31, 2028*	
Closed Circuit Water System	Inspection records	*Operating as Designed*	To be reported in "*Fluid Tailngs Management Report*" submitted annually to AER.
Groundwater	Refer to Groundwater Monitoring Program		
Notes:			
[1] Suncor utilizes Dean Stark method to determine BMW, and Analytical Protocol for Naphtha Content in Tailings by Coanda Research & Development Corporation.			

Tailings Asset	Pond 6 - Phase 2		
Deposit Descriptions			
Asset contains RTR FT			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Expressed Water Quality	Routine Water Chemistry	n/a	Water sample collected from drain at pump (81G-339A/B) discharge. Expressed water mixed with precipitation; Refer to Appendix 10.7 '*Water Quality Testing Guide* "
Expressed Water Volume	Line flow volumes	n/a	Expressed water mixed with precipitation
FT Volume	Volume	n/a	
FT Composition	CWR, BMW[(1)], PSD and NORMs	n/a	
Settlement, Strength and Dewatering	Annual Settlement vs. Predicted Curve	*Settlement follows model*	
Closed Circuit Water System	Inspection Records	*Operating as Designed*	To be reported in "*Fluid Tailngs Management Report* " submitted annually to AER.
Groundwater	Refer to Groundwater Monitoring Program		

Tailings Asset	Pond 7 - Phase 1		
Deposit Descriptions			
Asset contains FT Asset has an operational watercap			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Watercap Volume	Volume	n/a	
Watcap Quality	Routine Water Chemistry	n/a	Water sample collected from vent at pump (300G/42A/B/C/D) suction. Refer to *Appendix 10.7 "Water Quality Testing Guide"*
FT Volume	Volume	n/a	
FT Composition	CWR, BMW(1), PSD and NORMs	n/a	
FT Volume Transferred	Volume and Destination	n/a	
Mitigation Installed(3)	Air photo showing mitigation installation map	*Complete Dec 31, 2033*	
Closed Circuit Water System	Inspection records	*Operating as Designed*	To be reported in "*Fluid Tailngs Management Report*" submitted annually to AER.
Groundwater	Refer to Groundwater Monitoring Program		

Tailings Asset	Pond 7 - Phase 2		
Deposit Descriptions			
Asset contains RTR FT			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Expressed Water Quality	Routine Water Chemistry	n/a	Water sample collected from vent at pump (300G/42A/B/C/D) suction. Expressed water mixed with precipitation; Refer to Appendix 10.7 '*Water Quality Testing Guide* "
Expressed Water Volume	Line flow volumes	n/a	Expressed water mixed with precipitation
FT Volume	Volume	n/a	
FT Composition	CWR, BMW(1), PSD and NORMs	n/a	
Mitigation(3) Cap / FT Interface Elevation	Elevation survey for Site 3	298.3m	RFR achieved when the top of the FT elevation at Site 3 reaches 298.3 m
Settlement, Strength and Dewatering	Annual settlement vs. Predicted Curve	*Settlement follows model*	
Closed Circuit Water System	Inspection Records	*Operating as Designed*	To be reported in "*Fluid Tailngs Management Report* " submitted annually to AER.
Groundwater	Refer to Groundwater Monitoring Program		

Tailings Asset	MD9 Co-disposal - Phase 2 (MD9 Settlement Monitoring)		
Deposit Descriptions			
MD9 Asset is used to permanently store co-disposed treated FT from DDA1 and overburden.			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Expressed Water Volume	Volume	n/a	Expressed water mixed with precipitation; Frequency determined in design submitted in 2023
Expressed Water Quality	Routine Water Chemistry	n/a	Water sample collected from pumping system. Expressed water mixed with precipitation; Frequency determined in design submitted in 2023
Co-Disposed Treated FT / Overburden Volume	Volume	n/a	Frequency determined in design submitted in 2023
Co-Disposed Treated FT / Overburden Composition	CWR, BMW[(1)], and NORMs	n/a	Every 3 years
Deposit Settlement	Surface Surveys, settlement monuments and Slope movement indicators	*1-3 m settlement remaining*	*Refer to "MD9 Co-Disposal area Settlement Plan" (Suncor 2018a)*
Closed Circuit Water System	Inspection records	*Operating as Designed*	To be reported in "*Fluid Tailngs Management Report* " submitted annually to AER.
Groundwater	Refer to Groundwater Monitoring Program		

Tailings Asset	MD9 South - Phase 1 (Operational Placement)		
Deposit Descriptions			
DDA1 treated tailings and Pond 8B remnant FT is relocated by haul truck to MD9 South co-disposal area. DDA1 treated tailings and Pond 8B remnant FT in MD9 South is placed in co-disposal cells along with overburden.			
Measurement Reporting Requirements			
MD9 South			
Reported Items	Measurement	Criteria	Notes
Placed material volumes	Volume	Minimum OB:FT Ratio > 1	Based on source volumes
Co-Disposed Treated FT and Pond 8B Remant FT / Overburden Volume	MD9 South Volumetric surveys	n/a	
Co-Disposed Treated FT and Pond 8B Remant FT / Overburden Composition	CWR, BMW[1], and NORMs	n/a	
Closed circuit water system	Inspection records	*Operating as Designed*	To be reported in "*Fluid Tailngs Management Report* " submitted annually to AER.
Groundwater	Refer to Groundwater Monitoring Program		
Notes:			
[1] Suncor utilizes Dean Stark method to determine BMW, and Analytical Protocol for Naphtha Content in Tailings by Coanda Research & Development Corporation.			

Tailings Asset	MD9 South - Phase 2 (MD9 South Settlement Monitoring)		
Deposit Descriptions			
MD9 South Asset is used to permanently store co-disposed DDA1 treated FT, Pond 8B remnant FT, and overburden.			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Expressed Water Volume	Volume	n/a	Expressed water mixed with precipitation; Frequency determined in design submitted in 2023
Expressed Water Quality	Routine Water Chemistry	n/a	Water sample collected from pumping system. Expressed water mixed with precipitation; Frequency determined in design submitted in 2023
Co-Disposed Treated FT / Overburden Volume	Volume	n/a	Frequency determined in design submitted in 2023
Co-Disposed Treated FT / Overburden Composition	CWR, BMW[1], and NORMs	n/a	Every 3 years
Deposit Settlement	Surface Surveys, settlement monuments and Slope movement indicators	*Settlement remaining can be accomodated in final closure design*	
Closed Circuit Water System	Inspection records	*Operating as Designed*	To be reported in "*Fluid Tailngs Management Report*" submitted annually to AER.
Groundwater	Refer to Groundwater Monitoring Program		
Notes:			
[1] Suncor utilizes Dean Stark method to determine BMW, and Analytical Protocol for Naphtha Content in Tailings by Coanda Research & Development Corporation.			

Tailings Asset	DDA3 - Phase 1 and 2[2]		
Deposit Descriptions			
Asset will contain PASS treated FT			
Asset will contain an operational watercap			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Expressed Water Volume	Watercap Volume	n/a	Expressed water mixed with precipitation
	Volume removed	n/a	Expressed water mixed with precipitation
Expressed Water Quality	TSS	*Annual average (TSS ≤ 500 ppm)*	Expressed water mixed with precipitation
	Routine Water Chemistry	n/a	Water sample collected from drain at pump (502G-92240/92260) discharge, if ADW treatement is offline, and MIV 21115-1, if MFT treatment is online. Refer to *Appendix 10.7 "Water Quality Testing Guide"*
FT transported to PASS	Volume and Source Location	n/a	
PASS treated FT Volume	Volume	n/a	
PASS treated FT Composition	BMW[1] and NORMs	n/a	
	CWR	*CWR > 0.3*	Threshold based on deposit sampling and modelling
Closed circuit water system	Notated air photo records of field operations	*Operating as designed*	To be reported in "*Fluid Tailngs Management Report* " submitted annually to AER.
Groundwater	Refer to Groundwater Monitoring Program		
Notes:			

[1] Suncor utilizes Dean Stark method to determine BMW, and Analytical Protocol for Naphtha Content in Tailings by Coanda Research & Development Corporation.

[2] Suncor will provde an update to the Measurement System Plan for DDA3 - Phase 2, at least two years prior to completion of deposition of treated FT in DDA3.

Tailings Asset	STP		
Deposit Descriptions			
Asset contains FT Asset has an operational watercap			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Watercap Volume	Volume	n/a	
Watcap Quality	Routine Water Chemistry	n/a	Water sample collected from drain at pump (86G-93A/B or 86G-94) suction. Refer to *Appendix 10.7 "Water Quality Testing Guide"*
Total Containment	Volume from Pond Bottom	n/a	
FT Volume	Volume	n/a	
FT Volume Transferred	Volume and Destination	n/a	
FT Composition	CWR, BMW[(1)], and NORMs	n/a	

Average Watercap Chemistry data	**SD8/SD9/SD10**		
Deposit Descriptions			
Assets contain coarse tailings (sand)			
Assets contain FT			
Assets has an operational watercap			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Watercap Volume	Volume	n/a	
Watercap Quality	Routine Water Chemistry	n/a	Water sample collected from drain at pump (86G-84/87/90) suction. Refer to *Appendix 10.7 "Water Quality Testing Guide"*
Total Containment	Volume from Pond Bottom	n/a	
FT Volume	Volume	n/a	
FT Composition	CWR, BMW[(1)], and NORMs	n/a	

Tailings Asset	Pond 8B		
Deposit Descriptions			
Asset contains FT Asset has an operational watercap			
Measurement Reporting Requirements			
Reported Items	Measurement	Criteria	Notes
Watercap volume	Volume	n/a	
Watercap quality	Routine Water Chemistry	n/a	Water sample collected from dock on the pond. Refer to *Appendix 10.7 "Water Quality Testing Guide"*
Total containment	Volume from Pond Bottom	n/a	
FT Volume	Volume	n/a	
FT Volume transferred	Volume and Destination	n/a	
FT Composition	CWR, BMW[1], and NORMs	n/a	

10.10. Summary of Measurement of Water and Fluid Tailings Volume – Tools and Frequency

<table>
<tr><th rowspan="2">Parameter</th><th rowspan="2">Tool</th><th colspan="5">Density</th><th rowspan="2">Frequency</th></tr>
<tr><th>Pond 1A</th><th>Pond 2/3</th><th>Pond 5</th><th>Pond 6 – Phase 1</th><th>Pond 7</th></tr>
<tr><td>Water level</td><td>Survey</td><td colspan="2">Multiple readings at designated locations</td><td>N/A</td><td>Multiple readings at designated locations</td><td>Multiple readings at designated locations</td><td>Annually</td></tr>
<tr><td>Mitigation Surface</td><td>LiDAR</td><td>N/A</td><td>N/A</td><td>Modelled as continuous surface</td><td>N/A</td><td>N/A</td><td>Annually</td></tr>
<tr><td>Mudline</td><td>Sonar</td><td colspan="2">Modelled as continuous surface</td><td>N/A</td><td>Modelled as continuous surface</td><td>Modelled as continuous surface</td><td>Annually</td></tr>
<tr><td>Mudline</td><td>Sampling</td><td colspan="5">Minimum one-fifth density of G-CPT test;
Sample taken vertically every 200 cm</td><td>Annually</td></tr>
<tr><td>Bottom of Fluid Tailings</td><td>CT09</td><td colspan="2">1 test location per 35 ha</td><td>N/A</td><td>1 test location per 35 ha</td><td>1 test location per 35 ha</td><td>Annually</td></tr>
<tr><td>Bottom of Fluid Tailings</td><td>CPT</td><td colspan="5">1 test location per 35 ha</td><td>Annually</td></tr>
</table>

Parameter	Tool	Density					Frequency
		DDA1 – MD9	DDA3	STP	SD8/SD9/SD10	Pond 8B	
Water level	Survey	N/A	Multiple readings at designated locations				Annually
Mitigation Surface	LiDAR	Modelled as continuous surface	N/A	N/A	N/A	N/A	Annually
Mudline	Sonar	N/A	(Top of Pass-treated FT) Modelled as continuous surface		Modelled as continuous surface		Annually
Mudline	Sampling	MD9: Approx. 9 test sites; Sample taken vertically every 100cm	One-fifth density of G-CPT test; Sample taken vertically every 200 cm				Annually
Bottom of Fluid Tailings	CT09	N/A	1 test location per 35 ha			1 test location per 64.8 ha	Annually
Bottom of Fluid Tailings	CPT	N/A	1 test location per 35 ha			1 test location per 64.8 ha	Annually
Bottom of Fluid Tailings	Survey	Modelled as continuous surface	N/A		N/A	N/A	Annually

10.11. Summary of Measurement of Fluid Tailings Properties for Determination of RTR Status

Parameter	Tool	Density					Frequency
		Pond 5	Pond 6 – Phase 2	Pond 7 – Phase 2	MD9 Co-disposal and MD9 South Co-disposal	DDA3	
CWR	G-CPT	1 test location per 35 ha			MD9: Approx. 9 test sites	1 test location per 35 ha	Annually
CWR	Sampling	One-fifth density of G-CPT test; Sample taken vertically every 200 cm			MD9: Approx. 9 test sites; Sample taken vertically every 100cm	One-fifth density of G-CPT test; Sample taken vertically every 200 cm	Annually
% Solids by Weight	G-CPT	N/A					Annually
% Solids by Weight	Sampling	N/A					Annually
Fines content	G-CPT	N/A					Annually
Fines content	Sampling	N/A					Annually
In-situ Strength	G-CPT	1 test location per 35 ha			MD9: Approx. 9 test sites	Minimum 1 test site per 35 ha	Annually
In-situ Strength	Vane Shear	Number of sites and sampling interval done as per engineering judgment (for G-CPT validation)					Annually