

## Work Plan for Water Treatment Pilot Study *Faro Mine Remediation Project, TA 013*

PREPARED FOR: Government of Yukon  
Aboriginal Affairs and Northern Development Canada

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DATE: July 10, 2012

PROJECT NUMBER: 436662.13.PD.04.01

### 1. Introduction

This work plan describes the materials and methods associated with the upcoming pilot testing of water treatment at the Faro Mine Complex (FMC) site near Faro, Yukon, Canada. The overall purpose of pilot testing is to develop data to support the upcoming design of a new, full-scale water treatment plant (WTP) on the Faro side of the site to replace the existing Mill WTP that is in poor repair. The new Faro WTP will treat mining-influenced waters collected from the Faro and Tailings Areas. It might also treat waters from the Vangorda/Grum Area, depending on the outcome of the one versus two WTP feasibility evaluation (currently ongoing).

The principal treatment technology to be pilot tested is the high-density sludge (HDS) lime treatment process. Toward the end of the pilot study, the sulphide precipitation technology may also be tested as an add-on to the HDS process for potentially achieving lower concentrations of certain metal constituents. The pilot testing described in the work plan is scheduled to take place starting in late-July 2012. The purpose of this work plan is two-fold: to communicate the testing approach to YG staff, and to serve as a guide for CH2M HILL staff operating the pilot systems.

### 2. Technology Description

#### 2.1 High-Density Sludge

The HDS process is a modification of conventional lime precipitation designed to densify the sludge and substantially reduce the volume of sludge requiring management. Figure 1 is a flow diagram for the basic HDS process originally developed by Bethlehem Steel in 1967. Hydrated lime slurry,  $\text{Ca}(\text{OH})_2$ , and sludge (recycled from the thickener) are added to a small, mixed, conditioning reactor (A Reactor), where the lime adheres to the recirculated solids. The lime-treated solids from the A Reactor, along with influent water to be treated, flow to a larger, mixed and aerated, neutralization/oxidation reactor (B Reactor), where reduced metals (e.g., Fe[II] and Mn[II]) are oxidized, and these and other metals are precipitated as (oxy)hydroxides. The pH of the B Reactor is maintained at a selected setpoint by controlling lime addition to the A Reactor. In the HDS process, precipitates form preferentially on the surface of the lime-coated solids rather than as freely nucleating particles or on the equipment surfaces as scale. Repeated recirculation of the solids results in the growth of larger and denser particles compared to those formed by conventional lime precipitation. The B Reactor overflows to the thickener where solids/liquid separation occurs, often aided by the addition of a polymer flocculant. Clarified supernatant (process effluent) overflows from the thickener, often to a granular media filtration system where residual

*The document contained herein should be considered Final as approved by the Government of Yukon on August 27, 2014 with no changes made since the draft submission.*

suspended solids are removed. Sludge is withdrawn as thickener underflow for recycling or wasting. The waste sludge may be dewatered for offsite disposal or transferred directly to an onsite sludge repository. The thickener underflow sludge from an HDS plant typically has a much higher percent solids (e.g., 20- to 30-percent solids or higher) than sludge from a conventional lime neutralization system (~1- to 4-percent solids), greatly reducing the volume of sludge that must be managed for disposal. HDS solids also dewater more readily than conventional lime neutralization sludge and tend to allow easier filter operation.

## 2.2 Sulphide Precipitation

Many metals can be precipitated as highly insoluble metal sulphides, and sulphide precipitation can achieve lower aqueous-phase concentrations of certain metals than hydroxide precipitation. The soluble sulphide process is compatible with HDS and can be incorporated by injecting a sulphide solution between the B Reactor and Thickener. Metal sulphide solids are settled out and removed in the Thickener, along with the hydroxide sludge. Sulphide solutions are usually created from sodium sulphide ( $\text{Na}_2\text{S}$ ) or sodium hydrosulphide ( $\text{NaHS}$ ). The elevated pH conditions produced by lime addition in the HDS process maintain the unprecipitated sulphide in the soluble, ionic form ( $\text{HS}^-$ ), and minimize the formation and release of hydrogen sulphide gas ( $\text{H}_2\text{S}$ ).

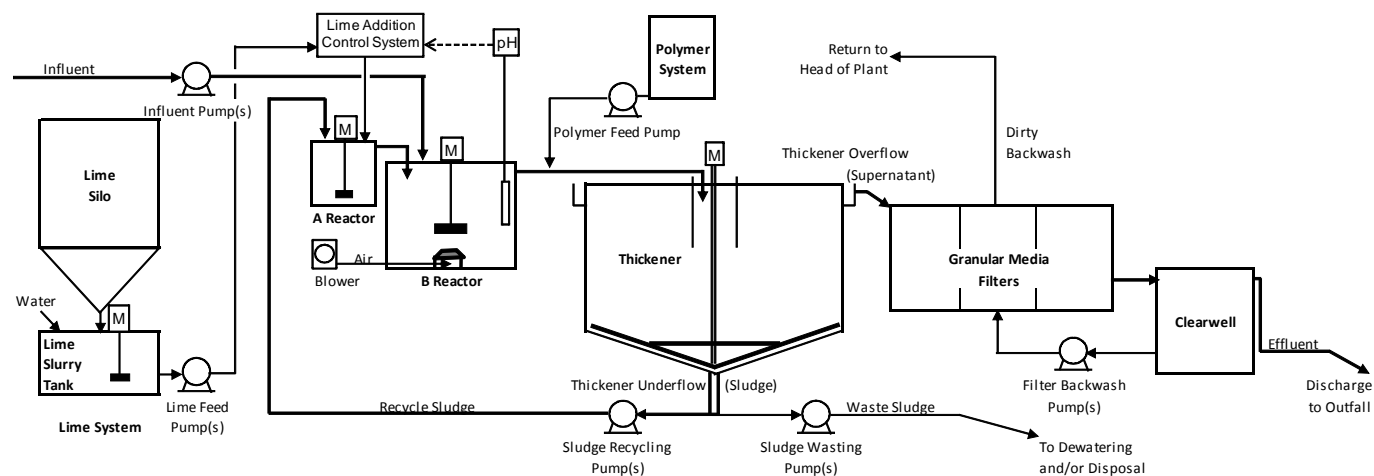


FIGURE 1  
 Basic HDS Process Flow Diagram

## 2.3 Granular Media Filtration

Granular media filtration is often used for post-HDS polishing to remove residual suspended solids that fail to settle out in the Thickener, and thereby reduce the effluent concentrations of *total* (as opposed to dissolved) metals and other elements. Granular media filters can use a single medium, such as sand, or multiple media (e.g., anthracite, sand, and garnet). A filtration system consists of a bank of individual filters. A filter is operated in service mode until backwashing is initiated by a predetermined trigger (such as a differential pressure setpoint or selected run-time). Then it is taken offline and backwashed using stored effluent to clean the filter media. Dirty backwash water is normally returned to the head of the WTP, often after removing settleable solids. Although we have incorporated filtration testing in HDS pilot studies in the past, it is generally not necessary to do so. The performance of sand filters can be adequately estimated from experience, and the effects of filtration on effluent *total* metals concentrations can be calculated from total suspended solids (TSS) and metals concentration data.

## 3. Study Objectives and Overview

The HDS pilot study objectives are to:

1. Conduct flow-through HDS pilot testing on selected influent waters representing a range of water qualities.
2. Evaluate HDS treatment performance, including sludge characteristics and effluent water quality achievable, for each influent.

3. If sulphide precipitation is tested as anticipated, assess the improvements in effluent water quality realized compared to HDS alone (i.e., which constituent concentrations are reduced, and to what levels).
4. Develop process design and operating data for each influent tested to support the full-scale basis of design, including:
  - Appropriate treatment pH
  - Lime requirement
  - Sludge production rate and solids content
  - Appropriate solids recycle ratio (SRR)
  - Need for polymer to enhance settling, along with type and dose
  - Thickener unit area requirement and Thickener sizing
  - Appropriate sulphide reagent dose, if needed

Challenges for designing a new Faro WTP include the considerable uncertainty about future influent water characteristics and effluent discharge limitations. Work is currently underway to evaluate and reduce the uncertainty associated with influent water quality. This work includes field data collection, hydrologic modelling, and geochemical assessments. However, since the results of these actions are not yet available, the proposed pilot testing approach is to operate three HDS pilot plants concurrently, using a range of influent water qualities intended to “bracket” those that a new Faro WTP might be exposed to during its service life. The three pilot plants and their planned influent water qualities are described in the rest of this section. The influent water characteristics and their selection rationale are discussed in the next section.

**HDS-1:** Current Mill WTP influent

**HDS-2:** Middle-case influent, with water quality intermediate between HDS-1 and HDS-3

**HDS-3:** Worst-case influent – that is, highest strength in terms of lime demand and solids formed (LD/SF)

Each pilot plant will be operated in a series of phases. After a startup and acclimation phase, each system will be operated under a selected set of conditions until it equilibrates and data are collected to assess performance. When complete, this will be repeated under a new set of conditions. The variables that will likely be adjusted after the first testing phase include the SRR, the treatment pH, and incorporation of sulphide addition.

The uncertainty about effluent discharge limitations poses a challenge for interpretation of pilot study results – specifically, what effluent constituent concentrations are low enough? It is for this reason that testing of sulphide precipitation is planned: to assess what reductions in constituent concentrations could be achieved using that technology in the event that lower effluent levels are required. Table 1 provides three sets of values, ranging from the relatively lenient current effluent quality standards for the site, to the very stringent Canadian Environmental Quality Guidelines for the Protection of Aquatic Life. It is expected that new WTP discharge limits established for the FMC site will fall within the range represented by these datasets.

TABLE 1  
 Example Water Quality Standards and Guidelines  
 Faro Mine Remediation Project

Parameter	Units	Current Effluent Quality Standards <sup>a</sup>	SRK Target Effluent Limits <sup>b</sup>	Canadian Environmental Quality Guidelines <sup>c</sup>
Aluminum	µg/L	--	10	5 if pH<6.5 100 if pH>6.5
Antimony		100	--	--
Arsenic		50	5	5
Barium		1,000	--	--
Beryllium		--	5	--
Boron		--	100	1,500
Cadmium		20	5	0.033 <sup>d</sup>
Cobalt		--	5	--
Copper		200	9	2.36 <sup>d</sup>
Iron		--	5	300
Lead		200	15	3.18 <sup>d</sup>
Magnesium		--	25	--
Manganese		--	300	--
Mercury		5	--	0.026
Molybdenum		500	--	73
Nickel		500	60	95.6 <sup>d</sup>
Selenium		50	--	1
Silver		100	--	0.1
Thallium		--	--	0.8
Zinc		500	100 (without filtration) 50 (with filtration)	30

<sup>a</sup> Source: Yukon Water Board, 2004.

<sup>b</sup> Source: SRK, 2010. Note: Inclusion of these target values does not constitute endorsement by CH2M HILL.

<sup>c</sup> Source: CCME, 2012. Note: Long-term, freshwater values are shown.

<sup>d</sup> Guideline is hardness-dependent; value shown is for a hardness of 100 mg/L as CaCO<sub>3</sub>.

µg/L – micrograms per litre

CaCO<sub>3</sub> – calcium carbonate

mg/L – milligrams per litre

## 5. Influent Waters

Table 2 provides the composition and rationale for choosing the pilot testing influents, and Table 3 provides their expected approximate characteristics (actual characteristics will vary due to changes in source water composition).

The influent waters will be collected independently every 2 days (approximately) during the pilot study, and transferred to their respective feed tanks at the test location. It is expected that water collection will be conducted using a pickup truck with a collection tank mounted in its bed, along with appropriate pumps for collection and transfer, as needed. Assuming a pilot plant flow rate of 300 millilitres per minute (mL/min), the daily volume usage will be 432 litres per day (L/d) per pilot plant. Assuming a collection volume equal to 2.5 days of operation, a collection tank and three feed tanks with a volume of at least 1,080 L (285 U.S. gallons [USG]) will be needed. Ideally, all four of these tanks will have bottom-level outlets for easy draining. Some changes in water

quality due to blending and oxidation will be inevitable. Efforts to mitigate these changes will include attempting to limit aeration and turbulence during collection and transfer, and refreshing the supply every 2 days.

TABLE 2  
Pilot Plant Influent Waters – Composition and Rationale  
*Faro Mine Remediation Project*

Pilot Plant	Influent Composition	Rationale
HDS-1: Current Mill WTP Influent	<p>Blend of:</p> <ul style="list-style-type: none"> <li>56% Faro Pit Water (X22)</li> <li>42% IP Water (X4)</li> <li>2% ETA Water (ETACombined)</li> </ul> <p>Percentages based on flow volume records for pumping to the Mill WTP (2008-2011 average), from 2011 Annual Monitoring Report (DES, 2012)</p>	This represents the approximate expected influent water quality when the new WTP is started up. It also may represent the lower end of the range in influent strength the WTP is subjected to over its service life (the current GoldSim model predicts that the water quality will increase in constituent concentrations and strength over time).
HDS-2: Middle-case Influent	<p>Blend of:</p> <ul style="list-style-type: none"> <li>30% Faro Pit Water (X22)</li> <li>40% Faro Seep Water (X23)</li> <li>30% Vangorda Pit Water (V22)</li> </ul> <p>Percentages based on existing water quality data and blend proportions calculated to create the target water characteristics shown in Table 2.</p>	This represents an intermediate water quality approximately half-way between that of HDS-1 and HDS-3, and roughly what we expect the current GoldSim model to predict as the strongest future water (after the model is modified to accurately reflect current handling of IP water). It also incorporates water from the Vangorda/Grum side of the site to incorporate spatial differences in water chemistry in the event that only one new WTP is constructed in the Faro Area to treat all site water.
HDS-3: Worst-case Influent	100% Faro Seep Water (X23)	This represents the upper end of the range of influent strength that could potentially occur at the site in the future, and a situation where the HDS sludge is dominated by gypsum (which has different properties than metal hydroxide sludge). Although stronger than any water quality predicted by the current GoldSim model, it is possible that the model does not fully capture the effects of escalating acid-forming reaction rates (this is under investigation).

Notes:  
ETA – Emergency Tailings Area  
IP – Intermediate Pond

TABLE 3  
Influent Water Characteristics Assumed for Pilot Study Planning  
*Faro Mine Remediation Project*

Parameter	Units	HDS-1 Current Mill WTP Influent <sup>a</sup>	HDS-2 Middle-Case Influent <sup>b</sup>	HDS-3 Worst-Case Influent <sup>c</sup>
LD <sup>d</sup>	g/L lb/1,000 USG	0.171 1.43	0.957 8.00	1.92 16.0
SF <sup>d</sup>	g/L lb/1,000 USG	0.304 2.54	1.50 12.5	3.00 25
Sulphate	mg/L	829	4,000	7,910
Iron, dissolved <sup>e</sup>	mg/L	17	90	187
Manganese, dissolved	mg/L	12	60	113
Zinc, dissolved	mg/L	33	400	843

<sup>a</sup> Source: Flow-weighted averages of 2012 monitoring data or 2011 monitoring data for July to September (if higher) for the three Mill WTP influent sources: Faro Pit water, IP water, and ETA water. LD and SF values determined in 2012 adjusted up by multiplying them by ratio of (2012 sulphate)/(July to September 2011 sulphate). Upward adjustments were made because the June 2012 data were, in some cases, lower than recent values for late-summer, apparently due to dilution from meltwater. Sulphate concentrations were used as an indicator of sulphide oxidation (acid-forming reactions) to adjust LD and SF.

<sup>b</sup> Source: Chosen to be approximately mid-way between HDS-1 and HDS-3.

<sup>c</sup> Source: 2012 monitoring data. For this location, the 2012 data showed good agreement with recent late-summer data, so were not adjusted.

<sup>d</sup> LD and SF at pH 10; LD is as hydrated lime, Ca(OH)<sub>2</sub>.

TABLE 3  
**Influent Water Characteristics Assumed for Pilot Study Planning**  
*Faro Mine Remediation Project*

Parameter	Units	HDS-1 Current Mill WTP Influent <sup>a</sup>	HDS-2 Middle-Case Influent <sup>b</sup>	HDS-3 Worst-Case Influent <sup>c</sup>
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<sup>e</sup> Virtually all dissolved Fe is Fe[II].

g/L – grams per litre

lb/1,000 USG – pounds per 1,000 U.S. gallons

Previous conversations with Tlicho Engineering and Environmental Services (TEES) staff indicated that TEES could provide feed tanks from equipment existing at the site. Also, we anticipate that influent collection will be done by either TEES staff or Affected Yukon First Nation (AYFN) staff assigned to CH2M HILL. Both of these items will be coordinated/confirmed as soon as possible.

## 6. Equipment and Supplies

Because of the limited availability of hardware and supplies near the FMC, the pilot equipment and supplies will be carefully assembled and tested at CH2M HILL’s Corvallis, Oregon laboratory before being packed and shipped to the site. These materials include treatment process equipment, field lab equipment, and supplies needed for onsite analyses and testing. Chemical reagents will be procured and shipped separately.

Each pilot plant will consist of the following:

- Vessels: Feed tank, lime slurry tank, A Reactor, B Reactor, and Thickener
- Pumps: Influent pump, lime slurry feed pump, and sludge recycle pump (all with variable-speed controllers)
- Mixers and Rakes: Lime slurry tank mixer, A Reactor mixer, B Reactor mixer, and Thickener rake mechanism and drive (all with variable-speed controllers)
- Aeration components: Air pump, B Reactor piping, and airstone
- Instrumentation and Controls: B Reactor pH probe, pH meter/controller (for lime feed to A Reactor), plus portable field pH meter for monitoring other locations
- Plumbing: Tubing for influent, lime slurry, effluent, sludge recycle, and aeration system air
- Sulphide precipitation equipment: Chemical feed tank, feed pump, and tubing

The pilot plants will be configured as shown in Figure 1, except without the lime silo and granular media filtration system. Also, polymer flocculant will not be added to the pilot plant flow; rather, the effects of polymer addition will be evaluated in batch settling tests. It is our understanding that it will be possible to discharge treated pilot plant effluent by gravity flow directly to a floor drain in the pilot study area that drains to the facility’s septic system. If it is determined that this discharge approach is not appropriate, an alternate effluent disposal method will be utilized.

During a prior site visit, TEES and CH2M HILL identified a suitable area for pilot testing. This area is a garage bay behind the main site administration building, next to the bay where the ambulance is parked. It has good access to power, water, washrooms, and other utilities. The three pilot plants will be set up in this area on three folding tables, with the feed tanks located just outside the bay door. In addition, two more folding tables will be set up as a field lab for onsite analysis and testing.

Chemical reagents used in the process include hydrated lime, polymer flocculant, and a sulphide chemical. Lime is used in, by far, the largest quantity. A liberal estimate of the quantity of lime needed for pilot testing is roughly 113 kilograms (kg) (250 lb), which will likely be obtained as five 22.5-kg (50-lb) bags.

## 7. Operation and Maintenance

The HDS pilot plants will run continuously during the test period and require close daily attention. System operations and maintenance (O&M) will consist of operating the HDS pilot plants to maintain control parameters

at their target values. Table 4 lists initial target values to be used during startup and Phase 1 of testing. Additional O&M activities will include:

- Daily system inspection and maintenance. Check that equipment is operating properly, and correct any clogs, blockages, overflows, and leaks
- Checking meter calibrations, and cleaning process pH probes
- Maintaining feed and reagent tank levels
- Conducting routine monitoring and testing, and collecting/submitting samples for offsite lab analysis
- Recording data, maintaining an operations log, and transmitting data to the task leads (G. Hickman and J. Stefanoff) every day or two
- Making system adjustments as directed by the task leads

Attachment A provides a detailed list of operational activities, and Attachment B includes data sheets for operations and monitoring parameters and other specialized tests (these are included as examples; electronic spreadsheet files will be used during operation).

TABLE 4  
Target Operating Conditions – Startup and Phase 1  
*Faro Mine Remediation Project*

Parameter	Units	HDS-1	HDS-2	HDS-3
Influent flow	mL/min	300	300	300
Lime slurry concentration	g/L	5.0	25	50
Lime slurry feed flow to A Reactor (estimated continuous rate) <sup>a</sup>	mL/min	15-17 (10.3)	15-17 (11.3)	15-17 (11.2)
Initial sludge recycle flow to A Reactor <sup>b</sup>	mL/min	20	40	30
SRR <sup>c</sup>	g/g	30:1	20:1	10:1
B Reactor pH <sup>d</sup>	s.u.	9.0	9.0	9.0

<sup>a</sup> Lime slurry will be fed intermittently, based on pH control, so the suggested flow rate for the lime slurry feed pump is roughly 1.5 times the estimated continuous rate.

<sup>b</sup> For start-up only. After ~2 days of building solids, the appropriate sludge recycle flow rate required to produce the target SRR in each system will be determined daily, based on the prior day's TU solids content and influent LD results, and the sludge recycle flows will be adjusted accordingly.

<sup>c</sup> SRR is defined as the mass of dry solids recycled to the A Reactor divided by the mass of SF from influent water (per unit time).

<sup>d</sup> Suggested initial setting for pH controllers: Low setpoint – 8.9, Deadband (hysteresis) – 0.2, High setpoint – 9.2.

Notes:

g/g – grams per gram

s.u. – standard units

TU – thickener underflow

After setup, the pilot plants will be operated according to the target conditions in Table 4 for sufficient time to build solids and reach approximate steady-state with respect to TU solids concentration (i.e., when the percent solids of TU reaches a plateau and becomes relatively constant). This is expected to require 1 week or less. Then, after a short data collection period, the pilot plants will be transitioned to the next phase of operation by changing one or more operating parameters. After the initial acclimation (solids building) period, each testing phase is expected to require no more than 2 weeks.

In Phase 2, the SRR of each system will be increased to determine if this change results in improved sludge quality: HDS-1 to 40:1, HDS-2 to 30:1, and HDS-3 to 20:1. A higher treatment pH (i.e., pH 9.5) will likely also be tested to evaluate the effects on effluent water quality, lime requirements, and sludge production. Phase 3 is reserved for testing sulphide addition. The precise target operating conditions for Phases 2 and 3 will be selected by the pilot study team based on the Phase 1 results and communicated to the operators to make the appropriate changes.

## 8. Monitoring Plan

Table 5 shows the HDS pilot plant monitoring plan, including measurements, analyses, and testing to be done onsite and at an offsite laboratory. Standard operating procedures (SOPs) for specialized field tests are provided in Attachment C (for LD/SF, Talmadge-Fitch [TF], Dorr-Oliver [DO], Buchner Funnel [BF], polymer jar testing, and TSS tests).

Offsite laboratory analyses will be performed by ALS Laboratories (ALS). Table 6 provides analytical methods and sampling information for onsite and offsite lab analysis and testing; the Quality Assurance Project Plan (QAPP) also provides details (CH2M HILL, 2012a). Sample containers (prepreserved, when appropriate), shipping coolers, shipping, and scheduling of analyses will be coordinated with the project chemist (B. Kidd). An accelerated turnaround time will be needed for offsite lab analysis of dissolved metals to allow timely decisions. This will also need to be coordinated with the project chemist. Quality assurance (QA) and quality control (QC) requirements for pilot testing consist of the standard offsite lab procedures.

TABLE 5  
**Monitoring Plan**  
*Faro Mine Remediation Project*

Parameter	Locations	Frequency	Notes
<b>Onsite Measurements and Tests</b>			
Flow rate	I, R, S	2/d	
pH	I, B, E,	2/d	
Temperature	I, E	2/d	
Conductivity	I, E	2/d	
Lime slurry tank level	L	2/d	
Sludge depth in thickener	T	1/d	
Sludge volume wasted	W	1/d	1
LD/SF	I	1/d	
TSS	I, E, R	1/d	2
SG	R	1/d	2
Polymer dose evaluation	F	1/phase	3
TF settling test	F	4/phase	4
DO clarification test	F	4/phase	4
BF dewatering test	R	4/phase	4
<b>Offsite Lab Analyses</b>			
Metals, total	I, E	4/phase	4,5
Metals, dissolved	I, E	4/phase	4,5
Hardness (calculation)	I, E	4/phase	6
Alkalinity	I, E	4/phase	
Sulphate	I, E	4/phase	
TSS	I, E	4/phase	7
TDS	I, E	4/phase	
XRD/XRF analysis (optional)	W	Once at end of study	TBD
Bioassay testing (optional)	E	Once at end of each phase	TBD

**Notes:**

- 1: Or whenever wasting is done - should include TU removed for testing in this value
- 2: % Solids is calculated from TSS and SG in the HDS Monitoring data sheet
- 3: After sludge equilibration, before TF and DO testing
- 4: For example, 1 during the equilibration period (middle of first week of phase) and 3 during the intensive data collection period (late in first week through second week of phase).



TABLE 5  
Monitoring Plan  
Faro Mine Remediation Project

Parameter	Locations	Frequency	Notes
5: Metals list: Analyze complete project list for first round, then pare back to only the "important" and detectable metals/elements for later rounds. Complete list = Al, Sb, As, Ba, Be, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Li, Mg, Mn, Hg, Mo, Ni, K, Se, Si, Na, Sr, S, Tl, Ti, U, V, Zn.			
6: Calculated parameter – Do not need to submit sample for this. Hardness [mg/L as CaCO <sub>3</sub> ] = 2.497(dis. Ca, mg/L) + 4.118(dis. Mg, mg/L)			
7: On days that effluent is sampled for metals analysis, run TSS on same sample (i.e., split sample)			
<b>Sample location codes:</b>			
I - Influent	B - B Reactor		
R - Sludge recycle to A Reactor (TU)	T - Thickener		
E - Effluent (thickener overflow)	F - Thickener Feed		
S - Sulphide solution feed (when applicable)	L - Lime Slurry Tank		
W - Waste sludge			
<b>Acronyms:</b>			
SG - specific gravity			
TBD – to be determined			
XRD - x-ray diffraction			
XRF - x-ray fluorescence			

TABLE 6  
Monitoring Methods and Sampling Information  
Faro Mine Remediation Project

Parameter	Method	Sample Volume and Container	Preservation	Holding Time
<b>Onsite Measurements and Tests</b>				
Flow rate	graduated cylinder/stopwatch	None	N/A	Immediate
pH	meter	~25 mL	None	Immediate
Temperature	meter	~25 mL	None	Immediate
Conductivity	meter	~25 mL	None	Immediate
Lime slurry tank level	observation	None	N/A	Immediate
Thickener sludge depth	probe	None	N/A	Immediate
Sludge volume wasted	grad cylinder	None	N/A	Immediate
LD/SF	SOP	500 mL	None	Immediate
TSS	SOP-SM2540D	Volume varies	None	Immediate
SG	graduated cylinder/balance	100 mL	None	Immediate
Polymer dose evaluation	SOP	2 L	None	Immediate
TF test	SOP	2 L	None	Immediate
DO test	SOP	9.5 L	None	Immediate
BF test	SOP	~250 mL	None	Immediate
<b>Offsite Lab Analyses</b>				
Metals, total	EPA6010B/6020A/7470A/245.7	250 mL, plastic	HNO <sub>3</sub> to pH<2, cool to 6°C	180 d (28 d for Hg)
Metals, dissolved	EPA6010B/6020A/7470A/245.7		Field-filter; preserve filtrate w/HNO <sub>3</sub> to pH<2, cool to 6°C	180 d (28 d for Hg)
Hardness (calculation)	SM2340B	None	N/A	N/A
Alkalinity	SM2320B	500 mL, plastic (shared)	Cool to 6°C	14 d
Sulphate	EPA300.0/SM4110B			28 d
TSS	SM2540D	500 mL, plastic	Cool to 6°C	7 d

TABLE 6  
**Monitoring Methods and Sampling Information**  
*Faro Mine Remediation Project*

Parameter	Method	Sample Volume and Container	Preservation	Holding Time
TDS	SM2540C	(shared)		

°C – degrees Celsius  
 N/A - not applicable

## 9. Data Management

Recordkeeping will consist of maintaining data sheets and an operator activities log on a daily basis. The activities log will be used to note observations, document changes made, and record any raw data not captured in other data sheets. Electronic data sheet templates for operations and monitoring data, as well as for selected onsite tests, will be provided for use by the operators. The O&M data sheets will be updated daily by the operators and transmitted by email to the task leads (Hickman and Stefanoff). Photographs will also be taken to record any pertinent observations.

The main decision points in the HDS testing program are (1) determining when the systems have approached steady-state and, therefore, when to begin intensive data collection, (2) deciding when to end a testing phase and start the next one, and (3) identifying the precise conditions for the next phase. These decisions will be made based on the available data on sludge and effluent quality, and so maintaining clear, up-to-date records is critical to support timely decision-making.

## 10. Residuals Management

Pilot plant residuals include unused influent, treated effluent, waste sludge, and testing residuals. Waste sludge from the different pilot plants will be kept segregated and saved in buckets labelled to indicate the source, for use in future testing (e.g., sequential leaching tests are planned to evaluate the stability of sludge disposed of in the bottom of a pit lake). Treated effluent will be discharged to a floor drain, and residual water from testing will be discharged to a floor drain or sink. It may be desirable to drain any unused influent water from the feed tanks whenever a fresh supply is collected. If this is done, an appropriate method of capturing and discharging this unused water will have to be devised in conjunction with TEES.

## 11. Reports

When the pilot testing is completed and all lab data are received, a draft report documenting test procedures, results, conclusions, and recommendations will be prepared and submitted to YG for review. The report will be finalized after receiving and incorporating internal and external review comments. Interim data updates will be communicated in conference calls, as appropriate.

## 12. Schedule

We expect to begin mobilization and setup in late July 2012. Setup and startup will require 1 to 2 weeks. We anticipate that each testing phase will require approximately 2 weeks to complete, or, allowing 1 week as contingency, a total of approximately 7 weeks after setup/startup. Demobilization will require an additional week to dismantle, clean, repack, and ship the equipment back to CH2M HILL's Corvallis office. A draft report will be submitted approximately 5 weeks after pilot testing completion (assuming all data is turned around within 2 weeks).

## 13. Staffing

Table 7 lists key staff for the pilot study.

TABLE 7  
Key Staff  
*Faro Mine Remediation Project*

Name	Affiliation	Role	Office Phone	Mobile Phone
Gary Hickman	CH2M HILL/CVO	Pilot Testing Task Lead	541-768-3521	541-740-4546
Jim Stefanoff	CH2M HILL/WYT	Pilot Testing Task Senior Technical Consultant	867-668-2201	509-981-5015
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Shawn Storrie	CH2M HILL/WYT	Health & Safety Officer	867-668-2201	867-336-2233
Boyd Barstad <sup>a</sup>	TEES/Faro Mine	Faro Site Manager or main contact	867-994-2600 x0001	
Bernice Kidd	CH2M HILL/RDD	Project Chemist	530-229-3203	
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Lionel Etheridge	CH2M HILL/WYT	Faro Project Manager	867-668-2201	867-335-4973

<sup>a</sup> Or someone else he designates to be our main point of contact for the pilot study

### Notes:

CVO = Corvallis, Oregon, USA

RDD = Redding, California, USA

VBC = Vancouver, British Columbia, Canada

WYT = Whitehorse, Yukon, Canada

## 14. Health and Safety

All work on this project will be conducted in accordance with the CH2M HILL Field Health and Safety Plan (CH2M HILL, 2012b) and health and safety procedures established by TEES for the FMC site.

## 15. References

Canadian Council of Ministers of the Environment (CCME). 2012. *Canadian Environmental Quality Guidelines*. Current online version.

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Dennison Environmental Services (DES). 2012. *2011 Annual Environmental Monitoring and Activities Report, Faro Mine Complex – Faro, YT*. Prepared for Yukon Government. February 29.

SRK Consulting (Canada) Inc. (SRK). 2010. *Faro Mine Complex, Final Closure and Remediation Plan, Project Description, Draft 4A*. Prepared for Indian and Northern Affairs Canada (INAC) and Yukon Government, Assessment and Abandoned Mines, March.

Yukon Water Board. 2004. Conditions of Water Use License QZ03-059, issued to Deloitte & Touche Inc. for the FMC site.

**Attachment A**  
**Pilot Plant Operation Activity List**

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TABLE A-1  
**HDS Pilot Plant Daily Operational Activities**  
*Faro Mine Remediation Project*

Morning Routine	
1	General system inspection. Check that the plant ran overnight; that there are no blockages, spills, overflows, or leaks; and that the B Reactor pH is in the correct range. Correct any malfunctions.
2	Transfer the prior day's solids samples from the drying oven to the dessicator (assuming they are dry). (Note: Maintain a supply of prepared glass fibre filters in dessicator for TSS analysis. Prepare by placing on filtering apparatus, rinsing with DI water, transferring to aluminum pan, drying, and dessicating.)
3	Make up lime slurry to fill the lime tank, if needed. Record the time, lime slurry concentration, volume in tank prior to replenishment, and lime slurry usage.
4	Measure and record the Influent flow rate. Adjust as necessary to match the target value.
5	Calibrate the pH and conductivity meters used for field measurements (both bench and field-portable units).
6	After allowing ~30 minutes (or more) in the dessicator to cool to room temperature, weigh the prior day's solids samples and complete the TSS calculations (for SF, Recycle sludge, Influent, and Effluent).
7	Determine the estimated Sludge Recycle flow rate required to produce the target SRR. This is calculated by the HDS Operations Data sheet when the prior day's SF, Sludge Recycle TSS, and Influent flow results are entered.
8	Measure the Sludge Recycle flow rate to the A Reactor. Adjust the flow to the new target value determined in Step 7 above.
9	Collect the following samples for onsite and lab testing. Notes: (1) It is often efficient to prepare prelabelled beakers for Influent, Effluent, and Sludge Recycle for each test system, and re-use them each day (thoroughly washing after each day's use); (2) It might be efficient to combine sample collection with flow rate measurement (for Influent and Sludge Recycle). <ul style="list-style-type: none"> <li>- Influent: Roughly 1 L (2 L or more if needed for offsite analyses)</li> <li>- Effluent: Roughly 0.5 L of Effluent (1 L or more if needed for offsite analyses)</li> <li>- Thickener Recycle: Exactly 100 mL in a tared, graduated cylinder for specific gravity measurement</li> <li>- Thickener Recycle: Exactly 25 mL in a small graduated cylinder for TSS analysis</li> <li>- Thickener Recycle: If a Buchner Funnel test is to be run, collect another ~250 mL</li> <li>- Thickener Feed: On days when Dorr-Oliver or Talmadge-Fitch tests are to be run, collect ~9.5 L or 2.5 L, respectively.</li> </ul>
10	Measure and record pH, temperature, and conductivity of Influent and Effluent samples.
11	Conduct the LD/SF test (at pH10) on Influent sample. Record the LD results (and the SF results the following day once the TSS is known).
12	Filter samples for TSS analysis (for SF, Influent, Effluent, and Sludge Recycle), using 47-mm-diameter <u>glass fibre filters</u> . Suggest filtering 250-mL aliquots for Influent and Effluent samples, 25-100 mL for SF samples (depending on water "strength," and 25 mL for Sludge Recycle samples (collected previously in small graduated cylinder). When finished filtering, place filters with solids residue on prelabelled aluminum pans (record IDs), and transfer to drying oven.
13	Determine the specific gravity (density) of the Sludge Recycle sample by weighing the 100-mL sample collected previously and subtracting the tare weight of the graduated cylinder. Set the graduated cylinder aside in a safe place for 24 hours and then record the settled sludge volume. These values will be used to calculate the percent solids (as-is and final dilution) in the HDS Operations Data sheet.
14	Measure and record the B Reactor pH using the calibrated field meter.
15	Inspect the online B Reactor probe, and check its calibration against the field meter. Recalibrate if needed. If the response is slow or there are signs of scaling, clean the probe with dilute HCl solution.
16	On days requiring offsite laboratory analyses (e.g., total metals, dissolved metals, alkalinity, sulphate, TSS, TDS) prepare samples, fill out chain-of-custody form, package samples with bagged ice in a cooler, and arrange transport to ALS. Use <u>0.45-µm membrane filters</u> for filtration of samples for dissolved metals and SO <sub>4</sub> , and use wide-mouth filtering jars so that filtrate passes directly into the clean sample containers (thus, avoiding contamination).

TABLE A-1  
**HDS Pilot Plant Daily Operational Activities**  
*Faro Mine Remediation Project*

<b>Early Afternoon Routine</b>	
1	Conduct Dorr-Oliver, Talmadge-Fitch, and Buchner Funnel testing according to SOPs, on the schedule required by the monitoring plan.
2	Perform routine and preventative maintenance, such as cleaning/replacing tubing, and cleaning A and B Reactors and outlet ports.
3	Complete recordkeeping to date. Enter daily monitoring data and lab data into prepared data sheets, and record the day's activities in the log book, including any pertinent observations and changes.
4	Measure and record the sludge level in the thickener, if any. This is the height along the straight sidewall.
<b>Late Afternoon Routine</b>	
1	Measure and record the Influent flow rate. Adjust if necessary. Collect samples for field monitoring.
2	Measure and record the Sludge Recycle flow rate to the A Reactor. Adjust if necessary.
3	Check the lab pH/conductivity meter calibration.
4	Measure and record pH, temperature, and conductivity of Influent and Effluent samples. Measure and record the B Reactor pH.
5	Record sludge (thickener underflow) volume wasted, if any. This value should include the volume intentionally wasted, plus any sample volume withdrawn for testing (and not replaced in the thickener).
6	Prior to leaving the site for the day, check the level in the lime slurry tank, and replenish if necessary (record the time, initial volume, lime concentration, and volume used).

## Notes:

$\mu\text{m}$  – micrometre  
 ALS – ALS Laboratories  
 DI – deionized  
 HCl – hydrochloric acid  
 HDS – high-density sludge  
 ID – identification  
 L – litre  
 LD/SF – lime demand/solids formed  
 mL – millilitre  
 mm – millimetre  
 SF – solids formed  
 $\text{SO}_4$  - sulphate  
 SOP – standard operating procedure  
 SRR – solids recycle ratio  
 TDS – total dissolved solids  
 TSS - total suspended solids

**Attachment B**  
**Example Data Sheets**

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TABLE B-1

HDS Monitoring Data Sheet  
Faro Mine Remediation Project

Pilot System ID: HDS- #

Note: use two (or more) rows per date in this sheet

Date	Time	Run h	Influent				Sludge mL/min	B Rctr s.u.	Lime Slurry Tank			Thickener cm	Sludge L	Effluent				Sulfide Solution			Notes	
			mL/min	s.u.	°C	mS/cm			mg/L	g/L	L			L	s.u.	°C	mS/cm	mg/L	mgS/L	mL/min		mg/L
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TABLE B-4

**Dorr-Oliver Test Data Sheet**

Faro Mine Remediation Project

Date:

Sample	Filtered vol [mL]	Time [min]	Solids dry wt [g]	TSS [mg/L]
<b>Test system:</b>		<b>HDS-#</b>		
Polymer [Y/N?]:Y				
Poly dose [mg/L]:				
DO-TSS	25	0.00		0
DO-1	100	10.00		0
DO-2	100	30.25		0
DO-3	100	60.50		0
DO-4	100	90.45		0
DO-5	100	121.00		0
DO-6	100	181.25		0
<b>Test system:</b>		<b>HDS-#</b>		
Polymer [Y/N?]:Y				
Poly dose [mg/L]:				
DO-TSS	25	0.00		0
DO-1	100	10.00		0
DO-2	100	30.25		0
DO-3	100	60.50		0
DO-4	100	90.45		0
DO-5	100	121.00		0
DO-6	100	181.25		0



**Attachment C**  
**Standard Operating Procedures**

---

# Lime Demand and Solids Formed Test Standard Operating Procedure

## Equipment and Supplies

500-millilitre (mL) test beakers, for testing  
150-250 mL beaker, for lime slurry  
Graduated cylinders (25, 100, and 1,000 mL)  
Two magnetic mixers with stir bars (or one mag mixer and one paddle stirrer)  
pH meter and combination electrode  
Support electrode stand with adjustable arm (desirable but not required)  
Standard pH calibration solutions (pH 4.0, 7.0, and 10.0)  
Squirt bottle with distilled water  
Pipets  
Hydrated lime [Ca(OH)<sub>2</sub>]  
Vacuum filtering apparatus, complete  
Whatman 934 AH filters, or equivalent  
Drying oven  
Desiccator  
Tweezers  
Aluminum drying pans  
Four-place analytical balance

## Procedure

1. Immediately before conducting the test, make up 100 mL of lime slurry with distilled water in a 150- to 250-mL beaker. Mix slurry continuously on the mag mixer during makeup and use. *Note: The appropriate lime slurry concentration may range from 1-10 percent (w/v) (10-100 grams per litre [g/L]), depending on sample acidity: for low acidity samples, use 1 percent; for higher acidity samples use 5 percent or higher. The intent is to use a lime slurry concentration that is high enough so that the amount added to achieve the target pH is low relative to the initial sample volume (e.g., less than or equal to 5 percent), while being low enough to allow sensitivity with respect to pH adjustment.*
2. For each target pH level to be evaluated, collect a 500-mL aliquot of influent water sample, and transfer to a test beaker. *Note: For routine monitoring, lime demand/solids formed (LD/SF) is usually evaluated at only one selected pH (usually pH 10.0). However, for treatability testing, it is sometimes desirable to evaluate LDS/SF at multiple pH values.*
3. Place the test beaker on a magnetic mixer or paddle stirrer, and begin mixing. Position the pH electrode and supporting stand so that the tip of the electrode is immersed in the mixing sample. *Note: Calibrate a pH meter following the instrument instructions before beginning test.*
4. Use pipets to add incremental aliquots of lime slurry to the sample until the target pH is achieved. Collect aliquots of lime slurry from approximately mid-depth in the lime slurry beaker. Allow sufficient time for the pH to stabilize between additions. Record the concentration of lime slurry used, the volume of lime slurry added, and the initial and final pH.
5. After achieving the target pH and while rapid mixing, collect a completely mixed sample from the beaker for total suspended solids (TSS) analysis. TSS sample size may be 25 to 100 mL, depending on the amount of solids present and sample filterability.

6. Analyze sample for TSS according to the standard procedure (“Standard Methods” or United States Environmental Protection Agency [USEPA]). Briefly, this method involves filtering a known volume of sample through a tared filter, drying the filter and retained residue in a drying oven at 104 degrees Celsius (°C), allowing the dried filter to cool in a dessicator, and weighing the dried filter and residue.

Calculation: 
$$\text{TSS [mg/L]} = (W_{fr} - W_f)/V_s$$

Where:

$W_{fr}$  = dry weight of filter plus residue [mg]

$W_f$  = dry (tare) weight of clean filter and weighing pan [mg]

$V_s$  = volume of sample filtered [L]

## Calculations

### Lime Demand

LD is simply the weight of lime added to adjust a volume of sample to the target pH.

$$\text{LD [g/L]} = V_{LS} \times C_{LS} \times 1000/V_s$$

Where:

$V_{LS}$  = volume of lime slurry to reach target pH [mL]

$C_{LS}$  = concentration of lime slurry [g/L]

$V_s$  = initial volume of sample [L].

Converting to units of more relevance for full-scale,

$$\text{LD [lb/kgal]} = \text{LD [g/L]} \times (3785.4 \text{ L/kgal})/453.6 \text{ g/lb}$$

Or, simplified,

$$\text{LD [lb/kgal]} = \text{LD [g/L]} \times 8.345$$

### Solids Formed

SF is the mass of suspended solids formed (through precipitation) when a volume of the sample is adjusted to the target pH.

$$\text{SF [g/L]} = \text{TSS} \times V_f \times 1000/V_s$$

$$\text{SF [lb/kgal]} = \text{SF [g/L]} \times 8.345$$

Where:

TSS = TSS measured for completely mixed sample after lime addition to reach the target pH [mg/L of final volume]

$V_f$  = final volume (initial sample volume plus added lime slurry volume) [L]

$V_s$  = initial volume of sample [L]

**NOTE:** When reporting LD and SF data, the target pH and the form of lime used should always be given. In some cases, reporting LD in terms of quicklime [CaO] rather than hydrated lime [Ca(OH)<sub>2</sub>] may be desired. The conversion factor is:

$$\text{LD as CaO} = \text{LD as Ca(OH)}_2 \times 56/74 = 0.757 \times \text{LD as Ca(OH)}_2.$$

# Kynch-Modified Talmadge-Fitch Test Standard Operating Procedure

GTH, Rev. 1/07

## Equipment and Supplies

Drying oven  
Desiccator  
2-L graduated cylinder  
Analytical balance, capable of measuring 0.1 milligram (mg)  
Six-revolutions per hour (rph) stirrer  
“Blunger” to mix graduated cylinder  
Lab timer  
Vacuum filter apparatus, complete  
25-mL graduated cylinder  
4-L beaker  
Stirring rod  
Balance, 3-kilogram (kg) capacity

## Procedure

1. Collect approximately 2.5 L of thickener feed in a 4-L beaker.
2. Mix thoroughly with the stirring rod. Collect a 25-mL aliquot, and determine TSS.
3. Determine the ft/mL ratio for the 2-L graduated cylinder, and the height [ft] corresponding to 2 L.
4. Measure the tare (empty) weight of the graduated cylinder ( $W_t$ ).
5. Fill the graduated cylinder to the 2-L mark with well-mixed thickener feed sample.
6. Weigh the full 2-L graduated cylinder ( $W_f$ ) and determine the specific gravity (SG) of the thickener feed slurry,  $SG [g/mL] = (W_f - W_t)/2000 \text{ mL}$ .
7. Thoroughly mix the cylinder with the blunger. *If polymer addition is to be included in the test, add the selected polymer dose to the sample in the cylinder, and mix vigorously with the blunger.* Start the timer stop watch as the blunger is withdrawn. Immediately insert the six-rph stirrer.
8. Record the slurry interface height every 1 minute until the change in height is less than 20 mL/min. Then record the interface height every 5 minutes until the change in height is less than 20 mL/5 min. Then record the interface height every 10 minutes until the change in height is less than 20 mL/10 min. Then record the interface height every 20 minutes up to a total time of 200 minutes.
9. Determine the final dilution interface height 24 hours after the start of the test. Calculate the “final dilution” solids concentration as percent solids.
10. When the test is complete, return the unused slurry to the pilot thickener.

## Data Analysis

1. Graph interface height (Y-axis) versus time (X-axis).
2. On the graph, draw a straight line through the initial interface heights and a straight line through the final interface heights.
3. Draw a line bisecting the angle formed by the intersection of the two lines in Step 2.
4. Draw a straight line parallel to the time axis through the final dilution interface height.



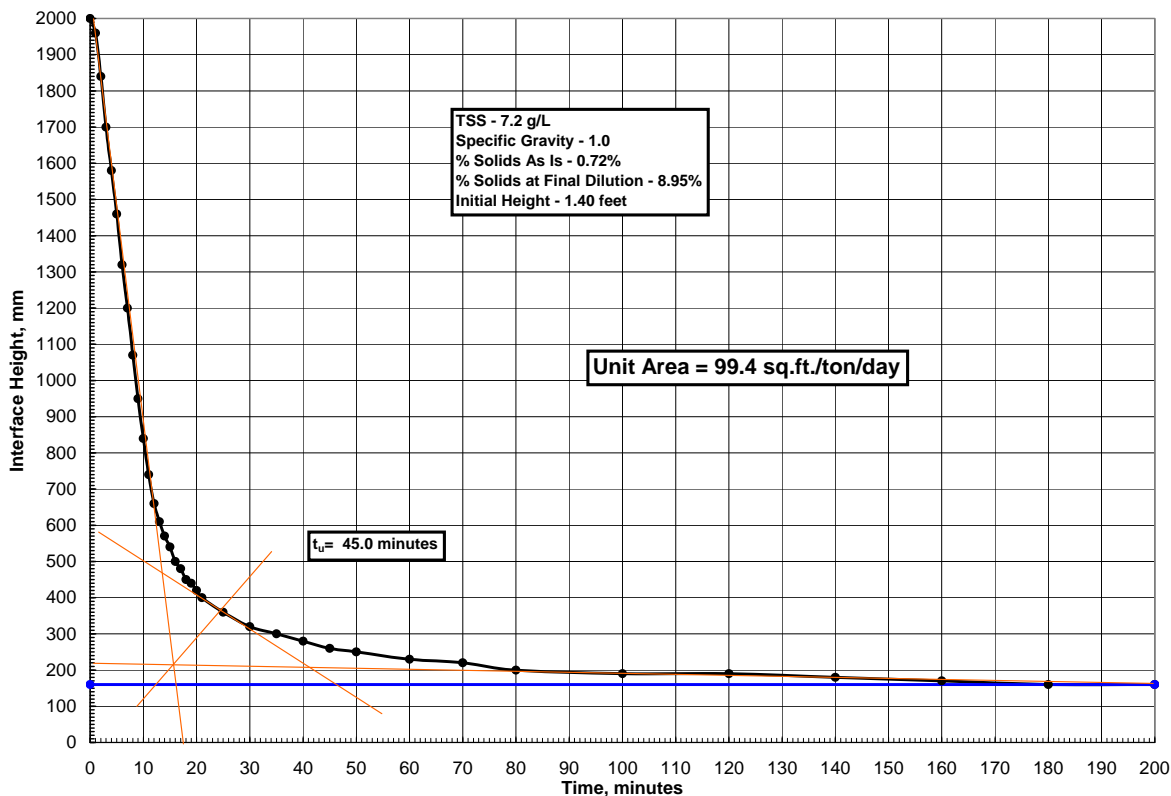
5. Draw a line tangent to the data curve at the intersection point of the bisector line, and extend it to the line representing the final dilution interface height. Read the time in minutes from the X-axis corresponding to the intersection of the tangent and final interface height lines. Divide that time by 1,440 minutes per day (min/d) to get days. That time =  $T_u$ . (Example shown below)
6. Thickener unit area  $[ft^2/ton/d] = T_u/C_oH_o$

Where:

$C_o = \text{initial TSS [g/L]} \times 3.12 \times 10^{-5}$

$H_o = \text{initial slurry height [ft]} - \text{height of 2 L of slurry}$

**Figure C-2. Kynch-Modified Talmadge-Fitch Unit Area Determination  
HDS-A1 11/23/05 (no polymer)**



# Dorr-Oliver Clarification Test Standard Operating Procedure

GTH, Rev. 1/07

## Equipment and Supplies

Drying oven  
Desiccator  
Vacuum filter apparatus, complete  
Whatman 934-AH filters  
Tweezers  
Aluminum weighing pans  
Four-place analytical balance  
10-L mix tank  
Overhead mixer  
Ring-stand assembly (to support mixer)  
Lab timer  
Stirring rod  
One 25-mL graduated cylinder  
Six 100-mL graduated cylinders  
Six 2-L clarification beakers, with sample ports

## Procedure

1. Prepare filters, and measure tare weight of filters and weigh pans.
2. Collect approximately 9.5 L of thickener feed in the 10-L mix tank.
3. Mix thoroughly with the overhead mixer. Take a 25-mL aliquot, and determine TSS.
4. Fill six clarification beakers to the 1,800-mL mark with the mixed slurry.
5. Stir the first beaker for 15 seconds. Stop stirring, and start the timer (Time 0). *If polymer addition is to be included in the test, add the selected polymer dose to each beaker prior to stirring, and stir vigorously.*
6. Immediately start stirring the second beaker, and stir for 15 seconds.
7. Stir the remaining four beakers in sequence for 15 seconds each.
8. After 10 minutes elapsed time ( $T = 10$  min) draw off a small sample from the first clarification beaker to clear the withdrawal tube and discard. Then collect a 100-mL aliquot in a 100-mL graduated cylinder for determination of TSS. (If desired, additional sample volume can be collected for total metals analyses.)
9. After 30 minutes and 15 seconds, repeat Step 8 for the second beaker.
10. Continue the procedure for the next four beakers at 60 minutes and 30 seconds, 90 minutes and 45 seconds, 121 minutes, and 181 minutes and 15 seconds.
11. When the test is complete, return the settled slurry from the six beakers to the pilot thickener.
12. Determine TSS of initial sample plus six clarification samples.

## Data Analysis

1. Graph TSS (Y-axis) versus time (X-axis).
2. Apply the correct areal efficiency factor, and calculate the required thickener diameter to achieve the desired effluent TSS.

# Buchner Funnel Test Standard Operating Procedure

GTH, Rev. 1/08

## Equipment and Supplies

Buchner funnel, ceramic, 110-millimetre (mm) diameter

Filtrate reservoir (e.g., 1-L graduated cylinder)

Stopper to fit reservoir, with hole to accommodate Buchner funnel and hole with fitting to attach vacuum tubing  
1-L graduated cylinder

1-L beaker

Vacuum source (~15 inches mercury [Hg]; a vacuum gauge desirable but not required)

Squirt bottle with distilled water

Filter papers – qualitative, medium retention (5 to 10 micrometres [ $\mu\text{m}$ ])

Drying oven

Desiccator

Metal spatula

Aluminum drying pans

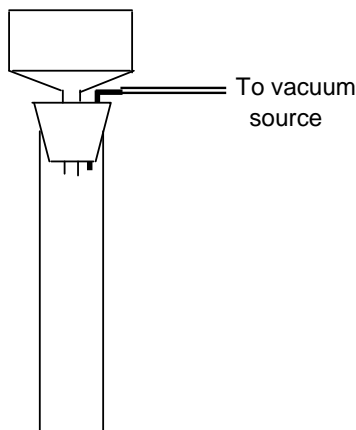
Analytical balance

Stirring rod

Timer

## Procedure

1. Set up Buchner Funnel Test apparatus (see diagram below). Place a filter in the funnel and thoroughly wet with water while applying vacuum to seat the filter paper. Stop vacuum, and discard the water filtrate.
2. Collect approximately 1 L of thickener underflow sample in the beaker. Mix the sample thoroughly, and collect a 25-mL aliquot of well-mixed sludge for analysis of initial (feed) percent solids. Re-mix the sample, and use the graduated cylinder to measure out the volume of well-mixed sample to be used in the Buchner Funnel Test.  
*Note: The appropriate sample size for the Buchner Funnel Test will vary depending on the solids concentration of the sample and the diameter of funnel used. Ideally, the sample volume should contain sufficient solids to form a “cake” with thickness of 1-2 centimetre (cm) (at least 0.5 cm). For 20-percent solids sludge and a 110–mm-diameter funnel, roughly 600-750 mL sample should suffice.*
3. Transfer sample to funnel, and simultaneously start the vacuum and timer.
4. Continue filtering until the cake cracks and the vacuum is lost. Record the time when this occurs and the volume of filtrate is produced.
5. Collect sample of the filter cake, either by dumping the entire cake into a pan and removing the filter paper, or by collecting most of the solids using a spatula. Analyze the percent solids of the filter cake and filter feed samples.



# Jar Testing for Polymer Evaluation

## Standard Operating Procedure

### Comments

This standard operating procedure (SOP) is intended to provide guidelines for testing rather than being a specific test method. This procedure can be used to compare different polymer products or to evaluate different doses of a single polymer product (e.g., dose optimization).

### Equipment and Supplies

Polymer product(s)

5-gallon bucket for sample to be tested

Stainless steel spoon or spatula for mixing the sample contents (or mixing device)

4- or 6-position paddle stirrer (this is ideal, but if not available, one or more individual paddle stirrers may be substituted)

4 or more 0.5-, 1-, 1.5-, or 2-L beakers (referred to as jars)

100-mL beakers for making up polymer solutions

Magnetic mixer and stirbars

Disposable plastic syringes, without needles (1-, 3-, and 5-mL are normally most useful)

### Procedure

1. Determine the test conditions to be evaluated. For polymer dose optimization, this might include the currently used polymer dose and a number of incremental doses above and below the current dose.
2. Make up a diluted polymer solution for use in lab testing according to the manufacturer's instructions. If no instructions are provided, use the following procedure:

**Dilution 1** – Place 100 (for dry polymer) or 99 mL (for liquid or emulsion polymer) of water in a beaker, and stir with a magnetic mixer. Add 1 g of dry polymer or 1 mL of liquid or emulsion polymer to the beaker. (Note: Using a syringe is the easiest way to transfer liquid or emulsion polymers or diluted polymer solutions.) Stir for sufficient time for the solution to become homogeneous (the solution will eventually form a gel, and the stirrer will stop turning). The nominal concentration of this solution is 10 mg/mL.

**Dilution 2** - Place 90 mL of water in a beaker, and stir with a magnetic mixer. Add 10 mL of Dilution 1 to the beaker, and stir for sufficient time for solution to become homogeneous. The nominal concentration of this solution is 1 mg/mL.

*Note: Some dry polymers require wetting with ethanol or methanol to facilitate makeup of Dilution 1. To do this, add the dry polymer, then 3 mL of the wetting reagent (swirl beaker to distribute), and then 97 mL of water, and mix.*

3. Collect several litres of thickener feed (or other sample to be tested) in a bucket. Stir vigorously to suspend solids and homogenize, and transfer aliquots of the well-mixed sample to jars (the size of aliquots depends on the jars used but should be 1-L minimum; the number of jars filled depends on the planned test conditions). Label the jars according to the test conditions to be evaluated.
4. Place the jars on the paddle stirrer, and start stirring at a speed representative of rapid-mix conditions (e.g., ~ 100-120 revolutions per minute [rpm]). If a 4- or 6-place stirrer is available, multiple tests can be conducted simultaneously; if not, the different conditions must be tested individually.
5. Using Dilution 2, add polymer to the jars according to the selected test conditions. Rapid mix for 30 to 60 seconds. If multiple tests are conducted simultaneously, all polymer additions should be completed quickly so that the rapid-mix time for all jars is within this range. Observe flocculation in the jars during rapid mixing.
6. Reduce the mixing speed to ~30 rpm, and slow mix for 5 minutes. *Note: A slow-mix period of 5 minutes is usually long enough for HDS systems because of the large mass of solids particles in the thickener feed. A*

*longer slow-mix time can be used if it appears that floc size is continuing to increase at 5 minutes; however, the time should be constant for all tests. HDS systems generally do not include flocculation tanks, so there is no set time for slow mixing; however, a short slow-mix period is used to allow particle contact and agglomeration as would occur in a mix chamber in the thickener, in the main portion of the thickener, or in both.*

7. Stop stirrer, remove jars from mixer, and allow them to settle under quiescent conditions for at least 30 minutes. *Note: This time is not intended to mimic the settling time in the thickener (which would be longer), but to allow evaluation of relative settling and compaction between the different test conditions.*
8. Record observations for each test condition. Observations should include: floc formation (particle agglomeration), floc size and morphology, settling rate (semi-quantitative or qualitative relative to other tests), supernatant clarity, solids compaction, and settled sludge volume.

## **Data Analysis**

Data evaluation and selection of the best treatment (polymer, dose, or both) should consider all the different types of observations. For example, in some cases, the treatment yielding the fastest settling rate may not produce the clearest supernatant, or the treatment yielding the largest floc size may not provide the best solids compaction and lowest settled sludge volume.