Dredging and Processing Arsenic Contaminated Sediment

Menominee River

Marinette, Wisconsin

tyco

CH2MHILL

ECCS NATIONWIDE
MOBILE LABORATORIES

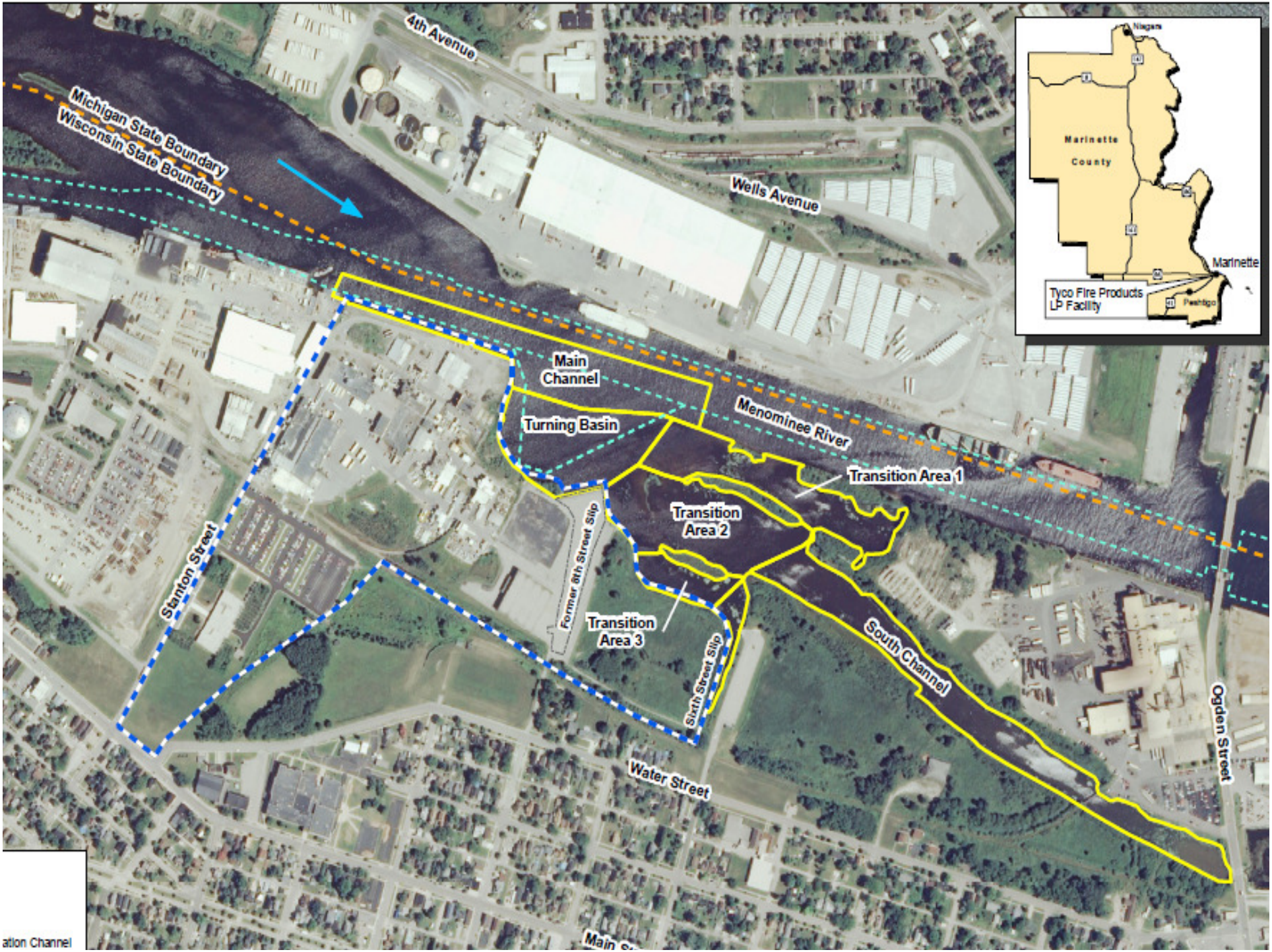
Sevenson Environmental Services, Inc.

Site Overview

- Menominee River in northern Marinette, Wisconsin
- Located next to an active manufacturing facility owned and operated by Tyco International.
- Facility began operations in 1915 as a lumber mill then produced cattle feed, refrigerants and specialty chemicals.
- Arsenic based herbicides produced between 1957 and 1977. Byproducts of this was a salt containing 2% Arsenic by weight which was stockpiled at several locations on the property.
- Arsenic from stockpiled salts entered site soils, sediment and groundwater.
- Tyco purchased the property (and inherited the liabilities for site soils, sediment and groundwater) in 1990. Current Products produced at the facility are fire protection products.

Site Layout

- Remedial Action divided into Four Distinct Sections:
  - **Main Channel:** Open to navigation, flowing current subject to turbidity concerns. Very little dredging here;
  - **Turning Basin:** Used periodically to turn large ships. Deep cuts of dense sediment laid down over many years. Collected debris over years due to it being relatively calm;
  - **Transition Area:** Shallower than Turning Basin area collects softer, more organic sediment that retains water. Also collected large amounts of debris over years. Equipment draft a concern.
  - **South Channel:** Small, even shallower (1'-5' depth) channel containing soft, organic sediments.


4th Avenue
Michigan State Boundary
Wisconsin State Boundary
Wells Avenue
Main Channel
Turning Basin
Menominee River
Transition Area 1
Transition Area 2
Transition Area 3
Former 8th Street Slip
Sixth Street Slip
Stanton Street
South Channel
Ogden Street
Water Street
Marinette County
Marinette
Tyco Fire Products LP Facility
Peshtigo

2012/2013 Remediation Stats

- Mechanical Dredging
    - Over 259,000 Cubic Yards of sediment removed of varying depths and hardness.
- Sediment Treatment and Stabilization
    - Approximately 395,000 tons of sediment treated and stabilized.
- Transport and Disposal
    - Over 470,000 tons of treated and stabilized sediment disposed.
    - 19,000 truckloads.
- Water Treatment
    - Nearly 8 million gallons of water treated and discharged.

Remediation - Dredging

- Mechanical Dredging:
  - Approximately 259,000 Cubic Yards of organic arsenic impacted sediments were dredged using an environmental clamshell bucket, a heavy digging clamshell bucket as well as conventional and specially fabricated digging buckets to remove some of the denser sediments.
  - Dredged Sediment was placed in a barge. Full barges were moved to the unloading dock, dewatered and sampled for treatability criteria prior to treatment and stabilization.
  - 2013 Dredging performed 24 hours per day, 6 days per week.

Remediation - Dredging

Dredging softer material with Clam Bucket.

Dredging denser material with digging bucket.

The softer dredge material would flatten out in the barge and retain water while the denser material stacked and would shed water.

Remediation – Treatment and Stabilization

- Sediment treatment and stabilization
  - Sediment was unloaded from the barges using two Sennebogen material handlers.
  - Unloaded sediment was passed through a debris screen and into a pit.
  - Screened sediment was taken from the feed pit and loaded into pugmills programmed with the specific mix of chemicals to be added for treatment.
    - Chemicals used for treatment included: Ferric Sulfate (liquid or dry depending on dredged material type) and Portland Cement.
  - Treated sediments exited the pugmills, was collected by loaders and placed in a containment bin for curing and sampling for landfill criteria.
  - Approximately 395,000 tons of sediment treated and stabilized.
  - 2013 Treatment and stabilization performed 24 hours per day, 6 days per week.

Remediation – Treatment and Stabilization

Unloading dredged material from barge.

Dredged material passed through screen to remove debris.

Remediation – Treatment and Stabilization

Loading pugmill with screened material.

Treated sediment exiting the pugmill.

Remediation – Treatment and Stabilization

Treated sediment loaded into storage bins for curing.

Loading bins and curing prior to transport and disposal.

Remediation – Transport and Disposal

- Transport and disposal
  - Bins sampled for leachable Arsenic. Passing bins were loaded out to the local landfill for non-hazardous disposal.
  - Trucks leaving site pass over wheel wash and weight scale.
  - Sampling and loading schedules managed to maintain bin space for treated materials, otherwise would interrupt treatment and dredging operations.
  - Over 470,000 tons transported and disposed as non-hazardous material. More than 19,000 loads.

Remediation – Transport and Disposal

Loading sediment for transport and disposal.

Trucks leaving site pass through wheel wash and scale.

Remediation – Water Treatment System

- Water treatment system
  - Installed and operated a 150 GPM onsite wastewater treatment plant to handle contaminated water generated from site activities.
  - Sources included: dewatering of sediment, contact water from rain events and decon water.
  - The onsite treatment system used a series of processes to treat water: pretreatment using coagulation/filtration in geotextile tube filters and separation process, and microfiltration ("MF") prior to treatment in a two-stage reverse osmosis ("RO") system.
  - Process wastewater and reject water were sent to a Vibratory Shear Enhanced Processing ("VSEP") unit, that concentrates the waste stream increasing the volume of water being returned to the Menominee River while decreasing the volume of the waste stream being sent offsite for disposal.
  - Nearly 8 million gallons of water treated and discharged.

Remediation – Water Treatment System

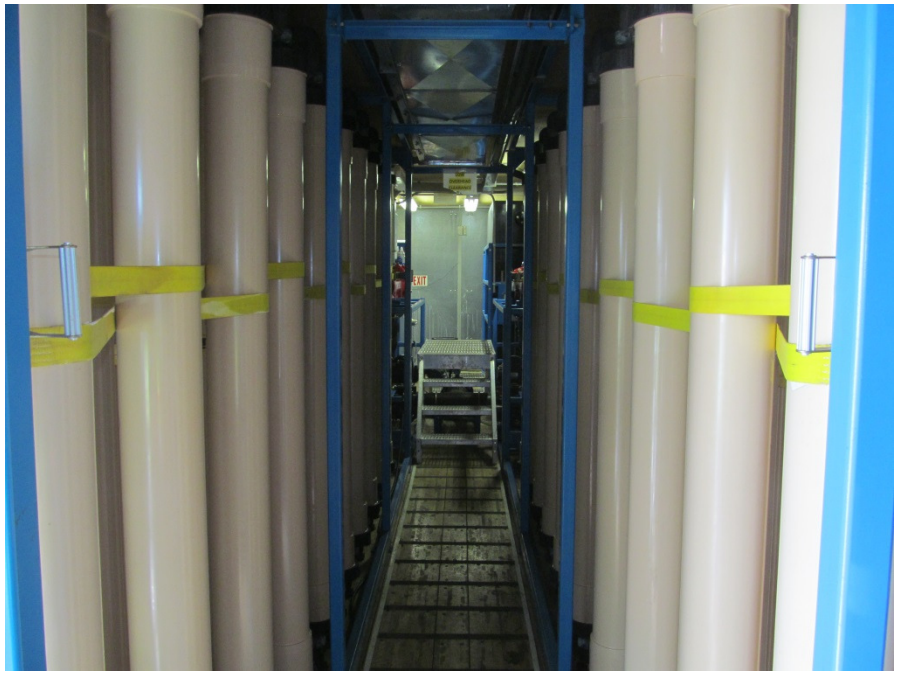
Remediation – Water Treatment System

Incoming water from decanted barges or processing pad is filtered using a flocculent and geobags.

Filtered water is send to equalization tanks for further treatment to remove contaminants.

Remediation – Water Treatment System

Water from equalization tanks is treated through the Pall mobile membrane filtration system.



Water continues treatment with the Ecolutia mobile reverse osmosis system.

Water passing through these filters is sent for discharge, reject water is sent to secondary RO unit for further treatment, reject from that is sent to VSEP unit.

Remediation – Water Treatment System

VSEP, Vibratory Shear Enhanced Processing unit, concentrates reject water from the micro filtration and reverse osmosis units so the total volume of water being returned to the Menominee River is increased while the total volume of the waste stream being sent offsite for disposal is reduced.

Challenges Encountered

- As the project evolved during the final stages of permitting with the State, design changes by CH2M HILL and changes in the construction methods required that the stabilization approach evolve as well.
- During the 2012 season production was limited by the ability to treat the material and dispose of it as nonhazardous.
- Additional treatability studies were conducted following the first season of dredging (winter 2012/13) to reevaluate reagents, chemicals, and dosage rates on the sediment.
- With the new treatability study data the team made a joint determination of a new stabilization approach that would allow for an increase in production levels to meet the dredge season's target completion date. Changes included:
    - Revised reagents and dosages;
    - Improvements to process equipment;
    - Improved site layout.

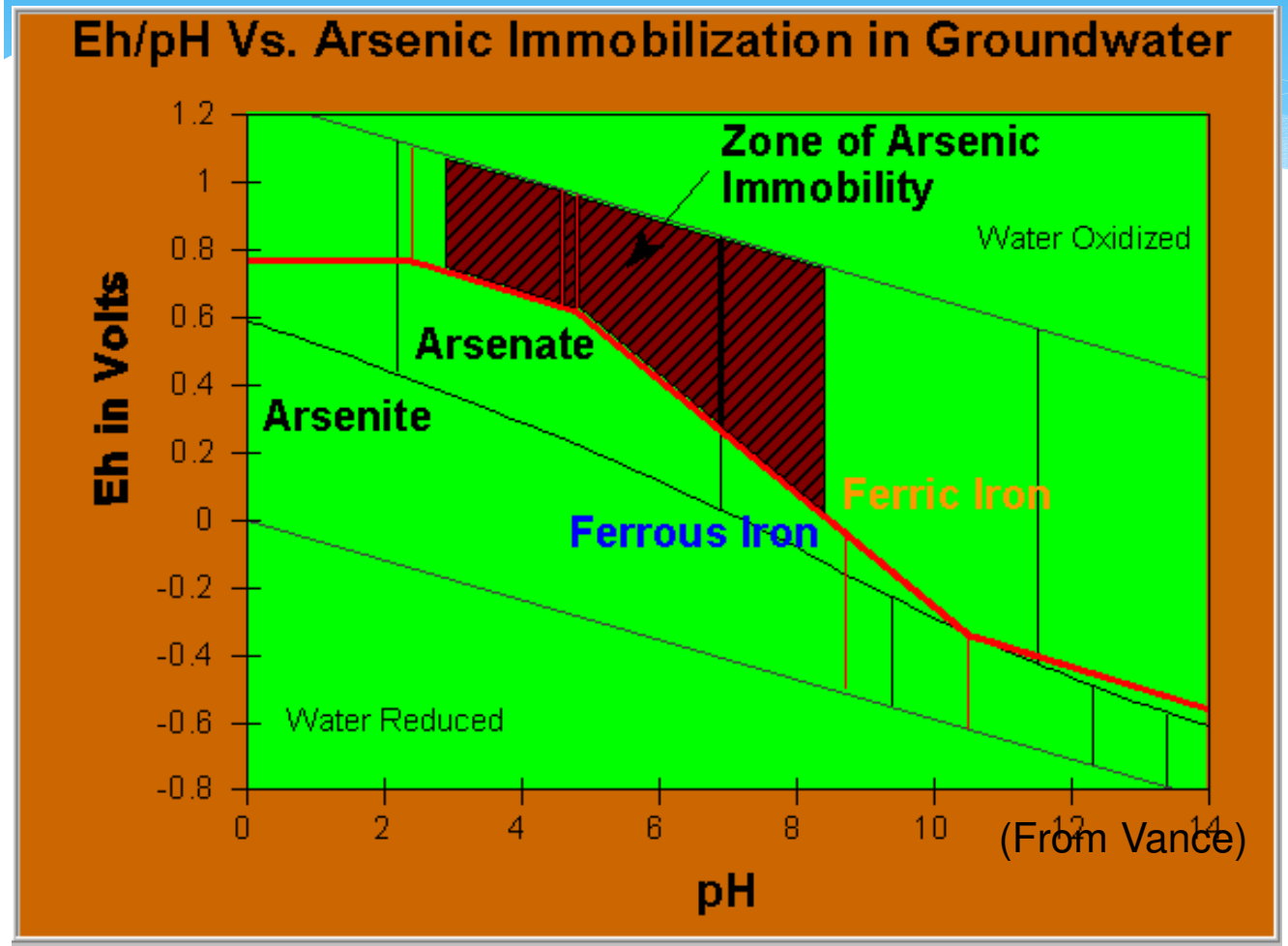
Challenge:
Treatment and Stabilization 2012

2012 Treatment resulted in wet, soupy product that was difficult to handle and needed additional stabilization before landfill acceptance. Additional handling caused bins to fill up and limited dredging production.

Treatability Study 2012-13

- Over 200 Mix Design Combinations
- Elevated TCLP-As leaching (up to 40 mg/L)
- High moisture content (up to 250%)
- High organic matter content (up to 10%)
- Curing intervals: 1 hour, 1, 2, 3, 7 and 28 days
- Pass TCLP-As criteria (< 5 mg/L) by Day 3
  - Impacted by pH, ORP
- Pass Paint Filter & Workability by Day 3

Ideal reagent—oxidizing, acidic to pH neutral, contains ferric iron [Fe(III)]



(From Vance)

Figure 4. Arsenic Mobility in Groundwater as Controlled by the Effect of Eh/pH Conditions on the Speciation of Arsenic and Iron

Reagents Tested:

- Peroxide
- Hypochlorite
- Ferric sulfate (wet/dry)
- Ferric chloride (wet)
- Enviroblend products
- Terrabond products
- BOF Iron Dust

- Lime (L)
- Portland Cement (PC)
- Cement Kiln Dust (CKD)
- Type C Fly Ash

- Adsorptive Polymers
- Wood chips , Sawdust, Starch
- Bentonite

Tiered Mix Design Testing

total As	6295	mg/kg	initial ORP	-309.1	
TCLP-As	34.6	mg/L	Intial pH	7.92	12097/12099 (75%) plus 12100 (25%)

FAIL TCLP

NT = Not Tested; visual free

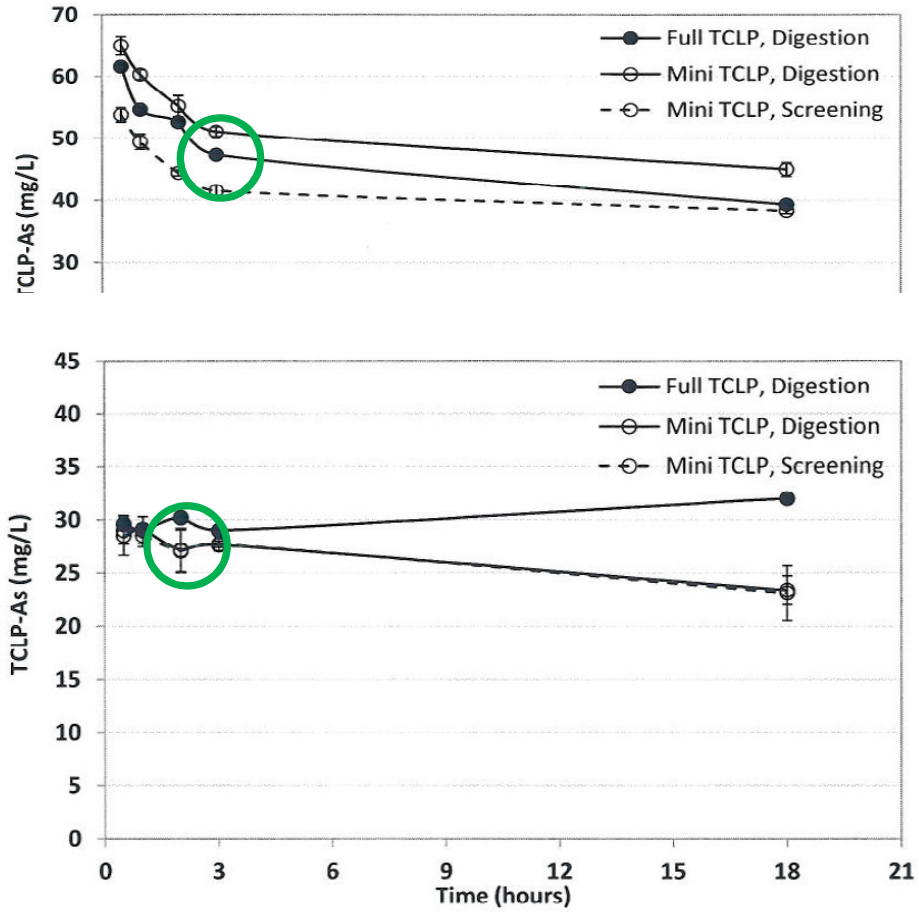
Target MC (%)	Actual MC (%)	Suite Number	Reagent 1 (g)	Reagent 2 (g)	Reagent 3 (g)	1st Cure Period (400 ml) Interval (HR/DAY)	Paint Filter	ORP (mV)	pH (SU)	Fluid (-)	TCLP-ORP (mV)	TCLP-pH (SU)	TCLP-As (mg/L)	Interval (HR/DAY)	28-Day Fluid (-)	28-Day TCLP-As (mg/L)	Reagent Cost ($/ton)
		Suite A	60% Fe2(SO4)3	PC Type I													
250	169		100 g (20 wt%)			1 HR	NT	439.2	2.39	1	0.4	4.43	1.92	2-DAY	1	1.69	$52.80
250	169		125 g (25 wt%)			1 HR	NT	445.4	2.35	1	22.7	4.34	1.73	2-DAY	1	2.25	$66.12
250	169		150 g (30 wt%)			1 HR	NT	450.8	2.28	1	42.8	4.18	1.52	2-DAY	1	1.86	$79.35
250	169		100 g (20 wt%)	50 g (10 wt%)		1 HR	NT	18.2	9.03	1	-154.4	6.43	1.43	2-DAY	2	5.78	$65.60
250	169		125 g (25 wt%)	50 g (10 wt%)		1 HR	NT	48.5	7.96	1	-71.8	5.45	0.67	2-DAY	1	2.21	$78.82
250	169		150 g (30 wt%)	50 g (10 wt%)		1 HR	NT	107.9	4.62	1	102.4	5.28	0.61	2-DAY	2	0.797	$92.05
		Suite B	38% FeCl3	PC Type I													
250	169		75 g (15 wt%)			1 HR	NT	478.2	2.38	1	90.4	4.46	14.5	2-DAY	1	1.26	$37.14
250	169		100 g (20 wt%)			1 HR	NT	491.7	2.25	1	85.9	4.26	21.7	2-DAY	1	0.914	$49.52
250	169		125 g (25 wt%)			1 HR	NT	501.1	2.13	1	91.7	3.97	30.4	2-DAY	1	0.707	$61.90
250	mini	TCLP	150 g (30 wt%)			1 HR	NT	507.9	2.06	1	81.0	3.88	32.1	2-DAY	1	1.24	$74.28
250	FULL	TCLP	150 g (30 wt%)			1 HR	NT	507.9	2.06	1	73.9	3.72	29.9	2-DAY	1	1.16	$74.28
250	169		75 g (15 wt%)	50 g (10 wt%)		1 HR	NT	-237.2	10.43	2	-177.4	5.52	2.40	2-DAY	2	3.26	$49.84
250	169		100 g (20 wt%)	50 g (10 wt%)		1 HR	NT	-205.3	8.28	1	-171.9	6.13	1.03	2-DAY	2	2.75	$62.22
250	169		125 g (25 wt%)	50 g (10 wt%)		1 HR	NT	-152.1	5.83	1	-180.3	5.30	0.48	2-DAY	1	2.19	$74.60
250	169		150 g (30 wt%)	50 g (10 wt%)		1 HR	NT	-124.6	4.81	1	-114.2	4.80	0.39	2-DAY	1	1.13	$86.98

200+ Mix Designs Ranked by:

1. TCLP-As<5 mg/L by 3 days (thru 28 days)
2. Pass Paint Filter by 3 days
3. Workability by 3 days
4. Cost

Cost differential offers significant value engineering opportunity

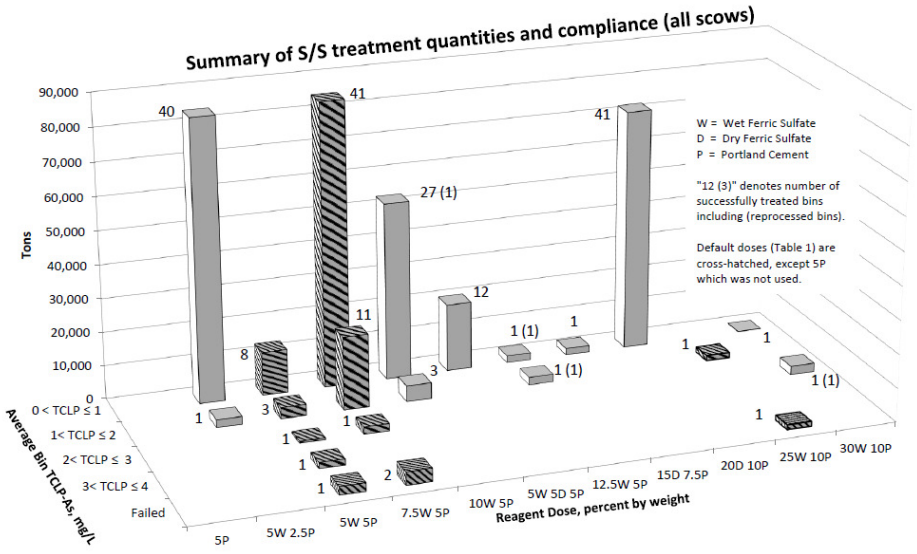
Rapid Screening Method developed for As Leachability (mini-TCLP)



e 4: Rapid TCLP-As Results for SCM 11 Semi-Consolidated Material (1066 mg/kg As)

* TCLP-As: ND to 42 mg/L
* TCLP takes 18 hours
* Opportunity: DM poorly buffered
  * Final pH attained quickly
* 3-hour mini-TCLP successful
  - Reduced mass (20 g)
  - Reduced time (3 hours)
  - Filtering & Acidification
  - No digestion
  - Conservative at high As
  - Within 1 mg/L at low As
* 3rd Party TCLP Certification Lab moved onsite
  - Rapid TAT across board

From Bench Study to Real Time Dosing



- Comparability of XRF determined onsite in May 2013 as well as a Rapid Dry Weight Procedure
- Scow samples delivered to Onsite Laboratory within minutes of collection
- Mini-TCLP and supporting data reported within 5 hours
- Dosing determined by CH2M
- 8 hours from dredging to treatment
- Treated bins sampled for disposal
- TCLP results within 30 hours

Onsite Laboratory Analyses

- Scow Samples
  - Mini-TCLP (3 hour)
  - ORP (Initial and Post)
  - pH (Initial and Post)
  - As by XRF (EPA 6200)
  - Rapid Dry Weight
- Bin Samples
  - Full TCLP (EPA 1311 & 6020)
  - Dry Weight (SM2540B)
  - Total As (EPA 6020)
  - pH (EPA 9040C & 9045D)
  - Paint Filter (EPA 9095)
- Confirmation Samples
  - Total As (EPA 6020)
  - Dry weight (SM2540B)
- WWTP Samples
  - Total As (EPA 6020)
- Wipe Samples
  - Total As (EPA 6020)

A Unique Challenge

TCLP Temperature Control

Mobilizing ICP-MS

Flexible Throughput

Treatment and Stabilization 2013

Treated sediment is dry, stacks well and is ready for load out to the landfill within 48-72 hours.

GLNPO PROJECT
The Clean-up Continued…

* Tyco, in partnership with GLNPO and WDNR, performed a betterment project in 2014/2015.
* Objective; Accelerate reduction in overall arsenic concentrations in remaining sediment by removal of sediment with concentrations between 50 and 20 ppm
* Dredging was completed in Fall 2014
* Sediment cover in the Turning Basin, site restoration and final demobilization scheduled for 2015
* Habitat restoration in the South Channel area to follow

2014 Remediation Stats

- Mechanical Dredging
    - Over 44,200 Cubic Yards of sediment removed of varying depths and hardness.
- Sediment Treatment and Stabilization
    - Approximately 66,000 tons of sediment treated and stabilized.
- Transport and Disposal
    - Approximately 72,896 tons of treated and stabilized sediment and 566 tons of debris disposed.
    - 2,700 truckloads.
- Water Treatment
    - Nearly 2.2 million gallons of water treated and discharged.