COST AND PERFORMANCE REPORT

FOR

THE EVALUATION OF TWO WATER TREATMENT TECHNOLOGIES

FOR A FULL-SCALE BIOSLURPER SYSTEM

AT

THE COASTAL SYSTEMS STATION, PANAMA CITY, FLORIDA

Prepared by:

BATTELLE
505 King Avenue
Columbus, OH 43201

Submission to:

Naval Facilities Engineering Service
1100 23rd Avenue
Port Huemene, CA 93043-4301

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Section 1.0: SITE INFORMATION

The Coastal Systems Station (CSS) Panama City is located along the St. Andrew Bay in Panama City, Florida. The site, Area of Concern (AOC) 1, currently is being managed under the Resource Conservation and Recovery Act (RCRA). The site is bound by parking to the west and south, by shipping and receiving facilities to the east, and by woodland and Solid Waste Management Unit (SWMU) 9 to the north. AOC 1 is a former fire-fighting training area that was operational from about 1955 to 1978. Primarily waste oil was used during fire-fighting training exercises; however, other materials that were reportedly ignited include diesel, gasoline, JP-5 jet fuel, and paint thinner. It is estimated that approximately 63,000 gallons of flammable hydrocarbons were released and ignited throughout the 23-year operation of this facility (ABB, 1995). AOC 1 was graded, paved, and used as an open storage area once it ceased to be used as a fire-fighting training area in 1978.

An initial assessment study (IAS) was performed by C. C. Johnson and Associates in 1985 to collect background information on chemicals used at the CSS and at specific sites where chemicals and wastes were known to have been used, stored, or disposed of. The IAS indicated the possibility of contamination at AOC 1. A confirmation study performed by Environmental Science and Engineering was begun in 1987 to confirm the results of the IAS. The results of the study recommended future, more detailed investigations at AOC 1 (ABB, 1996). In 1991, ABB Environmental Services initiated a RCRA Facility Investigation (RFI). The purpose of the RFI was to evaluate and characterize releases at the CSS. The presence of a light, nonaqueous-phase liquid (LNAPL) was identified at AOC 1. As a result of the findings of the RCRA investigation, ABB Environmental Services performed additional investigative work to determine the extent of the LNAPL contamination at AOC 1 and recommend an appropriate treatment technology. In 1994, 15 piezometers were installed to determine the extent of the LNAPL plume. The maximum apparent LNAPL thickness of 1.5 ft was measured immediately southeast of the center of the fire-fighting training area (ABB, 1996). The approximate extent of the plume as delineated by ABB in 1994 is shown in Figure 1.

ABB recommended a product recovery system consisting of two LNAPL collection trenches with a number of sumps containing product recovery pumps as an interim corrective measure at AOC 1. Because these types of recovery systems can operate for years without achieving cleanup goals, the Navy investigated other cost-effective treatment technologies. The Navy elected to implement bioslurping - an innovative treatment technology to remove LNAPL from the subsurface. Previous investigations (Battelle, 1997) have indicated that bioslurping recovers LNAPL about 10 times faster than conventional technologies such as skimming or dual-pump drawdown.

Battelle Memorial Institute performed a pilot-scale bioslurper test at AOC 1 during October 1996. Results indicated that bioslurping would be an appropriate remediation technology for implementation at AOC 1. However, the wastewater produced during the pilot test contained high levels of emulsified hydrocarbons and high concentrations of copper, lead, and zinc. Total petroleum hydrocarbon (TPH) concentrations in the wastewater ranged from 1,500 to 6,200 ppm. In addition, levels of copper, lead, and zinc as high as 69, 190, and 1,900 ppb, respectively, were observed. It was expected that water extracted during the full-scale bioslurper operation would exhibit similar characteristics. In an effort to select a cost-effective water treatment technology to treat the water generated by the full-scale bioslurper system, two technologies, coagulation/flocculation combined with dissolved air flotation and Oleofiltration™, were selected and demonstrated during startup of the full-scale bioslurper system. Information regarding the site and the evaluation of these technologies is presented in Table 1.

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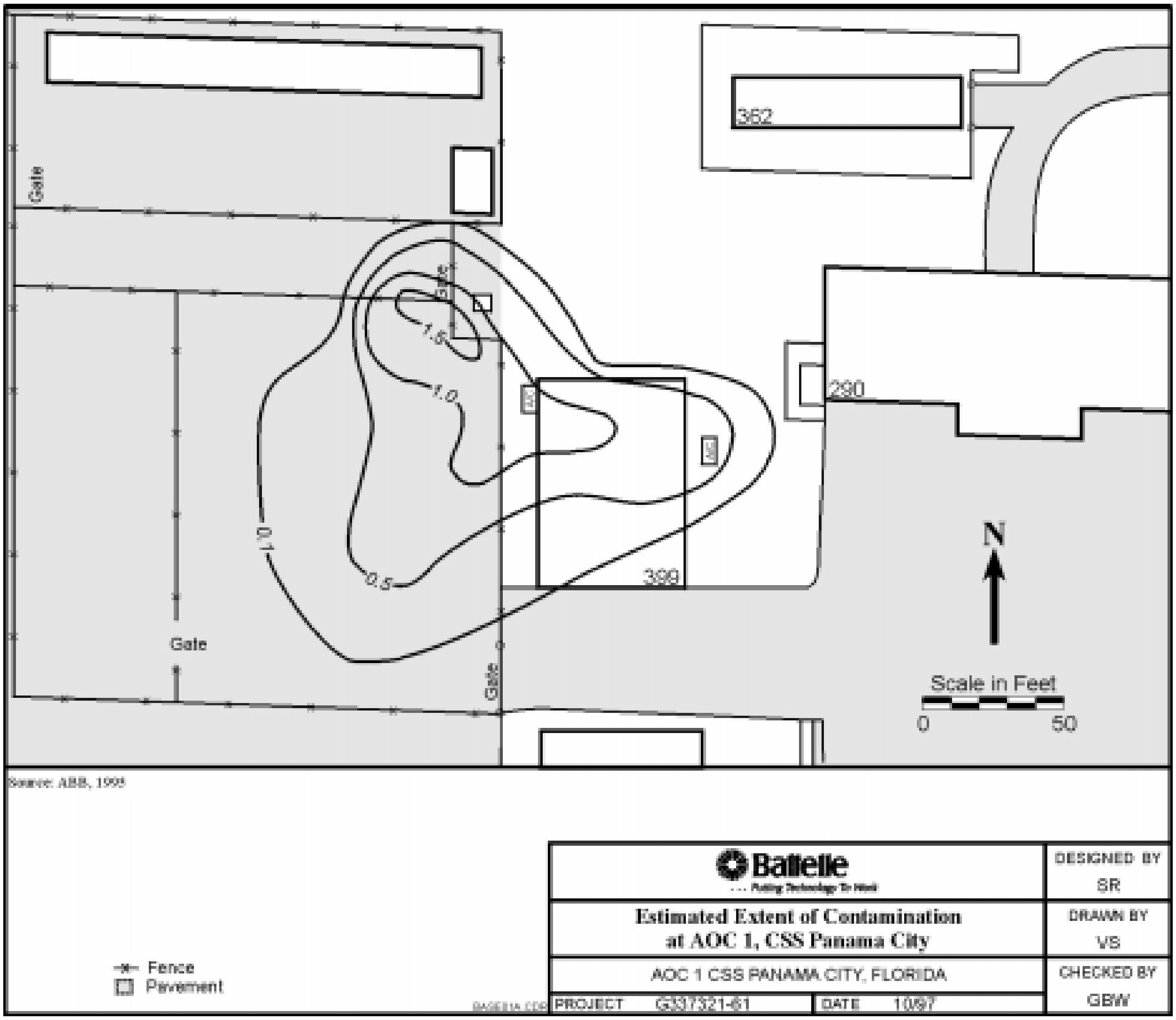

Figure 1. Extent of LNAPL Plume at Area of Concern 1

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Table 1. Site and Technology Information

Site:	Area of Concern 1 at the Coastal Systems Station, Panama City, Florida
Activity that Generated Contamination:	Fire-fighting training
Standard Industrial Classification Code:	2869; Industrial organic chemicals not elsewhere classified
Site Characteristics ***Media treated:*** ***Contaminants Treated:***	 Wastewater generated by a full-scale bioslurper process Emulsified oil/grease and heavy metals including copper, lead, and zinc
Treatment Systems (Water):	• Coagulation/flocculation combined with dissolved air flotation; manufactured by Great Lakes Environmental Inc., 315 S. Stewart Avenue, Addison, Illinois 60101 • Oleofiltration™; manufactured by North American Technologies Group Inc, Suite 301, 4710 Bellaire Blvd, Bellaire, Texas 77401
Cleanup Type:	Implementation and evaluation of water treatment technologies to treat wastewater generated by a full-scale bioslurper process
Period of Evaluation:	448 hours of operation beginning August 1997
Total Volume of Water Treated During Demo:	126,400 gallons

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Section 2.0: MATRIX DESCRIPTION

The matrix characteristics that affect the cost and/or performance of the water treatment system are presented in Table 2. The process water from the bioslurper system contained a high concentration of emulsified oil/grease. A concentration as high as 27,000 ppm was measured. During the demonstration, the water was milky yellow in appearance and had a strong hydrocarbon odor. Metal contaminants that were identified for removal during the demonstration include copper, lead, and zinc. Concentrations of copper, lead, and zinc as high as 228, 1,430, and 6,210 ppm, respectively, were measured in the bioslurper process water.

Table 2. Matrix Characteristics Affecting Treatment Cost and/or Performance

Parameter	Value(s)	Method of Measurement
TPH in Water (ppm)	5,000 to 27,000	EPA Mod. 8015
Copper in Water (ppm)	ND to 228	EPA 200.7/SW6010
Lead in Water (ppm)	62 to 1,430	EPA 239.2/SW7421
Zinc in Water (ppm)	697 to 6,210	EPA 200.7/SW6010
Total Suspended Solids (mg/L)	211 to 570	EPA 160.2
Influent Process Water pH	4.81 to 5.91	EPA 150.1

ND - below detection limit

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Section 3.0: TREATMENT SYSTEM DESCRIPTION AND OPERATION

Two types of treatment systems were evaluated for treating the wastewater produced by the full-scale bioslurper process. One system consisted of a chemical reaction and flocculation (CRF) tank and a dissolved air flotation (DAF) system, manufactured by Great Lakes Environmental, Addison, Illinois. Bench-scale tests performed on water samples collected during bioslurper pilot testing indicated that the CRF/DAF could achieve a 99% reduction of TPH in the process water. The other water treatment technology that was tested was an Oleofiltration™ system. The Oleofiltration™ system is a hydrocarbon recovery technology utilizing amine-coated oleophilic granules to separate suspended and emulsified hydrocarbons from water, manufactured by North American Technologies, Inc., Belaire, Texas. Literature (EPA, 1995) has indicated that a 97% reduction in TPH is achievable using this technology.

The objective of the demonstration was to evaluate the ability of the two water treatment systems to remove emulsified oil/grease from the bioslurper wastewater stream. A secondary objective was to determine if the CRF/DAF system could effectively remove metals, including copper, lead, and zinc, by increasing the pH of the process water.

3.1 Treatment System Description.

3.1.1 CRF/DAF Treatment System. The CRF system (Model CRF-15) consists of a two-stage chemical reaction tank, a polymer preparation mix tank, chemical metering pumps, constant and variable speed mixers, and associated instruments and controllers. A schematic illustration of the CRF system is shown in Figure 2. The aqueous effluent from the bioslurper process enters the two-stage mix tank. Coagulation is performed in the first stage by dosing and mixing a 50% ferric sulfate solution and a 50% sodium hydroxide solution into the process water. For optimum hydrocarbon removal the manufacturer recommends that the pH of the process water be maintained around 6. The water then enters the second stage where a flocculating polymer is mixed into the process water. Following the chemical addition, the stream gravity flows into the DAF system.

The DAF system (Model DAF-5) is shown in Figure 3. The unit is skid mounted. It contains a flotation chamber that includes a float skimmer and a float storage sump, an air dissolving tank, and appropriate controls and meters. An air compressor is required for operation. Microscopic bubbles are pumped into the water. The bubbles attach themselves to the flocs created in the CRF, giving them positive buoyancy that causes them to rise to the surface of the water. The skimmer skims the solids into a temporary storage compartment mounted inside the unit. If necessary, an auger can be installed to periodically pump out heavy solids that have settled at the bottom of the DAF unit. The resulting solids slurry is passed into a tank where it is allowed to settle. The separated liquid is recycled through the system. The sludge is transported off site by a waste disposal company and is recycled and blended for heat recovery.

3.1.2 Oleofilter™ Treatment System. The Oleofilter™ combines a conventional oil/water separator, a coalescing unit, and a ceramic granule filtration system. Figure 4 illustrates the concept. Any free-phase oil present in the wastewater is removed by the oil/water separator. Water containing emulsified oil then flows downward inside the unit's outer shell and upward past a series of coalescing plates. Any remaining emulsified oil is removed as the water flows upward through the center of the unit through a bed of oleophilic amine-coated ceramic granules. Over time, the Oleofilter™ bed will become saturated with hydrocarbons. When saturation occurs, the filtering bed automatically regenerates itself by backflushing. The wastewater and oil produced during the backflushing process is recycled through the system. Hence, no waste products (other than reclaimed oil) are generated.

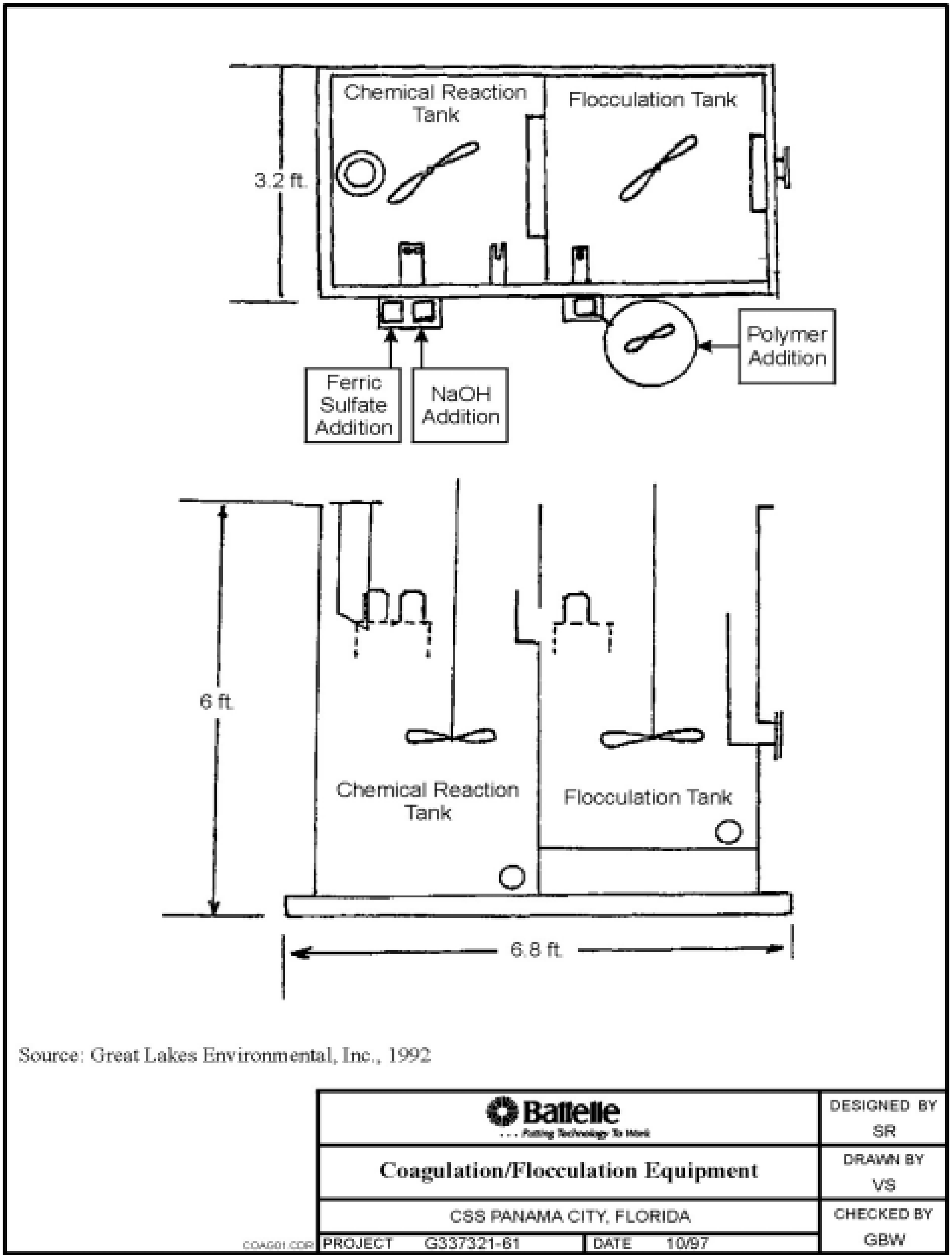


Figure 2. Chemical Reaction and Flocculation System

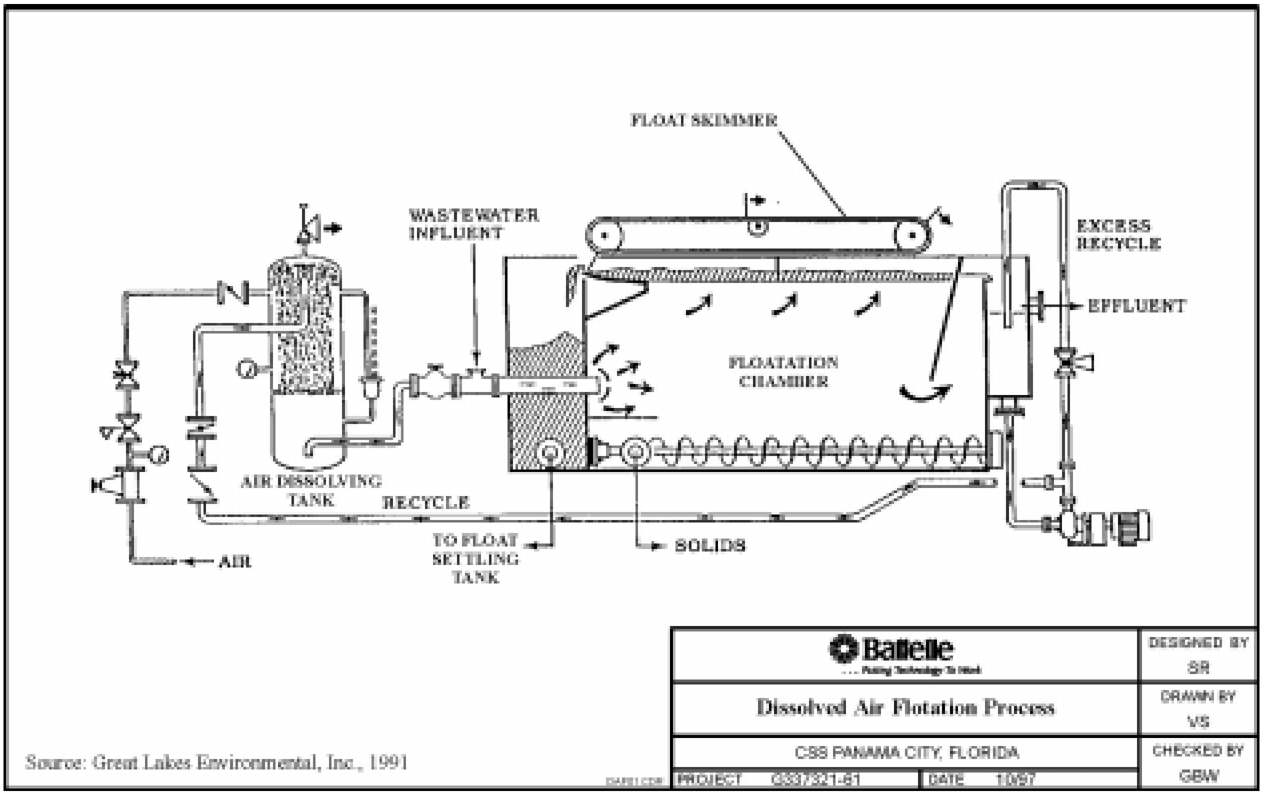
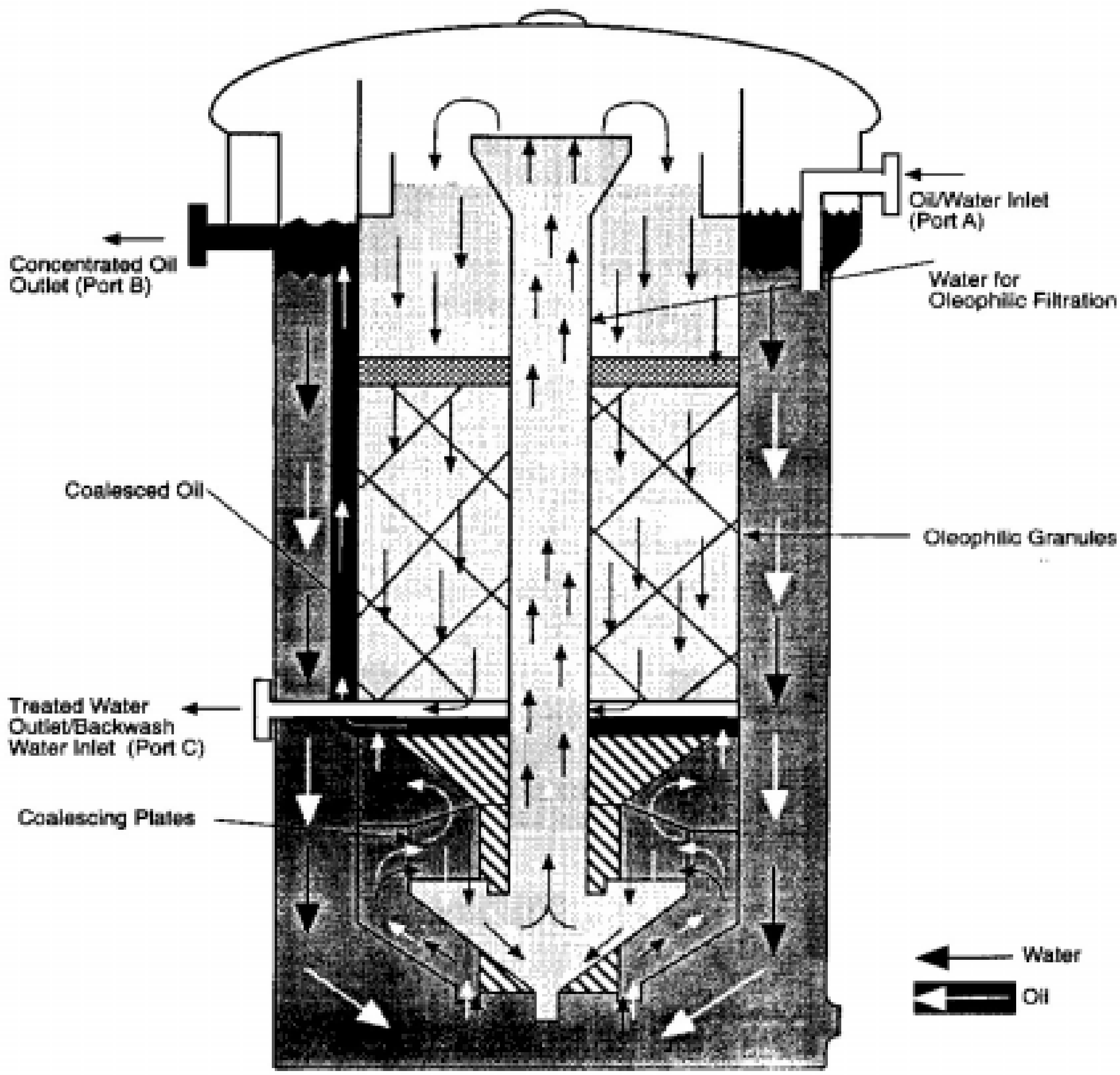


Figure 3. Dissolved Air Flocculation System



Note: The backwash water outlet (Port D)
is not shown in this view.

Source: Adapted from *SFC 0.5x Operating Manual*, 1992

Battelle ... Putting Technology To Work	DESIGNED BY SR
SFC 0.5 System Configuration	DRAWN BY VS
CSS PANAMA CITY, FLORIDA	CHECKED BY GBW
PROJECT G337321-61 DATE 10/97	

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Figure 4. Oleofilter™ Treatment System

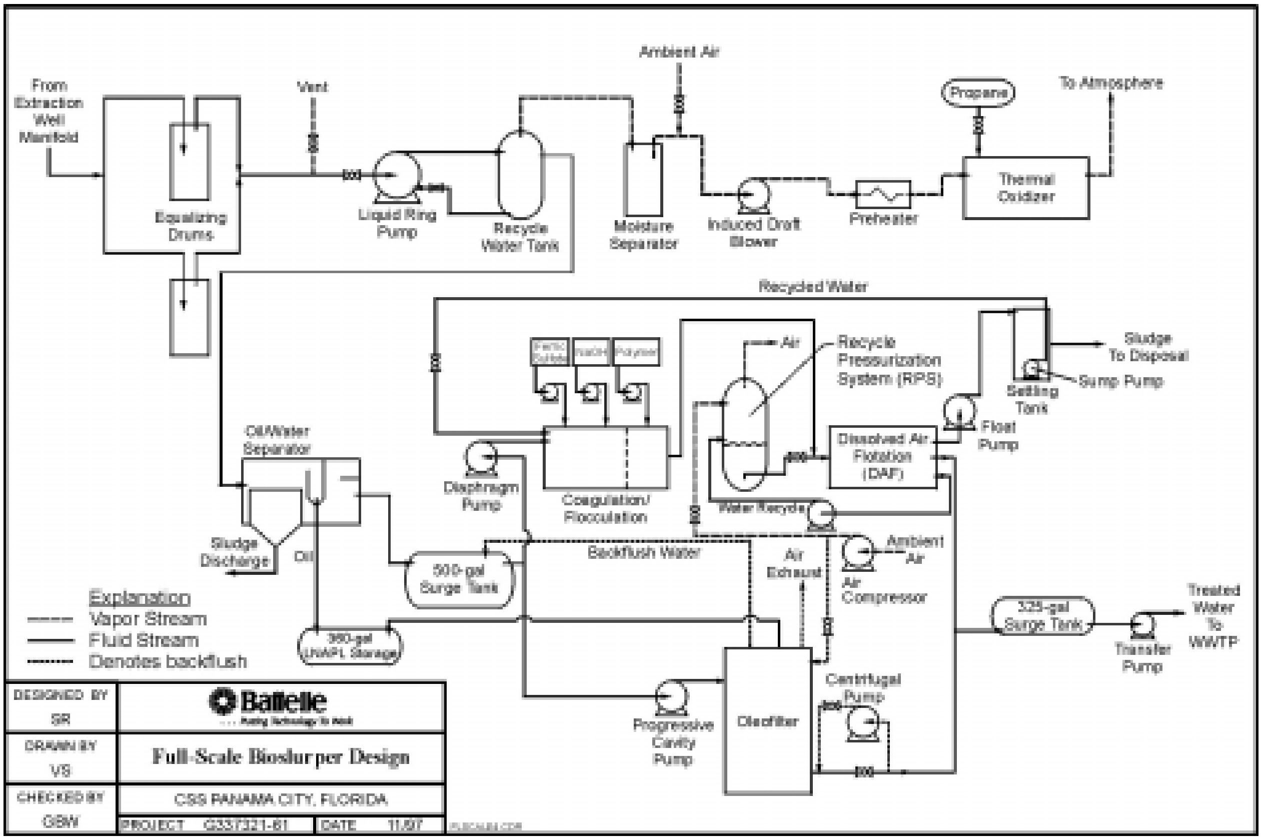

Figure 5. Full-Scale Bioslurper Process with Oleofilter™ and CRF/DAF in Series

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3.2 Operation. The CRF/DAF and Oleofiltration™ treatment systems were operated in parallel. The process flow is illustrated in Figure 5. Both treatment systems require a compressed air supply for proper operation. A weatherproof Ingersoll-Rand reciprocating air compressor (Model 2545E10P) was used to supply air to both processes. A pneumatic double-diaphragm pump was used to pump the wastewater from the bioslurper process to the 2-stage CRF tank. Electronic metering pumps were used to meter ferric sulfate and sodium hydroxide into the first stage of the tank and polymer into the second stage of the tank. The sodium hydroxide dosage was controlled using a GLI conventional pH combination electrode with a Model 672 pH controller with a set point range set between 8.7 and 9.2. This high pH range was selected to induce precipitation of metals in the first stage of the CRF. The rate of ferric sulfate and polymer addition was based on results of a bench-scale test performed on process water samples that had been collected during the pilot-scale bioslurper test. Results indicated that a dosage of 250 ppm ferric sulfate and 2 ppm polymer significantly reduced the concentration of emulsified oil/water in the process water. The chemically treated water gravity fed from the second stage of the CRF into the DAF through a schedule 80, 1.5-inch-diameter polyvinyl chloride (PVC) transfer pipe. This pipe was later replaced with a 2-inch-diameter clear polyethylene hose; fouling of the 1.5-inch-diameter pipe with flocculated material caused the CRF to overflow with water when the process flowrate was greater than 6 gpm.

The flocs were separated from the water by introducing microscopic air bubbles into the process stream inside the DAF. The air bubbles were introduced into a portion of treated water pumped from the DAF into the recycle repressurization tank using a 1.5-hp Grundfos™ centrifugal pump (Model CR2-50). A ¾-inch globe valve controlled the flowrate of aerated water bled into the influent process stream. An adjustable speed drag belt skimmer was used to skim the separated flocs floating on the surface of the treated water into the sludge reservoir located in the leftmost compartment of the DAF system. The sludge was pumped into a 2,550-gallon tank using a ½-inch-diameter ARO pneumatic double-diaphragm pump. The treated water gravity fed into the rightmost compartment of the DAF system. A 1-inch-diameter ARO pneumatic pump also was used to pump the water into a 325-gallon surge tank prior to discharging it into a sanitary sewer. The sludge that accumulated inside the 2,550-gallon tank was periodically dewatered. A ½-hp sump pump was used to pump water from the bottom of the sludge tank into the 500-gal surge tank that provided the process water to the water treatment processes. The operating parameters that affect the cost and/or performance for this technology are presented in Table 3. The range of values that were measured during the demonstration are shown in the second column.

A 10-gpm Oleofilter™ was tested. The Oleofilter™ was equipped with a 1-hp progressive cavity pump that pumped the process water from the 500-gallon surge tank into the top of the Oleofilter™. A 1-hp centrifugal pump was used to pump the treated water out of the Oleofilter™ into the 500-gallon surge tank. The influent and effluent pump flowrates were balanced using a bypass valve (1-inch-diameter globe valve) located on the inlet side of the progressive cavity pump. It was originally intended that the water treated by the Oleofilter™ be pumped into the 325-gallon treated water surge tank (Figure 5); however, visual observations indicated that a high concentration of oil/grease remained in the water after treatment by the Oleofilter™. Therefore, the water was recycled back into the 500-gallon surge tank. The LNAPL that was separated from the wastewater was gravity fed into the 360-gallon LNAPL storage tank. The operating parameters that affect the cost and/or performance for this technology are presented in Table 3

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Table 3. Water Treatment System Operating Parameters

Parameter	Value(s)	Method of Measurement
CRF/DAF		
Influent Water Flowrate (gpm)	1.5 to 6.5	Rotameter
Retention Time (min) • CRF, Stage 1 • CRF, Stage 2 • DAF	 37 to 160 22 to 94 13 to 55	Calculation based on flowrate and process equipment dimensions
Ferric Sulfate Dosage, 50% Concentration (ml/min)	1.2 to 23	Graduated cylinder
Polymer Dosage (ml/min) pH of Treated Process Water	20 to 47 8.25 to 9.26	Graduated cylinder Calibrated pH meter; laboratory method EPA 150.1
Average Volume of Sludge Produced, Dewatered (gal/day)	20	Graduations on tank
Recycle Water Flowrate (gpm)	10 to 18	Magnetrol™ flow indicator
Recycle Pressurization Tank Pressure (psig)	40 to 65	Pressure gauge
Oleofilter™		
Influent Water Flowrate (gpm)	5 to 7.5	Rotameter
Retention Time (min)	25 to 37	Calculation
Differential Pressure Across Oleofilter (psig)	1.5 to 4.5	Differential pressure gauge

The Oleofilter™ was equipped with an automatic backflush system to clean the packing media after it became saturated with hydrocarbons. It was set to activate when the pressure differential across the packing media exceeded 5 psig. The backflush process consisted of washing the packing by pumping treated water and compressed air through it. The wastewater produced during backflushing was pumped back into the 500-gallon surge tank and the small volume of air generated was vented to the atmosphere. The pressure differential remained below 5 psig during the demonstration; therefore, the backflush process never actuated automatically. However, a manual backflush was performed several times during the demonstration in an effort to troubleshoot and improve the efficiency of the unit.

3.3 Sampling and Analysis. Water samples were collected on a weekly basis; samples were collected from the bioslurper oil/water separator effluent, the DAF effluent, and the Oleofilter™ effluent. The Oleofilter™ was shut off for about 3 hours prior to collecting the DAF effluent sample so that the partially treated stream from the Oleofilter™ would not dilute the influent stream to the CRF/DAF, thereby biasing treatment results. Samples were analyzed for TPH as diesel (EPA Modified 8015), copper and zinc (EPA 200.7/SW6010), and lead (EPA 239.2/SW7421).

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Section 4.0: TREATMENT SYSTEM PERFORMANCE

4.1 Cleanup Goals. The full-scale bioslurper system is being operated in a manner to ensure that oil/grease and heavy metals in the treated water effluent from the CSS Waste Water Treatment Plant (WWTP) will not exceed current levels. Water samples from the effluent of the full-scale bioslurper system are collected monthly and are analyzed for TPH, copper, lead, and zinc. In the event that the flowrate of water to the WWTP approaches the maximum operating capacity of the WWTP, the vacuum-enhanced recovery system either will be adjusted to reduce the water flowrate to the WWTP or will be shut down until the flowrate to the WWTP returns to its normal operating range. Water samples are collected periodically from the effluent discharged from the WWTP to ensure that the treated water is in compliance with permitting requirements. This water treatment technology demonstration was performed to determine the percent removal of TPH, copper, lead, and zinc and the quality of the effluent water that is economically achievable using the CRF/DAF and Oleofilter™ water treatment technologies to treat the water generated by the full-scale bioslurper process.

4.2 Treatment Performance. Water samples were collected from the influent and effluent of each water treatment process and were analyzed for TPH, lead, copper, zinc, and total suspended solids (TSS). The analytical results were used to assess the performance of each treatment system. Treatment performance results are presented in Table 4. The TPH concentrations were measured as both diesel and motor oil; however, only the TPH as diesel is reported since in most instances the TPH concentration as motor oil was below the laboratory detection limit. The CRF/DAF system removed greater than 98% of the TPH compared to the 56 to 90% that was removed by the Oleofilter™. The high concentrations of TPH in the influent process water likely reduced the separation efficiency of the packing media inside the Oleofilter™. Previous investigations (US EPA, 1995) have indicated that the operating efficiency of the Oleofilter™ decreases when the influent concentration of TPH is greater than 500 ppm. The TPH analytical results are consistent with visual observations made regarding the operation of the treatment system. The influent water to the processes was a milky yellow color, indicating a high TPH concentration. The effluent from the CRF/DAF process was clear and had very little if any hydrocarbon odor associated with it. However, the effluent from the Oleofilter™ was milky, but not as yellow as the influent water. It had a strong hydrocarbon odor associated with it.

The ability of the CRF/DAF system to remove heavy metals, including copper, lead, and zinc, was evaluated. The first two sets of samples collected from the CRF/DAF were analyzed for 13 metals including antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. Of these metals, copper, lead, and zinc are the primary contaminants of concern since concentrations of these metals in the treated water from the CSS WWTP approach maximum allowable discharge concentrations. Analytical results for the remaining metals were below laboratory detection limits for both influent and effluent water to the water treatment processes. The performance results for removal of copper, lead, and zinc are presented in Table 4. In some instances the concentrations of metals in the influent and/or effluent streams were below laboratory detection limits. Matrix interferences encountered during the laboratory analyses prevented some of the samples from being reported at lower detection limits. Therefore, in some cases, it was impossible to accurately assess the percent removal of a particular metal. The detection limit was used to calculate the percent removal and the results are expressed with a greater-than sign.

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Table 4. Water Treatment System Performance Results

Constituent	Average Untreated Concentration (ppm)	Average Treated Concentration (ppm)	Range of Percent Removal (%)	Average Percent Removal (%)
CRF/DAF				
TPH as Diesel	10,950	43.8	98.2 to 99.9	99.5
Lead	442	<56.3	>67.7 to 98.9	>88.0
Copper	<101	<55	>90.2	>90.2
Zinc	2,450	<136	>81.3 to 97.9	>91.3
TSS	308	<12.2	92.1 to >98.2	>95.2
Oleofilter™				
TPH	10,950	4,687	55.6 to 90.3	72.6
Lead	442	55	12.5 to 75.3	50.8
Copper	<101	<100	NA	NA
Zinc	2,450	4,204	-827 to 73.3	0.322
TSS	308	237	-12.8 to 58.6	17.2

NA – Not applicable. Copper concentrations were below the detection limit both before and after treatment, therefore percent removal could not be calculated.

The effluent from the Oleofilter™ also was analyzed for copper, lead, and zinc. Although the Oleofilter™ was not expected to remove these metals from the process stream, samples were collected and analyzed for comparison with the CRF/DAF results. The results are presented in Table 4. The percent removal varies significantly from one sample to the next. The low pH (4.8 to 5.9) of the water may have been causing the metal cations to be absorbed by the unit and/or packing material. Eventually, these cations would have desorbed back into the process stream. This would account for the significant fluctuations observed in the data.

Water samples also were analyzed for TSS. The reduction of TSS after treatment by the CRF/DAF indicates a good separation of the coagulated/flocced material from the process water. If good separation and removal were not occurring, the concentration of TSS could potentially be much greater in the effluent than in the influent water samples.

4.3 Performance Data Assessment. This demonstration has indicated that the CRF/DAF system is effective at removing significant quantities of emulsified oils and metals from the process water. Good removal efficiency of metals was achievable by adding sodium hydroxide to increase the pH to about 9 in the CRF tank and removing the resulting precipitate as part of the oil saturated sludge that accumulates inside the DAF. The sludge was automatically pumped into a settling tank. It was periodically dewatered by turning on a sump pump located at the bottom of the tank. The resulting water was pumped back into the 500-gallon process water surge tank. An average of 20 gallons of dewatered sludge were accumulated each day of operation. A Toxicity Characteristic Leaching Procedure (TCLP) analysis was performed on the sludge to determine if it was hazardous. The results, presented in Appendix A, indicate that the sludge can be disposed of as a nonhazardous waste. In addition, the high oil/grease content in the sludge allows the sludge to be recycled and blended for heat recovery.

The Oleofilter™ did not perform as well as the CRF/DAF treatment system. The percent removal of hydrocarbons ranged between 56 and 90%. It is believed that removal would be greater when the concentration of emulsified hydrocarbons in the influent water to the unit is less. The Oleofilter™ is not designed to remove metals from the treatment stream. If this technology was used for the remainder of

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the full-scale remediation, a clarifier would need to be installed downstream of the Oleofilter ™ to remove metals to levels observed when using the CRF/DAF.

Operation and maintenance requirements for the CRF/DAF are significantly greater than for the Oleofilter™. The CRF/DAF system is equipped with 3 metering pumps, two mixers, a belt skimmer, a centrifugal pump, and two pneumatically operated diaphragm pumps. Each piece of equipment must be maintained and be functioning properly to meet the desired treatment goals. Ferric sulfate, sodium hydroxide, and polymer are automatically metered into the CRF tank. The operator must calculate and set the flowrates of the ferric sulfate and polymer metering pumps in order to treat the process water to the required treatment levels. The dosage of sodium hydroxide is controlled by a pH controller that uses a general-purpose electrode to measure pH. The pH controller held its calibration during the 4-week demonstration. It is recommended that the probe be rinsed once a week and that the controller be calibrated bimonthly. The ferric sulfate and sodium hydroxide solutions are supplied in 55-gallon drums. The operator must replace the drums periodically. One drum of ferric sulfate lasts approximately 1 month and a drum of sodium hydroxide lasts about 2 months. The polymer is shipped in a concentrated form. A 5-gallon bucket should last about 4 months, assuming water flowrates and contaminant loadings and polymer dosage rate remain consistent with what was observed during the demonstration. A solution of polymer must be made up every 72 hours. Approximately 1.3 cups of polymer is added to about 50 gallons of water.

During the 4-week demonstration, a number of operational difficulties with CRF/DAF were encountered. These problems, and the solutions to them, are presented in Table 5. The majority of the problems encountered were a result of integrating the CRF/DAF into the bioslurper process. In addition, the CRF and DAF units used were prototypes developed by Great Lakes Environmental, Inc. for use in relatively low flowrate applications.

Table 5. Problems and Resulting Solutions Encountered with the CRF/DAF System

Problem	Solution
Water does not flow fast enough from the CRF into the DAF at high process water flowrates, resulting in fouling of the CRF by sludge that accumulates in the unit	First raised CRF by 8 inches. Flowrate still not fast enough; therefore, replaced 1.5-inch PVC line with a 2-inch polypropylene hose.
Water effluent and sludge diaphragm pumps operate continuously.	Install timer to periodically turn on sludge pump. Install level switch inside DAF to turn on water effluent pump. An auxiliary control panel had to be installed to operate.
Vapor lock occurs in centrifugal recycle pump after extended periods of shut down	Uncouple effluent line from pump; allow air to bleed out.
Potential spill hazard from CRF and DAF if effluent pump shuts off.	Install high level switches in CRF and DAF to shut down diaphragm pump that supplies flow to the water treatment equipment.
Potential splashing of process water from high winds and rain; potential damage to mixers from rain.	Manufactured fabricated covers and supplied rain shields to protect tanks and mixers

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Minimal maintenance is required for the Oleofilter™. The unit consists of two pumps, a fixed-bed containing ceramic packing, and a number of pneumatically operated solenoid valves. The manufacturer has indicated that 8% of the packing will need to be replaced annually. During the demonstration, corrosion in the housing of the centrifugal pump resulted in a leak. The system had to be shut down until the housing could be repaired. No other mechanical difficulties were encountered during the 4-week demonstration period.

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Section 5.0: TREATMENT SYSTEM COST

The costs for treating the process water using the two water treatment technologies are standardized according to the format for the interagency work breakdown structure (WBS) (Member Agencies of the Federal Remediation Technologies Roundtable, 1995b). The interagency WBS specifies 9 before-treatment cost elements, 12 treatment cost elements, and 5 after-treatment cost elements. The cost breakdown for the CRF/DAF and Oleofiltration™ treatment systems are presented in Table 6. Travel costs have not been included in this estimate. The before-treatment costs include costs associated with procuring and installing the equipment. These costs were not broken down according to treatment process. However, it can be assumed that about half of the preparatory costs were associated with the procurement and mobilization of each water treatment process.

The treatment costs for each water treatment technology have been calculated. Treatment costs have been grouped into four categories consisting of setup, startup and evaluation, training, and operation. The costs for setup, startup and evaluation, and training were estimated based on actual costs associated with the project. The short-term operating costs (6 months of operation) were estimated based on data collected during demonstration of the equipment. These costs assume that the treatment equipment will be leased. The lease rate for the DAF is $4,500 per month and the monthly lease price for the Oleofilter™ is $2,500. If desired, the CRF/DAF system may be purchased for about $51,000 and the Oleofilter can be purchased for about $12,000.

Operating costs of the CRF/DAF are twice as great as those of the Oleofilter™. This is primarily a result of the greater rental cost associated with the CRF/DAF system. In addition, there is about twice as much labor associated with maintaining the CRF/DAF system than there is with maintaining the Oleofilter™. The additional labor results from having to supply and monitor the treatment chemical dosage rates. Another cost associated with operating the CRF/DAF system is the disposal cost for the sludge that the process generates (currently about $170/month).

The after-treatment costs include dismantling, demobilization, and reporting costs. The dismantling and demobilization costs presented in Table 6 are associated with the Oleofilter™. These estimates are based on actual labor hours and costs that were incurred while removing the Oleofilter™ from the system at the end of the demonstration. These costs do not include costs to remove subsurface plumbing that was installed from the bioslurper process to the Oleofilter™, since the plumbing was left in place at the site for possible future use during the remainder of full-scale bioslurper operation.

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Table 6. CRF/DAF and Oleofiltration™ Cost Elements

Cost Element	Cost ($)
Before Treatment Costs	
Mobilization and Preparatory Work	$9,120
CRF/DAF Treatment Costs	
Setup • Rental of DAF • Installation materials • Labor	$18,900
Startup and Evaluation • Labor • Analytical • Materials • Waste disposal	$7,160
Training	$688
Operation (short-term operating costs; assumes 6 months of operation) • Labor to perform routine O&M activities • Equipment (rental of CRF/DAF) and materials • Bulk chemicals • Waste disposal • Analytical	$45,400
Oleofiltration™ Treatment Costs	
Setup • Rental of Oleofilter™ • Installation materials • Labor	$6,260
Startup and Evaluation • Labor • Analytical • Materials • Waste disposal	$7,160
Training	$132
Operation (short-term operating costs; assumes 6 months of operation) • Labor to perform routine O&M activities • Equipment and materials • Bulk chemicals • Waste disposal • Analytical	$21,900
After-Treatment Costs	
Dismantling Oleofilter™	$392
Demobilizing Oleofilter™	$3,577
Reporting	$8,040

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Section 6.0: OBSERVATIONS AND LESSONS LEARNED

Performance observations and lessons learned:

- The CRF/DAF removed a greater percentage of TPH from the process water than did the Oleofilter™.
- The CRF/DAF system is capable of removing >99.9% TPH as diesel from an influent stream containing greater than 5,000 ppm TPH as diesel.
- The CRF/DAF system can precipitate and remove a significant concentration of copper, lead, and zinc. Greater than 90% removal of these metals was observed.
- Greater than 90% removal of TPH by the Oleofilter™ cannot be achieved at high influent water concentrations.

Cost observations and lessons learned:

- It costs twice as much to operate the CRF/DAF system than to operate the Oleofiltration™ system. It is estimated that it will cost about $7,580/month to lease and operate the CRF/DAF and about $3,650/month to lease and operate the Oleofiltration™ system.
- Excluding lease rates, the monthly operating costs for the CRF/DAF and Oleofilter™ are estimated to be $3,080 and $1,150, respectively.

General:

- Although the CRF/DAF system is more expensive to operate than the Oleofilter™, it has a much greater percent removal of TPH at high influent concentrations (5,000 to 27,000) ppm than does the Oleofilter™. In addition, it efficiently removes metals, including copper, lead, and zinc, from the process water. Therefore, it is believed that the CRF/DAF is the more appropriate technology for treating the bioslurper process water produced at AOC 1.
- The pH electrode in the CRF stage 2 tank should be rinsed once a week. The pH controller should be calibrated bimonthly.
- The CRF should be installed about 8 inches higher than the DAF, and a 2-inch-diameter or greater hose should be used to plumb the CRF effluent port to the DAF influent port. This allows the water to pass between the units at a greater flowrate.

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Section 7.0: REFERENCES

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