ALTERNATIVE TECHNOLOGY FOR SEDIMENT REMEDIATION

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COLERAINE MINERALS RESEARCH LABORATORY

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BACKGROUND

Duluth-Superior is a major port of the Great Lakes located at the extreme southwest end of Lake Superior in the cities of Duluth, Minnesota and Superior, Wisconsin. The harbor area occupies roughly 32 square miles and has 100 miles of waterfront. The harbor and lower St. Louis River have a history of water quality problems resulting primarily from municipal and industrial discharges in and upstream of the harbor. As a result, the harbor has been listed by the International Joint Commission as an Area of Concern (AOC) within the Great Lakes ecosystem. The 1995 progress report on the Remedial Action Plan (RAP) for the area identified sediment contamination as the major cause of many impaired uses in the St. Louis Estuary. Contaminants of concern include ammonia nitrogen, phosphorus, metals, oil and grease, PCBs, and PAHs. Contaminated sediments are thought to have detrimental effects on water quality, the diversity and abundance of aquatic and benthic organisms, human health, and disposal options for material dredged during harbor maintenance.

The dredged material is stored in the Confined Disposal Facility (CDF) at the Erie Pier in Duluth. The CDF is nearing its capacity, and additional space is required for storage of dredged materials either by construction of a new facility or by extending the life for the one currently used. The Coleraine Minerals Research Laboratory (CMRL) of the Natural Resources Research Institute (NRRI) has, in the past, conducted several research programs to evaluate the construction of a sediment treatment plant at the Erie Pier CDF as an effective way of extending its life. CMRL is currently contracted by the US Army Corps of Engineers (ACE) to develop and engineer a plant to treat the sediment contained in the CDF. This study is being conducted in response to Section 541 of the Water Resource Development Act of 1996, initiated by Congressman Jim Oberstar, which states: "The Secretary shall develop and implement methods for decontamination and disposal of contaminated dredged material at the Port of Duluth, Minnesota".

Various agencies including USEPA, Minnesota Pollution Control Agency (MNPCA), and NRRI conducted numerous research and survey projects. The sediments in the federal channels were analyzed as part of Dredged Material Management Plant (DMMP), and analyses revealed that metal concentrations in the sediments of all management units were comparable to those found in the regional soils, and that PCBs, pesticides, and PAHs were generally non-detectable. No PCBs and only low levels of PAHs were found in a survey study in Erie Pier CDF conducted by NRRI in 1997. Due to its relatively low contamination level, it is safe to study a number of variables before implementation of the technology to the other highly contaminated areas.

The treatment plant should generate data on the effectiveness of using mineral processing technology for separation and decontamination of the sediments. In some cases, the separation products could be cleaned and used for other purposes such as brick manufacturing, landfill cover, beach nourishment, construction fill, and/or habitat enhancement.

PRE-ENGINEERING OF THE TREATMENT PLANT

The existing Erie Pier CDF area consists of a diked area of the St. Louis River containing the spoils of the dredging operation in the Duluth-Superior Harbor and St. Louis River. The CDF has approximate dimensions of 1670 feet by 2070 feet and lies between the St. Louis River on the south and Burlington Northern Rail line on the north, near 40th Avenue West, in Duluth. The dike surrounding the CDF is from 2 to 10 feet above the level of the stored sediments and the dike is about 20 feet wide.

Process Flowsheet

Unlike the mining or gravel and sand companies' processing plants that receive carefully planned and blended material, the feedstock to the sediment processing plant contains various types of materials. The bulk of the sediment consists of boulders, gravel, and chunks of agglomerated sand, silt, and clay. The composition of this sediment could range from all sand to all clay. Pilot plant data indicates that the classification of the sediment with a screen and a cyclone will be sufficient to separate sand and fines, however, the large volume of sand and water generated in a full-scale plant presents a material handling problem. As shown schematically in Figure 1, the sediment treatment plant consists of a grizzly screen mounted on a feeder, a conveyor belt, a double decked vibrating screens, a mixing tank, a pump, hydrocyclones, and an optional screw classifier. The screw classifier could be used after the grizzly to help breakup on the lumps and provide a more uniform feed to the double deck screen. Another potential use of the screw classifier is to dewater the cyclone underflow if that product is not free draining.

Feeder with Grizzly Screen

To protect the equipment and guarantee a smooth operation, the first step of the processing plant is to remove boulders and break large chunks of sediment using a grizzly screen. A grizzly screen consists of a series of inclined steel bars spaced at certain intervals that would enable most of the material to fall through and large boulders to roll over the steel bars. The grizzly screen could be mounted directly on top of a feeder bin. The feeder consists of a conveyor belt with a variable speed drive that can control the feed rate to the processing plant. If the sediment contains a large of amount of free water, then a conveyor belt with a flexible wall could be used to prevent water from leaking out of the system. Cleats could be mounted on the belt to help provide a more constant feed.

Vibrating Screen

A double-decked screen should be applied in the next step to remove gravel at 1-inch and ¼-inch, which will enable fine material to be slurried and pumped. Spray water should be applied on both screen decks to increase the screen efficiency, to help break up the sediments and also to provide makeup water for the slurry tank.

Hydrocyclone

The slurried fines from the screen are pumped to the cyclones, which separate the silt/clay from sand. Under the optimal operation conditions, the sand discharged from the underflow stream should contain greater than 68% solids by weight and have a particle size 88% coarser than 75 microns. This material should be able to be stored either in cone or kidney shaped stockpiles. The overflow, which contains mostly clay, will be discharged to the first of two settling ponds connected in series. The relatively clean water from the second settling pond can be collected through a drainage ditch and fed back to the processing plant.

Screw Classifier

The screw classifier consists of a tank that is flared at one end to provide settling time and is sloped at the other end to allow material to be drained and removed. A continuous revolving spiral is used to move the material up the slope. The upward movement of the material on the steep slope provides drainage of sands to produce a cleaner and drier product. Agitation in the pool helps to break any settled lumps and agglomerates. There are two potential uses of the screw classifier in the flowsheet. One is to further dewater and clean the coarse sand generated from the hydrocyclone. This could further remove fines from the sand, and also produce a sand product containing less than 20% water, which could be directly loaded onto a truck or a conveyor belt. The second use of the screw classifier would be to break up the clay and sand chunks that might report to the screen oversize or that could blind the screen and render the screens ineffective.

High Pressure Belt Press

The high-pressure belt press is an optional method to treat the fine fraction from the hydrocyclone. The belt filter press uses a flocculent to produce a rapidly settling floc, which separates the solids from the majority of the water and then uses pressure to squeeze the water from the flocs. The capital investment and operational costs of a belt press are usually high. The chemicals alone, mostly polymer flocculent, could cost a quarter of the entire operation. The advantage of using this equipment is its fast dewatering capability, the production of clean water and that the solids produced can be hauled away by conventional trucks. The high-pressure belt press has been used in sewage plants, and full-scale operation in sediment treatment plants has been widely used in European countries. Because of relatively slow moving parts associated with belt press operation, it has high tolerance to the sand contained in the slurry to be dewatered.

Site Preparation

Sediment inside the CDF in general forms a pattern as presented in Figure 2. In the previous operation, the dredged materials were unloaded from the barge to the southeast corner of the CDF and washed into the rest of the CDF. Coarse sand settles rapidly while fine silt and clay is washed away. This creates a coarse sand beach on the southeast corner, and a lagoon toward the north side of the CDF where the fine material settles. According to previous sampling, the material near the south corner is clean sand and is being used as construction fill around the harbor area. The size criterion for construction use is that material contains less than 12% of the particles finer than 75-micron. The material that did not pass the criterion was stockpiled on the west side of the CDF. This material could be ideal feedstock for the treatment plant to demonstrate the ability to produce useful materials.

Before the year 2000 dredging season begins, ACE contractors will be preparing the southeast corner area for unloading the dredged materials and will be creating a sluice for washing material further north into the CDF. Since a large amount of material will be moved around inside the CDF areas, incorporating site preparation of this project into the ACE contractors preparations would benefit both the separation study and dredging operation.

Site Location

The primary objective of the ACE contractors is to complete the dredging operation and, therefore, the site for this project should be chosen in consideration of avoiding interference with dredging operations while utilizing their expertise on their downtime. As presented in Figure 3, the plant could be located on the south corner of the CDF by the river. Choosing this location could minimize the interference with dredging operations and would facilitate being close to different types of material that can be tested in the treatment plant.

Settling Pond and Process Water

Based on the previous study, there are two distinct settling rates for the hydrocyclone overflow. The silt fraction will settle at a relatively rapid rate while ultra-fine clay will settle more slowly and may require flocculation. The settled slit will compact to a higher degree than the clay especially if flocculents are use with the clays. As presented in Figure 4, a two-pond settling system will provide optimum settling space for storage of fine material from the treatment plant. If flocculation is needed, the flocculent can be added between two ponds where the water is overflowed to the second pond. The longitudinal settling pond will provide relatively clean recycled water for plant use.

Primary process water intake should be initially from the trench inside the CDF, and then the process water will be recycled through the settling pond. No processed water should be allowed to discharge to the lake. If the water level is low inside the CDF, make up water could be brought in from the lake. Water level of the settling pond should be maintained at its minimum to avoid overflow in case of heavy rain. Flocculent should not be applied at the initial stage, given that operation is not continuous through the evening and night, so natural settling would provide enough clarity for treatment plant use. If the ultra-fine material builds up in the process water, flocculent could then be added periodically on an as-needed basis.

Plant Layout

Since the plant is to be built only for temporary use, it is not advisable to build a concrete slab in the area. A stable platform with a low center of gravity plant has to be built to warrant a safe operation on less sturdy ground. As presented in Figure 5, only the hydrocyclones and screen will be mounted on a two-stage platform with lower stage sized at 15 feet by 15 feet. The hydrocyclones will be mounted 22 feet above the ground, so that the height of the hydrocyclones will provide a gravity feed through a launder to the sand products stockpile inside the CDF, and the excess water from the sand will be drained to the fine settling pond.

Sizing the Settling Pond and Stockpile

Using the currently available NRRI equipment as a basis, the nominal treatment rate would be 50 tons per hour. Since the characteristics of the feedstock may change daily, the aerial arrangement of the settling ponds and the sand stockpile should consider the two extreme cases; the feed material contains mostly fine silt and clay, which will require the most settling area, or the feed material consist of mostly coarse sand that will produce the largest sand pile.

Stockpile for the feed material should be enough to run the plant continuously for two weeks at a 50-ton per hour rate and should be located in close vicinity to the feeder. An area of 2,000 square feet is needed for the stockpile. The stockpile for the coarse product, in the extreme case, will be occupying the same volume as feed material, and a kidney shaped stockpile will be used for the convenience of stockpiling by direct discharge from the cyclone. The kidney shaped stockpile requires an area of 60 x 40 feet. The settling basin for fine product requires excavating a space to contain the fine material, surface area for fine settling and water recycling. The settling basin is expected to store the fine materials generated in the entire project. Approximately 30,000 cubic yards of fine slurry will be generated over the three-month period;

however, the water will be recycled. The volume of the fines is based on 35% solids in the settled fines. Two 12-foot deep, 60-foot wide, by 140-foot long ponds are needed, one for the fine settling and another for recirculating the water. A 50-ton per hour treatment plant, if the plant is encountering all fine materials, could generate the fines at 350 gallons per minute, for which a 50-feet by 100-feet surface area is needed for the settling according to previous settling tests without flocculent.

Utility Requirements

A mobile 200 HP, 440-volt generator could be rented to supply power for the plant operation. Water, either fresh or recycled, could be provided by a rented pump.

Other Issues

Since the amount of contamination in the CDF is generally low, the material could be used for many purposes such as construction fill, mine land reclamation, and topsoil. The treatment plant is designed to produce coarse sand that will meet specifications for the construction fill, less than 12% of material finer than 75 microns. Since the contaminants are usually associated with the fine fraction, the contamination level of the coarse material could be below background.

The possibility of utilizing the fine fraction requires further treatment. Besides the dewatering process discussed earlier, there is a concentration factor of the contaminants since most of them are associated with the fines. Further treatment of the fine fraction should be addressed. One of the possible treatments is using a high intensity magnetic separator to separate iron and iron oxides. Heavy metal pollutions are most likely to be contributed from nearby industry and mostly associated with the iron and steel industry; the heavy metals are likely to be associated with the iron. Removing iron particles could achieve the decontamination. A high intensity magnetic separator could be used on a batch basis to demonstrate the removal of metals from some of the processed material.

To utilize the materials, the purple loosestrife found in the CDF should be removed. The cyclone separation is based on particle size and specific gravity. The purple loosestrife seeds should have a specific gravity close to 1 and therefore, be isolated to the fine fraction, which consists of mostly silt and clay in the size range less than 30 microns. A fine screen could be used to screen the seeds out to be destroyed.

OPERATION AND EXPECTED OUTCOME

The sediment treatment plant has been designed to be an outdoor operation for the three summer months. For 60 8-hour days of operation, total material treated would be in the range of 20,000 to 40,000 cubic yards. The material will consist of three types:

fine silt, silt sandy, and mostly sandy material. US Army Corps of Engineer Duluth Office will coordinate contractors for moving material to and from the treatment plant.

Monitoring and Mass Balance

A closely monitored system is needed to obtain the maximum amount of information generated from the plant. There are many issues that have to be addressed for the future implementation of the plant, such as effectiveness of decontamination, bulking factor of the sediments, material handling, and water treatment. A detailed monitoring and sample analysis schedule is presented in Table 1. Overall mass balancing should be carried out through instrument recording and manual sampling. The combined data from a weightometer on the feed conveyor belt, and density gauge and flowmeter on the cyclone feed would provide an accurate measurement of the material being fed to the cyclone which can used along with the sampling discussed below to determine the mass balances throughout the plant.

Sampling and Analysis

Crude analyses, which will be conducted routinely, include % solids analysis of the slurry by "Marcy" cup, hand screen, and visual observation. Extensive sampling would mostly include the feed and the products of the hydrocyclones. Obtaining a representative sample of the bulk feed is difficult; therefore, the feed sample should be taken from the cyclone feed tank. The screen oversize should also be sampled so that the total feed can be calculated. Analysis of these samples will provide detailed information on feed rate, separation efficiency, contaminant level, and settling characteristics of the fines.

A daily composite sample will be obtained and sealed for heavy metal and organic chemistry analysis. Organic pollutants analyses include PCBs, PAHs, Oil and Grease, TOC, and TOX. Selected samples should be analyzed by screen fractions to examine the separation efficiency of the hydrocyclone. TOC will be extensively used since analysis is relatively inexpensive and in many cases can be used as surrogate of PCBs and PAHs. There will be attention paid to the Cadmium and Mercury analysis that is a concern in this area.

Monitoring

A uniform feed material to the hydrocyclone is the key to produce a consistent separation. The monitoring devices should include a differential pressure density gauge to monitor the slurry density and a flowmeter to monitor flowrate. The throughput can be calculated from the density and flow. There is no appropriate device to measure the flow of the products and, therefore, manual measurement such as timed sampling should be carried out on an as-needed basis.

Mass Balance

Since an accurate mass balance determines the applicability to other CDF operations and direct economic estimation, mass balances should be calculated by several approaches. The first approach could be by logging the volume of the sediment fed to and removed from the plant, which includes the feed stockpile, sand product pile and the settling pond volume. The mass balance can also be carried out by weight measurement, which will be based on the weightometer on the feed conveyor, and the mass flowrate through the hydrocyclone. Each point should be closely measured so that not only the sand and fine silt will be accounted for, but also the boulders and pebbles in screen oversize.

Applicability to Other CDFs

As mentioned in the site preparation section, the existing stockpile containing greater than 12% finer than 75-micron material should be ideal for the treatment plant to upgrade. Re-cleaning of the coarse product could be tested by running the material through the plant twice. Since the plant design is not limited to treating the Duluth Harbor sediment but also the CDFs around the Great Lakes Basin, the plant is also designed to treat various types of materials. On the north side of the stockpile there is an area filled with fine silt material. Treatment of this material in the plant should yield little or no sand, however, re-slurrying of this material and blending it with sand could produce desirable topsoil for mine land reclamation. The blended slurry requires a high-pressure belt press to dewater.

Operation

Feeding the material to the plant remains the biggest hurdle for a smooth operation. The agglomeration of the clay and sand presents challenges to operators to achieve a desired separation. The screw classifier could be used in front of the flowsheet to help to ensure the proper feed material to the plant. The double-decked screen is not intended to produce different sized product. The first deck is used to break large chunks and to protect the finer screen from rock impacts. An operation data log should be recorded in as detailed a manner as possible in order to track material balance, operation downtime, and problems encountered in the operations.

The high-pressure belt press should not be used until toward the end of the demonstration due to its relatively high cost. When all operations are running smoothly, the belt press should be brought in to test its feasibility for dewatering, to determine the characteristics of filter cake, and possible production of topsoil.

Expected Outcome

The expected outcome of this the treatment plant should be the most effective method for treating the sediments. A complete mass balance should be made indicating the amount of sand that will be produced for a given feedstock and what the bulking factor will be for the silt and clay fraction. This project should also track flow of the pollutant in both organic and inorganic materials. The material-handling problem should be observed, not only on the material to be handled through the plant, but also the products of dewatering and sand stockpiling. The operational and equipment cost of treating the sediment are best estimated through large-scale operation.

Although the material treated at Erie Pier CDF has a very low contamination level, the project should produce valuable data for the CDFs around the Great Lakes basin. The physical characteristics should be similar to most of the sediment stored in other CDFs. Although the chemical characteristics vary from site to site, there is a similarity in the flow of the pollutants.

ESTIMATED COST AND TIME FRAME OF THE PROJECT

This section assumes that NRRI's equipment is used for the treatment plant. Most of the existing equipment is in good operating condition, and other than dewatering equipment; there is no major equipment to purchase for the proposed plant. As presented in Table 2, the cost can be broken into two parts, one for the equipment erection and the other for operation. Each takes three months for three technicians to complete. For the most part, the supplies include the steel, belts, parts, and other miscellaneous items. With travel and other administrative costs, the total budget amounts to $266,720. If NRRI's equipment is not used, then the cost to purchase the equipment used in the process is listed in Table 3, which is estimated to be $217,155. The generator, excavator, high-pressure belt press, and other site preparation work will be contracted through ACE at an estimated cost of $65,000.

As presented in Table 4, operation of the sediment treatment plant is preferred to be arranged in the three summer months. The necessary platform and equipment support could be constructed over the winter at the NRRI facility where a large indoor workshop is available. By the end of May, the plant will be assembled at the NRRI facility prior to the shipment to the Erie Pier CDF. Allowing time for the completion of the chemical analysis, data collation, and reporting, a draft report for the project could be completed before the end December 2000.

SUMMARY

The purpose of the project is to find an alternative solution for the storage or use of the dredged material from St. Louis Harbor. The existing Erie Pier CDF in Duluth is nearing its capacity and additional space is required. The study is conducted in response to Section 541 of the Water Resource Development Act of 1996, to develop and implement methods for decontamination and disposal of contaminated dredged material at the port of Duluth, Minnesota.

The treatment plant using mineral processing methods should include a feeder with grizzly screen, vibrating screen, hydrocyclones, and possibly a screw classifier to process dredged material in order that the products, sand, silt, and clay, can be used as construction fill and topsoil.

Monitoring and sample analysis should be conducted extensively to collect information for the implementation of this technology not only to the port of Duluth, but also to the CDFs around the Great Lakes region. The data should include the material handling, mass balancing, decontamination efficiency, utilization of the material, and other environmental issues.

Assuming that NRRI's equipment is used, the cost of the project is estimated at $266,720, which includes equipment erection, operation, analyzing, and associated administrative costs. The project should be completed by December 2000.

Monitoring, Sampling and Analyzing

Monitoring

Manual

%Solids	Marcy Cup Method
Size	200 Mesh Tyler Hand Screen
Classification	Visual Observation

Device

Weighton Meter	Measure the Weight of Feed and Conveyor
%Solids	Differential Pressure on the Sump Tank
Flowrate	Magnetic Flowmeter

Sampling

Hydrocyclone Feed
Hydrocyclone Overflow (Silt and Clay Portion)
Hydrocyclone Underflow (Sand Portion)

Samples will be taken every hour and composite daily for chemical analysis

Chemical Analysis

For All Composite Samples:
TOC, TOX,
screen at 35, 48,65,100,200,270,and 325 mesh

For Selected Samples:
GC: PCBs, PAHs, and Oil and Grease
ICP: Fe, Cr, Ba, Pb, Cu Zn, and Ni
AA : Hg and Cd

Cost Estimation of NRRI

Erection:	
Salary and Fringe	60,000
Supply	5,000
Equipment Rental and Maintainace	35,000
Operation:	
Salary and Fringe	60,000
Supply	10,000
Travel	8,000
Overhead	88,720
NRRI Total:	**$266,720**

Table 2

List of the Equipment

Pumps:		
	Water Pump – 4/6 A&H Worthinton Pump, 40 HPMotor	$17,000
	Slurry Pump - 4/6 Cavity Warner Pump, 40 HP Motor	$35,000
	Step Pump - Robbins & Myers Pump 1/2 HP Motor	$3,000
Conveyors:		
	24"X50' Reeve Vari-Speed with 10 HP Motor	$11,555
	24" X 25' Baldor with 10 HP Moter	$8,500
	24" X 50' Staker	$8,500
Feeder:		
	Baldor Variable Speed, 5 HP Moter	$15,000
Screw Classifier		
	Westing House 5 HP Motor	$35,000
Screen		
	Aero-Vibro G502 with 5 HP Motor (4'X7')	$8,500
	Derrick DL333 with 2 HP Fine Screen (2'X3')	$15,000
Mixer & Tank		
	Lightening 5 HP	$5,000
Monitoring Equipment		
	Magnetic Flowmeters, F&P 6"	$6,600
	Density Gaugues, General Electric 6"	$12,000
	Differential Pressure Gaugue	$8,000
Magnetic Separator		
	Erize EZ402	$25,000
Hydrocyclone		
	Krebs DB15	$3,500
		$217,155

Table 3

Time Table of the Project

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Phase I Develop Plan																		
Site Visit	*****	*****																
Site Preparation Plan			*****															
Equipment Layout			*****	*****														
Review of Plan				*****	*****	*****	*****	*****	*****									
Phase II Erection and Testing																		
Flowsheet Engineering									***	*****								
Purchase and Lease of Equipment										*****	*****	*****						
Erection and Testing										*****	*****	*****						
Phase III Site Prep. and Testing																		
Pilot Plant Construction											*****	*****	*****					
Testing													*****	*****	*****			
Demonstration														*****	*****			
Dismantling Plant																*****		
Reporting																*****	*****	*****

Table 4

Treatment Plant Flowsheet

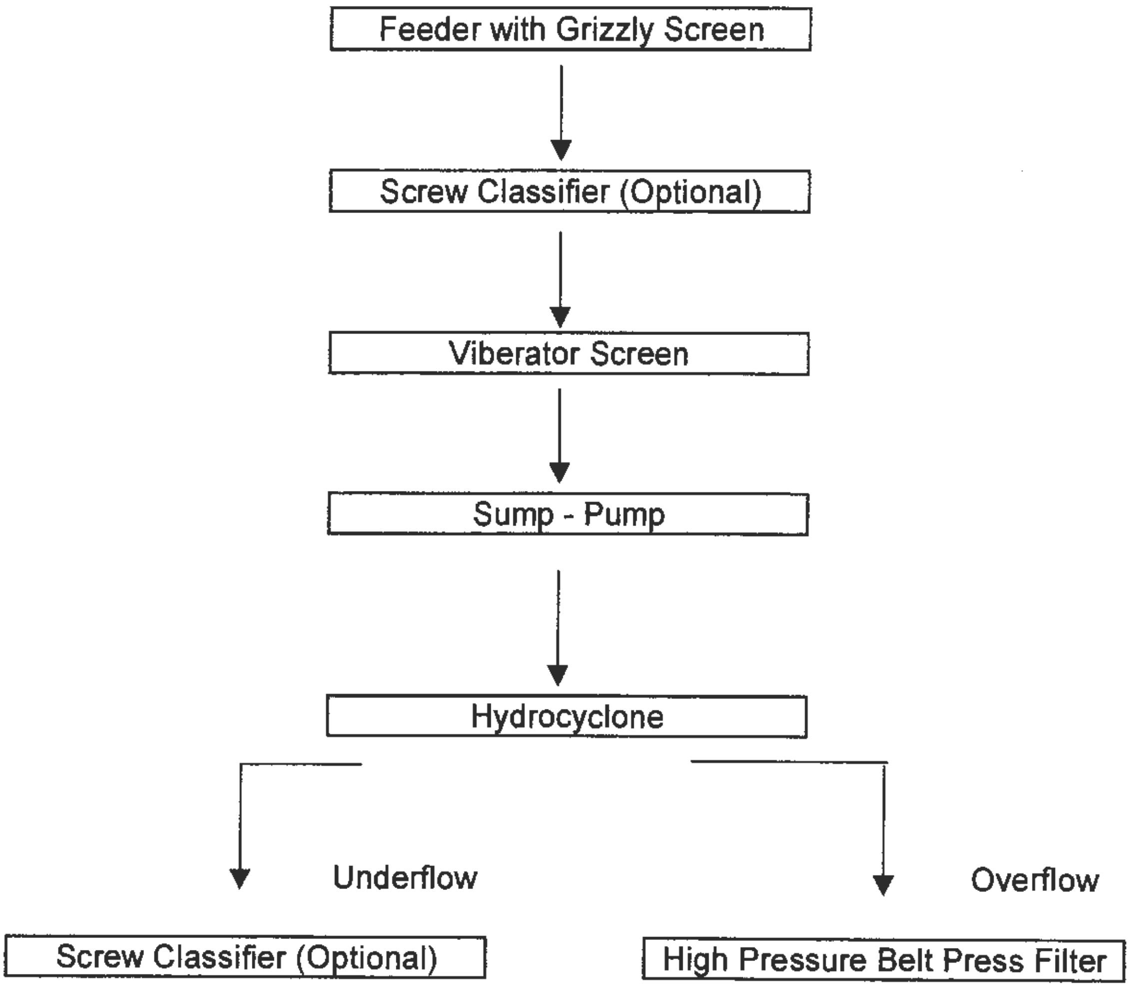

Figure 1

Cross Section of Erie Pier CDF

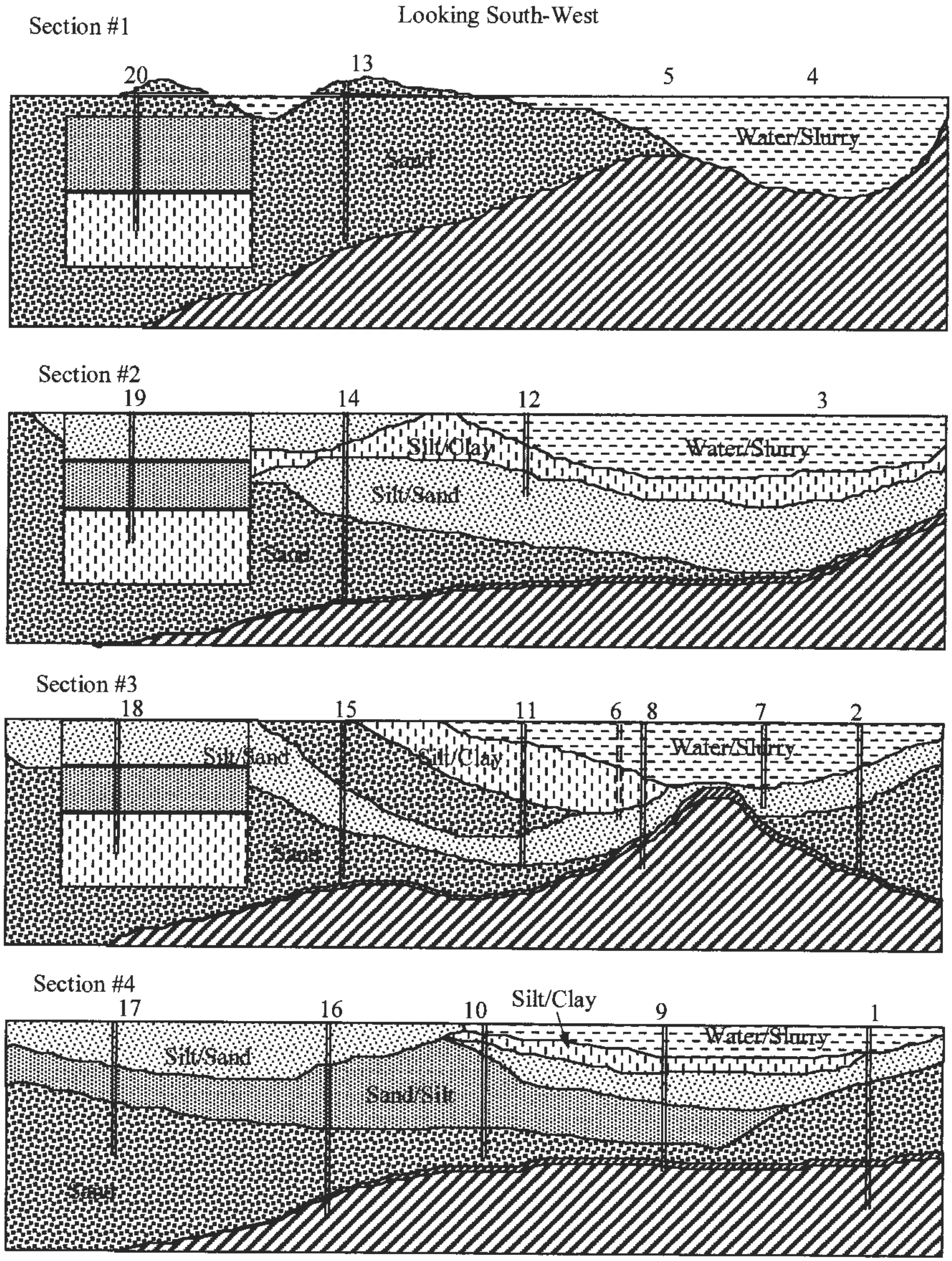

Figure 2

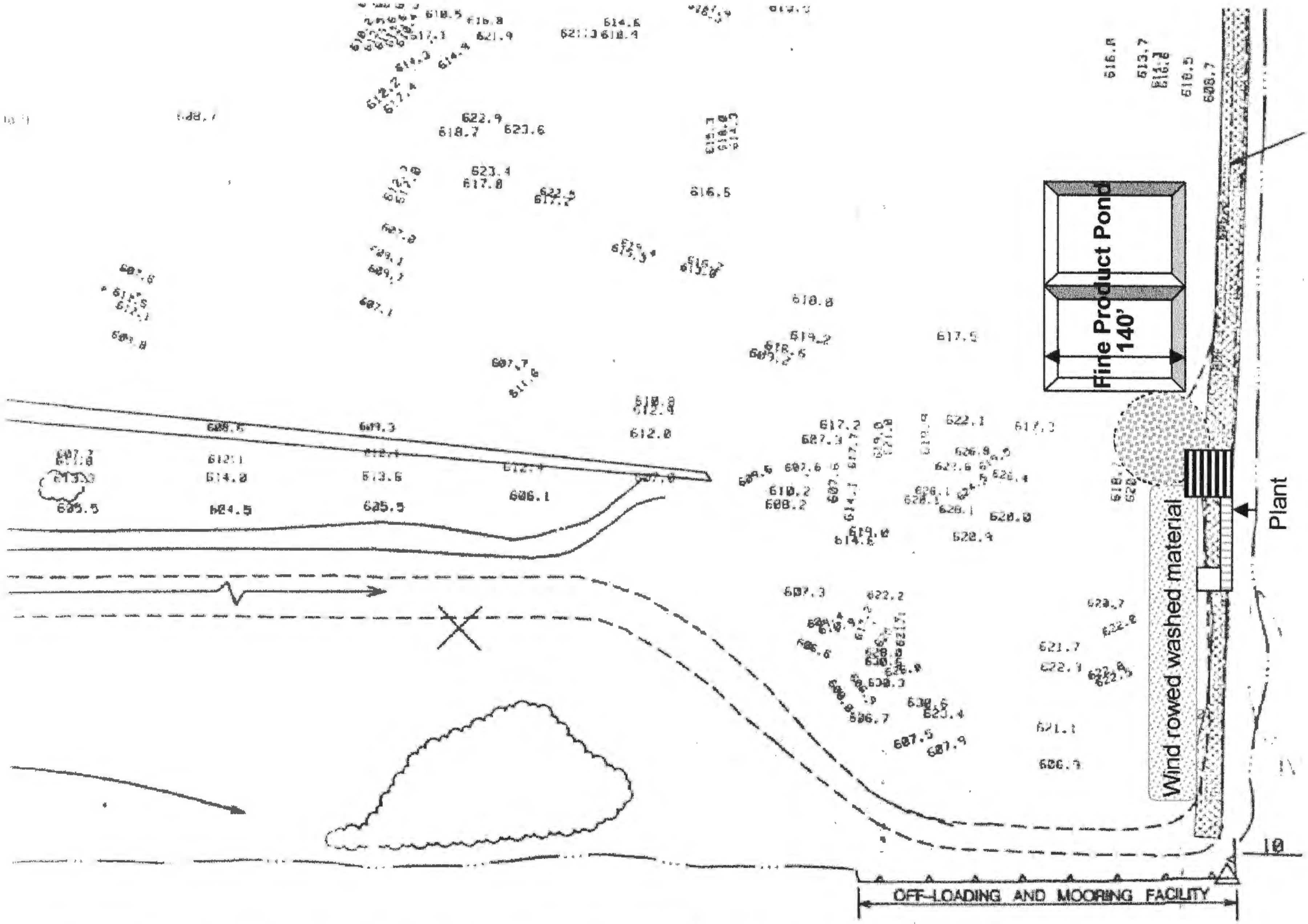

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Figure 3

Settling Pond

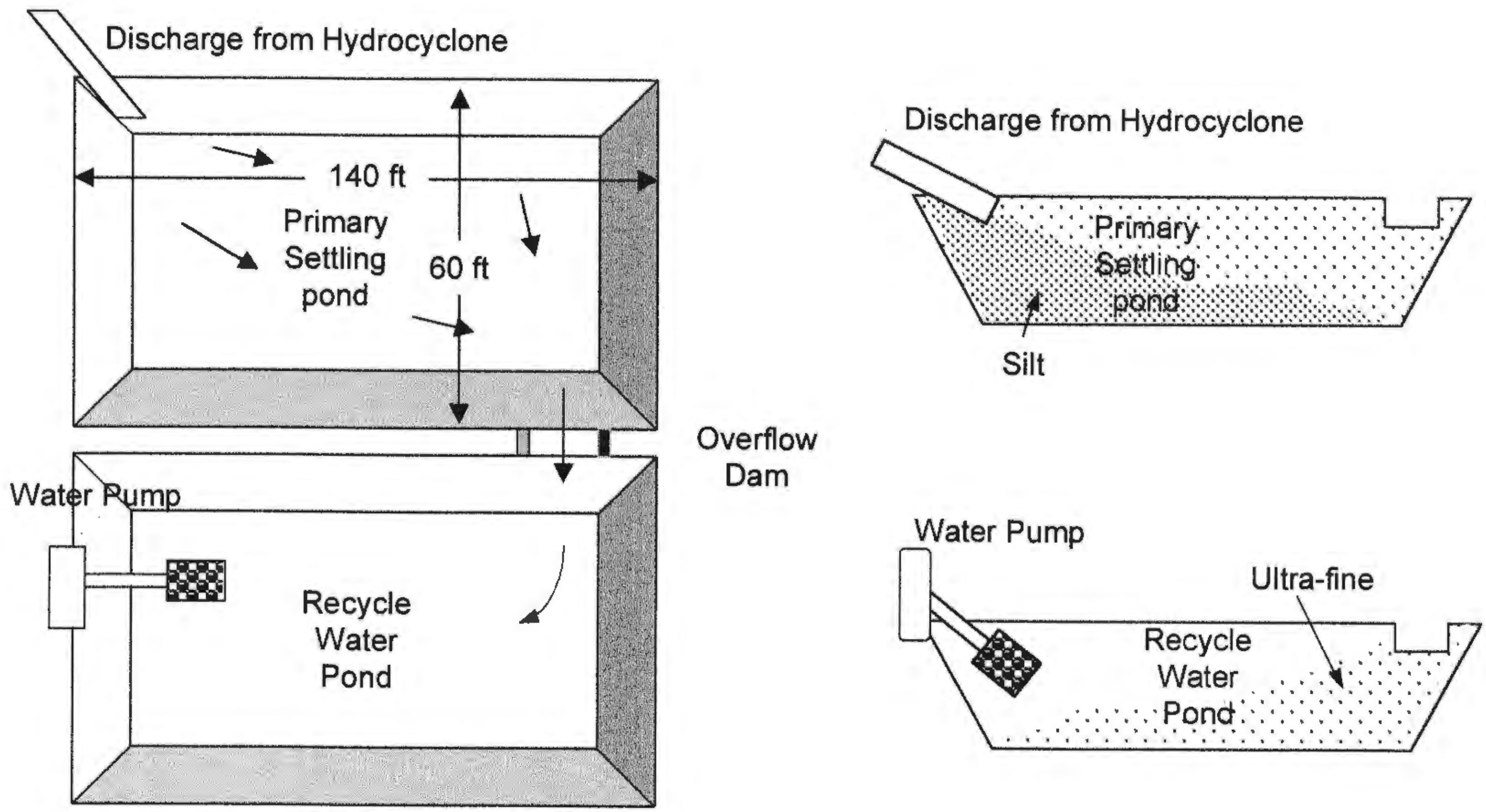

Figure 4

Plant Layout, Side View Looking North

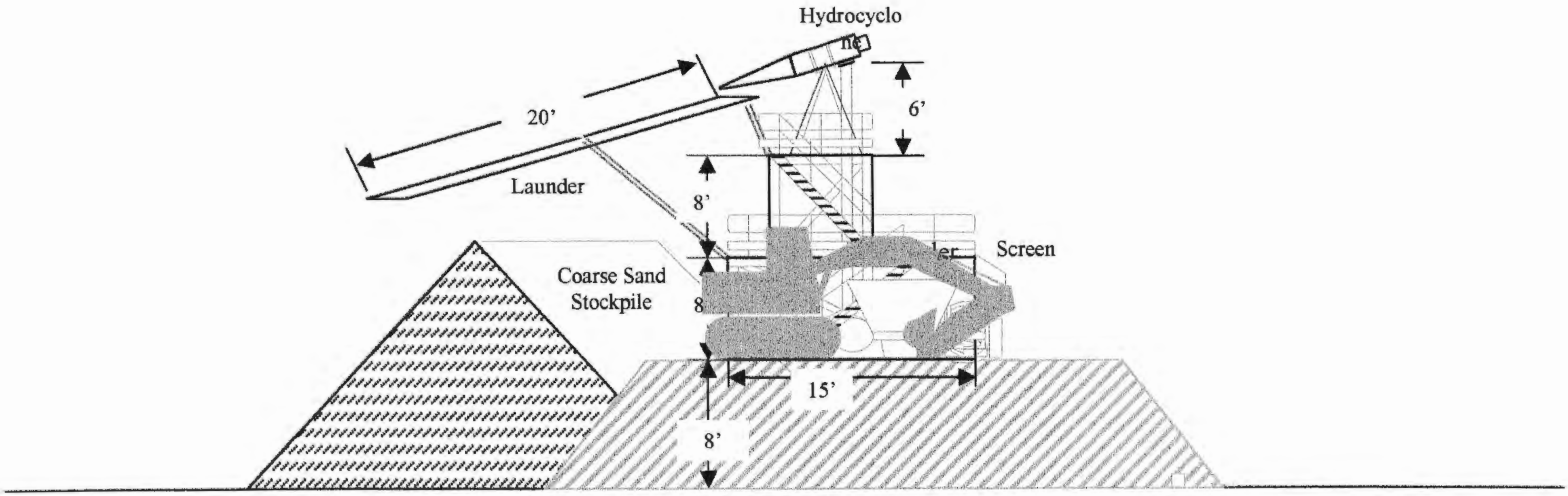

Figure 5