PREPRODUCTION INITIATIVE-NELP SWEEPER/SCRUBBER FOR PIER CLEANING FINAL REPORT

NAVAL STATION SAN DIEGO, CA

1.0 INTRODUCTION

The U.S. Navy has adopted a proactive and progressive position toward protecting the environment and complying with environmental laws and regulations. Rather than merely controlling and treating hazardous waste by end-of-the-pipe measures, the Navy has instituted a program for pollution prevention (P2) to reduce or eliminate the volume and toxicity of waste, air emissions, and effluent discharges.

P2 allows the Navy to meet or exceed current and future regulatory mandates and to achieve Navy-established goals for reducing hazardous waste generation and toxic chemical usage. P2 measures are implemented in a manner that maintains or enhances Navy readiness. Additional benefits include increased operational efficiency, reduced costs, and increased worker safety.

The Navy has truly set the standard for the procurement and implementation of P2 equipment. The Chief of Naval Operations (CNO), Environmental Protection, Safety, and Occupational Health Division (N45) established the P2 Equipment Program (PPEP), through which both the Naval Air Systems Command Lakehurst (NAVAIR LKE) and the Naval Facilities Engineering Service Center (NFESC) serve as procurement agents under the direction of N45. P2 equipment is specified and procured under two complementary initiatives: the Preproduction Initiative (*i.e.,* technology demonstration) and the Competitive Procurement Initiative. The Preproduction Initiative directly supports both the Navy Environmental Leadership Program (NELP) for P2 shore applications and the P2 Afloat program, which prototypes and procures P2 equipment specific to the needs of ships.

This report provides an analysis of the procurement, installation, and operation of P2 equipment under the Preproduction Initiative. Technology demonstrations and evaluations are primarily performed under NELP at two designated NELP sites—Naval Air Station North Island and Naval Station Mayport. Additional sites, such as Naval Station San Diego, have been added as required to meet specific mission goals. The program involves defining requirements, performing site surveys, procuring and installing equipment, training operators, and collecting data during an operational test period. The equipment is assessed for environmental benefits, labor and cost savings, and its ability to interface with site operations.

2.0 BACKGROUND

Naval Station (NAVSTA) San Diego currently supports operations on 14 piers. The piers range in size, but can be as large as 1000 feet long and 120 feet wide. While primarily used for ship berthing, the piers also are used for other activities such as physical training and ship maintenance. Operational and maintenance activities use both hazardous and nonhazardous materials, and generate waste and debris. In addition, birds often forage in the dumpsters on the piers, leaving behind significant droppings.

A number of Best Management Practices (BMPs) to prevent and minimize pollutants on the piers have already been implemented at NAVSTA San Diego. These BMPs include:

- Training both shore and ship personnel regarding stormwater pollution prevention
- Using tarps to capture waste generated by paint grinding and chipping
- Secondary containment for drum storage
- Compliance inspections to verify BMP implementation.

Nevertheless, there is still a potential for the piers to be contaminated with a wide variety of substances. Historically, numerous techniques have been used to clean the piers at NAVSTA San Diego. The most effective cleaning technique used saltwater hoses to wash accumulated contaminants into the bay; however, washing pollutants from industrial piers into the bay is now prohibited by the Navy. As an alternative, manual sweeping has been employed. On occasion, entire piers have been swept by groups of military and civilian personnel. More frequently, manual sweeping is limited to spot sweeping by individuals as they complete work in a given area and to housekeeping cleanup work by sailors. Manual sweeping is limited in effectiveness because of high labor costs, shrinking labor forces, and its inability to effectively remove dried residues (e.g., bird droppings).

At this time, there are no specific, numeric regulatory controls on stormwater discharges to San Diego Bay. However, the San Diego Regional Water Quality Control Board (SD RWQCB) does compare stormwater monitoring data to benchmark values taken from the U.S. Environmental Protection Agency (EPA) Multi-Sector General Stormwater Permit. The SD RWQCB uses this comparison to evaluate BMPs implemented by the discharger. Monitoring results that exceed the benchmark values are a flag to SD RWQCB staff that the discharger's BMPs may not be effective in reducing pollutants in stormwater discharges and may pose a threat to water quality.

Given the Navy's policy of meeting or exceeding all environmental regulations and the need to constantly evaluate and improve BMP implementation at Navy bases, NAVSTA San Diego has chosen to utilize mechanical sweepers and scrubbers as BMPs in an effort to reduce the environmental impact of its operations on San Diego Bay. It is anticipated that using mechanical sweepers and scrubbers to clean piers will reduce the variety and concentration of contaminants in the first flush of stormwater discharge (i.e., the first ¼ inch of rainfall).

2.1 Mechanical Sweeper Requirements

The selected mechanical sweeper must meet the following site requirements:

- High degree of maneuverability
- Dry dust suppression system
- Air filtration for particulates larger than 10 microns
- Automatic self-adjusting main broom
- Enclosed side brushes
- Front auxiliary brush
- Vacuum wand
- Rust-resistant hopper
- Ability to lift the hopper at least 9 feet for dumping.

2.2 Mechanical Scrubber Requirements

The selected mechanical scrubber must meet the following site requirements:

- High degree of maneuverability
- Capable of reusing water during operation
- Capable of using a biodegradable detergent.

3.0 EQUIPMENT DESCRIPTION

3.1 Vendor Selection

Extensive vendor searches were conducted for both types of cleaning machine. Based on this research, the Tennant 830-II Power Sweeper and the Tennant 550 Power Scrubber were selected as the machines most likely to meet the requirements of this project. Based on estimated site requirements, two sweepers and one scrubber were purchased for testing.

3.2 System Components

3.2.1 Tennant 830-II Power Sweeper

The Tennant 830-II Power Sweeper is a mechanical street sweeper that includes, but is not limited to, the following major components:

- 4-wheel power steering
- 2 high-volume vacuum fans for dry dust control
- Exhaust filter
- Centrally suspended main broom
- Dual side brushes and variable height auxiliary brush
- Vacuum wand extension

- Stainless steel hopper
- Ability to dump the hopper up to 9 feet-6 inches above ground surface.

3.2.2 Tennant 550 Power Scrubber

The Tennant 550 Power Scrubber is a mechanical street scrubber that includes, but is not limited to, the following major components:

- Articulated steering system
- Stainless steel debris hopper
- 265-gallon solution recycling tank
- 10-gallon detergent tank
- Tennant 658 Heavy Duty Recycling Cleaner as detergent.

3.3 Method of Operation and Modifications Made During the Evaluation

No modifications were made to the sweeper during this evaluation. The scrubber, as initially ordered, operated on propane. However, after additional evaluation by the site, it was determined that it would be more efficient to operate the scrubber on diesel fuel. Therefore, the manufacturer converted the scrubber from propane to diesel fuel for an additional fee.

3.3.1 Tennant 830-II Power Sweeper

The Tennant 830-II Power Sweeper uses multiple brushes and vacuum flows to collect dirt and trash from paved surfaces. Tennant sells sweepers with various optional brushes. The sweepers used during this evaluation had all of the available brushes installed before delivery. In addition, the sweepers included a 12-foot vacuum wand attachment that permits operators to clean areas that are inaccessible to the sweepers. Collected material is deposited into the hopper for containment prior to disposal. Optional high-lift capability permits the contents of the hopper to be emptied directly into a dumpster, dump truck, or other waste container. The filter on the exhaust from sweeping operations is effective on all particles larger than 3 microns.

Based on information provided by Tennant, the maximum emissions from the diesel engine used to power the sweepers are as follows:

- NO_x less than or equal to 0.77 lb./hr.
- CO less than or equal to 0.41 lb./hr.
- Particulates less than or equal to 0.06 lb./hr.
- Hydrocarbons less than or equal to 0.11 lb./hr.

Each sweeper requires 15 gallons of hydraulic fluid. Based on the scheduled maintenance recommended by the manufacturer, the hydraulic fluid should be changed after every 800 hours of operation. Each sweeper also requires 8 quarts of engine oil. The manufacturer recommends that the engine oil be changed after every 100 hours of operation.

3.3.2 Tennant 550 Power Scrubber

The Tennant 550 Power Scrubber applies a water and detergent cleaning solution with an undercarriage spray system to surfaces the machine drives over. Brushes agitate the cleaning solution on the surface. Squeegees and a vacuum system then collect the cleaning solution for reuse. The water and detergent are added to separate tanks before operations commence. As operations proceed, the detergent is automatically injected into the water stream before the water is applied to the surface being cleaned. In accordance with NAVSTA San Diego's Standard Operating Procedures (SOPs) for the scrubber, the cleaning solution is pumped out of the recycling tank after 8 hours of use or whenever it is determined to be too dirty for continued use, whichever comes first. Used cleaning solution is disposed of through the bilge oily wastewater treatment system (BOWTS).

Based on information provided by Tennant, the maximum emissions from the diesel engine that powers the scrubber are as follows:

- NOx less than or equal to 0.53 lb./hr.
- CO less than or equal to 0.29 lb./hr.
- Particulates less than or equal to 0.04 lb./hr.
- Hydrocarbons less than or equal to 0.07 lb./hr.

The scrubber requires 10 gallons of hydraulic fluid and 6 quarts of engine oil. As with the sweepers, the manufacturer recommends that the hydraulic fluid and engine oil be changed after 800 hours and 100 hours of operation, respectively.

3.4 Implementation Requirements

3.4.1 Tennant 830-II Power Sweeper

The specifications and requirements (as supplied by the manufacturer) for the Tennant 830-II Power Sweeper include:

- Dimensions (width x length x height): 70" x 206" x 100" (includes all brushes)
- Gross Weight: 13,600 lb. (with options)
- Engine: 90 hp, diesel
- Cleaning Path:
  - ➢ main broom only: 51"
  - ➢ with right side brush: 69"
  - ➢ with both side brushes: 87"
  - ➢ with auxiliary brush: 126"

- Filter: 211 ft^2, polyester
- Hopper Volume: 3.4 yds^3
- Hopper capacity (high dump): 4,000 lb.
- Hopper capacity (low dump): 7,000 lb.

3.4.2 Tennant 550 Power Scrubber

The specifications and requirements (as supplied by the manufacturer) for the Tennant 550 Power Scrubber include:

- Dimensions (width x length x height): 61.25" x 156.5" x 84"
- Gross Weight: 7,094 lb.
- Engine: 66 hp, diesel
- Cleaning Path: 50"
- Solution Recycling Tank: 265 gal.
- Cleaning Solution Tank: 10 gal.
- Minimum Aisle Turns
  - Right: 196"
  - Left: 191"
- Vacuum Fan Speed: 11,500 rpm
- Vacuum Water Lift: 51"

3.5 Overall Benefits

The mechanical sweeper and scrubber have several potential benefits, including:

- Improve the visible cleanliness of the piers.
- Reduce the concentration of pollutants on the piers.
- Reduce health risks from exposure to bird droppings.
- Reduce manpower required to maintain pier cleanliness.

4.0 DATA ANALYSIS

Quantitative data were collected regarding the operation and use of the sweepers and scrubbers through Daily and Monthly Operational Data Sheets provided in the project Test Plan. Quantitative data regarding the effect of the sweepers and scrubber on contaminants present on the pier was collected through the implementation of the project Sampling Plan.

Qualitative data regarding the performance of the sweepers and scrubber were collected using the Monthly Operational Data Sheets. Operators provided comments regarding the overall performance of the equipment, its interface with site activities, and problems encountered during the month.

4.1 Quantitative Analysis

4.1.1 Operational Data

Operational data were collected using the Daily and Monthly Operational Data Sheets provided with the Test Plan. Data regarding the sweepers were collected between March 2000 and February 2001. Data regarding the scrubber were collected between July 2000 and May 2001. The following table displays average statistics based on data collected during implementation of the project Test Plan.

Statistic	Each Sweeper	Scrubber
Average number of days used per year	180	96
Average number of hours used per year	720	228
Average percent downtime per year	9.97	8.79
Average gallons of fuel used per year	1,152	162
Average gallons of detergent used per year	Not applicable	91
Average volume of waste disposed of per year	434 yd^3	6,360 gallons

Based on the manufacturer's recommendations and the above data, it appears that the following fluids must be replaced:

- Hydraulic fluid in the sweepers—once per year
- Engine oil in the sweepers—eight times per year
- Hydraulic fluid in the scrubber—once every three years
- Engine oil in the scrubber—twice per year.

4.1.2 Sampling Data

Samples collected from the piers were intended to provide *initial* data concerning the effectiveness of the equipment. Samples were collected in accordance with the project Sampling Plan. Four test areas on the piers were selected based on their likely degree of contamination and consistent access for sampling. Each test area was divided into 10 foot x 10 foot test sections named for the method of cleaning employed in each section (e.g., the Sweeper/Scrubber section was cleaned using a sweeper and the scrubber). Samples of simulated stormwater (deionized water) were then collected from each test section. In addition, an equipment blank was collected for each test area sampled by running deionized water through the sampling equipment before the samples were collected. The equipment blanks were collected to confirm that the equipment used to perform the sampling did not contaminate the samples with constituents not present on the piers.

Three of the four test areas were located on Pier 13 and the fourth was on Pier 7. The first test area sampled (identified as the "initial test area") was divided into test sections identified as the Sweeper/Scrubber, Manual Sweeping, and No Clean sections. The other three test areas (i.e., Cleat 4S, Cleat 3S, and Pier 7) were divided into Sweeper/Scrubber and No Clean sections only. This change was made to reduce the extent of the test area, thus increasing the likelihood that contaminant loading would be similar across the sections. Figures showing each test area are included at the end of this report.

A total of 24 samples (not including equipment blanks) were collected during this project as described above. These samples were collected from the test areas as follows:

- Six samples were collected during two rounds of sampling from the No Clean, Manual Sweeping, and Sweeper/Scrubber sections of the initial test area.

- Six samples were collected during three rounds of sampling from the No Clean and Sweeper/Scrubber sections of the Cleat 4S test area.

- Six samples were collected during three rounds of sampling from the No Clean and Sweeper/Scrubber sections of the Cleat 3S test area.

- Six samples were collected during three rounds of sampling from the No Clean and Sweeper/Scrubber sections of the Pier 7 test area.

Each sample from the piers was analyzed using the following parameters:

- Total metals and mercury
- Semivolatile compounds
- Conductivity
- Oil and grease
- pH
- Total suspended solids
- Total and fecal coliforms
- Toxicity.

Toxicity testing was conducted in accordance with EPA Publication No. 600/4-90-027 dated September 1991. Briefly, each sample of simulated stormwater was diluted, usually to 12.5%, 25%, 50%, 75%, and 100% of the sample. Fish (specifically, *Menidia beryllina* or inland silverside) were then exposed to each mixture for 96 hours. The results report the percentage of fish still alive after 96 hours. Based on these results, the laboratory calculated the Lethal Concentration 50 (LC50), which is the concentration of the sample at which 50% of the test organisms are expected to die after 96 hours of exposure. Simultaneously with the exposure of fish to the diluted aliquots described above, additional fish were exposed to pure laboratory water (Laboratory Control) and laboratory water with added salts (Artificial Salt Control). Salts such as sodium carbonate and potassium chloride were added to the laboratory water so that the water accurately represented natural water. These two additional tests serve as controls to ensure that mortality in the test fish is due to exposure to the diluted sample rather than a problem with the laboratory water used to dilute the sample, the salts added to the laboratory water, or the fish stock itself. Generally, for the test results to be accepted, it is expected that no more than 10% of the fish exposed to controls will die (i.e., reported results should be 90% or greater).

In addition to the samples described above, one sample was collected from the water source used to fill the scrubber tank, and three rounds of samples were collected directly from the scrubber tank. These samples were collected to directly demonstrate the type and concentration of contaminants collected by the scrubber.

The Source Water sample was collected directly from the tap used to fill the scrubber tank. Each round of samples from the scrubber tank was collected using the following method:

- The scrubber tank was drained, cleaned, and refilled. A composite sample (identified as “Clean Tank Water”) was collected as the water in the tank was drained again.

- The scrubber tank was refilled with water and used on the piers.

- After eight hours of use or when the water was deemed too dirty for continued use according to the site SOP, a composite sample (identified as “Used Tank Water”) was collected as the water in the tank was drained for disposal to the BOWTS.

The Source Water sample and each scrubber tank sample were analyzed for the following parameters:

- Total metals
- Semi-volatile compounds
- Conductivity
- Oil and grease
- pH
- Total suspended solids
- Total and fecal coliforms.

Since the water used in the scrubber tank is disposed of through the BOWTS, aquatic life will not be directly exposed to it. Therefore, toxicity testing was not performed for these samples.

One sample of the detergent, diluted to the concentration used in the scrubber, was analyzed for the same parameters and by the same methods as the Source Water and scrubber tank samples. This sample was collected to determine whether the detergent was a source for the elevated oil and grease results found in the other samples.

The following tables present the data collected following the Sampling Plan and the additional samples collected for this initiative. The following conventions are used throughout the summary tables:

- Each table presents concentrations for those constituents detected at least once in each test area. If a constituent does not appear in a table, it was not detected in that test area.

- All values are presented in micrograms per liter (i.e., parts per billion, or ppb), except where otherwise noted.

- ND: The constituent was not detected during that sample event.

- NP: The test was not performed for that sample event.

- MPN: Most probable number of coliforms per 100 ml of sample.

- Toxicity test results:

  - The percentage listed in the Constituent column represents the percentage of sample in the water to which test organisms were exposed. For example, 75% in the Constituent column indicates that the test organisms were exposed to water made up of 75% sample water and 25% laboratory water.
  - The percentage listed in each Test Section column represents the percentage of test organisms still living after 96 hours of exposure to the sample-laboratory water mixture.
  - LC50 is the concentration of the sample at which 50% of the test organisms are dead after 96 hours of exposure. For tests where more than 50% of the organisms survived 96 hours of exposure to the pure sample (100% concentration), this value is calculated based on the mortality observed during the test.

Table 1
Results for Initial Test Area Samples

Constituent	8 June 2000			22 August 2000		
	No Clean	Manual Sweeping	Sweeper/ Scrubber	No Clean	Manual Sweeping	Sweeper/ Scrubber
Metals						
Aluminum	300	600	600	2,000	1,800	200
Chromium	ND	ND	ND	10	10	ND
Copper	70	130	50	150	160	30
Iron	850 [1]	1,680 [1]	920 [1]	3,560	3,430	260
Lead	10	20	30	30	30	ND
Mercury	ND	ND	ND	170	2.9	ND
Nickel	10	20	ND	20	20	ND
Zinc	170 [1]	270 [1]	130 [1]	760	730	60
Semi-volatiles						
Bis(2-ethyl hexyl) phthalate	ND	ND	12	10	14	24
Phenol	23	ND	ND	ND	ND	ND
Physical Tests						
Conductivity (µMHOS/cm)	113	123	84	164	166	74
Oil & Grease	ND	ND	ND	600	600	1,700
pH (standard unit)	7.4	7.0	7.6	7.5	7.6	9.2
TSS (mg/L)	24	27	18	58	61	6
Biological Tests						
Total Coliform (MPN)	<2	<2	<2	<2	<2	<2
Fecal Coliform (MPN)	<2	<2	<2	<2	<2	<2
Toxicity Tests						
Laboratory Control (0%)	80 [2]	85 [2]	80 [2]	90	90	90
Artificial Salt Control (0%)	90	90	80 [2]	80 [2]	60 [2]	60 [2]
12.5%	95	100	90	85	90	60
25%	90	90	100	90	90	95
50%	90	90	100	95	95	100
75%	95	100	100	85	95	85
100%	90	100	90	90	85	85
LC50	> 100%	> 100%	> 100%	> 100%	> 100%	> 100%

[1] Iron and zinc were detected in the equipment blank at concentrations of 20 ppb each.
[2] The result is below the 90% acceptance criterion for toxicity controls.

Table 2
Results for Cleat 4S Test Area Samples

Constituent	3 August 2000		17 August 2000		14 September 2000	
	No Clean	Sweeper/ Scrubber	No Clean	Sweeper/ Scrubber	No Clean	Sweeper/ Scrubber
Metals						
Aluminum	1,100	400	1,200	400	700	200
Chromium	ND	ND	10	ND	ND	ND
Copper	120	60	140	40	120	70
Iron	2,200	580	2,630	590	1,060	160
Lead	30	10	40	20	30	ND
Nickel	10	ND	20	ND	10	ND
Zinc	410	120	590	130	550	70
Semi-volatiles						
Bis(2-ethylhexyl) phthalate	13	24	12	19	12	26
Physical Tests						
Conductivity (µMHOS/cm)	139	158	134	108	149	145
Oil & Grease	ND	5,000	ND	1,400	900	2,600
pH (standard unit)	6.7	5.4	8.1	9.3	7.2	7.6
TSS (mg/L)	33	11	41	15	38	6
Biological Tests						
Total Coliform (MPN)	<2	<2	<2	4	23	<2
Fecal Coliform (MPN)	<2	<2	<2	<2	<2	<2
Toxicity Tests						
Laboratory Control (0%)	90	90	85 [3]	85 [3]	90	75 [3]
Artificial Salt Control (0%)	90	90	90	90	80 [3]	70 [3]
12.50%	85	100	NP	NP	70	60
25%	90	90	85	80	80	55
50%	65	95	80	95	60	45
75%	90	85	80	70	60	45
100%	70	95	80	65	50	20
LC50	>100%	>100%	>100%	>100%	100%	76.8%

[3] The result is below the 90% acceptance criterion for toxicity controls.

Table 3
Results for Cleat 3S Test Area Samples

Constituent	3 August 2000		17 August 2000		14 September 2000	
	No Clean	Sweeper/ Scrubber	No Clean	Sweeper/ Scrubber	No Clean	Sweeper/ Scrubber
Metals						
Aluminum	1,100	200	400	100	600	500
Chromium	ND	ND	ND	ND	ND	20
Copper	140	80	110	50	200	50
Iron	2,270	300	990	200	860	550
Lead	20	ND	ND	ND	10	70
Nickel	20	ND	10	ND	20	ND
Zinc	340	90	320	80	430	110
Semi-volatiles						
Bis(2-ethylhexyl) phthalate	16	23	ND	ND	ND	20
2,6-Dinitrotoluene	ND	ND	ND	ND	20	ND
Physical Tests						
Conductivity (µMHOS/cm)	136	146	148	75	401	117
Oil & Grease	ND	3,000	600	900	1,800	3,800
pH (standard unit)	6.9	6.8	7.1	8.6	7.1	8.6
TSS (mg/L)	30	8	17	ND	22	18
Biological Tests						
Total Coliform (MPN)	<2	17	7	<2	8	80
Fecal Coliform (MPN)	<2	<2	2	<2	<2	27
Toxicity Tests						
Laboratory Control (0%)	90	90	85 [4]	85 [4]	75 [4]	75 [4]
Artificial Salt Control (0%)	90	90	90	90	70 [4]	95
12.50%	90	95	NP	NP	50	65
25%	70	90	80	70	95	95
50%	95	80	75	80	70	55
75%	80	85	80	80	20	40
100%	50	90	50	85	25	40
LC50	100%	> 100%	100%	> 100%	66.9%	76%

[4] The result is below the 90% acceptance criterion for toxicity controls.

Table 4
Results for Pier 7 Test Area Samples

Constituent	23 August 2000		7 September 2000		20 September 2000	
	No Clean	Sweeper/ Scrubber	No Clean	Sweeper/ Scrubber	No Clean	Sweeper/ Scrubber
Metals						
Aluminum	900	ND	400	100	400	200
Copper	150	40	100	50	120	50
Iron	1,420 [5]	230 [5]	630	200	590	200
Lead	20	ND	20	ND	20	ND
Mercury	4	ND	ND	ND	ND	ND
Nickel	10	ND	10	ND	20	ND
Zinc	350	70	210	90	320	100
Semi-Volatiles						
Bis(2-chloro isopropyl) ether	ND	ND	ND	39 [6]	ND	ND
Physical Tests						
Conductivity (μMHOS/cm)	442	160	757	507	364	239
Oil & Grease	600	1,100	ND	700 [7]	ND	2,500
pH (standard unit)	6.7	7.1	7.4	7.6	6.7	6.8
TSS (mg/L)	35	6	30	9	20	ND
Biological Tests						
Total Coliform (MPN)	1,600	90	>1,600	8	<2	240
Fecal Coliform (MPN)	900	4	>1,600	4	<2	240
Toxicity Tests						
Laboratory Control (0%)	95	95	70 [8]	70 [8]	95	85 [8]
Artificial Salt Control (0%)	95	95	80 [8]	75 [8]	100	95
12.50%	95	80	55	85	95	95
25%	60	85	75	70	95	90
50%	30	90	65	60	100	85
75%	45	75	55	55	90	85
100%	30	65	20	40	75	60
LC50	40.5%	> 100%	89.1%	83.9%	> 100%	> 100%

[5] Iron was detected in the equipment blank at a concentration of 20 ppb.
[6] Bis(2-chloroisopropyl)ether was detected in the equipment blank at a concentration of 16 ppb.
[7] Oil & Grease were detected in the equipment blank at a concentration of 600 ppb.
[8] The result is below the 90% acceptance criteria for toxicity controls.

Table 5
Results for Source Water and First Round of Scrubber Tank Samples

Constituent	Source Water	Round 1 Clean Tank Water	Round 1 Used Tank Water
Metals			
Aluminum	800	1,700	15,000
Chromium	ND	ND	300
Copper	ND	70	1,100
Iron	150	2,290	25,200 [9]
Lead	ND	20	1,900
Nickel	ND	ND	200
Zinc	ND	210	6,900
Physical Tests			
Conductivity (μMHOS/cm)	667	683	4,460
Oil & Grease	ND	ND	2,190,000
pH (standard unit)	8.2	8.1	9.0
TSS (mg/L)	ND	65	123
Biological Tests			
Total Coliforms (MPN)	<2	>1,600	>1,600
Fecal Coliform (MPN)	<2	>1,600	<2 [10]

[9] Iron was detected in the equipment blank at a concentration of 20 ppb.
[10] This value was changed from ">1,600" to "<2" after the laboratory's QA/QC review. Given the values presented for the clean water sample in the tank, it is most likely that the appropriate value is ">1,600".

Table 6
Results for Second and Third Rounds of Scrubber Tank Samples

Constituent	Round 2		Round 3	
	Clean Tank Water	Used Tank Water	Clean Tank Water	Used Tank Water
Metals				
Aluminum [11]	600	7,000	800	19,400
Arsenic	ND	ND	ND	40
Cadmium	ND	10	ND	50
Chromium	ND	70	ND	170
Copper	20	280	30	2,320
Iron [12]	720	9,780	1,370	24,800
Lead	10	540	40	610
Nickel	ND	50	ND	130
Selenium	ND	ND	ND	20
Zinc	90	1,980	170	5,720
Physical Tests				
Conductivity (µMHOS/cm)	836	1,620	961	3,260
Oil & Grease	ND	148,000	ND	826,000
pH (standard unit)	8.5	7.4	8.0	9.5
TSS (mg/L)	28	283	37	1,090
Biological Tests				
Total Coliforms (MPN)	300	>1,600	>1,600	>1,600
Fecal Coliform (MPN)	2	>1,600	<2	22

[11] Aluminum was detected in the Source Water at a concentration of 800 ppb.
[12] Iron was detected in the Source Water at a concentration of 150 ppb.

Table 7
Results of Cleaning Solution Sample

Constituent	Detergent Solution
Metals	
Iron [13]	150
Selenium	20
Zinc	70
Physical Tests	
Conductivity (μMHOS/cm)	8,770
Oil & Grease	8,330,000
pH (standard unit)	> 12
TSS (mg/L)	791

[13] Iron was detected in the Source Water at a concentration of 150 ppb.

Potential sources of error are inherent in the sampling conducted for this project. The primary potential source of error is that given the wide range of activities on the piers and the fact that these activities were conducted on the piers without respect to the divisions of test areas, contaminant loading in each test section may have been unequal. It is difficult to ascertain whether this type of error will bias the results higher or lower than the average concentration of each constituent on the piers. In addition, as mentioned above, test areas were selected based on likely contamination and consistent access to the test area for the personnel conducting the sampling. This will tend to bias the results of the sampling toward higher concentrations of contaminants than the average concentration of each constituent on the piers. Another potential source of error is the limited quantity of water used to perform the sampling. During a storm, solids and debris on the piers will be washed into the bay by the stormwater, with heavier solids being washed into the bay by the rain that falls after the first flush. Due to the limited quantity of water used during sampling, some of these solids were not included in the sample because they were not sufficiently suspended within the simulated stormwater to be collected. This will tend to bias the results of the sampling toward lower concentrations of contaminants than the average concentration of each constituent on the piers. However, it should be noted that the sweepers and scrubber will collect this type of debris and prevent it from being discharged to the bay.

The above data were evaluated in two ways. The data for each Sweeper/Scrubber section was compared to the data from the No Clean and Manual Sweeping sections of the same test area to determine if the constituent levels were reduced after the equipment was used. Similarly, the data from the scrubber tank samples (i.e., the Clean Tank Water and Used Tank Water samples) were compared to determine which constituents the scrubber collected during operation. In addition, the data were compared to benchmark values found in the EPA Multi-Sector General Stormwater Permit to determine if the use of the mechanical sweeper and scrubber on the piers reduced the level of the constituents in the water to near or below the benchmark values. Benchmark values have not been established for all constituents detected by the analyses conducted for this project. Table 8 lists the available EPA Multi-Sector General Stormwater Permit benchmark values for constituents detected in the analyses. All values presented are in micrograms per liter, except where otherwise noted. The fecal coliform results were compared to established levels for contact recreational use (defined as recreation involving full immersion of the body in water).

Table 8
Benchmark Values

Constituent	Benchmark Value from EPA Multi-Sector General Stormwater Permit
Metals	
Aluminum	750
Arsenic	168
Cadmium	15.9
Copper	64
Iron	1,000
Lead	82
Mercury	2.4
Nickel	1,417
Selenium	238
Zinc	117
Semi-Volatiles	
Phenol	1,000
Physical Tests	
Oil & Grease	15,000
pH (standard unit)	6.0-9.0
TSS (mg/L)	100

Presented below is an evalutation of the sample results. Each constituent or parameter is listed alphabetically within its category (i.e., metal, semi-volatile, physical test, or biological test). It should be noted that the samples from the scrubber tank were collected after the scrubber had been used on several locations on the piers. Therefore, the results represent the concentration of collected contaminants. Although the results of the Source Water and scrubber tank samples were compared to the benchmark values presented in Table 8, this comparison should not be interpreted as representing noncompliance.

Metals

Aluminum was detected in 23 of the 24 samples collected from the test areas. In all but one sampling event, the concentration of aluminum detected in the Sweeper/Scrubber section sample was less than the concentration detected in the associated No Clean and Manual Sweeping test section samples. Five of the 11 samples collected from the No Clean sections and one of the two samples collected from the Manual Sweeping section exceeded the benchmark value for aluminum. None of the 11 samples collected from the Sweeper/Scrubber test sections exceeded the benchmark value for aluminum. Aluminum was detected in the Source Water sample and in all of the scrubber tank samples. In all cases, the concentration of aluminum in the Used Tank Water samples exceeded the concentration detected in the Clean Tank Water samples. In all but one of these samples, the concentration of aluminum detected exceeded the benchmark value.

Arsenic was not detected in any of the 24 samples collected from the test areas. However, it was detected in one Used Tank Water sample at a concentration below the benchmark value.

Cadmium was not detected in any of the 24 samples collected from the test areas. However, it was detected in two of the Used Tank Water samples. One of these samples reported a concentration of cadmium below the benchmark value, the other a concentration greater than the benchmark value.

Chromium was detected in 4 of the 24 samples collected from the test areas. These four samples were collected during three sampling events. In two of the three sampling events where chromium was detected, the concentration of chromium detected in the Sweeper/Scrubber test sections was less than that in the associated No Clean and Manual Sweeping test sections. The EPA Multi-Sector General Stormwater Permit did not establish a benchmark value for chromium. Chromium was not detected in the Source Water or Clean Tank Water samples; however, it was detected in each of the Used Tank Water samples.

Copper was detected in all 24 samples collected from the test areas. In each case, the concentration of copper detected in the Sweeper/Scrubber test section samples was less than the concentration detected in the No Clean and Manual Sweeping test sections. The concentration of copper exceeded the benchmark value in all of the samples collected from the No Clean and Manual Sweeping test sections. The concentration of copper exceeded the benchmark value in 2 of the 11 samples collected from the Sweeper/Scrubber test sections. Copper was not detected in the Source Water sample; however, it was detected in all of the Clean Tank Water and Used Tank Water samples. In all cases, the concentration of copper in the Used Tank Water samples exceeded the concentration detected in the Clean Tank Water samples. None of the copper concentrations in the Clean Tank Water samples exceeded the benchmark value; however, the copper concentrations in all of the Used Tank Water samples did exceed the benchmark value.

Iron was detected in all 24 samples collected from the test areas. In each case, the concentration of iron detected in the Sweeper/Scrubber test section samples was less than the concentration detected in the No Clean and Manual Sweeping test sections. The concentration of iron exceeded the benchmark value in 6 of the 11 samples collected from the No Clean test section. In addition, the concentration of iron exceeded the benchmark value in both of the samples collected from the Manual Sweeping test section. However, none of the iron concentrations detected in the samples from the

Sweeper/Scrubber test sections exceeded the benchmark value. Iron was detected in all of the Source Water, Clean Tank Water, and Used Tank Water samples. In all cases, the concentration of iron detected in the Used Tank Water samples was higher than that in the Clean Tank Water and Source Water samples. Except for the Source Water sample and one of the Clean Tank Water samples, the concentration of iron in all samples exceeded the benchmark value.

Lead was detected in 16 of the 24 samples collected from the test areas. These 16 samples were collected during 10 sampling events. In eight of the ten sampling events where lead was detected, the concentration of lead in the Sweeper/Scrubber test section samples was less than the concentration in the No Clean and Manual Sweeping test sections. The benchmark value for lead was not exceeded by any of the samples collected during this project. Lead was detected in all of the Clean Tank Water and Used Tank Water samples, but not in the Source Water sample. In all cases, the concentration of lead in the Used Tank Water samples was greater that in the Clean Tank Water samples. None of the concentrations of lead in the Clean Tank Water samples exceeded the benchmark value. All of the lead concentrations in the Used Tank Water samples exceeded the benchmark value.

Mercury was detected in 3 of the 24 samples collected from the test areas. These three samples were collected during two sampling events. Mercury was not detected in the Sweeper/Scrubber test section samples. All of the concentrations of mercury detected exceeded the benchmark values. Mercury was not detected in the Source Water, Clean Tank Water, or Used Tank Water samples.

Nickel was detected in 13 of the 24 samples collected from the test areas. These 13 samples were collected during 11 sampling events. In each case, the concentration of nickel in the Sweeper/Scrubber test section was less than that in the associated No Clean and Manual Sweeping test sections. The concentrations of nickel detected in these 13 samples did not exceed the benchmark value. Nickel was detected in the Used Tank Water samples only. None of the concentrations detected in these samples exceeded the benchmark value.

Selenium was not detected in any of the 24 samples collected from the test areas; however, it was detected in one of the Used Tank Water samples at a concentration below the benchmark value.

Zinc was detected in all 24 samples collected from the test areas. In each case, the concentration of zinc in the Sweeper/Scrubber test section was less than that in the No Clean and Manual Sweeping test sections. The concentration of zinc in all 11 samples collected from the No Clean test sections, as well as both samples collected from the Manual Sweeping test section, exceeded the benchmark value. The concentration of zinc in 3 of the 11 samples from the Sweeper/Scrubber test sections exceeded the benchmark value. Zinc was not detected in the Source Water sample; however, it was detected in all of the Clean Tank Water and Used Tank Water samples. The concentrations of zinc detected in the Used Tank Water samples were all significantly greater than the concentrations detected in the Clean Tank Water samples. The concentrations of zinc detected in two of the three Clean Tank Water samples and all three of the Used Tank Water samples exceeded the benchmark value.

<u>Semi-Volatiles</u>

Bis(2-chloroisopropyl) ether was detected in 1 of the 24 samples collected from the test areas. This sample was collected from the Sweeper/Scrubber section of the Pier 7 test area. It should be noted that this compound was also detected in the equipment blank for that same sampling event. The EPA Multi-Sector General Stormwater Permit did not establish a benchmark value for bis(2-chloroisopropyl) ether. Bis(2-chloroisopropyl ether was not detected in the Source Water, Clean Tank Water, or Used Tank Water samples.

Bis(2-ethylhexyl) phthalate was detected in 13 of the 24 samples collected from the test areas. These 13 samples were collected during 7 sampling events. In each case, the concentration of bis(2-ethylhexyl) phthalate detected in the Sweeper/Scrubber sections was higher than that in the associated No Clean and Manual Sweeping sections. The EPA Multi-Sector General Stormwater Permit did not establish a benchmark value for bis(2-ethylhexyl) phthalate. Bis(2-ethylhexyl) phthalate was not detected in the Source Water, Clean Tank Water, or Used Tank Water samples.

2,6-Dinitrotoluene was detected in 1 of the 24 samples collected from the test areas. This sample was collected from the No Clean test section of the Cleat 3S test area. The EPA Multi-Sector General Stormwater Permit did not establish a benchmark value for 2,6-Dinitrotoluene. 2,6-Dinitrotoluene was not detected in the Source Water, Clean Tank Water, or Used Tank Water samples.

Phenol was detected in 1 of the 24 samples collected from the test areas. This sample was collected from the No Clean test section of the Initial Test Area. The concentration of phenol detected was less than the benchmark value. Phenol was not detected in the Source Water, Clean Tank Water, or Used Tank Water samples.

<u>Physical Tests</u>

Conductivity was measured for each of the 24 samples collected from the test areas. In all but two cases, the conductivity of the sample collected from the Sweeper/Scrubber section was lower than those of the samples collected from the No Clean and Manual Sweeping sections. The EPA Multi-Sector General Stormwater Permit did not establish a benchmark value for conductivity. The conductivity of the Used Tank Water samples was significantly higher than those of the Source Water and Clean Tank Water samples.

Oil & grease were detected in 16 of the 24 samples collected from the test areas. These 16 samples were collected during 10 sampling events. In each case, the concentration of oil & grease detected in the Sweeper/Scrubber test section was greater than the concentrations detected in the No Clean and Manual Sweeping test sections. None of the concentrations of oil & grease detected in these samples exceeded the benchmark value. Oil & grease were not detected in the Source Water or the Clean Tank Water samples. However, the concentrations of oil & grease detected in the Used Tank Water samples were significantly higher than the benchmark value.

pH was measured for each of the 24 samples collected from the test areas. All but three of these measurements showed that the pH of the sample was within the range specified by the benchmark values. The three exceptions were found in samples collected from the Sweeper/Scrubber test sections. Of these three pH measurements, one was 0.6 standard units below the lower end of the benchmark range, and the other two measurements were 0.2 and 0.3 standard units greater than the upper end of the benchmark range. All but one of the Source Water, Clean Tank Water, and Used Tank Water samples were within the benchmark range. The one measurement outside of this range, found in a Used Tank Water sample, was 0.5 standard units above the upper bound.

TSS was measured for each of the 24 samples collected from the test areas. In two samples, both from Sweeper/Scrubber test sections, suspended solids were not detected. In each case, the concentration of suspended solids detected in the Sweeper/Scrubber test section samples was less than that detected in the associated No Clean and Manual Sweeping test sections. None of the concentrations of suspended solids detected in the samples exceeded the benchmark values. TSS was detected in each of the Clean Tank Water and Used Tank Water samples, but was not detected in the Source Water sample. None of the Clean Tank Water samples exceeded the benchmark value for TSS; however, all of the Used Tank Water samples exceeded the benchmark value.

<u>Biological Tests</u>

Total coliforms were detected at most probable numbers greater than 2 in 11 of the 24 samples collected from the test areas. These 11 samples were collected during 8 sampling events. The most probable number of total coliforms detected in the sample from the Sweeper/Scrubber section was greater than the most probable number detected in the No Clean section for four of these eight sampling events. The most probable number of total coliforms in the Manual Sweeping section samples was less than two. The most probable number of total coliforms in the Source Water sample was less than two. With the exception of one sample collected from the Clean Tank Water, the most probable number of total coliforms collected from the scrubber tank was greater than 1,600. The most probable number of total coliforms in the Clean Tank Water sample that was not greater than 1,600 was 300.

Fecal coliforms were detected in 7 of the 24 samples collected from the test areas. These 7 samples were collected during 5 sampling events. The most probable number of fecal coliforms detected in the Sweeper/Scrubber section sample was greater than the most probable number detected in the No Clean section for two of these five sampling events. Fecal coliforms were not detected in the Manual Sweeping section samples. The primary contact recreation standard for fecal coliforms is that the log mean of a minimum of five samples over any 30-day period must not exceed 200 per 100 milliliters, nor shall more than 10 percent of total samples during the same period exceed 400 per 100 milliliters. The samples collected from the pier can be divided into three 30-day periods:

- 3 August 2000 through 2 September 2000 (3 August 2000, 17 August 2000, 22 August 2000, and 23 August 2000 sampling events; six fecal coliform samples each from the No Clean and Sweeper/Scrubber sections)

- 17 August 2000 through 16 September 2000 (17 August 2000, 22 August 2000, 23 August 2000, 7 September 2000, and 14 September 2000 sampling events; seven fecal coliform samples each from the No Clean and Sweeper/Scrubber sections)

- 22 August 2000 through 21 September 2000 (22 August 2000, 23 August 2000, 7 September 2000, 14 September 2000, and 20 September 2000; six fecal coliform samples each from the No Clean and Sweeper/Scrubber sections).

The samples collected on 8 June 2000 were excluded because they were not collected within 30 days of any other samples. The samples collected from the Manual Sweeping section were excluded because only one sample falls within any of the 30-day periods examined. The mean for the No Clean section samples for the period beginning 3 August 2000 was 151. The mean for the Sweeper/Scrubber section samples for the same period was 1.5. The mean for the No Clean section samples for the period beginning 17 August 2000 was 358. The mean for the Sweeper/Scrubber section samples for the same period was 5.57. The mean for the No Clean section samples for the period beginning 22 August 2000 was 417.5. The mean for the Sweeper/Scrubber section samples for the same period was 46.17. Two of the three means from the No Clean section samples exceeded the limits described above. None of the three means from the Sweeper/Scrubber section samples exceeded the limits described above.

The most probable number of fecal coliforms in the Source Water sample was less than two. The most probable number of fecal coliforms reported in one Clean Water Tank sample was greater than 1,600. The other two Clean Water Tank samples reported the most probable number of fecal coliforms as two and less than two, respectively. The most probable number of fecal coliforms reported for the Used Tank Water samples was less than two, greater than 1600, and 22. It should be noted that the Used Tank Water sample reported as less than two was initially reported as greater than 1,600. Given the other sample results, the higher figure is more likely. Fecal coliform results from the Source Water, Clean Tank Water, and Used Tank Water samples were not compared to benchmark values because there were less than five samples for each.

<u>Summary</u>

Based on the sampling data and the above analysis, the cleaning action of the sweeper and scrubber generally reduced the concentration of constituents in the samples collected from the piers.

In general, the concentration of metals detected in the samples was lower in the Sweeper/Scrubber sections than in the No Clean and Manual Sweeping sections. It should be noted that a comparison of NAVSTA San Diego's last year's and prior years' stormwater monitoring data showed significant declines in the concentration of copper and zinc in stormwater from the piers, particularly in areas where the sweeper and scrubber were frequently used. Sampling of the scrubber tank showed significant increases in the concentration of metal constituents after the scrubber was used to clean areas of the piers. It should be noted that sampling of the scrubber tank revealed that concentrations of metals may remain in the scrubber tank after cleaning.

Although no specific source for bis(2-ethylhexyl) phthalate has been identified, there are several possibilities:

- Bis(2-ethylhexyl) phthalate is a product of fuel decomposition; therefore, the source of this constituent may be exhaust from vehicles or equipment operated on the pier during the sampling event.
- The action of the scrubber lifts contaminants present in oil spots on the pier, but may not collect all of the contaminants thus released. If this is the case, the concentration of bis(2-ethylhexyl) phthalate should decrease with continued use of the scrubber because the oil spots are cleaned more thoroughly with each pass.
- The differences observed between test sections may be due to uneven contaminant loading on the piers.

No sources for the other semi-volatile organic compounds detected during the sampling events (i.e., phenol; 2,6-dinitrotoluene; and bis[2-chloroisopropyl] ether) have been identified. It should be noted that each of these compounds was detected only once during the sampling program. The detection of these compounds may be due to maintenance actions that are rarely performed or to contamination of the samples, either during collection or in the laboratory.

Based on the results of the scrubber tank and detergent solution samples, the increased concentration of oil and grease in the Sweeper/Scrubber test sections is most likely due to constituents in the detergent used by the scrubber.

Using the sweepers and scrubber significantly reduced the mean number of fecal coliforms detected on the piers. Testing of the scrubber tank revealed that coliforms may remain in the tank after cleaning.

Based on the results of the toxicity testing, there did not appear to be any consistent, significant correlation between sample concentration and mortality in the samples for either the Sweeper/Scrubber or No Clean sections. It should be noted that, for some toxicity tests, the laboratory controls were below the acceptance criteria. Therefore, the mortality experienced by the test organisms may be due to the conditions in the laboratory rather than exposure to the samples.

4.1.3 Cost Analysis

Port Operations personnel estimated that manually sweeping all of the piers in their entirety would require more than 50 man-hours per week (2,600 man-hours per year). Given this investment of time, it is unlikely that manually sweeping all piers in their entirety will occur regularly, if at all. Manual sweeping of small work areas is likely to occur with or without the implementation of the sweeper and scrubber. Although the Navy currently has sovereign immunity from fines, Navy policy requires that facilities comply with federal, state, and local environmental requirements. Therefore, limited spot sweeping will not meet Navy goals for environmental compliance. Other concerns include the fact that the Navy may not always have sovereign immunity from fines and that future Executive Orders may impose stricter compliance standards.

In addition to the environmental compliance benefits, implementing the sweepers and scrubber provides other benefits that are not accounted for in the following costs because they cannot be quantified. A strictly qualitative benefit—but a significant benefit nevertheless—is the improved visible cleanliness of the piers.

Because the previous method (manual sweeping of all piers in their entirety), which is the most accurate comparison, is unlikely to be implemented, a Cost Analysis was not performed for this project. The following estimates of consumables, labor, and waste disposal costs are based on operational data provided by NAVSTA San Diego.

Consumables

Two Sweepers

Gallons of fuel used per year: 2,304
Price of fuel per gallon: $1.85
Total cost of fuel per year: $4,262.40

Gallons of hydraulic fluid used per year: 30
Cost of hydraulic fluid per gallon: $3.00
Total cost of hydraulic fluid per year: $90.00

Gallons of engine oil used per year: 32
Cost of engine oil per gallon: $3.00
Total cost of engine oil per year: $96.00

Number of main sweeping brushes per year: 8
Cost of one main sweeping brush: $303.20
Total cost of main sweeping brushes per year: $2,425.60

Number of side-sweeping brushes per year: 16
Cost of one side-sweeping brush: $120.80
Total cost of side-sweeping brushes per year: $1,932.80

Number of auxiliary sweeping brushes per year: 4
Cost of one auxiliary sweeping brush: $120.80
Total cost of auxiliary sweeping brushes per year: $483.20

Annual cost of consumables for two sweepers: $9,290.00

One Scrubber

Gallons of fuel used per year: 162
Price of fuel per gallon: $1.85
Total cost of fuel per year: $299.70

Gallons of hydraulic fluid used per year[1]: 10
Cost of hydraulic fluid per gallon: $3.00
Total cost of hydraulic fluid per year: $30.00

Gallons of engine oil used per year: 3
Cost of engine oil per gallon: $3.00
Total cost of engine oil per year: $9.00

Number of scrubbing brushes per year: 8
Cost of one scrubbing brush: $355.00
Total cost of scrubbing brushes per year: $2,840.00

Gallons of detergent used per year: 91
Cost of detergent per gallon: $10.11
Total cost of detergent per year: $920.01

Annual cost of consumables for one scrubber: $4,098.71

Total cost of consumables per year: $13,388.71

Labor

Note: The sweeper and the scrubber are each operated by two people at a time.

Average hours sweeper operated per year: 720
Average man-hours for sweeper per year: 1,440

Average hours scrubber operated per year: 228
Average man-hours for scrubber per year: 456

[1] For simplicity, this Cost Analysis assumes that the hydraulic fluid in the scrubber will be changed every year. The data gathered to date suggest that the hydraulic fluid will need to be changed every 3 years only based on the manufacturer's recommended maintenance practices.

Total average man-hours per year: 1,895
Average personnel pay rate (per hour)[2]: $16.64

Total labor costs per year: $31,532.80

<u>Waste Disposal</u>

Waste from the sweeper is placed into dumpsters for disposal. These costs have not been itemized for this project since they would likely be incurred regardless of whether the sweepers are implemented. Wastewater generated by the scrubber is disposed of through the BOWTS at NAVSTA San Diego. The BOWTS is a Navy PWC activity and therefore charges other Navy activities a nominal fee ranging from $0.04 to $0.15 per gallon to dispose of wastewater. The actual disposal cost depends on the specific identities and concentrations of the wastewater constituents. The higher figure is used for the costs presented below.

Two Sweepers

Gallons of hydraulic fluid disposed of per year: 30
Cost per gallon for disposal of hydraulic fluid: $3.00
Total cost per year of hydraulic fluid disposal: $90.00

Gallons of engine oil disposed of per year: 32
Cost per gallon for disposal of engine oil: $3.00
Total cost per year of engine oil disposal: $96.00

Annual cost of waste disposal for two sweepers: $186.00

Single Scrubber

Gallons of hydraulic fluid disposed of per year[1] 10
Cost per gallon for disposal of hydraulic fluid: $3.00
Total cost per year of hydraulic fluid disposal: $30.00

Gallons of engine oil disposed of per year: 3
Cost per gallon for disposal of engine oil: $3.00
Total cost per year of engine oil disposal: $9.00

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[1] For simplicity, this Cost Analysis assumes that the hydraulic fluid in the scrubber will be changed every year. The data gathered to date suggest that the hydraulic fluid will need to be changed every 3 years only based on the manufacturer's recommended maintenance practices.

[2] This is an unburdened, O-level, hourly pay rate for fiscal year 2000.

Gallons of wastewater disposed of per year: 6,360
Cost per gallon for disposal of wastewater: $0.15
Total cost per year of wastewater disposal: $954.00

Annual cost of waste disposal for a single scrubber: $993.00

Total cost of waste disposal per year: $1,179.00

<u>Total Annual Costs for Two Sweepers and One Scrubber</u>

Item	Cost
Consumables	$13,388.71
Labor	31,532.80[2]
Waste Disposal	1,179.00[1]
Total	$46,100.51

4.2 Qualitative Analysis

4.2.1 Installation

The sweeper and the scrubber require sufficient garage space for storage overnight and when not in use. The sweepers and scrubber used during this evaluation also require a supply of diesel fuel. Any naval facility that requires the use of these machines is likely to be able to meet both needs. It should be noted that the scrubber could operate on propane, if appropriately equipped.

4.2.2 Training

The sweeper and the scrubber are driven like regular vehicles. Training consists of showing operators how to operate the sweeper attachments and the scrubber water application/vacuum system, and how to empty and clean the sweeper hopper and scrubber tank. The manufacturer provided training on the use of the machines via a two-day site visit and a video included in the purchase price of the sweeper and the scrubber.

4.2.3 Maintainability

Both the sweeper and the scrubber required maintenance during the test period. Some of this maintenance was covered under the parts and labor warranty included with each machine. Tennant also offers a flat rate planned maintenance (PM) program, which consists of a monthly inspection by Tennant technicians. The PM inspection of the sweepers covers all major parts and fluids, except the drive chain and vacuum fan filters.

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[1] For simplicity, this Cost Analysis assumes that the hydraulic fluid in the scrubber will be changed every year. The data gathered to date suggest that the hydraulic fluid will need to be changed every 3 years only based on the manufacturer's recommended maintenance practices.

[2] This is an unburdened, O-level, hourly pay rate for fiscal year 2000.

The PM inspection of the scrubber covers all major parts and fluids except the drive chain and drive belt. PM costs $596 per month for each sweeper and $420 per month for the scrubber.

The following table shows the breakdown of equipment maintenance and repair costs during this study.

Equipment	Problem	Downtime	Maintenance & Repair Cost
Sweeper	Water penetrated the electrical seal plug, causing warning light to illuminate	1 day	No charge – PM repair
	Solenoid valve broke and caused hydraulic fluid to leak from parking brake	None	No charge – PM repair
	Side brush assembly damaged during an accident	10 days	$1,737.25 to replace 32" side brush, $399.00 for labor, $139.99 for miscellaneous charges
	Repair shroud assembly and replace 2 skirts damaged by wear and tear	4 hours	No charge – PM repair
	Hopper door lock failed	2 hours	$270.00 for labor
	Radiator leaked	1 day	No charge – PM repair
Scrubber	Replace two squeegees damaged by use in an area of dips and potholes	3 hours	No charge – PM repair
	Failure of a relay caused improper spray pattern	5 days	No charge – PM repair
	Flat tire	2 hours	No charge – PM repair

4.2.4 Interface with Site Operations

In general, the sweeper and scrubber interfaced easily with site operations. As mentioned above, work at NAVSTA San Diego includes maintenance of Navy ships. Contractors typically conduct this maintenance work. The contractors leave their equipment on the piers overnight. Therefore, one of the issues that arose during implementation was providing the cleaning machines with access to all portions of the pier regularly. At NAVSTA San Diego, this issue was resolved by having the cleaning machines operate in the areas that are accessible during the day and then cleaning each pier entirely as contractors complete their work and move their equipment off of the piers. The cleaning frequency goal established at NAVSTA San Diego is for each pier to be cleaned in its entirety no less than once per quarter.

4.2.5 *Overall Performance*

The operators at NAVSTA San Diego were satisfied with the performance of the sweeper and the scrubber.

4.2.6 *Future Uses*

The sweeper and the scrubber significantly improved the apparent cleanliness of the areas in which they were used. These machines can form an important BMP for controlling pollution in stormwater runoff; however, additional BMPs or other pollution prevention control measures may prove necessary at some Navy facilities, including the piers at NAVSTA San Diego.

4.3 *Project Costs*

The following table presents equipment costs incurred during the implementation of this project.

Item	Quantity	Unit Cost	Extended Cost
Equipment			
Tennant Model 830-II Diesel Sweeper	2	$95,989.72	$191,979.44
1 year flat rate maintenance plan for sweepers	2	$7,152.00	14,304.00
Tennant Model 550 SRS Scrubber with LP tank	1	$62,900.92	62,900.92
1 year flat rate maintenance plan for scrubber	1	$5,040.00	5,040.00
Conversion of scrubber from LP to diesel	1	$1,837.30	1,837.30
Detergent drum pump	1	$67.00	67.00
Consumables			
51" main sweeping polypropylene brush	8	$303.20	2,425.60
32" side-sweeping wire and polypropylene brush	16	$120.80	1,932.80
38" auxiliary/vario wire and polypropylene sweeping brush	4	$120.80	483.20
50" cylindrical scrubbing brush	8	$355.00	2,840.00
55 gal. 658 Heavy Duty Cleaner	15	$555.93	8,338.95
		Total Equipment Cost:	**$292,149.21**

The manufacturer provided videos and manuals for each piece of equipment, as well as two days of training at no additional charge. No expenses were incurred with respect to site preparation for this equipment. The costs of sampling were borne by Commander Navy Region Southwest (CNRSW) Environmental.

5.0 LESSONS LEARNED

The side-brush assembly on one sweeper was damaged from coming into contact with a heavy object. The scrubber squeegees were damaged when operated on surfaces with potholes or large dips. Therefore, care must be exercised when driving these machines. In addition, care must be taken when cleaning the scrubber tank to ensure that as many contaminants as possible are removed.

Based on the sampling conducted for this project, the increase in concentration of oil and grease in the Sweeper/Scrubber section samples is most likely due to the constituents in the detergent used by the scrubber. It should be noted that none of the oil and grease concentrations detected in the samples collected from the piers exceeded the benchmark values established in the EPA Multi-Sector General Stormwater Permit. If the increased concentration of oil and grease on the piers becomes a concern, a different detergent should be sought. However, oils are typically present in soaps of all kinds, and it may therefore prove difficult to identify a detergent that does not contain similar constituents.

Although it appears that the sweeper and the scrubber reduced the concentration of most contaminants on the pier, the reduction achieved may not be sufficient to remove regulatory burdens from all Navy locations. Therefore, implementation of other stormwater BMPs, operational SOPs, and discussion with the local regulatory boards should accompany implementation of these machines.

Based on the operational data, one sweeper and one scrubber may have been sufficient for NAVSTA San Diego's purposes. The proper number of sweepers and scrubbers for a given site will depend on several factors—type of contaminants present, physical extent of the areas to be cleaned, distance between these areas, and ability to transport the machines from location to location.

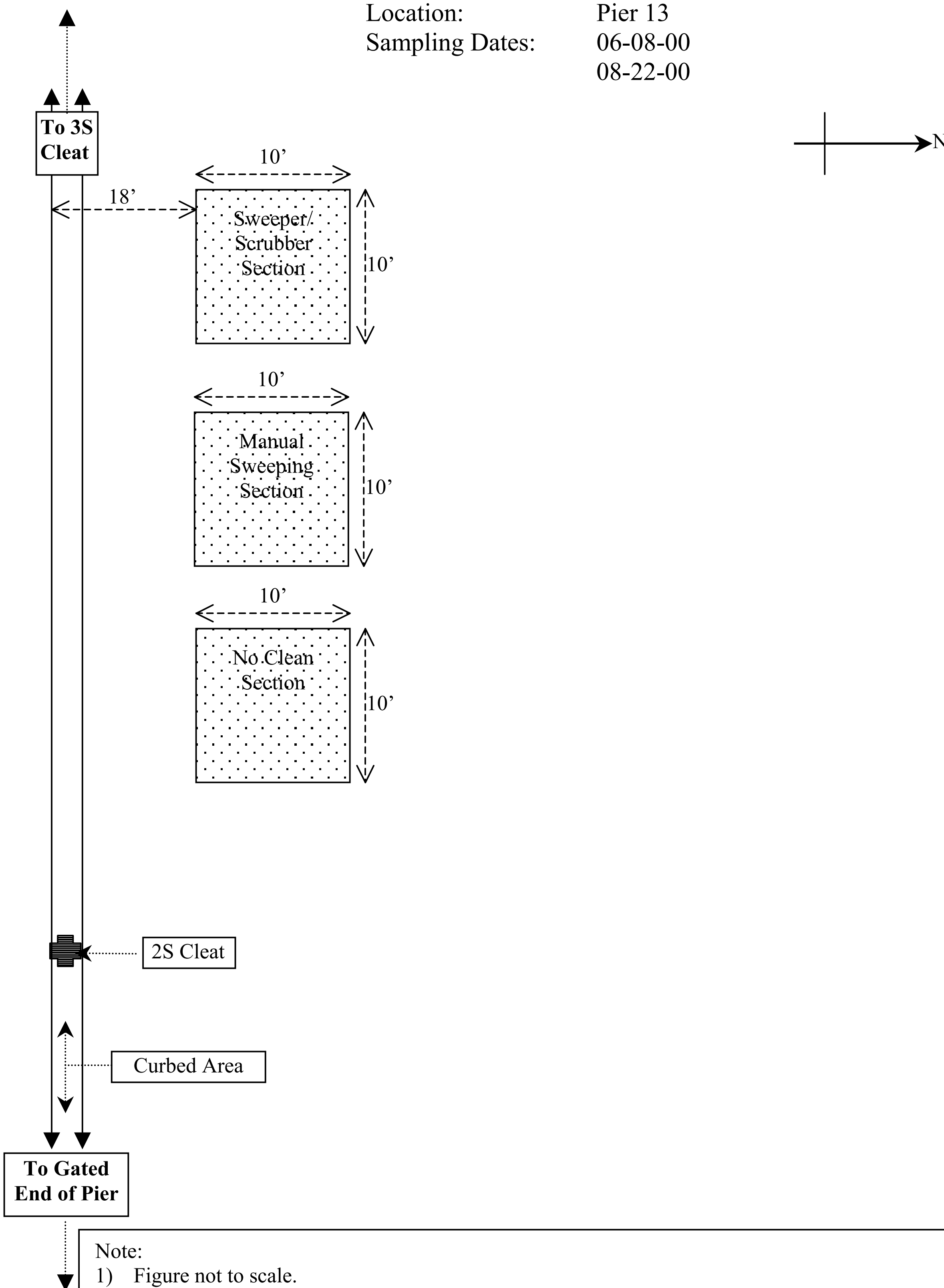
6.0 CONCLUSIONS

The sweeper and the scrubber greatly improved the visible cleanliness of the areas in which they were used. Although many factors effect the quality of stormwater runoff, based on the sampling conducted during this project and a comparison of historical stormwater monitoring data it appears that the use of the sweepers and scrubber generally reduced the concentration of contaminants on the piers. Therefore, depending on site-specific circumstances and requirements, the use of sweepers and scrubbers may prove to be an important BMP for maintaining compliance.

Figure 1. Initial Test Area

Location: Pier 13

Sampling Dates: 06-08-00
08-22-00

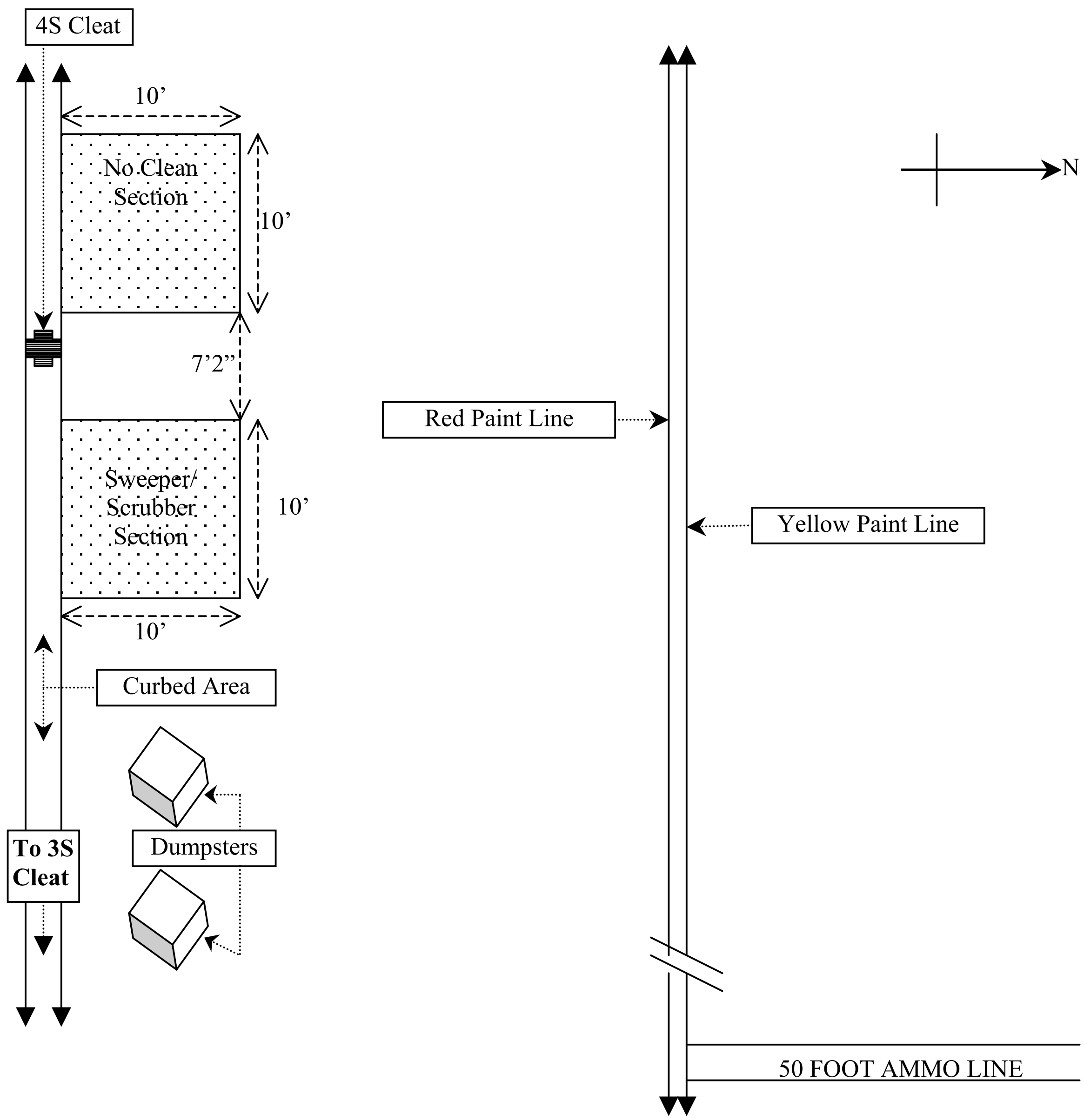


Note:
1) Figure not to scale.
2) Distances are approximate.
3) The Sweeper/Scrubber Section is approximately 285 feet from the gated end of the pier.
4) A ship berthing area is located immediately to the east of the Initial Test Area.

Figure 2. Cleat 4S Test Area

Location: Pier 13

Sampling Dates: 08-03-00
08-17-00
09-14-00

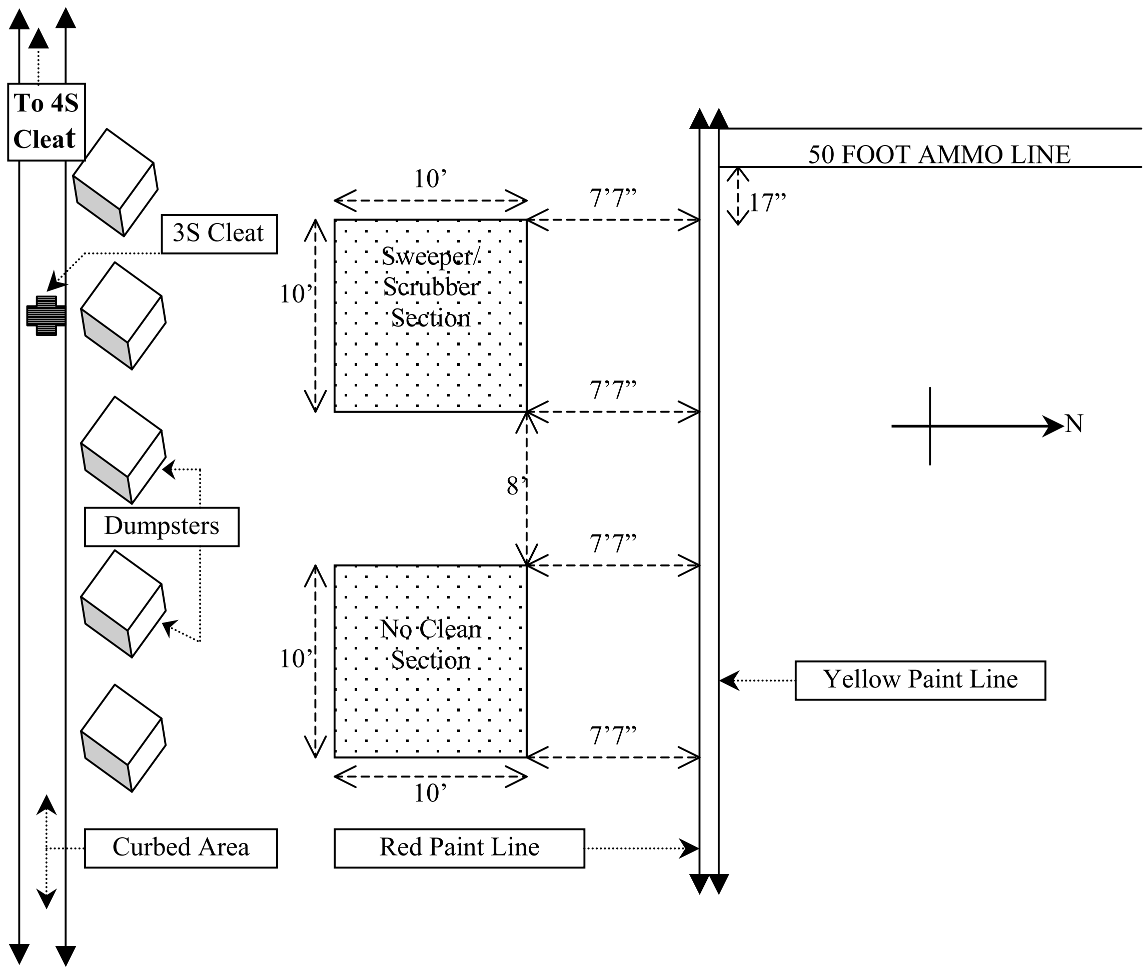


Note:
1) Figure not to scale.
2) Distances are approximate.
3) A ship berthing area is located immediately to the west of the Cleat 4S test area.

Figure 3. Cleat 3S Test Area

Location: Pier 13

Sampling Dates: 08-03-00
08-17-00
09-14-00

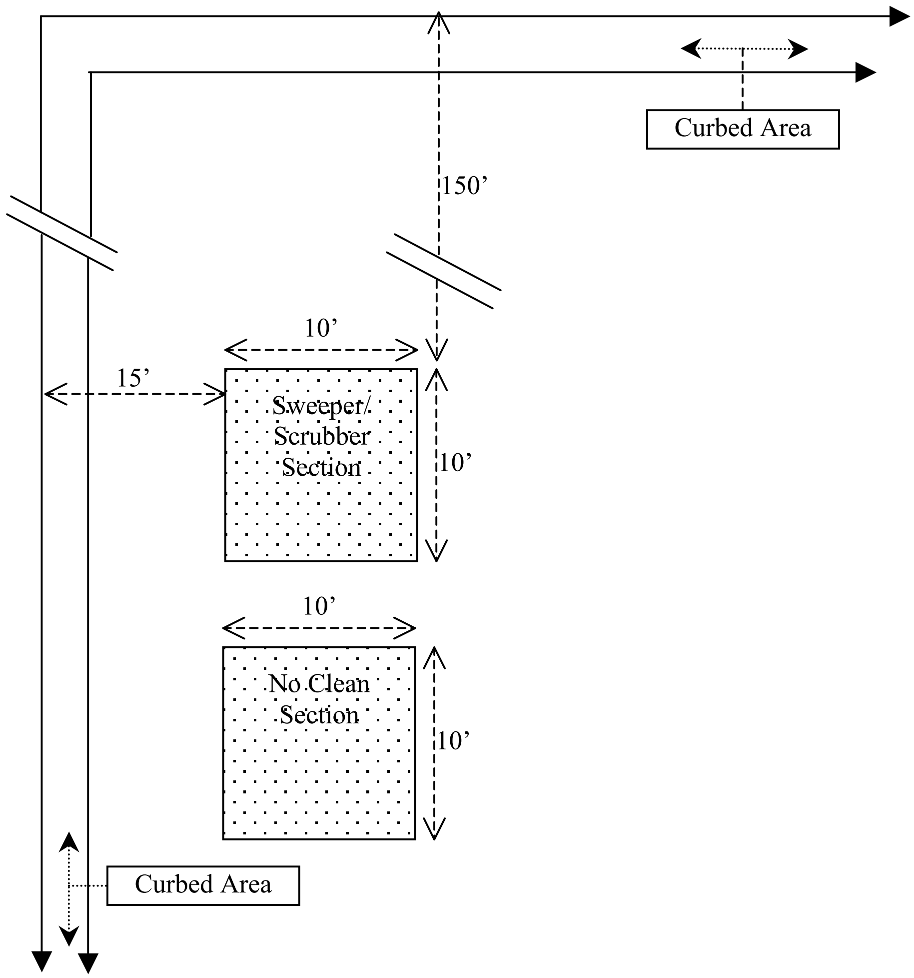


Notes:

1. Figure not to scale.
2. Distances are approximate.
3. During day-to-day operations, the dumpsters are typically located on top of the Cleat 3S test sections. The dumpsters were pushed against the curbed area to provide access for sampling.

Figure 4. Pier 7 Test Area

Location:	Pier 7
Sampling Dates:	08-23-00
	09-07-00
	09-20-00



Note:
1) Figure not to scale.
2) Distances are approximate.