

AN EVALUATION OF THE STANDARD ELUTRIATE TEST
AS AN ESTIMATOR OF CONTAMINANT RELEASE
AT THE POINT OF DREDGING

by

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(ABSTRACT)

While release of contaminants during dredged material disposal operations has long been the subject of environmental concern, the potential release of pollutants during the dredging process has recently come under the scrutiny of federal and state regulatory agencies. The mechanical action of a dredging operations causes resuspension of sediment particles and release of soluble contaminants to the water column. A predredging test is essential to estimate the amount of soluble release at or near the point of dredging to ascertain potential water quality impact. The Standard Elutriate Test has proven to be a good estimator of soluble contaminant release for dredged material disposal operations and researchers have recognized that the processes involved at the point of dredging are similar to those involved with the open-water disposal of dredged material.

This research is an evaluation of the Standard Elutriate Test as an estimator of soluble contaminant release at the point of dredging. Data and field studies were conducted by the U. S. Army Corps of Engineers Waterways Experiment Station at five sites around the United States. A direct comparison was made between elutriate test data from predredging bottom sediment and water sample analysis taken at or near the point of dredging.

The Standard Elutriate Test satisfactorily predicted the release of soluble contaminants at or near the point of dredging in four out of the five sites in this study. The fifth site had extenuating circumstances that may account for the failure at this site. In this investigation, the elutriate test appears to overestimate the release of organics, nutrients and some heavy metals (Hg, Mn, Fe, and Cr).

Statistical analysis provided a predictive equation that can be used to estimate the upper-bound value a constituent concentration will approach based on elutriate test data and a specified confidence level.

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Chapter 1. INTRODUCTION

While release of contaminants during dredged material disposal operations has long been the subject of environmental concern, the potential release of pollutants during the dredging process has recently come under the scrutiny of federal and state regulatory agencies. Maintenance of shipping channels requires the removal of sediments suspected to contain high concentrations of contaminants. As any dredging operation proceeds, sediments become resuspended to varying degrees according to sediment type, hydrologic conditions, type of dredging equipment used, and the operational procedures employed. Contaminants may be released in soluble form directly to the water column, or they may remain adsorbed to the fine resuspended sediment particles. The primary mode of environmental impact is from the soluble fraction as dissolved forms of pollutants are more available for aquatic biota uptake than the chemical species remaining adsorbed to sediment particles. Dissolved contaminants disperse into the surrounding water column from sediment interstitial water and through desorption from sediment particles (1-3). Therefore, a pre-dredging test is essential to estimate the potential release of contaminants induced by the agitation of bottom sediments during dredging operations (4,5).

The Standard Elutriate Test was jointly developed by the Corps of Engineers (CE) and the Environmental Protection Agency (EPA) to monitor the soluble release of contaminants into the water column during open-water disposal operations. Elutriate, as defined by Webster (6), is to purify, separate or remove by washing. As used in this test procedure it is the centrifuged/filtered clear liquid containing the soluble fraction of the sample sediment. The validity of the Standard Elutriate Test was demonstrated through extensive laboratory and field studies during the Dredged Material Research Program (DMRP) conducted by the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi from 1973 to 1978 (7).

Recent studies under the WES Improvement of Operations and Maintenance Techniques (IOMT) research program have been directed toward development of methods to predict the potential degree of sediment resuspension and contaminant release during dredging operations. During the early stages of the IOMT studies, researchers recognized that the processes involved with potential contaminant release at the point of dredging were similar to those involved with the open-water disposal of dredged material. Consequently, a preliminary investigation was initiated to determine the applicability of the elutriate test to estimate release at the point of dredging. Field

studies conducted for this investigation include collection of pre-dredging sediment samples and water samples taken during dredging to allow determination of concentrations of contaminants released to the water column during the dredging operation.

OBJECTIVES

The overall objective of this study was to make an evaluation of the usefulness of the Standard Elutriate Test for estimating the release of contaminants at or near the point of dredging. To meet this objective the following tasks were performed:

a. Review the literature to confirm the logic of using the Standard Elutriate Test, or a modified version of it, to estimate potential release at the point of dredging.

b. Sort, categorize and determine a method to analyze data from field studies and laboratory reports provided by WES.

c. Develop conclusions and make recommendations for further studies to answer the question, "Is the Standard Elutriate Test a good pre-dredging estimator of contaminant release?".

APPROACH

The Waterways Experiment Station has collected field data and performed laboratory analyses from five dredging sites over the course of the past four years for the purpose of making this comparative study. Protocol for data collection at each site was established based on the contaminant of concern at the site, thus causing some inconsistency among data for the five sites. Collected data includes pre-dredging sediment samples, water samples taken at various depths and distances from the operating dredge, and a variety of site parameters including dredge equipment type, location, dates of sampling, sediment characterization, current, and salinity.

The approach used for this evaluation was to make a direct comparison between the elutriate test data and the dredging water sample analysis for each site. The primary hypothesis for comparative evaluation was that the elutriate value for each constituent should approximate (within one order of magnitude) the actual constituent concentration found at or near the point of dredging as determined by water samples collected during the dredging operation. A secondary hypothesis was that the Standard Elutriate Test is a conservative estimator of the amount of soluble release, thus any elutriate values beyond one

order of magnitude should be higher in value than the corresponding water sample analysis.

Additionally, statistical analysis was utilized to develop empirical correction coefficients for use with a predictive equation. The equation, adjustable to preselected probability of occurrence levels, will estimate the upper bound constituent concentration in the water column at or near the point of dredging based on elutriate test data from the site.

CHAPTER 2. LITERATURE REVIEW

Various references quote annual dredging quantities in the United States to be between 280 to 380 million cubic yards (CY) (8-10). While approximately 90 percent of this amount is considered to be "clean" (11), the remaining ten percent poses water quality problems at two locations: the dredging site and the disposal site (4). Research literature and implementation guidance (1,2) is readily available for the management and control of disposal operations, but potential problems that can occur in the water column at the dredging site from disturbances of sediments have only recently been studied.

Although the surface layer of sediment is generally assumed to be in dynamic equilibrium with the overlying water (12), a number of investigators (3,12,13) report that physical disturbances of contaminated sediment may release some of the contaminants to the water column through dispersal of the interstitial pore water and from desorption of constituents from the resuspended sediment particles. Lee and Plumb (4) and Engler (5) both recommended the development of a predredging test to evaluate the potential impact from disturbances of the bottom prior to the start of a dredging operation.

The EPA (14) recognized that any test for contaminant release should be quick, simple and reliable. Bulk sediment analysis was investigated as a test, but researchers (4,15) have not found this method to be a technically sound approach for predicting the soluble release to the water column because bulk sediment analysis only reveals the composition of the sediment, not the potential desorption of contaminants.

Bioassay is another testing method accepted by the EPA (16) as a means to measure potential water quality impact. Although bioassay is the preferred method for assessing long range environmental effects to the biota, it has been dismissed for estimation of soluble contaminant release for several reasons, specifically the variability of investigative techniques (2), lack of indication of the true effects from contaminated sediment, and because it is based on acute toxicity and utilizes mortality as an endpoint (15).

A third approach for determining the potential impact to water quality is to compare concentrations of water sample analysis to sediment elutriate data (12). This approach was taken in the development of the Standard Elutriate Test by EPA and the Corps of Engineers. The validity of the test as a means of predicting the impact of disposal of dredged materials has been demonstrated by extensive laboratory and field studies under the Dredged

Material Research Program (DMRP) conducted by the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi (7).

The Standard Elutriate Test is an empirical test (4,14) that compares the chemical analysis of the elutriate from a sediment/disposal water mixture to a similar analysis of the disposal site water. Any variance from set standards causes the sediment to be classified as contaminated which requires special disposal techniques. Two key areas for refining the Standard Elutriate Test are the application of the data and the testing procedures. Because the test is empirical, Lee and Plumb (4) and the EPA (14) suggest development of correction coefficients to adjust elutriate test data to more closely simulate concentrations actually found in water samples.

Potential concerns with test procedures include: pH changes, salinity, contact time, and solid-liquid ratio (14). In this regard, the original elutriate test, as published in the Federal Register (17,18) by the EPA, has been modified in later registers (16) and by EPA implementation guidance (2). Specifically, forced air agitation of the sediment/water mix was added to correct a potential reduced pH problem that arises when the Standard Elutriate Test turns anaerobic due to sediment oxygen demand. Reduced pH increases the solubility of many chemical forms and adversely affects the test results.

Bender et al. (19) cited in their literature review that Hugget et al. (20) and Strobel et al. (21) both dismiss salinity as a potential problem area and that Karickhoff et al. (22) observed that salinity played only a minor role in the release of contaminants from a sediment.

Bender et al. (19) also conducted some limited factorial experiments concerning contact times and solid-liquid ratios. They concluded that by reducing contact time and the solid-liquid ratio, the values achieved from the elutriate test for TKN are less conservative and more closely approximate the concentrations found at the disposal site.

Jones and Lee (23) found that the Standard Elutriate Test predicted release of heavy metals and ammonia within an order of magnitude of concentrations found in the field and would generally indicate phosphorus and chlorinated hydrocarbons levels. Additional literature (4,9,24) also sites a tendency for the Standard Elutriate Test to overestimate the chemical releases experienced at disposal sites, and thus give a conservative prediction of contaminant release.

CHAPTER 3. METHODS AND PROCEDURES

Dredged material evaluation procedures must consider the potential environmental harm caused by changes in water quality due to the release of available chemical species present in bottom sediments (12). The primary water quality impact associated with sediment resuspension occurs from the soluble constituents of the interstitial water and the easily desorbed chemical species from sediment particles. The Standard Elutriate test was developed jointly by the U. S. Environmental Protection Agency (EPA) and the U. S. Army Corps of Engineers (CE) as a means of predicting the release of soluble constituents to the water column during disposal operations. The purpose of this investigation was to evaluate the usefulness of an elutriate test for estimating the release of contaminants at the point of dredging.

STANDARD ELUTRIATE TEST PROCEDURE

Procedures established for field studies under this investigation (illustrated in Figure 1.) specify that 20% by volume of undisturbed bottom sediments from the dredging site be mixed with 80% by volume of water from the dredging site. This mixture is then vigorously

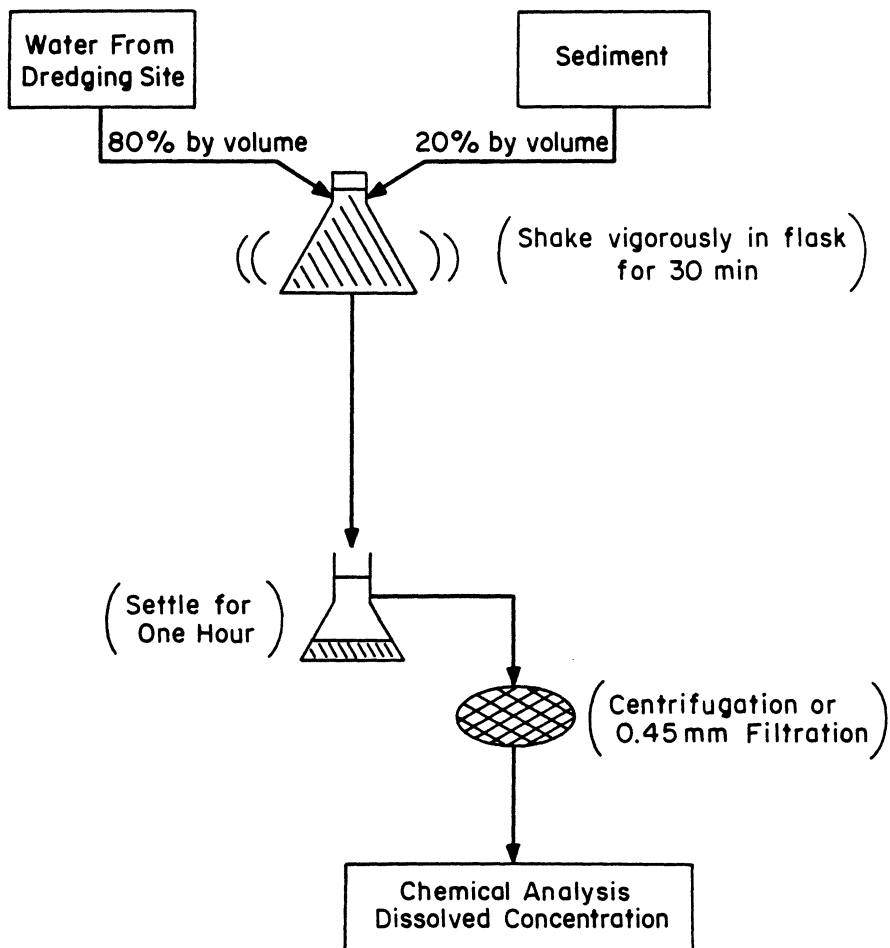


Figure 1. Standard Elutriate Test.

agitated by mechanical shaking and release of compressed air through a diffuser tube for 30 minutes (2). The infusion of oxygen into the system during mixing is used to offset any potential oxygen demand exerted by the sediments. Reduction in dissolved oxygen causes a drop in pH that may result in the release of chemical forms that do not normally occur at the dredging site. The addition of oxygen has also been shown to increase the reproducibility of the test (13).

The mixed system is allowed to settle for one hour, after which the supernatant is collected, centrifuged or filtered through a 0.45 micron filter, and then analyzed. Chemical analysis of the supernatant (elutriate) from the bottom sediment samples is then compared with a corresponding analysis of water samples taken while dredging. Water samples undergo laboratory analysis for total and dissolved fractions with the dissolved fraction being centrifuged or filtered through a 0.45 micron filter prior to analysis.

DESCRIPTION OF FIELD SITES

Field data and samples for laboratory analysis were obtained over a four year time span at five sites: Black Rock Harbor near Bridgeport, Connecticut; the Calumet River in Chicago, Illinois; the Duamish River in Seattle,

Washington; the James River near Jamestown, Virginia; and Lake Pepin on the Upper Mississippi River at Lake City, Minnesota.

These investigations were conducted as satellite studies by Corps of Engineer Districts during maintenance dredging operations. Although all field sample collection procedures and laboratory analyses methods were accomplished in accordance with required procedures (14), the constituents studied varied from site to site based on the contaminant of concern at the site. Consequently this limited the sample size available for the statistical analysis.

Black Rock Harbor, Connecticut

The field studies were conducted on 2 May and 5-6 May 1983 at Bridgeport, Connecticut during maintenance dredging of Blackrock Harbor (Figure 2). The sediments were dark to black in color and classified as sandy organic clay. Known contaminants included PCB's and petroleum products. Average salinity was 18 parts per thousand (ppt) and any current was tide induced. A 10-CY standard open clamshell bucket was used to remove the sandy organic clay sediments at a depth of approximately 20 feet.

Sediment sample collection was conducted on 2 May, with water sample collection 5 and 6 May. Dredge

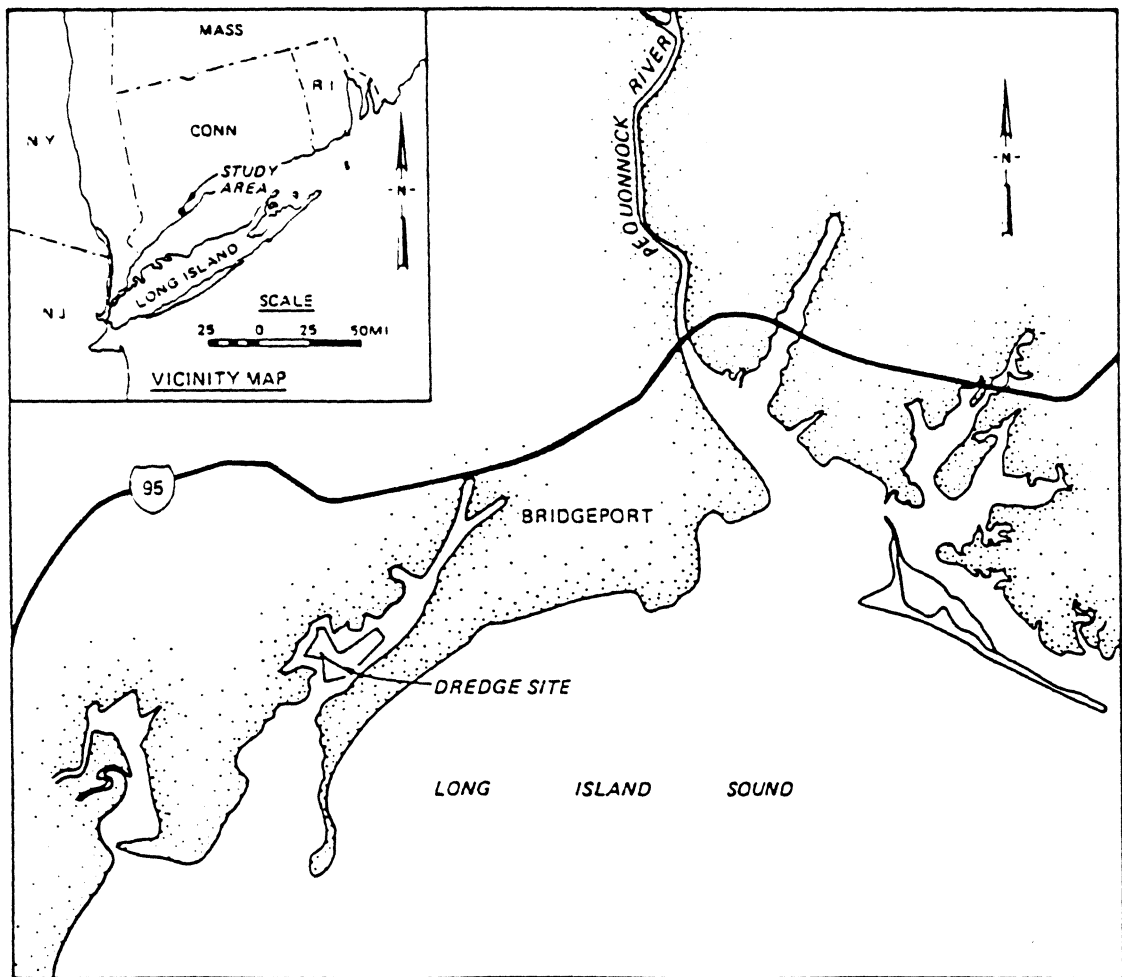


Figure 2. Site Location Map for the Black Rock Harbor Dredging Project.

procedure was to excavate a 55 by 30 foot section three to four feet deep, drag the bottom with the bucket to smooth the cut, and move to the next section. A total of twenty-seven water samples were collected at bottom, mid-depth, and top, and distances of 30, 80, and 130 feet from the dredging operation. The three repetitions of dredging water samples collected on the bottom and thirty feet from dredging operations satisfy the criteria set for this evaluation.

Calumet River, Illinois

The Calumet River is a navigational channel serving the city of Chicago (Figure 3). Samples were collected 20-23 August 1985, during an ongoing maintenance dredging operation near the northern bank of Turning Basin Number 5. A 10-CY standard open clamshell bucket was used to remove the soft organic clay/silt sediments. The dredge would cut an approximate 100 foot width, smooth the bottom by dragging the bucket, and then move ahead.

Elutriate test sediment samples were collected on 20 August, and dredging water samples were collected during dredging operations on 22-23 August. Dredging water samples were collected from near surface (5 ft below surface), mid-depth (15 ft), and near bottom (27 ft) and sampling stations were setup at 200 and 100 feet upstream of the dredge, at the point of dredging (0.0 feet), and

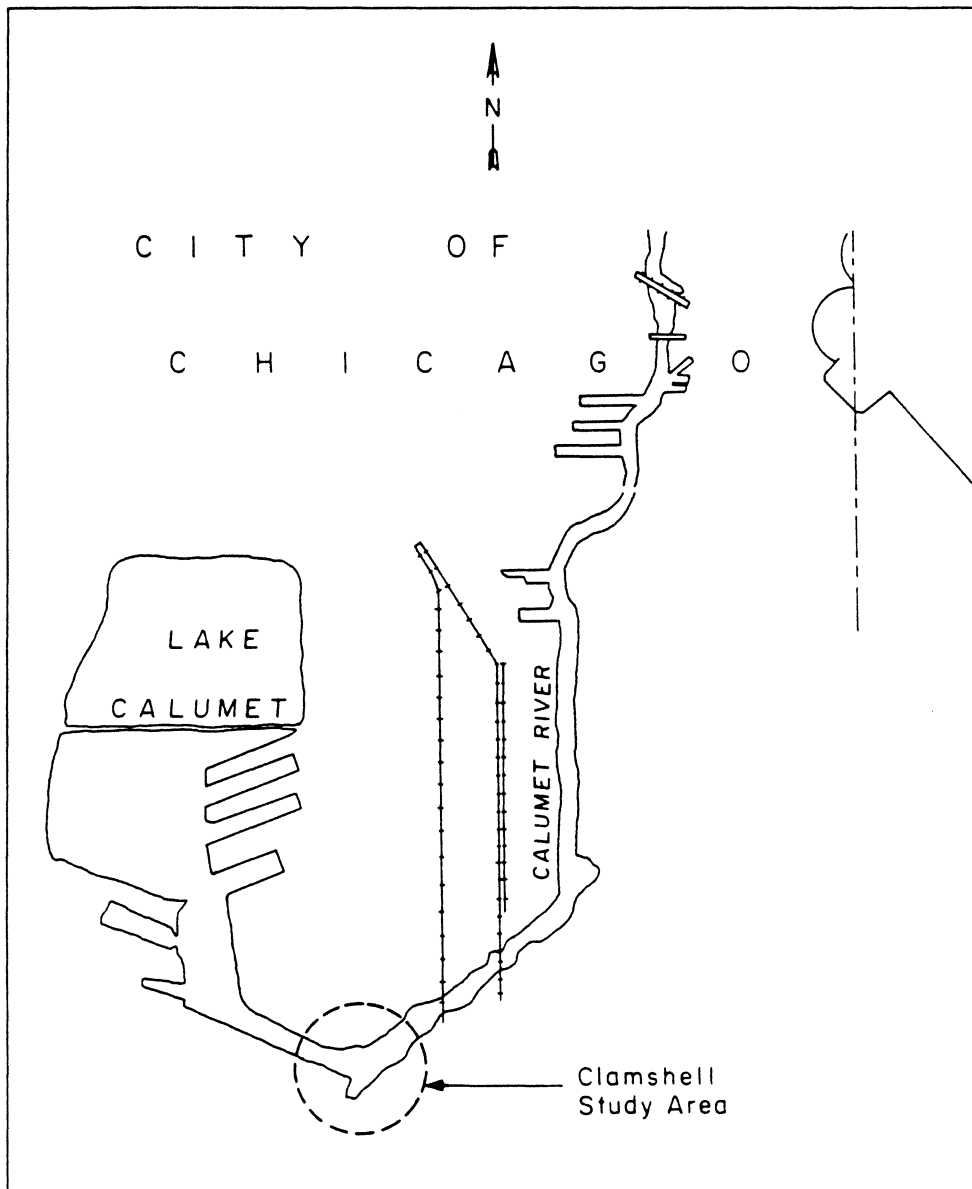


Figure 3. Location Map of Calumet River Clamshell Demonstration.

50, 200, 400, 600, and 800 feet downstream from the dredging site. The bottom data from zero and 50 feet were used for this evaluation. Current was less than 0.18 feet per second (fps) for the sampling period, and salinity was not reported.

Duamish Waterway, Washington

The Seattle District (CE) contracted for maintenance dredging of the upper Duamish River (Figure 4) in a heavy industrial and commercial area. The sandy clayey silt sediments were known to be contaminated with heavy metals and chlorinated hydrocarbons. Currents averaged 0.7 fps, and the average salinity was 14 ppt.

A standard open clamshell bucket was used for dredging and overflow of sediment from the disposal barges was not allowed to minimize suspended solids concentrations in the adjacent water column. Two sets of sediment samples were collected, the first two days and the other 30 minutes prior to start of dredging operations. Dredging commenced on 26 March 1984, with dredging water samples collected from depths of 5, 15 and 30 feet and distances of 0, 100, 150, 200, 225 and 300 feet from the point of dredging. Samples were analyzed for selected heavy metals and PCB's, with three replicates of data at zero feet from the dredging operation and at the bottom used for this evaluation.

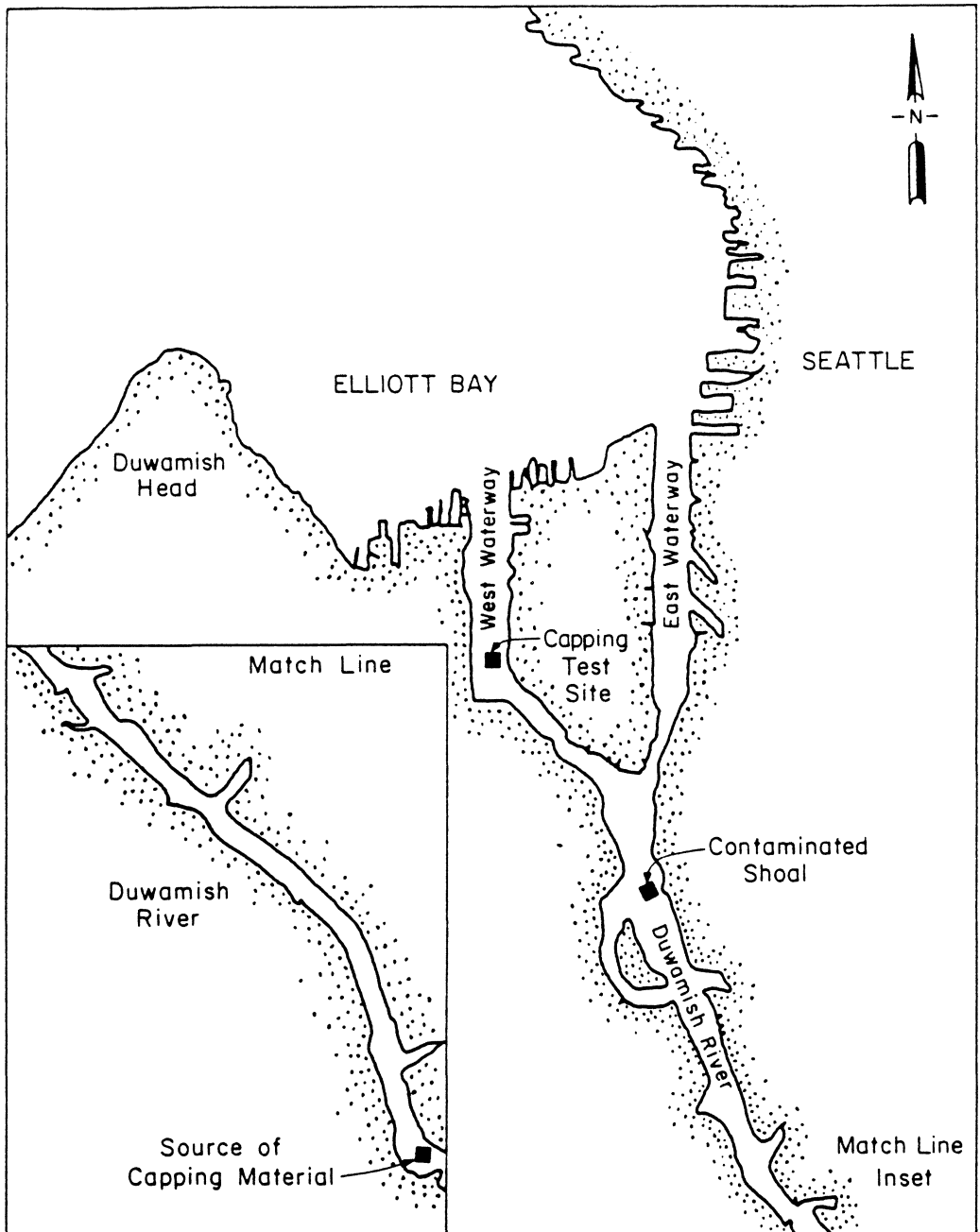


Figure 4. Site Location Map for the Duwamish Waterway Dredging Project.

James River, Virginia

Sampling for this study was conducted by the Virginia Institute of Marine Sciences (VIMS), under contract with WES, and in conjunction with a dredging project by the Corps of Engineers Norfolk District (19). The purposes of the James River demonstration was to remove a layer of contaminated sediment at in-situ density while minimizing resuspension at the dredge head. All information used in this investigation was extracted from the final report under WES Contract # DACW 65-82-C0001 (19).

The silty clay sediment samples were collected in March 1982, from a dredging site near the Jamestown Ferry Pier, James River, Virginia (Figure 5). Twenty-five sediment samples were obtained, pooled into two groups, and homogenized before use in the elutriate test. Water samples were taken during dredging operation on 17 and 24 June 1982.

Dredging water samples were taken at near bottom depth in close proximity to the dredging activity since the sampling apparatus was attached to the cutterhead mechanism of the dredge. A five foot diameter "basket" cutterhead was used during this phase of the dredging operation. Current ranged from 0.5 to 2.3 fps and salinity was reported at <0.1 ppt.

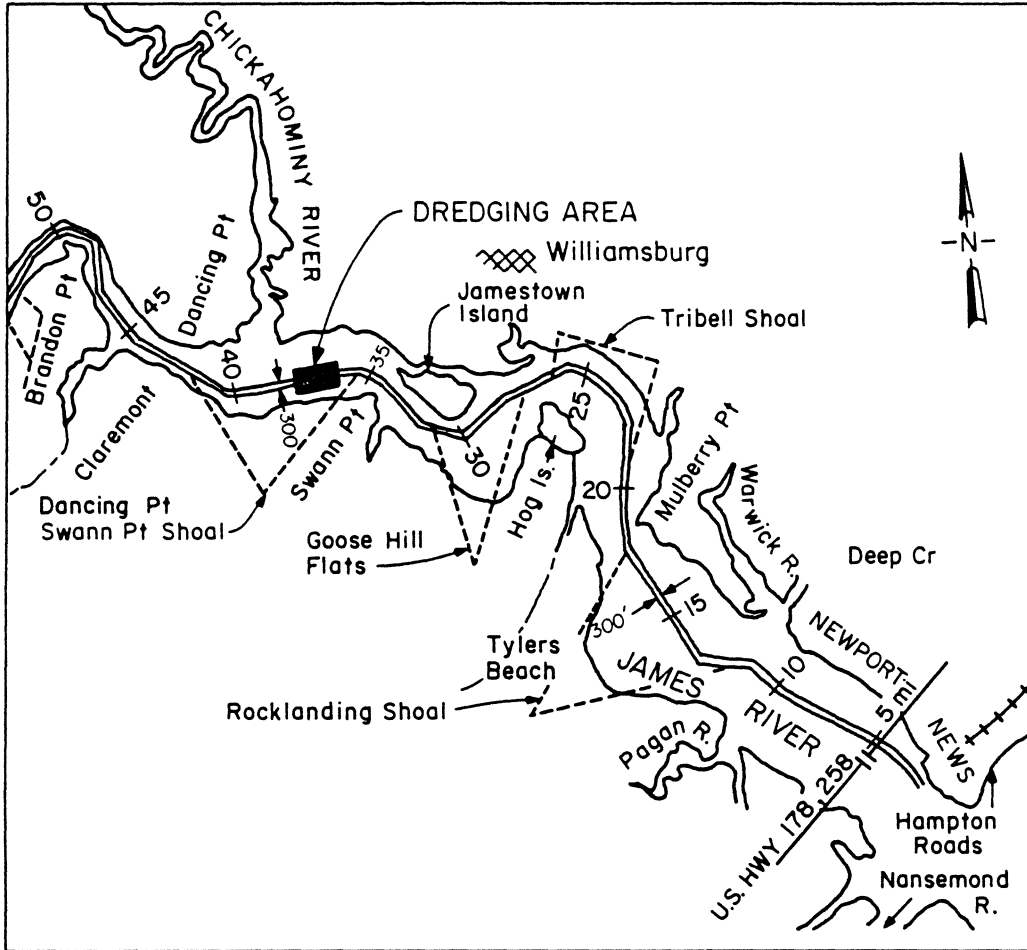


Figure 5. James River Demonstration Area.

Lake City, Minnesota

These field studies were done in conjunction with the construction of a breakwater in Lake Pepin on the Mississippi River at Lake City, Minnesota (Figure 6). Organic sediment was removed to provide an acceptable foundation for the breakwater. WES became involved with this project for two reasons, first, to gather field data for this investigation and, second, to evaluate the effectiveness of a closed clamshell bucket in reducing sediment resuspension. The latter work was part of an IOMT (Improvement of Operations and Maintenance Techniques) study. Conclusions of that study indicate that use of the closed clamshell bucket has little impact on the amount of sediment resuspended (27).

All field samples were collected 11-16 April 1984. The dredging on April 11 and 12 April was done with a four-CY closed clamshell bucket (Figure 7), and dredging done on 13 and 16 April was accomplished using a 3.75-CY open bucket (standard) clamshell. Dredging water samples were collected at the top, midpoint, and bottom and at distances of 50, 100, 200, and 400 feet from the point of dredging. Bottom samples from the 50-foot station were used for this evaluation. Current ranged from 0 to 0.2 fps, salinity was not reported, and suspended solids concentrations were reported at 22 times the background level.

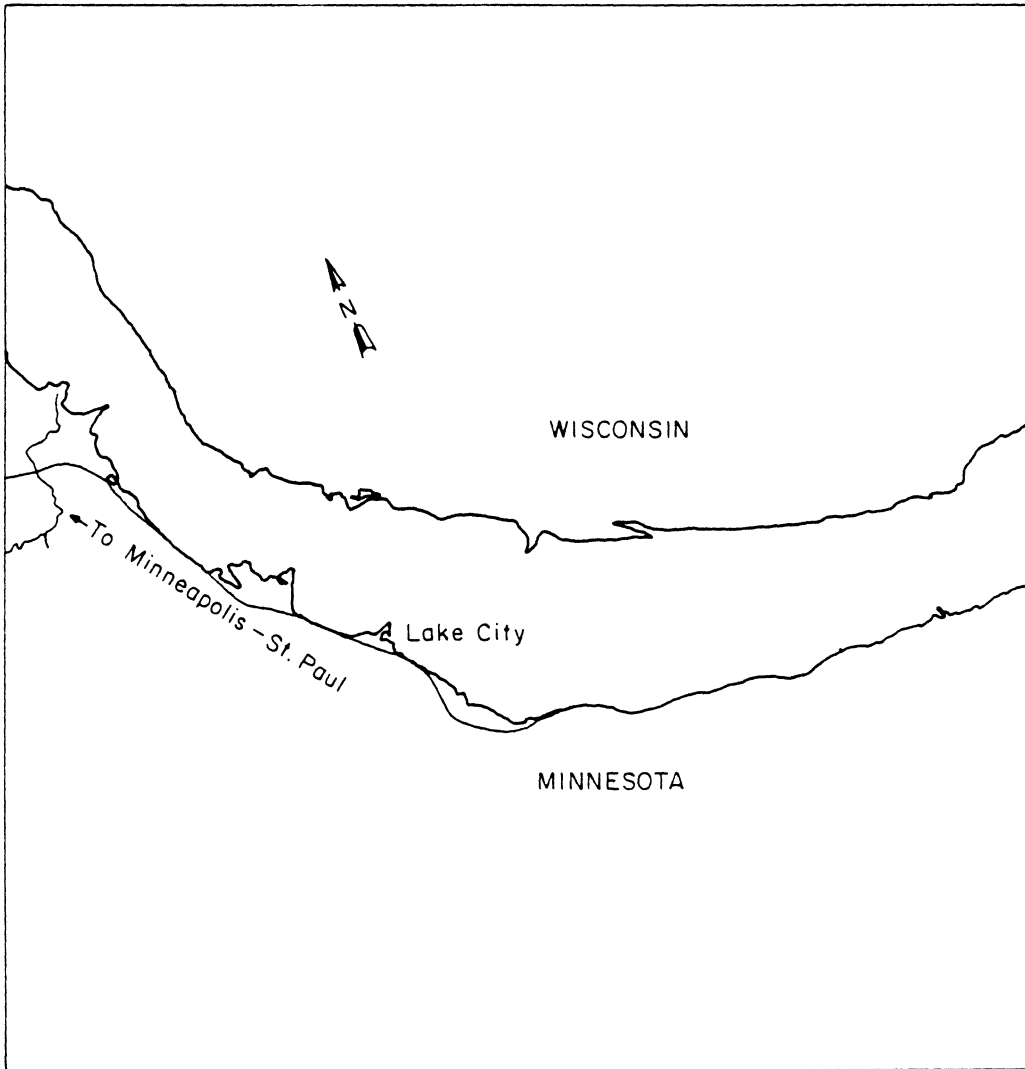


Figure 6. Site Location Map for the Lake City Dredging Project.

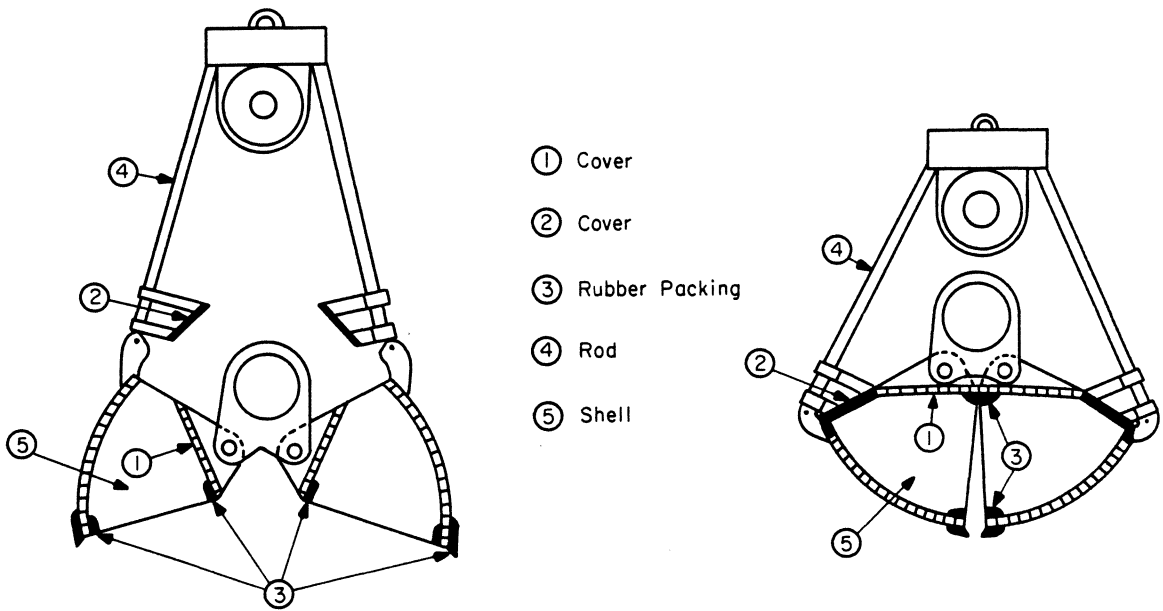


Figure 7. Open and Closed Position of a Closed Clamshell Bucket.

SAMPLING PROCEDURE

Sediment samples for the elutriate test were collected from the sites prior to dredging activities. A minimum of three sampling stations per dredging area were used to insure reliable characterization of the sediment. The collection, mixing, and analysis of each sample was in accordance with procedures outlined for the Standard Elutriate Test (2).

A major consideration concerning water sample collection was the selection of sampling stations. In most of the field studies, the opportunity to collect field samples in close proximity to the operating dredge was limited by safety and logistical constraints. Ideally, the closer the sample can be taken to the operating mechanism (cutterhead, clamshell bucket, or suction head), the more representative it should be. Barnard (25) has shown that the turbidity caused by the dredging operation decreases rapidly with increasing distance, and McLellan et al. (26) reported that primary resuspension of sediments remains closely associated with the bottom. To better simulate the conditions expected at or near the point of dredging, only data from bottom sampling sites 50 feet or nearer the point of dredging were used for comparison with the predredging sediment elutriate data.

STATISTICAL ANALYSIS METHODS

The statistical analysis for this investigation was conducted by members of the Department of Statistics at Virginia Polytechnic Institute & State University, Blacksburg, Virginia. The analysis process consisted of the following steps: data transformation, estimation of variances, and development of correction coefficients. Data were analyzed to develop a correction coefficient (k value) to predict the upper-value concentration of various constituents based upon values determined from a predredging elutriate test.

Initial analysis of the data showed that low concentration samples had small variances, whereas high numeric value samples had large variances. To improve the mean to variance relationship, logarithmic transformation (base e) was applied only to the dredging water values and not to the elutriate data.

The second step was to estimate the variance assuming a normal distribution. Some constituents exhibited zero variance because the minimum detectable limit was recorded for all sampling observations. Those constituents were eliminated from further analysis because they did not provide any information. One water sample of the three taken for PCB 1242 at the Black Rock Site was also purged from the data base because it was deemed to be

inaccurate by being two orders of magnitude lower than the other two samples at the site.

All samples (bottom depth and \leq fifty feet from the point of dredging) from the four sites (Lake City was omitted because of abnormally high concentrations of suspended solids at the dredging site) were lumped together for computation of one k value. Still, the number of observations was relatively small and the goal of one k value to cover all constituents proved to be unrealistic. Categories of constituents were determined based on similar mean values and pooled estimator of variance (weighted arithmetic mean of variances) was used to determine the category variance.

The last step in the statistical analysis was to develop correction coefficients, k , for each of the constituent categories. The k value equals the standard deviation times a standardized variable (or z score); where z represents the probability that the predicted water sample concentration will exceed the actual field water sample value. For this investigation levels of significance were preselected at 0.05, 0.1, 0.15 and 0.2, or that we were 80, 85, 90 or 95% confident that the predicted concentration would be no higher than the upper bound value found in the field water sample.

CHAPTER 4. DISCUSSION, SITE COMPARISONS
AND STATISTICAL ANALYSIS RESULTS

DISCUSSION

Evaluation of the Standard Elutriate Test was based on a direct comparison of data extracted from laboratory analysis of field water samples and predredging sediment elutriates. Fundamentally, the evaluation sought to determine whether constituent values derived by the Standard Elutriate Test would estimate the actual concentration as determined from field water samples collected during the dredging operation.

The evaluation hypothesis was that the elutriate test would predict within an order of magnitude (23) the concentrations found during field water sampling. A secondary expectation, based on the elutriate test being conservative (4,9,24), was that elutriate values could be greater than one order of magnitude higher than water sample values. Values that were within the same order of magnitude, or when elutriate values exceeded the water sample concentrations by greater than an order of magnitude, were considered to validate the hypothesis.

The elutriate refers to data gathered from the predredging site sediments processed in accordance with the protocol developed for the elutriate test and

described in Chapter 3, Standard Elutriate Test Procedure. Dredging water elutriate refers to water samples collected while the dredging operation was actively removing bottom sediments. These water samples were also processed in accordance with elutriate test protocol except that no sediment was added. Dredging water samples used for this comparison were from bottom sampling points within 50 ft of the operating dredge with the intent of selecting data that represent conditions found at or near the point of dredging. Various investigators (8,24,25,27,28) report findings of reduced suspended solids, decreased turbidity, and a return to background water quality within a few hundred feet of a dredging operation. McLellan et. al. (26) reported that the highest suspended solids concentrations were at or near the bottom and within fifty feet of the point of dredging.

Some findings of the laboratories conducting the chemical analyses reflect values that are at or below the minimum detectable (measurable) limit for a particular constituent. In the direct comparison portion of this evaluation, the average constituent concentration is based on using the detection limit value for any constituent sample where less than the minimum value was recorded. For the statistical analysis, these findings were totally excluded from the procedures.

SITE COMPARISONS

Black Rock Harbor

Tables A-1 and A-2 in the Appendix are extracts of the laboratory analyses conducted on the field samples collected on 2-6 May 1983. Three replicates of sediment sample were collected on 2 May prior to the commencement of dredging. The water samples were collected during dredging operations on 5 and 6 May at a point approximately 30 feet from the operating cutterhead and five feet above the bottom.

Table 1 and Figure 8 are comparisons of the average constituent concentrations from water sample analysis and predredging sediment elutriate test. They show the sediment elutriate test concentration to be higher or equal for 12 out of 15 constituents sampled. The three constituents (copper, iron, PCB 1242) that had higher water sample concentrations are within the same order of magnitude as the elutriate test value and therefore validate the use of the test.

Constituents having equal values for both the water analysis and the elutriate test (Cd and As), reflect findings of less than the minimum detectable concentration limit. No quantitative conclusions can be drawn from these constituents, but qualitatively the Standard Elutriate Test does typify what was found from water analysis. For

Table 1. Black Rock Harbor Comparison of Average
Constituent Concentration.

Constituent	Water Analysis Avg of 3 (ppm)	Elutriate Test Avg of 3 (ppm)
Cd	0.001	0.001
Zn	0.026	0.03
Pb	0.003	0.005
Cu	0.009	0.002
Hg	0.0001	0.0004
As	0.01	0.01
Cr	0.0012	0.013
Mn	0.119	0.245
Fe	0.6	0.43
Ni	0.012	0.039
T-Phosphorus	0.106	3.02
NH3	4.71	18.1
PCB 1242	0.0053	0.002
PCB 1254	0.00002	0.00018
PCB 1260	0.00002	0.00006

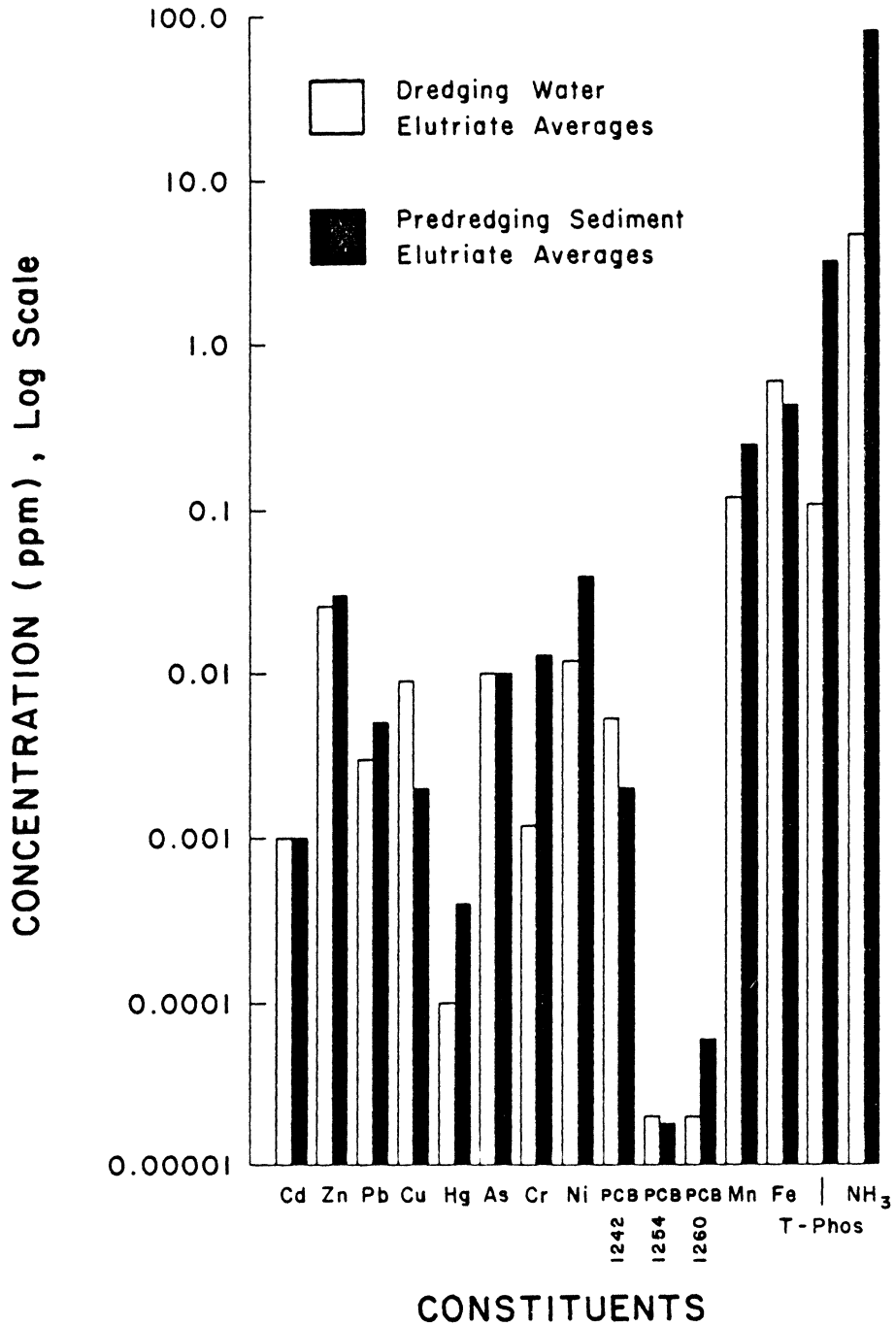


Figure 3. Black Rock Harbor Comparison of Average Constituent Concentration.

this site, comparison of the data indicates that the elutriate test is a good estimator of contaminant release during dredging operations.

Calumet River

Calumet River data were collected in conjunction with an ongoing maintenance dredging project. Sediment samples were collected on 20 August 1985, prior to the start of dredging. Table A-3 summarizes the chemical analysis of the four replicates of bottom sediment elutriate. Dredging water samples were collected while the dredge operated on 22 and 23 August, and Table A-4 depicts analysis of the six replicates collected from a depth of approximately 27 ft and as close to the operating dredge as safety would allow.

Table 2 and Figure 9 compare the average concentration of the water sample analyses to the corresponding predredging elutriate test values. Five of the constituents concentrations (Cd, Cu, Cr, Ni, and PCB) were the minimum detectable limit for both values, qualitatively validating the hypothesis.

Of the remaining nine constituents, eight had elutriate test values that were higher than the corresponding water analysis concentrations. Zinc showed a higher concentration in the dredging water elutriate;

Table 2. Calumet River Comparison of Average Constituent Concentration.

Constituent	Water Analysis Avg of 6 (ppm)	Elutriate Test Avg of 4 (ppm)
Cd	0.01	0.01
Zn	0.03	0.02
Pb	0.01	0.015
Cu	0.01	0.01
Hg	0.0001	0.1
As	0.001	0.007
Cr	0.01	0.01
Mn	0.01	0.7
Fe	0.11	2.75
Ni	0.01	0.01
T-Phosphorus	0.025	0.075
TKN	0.25	22.3
NH3	0.5	25.89
PCB	0.001	0.001

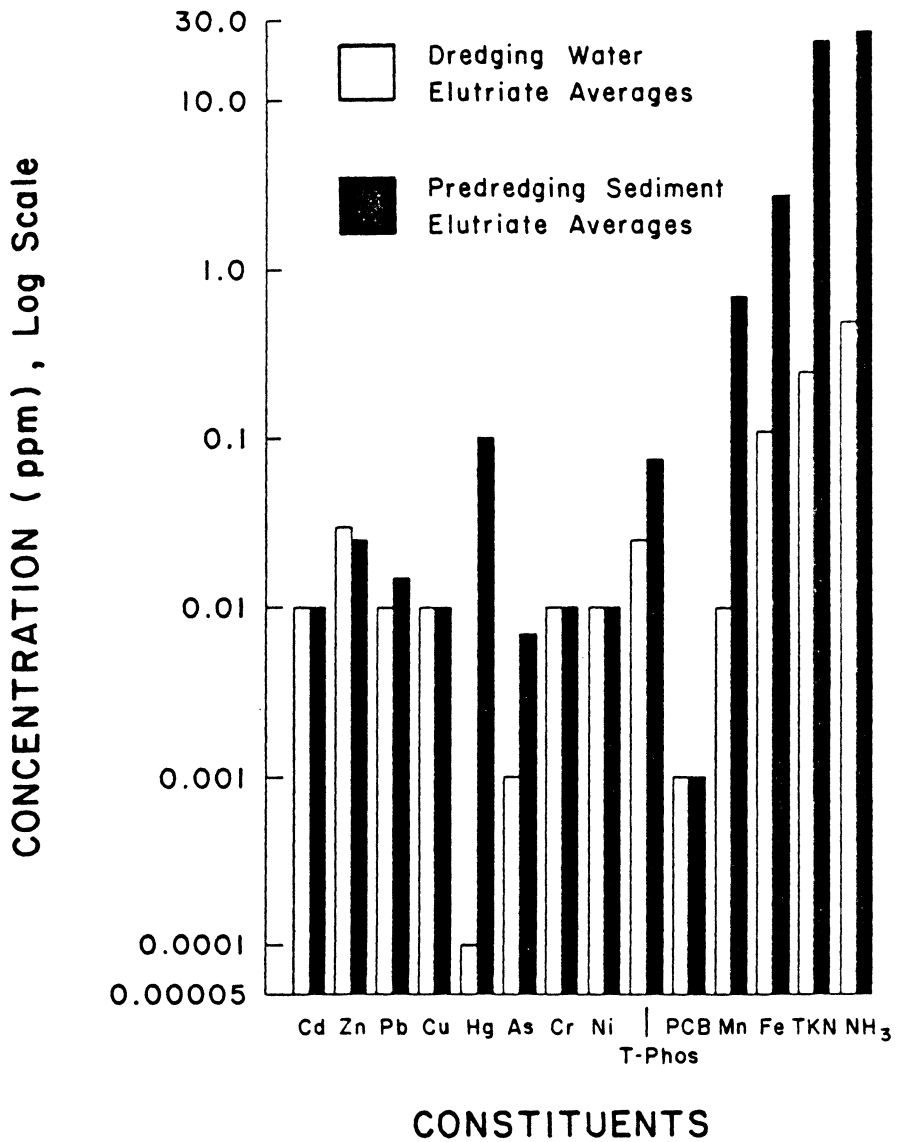


Figure 9. Calumet River Comparison of Average Constituent Concentration.

however, the difference was not significant since the two values were of the same order of magnitude.

Overall, the elutriate test again predicted the release of contaminants upon resuspension by the dredging operation, but the values estimated by the Standard Elutriate Test for five of the constituents (Hg, Mn, Fe, TKN, and NH_3) were greater than one order of magnitude higher (4 for Hg and 2 for the other four), indicating the conservatism of the elutriate test for some constituents.

Duamish Waterway

Sediment samples were collected on 24 and 25 March 1984 from the center of the proposed dredging site. Table A-5 reflects the chemical analysis performed on the four replicates of sediment collected. Bottom water samples were collected during the clamshell dredging operation on 26 March from a sampling position on the dredge (Table A-6).

Comparison of the averages (Table 3 and Figure 10) indicates that the sediment elutriate values closely estimated the water analysis concentrations. Two of the three constituents evaluated at this site had dredging water concentrations that were higher than the elutriate test value, but all were within the same order of magnitude. Although not as conservative as the other

Table 3. Duamish Waterway Comparison of Average Constituent Concentration.

Constituent	Water Analysis Avg of 3 (ppm)	Elutriate Test Avg of 4 (ppm)
Zn	0.024	0.015
Pb	0.007	0.005
Cu	0.002	0.005

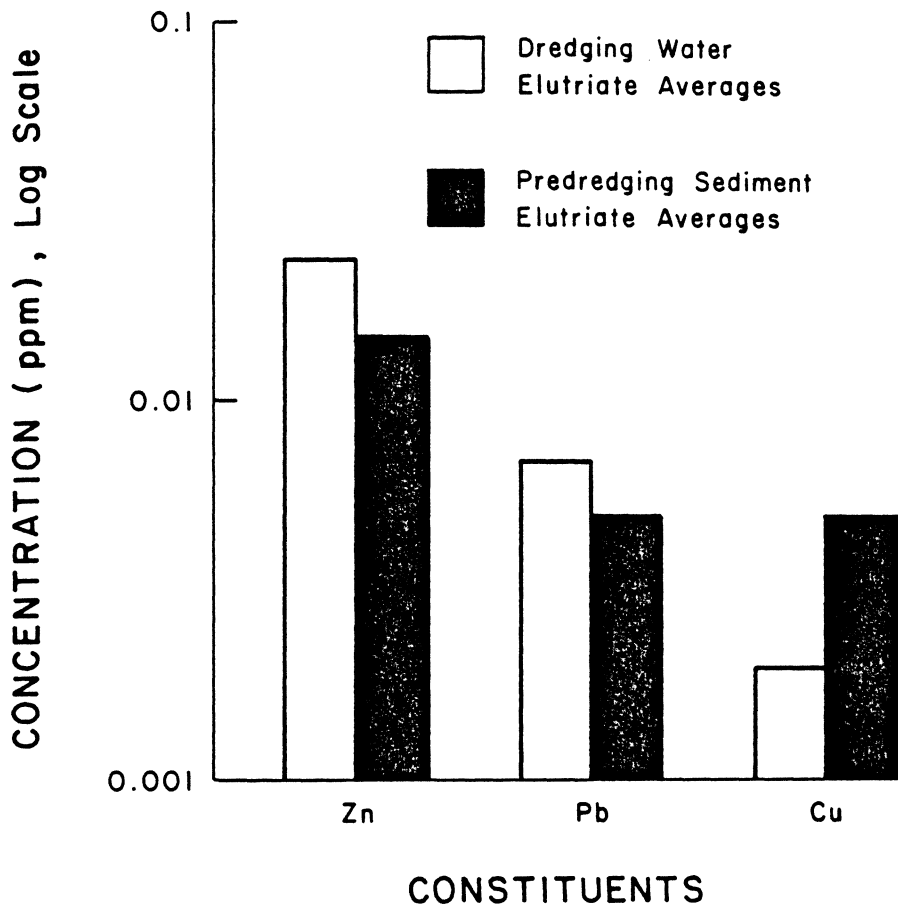


Figure 10. Duamish Waterway Comparison of Average Constituent Concentration.

sites, the use of the Standard Elutriate Test was still validated.

Part of the reason for the closeness of the values may be due to the conduct of the dredging at this site, since the amount of constituent release is related to the suspended solids loading of the water column being tested. The dredging operations on the Duamish Waterway had been carefully executed in an attempt to minimize resuspension both during clamshell operation and by limiting overflow of the disposal barge. Operators were able to limit the suspended solids concentration to a maximum of seven times the background level, which may represent a target level for the management of dredging operations.

James River

Data depicted in Tables A-7 and A-8, Table 4 and Figure 11 have been extracted from a study (Bender et al. 1984) sponsored by WES and conducted by the Virginia Institute of Marine Science (VIMS). This study consisted of analysis of field samples in addition to a laboratory study designed to evaluate the elutriate test as a means of predicting contaminant release during dredging. The VIMS study compared the Standard Elutriate Test (29) to modifications which would simplify analytical procedures or more realistically represent environmental conditions. A limited laboratory experimental program was undertaken

to investigate the effects of short agitation time (contact time) and low sediment concentrations (sediment/liquid ratio). Bender et al. (19) reasoned that the 30 minute agitation time and 1:4 ratio of sediment to water by volume in the standard test was selected to represent agitation and concentrations present in open-water disposal operations. The time available for initial agitation during the action of resuspension due to the operating dredge was considered to be a time substantially less than 30 minutes and the sediment to water ratio was found to be much lower than the ratio used for the Standard Elutriate Test.

Conclusions from the VIMS study include a recommendation to modify the standard test to reduce the sediment volume to one percent and agitation time to five minutes for sediments that contain only contaminants of low water solubility. The reduced sediment ratio and agitation time showed promise in more accurately estimating the release of total Kjeldahl nitrogen (TKN) and total phosphorus; although phosphorus concentrations were still overestimated. Changes in mixing time and sediment ratio for estimation of the release of metals did not show any significant change in the accuracy of the estimation.

Comparison of the data (Table 4 and Figure 11) used for this investigation shows that the elutriate test

Table 4. James River Comparison of Average Constituent Concentrations.

Constituent	Water Analysis Avg of 2 (ppm)	Elutriate Test Avg of 4 (ppm)
Cd	0.0024	0.0024
Zn	0.0016	0.0023
Pb	0.009	0.007
Cu	0.011	0.018
T-Phosphorus	0.01	0.05
TKN	0.27	5.2

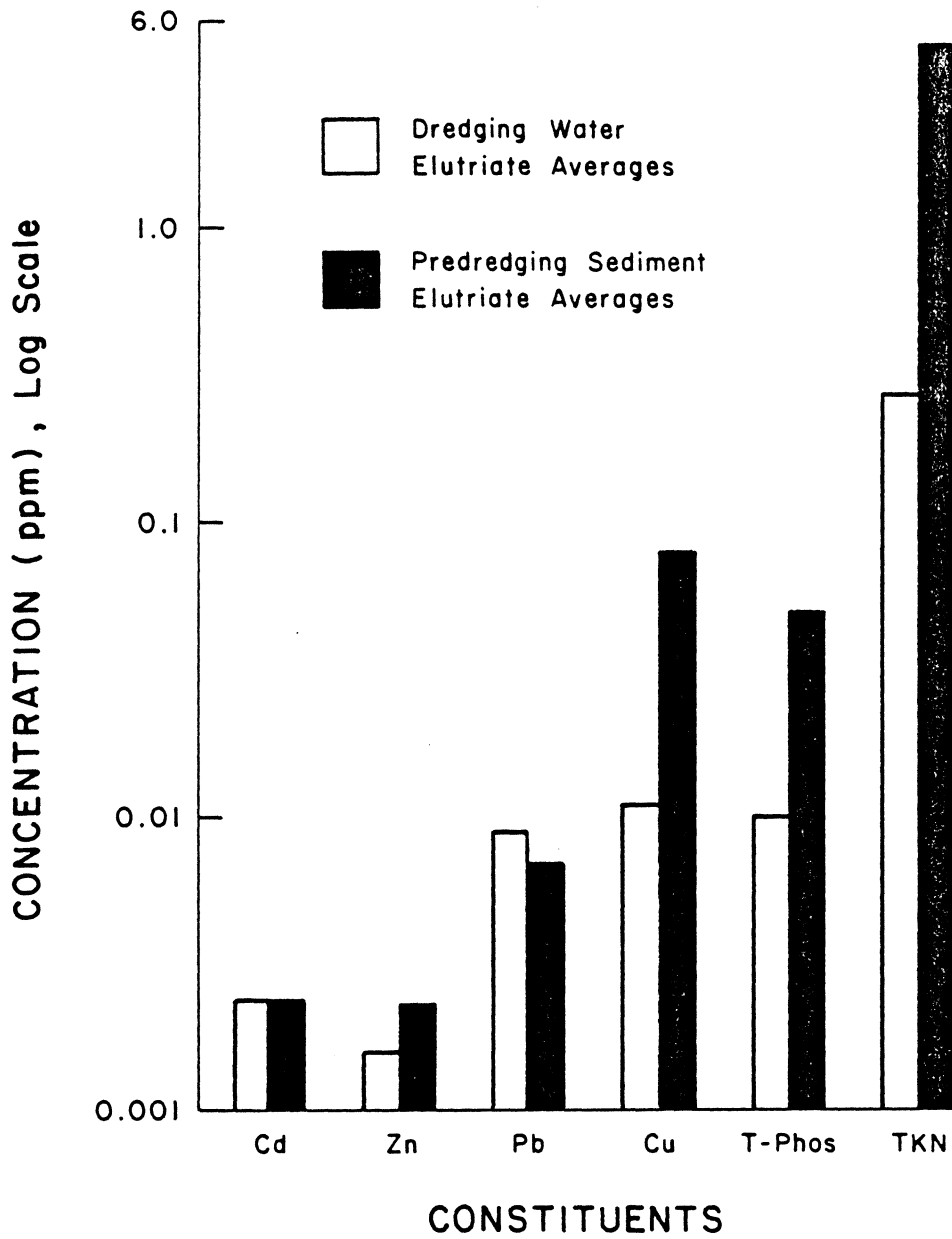


Figure 11. James River Comparison of Average Constituent Concentration.

values were equal or higher for five of the six constituents studied and the sixth (Pb) was within an order of magnitude of the water analysis concentration. The TKN value estimated by the Standard Elutriate Test was approximately 19 times that found during the water analysis, thus supporting the conclusion of the VIMS study that for certain constituents the elutriate test causes overestimated concentrations.

Lake City

Dredging at Lake City was conducted under the IOMT program to compare the sediment resuspension of sediments from a closed bucket (Figure 7) to that of a standard open bucket clamshell. The draft findings report prepared by the St. Paul District, Corps of Engineers (27) concludes that the highest concentration of resuspended sediments occurs at the lowest depth and close-in to the dredging activity. Also, the use of a closed bucket had little effect on reducing resuspension of sediments during the study. Table A-9 includes water sample data from both open and closed bucket dredge testing. Sediment samples (Table A-10) were collected on 5 April 1984, prior to the start of the bucket tests.

Comparing the average constituent concentrations (Table 5 and Figure 12), the elutriate test satisfied the requirements of the hypothesis only 73% of the time

Table 5. Lake City Comparison of Average
Constituent Concentration.

Constituent	Water Analysis Avg of 4 (ppm)	Elutriate Test Avg of 4 (ppm)
Cd	0.0002	0.0003
Zn	0.033	0.01
Pb	0.004	0.005
Cu	0.065	0.003
Hg	0.0002	0.0002
As	0.0035	0.003
Cr	0.019	0.002
Mn	0.59	3.4
Fe	6.5	1.1
Ni	0.024	0.001
T-Phosphous	0.54	0.04
NH3	0.1	7.3
PCB	0.00002	0.00002
DDD	0.0001	0.0001
DDE	0.00004	0.00004

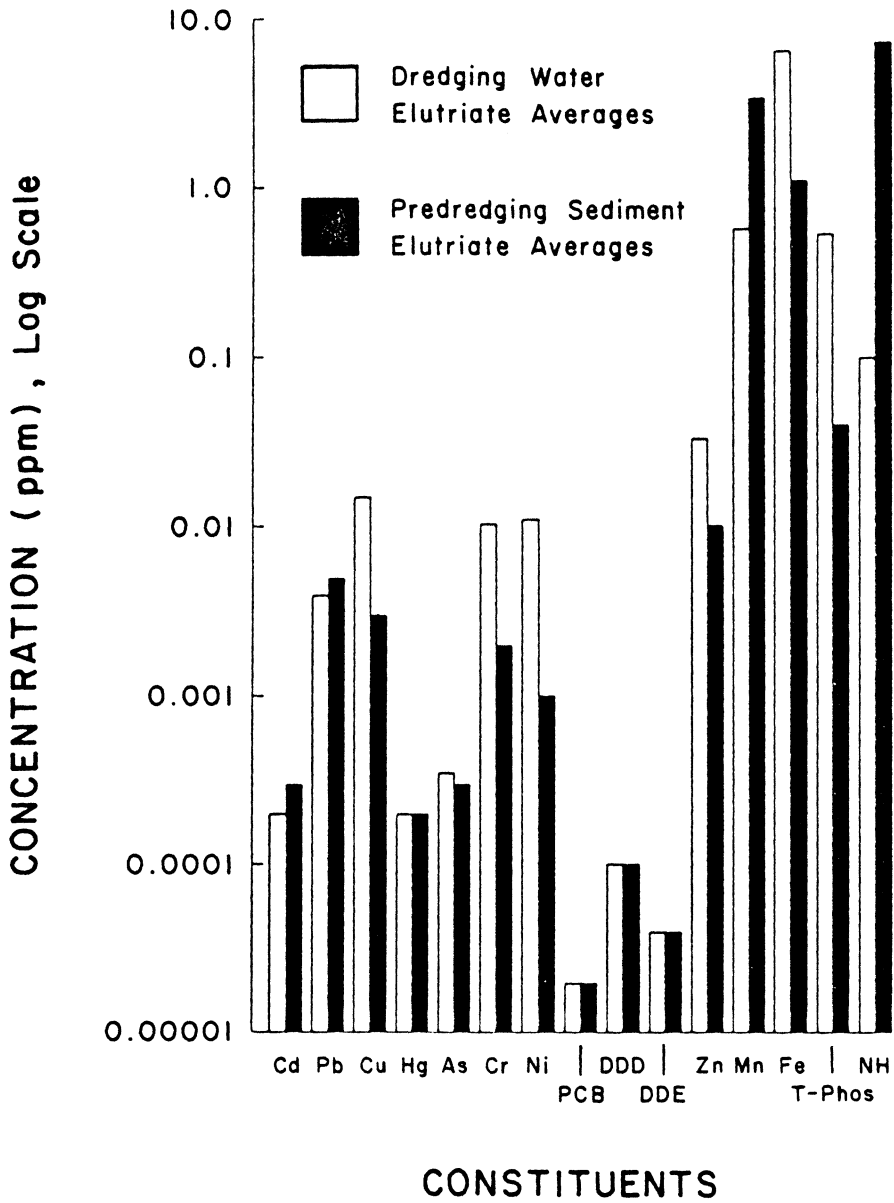


Figure 12. Lake City Comparison of Average Constituent Concentration.

compared to 100% validation at the other four sites. Four constituents (27%) had elutriate test values that were two orders of magnitude lower than the corresponding water analysis concentration. The dredging operation may explain the reason for the anomalies.

The project called for dredging to clear a foundation for a breakwater. Sediments excavated were disposed of adjacent to the dredging site. Additionally, while the sampling and dredging was being conducted, material was being deposited in the water to form the breakwater. The breakwater was also undergoing shaping, thus creating a greatly increased suspended particle load (22 times the background level) on the dredge site water. Since constituent release is proportional to the amount of suspended solids present, the data from Lake City were deemed a poor comparison and eliminated from further evaluation.

STATISTICAL ANALYSIS RESULTS

The primary goal of the statistical analysis was to develop a method to predict the upper bound which a constituent concentration might approach based on a preselected confidence level (probability of occurrence).

As explained in Chapter 3, variances were estimated (Table 6) and correction coefficients determined (Table 7).

The following predictive equation was then developed to describe the upper bound of constituent concentration to be expected at the site of dredging;

$$\text{PUB} = \text{AETV} * e^{k/\sqrt{n}}$$

Where:

PUB = Predicted Upper Bound; highest value expected for a water sample concentration based on a selected confidence interval.

AETV = Average Elutriate Test Value; the average concentration of a constituent as determined from Standard Elutriate Testing of predredging bottom sediments.

n = Number of sediment samples used to establish AETV.

k = Correction Coefficient; standard deviation times a standardized variable (z score) representing the probability of achieving a selected confidence interval.

Table 6. Pooled Variances for Constituent Categories
From the Following Sites: Black Rock Harbor,
Calumet River, Duamish River, and James River.

Constituent Category	Variance, Sp ²
Metals (minus Fe)	0.2
Fe	2.0
NH ₃	0.2
PCB's (all)	1.2
Phosphates (Ortho & Total)	3.1 ± 2.5

Table 7. K values for the Constituent Categories Based on Selected Confidence Intervals.

Constituent Category	Confidence Interval			
	80%	85%	90%	95%
Metals (minus Fe)	0.37	0.5	0.6	0.7
Fe	1.2	1.5	1.8	2.3
NH ₃	0.37	0.5	0.6	0.7
PCB's (all)	0.9	1.2	1.4	1.8
Phosphates (Ortho and Total)	1.5	1.8	2.2	2.9

CHAPTER 5. SUMMARY AND CONCLUSIONS

SUMMARY

The hypothesis for this evaluation of the Standard Elutriate Test was that an elutriate test would estimate within one order of magnitude the constituent concentration found by water analysis at or near the point of dredging. A secondary hypothesis was that the elutriate test would overestimate soluble constituent release and therefore, any elutriate values beyond one of magnitude would be higher than the corresponding water analysis value. Table 8 is a summary of 38 constituent evaluated during this evaluation.

The Standard Elutriate Test satisfactorily predicted the release of contaminants at or near the point of dredging. For 74% of the constituents studied, the Standard Elutriate Test closely estimated (within one order of magnitude) the amount of release. The remaining 26% of the constituents met the secondary expectations of this investigation.

Table 8. Summary of Comparison Data From the Four Sites.

Site	Constituents that Validate Primary Hypothesis (Within one order of magnitude)	Constituents that Validate Secondary Hypothesis (> one order of magnitude)	Invalid
Black Rock	11	4	0
Calumet	9	5	0
Duamish	3	0	0
James River	5	1	0
TOTALS	28	10	0

CONCLUSIONS

Based on the data provided for this investigation, the following conclusions are made:

1. There are no apparent problems in using the Standard Elutriate Test for estimating the potential contaminant release at or near the point of dredging.
2. The elutriate test satisfactorily predicted release of contaminants at the point of dredging in four out of five of the sites in this study. The fifth site, Lake City, had extenuating circumstances that may account for the failure of the elutriate test in predicting release of contaminants.
3. The results of this investigation indicate that no special adjustments of the Standard Elutriate Test are required, although the test does appear to be especially conservative in estimating the release of organics, nutrients and some of the heavy metals (Hg, Mn, Fe, and Cr).
4. The statistical analysis provided the following predictive equation for estimating the upper-bound

value a constituent concentration will approach based on elutriate test data and a specified confidence level:

$$\text{PUB} = \text{AETV} * e^{k / \sqrt{n}}$$

Where:

PUB = Predicted Upper Bound; highest value expected for a water sample concentration based on a selected confidence level.

AETV = Average Elutriate Test Value; the average concentration of a constituent as determined from Standard Elutriate Testing of predredging bottom sediments.

n = Number of sediment samples used to establish AEDTV.

k = Correction Coefficient; standard deviation times a standardized variable (z score) representing the probability of achieving a selected confidence interval.

CHAPTER 6. RECOMMENDATIONS FOR FURTHER STUDY

Although the Standard Elutriate Test works reasonably well, additional studies may improve the ability of the test to accurately estimate the soluble release of contaminants. From the conclusions of this investigation and background research, the following recommendations for further studies are made:

1. Conduct additional testing to increase the number of samples available. This would allow for the correction coefficients to be better defined and the predictive equation to be more indicative of the release at or near the point of dredging.
2. Testing for suspended solid concentration in the water column should be tied to the Standard Elutriate Test procedure to identify potential problems similar to the sampling interference found at the Lake City site.
3. Conduct studies of the solids/liquids ratio in the Standard Elutriate Test procedure to reduce the tendency of the elutriate test to overestimate soluble contaminant release.

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APPENDIX A

Table A-1. Black Rock Harbor Sediment Elutriate Test Data.

Constituent	Sample 1 (ppm)	Sample 2 (ppm)	Sample 3 (ppm)	Average (ppm)
Cd	0.001	0.001	0.001	0.001
Zn	0.05	0.02	0.02	0.03
Pb	0.0006	0.0005	0.0005	0.0005
Cu	0.002	0.002	0.002	0.002
Hg	0.00077	0.00034	0.0001	0.0004
As	0.01	0.01	0.01	0.01
Cr	0.016	0.008	0.015	0.013
Mn	0.234	0.232	0.27	0.245
Fe	0.4	0.4	0.5	0.43
Ni	0.033	0.036	0.047	0.039
T-Phosphorus	3.05	2.85	3.15	3.02
NH ₃	17.4	15.1	21.8	18.1
PCB 1242	0.0023	0.0015	0.0022	0.002
PCB 1254	0.00023	0.0002	0.00012	0.00018
PCB 1260	0.00009	0.00005	0.00004	0.00006

Table A-2. Black Rock Harbor Operating Dredge Water
Analysis.
(Bottom samples within 50 ft of the dredge)

Constituent	Sample 1 (ppm)	Sample 2 (ppm)	Sample 3 (ppm)	Average (ppm)
Cd	0.001	0.001	0.001	0.001
Zn	0.04	0.02	0.02	0.026
Pb	0.005	0.003	0.002	0.003
Cu	0.022	0.002	0.002	0.009
Hg	0.0004	0.00019	0.00011	0.00011
As	0.01	0.01	0.01	0.01
Cr	0.007	0.02	0.008	0.0012
Mn	0.094	0.132	0.131	0.119
Fe	0.4	0.7	0.7	0.6
Ni	0.019	0.007	0.01	0.012
T-Phosphorus	0.05	1.15	0.97	1.06
NH ₃	2.72	6.5	4.9	4.71
PCB 1242	0.00085	0.0087	0.0018	0.0053
PCB 1254	0.00002	0.00002	0.00002	0.00002
PCB 1260	0.00002	0.00002	0.00002	0.00002

Table A-3. Calumet River Sediment Elutriate Test Data.

Constituent	Sample 1 (ppm)	Sample 2 (ppm)	Sample 3 (ppm)	Sample 4 (ppm)	Average (ppm)
Cd	0.01	0.01	0.01	0.01	0.01
Zn	0.02	0.02	0.02	0.02	0.02
Pb	0.02	0.01	0.01	0.02	0.015
Cu	0.01	0.01	0.01	0.01	0.01
Hg	0.1	0.1	0.1	0.1	0.1
As	0.007	0.007	0.007	0.007	0.007
Cr	0.01	0.01	0.01	0.01	0.01
Mn	0.98	0.89	0.89	0.1	0.7
Fe	3	2.5	2.5	3	2.75
Ni	0.01	0.01	0.01	0.01	0.01
T-Phosphorus	0.09	0.07	0.08	0.06	0.075
TKN	23	22	22	22	22.3
NH3	25	26	26	26	25.89
PCB	0.001	0.001	0.001	0.001	0.001

Table A-5. Duamish Waterway Sediment Elutriate Test Data.

Constituent	Sample 1 (ppm)	Sample 2 (ppm)	Sample 3 (ppm)	Sample 4 (ppm)
Zn	0.019	0.016	0.013	0.013
Pb	0.005	0.005	0.005	0.005
Cu	0.005	0.005	0.005	0.005

Constituent	Sample 1 (ppm)	Sample 2 (ppm)	Average (ppm)
Cd	0.0024	0.0023	0.0024
Zn	0.0016	0.0015	0.0016
Pb	0.0090	0.0080	0.0085
Cu	0.0110	0.0100	0.0105
T-phosphorus	---	---	0.0100
TKN	---	---	0.2700

(Source: Bender et al., 1984)

Table A-6. Duamish Waterway Operating Dredge Water
Analysis.
(Bottom samples within 50 ft of the dredge)

Constituent	Sample 1 (ppm)	Sample 2 (ppm)	Sample 3 (ppm)	Average (ppm)
Zn	0.016	0.041	0.016	0.024
Pb	0.005	0.010	0.005	0.007
Cu	0.002	0.002	0.002	0.002

Table A-7. James River Sediment Elutriate Test Data.

Constituent	Sample 1 (ppm)	Sample 2 (ppm)	Sample 3 (ppm)	Sample 4 (ppm)	Average (ppm)
Cd	0.0024	0.0027	0.0018	0.0025	0.0024
Zn	0.0023	0.0015	0.0023	0.0029	0.0023
Pb	0.007	0.14	0.004	0.0031	0.007
Cu	0.018	* 0.013	0.019	0.022	0.018
T-phosporous	--	--	--	--	0.05
TKN	--	--	--	--	5.2

(Source: Bender et al., 1984, Table 2, High Composite Figures)

Table A-8. James River Operating Dredge Water Analysis.

Constituent	Sample 1 (ppm)	Sample 2 (ppm)	Average (ppm)
Cd	0.0024	0.0023	0.0024
Zn	0.0016	0.0015	0.0016
Pb	0.0090	0.0080	0.0085
Cu	0.0110	0.0100	0.0105
T-phosphorus	---	---	0.0100
TKN	---	---	0.2700

(Source: Bender et al., 1984)

Table A-10. Lake City Sediment Elutriate Test Data.

Constituent	Sample 1 (ppm)	Sample 2 (ppm)	Sample 3 (ppm)	Sample 4 (ppm)	Average (ppm)
CD	0.0001	0.0001	0.0008	0.0001	0.0003
Zn	0.01	0.01	0.01	0.02	0.01
Pb	0.005	0.001	0.013	0.001	0.005
Cu	0.005	0.001	0.003	0.002	0.003
Hg	0.0002	0.0002	0.0002	0.0002	0.0002
As	0.003	0.003	0.003	0.002	0.003
Cr	0.001	0.001	0.003	0.001	0.002
Mn	2.9	3.6	3.5	3.8	3.4
Fe	0.53	1.4	1.7	0.81	1.1
Ni	0.001	0.001	0.001	0.001	0.001
T-Phosphorus	0.04	0.04	0.04	0.04	0.04
NH3	7.4	8	7.5	6.4	7.3
PCB	0.00005	0.00001	0.00001	0.00003	0.00002
DDD	0.0001	0.0001	0.0001	0.0001	0.0001
DDE	0.00004	0.00004	0.00004	0.00004	0.00004

Table A-11. Lake City Operating Dredge Water Analysis.
(Bottom samples within 50 ft of the dredge)

Constituents	Sample 1 Closed Bucket (ppm)	Sample 2 Closed Bucket (ppm)	Sample 3 Open Bucket (ppm)	Sample 4 Open Bucket (ppm)	Average (ppm)
Cd	0.0001	0.0001	0.0005	0.0001	0.0002
Zn	0.04	0.04	0.03	0.02	0.033
Pb	0.001	0.0014	0.001	0.001	0.001
Cu	0.15	0.03	0.019	0.06	0.065
Hg	0.0002	0.0003	0.0002	0.0002	0.0002
As	0.002	0.007	0.003	0.002	0.0035
Cr	0.011	0.043	0.015	0.007	0.019
Mn	0.09	1.7	0.48	0.1	0.59
Fe	1.1	17	6.5	1.4	6.5
Ni	0.02	0.073	0.014	0.005	0.024
T-Phosphorus	0.2	1	0.76	0.2	0.54
NH ₃	0.1	0.1	0.1	0.1	0.1
PCB	0.00001	0.00006	0.00001	0.00001	0.00002
DDD	0.0001	0.0001	0.0001	0.0001	0.0001
DDE	0.00004	0.00004	0.00004	0.00004	0.00004

The vita has been removed
from the scanned document