Espey, Huston & Associates, Inc.
Engineering & Environmental Consultants

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LAGUNA MADRE, TEXAS
CONTAMINANT ASSESSMENT

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ABSTRACT

In August 1994, the Galveston District of the U S. Army Corps of Engineers awarded Contract No DACW64-94-D-0014 (Contract) to Espey, Huston & Associates, Inc for Environmental Services within the boundaries of the Galveston District Delivery Order 0058 of the Contract requires specific testing for the Interagency Coordination Team for the Laguna Madre, Texas under an Interagency Agreement issued by the U S Environmental Protection Agency, Region VI.

The required testing included chemical analyses of water, sediment, and elutriates, grain size analyses, and bioassays/bioaccumulation studies. All required testing from 26 stations in the GIWW and two reference stations in the Gulf of Mexico, collected in June 1997, have been completed and are the subject of this report

The concentrations of all organics, except total petroleum hydrocarbons, were below detection limits for water and elutriate samples The exceedance of acute, marine Texas Water Quality Standards for copper and lead in water and elutriate samples and zinc in water samples indicated a potential cause for concern but dilution analysis indicated the limiting permissible concentration for the water column would not be exceeded The only organics detected in the sediment consisted of total organic carbon at Station LM-1, pyrene from Station LM-4 and five compounds detected from Station BA-6 Ten metals were found in one or more of the sediment samples, as were total sulfide and ammonia-nitrogen Of the metals, only a small number of concentrations as noted in Section 3 2 were exceedingly high There was an apparent trend of increasing concentrations of the majority of metals, total sulfide, and ammonia-nitrogen with increasing percent fines for the stations adjacent to Baffin Bay south toward the land cut

The 10-day solid phase bioassay was conducted to determine the potential impact of the dredged material on benthic organisms The organisms tested were amphipods, *Ampelisca abdita* and grass shrimp, *Palaemonetes pugio* Survival in the tests with the Upper Laguna Madre sediments was not lower than survival in the Reference Control in any instance Survival in the tests with the Lower Maguna Madre sediments was lower than survival in the Reference Control in six instances all stations for *A. abdita* and for total organisms. The difference between Reference Control mean survival and test mean survival for *A abdita* at Station BA-4 was >20% and statistical analyses were required. There was a significant difference between mean survival in the Reference Control and in Station BA-4 sediment Therefore, the limiting permissible concentration for benthic toxicity is not met

There were no organic compounds found above detection limits in test organism tissues. The concentrations of barium (Stations BA-1, BA-5, and BA-6) and chromium (Station BA-5) in tissues of *N virens* were significantly higher than the respective concentrations in Reference Control organisms but not Archive organisms The mean concentration of barium in tissues of *M masuta* exposed to BA-1 sediments was significantly higher than the mean concentration on Reference Control clams As discussed in Section 3 3.1, there are no Food and Drug Administration Action Levels for barium and chromium and significant ecological effects would not be expected from the tissue concentrations at their respective stations due the concentrations detected and low toxicity that these compounds exhibit

In conclusion, the water and elutriate chemistry results given here provide a potential cause for concern to the water column of the designated placement areas due to the exceedances of Texas Water Quality Standards for copper The solid phase bioassay results reported here indicate that the limiting permissible concentration for benthic toxicity is not met for *A. abdita* exposed to Station BA-4 sediments. Bioaccumulation appeared to occur for barium and chromium in *N virens* tissues and did occur for barium in *M nasuta* tissues Based on a strict interpretation of the guidance given in the Green Book, the authors of this report cannot conclude that reasonable assurance is given that significant ecological impacts could not result from the ocean placement of the test sediments, notwithstanding the facts that (1) only a small dilution will reduce the copper concentration to below the Texas Water Quality Standards, (2) the toxicity exhibited by the solid phase was slight, and (3) the barium and chromium accumulation would not indicate a concern However, had the limiting permissible concentration for benthic toxicity been met, the conclusion that significant ecological impacts would not likely result from the ocean placement of the test sediments would have been justified Therefore, it would appear that additional solid phase bioassays with sediment from Station BA-4 would be necessary to determine the acceptability of Station BA-4 sediment for ocean placement

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1 0 INTRODUCTION

In August 1994, the Galveston District of the U.S Army Corps of Engineers (USACE) awarded Contract No DACW64-94-D-0014 (Contract) to Espey, Huston & Associates, Inc. (EH&A) for Environmental Services within the boundaries of the Galveston District. Delivery Order 0058 of the Contract requires specific testing for the Interagency Coordination Team (ICT) for the Laguna Madre, Texas under an Interagency Agreement (IAG) issued by the U.S Environmental Protection Agency, Region VI (EPA) The program was designed by Lee Wilson & Associates (LW&A), the EPA contractor, with assistance from Coastal Environments, Inc. (CEI) and EH&A. Water and sediments were collected from 26 stations within the channel and two reference stations for chemical and grain size analyses and bioassays/bioaccumulation studies. The purpose of the work performed for this item was to determine any potential environmental impact from the ocean placement of material to be dredged to maintain the GIWW. The analyses and bioassays/bioaccumulation studies on these samples have been completed and are the subject of this report Procedures for the bioassays/bioaccumulation studies are detailed in the Green Book (EPA/USACE, 1991).

The work performed consisted of chemical analyses of water, sediment, and elutriate samples, grain size analyses; solid phase bioassays, and bioaccumulation studies. Bulk sediment analyses allow for the determination of a cause for concern The elutriate test is designed to simulate the mixing that occurs upon dredging and thus, when compared to ambient water concentrations, can provide information about possible water column contamination during dredging and placement The bioassays and bioaccumulation studies are designed to determine the potential impact of the placement of the dredged material on designated sensitive marine organisms living on the bottom of the Gulf of Mexico (40 CFR §220-229) Sample collection was conducted by personnel of CEI, Baton Rouge, LA, and EH&A aboard the Louisiana Universities Marine Consortium (LUMCON) vessel, *Acadiana* All chemical analyses were performed by Anacon, Inc , Houston, Texas (Anacon) and the bioassays/bioaccumulation studies were conducted by the EH&A Bioassay Laboratory, Houston, Texas

2 0 METHODS AND MATERIALS

The methods and materials for the work performed followed the specifications of the Scope of Work, accompanying Delivery Order 0058, the Quality Assurance Project Plan (QAPP), prepared by LW&A and CEI with input by the EPA, USACE, and EH&A; and the Green Book and are detailed in the following sections. All equipment was cleaned according to QAPP specifications, which included a detergent wash, an acid soak, and a deionized-water rinse

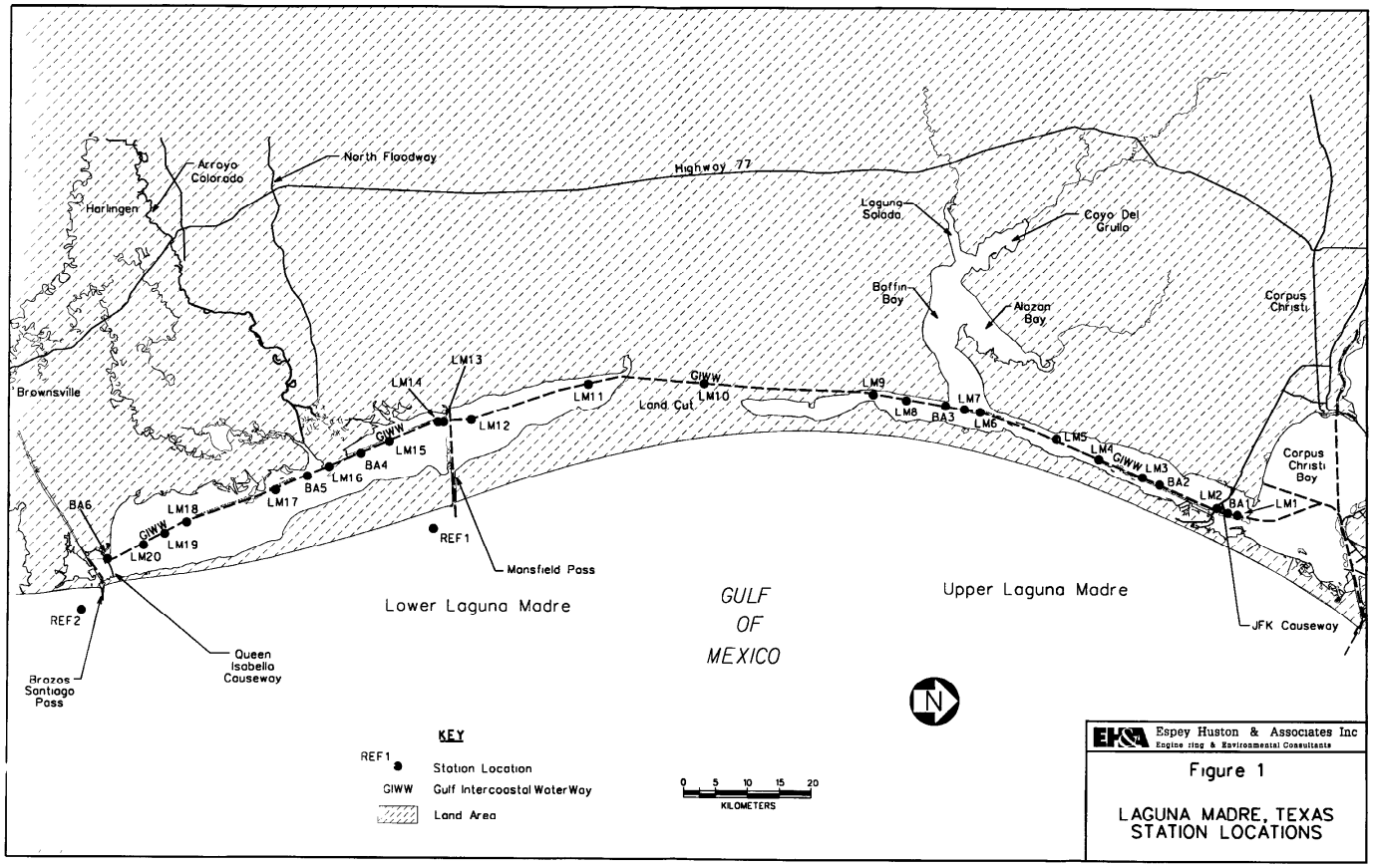
2 1 STATION LOCATIONS

The locations of the 26 stations within the channel and two reference stations, based on the GPS readings taken at each sampling site, are shown on Figure 1 and presented in Table 1 The BA stations were for bioassay/bioaccumulation and Stations BA5 and BA6 were also "ultraclean stations" as described in the QAPP

In practice, the RV *Acadiana* was brought as close to the expected coordinates as possible, a centerline was established by the Captain via the nearest navigation buoys, the coordinates were taken, and the centerline station was sampled. The boat then idled toward the edges of the channel until the bottom began to shoal, the boat returned to channel depth and the east or west offset sample and the position were taken This process was repeated for the other offset station The clean sand for the true control was collected from Galveston East Beach, near the south jetty

2.2 SAMPLE COLLECTION AND STORAGE

Sediment from the test stations and reference stations was collected with a stainless steel, Gulf of Mexico Box Corer, rented from LUMCON Water depth at the centerline of the test stations was 10 3 - 20.1 feet below mean low tide (mlt) Water depth at REF1 and REF2 was 45 and 47 feet, respectively. The clean sand for the true control was collected with a clean, non-contaminating shovel All samples for bioassays/bioaccumulation studies were put in air-tight linear polyethylene containers which were filled to beyond capacity, sealed to exclude air, and stored in the dark at 2-4°C within 24 hours of collection and until used Sediments for chemical analysis were removed from the Box Corer by dumping into a stainless steel bucket and removal with a stainless steel spatula, avoiding the edges, and placed into contractor-cleaned glass bottles with teflon-lined lids These bottles were filled to beyond capacity, sealed to exclude air, and stored in the dark at 2-4°C until used. Test sediments for chemical analyses were composites of grabs from the centerline and on either side of the centerline.



Espey Huston & Associates Inc
Engineering & Environmental Consultants

Figure 1

LAGUNA MADRE, TEXAS
STATION LOCATIONS

TABLE 1

STANDARD PARAMETERS
LAGUNA MADRE, TEXAS
JUNE 1997

STATION	SAMPLE DATE	DEPTH (ft)		DO (mg/L)	pH	SALINITY (‰)	WATER TEMP (°C)	SECCHI DEPTH (ft)	COORDINATES	
		Water	Sample						North	West
REF 1	6/7/97	45 0	3 0 10 0 20 0 30.0 40 0	6 75 6 70 6 11 6 09 4 70	8 12 8.14 8 10 8 12 8 07	32.7 32 7	23 97 23 55 22 70 22 68 21 68	4 50	26° 32.05'	97° 14 11'
REF 2	6/8/97	47 0	3 0 10 0 20 0 40 0	6 73 6 58 6 58 5.78	8.20 8 20 8 20 8 18	33 3 33 2 33 3	25 11 25 08 24 71 24 31	6 20	26° 02 11'	97° 07 12'
LM1	6/5/97	11 0	3.0 10 0	7 64 6 55	8 41 8 47	28 1 31 0	27 97 27.95	4 00	27° 40 06'	97° 13 82'
LM2	6/5/97	14 0	3 0 16 0	5 85 5 26	8 67 8 65	38 0 38 2	28 16 28 07	3 00	27° 38.31'	97° 14 52'
LM3	6/5/97	13 5	3 0 12 0	5 58 5.15	8 52 8.52	40 1 40 1	27.99 28.02	2.50	27° 31 99'	97° 17.60'
LM4	6/5/97	14 0	3 0 12.0	6 06 5 50	8 56 8 58	39 0 39.1	27 77 27 87	2 50	27° 28 37'	97° 19 45'
LM5	6/9/97	16 0	3 0 14 0	6 03 2 75	8 61 8 55	35 4 35 7	29.82 28 99	3 00	27° 24.85'	97° 21 49'

TABLE 1

STANDARD PARAMETERS
LAGUNA MADRE, TEXAS
JUNE 1997

STATION	SAMPLE DATE	DEPTH (ft.)		DO (mg/L)	pH	SALINITY (‰)	WATER TEMP (°C)	SECCHI DEPTH (ft)	COORDINATES	
		Water	Sample						North	West
LM6	6/9/97	17 0	3 0 15.0	5.27 4 18	8 50 8 51	33.2 36 1	29 13 29 14	2 50	27° 18 45'	97° 24 22'
LM7	6/9/97	16 0	3 0 14 0	5 02	8 46 8 39	32 9 33 7	29 07 28 82	2 00	27° 17 12'	97° 24 52'
LM8	6/9/97	19 0	3 0 17 0	5 86 3 44	8 62 8 02	28 7 28 5	28 83 28 83	2 20	27° 12 26'	97° 25 48'
LM9	6/9/97	15 0	3 0 10 0 13 0	5 64 4 06 4 18	8 64 8.69 8 68	25 6 26 1 30 5	28 39 28 54 28 35	3 00	27° 09 46'	97° 26 10'
LM10	6/6/97	20 1	3 0 15 0	5 85 5 66	8 52 8 57	27 5 27 2	28 98 28 92	2 50	26° 55 18'	97° 27 46'
LM11	6/6/97	13 0	3 0 13 0	6 45 6 34	8 49 8 47	25 7 26 1	29 03 28 45	3 00	26° 45 39'	97° 27 57'
LM12	6/6/97	12 5	3 0 10 0	6 73 6 36	8 47 8 45	24 2 24 2	28 90 28 95	2 25	26° 35 42'	97° 24 41'
LM13	6/6/97	16 5	3 0 8.0 14 0	6 18 5.79 4 57	8 60 8 60 8 55	25 7 27 2 29 7	29 23 29 06 28 15	3 00	26° 33 09'	97° 24 25'
LM14	6/6/97	10.3	3 0 10.0	6 04 6 09	8 59 8.59	25.2 25 5	29 19 28 99	1.75	26° 32 61'	97° 24 24'

TABLE 1

STANDARD PARAMETERS
LAGUNA MADRE, TEXAS
JUNE 1997

STATION	SAMPLE DATE	DEPTH (ft)		DO (mg/L)	pH	SALINITY (‰)	WATER TEMP (°C)	SECCHI DEPTH (ft)	COORDINATES	
		Water	Sample						North	West
LM15	6/8/97	14 0	3 0 12 0	6 12 6 09	8 91 8 91	29 0 29 0	29 04 29.04	2 00	26° 28 43'	97° 22 47'
LM16	6/8/97	19 5	3 0 17 0	7 04 4 90	8 79 8 80	23 5 28 2	29.25 27 95	2.00	26° 23 31'	97° 20.16'
LM17	6/8/97	20 0	3.0 14 0	5 20 4 80	8 94 8 93	30 8 31 1	27 94 27 73	3 00	26° 18.71'	97° 18 03'
LM18	6/8/97	13 0	3 0 11 0	5 55 5 26	8.32 8 31	30 5 30 7	28.37 28 28	2.00	26° 11 22'	97° 15 20'
LM19	6/8/97	11 0	3 0 11 0	5 56 5.26	8 45 8 45	31 4 31 3	27.75 27 65	4 00	26° 09 34'	97° 14 17'
LM20	6/8/97	16 0	3 0 14 0	5 97 5 96	8 32 8 32	33 0 32 9	25.92 28 86	5 00	26° 07 53'	97° 13 13'
BA1	6/5/97	14 0	3 0 12.0	7.06 5 75	8 52 8 67	29.3 37 6	27 86 28 16	5 00	27° 39 24'	97° 14 05'
BA2	6/5/97	10 3	3 0 10 0	5 15 4 91	8 54 8 54	40 0 40 1	27.94 27 94	2.40	27° 33 45'	97° 16 86'
BA3	6/9/97	18 6	3.0 16 0	5 49 4 23	8 61 8 58	31 8 33.0	29 06 29 07	2.80	27°15 54'	97° 24 88'

TABLE 1

STANDARD PARAMETERS
LAGUNA MADRE, TEXAS
JUNE 1997

STATION	SAMPLE DATE	DEPTH (ft)		DO (mg/L)	pH	SALINITY (‰)	WATER TEMP (°C)	SECCHI DEPTH (ft)	COORDINATES	
		Water	Sample						North	West
BA4	6/8/97	19 7	3 0 14 0	6 33 6 34	8 88 8 87	28 2 28 7	28 73 28 11	1 80	26° 26 01'	97° 21 38'
BA5	6/8/97	19 0	3 0 17.0	5 61 5 64	8 93 8 93	30 9 31 2	27 76 27 66	3.50	26° 21 44'	97° 19 30'
BA6	6/7/97	20 0	3 0 10 0 20 0	5 96 5 28 5.40	8 20 8 13 8 13	32 1 32 3 33 6	26 03 23 27 23 24	4 00	26° 04 44'	97° 11 86'

Water for chemical analyses was taken with a non-contaminating pump and placed into bottles provided by Anacon The bottles were cleaned by Anacon and contained the necessary preservatives. The water samples were stored in the dark at 2-4°C until used Water samples were collected at the centerline of the GIWW Water from each of the reference stations was a composite from the three reference sub-stations

2 3 LABORATORY FACILITIES

The EH&A Laboratory has separate areas for water and sediment storage, culture of test organisms, and testing.

Testing was performed in a 20°C test chamber for the amphipod and grass shrimp solid phase bioassays. Lighting was arranged for each test phase so that light intensity was approximately 1200 $\mu w/cm^2$ using cool-white fluorescent bulbs with a 14-hour light and 10-hour dark cycle

2 4 ORGANISM ACQUISITION

Two organisms were tested in the solid phase bioassay the infaunal amphipod, *Ampelisca abdita*, and the grass shrimp, *Palaemonetes pugio* and two in the bioaccumulation studies· the bentnose clam, *Macoma nasuta*, and the sandworm, *Nereis virens*

The organisms used in the solid phase bioassay were purchased from commercial dealers *A. abdita* and *M. nacoma* were purchased from Brezina and Associates, Dillon Beach, California. *P pugio* and *N. virens* were purchased from Aquatic Research Organisms, Inc , Hampton, New Hampshire

The polychaetes were shipped dry in seaweed and were allowed to come to test temperature in the shipping containers, from which they were introduced into the test vessels The clams and shrimp were shipped in bags of seawater, which, upon receipt, were aerated and allowed to come to test temperature These organisms were then randomly introduced into the test or control sediment The amphipods were shipped in water and sediment When the shipping material was at test temperature, the amphipods were sieved, counted, and randomly introduced into the test containers. Any polychaetes, clams, or amphipods that did not burrow and any organisms that exhibited abnormal behavior in the first four hours after being put into the test vessels were replaced by healthy organisms No organisms were held for more than three weeks

2 5 TEST MEDIA PREPARATION

The elutriate was prepared from site sediment and site water, combined at a 1:4 ratio, respectively, and prepared by Anacon personnel, as designated in the Green Book

All sediment used in the solid phase bioassays or bioaccumulation studies was sieved through a 1 0-millimeter (mm) screen All animal tissue was removed and the remaining material recombined with the sediment from which it had been removed All sediment was screened as soon as possible after collection to prevent the decay of organic material Following this, the sediment was stored at 2-4°C until needed.

2.6 CHEMICAL ANALYSES

Sediment and water samples from the test and reference stations were delivered to Anacon for chemical analyses Chemical analyses were for the parameters listed in Table 2 Analytical methodology and minimum detection limits were provided in the QAPP and are included in Appendix A. Metals measured in water samples are total, not dissolved, concentrations Metals measured in elutriate samples are dissolved concentrations because of the elutriate preparation methodology

2 7 BIOASSESSMENT PROCEDURES

2.7 1 Randomization

Test and control vessel locations in the testing chambers were randomized using numbers from a PC random number generator

2 7 2 Solid Phase Bioassay/Bioaccumulation Assessment

The solid phase bioassay consisted of a one-day settling period after the sediment was added, followed by ten days (Days 1-10) of test-organism exposure at 20°C The bioassay vessels were partially filled with artificial seawater and enough sediment (test station, Reference, or True Control) was placed in each vessel to meet the needs of the test organisms and to make at least a 2-cm layer on the bottom. Five replicates were prepared for each of the test stations, for the Reference Control, and for the True Control Different 10-gallon aquaria were used for each replicate of both the polychaetes and

TABLE 2
PARAMETERS DETERMINED BY
CHEMICAL ANALYSES

Metals	
Arsenic	Mercury
Barium	Nickel
Cadmium	Selenium
Chromium	Silver
Copper	Zinc
Lead	
Pesticides	
Aldrin	Dieldrin
Alpha-BHC	Endosulfan I
Beta-BHC	Endosulfan II
Delta-BHC	Endosulfan Sulfate
Gamma-BHC	Endrin
Chlordane	Endrin Aldehyde
4,4'-DDD	Heptachlor
4,4'-DDE	Heptachlor Epoxide
4,4'-DDT	Toxaphene
PCBs, total	
PAHs	
Acenaphthene	Chrysene
Acenaphthylene	Dibenzo(a,h)anthracene
Anthracene	Fluoranthene
Benzo(a)anthracene	Fluorene
Benzo(a,e)pyrene	Indeno(1,2,3-c,d)pyrene
Benzo(b)fluoranthene	Naphthalene
Benzo(k)fluoranthene	Phenanthrene
Benzo(g,h,i)perylene	Pyrene
Total	
Ammonia-Nitrogen	
Percent Solids	
Percent Volatile Solids	
Phenol	
Total Organic Carbon	
Total Petroleum Hydrocarbons	
Total Sulfides	
Total Lipids (tissue analysis only)	

clams and one-quart jars were used for the amphipods. A loading factor of no more than one-half gram of tissue per liter of test or control medium was maintained

Twenty-four hours after the addition of the sediment, the water was changed, and 20 organisms per replicate for the solid phase bioassay and 20 per replicate for the bioaccumulation study were placed in the test vessels

Temperature, dissolved oxygen, pH and salinity were recorded daily (Appendices B (Table B-1) and C (Table C-1)) Seventy-five percent of the water was siphoned off and replaced one hour before and 48 hours after test initiation and at 48-hour intervals thereafter Aeration was supplied to the clams and polychaetes to keep the dissolved oxygen level above 40% of saturation Except for *P pugio*, which are fed *Artemia* and Tetra Min flakes twice per day, there is no feeding in the solid phase bioassays or bioaccumulation studies

After ten days, the solid phase bioassay was terminated The sediment was wet-sieved (0.5-mm screen) to remove surviving organisms These organisms were then counted and discarded The bioaccumulation study was conducted for 28 days following the same procedures as the solid phase bioassay. After 28 days, the bioaccumulation study was terminated and the clams and polychaetes were placed, by replicate, in clean aquaria filled with artificial seawater and allowed to purge for 24 hours After the purge period, these organisms were sacrificed, the clams were removed from their shells, all tissue was homogenized, frozen and delivered to Anacon for tissue analysis

2 8 STATISTICAL ANALYSES

Statistical analyses are described in detail in the QAPP and the Green Book and are designed to determine whether the test results are significantly different from the results of the reference control All statistical comparisons are at the 95% confidence level

2.8 1 Use

For the solid phase bioassay, statistical comparisons of mean survival are made for each species and for the total number of organisms, if (1) mean survival for any station test is less than that for the reference control and (2) there is greater than a 10% difference between Reference Control and test survival (20% for amphipods) For the bioaccumulation assessment, statistical comparisons of mean

concentrations were made for each parameter and species, if mean concentration of the parameter for any station test was greater than that for the Reference Control

2 8.2 Methods

The Chi-square test was used to determine if the data are normally distributed Cochran's test was used to determine the homogeneity or heterogeneity of the variances The calculated C value (C_{calc}) is the ratio of the largest variance (s^2_{max}) to the sum of all variances (Σs^2) or $C_{calc} = s^2_{max}/\Sigma s^2$ C_{calc} was compared to the 95%-confidence-level tabulated C value ($C_{0\ 05(k,\nu)}$), where k is the number of data sets being compared and ν is one less than the number (n) of observations contributing to each variance. If C_{calc} was less than $C_{0\ 05(k,\nu)}$, the variances were homogeneous, if C_{calc} was greater than $C_{0\ 05(k,\nu)}$, the variances were heterogeneous

To determine if the difference among the mean survival of organisms in the tests and in the control was statistically significant the following were used

1) If the data were normally distributed and the variances were homogeneous, with or without data transformation, and the number of replicates was the same for all treatments, an Analysis of Variance (ANOVA) is conducted (Box 9 1, Sokal and Rohlf, 1981) and the calculated F-value was compared to the tabulated F-value for the appropriate degrees of freedom If the calculated F-value was less than the tabulated F-value, the difference was not statistically significant

2) If the calculated F-value, determined by the ANOVA, was greater than the tabulated F-value, indicating a significant difference among the means, Dunnett's Procedure was used to determine which, if any, test mean was significantly different from the control mean The Dunnett's Procedure is similar to the Student's t-test except that the within-treatments mean square is used in place of the variances of the two treatments being compared

The Dunnett's t-statistic is calculated by the following formula

$$t_{calc} = \frac{| \bar{x}_{control} - \bar{x}_{test} |}{[(S_w^2)/(1/n_{control} + 1/n_{test}]^{1/2}}$$

where $\bar{X}$ is the mean survival, n is the number of replicates in the treatment, and S_w^2 is the within-treatments mean square If t_{calc} was less than the tabulated t-value at the 95% confidence level and for the appropriate degrees of freedom, the means were not statistically different. If t_{calc} was greater than the tabulated t-value, the difference between the means was statistically significant.

3) If the data were normally distributed and the variances were homogeneous, with or without data transformation, and the number of replicates was not the same for all treatments, the Bonferroni t-test is used to determine if there is a significant difference between treatment and control means (EPA, 1994).

4) Probable outliers were examined with the Dixon Test. This test compares the ratio, $(X_2 - X_1)/(X_n - X_1)$, to a tabulated value based on the number of points in the data set X_1 is the possible outlier, X_2 is the datum nearest in value to X_1 and X_n is the datum most distant in value from X_1

5) If the data were not normally distributed or the variances were heterogeneous, and could not be made normal or homogeneous by transformation, a rank sum test, the Kruskal-Wallis Test, was used to determine if there was a significant difference among the means. If so, Dunn's Multiple Comparison was used to compare the mean of each test data set to the mean of the reference control, unless the test mean was less than the reference control mean

3 0 RESULTS AND DISCUSSION

3 1 STANDARD PARAMETERS

Standard parameters are listed in Table 1 (Section 2.2) There are no trends evident, except for decreasing dissolved oxygen with increasing depth at most stations Nothing in the data indicates contamination from any source, although the dissolved oxygen was below 3 0 mg/L in bottom water at Station LM-5, which is located just north of the mouth of Baffin Bay (Figure 1)

3 2 CHEMISTRY

Water and elutriate concentrations of detected compounds are presented in Tables 3 and 4 Arsenic, barium, cadmium, chromium, copper, lead, zinc, and total petroleum hydrocarbons (TPH) were detected in water and elutriate samples Arsenic concentrations in the elutriates were numerically higher than those in the water for all stations Without replications, statistical significance cannot be assessed but, taking the relatively small variability in the water samples (1.00 - 2.20 mg/L) into account, the numerical differences would probably be significant for some stations (e g., LM-4 through LM-10) but would not be significant for others (e g , LM-3, LM-16, BA-6) In any case, the range of values (1 6-18 5 μg/L) in the elutriates is well below the marine acute (149 μg/L) criterion provided by the Texas Natural Resource Conservation Commission (TNRCC) for the protection of aquatic life (chronic criteria are not appropriate for grab samples) As with arsenic, barium concentrations in the elutriates were numerically higher than those in the water for all but Station LM-16 There are no Texas Water Quality Standards (TWQS) for barium but the Gold Book Criterion is 1,000 μg/L barium for domestic water supply The only value to exceed 1,000 μg/L barium was the Station LM-5 elutriate value of 1,320 μg/L Although navigation charts indicate oil/gas activity near LM-3 and LM-10, none is indicated near LM-5, which has the highest barium elutriate concentration. Cadmium concentrations in the elutriates versus the water varied from an increase by a factor of 7 5 for Station BA-4 to a decrease by a factor of 6 3 at Station LM-4 There was no apparent trend to the numerical changes in cadmium concentrations nor in the ratios of cadmium in the elutriates relative to cadmium in the water samples The marine acute criterion for cadmium was not exceeded at any station.

Chromium concentrations in elutriates were numerically higher than those in the water for all stations, except LM-1, BA-1, LM-2, LM-3, and BA-6 The chromium concentrations included large station-to-station variability and no apparent trends. Copper concentrations in the elutriates versus the water varied from an increase by a factor of 3 4 for REF1 to a decrease by a factor of 12 8 at Station

TABLE 3

CONCENTRATIONS OF DETECTED COMPOUNDS (µg/L)
WATER
LAGUNA MADRE

Parameter	Marine TWQS Acute	LM-1	BA-1	LM-2	BA-2	LM-3	LM-4	LM-5	LM-6	LM-7	BA-3	LM-8	LM-9	LM-10	REF-1
Arsenic	149	1 80	1 20	1 10	1 10	1 20	<1 00	1 40	1.50	1 70	1.70	1 30	1 60	1 50	<1 00
Barium	na	53 20	54 30	75 80	67 10	59 00	63 20	63 40	63 20	61 30	57 50	54 60	48 00	49 40	16 70
Cadmium	45 62	1 50	2 20	0 70	0 70	0 90	1 90	0 20	0 30	<0 10	0 20	0 30	0 30	0.70	1 10
Chromium	na	4 50	6 60	27 80	3 80	3 30	5 60	2 30	2 60	1.30	2 80	2 90	3 80	3 90	4 30
Copper	16 27	9 80	11 80	33 30	7 60	18 90	10 80	7 70	7 90	4 90	7 80	7 80	15 70	9 20	8 70
Lead	140	1.90	1 70	7 49	<1 00	<1 00	1 44	1 40	2 50	<1 00	1 30	<1 00	2 10	2 50	1 20
Zinc	98	34 40	47 40	51 20	20 40	29 40	46 90	78 60	133 00	10 10	201 00	129 00	415 00	42 10	26 50
TPH	na	<100	<100	<100	<100	<100	<100	<100	<100	5,400	<100	<100	<100	<100	<100

na = no criteria available

TABLE 3 (Concluded)

CONCENTRATIONS OF DETECTED COMPOUNDS (µg/L)
WATER
LAGUNA MADRE

Parameter	Marine TWQS Acute	LM-11	LM-12	LM-13	LM-14	LM-15	BA-4	LM-16	BA-5 / UC		LM-17	LM-18	LM-19	LM-20	BA-6 / UC		REF-2
Arsenic	149	1 60	1 90	1 60	1.90	1 80	2 10	2 20	2 10	1 50	1.40	1 50	1 40	1 40	1 40	1 50	1 20
Barium	na	40 00	52 20	42 00	50 50	51 90	49 40	56 00	48 80	44.70	42 60	34.90	22 20	15 90	17 70	16 80	12 10
Cadmium	45.62	0 80	2 00	0 60	3 60	<0 10	0 20	0 20	0 30	0 40	0.30	0 30	0 40	<0 10	1.80	0 30	1 70
Chromium	na	6.70	5 90	3 70	<1 00	1 50	3 11	2 20	2 30	3.40	3 60	3.50	4 30	1 50	9 40	3.10	6 40
Copper	16 27	10 20	12 40	10 50	9 70	7 70	5 60	7 50	7 80	7 10	8 80	10 80	11 30	6.50	7.90	5 80	10 00
Lead	140	6 80	1 90	3.10	2 90	<1 00	<1 00	<1 00	1 10	<1 00	1 90	1 40	1 20	<1 00	1 20	1 50	2 60
Zinc	98	63.50	38 70	39.80	33 10	24 80	27 70	158 00	38 90	23 70	29 50	33.00	36 70	28 60	31 50	28 20	25 30
TPH	na	<100	<100	<100	<100	130	<100	130	200	<100	<100	<100	<100	410	<100	<100	<100

na = no criteria available

UC = Ultraclean

TABLE 4

CONCENTRATIONS OF DETECTED COMPOUNDS (µg/L)
ELUTRIATE
LAGUNA MADRE

Parameter	Marine TWQS Acute	LM-1	BA-1	LM-2	BA-2	LM-3	LM-4	LM-5	LM-6	LM-7	BA-3	LM-8	LM-9	LM-10	REF-1
Arsenic	149	3 70	3 80	4 80	2 20	2 00	10.40	14 10	17 90	17 90	15 50	11 30	18.50	9 81	1 60
Barium	na	63 90	65 10	160 00	206 00	77 40	110 00	1,320.00	407 00	149 00	277 00	93 20	150 00	82 70	22 40
Cadmium	45.62	0 30	0 60	0 30	0 30	0 30	0 30	1 40	0 50	0 60	0.60	0 60	0 60	0 40	0 70
Chromium	na	4 30	5 10	1 60	9 40	2 30	10 70	5.00	8 40	6 20	5 40	7 00	5 00	8 10	4 50
Copper	16 27	7 70	7 90	2 60	6 50	5 60	15 90	10 80	25 50	10 00	9.50	17 50	10 10	8 70	29 30
Lead	140	1 40	<1 00	22 60	1 30	2 20	7 50	1 30	<1 00	<1 00	<1 00	<1 00	<1 00	1 20	1 40
Zinc	98	3 20	3 40	2 50	3 60	1 50	4 80	<1.00	2.60	2.50	3 50	3 40	3 00	4 20	2.50
TPH	na	<100	<100	<100	<100	<100	340	<100	<100	200	<100	<100	<100	1,090	<100

na = no criteria available

TABLE 4 (Concluded)

CONCENTRATIONS OF DETECTED COMPOUNDS (µg/L)
ELUTRIATE
LAGUNA MADRE

Parameter	Marine TWQS Acute	LM-11	LM-12	LM-13	LM-14	LM-15	BA-4	LM-16	BA-5	LM-17	LM-18	LM-19	LM-20	BA-6	REF-2
Arsenic	149	16 80	4 32	7 06	6 20	6 50	7 60	3 80	9 50	5 50	9 00	8 70	12 30	2 30	4 10
Barium	na	456 00	63 80	106 00	81 30	55 80	52 40	53 50	76 20	72 30	878 00	316 00	35 50	38 30	31 40
Cadmium	45 62	0 20	1 50	0 70	1 40	0 40	1 50	0.60	0.50	1.00	0 60	0 40	0 60	0 50	0 40
Chromium	na	10 60	8 60	9 40	8 30	5 30	6 10	3 10	5 10	5 40	6 10	5 70	4 00	4 60	4 30
Copper	16 27	9 80	17 70	7 80	13 10	14 90	13.00	11 40	11 0	16 70	14 00	12 40	13 60	10 10	12 30
Lead	140	2 60	1 40	2 20	1 80	1 30	1 50	<1.00	1 50	2.20	1 90	1.10	1 10	<1 00	<1 00
Zinc	98	3.60	26 50	15 60	1.50	3 50	1 50	4 60	4 80	<1 00	4 40	4 80	2 60	1 10	1.50
TPH	na	<100	<100	<100	<100	1,160	<100	<100	<100	<100	<100	<100	130	<100	<100

na = no criteria available

LM-2. The marine acute criterion (16.27 μg/L) for copper was exceeded at Stations LM-2 and LM-3 for water, and Stations LM-6, LM-8, REF1, LM-12, and LM-17 for elutriates Lead concentrations in the elutriates versus the water varied and no trends were evident The marine acute criterion (140 μg/L) for lead was not exceeded in any water or elutriate sample. Zinc concentrations in the water samples were numerically higher than those in the elutriate samples at all stations The marine acute (98 μg/L) criterion for zinc was exceeded in water samples from five stations (LM-6, BA-3, LM-8, LM-9, and LM-16), but in none of the elutriates Overall, four of the seven metals had the highest concentrations in water samples from Station LM-2. TPH was found in five water samples and five elutriate samples, with three being from the same stations (Tables 3 and 4) The TPH concentrations of 5,400 μg/L in water from Station LM-7, and 1,090 μg/L and 1,160 μg/L in elutriates from Stations LM-10 and LM-15, respectively, seem of an extreme nature in comparison to concentrations from all other stations With the exception of TPH, there were no organic compounds detected in the water and elutriate samples There were no apparent trends when comparing the results from the regular sampling and ultra-clean methods employed at Stations BA-5 and BA-6 (Table 3)

The exceedance of TWQS for copper in elutriate samples indicates a potential cause for concern. Using the tiered approach in the Green Book, this potential cause for concern is addressed by determining if the limiting permissible concentration (LPC) can be met by dilution The highest elutriate copper concentration in a GIWW sample is 25 5 μg/L at Station LM6 The average water copper concentration for REF1 and REF2 is 9 4 μg/L, while the acute marine TWQS for copper is 16.3 μg/L To meet the acute criterion for copper, a dilution of only 1 33 is needed, a very small dilution considering a water depth of greater than 40 feet, ocean dredged material placement sites ranging from 0 42 square nautical miles (Port Mansfield Channel, Brazos Island Harbor Channel) to 0 63 square nautical miles (Corpus Christi), and a 4-hour time period for initial dilution For example, appropriate modeling indicated that a dilution of 100,000 1 would be achieved in 3 5 hours in 12 feet of water in Galveston Bay (EH&A, 1995a)

The information noted above indicates that very little dilution would be needed to achieve the acute marine TWQS for the metal found above TWQS in the elutriates Therefore, the limiting permissible concentration (LPC) for the water column is not exceeded

Sediment concentrations of detected compounds plus grain size analyses are presented in Table 5 TOC, TPH, phenols, PCBs, and pesticides were below detection limits in all sediment samples except for TOC at Station LM1 (7.2 mg/kg) Ten metals were found in one or more of the sediment samples, as were total sulfide and ammonia-nitrogen Stations LM-1, REF1, and BA-6 each had the

TABLE 5

CONCENTRATIONS OF DETECTED COMPOUNDS (mg/kg)
SEDIMENT
LAGUNA MADRE

Parameter	LM-1	BA-1	LM-2	BA-2	LM-3	LM-4	LM-5	LM-6	LM-7	BA-3	LM-8	LM-9	LM-10	REF-1
Arsenic	0 66	2 20	1.75	5 00	1 84	2 19	4 68	3 60	2 36	4 59	2 28	2 31	0.21	4 75
Barium	63 90	69 00	225 00	215 00	114.00	260 00	266 00	39 90	274 00	205 00	188.00	136 00	38 30	10 10
Cadmium	<0 10	0 16	0 32	0 68	0 42	0 37	0 36	<0 10	<0 10	<0 10	40 10	<0 10	0 32	<0 10
Chromium	0 68	3 78	12 40	17 50	6.38	11 60	20 30	26 80	26 20	15 10	17 60	15 30	7 14	4 36
Copper	1 81	2 92	9 72	9 88	5 20	9 61	10 50	18 80	16 50	11 90	13 30	13 80	5 60	1 49
Lead	1 56	2 24	4 31	4 58	2 45	4 10	8 40	15 10	13 30	11 60	12.70	3 36	3 04	1 95
Mercury	<0 02	<0 02	<0 02	<0 02	<0 02	<0 02	<0 02	<0.02	<0 02	0.10	0 23	<0 02	0 05	<0 02
Nickel	2 72	2 28	8 26	9 29	4 29	5 86	12.00	17 00	17 00	12 30	13 70	12.20	5 53	1.27
Selenium	0 20	0 20	0 20	0 20	<0 20	<0 20	0 41	0 37	0 27	0 23	1 00	0 27	0 20	<0 20
Zinc	14.90	25 00	51.70	55.40	41 60	36 90	59 30	74 50	73 50	49.80	56 30	55 00	22 90	14 00
Total Sulfide	66.30	97 40	488 00	64 30	76 30	383 00	129 00	219.00	304 00	213.00	193 00	252 00	147.00	<0 10
Ammonia-N	2 34	3 75	56 80	82 60	4 55	31 40	52 10	273 00	240 00	208.00	217 00	378 00	31 50	2 26
% *Total Solids*	75 10	67 30	44 00	42 70	59 80	45 50	37 10	22 20	19 80	25 80	28 60	21 20	53 70	82 25
% *Volatile Solids*	1 31	2.26	3 54	3 32	2 60	3 90	4 48	3 74	4 19	4 07	4 07	4 46	3 60	1 11
% Sand	79 3	83 7	51 2	52 6	79.9	65 1	60 4	4.9	9 7	2 6	15 3	11 2	75.3	98 1
% Silt	17 7	8.9	30 4	40 3	18.4	28 7	10 9	85.5	74 9	85 0	68 0	83 8	19 5	1 7
% Clay	1 1	7.4	8 2	7 1	1 7	6 2	28 7	9 6	15 4	12 4	16 7	5 0	5 0	0 2

TABLE 5 (Concluded)

CONCENTRATIONS OF DETECTED COMPOUNDS (mg/kg)
SEDIMENT
LAGUNA MADRE

Parameter	LM-11	LM-12	LM-13	LM-14	LM-15	BA-4	LM-16	BA-5	LM-17	LM-18	LM-19	LM-20	BA-6	REF-2
Arsenic	583 00	4 64	5 56	11 40	2 31	4 67	1.51	2 60	2 50	2 73	5 11	3 99	383 00	4 65
Barium	58 00	91 00	94 80	80 40	54 70	114 00	73 10	125 00	121 00	164.00	97 40	174 00	22 10	57 20
Cadmium	<0 10	<0 10	0 31	<0 10	<0 10	10 00	0 18	<0 10	<0 10	<0 10	<0 10	<0 10	0 17	<0 10
Chromium	18 20	15 90	16 40	13 40	9 13	24 30	9 94	18 20	16 60	18 70	16 20	11 00	3 01	7 65
Copper	12 00	9 02	11 80	9 11	4 23	13 10	5 30	9 94	10 30	10 20	8.58	3 67	1 57	5.62
Lead	5.42	4 86	5 28	4 31	3 84	7 54	3 78	6 41	6 79	7 79	7 39	5 18	3 01	5 12
Mercury	<0 02	0 17	0 07	<0 02	<0 02	<0 02	<0 02	<0 02	<0 02	<0 02	<0 20	<0 02	0 08	0 07
Nickel	13 30	12 90	13 90	11 80	5 31	14 10	6 51	11 20	10 10	12 80	11 10	7 24	0 79	6 67
Selenium	0 20	0 20	<0 20	<0 20	<0 20	0 96	<0 20	<0.20	<0 20	<0 20	<0 20	<0 20	0 20	<0 20
Zinc	56.10	51 80	62 50	48.20	23 90	25.90	27 90	49 00	46 10	52.90	49 10	33.00	9 07	30 30
Total Sulfide	447 00	73 40	51 90	97 00	90 80	89 10	106.00	198 00	71 50	206 00	194 00	44 90	14 00	12 10
Ammonia-N	233.00	33 50	63 60	23.90	10 40	31 10	9.50	25 80	9 13	65 00	65 60	2.20	2 46	12 60
% *Total Solids*	31.30	36.50	38 63	43 31	78 90	50 40	56 28	53 60	53 90	42 70	44.56	56 30	74 81	77 20
% *Volatile Solids*	4 50	4 76	5 00	4 69	2 94	4 48	4 24	5 08	5 32	5 31	5 31	4 24	2 69	4 34
% Sand	14 6	20 6	8 4	34 6	32 2	56 0	54 6	36 6	34 8	18 0	26 8	65 8	52 9	67 4
% Silt	79 6	68.2	70 3	57 8	64 1	42 2	45 6	60.8	61 5	73 4	65 0	34 2	39 8	20.8
% Clay	5.8	11 2	21 3	7.6	3 7	1 8	0.0	2 6	3 7	8 6	8 2	0 0	7 3	11 8

lowest concentration of two of the ten metals Station LM-6 had the highest concentration of five of the ten metals, with Station LM-8 having the highest concentration of three metals In general, the highest concentrations of metals were found at the mouth of Baffin Bay south toward the land cut (Stations LM-6 through LM-9) As one might expect, these stations also exhibited the lowest percent sand and highest percent fines Notable concentrations of arsenic were detected at Station LM-11 (583 mg/kg) and Station BA-6 (383 mg/kg) Cadmium was also detected at notable concentrations at Station LM-8 (40 mg/kg) and Station BA-4 (10 mg/kg) There are no sediment criteria for which to compare these data, but the extreme nature of each in comparison with the other stations leads one to speculate that they may be aberrant values Station LM-2 had the highest total sulfide concentration and Station LM-9 had the most ammonia As with the metals data, the stations located in the vicinity of Baffin Bay toward the land cut demonstrated the highest total sulfide and ammonia concentrations, again possibly reflecting the respective grain size compositions

The only organics, except for the TOC at LM-1, detected in the sediment came from Stations LM-4 and BA-6 Pyrene was detected at Station LM-4 at a concentration of 84 μg/kg, while benzo(e)pyrene (105 μg/kg), pyrene (114 μg/kg), benzo(a)anthracene (56 μg/kg), benzo(b)fluoranthene (111 μg/kg), and benzo(k)fluoranthene (134 μg/kg) were detected at Station BA-6. The lack of TOC in these samples, considering the high sulfide and ammonia, indicative of reducing conditions, is surprising However, TOC is measured by Method 413 2 (SW-846), which determines total extractable organic carbon This includes freon-extractable materials such as petroleum products, hydrocarbons, oils, greases, fats, soaps, and waxes Decaying plant material is not readily extractable and might best be inferred from percent volatile solids, which ranged from 1 11 at REF-1 to 5 32 at LM-17.

3 3 BIOASSESSMENT STUDIES

3 3 1 Solid Phase Bioassays

Survival data from the solid phase bioassays and the bioaccumulation studies are presented in Tables 6 and 7, both by species and for total organisms for the upper (ULM) and lower (LLM) Laguna Madre, respectively, although no statistical analyses are pertinent for the bioaccumulation study organisms. The ranges of physical parameters and statistical analyses of the data are presented in Appendix B

Since neither Reference Control site was strictly applicable to either the ULM or the LLM, an average Reference Control survival was used for comparison to test survival. Survival in the tests

TABLE 6
THE NUMBER AND PERCENTAGES OF SURVIVING ORGANISMS
10-DAY SOLID PHASE BIOASSAYS & 28-DAY BIOACCUMULATION STUDY
UPPER LAGUNA MADRE

		Number of Survivors					
	Replicate (n=5)	True Control	Reference Control 1	Reference Control 2	BA1	BA2	BA3
A abdita	1	17	13	12	18	10	15
20/replicate	2	20	16	11	14	16	16
	3	20	9	5	12	18	17
	4	16	10	11	17	18	17
	5	18	14	12	17	18	18
	Average	18 2	12 4	10 2	15 6	16 0	16 6
	(%)	91 0%	62 0%	51 0%	78 0%	80 0%	83 0%
P pugio	1	20	20	19	20	20	20
20/replicate	2	20	19	20	20	20	20
	3	20	20	20	20	20	20
	4	20	20	20	20	20	20
	5	20	20	20	20	20	20
	Average	20 0	19 8	19 8	20 0	20 0	20 0
	(%)	100 0%	99 0%	99 0%	100 0%	100 0%	100 0%
Total Organisms	1	37	33	31	38	30	35
60/replicate	2	40	35	31	34	36	36
	3	40	29	25	32	38	37
	4	36	30	31	37	38	37
	5	38	34	32	37	38	38
	Average	38 2	32 2	30	35 6	36 0	36 6
	(%)	95 5%	80 5%	75 0%	89 0%	90 0%	91 5%
N virens	1	17	13	13	18	10	15
20/replicate	2	20	16	16	14	16	16
	3	20	9	9	12	18	17
	4	16	10	10	17	18	17
	5	18	14	14	17	18	18
	Average	18 2	12 4	12 4	15 6	16 0	16 6
	(%)	91 0%	62 0%	62 0%	78 0%	80 0%	83 0%
M nasuta	1	20	20	17	20	20	20
20/replicate	2	20	19	17	20	20	20
	3	20	20	14	20	20	20
	4	20	20	22	20	20	20
	5	20	20	18	20	20	20
	Average	20 0	19 8	17 6	20 0	20 0	20 0
	(%)	100 0%	99 0%	70 4%	100 0%	100 0%	100 0%

TABLE 7
THE NUMBER AND PERCENTAGES OF SURVIVING ORGANISMS
10-DAY SOLID PHASE BIOASSAYS & 28-DAY BIOACCUMULATION STUDY
LOWER LAGUNA MADRE

		Number of Survivors					
	Replicate (n=5)	True Control	Reference Control 1	Reference Control 2	BA4	BA5	BA6
A abdita	1	16	13	12	7	17	7
20/replicate	2	20	16	11	3	5	11
	3	18	9	5	10	10	7
	4	18	10	11	11	11	12
	5	18	14	12	5	11	8
	Average	18 0	12 4	10 2	7 2	10 8	9 0
	(%)	90 0%	62 0%	51 0%	36 0%	54 0%	45 0%
P pugio	1	20	20	19	20	20	20
20/replicate	2	20	19	20	20	20	20
	3	20	20	20	20	20	20
	4	20	20	20	20	20	20
	5	20	20	20	20	20	20
	Average	20 0	19 8	19 8	20 0	20 0	20 0
	(%)	100 0%	99 0%	99 0%	100 0%	100 0%	100 0%
Total Organisms	1	36	33	31	27	37	27
60/replicate	2	40	35	31	23	25	31
	3	38	29	25	30	30	27
	4	38	30	31	31	31	32
	5	38	34	32	25	31	28
	Average	38 0	32 2	30 0	27 2	30 8	29 0
	(%)	95 0%	80 5%	75 0%	68 0%	77 0%	72 5%
N virens	1	17	13	13	18	10	15
20/replicate	2	20	16	16	14	16	16
	3	20	9	9	12	18	17
	4	16	10	10	17	18	17
	5	18	14	14	17	18	18
	Average	18 2	12 4	12 4	15 6	16	16 6
	(%)	91 0%	62 0%	62 0%	78 0%	80 0%	83 0%
M nasuta	1	17	20	17	13	13	18
20/replicate	2	20	19	17	20	17	10
	3	15	20	14	5	16	16
	4	14	20	22	14	22	19
	5	14	20	18	9	15	22
	Average	16	19 8	17 6	12 2	16 6	17
	(%)	64 0%	99 0%	70 4%	48 8%	66 4%	68 0%

with the ULM sediments was not lower than survival in the Reference Control in any instance (Table 6) Survival in the tests with the LLM sediments was lower than survival in the Reference Control in six instances (Table 7) all stations for *A abdita* and for total organisms The difference between Reference Control mean survival and test mean survival for *A abdita* at Station BA-4 was >20% (Green Book, Sec 2 8 1) and statistical analyses were required (Appendix B, Table B-2) The Bonferroni t-test indicated that there was a significant difference among mean survival in the Reference Control and in Station BA-4 sediment Therefore, the LPC for benthic toxicity is not met (Green Book, Sec 6.2)

Therefore, the data from the solid phase bioassay indicate a potential for environmentally unacceptable lethal impacts on benthic organisms from the placement of some LLM sediments. However, it should be noted that survival in REF2 and all of the LLM stations was low for *A. abdita*, the difference between Station BA-4 survival and the average Reference Control survival was 20 5% versus a cutoff-value of 20%, and the difference between the tabulated and calculated t-values was small.

3 3 2 Bioaccumulation

No organic chemicals were found above detection limits in test organism tissues. Of the metals, arsenic, barium, chromium, copper, lead, nickel, and zinc were found in tissue samples above detection limits The concentrations of detected metals in the tissue samples can be found in Tables 8 through 11, excepting silver (silver was detected once at 0 10 mg/kg versus a detection limit of 0.10 mg/kg, in one replicate of *N. virens* exposed to Station BA-6 sediment, but these data were not subjected to statistical analysis) The range of physical parameters in the 28-day study can be found in Appendix C (Table C-1) As was done for the solid phase survival data, the ULM and LLM test stations for *N virens* were compared to the average mean of both REF1 and REF2 because the tests were conducted simultaneously with the same group of organisms The ULM test stations (BA-1, BA-2, and BA-3) for *M. nasuta* were compared to REF1 while the LLM test stations (BA-4, BA-5, and BA-6) for *M. nasuta* were compared to REF2 because the tests were conducted on separate dates and with separate groups of organisms This is evident in the statistical analysis tables in Appendix C where there are 10 replicates for the Reference Control on Tables C-2 through C-9, but only five in Tables C-10 through C-14.

The concentrations of barium (Stations BA-1, BA-5, and BA-6) and chromium (Station BA-5) in tissues of *N virens* were significantly higher than the respective concentrations in Reference Control organisms (Tables 8 and 9, Appendix C, Tables C-2 through C-9) However, the concentration of barium in *N virens* tissues exposed to test sediments was not significantly higher than in archive tissue

TABLE 8
CONCENTRATIONS OF DETECTED COMPOUNDS
IN TISSUE SAMPLES OF
N virens
UPPER LAGUNA MADRE

Parameter	Replicate	STATION						
		True Control	Reference Control 1		Reference Control 2	BA-1	BA-2	BA-3	Background
Metals (mg/kg)									
Arsenic	1	1 390	1 220		1 140	0 940	1 140	1 020	1 410
	2	1 200	1 260		1 100	1 180	1 030	1 090	1 600
	3	0 980	1 510		1 240	1 000	1 050	0 890	1 420
	4	1 310	1 220		1 240	0 790	0 840	0 960	1 450
	5	0 990	1 260		1 530	0 740	1 160	0 650	1 430
	Total	5 870	6 470	AVG	6 250	4 650	5 220	4 610	7 310
	Average	1 174	1 294	1 272	1 250	0 930	1 044	0 922	1 462
		Parameter concentration in test tissues are not greater than in reference tissues therefore no statistical analyses of the data are required							
Barium	1	0 370	0 330		0 290	0 830	0 420	0 610	0 660
	2	0 350	0 360		0 350	0 380	0 630	0 260	0 780
	3	0 250	0 270		0 490	0 850	0 410	0 350	0 590
	4	0 580	0 350		0 460	0 890	0 310	0 230	0 430
	5	0 300	0 340		0 440	0 520	0 300	0 280	0 750
	Total	1 850	1 650	AVG	2 030	3 470	2 070	1 730	3 210
	Average	0 370	0 330	0 368	0 406	0 694	0 414	0 346	0 642
		Parameter concentration in test tissues are greater than in reference tissues therefore statistical analyses of the data are required							
Chromium	1	0 200	0 190		0 140	0 280	0 200	0 220	0 430
	2	0 170	0 160		0 270	0 130	0 140	0 100	0 440
	3	0 100	0 110		0 220	1 940	0 140	0 170	0 390
	4	0 270	0 230		0 140	0 300	0 180	0 120	0 250
	5	0 130	0 190		0 160	1 250	0 100	0 100	0 350
	Total	0 870	0 880	AVG	0 930	3 900	0 760	0 710	1 860
	Average	0 174	0 176	0 181	0 186	0 780	0 152	0 142	0 372
		Parameter concentration in test tissues are greater than in reference tissues therefore statistical analyses of the data are required							
Copper	1	2 430	1 330		1 880	2 620	2 050	2 250	2 370
	2	1 740	3 680		2 110	1 290	1 570	1 780	2 380
	3	1 540	1 490		2 730	2 950	1 710	1 700	1 760
	4	1 670	1 250		1 940	2 340	1 640	1 090	1 460
	5	1 550	2 930		1 630	1 170	1 050	0 970	1 720
	Total	8 930	10 680	AVG	10 290	10 370	8 020	7 790	9 690
	Average	1 786	2 136	2 097	2 058	2 074	1 604	1 558	1 938
		Parameter concentration in test tissues are not greater than in reference tissues, therefore no statistical analyses of the data are required							
Nickel	1	0 470	0 350		0 220	0 280	0 270	0 250	0 340
	2	0 360	0 320		0 350	0 110	0 320	0 140	0 290
	3	0 420	2 440		0 360	0 180	0 250	0 190	0 290
	4	0 220	0 290		0 320	0 260	0 230	0 140	0 170
	5	0 310	0 390		0 300	0 380	0 100	0 120	0 250
	Total	1 780	3 790	AVG	1 550	1 210	1 170	0 840	1 340
	Average	0 356	0 758	0 534	0 310	0 242	0 234	0 168	0 268
		Parameter concentration in test tissues are not greater than in reference tissues therefore no statistical analyses of the data are required							

TABLE 8
CONCENTRATIONS OF DETECTED COMPOUNDS
IN TISSUE SAMPLES OF
N virens
UPPER LAGUNA MADRE

Parameter	Replicate	STATION						
		True Control	Reference Control 1		Reference Control 2	BA-1	BA-2	BA-3	Background
Metals (mg/kg)									
Zinc	1	38 30	9 70		37 90	26 20	20 20	6 91	10 30
	2	29 00	8 07		38 20	49 70	14 00	21 70	26 30
	3	15 00	7 24		8 22	10 20	9 49	13 40	11 80
	4	20 30	7 40		24 30	26 90	34 40	10 40	17 40
	5	6 55	42 20		14 10	12 50	18 10	6 33	23 50
	Total	109 15	74 61	AVG	122 72	125 50	96 19	58 74	89 30
	Average	21 83	14 92	19 73	24 54	25 10	19 24	11 75	17 86

Parameter concentration in test tissues are greater than in reference tissues, therefore statistical analyses of the data are required

TABLE 9
CONCENTRATIONS OF DETECTED COMPOUNDS
IN TISSUE SAMPLES OF
N virens
LOWER LAGUNA MADRE

Parameter	Replicate	STATION						
		True Control	Reference Control 1		Reference Control 2	BA-4	BA-5	BA-6	Background
Metals (mg/kg)									
Arsenic	1	1 950	1 220		1 140	NA	1 280	1 390	1 590
	2	1 860	1 260		1 100	1 210	1 290	1 280	1 330
	3	1 510	1 510		1 240	1 050	1 560	1 250	1 370
	4	1 170	1 220		1 240	1 360	1 320	0 970	1 400
	5	1 770	1 260		1 530	1 110	1 150	1 090	1 560
	Total	8 260	6 470	AVG	6 250	4 730	6 600	5 980	7 250
	Average	1 652	1 294	1 272	1 250	1 183	1 320	1 196	1 450
		Parameter concentration in test tissues are greater than in reference tissues, therefore, statistical analyses of the data are required							
Barium	1	0 510	0 330		0 290	NA	0 900	0 630	0 630
	2	0 400	0 360		0 350	0 340	0 450	0 530	0 250
	3	0 620	0 270		0 490	0 630	1 240	0 430	0 300
	4	0 220	0 350		0 460	0 460	0 860	1 430	0 390
	5	0 290	0 340		0 440	0 420	6 690	0 440	0 540
	Total	2 040	1 650	AVG	2 030	1 850	10 140	3 460	2 110
	Average	0 408	0 330	0 368	0 406	0 463	2 028	0 692	0 422
		Parameter concentration in test tissues are greater than in reference tissues therefore, statistical analyses of the data are required							
Chromium	1	0 280	0 190		0 140	NA	0 250	0 260	0 370
	2	0 370	0 160		0 270	0 110	0 210	0 270	0 170
	3	0 230	0 110		0 220	0 240	0 360	0 220	0 240
	4	0 100	0 230		0 140	0 200	0 290	0 290	0 210
	5	0 170	0 190		0 160	0 190	0 210	0 100	0 260
	Total	1 150	0 880	AVG	0 930	0 740	1 320	1 140	1 250
	Average	0 230	0 176	0 181	0 186	0 185	0 264	0 228	0 250
		Parameter concentration in test tissues are greater than in reference tissues therefore, statistical analyses of the data are required							
Copper	1	2 310	1 330		1 880	NA	1 710	1 440	2 310
	2	2 500	3 680		2 110	1 130	2 480	2 020	1 740
	3	2 300	1 490		2 730	1 940	1 760	1 940	1 370
	4	0 910	1 250		1 940	2 120	1 500	2 720	1 430
	5	2 490	2 930		1 630	3 330	2 290	1 300	1 460
	Total	10 510	10 680	AVG	10 290	8 520	9 740	9 420	8 310
	Average	2 102	2 136	2 097	2 058	2 130	1 948	1 884	1 662
		Parameter concentration in test tissues are greater than in reference tissues therefore statistical analyses of the data are required							
Nickel	1	0 530	0 350		0 220	NA	0 310	0 410	0 500
	2	0 590	0 320		0 350	0 320	0 270	0 260	0 210
	3	0 620	2 440		0 360	0 340	0 480	1 810	0 250
	4	0 310	0 290		0 320	0 220	0 420	0 330	0 270
	5	0 600	0 390		0 300	0 290	0 290	0 250	0 180
	Total	2 650	3 790	AVG	1 550	1 170	1 770	3.060	1 410
	Average	0 530	0 758	0 534	0 310	0 293	0 354	0 612	0 282
		Parameter concentration in test tissues are greater than in reference tissues, therefore statistical analyses of the data are required							

TABLE 9
CONCENTRATIONS OF DETECTED COMPOUNDS
IN TISSUE SAMPLES OF
N virens
LOWER LAGUNA MADRE

Parameter	Replicate	STATION							
		True Control	Reference Control 1		Reference Control 2	BA-4	BA-5	BA-6	Background
Metals (mg/kg)									
Zinc	1	10 00	9 70		37 90	NA	16 80	15 70	23 00
	2	17 60	8 07		38 20	11 90	7 54	7 39	49 30
	3	22 30	7 24		8 22	25 10	2 76	24 00	11 40
	4	4 48	7 40		24 30	8 17	23 00	6 55	13 90
	5	20 30	42 20		14 10	22 90	8 13	24 40	29 30
	Total	74 68	74 61	AVG	122 72	68 07	58 23	78 04	126 90
	Average	14 94	14 92	19 733	24 54	17 02	11 65	15 61	25 38
		Parameter concentration in test tissues are not greater than in reference tissues therefore, no statistical analyses of the data are required							

NA = Not sufficient tissue for analysis

TABLE 10
CONCENTRATIONS OF DETECTED COMPOUNDS
IN TISSUE SAMPLES OF
M nasuta
UPPER LAGUNA MADRE

Parameter	Replicate	STATION					
		True Control	Reference Control 1	BA-1	BA-2	BA-3	Background
Metals (mg/kg)							
Arsenic	1	2 480	2 220	1 880	1 820	1 510	2 500
	2	2 580	2 040	1 920	1 790	1 490	2 500
	3	2 420	1 940	1 990	1 700	1 090	2 450
	4	2 440	1 790	2 060	1 430	1 380	2 320
	5	2 420	2 110	2 050	1 570	1 070	2 480
	Total	12 340	10 100	9 900	8 310	6 540	12 250
	Average	2 468	2 020	1 980	1 662	1 308	2 450
		Parameter concentration in test tissues are not greater than in reference tissues therefore no statistical analyses of the data are required					
Barium	1	0 360	1 360	1 730	0 760	0 830	0 610
	2	0 340	1 580	2 370	1 480	1 100	0 370
	3	0 580	1 360	1 940	1 820	0 680	0 420
	4	0 380	2 420	2 700	2 250	0 580	0 400
	5	0 460	0 870	3 850	2 560	0 760	0 330
	Total	2 120	7 590	12 590	8 870	3 950	2 130
	Average	0 424	1 518	2 518	1 774	0 790	0 426
		Parameter concentration in test tissues are greater than in reference tissues therefore statistical analyses of the data are required					
Chromium	1	0 270	0 340	0 100	0 150	0 310	0 270
	2	0 260	0 450	0 280	0 130	1 770	0 120
	3	0 230	0 430	0 270	0 190	0 200	0 200
	4	0 200	0 310	0 210	0 260	0 110	0 130
	5	3 170	0 340	0 500	0 260	0 150	0 140
	Total	4 130	1 870	1 360	0 990	2 540	0 860
	Average	0 826	0 374	0 272	0 198	0 508	0 172
		Parameter concentration in test tissues are greater than in reference tissues therefore statistical analyses of the data are required					
Copper	1	2 070	3 540	1 130	0 960	3 090	3 030
	2	4 160	4 640	2 430	1 700	2 090	3 440
	3	1 300	5 040	1 690	2 100	2 160	1 990
	4	1 860	3 490	1 690	2 420	1 000	1 600
	5	1 630	2 540	5 420	2 450	1 650	1 510
	Total	11 020	19 250	12 360	9 630	9 990	11 570
	Average	2 204	3 850	2 472	1 926	1 998	2 314
		Parameter concentration in test tissues are not greater than in reference tissues therefore, no statistical analyses of the data are required					
Lead	1	0 100	0 120	0 150	0 100	0 100	0 200
	2	0 100	0 120	0 180	0 140	0 120	0 200
	3	0 100	0 180	0 130	0 120	0 110	0 160
	4	0 110	0 130	0 130	0 140	0 100	0 190
	5	0 120	0 160	0 180	0 130	0 100	0 200
	Total	0 530	0 710	0 770	0 630	0 530	0 950
	Average	0 106	0 142	0 154	0 126	0 106	0 190
		Parameter concentration in test tissues are greater than in reference tissues therefore statistical analyses of the data are required					

TABLE 10
CONCENTRATIONS OF DETECTED COMPOUNDS
IN TISSUE SAMPLES OF
M nasuta
UPPER LAGUNA MADRE

Parameter	Replicate	STATION					
		True Control	Reference Control 1	BA-1	BA-2	BA-3	Background
Metals (mg/kg)							
Nickel	1	0 490	0 640	2 550	0 440	0 540	0 460
	2	0 440	0 670	0 650	0 410	0 470	0 530
	3	0 520	0 620	0 510	0 470	0 440	0 410
	4	0 460	0 620	0 610	0 620	0 460	0 480
	5	0 610	0 570	0 750	0 570	0 590	0 460
	Total	2 520	3 120	5 070	2 510	2 500	2 340
	Average	0 504	0 624	1 014	0 502	0 500	0 468
		Parameter concentration in test tissues are greater than in reference tissues therefore statistical analyses of the data are required					
Zinc	1	7 29	11 60	6 43	6 50	8 17	15 00
	2	7 02	9 51	9 87	8 05	7 89	9 13
	3	7 54	10 10	9 25	8 85	9 62	9 90
	4	7 87	8 78	8 87	7 33	7 35	9 70
	5	7 75	9 00	10 00	7 26	6 82	9 78
	Total	37 47	48 99	44 42	37 99	39 85	53 51
	Average	7 49	9 80	8 88	7 60	7 97	10 70
		Parameter concentration in test tissues are not greater than in reference tissues therefore, no statistical analyses of the data are required					

TABLE 11
CONCENTRATIONS OF DETECTED COMPOUNDS
IN TISSUE SAMPLES OF
M nasuta
LOWER LAGUNA MADRE

Parameter	Replicate	STATION					
		True Control	Reference Control 2	BA-4	BA-5	BA-6	Background
Metals (mg/kg)							
Arsenic	1	1 300	1 200	1 590	1 010	1 870	1 000
	2	1 180	1 160	1 340	0 870	2 010	1 220
	3	1 220	1 520	0 740	1 000	1 820	1 260
	4	1 330	1 440	1 060	1 140	NA	1 340
	5	1 850	2 950	0 900	0 950	1 590	1 550
	Total	6 880	8 270	5 630	4 970	7 290	6 370
	Average	1 376	1 654	1 126	0 994	1 823	1 274
		Parameter concentration in test tissues are greater than in reference tissues therefore statistical analyses of the data are required					
Barium	1	0 360	1 910	0 400	0 900	1 420	0 220
	2	0 350	3 980	1 090	4 950	2 790	0 220
	3	0 340	4 010	0 300	0 670	3 360	0 230
	4	0 370	2 620	1 280	1 430	NA	0 190
	5	0 480	7 110	0 670	0 780	4 240	0 200
	Total	1 900	19 630	3 740	8 730	11 810	1 060
	Average	0 380	3 926	0 748	1 746	2 953	0 212
		Parameter concentration in test tissues are not greater than in reference tissues therefore, no statistical analyses of the data are required					
Cadmium	1	0 100	0 100	0 100	0 100	0 100	0 100
	2	0 100	0 100	0 100	0 100	0 100	0 100
	3	0 100	0 100	0 100	0 100	0 110	0 100
	4	0 100	0 100	0 100	0 100	NA	0 100
	5	0 100	0 120	0 100	0 100	0 100	0 100
	Total	0 500	0 520	0 500	0 500	0 410	0 500
	Average	0 100	0 104	0 100	0 100	0 103	0 100
		Parameter concentration in test tissues are not greater than in reference tissues therefore no statistical analyses of the data are required					
Chromium	1	0 270	0 320	0 460	0 590	0 410	0 180
	2	0 180	1 230	0 350	0 230	0 350	0 180
	3	0 350	1 240	0 310	0 510	0 580	1 490
	4	0 570	0 630	0 530	0 220	NA	0 200
	5	0 690	1 540	0 290	0 210	0 780	0 200
	Total	2 060	4 960	1 940	1 760	2 120	2 250
	Average	0 412	0 992	0 388	0 352	0 530	0 450
		Parameter concentration in test tissues are not greater than in reference tissues, therefore no statistical analyses of the data are required					
Copper	1	3 900	2 430	5 420	5 710	3 220	2 620
	2	5 540	8 940	4 300	1 270	2 570	2 630
	3	9 980	9 010	5 430	4 300	3 080	2 050
	4	6 240	6 690	4 280	1 000	NA	2 850
	5	22 400	14 800	1 820	1 260	5 840	2 550
	Total	48 060	41 870	21 250	13 540	14 710	12 700
	Average	9 612	8 374	4 250	2 708	3 678	2 540
		Parameter concentration in test tissues are not greater than in reference tissues therefore no statistical analyses of the data are required					

TABLE 11
CONCENTRATIONS OF DETECTED COMPOUNDS
IN TISSUE SAMPLES OF
M nasuta
LOWER LAGUNA MADRE

Parameter	Replicate	STATION					
		True Control	Reference Control 2	BA-4	BA-5	BA-6	Background
Metals (mg/kg)							
Lead	1	0 100	0 100	0 100	0 100	0 120	0 120
	2	0 100	0 120	0 100	0 100	0 140	0 110
	3	0 100	0 180	0 100	0 100	0 140	0 130
	4	0 100	0 130	0 100	0 100	NA	0 120
	5	0 100	0 330	0 100	0 100	0 120	0 130
	Total	0 500	0 860	0 500	0 500	0 520	0 610
	Average	0 100	0 172	0 100	0 100	0 130	0 122
		Parameter concentration in test tissues are not greater than in reference tissues, therefore no statistical analyses of the data are required					
Nickel	1	0 690	0 710	0 510	0 670	0 680	0 420
	2	0 580	1 010	0 740	0 600	0 740	0 420
	3	0 610	1 020	0 500	0 590	1 000	0 450
	4	0 780	0 580	0 540	0 670	NA	0 500
	5	1 050	1 570	0 460	0 580	0 680	0 460
	Total	3 710	4 890	2 750	3 110	3 100	2 250
	Average	0 742	0 978	0 550	0 622	0 775	0 450
		Parameter concentration in test tissues are not greater than in reference tissues therefore no statistical analyses of the data are required					
Zinc	1	13 30	14 00	12 80	13 30	17 30	12 30
	2	14 70	13 00	15 00	9 76	15 00	14 90
	3	14 90	13 10	6 69	13 90	15 80	15 10
	4	14 60	11 20	9 96	14 80	NA	14 00
	5	14 50	25 90	11 60	13 10	11 70	15 40
	Total	72 00	77 20	56 05	64 86	59 80	71 70
	Average	14 40	15 44	11 21	12 97	14 95	14 34
		Parameter concentration in test tissues are not greater than in reference tissues therefore no statistical analyses of the data are required					

NA = Not sufficient tissue for analysis

(Appendix C, Tables C2a and C6a). Also, the concentration of chromium in *N. virens* tissues exposed to test sediments was not significantly higher than in archive tissue (Appendix C, Tables C3a and C7a)

The mean concentration of barium in tissues of *M. nasuta* exposed to BA-1 sediments was significantly higher than the mean concentration in the Reference Control clams (Appendix C, Table C-10) Comparison was not made to True Control and Archive tissue concentration means since those means were numerically lower than the Reference Control mean.

For barium, there is no FDA Action Level with which to compare results In most natural waters, there is sufficient sulfate or carbonate to precipitate the barium present in the water as a virtually insoluble, non-toxic compound (EPA, 1986) Recognizing that the physical and chemical properties of barium generally will preclude the existence of the toxic soluble form under usual marine conditions, a restrictive criterion for aquatic life appears unwarranted (EPA, 1986) As with barium, chromium has no FDA Action Level. The reason that chromium has no FDA Action Level is because of its essentialness in the human diet and low toxicity (Kramer, 1994).

The Green Book (Section 6 3) and the Regional Implementation Agreement (RIA) note two initial possibilities when examining bioaccumulation data where concentrations of contaminants are detected in tissue samples:

1 The concentrations are significantly greater than FDA Action Levels and, thus, the LPC for bioaccumulation is exceeded,

2 The concentrations are not significantly greater than FDA Action Levels or there are no FDA Action Levels and, therefore, there is insufficient information to determine if the LPC for bioaccumulation is exceeded

In the latter case, the tissue concentrations of organisms exposed to test sediments and reference sediments are compared statistically If there is no significant difference, the LPC is not exceeded. If the test tissues contain significantly greater concentrations than the reference tissues (Factor 1), the additional following factors are assessed by the EPA and USACE to evaluate the LPC on a case by case basis. The RIA notes that the EPA and USACE will evaluate factors 2-4 below first and if a determination on the LPC can not be reached at that point, factors 5-8 will be evaluated If a compliance decision still can not be reached, a sampling plan will be developed and agreed upon by the EPA and USACE to address Factor 9.

FACTOR

2 Magnitude by which bioaccumulation from the dredged material exceeds bioaccumulation from the reference material

The means of barium in *N. virens* tissues for which significance was determined varied from 0.692 mg/kg to 2.028 mg/kg versus means of 0.368 mg/kg and 0.532 mg/kg for the Reference Control and archive samples, respectively. The only mean for chromium in *N. virens* tissues which was significantly different from the Reference Control mean (0.181 mg/kg) was 0.264 mg/kg for BA-5 whereas the archive mean was 0.311 mg/kg. FDA levels of concern for chromium for edible shellfish range from 11-13 mg/kg. The only mean for barium in *M. nasuta* tissues which was significantly different from the Reference Control mean (1.518 mg/kg) was 2.518 mg/kg for BA-1.

3. Number of contaminants for which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material

Only two (nontoxic) contaminants were accumulated from the 49 for which analyses were conducted

4 Number of species in which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material

One of two species exhibited accumulation of chromium, both species exhibited accumulation of barium. However, only barium in *M. nasuta* tissues was significantly greater than both Reference Control tissues and archive sample tissues.

5 Toxicological importance of the contaminants whose bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material

As noted in Section 3.3.1, barium and chromium do not have FDA Action Levels because (1) the physical and chemical properties of barium generally preclude the existence of the toxic soluble form, and (2) chromium is essential to the human diet

and exhibits low toxicity. Additionally, a barium compound solution is ingested by persons before gastro-intestinal tract x-rays.

6. Phylogenetic diversity of the species in which bioaccumulation from the dredged material statistically exceeds bioaccumulation from the reference material

The burrowing polychaete, *N. virens*, exhibited bioaccumulation versus the Reference Control but not archive samples while the filter-feeding clam, *M. nasuta*, exhibited bioaccumulation of barium, at one station, relative to both.

7 Propensity for the contaminants with statistically significant bioaccumulation to biomagnify within aquatic food webs.

Significant biomagnification of chromium and barium is not likely. F. Prosi (in Forstner and Whitman, 1979) states, "Detritus-, sediment-, and filter-feeding organisms could be affected by heavy metals occurring in their environment. Nevertheless, these organisms apparently only transfer a small amount of their metal content to the higher levels of the food chain..." Prosi presents biomagnification factors of only 1.4 to 1.9 for lead from sediment-associated benthos to carnivorous nekton. No numbers are presented for barium or chromium.

8 Magnitude of toxicity and number and phylogenetic diversity of the species exhibiting greater mortality in the dredged material than in the reference material

As noted in Section 3.3.1, no toxicity was exhibited by the grass shrimp, *P. pugio*. Toxicity was exhibited by the burrowing amphipod, *A. abdita*.

9 Magnitude by which contaminants whose bioaccumulation from the dredged material exceeds that from the reference material also exceeds the concentrations found in comparable species living in the vicinity of the proposed disposal site

This factor is to be used only if agreement between the EPA and USACE cannot be reached based on the first eight factors and a field study must be designed and executed. It is the opinion of EH&A that since *N. virens* exhibited no bioaccumulation above archive tissue levels and since the only metal accumulated in *M. nasuta* tissues

was barium, the first eight factors indicate that significant ecological impacts would not be expected from the bioaccumulation exhibited by these bioaccumulation studies and, therefore, that a field study under Factor 9 is not necessary. Further, discussion of this factor is beyond the scope of this report.

The concentrations of none of the metals in tissues of *M nasuta* exposed to test sediments were significantly higher than the respective concentrations in Reference Control organisms, with the exception of Station BA-1 for barium (Tables 10 and 11, Appendix C, Tables C-12 through C-16). The concentrations of none of the metals in the tissues of *N. virens* exposed to test sediments were significantly higher than Reference Control tissues and archive tissues This indicates that there was not bioaccumulation of chromium and barium in *N. virens* exposed to test sediment, there was less depuration than there was in Reference Control organisms Bioaccumulation was only shown for barium in one species from one station and barium has no FDA Action Level because the physical and chemical properties of barium generally preclude the existence of the toxic soluble form under usual marine conditions (EPA, 1986) The FDA does not have a Guidance Document for barium

4.0 SUMMARY

Chemical analyses were conducted on water, elutriate, and sediment samples from 26 stations in the GIWW through the Laguna Madre and on samples from reference stations. Additionally, solid phase bioassays and bioaccumulation studies were conducted on sediment from six test stations, on Reference Control sediment, on a True Control (clean beach sand), and archive samples

The following summarizes the results of these studies:

1) Results of chemical analyses on the water and elutriate samples indicate a potential cause for concern from concentrations of copper in elutriate samples that exceed the TWQS for the protection of aquatic life However, an analysis of the dilution required to achieve the TWQS indicated that the LPC for the water column is not exceeded.

2) TPH, phenols, PCBs and pesticides were below detection limits in all sediment samples Detected metals in the sediment were not noticeably different from the reference samples with the exception of a limited number of extremely high values for arsenic and cadmium The only apparent trend was the increasing concentrations of metals, total sulfide, and ammonia-nitrogen in relation to increases in percent fines at the mouth of Baffin Bay south towards the land cut

3) Survival of organisms exposed to test sediments in the solid phase bioassays was not significantly different from survival of organisms exposed to the solid phase of the reference control, except for survival of *A. abdita* exposed to sediments from Station BA-4

4) Uptake of barium, at Station BA-1, was shown in *M nasuta* relative to Reference Control tissues The mean concentrations of barium (Stations BA-1, BA-5, and BA-6) and chromium (Station BA-5) in tissues of *N virens* were significantly higher than the respective average means in tissues from Reference Control and True Control, but not archive organisms.

In conclusion, the water and elutriate chemistry results given here provide a potential cause for concern to the water column of the designated placement areas due to the exceedances of TWQS for

copper. The solid phase bioassay results reported here indicate that the LPC for benthic toxicity is not met for *A abdita* exposed to Station BA-4 sediments Bioaccumulation appeared to occur for barium and chromium in *N. virens* tissues and did occur for barium in *M nasuta* tissues. Based on a strict interpretation of the guidance given in the Green Book, the authors of this report cannot conclude that reasonable assurance is given that significant ecological impacts could not result from the ocean placement of the test sediments, notwithstanding the facts that (1) only a small dilution will reduce the copper concentration to below the TWQS, (2) the toxicity exhibited by the solid phase was slight, and (3) the barium and chromium accumulation would not indicate a concern. However, had the LPC for benthic toxicity been met, the conclusion that significant ecological impacts would not likely result from the ocean placement of the test sediments would have been justified. Therefore, it would appear that additional solid phase bioassays with sediment from Station BA-4 would be necessary to determine the acceptability of Station BA-4 sediment for ocean placement.

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APPENDIX A
CHEMICAL METHODS

TABLE A-1

ANALYTICAL METHODOLOGY AND MINIMUM DETECTION LIMITS

Parameter	Detection Limit	EPA Method	Detection Limit	EPA Method
	Sediment		Water/Elutriate	
METALS				
Arsenic	100 µg/kg	7060	1 0 µg/L	206.2
Barium	100 µg/kg	7080	1 0 µg/L	210 2
Cadmium	100 µg/kg	7131	0 1 µg/L	213 2
Chromium	100 µg/kg	7191	1.0 µg/L	218 2
Copper	100 µg/kg	7211	1.0 µg/L	220 2
Lead	100 µg/kg	7421	1.0 µg/L	239.2
Mercury	200 µg/kg	7471	0.2 µg/L	245 1
Nickel	100 µg/kg	7521	1.0 µg/L	249 2
Selenium	200 µg/kg	7740	2 0 µg/L	270.2
Silver	100 µg/kg	7761	1 0 µg/L	272 2
Zinc	100 µg/kg	7951	1 0 µg/L	289 2
PESTICIDES				
Aldrin	10 µg/kg	8080	0.04 µg/L	608
Alpha-BHC	10 µg/kg	8080	0 02 µg/L	608
Beta-BHC	10 µg/kg	8080	0 02 µg/L	608
Gamma-BHC	10 µg/kg	8080	0.02 µg/L	608
Delta-BHC	10 µg/kg	8080	0.02 µg/L	608
Chlordane	10 µg/kg	8080	0.14 µg/L	608
p,p'-DDD	10 µg/kg	8080	0.12 µg/L	608
p,p'-DDE	10 µg/kg	8080	0 12 µg/L	608
p,p'-DDT	10 µg/kg	8080	0.12 µg/L	608
Dieldrin	10 µg/kg	8080	0.02 µg/L	608
Endosulfan I	20 µg/kg	8080	0.14 µg/L	608
Endosulfan II	20 µg/kg	8080	0 14 µg/L	608
Endosulfan Sulfate	20 µg/kg	8080	0 14 µg/L	608
Endrin	10 µg/kg	8080	0 06 µg/L	608
Endrin Aldehyde	10 µg/kg	8080	0 06 µg/L	608
Heptachlor	20 µg/kg	8080	0 03 µg/L	608
Heptachlor Epoxide	20 µg/kg	8080	0 03 µg/L	608
Toxaphene	50 µg/kg	8080	0 50 µg/L	608

TABLE A-1 (Continued)

Parameter	Detection Limit	EPA Method	Detection Limit	EPA Method
	Sediment		Water/Elutriate	
PAHs				
Acenaphthene	30 µg/kg	8270	2 00 µg/L	625
Acenaphthalene	30 µg/kg	8270	2.00 µg/kg	625
Anthracene	30 µg/kg	8270	0.50 µg/L	625
Benzo(a)anthracene	30 µg/kg	8270	1.00 µg/L	625
Benzo(b)fluoranthene	30 µg/kg	8270	0 10 µg/L	625
Benzo(k)fluoranthene	30 µg/kg	8270	0 10 µg/L	625
Benzo(ghi)perylene	30 µg/kg	8270	0 10 µg/L	625
Benzo(a)pyrene	30 µg/kg	8270	0 50 µg/L	625
Benzo(e)pyrene	30 µg/kg	8270	0.50 µg/L	625
Chrysene	30 µg/kg	8270	0.50 µg/L	625
Dibenzo(ah)anthracene	30 µg/kg	8270	0.50 µg/L	625
Fluoranthene	30 µg/kg	8270	0 50 µg/L	625
Fluorene	30 µg/kg	8270	0 50 µg/L	625
Indeno(123-cd)pyrene	30 µg/kg	8270	0 50 µg/L	625
Naphthalene	30 µg/kg	8270	2 00 µg/L	625
Phenanthrene	30 µg/kg	8270	1.00 µg/L	625
Pyrene	30 µg/kg	8270	0.50 µg/L	625
Total	500µg/kg	8270	5 00 µg/L	625
PCBs				
Total	5 µg/kg	8080	0 50 µg/L	608
MISCELLANEOUS				
Ammonia-N	0 1 mg/kg	Plumb, 1981	N/A	
Phenols	10 mg/kg	8040	50 µg/L	420.1
Total organic carbon	5 mg/kg	413 2	1000 µg/L	415 1
Total Petroleum Hydrocarbons	100 mg/kg	418.1	100 µg/L	418 1
Total Solids	0 01%	Plumb, 1981	N/A	
Total Sulfide	0 1 mg/kg	Plumb, 1981	N/A	
Total Volatile Solids	0 1 mg/kg	Plumb, 1981	N/A	
Total Lipids (tissue analysis only)	0.1%	Lee et al ,1989		

All methods unless noted are found in U S EPA, "Test Methods for the Evaluation of Solid Waste," SW-846, November, 1990

APPENDIX B
SOLID PHASE BIOASSAYS
LAGUNA MADRE

TABLE B-1

RANGE OF PHYSICAL PARAMETERS

SOLID PHASE BIOASSAYS - UPPER LAGUNA MADRE

Day	Temperature (°C)	Salinity (‰)	Dissolved O_2 (ppm)	pH
		Ampelisca abdita		
0	20	24	7.6	7 9
1	20	24	7 3 - 7.5	7.9 - 8.2
2	20	25	7 7	7 9
3	20	25	7 4 - 7.5	7 8 - 8 1
4	21	25	7 8	7 8
5	20	25	7 6 - 7 7	7.7 - 7 9
6	21	25	7.8	7.8
7	20	25	7 5 - 7.8	7 8 - 8 0
8	20	25	7 7	7.7
9	20	25	7 4 - 7 6	7 7 - 8 0
10	20	25	7 4 - 7 6	7 6 - 8.0
		Palaeomontes pugio		
0	20	25	7 8	7 3
1	19	25	7 9 - 8 0	7.5 - 7.7
2	20	24	7.7	7 4
3	19	25	7 6 - 7.7	7 8 - 7 9
4	20	24	6 0	8 1
5	19 - 20	26	8 4 - 8 9	7.9 - 8.0
6	21	25	8 7	8 0
7	19	25	7 3 - 7.7	7 9 - 8 2
8	20	26	7 5	7 5
9	19	26	7 6 - 7 8	7 7 - 8 1
10	19	26	7.5 - 7 8	7 8 - 7 9

TABLE B-1 (Concluded)

RANGE OF PHYSICAL PARAMETERS
SOLID PHASE BIOASSAYS - LOWER LAGUNA MADRE

Day	Temperature (°C)	Salinity (‰)	Dissolved O_2 (ppm)	pH
		Ampelisca abdita		
0	20	24	7.6	7 9
1	20	24	7 3 - 7 5	8 0 - 8 1
2	20	25	7 7	7.9
3	20	25	7.5 - 7 7	8 0 - 8 1
4	21	25	7.8	7 8
5	20	25	7 5 - 7 7	7 9 - 8.2
6	20	25	7 8	7 9
7	20	25	7 4 - 7 7	7 9 - 8 0
8	20	25	7.8	7 9
9	20	25	7 6 - 7 7	7 9 - 8 0
10	20	25	7.5 - 7 8	7 8 - 8 0
		Palaeomontes pugio		
0	20	25	7 8	7.3
1	19	24	7 1	7 6
2	19	25	7 7 - 8 0	8 0 - 8 1
3	20	26	7.6	8 3
4	19	26	7 4 - 7.6	7 7 - 8 0
5	20	24	6 5	8 1
6	19	25	7 6 - 8 2	7 4 - 7 9
7	20	26	8 6	7.4
8	19	24	7 7 - 8 4	7 5 - 7.8
9	19	25	8 2	7 8
10	18	24	7 4 - 7 8	7 7 - 8 0

TABLE B-2
STATISTICAL ANALYSIS
OF AMPELISCA ABDITA
SURVIVAL AFTER 10-DAY EXPOSURE TO
LOWER LAGUNA MADRE SEDIMENTS

REPLICATE	REFERENCE	BA4	BA5	BA6
1	12	7	17	7
2	11	3	5	11
3	5	10	10	7
4	11	11	11	12
5	12	5	11	8
6	13			
7	16			
8	9			
9	10			
10	14			
TOTAL	113	36	54	45
MEAN X	11 3	7.2	10 8	9.0
% SURVIVAL	56.5	36.0	54 0	45.0

BONFERRONI'S T-TEST

T VALUE			
- CALCULATED	2.3143	0 2822	1.2983
- TABULATED	2.2780	2.2780	2.2780
	S	NS	NS

S . DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0.05
NS : DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0.05

APPENDIX C
BIOACCUMULATION STUDIES
LAGUNA MADRE

TABLE C-1

RANGE OF PHYSICAL PARAMETERS
BIOACCUMULATION STUDY
UPPER LAGUNA MADRE

Day	Temperature (°C)	Salinity (‰)	Dissolved O_2 (ppm)	pH
		Nereis virens		
0	20	25	7 4	8 1
1	20	26	4.8 - 7 5	7 6 - 8.2
2	21	26	6 6	8 0
3	20	26	5 9 - 7 5	7.8 - 8 1
4	21	26	7.6	8 1
5	20	26	7 2 - 7 6	7 8 - 8 2
6	21	25	6 4	7 8
7	20	25	7.6 - 7 9	7 9 - 8.1
8	21	27	7 2	8.0
9	19	26	7 1 - 7.5	7 8 - 8 1
10	22	25	6 4	8 1
11	20	26	5 6 - 9 0	7 4 - 8.2
12	21	27	7 7	8 2
13	20	25	7.5 - 7 7	7.8 - 8 0
14	21	25	7 5	7 9
15	20	26	7 2 - 7 3	7 9 - 8 0
16	20	26	6 7	7 9
17	20	26	7 2 - 7 4	7 7 - 8 0
18	20	25	7 3	7 8
19	20	25	8 3 - 8 4	8 1 - 8.2
20	21	25	8 1	8.1
21	19	23	7 2 - 7 4	7.8 - 8 0
22	21	25	6 5	8 0
23	19	23	7 4 - 7 7	7 9 - 8.0
24	21	24	7 2	7 9
25	20	24	7 4 - 7.6	7 7 - 8.0
26	19	25	7 4	7.8
27	20	25	7 7 - 7 9	7.8 - 8 0
28	20	25	7 7	7 8 - 8.0

TABLE C-1 (Continued)

RANGE OF PHYSICAL PARAMETERS
BIOACCUMULATION STUDY
UPPER LAGUNA MADRE

Day	Temperature (°C)	Salinity (‰)	Dissolved O_2 (ppm)	pH
		Macoma nasuta		
0	15	25	8.1 - 8 8	7 5 - 7.8
1	14	25	7 9	7.8
2	13	25	8 6 - 8.8	7.5 - 7 8
3	14	25	8.4	7 6
4	12	25	8 6 - 8 7	7 7 - 7.8
5	13	25	8 5	7.7
6	13	25	8 3 - 8.6	7.6 - 7 8
7	15	25	8 0	7.6
8	14	25	8 6 - 8 7	7.7 - 7 8
9	14	25	8 8	7.8
10	15 - 16	24	7.3 - 7.7	7.9 - 8 2
11	16	26	6 6	8 2
12	14	25	8 7 - 9 1	7 8 - 7.9
13	14	24	8 9	7 6
14	14	26	8 9 - 9 1	7 7 - 7 8
15	13	25	8.4	7.8
16	13	25	8 5 - 8 7	7.8
17	14	25	7.9 - 8.2	7.8
18	16	26	8 2 - 8.3	7.8 - 7 9
19	16	25	8 2	7 9
20	14	25	8 9 - 9 2	7.7 - 7.9
21	14	25	8 8	7 9
22	14	25	8 2 - 8 4	7 6 - 7.8
23	14	26	7 8	8 1
24	15	26	9 2 - 9 3	7 7 - 7 8
25	16	26	9 3	7 8
26	15	26	8 9 - 9.0	7.8
27	15	25	8.9	7 8
28	15	25	9 1 - 9 2	7.5 - 7 7

TABLE C-1 (Continued)

RANGE OF PHYSICAL PARAMETERS
BIOACCUMULATION STUDY
LOWER LAGUNA MADRE

Day	Temperature (°C)	Salinity (‰)	Dissolved O_2 (ppm)	pH
		Nereis virens		
0	22	25	7 0	8.0
1	21	25	7 5 - 7 7	8.0 - 8 1
2	21	26	6 7	8 0
3	20	26	7 5 - 7 8	7 8 - 7 9
4	20	26	7.3	7 6
5	19	26	7 2 - 8 1	7 7 - 7 8
6	22	26	6 7	8 0
7	20 - 21	25	7 2 - 7 5	7 6 - 7.8
8	22	24	6.8	7 9
9	20	24	7 3 - 7 5	7 5 - 7.9
10	22	26	6 7	8 2
11	20	26	7 5 - 7 7	7 6 - 7.7
12	21	26	7 1	8 0
13	20	26	6 9 - 7 4	7 8 - 7 9
14	21	26	7 2	7.2 - 7 8
15	20	26	8 1 - 8 5	7.9 - 8 0
16	21	26	8 0	8 0
17	21	26	7 2 - 7 5	7 7 - 7.9
18	20	25	7 5	7.9
19	20	23	7 3 - 7 4	7.9 - 8.0
20	22	25	6 3	7 9
21	20	23	8.3 - 8 4	7.8 - 7 9
22	21	24	8 0	7 9
23	20	26	8.1 - 8 2	7 8 - 7 9
24	20	25	8 3	7.8
25	20	26	7.7 - 7.9	8.1 - 8 4
26	21	26	8 0	8 1
27	20	25	7 6 - 7 7	8 0
28	19	25	7 7 - 7 9	7 9 - 8.0

TABLE C-1 (Concluded)

RANGE OF PHYSICAL PARAMETERS
BIOACCUMULATION STUDY
LOWER LAGUNA MADRE

Day	Temperature (°C)	Salinity (‰)	Dissolved O_2 (ppm)	pH
		Macoma nasuta		
0	15	25	8 3 - 8 9	8 0 - 8.1
1	15	26	8 8	8 1
2	14	25 - 27	8.5 - 8 8	7 8 - 7 9
3	15	26	8 5	8.0
4	14	25	8.6 - 8.9	7.9
5	15	24	7 8	7.9
6	15	26	8 6 - 9 4	7 5 - 7 7
7	14	25	9 0	7 7
8	13	26	8.8 - 9 2	7 4 - 7 7
9	13	25	8 7	7 8
10	13	25	8 8 - 9 1	8 0
11	15	25	8 7	8 0
12	15	27	8 9 - 9 2	7 8 - 7.9
13	15	25	8 7	7 8
14	14	25	8 6 - 9 0	7 6 - 8 0
15	15	25	7 2	8 0
16	14	25	8 2 - 9.0	7 9 - 8.0
17	16	25	8 4	8.0
18	15	25	8 9 - 9 2	7.8 - 7 9
19	17	26	9 2	7 9
20	14	26	9 0 - 9 1	7 8 - 7.9
21	16	25	8 9	7.8
22	14	26	9 0 - 9 1	7.5 - 7 6
23	15	26	9.0	7 8
24	14	26	8 5 - 8 9	7 8
25	15	26	9 0	7 8
26	15	26	8 3 - 8.5	7 8 - 7.9
27	15	26	8 5	7 9
28	15	26	9 7 - 9 8	7 9 - 8 0

TABLE C-2
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF BARIUM
IN *N. virens*

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	0 33	0.83	0.42	0 61
2	0 36	0.38	0.63	0 26
3	0.27	0.85	0 41	0.35
4	0.35	0 89	0.31	0.23
5	0 34	0 52	0 30	0.28
6	0.29			
7	0 35			
8	0 49			
9	0.46			
10	0.44			
TOTAL	3.68	3.47	2.07	1.73
MEAN X	0.368	0.694	0.414	0 346
COEF VAR	19.67	33.03	32.07	44 52

THE VARIANCES ARE HETEROGENEOUS AND TRANSFORMATION WILL NOT HELP.

THE KRUSKAL/WALLIS TEST.
CALCULATED H= 9.193 CRITICAL H= 7 915 df= 3
SINCE CALC H > CRIT H, REJECT Ho: ALL GROUPS ARE EQUAL AT ALPHA = 0.05

SINCE Ho IS REJECTED, THE DUNN MULTIPLE COMPARISON WILL BE USED.

CONCENTRATION	DIFFERENCE IN MEAN RANKS	CRITICAL VALUE	SIGNIFICANT?
BA-1	9.800	7.895	YES
BA-2	1 800	7.895	NO
BA-3	3 600	7.895	NO

SIGNIFICANCE BETWEEN CONTROL AND TEST AT AN ALPHA LEVEL OF 0.025.

TABLE C-2a
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF BARIUM
IN *N. virens*

REPLICATE	ARCHIVE	BA-1	BA-2	BA-3
1	0.66	0.83	0.42	0.61
2	0.78	0.38	0.63	0.26
3	0.59	0.85	0.41	0.35
4	0.43	0.89	0.31	0.23
5	0.75	0.52	0.30	0.28
6	0.63			
7	0.25			
8	0.30			
9	0.39			
10	0.54			
TOTAL	5.32	3.47	2.07	1.73
MEAN X	0.532	0.694	0.414	0.346
COEF VAR	34.45	33.03	32.07	44.52

BONFERRONI'S T-TEST

T VALUE			
- CALCULATED	1.6462	1.1991	1.8900
- TABULATED	2.2780	2.2780	2.2780
	NS	NS	NS

S : DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0.05
NS : DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0.05

TABLE C-3
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF CHROMIUM
IN *N. virens*

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	0.19	0 28	0.20	0.22
2	0.16	0 13	0 14	0.10
3	0.11	1 94	0.14	0.17
4	0.23	0.30	0.18	0.12
5	0.19	1.25	0 10	0.10
6	0.14			
7	0.27			
8	0.22			
9	0.14			
10	0.16			
TOTAL	1.81	3.90	0 76	0.71
MEAN X	0.181	0 780	0.152	0.142
COEF VAR	26 87	100.73	25.65	36 73

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP.

THE KRUSKAL/WALLIS TEST.
CALCULATED H= 7 658 CRITICAL H= 7.915 df= 3
SINCE CALC H <= CRIT H, ACCEPT Ho: ALL GROUPS ARE EQUAL AT ALPHA = 0.05.

TABLE C-3a
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF CHROMIUM
IN *N. virens*

REPLICATE	ARCHIVE	BA-1	BA-2	BA-3
1	0.43	0.28	0 20	0.22
2	0.44	0.13	0 14	0.10
3	0.39	1 94	0 14	0.17
4	0.25	0 30	0.18	0.12
5	0.35	1 25	0.10	0.10
6	0 37			
7	0 17			
8	0.24			
9	0 21			
10	0.26			
TOTAL	3.11	3.90	0.76	0.71
MEAN X	0.311	0.780	0.152	0.142
COEF VAR	30.97	100 73	25.65	36.73

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP.

THE KRUSKAL/WALLIS TEST.
CALCULATED H= 12.943 CRITICAL H= 7.915 df= 3
SINCE CALC H > CRIT H, REJECT Ho ALL GROUPS ARE EQUAL AT ALPHA = 0 05.

SINCE Ho IS REJECTED, THE DUNN MULTIPLE COMPARISON WILL BE USED.

CONCENTRATION	DIFFERENCE IN MEAN RANKS	CRITICAL VALUE	SIGNIFICANT?
BA-1	0.750	7 892	NO
BA-2	9 850	7.892	YES
BA-3	11.150	7 892	YES

SIGNIFICANCE BETWEEN CONTROL AND TEST AT AN ALPHA LEVEL OF 0 025

TABLE C-4
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF ZINC
IN *N. virens*

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	9.70	26.20	20.20	6 91
2	8.07	49.70	14.00	21 70
3	7.24	10 20	9.49	13 40
4	7.50	26 90	34 40	10.40
5	42 20	12.50	18.10	6.33
6	37 90			
7	38 20			
8	8.22			
9	24.30			
10	14.10			
TOTAL	197 43	125.50	96.19	58.74
MEAN X	19.743	25 100	19.238	11.748
COEF VAR	73 66	62 69	48 94	53.22

BONFERRONI'S T-TEST

T VALUE			
- CALCULATED	0.7681	0.0724	1 1464
- TABULATED	2.2780	2.2780	2.2780
	NS	NS	NS

S DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0.05
NS DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0.05

TABLE C-5
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF ARSENIC
IN *N. virens*

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	1.14	1.21	1.28	1.39
2	1.10	1 05	1.29	1.28
3	1.24	1.36	1.56	1.25
4	1.24	1 11	1.32	0.97
5	1.53		1.15	1.09
6	1.14			
7	1.10			
8	1.24			
9	1 24			
10	1 53			
TOTAL	12 50	4.73	6.60	5.98
MEAN X	1.250	1 183	1.320	1.196
COEF VAR	12 69	11.46	11 30	13.86

BONFERRONI'S T-TEST

T VALUE			
- CALCULATED	0 7362	0 8246	0.6361
- TABULATED	2 2060	2 2060	2.2060
	NS	NS	NS

S : DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0.05
NS : DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0 05

TABLE C-6
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF BARIUM
IN *N. virens*

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	0.33	0.34	0.90	0.63
2	0.36	0.63	0.45	0 53
3	0.27	0.46	1.24	'0 43
4	0.35	0.42	0.86	1 43
5	0.34		6.69	0.44
6	0.29			
7	0.35			
8	0 49			
9	0 46			
10	0 44			
TOTAL	3.68	1.85	10.14	3 46
MEAN X	0 368	0 463	2 028	0.692
COEF VAR	19 67	26.44	129 25	60.75

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP.

THE KRUSKAL/WALLIS TEST
CALCULATED H= 12 242 CRITICAL H= 7.915 df= 3
SINCE CALC H > CRIT H, REJECT Ho. ALL GROUPS ARE EQUAL AT ALPHA = 0.05.

SINCE Ho IS REJECTED, THE DUNN MULTIPLE COMPARISON WILL BE USED.

CONCENTRATION	DIFFERENCE IN MEAN RANKS	CRITICAL VALUE	SIGNIFICANT?
BA-4	4 275	8.190	NO
BA-5	12.650	7.583	YES
BA-6	8 650	7.583	YES

SIGNIFICANCE BETWEEN CONTROL AND TEST AT AN ALPHA LEVEL OF 0.025.

TABLE C-6a
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF BARIUM
IN *N. virens*

REPLICATE	ARCHIVE	BA-4	BA-5	BA-6
1	0.66		0 90	0.63
2	0.78	0.34	0.45	0.53
3	0.59	0.63	1 24	0.43
4	0 43	0.46	0.86	1.43
5	0.75	0.42	6 69	0.44
6	0.63			
7	0 25			
8	0 30			
9	0.39			
10	0 54			
TOTAL	5.32	1 85	10 14	3.46
MEAN X	0 532	0.463	2.028	0.692
COEF VAR	34.45	26.44	129.25	60.75

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP

THE KRUSKAL/WALLIS TEST.
CALCULATED H= 6.565 CRITICAL H= 7 915 df= 3
SINCE CALC H <= CRIT H, ACCEPT Ho: ALL GROUPS ARE EQUAL AT ALPHA = 0.05

TABLE C-7
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF CHROMIUM
IN *N. virens*

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	0 19	0.11	0.25	0 26
2	0 16	0.24	0.21	0 27
3	0 11	0.20	0.36	0.22
4	0.23	0.19	0.29	0.29
5	0.19		0.21	0.10
6	0.14			
7	0.27			
8	0.22			
9	0.14			
10	0.16			
TOTAL	1 81	0.74	1.32	1.14
MEAN X	0.181	0.185	0.264	0.228
COEF VAR	26.87	29 44	23 90	33.32

BONFERRONI'S T-TEST

T VALUE			
- CALCULATED	0.1150	2.5764	1 4589
- TABULATED	2.2060	2.2060	2.2060
	NS	S	NS

S DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0 05
NS DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0 05

TABLE C-7a
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF CHROMIUM
IN *N. virens*

REPLICATE	ARCHIVE	BA-4	BA-5	BA-6
1	0.43		0 25	0.26
2	0.44	0.11	0 21	0.27
3	0.39	0.24	0 36	0.22
4	0.25	0.20	0 29	0.29
5	0.35	0.19	0.21	0.10
6	0.37			
7	0 17			
8	0.24			
9	0 21			
10	0 26			
TOTAL	3 11	0 74	1.32	1.14
MEAN X	0.311	0.185	0.264	0.228
COEF VAR	30.97	29 44	23.90	33.32

BONFERRONI'S T-TEST

T VALUE			
- CALCULATED	2.6277	1.0587	1.8696
- TABULATED	2.2060	2.2060	2.2060
	S	NS	NS

S : DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0.05
NS : DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0 05

TABLE C-8
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF COPPER
IN *N. virens*

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	1 33	1.13	1 71	1.44
2	3 68	1.94	2.48	2 02
3	1.49	2.12	1.76	1 94
4	1 25	3.33	1.50	2 72
5	2.93		2.29	1 30
6	1.88			
7	2.11			
8	2.73			
9	1.94			
10	1.63			
TOTAL	20 97	8.52	9 74	9.42
MEAN X	2.097	2 130	1.948	1.884
COEF VAR	37 50	42.65	21 36	29.78

BONFERRONI'S T-TEST

T VALUE			
- CALCULATED	0.0789	0.3849	0.5502
- TABULATED	2 2060	2.2060	2.2060
	NS	NS	NS

S DIFFERENCE IN MEANS IS SIGNIFICANT AT P=0 05
NS DIFFERENCE IN MEANS IS NOT SIGNIFICANT AT P=0.05

TABLE C-9
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF NICKEL
IN *N. virens*

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	0.35	0.32	0 31	0.41
2	0.32	0 34	0 27	0.26
3	2 44	0 22	0.48	1.81
4	0 29	0 29	0.42	0.33
5	0 39		0.29	0.25
6	0 22			
7	0 35			
8	0.36			
9	0.32			
10	0.30			
TOTAL	5.34	1 17	1.77	3.06
MEAN X	0.534	0.292	0 354	0.612
COEF VAR	125.72	17 96	25.78	109.93

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP.

THE KRUSKAL/WALLIS TEST
CALCULATED H= 1.311 CRITICAL H= 7.915 df= 3
SINCE CALC H <= CRIT H, ACCEPT Ho: ALL GROUPS ARE EQUAL AT ALPHA = 0 05.

TABLE C-10
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF BARIUM
IN *M. nasuta*

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	1 36	1.73	0.76	0.83
2	1 58	2.37	1.48	1 10
3	1 36	1.94	1.82	0 68
4	2 42	2 70	2 25	0.58
5	0.87	3 85	2 56	0.76
TOTAL	7 59	12 59	8 87	3 95
MEAN X	1 518	2.518	1.774	0.790
COEF VAR	37.37	33.13	39.47	24.90

THE LN X+1 TRANSFORM WILL BE USED FOR STATISTICAL ANALYSIS.
LN X+1 COEFFICIENTS OF VARIATION

COEF VAR	24.07	18 16	27 75	18 52

	DF	SUM SQUARES	MEAN SQUARE	F-CALC
TREATMENTS	3	1 115	0.372	8 032
ERROR	16	0.740	0 046	
F-TABULATED				3.240

SINCE F-CALCULATED > F-TABULATED, THE DIFFERENCE AMONG THE MEANS IS SIGNIFICANT AT P=0.05 AND THE DUNNETTS COMPARISON WILL BE PERFORMED.

MEAN COMPARISONS

DIFFERENCE IN MEANS

BA-1 VS REFERENCE				
1.237 -	0 904 =	0.333		SIGNIFICANT
BA-2 VS REFERENCE				
0 992 -	0.904 =	0.088	NOT	SIGNIFICANT
REFERENCE VS BA-3				
0.904 -	0.578 =	0 327		SIGNIFICANT

THE MINIMUM DETECTABLE DIFFERENCE = 0.30
DUNNETTS CRITICAL VALUE = 2.23

TABLE C-11
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF CHROMIUM
IN *M. nasuta*

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	0.34	0.10	0.15	0.31
2	0.45	0.28	0.13	1.77
3	0 43	0.27	0 19	0.20
4	0 31	0.21	0 26	0 11
5	0 34	0 50	0 26	0 15
TOTAL	1 87	1 36	0.99	2 54
MEAN X	0.374	0.272	0.198	0.508
COEF VAR	16.55	53.74	30.60	139 66

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP

THE KRUSKAL/WALLIS TEST.
CALCULATED H= 6.657 CRITICAL H= 7.915 df= 3
SINCE CALC H <= CRIT H, ACCEPT Ho: ALL GROUPS ARE EQUAL AT ALPHA = 0 05.

TABLE C-12
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF LEAD
IN *M. nasuta*

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	0 12	0 15	0.10	0.10
2	0 12	0 18	0 14	0.12
3	0.18	0 13	0.12	0.11
4	0.13	0 13	0.14	0.10
5	0.16	0 18	0.13	0.10
TOTAL	0.71	0.77	0.63	0.53
MEAN X	0 142	0.154	0.126	0.106
COEF VAR	18 90	16.30	13 28	8.44

	DF	SUM SQUARES	MEAN SQUARE	F-CALC
TREATMENTS	3	0 006	0.002	5.053
ERROR	16	0.007	0.000	
F-TABULATED				3.240

SINCE F-CALCULATED > F-TABULATED, THE DIFFERENCE AMONG THE MEANS IS SIGNIFICANT AT P=0 05 AND THE DUNNETTS COMPARISON WILL BE PERFORMED.

MEAN COMPARISONS

DIFFERENCE IN MEANS

BA-1 VS REFERENCE			
0.154 -	0.142 =	0 012	NOT SIGNIFICANT
REFERENCE VS BA-2			
0.142 -	0.126 =	0 016	NOT SIGNIFICANT
REFERENCE VS BA-3			
0 142 -	0 106 =	0.036	SIGNIFICANT

THE MINIMUM DETECTABLE DIFFERENCE = 0 03
DUNNETTS CRITICAL VALUE = 2.23

TABLE C-13
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF NICKEL
IN *M. nasuta*

REPLICATE	REFERENCE	BA-1	BA-2	BA-3
1	0.64	2.55	0.44	0.54
2	0.67	0.65	0.41	0.47
3	0.62	0.51	0 47	0 44
4	0.62	0.51	0 62	0 46
5	0 57	0 75	0.57	0.59
TOTAL	3.12	4.97	2.51	2.50
MEAN X	0.624	0.994	0.502	0.500
COEF VAR	5.84	88.10	17.78	12 57

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP.

THE KRUSKAL/WALLIS TEST.
CALCULATED H= 8 528 CRITICAL H= 7 915 df= 3
SINCE CALC H > CRIT H, REJECT Ho ALL GROUPS ARE EQUAL AT ALPHA = 0.05.

SINCE Ho IS REJECTED, THE DUNN MULTIPLE COMPARISON WILL BE USED.

CONCENTRATION	DIFFERENCE IN MEAN RANKS	CRITICAL VALUE	SIGNIFICANT?
BA-1	0.300	7.312	NO
BA-2	7.800	7.312	YES
BA-3	7.900	7.312	YES

SIGNIFICANCE BETWEEN CONTROL AND TEST AT AN ALPHA LEVEL OF 0 025.

TABLE C-14
STATISTICAL ANALYSIS
OF TISSUE CONCENTRATION
OF ARSENIC
IN *M. nasuta*

REPLICATE	REFERENCE	BA-4	BA-5	BA-6
1	1 20	1 59	1.01	1.87
2	1 16	1.34	0 87	2 01
3	1.52	0 74	1.00	1.82
4	1.44	1.06	1.14	1.59
5	2.95	0.90	0.95	0.00
TOTAL	8 27	5.63	4 97	7 29
MEAN X	1.654	1.126	0.994	1.823
COEF VAR	44.77	30.30	9.92	9.58

THE DATA ARE NOT NORMALLY DISTRIBUTED AND TRANSFORMATION WILL NOT HELP.

THE KRUSKAL/WALLIS TEST
CALCULATED H= 11 309 CRITICAL H= 7 915 df= 3
SINCE CALC H > CRIT H, REJECT Ho: ALL GROUPS ARE EQUAL AT ALPHA = 0.05.

SINCE Ho IS REJECTED, THE DUNN MULTIPLE COMPARISON WILL BE USED.

CONCENTRATION	DIFFERENCE IN MEAN RANKS	CRITICAL VALUE	SIGNIFICANT?
BA-4	5 300	6 973	NO
BA-5	7 600	6.973	YES
BA-6	3.775	7.396	NO

SIGNIFICANCE BETWEEN CONTROL AND TEST AT AN ALPHA LEVEL OF 0.025