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SEDIMENT TOXICITY REPORT FOR SITE 1 AND SITE 8 NAS KEY WEST FL

8/1/1999

TETRA TECH NUS

Sediment Toxicity Report

for

Sites IR 1 and 8

Naval Air Station
Key West, Florida

Southern Division
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888

Contract Task Order 0007

August 1999

Revision 1

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SEDIMENT TOXICITY REPORT FOR SITES IR 1 AND 8

NAVAL AIR STATION
KEY WEST, FLORIDA

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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1.0 INTRODUCTION

This document presents and discusses the results of recent investigations conducted at sites IR 1 and IR 8 at Naval Air Station (NAS) Key West, Florida on behalf of the U.S. Navy, Naval Facilities Engineering Command, Southern Division (NAVY SOUTHDIV) under the Comprehensive Long-Term Environmental Action-Navy (CLEAN) Contact Number N62467-94-0-0888, Contract Task Order 007. Sediment toxicity tests were recommended for IR 1 (Truman Annex Refuse Disposal Area) and IR 8 (Fleming Key South Landfill) as a result of an ecological risk assessment conducted for eight sites at NAS Key West. The ecological risk assessment was part of a Supplemental Resource Conservation and Recovery Act (RCRA) Facility Investigation and Remedial Investigation (RFI/RI) conducted on behalf of NAVY SOUTHDIV. The Eight-Site RFI/RI Report (B&R Environmental, 1998a) has been reviewed and approved by the U.S. Environmental Protection Agency (EPA) and the Florida Department of Environmental Protection (FDEP).

The ecological risk assessment concluded that potential site-related ecological risks from contaminants at both IR 1 and IR 8 are limited to benthic organisms. The risk assessment determined that the ecological contaminants of concern (COCs) at IR 1 consisted of copper, lead, zinc, Aroclor-1260, and organochlorine pesticides. Ecological COCs at IR 8 consisted of copper, lead, and zinc. The selection of COCs at these two sites was based primarily on exceedances of sediment benchmarks. However, the actual toxicity of sediment contaminants to benthic organisms at these sites was unknown. Thus, further study was recommended to better characterize the nature and extent of toxicity in site sediments before proceeding with a feasibility study. The NAS Key West Partnering Team determined that additional study should consist of sediment toxicity tests and additional chemical analyses. This document describes the subsequent sediment toxicity tests and chemical analyses conducted on samples collected from the vicinity of IR 1, IR 8, and two reference sites during October, 1998.

Section 2 of this document describes existing ecological conditions at IRs 1 and 8, and summarizes the results of the ecological risk assessment conducted for the Eight-Site RFI/RI Report. Section 3 describes investigation activities and methodologies. Section 4 presents the results of the investigation and Section 5 discusses the results. Finally, conclusions are summarized in Section 6.

2.0 BACKGROUND INFORMATION

Site descriptions and previous investigations are discussed in detail in the Eight-Site RFI/RI Report (B&R Environmental, 1998a) and are summarized below.

2.1 IR 1 - TRUMAN ANNEX REFUSE DISPOSAL AREA

2.1.1 Habitats and Ecological Receptors

IR 1 is located adjacent to the open ocean along the southern shore of Truman Annex on Key West (Figures 2-1 and 2-2). The site covers an area of approximately 7 acres, and consists primarily of a Navy antenna facility. A chain-link fence surrounds the site, and access to IR 1 is strictly controlled. The main sewer outfall line for Key West runs through the property. Treated sewage is pumped into the ocean at the outfall point 3,600 feet southwest of IR 1. From 1952 until the mid-1960s the Truman Annex Refuse Disposal Area was used for general refuse disposal and open burning (ABB 1995).

Terrestrial habitat at IR 1 consists largely of mowed turf grass enclosed by a chain link fence. Due to the overall lack of vegetation (other than turf grass) the site is probably utilized by few terrestrial receptors. Birds, however, forage occasionally in grassy areas on the site. There are no freshwater resources at IR 1. Prior to landfall of Hurricane Georges on September 25, 1998, a 5 to 15-foot strip of weeds and a few Australian pines (*Casuarina equisetifolia*) were present between the chain link fence and riprap along the shoreline. However, Hurricane Georges caused massive erosion of much of the area between the riprap and the chain link fence. Additional riprap, comprised primarily of large concrete rubble and boulders, has subsequently been placed along the shoreline as a temporary method of restoration and erosion control.

A diverse assemblage of marine life was observed within the near shore vicinity of IR 1 during sampling activities conducted in 1996 and 1998. Common aquatic plants included turtle grass (*Thalassia testudinum*), sea fan (*Gorgonia spp.*), sea plume (*Pseudopterogorgia spp.*), and sea whip (*Leptogorgia spp.*). Observed animal life included spiny lobster (*Panulirus argus*), queen conch (*Strombus gigas*), hawkwing conch (*Strombus raninus*), Caribbean vase conch (*Vasum muricatum*), green moray eel (*Gymnothorax funebris*), hermit crab (*Petrochirus diogenes*), tarpon (*Megalops atlanticus*), barracuda (*Sphyraena barracuda*), and several other fish.

2.1.2 Ecological Risk Summary

The ecological risk assessment (B&R Environmental, 1998a) was based on the analyses of groundwater and soil samples collected from IR 1, and the analyses of surface water, sediment, and tissue samples (spiny lobster, Caribbean vase conch, giant hermit crab, and turtle grass) collected from the near-shore vicinity of the site. Potential contaminant migration pathways from IR 1 consist of groundwater discharge to the ocean, overland runoff, and erosion from wind and wave action.

Ecological COCs identified in the ecological risk assessment in groundwater consist of endosulfan I, dieldrin, and gamma-BHC. Based on exceedances of ecological benchmark values, sediment COCs consist of Aroclor-1260, 4,4'-DDT, dieldrin, endrin, endosulfan, gamma-BHC, some daughter products of these pesticides, as well as copper, lead, and zinc. COCs in soil consist of copper, lead, and zinc. The use of the site by terrestrial receptors is minimal, and thus, these metals do not pose a potential risk to terrestrial receptors; however, they are considered soil COCs due to their potential for migration to aquatic habitats near IR 1. Copper and zinc were elevated (relative to background tissue samples) in some crab and lobster samples from the vicinity of IR 1, but most concentrations were not significantly elevated in comparison to concentrations of these metals reported in the literature for similar organisms from other background areas.

The ecological risk assessment concluded that potential ecological risks from metals and organic compounds appear to be limited to benthic organisms. However, the toxicity of sediment contaminants to benthic organisms was unknown, and thus, further study was recommended to better characterize the nature and extent of toxicity in IR 1 sediments before proceeding with a feasibility study.

2.2 IR 8 - FLEMING KEY SOUTH LANDFILL

2.2.1 Habitats and Ecological Receptors

IR 8 covers approximately 45 acres in the southwestern portion of Fleming Key (Figures 2-1 and 2-3). The southeastern portion of the site is bordered by the City of Key West Sewage Treatment Plant. A munitions storage area is located along the east boundary of the site. The remainder of the site is bordered by ocean water (Man of War Harbor). As much as 8,000 tons of various wastes reportedly were disposed at the landfill annually between 1962 and 1982.

A closed canopy of Australian pines exists throughout most of the site, and ground cover is generally sparse. Brazilian pepper (*Schinus terebinthifolius*) and weedy species such as sandbur (*Cenchrus* *tribuloides*) and *Cyperus* spp. occur in areas where sufficient sunlight can reach the ground. These areas are limited primarily to narrow dirt access roads within the site. There are no surface freshwater resources at IR 8. Since most of the site is a monoculture of Australian pines, the site provides poor habitat for terrestrial species. Nevertheless, a few species of mammals, reptiles, arboreal birds, and avian raptors utilize the site.

Turtle grass is abundant and is the dominant aquatic vegetation in near shore waters of IR 8. Aquatic marine life observed during sampling activities conducted in 1996 and 1998 included queen conch, milk conch (*Strombus costatus*), stone crab (*Menippe mercenaria*), spiny spider crab (*Mithrax spinosissimus*), true tulip snails (*Fasciolaria tulipa*), spiny lobsters, and several fish species.

2.2.2 <u>Ecological Risk Summary</u>

The ecological risk assessment (B&R Environmental, 1998a) was based on the analyses of groundwater and soil samples collected from IR 8, and the analyses of surface water, sediment, and tissue samples (spiny lobster, stone crab, spiny spider crab, true tulip, milk conch, and turtle grass) collected from the near shore vicinity of the site. Potential contaminant migration pathways from IR 8 consist of groundwater discharge to the ocean, overland runoff, and erosion from wind and wave action. However, the ecological risk assessment concluded that groundwater discharge of metals to the ocean appears to be the dominant migration pathway. Based on exceedances of ecological benchmark values, COCs at IR 8 consist of copper, lead, and zinc in sediment. These metals were also elevated (relative to background tissue samples) in some crab, lobster, and conch samples from the vicinity of IR 8, but most concentrations were not significantly elevated in comparison to concentrations of these metals reported in the literature for similar organisms from other background areas.

Interim Remedial Actions were completed at IR 8 in 1997. These actions consisted of the removal of debris from along the shoreline, the installation of shoreline protection structures, and revegetation (using native species) along the shoreline. The impact of these actions on sediments is not known. However, sediment concentrations of site-related contaminants are expected to gradually decrease as a result of the Interim Remedial Action activities. There was no visible shoreline erosion at IR 8 following Hurricane Georges.

The ecological risk assessment concluded that potential ecological risks at IR 8 are primarily confined to risks to benthic organisms from copper, lead, and zinc in sediments. However, the bioavailability and toxicity of these metals to benthic organisms was unknown, and thus, further study was recommended to better characterize the nature and extent of toxicity in IR 8 sediments before proceeding with a feasibility study.

2.3 REFERENCE SAMPLING LOCATIONS

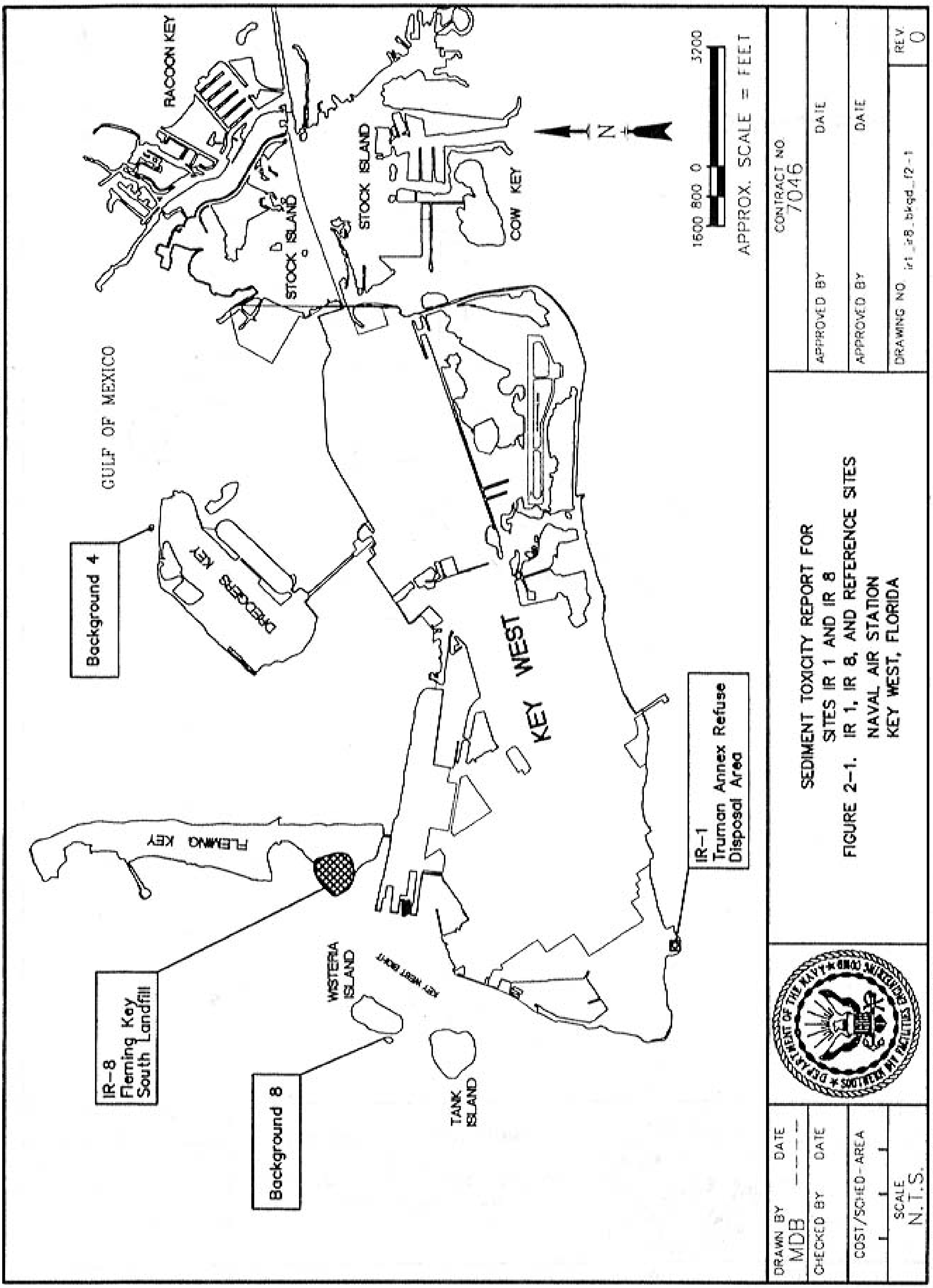
Reference sediment samples were collected from two locations that were utilized in the Eight-Site RFI/RI Report. The designations used in the Eight-Site RFI/RI Report (i.e., Background 4 and Background 8) will be retained when referring to these sites. Background 4 and Background 8 are similar to IRs 1 and 8 in terms of shoreline types, substrate, and near shore marine habitats. In addition, sediment chemical analyses conducted for the Eight-Site RFI/RI Report indicate that sediments at these locations are relatively uncontaminated. Sediment samples from the reference sites were used to provide data from areas similar to the IR sites but not subjected to site-related contaminants, in order to provide a site-specific basis for evaluating toxicity.

2.3.1 Background 4 - Dredgers Key

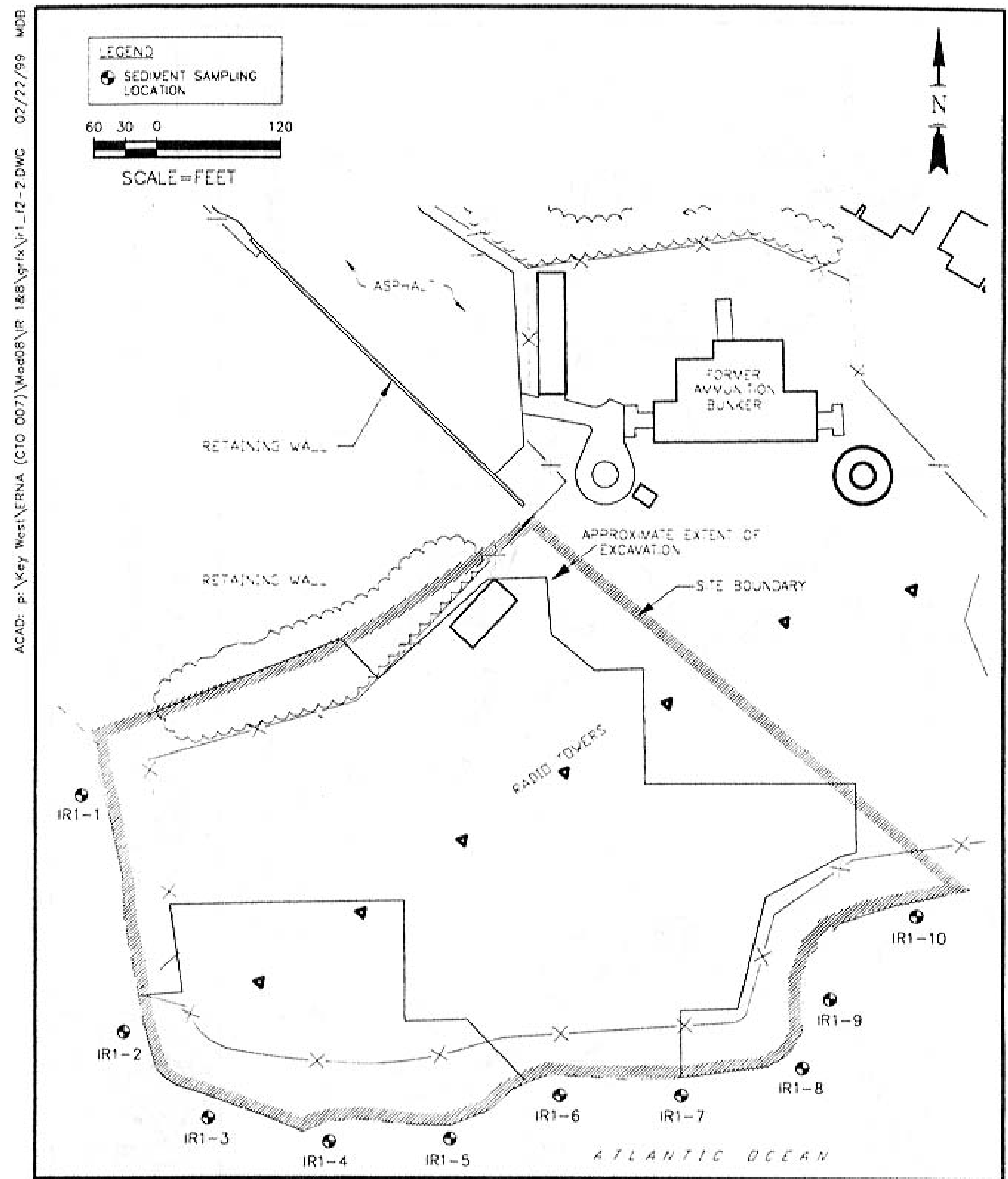
Dredgers Key is ½ mile north of Key West and 1 mile east of Fleming Key (Figure 2-1). Various U.S. Navy facilities exist on the western and central portions of Dredgers Key. The northeastern portion of the island is relatively undeveloped, and is dominated by Australian pines. Vegetation along the shoreline consists primarily of Australian pines and red mangroves (*Rhizophora mangle*). Sea grass communities exist in near shore waters. One sediment sample was collected from an area near the northeastern shoreline of Dredgers Key.

2.3.2 Background 8 - Wisteria Island

Wisteria Island is located approximately ½ mile northwest of Key West (Figure 2-1). No development exists on the island, which is covered with a dense canopy of Australian pines. The shoreline consists of calcareous rock and shell fragments. Submerged aquatic vegetation surrounding the island is dominated by turtle grass. One sediment sample was collected from an area along the western shoreline.



SEDIMENT TOXICITY REPORT FOR
SITES IR 1 AND IR 8
FIGURE 2-1. IR 1, IR 8, AND REFERENCE SITES
NAVAL AIR STATION
KEY WEST, FLORIDA



DRAWN BY MDB	DATE ----		SEDIMENT TOXICITY REPORT FOR SITES IR 1 AND IR 8 FIGURE 2-2. SITE LOCATION MAP – IR 1 NAVAL AIR STATION KEY WEST, FLORIDA	CONTRACT NO. 7046	
CHECKED BY	DATE			APPROVED BY	DATE
COST/SCHED-AREA				APPROVED BY	DATE
SCALE AS NOTED				DRAWING NO. IR1_F2-2	REV. 0

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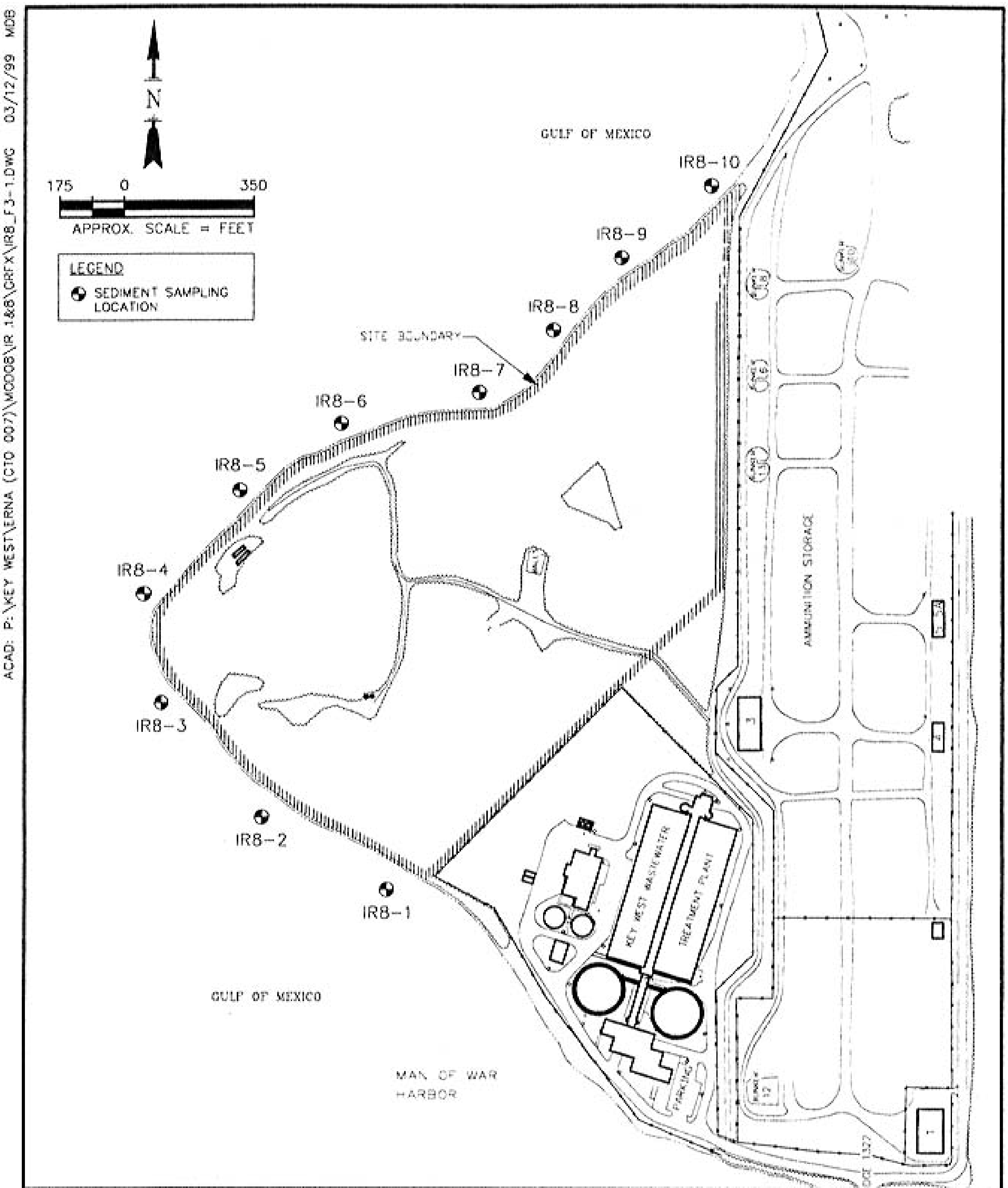

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CHECKED BY	DATE		SEDIMENT TOXICITY REPORT FOR SITES IR 1 AND IR 8 FIGURE 2-3. SITE LOCATION MAP – IR 8 NAVAL AIR STATION KEY WEST, FLORIDA	APPROVED BY	DATE
COST/SCHED-AREA				APPROVED BY	DATE
SCALE AS NOTED				DRAWING NO. IR3_F3-1	REV. 0

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3.0 INVESTIGATION ACTIVITIES

Sediment samples collected in October 1998 were analyzed for metals, pesticides, PCBs, total organic carbon, and particle size distribution. In addition, each sample was subjected to toxicity tests. Methods and procedures for sample management, equipment decontamination, and quality control/quality assurance are described in the RFI/RI Sampling and Analysis Plan (ABB, 1995) and Appendix C of the Eight-Site RFI/RI Report (B&R Environmental, 1998a), and were adhered to at all times. The following subsections describe how the sediment samples were collected, processed, and analyzed, and discuss the sediment toxicity test organism and toxicity test methodology.

3.1 SAMPLE COLLECTION AND PROCESSING

Sediment samples were collected by Tetra Tech NUS, Inc. biologists during October 13-15, 1998. All samples were collected using a ponar grab sampler or stainless steel scoop. Water depth at sediment sampling locations was approximately 4 to 12 feet at IR 1 and 4 to 10 feet at IR 8. Samples were collected primarily from the upper 2 to 3 centimeters of sediment, since this is often the most "biologically active" portion of sediments. Extreme care was taken to obtain the samples with as little disruption as possible and to retain the fine-grained portion of each sediment grab. Four or five deployments of the sampler were usually required to provide a sufficient volume of material for the toxicity tests and chemical analyses. Samples were collected from depositional areas if such areas were apparent at the sample location. Sediments were accumulated in a stainless steel bowl, after which the material was carefully homogenized in the field with a stainless steel spoon before it was distributed to prepared containers for each analysis.

Sediments were medium to light gray or grayish tan in color, with a consistency that ranged from fine to course. The fine grained sediments consisted of silt, clay and sand. The course grained sediments were generally a combination of sand, gravel, and shell fragments. A hydrogen sulfide (H_2S) odor was present in samples IR 1-8, IR 8-1, and BG 4. Organisms noted in sediments consisted of small clams and polychaete worms, but these were infrequently observed.

Ten composited samples were collected from sampling stations placed at approximately even intervals along the shorelines of IR 1 and IR 8, and one composited sample was collected from each reference site. The locations of the current and historical sediment sampling locations are shown in Figures 3-1 (IR 1) and 3-2 (IR 8). It should be noted, however, that none of the current or historical sample locations were recorded using GPS equipment. In addition, several of the historical samples shown on Figures 3-1 and 3-2 were collected by a previous contractor; the accuracy of those locations is not known. Therefore, all sampling locations shown in these figures are approximate. Samples were processed in accordance with FDEP standard operating procedures (FDEP 1992), the RFI/RI Sampling and Analysis Plan (ABB, 1995), and the Ecological Sampling Technical Memorandum (B&R Environmental, 1998b).

Samples were stored on ice immediately after collection. Samples were packed on ice at 4°C and shipped via overnight delivery to Accutest Laboratories, Orlando, Florida, for chemical analyses. Toxicity test samples were transferred to refrigerators in a secure field office at the end of daily field activities. Temperatures in the refrigerators were maintained at 3-4°C. At the end of the three-day collection period, samples were packed on ice at 4°C and relinquished to Hydrosphere Research Inc. employees for transport directly to the toxicity testing laboratory at Gainesville, Florida.

General field observations of habitat conditions (water depth, bottom type, cover type and extent, channel/basin morphology) and field measurements of physical and chemical water quality parameters (pH, conductivity, salinity, dissolved oxygen, and water temperature) were made using portable field instrumentation.

3.2 CHEMICAL ANALYSES

Chemical analyses were performed by Accutest Laboratories, Orlando, Florida. All samples were analyzed for Target Compound List (TCL) pesticide and PCB compounds, Target Analyte List (TAL) metals, total organic carbon (TOC), and particle (grain) size. Analyses were conducted in accordance with Naval Facilities Environmental Services Center (NFESC) Quality Assurance/Quality Control (QA/QC) criteria. Pesticides and PCB analyses followed SW-846 Methods 8081A and 8082 protocols. TAL metals, with the exception of mercury, were analyzed using SW-846 Method 6010A. Mercury analyses were conducted using SW-846 Method 7471A. TOC analyses were conducted using Corp. Eng. Method 81M, and particle size analyses were conducted using ASTM method E422-63.

Volatile and semivolatile organic compounds were not shown to be a concern in previous studies of IR 1 or IR 8, and thus, analyses for these compounds were not conducted on the latest round of samples discussed herein. Although pesticides and PCBs were not final ecological COCs at IR 8, analyses for these compounds were conducted on IR 8 samples, since concentrations were elevated in some sediment and tissue samples.

3.3 TOXICITY TESTING

Twenty-eight day whole sediment toxicity tests using the amphipod *Leptocheirus plumulosus* were performed on all samples. This organism is commonly used in laboratory toxicity tests, even though 28-day chronic sediment toxicity tests have not been standardized. Standard protocols, however, are being developed and are available in draft format. Methods provided in "The *Leptocheirus plumulosus* Chronic Sediment Toxicity Test Method for the Round-Robin Study" (EPA, 1997) served as the basis for the test methodology. This was supplemented by EPA 600/R-94/025, *Methods for Assessing the Toxicity of Sediment-associated Contaminants with Estuarine and Marine Amphipods* (EPA, 1994). Mortality, growth (dry weight), and reproduction (number of young/surviving female) were measured.

The toxicity tests were conducted by Hydrosphere Research, Inc., Gainesville, Florida. The tests were conducted in 1-liter glass chambers into which 175 mL of press-sieved sediment and 700 mL of overlay water were added. For each sediment sample [including the laboratory (i.e., negative) control], 20 neonate organisms in each of five replicate test chambers were used. Water used for acclimation, culture, and overlay during the tests was synthetic seawater with the salinity adjusted to 20 parts per thousand (ppt). Sediment used for the laboratory control sample was obtained by the testing laboratory from what appeared to be a relatively uncontaminated area near St. Augustine, Florida (Meyer, 1999). One-half of the overlay water was renewed every other day for the duration of the test. Test organisms were fed after water renewals. Chambers were held in temperature controlled water baths ($25 \pm 2^{\circ}$) with ambient laboratory lighting (16:8 light/dark hours). Aeration was provided at approximately 2 bubbles per second using 1 mL pipettes. Salinity and ammonia of the pore water were measured at the beginning and end of the test. Temperature, pH, and dissolved oxygen were measured daily. The test conditions are summarized in Table 3-1.

Data analyses conducted by the testing laboratory consisted of standard F-tests and T-tests to determine if each sample's data was significantly different compared to data from the reference sites. Survival data were arc-sine square root transformed prior to statistical analyses. The F-tests and T-tests were conducted using Excel 5.0 programs. Survival was less than acceptable in the first test using sample BG 8 (see Section 4.4), and thus, data from IR samples were compared to those in sample BG 4.

A detailed description of all aspects of test methodology and results is provided in the final toxicity testing report (Hydrosphere, 1999), which is presented in Appendix B.

3.4 DATA EVALUATION

3.4.1 Comparison to Reference Sites

Data from IR 1 and IR 8 were compared to data from the reference sites. Guidelines for contaminant concentrations tend to be conservative, and often they are below background conditions in an area of study. Therefore, comparison to reference, or background locations places concentrations observed in potentially impacted areas in an appropriate regional perspective. For sediment toxicity testing, statistical comparison to reference and control sediments provides the means for establishing sediment toxicity at potentially impacted locations.

3.4.2 Comparison to Guidelines

Contaminant concentrations were compared to sediment ecological screening values (ESVs) established by EPA Region 4 (1995) and FDEP (1994). Many Region 4 sediment ESVs are based on threshold effects levels (TELs) established by FDEP (1994), and for the analytes detected in the IR 1 and IR 8 samples, the ESVs from these two agencies were the same (Table 3-2). The TEL is the geometric mean of the 15th percentile in the effects data set and the 50th percentile in the no effects data set. Sediment contaminant concentrations below the TEL (i.e., the minimal effects range) are not considered to represent significant hazards to aquatic organisms (FDEP, 1994). The Probable Effects Level (PEL) is the geometric mean of the 50th percentile in the effects data set and 85th percentile in the no effects data set. The PEL represents the lower limit of the range of contaminant concentrations that are usually or always associated with adverse biological effects. Contaminant concentrations between the TEL and the PEL constitute the possible effects range (i.e., adverse biological effects are possible).

Effects range-low (ER-L) and effects range-median (ER-M) values established by Long et al. (1995) are also shown in Table 3-2. These values are loosely analogous to TELs and PELs, respectively, and are intended to indicate concentrations below which effects would be rarely observed (ER-L) and below which effects would occasionally occur (ER-M). Above the ER-M, effects would be probable, or they “would frequently occur” (Long et al., 1995).

The distinctions between TELs and PELs, and between ER-Ls and ER-Ms are important, because a guideline conservatively established to ensure that no risk is likely when concentrations are below it, may not be a reasonable predictor of risk for concentrations that exceed it. Therefore, FDEP recommends further investigation to determine if sediment contaminants represent significant hazards to aquatic organisms when sediment concentrations fall within the possible effects range, (FDEP, 1994). It is largely for this reason that sediment toxicity tests were undertaken at IR 1 and IR 8.

3.4.3 Linear Regression

Linear regression was used to investigate the effects of TOC, silt/clay content, and chemical concentrations on the toxicity test results. At each IR site, separate regressions were conducted for each chemical detected, TOC, and silt/clay content versus survival, growth, and reproduction. The critical value for the correlation coefficient, taken from Rohlf and Sokal (1969) at 10 (n-2) degrees of freedom, one independent variable, and α = 0.05, was 0.576. Thus, correlation coefficients greater than 0.576 were considered significant.

A value of one-half the detection limit was assigned to non-detected samples in the analyses of chemical concentrations. However, variable detection limits can create potential problems for analytes with some detects and some non-detects. Specifically, the variability in detection limits can potentially mask real trends in detected values. Thus, for analytes in samples where the use of one-half of the detection limit did not reduce the nondetected value below the lowest actual detected value, two additional approaches were taken:

(1) A value of zero was assigned to the sample(s) in question for the regression analysis,

(2) The lowest detected value was assigned to the sample(s) in question for the regression analysis.

Analytes and numbers of samples where this was required consisted of the following:

- DDD 5 samples at IR 1
- DDE 1 sample at IR 1, 5 samples (plus 2 reference samples) at IR 8
- DDT 6 samples at IR 1
- Copper 1 sample at IR 8
- Zinc 1 sample at IR 8

3.4.4 Ecological Assessment

This ecological assessment uses data pertaining to the nature and extent of contamination from the current and previous investigations, contaminant concentrations in relation to guidelines, previously collected tissue bioaccumulation data, and sediment toxicity testing to evaluate the effect of IR 1 and IR 8-related contaminants on the biota inhabiting or dependent upon IR 1 and IR 8. A weight of evidence approach is used in this assessment, with weighting dependent upon the best use of the data, the apparent quality of the data, and the nature and magnitude of associated uncertainties.

TABLE 3-1

SUMMARY OF TEST CONDITIONS FOR THE *LEPTOCHEIRUS PLUMULOSUS* 28-DAY TOXICITY TEST NAS KEY WEST

1. Test Type	Static
2. Temperature	25ºC ± 2ºC
3. Light quality	"Cool White" fluorescent lighting
4. Light intensity	Ambient lab lighting (90 ± 10 ft-c)
5. Photoperiod	16 hours light, 8 hours darkness
6. Test chamber size	1,000 ml glass beaker
7. Test solution volume	175 ml sediment in 700 ml overlay water
8. Renewal of test solutions	50/50 renewal of overlay water every other day
9. Size of organisms at start	Captured between 0.5 and 0.25 mm mesh screens
10. No. replicates per sample	5 (plus one for pore water quality)
11. Overlay water	Synthetic Seawater
12. Test duration	28 days
13. Endpoint	Survival, growth based on dry weight determination, reproduction as neonates/female
14. Test acceptability	Minimum 80 percent survival in reference sediments
15. Feeding after water change	30 mgs fish flake suspension day 1-14, then increasing to 60 mgs until test end

TABLE 3-2

ECOLOGICAL SCREENING VALUES FOR SEDIMENT
NAS KEY WEST

Chemical	EPA Region 4[1]	ER-L[2]	ER-M[3]	TEL[4]	PEL[5]	Other
METALS AND INORGANIC COMPOUNDS (mg/kg)						
Aluminum	NA	NA	NA	NA	NA	
Arsenic	7.24	8.2	70	7.24	41.6	
Barium	NA	NA	NA	NA	NA	20 - 60[6]
Chromium	52.3	81	370	52.3	160	
Cobalt	NA	NA	NA	NA	NA	50[7]
Copper	18.7	34	270	18.7	108	
Iron	NA	NA	NA	NA	NA	17,000 – 25,000[6] 20,000[8]
Lead	30.2	46.7	218	30.2	112	
Manganese	NA	NA	NA	NA	NA	460[8] 300 - 500[6]
Nickel	15.9	20.9	51.6	15.9	42.8	
Vanadium	NA	NA	NA	NA	NA	
Zinc	124	150	410	124	271	
PESTICIDES/PCBs (μg/kg)						
Aroclor-1260	21.6[9]	22.7[9]	180[9]	21.6[9]	189[9]	
4,4'-DDD	1.22	NA	NA	1.22	7.81	
4,4'-DDE	2.07	2.2	27	2.07	374	
4,4'-DDT	1.19	1.58[10]	46.1[10]	1.19	4.77	

NA Ecological screening value not available
1 Ecological Screening Value (EPA, 1995)
2 ER-L - Effects Range Low (Long et al., 1995)
3 ER-M - Effects Range Medium (Long et al., 1995)
4 TEL - Threshold Effects Level (FDEP, 1994)
5 PEL - Probable Effects Level (FDEP, 1994)
6 EPA Region 5 guideline indicating moderate pollution (Giesy and Hoeke, 1990)
7 Open water disposal guideline, Ontario Ministry of Environment (Giesy and Hoeke, 1990)
8 Ontario Ministry of Environment lowest effect level (Jones et al ,1997)
9 Value is for total PCBs; screening value not available for individual Aroclor mixtures
10 Value is for total DDT; screening value not available for 4,4'-DDT

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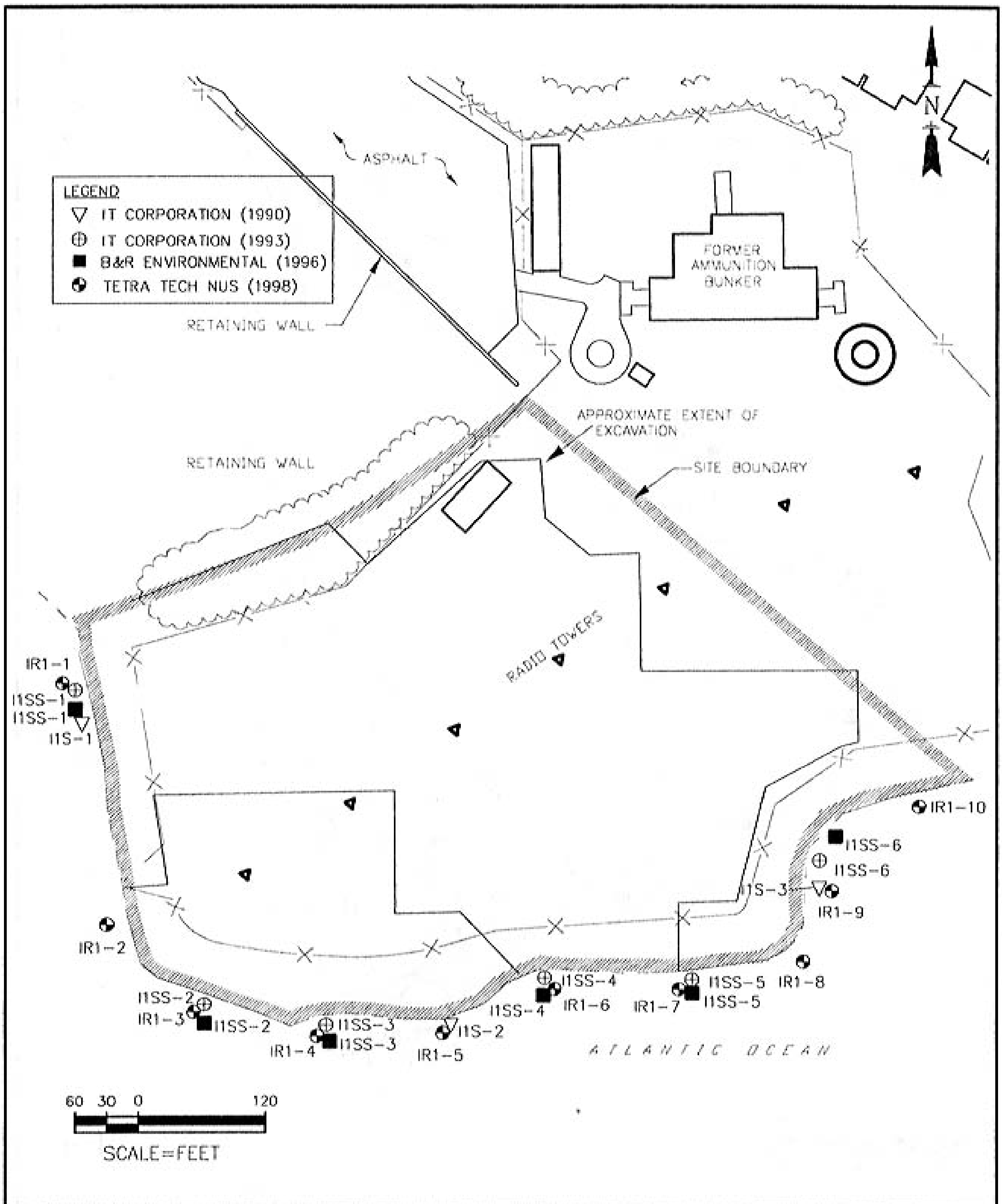

DRAWN BY MDB	DATE 8/99	SEDIMENT TOXICITY REPORT FOR SITES IR 1 AND IR 8	CONTRACT NO. 7046	
CHECKED BY	DATE	FIGURE 3-1. CURRENT AND PREVIOUS SEDIMENT SAMPLING LOCATIONS – IR1	APPROVED BY	DATE
COST/SCHED-AREA		NAVAL AIR STATION	APPROVED BY	DATE
SCALE AS NOTED		KEY WEST, FLORIDA	DRAWING NO. IR1_F3-1 SEDIMENT	REV. 0

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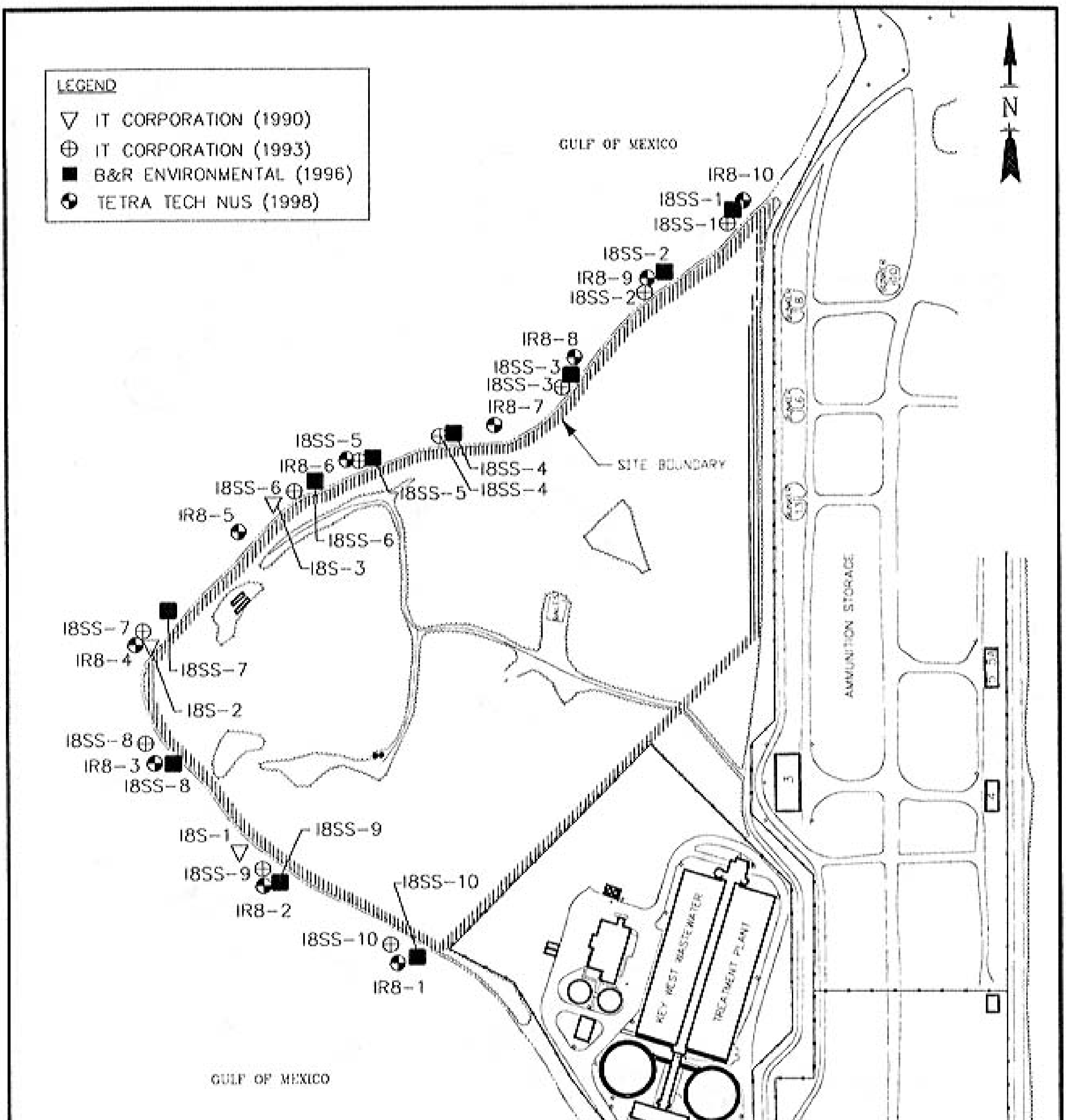

DRAWN BY MDB — DATE 8/99		SEDIMENT TOXICITY REPORT FOR SITES IR 1 AND IR 8	CONTRACT NO. 7046
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COST/SCHED-AREA		NAVAL AIR STATION	APPROVED BY — DATE
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FORM CADD NO. SDV_AV12.DWG - REV 0 - 1/20/98

4.0 RESULTS

4.1 FIELD MEASUREMENTS OF WATER QUALITY

Field measurements of water quality parameters (pH, turbidity, conductivity, salinity, dissolved oxygen, and water temperature) are shown in Table 4-1. Because the 10 sampling stations were in relatively close proximity to each other at each IR site, water quality parameters were not measured at all sampling stations. Instead, water quality parameters were measured at three IR 1 stations, two IR 8 stations, and at each reference site.

The parameters shown in Table 4-1 are similar to values measured during previous sampling events at the same sites. In addition, the data are within the range of expected values for marine surface water in the Florida Keys.

4.2 SEDIMENT CHEMISTRY

Sediment chemistry data for the October sampling event are presented in Tables 4-2 and 4-3 for IR 1 and IR 8, respectively. Tables 4-4 and 4-5 summarize the data for analytes detected at IR 1 and IR 8, respectively. Complete data packages from the analytical laboratory and data validation results are contained in Appendix B.

Twelve metals, one PCB compound (Aroclor-1260) and three pesticides were detected in samples from IR 1. The pesticides consisted of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT (hereafter referred to as DDD, DDE, and DDT, or collectively as DDTR). Twelve metals and two pesticides (DDD and DDE) were detected in samples from IR 8. The same metals were detected at IR 8 as at IR 1. Aluminum, barium, chromium, copper, iron, lead, manganese, vanadium, and zinc were frequently detected at both sites, while nickel and cobalt were infrequently detected at both sites. Arsenic was detected in only two samples at IR 1 and in seven IR 8 samples. Pesticides and PCBs were not detected at either reference site, nor were cobalt and nickel. Concentrations of other metals were usually less at both reference sites than at the IR sites.

Sample IR 1-4 was responsible for the maximum concentration of seven of the 12 analytes detected at IR 1. The concentration of Aroclor-1260 in this sample was especially high (8,920 μg/kg), as was DDE (119 μg/kg). DDE concentrations exceeded the ER-M and TEL (but not the PEL) in samples IR1-3 and IR1-4. The Aroclor-1260 concentration exceeded both the ER-M and PEL concentrations in samples IR1-1, IR1-2, IR1-3, and IR 1-4. Matrix interferences and subsequent dilution factors resulted in less than optimal detection limits for pesticides and/or PCBs in these same four samples.

4.3 SEDIMENT GRAIN SIZE DISTRIBUTION AND TOTAL ORGANIC CARBON

The grain size composition of sediment samples collected in October 1998 are presented in Table 4-6. Gravel was absent from 8 of 10 samples from IR 1. Gravel was present in all samples from IR 8, but generally comprised only about 1 to 5 percent of individual samples. All samples at both sites were composed of at least 91 percent sand. The silt/clay content ranged from 0.2 to 7.7 percent in IR 1 samples, and from 0.6 to 3.1 percent at IR 8. Grain size distribution in reference samples were similar to the IR sites, except that the gravel content at BG 4 (9.6 percent) was slightly greater, and the sand content (88.8 percent) was slightly less than most IR samples. Percent solids ranged from 45.2 to 74.0 percent at IR 1, and from 37.7 to 74.6 percent at IR 8. Percent solids in both reference samples were within these ranges.

Sediment total organic carbon (TOC) in October 1998 samples ranged from 0.4 to 10.4 percent at IR 1, with a mean value of 4.2 percent. TOC at IR 8 in October 1988 samples ranged from 0.3 to 9.5 percent, with a mean value of 2.9 percent. TOC was 0.74 and 0.82 percent at BG 4 and BG 8, respectively.

Grain size composition and TOC content of sediment samples collected in May 1998 are presented in Table 4-7 for comparison to values in October 1998. Values for TOC and percent solids were similar in May to those in October. However, the percent sand was usually less in May than in October, and the percent silt/clay was usually greater in May than in October.

4.4 SEDIMENT TOXICITY TESTS

4.4.1 <u>Test Conditions</u>

Pore water ammonia levels in all samples were less than 36 mg/L at test initiation and less than 7 mg/L at test termination. The maximum permissible level of pore water ammonia is 60 mg/L. Overlay waters salinity was 20 ppt for the duration of the tests. Dissolved oxygen levels were >4 mg/L throughout the tests. Temperatures remained within the range of 25 ± 2°C and pH values were within the acceptable range of 7.0 to 9.0 units. No predatory organisms were observed at test initiation or in the preserved and stained sediments during the neonate recovery process.

On day 27 of the toxicity tests, the tubing supplying aeration manifolds for samples IR 1-8 and IR 1-9 split. As a result, those two samples lost aeration during the night. The following morning when the problem was discovered, the dissolved oxygen was found to be unacceptably low (less than 4.0 mg/l). A few dead organisms were observed. The containers were immediately re-aerated until the end of the test on the following day. At test termination 100 percent mortality was found in both samples, but since it was impossible to determine how many organisms had died prior to the aeration failure, the two samples were retested, along with the two reference samples (BG 4 and BG 8). These tests were initiated within the suggested 8-week sediment holding time.

4.4.2 Reference Toxicant Test

A reference toxicant test using cadmium was conducted to assess the sensitivity of the test organisms to a reference toxicant. The reference toxicant tests yielded a mean LC_{50} of 400 mg/L. The LC_{50} values for the reference toxicant indicate that the organisms were of normal sensitivity. Details regarding the reference toxicant tests are contained in the laboratory report (Appendix B).

4.4.3 Amphipod Survival, Growth, and Reproduction

Results of the toxicity tests are summarized in Table 4-8. As a result of the aeration failure discussed in Section 4.4.1, the data shown in Table 4-8 for samples IR 1-8 and IR 1-9 are from the second round of tests, while the data for the other 18 IR samples are from the first round of tests. The statistically significant reductions reported and discussed below refer to comparisons of IR samples versus data from the concurrently tested reference site BG 4.

4.4.3.1 IR 1

Survival, growth, and reproduction were significantly reduced in IR 1-7 and IR 1-9 (Table 4-8). Survival was reduced in samples from IR 1-8 (72 percent) and IR 1-10 (69 percent), but the reductions were not significant. Survival in the remaining six IR 1 samples ranged from 88 to 97 percent. Amphipod growth was significantly reduced in IR 1-4 and IR 1-10.

4.4.3.2 IR 8

There were no significant reductions for any parameter in IR 8 samples. However, survival was less than normal in samples IR 8-8 (56 percent) and IR 8-9 (79 percent). The T value in the statistical test of survival for the IR 8-8 sample approached the $\alpha = 0.05$ level of significance ($p = 0.053$). Survival in the remaining eight IR 8 samples ranged from 87 to 96 percent. Reproduction, expressed as the number of neonates per surviving female, was lower than normal in sample IR 8-9, but the reduction was not significant. Reproduction was the most variable parameter among sites and among replicates in IR 1 and IR 8 samples. This is true of most toxicity tests, according to the testing laboratory.

4.4.3.3 BG 4 and BG 8

Survival in the BG 4 sample was 81 percent in both the first and second tests. Survival in the BG 8 sample was 92 percent in the second test but was low (70 percent) in the first test. Survival in two of the five replicate chambers for BG 8 during the first test was 20 percent and 55 percent, while survival in the other three replicate chambers was 95, 95, and 85 percent.

Growth was consistent between the first and second tests in both BG samples, with values of 1.65 and 1.52 mg/organism for BG 4, and 1.50 and 1.37 mg/organism for BG 8. Reproduction was 9.0 and 7.35 at BG 4. Reproduction was more variable at BG 8, with values of 16 (first test) and 8.5 (second test).

TABLE 4-1

SURFACE WATER QUALITY PARAMETERS DURING OCTOBER 1998 SAMPLING NAS KEY WEST

Location	pH	Turbidity (NTU)	Temperature (°C)	Conductivity (mS/cm)	Dissolved Oxygen (mg/L)	Salinity (%)
IR 1-1	5.91	10	28.9	54.9	7.14	3.65
IR 1-3	6.57	56	30.2	55.8	7.03	3.69
IR 1-5	7.91	10	30.9	54.9	7.94	3.64
IR 8-2	7.96	15	29.7	53.2	6.77	3.51
IR 8-5	7.95	5	29.7	53.4	6.44	3.50
BG 4	6.10	10	26.6	50.1	4.59	3.30
BG 8	7.83	15	29.5	53.2	6.78	3.51

TABLE 4-4

SUMMARY OF SEDIMENT ANALYTES DETECTED AT IR 1 AND REFERENCE SITES, OCTOBER 1998 NAS KEY WEST

Chemical	Reference Sites		IR-1				
	BG-4	BG-8	Frequency of Detection	Range of Nondetects	Range of Detections	Location of Maximum Concentration	Average of All Values[1]
METALS AND INORGANIC COMPOUNDS (mg/kg)							
Aluminum	402	213	9/10	143	102.5 - 689	IR1-5	225.7
Arsenic	3.3	ND[2]	2/10	2.1 - 4.8	4.9 - 7.1	IR1-3	3.8
Barium	9	37.4	10/10		9.6 - 17.2	IR1-1	12.3
Chromium	4.4	ND	6/10	3.5 - 5.6	6.6 -113	IR1-1	22.7
Cobalt	ND	ND	1/10	0.13 - 1.1	1.6	IR1-3	0.9
Copper	ND	7.8	10/10		6.8 - 152	IR1-7	54.4
Iron	431	400	10/10		456 -14300	IR1-4	3619.6
Lead	2.7	8.9	10/10		8.8 - 224	IR1-7	52.9
Manganese	5.7	5	10/10		8.5 - 73.6	IR1-4	26.5
Nickel	ND	ND	2/10	0.9 - 2.9	5.6 - 9.6	IR1-4	4.2
Vanadium	2.6	2.4	8/10	1.7 - 1.8	2.3 - 7.3	IR1-4	2.4
Zinc	ND	9.2	10/10		21 - 190	IR1-4	82.2
PESTICIDES/PCBs (µg/kg)							
Aroclor-1260	ND	ND	5/10	51 - 60	62 - 8920	IR1-4	1423.2
4,4'-DDD	ND	ND	3/10	5.3 - 190	3.7 - 7.5	IR1-2	5.1
4,4'-DDE	ND	ND	8/10	6.0 - 30	3.7 - 119	IR1-4	18.9
4,4'-DDT	ND	ND	2/10	5.3 - 380	4.2 -24	IR1-7	28.3

1 Averages were calculated using one-half the detection limit for non-detected analytes.
2 ND = Not detected at reference site.

TABLE 4-5

SUMMARY OF SEDIMENT ANALYTES DETECTED AT IR 8 AND REFERENCE SITES, OCTOBER 1998 NAS KEY WEST

Chemical	Reference Sites		IR-8				
	BG-4	BG-8	Frequency of Detection	Range of Nondetects	Range of Detections	Location of Maximum Concentration	Average of All Values[1]
Metals and Inorganic Compounds (mg/kg)							
Aluminum	402	213	10/10		269 - 3970	IR8-5	1101.8
Arsenic	3.3	ND[2]	7/10	1.7 - 4.6	4.8 - 25.85	IR8-4	6.1
Barium	9	37.4	10/10		5.3 - 32.6	IR8-10	16.7
Chromium	4.4	ND	5/10	2.6 - 5.9	5.3 - 78.5	IR8-5	14.1
Cobalt	ND	ND	1/10	0.12 - 1.3	2.8	IR8-4	1.5
Copper	ND	7.8	9/10	12	2.5 - 43.4	IR8-5	10.8
Iron	431	400	10/10		409 -52750	IR8-4	8064.5
Lead	2.7	8.9	10/10		3.6 - 145.8	IR8-4	41.9
Manganese	5.7	5	10/10		4.7 - 173.5	IR8-4	31.9
Nickel	ND	ND	3/10	0.87 - 2.4	6.1 - 15.3	IR8-4	5.9
Vanadium	2.6	2.4	9/10	2.5	3.6 -16.6	IR8-4	4.6
Zinc	ND	9.2	9/10	33.5	11.7 - 259	IR8-5	46.7
Pesticides/PCBs (µg/kg)							
4,4'-DDD	ND	ND	1/10	4.6 - 8.8	4.4	IR8-6	3.9
4,4'-DDE	ND	ND	5/10	5.9 - 8.8	2.5 - 9.8	IR8-6	4.4

1 Averages were calculated using one-half the detection limit for non-detected analytes.
2 ND = Not detected at reference site.

TABLE 4-6

SUMMARY OF SEDIMENT PHYSICAL CHARACTERISTICS IN SAMPLES COLLECTED OCTOBER 13 15, 1998 NAS KEY WEST

Site	Sample ID #	TOC (percent)	Percent Solids	Particle Size Distribution		
				Percent Gravel	Percent Sand	Percent Silt/Clay
IR 1	IR1-1	10.4	45.2	0	92.3	7.7
	IR1-2	9.42	55.6	0	96.2	3.8
	IR1-3	0.69	74.0	2.0	96.9	1.1
	IR1-4	0.58	70.4	0	98.4	1.6
	IR1-5	0.82	55.5	3.6	96.1	0.3
	IR1-6	1.07	58.3	0	94.9	5.1
	IR1-7	0.40	65.0	0	94.7	5.3
	IR1-8	1.14	55.7	0	93.2	6.8
	IR1-9	8.88	64.4	0	99.0	1.0
	IR1-9 dup	9.46	61.8	0	99.8	0.2
	IR1-10	7.79	56.1	0	98.6	1.4
IR 8	IR8-1	9.50	56.4	1.6	96.9	1.5
	IR8-2	1.14	47.6	2.5	95.7	1.8
	IR8-3	1.15	50.1	5.2	91.7	3.1
	IR8-4	0.56	71.1	3.2	95.9	0.9
	IR8-4 dup	0.17	74.6	10.3	89.1	0.6
	IR8-5	1.54	43.3	2.3	95.9	1.8
	IR8-6	1.31	51.6	4.5	94.1	1.4
	IR8-7	0.26	57.3	1.1	96.6	2.3
	IR8-8	5.56	44.4	1.9	95.7	2.4
	IR8-9	2.01	37.7	2.7	95.3	2.0
	IR8-10	5.71	54.5	0.7	97.8	1.5
BG 4[1]	BG4	0.74	57.2	9.6	88.8	1.6
BG 8	BG8	0.82	66.0	0	96.7	3.3

1 BG 4 and BG 8 are locations from which reference samples were collected.

TABLE 4-7

SUMMARY OF SEDIMENT PHYSICAL CHARACTERISTICS IN SAMPLES COLLECTED MAY 12 14, 1998 NAS KEY WEST

Site	Sample ID #	Redox (mV)	TOC (percent)	Percent solids	Particle Size Distribution			
					% Gravel	% Sand	% Silt	% Clay
IR 1	IR1-1	159	4.00	51	0.0	79.8	10.4	9.8
	IR1-2	111	3.40	70	3.7	87.7	6.2	2.4
	IR1-3	122	0.39	82	20.2	75.6	2.8	1.4
	IR1-4	120	0.43	64	0.0	96.5	1.8	1.7
IR 8	IR8-1	53	1.70	53	7.2	50.0	33.6	9.2
	IR8-2	119	3.80	67	18.8	74.4	4.3	2.5
	IR8-3	139	1.20	68	13.7	79.4	4.4	2.5
	IR8-4	56	1.50	45	2.9	47.4	40.7	9.0
BG4[1]	B4-1	139	1.50	52	0.0	41.8	47.8	10.4
	B4-2	N/A	1.60	49	0.0	30.0	59.8	10.2
BG8	B8-1	112	1.90	38	3.3	86.1	6.6	4.0
	B8-2	39	1.50	60	0.6	90.1	6.5	2.8
	B8-3	108	2.10	67	8.7	87.8	2.1	1.4

1 BG 4 and BG 8 are locations from which reference samples were collected.

TABLE 4-8

SUMMARY OF RESULTS OF *LEPTOCHEIRUS PLUMULOSUS* 28-DAY TOXICITY TESTS NAS KEY WEST

Sample ID	Percent Silt/Clay	Final Survival (percent)	Average Growth (mg/org.)	Neonates Per Female
BG 4	1.6	81	1.65	9
BG 4 2nd Test	1.6	81	1.52	7.35
BG 8	3.3	70	1.50	16
BG 8 2nd Test	3.3	92	1.37	8.5
IR1-1	7.7	94	2.03	19.6
IR1-2	3.8	97	1.77	15.2
IR1-3	1.1	88	1.57	12.9
IR1-4	1.6	90	1.30*	7.4
IR1-5	0.3	90	1.89	13.1
IR1-6	5.1	92	1.49	14
IR1-7	5.3	53*	0.82*	2.1*
IR1-8	6.8	72	1.77	9.1
IR1-9	0.6	59*	0.75*	0.67*
IR1-10	1.4	69	1.03*	9.8
IR8-1	1.5	87	1.90	12.7
IR8-2	1.8	80	2.29	13.8
IR8-3	3.1	88	1.98	15.9
IR8-4	0.8	93	1.93	17.7
IR8-5	1.8	96	1.98	22.5
IR8-6	1.4	96	2.12	16
IR8-7	2.3	82	2.07	11.9
IR8-8	2.4	56	2.28	9
IR8-9	2.0	77	2.02	6.4
IR8-10	1.5	89	2.33	13.8
Mixed Sediment	No Data	87	1.97	11.6
Average of BG 4 and BG 8	2.45	81	1.51	10.2

*Denotes a statistically significant reduction compared to reference sediment BG-4.

5.0 DISCUSSION

5.1 SEDIMENT GRAIN SIZE AND FIELD OBSERVATIONS

The grain size composition of sediment samples collected in October 1998 differed from that in samples collected in May 1998 (Tables 4-6 and 4-7). Specifically, the percent sand was usually less in May than in October, and the percent silt/clay was usually greater in May than in October. Although the sample identification numbers in Table 4-7 are identical to those in Table 4-6, the sample locations are not identical between the May and October sampling efforts. Nevertheless, the differences between May and October samples are notable.

The grain size differences are presumed to be at least partially due to slightly different methods for determining grain size. Grain size in May samples was analyzed by Thompson Engineering, Mobile, Alabama. In their analyses, gravel consists of the portion of sediment that is retained on a No. 4 sieve; sand is the portion that passes through a No. 4 sieve but is retained on a No. 200 sieve; and silt/clay is the portion that passes through a No. 200 sieve. The laboratory then uses a hydrometer to separate silt (0.074 to 0.005 μm) from clay (<0.005 μm).

Grain size in October samples was analyzed by Accutest Laboratories, Orlando, Florida. In their analyses, sand is the portion that passes through a No. 4 sieve but is retained on a No. 230 sieve; and silt/clay is the portion that passes through a No. 230 sieve. Gravel is defined the same by both labs.

Thus, the greater silt/clay portion measured in the May samples could be due to the slightly larger sieve size (No. 200) compared to the No. 230 sieve size used for October samples. The difference is probably of little consequence, except that the selection of *Leptocheirus plumulosus* as a test organism was based primarily on the physical characteristics of samples collected in May. According to EPA draft methods for *Leptocheirus plumulosus* chronic sediment toxicity tests, the tolerance limits for this organism is ">5 percent silt/clay". The silt/clay content in most of the October sediment samples were less than 5 percent silt clay. However, according to Science Applications International (SAIC), which has extensive experience in the culture and chronic testing of *Leptocheirus plumulosus*, this organism has exhibited ≥90 percent survival in sediments ranging from ~100 percent sand to ~100 percent silt/clay (SAIC 1993a,b). Furthermore, silt/clay content was not correlated with organism response (Appendix C). As shown in Table 4-8, many of the highest values for survival, growth, and reproduction were in samples where the silt/clay content was less than 1.5 percent.

An alternate hypothesis for the differing grain sizes between May 1998 and October 1998 is that storm events could have altered the substrate between May and October. The shoreline at IR 1 faces southward, the direction from which Hurricane Georges struck Key West on September 25, 1998. IR 8 is better protected, relative to IR 1, from storm-related erosion. It would be reasonable to speculate that this hurricane resulted in the removal of some silt, clay, and fine sand from areas where these portions of sediment had previously accrued, especially at IR 1. During the October sampling activities, Tetra Tech NUS biologists searched (via snorkeling) for signs of storm impacts on the substrate at IR 1 and IR 8; no impacts were noted. However, such impacts might not be readily apparent.

5.2 IR 1

5.2.1 Chemistry Data

An examination of the analytical chemistry data from the October 1998 samples collected at IR 1 (Tables 4-2 and 4-4) indicates that concentrations of most metals were unremarkable. Concentrations of arsenic and nickel were less than the lowest available ESVs shown in Table 3-2. ESVs for aluminum, barium, cobalt, iron, manganese, and vanadium have not been established by EPA Region 4 or FDEP. However, concentrations of these metals were either less than other available guidelines shown in Table 3-2, or were less than or similar to concentrations in BG 4 and BG 8 samples. Chromium exceeded the lowest ESV only in sample IR 1-1. Concentrations of copper, lead, and zinc (metals identified as sediment COCs in the previous ecological risk assessment [B&R Environmental, 1998a]) exceeded the lowest ESV in some samples. Copper concentrations exceeded the PEL value in samples IR 1-3 and IR 1-7, while lead exceeded the PEL in sample IR 1-7. Zinc concentrations exceeded the lowest ESV only in samples IR 1-1 and IR 1-4; but were less than the PEL in both samples.

All detected concentrations of Aroclor-1260 and DDTR exceeded the lowest ESVs, and some concentrations exceeded PEL values. Concentrations of these compounds tended to be greatest in samples IR 1-1, IR 1-2, IR 1-3, IR 1-4, and IR 1-7. Samples IR 1-1 through IR 1-4 represent the southwestern portion of the peninsula on which IR 1 is located. This area was also where pesticide and PCB concentrations were greatest during previous sampling efforts (Appendix D). IR 1-7, where PEL values for lead, copper, and DDT were exceeded, approximates the location known in previous sampling efforts as I1SS-5 (Appendix D). Concentrations of lead and DDT exceeded the PEL in a sediment sample collected in 1996 from I1SS-5 (Appendix D).

5.2.2 Toxicity Tests

Linear regression indicated that the toxicity test results were not correlated to either TOC or silt/clay content. Survival was correlated with concentrations of aluminum and vanadium, and growth was correlated with concentrations of aluminum and chromium (Appendix C). However, these were *positive* correlations, i.e., survival and growth increased as the concentrations of these metals increased. These correlations are not considered to be toxicologically significant. Survival was correlated with concentrations of DDT (r = -0.655), while growth (r = -0.515) and reproduction (r = -0.540) approached the critical value of r = 0.576 for DDT (Figure 5-1) when a value of zero was assigned to samples where this compound was not detected. However, DDT was detected in only two samples; thus reducing the value of the regression analyses for this compound. This is evident in Figure 5-1, which indicates that only one data point (IR 1-7, 24 μg/kg) was separated from the other 11 data points.

The regression analysis did not test the possibility of cumulative or synergistic effects from a combination of several chemicals. The possibility that one or more chemicals may be impacting sediments is discussed below.

5.2.3 Cause and Effects Relationships

Potential cause and effect relationships can often be ascertained by comparing data for chemical concentrations to toxicity testing endpoints. However, such relationships are not always evident, and spurious responses in toxicity tests can make the data difficult to interpret. For example, survival, growth, and reproduction were significantly reduced in sample IR 1-9. However, concentrations of metals were unremarkable in this sample (none exceeded ecological screening values), and the single detected organic compound (DDE) in this sample only slightly exceeded the most conservative ESV. Survival was normal in 2 of 5 replicates for this sample, but growth and reproduction was poor in all five replicates. While there is a tendency to speculate that the results in this sample were due to laboratory procedures, the overwhelming majority of replicates in most samples do not support this conclusion. No unusual visual characteristics or odors were noted upon collection of this sample. The laboratory, however, noted that this sample had a moderate H_2S odor (Appendix B). Sulfides were not analyzed, so the potential impacts of H_2S or other sulfide compounds cannot be determined. H_2S is a naturally occurring compound in some sediments, and can be present even at the shallow (2-3 cm) depth at which these samples were collected. H_2S can be a confounding factor in sediment toxicity tests by producing natural toxicity, although its effects on toxicity are minimized via continuous aeration.

The historical samples nearest to the 1998 IR 1-9 location are I1S-3 and I1SS-6, collected in 1990 and 1993, respectively (Figure 3-1). Since the locations shown in Figure 3-1 are approximate, the extent to which the toxicity tests conducted in 1998 can be related to chemical concentrations measured six to nine years ago is limited. Nevertheless, an evaluation of historical sediment data in nearby samples can still be useful to evaluate these relationships. Copper, lead, mercury, bis(2-ethylhexyl)phthalate, DDE, DDT, and seven PAH compounds were detected in 1990 at concentrations exceeding TEL values in sample I1S-3 (Appendix D), the historical sample nearest to IR 1-9. DDT was the only compound whose concentration exceeded its PEL value in the 1990 sample. Copper, lead, zinc, DDE, and DDT were detected in 1993 at concentrations exceeding TEL values in sample I1SS-6, collected slightly north of IR 1-9. DDT was the only compound whose concentration exceeded its PEL value in 1993. DDT was not detected in sample IR 1-9, however, and the concentration of DDT's metabolite DDE in IR 1-9 was considerably less than in IR 1-3, where the survival, growth, and reproduction of test organisms were normal. Although concentrations of some metals previously exceeded TEL values in the two samples collected near IR 1-9, concentrations of all metals were less than their respective ESVs in sample IR 1-9.

It is possible that PAH compounds could have been responsible for the reduced survival, growth, and reproduction in sample IR 1-9. This sample is unusual in having a low silt/clay content (1.0 percent; 0.2 percent in its duplicate), but a high TOC content (8.9 percent; 9.5 percent in its duplicate) (Table 4-6). A high organic carbon content in sandy sediments can be the result of PAH compounds. Concentrations of seven PAH compounds exceeded TEL values in nearby sample I1S-3, collected in 1990. Concentrations of PAH compounds did not exceed ESVs in the two nearest 1996 samples (I1SS-5 and I1SS-6), and the most recent ERA concluded that PAH compounds were not COCs (B&R Environmental, 1998a). For this reason, analyses for PAHs were not conducted in the current study. Thus, the possibility that PAH compounds were at least partially responsible for the reduced survival, growth, and reproduction in IR 1-9 cannot be ruled out.

A possible explanation for the low chemical concentrations, but low survival, growth, and reproduction in sample IR 1-9 is that the sample was not adequately mixed. Each sample was a composite of four to five sub-samples that were homogenized in the field prior to distribution into prepared containers for each analysis. If sub-samples were collected from "hot spots" of contaminants (such as those potentially represented by DDT in the nearby historical sample locations I1S-3 and I1SS-6) as well as from relatively "clean" areas, and were not adequately homogenized, then it would be possible for a relatively "clean" sub-sample to be sent to the chemical laboratory while a relatively contaminated sub-sample was sent to the toxicity test laboratory. This is conceivable, but the careful homogenization of sub-samples conducted by the sampling team would appear to render this an unlikely possibility.

In summary, an adequate explanation for the contradictory chemistry/toxicity test results in sample IR 1-9 cannot be determined. Possible explanations include sulfides, PAH compounds, inadequate sampling techniques, laboratory procedures, or unknown factors. However, the results of the chemical analyses suggest that site-related COCs do not appear to be responsible for the low survival, growth, and reproduction in this sample.

A similar situation exists for sample IR 1-10, in which growth was significantly reduced and survival was low relative to the reference sample (but the difference was not significant). Again, concentrations of metals were unremarkable in this sample, and the single detected organic compound (DDE) in this sample only slightly exceeded the most conservative ESV. As a result, chemistry results from the sample collected in 1998 suggest that the low values for survival and growth were not the result of site-related contaminants present in this sample. Samples were not previously collected from the vicinity of IR 1–10.

Survival in sample IR 1-8 was slightly reduced compared to BG 4, but the difference was not significant. This sample was one of three in which an H_2S odor was noted upon collection. Since growth and reproduction in this sample exceeded that in BG 4, and since pesticides and PCBs were not detected and concentrations of metals were less than ESVs, the reduced survival must be assumed to be due to factors other than site-related contaminants.

Samples collected from the southwestern portion of IR 1 (IR 1-1 through IR 1-4) tended to contain high concentrations of Aroclor-1260 and DDTR in the current study and in the previous ecological risk assessment. The concentration of Aroclor-1260 (3,750 μg/kg) was especially high relative to ESVs in sample IR 1-3. However, survival, growth, and reproduction in IR 1-1, IR 1-2, and IR 1-3 were normal. Therefore, based on the results of the toxicity tests, potential ecological risks from contaminants at these three sampling locations appear to be negligible.

Survival was normal but growth was significantly reduced in sample IR 1-4. Measurements of growth were reduced in all five replicates of this sample. Reproduction was slightly (but not significantly) reduced, and was within the range of BG 4 values for the first and second test. The concentration of Aroclor-1260 in this sample was especially high (8,920 μg/kg) as was DDE (119 μg/kg). The concentration of Aroclor-1260 was 47 times greater than the PEL (the value which represents the lower limit of the range of total PCB concentrations that are usually or always associated with adverse biological effects). This sample was collected in the general vicinity of the sample location known in previous investigations as I1SS-3. Historical concentrations of Aroclor-1260 and DDTR were elevated (Appendix D), but not as high as in the sample collected for the present study. Concentrations of DDTR and Aroclor-1260 in conchs collected from this area in 1996 exceeded concentrations in conchs collected from reference sites, but were less than published toxicity threshold concentrations for prey items of piscivorous receptors. (Tissue concentrations considered to be protective of the conchs themselves were not available). In summary, although the survival of *Leptocheirus* test organisms was normal in this sample, growth was significantly reduced, and was low in all five replicates of this sample. Concentrations of Aroclor-1260 and DDE were elevated. These two compounds, however, do not appear to have accumulated in tissues of aquatic species, based on samples collected in 1996. The potential impacts of PCBs and pesticides appear to be minor to *Leptocheirus plumulosus*, but could be greater to more sensitive organisms.

The remaining sample with poor performance in toxicity tests was IR 1-7, where survival, growth, and reproduction were significantly reduced. All five replicates in this sample performed poorly. Chemical concentrations of DDD and DDE were between the TEL and the PEL in this sample. In addition, this sample was responsible for the maximum concentrations observed at IR 1 for DDT, copper, and lead, all three of which exceeded the PEL. Furthermore, this sample is located in close proximity to the sample location known in previous investigations as I1SS-5, and at which concentrations of lead and DDT exceeded the PEL in a sediments collected in 1996 (Appendix D). The TOC was low (0.4 percent) in this sample, and thus effects of organic and inorganic contaminants are less likely to be ameliorated due to adsorption and complexation. In view of the chemistry data and consistently poor performance among replicates in the toxicity tests, it is assumed that potential ecological risks due to DDTR, lead, and possibly copper exist in the vicinity of this sample.

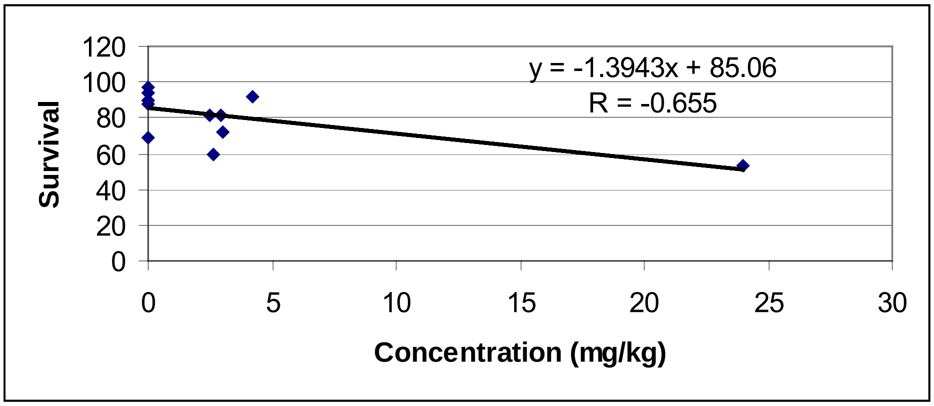
5.3 IR 8

5.3.1 <u>Chemistry Data</u>

An examination of the analytical chemistry data from the October 1998 samples collected at IR 8 (Tables 4-3 and 4-5) indicates that DDD and DDE concentrations only slightly exceeded TEL values, and concentrations of most metals were unremarkable. Concentrations of nickel in all samples were less than the lowest available ESVs shown in Table 3-2. ESVs for aluminum, barium, cobalt, iron, manganese, and vanadium have not been established by EPA Region 4 or FDEP. However, with the exception of iron, concentrations of these metals were either less than other available guidelines shown in Table 3-2, were less than or similar to concentrations in BG 4 and BG 8 samples, or were less than or similar to background values at background sites used in earlier ecological investigations (B&R Environmental, 1998a). Iron concentrations exceeded “other available” guidelines (Table 3-2) only in

FIGURE 5-1

CORRELATIONS OF AMPHIPOD TOXICITY TEST RESULTS VS. SEDIMENT DDT CONCENTRATIONS AT IR 1 AND REFERENCE SITES



NAS KEY WEST

Figure 5-1a: Percent survival as a function of sediment concentration of DDT using a value of zero for non-detected samples.

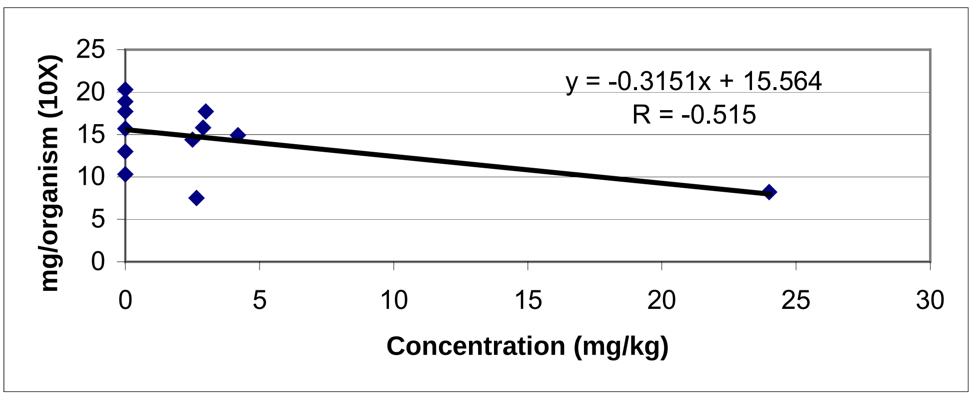


Figure 5-1b: Growth as a function of sediment concentration of DDT using a value of zero for non-detected samples.

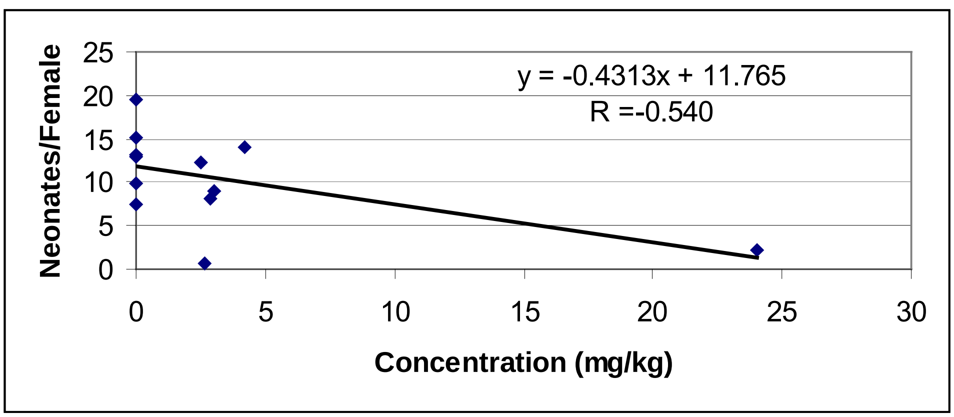


Figure 5-1c. Reproduction as a function of sediment concentration of DDT using a value of zero for non-detected samples.

6.0 CONCLUSIONS

6.1 IR 1

The recent ecological risk assessment conducted at IR 1 (B&R Environmental, 1998a) was based on data from groundwater, surface soil, sediment, surface water, and aquatic biota collected at the site. That report concluded that potential ecological risks at IR 1 are primarily confined to risks to benthic organisms from Aroclor-1260, organochlorine pesticides, copper, lead, and zinc in sediments. Further study was recommended to better characterize the nature and extent of toxicity in IR 1 sediments. Subsequently, additional sediment samples were collected and analyzed for chemical analytes and subjected to toxicity tests to investigate chronic toxicity to benthic organisms. Based on the results of these toxicity tests, potential ecological risks from site-related contaminants appear to be limited to the vicinity of sample locations IR 1-7 and IR 1-4.

Survival, growth, and reproduction were low in all five replicates of sample IR 1-7, and the tested parameters were significantly reduced, relative to reference site BG 4. Chemical concentrations of DDT and its metabolites, as well as lead and copper were elevated in this sample. Previous investigations found elevated concentrations of lead and DDT in the vicinity of this sample. In view of the chemistry data and consistently poor performance among replicates in the toxicity tests, it is assumed that potential ecological risks due to DDT, lead, and possibly copper exist in the vicinity of IR 1-7.

The slightly reduced growth of *Leptocheirus* test organisms at IR 1-4 is assumed to be due to the extremely high concentration of Aroclor-1260 in that sample, possibly combined with the moderately elevated concentration of DDE. These contaminants, however, do not appear to have accumulated in tissues of aquatic species, based on samples collected in 1996. The potential impacts of PCBs and pesticides are minor to *Leptocheirus plumulosus*, but could be greater to more sensitive organisms. Overall, however, potential risks from site-related contaminants in sample IR 1-4 appear to be negligible.

6.2 IR 8

The recent ecological risk assessment conducted at IR 8 (B&R Environmental, 1998a) was based on data from groundwater, surface soil, sediment, surface water, and aquatic biota collected at the site. That report concluded that potential ecological risks at IR 8 are primarily confined to risks to benthic organisms from copper, lead, and zinc in sediments. Further study was recommended to better characterize the nature and extent of toxicity in IR 8 sediments. Subsequently, additional sediment samples were collected and analyzed for chemical analytes and subjected to toxicity tests to investigate chronic toxicity to benthic organisms. Based on the results of these toxicity tests, potential ecological risks from site-related contaminants appear to be negligible.

7.0 REFERENCES

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APPENDIX A

RESPONSE TO COMMENTS ON THE SEDIMENT TOXICITY REPORT FOR SITES IR 1 AND 8

APPENDIX A. RESPONSE TO COMMENTS ON THE SEDIMENT TOXICITY REPORT FOR SITES IR 1 AND 8

U. S. ENVIRONMENTAL PROTECTION AGENCY TECHNICAL REVIEW COMMENTS ON THE SEDIMENT TOXICITY REPORT FOR SITES IR 1 AND IR 8, REV. 0 NAVAL AIR STATION, KEY WEST, FLORIDA

GENERAL COMMENTS

Comment 1: Overall, the performance of the toxicity test is in accordance with standard toxicity test methods. The data provided by the laboratory that performed the toxicity test is well presented and indicates that appropriate procedures were followed. However, it is not clear from the report text or the electronic data on the CD whether a clean control sediment sample was utilized in the performance of the toxicity test. The EPA 1994 Methods for Assessing the Toxicity of Sediment-associated Contaminants with Estuarine and Marine Amphipods recommends the use of a clean control sediment sample. The text should clarify whether a clean control sample was used in this test.

Response: *Concur. Although not clearly explained in the text of the laboratory's report, the toxicity tests did include a clean control sediment sample. The test results from this sample are shown in Table 3.1 of the laboratory's report (sample ID = "Mixed Lab"), in Appendix A of the laboratory report (sample ID = 01), and in Table 4-8 of the Navy's Sediment Toxicity Report (sample ID = "Mixed Sediment"). The laboratory study co-director has stated that the sample was obtained from what appeared to be a relatively uncontaminated area near St. Augustine, Florida (Meyer, 1999). The text will be revised as requested to clarify the use of the control sample.*

Comment 2: The report presentation does not readily lend itself to evaluation of the spatial proximity of the sediment sampling locations collected for toxicity testing to historical sediment sampling locations. It would be helpful to provide an additional figure in the report that depicts both the historical sample locations for chemical analysis and the sediment sampling locations collected for toxicity testing. Currently, the historical/prior sampling locations are presented in a report appendix on figures that are of a different spatial scale than the figure that depicts the sediment sampling locations collected for toxicity testing.

Response: *Concur. The idea of incorporating all sample locations into one figure was considered, but rejected, for the Rev. 0 report because of the inaccuracy inherent in the depicted sampling locations. Specifically, all locations shown in the figures contained in the report are approximate; i.e., none were surveyed or generated using GPS equipment. Useful landmarks along the shorelines from which* *accurate and precise locations could be measured are sparse. Furthermore, several of the locations shown on the figures in Appendix D were sampled by a previous contractor and the accuracy of those locations is not known. Nevertheless, the Navy concurs that the requested figures would aid in evaluating the historical analytical results versus the current analytical and toxicity test results. Therefore, additional figures (one for IR1 and one for IR 8) that depict the previous sampling locations and the locations from which samples were collected for toxicity tests in the current study will be added to the report as requested. Appropriate caveats regarding the accuracy of the depicted locations will be added to the text.*

SPECIFIC COMMENTS

Comment 1: Section 4.4.2. The first sentence in this paragraph needs clarification. The water reference toxicity test is primarily performed to assess the sensitivity of the culture organisms to a toxicant, not to assess the "health" of the organism as indicated in the report.

Response: *Concur. Water-only reference toxicity tests are conducted "…to determine the health and sensitivity of the organisms, to compare the relative sensitivities of substances by using the control as an internal standard, to perform interlaboratory calibrations, and to evaluate the reproducibility of test data with time" (Rand and Petrocelli, 1985). The first sentence in Section 4.4.2 will be revised to state that the reference toxicity test was conducted to assess the sensitivity of the test organisms to a reference toxicant.*

Comment 2:. Table 4-8. The IR1-7 average growth is reported in Table 4-8 differently than reported in the electronic data. The electronic data Table 3-1 presents 8.2 mg/Org average growth while Table 4-8 in the report presents 0.82 mg/Org average growth. Table 4-8 should be corrected.

Response: *The value of 8.2 mg/organism for sample IR1-7 is in error in the electronic data set; the correct value is 0.82 mg/organism as shown in Table 4-8. This can be verified by examining Appendix A of the laboratory report. Specifically, page 2 of Appendix A, which is the laboratory raw data sheet for lab sample I (IR1-7), shows the growth data for each of the five replicates; the average of these five values is 0.82 mg/organism.*

The electronic version of the laboratory report was generated from a draft report received from the testing laboratory. The error was discovered and corrected by the laboratory, and the final laboratory report contains the correct value. However, the electronic data on the CD submitted to the NAS Key West Partnering Team was inadvertently copied from the draft report. Similarly, the bar graph on page 6 of the electronic version of the laboratory report contained a minor error that was subsequently corrected. The Navy will resubmit the corrected electronic version of the laboratory toxicity report to the Partnering Team in the Rev. 1 version of the toxicity report.

Comment 3: Section 5.2.3 and Section 6.1. The discussion of the cause and effect relationship for sample IR1-9 should include the chemical concentrations previously detected in sediment samples as depicted on Figure 5-10 in Appendix D of the report. The conclusion that site-related COCs are not responsible for the significantly reduced survival, growth, and reproduction in sample IR1-9 needs to be better supported in the report.

Response: *The discussion regarding IR1-9 will be revised to include previous analytical results. The previous samples nearest to the 1998 IR1-9 location are I1S-3 (collected in 1990) and I1SS-6 (collected in 1993). As discussed in the response to general comment # 2, these locations are approximate, and the degree of accuracy is uncertain. Thus, the extent to which the toxicity tests conducted in 1998 can be compared to chemical concentrations measured six to nine years ago is limited. A more defendable approach is to compare the 1998 analytical results to the toxicity test results, since both these samples were collected from the same composite sample. The Rev. 0 report takes this approach, and also discusses other possible explanations for the poor toxicity test results. Unfortunately, an adequate explanation for the poor toxicity test results in sample IR1-9 has not been determined. Nevertheless, the data will be re-evaluated to identify any additional reasons for the results obtained from sample IR1-9.*

Comment 4: Section 7. The reference section of the report does not include the reference for the chronic sediment toxicity test method for the round robin study revised in 1997. This reference was provided in full, on the compact disk electronic data, by the laboratory that performed the toxicity tests. The reference for the chronic sediment toxicity test method for the round robin study revised in 1997 should be provided in section 7 of the report.

Response: *Concur. Section 7 of the report (References) will be revised to include the full citation of the 1997 round robin study.*

FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION
TECHNICAL REVIEW COMMENTS ON THE SEDIMENT TOXICITY REPORT
FOR SITES IR 1 AND IR 8, REV. 0
NAVAL AIR STATION, KEY WEST, FLORIDA

General Comments

Comment 1: The study design was well thought out and sampling appears to have been carefully and properly performed.

The report concludes that one site, IR 1-7, presented an environmental risk. I concur with this conclusion, but examination of the pattern of results contained in the report would lead one to conclude that the area around IR 1-7 would warrant further consideration. The pattern of contaminant concentration shows a peak of some contaminants for IR 1-7, with lesser enrichment for those contaminants in the samples adjacent to IR 1-7 (IR 1-6 and IR 1-8).

As there is no information presently available on the fine-scale variability of the sediment contaminant distribution, prudence would dictate either more clearly delineating the boundaries of the contaminated sediments or including the adjacent sites in any cleanup plans.

Response: *The data in Table 4-2 of the Sediment Toxicity Report for Sites IR 1 and IR 8 show that concentrations of all metals in sample IR 1-8 (the sample immediately east of sample IR1-7) were less than the most conservative ecological screening values (ESVs) presented in Table 3-2 of the report. In addition, pesticides and PCBs were not detected in this sample. Therefore, the analytical data indicate no contamination problems for this sample.*

Concentrations of analytes in sample IR1-6 (the sample immediately west of sample IR1-7) that exceeded ESVs consisted of copper, DDT, and the daughter products of DDT (i.e. DDD and DDE). The concentrations of these four analytes were between the threshold effects level (TEL) and the probable effects level (PEL) in this sample. However, the survival, growth, and reproduction of test organisms in the chronic sediment toxicity tests were normal. Thus, the toxicity test results indicate no apparent toxicity in sample IR 1-6 from these contaminants of potential concern (COPCs). In addition, analyses of tissues from lobsters, hermit crabs, conchs, and turtle grass collected from the vicinity of IR-1 indicate that bioaccumulation of these COPCs does not appear to be of concern (see "Supplemental RCRA Facility Investigation and Remedial Investigation Report for Eight Sites," 1998).

The sample locations in question (IR1-6, -7, and -8) were approximately 120 feet apart (See Figure 2-2 in the toxicity report). With this in mind, the Navy concurs that the extent of contamination centering on sample IR 1-7 has not been fully delineated. The extent of contamination, however, appears to be limited to a relatively small area. Based on evidence to date (especially the relatively small area of contamination in the vicinity of sample IR-7) the Navy believes that long term monitoring of this site is the most prudent course of action.

APPENDIX B

ELECTRONIC DATA

APPENDIX B. ELECTRONIC DATA

There are seven files of electronic data included on the compact disk (CD) included with Revision 1 of this document. The first file is entitled "28-Day Toxicity Tests". This is a copy of the final report received from Hydrosphere Research, Inc., describing the sediment toxicity tests that were conducted on samples collected from IR1, IR8, and reference sites. The remaining six files contain the analytical results from sediment samples collected for this study. Viewing these files requires Pagis Viewer©.

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APPENDIX C

REGRESSION ANALYSIS

APPENDIX C. REGRESSION ANALYSIS

As discussed in Section 3.4.3, linear regression was used to investigate the effects of total organic carbon content (TOC), silt/clay content, and chemical concentrations versus the toxicity test results. The results of these regressions are contained in this appendix as Table C-1 (IR 1 and reference sites) and C-2 (IR 8 and reference sites). The tables show the value for each parameter (chemical concentration, silt/clay content, and TOC) and the corresponding sample location and toxicity test result for survival, growth, and reproduction. The values for chemical concentrations, silt/clay contents, and TOC have been sorted in ascending order to assist the reader in observing potential trends in the toxicity test data.

Correlation coefficients for each combination of chemical, TOC, and silt/clay versus survival, growth, and reproduction are included in the tables. The critical value for the correlation coefficient, at 10 (n-2) degrees of freedom, one independent variable, and $\alpha = 0.05$, was 0.576. Thus, correlation coefficients greater than 0.576 or less than – 0.576 are considered to be statistically significant.

A value of one-half the detection limit was assigned to non-detected samples for the regression analyses of chemical concentrations. However, variable detection limits in non-detected samples can potentially mask real trends in detected values. Thus, for analytes in samples where the use of one-half of the detection limit did not reduce the nondetected value below the lowest actual detected value, two additional approaches were taken:

(1) A value of zero was assigned to the sample(s) in question for the regression analysis,

(2) The lowest detected value was assigned to the sample(s) in question for the regression analysis.

Analytes and numbers of samples where this was required consisted of the following:

- DDD 5 samples at IR 1
- DDE 1 sample at IR 1, 5 samples (plus 2 reference samples) at IR 8
- DDT 6 samples at IR 1
- Copper 1 sample at IR 8
- Zinc 1 sample at IR 8

Bold lines in Tables C-1 and C-2 separate the three approaches described above for assigning values to non-detected samples of DDD, DDE, and DDT. The three approaches had no impact on the regressions of copper and zinc concentrations and are not shown in Table C-2.

APPENDIX C-1. REGRESSION ANALYSIS IR 1

- Chemical Concentration vs. Toxicity Test Results
- Percent Silt/Clay Vs Toxicity Test Results
- TOC Vs Toxicity Test Results

APPENDIX C-2. REGRESSION ANALYSIS IR 8

- Chemical Concentration Vs Toxicity Test Results
- Percent Silt/Clay Vs Toxicity Test Results
- TOC Vs Toxicity Test Results

APPENDIX D

PREVIOUS SEDIMENT CHEMICAL CONCENTRATIONS AT IR 1 AND IR 8

Note: The figures in this Appendix were taken from the Supplemental RCRA Facility Investigation and Remedial Investigation Report for Eight Sites, Naval Air Station Key West, Florida (B&R Environmental, 1998).