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FIELD INVESTIGATION OF SOIL AND GROUNDWATER CONDITIONS AT THE FORMER  
SITES OF BUILDINGS 168 AND 169 EXCESSED LAND OF TRUMAN ANNEX NAS KEY  
WEST FL  
8/1/1988  
GERAGHTY AND MILLER INC

FIELD INVESTIGATION OF SOIL  
AND GROUND-WATER CONDITIONS  
AT THE FORMER SITES OF  
BUILDINGS 168 AND 169,  
EXCESSED LAND OF TRUMAN ANNEX  
NAVAL AIR STATION  
KEY WEST, FLORIDA

Prepared for

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## 1.0 INTRODUCTION

A parcel (103 acres of the Truman Annex) of the Naval Air Station-Key West (NAS) property (Figure 1) was purchased by the Truman Annex Company for redevelopment. During demolition of former Navy Buildings 168 and 169 located on this parcel of land (Figure 2), and subsequent regrading of the ground, soil exhibiting a yellow discoloration was observed. The Truman Annex Company (TAC) contracted Environmental Technology, Inc., (ET) of Richmond, Virginia, in October 1987 to analyze the soil. ET collected soil samples from depth intervals of 0 to 6 inches, 12 to 18 inches, and 24 to 30 inches. In some samples, chromium exceeded the Resource Conservation and Recovery Act (RCRA) maximum concentration level of 5 milligrams per liter (mg/L) when analyzed by the Extraction Procedure Toxicity (EP Tox) method (40 CFR, Part 261.24). Additionally, ET reported that the chromium concentrations in the soil samples having a yellowish discoloration were generally higher than soils that were not discolored.

Accordingly, the Truman Annex Company excavated the discolored soils to maximum depths of about 7 feet (ft). Reportedly, the excavated soils, were properly transported and disposed as a hazardous material at a U.S. Environmental Protection Agency (EPA) approved landfill.

The Navy retained Geraghty & Miller, Inc., (G&M) in December 1987 to conduct a Project Remedial Field Investigation (PRFI). The purpose of the PRFI was to evaluate the effectiveness of the excavation for removal of chromium-contaminated soils. The PRFI program was initiated in January 1988 and consisted of an initial site survey, installation of monitor-wells, and soil and ground-water sampling and analyses. In July 1988, additional ground-water samples were collected as part of the PRFI. The

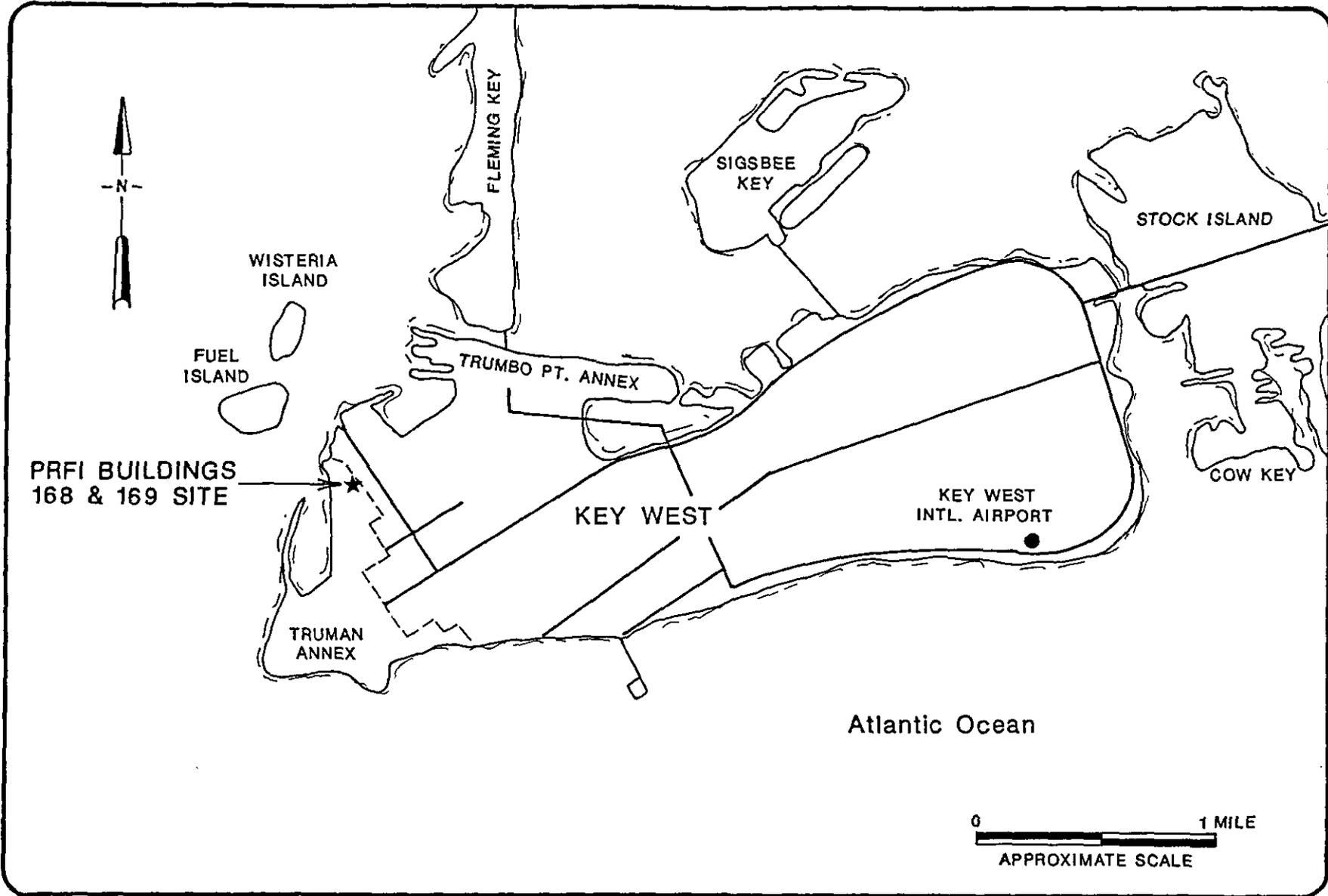


 Figure 1.  
Location of the PRFI Site at Truman Annex, Key West, Florida.

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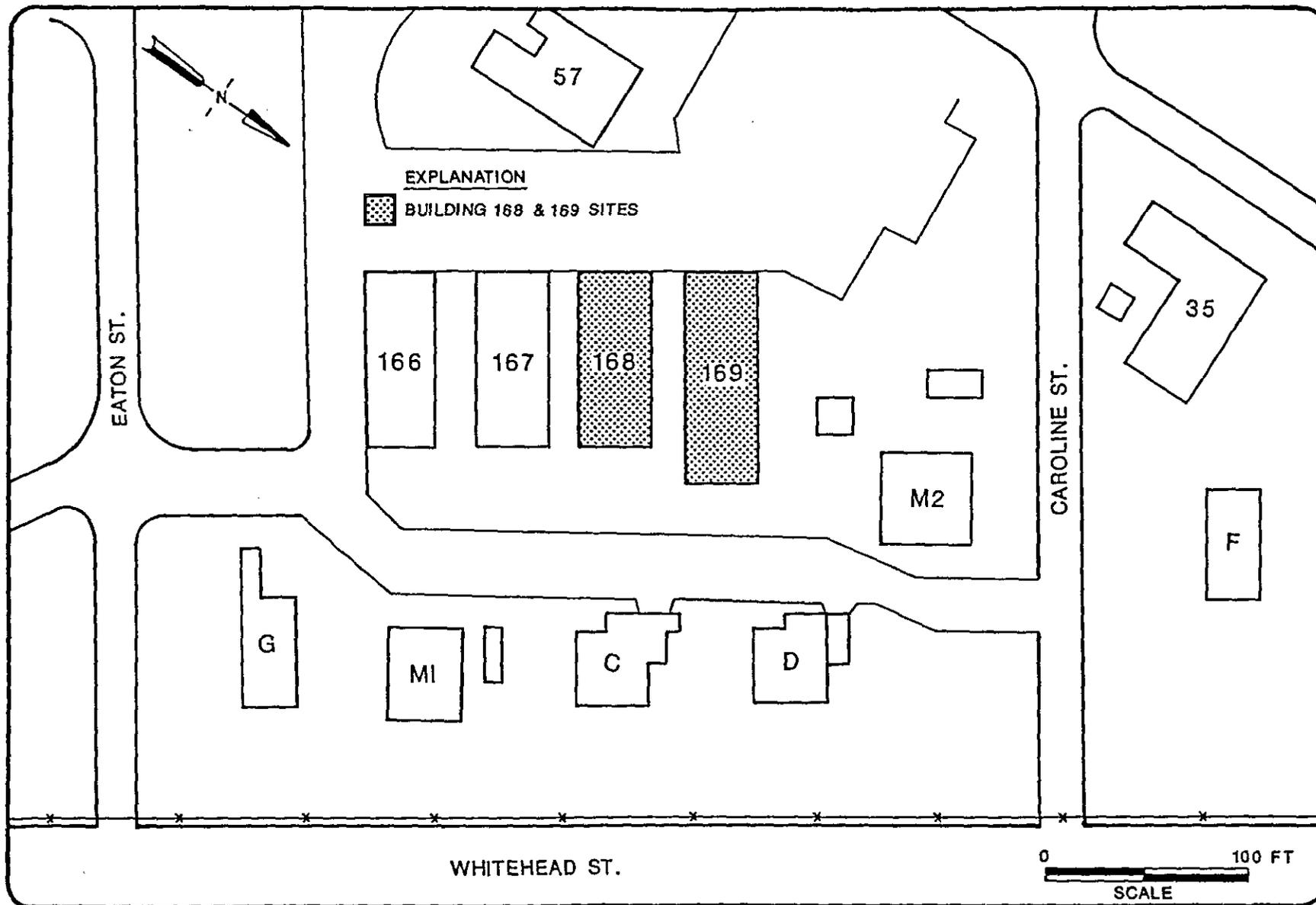


Figure 2.

Locations of Former Buildings 168 and 169.

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following report describes the work performed, the results of analyses, a risk assessment, and the conclusion and recommendation resulting from the investigation.

## 2.0 HYDROGEOLOGIC SYSTEM

### 2.1 TOPOGRAPHY AND DRAINAGE

The topography of Key West is generally flat, with land-surface elevations ranging from about 0 to 15 ft above mean sea level (msl). Average rainfall in Key West is approximately 40 inches per year, 70 percent of which is estimated to be lost to the atmosphere by evapotranspiration. The remaining rainfall either percolates rapidly into the permeable surficial sediments or is conveyed quickly to the sea via the storm drainage system.

### 2.2 GEOLOGY

The uppermost geologic formation in the lower Florida Keys is the Miami Oolite. This unit, encountered during the field investigation (see lithologic logs in Appendix A) is approximately 20 ft thick and is composed of sand-sized, rounded carbonate accretionary grains (oolites) mixed with carbonate sands and shelly material (White, 1970).

### 2.3 HYDROLOGY

Only thin lenses of fresh ground water may be found floating on denser underlying salt water in the larger islands of the Florida Keys. Such fresh-water lenses are generally absent on the smaller islands. During the rainy season, the fresh-water lenses may increase slightly in thickness, but during the dry season they tend to disappear rapidly through seepage to the sea and by evapotranspiration (Parker, 1955).

As reported in the Initial Assessment Study prepared by Envirodyne Engineers, Inc., in 1985, only a few wells in the Key West area yield relatively fresh water, and all water

needed for potable supplies is obtained from either rainwater catchments (cisterns) or the Florida Keys Aqueduct Authority via a 130-mile-long pipeline from the mainland. A report prepared by Dames and Moore, Inc., (D&M) in 1987 indicates that there are several wells located on Key West and that some residences might use these wells for drinking-water. However, D&M notes that water from these wells has not been approved for drinking by the Monroe County Health Department nor the Florida Department of Health and Rehabilitative Services.

### 3.0 WORK PERFORMED DURING THE FIELD INVESTIGATION

#### 3.1 SITE SURVEY

Prior to initiating the field work, a site visit was conducted to observe the physical setting of the site, interview persons knowledgeable about Buildings 168 and 169, and collect pertinent information concerning site history. This information indicated that the buildings have been leased to civilian interests beginning in 1976 and were used for storing a variety of materials until mid-1987; the records did not specifically indicate whether or not chromium-containing substances were stored in these buildings. This information was used to design the field investigation, and to prepare a Quality Assurance/Quality Control Plan (QA/QCP), a Health Monitoring Plan, and a Safety/Training Plan. Additionally, engineering plans of underground utilities around the site were reviewed to locate possible obstructions to the subsequent soil boring/monitor-well installation program.

#### 3.2 MONITOR-WELL INSTALLATION

Four monitor wells were installed on January 11 and 12, 1988, to a depth of about 15 ft at locations shown in Figure 3. Continuous split-spoon samples were collected while drilling the first of the four monitor wells to determine the general lithology of the site. Subsequently, cuttings from the remaining boreholes were collected, described, and observed for the presence of residual chromium discoloration. The lithologic descriptions prepared during drilling are presented in Appendix A.

Monitor-well installation was performed using the hollow-stem auger drilling method. When the augers had penetrated to a depth of 15 ft, 10 ft of 2-inch-diameter

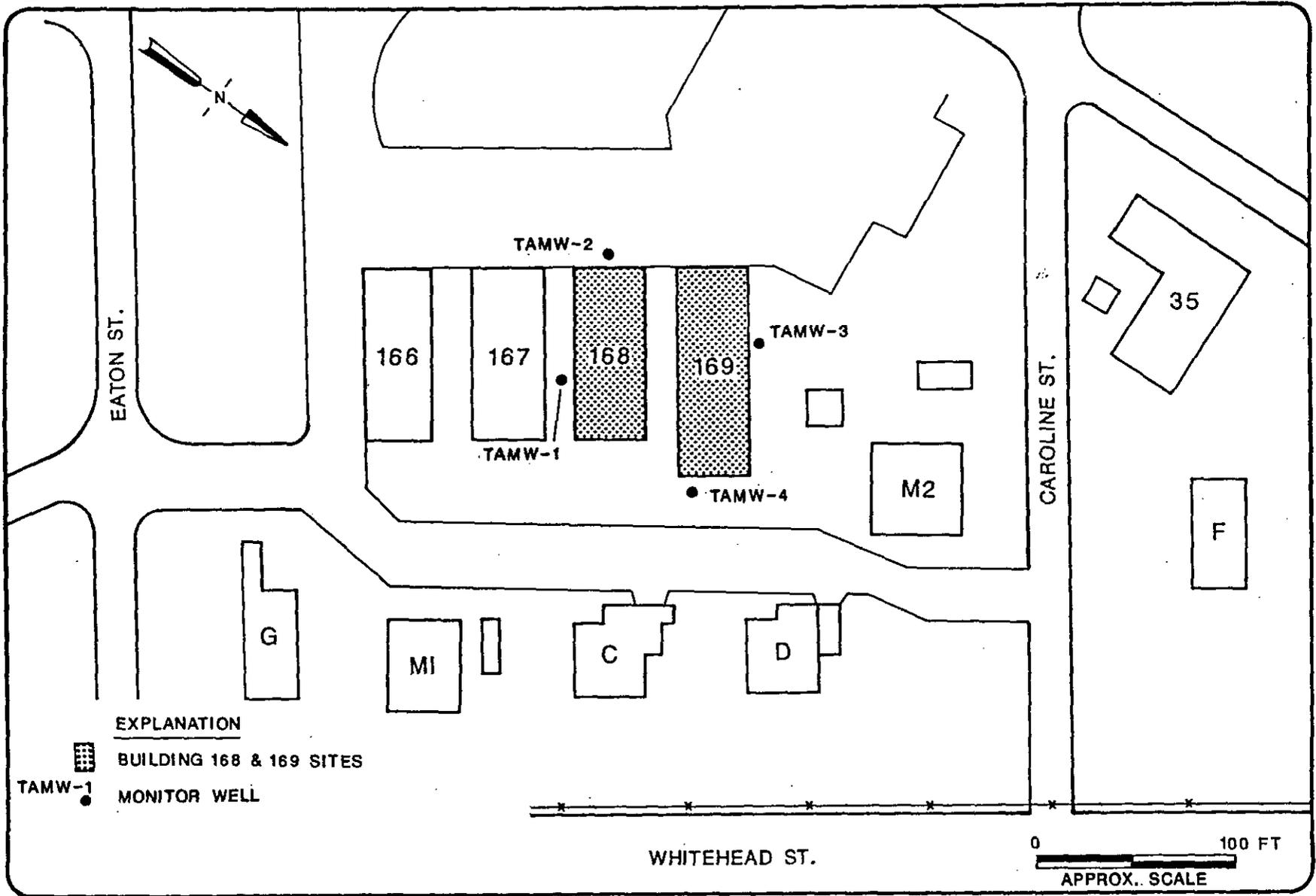


Figure 3.

Location of Monitor Wells.

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slotted PVC well screen (0.010-inch slot size) attached to 5 ft of 2-inch-diameter PVC riser pipe was installed. A graded silica sand (6/20 sieve size) then was emplaced in the annular space around the well casing and borehole wall to 1.5 ft above the top of the well screen. A fine sand cap (about 0.5 ft) then was installed on the sand pack. The remaining annular space was filled to land surface with a neat cement grout. The wells were fitted with locking caps, and a protective manhole cover was installed into the cement seal to protect the well from vandalism and vehicular traffic. The wells were developed by pumping until sand-free water was produced. The water produced during development, along with drill cuttings, were containerized in Department of Transportation Type 17-H drums. Navy personnel then removed the drums from the site. A well-construction diagram is shown in Figure 4 and construction specifications for each well are given in Table 1.

The tops of the monitor well casings were surveyed by a licensed land surveyor (State of Florida No. 2749) and referenced to a common datum, mean sea level (msl). Ground-water levels were measured in the wells on January 13 and 15 and July 28, 1988, and converted to elevations using this datum (Table 2). A water-table contour map for January 13, 1988 (Figure 5) indicates that the shallow ground-water flow direction is generally eastward, and that the hydraulic gradient is low.

### 3.3 GROUND-WATER SAMPLING

Ground-water samples were collected in accordance with the QA/QCP on January 13, 1988 from monitor wells TAMW-1 through TAMW-4. Prior to sample collection with a Teflon bailer, approximately five well volumes of water were removed from each well with a peristaltic pump. Measurements of temperature, pH, and specific conductance were made in the

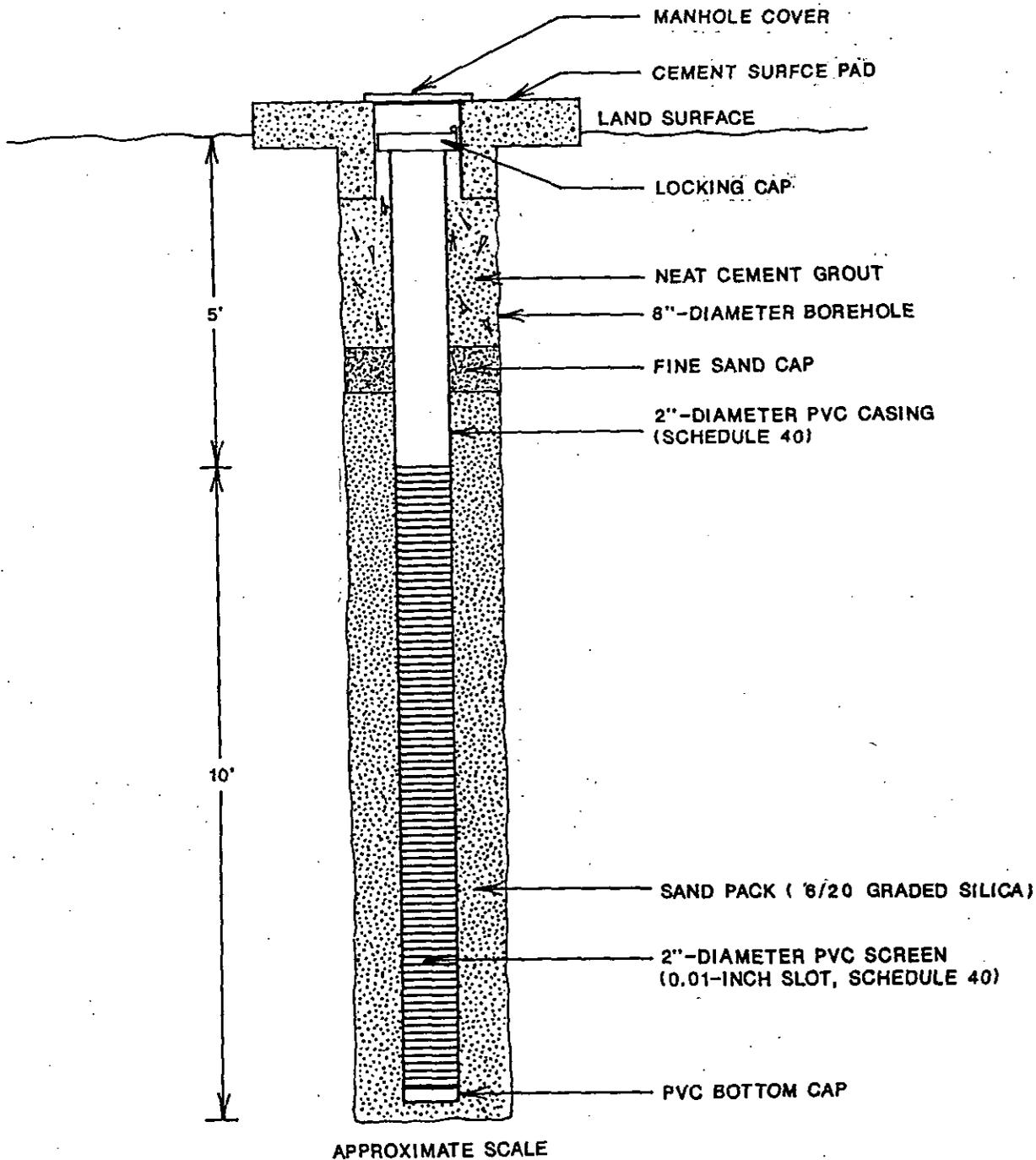


Figure 4.

Construction Diagram of  
Typical Monitor Wells.

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Table 1. Construction Details of Monitor Wells  
 Installed January 11 and 12, 1988

	Monitor-Well Number			
	TAMW-1	TAMW-2	TAMW-3	TAMW-4
Total Depth (ft bls) <sup>1/</sup>	15	15	15	15
Screened Interval (ft bls)	5-15	5-15	5-15	5-15
Cased Interval (ft bls)	0-5	0-5	0-5	0-5

<sup>1/</sup> ft bls = feet below land surface

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Table 2. Water-Table Elevations Collected  
on January 13 and 15, and July 28, 1988

	Monitor-Well Number			
	TAMW-1	TAMW-2	TAMW-3	TAMW-4
Measuring Point <sup>1/</sup> Elevation (ft msl) <sup>2/</sup>	7.38	7.33	6.86	7.82
Water-Level Elevation (ft msl)				
January 13, 1988	1.34	1.50	1.49	1.34
January 15, 1988	1.57	1.60	1.47	1.41
July 28, 1988	1.60	1.76	1.76	1.53

<sup>1/</sup> Measuring point is the north side of the top of locking well casing.

<sup>2/</sup> ft msl = feet above mean sea level.

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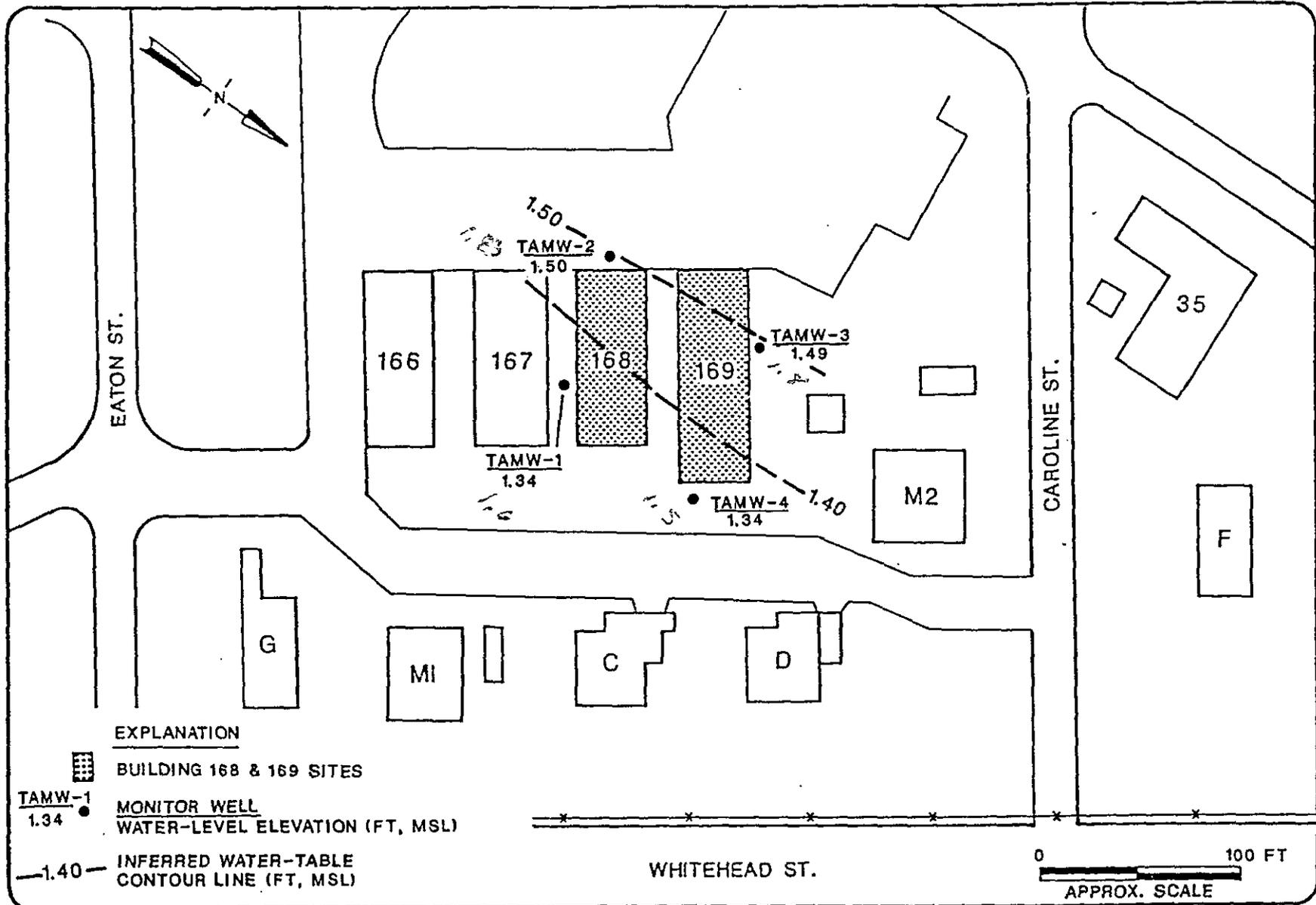


Figure 5.

Water-Table Contour Map, January 13, 1988.

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field during sampling and are summarized in Table 3. After filling the sample containers, they were placed on ice and shipped within 24 hours of collection to Pioneer Laboratory, Inc., to be analyzed for chloride (EPA Method 325.1), total dissolved solids, total chromium (EPA Method 218.1), and hexavalent chromium (EPA Method 218.5).

On July 28, 1988, a ground-water sample was collected in accordance with the QA/QCP from monitor well TAMW-2 for analysis of total and dissolved chromium (EPA Method 218.1), chloride (EPA Method 325.1), and total dissolved solids. To collect the sample, approximately five volumes of water were removed from the monitor well with a peristaltic pump prior to filling the sample containers. The sample that was to be analyzed for dissolved chromium was filtered with a 0.45 micron filter before being containerized. After the sample containers were filled, they were placed on ice and shipped via overnight delivery to Pioneer Laboratory, Inc. for analysis. Measurements of temperature, pH, and specific conductance were made in the field during sampling. The laboratory reports of all analyses are presented in Appendix B, and the results are presented in Table 3.

#### 3.4 SOIL SAMPLING

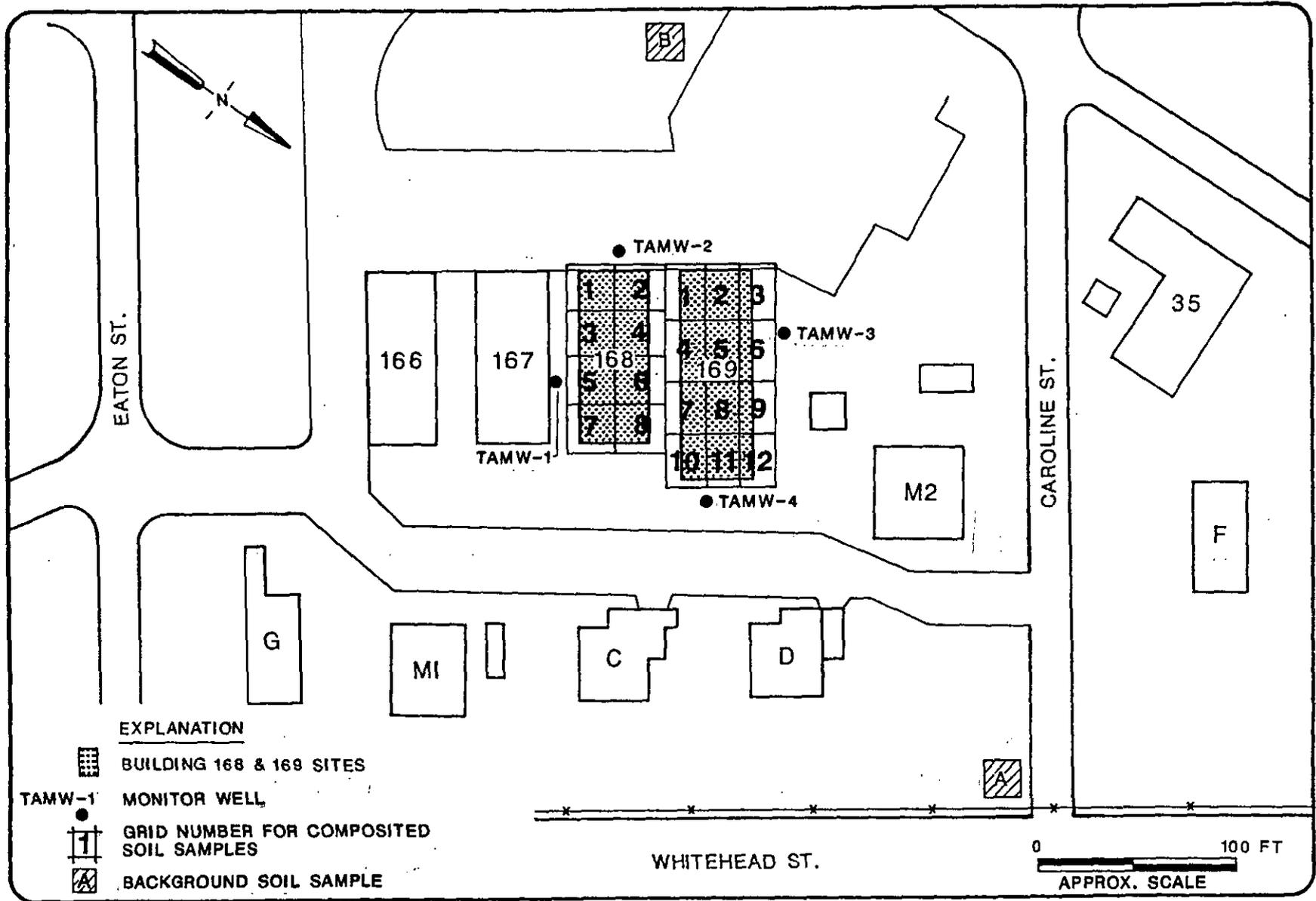
As previously discussed, soil had been excavated in selected locations to depths ranging from about 0.5 to 7 ft. The G&M soil sampling program was performed to evaluate whether the soil excavation program effectively removed all chromium-contaminated soil. On January 13 and 14, 1988, twenty soil samples were collected from the surface of the excavated areas to depths of 0.5 ft. Depending on the depth of excavation in a given area, these soil samples were collected from approximately 0.5 to 7.5 ft below the original land surface. Each of the samples (including 2 background samples collected at locations shown in Figure 6) consisted

Table 3. Results of Field Measurements  
and Laboratory Analyses of Ground-Water Samples  
Collected on January 13 and July 28, 1988

	January 13, 1988				July 28, 1988
	TAMW-1	TAMW-2	Monitor-Well TAMW-3	Monitor-Well TAMW-4	TAMW-2
<u>Field Parameters</u>					
pH (units)	7.22	6.93	6.73	7.15	7.05
Specific Conductance (umhos/cm) <sup>1/</sup>	800	1,810	1,030	720	1,560
Temperature °C <sup>2/</sup>	27	27	28	28	30
<u>Laboratory Parameters</u>					
Chloride (ppm) <sup>3/</sup>	179	308	118	37	215
Chromium (ppm)					
Total	BDL <sup>4/</sup>	2.02	BDL	BDL	2.7
Dissolved	-- <sup>5/</sup>	--	--	--	2.5
Hexavalent Chromium (ppm)	BDL	BDL	BDL	BDL	--
Total Dissolved Solids (ppm)	540	1,290	799	556	993

- 1/ umhos/cm = micromhos per centimeter  
2/ °C =degrees centigrade  
3/ ppm = parts per million  
4/ BDL = below laboratory detection limit  
5/ -- = analysis not performed

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**Figure 6.**  
Locations of Soil Samples.

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of 3 composited subsamples. Where possible, the subsamples were collected from areas having a yellow discoloration with large plastic spoons, composited in plastic bowls, and placed in plastic sample containers provided by the laboratory. Soil from each subsample location was also retained in a separate container and stored at the NAS-Key West should additional analyses be required.

The samples were designated according to the grid number and former building area (Figure 6) from which it was collected. The background soil samples were collected away from Buildings 168 and 169 in areas assumed to be free of chromium contamination. The locations of each subsample within each grid area were noted, photographed, and are on file in the G&M Tampa office.

The soil samples were preserved with ice and shipped via overnight delivery to Pioneer Laboratory, Inc., in Pensacola, Florida, for analysis. The samples were analyzed for pH and by the EP Tox method for chromium. Results of these analyses are presented in Table 4, and the laboratory reports are included in Appendix B.

Table 4. Results of Analyses of Soil Samples  
 Collected on January 13 and 14, 1988

Former Bldg. No.	Grid Number	Sample Number	pH (units)	EP Toxicity for Chromium (ppm <sup>1/</sup> )
168	1	SS8-1	9.29	1.7
168	2	SS8-2	9.02	3.5
168	3	SS8-3	7.96	3.1
168	4	SS8-4	9.43	0.82
168	5	SS8-5	9.26	0.15
168	6	SS8-6	9.44	0.75
168	7	SS8-7	9.14	0.67
168	8	SS8-8	9.45	0.10
169	1	SS9-1	9.33	0.43
169	2	SS9-2	7.77	1.8
169	3	SS9-3	9.00	2.6
169	4	SS9-4	9.18	0.08
169	5	SS9-5	8.63	0.37
169	6	SS9-6	8.72	3.2
169	7	SS9-7	9.22	1.9
169	8	SS9-8	9.24	0.20
169	9	SS9-9	9.40	0.02
169	10	SS9-10	9.20	0.58
169	11	SS9-11	8.94	0.92
169	12	SS9-12	9.52	0.09
Background				
A		SSBG-A	8.24	BDL <sup>2/</sup>
B		SSBG-B	8.96	BDL

<sup>1/</sup> ppm = parts per million

<sup>2/</sup> BDL = below laboratory detection limit of 0.01 ppm

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## 4.0 RESULTS OF WATER-QUALITY AND SOIL ANALYSES

### 4.1 GROUND WATER

Chloride and total dissolved solids concentrations in ground-water samples collected on January 13 and July 28, 1988, ranged from 37 parts per million (ppm) to 308 ppm; and 540 ppm to 1,290 ppm, respectively. The pH of the water was nearly neutral, ranging from 6.73 to 7.22.

Analyses of ground-water samples collected on January 13, 1988, indicated that no hexavalent chromium was detected, and samples from only one of the four monitor wells (TAMW-2) contained total chromium at 2.0 ppm. Monitor well TAMW-2 was resampled on July 28, 1988, and analysis indicated concentrations of total chromium (unfiltered) of 2.7 ppm and dissolved chromium (filtered) of 2.5 ppm.

### 4.2 SOIL

When performing the EP Tox method, the pH of the soil/extracting solution mixture was adjusted to approximately 5. Total chromium was then determined in the extracting solution. The soil's natural pH was alkaline with a range of 7.77 to 9.52 (Table 4). This condition reduces the solubility and mobility of chromium in the soil (Bartlett and Kimble, 1976). Because of the alkaline condition, the amount of chromium available to water percolating through the soil is much less than is indicated by the more acidic EP Tox leaching results.

All of the EP Tox test results for chromium were below the maximum contaminant level of 5 ppm (Table 4 and Appendix B) which designates whether a solid waste is hazardous or nonhazardous (40 CFR 261.24). As a further indicator of acceptability, 65 percent of the samples produced chromium

concentrations of less than 1 ppm. The distribution of chromium at the site seems to be random and does not indicate a point-source area. Furthermore, it should be noted that samples were collected from discolored areas which were suspected by previous investigators to correspond to areas of highest chromium contamination. No chromium was detected in the background samples above the laboratory detection level of 0.01 ppm.

## 5.0 RISK ASSESSMENT

The objective of a Risk Assessment (RA) is to evaluate the magnitude and degree of existing or potential risk to public health and the environment. The RA report prepared for the PRFI site was used to identify the health impacts of a no action alternative, and as a consequence, determine if there is a need for remediation.

This RA report has been written using the U.S. Environmental Protection Agency (EPA) Superfund Public Health Evaluation Manual for guidance. The analytical and site-specific data used to assess risk at the site has been assembled in a previous section of this report (Section 4.0) and Appendix B.

### 5.1 DESCRIPTION OF FACILITY

The description of the facility presents the physical circumstances of the contaminated site and provides relevant information about the site geology, hydrology, topography, drainage, surrounding land use, and a description of the most likely human and environmental receptor populations. Information presented in the facility description often is used to substantiate exposure scenarios posed in the exposure evaluation and risk characterization parts of the report. The description of the facility is presented in Sections 1.0, 2.0, and below.

The PRFI site is located in an area formerly Navy property and part of the Truman Annex. This property is presently being developed by the TAC into a private condominium/single-family home residential community. At present, access to the development is limited by an 8-ft high fence positioned along the northeast side of the property. The remaining property is bordered by the ocean or by Navy

property that is limited to access by U.S. Navy personnel only. During the field investigation, entrance to the TAC-owned part of the Truman Annex was monitored by a guard. The area adjacent to this development is primarily residential and consists of single-family homes, apartments, shops, hotels, and restaurants. The large number of permanent residents living within 1/4-mile of the site suggests that the residents be considered as potential receptors in the contaminant exposure evaluation.

The site exhibits physical and aesthetic features that are unattractive to nearby residents and tourists to Key West. The location of the site is on private property and parts of the development are undergoing demolition while others are under construction. In addition, local residents and tourists are most likely to be attracted to beaches and resort areas other than the construction site. Future building plans at the PRFI site show the construction of condominiums, parking lots, and a swimming pool.

## 5.2 CONTAMINANT EVALUATION

The contaminant evaluation process identified the extent of contamination. Within this process, a description of the analytical results for chromium was presented from samples obtained from ground water, and soil. This information is described in Section 4.0 of this report.

### 5.2.1 Toxicity Profile

An extensive toxicity review for chromium is provided in Appendix C. This section is presented to review the potential health effects as described in Health Advisory documents prepared by the EPA Office of Drinking Water. A brief toxicological profile of chromium follows:

### 5.2.2 Chromium

Chromium is a relatively rare, naturally occurring element in the earth's crust and occurs in most rocks and minerals at concentrations of 200 ppm. A few minerals contain chromium at concentrations of 2,000 to 3,000 ppm. Chromium is not mined in the United States commercially and is imported. Chromium and its compounds are used in alloys, pigments, the manufacturing of leather and textiles, catalysts, and wood preservatives, and is released to the environment during industrial activities.

Chromium can exist in several oxidation states from -2 to +6. In the natural oxygenated environment, chromium exists in three principal states: elemental ( $\text{Cr}^0$ ), trivalent ( $\text{Cr}^{+3}$ ), and hexavalent ( $\text{Cr}^{+6}$ ).

In general,  $\text{Cr}^{+6}$  compounds are more toxic than  $\text{Cr}^{+3}$  compounds because  $\text{Cr}^{+6}$  can transverse biological membranes by diffusion or facilitated transport. The toxicity of chromium has been attributed primarily to  $\text{Cr}^{+6}$ , which has been shown to produce liver and kidney damage, internal hemorrhage, dermatitis, and respiratory problems. The immediate symptoms of exposure are generally nausea, repeated vomiting, and diarrhea (U.S. EPA, 1985).

Subchronic and chronic dermal exposure to  $\text{Cr}^{+6}$  in the form of chromic acid may cause contact dermatitis and ulceration of the skin (Burrows, 1978). Chronic inhalation of dust or air containing  $\text{Cr}^{+6}$  may cause respiratory problems including ulcerated nasal septa and decreased respiratory volumes (U.S. EPA, 1985).

There is inadequate evidence to determine whether or not oral exposure to chromium can lead to cancer. No increase in the frequency of tumor formation over that of control animals

was observed in rats exposed to  $\text{Cr}^{+3}$  at concentrations of 293, 586, or 1,466 mg/kg/day in the diet for two years (Ivankovic and Preussmann, 1975).

The carcinogenicity of inhaled  $\text{Cr}^{+6}$  is well established for humans in an occupational setting (Hayes et al., 1979). Under these circumstances, the effects are observed only in the respiratory passages and in the lungs and are believed to have no bearing on carcinogenic risk following oral exposure to the metal (U.S. EPA, 1985).

The U.S. EPA Office of Solid Wastes has derived an RfD of 1.0 milligrams per kilogram per day (mg/kg/day) for  $\text{Cr}^{+3}$  and 0.005 mg/kg/day for  $\text{Cr}^{+6}$ . The U.S. EPA has a Maximum Contaminant Level (MCL) of 50 ug/L for total chromium in drinking water and proposed a Maximum Contaminant Level Goal (MCLG) of 120 micrograms per liter (ug/L). The EPA has classified the potential carcinogenicity of chromium as Class D: Not Classified. This category is for chemical agents with inadequate animal evidence of carcinogenicity. The analysis of ground-water samples obtained at the site for trivalent and hexavalent chromium ions did not report the presence of the hexavalent species. Thus, the RfD of 1.0 mg/kg/day for  $\text{Cr}^{+3}$  will be used to calculate the hazard index associated with human exposure to this compound, and calculations of dose and corresponding health risk will be based on noncarcinogenic effects.

### 5.3 DOSE-RESPONSE EVALUATION

In this section of the RA, the toxicological features of the indicator chemicals are identified. Since chromium is the only chemical detected at the site, the dose/response assessment will address the health hazards of chromium.

### 5.3.1 Toxicity

The recognized toxic responses associated with chromium are summarized in Table 5. A major distinction in the classification of toxic effects is between carcinogenic and noncarcinogenic effects. Due to the current regulatory approach to carcinogens, acceptable levels of exposure are based on extremely low hypothetical cancer incidence rates (1 in 10,000 to 1 in 1,000,000) rather than the observed finite threshold limits used for noncarcinogens. Because the method of calculating potential risk differs between carcinogens and noncarcinogens, the level of risk associated with carcinogenic effects is usually much higher than for noncarcinogenic effects. The discussion of adverse effects for the indicator chemicals is usually divided into carcinogenic and noncarcinogenic effects. However, since hexavalent chromium (a carcinogen) was analyzed but not detected in ground-water samples obtained at the site, it is assumed that reported chromium concentrations are  $\text{Cr}^{+3}$  and not  $\text{Cr}^{+6}$ . The RA will be restricted to the evaluation of the noncarcinogenic effects.

### 5.3.2 Noncarcinogenic Effects

Noncarcinogenic responses are generally believed to have a threshold value, which is a finite dose at which adverse responses are not elicited. A single compound might elicit several adverse effects depending on the dose and the length and route of exposure. In developing standards of criteria for a compound, the critical toxicity value, RfD or dose which elicits the most sensitive response in the most sensitive test organism, is used to establish the RfDs. In assessing risks, the most sensitive response is used to determine whether exposure is acceptable.

Table 5. Summation of Chromium Hazards

Chemical	CAS Number	Carcinogenicity <sup>1/</sup>	Reproductive/ Teratogenicity <sup>2/</sup>	Mutagenicity <sup>3/</sup>
Chromium	7440-47-3	X (Hexavalent Chromium only)	X	X

Adopted from "Chemical, Physical, and Biological Properties of Compounds Present at Hazardous Waste Sites," Office of Waste Programs Enforcement (OWPE), U.S. EPA, 1985. Criteria presented in this table is that of OWPE. An "X" indicates the chemical meets the criteria outlined by OWPE for the particular toxic effect classification. The lack of an "X" under a classification does not necessarily imply that the chemical cannot have a toxic effect.

<sup>1/</sup> A compound is classified as carcinogenic: if it is a known or suspected human carcinogen; if it has been shown to be carcinogenic at a particular site in more than one species or set in an animal bioassay; or if it has been shown to increase the incidence of site-specific malignant tumors in a single species or sex, and there is a statistically significant dose-response relationship in more than one exposed group.

<sup>2/</sup> Chemicals are classified as teratogens and reproductive toxins if there is suggestive evidence of an effect in humans or if at least one study in whole animals is clearly positive. Unsupported in vitro evidence is considered sufficient to classify a chemical as a reproductive toxicity/teratogenicity hazard.

<sup>3/</sup> A chemical is classified as mutagenic if it has given a positive result in at least one of the mammalian in vivo or bacterial mammalian cell in vitro assays for mutagenicity.

### 5.3.3 Comparison with Applicable or Relevant and Appropriate Requirements (ARAR)

Comparison between the maximum chromium concentrations reported in the ground water at the site and the current federal guidelines (Table 6) provides an initial method of distinguishing potential risks. With regard to the criteria to protect aquatic and marine life, the reported concentrations of chromium are several orders of magnitude less than the environmental criteria presented in Table 6.

### 5.4 EXPOSURE EVALUATION

The purpose of the exposure assessment is to identify the routes of exposure (inhalation, dermal contact, and ingestion) by which contaminants are transported from the site, and the contaminant dosage to human receptors.

A summary of the potential human exposure routes (Table 7) shows that five potential contaminant exposure routes are completed at the site. These are: dermal contact with surface soil, dermal contact with surface water in the excavation, dermal contact with ground water, ingestion of ground water, and the inhalation of fugitive dust. For convenience, the five exposure pathways have been combined into three to more correctly quantify the contaminant dose following exposure. These are: dermal contact/ingestion of soil, dermal contact/ingestion of ground water, and the inhalation of fugitive dust. Dermal contact with surface water in the excavation was not calculated because surface-water samples were not collected and the exposure scenario for ground water (dermal contact/ingestion) will quantify the health risks associated with exposure to water at the site.

Dermal contact and ingestion of soil at the site was described as an exposure event of low (current) and absent

Table 6. Applicable or Relevant, and Appropriate Requirements (ARARs)

Indicator Chemical	State of Florida Water Quality Standards (mg/L) <sup>1/</sup>	EPA <sup>2/</sup> MCL (mg/L)	EPA <sup>3/</sup> Proposed MCLG (mg/L)	ACGIH <sup>4/</sup> TLV <sub>3</sub> (mg/m <sup>3</sup> )	Federal Water Quality Criteria <sup>5/</sup>						Maximum Reported Concentration in Ground Water (mg/L)
					Fish Consumption Only (mg/L)	Water and Aquatic Life (mg/L)	Aquatic Life (Acute Toxicity) (mg/L)	Aquatic Life (Chronic Toxicity) (mg/L)	Marine Life (Acute Toxicity) (mg/L)	Marine Life (Acute Toxicity) (mg/L)	
Chromium (III)	.050	.050	.120	0.5	3433	170	1,700	210	10,300	---	2.02

1/ State of Florida Water Quality Standards

2/ Federal Register (7/8/87)

3/ Federal Register (10/11/85, 11/13/85)

4/ American Conference of Governmental Industrial Hygienists, 1987-1988

5/ USEPA, Office of Water, Regulations and Standards, Quality Criteria for Water 1986

--- Not available

Table 7. Present Potential Human Exposure Routes from the PRFI Site

Route of Exposure	Physical and Chemical Features	Environmental	Receptor Population	Current Probability of Exposure	Future Probability of Exposure Without Remedial Action	Pathway Complete
Dermal contact with soil in the excavated area.	Chromium is weakly adsorbed to soil particles.	The excavated area is covered with plastic tarps, but the public is not restricted from accessing the area, although the site is on private property.	Residents or tourists visiting the site. The site is in a residential area, but on private property that is under development.	low	absent	yes
Dermal contact with water accumulated in the excavated area.	Chromium is soluble in water. Chromium is not easily absorbed by skin.	The excavated area is covered with plastic tarps, but the public is not restricted from accessing the area, although the site is on private property.	Residents or tourists visiting the site. The site is in a residential area, but on private property that is under development.	low	absent	yes
Dermal contact with ground water.	Chromium is soluble in water. Chromium is not easily absorbed by skin.	Residential wells used for irrigation or to fill swimming pools present within 1/4-mile radius of the site.	Residents or tourists exposed to lawn irrigation or swimming in pools.	low	low	yes
Ingestion of ground water.	Chromium was detected in ground water above Florida drinking water standards.	Ground water is not the source of a public potable supply in this area. Some residents may be using ground water from wells within a 1/4-mile radius of the site. This practice is discouraged by city officials due to poor natural water quality.	Residents not using public potable water.	low	low	yes
Inhalation of fugitive dust.	The site is covered with plastic tarps to limit the release of fugitive dust.	The site is accessible to pedestrian traffic from adjacent residential areas.	Residents or tourists visiting the site. The site is on private property.	low	absent	yes

(future) probabilities of occurrence. Although the site does not attract trespassers and development plans indicate that the site will be paved over, an exposure scenario was devised. The exposure scenario quantifies the noncarcinogenic risk posed by a Key West resident who covers his or her face, neck, hands, and feet with chromium contaminated soil and consumes 10 mg of soil each day. Additional assumptions used to develop the dermal contact/ingestion exposure scenario are presented in Appendix D. Calculation of the Hazard Index (Chronic Daily Intake [CDI]/Reference Dose [RfD]) (Table 8 and Appendix E) shows that calculated CDI ( $2.4 \times 10^{-4}$  mg/kg/day) is less than the RfD (1.0 mg/kg/day) following dermal contact and ingestion of contaminated soil from the site (Table 8 and Appendix E).

Dermal contact and ingestion of ground water at the site was described as an exposure event with a low (current and future) probability of occurrence. Some local residents within 1/4-mile are believed to have shallow wells on their property. Although it is not known if these wells are used for potable supplies, city health officials do not condone the practice and advise that all residents use the municipal water supply. An exposure scenario was devised to address this possibility and to quantify the health risks associated with the consumption of and dermal contact with ground water. The exposure scenario simulates the use of ground water from a shallow well located at the site that intercepts the contaminated shallow aquifer. The assumptions used to develop the dermal contact/ingestion exposure scenario are presented in Appendix D. Calculation of the Hazard Index shows that the calculated CDI ( $7.1 \times 10^{-2}$  mg/kg/day) is less than the RfD for chromium (1.0 mg/kg/day) following dermal contact and ingestion of contaminated ground water from the site (Table 8 and Appendix E).

561/42

Table 8. Health Risk Summary  
(Noncarcinogenic Effects)

Route of Exposure	Receptor	Constituent/ Reported Concentration	CDI <sup>1</sup> mg/kg/day	RfD <sup>2</sup> mg/kg/day	Hazard Index <sup>3</sup>
Dermal Contact/ Ingestion of Soil	Adult	Chromium <sup>+3</sup> / maximum	$2.4 \times 10^{-4}$	$1.0 \times 10^0$	$2.4 \times 10^{-4}$ <del><math>1.8 \times 10^{-3}</math></del>
Dermal Contact/ Ingestion of Ground Water	Adult	Chromium <sup>+3</sup> / maximum	$7.1 \times 10^{-2}$	$1.0 \times 10^0$	$7.1 \times 10^{-2}$
Inhalation of Fugitive Dust	Adult	Chromium <sup>+3</sup> / maximum	$1.9 \times 10^{-5}$	$1.0 \times 10^0$	$1.9 \times 10^{-5}$ $2 \times 10^{-5}$

Total Health Risk (soil, ground water, and air)

$7.1 \times 10^{-2}$

- 1 Chronic daily intake
- 2 Reference dose
- 3 Hazard Index = CDI/RfD

The inhalation of fugitive dust at the site was considered an exposure event of low (current) and absent (future) probabilities of occurrence. The exposure scenario assumes that a resident will inhale contaminated fugitive dust from the site all day (24 hours). The assumptions used to develop the inhalation exposure scenario are presented in Appendix D. Calculation of the Hazard Index shows that the calculated CDI ( $1.9 \times 10^{-5}$  mg/kg/day) is less than the RfD for chromium (1.0 mg/kg/day) following the inhalation of fugitive dust from the site (Table 8 and Appendix E).

## 5.5 RISK CHARACTERIZATION

Risk characterizations are developed to evaluate the impact to public health. The environmental risk assessment qualitatively assesses the potential risk based on published aquatic toxicity data for chromium. The risk characterization for potential impacts to public health has been developed from analytical data and toxicological profiles.

This quantitative risk assessment involves the calculation of health risk levels that represents the possibility of exceeding the RfD (noncarcinogens) under the conditions described in the exposure scenario. Calculations of risk are made to overestimate the actual risks so as to evaluate the "worst case" scenarios for the purpose of determining the regulatory impact.

The health risk estimate for exposure to a noncarcinogen (Hazard Index) is determined by dividing the Chronic Daily Intake (CDI) or estimated dose by the Risk Reference Dose (RfD). The RfD is an estimate of the daily exposure to the human population that is likely to be without appreciable risk of deleterious effects over a lifetime, and is derived from the No-Observed-Adverse-Effect-Level (NOAEL), identified from a chronic (or subchronic) study, divided by an

uncertainty factor(s). This method of health risk estimate allows for the evaluation of a single chemical or multiple subthreshold chemical exposures. When the hazard index of any chemical (or many chemicals that induce the same effect on the same mechanism) poses an exposure dose level greater than the reference dose level (hazard index ratio greater than one), there may be concern for a potential health risk.

#### 5.5.1 Human Health Risk

##### 5.5.1.1 Dermal Contact and Ingestion of Soil

The total health risk posed by dermal contact/ingestion of soil for a resident near the site is several orders of magnitude less than the RfD for chromium (Table 8). The hazard index for an adult exposed to contaminated soil is  $2.4 \times 10^{-4}$  for the maximum reported concentration of chromium.

##### 5.5.1.2 Dermal Contact and Ingestion of Groundwater

The total health risk posed by dermal contact/ingestion of groundwater for a resident near the site is less than the RfD for chromium (Table 8). The hazard index for an adult exposed to contaminated groundwater is  $7.1 \times 10^{-2}$  for the maximum reported concentration of chromium.

##### 5.5.1.3 Inhalation of Fugitive Dust

The total health risk posed by the inhalation of fugitive dust contaminated with the highest reported concentrations of chromium are less than the RfD for chromium (Table 8). The hazard index for an adult that inhales contaminated fugitive dust is  $1.9 \times 10^{-5}$  as derived from the maximum reported concentration of chromium in the soil.

A risk characterization of the current and future human contaminant exposure routes at the site has shown that none of the routes of exposure pose a health risk in excess of the RfD for chromium. In addition, the health risks posed by the sum of all three exposure scenarios ( $7.1 \times 10^{-2}$ ) are below the RfD for chromium (Table 8).

#### 5.5.2 Environmental Health Risks

Adverse environmental effects beyond the chromium disposal area and the property boundary should not occur based on comparisons to environmental standards and information describing the extent of contamination.

### 5.6 RISK ASSESSMENT SUMMARY

This RA has evaluated the PRFI site located at the Truman Annex in Key West, Florida, to identify the existing or potential hazard(s) to public health and the environment. Estimated chronic daily intake for potential human exposure scenarios were determined to be less than health criteria (RfD) for chromium indicating an acceptable level of exposure. These exposure scenarios are as follows:

- o Ingestion and dermal contact with soil at the site;
- o Ingestion and dermal contact with ground water at the site; and
- o Inhalation of contaminated fugitive dust within the vicinity of the site.

Comparison of ground-water data to appropriate marine and aquatic chronic and acute criteria indicate that these health criteria have not been exceeded at the site.

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

Although residual chromium has been detected in the soil at the excavation area, the observed concentrations are below the limit that classifies the soil as being hazardous waste. The natural alkaline pH of the soil will help minimize the release of chromium that is bound to the soils by such processes as specific adsorption and ion exchange. Chromium was detected in only one of four ground-water samples which was located in an apparent upgradient position.

Based on a comprehensive risk assessment, the potential intake(s) and associated hazards to public health and the environment in the surrounding area are acceptable. Furthermore, future development activities that will reduce the amount of water percolating through the soils at the site will decrease the potential for migration of any residual chromium. Such activities would include paving, building construction, and the abandonment of the on-site monitor wells.

Based on the information collected and the findings of this investigation, additional remediation of the site is not recommended.

## 7.0 REFERENCES

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APPENDIX A  
Lithologic Logs

## LITHOLOGIC LOG FOR MONITOR WELL TAMW-1

<u>Description</u>	<u>Depth (ft)</u>	<u>Thickness (ft)</u>
Sand, quartz, fine-grained, gray to tan, mixed with organics.....	0 - 0.5	0.5
Limestone, oolitic, moderately to poorly lithified, silty, buff.....	0.5 - 16.0	15.5

## LITHOLOGIC LOG FOR MONITOR WELL TAMW-2

<u>Description</u>	<u>Depth (ft)</u>	<u>Thickness (ft)</u>
Sand, quartz, fine-grained, gray to tan, mixed with organics.....	0 - 0.5	0.5
Limestone, oolitic, moderately to poorly lithified, silty, buff.....	0.5 - 15.0	14.5

## LITHOLOGIC LOG FOR MONITOR WELL TAMW-3

<u>Description</u>	<u>Depth (ft)</u>	<u>Thickness (ft)</u>
Sand, quartz, fine-grained, gray to tan, mixed with organics.....	0 - 0.5	0.5
Limestone, oolitic, moderately to poorly lithified, silty, buff.....	0.5 - 15.0	14.5

## LITHOLOGIC LOG FOR MONITOR WELL TAMW-4

<u>Description</u>	<u>Depth (ft)</u>	<u>Thickness (ft)</u>
Sand, quartz, fine-grained, gray to tan, mixed with organics.....	0 - 0.5	0.5
Limestone, oolitic, moderately to poorly lithified, silty, buff.....	0.5 - 15.0	14.5

APPENDIX B

Laboratory Analyses of Ground-Water  
and Soil Samples



11 EAST OLIVE ROAD PENSACOLA, FLORIDA 32514  
PHONE (904) 474-1001

Client: GERAGHTY & MILLER  
07001 3820 NORTHDAL BLVD.  
SUITE 200  
TAMPA FL 33624-0000

Lab I.D.#: 88-0144  
Order Number: P10196  
Order Date: 01/14/88  
Sampled By: T. GIPE  
Sample Date: 01/13/88  
Sample Time: 1700

Project Number: 88-0144  
Project Name: T0290TA01  
Sample Site: TRUMAN ANNEX  
Sample Type: GROUNDWATER

N/S = Not Submitted

Lab ID	Sample ID	Parameter	Units	Results	Detection Limit
88-0144-01	TAMW-1	CHLORIDE	PPM	179	1
88-0144-02	TAMW-2	CHLORIDE	PPM	308	1
88-0144-03	TAMW-3	CHLORIDE	PPM	118	1
88-0144-04	TAMW-4	CHLORIDE	PPM	37	1
88-0144-05	TAFB	CHLORIDE	PPM	BDL	1
88-0144-06	TARS	CHLORIDE	PPM	BDL	1
88-0144-07	TRIP BLANK	CHLORIDE	PPM	BDL	1
88-0144-01	TAMW-1	CHROMIUM	PPM	BDL	0.01
88-0144-02	TAMW-2	CHROMIUM	PPM	2.02	0.01
88-0144-03	TAMW-3	CHROMIUM	PPM	BDL	0.01
88-0144-04	TAMW-4	CHROMIUM	PPM	BDL	0.01
88-0144-05	TAFB	CHROMIUM	PPM	BDL	0.01
88-0144-06	TARS	CHROMIUM	PPM	BDL	0.01
88-0144-07	TRIP BLANK	CHROMIUM	PPM	BDL	0.01
88-0144-01	TAMW-1	CHROMIUM HEXAVALENT	PPM	BDL	0.01
88-0144-02	TAMW-2	CHROMIUM HEXAVALENT	PPM	BDL	0.01
88-0144-03	TAMW-3	CHROMIUM HEXAVALENT	PPM	BDL	0.01
88-0144-04	TAMW-4	CHROMIUM HEXAVALENT	PPM	BDL	0.01
88-0144-05	TAFB	CHROMIUM HEXAVALENT	PPM	BDL	0.01
88-0144-06	TARS	CHROMIUM HEXAVALENT	PPM	BDL	0.01
88-0144-07	TRIP BLANK	CHROMIUM HEXAVALENT	PPM	BDL	0.01
88-0144-01	TAMW-1	TOTAL DISSOLVED SOLIDS	PPM	540	1
88-0144-02	TAMW-2	TOTAL DISSOLVED SOLIDS	PPM	1290	1
88-0144-03	TAMW-3	TOTAL DISSOLVED SOLIDS	PPM	799	1
88-0144-04	TAMW-4	TOTAL DISSOLVED SOLIDS	PPM	556	1
88-0144-05	TAFB	TOTAL DISSOLVED SOLIDS	PPM	BDL	1
88-0144-06	TARS	TOTAL DISSOLVED SOLIDS	PPM	BDL	1
88-0144-07	TRIP BLANK	TOTAL DISSOLVED SOLIDS	PPM	BDL	1

Comments: PPM = Parts Per Million, mg/l; BDL = Below Detection Limit;  
Method Reference: EPA 600/4-79-020, Revised March 1983.

Approved By : W. F. Bowers  
B-1 end of report





11 EAST OLIVE ROAD PENSACOLA, FLORIDA 32514  
PHONE (904) 474-1001

Client: GERAGHTY & MILLER  
07001 3820 NORTHDALE BLVD.  
SUITE 200  
TAMPA FL 33624-0000

Lab I.D.#: 88-0173  
Order Number: P10235  
Order Date: 01/16/88  
Sampled By: HEBERT/GIPE  
Sample Date: 01/16/88  
Sample Time: N/S

Project Number: 88-0173  
Project Name: GERAGHTY & MILLER  
Sample Site: T0290TA01/TRUMAN ANNEX  
Sample Type: SOIL BORINGS

N/S = Not Submitted

Lab ID	Sample ID	Parameter	Units	Results	Detection Limit
88-0173-01	SSBG-B	CHROMIUM	PPM	BDL	0.01
88-0173-02	SS9-4	CHROMIUM	PPM	0.08	0.01
88-0173-03	SS9-5	CHROMIUM	PPM	0.37	0.01
88-0173-04	SS9-6	CHROMIUM	PPM	3.2	0.01
88-0173-05	SS9-7	CHROMIUM	PPM	1.9	0.01
88-0173-06	SS9-8	CHROMIUM	PPM	0.20	0.01
88-0173-07	SS9-10	CHROMIUM	PPM	0.58	0.01
88-0173-08	SS9-11	CHROMIUM	PPM	0.92	0.01
88-0173-09	SS9-12	CHROMIUM	PPM	0.09	0.01
88-0173-10	SS9-9	CHROMIUM	PPM	0.02	0.01
88-0173-11	SS8-2	CHROMIUM	PPM	3.5	0.01
88-0173-12	SS8-4	CHROMIUM	PPM	0.82	0.01
88-0173-13	SS8-6	CHROMIUM	PPM	0.75	0.01
88-0173-14	SS8-3	CHROMIUM	PPM	3.1	0.01
88-0173-15	SSB6-A	CHROMIUM	PPM	BDL	0.01
88-0173-16	SS8-1	CHROMIUM	PPM	1.7	0.01
88-0173-17	SS8-5	CHROMIUM	PPM	0.15	0.01
88-0173-18	SS8-7	CHROMIUM	PPM	0.67	0.01
88-0173-19	SS8-8	CHROMIUM	PPM	0.10	0.01
88-0173-20	SS9-1	CHROMIUM	PPM	0.43	0.01
88-0173-21	SS9-2	CHROMIUM	PPM	1.8	0.01
88-0173-22	SS9-3	CHROMIUM	PPM	2.6	0.01
88-0173-23	RINSATE	CHROMIUM	PPM	BDL	0.01
88-0173-24	FIELD BLANK	CHROMIUM	PPM	BDL	0.01
88-0173-01	SSBG-B	PH	UNIT	8.24	
88-0173-02	SS9-4	PH	UNIT	9.18	
88-0173-03	SS9-5	PH	UNIT	8.63	
88-0173-04	SS9-6	PH	UNIT	8.72	
88-0173-05	SS9-7	PH	UNIT	9.22	
88-0173-06	SS9-8	PH	UNIT	9.24	
88-0173-07	SS9-10	PH	UNIT	9.20	

Comments: PPM = Parts Per Million, mg/l; BDL = Below Detection Limit  
Method Reference: SW-846, 3rd Edition, November 1986.  
Total Chromium analyses were performed on EP Toxicity Extract.

Approved By : W. F. Bowers



11 EAST OLIVE ROAD PENSACOLA, FLORIDA 32514  
PHONE (904) 474-1001

Client: GERAGHTY & MILLER  
07001

Lab I.D.#: 88-0173  
Order Date: 01/16/88  
Sampled By: HEBERT/GIPE

Sample Site: T0290TAO1/TRUMAN ANNEX  
Sample Type: SOIL BORINGS

Single Tests continued Sample Date: 01/16/88 Time: N/S

Lab ID	Sample ID	Parameter	Units	Results	Detection Limit
88-0173-08	SS9-11	PH	UNIT	8.94	
88-0173-09	SS9-12	PH	UNIT	9.52	
88-0173-10	SS9-9	PH	UNIT	9.40	
88-0173-11	SS8-2	PH	UNIT	9.02	
88-0173-12	SS8-4	PH	UNIT	9.43	
88-0173-13	SS8-6	PH	UNIT	9.44	
88-0173-14	SS8-3	PH	UNIT	7.96	
88-0173-15	SSB6-A	PH	UNIT	8.96	
88-0173-16	SS8-1	PH	UNIT	9.29	
88-0173-17	SS8-5	PH	UNIT	9.26	
88-0173-18	SS8-7	PH	UNIT	9.14	
88-0173-19	SS8-8	PH	UNIT	9.45	
88-0173-20	SS9-1	PH	UNIT	9.33	
88-0173-21	SS9-2	PH	UNIT	7.77	
88-0173-22	SS9-3	PH	UNIT	9.00	
88-0173-23	RINSATE	PH	UNIT	5.43	
88-0173-24	FIELD BLANK	PH	UNIT	5.28	



11 EAST OLIVE ROAD PENSACOLA, FLORIDA 32514  
PHONE (904) 474-1001

Client: GERAGHTY & MILLER  
07001 3820 NORTHDAL BLVD.  
SUITE 200  
TAMPA FL 33624-0000

Lab I.D.#: 88-2630  
Order Number: P14248  
Order Date: 07/29/88  
Sampled By: T. GIPE  
Sample Date: 07/28/88  
Sample Time: N/S

Project Number: TF0290KW08  
Project Name: TRUMAN ANNEX  
Sample Site: NAS KEY WEST  
Sample Type: GROUNDWATER

N/S = Not Submitted

Lab ID	Sample ID	Parameter	Units	Results	Detection Limit
88-2630-1	RNS-A	CHLORIDE	PPM	BDL	1
88-2630-2	TAMW-2	CHLORIDE	PPM	215	1
88-2630-1	RNS-A	CHROMIUM, TOTAL	PPM	0.08	0.05
88-2630-2	TAMW-2	CHROMIUM, TOTAL	PPM	2.7	0.05
88-2630-1	RNS-A	CHROMIUM, DISSOLVED	PPM	BDL	0.05
88-2630-2	TAMW-2	CHROMIUM, DISSOLVED	PPM	2.5	0.05
88-2630-1	RNS-A	TOTAL DISSOLVED SOLIDS	PPM	15	1
88-2630-2	TAMW-2	TOTAL DISSOLVED SOLIDS	PPM	993	1

AUG 1 1 88

Comments: PPM = Parts Per Million, mg/l; BDL = Below Detection Limits.  
Method Reference: EPA 600/4-79-020, Revised March 1983.

Approved By : W. F. Brown  
end of report

APPENDIX C

Chromium  
Health Advisory  
Office of Drinking Water  
U.S. Environmental Protection Agency

## CHROMIUM

Health Advisory  
Office of Drinking Water  
U.S. Environmental Protection Agency

I. INTRODUCTION

The Health Advisory (HA) Program, sponsored by the Office of Drinking Water (ODW), provides information on the health effects, analytical methodology and treatment technology that would be useful in dealing with the contamination of drinking water. Health Advisories describe nonregulatory concentrations of drinking water contaminants at which adverse health effects would not be anticipated to occur over specific exposure durations. Health Advisories contain a margin of safety to protect sensitive members of the population.

Health Advisories serve as informal technical guidance to assist Federal, State and local officials responsible for protecting public health when emergency spills or contamination situations occur. They are not to be construed as legally enforceable Federal standards. The HAs are subject to change as new information becomes available.

Health Advisories are developed for One-day, Ten-day, Longer-term (approximately 7 years, or 10% of an individual's lifetime) and Lifetime exposures based on data describing noncarcinogenic end points of toxicity. Health Advisories do not quantitatively incorporate any potential carcinogenic risk from such exposure. For those substances that are known or probable human carcinogens, according to the Agency classification scheme (Group A or B), Lifetime HAs are not recommended. The chemical concentration values for Group A or B carcinogens are correlated with carcinogenic risk estimates by employing a cancer potency (unit risk) value together with assumptions for lifetime exposure and the consumption of drinking water. The cancer unit risk is usually derived from the linear multistage model with 95% upper confidence limits. This provides a low-dose estimate of cancer risk to humans that is considered unlikely to pose a carcinogenic risk in excess of the stated values. Excess cancer risk estimates may also be calculated using the One-hit, Weibull, Logit or Probit models. There is no current understanding of the biological mechanisms involved in cancer to suggest that any one of these models is able to predict risk more accurately than another. Because each model is based on differing assumptions, the estimates that are derived can differ by several orders of magnitude.

This Health Advisory is based on information presented in the Office of Drinking Water's Health Effects Criteria Document (CD) for chromium (U.S. EPA, 1985). The HA and CD formats are similar for easy reference. Individuals desiring further information on the toxicological data base or rationale for risk characterization should consult the CD. The CD is available for review at each EPA Regional Office of Drinking Water counterpart (e.g., Water Supply Branch or Drinking Water Branch), or for a fee from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161, PB #86-118072/AS. The toll-free number is (800) 336-4700; in the Washington, D.C. area: (703) 487-4650.

## II. GENERAL INFORMATION AND PROPERTIES

### CAS No.

- Chromium -- 7440-47-3
- Chromium (III) Chloride -- 10025-73-7
- Chromic Acid, Dipotassium Salt -- 7789-00-6

### Synonyms

- None

### Uses

Chromium and its salts have a variety of uses including the following (for additional information see Hartford, 1979):

- Hexavalent chromium compounds are used widely in industry for chrome alloy and chromium metal production, for metal finishing and corrosion control (Love, 1947) and as mordants in the textile industry (Iler, 1954).
- Chromium salts are used as anticorrosive agents in cooling waters, in the leather tanning industry, in the manufacture of catalysts, in pigments and paints, and in fungicides and wood preservatives (Hartford, 1979).

Properties (Hem, 1970; Weast, 1971; Windholz, 1976)

- The properties of chromium compounds vary with the specific compound; some examples are as follows:

	<u>Chromium</u>	<u>Chromium (III) Chloride</u>	<u>Chromic Acid, Dipotassium Salt</u>
Chemical Formula	Cr	CrCl <sub>3</sub>	K <sub>2</sub> CrO <sub>4</sub>
Atomic/Molecular Weight	51.996	122.90	194.20
Physical State	blue-white solid	solid	solid
Boiling Point	2,642°C	--	--
Melting Point	1,900°C	83°C	968.3°C
Density	7.14 gm/cm <sup>3</sup>	2.76 g/cm <sup>3</sup> (15°C)	2.732 g/cm <sup>3</sup> (18°C)
Vapor Pressure	--	--	--
Water Solubility	0.5 ug/L	insoluble	62.9 g/100 mL (20°C)
Log Octanol/Water Partition Coefficient	--	--	--
Taste Threshold	--	--	--
Odor Threshold	--	--	--

Occurrence

- Chromium is a relatively rare, naturally occurring element in the earth's crust. Chromium occurs in most rocks and minerals at levels of 200 ppm. A few minerals contain chromium at levels of 2-3,000 ppm. Chromium is not mined in the U.S. commercially; it is imported. Chromium is released to the environment during industrial activities. However, current data suggest that surface and ground water levels of chromium are the result of naturally-occurring chromium leaching from mineral deposits. Soluble chromium has been reported to occur in surface waters at levels up to 84 ug/L and in ground water at levels of 50 ug/L (U.S. EPA, 1987).
- Federal surveys of surface and ground water drinking water supplies have reported that most supplies contain less than 5 ug/L. Currently, 17 ground water supplies and one surface water supply exceed the interim standard of 50 ug/L (U.S. EPA, 1987).

III. PHARMACOKINETICSAbsorption

In general, with the exception of the Cr III glucose tolerance factor (GTF), Cr VI is more readily absorbed than Cr III:

- In humans and experimental animals, gastrointestinal absorption of inorganic salts of Cr III is low (from 0.5% to 3%). However, Cr VI and organic complexes of Cr III are more readily absorbed (approximately 2% to 10% for Cr VI and 10% to 25% for organic complexes of Cr III) (U.S. EPA, 1985E).

- In humans administered 20 ng of Cr III as  $^{51}\text{CrCl}_3$  in water, 0.5% of the dose was recovered in the urine, indicating little absorption (Donaldson and Barreras, 1966). In rats, Mertz et al. (1965) reported 2% to 3% absorption of Cr(III) based on total body counting of animals administered  $^{51}\text{CrCl}_3$  by intubation at doses ranging from 1.5 to 100 ug/kg.
- GTF, an organic complex of Cr III with nicotinic acid and an amino acid that is found in brewer's yeast, was absorbed in rats at 10% to 25% of the administered dose (Mertz, 1976; Mertz et al., 1978).
- An estimate of 2.1% absorption of Cr VI based on recovery in urine was reported for humans administered 20 ng of  $\text{Na}_2^{51}\text{CrO}_4$  in water (Donaldson and Barreras, 1966)..
- Rats administered drinking water containing 25 mg/L Cr III as chromic chloride had 12.5 times greater tissue levels of chromium than rats whose drinking water contained 25 mg/L Cr VI as potassium chromate (Mackenzie et al., 1958).

#### Distribution

Depending on the particular compound (e.g., GTF) Cr III and Cr VI differ in their distribution within an organism; in general Cr III crosses membranes much more slowly than Cr VI (U.S. EPA, 1985):

- Chromium circulates in the plasma primarily in a nondiffusible form. A small fraction (9% to 12%) is in a more diffusible form which is filtered and partially reabsorbed in the kidney (Collins et al., 1961). An approximate plasma half-life of 6 hours for  $^{51}\text{Cr}$  III in rats was reported by Hopkins (1965) after intravenous administration of either 0.1 or 1.0 ug/kg.
- Cr III has an affinity for iron-binding proteins (Gray and Sterling, 1950; Hopkins and Schwarz, 1964).
- The spleen and kidneys were shown to have the highest concentrations of chromium when rats were administered Cr III as chromium chloride in intravenous doses of 0.1 or 1.0 ug/kg (Hopkins, 1965). Similar results were reported by Mackenzie et al. (1958) when rats received drinking water containing 25 mg/L of either Cr III as chromic chloride or Cr VI as potassium chromate. The calculated doses were 1.87 mg/kg/day for males and 2.41 mg/kg/day for females.
- The placenta appears to be highly selective in its permeability to the various forms of chromium. Inorganic Cr III administered as  $^{51}\text{CrCl}_3$  (chromium chloride) intravenously or by stomach intubation does not cross the placental barrier to an appreciable extent in rats (Mertz et al., 1969). However, Cr III administered by stomach intubation to pregnant rats in the form of GTF (obtained from yeast) is recovered readily from the fetus (Mertz and Roginski, 1971). The dosages in these two studies were unspecified.

- Cr VI traverses biological membranes by diffusion or facilitated transport, possibly via an anion transport system (Alexander et al., 1982). It is reduced to Cr III intracellularly by the cytochrome P-450 system in the presence of NADPH. Cr III reacts with nucleophilic ligands and cellular macromolecules (Gruber and Jennette, 1978).

#### Metabolism

- The metabolism of chromium in mammalian species is not well understood and is complicated by the presence of the two oxidation states, Cr III and Cr VI (U.S. EPA, 1985).

#### Excretion

The kidney appears to be the principal route of excretion of chromium compounds:

- The urinary system is the major excretory route for absorbed chromium, accounting for 80% or more of chromium excretion (Kraintz and Talmage, 1952). Very little is known about the form in which chromium is excreted.
- After intravenous administration, chromium is also excreted in the feces, although reports in the literature vary considerably on the percentage. Hopkins (1965) reported that 0.5% to 1.7% of the initial dose of Cr III was excreted in the feces of rats eight hours after intravenous administration of  $^{51}\text{CrCl}_3$  at 0.1 ug/100 g.

### IV. HEALTH EFFECTS

#### Humans

In general, Cr VI compounds are more toxic than Cr III compounds:

- The toxicity of chromium has been attributed primarily to Cr VI, which has been shown to produce liver and kidney damage, internal hemorrhage, dermatitis and respiratory problems. The immediate symptoms are generally nausea, repeated vomiting and diarrhea (U.S. EPA, 1985).
- Doses of 0.5 to 1.5 g of  $\text{K}_2\text{Cr}_2\text{O}_7$  have been fatal in humans. The estimated  $\text{LD}_{50}$  for  $\text{K}_2\text{Cr}_2\text{O}_7$  in children is 26 mg/kg (Cr VI at 9.2 mg/kg) (NIOSH, 1983).
- Subchronic and chronic dermal exposure to Cr VI in the form of chromic acid may cause contact dermatitis and ulceration of the skin (Burrows, 1978). For example, Denton et al. (1954) reported information on an individual who was patch-tested on three occasions with 0.005% potassium dichromate solution and the filtrate of two cement samples which contained 0.0001% and 0.0004% Cr VI. The individual repeatedly showed a positive erythematous, edematous, papulovesicular patch-test reaction to each test solution.

- Chronic inhalation of dust or air containing Cr VI may cause respiratory problems including perforated or ulcerated nasal septa and decreased spirometric values (U.S. EPA, 1985). For example, Bloomfield and Blum (1928) reported perforated/ulcerated nasal septa and inflamed nasal mucosa in workers exposed to chromic acid (Cr VI) (0.1 to 5.6 mg/m<sup>3</sup> air) for one week to three years,

### Animals

#### Short-term Exposure

In general, Cr VI compounds are more toxic than Cr III compounds:

- The oral LD<sub>50</sub> for various salts of Cr III range from 600 to 2,600 mg/kg (Smyth et al., 1969).
- The oral LD<sub>50</sub> of Cr VI (as Na<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>) in rats is 19.8 mg/kg (NIOSH, 1983).
- Rats were exposed to drinking water containing Cr VI (K<sub>2</sub>CrO<sub>4</sub>) at levels of both 80 and 134 mg Cr VI/L for 60 days (8.3 and 14.4 mg Cr VI/kg/day respectively) without adverse effect (Gross and Heller, 1946).

#### Long-term Exposure

- In a one year rat drinking water study, consumption of water containing 0 to 25 mg/L of either Cr III (CrCl<sub>3</sub>) or Cr VI (K<sub>2</sub>CrO<sub>4</sub>) (0 to 1.87 mg/kg/day for male rats and 0 to 2.41 mg/kg/day for female rats) produced no significant differences in weight gain, appearance or pathological changes in the blood or other tissues (Mackenzie et al., 1958). NOAELs of 1.87 mg/kg/day (males) and 2.41 mg/kg/day (females) can be identified from the results of this study.
- In a rat drinking water study in which 5 mg/L Cr III (about 0.42 mg/kg/day) was administered from the time of weaning until death, no adverse effects were observed (Schroeder et al., 1965). A NOAEL of 0.42 mg/kg/day can be identified from the results of this study.
- In a four year female dog drinking water study (five dose groups with two animals per group), Cr VI (K<sub>2</sub>CrO<sub>6</sub>) at 0.45 to 11.2 mg/L (0.012 to 0.30 mg/kg Cr VI) was without effect in terms of changes in physical condition, food consumption, growth rate, organ weights, urinalysis results and hematological analyses. Therefore, a NOAEL of 0.30 mg/kg/day can be identified from the results of this study (Anwar et al., 1961).

#### Reproductive Effects

- No information was found in the available literature on the reproductive effects of chromium.

#### Developmental Effects

- No information was found in the available literature on the developmental effects of chromium.

Mutagenicity

- ° The genotoxic effects of chromium are well documented both in in vivo and in vitro studies. The pathway by which chromium exerts these effects is believed to involve penetration of the cell membrane by Cr VI, followed by intracellular reduction to Cr III. Extracellular Cr III crosses the cell membrane, but less efficiently. Once inside the cell, Cr III can form tight complexes with DNA, accounting for its mutagenic potential (U.S. EPA, 1985).
- ° Compounds of both Cr III and Cr VI increase non-complementary nucleotide incorporation into DNA (Raffetto et al., 1977; Majone and Rensi, 1979), with Cr VI producing effects at lower doses. Exposure of cells from rat liver and kidney to Cr VI leads to increased cross-linking in DNA. Petrilli and De Flora (1978) reported positive Ames tests for Cr VI. However, Cr III exerted no effect at relatively high concentrations (presumably because of its inability to penetrate cells). Similar results were reported by Gentile et al. (1981).
- ° The difficulty of observing mutagenic effects of Cr III may be related to its slight uptake by cells under most conditions. Warren et al. (1981), studied the mutagenicity of a series of hexacoordinate Cr III compounds and concluded that, in the proper ligand environment, the metal possesses considerable genetic toxicity.

Carcinogenicity

There is inadequate evidence to determine whether or not oral exposure to chromium can lead to cancer:

- ° No increase in tumor rates over that of the control animals was observed in rats exposed to Cr III (chromium oxide pigments) at 293, 586 or 1,466 mg/kg/day in the diet for two years (Ivankovic and Preussmann, 1975).
- ° While the carcinogenicity of inhaled Cr VI is well established for occupational exposure of humans (Hayes et al., 1979), the effects are observed only in the respiratory passages and in the lungs, and are believed to have no bearing on carcinogenic risk following oral exposure to the metal (U.S. EPA, 1985).

V. QUANTIFICATION OF TOXICOLOGICAL EFFECTS

Health Advisories (HAs) are generally determined for One-day, Ten-day, Longer-term (approximately 7 years) and Lifetime exposures if adequate data are available that identify a sensitive noncarcinogenic end point of toxicity. The HAs for noncarcinogenic toxicants are derived using the following formula:

$$HA = \frac{(\text{NOAEL or LOAEL}) \times (\text{BW})}{(\text{UF}) \times (\text{L/day})} = \text{--- mg/L (--- ug/L)}$$

where:

NOAEL or LOAEL = No- or Lowest-Observed-Adverse-Effect-Level  
in mg/kg bw/day.

BW = assumed body weight of a child (10 kg) or  
an adult (70 kg).

UF = uncertainty factor (10, 100 or 1,000), in  
accordance with NAS/ODW guidelines.

\_\_\_ L/day = assumed daily water consumption of a child  
(1 L/day) or an adult (2 L/day).

In considering the toxicity of chromium compounds, it is important to realize that chromium III is an essential nutrient required in trace quantities for normal glucose metabolism - i.e. GTF. Some forms of chromium may also be important in the metabolism of lipids and other carbohydrates (U.S. EPA, 1985).

The Health Advisories will be determined on the basis of the effects of Cr VI measured as total chromium. Separate Health Advisories will not be established for Cr III for the following reasons:

1. Based on the work of Schroeder and Lee (1975), there is reason to believe that oxidizing agents (e.g. due to chlorination of water) may accelerate the normal conversion of Cr III to Cr VI at the point of consumption (i.e., the tap).
2. Health Advisories based on total chromium will allow for the possible conversion of Cr III to Cr VI.
3. As discussed in this document, there is reason to believe that Cr VI is more toxic than Cr III. Thus Health Advisories based on the effects of Cr VI will conservatively protect against the toxic effects of any Cr III not converted to Cr VI.

#### One-day Health Advisory

The available data are insufficient to develop a One-day HA for chromium. It is recommended that the Ten-day HA of 1.4 mg/L be used as the One-day HA for the 10 kg child.

#### Ten-day Health Advisory

Gross and Heller (1946) exposed both male and female rats for 60 days to drinking water containing  $K_2CrO_4$  at either 300 or 500 mg/L (Cr VI at 80 mg/L and 134 mg/L, respectively). Using reported average body weights of 270 and 260 g, respectively, and assuming consumption of 28 mL water per day, the average ingested doses of Cr VI are calculated to be 8.3 and 14.4 mg/kg/day, respectively. After two months, the rats receiving Cr VI at 8.3 mg/kg/day were described as normal. A "slight roughness of coat" was noted in rats receiving 14.4 mg/kg/day, but this is not considered to be an adverse health effect; this observation is not associated with other adverse health effects. Therefore, 14.4 mg/kg/day represents the NOAEL for Cr VI in this study.

The Ten-day HA for a 10-kg child is calculated as follows:

$$\text{Ten-day HA} = \frac{(14.4 \text{ mg/kg/day}) (10 \text{ kg})}{(100) (1 \text{ L/day})} = 1.4 \text{ mg/L (1400 ug/L)}$$

where:

14.4 mg/kg/day = NOAEL based on the absence of adverse effects in rats exposed to chromium in drinking water.

10 kg = assumed body weight of a child.

100 = uncertainty factor, chosen in accordance with NAS/ODW guidelines for use with a NOAEL from an animal study.

1 L/day = assumed daily water consumption of a child.

#### Longer-term Health Advisory

Mackenzie et al. (1958) studied the effects of chronic ingestion of Cr III and Cr VI in rats. Both male and female Sprague Dawley rats (34 days old) were supplied with drinking water containing Cr as  $\text{CrCl}_3$  (Cr III) or as  $\text{K}_2\text{CrO}_4$  (Cr VI) in a series of doses up to 25 mg/L for a period of one year. Assuming an average weight of 375 g for males and 290 g for females, and an average daily water intake of 28 mL (Arrington, 1972), the average dose for males and females receiving 25 mg/L is calculated to be 1.87 and 2.41 mg Cr VI/kg/day, respectively. No significant adverse effects on appearance, weight gain, food consumption or blood chemistry were noted at any of the dose levels. However, the animals receiving the highest dose (25 mg/L) of Cr VI showed an approximate 20% reduction in water consumption.

Cr VI at 2.41 mg/kg/day was identified as the NOAEL in this study. The Longer-term HAs are calculated as follows:

For a 10-kg child:

$$\text{Longer-term HA} = \frac{(2.41 \text{ mg/kg/day}) (10 \text{ kg})}{(100)(1 \text{ L/day})} = 0.24 \text{ mg/L (240 ug/L)}$$

where:

2.41 mg/kg/day = NOAEL based on the absence of adverse effects in rats exposed to chromium in drinking water.

10 kg = assumed body weight of a child.

100 = uncertainty factor, chosen in accordance with NAS/ODW guidelines for use with a NOAEL from an animal study.

1 L/day = assumed daily water consumption of a child.

For a 70-kg adult:

$$\text{Longer-term HA} = \frac{(2.41 \text{ mg/kg/day}) (70 \text{ kg})}{(100) (2 \text{ L/day})} = 0.84 \text{ mg/L (840 ug/L)}$$

where:

2.41 mg/kg/day = NOAEL based on the absence of adverse effects in rats exposed to chromium in drinking water.

70 kg = assumed body weight of an adult.

100 = uncertainty factor, chosen in accordance with NAS/ODW guidelines for use with a NOAEL from an animal study.

2 L/day = assumed daily water consumption of an adult.

### Lifetime Health Advisory

The Lifetime HA represents that portion of an individual's total exposure that is attributed to drinking water and is considered protective of noncarcinogenic adverse health effects over a lifetime exposure. The Lifetime HA is derived in a three step process. Step 1 determines the Reference Dose (RfD), formerly called the Acceptable Daily Intake (ADI). The RfD is an estimate of a daily exposure to the human population that is likely to be without appreciable risk of deleterious effects over a lifetime, and is derived from the NOAEL (or LOAEL), identified from a chronic (or subchronic) study, divided by an uncertainty factor(s). From the RfD, a Drinking Water Equivalent Level (DWEL) can be determined (Step 2). A DWEL is a medium-specific (i.e., drinking water) lifetime exposure level, assuming 100% exposure from that medium, at which adverse, noncarcinogenic health effects would not be expected to occur. The DWEL is derived from the multiplication of the RfD by the assumed body weight of an adult and divided by the assumed daily water consumption of an adult. The Lifetime HA is determined in Step 3 by factoring in other sources of exposure, the relative source contribution (RSC). The RSC from drinking water is based on actual exposure data or, if data are not available, a value of 20% is assumed for synthetic organic chemicals and a value of 10% is assumed for inorganic chemicals. If the contaminant is classified as a Group A or B carcinogen, according to the Agency's classification scheme of carcinogenic potential (U.S. EPA, 1986), then caution should be exercised in assessing the risks associated with lifetime exposure to this chemical.

The study by MacKenzie et al. (1958) (described under the Longer-term HA) is considered appropriate to serve as the basis for the Lifetime HA. The Anwar et al. (1961) study was not selected because only two animals per dose group were used.

Using the NOAEL of 2.41 mg/kg/day, the Lifetime HA is derived as follows:

Step 1: Determination of the Reference Dose (RfD)

$$\text{RfD} = \frac{(2.41 \text{ mg/kg/day})}{(100) (5)} = 0.0048 \text{ mg/kg/day}$$

where:

2.41 mg/kg/day = NOAEL based upon the absence of adverse effects in rats exposed to chromium in drinking water.

100 = uncertainty factor, chosen in accordance with NAS/ODW guidelines for use with a NOAEL from an animal study.

5 = additional uncertainty factor to compensate for less-than-lifetime exposure.

Step 2: Determination of the Drinking Water Equivalent Level (DWEL)

$$\text{DWEL} = \frac{(0.0048 \text{ mg/kg}) (70 \text{ kg})}{(2 \text{ L/day})} = 170 \text{ ug/L}$$

where:

0.0048 mg/kg = RFD.

70 kg = assumed body weight of an adult.

2 L/day = assumed daily water consumption of an adult.

Step 3: Determination of Lifetime Health Advisory

$$\text{Lifetime HA} = (170 \text{ ug/L}) (71\%) = 120 \text{ ug/L}$$

where:

170 ug/L = DWEL.

71% = assumed relative source contribution from water.

#### Evaluation of Carcinogenic Potential

- There is no evidence of carcinogenic effects following oral exposure to chromium. Thus, no assessments for carcinogenic risks from oral exposure to chromium have been conducted. Inhalation of chromium, however, is associated with an increased frequency of lung cancer in humans.
- EPA's CAG has estimated the lifetime cancer risk due to a constant exposure to air containing 1 ug/m<sup>3</sup> of elemental chromium to be 1.2 x 10<sup>-2</sup> (U.S. EPA, 1983).
- Based on exposure to chromium via inhalation, IARC (1982) has classified chromium and certain chromium compounds in Group 3 (Chromium VI); sufficient evidence for carcinogenicity in humans and animals.
- Applying the criteria described in EPA's guidelines for assessment of carcinogenic risk (U.S. EPA, 1986), chromium may be classified in Group A: Human carcinogen. This category is for agents for which

there is sufficient evidence to support the causal association between exposure to the agents and cancer. However, as there are inadequate data to conclude that chromium is carcinogenic via ingestion, chromium is dealt with here as Group D: Not classified. This category is for agents with inadequate animal evidence of carcinogenicity.

#### VI. OTHER CRITERIA, GUIDANCE AND STANDARDS

Recommended or established standards for chromium in the United States include:

- 50 ug Cr VI per liter for drinking water (U.S. PHS, 1962).
- 50 ug total chromium per liter for drinking water (NAS, 1974; U.S. EPA, 1976).
- 1 ug/m<sup>3</sup> for carcinogenic forms of Cr VI in workplace air (NIOSH, 1975).
- 25 ug/m<sup>3</sup> TWA or 50 ug/m<sup>3</sup> ceiling for non-carcinogenic forms of Cr VI in workplace air (NIOSH, 1975).
- The recommended ambient water quality criterion for Cr VI is 50 ug/L (U.S. EPA, 1980).
- An estimated adequate and safe intake for chromium of 50 to 200 ug/day for adults has been established (NAS, 1980a,b). This range is based on the absence of signs of chromium deficiency in the major portion of the U.S. population which consumes an average of 60 ug of chromium per day.
- The OSHA 8-hour time-weighted average exposure limit for chromium, soluble chromic, and chromous salts as chromium is 0.5 mg/m<sup>3</sup> (OSHA, 1985).

#### VII. ANALYTICAL METHODS

- Determination of chromium is by atomic absorption (AA) using either direct aspiration into a flame (U.S. EPA, 1979a) or a furnace technique (U.S. EPA, 1979b).
- The direct aspiration AA procedure is a physical method based on the absorption of radiation at 357.9 nm by chromium. The sample is aspirated into an air-acetylene flame and atomized. A light beam is directed through the flame into a monochromator, and onto a detector that measures the amount of light absorbed. Absorbance is proportional to the concentration of chromium in the sample. The detection limit is 50 ug/L using this procedure.
- The furnace AA procedure is similar to direct aspiration AA except that a furnace, rather than a flame, is used to atomize the sample. The detection limit is 1 ug/L using this procedure.

VIII. TREATMENT TECHNOLOGIES

- ° The treatment technologies that are available to remove chromium from water include coagulation/filtration, lime softening, ion exchange and reverse osmosis. However, the type of treatment that may be applied is dependent on the species of chromium present.
- ° Laboratory and pilot plant studies indicated that using ferric sulfate, Cr III removals were near 100 percent in the range of pH 6.5 to 9.5. Alum was less effective between pH 7.5 and 8.5, with removals around 90 percent or better. Above and below this pH range, removals were slightly lower, 80 to 90 percent. In removing Cr VI, laboratory and pilot-plant tests confirmed that of the three coagulants used, only ferrous sulfate was effective. With alum and ferric sulfate, Cr VI removals did not exceed 30 percent. By comparison, ferrous sulfate coagulation achieved 90 percent removal or better (U.S. EPA, 1977).
- ° Results of jar and pilot-plant tests indicate that Cr III removal efficiencies with lime softening were approximately 72 percent at pH 8.5 to 9.5 and greater than 99 percent at pH 11 to 11.5. Results with Cr VI in the same tests in all cases were less than 10 percent (U.S. EPA, 1977; Sorg, 1979).
- ° Since Cr III occurs in cationic species and Cr VI in anionic species, a cation exchanger in series with an anion exchanger may be required for their removal. Removal of Cr VI from sewage (Sorg, 1979), industrial wastewater, rinse waters from chromium plating operations (Miller and Mindler, 1978), cooling tower blowdown (Richardson et al., 1968; Miller and Mindler, 1978), and metal recovery (Sussman et al., 1945) has been demonstrated. Laboratory tests on a simulated Arizona well water (TDS 174 mg/L, pH 7.85) having 0.019 mg/L of Cr VI showed a breakthrough of Cr VI at roughly 12,000 bed volumes (U.S. EPA, 1982). Reports concerning industrial wastewater treatment indicate that ion exchange can successfully remove Cr III to below 0.05 mg/L (Patterson, 1975). Strong acid cationic resins have been used for removing Cr III as a contaminant from metal plating rinse waters and from chromate treated cooling waters. Vendor information indicates that operating pH levels of between 6 and 8 are adequate for Cr III removal with pH above 7 being slightly better than pH below 7 (Rohm and Haas Co., 1980). Ion exchange softening using standard strong acid synthetic resins operating in the sodium cycle should effectively remove Cr III with 90 percent or greater efficiency (Amore, 1977). In tests of home softeners with tap water spiked with 1 mg/L of chromium nitrate, the chromium content continued to be reduced to 0.020 mg/L after 192 cycles, at which point the test was discontinued.
- ° Reverse osmosis (RO) membranes can efficiently remove from 82 to 99 percent of the chromium in a feed water source (Fox, no date; Mixon, 1973; Johnston et al., 1978). Pilot plant tests using both cellulose acetate and hollow fiber (polyamide) membranes demonstrated their effectiveness in removing both Cr III and Cr VI. Cr III removal ranged from 90 to 98 percent and Cr VI removal ranged from 82 to 97 percent. Slightly better removal was achieved with the hollow fiber than with the cellulose acetate membranes (Fox, no date).

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APPENDIX D

Assumptions Used to Derive  
the Exposure Scenarios

Dermal Contact and Ingestion of Soil at the Disposal Site  
(Current/Baseline Conditions)

Constituent/Concentrations: Maximum reported concentration of chromium in the soil.

Area of Contact: The surface area of the hands, feet, face, and neck of an adult. Surface skin areas used for the exposure scenario were derived from:

U.S. Environmental Protection Agency (EPA) 1984. Review of Dermal Absorption, Exposure Assessment Group, Office of Health and Environmental Assessment, Office of Research and Development, October 1984.

Body Weight: 70 kg (adult). This data was obtained from the Superfund Exposure Assessment Manual, January 14, 1986.

Soil Consumption: 10 mg. This value was obtained from the Superfund Exposure Assessment Manual, January 14, 1986.

Soil Adherence Factor: 1.45 mg/cm<sup>2</sup>. Data describing dust adherence to skin are limited, although experimental values for (soil-related) dust adherence were reported by the Toxic Substance Control Commission of the State of Michigan (Harger, 1979). Commercial potting soil adheres to the land at 1.45 mg/cm<sup>2</sup>.

Absorption Factor: (intestinal). The soil absorption factor was based on the highest absorption factor reported for chromium +3 in the gastrointestinal tract.

Health Advisories for Legionella and Seven Inorganics, U.S. Environmental Protection Agency, Office of Drinking Water, March 1987.

Exposure Scenario Assumption: The proposed exposure scenario is hypothetical and does not reflect actual conditions observed at the site. The exposure scenario is considered a liberal exposure estimate since it takes into account both soil ingestion and dermal contact in an area that is restricted.

Dermal Contact and Ingestion of Groundwater  
(Current/Baseline Conditions)

Constituent/Concentration: The maximum reported concentration of chromium. The exposure scenario assumes that the human receptor has access, i.e., a potable supply well intercepting the contaminated ground water.

Water Consumption: 2 L/day (adult). This data was obtained from the Superfund Exposure Assessment Manual, January 14, 1986.

Body Weight: 70 kg (adult). This variable was obtained from the Superfund Exposure Assessment Manual.

Water Flux: 0.5 m/cm<sup>2</sup>-hour. The water flux through the skin was taken to be between 0.2 mg/cm<sup>2</sup>-hour and 0.5 mg/cm<sup>2</sup>-hour. These values were obtained from the Review of Dermal Absorption (U.S. EPA, 1984).

Absorption Factor: 3% (skin). The absorption factor for chromium on the skin was obtained from the maximum reported range in the gastrointestinal tract.

Exposure Scenario Assumption: The ingestion of ground water from the shallow aquifer will most likely never occur on or near the disposal area. Consideration of this exposure scenario in the RA is strictly hypothetical and is presented to satisfy health risk considerations in the endangerment assessment process. The availability of a municipal water supply further substantiates the hypothetical nature of this exposure scenario.

Inhalation of Fugitive Dust in Air  
(Current/Baseline Conditions)

Constituent/Concentration: The maximum reported concentration of chromium in the air as fugitive dust was extrapolated from the analysis of soil samples at the site. The concentration of chromium used in the exposure scenario was based on the worst-case assumption that the highest concentration of dust that can be suspended in air is approximately  $10 \text{ mg/m}^3$ . Based on this assumption, the concentration was derived for the equation ( $2.02 \times 10^{-5} \text{ mg/m}^3$ ) by converting the soil concentration of chromium to suspended dust.

Inhalation Rate: The inhalation rate of  $20 \text{ m}^3/\text{day}$  was obtained from the Superfund Exposure Assessment Manual, January 14, 1986.

Body Weight:  $70 \text{ kg}$  (adult). This value was obtained from the Superfund Exposure Assessment Manual, January 14, 1986.

Percentage Absorption: The exposure scenario assumes that all of the chromium inhaled is absorbed by the body.

Exposure Scenario Assumptions: The exposure scenario assumes that a resident (adult) would be exposed to fugitive dust emanating from the site all day.

APPENDIX E

Chronic Daily Intake Calculations

SOIL DERMAL CONTACT/INGESTION: DAILY EXPOSURE

EQUATION

$$\begin{aligned}
 \text{Chronic Daily Intake (CDI)} = & \text{Soil concentration (mg/kg)} \times \\
 & \left[ \frac{\text{Skin surface area (sq cm)}}{\text{Body weight (kg)}} \times \right. \\
 & \quad \text{Soil adherence factor (mg/sq cm/day)} \times \\
 & \quad \text{Absorption factor} + \\
 & \left. \frac{\text{Soil consumption (mg/day)}}{\text{Body weight (kg)}} \right] \times \\
 & \text{Unit conversion factor (kg/mg)}
 \end{aligned}$$

Example Calculation for Chromium III

$$\begin{aligned}
 \text{CDI} = & 3.5000 \text{ mg/kg} \times \frac{3390.00 \text{ sq cm}}{70.00 \text{ kg}} \times \\
 & \frac{2.71 \times 10^{-4} \text{ mg/sq cm/day}}{1.45} \times 1.00 + \\
 & \frac{10.00 \text{ mg/day}}{70.00 \text{ kg}} \times 0.000001 \text{ kg/mg} \\
 = & 0.00024628 \text{ mg/kg/day} \\
 & 0.0018
 \end{aligned}$$

271,42857

Daily Exposure Summary

Constituent	Concentration (mg/kg)	CDI (mg/kg/day)
Chromium III	3.5000	0.00024628

SOIL DERMAL CONTACT/INGESTION: DAILY EXPOSURE

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EQUATION

$$\text{Health Risk Ratio} = \frac{\text{Chronic Daily Intake (mg/kg/day)}}{\text{Reference Dose (mg/kg/day)}}$$

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Health Risk Ratio Summary

Constituent	CDI (mg/kg/day)	Reference Dose (mg/kg/day)	Health Risk Ratio
Chromium III	0.00024628	1.0000000	0.0002

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Total Health Risk Ratio

0.0002  
0.0018

GROUND-WATER DERMAL CONTACT/INGESTION: DAILY EXPOSURE

EQUATION

$$\begin{aligned}
 \text{Chronic Daily Intake (CDI)} = & \text{Ground-water concentration (mg/L)} \times \\
 & \left[ \frac{\text{Skin surface area (sq cm)}}{\text{body weight (kg)}} \times \right. \\
 & \text{Water flux (mg/sq cm/hr)} \times \\
 & \text{Absorption factor} \times \\
 & \text{Exposure duration (hrs/day)} \times \\
 & \left. \text{Unit conversion factor (kg/mg)} + \right. \\
 & \left. \frac{\text{Water Consumption (L/day)}}{\text{Body weight (kg)}} \right]
 \end{aligned}$$

Example Calculation for Chromium III

$$\begin{aligned}
 \text{CDI} = & 2.5000 \text{ mg/L} \times \left( \frac{19000.00 \text{ sq cm}}{70.00 \text{ kg}} \right) \times \\
 & 0.50 \text{ mg/sq cm/hr} \times 1.00 \times 0.25 \text{ hrs / day} \times \\
 & 0.000001 \text{ kg/mg} + \frac{2.00 \text{ L/day}}{70.00 \text{ kg}} \\
 = & 0.07151339 \text{ mg/kg/day}
 \end{aligned}$$

Daily Exposure Summary

Constituent	Concentration (mg/L)	CDI (mg/kg/day)
Chromium III	2.5000	0.07151339

GROUND-WATER DERMAL CONTACT/INGESTION: DAILY EXPOSURE

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EQUATION

Health Risk Ratio = Chronic Daily Intake (mg/kg/day) /  
Reference Dose (mg/kg/day)

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Health Risk Ratio Summary

Constituent	CDI (mg/kg/day)	Reference Dose (mg/kg/day)	Health Risk Ratio
Chromium III	0.07151339	1.0000000	0.0715

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Total Health Risk Ratio 0.0715

AIR INHALATION: DAILY EXPOSURE

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EQUATION

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$$\begin{aligned} \text{Chronic Daily Intake} &= \text{Air concentration (mg/cubic meter)} \times \\ \text{(CDI)} & \quad \text{Inhalation rate (cubic meters/hr)} \times \\ & \quad \text{Body weight (kg)} \\ & \quad \text{Exposure duration (hrs/day)} \end{aligned}$$

---

Example Calculation for Chromium III

$$\begin{aligned} \text{CDI} &= 0.000020200000 \text{ mg/cubic meter} \times \\ & \quad \checkmark 2.80 \text{ cubic meters/hour} / 70.00 \text{ kg} \times \\ & \quad \checkmark 24.00 \text{ hrs / day} \\ & = 0.00001939 \text{ mg/kg/day} \end{aligned}$$

---

Daily Exposure Summary

<u>Constituent</u>	<u>Concentration</u> <u>(mg/cubic meter)</u>	<u>CDI</u> <u>(mg/kg/day)</u>
Chromium III	0.000020200000	0.00001939

AIR INHALATION: DAILY EXPOSURE

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EQUATION

Health Risk Ratio = Chronic Daily Intake (mg/kg/day) /  
Reference Dose (mg/kg/day)

---

Health Risk Ratio Summary

<u>Constituent</u>	<u>CDI (mg/kg/day)</u>	<u>Reference Dose (mg/kg/day)</u>	<u>Health Risk Ratio</u>
Chromium III	0.00001939	1.0000000	0.00001939

---

Total Health Risk Ratio 0.00001939  
0,00003