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Office of
Emergency and
Remedial Response

EPA/ROD/R06-90/062
September 1990



Superfund Record of Decision:

Crystal Chemical, TX

ENVIRONMENTAL
PROTECTION
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16. Abstract (Limit: 200 words) The 24-acre Crystal Chemical site consists of a 7-acre abandoned herbicide manufacturing facility (referred to as the onsite area) and 18 acres of affected surrounding properties (referred to as the offsite area) in Houston, Harris County, Texas. The site lies within the 100-year floodplain of an adjacent flood control channel, and is underlain by a shallow aquifer system. Surrounding land use is commercial/industrial. From 1968 to 1981, herbicides, including arsenide compounds were manufactured at the site. During that time several structures, four evaporation ponds, and many storage tanks were utilized. Drums of raw and finished product were routinely stored in the open. Onsite soil was contaminated by herbicides spilled from drums during transfer of raw materials from rail cars. Contamination of offsite soil and sediment was a result of periodic flooding, which caused contaminated onsite materials to be relocated offsite. In 1981, the site was abandoned, and approximately 99,000 gallons of chemical liquids in a storage tank and 600,000 gallons of wastewater in the evaporation ponds were left onsite. Emergency Removal Actions conducted intermittently from 1981 to 1988, included removing chemical liquids and wastewater, temporarily capping the site, (See Attached Page)				
17. Document Analysis a. Descriptors Record of Decision - Crystal Chemical, TX First Remedial Action - Final Contaminated Media: soil, sediment, gw Key Contaminants: metals (arsenic) b. Identifiers/Open-Ended Terms c. COSATI Field/Group				
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Abstract (Continued)

dismantling and decontaminating structures, constructing drains and fencing, and placing fill material onsite. The primary contaminant of concern affecting the soil, sediment, and ground water is arsenic.

The selected remedial action for this site includes excavating approximately 55,000 cubic yards of offsite soil and sediment with arsenic levels greater than 30 mg/kg and redepositing the materials onsite; treating approximately 16,500 cubic yards of onsite soil and sediment with levels of arsenic greater than 300 mg/kg using in-situ vitrification; covering the onsite area with a multi-layer cap; pumping and treating approximately 3 million gallons of contaminated ground water using ferric hydroxide precipitation, flocculation, clarification, filtration, and ion exchange; discharging the treated water offsite to a publicly owned treatment works (POTW), to surface water, or reinjecting the treated water onsite; disposing of residual sludges at an offsite facility; conducting long-term ground water monitoring; and implementing institutional controls including land use restrictions. The estimated present worth cost for this remedial action is \$18,590,740, which includes an annual O&M cost of \$140,079 for 30 years.

PERFORMANCE STANDARDS OR GOALS: The excavation level of arsenic is 30 mg/kg for offsite soil and sediment and is based on calculated health standards. Treatment of onsite soil with greater than 300 mg/kg arsenic will effectively treat 95% of the onsite contamination and will reduce the amount of leachable arsenic to 5 mg/kg. The cleanup standard for ground water is arsenic 0.05 mg/kg, which is based on the Federal MCL.

Record of Decision

Crystal Chemical Company Site



**U.S. Environmental Protection Agency
Region 6
September 1990**

**Statutory Preference for Treatment as a
Principal Element is Met
and Five-Year Site Review is Required**

SITE NAME AND LOCATION

Crystal Chemical Company
3502 Rogerdale Road
Houston, Texas

STATEMENT OF BASIS AND PURPOSE

This decision document presents the selected remedial action for the Crystal Chemical Company site, Houston, Texas, was chosen in accordance with Comprehensive Environmental Response, Compensation, and Liability Act, as amended by Superfund Amendments and Reauthorization Act, 42 U.S.C. Section 9601, et seq., and to the extent practicable the National Oil and Hazardous Substances Pollution Contingency Plan, 40 CFR Part 300. This decision is based on the administrative record for this site.

The State of Texas concurs with the selected remedy.

ASSESSMENT OF THE SITE

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this Record of Decision, may present an imminent and substantial endangerment to public health, welfare, or the environment.

DESCRIPTION OF THE REMEDY

This Record of Decision addresses the contaminated soils on and off-site as well as the contaminated groundwater as one unit. The remedy for the soil contamination addresses the principal threats at the site by eliminating potential exposure via ingestion, inhalation or direct contact with contaminants and by reducing the potential for the soil to act as a continued source for surface water and ground water contamination. The remedy for the ground water contamination, too, addresses the principal threats by eliminating potential exposure via ingestion and direct contact with contaminants and by eliminating the potential for migration of contaminants to deeper zones of ground water.

The major components of the selected remedy include:

- Excavate arsenic-contaminated soil above 30 parts per million (ppm) from off-site and place it on the site.
- Treat soil with arsenic contamination greater than 300 ppm with the in-situ vitrification process.

- Install a multi-layer cap over the entire site.
- Pump ground water from contaminated aquifer(s), and treat the groundwater onsite by chemical precipitation, filtration, and ion exchange.
- Discharge treated water to Publicly Owned Treatment Works, an area surface water, or reinject into the ground.

DECLARATION


The selected remedy is protective of public health and welfare and the environment, complies with Federal and State requirements that are legally applicable or relevant and appropriate to the remedial action, and is cost-effective. This remedy utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable and satisfies the statutory preference for remedies that employ treatment that reduces toxicity, mobility, or volume as a principal element.

Because this remedy will result in hazardous substances remaining on site (i.e., soils contaminated with arsenical compound concentrations less than 60 parts per million), a review will be conducted within five years after commencement of remedial action to ensure that the remedy continues to provide adequate protection of public health and welfare and the environment.

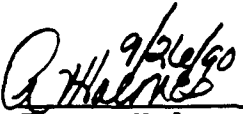
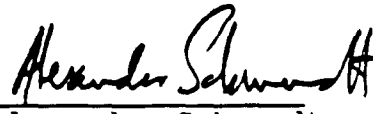
Robert E. Layton Jr. SEP 8 1 1990

Robert E. Layton Jr., P.E.
Regional Administrator
Region VI


RECORD OF DECISION
CRYSTAL CHEMICAL COMPANY SITE
HOUSTON, TEXAS
CONCURRENCE
SEPTEMBER 1990



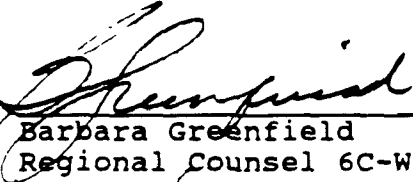
Stan Hitt, Section Chief
Texas Enforcement Section 6H-ET

 9/26/90  9/26/90

Renee Holmes/Alexander Schmandt
Assistant Regional Counsel 6C-WT



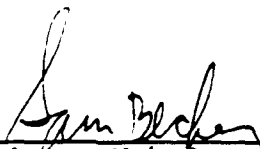
Pam Phillips
Assistant Regional Counsel 6C-WT




Barbara Greenfield
Regional Counsel 6C-W



George Alexander
Regional Counsel 6C



Sam Becker, Chief
Superfund Enforcement Branch 6H-E



Allyn M. Davis
Director
Hazardous Waste Management Division 6H

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ATTACHMENT 3 - ADMINISTRATIVE RECORD INDEX

**DECISION SUMMARY
FOR THE
CRYSTAL CHEMICAL SITE
HOUSTON, TEXAS**

I. SITE NAME AND LOCATION

The Crystal Chemical Company site ("Crystal Chemical site" or "the site") is located at 3502 Rogerdale Road, in southwestern Houston, Harris County, Texas. The company operated on approximately 6.8 acres. The acreage is bounded on the west by the Harris County Flood Control Channel and lies immediately south of Westpark Drive. The areal extent of contamination, however, covers approximately 24.4 acres. (All further discussions referring to the "onsite contamination" refer to the 6.8 acres on which the Crystal Chemical Company operated, and discussions of "offsite contamination" refer to the estimated areal extent of contamination off of the site that covers approximately 17.6 acres.) The site is located east of the area of Harris County known as Alief (see Figure 1). While the Crystal Chemical Company was operating, four evaporation ponds, several structures, and many storage tanks existed on the site (see Figure 2). The site is now fenced, and all above ground structures have been removed. The site has also been capped and graded in order to promote drainage (see Figure 3). The land immediately surrounding the site is vacant, commercial, and industrial. An estimated 20,000 people, however, live within a one-mile radius of the site. Approximately 20 water wells are located within a one-mile radius of the Crystal Chemical site. These include public drinking water wells, and industrial, irrigation, and observation wells.

The Harris County Flood Control Channel bounds the Crystal Chemical site on the west. Surface waters that enter the flood control channel flow south and are discharged into the Brays Bayou, approximately one mile south of the site. Brays Bayou eventually drains into the Houston Ship Channel, which enters Scott Bay and eventually Galveston Bay. There is no designated Texas significant habitat, agricultural land, or historic/landmark site directly or potentially effected. A Preliminary Natural Resource Survey was conducted by the National Oceanic and Atmospheric Administration ("NOAA") in February 1989. To date, NOAA has not indicated whether that there is direct impact to NOAA resources. Additionally, there are no endangered species or critical habitats within close proximity of the site.

II. SITE HISTORY AND ENFORCEMENT ACTIVITIES

Crystal Chemical Company produced arsenical, phenolic and amine-based herbicides from 1968 to 1981. Operation and maintenance problems at the Crystal Chemical facility during the late 1970s resulted in several violations of the environmental standards of the Texas Department of Water Resources ("TDWR"), now the Texas

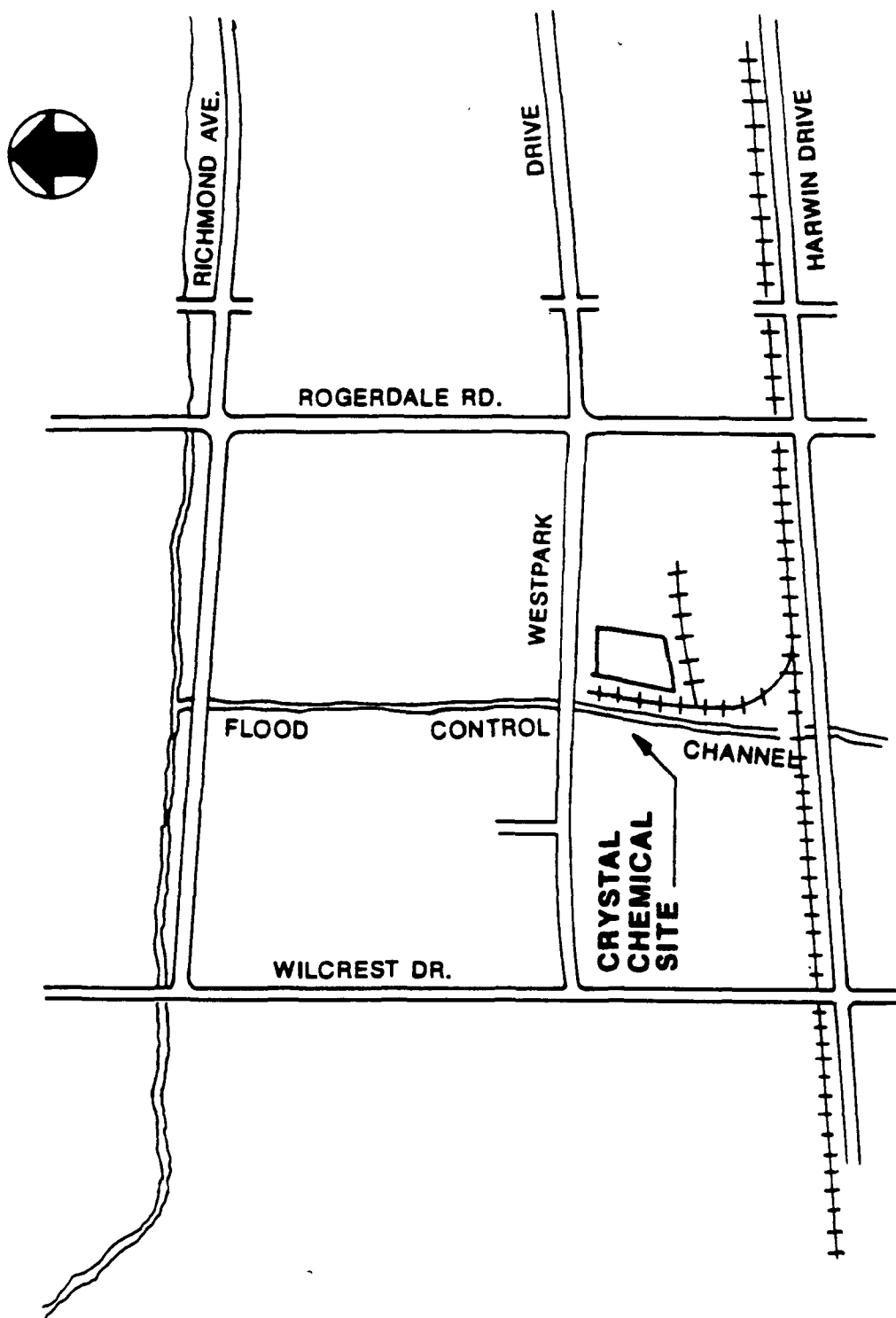


FIGURE 1
SITE AREA MAP

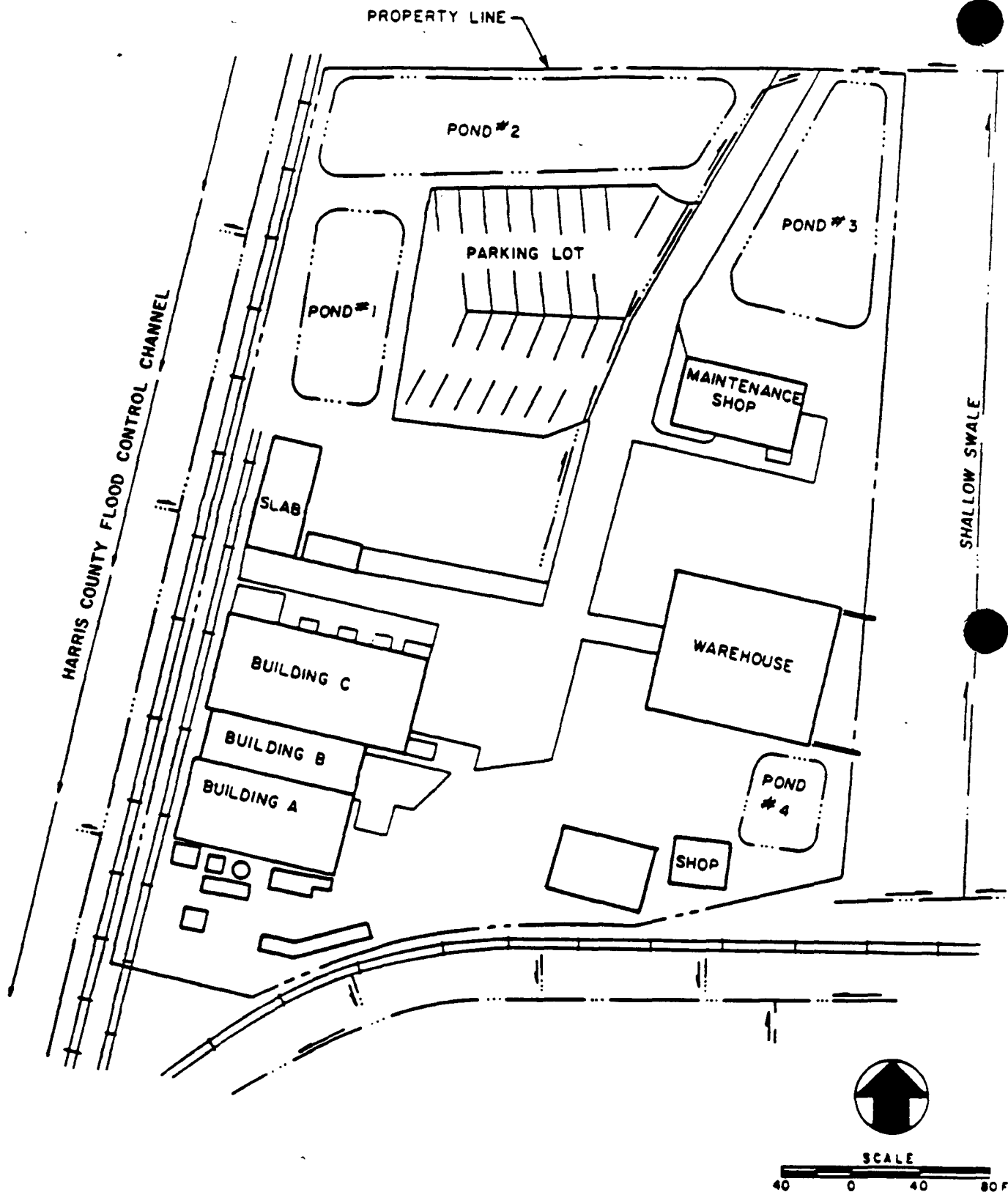


FIGURE 2
HISTORIC SITE MAP

SOURCE: D'APPOLONIA/ERT/BFI
SITE INVESTIGATION
JANUARY, 1984

METCALF & EDDY

Water Commission ("TWC"). The primary problem was repeated flooding of the site which carried arsenic-contaminated wastewater offsite. In 1978 the Crystal Chemical Company applied to the State of Texas for an onsite deep well injection permit to dispose of the facility's wastewaters which were being stored in the four onsite wastewater evaporation ponds. The permit was denied.

In September 1981, Crystal Chemical filed for bankruptcy and abandoned the site, leaving approximately 99,000 gallons of arsenic trioxide in a storage tank and approximately 600,000 gallons of wastewater in the evaporation ponds. Arsenic trioxide is a substance used in the manufacturing of weed killers, enamels, and pesticides. It may be highly toxic and a potential cause of cancer.

The United States Environmental Protection Agency ("EPA") initiated a number of Emergency Removal Actions between September 1981 and February 1983 to stabilize the site. During the first EPA emergency cleanup, the wastewater was removed from the ponds and disposed of at an offsite commercial waste disposal facility. The top foot of soil was removed, mixed with lime, then deposited back into the wastewater ponds. A temporary cap, which included a plastic cover topped by a layer of clay, was placed over the area to limit the infiltration of water into contaminated soil. The arsenic trioxide was sold, and the buildings and process equipment were disassembled, decontaminated and sold, essentially leaving the site vacant. The only remaining structures onsite are two concrete slabs. Subsequently, EPA has taken further measures to control surface runoff and site access, and to enhance the integrity of the temporary cap. Steps taken by EPA in 1983 and 1988 included construction of drains, fencing, and placement of additional fill onsite. The total cost of these removal actions was approximately \$1.3 million.

In 1983, the Crystal Chemical property was added to the National Priorities List ("NPL"), pursuant to Section 105 of the Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA"), 42 U.S.C. Section 9605, as amended, qualifying the site for investigation and remediation under CERCLA, more commonly known as Superfund.

In 1982 and 1983, EPA identified 13 potentially responsible parties ("PRPs") for the site. All PRPs declined the opportunity to participate in the Remedial Investigation/Feasibility Study ("RI/FS") for the site. Therefore in 1983, TDWR through a cooperative agreement with EPA initiated a study of the site to define the types and extent of contamination at the Crystal Chemical site. The investigation involved field sampling and testing of surface soil, subsurface soil, sediment, storm water, site runoff, and air at and near the site. Ground water wells were also installed to collect samples and to define subsurface conditions. Arsenic and, to a lesser degree, phenol were among the

contaminants detected in surface and subsurface soil and ground water. Phenol is a chemical used in the production of plastics, disinfectants, pharmaceuticals, and other industrial compounds, and it may be toxic. The report was completed in January 1984 and is entitled "Final Report Site Investigation Crystal Chemical Company Houston, Texas."

The initial Feasibility Study ("FS") was completed in June 1984. This study described a range of alternatives to treat and contain contaminated soil and ground water. EPA selected Alternative F as its preferred alternative for remediation of the site. This alternative called for extensive excavation of the contaminated soils on site, construction of slurry walls around the site to isolate the contaminated ground water, removal of the contaminated soils offsite to a level of 100 parts per million ("ppm"), offsite disposal of all excavated soils, and capping of the site.

Public comments, however, questioned the cost associated with Alternative F's proposal. The public questioned if after excavation of the offsite soils and the construction of a cap onsite, was the offsite disposal of the soils more protective of public health and the environment. In response to these comments, EPA and TDWR conducted an Addendum Feasibility Study ("AFS") to evaluate Alternative G, which proposed to cap the onsite contaminated area after excavating all offsite soils contaminated with arsenic greater than 100 ppm. The AFS was completed in December 1984, and it concluded that Alternatives F and G would protect the public health and welfare and the environment equally well. Accordingly, the EPA selected Alternative G as its preferred remedy for the site since Alternative G was more cost-effective.

Between May 1985 and October 1986, EPA negotiated with Southern Pacific Transportation Company ("Southern Pacific") to conduct the Remedial Design/Remedial Action ("RD/RA") for the site. Southern Pacific previously owned the property on which the site is located and responded to EPA's request in August of 1984 to participate in the RD/RA process.

The negotiations, however, were superseded by the passage of the Superfund Amendments and Reauthorization Act of 1986 ("SARA"). EPA determined that the Crystal Chemical Remedial Investigation and Feasibility Study ("RI/FS") should be supplemented with an additional study (the Supplemental Feasibility Study) which would focus on the use of technologies to treat contaminants at Crystal Chemical. SARA expresses a strong legislative preference for remedial actions in which hazardous wastes are treated to "permanently and significantly" reduce their volume, toxicity or mobility over remedial actions not involving such treatment. The FS and AFS for the site did not fully investigate treatment options.

On May 3, 1987, EPA entered into an Administrative Order on Consent ("AOC") with Southern Pacific Transportation Company to conduct the Supplemental Feasibility Study ("SFS"). The SFS involved additional field sampling and testing of surface soil, sediment and surface water. Additional ground water wells were installed to collect samples and to examine the movement of ground water in the upper soil layers. Samples from the former pond areas were taken in order to evaluate technologies which might be used to treat contaminated soils at the site.

Southern Pacific suspended work on the SFS in January 1988, because existing federal regulations prohibited Southern Pacific from conducting the offsite bench-scale treatability studies required to complete the SFS. Southern Pacific agreed to a revised schedule to complete the SFS in February 1989 after new regulations authorizing offsite treatability studies were promulgated. In September 1989, Southern Pacific requested an extension of time to complete the SFS, a request EPA denied. EPA completed the SFS in May 1990.

III. HIGHLIGHTS OF COMMUNITY PARTICIPATION

The SFS and the Proposed Plan for the Crystal Chemical site were released to the public in June 1990. These documents were made available to the public at both the administrative record and the information repository locations. A summary of the Proposed Plan and the notice of availability of these documents and the administrative record was published in the Houston Post on May 27, 1990. A public comment period was held from June 11, 1990 through July 11, 1990. Informal Open Houses were held in the Houston area on two separate occasions, April 10 and June 5, 1990. Additionally, a public meeting was held on June 21, 1990. Representatives from EPA, TWC, the Agency for Toxic Substances and Disease Registry ("ATSDR"), and from the Texas Health Department participated in this meeting and answered questions about problems at the site and the remedial alternatives under consideration. A response to the comments received during this period including those expressed verbally at the public meeting is included in the Responsiveness Summary, which is part of this Record of Decision as Appendix A. This decision document presents the selected remedial action for the Crystal Chemical site, Houston, Texas, chosen in accordance with CERLCA, as amended by SARA and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan ("NCP"), 40 CFR Part 300. The decision for this site is based on the administrative record. An index for the administrative record is included as Attachment 3 to this document.

IV. SITE CHARACTERISTICS

The principal threats identified at the Crystal Chemical site are the contaminated soils and sediments and the shallow ground water. The contaminated soils and sediments were determined to be a principal threat at the site because of direct contact, ingestion, and inhalation risks and because of the soil's impact on ground water. The contaminated shallow ground water was also determined to be a principal problem at the site because of the potential exposure of the public to the site contaminants and because of the threat of migration of contaminants to deeper zones of ground water. The deeper ground water zones are used for industrial, irrigation, and drinking water purposes.

Regional Geology

The Crystal Chemical site is located within an outcrop of the Beaumont Formation which is of Pleistocene age (approximately 1.6 million years old). The Beaumont Formation is characterized by backswamp, point bar, natural levee and stream channel deposits consisting of silt, clay, and sand. Such depositional environments are typified by predominantly fine-grained deposits representing low energy deposition. These are the clays, silty clays and clayey silts. Interspersed within this fine-grained matrix are the channel deposits generally consisting of fine sand and silty fine sand. The channel deposits typically are thin (less than 20 feet in thickness) and of limited areal extent. Because of the depositional environment of these sands, their geometry is commonly narrow and sinuous. They are often completely isolated in three dimensions because of channel cut-offs and reworking of channel sediments. Iron concretions along with calcium carbonate deposits are commonly present in the first 30 feet of weathered zones.

Underlying the Beaumont Formation are the Montgomery, Bently and Willis Formations which are of Pleistocene age, and the Goliad Sand and Fleming Formations which are of Pliocene age.

Regional Hydrogeology

There are four aquifers of regional significance in the area of the Crystal Chemical site. These aquifers are the Upper Chicot Aquifer, the Lower Chicot, the Evangeline Aquifer, and the Jasper Aquifer.

The Upper unit of the Chicot Aquifer occurs within the Beaumont and Montgomery Formations and is a minor source of water in the area. The base of this unit occurs at an elevation of approximately -180 feet National Geodetic Vertical Datum ("NGVD") in the site area.

The Lower unit of the Chicot Aquifer occurs within the Montgomery, Bently and Willis Formations and is a source of water in the area. The base of the unit occurs at an elevation of about -650 to -700 feet NGVD.

The Evangeline Aquifer is the major source of ground water in the area and occurs within the Goliad Sand and the upper portion of the Fleming Formation. It represents the deepest aquifer in the area containing water with less than 1,000 mg/l (ppm) of total dissolved solids. The base of the aquifer occurs at an elevation of about -2200 to -2300 feet NGVD. The Burkeville Confining Layer occurs within the Fleming Formation and separates the Evangeline Aquifer from the more highly mineralized Jasper Aquifer. It occurs in the approximate interval of -2200 to -2300 feet NGVD in the area.

The Jasper Aquifer occurs within the Fleming Formation and is generally not used for water supply due to the high dissolved solids concentration. Direction of ground water flow in both the Chicot Aquifer and the Evangeline Aquifer is toward centers of ground water withdrawal. Generally, the regional gradient from the site is north.

Historic Site Operations and Potential Sources of Contamination

The Crystal Chemical site is an abandoned herbicide manufacturing plant. During its operation, the production facilities were located on the southwestern portion of the property. Dikes around the site perimeter were constructed to contain production wastewater and surface water run-off on the property. Surface water run-off and process wastewater was diverted away from the process operations to storage/treatment ponds. There were four of these ponds on the site: three ponds at the north end of the property and one smaller pond in the southeastern corner (see Figure 2).

The ponds were constructed at different times during the plant's operation and were used for various purposes. Pond No. 4 was the first pond constructed and was used as a water recycling lagoon. Pond No. 1 served as a spray evaporation pond and as a holding pond for process wastes. Pond Nos. 2 and 3 which were constructed in early 1978 provided storage for process and surface run-off water. Pond No. 2 received surface run-off from the west side (i.e., the process side) of the plant, while Pond No. 3 collected run-off from the east side (i.e., the non-process side) of the plant. During EPA's first Emergency Removal Action, approximately 825,000 gallons of contaminated liquid were removed from the ponds. Arsenic concentrations in the liquid averaged 15,000 ppm.

One of the most significant factors that contributed to the spread of arsenic-containing materials (arsenic has been identified as the only contaminant of concern, see Section V. SUMMARY OF SITE RISK for a complete discussion) outside of the process areas and offsite

was the periodic flooding of the site due to poor site drainage and the site's proximity to Harris County Flood Control Channel, D-124-00-00. In June 1976, an extended period of wet weather flooded the site. The capacity of the dikes was exceeded and surface runoff from process and material storage areas flowed in a northerly direction toward the property line. The discharges led to litigation between the State of Texas and Crystal Chemical Company in December 1977. Initially, the perimeter dikes contained the water on the site, however, sampling conducted during the SI (1984) and for the SFS indicated that water overflowed and seeped into adjacent drainage ditches. These drainage ditches discharge into Brays Bayou.

Airborne arsenic was released offsite during the plant's operation through aerosol drift from the mechanical aeration in the wastewater evaporation ponds. Arsenic contamination in air conditioning filters in downwind residences was reported by citizens of the Brays Village apartment complex (SI, 1984).

During the plant operations from 1968 to 1981, Crystal Chemical Company produced arsenic-based herbicides such as monosodium methylarsenate ("MSMA" or "mesamate (R)"), along with a wide spectrum of phenolic-and amine-based herbicides (Dinitro General, Dinitro 3, Naptalam, Naptro, Dimethoate 267 and Crysthyon 2-L). These arsenic- and phenol-based products, along with the raw materials required for their production (e.g., arsenic trioxide, sodium arsenite, dinitrophenol) were major sources of the contamination at the site. Both raw and finished containerized (e.g., drummed) materials were stored on the ground, in the open. These materials occasionally spilled and, therefore, leaked onto and into surface soils. Arsenic trioxide was received in bulk from rail cars, and poor containment of the arsenic during loading and unloading operations was a frequent source of contamination.

Chemistry, Mobility, and Toxicity of Contaminants

Chemistry of Arsenic

Arsenic is a metalloid with chemical properties intermediate between metallic and nonmetallic elements. It ranks twentieth (20th) in abundance among the elements of the earth's crust. The chemistry of arsenic in the environment is fairly well understood, and arsenic is often used for the control of fungus, weeds, and parasites.

Arsenic is usually found in one of two valence states, trivalent arsenite (As^{+3}) and the pentavalent arsenate (As^{+5}). These two valence states have markedly different toxicities, solubilities and soil binding characteristics.

Arsenic trioxide was historically and is currently used as a raw material in the manufacturing of herbicides. In today's market, however, the primary active ingredients in arsenic-based herbicides are methylated arsenic acid salts (monosodium methanearsonic acid and disodium methanearsonic acid). Vegetable crops are less susceptible to these active ingredients. Methylated arsenical compounds are also preferred since they are two orders of magnitude less toxic to man and domestic animals.

In most aerobic soil and aquatic environments, arsenical compounds are readily oxidized or dimethylated to form arsenates. While arsenate will be the primary form, some methylated arsenates may also be present. Given anaerobic conditions, arsenites (e.g., arsenosulfides), which are significantly more toxic, may be present. Soil microbial action can also result in the evolution of alkylarsine gases, but the concentrations are sufficiently low to be of limited concern to public health. Arsine gas may also be generated chemically by the action of strong acids on arsenic compounds. This is considered to be unlikely under present site conditions, since previous acid spills have been largely neutralized by natural soil buffering, and no remaining sources of concentrated acids are known.

Regardless of the compound applied, arsenic is primarily found as arsenate in most biologically active and aerated soils. In anaerobic soils (especially stream sediments), arsenite may be the predominant form. The solubility of arsenite (e.g., as arsenic trioxide) is four to ten times greater than for arsenates; however, microbial activity in most soils readily converts arsenite to arsenate. When applied as a methylarsenical compound (e.g., MSMA, DSMA), the arsenical compound is converted in most aerobic soils into inorganic arsenate within a half year. Arsenate can also be methylated by bacterial activity, therefore, competing mechanisms and the form and method of the arsenic application determine the relative quantities of organic and inorganic arsenic in soils.

Most arsenites and arsenates are relatively insoluble, nevertheless they generally nucleate and precipitate very slowly. Solubility products for many inorganic compounds range from 10^{-15} to 10^{-22} . Arsenites and alkylarsenates are the most mobile. Because of the significant differences in the toxicities and mobility of arsenical compounds, the identification of the arsenic species present is important in the determination of the potential for future migration and the assessment of environmental risk. Tests to assess the amount of available or soluble arsenic are also important.

Mobility of Arsenic

In contact with soil, arsenates and methylarsenates are relatively insoluble. The amount of soluble arsenic in soils depends on the

relative amounts of sorptive components, principally iron, aluminum, calcium, and magnesium. Trimethylarsine (probably as an oxide, "TMO") also has a correspondingly low solubility. Mobility of inorganic arsenic in ground water is often controlled by the redox potential, with mildly reducing conditions generally producing the greatest mobility.

The texture of the soil (i.e., soil surface area), oxidation-reduction potential, soil pH, and time elapsed since application or contamination also are factors which affect the relative amount of fixed or soluble arsenic in the soil. Under the appropriate conditions, significant leaching and removal of arsenic from soils can occur. However, continual arsenic application and the predominance of fine-textured soils (such as the clays covering the upper 20 to 30 feet of the site) usually result in accumulation since little arsenic is available for solubilization (i.e. dissolving). In such soils, the vertical penetration is limited. Wind and water erosion and, to a limited extent, reduction to alkylarsines emitted to the atmosphere are the primary loss mechanisms. Arsenic loss from clay soils through plant uptake is relatively insignificant.

The arsenic not bound to soil particles and in solution is available for uptake by plants or for migration through the soil profile. Depending on the plant species and soil type, soluble (or available) arsenic levels of 3 to 28 ppm are phytotoxic. Species tolerant to 5 ppm available arsenic include most grasses, specifically, sensitive species that include alfalfa and legumes.

Arsenic uptake by plants and the resulting impact on animals consuming the plants are usually of limited concern. Plants seldom accumulate dangerous levels since arsenic is toxic to many plant species (i.e., the plants would die before they could accumulate concentrations high enough to be toxic to anything that might eat the vegetation). In addition, biomagnification (as occurs with mercury) does not occur with arsenic. Animals readily excrete ingested arsenic. Consequently, plant ingestion does not produce intoxication in animals. Cases of arsenic intoxication by foraging animals are attributable to ingestion of dusted vegetation or contaminated soil rather than arsenic uptake by plants.

Several investigators have proposed models to explain observed arsenic movement and transformations within aqueous ecosystems. In water, arsenite is readily oxidized to arsenate. Methylated arsenical compounds are usually adsorbed by sediments in streams and demethylated. Consequently, most arsenic is found as arsenates fixed to bottom sediments. Desorption into solution or methylation and reduction to form volatile alkylarsines and perhaps arsine can occur. The volatile alkylarsines persist in the atmosphere only a short while before being oxidized, eventually carried by rain and

then readsorbed to sediments. Arsenosulfides (arsenites) may form in anaerobic sediments when sufficient sulfur compounds are present.

Arsenic can be introduced into the atmosphere as dust or as a gas. Arsine gas and alkylarsine gases are readily oxidized to form oxides that fall as dust or are washed from the air by rain.

Toxicological Properties of Arsenic

The toxicological properties and health effects associated with arsenic compounds have been thoroughly reviewed by the Agency of Toxic Substances and Disease Registry ("ATSDR") in the Toxicological Profile for Arsenic (March 1989). Arsenic is a naturally occurring element which exists in a variety of chemical forms with variable toxicities. In general inorganic forms of arsenic, such as oxides and salts, are more toxic than methylated or more complex organic arsenic compounds. Organic arsenicals, which occur naturally in some foods such as fish, are more readily metabolized and excreted than inorganic forms of arsenic. Consequently, organic arsenic compounds are not generally considered to be of major importance in most discussions of ambient environmental exposures.

Among inorganic arsenic compounds, those containing trivalent arsenic (As^{+3}) are generally observed to be more toxic than pentavalent arsenic (As^{+5}) species. The pentavalent arsenate is the form most commonly encountered in nature. In this form, arsenate tends to be fairly rapidly excreted by the kidneys and probably does not accumulate to any great extent. Trivalent arsenites, such as arsenic trioxide, are the most commonly encountered man-made forms of arsenic. However, trivalent arsenic compounds also occur naturally. Trivalent arsenites have greater ability to bind with tissue proteins and interfere with enzymatic functions than other forms of arsenic. Inorganic forms of arsenic are viewed collectively when discussing ambient exposures.

Inorganic arsenic is almost ubiquitous in the ambient environment. Consequently, humans and other animals experience ongoing exposures to naturally occurring levels of arsenic. Ground water may contain concentrations of inorganic arsenic ranging from 0.2 to 10 $\mu\text{g}/\text{l}$. Epidemiologic evidence suggests that ingestion of drinking water containing approximately 400 μg arsenic/l or higher may be associated with signs of systemic toxicity. Concentrations of arsenic in ambient air are usually in the range of 2 to 10 ng/m^3 . These concentrations have not been associated with systemic toxicity. Dietary sources provide the largest portion of human intake of inorganic arsenicals. U.S. EPA has estimated that diet contributes approximately 25 to 50 μg arsenic per day.

Studies indicate that humans are more sensitive to the toxic effects of arsenicals than laboratory animals. Lethal doses of inorganic arsenic reported for animals (10 to 300 mg/kg) are higher

than lethal doses reported in humans (0.6 to 2 mg/kg). Humans exposed to chronic oral doses of 50 to 100 μg inorganic arsenic/kg per day may display toxic effects on the nervous system (neurological) and/or blood (hematological).

Extent of Contamination

Air and Surface Soils

In January 1989, surface soils samples were collected for the SFS to determine background levels of arsenic in soils around the Crystal Chemical site. Samples were collected from the upper three to four inches of soil in empty fields adjacent to commercial or residential areas (see Figure 4), and the samples were analyzed for the site's primary contaminant, arsenic. The samples contained arsenic at levels below the analytical laboratory's detection limit (see Table 1). The values were reported as less than 1.2 to 1.6 mg/kg or ppm total arsenic.

Soils samples were collected from 1983 to 1989 in the vicinity of the site. Figure 5 illustrates the location from where these samples were taken, and a summary of the analytical results are presented in Table 2. The approximate extent of soils contaminated with arsenic is presented in Figure 6. Based on this figure, the areal extent of contamination covers approximately 24.4 acres. All further discussions referring to the "onsite contamination" refer to the 6.8 acres on which the Crystal Company operated, and discussions of "offsite contamination" refer to the estimated areal extent of contamination off of the site that covers approximately 17.6 acres. The volume of offsite soils contaminated with arsenic greater than 30 ppm is estimated to be 55,000 cubic yards. The volume of onsite soils contaminated with arsenic greater than 300 ppm is estimated to be 16,500 cubic yards, and there is estimated to be 101,000 cubic yards of onsite soil contaminated with arsenic greater than 30 ppm.

The current spread of contaminants through the air and onto surface soils is assumed to be negligible since plant operations ceased in 1981 and since the entire site was capped during the EPA Emergency Removal Action in 1983. However, the primary sources of airborne contamination during plant operations were most likely wind-blown raw materials, aerated pond mist, cooling tower drift and wind blown dust.

The levels of airborne arsenic measured in the vicinity of the site during the SI (1984) ranged from 0.0005 to 0.50 $\mu\text{g}/\text{m}^3$. These levels are higher than background levels measured by the Harris County Health Department but of the same order of magnitude as documented airborne arsenic concentrations in industrial urban centers (EPA Endangerment Assessment, 1988). If remediation of the site were not planned and the temporary cap constructed on the site

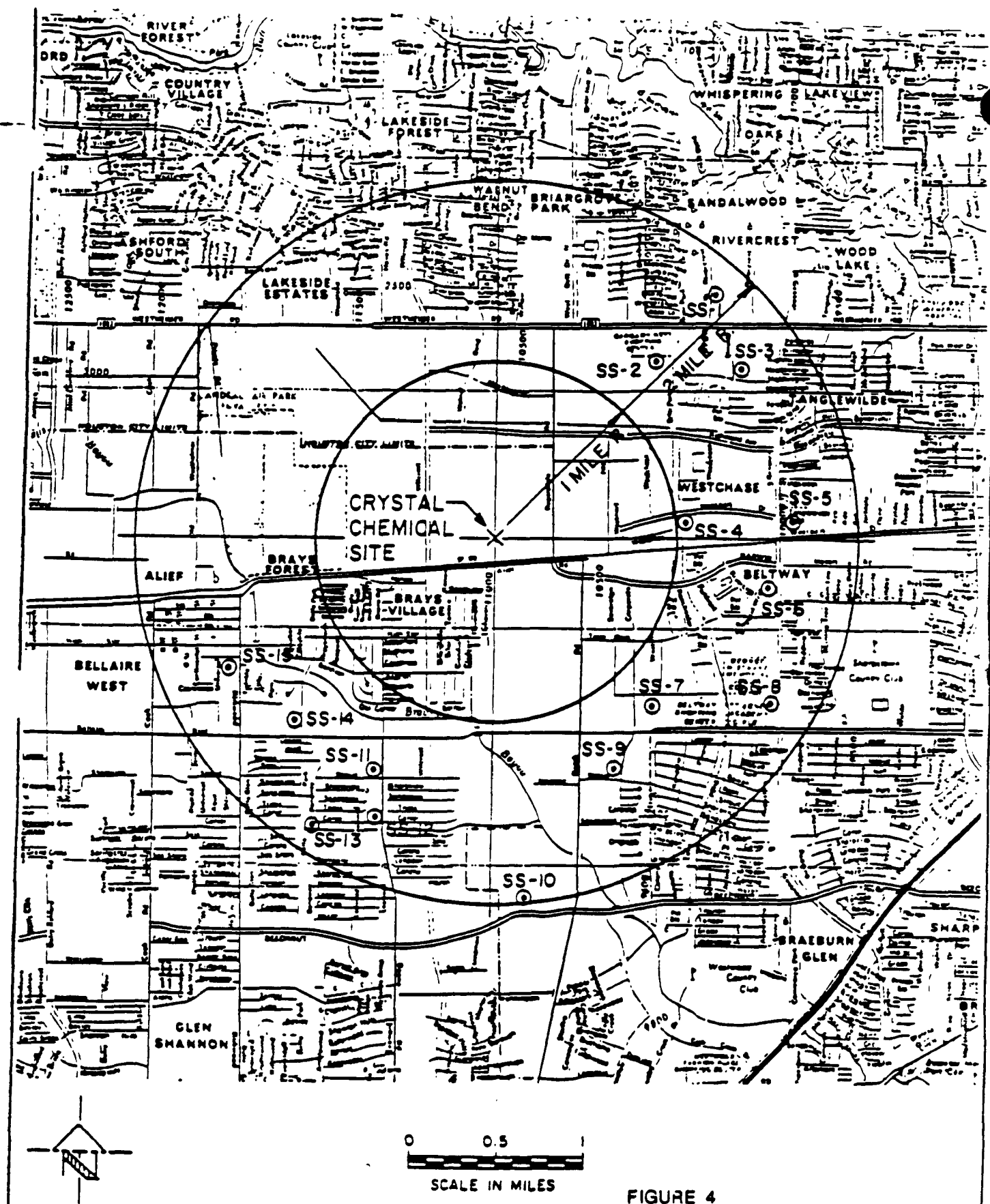


FIGURE 4


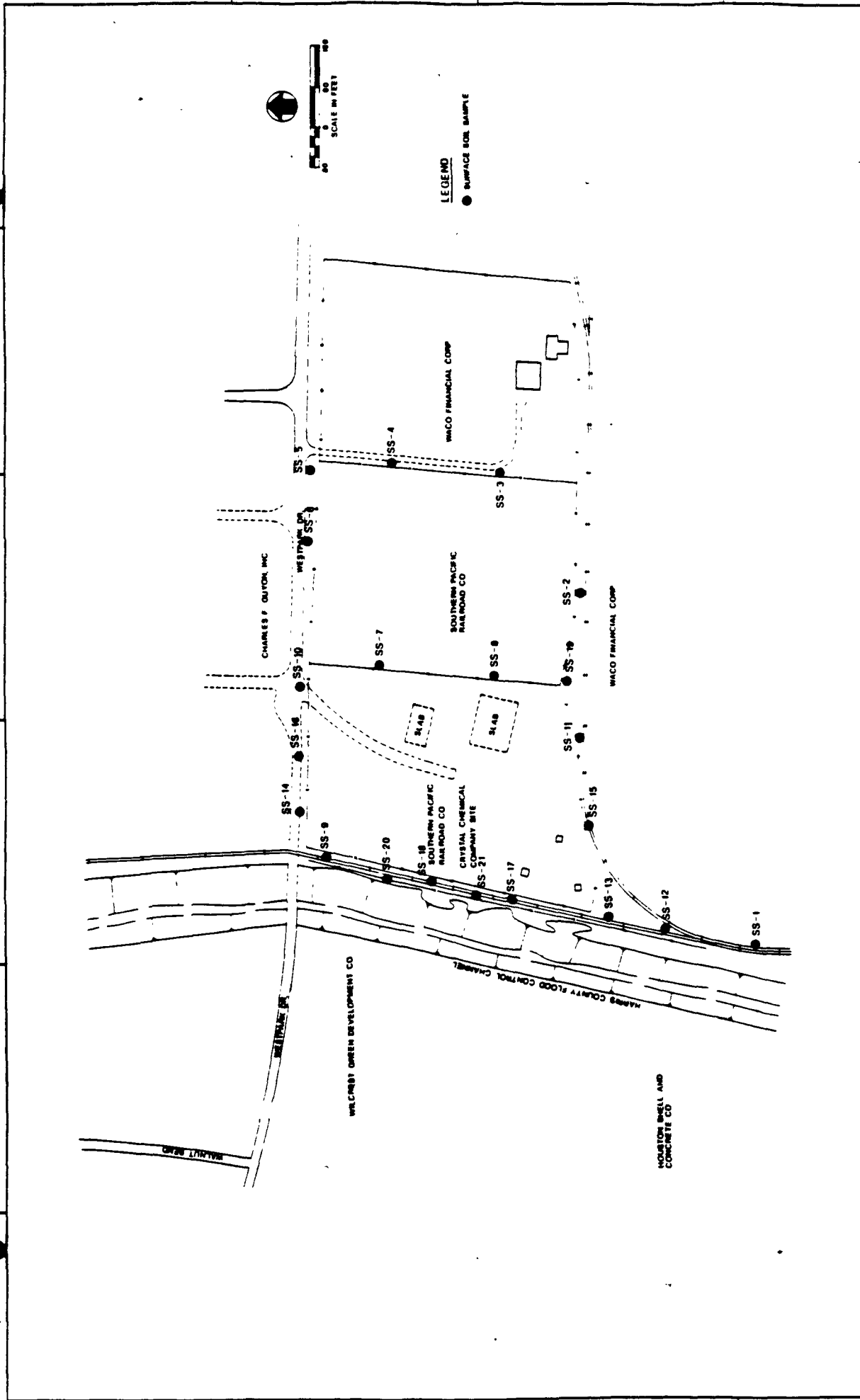
<p>SCALE GRAPHIC</p> <p>DWN. BY KMK</p> <p>CHK'D BY TRH</p> <p>APPR BY TRH</p>	 <p>Applied Engineering Science</p>	<p>BACKGROUND SOIL SAMPLE LOCATIONS</p> <p>SPTC - CRYSTAL CHEMICAL</p>	<p>DATE MARCH, 89</p> <p>DWG. NO. 4056 A</p> <p>SHEET NO</p>
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TABLE 1
SUMMARY OF BACKGROUND SOIL SAMPLING
Crystal Chemical Site
January 26, 1989

<u>Sample I.D.</u>	<u>Total Arsenic</u> (mg/kg)
1	<1.40
2	<1.40
3	<1.40
4	<1.40
5	<1.20
6	<1.30
7	<1.20
8	<1.30
9	<1.30
10	<1.40
10 (DUP)	<1.40
11	<1.40
12	<1.60
13	<1.30
14	<1.50
15	<1.40

Note:

() - Duplicate Sample Analysis



CRYSTAL CHEMICAL		METCALF & EDDY		CRYSTAL CHEMICAL	
SUPPLEMENTAL FEASIBILITY STUDY		METCALF & EDDY		SUPPLEMENTAL FEASIBILITY STUDY	
SURFACE SOIL SAMPLING LOCATIONS		METCALF & EDDY		SURFACE SOIL SAMPLING LOCATIONS	
DATE: 11/1/82		DATE: 11/1/82		DATE: 11/1/82	
BY: J. B. EDDY		BY: J. B. EDDY		BY: J. B. EDDY	
CHECKED: J. B. EDDY		CHECKED: J. B. EDDY		CHECKED: J. B. EDDY	
APPROVED: J. B. EDDY		APPROVED: J. B. EDDY		APPROVED: J. B. EDDY	

TABLE 2
SUMMARY OF
SURFACE SOIL SAMPLING
Crystal Chemical Company Site

Sample Number	Date	Total Arsenic (mg/kg)	Total Phenols (mg/kg)
O	1/27/81	1629.5	NA
P	2/10/81	38.1	NA
R	2/16/81	163.3	NA
S	2/16/81	100.3	NA
J	7/07/81	0.39	NA
P(1)	8/05/81	15244	NA
P(2)	8/05/81	7357	NA
P(3)	8/05/81	9191	NA
1	1/7/83	11	NA
3	1/7/83	18	NA
4	1/7/83	23	NA
5	1/7/83	32	NA
6	1/7/83	62	NA
9	1/7/83	670	NA
10	1/7/83	130	NA
12	1/7/83	47	NA
13	1/7/83	172	NA
1	4/26/83	520	NA
2	4/26/83	4385	NA
3	4/26/83	2128	NA
4	4/26/83	3599	NA
5	4/26/83	1597	NA
6	4/26/83	605	NA
7	4/26/83	510	NA
8	4/26/83	5749	NA
9	4/26/83	7936	NA
10	4/26/83	4222	NA
11	4/26/83	802	NA
SS-1	1983 SI	636	NA
SS-2	1983 SI	242	NA
SS-3	1983 SI	345	NA
SS-4	1983 SI	23	NA
SS-5	1983 SI	39	NA
SS-6	1983 SI	26	NA
SS-7	1983 SI	66	NA
SS-8	1983 SI	49	NA
SS-9	1983 SI	52	NA
SS-10	1983 SI	72	NA
SS-11	1983 SI	37	NA
SS-12	1983 SI	33	NA
SS-13	1983 SI	28	NA
SS-14	1983 SI	45	NA
SS-15	1983 SI	49	NA
SS-16	1983 SI	34	NA

TABLE 2 (continued)
SUMMARY OF
SURFACE SOIL SAMPLING
Crystal Chemical Company Site

Sample Number	Date	Total Arsenic (mg/kg)	Total Phenols (mg/kg)
SS-17	1983 SI	36	NA
SS-18	1983 SI	36	NA
SS-19	1983 SI	7.5	<1.8
SS-20	1983 SI	17	NA
SS-21	1983 SI	41	<1.9
SS-22	1983 SI	43	NA
SS-23	1983 SI	NA	NA
SS-24	1983 SI	5	NA
SS-25	1983 SI	NA	NA
SS-26	1983 SI	4	NA
SS-27	1983 SI	NA	NA
SS-28	1983 SI	<2	NA
SS-29	1983 SI	<2	NA
SS-30	1983 SI	12	NA
SS-31	1983 SI	3	NA
SS-32	1983 SI	3	NA
SS-33	1983 SI	9	NA
SS-34	1983 SI	30	NA
SS-35	1983 SI	38	NA
SS-36	1983 SI	41	NA
SS-37	1983 SI	5	NA
SS-38	1983 SI	4	NA
SS-39	1983 SI	4	NA
SS-40	1983 SI	20	NA
SS-41	1983 SI	2	NA
SS-42	1983 SI	7	NA
SS-43	1983 SI	NA	NA
SS-44	1983 SI	39	NA
SS-45	1983 SI	6	NA
SS-46	1983 SI	9	NA
SS-47	1983 SI	12	NA
SS-48	1983 SI	9	NA
SS-49	1983 SI	77	NA
SS-1*	10/23/87	52	3.0
SS-2*	10/23/87	50	1.8
SS-3*	10/23/87	156	1.9
SS-4*	10/23/87	107	1.9
SS-5*	10/23/87	41	4.0
SS-6*	10/23/87	265	2.4
SS-7*	10/23/87	127	4.5
SS-8*	10/23/87	957	1.2
SS-9*	10/23/87	866	<0.1
SS-10*	10/23/87	281	1.9
SS-11*	10/23/87	23	2.2
SS-12*	10/23/87	336	2.6
SS-13*	10/23/87	561	3.4

TABLE 2 (continued)
SUMMARY OF
SURFACE SOIL SAMPLING
Crystal Chemical Company Site

Sample Number	Date	Total Arsenic (mg/kg)	Total Phenols (mg/kg)
SS-14*	10/23/87	520	2.5
SS-15*	10/23/87	250	3.5
SS-16*	10/23/87	423	2.2
SS-17*	10/23/87	352	2.1
SS-18*	10/23/87	14.2(11.8)	2.5(2.3)
SS-19*	10/23/87	886(750)	2.7(2.7)
SS-20*	10/23/87	97.1	4.6
SS-21*	10/23/87	1220	4.2

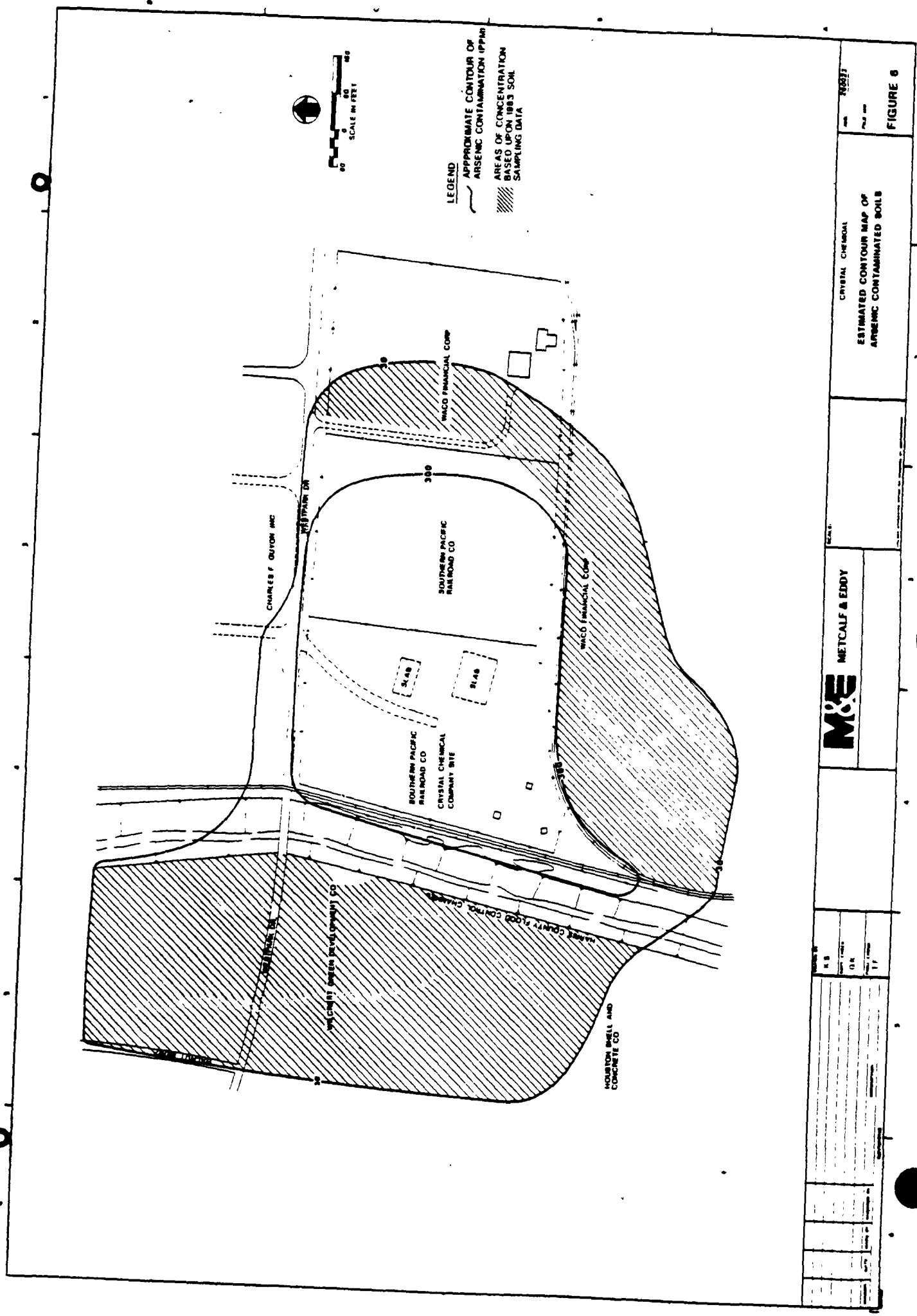
Notes:

NA = Not analyzed

SI Site Investigation

* Sampling performed by Applied Engineering and Science,
Inc.

() Duplicate Sample



in 1983 was not maintained, the degradation of the cap could result in higher ambient arsenic releases, therefore, potentially increasing the risk to nearby populations.

Surface soil contamination, possibly related to past airborne releases of arsenic, may be the source for the 72 ppm of arsenic that was detected in 1984 (SI) on the west side (site is on the east side) of the Harris County Flood Control Channel. This is the highest level of contamination found in nearby offsite surface soils that may not be attributable to surface water or ground water transport. However, as the flood control channel was not constructed until 1977, it is possible that surface water run-off from the Crystal Chemical site may have crossed the farm road which previously existed at the present right-of-way of the channel and ponded in this area.

Surface Water/Sediments

There are three major surface water features in the site area: Harris County Flood Control Channel (D-124-00-00), Brays Bayou (D-100-00-00), and Buffalo Bayou (W-100-00-00). The flood control channel has an average depth of 15 feet and flows southward to Brays Bayou, which is located about one mile south of the site. The bayou drains in an easterly direction to the Houston Ship Channel and ultimately into Galveston Bay.

Buffalo Bayou is located about 2.5 miles north of the site. A Texas Water Quality Board Memorandum (August 5, 1977) reported that drainage from the Crystal Chemical site and from the area around the site had been directed into Buffalo Bayou until March 3, 1977. This was conceivably before the flood control channel directing drainage into Brays Bayou had been completed. Buffalo Bayou also drains to the Houston Ship Channel and Galveston Bay.

Drainage ditches to the north and south of the site receive drainage directly from the site and discharge into the Harris County Flood Control Channel. Along the western site boundary, surface drainage, as well as subsurface seepage from the site enters the flood control channel directly.

Although the Crystal Chemical site is not located within a flood prone area as defined by the Federal Emergency Management Agency, it has flooded repeatedly. In fact, local studies indicate that the site lies within the limits of the 100-year floodplain of the adjacent Harris County Flood Control Channel.

Contamination of surface water is likely attributable to a combination of three factors: (1) continuing seepage from beneath the clay cap and liner during and following rainfall events, especially apparent along the western site boundary; (2) residual contaminants from previous events leached or re-suspended from

drainageways, contaminated off site soils and standing water pools during and following rainfall events, (3) residual contaminants being leached or re-suspended in run-off directly from the capped site. The 1984 SI report estimated that the annual run-off from the site is 633,798 ft³/yr.

Tables 3 and 4 present a summary of surface water and sediment samples taken in the site vicinity. Sample locations are illustrated in Figure 7. Two series of samples were taken, in April 1983 and October 1987. Three of the samples collected in 1987 show that arsenic contamination exceeded the ambient water standard of 0.0175 µg/l (ppb) for arsenic (Clean Water Act, as amended, 33 CFR 303). However, overall trends over time are inconclusive, with some areas showing increases in contamination and others showing decreases.

Most of the arsenic in surface run-off is deposited or adsorbed to sediments. After adsorption, the arsenic undergoes desorption in solution and further transport, or methylation/reduction to form organoarsenical compounds.

During heavy rains, water in the drainage ditches may backup into connecting ditches, creating the potential for contamination of upstream sediments. Several deep erosion gullies (formed due to lack of vegetation) are present in the bank of the flood control channel along the west side of the site.

With time, it is possible that the extent of contamination will spread to previously uncontaminated downstream sediments as arsenic-bearing sediments migrate. The rate of migration depends primarily on sediment transport rates and on arsenic dissolution and precipitation mechanisms. Insufficient data are available to predict the rate of migration but the rate was judged to be relatively slow in the SI (1984).

Subsurface Soil and Ground Water

Results of 1983 and 1987 soil and ground water sampling in onsite and offsite monitor wells and in subsurface borings indicate that arsenic and phenol contamination has occurred in the subsurface environment. Contamination of ground water and subsurface soils at the Crystal Chemical site has probably been advanced by percolation of surface water into the subsurface through the soil matrix, through natural subsurface discontinuities and imperfections, and/or by previous site and construction and operating activities. Offsite subsurface soil contamination is most likely associated with past storm water run-off episodes and percolation with time into the subsurface.

Subsurface soil arsenic contamination has been identified across the site to an average depth of five to six feet. Figure 8

TABLE 3
SUMMARY OF
SURFACE WATER SAMPLING
Crystal Chemical Company Site

Sample Number	Total Arsenic (mg/l)	Total Phenols (mg/l)
SW-1	<0.005 (0.016)	0.059 (0.62)
SW-2	0.017	NA
SW-3	0.066	0.045
SW-4	0.060	0.068
SW-15	0.506	0.092

Notes:

NA = Not analyzed, container broken in transit

() Duplicate Sample

Samples taken on 10/23/87 by Applied Engineering and
Science, Inc.

TABLE 4
SUMMARY OF
SEDIMENT SAMPLING
Crystal Chemical Company Site

Sample Number	Date	Total Arsenic (mg/kg)	Total Phenols (mg/kg)
AB-1	APRIL 1983	227.0	NA
AB-2	APRIL 1983	51.7	NA
AB-3	APRIL 1983	32.2	NA
AB-4	APRIL 1983	22.4	NA
AB-5	APRIL 1983	20.3	NA
AB-6	APRIL 1983	49.4	NA
SED-1	10/23/87	28 (27)	3.0
SED-2	10/23/87	278	1.2
SED-3	10/23/87	54	2.3
SED-4	10/23/87	5.2	2.0
SED-5	10/23/87	66	1.3
SED-6	10/23/87	44	2.6
SED-7	10/23/87	37	3.2
SED-8	10/23/87	904	2.5
SED-9	10/23/87	306	6.1
SED-10	10/23/87	924	5.2
SED-11	10/23/87	850	5.3
SED-12	10/23/87	437	2.9
SED-13	10/23/87	482	3.1
SED-14	10/23/87	53	2.1
SED-15	10/23/87	98	1.9
SED-16	10/23/87	35	2.6

Notes:

NA = Not analyzed

() Duplicate Sample

illustrates subsurface soil sampling locations (soil borings and borings associated with monitoring well construction) and Tables 5 and 6 show the summary of the analytical results. Gross arsenic contamination of 5,000 ppm arsenic has penetrated nearly three to four feet (not including the cap thickness) in the rail car off loading area, nearly five to six feet in the arsenic trioxide tank area and below Pond No. 2 and to depths greater than ten feet below the bottom of Pond No. 1 (assuming its working depth was about seven to eight feet). Offsite borings revealed arsenic concentrations greater than 50 ppm at depths ranging from two and one-half to seven feet and to as deep as nine feet. These samples were collected within 70 feet of the site boundaries.

Selected soil samples collected from the monitoring well installations and during the pond borings were analyzed further for the purposes of identifying the types or forms of the arsenic. Both organic and inorganic forms of arsenic were found. The principle forms of organic arsenic were cacodylic acid and methane arsenic acid. Inorganic arsenic was found to occur as arsenite (As^{+3}) and arsenate (As^{+5}). The concentrations of the organic and inorganic forms of arsenic were found to vary throughout the site.

The maximum concentration of phenolic compounds detected in soil was 157 ppm in MW-4 at a depth of 40 feet. A phenolic concentration of 0.75 ppm was detected in a water sample collected from MW-4. Analysis of soil collected from boring B-7, about 120 feet northeast of the Crystal Chemical site, recorded a phenol concentration of 110 ppm at a depth of 8.5 feet. This boring was located in the abandoned flood control channel right-of-way which may have served, up through 1977, as the primary offsite drainage path to Buffalo Bayou. In ten other subsurface soil samples, phenolic concentrations ranged from 2 to 28 ppm. The samples were collected at depths of 1.5 to 20 feet, in locations onsite or within about 35 feet of the site. In the remaining soil samples, concentrations of phenolics were below the detection limit (2 ppm).

Subsurface information gathered from the 24 monitoring well borings was used to create a generalized three dimensional geologic model (SFS 1990). Three water-bearing zones were identified at 15 feet, 35 feet, and 100 feet below the ground surface. All three of these water-bearing zones are classified as Class IIb ground water units Per "EPA Guidelines for Ground-Water Classification" - Final Draft, December 1986.

Stratigraphically, the top 13 feet consists of dark-gray silty clay, grading to a calcareous clay with calcareous nodules and iron-rich concretions. Underlying this unit is a very fine reddish sand which ranges from 0 to 13 feet thick. This unit is also referred to as the 15-foot water-bearing zone, and occurs only in the north central and northeastern portion of the area. Underlying this unit is calcareous clay and calcarenite (a deposit of sand-sized grains composed of calcite) which range from 10 to 20 feet

TABLE 5
SUMMARY OF
POND BORING SAMPLING
Crystal Chemical Company Site

Sample Number	Sample Depth (ft)	Total Arsenic (mg/kg)	Phenol (mg/kg)
PB-1,ST-4	4	26800	19.0
PB-1,ST-8	7.5	12300	8.0
PB-1,ST-12	11	15300	<2.2
PB-1A,ST-14	13.5	10800	<1.6
PB-1A,ST-17	18	5850	<1.7
PB-1A,ST-19	21	928	<1.9
PB-1A,ST-21	24	923	<1.7
PB-3,ST-3	2	2360	4.0
PB-3,ST-5	4	2490	1.8
PB-3,ST-9	10	531	<1.9
PB-4,ST-3	2.5	3150	NA
PB-4,ST-7	8	71	NA
PB-6,ST-2	2	NA	<2.2
PB-6,ST-2W	2.5	NA	3.5
PB-6,ST-4	5	NA	7.4
PB-6,ST-5	6.5	8460	2.7
PB-6,ST-7	9.5	3620	<1.6
PB-6,ST-10	14	932	<1.7

Notes:

NA = Not analyzed

From 1984 Site Investigation Report

TABLE 6
SUMMARY OF SUBSURFACE SOIL SAMPLING
Crystal Chemical Company Site

Sample Number	Sample Depth (ft)	Total Arsenic (mg/kg)	Phenol (mg/kg)
B-1,ST-1D	1	5280	<2.6
B-1,ST-2A	3	NA	<2.2
B-1,ST-3B	3.5	570	2.6
B-1,ST-3A	3.5	NA	<1.8
B-1,ST-3A	3.5	7130	0.6
B-1,ST-4B	6	219	8.4
B-1,ST-5A	7	18200	17
B-1,ST-6B	9	53	15
B-2,ST-2A	2	201	<2.1
B-2,ST-4	5.5	191	<2.2
B-2,ST-6	8.5	122	5.2
B-3,ST-2	2.5	46	<2.3
B-3,ST-4	5.5	28	7.8
B-3,ST-6	8.5	9.2	20
B-4,ST-2A	1.5	1300	15
B-4,ST-4	4.5	20	2.2
B-4,ST-6B	7.5	17	<2.2
B-5,ST-1	1	5	NA
B-5,ST-2	2.5	36	<2.3
B-5,ST-3	4	37	<2.1
B-5,ST-4	5.5	31	2.3
B-5,ST-5	7.0	NA	<2.0
B-6,ST-2	2.5	24	<1.7
B-6,ST-4	5.5	20	2.0
B-6,ST-5	7	8.6	<1.6
B-7,ST-2	2.5	53	2.9
B-7,ST-4	5.5	36	19
B-7,ST-6	8.5	26	110
B-8,ST-2	2.5	20	3.3
B-8,ST-4	5.5	29	4.0
B-8,ST-6	8.5	27	2.3
B-9,ST-1	1	450	1.8
B-9,ST-3	4	39	14
B-9,ST-4	5.5	34	19
B-9,ST-6	8.5	NA	<1.7
B-10,ST-1	1	1570	2.4
B-10,ST-2	2.5	950	NA
B-10,ST-3	4	44	2.3

TABLE 6 (continued)
SUMMARY OF SUBSURFACE SOIL SAMPLING
Crystal Chemical Comapny Site

Sample Number	Sample Depth (ft)	Total Arsenic (mg/kg)	Phenol (mg/kg)
B-10,ST-4	5.5	34	<2.1
B-11,ST-1	1	27	<1.6
B-11,ST-3	4.5	42	<2.8
B-11,ST-4	6	41	30
B-11,ST-5	8	NA	<2.2
B-12,ST-2	2.5	30	<2.6
B-12,ST-3	4	32	<2.1
B-12,ST-5	7	40	<2.4
B-12,ST-6	8.5	3	NA
B-13,ST-2	2.5	28	<2.0
B-13,ST-3	4	35	<2.0
B-13,ST-5	7	395	<2.1
B-13,ST-6	8.5	<1	NA
B-14,ST-2	2.5	55	<1.5
B-14,ST-3	4	32	<1.6
B-14,ST-5	7	NA	<1.5
B-15,ST-2	2.5	56	<2.0
B-15,ST-3	4	45	<1.6
B-15,ST-5	8.5	642	<1.8
MW-1 ⁽²⁾ ,ST-1	1	65	<2.2
MW-1,ST-2	3	3690	<2.2
MW-1,ST-5	9.5	73	<1.9
MW-1,ST-10	19.5	68	<2.0
MW-1,ST-13	34	42.6	NA
MW-1,S-1	39	18.7	<1.9
MW-1,ST-14T	39.5	7	<1.5
MW-1,ST-14B	41.5	10	<2.2
MW-2 ⁽²⁾ ,ST-1	1.5	191	7.6
MW-2,ST-2	3.5	48	4.8
MW-2,ST-3	5.5	49	2.0
MW-2,ST-5	9.5	30	45
MW-2,ST-8A	15	221	<2.3
MW-2,ST-11	30	224	<1.4
MW-2,ST-12	35	12	<2.1
MW-2,S-2	39	36	22
MW-3 ⁽²⁾ ,ST-1	1.5	62	2.7
MW-3,ST-2	2.5	7280	142
MW-3,ST-3A	3.5	16140	2.0
MW-3,ST-3B	4	27310	2.6

TABLE 6 (continued)
SUMMARY OF SUBSURFACE SOIL SAMPLING
Crystal Chemical Company Site

Sample Number	Sample Depth (ft)	Total Arsenic (mg/kg)	Phenol (mg/kg)
MW-3 ⁽²⁾ , ST-4	5	5930	2.0
MW-3, ST-6	9.5	1750	29
MW-3, ST-12	19	NA	16
MW-3, ST-13A	23.5	28	<1.7
MW-3, ST-15A	34	12	<1.8
MW-3, S-1	42	46	<2.2
MW-3, ST-16	45	252	<1.5
MW-4 ⁽³⁾ , ST-1B	1.5	2470	42
MW-4, ST-2	3.5	2510	41
MW-4, ST-3	5	346	46
MW-4, ST-4	7	19	NA
MW-4, ST-10	24	30	45
MW-4, ST-13	39	21	157
MW-4, ST-14	44	NA	<1.9
MW-4, ST-15	49	54	<1.9
MW-4, ST-16	54	59	1.5
MW-4, ST-18	69	22.1	1.0
MW-4, ST-20	89	43.3	NA
MW-4, S-1	99	12	<2.9
MW-5 ⁽²⁾ , B-1	0.5	<2	5.1
MW-5, ST-1	2	2	3.2
MW-5, ST-2	4	<2	<2.3
MW-5, ST-5	10	4	2.0
MW-5, ST-7	14	<1	<1.7
MW-5, ST-10	20	4	<1.3
MW-5, ST-1T	34.5		<1.3
MW-5, S-1	35	2	<1.1
MW-5, S-1B	35.5		<2.2
MW-5, ST-13	39	9	<1.7
MW-6 ⁽²⁾ , ST-1	1	18	<1.8
MW-6, ST-2	3	<2	<1.7
MW-6, ST-5	9	5	<1.5
MW-6, S-1	39	1	<1.2
MW-7 ⁽²⁾ , ST-1A	1	8	<2.2
MW-7, ST-2B	3	<1	<1.7
MW-7, ST-3B	5	<2	<2.0
MW-7, S-1B	33	<1	<1.5
MW-8 ⁽²⁾ , ST-1	1	9	<1.8
MW-8, ST-2	3	13	<1.0
MW-8, ST-3	5	12	<1.3
MW-8, S-1A	33	4.4	<1.3

TABLE 6 (continued)
SUMMARY OF SUBSURFACE SOIL SAMPLING
Crystal Chemical Company Site

Sample Number	Sample Depth (ft)	Total Arsenic (mg/kg)	Phenol (mg/kg)
MW-9 ⁽²⁾ , ST-1	1	16 ⁽⁴⁾	NA
MW-9, ST-4	5	13	NA
MW-9, S-1	34	6	NA
MW-10 ⁽²⁾ , ST-1	1	116	NA
MW-10, ST-4	5	17	NA
MW-10, ST-7	36	13	NA
MW-11 ⁽²⁾ , ST-1	1	5 ⁽⁴⁾	NA
MW-11, ST-4	5	16	NA
MW-11, S-1	33	11	NA
MW-12 ⁽²⁾ , ST-1	1	12	NA
MW-12, ST-4	5	12	NA
MW-12, ST-5A	25	3 ⁽⁴⁾	NA
MW-13 ⁽²⁾ , ST-1	1	8	NA
MW-13, ST-4	5	9	NA
MW-13, ST-7	36	6	NA

Notes:

NA = Not analyzed

(1) Monitoring Wells Screened in 15 Foot Water-Bearing Zone

(2) Monitoring Wells Screened in 35 Foot Water-Bearing Zone

(3) Monitoring Well Screened in 100 Foot Water-Bearing Zone

(4) Average of Two Readings

These data were collected for the 1984 Site Investigation

thick.. At a depth of about 30 feet, a reddish-gray very fine sand is encountered with a thickness ranging from 0 to 17 feet. This sand unit is also referred to as the 35-foot water-bearing zone, and appears to grade to silty clay and pinch out to the south and west of the site.

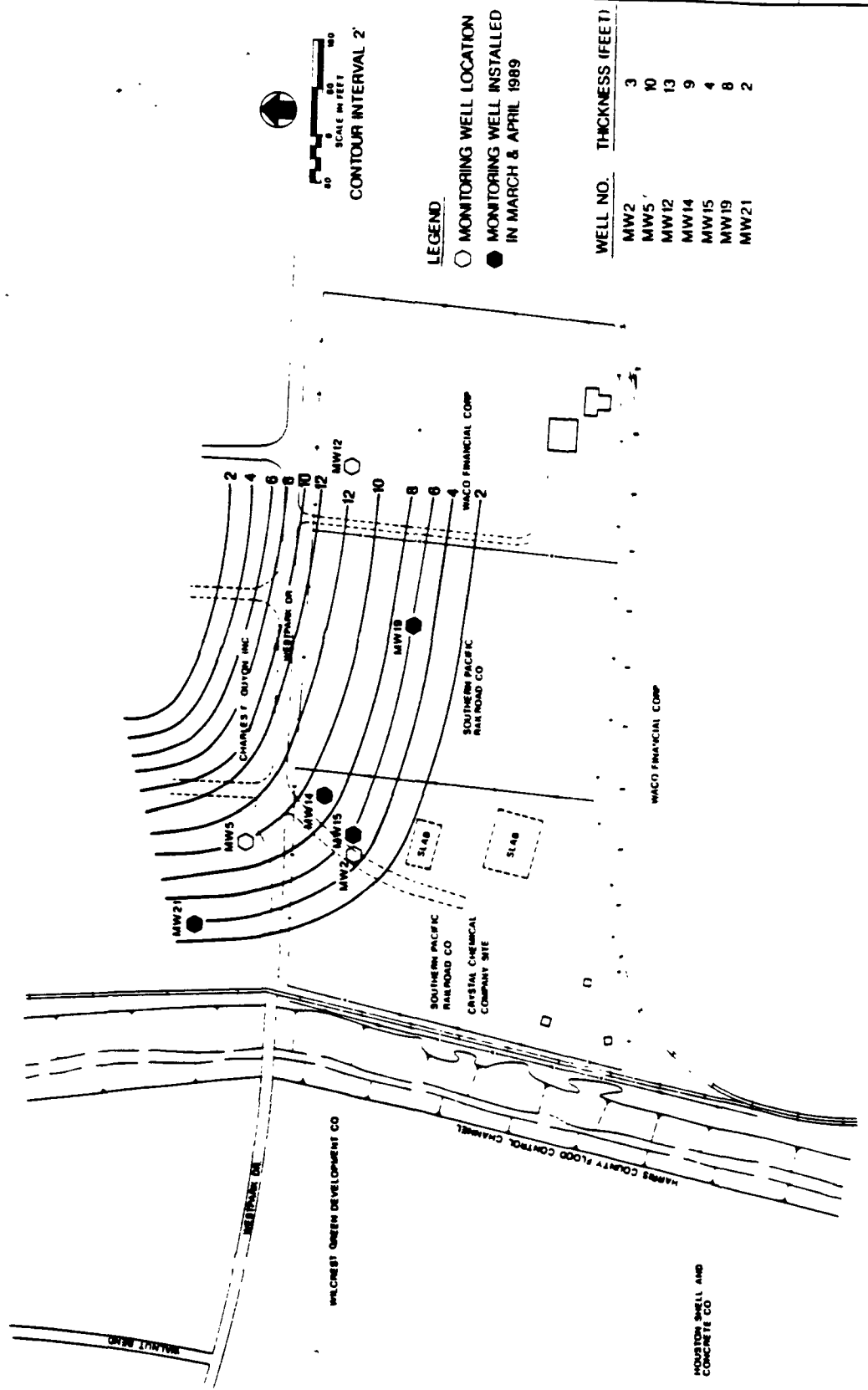
The 35-foot water-bearing zone is underlain by a thick clay unit which separates it from the 100-foot water-bearing zone. This lower confining unit is approximately 60 feet thick at MW-4, the only monitoring well on site which extends into the 100-foot zone. Logs of other wells in the vicinity of the Crystal Chemical site indicate that this confining unit is laterally extensive and is relatively uniform in thickness.

Isopach maps, showing the thickness of the units, have been prepared for the 15-foot and 35-foot water-bearing zones and are presented as Figures 9 and 10.

Several sets of static water levels taken from the monitoring wells and piezometers have not indicated a consistent ground water flow gradient over time. Seasonal fluctuations may be responsible for these variations.

Hydrologic aquifer testing (slug, step drawdown, and pump tests) was conducted during the spring of 1989 for the SFS. The hydraulic conductivity of the 15-foot water-bearing zone ranges from 1.0×10^{-4} to 3.3×10^{-3} cm/sec. For the 35-foot water-bearing zone, transmissivity ranges from 80 to 360 ft²/day while storativity ranges from 3.6×10^{-4} to 2.4×10^{-3} . The 15-foot water-bearing zone is under water table conditions while the 35-foot zone is under leaky artesian conditions. The vertical hydraulic conductivity of the confining unit between the two water-bearing zones ranges from 1.8×10^{-6} to 7.4×10^{-5} cm/sec. Given these numbers, the response of the 35-foot water-bearing zone to pumping and the contaminant distribution, it is apparent that the 35-foot zone is recharged from the shallower unit. During SFS field activities conducted in the spring of 1989, the vertical gradient between the 15- and 35-foot water-bearing zones was downward in some areas of the site and upward in at least one location. It is possible that this head relationship varies seasonally or with individual rainfall events as well as aerally over the site.

For the 1984 SI, 13 monitoring wells were installed. For the SFS, eight additional monitoring wells were installed. Two wells (CC-1 and CC-2) existed on site prior to EPA's removal activities in 1982. Of these 21 wells, six are screened in the 15-foot water-bearing zone, 14 in the 35-foot zone, and one in the 100-foot zone. Well locations are presented in Figure 11, and a listing of the monitoring wells and the zones that they monitor are presented in Table 7.



SCALE IN FEET
0 50 100
CONTOUR INTERVAL 2'

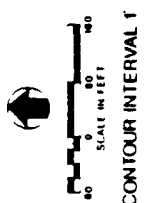
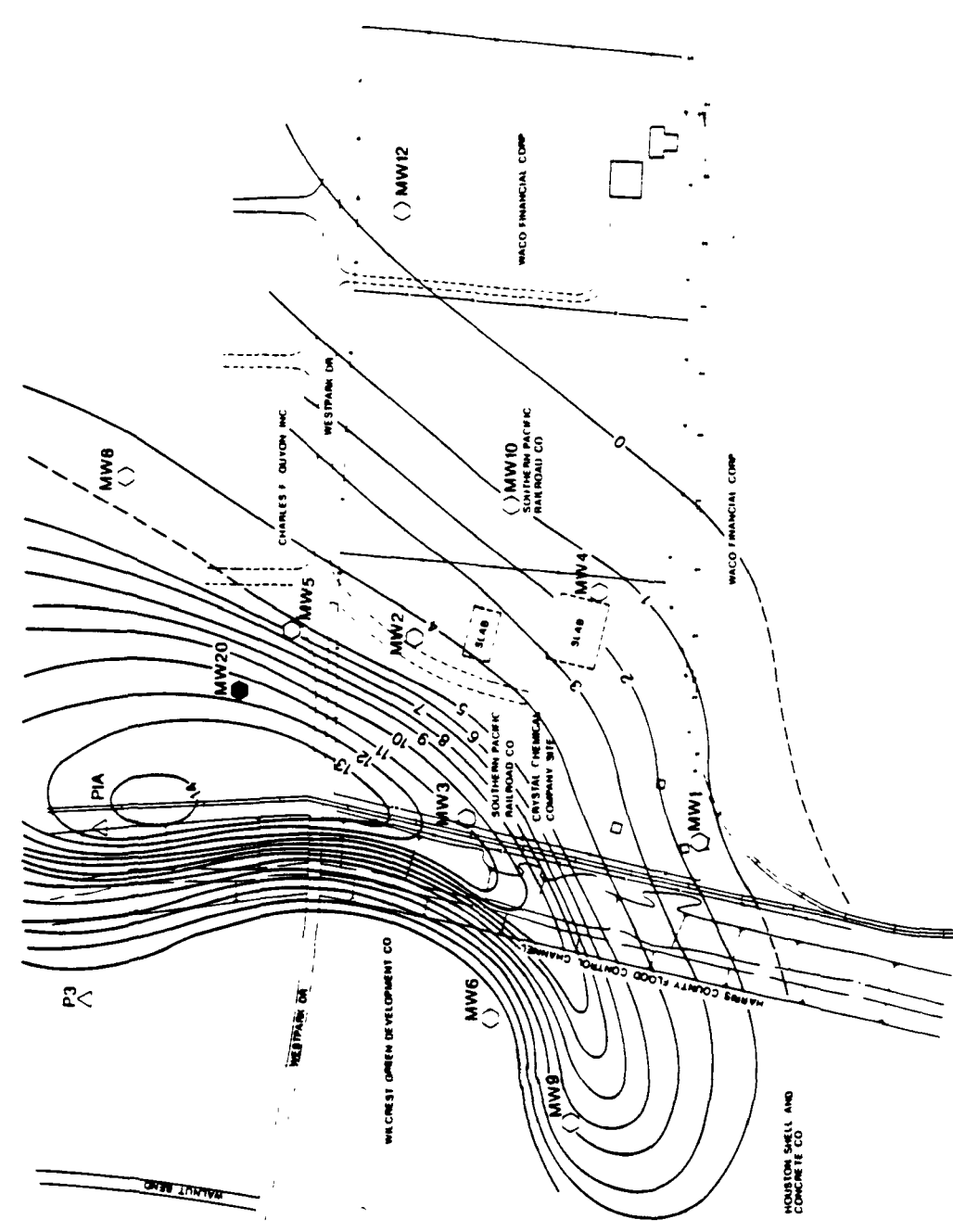
LEGEND

- MONITORING WELL LOCATION
- MONITORING WELL INSTALLED IN MARCH & APRIL 1989

WELL NO.	THICKNESS (FEET)
MW2	3
MW5	10
MW12	13
MW14	9
MW15	4
MW18	8
MW21	2

		CRYSTAL CHEMICAL ISOPACH MAP OF THE 13' WATER BEARING ZONE		2000 JUL 1989	FIGURE 9
PROJECT NO. 13-1		SHEET NO. 1		DATE 7/1/89	
DRAWN BY J. L. EDDY		CHECKED BY J. L. EDDY		SCALE 1" = 100'	

○ MW11



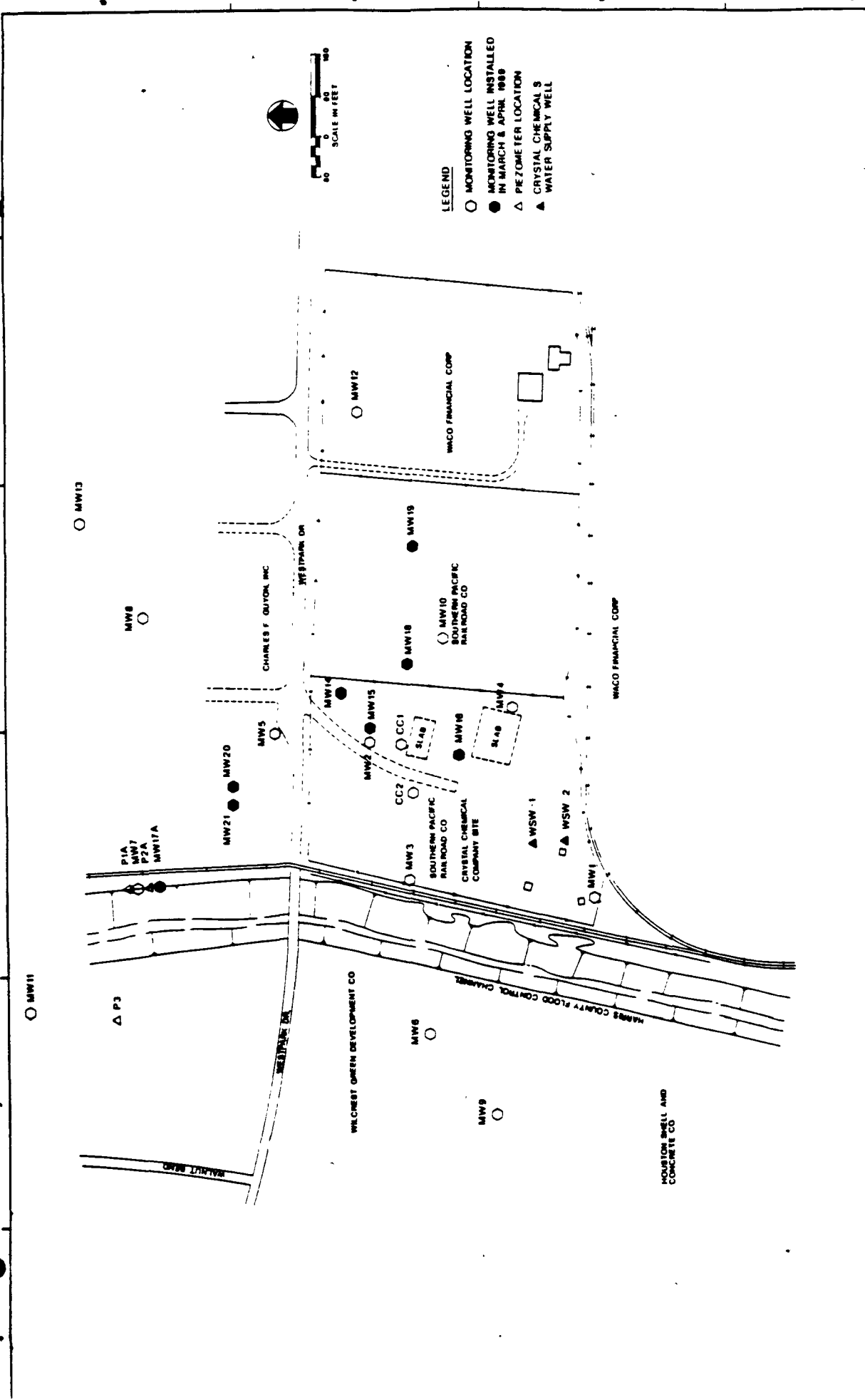
LEGEND

- MONITORING WELL LOCATION
- MONITORING WELL INSTALLED IN MARCH & APRIL 1989
- △ PIEZOMETER LOCATION

WELL NO. THICKNESS (FEET)

MW1	14
MW2	4.5
MW3	10.5
MW4	15
MW5	5
MW6	1.9
MW8	4
MW9	4
MW10	1
MW11	3.5
MW12	0.5
MW20	13
PIA	14
P3	15

CRYSTAL CHEMICAL		280023	
ISOPACH MAP OF THE 35 WATER BEARING ZONE		FIGURE 10	
M&E METCALF & EDDY		DATE: 1989 BY: J.E.	
		SCALE: 1" = 180'	



		CRYSTAL CHEMICAL WELL AND PIEZOMETER LOCATION	
PROJECT NO. 104922		SHEET NO. 11	
DATE: 11/89		FIG. 11	
DRAWN BY: J. L.		CHECKED BY: J. L.	
SCALE: 1" = 400'		DATE: 11/89	

FIGURE 11

TABLE 7
SUMMARY OF MONITORING WELL ZONES
Crystal Chemical Company Site

Monitoring Wells Screened in 15-Foot Water-Bearing Zone

<u>Well No.</u>	<u>Elev. of Screened Interval</u>
MW-14	63.4 - 53.4
MW-15	63.2 - 58.2
MW-16	62.0 - 57.0
MW-18	61.7 - 56.7
MW-19	65.1 - 55.1
MW-21	64.8 - 59.8

Monitoring Wells Screened in 35-Foot Water-Bearing Zone

<u>Well No.</u>	<u>Elev. of Screened Interval</u>
MW-1	44.9 - 40.2
MW-2	48.3 - 38.3
MW-3	46.0 - 36.0
MW-5	45.9 - 40.9
MW-6	43.9 - 38.9
MW-7	44.8 - 24.8
MW-8	46.8 - 41.8
MW-9	45.0 - 40.0
MW-10	43.0 - 38.0
MW-11	47.9 - 42.9
MW-12	56.6 - 51.6
MW-13	39.1 - 34.1
MW-17a	44.5 - 29.5
MW-20	42.3 - 32.3

Monitoring Well Screened in 100-Foot Water-Bearing Zone

<u>Well No.</u>	<u>Elev. of Screened Interval</u>
MW-4	-20.8 - -30.8

Ground water samples collected from these monitoring wells have been analyzed during several rounds of sampling in 1983, 1987, and 1989. A summary of the analyses are presented in Table 8 (additional field parameters and additional analytical constituents detected in lower concentrations are included in the SFS report).

In July 1989, nine water supply wells in the vicinity of the site were sampled. Their locations are illustrated on Figure 12, and analytical results are included in Table 9. Based on all the past ground water sampling data, the estimated extent of ground water contamination is presented in Figure 13. The volume of ground water contaminated with arsenic is estimated to be approximately 3,000,000 gallons.

Exposure Routes

There is a potential for the contaminants at the Crystal Chemical site to reach the public through a number of pathways. Approximately 20,000 people live within a one-mile radius of the site. The routes with the most potential appear to be ingestion of or direct contact with either onsite or offsite contaminated soils and sediments. The other pathways identified include ingestion of or direct contact with surface water or ground water, inhalation of ambient air and ingestion of contaminated crawfish. Each identified pathway is described below:

Contaminated Soils

Possible ingestion of or direct contact with contaminated soils and sediments on site and off site constitute major exposure routes. Although the degree of arsenic contamination is less at the offsite exposure locations, it is important because the public has direct access to these soils. The area of concern for direct physical contact is the site itself and a minimum area around the site of approximately 100 to 150 feet.

Surface Water and Sediment

Exposure to arsenic can occur by ingestion of or direct contact with contaminated surface water or sediments. The primary exposure point for this pathway is in the flood control channel west of the site. Contaminants are leached from the site soils by surface water run-off and carried over land or by drainageways to the flood control channel where the contaminated water collects. As the contaminated surface run-off flows over land and in drainageways and the flood control channel, contaminants are spread to offsite soils and sediments, thereby contaminating these media. Dilution

TABLE 8
SUMMARY OF GROUNDWATER SAMPLING
Crystal Chemical Company Site

Monitor Well No.	Sample Number	Date Sampled	Concentrations (ppm)			
			As ⁽¹⁾⁽⁶⁾	Phenol	TOC ⁽²⁾	TOC ⁽³⁾
MW-1	GW-7	05-20-83	0.19	<0.05	22	NA ⁽⁴⁾
MW-1	GW-12	05-28-83	1.1	<0.05	12	NA
MW-1	GW-21	06-07-83	0.56	0.04	NA	3400
MW-1	GW-35	08-26-83	0.07	NA	NA	NA
MW-1	GW-47	11-05-83	0.06	NA	NA	NA
MW-1	-	10-21-87	0.02	0.025	NA	NA
MW-2	GW-4	05-18-83	73	<0.05	160	NA
MW-2	GW-16	05-28-83	70	<0.05	220	NA
MW-2	GW-26	06-07-83	384	0.11	NA	10000
MW-2	GW-37	08-26-83	388	NA	NA	NA
MW-2	GW-50	11-05-83	623 ⁽⁵⁾	NA	NA	NA
MW-2	-	10-22-87	291	0.061	NA	NA
MW-3	GW-5	05-19-83	29	0.10	10	NA
MW-3	GW-15	05-28-83	95	<0.05	25	NA
MW-3	GW-25	06-07-83	225	0.03	NA	6200
MW-3	GW-36	08-26-83	341 ⁽⁵⁾	NA	NA	NA
MW-3	GW-49	11-05-83	363	NA	NA	NA
MW-3	-	10-22-87	359	0.23	NA	NA
MW-4	GW-6	05-20-83	0.04	<0.05	21	NA
MW-4	GW-10	05-27-83	0.08	0.75	<1	NA
MW-4	GW-20	06-07-83	NA	NA	NA	NA
MW-4	GW-31	08-26-83	NA	NA	NA	NA
MW-4	GW-46	11-04-83	0.01	NA	NA	NA
MW-4	-	10-21-87	0.007	<0.01	NA	NA
MW-4	-	04-17-89	0.004/ 0.003	<0.01	NA	NA
MW-5	GW-8	05-23-83	504	0.60	360	NA
MW-5	GW-18	05-28-83	101	0.05	260	NA
MW-5	GW-27	06-07-83	390	NA	NA	NA
MW-5	GW-28	06-07-83	310	NA	NA	NA
MW-5	GW-29	06-07-83	400	0.04	NA	6400
MW-5	GW-30	06-07-83	-	NA	NA	NA
MW-5	GW-38	08-26-83	607	NA	NA	NA
MW-5	GW-51	11-05-83	517 ⁽⁵⁾	NA	NA	NA
MW-5	GW-53	12-20-83	-	NA	NA	NA
MW-5	-	10-22-87	366	0.12	NA	NA

TABLE 8 (continued)
SUMMARY OF GROUNDWATER SAMPLING
Crystal Chemical Company Site

Monitor Well No.	Sample Number	Date Sampled	Concentrations (ppm)			
			As ⁽¹⁾⁽⁶⁾	Phenol	TOC ⁽²⁾	TOC ⁽³⁾
MW-6	GW-9	05-26-83	4	0.12	7	NA
MW-6	GW-13	05-28-83	6.1	<0.05	<1	NA
MW-6	GW-23	06-07-83	0.04	0.02	NA	2300
MW-6	GW-32	08-26-83	0.02	NA	NA	NA
MW-6	GW-44	11-04-83	0.01	NA	NA	NA
MW-6	-	10-21-87	<0.005	<0.01	NA	NA
MW-7	GW-11	05-27-83	0.13	<0.05	5	NA ⁽⁴⁾
MW-7	GW-14	05-28-83	2.4	<0.05	<1	NA
MW-7	GW-22	06-07-83	0.08	0.03	NA	905
MW-7	GW-33	08-26-83	0.02	NA	NA	NA
MW-7	GW-45	08-04-83	0.01	NA	NA	NA
MW-8	GW-19	05-28-83	12	0.05	4	NA
MW-8	GW-24	06-07-83	0.04	0.03	NA	1400
MW-8	GW-34	08-26-83	0.02	NA	NA	NA
MW-8	GW-41	11-04-83	0.03	NA	NA	NA
MW-8	-	10-21-87	<0.005	<0.01	NA	NA
MW-9	GW-43	11-04-83	0.01	NA	NA	NA
MW-9	-	10-22-87	0.005	0.053	NA	NA
MW-10	GW-48	11-05-83	0.01	NA	NA	NA
MW-10	-	10-20-87	<0.005	0.049	NA	NA
MW-11	GW-42	11-04-83	0.01	NA	NA	NA
MW-11	-	10-20-87	<0.005	0.059	NA	NA
MW-12	GW-39	11-04-83	0.01	NA	NA	NA
MW-12	-	10-22-87	<0.01	0.029	NA	NA
MW-13	GW-40	11-04-83	0.01	NA	NA	NA
MW-13	-	10-21-87	<0.005	0.01	NA	NA
MW-14	-	04-18-89	0.029/ 0.005	0.01	NA	NA
MW-15	-	04-18-89	161/171	<0.01	NA	NA

TABLE 8 (continued)
SUMMARY OF GROUNDWATER SAMPLING
Crystal Chemical Company Site

Monitor Well No.	Sample Number	Date Sampled	Concentrations (ppm)			
			As ⁽¹⁾⁽⁶⁾	Phenol	TOC ⁽²⁾	TOC ⁽³⁾
MW-16	-	04-18-89	0.031/ 0.033	<0.01	NA	NA
MW-17A	-	04-18-89	0.036/ 0.006	<0.01	NA	NA
MW-18	-	04-18-89	0.014/ 0.017	<0.01	NA	NA
MW-19	-	04-17-89	0.021/ 0.033	<0.01	NA	NA
MW-20	-	04-17-89	258/272	0.022	NA	NA
MW-21	-	04-18-89	0.006/ 0.007	<0.01	NA	NA
P-1a	-	04-18-89	<0.002/ <0.002	<0.01	NA	NA
CC-1	GW-1	05-17-83	0.03	<0.05	29	NA
CC-1	-	10-22-87	0.006	0.057	NA	NA
CC-2	GW-2	05-17-83	0.23	<0.05	25	NA
CC-2	-	10-22-87	0.483	0.046	NA	NA
Guyon Well	-	05-11-83	0.06	<0.05	2	-
		08-26-83	0.01	NA	NA	-
		11-04-83	0.002	NA	NA	-
		10-23-87	<0.005	0.034	NA	NA
		04-18-89	<0.002/ <0.002	<0.010	NA	NA

Notes:

(1) Total Dissolved Arsenic

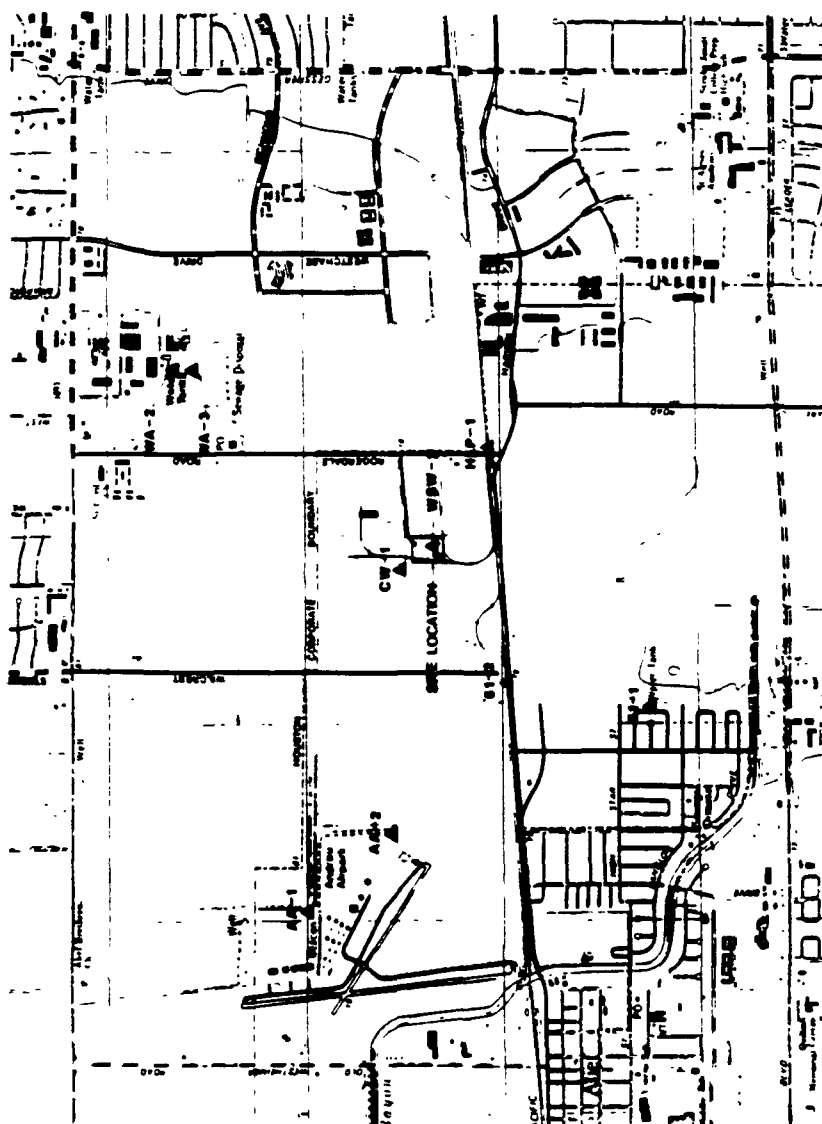
(2) Total Organic Carbon

(3) Total Dissolved Solids

(4) NA = Not Analyzed

(5) Average of two readings

(6) (Total/Dissolved) = Total and Dissolved Arsenic Concentrations



1000 0 1000 2000
SCALE IN FEET

LEGEND
▲ DEEP WELL SAMPLING LOCATION

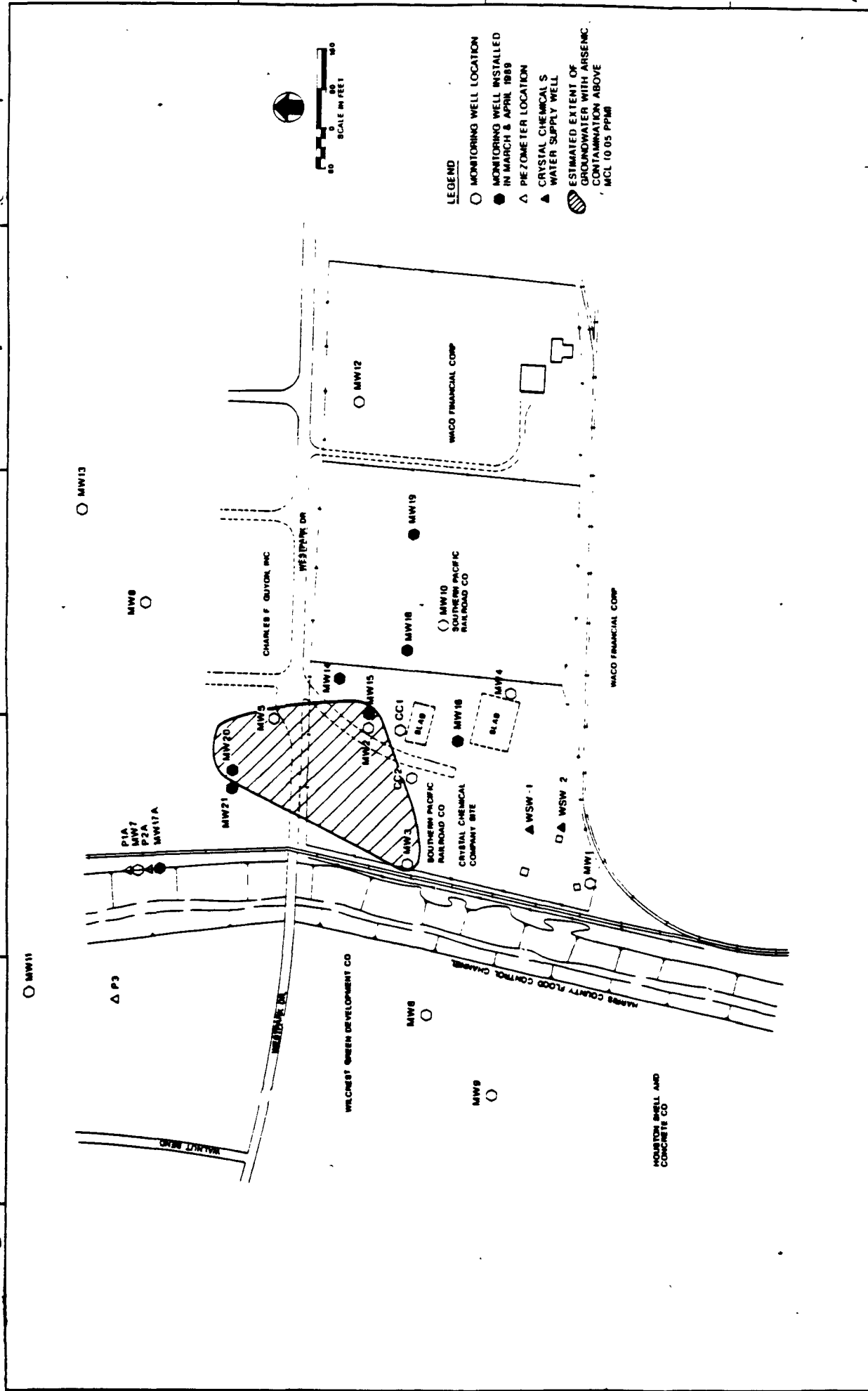
<div> <div>200025</div> <div>PL 1</div> <div>PL 2</div> <div>FIGURE 12</div> </div>	<div>CRYSTAL CHEMICAL</div> <div>DEEP WELL LOCATIONS</div>	<div>SCALE 1" = 1000'</div>	<div>M&E</div> <div>METCALF & EDDY</div>	<div>DATE</div> <div>BY</div> <div>CHKD</div> <div>APP'D</div>	<div>DATE</div> <div>BY</div> <div>CHKD</div> <div>APP'D</div>	<div>DATE</div> <div>BY</div> <div>CHKD</div> <div>APP'D</div>	<div>DATE</div> <div>BY</div> <div>CHKD</div> <div>APP'D</div>
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TABLE 9
SUMMARY OF DEEPER AREA WELL SAMPLING
July 25, 26, and 27, 1989
Crystal Chemical Site

<u>Sampling Location</u>	<u>Total Arsenic (ppb)</u>	<u>Total Arsenic Split Sample (ppb)</u>	<u>Phenol (ppb)</u>
Onsite Well WSW-1	928	1700	10.0
Onsite Well WSW-1 (duplicate)	751	3600	15.0
Tap on City Supply Line CW-1	10.5	5	<10.0
Andrau Airport #1 AA-1	<3.3	BDL	<10.0
Andrau Airport #2 AA-2	7.6	BDL	<10.0
Western Atlas #2 WA-2	32.4	BDL	<10.0
Western Atlas #3 WA-3	<3.3	BDL	<10.0
City Well 51-1	4.4	5	10.0
City Well 51-2	4.9	9	<10.0
HL&P Substation HLP-1	4.0	BDL	<10.0
HL&P Substation (duplicate)	55.4	NA	<10.0

Notes:

BDL = Below Detection Limits (for split samples, detection limit is 5 ppb)
NA = Not analyzed



		CRYSTAL CHEMICAL ESTIMATED EXTENT OF ARSENIC CONTAMINATED GROUNDWATER		780922 P. 1 of 1
FIGURE 13				

of the flood control channel water as it is washed downstream reduces contaminant concentrations in the surface water and sediments downstream.

Ambient Air

Airborne migration is not a pathway posing an immediate risk. Although offsite surface soils contain arsenic, air sampling during the site investigation indicated that these soils are not causing air releases. This pathway remains a concern, however, since the potential for erosion and degradation of the temporary cap exists.

Ground Water

Potential exposure to arsenic may occur by ingestion of or direct contact with contaminated ground water pumped to the surface by water supply wells. Twenty water wells exist (or have existed) within a one-mile radius of the Crystal Chemical site. These wells include observation wells, public supply wells, industrial wells and irrigation wells that pump primarily from the Upper Chicot aquifer and aquifers below it, where the extent of the contamination has been minimal. These major aquifers are unlikely to become contaminated in the future unless an artificial penetration or unknown natural conduits allow the contaminants to bypass the overlying thick clay formation.

High levels of arsenic contamination have been found at relatively shallow depths compared to the depths of major aquifer supplies. The major ground water contamination occurs in the 35- to 50-foot sand layer. Currently, this layer is not used for water supplies and no known exposure points exist for the shallow, contaminated ground water. A future installation could constitute an exposure point if the 35-foot water-bearing zone is encountered (e.g., digging that may be required as a part of remedial action efforts, the installation of a water supply or test well or eventual development of neighboring properties that may employ excavation work). Depending on the relative location of the exposure point to the contaminant plume, contact with the 35-foot water-bearing zone could be a significant exposure route because of the high levels of arsenic present.

Food Chain

Arsenic is bioaccumulated from water in fish, shellfish and crustaceans, but the arsenic in the tissues of these organisms ("Fish arsenic") is in an organic form that has very low toxicity. Consequently, human exposure to arsenic due to ingestion of aquatic species (e.g., crawfish from the flood control channel) is not generally considered to be a significant health risk (ATSDR 1987).

V. SUMMARY OF SITE RISKS

During the SFS, a Health Assessment was prepared for EPA by the Agency for Toxic Substances and Disease Registry ("ATSDR"). This report reviewed the potential risks to human health posed by the Crystal Chemical site in regards to contaminant sources and potential contacts to the population. The ATSDR determined that arsenic was the only contaminant of concern with respect to public health. Arsenic ranks twentieth (20th) in abundance among the natural elements in the Earth's crust and, therefore, is found naturally occurring in rocks and soils. It is widely used in herbicides and is found in both organic as well as inorganic forms on the Crystal Chemical site. The arsenic found on the Crystal Chemical site exhibits characteristics of a substance that is regulated under the Resource Conservation and Recovery Act ("RCRA"), as amended, 42 U.S.C. Section 6901, et seq., and a specific type of arsenic (i.e., K031 - by-product salts generated in the production of monosodium methylarsenate ("MSMA") and cacodylic acid) that is listed and regulated under RCRA was produced on the site. ATSDR determined that the areas of concern where potential exposure to the arsenic contamination was most likely to occur would be surface soil and surface water. The susceptible populations were identified as children who may play in the immediate vicinity of the site and workers who may be involved in maintenance and remediation activities at the site. The identified exposure pathways include direct skin contact, ingestion of contaminated ground water, surface water and surface soil, and inhalation of contaminated airborne dusts.

Also, during the SFS, an analysis was conducted to estimate the health or environmental problems that could result if no action were taken on the soil contamination at the Crystal Chemical site. This analysis is commonly referred to as an endangerment assessment. The primary purpose of the endangerment assessment is to evaluate potential health effects that could result from direct exposure to the contaminant as a result of contaminated soil, surface water or airborne dust coming in contact with an individual through direct contact with the skin, ingestion (eating or drinking), or inhalation, and to determine appropriate remediation levels of the contaminant of concern. In this case, arsenic in its most toxic form (trivalent, inorganic arsenic) is the contaminant of concern. Although phenol has been found onsite, the ATSDR Health Assessment determined that phenolic compounds did not present a potential health problem to area residents and workers in the area due to the low levels that were detected at the site. Although phenol has been found onsite at a maximum concentration of 157 ppm, the endangerment assessment did not evaluate risk because concentrations of this compound were well below any health-based levels of concern.

With respect to potential health effects, the results of the endangerment assessment supported the ATSDR Health Assessment and

identified the following five specific potential ways in which individuals could become exposed at the site:

- Ingestion of or direct contact with soil and sediments,
- ingestion of or direct contact with surface water,
- ingestion of shallow ground water,
- inhalation of wind dispersed dust, or
- ingestion of contaminated fish.

Human exposure levels were developed by assuming daily intakes for two exposure durations, and their respective exposure concentrations, subchronic and chronic. Subchronic exposures were developed for average concentrations expected during a 10- to 90-day period, while chronic exposures assumed a 70-year lifespan. The calculations for the Human Intake Factors ("HIF") for the various exposure rates are provided in Appendix 1 of the Crystal Chemical Endangerment/Risk Assessment (1988). Some assumptions utilized in these HIF calculations are as follows: ✓

Area children residents were assumed to be six years old, with a potential for swimming (water or sediment ingestion) in the flood control ditch three days per week, nine months per year. Chronic exposures of area children to future well water, offsite surface soils, and solids suspended in air (dust) were assumed to occur seven days per week, 12 months per year.

Area adult residents were assumed to have chronic exposures to flood control waters and sediments two days per week, nine months per year. Chronic exposures of area adults to future well water, offsite surface soil, and dust were assumed to occur seven days per week, 12 months per year.

Onsite workers were assumed to have subchronic exposures to ingestion of standing water two days per week, ingestion of and dermal contact with soils for five days per week, and inhalation of dust eight hours per day, five days per week.

The concentrations of arsenic on which the endangerment assessment was based are derived from the site investigation data and are presented in Table 10. These data evaluate exposure based on a best-estimate and worst-case (upper-bound) of the environmental concentrations. The best estimate at each exposure point is taken to be the mean of all monitoring data in each medium, and the worst-case (upper-bound) is taken to be the highest value detected in each medium.

In December 1989, EPA's Office of Emergency and Remedial Response published the interim final Risk Assessment Guidance for Superfund

TABLE 10

SUMMARY OF EXPOSURE POINT CONCENTRATIONS OF ARSENIC
Crystal Chemical Company Site

<u>Exposure Point</u>	<u>Medium</u>	<u>Concentration, ppm</u>	
		<u>Best-Estimate</u>	<u>Upper-Bound</u>
On-site	Soil (1 - 10 feet)	3,700	27,310
	Storm water	200	3,740
Off-site	Surficial soil	51	636
	Flood control channel water	0.11	0.51
	Flood control channel sediment	200	1,340
	Ambient air	1.9E-5 ^(a)	5.0E-5 ^(a)
	Ground water (35-foot sand)	455	917
	Ground water (100-foot sand)	0.063	0.17

Notes:

^(a) Units are mg/m³.

("RAGS") - Volume I. The purpose of this guidance was to supersede the Superfund Public Health Evaluation Manual ("SPHEM") and Endangerment Assessment Handbook which, to that date, had been used for assessing the effects of chemical contamination on human health. RAGS revised the SPHEM methodology in several ways, including the introduction of the concept of Reasonable Maximum Exposure ("RME"). RME is defined as the highest exposure that could reasonably be expected to occur at a site. This approach differs from the SPHEM approach of defining worst-case exposure to site contaminants. While SPHEM utilized a "worst-case" scenario based on continued exposure to the maximum detected concentration of a chemical constituent at the site, RME bases the maximum exposure on the 95% upper confidence limit of the mean, providing a spatially averaged exposure concentration.

This Record of Decision summarizes the results of the risk assessment conducted in 1988 under SPHEM guidance. While there are advantages and disadvantages realized in both the SPHEM and RAGS methods, the underlying assumptions utilized under SPHEM were at least as conservative as those in RAGS. Therefore, the results of the site risk assessment are at least as protective as those which would have been derived under exposure parameters (i.e., body weight, ingestion rates, exposure frequency and duration, etc.) consistent with the RAGS. However, whenever the terminology used for SPHEM and for RAGS is interchangeable, RAGS terminology is used.

The endangerment assessment went further to conclude that the most prominent risks posed to the public by the site involved those listed below:

- Noncarcinogenic risk to onsite workers, or area residents (children or adults) resulting from incidental ingestion or dermal (skin) contact with contaminated soil or surface water (i.e., ingestion of arsenic can cause skin abnormalities such as dark and light spots on the skin and direct contact with the skin can result in mild to severe irritation of the skin, eyes or throat).
- Risk of skin cancer in area residents due to chronic (lifetime) ingestion or dermal contact with contaminated soil, surface water or sediment.
- Risk of lung cancer in area resident due to chronic (lifetime) inhalation of arsenic contaminated soil particles suspended in air.

The risk characterization for each population by each pathway is presented in Table 11.

TABLE 11A
SUMMARY OF ESTIMATED SUBCHRONIC HUMAN INTAKE LEVELS OF ARSENIC
Crystal Chemical Company Site

Exposed Population	Exposure Route	Exposure Medium	HIF _s (a)	Best-Estimate		Upper-Bound	
				Concentration, ppm (b,c)	Daily Intake, mg/kg/day	Concentration, ppm (c,d)	Daily Intake, mg/kg/day
On-site Workers	Ingestion	Soil	1.0E-6	3.7E+3	3.7E-3	2.73E+4	2.7E-2
		Surface water	4.1E-5	2.0E+2	8.2E-3	3.74E+3	1.5E-1
	Dermal	Soil	1.3E-6	3.7E+3	4.0E-3	2.73E+4	3.5E-2
		Surface water	NC	2.0E+2	NC	3.74E+3	NC
Child residents: Area school children	Inhalation	Soil in air	6.5E-2	1.9E-5	1.2E-6	5.0E-5	3.3E-6
	Ingestion	Soil	2.0E-5	5.1E+1	1.0E-3	6.36E+2	1.3E-2
		Control channel water	2.2E-3	1.1E-1	2.4E-4	5.1E-1	1.1E-3
		Control channel sediment	4.3E-6	2.0E+2	8.6E-4	1.34E+3	5.8E-3
	Dermal	Soil	6.6E-6	5.1E+1	3.4E-4	6.36E+2	4.2E-3
		Control channel water	NC	1.1E-1	NC	5.1E-1	NC
		Control channel sediment	1.4E-6	2.0E+2	2.8E-4	1.34E+3	1.9E-3
	Inhalation	Soil in air	1.6E-1	1.9E-5	3.0E-6	5.0E-5	8.0E-6
	Ingestion	Soil	1.4E-6	5.1E+1	7.1E-5	6.36E+2	8.9E-4
		Control channel water	4.0E-5	1.1E-1	4.4E-6	5.1E-1	2.0E-5
		Control channel sediment	4.1E-7	2.0E+2	8.2E-5	1.34E+3	5.5E-4
	Dermal	Soil	1.8E-6	5.1E+1	9.2E-5	6.36E+2	1.1E-3
		Control channel water	NC	1.1E-1	NC	5.1E-1	NC
		Control channel sediment	5.2E-7	2.0E+2	1.0E-4	1.34E+3	7.0E-4
Flood control channel maintenance workers	Inhalation	Soil in air	9.1E-2	1.9E-5	1.7E-6	5.0E-5	4.6E-6
	Ingestion	Control channel water	1.0E-4	1.1E-1	1.1E-5	5.1E-1	5.1E-5
		Control channel sediment	1.0E-6	2.0E+2	2.0E-4	1.34E+3	1.3E-3
	Dermal	Control channel water	NC	1.1E-1	NC	5.1E-1	NC
		Control channel sediment	1.3E-6	2.0E+2	2.6E-4	1.34E+3	1.7E-3
Future residents (adult)	Ingestion	35-foot aquifer	2.9E-2	4.55E+2	1.3E+1	9.17E+2	2.7E+1
		100-foot aquifer	2.9E-2	6.3E-2	1.8E-3	1.7E-1	4.9E-3
Future residents (child)	Ingestion	35-foot aquifer	1.0E-1	4.55E+2	4.6E+1	9.17E+2	9.2E+1
		100-foot aquifer	1.0E-1	6.3E-2	6.3E-3	1.7E-1	1.7E-2

(a) Refer to the Risk/Endangerment Assessment (Appendix 1) for detailed description and assumptions involved in HIF_s derivations.

(b) Taken to be the mean concentration of all values measured at the exposure point (Table 9).

(c) Units are mg/kg for soil, mg/L for water and mg/m³ for air.

(d) Taken to be the highest concentration of all values measured at the exposure point (Table 9).
Not calculated, due to lack of suitable data on dermal permeability coefficient for arsenic in water.

TABLE 11B
SUMMARY OF ESTIMATED CHRONIC HUMAN INTAKE LEVELS OF ARSENIC
Crystal Chemical Company Site

Exposed Population	Exposure Route	Exposure Medium	HIF _c (a)	Best-Estimate		Upper-Bound	
				Concentration, ppm (b,c)	Daily Intake, mg/kg/day	Concentration, ppm (c,d)	Daily Intake, mg/kg/day
Child residents; Area school children	Ingestion	Soil	2.0E-5	5.1E+1	1.0E-3	6.36E+2	1.3E-2
		Control channel water	1.6E-3	1.1E-1	1.0E-4	5.1E-1	8.2E-4
		Control channel sediment	3.2E-6	2.0E+2	6.4E-4	1.34E+3	4.3E-3
	Dermal	Soil	6.6E-6 (e)	5.1E+1	3.4E-4	6.36E+2	4.2E-3
		Control channel water	NC	1.1E-1	NC	5.1E-1	NC
		Control channel sediment	1.1E-6	2.0E+2	2.2E-4	1.34E+3	1.5E-3
Adult residents	Inhalation	Soil in air	1.6E-1	1.9E-5	3.0E-6	5.0E-5	8.0E-6
		Soil	1.4E-6	5.1E+1	7.1E-5	6.36E+2	8.9E-4
		Control channel water	3.0E-5	1.1E-1	3.3E-6	5.1E-1	1.5E-5
	Dermal	Control channel sediment	3.1E-7	2.0E+2	6.2E-5	1.34E+3	4.2E-4
		Soil	1.8E-6	5.1E+1	9.2E-5	6.36E+2	1.1E-3
		Control channel water	NC	1.1E-1	NC	5.1E-1	NC
Future residents (adult)	Inhalation	Control channel sediment	3.9E-7	2.0E+2	7.8E-4	1.34E+3	5.2E-4
		Soil in air	9.1E-2	1.9E-5	1.7E-6	5.0E-5	4.6E-6
		35-foot aquifer	2.9E-2	4.6E+2	1.3E+1	9.17E+2	2.7E+1
Future residents (child)	Ingestion	100-foot aquifer	2.9E-2	6.3E-2	1.8E-3	1.7E-1	4.9E-3
		35-foot aquifer	1.0E-1	4.5E+2	4.6E+1	9.17E+2	9.2E+1
		100-foot aquifer	1.0E-1	6.3E-2	6.3E-3	1.7E-1	1.7E-2

(a) Refer to the Risk/Endangerment Assessment (Appendix 1) for detailed description and assumptions involved in HIF_c derivations.

(b) Taken to be the mean concentration of all values measured at the exposure point (Table 9).

(c) Units are mg/kg for soil, mg/L for water and mg/m³ for air.

(d) Taken to be the highest concentration of all values measured at the exposure point (Table 9).

(e) Not calculated, due to lack of suitable data on dermal permeability constant for arsenic in water.

TABLE 11C
SUMMARY OF SUBCHRONIC NONCARCINOGENIC RISKS FROM ARSENIC
Crystal Chemical Company Site

			Best-Estimate			Upper-Bound		
Exposed Population	Exposure Route	Exposure Medium	Daily Intake, mg/kg/day	Acceptable Intake, mg/kg/day	Ratio (Daily Intake/ Acceptable Intake)	Daily Intake, mg/kg/day	Acceptable Intake, mg/kg/day	Ratio (Daily Intake/ Acceptable Intake)
On-site Workers	Ingestion	Soil	3.7E-3	1.0E-3	3.7E+0	2.7E-2	1.0E-3	2.7E+1
		Surface water	8.2E-3	1.0E-3	8.2E+0	1.5E-1	1.0E-3	1.5E+2
Dermal		Soil	4.8E-3	1.0E-3	4.8E+0	3.5E-2	1.0E-3	3.5E+1
		Surface water	NC	1.0E-3	NC	NC	1.0E-3	NC
Child residents; Area school children	Inhalation	Soil in air	1.2E-6	8.6E-4	1.4E-3	3.3E-6	8.6E-4	3.8E-3
	Ingestion	Soil	1.0E-3	1.0E-3	1.0E+0	1.3E-2	1.0E-3	1.3E+1
		Control channel water	2.4E-4	1.0E-3	2.4E-1	1.1E-3	1.0E-3	1.1E+0
		Control channel sediment	8.6E-4	1.0E-3	8.6E-1	5.8E-3	1.0E-3	5.8E+0
	Dermal	Soil	3.4E-4	1.0E-3	3.4E-1	4.2E-3	1.0E-3	4.2E+0
		Control channel water	NC	1.0E-3	NC	NC	1.0E-3	NC
Adult residents; Area employees		Control channel sediment	2.8E-4	1.0E-3	2.8E-1	1.9E-3	1.0E-3	1.9E+0
	Inhalation	Soil in air	3.0E-6	8.6E-4	3.5E-3	8.0E-6	8.6E-4	9.3E-3
	Ingestion	Soil	7.1E-5	1.0E-3	7.1E-2	8.9E-4	1.0E-3	8.9E-1
		Control channel water	4.4E-6	1.0E-3	4.4E-3	2.0E-5	1.0E-3	2.0E-2
		Control channel sediment	8.2E-5	1.0E-3	8.2E-2	5.5E-4	1.0E-3	5.5E-1
	Dermal	Soil	9.2E-5	1.0E-3	9.2E-2	1.1E-3	1.0E-3	1.1E+0
Control channel water		NC	1.0E-3	NC	NC	1.0E-3	NC	
Flood control channel maintenance workers		Control channel sediment	1.0E-4	1.0E-3	1.0E-1	7.0E-4	1.0E-3	7.0E-1
	Inhalation	Soil in air	1.7E-6	8.6E-4	2.0E-3	4.6E-6	8.6E-4	5.3E-3
	Ingestion	Control channel water	1.1E-5	1.0E-3	1.1E-2	5.1E-5	1.0E-3	5.1E-2
		Control channel sediment	2.0E-4	1.0E-3	2.0E-1	1.3E-3	1.0E-3	1.3E+0
		Dermal	Control channel water	NC	1.0E-3	NC	NC	1.0E-3
		Control channel sediment	2.6E-4	1.0E-3	2.6E-1	1.7E-3	1.0E-3	1.7E+0
Future residents (adult)	Ingestion	35-foot aquifer	1.3E+1	1.0E-1	1.3E+4	2.7E+1	1.0E-3	2.7E+4
		100-foot aquifer	1.8E-3	1.0E-3	1.8E+0	4.9E-3	1.0E-3	4.9E+0
Future residents (child)	Ingestion	35-foot aquifer	4.6E+1	1.0E-3	4.5E+4	9.2E+1	1.0E-3	9.2E+4
		100-foot aquifer	6.3E-3	1.0E-3	6.3E+0	1.7E-2	1.0E-3	1.7E+1

(a) Acceptable intake by the dermal route is assumed to be equal to the acceptable intake by the oral route.
(b) Calculated, due to lack of suitable data on dermal permeability constant for arsenic in water

TABLE 11D
SUMMARY OF CHRONIC NONCARCINOGENIC RISKS FROM ARSENIC
Crystal Chemical Company Site

Exposed Population	Exposure Route	Exposure Medium	Best-Estimate			Upper-Bound		
			Daily Intake, mg/kg/day	Acceptable ^(a) Intake, mg/kg/day	Ratio (Daily Intake/ Acceptable Intake)	Daily Intake, mg/kg/day	Acceptable Intake, mg/kg/day	Ratio (Daily Intake/ Acceptable Intake)
Child residents; Area school children	Ingestion	Soil	1.0E-3	1.0E-3	1.0E+0	1.3E-2	1.0E-3	1.3E+1
		Control channel water	1.8E-4	1.0E-3	1.8E-1	8.2E-4	1.0E-3	8.2E-1
		Control channel sediment	6.4E-4	1.0E-3	6.4E-1	4.3E-3	1.0E-3	4.3E+0
	Dermal	Soil	3.4E-4	1.0E-3	3.4E-1	4.2E-3	1.0E-3	4.2E+0
		Control channel water	NC ^(b)	1.0E-3	NC	NC	1.0E-3	NC
		Control channel sediment	2.2E-4	1.0E-3	2.2E-1	1.5E-3	1.0E-3	1.5E+0
Adult residents;	Inhalation	Soil in air	3.0E-6	8.6E-4	3.5E-3	8.0E-6	8.6E-4	9.3E-3
	Ingestion	Soil	7.1E-5	1.0E-3	7.1E-2	8.9E-4	1.0E-3	8.9E-1
		Control channel water	3.3E-6	1.0E-3	3.3E-3	1.5E-5	1.0E-3	1.5E-2
		Control channel sediment	6.2E-5	1.0E-3	6.2E-2	4.2E-4	1.0E-3	4.2E-1
	Dermal	Soil	9.2E-5	1.0E-3	9.2E-2	1.1E-3	1.0E-3	1.1E+0
		Control channel water	NC	1.0E-3	NC	NC	1.0E-3	NC
Future residents (adult)	Inhalation	Control channel sediment	7.8E-5	1.0E-3	7.8E-1	5.2E-4	1.0E-3	5.2E-1
		Soil in air	1.7E-6	8.6E-4	2.0E-3	4.6E-6	8.6E-4	5.3E-3
	Ingestion	35-foot aquifer	1.3E+1	1.0E-3	1.3E+4	2.7E+1	1.0E-3	2.7E+4
		100-foot aquifer	1.8E-3	1.0E-3	1.8E+0	4.9E-3	1.0E-3	4.9E+0
	Ingestion	35-foot aquifer	4.5E+1	1.0E-3	4.5E+4	9.2E+1	1.0E-3	9.2E+4
		100-foot aquifer	6.3E-3	1.0E-3	6.3E+0	1.7E-2	1.0E-3	1.7E+1

(a) Acceptable intake by the dermal route is assumed to be equal to the acceptable intake by the oral route.

(b) Not calculated, due to lack of suitable data on dermal permeability constant for arsenic in water.

A Preliminary Natural Resource Survey was conducted by the National Oceanic and Atmospheric Administration ("NOAA") in February 1989. To date, NOAA has not indicated whether that there is direct impact to NOAA resources. Additionally, there are no endangered species or critical habitats within close proximity of the site.

Evaluation of Noncarcinogenic Risks

Potential concern for noncarcinogenic effects of a single contaminant in a single medium (e.g. soil or water) is expressed as the hazard quotient ("HQ"). By adding the HQs for all contaminants within a medium or across all media to which a given population may reasonably be exposed, the hazard index ("HI") can be generated. The HI provides a useful reference point for gauging the potential significance of multiple contaminant exposures within a single medium or across media.

The risk of adverse noncarcinogenic effects of exposure to arsenic is expressed in terms of the HI. The HI is the ratio of the estimated dose which a human receives to the estimated dose level believed to be safe, and is calculated both for chronic and subchronic exposures. A summary of the calculations of noncarcinogenic risks is provided in Table 12.

Reference doses (RfDs) have been developed by EPA for indicating the potential for adverse health effects from exposure to chemicals exhibiting noncarcinogenic effects. RfDs, which are expressed in units of mg/kg-day, are estimates of lifetime daily exposure levels for humans, including sensitive individuals. Estimated intakes of chemicals from environmental media (e.g., the amount of a chemical ingested from contaminated drinking water) can be compared to the RfD. RfDs are derived from human epidemiological studies or animal studies to which uncertainty factors have been applied (e.g., to account for the use of animal data to predict effects on humans). These uncertainty factors help ensure that RfDs will not underestimate the potential for adverse noncarcinogenic effects to occur. The RfD for arsenic for the oral pathway is 1×10^{-3} mg/kg-day.

Based on the calculated HI values, it is evident that unprotected workers onsite may experience significant risk of noncarcinogenic health effects due to ingestion or dermal contact with surface water or soil. Similarly, area children playing in nearby yards and fields or in the flood control channel may experience noncarcinogenic risk due to ingestion or dermal contact with surface soils or contaminated sediments. Area adults and flood control channel maintenance workers are not likely to experience noncarcinogenic effects except under worst-case (upper bound) exposure conditions. The concentration of arsenic in the 100-foot aquifer is slightly too high to be acceptable for use as human drinking water, while the water in the 35-foot water-bearing zone

TABLE 12

**SUMMARY OF NONCARCINOGENIC RISKS FROM ARSENIC
Crystal Chemical Company Site**

Exposed Population	Exposure Route	Exposure Medium	Subchronic HI		Chronic HI	
			Best Estimate	Upper Bound	Best Estimate	Upper Bound
On-site workers	Ingestion	Soil	3.70	27.00	---- ^(a)	---
		Surface water	8.20	150.00	----	---
	Dermal	Soil	4.80	35.00	----	---
		Surface water	NC ^(b)	NC	----	---
	Inhalation	Soil in air	0.00 ^(c)	0.00	----	---
		Total: (d)	16.70	212.00		
Child residents; area school children	Ingestion	Soil	1.00	13.00	1.00	13.00
		Control channel water	0.24	1.10	0.18	0.82
		Control channel sediment	0.86	5.80	0.64	4.30
	Dermal	Soil	0.34	4.20	0.34	4.20
		Control channel water	NC	NC	NC	NC
		Control channel sediment	0.28	1.9	0.22	1.50
	Inhalation	Soil in air	0.00	0.00	0.00	0.01
		Total: (d)	2.72	26.00	2.38	23.83
Adult residents; area employees	Ingestion	Soil	0.07	0.89	0.07	0.89
		Control channel water	0.00	0.02	0.00	0.02
		Control channel sediment	0.08	0.55	0.06	0.42
	Dermal	Soil	0.09	1.10	0.09	1.10
		Control channel water	NC	NC	NC	NC
		Control channel sediment	0.10	0.70	0.08	0.52
	Inhalation	Soil in air	0.00	0.01	0.00	0.01
		Total: (d)	0.34	3.27	0.30	2.96
	Flood control channel maintenance workers	Control channel water	0.01	0.05	----	---
		Control channel sediment	0.20	1.30	----	---
Future residents (adult)	Ingestion	35-ft aquifer	13,000	27,000	13,000	27,000
		100-ft aquifer	1.80	4.90	1.80	4.90
	Future residents (child)	35-ft aquifer	45,000	92,000	45,000	92,000
Future residents (child)	Ingestion	100-ft aquifer	6.30	17.00	6.30	17.00

(a) Not quantified since chronic exposure not anticipated.

(b) NC = not calculated.

(c) All values less than 0.005 (5.0E-3) reported here as 0.00.

(d) Does not include risk from dermal absorption from water.

in its present condition is grossly contaminated and is entirely unfit for human use.

Evaluation of Carcinogenic Risks

The risk of cancer from exposure to a chemical is described in terms of the probability that an individual exposed for his or her entire lifetime will develop cancer. Cancer slope factors ("CSFs") have been developed by EPA's Carcinogenic Assessment Group for estimating excess lifetime cancer risks associated with exposure to potentially carcinogenic chemicals. CSFs, which are expressed in units of $(\text{mg/kg-day})^{-1}$, are multiplied by the estimated intake of a potential carcinogen to provide an upper-bound estimate of the excess lifetime cancer risk associated with exposure at the intake level. The term "upper bound" reflects the conservative estimate of the risks calculated from the CSF. Use of this approach makes underestimation of the actual cancer risk highly unlikely. CSFs are derived from the results of human epidemiological studies or chronic animal bioassays to which animal-to-human extrapolation and uncertainty factors have been applied.

The CSFs for arsenic for the oral and inhalation exposure routes are 1.5 and 50 $(\text{mg/kg-day})^{-1}$, respectively. A summary of calculations of carcinogenic risks is included as Table 13.

The cancer risk calculations indicate that chronic exposure to soils and sediments around the site is associated with significant risk of cancer. The principal risk associated with exposure by ingestion or dermal absorption is skin cancer. The principal risk associated with inhalation exposure is lung cancer. All of these exposure pathways are of concern, with substantial combined risks.

Remediation Goals

The contaminated soil was determined to be a principal threat at the site because of direct contact, ingestion, and inhalation risks and because of the soil's impact on ground water. The remedial objectives for the soil are to eliminate potential exposure via ingestion, inhalation or direct contact with contaminants and by reducing the potential for the soil to act as a continued source for surface water and ground water contamination.

The contaminated shallow ground water was also determined to be a principal problem at the site because of the potential exposure of the public to the site contaminants and because of the threat of migration of contaminants to deeper zones of ground water. The deeper ground water zones are used for industrial, irrigation, and

TABLE 13
SUMMARY OF CARCINOGENIC RISKS FROM ARSENIC
Crystal Chemical Company Site

Exposed Population	Exposure Route	Exposure Medium	Best-Estimate			Upper-Bound		
			Chronic Daily Intake, mg/kg/day	CSF, (mg/kg/day) ⁻¹	Cancer Risk	Chronic Daily Intake, mg/kg/day	CSF, (mg/kg/day) ⁻¹	Cancer Risk
Adult residents	Ingestion	Soil	7.1E-5	1.5E+0	1.1E-4	8.9E-4	1.5E+0	1.3E-3
		Control channel water	3.3E-6	1.5E+0	5.0E-6	1.5E-5	1.5E+0	2.3E-5
		Control channel sediment	6.2E-5	1.5E+0	9.3E-5	4.2E-4	1.5E+0	6.3E-4
	Dermal	Soil	9.2E-5	1.5E+0	1.4E-4	1.1E-3	1.5E+0	1.7E-3
		Control channel water	NC	1.5E+0	NC	NC	1.5E+0	NC
		Control channel sediment	7.8E-5	1.5E+0	1.2E-4	5.2E-4	1.5E+0	7.8E-4
		Subtotal:			4.7E-4			4.4E-3
	Inhalation	Soil in air	1.7E-6	5.0E+1	8.5E-5	4.6E-6	5.0E+1	2.3E-4
		Total:			5.5E-4			4.7E-3
Future residents (adult)	Ingestion	35-foot aquifer	1.3E+1	1.5E+0	1.0	2.7E+1	1.5E+0	1.0E+0
		100-foot aquifer	1.8E-3	1.5E+0	2.7E-3	4.9E-3	1.5E+0	7.4E-3

(a) Acceptable intake by the dermal route is assumed to be equal to the acceptable intake by the oral route.

drinking water purposes. The remedial objective is to reduce the amount of contamination to human health-based standards in order to eliminate or minimize the risks associated with the contaminated shallow ground water.

Arsenic was determined by ATSDR to be the contaminant of concern at the Crystal Chemical site, therefore, all remediation goals are set for arsenic. The only other contaminant found at the site which may be of concern was phenol. Remediation levels assuming chronic daily exposure in order to protect against noncarcinogenic effects were calculated for the phenolic compounds. The remediation levels were calculated to be 420,000 ppm for an adult and 50,000 ppm for a child. The remediation levels for phenolics have no significant effect on the volumes of soil or ground water requiring remediation at the site, and because these levels are relatively high compared to phenolic levels found at the site (approximately 160 ppm), the remediation levels for the phenols are not discussed in the review and evaluation of remedial technologies.

The selection of an appropriate remediation level for arsenic was based primarily on an evaluation of the potential health effects caused by human exposure to the contaminant, assuming that the future land use will be residential and commercial/industrial. The reasoning behind designating the future land use as possibly residential is that the City of Houston does not, at this time, have zoning ordinances, therefore, EPA takes a conservative approach and calculates risk so that all potential scenarios are taken into consideration.

To a lesser extent remediation levels for arsenic were based on the naturally occurring background conditions of arsenic in soils. Arsenic is a naturally occurring metallic constituent of soils, derived from the rock or parent materials, from which the soil was formed. Background concentrations of metals in soil may vary from region to region. For example, the United States Geological Survey (1975) reports that the mean and range of background arsenic concentrations in western soils is 6.1 ppm and 0.2-97 ppm, respectively.

A limited number of soil samples collected from offsite areas within two miles of the Crystal Chemical site found background arsenic concentrations to be less than 1.6 ppm. Soil sampling at the site found arsenic concentrations on the order of several hundred to several thousand ppm. As determined in the endangerment assessment, leaving this contamination on site without treatment would result in a one in ten thousand (10^{-4}) risk of cancer over the lifetime of individuals who may come in contact with this contamination. This estimate was developed by taking into account various conservative assumptions about the likelihood of a person being exposed to the contaminated soil, and in consideration of the toxicological effects of arsenic exposure.

The national risk of getting some form of cancer over a 70 year life span is very high, estimated at one chance in five or 0.2. The one in five probability is the baseline situation or "natural incidence" of cancer. A one in ten thousand (10^{-4}) risk is an increment above the baseline risk (an increase from 0.200 to 0.201). EPA policy calls for an evaluation of remediation levels that range from a cancer risk of one in ten thousand to one in one million (10^{-4} to 10^{-6}), using one in one million as a point of departure.

Utilizing conclusions made concerning the public to be protected and the amount and duration of exposure, the endangerment assessment calculated health standards for arsenic in surface soil and sediment. These goals call for the removal of offsite soils to a concentration of 30 ppm for arsenic, which represents a one in one hundred thousand (10^{-5}) cancer risk level. Since the average background concentration of arsenic in western soils (6.1 ppm) exists at a level in excess of EPA's standard point of departure (one in one million cancer risk - at a 3 ppm concentration of arsenic), 30 ppm was determined to represent a safe health-based action level. These soils will be placed back on to the Crystal Chemical site. Additionally, the selected remedy will require that all heavily contaminated areas onsite with soil-arsenic concentrations in excess of 300 ppm be treated using in-situ vitrification. Such an approach will effectively treat 95% of the arsenic found on the site. The treatment goal for the soils is to eliminate potential exposure and to reduce the amount of arsenic that is able to leach to 5.0 ppm of arsenic after treatment when analyzed using the Toxicity Characteristic Leaching Procedure ("TCLP"), 40 CFR 261.25. The entire site will be covered with a multi-layer cap after the treatment has been completed. The average concentration of arsenic found in these remaining areas (not subject to treatment) is 60 ppm. Once the entire remedy is complete, the resulting cancer risk will be reduced to less than one in one million (at or near the original background conditions).

The endangerment assessment did not address cleanup levels in ground water. The Maximum Contaminant Level ("MCL") standard for arsenic is considered an applicable or relevant and appropriate federal requirement ("ARAR") for the Crystal Chemical Company site. Therefore, EPA has determined that the MCL standard for arsenic, 0.05 ppm, will be the target remediation level for ground water. Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this ROD, may present an imminent and substantial endangerment to public health, welfare, or the environment.

VI. SCOPE AND ROLE OF RESPONSE ACTION

The studies undertaken at the Crystal Chemical site have identified two principal threats (i.e., contaminated soil and shallow ground

water), and the remedies to eliminate or minimize these threats that are included in this Record of Decision and are addressed as one operable unit.

The contaminated soil was determined to be a principal threat at the site because of direct contact, ingestion, and inhalation risks and because of the soil's impact on ground water. The remedial objectives for the soil are to eliminate potential exposure via ingestion, inhalation or direct contact with contaminants and by reducing the potential for the soil to act as a continued source for surface water and ground water contamination.

The contaminated shallow ground water was also determined to be a principal problem at the site because of the potential exposure of the public to the site contaminants and because of the threat of migration of contaminants to deeper zones of ground water. The deeper ground water zones are used for industrial, irrigation, and drinking water purposes. The remedial objective is to reduce the amount of contamination to human health-based standards in order to eliminate or minimize the risks associated with the contaminated shallow ground water.

VII. DESCRIPTION OF ALTERNATIVES

The descriptions of remedial alternatives are separated into those addressing soil contamination and those addressing ground water contamination.

A. Soil Contamination Remedial Alternatives

The alternatives for the soil remediation are the following:

- . Alternative A-1: Excavation and Offsite Disposal
- . Alternative A-2: In-Situ Vitrification
- . Alternative A-3: Solidification/Stabilization
- . Alternative A-4: Soil Washing
- . Alternative A-5: Partial In-Situ Vitrification and Capping
- . Alternative A-6: Partial Solidification/Stabilization and Capping
- . Alternative A-7: Partial Soil Washing and Capping
- . Alternative A-8: Capping
- . Alternative A-9: No Action
- . Alternative A-10: Limited Action

Common Elements. Except for the "No Action" and "Limited Action" alternatives, all of the alternatives that were considered for the site included a number of common elements. Each of the alternatives includes long-term operation and maintenance (O&M) activities for ground water treatment, which could take as long as 30 years to complete, and all the alternatives call for long-term monitoring. These monitoring activities will be conducted to

ensure that the remedy is effective. In addition, restrictions will be placed on the site to prohibit certain activities, such as soil removal or any type of commercial or residential activity on the site, and site access will be restricted.

All of the alternatives involve the removal of offsite soil and sediments with arsenic contamination greater than 30 ppm, EPA's offsite remediation level, and these offsite areas will be backfilled to previously existing grades. See Section V. Summary of Site Risks for a complete explanation of the remediation goals. Alternative A-1 proposes to dispose of the contaminated soils at an offsite landfill; all other alternatives involve onsite placement of the offsite soil and sediments. With all the alternatives, the onsite water supply wells and all of the monitoring wells not necessary for the remedial action or for the long-term O&M will be closed in accordance with regulations of the State of Texas. Two concrete slabs remain on the site. Soil alternatives A-1 through A-4 call for removing the slabs and disposing of them off site. Alternatives A-5 through A-8 call for removing the slabs, breaking them into smaller pieces, and placing them under the multi-layer cap that is to be constructed over the site. All costs and time required to implement all of the alternatives are estimates. Table 14 summarizes estimated costs and implementation times for all of the alternatives.

When remediating a site, there are applicable or relevant and appropriate requirements ("ARARs") that the remedy(s) must meet in order to be in compliance with Federal and State laws. Given that the arsenic found on the site exhibits characteristics of a substance that is regulated under RCRA, 40 CFR Subpart C, and that a type of arsenic (i.e., K031 - by-product salts generated in the production of MSMA and cacodylic acid) that is specifically listed and regulated under RCRA, 40 CFR Subpart D, was produced on the site, certain ARARs apply. If a waste leaches above 5.0 ppm of arsenic when analyzed using TCLP, it is considered a hazardous waste and is regulated under RCRA. Furthermore, if a RCRA regulated waste is treated, additional ARARs apply.

On June 1, 1990 a regulation identifying vitrification as the best demonstrated available treatment technology ("BDAT") for arsenic as a RCRA characteristic waste as well as a RCRA listed waste was published (55 Fed. Reg. 106 at 22556 to 22561). The effective date of this regulation was August 8, 1990. Associated with the BDAT is a concentration-based treatment standard of 5.6 ppm for K031 nonwastewaters, and the BDAT concentration-based treatment standard for arsenic as a characteristic (D004) nonwastewater is 5.0 ppm. When the soils treatment and replacement triggers placement (Soils Alternatives A-3, A-4, A-6, and A-7) or when offsite disposal of contaminated soil is involved which, too, triggers placement (Soil Alternative A-1) under RCRA's Land Disposal Restrictions ("Landban"), 40 CFR 268, the 5.6 ppm treatment standard for nonwastewaters is required per 40 CFR 268.9.

TABLE 14
SOIL REMEDIAL ALTERNATIVES COST ESTIMATES AND
IMPLEMENTATION TIMES
Crystal Chemical Company Site

ALTERNATIVE A-1					
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time	Total Present Worth
\$ 75,974,176	\$ 5,814	30 years	\$ 29,070	2.5 years	\$ 76,004,379
ALTERNATIVE A-2					
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time	Total Present Worth
\$ 76,602,296	\$ 5,814	30 years	\$ 174,420	7.75 years	\$ 76,709,543
ALTERNATIVE A-3					
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time	Total Present Worth
\$ 29,448,314	\$ 5,814	30 years	\$ 174,420	3 years	\$ 29,555,561
ALTERNATIVE A-4					
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time	Total Present Worth
\$121,403,333	\$ 5,814	30 years	\$ 174,420	6 years	\$121,510,580

TABLE 14 (continued)
SOIL REMEDIAL ALTERNATIVES COST ESTIMATES AND
IMPLEMENTATION TIMES
Crystal Chemical Company site

ALTERNATIVE A-5					
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time	Total Present Worth
\$ 13,585,282	\$ 9,816	30 years	\$294,480	3 years	\$ 13,766,352
ALTERNATIVE A-6					
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time	Total Present Worth
\$ 8,150,131	\$ 9,816	30 years	\$294,480	2.5 years	\$ 8,331,201
ALTERNATIVE A-7					
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time	Total Present Worth
\$ 19,317,774	\$9,816	30 years	\$294,480	3.75 years	\$ 19,498,844
ALTERNATIVE A-8					
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time	Total Present Worth
\$ 5,053,261	\$ 9,816	30 years	\$294,480	2.25 years	\$ 5,234,331

TABLE 14 (continued)
SOIL REMEDIAL ALTERNATIVES COST ESTIMATES AND
IMPLEMENTATION TIMES
Crystal Chemical Company Site

ALTERNATIVE A-9					
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time	Total Present Worth
\$ 0	\$ 0	0	\$ 0	0	\$ 0

ALTERNATIVE A-10					
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time	Total Present Worth
\$ 0	\$ 5,236	30 years	\$ 96,585	0	\$ 96,585

The treatment goal for those alternatives that do not trigger placement under RCRA is to reduce the amount of leachable arsenic after treatment to 5.0 ppm.

**Soil Alternative A-1:
EXCAVATION AND OFFSITE DISPOSAL**

This alternative calls for excavating all onsite and all offsite soils and sediments with arsenic contamination greater than 30 ppm. The estimated volume of soils contaminated with arsenic greater than 30 ppm is 156,000 cubic yards. These excavated soils would then be transported offsite for disposal in a landfill that is allowed to accept arsenic-contaminated soils. All excavated areas would be back-filled with soil to previously existing grades and the area would be revegetated. The total cost of this alternative is approximately \$76,004,379, and the estimated time required to implement this alternative would be 2.5 years.

Although this alternative reduces the risk at the site itself, it would require the removal of and disposal of soil that is contaminated at levels which may pose health or environmental risks. Therefore, this alternative may not be implementable due to Federal Landban regulations.

**Soil Alternative A-2:
IN-SITU VITRIFICATION**

This alternative calls for the excavation of offsite contaminated soils and sediments, placing these soils and sediments on the site, and the treatment of all arsenic-contaminated soils using the in-situ vitrification technology. The volume of soils estimated to require treatment with this alternative is 156,000 cubic yards. In-situ vitrification is a process which uses electricity to generate heat which will melt the contaminated soil. The equipment necessary to conduct this technology consists of four electrodes which are inserted into the contaminated soils and a mobile hood which is placed over the area undergoing treatment. The electrodes are placed into the soils 3.5 meters to 5.5 meters apart to form a square which defines the area to undergo treatment. This hood captures and collects any gases that may be formed or released during the treatment process. The off-gas treatment system cools, scrubs, and filters the gaseous effluents exhausted from the hood. A major element of the off-gas support system is a glycol cooling system. This system cools the scrub solution by extracting thermal energy that builds up in the off-gas treatment system. The heat is released to the atmosphere through an air-cooled heat exchanger. Any arsenic that is captured in the off-gas system is collected and placed in the next area of treatment. The process destroys many contaminants when the soil is heated and permanently bonds other contaminants into the glass-like material as it cools. The average

in-situ vitrification processing rate is 4.58 tons per hour. The glass-like material is expected to remain stable for thousands of years.

Soils from the Crystal Chemical site were actually treated using this process, and tests conducted on the glass-like material have shown that only a very small amount of arsenic is able to leach after treatment (see Table 15). The levels that do leach are below the treatment goal set for treatment technologies that do not trigger placement at the Crystal Chemical site, i.e., 5.0 ppm of arsenic. Therefore, this alternative satisfies the Federal environmental regulations that request that contamination be reduced in volume, toxicity, or ability to move in soil, air, and water. The cost of this alternative is approximately \$76,800,000 and would take approximately 7.75 years to implement.

EPA does not favor this alternative because it is not as cost-effective and is no more protective of human health than alternative A-5.

Soil Alternative A-3: SOLIDIFICATION/STABILIZATION

Solidification/stabilization is a process which mixes cement, lime, or other kinds of binding materials with contaminated soil in order to reduce the ability of the contaminants to leach out of the soil into the surrounding environment. The stabilization is accomplished through either chemical or physical immobilization of contaminants. A treatment rate of 1,000 cubic yards per day is possible. For this alternative, all offsite and onsite arsenic-contaminated soils and sediments would be excavated and then treated using the solidification/stabilization process. The site would be backfilled with the treated soil. The volume of offsite soils requiring excavation is estimated to be 55,000 cubic yards, and the total volume of soils requiring treatment with this alternative is estimated to be 156,000 cubic yards. The total cost of this alternative is approximately \$29,600,000 and it would take approximately 3 years to implement this remedy.

Solidification/stabilization has been used successfully many times on hazardous waste sites and does comply with the Federal environmental regulations that require that contaminants be treated. However, treatability tests conducted for the SFS on contaminated soil from the Crystal Chemical site treated using the solidification/stabilization process have shown that a high concentration of the arsenic continues to leach out of the soil after treatment (see Table 15). Given that this treatment technology triggers placement under RCRA, the levels that leach are above 5.6 ppm of arsenic ARAR for the Crystal Chemical site. Furthermore, this technology may significantly increase the volume of the contaminated soil that will need to be put back on to the

TABLE 15
SUMMARY OF BENCH SCALE TREATABILITY TESTING
Crystal Chemical Company Site

<u>Extraction Method</u>	<u>Before Treatment</u>	<u>After Treatment</u>
<u>ARSENIC LEVELS IN SOILS BEFORE AND AFTER ISV TREATMENT</u>		
Total Arsenic		
Inorganic mg/l	NA (2940)	NA (514)
Organic (mg/l)	NA (6210)	NA (<10.0)
EP Toxicity (mg/l)	250 (263)	#1 2.2 (0.48) #2 1.5
TCLP (mg/l)	214 (243)	#1 0.75 (1.10) #2 0.46

<u>ARSENIC LEVELS IN SOILS BEFORE AND AFTER SOLIDIFICATION/STABILIZATION TREATMENT</u>		
Total Arsenic (mg/l)	7880 (9150)	Mix A NA (2140) Mix Z NA (5640)
EP Toxicity (mg/l)	268 (263)	21.2 (20.9) 13.0 (68.0)
TCLP (mg/l)	NA (243)	50 (78.0) 109.5 (288.2)

<u>ARSENIC LEVELS IN SOILS BEFORE AND AFTER SOIL WASHING TREATMENT</u>		
Total Arsenic		
Inorganic (mg/l)	2940	811.0
Organic (mg/l)	6210	<10.0

TABLE 15 (continued)
SUMMARY OF BENCH SCALE TREATABILITY TESTING
Crystal Chemical Company Site

<u>Extraction Method</u>		<u>Before Treatment</u>	<u>After Treatment</u>
EP Toxicity	Inorganic (mg/l)	263	7.8
	Organic (mg/l)	-	<0.1
TCLP	Inorganic (mg/l)	243	22.5
	Organic (mg/l)	-	<0.1

Note: These results are from samples sent to AES. Controls for Environmental Pollution completed the analysis of these samples.

NA	-	Not Analyzed
()	-	Data from sample sent to AES. Analysis performed by Controls for Environmental Pollution
EP	-	Extraction Procedure
TCLP	-	Toxicity Characteristics Leaching Procedure

site. EPA does not favor this alternative for these reasons, and because it may not comply with Superfund mandates (i.e., reduction of toxicity, mobility, or volume) as well as EPA's selected remedy (A-5).

**Soil Alternative A-4:
SOIL WASHING**

Soil Washing is a process which removes contaminants from soil by mixing the excavated contaminated soils with a liquid. During the mixing process, the contaminants are washed from the soil. The liquid containing the contaminants is then drained from the soil and is treated using conventional wastewater treatment systems or disposed in a landfill which is allowed to accept arsenic contaminated liquids. The soil processing rate for this technology is approximately 200 cubic yards per day. This alternative calls for the excavation of all offsite and onsite arsenic-contaminated soils and sediments. The volume of soils estimated to require treatment with this alternative is 156,000 cubic yards. After the washing process, the site would be backfilled with the washed soil. This alternative would take approximately 6 years to implement and would cost an estimated \$121,510,580.

This alternative does involve treatment and does reduce the toxicity, which is the degree of danger posed by the contaminant to humans or animals, of the contaminants. However, the disposal of the liquid containing the contaminants may be difficult and may require pretreatment because of state and Federal environmental regulations prohibiting land disposal of certain contaminants. Additionally, tests conducted on contaminated soils from the Crystal Chemical site treated using the soil washing process have shown that high concentrations of arsenic continue to leach out of the soil after treatment (see Table 15). Given that this treatment technology triggers placement under RCRA, the levels that leach are above the 5.6 ppm of arsenic ARAR for the Crystal Chemical site. Therefore, EPA does not favor this alternative because it is not as protective of public health and the environment as EPA's selected alternative (A-5).

**Soil Alternative A-5:
PARTIAL IN-SITU VITRIFICATION AND CAPPING**

This alternative is similar to Soil Alternative A-2, however, only those soils with arsenic contamination greater than 300 ppm would be treated using the in-situ vitrification process. The volume of soils estimated to require treatment is 16,500 cubic yards. A multi-layer cap consisting of clay, plastic, sand, topsoil, and vegetation would be constructed over the entire site after the soils have been treated. This cap acts as a barrier that restricts the flow of water through the soils which are not subjected to water table conditions and prevents the release of the soil and

residual contaminants into the air. The alternative will take approximately 3 years to implement and will cost an estimated \$13,766,352.

Although only those soils contaminated with arsenic greater than 300 ppm would be treated using this alternative, calculations have shown that approximately 95% of all the arsenic contamination on the site would be treated with this alternative. That is to say that, 95% of the arsenic on the site is found in areas where the arsenic levels are above 300 ppm. This alternative not only complies with Federal environmental regulations calling for treatment, but also reduces the toxicity and volume of the contaminated soils and the ability of the contaminants to leach into the environment. EPA, therefore, favors this technology.

Soil Alternative A-6:

PARTIAL SOLIDIFICATION/STABILIZATION AND CAPPING

This alternative is similar to Soil Alternative A-3, however, only those soils with arsenic contamination greater than 300 ppm would be treated using the solidification/stabilization process. The volume of soils requiring treatment is estimated to be 16,500 cubic yards. A multi-layer cap consisting of clay, plastic, sand, topsoil, and vegetation would be constructed over the entire site after the soils had been treated. The cap acts as a barrier that restricts the flow of water through the soils which are not subjected to water table conditions and prevents the release of soil and residual contaminants into the air. This alternative would cost approximately \$8,331,201 and would take an estimated 2.5 years to implement.

As in the discussion of Soil Alternative A-3, this alternative has certain drawbacks that outweigh its effectiveness. This alternative would decrease site risk by reducing the mobility of contaminants present in the soil, is implementable, and it would comply with Federal and State environmental laws. However, there would be no reduction in the toxicity or volume of contaminants, therefore, this alternative is not as protective of public health and the environment as EPA's selected remedy (A-5).

Alternative A-7:

PARTIAL SOIL WASHING AND CAPPING

This alternative is similar to Soil Alternative A-4, however, only those soils with arsenic contamination greater than 300 ppm would be treated using the soil washing process. The volume estimated to require treatment is 16,500 yards. A multi-layer cap consisting of clay, plastic, sand, topsoil, and vegetation would be constructed over the entire site after the soils had been treated. The cap acts as a barrier that restricts the flow water through

soils which are not subjected to water table conditions and prevents the release of soil and residual contaminants into the air. This alternative would cost approximately \$19,498,844 and would take an estimated 3.75 years to implement.

As with Soil Alternative A-4, there are certain drawbacks to this alternative, the most important being its ineffectiveness in treating the soils and the disposal of the liquid containing the contaminants. Therefore, with the possibility of capacity problems in offsite disposal areas coupled with other short-comings of this approach, EPA does not favor this alternative.

**Alternative A-8:
CAPPING**

The capping alternative calls for all soils and sediments from offsite that have arsenic contamination greater than 30 ppm to be brought back on to the site. Then a cap consisting of clay, plastic, gravel, topsoil, and vegetation would be constructed over the entire site. No treatment of the soils would be done before the site was capped.

Although the mobility of the contaminants in the soil would be reduced if a cap were constructed over the site, neither the volume of the contaminated soils nor the toxicity of the contaminants would be reduced. Additionally, the Federal environmental regulations prefer that contaminants be treated instead of untouched under a cap. This alternative is not as protective of public health and the environment as EPA's selected alternative (A-5).

**Alternative A-9:
NO ACTION**

The Superfund program requires that a no action alternative be considered at every site as a basis of comparison when evaluating other alternatives. No action assumes that nothing would be done to restrict site access, monitor offsite contaminated soil, or to maintain the existing temporary cap. Therefore, there would be no costs associated with this alternative. This alternative is not favored by EPA because it would not decrease the toxicity, mobility, or volume of contaminants or reduce public health or environmental risks.

**Alternative A-10:
LIMITED ACTION**

This alternative involves site access and land use restrictions that include prohibiting activities such as soil removal or any

type of commercial or residential activity on the site. The costs associated with this alternative are approximately \$96,585, and the restrictions would be enforced in perpetuity.

This alternative would somewhat reduce risks to public health and the environment by restricting site use and access. However, it would not prevent continued ground water contamination. EPA does not favor this alternative because it would not comply with Federal and State environmental laws, provide long-term protection to public health or the environment, or reduce the toxicity, mobility, or volume of contaminants.

B. Ground Water Remedial Alternatives

The alternatives for the ground water cleanup are the following:

- . Alternative B-1a: Extraction and Discharge to a Publicly Owned Treatment Works ("POTW")
- . Alternative B-1b: Extraction, Treatment, and Discharge to POTW, to surface water, or reinject
- . Alternative B-2: Slurry Wall
- . Alternative B-3: No Action
- . Alternative B-4: Limited Action

Common Elements. Except for the "No Action" and "Limited Action" alternatives, all of the alternatives that were considered for the site included a number of common elements. Each of the alternatives includes long-term operation and maintenance (O&M) activities for ground water extraction, treatment or monitoring, with the more conservative time-frame for the O&M being 30 years. In addition, site access and land use restrictions prohibiting soil removal or any commercial or residential activity will be placed on the site. With all the alternatives, the onsite water supply wells and all of the monitoring wells not necessary for the remedial action or for the long-term O&M will be closed in accordance with regulations of the State of Texas. With alternatives B-1a and B-1b, a series of ground water recovery wells will be installed. For alternatives B-1a and B-1b the O&M will include maintenance of the ground water extraction system that may operate 24 hours per day. In addition to the extraction system for alternative B-1b, a treatment system that may operate eight hours per day must be maintained. Storage of water after extraction for alternative B-1a and B-1b or after extraction and treatment for alternative B-1b may be necessary prior to discharge. Ground water monitoring activities in the area around the site will be maintained to ensure the effectiveness of the remedy for the B-1 alternatives and for alternative B-2 for 30 years. All costs and time required to implement all of the alternatives are estimates. Table 16 summarizes estimated costs and implementation times for all of the alternatives.

TABLE 16
GROUND WATER REMEDIAL ALTERNATIVES
COST ESTIMATES AND
IMPLEMENTATION TIMES
Crystal Chemical Company Site

ALTERNATIVE B-1a				
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time
\$ 596,841	\$12,033	30 years	\$ 360,989	30 years
				Total Present Worth \$ 957,830

ALTERNATIVE B-1b				
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time
\$ 933,816	\$130,263	30 years	\$ 3,907,897	30 years
				Total Present Worth \$4,824,388

ALTERNATIVE B-2				
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time
\$1,421,421	\$310,605	30 years	\$ 9,318,150	1.25 years
				Total Present Worth \$6,196,038

TABLE 16 (continued)
GROUND WATER REMEDIAL ALTERNATIVES
COST ESTIMATES AND
IMPLEMENTATION TIMES
Crystal Chemical Company Site

ALTERNATIVE B-3					
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time	Total Present Worth
\$ 0	\$ 0	0	\$ 0	0	\$ 0
ALTERNATIVE B-4					
Capital Cost	Annual O&M	Duration	Total O&M Cost	Implementation Time	Total Present Worth
\$ 0	\$ 4,002	30 years	\$ 120,060	30 years	\$ 73,822

For alternatives B-1a and B-1b the goal of the remedial action is to restore the ground water to a useable state, i.e., removing the arsenic to the MCL throughout the area of attainment. The extent of ground water contamination is illustrated on Figure 13. Based on information obtained during the SI, the original FS, the SFS, and the analysis of all four remedial alternatives, EPA believes that this goal is attainable. Contamination of ground water by arsenic may be especially persistent in the immediate vicinity of the contaminants' source, where concentrations are relatively high. The ability to achieve cleanup goals throughout the area of attainment cannot be determined until the extraction system has been implemented, modified as necessary, and the plume response monitored over time. If the selected remedy cannot meet the remediation goal of 0.05 ppm, the MCL for arsenic and an ARAR for the Crystal Chemical site throughout the area of attainment during the implementation, contingency measures and goals may replace the selected remedy and goals. These measures will be protective of human health and the environment, and are technically practicable under the corresponding circumstances.

To determine if contingency measures are necessary, the ground water extraction system for alternatives B-1a and B-1b will be closely monitored for an estimated period of 10 years. After 10 years, the system's performance will be carefully evaluated. If it appears that the system cannot attain the remedial goals set for the site, contingency measures including one, some or all of the activities below will be implemented:

- a) discontinuing operation of extraction wells in areas where cleanup goals have been attained;
- b) alternating pumping at wells to eliminate stagnation points;
- c) establishing an Alternate Concentration Limit ("ACL") for arsenic throughout the area of attainment provided compliance with CERCLA Section 121(d)(2)(B)(ii) can be demonstrated;
- d) waiving the ground water ARAR for those portions of the aquifer based on the technical impracticability of achieving further contaminant reduction;
- e) implementing low level pumping as a long-term gradient control or construction of a containment measure such as a slurry wall; and/or,
- f) implementing additional source control treatment to further reduce arsenic migration to ground water.

Ground Water Alternative B-1a:

EXTRACTION AND DISCHARGE TO A PUBLICLY OWNED TREATMENT WORKS (POTW)

This alternative calls for pumping ground water from the two contaminated water-bearing zones and discharging this water directly to the POTW. A ground water monitoring system utilizing existing monitoring wells and area supply wells would be maintained and restrictions prohibiting construction on the site would be enforced. The volume of contaminated water requiring extraction is estimated to be 3,000,000 gallons. The estimated time to implement this alternative and to remove the contaminated water down to the MCL for arsenic (0.05 ppm) is 30 years, and the cost associated with this alternative is \$957,830.

This alternative would reduce site risk by substantially decreasing ground water contamination present in the area surrounding the site. However, if the POTW does not accept the contaminated ground water, this alternative may not be feasible. In fact, the Houston Department of Public Works ("HDPW") has indicated that the allowable arsenic limits for discharge to a POTW in the City of Houston and surrounding communities are 0.2 ppm (composite sample) and 0.3 ppm (grab sample). Given that ground water contamination at the Crystal Chemical site ranges from 0 to 400 ppm, discharge to a POTW without pretreatment may not be feasible. Additionally, this alternative does not meet the Superfund preference for treatment of contaminants. For these reasons EPA does not favor this alternative.

Alternative B-1b:

EXTRACTION, TREATMENT, AND DISCHARGE TO POTW, TO AN AREA SURFACE WATER, OR REINJECT

Like alternative B-1a, the estimated 3,000,000 gallons of contaminated ground water would be pumped from the two water-bearing zones on the Crystal Chemical site, however, with this alternative the ground water would be treated to remove the arsenic prior to discharge. The treatment of contaminated ground water would consist of ferric hydroxide precipitation and flocculation, followed by clarification, filtration, and final polishing of the water with ion exchange. Ion exchange treatment is a process where contaminants are removed from water through the exchange of nontoxic materials (ions) from an ion exchange material. The toxic materials are retained in the exchange material. A treatability study to investigate the precise requirements of the treatment system necessary to remove the arsenic contamination will have to be conducted. Once treated, the water would be discharged either to a POTW or into an area surface water (i.e., the Harris County Flood Control Channel), or reinjected into the ground. If the water is to be reinjected, injection wells will need to be installed. The advantage to reinjection is that the contaminants are flushed out, therefore possibly accelerating the removal of

arsenic from the water-bearing zone and shortening the extraction time required to meet the remediation goal. Additionally, an onsite pilot study should be conducted to identify number of wells, well placement for the most effective extraction method and to fully investigate the reinjection option. The extraction and treatment would continue until MCLs (0.05 ppm) for arsenic are met throughout the area of attainment. The contaminants that would be concentrated through the treatment process will need disposal in a landfill approved to handle arsenic and may require treatment prior to disposal. The time required to implement this alternative is estimated to take 30 years and cost approximately \$4,824,388.

Although this alternative provides for no net reduction of toxicity or mobility of the contaminants, it does reduce site risks by substantially decreasing the volume of contaminated ground water present on and in the vicinity of the site. It would comply with Federal and State environmental laws and the Superfund preference for treatment of contaminants even though the arsenic will be concentrated in a sludge. Although the sludge may require offsite treatment prior to disposal due to the fact that the untreated sludge may exhibit characteristics that would disallow its disposal given the RCRA Landban ARAR, EPA favors this technology.

Ground Water Alternative B-2: SLURRY WALL

This alternative calls for construction of a slurry wall around the ground water contamination. A slurry wall is a trench filled with materials that limit the flow of ground water through the area surrounded by the trench. The objective of installing a slurry wall is to minimize the lateral migration of contamination in the two water-bearing zones. The low permeability of the naturally occurring clay layer separating the 35-foot and 100-foot water-bearing zones minimizes any vertical movement of ground water. As part of this alternative, a pressure relief system would have to be installed within the containment areas to prevent the rise of ground water levels. Ground water removed from the pressure relief wells would be transported offsite for treatment. This alternative would cost approximately \$6,196,038 and take 1.25 years to implement.

A slurry wall would reduce site risk by minimizing further migration of contaminants. This alternative, however, would not reduce the toxicity or volume of contaminants present in ground water, and it would not meet the Superfund preference for treatment of contaminants. Additionally, it may be difficult to locate a facility willing to take the contaminated ground water recovered from the pressure relief system. This alternative would be the most expensive ground water alternative to implement, and the additional costs do not increase the overall protectiveness of the alternative. Therefore, EPA does not favor this alternative.

**Ground Water Alternative B-3
NO ACTION**

This alternative assumes that no offsite or onsite monitoring would be performed. No action would be taken to prevent further migration of contaminated ground water at the site, and no costs are associated with the alternative. With this alternative, future use of contaminated ground water offsite could result in unacceptable public health risks. This alternative would not reduce mobility, toxicity, or volume of contaminants and, therefore, is not favored by EPA.

**Ground Water Alternative B-4
LIMITED ACTION**

This alternative calls for monitoring the existing monitoring wells and ground water wells in the vicinity of the site. Additionally, restrictions would be placed on the site to prohibit activities such as soil removal or any type of commercial or residential activity. The costs associated with this alternative are estimated to be \$73,822, and the situation would be monitored for 30 years.

This alternative reduces risk by restricting site use and access. However, contaminants would continue to adversely affect the surrounding environment. This alternative would not comply with Federal and State environmental laws, therefore, it is not favored by EPA.

VIII. SUMMARY OF COMPARATIVE ANALYSIS OF ALTERNATIVES

The nine (9) criteria used in evaluating all of the alternatives identified in the SFS are as follows:

- Overall protection of human health and the environment,
- Compliance with applicable or relevant and appropriate requirements,
- Long-term effectiveness and permanence,
- Reduction of toxicity, mobility, or volume through treatment,
- Short-term effectiveness,
- Implementability,
- Cost,
- State/support agency acceptance, and
- Community acceptance.

Explanation of Evaluation Criteria

- . Overall Protection of Human Health and Environment addresses whether or not a remedy provides adequate protection and describes how risks posed through each pathway are eliminated,

reduced, or controlled through treatment, engineering controls or institutional controls.

- . Compliance with ARARs addresses whether or not a remedy will meet all of the applicable or relevant and appropriate requirements of other Federal and State environmental statutes and/or provide grounds for invoking a waiver.
- . Long-term effectiveness and permanence refers to the magnitude of residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time once cleanup goals have been met.
- . Reduction of toxicity, mobility, or volume through treatment is the anticipated performance of the treatment technologies that may be employed in a remedy.
- . Short-term effectiveness refers to the speed with which the remedy achieves protection, as well as the remedy's potential to create adverse impact on human health and the environment that may result during the construction and implementation period.
- . Implementability is the technical and administrative feasibility of a remedy, including the availability of materials and services needed to implement the chosen solution.
- . Cost includes capital and operation and maintenance costs.
- . State Acceptance indicates whether, based on its review of the RI/FS and Proposed Plan, the State concurs with, opposes, or has no comment on the preferred alternative.
- . Community Acceptance will be assessed in the Record of Decision following a review of the public comments received on the RI/FS report and the Proposed Plan.

A symbolic ranking of the comparative analysis for the soil remedial alternatives and for the ground water alternatives are included (see Tables 17 and 18). The symbolic ranking is based on the narrative analysis that follows.

A. Analysis of Soil Remedial Alternatives

Overall Protection. All of the alternatives, with the exception of the "No Action" and "Limited Action" alternatives, would provide adequate protection of human health and the environment by eliminating, reducing, or controlling risk through treatment, capping, or deed and land use restrictions. The preferred treatment technology is in-situ vitrification because it was the only technology that significantly reduced the toxicity and

TABLE 17
COMPARATIVE ANALYSIS FOR SOIL REMEDIAL ALTERNATIVES
Crystal Chemical Company Site

CRITERION	ALTERNATIVE
Overall Protection of Human Health and the Environment	<u>Most</u>
	A-8
	A-1
	A-2 A-5
	A-3 A-6
	A-4 A-7
	<u>Least</u>
Compliance with ARARs	<u>Most</u>
	A-2 A-5
	A-8
	A-3 A-4 A-6 A-7
	A-1
	<u>Least</u>
Long-term Effectiveness and Permanence	<u>Most</u>
	A-2
	A-4
	A-3
	A-1
	A-5
	A-7
	A-6
	A-8
	<u>Least</u>
Reduction of Toxicity, Mobility, or Volume through Treatment	<u>Most</u>
	A-2
	A-4
	A-3
	A-5
	A-7
	A-6
	A-1
	A-8
	<u>Least</u>

TABLE 17 (continued)
COMPARATIVE ANALYSIS FOR SOIL REMEDIAL ALTERNATIVES
Crystal Chemical Company Site

Short-term Effectiveness	<u>Most</u> A-8 A-6 A-7 A-1 A-3 A-4 A-5 A-2 <u>Least</u>
Implementability	<u>Most</u> A-3 A-4 A-5 A-6 A-7 A-2 A-1 A-8 <u>Least</u>
Cost	<u>Least Expensive</u> A-8 A-6 A-5 A-7 A-3 A-1 A-2 A-4 <u>Most Expensive</u>

TABLE 18
COMPARATIVE ANALYSIS
GROUND WATER ALTERNATIVES
Crystal Chemical Company Site

CRITERION	ALTERNATIVE
Overall Protection of Human Health and the Environment	<u>Most</u> B-1b B-1a B-2 <u>Least</u>
Compliance with ARARs	<u>Most</u> B-1b B-1a B-2 <u>Least</u>
Long-term Effectiveness and Permanence	<u>Most</u> B-1b B-1a B-2 <u>Least</u>
Reduction of Toxicity, Mobility, or Volume through Treatment	<u>Most</u> B-1b B-1a B-2 <u>Least</u>

TABLE 18 (continued)
COMPARATIVE ANALYSIS
GROUND WATER ALTERNATIVES
Crystal Chemical Company Site

Short-term Effectiveness	<u>Most</u>
	B-1a
	B-1b
	B-2
	<u>Least</u>

Implementability	<u>Most</u>
	B-1b
	B-1a
	B-2
	<u>Least</u>

Cost	<u>Least Expensive</u>
	B-1a
	B-1b
	B-2
	<u>Most Expensive</u>

mobility of the arsenic contamination during the treatability testing conducted on soils from the Crystal Chemical site, i.e., after the treatment the leachability of the arsenic was reduced to below 5.0 ppm. Additionally, the treatment technology yielded a 20% to 30% volume reduction. The technology provides for a long-term and permanent solution to the contamination problem at the Crystal Chemical site. The reason for selecting the partial in-situ vitrification and capping alternative over in-situ vitrification of the entire site is that, although only those soils contaminated with arsenic greater than 300 ppm would be treated using this partial treatment remedy, calculations have shown that approximately 95% of all the arsenic contamination on the site would be treated with this alternative. That is to say that 95% of the arsenic on the site is found in areas where the arsenic levels are above 300 ppm.

Therefore, the highest level of contaminants (95% of the arsenic) are captured or destroyed, the offsite soil and sediments that are contaminated with arsenic greater than 30 ppm is excavated and placed back on the site, and a cap is constructed over all of the treated and excavated materials. The cap will eliminate the risks associated with direct contact with the residual contamination, will act as a barrier that restricts the flow of water through the soils which are not subjected to water table conditions, and will prevent the release of soil and contaminants into the air. The partial in-situ vitrification alternative addresses the risks to public health and welfare and the environment while being cost effective.

Because the "No Action" and "Limited Action" alternatives are not protective of human health and the environment, they will not be discussed any further.

Compliance with Applicable or Relevant and Appropriate Requirements ("ARARs"). ARARs are the Federal and State requirements that a selected remedy must meet. Given that the arsenic found on the site exhibits characteristics of a substance that is regulated under RCRA, 40 CFR Subpart C, and that a type of arsenic (i.e., K031 - by-product salts generated in the production of MSMA and cacodylic acid) that is specifically listed and regulated under RCRA, 40 CFR Subpart D, was produced on the site, certain ARARs apply. If a waste leaches above 5.0 ppm of arsenic when analyzed using TCLP, it is considered a hazardous waste and is regulated under RCRA. Furthermore, if a RCRA regulated waste is treated, additional ARARs apply.

On June 1, 1990 a regulation identifying vitrification as the best demonstrated available treatment technology ("BDAT") for arsenic as a RCRA characteristic waste as well as a RCRA listed waste was published (55 Fed. Reg. 106 at 22556 to 22561). The effective date of this regulation was August 8, 1990. Associated with the BDAT

is a concentration-based treatment standard of 5.6 ppm for K031 nonwastewaters, and the BDAT concentration-based treatment standard for arsenic as a characteristic (D004) nonwastewater is 5.0 ppm. When the soils treatment and replacement triggers placement (Soils Alternatives A-3, A-4, A-6, and A-7) or when offsite disposal of contaminated soil is involved which, too, triggers placement (Soil Alternative A-1) under RCRA's Land Disposal Restrictions ("Landban"), 40 CFR 268, the 5.6 ppm treatment standard for nonwastewaters is required per 40 CFR 268.9.

Alternatives A-1, A-3, A-4, A-6 and A-7 may fail to meet two federal ARARs. The first ARAR regards closure requirements for surface impoundments containing materials that migrate out of soil above levels acceptable to EPA (i.e., TCLP level of 5.6 ppm for arsenic). This ARAR is relevant and appropriate because the four evaporation ponds that existed on the site during Crystal Chemical Company's operation were not closed per the RCRA regulations during the EPA Emergency Removal Actions conducted on site. The second involves performance standards for redeposited, treated soil regulated under the Landban restrictions. The in-situ vitrification technology and the two alternatives that use this technology, A-2 and A-5, will meet or exceed the ARARs and remedial action goals for the Crystal Chemical site.

Long-term Effectiveness and Permanence. The in-situ vitrification technology (alternatives A-2 and A-5) provides a permanent reduction in the volume, mobility, and the toxicity of the soil contaminated with arsenic. In the case of partial in-situ vitrification (A-5), the multi-layer cap would provide protection from direct contact with the remaining contaminants on site and prevent the release of soil and contaminants into the air. Additionally, the vitrification with the cap will restrict the flow of water through the soil containing the remaining 5% arsenic, thus minimizing the ability of the arsenic to migrate into the ground water.

Alternative A-1 would eliminate the onsite and offsite risks of direct contact and the continued release of contaminants into the air and ground water, but offsite disposal of the contaminated soil without treatment is not possible due to Landban restriction.

Alternative A-2 would provide long-term protection of human health and the environment by vitrifying all soil above the health standard. During bench scale treatability tests using actual contaminated soils from the site, Alternatives A-3 and A-4 failed to demonstrate that these treatment techniques will result in an acceptable decrease (i.e., 5.6 ppm) in the amount of arsenic that is able to leach out of the treated soil (see Table 15). Therefore, Alternatives A-3 and A-4 are not as effective therefore not as permanent as the alternatives A-2 and A-5. However, the addition of a multi-layer cap to these treatment methods

(Alternatives A-6 and A-7) would reduce the ability of contaminants to leach out of the treated soils by preventing water from flowing through the soils therefore increasing its effectiveness. The cap in these alternatives would also restrict direct contact with the treated soils as well as the untreated soils and reduce dust.

Alternative A-8 involves excavation of contaminated offsite soil and capping all contaminated soils without performing any treatment. This capping provides long-term reductions in the amount of water that otherwise would pass through the contaminated soil and would continue to carry the contaminants into surrounding soils and ground water. Although the direct contact risk would be eliminated with this alternative, because there is no treatment of the contaminants involved, this alternative is only as permanent as the cap.

Reduction of Toxicity, Mobility, or Volume of the Contaminants Through Treatment. Three methods of treatment are proposed, alone and in conjunction with capping. Alternatives A-2 and A-5 involve treatment by in-situ vitrification, which destroys many contaminants and permanently bonds other contaminants. This technique was successful in the site's treatability study in significantly reducing arsenic mobility to below acceptable (i.e., TCLP level of 5.0 ppm for arsenic as a RCRA regulated characteristic waste) concentrations after treatment (see Table 15). The technique also yields a 20% to 30% volume reduction.

Alternatives A-3 and A-6 involve treatment by solidification/stabilization which physically or chemically bonds contaminants. The site's treatability study produced a stabilized mixture with reduced arsenic mobility, but the mixture continued to leach arsenic greater than 5.6 ppm of arsenic after treatment (see Table 15). Also, this treatment process increases soil volume after treatment by approximately 10% to 30%.

Alternatives A-4 and A-7 involve treatment by soil washing which concentrates the contaminants into the wash liquid. The site's treatability study produced a washed soil with reduced arsenic. However, the mixture still allowed migration of arsenic greater than 5.6 ppm (see Table 15).

Given that alternatives A-1 and A-8 do not involve treatment, they do not satisfy this criteria.

Short-term Effectiveness. Alternative A-8 would contain the contaminated soil within an estimated 2.25 years, with a potential risk to the community as a result of fugitive dust emissions during excavation and construction. Two alternatives, A-1 and A-6, could be implemented in 2.5 years. Alternative A-1 involves some risks to the community related to dust production and transportation

accidents. Alternative A-6 also includes the risk of dust production during excavation and treatment of the soil.

Alternative A-5 would be implemented in only a slightly longer period, approximately 3 years. With this alternative, community protection is easily accomplished. Air emissions produced by the vitrification technology will be controlled by a gas collection system over the area being treated. Dust control measures may be required during the excavation and transfer of offsite soil that are to be brought back on site.

Alternative A-2 would take an estimated 7.75 years to implement. It involves the same potential risks to the community as Alternative A-5. Alternative A-7 would take 3.75 years to implement. It involves the risk of dust production during soil excavation and treatment.

The short-term risks for all alternatives involve dust emission due to excavation of offsite soils contaminated with arsenic in levels greater than 30 ppm. Additionally, Alternatives A-3, A-4, A-6, and A-7 would involve excavating onsite contaminated soils prior to their treatment. Alternative A-1 would also involve the onsite excavation of soils prior to offsite disposal. Alternatives A-5 and A-2 do not require any excavation of onsite contaminated soils, however, gases may be formed during the treatment process. The air emissions formed during the vitrification will be controlled by a gas collection system over the area being treated. With all these alternatives, dust suppression measures and air monitoring would take place to reduce the potential air emission problems. **Implementability.** Alternative A-1 calls for all contaminated soils both offsite and onsite to be excavated and disposed offsite. Federal regulations restricting offsite disposal of certain wastes may preclude this alternative from being implementable.

Alternative A-2 and A-5 have some implementability limitations. The number of commercial vendors that can perform the technology are limited, and specialized workers are required. Also, once a soil mass is vitrified to a certain depth, it is difficult to perform additional vitrification.

Alternatives A-3 and A-4 (solidification/stabilization technology) are technically easier to implement than alternatives A-6 and A-7 (soil washing technology) and all are technically easier to implement than the alternatives using the in-situ vitrification technology. However, administratively, the in-situ vitrification technology is easier to implement. The results of treatability studies have indicated that the in-situ vitrification technology is the most successful in reducing the amount of leachable arsenic in the Crystal Chemical soils after treatment.

Cost. The cost of alternative A-5 is \$13,766,352. The lowest-cost alternative is Alternative A-8 at \$5,234,331. The highest-cost alternative is Alternative A-4 at \$121,510,580.

B. Analysis of Ground Water Remedial Alternatives

Overall Protection. Overall protection of human health and the environment is provided by all of the alternatives, with the exception of the No Action and Limited Action alternatives. Alternative B-1b provides added protection because of pretreatment of ground water prior to discharging.

The No Action and Limited Action alternatives are not protective of human health and the environment, therefore, they will not be discussed further in this analysis.

Compliance with Applicable or Relevant and Appropriate Requirements ("ARARs"). ARARs are the Federal and State requirements that a selected remedy must meet. All of the ARARs for the extraction, treatment, and discharge to a POTW or the Harris County Flood Control Channel, or reinjection can be met. Alternatives B-1a and B-2 do not meet all of the ARARs because the alternatives either do not call for treatment of the contaminated ground water to meet the 0.05 ppm arsenic ARAR, or they do not include treatment prior to discharge.

Alternative B-1b calls for the treatment of the contaminated ground water, and the arsenic after treatment will be concentrated in a sludge. The sludge may exhibit characteristics of a waste regulated under RCRA, therefore, applicable RCRA requirements for the handling of the sludge (40 CFR 262 and 264) and for possible offsite treatment prior to disposal due to Landban (40 CFR 268) will be applied. Additionally, if reinjection of the treated ground water is chosen for B-1b, an ARAR detailing certain reinjections requirements may be relevant and appropriate (40 CFR 144) to the Crystal Chemical site.

Short-term Effectiveness. Precautions will be taken to eliminate any risk to the public during the construction of the extraction wells that will be used to pump the ground water or during the construction of the slurry wall. Other risks associated with Alternative B-1b may come from the arsenic contaminated sludge that will be generated during treatment. Furthermore, the sludge may require offsite treatment prior to disposal due to the fact that the untreated sludge may exhibit characteristics that would disallow its disposal given land disposal restrictions. The actual time to pump the ground water to a level that the arsenic contamination is less than 0.05 parts ppm (the MCL for arsenic) throughout the area of attainment may take up to 30 years.

Long-term Effectiveness and Permanence. Alternatives B-1a and B-1b call for the removal of arsenic down to 0.05 ppm in the ground water. The risk from ingestion of or direct contact with the contaminated ground water will be all but eliminated, therefore, these alternatives are very effective in the long-term and are considered permanent. With Alternative B-2, unless deed and site access restrictions are enforced, the risk to human health will be the same as if nothing were done. Additionally, the slurry wall cannot be considered a permanent remedy since no ground water treatment will be effected. Although the actual time to pump the ground water down to the 0.05 ppm of arsenic level may take up to 30 years, the adequacy and reliability of the pump and treat technologies have been well proven.

Reduction of Toxicity, Mobility, or Volume of the Contaminants through Treatment. Alternative B-1a would result in the reduction of volume of contaminants on the site but calls for discharging the contaminated water to a POTW. Alternative B-1b provides more control over the removal of arsenic through pretreatment and a reduction in the volume of contaminated ground water, however, this alternative provides for no net reduction of toxicity or mobility. The arsenic with this alternative is concentrated in the sludge generated from the ground water treatment, and this sludge may require treatment prior to its ultimate offsite disposal.

Implementability. If the POTW does not accept the contaminated ground water, alternative B-1a may not be implementable. In fact, the Houston Department of Public Works has indicated that the allowable arsenic limits for discharge to a POTW in the City of Houston and surrounding communities are 0.2 ppm (composite sample) and 0.3 ppm (grab sample). Therefore, it appears that the contaminated ground water from the Crystal Chemical site must receive some form of pretreatment prior to discharge to a POTW, like with alternative B-1b.

Cost. The cost of the preferred alternative is \$4,824,388. The most costly alternative is Alternative B-2 estimated to cost \$6,196,038, and the lowest cost alternative is B-1a at a cost of \$957,830.

State Acceptance. The State of Texas, through the Texas Water Commission, concurs with the remedy selected by EPA (Attachment 2).

Community Acceptance. The community has voiced limited support for the partial in-situ vitrification and capping remedy for the soils and for the extraction, treatment, and discharge remedy for the ground water.

IX. SELECTED REMEDY

Based on consideration of the requirements of CERCLA, the detailed analysis of the alternatives, and public comments, EPA has determined that soil alternative A-5 (Partial in-situ Vitrification and Capping), and that ground water alternative B-1b (Extraction, Treatment, and Discharge to a POTW, the Harris County Flood Control Channel, or reinjection) are the most appropriate remedies for the Crystal Chemical Company site in Houston, Texas.

The remediation goals selected for both arsenic-contaminated soils and ground water are protective of human health and welfare and the environment. They were selected to eliminate or reduce risks associated with potential exposure to the contaminants via ingestion or direct contact with soil, sediments and surface water; ingestion of contaminated shallow ground water and contaminated fish; and inhalation of wind dispersed dust. The goals for the soil contamination call for the removal of offsite soils and sediments to a concentration of 30 ppm for arsenic, which represents a one in one hundred thousand (10^{-5}) excess cancer risk level. Since the average background concentration of arsenic in western soils (6.1 ppm) exists at a level in excess of EPA's standard point of departure (one in one million cancer risk - at a 3 ppm concentration of arsenic), 30 ppm was determined to represent a safe health-based action level. These soils will be placed back on to the Crystal Chemical site. Additionally, the selected remedy requires that all heavily contaminated areas onsite with soil-arsenic concentrations in excess of 300 ppm, or a lower concentration level if determined to be necessary and feasible based on the evaluation defining the relationship between contaminated soils and ground water to be conducted during the remedial design, will be treated using in-situ vitrification. Such an approach will effectively treat 95% of the arsenic found on the site. The treatment goal for the soils is to reduce the amount of arsenic that is able to leach to 5.0 ppm of arsenic after treatment when analyzed using the Toxicity Characteristic Leaching Procedure ("TCLP"), 40 CFR 261.25. The entire site will be covered with a multi-layer cap after the treatment has been completed. The average concentration of arsenic found in these areas (not subject to treatment) is 60 ppm. Once the entire remedy is complete, the resulting cancer risk will be reduced to less than one in one million (at or near the original background conditions). The MCL standard for arsenic, 0.05 ppm, is an ARAR for the Crystal Chemical site, and EPA has determined that the MCL will be the target remediation level for ground water. The MCL will be met throughout the area of attainment.

Approximately 55,000 cubic yards of offsite soils and sediments contaminated with arsenic above 30 ppm will be excavated and brought back on to the site. In order to ensure that all offsite soils and sediments contaminated with arsenic greater than 30 ppm from the Crystal Chemical site are identified, offsite areas

previously identified as contaminated will be resampled to verify the need for excavation. This will include, but will not be limited to, adjacent properties, the Harris County Flood Control Channel, and all properties potentially affected by drainage from the site by way of the flood control channel. All soils contaminated with arsenic greater than 300 ppm will be treated using the in-situ vitrification technology. The volume, therefore, requiring treatment is estimated to be 16,500 cubic yards.

During the design phase of this remedial action, an evaluation defining the relationship between the contaminated soils and the ground water will be conducted. This study will determine the depth and arsenic concentration of the soils which require treatment so as to allow the ground water remedial goal of 0.05 ppm for arsenic to be achieved. The objective of this study will be to determine the need for and feasibility of deeper and more extensive soil treatment that will enable the ground water to be remediated to the MCL within the shortest practical timeframe. This study may include a further soils investigation to more fully delineate subsurface arsenic distribution and speciation.

In-situ vitrification is a patented process for the indirect treatment of contaminated soils. In-situ vitrification thermally converts contaminated soil into a chemically inert, stable, crystalline product. The treatment process consists of placing a graphite-containing starter material on the surface of contaminated soils between an array of electrodes which are placed in the ground. The graphite starter material acts as a conductive path between the electrodes. An electrical current is passed between the electrodes which creates temperatures high enough to melt the soil (1600 - 2000° Celsius). The molten zone grows downward and outward destroying or encapsulating hazardous substances in the soils. Upon cooling, the product of in-situ vitrification is a glass-like material resembling natural obsidian.

Figure 14 illustrates the disposition of materials during the in-situ vitrification process. Gases released during the melting process are collected in an off-gas hood and treated. Inorganic materials in the soil either melt, dissolve, or immobilize into the molten mass.

The in-situ vitrification process can treat both large and small areas of contamination, but the system is limited at the time of this Record of Decision to treating soils no deeper than approximately 25 feet below the ground surface.

This technology can be used on most known soils, including those saturated with water. In doing so, the process heats the inorganic matrix materials to 100° Celsius, at which temperature water is removed by vaporization. However, it requires approximately the same amount of electrical energy to remove one pound of water as it does to melt one pound of soil. Therefore, it is best maintain

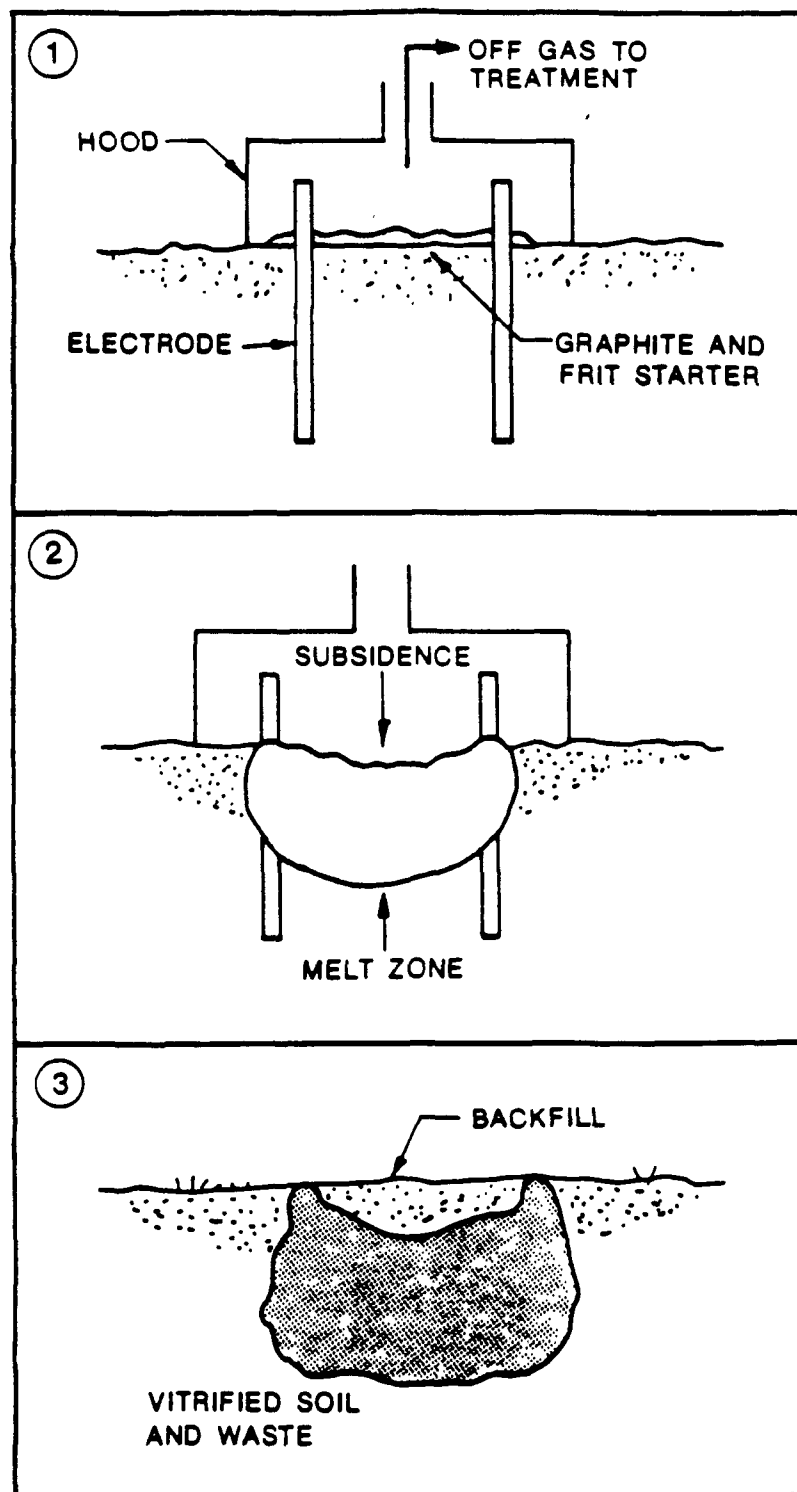


FIGURE 14
IN-SITU VITRIFICATION SCHEMATIC

the treatment volume in as dry a condition as possible prior to implementation of this technology. Because of this, a temporary dewatering system may be utilized during the implementation of the remedial action if it is determined to be necessary during the design phase of this project.

As subsidence of the soils occurs upon cooling of treated area, backfill would be required to bring the treated area to grade. Once the soils treatment has been completed, the site will then be covered with a multi-layer cap consisting of clay, plastic, sand, topsoil, and vegetation. Following the completion of the soils treatment, verification of the success of the treatment technology will be conducted. The verification process will include, but will not be limited to, a subsurface investigation along the periphery of the treatment areas to ensure that migration of arsenic outside of the treatment areas has not occurred.

The ground water remedy calls for a ground water extraction system that will pump arsenic-contaminated ground water from water-bearing zones contaminated by the Crystal Chemical site. Because arsenic contamination has been detected in the 100-foot water-bearing zone (MW-4) and in the WSW-1 (one of the onsite water-supply wells) on the Crystal Chemical site itself, additional hydrogeologic and geochemical characterization of the 100-foot zone and the zone in which WSW-1 is screened (at an approximate 300 foot depth) needs to be done. Furthermore, valid monitoring points for these two zones must be established to more fully identify the possible extent of contamination. Attempts to verify the construction of the two onsite water supply wells have been unsuccessful, therefore, they are not considered valid monitoring points. A naturally occurring arsenic background concentration in the ground waters of the upper 2000 feet in the site vicinity will also be established during this characterization. These data will be used to evaluate detected levels of arsenic in area wells. If after the completion of the characterization additional water-bearing zones are determined to be contaminated, they will be included in the ground water extraction and treatment remedy for the site. The onsite water supply wells (WSW-1 and WSW-2) and all of the monitoring wells not necessary for the remedial action or for the long-term O&M will be closed in accordance with regulations of the State of Texas.

The treatment of the contaminated ground water would consist of ferric hydroxide precipitation and flocculation, followed by clarification, filtration, and final polishing of the water with ion exchange. Ion exchange treatment is a process where contaminants are removed from water through the exchange of nontoxic materials (ions) from an ion exchange material. The toxic materials are retained in the exchange material. A treatability study to investigate the precise requirements of the treatment system necessary to remove the arsenic contamination will need to be conducted. Once treated, the water would be discharged either

to a POTW or into an area surface water or it would be reinjected into the ground (see Figure 15). If the water is to be reinjected, injection wells will have to be installed. The advantage to reinjection is that the contaminants are flushed out and then treated using this technology. Additionally, an onsite pilot study should be conducted to identify well placement for the most effective extraction method and to investigate the reinjection option.

The goal of this remedial action is to restore the ground water to a useable state, i.e., removing the arsenic to the MCL within the area of attainment. The area of attainment constitutes the site boundary and up to the boundary of the contaminant plume for the shallow water-bearing zones (i.e., the 15' and 35' zones). However, the area of attainment for any area in deeper water-bearing zone found to be contaminated with arsenic from the Crystal Chemical site will be the lateral extent of the contaminant plume, due to the potential for migration into deeper zones. Based on information obtained during the SI, the original FS, the SFS, and the analysis of all four remedial alternatives, EPA believes that the alternative selected will achieve this goal and therefore meet the ARAR for remediating the ground water to 0.05 ppm arsenic. Contamination of ground water by arsenic may be especially persistent in the immediate vicinity of the contaminants' source, where concentrations are relatively high. The ability to achieve cleanup goals throughout the area of attainment cannot be determined until the extraction system has been implemented, modified as necessary, and the plume response monitored over time. If the selected remedy cannot meet the remediation goal of 0.05 ppm, the MCL for arsenic throughout the area of attainment during the implementation, contingency measures and goals may replace the selected remedy and goals. These measures will be protective of human health and the environment, and are technically practicable under the corresponding circumstances.

To determine if contingency measures are necessary, the extraction system which is part of the selected remedy will be closely monitored for an estimated 10 years. During this time the system's performance will be carefully evaluated using performance data collected. If after the evaluation it appears that the system cannot produce the remedial goals set for the site, contingency measures including one, some or all of the activities below will be implemented:

- a) discontinuing operation of extraction wells in areas where cleanup goals have been attained;
- b) alternating pumping at wells to eliminate stagnation points; and/or,

- c) establishing an Alternate Concentration Limit ("ACL") for arsenic throughout the area of attainment provided compliance with CERCLA Section 121(d)(2)(B)(ii) can be demonstrated;
- d) waiving the ground water ARAR for those portions of the aquifer based on the technical impracticability of achieving further contaminant reduction;
- e) implementing low level pumping as a long-term gradient control or construction of a containment measure such as a slurry wall; and/or,
- f) implementing additional source control treatment to further reduce arsenic migration to ground water.

The decision to invoke any or all of these measures may be made during a periodic review of the remedial action, which will occur at five-year intervals. Depending on whether a significant or fundamental change is proposed, an **Explanation of Significant Differences** or an **Amendment to the Record of Decision** will be issued to inform the public of the details of the modification. A change from active restoration to passive restoration would be considered a fundamental change.

X. STATUTORY DETERMINATIONS

Under its legal authorities, EPA's primary responsibility at Superfund sites is to undertake remedial actions that achieve adequate protection of human health and the environment. In addition, Section 121 of CERCLA establishes several other statutory requirements and preferences that the selected remedy must meet. Section 121 of CERCLA specifies that when complete, the selected remedial action for this site must comply with ARARs established under Federal and State environmental laws unless a statutory waiver is justified. The selected remedy, also, must be cost-effective and utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable. Finally, the statute includes a preference for remedies that employ treatment that permanently and significantly reduce the volume, toxicity, or mobility of hazardous wastes as their principal element. The following sections discuss how the selected soil and ground water remedies meet these statutory requirements.

Protection of Human Health and the Environment:

The selected soil remedy protects human health and the environment by excavating all offsite soils contaminated with arsenic above 30 ppm, treating by the in-situ vitrification process. all soils

contaminated with arsenic greater than 300 ppm, and by capping the entire site after the treatment has been completed. The site will be covered with a multi-layer cap to act as a barrier that restricts the flow of water through the soil and to prevent the release of the soil and residual contaminants into the air. Site access and land use restrictions prohibiting soil removal and any commercial or residential activity will be implemented.

Removing all offsite soils and sediments contaminated with arsenic greater than 30 ppm will eliminate the threat of exposure from direct contact with the contaminated soils outside of the current boundaries of the site. The vitrification (i.e., melting) of the arsenic-contaminated soil above 300 ppm will eliminate the threat of exposure from direct contact, inhalation, or ingestion of the heavily contaminated soil, and it will minimize leaching of arsenic into the ground water. The melting process destroys many contaminants and permanently bonds other contaminants when the soil is melted and cools into a stable glass-like material.

The current risks associated with these exposure pathways from the contaminated soils, as discussed in the SUMMARY OF SITE RISKS Section of this ROD, are unacceptable. By treating the most highly contaminated areas, i.e., those areas where the arsenic contamination is greater than 300 ppm, calculations have shown that approximately 95% of all the arsenic contamination on the site would be treated. That is to say that 95% of the arsenic on the site is found in areas where the arsenic levels are above 300 ppm. The average concentration of arsenic found on the site, outside of the heavily contaminated areas, is 60 ppm. Therefore, the residual contamination outside the current boundaries of the site will constitute a two in one hundred thousand (10^{-5}) cancer risk level. As an added protective measure, the entire site, after treatment has been completed, will be capped. The capping will eliminate all threats relating to direct contact with and inhalation of the residual contamination. This will reduce the risk posed by this site to less than one in one ten million (10^{-7}). EPA policy calls for remediation levels that range from a cancer risk of one in ten thousand to one in one million (10^{-6} to 10^{-5}). Additionally, the soils treatment and site capping will all but eliminate the continued migration of arsenic from the soils into the ground water. There are no short-term threats associated with the selected remedy that cannot be readily controlled. Further, no adverse cross-media impacts are expected from the soil remedy.

The selected ground water remedy protects human health and the environment by pumping ground water from the two contaminated water-bearing zones (15' and 35') and then treating contaminated ground water onsite by chemical precipitation, filtration, and ion exchange treatment. Following treatment, the water will either be discharged to a publicly owned treatment works ("POTW") or to the Harris County Flood Control Channel, or it will be reinjected into the ground. The current ground water monitoring system will be

maintained or a new system designed to ensure that the remedial action goals are being met. Site access and land use restrictions prohibiting soil removal and construction will be implemented.

The capture and treatment of the arsenic-contaminated ground water will eliminate threats of direct contact and ingestion posed by the site. The current risks associated with these pathways are unacceptable. The endangerment assessment for the Crystal Chemical site did not address remediation levels in ground water, and no risk ranges have been established for arsenic as it relates to this site. EPA has determined, however, that the Maximum Contaminant Level ("MCL") standard for arsenic, 0.05 ppm, will be the target remediation goal for the ground water. However, if after monitoring the contaminant levels in the ground water being pumped for treatment it appears that the remediation goal cannot be met, contingency measures may be implemented, as discussed in the SELECTED REMEDY Section of this ROD. By maintaining a ground water monitoring program in conjunction with the pump and treatment system, elimination of the threats posed by possible ingestion or direct contact can be assured. There are no short-term threats associated with the selected remedy that cannot be readily controlled. Also, no adverse cross-media impacts are expected from the selected ground water remedy.

Compliance with Applicable or Relevant and Appropriate Requirements:

Soil Remediation:

The selected soil remedy of excavation of offsite arsenic-contaminated soils greater than 30 ppm, in-situ vitrification of soils contaminated greater than 300 ppm, and capping the entire site will comply with all applicable relevant and appropriate action-, chemical-, and location-specific requirements ("ARARs"). The ARARs are presented as follows:

Action-specific Soil Remediation ARARs:

Applicable Resource Conservation and Recovery Act ("RCRA") requirements for landfill closure, 40 CFR 264.111 Subpart G, which specify a cap with a permeability less than or equal to the permeability of any bottom liner or natural sub-soils present at the site. In addition, applicable specific closure requirements which are provided for surface impoundments, 40 CFR 264.228 Subpart K, and applicable requirements for landfills, 40 CFR 264.310 Subpart N, may also apply.

Post-closure and monitoring applicable requirements for 30 years or another period determined by the Regional Administrator, 40 CFR 264.117 (a)(1).

Applicable ambient air quality standards per 40 CFR 50 to protect the quality of the air during the implementation of the remedial action.

Chemical-specific Soil Remediation ARARs:

As required by the Clean Water Act ("CWA") (33 CFR 303), onsite surface water must meet applicable ambient water quality criteria for arsenic (0.0175 µg/l).

Location-specific Soil Remediation ARARs:

Applicable RCRA requirements, 40 CFR 264.18, for location of a Transportation, Storage or Disposal ("TSD") facility in a 100-year floodplain, and also general applicable requirements for protection of floodplains, 40 CFR 6, Appendix A.

Ground water Remediation:

The selected ground water remedy of extraction and treatment, followed by discharge to a publicly owned treatment works ("POTW"), surface water, or reinjection into the ground will comply with all applicable or relevant and appropriate action-, chemical-, and location-specific requirements ("ARARs"). The ARARs are presented as follows:

Action-specific Ground Water Remediation ARARs:

Applicable Resource Conservation and Recovery Act ("RCRA") requirements, 40 CFR 262, Subparts A-D. These requirements detail standards applicable to generators of hazardous waste.

Applicable RCRA requirements, 40 CFR 264, Subparts A-G, J and K. These requirements detail standards for owners and operators of hazardous waste treatment, storage, and disposal facilities and would apply with regard to hazardous sludges generated by ground water treatment.

Applicable RCRA requirements, 40 CFR 268, Subparts A-E. These requirements detail land disposal restrictions as they pertain to any hazardous sludge resulting from ground water treatment.

Applicable RCRA requirements, 40 CFR 122-125, with regard to the National Pollutant Discharge Elimination System ("NPDES") program which requires permits for discharge to surface waters.

Applicable RCRA requirements, 40 CFR 403.5 with regard to allowed discharge to Publicly Owned Treatment Works ("POTW").

Applicable requirements of the Clean Water Act ("CWA") (33 CFR 303) specifically regarding ambient water quality standards, CWA 402.

Applicable Texas Ground Water Protection Act of 1989, as it specifies the ground water protection goals for the state.

Chemical-specific Ground Water Remediation ARARs:

Applicable RCRA requirements, 40 CFR 264.94 with regard to ground water protection standards (equivalent to Federal Maximum Contaminant Levels ("MCLs"); 0.05 ppm arsenic allowed).

Location-specific Ground Water Remediation ARARs:

Applicable RCRA requirements, 40 CFR 264.18 for location of TSD facility in a 100-year floodplain and also general applicable requirements for protection of floodplains, 40 CFR 6, Appendix A.

Cost-Effectiveness:

The selected soil remedy is cost-effective because it has been determined to provide overall effectiveness proportional to its costs, the net present worth value being \$13,766,352. The estimated costs of the selected soil remedy are within an order of magnitude (less than three times) of the costs associated with onsite capping of the contaminated soils, and yet the selected remedy assures a much higher degree of certainty that the remedy will be effective in the long-term due to the significant reduction of the toxicity and mobility of the wastes achieved through in-situ vitrification of heavily contaminated soils prior to capping. While the selected soil remedy effectively reduces the hazards posed by contaminants at the site by essentially treating an estimated 95% of arsenic-contaminated soils onsite, its costs are only 18 percent of the alternatives involving total excavation and offsite disposal or in-situ vitrification of the entire site, \$76,004,379 and \$76,709,543, respectively.

The selected ground water remedy is also cost-effective, its present worth value being \$4,824,388. The estimated costs of the selected remedy are less than the cost associated with installation of a slurry wall (\$6,196,038) but are more than the costs associated with directly discharging the extracted ground water to a POTW (\$957,830). However, it is unlikely that an untreated discharge would have been allowed by the POTW due to contaminant discharge requirements. Furthermore, the selected remedy is the most protective due to the concentration of the contaminants through treatment on site and the eventual disposal of these contaminants in an approved manner.

Utilization of Permanent Solutions and Alternative Treatment Technologies (or Resource Recovery Technologies) to the Maximum Extent Practical:

EPA has determined that the selected soil and ground water remedies represent the maximum extent to which permanent solution and treatment technologies can be utilized in a cost-effective manner for source control and remediation at the Crystal Chemical site. Of those alternatives that are protective of human health and the environment and comply with ARARs, EPA has determined that the selected soil and ground water remedies provide the best balance of trade offs in terms of long-term effectiveness and permanence, reduction in toxicity, mobility, or volume achieved through treatment, short-term effectiveness, implementability, costs, also considering the statutory preference for treatment as a principal element and considering State and community acceptance.

The in-situ vitrification technology affords the most permanent and long-term effective solution to the contamination problem posed by the Crystal Chemical site. The rationale behind selecting the partial implementation of the technology over treating the entire site is that the partial approach will effectively treat 95% of the arsenic found on the site. The increase in the cost associated with treating the entire site to capture or destroy the remaining 5% does not afford any more protection given that the site must be capped and the capped maintained in perpetuity.

The other two treatment technologies investigated as possible remedies for the site were soil washing and solidification/stabilization. Both of these treatment technologies when implemented on a complete scale (i.e., is over the entire site) and the excavation and offsite disposal alternative are more permanent because all of the contamination is being addressed. However, the long-term effectiveness of the two treatment technologies has not been proven. The treated waste continues to leach unacceptable concentrations of the contaminant into the environment. The problems associated with offsite disposal (alternative A-1) outweigh the benefits of onsite treatment.

The in-situ vitrification technology, again, affords the best solution when addressing the reduction of toxicity, mobility, or volume through treatment. When, again, considering the selection of the partial over the complete treatment, the additional costs associated with implementing the complete treatment, thus addressing the other 5% of the contaminants onsite, provide for very little added protection. The other treatment technologies do address reduction of toxicity, mobility, or volume, however, the disadvantages of the alternatives associated with the technologies outweigh the benefits.

Admittedly, when discussing short-term effectiveness, implementation, and the costs associated with the selected remedy,

other alternatives better meet these criteria. Almost all of the alternatives satisfy the short-term effectiveness criteria better than the alternatives utilizing the in-situ vitrification technology, however, the short-term risk associated with implementing the selected remedy are of a manageable magnitude, therefore, do not tip the scale greatly when balancing all of the criteria. The implementation of the selected remedy, too, will not be accomplished as easily as would be implementing the alternatives utilizing the solidification/stabilization technology. There is, to date, only one commercial vendor that can perform the technology. However, the implementation problems do not appear to outweigh the benefits of this technology. Lastly, the selected remedy is the not the least expensive alternative investigated nor is it the most expensive. The least expensive alternative calls for capping the site without any treatment of the contaminated soils. The second least expensive alternative calls for implementing solidification/stabilization technology on the most heavily contaminated soils. The selected remedy falls third in the hierarchy of expense. The cost savings of implementing one of the less expensive alternatives do not outweigh the fact that these two less costly alternatives are less protective of human health and the environment. Cost is not a trade-off for protection.

The selected ground water remedy satisfies the long-term effectiveness and permanence, reduction of toxicity, mobility, or volume through treatment, and implementability criteria better than all of the other alternatives investigated for possible solutions to the contamination problems on the Crystal Chemical site. It does, however, fall behind alternative B-1a, which calls for the extraction and discharge of contaminated ground water to a POTW, when discussing the short-term effectiveness and cost criteria. The short-term risks associated with the selected ground water remedy are composed of possible exposure of workers and the community to the ground water treatment system, however, these potential risks are easily controlled, therefore all but eliminated. Again, the cost associated with implementing the selected ground water remedy is more than the cost associated with implementing the less protective extraction and discharge alternative. However, discharge without treatment may not be possible, and cost is not a trade-off for protection.

Preference for Treatment as a Principal Element:

By treating heavily contaminated soils with the in-situ vitrification process, and by removal of contaminants in extracted ground water through chemical precipitation, filtration, and ion exchange, the selected soil and ground water remedies address the principal threats posed by the site through the use of treatment technologies. Therefore, the statutory preference for remedies that employ treatment as a principal element is satisfied. Thus, the selected remedies meet the statutory requirement to utilize

permanent solutions and treatment technologies to the maximum extent practicable.

XI. DOCUMENTATION OF SIGNIFICANT CHANGES

The Proposed Plan for the Crystal Chemical Company site was released for public comment in June 1990. The Proposed Plan identified soils alternative A-5 (Partial in-situ Vitrification and Capping), and that ground water alternative B-1b (Extraction, Treatment, and Discharge to a POTW, the Harris County Flood Control Channel, or reinjection) as the preferred alternatives for the site. EPA reviewed all written and verbal comments submitted during the public comment period. Upon review of these comments, it was determined that no significant changes to the remedy, as it was originally identified in the Proposed Plan, were necessary.

ATTACHMENT 1

RESPONSIVENESS SUMMARY

CRYSTAL CHEMICAL COMPANY SITE RESPONSIVENESS SUMMARY

The Community Relations Responsiveness Summary has been prepared to provide written responses to comments submitted regarding the Proposed Plan at the Crystal Chemical Company site. The summary is divided into two sections.

Section I. Background of Community Involvement and Concerns. This section provides a brief history of community interest and concerns raised during the remedial planning activities at the Crystal Chemical Company site.

Section II. Summary of Major Comments Received. The comments (both oral and written) are presented and EPA's responses are provided.

I. Background of Community Involvement and Concerns

The community has been involved on a limited basis with activities at the Crystal Chemical Company site. They attended the open houses and the public meeting in limited numbers, however, approximately 300 people receive mailings from EPA on Crystal Chemical Company site activities. The comments that were received from the local community concentrated on possible inconveniences that they might experience during and following the completion of the remedial action.

II. Summary of Major Comments

Public notice announcing the public comment period and the public meeting was published in the Houston Post on May 27, 1990. The Proposed Plan was distributed through the mail in early June 1990, and the public comment period began on June 11, 1990 and ended on July 11, 1990. Informal Open Houses were held in the Houston area on two separate occasions, April 10 and June 5, 1990. The public meeting was held on June 21, 1990 at the Alief High School in Alief, Texas. The purpose of this meeting was to discuss all the proposed alternatives and EPA's preferred alternative for the Crystal Chemical Company site.

Approximately 30 people attended the public meeting and 7 people asked questions or made comments. Four sets of written comments were received during the public comment.

A. Comments and Questions received during the public meeting.

EPA received oral comments during a public meeting which was held at the Alief Elsie High School in Houston, Texas, on June 21, 1990. Comments pertinent to EPA's proposed plan of action are summarized below followed by EPA's response. A full account of the public meeting can be found in the public meeting transcripts which are documented in the Crystal Chemical Administrative Record.

COMMENT - MR. ED WINTER (Citizen):

Mr. Winter made several comments and recommendations:

1) indicating that he had observed "plenty of fish" in the flood control ditch that runs adjacent to the site; 2) the flood control ditch should be cleaned to more effectively handle the flow of water; and, 3) Westpark should be open for traffic.

EPA RESPONSE:

EPA concurs that there are fish in the flood control ditch. Relative to cleaning the flood control ditch, improvements will be made to the ditch as part of the remedial action. Additionally, the Harris County Flood Control District is responsible for maintaining the flood control channels. With respect to Westpark Drive, EPA will seek to have the contamination problems associated with right-of-way remediated in an expeditious manner in order that the entire east-west artery (Westpark Drive) can be placed into service by the City of Houston.

COMMENT MR. WINTER (CITIZEN):

Wanted to know if the kids [found to have increased arsenic levels in their urine samples] hadn't been playing on some yards that had been sprayed with an arsenic-containing weed control, possibly in addition to or instead of any contact with contaminated soils near the site?

RESPONSE - DR. JEAN BRENDER (Texas Department of Health):

We [public health officials conducting the health study] asked the parents of those children [included in the survey who lived and played near the site] whether there had been any exposure to yards and golf courses and other potential sources of contamination. And we pretty much ruled out as many sources as we could.

COMMENT - MR. CLYDE BRAGG (City of Houston Parks & Recreation):

Indicated that the City of Houston owned a piece of property south of the Crystal Chemical Site. It is bounded by Harwin and the common Harris County flood control drainage structure. His question was what, if any, arsenic is in that ditch and at what levels and should we be concerned in the development of that park? Also, would EPA be willing to do further testing of the flood control ditch?

EPA RESPONSE:

Based on the information provided in the Supplemental Feasibility Study (p. 2-63) sediment in the drainage canal contains less than 60 ppm arsenic in samples collected north and northwest of the site. Whereas, the sediment samples collected west of the site in the drainage canal contained 278 ppm arsenic and south of the site (downstream) arsenic was detected at 28 ppm. Apparently, the concentrations of arsenic decrease below levels of concern [from a public health standpoint] as you move downstream to the park referenced in Mr. Bragg's comment. However, EPA will require further testing of the flood control ditch during remedial action

to verify previous testing and further define the situation. Also, upon completion of the remedy EPA will require stream sediment sampling to evaluate the effectiveness of the remedy to eliminate the migration of arsenic-contaminated soils.

COMMENT - MR. JIM MURPHY (Westchase Business Council):

Mr. Murphy indicated that his organization had the following comments and recommendations: 1) they did not object to the remediation plan established by EPA, they thought it was a good plan; 2) their main concern was with the timing of cleanup (i.e. they would like activities to proceed as quickly as possible); 3) they felt that maybe there was an opportunity to clean-up the Westpark right-of-way separate from cleaning up the whole site; 4) the organization is concerned with the public awareness and the possibility of exposure; 5) they were pleased to see that there is off-site excavation of contaminated soil; and 6) urge EPA to include continued testing of both water [surface water and ground water] the soil, and maybe even the air, as part of the remediation plan.

EPA RESPONSE:

EPA welcomes the support of the Westchase Business Council relative to the agency's proposed plan for remedial action (i.e. partial in-situ vitrification and ground water pump and treatment). Timing is also of great concern to EPA. As an agency we are committed to initiating remedial action as quickly as possible. After the remedy is selected (evidenced by the signing of the Record of Decision) EPA may provide the potentially responsible parties an opportunity to negotiate the terms of a settlement to perform the remedy. Such a settlement would be phrased in a Consent Decree and entered in the local Federal District Court. If settlement can not be reached, EPA will explore its enforcement options to ensure that remediation is completed in a timely manner. This might include EPA doing the work itself and seeking cost reimbursement from potentially responsible parties. If settlement is achieved and the Consent Decree signed by the Court, the remedial design can be initiated and upon approval by EPA, the remedial action can begin. With respect to Westpark Drive, EPA is committed to cleaning up the right-of-way on an expedited schedule. Currently we are developing the means by which contaminated soils would be removed from the right-of-way in an effort to provide access to the City of Houston for completion of the road.

Related to public awareness, EPA does its best to get the word out to the public. Fact sheets, open houses, workshops, and community meetings are used as tools by EPA to keep interested persons informed of site activities. A toll free number (1-800-533-3508) has been established by EPA so that interested citizens can call to obtain specific information to specific inquiries. At the completion of the public health study conducted by the Agency of Toxic Substances and Disease Registry, the Texas Department of Health, and the City of Houston, a meeting was set up with local

residents to discuss the results. EPA also held two open houses before the formal public meeting for the purpose of answering questions concerning the site. We also intend on maintaining close communications with the public as we proceed with the project. Finally, EPA will require testing of ground water and air during the remedial action and will further evaluate the need for surface water testing.

COMMENT - MR. ED WINTER (Citizen):

Have they found any [arsenic] in the air? What is the worry about Westpark -- not letting people go through Westpark?

EPA RESPONSE:

Initial air monitoring found inorganic arsenic levels at the site ranged from 0.005 - 0.050 micro-grams per cubic meter (Table 5-17, Site Investigation Report, January 1984). Based on this study, the air contaminant pathway does not appear to be presenting a public health threat (Health Assessment, ATSDR, February 1988).

Regarding Westpark Drive as it passes by the Crystal Chemical site, there are some highly contaminated soils on the Westpark right-of-way that, if people came into contact with these soils, might present a public health threat. These contaminated soils have to be removed from the right-of-way to the level prescribed by EPA (30 ppm) before the agency will consider the area safe for public use.

COMMENT - MR. JOHN ELDRIDGE (Andrews & Kurth representing McKinney Properties which is owned by Texas Commerce Bank)

McKinney owns a nearby property at 11111 Wilcrest Green, it is a recently acquired commercial office building. Mr. Eldridge expressed the following concerns: 1) In general terms, his client is interested that the site be cleaned up adequately to protect human health, the environment and the long-term property values in the neighborhood; 2) that the site be cleaned up expeditiously; 3) that the clean-up process not affect nearby properties any more than necessary; 4) that interested persons such as McKinney and the bank be apprised of the process appropriately so that they can participate when decisions that will affect them are being made and that the appearance of the site be maintained as adequately as possible during the remedial process; 5) with respect to the remedial alternatives presented in the Supplemental Feasibility Study (SFS), the bank considers options A-1, A-8, A-9 and A-10 to be unacceptable; and, 6) based on their review of the SFS, they would be inclined to support the vitrification remedy. With regard to whether it's the partial or the complete option on vitrification, soil washing or solidification, cost would be a concern.

They believe that the cutoff of 300 parts per million arsenic in soil would be protective of human health and the environment, and

that it would not be necessary to clean up to 30 parts per million or below in order to accomplish those necessary goals.

With regard to ground water options they felt that the EPA's recommendation was appropriate. They do believe that ground water remedial efforts are necessary given the arsenic levels that are indicated. They did have some concerns about how expeditiously the ground water can be remediated. The sooner the better. If that involves the reinjection process, they would prefer that.

Concerning air emissions, whether it be fugitive emissions from dust or gases from the in-situ vitrification process, or even potential emissions or odors from the waste water treatment facility that would be constructed, those are going to be concerns for neighboring property owners. And they ask that EPA take, very seriously, those items into account in adopting your technology requirements and implementing the remedy.

One final point, and this may be more important than some of the others even for the nearby neighbors of this facility. That is truck traffic patterns. There will be trucks and equipment moving through the area as this process begins and gets implemented. And the routes that those trucks take can have quite an impact on the neighborhood and on the streets. So they urge the agency to carefully consider traffic patterns and restrict some of those times when the traffic will be moving through the area.

EPA RESPONSE:

Superfund law mandates that selected remedies must be protective of human health and the environment. EPA's preferred methods of treatment (i.e. partial in-situ vitrification and ground water pump and treatment) satisfies this mandate. On the other hand, EPA has very little control over the impact that a Superfund site might have on surrounding property values. Property values depend almost entirely on peoples' perception; therefore, they will plummet if people perceive the area as unsafe, whether it is or is not safe. If enough hysteria develops about the area being unsafe, property values suffer greatly. EPA can only make assurances to the public that the selected remedy will ensure protection of human health and the environment.

As indicated in a previous response above, timing is also of great concern to EPA and we are committed to initiating remedial action as quickly as possible. Furthermore, the EPA has a great deal of interest in ensuring minimal impact to any adjacent property owner. We don't anticipate any problems during remedial action, however, we are always willing to listen to concerned citizens or other groups and will try to accommodate there concerns. Information concerning the progress of the project will be released by EPA through various mechanisms such as newsletters, facts sheets, informal open houses, workshops, and community meetings. We welcome input from any party throughout the remediation process.

EPA's preferred alternative for soils is partial in-situ vitrification. This remedy includes removing arsenic-contaminated soils from offsite areas that exhibits concentrations greater than 30 ppm. This standard is based on EPA methodologies for determining long-term exposure to arsenic-contaminated soils. EPA feels that for areas outside the fence line of the site, 30 ppm is a safe level. Treating onsite soils that exceed 300 ppm takes care of an estimated 95 percent of the arsenic on the site. EPA believes that this rationale provides a cost effective remedy that effectively treats the contamination problem and provides a safe and protective solution.

Relative to the comments on the preferred alternative for ground water, EPA appreciates the support and concurs with the notion that the quicker the remedy can be completed the better.

As far as air emissions are concerned, EPA is equally concerned about air emissions during remedial action. The in-situ vitrification process itself includes devices that would control emissions. Additionally, we would include some type of particulate sampling during remedial action to ensure that we don't create a problem during soil disturbance activities. In most remedial actions you will have dust suppression activities on-going to minimize any such problems.

Regarding truck traffic, EPA will be willing to listen to any party who may have a particular concern. If a problem arises, we will work very hard to resolve the issue.

COMMENT - MR. V. F. HILL (Halliburton Environmental Technologies):
1) How widely has in-situ vitrification been used? 2) How many successful applications of that particular technique have been made? 3) How many unsuccessful attempts have been made [using in-situ vitrification], and what lead to the unsuccessful application? 4) Was the solidification test (carried out during the feasibility study) done by a firm that specializes in solidification, that does it for their living? 5) If evidence could be supplied to you that this material can be successfully stabilized, would that affect your selection of the remedy?

EPA RESPONSE:

Battelle Memorial Institute is exclusively licensed by the U.S. Department of Energy to perform in-situ vitrification. Geosafe Corporation, primarily owned by Battelle, holds the exclusive sublicense to perform in-situ vitrification commercially. Geosafe and Battelle combined have performed more than 70 tests of various scales for the Department of Energy and other clients. At the Department of Energy Hanford site in Washington state, in-situ vitrification has successfully treated soils contaminated with radioactive wastes. In-situ vitrification has also been selected for evaluation under EPA's Superfund Innovative Technology Evaluation (SITE) Program. Currently, in-situ vitrification has

been selected for use at three EPA Superfund sites. EPA has no information related to any unsuccessful attempts at using this technology.

The solidification tests performed during the Supplemental Feasibility Study were conducted by vendors selected by the potentially responsible parties. These parties had to invest a great deal of money for soil samples to be collected and the tests to be performed. It is in their best interest to use a reputable vendor(s) to run the analyses.

The remedy selection process depends on an evaluation of nine criteria, namely 1) overall protection of human health and the environment, 2) compliance with regulations (ARARs), 3) long-term effectiveness and permanence, 4) reduction of toxicity, mobility, or volume through treatment, 5) short-term effectiveness, 6) implementability, 7) cost, 8) community acceptance, and 9) state acceptance. Therefore, in response to the question, if there was evidence of "successful" stabilization, would that affect EPA's decision? EPA would have to evaluate the approach against the nine criteria identified above. It is not as straight forward as determining the success or failure of the treatment technology.

COMMENT - MR. STEPHEN WENTLAND (Citizen):

Mr. Wentland commented that he felt 30 parts per million was a good cleanup level. He also inquired as to how much of a financial burden it would be to get the arsenic down to even lower concentrations and whether arsenic from the Crystal Chemical Company has seeped into the drinking water supply.

EPA RESPONSE:

First, the financial demand of treating greater volumes of contaminants is great. For example, EPA estimates that the cost using in-situ vitrification over the entire site would increase the cost (compared to partial vitrification) from \$14 million to approximately \$76 million. Secondly, all of the drinking water wells within a one-mile radius of the site were sampled in 1989 and no contamination problems were evident.

COMMENT - MS. JULIE SCHOENEGBERG (Advocate Newspaper):

Asked where funding will come for these different [treatment] alternatives?

EPA RESPONSE:

Our first approach will be to notify the various potentially responsible parties of the opportunity to come forward and conduct the remedy themselves, in which case we would negotiate a document, referred to as a Consent Decree, that outlines what is to be done in terms of the remedial action. The Consent Decree would be

lodged in the Federal District Court. And during those negotiations we would establish who would be paying for what activities, both past and future.

If we do not receive any favorable response from responsible parties, then we would evaluate our enforcement options. We could perform the remedial action ourselves and try and recover our costs from these parties through future legal actions. Or we could issue a Unilateral Administrative Order to these parties essentially ordering them to conduct the action. If they do not comply with the Order then EPA can choose to conduct the remedial action itself or can take legal action against the parties.

B. Comments and Questions received during the public comment period.

Comments received from Southern Pacific Transportation Company

Comment:

Section I. General Comments.

"The NCP, however, supports selection of a remedy in the range of 10^{-4} to 10^{-6} ."

Response:

Comment noted. National Oil and Hazardous Substances Pollution Contingency Plan; Final Rule 55 Fed. Reg. 46 (March 8, 1990).

Note: All comments made by Southern Pacific Transportation Company in Section II. pertain to their evaluation of the solidification/stabilization technology. Subpart A. specifically pertains to additional treatability studies on solidification/stabilization studies that were performed under the initiative of Southern Pacific Transportation Company and the data was sent to EPA during the public comment period. This data is not included in the Remedial Investigation/Feasibility Study ("RI/FS") or Supplemental Feasibility Study ("SFS") reports for the Crystal Chemical Company site.

Comment:

Section II. A. 1. pg. 7

"The laboratory analysis was performed according to Contract Laboratory Program (CLP) procedures which included required duplicate sample analysis, matrix spikes and matrix spike duplicates. The matrix spike and matrix spike duplicate analysis data are not included in the summarized data...however, they are available upon request."

Response:

In order to certify compliance with CLP procedures and to document the integrity of the data presented, QA/QC documentation as well

as chain of custody reports, sample analysis request forms, laboratory notes/logbook entries, and any other information that is customarily required to ensure high quality data should have been included with the submission of the data.

Comment:

Section II. A. 1. pg. 7

"Results from these treatability studies are included... Included are the analytical data from untreated soil samples. As can be seen from the results of treated samples, three vendors...were able to reduce the leachable concentrations of arsenic to near 5.0 ppm."

Section II. B. 1. pg. 13-14

"EPA's conclusion that solidification/stabilization does not meet ARARs was based on Wastech data that has subsequently been refuted by the more recent treatability data."

Section II. C. pg. 23

"The treatability data discussed above indicates that stabilization/solidification will reduce the leachability of arsenic to the same extent as [in-situ vitrification]."

Response:

This recent treatability study data was submitted during the comment period, therefore, was not available during the initial evaluation of the solidification/stabilization technology. Additionally, in order to certify compliance with CLP procedures and to document the integrity of the data presented, QA/QC documentation as well as chain of custody reports, sample analysis request forms, laboratory notes/logbook entries, and any other information that is customarily required to ensure high quality data should have been included with the submission of the data.

However, according to the information that was submitted to EPA, in only one of seven samples, from these three vendors, had the leachability of arsenic reduced to below 5.0 ppm. The other treated samples leached during TCLP testing. The samples leached from 6.4 ppm to 24.0 ppm of arsenic after treatment. The other seven vendors were not able to reduce the leachability of arsenic to acceptable levels after treatment, i.e., the samples leached arsenic from 62.0 ppm to 410.8 ppm. Therefore, EPA disagrees that the treatability studies were as successful as the treatability studies utilizing the vitrification technology.

Comment:

Section II. A. 3. pg. 9

"As part of the treatability studies, the four vendors were requested to provide information related to the process used to treat the samples of soils and costs for full scale treatment."

Response:

Complete cost information associated with the implementing the

solidification/stabilization technology from the new vendors were not included; therefore, EPA cannot evaluate this technology for its cost-effectiveness.

Comment:

Section II. B. 2. pg. 14

"Southern Pacific disagrees that [Land Disposal Restrictions] should be ARARs. In the Preamble to the NCP, EPA identifies the issues that are being considered by EPA at the national level in the debate over whether LDRs should be ARARs at CERCLA sites. These issues include whether replacement of treated residuals in the proximate area should constitute [sic] placement, whether LDRS will support CERCLA's carefully articulated and balanced approach to remedy selection, and whether an entire CERCLA site should be considered one unit."

Response:

Many discussions continue on the national level. However, this not the proper forum for commenting on EPA's position regarding the applicability of RCRA Land Disposal Restrictions ("LDRs") at a CERCLA site. The commentor should have addressed any such comments to the proposed revisions to the NCP, rather than to EPA's Proposed Plan for the remediation of the Crystal Chemical site. EPA's position on the applicability of LDRs at CERCLA sites is discussed at 55 Fed. Reg. 46 at 8758-8760, and this position was applied to the Crystal Chemical Company site.

Comment:

Section II. B. 2. pg. 21

"To the extent that solidification/stabilization would need a [treatability] variance, however, EPA should set forth the information in the SFS to support a variance,..."

Response:

EPA has selected a technology and a remedy that meets or exceeds the treatment standards that are required, therefore, no treatability variance is required.

Comment:

Section II. B. 3. pg. 21

"Southern Pacific also disagrees that the EP Toxicity level for arsenic should be an ARAR."

Response:

Arsenic is a designated toxic pollutant, 40 CFR 401.15, and is a characteristic hazardous waste if it exceeds 5 mg/l when subjected to the EP Toxicity Test, 40 CFR 261.24. Additionally, by-product salts that are generated in the production of cacodylic acid and of monosodium methylarsenate ("MSMA") are a listed hazardous waste (K031), 40 CFR 261.32. MSMA was one the major

products that Crystal Chemical Company produced and is a contaminant on the site. All corresponding regulatory requirements are ARARs.

Comment:

Section II. B. 3. pg. 22

"EPA, in fact, expressly stated in its recent toxicity characteristic rulemaking that the characteristic levels are not cleanup standards."

Response:

EPA has never stated that arsenic EP Toxicity characteristic levels are the "cleanup" standards for the Crystal Chemical.

Comment:

Section II. B. 4. pg. 22

"The SFS discussion of this ARAR [surface impoundment closure requirement] is premised on the conclusion that soils redeposited into an excavation would be characteristic for arsenic."

Response:

The ARAR for surface impoundment closure was included in the SFS because the four surface evaporation ponds on the site were not closed as required by the RCRA regulations during the EPA Emergency Removal Actions, therefore, the surface impoundment closure requirement is an applicable requirement for the Crystal Chemical site during the remedial action.

Comment:

Section II. C. pg. 23

"[T]his alternative [solidification/stabilization] should be considered irreversible since the soils will be separated from any leaching fluids or subsurface conditions by a subsurface cap."

Response:

EPA is unclear as to what the commentor means by a "subsurface cap." However if by a "subsurface cap" the commentor meant a subsurface liner, a liner was not evaluated in the SFS nor is it considered necessary with the in-situ vitrification remedy selected in this Record of Decision.

Comment:

Section II. C. pg. 24

"In several other RODs...EPA has concluded that solidification is permanent and is capable of locking contaminants both physically and chemically into an unreactive product."

Section II. G. pg. 30

"A review of RODs involving cleanup of arsenic in soils also indicate EPA's confidence in this [solidification/stabilization] technology."

Response:

EPA Region 6 is not disputing the effectiveness of the solidification/stabilization technology, but it believes that in-situ vitrification is more effective in this case. The selection of the in-situ vitrification technology is being made following completion of a study to identify all possible treatment technologies and alternatives that could address the contamination problem at the site. Solidification/stabilization was one of the treatment technologies that was evaluated for the site. Although EPA acknowledges that the solidification/stabilization technology has been proven effective on other sites and specifically those sites contaminated with arsenic, EPA, based on specific data generated for the Crystal Chemical Company site and based on the Agency's general knowledge of the technology, has in good faith proposed a remedy for the Crystal Chemical Company site that utilizes the in-situ vitrification technology.

Comment:

Section II. D. pg. 25

"EPA's proposed Plan of Action at page 6 incorrectly describes this criterion as requiring a reduction of toxicity, mobility and volume. The NCP carefully follows the statutory language in requiring a reduction of toxicity, mobility, or volume."

Response:

Comment noted.

Comment:

Section II. D. pg. 26

"While the SFS claims that volume of the material will increase (see SFS at 5-46), actually the volume of hazardous substances will remain the same. Section 121 (b) of CERCLA, 42 U.S.C. [Section] 9621, requires that the volume of only hazardous substances, not the entire waste material, be taken into account."

Response:

EPA disagrees with this interpretation of the CERCLA statutory provision. The statutory provision states in part "...treatment which permanently and significantly reduces the volume, toxicity or mobility of the hazardous substances, pollutants, and contaminants [emphasis added] ..." The NCP, 40 CFR 300.430(e)(9)(iii)(D)(3) (55 Fed. Reg. 46 at 8849) specifically states that certain factors shall be considered when evaluating the reduction of toxicity, mobility, or volume through treatment. One of the factors is "[t]he degree of expected reduction in toxicity, mobility, or volume of the waste due to treatment or recycling and the specification of which reduction(s) are occurring;" Further, the RCRA "Derived-from Rule" in 40 CFR 261.3(c)(2) states that any solid waste derived from the treatment, storage, or disposal of a listed RCRA hazardous waste is itself a listed hazardous waste regardless of the concentration of hazardous constituents. Furthermore, the RCRA "Mixture Rule", 40 CFR 261.3(a)(2), states

that when any solid waste and a listed hazardous waste are mixed, the entire mixture is a listed hazardous waste and that mixtures of solid wastes and characteristic hazardous wastes are hazardous if the mixture exhibits a characteristic of hazardous waste.

Comment:

Section II. G. pg.29

"Lime is the only contaminant that would be expected to interfere with the stabilization treatment process for soils at the Crystal site. As discussed previously, the addition of lime [during an EPA Emergency Removal Action] to the former pond areas increased the leachability of arsenic."

Response:

EPA is unfamiliar with the basis for Southern Pacific Transportation Company's conclusion that the addition of lime to arsenic contaminated soil increases the arsenic's leachability. In reviewing available literature on the fate and transport of arsenic in soil systems, EPA was unable to locate any reference to the addition of hydroxyl ions causing increased solubility of arsenic. The solubility of sodium methanearsonate is 57 g/100 cm³ in water, which is more than 4,000 times greater than that of calcium arsenate which has a solubility of 0.013 g/100 cm³ in water. Additionally, comments provided to EPA by Edwin A. Woolson on behalf of the Voluntary Purchasing Group, Inc. indicate that the addition of lime during removal action would not have increased the leachability of arsenic. Dr. Woolson states that the arsenic becomes fixed in environments rich in iron and hydroxyl ions. Dr. Woolson is the author or co-author of 71 publications dealing with arsenical chemicals and their fate and transport in the environment.

Comment:

Section II. G. pg. 31

"With respect to the Midco [a Superfund site in Gary, IN - Region 4] ROD, EPA rejected [in-situ vitrification] in favor of solidification partly because [in-situ vitrification] had not been demonstrated in a full scale application and the commercial availability of the equipment was limited."

Response:

The CERCLA statute states in part that "[t]he President may select an alternative remedial action meeting the objectives of this subsection whether or not such action has been achieved in practice at any other facility or site that has similar characteristics" Section 121 (b)(2) of CERCLA, 42 U.S.C. Section 9621. The in-situ vitrification technology was selected because it is the most-effective technology evaluated for the Crystal Chemical site. Additionally, vitrification has been identified as the best demonstrated available technology ("BDAT") for arsenic characteristic waste and for K031 (by-product salts generated in

the production of MSMA and cacodylic acid) listed waste (55 Fed. Reg. 106 at 22556 to 22561).

Comment:

Section II. H. pg. 31

"While the pretreatment step to reduce the pH of the wastes will increase the costs over those taken into account in the SFS, the costs of solidification/stabilization are still much less than those for [in-situ vitrification]."

Section II. H. pg. 33

"Information on cost also dictates that solidification/stabilization is cost-effective."

Response:

The cost difference between the alternative involving partial implementation of solidification/stabilization and the partial implementation of in-situ vitrification is \$5,435,151, the in-situ vitrification being the more expensive alternative. EPA cannot evaluate the cost-effectiveness of the solidification/stabilization technology using the pretreatment step because the cost figures for such a scenario have not been provided to EPA. Note that cost was not the deciding factor between choosing the selected remedy over the partial implementation of the solidification/stabilization technology.

Comment:

Section II. H. pg. 32

"At the Midco II site, EPA specifically rejected [in-situ vitrification] in favor of solidification/stabilization partly because it was more expensive and 'would do little to further reduce risk.'... At the Palmetto Wood Preserving site in South Carolina, the ROD ... eliminated [in-situ vitrification] during the screening process because it was 'expensive, [had] high energy requirements, [and was] unproven'."

Response:

Again, EPA is not disputing the effectiveness or the appropriateness of this technology (i.e. solidification/stabilization) at other sites. The in-situ vitrification technology has proven to be overall the best technology for the Crystal Chemical site.

Comment:

Section III. A. pg.35

"[The] Section Chief of EPA Waste Treatment Section, advised AES on November 1, 1989 that EPA had only one pilot scale study of arsenic, which was performed at Montana State University, to support the BDAT for K031 wastes... The information currently available to us indicates that the Montana study show that arsenic migrates in an uncontrolled manner."

Response:

Data generated from a study conducted at the Montana College of Mineral Science and Technology ("Montana Tech"), not Montana State University, was used in developing the BDAT concentration-based treatment standard of 5.6 mg/l for arsenic in a EP toxicity leachate. Mr. L.G. Twidwell of Montana Tech conducted some immobilisation and leach tests of arsenic-bearing copper smelter flue dust. A summary paper on Mr. Twidwell's work was published in Nuclear and Chemical Waste Management ("Disposal of Arsenic Bearing Copper Smelter Flue Dust", Vol.5, pp 297-303, 1985).

The Montana Tech tests were designed to assess the leachability of arsenic from stabilized flue dust. Stabilisation processes included melting and chemical stabilisation. The study did demonstrate how arsenic can be effectively dissolved into a molten iron silicate slag matrix without volatilisation of arsenic oxide.

Following their review of Mr. Twidwell's paper and based on discussions with Mr. Twidwell, Geosafe Corporation has informed EPA that it does not believe that the subject flue dust work is at all applicable to the potential use of in-situ vitrification at the Crystal Chemical site. The flue dust test work identified that arsenic leachability was a function of pH. Such would not be the case for in-situ vitrification because the matrix in which the arsenic is immobilized is a silicate with strong covalent and ionic bonds, and this type of chemical structure is very resistant to leaching by water in a wide range of pH levels. The results of the Montana Tech tests, however, do not indicate that arsenic during the process would migrate away from the treatment center in an uncontrolled manner. Following the in-situ vitrification process, the arsenic is immobilized in a silicate matrix with strong covalent and ionic bonds making uncontrolled migration unlikely.

Comment:

Section III. B. pg. 36

"EPA has not compared the radioactive properties of the soils treated in the four large scale applications to the Crystal soils."

Response:

EPA is assuming that the commentor is questioning whether the physical properties of the soils contaminated with radioactive waste where the four large-scale applications of the in-situ vitrification technology has been applied, and the physical properties of the soils at the Crystal Chemical Company site were compared. EPA is assuming that this is what the commentor meant because there are no radioactive wastes at the Crystal Chemical Company site.

The textural variability of soils has very little to do with the ability to vitrify it using the in-situ vitrification technology. The textural differences between the soils at the Hanford Department of Energy site where the in-situ vitrification

technology has been implemented on a large scale and the soils at the Crystal Chemical site, according to Geosafe Corporation are great. However, the important factors in determining the success of the technology are the concentrations of the oxides of silicon, aluminum, calcium and the monovalent alkali earth elements, with the concentrations of silicon and the alkali earth elements being the most important factors. The data provided to EPA from Geosafe Corporation illustrates that the concentrations of these important elements are similar for the Crystal Chemical site soils and for the Hanford site soils.

Comment:

Section III. B. pg. 36

"Southern Pacific retained Geosafe to conduct a second treatability test on the Crystal soils... A review of that report highlights the uncertainties associated with this technology. Geosafe could not account for 50 percent of the arsenic in this treatability test. Without any supporting data, it assumed that the unaccounted 50 percent arsenic fraction was locked in the vitrified glass. Geosafe failed to explain why 17.5 grams of arsenic out of the total 51.4 grams was determined to be in the resultant glass when 25.9 grams could not be identified through the analytical results."

Section III. B. pg. 37

"In the second treatability test, migration of arsenic to the uncontaminated area, which is beyond the so-called 'projected' 6.7 grams, could also have occurred."

Response:

According to Geosafe Corporation, the data provided to Southern Pacific Transportation Company in the second treatability study supports the conclusion that the 25.9 grams of arsenic is contained in the glass product. As shown in the report, the arsenic concentrations in the glass and sintered regions ranged from 96 to 1800 mg/kg. Therefore, there is an uneven distribution of the arsenic throughout the glass matrix after the in-situ vitrification process. Based on the statistical variation in the concentration of arsenic in the glass, the arsenic could easily be present and not be found even with additional sampling. The only way to show 100% confidence in the concentration of the arsenic in the glass is to analyse the entire glass and sintered matrix; i.e., to create a homogeneous mass by even distribution of the arsenic (that is now immobilized in the matrix) prior to analysis.

The amount of arsenic believed to be in the adjacent soils is based upon the mean concentration of arsenic found in the adjacent soils averaged over the upper 8 inches of soil and within 2 inches of the vitrified mass, according to Geosafe Corporation. Since arsenic cannot exist in the vapor state below a temperature of 615°C, it is reasonable to assume that if the arsenic is there it will be detected. Therefore, without analysing all of the soil within the test container for the second treatability study which contained

approximately 1000 pounds of material, 100% confidence in the statistics cannot be verified.

Comment:

Section III. B. pg. 37

"Although the chemical nature of the arsenic is not well known, it can be reasoned that most is in the form of various metal arsenates or arsenious (ic) acid chemisorbed on clay. Virtually all will thermally decompose to volatile oxides of arsenic well below the anticipated soil fusion temperature. Arsenic should, therefore, migrate away from the fusion zone and form a condensation halo in the surrounding cooler soil or be recovered in the vapors emanating from the perisphere of the treatment zone. In the former instance, arsenic will neither be stabilized nor recovered."

"In the field, this [arsenic] migration could result in additional groundwater or soil contamination. This fraction could also be present in the 'Isothermal Band,' which was not specifically checked and which could perpetually migrate without recourse to treatment."

Response:

Arsenic sublimates into its vapor state at 615°C, and according to Geosafe Corporation, can exist between the 615°C isotherm and melt during the entire period of vitrification. Since the vapor is thermally buoyant, it continuously moves toward the surface of the melt due to its density-related buoyancy, as was the case in the treatability studies conducted on soils from the Crystal Chemical site. Therefore, any arsenic in the vapor state that escapes the melt would be captured by the off-gassing system.

Based upon previous tests performed on arsenic-contaminated soil and upon the anomalous soil conditions present in the second Crystal Chemical test, Geosafe believes that no statistically or environmentally significant amount of arsenic will diffuse outward or downward from the treatment area. Since the soils at the Crystal Chemical site are predominantly clay and clay-containing sands and possess significant water saturation, the pathways through which arsenic vapors can diffuse are minimal.

However, in the second treatability study, Geosafe Corporation documented large voids in the soils while they were being prepared for treatment. These large voids allowed arsenic vapors to diffuse uninhibited into the soils adjacent to the melt. As a result, arsenic was found next to the vitrified mass. Geosafe Corporation did state that the voids which caused the diffusion of the arsenic are not likely to be found at the site since the soil at the site has not been disrupted in the manner that the soil was disrupted for the treatability test. However, if conditions exist that allow for such a diffusion of arsenic out into adjacent soils, the design implementation of the technology can allow for overlapping of the

treatment areas so that any arsenic that may have diffused from the treatment area will be incorporated.

Comment:

Section III. B. pg. 38

"EPA, however, does not address why "placement" would not occur when volatile arsenic recovered in the off-gas system is recycled back to contaminated soil for further treatment."

Response:

As discussed in EPA's Superfund LDR Guide #5, "Determining When Land Disposal Restrictions (LDRs) Are Applicable to CERCLA Response Actions" (OSWER 9347.3-05FS) (July 1989), placement is triggered when wastes are "[e]xcavated from an [area of contamination], placed in a separate unit, such as an incinerator or tank that is within the [area of contamination], and redeposited into the same [area of contamination]." The operative word in this statement is "excavated." With an in-situ treatment technology, placement under LDRs does not occur when wastes are treated in-situ. See LDR Guide #5. Additionally, the LDR regulations state that "movement within the unit does not constitute placement" and that "[p]lacement does not occur when waste is consolidated within an [area of contamination]..." MCP 55 Fed. Reg. 46 at 8758. Recycling of the arsenic captured in the off-gas system back for treatment, therefore would not trigger placement because it is consolidation.

Comment:

Section III. B. pg. 38

"The SFS has also failed to address how the reinjection would comply with underground injection control requirements under the Safe Drinking Water Act."

Response:

The only restraints or requirements that have been identified to date as impacting the injection of the treated ground water or of any water from actions associated with the remedial action are the requirements under the UIC Program, 40 CFR 144. The proposal for the injection of treated ground water or scrubbed water will comply with any applicable requirements.

Comment:

Section III. E. pg. 40

"[T]he combination of extremely high temperatures and toxic gases (arsenic sublimates at 613°C) may require greater levels of protection to workers. The possibility of exposure to danger could include explosion or rapid evolution of gas and molten product due to unknown pressure build-up of entrapped steam, and is of major concern due to lack of full scale testing."

Section III. E. pg. 41

"The application of large-scale electrothermic fusion is a physical situation characterized by a moist foundation, or substrate is

inherently dangerous."

Section III. E. pg. 41

"The hood control system could also fail as a result of a breakdown of the vapor sump fan or scrubber pumps, or the plugging of the scrubber... Emissions of toxic gases, vapors, and dust may not be limited to the hooded area."

Response:

The pyrolysis products produced by the in-situ vitrification treatment process, according to information supplied to EPA by the Geosafe Corporation, combust immediately upon reaching the surface because they are so hot. These gases never have an opportunity to accumulate, therefore, there is no danger of explosion.

The buildup of pressure in the in-situ vitrification treatment process is not possible unless a pressurized container is present in the treatment volume. During the treatment process, most of the water is vaporized adjacent to the base of the molten zone since the predominant melt growth is downward. When the water is converted to steam, it is buoyant. Because there is nothing to contain or pressurize the steam in this environment, the steam and any other associated vapors immediately rise in the molten liquid as bubbles. These bubbles, according to Geosafe Corporation, rise slowly through the melt, and when they reach the surface, release their contents under the off-gas hood.

The in-situ vitrification off-gas treatment system is equipped with a completely independent, self powered back-up off-gas treatment system in case of a failure of the main system. In the event of a failure of some type, power to the electrodes is immediately and automatically shut down. At the same time the diesel-powered generator starts and supplies power to the back-up off-gas treatment system which continues to process the off-gas. This entire process occurs automatically thus minimizing the chance for hood pressurization.

Gases generated during the in-situ vitrification process will find their way to the surface via the path of least resistance. This path is either through the melt as bubbles form along side the melt in the dry zone where gas permeabilities are highest. Escape of gas outside of the hood, according to Geosafe Corporation, has never been detected. During the implementation of the remedial action at the Crystal Chemical site, EPA will require air monitoring to ensure safety to human health.

Comment:

Section III. E. pg. E. pg. 42

"Geosafe's estimates of the melt progress of 1 to 2 inches per hour may not apply to engineering scale equipment and is not proven in any full scale application."

Response:

The rate of melting (1 to 2 inches per hour) is based upon full scale operations monitored by thermocouples, according to Geosafe Corporation. This rate can be controlled by variation of the power level applied to the system. Geosafe's treatability test system was designed to duplicate the measured full-scale power density. Therefore, tests performed with the engineering-scale system are representative of a full-scale application. There is no reason to assume that conditions during engineering scale operations are different than those for full-scale operations.

Comment:

Section III. G. pg. 44

"According to Davy Environmental, the scale-up problems in actual full-scale work could be formidable."

Response:

The only "problems" associated with applying the technology at full-scale at the Crystal Chemical site, according to Geosafe Corporation, are those which would be experienced with any mobile technology such as damage to equipment in transit, transport permits, assuring that utilities are in place upon arrival, and site security. The worst case scenario would involve severe damage to the in-situ vitrification transformer in transit.

Comment:

Section III. G. pg. 44

"The Crystal site is located in the Houston area which experiences high precipitation... Moreover, sudden or continuous heavy precipitation would have a tendency to hinder [in-situ vitrification], if not completely prevent [in-situ vitrification] from being performed."

Response:

As a prudent operations policy, the in-situ vitrification system would be shut down for very heavy thunderstorms. However, the treatment process can continue during rainfall in most cases. The concern is not related to lightning or other electrical phenomenon but to general site safety.

Comment:

Section III. G. pg. 44

"[S]oil moisture content of the tested Crystal sample was 22 percent by weight. Under field conditions, the moisture could be much higher and thus lead to higher costs."

Section III. H. pg. 47

"The costs of treating the soils in the former pond areas were provided at \$225 to \$240 per ton [for the in-situ vitrification technology]. During the additional treatability tests completed by Geosafe,...the costs for treatment increased to \$280 to \$305 per ton."

Section III. H. pg. 48

"[I]ncreases in the soil moisture content results in increased power requirements, thus increased cost."

Section III. H. pg. 48

"Portions of the site would require treatment of soils through the 15-foot water bearing zone. In order for the melt to go through the 15-foot zone, the water would need to be evaporated. This evaporation would require a significant increase in power requirements. Geosafe did not take this factor into consideration when developing its cost estimate. This factor will lead to an increase in costs for [in-situ vitrification] treatment."

Response:

According to Geosafe Corporation, hydraulic conductivities of aquifers or water-bearing zones $>1 \times 10^{-4}$ cm/sec, within the depth range that in-situ vitrification is to be processed, will result in water flow into the process area at rates which will inhibit the vitrification process. This situation, however, does not preclude the use of the technology. If this is the case as it is at Crystal Chemical, temporary dewatering measures in the treatment area must be implemented. These temporary dewatering measures can include installation of a slurry wall or sheet pile, installation of dewatering well points or the installation of well points where slug material (i.e., slurried bentonite) would be injected to inhibit the flow of water temporarily.

Geosafe Corporation has performed price sensitivity analysis for moisture and has determined that it has the effect of approximately \$1.00 to \$2.00/moisture weight percent/ton of waste.

Geosafe Corporation acknowledges that there was an erroneous statement made in the second treatability study. The second treatability study suggests that the increased cost per ton is attributable to a higher soil moisture content when in actuality the soils moisture were approximately the same. According to Geosafe, the predominant factor which changed the unit price was the assumed depth of processing. The assumed depth of processing used to estimate costs in the first treatability study was 24 feet, whereas the second study assumed 12 feet. The cost of treatment, according to Geosafe, is inversely proportional (non-linear) to the depth of processing because the treatment is a batch process.

Comment:

Section III. G. pg. 46

"Unlike solidification/stabilization involving an above-ground process where the performance of the technology can be certified, the in situ process occurs in an uncontrolled environment where it is impossible to certify the results."

Response:

Verifying the effectiveness of the in-situ vitrification technology

can be easily accomplished. During the process, the depth and width of the vitrified mass is continuously monitored using one or more of several techniques including thermocouples, fiber optic array, seismic profiling and depth sensing with movable electrodes. Due to the high resistivity of the melt and the behavior of electrical current in this media, the melt always forms a symmetrical shape. Once the process has been completed, verification of success can be accomplished with a simple drilling and boring technique.

Comment:

Section IV. pg. 49

"Prior to the full scale implementation of this [ground water] treatment system, additional testing should be performed to demonstrate that this complete system will be effective in treating the groundwater, especially with respect to the polishing step of ion exchange."

"With respect to the extraction of groundwater, further aquifer tests are required to determine the potential effects of long term pumping on groundwater levels and contaminant removal. These tests should be completed prior to initiating the design of the extraction and treatment system."

Response:

The Record of Decision for the Crystal Chemical states that a treatability study for contaminant removal from the ground water should be conducted. Additionally, the Record of Decision calls for an onsite pilot study to be conducted during design in order to fully investigate well placement and the most effective extraction method, and to fully investigate the injection option. Additionally, during the design phase of this remedial action, an evaluation defining the relationship between the contaminated soils and the ground water will be conducted. From this evaluation, the effects of the contaminated soils on the ability for the remedial action for the ground water to meet the remedial goal of 0.05 ppm of arsenic shall be determined. The objective of the study will be to determine the optimum depth to treatment, technically feasible, that will enable the ground water to be remediated to the MCL within the shortest practical timeframe.

Comment:

Section IV. pg. 50

"Throughout the SFS, the O&M costs presented for groundwater remediation alternatives B-1a, b, c and d were stated as annual costs when in fact these costs were present worth costs for over a 30 year time frame....This point should be clarified throughout the text of the SFS."

Response:

Comment noted.

Note: All comments made by Southern Pacific Transportation Company in Section V. pertain to a memo dated March 20, 1990 written by Jon Rauscher, EPA Region 6 Toxicologist, to the Remedial Project Managers for the Crystal Chemical Company site regarding the risk assessment basis for remediation goals.

Comment:

Section V. B. 1. a. Gastrointestinal Absorption from Soil. pg. 53
"The Rauscher memorandum applied the assumption of an arsenic oral absorption fraction from soil of 0.05 (5 percent). The basis for this assumption is unclear."

Response:

The arsenic oral absorption fraction from soil of 0.05 was based on a conservative default assumption given that an assumption of 100% would be overall conservative and inappropriate. Metals, like arsenic, tend to be poorly absorbed by the gastrointestinal tract, therefore in the absence of chemical specific data, the relatively conservative 5% absorption fraction was used.

Comment:

Section V. B. 1. and 2. b. Oral Slope Factor. pgs. 54 and 56
"The current EPA oral slope for inorganic arsenic is 1.75 (mg/kg/day)⁻¹ vs. 1.5 (mg/kg/day)⁻¹ (applied in the Rauscher memorandum). This discrepancy should be corrected."

Response:

The slope factor used in the Rauscher memorandum was not a discrepancy, but was based on risk assessment information available at the time of the drafting of the risk assessment for the Crystal Chemical site. Admittedly, the EPA oral slope factor for inorganic arsenic has undergone several modifications as new toxicological information has become available. However, the oral slope factor for inorganic arsenic presented in the Crystal Chemical Company Endangerment Assessment (1988) and TERRA, Inc.'s response to the assessment was 1.5 (mg/kg/day)⁻¹. Therefore, for consistency the Rauscher memorandum used this oral slope factor for inorganic arsenic.

Comment:

Section V. B. 1., 2., and 3. c. Exposure Duration. pgs. 54, 56, 58
"The Rauscher memorandum assumes that exposure to soil at the site occurs over an individual's entire (i.e., 70-year) lifetime. This is in contrast with the average and reasonable maximum residential exposure durations of 9 to 30 years, respectively, recommended by EPA."

Response:

The average and reasonable maximum residential exposure duration of 9 and 30 years, respectively, assumes daily exposure (365 days per year). The Rauscher memorandum assumed a lifetime exposure (70

years) with an exposure frequency of 2 days per week and 9 months per year.

The commentor suggested an exposure duration of 30 years be applied to the estimation of remediation goals. However, the commentor used the same exposure frequency as the Rauscher memorandum. This exposure frequency is not acceptable to EPA for a 30-year exposure timeframe. If exposure duration of 30 years is used, the exposure frequency should be 365 days per year.

Comment:

Section V. B. 2. a. Surface Adherence Factor. pg. 55

"The Rauscher memorandum applied a surface adherence factor of 2.8×10^{-6} Kg/cm². The results of a recent study conducted for EPA of soil adherence factors in various soil types indicates that the factor applied in the assessment was a substantial overestimate... We propose that the mean adherence factor of 0.58×10^{-6} Kg/cm² is a more appropriate assumption to apply."

Response:

The Rauscher memorandum applied an adherence factor suggested in the Superfund Exposure Assessment Manual, April 1988 (OSWER Directive 9285.5-1), which was guidance in effect at the time of the drafting of the Endangerment Assessment for the Crystal Chemical site.

Comment:

Section V. B. 3. a. Air Arsenic Concentration from Contaminated Soil. pg. 57

"The [Air Arsenic Concentration for Surficial Soil] applied in the [Rauscher] memorandum was 3.7×10^{-7} Kg/m³ (= 370 µg/m³), with the reference for this factor reported to be the Endangerment Assessment. Upon reviewing the Endangerment Assessment, it appears that this factor is actually a soil concentration in air, rather than an arsenic air concentration."

Response:

Comment noted.

Comment:

Section V. B. 3. b. Inhalation Slope Factor. pg. 57

"The current EPA inhalation slope factor for inorganic arsenic is 50 (mg/kg/day)⁻¹ based upon a 30 percent absorbed dose. The calculation of the inhalation human intake factor in the Rauscher memorandum, however, was based upon a 100 percent absorbed dose... On the basis of this error the resultant inhalation risk estimated is too high by a factor of 3.33 (i.e., 1/.3)."

Response:

The EPA Endangerment Assessment for the Crystal Chemical Company site was written in July 1988 under the guidance of the Superfund Public Health Evaluation Manual ("SPHEM"). The proposed

remediation goals of 15.0, 1.5, and 0.15 mg/kg for the excess lifetime cancer risk levels of 10^{-4} , 10^{-5} , 10^{-6} , respectively. These levels were subsequently adjusted to account for site specific exposure patterns. The adjusted remediation goals were 300, 30.0 and 3.0 mg/kg for the excess lifetime cancer risk levels of 10^{-4} , 10^{-5} , 10^{-6} , respectively (Reitman memo, September 1988).

The commentor is correct in identifying that the current inhalation slope factor is adjusted for absorption, however, the inhalation slope factor for the original endangerment assessment did not take into account this adjustment because SPHEM did not differentiate between administered dose and absorbed dose. Therefore, for consistency the Rauscher memorandum used this inhalation slope factor.

Although the Rauscher memorandum states that adjustments were made to account for not only site specific conditions but also to account for changes in risk assessment guidance from SPHEM to the Risk Assessment Guidance for Superfund, Human Health Manual, Volume 1, Part A ("RAGS"), the memorandum was incorrect. The adjustments to the excess lifetime cancer risk levels were made prior to the RAGS guidance, therefore, the citation of RAGS guidance is not appropriate in this instance.

Comment:

Section V. C. 1. a. Ingestion of Contaminated Soil. pg. 59

The commentor, based on differing assumptions, calculated a HIF for ingestion.

Response:

EPA does not agree with the exposure duration used in the calculation. The commentor suggested an exposure duration of 30 years be applied in the calculation. However, the commentor used the same exposure frequency as the Rauscher memorandum. This exposure frequency is not acceptable to EPA for a 30-year exposure timeframe. If the exposure duration of 30 years is used, the exposure frequency should be 365 days per year.

Comment:

Section V. C. 1. c. Remediation Goal Based on Ingestion and Dermal Exposure Combined. pg. 61

Section V. C. 1. d. Remediation Goal Based on Ingestion Exposure. pg. 61

The commentor, based on differing assumptions, calculated remediation goals based on ingestion and dermal exposure combined and on ingestion exposure.

Response:

The EPA target risk range is 10^{-6} or one in one million to 10^{-4} or one in ten thousand excess lifetime cancer risk. If this risk range proposed by the commentor were used, the remediation goal

based on a combined ingestion and dermal exposure, and for an ingestion exposure would be from 16 mg/kg. to 1620 mg/kg and from 18 mg/kg to 1790 mg/kg, respectively. EPA does not agree with the parameters within which these exposure scenarios were formulated nor does EPA agree with the basic assumptions used when calculating these values. However, the 30 ppm arsenic offsite remediation goal and the 300 ppm arsenic onsite treatment level do fall within the commentor's risk range.

Comment:

Section V. D. pg. 63

Commentor requests that EPA adopt a remediation goal for the site at the upper end of the acceptable risk range, i.e., at the 10^{-5} level instead of the 10^{-6} level.

Response:

The NCP, 40 CFR 300.430(e)(2), states in part that for known or suspected carcinogens "[t]he 10^{-6} risk level shall be used as the point of departure for determining remediation goals..." Therefore, the 10^{-6} risk level is the starting point when determining remediation goals and departure from this 10^{-6} is to be based on site-specific or remedy-specific conditions. In the case of Crystal Chemical where the 10^{-6} to 10^{-4} range is from 3 to 300 ppm, the 10^{-5} risk level was determined to be acceptable. For a complete explanation of the remediation goals, refer to the SUMMARY OF SITE RISKS Section of this Record of Decision.

Comment:

Section V. D. 1. pg. 65

"The current maximum contaminant level (MCL) for arsenic in drinking water is 50 $\mu\text{g/l}$. This level corresponds to an excess lifetime cancer risk of one in 400, assuming the EPA-derived CPF is correct. Although we understand that the MCL may be lowered, a 10-fold lowering will not reduce risk below one in 4,000. This suggests either a major shift in EPA policy regarding levels of tolerable risk for arsenic or substantial doubt within the agency about the reliability or the CPF."

Response:

"EPA's Superfund program uses EPA's Ground-Water Protection Strategy as guidance when determining the appropriate remediation for contaminated ground water at CERCLA sites... For Class I and II ground waters, preliminary remediation goals are generally set at maximum contaminant levels..." 55 Fed. Reg. 46 at 8732. MCLs are enforceable limits set as close to maximum concentration limit goals (MCLGs) as feasible, however other factors are taken into consideration (e.g., availability of treatment technologies and cost of compliance). MCLGs are non-enforceable health-based limits set at a level at which no adverse effects on human health exist. The MCLG for arsenic is zero (0). Trying to equate a site-specific excess lifetime cancer risk of a contaminant to its ground water MCL is inappropriate.

Comment:

Section V. D. 2. pg. 66

"It is not at all clear why EPA's CPF might be in error."

Section V. D. 2. pg. 67

"Given the considerable uncertainty related to the cancer potency factor for arsenic, and the strong evidence that it likely overestimates substantially the cancer risk associated with low level exposures, a relatively high acceptable risk level is supported when this CPF is applied."

Response:

The cancer unit risk for arsenic provided in the Integrated Risk Information System has undergone extensive peer review by the EPA-wide Carcinogenic Risk Assessment Verification Endeavor ("CRAVE") workgroup and represents an Agency consensus.

Comment:

Section V. D. 3. pg. 68

"Arsenic at the Crystal Chemical site is primarily in organic forms...which are generally considered less toxic than the inorganic salts. The cancer potency factors that EPA has developed, however, apply to inorganic arsenic, and would therefore likely overestimate the cancer potential of the arsenic forms at the Crystal Chemical site."

Response:

Arsenic speciation is important, however, organisms can transform arsenic from a less toxic form to a more toxic form. EPA approaches risk conservatively and, therefore calculated risk for the Crystal Chemical Company site using the most toxic form of arsenic.

Comment:

Section V. D. 4. pg. 68

"The remediation goals for the Crystal Chemical site were estimated based on the assumption that future land use will be strictly residential... [T]he total potential arsenic exposure to an industrial receptor would likely be substantially less than that to a lifetime resident."

Response:

Although a site may be used for commercial or industrial use or located in an area that is predominantly commercial or industrial at the time of remediation and institutional controls or site restrictions may be placed on the site, there are no assurances that the area land use will remain the same. The City of Houston does not at this time have zoning ordinances, therefore EPA takes a conservative approach and calculates risk so that all potential scenarios are taken into consideration.

Comment:

Section V. D. 5. pg. 69

"Ingested inorganic arsenic is associated with a nonfatal form of skin cancer. On the basis of the nonfatality of this tumor type, EPA has issued guidance that a 10-fold higher acceptable risk level may be justified."

Response:

EPA is unclear as to what specific guidance the commentor is referring to, however, even if EPA assumed a 10-fold higher risk level, this would not affect EPA's remediation goals for arsenic at the Crystal Chemical Company site.

Comments received from Waco Financial Corporation

Question:

"We would like to know if the fact that your preferred plan of action calls for all off-site soils to have up to 30 parts per million (ppm) of arsenic would limit any future activities we might have for our property; that is, if that would preclude us from having apartments or single family residences, etc."

Response:

The 30 ppm arsenic contamination level was determined to represent a 10^{-5} excess lifetime cancer risk level. EPA requires that remediation levels be set some where between a 10^{-4} and a 10^{-6} cancer risk. For the Crystal Chemical site that translates into a range from 300 ppm to 3 ppm. The 10^{-5} (i.e., 30 ppm arsenic) remediation level was determined to represent a safe health-based action level. Therefore, this would not preclude any future use of the offsite areas affected by the remedial action, once the contaminated soil has been removed from the property. For a complete discussion of the remediation goals for the site see Section V. SUMMARY OF SITE RISKS in this Record of Decision.

Question:

"It appears to us that through the remediation process, which includes capping, there would be no arsenic present on the surface of the Crystal Site, but your plan calls for leaving 30 ppm on off-site properties. We wonder why you would leave higher levels of arsenic off-site than would be present after the remediation of the site itself."

Response:

The remediation goals for the Crystal Chemical site were addressed in an earlier question from Waco Financial, however, the remediation of the site itself has other factors involved. The cap that will be constructed on the site after the in-situ vitrification treatment process has been completed will serve two purposes. The main purpose of the cap is to prevent the continued infiltration of water (i.e., rain) through the soils containing

residual amounts of arsenic contamination. This cap will eliminate the potential migration pathway from the residual arsenic contaminated into the ground water. The second purpose of the cap is to prevent direct contact with the treated material on site. The in-situ vitrification technology basically melts the contaminated soil. When it cools, it resembles glass. Although the structural integrity of the mass is not in question, EPA would prefer not to leave the treated mass exposed to the elements.

Question:

"The proposed cap appears to be 5 feet in thickness and we wish to know exactly what sort of grading or drainage provisions will be made so that our tract will not be adversely be affected."

Response:

During the design phase of the remedial process, the engineering design specifications required to ensure proper onsite and offsite drainage will be determined. A public workshop at the end of design will be conducted so that EPA can discuss and you can evaluate the impacts of the drainage control system.

Question:

"Addressing the treatment of the underground water, we wish to know if it would be necessary for any pumps to be placed on our property, and if our property's use will be restricted in any way during the treatment of the underground water."

Response:

Again, during the design phase of the remedial process for the Crystal Chemical site, a study will be conducted on the site to investigate the most effective method for extracting the contaminated ground water. The extraction method will include the placement of wells, however, the location of these wells won't be determined until the site is more thoroughly investigated. It is possible that wells may need to be located on your property, however, their placement would not be finalized until we have contacted you and obtained your permission. If EPA does place extraction or reinjection wells on your property, the restrictions on your use of your property would be limited to ensuring that any activities that you planned for the property would not adversely affect the wells or the ground water flow in the area.

Question:

"We wish to ascertain as to whether or not the treatment of the Crystal Site will create any nuisances, such as noise, dust, odor, etc."

Response:

Given that offsite soils contaminated with arsenic will need to be excavated and relocated back on to the site, heavy equipment such as bulldozers and trucks will be used and there is a possibility of dust emissions during the excavation. However, precautions such

as dust suppression and heavy equipment traffic control will be implemented during the remedial activities onsite to minimize any problems.

Comments received from Andrew & Kurth

Comment:

"The arsenic and other contaminants at the site should be cleaned up adequately to protect the environment and the health and safety of those working and living nearby."

Response:

Protection of human health and the environment is a mandate of Superfund law. EPA's preferred method of treating the contamination problems at the Crystal site satisfies this mandate and should satisfy your concerns.

Comment:

"The site should be cleaned up expeditiously."

Comment noted.

Comment:

"The clean-up project should be designed and implemented so as not to affect nearby property owners or residents any more than absolutely necessary."

Comment noted.

Comment:

"Interested persons should be kept informed of EPA's work and the remedial process so that they may participate adequately to protect their interests."

Response:

Fact sheets, open houses, workshops, and community meetings are used as tools by EPA to keep interested persons informed of site activities. A toll free number (1-800-533-3508) has been established by EPA so that interested citizens can call to obtain specific information to specific inquiries.

Comment:

"Alternatives A-8 (capping only), A-9 (no action) and A-10 (limited action) for soil contamination are unacceptable to McKinney because they would not provide sufficient "source control" of the contamination."

Comment noted.

Comment:

"Alternative A-1 (excavation/offsite disposal) is unacceptable

because massive soil excavation and transportation through the neighborhood would have major negative impacts on the health and safety of people living and working nearby (e.g., due to truck traffic and contaminated dust)."

Comment noted.

Comment:

"EPA's determination to clean or remove soil that is contaminated with arsenic at levels above 300 ppm appears to be reasonable."

Response:

Actually, EPA will be excavating all offsite soils contaminated with arsenic above 30 ppm, and will be treating all soils with the in-situ vitrification treatment process that are contaminated with arsenic greater than 300 ppm.

Comment:

"Alternatives A-2 (vitrification) and A-4 (soil washing) would take roughly twice as long to implement as Alternatives A-3 (solidification), A-5 (partial solidification), A-6 (partial solidification) and A-7 (partial soil washing), and are therefore less desirable."

Comment noted.

Comment:

"EPA has determined that in situ vitrification substantially reduces the likelihood of arsenic leaching to the groundwater (as compared the post-solidification leaching). To the extent that this critical determination is accurate, vitrification would appear to be the preferred alternative."

Comment noted.

Comment:

"EPA should carefully evaluate and plan for the movement of construction vehicles in the neighborhood. The transportation routes should avoid residential and commercial properties such as McKinney's whenever possible."

Response:

EPA will make every attempt during the implementation of the remedial action to inconvenience everyone as little as possible.

Comment:

"Of the groundwater remedial alternatives, B-3 (no action) and B-4 (limited action) are unacceptable because they do not provide source control and do not prevent or reverse offsite migration of contamination. Alternative B-2 (slurry wall) would be intended to prevent further migration but would not reduce the contamination levels."

Comment noted.

Comment:

"Groundwater remediation alternatives B-1a (extraction, discharge to POTW) and B-1b (extraction, treatment, discharge to surface water) appear to be reasonable and supported by the information contained in the administrative record. The difficulty of discharging to a POTW appears to constitute a basis for selecting option B-1b over B-1a."

Comment noted.

Comment:

"Air emissions from onsite activities, especially fugitive dust and gases from the groundwater treatment plant, must be stringently controlled and carefully monitored."

Response:

EPA will implement actions to minimize air emissions and will monitor for air emissions during all phases of the remedial action pursuant to 40 CFR 50.

Comments received from Mr. Steve Sheffield

Comment:

"I am of the understanding that there are not 1, but 2 contaminated aquifers (one at 15', one at 35') - your report only addresses one - the shallow one."

Response:

The Record of Decision addresses both the 15' and 35' water-bearing zones at the Crystal Chemical Company site. Collectively, they are referred to as the shallow water-bearing zone since they are hydraulically interconnected. Additionally, the Record of Decision calls for a more thorough investigation of the deeper water-bearing zones and calls for their remediation if warranted.

Comment:

"Children do play in the immediate area. Adults also frequent this area,... On more than one occasion, I've kicked several kids out from inside the fence (on the site)."

Response:

EPA fenced the perimeter of the site and posted the fence with warning signs documenting that the site is a hazardous waste site. The public in the area has been notified of the hazards of the site through EPA's community relations outreach. Although EPA has undertaken actions to prohibit unauthorized entry to the site, it is acknowledged that there may be some unauthorized entry.

Comment:

"[R]egarding the 5 specific potential pathways of exposure at the site listed [in the proposed plan], #5 [ingestion of contaminated fish from the flood control ditch] is virtually impossible... Also, no one ingests the shallow ground water (from the 15' aquifer), so this route of exposure is virtually impossible."

Response:

EPA and the Agency for Toxic Substances and Disease Registry approach health assessments and exposure scenarios conservatively. The five specific exposure scenarios are potentials and are identified as such. It has been documented that people have been seen fishing in the Harris County Flood Control Channel, therefore EPA must assume that they may eat whatever they catch. The 15' water-bearing zone, because it is hydraulically interconnected with the 35' water-bearing zone and meets the Class IIb aquifer flow potential, constitutes a potential public water source. Therefore, it must be considered a potential exposure pathway.

Comment:

"My biggest problem with your plan of action isn't the plan itself, but what your numbers that you're using are based on. For example, you are using western US arsenic [concentrations] as backgrounds - it is a well-known fact that soils in the west are naturally much more rich in arsenic than soils in the east... I think you should have used arsenic [concentrations] from the eastern US as backgrounds. This would provide us with more natural background numbers, and would provide the people who live out near Crystal with more protection."

"Removal of off-site soils to a [concentration] of 30 ppm is not enough! 30 ppm of [arsenic] can cause a lot of problems in the environment. Besides, the 30 ppm is based on the background [concentration] of arsenic in western soils,..."

Response:

The soil remediation goals for the Crystal Chemical site are risk-based generated numbers and are not based on naturally occurring background levels of arsenic in either the western or eastern soils. The 30 ppm arsenic offsite contamination level was determined to represent a 10^{-5} cancer risk level. EPA requires that remediation levels be set some where between a 10^{-4} and a 10^{-6} cancer risk. For the Crystal Chemical site that translates into a range from 300 ppm to 3 ppm. The 10^{-5} (i.e., 30 ppm arsenic) remediation level was determined to represent a safe health-based action level and was deemed appropriate since background mean arsenic levels found in natural soils is 6.1 and 4.8 ppm in western and in eastern soils, respectively. Therefore, there is not a significant difference in the mean concentration of arsenic detected in western and eastern soils. For a complete discussion of the remediation goals for the site see Section V. SUMMARY OF SITE RISKS in this Record of Decision.

Comment:

"I don't understand how you are going to deal with vitrifying the soil between the aquifers. The soil is contaminated at the site down to 40 feet; how will you deal with getting at the deeper soil? How do you vitrify through an aquifer?"

Response:

The in-situ vitrification technology at this time is limited in its effective treatment depth. To date, in-situ vitrification has been effectively used to treat contaminated soils to a depth of 16 feet. However, at the time of the implementation of the technology, the effective treatment depth may be greater. Regardless, the depth limitation of the technology is an acceptable limitation to EPA because of the selected ground water remedy. Additionally, saturated soils do not inhibit the vitrification treatment process, though it does make it more costly. If it is determined that treatment must be done below the permanent water table to ensure the effectiveness of the total remedy and it is technically feasible to do so, then some sort of dewatering may be required to extend the depth of treatment.

Comment:

"I believe that the treatment alternatives that you've chosen are probably the best that you've got and seem to make sense. I question the figures and concentrations that you are using, though. I think they are biased and unsound. I really don't think 30 ppp should be left outside the site, but I could probably live with the 95% of all the arsenic on the site being vitrified as long as the other 5% is guaranteed contained by the multi-layer cap."

Response:

The multi-layer cap will be constructed over the entire site once the soils treatment has been completed. The site will require long-term O&M and the cap will have to be maintained in perpetuity.

Comments received on behalf on Voluntary Purchasing Group, Inc.

Comment:

INTRODUCTION pg. 4

"The ponds were emptied of water, and the site sealed with plastic and capped with a clay layer by EPA under an Emergency Action in 1983/1984 era."

Response:

The evaporation ponds contained 600,000 gallons of wastewater with an average concentration of arsenic of 15,000 ppm. This material was pumped and disposed. The EPA Emergency Removal Action commenced in September 1981 and was completed in February 1983.

Comment:

The author of the comments, Edwin A. Woolson, Ph.D., suggests that

a remedial plan that "includes treating selected portions of arsenic laden soils with ferrous sulfate, reworking some surface soils on-site to facilitate surface runoff management, building a cap, and constructing a parking lot/building to isolate contaminated soils" be implemented at the Crystal Chemical Company site.

Response:

Solidification/stabilization technology was evaluated during the course of completing the Supplemental Feasibility Study for the site. Specifically, the addition of ferrous sulfate as the solidification/stabilization agent was not explored during the treatability studies. Therefore, its appropriateness cannot be evaluated.

Comment:

Dr. Woolson proposes remedial action arsenic-contaminated soil levels different from EPA. "Threshold concentrations for arsenic in a soil are suggested to be set at 0 to 200 ppm (acceptable to leach in place; not phytotoxic), 200 to 1,500 ppm (stable in native soils; no need for isolation unless at surface), 1,500 to 5,000 ppm (stable in native soils; recommended for isolation), and greater than 5,000 ppm (appear stable in native soils; recommended for chemical stabilization and isolation)."

Response:

EPA's remediation goals for the arsenic-contaminated soils at the Crystal Chemical Company site are risk-based numbers and are not based on the stability of the arsenic in a soil matrix.

Comment:

"CERCLA requires that the Site be placed under institutional control if any contamination remains after completion of the Remedial Action... However, permitting this land to remain fallow would also be disadvantageous to the continued economic growth of the surrounding property, and might tend to diminish the value of any adjoining land."

Response:

CERCLA does require that the a review of the remedial action occur "no less often than each 5 years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented" if the remedial action results in any hazardous substances, pollutants, or contaminants remaining at the site, CERCLA Section 121(c), 42 U.S.C. Section 9621. Such is the case with the selected remedial action for the site and it would also be the case with the implementation of the remedial action proposed by Dr. Woolson. In addition to the 5 year review, because of the implementation of a ground water remedy, site access and land use restrictions would be enforced until the ground water remediation goal was met, which could take as long as 30 years. Furthermore, the implementation

of EPA's selected remedy as well as in the case of the remedial action proposed by Dr. Woolson, requires that a multi-layer cap be constructed over the site following completion of the soils treatment. If the site were allowed to be used as a parking lot or as the foundation for a building, special and maybe very costly site preparation would be required. Additionally, the site would have to be maintained in such a way as to not compromise the integrity of the multi-layer cap and to ensure that the treated soils remain intact and protected from exposure.

Any remediation of the Crystal Chemical Company site should improve existing conditions. EPA's job, however, is to protect human health, welfare, and the environment, not to ensure that the value of property surrounding a CERCLA site either increases or decreases in value.

Comments received from Gerald P. Motl, Vice President of Halliburton Environmental Technologies, Inc.

Comment: Mr. Halliburton, on behalf of his company, commented that he concurred that in-situ vitrification "can be used effectively to remediate soils contaminated with heavy metals", however, he felt that solidification/stabilization had not been given a "comprehensive evaluation." Mr. Halliburton offered, on behalf of his company, to perform treatability tests at not cost to EPA.

Response:

The selection of this remedy is being made following completion of a study to identify all possible treatment technologies and alternatives that could address the contamination problem at the site. Solidification/stabilization was one of the treatment technologies that was evaluated for the site. Although EPA acknowledges that the solidification/stabilization technology has been proven effective on other sites and specifically those sites contaminated with arsenic, EPA, based on specific data generated for the Crystal Chemical Company site and based on the Agency's general knowledge of the technology, has in good faith proposed a remedy for the Crystal Chemical Company site that utilizes the in-situ vitrification technology. Therefore, EPA will not be conducting any additional treatability testing for the site. EPA did, however, appreciate the offer of conducting additional treatability studies.

C. Comments Received from Texas Water Commission.

TWC Comment:

"Section 300.430(f)(1)(ii)(B) of the National Contingency Plan (NCP) requires that on-site remedial actions selected in a ROD must

attain those applicable or relevant and appropriate requirements (ARARs) that are identified at the time of ROD signature ... The maximum contaminant level (MCL) for arsenic of 0.05 mg/l is an ARAR for the ground water...feasibility study (FS) ... fail to comprehensively evaluate the range of available source control and ground water remedial actions necessary to ensure compliance with this ground water ARAR."

EPA Response:

The NCP citation in question deals with the "attainment of ARARs." The argument as to whether the SFS "comprehensively evaluates the range of alternatives necessary to ensure compliance" with the ground water ARAR, is a matter of opinion which is not shared by EPA.

According to EPA guidance (i.e. Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites, December 1988), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA) principally requires that remedial actions protect human health and the environment and meet ARARs. This requirement is essentially reiterated in the NCP.

Examination of the SFS will reveal that there are ten (10) source control alternatives and four ground water alternatives, that survived initial screening, for consideration of use at the site. EPA's preferred alternative of partial in-situ vitrification (for the source) and pump and treat (for the ground water) satisfy the requirements of both the statute and the NCP. Relative to the attainment of ARARs, the ground water alternatives described under the "Extraction and Treatment" scenarios will have a goal of meeting the 0.05 mg/l MCL for arsenic (which is the ARAR), as discussed in the Section 5.3.1.2 entitled "ARARs Compliance." These discussions are also carried forward in the Record of Decision.

TWC Comment:

The [S]FS does not satisfy the requirement of Section 300.430(e)(9)(iii)(C)...to assess the long-term effectiveness ..."

EPA Response:

Section 300.430(e)(9)(iii)(C) of the NCP establishes the procedures set forth by EPA to perform the detailed analysis of alternatives in the feasibility study, specifically the evaluation of each alternative against the nine criteria (i.e. (1) overall protection of human health and the environment, (2) compliance with ARARs, (3) long-term effectiveness and permanence, (4) reduction of toxicity, mobility, or volume through treatment, (5) short-term effectiveness, (6) implementability, (7) cost, (8) state acceptance, and (9) community acceptance.

The NCP requires that in evaluating alternatives for "long-term effectiveness" the following factors be "considered" as appropriate: (1) magnitude of residual risk remaining after treatment; and, (2) adequacy and reliability of controls necessary to manage treatment residuals and untreated wastes. EPA's evaluation of the alternatives in the SFS complies with the NCP. For example, EPA's preferred alternative (A-5 - In Situ Vittrification/Multi-layer Cap) in Section 5.2.5.4 of the SFS (page 5-39) entitled "Long-Term Effectiveness and Permanence" indicates that "the magnitude of risk ... will be below the 10⁻⁶ increased cancer [risk] level. The remaining sources of inhalation and direct contact risk from untreated (deep) soils following the remedial action will be insignificant ... Studies have suggested that the vitrified soils, however, will retain their physical and chemical integrity in excess of 1000 years." The SFS goes on to say that the "adequacy and reliability" of the treatment technology has been demonstrated thorough numerous bench- and pilot-scale tests. Relative to the controls necessary to manage treatment residuals and untreated wastes, EPA proposed the use of a cap to reduce the potential for migration of contaminants from the site and to minimize any direct contact threat. Maintenance activities are also proposed in the SFS and the Record of Decision to ensure proper operation of the remedy. Institutional controls (restricting site use) are proposed in the Record of Decision to further ensure proper operation of the remedy and also to reduce the probability of any direct contact threat with contaminant residuals. Finally, the 5-year review mandated by the Superfund statute will provide EPA an opportunity to monitor the long-term effectiveness of the remedy.

TWC Comment:

"The available documents fail to adequately consider the relationship between the extent of the source control remedial action and the ability to restore ground water at the site to the required level."

"These soil remediation levels were not based on an evaluation of the soil arsenic levels that will allow the MCL for arsenic to be achieved in ground water ... there is no analysis in ... the SFS to demonstrate that the selected soil remediation level will allow the ground water to be adequately restored."

EPA Response:

The commentor is correct in pointing out that the soil remediation plan does not consider the relationship between the extent of source control and the ability to restore the ground water. EPA's preferred remedy is comprised of two components, which together are conceived to address both the arsenic contaminated soils (the source) and the contaminated ground water. During the design phase of the remedial action, an evaluation will be conducted to assess the relationship between the contaminated soils and the ground water. From this evaluation, the effects of the contaminated soils

on the ability for the ground water remedial action to achieve the remediation goal of 0.05 mg/l of arsenic shall be determined. The objective of the study will be to determine the optimum depth of soil treatment, technically feasible, that will enable the ground water to be remediated to the MCL within the shortest practical timeframe.

In response to the second comment, Section 300.430 of the NCP mandates that remedies be selected that eliminate, reduce, or control risks to human health and the environment. To help meet this mandate, EPA has developed a human health evaluation process as part of its remedial response program. The process of gathering and assessing human health risk information is described in EPA guidance entitled "Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A)", December 1989. The risk assessment for the Crystal Chemical site can be found in Appendix D of the SFS (Volume II). Soil remediation levels outlined in the SFS are based on the findings of the risk assessment as discussed in Section 2.4 of the SFS (pages 2-94 - 2-102). The resulting remediation goals established by EPA are consistent with the intent of the NCP in that they succeed in providing EPA with a remedy that is protective of human health and the environment.

TWC Comment:

B. Maximum Depth of Treatment

"An arbitrary assumption was made in the FS with regard to the maximum depth of treatment."

EPA Response:

For the purposes of the SFS, the selection of "15 feet below the ground surface, or to the ground water level, whichever is less" was a logical demarcation. Assumptions have to be made in the SFS to allow for the development of cost estimates. Additionally, EPA is obligated to consider the various limitations of the technology including the maximum achievable depth of treatment, variability associated with dewatering, and cost of primary treatment v. secondary recovery and treatment of ground water through pump and treatment. Many of these unknowns will be determined during the remedial design. Additionally, as indicated in EPA's response to TWC Comment 3, the optimal depth of treatment will be specified as a result of this additional work.

TWC Comment:

"This approach is not consistent with Section 300.430(e)(3)(i) of the NCP which requires the lead agency to develop a range of alternatives in which treatment that reduces the toxicity, mobility, or volume ... as a principle element" [referring to the depth of treatment].

EPA Response:

The NCP citation above includes clarifying statements to the extent that the range of alternatives be "appropriate" and include options that "removes or destroys hazardous substances, pollutants, or contaminants to the maximum extent feasible, ..." "Appropriate and feasible" are important elements of this requirement. The SFS establishes a wide range of alternatives that address both the source and ground water contamination problems at the Crystal Chemical site. Considering the limited feasibility of gaining access to contaminants beneath a depth of 15 feet or beneath the ground water table, the source control alternatives outlined in the SFS are appropriate and comply with the requirements of the NCP.

The TWC comments maintain that there are significant levels of contaminants below the water table at the site which may slow the rate of ground water cleanup. The draft ROD acknowledges this possibility by costing the remediation using a 30-year extraction and treatment period. This timeframe would allow for numerous pore volumes of contaminated water (up to 10) to be removed so that the contamination sorbed to the aquifer skeleton can desorb and also be treated. However, regardless of the assumptions made in the SFS and draft ROD, more data will be evaluated in during the remedial design which will allow for the determination an optimum depth of treatment.

TWC Comment:

"EPA's rationale for selection of the partial treatment remedy is not consistent with Section 300.430(f)(1)(D) of the NCP. This section requires each remedial action selected to be cost-effective provided that it first satisfies the threshold criteria of being protective of human health and the environment and attaining ARARs."

EPA Response:

Section 300.430(f)(1)(i) of the NCP establishes that the criteria noted in Section 300.430(e)(9)(iii) shall be used to select a remedy. Section VIII. of the Record of Decision, entitled Summary of Comparative Analysis of Alternatives, sets forth EPA's evaluation of the various alternatives against the nine criteria (cited in Section 300.430(e)(9)(iii)). Table 17 presents this evaluation in tabular form for all of the soil remedial alternatives. This information establishes EPA's preferred alternatives as the remedies of choice, thus is in compliance with the NCP. However, the above comment appears to question whether EPA's selected remedy is protective of human health and the environment and attains ARARs. EPA's response to TWC Comment 3 above set forth the rationale for incorporating the human health evaluation process into the remedial response program. EPA's risk assessment (as outlined in Section 2.4 and Appendix D of the SFS) established a remediation plan that is both protective of human health and the environment and meet the intent of the NCP. These findings as well as the recommended soil and ground water

remediation goals have been reviewed by the proper public health agencies and have been accepted. EPA's response to TWC comment 1 addressed the issue of attaining ARARs. Again, EPA has established the MCL (0.05 mg/l) for arsenic as the remediation goal in ground water. The MCL is the ARAR, thus EPA has complied with in NCP.

TWC Comment:

2. Ground Water Alternatives for the 15 and 35 Foot Aquifers

A. Range of Alternatives

"the FS does not comply with Section 300.430(e)(4) of the NCP which requires the lead agency to develop a limited number of remedial alternatives that will attain site-specific remediation levels within different restoration time periods ..."

EPA Response:

Given the small areal extent and depth of the plume at the site, the time needed to attain remedial goals will be governed largely by the partitioning behavior of arsenic rather than the number of extraction wells or pumping rate. Therefore, in theory, it would be a somewhat meaningless exercise to vary pumping rates and numbers of wells to develop different timeframes for what is essentially the same alternative. During the design of the remedy, pilot testing will be conducted to optimize the efficiency of the extraction system to achieve remedial goals as quickly as possible.

TWC Comment:

"It is clear ... that the 30 year remediation period is based on a standard assumption rather than a calculated or other realistic estimate of the restoration timeframe ... the NCP describes EPA's expectation of returning useable ground water to their beneficial use whenever practicable, within a time frame that is reasonable ... a reasonable time frame cannot be made given the analysis ..."

EPA Response:

The commentor is correct in stating that it is not possible to determine the exact restoration timeframe from the ROD since only a worst-case timeframe of 30 years is discussed. However, given the problems that have been encountered in predicting cleanup timeframes at ground water sites across the country, EPA determined it appropriate to use a worst-case scenario rather than an estimate calculated on insufficient data. Before a revised estimate is made, pilot testing will be conducted in the design phase of the project.

TWC Comment:

B. Off-Site Water Supply Wells Within About 1000 Feet

C. Off-Site Water Supply Wells Within About 1 Mile

"EPA should pursue whatever additional analysis of study is necessary to provide satisfactory explanation of these higher than expected ground water arsenic values."

EPA Response:

The detection of arsenic at levels below the MCL in off-site wells does not warrant a trouble-shooting expedition to find a "satisfactory explanation" for these values.

ATTACHMENT 2

STATE OF TEXAS CONCURRENCE LETTER

TEXAS WATER COMMISSION

B. J. Wynne III, Chairman
John E. Birdwell, Commissioner
Cliff Johnson, Commissioner

John J. Vay, General Counsel
Michael E. Field, Chief Hearing Examiner
Brenda W. Foster, Chief Clerk

Allen Beinke, Executive Director

September 25, 1990

Allyn M. Davis, Ph.D., Director
Hazardous Waste Management Division
U. S. Environmental Protection Agency
Region 6
1445 Ross Avenue
Dallas, Texas 75202-2733

Re: Crystal Chemical Company Superfund Site
Draft Record of Decision

Dear Dr. Davis:

We have reviewed the proposed Record of Decision (ROD) for the Crystal Chemical Company Superfund site. We note that EPA has addressed many of the issues raised by TWC after review of the draft ROD. The most significant issues were the need for further investigation of the 100 foot aquifer and our concern as to whether the source control was comprehensive enough to ensure the attainment of ground water ARARs. We are encouraged by your statement in the revised ROD that a study of the relationship between the contaminated soils and the ground water will be conducted during the remedial design in order "to determine the need for and feasibility of deeper, more extensive soil treatment that will enable the ground water to be remediated to the MCL within the shortest practical timeframe." We believe that this is a key component of the proposed remedy. We agree with the proposed remedy as presented to us on the condition that EPA ensure that all necessary and feasible efforts be made to eliminate all sources of contamination affecting attainment of the ground water MCL.

Sincerely,

Allen Beinke
Allen Beinke,
Executive Director

ATTACHMENT 3

ADMINISTRATIVE RECORD INDEX