PREASSESSMENT SCREEN DETERMINATION
Rocky Mountain Arsenal Superfund Site
Denver, Colorado
Final, January 12, 2007

I. INTRODUCTION

A. Action

This document is a Preassessment Screen Determination ("PASD") for the Rocky Mountain Arsenal ("the Arsenal"), a federal facility operated by the United States Army from 1942 to the present, with portions of the facility leased to the Shell Chemical Company from 1952 to 1982. The PASD was prepared by the Office of the Colorado Attorney General in consultation with and on behalf of all the Natural Resources Trustees for the State of Colorado, who were designated pursuant to section 107(f)(2)(B) of CERCLA.

B. Authority

The Comprehensive Environmental Response, Compensation, and Liability Act, as amended by the Superfund Amendments and Reauthorization Act, 42 U.S.C. § 9601 et seq. (CERCLA), authorizes the State to recover, on behalf of its citizens, damages for injuries to natural resources, including the supporting ecosystems, that belong to, are managed by, appertain to, or are otherwise controlled by the State.

The trustees may only recover natural resource damages for injuries that exceed "baseline" conditions. Baseline means the condition or conditions that would have existed at the assessment area had the release of the hazardous substance not occurred. *43 C.F.R. § 11.14(e).* Baseline considerations require that the trustees distinguish between the injuries resulting from the actions of the responsible parties and injuries resulting from other causes. The baseline level is compared to the level existing or anticipated upon completion of the response action to determine the residual injury. *50 Fed. Reg. 52126, 52133 (December 20, 1985).* In addition, the Trustees may recover damages for interim lost use and value of the natural resource during the period of time required to restore, replace or acquire the equivalent of the injured natural resource. *In re Acushnet River & New Bedford Harbor: Proceedings re Alleged PCB Contamination*, 712 F.Supp. 1019, 1035 (D. Mass. 1989).

C. Regulatory Guidance

Pursuant to section 301(c) of CERCLA, the Department of the Interior ("DOI") promulgated regulations for natural resource damage assessments ("NRDA"), which can be found at 43 C.F.R. Part 11. Adherence to these regulations is not mandatory and does not preclude the State Trustees' use of alternate methods of assessing damages or arriving at a negotiated settlement with responsible parties. However, under CERCLA section 107(f)(2)(C), an assessment made in

accordance with the regulations has the force and effect of a rebuttable presumption of correctness on behalf of the trustees.

D. Purpose

The purpose of the PASD is to determine whether a discharge or release of a hazardous substance warrants conducting a Natural Resource Damages Assessment (NRDA) and to "ensure that there is a reasonable probability of making a successful claim." (*43 C.F.R. § 11.23(a)(b)).* This PASD is not intended to serve as an actual assessment of natural resource injuries or damages.

E. Site Overview

The Arsenal covers approximately 27 square miles and is located about 10 miles northeast of downtown Denver, just west of Denver International Airport within the South Platte River drainage and the Denver Basin. *See* Figures 1 and 2, attached. Colorado's Front Range and Great Plains, where the Arsenal is situated, have an average annual precipitation of about 12 to 16 inches, unevenly distributed with extreme seasonal variability. The regional soil type in the vicinity of the Arsenal is of the Ascalon-Vona-Truckton Association. This association consists of loamy and sandy soils formed in wind-laid deposits on uplands that are somewhat excessively drained to well drained. *Installation Restoration of the Rocky Mountain Arsenal, Part I, Kolmar and Andrews, 1977 (RIC 81295R07).* Surface and ground waters at the Arsenal generally flow in a north-northwesterly direction. The only natural stream on the Arsenal is First Creek, which drains the eastern half of the Arsenal, with an on-post length of 9.4 km, and a maximum discharge capacity of between 250 and 300 cfs. *Aquatic Resources of Rocky Mountain Arsenal, MK Environmental for Shell Oil, September (1989*).

In 1942, the United States Army ("Army") established the Arsenal for the purpose of manufacturing chemical warfare agents and incendiary munitions for use in World War II. Chemical warfare weapons included munitions such as rockets and projectiles that contained blister agents (e.g., mustard gas). After World War II, the Army continued to produce chemical agents, including nerve agents (e.g., Sarin nerve agent) at the Arsenal until 1957. The Army also produced other weapons, including lewisite, phosgene bombs, incendiary bombs, and napalm, continuing until 1969. The Army used the Arsenal for demilitarization operations through the early 1980s. *History of Pollution Sources and Hazards at the Rocky Mountain Arsenal, Casimir Kuznear & William L. Trautmann for U.S. Army (September 1980).*

In 1946, Julius Hyman and Company leased part of the Arsenal from the Army for the purpose of producing pesticides. In 1952, Shell Chemical Company (now Shell Oil Company and henceforth "Shell") merged with Julius Hyman and took over operations. Shell produced pesticides, insecticides, and herbicides at the Arsenal for thirty years, ceasing manufacturing operations in 1982. *Kuznear & Trautmann, id.*

The Rocky Mountain Arsenal was listed on the National Priorities List ("NPL") under the authority of CERCLA and the Superfund Amendments and Reauthorization Act ("SARA") in 1987. *52 Fed. Reg. 27619.* The off-post Record of Decision ("ROD") was signed in December 1995, and the on-post ROD was signed in June 1996. The RODs reflect the Army's selected

remedies to address contamination at the Arsenal. Since 2003, thousands of acres have been deleted from the NPL because EPA found that all appropriate response actions were complete.

F. Responsible Parties

The Army and Shell have been found liable as responsible parties for releases of hazardous substances at the Arsenal. *Bench ruling by Jim R. Carrigan in the United States District Court for the District of Colorado, 83-C-2386; 42 U.S.C. § 9607(a)(4).* The Army is the current and historical owner and operator of the Arsenal site, and is therefore liable under section 107(a)(1) and (2) of CERCLA. Shell was an arranger and operator at the site from 1952 until 1982, and is therefore liable under section 107(a)(1) and (3) of CERCLA.

II. RELEASES OF HAZARDOUS SUBSTANCES AT THE ARSENAL

A. Time, Quantity, Duration, and Frequency of Releases

From 1942 until 1982, activities of the Army and Shell at the Arsenal resulted in the release of at least 176,000 tons of hazardous substances into the environment.[1] Releases varied from sporadic leaks, spills, and overflows to continual and ongoing releases from routine disposal practices, exacerbated by inadequate repositories for Army and Shell waste streams. These releases caused extensive contamination of soils, surface water, and groundwater, both on and off the Arsenal. *Assessment of CERCLA Hazardous Substances Released by Shell and the Army at the Rocky Mountain Arsenal, United States Department of Justice, p. 1-3 (December 30, 1986).* The releases did not cease in 1982, as there are documented continued releases during cleanup operations at the Arsenal. Contaminants contained in soils, sediments, and water continue to be re-released into the environment.

B. Identification of Hazardous Substances

Contaminants of concern ("COC") at or released from the Arsenal include, but are not limited to, those set out in Table 1:

Table 1. Contaminants of Concern, Rocky Mountain Arsenal [a]

Contaminant	CERCLA hazardous substance [b]
aldrin	yes
allyl chloride	yes
arsenic	yes
benzene	yes
benzothiazole	no
cadmium	yes
carbon tetrachloride	yes
chlordane	yes
chloride	no
chlorobenzene	yes
chloroform	yes
chlorophenyl methyl sulfide (CPMS)	no

[1] Contamination levels for some of the constituents and groundwater standards are in Appendices A1 and A2. See also Appendix D.

Contaminant	CERCLA hazardous substance [b]
chlorophenyl methyl sulfoxide (CPMSO)	no
chlorophenyl methyl sulfone ($CPMSO_2$)	no
copper	yes
cyanazine (Bladex)	no
dibromochloropropane (DBCP)	yes
dicyclopentadiene (DCPD)	no
1,1-dichloroethylene	yes
DDE	yes
DDT	yes
dieldrin	yes
diisopropylmethyl phosphonate (DIMP)	no
dimethylmethyl phosphonate (DMMP)	no
Dithiane	no
endrin	yes
Ethylbenzene	yes
fluoride	no
heptachlor	yes
heptachlor epoxide	yes
hexachlorobicycloheptadiene (Hex)	no
isodrin	yes
lead	yes
Malathion	yes
mercury	yes
methyl parathion	yes
methylene chloride	yes
methylphosphonic acid (MPA)	no
mustard	no
n-nitrosodimethylamine (NDMA)	yes
1,4-oxathiane	no
oxychlordane	no
parathion	no
PCBs	yes
tetrachloroethylene (PCE)	yes
thiodiglycol	no
toluene	yes
trichloroethylene (TCE)	yes
xylene	yes
zinc	yes

[a] Representative but not necessarily complete
[b] As listed in Table 302.4 at 40 C.F.R. § 302.4

C. History of Operations at the Arsenal and Releases of Hazardous Wastes by Major Source

From 1942 through 1982, the Army and Shell disposed of liquid and solid wastes in one lined and numerous unlined disposal basins and trenches, which leaked to groundwater, surface water, and soil. The Army and Shell also buried wastes. In addition, Arsenal operations resulted in accidental leaks and spills. By the 1950s, neighboring farmers to the north began to complain that livestock and crops were being harmed by contaminated groundwater. *See, e.g., Investigations of Waterfowl Mortality at the Rocky Mountain Arsenal, Wildlife Research Laboratory, U.S. Fish and Wildlife Service, Robert B. Finley, Jr. (1959); Kuznear & Trautmann, at Appendix E;* and various *Phase I Contamination Assessment Reports.*

Some of the major areas of operations and waste disposal at the Arsenal include:

- disposal Basins A through E, used for the bulk of both Army and Shell waste disposal from the early 1940s until 1956;
- disposal Basin F, the lined basin built in 1956 to replace Basin A, used for most waste disposal by both Army and Shell from late 1956 until at least 1982;
- the Hydrazine Blending and Storage Facility, built in 1960, used by the Army until 1982 to blend and store jet and rocket fuels;
- the North Plants complex, used by the Army from 1953 until 1984 for nerve agent production, filling weapons, and demilitarization;
- the South Plants Manufacturing area, used by the Army for the production of chemical warfare agents and incendiary munitions, and by Shell for the manufacture of insecticides, herbicides, and pesticides;
- the South Plants Tank Farm, where from 1947 to 1978, large tanks stored DCPD, fuel oil, and BCHPD/DCPD bottoms;
- the chemical sewer system, constructed in various stages from the 1940s and dismantled in 1982, used to carry liquid wastes from all the process facilities of both the Army and Shell;
- the South Lakes, Lower Derby and Ladora, predated the Arsenal but were expanded for use as process cooling water for the South Plants operations, and Lake Mary received overflow from Lake Ladora;
- the waste disposal area known as the Army Complex Disposal Trenches, 107 acres in Section 36 used for burning munitions, burial of munitions and other wastes in pits or trenches, and for open dumping;
- the waste disposal area known as the Shell Section 36 Burial Trenches, actively used from 1952 until 1965, and open until 1974, which was a 7 acre landfill in Section 36, used for bulk and drummed wastes from South Plants production;
- the waste disposal area called the Lime Settling Basins, unlined basins approximately three acres in size, used from the late 1940s to precipitate metals and remove arsenic from process water prior to discharge into Basin A;
- the Motor Pool, used for servicing equipment, vehicles and railroad cars from the 1940s through at least 1997;
- the Rail Classification Yard, constructed in 1942 and 1943, used for temporary housing, entomology and plant laboratories, servicing railcars and storing chemical, fuels and oils; and
- the Toxic Storage Yard, which consisted of several discrete areas used to store chemical agents, ton containers, munitions, and gas containers from 1945 until the cleanup began.

See Figure 3 below.

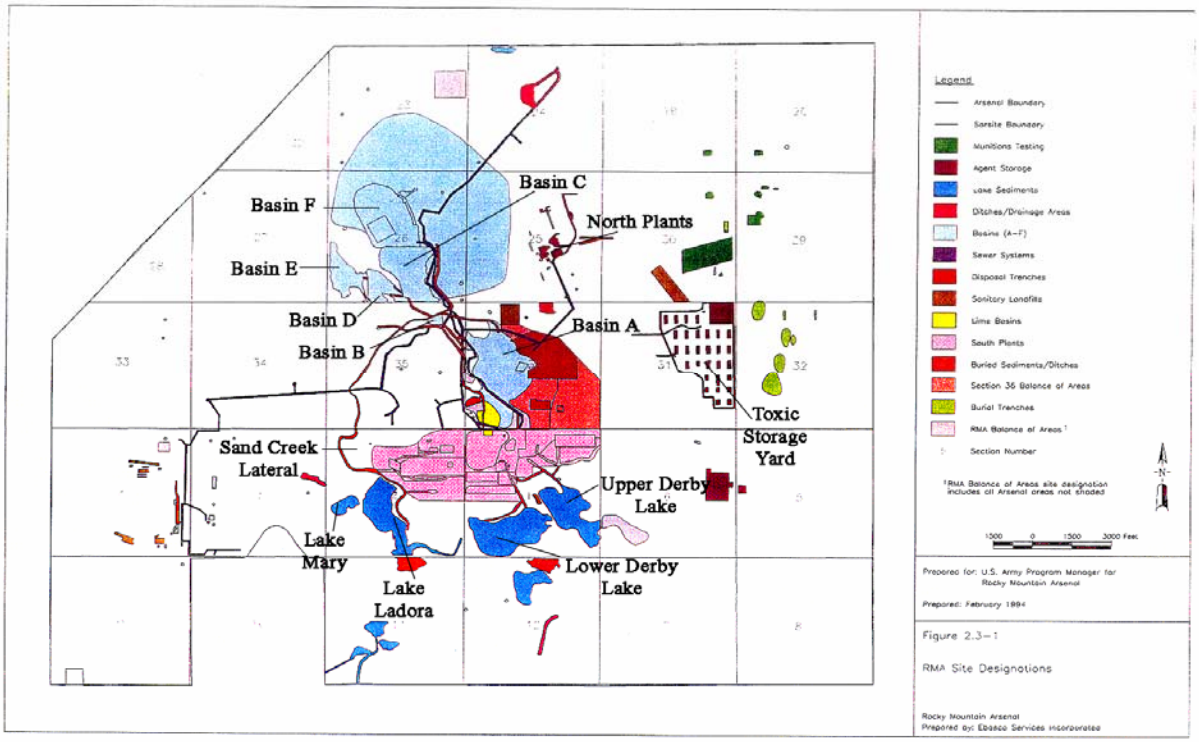


Figure 3: Locations of major facilities and areas of potential contamination at Rocky Mountain Arsenal.
Base map from Figure 2.3-1 in Ebasco Services Incorporated, 1994.

1. <u>Disposal Basins</u>

The vast majority of all liquid waste streams were sent to six waste disposal "basins," A, B, C, D, E, and F, of which only Basin F was lined. Hazardous substances have been and are being released directly or indirectly to soils, surface waters and groundwaters, down-gradient and off-post of the Arsenal site from disposal Basins A, B, C, D and F. *See Final Phase I Contamination Assessment Report: Basin F, Site 26-6, Environmental Science and Engineering for United States Army Program Manager's Office, p. 12 (May 1988)* ("Final Site 26-6 CAR"); *Final Phase 1 Contamination Assessment Report for Site 36-1, Basin A, Environmental Science and Engineering for U.S. Army (July 1987);* and *Basin F Investigative Studies, Parts 1 and 2, Robert Buhts and Norman Francingues, U.S. Army Waterways Experiment Station, 1978 and 1979, respectively.*

a.) Basins A – E and Sand Creek Lateral

In 1943 the Army began depositing liquid and other wastes in a natural depression identified as "Basin A." Basin A was unlined and only inches from the water table in places. Although Basin A spanned 90 to 100 acres, it was too small to accommodate the waste streams. The Army and Shell allowed liquid wastes to overflow from Basin A into other adjacent natural depressions (Basins B, C, D, and E). Between 1943 and 1956, an estimated 52,000 tons of untreated wastes were deposited into these unlined basins. *U.S. Department of Justice, at pp. A-2, C-2; Kuznear & Trautmann, at p. 10.* In 1956 all liquid

wastes were pumped to Basin F, but Basin A remained an active, ongoing source of contamination via windborne deposition of dry sediments and leaching of precipitation to groundwater.

The Army discharged over 17,000 tons of aqueous waste into Basin A from numerous chemical weapon production processes, including those associated with Sarin nerve agent, lewisite blister agent, phosgene gas and incendiary chemicals such as white phosphorous. The demilitarization of numerous chemical munitions added to the waste streams. This additional waste included aluminum chloride, ammonium chloride, arsenic trichloride, chlorinated paraffin, benzene, Freon, Sarin nerve agent, hydrochloric acid, lewisite, crude mustard, white phosphorous and various carcinogenic organic solvents. *U.S. Department of Justice 1986, at Appendix A.*

From 1952 to 1982, Shell produced pesticides, insecticides, and herbicides, including hazardous substances such as aldrin, dieldrin, endrin, chlordane, isodrin, methyl parathion, and dibrom at the Arsenal. *Kuznear & Trautmann, at B-2*. Between 1950 and 1957, Shell deposited over 35,842 tons of waste into Basin A. *U.S. Department of Justice 1986, at pp. C-3 – C-17.*

Basin D was an unlined natural depression covering approximately 21 acres. It received Army and Shell waste overflow from the Sand Creek Lateral and Basin A. Prior to 1946, Army waste from the chlorine plant and white phosphorous filling operations in the South Plants area traveled up the Sand Creek Lateral and emptied into Basin D through a head gate in Section 35. In 1946, the Army built a dam to increase the capacity of Basin A and an overflow ditch that carried waste to Basin B and under the Sand Creek Lateral to Basin D. In the summer of 1952, the Army built a new Basin A spillway to control basin levels. The Army opened this spillway until October 17, 1952, allowing 113 million gallons of Shell and Army waste to flow into Basin D over a three-month period. *Final Phase I CAR for Site 26-4, Basin D, ESE for U.S. Army, October 1987, p. 10.*

From September 1953 through January 1954, the Army constructed permanent earthen dikes on the western perimeter of Basin D as part of a project to expand the reservoir capacity at the Arsenal. The project created Basins C and E, with new outlet structures connecting Basin C to D and Basin D to E. The outlet structure at Basin B was modified to divert Basin A overflows to the Sand Creek Lateral; the culvert under the Sand Creek Lateral adjacent to the outfall from Basin B was blocked, and the connection between the Sand Creek Lateral and Basin D was closed. *Final Site 26-4 CAR, id.* The Sand Creek Lateral received all liquid wastes except caustic from the Chlorine Plant through a storm sewer; the Lateral then emptied into Basin D. Basin D was used to store overflow from Basins A, B, and C from 1952 through 1957. *Draft Final Source Report for Source 26-4, ESE for U.S. Army, August 1986, p. 26-4-7.* During Shell Dichlor operations in the Mustard Plant, aluminum hydroxide byproduct was diverted to the same “canal” that received chlorine plant wastes, i.e., the storm sewer/Sand Creek Lateral to Basin D. *G. Donnelly Memo: Water Contamination RMA, June 28, 1960.* Wastes from the white phosphorus filling operations in Bldg. 532A were also sent to the storm sewer, which

drained to the Sand Creek Lateral and into Basin D. *Final Phase I CAR, Chemical Sewers South Plants, Ebasco for U.S. Army, (September 1988), pp. 14-15.*

Overflow from Basin C traveled through a concrete overflow structure and outlet ditch to Basin D, and then to Basin E via a concrete weir and riprap spillway. *Final Site 26-4 CAR, id.* Basin E began receiving overflow from Basin A in the late 1940s, and became the final repository for South and North Plants wastewater overflow from Basin C until Basin F was completed. *Final Phase I CAR for Site 26-5, Basin E, ESE for U.S. Army, July 1987, p. 11.*

b.) Basin F

In 1954, farmers north of the Arsenal complained of crop damage resulting from contaminated groundwater used in irrigation. The Army and the U.S. Geological Survey conducted vegetative uptake and groundwater flow studies and found that the waste streams originating at the Arsenal were responsible for this off-post groundwater pollution. *Buhts & Francingues, Phase I, p.12.* As a result of the studies, the Army, in 1956, constructed a 92.7 acre asphalt-lined chemical waste disposal basin designated "Basin F," with a holding capacity of 240 million gallons. The Army claimed that solar evaporation was the most feasible and cost effective means for the elimination of large volumes of contaminated liquid waste. *Final Site 26-2 CAR, p. 12.*

Hazardous substances discharged to Basin F from Shell manufacturing and processing activities included acetaldehyde, acetic acid, acetone, acetonitrile, aldrin, allyl chloride, ammonium chloride, ammonium sulfite, benzene, carbon tetrachloride, chloral, chlorine impurities, chlorine 1-chloroethylbenzene, chloroform, p-chlorophenylmethyl sulfone, cuprous sulfate, cyclohexane, cyclopentadiene, dibrom, dichloromethane, dieldrin, hexachlorobicycloheptadiene ("HEX"), hydrochloric acid, isopropanol, sodium hypochlorite, sulfuric acid, and vinyl chloride. *Final Site 26-6 CAR, p. 17.* Shell deposited approximately 107,000 tons of these and other chemicals into Basin F. *U.S. Department of Justice 1986, pp. C-3 – C-17.*

Hazardous substances deposited into Basin F from Army operations included ammonium chloride, asbestos, chromic acid, cyanogen chloride, hydrazine, hydrochloric acid, isopropanol, nitric acid, sodium fluoride, sulfuric acid, and cancer-causing organic solvents, including but not limited to benzene, carbon tetrachloride, chloroform, and dichloromethane. The Army deposited over 1,000 tons of these and other chemicals into Basin F. *Final Site 26-6 CAR, pp. 17-18.*

The Basin F liner, a 3/8-inch layer of catalytically-blown asphalt and one foot of soil, proved to be an inadequate barrier between the toxic mixture contained in Basin F and the groundwater. The liner was designed for an approximate life-expectancy of 15 years. *Buhts and Francingues, Phase 1, p. 12.* The liner was in use and leaking until the initiation of the Basin F Interim Response Action ("IRA") in 1988, thus exceeding its life expectancy by many years. In April 1957, wind-induced waves on the surface washed away portions of the protective soil blanket and fractured the liner at the water line for a length of 1,320 feet along the northern perimeter of the basin. The Basin F contents were

pumped into unlined Basin C while the Army made repairs. Leakages from Basin F nonetheless persisted due to fractures, combined with the degradation of the liner from solvents that were incompatible with the asphalt. *Final Site 26-6 CAR, pp. 17-18, 60; Biota Transcripts of Assessment: Draft Final Phase II Technical Plan, Environmental Science and Engineering for U.S. Army, pp. 2-8, 2-9 (August 1986).*

From 1961 through 1966, the Arsenal used a spray raft to enhance evaporation of the waste liquids in Basin F. *RMA IRA Summary Report, Basin F Liquids & Sludges, Element 1, January 1991, p. 2.* When in operation, the spray raft averaged approximately 140 gpm during the eight months of the year when conditions were favorable for use. Its operation was intermittent because it caused air pollution problems (i.e., foul odors and wind dispersion of dried salts). *Buhts and Francingues, Phase I, p. 45*. This enhanced evaporation project and resulting volatilization of hazardous substances may have contributed to air contamination.

Volatilization of hazardous substances was also a concern during the Basin F Interim Remedial Action (IRA) in 1988-1989. During the interim action, approximately five million gallons of Basin F liquid were stored in temporary surface impoundments, Ponds A and B, and hundreds of thousands of cubic feet of excavated soil and sediment were mixed in the open to accelerate drying before being placed in a temporary waste pile in the south area of the basin. As a result, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) were emitted to the air. These emissions generated noxious "pesticide" odors, both on- and off-post, causing residents north and northwest of the Arsenal to complain about the stink, headaches, burning eyes and nausea, and to demand halting operations or evacuating the affected neighborhoods. *Basin F Task Meetings, 1988, Ebasco; Summary of Findings Concerning Odor Complaints received by EPA for period of July 25-August 4, 1988; Basin F Interim Action Close-Out Safety Report, Final Draft, Vol. I, September, 1989, pp. 5-1 – 5-3.*

2. <u>Hydrazine Blending and Storage Facility</u>

The Hydrazine Blending and Storage Facility ("HBSF") was built in 1960 in an open storage area, in use since 1948, just east of the South Plants in Section 1. The Army operated the HBSF from 1961 through 1982 to blend hydrazine (jet and rocket fuels) for the U.S. Air Force. The Army stored these fuels under a blanket of nitrogen gas. *Final Phase I Contamination Assessment Report for Site 1-7, Hydrazine Blending and Storage Facility, Ebasco Services Inc. for U.S. Army (September 1988).* Hydrazine is carcinogenic, toxic, explosive, flammable, and an EPA "extremely hazardous substance." *See ATSDR ToxFAQs, <http://www.atsdr.cdc.gov/tfacts100.html.>* Hydrazine's breakdown product NDMA is carcinogenic and EPA recommends that levels in water be limited to 0.00069 ug/L to prevent possible adverse health effects from drinking water or eating fish contaminated with NDMA. *See ATSDR Public Health Statement for* n-*Nitrosodimethylamine, <http://www.atsdr.cdc.gov/toxprofiles/phs141.html.>*

An estimated 300,000 gallons of contaminated wastewater were generated annually at the HBSF from the combination of surface runoff, wash water, and process water. The

wastewater was diverted to an in-ground concrete tank, where it was treated with calcium hypochlorite and then sent to Basin F through the chemical sewer. Large quantities of sediment and sludge were generated through this process and dumped into pits in Section 36 at unspecified locations. Sources of contamination from the HBSF included spills and leaks of hydrazine. Leaks occurred from storage tanks, pressure lines, drum loading station valves, arm valves on load and unload stations, and blender valves. *Final Site 1-7 CAR, pp. 14-23.*

3. North and South Plants Manufacturing Complexes

a.) The South Plants complex was part of the original construction at the Arsenal and contained over 150 buildings. The Army used the complex for the production of mustard, lewisite, phosgene, white phosphorus, incendiary mixtures, and explosives. Munitions were also filled with chemical agents and stored in the complex. After 1952, Shell leased some of the buildings for the manufacturing of chlordane, dieldrin, aldrin, and other pesticides and herbicides.

The total quantity of Shell spills and leaks in the South Plants area was in excess of two million pounds. The following abridged list includes only spills and leaks of chemicals onto the ground, as opposed to inside contained areas, and only where there is no evidence that the release was cleaned up:

Acetic Acid, 13,547 pounds
Acetone, 11,352 pounds
Aldrin/Benzene, 144,900 pounds
Allyl Chloride, 21,802 pounds
Benzene, 139,270 pounds
Bicycloheptadiene/dicyclopentadiene bottoms, 1,740,000 pounds
Chloroform, 11,990 pounds
Dibromochloropropane (DBCP), 39,792 pounds
Hexachlorocyclopentadiene (HEX), 28,714 pounds
Hexane, 12,107 pounds
Sulfuric acid, 30,654 pounds

U.S. Department of Justice 1986, pp. D-2 to D-13.

The following list is CERCLA hazardous substances the Army released into the environment from the South Plants. This amount includes only spills and leaks of chemicals onto the ground, as opposed to inside contained areas, and only where there is no evidence that the release was cleaned up. The total quantity of documented leaks and spills onto the ground by the Army in the South Plants area is 91,542 pounds:

Arsenic Trichloride, 2,170 pounds
Arsenic Trioxide, 1,400 pounds
Dichlor, 82,522 pounds
Sulfur Monochloride, 2,800 pounds

Unsymmetrical Dimethylhydrazine, 2,000 pounds

U.S. Department of Justice 1986, pp. B-3 to B-4. See also Final Decision Document, Other Contamination Sources, Interim Response Action, South Tank Farm Plume, MK Environmental Services, Prepared for Shell Oil Co., pp. 4-5 (April 1991).

b.) The South Tank Farm in the South Plants was used from 1947 until 1978. At least two tanks stored DCPD and bicycloheptadiene (BCHPD) bottoms generated by Shell manufacturing. The tanks were cleaned in 1956, 1966, and 1967; in 1957, BCHPD bottoms were pumped onto the ground. In 1966, residue from a mixture of BCHPD bottoms containing DCPD and fuel oil was "collected" in a low spot in the South Tank Farm, for later drumming and offsite shipment. From 1960 through 1963, an unknown amount of leakage of BCHPD/DCPD bottoms occurred from pipes connected to one of the tanks. Unknown amounts were also spilled in 1964 and 1978. *South Tank Farm Plume IRA Summary Report, July 1999, p. 2*. Additionally, a large spill of benzene containing toluene and xylene impurities occurred in the South Tank Farm in 1948. *Id*.

c.) The North Plants, which covered 90 acres, were operated by the Army from 1953 through 1984. The Army initially constructed the North Plants for manufacturing Sarin nerve agent. After the Army halted the manufacture of chemical agents in 1957, the complex was used to store other chemical agents and explosives, as well as for assembling Sarin cluster bombs and conventional explosive button bombs. Beginning in the 1950s, the Army used North Plants to demilitarize agents and munitions, including Sarin nerve agent, mustard, lewisite, and phosgene.

Chemical wastes from North Plants were neutralized with caustic in an 80,000 gallon disposal sump located in building 1727 ("1727 sump"). From 1952 to 1956, those wastes were sent through the chemical sewers to Basin A; from 1956 until 1982, these wastes went to Basin F. The 1727 sump was the recipient of all industrial chemical wastes from North Plants, including byproducts from the manufacturing of Sarin nerve agent, munitions filling, and demilitarization. The wastes from these processes included trichloroethylene (TCE), tetrachloroethylene, dimethyl methlyphosphonate (break-down product of Sarin nerve agent), sodium hydroxide, methylphosphonic dichloride, and hydrogen fluoride. The 1727 sump often overflowed into ditches leading to First Creek. *Final Phase I Contamination Assessment Report for the North Plants Complex, Ebasco Services for U.S. Army (September 1988), Table NP-2 at p. 11; pp. 11, 25-26.*

Enhanced evaporation of hazardous substances in the form of spray drying was in use at the North Plants adjacent to Bldg. 1703 from 1973 to 1985. From 1973 to 1976, all contaminated liquids from the 1727 sump went to the spray dryer, and liquids deemed uncontaminated went to Basin F. After 1976, all sump wastes went to the spray dryer until its use was discontinued in 1985. *Interim Response Summary Report, Building 1727 Sump Liquid, EPA and U.S. Army, June, 2000, p. 2*.

4. Chemical Sewers

The North Plants, South Plants, and the HBSF were all connected to the various waste basins by a chemical sewer, which ran for miles throughout the Arsenal's manufacturing areas. The chemical sewers were largely constructed of cast iron or vitrified clay pipe, whose joints, man-holes, and pipes deteriorated, cracked and leaked extensively through the decades of active Arsenal production. *See, e.g., Final Phase I Contamination Assessment Report for Site 24-5, Chemical Sewers North and South Plants, Ebasco Services for U.S. Army, (September 1988), Final Phase I Contamination Assessment Report for the Sanitary Sewers, South Plants, Ebasco Services for U.S. Army, (June 1988), Final Phase I Contamination Assessment Report for the Sanitary Sewers, North Plants, Ebasco Services for U.S. Army,(April 1988),* and *Final Phase I CAR North Plants Complex.*

5. South Lakes and Drainage Ditches

Lower Derby Lake and Lake Ladora were constructed around 1919 for use as irrigation reservoirs by farmers. Upper Derby was constructed somewhat later for additional storage volume. Shell used Upper Derby, Lower Derby and Ladora Lakes for storage and recycling of cooling water for its chemical plants. Shell pumped water from Lake Ladora through its process water cooling system and then returned the water to Upper Derby Lake through ditches. The water flowed from there into lower Derby Lake and back into Lake Ladora, where it was re-circulated. *Final Phase I Contamination Assessment Report, Site 1-2, Upper and Lower Derby Lakes, Ebasco Services for U.S. Army, p. 13, (June 1987).* Because Lake Mary is located below the Lake Ladora dam, it receives overflow from Lake Ladora, as well as subsurface seepage from the upper lake. Surface water also drains into Lake Mary from a storm drain to the northeast. *Final Phase I Contamination Assessment Report, Site 2-17, Lake Ladora and Lake Mary, Ebasco Services for U.S. Army, p. 7 (July 1987).*

Dieldrin and aldrin from Shell manufacturing at South Plants entered the process cooling water in unknown quantities through condenser leaks, sampling discards, leaking pump packs, and accidental spills. *Final Phase I CAR, Site 2-17, Lake Ladora and Lake Mary, id., p. 13.* Due to these accidental and negligent releases of aldrin and dieldrin into the process cooling water, as well as surface run-off, the lakes became contaminated with the organochlorine pesticides aldrin and dieldrin, and inorganic compounds like mercury. *Comprehensive Monitoring Program, Final Technical Plan: Final Biota Annual Report for 1989, R.L. Stollar and Assoc. for U.S. Army (June 1990).* Evacuation and dredging of both lakes began in summer of 1964. Final sediment remediation began in June 1999. *Lake Sediments Remediation Project, Construction Completion Report, Foster Wheeler for U.S. Army, Shell Oil Co., and U.S. Fish and Wildlife Service, pp. 1-3, 5 (February 2000).*

Unlined drainage ditches, such as the Site 2-1 Drainage Ditches that included part of the Sand Creek Lateral in Section 2, were used for waste disposal. The Site 2-1 ditches and tributaries, 24,000 feet in total length, ran along the eastern shore of Lake Ladora north into Section 35. These ditches were used from the 1940s to collect drainage and waste, which

were routed to the Sand Creek Lateral. Contaminants include methylene chloride, tetrachloroethylene, toluene, aldrin, CPMSO, dieldrin, isodrin, and heavy metals such as mercury and arsenic. Other ditches, e.g., the Sites 3-2 and 3-3 Drainage Ditches in the southwest quadrant of Section 3, were constructed to carry overflow from Lake Ladora to Lake Mary to an overflow basin. Contaminants included methylene chloride, cadmium, arsenic, and mercury. *See, e.g., Final Phase I Contamination Assessment Reports for Sites 2-1, 2-17a, 2-17b, 2-18, 3-2, 3-3, 1-1* and *1-2*.

6. Army Complex Disposal Trenches

The Complex Disposal Trenches occupied approximately 107 acres and were used by the Army for open burning of chemical wastes and for disposal of live munitions. Destruction through burning was accomplished by laying four to five tons of lumber at the bottom of the pit, placing the contaminated material on the lumber, and pouring approximately 300 to 500 gallons of fuel oil into the pit. On occasion, rejected lots of napalm from the Army's M-47 incendiary bomb filling operation, or the incendiary bombs themselves, were used as the fuel. The pit was then backfilled, with new pits dug as needed.

The trenches were suspected to contain manufacturing/military wastes that included white phosphorous, unknown containerized waste, and burned incendiary munitions. Soil contamination from these disposal activities included mustard, chlordane, and dibromochloropropane ("DBCP"). *Final Phase I Contamination Assessment Report, Site 36-17: Complex Disposal Activity, Environmental Science and Engineering for U.S. Army, pp. 47, 60-68 (January 1988).* The Remedial Investigation ("RI") included very limited investigation of these trenches due to fear of encountering chemical agents and other hazards.

7. Shell Section 36 Burial Trenches

From 1952 to 1962, Shell used 18 unlined trenches south of the Army complex disposal trenches in Section 36 for land disposal of liquid and solid wastes generated during the manufacture of pesticides, herbicides, and insecticides at South Plants. The trenches were dug five to ten feet below ground surface to the approximate top of the water table and covered approximately seven acres. *Results of Field Investigations Conducted August and September 1989, Shell Section 36 Trenches, MK Environmental Services, for Shell Oil Co., p. 5 (December 1989).* Shell buried an estimated six million pounds, or 3,054 tons, of chemical wastes from pesticide, insecticide, and herbicide operations directly into the unlined trenches, including the following: aldrin, bidrin, dieldrin, endrin, isodrin, planavin, benzene, carbon tetrachloride, chlorobenzene, DCPD, dipropylamine hydrochloride, hexachlorocyclopentadiene (HEX), methanol, nemagon, octochlorocyclopentene, perchlorobenzene, and sulfuryl chloride. *Army Proposed Stipulations for Shell Waste Disposal and Storage in the Section 36 Burial Trenches and Drum Storage Area (1986).* During the RI, the most prevalent detections from trench boring samples were organochlorine pesticides, including aldrin, dieldrin, endrin, isodrin and DBCP. *Final Phase I Contamination Assessment Report, Site 36-3: Insecticide Pit, Environmental Science and Engineering for United States Army, p. 24 (June 1987).*

Shell discontinued burying wastes in these trenches in 1965 and began storing the waste in drums and placing the drums in a storage area directly to the south of the trenches. Many of the drums corroded, resulting in the leakage of approximately 50,000 gallons of known carcinogenic organic solvents and pesticides into the ground. *Final Phase I Contamination Assessment Report, Site 36-4: Lime Settling Basins, Environmental Science and Engineering for United States Army, p. 5 (June 1987).*

8. Lime Settling Basins

The lime settling basins consisted of three unlined basins which served as the initial receptors for all wastewater from South Plants. The purpose of the lime basins was to raise the pH and precipitate arsenic and heavy metals from the wastes before releasing them to Basin A. The Army released arsenic and mercury into the basins, generated from its manufacture of lewisite. Hazardous substances released into the lime basins by Shell included aldrin, dieldrin, endrin, isodrin, chlordane, DDE, and DDT. Shell's releases of these wastes totaled nearly 955 tons, most notably organochlorine pesticides, including aldrin, dieldrin, endrin, isodrin, DDE, and DDT. *Final Site 36-4 CAR Lime Settling Basins, pp. 1-16, 26; U.S. Department of Justice 1986, p. 18, C-15.*

9. Motor Pool

The Motor Pool was located in Section 4 in the western part of the Arsenal. It was used for servicing equipment, vehicles, and railroad cars, including the roundhouse for railroad equipment. The Motor Pool stored fuel, road oil, and flammable liquids, and included an above-ground tank farm for gasoline and diesel fuels. Solvents, caustics, rust inhibitors and stripping agents were used throughout Motor Pool operations from the 1940s onward. The area was still in use for vehicle and railcar maintenance in 1997.

In 1986, soil-gas studies identified the Motor Pool area as a possible source of TCE to the groundwater. In 1989, 80 soil-gas samples and six soil samples were collected at depths from 5 to 20 feet below the surface, and these samples showed contamination from the Motor Pool impacted soil and groundwater. TCE was found in the soils beneath a man-made drainage ditch, which was also north-trending. Methylene chloride, aldrin, and trichloropropene were also present in soil at the roundhouse; cadmium, chromium, copper, lead, zinc, and arsenic above background levels were found in near-surface soils at the ditch, which have been attributed to sanding/stripping operations of the Motor Pool. Soils in the fuel tank area showed detections of methylcyclohexane, benzene, ethyl benzene, toluene, m-xylene, and methyl naphthalene.

Groundwater in the Motor Pool area lies 60 to 65 feet below the ground. Sampling showed that the TCE alluvial groundwater plume originated at the Motor Pool, since TCE was not detected up-gradient of the area but was found in alluvial wells down-gradient. The plume appeared to be limited to the upper, unconfined aquifer. *Final Interim Response Action Summary Report, U.S. Army, pp. 2-5 (October 1997).*

10. Rail Classification Yard

The Rail Classification Yard, built in 1942-43 on former farmland in the western half of Section 3, was used for temporary housing, entomology and plant laboratories, servicing railcars, and storing various chemicals, fuels, and oils. Spills and leaks of DBCP from railcars are thought to be a source of contamination for groundwater and soil.

In 1980, DBCP, a carcinogen, was found in the alluvial aquifer near the Irondale community. The Army studied soil borings and concluded that a continuous DBCP plume probably emanated from the Rail Yard and constructed the Irondale Containment System to capture the plume at the western boundary of the Arsenal. *Draft Final Interim Response Action Summary Report for the Rail Classification Yard, U.S. Army, pp. 2-3 (August 1997).*

11. Toxic Storage Yard

The Toxic Storage Yard (TSY) consisted of several discrete areas: a storage yard in the northeast corner of Section 31 (CAR site 31-4), a toxic gas storage yard in Section 6 (CAR site 6-6), and two sets of storage yard sheds, one on the east boundary of Section 31 (CAR site 31-6), the other in the northeastern portion of Section 31 (CAR site 31-7). There was also an "overflow area" (ESA-3a) along the western edge of Section 5 and an open storage area (ESA-3g) for the "New Toxic Storage Yard," also in Section 31.

Before 1952, Site 31-4 was in use to store chemical agents, including lewisite, mustard, phosgene, GB (Sarin), VX, and decontamination agents. The area was approximately 16 acres. *Final Phase I Contamination Assessment Report, Site 31-4, Toxic Storage Yard, Ebasco for U.S. Army (June 1988), pp. ES, 1, 3.* By August of 1954, the Army was storing ton containers of agent in the yard—most likely GB nerve agent (Sarin). *Id. at p. 12*. By 1959, M-34, M-34A1, and M-31 clusters, mustard-filled bombs and other munitions were stored here. *Id., p. 15*. In the late 1960s to early 1970s, Site 31-4 was used to store airplane spray tanks of VX, a nerve agent. A 1973 report suggested that raw VX was poured onto the ground. *Id., p. 19.* It is likely that at least some of the 25,000 drums of GB-demilitarization salts were stored at Site 31-4 from the late 1970s. By April 1985, the Army had ceased storing "surety materials" at the Arsenal. *Id., p. 22*. Chromium, lead, zinc, and arsenic were detected above indicator ranges in Phase I investigations. *Id., p. 27.*

Site 6-6, the Toxic Gas Storage Yard, was a 28 acre area along the central-eastern border of Section 6, constructed before 1945 as open storage for filled containers of toxic gasses, such as phosgene, crude mustard, and distilled mustard. The area was in use until at least 1982. The area was also used to store incendiary bombs. *Final Phase I Contamination Assessment Report, Site 6-6, Former Toxic Gas Storage Yard, Ebasco for U.S. Army (June 1988), pp. ES, 1, 11-12.* In 1946, 16 "empty" phosgene ton containers were found to be leaking phosgene. At room temperature, phosgene is a gas that dissipates quickly in open air. From 1947 until 1950, obsolete and deteriorating shells of crude mustard were put into ton containers and stored in the gas yard. *Id.* Other mustard leaks occurred through the years. *Id., p. 14*. In 1960, several containers of crude mustard were found leaking due to corrosion. *Id., p. 15*. Dithiane and thiodiglycol (mustard degradation products), as well as

cadmium, lead, zinc, and arsenic were found in the soils during Phase I investigations. *Id., p. 20*.

Site 31-6, toxic storage sheds, constructed beginning sometime in 1956, was used to store munitions and GB-filled Weteye bombs, demilitarization salt drums, and ton containers, as well as laboratory samples. In 1987, the inventory included containers of contaminated garments, DDT-contaminated waste, soot and salt from North Plants operations, hydrazine facility trash, demilitarized Weteye bombs, oily rags, and empty ton containers. *Final Phase I Contamination Assessment Report, Site 31-6, Toxic Storage Yard Sheds, Ebasco for U.S. Army (June 1988), pp. ES, 11*. Any ground spills or contaminated surfaces noted during daily inspections were chemically decontaminated and flushed with water. Calcium hypochlorite or supertropical bleach were used for mustard decontamination; GB spills were neutralized with a sodium hydroxide solution; phosgene was washed with water or caustic soda. *Id., p. 12*. Toluene, tetrachloroethylene, cadmium, chromium, lead, zinc and arsenic were all sampled at or above the indicator level during Phase I investigations. *Id., pp. 28, 43.*

Site 31-7, more toxic storage yard sheds in the northeastern portion of Section 31, covered approximately 513.4 acres. This site was built in 1956 as storage for munitions and miscellaneous materials. A 1987 inventory included barrels of salts and soil, demilitarized Weteye bombs and bomb parts, and miscellaneous trash. *Final Phase I Contamination Assessment Report, Site 31-7, Toxic Storage Yard Sheds, Ebasco for U.S. Army (May 1988), p. ES.* Phase I sampling found dithiane and thiodiglycol (mustard degradation products), as well as chromium, copper, lead, zinc, and arsenic at or above indicator levels. Some probable 1,4-oxathiane, 1,1-sulfonylbis benzene, and 4-oxide were also found. *Id.* Some of the 240 leaking M-34 clusters found in 1961 may have been stored at Site 31-7, or may have been taken there. *Id., p. 14.* In the late 1970s, glass bottles of lewisite removed from Basin A were stored at Site 31-7, as well as cyanogen chloride in steel containers, 55 gallon drums of the insecticide heptachlor, and scrap material from leaking Weteye bombs. *Id., p. 18*. There was also open storage between the sheds, including steel drums of mustard-contaminated soil, some of which split and leaked. *Id., p. 19.* Additionally, phosgene ton containers at the site leaked, and some human exposures occurred. *Id., p. 20*.

D. Relevant Operations Occurring At or Near the Arsenal Site

The only continuing operations at the Arsenal are the on-post remedial and wildlife refuge-related activities. On-site water treatment is anticipated to continue for at least 30 to 50 years and perhaps in perpetuity. The area surrounding the Arsenal contains a mix of residential developments and commercial and industrial operations.

E. No Statutory Exclusions From Liability Under CERCLA

Injuries resulting from the discharge or release of hazardous substances from the Rocky Mountain Arsenal were not identified as irreversible or irretrievable in any environmental impact statement, pursuant to the National Environmental Policy Act, as amended, 42 U.S.C. § 4321 et seq., or any comparable analysis, and therefore are not excluded from liability under 42 U.S.C § 9607 (f)(1).

Releases of hazardous substances and resultant damages at the Rocky Mountain Arsenal are ongoing and did not occur wholly before enactment of CERCLA, and are therefore not excluded from liability under 42 U.S.C. § 9607(f)(1).

None of the natural resource injuries at the Rocky Mountain Arsenal were caused by or resulted from the application of a FIFRA-registered pesticide product, and therefore are not excluded from liability under 42 U.S.C. § 9607(f)(1).

Injuries resulting from the discharge or release of the hazardous substances at the Rocky Mountain Arsenal did not result from any federally-permitted release as defined in CERCLA § 101(10) and therefore are not excluded from liability under 42 U.S.C. § 9607(f)(1).

The hazardous substances identified at the Rocky Mountain Arsenal are not recycled oil products as described in CERCLA § 107(a)(3) or (4). Injuries resulting from the discharge or release of the hazardous substances at the Arsenal therefore did not result from release of a recycled oil product.

III. NATURAL RESOURCES FOR WHICH THE TRUSTEES MAY ASSERT TRUSTEESHIP UNDER CERCLA HAVE BEEN ADVERSELY AFFECTED BY THE DISCHARGE OR RELEASE OF HAZARDOUS SUBSTANCES

A. Preliminary Pathway Identification

The federal regulations at 43 CFR Part 11 define "pathway" as the route or medium through which a hazardous substance is transported from the source of the discharge or release to the injured resource. 43 CFR § 11.14(dd). Available data suggest that, at the Arsenal, hazardous substances were released, and in some cases continue to be released, to groundwater, surface water, sediments, soil and air, resulting in the contamination of these resources and in contamination to biological receptors dependent upon the resources.

1. Soil Pathway

Contaminated soil is a direct pathway to plants and other biota through ingestion, dermal absorption, inhalation, and indirectly through the food chain. It is a pathway to groundwater through leaching of precipitation and runoff. It is a pathway to air through dispersal of soil and dust.

Basin A at least, and probably Basin C, the "straw-bottomed basin," did not act as evaporation ponds as intended, and much of the liquid wastes in these basins seeped into the ground. At Basin A, the groundwater table was only one to four inches below the ground surface, and hazardous substances swiftly moved into the groundwater. *Final Site 36-1 CAR Basin A, p. 52; Buhts and Francingues, pp. 11-14.*

Leaks from Basin F contaminated the alluvial aquifer and the underlying Denver groundwater formation. Sampling of wells down-gradient from Basin F in 1986 revealed numerous hazardous substances. *Final Site 26-6 CAR, pp. 34-38, 60.*

Groundwater contamination under and around the South Plants has been directly linked to waste streams from the South Plants complex. *Final Phase I Data Presentation Report, South Plants Regional Study Area, South Plants Manufacturing Complex, Ebasco Services, Inc. for United States Army, pp. 6-7 (October 1988); Final Phase I Contamination Assessment Report, Sites 1-13 and 2-18, South Plants Manufacturing Complex, Shell Company Spill Sites, Ebasco Services, Inc. for U.S. Army, pp. 6-8 (July 1988).* The pipes of the chemical sewers carried liquid wastes from the North and South Plants to the disposal basins. The pipes deteriorated and leaked into the deep soils where contaminants leached to the groundwater. Some Army operations were not connected to the sewers, so the Army released liquid wastes directly into neighboring ditches (i.e. M-47 incendiary filling bomb operation in Bldg. 742). *Draft Final Contamination Assessment Report, Chemical Sewers, North Plants and South Plants, Environmental Science and Engineering for U.S. Army, pp. 13-20, 39 (February 1988),*and *Final Phase I Data Presentation Report, Army Spill Sites, South Plants, Ebasco for U.S. Army, p. 29 (1988).*

In addition, in the North Plants, the 1727 sump leaked. As a consequence, most of the contamination in the North Plants was concentrated around the building 1727 sump, the ditches surrounding the area, and the various areas where spills occurred, allowing leaks and precipitation to leach through the soil to groundwater. *Final North Plants Complex CAR, pp. 9, 25-26.* Overflow from the 1727 sump was routed to First Creek, the only natural stream on the Arsenal. North Plants contaminants included the hazardous substances chloride, chloroform, tetrachloroethylene, and trichloroethylene (TCE). These entered the groundwater through First Creek and via leaching from the soil. *Final Groundwater Monitoring Evaluation Report for Water Year 1995, U.S. Geological Survey for U.S. Army, Figures 12, 18, 21, and 22 (January 1998).*

The Hydrazine Blending and Storage Facility generated large quantities of sediment and sludge, which were dumped into pits in Section 36 at unspecified locations. Nine monitoring wells in the vicinity of the hydrazine facility revealed measurable levels of hazardous substances, including carbon tetrachloride, chloroform, trichloroethylene (TCE), aldrin, dieldrin, endrin, isodrin and DDD, indicating pollution of the groundwater through leaching from the buried sediments and sludges of the HBSF. *Draft Final Site 1-7 CAR, p. 11.*

The Army Complex Disposal trenches in Section 36 were dug to a depth of 8 to 10 feet. At times the groundwater in this area was less than 10 feet below the surface, which resulted in direct releases of contaminants into the groundwater. These releases resulted in two discrete groundwater contamination plumes, referred to as the Section 36 Bedrock Ridge Plumes. *Final Detailed Analysis of Alternatives Report, Foster Wheeler for U.S. Army, Vol. III, pp. 14-2 to 14-3 (October 1995).* The Shell trenches in Section 36 were unlined and dug in a groundwater recharge zone, where the water table is also less than 10 feet below the surface, causing additional direct releases to the groundwater of hazardous

substances. *Final Water Remedial Investigation Report, Ebasco for U.S. Army, p. 2-4 (July 1989).*

The Army identified the drum storage area as a likely source of groundwater contamination, from leaks and leaching through the soil. *Final Detailed Analysis of Alternatives Report, Soil DAA, Volume III, pp. 14-17 to 14-18.*

At the Lime Settling Basins, the groundwater table was only two to four feet below the surface, and the contaminated materials in the lime basins extend 16 feet below the surface. Thus, hazardous substances were directly released into the groundwater. Monitoring wells down-gradient of the lime basins have revealed many of the constituents from Shell's activities, most notably the organochlorine pesticides, including aldrin, dieldrin, endrin, isodrin, DDE, and DDT. The Army released arsenic and mercury into the basins from the manufacture of lewisite. *Final Site 36-4 CAR, Lime Settling Basins, pp. 1-16, 26; U.S. Department of Justice 1986, pp. 18, C-15.*

The releases of hazardous substances have caused several groundwater contaminant plumes. Each plume group has various sources of contaminants. The North Boundary Plume group includes contaminants from Basins C and F and the North Plants. The Northwest Boundary Plume is primarily the result of releases of contaminants from Basin A and the South Plants. The Basin A Plume Group is a result of contamination from Basin A, the South Plants and the Disposal Trenches in Section 36. Contamination of the Off-Post Plume originates from a number of sources, as discussed above.

2. Groundwater Pathway

Contaminated groundwater is a pathway to surface water through seepage. The groundwater at the Arsenal is hydraulically connected to the surface water so it has the potential to enter and contaminate the surface water.

3. Surface Water and Sediments Pathways

Contaminated surface water and its sediments are direct pathways to biota through ingestion and dermal exposure and indirectly through the food chain. Surface water was contaminated by accidental and negligent releases of hazardous substances. The Lower Lakes (Ladora, Upper and Lower Derby) were directly contaminated due to accidental and negligent releases of aldrin and dieldrin into the process cooling water, as well as surface run-off. Lake Mary was contaminated by overflow of water from Lower Derby. *Comprehensive Monitoring Program, Final Technical Plan, R.L. Stollar and Assoc. for U.S. Army (1990).*

The North Plants' 1727 sump contributed to surface water contamination due to its overflows, which forced the waste into the storm drains that led to First Creek, thereby constituting a direct pathway to a natural stream. First Creek is an intermittent stream that ultimately empties into the South Platte River north of the Arsenal. *Final North Plants Complex CAR, pp. 9, 25-26.* Contaminated surface water and sediments are direct

pathways to biota through ingestion, dermal exposure and indirectly through the food chain. The Army's 1989 Biota Remedial Investigation showed two principal chemicals of concern in the Arsenal's aquatic ecosystems: dieldrin and mercury, which were nearly ubiquitous in the sampling. These chemicals were also the contaminants most frequently found in the waters/sediments of the Lower Lakes. DDE was found in Lake Derby and the Biota RI indicated that DDE was magnifying up the food chain to Lake Derby fish. *See Final Biota Remedial Investigation Report, Environmental Science and Engineering for United States Army (1989), Table 4.3-5, "Contaminant Levels in Aquatic Ecosystems."* Direct exposures to sediments or water are not the only source of aquatic exposures. Contamination is also transferred from lower biotic trophic levels to upper levels through predation. *State's Summary of Biota RI & CMP, (1989). See also Appendix C.* Terrestrial, avian and mammalian biota were also exposed to pesticides and inorganic compounds released to the surface waters and sediments.

4. Air as Pathway

Deposition of contaminants from the air, as well as contamination transport through the air, are pathways to soil and surface water. Inhalation of VOCs, SVOCs, or contaminated dust is a pathway to biota from the air.

5. Disposal, Spills, and Leaks Pathway

Volatilization of organic compounds from the various waste disposal areas, wind/wave action from the open disposal basins, and windblown releases of contaminated sediments from the basins are pathways to air. Leaks from cracked or broken sewer lines are direct pathways to the soil. Seepage of the contaminated liquids from the various disposal basins are direct pathways to the soil and sometimes (Basin A) the groundwater. Leaks or spills from pipelines are direct pathways to the surface water (Lower Lakes). Spills and leaks or discharges from tanks are pathways to the soil and possibly to surface water (First Creek).

See Table 2 summary on the following page.

Table 2: Summary of Pathways Analysis

Hazardous Substance Sources	Transport Pathways *Mechanism*	Transport Pathways *Medium*	Trustee Resources Exposed
• Disposal Basins A – E F	Direct release of liquid & solid wastes	soils, surface water, groundwater	• Air
• Hydrazine Blending & Storage Facility	Windborne deposition of soils & wastes	soils and surface water	• Surface water • Sediments • Groundwater
• North Plants Complex	• Spills from pipelines & disposal basins	soils, surface & groundwater	• Fish
• South Plants Complex	• Leaking of wastes	groundwater, soil contaminated surface water, sediments	• Mammals
• Chemical Sewer System			• Birds
• Army Complex Trenches	• Precipitation runoff through contaminated soils	surface & groundwater	• Terrestrial & aquatic plants
• Shell Sect. 36 Trenches Ditches			• Terrestrial & aquatic habitats
• Lime Settling Basins	• Volatilization of hydrocarbons – inhalation	biota	
• Motor Pool	• Ingestion of water		
• Rail Classification Yard	• Dermal exposure from water, air, soil	contaminated surface water, sediments	
• Toxic Storage Yard	•Food chain – aquatic & terrestrial food		
	• Seepage of groundwater	surface water	

B. Estimated Areas of Exposure

This section contains preliminary estimates of exposed areas based on a rapid review of readily available information. This section is not a comprehensive quantification of all exposed areas. Areas exposed to hazardous substances at the Arsenal include the soils, sediments, air, surface waters and groundwater, as well as areas down-gradient (groundwater) and down-wind of the site (air). Several plumes of contaminated groundwater extend off-site. Potentially affected areas include the lands immediately north of the Arsenal boundary, especially those lands over the various groundwater plumes.

Groundwater

The estimated extent of the existing groundwater plumes for benzene, DBCP, dieldrin, chloroform, and TCE is 2889.8 acres. *RMA Plume/Estimated Reduction in Plume Area and Volume Over Time, D. Folkes, September 1, 2005*. This estimate includes both the on- and off-post plumes.

Surface water

First Creek drains most of the eastern half of the Arsenal and flows for 9.4 kilometers on Arsenal property. Extensive marshy areas exist alongside it. It has a fairly persistent flow and defined channel but in dry years only contains water in the spring following major precipitation.

There are four lakes on the Arsenal. Lower Derby Lake covers 89 acres, has an average depth of 2-3 meters and is the largest lake on the Arsenal. Upper Derby Lake is generally dry as it is designed to take overflow in case of flood. It covers 85 acres and, when wet, has an average depth of less than 2 meters. Lake Mary covers 7.9 acres and has an average depth of 2.7 meters. Lake Ladora covers 64 acres and has an average depth of less than 2 meters.

Air

The amount of air exposed to contaminants and noxious odors is difficult to estimate because of limited data and the nature of the natural resource. At a minimum the exposed area consisted of the Arsenal and an undefined area off-site to the north and northwest.

Soils

The Arsenal covers 27 square miles (over 17,000 acres). The major sources of releases of hazardous substances described in this PASD extend over at least 1500 acres. The documents reviewed for this PASD lacked acreages for Basins C and E, the Rail Classification Yard, the chemical sewers, the disposal ditches and the Sand Creek Lateral, and part of the South Plants and Toxic Storage Yard.

C. Natural Resources Subject to State Trusteeship

CERCLA establishes liability to a state "[i]n the case of an injury to, destruction of, or loss of natural resources … within the State or belonging to, managed by, controlled by, or appertaining to such State." *42 U.S.C. 9706(f)(1).* Colorado's constitution and statutes firmly establish the fundamental principle that all water in or tributary to natural surface streams is the property of the public and dedicated to the use of the people of the State. *See COLO. CONST., art. XVI, § 5 and C.R.S. § 37-92-102(1)(a).* The State manages and controls all waters of the State. C.R.S. § 37-92-501(1), 37-92-101(1), 5 CCR 1002-41 (Regulation 41). All wildlife in Colorado that is not privately owned is the property of the State and the control and regulation of wildlife is to be exercised as a trust for the benefit of the people. *C.R.S. § 33-1-101(2), Maitland v. People, 23*

P.2d 116 (Colo. 1933) and Mountain States Legal Foundation v. Hodel. 799 F. 2d 1423, 1426 (10th Cir. 1986). Natural resources (as defined in *43 CFR § 11.14(z*)) for which the Trustees have trusteeship that are likely to or have been adversely affected by releases of hazardous substances include, but may not be limited to, the following:

- birds
- fish and other aquatic species
- mammals
- habitat or supporting ecosystems for the above resources, provided by surface water and terrestrial vegetation
- groundwater
- air
- surface water/sediments.

D. Quantity and Concentration of Released Hazardous Substances Are Sufficient To Cause Injury

This section presents examples of concentrations of hazardous substances that have been measured in natural resources both on-post and off-post of the Arsenal based on a review of available information. This section is not a comprehensive review of all studies that have been conducted at the Site. Rather, this section presents examples drawn from a rapid review of the readily-available literature. Appendix D, attached, shows a representative sample of contamination detected at the sources. Figures 4 and 5, attached, show the approximate extent of contaminated groundwater plumes for two contaminants, chloroform and dieldrin. Figure 6, page 26 below, shows approximate extent of on-post soil with a hazard index greater than one.

1.) Groundwater

Definitions of injury to groundwater presented in the Department of Interior (DOI) regulations include the following:

- concentrations of hazardous substances exceeding SDWA or other relevant federal or state criteria or standards (*43 CFR § 11.62 (c)(1)(i),(ii),(iii)*)
- concentrations of hazardous substances sufficient to cause injury to other natural resources that come in contact with the groundwater (*43 CFR § 11.62(c)(1)(iv)*).

Water treatment to remove hazardous substances from the groundwater has been in operation for many years and will continue well beyond the completion of the soils phase of the remedial action. The contaminated groundwater plume on-site will continue for at least 30 to 50 years, perhaps into perpetuity. The off-site groundwater contaminant plume is shrinking but is expected to persist for at least 30 years. As a result, groundwater contamination persists in many plume groups. The contaminant concentrations are in excess of drinking water standards, public water supply standards and domestic water supply standards. The approximate concentration ranges of major contaminants in each plume group that are the drivers for the plume mapping, as well as the applicable regulatory or risk-based standards, termed Containment System Remediation Goals (CSRGs), are summarized in the table in Appendix A1. Appendix A2 identifies the primary contaminants in each plume group based on sampling from 1989 to 1994 that was done in

preparation for the remedial decisions as memorialized in the CERCLA Records of Decision (RODs).

Nine monitoring wells in the vicinity of the HBSF revealed measurable levels of hazardous substances, including carbon tetrachloride, chloroform, trichloroethylene (TCE), aldrin, dieldrin, endrin, isodrin and DDD. *Draft Final Phase I Contamination Assessment Report, Site 1-7 Hydrazine Blending and Storage Facility, Ebasco for U.S. Army, p. 11 (January 1988).* Most notable were concentrations of NDMA, a chemical formed when hydrazine is exposed to air. This substance, with a recommended cleanup standard of 0.00069 ug/L, is one of the most toxic constituents in the groundwater at the Arsenal. NDMA was found in concentrations exceeding 10 parts per billion. *Groundwater Monitoring Program Evaluation Report for Water Year 1995, U.S. Geological Survey, Figure 10 (January 1998).*

Field investigations at the South Tank Farm between 1979 and 1984 identified a contaminated groundwater plume consisting primarily of benzene, toluene, and xylene extending from the South Tank Farm toward Lower Derby Lake. *South Tank Farm Plume Summary Report, p. 3.* Concentrations of benzene appeared to increase by almost an order of magnitude between 1983-84 and 1988. In 1989, further investigation defined the LNAPL plume from the STF. *Id., p. 4.* Recent sampling (*see* July 14, 2006 RVO email on Groundwater Mass Removal Project) revealed benzene free-product (maximum 21 inches thick) in the STFP at a groundwater concentration of 1,400,000 µg/L. *See., e.g., Ebasco Services Remedial Investigation Report figure SPSA 3.3-9; 1995 Water Detailed Analysis of Alternatives, South Plants Plume Group, p. 8-2*. Additional documentation for free product DCPD is also found for this area, reportedly contaminated by a leak from tank 464A at the South Tank Farm. *1991 Morrison Knudsen Environmental LNAPL/SVE Treatability Study Report*.

A TCE plume in groundwater migrated north-northwest from the Motor Pool toward the Irondale Containment System; soil contamination was found at depths up to 30 feet. *Final IRA Summary Report, pp. 2-5*.

At the Lime Settling Basins, benzene has been found at 6 ppm, chlorobenzene and methylene chloride at 2 ppm, and chloroform at 7 ppm. Aldrin has been detected at 600 ppm, and dieldrin at 120 ppm. *Final Site 36-4 CAR, Lime Settling Basins, pp. 1-16, 26.*

At the Rail Classification Yard, DBCP was the only compound consistently found in the groundwater in concentrations greater than the remediation goal of 0.2 µg/l. Soil-gas surveys concluded that sources of DBCP in the groundwater were unsaturated soils and sediments. The estimated average flow of the DBCP plume was approximately 100 gpm. The upgradient configuration of this plume showed several fingers of contamination emanating from small sources of DBCP in the Rail Yard. Concentrations of DBCP in the groundwater decreased with depth, and decreased in time after a peak in 1984. *Draft Final IRA Summary, pp. 2-3.*

2.) Biological resources

Pursuant to the DOI regulations, an injury to biologic resources occurs if the concentration of the released hazardous substances:

- cause the biological resource or its offspring to undergo at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiologic malfunctions (including malfunctions in reproduction), or physical deformations;
- exceed action or tolerance levels established under section 402 of the Food, Drug and Cosmetic Act, 21 U.S.C. 342, in edible portions of organisms;
- exceed levels for which an appropriate state health agency has issued directives to limit or ban consumption of such organism.

Wildlife

Releases at the Arsenal to surface water, soils and sediments, and groundwater may have caused death, behavioral and reproductive abnormalities, physiologic malfunctions, eggshell thinning in avian species and reduced avian reproductions. Organochlorine pesticides (aldrin, dieldrin, endrin) released at the Arsenal are neurotoxins that interfere with ion movements across cell membranes and cause paralysis, convulsions and death in insects. Similar toxic symptoms occur in birds and mammals. *Agency for Toxic Substances and Disease Registry, 1993, 1994, 1996, 2002.* Dieldrin is also a carcinogen.

Pursuant to the *Assessment of Residual Ecologic Risk, Final, Rocky Mountain Arsenal Biological Advisory Subcommittee (April 2002),* a dieldrin soil concentration of .13 ppm equals a hazard quotient (HQ) of 2. An HQ is defined as an exposure estimate divided by an estimated safe level. The subcommittee considered a HQ greater than 2 to be an unacceptable risk to wildlife. The subcommittee report establishes that there are/were areas on the Arsenal with unacceptable risk to biota.

The Army determined the majority of the total area of the Arsenal presented a potential risk to birds and mammals. The Army defined a potential risk as a Hazard Index greater than 1. See Figure 6 below, which illustrates the area of the Arsenal with a Hazard Index greater than 1. *Final Integrated Endangerment Assessment /Risk Characterization, Version 4.1, Volumes I and II of IV, Replacement Pages, Ebasco, pp. 4-22-4-23 (July 1994).*

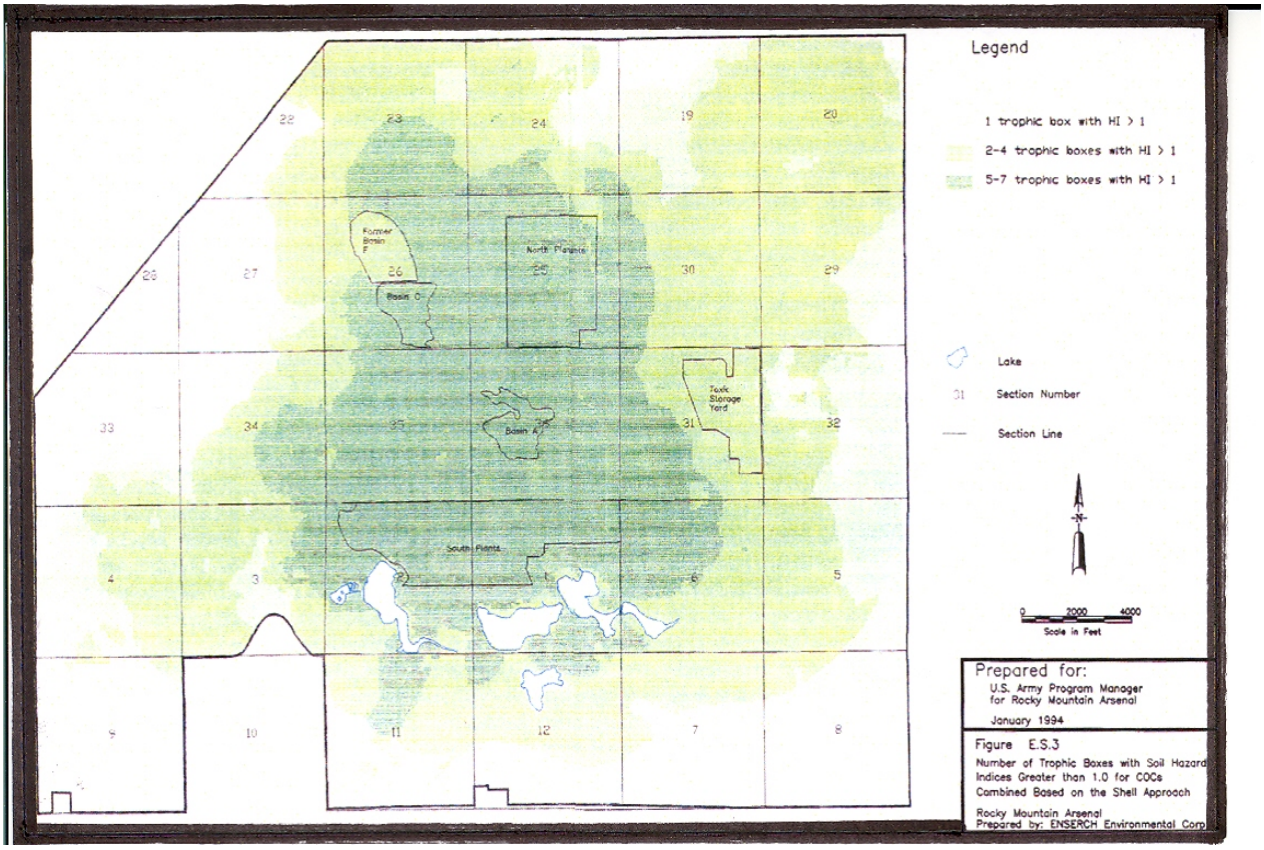


Figure 6 *(Fig. E.S.3, from the Integrated Endangerment Assessment)*

Trophic boxes refer to exposure through the food chain. The trophic boxes in Figure 6 represent the bald eagle, great horned owl, American kestrel, small bird, shore bird, small mammal and medium mammal. All of these wildlife reside at the Arsenal.

Dieldrin is the predominant contaminant in the terrestrial biotic environment. Concentrations were highest in burrowing animals living in the vicinities of the South Plants and the waste basins, but nearly all sampled species showed evidence of dieldrin contamination. A badger carcass found in 1992 had 75 ppm dieldrin in its body fat**.** Prairie dogs were heavily contaminated with mercury and organochlorine pesticides. *Biota Remedial Investigation, Table 4.3-5.* The Army's 1988 Biota Comprehensive Monitoring Program (CMP) showed similar results. The Army eradicated some prairie dog colonies because their tissue concentrations of hazardous substances posed a threat to the viability of raptors. Army references reported that dieldrin concentrations in excess of 4 ppm are lethal for small animals. *State Summary, 1989.*

<u>Mortality Data</u>

In 1952, field and laboratory studies revealed that approximately 1,200 ducks died in that spring alone in and around the Lower Lakes. These deaths appeared to be the result of an "oily scum" that contained a central nervous toxin that entered the lakes through a process water drain from the South Plants. *Final Site 2-17 CAR, Lake Ladora and Lake Mary, p. 16*. In 1955, U.S. Fish and Wildlife Service analyzed the liver and fat of ducks found near the Lower Lakes and found

concentrations of dieldrin and related compounds as high as 261 ppm (current FDA Action Level is 3 ppm). *Lake Sediments Remediation Report, p. 2.*

In 1959 dead birds, rabbits, frogs and other animals were scattered along the shores of Lake Ladora and the canal that skirted the north side of the lake. *Investigations of Waterfowl Mortality(1959), pp. 3-4.* The U.S. Fish and Wildlife Service estimated that approximately 1,200 ducks died around Lake Ladora from January through April 1959, and estimated that there were at least 2,000 duck mortalities per year during the previous ten years. *Lake Sediments Remediation, p. 2.*

Dead wildlife were also found at Basin F. In a two-week period in early April of 1973, approximately 750 dead ducks and grebes were collected around the Basin. *Research Prospectus, Studies to Elucidate the Cause of Waterfowl Mortalities at Basin F and Vicinity, Rocky Mountain Arsenal, Colorado, Edgewood Arsenal/Dugway Proving Ground Ecological Research Team (August 1973).* In 1975, U.S. Fish and Wildlife Service Region 6 Law Enforcement personnel reported that 291 carcasses of several species of birds were removed from Basin F shorelines over a two-day period. *U.S. Fish and Wildlife Service Investigations of Chemical Contaminants in Animals and Habitats of the Rocky Mountain Arsenal, p. 2 (May 1984).*

Wildlife mortalities continued through the 1980s and 1990s. On just one afternoon visit to the Arsenal in 1980, Colorado Division of Wildlife officials collected 389 wildlife carcasses, while observing birds that were still alive but unable to fly or walk. *Interoffice Memo from John Seidel to Darryl Todd, Colorado Division of Wildlife (May 8, 1980).* In 1982, the USFWS measured organochlorine residues in the brain tissues of birds found dead at the Arsenal that year. Ten birds had dieldrin concentrations in the brain above 3 ppm, a level sufficient to cause death. *Letter re Summary table showing organochlorine residues in brain tissues of some animals found dead at Arsenal in 1982, L.C. McEwen to William McNeill, 1983.* Waterfowl mortality counts at Basin F from 1981 to 1987 ranged between 139 and 444 per year.

Table 3. Reported waterfowl mortalities at Basin F (1981-1987)

Year	Number found dead
1981	202
1982	222
1983	444
1984	418
1985	140
1986	236
1987	139
Total	**1,801**

Source: Table 4.1-1 in ESE, 1989

A total of 102 bird mortalities in 19 species were attributed to dieldrin or endrin poisoning between 1990 and 1998. *Rocky Mountain Arsenal National Wildlife Refuge Fiscal Year 1999 Annual Progress Report, USFWS, (February 2000).*

Table 4. Bird species at RMA for which mortality was attributed to dieldrin or endrin poisoning, 1990-1998

Omnivorous birds	Seed eating birds	Raptors
European starling	House finch	Great horned owl
American robin	Mourning dove	American kestrel
Western kingbird	House sparrow	Red-tailed hawk
Black-billed magpie	Pigeon	Barn owl
Western meadowlark	Chipping sparrow	Burrowing owl
Brewer's blackbird		
Eastern kingbird		
Common grackle		
Northern mockingbird		

Source: Table 1-8, Rocky Mountain Arsenal National Wildlife Refuge, Annual Progress Report FY 1999, U.S. Fish and Wildlife Service, 2000

Testing of the carcasses from Basin F and other areas of the Arsenal revealed high levels of contaminants, including dieldrin and DDE, with contamination levels up to 15.6 ppm for dieldrin (mortality threshold starts at 3 ppm) and 10.3 ppm for DDE. *Biota Remedial Investigation, at pp. 4-42.* Ten of fourteen raptor carcasses collected or reported had measurable dieldrin in their brains, the concentrations ranging from 0.175 to 15.6 ppm. Brain concentrations of 5 ppm are believed to be lethal. *Biota Remedial Investigation, pp. 5-155.*

Through the late 1980s and early 1990s, dead and dying raptors were observed around the lakes. Tissue concentration data and food-web model results supported the conclusion that the mortalities were a result of organochlorine pesticide contamination. *Final IEA/RC, Vol. I, pp. 2-4.* Testing of fortuitous raptor samples between 1986 and 1998 showed maximum concentrations of dieldrin of 15.6 ppm, much higher than the brain toxicity threshold of 9 ppm set by the U.S. Fish and Wildlife Service. *USFWS 1994 Annual Progress Report, 1995.* The U.S. Food and Drug Administration action level for dieldrin residues in poultry is 0.3 ppm. Table 5 shows dieldrin concentrations in four commonly consumed game birds above the FDA action level.

Table 5: Examples of dieldrin concentrations in game birds at RMA in excess of FDA action level of 0.3 ppm for poultry

Species	Tissue type	Maximum concentration
Mallard	Adult carcass	4.53 ppm
Mallard	Juvenile carcass	0.52 ppm
Ring-necked pheasant	Juvenile carcass	1.33 ppm
Ring-necked pheasant	Adult carcass	2.92 ppm
Redhead	Muscle	0.32 ppm
American coot	Muscle	1.77 ppm

Source: Tables 4.3-1 and 4.3-2 in ESE, 1989.

Lost human use

In 1981, the Colorado Department of Health and the Colorado Division of Wildlife were sufficiently concerned about reports of wildlife contamination that the agencies issued a heath advisory warning against consumption of birds and other wildlife hunted close to the Arsenal, because significant levels of chemicals in the meat, sometimes above FDA limits, posed a threat to human health. *News Release, Colorado Department of Health, December 10, 1981.* In response

to these concerns, Shell initiated another round of sampling of the lake beds and connecting ditches that revealed varying concentrations of aldrin, dieldrin, endrin, and mercury. *Lake Sediments Remediation Project, p. 2.*

Sub-lethal effects

Avian wildlife at the lakes exhibited clinical signs of organochlorine pesticide poisoning, such as flying into buildings and attempting to land while several feet above the ground. Physiological malfunctions, such as eggshell thinning and reduced reproduction, are known to be caused by organochlorine pesticides and were extensively documented in the American Kestrel at the Arsenal. *Biota Assessment: Draft Final Phase II Technical Plan, Environmental Science and Engineering for U.S. Army, pp. 2-34 (August 1986). See also* Appendix B, attached, an abridged list of the adverse health of some contaminants on humans and animals.

Fish

Fish in the RMA Lower Lakes also contained dieldrin concentrations in excess of FDA recommended levels for ingestion by humans, which resulted in a complete consumption ban for fish in RMA lakes in 1984. The catch and release policy remains in effect today. In the 1990s, the U.S. Fish and Wildlife Service found that concentrations of dieldrin and DDE were responsible for mortalities of largemouth bass from Lower Derby Lake and catfish from Lake Mary, both of which had elevated tissue concentrations of dieldrin and DDE. *Final Biota Remedial Investigation,, Table 1.3-1.* While arsenic was often elevated in lower aquatic trophic levels at RMA, arsenic did not magnify through the food chain to higher levels as did dieldrin, mercury, and DDE, all of which were consistently found in carnivorous fish at the top of the food chain. *State Summary, 1989.*

3.) Surface water/sediments

Pursuant to the DOI regulations, an injury to surface water occurs when the concentrations and durations of hazardous substances in the waters are sufficient to cause injury to biologic resources when they are exposed to surface water, suspended sediments, or bed, bank and shoreline sediments, (*43 CFR § 11.62(b)(1)(v*). Most of the contaminants were concentrated in the sediments of the beds of the lakes, ponds and First Creek. Sampling of surface water in and adjacent to First Creek in the northern Arsenal Off-Post area in 1988 detected concentrations of dieldrin, arsenic, dithiane, DDT and chloride in excess of Critical Reporting Limits ("CRL") *Office Memorandum, Harding Lawson Associates, December 14, 1988.* The quantity and concentration of the released hazardous substances in the surface water and sediments were sufficient to cause injury to biological resources through ingestion and direct and indirect exposure as described above. A 1983 study found widespread concentrations of aldrin, dieldrin and mercury in Lower Derby Lake and aldrin and dieldrin in the Rod and Gun Club Pond. *Meyers et al., 1983 RIC84086ROI, U. S. Army Engineers Waterways Experiment Station.* Surface water samples in 1984 from Lake Ladora and Lake Mary showed measurable amounts of endrin, dieldrin and mercury (up to 0.4 micrograms per liter). *Final Site 2-17 CAR.* The CRL for dieldrin is .05µg/l. Sediment sampling of Upper Derby Lake was similar to that of Lower Derby Lake. Arsenic was detected in the sediments of Upper Derby Lake in 1992.

In late 1963, Shell and the Army agreed that the lakes were contaminated with several organic compounds at concentrations as high as 2,400 ppm. Additional sampling of sediments in 1964 by Shell revealed that concentrations of aldrin (up to 183 ppm), dieldrin (up to 12.7 ppm), isodrin (up to 8.3 ppm), and endrin (up to 10 ppm) occurred in the lake sediments. Sampling in 1982 and 1983 showed varying concentrations of aldrin, dieldrin, endrin, and mercury in the Derby lakes and connecting ditches. *Lake Sediments Construction Completion Report, pp. 1-3, 5.*

4.) Air resources

Pursuant to the DOI regulations, an injury to the air resource results from the release of hazardous substances if one or more of the following changes in the physical and chemical quality of the resource is measured:

- concentrations of emissions in excess of standards for air pollutants established by section 112 of the Clean Air Act, 42 U.S.C. 7412, or by other Federal or State air standards established for the protection of public welfare or natural resources;
- concentrations and duration of emissions sufficient to have caused injury to surface water, groundwater, geologic, or biological resources when exposed to the emissions.

At this point, readily available data do not indicate that the concentrations of emissions on- and off-post at the Arsenal exceeded standards for hazardous air pollutants established by section 112 of the Clean Air Act, 42 U.S.C. 7412, or any other federal or state air standards established for the protection of public welfare or natural resources. Nor is there any readily available data to support an injury to other natural resources as a result of the concentration and duration of emissions as required by the DOI regulations. However, the courts recognize that a natural resource can suffer a compensable aesthetic injury as a result of the release or discharge of a hazardous substance. *See In re Acushnet River & New Bedford Harbor*, 716 F. Supp. 676, 686, n 15 (D.Mass., 1989). The degree and duration of noxious odors emitted from Basin F substantiate such an aesthetic injury to air because these emissions resulted in at least 200 complaints of nausea and burning eyes from area residents, and caused the Army to provide air purifiers to many of these residents.

The Interim Response Action at Basin F, which began in March 1988, resulted in the emission of noxious odors both on and off the Arsenal. The first odor complaints, in July 1988, came from residents north and northwest of the Arsenal. The complaints occurred on an almost daily basis. In October of 1988, the Ralston Purina Company, on behalf of its customers and employees, complained of a “pesticide odor” that irritated the eyes and caused nausea.

People living near the Arsenal complained of nausea, headaches, and burning eyes, and raised questions regarding potential adverse health effects from the odors. The Army provided air purifiers to many of the residents immediately north and northwest of the Arsenal boundary. Contractors working in Basin F wore protective clothing and used respirators. Over 200 complaints were received between July 1988 and January 1989. The cleanup was discontinued in March 1989, and there were no further complaints of odors or physical symptoms attributed to the odors. *Transcripts from Basin F Meetings, 1988,* and *State’s Comments to Basin F Tasks.*

E. Availability of Data For a Reasonable Cost Damage Assessment

Data regarding the natural resource injuries at the Arsenal have been collected as part of the removal and remedial response actions. There are a number of academic studies, as well. Data include information on hazardous substance sources, releases, and concentrations in surface water, sediments, groundwater, air, wildlife, as well as wildlife toxicity.

F. Preliminary Estimate of Affected Services

Services affected by injured or potentially injured resources include, but are not limited to:

- supporting habitat for wildlife, including food, shelter, breeding and rearing areas, and other factors essential to long-term survival;
- consumptive and non-consumptive outdoor recreation, including hunting, fishing, hiking, wildlife viewing, and photography;
- passive use and option values;
- other ecological and biological services provided by natural resources;
- drinking water and water for agricultural and industrial use.

Passive use values are values unrelated to one's own use of the injured resource. These values can be bequest values (value for use by future generations) or existence values (value of the resource even if it is never used by anyone). *See 56 Fed. Reg. 19760.* Ecological services provided by natural resources include habitat, biodiversity, carbon sequestration, nutrient cycling, food sources, and other biological, chemical, and physical functions and processes.

Groundwater may provide ecological and biological services, as well as other services to society, including potable drinking water, irrigation for crops, livestock watering, water for manufacturing, and electricity generation. Groundwater recharge also provides a pathway to support surface water services (Natural Research Council, 1997).

Water is a scarce commodity in Colorado due to the natural semi-arid climate and the drought conditions that have occurred with increasing frequency in the past few years.

G. Response Actions, Carried Out or Planned, Do Not or Will Not Sufficiently Remedy the Injury to Natural Resources Without Further Action

Response actions at the Arsenal are being conducted pursuant to CERCLA, which addresses sites that have been contaminated by hazardous substances, pollutants or contaminants. *CERCLA § 9601, et. seq.* The remedial activities necessary to abate threats from RMA releases are set forth in two Records of Decision ("ROD"), one for on-post and one for off-post remediation.

The off-post ROD was finalized in 1995 and the on-post ROD in 1996. As decided by the parties and memorialized in the RODs, the Army and Shell, pursuant to an agreed-upon allocation of costs (80 percent Army, 20 percent Shell), have been actively cleaning up the Site. On-the-ground remediation is currently scheduled to continue until 2011. As a result of the selected remedy, a plume of groundwater of almost 3,000 acres contaminated above standards remains. Pump-and-

treat operations for contaminated groundwater plumes flowing off the Arsenal are expected to continue for at least 30 to 50 years, and may continue in perpetuity.

Principal threat wastes will be left on-site after the remedy is complete. Principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur. *A Guide to Principal Threat and Low Level Threat Wastes, OSWER 9380.3-06FS, Environmental Protection Agency (1991).* When the remedy is concluded, 558,000 cubic yards of principal threat soil and 1,270,000 cubic yards of soil in excess of human health standards will be contained in triple-lined disposal facilities in the central area of the Arsenal.

The selected CERCLA remedy for the principal threat waste sites associated with the Shell trenches, Army complex trenches, Basin A disposal areas, former Basin F, and South Plants central processing area is capping in place. An estimated 800,000 cubic yards of principal threat soil and soils in excess of human health standards, as well as 130,000 cubic yards of unexploded ordnance debris, will remain in the Army complex trenches. In the Basin A area, an estimated 328,000 cubic yards of highly contaminated soil, along with nearly 800,000 cubic yards of consolidated materials from other sites, will be contained under a future 150-acre soil cover. In addition, 550,000 cubic yards of soil in excess of human health standards, along with 350,000 cubic yards of contaminated soil consolidated from other areas, will be stored under the 125-acre former Basin F soil cover. The Lime Settling Basins will be covered with the contamination left in place. Finally, due to the presence of utility piping and sewers in the South Plants central processing area, the remedy involves a 215-acre soil cover to contain 76,000 cubic yards of highly contaminated soil at depths greater than five feet. *On-Post ROD, Volume I, Table 9.3-1, 9.3-3 (1996).*

Pursuant to the selected remedy, the Army will retain approximately 900 acres at the Arsenal after the remedy is completed for the disposal of hazardous waste. This land cannot be transferred to the U.S. Fish and Wildlife Service for the National Wildlife Refuge because engineered soil covers that entomb 3,390,000 cubic yards of untreated soil in excess of protective standards must be maintained in perpetuity. *On-Post ROD, id., Table 9.3-3*. This volume does not include the 1,100,000 cubic yards of untreated soil already placed in the on-site hazardous waste landfill and the 690,000 cubic yards of untreated soil to be disposed in the on-site enhanced, triple lined, hazardous waste landfill. These areas reduce available habitat, and to the extent that the selected remedy reduces habitat, it does not address injury to supporting ecosystems.

None of the remedial actions will remedy or compensate the Trustees for the interim loss of use and value associated with the injured resources from the time of the release to such time as baseline conditions are met.

IV. CONCLUSIONS

Based on review of readily available data and the evaluation of the preassessment determination criteria, summarized in this document, the State Trustees conclude:

1. Releases of hazardous substance have occurred;
2. Natural resources for which the Trustees may assert trusteeship under CERCLA have likely been adversely affected by the discharge or release of hazardous substances;
3. The quantity and concentration of the released hazardous substances are sufficient to cause or potentially case injury to natural resources;
4. Data sufficient to pursue an assessment are readily available or can be obtained at a reasonable cost; and
5. Current and planned response actions will not sufficiently remedy the injury to natural resources without further action.

The Trustees have determined that further investigation and assessment are warranted, in accordance with the federal regulations at 43 CFR Part 11. The Trustees further determine that there is a reasonable probability of making a successful Natural Resource Damages claim pursuant to Section 107 of CERCLA.

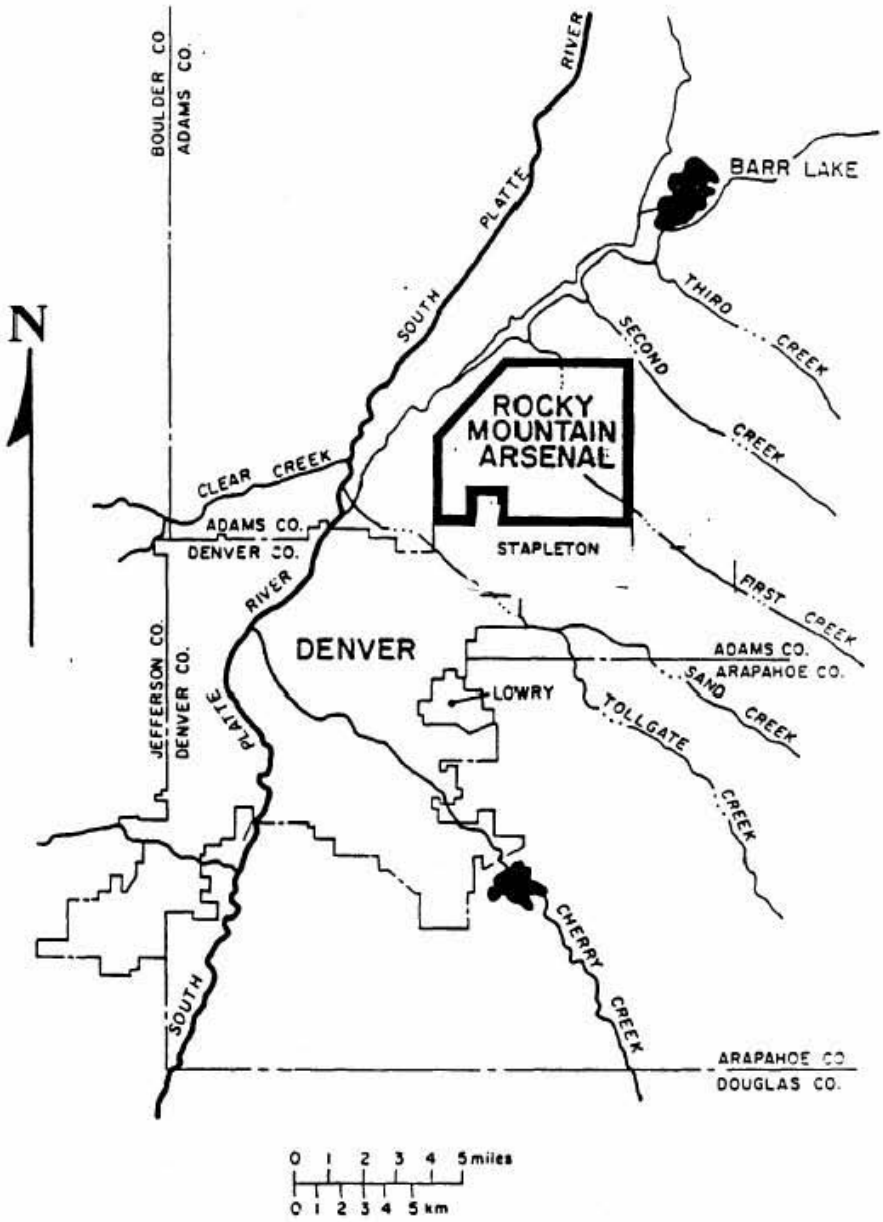


FIGURE 1 LOCATION MAP ROCKY MOUNTAIN ARSENAL.

(from Aquatic Resources of Rocky Mountain Arsenal, MKE for Shell Oil, Sept. 1989)

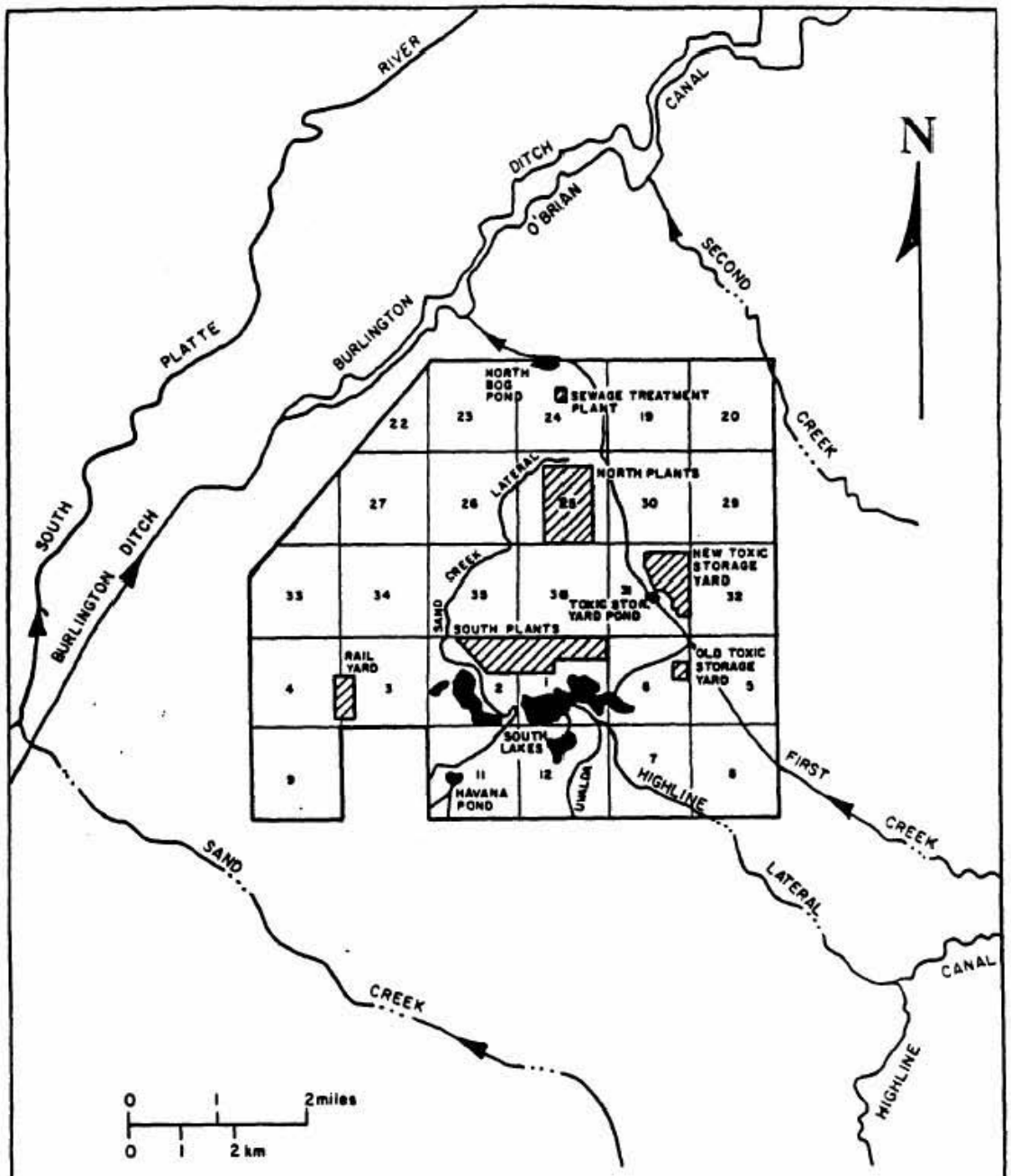


FIGURE 2 SURFACE WATERS OF ROCKY MOUNTAIN ARSENAL AND VICINITY.

(from Aquatic Resources of Rocky Mountain Arsenal, MKE for Shell Oil, 1989)

APPENDIX A.1

ABRIDGED CURRENT RANGES OF GROUNDWATER CONTAMINATION[2] FOR CONSTITUENTS THAT DRIVE PLUME MAPPING

Constituents	North Boundary	Northwest Boundary	Basin A	South Plants	Off-Post
Benzene Standards: 3 ug/L CSRG; 5 µg/L MCL	1.27 to 100 µg/L		1.27 to 100 µg/L	1.27 to 100 µg/L (including South Tank Farm 64,000 µg/L)	
Chloroform Standards: 3.5 ug/L CSRG; 6 µg/L WQCA	0.5 to 100,000 µg/L	0.5 to 100 µg/L	1.27 to 10,000 µg/L	0.5 to 1,000,000 µg/L	0.5 to 100 µg/L
Dieldrin Standards: 0.002 ug/L CSRG; 0.002 µg/L WQCA	0.05 to 0.5 µg/L	0.05 to 0.5 µg/L	0.05 to 0.5 µg/L	0.05 to 0.5 µg/L	0.05 to 0.1 µg/L
Trichloroethylene (TCE) Standards: 3 ug/L CSRG; 5 µg/L MCL	0.5 to 100 µg/L			0.5 to 1,000 µg/L	
Dibromochloropropane (DBCP) Standards: 0.2 ug/L CSRG; 0.2 µg/L MCL	0.2 to 50 µg/L		0.2 to 1,000 µg/L	0.2 to 3,500 µg/L	

[2] *Long Term Monitoring Plan, prepared by Foster Wheeler Environmental Corp. for U.S. Army (December 1999).*

APPENDIX A.2

ABRIDGED LIST OF PRIMARY GROUNDWATER CONTAMINANT CONCENTRATIONS BASED ON DATA FROM 1989-1994[3]

Constituents	North Boundary	Northwest Boundary	Basin A	South Plants	Off-Post
Benzene Standards: 3 ug/L CSRG; 5 µg/L MCL	O.5 to 460 µg/L		1.1 to 100,000 ug/L	1.0 to 1,500,000 ug/L	
Chloroform Standards: 3.5 ug/L CSRG; 6 µg/L WQCA	0.5 to 85,000 µg/L	0.5 to 30 µg/L	0.5 to 2,900,000 µg/L	1.6 to 500,000 µg/L	0.68 to 67.5 µg/L
Dieldrin Standards: 0.002 µg/L CSRG; 0.002 µg/L WQCA	0.5 to 440 µg/L	0.05 to 3.5 µg/L	0.05 to 65 µg/L	0.092 to 32 µg/L	0.034 to 0.21 µg/L
Trichloroethylene (TCE) Standards: 3 ug/L CSRG; 5 µg/L MCL	0.5 to 790 µg/L		0.56 to 8,200 µg/L	0.56 to 1,500 µg/L	
Dibromochloropropane (DBCP) Standards: 0.2 ug/L CSRG; 0.2 µg/L MCL	0.6 to 71 µg/L		0.13 to 10,000 µg/L	0.13 to 1,900 µg/L	
Sulfate Standards: 540,000 µg/L CSRG	180 to 10,000,000 µg/L	190,000 to 2,400,000 µg/L			148,000 to 1,118,000 µg/L
DDT Standards: 0.1 µg/L CSRG	0.049 to 27 µg/L				0.033 to 0.11 µg/L
Methylene chloride Standards: 5 µg/L CSRG			2.5 to 910,000 µg/L	2.5 to 3,800 µg/L	
Aldrin Standards: 0.002 µg/L CSRG			0.05 to 300 µg/L	0.05 to 310 µg/L	0.029 to 0.12 µg/L
Chlordane Standards: 0.03 µg/L CSRG			0.095 to 4600 µg/L	0.095 to 29 µg/L	0.18 to 0.54 µg/L
Carbon Tetrachloride Standards: 0.3 µg/L CSRG				0.99 to 1,500 µg/L	0.76 µg/L

[3] *Record of Decision for the On-Post Operable Unit, Volume 1, Version 3.1, tables 5.4-1 to 5.4-5 (June 1996); Rocky Mountain Arsenal Off-Post Operable Unit Final Record of Decision, Table 6.1 (December 1995).*

APPENDIX B

ABRIDGED LIST OF HAZARDOUS SUBSTANCE SUMMARIES & KNOWN ADVERSE HEALTH EFFECTS ON HUMANS & ANIMALS

Aldrin/Dieldrin	Large amounts ingested cause severe convulsions and death; moderate levels of exposure cause headaches, dizziness, irritability, vomiting, and uncontrolled muscle movement; animals exposed suffered nervous system effects resulting from exposure; aldrin and dieldrin are probable human carcinogens.
Benzene	Breathing high levels of benzene results in drowsiness, dizziness, rapid heart rate, headaches, tremors, confusion, unconsciousness and death; ingesting high amounts may cause vomiting, stomach irritation, dizziness, sleepiness, convulsions, rapid heart rate, and death; long-term exposure (one year or longer) decreases red blood cells leading to anemia; excessive bleeding and adverse immune system effects also result from exposure; animals had low birth weights, delayed bone formation, and bone marrow damage; benzene is a known human carcinogen causing leukemia and cancer of blood-forming organs.
Dichlorodiphenyltrichloroethane (DDT) **Dichlorodiphenyldichloroethylene (DDE)** **Dichlorodiphenyldichloroethane (DDD)**	DDT affects the nervous system causing tremors and seizures; DDE increases the chance of premature babies; DDE and DDD are both probable human carcinogen; DDT is a known human carcinogen; it causes eggshell thinning and reproductive problems in avian species.
Endrin	Endrin does not dissolve in water and may remain in the soil for up to 10 years; exposure causes severe central nervous system injury and death within minutes of consuming large amounts; headaches, dizziness, nervousness, confusion, nausea, vomiting, and convulsions also may result; endrin shares a similar structure with aldrin/dieldrin, both of which are known animal carcinogens.
Chloroform	Chloroform remains in groundwater for a long period of time; exposure results in dizziness, fatigue, and headache; prolonged exposure produces liver and kidney damage; chloroform causes miscarriages and birth defects in animals; chloroform may reasonably be considered a human carcinogen; animals developed cancer of the liver and kidneys after chloroform exposure.
Vinyl Chloride	Causes dizziness or sleepiness; very high levels result in unconsciousness or death; prolonged exposure changes liver structure, causes nerve damage, adverse immune reactions, birth defects, and the break down of finger bones; vinyl chloride is a known human carcinogen that causes liver cancer.
Trichloroethylene (TCE)	Remains in groundwater for a long period of time; small amounts cause headaches, lung irritation, dizziness, poor coordination, and difficulty concentrating; exposure to large amounts causes impaired heart function, unconsciousness, and death; prolonged exposure results in nerve, kidney, and liver damage; TCE in water causes nausea, liver

	damage, unconsciousness, heart problems, and death; drinking small amounts of TCE for a prolonged time period results in liver/kidney injury, impaired immune system function, and stunted fetal development; high levels of TCE in drinking water lead to an increased risk of cancer in humans.
Dibromochloropropane (DBCP)	Adversely affects the male's ability to reproduce; also causes headaches, nausea, lightheadedness, and weakness; animals experienced the inability to reproduce and had damaged stomachs, livers, kidneys, brains, spleens, blood, and lungs; direct contact causes skin and eye damage; reasonably anticipated to be a carcinogen.
***n*-Nitrosodimethylamine (NDMA)**	High amounts cause liver damage; ingestion or inhalation of extremely high levels of NDMA result in death; animals also suffer liver damage when exposed to NDMA and a high rate of stillborn fetuses; NDMA causes liver and lung cancer in animals and is reasonably anticipated to be a human carcinogen; NDMA is structurally related to other known human carcinogens.
Hexachlorocyclopentadiene (HEX)	Does not dissolve in water; HEX causes breathing difficulties, headaches, and liver/kidney damage; in animals, HEX causes bleeding, swelling, and fluid buildup in the lungs; exposure to large quantities results in respiratory difficulty and death; most animals die after HEX exposure.

Sources: Environmental Protection Agency, Integrated Risk Information System, Substance Summary Reports, *available at* http://www.epa.gov/iris/subst.htm; Agency for Toxic Substances & Disease Registry, Toxic Substance Reports, *available at* www.atsdr.cdc.gov/.

APPENDIX C Contaminant Levels in Aquatic Ecosystems.

SPECIES	Tissue	Location	Contaminant Level in parts per million (mg/kg wet weight basis) (Range/mean*)						
			Arsenic (n/nt)	Mercury (n/nt)	Aldrin (n/nt)	Dieldrin (n/nt)	Endrin (n/nt)	DDE (n/nt)	p,p '-DDT (n)
Bluegill	Fillet	RMA Lake Mary, 1986	BDL (3)	<0.050-0.099 0.074 (2/3)	BDL (3)	<0.031-0.041 (1/3)	BDL (3)	BDL (3)	BDL (3)
	Whole	RMA Lake Mary, 1986	BDL (6)	<0.050-0.137 0.061 (3/6)	BDL (6)	<0.031-0.158 0.085 (5/6)	BDL (6)	BDL (6)	BDL (6)
Bluegill	Whole	RMA Lower Derby, 1988	BDL (6)	<0.050-0.091 0.056 (3/6)	BDL (6)	<0.031-0.129 0.074 (4/6)	BDL (6)	BDL (6)	BDL (6)
	Whole	RMA Lower Derby, **1986**	BDL (3)	BDL (3)	BDL (3)	0.142-0.161 0.149 (3/3)	BDL (3)	BDL (3)	BDL (3)
Bluegill	Whole	RMA Lake Ladora,l986	BDL (3)	0.059-0.124 0.084 (3/3)	BDL (3)	0.065-0.153 0.100 (3/3)	BDL (3)	BDL (3)	BDL (3)
Bluegill	Fillet	Offpost Control, 1988	BDL (5)	0.081-0.256 0.188 (5/5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)
	Remainder	Offpost Control, 1988	BDL (5)	<0.050-0.171 0.104 (4/5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)
	Compos.(Whole)	Offpost Control,1988	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)	BDL (2)
	Whole(Reconst.)	Offpost Control, **1988**	BDL (5)	0.088-0.178 0.141 (5/5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)	BDL (5)
Northern Pike	Fillet	RMA Lower Derby, 1986	BDL (3)	0.278-0.470 0.405 (3/3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)	BDL (3)
ch	Fillet	RMA Lake Ladora,l986	BDL (2)	**G.289-0.366** (2/2)	BDL (2)	<0.031-0.044 (1/2)	BDL (2)	BDL (2)	BDL (2)
Fathead Minnows	Composite	RMA North Bog, 1986	BDL (1)	BDL (I)	BDL (I)	BDL (I)	BDL (I)	BDL (1)	BDL (I)
Black Bullhead	Whole	RMA Lower Derby, 1986	BDL (3)	<0.050-0.052 (1/3)	BDL (3)	0.085-0.209 0.144 (3/3)	BDL (3)	<0.094-0.098 (1/3)	BDL (3)

* Mean is calculated when 50 percent or more of samples (n > 2) have detectable contaminant levels. If less than 50 percent of samples have detectable contaminant levels, only the range of values are presented. When calculating the mean, values of 1/2 the detection limit are substituted for 'BDL'.

BDL = Below Detection Limit (Below Certified Reporting Limit).

n = Number of samples analyzed that contain detectable contaminants, nt = total number of samples.

Compos. (Whole) = A number of small fish in a composite sample.

Whole (Reconst.) = A sample comprised of a portion of the fillet and remainder samples reconstituted into a 'whole' sample. Source:

Source: MKE, 1988 and ESE, 1988.

Appendix D
Detections of Contaminants at Major Sources
(not comprehensive)

SOURCE	CONTAMINANTS / # OF DETECTIONS	CONCENTRATION	ACTION LEVEL [1]
BASIN A			
soils (Table 36-1-3, Dr Final Phase II Source Report for 36-1, 36-7, 36-15, ESE April 1986)	chloroform / 2	0.8 ppm	100 ppm
	methylene chloride / 3	1 – 2	90
	aldrin / 13	0.7 – 300	0.04
	dieldrin / 26	0.4 – 400	0.04
	DDT / 2	2 – 10	2
	endrin / 6	5 – 200	20
	chlordane / 9	6 – 400	0.5
	DDE / 1	2	2
	isodrin / 8	1 – 200	
	DCPD / 1	0.4	
	DBCP / 3	0.0007 – 0.11	
	cadmium / 32	0.60 – 9.4	40
	chromium / 102	7 – 100	400
	copper / 108	6 – 63	
	lead / 26	18 – 110	
	zinc / 87	29 – 200	
	arsenic / 77	5.5 – 660	80
	mercury / 51	0.050 – 64	20
groundwater (Table 36-1-6, Dr Final Phase II Source Report for 36-1, 36-7, 36-15, ESE April 1986)	aldrin / 4 or more	<0.2 µg/l	[2]
	dieldrin	<0.2	0.1 µg/l
	endrin	<0.2	0.2
	isodrin	<0.2 – 9.42	
	DBCP	<0.2 – 0.23	
	DCPD	<1.0 – 1000	
	dithiane	<20 – 611	
	carbon tetrachloride	<1.0	0.3 – 1
	chloroform	11 – 1535	6
	trichloroethylene	<1.0 – 1089	5
	tetrachloroethylene	<1.0 – 274	5
	benzene	<1.0 – 129	5
	chlorobenzene	<1.0 – 76	
	dichlorobenzene	<1.0	
	toluene	<1.0	
	xylene	<0.1 – 2	
BASINS B - E			
soils (Table 35-3-2 Final Site 35-3 Basin B CAR, ESE July 1987)	BASIN B		0.04 ppm
	dieldrin / 1	1 ppm	
	Dithiane / 1	0.5	40
	cadmium / 4	0.8 – 2.9	400
	chromium / 12	11 – 32	
	copper / 14	11 – 28	
	lead / 4	22 – 55	
	zinc / 13	37 – 140	80 ppm
	arsenic / 10	8.1 – 170	20 ppm
	mercury / 4	0.12 – 0.55	
	BASIN C		0.04 ppm

SOURCE	CONTAMINANTS / # OF DETECTIONS	CONCENTRATION	ACTION LEVEL [1]
(Table 26-3-11.2 Sum'y of Analytical Results Site 26-3 Phase II Soil Samples, Final Ph II Data Addendum Site 26-3 Basin C, ESE, September 1988)	aldrin / 16	0.006 – 0.49 ug/g	
	isodrin / 13	0.002 – 0.019	2
	DDE / 6	0.005 – 0.11	0.04
	dieldrin / 39	0.002 – 3.2	20
	endrin /25	0.002 – 0.43	2
	DDT / 4	0.006 – 0.19	90
	methylene chloride / 5	0.4 – 0.7	40
	cadmium / 15	0.93 – 13	400
	chromium / 63	8.2 – 20	
	copper / 92	5.8 – 110	
	lead / 25	21 – 61	
	zinc / 100	17 – 130	80
	arsenic / 19	5.8 – 27	20
	mercury /20	0.059 – 0.30	
	BASIN D		0.04 ppm
(Table 26-4-11.1, Sum'y of Analytical Result Site 26-4 Ph II Soil Samples, Final Ph II Data Addendum Site 26-4 Basin D, ESE September 1988)	aldrin / 6	0.002 – 0.41 ppm	2
	DDE / 3	0.029 – 0.052	0.04
	dieldrin / 23	0.002 – 3	20
	endrin / 12	0.001 – 0.027	2
	DDT / 3	0.022 – 0.030	
	cadmium / 6	0.93 – 1. 4	
	chromium / 33	8.2 – 18	
	copper / 41	5.1 – 17	
	lead / 18	21 – 270	
	zinc /44	25 – 60	80
	arsenic / 14	5.7 – 14	20
	mercury / 4	0.087 – 0.39	
BASIN F			
soils (Table 26-6-12, Final Site 26-6 CAR, ESE ,May 1988)	chlorobenzene / 2	0.8 – 5 ppm	2000 ppm
	chloroform / 2	0.3 – 70	100
	1,2-dichloroethane / 1	1	
	bicycloheptadiene / 5	2 – 30	
	ethylbenzene / 2	1 – 8	
	tetrachloroethene / 7	1 – 40	
	toluene / 7	1 – 1000	
	1,1,1-trichloroethane / 1	0.4	
	m-xylene / 2	0.4 – 5	
	MIBK / 3	0.4 - 1	
	DMDS / 3	2 – 70	
	benzene / 3	1 – 3	
	o,p-xylene /1	10	
	aldrin /15	0.7 – 4000	0.04
	dieldrin / 17	0.5 – 2000	0.04
	endrin / 12	2 – 900	20
	isodrin / 11	1 – 3000	
	DCPD / 10	0.4 – 4000	
	CPMS / 8	0.5 – 700	
	CPMSO /12	0.5 – 70	
	DMMP / 9	0.5 – 70	
	CPMSO2 / 28	0.4 – 300	
	DBCP / 7	0.04 – 8	
	cadmium / 1	2	40

SOURCE	CONTAMINANTS / # OF DETECTIONS	CONCENTRATION	ACTION LEVEL [1]
	chromium / 52	9.5 -34	400
	copper / 56	5 – 2300	
	lead / 5	18 – 35	
	zinc / 51	30 – 320	
	arsenic / 22	4.8 – 18	80
	mercury / 2	0.08 – 0. 09	20
groundwater (Table 26-6-8 Initial Quarter Screening, Basin F Area, Final Site 26-6 CAR, ESE, May 1988)	aldrin / 4	0.4 – 2 µg/l	0.002 µg/l [4]
	isodrin / 3	0.09 – >1	
	dieldrin / 8	0.08 – 6	0.002
	endrin / 5	0.5 – 71	2
	DCPD / 2	32.4 – 512	
	MIBK / 1	130	
	DBCP / 1	31	0.2
	DMMP / 1	17,400	
	DMDS / 2	4.7 – 11	
	oxathiane / 2	6.6	
	dithiane / 4	3.6 – 722	
	CPMS / 2	725	
	CPMSO / 4	14 – 7110	
	CPMSO2 / 6	7.5 – 7110	
	benzene / 4	2.34 – 496	5
	toluene / 2	1250 – 3412	1000
	o,p-xylene / 1	54.1	
	methylene chloride / 1	560	5
	1,1-dichloroethane / 1	17	
	chloroform / 2	79.9 – 60,800	6
	TCE / 1	33	5
	PCE / 1	350	5 l
	chloride / 12	22,200 – 25,900,000	250,000
sediments (Table 26-6-7, Basin F bottom sediments 1978, Final Site 26-6 CAR, ESE May 1988)	aldrin / 10	16 – 10,700 ppm	0.04 ppm
	isodrin / 10	2 – 870	
	dieldrin / 10	4 – 3600	0.04
	endrin / 10	2 – 1100	20
	DDT / 10	<2 – 198	2
	DMMP / 10	<1 – 82	
	CMPS / 10	14 – 290	
	copper/ 10	230 – 21,000	
soils, Ph. II (Table 26-6-II b-1, Final Phase II b Data Addendum, Site 26-6, Ebasco January 1989)	1,1,1-trichloroethane / 1	0.6 ppm	
	benzene / 1	0.3	
	bicycloheptadiene / 1	1	100 ppm
	chloroform / 9	0.4 – 3	
	DCPD / 13	0.9 – 2000	90
	methylene chloride / 1	3	
	toluene / 13	0.3 – 2000	0.04
	aldrin / 8	0.8 – 2000	
	CPMS / 1	50	
	CPMSO / 23	0.3 -30	
	CPMSO2 / 3	2 – 3	
	DBCP /1	20	
	dicyclopentadiene / 8	20 – 3000	0.04
	dieldrin / 12	0.8 – 500	20
	endrin / 3	10 – 400	

SOURCE	CONTAMINANTS / # OF DETECTIONS	CONCENTRATION	ACTION LEVEL [1]
	isodrin / 7	0.4 - 2000	40
	cadmium / 15	0.88 – 2.4	400
	chromium / 73	9.5 – 37	
	copper / 72	5.7 – 1400	
	lead / 50	10 – 38	
	zinc / 127	11 – 78	80
	arsenic / 46	2.5 – 48	20
	mercury / 85	0.029 – 0.34	
	chloroacetic acid / 30	5.1 -7900	
	thiodiglycol / 15	6 – 570	
	IMPA / 48	4.l8 – 4600	
HYDRAZINE BSF			
soils (Table 1-7-II-b, Final Phase II Data Addendum, Site 1-7, HBSF, Ebasco, February 1989)	aldrin /2	0.002 – 0.01 ppm	0.04 ppm
	hex /1	0.003	600
	dieldrin / 1	0.5	0.04
	endrin / 1	0.02	20
	isodrin / 1	0.003	
	dichlorodiphenylethane / 1	0.01	
	dichlorodiphenyltrichloroethane /1	0.02	
	cadmium / 4	1.4 – 3. 8	40
	chromium / 25	11 – 27	400
	copper / 18	7.1 – 95	
	lead /11	12 – 140	
	zinc / 26	30 – 630	
	arsenic / 4	3.4 – 20	80
	mercury / 1	0.083	20
waste water (Table 2-1: HBSF Final Task Plan, HBSF IRA Implementation, HLA, August 1989)	arsenic	7 µg/l	48 µg/l [6]
	cadmium	2.2	1.1
	chromium	1.0	
	lead	1.0	3.2 or 82
	mercury	5.0	0.012
	selenium	4.0	
	silver	2.0	
	sodium hypochlorite	25	
	hydrazine	<5000 – 15,000,000	
	monomeythyl hydrazine (MMH)	<5000 – 104,000	
	unsymmetrical dimethyl hydrazine (UDMH)	<5000 – 160,000,000	
	n-nitrosodimethylamine (NDMA)	2900 – 360,000	0.007
	methylene chloride	60 – 3300	5
	chloroform	<5 – 15 ,000	1240 or 28900
	1,1-dichloroethane	<1700 – 1980	
	1,1-dichloroethylene	<730 – 5000	
	tetrachloroethane	<20,000	
	dimethylcyanamide	<20,000	
	n-n-dimethylformamide	<20,000	
	endrin	10	0.0023
	Lindane	10	
	methoxychlor	200	
	toxaphene	10	
	Silvex	100	
NORTH PLANTS			

SOURCE	CONTAMINANTS / # OF DETECTIONS	CONCENTRATION	ACTION LEVEL [1]
soils (Table NP-3 Analytical Summary, Final Ph. 1 CAR, North Plants Complex, Ebasco, September 1988)	1,1,1-trichloroethane / 1	0.6 ppm	
	benzene / 10	0.4 – 1	
	chloroform / 1	0.6	100 ppm
	tretrachloroethylene / 3	0.3 – 0.6	
	dieldrin / 2	0.3 – 3	0.04
	chloroacetic acid / 1	57	
	cadmium / 10	1 – 11	40
	chromium / 171	8.2 – 120	400
	copper / 173	6.1 – 110	
	lead / 88	11 – 110	
	zinc / 193	12 – 210	
	arsenic / 39	2.7 – 4800	80
	mercury / 13	0.082 – 2.9	20
groundwater [7]	fuel oil free product, 24" thick		
SOUTH PLANTS			
soil (Table SPSS-1, Final Shell Spill Sites CAR, Sites 1-13 and 2-18, July 1988)	aldrin / 48	0.3 – 3000 (???)	0.04 ppm
	benzene / 8	0.3 – 10	
	chlordane / 7	2 – 50	0.5
	chlorobenzene / 2	4 – 40	2000
	DBPC / 25	0.-0060 – 11,000	
	DCPD / 23	0.5 – 3000	
	dieldrin / 85	0.4 – 3000	0.04
	endrin / 8	0.8 – 70	20
	Hex / 11	1 – 100	600
	isodrin / 22	0.6 – 200	
	methylene chloride / 12	0.9 – 200	90
	MIKB / 8	0. 4 – 40	
	toluene / 9	0.4 – 30	
	cadmium / 25	0.83 – 1900	40
	chromium / 99	6.1 – 47	400
	copper / 223	5.7 – 250	
	lead / 74	1.4 – 830	
	zinc / 248	12 – 1200	
	arsenic / 68	2.9 – 49,000	80
	mercury / 76	0.050 – 6100	20
groundwater (7/14/06 RVO email, id; Ebasco SPSA fig. 3.3-9; Water DAA, So. Plants Plume Group, 1995, p. 8-2)	dieldrin	5 – 21 ug/L	0.1 ppm
	benzene	100,000 – 1,400,000 ug/L	5
	DCPD	free product	
	chloroform	10,000 – 100,000	6
	DBCP	1000 – 3500	
	tetrachloroethylene	1000 – 10,000	5
	tricloroethylene	10 – 100	5
CHEMICAL SEWERS			
soils (Table CS-SP-3, Final CAR Chemical Sewers North and South Plants, Ebasco, Sept. 1988)	SOUTH PLANTS		5 ppm
	carbon tetrachloride / 4	3.7 – 300 ppm	2000
	chlorobenzene / 2	4.1 – 10	100
	chloroform / 6	2 – 100	90
	methylene chloride / 19	2.3 – 14	
	MIBK / 1	21	
	xylenes / 4	3.7 – 15	10
	tetrachloroethylene / 9	4.1 – 60	
	toluene / 7	3.0 – 29	0.04

SOURCE	CONTAMINANTS / # OF DETECTIONS	CONCENTRATION	ACTION LEVEL [1]
	aldrin / 10	710 – 20,000	
	DBCP / 6	19 – 7500	
	dichlorodiphenyltrichoroethane / 2	30 – 100	
	DCPD / 1	1.6	20
	endrin / 2	2.0 – 11	
	isodrin / 7	10 – 300	80
	arsenic / 15	6.4 – 520	20
	mercury / 13	0.20 – 20	
	NORTH PLANTS		90 ppm
	methylene chloride / 10	2.2 – 6.7 ppm	0.04
(Table SC-NP-2, Final CAR, id., Sept. 1988)	aldrin / 1	0.64	80
	arsenic / 2	2.3 – 2.5	20s
	mercury / 1	0.68	
SOUTH LAKES			
sediments	LADORA		
(Table 2-17-2, Ladora, Final Ph I CAR, Site 2-17, Lake Ladora & Lake Mary Ebasco, July 1987)	methylene chloride / 2	1 – 2 ppm	90 ppm
	MIBK / 1	1	
	tetrachloroethylene / 1	1	
	DBCP / 2	0.01 – 0.097	
	chromium / 19	9.9 – 43	400
	copper / 26	8.6 – 99	
	lead / 17	12 – 56	
	zinc / 27	20 – 170	
	arsenic / 8	2.9 – 16	80
	mercury / 14	0.059 – 2	20
	MARY		
(Table 2-17-5, Mary, Final Ph. 1 CAR Site 2-17, id.)	chromium / 6	12 – 25 ppm	400 ppm
	copper / 7	8 – 21	
	lead / 1	18	
	zinc / 7	28 – 80	
	arsenic / 2	6.1 – 8.9	80
	PHASE II, LADORA & MARY		
	1,1,1-trichloroethane / 1	0.6 ppm	
(Table 2-17-II-1, Summary for Site 2-17, Final Ph. II Data Addendum, Lakes Ladora & Mary, Ebasco, October 1988)	methylene chloride / 6	1 – 2	90 ppm
	DBCP / 2	0.0074 – 0.016	
	aldrin / 9	0.0029 – 0.15	0.04
	dieldrin / 3	0.00038 – 0.053	0.04
	endrin / 2	0.0069 – 0.0088	20
	isodrin / 3	0.0042 – 0.042	
	cadmium /1	1.1	40
	chromium / 13	9 – 28	400
	copper / 15	7.1 – 34	
	lead / 7	12 – 64	
	zinc / 18	22 – 120	
	arsenic / 2	3/1 – 5/2	80
	LOWER DERBY		
	DBCP / 11	0.0068 – 0.30 ppm	
	2,2-bis-1,1-dichloroethane / 8	0.0037 – 0.059	
(Table 1-2-II-1a, Summary Lower Derby Lake, Final Ph. II Data Addendum	2,2-bis-1,1,1trichloroethane (PPDDT) / 5	0.0037 – 0.045	2 ppm
	aldrin / 17	0.0037 – 0.13	0.04
	chlordane / 3	0.052 – 0.30	0.5

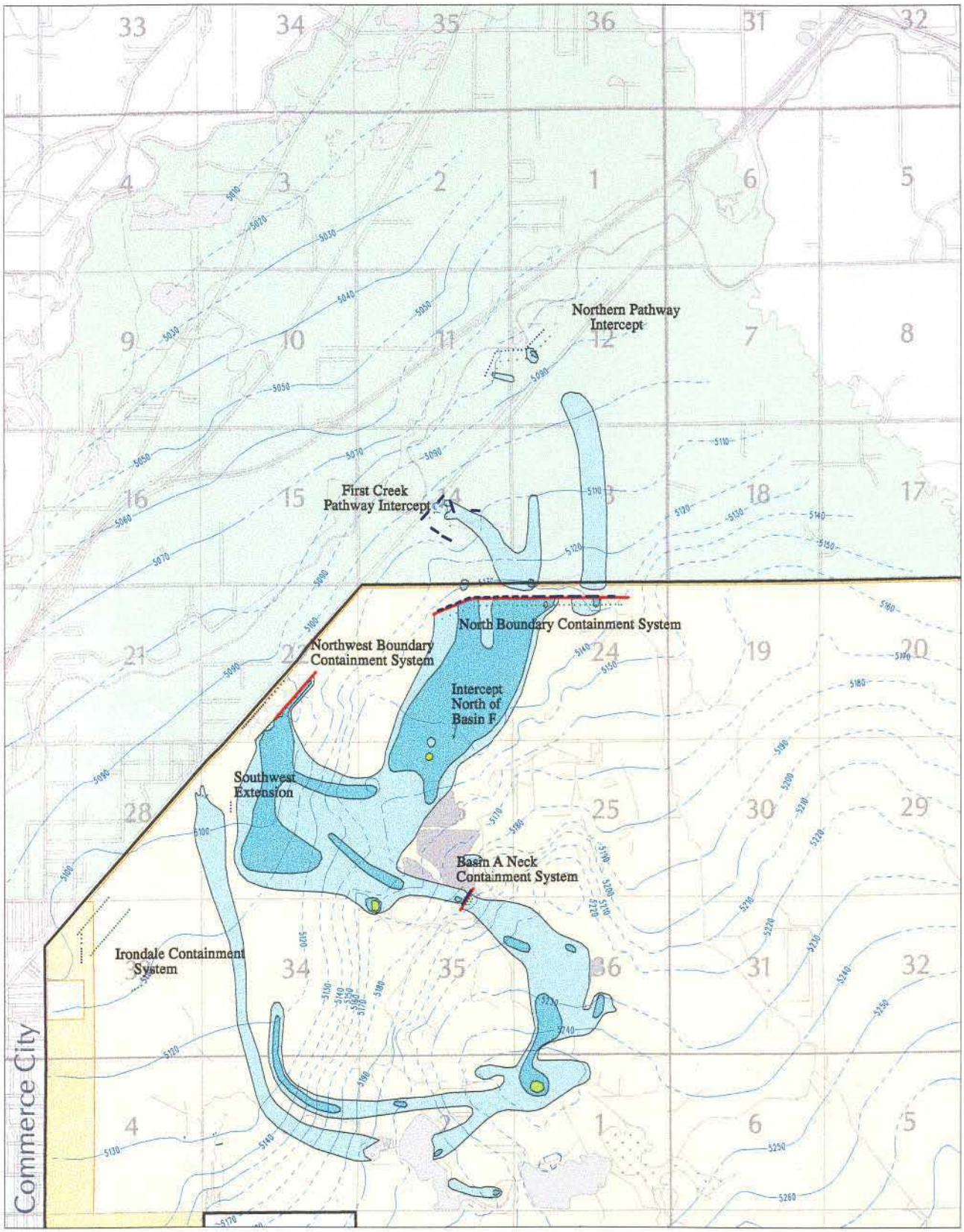
SOURCE	CONTAMINANTS / # OF DETECTIONS	CONCENTRATION	ACTION LEVEL [1]
Site 1-2, Upper and Lower Derby Lakes, Ebasco October 1988)	dieldrin / 6	0.0045 – 0.11	0.04
	endrin / 2	0.013 – 0.11	0.04
	isodrin / 4	0.0028 – 0.15	
	cadmium / 3	1.3 – 1.8	40
	chromium / 22	9.3 – 150	400
	copper / 21	1 – 35	
	lead / 22	12 – 42	
	zinc / 26	22 – 110	
	mercury / 10	0.057 – 1.2	20
	UPPER DERBY		
(Table 1-2-II-1b, Summary Upper Derby Lake, Final Ph. II Data Addendum Site 1-2, id.)	SVOC dieldrin / 1	3 ppm	0.04 ppm
	2,2-bis-1,1-dichloroethane / 14	0.0031 – 1.3	
	2,2-bis-1,1,1trichloroethane (PPDDT) / 90	0.0035 – 2.2	2
	aldrin / 21	0.0038 – 27	0.04
	chlordane / 15	0.0040 – 5.1	0.5
	dieldrin / 27	0.0088 – 0.23	0.04
	endrin / 8	0.0061 – 0.35	20
	Hex / 5	0.0061 – 0.35	600
	isodrin / 6	0.0099 – 0.36	
	chromium / 10	8.5 – 32	400
	copper / 9	6 – 35	
	lead / 8	10 – 68	
	zinc / 13	20 – 170	
	arsenic / 1	6	80
	mercury / 24	0.071 – 18	20
	DRAINAGE DITCHES/SAND CREEK LATERAL		
(Table 2-1-1, Final Phase I CAR, Site 2-1 Drainage Ditches, Ebasco July 1987)	methylene chloride / 1	200 ppm	90 ppm
	tetrachloroethylene / 1	0.3	60
	toluene / 1	0.3	
	aldrin / 12	1 – 400	0.04
	dieldrin / 14	0.3 – 100	0.04
	isodrin / 1	4	
	2,2-bis-1,1,1trichloroethane (PPDDT) / 1	6	2
	cadmium / 2	0.98 – 1.3	40
	chromium / 17	6.5 – 36	400
	copper / 23	6.2 – 44	
	lead / 17	13 – 1200	
	zinc / 37	17 – 160	
	arsenic / 3	4.2 – 4.9	80
	mercury / 8	0.059 – 0.86	20
	Phase II		
(Table 2-1-II-2, Final Ph. II Data Addendum, Site 2-1 Drainage Ditches/SCL Ebasco October 1988)	SVOC dieldrin / 2	0.3 – 0.5 ppm	0.04
	2,2-bis-1,1-dichloroethane / 28	0.0028 – 4.6	
	2,2-bis-1,1,1trichloroethane (PPDDT) / 24	0.0025 – 2.4	2
	aldrin / 40	0.0022 – 1100	0.04
	chlordane / 15	0.026 – 9.2	0.5
	dieldrin / 53	0.0038 – 130	0.04
	endrin / 22	0.0055 – 3.4	20
	Hex / 14	0.0043 – 0.2	600
	isodrin / 23	0.0013 – 19	
	cadmium / 2	1.1 – 6.4	40

SOURCE	CONTAMINANTS / # OF DETECTIONS	CONCENTRATION	ACTION LEVEL [1]
	chromium / 48	8.1 – 100	400
	copper / 43	5.9 – 74	
	lead / 23	12 – 900	
	zinc / 51	15 – 210	
	mercury / 11	0.061 – 0.76	80
	SITE 1-1 PROCESS WATER DITCHES		
	toluene / 1	0.4 ppm	
(Table 1-1-2, Final Ph. 1 CAR Site 1-1 Ditches Ebasco May 1987)	aldrin / 3	1 – 30	0.04 ppm
	dieldrin / 3	0.45	0.04
	isodrin / 1	2	
	chromium / 7	8.5 – 18	400
	copper / 15	5.8 – 34	
	lead / 3	12 – 17	
	zinc / 16	18 – 130	
	arsenic / 1	4. 8	80
	mercury / 8	0.052 – 0.14	20
ARMY COMPLEX TRENCHES			
soils [5]	aldrin / 3	1 – >1000 ppm	0.04 ppm
(Table 36-17-1, Final Phase I CAR, Site 36-17, Complex Disposal Trenches, ESE, January 1988)	dieldrin / 6	0.3 – >500	0.04
	endrin / 1	0.9	20
	chlordane / 2	60 – 70	0.5
	dichlorodiphenylethane / 1	3	
	DBCP / 6	0.012 – 0.44	
	cadmium / 12	0.70 – 13	40
	chromium / 83	7.3 – 1400	400
	copper / 95	5 – 660	
	lead / 25	17 – 7100	
	zinc / 88	24 -12,000	
	arsenic / 23	4.7 – 29	80
	mercury / 26	0.050 – 1.2	20
groundwater	arsenic	50 – 500 ppm	48 ppm
	benzene	100 – 1000	5
(RMA Gr'water Mass Removal Project, id., 12/05)	chloroform	1000 – 10,000	6
	DBCP	5 – 50	
	dithiane	1000 – 7000	
	1,4-oxathiane	1000 – 7000	
	tetrachloroethylene	10,000 – 15,000	5
	trichloroethylene	1000 – 7500	5
SHELL SEC. 36 TRENCHES			
soils	chloroform / 1	2 ppm	100 ppm
	bicycloheptadiene / 1	1	
(Table 36-3-1, Final Phase I CAR Site 36-3 Shell Section 36 Insecticide Pit, ESE, June 1987)	methylene chloride / 1	1	90
	PCE / 1	0.6	
	benzene / 1	0.9	
	toluene / 1	8	
	aldrin / 4	1 – 100	0.04
	dieldrin / 10	0.4 – 20	0.04
	endrin / 5/	2 – 10	20
	isodrin / 4	0.5 – 20	
	DCPD / 1	20	
	DBCP / 6	0.009 – 2.2	
	cadmium / 7	1.0 – 3.5	40

SOURCE	CONTAMINANTS / # OF DETECTIONS	CONCENTRATION	ACTION LEVEL [1]
	chromium / 13 copper / 13 lead / 8 zinc / 16 arsenic / 5 mercury / 10	9 – 21 6 -29 17 -68 16 -65 4.9 – 5.3 0.060 – 0.45	400 80 20
groundwater (RMA Gr'water Mass Removal Project, id., 12/05)	benzene chloroform DBCP dieldrin tetrachloroethylene trichloroethylene	15,000 ppm 15,000 50 – 1000 0.5 – 5 1000 100 – 1000	5 ppm 6 0.1 5 5
LIME SETTLING BASINS			
soils (Table 36-4-1, Final Phase I CAR Site 36-4, Lime Settling Basins, ESE, June 1987)	benzene / 2 methylene chloride / 3 chlorobenzene / 1 1,1 dichloroethane / 4 aldrin / 0 chlordane / 1 DCPD / 2 dieldrin / 12 endrin / 4 isodrin / 7 DDE / 2 DDT / 1 DBCP / 3 cadmium / 6 chromium / 15 copper / 18 lead / 8 zinc / 14 arsenic / 16 mercury / 17	5 – 6 ppm 0.7 – 2 2 2 – 7 2 – 600 30 0.7 – 2 0.6 – 70 2 – 20 0.4 – 300 0.6 – 10 7 0.006 – 0.016 1.1 – 3.7 9 – 33 6 – 270 19 – 230 20 – 500 5.7 – 370 0.017 – 11	90 ppm 2000 0.04 0.5 0.04 20 2 2 40 ppm 400 pp, 80 20
groundwater (Gr'water Mass Removal Project, Gr'water Extraction/Recharge Design Analysis, 12/05)	arsenic benzene chloroform	5000 – 7500 – 179,000 ppm 10,000 – 100,000 100,000 – 1,100,000	48 ppm 5 6
MOTOR POOL			
soil (Table 4-6-1a Final Site 4-6 CAR, July 1988 & Table 1 Motor Pool IRA Summary Report, October 1997)	aldrin / 2 arsenic / 16 cadmium / 13 chromium / 62 copper / 100 lead / 37 zinc / 146 mercury / 14 toluene / 2 methylene chloride / 1	0.9 – 3 ppm 2.6 – 27 1.4 – 30 6.5 – 490 5.7 – 220 9.8 – 2000 11 – 2300 0.057 – 0.38 2 – 4 3	0.04 ppm 80 40 400 20 90
groundwater (Table 2 Motor Pool IRA Summary Report, October	chloroform / 14 trichloroethylene / 24 benzene / 3	0.54 – 6.0 µg/l 1.7 – 260 3 – 270	[3] 5 µg/l

SOURCE	CONTAMINANTS / # OF DETECTIONS	CONCENTRATION	ACTION LEVEL [1]
1997)	toluene / 1 DBCP / 1 chromium /1 lead / 1 zinc / 6	1.5 0.67 14 22 34 – 100	 0.2
RAIL CLASS. YARD			
soil (Table 3-4-1, Analytical Summary, for Site 3-4 (includes Rail Yard), Final Site 3-4 CAR Nemagon Spill Area, Ebasco, March 1988)	benzene / 1 carbon tetrachloride / 1 methylene chloride / 15 tetrachloroethylene / 1 cadmium / 4 chromium / 41 copper / 57 lead / 20 zinc / 95 arsenic / 1 mercury / 2	0.6 ppm 0.3 1 – 5 0.4 0.97 – 1.4 6.5 – 21 5.6 – 19 11. 24 11 – 190 3 0.070 – 0.20	 5 ppm 90 40 400 80 20
groundwater (Draft Final Alternatives Assessment –Other Contamination Sources, Rail Yard, MKE, 8/89)	DBCP	0.13 – 23 ppm	

[1] From Table A-10, TBCs for Soil and Sediments, Final DAA, Vol. VII, October 1995
[2] From Table A-6, Basin A Neck Gr'H2O ARARs, Final DAA October 1995
[3] From Table A-4, Irondale Containment System ARARs, Final DAA October 1995
[4] From Table A-5, Groundwater North Boundary of RMA ARARs, Final DAA October 1995
[5] Does not include many COCs; see Appendices 36-17-B and 36-17-D
[6] Tables A-8 and A-9, ARARs and TBCs for Surface Water, Final DAA October 1995
[7] RMA Contingency Plan, Draft, December 1990; RMA North Plants Soil Remediation Project, 30% Design Analysis Draft, 12/25/05; Draft 2005 RMA 5-Year Review.



Dieldrin Distribution (4th Quarter 1994)
Concentration in ppb

- 0.0500 to < 0.500
- 0.500 to < 5.00
- 5.00 to 21.0

- Basins / Lakes
- Rocky Mountain Arsenal (On-Post Operable Unit)
- Off-Post Study Area
- RMA Out Grants / Sale Property
- Water Table Elevation [10' Contour Interval (Dashed where inferred); USGS Final GMP Fall 1994]

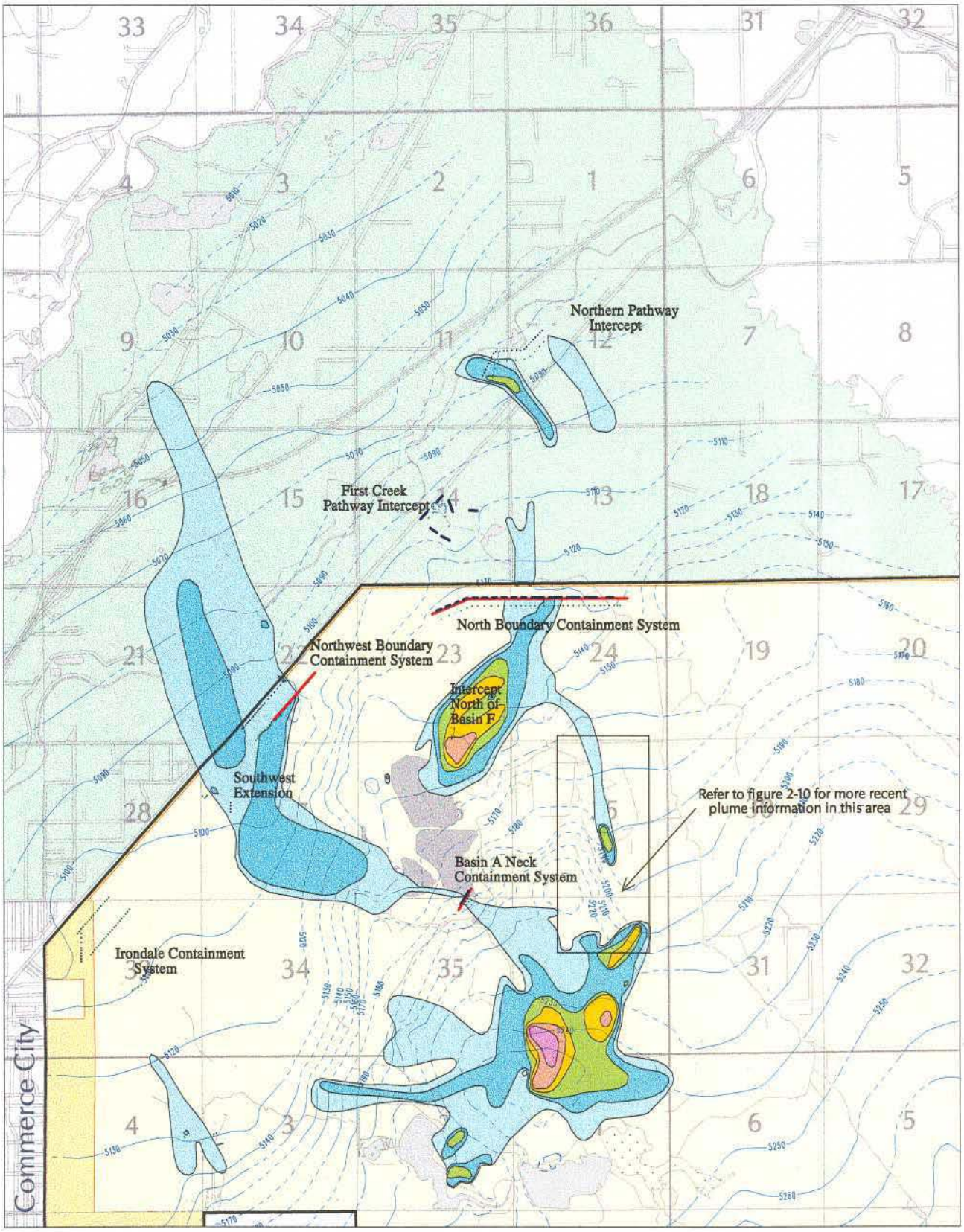
Scale: 1:57600
1 inch = 4800 Feet
0 2400 4800 Feet

State Plane Coordinate System, CO North Zone
NAD27-NGVD29 Datum

Remediation Venture Office GIS

GIS Analyst: S. Miller	Figure 2-6
Date: 12/09/99	
Scale: 1:57600	
Prepared For: E. Kaastrup	
Approved:	DP Associates, Inc.
File Location: /disk05/projects/ltgmp/amls/plumes94_loop.aml	

FIG. 4



Chloroform Distribution (4th Quarter 1994)
Concentration in ppb

- 0.500 to < 6.00
- 6.00 to < 100
- 100 to < 1,000
- 1,000 to < 10,000
- 10,000 to < 100,000
- 100,000 to 1,100,000

- Basins / Lakes
- Rocky Mountain Arsenal (On-Post Operable Unit)
- Off-Post Study Area
- RMA Out Grants / Sale Property
- Water Table Elevation [10' Contour Interval (Dashed where inferred); USGS Final GMP Fall 1994]

Scale: 1:57600
1 Inch = 4800 Feet
0 2400 4800 Feet

State Plane Coordinate System, CO North Zone
NAD27-NGVD29 Datum

Remediation Venture Office GIS

GIS Analyst: S. Miller	Figure 2-5
Date: 12/09/99	
Scale: 1:57600	
Prepared For: E. Kaastrup	
Approved:	Dp Associates, Inc.
File Location: /disk05/projects/ltgmp/aml s/plumes94_loop.aml	

FIG. 5