AP - 51

STAGE 2
ABATEMENT
PLAN

March 2012

Griswold, Jim, EMNRD

From:	Griswold, Jim, EMNRD
Sent:	Tuesday, April 03, 2012 5:00 PM
To:	'Oakleaf, Catherine'
Cc:	Jayroe, Jason
Subject:	RE: Public Notice for Former Caribou Refinery

Cadee,

The draft public notice, as modified, is acceptable. Please proceed with public notification. Please print a copy of this email for your files as no hardcopy will be sent. Thanks.

Jim Griswold
Senior Hydrologist
EMNRD/Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, New Mexico 87505
direct: 505.476.3465
email: jim.griswold@state.nm.us

From: Oakleaf, Catherine [mailto:Catherine.Oakleaf@aecom.com]
Sent: Tuesday, April 03, 2012 4:54 PM
To: Oakleaf, Catherine; Griswold, Jim, EMNRD
Cc: Jayroe, Jason
Subject: RE: Public Notice for Former Caribou Refinery

Jim,

I am attaching the public notice that reflects the updates you requested. We will run the public notice as planned upon your approval.

Thanks,

Cadee Oakleaf
Staff Engineer
Environment
D 970.530.3522
catherine.oakleaf@aecom.com

AECOM
1601 Prospect Parkway, Fort Collins, CO 80525
T 970.493.8878 F 970.493.0213
www.aecom.com

From: Oakleaf, Catherine
Sent: Tuesday, April 03, 2012 2:29 PM
To: 'Jim.griswold@state.nm.us'
Cc: Jayroe, Jason
Subject: Public Notice for Former Caribou Refinery

Mr. Griswold,

Please find attached, for your review and approval, the public notice and surface owner letter for the Former Caribou Refinery Stage II Abatement Plan (AP-51). We plan on publishing the public notice on April 9, 2012 and mailing written notice to the parties specified in the letter from the OCD as soon as possible. If you have any questions, please do not hesitate to contact me.

Thanks,

Cadee Oakleaf
Staff Engineer
Environment
D 970.530.3522
catherine.oakleaf@aecom.com

AECOM
1601 Prospect Parkway, Fort Collins, CO 80525
T 970.493.8878 F 970.493.0213
www.aecom.com

April 3, 2012

Subject: Stage II Abatement Plan for the Former Caribou Refinery

Dear Landowner:

Enclosed is a copy of the Public Notice describing the Stage II Abatement Plan for the Former Caribou Refinery site in Kirtland, New Mexico. The proposed Abatement Plan has been developed by Maverik, Inc.

As stated in the enclosed notice, the plan can be viewed at both the OCD Santa Fe and Aztec offices as well on the OCD's website referring to Abatement Plan AP-51. The OCD will accept written comments and requests for a public hearing, including reasons why a hearing should be held, for a period of 30 days after the date of public notice (see address below).

Jami Bailey, Division Director
Oil Conservation Commission
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

If you would like more information regarding the proposed project, please contact:

Dennis Riding
Maverik, Inc.
880 West Center Street
North Salt Lake, Utah 84054-2913
801-936-5557

Sincerely,

Cadee Oakleaf Jason Jayroe
Staff Engineer Project Manager

Public Notice

Notice is hereby given that pursuant to New Mexico Oil Conservation Division (OCD) Regulations, the following Stage II Abatement Plan has been submitted to the OCD, 1220 South St. Francis Drive, Santa Fe, New Mexico 87505, Telephone (505) 476-3440:

> Dennis Riding, Maverik, Inc., Telephone 801-936-5557, 880 West Center Street, North Salt Lake, Utah 84054-2913, formercaribourefinery@gmail.com, has submitted a Stage II Abatement Plan Proposal to abate the ground water contamination at the Former Caribou Refinery site located at the NE ¼, NE ¼ of Section 17, Township 29 North, Range 14 East, NMPM, San Juan County, New Mexico. The site was a small crude topping refinery that operated from 1963 until April 1982. Contamination was discovered in 1985 during a site inspection. Further site investigations were conducted that defined the contaminant source areas to be localized within the footprint area of the former refinery site. Currently all contamination is contained within a slurry wall located on-site that serves to prevent the off-site migration of affected ground water. The Stage II Abatement Plan Proposal specifies that Maverik will: make public notice and provide for public participation; implement an in-situ chemical oxidation (ISCO) pilot test by conducting chemical oxidant injection events, monitor and analyze groundwater, and submit reports of all remediation activities.

Any interested person may obtain further information from the OCD and may submit comments to the Director of the Oil Conservation Division (Jami Bailey) at the address given above. The Stage II Abatement Plan Proposal may be viewed at the above address or at the OCD Aztec District Office, 1000 Rio Brazos Road, Aztec, New Mexico 87410, Telephone (505) 334-6178, as well as on the OCD's website referring to Abatement Plan AP-51. The OCD will accept written comments and requests for a public hearing, including reasons why a hearing should be held, for a period of 30 days after the date of this public notice.

State of New Mexico
Energy, Minerals and Natural Resources Department

Susana Martinez
Governor

John Bemis
Cabinet Secretary

Brett F. Woods, Ph.D.
Deputy Cabinet Secretary

Jami Bailey
Division Director
Oil Conservation Division

March 19, 2012

Dennis Riding
Maverik Country Stores, Inc.
800 West Center Street
North Salt Lake, Utah 84054-2913

RE: Stage 2 Abatement Plan for the Former Caribou Refinery (AP-51)

Mr. Riding,

On March 9, 2012 the Oil Conservation Division (OCD) received the Stage 2 Abatement Plan for the former Caribou Refinery in Kirtland dated March 2012 and prepared by AECOM. Having satisfied the requirements of Paragraph (2) of Subsection D of 19.15.30.13 NMAC, this plan is deemed administratively complete. Public notice is required by your firm in conformance with 19.15.30.15 NMAC. Written notice pre-approved by the division must be provided to:

- All surface owners within one mile of the former refinery's perimeter.
- The San Juan County Commission
- The City of Kirtland
- The New Mexico Natural Resources Trustee, F. David Martin
- President of the Navajo Nation, Ben Shelley

Furthermore, within the next 15 days you must issue notice in an OCD-approved form in a newspaper of general circulation within San Juan County as well as a statewide newspaper of general circulation. That notice must include:

- Your corporate name and address along with contact information.
- The location of the former refinery.
- A description of the source, extent and estimated volume of the historic release(s).
- That the release occurred into the vadose zone but subsequently migrated both into surface waters within the former irrigation ditch as well as into groundwater.
- A description of the newly proposed abatement plan.
- A statement that the plan can be viewed at both the OCD Santa Fe and Aztec offices as well on the OCD's website referring to Abatement Plan AP-51.
- A statement that the OCD will accept written comments and requests for a public hearing, including reasons why a hearing should be held, for a period of 30 days after the date of public notice.
- The address, email and phone number wherein interested persons may obtain further information.

Please submit drafts of the required public notices to us as soon as possible for review before publication. If a hearing is not held, the OCD shall either approve the proposed plan with possible conditions or notify you of any deficiencies in the plan on or before June 7, 2012. Contact Jim Griswold with any questions at (505) 476-3465 or by email at *jim.griswold@state.nm.us*.

Respectfully,

Daniel J. Sanchez
Compliance & Enforcement Manager

cc: Brandon Powell, OCD District III Office, Aztec
Jason Jayroe, AECOM

1220 South St. Francis Drive • Santa Fe, New Mexico 87505
Phone (505) 476-3440 • Fax (505) 476-3462 • www.emnrd.state.nm.us/ocd

AECOM

AECOM
1601 Prospect Parkway
Fort Collins, CO 80525-9769

970.493.8878 tel
970.493.0213 fax

Letter of Transmittal

Attention:
Daniel Sanchez
New Mexico Energy,
Minerals and Natural
Resources Department
Oil Conservation Division
1220 South St. Francis Dr.
Santa Fe, New Mexico
87505

Date: March 8, 2012

RECEIVED OCD
2012 MAR -9 P 1:15

Project reference: Stage II Abatement Plan

Project number: 60139478

We are sending you the following:

Number of originals:	Number of copies:	Description:
3	2	Maverik Former Caribou Refinery Kirtland New Mexico – Stage II Abatement Plan

RECEIVED OCD
2012 MAR -9 P 1:15

Mr. Sanchez

Please find attached 3 paper copies of the Maverik Former Caribou Refinery Kirtland New Mexico Stage II Abatement Plan.

Should you have any questions, please feel free to call me 970-493-8878.

Jason Jayroe Project Manager

cc: Dennis Riding, Maverik, Inc.
Jenny Phillips, AECOM

AECOM

Environment

Submitted to:
Maverik
Salt Lake City, Utah

Submitted by:
AECOM
Fort Collins, Colorado
60139478.210
March 2012

Maverik Former Caribou Refinery Kirtland, New Mexico

Stage II Abatement Plan

AECOM Environment

Submitted to:
Maverik
Salt Lake City, Utah

Submitted by:
AECOM
Fort Collins, Colorado
60139478.210
March 2012

Maverik Former Caribou Refinery
Kirtland, New Mexico

Stage II Abatement Plan

Catherine Oakleaf

Prepared by Catherine Oakleaf, Staff Engineer

Gregg Somermeyer

Reviewed by Gregg Somermeyer, PE, Senior Engineer

JASON JAYROE

Reviewed by Jason Jayroe, Project Manager

List of Acronyms

1,2-DCA	1,2-Dichloroethane
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
EID	Environmental Improvement Division
HASP	Health and Safety Plan
ISCO	In-situ Chemical Oxidation
MNA	Monitored Natural Attenuation
NMAC	New Mexico Administrative Code
OCD	Oil Conservation Division
ORC	Oxygen Releasing Compound
OVA	Organic Vapor Analyzer
POP	Project Operating Procedure
SVOCs	Semivolatile Organic Compounds
USEPA	United States Environmental Protection Agency
USEPA MCL	U.S. Environmental Protection Agency Maximum Contaminant Level
VOCs	Volatile Organic Compounds

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1.0 Introduction

This document has been prepared by AECOM Technical Services, Inc (AECOM) on behalf of Maverik, Inc. The purpose of this Stage II Abatement Plan is to provide an evaluation of remediation alternatives and a design of the recommended alternative with the goal of attaining the abatement standards and requirements set forth in 19.15.30.9 of the New Mexico Administrative Code (NMAC) for the former Caribou Refinery located in Kirtland, New Mexico. Refer to **Figure 1-1** for a site location map. This document presents the site history, project history, current conditions, alternative options evaluation, Remedial Action Work Plan, design components and monitoring plan, operation and maintenance plan, permits, schedule, and references.

2.0 Site History

2.1 Site Operation History

Maverik, Inc. (Maverik), previously known as Caribou Four Corners Inc., operated a small crude topping refinery (Site) near Kirtland, New Mexico, from 1963 until April 1982. During operation, crude oil was refined into regular and leaded gasoline, diesel fuel and No. 5 fuel oil. Process units included a crude distillation unit, naphtha hydrotreating unit, and naphtha reformer unit. Due to the plant design, there was no wastewater process stream and, therefore, there was no API separator or dissolved air flotation unit. Within a few months of shutdown, all remaining product, feedstocks, and intermediate products were removed from storage tanks and sold.

2.2 Site Location and Description

The former refinery is located 0.5 to 0.75 miles north of the San Juan River in Kirtland, New Mexico (**Figure 1-1**). The Site is bounded by two unlined irrigation ditches, the Farmer's Mutual Irrigation Ditch and one of its branches, with the exception of approximately 300 feet where Caribou installed a concrete pipe. The Farmer's Mutual Irrigation Ditch runs along the terrace between the refinery area and the tank farm area. The branch of the Farmer's Mutual Irrigation Ditch borders the west side of the Site.

The tank farm on the Site was located within the floodplain of the San Juan River, with its northern boundary paralleling the edge of the floodplain. The former refinery Site is located immediately to the north of the tank farm and out of the floodplain.

Based on the United States (U.S.) Geological Survey map of the Kirtland Quadrangle (1955), the Site is located in an area consisting primarily of Quarternary valley fill alluvium, and Quaternary terrace gravel, which consists primarily of a veneer of unconsolidated gravel and sand on river and stream terrace surfaces. Bedrock at the Site consists of the lower shale of the Cretaceous Kirtland Shale Formation.

The aquifer at the Site is part of the regional groundwater discharge system to the San Juan River. It consists of shallow coarse sand-gravel-cobble river channel (alluvial) deposits along the floodplain of the San Juan River. The underlying bedrock is the Kirtland Shale Formation, which is dry, even though it is overlain by saturated, highly transmissive river channel deposits.

Flows in the alluvial gravel aquifer are from the north-northeast to the south-southwest, ultimately discharging toward the San Juan River. The hydraulic gradient is approximately 0.01 ft/ft along the top of the underlying unsaturated Kirtland Shale Formation. The Westside irrigation ditch appears to serve as a groundwater sink when it is not flowing and as a groundwater recharge source and divide when it is flowing. The groundwater velocity in the coarse alluvial aquifer at the Site is estimated at 3 feet per day, based on the hydraulic gradient and a porosity of 0.3.

3.0 Project History

3.1 Project Initiation

New Mexico Environmental Improvement Division (EID) personnel conducted an inspection at the former refinery in December 1985. As part of this inspection, samples for chemical analysis were taken of soil, waste, surface water, and groundwater at and near the Site. One of the samples, an oily water sample from a drainage ditch along the west boundary of the Site, contained significant concentrations (280 micrograms per liter [µg/l] to 850 µg/l) of the typical refinery-related volatile organics benzene, toluene, ethylbenzene and xylenes (BTEX); in addition this sample contained 15 µg/l of 1,2-dichloroethane (1,2-DCA). 1,2-DCA was also detected in a water sample about 1 mile further down this ditch at the detection limit of 1 µg/l and in a 40-foot-deep private well located approximately 0.2 mile downgradient of the Site at a concentration of 9 µg/l.

In April and May 1987, EID water quality sampling was conducted on 24 private wells in the area. The results of the sampling did not reveal the presence of aromatic or halogenated volatiles above the 1 to 2 µg/l detection limits except for one downgradient private well, located approximately 0.2 mile from the refinery site, which had a 1,2-DCA concentration of 8 µg/l.

Maverik covered the costs incurred by the local downgradient homeowners that hooked up their water lines to the Kirtland public water supply as a result of contamination from the tank farm. In November 1987, oily waste product was observed along the Westside irrigation ditch and immediately afterwards Maverik placed a series of pads along the ditch to absorb the product.

3.2 Phase I Hydrogeologic Evaluation

The Phase I investigation, which was completed by Dames and Moore, consisted of an area-wide survey for volatile organics using soil-gas techniques to determine the most appropriate locations for monitoring wells; installation of 13 monitoring wells, 5 well points and a deep borehole; sampling of the 13 monitoring wells, 3 private wells, and 6 surface water sites in November 1987 and analysis of these samples for organics and common ions; obtaining measurements of groundwater and surface water elevations; performing aquifer characterization tests; conducting an inventory of private well locations and surface water users; review and analysis of data obtained during this and other investigations. A second round of water quality sampling was completed in February of 1988 at all of the same wells and 3 of the 6 surface water sites. The results of the second round of sampling were included as an addendum to the Phase I Hydrogeologic Evaluation report. A third round of sampling was completed in October 1988 to continue to monitor, at key points and prior to any additional groundwater remediation, the changes in concentration of the organic contaminants in the groundwater.

The results of the Phase I investigation produced the following major findings:

- Significant concentrations of the typical refinery-related volatile organics, BTEX and 1,2-DCA, were found in one of the six monitoring wells installed at the refinery tank farm. Based on the results of groundwater sampling Rounds 1 and 2, significant biodegradation of organic compounds appeared to be occurring on-site, particularly in the shallow zone at the highly contaminated monitoring well.
- Benzene, xylene or ethylbenzene were found in 3 of 10 off-site monitor wells at concentrations just above detection limits but below the New Mexican Water Quality Control Commission groundwater protection standards (groundwater protection standards) for these compounds. 1,2-DCA was found in four other off-site monitoring wells, but only one, at concentrations ranging from 7.7 to 16 µg/l, exceeded the groundwater protection standard of 10 µg/l.

- Product seepage from contamination of the western part of the tank farm to the Westside Irrigation Ditch was confirmed. However, even under no- and low-flow conditions which existed during sampling, off-site downstream contamination of this water body was not significant. Construction and pumping at the on-site interceptor trench reduced product migration off-site to the Westside Irrigation Ditch.
- The shallow, silty, sand alluvial zone on-site that was significantly impacted by the tank farm had not impacted the deeper gravel zone. Very low levels of contaminants were observed in the deeper monitoring wells and private wells downgradient from the tank farm. This was a result of high permeability, recharge from the irrigation ditches, high flow rates and apparent lithologic separation of the gravel zone from the upper silty-sand zone. The private wells average about 20 feet in depth and are generally open through at least 15 feet of saturated, highly permeable gravels, cobbles, and sands.
- Contamination of the shallow alluvial aquifer and Westside irrigation ditch from the tank farm appeared to have occurred over an area about 200 to 400 feet-wide in an east-west direction and about 1,800 to 2,000 feet-long in a north-south direction toward the San Juan River. The areal extent of organic contamination off-site appeared to increase slightly with the recharge and resultant on-site aquifer flushing from seepage of irrigation ditch waters. Groundwater quality was strongly influenced by the direction of flows in the irrigation ditches. Off-site contamination appeared to be restricted to a more permeable alluvial (gravel, cobble, sand) zone that trended northeast to southwest to the San Juan River.
- The low concentrations of the contaminants detected off-site, their characteristics, the hydrogeologic setting, and the non-use of water from private wells in the contaminated area for drinking water purposes, all lead to the conclusion that the releases from the tank farm did not pose a threat to human health and the environment.

A more detailed description and analysis of the Phase I investigation results can be found in the following reports:

- Phase I Hydrogeologic Evaluation (Dames and Moore 1988a)
- Addendum to Phase I Hydrogeologic Evaluation (Dames and Moore 1988b)
- Water Quality Data Summary Report for Completion of the Hydrogeologic Evaluation (Dames and Moore 1989a)

3.3 Phase II Subsurface Soil and Solid Waste Contaminant Evaluation

The Phase II investigation, which was completed by Dames and Moore, consisted of the following: aquifer drilling and sampling of solid waste samples and core samples from 43 boreholes; field testing for organic vapor contamination in 101 drill core samples and surface solid waste samples; laboratory analysis of 37 selected soil samples for organics and metals and percent oil, water and solids; analysis of the data obtained during this investigation and review of all of the data obtained from previous investigations.

The results of the Phase II investigation produced the following major findings:

- BTEX and other hydrocarbons were primarily found in the upper 7 to 12 feet of the silty-clayey sand zone at the refinery tank farm in the southwest corner where a leaded gasoline spill occurred, where the crude oil tank sludge was placed and near the gasoline and gasoline blending tanks. High levels of these volatile organic compounds (VOCs) also were detected in the northwest corner of the refinery tank farm but in the shallow sands and gravels which grade into silty-clayey sands to the south. No 1,2-DCA was detected in the soils or sludge due to its high solubility and transport by ground and surface waters.

- High concentrations of the semivolatile organic compounds (SVOCs), including bis(2-ethylhexyl)phthalate, l-methyl-naphthalene, naphthalene, phenanthrene, and chrysene, were detected on-site primarily in the northwest corner, in the central part, in the eastern sludge pit and in the upper 7 feet in the southwest corner of the tank farm.
- Elevated concentrations of hydrocarbons, primarily oil, gasoline and diesel fuel, were detected throughout the western part of the tank farm, in the sludges found on-site in the northwest corner and in the eastern sludge pit, within the tank farm boundaries. High levels of hydrocarbons, primarily gasoline and diesel fuel were found in shallow subsurface soils in the central part of the tank farm and some were detected in the far southwest corner.
- The concentrations of the eight Resource Conservation and Recovery Act metals tested using the U.S. Environmental Protection Agency (USEPA) toxicity test indicated that their concentrations in the subsurface soils were very low and not at levels considered toxic. The total metals concentrations in the subsurface soils in the southwest part of the tank farm as well as in the sludge samples in the east and northwest corner were low and typical of metals concentrations in the soils.
- Off-site contamination of the subsurface soils appeared to be limited to two areas: a small 100-foot-long, 10-foot-deep and 100-foot-wide zone immediately west of the southwest corner of the tank farm in the silty clayey sand, and a small 80-foot-diameter area just south of the refinery and about 300 feet west of the northwest corner of the tank farm. The concentrations of the VOCs in the subsurface soils off-site to the southwest were either below detection levels and/or were much lower than on-site, with BTEX being the only VOC detected. Low field organic vapor analyzer (OVA) readings in the northwest (4 to 300 ppm) were recorded in the 80-foot-diameter zone off-site.
- The subsurface soil laboratory data analysis for 37 samples and the field OVA data for 101 samples verified that the major contamination to the underlying soils from the tank farm operations was within the upper 7 to 12 feet and was not detected beyond a depth of about 15 to 20 feet. In the southwest part of the tank farm and downgradient to the south and west and off site, the contaminated zone was principally a silty-clayey fine sand zone that overlies the coarser sand and gravel zone from which the downgradient private wells received their water.
- The contaminant source areas defined from the Phase II study included: the solid waste sludges in the northwest corner of the tank farm; the eastern sludge pit; the subsurface soils in the southwest corner contaminated from the leaded gasoline spill; the west-central part of the tank farm near the no. 5 fuel oil tanks; the crude oil tank and the no-leaded gas tanks; and, the sludge disposal area south of the crude oil tank.
- The significantly high concentrations of VOCs and SVOCs at the tank farm in both the sludges and subsurface soils, and the low concentrations of these same constituents in the groundwater off-site, were accounted for by the Westside Irrigation Ditch effects. When dry, the ditch served as an effective interceptor for contaminated groundwater that moved off-site to the southwest. The ditch prevented widespread movement of contaminated groundwater off site. When flowing, the ditch served as a groundwater boundary and recharge (dilution) mechanism to groundwater movement off-site. The interceptor trench, built in March 1988, was even more effective than the ditch in collecting contaminants before they could migrate off-site.

A more detailed description and analysis of the Phase II investigation results can be found in the following report:

- Phase II Subsurface Soil and Solid Waste Containment Evaluation (Dames and Moore 1988c)

3.4 Preliminary Assessment of Off-site Contamination

Surface and subsurface conditions were evaluated by Dames and Moore off-site in the area immediately south of the refinery and west of the tank farm, and in the drainage ditches west-southwest of the tank farm. In May 1989, data was collected to better define the extent of the refinery-related off-site soil contamination observed in April 1988. An additional 19 boreholes were hand-augered to depths varying from 3 to 15.5 feet below ground surface on property owned by Virginia Murray and Hugh Sterling.

The results of the preliminary off-site property contaminant assessment indicated:

- Off-site contamination from gasoline in the subsurface soils and possibly shallow groundwater immediately south of the Site, on Hugh Sterling and Virginia's properties. The extent of this contamination appeared to extend over approximately 1 acre, to a depth of 10 to 15 feet.
- Off-site contamination from the tank farm in the subsurface soil and shallow groundwater immediately west-southwest of the Site, on Virginia Murray's property. The extent of this contamination appeared to extend over approximately 0.2 acre, to a depth of 10 to 12 feet.
- Off-site contamination, believed to be related to contamination from the tank farm, along the banks and in the surface waters in the ditches in the southern part of Virginia Murray's property and along the Westside Irrigation Ditch.

A more detailed description and analysis of the preliminary assessment of off-site contamination can be found in the following report:

- Preliminary Assessment of the Off-Site Property Contamination (Dames and Moore 1989b)

3.5 Remediation Activities

The following remediation work was completed on and near the former refinery:

March 1988:

- Construction of interceptor trench along west side of tank farm. Trench served as a passive collection system to reduce amount of product entering the Westside Irrigation Ditch.

April/May 1989:

- 12-inch-diameter plastic pipe was installed in the Westside Irrigation Ditch along the entire western edge of the tank farm to contain the irrigation water. It was determined that by piping the irrigation water, the amount of refinery tank farm related free-product phase contaminants that could enter the irrigation ditch waters would be limited.
- An on-site aquifer pumping test was completed in the southwest corner of the refinery tank farm. The results of the pumping test indicated that the upper saturated silty, clayey fine-grained sand zone has a low hydraulic conductivity (5 feet/day), a low transmissivity (300 gpd/feet), and a yield of about 0.02.
- The first round of long-term groundwater monitoring and sampling was completed. The results of the sampling indicated that the groundwater quality 100 feet south of the refinery tank farm at well MW-15 had not been impacted. Total xylene and toluene were detected in well MW-14, 130 feet west-southwest of the tank farm. The concentrations of 3.2 μg/l and 1.1 μg/l for total xylene and toluene, respectively, were below the groundwater protection standard.
- Water quality data from the aquifer pump test well located in the southwest corner of the tank farm about 150 feet south of MW-12 indicated that the high concentrations of organic contaminants found in the shallow sand zone at MW-12 were not present at the aquifer pump test well.

July through September 1989:

- The second round of long-term groundwater monitoring and sampling was completed. The results were similar to those of Round 1 of the long-term sampling.
- Off-site soil and groundwater samples were collected from soils at a seep located immediately downgradient of the refinery and the Farmers Mutual Irrigation Ditch (OSS-5); from soils along Virginia Murray's drainage ditches located just west of the tank farm (OSS-1 through OSS-4); and from surface waters in two of these ditches (OSSW-1 and OSSW-2). The results of this sampling indicated that off-site contamination from the tank farm and refinery was not significant.

November 1989 through January 1990:

- Soil and groundwater samples were collected from the southwest corner of the tank farm for characterization of the contaminated soil environment and the microbial consortium, and to conduct a primary biodegradation screen. The following results were concluded from analysis of the samples:
- The groundwater quality in the deep aquifer on-site at MW-11 meets the groundwater protection standard for the parameters tested. The groundwater quality in the deeper aquifer has remained stable.
- The shallow groundwater was significantly contaminated. The low sulfate and dissolved oxygen concentrations detected at monitor well MW-12, well N-OW, and the north-south interceptor trench indicated that biodegradation was occurring in the subsurface of the southwest area of the tank farm.
- The petroleum hydrocarbon contaminants tended to be absorbed by the lower permeable silt and clay stringers encountered in the shallow aquifer.
- All remaining product was removed and tanks were cleaned by Rocky Mountain Construction Company, Inc. All tank piping was dismantled, drained and capped to prevent potential product leakage from the piping in the future.
- A 10-inch-diameter steel cased well (W-3) located in the southwest corner of the tank farm was grouted to eliminate a potential pathway for contaminant migration to the underlying aquifer.
- Groundwater quality samples were collected from the southwest corner of the tank farm (MW-11 and MW-12), the eastern observation well (E-OW), the northern observation well (N-OW), and the north-south interceptor trench.
- Two boreholes were hand-augered along the eastern and western edges of the southwestern corner of the tank farm to depths of 8.5 feet and 8 feet, respectively, to better define the extent of subsurface contamination along the eastern and western boundaries of the area scheduled for remediation.
- Two composited samples of sludge were collected from the eastern sludge pit for hazardous waste characterization tests. Laboratory analytical tests indicated that the sludge was not hazardous.
- Third round of long-term groundwater quality sampling. Rounds 1, 2, and 3 of long-term groundwater sampling results indicated that off-site groundwater contamination from the tank farm is not significant.

May-July 1990:

- Wells MW-11, MW-12, the test well, and the northern and eastern observation wells were abandoned by pressure grouting prior to slurry wall construction to prevent potential subsurface contamination during construction of the slurry wall.

- The north-south interceptor trench was backfilled just prior to slurry wall construction. No free product was observed in the trench at the time it was backfilled.
- A bentonite slurry wall was constructed. The slurry wall was designed to isolate and control potential off-site contaminant migration from the contaminated areas on-site. The wall encompasses the southwestern corner of the tank farm where the historical leaded gasoline spill occurred and it extends to depths ranging from about 12 to 25 feet, penetrating through the upper silty clayey sand zone, keying into the underlying clay (June 1990).
- The fourth round of long-term groundwater quality sampling was completed. Rounds 1 through 4 of long-term groundwater sampling results indicated that downgradient from the tank farm, within about 100 to 250 feet, the number and concentrations of organic constituents detected had decreased to only one constituent at concentrations near detection limits. Round 4 sampling analytical data indicated that 1,2-DCA was the only volatile organic constituent detected in one on-site and one off-site monitoring well.

<u>August-September 1990</u>:

- Sludge and contaminated soil located on-site at five designated locations at the tank farm were excavated.
- The upper 3 feet of the unsaturated soils located within the slurry wall were excavated and aerated. The soils were then fertilized with 4,000 pounds of ammonium phosphate fertilizer, aerated with about 11,000 gallons of water.
- Seven new shallow monitoring wells (ranging in depths from 12 to 15 to the top of the first clay zone) were constructed using a hollow-stem auger drilling rig. Six of these wells were completed on-site, two of which (MW-17 and MW-22) were completed for the purpose of monitoring water quality changes in the upper shallow zone within the slurry wall. Well MW-18 was completed about 60 feet north (upgradient) of the slurry wall. Well MW-21 was located about 20 feet east of the slurry wall boundary. Wells MW-19 and MW-20 were completed about 70 feet south of the western and eastern corners of the slurry wall, respectively. Well MW-16 was completed off-site, approximately 90 feet west of and 120 feet south of the northwestern corner of the slurry wall.
- The fifth round of long-term groundwater quality sampling was completed.

A more detailed description and analysis of the remediation activities can be found in the following reports:

- Status Report, Remediation Work, Aquifer Pump Test and Round 1 Long-term Ground Water Quality Monitoring Data Results (Dames and Moore 1989c)
- Status Report, Remediation Work and Round 2 Long-term Ground Water Quality Monitoring Data Results (Dames and Moore 1989d)
- Status Report, Remediation Work and Round 3 Long-term Ground Water Quality Monitoring Data Results (Dames and Moore 1990a)
- On-Site Ground, Surface Water and Sludge Laboratory Analytical Data and Modified Ground Water Remediation Plan (Dames and Moore 1990b)
- Status Report, Remediation Work and Round 4 Long-term Ground Water Quality Monitoring Data Results (Dames and Moore 1990c)
- Status Report, Remediation Work and Round 5 Long-term Ground Water Quality Monitoring Data Results (Dames and Moore 1990d)

3.6 Groundwater Sampling

Quarterly groundwater sampling began in March 1991 and continued through March 1993, at which point sampling frequency was changed to semi-annually. This change in frequency was initiated due to the sampling results that demonstrated containment of the gasoline-related organics associated with the original spill and that showed that the biodegradation of the organic contaminants was taking place and that the concentration of the organics in off-site wells was below the groundwater protection standards. Semi-annual groundwater sampling was conducted from May 1993 through December 1998. Due to the laboratory results of the collected samples, sampling frequency was changed to an annual basis, starting in October 1999 and continuing through the present. The monitoring well network for the Site is presented in **Figure 3-1**. A current groundwater contour map and detections from the November 2011 annual groundwater sampling event are displayed on **Figures 3-2** and **3-3**, respectively.

The long-term groundwater sampling results have demonstrated that concentrations of 1,2-DCA and BTEX in all off-site wells have continually been below the groundwater protection standards and USEPA Maximum Contaminant Levels (MCLs). The on-site wells located outside the slurry wall have also continually been below groundwater protection standards and USEPA MCLs since May 1994. Currently, the only constituent above the groundwater protection standard is benzene in monitoring well MW-17.

The consistently low concentrations of 1,2-DCA and BTEX, both on- and off-site, and the significant and continued decrease in concentrations in all of the monitoring wells indicate that the slurry wall has prevented constituent migration from within the slurry wall and that concentrations within the wall will continue to decrease over time. Long-term groundwater monitoring results can be found in **Table 3-1**.

A more detailed description and analysis of the long-term groundwater sampling can be found in the following reports:

- Status Report, Remediation Work, Aquifer Pump Test and Round 1 Long-term Ground Water Quality Monitoring Data Results (Dames and Moore 1989c)
- Status Report, Remediation Work and Round 2 Long-term Ground Water Quality Monitoring Data Results (Dames and Moore 1989d)
- Status Report, Remediation Work and Round 3 Long-term Ground Water Quality Monitoring Data Results (Dames and Moore 1990a)
- Status Report, Remediation Work and Round 4 Long-term Ground Water Quality Monitoring Data Results (Dames and Moore 1990c)
- Status Report, Remediation Work and Round 5 Long-term Ground Water Quality Monitoring Data Results (Dames and Moore 1990d)
- Report, Semiannual Ground Water Monitoring Report (Dames and Moore 1991)
- Report, Ground Water Quality Monitoring (GeoWest Golden, Inc. 1992a)
- 1992 2nd Quarter Sampling Results, Maverik Kirtland Refinery (GeoWest Golden, Inc. 1992b)
- Report, Ground Water Quality Monitoring Results (GeoWest Golden, Inc. 1993a)
- Ground Water Quality Monitoring Report, Maverik Refinery and Tank Farm, Kirtland, New Mexico (GeoWest Golden, Inc. 1993b)
- Report, Ground Water Quality Monitoring Results (GeoWest Golden, Inc. 1994)
- Report, Ground Water Quality Monitoring Results (Ecova Corporation 1995)
- Report, Groundwater Quality Monitoring Results (TriTechnics Corporation 1996)
- 1996 Annual Groundwater Monitoring Report (TriTechnics Corporation 1997)
- 1998 Annual Groundwater Monitoring Report (ThermoRetec 1999a)

- 1999 Annual Groundwater Monitoring Report (ThermoRetec 1999b)
- 2000 Annual Groundwater Monitoring Report (ThermoRetec 2000)
- 2001 Monitoring Report (R.T. Hicks Consultants, Ltd. 2002)
- Maverik Refinery Tank Farm: 2002 Ground Water Monitoring Report (R.T. Hicks Consultants Ltd. 2003)
- Maverik Refinery Tank Farm: 2003 Ground Water Monitoring Report (R.T. Hicks Consultants Ltd. 2004)
- Maverik Refinery Tank Farm: 2004 Ground Water Monitoring Report (R.T. Hicks Consultants Ltd. 2005)
- Stage 1 Report, Former Maverik (Caribou) Refinery, Kirtland, New Mexico (Retec 2006)
- 2007 Annual Groundwater Report, Former Refinery, Kirtland, New Mexico (ENSR/AECOM 2008)
- 2008 Annual Groundwater Report, Former Caribou Refinery, Kirtland, New Mexico (AECOM 2009)
- 2009 Annual Groundwater Report, Maverik Country Stores (Former Caribou Refinery), Kirtland, New Mexico (AECOM 2010)
- 2010 Annual Groundwater Report, Maverik Country Stores (Former Caribou Refinery), Kirtland, New Mexico (AECOM 2011)

3.7 Other Site Activities

June 1993:

- A limited asbestos survey was conducted by Envirotech to determine the presence of asbestos containing material. The survey included a visual walk over inspection of the Site and collection of samples of insulation materials for laboratory analysis. Based on the Site visit and laboratory results, it was determined that the Site did not contain any asbestos.

June 1994:

- Nutrient addition operations to stimulate hydrocarbon biodegradation were conducted within the area enclosed by the slurry wall by Rosenbaum Construction of Farmington, New Mexico. The area was leveled by using a dozer blade and the ground surface ripped to a depth of 4 feet. Then, 4,000 pounds of 16-20-0 ammonium phosphate granular fertilizer were applied to the area and disked into the soil. The fertilizer was watered in over a 2-day period using approximately 150,000 gallons of water.

June 1995:

- Nutrient addition operations to stimulate hydrocarbon biodegradation were conducted within the area enclosed by the slurry wall by Rosenbaum Construction of Farmington, New Mexico. The area was leveled by using a dozer blade and the ground surface ripped to a depth of 4 feet. Then, 4,000 pounds of 16-20-0 ammonium phosphate granular fertilizer were applied to the area and disked into the soil. The fertilizer was watered in over a 2-day period using approximately 150,000 gallons of water.

June 1996:

- Nutrient addition operations to stimulate hydrocarbon biodegradation were conducted within the area enclosed by the slurry wall by Rosenbaum Construction of Farmington, New Mexico. The area was ripped to a depth of 4.5 feet. Then, 4,000 pounds of 16-20-0 ammonium phosphate granular fertilizer were applied to the area and disked into the soil. The fertilizer was watered in over a 2-day period using approximately 150,000 gallons of water.

<u>March 2006</u>:

- A Stage 1 field investigation and laboratory testing program was conducted in March 2006 to evaluate the integrity of the soil-bentonite slurry wall installed in 1990. Samples for permeability testing were collected using a hollow-stem auger drill rig. Each sample was collected by driving 3-inch diameter Shelby Tubes in 2-foot intervals. Five samples were collected including one from the vadose zone and four from the saturated zone. After sample collection, each boring was backfilled with bentonite chips and hydrated.

  Permeability tests were conducted on each sample by a laboratory using test method ASTM D5084. Three of the samples were found to have permeability less than or near 1 x 10-7 cm/sec, a typical performance standard for soil-bentonite slurry walls. One sample was slightly higher at 7.7x10-7 cm/sec from the south wall saturated zone and one sample was at 3.2x10-6 cm/sec from the east wall vadose zone. While these two samples exhibited permeability higher than 1 x 10-7 cm/sec, the results of the March 2006 investigation indicate that the slurry wall is still functioning as an effective containment system to prevent horizontal migration of impacted groundwater.

A more detailed description and analysis of the other Site activities can be found in the following reports:

- Limited Asbestos Survey, Former Caribou Refinery Tank Farm, Kirtland, New Mexico (Envirotech Inc. 1993)
- Report, Ground Water Quality Monitoring Results (Ecova Corporation 1995)
- Report, Groundwater Quality Monitoring Results (TriTechnics Corporation 1996)
- 1996 Annual Groundwater Monitoring Report (TriTechnics Corporation 1997)
- Stage 1 Report, Former Maverik (Caribou) Refinery, Kirtland, New Mexico (Retec 2006)

4.0 Current Site Conditions

As mentioned in section 3.6, annual Site groundwater monitoring is ongoing. The most recent annual groundwater sampling event at the former Caribou Refinery was completed during the week of November 14, 2011. Nine wells in and around the slurry wall impoundment area were sampled using low-flow methods for VOCs. Five additional wells were sampled as part of the off-site investigation requested by the Oil Conservation Division (OCD) during a meeting on November 2, 2011. Groundwater results, including those from the five additional wells requested by OCD, were below analytical reporting limits for all 8260 VOCs with the exception of wells located within the slurry wall impoundment area (MW-17 and MW-22). Groundwater concentrations within the slurry wall contain a suite of VOCs, primarily benzene, ethylbenzene, xylenes, and trimethylbenzene compounds. The maximum benzene concentration was 34 µg/L in MW-17. Groundwater sampling detections from the November 2011 annual groundwater sampling event are displayed on **Figure 3-3**. The results of the November 2011 groundwater sampling event are consistent with previous sampling events. The results of all sampling events since October 2000 demonstrate that the only remaining impacts detected above the groundwater protection standards are located within the slurry wall.

Fluid levels were measured in 21 wells to establish groundwater flow conditions. **Figure 3-2** displays the groundwater contour map from November 2011. Groundwater flow continues to the south-southwest across the Site toward the San Juan River.

Since the refinery shutdown in 1982, the groundwater VOC concentrations have declined appreciably at the Site, including a reduction in benzene concentrations by as much as 99.96 percent. Compounds such as 1,2- DCA are no longer detected in Site groundwater and VOCs, such as benzene, have decreased since the early 1990s. As indicated in Section 3.6, monitoring wells MW-17 and MW-22 are located within the confines of the slurry wall where elevated hydrocarbon results have been historically encountered. Analytical results from the past 20 years of monitoring indicate a decreasing trend of BTEX concentrations in groundwater at the Site (**Figures 4-1** and **4-2**). The decrease in BTEX concentrations is likely a cumulative effect of biodegradation within the aquifer and volatilization of BTEX from the unsaturated zone. Overall, the slurry wall has contained the dissolved phase impacts and no constituents of concern are detected outside of the containment wall.

5.0 Alternative Options Evaluation

Currently, all constituents in both the on- and off-site wells are below the New Mexico's Water Quality Control Commission groundwater protection standards found in 20.6.2.3103 NMAC, with the exception of a concentration of benzene of 34 µg/L in monitoring well MW-17. Monitoring well MW-17 is located within the slurry wall on-site and based on the analytical data, will be the focus of the in-situ remediation efforts. Groundwater abatement will be considered successful and complete once the constituent concentrations found at the Site are below the groundwater protection standards for eight consecutive quarters of groundwater sampling.

Four in-situ remediation technology alternatives were developed and evaluated as part of the Stage II Abatement Plan for site remediation. The technologies evaluated include monitored natural attenuation (MNA), oxygen releasing compound (ORC) injections, in-situ chemical oxidation (ISCO) injections, and air sparging. Eight consecutive quarterly sampling events will take place after the selected alternative is implemented to ensure that groundwater abatement is complete and rebound does not occur.

5.1 Basis for Analysis

The remediation alternatives were evaluated based on three general standards: protection of human health and the environment, ability to attain media cleanup standards, and compliance with applicable standards for management of wastes. Additionally, they were evaluated based on their reliability and effectiveness, ability to reduce toxicity or volume of constituents, treatment timeframe, implementability, and cost. Below is a description of each criterion:

General Standards

1. Be Protective of Human Health and the Environment. This criterion addresses the alternative's overall ability to provide adequate protection of human health and the environment through eliminating, reducing, or controlling potential exposure.
2. Attain Media Cleanup Standards. Each alternative is evaluated based on its ability to achieve the media cleanup objectives. The media cleanup standards are the groundwater protection standards found in 20.6.13.3103 NMAC.
3. Comply with Any Applicable Standards for Management of Wastes. This criterion requires that wastes generated during the implementation of the alternative will be managed in compliance with applicable regulations.

Remedy Selection Decision Factors

4. Reliability and Effectiveness. This criterion addresses whether the alternative is reliable and effective in protecting human health and the environment during the life of the alternative. The life of the alternative is the length of time the alternative must be operated and maintained and/or a monitoring program implemented. Timeframes used in this Stage II Abatement Plan are based on the time to reach media cleanup goals determined by calculated degradation rates or estimated alternative implementation duration.
5. Reduction in Toxicity and/or Volume of Wastes. This criterion considers how each alternative reduces the toxicity and/or volume of wastes.
6. Treatment Timeframe. This criterion considers the timeframe required to reach media cleanup goals for the alternative.
7. Implementability. The constructability of each alternative was considered, as well as the ability to monitor the effectiveness of the alternative.

8. Cost. The relative cost of each alternative was considered. Costs include capital construction; engineering design, construction oversight, and project management; and periodic costs. As described above, the timeframe of each alternative is based on the time to reach media cleanup goals determined by calculated degradation rates or estimated alternative implementation duration. A summary of the capital cost for each alternative is presented in **Table 5-2**.

5.2 Alternative 1 - Monitored Natural Attenuation

MNA works by allowing concentrations to naturally decline. Annual groundwater sampling will take place to monitor the concentrations of the constituents found within the slurry wall and to ensure that no migration outside of the slurry wall is taking place. The nine monitoring wells that have been sampled annually since 1999 will continue to be sampled annually for volatile organic compounds (VOCs) via USEPA Method 8260. In addition to being analyzed for VOCs, samples collected from monitoring wells MW-17 and MW-22 will be analyzed for Nitrate, Manganese, Dissolved Ferrous Iron, Sulfate, and Methane in the first and last year of MNA sampling.

MNA protects human health and the environment by monitoring constituent concentrations to ensure that no off-site migration is occurring and concentration levels within the slurry wall are continuing to decrease. Natural attenuation is a proven strategy to attain media cleanup objectives. MNA will produce minimal waste, in the form of purge water, needing management. Natural attenuation is effective at remediating subsurface impacts and with the slurry wall in place it is a reliable alternative. Although it is effective at reducing the volume of subsurface impacts, the treatment timeframe for MNA will be longer than if enhanced biodegradation were to occur due to the anaerobic conditions at the Site. No work will need to be completed in addition to the annual groundwater sampling that is already occurring, making this alternative quick and technically easily to implement, and cost effective.

MNA will continue until all groundwater protection standards have been met. The dissolved oxygen concentrations measured in the field during annual sampling indicate there are anaerobic conditions within the slurry wall. Anaerobic conditions lead to a slower degradation rate compared to aerobic conditions. First order degradation rates were calculated for benzene, ethylbenzene, toluene, and BTEX, using the historical groundwater data from MW-17 and MW-22. As predicted by the calculated degradation rates, ethylbenzene, toluene, and total xylenes have already degraded below their groundwater protection standards of 750 µg/L, 750 µg/L, and 620 µg/L, respectively. Benzene is predicted to reach the groundwater protection standards no later than 2019 at MW-17 and 2012 at MW-22. Annual sampling will be converted to quarterly confirmation sampling after the analytical results from the MNA sampling demonstrate that the groundwater protection standards have been met. Monitoring wells MW-17, MW-19, and MW-22 will be sampled during the first, second, and third quarters. During the fourth quarter, samples will be collected from the nine on- and off-site monitoring wells (MW-09, MW-10, MW-16, MW-17, MW-18, MW-19, MW-20, MW-21, and MW-22) that are currently sampled annually.

5.3 Alternative 2 - Oxygen Releasing Compound Injection

Alternative 2 combines MNA, as described in Alternative 1, with ORC injections. ORC works by slowly releasing oxygen over a period of up to 12 months. The released oxygen increases the dissolved oxygen concentration in the groundwater providing more oxygen for microorganisms to perform aerobic biodegradation. The rate of aerobic BTEX biodegradation is faster than anaerobic biodegradation. Therefore, creating aerobic conditions enhances biodegradation, which in turn reduces concentrations of impacts in the groundwater at a greater rate. Enhanced biodegradation is a proven technology for remediating hydrocarbon impacts found at the Site.

Enhancing biodegradation through the injection of ORC combined with MNA helps to protect human health and the environment by reducing the volume of constituents in the treatment area and monitoring to ensure that no off-site migration is occurring. The reduction in volume of constituents also aids in the attainment of media cleanup objectives. Injecting ORC will produce additional waste to that produced during MNA groundwater sampling, however, the waste can be managed and disposed of properly, adhering to applicable waste management standards. ORC has been proven to be an effective and reliable remediation technology for BTEX reduction based on previous successful remediation projects. The volume of constituents within the treatment area will be reduced due to the enhancement of biodegradation by creating aerobic conditions. Additionally, by enhancing biodegradation, the treatment timeframe will be reduced when compared to MNA. Construction of the injection system will consist of installing shallow injection wells and injections into the wells can be implemented using standard construction techniques and injection equipment, respectfully. Due to the high cost of ORC, this alternative is not as cost effective as the other alternatives evaluated.

A pilot test will be completed to determine the effectiveness and feasibility of using ORC injections to remediate the site. A full scale injection event may be implemented based on the results of the pilot test. Annual MNA sampling events will commence 9 to 12 months after the final ORC injection event to allow for sufficient biodegradation prior to collecting samples. It is anticipated that the timeframe for MNA, when combined with ORC injections, will be reduced to approximately 4 years. Annual sampling will be converted to quarterly confirmation sampling after the analytical results from MNA sampling demonstrate that groundwater protection standards have been met.

5.4 Alternative 3 – In-Situ Chemical Oxidation

Alternative 3 combines MNA, as described in Alternative 1, with ISCO. ISCO involves injecting an oxidant into the subsurface, which then chemically destroys the hydrocarbon compounds found at the Site. In addition to breaking down the hydrocarbons, ISCO injections will increase the oxygen levels in the injection area, creating aerobic conditions which will increase the rate of biodegradation in comparison to the current anaerobic site conditions.

ISCO, combined with MNA, helps to protect human health and the environment by reducing the toxicity and volume of constituents in the treatment area and monitoring to ensure that no off-site migration is occurring. The reduction in volume of constituents and reducing the toxicity of the constituents through chemical destruction aids in the attainment of media cleanup objectives. ISCO will produce additional waste to that produced during MNA groundwater sampling, however, the waste can be managed and disposed of properly, adhering to applicable waste management standards. ISCO has been proven to be an effective and reliable technology for remediating BTEX based on previous successful remediation projects. The volume and toxicity of constituents within the treatment area will be reduced due to the chemical destruction of the hydrocarbon compounds found at the Site. Additionally, chemical oxidants also release oxygen into the treatment area over time, creating aerobic conditions and therefore enhancing biodegradation. The reduced chemical volume and toxicity through chemical destruction and enhancing biodegradation will reduce the treatment timeframe when compared to MNA alone. Construction of the injection system will consist of installing shallow injection wells and injections into the wells can be implemented using standard construction techniques and injection equipment, respectfully. The cost of purchasing chemical oxidants reduces the cost effectiveness of this alternative, however it remains more cost effective than purchasing ORC.

A chemical oxidation injection pilot test using activated persulfate (Klozur® CR, a commercially available chemical oxidant), will be completed to determine the effectiveness and feasibility of ISCO for site remediation. The results of the pilot test will be analyzed and used in the evaluation of implementing full-scale ISCO. Annual MNA sampling events will continue throughout the pilot test and, if implemented, the full-scale injection event. It is anticipated that the timeframe for MNA, when combined with ISCO, will be reduced to 3 years. Annual sampling will be converted to quarterly confirmation sampling after the analytical results from MNA sampling demonstrate that groundwater protection standards have been met.

5.5 Alternative 4 - Air Sparge

Alternative 4 combines MNA, as described in Alternative 1, with air sparge. Air sparge is a proven technology used to treat volatile dissolved phase hydrocarbon impacts. Air sparge strips the volatile compounds from the groundwater and is an effective technology used in removing volatile compounds, including BTEX, from groundwater. Although air sparge is effective in removing VOC from groundwater, due to groundwater movement, multiple air sparge events may be required to successfully reduce the impact concentrations to meet the groundwater protection standards.

Air sparge, combined with MNA, helps to protect human health and the environment by reducing the mass of constituents in the treatment area through volatilization and biodegradation, and monitoring to ensure that no off-site migration is occurring. The reduction in volume of constituents also aids in the attainment of media cleanup objectives. Air Sparge will not produce additional waste to that produced during MNA groundwater sampling. Air Sparge has been proven to be an effective and reliable remediation technology for BTEX compounds based on many previous successful remediation projects involving sites impacted with petroleum hydrocarbons. The mass of constituents within the treatment area will be reduced due to the mechanical stripping of the constituents from the groundwater. Additionally, air sparge will temporarily increase the dissolved oxygen concentration in the groundwater, creating aerobic conditions, enhancing the biodegradation of constituents for a period after air sparging has taken place. Because of the reduction in constituent mass through volatilization and enhanced biodegradation, the treatment timeframe will be reduced when compared to MNA. Temporary air sparge systems, as would be installed at the former Caribou Refinery, are not as common as ORC injections or ISCO and therefore Alternative 4 will be slightly more difficult to implement than the other alternatives. However, since no injection materials will need to be purchased, air sparge is reasonably cost effective.

An air sparge pilot test will be completed to determine the effectiveness and feasibility of air sparge for site remediation. The results of the pilot test will be analyzed and used in the evaluation of implementing a full-scale air sparge event. It is anticipated that four air sparge events may be needed in addition to the pilot test to reach groundwater abatement. Annual MNA sampling events will continue during the pilot test and after the full-scale air sparging events, if needed, have been completed. It is anticipated that MNA, when combined with air sparging, will be reduced to 4 years. Annual sampling will be converted to quarterly confirmation sampling after the analytical results from the MNA sampling demonstrate that the groundwater protection standards have been met.

5.6 Alternative Comparison

The four alternatives were evaluated based on the general standards and remedy selection decision factors described in Section 5.1. All alternatives were found to be acceptable based on the general standards. Each alternative received a score, relative to the other alternatives, for each remedy selection decision factor. See **Table 5-1** for the alternative ranking table.

5.6.1 Alternative Ranking

Alternative 1 is the second highest ranked among the four alternatives when referring to the remedy selection decision factors. Alternative 1, compared to the other three alternatives, ranked highest for reliability and effectiveness, implementability, and cost based on its proven effectiveness and reliability for BTEX remediation in an easily implemented and cost effective manner. It ranked second in reducing toxicity or volume due to the longer timeframe needed to reduce the volume when compared to the other alternatives. Alternative 1 ranked lowest for treatment timeframe due to the relatively slower degradation rate caused by the current on-site anaerobic conditions.

Alternative 2 received the third highest overall rank among the four alternatives when comparing the remedy selection decision factors. It received the highest score for reduction in toxicity or volume, and reliability and effectiveness based on its proven ability to reduce the volume of impacts in an effective and reliable manner. It received the second highest score for treatment timeframe and implementability based on the extended treatment timeframe when compared to Alternative 3 but reduced when compared to Alternative 1. It received the lowest score for cost based on it being the most expensive alternative.

Alternative 3 ranked highest overall among the four alternatives based on evaluation of remedy selection decision factors. It received the highest score for reliability and effectiveness, reduction in toxicity or volume, and treatment timeframe. It received the second highest score for implementability due to the additional well installation and need for multiple injections. It also received the second highest score based on it being relatively similar to Alternative 4 in cost, but more expensive than Alternative 1 and less expensive than Alternative 2.

Alternative 4 received the lowest rank among the four alternatives when referring to the remedy selection decision factors. It received the highest score available for reduction in toxicity or volume and reliability and effectiveness based on its proven ability to reduce the volume of impacts in an effective and reliable manner. However, it received the second highest score available for the treatment timeframe due to the extended time when compared to Alternative 3 but the reduced timeframe when compared to Alternative 1. Due to the additional work involved with installing a temporary air sparge system when compared to the other alternatives, it received the lowest score for implementability. It received the second highest score based on it being relatively similar to Alternative 3 in cost, but more expensive than Alternative 1 and less expensive than Alternative 2.

5.6.2 Recommended Alternative

Alternative 3 received the highest overall ranking and is the recommended alternative. ISCO is a proven technology used in the remediation of BTEX and should be implementable and effective given the target compounds and geological setting of the former Caribou Refinery. However, to ensure success and refine plans for implementation, a pilot test is recommended prior to implementing a full-scale ISCO and MNA design.

6.0 Remedial Actions Plan

6.1 Objectives

The objective of the proposed activities described in this Remedial Actions Plan is to determine the effectiveness and feasibility of using chemical oxidation to reduce the total mass of hydrocarbons at the Former Caribou Refinery to below the groundwater protection standards set forth in section 20.6.2.3103 of the New Mexico Administrative Code. The ultimate goal is to successfully abate the groundwater on-site, which will be obtained by reaching and maintaining impact concentrations at or below the groundwater protection standards.

6.2 Scope of Work

This section presents the scope of work required to implement the proposed remediation activities at the Site. In order to complete groundwater abatement, a chemical oxidation pilot test will be performed to verify its effectiveness and finalize details for full scale implementation. While the pilot test is being implemented and its results evaluated, the current annual groundwater sampling will continue. All remedial activities will be conducted according to the procedures set forth in this work plan and the site-specific Health and Safety Plan (HASP).

6.2.1 In-Situ Chemical Oxidation Pilot Test

An ISCO pilot test will be conducted at MW-17, the only monitoring well with impacts exceeding the groundwater protection standards. The pilot test will be used to assess the effectiveness and feasibility of using activated persulfate (Klozur® CR) and to design for additional application, if needed, to reach and maintain abatement. The following parameters for a full-scale design, if needed, will be determined during the pilot test:

- Injection radius of influence
- Injection flow rate
- Injection concentration and dosage requirements
- Cleanup time
- Construction limitations
- Site soil oxygen demand (SOD), chemical oxygen demand (COD), and natural oxidant demand NOD)

6.2.1.1 Chemical Oxidant Selection

Activated persulfate (Klozur® CR) was chosen as the chemical oxidant for injection at the site due to its effectiveness in remediating BTEX. Activated persulfate is a slow but strong oxidant that can be injected to breakdown petroleum compounds, including BTEX. Persulfate is very stable with respect to decomposition in the subsurface, despite being a strong oxidant, therefore allowing it to last, on average, four to eight weeks following injection.

Klozur® CR combines persulfate chemical oxidation with aerobic biodegradation. Klozur® CR is a single, formulated product consisting of high pH-activated Klozur® persulfate and PermeOx® Plus engineered calcium peroxide, combining the strengths of both products. High pH-activated Klozur® persulfate is a strong oxidant, which will breakdown the BTEX on contact, and the PermeOx® Plus will release oxygen for up to nine months, creating aerobic conditions to enhance biodegradation. Klozur® CR is manufactured by FMC Corporation of Philadelphia, Pennsylvania with technical support by

ChemRem International of Albuquerque, New Mexico. The material safety data sheet and technical data for Klozur® CR can be found in **Appendix A**.

6.2.1.2 Pilot Test Design Parameters

The ISCO pilot test will consist of three injection events. Prior to the first injection event, four injection wells will be installed surrounding monitoring well MW-17. The proposed injection wells will be 2-inches in diameter, Schedule 40 PVC construction, drilled to a depth of 15 feet, and screened between 5 and 15 feet below ground surface. Wells will be completed in accordance with 19.27.4 NMAC. Samples will be collected during well installation to determine the SOD, COD, and NOD of the treatment area. Collected samples will also be analyzed for benzene. The proposed injection well locations will be surveyed after installation.

Since benzene is the only constituent above the groundwater protection standard, it is the primary chemical of concern during the pilot test. The plume thickness is estimated to be approximately 15 feet. Based on the plume geometry, soil parameters, contaminant data, and injection area, the approximate calculated dissolved mass of benzene is 0.0051 kilograms (kg) and adsorbed benzene mass is 0.0013 kg for a total residual mass to be 0.0064 kg of benzene.

0.64 pounds of Klozur® CR is needed based on the stoichiometry of chemical oxidation of benzene by Klozur® CR . Additionally, 444 pounds is required based on the calculated natural oxidant demand. A total of approximately 445 pounds of Klozur® CR is thus calculated to treat the target area. Approximately 37.5 pounds of Klozur® CR, mixed with approximately 330 gallons of water, will be injected into each well during each of the three injection events. The Klozur® CR will be injected under pressure as a slurry with an estimated radius of influence of approximately 7.5 feet.

6.2.1.3 Remediation Effectiveness Evaluation

To determine the remediation effectiveness, the results from the 2011 annual groundwater sampling event will be compared to the results of the groundwater sampling event that will be conducted after all three injection events have been completed. If determined to be effective, the feasibility and necessity of full-scale ISCO implementation will be evaluated. However, if ISCO is found not to be an effective and/or feasible remediation technology for the former Caribou Refinery, another alternative may be evaluated for use in subsequent site remediation.

6.2.2 Monitoring Plan

Groundwater monitoring will continue at the Site during the pilot testing phase in accordance with the current annual monitoring plan. Annual groundwater monitoring will include collecting fluid level data from monitoring wells MW-1 through MW-22, piezometers P-1 through P-4, and proposed injection wells, as available, to provide groundwater elevation data. Fluid-level gauging will be conducted using an electric oil/water interface probe and consistent with AECOM Project Operating Procedure (POP) 231 (**Appendix B**). All fluid levels will be recorded in the field book and/or on a fluid level monitoring log. Decontamination of the electric oil/water interface probe will follow the procedures outlined in AECOM POP 120 (**Appendix B**).

Groundwater samples will be collected annually from the nine on- and off-site monitoring wells (MW-09, MW-10, MW-16, MW-17, MW-18, MW-19, MW-20, MW-21, and MW-22) that are currently sampled annually. The samples will be sent to a laboratory for analysis of BTEX and 1,2-DCA using USEPA Method 8260. For quality assurance, one blind duplicate sample will be collected and one trip blank will be placed in each cooler to accompany the groundwater samples during shipment to the analytical laboratory. The blind duplicate and the trip blank(s) will be analyzed for the same constituents as and using the same methods as the collected samples. All samples will be collected and shipped in accordance with AECOM POPs 230 and 110 (**Appendix B**), respectively.

6.3 Health and Safety

All companies on-site during the site remediation activities will complete a site-specific HASP. All site work will be conducted by employees in accordance with their company's site-specific HASP. All HASPs will be available for on-site inspection. In addition, a safety "tailgate" meeting will be initiated at the inception of field work each day and after lunch or breaks at the discretion of the field manager.

The current AECOM site-specific HASP will be updated to include the health and safety information for the approved remedial activities prior to mobilization to the Site. The AECOM HASP will include contingency measure in the event of unanticipated situations during fieldwork operations.

One Call of New Mexico will be contacted at least 2 days prior to initiating any ground disturbance field activities for utility notification.

6.4 Reporting and Data Evaluation

An annual report of all remediation activities, including pilot tests, full-scale implementation (if completed), and sampling events, will be submitted for each year work is completed at the Site until abatement requirements have been met. The results and evaluation of the pilot test and any full-scale activities will be included in the annual reports. Additionally, the results and evaluation of the groundwater sampling analytical laboratory data will be included in the annual reports. The annual reports will include a summary of the work completed, the analytical results for any sampling events occurring in that year, a presentation of the data collected, and any other information related to the Stage II Abatement Plan activities.

After the standards and requirements of 19.15.30.9 NMAC are met, an abatement completion report, documenting compliance with the standards and requirements, will be submitted to the director for approval.

7.0 Design Components and Monitoring Plan

7.1 Design Components

The chemical oxidation pilot test will be analyzed for effectiveness and the feasibility of completing full-scale implementation. If Alternative 3 is determined to be an effective and feasible remediation alternative based on the results of the pilot test, a full-scale design may be completed. However, if determined to not be effective and/or feasible, another alternative may be evaluated for implementation.

7.2 Monitoring Plan

An updated groundwater monitoring plan will be written based on the results of the pilot test. The groundwater monitoring plan will be submitted under separate cover. The groundwater monitoring plan will include the required monitoring and sampling necessary to reach groundwater abatement, including the sampling frequency, wells to be sampled, target analytes, sampling procedures, and analytical methodologies.

8.0 Operations and Maintenance

No permanent remediation system will be installed; therefore no continuous operations or regular maintenance will be required at the Former Caribou Refinery site.

9.0 Required Permits

In accordance with 19.15.14 NMAC, a well permit will be filed for each injection well installed as part of the completed remediation activities. Additionally, a notice of intent to inject will be filed with the Ground Water Quality Bureau. The notice shall include all of the information required by 20.6.2.1201 NMAC. A discharge permit will then be filed, if required by the Ground Water Quality Bureau.

10.0 Schedule

The Stage II Abatement Plan submittal date is March 8, 2012, in accordance with the letter from OCD to Maverik, dated November 8, 2011. Based on 19.15.30.16 NMAC, Maverik anticipates approval of this plan by early June 2012. If no comments are received by the end of June, Maverik understands this to be tantamount to the agency explicitly stating that OCD has no comments and that the plan is approved as written. As such, Maverik will proceed in securing the necessary permits and implement the Remedial Actions Plan as described in Section 6.0. Based on the assumption that approval is received by the end of June, the tentative project schedule is presented below. The schedule is dependent upon and subject to change based on comments on and/or approval of this Stage II Abatement Plan and receipt of permits.

- June 2012 – Stage II Abatement Plan approval
- July 2012 – Required permits received
- August 2012 – Initiation of ISCO pilot test
- September 2012 – Second ISCO pilot test injection event
- October 2012 – Third ISCO pilot test injection event
- November 2012 – Annual groundwater sampling event

11.0 Public Notice

A public notice will be issued by Maverik within 15 days after the division determines that this Stage II Abatement Plan is administratively complete. The public notice will be issued in a division-approved form in a newspaper of general circulation in San Juan County. The public notice will include all information as required by 19.15.30.15 NMAC.

12.0 References

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Tables

Table 3-1 Long-term Groundwater Sampling Results

MW-17 (Within Slurry Wall)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		10	10.0	750	620	750
	Sep-90	360	11,000	1,160	13,000	15,000
	Mar-91	400	11,000	1,900	15,000	10,000
	Jun-91	420	9,800	1,800	16,000	6,300
	Jan-92	MSG	MSG	MSG	MSG	MSG
	Jun-92	45	9,240	1,150	7,190	7,580
	Aug-92	27	7,710	669	5,130	1,920
	Dec-92	17.3	7,990	638	4,600	4,740
	Mar-93	16.8	13,800	1,110	6,930	6,830
	May-93	12.5	13,700	993	10,530	6,360
	Nov-93	30.9	8,590	636	4,880	2,820
	May-94	8.3	10,900	823	5,660	4,340
	Oct-94	4.9	5,130	409	2,818	1,160
Duplicate	Oct-94	< 1	2,070	350	2,013	807
	May-95	< 10	9,320	694	3,782	2,510
Duplicate	May-95	< 10	12,800	944	5,710	4,460
	Oct-95	2.3	3,000	244	1,079	464
	May-96	2.2	7,700	530	1,800	1,200
Duplicate	May-96	< 5	7,300	490	1,800	1,200
	Oct-96	< 5	3,600	290	1,500	880
	Jun-97	<0.5	5,500	23	180	51
	Oct-97	<5	590	140	1,300	920
Duplicate	Oct-97	<5	490	95	930	680
	May-98	NS	NS	NS	NS	NS
Duplicate	Dec-98	180	4,000	870	4,500	970
	Dec-98	<10	2,300	370	1,300	44
	Oct-99	<5	440	110	930	140
	Oct-00	<5	500	180	1,600	57
	Dec-01	NA	6,200	1,900	17,200	6,000
	Dec-02	< 1	4,200	1,700	13,000	1,900
	Nov-03	NA	420	87	1,060	120
	Jan-05	<100.0	4,800	840	7,400	440
	Mar-06	< 100	3,800	310	2,800	57 J
	Nov-07	< 4.0	22	2.9 J	31	< 4.0
	Dec-08	< 2.0	85	7.2	35	1.9 J
	Dec-09	< 10	450	28	120	7.9 J
	Nov-10	< 1.0	20	2.8	4	0.18 J
	Nov-11	< 1.0	34	4	8	0.42 J

Table 3-1 Long-term Groundwater Sampling Results

MW-22 (Within Slurry Wall)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		**10**	**10.0**	**750**	**620**	**750**
	Sep-90	7,200	21,000	1,100	8,300	20,000
	Mar-91	2,200	17,000	910	6,600	9,500
	Jul-91	3,600	15,000	760	3,000	3,200
	Jan-92	5,400	36,000	1,900	13,500	27,000
	Jun-92	3,170	21,200	1,040	5,730	7,540
	Aug-92	568	20,500	588	3,280	4,610
	Dec-92	908	12,100	514	3,254	4,220
	Mar-93	1,930	29,800	1,170	7,030	14,100
	May-93	28	17,000	1,100	6,150	6,520
	Nov-93	2,780	18,400	1,150	7,300	8,480
	May-94	379	9,340	845	3,725	2,250
	Oct-94	566	10,500	1,390	8,350	5,890
	May-95	62	7,510	1,000	6,520	1,750
Duplicate	May-95	67	9,020	1,230	7,310	2,620
Duplicate	Oct-95	42	5,700	1,580	9,000	2,430
	Oct-95	< 1	5,120	1,540	8,320	2,130
	May-96	37	4,600	1,300	10,000	410
	Oct-96	38	880	710	4,100	250
	Jun-97	24	4,300	510	5,500	580
Duplicate	Jun-97	21	5,800	750	7,300	930
	Oct-97	NS	NS	NS	NS	NS
	May-98	12	3,300	610	3,400	300
Duplicate	May-98	14	3,500	630	3,600	310
	Dec-98	190	3,700	720	4,000	910
	Oct-99	<5	580	150	820	210
Duplicate	Oct-99	<5	730	180	1000	270
	Oct-00	<10	210	220	830	120
	Dec-01	NA	410	120	470	19
	Dec-02	17	1,200	220	640	30
	Nov-03	NA	330	200	222	20
	Jan-05	< 10.0	770	820	120	18
	Mar-06	< 20	440	250	< 40	7.9 J
	Nov-07	< 1.0	14	15	3.6	0.41 J
	Dec-08	< 2.0	75	64	0.73 J	< 2.0
	Dec-09	< 2.0	85	41	5.6	0.54 J
	Nov-10	< 1.0	16	22	0.22 J	0.31 J
Duplicate	Nov-10	< 1.0	16	22	0.21 J	0.29 J
	Nov-11	< 1.0	5.9 J	3.1 J	< 2.0	< 1.0

Table 3-1 Long-term Groundwater Sampling Results

P-1 (Within Slurry Wall)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		10	10.0	750	620	750
	May-93	< 1	4,110	361	2,522	18.8
	Nov-93	< 1	3,580	506	3,215	10.2
	May-94	NS	NS	NS	NS	NS
	Oct-94	< 1	8.9	1.9	11.8	< 1
	May-95	NS	NS	NS	NS	NS
	Oct-95	NS	NS	NS	NS	NS
	May-96	NS	NS	NS	NS	NS
	Oct-96	NS	NS	NS	NS	NS
	Jun-97	NS	NS	NS	NS	NS
	Oct-97	NS	NS	NS	NS	NS
	May-98	NS	NS	NS	NS	NS
	Dec-98	NS	NS	NS	NS	NS
	Oct-99	NS	NS	NS	NS	NS
	Oct-00	NS	NS	NS	NS	NS
P-2 (Within Slurry Wall)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		10	10.0	750	620	750
	May-93	3.2	5.2	< 1	< 1	< 1
	Nov-93	< 1	< 1	< 1	< 1	< 1
	May-94	1.3	< 1	< 1	< 1	< 1
	Oct-94	3.6	< 1	< 1	< 1	< 1
	May-95	NS	NS	NS	NS	NS
	Oct-95	NS	NS	NS	NS	NS
	May-96	0.8	< 0.5	< 0.5	< 0.5	< 0.5
	Oct-96	NS	NS	NS	NS	NS
	Jun-97	NS	NS	NS	NS	NS
	Oct-97	NS	NS	NS	NS	NS
	May-98	NS	NS	NS	NS	NS
	Dec-98	NS	NS	NS	NS	NS
	Oct-99	NS	NS	NS	NS	NS
	Oct-00	NS	NS	NS	NS	NS

Table 3-1 Long-term Groundwater Sampling Results

P-3 (Within Slurry Wall)

	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		**10**	**10.0**	**750**	**620**	**750**
	May-93	10.6	< 1	< 1	< 1	< 1
	Nov-93	11.5	< 1	< 1	< 1	< 1
	May-94	12.1	< 1	< 1	< 1	< 1
	Oct-94	12.6	< 1	< 1	< 1	< 1
	May-95	NS	NS	NS	NS	NS
	Oct-95	NS	NS	NS	NS	NS
	May-96	3.4	< 0.5	< 0.5	< 0.5	< 0.5
	Oct-96	NS	NS	NS	NS	NS
	Jun-97	NS	NS	NS	NS	NS
	Oct-97	NS	NS	NS	NS	NS
	May-98	NS	NS	NS	NS	NS
	Dec-98	NS	NS	NS	NS	NS
	Oct-99	NS	NS	NS	NS	NS
	Oct-00	NS	NS	NS	NS	NS

P-4 (Within Slurry Wall)

	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		**10**	**10.0**	**750**	**620**	**750**
	May-93	8.3	6,690	559	6,260	4,090
	Nov-93	2.1	6,400	900	7,700	4,420
	May-94	NS	NS	NS	NS	NS
	Oct-94	NS	NS	NS	NS	NS
	May-95	NS	NS	NS	NS	NS
	Oct-95	NS	NS	NS	NS	NS
	May-96	NA	NA	NA	NA	NA
	Oct-96	NS	NS	NS	NS	NS
	Jun-97	NS	NS	NS	NS	NS
	Oct-97	NS	NS	NS	NS	NS
	May-98	NS	NS	NS	NS	NS
	Dec-98	NS	NS	NS	NS	NS
	Oct-99	NS	NS	NS	NS	NS
	Oct-00	NS	NS	NS	NS	NS

Table 3-1 Long-term Groundwater Sampling Results

MW-10 (On-Site)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		**10**	**10.0**	**750**	**620**	**750**
	Apr-89	3.3	< 0.5	< 0.5	< 1	< 0.5
	Aug-89	1.6	< 0.5	< 0.5	< 1	< 0.5
	Dec-89	2.8	< 0.5	< 0.5	< 1	< 0.5
	May-90	2	< 0.5	< 0.5	< 1	< 0.5
	Sep-90	1.4	< 0.5	< 0.5	< 1	< 0.5
	May-91	< 1	< 0.5	< 0.5	< 0.5	< 0.5
	Jun-91	NA	NA	NA	NA	NA
	Jan-92	< 5	< 5	< 5	< 5	< 5
	Jun-92	1.6	< 1	< 1	< 1	< 1
	Aug-92	< 1	< 1	< 1	< 1	< 1
	Dec-92	< 1	< 1	< 1	< 1	< 1
	Mar-93	< 1	< 1	< 1	< 1	< 1
	May-93	< 1	< 1	< 1	< 1	< 1
	Nov-93	< 1	< 1	< 1	< 1	< 1
	May-94	< 1	< 1	< 1	< 1	< 1
	Oct-94	< 1	< 1	< 1	< 1	< 1
	May-95	< 1	< 1	< 1	< 1	< 1
	Oct-95	< 1	< 1	< 1	< 1	< 1
	May-96	1	< 0.5	< 0.5	< 0.5	< 0.5
	Oct-96	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Jun-97	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Oct-97	0.5	< 0.5	< 0.5	< 0.5	< 0.5
	May-98	1	< 0.5	< 0.5	< 0.5	< 0.5
	Dec-98	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Oct-99	<0.5	<0.5	<0.5	<0.5	<0.5
	Oct-00	<0.5	<0.5	<0.5	<0.5	<0.5
	Dec-01	NA	<1.0	<1.0	< 2.0	<1.0
	Dec-02	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-03	ND	ND	ND	ND	ND
	Jan-05	<1.0	<1.0	<1.0	<1.0	<1.0
	Mar-06	<1.0	<1.0	<1.0	1.6 J	<1.0
	Nov-07	<1.0	<1.0	<1.0	< 2.0	<1.0
	Dec-08	<1.0	<1.0	<1.0	< 2.0	<1.0
	Dec-09	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-10	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-11	<1.0	<1.0	<1.0	<2.0	<1.0

Table 3-1 Long-term Groundwater Sampling Results

MW-18 (On-Site)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		**10**	**10.0**	**750**	**620**	**750**
	Mar-91	< 1	26	85	770	< 12
	Jun-91	< 1	< 25	78	930	< 25
	Jan-92	MSG	MSG	MSG	MSG	MSG
	Jun-92	< 1	313	200	1710	1
	Aug-92	< 1	527	258	2075	11
	Dec-92	< 25	294	224	1,460	< 25
	Mar-93	< 1	117	96	226	8
	May-93	< 1	73	31.2	259	< 1
	Nov-93	< 1	337	261	1,352	4.9
	May-94	< 1	51	7	99	10
	Oct-94	< 1	210	46	483	10.9
	May-95	< 1	128	10.4	274	< 1
	Oct-95	< 1	118	20	296	12.2
	May-96	< 0.5	48	3.4	150	0.5
	Oct-96	< 0.5	37	14	110	11
Duplicate	Oct-96	< 0.5	33	12	120	0.8
	Jun-97	< 0.5	130	15	200	<0.5
	Oct-97	< 0.5	55	19	150	0.5
	May-98	< 0.5	16	< 0.5	2.1	<0.5
	Dec-98	<2.5	44	21	<2.5	<2.5
	Oct-99	0.5	33	11	60	4
	Oct-00	0.9	9.5	<0.5	6.9	<0.5
	Dec-01	NA	4.2	<1.0	< 2.0	<1.0
	Dec-02	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-03	NA	1.4	<1.0	< 2.0	<1.0
	Jan-05	<1.0	<1.0	<1.0	5.7	<1.0
	Mar-06	<1.0	0.25 J	<1.0	0.34 J	<1.0
	Nov-07	<1.0	0.27 J	0.41 J	0.21 J	<1.0
	Dec-08	<1.0	0.24 J	1.0	0.66 J	<1.0
	Dec-09	<1.0	<1.0	0.40 J	< 2.0	<1.0
	Nov-10	<1.0	<1.0	0.40 J	< 2.0	<1.0
	Nov-11	<1.0	<1.0	<1.0	<2.0	<1.0

Table 3-1 Long-term Groundwater Sampling Results

MW-19 (On-Site)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		**10**	**10.0**	**750**	**620**	**750**
	Sep-90	45	< 0.5	1.1	1.9	< 0.5
	May-91	35	< 0.5	< 0.5	< 0.5	< 0.5
	Jun-91	44	< 0.5	5.9	< 0.5	< 0.5
	Jan-92	14	< 5	< 5	< 5	< 5
	Jun-92	11.4	< 1	< 1	< 1	< 1
	Dec-92	6.6	< 1	< 1	< 1	< 1
	Mar-93	2.4	< 1	< 1	< 1	< 1
	May-93	7.9	< 1	< 1	< 1	< 1
	Nov-93	6.6	< 1	< 1	< 1	< 1
	May-94	8	< 1	< 1	< 1	< 1
	Oct-94	7.9	< 1	< 1	< 1	< 1
	May-95	8.6	< 1	< 1	< 1	< 1
	Oct-95	8.8	< 1	< 1	< 1	< 1
	May-96	8.6	< 0.5	< 0.5	< 0.5	< 0.5
	Oct-96	4	< 0.5	< 0.5	< 0.5	< 0.5
	Jun-97	3	< 0.5	< 0.5	< 0.5	< 0.5
	Oct-97	2.2	< 0.5	< 0.5	< 0.5	< 0.5
	May-98	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Dec-98	<0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Oct-00	<0.5	<0.5	<0.5	<0.5	<0.5
	Dec-01	NA	<1.0	<1.0	< 2.0	<1.0
	Dec-02	< 1	<1.0	<1.0	< 2.0	<1.0
	Nov-03	NA	<1.0	<1.0	< 2.0	<1.0
	Jan-05	<1.0	<1.0	<1.0	<1.0	<1.0
	Mar-06	<1.0	<1.0	<1.0	1.4 J	<1.0
	Nov-07	<1.0	<1.0	<1.0	< 2.0	<1.0
	Dec-08	<1.0	<1.0	<1.0	< 2.0	<1.0
	Dec-09	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-10	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-11	<1.0	<1.0	<1.0	<2.0	<1.0

Table 3-1 Long-term Groundwater Sampling Results

MW-20 (On-Site)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		10	10.0	750	620	750
	Sep-90	< 1	< 0.5	< 0.5	< 1	< 0.5
	May-91	2	< 0.5	< 0.5	0.7	< 0.5
	Jun-91	NA	NA	NA	NA	NA
	Jan-92	< 5	< 5	< 5	< 5	< 5
	Jun-92	< 1	< 1	< 1	< 1	< 1
	Aug-92	< 1	< 1	< 1	< 1	< 1
	Dec-92	< 1	< 1	< 1	< 1	< 1
	Mar-93	2.1	< 1	< 1	< 1	< 1
	Oct-00	<0.5	<0.5	<0.5	<0.5	<0.5
	Dec-01	ND	ND	ND	ND	ND
	May-93	< 1	< 1	< 1	< 1	< 1
	Nov-93	< 1	< 1	< 1	< 1	< 1
	May-94	< 1	< 1	< 1	< 1	< 1
	Oct-94	< 1	< 1	< 1	< 1	< 1
	May-95	< 1	< 1	< 1	< 1	< 1
	Oct-95	< 1	< 1	< 1	< 1	< 1
	May-96	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Oct-96	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Jun-97	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Oct-97	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	May-98	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Dec-98	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Oct-99	<0.5	<0.5	<0.5	<0.5	<0.5
	Oct-00	<0.5	<0.5	<0.5	<0.5	<0.5
	Dec-01	NA	<1.0	<1.0	< 2.0	<1.0
	Dec-02	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-03	NA	<1.0	<1.0	< 2.0	<1.0
	Jan-05	<1.0	<1.0	<1.0	<1.0	<1.0
	Mar-06	<1.0	<1.0	<1.0	< 2.0	<1.0
Duplicate	Mar-06	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-07	0.21 J	<1.0	<1.0	< 2.0	<1.0
Duplicate	Nov-07	<1.0	<1.0	<1.0	< 2.0	<1.0
	Dec-08	<1.0	<1.0	<1.0	< 2.0	<1.0
Duplicate	Dec-08	<1.0	<1.0	<1.0	< 2.0	<1.0
	Dec-09	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-10	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-11	<1.0	<1.0	<1.0	<2.0	<1.0

Table 3-1 Long-term Groundwater Sampling Results

MW-21 (On-Site)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		**10**	**10.0**	**750**	**620**	**750**
	Sep-90	67	<0.5	1.1	5	1.5
	Mar-91	44	<0.5	<0.5	<0.5	<0.5
	Jun-91	40	<0.5	<0.5	<0.5	<0.5
	Jan-92	8.8	< 5	< 5	< 5	< 5
	Jun-92	21.9	< 1	< 1	< 1	< 1
	Aug-92	8.3	< 1	< 1	< 1	< 1
	Dec-92	1.7	< 1	< 1	< 1	< 1
	Mar-93	5.9	< 1	< 1	< 1	< 1
	May-93	14.8	< 1	< 1	< 1	< 1
	Nov-93	3.7	< 1	< 1	< 1	< 1
	May-94	8.3	< 1	< 1	< 1	< 1
	Oct-94	5.5	< 1	< 1	< 1	< 1
	May-95	<	< 1	< 1	< 1	< 1
Duplicate	May-95	5.4	< 1	< 1	< 1	< 1
	Oct-95	2.1	< 1	< 1	< 1	< 1
	May-96	1	<0.5	<0.5	<0.5	<0.5
	Oct-96	3.6	<0.5	<0.5	<0.5	<0.5
	Jun-97	<0.5	<0.5	<0.5	<0.5	<0.5
	Oct-97	<0.5	<0.5	<0.5	<0.5	<0.5
	May-98	<0.5	<0.5	<0.5	<0.5	<0.5
	Dec-98	NS	NS	NS	NS	NS
	Oct-99	<0.5	<0.5	<0.5	<0.5	<0.5
	Oct-00	<0.5	<0.5	<0.5	<0.5	<0.5
Duplicate	Oct-00	<0.5	<0.5	<0.5	<0.5	<0.5
	Dec-01	NA	<1.0	<1.0	< 2.0	<1.0
	Dec-02	< 1.0	< 1.0	< 1.0	< 2.0	< 1.0
	Nov-03	NA	<1.0	<1.0	< 2.0	<1.0
	Jan-05	<10.0	<10.0	<10.0	<10.0	<10.0
	Mar-06	< 1.0	< 1.0	< 1.0	< 2.0	< 1.0
	Nov-07	< 1.0	< 1.0	< 1.0	< 2.0	< 1.0
	Dec-08	< 1.0	< 1.0	< 1.0	< 2.0	< 1.0
	Dec-09	< 1.0	< 1.0	< 1.0	< 2.0	< 1.0
	Nov-10	< 1.0	< 1.0	< 1.0	< 2.0	< 1.0
	Nov-11	<1.0	<1.0	<1.0	<2.0	<1.0

Table 3-1 Long-term Groundwater Sampling Results

MW-9 (Off-Site)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		10	10.0	750	620	750
	Apr-89	4.5	< 0.5	< 0.5	< 1	< 0.5
	Aug-89	3.4	< 0.5	< 0.5	< 1	< 0.5
	Dec-89	2.6	< 0.5	< 0.5	< 1	< 0.5
	May-90	3.3	< 0.5	< 0.5	< 1	< 0.5
	Sep-90	2.1	< 0.5	< 0.5	< 1	< 0.5
	Mar-91	1.8	< 0.5	< 0.5	< 0.5	< 0.5
	Jun-91	NA	NA	NA	NA	NA
	Oct-92	< 5	< 5	< 5	< 5	< 5
	Jun-92	1.5	< 1	< 1	< 1	< 1
	Aug-92	< 1	< 1	< 1	< 1	< 1
	Dec-92	< 1	< 1	< 1	< 1	< 1
	Mar-93	1.5	< 1	< 1	< 1	< 1
	May-93	NA	NA	NA	NA	NA
	Nov-93	< 1	< 1	< 1	< 1	< 1
	May-94	NS	NS	NS	NS	NS
	Oct-94	1.2	< 1	< 1	< 1	< 1
	May-95	NS	NS	NS	NS	NS
	Oct-95	< 1	< 1	< 1	< 1	< 1
	May-96	NS	NS	NS	NS	NS
	Oct-96	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Jun-97	NS	NS	NS	NS	NS
	Oct-97	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	May-98	NS	NS	NS	NS	NS
	Dec-98	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Oct-99	NS	NS	NS	NS	NS
	Dec-01	NA	<1.0	<1.0	< 2.0	<1.0
	Dec-02	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-03	NA	<1.0	<1.0	< 2.0	<1.0
	Jan-05	<1.0	<1.0	<1.0	<1.0	<1.0
	Mar-06	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-07	0.17 J	<1.0	<1.0	< 2.0	<1.0
	Dec-08	<1.0	<1.0	<1.0	< 2.0	<1.0
	Dec-09	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-10	<1.0	<1.0	<1.0	< 2.0	<1.0
	Nov-11	<1.0	<1.0	<1.0	<2.0	<1.0

Table 3-1 Long-term Groundwater Sampling Results

MW-13 (Off-Site)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		10	10.0	750	620	750
	Apr-89	7.4	< 0.5	< 0.5	< 1	< 0.5
	Dec-89	< 1	< 0.5	< 0.5	< 1	< 0.5
	May-90	< 1	< 0.5	< 0.5	< 1	< 0.5
	Sep-90	< 1	< 0.5	< 0.5	< 1	1.5
	Mar-91	< 1	< 0.5	< 0.5	< 0.5	< 0.5
	Jun-91	NA	NA	NA	NA	NA
	Jan-92	NA	NA	NA	NA	NA
	Jun-92	<1	<1	<1	<1	<1
	Aug-92	<1	<1	<1	<1	<1
	Dec-92	NA	NA	NA	NA	NA
	Mar-93	<1	<1	<1	<1	<1
	May-93	NA	NA	NA	NA	NA
	Nov-93	<1	<1	<1	<1	<1
	May-94	NS	NS	NS	NS	NS
	Oct-94	<1	<1	<1	<1	<1
	May-95	NS	NS	NS	NS	NS
	Oct-95	<1	<1	<1	<1	<1
	May-96	NS	NS	NS	NS	NS
	Oct-96	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	Jun-97	NS	NS	NS	NS	NS
	Oct-97	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	May-98	NS	NS	NS	NS	NS
	Dec-99	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Destroyed	Oct-99	NS	NS	NS	NS	NS

Table 3-1 Long-term Groundwater Sampling Results

MW-14 (Off-Site)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		**10**	**10.0**	**750**	**620**	**750**
	Apr-89	< 1	< 0.5	< 0.5	3.2	1.1
	Aug-89	3.2	< 0.5	< 0.5	< 1	< 0.5
	Dec-89	3.4	< 0.5	< 0.5	< 1	< 0.5
	May-90	< 1	< 0.5	< 0.5	< 1	< 0.5
	Sep-90	2	< 0.5	< 0.5	<1	< 0.5
	Mar-91	<1	< 0.5	< 0.5	1.7	< 0.5
	Jun-91	NA	NA	NA	NA	NA
	Jan-92	< 5	< 5	< 5	< 5	< 5
	Jun-92	2.3	<1	<1	<1	<1
	Aug-92	<1	<1	<1	<1	<1
	Dec-92	<1	<1	<1	<1	<1
	Mar-93	<1	<1	<1	<1	<1
	Nov-93	1.2	<1	<1	<1	<1
	May-94	NS	NS	NS	NS	NS
	Oct-94	1.9	<1	<1	<1	<1
	May-95	NS	NS	NS	NS	NS
	Oct-95	<1	<1	<1	<1	<1
	May-96	NS	NS	NS	NS	NS
	Oct-96	0.7	<0.5	<0.5	<0.5	<0.5
	Jun-97	NS	NS	NS	NS	NS
	Oct-97	<0.5	<0.5	<0.5	<0.5	<0.5
	May-98	NS	NS	NS	NS	NS
	Dec-98	<0.5	<0.5	<0.5	<0.5	<0.5
	Oct-99	<0.5	<0.5	<0.5	<0.5	<0.5
	Oct-00	<0.5	<0.5	<0.5	<0.5	<0.5

Table 3-1 Long-term Groundwater Sampling Results

MW-15 (Off-Site)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		10	10.0	750	620	750
	May-90	< 1	< 0.5	< 0.5	< 1	< 0.5
	Aug-89	< 1	< 0.5	< 0.5	< 1	< 0.5
	Dec-89	< 1	< 0.5	< 0.5	< 1	< 0.5
	Sep-90	< 1	< 0.5	< 0.5	<1	< 0.5
	Mar-91	< 1	< 0.5	< 0.5	< 0.5	< 0.5
	Jun-91	NA	NA	NA	NA	NA
	Jan-92	< 5	< 5	< 5	< 5	< 5
	Jun-92	< 1	< 1	< 1	< 1	< 1
	Aug-92	< 1	< 1	< 1	< 1	< 1
	Dec-92	NA	NA	NA	NA	NA
	Mar-93	< 1	< 1	< 1	< 1	< 1
	May-93	NA	NA	NA	NA	NA
	Nov-93	< 1	< 1	< 1	< 1	< 1
	May-94	NS	NS	NS	NS	NS
	Oct-94	< 1	< 1	< 1	< 1	< 1
	May-95	NS	NS	NS	NS	NS
	Oct-95	< 1	< 1	< 1	< 1	< 1
	May-96	NS	NS	NS	NS	NS
	Aug-89	< 1	< 0.5	< 0.5	< 1	< 0.5
	Dec-89	< 1	< 0.5	< 0.5	< 1	< 0.5
	Oct-96	<0.5	<0.5	<0.5	<0.5	<0.5
	Jun-97	NS	NS	NS	NS	NS
	Oct-97	<0.5	<0.5	<0.5	<0.5	<0.5
	May-98	NS	NS	NS	NS	NS
	Dec-99	<0.5	<0.5	<0.5	<0.5	<0.5
	Oct-99	NS	NS	NS	NS	NS

Table 3-1 Long-term Groundwater Sampling Results

MW-16 (Off-Site)						
	Date	1,2-DCA	Benzene	Ethylbenzene	Total Xylenes	Toluene
		ug/L	ug/L	ug/L	ug/L	ug/L
Protection Standard[1]		10	10.0	750	620	750
	Sep-90	< 1	< 0.5	< 0.5	<1	< 0.5
	May-91	< 1	< 0.5	< 0.5	< 0.5	< 0.5
	Jun-91	NA	NA	NA	NA	NA
	Jan-92	< 5	< 5	< 5	< 5	< 5
	Jun-92	< 1	< 1	< 1	< 1	< 1
	Aug-92	< 1	< 1	< 1	< 1	< 1
	Dec-92	< 1	< 1	< 1	< 1	< 1
	Mar-93	< 1	< 1	< 1	< 1	< 1
	May-93	NA	NA	NA	NA	NA
	Nov-93	< 1	< 1	< 1	< 1	< 1
	May-94	NS	NS	NS	NS	NS
	Oct-94	< 1	< 1	< 1	< 1	< 1
	May-95	NS	NS	NS	NS	NS
	Oct-95	< 1	< 1	< 1	< 1	< 1
	May-96	NS	NS	NS	NS	NS
	Oct-96	<0.5	<0.5	<0.5	<0.5	<0.5
	Jun-97	NS	NS	NS	NS	NS
	Oct-97	<0.5	<0.5	<0.5	<0.5	<0.5
	May-98	NS	NS	NS	NS	NS
	Dec-98	<0.5	0.5	<0.5	<0.5	<0.5
	Oct-99	<0.5	<0.5	<0.5	<0.5	<0.5
	Oct-00	<0.5	<0.5	<0.5	<0.5	<0.5
	Dec-01	NA	< 1.0	< 1.0	< 2.0	< 1.0
	Dec-02	< 1.0	< 1.0	< 1.0	< 2.0	< 1.0
	Nov-03	NA	< 1.0	< 1.0	< 2.0	< 1.0
	Jan-05	<1.0	<1.0	<1.0	<1.0	<1.0
	Mar-06	< 1.0	< 1.0	< 1.0	< 2.0	< 1.0
	Nov-07	< 1.0	< 1.0	< 1.0	< 2.0	< 1.0
	Dec-08	< 1.0	< 1.0	< 1.0	< 2.0	< 1.0
	Dec-09	< 1.0	< 1.0	< 1.0	< 2.0	< 1.0
	Nov-10	< 1.0	< 1.0	< 1.0	< 2.0	< 1.0
	Nov-11	<1.0	<1.0	<1.0	<2.0	<1.0

Notes:

1. Protection Standard based on the New Mexican Water Quality Control Commission Groundwater Protection Standards.

1,2-DCA = 1,2-dichloroethane

ug/L = micrograms per liter

J = estimated result. Result is less than reporting limit.

NA = not analyzed

NS = not sampled

MSG = well missing

Table 5-1 Stage II Abatement Plan Alternatives, Ranking Against Evaluation Criteria
Maverik, Kirtland, New Mexico

Ranking: Each alternative is assigned a score of 1 to 3, with 3 being the highest (best fit of evaluation criteria) and 1 the lowest (poorest fit of evaluation criteria).

Corrective Measures Alternatives Evaluation Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	MNA and Confirmation Sampling	**MNA, ORC Injections, and Confirmation Sampling**	**MNA, ISCO, and Confirmation Sampling**	**MNA, Air Sparge, and Confirmation Sampling**
General Standards for Remedies				
Be Protective of Human Health and the Environment	Acceptable	Acceptable	Acceptable	Acceptable
Attain Media Cleanup Objectives	Acceptable	Acceptable	Acceptable	Acceptable
Comply with Any Applicable Standards for Management of Wastes	Acceptable	Acceptable	Acceptable	Acceptable
Remedy Selection Decision Factors				
Reliability and Effectiveness	3	3	3	3
Reduction in toxicity or volume	2	3	3	3
Treatment Time Frame	1	2	3	2
Implementability	3	2	2	1
Cost	3	1	2	2
Total Score	**12**	**11**	**13**	**11**
Overall Rank	**2**	**3**	**1**	**3**

Notes:

MNA - Monitored Natural Attenuation
ORC - Oxygen Releasing Compounds
ISCO - In-Situ Chemical Oxidation

Table 5-2 Alternative Cost Estimate Summary

Abatement Alternatives		Number of Years	Capital
1	MNA	7	$134,500
	Quarterly Confirmation Sampling	2	$123,200
			$257,700
2	Performance Sampling	4	$79,000
	ORC Injections		$122,300
	Quarterly Confirmation Sampling	2	$123,200
			$324,500
3	Performance Sampling	3	$60,500
	Chemical Oxidation		$115,000
	Quarterly Confirmation Sampling	2	$123,200
			$298,700
4	Performance Sampling	4	$79,000
	Air Sparge		$99,856
	Quarterly Confirmation Sampling	2	$123,200
			$302,056

Notes:

MNA - Monitored Natural Attenuation

ORC - Oxygen Releasing Compounds

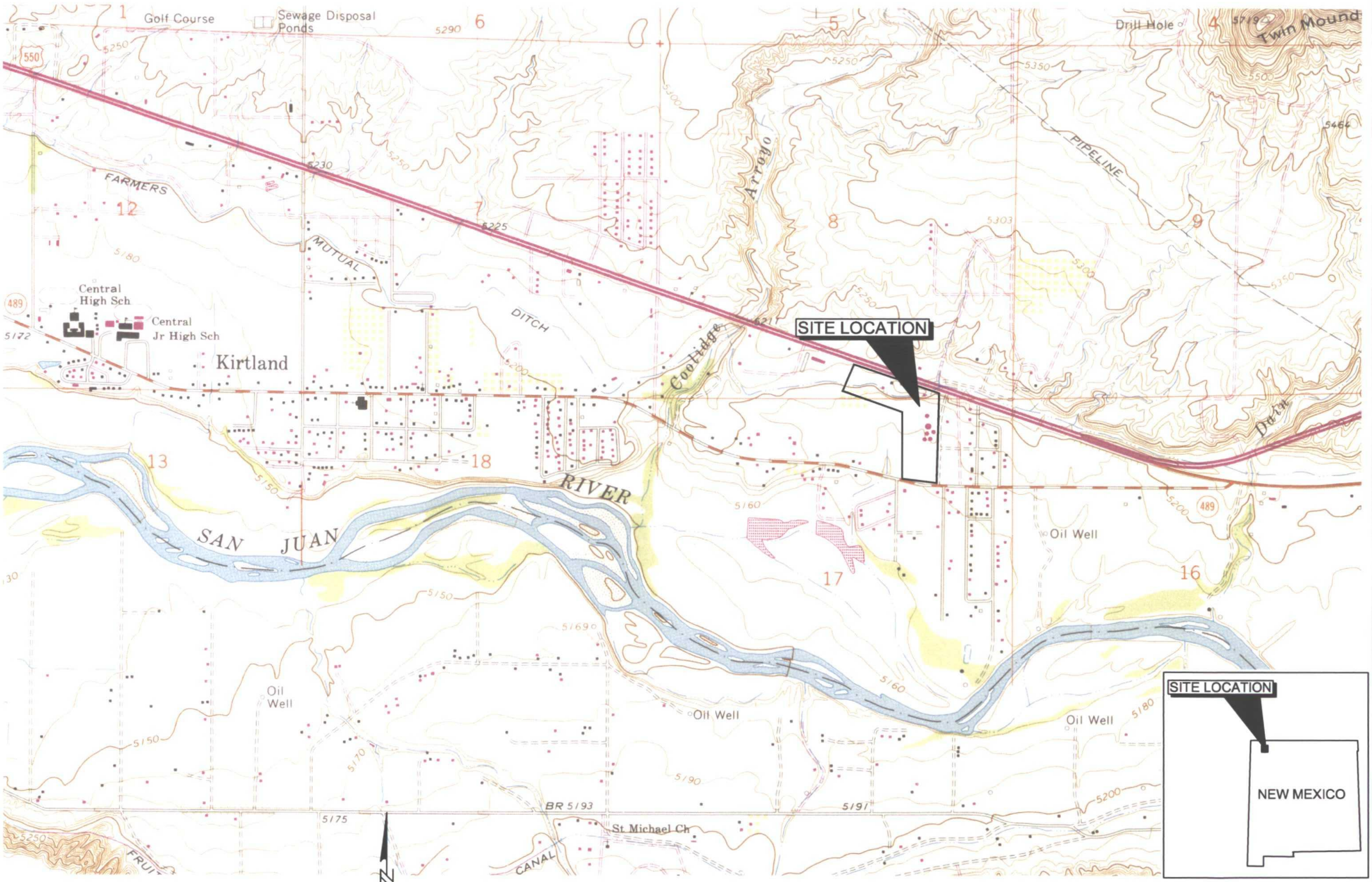
This cost summary includes contractor installation and operation as well as engineering design and oversight

Number of years for MNA for Alternative 1 was calculated based on historical data

Number of years for Performance Sampling for Alternatives 2-4 is estimated

Figures

File: Z:\Maverik\2012\Stage II Abatement\AGWR10_Figure 1 Site Location Map.dwg Layout: FIGURE 1 User: oakleafc Plotted: Feb 13, 2012 – 10:25am Xref's:



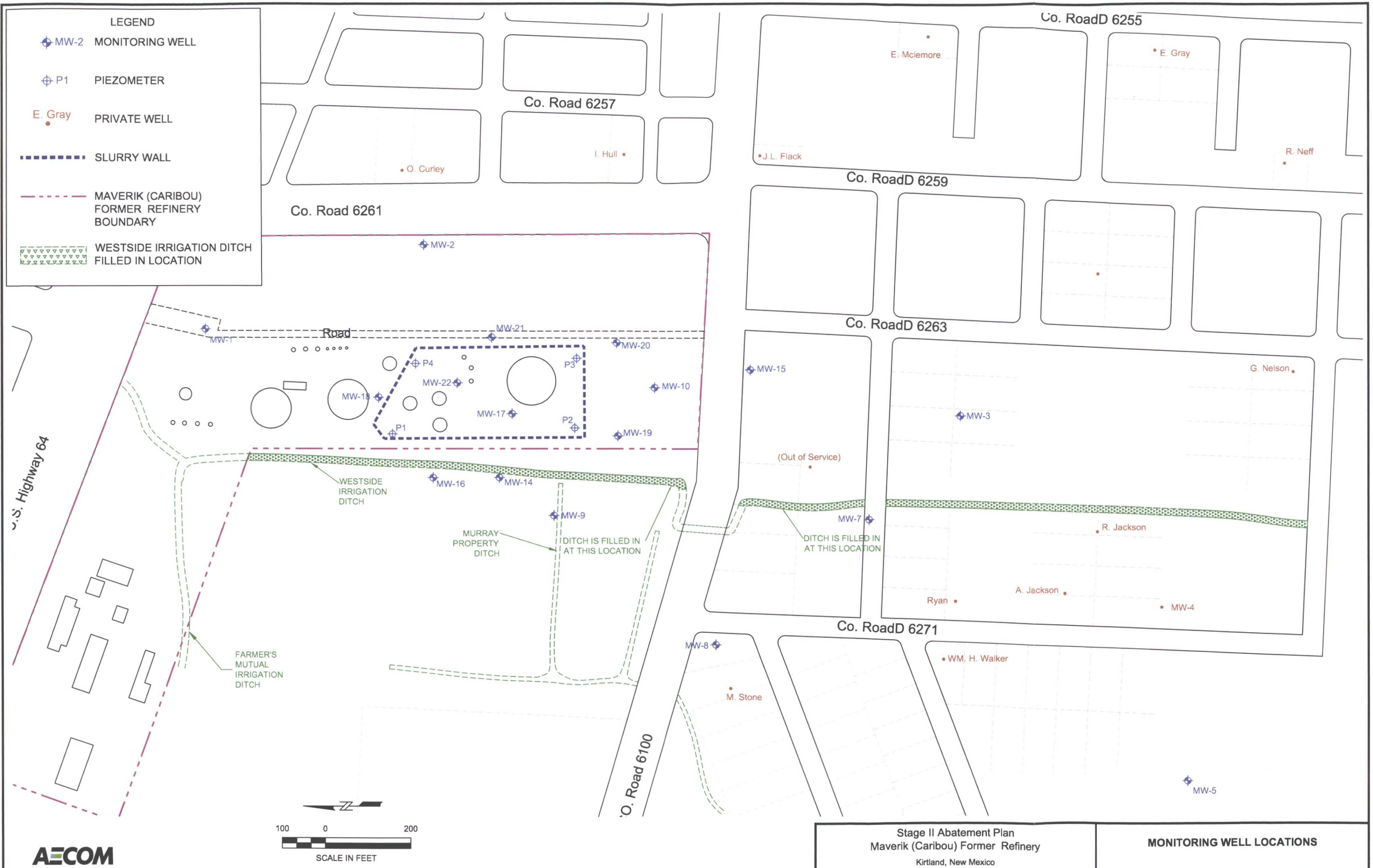
AECOM

Stage II Abatement Plan
Maverik (Caribou) Former Refinery
Kirtland, New Mexico

DATE: 1/13/12
DRWN: EM/FTC

SITE LOCATION MAP

FIGURE 1-1



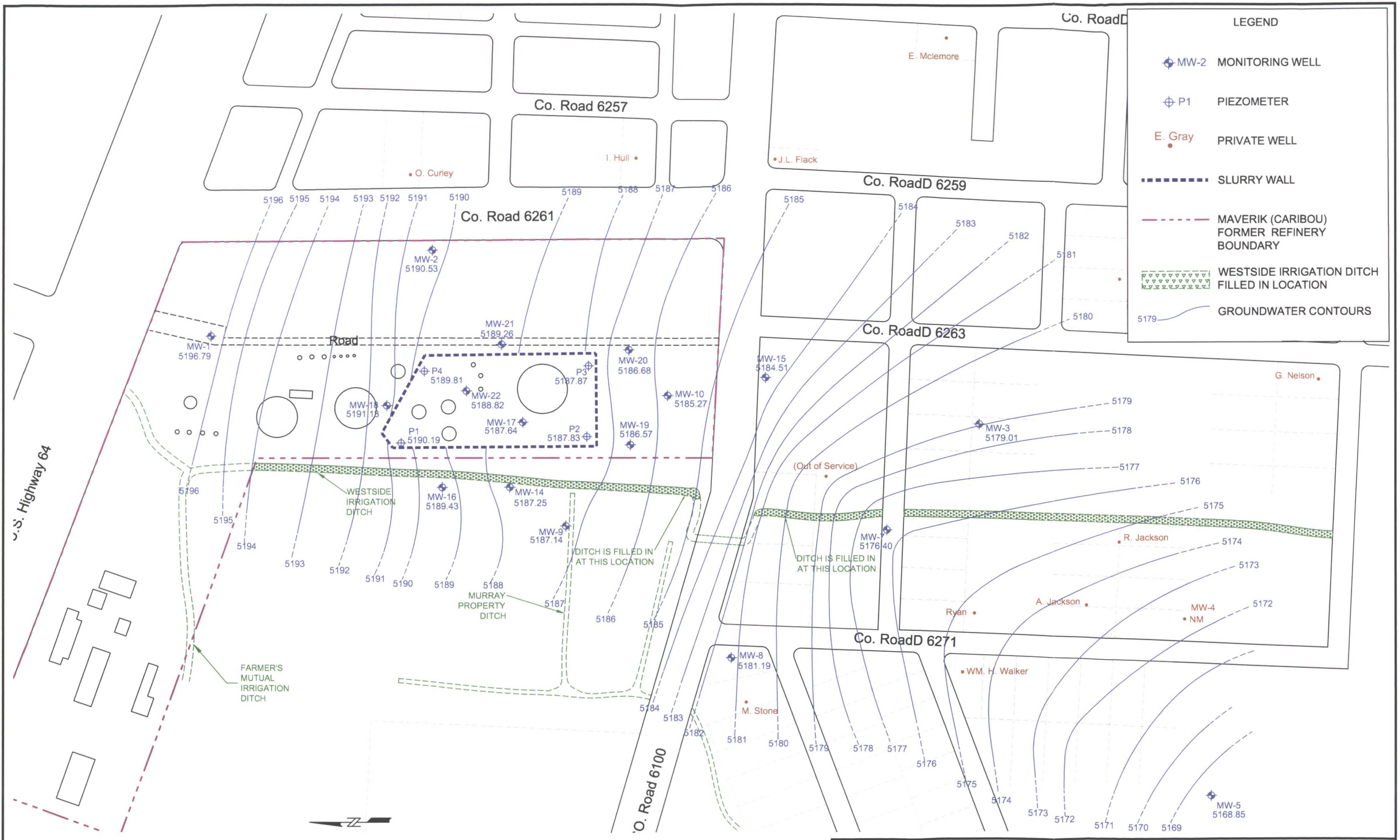
Stage II Abatement Plan
Maverik (Caribou) Former Refinery
Kirtland, New Mexico

DATE: 1/13/12 DRWN: CO/FTC

MONITORING WELL LOCATIONS

FIGURE 3-1

File: Z:\Maverik\2012\Stage II Abatement\Figure 3-1 Monitoring Well Locations.dwg Layout: FIGURE 3-1 User: oakleafc Plotted: Feb 27, 2012 - 8:39am Xref's:



AECOM

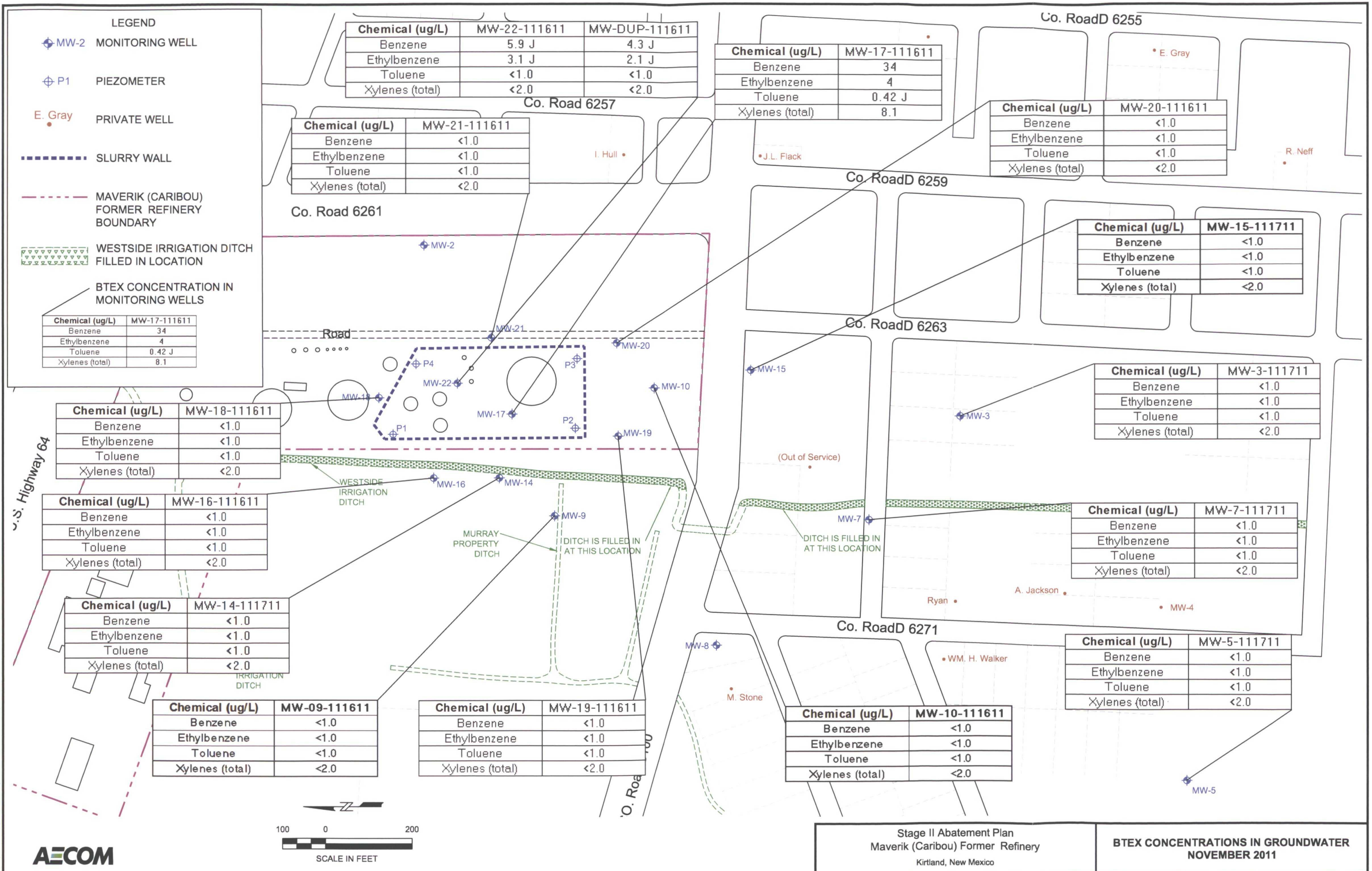
Stage II Abatement Plan
Maverik (Caribou) Former Refinery
Kirtland, New Mexico

DATE: 1/11/12
DRWN: CO/FTC

POTENTIOMETRIC SURFACE MAP
NOVEMBER 2011

FIGURE 3-2

File: Z:\Maverik\2012\Stage II Abatement\Figure 3-2 GW Potentiometric Map.dwg Layout: FIGURE 3-2 User: oakleafc Plotted: Feb 27, 2012 – 8:45am Xref's:



Chemical (ug/L)	MW-17-111611
Benzene	34
Ethylbenzene	4
Toluene	0.42 J
Xylenes (total)	8.1

Chemical (ug/L)	MW-22-111611	MW-DUP-111611
Benzene	5.9 J	4.3 J
Ethylbenzene	3.1 J	2.1 J
Toluene	<1.0	<1.0
Xylenes (total)	<2.0	<2.0

Chemical (ug/L)	MW-17-111611
Benzene	34
Ethylbenzene	4
Toluene	0.42 J
Xylenes (total)	8.1

Chemical (ug/L)	MW-20-111611
Benzene	<1.0
Ethylbenzene	<1.0
Toluene	<1.0
Xylenes (total)	<2.0

Chemical (ug/L)	MW-21-111611
Benzene	<1.0
Ethylbenzene	<1.0
Toluene	<1.0
Xylenes (total)	<2.0

Chemical (ug/L)	MW-15-111711
Benzene	<1.0
Ethylbenzene	<1.0
Toluene	<1.0
Xylenes (total)	<2.0

Chemical (ug/L)	MW-3-111711
Benzene	<1.0
Ethylbenzene	<1.0
Toluene	<1.0
Xylenes (total)	<2.0

Chemical (ug/L)	MW-18-111611
Benzene	<1.0
Ethylbenzene	<1.0
Toluene	<1.0
Xylenes (total)	<2.0

Chemical (ug/L)	MW-16-111611
Benzene	<1.0
Ethylbenzene	<1.0
Toluene	<1.0
Xylenes (total)	<2.0

Chemical (ug/L)	MW-7-111711
Benzene	<1.0
Ethylbenzene	<1.0
Toluene	<1.0
Xylenes (total)	<2.0

Chemical (ug/L)	MW-14-111711
Benzene	<1.0
Ethylbenzene	<1.0
Toluene	<1.0
Xylenes (total)	<2.0

Chemical (ug/L)	MW-5-111711
Benzene	<1.0
Ethylbenzene	<1.0
Toluene	<1.0
Xylenes (total)	<2.0

Chemical (ug/L)	MW-09-111611
Benzene	<1.0
Ethylbenzene	<1.0
Toluene	<1.0
Xylenes (total)	<2.0

Chemical (ug/L)	MW-19-111611
Benzene	<1.0
Ethylbenzene	<1.0
Toluene	<1.0
Xylenes (total)	<2.0

Chemical (ug/L)	MW-10-111611
Benzene	<1.0
Ethylbenzene	<1.0
Toluene	<1.0
Xylenes (total)	<2.0

AECOM

Stage II Abatement Plan
Maverik (Caribou) Former Refinery
Kirtland, New Mexico

DATE: 1/13/12
DRWN: CO/FTC

BTEX CONCENTRATIONS IN GROUNDWATER
NOVEMBER 2011

FIGURE 3-3

File: Z:\Maverik\2012\Stage II Abatement\Figure 3-3 2011 BTEX Concentrations in Groundwater.dwg Layout: FIGURE 3-3 User: oakleafc Plotted: Feb 27, 2012 - 8:42am Xref's:

Figure 4-1 Concentrations of 1,2-DCA and BTEX in Well MW-17

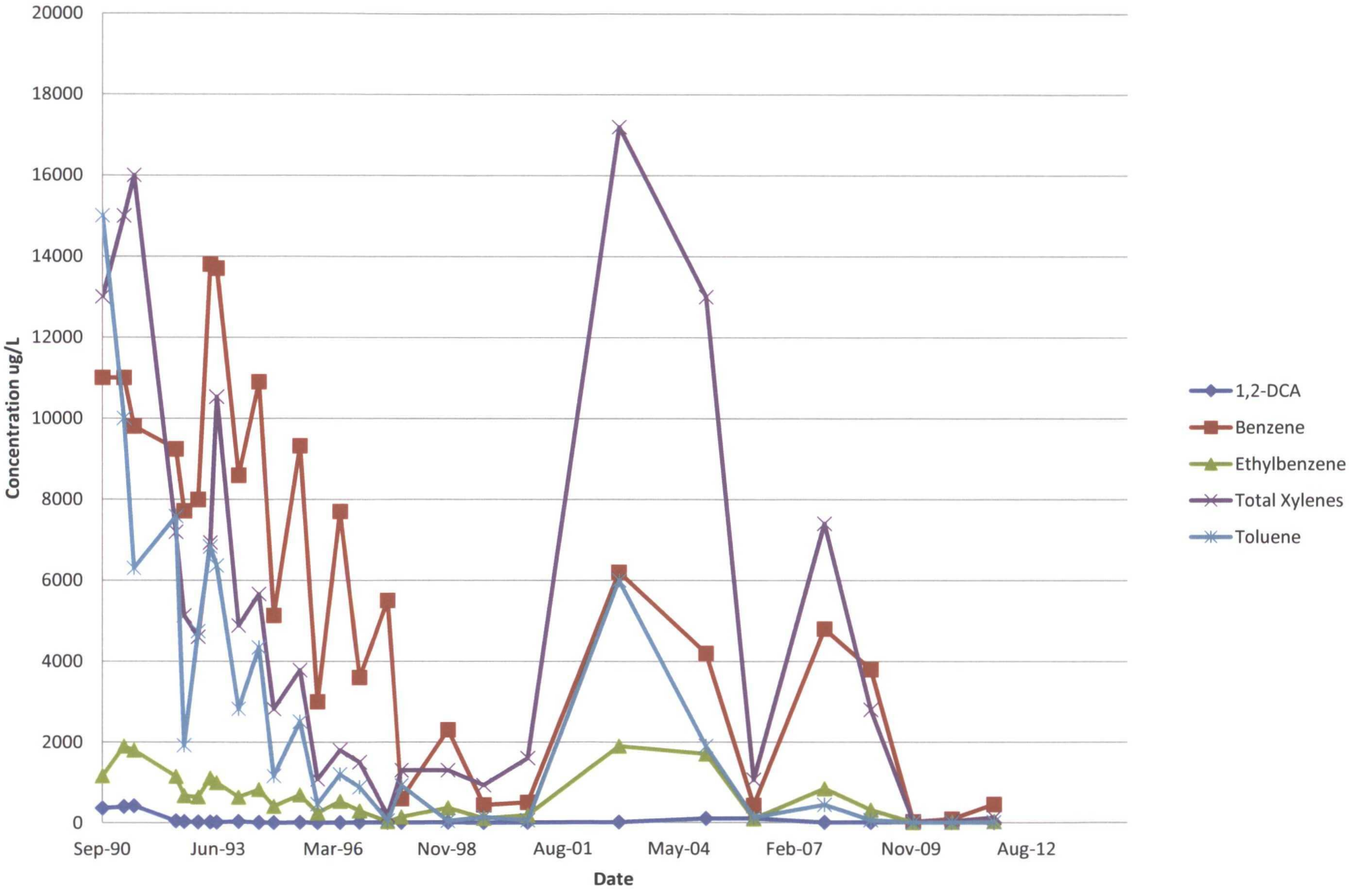
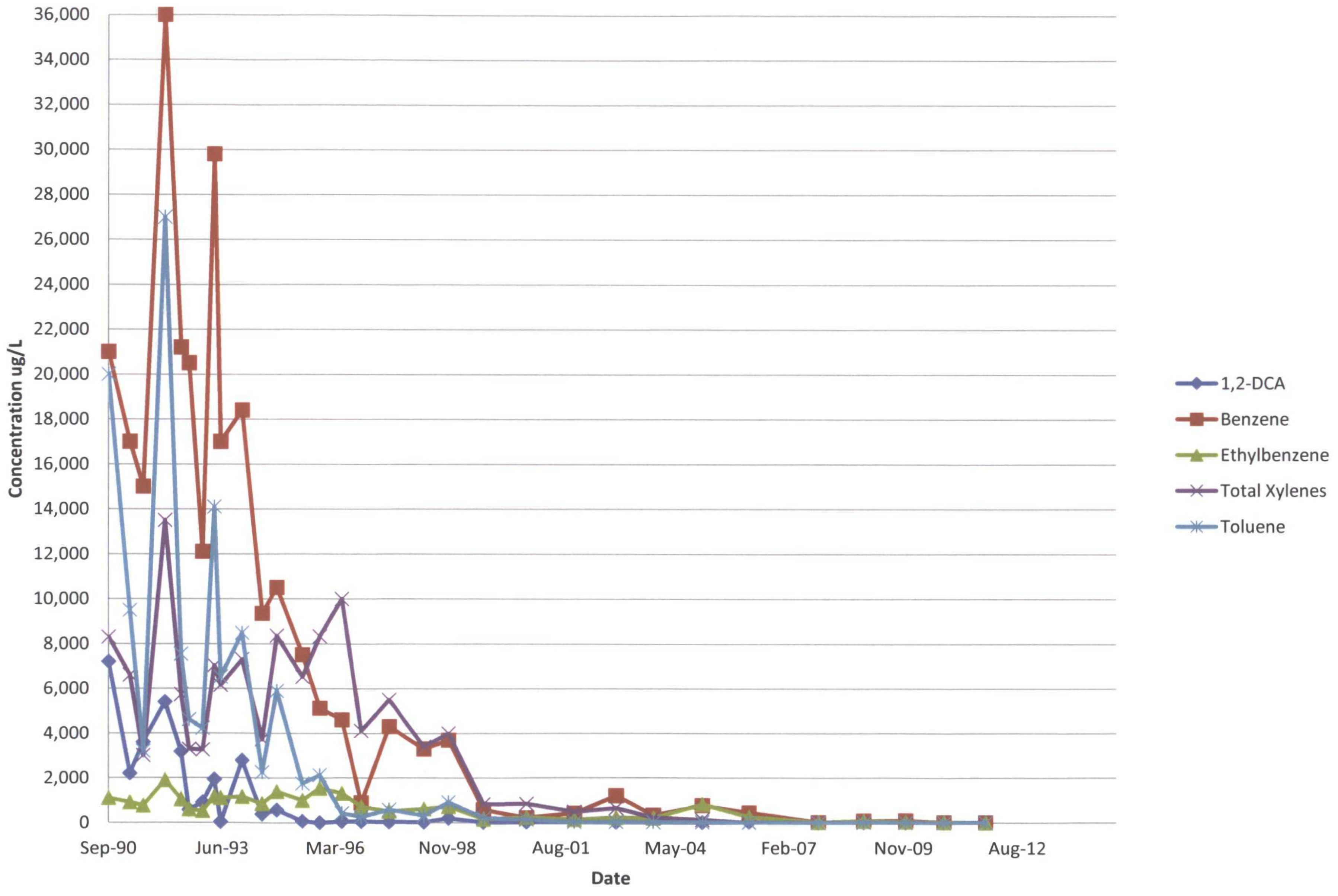


Figure 4-2 Concentrations of 1,2-DCA and BTEX in Well MW-22



Appendix A

Klozur® Safety Information

MATERIAL SAFETY DATA SHEET

Klozur® CR

MSDS Ref. No.: F18-44-9
Date Approved: 01/03/2008
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This document has been prepared to meet the requirements of the U.S. OSHA Hazard Communication Standard, 29 CFR 1910.1200 and Canada's Workplace Hazardous Materials Information System (WHMIS) requirements.

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1. PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME:	Klozur® CR
GENERAL USE:	For chemical oxidation and aerobic bioremediation, petroleum hydrocarbon remediation, creosote remediation and partially halogenated hydrocarbon remediation.

MANUFACTURER

FMC CORPORATION
FMC Peroxygens
1735 Market Street
Philadelphia, PA 19103
(215) 299-6000 (General Information)
msdsinfo@fmc.com (Email - General Information)

EMERGENCY TELEPHONE NUMBERS

(303) 595-9048 (Medical - U.S. - Call Collect)

For leak, fire, spill, or accident emergencies, call:
(800) 424-9300 (CHEMTREC - U.S.A. & Canada)

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2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW:

- Odorless, off-white fine granular solid (may have separation or noticeable two-tone appearance).
- Oxidizer.
- Contact with combustibles may cause fire.
- Under fire conditions product may decompose releasing oxygen that intensifies fire.
- Decomposes in storage under conditions of moisture (water/water vapor) and/or excessive heat causing release of oxides of sulfur and oxygen that supports combustion. Decomposition could form a high temperature melt. See Section 10 ("Stability and Reactivity").
- Deluge container with water at safe distance or in protected area.
- May be severely irritating to the eyes.
- May be harmful if swallowed.

POTENTIAL HEALTH EFFECTS: Airborne dust may be irritating to eyes, nose, lungs, throat and skin upon contact. Exposure to high levels of dust may cause difficulty in breathing in sensitive persons.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Name	CAS#	Wt.%	EC No.	EC Class
Proprietary Mixture			None	Not classified

COMMENTS: FMC is withholding the specific chemical identity under provision of the OSHA Hazard Communication Rule Trade Secrets (1910.1200(i)(1)). The specific chemical identity will be made available to health professionals in accordance with 29 CFR 1910.1200(i) (1) (2) (3) (4). This Material Safety Data Sheet provides information for employee training and hazard identification.

4. FIRST AID MEASURES

EYES: Immediately flush with water for at least 15 minutes, lifting the upper and lower eyelids intermittently. See a medical doctor or ophthalmologist immediately.

SKIN: Wash with plenty of soap and water. Get medical attention if irritation occurs and persists.

INGESTION: Rinse mouth with water. Dilute by giving 1 or 2 glasses of water. Do not induce vomiting. Never give anything by mouth to an unconscious person. See a medical doctor immediately.

INHALATION: Remove to fresh air. If breathing difficulty or discomfort occurs and persists, obtain medical attention.

NOTES TO MEDICAL DOCTOR: Direct contact with the eyes may have serious consequences; therefore, direct contact with eyes should be avoided. Contaminated external surfaces should be flooded with water, and direct eye contact deserves ophthalmologic evaluation. If ingested, gastrointestinal irritation but not caustic burns are to be expected; dilution with water indicated as may be gastric evacuation via emesis or lavage if large doses or severe irritation is evident.

5. FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA: Deluge with plenty of water.

FIRE / EXPLOSION HAZARDS: Product is non-combustible. Under fire conditions, may decompose and release oxygen gas, which may intensify fire. Presence of water accelerates decomposition. Mixtures with polysulfide polymers may ignite.

FIRE FIGHTING PROCEDURES: Use flooding quantities of water. Use water spray to keep fire exposed containers cool. Do not use carbon dioxide or other gas filled fire extinguishers; they will have no effect on decomposition. Wear full protective clothing and self-contained breathing apparatus.

FLAMMABLE LIMITS: Non-combustible

SENSITIVITY TO IMPACT: Oxidizable materials can be ignited by grinding and may become explosive.

SENSITIVITY TO STATIC DISCHARGE: Not available

6. ACCIDENTAL RELEASE MEASURES

RELEASE NOTES: Confine and collect spill, put into an approved DOT container (do not return to original container) and isolate for disposal. Isolated material should be monitored for signs of decomposition (fuming / smoking). If spilled material is wet, dissolve with large quantities of water and dispose as a hazardous waste. Runoff to sewer may create fire or explosion hazard (do not flush powdered material into sewer). Dispose of wastes according to the method outlined in Section 13, "Disposal Considerations".

7. HANDLING AND STORAGE

HANDLING: Avoid contact by using personal protective equipment. Use respiratory protective equipment when release of airborne dust is expected. If compounded with organics or combustible materials be sure to exclude moisture. Use clean plastic or stainless steel scoops only.

STORAGE: Keep dry (reacts with moisture). Use first in, first out storage system. Store unopened in a cool, clean, dry place away from point sources of heat (e.g. steam pipes, radiant heaters, hot air vents or welding sparks). Keep container tightly closed when not in use. Avoid contamination of opened product. Avoid contact with reducing agents. In case of fire or decomposition (fuming / smoking) deluge with plenty of water to control decomposition. Fore storage, refer to NFPA Bulletin 430 on storage of liquid and solid oxidizing materials.

COMMENTS: VENTILATION: Provide mechanical general and/or local exhaust ventilation to prevent release of dust into work environment. Spills should be collected into suitable containers to prevent dispersion into the air. If ventilation is inadequate or not available, use dust respirator and eye protection.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

EXPOSURE LIMITS

Chemical Name	ACGIH	OSHA	Supplier
Proprietary Ingredient	5 mg/m^3 (TWA)	5 mg/m^3 (TWA)	5 mg/m^3 (TWA)
Proprietary Ingredient	0.1 mg/m^3 (TWA)		

ENGINEERING CONTROLS: Provide mechanical local exhaust ventilation to prevent release of dust into the work area. If release is expected use respiratory protection. Remove contaminated clothing immediately and wash before reuse.

PERSONAL PROTECTIVE EQUIPMENT

EYES AND FACE: Use cup type chemical goggles. Full face shield may be used.

RESPIRATORY: Use approved dust respirator with full face piece.

PROTECTIVE CLOTHING: Long sleeve shirt, impervious apron or clothing. Rubber or neoprene footwear.

GLOVES: Rubber or neoprene gloves. Thoroughly wash the outside of gloves with soap and water prior to removal. Inspect regularly for leaks.

9. PHYSICAL AND CHEMICAL PROPERTIES

ODOR:	Odorless
APPEARANCE:	Off-white fine granular solid
AUTOIGNITION TEMPERATURE:	Non-combustible
BOILING POINT:	No data available
COEFFICIENT OF OIL / WATER:	Not available
DENSITY / WEIGHT PER VOLUME:	(Bulk) 51.8 lbs/ft^3 (loose)
EVAPORATION RATE:	Not applicable (Butyl Acetate = 1)
FLASH POINT:	Not applicable
MELTING POINT:	Decomposes on heating (About 275°C)
OXIDIZING PROPERTIES:	Oxidizer
PERCENT VOLATILE:	Not applicable

pH:	11.2 slurry (1% solution)
SOLUBILITY IN WATER:	Sparingly soluble
SPECIFIC GRAVITY:	1 - 1.19 (5% to 30% slurries)
VAPOR DENSITY:	Not applicable (Air = 1)
VAPOR PRESSURE:	Not applicable

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10. STABILITY AND REACTIVITY

CONDITIONS TO AVOID:	Heat (decomposes at 275°C), moisture, reducing agents. Grinding with organics.
STABILITY:	Stable (decomposition could occur when exposed to heat or moisture)
POLYMERIZATION:	Will not occur
INCOMPATIBLE MATERIALS:	Grinding mixtures with organics (oxidizable materials can be ignited by grinding and may become explosive); heavy metals. Grinding mixtures with organics (oxidizable materials can be ignited by grinding and may become explosive); heavy metals. Acids, alkalis, halides (fluorides, chlorides, bromides and iodides), combustible materials, most metals and heavy metals, oxidizable materials, other oxidizers, reducing agents, cleaners, and organic or carbon containing compounds. Contact with incompatible materials can result in a material decomposition or other uncontrolled reactions.
HAZARDOUS DECOMPOSITION PRODUCTS:	Oxygen that supports combustion and oxides of sulfur, nitrogen, and calcium hydroxide.

COMMENTS: PRECAUTIONARY STATEMENT: Use of persulfates in chemical reactions requires appropriate precautions and design considerations for pressure and thermal relief. Decomposing persulfates will evolve large volumes of gas and/or vapor, can accelerate exponentially with heat generation, and create significant and hazardous pressures if contained and not properly controlled or mitigated. Use with alcohols in the presence of water has been demonstrated to generate conditions that require rigorous adherence to process safety methods and standards to prevent escalation to an uncontrolled reaction.

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11. TOXICOLOGICAL INFORMATION

EYE EFFECTS: No data available for the formulation.
Proprietary Component: Severely irritating to unwashed eyes; minimally irritating to washed eyes (rabbit) [FMC Ref. I88-1053]
Proprietary Component: Non-irritating (rabbit) [FMC Ref. ICG/T-79.029]

SKIN EFFECTS: No data available for the formulation.
Proprietary Component: Non-irritating (rabbit) [FMC Ref. I88-1054]
Proprietary Component: Non-irritating (rabbit) [FMC Ref. ICG/T-79.029]

DERMAL LD_{50}: No data available for the formulation.
Proprietary Component: > 10 g/kg (rat) [FMC Ref. ICG/T-79.026 and 79.029]

ORAL LD_{50}: No data available for the formulation.
Proprietary Component: > 5 g/kg (rat) [FMC Ref. I88-1052]
Proprietary Component: 895 mg/kg (rat) [FMC Ref. ICG/T-79.029]

INHALATION LC_{50}: No data available for the formulation.
Proprietary Component: > 17 mg/l (1 h) (rat) [FMC Ref. ICG/T-79.026]
Proprietary Component: 5.1 mg/l (rat) [FMC Ref. I95-2017]

SENSITIZATION: No data available for the formulation.
Proprietary Component: (Skin) May be sensitizing to allergic persons. [FMC Ref. ICG/T-79.029]

TARGET ORGANS: Eyes, skin, respiratory passages

ACUTE EFFECTS FROM OVEREXPOSURE: May be harmful if swallowed. Direct contact with the eyes may have serious consequences; therefore, direct contact with eyes should be avoided. Airborne dusts may be irritating to the nose, throat and lungs, causing wheezing and/or shortness of breath. Dusts may also be irritating to eyes and skin upon contact; therefore, flooding of exposed areas with water is suggested.

CHRONIC EFFECTS FROM OVEREXPOSURE: No data available for the product. Sensitive persons may develop dermatitis and asthma. One of the proprietary components was fed to groups of male and female rats at 0, 300 and 3,000 ppm in the diet for 13 weeks, followed by 5,000 ppm for 5 weeks. Microscopic examination of tissues revealed some injury to the gastrointestinal tract at the highest dose (3,000 ppm) only. This effect is not unexpected for an oxidizer at high concentrations.

CARCINOGENICITY:

NTP:	Not listed
IARC:	Not listed
OSHA:	Not listed
OTHER:	Not Listed (ACGIH)

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12. ECOLOGICAL INFORMATION

ENVIRONMENTAL DATA: Biodegradability does not apply to inorganic substances. As indicated by chemical properties oxygen is released into the environment.

ECOTOXICOLOGICAL INFORMATION: No data available for the formulation.

Proprietary Component

Bluegill sunfish, 96-hour LC_{50} = 771 mg/L [FMC Study I92-1250]
Rainbow trout, 96-hour LC_{50} = 163 mg/L [FMC Study I92-1251]
Daphnia, 48-hour LC_{50} = 133 mg/L [FMC Study I92-1252]
Grass shrimp, 96-hour LC_{50} = 519 mg/L [FMC Study I92-1253]

13. DISPOSAL CONSIDERATIONS

DISPOSAL METHOD: Dissolve in water to allow the release of oxygen and dispose via a treatment system in accordance with governmental agencies regulations. Contact appropriate regulatory agency prior to disposal.

14. TRANSPORT INFORMATION

U.S. DEPARTMENT OF TRANSPORTATION (DOT)

PROPER SHIPPING NAME:	Oxidizing solid, n.o.s. (sodium persulfate, calcium peroxide)
PRIMARY HAZARD CLASS / DIVISION:	5.1 (Oxidizer)
UN/NA NUMBER:	UN 1479
PACKING GROUP:	II
LABEL(S):	5.1 (Oxidizer)
PLACARD(S):	5.1 (Oxidizer)
MARKING(S):	Oxidizing solid, n.o.s. (sodium persulfate, calcium peroxide), UN1479
ADDITIONAL INFORMATION:	Hazardous Substance/RQ: Not applicable 49 STCC Number: 4918733 This material is shipped in 45 lb. polyethylene pail with vented screw-on lid (approx 5.5 gallon)

INTERNATIONAL MARITIME DANGEROUS GOODS (IMDG)

PROPER SHIPPING NAME:	Oxidizing solid, n.o.s. (sodium persulfate, calcium peroxide)

INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO) / INTERNATIONAL AIR TRANSPORT ASSOCIATION (IATA)

PROPER SHIPPING NAME:	Oxidizing solid, n.o.s. (sodium persulfate,

calcium peroxide)

ADDITIONAL INFORMATION:	Combination packaging is recommended for air transport.

OTHER INFORMATION:

Place spilled product in suitable container and wash residue with plenty of water.
See Section 6 (Accidental Release Measures) above for additional instructions.

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15. REGULATORY INFORMATION

UNITED STATES

SARA TITLE III (SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT)

SECTION 311 HAZARD CATEGORIES (40 CFR 370):
Fire Hazard, Immediate (Acute) Health Hazard

SECTION 312 THRESHOLD PLANNING QUANTITY (40 CFR 370):
The Threshold Planning Quantity (TPQ) for this product, if treated as a mixture, is 10,000 lbs; however, this product contains the following ingredients with a TPQ of less than 10,000 lbs.: None

SECTION 313 REPORTABLE INGREDIENTS (40 CFR 372):
Not listed

CERCLA (COMPREHENSIVE ENVIRONMENTAL RESPONSE COMPENSATION AND LIABILITY ACT)

CERCLA DESIGNATION & REPORTABLE QUANTITIES (RQ) (40 CFR 302.4):
Proprietary component: Unlisted, RQ = 100 lbs., Ignitability

TSCA (TOXIC SUBSTANCE CONTROL ACT)

TSCA INVENTORY STATUS (40 CFR 710):
Listed

RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)

RCRA IDENTIFICATION OF HAZARDOUS WASTE (40 CFR 261):
Waste Number: D001

CANADA

WHMIS (WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM):

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all the information required by the Controlled Products Regulations.

Hazard Classification / Division: C
D2B
D2A
E

Domestic Substance List: Listed (all components)

INTERNATIONAL LISTINGS

Proprietary Component
Australia (AICS): Listed
China: Listed
Japan (ENCS): (1)-190
Korea: KE-04597
Philippines (PICCS): Listed

Proprietary Component
Australia (AICS): Listed
China: Listed
Japan (ENCS): (1)-181
Korea: KE-04518
Philippines (PICCS): Listed

Proprietary Component
Australia (AICS): Listed
China: Listed
Japan (ENCS): (1)-1131
Korea: KE-12369
Philippines (PICCS): Listed

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16. OTHER INFORMATION

HMIS

Health	2
Flammability	0
Physical Hazard	1
Personal Protection (PPE)	J

Protection = J (Safety goggles, gloves, apron & combination dust & vapor respirator)

HMIS = Hazardous Materials Identification System

Degree of Hazard Code:
4 = Severe
3 = Serious
2 = Moderate
1 = Slight
0 = Minimal

NFPA

Health	2
Flammability	0
Reactivity	1
Special	OX

SPECIAL = OX (Oxidizer)

NFPA = National Fire Protection Association

Degree of Hazard Code:
4 = Extreme
3 = High
2 = Moderate
1 = Slight
0 = Insignificant

REVISION SUMMARY:
New MSDS.

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Technical Data

Klozur® CR

Proprietary Mixture of Klozur® Persulfate and PeremOx® Plus

Formula	$Na_2S_2O_8 + CaO_2$	
Typical active oxygen content		11.3%
pH of solution	**wt%**	**pH**
	1%	11.2

Typical properties

Odor	None
Appearance	Off white fine granular solid
Melting point	Decomposes
Solubility @ 25 ºC	Sparingly soluble
Loose bulk density	51.8 lb / ft^3
Slurry specific gravity	1 – 1.19 (5 – 30% slurry wt%)

Typical metallic impurity concentrations (ppm)

Iron	1
Copper	< 0.3
Chromium	< 0.08
Lead	< 0.6
Mercury	< 2.5

Uses

Chemical oxidation and bioremediation of organic contaminants in soil and groundwater

Shipment / container information:

DOT Classification: 5.1 (Oxidizer), yellow Oxidizer label
45 lb (20.4 kg) vented pail;
1,800 lb (816.5 kg) woven polypropylene sack with polyethylene line

HMIS classification:

Health	2
Flammability	0
Physical Hazard	1
Personal protection	J

Document number 02-01-EIT-DG

Appendix B

AECOM project Operating Procedures (POPs)

AECOM Project Operating Procedure (POP) 110 Packing and Shipping Samples

1.0 Purpose and Applicability

AECOM POP 110 describes proper packaging methods and shipment of samples to minimize the potential for sample breakage, leakage, or cross-contamination, and provide a clear record of sample custody from collection to analysis. Specific project requirements as described in an approved Work Plan, Sampling Plan, Quality Assurance Project Plan, Job Hazard Analysis (JHA), or Site-Specific Health and Safety Plan (HASP) will take precedence over the procedures described in this document.

The Environmental Protection Agency (EPA) Resource Conservation and Recovery Act (1976) (RCRA) regulations (40 CFR Section 261.4 (d)) specify that samples of solid waste, water, soil, or air collected for the purpose of testing are exempt from regulation when any of the following conditions apply:

- Samples are being transported to a laboratory for analysis
- Samples are being transported to the collector from the laboratory after analysis
- Samples are being stored:
  - By the collector prior to shipment for analysis
  - By the analytical laboratory prior to analysis
  - By the analytical laboratory after testing but prior to return of sample to the collector or pending the conclusion of a court case

Samples collected by AECOM are generally qualified for these exemptions. AECOM POP 110 deals only with these sample types. If you have any addition questions about shipping requirements refer to POP 111 Hazardous Materials Shipping or contact the AECOM Safety, Health, and Environment (SH&E) Department.

2.0 Responsibilities

The field sampling coordinator is responsible for the enactment and completion of the chain-of- custody and the packaging and shipping requirements outlined here and in project-specific sampling plans.

3.0 Health and Safety

This section presents the generic hazards associated with packing and shipping samples and is intended to provide general guidance in preparing site-specific health and safety documents. The Site-Specific HASP and JHAs will address additional requirements and will take precedence over this document. Note that packing and shipping samples usually requires Level D personal protection unless there is a potential for airborne exposure to site contaminants. Under circumstances where potential airborne exposure is possible respiratory protective equipment may be required based on personal air monitoring results. Upgrades to Level C will be coordinated with your Site Safety and Health Officer (SSHO) or SH&E Coordinator.

Health and safety hazards with packing and shipping of samples include the following:

- Exposure to sample preservatives – Know the types of sample preservatives sent to you by the analytical laboratory. Understand the potential exposures (inhalation, ingestion skin contact) and use chemically impervious gloves to protect your hands from acids in particular.
- Anticipate the potential for spills – Glass containers are subject to breakage and if dropped on the floor will create a spill. Know how to contain the spill, have spill response materials available, and understand the proper disposal methods for spilled materials. Wear personal protective equipment (PPE) to clean up the spill as appropriate (Level C or D).
- Broken glass – Be aware of the possibility for broken glass in previously used coolers. Inspect the cooler before you place samples in it and clean out any broken glass safely (i.e. with a small brush).
- Coolers can be heavy – Use proper lifting techniques to pick up loaded coolers. Bend your legs and lift with a straight back to avoid a back injury.
- Do not use your teeth to cut tape to size, use a tape dispenser.

4.0 Supporting Materials

The following materials must be on hand and in sufficient quantity to ensure that proper packing and shipping methods and procedures may be followed:

- Chain-of-custody forms and BTEX free tape
- Sample container labels
- Coolers or similar shipping containers
- Duct tape or transparent packaging tape

- Zip-lock type bags
- Protective wrapping and packaging materials
- Ice
- Shipping labels for the exterior of the ice chest
- Transportation carrier forms (Federal Express, Airborne, etc.)
- PPE as specified in the Site-Specific HASP
- Material Safety Data Sheets (MSDSs) for any chemicals or site-specific contaminants (including sample preservatives)
- A copy of the Site-Specific HASP

5.0 Methods and Procedures

All samples must be packaged so they do not leak, break, vaporize, or cause cross-contamination of other samples. Waste samples and environmental samples (e.g., groundwater, soil, etc.) should not be placed in the same shipping container. Each individual sample must be properly labeled and identified. A chain-of-custody record must accompany each shipping container. When refrigeration is required for sample preservation, samples must be kept cool during the time between collection and final packaging.

All samples must be clearly identified immediately upon collection. Each sample bottle label will include the following information:

- Client or project name, or unique identifier, if confidential
- A unique sample description
- Sample collection date and time
- Sampler's name or initials
- Indication of filtering or addition of preservative, if applicable
- Analyses to be performed

After collection, identification, and preservation (if necessary), the samples will be maintained under chain-of-custody procedures as described below.

5.1 Chain-Of-Custody

A sample is considered to be under custody if it is in one's possession, view, or in a designated secure area. Transfers of sample custody must be documented by chain-of-custody forms. The chain-of-custody record will include, at a minimum, the following information:

- Client or project name, or unique identifier, if confidential
- Sample collector's name
- AECOM's mailing address and telephone number
- Designated recipient of data (name and telephone number)
- Analytical laboratory's name and city
- Description of each sample (i.e., unique identifier and matrix)
- Date and time of collection
- Quantity of each sample or number of containers
- Type of analysis required
- Date and method of shipment

Additional information may include type of sample containers, shipping identification air bill numbers, etc.

When transferring custody, both the individual(s) relinquishing custody of samples and the individual(s) receiving custody of samples will sign, date, and note the time on the form. If samples are to leave the collector's possession for shipment to the laboratory, the subsequent packaging procedures will be followed.

5.2 Packing for Shipment

To prepare a cooler for shipment, the sample bottles should be inventoried and logged on the chain-of-custody form. At least one layer of sorbent protective material should be placed in the bottom of the container. Be careful for any broken glass. A heavy-duty plastic bag, if available, should be placed in the shipping container to act as an inner container. As each sample bottle is logged on the chain-of-custody form, it should be wrapped with protective material (e.g., bubble wrap, matting, plastic gridding, or similar material) to prevent breakage. The protective material should be secured with tape. The sample should then be placed in a zip-lock type bag. Each sample bottle should be placed upright in the heavy-duty plastic bag inside the shipping container. Each sample bottle cap should be checked during wrapping and tightened, if needed. Avoid over tightening, which may cause bottle cap to crack and allow leakage. Additional packaging material, such as bubble wrap, should be spread throughout the voids between the sample bottles.

Most samples require refrigeration as a minimum preservative. To ensure that samples are received by the laboratory within required temperature limits, place cubed ice directly over packed samples, making sure that ice is present on all sides of each sample (a 2-inch layer of ice should be present on top of the samples prior to shipment).

If applicable, secure the inner heavy-duty bag with clear packing tape. This will prevent water from leaking out of the package, thus stopping shipment (package handling companies will not ship a leaking package).

Place the original completed chain-of-custody record in a zip-lock type plastic bag and place the bag on the top of the contents within the cooler or shipping container. Alternatively, the bag may be taped to the underside of the container lid. Retain a copy of the chain-of-custody record with the field records.

Close the top or lid of the cooler or shipping container and rotate/shake the container to verify that the contents are packed so that they do not move. Add additional packaging if needed and reclose. Place signed and dated chain-of-custody seal at two different locations (front and back) on the cooler or container lid and overlap with transparent packaging tape. The chain-of-custody seal should be placed on the container in such a way that opening the container will destroy the tape. Packaging tape should encircle each end of the cooler at the hinges. Use proper lifting techniques when picking up the cooler.

Sample shipment should be sent via an overnight express service that can guarantee 24-hour delivery. Retain copies of all shipment records as provided by the shipper.

6.0 Quality Assurance/Quality Control

Recipient of sample container should advise shipper and/or transporter immediately of any damage to the container, breakage of contents, or evidence of tampering.

7.0 Documentation

The documentation for support of proper packaging and shipment will include AECOM or the laboratory chain-of-custody records and transportation carrier's airbill or delivery invoice. All documentation will be retained in the project files.

AECOM Project Operating Procedure (POP) 120
Decontamination

1.0 Purpose and Applicability

AECOM POP 120 describes the methods to be used for the decontamination of items that may become contaminated during field operations. Decontamination is performed as a quality assurance measure, and as a safety and health precaution. It prevents cross-contamination between samples and also helps maintain a clean working environment. Equipment requiring decontamination may include hand tools, monitoring and testing equipment, personal protective equipment (PPE), or heavy equipment (e.g., loaders, backhoes, drill rigs, etc.).

Decontamination is achieved mainly by rinsing with liquids, which may include soap and/or detergent solutions, tap water, distilled water, and methanol or isopropyl alcohol. Equipment may be allowed to air dry after being cleaned or may be wiped dry with paper towels or chemical-free cloths.

All sampling equipment will be decontaminated prior to use and between each sample collection point. Waste products produced by the decontamination procedures, such as rinse liquids, solids, rags, gloves, etc., will be collected and disposed of properly, based on the nature of contamination and site protocols. Any materials and equipment that will be reused must be decontaminated or properly protected before being taken off site.

Specific project requirements as described in an approved Work Plan, Sampling Plan, Quality Assurance Project Plan, the AECOM Corporate Safety, Health, and Environment (SH&E) Manual, Job Hazard Analysis (JHA), or Site-Specific Health and Safety Plan (HASP) will take precedence over the procedures described in this document.

2.0 Responsibilities

It is the responsibility of the field sampling coordinator to ensure that proper decontamination procedures are followed and that all waste materials produced by decontamination are properly managed. It is the responsibility of any subcontractors (e.g., drilling or sampling contractors) to follow the designated decontamination procedures that are stated in their contracts and outlined in the project HASP. It is the responsibility of all personnel involved with sample collection or decontamination to maintain a clean working environment and to ensure that no contaminants are inadvertently introduced into the environment, tracked out of the contamination reduction zone (CRZ), or passed from one sample point to another.

3.0 Health and Safety

This section presents the generic hazards associated with decontamination and is intended to provide general guidance in preparing site-specific health and safety documents. The Site-Specific HASP and JHAs will address additional requirements and will take precedence over this document. Note that decontamination usually requires Level D personal protection unless there is a potential for airborne exposures to site contaminants. Under circumstances where potential airborne exposure is possible respiratory protective equipment may be required based on personal air monitoring results. Upgrades to Level C will be coordinated with your Site Safety and Health Officer (SSHO) or SH&E Coordinator.

Health and safety hazards potentially involved decontamination include the following:

- Skin contact with decontamination solvents. Wear solvent impervious gloves when decontaminating equipment. Methanol and isopropanol are approved but use the solvents sparingly and dispense only from pre-labeled polypropylene solvent wash bottles. Whenever possible use an aqueous based non-toxic cleaning agent in lieu of solvents. **Hexane is prohibited from use for decontamination.**
- Avoid contact with site contaminants. Exposure to contaminated media is possible when either removing contaminated personal protective equipment (PPE) or decontaminating heavy equipment. Take care to prevent slips and falls when scrubbing over boots in the CRZ and remove PPE using proper "inside-out" techniques to minimize airborne exposure to potentially contaminated particulate. In addition to Level D PPE, wear a face shield when brushing off heavy equipment or using a pressure washer. Consult the Corporate SH&E Manual for additional precautions.
- Decontamination pad liquids. If large volumes of rinsates are generated, wash water must be properly characterized prior to disposal. Avoid contact and wear PPE during liquids transfer.

4.0 Supporting Materials

The following materials should be on hand in sufficient quantity to ensure that proper decontamination methods and procedures are followed:

- Cleaning liquids and dispensers (phosphate-free soap and/or detergent solutions, tap water, distilled water, deionized water, reagent grade methanol or isopropyl, etc.)
- PPE, as defined in the project HASP
- Paper towels or chemical-free cloths
- Disposable chemically impervious gloves

- Waste-storage containers (e.g., drums, boxes, plastic bags)
- Drum labels, if necessary
- Cleaning containers (e.g., plastic and/or galvanized steel pans or buckets)
- Cleaning brushes
- Plastic sheeting
- Material Safety Data Sheets (MSDSs) for any chemicals or site-specific contaminants and decontamination solvents
- A copy of the Site-Specific HASP (consult for heavy equipment decontamination)

5.0 Methods and Procedures

The extent of known contamination will determine the degree of decontamination required. When the extent of contamination cannot be readily determined, cleaning should be done according to the assumption that the equipment is highly contaminated.

Standard operating procedures listed below describe the method for full field decontamination. If different technical procedures are required for a specific project, they will be spelled out in the project plans.

Such variations in decontamination may include all or an expanded scope of these decontamination procedures:

- Remove gross contamination from the equipment by brushing and then rinse with tap water.
- Wash with detergent or soap solution (e.g., Alconox and tap water).
- Rinse with tap water or distilled water.
- Rinse with deionized water (distilled water is an acceptable substitute if deionized water is unavailable).
- Repeat entire procedure or any parts of the procedure as necessary.
- After decontamination procedure is completed, avoid placing equipment directly on ground surface to avoid re-contamination.

Downhole drilling equipment, such as augers, split spoons, Shelby tubes, and sand lines, will be decontaminated with pressurized hot water or steam wash, followed by a fresh water rinse. No additional decontamination procedures will be required if the equipment appears to be visually clean. If contamination is visible after hot water/steam cleaning, then a detergent wash solution with brushes (if necessary) will be used. Items heavily contaminated with product may require more aggressive decontamination techniques. If the items cannot be discarded, consult your SH&E coordinator to obtain guidance in this regard.

6.0 Quality Assurance/Quality Control

To assess the adequacy of decontamination procedures, rinsate blanks should be collected and analyzed for the same parameters as the field samples. Specific number of blanks will be defined in the project-specific sampling plan. In general, one rinsate blank will be collected per 20 samples.

7.0 Documentation

Field notes describing procedures used to decontaminate equipment/personnel and for collection of the rinsate blanks will be documented by on-site personnel. Field notes will be retained in the project files.

AECOM Project Operating Procedure (POP) 230
Groundwater Sampling

1.0 Purpose and Applicability

AECOM POP 230 describes the collection of valid and representative samples from groundwater monitoring wells. Specific project requirements as described in an approved Work Plan, Sampling Plan, Quality Assurance Project Plan, or Health & Safety Plan will take precedence over the procedures described in this document.

2.0 Responsibilities

The field sampling coordinator will have the responsibility to oversee and ensure that all groundwater sampling is performed in accordance with the project specific sampling program and this POP. In addition, the field sampling coordinator must ensure that all field workers are fully apprised of this POP.

3.0 Supporting Materials

The list below identifies the types of equipment which may be used for a range of groundwater sampling applications. From this list, project specific equipment will be selected based upon project objectives and site conditions (e.g., the depth to groundwater, purge volumes, analytical parameters, well construction, and physical/chemical properties of the analytes). The types of sampling equipment are as follows:

- Purging/Sample Collection
    - Bailers and bailer cord
    - Centrifugal pump
    - Bladder pump or Peristaltic pump

The most widely applicable equipment that will contact the water must be made of inert materials, preferably stainless steel or fluorocarbon resin.

- Sample Preparation/Field Measurement
    - pH meter
    - Specific conductance meter
    - Thermometer
    - Filtration apparatus
    - Water-level measurement equipment

All equipment will be calibrated before use following the manufacturer's specifications.

- General
    - Distilled water dispenser bottle
    - Methanol or isopropyl dispenser bottle
    - Decontamination equipment
    - Personal protection equipment as specified in the Project Health and Safety Plan
    - Field data sheets and field book
    - Sample containers, labels, and preservation solutions
    - Buckets and drums
    - Coolers and ice
    - Paper towels or chemical-free cloths

4.0 Methods and Procedures

The following sections describe the methods and procedures required to collect representative groundwater samples.

4.1 Water-Level Measurement

After unlocking and/or opening a monitoring well, the first task will be to obtain a water-level measurement. A static-water level will be measured in the well prior to the purging and collection of any samples. The water level is needed for estimating the purge volume and may also be used for mapping the potentiometric surface of the groundwater. Water-level measurements will be made using an electronic or mechanical device following the methods described in POP 231.

Measurement of point location for the well should be clearly marked on the outermost casing or identified in previous sample collection records. This point is usually established on the well casing itself, but may be marked on the protective steel casing in some cases. In either case, it is important that the marked point coincide with the same point of measurement used by the surveyor. If not marked from previous investigations, the water level measuring point should be marked on the north side of the well casing and noted in the groundwater sampling form (Figure 1). Whatever measuring point is used, the location should be described on the groundwater sampling form.

To obtain a water level measurement lower a decontaminated mechanical or an electronic sounding unit into the monitoring well until the audible sound of the unit is detected or indicates water contact. At this time the precise measurement should be determined by repeatedly raising and lowering the tape or cable to converge on the exact measurement. The water-level measurement should be entered on the groundwater sampling form. The water-level measurement device shall be decontaminated immediately after use following the procedures outlined in POP 120.

4.2 Purging and Sample Collection Procedures

Well purging is the activity of removing some volume of water from a monitoring well in order to induce "fresh" groundwater to flow into the well prior to sampling. Under most well construction and hydrogeologic conditions, this provides water that is more representative of the groundwater in saturated materials adjoining the well.

The volume of water to be removed, referred to as the purge volume, is a function of the water- yielding capacity of the well, the well diameter and depth, and the depth to water made just prior to purging. The well depth should be sounded with the water-level cable or tape just before or after measuring the static depth to water. A well volume is defined as the product of the length of water column and the volume per unit length of well casing, a function of casing inside diameter. The following data can be used in this field calculation:

Inside Diameter, inches	**Gallons/foot**
1 1/4	0.077
1 1/2	0.10
2	0.16
3	0.37
4	0.65
6	1.64

According to the TEGD (USEPA, 1986), the purge volume should equal at least three well volumes when the earth materials will yield relatively large quantities of water, and between one and two well volumes when the earth materials will only yield small quantities to the well. From a field operations viewpoint, large quantities (high yield) means that the well can not be pumped or bailed "dry" by removing three well volumes. Small quantities (low yield) are identified when the well can be pumped or bailed "dry".

Based on experience and recent scientific literature, it will be The RETEC Group, Inc. (RETEC) policy to minimize the generation of water turbidity when purging. Turbidity is especially of concern when testing the samples for metals or for selected organics that may be sorbed to the sediment. Turbidity will be minimized by:

- Using a low-pumping rate submersible pump such as a compressed- gas driven bladder pump
- Slowly moving the bailer in and out of the water column; avoid dropping the bailer and removing it quickly

Purging will be performed for all groundwater monitoring wells prior to sample collection.

Three general methods are used for well purging. Well purging may be achieved using bailers, surface pumps, or down-well submersible pumps. In all cases pH and specific conductance will be monitored during purging. Field parameter values will be entered on the groundwater sampling form along with the corresponding purge volume. The following sections explain the procedures to be used to purge and collect samples from monitoring wells.

4.2.1 Bailing

Obtain a clean decontaminated bailer and a spool of polypropylene rope or equivalent bailer cord. Using the rope at the end of the spool, tie a bowline knot, or equivalent, through the bailer loop. Test the knot for adequacy by creating tension between the line and the bailer. Tie again if needed.

Lower the bailer to the bottom of the monitoring well and remove an additional five feet of cord from the spool. Cut the cord at the spool and secure the rope to the well head or the wrist of the person who shall perform the bailing.

Raise the bailer by grasping a section of cord using each hand alternately. This bailer lift method is used so that the bailer cord will not come into contact with the ground or other potentially contaminated surfaces.

Samples collected by bailing will be poured directly into sample containers from bailers which are full of fresh groundwater. Samples will be collected in the following order:

- Volatile organic compounds
- Semivolatile organic compounds
- Pesticides/Herbicides/PCBs/Dioxins
- Organic indicator compounds
- Metals (total and/or dissolved)
- Miscellaneous inorganic compounds
- Radiometric compounds
- Microbial analyses

During sample collection, bailers will not be allowed to contact the sample containers.

4.2.2 Pumping

Groundwater withdrawal using pumps is commonly performed with centrifugal, peristaltic, submersible, or bladder pumps. Peristaltic and centrifugal pumps are limited to conditions where groundwater need only be raised through approximately 20 to 25 feet of vertical distance. Submersible or bladder pumps can be used when groundwater is greater than 25 feet below grade. Specific methods for pumps will be discussed in the project specific sampling plan. Pumping for collection of samples to be analyzed for volatile organics will only be with bladder pumps.

Samples collected by pumping will be transferred directly from the pump discharge tubing into the sample containers. Samples will be collected in the following order:

- Volatile organic compounds
- Semivolatile organic compounds
- Pesticides/Herbicides/PCBs/Dioxins
- Organic indicator compounds
- Metals (total and/or dissolved)
- Miscellaneous inorganic compounds
- Radiometric compounds
- Microbial analyses

During sample collection, the discharge tubing will not be allowed to contact the sample containers.

4.3 Sample Preparation and Filtration

Specific procedures pertaining to the handling and shipment of samples shall be in accordance with POP 110. A clean pair of gloves and decontaminated sampling tools will be used when handling the samples during collection to prevent cross contamination.

Prior to transport or shipment, groundwater samples may require preparation and/or preservation. Field preparation may entail filtration, preservation in the form of chemical additives, or temperature control. Specific preservation requirements will be described in the project specific sampling plans.

Groundwater samples collected for dissolved metals analyses will be filtered prior to being placed in sample containers. Groundwater filtration is performed using a peristaltic pump and a 0.45 micron water filter unless otherwise specified in the project specific sampling plan. For most dissolved metal analyses, pH adjustment of the sample is also required and shall be performed after filtration.

5.0 Quality Assurance/Quality Control

Quality Assurance/Quality Control (QA/QC) requirements include, but are not limited to, blind field duplicates, blind rinsate blanks, and blind field blanks. These samples will be collected on a frequency of one QA/QC sample per 10 field samples or a minimum of one QA/QC sample per day unless otherwise specified in the project specific sampling plan.

6.0 Documentation

Various documents will be completed and maintained as a part of Groundwater Sample collection. These documents will provide a summary of the sample collection procedures and conditions, shipment method, analyses requested, and the custody history. These documents may include:

- Field book
- Groundwater sampling forms
- Sample labels
- Chain-of-custody
- Shipping receipts

All documentation will be stored in the project files.

7.0 References

Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells, EPA 600/4-89/034, published by National Water Well Association, 1989.

RCRA Ground Water Monitoring Technical Enforcement Guidance Document, published by National Water Well Association, 1986.

A Compendium of Superfund Field Operations, EPA 540/P-87/001, published by the Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, US EPA, 1987.

Figure 1 Groundwater Sampling Form

AECOM Project Operating Procedure (POP) 231 Water-Level Measurements

1.0 Purpose and Applicability

AECOM POP 231 describes the measurement of water levels in groundwater monitoring wells or piezometers. Water-level measurements are fundamental to groundwater and solute transport studies. Water-level data are used to indicate the directions of groundwater flow and areas of recharge and discharge, to evaluate the effects of manmade and natural stresses on the groundwater system, to define the hydraulic characteristics of aquifers, and to evaluate stream-aquifer relations. Measurements of the static-water level are also needed to estimate the amount of water to be purged from a well prior to sample collection.

Specific project requirements as described in an approved Work Plan, Sampling Plan, Quality Assurance Project Plan, Job Hazard Analysis (JHA), or Site-Specific Health and Safety Plan (HASP) will take precedence over the procedures described in this document.

2.0 Responsibilities

The field sampling coordinator will have the responsibility to oversee and ensure that all procedures are performed in accordance with the project-specific sampling program and this POP.

3.0 Health and Safety

This section presents the generic hazards associated with the collection of water-level measurements. The site-specific HASP and JHAs will address additional requirements and will take precedence over this document. Appropriate personal protective equipment (PPE) must be worn as determined in the Site-Specific HASP, which typically consists of Level D protection. Under circumstances where potential airborne exposure is possible respiratory protective equipment may be required based on personal air monitoring results. Upgrades to Level C will be coordinated with your Site Safety and Health Officer (SSHO) or Safety, Health and Environment (SH&E) Coordinator.

Health and safety hazards during groundwater level measurements may involve:

- Slip, trips, and falls in tall grasses over obstacles and berms near well locations. Review terrain hazards prior to conducting these operations. Ensure that you have safe means of access/egress to the wellhead.

- Exposure to site contaminants. If there is product in the well (especially gasoline) take all precautions necessary to prevent fire/explosion and/or exposure to airborne vapors.

- Ergonomics. Use appropriate ergonomic techniques when inserting or retrieving equipment for the wells to preclude injury to the arms, shoulders or back.

If the well is suspected of being contaminated, or has a history of contamination, the static water-level measurements should be made while wearing appropriate personal protective equipment (PPE). The air in the wellhead should be sampled for organic vapors using a Photo Ionization Detector (PID). The results shall be recorded in the Fluid-Level Monitoring Log or the project field book. This is the first indication of the presence of a non-aqueous phase liquid (NAPL). If the potential for fire or explosion exists, use of the probe ground wire is required.

4.0 Supporting Materials

This section identifies the types of equipment that may be used for measurement of groundwater levels. Based on project objectives, observed or probable well contamination, and well construction, a project-specific equipment list will be determined from the following equipment:

- Water-level and/or product-level measuring device

- Distilled water dispenser bottle

- Methanol or isopropyl in properly labeled dispenser bottles

- Plastic sheeting

- PPE as specified in the Site-Specific HASP

- Fluid-level monitoring logs and field book

- Paper towels or chemical-free cloths

- Material Safety Data Sheets (MSDSs) for any chemicals or site-specific contaminants

- A copy of the Site-Specific HASP

5.0 Methods and Procedures

When taking a series of fluid-level measurements at a number of monitoring wells, it is generally good practice to go in order from the least- to the most contaminated well. Additionally, the measurement of all site wells should be done consecutively and before any sampling activities begin. This will ensure the data are representative of aquifer conditions. All pertinent data should be entered in the Fluid-Level Monitoring Log or the project field book.

5.1 Well Evaluation

Upon arrival at a monitoring well, the surface seal and well protective casing should be examined for any evidence of frost heaving, cracking, or vandalism. All observations should be recorded in the fluid-level monitoring log or the project field book.

The area around the well should be cleared of weeds and other materials prior to measuring the static-water level (avoid contact with poison ivy or other allergenic plants). A drop cloth or other material (e.g., plastic garbage bag) should be placed on the ground around the well, especially if the ground is disturbed or potentially contaminated. This will save time and work for cleaning equipment or tubing if it falls on the ground during preparation or operation. The well protective casing should then be unlocked and the cap removed.

5.2 Measuring Point Location

The measuring point location for the well should be clearly marked on the outermost casing or identified in previous sample collection records. This point is usually established on the well casing itself, but may be marked on the protective steel casing in some cases. In either case, it is important that the marked point coincide with the same point of measurement used by the surveyor. If not marked from previous investigations, the water-level measuring point should be marked on the north side of the well casing and noted in the Fluid-Level Monitoring Log or the project field book. Monitoring well measurements for total depth and water level should be consistently measured from one reference point so that these data can be used for assessing trends in the groundwater.

5.3 Water-Level Measurement

Water-level measurements shall be made using an electronic or mechanical device. Several methods for water-level measurement are described below. The specific method to be used will be defined in the project-specific sampling plan.

5.3.1 Graduated Steel Tape

The graduated steel-tape method is considered an accurate method for measuring the water level in nonflowing wells. Steel surveying tapes in lengths of 100, 200, 300, 500, and 1,000 feet are commonly used; a black tape is better than a chromium-plated tape. The tapes are mounted on hand-cranked reels up to 500-foot lengths; for greater depth, a motor-driven tape drive is usually required. A slender weight is attached to the ring at the end of the tape to ensure plumbness and to permit some feel for obstructions.

The lower few feet of tape are chalked by pulling the tape across a piece of blue carpenter's chalk. The wet chalk mark identifies the portion of the tape that was submerged. Lower the graduated steel-tape from the measuring point at the top of the well until a short length of the tape is submerged. The weight and tape should be lowered into the water slowly to prevent splashing. Submergence of the weight and tape may temporarily cause the water level to rise in wells or piezometers having very small diameters. This effect can be significant if the well is in materials of very low hydraulic conductivity.

Under dry surface conditions, it may be desirable to pull the tape from the well by hand, being careful not to allow it to become kinked, and reading the water mark before rewinding the tape onto the reel. In this way, the watermark on the chalked part of the tape is rapidly brought to the surface before the wetted part of the tape dries. In cold regions, rapid withdrawal of the tape from the well is necessary before the wet part freezes and becomes difficult to read. Read the tape at the measuring point, and then read the watermark on the tape. The difference between these two readings is the depth to water below the measuring point. Errors resulting from the effects of thermal expansion of tapes and of stretch due to the suspended weight of the tape and plumb weight can become significant at high temperatures and for measured depths in excess of 1,000 feet.

The observer should make two measurements. If two measurements of static-water level made within a few minutes do not agree within 0.01 or 0.02 foot in observation wells having a depth to water of less than a couple hundred feet, continue to measure until the reason for the lack of agreement is determined or until the results are shown to be reliable. Where water is dripping into the well or covering the well casing wall, it may be impossible to get a good watermark on the chalked tape.

Water-level measurement should be entered in the fluid-level monitoring log or the project field book. The water-level measurement device shall be decontaminated immediately after use.

5.3.2 Electrical Methods

Many types of electrical instruments are available for water-level measurement; most operate on the principle that a circuit is completed when two electrodes are immersed in water. Electrodes are generally contained in a weighted probe that keeps the tape taut while providing some shielding of the electrodes against false indications as the probe is being lowered into the well. Before lowering the probe into the well, the circuitry can be checked by dipping the probe in water and observing the indicator (a light, sound, and/or meter).

To obtain a water-level measurement, slowly lower the decontaminated probe into the monitoring well until the indicator (light, sound, and/or meter) shows water contact. At this time, the precise measurement should be determined by repeatedly raising and lowering the tape or cable to converge on the exact measurement.

In wells having a layer of NAPL floating on the water, the electric tape will not respond to the oil surface and, thus, the fluid level determined will be different than would be determined by a steel tape. The difference depends on how much NAPL is floating on the water. Dual media tapes are recommended in that instance to measure both NAPL and water levels using the same measuring device. The procedure is discussed in Section 5.4.

Water-level measurement should be entered in the fluid-level monitoring log or the project field book. The water-level measurement device shall be decontaminated immediately after use.

5.3.3 Airline

The airline method is especially useful in pumped wells where water turbulence may preclude using more precise methods. A small diameter air-type tube of known length is installed from the surface to a depth below the lowest water level expected. Compressed air is used to purge the water from the tube. The pressure, in pounds per square inch (psi), needed to purge the water from the airline multiplied by 2.31 (feet of water for one psi) equals the length in feet of submerged airline. The depth to water below the center of the pressure gauge can be easily calculated by subtracting the length of airline below the water surface from the total length of airline (assuming the air line is essentially straight).

Accuracy depends on the precision to which the pressure can be read. The accuracy of an airline or pressure gauge measurement depends primarily on the accuracy and condition of the gauge. It is normally within 1 foot of the true level as determined by means of a steel-tape measurement. The airlines themselves, however, have been known to become clogged with mineral deposits or bacterial growth, or to develop leaks and consequently yield false information. A series of airline measurements should be checked periodically by the use of a steel tape or an electric water-level indicator.

The airline and any connections to it must be airtight throughout the entire length. A long-term increase in airline pressure may indicate gradual clogging of the airline. A relatively sudden decrease in airline pressure may indicate a leak or break in the airline. Airline pressures that never go above a constant low value may indicate that the water level has dropped below the outlet orifice of the airline. To minimize the effect of turbulence, the lower end of the airline should be at least 5 feet above or below the pump intake. Corrections should be made for fluid temperatures much different from 20° C and for vertical differences in air density in the well column for cases where the depth to water is very large.

5.4 Procedures for Immiscible Fluids

At those facilities where monitoring to determine the presence or extent of immiscible fluids is required, the sampler will need to use special procedures for the measurement of fluid levels. The procedures required will depend on whether light NAPL (LNAPL) that form lenses floating on top of the water table or dense NAPL (DNAPL) that sink through the aquifer and form lenses over lower permeability layers are present.

In the case of LNAPL, measurements of immiscible fluid and water level usually cannot be accomplished by using normal techniques. For example, a chalked steel-tape measurement will only indicate the depth to the immiscible fluid (not the depth to water) and a conventional electric water-level probe will not generally respond to nonconducting immiscible fluids.

To circumvent these problems, the use of special techniques and equipment can be specified. These techniques have been specially developed to measure fluid levels in wells containing LNAPL or DNAPL, particularly petroleum products. One method is similar to the chalked steel-tape method. The difference is the use of a special paste or gel rather than ordinary carpenters chalk. Such indicator pastes, when applied to the end of the steel tape and submerged in the well, will show the top of the oil as a wet line and the top of the water as a distinct color change. Another method, similar to the electric-tape method, uses a dual purpose probe and indicator system. The probe can detect the presence of any fluid (through the wetting effect) and can also detect fluids that conduct electricity. Thus, if a well is contaminated with low density, nonconducting LNAPL such as gasoline, the probe will first detect the surface of the gasoline, but it will not register electrical conduction. However, when the probe is lowered deeper to contact water, electrical conduction will be detected. The detection of a DNAPL would be similar.

5.5 Measurement of Total Depth

During water-level measurement, the total depth of the well may also be measured. This measurement gives an indication of possible sediment buildup within the well that may significantly reduce the screened depth. The same methods used for measuring water levels (e.g., steel tape or electrical probes) may be used to measure the total well depth. The most convenient time to measure the total well depth is immediately following measurement of the water level and prior to removing the measurement device completely from the well. The measurement device (steel tape or electrical probe) is lowered down the well until the measurement tape becomes slack indicating the weighted end of the tape or probe has reached the bottom of the well. While the probe remains touching the bottom and the tape pulled taut, the total well depth shall be recorded into the field book.

6.0 Quality Assurance/Quality Control

To ensure that accurate data are collected, repeated measurements of the fluid depths should be made. The readings should be within 0.01 to 0.02 feet of each other. A secondary check, if data are available, is to compare previous readings collected under similar conditions (e.g., summer months, wells pumping, etc.).

7.0 Documentation

Data will be recorded into the fluid-level monitoring log form, the project field book, or, if groundwater sampling, the groundwater sample collection record. Additional comments, observations, or details will also be noted. These documents will provide a summary of the water-level measurement procedures and conditions and will be kept the in project files.