FINAL

FINAL REPORT ON THE GROUNDWATER INVESTIGATION OF THE RAMSDELL QUARRY LANDFILL

RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO

PREPARED FOR

US Army Corps
of Engineers®

LOUISVILLE DISTRICT

CONTRACT No. DACA27-97-D-0025
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August 2000

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Prepared for
U.S. Army Corps of Engineers
Louisville District
Under Contract Number DACA27-97-D-0025
Delivery Order No. 003

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ABBREVIATIONS

amsl	above mean sea level
AOC	area of concern
BGS	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COD	chemical oxygen demand
COPC	contaminant of potential concern
CSM	conceptual site model
1,3-DNB	1,3-dinitrobenzene
2,4-DNT	2,4-dinitrotoluene
2,6-DNT	2,6-dinitrotoluene
DQO	Data Quality Objective
DWS	Drinking Water Standards
EPA	U.S. Environmental Protection Agency
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
IRP	Installation Restoration Program
MCL	maximum contaminant level
OAC	Ohio Administrative Code
Ohio EPA	Ohio Environmental Protection Agency
OVA	organic vapor analyzer
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PID	photoionization detector
PRG	preliminary remediation goal
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RI	Remedial Investigation
RQL	Ramsdell Quarry Landfill
RVAAP	Ravenna Army Ammunition Plant
SAIC	Science Applications International Corporation
SVOC	semivolatile organic compound
TAL	Target Analyte List
TOC	total organic carbon
2,4,6-TNT	2,4,6-trinitrotoluene
USACE	U.S. Army Corps of Engineers
VOC	volatile organic compound

EXECUTIVE SUMMARY

This report presents the results of the Groundwater Investigation of Ramsdell Quarry Landfill (RQL) at the Ravenna Army Ammunition Plant (RVAAP), Ravenna, Ohio. This investigation was conducted by Science Applications International Corporation (SAIC) for RVAAP under contract DACA27-97-D-0025, Delivery Order 003, with the U.S. Army Corps of Engineers (USACE), Louisville District. The investigation was conducted consistent with Department of Defense Installation Restoration Program (IRP) guidelines, following work plans approved by the Ohio Environmental Protection Agency (Ohio EPA), Northeast District Office, Division of Solid and Infectious Waste.

ES.1 INVESTIGATION OBJECTIVES AND SCOPE

The purpose of the Groundwater Investigation at RQL was to determine the shallow groundwater hydrogeologic conditions, including groundwater flow direction, seasonal changes, and the hydraulic and geochemical relationships between the surface water in the pond and the groundwater. The study was designed to: (1) evaluate whether the closed landfill is in compliance with Ohio solid waste post-closure requirements; (2) close data gaps in the RQL post-closure monitoring program; and (3) address potential impacts upon groundwater related to historical operations at Ramsdell Quarry prior to use of the site for landfill operations. The following data quality objectives (DQOs) for the RQL Groundwater Investigation were developed jointly by the Ohio EPA, USACE, RVAAP, and SAIC to achieve this purpose:

- Assess the hydrogeologic conditions and groundwater quality in shallow groundwater beneath the site using newly installed monitoring wells of known integrity suited to this purpose.

- Evaluate the Ramsdell Quarry pond (surface water and sediment) for evidence of chemical contamination either through groundwater influx into the pond or as a result of incipient contamination from historical operations on the quarry floor.

- Provide a comparative assessment of water levels in the Ramsdell Quarry pond and surrounding monitoring wells to evaluate potential hydraulic connection with shallow groundwater and identify whether the pond is a source of recharge.

- Conduct quarterly monitoring of newly installed monitoring wells and sampling during baseflow conditions (dry season) and following a storm event to provide characterization of groundwater chemical quality and examine potential episodic migration of contamination in relation to rainfall events.

- Conduct a comparative analysis of hydrologic and chemical data from newly installed wells versus an existing monitoring network to determine if geochemical stratification exists within the groundwater system and whether distinct hydraulic systems exist within the bedrock interval.

To achieve the project DQOs, two phases (initial and follow-on) of work were conducted. All work was conducted in accordance with the *Facility-Wide Sampling and Analysis Plan for the Ravenna Army Ammunition Plant* (USACE 1996a) and the *Sampling and Analysis Plan Addendum for the Groundwater Investigation of the Former Ramsdell Quarry Landfill* (USACE 1998a). The initial phase, conducted in July 1998, involved: (1) the installation and sampling of six new monitoring wells; (2) the sampling of the existing RQL post-closure monitoring well system; (3) the sampling of sediment and surface water within the quarry; and (4) the construction of a staff gauge within the main quarry pond. Results of the initial phase of the investigation were presented in the *Initial Phase Report, Groundwater Investigation Ramsdell Quarry Landfill, Ravenna Army Ammunition plant, Ravenna, Ohio* (USACE 1999a).

The follow-on phase of the investigation, which extended until July 15, 1999, included: (1) quarterly, dry season, and wet season (storm event) sampling of the new monitoring well network and quarry pond surface water; (2) collection of long-term water levels (at two-hour intervals) from the new monitoring well network and quarry pond; (3) monthly manual water level measurements from all wells and the pond staff gauge; and (4) collection of precipitation data.

ES.2 SITE CONDITIONS AND RESULTS OF THE INVESTIGATION

Ramsdell Quarry is located in the northeastern portion of RVAAP and encompasses about 5.7 ha (14 acres). Ramsdell Quarry is underlain by sandstone of the Sharon Member of the Pennsylvanian Pottsville Formation. Quarry operations were discontinued about 1941. From 1946 to the 1950s, the bottom of the quarry was used to burn waste explosives from Load Line 1 and napalm bombs. Also, the western and southern portions of the abandoned quarry were used for landfill operations (RQL) between 1941 and 1976. Beginning in 1976, the southern and western portions of the quarry were used to dispose of nonhazardous solid waste in the RQL; a formal permit for sanitary waste disposal was granted by the state of Ohio in 1978. The solid waste landfill was closed in 1989 with a compacted soil cover. Formal closure under Ohio solid waste regulations was completed in May 1990.

Landfill wastes may include domestic, commercial, and industrial solid and liquid wastes, including explosives [e.g., 2,4,6-trinitrotoluene (2,4,6-TNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), Composition B], napalm, gasoline, acid dip liquor, annealing residue (e.g., sulfuric acid, shell casings, sodium orthosilicate, chromic acid, and alkali), aluminum chloride, and inert material. Interviews with former RVAAP personnel have indicated that much of the landfilled wastes and debris at the abandoned quarry were removed in the early 1980s.

ES.2.1 Contaminant Occurrence and Distribution

Groundwater

Groundwater contains low, but consistently detectable, concentrations of explosive compounds and the propellant nitroglycerin. No explosives exceeded U.S. Environmental Protection Agency (EPA) Region 9 tap water preliminary remediation goals (PRGs). Nitroglycerin was less than its PRG. Arsenic, iron, and manganese levels exceeded EPA Region 9 tap water PRGs in a majority of samples. Multiple trace metals were present above facility-wide background criteria, as well as Ohio drinking water standards in both unfiltered and filtered samples. The most prevalent of these were aluminum, arsenic, cobalt, manganese, mercury, nickel, and zinc. Sporadic detections of bis(2-ethylhexyl)phthalate and volatile organic compounds (VOCs) were noted. Toluene and methylene chloride were the most frequently detected VOCs. No VOC results exceeded Ohio primary maximum contaminant levels. Bis(2-ethylhexyl)phthalate (four results) and benzene (one result) were the only semivolatile organic compound (SVOC) or VOC to exceed EPA Region 9 tap water PRGs. The upgradient well (RQLmw-006) and two wells (RQLmw-007 and RQLmw-008) located at the toe of the landfill typically had the highest percentages of detected contaminants. The furthest downgradient well (RQLmw-011) also had a comparatively high frequency of metals above background criteria.

Sediment

Multiple metals and cyanide were detected in initial phase sediment samples in excess of facility-wide background criteria. The maximum detected values for all inorganic analytes exceeded their respective background criteria where available. A number of metals also exceed EPA Region 9 soil screening values for leaching to groundwater. Numerous SVOCs, primarily polyaromatic hydrocarbons (PAHs), were also detected at low concentrations. Volatile constituents were sporadic and limited to estimated concentrations of acetone, 2-butanone, and methylene chloride below reporting limits. Seven explosive compounds were detected at low concentrations in at least one sample. The most frequently detected were 2,4,6-TNT (three detects) and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) (eight detects). Nitrocellulose was detected in three samples.

Surface Water

Aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, thallium, vanadium, and zinc concentrations in surface water exceeded facility-wide surface water background criteria on at least two of nine sampling events. Iron and manganese exceed their respective Ohio statewide surface water quality criteria; however, background values for these constituents also exceed these criteria. Arsenic, iron, manganese, and lead levels exceeded EPA Region 9 tap water PRGs in at least 30 percent of the samples collected. Metals detected above background occurred primarily in the dry season when quarry pond water levels were extremely low, which likely produced evaporative concentration of dissolved constituents. One explosive (4-nitrotoluene) was detected only on one occasion, and propellants were not detected. Acetone, methylene chloride, and tetrachloroethene were each detected on one occasion. No SVOCs were detected. Aldrin was detected in one sample and was the only detected pesticide or PCB. Of the detected organic compounds, aldrin and methylene chloride each exceeded the EPA Region 9 tap water PRG.

ES.2.2 Hydraulic and Geochemical Data

Potentiometric surface hydrographs were constructed from continuous water level data collected at two-hour intervals from the six new wells and quarry pond stilling well from July 1998 through July 15, 1999. Manual water level measurements from all wells and visual readings of the staff gauge collected on a monthly frequency were used to develop potentiometric surface maps for each sampling event.

The hydrographs show that well RQLmw-006 was consistently upgradient during dry periods of the year. During baseflow conditions, the pond surface represents the water table and the pond likely acts as a groundwater discharge point as a result of increased evapotranspiration rates during the summer. Wells RQLmw-007, RQLmw-008, and RQLmw-009, located along the toe of RQL, had nearly identical groundwater elevations and storm event response patterns and are hydraulically connected to the quarry pond. Wells RQLmw-010 and RQLmw-011 were consistently downgradient throughout the duration of the monitoring effort and showed strikingly similar responses to precipitation events.

Potentiometric data indicate that, during the wet season, enough hydraulic head is generated so that the quarry pond acts as a recharge point for groundwater, resulting in localized radial flow outward from the pond. Following significant rainfall events, the rapid and large responses in wells at the toe of RQL indicate that localized, short-term horizontal gradient reversals occur due to increased recharge from the pond.

Hydraulic data and major ion geochemistry indicate that fracture flow paths are sufficiently well connected so that new and existing wells monitor essentially the same flow system from a hydraulic and geochemical perspective.

ES.3 RELATED CERCLA ACTIVITIES

Load Line 1, located approximately 244 m (800 feet) to the south of RQL, is a known source area for explosives, propellants, metals, and PCBs/pesticides (USACE 1998b). Data obtained during the course of Phase I remedial investigation activities have not confirmed that Load Line 1 is a source of explosives contamination to groundwater. This class of compounds was not detected in the well located closest to RQL in the northern portion of Load Line 1 (LL1MW-067). Available potentiometric data indicate that the northern portion of the load line is hydraulically sidegradient or even possibly upgradient of RQL; thus, groundwater flow toward RQL is possible via fracture pathways. While metals contaminants were observed in Load Line 1 groundwater samples, high adsorption coefficients for this class of constituents may significantly reduce long-distance transport to RQL. Additional groundwater data are being collected at Load Line 1 under the scope of a Phase II remedial investigation. These data may provide further information on whether Load Line 1 is a potential source term for groundwater contaminants at RQL.

ES.4 CONCEPTUAL SITE MODEL AND CONCLUSIONS

Using available data collected during the Groundwater Investigation for RQL, a conceptual site model (CSM) was developed that provides an integrated summary of potential contaminant sources, impacted environmental media, contaminant occurrence and distribution, and groundwater and contaminant migration mechanisms.

ES.4.1 Source Term and Release Mechanisms

Four potential source terms were evaluated as part of development of the CSM: (1) RQL, (2) quarry pond sediment, (3) Load Line 1, and (4) waste materials in place beneath RQL from historical disposals between 1941 and 1976. As noted above, Load Line 1 is not thought to represent a significant source term for RQL groundwater based on available data. Results of the Groundwater Investigation indicate that RQL and/or underlying historical wastes are a source term for metals, explosives, nitroglycerin, and trace levels of VOCs to groundwater via infiltration of precipitation and leaching either through the soil cover layer or from upslope areas beneath the edge of the cover. Source differentiation between RQL and underlying wastes disposed between 1941 and 1976 cannot be made using available data.

Review of signature contaminants in the quarry sediments (cyanide, PAHs, and explosives) do not provide conclusive evidence that they act as a secondary source term to groundwater or surface water. A potential does exist that the quarry sediments may contribute some metals contaminants to groundwater.

ES.4.2 Groundwater Flow and Contaminant Migration Pathways

Groundwater flow at Ramsdell Quarry occurs primarily through permeable fracture pathways within bedrock. Infiltration occurs almost directly to bedrock throughout a majority of the site. While the sediment layer present in the quarry pond may dampen recharge effects to some degree, hydrographs for the wells located at the toe of the landfill clearly indicate rapid, strong response to storm events.

During dry periods, groundwater flow is consistently to the north–northeast providing the mechanism for contaminant migration to wells located at the toe of RQL and to RQLmw-011. During the wet season of the year, the quarry pond acts as a recharge point for groundwater and produces sufficient hydraulic head to generate slight, localized horizontal flow gradient reversals, which produce short-term radial flow outward from the pond. These reversals likely allow migration of contaminants to upgradient well RQLmw-006.

ES.4.3 Uncertainties

Uncertainties are inherent in the CSM where selected data do not exist or are sparse. The uncertainties within the CSM for the RQL include the following:

- Uncertainty exists regarding the nature and types of contaminants to be expected from RQL and/or historical wastes (1941–1976) due to lack of detailed waste inventories.

- Due to extremely dry conditions during the investigation, the degree of recharge provided by the quarry pond and the duration and severity of groundwater flow reversals under typical precipitation and groundwater flow conditions have not been characterized.

- Because of the dry conditions stated above, the degree to which quarry pond sediments may act as a secondary source under typical hydrologic conditions has not been characterized. Under average rainfall conditions, leachate development and mass transfer of contaminants may be greater than during conditions represented by this study. Alternately, increased rainfall could potentially dilute contaminant concentrations during partitioning to groundwater.

ES.4.4 Conclusions

Summary conclusions of the study as related to the project DQOs are as follows:

- Assessment of site hydrogeology and quality of shallow groundwater beneath the site using the new monitoring network indicates that RQL and/or underlying historical wastes are sources for metals, VOCs, explosives, and low concentrations of propellants via leaching mechanisms.

- Although contaminants were consistently detected in groundwater at RQL, overall severity of groundwater quality impacts is low. Few inorganic constituents exceeded EPA Region 9 tap water PRGs on a consistent basis; organic compounds rarely exceeded their criteria. Migration of contaminants in groundwater appears to be limited based on the lack of signature explosives in wells furthest downgradient of RQL.

- The Ramsdell Quarry pond (surface water and sediment) does not appear to represent a significant source of contaminant flux to groundwater, with the possible exception of metals.

- The Ramsdell Quarry pond is hydraulically connected with shallow groundwater and is a source of recharge during the wet season.

- Analytical results suggest episodic flushing of metals and anions with generally higher concentrations occurring in the wet season. Seasonal variation in the frequency of detection of explosives was not observed. However, the maximum detected values for five of eight detected explosives occurred during the dry season indicating dilution effects during the wet season. Almost all detected VOC values occurred in the dry season.

- Comparison of potentiometric data and major ion chemistry from the new and existing monitoring networks shows that the wells monitor the same flow system from a hydraulic and geochemical perspective.

ES.5 RECOMMENDATIONS

The following recommendations are made based on the results of this investigation:

- Continue sampling of the existing groundwater monitoring network in accordance with Ohio Administrative Code (OAC) 3745-27-10, as evaluation of existing data does not indicate extensive or significant migration of contaminants.

- Utilize EPA Region 9 tap water PRGs as indicators for potential future increases in contaminant extent or flux from RQL.

- Evaluate data from future monitoring at RQL with respect to additional groundwater results obtained from Load Line 1 during the course of the Phase II RI to assess whether contaminant migration from upgradient source areas may occur in the future.

1.0 INTRODUCTION

This report presents the results of the Groundwater Investigation of Ramsdell Quarry Landfill (RQL) at the Ravenna Army Ammunition Plant (RVAAP), Ravenna, Ohio. This investigation was conducted by Science Applications International Corporation (SAIC) for RVAAP under contract DACA27-97-D-0025, Delivery Order 003, with the U.S. Army Corps of Engineers (USACE), Louisville District. The investigation was conducted consistent with Department of Defense Installation Restoration Program (IRP) guidelines, following work plans approved by the Ohio Environmental Protection Agency (Ohio EPA), Northeast District Office, Division of Solid and Infectious Waste.

The RQL Groundwater Investigation at RVAAP (Figure 1-1) was conducted from July 1998 through June 1999 to provide supplemental characterization of the shallow groundwater flow regime and chemical water quality at this closed solid waste disposal facility. This investigation was conducted independently of semiannual post-closure monitoring of the RQL Landfill required under Ohio Administrative Code (OAC) 3745-27-10, currently conducted by TolTest, Inc. However, data from the investigation may be used to establish that the new groundwater monitoring system meets the requirements of OAC 3745-27-10(B). In addition, sampling and analytical protocols conducted in February, April, and May 1999 were adjusted to be consistent with OAC 3745-27-10 requirements and to allow use of the data generated by this investigation to satisfy reporting requirements of the post-closure program.

1.1 PURPOSE OF STUDY

The purpose of the Groundwater Investigation at RQL is to determine the shallow groundwater hydrogeologic conditions, including groundwater flow direction, seasonal changes, and the hydraulic and geochemical relationships between the surface water in the quarry pond and the groundwater. These characteristics must be clearly defined to evaluate whether the closed landfill is in compliance with Ohio solid waste post-closure requirements. The Groundwater Investigation was designed to close data gaps in the RQL post-closure monitoring program and address potential groundwater impacts related to historical operations at Ramsdell Quarry. The following data quality objectives (DQOs) for the RQL Groundwater Investigation were developed jointly by the Ohio EPA, USACE, RVAAP, and SAIC:

- Assess the hydrogeologic conditions and groundwater quality in shallow groundwater beneath the site using newly installed monitoring wells of known integrity suited to this purpose.

- Evaluate the Ramsdell Quarry pond (surface water and sediment) for evidence of chemical contamination either through groundwater influx into the pond or as a result of incipient contamination from historical operations on the quarry floor.

- Provide a comparative assessment of water levels in the Ramsdell Quarry pond and surrounding monitoring wells to evaluate potential hydraulic connection between the pond and shallow groundwater and identify whether the pond is a source of recharge.

- Conduct quarterly monitoring of newly installed monitoring wells and sampling during baseflow conditions (dry season) and following a storm event to provide characterization of groundwater chemical quality and examine potential episodic migration of contamination in relation to rainfall events.

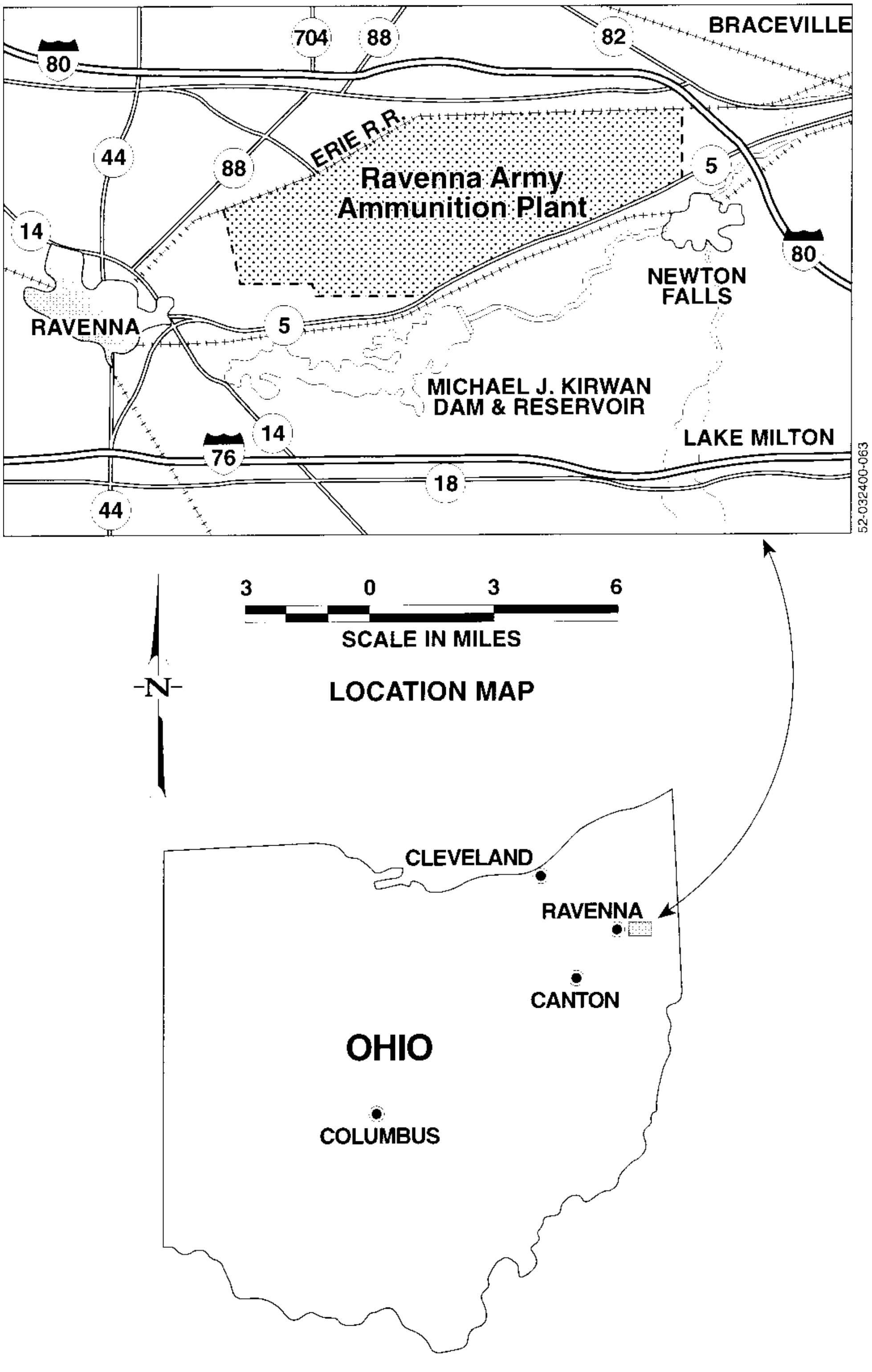


Figure 1-1. General Location and Orientation of RVAPP

- Conduct a comparative analysis of hydrologic and chemical data from newly installed wells versus an existing monitoring network to determine if geochemical stratification exists within the groundwater system and whether distinct hydraulic systems exist within the bedrock interval.

To achieve the project DQOs, the general scope of the investigation included an initial phase of work in July 1998 and a follow-on phase. Results of the initial phase of the investigation were presented in the *Initial Phase Report, Groundwater Investigation Ramsdell Quarry Landfill, Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 1999a).

In the follow-on phase of the investigation, additional monitoring activities were conducted including:

- collection of groundwater samples from the new monitoring well network and quarry pond surface water/sediment during three quarterly monitoring events (October 1998, February 1999, April 1999).

- collection of groundwater samples from the new monitoring well network and quarry pond surface water/sediment during dry season baseflow conditions (September 1998) and during wet season conditions following a storm event (May 1999).

- collection of long-term water levels from July 1998 to July 1999 using automated equipment in the new monitoring well network and the Ramsdell Quarry pond staff gauge (when weather conditions allowed).

- collection of manual water level measurements from all wells at the site and the quarry pond staff gauge on a monthly frequency.

In addition, precipitation data were obtained from a rain gauge located at Ramsdell Quarry maintained by TolTest, Inc. for the purposes of long-term monitoring of the Ramsdell Quarry under OAC 3745-27-10(B). These data were incorporated into the groundwater investigation to examine aquifer response to rainfall events and identify if storm pulse contaminant migration mechanisms may be active at the site.

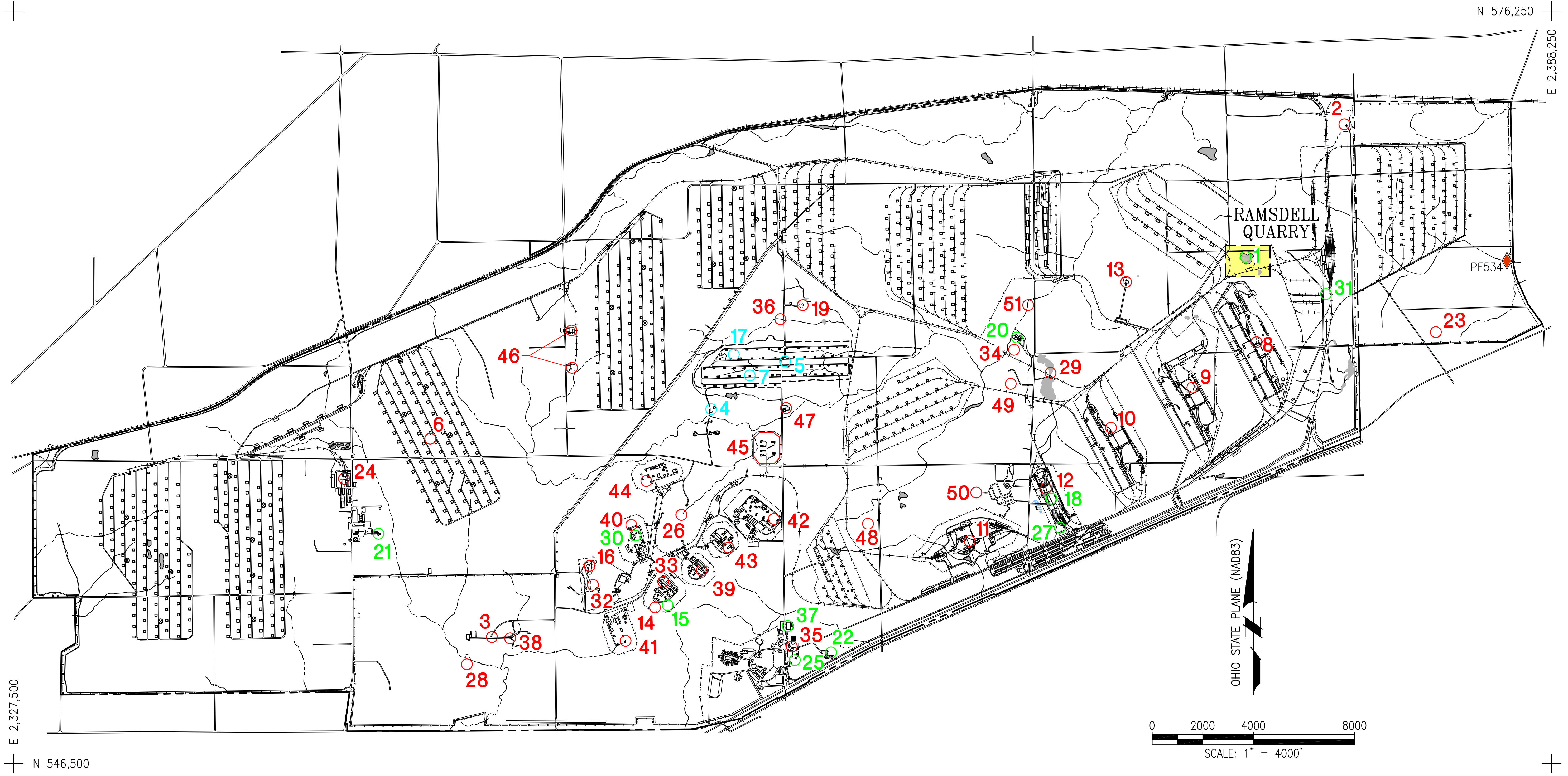
Summary results for the follow-on work through the April 1999 monitoring event were presented in a series of three separate quarterly letter reports including: (1) September and October 1998 sampling events (SAIC 1998); (2) February 1999 sampling event (SAIC 1999a); and (3) April 1999 sampling event (SAIC 1999b). The results for the storm flow sampling event (May 1999) are presented exclusively in this report.

1.2 SITE BACKGROUND

A detailed history of process operations and waste processes for each area of concern (AOC) at RVAAP is presented in the *Preliminary Assessment for the Characterization of Areas of Concern for the Ravenna Army Ammunition Plant, Ravenna, Ohio* (USACE 1996b). The following is a summary of the operational history and potential related contaminants for RQL.

1.2.1 Operational History and Site Description

Ramsdell Quarry is located in the northeastern portion of RVAAP and encompasses about 5.7 ha (14 acres) (Figures 1-2 and 1-3). The quarry was excavated about 9 to 12 m (30 to 40 feet) below existing grade into the Sharon Member of the Pottsville Formation (Figure 1-4). The original unconsolidated glacial material overlying the sandstone was only a few feet (less than 10 feet) thick



LEGEND OF SITES:

1	RAMSDELL QUARRY LANDFILL
2	ERIE BURNING GROUNDS
3	DEMOLITION AREA 1
4	DEMOLITION AREA 2
5	WINKLEPECK BURNING GROUNDS
6	C BLOCK QUARRY
7	BLDG 1601 HAZARDOUS WASTE STORAGE
8	LOAD LINE 1 AND DILUTION/SETTLING POND
9	LOAD LINE 2 AND DILUTION/SETTLING POND
10	LOAD LINE 3 AND DILUTION/SETTLING POND
11	LOAD LINE 4 AND DILUTION/SETTLING POND
12	LOAD LINE 12 AND DILUTION/SETTLING POND
13	BLDG 1200 AND DILUTION/SETTLING POND
14	LOAD LINE 6, EVAPORATION UNIT
15	LOAD LINE 6, TREATMENT PLANT
16	QUARRY LANDFILL/FORMER FUZE & BOOSTER BURNING PITS
17	DEACTIVATION FURNACE
18	LOAD LINE 12 PINK WASTEWATER TREATMENT
19	LANDFILL NORTH OF WINKLEPECK BURNING GROUND
20	SAND CREEK SEWAGE TREATMENT PLANT
21	DEPOT SEWAGE TREATMENT PLANT
22	GEORGE ROAD SEWAGE TREATMENT PLANT
23	UNIT TRAINING SITE WASTE OIL TANK
24	RESERVE UNIT MAINTENANCE AREA WASTE OIL TANK
25	BLDG 1034 MOTOR POOL WASTE OIL TANK
26	FUZE BOOSTER AREA SETTLING TANKS
27	BLDG 854–PCB STORAGE
28	MUSTARD AGENT BURIAL SITE
29	UPPER AND LOWER COBBS POND COMPLEX
30	LOAD LINE 7 PINK WASTEWATER TREATMENT PLANT
31	ORE PILE RETENTION POND
32	40– AND 60–MM FIRING RANGE
33	FIRESTONE TEST FACILITY
34	SAND CREEK DISPOSAL ROAD LANDFILL
35	1037 BUILDING–LAUNDRY WASTEWATER SUMP
36	PISTOL RANGE
37	PESTICIDE STORAGE BUILDING T–4452
38	NACA TEST AREA
39	LOAD LINE 5 / FUZE LINE 1
40	LOAD LINE 7 / BOOSTER LINE 1
41	LOAD LINE 8 / BOOSTER LINE 2
42	LOAD LINE 9 / DETONATOR LINE
43	LOAD LINE 10 / PERCUSSION ELEMENT
44	LOAD LINE 11 / ARTILLERY PRIMER
45	WET STORAGE AREA
46	BUILDINGS F–15 AND F–16
47	BUILDING T–5301 DECONTAMINATION
48	ANCHOR TEST AREA
49	CENTRAL BURN PITS
50	ATLAS SCRAP YARD
51	DUMP ALONG PARIS–WINDHAM ROAD
○	CERCLA
○	RCRA
○	OTHER REGULATORY
◆	SURFACE WATER QUALITY MONITORING STATION PF534

US Army Corps
of Engineers
Louisville District

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO
FACILITY MAP

DRAWN BY:	REV. NO./DATE:	CAD FILE:
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Figure 1–2. RVAAP AOC Map

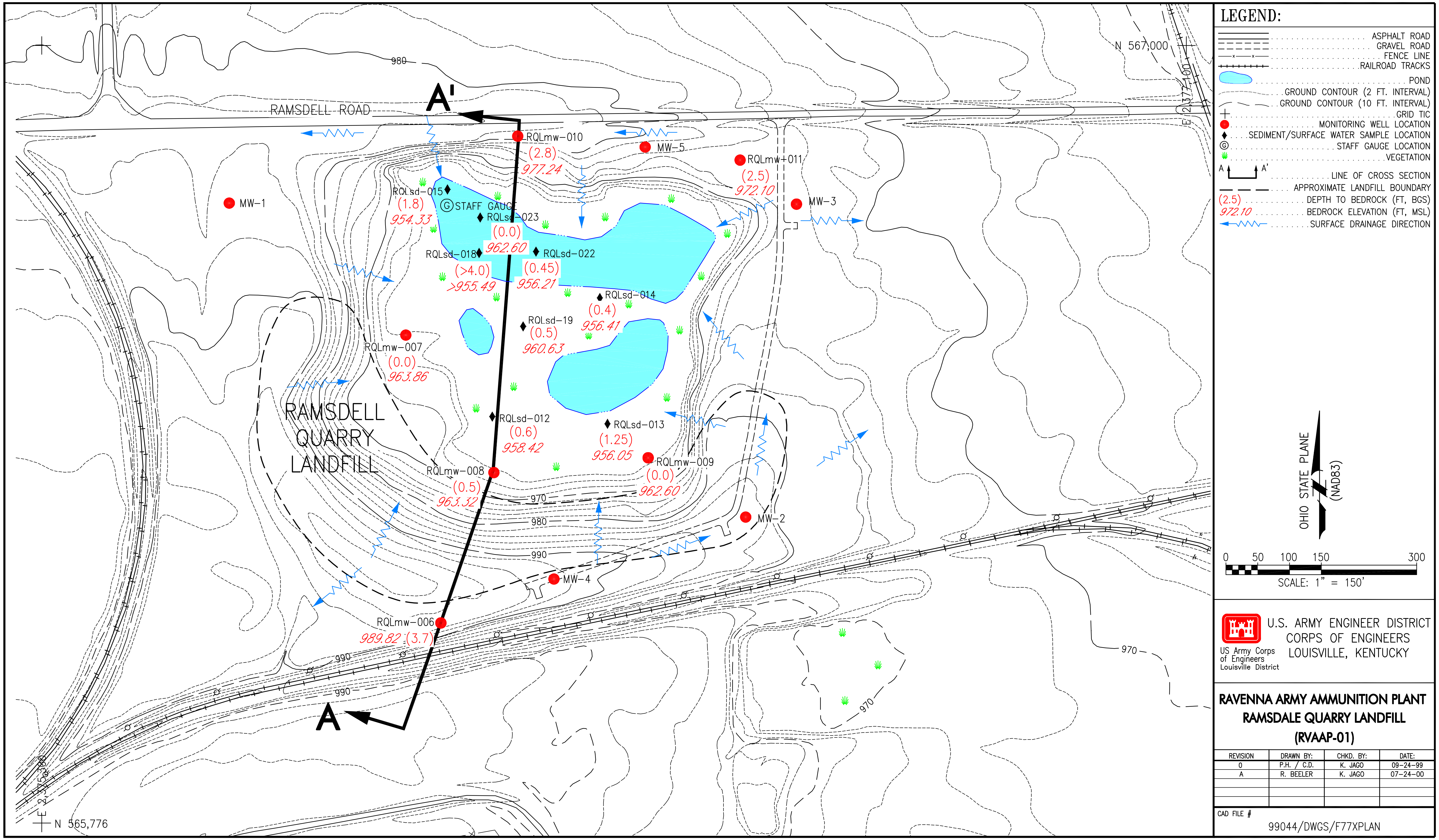
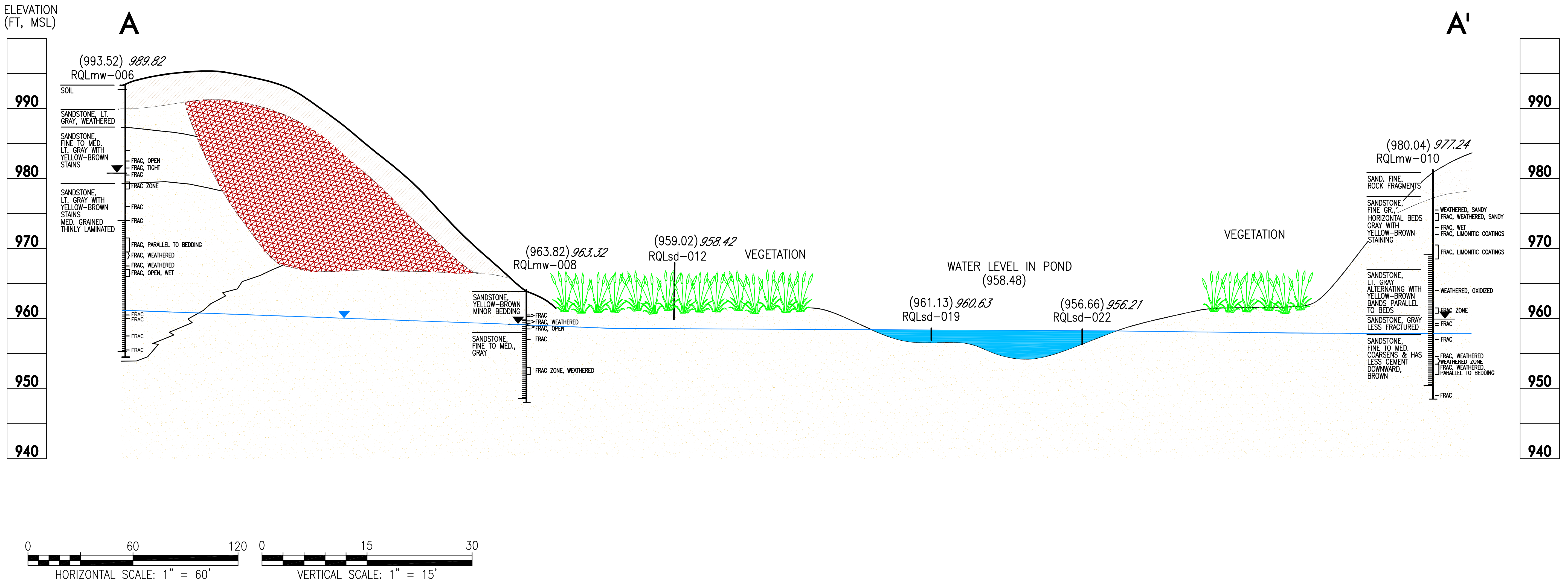


Figure 1-3. Ramsdell Quarry Site Map and Groundwater Investigation Sampling Locations



REFERENCE FIGURE 2-3. FOR CROSS-SECTION LOCATION.

LEGEND:

▼	STATIC WATER LEVEL
☐	COMPACTED SOIL COVER
▨	WASTE MATERIAL
☐	SAND
☐	SANDSTONE
⌒	EXTENT UNKNOWN
FRAC	FRACTURE ZONE
963.32	BEDROCK ELEVATION (FT, MSL)
(963.82)	GROUND SURFACE ELEVATION (FT, MSL)
▼	WATER LEVEL DURING DRILLING
	WELL SCREEN

US Army Corps of Engineers Louisville District

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO
RAMSDELL QUARRY LANDFILL
(RVAAP-01)

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Figure 1-4. Geologic Cross Section of Ramsdell Quarry

and appears to have been entirely removed. The excavated material, consisting of sandstone and quartz pebble conglomerate was used for road and construction ballast. Quarry operations were discontinued about 1941.

The western and southern portions of the abandoned quarry was subsequently used for landfill operations (RQL) between 1941 and 1976 (Figure 1-3). No information is currently available regarding the types of landfill wastes disposed of during this period. From 1976 until the landfill was closed in 1989, only nonhazardous solid waste was deposited in the RQL. In 1978, a portion of the abandoned quarry was permitted as a sanitary landfill by the state of Ohio. The permit required a 30-m (100-foot) buffer be maintained between the landfill and the pond; the extent of the pond prior to this time is not known. Interviews with former RVAAP personnel have indicated that much of the landfilled wastes and debris at the abandoned quarry were removed in the early 1980s. Closure of the permitted sanitary landfill was completed in May 1990 under state of Ohio solid waste regulations (OAC 3745-27-10). A requirement of closure was installation and semiannual monitoring of monitoring wells MW-1 through MW-5 (Figure 1-3).

In addition, from 1946 to the 1950s, the bottom of the quarry was used to burn waste explosives from Load Line 1 and napalm bombs. Approximately 18,000 225-kg (500-pound) incendiary or napalm bombs were reported to have been burned in the abandoned quarry. Liquid residues from annealing operations were also dumped in the quarry.

Based upon available landfill waste information and past uses of the abandoned quarry, wastes may include domestic, commercial, and industrial solid and liquid wastes, including explosives [e.g., 2,4,6-trinitrotoluene (2,4,6-TNT); hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX); Composition B], napalm, gasoline, acid dip liquor, annealing residue (e.g., sulfuric acid, shell casings, sodium orthosilicate, chromic acid, and alkali), aluminum chloride, and inert material (Jacobs Engineering 1989).

A much smaller quarry (also abandoned) was located directly southeast of RQL (Figure 1-3). Although some aerial photographs have shown a small pond in this location, the pond is evidently of seasonal character, because no standing water was present at this location at the time of the field investigation. No documentation of waste disposal or treatment exists for this quarry.

1.2.2 Topography, Surface Water, and Site Geology

Figures 1-3 and 1-4 depict topographic and geologic conditions at the Ramsdell Quarry. Because of former quarry operations, the RQL surroundings are characterized by bedrock often exposed on the ground surface or thin soil cover. Ramsdell Quarry is underlain by weathered, fractured, fine- to medium-grained quartz sandstone of the Sharon Member of the Pennsylvanian Pottsville Formation. Bedrock is thinly to medium-bedded with prevalent cross bedding. Topographic relief between the surface of the pond and the top of the closed landfill is about 13 m (40 feet), representing the former extent of quarrying in this area. The closed landfill is U-shaped and has a compacted-soil cover that is vegetated and appears to be intact.

The quarry pond is generally less than 1.3 m (4 feet) deep and is underlain by thin deposits of sediment over bedrock. During the period of this groundwater investigation, very dry conditions persisted at RVAAP. The pond dried up on two occasions; once in the fall of 1998 and again in the late spring and summer of 1999. Personnel at RVAAP indicated that the pond had not dried completely at least since the time of closure of the landfill. Figures 1-5 and 1-6, respectively, illustrate conditions at the site during full pool levels in the spring 1998 and in July 1999 when the pond was dry. No perennial streams exist in the immediate vicinity of the site.

Figure 1-5. Site Conditions at Ramsdell Quarry, Spring 1998

Figure 1-6. Site Conditions at Ramsdell Quarry, Summer 1999

Several drainage ways and ditch lines are located along access roads and the rail line; however, these contain water only during storm flow conditions. Overall drainage patterns in the immediate site vicinity are toward the quarry pond, which is the lowest point in the area. No surface water drainage out of the quarry pond occurs (Figure 1-3).

1.2.3 Previous Investigations

Previous investigations at Ramsdell Quarry include monitoring related to post-closure of RQL and the initial phase of this Groundwater Investigation. A summary of the post-closure monitoring program is included in the following sections. Results of the initial phase of the Groundwater Investigation were presented in the Initial Phase Groundwater Investigation Report (USACE 1999a). A synopsis of the results of the initial phase of the Groundwater Investigation is also included in the following sections. The initial phase data have been incorporated into hydrologic and water quality evaluations included in this final report to ensure that a complete representation of site conditions is provided.

In addition to these studies, the USACE completed a topographic survey (± 0.02 feet) of RQL in February 1998, including collection of new elevation data on the existing monitoring wells to correct discrepancies in water level elevations. Both new and existing monitoring wells were re-surveyed during the initial phase of the Groundwater Investigation to ensure that recent, consistent data were obtained for comparative purposes. A comparison of 1997 survey data for existing wells with that obtained in 1998 (Table 1-1) is as follows:

Table 1-1. Comparison of 1997 Survey Data and 1998 Survey Data for Existing Monitoring Wells at RQL

Well	Top of Riser Casing 1997 Values	Top of Riser Casing 1998 Values
MW-1	986.08	986.13
MW-2	981.92	981.90
MW-3	974.54	974.54
MW-4	991.75	991.80
MW-5	977.38	977.38

1.2.3.1 Post-Closure Monitoring Program

The plan submitted to Ohio EPA for the closure of RQL in 1989 provides additional characterization information about the site. The closure plan contains stratigraphic information as well as lithologic cross-sections showing the elevation of the lower limit of waste placement for the sanitary landfill. According to the design drawings filed as a part of this plan, the lower limit of waste placement was many feet above the water level in the pond, which was presumed to mimic the elevation of the potentiometric surface.

Groundwater samples from RQL have been collected since 1987, beginning with semiannual detection monitoring in five open boreholes. Monitoring wells MW-1 through MW-5 (Figure 1-3) were completed in these boreholes in January 1988 (USAEHA 1992). Semiannual monitoring continued until November 1991, when quarterly sampling was initiated. Quarterly sampling continued through February 1993, when semiannually monitoring was again initiated according to the requirements of OAC 3745-27-10 (March 1990). Current post-closure monitoring program protocols are specified in a Groundwater Monitoring Plan for RQL (Revised), dated March 1995 (RVAAP 1995). In the semiannual monitoring program, unfiltered samples are analyzed for the volatile organic compounds (VOCs), five explosives, eleven metals, and indicator parameters listed in Table 1-2. In addition, the Portage County Health Department has sampled and analyzed surface water from the Ramsdell Quarry pond.

Gaps in the monitoring data gathered by the RQL post-closure monitoring program were identified by Ohio EPA that led to uncertainty as to whether closure requirements were being met (Ohio EPA 1997). The most significant identified deficiencies included:

- Water table elevation data from the original monitoring wells (installed in 1988) show that a number of the wells failed in about 1995. Prior to 1995, wells MW-1, MW-2, MW-3, and MW-5 were consistently downgradient of well MW-4 (see Section 2.3). After 1995, only one well (MW-5) is downgradient from the RQL. Therefore, water table elevation data after 1995 were suspect. In addition, no monitoring wells were installed immediately downgradient of the toe of the landfill. Ohio regulations require a minimum of three downgradient wells at all times. These combined factors required that the existing monitoring wells be replaced.

- Lack of continuous water level data and lack of manual potentiometric measurements more frequent than those collected during semiannual sampling prevented the observation of seasonal or storm-event shifts (reversals) in groundwater flow direction.

- The original monitoring wells were screened 3 to 9 m (10 to 30 feet) below the water table, resulting in a concern that the upgradient wells do not monitor the same water-bearing interval as the downgradient well.

- No information existed to determine the relationship between water levels in the uppermost groundwater zone and the surface of the pond.

- Explosives were detected in groundwater from all five monitoring wells in at least three sampling events, thus casting some doubt as to the representativeness of the “upgradient” well (MW-4).

- Previous evaluations of groundwater at RQL have produced inconclusive results. Statistical analysis of water quality indicator parameters has shown some local impacts on the groundwater (e.g., specific conductance, total organic carbon, and total dissolved solids have been statistical triggers in both upgradient and downgradient wells).

1.2.3.2 Initial Phase of the Groundwater Investigation

The groundwater investigation was commissioned to collect and evaluate data needed to address the data gaps identified by the Ohio EPA noted above. Activities conducted during the initial phase of work in July 1998 included:

- installation, development, testing, sampling, and water level measurements from six new monitoring wells;

- testing, sampling, and water level measurements within five existing wells constructed in 1988 for hydrologic comparisons to newly installed wells;

- collection of sediment samples at eight locations and co-located surface water samples from four locations within the Ramsdell Quarry pond and bottom of the quarry to evaluate the source term; and

Table 1-2. List of Analytes for Ramsdell Quarry Landfill Semiannual Groundwater Monitoring

Inorganics (total)	**Volatile Organic Compounds**
Arsenic	Acetone
Barium	Acrolein
Cadmium	Acrylonitrile
Calcium	Benzene
Chromium	Bromodichloromethane
Copper	*cis*-1,3-Dichloropropene
Iron	*trans*-1,3-Dichloropropene
Lead	Ethylbenzene
Magnesium	Ethyl Methacrylate
Mercury	Bromoform
Potassium	Bromomethane
Nickel	2-Butanone
Selenium	Carbon Disulfide
Silver	Carbon Tetrachloride
Sodium	Chlorobenzene
Zinc	Chloroethane
Explosives	2-Chloroethyl Vinyl Ether
2,4,6-Trinitrotoluene	Chloroform
2,4-Dinitrotoluene	Chloromethane
2,6-Dinitrotoluene	Dichlorodifluoromethane
HMX	1,1-Dichloroethane
RDX	1,2-Dichloroethane
Inorganic/Indicator Parameters	2-Hexanone
Total Alkalinity	Methylene Chloride
Chloride	4-Methyl 2-Pentanone
Chemical Oxygen Demand	1,1-Dichloroethene
Cyanide	*trans*-1,2-Dichloroethene
Specific Conductivity	Styrene
Dissolved Fluoride	1,1, 2,2-Tetrachloroethene
MBAS, Colorimetric	Toluene
Nitrate (as N)	1,1,1-Trichloroethane
Ammonia (as N)	1,1,2-Trichloroethane
pH	Trichloroethene
Total Dissolved Solids	Trichlorofluoromethane
Sulfate	1,2,3-Trichloropropane
Total Organic Carbon	Vinyl Acetate
Temperature	Vinyl Chloride
Nitrate-nitrite	Xylene
Phosphorus	Phenols
Turbidity	

Source: USAEHA 1992

- construction of an instrumented staff gauge at the Ramsdell Quarry pond to examine the connection between water levels in adjacent monitoring wells and those in the pond.

The new monitoring wells installed as part of the initial phase of the project were designed to ultimately replace the existing inadequate monitoring network, pending evaluation of the results of the project and documentation, with Ohio EPA approval, that the new wells met the requirements of OAC 3745-27-10. Wells borings were drilled by coring with overdrilling of the cored interval using air rotary drilling methods. Construction characteristics of both the new and old monitoring networks are included in Table 1-3.

Table 1-3. Ramsdell Quarry Groundwater Monitoring Well Construction Data

Monitoring Well ID	1998 Surveyed Top of Casing Elevation (ft amsl)	1998 Surveyed Ground Surface Elevation (ft amsl)	Screened Interval Elevation (ft amsl)	Riser and Screen Type/Diameter (inches)
MW-1	986.13	985.53	930–940[a]	PVC/2.0
MW-2	981.90	982.74	942–952[a]	PVC/2.0
MW-3	974.54	973.55	929–939[a]	PVC/2.0
MW-4	991.80	990.85	935–945[a]	PVC/2.0
MW-5	977.38	976.14	938–948[a]	PVC/2.0
RQLmw-006	995.39	993.52	954.12–974.12	PVC/2.0
RQLmw-007	965.91	963.86	947.91–957.91	PVC/2.0
RQLmw-008	966.08	963.82	947.82–957.82	PVC/2.0
RQLmw-009	964.58	962.60	946.7–956.7	PVC/2.0
RQLmw-010	982.14	980.04	947.58–967.58	PVC/2.0
RQLmw-011	976.57	974.60	942.2–962.2	PVC/2.0
Pond Staff Gauge	961.66[b]	--	--	N/A

[a] Estimated according to Ohio Drilling Co. (1988)
[b] Top of stilling well casing
amsl = above mean sea level

Hydrogeologic Data

Ramsdell Quarry is underlain by weathered, fractured, fine- to medium-grained quartzose sandstone of the Sharon Member of the Pennsylvanian Pottsville Formation. The Sharon Member is characterized by widespread cross-bedding. Lithologies appear to be quite uniform across the site, with the exception of an occurrence of a more competent (unfractured), gray, poorly sorted sandstone with thinly bedded shale at RQLmw-006 and RQLmw-011. This lithology differs significantly from the surrounding quartz sandstone in that it contains a wider range of grain sizes and other non-quartz minerals. Thin bedding-plane laminations, consisting of finer-grained gray or black material, were observed in all cores ranging in orientation from horizontal to approximately 100 degrees from the core axis. Open, re-cemented, and highly weathered fractures were observed in each of the cores. Fracturing occurs both parallel to and at oblique angles to bedding planes, as well as in massive zones. Weathering along fractures has been sufficient to completely break down the cement in some cases.

The results of the initial phase of the investigation showed that both primary (matrix intergranular) and secondary (fracture) porosity affect groundwater migration. The bulk of groundwater is transmitted via pervasive, interconnected fractures in the sandstone as evident from iron oxide staining and limonite coatings observed along fracture walls. Hydraulic conductivity values calculated from slug tests performed in the initial phase of work are provided in Table 1-4. Aggregate hydraulic conductivities were similar among all wells and were within the range expected for sandstone (Freeze and Cherry 1979).

Table 1-4. Horizontal Hydraulic Conductivities Measured During the RQL Groundwater Investigation

Monitoring Well ID	Screened Interval (depth BGS, ft)	Total Depth (ft)	Geologic Material Adjacent to Screen	Hydraulic Conductivity (cm/s)
MW-1	45–55	54.26	gray-white sandstone	1.6×10^{-3}
MW-2	35–45	44.60	white sandstone	4.7×10^{-3}
MW-3	35–45	46.86	brown sandstone	2.3×10^{-3}
MW-4	45–55	56.98	white sandstone	1.8×10^{-3}
MW-5	33–43	40.76	brown sandstone	1.5×10^{-3}
RQLmw-006	19.4–39.4	42.08	weathered, fractured sandstone	2.0×10^{-4}
RQLmw-007	5.95–15.95	18.66	weathered, fractured sandstone	9.2×10^{-3}
RQLmw-008	6–16	18.70	fractured sandstone	5.4×10^{-3}
RQLmw-009	5.9–15.9	18.84	fractured sandstone	2.0×10^{-3}
RQLmw-010	12.46–32.46	35.36	weathered, fractured sandstone	6.7×10^{-4}
RQLmw-011	12.4–32.4	35.36	weathered, fractured sandstone	3.9×10^{-4}

Source: MW-1 through MW-5, according to Ohio Drilling Co. (1988).
BGS = below ground surface

Water level measurements in the six new wells and pond staff gauge indicated a local hydraulic gradient to the northeast. Water level measurements collected during this investigation from the original five monitoring wells illustrated the same general potentiometric surface geometry, although the data may not be completely representative due to failure of the wells in 1995. Water levels in the pond appeared to mimic those in both the original monitoring wells and in the new wells, indicating vertical hydraulic communication along permeable primary and secondary flow paths in the highly fractured and weathered sandstone. The presence of a sediment layer (up to 4 feet thick) in the bottom of the pond may effectively reduce the amount of any hydraulic communication that may exist between the water-bearing zone in the sandstone and the pond, especially at times when the water level (i.e., the hydraulic head) in the pond is low.

Groundwater Quality Results

Analytical data from the new monitoring well network showed low levels of explosives such as RDX, 1,3-dinitrobenzene (1,3-DNB), and 2,4-dinitrotoluene (2,4-DNT) in both the new upgradient well (RQLmw-006) and one or more of the downgradient wells. The propellant nitroglycerine was also identified in the upgradient well, and in one downgradient well, in low concentrations. These occurrences suggested either (1) a contaminant source upgradient of the former quarry (potentially Load Line 1), or (2) reversal of flow in the groundwater system whereby contaminants from RQL, quarry pond sediment, or historical wastes beneath RQL were transported to the upgradient location. Arsenic, cobalt, and nickel were identified in filtered samples from RQLmw-006 and five or more downgradient wells. Semivolatile organic compounds (SVOCs) were not present above detection levels in groundwater. Table 1-5 presents summary results for the initial phase groundwater sampling. Section 2.1 presents additional discussion of groundwater flow patterns based on the results of the final phase of the investigation.

Table 1-5. Summary of Groundwater Analytical Results from the Initial Phase of the Groundwater Investigation[a]

Analyte	No. of Detects	Minimum	Maximum	Location of Maximum	Background Criteria	DWS[b]	Region 9 EPA PRG[c]
Filtered Metals and Cyanide							
Aluminum	2	83J	776	RQLmw-011	NB	50	36,498
Antimony	ND	--	--	--	NB	6	14.6
Arsenic	6	3.1	62.7	RQLmw-007	NB	50	0.04482
Barium	9	16.7	62.6	RQLmw-007	256	2,000	2,555
Beryllium	1	--	0.91J	RQLmw-011	NB	4	73.0
Cadmium	1	--	2.4	MW-2	NB	5	18.25
Chromium (total)	ND	--	--	--	NB	100	109.5
Cobalt	6	18.7J	206	RQLmw-006	NB	NA	2,190
Copper	1		3.4	MW-4	NB	1,300[d]	1,356
Iron	9	93.5J	140,000	RQLmw-008	1,430	300	10,950
Lead	ND	--	--	--	NB	0[d]	4
Magnesium	11	9190	67,700	RQLmw-007	15,000	NA	NA
Manganese	11	12.6J	6960	MW-5	1,340	50	876
Mercury	9	0.081J	0.1J	RQLmw-011	NB	2	3.7
Nickel	11	15J	945	RQLmw-006	83.4	100	730
Selenium	ND	--	--	--	NB	50	182.5
Silver	ND	--	--	--	NB	NA	182.5
Thallium	5	1.1J	1.9J	RQLmw-008	NB	2	2.6
Zinc	10	29.6	1040	MW-2	52.3	5,000	10,950
Cyanide	ND	--	--	--	NB	200	730
Explosives and Propellants							
2,4,6-TNT	1	--	0.27J	MW-5	NA	NA	2241
2,6-DNT	1	--	0.085J	MW-4	NA	NA	36.50
2,4-DNT	1	--	0.13J	RQLmw-008	NA	NA	73
HMX	2	0.06J	0.076J	RQLmw-011	NA	NA	1,825
RDX	3	0.12J	0.28J	MW-3	NA	NA	0.6112
Tetryl	2	0.086J	0.12J	MW-4	NA	NA	365
1,3-DNB	1	--	0.099J	RQLmw-006	NA	NA	3.65
4-nitrotoluene	1	--	0.082J	MW-5	NA	NA	60.8
Nitrobenzene	1	--	0.091J	RQLmw-011	NA	NA	3.4
Nitroglycerine	1	2.0J	2.8J	RQLmw-006	NA	NA	4.8
Volatile Organics							
Acetone	2	8.1J	9.0	RQLmw-008	NA	NA	608.3
Benzene	1	--	0.52J	RQLmw-006	NA	5	0.41
Carbon Disulfide	1	--	2.4J	RQLmw-006	NA	NA	1,043
Toluene	1	0.51J	0.72J	RQLmw-010	NA	1,000	723.4

[a] Concentrations in µg/L

[b] All Drinking Water Standards (DWS) are primary or secondary Ohio Maximum Contaminant Levels, unless indicated as federal Maximum Contaminant Level Goals.

[c] PRG values reflect most recent revisions as of December 3, 1999.

[d] Values are Maximum Contaminant Level Goals. The Safe Drinking Water action level for copper is 1,300 µg/L; the action level for lead is 15 µg/L.

J - estimated value less than laboratory reporting limits.
NA = not available or not applicable
NB = no background value available, constituent not detected in background data set
ND = not detected
NOTE: Number of detects shown in table includes duplicates as well as primary samples.

Sediment Sampling Results

Sediment and surface water samples were collected from eight locations during the initial phase of the Groundwater Investigation (Figure 1-3). Sediment samples were collected from the 0 to 0.15-m (0 to 0.5-foot), 0.15 to 0.57-m (0.5 to 2.0-foot), and 0.57 to 1.15-m (2.0- to 4.0-foot) depth intervals unless refusal occurred. Samples from the 0- to 0.15-m (0- to 0.5-foot) sampling interval were observed to contain the greatest concentrations of contaminants. Antimony and silver were never detected. Occurrences of selenium, thallium, and cadmium were limited to five or fewer of the eight sediment sampling locations. The remaining analytes were present above detection limits in nearly every sample. The maximum detected values for all inorganic analytes exceeded their respective background values where available. Maximum detected values for arsenic, barium, cadmium, chromium, nickel, selenium, thallium, zinc, 2,6-dinitrotoluene (2,6-DNT), and 2,4-DNT exceed respective U.S. Environmental Protection Agency (EPA) Region 9 soil screening criteria for leaching to groundwater. In general, where two or more depth intervals were sampled, concentrations of metals decreased with increasing depth. Cyanide was detected at 2.8 mg/kg in one sediment sample, RQLsd-023, in the 0- to 0.15-m (0- to 0.5-foot) interval. Seven explosive compounds were detected in the 0- to 0.15-m (0- to 0.5-foot) interval; octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) was present at depths of 0.15 to 0.60 m (0.5 to 2 feet) or greater. The propellant nitrocellulose was present in three samples in low concentrations. Numerous polycyclic aromatic hydrocarbons (PAHs) were present in five of the eight sediment sampling locations at concentrations up to 2000 mg/kg. VOCs in sediment were generally not present above detection levels. A summary of the metals, explosives, propellants, and VOC results for sediments is shown in Table 1-6. Where multiple depth intervals were sampled, the depth interval of the maximum concentration is noted. Section 2.4 provides additional information regarding sediment sampling conducted during the initial phase of the groundwater investigation. Complete results of the sediment sampling effort are provided in the Initial Phase Report (USACE 1999a).

Surface Water Sampling Results

Explosives, propellants, cyanide, VOCs, and SVOCs were not detected in the pond water. Iron, magnesium, and manganese were detected in most filtered surface water samples. Arsenic and barium were present in three or fewer samples at low concentrations. Comparison of unfiltered surface water sample data to statewide water quality criteria for the protection of human health (OAC 3745-1-07) indicated exceedances only for iron and manganese. For filtered samples only the maximum manganese value exceeded the statewide water quality criterion. Section 2.2 presents additional discussion of surface water quality based on results of follow-on sampling conducted during the final phase of the investigation.

1.3 REPORT ORGANIZATION

This final report encompasses the evaluation of all data collected during both the initial and follow-on phases of the groundwater investigation. Detailed discussion of initial phase field methods and activities presented in the Initial Phase Report (USACE 1999a) is not reiterated in this document. Information on follow-on activities provided in previous letter report format is reiterated in detail. Chapter 2.0 describes field activities conducted during the follow-on phase of work, as well as the results for both chemical sampling and hydrologic monitoring. A comparison of data collected from the existing and new monitoring well networks is also provided. Chapter 3.0 discusses related Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) activities. Chapter 4.0 presents a conceptual site model (CSM) for Ramsdell Quarry that provides a relational

Table 1-6. Summary of Sediment Analytical Results from the Initial Phase of the Groundwater Investigation

Analyte	No. of Detects	Minimum	Maximum	Location of Maximum	Background Criteria	EPA Region 9 Migration to Groundwater Soil Screening Level
Metals (mg/kg)						
Arsenic	12	7.6	32.5	RQLsd-022	19.50	1.0
Barium	12	33J	145	RQLsd-022	123.00	82
Beryllium	9	0.33	0.65	RQLsd-018, 0.5 to 2 feet	0.38	3.0
Cadmium	4	1.4	6.4	RQLsd-018	NB	0.4
Chromium (total)	12	8.7	30.9	RQLsd-022	18.10	2.0
Cobalt	12	5J	33.6	RQLsd-022	9.10	–
Copper	12	19.5	134	RQLsd-022	27.60	–
Iron	12	13,700	54,500	RQLsd-018, 0.5 to 2 feet	NB	–
Lead	12	21.1	87.2	RQLsd-022	27.40	–
Magnesium	12	1300J	58,000J	RQLsd-022	2760.0	–
Manganese	12	189J	2590J	RQLsd-022	1950.0	–
Mercury	12	0.033J	0.89J	RQLsd-012	0.06	–
Nickel	12	12.8	86.8	RQLsd-022	17.70	7.0
Selenium	5	0.6	2	RQLsd-013, 0.0 to 0.5 feet	1.70	0.3
Thallium	3	1.2	1.9	RQLsd-022	0.89	0.4
Vanadium	12	9J	40.7	RQLsd-013, 0.0 to 0.5 feet	26.10	30
Zinc	12	100	894	RQLsd-022	532.0	62
Cyanide	1	2.8	2.8	RQLsd-023, 0.0 to 0.5 feet	NB	2.0
Volatile Organics (mg/kg)						
Acetone	11	0.0037J	0.026J	RQLsd-024, 0.5 to 2 feet	NA	0.8
2-butanone	3	0.0065J	0.010J	RQLsd-023	NA	–
Methylene chloride	1	--	0.00073J	RQLsd-019	NA	0.001
Explosives and Propellants (mg/kg)						
2,3,6-TNT	3	0.021J	0.47J	RQLsd-018 and RQLsd-109	NA	–
2,6-DNT	1	0.076J	0.076J	RQLsd-012, 0.0 to 0.5 feet	NA	0.004
2,4-DNT	1	0.034J	0.034J	RQLsd-023, 0.5 to 2.0 feet	NA	0.004
HMX	8	0.11J	0.14	RQLsd-018, 1.0 to 2.0 feet	NA	–
2-nitrotoluene	1	0.07J	0.07J	RQLsd-013, 0.0 to 0.5 feet	NA	–
3-nitrotoluene	2	0.071J	0.13J	RQLsd-023, 1.0 to 2.0 feet	NA	–
4-nitrotoluene	1	0.07J	0.07J	RQLsd-012, 0.0 to 0.5 feet	NA	–
Nitrocellulose	3	1.7J	4.3	RQLsd-015, 0.0 to 0.5 feet	NA	–

J - estimated value less than laboratory reporting limits.
NA = not available or not applicable
NB = no background value available, constituent not detected in background data set.

framework depicting general hydrogeologic conditions, contaminant source terms and release mechanisms, contaminant occurrence and distribution, and groundwater and contaminant migration pathways. Chapter 5.0 contains conclusions regarding the technical adequacy of the new monitoring well network relevant to OAC 3745-27-10 and recommendations for future monitoring and characterization activities. Appendixes A through J contain analytical results, monthly manual water level data, rainfall data, field log information, potentiometric maps and hydrographs, and quality control summary report.

2.0 INVESTIGATION RESULTS

All sampling activities, including sample collection and preservation, decontamination, sample management, and documentation for the initial and follow-on phases of the Groundwater Investigation at RQL were conducted according to guidance in the *Facility-Wide Sampling and Analysis Plan for Ravenna Army Ammunition Plant* (USACE 1996a) and the *Sampling and Analysis Plan Addendum for the Groundwater Investigation of the Former Ramsdell Quarry Landfill* (USACE 1998a).

Initial phase work, including the first round of sampling, was conducted in July 1998. Quarterly follow-on sampling was conducted in October 1998, February 1999, and April 1999. The latter two quarterly sampling events were originally scheduled for January and March 1999. However, in response to technical comments from the Ohio EPA and the USACE on the initial phase report, these events were shifted to February and April, respectively, to coincide and eliminate redundancies with the ongoing post-closure monitoring program. The analyte lists were modified to be consistent with OAC 3745-27-10, and the data were submitted to the subcontractor preparing semiannual statistical evaluations and reporting. Two special sampling events were conducted as scheduled and included dry season/baseflow sampling in September 1998 and wet season/storm event sampling in May 1999.

Manual water level measurements were collected monthly throughout the project from all monitoring wells and the staff gauge. Automated, continuous water level measurements were collected (2-hour intervals) beginning in July 29, 1998 and ending July 15, 1999. A complete record of water level measurements were collected during the period from all monitoring wells; however, a large portion of data are missing from the staff gauge stilling well. Automated water level data are missing from the quarry pond because the transducer within the staff gauge stilling well had to be removed during the winter to avoid freeze damage. In addition, water levels within the pond fell below the transducer range over much of the period of the investigation.

2.1 GROUNDWATER QUALITY DATA

In the follow-on phase of work, the six new monitoring wells were sampled during September and October 1998 for explosives, propellants (including nitroguanidine, nitrocellulose, and nitroglycerine), Target Analyte List (TAL) metals, cyanide, VOCs, and SVOCs. Beginning with the February 1999 sampling event, the parameter list was expanded to include additional VOCs, pesticides, polychlorinated biphenyl (PCB) compounds, anions, and groundwater quality indicator parameters required by OAC 3745-27-10. Both total (unfiltered) and dissolved (filtered) TAL metals samples were collected and submitted for analysis. The validated analytical data for the follow-on phase of the groundwater investigation are presented in their entirety in Appendix A. Tables in Appendix A present the data both by analyte and by sample station.

To provide a consistent framework for evaluation of the occurrence, distribution, and severity of contamination, comparisons of detected results to three sets of criteria were performed. Ohio primary and secondary drinking water standards (DWS), which include maximum contaminant levels (MCLs) promulgated under OAC 3745-81-11, were used as part of the evaluation of groundwater quality; federal action levels were used for copper and lead. Secondly, data were compared to facility-wide background criteria developed during the Phase II Remedial Investigation (RI) for Winklepeck Burning Grounds (USACE 1999b). Because all of the new wells at RQL are bedrock wells, the bedrock filtered and unfiltered groundwater background criteria were employed for the comparison. EPA Region 9 preliminary remediation goals (PRGs) for tap water are the final set of comparative criteria used to provide an indication of severity of groundwater quality impacts. Standard method reporting limits for some VOC compounds (i.e., vinyl chloride, tetrachloroethene, trichloroethene) are higher than promulgated drinking water standards; however, any estimated detected values ("J" qualifier) between the reporting limits and the practical quantitation limit are provided.

The headspace in each well was field screened for VOCs using a hand-held photoionization detector (PID) organic vapor analyzer (OVA) during groundwater sample collection. Volatile organic vapors were not detected during field screening. In addition, field measurements of pH, temperature, specific conductance, and dissolved oxygen were recorded for each sample. All monitoring wells were purged prior to sampling using micropurge techniques and dedicated equipment, including bladder pumps and tubing. Very small amounts of water (typically less than 3 gallons) were removed from the wells during purging; no difficulties were noted in achieving requisite stabilization of groundwater quality field indicator parameters.

2.1.1 General Groundwater Geochemistry

In general, water quality in the vicinity of Ramsdell Quarry is characteristically slightly acidic with consistently elevated iron, manganese, and sulfate. Groundwater typically has low chemical oxygen demand (COD) and total organic carbon (TOC). Low but detectable concentrations of chloride are persistent. Alkalinities ranged from 14 mg/L to a maximum of 710 mg/L in well RQLmw-007 (Table 2-1). The higher alkalinity levels present in well RQLmw-007 correspond to higher pH, conductivity, and total dissolved solids values (i.e., maximum alkalinity corresponded to a maximum observed pH of 6.7). These levels observed in RQLmw-007 are somewhat anomalous considering the bedrock lithology and overall groundwater chemistry at the site.

2.1.2 Explosives and Propellants

Explosives

Trace quantities of seven explosives were detected in RQL groundwater during the follow-on phase of the investigation. The suite of explosives detected was the same as that detected during the initial phase of the investigation with the exception of 2,4,6-TNT and 2,6-DNT, which were detected in the initial phase only (wells MW-5 and MW-4, respectively). Also, 2-nitrotoluene was detected on one occasion during only the follow-on phase (well RQLmw-008, 9/19/98). All detected results for explosives constitute exceedances of background values; however, no explosive compound exceeded EPA Region 9 tap water PRGs. Figure 2-1 presents a summary of detected explosives in groundwater during both the initial and follow-on phases of the investigation. Table 2-1 provides summary statistics for all explosive compounds detected in both phases of work and lists the results of the comparison to EPA Region 9 tap water PRGs.

Of the detected explosives, nitrobenzene; 1,3-DNB; and 2,4-DNT were the most consistently detected. These three compounds were not detected during the initial phase sampling of existing wells, rather, only in the new monitoring wells during both the initial and follow-on phases of sampling. Nitrobenzene was the most prevalent compound, detected in 9 of the 36 total samples collected during the investigation. This compound was most frequently detected in well RQLmw-008 (3 of 6 samples) and was also detected at least once in every new monitoring well, except for RQLmw-010, which had no detectable quantities of explosives during the investigation. Well RQLmw-006 accounted for all five of the detected values of 1,3-DNB. Well RQLmw-008 accounted for four of the eight detected results of 2,4-DNT, as well as the maximum detected value. This compound was also detected on two occasions in wells RQLmw-006 and RQLmw-007.

Table 2-1. Summary Statistics for Detected Groundwater Constituents

Chemical	Units	Proportion Detected	Min Detect	Max Detect	Mean[a]	DWS[b]	Proportion >DWS	Background Criteria	Proportion >Background	PRG[c]	Proportion > PRG	ID of Max Concentration	Date of Max Concentration
TAL Metals													
Aluminum	mg/L	17/ 36	0.0584	15.2	0.725	0.05	17/ 36	9.41	1/ 36	36.4987	0/ 36	RQLmw-011-0108-GW	02/13/99
Aluminum (filtered)	mg/L	10/ 36	0.083	2.12	0.29	0.05	10/ 36	NB	NA	36.4987	0/ 36	RQLmw-011-0122-GW	05/27/99
Antimony	mg/L	1/ 36	0.0243	0.0243	0.00549	0.006	1/ 36	NB	1/ 36	0.0146	1/ 36	RQLmw-011-0108-GW	02/13/99
Arsenic	mg/L	23/ 36	0.0031	0.0747	0.0224	0.05	7/ 36	0.0191	15/ 36	4.4821E-05	23/ 36	RQLmw-011-0108-GW	02/13/99
Arsenic (filtered)	mg/L	22/ 36	0.0032	0.0627	0.019	0.05	6/ 36	NB	22/ 36	4.4821E-05	22/ 36	RQLmw-007-0009-GW	07/22/98
Barium	mg/L	35/ 36	0.0044	0.085	0.0318	2	0/ 36	0.241	0/ 36	2.555	0/ 36	RQLmw-008-0119-GW	05/28/99
Barium (filtered)	mg/L	35/ 36	0.004	0.0878	0.0312	2	0/ 36	0.256	0/ 36	2.555	0/ 36	RQLmw-008-0119-GW	05/28/99
Beryllium	mg/L	2/ 36	0.001	0.014	0.00375	0.004	1/ 36	NB	2/ 36	0.073	0/ 36	RQLmw-011-0108-GW	02/13/99
Beryllium (filtered)	mg/L	1/ 36	0.00091	0.00091	0.00347	0.004	0/ 36	NB	1/ 36	0.073	0/ 36	RQLmw-011-0017-GW	07/27/98
Calcium	mg/L	36/ 36	11.8	152	71.7	NA	NA	48.2	22/ 36	NA	NA	RQLmw-007-0068-GW	09/20/98
Calcium (filtered)	mg/L	36/ 36	12	159	71	NA	NA	53.1	22/ 36	NA	NA	RQLmw-007-0009-GW	07/22/98
Chromium (total)	mg/L	2/ 36	0.004	0.01	0.00983	0.1	0/ 36	0.0195	0/ 36	0.1095	0/ 36	RQLmw-006-0096-GW	10/19/98
Chromium (filtered) (total)	mg/L	1/ 36	0.0094	0.0094	0.00998	0.1	0/ 36	NB	1/ 36	0.1095	0/ 36	RQLmw-006-0096-GW	10/19/98
Cobalt	mg/L	17/ 36	0.0195	0.439	0.0673	NA	NA	NB	17/ 36	2.19	0/ 36	RQLmw-006-0117-GW	05/27/99
Cobalt (filtered)	mg/L	18/ 36	0.0187	0.438	0.0675	NA	NA	NB	18/ 36	2.19	0/ 36	RQLmw-006-0117-GW	05/27/99
Copper	mg/L	4/ 24	0.0042	0.0113	0.0196	1.3[d]	0/ 24	0.017	0/ 24	1.3557	0/ 24	RQLmw-009-0113-GW	04/11/99
Copper (filtered)	mg/L	3/ 24	0.0054	0.0214	0.021	1.3[d]	0/ 24	NB	3/ 24	1.3557	0/ 24	RQLmw-006-0103-GW	02/13/99
Iron	mg/L	33/ 36	0.148	178	34.6	0.3	30/ 36	21.5	12/ 36	10.95	14/ 36	RQLmw-008-0119-GW	05/28/99
Iron (filtered)	mg/L	31/ 36	0.0666	177	29	0.3	29/ 36	1.43	26/ 36	10.95	13/ 36	RQLmw-008-0119-GW	05/28/99
Lead	mg/L	2/ 36	0.0032	0.0435	0.00413	0.0[d]	2/ 36	0.023	1/ 36	0.004	1/ 36	RQLmw-011-0108-GW	02/13/99
Magnesium	mg/L	36/ 36	8.24	116	42.7	NA	NA	13.7	30/ 36	NA	NA	RQLmw-007-0104-GW	02/14/99
Magnesium (filtered)	mg/L	36/ 36	8.17	420	52.5	NA	NA	15	29/ 36	NA	NA	RQLmw-006-0096-GW	10/19/98
Manganese	mg/L	36/ 36	0.0677	7.66	2.65	0.05	36/ 36	1.26	22/ 36	0.876	30/ 36	RQLmw-006-0117-GW	05/27/99
Manganese (filtered)	mg/L	36/ 36	0.0539	7.72	2.67	0.05	36/ 36	1.34	21/ 36	0.876	27/ 36	RQLmw-006-0117-GW	05/27/99
Mercury[e]	mg/L	6/ 36	0.000078	0.0001	0.000181	0.002	0/ 36	NB	6/ 36	0.0037	0/ 36	RQLmw-008-0011-GW	07/22/98
Mercury (filtered) [e]	mg/L	4/ 36	0.000082	0.0001	0.000188	0.002	0/ 36	NB	4/ 36	0.0037	0/ 36	RQLmw-011-0017-GW	07/27/98
Nickel	mg/L	26/ 36	0.0163	1.47	0.179	0.1	14/ 36	0.0853	14/ 36	0.73	3/ 36	RQLmw-006-0117-GW	05/27/99
Nickel (filtered)	mg/L	26/ 36	0.0155	1.47	0.181	0.1	14/ 36	0.0834	15/ 36	0.73	3/ 36	RQLmw-006-0117-GW	05/27/99
Potassium	mg/L	36/ 36	2.21	11.4	5.07	NA	NA	6.06	10/ 36	NA	NA	RQLmw-007-0068-GW	09/20/98
Potassium (filtered)	mg/L	36/ 36	2.2	12	5	NA	NA	5.77	10/ 36	NA	NA	RQLmw-007-0009-GW	07/22/98
Selenium	mg/L	4/ 36	0.0039	0.0048	0.00491	0.05	0/ 36	NB	4/ 36	0.1825	0/ 36	RQLmw-007-0009-GW	07/22/98
Sodium	mg/L	30/ 36	1.37	26.1	7.13	NA	NA	49.7	0/ 36	NA	NA	RQLmw-007-0068-GW	09/20/98
Sodium (filtered)	mg/L	30/ 36	1.44	25.6	7.1	NA	NA	51.4	0/ 36	NA	NA	RQLmw-007-0068-GW	09/20/98
Thallium[f]	mg/L	6/ 36	0.001	0.002	0.00192	0.002	0/ 36	NB	6/ 36	0.0026	0/ 36	RQLmw-008-0011-GW	07/22/98
Thallium (filtered) [f]	mg/L	8/ 36	0.0011	0.002	0.0019	0.002	0/ 36	NB	8/ 36	0.0026	0/ 36	RQLmw-008-0069-GW	09/19/98
Zinc	mg/L	17/ 33	0.0187	1.94	0.191	5	0/ 33	0.193	6/ 33	10.95	0/ 33	RQLmw-006-0117-GW	05/27/99
Zinc (filtered)	mg/L	14/ 33	0.0195	1.91	0.18	5	0/ 33	0.0523	10/ 33	10.95	0/ 33	RQLmw-006-0117-GW	05/27/99

Table 2-1 (continued)

Chemical	Units	Proportion Detected	Min Detect	Max Detect	Mean[a]	DWS[b]	Proportion >DWS	Background Criteria	Proportion >Background	PRG[c]	Proportion > PRG	ID of Max Concentration	Date of Max Concentration
Explosives and Propellants													
1,3-Dinitrobenzene	mg/L	5/ 31	0.000063	0.000099	0.000181	NA	NA	NA	NA	0.00365	0/ 31	RQLmw-006-0007-GW	07/25/98
2,4-Dinitrotoluene (as explosive)	mg/L	8/ 33	0.000033	0.00035	0.000152	NA	NA	NA	NA	0.073	0/ 33	RQLmw-008-0105-GW	02/14/99
2-Nitrotoluene	mg/L	1/ 31	0.00016	0.00016	0.000199	NA	NA	NA	NA	0.0608	0/ 31	RQLmw-008-0069-GW	09/19/98
HMX	mg/L	3/ 32	0.00006	0.00009	0.00046	NA	NA	NA	NA	1.825	0/ 32	RQLmw-009-0070-GW	09/19/98
Nitrobenzene (as explosive)	mg/L	9/ 36	0.000044	0.00062	0.000238	NA	NA	NA	NA	0.0034	0/ 36	RQLmw-007-0097-GW	10/20/98
Nitroglycerin	mg/L	3/ 32	0.0015	0.0028	0.00246	NA	NA	NA	NA	0.0048	0/ 32	RQLmw-006-0007-GW	07/25/98
RDX	mg/L	3/ 31	0.00012	0.00049	0.000758	NA	NA	NA	NA	0.0006112	0/ 31	RQLmw-007-0111-GW	04/11/99
Tetryl	mg/L	1/ 31	0.00016	0.00016	0.000199	NA	NA	NA	NA	0.365	0/ 31	RQLmw-008-0119-GW	05/28/99
Pesticides and PCBs													
Beta-BHC	mg/L	1/ 18	0.000016	0.000016	0.0000481	NA	NA	NA	NA	3.7340E-05	0/ 18	RQLmw-010-0121-GW	05/27/99
Delta-BHC	mg/L	1/ 18	0.000031	0.000031	0.0000489	NA	NA	NA	NA	NA	NA	RQLmw-010-0121-GW	05/27/99
Endrin Aldehyde	mg/L	1/ 18	0.000012	0.000012	0.0000479	NA	NA	NA	NA	NA	NA	RQLmw-006-0117-GW	05/27/99
SVOCs													
Bis(2-ethylhexyl)phthalate	mg/L	8/ 36	0.0033	0.084	0.0114	0.006	3/ 36	NA	NA	0.0048	4/ 36	RQLmw-011-0122-GW	05/27/99
VOCs													
Acetone	mg/L	2/ 36	0.0081	0.009	0.00992	NA	NA	NA	NA	0.6083	0/ 36	RQLmw-008-0011-GW	07/22/98
Benzene	mg/L	1/ 36	0.00052	0.00052	0.00488	0.005	0/ 36	NA	NA	0.00041	1/ 36	RQLmw-006-0007-GW	07/25/98
Carbon Disulfide	mg/L	2/ 36	0.00067	0.0024	0.00481	NA	NA	NA	NA	1.0428	0/ 36	RQLmw-006-0007-GW	07/25/98
Methylene Chloride	mg/L	6/ 35	0.00058	0.0037	0.00434	0.005	0/ 35	NA	NA	0.0043	0/ 35	RQLmw-007-0097-GW	10/20/98
Tetrachloroethene	mg/L	3/ 36	0.00065	0.00066	0.00464	0.005	0/ 36	NA	NA	0.0011	0/ 36	RQLmw-006-0103-GW	02/13/99
Toluene	mg/L	6/ 36	0.00046	0.00072	0.00426	1	0/ 36	NA	NA	0.7234	0/ 36	RQLmw-010-0015-GW	07/25/98
Indicator Parameters and Anions													
Alkalinity, Total	mg/L	16/ 18	14	710	234	NA	NA	NA	NA	NA	NA	RQLmw-007-0104-GW	02/14/99
Chemical Oxygen Demand (COD)	mg/L	10/ 18	11	190	32	NA	NA	NA	NA	NA	NA	RQLmw-009-0113-GW	04/11/99
Conductivity	μmhos/cm	18/ 18	180	1300	611	NA	NA	NA	NA	NA	NA	RQLmw-007-0118-GW	05/28/99
Nitrogen, as Ammonia	mg/L	1/ 17	2	2	1.06	NA	NA	NA	NA	NA	NA	RQLmw-008-0119-GW	05/28/99
Phenols, Total	mg/L	2/ 18	0.024	0.047	0.0217	NA	NA	NA	NA	NA	NA	RQLmw-010-0121-GW	05/27/99
Total Dissolved Solids	mg/L	18/ 18	140	940	454	500	8/ 18	NA	NA	NA	NA	RQLmw-007-0118-GW	05/28/99
Total Organic Carbon	mg/L	16/ 18	1	13	4.83	NA	NA	NA	NA	NA	NA	RQLmw-007-0118-GW	05/28/99
pH	std unit	18/ 18	4.4	6.7	6.07	7.0-10.5	18/18	NA	NA	NA	NA	RQLmw-007-0104-GW	02/14/99
Chloride	mg/L	18/ 18	1.3	18.4	4.43	250	0/ 18	NA	NA	NA	NA	RQLmw-010-0121-GW	05/27/99
Sulfate	mg/L	18/ 18	29.9	380	127	250	2/ 18	NA	NA	NA	NA	RQLmw-006-0117-GW	05/27/99
Nitrate/Nitrite	mg/L	3/ 18	0.1	0.3	0.122	10	2/18	NA	NA	NA	NA	RQLmw-010-0114-GW	04/10/99

[a] Nondetects were set to one-half the reporting limit to calculate the mean values.

[b] All Drinking Water Standards (DWS) are Primary or Secondary Ohio Maximum Contaminant Levels, unless indicated as federal Maximum Contaminant Level Goals.

[c] PRGs reflect most recent revisions as of December 3, 1999.

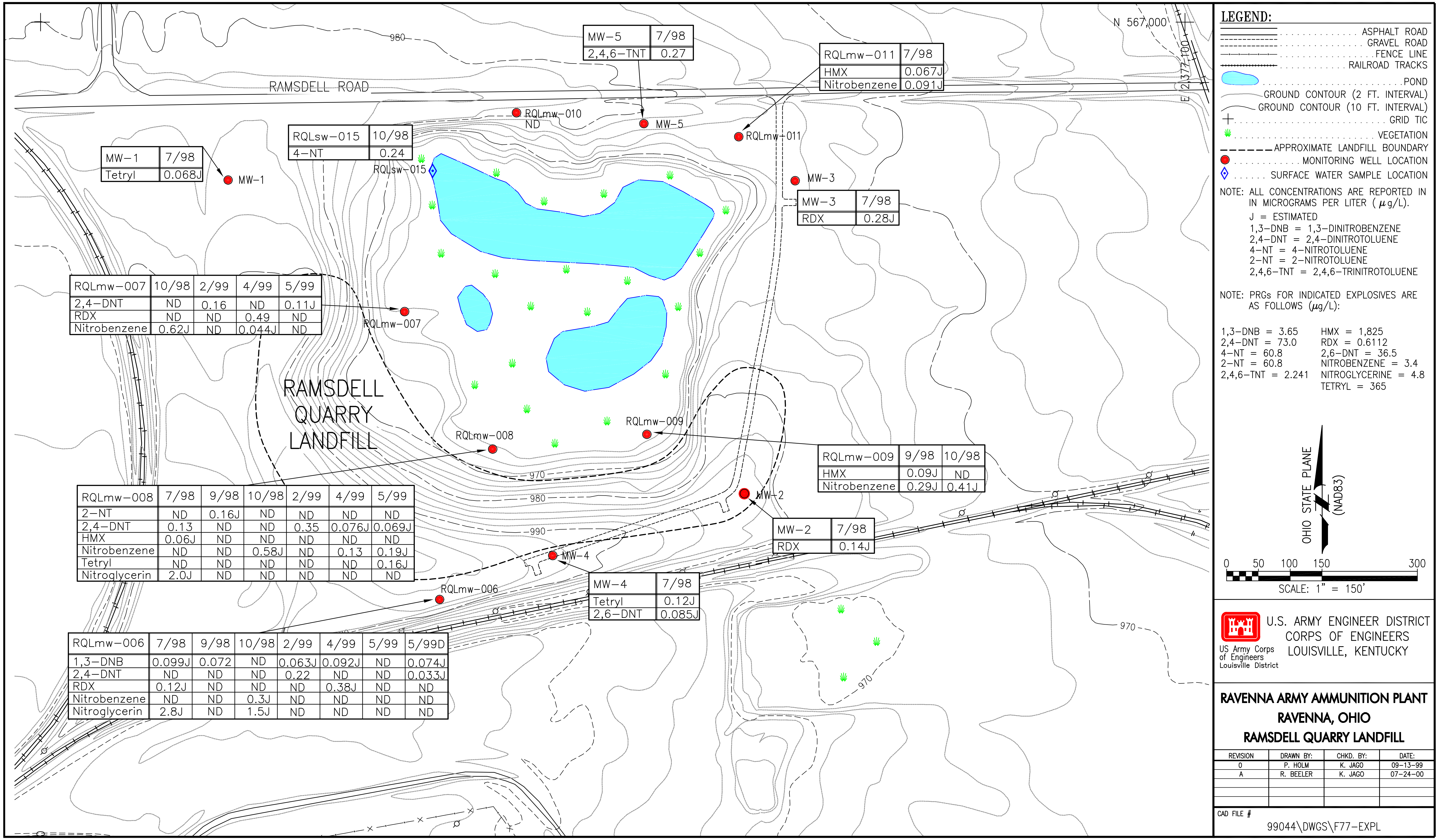
[d] Values are Maximum Contaminant Level Goals. The Safe Drinking Water Act action level for copper is 1.3 mg/L; the action level for lead is 0.015 mg/L.

[e] EPA Region 9 PRG for methylmercury was used for mercury.

[f] EPA Region 9 PRG for thallic oxide was used for thallium.

NA= No standard available or not applicable.

NB = No background values available.



MW-5	7/98
2,4,6-TNT	0.27

RQLmw-011	7/98
HMX	0.067J
Nitrobenzene	0.091J

RQLsw-015	10/98
4-NT	0.24

MW-1	7/98
Tetryl	0.068J

MW-3	7/98
RDX	0.28J

RQLmw-007	10/98	2/99	4/99	5/99
2,4-DNT	ND	0.16	ND	0.11J
RDX	ND	ND	0.49	ND
Nitrobenzene	0.62J	ND	0.044J	ND

RQLmw-009	9/98	10/98
HMX	0.09J	ND
Nitrobenzene	0.29J	0.41J

RQLmw-008	7/98	9/98	10/98	2/99	4/99	5/99
2-NT	ND	0.16J	ND	ND	ND	ND
2,4-DNT	0.13	ND	ND	0.35	0.076J	0.069J
HMX	0.06J	ND	ND	ND	ND	ND
Nitrobenzene	ND	ND	0.58J	ND	0.13	0.19J
Tetryl	ND	ND	ND	ND	ND	0.16J
Nitroglycerin	2.0J	ND	ND	ND	ND	ND

MW-2	7/98
RDX	0.14J

MW-4	7/98
Tetryl	0.12J
2,6-DNT	0.085J

RQLmw-006	7/98	9/98	10/98	2/99	4/99	5/99	5/99D
1,3-DNB	0.099J	0.072	ND	0.063J	0.092J	ND	0.074J
2,4-DNT	ND	ND	ND	0.22	ND	ND	0.033J
RDX	0.12J	ND	ND	ND	0.38J	ND	ND
Nitrobenzene	ND	ND	0.3J	ND	ND	ND	ND
Nitroglycerin	2.8J	ND	1.5J	ND	ND	ND	ND

LEGEND:

ASPHALT ROAD
GRAVEL ROAD
FENCE LINE
RAILROAD TRACKS
POND
GROUND CONTOUR (2 FT. INTERVAL)
GROUND CONTOUR (10 FT. INTERVAL)
GRID TIC
VEGETATION
APPROXIMATE LANDFILL BOUNDARY
● MONITORING WELL LOCATION
◊ SURFACE WATER SAMPLE LOCATION

NOTE: ALL CONCENTRATIONS ARE REPORTED IN IN MICROGRAMS PER LITER (μg/L).

J = ESTIMATED
1,3-DNB = 1,3-DINITROBENZENE
2,4-DNT = 2,4-DINITROTOLUENE
4-NT = 4-NITROTOLUENE
2-NT = 2-NITROTOLUENE
2,4,6-TNT = 2,4,6-TRINITROTOLUENE

NOTE: PRGs FOR INDICATED EXPLOSIVES ARE AS FOLLOWS (μg/L):

1,3-DNB = 3.65
2,4-DNT = 73.0
4-NT = 60.8
2-NT = 60.8
2,4,6-TNT = 2.241
HMX = 1,825
RDX = 0.6112
2,6-DNT = 36.5
NITROBENZENE = 3.4
NITROGLYCERINE = 4.8
TETRYL = 365

US Army Corps of Engineers
Louisville District

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
LOUISVILLE, KENTUCKY

RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO
RAMSDELL QUARRY LANDFILL

REVISION	DRAWN BY:	CHKD. BY:	DATE:
0	P. HOLM	K. JAGO	09-13-99
A	R. BEELER	K. JAGO	07-24-00

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Figure 2-1. Summary of Explosives Results in Groundwater

Other detected explosives included RDX and HMX, which were detected on three occasions in new wells. RDX was also detected in two of the existing wells sampled during the initial phase of work, while HMX was not detected in the existing wells. No observed clustering of detectable levels of HMX and RDX in specific wells was noted during evaluation of the data. Tetryl was observed in two of the existing wells during the initial phase (MW-1 and MW-4); however, the compound was subsequently detected on only one other occasion during the follow-on phase (RQLmw-007). The remaining explosive compounds (2,6-DNT; 2,4,6-TNT; and 2-nitrotoluene) were detected only once in different monitoring wells. No increasing or decreasing trends of explosive concentrations were evident in wells RQLmw-006 and RQLmw-008, which had the most consistent detections.

Propellants

Nitroglycerine was detected in two samples during the initial phase of the Groundwater Investigation (RQLmw-008 at 2J µg/L and RQLmw-006 at 2.8J µg/L); however, it was detected only once during the follow-on phase of work (RQLmw-006 at 1.5J µg/L). No EPA Region 9 PRG exists for this compound. No other propellants were detected in groundwater during the investigation.

2.1.3 TAL Metals and Cyanide

Metals were analyzed in both filtered and unfiltered samples from each groundwater sampling location. Both sets of results are discussed below. Filtered sample results represent the dissolved phase composition of the groundwater. Unfiltered samples include metals sorbed onto particulates, especially clay and silt fractions, as well as colloidal particles, such as iron and manganese oxyhydroxides. When unfiltered samples are acidified for preservation, metals sorbed onto particulates may be liberated and can result in skewed (elevated) results. Elevated levels of turbidity and suspended solids produced by purging can enhance this effect, although the micropurge methods employed during the groundwater investigation minimize potential interferences. Table 2-1 includes summary statistics for trace metals inclusive of the initial and follow-on phases of work, results of the comparison to background and results of the comparison to EPA Region 9 tap water PRGs.

Major geochemical constituents normally derived through weathering processes (calcium, iron, potassium, magnesium, and sodium) were detected in nearly all filtered and unfiltered samples. Iron concentrations routinely exceeded the Ohio secondary MCL of 0.3 mg/L and EPA Region 9 tap water PRG. However, both filtered and unfiltered facility-wide background values for iron are greater than the secondary MCL. Comparison to background values showed that iron exceeded background values in only 33 percent of unfiltered samples and 72 percent of filtered samples. A majority of calcium and magnesium values exceeded filtered and unfiltered background criteria. Well RQLmw-007 consistently exhibited the highest levels of major elements in unfiltered samples; this well also had the highest observed alkalinity, conductivity, total dissolved solids, and pH values (Table 2-1) suggesting a causal relationship and potential interferences resulting from the sampling process. Although elevated in some cases, these major elements are essential nutrients; thus, they are not further considered as potential contaminants at RQL.

Prevalent trace metals present in groundwater samples collected from the new wells included aluminum, arsenic, barium, cobalt, manganese, nickel, and zinc. Each of these constituents were detected in 50 percent or more of both unfiltered and filtered samples from the new wells, with the exception of total and dissolved aluminum (47 percent and 30 percent frequency of detection, respectively) and dissolved zinc (42 percent frequency of detection). Wells RQLmw-006 and RQLmw-011 contained the maximum detected values for most trace metals. Well RQLmw-006 contained the maximum detected values for chromium (unfiltered/filtered), cobalt (unfiltered/filtered), copper (filtered), manganese (unfiltered/filtered), nickel (unfiltered/filtered), and zinc (unfiltered/filtered).

Well RQLmw-011 contained the maximum detected values for aluminum (unfiltered/filtered), arsenic (unfiltered), beryllium (unfiltered/filtered), lead (unfiltered), and mercury (unfiltered/filtered). Wells RQLmw-006, RQLmw-007, RQLmw-008, and RQLmw-011 had the majority of values greater than background criteria. Figure 2-2 illustrates the distribution of four of the principal metals exceeding background (aluminum, arsenic, manganese, nickel), as well as DWS and PRGs. Results for the primary trace metals detected during the groundwater investigation are as follows:

- All detected aluminum values in both unfiltered and filtered samples from the new wells exceeded Ohio secondary MCLs. Only one unfiltered result (well RQLmw-011) exceeded background. A preponderance of detected filtered values occurred in wells RQLmw-009 and RQLmw-011.

- Arsenic was detected on 15 and 22 occasions in unfiltered and filtered samples, respectively, above background values. All unfiltered results greater than background occurred in wells RQLmw-006 (five results), RQLmw-007 (five results), RQLmw-008 (four results), and RQLmw-011 (one result). The same wells exhibited the identified filtered results greater than background, with the addition of three results from well RQLmw-009. Of these results greater than background, seven unfiltered results and six filtered results exceeded Ohio primary MCLs. Twenty-three and 22 total and filtered results, respectively, exceeded EPA Region 9 tap water PRGs.

- Cobalt was detected in about 50 percent of both unfiltered and filtered samples from the new monitoring well network. Because cobalt was not detected in the background data sets, all results are greater than background. For unfiltered samples, the distribution of detected cobalt included wells RQLmw-006 (six results), RQLmw-011 (six results), RQLmw-007 (two results), and RQLmw-008 (three results). For filtered samples, the distribution was the same, with an additional detected result in well RQLmw-007.

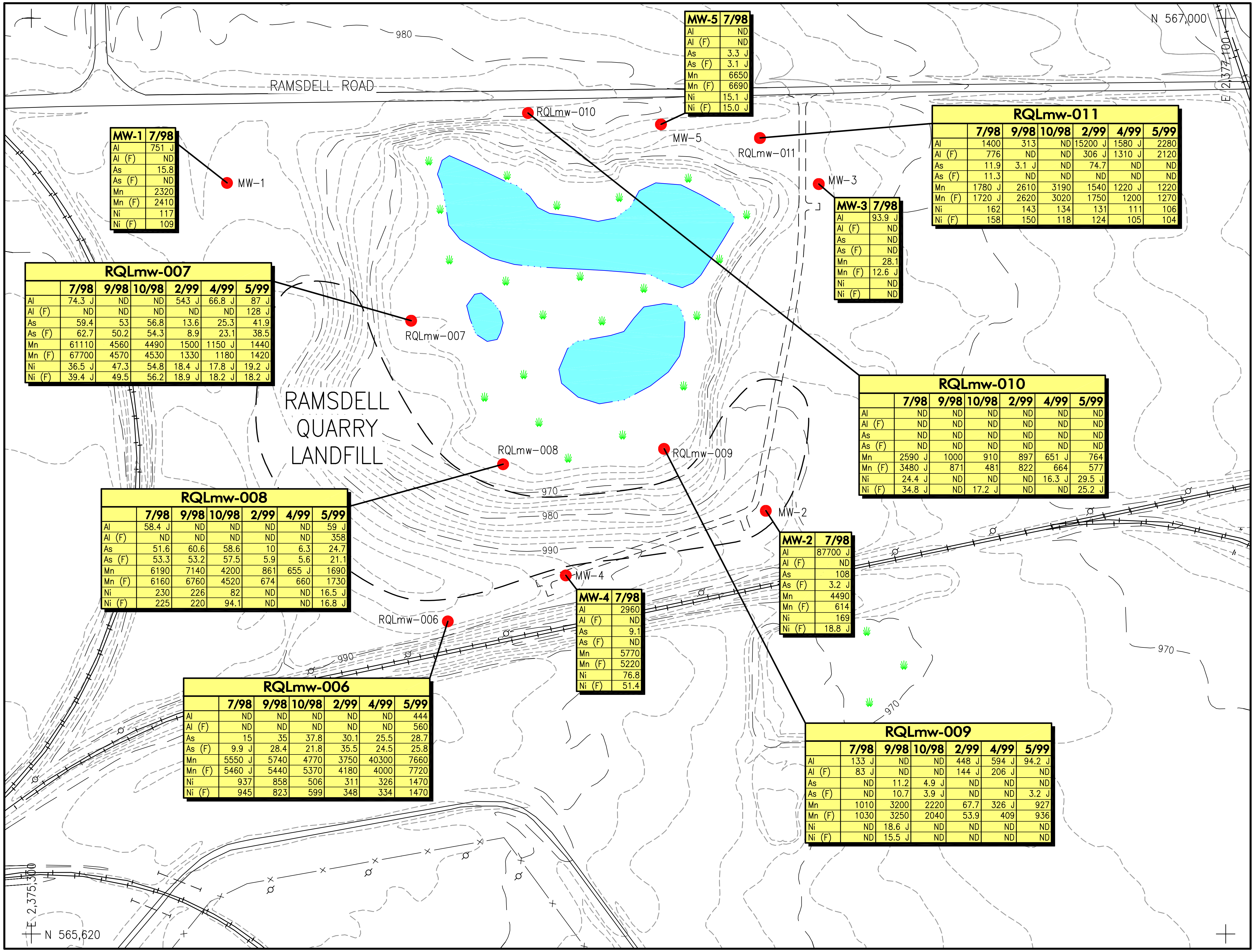
- Manganese was ubiquitous, occurring above background in 22 unfiltered and 21 filtered samples. All results from filtered and unfiltered samples collected from the new wells exceeded the Ohio secondary MCL. Both filtered and unfiltered detected values occurred primarily in wells RQLmw-006, RQLmw-007, RQLmw-008, and RQLmw-011. Two filtered and associated unfiltered samples from well RQLmw-009 contained manganese above background, and one unfiltered and filtered sample from well RQLmw-010 contained the constituent above background criteria. Thirty total results and 27 filtered sample results exceeded EPA Region 9 tap water PRGs.

- Nickel was detected in 72 percent of both filtered and unfiltered samples collected from the new wells; 14 unfiltered results (39 percent) exceeded both the background value and the Ohio primary MCL. Fifteen filtered results exceeded background, with 14 of these above the MCL. However, only three results exceeded EPA Region 9 tap water PRGs for both total and filtered samples. Eighty percent of the nickel values above background occurred in wells RQLmw-006 and RQLmw-011.

- Zinc was detected in 51 percent of unfiltered and 42 percent of filtered samples collected from the new wells. Six unfiltered and 10 filtered results exceeded background levels. The majority of both unfiltered and filtered results greater than background occurred in wells RQLmw-006, RQLmw-007, and RQLmw-008.

In addition to the prevalent trace metals denoted above, other trace metals potentially indicative of site-related contamination were evaluated. The results for these constituents are as follows:

- Silver and cadmium were not detected in the new wells during the initial or follow-on phases of work.



MW-5	7/98
Al	ND
Al (F)	ND
As	3.3 J
As (F)	3.1 J
Mn	6650
Mn (F)	6690
Ni	15.1 J
Ni (F)	15.0 J

MW-1	7/98
Al	751 J
Al (F)	ND
As	15.8
As (F)	ND
Mn	2320
Mn (F)	2410
Ni	117
Ni (F)	109

RQLmw-011

	7/98	9/98	10/98	2/99	4/99	5/99
Al	1400	313	ND	15200 J	1580 J	2280
Al (F)	776	ND	ND	306 J	1310 J	2120
As	11.9	3.1 J	ND	74.7	ND	ND
As (F)	11.3	ND	ND	ND	ND	ND
Mn	1780 J	2610	3190	1540	1220 J	1220
Mn (F)	1720 J	2620	3020	1750	1200	1270
Ni	162	143	134	131	111	106
Ni (F)	158	150	118	124	105	104

MW-3	7/98
Al	93.9 J
Al (F)	ND
As	ND
As (F)	ND
Mn	28.1
Mn (F)	12.6 J
Ni	ND
Ni (F)	ND

RQLmw-007

	7/98	9/98	10/98	2/99	4/99	5/99
Al	74.3 J	ND	ND	543 J	66.8 J	87 J
Al (F)	ND	ND	ND	ND	ND	128 J
As	59.4	53	56.8	13.6	25.3	41.9
As (F)	62.7	50.2	54.3	8.9	23.1	38.5
Mn	61110	4560	4490	1500	1150 J	1440
Mn (F)	67700	4570	4530	1330	1180	1420
Ni	36.5 J	47.3	54.8	18.4 J	17.8 J	19.2 J
Ni (F)	39.4 J	49.5	56.2	18.9 J	18.2 J	18.2 J

RQLmw-010

	7/98	9/98	10/98	2/99	4/99	5/99
Al	ND	ND	ND	ND	ND	ND
Al (F)	ND	ND	ND	ND	ND	ND
As	ND	ND	ND	ND	ND	ND
As (F)	ND	ND	ND	ND	ND	ND
Mn	2590 J	1000	910	897	651 J	764
Mn (F)	3480 J	871	481	822	664	577
Ni	24.4 J	ND	ND	ND	16.3 J	29.5 J
Ni (F)	34.8 J	ND	17.2 J	ND	ND	25.2 J

RQLmw-008

	7/98	9/98	10/98	2/99	4/99	5/99
Al	58.4 J	ND	ND	ND	ND	59 J
Al (F)	ND	ND	ND	ND	ND	358
As	51.6	60.6	58.6	10	6.3	24.7
As (F)	53.3	53.2	57.5	5.9	5.6	21.1
Mn	6190	7140	4200	861	655 J	1690
Mn (F)	6160	6760	4520	674	660	1730
Ni	230	226	82	ND	ND	16.5 J
Ni (F)	225	220	94.1	ND	ND	16.8 J

MW-2	7/98
Al	87700 J
Al (F)	ND
As	108
As (F)	3.2 J
Mn	4490
Mn (F)	614
Ni	169
Ni (F)	18.8 J

MW-4	7/98
Al	2960
Al (F)	ND
As	9.1
As (F)	ND
Mn	5770
Mn (F)	5220
Ni	76.8
Ni (F)	51.4

RQLmw-006

	7/98	9/98	10/98	2/99	4/99	5/99
Al	ND	ND	ND	ND	ND	444
Al (F)	ND	ND	ND	ND	ND	560
As	15	35	37.8	30.1	25.5	28.7
As (F)	9.9 J	28.4	21.8	35.5	24.5	25.8
Mn	5550 J	5740	4770	3750	40300	7660
Mn (F)	5460 J	5440	5370	4180	4000	7720
Ni	937	858	506	311	326	1470
Ni (F)	945	823	599	348	334	1470

RQLmw-009

	7/98	9/98	10/98	2/99	4/99	5/99
Al	133 J	ND	ND	448 J	594 J	94.2 J
Al (F)	83 J	ND	ND	144 J	206 J	ND
As	ND	11.2	4.9 J	ND	ND	ND
As (F)	ND	10.7	3.9 J	ND	ND	3.2 J
Mn	1010	3200	2220	67.7	326 J	927
Mn (F)	1030	3250	2040	53.9	409	936
Ni	ND	18.6 J	ND	ND	ND	ND
Ni (F)	ND	15.5 J	ND	ND	ND	ND

LEGEND:

═	ASPHALT ROAD
╍	GRAVEL ROAD
—x—	FENCE LINE
┼┼┼	RAILROAD TRACKS
⬭	POND
╌	GROUND CONTOUR (2 FT. INTERVAL)
—	GROUND CONTOUR (10 FT. INTERVAL)
+	GRID TIC
●	MONITORING WELL LOCATION
ѱ	VEGETATION
— —	APPROXIMATE LANDFILL BOUNDARY

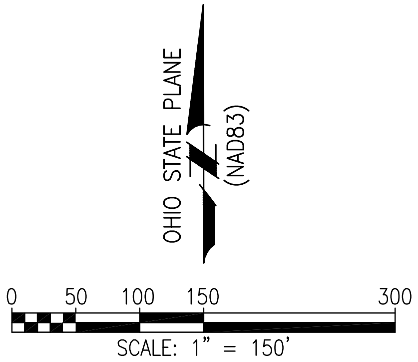
NOTE: ALL CONCENTRATIONS ARE REPORTED IN MICROGRAMS PER LITER (μg/L).

J = ESTIMATED
ND = NOT DETECTED
(F) = FILTERED SAMPLE

NOTE: OHIO PRIMARY OR SECONDARY DRINKING WATER STANDARDS (DWS) AND EPA REGION 9 TAP WATER PRGs ARE AS FOLLOWS (μg/L):

ANALYTE	DWS	PRG
Al	50∗	36499
As	50	0.04482
Mn	50∗	876
Ni	100	730

∗ SECONDARY DWS



U.S. ARMY ENGINEER DISTRICT
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US Army Corps
of Engineers
Louisville District

RAVENNA ARMY AMMUNITION PLANT
RAVENNA, OHIO
RAMSDELL QUARRY LANDFILL
(RVAAP-01)

DRAWN BY:	REV. NO./DATE:	CAD FILE:
R. BEELER	REV. A / 08-21-00	/99044/DWGS/D69RQ06.DWG

Figure 2-2. Summary of Principal Metals in Groundwater Exceeding Drinking Water Standards or Preliminary Remediation Goals

- Antimony was detected once in the unfiltered sample collected from well RQLmw-011 in February 1999 (24.3 µg/L); this result exceeded the background criterion, Ohio primary MCL, and EPA Region 9 tap water PRG. This constituent was not detected in any well during the initial phase of the investigation.

- Beryllium was detected in one unfiltered sample (RQLmw-011, February 1999) during the follow-on phase of work. This trace metal was also detected in both the unfiltered and filtered samples from well RQLmw-011 during the initial phase of work. All detected results exceeded background criteria, and the maximum unfiltered result exceeded the Ohio primary MCL.

- Chromium was detected in unfiltered samples from well RQLmw-006 on two occasions (4J µg/L in September 1998 and 10 µg/L in October 1998) and in one corresponding filtered sample (9.4J µg/L in October 1999). Only the filtered result from October 1998 exceeded background values; no result exceeded the Ohio primary MCL.

- Copper was detected in four unfiltered and three filtered samples collected from four of the new monitoring wells during the groundwater investigation. Unfiltered concentrations ranged from 3.9J to 11.3J µg/L, and filtered concentrations ranged from 5.4J to 21.4J µg/L. Only the three filtered results exceed background values (two results from well RQLmw-006 and one result from well RQLmw-009). No concentrations exceeded the Ohio primary MCL. Well RQLmw-009 was the only location having somewhat consistent detectable concentrations (three of six unfiltered samples) during the course of the groundwater investigation.

- Lead was detected on only two occasions in unfiltered samples collected from the new monitoring wells during the course of the investigation. Well RQLmw-011 had the maximum value (43.5 µg/L in February 1999), which exceeded background, federal drinking water action levels, and the EPA Region 9 tap water PRG.

- Mercury was detected in six unfiltered samples and four filtered samples collected from new wells during the initial and follow-on phases of work. All of the detected values in filtered samples and three of the unfiltered detected values occurred in the initial phase of work only. In the follow-on phase of work, unfiltered samples from wells RQLmw-006 (May 1999 event), RQLmw-007 (April event), and RQLmw-008 (February 1999 event) contained detectable mercury. Wells RQLmw-007, RQlmw-008, and RQLmw-009 had the preponderance of detected values. Well RQLmw-008 had the maximum unfiltered result, and well RQLmw-011 had the maximum filtered result. All values exceeded the background criteria, as mercury was not detected in the background data set. However, no value exceeded the Ohio primary MCL.

- Selenium was detected once in four of the new wells during the groundwater investigation. Three of the four detected values occurred in the follow-on phase of work during the September 1998 sampling event (wells RQLmw-008 , RQLmw-010, and RQLmw-011). The maximum detected value was 4.91 µg/L in well RQLmw-007 (July 1998 event), which did not exceed the Ohio primary MCL. All detected values exceeded the background criteria of zero (undetected in the background data set).

- Thallium concentrations in unfiltered samples collected from new wells exceeded detection limits on six occasions; eight filtered samples had detectable quantities of thallium. This metal was detected in unfiltered and/or filtered samples collected from well RQLmw-007 during three of the six sampling events. Wells RQLmw-008 and RQLmw-011 had two detected values each. Wells RQLmw-009 and RQLmw-010 each had a single detected value. The maximum detected value for thallium occurred in well RQLmw-008 (July 1998 event). All detected values exceeded background criteria. No results exceeded the Ohio primary MCL.

VOCs

Detected VOCs in new monitoring wells included acetone, benzene, carbon disulfide, methylene chloride, tetrachloroethene, and toluene. No VOCs were detected in existing wells during the initial phase of work. Acetone and benzene were limited to one sample collected from well RQLmw-006 during the July 1998 event (8.1J and 0.52J µg/L, respectively). Carbon disulfide was detected on two occasions: wells RQLmw-006 in July 1998 (2.4J µg/L) and RQLmw-008 in April 1999 (0.67J µg/L). Methylene chloride was detected in every new monitoring well during the October 1998 sampling event; this compound was not detected in any well during the other sampling events. The values observed during the October event are considered anomalous based on the lack of preceding or subsequent detections. Tetrachloroethene was detected in wells RQLmw-006, RQLmw-008, and RQLmw-009 during the February sampling event only. Toluene was detected in six samples as follows: well RQLmw-006 in September 1998 (0.54J µg/L) and February 1999 (0.48J µg/L); RQLmw-008 in February 1999 (0.54J µg/L); RQLmw-010 in July 1998 (0.72 µg/L); and RQLmw-011 in July 1998 (0.51J µg/L) and February 1999 (0.46J µg/L, respectively. Ohio primary drinking water standards for benzene, methylene chloride, tetrachloroethene, and toluene were not exceeded (Table 2-1). The single detected benzene result exceeded its EPA Region 9 tap water PRG.

SVOCs

No SVOCs were present at concentrations above detection limits in groundwater samples collected during the initial phase of the investigation. In the follow-on phase of work, bis(2-ethylhexyl)phthalate was detected in eight samples collected. Each of the new wells had at least one detected result, except well RQLmw-008. Well RQLmw-006 had two detected results (3.4J and 4.7J µg/L in September 1998 and May 1999, respectively). Well RQLmw-011 had three detected results (4.1J in September 1998, 14 µg/L in February 1999, and 84 µg/L in May 1999). Wells RQLmw-007, RQLmw-009, and RQLmw-010 each had single detects in the May sample event. Four results exceeded the EPA Region 9 tap water PRG of 4.8 µg/L. The Ohio primary MCL of 6 µg/L was exceeded on three occasions in wells RQLmw-010 (May 1999, 11 µg/L) and RQLmw-011 (February 1999 and May 1999).

2.1.4 Summary of Groundwater Quality Data

Results of the sampling of the new groundwater monitoring network show that groundwater quality impacts have occurred due to explosives, metals, and VOCs. However, with exception of some metals, results were generally below EPA Region 9 tap water PRGs. Wells RQLmw-006, RQLmw-007, and RQLmw-008 had the greatest numbers and concentrations of contaminants. Well RQLmw-011 also exhibited metals contaminants above facility-wide background criteria. Comparison of data collected from the new monitoring network to that from the initial phase sampling of the existing wells shows generally consistent occurrences and concentrations of metals. Explosives were more prevalent in the new monitoring wells. VOCs were detected only in the new monitoring wells, and SVOCs were generally absent in both sets of wells.

Evaluation of seasonal and potential episodic flushing of constituents showed no variation in frequency of detection for explosives. However, the maximum concentrations of five of the eight detected explosives occurred during the dry season, suggesting seasonal dilution effects during the wet season. Episodic flushing of metals is indicated with about 30 percent of the maximum concentrations occurring during the May 1999 storm event sampling and generally higher concentrations during the wet season. Maximum values for anions and general water quality parameters were almost exclusively associated with the storm event sampling. Almost all detected VOCs occurred during dry season sampling events; thus, episodic flushing is not indicated.

2.2 SURFACE WATER QUALITY DATA

The chemical water quality of the Ramsdell Quarry pond was evaluated through sampling of surface water at station RQLsw-015 during the follow-on phase of the investigation (Figure 1-3). Additional sediment samples were not collected during the follow-on phase of work.

2.2.1 Explosives

Explosives were not present at concentrations above detection limits in any samples collected during the initial phase of work. During the follow-on phase of work, 4-nitrotoluene (0.24 µg/L) was detected in the sample collected during the October 1998 event. No other explosives were detected in surface water.

2.2.2 Propellants

Propellants were not present at concentrations above detection limits in the surface water samples collected during either the initial or follow-on phases of the investigation.

2.2.3 TAL Metals and Cyanide

Metals were analyzed in both filtered and unfiltered samples during the follow-on phase of work. Both sets of results are discussed below. Comparisons to Ohio statewide water quality criteria and RVAPP facility-wide background values (USACE 1999b) were conducted. Background criteria are available only for unfiltered metals. Table 2-2 presents summary statistics and comparisons of metals results to background values and PRGs for both initial phase and follow-on phase samples. As previously noted, follow-on phase sampling was conducted only at RQLsw-015; these results are presented in Table 2-3. Thus, detailed discussion of the occurrence of metals is limited to this sampling station; summary results for the initial phase sampling at other stations is presented in Chapter 1.0.

Essential nutrients such as calcium, iron, magnesium, potassium, and sodium were present above detection levels in all samples. These constituents are not considered potential contaminants related to RQL. Iron exceeded the statewide water quality criteria for soluble iron (300 µg/L) for the protection of human health (OAC 3745-1-07) in all unfiltered samples and one filtered sample (October 1998 event). Three unfiltered results and one filtered result exceeded the EPA Region 9 PRG. However, it is noted that the facility-wide background criterion for iron is also above the Ohio water quality criterion; only four of nine initial and follow-on phase samples exceeded the background criterion. Cyanide was analyzed in all unfiltered surface water samples collected; this constituent was not detected during the follow-on phase.

During the initial phase of the investigation, barium, manganese, lead, and zinc, in addition to the essential nutrients noted above, were above detection limits at station RQLsw-015. In the follow-on phase, these four metals were also detected. However, arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, thallium, and vanadium were also detected on at least one occasion (Table 2-3). Antimony, beryllium, and silver were not detected during either phase of work. Aluminum exceeded its EPA Region 9 tap water PRG in one unfiltered sample. All detected arsenic

Table 2-2. Summary of Metals Detected in Ramsdell Quarry Pond Surface Water Compared to Background

Chemical	Units	Proportion Detected	Min Detect	Max Detect	Mean[a]	Background Criteria[b]	Proportion >Background	PRG[c]	Proportion > PRG	ID of Max Concentration	Date of Max Concentration
Aluminum	mg/L	6/ 9	0.136	49.6	11.1	3.37	3/ 9	36.4987	1/ 9	RQLsw-012(p)-0018-SW	07/08/98
Aluminum (filtered)	mg/L	2/ 9	0.072	0.0929	0.143	[d]		36.4987	0/ 9	RQLsw-012(p)-0018-SW	07/08/98
Arsenic	mg/L	4/ 9	0.0114	0.0393	0.0145	0.0032	4/ 9	4.5E-05	4/ 9	RQLsw-012(p)-0018-SW	07/08/98
Arsenic (filtered)	mg/L	3/ 9	0.0037	0.0055	0.00647	[d]		4.5E-05	3/ 9	RQLsw-015(p)-0073-SW	09/20/98
Barium	mg/L	9/ 9	0.0276	0.405	0.133	0.0475	4/ 9	2.555	0/ 9	RQLsw-012(p)-0018-SW	07/08/98
Barium (filtered)	mg/L	9/ 9	0.0152	0.124	0.0507	[d]		2.555	0/ 9	RQLsw-015(p)-0073-SW	09/20/98
Cadmium	mg/L	2/ 9	0.0015	0.0042	0.00406	0[e]	2/ 9	0.01825	0/ 9	RQLsw-015(p)-0102-SW	10/19/98
Calcium	mg/L	9/ 9	15.1	96.7	42.8	41.4	5/ 9	NA	NA	RQLsw-015(p)-0102-SW	10/19/98
Calcium (filtered)	mg/L	9/ 9	12.3	98	38.6	[d]		NA	NA	RQLsw-015(p)-0102-SW	10/19/98
Chromium (total)	mg/L	4/ 9	0.0036	0.0647	0.0196	0[e]	4/ 9	0.1095	0/ 9	RQLsw-012(p)-0018-SW	07/08/98
Cobalt	mg/L	2/ 9	0.0286	0.0295	0.0453	0[e]	2/ 9	2.19	0/ 9	RQLsw-012(p)-0018-SW	07/08/98
Copper	mg/L	5/ 7	0.005	0.16	0.0405	0.0079	4/ 7	1.3557	0/ 7	RQLsw-012(p)-0018-SW	07/08/98
Copper (filtered)	mg/L	1/ 7	0.0174	0.0174	0.0213	[d]		1.3557	0/ 7	RQLsw-015(p)-0073-SW	09/20/98
Iron	mg/L	9/ 9	0.377	80.2	23.7	2.56	4/ 9	10.95	3/ 9	RQLsw-012(p)-0018-SW	07/08/98
Iron (filtered)	mg/L	8/ 9	0.0515	12.3	1.52	[d]		10.95	1/ 9	RQLsw-015(p)-0102-SW	10/19/98
Lead	mg/L	5/ 9	0.0032	0.143	0.0337	0[e]	5/ 9	0.004	4/ 9	RQLsw-015(p)-0102-SW	10/19/98
Magnesium	mg/L	9/ 9	25	202	57.6	10.8	9/ 9	NA	NA	RQLsw-012(p)-0018-SW	07/08/98
Magnesium (filtered)	mg/L	9/ 9	25.6	168	53.2	[d]		NA	NA	RQLsw-012(p)-0018-SW	07/08/98
Manganese	mg/L	9/ 9	0.0672	5.62	1.61	0.391	6/ 9	0.8760	3/ 9	RQLsw-015(p)-0102-SW	10/19/98
Manganese (filtered)	mg/L	9/ 9	0.0088	5.18	0.899	[d]		0.8760	2/ 9	RQLsw-015(p)-0102-SW	10/19/98
Mercury[f]	mg/L	4/ 9	0.000073	0.00026	0.000183	0[e]	4/ 9	0.0037	0/ 9	RQLsw-012(p)-0018-SW	07/08/98
Mercury (filtered)	mg/L	1/ 9	0.000094	0.000094	0.000188	[d]		0.0037	0/ 9	RQLsw-015(p)-0109-SW	02/12/99
Nickel	mg/L	3/ 9	0.0351	0.0701	0.0459	0[e]	3/ 9	0.73	0/ 9	RQLsw-015(p)-0102-SW	10/19/98
Nickel (filtered)	mg/L	1/ 9	0.0207	0.0207	0.0379	[d]		0.73	0/ 9	RQLsw-015(p)-0109-SW	02/12/99
Potassium	mg/L	9/ 9	1.05	9.55	4.32	3.17	5/ 9	NA	NA	RQLsw-012(p)-0018-SW	07/08/98
Potassium (filtered)	mg/L	9/ 9	1.02	6.68	2.88	[d]		NA	NA	RQLsw-015(p)-0102-SW	10/19/98
Selenium	mg/L	1/ 9	0.0046	0.0046	0.00496	0[e]	1/ 9	0.1825	0/ 9	RQLsw-015(p)-0102-SW	10/19/98
Selenium (filtered)	mg/L	1/ 9	0.0046	0.0046	0.00496	[d]		0.1825	0/ 9	RQLsw-015(p)-0073-SW	09/20/98
Sodium	mg/L	8/ 9	1.49	6.15	3.45	21.3	0/ 9	NA	NA	RQLsw-015(p)-0102-SW	10/19/98
Sodium (filtered)	mg/L	8/ 9	1.51	3.86	2.46	[d]		NA	NA	RQLsw-015(p)-0073-SW	09/20/98
Thallium[g]	mg/L	3/ 9	0.0013	0.0018	0.00187	0[e]	3/ 9	0.0026	0/ 9	RQLsw-013(p)-0019-SW	07/08/98
Vanadium	mg/L	3/ 9	0.0381	0.0853	0.0515	0[e]	3/ 9	0.2555	0/ 9	RQLsw-012(p)-0018-SW	07/08/98
Zinc	mg/L	6/ 9	0.0169	1.57	0.318	0.042	5/ 9	10.95	0/ 9	RQLsw-015(p)-0102-SW	10/19/98
Zinc (filtered)	mg/L	2/ 9	0.0442	0.329	0.0638	[d]		10.95	0/ 9	RQLsw-015(p)-0109-SW	02/12/99

[a] Nondetects were set to one-half the reporting limit to calculate the mean values.
[b] Background criteria are the smaller of the 95% upper tolerance limit of the 95th percentile or the maximum detect.
[c] PRGs reflect most recent revisions as December 3, 1999.
[d] A blank background criterion indicates that the analyte was not measured in the background samples or that a background criterion was not calculated.
[e] A background criterion of zero indicates that the analyte was not detected in the background samples.
[f] EPA Region 9 PRG for methylmercury was used for mercury.
[g] EPA Region 9 PRG for thallic oxide was used for thallium.

Table 2-3. Summary of TAL Metals Detected in Follow-on Phase Surface Water Samples

Station Sample ID Sample Date Parameter	Units	RQLsw-015 RQ0073 09/20/98 Total	RQLsw-015 RQ0073 09/20/98 Dissolved	RQLsw-015 RQ0102 10/19/98 Total	RQLsw-015 RQ0102 10/19/98 Dissolved	RQLsw-015 RQ0109 02/12/99 Total	RQLsw-015 RQ0109 02/12/99 Dissolved	RQLsw-015 RQ0116 04/10/99 Total	RQLsw-015 RQ0116 04/10/99 Dissolved	RQLsw-015 RQ0123 05/26/99 Total	RQLsw-015 RQ0123 05/26/99 Dissolved
Aluminum	mg/L	2.39 =	0.138 U	21.5 =	0.117 U	0.136 J	0.2 UJ	0.340 J	0.2 UJ	0.0725 U	0.0667 U
Arsenic	mg/L	0.0114 =	0.0055 =	0.0316 =	0.004 J	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
Barium	mg/L	0.163 J	0.124 J	0.290 =	0.114 J	0.0336 J	0.0329 J	0.033 J	0.031 J	0.0276 J	0.0268 J
Cadmium	mg/L	0.005 U	0.005 U	0.0042 J	0.005 U	0.0008 U	0.00082 U	0.005 U	0.005 U	0.005 U	0.005 U
Calcium	mg/L	31.1 =	31.5 =	96.7 J	98 J	45.1 =	46.3 =	55.6 =	59 =	48.7 =	48 =
Chromium (total)	mg/L	0.0036 J	0.010 U	0.0282 =	0.010 U	0.010 U	0.010 U	0.010 UJ	0.010 UJ	0.010 U	0.010 U
Cobalt	mg/L	0.05 U	0.050 U	0.0286 J	0.050 U	0.050 U	0.050 U	0.050 UJ	0.050 U	0.050 U	0.050 U
Copper	mg/L	0.011 J	0.0174 J	0.103 R	0.025 R	0.0128 J	0.0066 U	0.005 J	0.025 UJ	0.025 R	0.025 R
Iron	mg/L	7.11 =	0.223 =	78.3 =	12.3 =	0.660 =	0.192 U	2.18 J	0.226 =	0.969 =	0.188 =
Lead	mg/L	0.008 =	0.003 U	0.143 =	0.003 U	0.003 U	0.003 U	0.0032 =	0.003 U	0.003 U	0.003 U
Magnesium	mg/L	2.91 =	31.1 =	42.8 J	40.1 J	25 =	25.6 =	34.3 =	37.1 =	47.6 =	47.1 =
Manganese	mg/L	1.82 =	1.14 =	5.62 =	5.18 =	0.744 =	0.767 =	0.57 J	0.549 =	0.104 =	0.0646 =
Mercury	mg/L	0.0002 U	0.0002 U	0.00016 J	0.0002 U	0.000073 J	0.000094 J	0.0002 UJ	0.0002 UJ	0.0002 U	0.0002 U
Nickel	mg/L	0.040 U	0.040 U	0.0701 =	0.040 U	0.040 U	0.0207 J	0.040 U	0.040 U	0.040 U	0.040 U
Potassium	mg/L	6.53 =	6.37 =	8 J	6.68 J	3.19 J	3.16 J	3.02 J	3.17 J	1.27 J	1.2 J
Selenium	mg/L	0.005 U	0.0046 J	0.0046 J	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
Sodium	mg/L	6.06 =	3.86 J	6.15 =	2.48 J	2.04 J	2.11 J	4.12 J	2.43 J	2.68 U	2.75 U
Thallium	mg/L	0.002 U	0.002 U	0.0013 J	0.002 U	0.002 U	0.002 U	0.002 U	0.002 UJ	0.002 U	0.002 U
Vanadium	mg/L	0.050 U	0.050 U	0.0381 J	0.050 U	0.050 U	0.050 U	0.050 U	0.050 U	0.050 U	0.050 U
Zinc	mg/L	0.102 U	0.0778 U	1.57 J	0.0289 U	0.323 J	0.329 J	0.0636 J	0.0442 J	0.0144 U	0.0147 U

J - estimated value less than laboratory reporting limits.
U - value was not detected at the indicated laboratory reporting limit.
UJ - value is estimated at the laboratory reporting limit.
= - result detected above laboratory reporting limits.
R - result was rejected as a result of the data validation process.

results exceeded its PRG. Four of the five lead results greater than detection limits exceeded the EPA Region 9 tap water PRG. The only other metal greater than PRGs was manganese (three total results and two filtered results). Other than iron and manganese as noted above, no other metal exceeded either statewide water quality criteria for the protection of human health or for the protection of agricultural uses as promulgated under OAC 3545-1-07.

VOCs

VOCs were not present at concentrations above detection limits in surface water samples collected during the initial phase of the investigation. In the follow-on phase of work, acetone (6.3J µg/L, October 1998 event), methylene chloride (12 µg/L, October 1998 event), and tetrachloroethene (0.6J µg/L, February 1999 event) were each detected on one occasion. The methylene chloride result was greater than its EPA Region 9 tap water PRG. The occurrence of methylene chloride in the October 1998 sampling event corresponds to the observed anomalous detections in all groundwater samples collected during that same event.

SVOCs

SVOCs were not present at concentrations above detection limits in surface water samples collected during either the initial or follow-on phases of the investigation.

Pesticides and PCBs

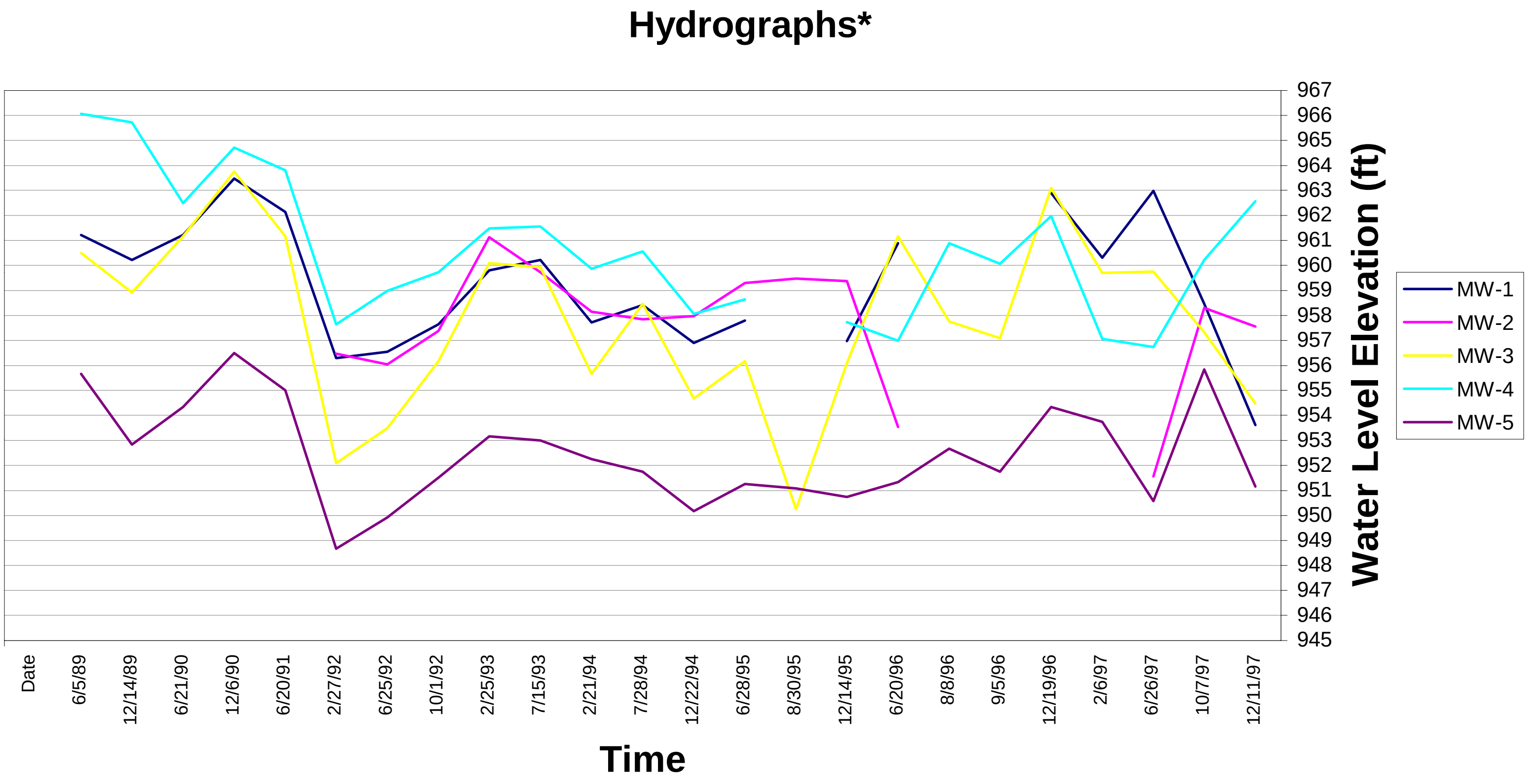
Aldrin was the only constituent detected among this class of chemical analytes (station RQLsw-015, May 1999). This result exceeded the EPA Region 9 tap water PRG.

2.2.4 Summary of Surface Water Quality Data

Analytical data from Ramsdell Quarry surface water sampling stations show that metals are the class of contaminants most frequently detected above background criteria. Few results, with the exception of arsenic, lead, and manganese, exceeded EPA Region 9 PRGs. Cyanide was detected only during the initial phase of work. Explosives, propellants, VOCs, and SVOCs were largely absent in surface water collected both during the initial and follow-on phases of work. The preponderance of metals detected above background occurred in September and October 1998 under dry season conditions and extremely low water levels. The observed distribution indicates that metals were concentrated in the quarry pond during this period of time due to evaporation. No maximum detected values occurred in samples collected during the April and May 1999 sampling events under wet season conditions and following an extended period of full pool levels in the pond.

2.3 HYDROLOGIC DATA

As discussed in Section 1.2.3.1, water table elevation data from the existing wells show that wells MW-1, MW-2, MW-3, and MW-5 were consistently downgradient of well MW-5 between the time of installation (1988) until about 1995. After 1995, the hydrographs show a significant departure from historical patterns (Figure 2-3) indicating failure of wells to adequately represent flow conditions at the site. This trend was a primary rationale for installing the new wells.



*Reference Appendix B, Table B-1 for manual water level measurement data.

Figure 2-3. Potentiometric Surface Data for Existing Wells, June 1989 to December 1997

Continuous water level data were collected at 2-hour intervals from the six new wells installed during the initial phase of investigation conducted in July 1998 and a staff gauge and stilling well installed in the quarry pond. Pressure transducers and data recorders were used from July 1998 through July 15, 1999 to monitor changes in water level within each well and at the stilling well located at the northeast corner of the quarry. Automated water levels readings were not obtained from the stilling well over much of the year because either the water levels were too low to measure with the stilling well or the transducer was removed to prevent freeze damage during the winter. Also, data obtained in May 1999 from the quarry pond transducer do not match corresponding visual readings indicating potential problems with transducer calibration. Manual water level measurements and a visual reading of the staff gauge were also collected on a monthly frequency. Manual measurements were conducted prior to well purging and on the same day to obtain representative, contemporaneous data. Daily rainfall data were also obtained from a rain gauge located at the site, with the exception of September 1998, which was obtained from a gauge at the Kirwan Reservoir located several miles southeast of the site. The resulting hydrographs along with the daily rainfall totals are presented in Figure 2-4. The hydrographs for individual wells and the stilling well are included in Appendix I.

The hydrographs suggest that the water level at the RQL is in part seasonally dependent. During the period of time for which monitors were employed, water levels reached a low in early to mid-January 1999 and then begin to climb as a result of the wetter winter and decreased effects of evapotranspiration. Water levels again began falling in May 1999 and that decreasing trend continued until the monitors were removed in July 1999. The northeastern portion of Ohio was extremely dry during the period of the investigation. The effects of the regional drought are reflected in both groundwater levels within the shallow aquifer and the quarry pond. Groundwater potentiometric levels were observed to be abnormally low both at Ramsdell Quarry and in recently installed wells to the southeast at Load Line 1. The quarry pond had 0.38 m (1.25 feet) of water in September 1998, which decreased to less than 0.07 m (0.25 foot) of water by November 1998; the pond was completely dry in December 1998. Recovery of pond water levels occurred over January and February 1999, with up to 0.96 m (3.15 feet) of water accumulating in the pond by mid-February. However, water levels began a subsequent decline and, by mid July 1999, the pond was again dry.

Evaluation of the resulting hydrographs shows that all wells exhibit similar seasonal trends. Well RQLmw-006 was consistently upgradient during most of the monitoring period; however, as noted below, a flat gradient and even potential short-term flow reversals were evident during the wet season. Wells RQLmw-010 and RQLmw-011 were consistently downgradient throughout the duration of the monitoring effort. Wells RQLmw-007, RQLmw-008, and RQLmw-009, located along the toe of the landfill, had nearly identical groundwater elevations and response patterns.

Well RQLmw-006 and the furthest downgradient monitoring wells (RQLmw-010 and RQLmw-011) responded generally in a similar manner to precipitation events, exhibiting subdued response patterns, and showed similar seasonal fluctuations. The downgradient wells RQLmw-010 and RQLmw-011 showed strikingly similar responses to short-term influences as evidenced by their parallel, but nearly identical, hydrographs (Figure 2-4). Water levels within wells RQLmw-007 and, particularly RQLmw-008 and RQLmw-009, appear to respond much quicker to precipitation events than wells RQLmw-006, RQLmw-010, and RQLmw-011. Although a complete data record is not available for the quarry pond, water level elevations and water level responses observed in the pond were similar to those observed in monitoring wells RQLmw-007, RQLmw-008, and RQLmw-009 at the toe of RQL. These observed patterns suggest that these three wells and the pond are hydraulically connected to some degree.

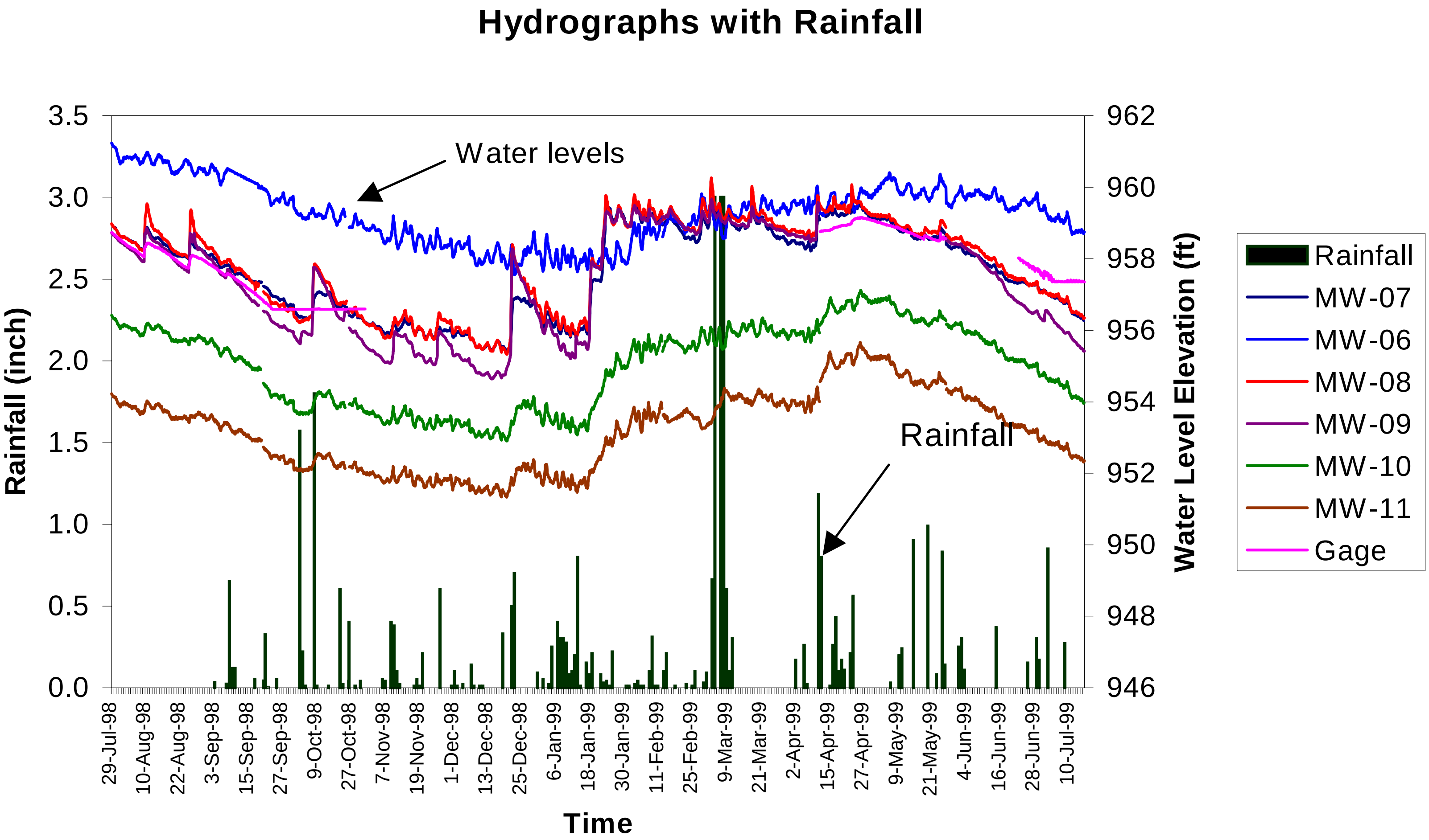


Figure 2-4. Potentiometric Surface Hydrographs for New Monitoring Wells

Between late January and late April, groundwater elevations for the wells located at the toe of RQL were essentially equal to those observed in well RQLmw-006 and, for short periods of time, one or more of these wells had higher potentiometric head than the upgradient well. During this time period, the quarry pond contained approximately 3 feet of water, as compared to 1.5 feet or less during other months of the year. These data indicate when sufficient water is present in the pond during the wet season, enough hydraulic head is generated so that it acts as a recharge point for groundwater, with a resulting localized radial flow component outward in the near vicinity of the pond, creating an essentially flat hydraulic gradient in the southern half of the site. Furthermore, under certain conditions (i.e., following significant rainfall events), the rapid and large responses in wells at the toe of RQL indicate that the pond produces sufficient recharge to cause short-term groundwater flow reversals (radial) toward well RQLmw-006.

Monthly manual water level measurements from new wells, existing wells, and the quarry pond staff gauge were used to construct potentiometric surface maps to represent conditions during each sampling event. These maps are presented in Appendix I. One set of maps was prepared using only data from newly installed wells. A second set of potentiometric maps was prepared using data from the existing wells for comparative purposes. Data from the new wells are believed to best represent groundwater conditions at RQL. In addition, a set of potentiometric maps was constructed from the final round of measurements collected in mid-July 1999 to illustrate conditions following an extremely dry period during June and early July 1999. The data collected during the February, April, and May sampling periods best represent wet weather conditions; the May data illustrate conditions within 48 hours following a precipitation event of 2.54 cm (1.0 inch) of rainfall. The contoured data from each of those events support the theory that the pond and the base of the floor of the quarry serve as a recharge zone at least during the wet season and following periods of precipitation when the pond contains water.

The September and October 1998 and July 1999 maps illustrate dry season (baseflow) conditions. During these periods, groundwater flow is consistently to the northeast with well RQLmw-006 consistently upgradient of the site. The horizontal potentiometric surface gradient during dry season conditions averaged approximately 0.0024 m/m (0.008 foot/foot). The potentiometric surface maps from these periods do not suggest that the pond is acting as a point of recharge. In fact, the water surface of the pond represents the water table, and the pond may actually be acting as a groundwater discharge point as a result of increased evapotranspiration rates expected during the summer.

2.3.1 Comparison of New and Existing Monitoring Wells

Uncertainties regarding the age, integrity, and construction characteristics of the existing RQL post-closure monitoring network provided an impetus for the Groundwater Investigation and the need to assess the hydrogeologic conditions and groundwater quality in shallow groundwater beneath the site using monitoring wells of known integrity. Chemical and hydraulic data were collected during the initial phase of the investigation for comparative purposes to help determine the suitability of the new monitoring wells for post-closure monitoring. Following the initial phase of the investigation, the Ohio EPA, USACE, and RVAAP determined that the new wells were suitable for use for post-closure monitoring. Quarterly follow-on phase data from the new wells were used to establish a new baseline data set for future statistical comparisons, while the existing wells continued to be monitored at a semiannual frequency until June 1999.

Although the depths, locations, and construction characteristics of the existing monitoring wells were not compliant with current Ohio solid waste regulations, the data obtained from both existing and new wells during the follow-on phase provided the opportunity for a more comprehensive assessment of the general geochemical and hydraulic characteristics of the groundwater system at the site. Because the new and existing monitoring wells were not sampled contemporaneously during the follow-on phase of work, quantitative (statistical) comparisons of frequency of occurrence and concentrations of potential site-related groundwater contaminants between the two monitoring networks could not be conducted. Qualitative observations regarding the occurrence of potential site-related contaminants in both monitoring systems was done as part of the initial phase of the investigation when both systems were sampled simultaneously (USACE 1999a).

2.3.1.1 Comparison of Water Quality and Geochemical Characteristics

Review of chemical data in the initial phase report showed no observable differences in the number of TAL metals detected in unfiltered groundwater samples; however, the maximum observed concentrations were more frequently observed in the existing wells. This pattern was skewed primarily due to the fact well MW-02 was the locus of maximum concentrations for 11 of the 23 detected TAL metals. For filtered metals, this pattern was not evident; wells in the new monitoring system had the maximum concentrations of 9 of the 13 detected constituents. The number of explosive compounds detected in the new monitoring network generally were higher than in the existing wells and propellant compounds were detected only in the new monitoring wells. SVOCs were not present in either set of wells; follow-on monitoring of the new wells indicated sporadic bis(2-ethylhexyl)phthalate that may or may not be site-related. VOCs were not detected in the existing monitoring system during the initial phase of the investigation. However, both initial phase and follow-on phase data collected from the new monitoring network showed low levels of VOCs in groundwater.

In order to evaluate the hydrogeologic characteristics of the shallow groundwater system and degree of hydraulic connection of the shallow and deeper groundwater systems, major ion chemistry was examined using Piper diagrams. Analytical results for samples obtained from the new monitoring system on May 27, 1999 and from the existing monitoring system on June 8, 1999 were plotted to assess lateral geochemical variability and geochemical stratification relative to depth (Figure 2-5). For purposes of general chemistry evaluation, these dates are sufficiently close to provide an essentially contemporaneous comparison. Groundwater composition was characterized by generally equal molar proportions of calcium and magnesium, except for MW-02 and MW-04 (higher in calcium) and RQLmw-009 (higher in magnesium). Groundwater samples universally contained low proportions of sodium, potassium, and chloride. High molar proportions of sulfate were a defining characteristic of the groundwater composition. No bimodal distribution was evident between new and old wells. In addition, the milliequivalent/liter (meq/L) range of both of the pairs sulfate/chloride and carbonate/bicarbonate is from <20% to >80% with no obvious vertical stratification or lateral patterns. These data indicate that groundwater compositions are not different between the deeper existing monitoring system and shallower new monitoring system. Lateral variations in composition (i.e., from upgradient to downgradient) were not evident.

The observed geochemical signatures in groundwater at RQL are believed to represent naturally low-molar proportions of sodium and potassium relative to calcium and magnesium. The higher calcium/magnesium proportions likely reflect geochemical signatures due to mineralogical composition of the Pennsylvanian sandstone aquifer matrix, in particular, secondary minerals such as iron and magnesium oxides/hydroxides (limonite), iron/manganese sulfides, and carbonate integranular cements. These mineralogical compositions typically result in relative enrichment of iron, magnesium, and manganese. Groundwater is also enriched in sulfate relative to chloride for these same reasons.

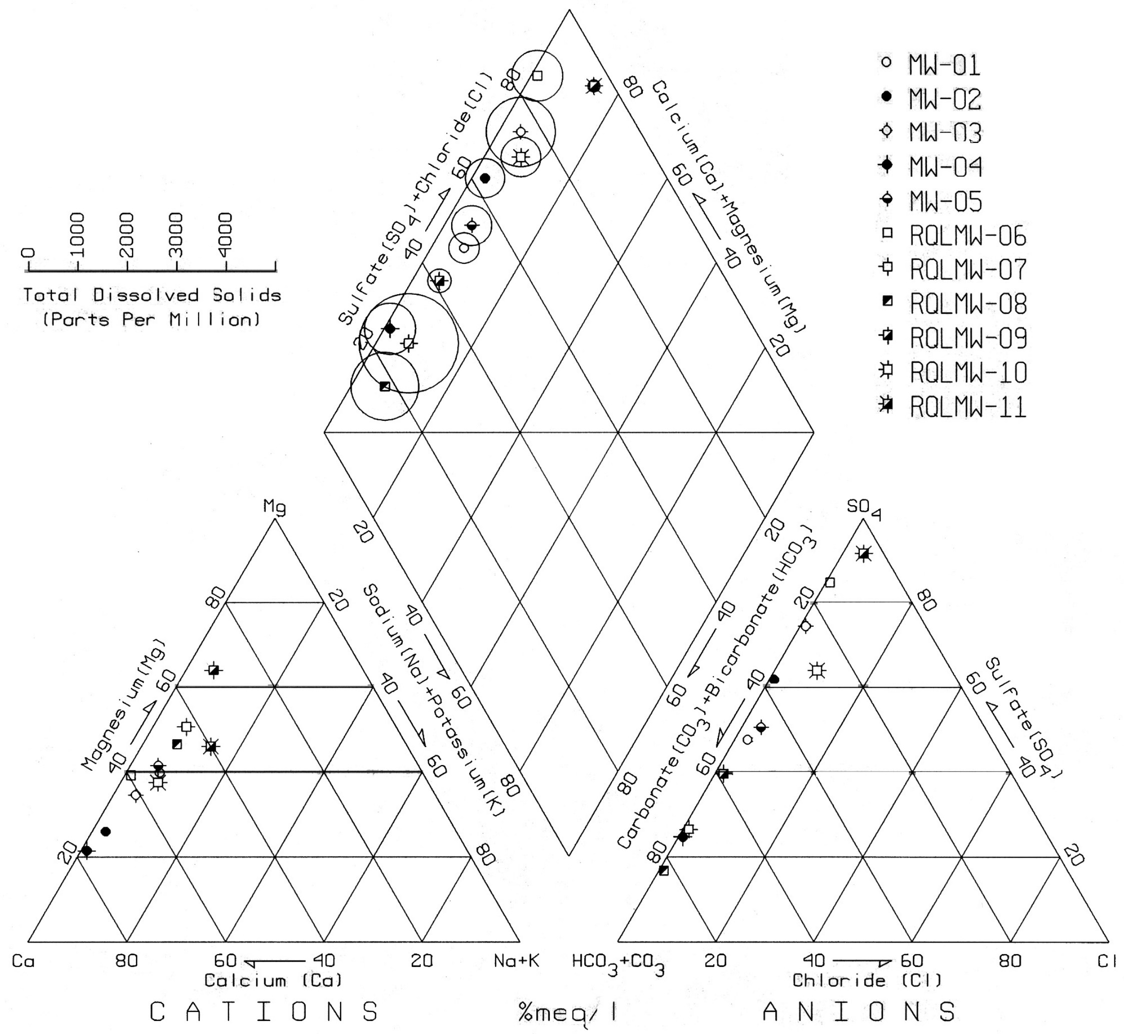


Figure 2-5. Groundwater Composition at RQL

2.3.1.2 Comparison of Hydrologic Data

The potentiometric surface maps presented in Appendix I are constructed from data obtained from both the newly installed wells and from the pre-existing wells. The data were divided accordingly because the existing well network is, on average, screened deeper than the new wells, which were constructed with screens just below the water table as encountered during drilling. Comparison of the constructed potentiometric surface maps indicates that fracture flow paths appear to be sufficiently prevalent and well connected so that each set of wells monitors essentially the same flow system from a hydraulic perspective. However, as noted above, subtle differences may be observed during the wetter periods of the year when a slight downward vertical gradient is suggested near the toe of the landfill (i.e., the pond acts as a recharge point). A slight upward gradient appears to exist during the wet season in the northeast (furthest downgradient) portion of the site, based on comparisons of manual water level measurements in wells MW-03 and RQLmw-011 (see potentiometric surface maps found in Appendix I). It is important to note that these wells are not nested, consequently, the observations are considered qualitative. Furthermore, potentiometric data collected after 1995 from the existing wells are suspect.

The observed subtle differences in potentiometric head may be expected in an anisotropic flow system. Even though the vertical fractures may be prevalent and widespread, the horizontal hydraulic conductivity along bedding planes and discrete horizontal and vertical fractures zones can vary considerably producing such observed anisotropies. Consequently, it is suspected that groundwater flow in either the up or down direction with respect to the deeper units may lag behind the response measured in the more shallow monitor wells.

2.4 SEDIMENT DATA

Sediment sampling was performed only during the initial phase of the investigation. A summary of the results of the initial phase sediment sampling is presented in Section 1.2.3.2 and is not reiterated here. A complete discussion of the sediment sampling effort is contained in the Initial Phase Report (USACE 1999a).

3.0 RELATED CERCLA ACTIVITIES

Various environmental investigations have been conducted in the vicinity of Ramsdell Quarry, including both general assessments to identify potential AOCs or specific investigations at established AOCs with known or suspected contamination (i.e., Ore Piles and Load Line 1). The ongoing CERCLA RI at Load Line 1 is most relevant to the Groundwater Investigation of RQL considering that this major AOC is located about 244 m (800 feet) south of Ramsdell Quarry. Although not documented to date, uncertainties have existed as to whether Load Line 1 could influence groundwater quality at Ramsdell Quarry and represent a possible upgradient source of groundwater contaminants. Accordingly, a brief summary of the investigative activities and results obtained to date is presented in this section to provide information related to this issue.

Load Line 1 is located in the southeastern portion of RVAAP (Figure 1-2), began operation in 1941, and was used until 1971. All load lines operated at full capacity from 1941 through 1945. During World War II and the Korean War, Load Line 1 was used to melt and load 2,4,6-TNT and Composition B explosives into large-caliber shells (Composition B is a mixture of 2,4,6-TNT and RDX). Cadmium was applied to the shells as a rust deterrent. Other various industrial operations associated with the munitions-loading process were also active during the operation of Load Line 1. These operations included painting, machining, vehicle and equipment maintenance, waste and equipment storage, and use of bulk storage tanks. Load line operations produced explosive dust, spills, and vapors that collected on the floors and walls of several buildings. These residues were periodically washed from walls and floors with water and steam. The majority of the wastewater, known as “pink water,” was collected in concrete sumps located throughout the load line area. The pink water was then pumped to a sawdust filtration unit for chlorification and removal of nitro-compounds prior to discharge. Treated effluents discharged to an earthen settling pond (Griggy’s Pond) via an unlined ditch and subsequently exited the installation southeast of the site. During building washdown, pink water or loose explosive flakes or dust were occasionally swept out of doorways onto the ground.

Load Line 1 was the subject of a Phase I RI in 1996 (USACE 1998b). The purpose of the Phase I RI was to confirm whether contamination is present in soil, groundwater, surface water, and sediment at the site and determine the nature of the contaminants of potential concern (COPCs). Also, since 1996, Load Line 1 has been undergoing decontamination and decommissioning, including removal of telephone lines, major rail spurs across the site, overhead steam lines, friable asbestos shielding, steel piping, trim, overhead lighting (with PCB ballasts), and some structural steel. Phase II RI field activities were initiated in August 1999 with the installation, hydraulic testing, and sampling of eight new groundwater monitoring wells; however, analytical data were not available for review at the time of preparation of this report.

The Phase I RI performed in 1996 included sampling and analysis of groundwater, surface soils, ditch sediment, and sediment from Griggy’s and Charlie’s Ponds. The Phase I RI indicated that elevated concentrations of explosives, inorganics, and organics occur in shallow soils in the central portion of the complex. Residual propellant pellets were found on the ground in the northern portion of the AOC. Aluminum, arsenic, barium, cadmium, chromium, iron, lead, manganese, magnesium, mercury, selenium, and zinc in soils were commonly present above background criteria. Maximum concentrations of inorganics in soils are higher at Load Line 1 than at any of the remaining high priority AOCs investigated, but occurrences of high concentrations of metals do not coincide with high concentrations of explosives. Pond sediment samples did not contain explosives. Potential site-related groundwater constituents detected included cyanide, arsenic, barium, beryllium, cobalt, copper, manganese, mercury, nickel, and zinc. Major geochemical constituents detected, but not related to site operations, included aluminum, calcium, iron, magnesium, potassium, and sodium. Explosives were not detected in groundwater.

Topographic and potentiometric data collected during the Phase I RI suggested that groundwater may flow from the northern end of Load Line 1 toward Ramsdell Quarry. In early September 1999, manual potentiometric surface measurements were collected from all Load Line 1 monitoring wells and RQL monitoring wells, with the exception of MW-5 and RQLmw-011 at RQL and LL1mw-063. These data were collected in order to map the potentiometric surface over the combined Ramsdell Quarry and Load Line 1 area and evaluate groundwater flow patterns (Figure 3-1). A groundwater divide exists in the south–central portion of Load Line 1, corresponding to a topographic high that exceeds 1020 feet above mean sea level (amsl). Potentiometric contours indicate radial flow away from the divide and a potentiometric surface that is a subdued replica of the regional topography. Based on these data, groundwater in the southern third of Load Line 1 flows to east–southeast and in the northern two-thirds of the AOC flows toward the north–northeast. Potentiometric surface gradients were much greater to the southeast (0.014) as compared to the northeast (0.008). The well within Load Line 1 located closest to RQL (LL1mw-067) had a potentiometric head elevation 1.48 feet higher than the upgradient well at RQL (RQLmw-006). These data suggest RQL is at least sidegradient and, possibly, downgradient of Load Line 1.

The absence of explosive contaminants in intervening wells (i.e., LL1mw-067) between Load Line 1 and RQL indicates that signature contaminants are not effectively migrating along these pathways due to factors such as dilution within the water table interval and retardation. Thus, although not conclusively documented, Load Line 1 is not thought to represent an upgradient source of contaminants to groundwater at RQL. Additional data collected under the ongoing Phase II RI will help to determine whether or nor Load Line 1 is a source term for groundwater at RQL.

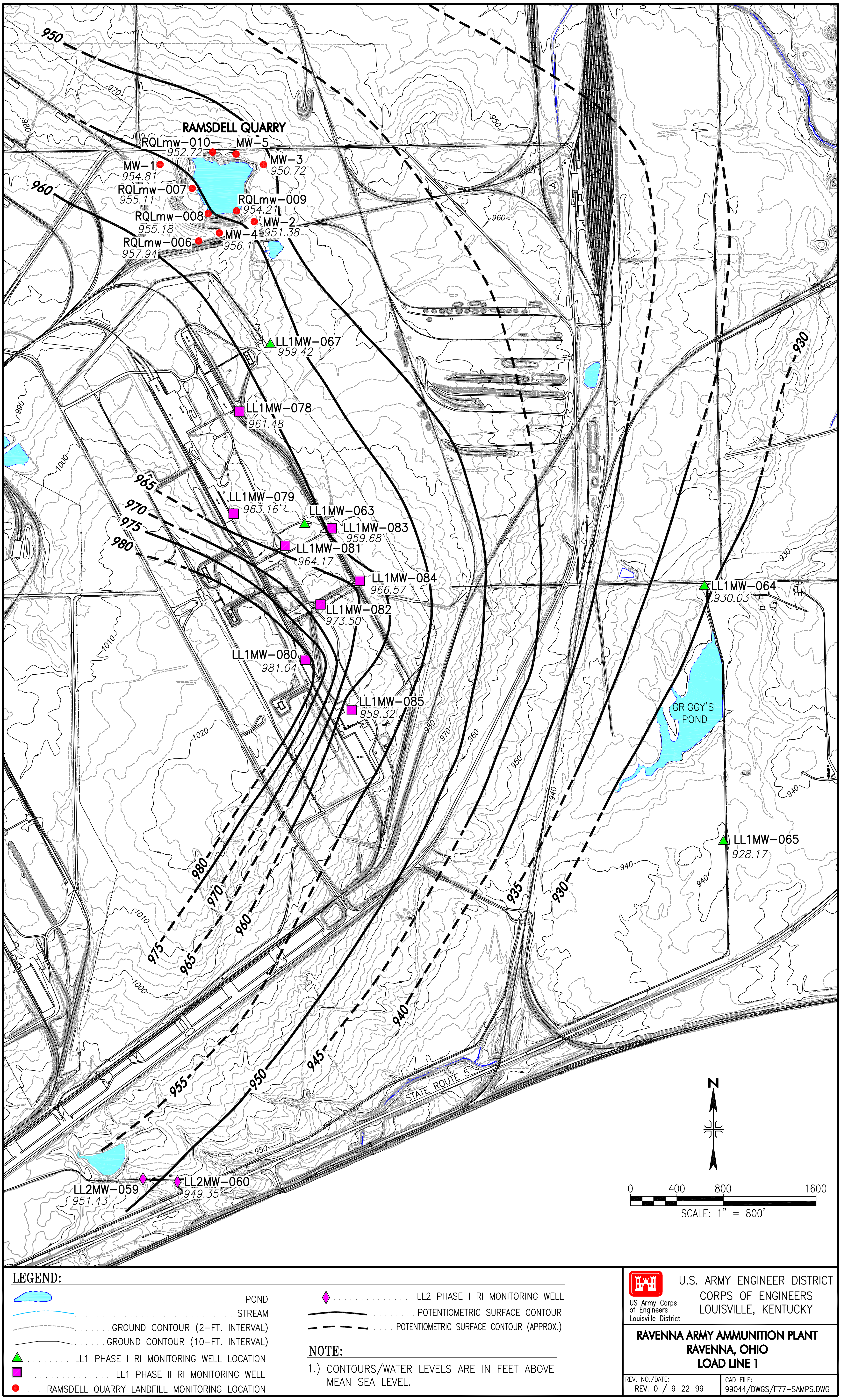


Figure 3-1. Potentiometric Map of Load Line 1 and Ramsdell Quarry, Conditions on September 8, 1999.

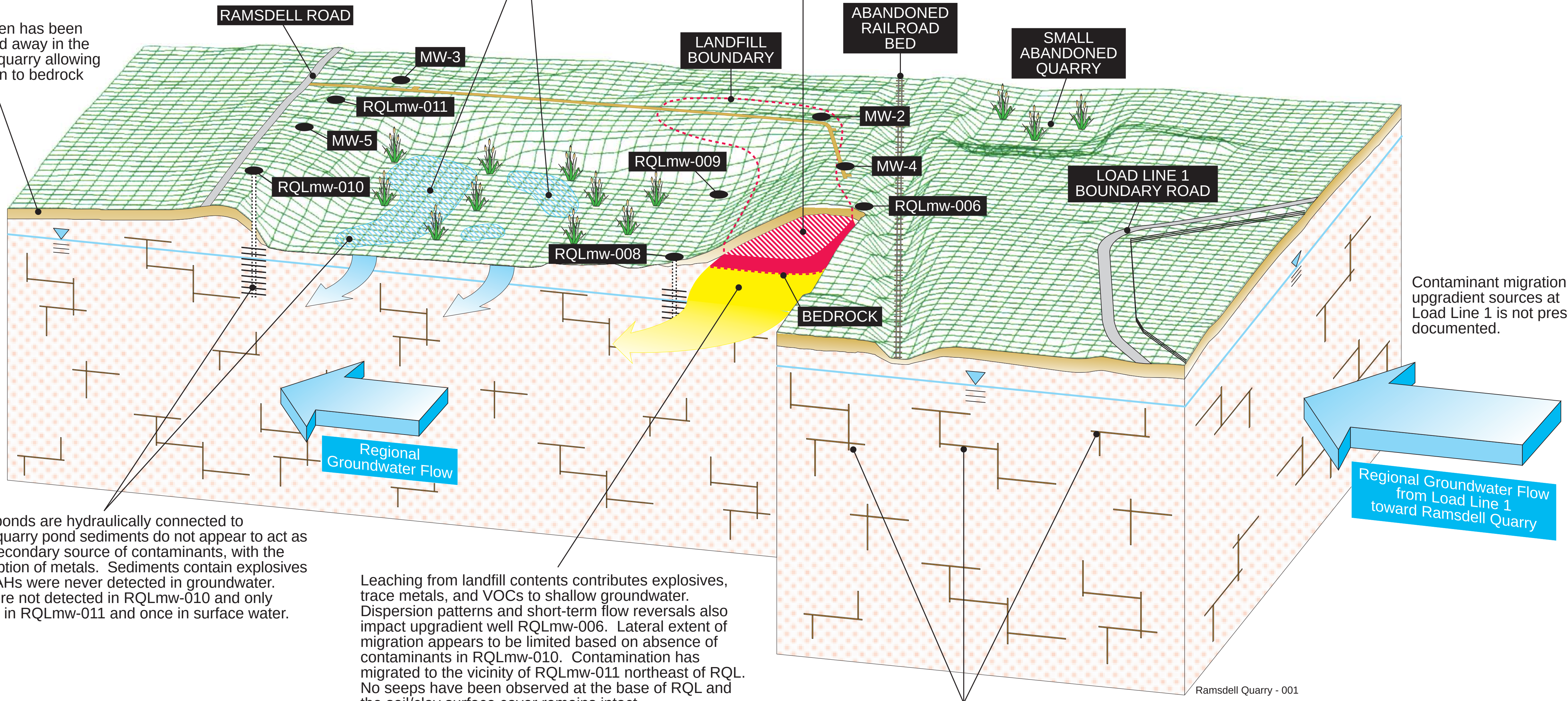
4.0 CONCEPTUAL SITE MODEL AND CONCLUSIONS

Using available data collected during the Groundwater Investigation for RQL, a CSM was developed that provides an integrated summary of potential contaminant sources, impacted environmental media, contaminant occurrence and distribution, and groundwater and contaminant migration mechanisms. The model relates the contaminant source to migration pathways and summarizes the hydrogeologic characteristics of the site. Basic components of the CSM include source term definition and contaminant release mechanisms, groundwater and contaminant migration pathways, and uncertainties. A CSM normally also discusses contaminant migration pathway exit points (i.e., baseflow to streams or springs); however, definition of this element was not deemed to be a critical concern for the Groundwater Investigation based upon known hydrogeologic characteristics of the site and lack of such features in the vicinity of the site. The CSM is illustrated on Figure 4-1.

4.1 SUMMARY OF CONTAMINANT OCCURRENCE AND DISTRIBUTION

Groundwater contains low, but consistently detectable, concentrations of explosive compounds and nitroglycerin. However, no explosives results exceeded EPA Region 9 tap water PRGs. Nitrobenzene; 2,4-DNT; and 1,3-DNB were the most common detected explosives. Wells RQLmw-006 and RQLmw-008 had the highest percentages of detected explosives. Well RQLmw-010 contained no detectable explosives during the investigation. Nitroglycerin was detected on three occasions in groundwater (twice in RQLmw-006 and once in RQLmw-008); no other propellants were detected. In addition to major geochemical constituents (i.e., calcium, iron, magnesium, potassium, and sodium), multiple trace metals were present above facility-wide background criteria. Comparatively fewer results exceeded Ohio DWS and EPA Region 9 tap water PRGs. The most prevalent trace metals were arsenic, cobalt, manganese, mercury, nickel, and zinc. Aluminum, beryllium, chromium, copper, lead, and selenium were sporadically detected above background criteria. Wells RQLmw-006 and RQLmw-011 contained the maximum detected values for most trace metals. Samples from wells RQLmw-006, RQLmw-007, RQLmw-008, and RQLmw-011 had the greatest percentages of results greater than background criteria. Sporadic detections of bis(2-ethylhexyl)phthalate and VOCs (acetone, benzene, carbon disulfide, methylene chloride, tetrachloroethene, and toluene) were noted. No VOC results exceeded Ohio primary MCLs and only one benzene result exceeded the EPA Region 9 tap water PRG. Toluene and methylene chloride were the most common detected VOCs. Well RQLmw-006 had the greatest percentage of maximum detected values.

Analyses of sediment samples collected during the initial phase of the investigation detected multiple metals and cyanide. For trace metals, (i.e., excluding calcium, iron, magnesium, potassium, and sodium) the maximum detected results, at a minimum, for every constituent exceeded facility-wide background criteria. Trace metals were detected in all 12 samples collected, with the following exceptions: beryllium (nine detects), cadmium (four detects), selenium (five detects), and thallium (three detects). Station RQLsd-012 had the preponderance of maximum detected metals and cyanide values (12 of 18 detected constituents); the maximum detected values for the remaining metals occurred at stations RQLsd-012, RQLsd-013, and RQLsd-018. Numerous SVOCs, primarily PAHs, were present in the initial phase sediment samples. Volatile constituents were sporadic, present at low concentrations (all results were estimated values less than reporting limits), and limited to acetone, 2-butanone, and methylene chloride. Seven explosive compounds were detected at least once. The most persistent of these were 2,4,6-TNT (three detects) and HMX (eight detects). All values were



Quarry ponds act as recharge points during the wet season. Mounding of the water table during wet periods produces a flat potentiometric surface and temporary, short-term flow reversals in the water table interval. The ponds act as a potential sink during periods of dry weather due to evapotranspiration. Sediment layer in the pond may slightly retard infiltration.

Nonhazardous solid wastes (hachured area) were placed in RQL between 1976 and 1989. Historical landfilled wastes containing explosives, metals, and possibly other organics (solid red) were placed between 1941 and 1976. About 1980-1981 wastes within the bottom and north side of Ramsdell Quarry were removed. Historical wastes beneath RQL were not removed. During periods of high water table levels, historical wastes may be partially inundated; thereby enhancing leachate development.

Thin overburden has been largely stripped away in the bottom of the quarry allowing rapid infiltration to bedrock

Contaminant migration from upgradient sources at Load Line 1 is not presently documented.

Although the ponds are hydraulically connected to groundwater, quarry pond sediments do not appear to act as a significant secondary source of contaminants, with the potential exception of metals. Sediments contain explosives and PAHs. PAHs were never detected in groundwater. Explosives were not detected in RQLmw-010 and only detected once in RQLmw-011 and once in surface water.

Leaching from landfill contents contributes explosives, trace metals, and VOCs to shallow groundwater. Dispersion patterns and short-term flow reversals also impact upgradient well RQLmw-006. Lateral extent of migration appears to be limited based on absence of contaminants in RQLmw-010. Contamination has migrated to the vicinity of RQLmw-011 northeast of RQL. No seeps have been observed at the base of RQL and the soil/clay surface cover remains intact.

Groundwater flow occurs predominantly through connected fractures bounding lower permeability blocks of bedrock matrix.

Figure 4-1. Conceptual Site Model for Ramsdell Quarry estimated results less than reporting limits, with the exception of the maximum detected HMX values (0.14 mg/kg). Nitrocellulose was detected in three samples.

Surface water sampling indicated that arsenic, chromium, copper, lead, manganese, mercury, and zinc concentrations exceeded facility-wide surface water background on at least two occasions. Iron and manganese exceeded their respective Ohio statewide surface water quality criteria; however, background values for these constituents also exceeded these criteria. Arsenic, iron, and manganese were the only constituents that regularly exceeded EPA Region 9 tap water PRGs. The majority of metals detected above background occurred in the dry season September and October 1998 sampling events at RQLsw-015 when quarry pond water levels were extremely low, which likely produced evaporative concentration. Explosive compounds were detected only on one occasion and propellants were not detected.

4.2 SOURCE TERM AND RELEASE MECHANISMS

Four potential source terms were evaluated as part of development of the CSM: (1) RQL, (2) quarry pond sediment, (3) Load Line 1, and (4) waste materials in place beneath RQL from historical disposals between 1941 and 1976 (Figure 4-1). Available records for RQL indicate that only nonhazardous solid waste was disposed of between 1976 and 1989. No information regarding landfill disposal activities is available for the period 1941 to 1976; however, based on operation history, it may be assumed that aerosol cans, paint residues, pesticide containers, common degreasers, and waste petroleum products and containers were likely placed into the landfill. Disposal of materials containing explosives or propellants residues is not known. As such, a wide variety of potential source-related contaminants may be present. Source term differentiation between RQL and the underlying wastes disposed between 1941 and 1976 cannot be made based on available data. Thus, these two potential sources are considered as a single source term in the current conceptual model. RQL and historical landfilled wastes overlie bedrock and are unlined, and a leachate collection system was not part of the engineered controls. Closure did not involve the placement of an engineered cap and vent system over the landfill. Results of the Groundwater Investigation indicate that RQL and/or historical wastes are a source term for metals, explosives, nitroglycerin, and trace levels of VOCs in groundwater. The RQL and historical wastes do not appear to represent a source of SVOCs. The primary current release mechanism to groundwater likely includes infiltration of precipitation either through the soil cover layer or from upslope areas beneath the edge of the cover. Subsequently, leaching and episodic flushing of contaminants from landfilled wastes occurs through fractures in the bedrock vadose zone until intercepting the water table. Prior to landfill closure, surface water leaching and erosional transport processes also may have mobilized contaminants from primary waste materials, either in dissolved phase or particulate bound, and resulted in accumulation within sediment in low-lying areas of the quarry.

Ramsdell Quarry was used for open burning of waste explosives and munitions, as well as annealing residues. Results of this study show that the pond sediments contain residual metals, cyanide, SVOCs, and explosive and propellant compounds. Review of signature contaminants in the quarry pond sediments (cyanide, PAHs, and explosives) do not provide conclusive evidence that they act as a secondary source term. Explosives were detected on only one occasion in new monitoring wells immediately downgradient of sediment sources (RQLmw-010 and RQLmw-011), as compared to multiple detections in those wells immediately upgradient at the toe of RQL (wells RQLmw-007, RQLmw-008, and RQLmw-009). In addition, PAHs were not detected in any of the site monitoring wells. Explosives, propellants, cyanide, and SVOCs were not detected in associated surface water samples, indicating that contaminant mass transfer from sediment to surface water with subsequent infiltration of contaminated surface water is not a significant release mechanism. A potential does exist that the quarry sediments may contribute some metals contaminants to groundwater, based on the frequency of occurrence of this class of contaminants, in well RQLmw-011.

Load Line 1, located approximately 244 m (800 feet) to the south of RQL, is a known source term for explosives, propellants, metals, and PCBs/pesticides (USACE 1998b). Available potentiometric data indicate that the northern portion of the load line is hydraulically upgradient to RQL; thus, groundwater flow is possible via fracture pathways. However, data obtained during the course of Phase I RI activities have not confirmed that Load Line 1 is a source of contamination to groundwater. Analytical data from the northernmost well at Load Line 1 have not shown the presence of signature contaminants (i.e., explosives). While metals contaminants were observed in Load Line 1 groundwater samples, high adsorption coefficients for this class of constituents minimizes the potential for long distance transport to RQL. In addition, the probability of attenuation and dilution within shallow, active groundwater pathways greatly reduces possible migration of any explosive and propellant compounds that may be present in groundwater. On this basis, Load Line 1 is not thought to impact groundwater quality at RQL. Data from the Phase II RI at Load Line 1 will determine if upgradient sources are present that could potentially impact groundwater quality at RQL in the future. These data, if available, may be considered during the preparation of future monitoring reports for RQL.

4.3 GROUNDWATER FLOW AND CONTAMINANT MIGRATION PATHWAYS

A majority of groundwater flow at Ramsdell Quarry occurs through permeable fracture pathways within bedrock (Figure 4-1). The overburden layer in the site vicinity is characteristically thin and has been largely removed within the quarry by past operations; therefore, infiltration occurs almost directly to bedrock. While the sediment layer present in the quarry pond may dampen infiltration to some degree, hydrographs for the wells located at the toe of the landfill clearly indicate rapid, strong response to storm events.

Potentiometric data show that horizontal potentiometric gradients are consistently to the northeast during dry periods of the year. During these periods, the quarry pond is a static representation of the water table and may even function as a groundwater discharge area through evapotranspiration processes. During the wet season of the year, a sufficient reservoir of water exists in the quarry pond to induce a downward vertical hydraulic gradient (recharge) and induce localized radially outward flow. As a result, potentiometric surface elevations in upgradient well RQLmw-006 and those at the toe of the landfill are essentially equal. Rainfall events during the wet period of the year provide additional volume to the quarry pond and produce sufficient hydraulic head to produce slight, localized flow gradient reversals between the pond and well RQLmw-006 for short periods of time. Wells RQLmw-010 and RQLmw-011 remain consistently downgradient of RQL throughout the year. Evaluation of hydraulic data and major ion chemistry indicates that fracture flow paths are sufficiently prevalent and interconnected so that the new and existing wells monitor essentially the same flow system. Subtle (observed) differences in hydraulic head may be expected in an anisotopic flow system where horizontal hydraulic conductivities along fracture flow pathways and bedding planes can vary widely.

The distribution of contaminants in wells at RQL are consistent with the observed hydraulic characteristics. Considering that the horizontal potentiometric gradient during the wet season is flat and exhibits short-term reversals, leaching from RQL and/or underlying historical wastes is the likely source of observed contaminants in well RQLmw-006 (Figure 4-1). For a majority of the year, groundwater flow is consistently to the north–northeast providing the mechanism for contaminant migration to wells located at the toe of RQL and to RQLmw-011.

4.4 UNCERTAINTIES

The CSM is developed based on available hydrogeologic and chemical data. Uncertainties are inherent in the CSM where selected data do not exist or are sparse. The uncertainties within the CSM for the RQL include the following:

- Uncertainty exists regarding the nature and types of contaminants to be expected from RQL and/or underlying historical wastes due to the lack of detailed waste inventories. Thus, the RQL and/or historical wastes are assumed, but not confirmed, as the primary source for groundwater contaminants, such as explosives, propellants, and VOCs.

- Due to extremely dry conditions that persisted during the period of the investigation, water levels in the quarry pond were abnormally low. Therefore, the degree of recharge provided by the quarry pond has not been characterized under typical hydrologic conditions. During periods of normal precipitation, the pond would be expected to remain at full pool for longer periods of time. Accordingly, the duration and severity of observed groundwater flow reversals differ substantially from that observed under conditions represented in this study.

- Because of the very dry conditions stated above, the degree to which quarry pond sediments may act as a secondary source under typical hydrologic conditions has not been fully assessed by this investigation. Under average rainfall conditions, leachate development and mass transfer of contaminants may be greater than during conditions represented by this study. Conversely, the increased rainfall could potentially dilute concentrations of contaminants from quarry sediment as they partition to groundwater.

4.5 CONCLUSIONS

Results of the RQL Groundwater Investigation achieved the project DQOs, as described in Section 1.1. Summary conclusions of the study as related to each of these DQOs are as follows:

- Assessment of site hydrogeology and quality of shallow groundwater beneath the site using the new monitoring network indicates that RQL and/or underlying historical wastes are sources for metals, VOCs, explosives, and low concentrations of propellants via leaching mechanisms.

- Although contaminants were consistently detected in groundwater at RQL, overall severity of groundwater quality impacts is low. Few metals exceeded EPA Region 9 tap water PRGs on a consistent basis (arsenic, iron, manganese, and lead); organic compounds rarely exceeded their criteria. Migration of contaminants in groundwater appears to be limited based on the lack of signature explosives in wells furthest downgradient of RQL.

- The Ramsdell Quarry pond (surface water and sediment) does not appear to represent a significant source of contaminant flux to groundwater, with the possible exception of metals.

- Comparative assessment of water levels in the Ramsdell Quarry pond and surrounding monitoring wells show hydraulic connection with shallow groundwater, particularly wells at the toe of the landfill, and that the pond is a source of recharge during the wet season.

- Quarterly monitoring of the new monitoring network during baseflow conditions (dry season) and wet season conditions suggests episodic flushing of metals and generally higher concentrations occurring in the wet season. Maximum values for general water quality indicators and anions were almost exclusively associated with the storm event sampling in May 1999. No observed seasonal variation in the frequency of detection of explosives was noted. However, the maximum detected values for five of eight detected explosives occurred during the dry season indicating dilution effects during the wet season. Episodic flushing of VOCs was not indicated, with almost all detected values occurring in the dry season.

- Comparison of potentiometric data and major ion chemistry from the new and existing monitoring networks shows that the wells monitor the same flow systems from a hydraulic and geochemical perspective.

5.0 RECOMMENDATIONS

The following recommendations are made based on the results of this investigation:

- Continue sampling of the existing groundwater monitoring network in accordance with OAC 3745-27-10, as evaluation of existing data does not indicate extensive migration of contaminants downgradient of RQL.

- Utilize EPA Region 9 tap water PRGs as indicators for potential future increases in contaminant extent or flux from RQL.

- Evaluate data from future monitoring at RQL with respect to additional groundwater results obtained from Load Line 1 during the course of the Phase II RI to assess whether contaminant migration from upgradient source areas occurs in the future.

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