Draft

Well Abandonment Work Plan for RVAAP-66 Facility-Wide Groundwater

Former Ravenna Army Ammunition Plant
Portage and Trumbull Counties, Ohio

February 19, 2016

Contract Number: W9133L-14-D-0008
Task Order Number: 0003

Prepared for:

National Guard Bureau
NGB-ZC-AQ
111 South George Mason Drive
Building 2, 4th Floor
Arlington, VA 22204-1373

Prepared by:

TEC-WESTON Joint Venture
2496 Old Ivy Road, Suite 300
Charlottesville, VA 22903-4895

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Brent Ferry
Michael Chapa
TEC-WESTON Joint Venture
2496 Old Ivy Road, Suite 300
Charlottesville, VA 22903-4895

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TEC-WESTON Joint Venture
2496 Old Ivy Road, Suite 300
Charlottesville, VA 22903-4895

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National Guard Bureau
NGB-ZC-AQ
111 South George Mason Drive
Building 2, 4th Floor
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14. ABSTRACT

This Well Abandonment Work Plan (WAWP) describes the activities associated with performing abandonment of historical groundwater production wells and selected monitoring wells at the Former Ravenna Army Ammunition Plant (RVAAP), now known as the Camp Ravenna Joint Military Training Center (CRJMTC/Camp Ravenna; also termed "site" in this WAWP), in Portage and Trumbull counties, Ohio (Figure 1-1). The WAWP has been prepared by the TEC-WESTON Joint Venture (JV) under Task Order 0003, Contract W9133L-14-D-0008 for the National Guard Bureau (NGB) to provide a prescribed methodology for well abandonment services at Camp Ravenna.

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U	U	U	SAR	229	19b. TELEPHONE NUMBER *(Include area code)* 512-651-7108 office 309-236-9235 cell

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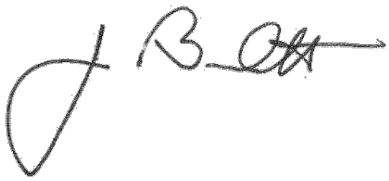
CONTRACTOR STATEMENT OF INDEPENDENT TECHNICAL REVIEW

TEC-Weston Joint Venture (JV) has completed the Draft Well Abandonment Work Plan. Notice is hereby given that an independent technical review has been conducted that is appropriate to the level of risk and complexity inherent in the project. During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of data quality objectives; technical assumption; methods, procedures, and materials to be used; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the customer's needs consistent with law and existing National Guard Bureau policy.

2/17/2016

David G. Wazny, P.G. TEC-Weston JV — Date
Field Team Lead



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Jim Brackett, PA PMP, TEC-Weston JV — Date
Independent Technical Review Team Leader

Significant concerns and the explanation of the resolutions are as follows:

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Portage and Trumbull Counties, Ohio

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Justin Burke, Ohio EPA Contracting Officer — 1 HC of transmittal letter only

ARNG = Army National Guard
OHARNG = Ohio Army National Guard

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LIST OF ACRONYMS / ABBREVIATIONS

ANSI/NSF	American National Standards Institute/National Sanitation Foundation
AOC	Area of Concern
APP-SSHP	Accident Prevention Plan and Site Safety and Health Plan
ARNG	Army National Guard
ATV	all-terrain vehicle
bgs	below ground surface
Camp Ravenna	Camp Ravenna Joint Military Training Center
CFR	Code of Federal Regulations
COPC	contaminant of potential concern
CRJMTC	Camp Ravenna Joint Military Training Center
DOD	Department of Defense
DOT	Department of Transportation
DRMO	Defense Reutilization Marketing Office
EPA	Environmental Protection Agency
EQM	Environmental Quality Management
ft	foot/feet
FWGW	facility-wide groundwater
FWSAP	Facility-Wide Sampling and Analysis Plan
HASP	Health and Safety Plan
IDW	investigation-derived waste
INRMP	Integrated Natural Resources Management Plan
IRP	Installation Restoration Program
JV	Joint Venture
m^2	square meters
mg/L	milligrams per liter
MRS	Munitions Response Site
NGB	National Guard Bureau
ODNR	Ohio Department of Natural Resources
OHARNG	Ohio Army National Guard
Ohio EPA	Ohio Environmental Protection Agency
OWRC	Ohio Water Resources Council
PCBs	polychlorinated biphenyls
Plexus	Plexus Scientific Corporation

POC	Point of Contact
RI	Remedial Investigation
RIWP	Remedial Investigation Work Plan
RVAAP	Former Ravenna Army Ammunition Plant
SAIC	Science Applications International Corporation
SDS	safety data sheets
SVOC	semi-volatile organic compound
TAL	target analyte list
TCL	target compound list
TCLP	Toxicity Characteristic Leaching Procedure
TGM	Technical Guidance Manual
TOC	top of casing
UFP-QAPP	Uniform Federal Policy Quality Assurance Project Plan
USEPA	United States Environmental Protection Agency
USP&FO	United States Property and Fiscal Officer
Vista	Vista Sciences Corporation
VOC	volatile organic compounds
WAWP	Well Abandonment Work Plan

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1.0 INTRODUCTION

This Well Abandonment Work Plan (WAWP) describes the activities associated with performing abandonment of historical groundwater production wells and selected monitoring wells at the Former Ravenna Army Ammunition Plant (RVAAP), now known as the Camp Ravenna Joint Military Training Center (CRJMTC/Camp Ravenna; also termed "site" in this WAWP), in Portage and Trumbull counties, Ohio (**Figure 1-1**). The WAWP has been prepared by the TEC-WESTON Joint Venture (JV) under Task Order 0003, Contract W9133L-14-D-0008 for the National Guard Bureau (NGB) to provide a prescribed methodology for well abandonment services at Camp Ravenna.

For continuity of format, procedural and documentation protocols, and overall content, the JV extensively utilized the Ohio Environmental Protection Agency (Ohio EPA)-approved Final Interim Removal Action Work Plan for Historical Well Abandonment Activities (Plexus Scientific Corporation [Plexus], 2015) during the preparation of this WAWP.

1.1 WORK PLAN PURPOSE

The purpose of this WAWP is to outline the methods and procedures for the abandonment of historical water production wells and monitoring wells located within or downgradient of known Areas of Concern (AOCs) or Munitions Response Sites (MRSs) or within potentially impacted groundwater plumes. The activities described in this WAWP include the processes for abandonment of production wells and monitoring wells. The abandonment of the production wells will eliminate a potential chemical hazard pathway by preventing a conduit for potential groundwater contamination migration between aquifers. Physical hazards will also be eliminated by the removal of a direct physical exposure pathway to the groundwater via the wells.

This WAWP is intended to provide a description of the site procedures and abandonment processes anticipated during site work. This WAWP is not intended to provide an evaluation of groundwater at Camp Ravenna.

Abandonment of the wells will be performed as described in the State of Ohio Regulations and Technical Guidance for Sealing Unused Water Wells and Boreholes (Technical Guidance) (Ohio

Water Resources Council [OWRC], 2015) (**Appendix A**), documented in accordance with Ohio Revised Code 1521.05(B) (**Appendix B**), performed per the Technical Guidance Manual (TGM) Chapter 9, Sealing Abandoned Monitoring Wells and Boreholes (**Appendix C**), and per relevant portions of the Facility-Wide Sampling and Analysis Plan (FWSAP) (Science Applications International Corporation [SAIC], 2011).

1.2 WORK PLAN ORGANIZATION

This WAWP is comprised of the following sections:

Section 1.0 – Introduction
Section 2.0 – Facility Description
Section 3.0 – Well Abandonment Approach
Section 4.0 – Well Abandonment Report
Section 5.0 – Schedule
Section 6.0 – References

Appendices are provided following Section 6.0.

2.0 FACILITY DESCRIPTION

The former RVAAP, now known as the CRJMTC (Camp Ravenna), located in northeastern Ohio within Portage and Trumbull counties, is approximately 3 miles east/northeast of the City of Ravenna and 1 mile north/northwest of the City of Newton Falls. The facility is approximately 11 miles long and 3.5 miles wide. The facility is bounded by State Route 5, the Michael J. Kirwan Reservoir, and the CSX System Railroad to the south; Garret, McCormick, and Berry Roads to the west; the Norfolk Southern Railroad to the north; and State Route 534 to the east. In addition, the facility is surrounded by the communities of Windham, Garrettsville, Charlestown, and Wayland.

Administrative accountability for the entire 21,683-acre facility has been transferred to the United States Property and Fiscal Officer (USP&FO) for Ohio and the property subsequently licensed to the Ohio Army National Guard (OHARNG) for use as a military training site, Camp Ravenna. The RVAAP restoration program involves cleanup of former production/operational areas throughout the facility related to former activities conducted under the RVAAP. References in this document to Camp Ravenna relate to previous activities at the facility as related to former munitions production activities or to activities being conducted under the restoration/cleanup program. Past Department of Defense (DOD) activities at Camp Ravenna date back to 1940 and include the manufacturing, loading, handling, and storage of military explosives and ammunition.

The Camp Ravenna Installation Restoration Program (IRP) encompasses investigation and cleanup of past activities over the entire 21,683 acres of the facility. Therefore, references to Camp Ravenna in this document, unless otherwise stated, shall include the acreage of both the Former RVAAP and Camp Ravenna.

2.1 HISTORICAL PRODUCTION WELL INFORMATION

Limited information exists regarding the historical production wells located at Camp Ravenna. The 2013 *Final Former Water Production Wells and Oil and Gas Wells Survey* (Vista Sciences Corporation [Vista], 2013) identified 44 historical production wells at the facility. Of the 44 wells located, 38 were identified visually and 6 were identified as geophysical anomalies at their expected locations. To date, 25 wells have been properly closed under the RVAAP restoration program and 9 wells were properly closed by the OHARNG. Ten wells remain closed and will be

covered under this contract. A summary of the known information regarding these 10 production wells is provided in **Table 2-1**. This summary information includes historical production well locations, their known depths, and the conditions in the area around the wells.

2.2 MONITORING WELL INFORMATION

The existing monitoring well network includes approximately 284 monitoring wells installed for multiple purposes, with additional wells to be installed as part of the RVAAP-66 Remedial Investigation (RI). Ohio Administrative Code Chapter 3701-28-17 requires that all water wells that are not in service shall be either sealed in accordance with the rules or maintained in strict compliance with all applicable requirements. Wells must be properly abandoned to prevent contamination of the groundwater; prevent physical hazards; eliminate unnecessary, inadequate, and/or improperly installed monitoring wells; and minimize threats to the various aquifers and related groundwater receptors.

A summary of the known information regarding the existing monitoring wells is presented in **Table 2-2**, including monitoring well locations and depths.

2.2.1 Geology

Camp Ravenna consists of horizontal to gently dipping bedrock strata of Mississippian- and Pennsylvanian-age overlain by varying thicknesses of unconsolidated glacial deposits.

The unconsolidated glacial deposits at the Camp Ravenna are overlain by deposits of the Wisconsin-aged Lavery Till located in the western portion of the site. The younger Hiram Till and associated outwash deposits are observed in the eastern two-thirds of the site and vary considerably in their character and thickness across the site.

2.2.2 Hydrogeology

Groundwater at Camp Ravenna is present in both the overlying unconsolidated glacial deposits and in selected bedrock units. Groundwater within unconsolidated glacial deposits and bedrock aquifers predominantly flows in an eastward direction; however, there are local groundwater flow variations that are influenced by topography and drainage patterns on the western portion of Camp Ravenna resulting in surface discharge of the groundwater in some of the lower lying drainage

areas. Additionally, topographic ridges between surface water drainage features act as groundwater divides in the unconsolidated glacial deposits (Environmental Quality Management [EQM], 2013). **Figures 2-2** and **2-3** illustrate the potentiometric surfaces of the unconsolidated and bedrock aquifers across Camp Ravenna, respectively.

The bedrock potentiometric surface shows a more uniform and regional eastward flow direction that is not as affected by local surface topography as the unconsolidated aquifer system. Due to the lack of well data in the western portion of Camp Ravenna, groundwater occurrence in the eastern portion of the facility is better understood compared to the western portion. For much of the eastern portion, the bedrock potentiometric surface is higher than the overlying unconsolidated aquifer potentiometric surface, indicating an upward hydraulic potential affected in part by confining layers that separate the unconsolidated and bedrock aquifers. The sandstone units of the Pennsylvanian-age Pottsville formation are the major aquifers at Camp Ravenna and across the region. Within this formation, the Sharon Conglomerate (primarily sandstone with a variable occurrence of "conglomerate" characteristics at depth) is the most productive of these aquifers, and is the major bedrock aquifer in northeastern Ohio.

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3.0 WELL ABANDONMENT APPROACH

3.1 WELL ABANDONMENT LIST

Historical production wells and monitoring wells determined to be no longer necessary will be removed pursuant to the procedures identified within this WAWP. The abandonment of these wells removes the potential for direct human exposure to contaminants of potential concern (COPCs), and eliminates the risk of cross contamination, which may lead to long-term effects on human health and the environment.

This WAWP lists the 10 production wells identified by the NGB to be abandoned prior to completion of the Record of Decision. Monitoring wells will be selected for abandonment based on Ohio EPA concurrence with the final monitoring network, which will be determined later in the facility-wide groundwater (FWGW) RI schedule.

The 10 historical production wells to be abandoned are listed in **Table 3-1** and depicted on **Figure 3-1**. The current monitoring well network is summarized in **Table 2-2**.

The WAWP will be modified by addendum as monitoring wells selected for abandonment are definitively identified during the RI. As these wells are identified, **Table 2-2** will be modified and a figure will be developed. Both the modified table and figure will be inserted as addendum items (**Appendix J**) to this document. A final list and map showing all monitoring wells to be abandoned will be provided to the Ohio EPA for review and approval prior to field activities.

3.2 PREPARATORY ACTIVITIES

3.2.1 Reconnaissance of the Ten Production Well Locations

The JV's Field Team Lead, Mr. Dave Wazny, P.G., met with Mr. Kevin Sedlak (Army National Guard [ARNG]) and Ms. Katie Tait (OHARNG) on November 13, 2015 to evaluate the locations, general conditions, and potential routes accessing the 10 production wells planned for abandonment. Route maps presented in **Appendix D** were prepared based on the nearest roadway to each well, and field observations including terrain, vegetation, habitat, and overall access limitations.

3.2.2 Health and Safety

Field activities will be performed in accordance with the Facility-Wide Accident Prevention Plan and Site Safety and Health Plan (APP-SSHP) (SAIC, 2011), and the Health and Safety Plan (HASP) prepared as part of the FWGW RI.

3.2.3 Wetlands Delineation and Stream Management Avoidance

Wetlands are present near some of the well abandonment sites. To assure wetlands avoidance, a wetlands biologist will demarcate the temporary access routes to each well site prior to beginning tree clearing operations (see **Subsection 3.3.2**). The wetlands biologist will perform a verification site visit prior to the start of abandonment operations to verify that temporary access routes avoid wetlands. If any new wetland areas are observed during the verification visit, access routes may be altered to avoid these areas. If a stream or ditch must be temporarily crossed to access a well, crane mats will be used to avoid disturbing these areas.

Potential wetland areas identified near the wells and proposed temporary access routes are shown on the well access figures in **Appendix D**. The wetlands shown were taken from United States Geological Survey National Wetlands Inventory map layers and the wetlands data from the *Integrated Natural Resources Management Plan* at the Camp Ravenna Joint Military Training Center, Portage and Trumbull Counties, Ohio (INRMP) (OHARNG, 2014a).

As well access routes are developed and modified, they will be inserted as addenda (**Appendix J**) to this document. The Contractor will make every attempt to conduct well abandonment activities in dry weather to avoid impacts to wetlands.

3.2.4 Management Considerations for Northern Long Eared Bat

Well abandonment activities must comply with Northern Long Eared Bat management practices, which require the marking of trees and brush 3-inches in diameter or greater for removal, and OHARNG approval by the Camp Ravenna Environmental Office. It is required to flag and coordinate access routes and trees/brush to be removed prior to cutting. Once approved, cutting may occur between 1 October and 31 March.

3.2.5 Cultural Resources Management

The OHARNG will assemble an internal memorandum reviewing all previous cultural resource surveys to document and identify any potential cultural resource sites within and in the vicinity of the well abandonment sites. Due to prior disturbance associated with initial well installations and the previous industrial activities in the areas of the wells, the well abandonment activities will have no effect on the cultural resources at the facility. In the event that cultural materials are inadvertently discovered, the JV will stop work and comply with OHARNG *Procedures for Inadvertent Discovery of Cultural Materials at Camp Ravenna* as per the CRJMTC, Contractor Information dated 2 April 2014 (OHARNG, 2014b) (**Appendix E**).

3.2.6 Mobilization

Field activities will be coordinated with the OHARNG/ARNG and Ohio EPA prior to field work. Activities such as utility clearance will be coordinated through the Camp Ravenna Department of Public Works Office (Engineering). Access rosters will be sent to the Camp Ravenna Operations/Security Office via Vista for approval no later than 48 hours prior to start of work, and will coincide with the duty days and hours of the facility (Monday-Friday 0730 to 1630) as outlined in the Contractor Information, April 2014. If extended work schedules are required, a request will be made to the ARNG and OHARNG who will submit the request to Camp Ravenna Range Control for approval. The JV will also work with the OHARNG/ARNG to locate equipment staging areas and coordinate activities with other site contacts. The area near Building 1036 has been identified by OHARNG as the main staging and storage area during the well drilling and abandonment activities. In the event that another location is needed for storage during these activities, field personnel will coordinate with the Camp Ravenna Operations office to minimize potential impacts to the daily facility operations. Equipment and materials to be used during these activities include, but may not be limited to, the following: blade trimmers, chain saws, brush cutters, drill rigs, large trucks, tanks, and drums. During field activities, TEC-Weston JV will keep in close contact and will coordinate field locations with Camp Ravenna Range Control and the Camp Ravenna Environmental Office.

3.2.7 Utility Clearance

Some anticipated activities associated with the well abandonment tasks will have the potential for exposing or contacting subsurface utilities. TEC-Weston JV will contact the Ohio Utilities Protection Service (for wells outside of the perimeter fence) at least 48 hours, but no more than 10 working days, before beginning intrusive field activities. The contractor will prepare a map of the well abandonment locations and present it to the Camp Ravenna Director of Public Works Operations office for utility clearance. TEC-Weston JV will coordinate with the Camp Ravenna Operations office as outlined in the Contractor Information, April 2014 (OHARNG, 2014b) (**Appendix E**) to locate and mark areas of anticipated subsurface impact.

3.2.8 Vegetation Removal

To gain access as necessary to implement the well abandonment procedures, vegetation will be cleared along some of the temporary access routes. Vehicles capable of off-road travel will be used to avoid disturbing the ground surface to the extent possible. As previously noted, vegetation removal will also adhere to the cutting restrictions developed for the Northern Long Eared Bat. All clearing activities will be performed to minimize erosion and sedimentation in accordance with Federal, State, and facility regulations. Detailed access routes to each well identified for abandonment are illustrated in **Appendix D**.

Access routes to the well locations will be cleared using a brush cutter and other relevant above grade vegetation removal equipment. A chainsaw or the equivalent will be used for the felling of trees. In accordance with facility requirements, all 8.5 feet (ft) and longer straight portions of hardwood and conifer trees, as measured from an 18-inch stump height to a 10-inch diameter outside of bark top will be felled, limbed flush to the tree bole, and neatly stacked in a location designated by OHARNG to be salvaged as sawtimber. All other hardwood trees shorter than 8.5 ft, or with diameters greater than 4 inches, or trees that are too crooked or deformed to be used as sawtimber, will be cut into lengths of 4.5 or 9 ft and will be salvaged and placed in a location designated by OHARNG to be used as firewood/biomass. All non-sawtimber portions of felled conifers and small portions of hardwoods along with all other woody brush not salvaged for firewood/biomass will be chipped and blown onto the site but not in piles. Stumps from felled trees

will be cut as low to the ground surface as possible to facilitate the passing of vehicles during the abandonment process.

Following the completion of well abandonment activities, TEC-Weston field personnel will ensure the re-vegetation of any small areas of soil disturbance in compliance with the INRMP (OHARNG, 2014a). Erosion controls will be maintained until the site work is completed and 70% of the area is revegetated. Total soil disturbance during all abandonment operations is expected to be less than 1 acre.

3.2.9 Well Locating

Prior to well abandonment activities, the locations of the 10 production wells outlined in **Table 3-1** (and eventually the monitoring wells to be outlined in **Table 3-1a** as an addendum) will be confirmed and coordinated during site walk activities with the use of geospatial data. For the well abandonment tasks, if wellheads are determined to be buried, the buried well casings will be exposed by excavating up to 4 ft of soil cover using hand tools, a small excavator, or a backhoe. If the well casing is not encountered within the top 4 ft of soil, the OHARNG/ARNG will be contacted to discuss the appropriate measures to be taken.

3.2.10 Wellhead Clearing

Wells may require heavy equipment to remove obstructions surrounding the well casing. All equipment and materials for these processes will be brought as close to the well as possible; however, in the instances where this may not be possible, due to the steepness of the terrain for example, other measures may be employed to gain access. Equipment such as all-terrain vehicles (ATVs), skid steers, and other relevant equipment may be used to access the wellheads. At locations where grout mixing equipment is not able to access the wellhead, hoses will be used to pump the grout from the mixing location to the wellhead.

Any soil disturbing activities will proceed in a manner to reduce the risk of erosion and sedimentation in accordance with the INRMP (OHARNG. 2014a)**.** All earthwork, grading, movement of equipment, and other operations, will be planned and performed to avoid pollution or sediment discharge into adjacent waters. Where necessary, and in accordance with the INRMP (OHARNG, 2014a), silt fence will be installed at well locations where disturbance will be greater

than 15 square meters (m^2). The fence will be inspected on a weekly basis as necessary to ensure its integrity and will be replaced or repaired as needed. The storm water inspection form is provided in **Appendix F**. These inspection forms will be included in the final report to the Ohio EPA. The total areas that will be disturbed during field activities are not anticipated to be greater than 1 acre. This *de minimus* impact is less than the minimum acreage required by the Ohio EPA for Small Construction Projects (Ohio EPA, 2015). Best management practices for storm water will be utilized and a formal Storm Water Pollution Prevention Plan will not be required. In areas less than 15 m^2, straw bales/sandbags may be used, as necessary, to intercept potential runoff at the well locations during any surface preparation or abandonment activities.

3.3 WELL ABANDONMENT

All well abandonment activities will be conducted in accordance with State of Ohio *Regulations and Technical Guidance for Sealing Unused Water Wells and Boreholes* (OWRC, 2015) (**Appendix A**), documented in accordance with Ohio Revised Code 1521.05(B) (**Appendix B**), conducted in accordance with the TGM Chapter 9, *Sealing Abandoned Monitoring Wells and Boreholes* (**Appendix C**), and also conducted in accordance with relevant portions of *FWSAP* (SAIC, 2011).

Abandonment activities will include abandonment of wells and the removal of any wellhead equipment, any downhole materials recovered (i.e., pumps and piping), and well housings. Disposal of investigation-derived waste (IDW) is discussed in **Subsection 3.5**. Well sealing reports (**Appendix B**) will be submitted to the Ohio Department of Natural Resources (ODNR) Division of Soil and Water Resources in accordance with the Ohio Revised Code 1521.05(B).

A letter will be composed notifying the Ohio EPA prior to beginning any abandonment activities. Submittal of the letter will be coordinated with OHARNG/ARNG. Additionally, prior to beginning abandonment activities at each well, depths to groundwater and depths to bottom will be measured from the top of casing (TOC) and ground surface for submittal to the ODNR in the well sealing reports. Any observations made during the abandonment process such as odor, sheen on the surface of water, or debris within the well, as well as the static water levels and total depths, will be recorded and be included as notes within the depth to water table in the completion report. Water table elevations will also be calculated and provided in the table using the depth to water from

ground surface and survey elevations provided in the *Final Former Water Production Wells and Oil and Gas Wells Survey* (Vista, 2013). These notes will also be submitted with the well sealing reports to the ODNR.

3.3.1 Disinfection

The State of Ohio Technical Guidance suggests that unused potable water wells (i.e., production wells) undergo disinfection with a chlorine solution to kill any bacterial organisms that may exist in the water and to prevent contamination of wells that are downgradient in the aquifer. In accordance with the Technical Guidance, chlorine incorporated as calcium hypochlorite tablets in solution will be used to disinfect the wells (historical production wells only) at concentrations of 50 to 100 milligrams per liter (mg/L); thereby preventing the bacterial contamination of any wells that may be downgradient of the sealed well within the same aquifer. As outlined in the Technical Guidance, the disinfectant will be American National Standards Institute/National Sanitation Foundation (ANSI/NSF) 60 certified. The calcium hypochlorite will be introduced into the well at a rate recommended by the manufacturer. The solution with the disinfectant will be introduced into the well by slowly wetting the circumference of the well or borehole starting at the bottom, ensuring that all sides of the borehole or well are wetted with the solution. The solution will be well mixed within the well/borehole prior to sealing with grout.

The calcium hypochlorite tablets will be stored in the hazardous materials corrosives lockers provided by the OHARNG in Building 1036 as identified in the CRJMTC Hazardous Materials Management Guidelines (**Appendix E**). Safety data sheets (SDSs) including instructions for the safe use and potential hazards associated with the use of chlorine will be submitted to the Camp Ravenna Environmental Office in accordance with the *FWSAP*. The calcium hypochlorite tablets stored onsite during the abandonment process will be clearly labeled, inventoried, and inspected on a weekly basis. All unused hazardous materials will be removed from the site following completion of the well abandonment activities in accordance with the Hazardous Materials Management Guidelines of the CRJMTC.

3.3.2 Grouting/Sealing Process

Due to the limited information regarding the construction details of the historical production wells, along with the ages (greater than 70 years) of the wells, and in accordance with the Technical

Guidance regarding wells of unknown construction, no attempt will be made to remove the well casings associated with on-site production wells. Other than cutting them below grade, the casing will be left in place to prevent any mixing of groundwater from saturated zones.

Monitoring wells will be sealed in-place when the construction details are known, the annular seal is intact, and the filter pack does not cross more than one groundwater zone. If this information cannot be verified, the well casing and well screen will be removed by pulling or bumping the casing, overdrilling around the casing using a hollow-stem auger, or drilling out the well using a solid stem auger or rotary bit in accordance with TGM Chapter 9, *Sealing Abandoned Monitoring Wells and Boreholes* (**Appendix C**)

If the construction details are known, the monitoring well will be filled with clean (ANSI/NSF 61) disinfected sand to 1 foot above the screen when the screened area is adjacent to a highly permeable formation.

One foot of bentonite chips/pellets will be placed above the screen in a manner that prevents bridging (i.e., through a tremie pipe or by tamping after installation). (Note: Chips are recommended below the water table because they will sink, whereas pellets will often float to the water table.) The chips/pellets will be hydrated if placed above the water table.

To allow the sealant to permeate and be effective, the casing will be perforated to 1 foot above the bentonite seal either by splitting it vertically (synthetic casing) or by making horizontal cuts every 2 feet with a retractable blade (steel casing).

All wells (i.e., production and monitoring) will be grouted with a bentonite/cement slurry composed of Type I Portland cement in accordance with the Technical Guidance and the *FWSAP*. In accordance with the Technical Guidance, the bentonite/cement slurry will consist of 5 pounds of dry bentonite per one 94-pound sack of dry cement and approximately 9 gallons of water.

In accordance with the Specific Well Sealing Procedures discussed in the Technical Guidance, the wells will be sealed by pressure grouting. As written in the Technical Guidance, pressure grouting involves pumping the cement or bentonite slurry down a tremie pipe lowered to the bottom of the well. As the slurry is pumped into the well, the tremie pipe will gradually be raised while keeping the end of the tremie pipe submerged below the slurry already emplaced in the well. The slurry

will be applied as one continuous procedure in an effort to prevent segregation, dilution, and bridging within the well. The slurry is denser than water to displace any water within the well. Any water displaced from the well during the grouting process will be captured in a tank and pumped to a storage tank prior to final containerization (see **Subsection 3.5**). If the grout mixing equipment is unable to access the wellhead, the grout will be pumped to the wellhead through hoses. The well will be considered completely filled with slurry material when all of the existing water has been removed and the slurry is 2 to 3 feet below ground surface (bgs). Once the grouting process has been completed, the slurry will be allowed to settle for at least 24 hours before proceeding with the final steps of the abandonment process. The well will be topped off with grout following any possible settling that may occur. Any unused slurry will be allowed to dry and will be disposed with the concrete demolition debris discussed in **Subsection 3.5**.

If any wells are observed to be installed in highly fractured zones, the slurry may not rise to the ground surface. If the boring is not filling and voids or fractures are suspected, in accordance with the Technical Guidance, downhole video cameras or geophysical logging such as calipers logs will be used to accurately determine the location and size of subsurface voids. Following camera or geophysical logging, if the borehole is observed to be drilled past the void, at least two shale traps will be installed into the grout-filled portion of the borehole. The shale traps will be stacked one on top of the other and aligned at least 2 to 3 feet above the top of the void. If multiple voids are observed, in an effort to isolate the different zones, shale traps will be placed above each of the void zones. Following placement of the shale traps, a tremie pipe will simultaneously be inserted into the borehole to just above the lowermost set of shale traps. The lowermost zone will be sealed first and the tremie tube pulled up above the remaining set of shale traps. The grouting process of the well will be continued as outlined above. If it is observed that the cavernous or fractured zone is less than a few feet in thickness, the well or borehole will be filled with coarse gravel to the top of the void, and then pressure grouted with cement from the top of that zone to the ground surface.

After the slurry has reached the surface, the casing will be cut off to a depth of at least 2 feet bgs. Any small remaining voids will be backfilled with bentonite chips. At locations where the casings were exposed at the surface, the remaining open hole will be 12 inches or less and the hole will be backfilled with bentonite chips. At locations where buried casings were exposed by removing soil over and around the casing, additional cement slurry or bagged gravel pack will be emplaced at

the bottom of the excavated area if it is required to make up for any lost volume. The remaining depression will be backfilled with the soil removed to expose the casing. Care will be taken to slightly mound the surface completion to ensure drainage of surface water away from the well. Specific surface restoration procedures are discussed in **Subsection 3.11.**

Should site conditions make access to the wellhead difficult (i.e., wetlands, streams, brush, or forested areas), coarse grade bentonite or coated coarse grade bentonite may be used instead of slurry to abandon the wells. All activities will be completed in accordance with *Regulations and Technical Guidance for Sealing Unused Water Wells and Boreholes* (OWRC, 2015) (**Appendix A**). Pursuant to the cited technical guidance, coarse grade bentonite, also referred to as crushed or chip bentonite, is processed by the manufacturer to provide a large particle size and density. The bentonite particles typically are available in nominal sizes of 3/8- to 3/4-inch and are intended to fall through a column of water. Prior to using this material, the bentonite will be sieved through 1/4-inch mesh screen to remove any fines that have accumulated in the bag during shipment. These fines, if not removed, will clump when they encounter water and increase chances of bridging.

When sealing wells with coarse grade bentonite products, precautions will be taken to ensure that the sealing material does not bridge. Coarse grade bentonite products can be used in wells up to 200 feet deep. Pelletized bentonite products can be used in wells up to 100 feet deep. If the well is less than 4 inches in diameter and over 100 feet deep, dry pouring will not be allowed. All coarse grade products used in wells less than 24 inches in diameter will be poured over a wire mesh screen to eliminate the fine bentonite powder that could cause bridging. These products will be slowly poured at a rate no faster than 3 minutes per 50-pound bag. The pouring process will be occasionally halted to lower a weighted measuring tape into the well until it reaches the top of the sealing products to confirm that bridging has not occurred. Adequate time for settling of the coarse grade bentonite will be allowed before measurements are recorded. A tamping device will be used to break any bridges that form. The total volume of products used to fill the well should be no less than 80% of the estimated amount needed for sealing. Where the borehole or well is dry, the bentonite will be periodically hydrated with water in accordance with the manufacturer's requirements. When placed properly, the coarse grade bentonite provides a flexible high density, low permeability downhole seal.

All downhole equipment (e.g., water level meters, tremie pipes, etc.) will be decontaminated after use in each well to ensure there is no potential for cross contamination between wells or aquifers.

3.4 INVESTIGATION-DERIVED WASTE

All IDW generated during the well abandonment activities will be handed in accordance with the Camp Ravenna Waste Management Guidelines (OHARNG, 2015). All IDW field activities will be coordinated though the Camp Ravenna Point of Contact (POC), as identified in the Camp Ravenna Waste Management Guidelines (OHARNG, 2015). A final copy of the IDW report and associated waste paperwork will be included in the Final Completion Report.

Coordination:

- Coordinate all waste generation, manifests, profiles, and shipments with the appropriate Camp Ravenna POC listed on the Camp Ravenna Water Management Guidelines.
- Notify Camp Ravenna POC prior to waste sampling for characterization. Details about sampling activities must be included (i.e., number of sample, analyticals etc.).
- All Hazardous and Non-Hazardous waste management storage locations must be pre-approved prior to generation.
- Ensure all labels include: Date, Contractor, and Waste Type.
- When contractors have waste onsite, a weekly inspection inventory must be completed and submitted to the appropriate POC in the Camp Ravenna Environmental Office. This form is contained in **Attachment G**.
- All wastes shall be tracked and logged throughout the duration of the project. Contractor will provide the Camp Ravenna POC with a monthly rollup report of all waste and recycled streams generated by no later than the 10th day of the following month.

In addition to IDW management, an effort will be made to minimize all solid waste and recyclable materials. Good housekeeping will be implemented at all work sites to ensure a safe and clean working environment. The quantity of solid waste and recyclable materials generated during the course of this investigation is anticipated to be *de minimis*.

3.5 INVESTIGATION-DERIVED WASTE COLLECTION AND CONTAINERIZATION

Two types of IDW may be generated during well abandonment activities: indigenous and non-indigenous. Indigenous IDW consists of IDW that is native to Camp Ravenna (e.g., soils and waters). Non-indigenous IDW consist of IDW that is not native to Camp Ravenna (e.g., rinsate waters or acids from sampling containers). The generation of indigenous and non-indigenous IDW is anticipated. Once containerized, IDW will be documented and tracked using the "Weekly Waste Inventory and Container Log Sheet" (**Appendix G)**.

All liquid and soil indigenous (i.e., water and soil from well abandonment activities) IDW generated may be composited from multiple boreholes, wells, or AOCs until the drum is full. Similarly, all non-indigenous (e.g., decontamination rinse water) IDW may be composited from multiple AOCs until the drum is full. Drum labels will include the AOCs/MRSs location where the waste was generated. All indigenous IDW will be collected either in labeled Department of Transportation (DOT)-approved, new 55-gallon, closed-top drums (liquids), labeled polyethylene storage tanks, open-top drums (solids), or roll-offs (solids), as applicable. Sampling of IDW for disposal characterization will be performed using a composite grab sampling technique.

All non-contaminated, non-indigenous IDW (i.e., municipal solid wastes) will be contained in trash bags with potentially contaminated non-indigenous IDW being additionally contained in labeled, DOT-approved, open-top 55-gallon drums equipped with plastic drum liners and sealed with bung-top lids.

3.5.1 Liquid Investigation-Derived Waste Composite Sampling Procedure

Although soil IDW is not anticipated during well abandonment activities, if encountered, soil IDW will be handled in accordance with the protocols described in this section. All IDW will be characterized at the conclusion of each well abandonment event. Following guidance of the *FWSAP* (Section 8.4.2), sampling of liquid IDW (groundwater and decontamination water) for disposal characterization will be performed using a composite grab sampling technique. The equipment used in liquid IDW sampling will consist of sample containers and disposable or decontaminated sampling equipment (e.g., bailers, pump tubing, and drum thief). Coliwasa samplers should be used if the liquid IDW is determined or expected to be stratified. The handling, storage, and shipment of IDW samples will follow procedures as described in Section 7.1 of this

document. Liquid IDW (i.e., groundwater and decontamination rinse water) will be sampled and analyzed separately. Composite grab sample collection will be performed as follows:

1. Correlate the number of grab samples and sample volume required by the laboratory to determine the volume needed to provide equal amounts of aliquot from each grab sample (drum container) at the recommended sample volume (e.g., five 20-mL aliquots from five discrete grab samples to generate a 100-mL composite sample representing five IDW containers).
2. Using decontaminated or clean disposable equipment, collect discrete grab samples from each drum.
3. Using a clean pipette or equivalent clean measuring device, deliver equal aliquots of the grab samples directly into sample container(s) to be sent to the laboratory.
4. Repeat this process until equal amounts of each aliquot from each grab sample have been collected. Each discrete grab sample should be collected in identical fashion.
5. Seal the sample container and shake well to mix. Prepare the container for shipment to the laboratory.

3.5.2 Soil Investigation-Derived Waste Composite Sampling Procedure

All IDW will be characterized at the conclusion of each sampling event. Following guidance of the *FWSAP* (Section 8.4.1), sampling of soil IDW for disposal characterization will be performed using a composite grab sampling technique. The equipment used in soil IDW sampling will consist of sample containers and disposable or decontaminated sampling equipment (e.g., small-diameter hand augers or soil push probes, stainless steel bowls, and mixing instruments [e.g., knives and spoons]). The handling, storage, and shipment of IDW samples will follow procedures as described in Section 7.1 of this document. Composite grab sample collection will be performed as follows:

1. Collect discrete grab samples using clean, decontaminated, or disposable equipment such as small-diameter hand augers or soil push probes from each segregated IDW waste container. Each discrete grab sample should be collected in an identical fashion (frequency and volume).

a. For volatile organic characterization, grab samples of equal proportions will be transferred directly from each IDW waste container to the sample container with minimum head space for laboratory analysis.
b. For all analyses other than VOCs, individual grab samples will be transferred into a sample bowl for homogenizing.

2. Homogenize individual grab samples using a sampling bowl and mixing instrument by stirring and turning over the sample until the mixture is adequately homogenized. The mixture is then divided by half, and equal portions from each half will be used to fill sample containers.
3. Assemble the sample containers that contain the homogenized grab samples that will make up a specific composite sample.
4. Remove an aliquot of sample from each container to be sampled and place it in a decontaminated stainless steel mixing bowl. Each aliquot amount is to be as identical as possible to facilitate representativeness.
5. Homogenize the aliquots as described in Step 2.
6. Remove sample amounts from the homogenized composite sample and place them into the proper containers for shipment to the laboratory.

3.6 WASTE CONTAINER LABELING

All waste containers will be labeled in accordance with the Camp Ravenna Contractor Guidelines, the Camp Ravenna Waste Management Guidelines, and the FWSAP to identify their source, contents, date of generation, and status. In accordance with Section 8.2 of the *FWSAP*, all containers, including empty ones, must be properly labeled. All waste storage containers (drums and polytanks) will be labeled immediately before and continuously during their use to ensure proper management of the contained wastes. All labels will be weather-resistant, commercially available labels. Two labels will be affixed and located on opposite sides on the upper one-third of each storage container. Labels will be legibly completed using indelible ink. The drum number will be legibly recorded directly on a clean dry drum surface on the top and upper one-third of each storage container using an indelible paint marker. Additional label information may be recorded directly on a clean dry drum surface.

The following procedure will be used for waste container labeling:

- Place each label on a smooth part of the container and do not affix it across drum bungs, seams, ridges, or dents.
- Upon use of a container, replace the empty label with a drum label filled out with the information listed below.
- When sampling each container per the procedures outlined in Section 7.1.1 of this document, affix an appropriate pending analysis label to the container.
- When classifying the IDW based on analytical results, affix the appropriate hazardous or non-hazardous label to the drum.
- Record the following information on each label:
    - Contractor-assigned container number;
    - Contents;
    - Source of waste;
    - Source location (if applicable);
    - Project name and AOC identification;
    - Physical characteristic of the waste;
    - Generation date(s);
    - Address of waste generation; and
    - Contact information for a contractor contact and the Camp Ravenna POC.
- Record all information on container labels with indelible ink (permanent marker or paint pen) and record necessary information in a field logbook or on an appropriate field form.
- Protect all container labels so that damage or degradation of the recorded information is prevented.
- Drum labels will be photographed when affixed to the container. Photographs will be provided to the Camp Ravenna Environmental Office. New photographs will be collected whenever drum status is updated (i.e., pending analysis, final classification).

3.7 INVESTIGATION-DERIVED WASTE FIELD STAGING

Nonhazardous IDW will be stored onsite at Building 1036 pending analysis and disposal. Liquid waste, whether drums or poly tanks, will be stored within secondary containment. In the unlikely event that hazardous waste is generated, it will be stored at Building 1047. In accordance with the Camp Ravenna Waste Management Guidelines (OHARNG, 2015) (**Appendix E)**, all satellite accumulation storage sites and containers will comply with 40 Code of Federal Regulations (CFR) 262.34(c)(1):

- Any material that is subject to Hazardous Waste Manifest Requirements of the United States Environmental Protection Agency (USEPA) must comply with 40 CFR Part 262.
- From the time any waste is placed in a satellite storage container, proper labeling must be on the container (proper labeling includes date, contractor's name, and product type).
- Pending analysis label is to be used from the time the sample is taken until the results are received.
- In no case will waste labeled pending analysis exceed 45 days.

3.8 INVESTIGATION-DERIVED WASTE CHARACTERIZATION AND CLASSIFICATION FOR DISPOSAL

For the FWGW RI, liquid and soil IDW will be analyzed for the following (as applicable to the waste stream):

- Toxicity Characteristic Leaching Procedure (TCLP) volatile organic compounds (VOCs);
- TCLP semi-volatile organic compounds (SVOCs);
- TCLP metals;
- TCLP herbicides;
- TCLP pesticides;
- Total sulfide;
- Total cyanide;
- Corrosivity (pH); and
- Flashpoint for proper disposal.

Specific bottle ware, preservatives, holding times, and analytical methods for IDW analysis is presented in Worksheet #19 of the Uniform Federal Policy Quality Assurance Project Plan (UFP-QAPP) (Part II of Appendix B of the FWGW Remedial Investigation Work Plan [RIWP]).

Analytical results from the subcontracted laboratory will be reviewed to determine if any potentially hazardous wastes exist. This review includes a comparison of the TCLP criteria against the liquid analytical results and the leachate concentrations for soil (i.e., TCLP Preparation Method 1311). Analytical results for TCLP analysis will be compared to **Table 3-2** (originally Table 8-1 of the *FWSAP*) and non-TCLP analysis will be compared to **Table 3-3** (originally Table 8-2 of the *FWSAP*) to determine if the IDW is classified as hazardous or non-hazardous.

After all analytical results have been received for each investigation and prior to the disposal of any waste, an IDW Characterization and Disposal Plan will be prepared by the FTL and will include:

- An inventory of all stored IDW.
- The analytical results and IDW characterization.
- Recommendations for the disposal of all IDW.

The recommendations for IDW disposal presented in the IDW Characterization and Disposal Plan will be submitted to the OHARNG/ARNG and, upon approval, implemented. A copy of the approved IDW Plan will be included in the corresponding sampling reports.

3.8.1 Neutralization of Corrosive Liquids

If the liquid IDW is determined to be characteristically hazardous due solely to corrosivity (pH greater than 12.5 due to residual grout in wastewater), a request will be submitted to the OHARNG to perform on-site elementary neutralization as allowed by Ohio Administrative Code Rule 3745-50-45. In accordance with a summary of elementary neutralization policy located on the Ohio EPA website (*see "neutralizing-corrosive-(acid-or-base)-waste-in-a-container*), storage tanks and drums can serve as elementary neutralization units. Muriatic acid, which is a commercially available acid commonly used in swimming pool treatment, will be used to lower the pH to an acceptable level. Following treatment, liquid IDW will be tested with a pH meter by USEPA Method 9040C, and if observed to be less than the allowable level, will be discharged on-site or

disposed of off-site as a non-hazardous waste depending on the results of the other analyses. Handling and storage of muriatic acid is discussed in **Section 3.9.2**.

3.8.2 Onsite Hazardous Materials

It is anticipated that chlorine, incorporated as calcium hypochlorite tablets, to be used for disinfecting the wells will be the only hazardous material brought onto the facility during the abandonment process. The calcium hypochlorite tablets will be stored in the hazardous materials corrosives lockers provided by the OHARNG in Building 1036 as identified in the *CRJMTC Hazardous Materials Management Guidelines.*

It is also possible that muriatic acid will be used for on-site neutralization of liquid IDW. If muriatic acid is used for onsite neutralization, it will be stored in the hazardous materials acids lockers provided by the OHARNG in Building 1036 as identified in the *CRJMTC Hazardous Materials Management Guidelines.*

The SDS for each hazardous material to be used will be provided to the Camp Ravenna Environmental Office prior to the start of work. All hazardous materials brought onto the facility will be clearly labeled, inventoried, and inspected on a weekly basis. Labels will be legibly completed using indelible ink. All unused hazardous materials will be removed from the site following completion of the well abandonment activities in accordance with the *CRJMTC Hazardous Materials Management Guidelines*. In accordance with the *FWSAP*, a spill kit will also be retained onsite.

3.9 INVESTIGATION-DERIVED WASTE DISPOSAL

In accordance with the Camp Ravenna Waste Management Guidelines (OHARNG, 2015) (**Appendix E)**, should a waste be determined to be hazardous, "Contractors are required to utilize hazardous waste haulers and Treatment, Storage, and Disposal Facilities on the latest Defense Reutilization Marketing Office (DRMO) approved list." The current qualified waste hauler and Treatment, Storage, Disposal Facilities list can be viewed by following the "Qualified Facilities" and "Qualified Transporters" links found on the Defense Logistics Agency Hazardous Waste Disposal Homepage.

If the waste is non-hazardous, a waste hauler/recycler will be identified and submitted to the OHARNG/ARNG for approval and a recommendation for disposal or recycling will be made. Should on-site discharge or dispersal for non-hazardous non-contaminated wastes (i.e., soils and water) be a potential option, the OHARNG/ARNG will be provided a plan for approval. The process necessary to discharge or disperse the materials on-site will be presented within the plan.

For Hazardous or Non-Hazardous manifests, the following must be included:

- Restoration Program Waste Site Name = Former Ravenna Army Ammunition Plant. Mailing address is Camp Ravenna ENV, 1438 State Route 534 SW, Newton Falls, Ohio 44444. Site address: 8451 State Route 5, Ravenna, Ohio 44266, (614) 336-6136. Ohio EPA ID # – OH5210020736.
- Contractor's shipping Hazardous Waste must provide a Land Disposal Restriction in accordance with 40 CFR Part 268.
- Profiling:
  - The required shipping documentation (i.e., waste profile and summary of lab reports (IDW Plan) need to be submitted to appropriate Camp Ravenna POC or designee(s) for approval and signature prior to shipping.

- Results of characterization must be submitted to appropriate Camp Ravenna POC within 30 days after collecting the sample.
- Manifests - Hazardous and Non-Hazardous:
  - The waste carrier/transporter provides appropriate manifest to the contractor.
  - The contractor is required to:
    - Ensure that Camp Ravenna POC or designee(s) is available to sign the manifest on the scheduled day of shipment;
    - Verify that each manifest is properly completed and signed by Camp Ravenna POC or designee(s);
    - Provide the Generator copy of the manifest to Camp Ravenna POC or designee(s); and

- Ensure that the original Generator copy of the manifest signed by the treatment storage disposal facility is returned to Camp Ravenna within 30 days of the shipping date for Hazardous and Non-Hazardous Waste.
- The use of a Bill of Lading, in lieu of a waste manifest, must be approved by the Camp Ravenna environmental office.

3.10 SITE RESTORATION

In accordance with the 2014 INRMP, the restoration of the areas that may have been disturbed following the well abandonment activities will be ensured. Any soils disturbed as part of abandonment activities will be restored to match existing grade. Areas made bare will be re-vegetated with grasses or other appropriate vegetation using the approved native seed mix as outlined on page 92 of the 2014 INRMP, which is summarized in **Table 3-4**.

All backfill material brought onto the facility will be free of contaminants and organic matter prior to being brought onsite. All backfill will be sampled in accordance with Camp Ravenna requirements for backfill soil intended for use at the facility. Note that the TEC-WESTON JV intends to use the same backfill material approved for use in the *Final Interim Removal Action Work Plan for Historical Well Abandonment Activities* (Plexus, 2015). See **Appendix H** for the analytical results for that material. If a different source of material is used, samples will be collected every 4,000 cubic yards using incremental sampling methods. Samples will be sent to an Ohio EPA approved laboratory to be analyzed for target compound list (TCL) VOCs, TCL SVOCs, TCL pesticides, polychlorinated biphenyls (PCBs), explosives including nitroglycerine, nitro-guanidine and nitrocellulose, target analyte list (TAL) metals, and pH. Results of the analyses will be screened against facility-provided background levels. In accordance with facility regulations, approved fill will be at or below facility-wide background values. The backfill source identified and approved will be used on all areas across the facility in the event that backfill material is required.

All areas made bare will be seeded within 7 days following stripping activities in accordance with OHARNG *Approved Grass Seed Mixes for Temporary Cover and Final Site Closures* (OHARNG, 2014a). All areas that are seeded with grass will also be mulched with a minimum of three square bales of straw per 1,000 square feet of seeded area, and mulch netting will be used instead of straw

on slopes that exceed 6%. Following restoration activities, any erosion and sediment control measures installed for well abandonment activities will be removed. Areas of disturbance where storm water controls are employed will be inspected weekly until 70% of the groundcover is reestablished. The aforementioned areas will also be inspected after any rain event per facility requirements. Inspection reports will be submitted to the Camp Ravenna Environmental Office on a weekly basis detailing the progress of regrowth. These reports will be included in the final report to the Ohio EPA.

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4.0 WELL ABANDONMENT REPORT

A Preliminary Draft Well Abandonment Report will be submitted to OHARNG/ARNG following the completion of all well abandonment activities. The report will summarize the well abandonment processes and procedures used during all field activities conducted. It will describe pre-mobilization, mobilization, site preparation, depth to water and total depth measurements, casing diameters, decontamination, waste management, and the chronology of events. It will include associated figures and tables. The report will also include the ODNR well sealing reports for all of the abandoned wells.

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5.0 SCHEDULE

Upon approval of the Final WAWP and Final RIWP, the production well abandonment activities will be scheduled. Monitoring well abandonment planning will not be completed until the RI progresses and well selections can be made. Tree clearing activities may only be performed between October 1 and March 31 since no cutting is allowed during April – September due to a sensitive endangered species inhabiting the trees at the facility. The Preliminary Draft Well Abandonment Report (for production wells) will be submitted following receipt of the IDW analytical data and subsequent disposal. The schedule (**Table 5-1**) of anticipated activities will be updated after the Final RIWP is issued.

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6.0 REFERENCES

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TABLES

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Table 2-1 Historical Production Well Location Data

Former Production Well Number	X-Coordinate	Y-Coordinate	Casing Diameter (in) and Length (ft)	Recorded Depth (ft)	Confirmed Well Casing	Suspected Well Casing	Site Conditions
3	2367248	556387	8" x 38.5'	149	X		Wooded/Brush
5	2366730	561922	8" x 34	100		X	Brush
6	2366670	561452	8" x 50'	95	X		Brush
7	2366910	563056	6" x 34.5'	60	X		Mowed Area
8	**2367368**	**554478**	**6" x 22.5'**	**175**	**X**		**Mowed Area**
10	2357892	549618	6" x 52'	250		X	Mowed Area
12	2357703	567263	6" x 26'	222	X		Brush
13	2367594	569133	6" x 60'	120	X		Mowed Area
14	2380168	570036	6" x 36'	170	X		Wooded/Brush
16	2341542	548152	6" x 30'	238	X		Mowed Area
17	**2357916**	**557845**	**6" x 12'**	**215**	**X**		**Mowed Area**
18	**2349002**	**548415**	**6" x 36.5'**	**228**		**X**	**Brush**
20	2340712	561168	6" x 158'	195		X	Wooded/Brush
21	**2365472**	**556968**	**8" x 55.5'**	**158**	**X**		**Wooded/Brush**
22	**2371803**	**569037**	**6" x 11.2'**	**91**	**X**		**Wooded/Brush**
23	2367760	568078	6" x 73'	133	X		Mowed Area
24	2377157	563190	6" x 8.8'	167	X		Brush
31	2375326	558868	6" x 8.5'	101	X		Paved Area
32	2366388	561916	8" x 41'	106		X	Wooded/Brush
33	2365883	569454	6" x 112'	156	X		Brush
35	**2374164**	**566933**	**6" x 11'**	**143**	**X**		**Wooded/Brush**
36	2374395	560215	6" x 14.5'	118	X		Brush

Table 2-1 Historical Production Well Location Data (continued)

Former Production Well Number	X-Coordinate	Y-Coordinate	Casing Diameter (in) and Length (ft)	Recorded Depth (ft)	Confirmed Well Casing	Suspected Well Casing	Site Conditions
37	2373666	561682	6" x 16'	155	X		Wooded/Brush
38	2375918	564287	6" x 9'	169		X	Wooded/Brush
39	2376468	559647	6" x 12'	137	X		Brush
41	**2359449**	**554449**	**6" x 36'**	**130**	**X**		**Wooded/Brush**
48	**2354624**	**552949**	**12" x 10.67'**	**175**	**X**		**Wooded/Brush**
49	2356709	549780	12" x 37.7'	173	X		Wooded/Brush
49A	2356724	549776	4" x Unknown	Unknown	X		Wooded/Brush
50	2371487	558338	6" x 19'	136	X		Mowed Area
51	2370696	559817	6" x 9'	142	X		Mowed Area
53	2350457	567212	8" x 39.4'	250	X		Brush
54	2335387	553102	6" x 17'	150	X		Wooded/Brush
55	2335040	558626	6" x 22'	150	X		Wooded/Brush
56	2344846	558709	6" x 27.4'	148	X		Wooded/Brush
57	2352878	561019	6" x Unknown	176	X		Wooded/Brush
58	2350849	560675	6" x 96.6'	182	X		Wooded/Brush
62	2351981	557152	12" x 43'	221	X		Wooded/Brush
63	**2353790**	**556509**	**12" x 41'**	**214**	**X**		**Wetlands**
66	2365874	555471	6" x 50'	172	X		Wooded/Brush
95	2357876	560572	6" x Unknown	NA	X		Brush
96	**2344436**	**551180**	**4" x Unknown**	**NA**	**X**		**Wooded/Brush**
98	2345492	551728	6" x Unknown	NA	X		Mowed Area
100	2358044	570306	6" x Unknown	98	X		Brush

Notes: in: inch; ft: feet; NA: Not Applicable
Bold and Shaded: Well to be Abandoned by the JV per this WAWP.
Source: Vista, 2013.

Table 2-2 Monitoring Well Location Data

RVAAP Area	Well ID	Ohio State Plane Easting	Ohio State Plan Northing	Ground Level Elevation	Total Drilled Depth	TOC Elevation	Wellhead Type	Monitored Zone	Top of Screen (ft bgs)	Top of Screen Elevation	Bottom of Screen (ft bgs)	Bottom of Screen Elevation	Bottom of Inner Casing Plug or End Cap	Stickup Height	Reported Bottom of Inner Casing	May 2014 Measure Bottom of Inner Casing	Sediment Accumulation	Description of Bottom
Atlas Scrap Yard	ASYmw-001	2366260.85	558404.04	978.40	22.0	981.13	A	Sharon	11.0	967.4	21.0	957.4	21.0	2.73	23.7	23.12	0.58	hard
Atlas Scrap Yard	ASYmw-002	2366170.86	557887.86	982.00	20.0	985.24	A	Sharon	10.0	972.0	19.5	962.5	19.5	3.24	22.7	22.93	0.00	soft
Atlas Scrap Yard77	ASYmw-003	2366651.49	558015.94	979.70	21.5	982.21	A	Sharon	11.0	968.7	21.0	958.7	21.0	2.51	23.5	23.50	0.00	hard
Atlas Scrap Yard	ASYmw-004	2367166.04	557640.81	977.10	27.8	979.66	A	Sharon	17.0	960.1	27.0	950.1	27.0	2.56	29.6	29.84	0.00	hard
Atlas Scrap Yard	ASYmw-005	2367448.16	557783.01	977.60	25.0	979.80	A	Sharon	14.0	963.6	24.0	953.6	24.0	2.20	26.2	27.15	0.00	hard medium
Atlas Scrap Yard	ASYmw-006	2366746.73	557257.72	980.20	27.0	983.01	A	Sharon	16.0	964.2	26.0	954.2	26.0	2.81	28.8	28.90	0.00	hard
Atlas Scrap Yard	ASYmw-007	2366834.49	556818.08	981.40	28.0	984.16	A	Unconsolidated	16.0	965.4	26.0	955.4	26.0	2.76	28.8	28.88	0.00	medium
Atlas Scrap Yard	ASYmw-008	2367475.07	557087.66	976.20	26.0	978.85	A	Unconsolidated	15.0	961.2	25.0	951.2	25.0	2.65	27.7	27.20	0.50	medium
Atlas Scrap Yard	ASYmw-009	2366631.94	557603.68	979.90	22.0	982.70	A	Sharon	11.5	968.4	21.5	958.4	21.5	2.80	24.3	24.19	0.11	soft
Atlas Scrap Yard	ASYmw-010	2366985.37	557270.61	978.20	28.0	981.05	A	Unconsolidated	17.0	961.2	27.0	951.2	27.0	2.85	29.8	31.14	0.00	hard
Building 1200	B12mw-010	2371292.81	565827.43	1002.72	21.0	1005.92	A	Sharon	10.0	992.7	20.0	982.7	20.0	3.20	23.2	22.80	0.40	hard
Building 1200	B12mw-011	2371416.15	565687.82	1003.76	24.7	1006.70	A	Sharon	14.0	989.8	24.0	979.8	24.0	2.94	26.9	26.68	0.22	hard
Building 1200	B12mw-012	2371430.41	565828.01	1003.43	22.3	1006.32	A	Sharon	12.0	991.4	22.0	981.4	22.0	2.89	24.9	24.82	0.08	hard
Building 1200	B12mw-013	2371221.00	565904.00	1001.80	22.0	1004.48	A	Sharon	11.5	990.3	21.5	980.3	21.8	2.68	24.25	24.15	0.10	hard
Background	BKGmw-004	2368852.97	569464.76	965.16	19.5	967.66	A	Unconsolidated	9.2	956.0	19.2	946.0	19.5	2.50	22	22.22	0.00	hard
Background	BKGmw-005	2340835.86	562288.45	1149.44	19.0	1151.94	A	Unconsolidated	8.2	1141.2	18.2	1131.2	18.5	2.50	21	20.92	0.08	hard
Background	BKGmw-006	2358643.96	571910.47	1026.38	35.1	1028.88	A	Sharon	24.7	1001.7	34.7	991.7	35.1	2.50	37.6	37.56	0.04	hard
Background	BKGmw-008	2372741.08	569654.23	970.40	25.0	972.90	A	Sharon	14.7	955.7	24.7	945.7	25.0	2.50	27.5	27.37	0.13	hard
Background	BKGmw-010	2371372.86	565540.54	1003.80	22.0	1006.18	A	Sharon	8.9	994.9	18.9	984.9	19.2	2.38	21.6	21.97	0.00	hard
Background	BKGmw-012	2367795.23	563918.86	997.57	59.8	1000.07	A	Sharon	38.6	959.0	59.6	938.0	59.8	2.50	62.3	62.01	0.29	soft
Background	BKGmw-013	2361627.39	558269.16	986.59	25.5	989.09	A	Unconsolidated	15.2	971.4	25.2	961.4	25.5	2.50	28	28.01	0.00	hard
Background	BKGmw-015	2361482.22	569339.87	1037.90	51.0	1040.40	A	Sharon	30.1	1007.8	50.1	987.8	50.4	2.50	52.9	52.99	0.00	hard
Background	BKGmw-016	2342407.08	553983.50	1098.42	19.0	1100.92	A	Unconsolidated	8.4	1090.0	18.5	1079.9	18.6	2.50	21.1	21.15	0.00	hard
Background	BKGmw-017	2346115.35	562452.04	11327.80	34.8	1135.30	A	Unconsolidated	23.2	1109.6	33.3	1099.5	33.6	2.50	36.1	35.91	0.19	medium
Background	BKGmw-018	2354993.91	570873.35	1043.06	24.7	1045.56	A	Sharon	14.5	1028.6	24.5	1018.6	24.7	2.50	27.2	27.53	0.00	hard
Background	BKGmw-019	2349882.14	559864.55	1108.24	34.0	1110.74	A	Unconsolidated	23.0	1085.2	33.0	1075.2	33.2	2.50	35.7	35.59	0.11	hard
Background	BKGmw-020	2357856.24	558756.24	1065.00	30.7	1067.50	A	Unconsolidated	20.5	1044.5	30.5	1034.5	30.7	2.50	33.2	33.22	0.00	hard
Background	BKGmw-021	2367622.95	571016.75	972.16	19.0	974.66	A	Unconsolidated	7.7	964.5	17.8	954.4	18.1	2.50	20.6	21.45	0.00	hard
C-Block Quarry	CBLmw-001	2343657.08	559403.12	1178.50	50.0	1181.08	A	Homewood	39.0	1139.5	49.0	1129.5	49.0	2.58	51.6	50.49	1.11	hard
C-Block Quarry	CBLmw-002	2343845.22	559044.48	1172.50	45.3	1175.24	A	Homewood	34.5	1138.0	44.5	1128.0	44.5	2.74	47.2	47.35	0.00	hard
C-Block Quarry	CBLmw-003	2343970.00	559695.52	1172.22	44.0	1175.06	A	Homewood	33.0	1139.2	43.0	1129.2	43.0	2.84	45.8	44.77	1.03	hard

Table 2-2 Monitoring Well Location Data (continued)

RVAAP Area	Well ID	Ohio State Plane Easting	Ohio State Plan Northing	Ground Level Elevation	Total Drilled Depth	TOC Elevation	Wellhead Type	Monitored Zone	Top of Screen (ft bgs)	Top of Screen Elevation	Bottom of Screen (ft bgs)	Bottom of Screen Elevation	Bottom of Inner Casing Plug or End Cap	Stickup Height	Reported Bottom of Inner Casing	May 2014 Measure Bottom of Inner Casing	Sediment Accumulation	Description of Bottom
C-Block Quarry	CBLmw-004	2343688.76	559951.58	1172.08	45.0	1174.84	A	Homewood	34.0	1138.1	44.0	1128.1	44.0	2.76	46.8	47.00	0.00	hard
C-Block Quarry	CBLmw-005	2344572.00	558686.00	1155.60	31.0	1158.10	A	Homewood	22.0	1133.6	30.0	1125.6	30.3	2.50	32.42	32.35	0.07	hard
Central Burn Pits	CBPmw-001	2367095.37	561616.01	972.71	32.3	975.84	A	Unconsolidated	21.8	950.9	31.8	940.9	31.8	3.13	34.9	34.25	0.65	medium
Central Burn Pits	CBPmw-002	2367295.66	561865.83	967.33	30.0	970.04	A	Unconsolidated	19.5	947.8	29.5	937.8	29.5	2.71	32.2	31.61	0.59	medium
Central Burn Pits	CBPmw-003	2366768.68	561944.14	972.04	25.0	974.67	A	Unconsolidated	14.5	957.5	24.5	947.5	24.5	2.63	27.1	30.14	0.00	hard
Central Burn Pits	CBPmw-004	2366978.80	562123.80	968.58	27.5	971.13	A	Unconsolidated	17.0	951.6	27.0	941.6	27.0	2.55	29.5	29.64	0.00	medium
Central Burn Pits	CBPmw-005	2366919.66	562311.88	968.83	25.0	971.59	A	Unconsolidated	14.5	954.3	24.5	944.3	24.5	2.76	27.3	27.38	0.00	medium
Central Burn Pits	CBPmw-006	2367243.68	562311.87	965.01	23.0	967.64	A	Unconsolidated	12.5	952.5	22.5	942.5	22.5	2.63	25.1	25.19	0.00	medium
Central Burn Pits	CBPmw-007	2366512.62	562006.41	973.47	30.0	976.37	A	Unconsolidated	19.5	954.0	29.5	944.0	29.5	2.90	32.4	31.81	0.59	hard
Central Burn Pits	CBPmw-008	2366757.21	562668.84	970.57	25.5	973.19	A	Unconsolidated	15.0	955.6	25.0	945.6	25.0	2.62	27.6	27.94	0.00	hard
Central Burn Pits	CBPmw-009	2367174.00	561797.00	969.90	65.0	972.48	A	Sharon	54.0	915.9	64.0	905.9	64.3	2.58	66.55	66.80	0.00	medium
Cobbs Pond	CPmw-001	2368948.81	560440.91	975.46	16.0	975.26	F	Unconsolidated	5.5	970.0	15.5	960.0	15.5	-0.20	15.3	14.60	0.70	hard
Cobbs Pond	CPmw-002	2368239.23	560311.26	972.72	16.0	972.31	F	Unconsolidated	5.5	967.2	15.5	957.2	15.5	-0.41	15.1	14.95	0.15	hard
Cobbs Pond	CPmw-003	2368796.49	560676.30	973.27	18.5	972.92	F	Unconsolidated	8.0	965.3	18.0	955.3	18.0	-0.35	17.6	17.70	0.00	hard
Cobbs Pond	CPmw-004	2368674.31	561843.46	978.51	20.0	981.20	A	Unconsolidated	9.5	969.0	19.5	959.0	19.5	2.69	22.2	22.62	0.00	hard
Cobbs Pond	CPmw-005	2367900.41	561846.78	970.71	40.0	973.58	A	Unconsolidated	29.5	941.2	39.5	931.2	39.5	2.87	42.4	43.40	0.00	soft
Cobbs Pond	CPmw-006	2367727.13	562830.13	962.97	18.5	965.13	A	Unconsolidated	8.0	955.0	18.0	945.0	18.0	2.16	20.2	20.62	0.00	hard
Demolition Area 2	DA2mw-104	2354773.79	561129.59	1070.82	27.0	1073.89	A	Unconsolidated	16.3	1054.5	26.3	1044.5	26.5	3.07	29.6	29.22	0.38	hard
Demolition Area 2	DA2mw-105	2354557.62	560572.58	1042.66	14.0	1045.34	A	Unconsolidated	8.3	1034.4	13.3	1029.4	13.5	2.68	16.2	16.20	0.00	hard
Demolition Area 2	DA2mw-106	2354848.85	560560.49	1041.19	16.0	1043.79	A	Unconsolidated	8.3	1032.9	15.3	1025.9	15.5	2.60	18.1	16.77	1.33	hard
Demolition Area 2	DA2mw-107	2354924.29	560480.05	1039.18	15.0	1041.63	A	Unconsolidated	8.8	1030.4	13.8	1025.4	14.0	2.45	16.5	16.85	0.00	hard
Demolition Area 2	DA2mw-108	2355604.43	560181.78	1029.92	15.0	1032.36	A	Unconsolidated	9.3	1020.6	14.3	1015.6	14.5	2.44	16.9	17.18	0.00	hard
Demolition Area 2	DA2mw-109	2354793.14	559897.89	1068.66	24.0	1071.29	A	Unconsolidated	11.3	1057.4	21.3	1047.4	21.5	2.63	24.1	24.29	0.00	soft
Demolition Area 2	DA2mw-110	2355195.91	559927.02	1061.39	20.0	1063.78	A	Unconsolidated	9.3	1052.1	19.3	1042.1	19.5	2.39	21.9	22.33	0.00	hard
Demolition Area 2	DA2mw-111	2354728.33	560222.94	1039.63	12.6	1042.12	A	Unconsolidated	7.1	1032.5	12.1	1027.5	12.3	2.49	14.8	14.77	0.03	hard
Demolition Area 2	DA2mw-112	2355018.98	560378.36	1034.87	15.0	1037.44	A	Unconsolidated	8.8	1026.1	13.8	1021.1	14.0	2.57	16.6	17.05	0.00	hard
Demolition Area 2	DA2mw-113	2355153.13	560394.81	1034.51	14.0	1037.11	A	Unconsolidated	8.3	1026.2	13.3	1021.2	13.5	2.60	16.1	16.29	0.00	hard
Demolition Area 2	DA2mw-114	2355785.00	560109.00	1029.50	19.5	1031.90	A	Sharon Shale	9.2	1020.3	19.2	1010.3	19.5	2.40	21.8	21.79	0.01	hard
Demolition Area 2	DA2mw-115	2355269.00	560459.00	1035.40	44.0	1038.08	A	Sharon	33.8	1001.7	43.8	991.7	44.1	2.68	46.8	46.75	0.05	hard
Demolition Area 2	DET-001B	2354959.47	560820.03	1064.35	39.0	1065.85	A	Unconsolidated	34.0	1030.4	39.0	1025.4	39.0	1.50	40.5	38.55	1.95	hard
Demolition Area 2	DET-002	2355360.33	560664.71	1060.24	39.0	1061.24	A	Unconsolidated	34.0	1026.2	39.0	1021.2	39.0	1.00	40	42.06	0.00	soft

Table 2-2 Monitoring Well Location Data (continued)

RVAAP Area	Well ID	Ohio State Plane Easting	Ohio State Plan Northing	Ground Level Elevation	Total Drilled Depth	TOC Elevation	Wellhead Type	Monitored Zone	Top of Screen (ft bgs)	Top of Screen Elevation	Bottom of Screen (ft bgs)	Bottom of Screen Elevation	Bottom of Inner Casing Plug or End Cap	Stickup Height	Reported Bottom of Inner Casing	May 2014 Measure Bottom of Inner Casing	Sediment Accumulation	Description of Bottom
Demolition Area 2	DET-003	2355204.94	560456.10	1035.81	15.0	1036.81	A	Unconsolidated	7.0	1028.8	12.0	1023.8	12.0	1.00	13	15.98	0.00	hard
Demolition Area 2	DET-004	2355072.36	560454.22	1037.68	11.0	1038.68	A	Unconsolidated	6.0	1031.7	11.0	1026.7	11.0	1.00	12	13.80	0.00	hard
Erie Burning Grounds	EBGmw-123	2380049.21	571747.04	945.59	32.0	947.82	A	Unconsolidated	21.0	924.6	31.0	914.6	31.5	2.23	33.7	34.74	0.00	hard
Erie Burning Grounds	EBGmw-124	2380030.24	571618.07	939.02	32.0	941.39	A	Unconsolidated	20.0	919.0	30.0	909.0	30.5	2.37	32.9	32.65	0.25	soft
Erie Burning Grounds	EBGmw-125	2379679.20	571655.63	947.55	25.0	949.89	A	Unconsolidated	14.0	933.6	24.0	923.6	24.5	2.34	26.8	27.42	0.00	hard
Erie Burning Grounds	EBGmw-126	2380307.31	572348.81	938.20	28.0	940.61	A	Unconsolidated	15.2	923.0	25.2	913.0	25.5	2.41	27.9	27.75	0.15	hard
Erie Burning Grounds	EBGmw-127	2380172.16	571083.61	940.21	30.0	943.07	A	Unconsolidated	19.0	921.2	29.0	911.2	29.5	2.86	32.4	32.82	0.00	hard
Erie Burning Grounds	EBGmw-128	2379892.79	570970.32	942.47	28.0	945.13	A	Unconsolidated	15.0	927.5	25.0	917.5	25.3	2.66	28	28.25	0.00	hard
Erie Burning Grounds	EBGmw-129	2379240.52	572035.68	941.97	29.0	944.36	A	Unconsolidated	16.0	926.0	26.0	916.0	26.0	2.39	28.4	30.94	0.00	hard
Erie Burning Grounds	EBGmw-130	2379220.69	570695.61	941.18	26.0	944.00	A	Unconsolidated	15.2	926.0	25.2	916.0	25.5	2.82	28.3	28.36	0.00	hard
Erie Burning Grounds	EBGmw-131	2379666.00	571655.00	947.50	71.0	950.08	A	Sharon	60.5	887.0	70.5	877.0	70.8	2.58	73.1	72.24	0.86	hard
Fuze and Booster Quarry	FBQmw-166	2349584.33	553123.86	1104.87	16.0	1108.86	A	Unconsolidated	5.5	1099.4	15.5	1089.4	15.5	3.99	19.5	19.88	0.00	hard
Fuze and Booster Quarry	FBQmw-167	2349675.45	553556.12	1112.05	18.0	1115.90	A	Unconsolidated	5.0	1107.1	15.0	1097.1	15.0	3.85	18.9	19.04	0.00	hard
Fuze and Booster Quarry	FBQmw-168	2350066.87	553620.85	1131.27	19.5	1133.91	A	Homewood	9.0	1122.3	19.0	1112.3	19.0	2.64	21.6	21.29	0.31	medium
Fuze and Booster Quarry	FBQmw-169	2349730.90	553681.21	1117.36	16.0	1120.58	A	Homewood	5.0	1112.4	15.0	1102.4	15.0	3.22	18.2	18.16	0.04	hard
Fuze and Booster Quarry	FBQmw-170	2350102.41	553975.40	1139.67	30.5	1142.26	A	Homewood	20.0	1119.7	30.0	1109.7	30.0	2.59	32.6	32.76	0.00	hard
Fuze and Booster Quarry	FBQmw-171	2350072.44	554230.93	1140.49	30.0	1143.55	A	Homewood	18.0	1122.5	28.0	1112.5	28.0	3.06	31.1	31.48	0.00	hard
Fuze and Booster Quarry	FBQmw-172	2349907.37	554322.17	1145.71	33.0	1150.09	A	Homewood	20.0	1125.7	30.0	1115.7	30.0	4.38	34.4	34.43	0.00	hard
Fuze and Booster Quarry	FBQmw-173	2350449.01	554491.35	1162.43	50.0	1165.94	A	Homewood	29.5	1132.9	49.5	1112.9	49.5	3.51	53	53.02	0.00	hard
Fuze and Booster Quarry	FBQmw-174	2350289.81	554142.44	1135.78	22.5	1139.97	A	Homewood	12.0	1123.8	22.0	1113.8	22.0	4.19	26.2	23.08	3.12	hard
Fuze and Booster Quarry	FBQmw-175	2350297.98	553989.24	1137.16	22.5	1140.73	A	Homewood	12.0	1125.2	22.0	1115.2	22.0	3.57	25.6	25.79	0.00	hard
Fuze and Booster Quarry	FBQmw-176	2350219.45	553273.33	1129.57	21.5	1131.91	A	Unconsolidated	11.0	1118.6	21.0	1108.6	21.0	2.34	23.3	23.56	0.00	soft
Fuze and Booster Quarry	FBQmw-177	2350112.18	553321.94	1125.73	22.5	1128.57	A	Homewood	12.0	1113.7	22.0	1103.7	22.0	2.84	24.8	24.72	0.08	soft
Facility-Wide	FWGmw-001	2368321.00	565739.00	953.60	17.5	956.62	A	Unconsolidated	7.0	946.6	17.0	936.6	17.3	3.02	20.05	19.99	0.06	hard
Facility-Wide	FWGmw-002	2367606.00	571015.00	970.60	71.0	973.10	A	Unconsolidated	57.0	913.6	67.0	903.6	67.3	2.50	70.05	69.60	0.45	medium
Facility-Wide	FWGmw-003	2344042.00	563118.00	1129.40	19.0	1131.96	A	Unconsolidated	8.5	1120.9	18.5	1110.9	18.8	2.56	21.1	21.06	0.04	hard
Facility-Wide	FWGmw-004	2356970.00	549319.00	1034.50	20.0	1037.15	A	Unconsolidated	9.5	1025.0	19.5	1015.0	19.8	2.65	22.6	22.47	0.13	medium
Facility-Wide	FWGmw-005	2338973.00	558510.00	1167.50	29.5	1170.10	A	Homewood	19.3	1148.3	29.3	1138.3	29.6	2.60	31.9	31.97	0.00	soft
Facility-Wide	FWGmw-006	2335421.00	553142.00	1181.90	18.0	1184.33	A	Unconsolidated	7.5	1174.4	17.5	1164.4	17.8	2.43	19.25	19.28	0.00	hard
Facility-Wide	FWGmw-007	2344785.00	548356.00	1072.80	30.0	1075.41	A	Unconsolidated	19.5	1053.3	29.5	1043.3	29.8	2.61	32.35	32.15	0.20	hard
Facility-Wide	FWGmw-008	2341569.00	555735.00	1109.00	21.0	1111.61	A	Unconsolidated	10.0	1099.0	20.0	1089.0	20.3	2.61	22.1	21.80	0.30	medium

Table 2-2 Monitoring Well Location Data (continued)

RVAAP Area	Well ID	Ohio State Plane Easting	Ohio State Plan Northing	Ground Level Elevation	Total Drilled Depth	TOC Elevation	Wellhead Type	Monitored Zone	Top of Screen (ft bgs)	Top of Screen Elevation	Bottom of Screen (ft bgs)	Bottom of Screen Elevation	Bottom of Inner Casing Plug or End Cap	Stickup Height	Reported Bottom of Inner Casing	May 2014 Measure Bottom of Inner Casing	Sediment Accumulation	Description of Bottom
Facility-Wide	FWGmw-009	2341998.00	556784.00	1099.50	18.5	1102.14	A	Unconsolidated	8.0	1091.5	18.0	1081.5	18.3	2.64	20.4	20.37	0.03	medium
Facility-Wide	FWGmw-010	2379060.00	565077.00	959.50	17.3	962.15	A	Unconsolidated	6.0	953.5	16.0	943.5	16.3	2.65	19.1	19.15	0.00	medium
Facility-Wide	FWGmw-011	2380390.00	566801.00	939.00	17.5	941.61	A	Unconsolidated	6.0	933.0	16.0	923.0	16.3	2.61	17.8	17.76	0.04	soft
Facility-Wide	FWGmw-012	2380389.00	566790.00	938.90	40.0	941.39	A	Sharon Shale	29.5	909.4	39.5	899.4	39.8	2.49	42.45	42.49	0.00	soft
Facility-Wide	FWGmw-013	2357460.00	559483.00	1057.10	34.5	1059.51	A	Sharon	24.0	1033.1	34.0	1023.1	34.3	2.41	36.7	36.70	0.00	hard
Facility-Wide	FWGmw-014	2341064.00	560957.00	1135.00	18.5	1137.57	A	Unconsolidated	8.3	1126.8	18.3	1116.8	18.6	2.57	21.15	21.11	0.04	hard
Facility-Wide	FWGmw-015	2358353.00	550179.00	1012.10	26.0	1014.51	A	Unconsolidated	13.5	998.6	23.5	988.6	23.8	2.41	26.35	26.24	0.11	soft
Facility-Wide	FWGmw-016	2358364.00	550171.00	1011.90	65.0	1014.39	A	Sharon	54.5	957.4	64.5	947.4	64.8	2.49	67.5	68.15	0.00	hard
Load Line 1	LL1mw-063	2376841.36	563650.53	992.20	27.4	994.84	A	Sharon	17.1	975.1	27.1	965.1	27.4	2.64	30	30.10	0.00	hard
Load Line 1	LL1mw-064	2380286.97	563118.74	932.32	18.4	935.10	A	Unconsolidated	8.0	924.3	18.0	914.3	18.4	2.78	21.1	21.09	0.01	hard
Load Line 1	LL1mw-065	2380452.00	560916.92	941.53	20.5	944.41	A	Unconsolidated	10.2	931.3	20.2	921.3	20.5	2.88	23.4	23.12	0.28	hard
Load Line 1	LL1mw-067	2376545.30	565201.14	977.55	22.8	980.36	A	Sharon	12.8	964.8	22.5	955.1	22.8	2.81	25.6	25.73	0.00	hard
Load Line 1	LL1mw-078	2376275.85	564623.87	993.40	38.7	995.84	A	Sharon	28.7	964.7	38.2	955.2	38.7	2.44	41.1	41.14	0.00	hard
Load Line 1	LL1mw-079	2376228.31	563739.63	995.30	29.5	997.87	A	Sharon	29.5	965.8	38.9	956.4	39.5	2.57	42	41.94	0.06	hard
Load Line 1	LL1mw-080	2376845.07	562479.73	993.70	19.5	996.27	A	Sharon	9.5	984.2	19.0	974.7	19.5	2.57	22	22.38	0.00	hard
Load Line 1	LL1mw-081	2376672.66	563462.73	996.40	39.4	998.92	A	Sharon	29.4	967.0	38.9	957.5	39.4	2.52	41.9	42.02	0.00	hard
Load Line 1	LL1mw-082	2376977.38	562956.86	1003.70	39.0	1006.45	A	Sharon	28.9	974.8	38.5	965.2	39.0	2.75	41.8	41.51	0.29	hard
Load Line 1	LL1mw-083	2377074.80	563612.75	992.80	39.3	995.20	A	Sharon	29.1	963.7	38.6	954.2	39.3	2.40	41.7	41.45	0.25	hard
Load Line 1	LL1mw-084	2377316.02	563160.44	996.40	37.0	998.73	A	Sharon	26.7	969.7	36.3	960.1	37.0	2.33	39.3	39.11	0.19	hard
Load Line 1	LL1mw-085	2377246.94	562046.25	994.30	42.1	996.84	A	Sharon	32.2	962.1	41.6	952.7	42.1	2.54	44.7	45.24	0.00	hard
Load Line 1	LL1mw-086	2380437.00	561714.00	938.00	75.0	940.63	A	Unconsolidated	64.5	873.5	74.5	863.5	74.8	2.63	77.38	77.76	0.00	medium
Load Line 1	LL1mw-087	2378732.00	560375.00	941.80	17.5	944.32	A	Unconsolidated	7.0	934.8	17.0	924.8	17.3	2.52	18.55	18.13	0.42	medium
Load Line 1	LL1mw-088	2380525.00	561746.00	936.30	24.0	938.63	A	Unconsolidated	13.9	922.4	23.9	912.4	24.5	3.00	27.54	27.33	0.21	medium
Load Line 2	LL2mw-059	2375453.00	558020.00	964.33	19.5	966.67	A	Sharon	9.3	955.0	19.1	945.2	19.5	2.34	21.8	21.91	0.00	hard
Load Line 2	LL2mw-060	2375978.00	558022.00	958.93	18.3	961.57	A	Sharon	8.1	950.8	17.9	941.0	18.3	2.64	20.9	20.83	0.07	hard
Load Line 2	LL2mw-261	2373317.81	561898.25	1009.55	22.5	1011.40	A	Sharon	9.8	999.8	19.8	989.8	20.0	1.85	21.9	22.48	0.00	hard
Load Line 2	LL2mw-262	2373970.79	562219.87	1011.12	21.2	1012.62	A	Sharon	10.6	1000.5	20.6	990.5	20.8	1.50	22.3	22.68	0.00	hard
Load Line 2	LL2mw-263	2374289.51	561591.19	1009.42	22.2	1011.47	A	Sharon	10.8	998.6	20.8	988.6	21.0	2.05	23	23.46	0.00	hard
Load Line 2	LL2mw-264	2374532.00	561173.60	1010.10	20.5	1011.88	A	Sharon	9.8	1000.3	19.8	990.3	20.0	1.78	21.7	22.40	0.00	hard
Load Line 2	LL2mw-265	2375594.06	557972.91	959.47	22.5	961.24	A	Sharon	11.8	947.7	21.8	937.7	22.0	1.77	23.8	24.45	0.00	hard
Load Line 2	LL2mw-266	2373744.03	561981.86	1014.09	20.5	1016.28	A	Sharon	9.8	1004.3	19.8	994.3	20.0	2.19	22.2	22.73	0.00	hard

Table 2-2 Monitoring Well Location Data (continued)

RVAAP Area	Well ID	Ohio State Plane Easting	Ohio State Plan Northing	Ground Level Elevation	Total Drilled Depth	TOC Elevation	Wellhead Type	Monitored Zone	Top of Screen (ft bgs)	Top of Screen Elevation	Bottom of Screen (ft bgs)	Bottom of Screen Elevation	Bottom of Inner Casing Plug or End Cap	Stickup Height	Reported Bottom of Inner Casing	May 2014 Measure Bottom of Inner Casing	Sediment Accumulation	Description of Bottom
Load Line 2	LL2mw-267	2373715.04	561393.22	1012.81	20.5	1014.81	A	Sharon	9.8	1003.0	19.8	993.0	20.0	2.00	22	22.08	0.00	hard
Load Line 2	LL2mw-268	2374157.30	560831.04	1015.47	28.8	1017.28	A	Sharon	17.3	998.2	27.3	988.2	27.5	1.81	29.3	29.90	0.00	hard
Load Line 2	LL2mw-269	2374756.07	559484.12	1009.49	28.0	1011.62	A	Sharon	17.1	992.4	27.1	982.4	27.3	2.13	29.4	30.30	0.00	hard
Load Line 2	LL2mw-270	2372858.41	562655.93	1009.93	20.5	1010.18	A	Sharon	9.8	1000.1	19.8	990.1	20.0	0.25	20.3	22.44	0.00	hard
Load Line 2	LL2mw-271	2375714.00	557827.00	958.70	24.0	961.19	A	Sharon	14.6	944.1	24.6	934.1	24.8	3.00	27.8	27.78	0.02	hard
Load Line 3	LL3mw-232	2369862.96	561365.91	998.59	37.8	1000.41	A	Sharon	26.8	971.8	36.8	961.8	37.0	1.82	38.8	39.77	0.00	soft
Load Line 3	LL3mw-233	2369934.52	560750.41	1002.47	31.1	1004.36	A	Sharon	20.1	982.4	30.1	972.4	30.3	1.89	32.2	31.49	0.71	soft
Load Line 3	LL3mw-234	2370297.47	560058.89	1004.47	20.5	1006.56	A	Sharon	9.8	994.7	19.8	984.7	20.0	2.09	22.1	22.64	0.00	medium
Load Line 3	LL3mw-235	2370642.47	559812.63	1008.05	21.2	1009.94	A	Sharon	10.1	998.0	20.1	988.0	20.3	1.89	22.2	22.97	0.00	hard
Load Line 3	LL3mw-236	2371178.58	559866.75	1008.94	25.5	1011.17	A	Sharon	13.8	995.1	23.8	985.1	24.0	2.23	26.2	26.60	0.00	hard
Load Line 3	LL3mw-237	2371475.00	559328.09	1003.57	23.9	1005.57	A	Sharon	12.7	990.9	22.7	980.9	22.9	2.00	24.9	25.78	0.00	hard
Load Line 3	LL3mw-238	2370625.34	559569.06	1004.75	20.7	1006.91	A	Sharon	10.5	994.3	20.5	984.3	20.7	2.16	22.9	23.37	0.00	hard
Load Line 3	LL3mw-239	2370895.01	559101.39	1001.70	35.7	1003.50	A	Sharon	24.9	976.8	34.9	966.8	35.0	1.80	36.8	36.90	0.00	soft
Load Line 3	LL3mw-240	2371309.57	558204.34	1005.60	35.5	1007.52	A	Sharon	24.4	981.2	34.4	971.2	34.6	1.92	36.5	36.64	0.00	soft
Load Line 3	LL3mw-241	2370332.80	559298.09	992.41	23.8	994.65	A	Sharon	12.7	979.7	22.7	969.7	22.9	2.24	25.1	25.57	0.00	hard
Load Line 3	LL3mw-242	2371993.30	557034.21	997.39	20.5	999.32	A	Sharon	9.8	987.6	19.8	977.6	20.0	1.93	21.9	22.53	0.00	hard
Load Line 3	LL3mw-243	2371532.61	556688.92	989.36	24.5	991.16	A	Sharon	13.8	975.6	23.8	965.6	24.0	1.80	25.8	26.36	0.00	hard
Load Line 3	LL3mw-244	2371456.00	556033.00	986.20	45.0	988.78	A	Sharon	34.5	951.7	44.5	941.7	44.8	2.58	47.25	46.87	0.38	medium
Load Line 3	LL3mw-245	2369249.00	558573.00	978.70	47.0	981.24	A	Sharon	36.5	942.2	46.5	932.2	46.8	2.54	48.9	48.78	0.12	medium
Load Line 3	LL3mw-246	2371441.00	555969.00	986.50	43.0	988.84	A	Sharon	32.8	953.7	42.8	943.7	43.0	2.75	45.75	45.59	0.16	hard
Load Line 4	LL4mw-193	2364237.44	554959.74	980.88	21.9	982.92	A	Unconsolidated	11.3	969.6	21.3	959.6	21.5	2.04	23.5	24.15	0.00	hard
Load Line 4	LL4mw-194	2364584.76	555088.18	981.87	22.0	983.76	A	Unconsolidated	11.3	970.6	21.3	960.6	21.5	1.89	23.4	23.49	0.00	hard
Load Line 4	LL4mw-195	2365198.84	555045.69	980.83	21.0	982.59	A	Unconsolidated	10.3	970.5	20.3	960.5	20.5	1.76	22.3	22.71	0.00	hard
Load Line 4	LL4mw-196	2365297.28	555212.59	982.56	20.0	984.55	A	Unconsolidated	9.2	973.4	19.2	963.4	19.4	1.99	21.4	21.76	0.00	hard
Load Line 4	LL4mw-197	2365385.95	555396.55	983.79	21.7	985.46	A	Unconsolidated	10.8	973.0	20.8	963.0	21.0	1.67	22.7	23.52	0.00	hard
Load Line 4	LL4mw-198	2364991.12	555440.99	981.61	22.0	983.42	A	Unconsolidated	10.3	971.3	20.3	961.3	20.5	1.81	22.3	21.70	0.60	hard
Load Line 4	LL4mw-199	2365421.66	554621.06	975.20	22.0	977.28	A	Unconsolidated	10.3	964.9	20.3	954.9	20.5	2.08	22.6	23.12	0.00	hard
Load Line 4	LL4mw-200	2365904.12	554579.72	985.97	23.5	987.93	A	Unconsolidated	12.6	973.4	22.6	963.4	23.0	1.96	25	25.10	0.00	hard
Load Line 4	LL4mw-201	2365417.00	554607.00	975.90	67.0	978.02	A	Sharon	56.5	919.4	66.5	909.4	66.8		70.15	70.00	0.15	hard
Load Line 5	LL5mw-001	2354625.07	554319.25	1125.00	24.0	1127.92	A	Homewood	14.0	1111.0	24.0	1101.0	24.0	2.92	26.9	27.33	0.00	medium
Load Line 5	LL5mw-002	2354571.52	554604.01	1125.80	25.0	1128.68	A	Homewood	15.0	1110.8	25.0	1100.8	25.0	2.88	27.9	27.54	0.36	hard

Table 2-2 Monitoring Well Location Data (continued)

RVAAP Area	Well ID	Ohio State Plane Easting	Ohio State Plan Northing	Ground Level Elevation	Total Drilled Depth	TOC Elevation	Wellhead Type	Monitored Zone	Top of Screen (ft bgs)	Top of Screen Elevation	Bottom of Screen (ft bgs)	Bottom of Screen Elevation	Bottom of Inner Casing Plug or End Cap	Stickup Height	Reported Bottom of Inner Casing	May 2014 Measure Bottom of Inner Casing	Sediment Accumulation	Description of Bottom
Load Line 5	LL5mw-003	2354964.47	554535.41	1124.70	21.0	1127.70	A	Unconsolidated	11.0	1113.7	21.0	1103.7	21.0	3.00	24	23.99	0.01	soft
Load Line 5	LL5mw-004	2355006.44	554073.73	1122.90	22.4	1125.81	A	Homewood	12.0	1110.9	22.0	1100.9	22.0	2.91	24.9	25.39	0.00	soft
Load Line 5	LL5mw-005	2354422.02	554152.73	1126.50	27.8	1129.42	A	Homewood	17.0	1109.5	27.0	1099.5	27.0	2.92	29.9	29.95	0.00	soft
Load Line 5	LL5mw-006	2354730.78	553984.82	1125.10	24.5	1128.00	A	Homewood	14.0	1111.1	24.0	1101.1	24.0	2.90	26.9	27.15	0.00	soft
Load Line 6	LL6mw-001	2353153.23	554214.84	NA	18.0	1124.16	F	Unconsolidated	7.0	#VALUE!	17.0	#VALUE!	17.0	0.00	17	17.61	0.00	hard
Load Line 6	LL6mw-002	2353820.09	553589.88	NA	23.0	1129.36	F	Unconsolidated	12.5	#VALUE!	22.5	#VALUE!	22.5	0.00	22.5	24.44	0.00	hard
Load Line 6	LL6mw-003	2353048.68	553544.34	NA	23.4	1125.38	A	Homewood	12.5	#VALUE!	22.5	#VALUE!	22.5	3.35	25.9	25.61	0.29	soft
Load Line 6	LL6mw-004	2353368.79	553431.82	NA	23.0	1125.39	A	Homewood	12.5	#VALUE!	22.5	#VALUE!	22.5	2.58	25.1	24.59	0.51	hard
Load Line 6	LL6mw-005	2353194.52	553170.76	NA	19.9	1120.47	A	Homewood	9.5	#VALUE!	19.5	#VALUE!	19.5	2.96	22.5	22.02	0.48	soft
Load Line 6	LL6mw-006	2352419.15	553165.28	NA	20.0	1124.37	A	Unconsolidated	7.0	#VALUE!	17.0	#VALUE!	17.0	0.00	17	17.82	0.00	hard
Load Line 6	LL6mw-007	2353354.89	552677.17	NA	20.0	1115.62	F	Homewood	9.5	#VALUE!	19.5	#VALUE!	19.5	0.00	19.5	19.41	0.09	hard
Load Line 6	LL6mw-008	2353616.00	553154.00	1121.30	17.8	1124.15	A	Unconsolidated	7.2	1114.1	17.2	1104.1	17.5	2.85	20.2	20.14	0.06	hard
Load Line 6	LL6mw-009	2353604.00	553149.00	1121.40	39.5	1123.75	A	Homewood	29.0	1092.4	39.0	1082.4	39.3	2.35	41.4	41.77	0.00	soft
Load Line 7	LL7mw-001	2352192.91	554925.77	1126.90	30.0	1129.64	A	Homewood	19.5	1107.4	29.5	1097.4	29.5	2.74	32.2	33.04	0.00	hard
Load Line 7	LL7mw-002	2351918.23	555126.55	1126.70	26.5	1129.55	A	Homewood	15.0	1111.7	25.0	1101.7	25.0	2.85	27.8	27.25	0.55	hard
Load Line 7	LL7mw-003	2352351.04	555417.04	1118.23	31.5	1120.84	A	Homewood	21.0	1097.2	31.0	1087.2	31.0	2.61	33.6	33.54	0.06	hard
Load Line 7	LL7mw-004	2352035.20	555581.14	1123.30	29.5	1126.32	A	Homewood	19.5	1103.8	29.5	1093.8	29.5	3.02	32.5	32.25	0.25	hard
Load Line 7	LL7mw-005	2351741.47	555581.80	1133.30	28.2	1135.87	A	Homewood	18.0	1115.3	28.0	1105.3	28.0	2.57	30.6	30.37	0.23	hard
Load Line 7	LL7mw-006	2351879.92	555990.59	1120.70	28.0	1123.56	A	Homewood	17.5	1103.2	27.5	1093.2	27.5	2.86	30.4	30.34	0.06	hard
Load Line 8	LL8mw-001	2351666.10	552607.06	1118.69	24.0	1121.46	A	Unconsolidated	14.0	1104.7	24.0	1094.7	24.0	2.77	26.8	27.44	0.00	soft
Load Line 8	LL8mw-002	2351010.33	552408.18	1121.67	30.4	1124.51	A	Unconsolidated	20.0	1101.7	30.0	1091.7	30.0	2.84	32.8	32.02	0.78	medium
Load Line 8	LL8mw-003	2351359.25	552231.14	1116.30	21.0	1119.05	A	Unconsolidated	10.5	1105.8	20.5	1095.8	20.5	2.75	23.3	23.04	0.26	hard
Load Line 8	LL8mw-004	2351261.83	551807.58	1112.73	20.5	1115.75	A	Unconsolidated	10.0	1102.7	20.0	1092.7	20.0	3.02	23	22.74	0.26	hard
Load Line 8	LL8mw-005	2351748.32	551522.48	1112.51	24.0	1115.73	A	Homewood	14.0	1098.5	24.0	1088.5	24.0	3.22	27.2	26.93	0.27	soft
Load Line 8	LL8mw-006	2351483.58	551296.77	1114.33	24.2	1117.17	A	Homewood	14.0	1100.3	24.0	1090.3	24.0	2.84	26.8	27.08	0.00	medium
Load Line 9	LL9mw-001	2355817.04	556125.81	NA	21.6	1134.62	A	Homewood	10.5	#VALUE!	20.5	#VALUE!	20.5	2.78	23.3	23.32	0.00	hard
Load Line 9	LL9mw-002	2355907.76	556755.11	NA	21.0	1127.30	A	Homewood	10.0	#VALUE!	20.0	#VALUE!	20.0	2.42	22.4	22.75	0.00	hard
Load Line 9	LL9mw-003	2356635.21	556445.31	NA	22.0	1135.76	A	Homewood	11.5	#VALUE!	21.5	#VALUE!	21.5	2.30	23.8	24.22	0.00	hard
Load Line 9	LL9mw-004	2357338.76	556002.00	NA	33.0	1131.83	A	Homewood	22.0	#VALUE!	32.0	#VALUE!	32.0	2.91	34.9	34.67	0.23	hard
Load Line 9	LL9mw-005	2356505.95	557063.36	NA	20.6	1130.93	A	Homewood	10.0	#VALUE!	20.0	#VALUE!	20.0	3.30	23.3	23.51	0.00	hard
Load Line 9	LL9mw-006	2357446.67	556434.79	NA	26.8	1129.88	A	Homewood	16.0	#VALUE!	26.0	#VALUE!	26.0	2.90	28.9	28.84	0.06	hard

Table 2-2 Monitoring Well Location Data (continued)

RVAAP Area	Well ID	Ohio State Plane Easting	Ohio State Plan Northing	Ground Level Elevation	Total Drilled Depth	TOC Elevation	Wellhead Type	Monitored Zone	Top of Screen (ft bgs)	Top of Screen Elevation	Bottom of Screen (ft bgs)	Bottom of Screen Elevation	Bottom of Inner Casing Plug or End Cap	Stickup Height	Reported Bottom of Inner Casing	May 2014 Measure Bottom of Inner Casing	Sediment Accumulation	Description of Bottom
Load Line 9	LL9mw-007	2357024.34	557000.56	NA	19.0	1119.99	F	Homewood	8.5	#VALUE!	18.5	#VALUE!	18.5	0.00	18.5	17.94	0.56	hard
Load Line 10	LL10mw-001	2355272.22	555816.25	1130.00	28.0	1132.77	A	Homewood	17.0	1113.0	27.0	1103.0	27.0	2.77	29.8	29.59	0.21	hard
Load Line 10	LL10mw-002	2355710.51	555523.36	1124.40	28.0	1127.13	A	Homewood	17.0	1107.4	27.0	1097.4	27.0	2.73	29.7	29.81	0.00	hard
Load Line 10	LL10mw-003	2355389.92	555494.71	1127.40	26.4	1130.28	A	Homewood	16.0	1111.4	26.0	1101.4	26.0	2.88	28.9	28.54	0.36	hard
Load Line 10	LL10mw-004	2355438.20	555236.59	1119.60	31.2	1122.39	A	Homewood	21.0	1098.6	31.0	1088.6	31.0	2.79	33.8	33.53	0.27	hard
Load Line 10	LL10mw-005	2355943.55	555380.53	1122.90	27.0	1125.67	A	Homewood	16.5	1106.4	26.5	1096.4	26.5	2.77	29.3	29.24	0.06	hard
Load Line 10	LL10mw-006	2355654.80	554995.25	1121.20	24.0	1123.83	A	Unconsolidated	13.5	1107.7	23.5	1097.7	23.5	2.63	26.1	26.50	0.00	medium
Load Line 11	LL11mw-001	2352778.89	557505.03	1097.46	23.0	1100.16	A	Unconsolidated	11.4	1086.1	21.4	1076.1	21.4	2.70	24.1	23.40	0.70	hard
Load Line 11	LL11mw-002	2353354.28	558310.52	1080.29	20.0	1080.00	F	Unconsolidated	6.3	1074.0	16.3	1064.0	16.3	-0.29	16	16.45	0.00	hard
Load Line 11	LL11mw-003	2352737.87	557999.62	1088.45	17.0	1088.48	F	Unconsolidated	5.9	1082.6	15.9	1072.6	15.9	0.03	15.9	16.00	0.00	hard
Load Line 11	LL11mw-004	2352737.24	558164.36	1084.60	17.0	1084.72	F	Unconsolidated	6.1	1078.5	16.1	1068.5	16.1	0.12	16.2	16.18	0.02	hard
Load Line 11	LL11mw-005	2352847.56	558501.02	1079.60	17.0	1079.40	F	Unconsolidated	6.2	1073.4	16.2	1063.4	16.2	-0.20	16	16.42	0.00	hard
Load Line 11	LL11mw-006	2352521.36	558263.28	1086.61	17.0	1086.50	F	Unconsolidated	5.6	1081.0	15.6	1071.0	15.6	-0.11	15.5	15.70	0.00	hard
Load Line 11	LL11mw-007	2352094.81	558189.71	1079.22	23.0	1082.00	A	Unconsolidated	12.4	1066.8	22.4	1056.8	22.4	2.78	25.2	25.26	0.00	soft
Load Line 11	LL11mw-008	2352388.60	557981.17	1087.90	17.0	1087.74	F	Unconsolidated	5.6	1082.3	15.6	1072.3	15.6	-0.16	15.4	15.60	0.00	hard
Load Line 11	LL11mw-009	2352577.18	557901.18	1088.38	17.0	1091.54	F	Unconsolidated	6.7	1081.7	16.7	1071.7	16.7	-0.10	16.6	19.48	0.00	hard
Load Line 11	LL11mw-010	2352039.00	557675.43	1080.22	22.0	1082.68	A	Unconsolidated	10.9	1069.3	20.9	1059.3	20.9	2.46	23.4	23.40	0.00	soft
Load Line 11	LL11mw-011	2351119.00	558680.00	1077.40	18.5	1080.20	A	Unconsolidated	7.8	1069.6	17.8	1059.6	18.1	2.80	20.45	20.31	0.14	hard
Load Line 11	LL11mw-012	2351125.00	558691.00	1077.90	115.0	1080.36	A	Sharon Shale	104.5	973.4	114.5	963.4	114.8	2.46	119.45	119.43	0.02	hard
Load Line 12	LL12mw-088	2368667.75	556393.79	978.94	29.0	981.06	A	Unconsolidated	14.8	964.1	24.8	954.1	25.0	2.12	27.1	27.32	0.00	hard
Load Line 12	LL12mw-107	2368595.67	556759.02	978.03	33.0	980.15	A	Unconsolidated	20.7	957.3	30.7	947.3	31.0	2.12	33.1	33.66	0.00	hard
Load Line 12	LL12mw-113	2368223.73	558345.37	977.67	23.0	980.18	A	Sharon Shale	12.3	965.4	22.3	955.4	22.5	2.51	25	20.65	4.35	soft
Load Line 12	LL12mw-128	2368293.20	557371.54	976.21	34.0	978.24	A	Unconsolidated	21.1	955.1	31.1	945.1	31.3	2.03	33.3	33.90	0.00	soft
Load Line 12	LL12mw-153	2368138.87	557823.23	975.34	26.0	977.85	A	Unconsolidated	12.3	963.0	22.3	953.0	22.5	2.51	25	25.06	0.00	hard
Load Line 12	LL12mw-154	2368183.88	557754.56	977.00	29.0	979.06	A	Unconsolidated	16.4	960.6	26.4	950.6	26.6	2.06	28.7	28.62	0.08	hard
Load Line 12	LL12mw-182	2368853.20	555890.35	982.20	36.1	984.42	A	Unconsolidated	25.2	957.0	35.2	947.0	35.5	2.22	37.7	38.01	0.00	hard
Load Line 12	LL12mw-182ss	2368867.00	555897.00	982.30	36.0	985.02	A	Unconsolidated	25.3	957.1	35.3	947.1	35.6	2.72	38.5	37.40	1.10	hard
Load Line 12	LL12mw-183	2369224.36	556068.15	980.59	36.0	982.98	A	Sharon Shale	23.3	957.3	33.3	947.3	33.6	2.39	36	36.32	0.00	hard
Load Line 12	LL12mw-184	2368997.48	556399.46	980.96	29.5	983.16	A	Unconsolidated	18.8	962.2	28.8	952.2	29.0	2.20	31.2	31.35	0.00	hard
Load Line 12	LL12mw-185	2368829.86	556946.75	979.09	24.0	981.31	A	Unconsolidated	10.8	968.3	20.8	958.3	21.0	2.22	23.2	23.24	0.00	hard

Table 2-2 Monitoring Well Location Data (continued)

RVAAP Area	Well ID	Ohio State Plane Easting	Ohio State Plan Northing	Ground Level Elevation	Total Drilled Depth	TOC Elevation	Wellhead Type	Monitored Zone	Top of Screen (ft bgs)	Top of Screen Elevation	Bottom of Screen (ft bgs)	Bottom of Screen Elevation	Bottom of Inner Casing Plug or End Cap	Stickup Height	Reported Bottom of Inner Casing	May 2014 Measure Bottom of Inner Casing	Sediment Accumulation	Description of Bottom
Load Line 12	LL12mw-186	2367912.39	559065.95	976.34	23.0	978.31	A	Sharon Shale	8.8	967.5	18.8	957.5	19.0	1.97	21	21.00	0.00	hard
Load Line 12	LL12mw-187	2368524.14	557633.10	977.90	29.0	979.94	A	Unconsolidated	17.2	960.7	27.2	950.7	27.4	2.04	29.4	29.90	0.00	hard
Load Line 12	LL12mw-188	2367908.82	558132.59	978.46	20.5	980.63	A	Unconsolidated	9.8	968.7	19.8	958.7	20.0	2.17	22.2	22.01	0.19	hard
Load Line 12	LL12mw-189	2367945.92	558569.27	976.17	18.5	978.04	A	Sharon Shale	7.5	968.7	17.5	958.7	17.7	1.87	19.6	19.55	0.05	hard
Load Line 12	LL12mw-242	2368545.29	558020.51	978.40	26.3	981.20	A	Unconsolidated	15.5	962.9	25.5	952.9	25.5	2.80	28.3	28.60	0.00	hard
Load Line 12	LL12mw-243	2368190.04	557376.32	978.10	24.0	980.79	A	Unconsolidated	13.0	965.1	23.0	955.1	23.0	2.69	25.7	24.30	1.40	hard
Load Line 12	LL12mw-244	2368751.42	557377.17	978.10	30.0	980.65	A	Unconsolidated	19.5	958.6	29.5	948.6	29.5	2.55	32.1	30.61	1.49	hard
Load Line 12	LL12mw-245	2368370.74	557044.55	977.50	29.0	980.04	A	Unconsolidated	18.0	959.5	28.0	949.5	28.0	2.54	30.5	29.84	0.66	hard
Load Line 12	LL12mw-246	2369432.17	556658.89	982.00	32.0	984.83	A	Unconsolidated	21.5	960.5	31.5	950.5	31.5	2.83	34.3	35.00	0.00	hard
Load Line 12	LL12mw-247	2368932.00	555141.00	981.30	20.5	984.25	A	Unconsolidated	10.0	971.3	20.0	961.3	20.3	2.95	22.6	22.54	0.06	hard
Landfill North of Winklepeck	LNWmw-024	2358403.21	564825.89	1035.30	24.0	1038.00	A	Unconsolidated	10.0	1025.3	20.0	1015.3	20.0	2.70	22.7	22.50	0.20	hard
Landfill North of Winklepeck	LNWmw-025	2358417.06	565071.92	1027.20	19.0	1029.13	A	Unconsolidated	8.0	1019.2	18.0	1009.2	18.0	1.93	19.9	20.30	0.00	hard
Landfill North of Winklepeck	LNWmw-026	2358952.24	564658.16	1025.00	24.0	1027.80	A	Unconsolidated	13.0	1012.0	23.0	1002.0	23.0	2.80	25.8	25.93	0.00	hard
Landfill North of Winklepeck	LNWmw-027	2358628.75	564517.41	1024.40	25.0	1027.13	A	Unconsolidated	14.0	1010.4	24.0	1000.4	24.0	2.73	26.7	26.82	0.00	hard
Suspected Mustard Agent Burial Site	MBS-001	2345323.00	550759.50	1079.68	30.0	1082.20	A	Unconsolidated	19.0	1060.7	28.7	1051.0	29.0	2.52	31.5	30.99	0.51	hard
Suspected Mustard Agent Burial Site	MBS-002	2345322.30	550886.20	1080.50	30.0	1083.22	A	Unconsolidated	18.0	1062.5	27.3	1053.2	28.0	2.72	30.7	31.12	0.00	hard
Suspected Mustard Agent Burial Site	MBS-003	2345172.40	550922.80	1082.45	30.0	1084.45	A	Unconsolidated	18.5	1064.0	28.2	1054.3	28.5	2.00	30.5	30.70	0.00	hard
Suspected Mustard Agent Burial Site	MBS-004	2345134.20	550767.90	1079.55	26.0	1081.80	A	Unconsolidated	14.7	1064.9	24.4	1055.2	24.7	2.25	27	27.19	0.00	hard
Suspected Mustard Agent Burial Site	MBS-005	2345354.10	550800.70	1080.50	30.0	1082.42	A	Unconsolidated	18.0	1062.5	28.0	1052.5	28.1	1.92	30.2	29.94	0.26	soft
Suspected Mustard Agent Burial Site	MBS-006	2345282.30	550726.10	1080.29	28.0	1081.83	A	Unconsolidated	16.5	1063.8	26.5	1053.8	26.6	1.54	28.2	28.06	0.14	hard
NACA Test Area	NTAmw-107	2345433.40	551697.29	1077.65	23.0	1080.30	A	Unconsolidated	12.0	1065.7	22.0	1055.7	22.0	2.65	24.6	24.16	0.44	soft
NACA Test Area	NTAmw-108	2345781.60	551916.22	1083.22	23.0	1085.62	A	Unconsolidated	12.0	1071.2	22.0	1061.2	22.0	2.40	24.4	24.51	0.00	medium
NACA Test Area	NTAmw-109	2345997.72	551293.25	1076.89	19.0	1079.84	A	Unconsolidated	8.0	1068.9	18.0	1058.9	18.0	2.95	20.9	20.54	0.36	soft

Table 2-2 Monitoring Well Location Data (continued)

RVAAP Area	Well ID	Ohio State Plane Easting	Ohio State Plan Northing	Ground Level Elevation	Total Drilled Depth	TOC Elevation	Wellhead Type	Monitored Zone	Top of Screen (ft bgs)	Top of Screen Elevation	Bottom of Screen (ft bgs)	Bottom of Screen Elevation	Bottom of Inner Casing Plug or End Cap	Stickup Height	Reported Bottom of Inner Casing	May 2014 Measure Bottom of Inner Casing	Sediment Accumulation	Description of Bottom
NACA Test Area	NTAmw-110	2346438.94	551351.46	1080.03	28.0	1082.62	A	Unconsolidated	17.0	1063.0	27.0	1053.0	27.0	2.59	29.6	29.80	0.00	hard
NACA Test Area	NTAmw-111	2346638.01	551538.60	1078.07	20.0	1080.94	A	Unconsolidated	9.5	1068.6	19.5	1058.6	19.5	2.87	22.4	22.12	0.28	hard
NACA Test Area	NTAmw-112	2346889.48	551712.14	1075.36	23.9	1078.33	A	Unconsolidated	13.9	1061.5	23.9	1051.5	23.9	2.97	26.9	26.72	0.18	soft
NACA Test Area	NTAmw-113	2347082.83	551488.52	1072.61	27.5	1075.68	A	Unconsolidated	17.0	1055.6	27.0	1045.6	27.5	3.07	30.6	29.69	0.91	hard
NACA Test Area	NTAmw-114	2347301.57	551592.94	1075.61	20.0	1078.71	A	Unconsolidated	9.5	1066.1	19.5	1056.1	19.5	3.10	22.6	22.81	0.00	hard
NACA Test Area	NTAmw-115	2347581.16	551791.78	1086.91	24.0	1089.65	A	Unconsolidated	12.5	1074.4	22.5	1064.4	22.5	2.74	25.2	25.31	0.00	hard
NACA Test Area	NTAmw-116	2348196.39	551748.00	1091.68	22.0	1094.33	A	Unconsolidated	10.0	1081.7	20.0	1071.7	20.0	2.65	22.6	22.61	0.00	hard
NACA Test Area	NTAmw-117	2347994.83	551584.57	1091.67	25.0	1094.54	A	Unconsolidated	14.5	1077.2	24.5	1067.2	24.5	2.87	27.4	27.56	0.00	hard
NACA Test Area	NTAmw-118	2347609.41	551335.04	1078.86	22.5	1081.44	A	Unconsolidated	12.0	1066.9	22.0	1056.9	22.0	2.58	24.6	24.77	0.00	soft
NACA Test Area	NTAmw-119	2346013.00	551286.00	1077.40	130.0	1080.07	A	Unconsolidated	90.0	987.4	100.0	977.4	100.3	2.67	104.6	104.41	0.19	soft
Ramsdell Quarry Landfill	RQLmw-006	2375927.71	566091.26	993.52	42.1	995.39	A	Sharon	19.4	974.1	39.4	954.1	39.6	1.87	41.4	42.01	0.00	hard
Ramsdell Quarry Landfill	RQLmw-007	2375872.56	566544.36	963.86	18.7	965.91	A	Sharon	6.0	957.9	16.0	947.9	16.2	2.05	18.2	18.62	0.00	hard
Ramsdell Quarry Landfill	RQLmw-008	2376011.08	566327.94	963.82	18.7	966.08	A	Sharon	6.0	957.8	16.0	947.8	16.2	2.26	18.5	18.68	0.00	hard
Ramsdell Quarry Landfill	RQLmw-009	2376253.65	566351.20	962.60	18.8	964.58	A	Sharon	5.9	956.7	15.9	946.7	16.4	1.98	18.4	18.78	0.00	hard
Ramsdell Quarry Landfill	RQLmw-010	2376048.58	566857.39	980.04	35.4	982.14	A	Sharon	12.5	967.5	32.5	947.5	33.0	2.10	35.1	35.34	0.00	soft
Ramsdell Quarry Landfill	RQLmw-011	2376398.19	566819.66	974.60	35.4	976.57	A	Sharon	12.4	962.2	32.4	942.2	32.6	1.97	34.6	35.38	0.00	hard
Ramsdell Quarry Landfill	RQLmw-012	2376558.19	566551.95	975.12	30.5	977.65	A	Sharon	19.8	955.3	29.8	945.3	30.0	2.53	32.5	32.65	0.00	hard
Ramsdell Quarry Landfill	RQLmw-013	2376204.93	566928.09	978.04	34.4	980.71	A	Sharon	23.7	954.3	33.7	944.3	33.9	2.67	36.6	35.96	0.64	soft
Ramsdell Quarry Landfill	RQLmw-014	2376519.38	566941.29	970.83	29.4	973.49	A	Sharon	18.6	952.2	28.6	942.2	28.9	2.66	31.6	31.53	0.07	hard
Ramsdell Quarry Landfill	RQLmw-015	2375490.96	566560.90	989.19	40.1	991.26	A	Sharon	29.2	960.0	39.2	950.0	39.5	2.07	41.6	41.97	0.00	soft
Ramsdell Quarry Landfill	RQLmw-016	2375649.55	566177.68	994.02	39.5	996.60	A	Sharon	28.5	965.5	38.5	955.5	39.0	2.58	41.6	41.66	0.00	hard
Ramsdell Quarry Landfill	RQLmw-017	2376124.18	565931.38	988.69	30.5	991.23	A	Sharon	19.8	968.9	29.8	958.9	30.0	2.54	32.5	32.75	0.00	hard
Sharon Conglomerate	SCFmw-001	2353178.98	554768.62	1118.53	230.0	1120.71	A	Sharon Cong.	201.0	917.5	211.0	907.5	NA	2.18	213.61	214.30	0.00	hard
Sharon Conglomerate	SCFmw-002	2368927.36	555152.38	982.28	153.0	984.56	A	Sharon Cong.	137.0	845.3	147.0	835.3	NA	2.28	149.65	150.05	0.00	medium
Sharon Conglomerate	SCFmw-003	2375843.20	557957.67	956.14	140.0	958.47	A	Sharon Cong.	125.5	830.6	135.5	820.6	NA	2.33	139.65	139.63	0.02	hard
Sharon Conglomerate	SCFmw-004	2378730.23	560361.03	941.87	120.0	944.17	A	Sharon Cong.	100.0	841.9	110.0	831.9	NA	2.30	112.47	112.50	0.00	hard
Sharon Conglomerate	SCFmw-005	2377014.05	567302.35	958.43	160.0	960.80	A	Sharon Cong.	139.0	819.4	154.0	804.4	NA	2.37	156.41	156.10	0.31	hard
Sharon Conglomerate	SCFmw-006	2369394.54	569583.41	963.69	90.0	965.92	A	Sharon Cong.	76.0	887.7	86.0	877.7	NA	2.23	88.32	87.90	0.42	hard
Winklepeck Burning Grounds	WBGmw-005	2357163.55	563037.18	1052.20	19.0	1054.70	A	Unconsolidated	8.3	1043.9	18.3	1033.9	18.6	2.50	21.1	21.18	0.00	hard

Table 2-2 Monitoring Well Location Data (continued)

RVAAP Area	Well ID	Ohio State Plane Easting	Ohio State Plan Northing	Ground Level Elevation	Total Drilled Depth	TOC Elevation	Wellhead Type	Monitored Zone	Top of Screen (ft bgs)	Top of Screen Elevation	Bottom of Screen (ft bgs)	Bottom of Screen Elevation	Bottom of Inner Casing Plug or End Cap	Stickup Height	Reported Bottom of Inner Casing	May 2014 Measure Bottom of Inner Casing	Sediment Accumulation	Description of Bottom
Winklepeck Burning Grounds	WBGmw-006	2359087.79	563008.87	1012.16	19.0	1014.66	A	Unconsolidated	7.6	1004.6	17.6	994.6	17.9	2.50	20.4	20.18	0.22	hard
Winklepeck Burning Grounds	WBGmw-007	2360420.44	562479.87	998.09	24.0	1000.59	A	Unconsolidated	13.5	984.6	23.5	974.6	23.8	2.50	26.3	26.42	0.00	hard
Winklepeck Burning Grounds	WBGmw-008	2359700.57	562010.35	1005.71	18.5	1008.21	A	Unconsolidated	8.1	997.6	18.2	987.5	18.5	2.50	21	20.85	0.15	medium
Winklepeck Burning Grounds	WBGmw-009	2357159.20	561603.54	1045.03	24.0	1047.53	A	Unconsolidated	11.4	1033.6	21.4	1023.6	21.5	2.50	24	24.28	0.00	hard
Winklepeck Burning Grounds	WBGmw-010	2356051.96	562893.20	1067.10	21.0	1069.85	A	Unconsolidated	10.5	1056.6	20.5	1046.6	20.8	2.75	23.6	23.35	0.25	hard
Winklepeck Burning Grounds	WBGmw-011	2356187.29	562609.18	1069.70	22.0	1072.38	A	Unconsolidated	11.0	1058.7	21.0	1048.7	21.3	2.68	24	23.79	0.21	soft
Winklepeck Burning Grounds	WBGmw-012	2354810.65	562240.90	1076.50	30.0	1079.11	A	Unconsolidated	19.0	1057.5	29.0	1047.5	29.4	2.61	32	31.62	0.38	hard
Winklepeck Burning Grounds	WBGmw-013	2355223.25	561518.27	1069.10	22.0	1071.70	A	Unconsolidated	11.0	1058.1	21.0	1048.1	21.3	2.60	23.9	24.08	0.00	hard
Winklepeck Burning Grounds	WBGmw-014	2360439.22	562061.26	994.10	23.0	996.78	A	Unconsolidated	12.0	982.1	22.0	972.1	22.3	2.68	25	25.00	0.00	hard
Winklepeck Burning Grounds	WBGmw-015	2359182.41	562340.12	1009.10	22.0	1011.60	A	Unconsolidated	11.0	998.1	21.0	988.1	21.3	2.50	23.8	23.41	0.39	hard
Winklepeck Burning Grounds	WBGmw-016	2360645.88	562709.13	994.90	24.0	997.03	A	Unconsolidated	13.0	981.9	23.0	971.9	23.3	2.13	25.4	25.11	0.29	medium
Winklepeck Burning Grounds	WBGmw-017	2359603.84	562913.24	1004.00	22.0	1006.62	A	Unconsolidated	11.0	993.0	21.0	983.0	21.3	2.62	23.9	23.34	0.56	soft
Winklepeck Burning Grounds	WBGmw-018	2361302.00	562659.00	990.50	24.0	991.45	A	Unconsolidated	13.5	977.0	23.5	967.0	23.8	0.95	24.8	24.81	0.00	medium
Winklepeck Burning Grounds	WBGmw-019	2361304.00	562645.00	989.30	50.0	990.25	A	Sharon	39.6	949.8	49.6	939.8	49.9	0.95	50.5	50.49	0.01	hard
Winklepeck Burning Grounds	WBGmw-020	2357161.00	561623.00	1043.40	43.3	1044.31	A	Sharon	32.9	1010.5	42.9	1000.5	43.2	0.91	43.8	43.58	0.22	hard
Winklepeck Burning Grounds	WBGmw-021	2359106.00	563009.00	1010.00	42.5	1010.92	A	Sharon	32.0	978.0	42.0	968.0	42.3	0.92	43.1	43.01	0.09	hard

Notes: RVAAP: Former Ravenna Army Ammunition Plant; TOC: top of casing; ft: feet; bgs: below ground surface

Table 3-1 Historical Production Wells Identified for Abandonment

Production Well Number	Abandonment Methodology
8	Bentonite Grout
17	Bentonite Grout
18	Bentonite Grout
21	Bentonite Grout
22	Bentonite Grout
35	Bentonite Grout
41	Bentonite Grout
48	Bentonite Grout
63	Bentonite Chips/Pellets
96	Bentonite Grout

Notes:
Well abandonment methodology may change dependent on site conditions. Any potential modification will be completed in accordance with OWRC, 2015. Any modification will be proposed to the OHARNG/ARNG for approval prior to implementation.
Production Well #63 will be abandoned using bentonite chips/pellets and the casing will be left in place due to its location within a Class III Wetland – well can only be accessed by foot.

Table 3-2 Maximum Concentration of Contaminants for Toxicity Characteristics (40 CFR 261.24)

USEPA Hazardous Waste Number	Contaminant	CAS Number	Regulatory Level (mg/L)
D004	Arsenic	7440-38-2	5
D005	Barium	7440-39-3	100
D018	Benzene	71-43-9	0.5
D006	Cadmium	7440-43-2	1
D019	Carbon Tetrachloride	56-23-5	0.5
D020	Chlordane	57-74-9	0.03
D021	Chlorobenzene	108-90-7	100
D022	Chloroform	67-66-3	6
D007	Chromium	7440-47-3	5
D023	o-Cresol	95-48-7	200.0a
D024	m-Cresol	108-39-4	200.0a
D025	p-Cresol	106-44-5	200.0a
D026	Cresol	--	200.0a
D016	2,4-D	94-75-7	10
D027	1,4-Dichlorobenzene	106-46-7	7.5
D028	1,2-Dichloroethane	107-06-2	0.5
D029	1,1-Dichloroethene	75-35-4	0.7
D030	2,4-Dinitrotoluene	121-14-2	0.13b
D012	Endrin	72-20-8	0.02
D031	Heptachlor (and its epoxide)	76-44-8/1024-57-3	0.008
D032	Hexachlorobenzene	118-74-1	0.13b
D033	Hexachlorobutadiene	87-68-3	0.5
D034	Hexachloroethane	67-72-1	3
D008	Lead	7439-92-1	5
D013	Lindane	58-89-9	0.4
D009	Mercury	7439-97-6	0.2
D014	Methoxychlor	72-43-5	10
D035	Methyl ethyl ketone (2-Butanone)	78-93-3	200
D036	Nitrobenzene	98-95-3	2
D037	Pentachlorophenol	87-86-5	100
D038	Pyridine	110-86-1	5
D010	Selenium	7782-49-2	1

Table 3-2 Maximum Concentration of Contaminants for Toxicity Characteristics (40 CFR 261.24) (continued)

USEPA Hazardous Waste Number	Contaminant	CAS Number	Regulatory Level (mg/L)
D011	Silver	7440-22-4	5
D039	Tetrachloroethene	127-18-4	0.7
D015	Toxaphene	8001-35-2	0.5
D040	Trichloroethene	79-01-6	0.5
D041	2,4,5-Trichlorophenol	95-95-4	400
D042	2,4,6-Trichlorophenol	88-06-2	2
D017	2,4,5-TP (Silvex)	93-72-1	1
D043	Vinyl Chloride	75-01-4	0.2

Notes:
a = If o-, m-, and p-Cresol concentrations cannot be differentiated, total cresol (D026) concentration used. Regulatory limit is 200 mg/L.
b = Quantitation limit is greater than the calculated regulatory level. The quantitation limit, therefore, becomes the regulatory level.
-- = No standard exists
CAS = Chemical Abstracts Service
mg/L = milligram per liter
USEPA = United States Environmental Protection Agency
CFR = Code of Federal Regulations

Table 3-3 Maximum Concentration of Non-TCLP Analytes for Hazardous Waste Determination

USEPA Hazardous Waste Number	Analyte	CAS Number	Aqueous Reporting Limit	Solid Reporting Limit
D002	pH/Corrosivity	Q183	2 ≤ pH ≤ 12.5	--
D003	Cyanide, total	57-12-5	0.01 mg/L	0.66 mg/kg
D001	Flashpoint	Q376	<140°F	<180°F
D003	Sulfide, total	Q1314	3.0 mg/L	39.5 mg/kg

Source: SAIC 2011.

Table 3-4 Re-Vegetation Guidance – Approved Native Seed Mix

Need		Species and Proportion	Application
Temporary Cover for Ongoing Projects	Areas left idle for greater than 21 days, but scheduled for disturbance within the same growing season	100% Annual Ryegrass *(Lolium multiflorum)*	Broadcast at 30 pounds per acre. Drill at 20 pounds per acre. Mulch with a minimum of 3 bales of straw per 1,000 ft^2. Use mulch netting instead of straw on slopes > 6%.
Temporary Cover for Ongoing Projects	Areas that will remain unfinished indefinitely	40% Nodding Wild Rye (*Elymus Canadensis*) 40% Virginia wild rye (*Elymus virginicus*) 15% Partridge Pea (*Chamaecrista fasciculate*) 5% Black-eyed Susan (*Rudbeckia hirta*) Add 10 lbs/ac Annual Ryegrass *(Lolium multiflorum)*/acre	Broadcast at 35 pounds per acre. Drill at 25 pounds per acre. Mulch with a minimum of 3 bales of straw per 1,000 ft^2. Use mulch netting instead of straw on slopes > 6%.
Temporary Cover for Ongoing Projects	Late Season (after 15 September) quick, temporary cover	23.5% Nodding Wild Rye (*Elymus Canadensis*) 25% Virginia wild rye (*Elymus virginicus*) 18.75% Partridge Pea (*Chamaecrista fasciculate*) 1.5% Black-eyed Susan (*Rudbeckia hirta*) 31.25% Little Bluestem (*Schizachyrium scoparium*) Add 10 lbs/ac Annual Ryegrass *(Lolium multiflorum)*/acre	Broadcast at 25 pounds per acre. Drill at 18 pounds per acre. Mulch with a minimum of 3 bales of straw per 1,000 ft^2. Use mulch netting instead of straw on slopes > 6%.

Table 3-4 Re-Vegetation Guidance – Approved Native Seed Mix (continued)

Need			Application
Permanent Cover for Site Closure	Open Areas	23.5% Nodding Wild Rye (*Elymus Canadensis*) 25% Virginia wild rye (*Elymus virginicus*) 22% Little Bluestem (*Schizachyrium scoparium*) 18.75% Partridge Pea (*Chamaecrista fasciculate*) 7.75% Thin-leaved Coneflower (*Rudbeckia triloba*) 1.5% Brown fox sedge (*Carex vulpinoidea*) 1.5% Black-eyed Susan (*Rudbeckia hirta*) Add 10 lbs/ac Annual Ryegrass *(Lolium multiflorum)*/acre	Broadcast at 18 pounds per acre. Drill at 12 pounds per acre. Mulch with a minimum of 3 bales of straw per 1,000 ft^2. Use mulch netting instead of straw on slopes > 6%.
Permanent Cover for Site Closure	Shaded, Partial Sun, Openings In Woods	31% Deertongue (*Panicum clandestinum*) 25% Virginia wild rye (*Elymus virginicus*) 25% Nodding Wild Rye (*Elymus Canadensis*) 10% Big Bluestem (*Andropogon gerardii*) 9% Side-Oats Grama (*Bouteloua curtipendula*) Add 10 lbs/ac Annual Ryegrass *(Lolium multiflorum)*/acre	Broadcast at 30 pounds per acre. Drill at 20 pounds per acre. Mulch with a minimum of 3 bales of straw per 1,000 ft^2. Use mulch netting instead of straw on slopes > 6%.

Note: OHARNG 2014a.

Table 5-1 Anticipated Project Schedule

Activity	Anticipated Completion Date
Approval of Draft Well Abandonment Work Plan	April 2016
Approval of Draft Well Abandonment Work Plan	June 2016
Tree Removal from Access Routes and Wetlands Delineation Field Work (performed prior to cutting restriction beginning April 1)	TBD – first mobilization anticipated March 2016
Wetlands Verification Visit	July - August 2016 (production well abandonment) and then on-going as part of monitoring well abandonment activities (TBD).
Production Well Abandonment	September-October 2016
Prepare Tech Memo and IDW Report	October 2016
Monitoring Well Abandonment	July-September 2017
Prepare Tech Memo and IDW Report	October 2017
Well Sealing Report	September 2017 to April 2018

FIGURES

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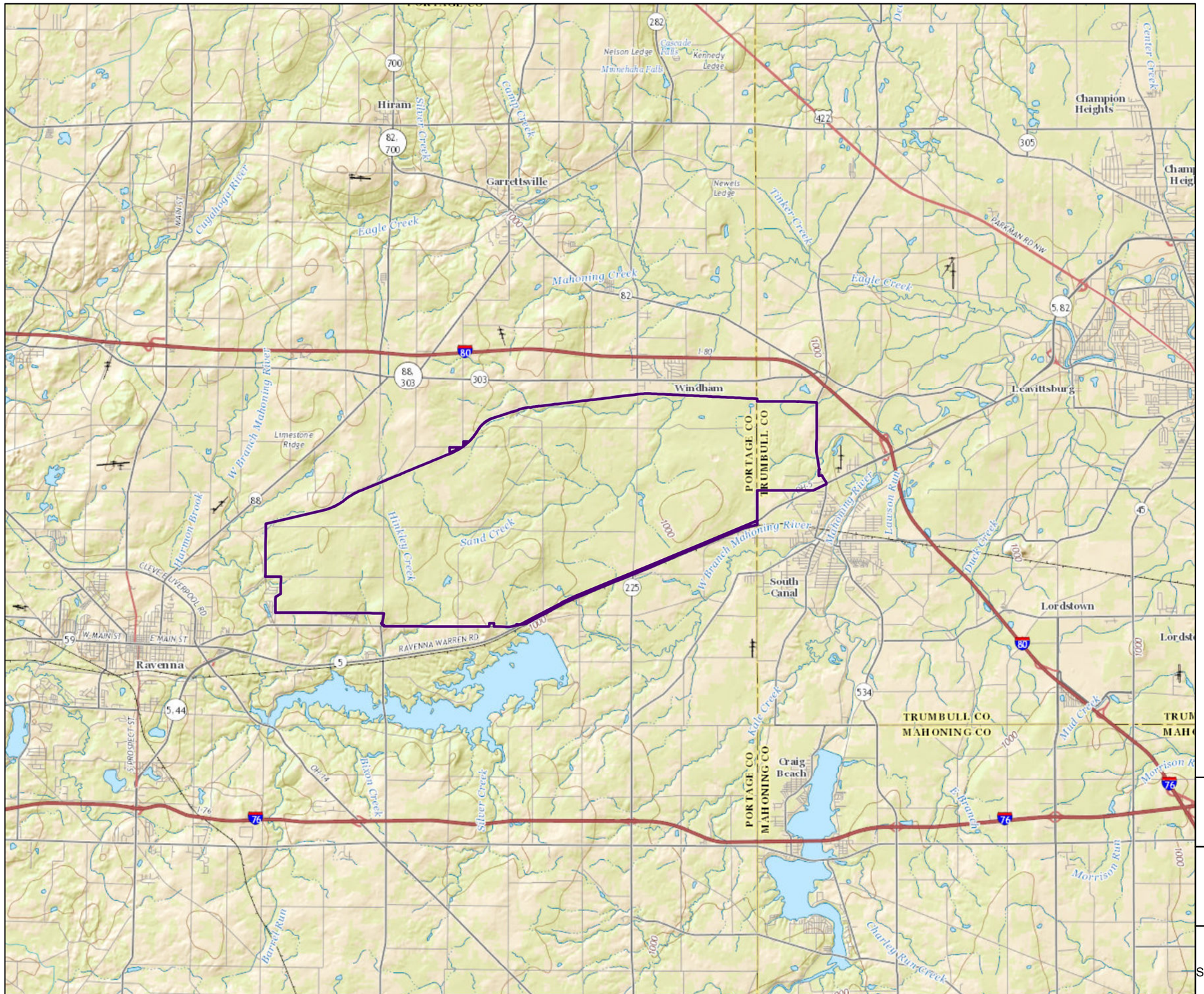

Overview Map

Legend

Camp Ravenna Property Line

Notes:
- Basemap Source: ESRI Map Service - USGSTopo

N

0 1 2 3 4 Miles

1:7,654,372
NAD83 UTM Zone 17N

TEC-Weston Joint Venture

SITE LOCATION MAP

Groundwater and Environmental Investigation Services for RVAAP-66 Facility-Wide Groundwater
Former RVAAP/Camp Ravenna
Ravenna, Ohio

Figure: 1-1

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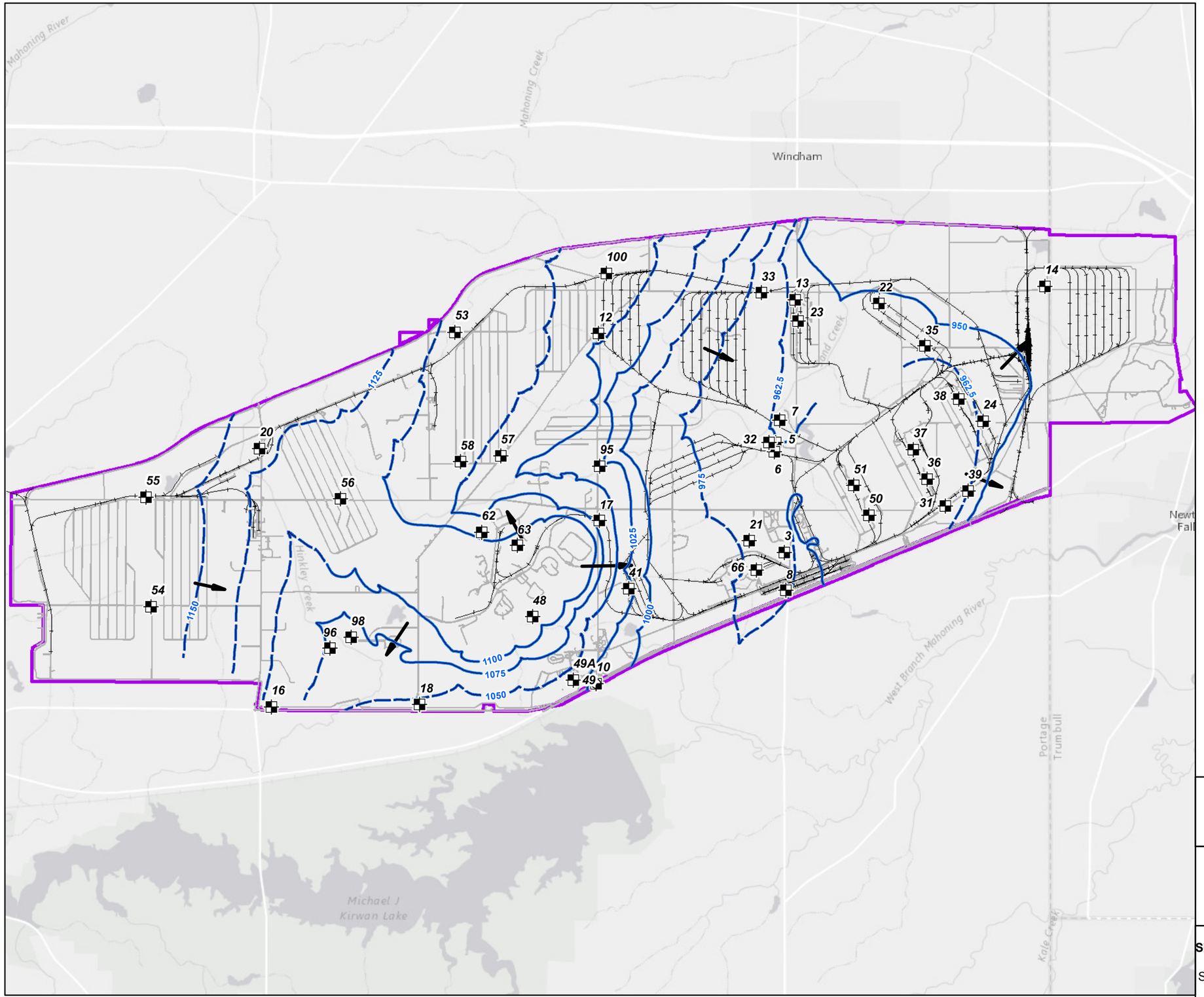

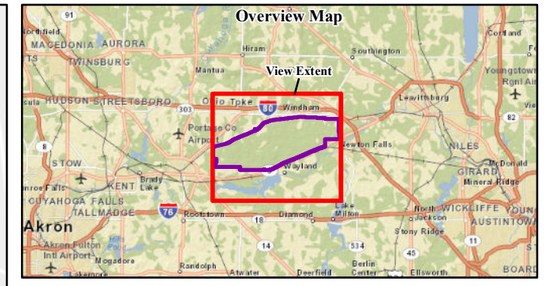

Legend

- Former Groundwater Production Well
- Potentiometric Surface Unconsolidated Unit (May 2014)
- Roads
- Railroad
- Camp Ravenna Property Line

Notes:

- Potentiometric Surfaces from *Final Facility-Wide Groundwater Monitoring Program RVAAP-66 Facility-Wid Groundwater Annual Report for 2014*, EQM, March 30, 2015
- Basemap Sources: ESRI Map Services - Canvas/World_Light_Gray_Base and World_Street_Map

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NAD83 UTM Zone 17N

TEC-Weston Joint Venture

GROUNDWATER POTENTIOMETRIC SURFACE MAP - UNCONSOLIDATED DEPOSITS
Groundwater and Environmental Investigation Services for RVAAP-66 Facility-Wide Groundwater
Former RVAAP/Camp Ravenna
Ravenna, Ohio

Figure: 2-1

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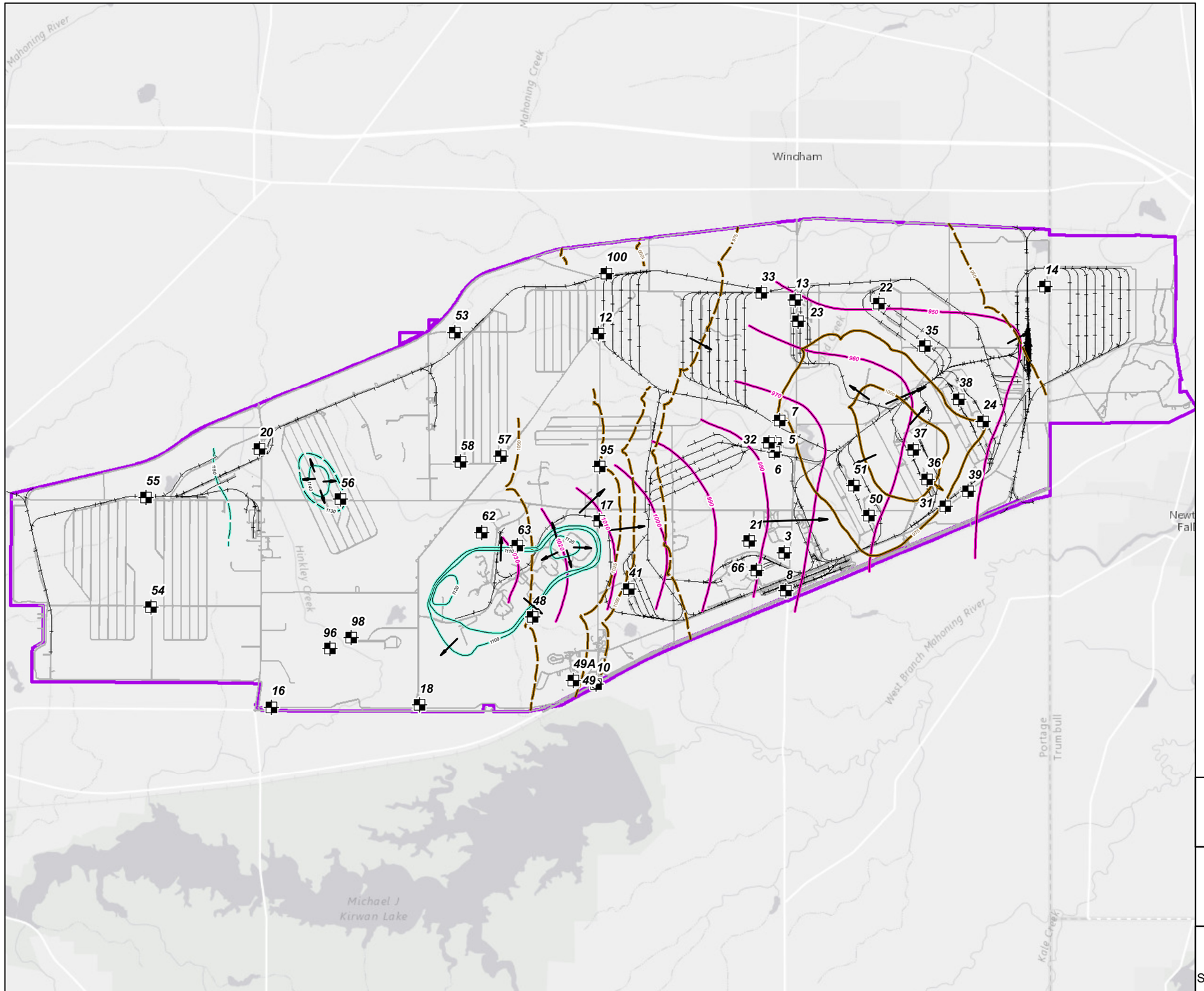

Legend

- Former Groundwater Production Well
- Potentiometric Surface Homewood Unit (May 2014)
- Potentiometric Surface Upper Sharon Unit (May 2014)
- Potentiometric Surface Sharon Conglomerate (May 2014)
- Roads
- Railroad
- Camp Ravenna Property Line

Notes:

- Potentiometric Surfaces from *Final Facility-Wide Groundwater Monitoring Program RVAAP-66 Facility-Wid Groundwater Annual Report for 2014*, EQM, March 30, 2015
- Basemap Sources: ESRI Map Services - Canvas/World_Light_Gray_Base and World_Street_Map

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NAD83 UTM Zone 17N

TEC-Weston Joint Venture

GROUNDWATER POTENTIOMETRIC SURFACE MAP - BEDROCK DEPOSITS

Groundwater and Environmental Investigation Services for RVAAP-66 Facility-Wide Groundwater
Former RVAAP/Camp Ravenna
Ravenna, Ohio

Figure: 2-2

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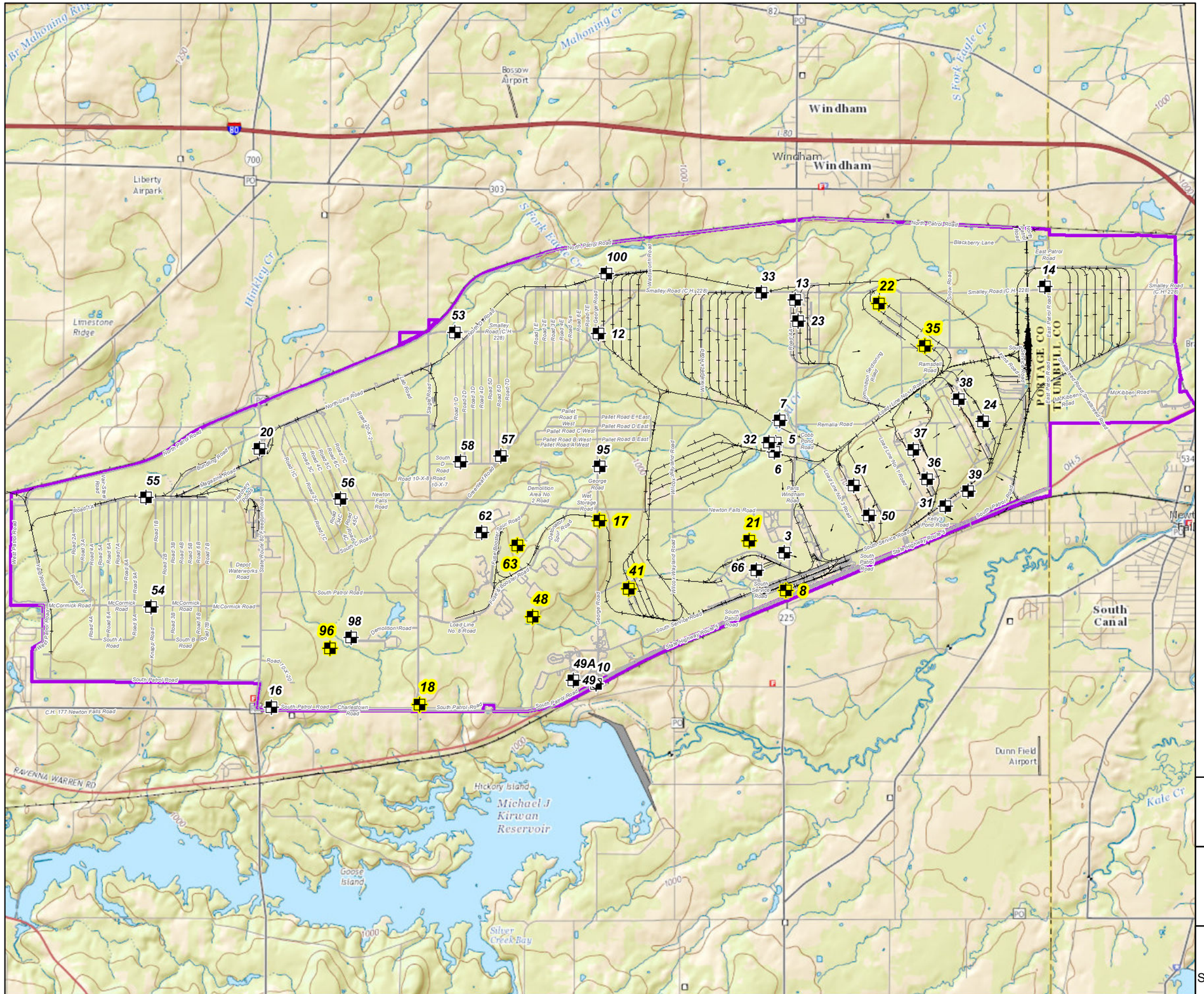

Legend

- Former Groundwater Production Well to be Abandoned by JV Team
- Former Groundwater Production Well to be Abandoned by Others
- Roads
- Railroad
- Camp Ravenna Property Line

Notes:
- Basemap Source: ESRI Map Sservice - USGSTopo

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0 2,500 5,000 7,500 10,000 Feet

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NAD83 UTM Zone 17N

TEC-Weston Joint Venture

LOCATION OF FORMER PRODUCTION WELLS TO BE ABANDONED
Groundwater and Environmental Investigation Services for RVAAP-66 Facility-Wide Groundwater
Former RVAAP/Camp Ravenna
Ravenna, Ohio

Figure: 3-1

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APPENDIX A

STATE OF OHIO REGULATIONS AND TECHNICAL GUIDANCE FOR SEALING UNUSED WATER WELLS AND BOREHOLES

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State of Ohio
Ohio Water Resources Council
State Coordinating Committee on Ground Water

REGULATIONS AND TECHNICAL GUIDANCE FOR SEALING UNUSED WATER WELLS AND BOREHOLES

March 2015

John R. Kasich, Governor
Mary Taylor, Lt. Governor

STATE OF OHIO
REGULATIONS AND TECHNICAL GUIDANCE FOR SEALING UNUSED WATER WELLS AND BOREHOLES

Ohio Water Resources Council
State Coordinating Committee on Ground Water
March 2015
(Revision of 1996 document titled "Technical Guidance for Sealing Unused Wells")

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Acknowledgements

The preparation of this document involved the contribution and hard work of a number of individuals on the Well Sealing Workgroup of the State Coordinating Committee on Ground Water. The development of the Technical Guidance was supported by the State Coordinating Committee on Ground Water and its member agencies. The workgroup also thanks the industry professionals who graciously took the time to participate in developing the guidelines. In addition, special thanks goes to Katherine Sprowls and David Orr of the Ohio Department of Natural Resources for the time and effort they devoted to editing and generating/modifying the figures found in the guidelines. Also, thanks goes out to Russell Smith, Ohio Department of Health, Ron Clinger, Defiance County Health Department, and Jim Raab, Ohio DNR for providing pictures printed in this document. Grateful acknowledgement is given to the following workgroup members for their technical research and text authorship, report editing and preparation:

Well Sealing Workgroup Members

Jim Raab (Chair)	Division of Soil and Water Resources, Ohio Department of Natural Resources
Mike Dillman	Division of Mineral Resources Management, Ohio Department of Natural Resources
Rebecca Fugitt	Bureau of Environmental Health, Ohio Department of Health
Russell Smith	Bureau of Environmental Health, Ohio Department of Health
Steven Schmidt	Bureau of Environmental Health, Ohio Department of Health
Lisa Koenig	Division of Drinking and Ground Waters, Ohio Environmental Protection Agency
Craig Smith	Division of Drinking and Ground Waters, Ohio Environmental Protection Agency
Andy Ety	Ohio Department of Agriculture
Ralph Haefner	United States Geological Survey
Ronald Clinger	Defiance County Health Department
Brandon Mantel	Donamarc Water Systems/Ohio Water Well Association
Steve Wright	Frontz Drilling/ National Drillers Association
Dave Yeager	Yeager Well Drilling/Ohio Water Well Association
Ed Anderson	Halliburton
Wesley Gibson	CETCO
Norm Pelak	Wyoben

State Coordinating Committee on Ground Water Member Agencies

(See Appendix 1 for contact information)

Ohio Environmental Protection Agency
Ohio Department of Natural Resources
Ohio Department of Health
Ohio Department of Agriculture
Ohio Public Utilities Commission
Ohio Department of Commerce - State Fire Marshal
Ohio Department of Transportation
United States Geological Survey
Natural Resources Conservation Service

Preface

In early 1992, the State Coordinating Committee on Ground Water (SCCGW) identified the lack of consistent standards and regulations regarding the sealing of abandoned water wells and test borings as a major issue of concern by the Committee. The SCCGW formed a subgroup in June, 1994 to develop consistent technical standards for sealing abandoned wells and test borings. Based on the standards finalized in 1996, both the Ohio Environmental Protection Agency and the Ohio Department of Health revised their rules regarding well sealing. Since the initial development of this guidance, new state regulations and research in sealing material technologies and procedures, along with practical experience in the field, have prompted an update to the guidance document. In 2013, a workgroup was formed to re-write/edit the original document. This document is the product of the workgroup.

Throughout this document are references to proprietary materials or products. These references should in no way be interpreted as endorsements for any particular brand name or manufacturer, and are used only for illustrative or comparative purposes.

This guidance does not apply to wells constructed for the purpose of injecting fluids into the subsurface (except as it may augment, not supersede, rule requirements), nor does it apply to oil and gas wells. The authority over injection wells depends on the well classification. For more information contact the Ohio Environmental Protection Agency, Division of Drinking and Ground Waters, Underground Injection Control Unit.

At the time that this guidance document was prepared, the guidance followed the applicable rules for regulated wells. However, rules can change and may have since this document was prepared. Therefore, if there are any discrepancies between an existing rule and this guidance document, follow the rule.

Introduction

Unused or abandoned water **wells**[1] or boreholes are those that are no longer in service or are in such a state of disrepair that continued use for the purposes of accessing **ground water** is unsafe or impracticable. Abandoned wells can be found almost anywhere: on farms, industrial sites, and in urban areas. Those marked by windmill towers and old hand pumps are easy to spot. Many lie hidden beneath weeds and brush. These wells are open traps waiting for unsuspecting children, hunters, and animals (Gordon, 1988). No accurate accounting of abandoned wells exists for the State of Ohio.

Each year, many wells are abandoned when homes are connected to community water supplies. Many exploratory borings are installed, data gathered, and then the borehole left as an open conduit to the aquifer. In addition, wells are often abandoned when their **yield** has diminished, or the quality of the water they supply has degraded. It has been estimated that there could be more than tens of thousands of unused wells and boreholes in Ohio. For the purposes of this document, wells refer to both wells and boreholes.

This document is intended to discuss the sealing requirements for the different types of wells and boreholes that are regulated in Ohio and provide guidance for those wells and boreholes that are not regulated. Table 1 is a list of different types of wells and boreholes with the associated rule if regulated. Any well or boring that is over ten feet in depth should follow the guidance if no regulatory authority already exists.

The number of potential contaminants that may enter these wells is unlimited. Fuel, fertilizer, solvents, sewage, animal waste, pesticides and numerous other contaminants have been introduced into ground water through unsealed abandoned wells or improperly sealed wells. If a substance can be dissolved, carried, or mixed in water, it has the potential for entering ground water through an improperly sealed abandoned water well (King, 1992). Abandoned wells also pose a physical hazard; there have been numerous accidents documented with children and pets falling into unsealed water wells.

Any well or borehole to be abandoned should be sealed to prevent vertical movement of water. The sealing method chosen should be dependent on both well construction and site **geologic/hydrogeologic conditions**. Whenever there is doubt about either the construction of the well or the site hydrogeology, the choices of sealing material and procedure should be those affording the greatest probability of providing a permanent seal.

This document also outlines the materials and methodologies that should be used to properly seal a well. It is intended to provide a comprehensive discussion of all elements involved in the well sealing process, including basic ground water principles and an introduction to well drilling and construction methods. Readers familiar with these topics can move directly to the sections dealing with well sealing procedures.

[1] All terms in bold print can be found in the glossary

Overview of the Regulations

Current regulations for private (Ohio Administrative Code (OAC) 3701-28-17) and public water wells (OAC 3745-9-10) require that boreholes not converted into wells, and wells not being used to obtain water or provide information on quality, quantity, and water level be sealed or else maintained in compliance with the respective rules.

This document is intended to cover all types of water wells and borings. The authority for enforcement lies within a few state agencies depending on the type of well. For example, the authority for enforcement for public water supplies is the Ohio Environmental Protection Agency (Ohio EPA)/Division of Drinking and Ground Waters (DDAGW) Drinking Water Program and the authority for enforcement for private wells is the Ohio Department of Health (ODH) and local health departments. Table 1 lists the different types of wells and the associated regulatory agency and legislative reference.

Table 1. Types of water wells and borings with the associated regulatory authority (if any).

Type of Water Well Being Sealed	Regulatory Agency	Applicable Regulations and Guidance
Cathodic Protection	None	None
Dewatering (non-potable well)	Ohio EPA	OAC 3745-9-10
Geophysical boreholes	None	None
Geotechnical	None	None
Geothermal – Closed loop	None	Recommendations for Geothermal Heating and Cooling Systems - Guidance for Protecting Ohio's Water Resources
Geothermal – Extraction (non-potable well)	Ohio EPA	OAC 3745-9-10
Geothermal – Return or Recharge Well (Class V)	Ohio EPA	OAC 3745-34-07 & OAC 3745-34-11
Industrial Use (non-potable well)	Ohio EPA	OAC 3745-9-10
Injection – Class V	Ohio EPA	OAC 3745-34-07 & OAC 3745-34-11
Injection - Remediation (Class V)	Ohio EPA	OAC 3745-34-07 & OAC 3745-34-11
Irrigation Use (non-potable well)	Ohio EPA	OAC 3745-9-10
Mineral Exploration Boreholes / Mine Boreholes / Mineral Exploration Test Holes	ODNR-Mineral Resources Management	Coal: OAC 1501:13-9-02 and either OAC 1501:13-4-05 or OAC 1501:13-4-14 Industrial Minerals: OAC 1501:14-4-01
Monitoring	Ohio EPA	Technical Guidance Manual for Ground Water Investigations
Piezometer	Ohio EPA	Technical Guidance Manual for Ground Water Investigations
Pressure Relief	None	None
Private Water Systems	Ohio Dept. of Health	OAC 3701-28-17
Industrial Process Water (non-potable well)	Ohio EPA	OAC 3745-9-10
Public Supply Wells	Ohio EPA	OAC 3745-9-10
Test Borings	Ohio EPA, Ohio Dept. of Health Ohio Dept. of Agriculture	OAC 3745-9-10, OAC 3701-28-17, OAC 901:10-2-03

The sealing of all abandoned wells and boreholes that penetrate an **aquifer** (see Table 1) must be properly documented in accordance with Section 1521.05 (B) of the Ohio Revised Code. A **well sealing report** (see Figure 1) must be submitted to the Ohio Department of Natural Resources (ODNR), Division of Soil and Water Resources within 30 days of the sealing. The on-line filing process is the preferred method of submitting the well sealing form (http://soilwater.ohiodnr.gov/search-file-well-logs). If you do not have access to a computer, you can order a paper well sealing form from the ODNR (614-265-6740).

If the well or test hole is or was part of a **private water system**, OAC Rule 3701-28-17 requires that a permit be obtained from a local health district prior to sealing. If an existing well is to be sealed when a new well is drilled, then the well sealing is included in the private water system replacement permit. The local health department is to be provided a copy of the sealing report when an abandoned well has been sealed.

The Ohio EPA regulates **public water systems** in Ohio. They also have authority for nonpotable (non-drinking) water wells, Class I, IV, and V **underground injection wells**, and **monitoring wells**. Regulations for public water system wells and **non-potable wells** require that an abandoned well be sealed in accordance with OAC 3745-9-10 and OAC 3745-9-07, with this document used as a guide. A public water system may apply to the director for a variance from these requirements in accordance with the provisions of OAC 3745-9-2. Test holes that were not converted into wells and wells not being used to obtain water or provide information on quality, quantity, and water level must be properly sealed and the sealing properly documented. The authority for enforcing well sealing rules for public water system and non-potable wells is the Ohio EPA/Division of Drinking and Ground Waters (DDAGW).

Regulations for Class V Underground Injection Control (UIC) wells require that a Class V well be sealed in a manner that prevents the movement of fluids containing contaminants that may cause an underground source of drinking water to exceed any primary drinking water standard, or may otherwise adversely affect the health of persons. Prior notification for sealing is required (OAC 3745-34-11(O)) and for permitted Class V wells a sealing plan is required. In some cases OAC 3745-9-10 and this document may be used as guidance for the proper means of sealing a well. The authority for enforcement for Class V injection wells is the Ohio EPA/DDAGW, UIC Program. Please contact the UIC program prior to sealing a Class V well.

Regulations for monitoring wells (OAC 3745-9-03) require that a monitoring well be sealed if the well is damaged or deteriorated and will not be repaired, or if the well is no longer being used. Unless an agency or program has specific requirements for sealing a monitoring well required by its rules, the sealing procedures found in Chapter 9 (Sealing Abandoned Monitoring Wells and Boreholes) of the "Ohio EPA Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring" is to be used as a guide for monitoring well sealing to prevent the contamination of ground water. The authority for enforcement for monitoring wells is the Ohio EPA/DDAGW and the agency, board, or commission that required the monitoring well.

Please note that each of the OAC chapters cited in this document may use unique or uncommon terms or may have a very specific use for a familiar term. These terms are usually defined in the first section of the chapter; for example definitions for terms used for private wells can be found in OAC 3701-28-01 and terms used for Class V wells can be found in OAC 3745-34-01

Reasons to Properly Seal an Unused Well

There are many reasons for properly sealing unused wells. The most important of these include: eliminating physical hazards, preventing ground water contamination, and preventing further loss of confining pressure in confined aquifers.

Dug well in front yard of residence.

Eliminate Physical Hazard

One of the most obvious reasons to properly seal a well is the physical hazard (Figure 2). A good example of this danger was seen in the early 1990's as the nation witnessed the rescue of a small child from an unsealed abandoned water well that was less than 10 inches in diameter. It is also quite common to find animal remains in unsealed abandoned wells.

DNR 7810.12e

WATER WELL SEALING REPORT e-FORM
OHIO DEPARTMENT OF NATURAL RESOURCES
Division of Soil and Water Resources
2045 Morse Road, Bldg B
Columbus, OH 43229-6693
Voice: (614) 265-6740 Fax: (614) 265-6767

Sealing Report No. 0

LOCATION

County GEAUGA Township PARKMAN Section No. _____ Lot No. _____

Owner E. J. FUDD

Address of Well Location 1234 NOTKNOWN RD.

City ANYTOWN Zip Code 00000-1230

Well Location Description (120 Characters): 1/2 mile south of Maindrag on west side of Notknown.

Location of Well in either: State Plane N ☐ S ☐ X _____ +/- _____ ft. Y _____ +/- _____ ft. OR Latitude/Longitude Latitude 41.41234 Longitude -81.01234

Elevation of Well 1022.00 +/- _____ ft. Datum Plane: ☐ NAD27 ☒ NAD83

Source of Coordinates: ☒ GPS ☐ Survey ☐ Other _____

Source of Elevation: ☒ GPS ☐ Survey ☐ Other _____

WELL IDENTIFICATION ODNR Well Log Number 123456 Project Well ID _____

MEASURED CONSTRUCTION DETAILS

Date of measurements 08/06/2012

Depth of Well 106 ft. Static Water Level 83 ft.

Borehole Depth 106 ft. Borehole Diameter _____ in.

Casing Diameter 5.63 in. Casing Length 27 ft. Casing Type steel

SEALING PROCEDURE

Placement:	Sealing Material	Volume/Weight Used (Units Required)	Placement Method
From 0 ft. To 106 ft.	Bentonite/polymer slurry	115 gals/250 Lbs	Pumped w/tremie pipe
From _____ ft. To _____ ft.			
From _____ ft. To _____ ft.			
From _____ ft. To _____ ft.			

Condition of Casing good Was Casing Removed? ☐ Yes or ☒ No (check one)

If casing **Not Removed**, was it Perforated? ☐ Yes or ☒ No (check one) Perforations: From _____ ft. To _____ ft.

Date Sealing Performed 08/08/2012

Comments/Reason for Sealing: VERY HIGH IRON LEVELS WHICH KEEPS SEALING OFF THE WATER

CONTRACTOR

Name ACME DRILLING COMPANY ODH Registration # 9876

Address 1234 MAIN ST.

City/State/Zip SOCKERDOWNE, OH 56789

e-Signature W. E. COYOTE Filed electronically on 08/06/2012

I hereby certify the information given is accurate and correct to the best of my knowledge.

Completion of this form is required by section 1521.05, Ohio Revised Code - file within 30 days after completion of sealing.
Distribute additional copies to: Customer, Driller and Local Health Department.

Figure 1. Example of an official Ohio water well sealing report form.

Other than being the reason for the unfortunate creature's demise, an additional hazard is the possible bacterial contamination of the aquifer caused by the decay of the animal. There also have been cases cited where improperly sealed **geotechnical borings**, used to obtain **stratigraphic** information during highway construction, have caused potholes to occur in newly-constructed highways (Smith, 1994). Geotechnical and mineral exploration borings are often drilled on farmland or pasture land. Imagine the consequences if the farmer's prize-winning Guernsey (or other livestock, for that matter) steps into an open **borehole** and breaks a leg. These are just a few of the hazards that could result from the existence of unsealed abandoned wells of any type.

Prevent Ground Water Contamination

Another reason to properly seal a well is to prevent ground water contamination (Figure 2). There are four ways that an unsealed abandoned well could contaminate the ground water: by intermixing of waters between aquifers, by surface water entering the aquifer, by illegal disposal of contaminants down the well, and by microbial contamination from decomposition of animal bodies and waste products.

Poorly constructed wells or wells that are screened across multiple aquifers can cause intermixing of water between the aquifers. Depending on the hydrogeologic conditions, poor quality water can move upward or downward into a pristine aquifer. Ground water zones penetrated by a well may have physical or chemical qualities that are incompatible. Chemical reactions may occur that result in undesirable products such as iron sulfides and calcium sulfate (Smith, 1994).

Surface water can enter a well if the well cap has been broken or removed, or if there are holes in the **well casing** due to damage or deterioration with age. In addition, surface water can seep down along the space (called the **annular space**) between the casing and the **formation** of an improperly grouted well. This is an important consideration because most older water wells are not grouted and do not meet today's construction standards. Surface water can carry contaminants, feces, trash, debris and even dead animals into an unsealed well.

Illegal disposal of contaminants down unused wells still occurs. Open wells offer tempting disposal receptacles for liquid and solid waste. People seem naturally compelled to throw or pour unwanted material down an open hole (Smith, 1994).

Abandoned wells are often preferred havens for a host of arthropods (spiders, earwigs, and centipedes) that prefer dark, moist, calm places. Also these can become subsurface dwellings for rodents and reptiles. The bodies and waste products of these colonists add nutrients and undesirable microbes to the ground water (Smith, 1994).

Minimize Further Loss of Confining Pressure

It is important to seal a well penetrating a **confined aquifer**(s) to preserve the confined (or "pressurized") conditions (Figure 2). These confining conditions allow the water to reach a certain level in a well (called the **static level**). The static level will be higher than the depth at which the water is encountered in the aquifer; in some cases, water will flow out the top of the well because the static level is higher than the ground surface. A reduction in the confining pressure may cause water levels in neighboring wells to drop because the **hydraulic head** is no longer high enough to allow the water in these wells to maintain their original static levels. Reduced confining pressures may result from water in a deeper aquifer moving upward into formations containing no water, or into **saturated zones** of lower hydraulic head. In the case of **flowing wells**, the pressure can be reduced simply because of the constant flow of water from the aquifer onto the ground surface. Therefore, it is especially important to ensure that abandoned wells penetrating confined aquifers are properly sealed.

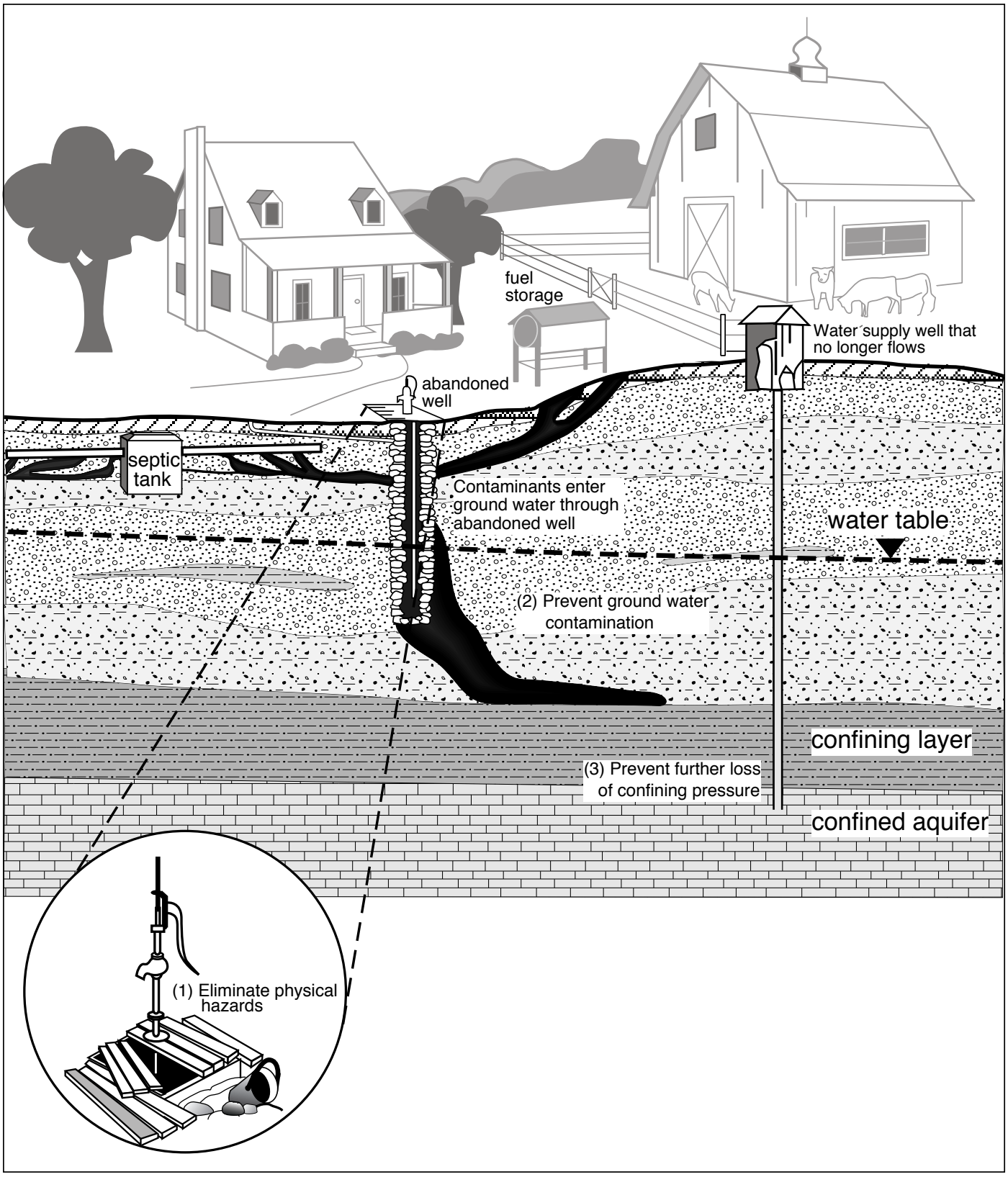

Figure 2. Reasons to properly seal an unused well. (After Glanville, 1989, and King, 1992)

Deciding Who Should Perform Well Sealing

Based on the difficulty in sealing many wells, and the equipment and knowledge involved, it is strongly recommended that well sealing be completed by an experienced registered drilling contractor. Owners of a primary or secondary property, or property rentals who want to work on their own well must be registered with the Ohio Department of Health before they seal their well and may only perform work on residences they own. At a minimum, in all sealing situations, an experienced registered drilling contractor should be consulted. Some work may also need to be supervised by a qualified hydrogeologist or qualified engineer. Under rare circumstances, state oversight or observation might be required. It should be noted that all professional contractors do not have the same experience. An experienced contractor should be able to provide a description of work to be performed and a list of references proving his/her qualifications. On sites with potential for exposure to contamination or other hazards, personnel should be trained and equipped for such conditions (Smith, 1994). No one should enter a confined space (i.e. well pit) without having the proper training and also knowing the air quality of the confined space. For more information on confined space standards and regulations see OSHA's 29 CFR 1910.146.

Once a well has been sealed improperly, it is costly to correct because the defective seal has to be drilled out. In some situations, there could be irreparable damage to the aquifer or confining layers. It is recommended that wells with one or more of the following characteristics be sealed by an experienced registered contractor only:

- drilled wells,
- flowing wells,
- wells greater than 100 feet in depth,
- wells less than 3 inches in diameter,
- wells where water is seeping from around the casing,
- wells where pumping equipment is difficult to remove,
- wells that have been damaged,
- wells which produce gas,
- wells that have been contaminated,
- monitoring wells,
- wells that may have encountered cavernous geologic conditions, and
- wells that may have encountered mine voids.

Types of Wells as Defined by Method of Construction

Wells can be described in different ways; by their method of construction, and by the type of aquifer in which they are developed. There have been three commonly used methods of well construction over the years: digging (by hand or by backhoe), driving, and drilling.

Dug Wells

A **dug well** can be defined as any well not installed by drilling rigs. They are usually large diameter (greater than 24 inches) and fairly shallow (25 feet or less), and are constructed by digging with a backhoe or by hand. Casing installed in dug wells can vary from concrete pipe and vitrified tile to cobbles and bricks. (see Figure 3 for diagrams showing two common dug well construction techniques) In some cases, dug wells are improperly used as **cisterns** for roof runoff or hauled water.

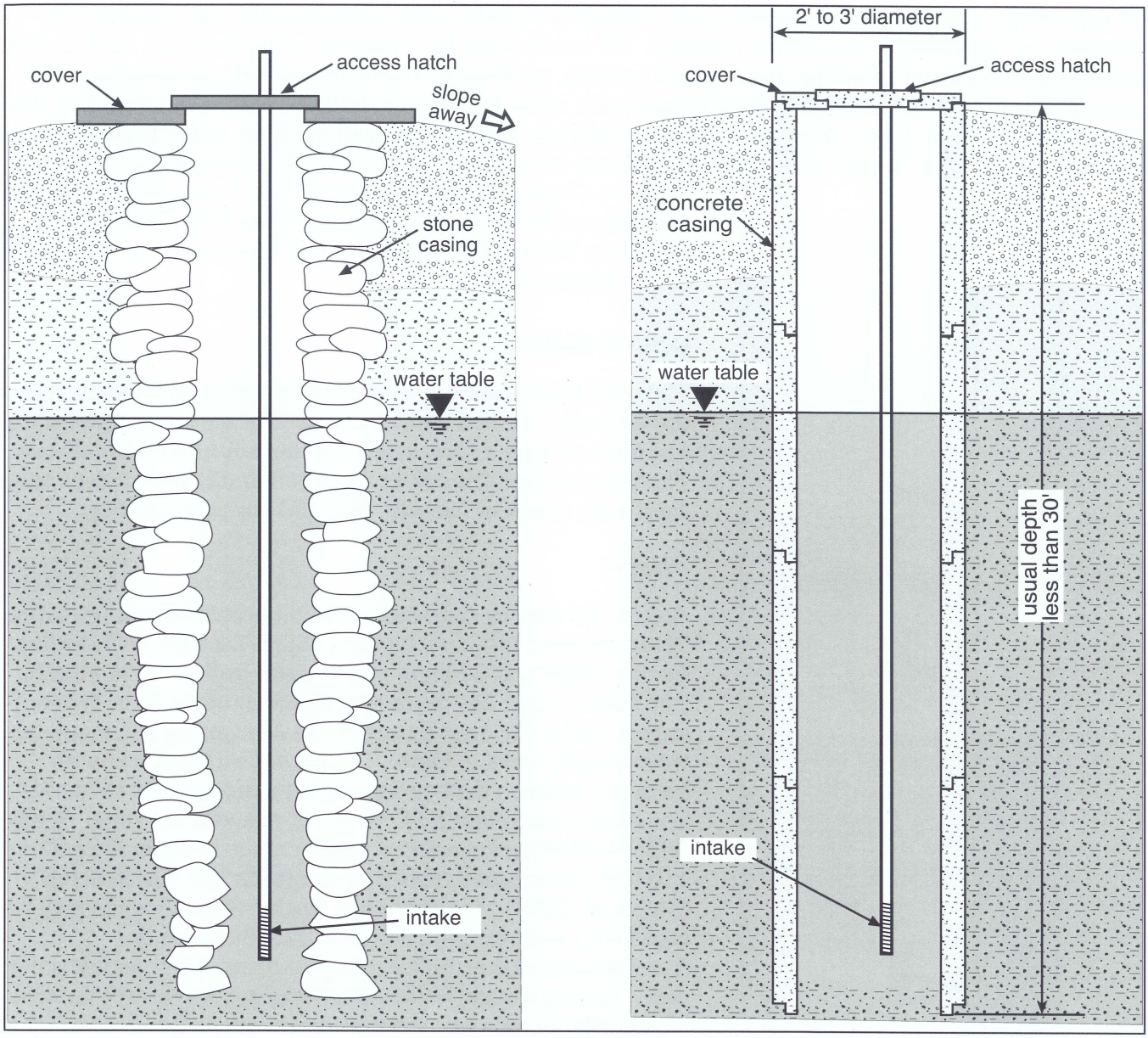

Figure 3. Typical dug well designs using either natural rock like limestone or sandstone (left), or using precast concrete (right).

Driven Wells

Driven wells are installed by pushing a pipe into the ground by hand or machine. There is no annular space around the outside of the pipe since the pipes are pushed into the ground. There are two types of driven wells: well points and Direct Push (DP). Well points are installed only in **unconsolidated** formations. Well points are typically small diameter, shallow wells used to supply water for a single household. Many of these wells are installed by the homeowners themselves. Well points consist of a **well screen** with a hardened point on the end of the screen which is hammered into place (by hand or machine) using a large weight. Sections of pipe are added to the screen in order to advance the screen to the desired depth (see Figure 4 for diagram).

DP technology devices are investigative tools that drive or push small-diameter rods and tools into the subsurface by hydraulic or percussive methods. DP can be used for a number of applications, such as soil sampling, ground water sampling, geophysical sensing, geochemical sensing, and soil gas sampling. DP technology is used in unconsolidated sediments and is most suitable for shallow depths (less than 100 feet), but may be able to go deeper depending on site conditions. Due to the small diameter of DP probeholes and wells, sealing presents special challenges. Additional information on direct push monitoring wells can be found in Chapter 15 (Use of Direct Push Technologies for Soil and Ground Water Sampling) in the Ohio EPA Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring.

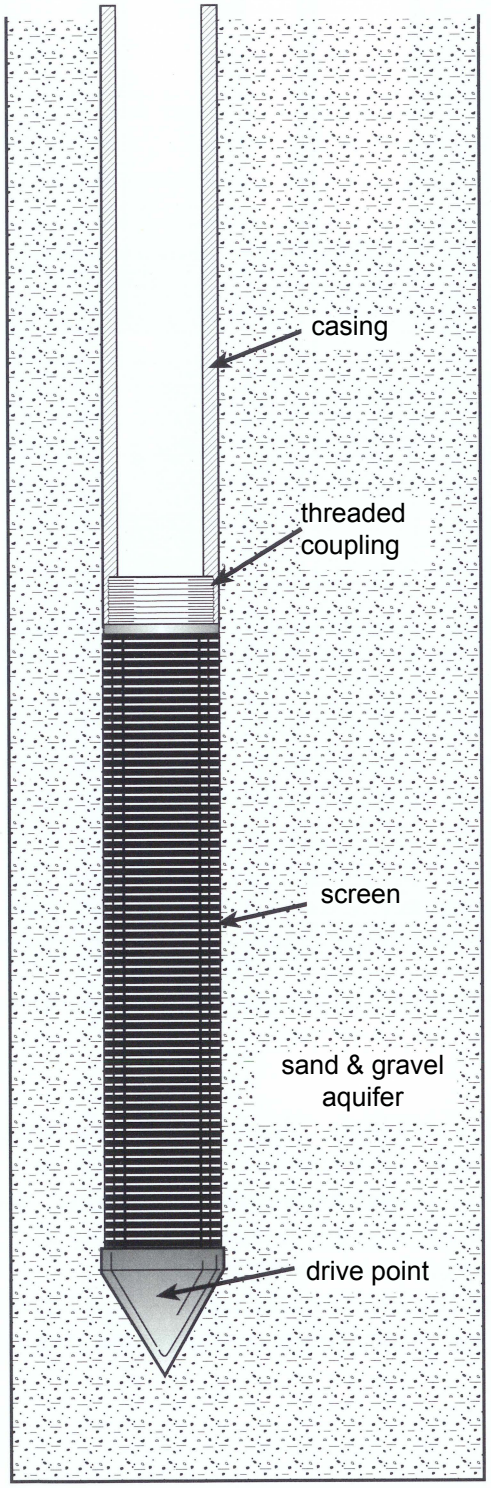

Figure 4. Driven well construction showing drive point, well screen and steel casing.

Drilled Wells

The third major category of well construction methods is that of drilled wells. Drilled wells are those that are constructed using machines designed specifically for the task of well installation. There are several drilling methods commonly used today: **auger,** cable tool, rotary or hammer rigs, and vibratory drilling.

Auger

Augers are used to construct wells in unconsolidated formations. There are three principal types of augers used for well drilling: **bucket augers, solid-stem augers, and hollow-stem augers**. The bucket auger has the largest diameter of the three types of augers, and is the most frequently used augering technique for water supply wells in Ohio. The bucket is cylindrical with hardened teeth on the bottom and has a diameter of 18" to 48". The bucket can remove 24" to 48" of material at a time. Wells drilled with a bucket auger normally range in depth from 25 to 150 feet, but in some areas they can reach 250 feet in depth (Mehmert, 2007). In Ohio, older bucket-augered wells may be cased with concrete pipe, vitrified tile, fiberglass or thermoplastic casing, and in many respects will resemble a dug well. Solid-stem and hollow-stem augers are typically used in the installation of monitoring wells.

Solid-stem augers consist of spiral flanges welded to a pipe. One length of pipe (or auger section) is called a flight; multiple auger sections are often referred to as continuous flighting. The leading auger flight has a special bit or cutter head attached that cuts a hole for the flights to follow. Flights are added as the hole is drilled deeper. **Cuttings** from the drilling process are brought to the surface by the action of the augers (Driscoll, 1986). Boreholes constructed with **solid stem augers** are typically used for geotechnical, or, less commonly, environmental purposes, rather than water supply wells.

Hollow-stem augers are similar to solid stem augers in design, except that **drill rods** can pass through the auger sections. The leading drill rod has a pilot assembly attached to drill slightly ahead of the lead auger flight (see Figure 5). The outside diameter of these augers can range from 4 1/4" to 18", with corresponding inside diameters of 2 1\4" to 12 1/4". Because the

flights are hollow, they can be used as temporary casing to hold the hole open while the permanent casing is installed or to collect soil samples before the casing is installed. As the well is being installed, the augers are removed. Wells drilled with hollow stem augers have been used to construct water supply wells, but they are more often used to construct monitoring wells.

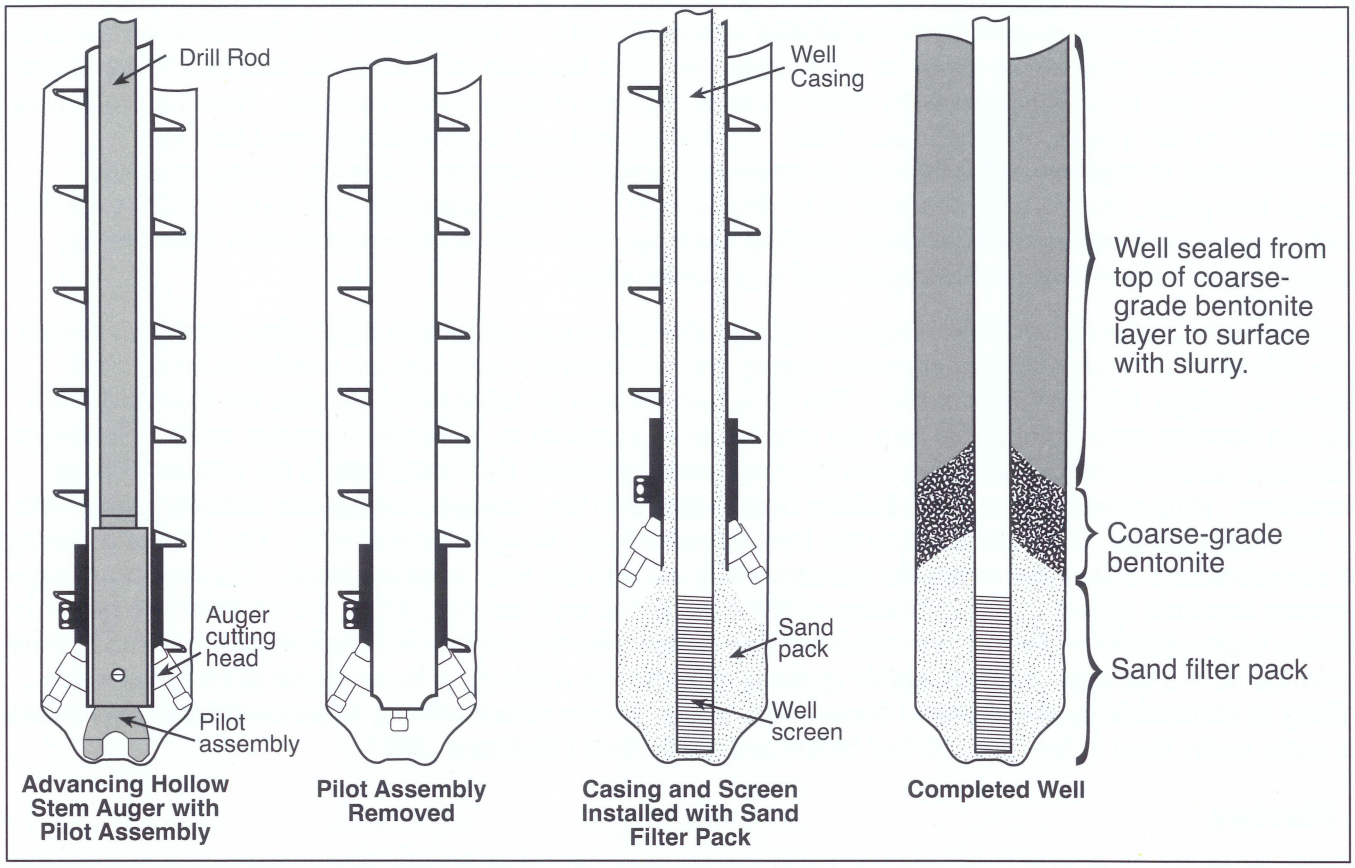

Figure 5. Well construction using hollow stem augers. (Modified from Hackett, 1987)

Cable Tool

Cable tool rigs operate by repeatedly lifting and dropping a string of **drill tools** into the hole. The **drill bit** at the bottom of the drill tools breaks or crushes the formation and when this material is mixed with water, it forms a slurry. When the penetration rate becomes unacceptable, the bit and tools are pulled from the hole and the slurry is removed by **bailing**. In unconsolidated formations, casing is driven into the hole behind the drill bit so that the hole will stay open. When the desired depth has been reached, the casing can be pulled back to expose a screen, if one is to be installed. Otherwise, the casing is driven until a solid rock formation is encountered, and the casing is set a few feet into the bedrock. In some situations an outer casing may have been used. (see Figure 6 for diagrams of properly constructed, cable tool-drilled wells).

Rotary

Rotary rigs use one of two methods to rotate the drill bit: a table drive or top head drive. The rotation of the table or top head is transferred to the drill rods, which in turn rotate the bit. Mud rotary rigs use a roller cone bit at the end of the drill rods. The drill cuttings are circulated out of the hole with water or **drilling mud**. When the appropriate depth has been reached, the drill rods are withdrawn from the hole. The casing and screen (if needed) can then be set in the open borehole. Since it is necessary to drill an oversized borehole with this type of drilling method, the diameter of the borehole will be at least three inches greater

than the outside diameter of the well casing. The annular space is sealed to prevent contamination from the surface, and to hold the casing in place in the borehole.

Air rotary drilling rigs operate in basically the same way as mud rotary. However, instead of using drilling mud to clean the cuttings out of the borehole, a combination of compressed air and water is used. Air rotary rigs also run roller cone bits, but, in addition, they have the capability to run a down-the-hole hammer. The down-the-hole hammer is used for **consolidated** formations only. Compressed air is forced down the drill rods to operate the piston-like action of the hammer bit. The hammer pulverizes the material being drilled through. The air, in combination with water or foam, lifts the cuttings out of the hole. Hole sizes can range from 4 1/8" to 30" (Ingersoll-Rand Co., 1988). Usually a well will be drilled with mud through unconsolidated formations to the bedrock formation, if that is the aquifer. After the casing is set and grouted into place, the well can continue to be drilled with a combination of air and water until the desired depth is reached. Both methods of rotary drilling are frequently used in Ohio to construct water supply wells. Figure 7 shows a typical rotary-drilled well construction.

Another method of rotary drilling is reverse rotary. Reverse rotary drilling is most often used to construct large diameter (24 inches or greater) water supply wells. Reverse rotary rigs are similar to air or mud rotaries in design, but are larger in size. The bit is only rotated by **table drive** because the top head drive does not develop enough torque to turn the size of the bit required to drill large diameter wells. The major difference between the reverse rotary and the other rotary methods described here is the pattern of fluid circulation. With reverse rotary, the drilling fluid is added to the borehole through the annular space, then the fluid and cuttings are removed from the hole by suction up through the drill rods. The fluid and cuttings are deposited into a mud pit, where the cuttings settle out and the fluid is recirculated. The resulting large-diameter borehole allows easy installation of **filter pack** and well screens, which are necessary to properly develop high capacity wells in unconsolidated formations. Reverse rotary drilling can also be used in most consolidated formations. A considerable quantity of make-up water must be available at all times when drilling in permeable sand and gravel formations. Also, reverse rotary drilling is not commonly used when the static water level is less than 10 feet below ground surface (Mehmert, 2007).

Vibratory

Vibratory drilling (referred to as sonic or rotosonic drilling) involves the use of a resonance source through the drill rods to advance a core barrel to the desired depth. In overburden, the vibratory action causes the surrounding soil particles to fluidize, thereby allowing effortless penetration. In rock, the drill bit causes fractures at the rock face, creating rock dust and small rock particles, which facilitates advancement of the drill bit. In many instances the drilling and coring of rock and earth can be accomplished without the use of any drilling fluid. The resonance through the rods pushes the cuttings into the side wall of the hole and into the center of the core barrel. Once the core barrel has been advanced, casing can then be advanced down to the depth of the core barrel. The core barrel is retrieved and the sample is removed. After the core is removed, the core barrel is re-inserted into the well and advanced ahead of the casing. This drilling method allows the borehole to be cased after the coring tool has been advanced to the next sample interval. This method produces a minimal amount of cuttings, uses no drilling mud, and can produce a continuous core. Drilling in dense bedrock formations could be difficult.

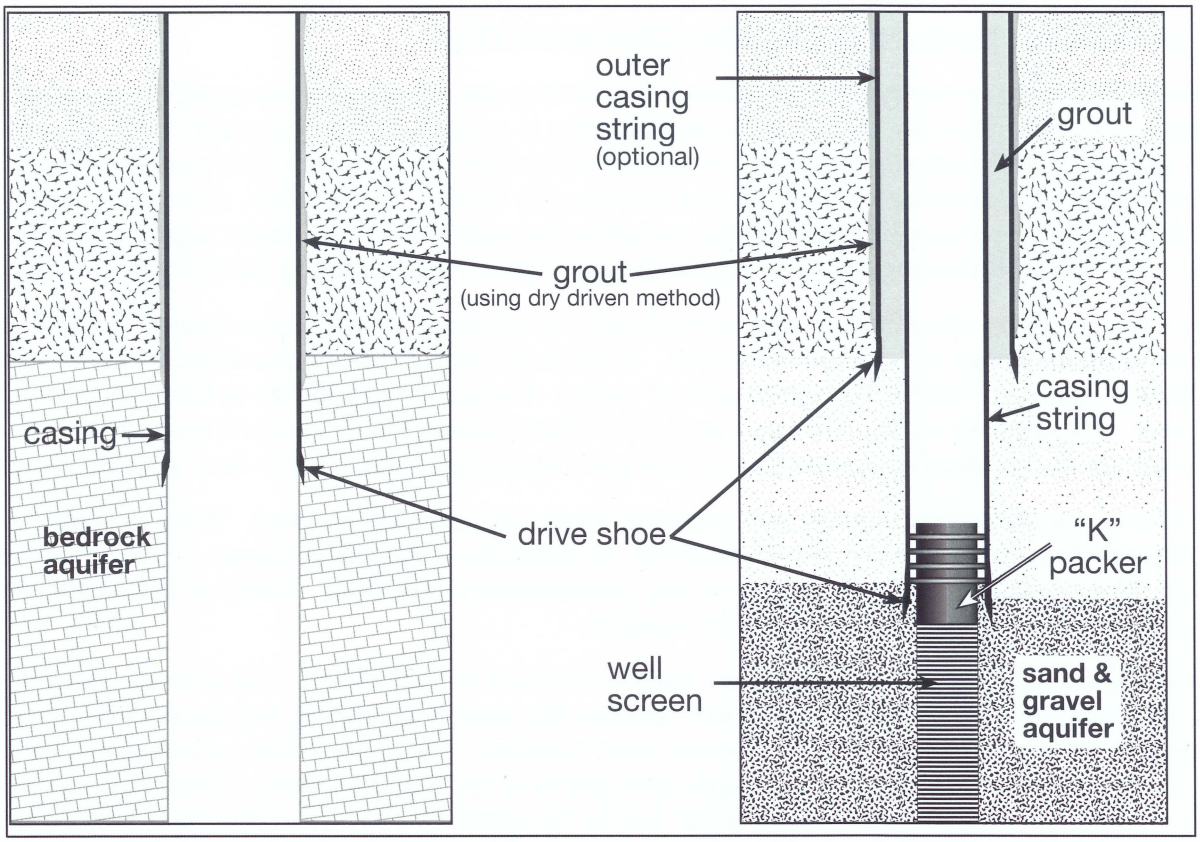

Figure 6. Cable tool-drilled wells showing water well completion in bedrock (left) and in sand and gravel (right).

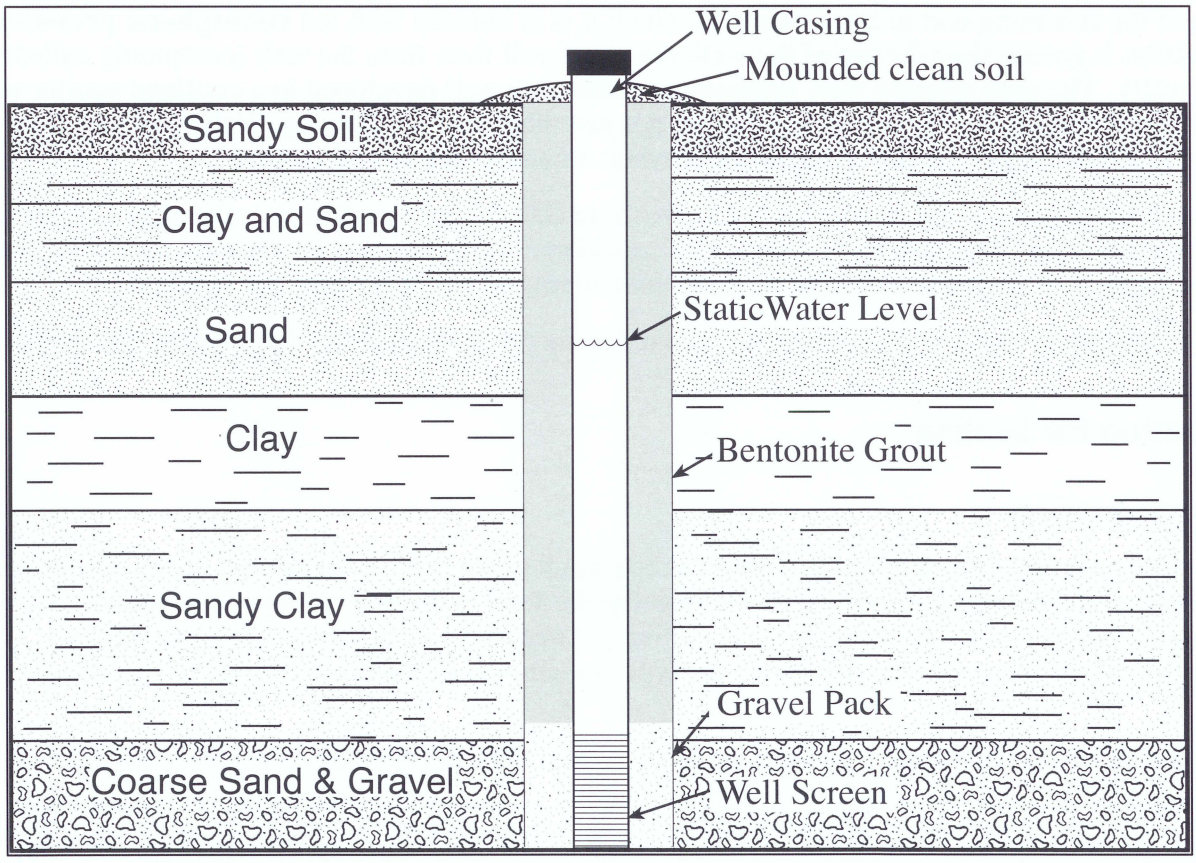

Figure 7. Rotary-drilled well with screen, developed in a sand and gravel aquifer.

Types of Wells as Defined by Aquifer Characteristics

Wells can be described by the types of aquifers in which they are developed. An aquifer is a geologic formation, group of formations, or part of a formation that is capable of yielding water to a well or spring. Figure 8 shows the distribution statewide of expected well yields from aquifers (this map is very general and should not be used to determine well yields on a site-specific basis). These yields, of course, are directly related to the types of geologic formations that comprise the aquifers. For example, aquifers that consist of shales, or interbedded limestone and shale, typically yield less than five gallons per minute to a well.

Geologic formations are classified as either consolidated or unconsolidated. Consolidated formations are those that are lithified, that is, hardened into rock. A borehole penetrating a consolidated formation would be able to stay open indefinitely without benefit of casing. Consolidated aquifers in Ohio generally consist of sandstone, limestone, or shale. The most productive consolidated aquifer is cavernous limestone. Sealing wells set in fractured and cavernous rock present special problems due to loss of **grout** material.

Unconsolidated formations are usually soft and loose (there are some exceptions). Wells penetrating unconsolidated formations must be cased, otherwise the borehole walls will collapse. Unconsolidated aquifers in Ohio consist of silt, sand, gravel, or any combination of the three. Many of the state's most prolific wells are developed in sand and gravel aquifers.

Consolidated and unconsolidated aquifers can also be confined or unconfined. Unconfined aquifers are aquifers in which there are no **confining layers** between the zone of saturation and the surface (see Figure 9 for example). They are often referred to as water table aquifers. The upper surface of an unconfined aquifer is in direct contact with the atmosphere through open **pores** of the material above. Therefore, the static level in a well penetrating an unconfined aquifer will be the same as the level of the water table. Confined aquifers are overlain by a confining bed (see Figure 9 also). The confining bed has a significantly lower **permeability** than the aquifer. When a confined aquifer is penetrated by a well, the water will rise above the base of the confining unit to an elevation at which it is in balance with the **atmospheric pressure**. If this elevation is greater than the top of the well, the water will flow from the well (commonly called an artesian well). The term artesian well, however, includes any well developed in a confined aquifer where the water level rises above the top of the aquifer, not just those that are flowing. Wells completed in confined aquifers can present special challenges when it comes time to seal them.

Wells screened across several aquifers will require more care in sealing. Wells screened in a single aquifer but penetrating several aquifers will need careful consideration in choosing an appropriate sealing method. These wells must be sealed in a manner that prevents mixing of water between the aquifers.

These scenarios and others will be addressed in the section titled **Procedures for Sealing the Well**.

Preparation for Sealing

Well Information

Information concerning the geology and physical condition of the well, such as total depth, formations encountered, and diameter is important in determining the sealing method. Geologic conditions vary throughout the state and different methods of sealing are needed to meet these varying conditions. Well construction details are needed to determine the type and amount of materials needed to seal the well.

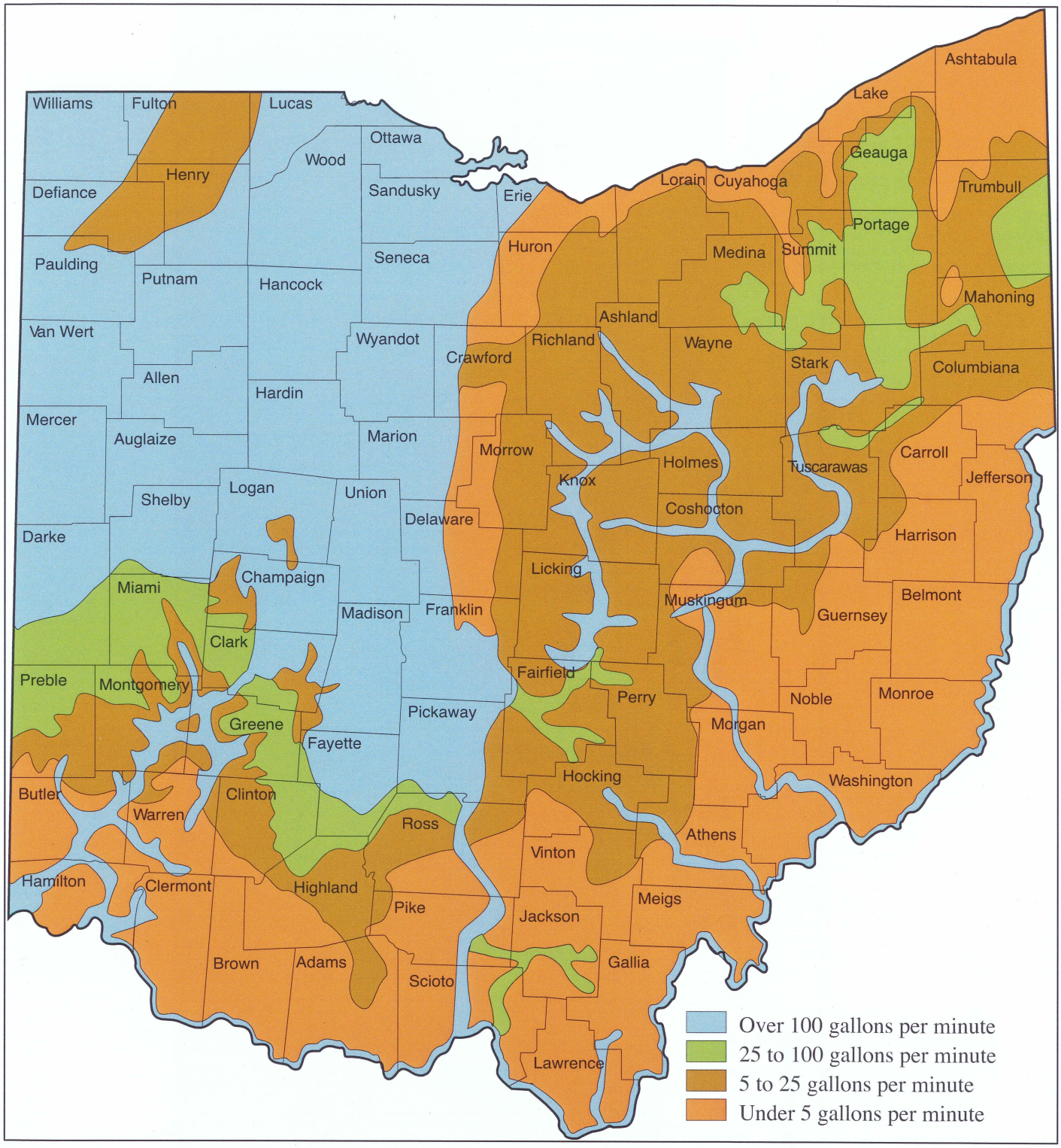

Figure 8. Generalized map of water well yields in Ohio.

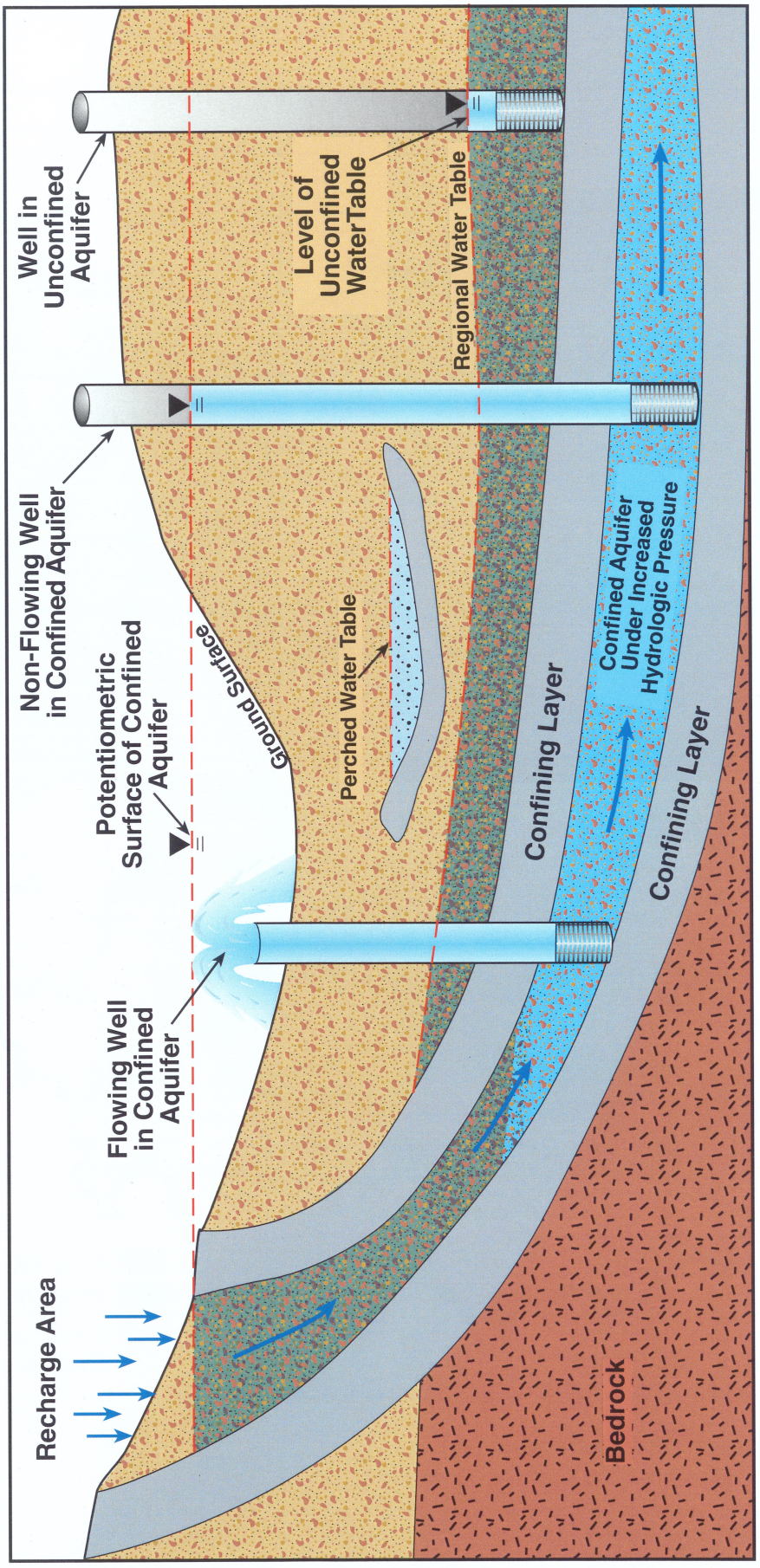

Figure 9. Confined and unconfined aquifers. (After U. S. Department of the Interior, 1977)

The best source of information is the `**Well Log and Drilling Report**' that was completed by the driller at the time of construction. These reports contain well construction information and a record of formations encountered during well installation. Figure 10 is an example of a well log and drilling report. An accurate well log and drilling report will enable a drilling contractor to select the most appropriate sealing method for that well. These reports have been filed since 1947 with the Ohio Department of Natural Resources, Division of Soil and Water Resources and, within the last 25-30 years, with each local health district. Copies of public water supply well records may be kept at the appropriate Ohio EPA District Office. To obtain a copy of a well log and drilling report, it is necessary to know the county in which the well was drilled, the township within that county, the street address, the name of the property owner at the time the well was drilled, and the approximate year in which the well was drilled. The water well record database can be searched on-line at http://soilwater.ohiodnr.gov/search-file-well-logs or a Division of Soil and Water Resources employee can do a file search with the information that is available. Occasionally, a well log and drilling report may not be on file, either because the well was drilled before the filing law went into effect (1947) or because, for some reason, the log was not sent to the Division. To have the Division of Soil and Water Resources search for a specific well log and drilling report, call 614-265-6740 or e-mail at dswc@dnr.state.oh.us.

Logs for nearby wells should be reviewed if a well log and drilling report cannot be located. Often, wells on adjacent properties will be of similar depth and construction. Review of well logs may indicate one of several conditions that may require special sealing techniques. These conditions may include:

- **karst** and **paleokarst,**
- flowing or **artesian** conditions, and
- underground mine shafts or rooms.

These conditions may necessitate changing the method selected for dealing with the casing, revising plans for grout selection and selecting different equipment. Review of information available about the local aquifer or aquifers may be needed. Potential sources of information regarding geologic and ground water conditions, siting restrictions and water and waste water infrastructure locations are included in Table 2.

Table 2. Sources of information available during a pre-design review*.

Area of Concern	Potential Sources of Information
Karst geology	ODNR-DGS, ODNR-DSWR
Coarse sand and gravel deposits	ODNR-DGS, ODNR-DSWR, USGS-OWSC
Flowing or artesian conditions	ODNR-DSWR, USGS-OWSC
Ground water contamination	Ohio EPA-DDAGW; Ohio EPA-DERR; BUSTR
Other local ground water conditions	ODNR-DGS, ODNR-DSWR, Ohio EPA-DDAGW, USGS-OWSC, Local health districts and departments
Active and abandoned underground mines	ODNR-DMRM
Mining activity	ODNR-DMRM

*A list of the abbreviations used in this table can be found in Appendix 4.

If a well is free of obstructions (including old pumps), then the total depth and depth to water may be easily determined with a weighted measuring tape or rope. Local drilling contractors will also be familiar with the general geologic conditions in the area.

DNR 7802.05e

WELL LOG AND DRILLING REPORT

Ohio Department of Natural Resources
Division of Water, 2045 Morse Road, Columbus, Ohio 43229-6605
Voice (614) 265-6740 Fax (614) 265-6767

Well Log Number: 0

Page 1 of 1 for this record.

WELL LOCATION

County: STARK Township: JACKSON

R. D. RUNNER
Owner/Builder

12345 RINGS ROAD
Address of Well Location

City: CANTON Zip Code +4: 44718

Permit No.: N/A Section: 27 and/or Lot No.:

Use of Well: AGRIC/IRRIG

Coordinates of Well (Use only one of the below coordinate systems)

State Plane Coordinates

N ☐ X: +/- ft.

S ☐ Y: +/- ft.

Latitude, Longitude Coordinates

Latitude: 40.81234 Longitude: -81.41234

Elevation of Well in feet: 1107 +/- ft.

Datum Plane: ☐ NAD27 ☑ NAD83 Elevation Source: GPS

Source of Coordinates: GPS

Well location written description:

Comments on water quality/quantity and well construction:

HARDNESS: 10 GPG
IRON: 2 PPM
PH 7.8
TDS: 319 PPM

WELL TEST *

Pre-Pumping Static Level: 27.0 ft. Date: 02/18/2013

Measured from: GROUND LEVEL

Pumping test method: AIR

Test Rate: 20 gpm Duration of Test: 0.5 hrs.

Feet of Drawdown: 40.0 ft. Sustainable Yield: 20 gpm

*(Attach a copy of the pumping test record, per section 1521.05, ORC)

Is Copy Attached? ☐ Yes ☑ No Flowing Well? ☐ Yes ☑ No

PUMP/PITLESS

Type of pump: SUBMERSIBLE Capacity: 10 gpm

Pump set at: 140 ft. Pitless Type: AQUA SEAL

Pump installed by: ACME DRILLING COMPANY

I hereby certify the information given is accurate and correct to the best of my knowledge.

Drilling Firm: ACME DRILLING COMPANY

Address: 1234 MAIN ST.

City, State, Zip: SOCKERDOWN, OH 56789

Signed: W. E. COYOTE Date: 02/26/2013

(Filed electronically by ID #)

ODH Registration Number: 3456

CONSTRUCTION DETAILS

Drilling Method: ROTARY

BOREHOLE/CASING (Measured from ground surface)

1 Borehole Diameter: 9.000 inches Depth: 84.0 ft.
Casing Diameter: 5.000 in. Length: 85 ft. Thickness: 0.2650 in.

2 Borehole Diameter: 5.000 inches Depth: 175.0 ft.
Casing Diameter: in. Length: ft. Thickness: in.

Casing Height Above Ground: 1.0 ft.

Type 1: PVC
Type 2:

Joints 1: O-RING
Joints 2:

SCREEN

Diameter: in. Slot Size: in. Screen Length: ft.

Type: Material:

Set Between: ft. and: ft.

GRAVEL PACK (Filter Pack)

Material/Size: Vol/Wt. Used:

Method of Installation:

Depth: Placed From: ft. To: ft.

GROUT

Material: Bentonite/polymer slurry Vol/Wt. Used: 600 lbs./275 gallons

Method of Installation: Pumped w/tremie pipe

Depth: Placed From: 84.0 ft. To: 0.0 ft.

DRILLING LOG*

FORMATIONS INCLUDE DEPTH(S) AT WHICH WATER IS ENCOUNTERED.

Color	Texture	Formation	From	To
BROWN		SANDGRAVELBOULDERS	0.0	20.0
GRAY		SANDGRAVELBOULDERS	20.0	51.0
GRAY		SAND AND GRAVEL	51.0	78.0
GRAY		SHALE	78.0	82.0
GRAY		SANDSTONE	82.0	107.0
GRAY	SANDY	SANDSTONE AND SHALE	107.0	140.0
GRAY		SANDSTONE	140.0	175.0
		WATER AT	100.0	107.0
		WATER AT	140.0	175.0

Aquifer Type (Formation producing the most water.): SANDSTONE

Date of Well Completion: 02/23/2013 Total Depth of Well: 175.0 ft.

Completion of this form is required by section 1521.05, Ohio Revised Code - file within 30 days after completion of drilling.
Distribute copies of this record to Customer and Local Health Department.

Figure 10. Example of an official Ohio well log and drilling report form.

Well Inspection

Well casing is usually constructed of polyvinyl chloride (PVC) plastic or steel (in drilled wells), or concrete pipe, vitrified tile, brick, or cobbles (in dug wells). Although concrete pipe, vitrified tile, brick, and cobbles are not approved casing materials for private water systems, older wells were constructed with these materials. The length and the condition of the casing should be examined. A determination should be made if a **well screen** was used in the well and if so, the approximate depth. In many older wells, it was common practice to cut slots with a torch in the bottom two or three feet of casing to produce a home-made screen. These types of "screens" are highly inefficient and susceptible to corrosion and plugging. If there is no well log or other information about the construction of the well, or if the well casing is in poor condition, removing the casing may damage the aquifer or confining layer.

Methods for examining the condition of a well include borehole video cameras, casing-depth indicators, and geophysical logging equipment such as calipers and gamma-ray probes. These tools are commonly used in the maintenance of public supply wells and in scientific investigations. Geophysical logging equipment such as calipers and gamma-ray probes are expensive and most wells will not need such detailed investigations. If necessary, local drilling contractors should be able to locate firms possessing this equipment.

Water Quality

The existing water quality is important to know so that the most appropriate material is used to seal the well. Sulfates, pH, iron, chlorides, and calcium concentrations are important to know when determining which grout to use. These factors are discussed in the Sealing Materials section.

Access to Well

Accessibility of the well is important in determining how the well can be sealed. Access to the well and well site will be important if drill rigs or pump hoist vehicles are to be used in preparing for sealing the well.

Past Land Uses

Prior to sealing a well there should be a review of information about the property, surrounding properties and past land uses. The review will help identify local conditions that may dictate the methods used to seal the well. These conditions may include:

- contaminated ground water,
- underground mine shafts or rooms, or
- areas previously used for surface mining.

These conditions may necessitate changing the method selected for dealing with the casing, revising plans for grout selection and selecting different equipment. This should include a review of public records to identify contaminated zones in soil and ground water, past practices and other hazards that may complicate the process of sealing the well. Potential sources of information regarding geologic and ground water conditions, siting restrictions and water and waste water infrastructure locations are included in Table 2.

Procedure Planning

No single method and material are suitable for all situations and site-specific conditions may require modifications to normal operations. To ensure that the well owner and driller are prepared, a work plan summarizing what is known about the well and the details for sealing it should be prepared prior to sealing a well.

The plan should include:

- the reason for sealing the well,
- copies of any permits required for well sealing or site access,
- a summary of information concerning the physical condition of the well, including the results of any well inspections,
- information about special requirements for accessing the well,
- information about local water quality, special environmental and geologic conditions,
- the method(s) and materials for sealing the well,
- an estimate of the volume of sealing material needed (for more on calculating the volume of the void being sealed see Table 8),
- special equipment requirements including an estimate of the amount of water that may need to be brought to the site,
- the final site restoration requirements, and
- a health and safety plan.

Sealing Materials

There are a variety of materials that can be used for well sealing including grouts, clay, and other inert materials. Grout materials used for sealing abandoned water wells must have certain properties to make them desirable for use.

The ideal grout should:

- be of low permeability to resist flow of water,
- be capable of bonding to both the well casing (if present) and borehole wall to provide a tight seal,
- be chemically inert or nonreactive with formation materials or constituents of the ground water with which the grout may come in contact,
- be readily available at a reasonable cost, and
- be safe to handle.

For pumpable grouts, the grout should:

- be easily mixed,
- be of a consistency that will allow the grout to be pumped and remain in a pumpable state for an adequate period of time,
- be capable of placement into the well through a 1-inch diameter pipe,
- be self-leveling in the well,
- have minimal penetration into permeable zones, and
- be capable of being easily cleaned from mixing and pumping equipment.

Pourable grouts should be easy to place by gravity through standing water.

Grout materials currently approved for use in water wells are comprised of either **cement**, **concrete**, **bentonite**, and /or bentonite-cement mixtures. Table 3 lists advantages and disadvantages of cement and bentonite grouts.

The permeability of the grout should be no greater than 1×10^{-7} centimeters per second to retard fluid movement and adequately seal a well or borehole.

Cement–Based Grouts

Cement Properties

All cement placed into the wellbore should be Portland cement that is manufactured to meet the standards of API "10 A Specification for Cements and Materials for Well Cementing" or ASTM "C150/C150M Standard Specification for Portland Cement". Portland cement is the main ingredient in cement-based grouts such as neat cement or concrete. Cement is a mixture of lime, iron, silica, alumina, and magnesia. The raw materials are combined and heated to produce cement clinker. The clinker is ground up and mixed with a small amount of gypsum or anhydrite to control setting time.

When Portland cement is mixed with water (producing neat cement), several chemical reactions occur. Heat is generated as the mixture cures and changes from a slurry to a solid. This is referred to as the heat of hydration and results in a temperature increase at the cement's interface with the formation or the well casing, if any remains in the hole (Troxell et al., 1968; Portland Cement Association, 1979). The amount of heat given off is dependent upon several factors such as cement composition, cement additives, and surrounding temperatures. Excessive heat of hydration may adversely affect the structural properties of PVC well casing left in the borehole (Molz and Kurt, 1979; Johnson et al., 1980).

The setting of cement is controlled by temperature, pressure, water loss, water quality, and other factors (Smith, 1976). Warm water used for slurry preparation and warmer air temperature will cause faster setting than cold water and cooler air temperature. Cement in the borehole will tend to set faster at the bottom since the weight of the cement column will increase hydrostatic pressure on the cement at the bottom. Water expelled from the cement into permeable zones will also result in an increased rate of setting. Standard Portland cement will reach its initial set in about 4 hours at a 50^{o}F curing temperature. Table 4 shows the total curing times for various cement grouts.

Table 3. Grout Properties for Sealing

	ADVANTAGES	DISADVANTAGES
Cement-based Grouts	Suitable permeability	Shrinkage & settling
	Easily mixed & pumped	Long curing time
	Hard-positive seal	High fluid loss to formation
	Supports casing	Heat of hydration
	Suitable for most formations	Can be affected by water quality
	Proven effective over decades of field use	Equipment clean-up essential
	Properties can be altered with additives	
Bentonite-based Grouts	Suitable permeability with high solids grouts	Less working time
	Non-shrinking & self-healing	Subject to wash out in moving water (voids)
	No heat of hydration	Subject to failure from contaminated/poor quality water
	Low density	Low structural strength
	Less setting time than cement	
	Ease of placement	
Cement-Bentonite Grouts	Suitable permeability	Shrinkage and settling
	Easily mixed and pumped	Long curing time
	Hard positive seal	Low compressive strength
	Suitable for most formations	
	Low heat of hydration	
	Lower density reduces shrinkage and settling	

Cement Types

Several types of cement are manufactured to accommodate various chemical and physical conditions which may be encountered. ASTM Specification C150 is the standard used by cement manufacturers. The different types of cement and their appropriate uses are described in Table 4.

Table 4. Grout uses, curing times and mix ratios *

Sealant Type	Use	Curing Time (hrs)	Mix Ratios
Cement Type I	General purpose cement suitable where special properties are not required.	24	94 lbs cement, 5.2 gallons of water. **
Cement Type II	Moderate sulfate resistance. Lower heat of hydration than Type I. Recommended for use where sulfate levels in ground water are between 150 and 1500 parts per million (ppm).	24	94 lbs cement, 5.2 gallons of water. **
Cement Type III	High-early-strength. Ground to finer particle size which increases surface area and provides faster curing rate (approximately 1/4 of the time it takes for Type I to cure).	12	94 lbs cement, 6.3 to 7 gallons of water. **
Cement Type IV	Low heat of hydration cement designed for applications where the rate and amount of heat generated by the cement must be kept to a minimum. Develops strength at a slower rate than Type I.	24	94 lbs cement, 5.2 gallons of water. **
Cement Type V	Sulfate-resistant cement for use where ground water has a high sulfate content. Recommended for use where sulfate levels in ground water exceed 1500 ppm.	24	94 lbs cement, 5.2 gallons of water. **
Cement/Bentonite Mix	Suitable for sealing where a hard positive seal and low heat of hydration are required.	24-36	94 lbs. Cement: 50 lbs Bentonite Grout: 31 Gal. water
Bentonite	Suitable for general purpose sealing. Easily placed where low density and low heat of hydration are required.	2-4	50 lbs Bentonite Grout: 27 Gal. water**
Bentonite chips	Suitable for general purpose sealing where a hard positive seal and a low heat of hydration are required. Used where accessibility for placement allows.	1***	n/a not mixed
Bentonite pellets	Suitable for general purpose sealing where a hard positive seal and a low heat of hydration are required. Used where accessibility for placement allows.	1***	n/a not mixed

* Typical 20% high solids bentonite grout mix ratio shown; see manufacturers' recommendations for exact mixing ratios.

** Based on American Petroleum Institute (API) and Portland Cement Association recommendations

*** If an adequate amount of water for hydration is present

Neat Cement Grout

Neat cement slurry is comprised of Portland cement and fresh water, with no aggregate present. Field experience has shown it to be effective for sealing off formations when properly placed. It can be mixed using a wide variety of methods. Generally, lower pressures are developed while pumping neat cement grouts. The main disadvantages with neat cement are shrinkage upon curing, possible formation of a **microannulus** around the casing, and, in some cases, mixing according to manufacturer's specifications, which can result in a thick mixture that is difficult to pump. Neat cement should not be used when the borehole diameter or annular space exceeds 6 inches.

The amount of shrinkage or settling, and compressive strength, of neat cement are dependent upon the proportion of water to cement in the slurry (Coleman and Corrigan, 1941; Halliburton, 2000). As the water to cement ratio increases, the compressive strength of the neat cement will decrease and shrinkage will increase. Laboratory studies and field experience have demonstrated that settling of cement particles will occur, resulting in a drop in the grout level (Coleman and Corrigan, 1941; Kurt, 1983). The top of the hardened neat cement grout mass will generally be a few feet below the slurry level due to this settling. Field observations show that the amount of settling will usually be 5 to 10 percent of the total grouted depth if the neat cement is mixed at 5 to 6 gallons of water per sack. Table 4 shows the curing times for various cement grouts.

At weights greater than 16 lbs./gal, pumping of the slurry becomes difficult due to higher **viscosity** and pumping pressure. **Density** measurements of the slurry using a **mud balance** are recommended to assure proper water-to-cement ratios.

Under certain conditions it may be necessary for a consulting engineer or the regulatory agency to specify an increase in the water-to-cement ratio. There are also numerous specialized commercial cement products available such as expanding, self-healing cements. Factors such as the cement type, addition of additives, and quality of ground water will affect the cement performance and should be considered when planning the grouting operation. Any variations from these required mix ratios should be discussed with the regulatory agency.

Concrete Grout

Concrete grout for sealing wells and boreholes consists of Portland cement, sand, and water. The proper mix ratio is 94 pounds of cement mixed with an equal amount of sand, with no more than 6 gallons of water to result in a density of 17.5 pounds per gallon. The addition of sand to a neat cement slurry results in less shrinkage and tighter bonding to the casing and borehole. The sand in the slurry will also aid in bridging pores in permeable formations. Sand particles range in size from 0.0625 mm (or 1⁄16 mm) to 2 mm in diameter. In the United States, sand is commonly divided into five sub-categories based on size: very fine sand (1⁄16 – 1⁄8 mm diameter), fine sand (1⁄8 mm – 1⁄4 mm), medium sand (1⁄4 mm – 1⁄2 mm), coarse sand (1⁄2 mm – 1 mm), and very coarse sand (1 mm – 2 mm). To help improve the flow of the concrete into small fractures and gaps in wells and boreholes, the use of finer, more uniform sand should be considered to be mixed into concrete. Concrete grout should be used only under specific sealing circumstances, such as when the borehole or annular space diameter is greater than 6 inches, for sealing flowing wells, sealing water wells with natural gas or methane present, and sealing wells with cavernous zones. Concrete should be handled only by experienced registered drilling contractors due to the exacting requirements for its successful installation. It is advisable to consult with the appropriate regulatory agency to make sure the use of concrete is appropriate or allowed.

In most cases concrete grout should be pumped down a tremie pipe when water is present in the borehole. Placing concrete grout through greater than a few feet of water will cause separation of the slurry – the sand may drop out of suspension - which may result in placement problems. If concrete grout is used on a

routine basis, it should be pumped through a metallic grout pipe because it is highly abrasive to plastic pipe. The sand in the concrete slurry can also cause excessive pump wear. Concrete grouts may be placed by gravity where minimal water is present in the borehole and the diameter is larger than 4 inches.

Commercially Packaged Concrete Sack Mixes

Commercially packaged concrete sack mixes such as "Quikrete®" or "Sakrete®" may be used in some limited situations for small jobs such as shallow, dry boreholes. There are many commercially packaged concrete products available and the choices for sealing should be carefully evaluated based on design characteristics of the specific products. Many of these already meet ASTM Standard C150. They must also meet any of the other appropriate ASTM standards the job may require.

When using commercially packaged concrete sack mixes only prepare the amount of material able to be used within a 15 minute period. Since these products tend to set or harden quickly, mixing more than can be placed into the borehole within this period will complicate proper grout placement. The concrete needs to be fluid enough to properly seal the entire borehole. Commercially packaged cement or concrete products should be mixed with the proper amount of water prior to placement. Dry packaged cement or concrete products should never be placed into a well or borehole and then hydrated in the hole. One 50 pound sack of commercially packaged concrete will only fill about 2.5 feet in a 6 inch borehole.

Cement Additives

There are hundreds of additive products available for a wide variety of cement and concrete applications. The suitability of an additive for sealing a well or borehole should be evaluated based on the requirements of the individual job. Some additives are typically used in combination with other additives, while some should not be used together. Always review the product use labels thoroughly for compatibility.

Admixtures are classified according to function. There are five distinct classes of admixtures: air-entraining, water-reducing, retarding, accelerating, and plasticizers or super-plasticizers (Portland Cement Association, 2014). Super-plasticizers are also known as high-range water reducers. All other varieties of admixtures fall into the specialty category whose functions include corrosion inhibition, shrinkage reduction, alkali-silica reactivity reduction, workability enhancement, bonding, damp proofing, and coloring. (Portland Cement Association, 2014). ASTM Standard C494 specifies the requirements for seven chemical admixture types.

- Type A: Water-reducing admixtures
- Type B: Retarding admixtures
- Type C: Accelerating admixtures
- Type D: Water-reducing and retarding admixtures
- Type E: Water-reducing and accelerating admixtures
- Type F: Water-reducing, high range admixtures
- Type G: Water-reducing, high range, and retarding admixtures

ASTM Standard C494-98 does not currently contain specifications for shrinkage-reducing and mid-range water reducing admixtures.

Accelerators may be added to cement to decrease its setting time when attempting to stop flows in and around casings. These admixtures allow the cement to set before it is washed out of the hole. Calcium chloride is the most common and readily available accelerator. It is generally used at between 2 and 4 percent by weight of cement. Accelerators should be used with caution since miscalculations or equipment breakdown can result in a cemented grout pump or hose. Other additives such as set-retarders, weight-reducing agents, weighting agents including barite and hematite, circulation-loss control agents, and water-reducing agents are available for cements and may be used for water well sealing when conditions warrant.

Cement shrinkage can be complex and happens in a variety of ways including plastic shrinkage, thermal shrinkage, autogenous shrinkage, and drying shrinkage. Specific admixtures to control shrinkage typically affect only the specific types of shrinkage they are designed for. High-range water reducers reduce water content by 12 to 30 percent and can be added to concrete with a low-to-normal slump and water-cement ratio to make high-slump flowing concrete. Adding bentonite to a cement mixture increases the amount of water that can be absorbed by the mixture. This both lowers the density and increases the mass of the mixture. The lower density reduces the slurry loss to the formation which in turn reduces shrinkage and settling. The increased mass lowers the heat of hydration. The addition of bentonite increases the set time and decreases the strength of the cement while improving the pumpability of the mixture. This allows for easier placement and increased flexibility when compared to neat cement.

Table 5. Examples of cement and concrete additives

Admixture Class	Examples of Admixture Compound	Function	Potential Issues
Accelerator	- Calcium chloride - Calcium nitrate - Sodium nitrate	Decrease setting time, 2 and 4 percent by weight of cement. Useful for modifying the properties of concrete in cold weather.	Miscalculations can result in rapid setting that may damage equipment.
Retarder	-Sucrose -Sodium gluconate -Glucose -Citric acid -Tartaric acid -Sodium citrate	Cement setting times can be more controlled and adjusted accordingly.	High concentrations may decrease the effectiveness of cellulose-based fluid-loss additives (Halliburton, 2014).
Water-reducing admixture **aka Plasticizers.**	Lignosulfonate Sugars/Sugar Acids (molasses, corn syrup, and gluconate) -Melamine Sulfonate Formaldehyde Condensate (MSFC) -Naphthalene Sulfonate Formaldehyde Condensate (NSFC) -Polycarboxylate Ether	-Reduces the required water content for a concrete mixture by about 5 to 10 percent. -Higher strength concrete can be produced without increasing the amount of cement. -More stable over a wider range of temperatures	Limited setting times depending on the product and dosage rate, followed by a rapid loss in workability.
Plasticizer and Super plasticizer aka high-range water reducers	-Lignosulfonate -sulfonated naphthalene formaldehyde condensate, -sulfonated melamine formaldehyde condensate -acetone formaldehyde condensate -Polycarboxylate ethers.	-Reduce water content by 12 to 30 percent and can be added to concrete with a low-to-normal slump and water-cement ratio to make high-slump flowing concrete - Super plasticizers used to increase workability more than is practical with traditional plasticizers.	Limited setting times depending on the product and dosage rate, followed by a rapid loss in workability.

Admixture Class	Examples of Admixture Compound	Function	Potential Issues
Specialty Admixtures:			
Shrinkage-reducing admixtures	-Poly(ethylene glycol-co-propylene glycol monobutyl ether -Oxirane, methyl-, polymer with oxirane, monobutyl ether	Used to control drying shrinkage and minimize cracking.	-Different combinations of cementitious materials, aggregates, water and chemical admixtures can result in concretes with differing amounts of shrinkage. -Admixture is a potentially combustible material.
Alkali-silica reactivity inhibitors	Lithium-based	Control durability problems associated with alkali-silica reactivity due to certain siliceous mineral aggregates that react with soluble alkalis.	Can accelerate the initial setting time of concrete.
Corrosion inhibitors	Non-chloride-containing admixtures	Used as a defensive strategy for concrete structures, such as marine facilities, highway bridges, and parking garages, that will be exposed to high concentrations of chloride.	Possible decrease in compressive strength.
Circulation-loss control agents	Gilsonite (trademark name) Uintaite or uintahite form of natural asphalt mined in underground shafts and resembles shiny black obsidian	Inert plugging particulates which seal off high permeability thief zones or bridge off natural fractures. - Provide higher strength than heavier additives with high water requirements. (Halliburton, 2014)	Can also cause the additive to separate to the top of thin slurries and slurries containing dispersants. Adding 2% or more bentonite to the slurry will help prevent separation. (Halliburton, 2014)
Other Additives			
Weighting agents	Hematite (Fe_2O_3) - most commonly used Ilmenite (FeO TiO_2) Hausmannite (Mn_3O_4) Barite ($BaSO_4$)	Used to increase slurry density for control of highly pressured wells.	Barite is not normally used in cementing as a weighting agent because of its high surface area and high water demand.
Weight-reducing agents	Expanded Perlite	Used to reduce the weight as water is added with its addition. Can be used to achieve a slurry weight as low as 12.0ppg.	Without bentonite the pearlite separates and floats to the upper part of the slurry. Bentonite in concentrations of 2–4% is added to prevent segregation of particles and slurry.

Bentonite-Based Grouts

Sodium bentonite is used for grouting because it expands when wet, absorbing as much as several times its dry mass in water. The property of swelling on contact with water makes sodium bentonite useful as a sealant, since it provides a self-sealing, low permeability barrier to seal off the annulus of a water well, or to plug old wells. Similar uses include making slurry walls, waterproofing of below-grade walls, and forming other impermeable barriers. Calcium bentonite does not absorb as much water as sodium bentonite and provides a lesser-quality sealant.

Other industrial or commercial uses of bentonite include: drilling fluids, decolorizing oils, clarifying wine, liquor and beer, cat litter, dermatologic formulas, pelleting aids, anti-caking agents, flow agents, binders for livestock and poultry feeds, and digestive aids. Only sodium bentonite products specifically designed for use in well sealing should be used when sealing a water well.

Clay Mineral Properties

Clay minerals are the principal ingredient of all bentonite-based grouts and drilling muds. They may be characterized as naturally-occurring substances which exhibit colloidal-like properties (remain in suspension in water for a long period of time) and varying degrees of **plasticity** when wet (Bates, 1969).

The common characteristic associated with clay minerals is the very small particle size that has a very high surface area-to-mass ratio. Negative electrical charges on the particle surface result in the interaction of clays with other particles and water. Hydration occurs with incorporation of the water molecule into and around the lattice structure of the clay mineral, during the shearing process of mixing the water and bentonite. This explains the ability of certain clays to swell many times their original volume when **hydrated**.

The variety of bentonite commonly used in grouting materials and drilling muds is one in which the clay mineral is predominantly sodium-rich montmorillonite. Mined at relatively few locations, the majority of the high-grade sodium bentonite is obtained in Wyoming, Montana, and South Dakota (Gray and Darley, 1981). These clays are characterized by their ability to absorb large quantities of water and swell 10 to 12 times in volume. When placed in water, the bentonite particles tend to remain in suspension for an indefinite period of time. The resulting slurry has a low density and high viscosity. Bentonites that have calcium as the predominant exchangeable ion are less desirable as sealing materials because they have significantly lower swelling ability (Gaber and Fisher, 1988).

Properties of Bentonite Grout

Three important physical properties of a grout are: 1) density, 2) **gel strength**, and 3) viscosity. A review of these properties will aid in understanding what makes a good bentonite grout.

Density is defined as the weight per unit volume of a fluid and is commonly expressed in pounds per gallon. The terms weight and density, although technically distinct, are frequently used interchangeably in the drilling industry. The density of grout determines how much pressure is exerted on the formation when the fluid is at rest and is a direct indicator of the amount of clay solids present. The higher the density, the more solids are suspended in solution. A dense grout is needed to keep a borehole from collapsing. Density is measured using a mud balance. A mud balance measures a specific volume of grout slurry in pounds per gallon. The densities of various sealing materials can be seen in Table 6. It is important to choose a grout that has at least 20% solids and has a permeability less than 1×10^{-7} cm/sec.

A density measurement should be taken before grout placement and a grout sample should also be collected after the grout appears at the surface. To obtain the best seal the grout discharged from the well should have a density equal to that of the grout before it was pumped. Therefore, the grout must be pumped into the well until dilution is minimal. When conducting density tests it is important to make sure air is not trapped within the grout, as this will affect the measurements.

Gel strength is a measure of internal structural strength. It is an indication of a fluid's ability to support suspended particles when the fluid is at rest. Gel strength is caused by the physical alignment of positive and negative charges on the surface of the clay particles in solution. Gel strength is responsible for the quasi-solid (plastic) form of a clay/water mixture. It is not necessary to test the gel strength but it is important to follow the manufactures' recommendations for mixing.

Viscosity is a measure of a fluid's resistance to flow. The higher the viscosity of a fluid, the more difficult it becomes to pump. The viscosity of bentonite-based grouts is dependent upon a number of factors including: 1) the density, 2) the size and shape of the clay particles, and 3) the charge interaction between the particles (Peterson and Rothauge, 2007). It is not necessary to test the viscosity of the grout but is important to follow the manufactures' recommendations for mixing.

The quality of the water in the well and geologic formation must also be considered when using bentonite based grouts. Bentonite grout slurries should not be used for sealing a well or borehole when the total dissolved solids content of the water in the hole exceeds 1,500 milligrams per liter (mg/l) , unless the dissolved iron is less than 15 mg/l, chloride is less than 500 mg/l and calcium is less than 500 mg/l. The presence of highly mineralized water may prevent the full hydration of the bentonite slurry and lead to incomplete sealing of the well or borehole. Coarse grade or pelletized bentonite should not be used as a sealing material when the total dissolved solids content of water in the well or borehole exceeds 1,500 mg/l.

Make-up water for pumpable grouts should have total dissolved solids of less than 1,500 ppm and total hardness of less than 500 ppm. It is important to treat make up water with soda ash to achieve a target pH between 8 and 9, to insure the proper hydration and suspension of the bentonite grout. Soda ash will first tie up the hardness before it affects the pH of the make-up water.

Table 6. Grout Slurry Densities

Product	Water Ratio	Minimum Density lbs/gal	Volume cu. ft./sack (or batch)
Neat Cement	6.0 gal./sack of cement 5.2 gal. recommended/sack of cement	15.0 15.6	1.28 1.18
Neat Cement & CaCl (accelerator)	6.0 gal./sack of cement CaCl - 2 to 4 lbs. sack of cement	15.0	1.28
Concrete Grout	1 sack of cement and an equal volume of sand per 6 gallon water maximum	17.5	2.0
Bentonite 30% WT*	14 gal/50# bag	9.8	2.27
Bentonite 20% WT	24 gal/50# bag	9.3	3.61
Cement/Bentonite mix 41% WT	24 gal/94# bag cement and 50# bag bentonite	11.0	4.14
Cement/Bentonite mix 57% WT	9 gal/94# bag of cement and 5# bentonite	13.8	1.7

*Percentage of product by weight

Bentonite Grout Products

The bentonite-based grouts widely used for sealing can be grouped into four classifications reflecting the degree of processing and the particle size of the bentonite. The four classes are: 1) powdered bentonite, 2) granular bentonite, 3) coarse grade bentonite, and 4) pelletized bentonite. All bentonite grout products should be American National Standards Institute (ANSI) NSF 60 certified. Each class of bentonite requires

a different handling and placement method. Manufacturers recommend that mixing and placement methods should be assessed with regard to ground water quality, the depth to the water table, the required depth of grout placement, and other pertinent geological information.

Bentonite products are designed to be easy to mix, pump, place, and clean up. Some products require the use of chemical additives when mixing to control the development of viscosity and gel strength thus increasing the work time. Difficulties in pumping and placement may be encountered if proper mixing guidelines are not followed or if working times are extended. Generally, bentonite grouts require higher pumping pressures than neat cement grouts (Gaber and Fisher, 1988). It also is important to know the environment into which the bentonite will be placed.

Powdered Bentonite/Clay Grout

Powdered bentonite is commonly used in environmental and geothermal applications. Powdered bentonite/clay products available are similar in texture, appearance, and packaging to the high-yield drilling mud-grade bentonite. Use of feed-grade bentonite is not allowed. Powdered bentonite grouts are finely ground single bag, single step grouts designed to have adequate work time to allow placement and to achieve a flexible, low permeability seal with between 20% and 30% concentration by weight solids. While these grouts can be mixed and placed with most available pumping equipment, paddle mixers and positive displacement or progressive cavity pumps work best for placing these viscous materials. Powdered bentonite grouts can be adapted by varying the amount of water added to the mix to change the available work time and pumping viscosity. Local regulations may not allow such changes in mix ratio.

Failure to meet manufacturer's density requirements or placement of the grout on top of a lower density material (e.g., drilling mud or water) may result in a settling of the grout material to the bottom of the well. These grouts can be used to displace lower density materials if placed by a tremie pipe. Proper use of these products requires placement of the material the entire length of the borehole starting at the bottom of the borehole. A bentonite pellet or neat cement cap a few feet thick is also recommended near the surface to complete the grout seal.

Granular Bentonite Slurries

Granular bentonites are generally manufactured from high-yield, non-drilling-grade bentonite. The bentonite is processed to provide coarse granular particles in the 8 to 20 nominal **mesh size ranges**. The larger particles possess lower surface area-to-mass ratios than the finely ground, powdered bentonite. This results in considerably less dust while mixing and slower water absorption and delayed hydration and expansion when compared to a finely ground bentonite. See Table 7 for bentonite grout particle sizes.

Table 7. Bentonite grout particle sizes

Product	Nominal Size	Actual Size
Powdered Bentonite Grouts	200 mesh (.0029”)	80 – 325 mesh (.0070” - .0017”)
Granular Bentonite Grouts	8 mesh (.0937”), 20 mesh (.0331”),	8 – 40 mesh (.0937” - .0165”) 10 – 30 mesh (.0787” - .0232”)
Coarse Grade Bentonite (Chips)	3/8” medium, 3/4” coarse	-3/8” + 1/4” -3/4” + 3/8”
Pelletized Bentonite (Pellets)	1/4” 3/8” 1/2"	1/4” 3/8” 1/2"

One advantage of the granular bentonite slurry is that the delay in swelling of the bentonite particles allows preparation of a slurry possessing a lower viscosity for a short period of time (15 minutes or less). If mixing and pumping are done efficiently, the granular bentonite slurries allow placement of a high density grout in a low viscosity state. The hydration and expansion process is then completed in the well or borehole. Granular bentonite must be prepared with no less than 20 percent bentonite content by weight. This results in a set grout which exhibits desired permeability and gel strength characteristics.

These products rely on the addition of a polymer to suppress hydration and delay swelling of the bentonite particles. These additives can be added either by the manufacturer for a single step mix or added to the mix in the field. All additives should be ANSI NSF 60 certified. The use of such products requires particular attention to the manufacturer's mixing recommendations. Mixing requires the use of blade or paddle-type mixers or grout mixers with recirculation; centrifugal pumps are not recommended for mixing or pumping granular bentonite slurries. Placement of the grout must be accomplished before swelling of the bentonite occurs. If expansion occurs prematurely the slurry cannot be pumped and the batch is wasted.

Coarse Grade Bentonite

Coarse grade bentonite, also referred to as crushed or chip bentonite, is processed by the manufacturer to provide a large particle size and density. The bentonite particles typically are available in nominal sizes of 3/8 to 3/4 inch and are intended to fall through a column of water. When placed properly, the coarse grade bentonite provides a flexible high density, low permeability, down-hole seal. Be aware that the ODH and Ohio EPA well standards may limit the placement of this product.

Due to the size of the coarse grade bentonite products, care should be taken in their use and adequate time allotted for slow placement. Since the material cannot be pumped, placement requires pouring from the surface and care should be taken with the rate of placement. The settling rate for coarse bentonite chips is 1 foot per second; adequate time must be allotted for the product to settle into position. Placement may be accompanied by tamping to insure that bridging has not occurred. The product must be poured slowly, and the pouring rate should not exceed the manufacturer's specifications. If the borehole was just drilled and needs to be sealed, clean the borehole of all the drilling fluids before sealing. Do not pour coarse grade bentonite through drilling muds.

Prior to using this material, it should be sieved through 1/4-inch mesh screen to remove any fines which have accumulated in the bag during shipment. These fines, if not removed, will clump if they hit water and increase chances of bridging. It is also recommended that water be poured on top of any coarse grade bentonite above the water table to induce hydration.

Pelletized Bentonite

The pelletized bentonite products are compressed pellets with nominal sizes of ¼, 3/8 and 1/2-inch. As with coarse grade bentonite, pelletized bentonite provides a dense and flexible seal. It can be poured directly into the well through standing water. The pellets come in a coated version to slow down hydration. Precautions similar to those for the use of coarse grade bentonite are required to avoid bridging.

Other Fill Materials

Other materials are available for sealing wells with specific construction methods or in unique geologic conditions. These include gravel, sand, and clay. Gravel includes siliceous, well-rounded particles that range from fine (2 millimeter [mm]) to coarse (76 mm) in size. Sand should also be siliceous and well-rounded particles that range from very fine (.05 mm) to very coarse (2 mm) in size. Clay includes particles that are less than .002 mm in size and may include kaolinite, chlorite, illite and smectite-based clays. All fill materials considered for well sealing should be sized to the well being sealed, meaning that the material should have particle-size diameters small enough not to cause bridging (Gordon,1988). Any fill materials used for well sealing must be clean and free of sticks, leaves, or other foreign matter. Additionally, the material should be free of any toxic chemical residues that could cause contamination of ground water.

Clays mined from glacial deposits or from underclays in the coal-bearing regions of the state may be used for sealing some wells. The ability of these clays to serve as an effective sealing agent was evaluated by Carlton (1975). These clays should be evaluated to ensure that the clay-size particle content exceeds 40%, the remaining particle sizes should vary to ensure good compaction and minimize porosity in the sealing materials. Clays with a mixed clay mineralogy will provide the best seal. Native clays do not seal as effectively as commercially prepared bentonite products and may not be used as a sealing material or fill material in some types of wells (Carlton, 1975) Native clays can bridge in deeper, smaller diameter wells.

Clays should be wetted to help disperse the particles and improve compaction. The material must contain sufficient moisture to easily form by hand into a moist, somewhat soft, ball without developing any cracks (NRCS, 2010). Clays should be placed in lifts no more than 1 foot thick and be firmly compacted in the borehole before placement of the next lift. Clays must be layered with concrete, coarse grade or pelletized bentonite to ensure a uniform, impermeable seal of the borehole.

Alternative fill materials may be used in wells that have very large volumes in the borehole, such as dug or bucket auger wells, where it may not be economically feasible to recommend complete filling with a bentonite or cement material. Most wells in this category are large in diameter and, therefore, present a physical hazard if they are not properly sealed. This type of well must be filled with load-bearing materials (Gordon, 1988). Large diameter, shallow dug wells can be filled with clean gravel adjacent to the water producing zones, and the remainder of the borehole filled with clean clay to a depth specified in ODH or Ohio EPA rules.

There are other geologic conditions where alternative fill materials may be placed in a portion or portions of the borehole during the sealing process. These include wells completed in fractured bedrock or extremely coarse gravel where there may be excessive loss of sealing materials during and after placement. In such instances, gravel can be used to bridge fractures or fill areas of large voids in the water-producing zone before sealants are emplaced (Gordon, 1988). ODH rules permit the placement of clean gravel adjacent to known water bearing zones to help reduce well sealing costs where well log data is available to ensure proper depth placement of these materials.

Procedures for Sealing the Well

General Sealing Procedures

It is highly recommended that wells and boreholes be sealed by an experienced registered water systems contractor. Private water system wells must be sealed by a private water systems contractor registered with ODH. If the well to be sealed is regulated by a state agency, the applicable rules should be followed.

1. **Remove obstructions from the well**

   The first step in the well sealing process is to remove all obstructions from the well. These obstructions can include pumps and related equipment, such as drop pipes, **pitless adaptors** or **pitless units**, and

suction lines. Pumps that are stuck and cannot be pulled should be pushed to the bottom of the hole, if possible. Other obstructions may consist of trash, animal remains, and debris such as large rocks or pieces of wood. If there is a possibility that the well has been contaminated, which could be evidenced by the presence of items such as empty pesticide containers, fertilizer bags, or a strong odor, the well owner should inform the appropriate agency (see Appendix 1) before sealing begins. Cap off the water supply line either in the house or near the well, ideally as close to the well as possible.

2. Evaluate the condition of the casing

After the obstructions have been removed from the well, the next step is to decide what to do with the casing and any liner pipe that may be present. Remove any liner pipe that is not permanently attached to the casing. Whether or not the casing is left intact will depend on the type of casing, its condition, and the type of well being sealed. Under normal situations, leaving the casing in place is recommended. If the annular seal is determined to be adequate, then the casing may be left in place unless other site conditions warrant removal or perforation of the casing. If there is a suspected breach in the annular seal, a dye trace may be conducted to determine the integrity of the annular seal.

When the following conditions exist an evaluation should be made to determine if the casing should be removed:

- there is water flowing from around the outside of the well casing (this condition can occur in flowing wells), or
- the well is located in an area of known contamination, or
- there is gravel packing connecting two or more hydraulic zones, or
- voids are known to exist between the casing and the formation, or
- there is a gravel pack (type of filter pack) between the two casings of a double-cased well, or
- the well is located in an area of known ground water contamination and one of the above conditions exists.

Methods for removing the casing include overdrilling, pulling, or drilling out the casing. Overdrilling is not commonly used by the water well industry to remove casing. It is more commonly used to remove casings from wells used for environmental monitoring and remediation. Overdrilling a well requires the contractor to drill a larger diameter borehole around the existing well. The depth of the overdrilled borehole will depend on the construction of the well and local hydrogeologic conditions. After overdrilling, the casing can then be pulled from the ground. When the old casing is removed efforts should be made to prevent collapse of the native materials into the open borehole.

Drilling out the casing may be possible for shallow, small diameter wells when the casing is made of PVC or Teflon. This method of removing the casing uses a solid stem or rotary bit to drill vertically through the casing, destroying the casing as the drilling progresses. This method of removing casing presents risks to the drilling equipment, including excessive wear on drill bits, which may add to the costs of sealing the well. These added costs and the environmental benefit gained by removing the casing using this method should be considered before deciding to drill out the casing.

In rare cases, ripping or perforating a casing should be performed. Perforating or ripping should always be done by an experienced registered drilling contractor that has the specialized tools, including **packers** and high pressure equipment, needed for this work. Ripping or perforating the casing may be considered if the annular seal is not in good condition and trying to remove the casing can do harm to the aquifer, a confining unit or will create additional pathways for contamination to reach the aquifer.

3. Calculate the amount of sealing and fill material needed

The materials to be used in sealing the well and their method of placement will be determined by the well construction, geologic conditions and applicable rules. In most situations (except for shallow wells), the method that provides the easiest placement and best seal is pressure grouting with a neat cement or bentonite slurry. As discussed in the Sealing Materials section of this document, local water

quality should be taken into account before a sealing product and technique are chosen. Water used in well sealing may be treated as needed to ensure the grout is properly mixed.

The amount of grout required to seal a well can be estimated in three ways:

a) On-line grout volume calculator: Many of the bentonite manufacturing companies have calculators for estimating the amount of grout needed to seal a well available on their websites. Also, ODH has developed a downloadable spreadsheet for making a grout volume estimate. Links to these calculators are listed below. Table 8 provides volumes of different well sealing materials required to seal a 100-foot deep well.

ODH worksheet - http://www.odh.ohio.gov/en/odhprograms/eh/water/PWSForms/LHDForms.aspx
Wyoben - http://www.wyoben.com/
Cetco - http://drillingproducts.cetco.com/
Baroid - http://www.baroididp.com/

b) Quick estimate method: The hole diameter (in inches) multiplied by itself then divided by 24.5 will give the approximate grout volume in gallons per foot. [Hole Diameter (inches) x Hole Diameter (inches)/24.5 = Hole Volume (Gal/ft)]

$$\text{Approximate grout volume per unit length of borehole (gallons/foot)} = \frac{d^2}{24.5}$$

(Where d = diameter of borehole in inches.)

c) Exact calculation method: The hole radius (in inches) multiplied by itself and then multiplied by π (3.1415). Divide this result by 1728 to find the hole volume in cubic feet per inch of hole. Then multiply this number by 12 to get the cubic feet per foot of hole. Multiply this number by 7.48 to get the volume in gallons per foot of hole. [Hole radius (inches) x Hole radius (inches)][3.1415]/1728 = Hole Volume (cubic ft/in) x 12 in/ft = hole volume (cubic ft/ft). Hole Volume (cubic ft/ft) x 7.48 gal./cu. ft = Hole Volume (Gal/ft).]

$$\text{Grout volume per unit length of borehole (gallons/foot)} = (\pi r^2 / 1728\ \text{in}^3/\text{ft}^3) \times 12\ \text{in/ft} \times 7.48\ \text{gal/ft}^3$$

(Where: r = Hole radius in inches.)

Table 8. Comparing volumes of different well sealing materials required to seal a 100-foot deep well*

Hole Diameter (Inches)	Gallons Per Foot	Gallons to be Plugged in 100' Well	Minimum Bags Required to Plug a 100 foot Well		Hole Volume Cu Ft/Ft Depth	Feet filled by one bag of Coarse Grade Bentonite (3/8"-3/4")	Bags of Bentonite Pellets or Chunks to Fill a 100' Well	Cu Ft of #8 Aggregate to Fill a 100' Well
			Bentonite Slurry	Neat Cement				
2	0.17	17	1	2	0.022	31.3	4	2.2
3	0.38	38	2	4	0.049	14.3	7	4.9
4	0.67	67	3	7	0.087	7.9	13	8.7
5	1.00	100	5	11	0.136	5.1	20	13.6
6	1.51	151	7	16	0.196	3.5	29	19.6
7	2.05	205	10	22	0.267	2.6	39	26.7
8	2.7	270	13	28	0.349	2.0	51	34.9
9	3.4	340	16	35	0.442	1.6	64	44.2
10	4.2	420	19	44	0.545	1.3	79	54.5
11	5.0	500	23	52	0.66	1.1	95	66.0
12	6.0	600	27	62	0.785	0.9	113	78.5
15	9.5	950	43	98	1.227	0.6	177	122.7
18	13.6	1360	61	140	1.767	0.4	255	176.7
20	16.8	1680	75	173	2.181	0.3	315	218.1
25	26.0	2600	117	267	3.409	0.2	491	340.9
30	38.0	3800	170	390	4.909	0.1	707	490.9
60	152.0	15200	679	1559	20.322	0.04	2500	2032.2

*-Provisions should be made to have up to 20% additional material available should inconsistencies in well diameter be encountered while sealing.

4. Placement of the sealing and fill material

There are four recommended procedures for sealing a well. They include:

a. Pressure grouting bentonite or cement slurries

Pressure grouting involves pumping the cement or bentonite slurry down a plastic pipe (called a tremie pipe) lowered to the bottom of the borehole or well (see Figure 11). As the slurry is pumped, the pipe is pulled back at a rate that keeps the end of the pipe submerged in the slurry as each batch is mixed and pumped. The slurry is denser than water and will displace any water in the well and force it up in the borehole. When the slurry that reaches the surface is the same density as the slurry being pumped through the tremie, the well has been properly sealed. Time should be allowed for settling to occur and the sealing material to achieve its final volume before the final steps in the sealing procedure are completed. The actual volume of sealing material used should be compared to the

Pressure grouting – early stage.

calculated volume to either confirm adequate sealing material has been used or to identify potential problems. (See Table 4 for approximate times)

b. Wet pouring cement or concrete slurries

Cement and concrete grouts may be gravity poured into a dry hole where no water is present in the well or borehole. In low-yielding wells, it may be possible to pump the well dry and then pour the cement or concrete before too much water re-enters the well, thus diluting the concrete or cement. In higher-yielding wells, it is very unlikely that the well can be dewatered or stay dewatered long enough for the cement or concrete to be poured into the well.

c. Dry pouring coarse grade or pelletized bentonite

When sealing wells with coarse grade bentonite products, precautions must be taken to ensure that the sealing material does not bridge. Coarse grade bentonite products can be used in wells up to 200 feet deep. Pelletized bentonite products can be used in wells up to 100 feet deep. If the well is less than 4 inches in diameter and over 100 feet deep, dry pouring is not allowed. All coarse grade products used in wells less than 24" in diameter should be poured over a wire mesh screen to eliminate the fine bentonite powder that could cause **bridging**. These products should be slowly poured at a rate no faster than 3 minutes per 50 pound bag (see Figure 12). The pouring process should be halted occasionally in order to lower a weighted measuring tape into the well until it reaches the top of the sealing products to confirm that bridging has not occurred. Adequate time for settling of the coarse grade bentonite needs to be allowed before measurements are taken. A tamping device can be used to break any bridges that form. The total volume of products used to fill the well should be no less than 80% of the estimated amount needed for sealing. Where the borehole or well is dry, the bentonite must be periodically hydrated with water in accordance with the manufacturer's requirements.

Pouring coarse grade bentonite over mesh screen to filter out fine particles.

d. Dry pouring sand, gravel or **fire clay**

Where the borehole conditions and geologic formations are known through an accurate well log, the well was recently completed or a downhole camera inspection was performed, materials other than bentonite or cement may be used. In some cases clean gravel may be placed from the bottom of the well to the top of the aquifer or to twenty-five feet below ground surface, whichever is encountered first. For some wells sand or fire clay may also be used to accomplish sealing. If the depth to the aquifer is unknown, then the entire borehole shall be filled with cement, concrete, or bentonite. Well sealing must always ensure that no mixing of water between aquifers will occur. For more information on the appropriate use of clean gravel, sand or fire clay see the Specific Well Sealing Procedures section of this document and consult the rules applicable to the well or the appropriate regulatory agency.

5. **Grout material set-up**

After the grout and other sealing materials have been placed into the well, dry hole or test hole, the sealing material shall be left a minimum of twelve hours to assess whether any settling of the sealing

material has occurred. If settling has occurred, then additional grout shall be placed into the remaining void space.

6. **Surface completion**

When the installation of sealing material has been completed, any remaining casing must be cut off to a depth of at least two or three feet below ground level, depending on the type of well or borehole being sealed. The remaining hole should be filled with clean soil or clean clay and the finished ground surface mounded to ensure that surface water will drain away from the area. Variations of this procedure may occur depending on future use of the property and the location of the well, for example, within a building or pumphouse. Consult appropriate regulatory agency for assistance.

Cutting off the casing.

7. **Recordkeeping and filing**

The final step in the well sealing process is submitting a well sealing report to the Ohio Department of Natural Resources, Division of Soil and Water Resources and to the local health district or the appropriate Ohio EPA District Office depending on the use of the well (see Figure 1). This form can be filled out on-line by going to http://soilandwater.ohiodnr.gov/search-file-well-logs or a blank form can be obtained from the ODNR - Division of Soil and Water Resources upon request.

Specific Well Sealing Procedures

It should be noted that where there are existing regulations for sealing a well or borehole, the procedures spelled out in the regulations should be followed. This guidance document should be followed if no regulations are available. If conditions indicate that sealing methods other than those spelled out in the regulations may be needed to properly seal the well or borehole contact the appropriate regulatory agency.

Sealing Dug Wells

The procedure for sealing dug wells differs somewhat from the general procedures described earlier in this guidance (see Figure 13 for details). Once any obstructions, loose debris, drop pipes, and pump are removed, the casing wall or liner material (i.e. stone, brick, concrete, tile, etc.) should be left intact except for the upper three to five feet depending on the type of well and the depth of the static water level. The area should be excavated at least six inches beyond the original borehole. If the well contains water, it should be pumped dry, if possible.

The well or borehole can be filled with clean clay, cement grout, coarse grade bentonite chips or concrete. The well or borehole can be filled with gravel adjacent to the water-producing zone. A layer of bentonite or cement grout at least one foot thick must be placed in the abandoned well. This layer will either be placed at the elevation of the static water level or from 15 to 14 feet below the natural ground surface, depending on the appropriate rules. If dry-poured bentonite is used it must be hydrated with five gallons of water per fifty pounds of bentonite. The remainder of the well must be filled with concrete, coarse grade or pelletized bentonite, fire clay, clay, or cuttings. To provide structural strength and minimize permeability, an equal part mixture of gravel and bentonite chips could be used. Some wells will also need to have a minimum one foot thick layer of coarse grade or pelletized bentonite or concrete grout placed at the elevation to which the casing has been removed. Settling may occur over time requiring additional fill to maintain drainage away from the well.

If the well owner wants to keep the well because of historical significance, the well owner should contact either the Ohio Department of Health or the Ohio EPA to determine the appropriate safety measures to reduce physical hazards and protect the aquifer.

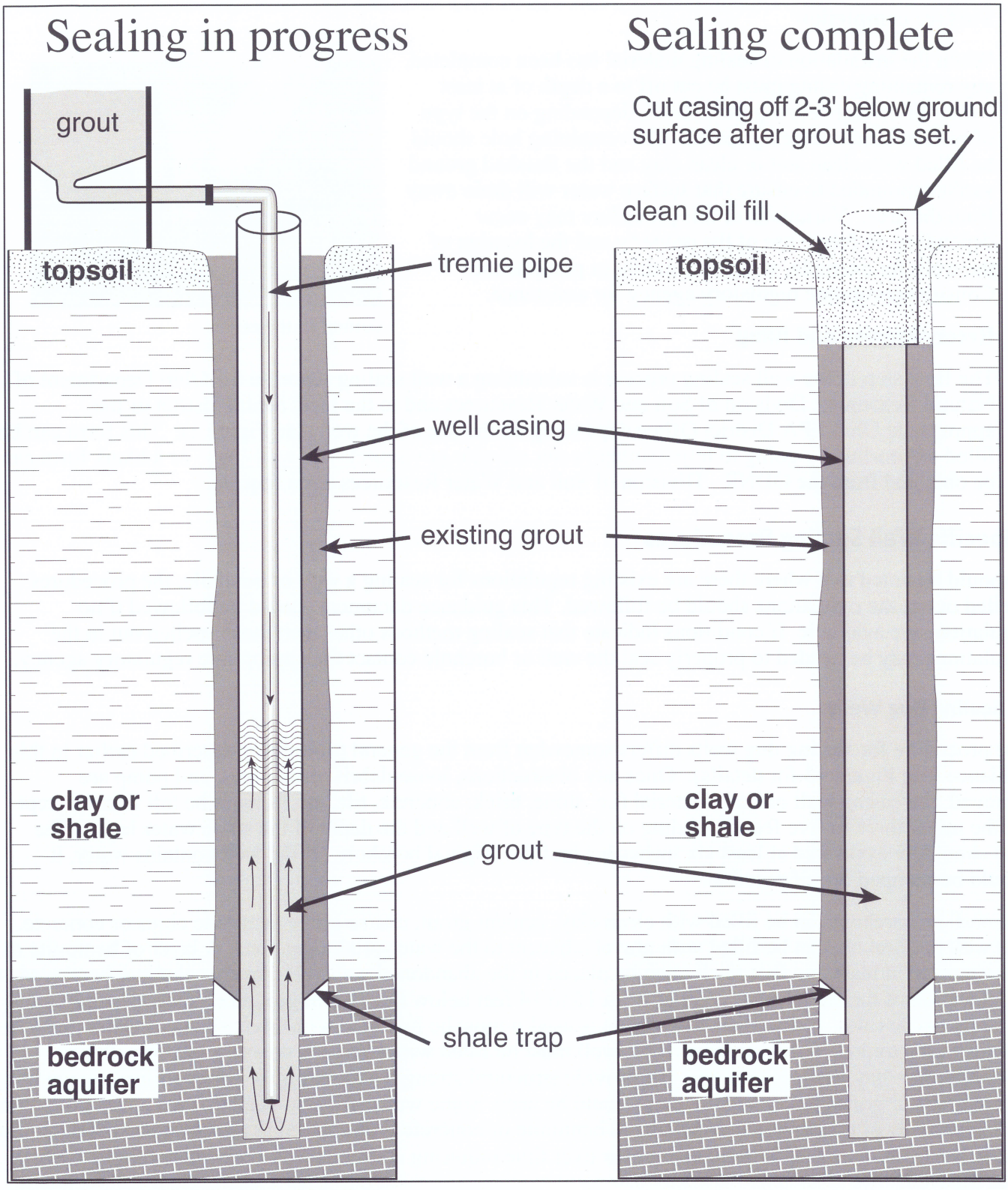

Figure 11. Grouting a bedrock well using the tremie pipe method.

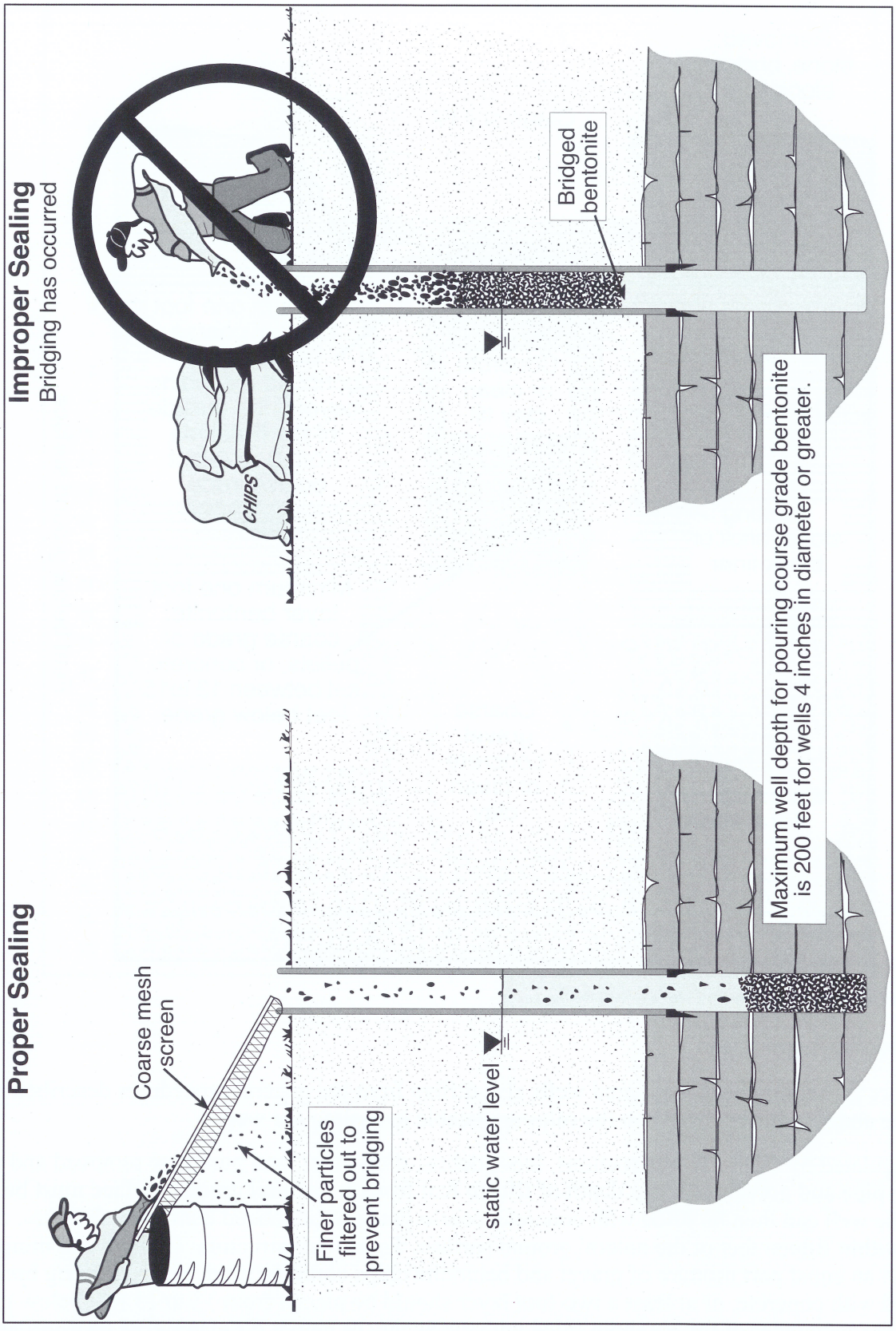

Figure 12. Sealing wells with coarse grade bentonite products showing the correct pouring method on the left and the incorrect pouring method on the right. (Modified from Wisconsin Department of Natural Resources, 1993)

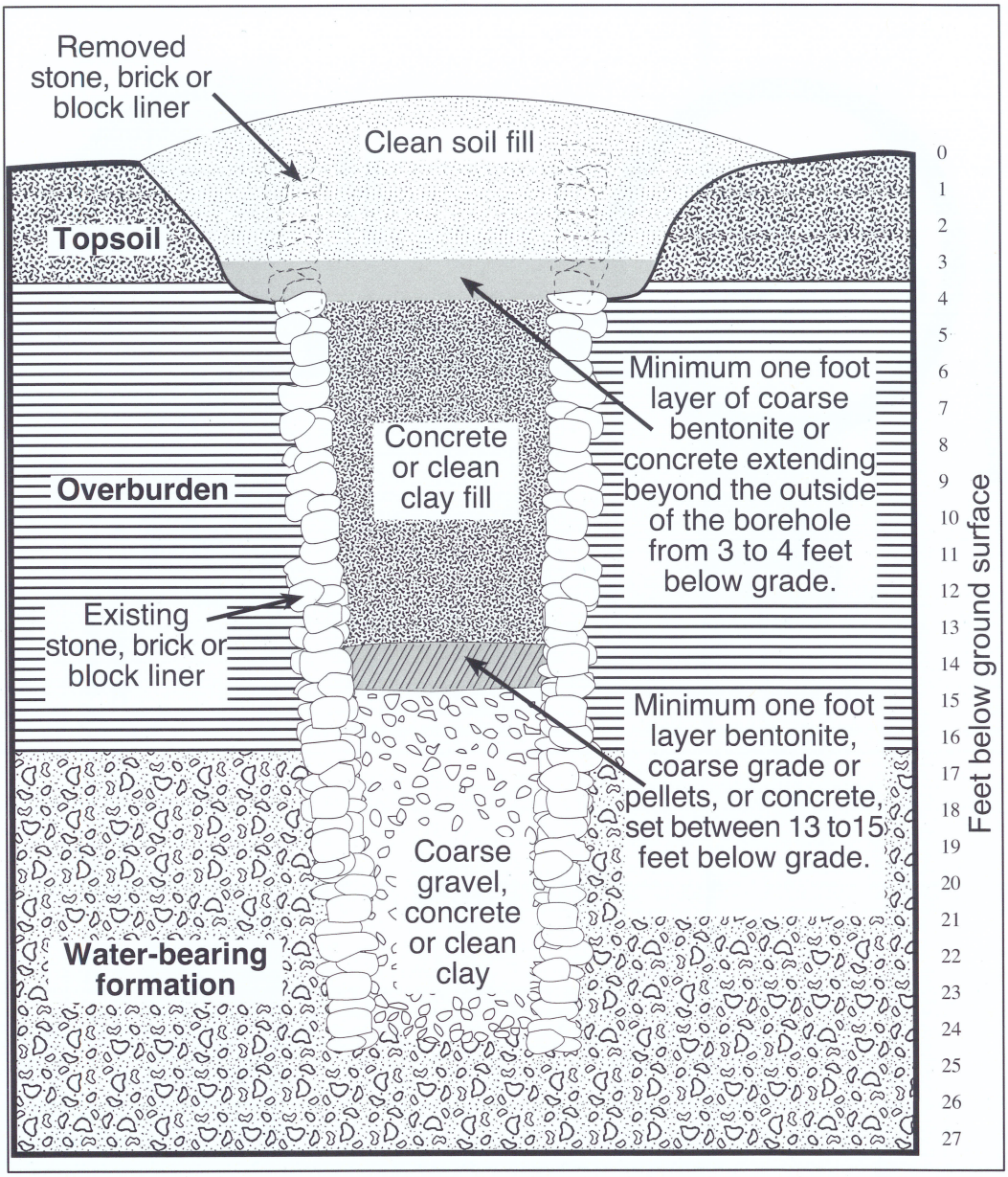

Figure 13. Cross section of a properly sealed dug well.

Sealing Bucket Auger Wells

The procedure for sealing bucket augered wells also differs from the general procedures described earlier in this guidance and also differs based on the rules applicable to sealing the well.

For wells regulated by ODH, all obstructions, loose debris, drop pipes, and pump are removed and all well casing, liner pipe and gravel pack to a depth of fifteen feet from the natural ground surface must be removed. The well can then be filled with concrete, coarse grade or pelletized bentonite, fire clay, clay, or cuttings to within fifteen feet of the natural ground surface. To provide structural strength and minimize permeability, an equal part mixture of gravel and bentonite chips could be used. The remaining borehole can then be filled with concrete, or at least a two foot layer should be placed from 13 to 15 feet below ground surface and the remainder of the borehole filled with clean clay or native fill material as appropriate for the site. The surface should be graded to ensure drainage away from the well (see Figure 14). Settling may occur over time which may require addition fill to maintain drainage away from the well.

For wells regulated by Ohio EPA, all obstructions, loose debris, drop pipes, and pump must be removed and the casing or liner material should be left intact except for the upper four or five feet depending on the depth of the static water level. The area should be excavated at least six inches beyond the original borehole. If the well contains water, it should be pumped dry, if possible. The well or borehole can be filled with clean clay or cement grout; the well or borehole may be filled with gravel adjacent to the water-producing zone. A layer of bentonite or cement grout at least one foot thick must be placed in the abandoned well at the elevation of the static water level. If dry-poured bentonite is used it must be hydrated with five gallons of water per fifty pounds of bentonite. The remainder of the well must be filled with clean clay and the surface should be graded to ensure drainage away from the well. Settling may occur over time which may require additional fill to maintain drainage away from the well.

The caisson of a **Ranney collector well** should be sealed in a similar method as stated in the above paragraph for bucket augered wells. The ports for the horizontal laterals should be sealed shut which usually involves installing a steel plate over the port opening. Attempting to install fill material in the laterals is not required. The caisson above land surface and any building attached to the caisson should be dismantled and removed. The land surface should be mounded to allow for settling.

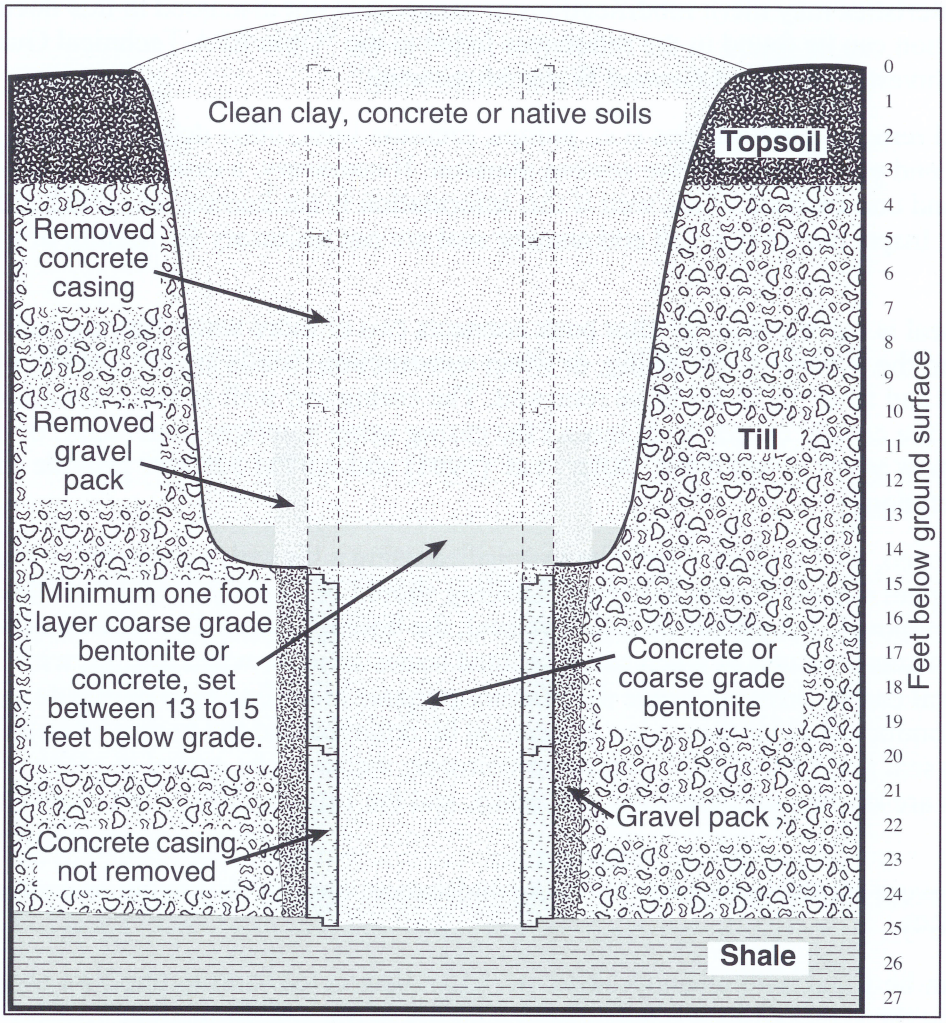

Figure 14. Cross section of a properly sealed bucket auger well per ODH rules.

Sealing Driven or Small Diameter (2 inches or less) Wells

Small diameter wells or boreholes (≤2 inches) may present special challenges. A small diameter (3/4 inch) grout pipe can be used; however, high pumping pressures or less viscous materials may be necessary

(ASTM D5299). Grouting machines are available for use with small diameter wells. A grouting machine reduces problems of bridging and incomplete seals associated with adding materials from the ground surface. The two most common small-diameter well types are drive points for domestic water supply and environmental wells and boreholes.

Sealing Water Supply Wells

After inspection and removal of any obstructions, casing removal should be attempted. The borehole must then be filled with coarse grade or pelletized bentonite, bentonite slurry, or cement slurry to ground surface. If the casing was not removed, it should be cut off two or three feet below the ground surface and filled with grout. If the casing was removed, the sealing should occur immediately before the borehole can collapse. The area excavated around the well should be filled with clean soil and mounded at ground surface to ensure drainage of surface water away from the well. For wells located in basements or in slabs, the top should be finished with a level concrete pour.

Sealing Environmental Wells and Boreholes

When sealing monitoring wells and boreholes no single method and material are suitable for all situations. Site-specific characteristics may merit modifications or procedures not discussed in this document. Additional information can be found in the references listed in the "Ohio EPA Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring".

Inspect the well and remove any obstacles (i.e., pumps, pressure lines, other debris, etc.) that may interfere with the placement and performance of the sealing material. If necessary, a camera survey can help to identify the depth and construction of the well if this information is not known. The outer protective casing should be removed. Inspection of the well and annular seal are not necessary for sealing of exploratory boreholes.

When the annular seal is inadequate, the filter pack connects two or more water bearing zones, water is flowing from around the outside of the casing, or when construction details are not known, the casing, screen, annular seal and filter pack should be removed. The casing and well screen can be removed by pulling or bumping the casing, overdrilling around the casing using a hollow stem auger, or drilling out the well using a solid stem auger or rotary bit. Aller et al. (1991) and ASTM 5299-99 provide a discussion on various removal techniques.

If overdrilling is chosen, the borehole should be overdrilled using a bit with a diameter at least 1.5 times greater than the original diameter of the borehole. Drilling should be slightly deeper than the original depth to assure complete removal. To achieve an effective seal, the borehole should be cleared of any excess mud filtercake. In some instances, such as when safety-related issues arise or when dealing with large diameter wells, casing removal can be difficult. Since the primary purpose of sealing is to eliminate vertical fluid movement, it is recommended that the casing and screen be removed and the boring be overdrilled to remove the annular seal and filter pack. However, monitoring wells can be sealed in-place when the construction details are known, the annular seal is intact, and the filter pack does not cross more than one ground water zone.

If circumstances prevent complete removal of casing and screen, then the following procedure can be used (based on Renz, 1989):

- The well can be filled with clean (ANSI/NSF 613) disinfected sand to one foot above the screen in the event that the screened area is adjacent to a highly permeable formation.

- One foot of bentonite chips/pellets can be placed above the screen in a manner that prevents bridging, such as through a tremie pipe or by tamping after installation. Chips are recommended below the water table because they will sink, whereas pellets will often float on the water table.

- The chips/pellets should be hydrated, if placed above the water table.

- To allow the sealant to permeate and be effective, the casing should be perforated to one foot above the bentonite seal either by splitting it vertically (synthetic casing) or by making horizontal cuts every two feet with a retractable blade (steel casing).

If no casing was ever installed, the borehole can be either pressure grouted from bottom to top with neat cement, bentonite or a cement/bentonite mix, or be sealed by slowly pouring coarse grade or pelletized bentonite. If pouring is conducted, the bentonite should be poured over a screened trough to filter out the fine bentonite before it enters the borehole. If the borehole is mostly dry, water should be added to hydrate the bentonite. The upper two to three feet of the borehole can be filled in with native soils or finished to match the surrounding surface (i.e. blacktop parking area).

Where evidence of microbiological growth is present, a monitoring well may need to be disinfected. Before disinfecting the monitoring well, the effect on water quality monitoring results in the proximity of the well to be sealed should be evaluated. Wells should be disinfected by slowly wetting the circumference of the well/borehole with the disinfection solution starting from the bottom of the well and working upwards using a tremie pipe to assure that all sides are wetted by the solution. The solution should be well-mixed within the well/borehole and purged before sealing with grout. Contact of disinfectant with bentonite should be avoided.

The disinfectant should:

- Have a concentration in the water column of approximately fifty milligrams per liter (mg/L) total chlorine, but no more than 100 mg/L.

- Have standard ANSI/NSF 60 certification. Standard ANSI/NSF 60 refers to "Standard ANSI/NSF 60, Drinking Water Treatment Chemicals - Health Effects", February 9, 2001, Document Number NSF/ANSI 60-2001 (NSF Web Site).

The borehole should be pressure grouted using a tremie pipe as the drilling stem is removed. The sealant should be applied in one continuous procedure to prevent segregation, dilution, and bridging (Aller et al., 1991). The pipe should be submerged in the sealant to prevent air pockets from forming. The borehole should be sealed from the bottom up to the frost line - approximately two to three feet from the surface. The overflowing grout should be regularly evaluated as it reaches the surface. The density of the grout should be monitored as discussed in the Properties of Grout section of the document to ensure an adequate seal is achieved.

When sealing wells that have two or more saturated zones or in flowing wells, it may be necessary to use a packer assembly. An inflatable packer can be placed at the top of the producing water zone to stop or restrict flow. The borehole can be sealed by pressure grouting from the bottom of the hole to the top of the packer. The packer can then be deflated and the grouting process continued. If dry sealant is introduced by gravity pouring, care must be taken that bridging does not occur. This can be accomplished by slowly adding the grout and stopping periodically (e.g., every five feet) to measure, tamp the grout and add water to hydrate. The amount of added water should be in accordance with manufacturer specifications. Coarse grade or bentonite pellets should be poured over a wire mesh to remove fines.

The grout plug should be inspected 24 hours after installation to check for settling; grout should be added if needed. If the well is sealed in-place, the casing should be cut off approximately three feet below ground level and a PVC or stainless steel cap should be placed over the sealed well. Monitoring wells sealed in-place should be marked with a piece of metal to allow for location by a metal detector or magnetometer (Aller et al., 1991).

The area above the plug should be finished in a manner that is compatible with the site. For example, its top can be covered with soil, mounded at ground surface to ensure drainage of surface water away from the well, and planted if vegetation is desired. If the area is to be surfaced, then the final seal can be completed with cement, concrete, or blacktop.

For additional information see Chapter 9 Sealing Abandoned Monitoring Wells and Boreholes, from "Ohio EPA Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring". Additional information covering special requirements for small diameter wells, wells penetrating multiple aquifers and confined aquifers can be found in other sections of this document.

Sealing Wells Drilled Through Multiple Aquifers

If the well penetrates multiple aquifers but is open only to one, or penetrates multiple aquifers and is screened across multiple zones, it is recommended that the well be pressure grouted from the bottom of the well to ground surface with bentonite or cement slurry. The casing should be pulled if there is any uncertainty as to the integrity of the annular grout seal. If there is detailed information available on the depth and thickness of each aquifer penetrated and the casing will be removed, it may be possible to place clean sand and/or gravel within each aquifer zone, and place an impermeable sealing material, such as neat cement or bentonite products, between each aquifer corresponding to the confining unit present (see Figure 15 for details). Then the well should be sealed from the top of the uppermost aquifer or from a depth of 25 feet to within two or three feet of the land surface with neat cement or bentonite products. The remainder of the well must be filled with clean clay and the surface should be graded to ensure drainage away from the well. Settling may occur over time which may require additional fill to maintain drainage away from the well.

Sealing Wells Drilled Through Confined Aquifers

Wells drilled through confined aquifers can be difficult to seal because water can be flowing out the top of the casing. This guidance strongly recommends that an experienced registered drilling contractor be consulted in all sealing situations, but it is especially important when dealing with these types of wells. To successfully seal a flowing well, the weight of the sealing materials must exceed the pressure of the water flowing out of the well, and the sealing materials must bond to the borehole or casing so that water cannot continue to flow to the surface. The grouting operation needs to occur quickly and uniformly to ensure that the weight of the grout is able to hold the water in the formation and provide an effective seal.

If the well is not flowing, clean sand and/or gravel may be placed from the bottom of the well to the top of the producing zone or to twenty-five feet below the ground surface, whichever is encountered first. This should be followed by pressure grouting with cement or bentonite slurry, or by slowly pouring in coarse grade bentonite products or pelletized bentonite, from twenty-five feet to ground surface. Any coarse grade bentonite products used should be periodically hydrated, if necessary, and tamped to prevent bridging. If the well is over 200 feet deep, pouring of coarse grade bentonite is not permissible. Pressure grouting should be performed.

If the well is flowing from within the casing only (Figure 16a), an attempt should be made to determine the hydraulic head. If the hydraulic head is low enough to permit casing extension, extend the casing high enough to keep the well from flowing (Figure 16b). Pressure grout with concrete or cement from the bottom of the well to the ground surface. If the flow has been completely stopped by the casing extension, and if the depth of the well is less than 200 feet, coarse grade bentonite products may be poured into the wells. If the well is less than 100 feet deep, pelletized bentonite may be used. The well should be grouted to ground surface. The casing can then be cut off two to three feet below ground surface, and the remaining excavation filled with clean soil and mounded.

If the hydraulic head is too high to permit casing extension, the well can be sealed by attempting to stop the flow, or by other methods that will allow sealing while the well is flowing. To control the flow, a packer should be placed above the producing formation (Figure 17b). Then the well can be pressure grouted with cement from the bottom of the well to the bottom of the packer. The sealing materials must be allowed to set to gain sufficient strength to withstand the hydraulic head pressures before the packer is deflated. The packer can then be deflated and brought to the surface provided no additional flow occurs. Continue pressure grouting to the surface (Figure 17c).

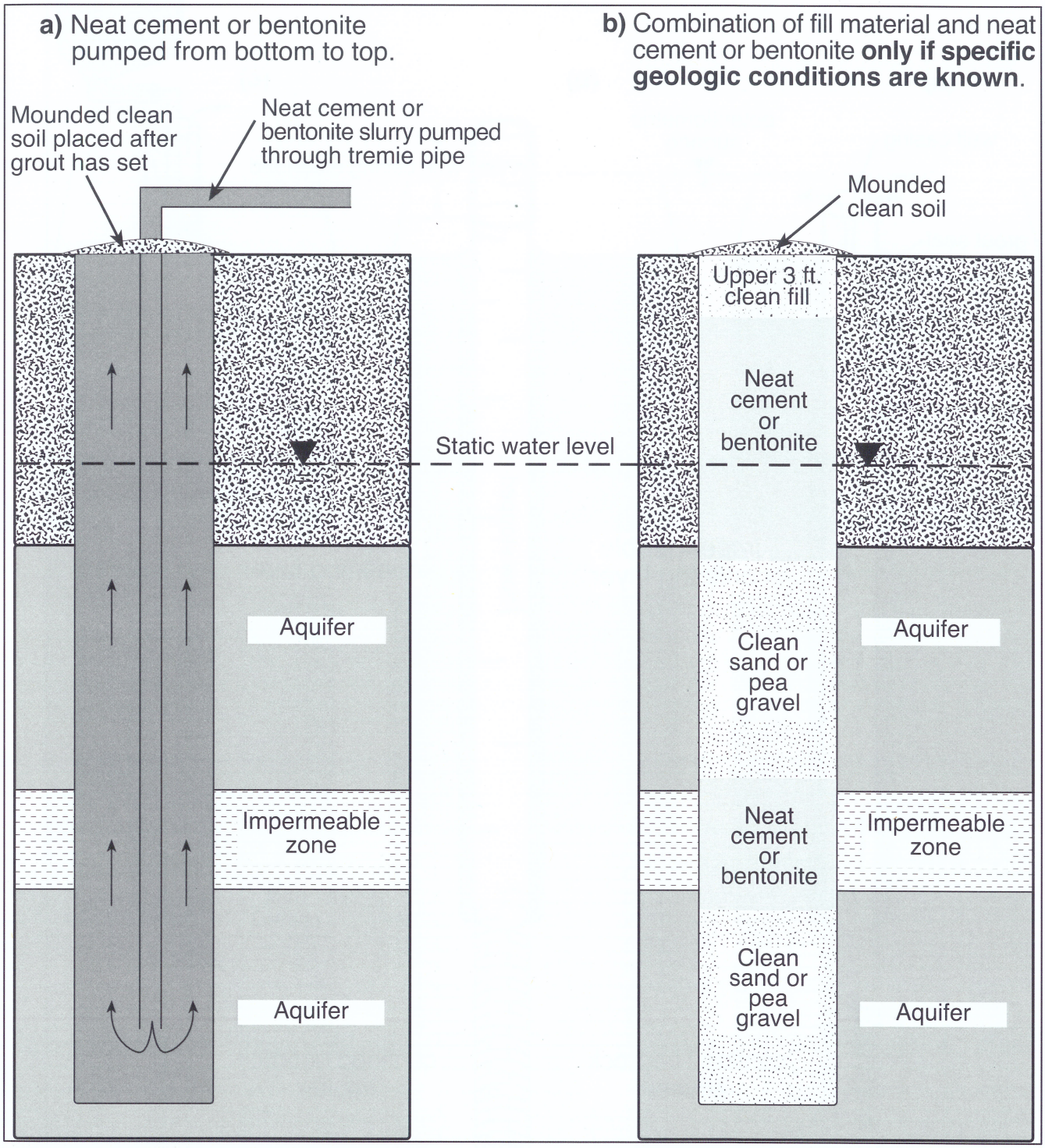

Figure 15. Methods for sealing wells penetrating multiple aquifer. a) Pressure grouting from bottom to land surface. b) Installing permeable material in aquifer zones and neat cement or bentonite in impermeable zones and above the uppermost aquifer.

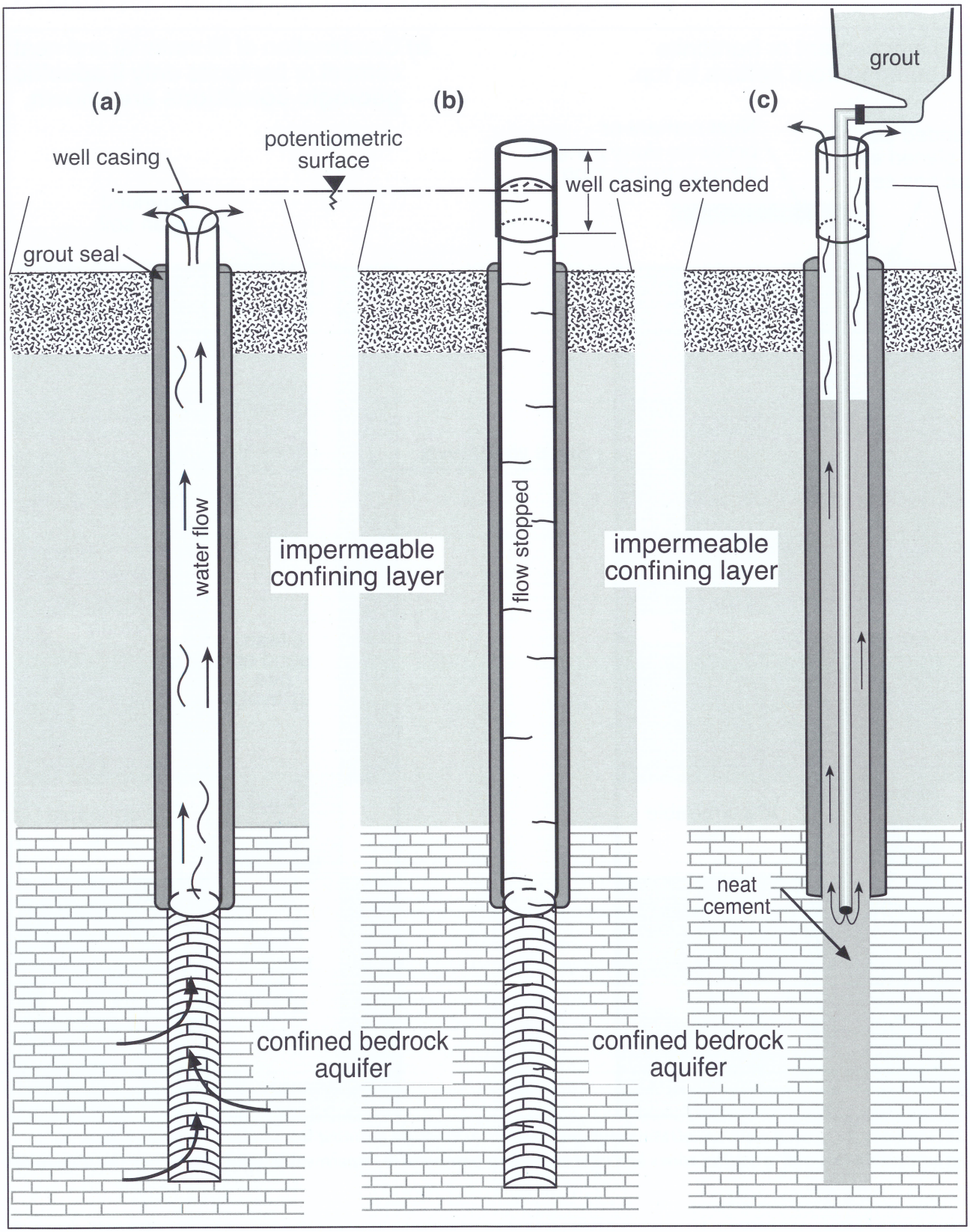

Figure 16. Reducing or stopping flow of well by casing extension. a) Water is flowing out the top of the casing. b) Casing has been extended to stop the flow of water out the top of the casing. c) Pressure grouting of the well with cement. (After Wisconsin regulations, 1994)

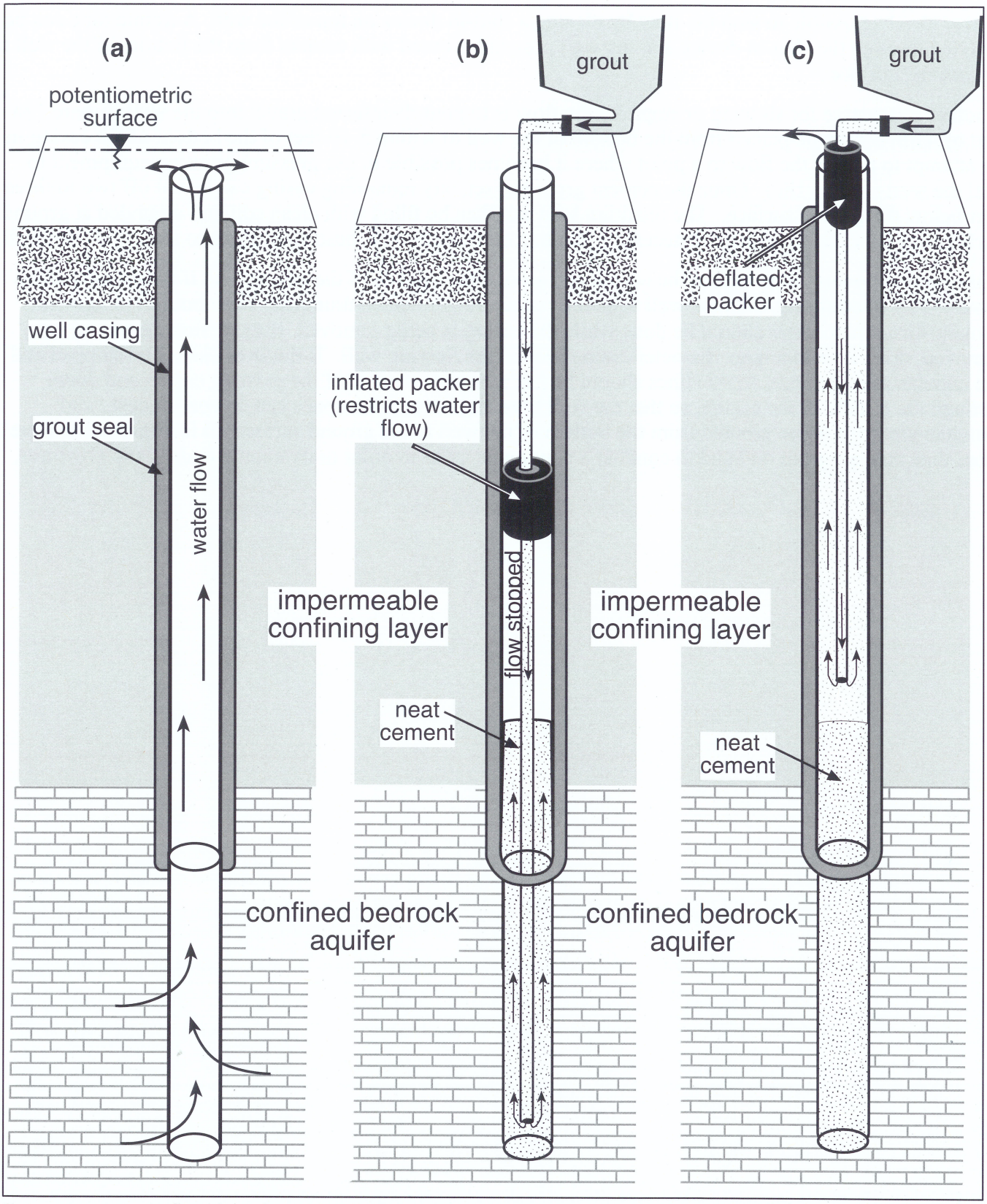

Figure 17. Using an inflatable packer to restrict flow. a) Water is flowing out the top of the casing. b) A packer has been inserted into the well and inflated to stop the flow of water out the top of the casing. The first stage of pressure grouting with cement is occurring. c) Pressure grouting with cement of the well to the land surface. (After Wisconsin regulations, 1994)

It may also be possible to stop the flow by placing a shut-in device on top of the well. A tremie tube can be inserted through the shut-in device and the well pressure grouted with cement from the bottom of the well to the ground surface.

Another alternative for slowing or stopping the flow is to pour disinfected gravel into the well (Figure 18a and b). Gravel may be placed from the bottom of the well to within 5-10 feet of the bottom of the casing in an attempt to reduce the flow to a point where it becomes possible to use pressure grouting equipment to seal the well (Figure 18c). Once the cement grout has set, any remaining casing can be cut off two to three feet below the ground surface. The resulting hole can then be filled with clean soil and mounded at ground surface. In some cases, it may be necessary to use a combination of these techniques to seal a flowing well.

If the well is flowing from within the casing and around the outside of the casing, and if the casing can be removed by overdrilling, then the well should be pressure grouted continuously from bottom to top with cement. Grout placement should be done while the casing is being removed. If the casing cannot be removed, drive or drill a large diameter casing around the flowing well. If the flow cannot be stopped and the annular space is open, tremie lines should be run along the outside of the existing casing and down through the middle of the casing, so that the well bore and the annular space can be continuously and simultaneously pressure grouted from the bottom of the well to the ground surface. It is important to have more than enough grout on hand to conduct a continuous pour in order to overcome hydrostatic pressures.

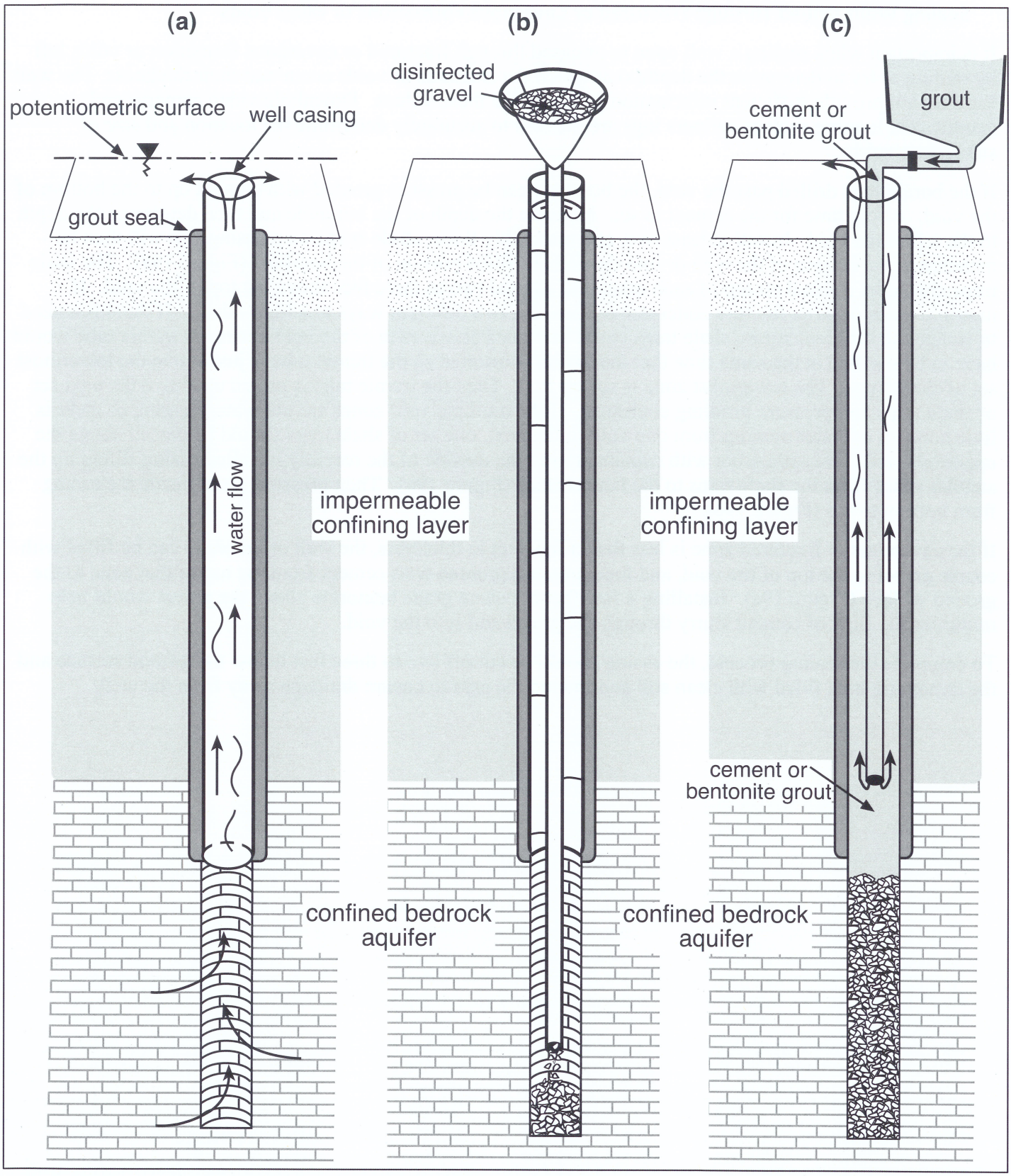

Figure 18. Pouring disinfected gravel into well to reduce flow. a) Water is flowing out the top of the casing. b) Gravel is being poured into the well to stop the flow of water out the top of the casing. c) Pressure grouting with cement or bentonite of the well to the land surface. (After Wisconsin regulations, 1994)

Sealing Wells Drilled Through Fractured or Cavernous Formations or Mine Voids

It is important when sealing a well open to or cased through fractured or cavernous formation or voids left by mining to try to determine the depth(s) at which the fractures or voids occur and their thickness. The well log may not provide sufficient information to determine these values. Downhole video cameras and geophysical logging such as calipers logs are the best to accurately determine the location and size of subsurface voids.

If the borehole is drilled past the void, the borehole can be pressure grouted with cement up to the bottom of the void. Allow time for the cement to set. Measure the depth of the borehole and then determine the depth to the top of the void. Install at least two, and preferably three, **shale traps** on a casing that will then be installed to the bottom of the well or into the cement-filled portion of the borehole (Figure 19a). The shale traps should be stacked on top of each other and aligned two to three feet above the top of the void. If multiple voids or large fracture zones occur, there are two different ways to address them. If there is a need to isolate the different zones, shale traps could be placed above each of the void zones. A tremie tube would have to be inserted at the same time that the casing is inserted so the tremie tube is just above the lowermost set of shale traps. The lowermost zone is sealed first. Then the tremie tube is pulled up above the next set of shale traps and pressure grouting continues. If the multiple void zones are not water-bearing or there is little concern of water moving from one void to the next, one set of shale traps should be placed above the uppermost void. Pressure grout with cement around the outside of the recently installed casing filling up the annular space from the shale traps to the land surface (Figure 19a). Then pressure grout inside the casing from bottom to top (Figure 19b).

If the cavernous or fractured zone is less than a few feet in thickness, the well or borehole can be filled with coarse gravel to the top of the void, and then pressure grouted with cement from the top of that zone to the ground surface (Figure 19c). Installing a few feet of coarse grade bentonite above the gravel would help minimize the flow of cement slurry through the gravel and into the void.

To complete the sealing process, the casing should be cut off two to three feet below the ground surface and the remaining hole filled with clean soil and mound the area to ensure drainage away from the well.

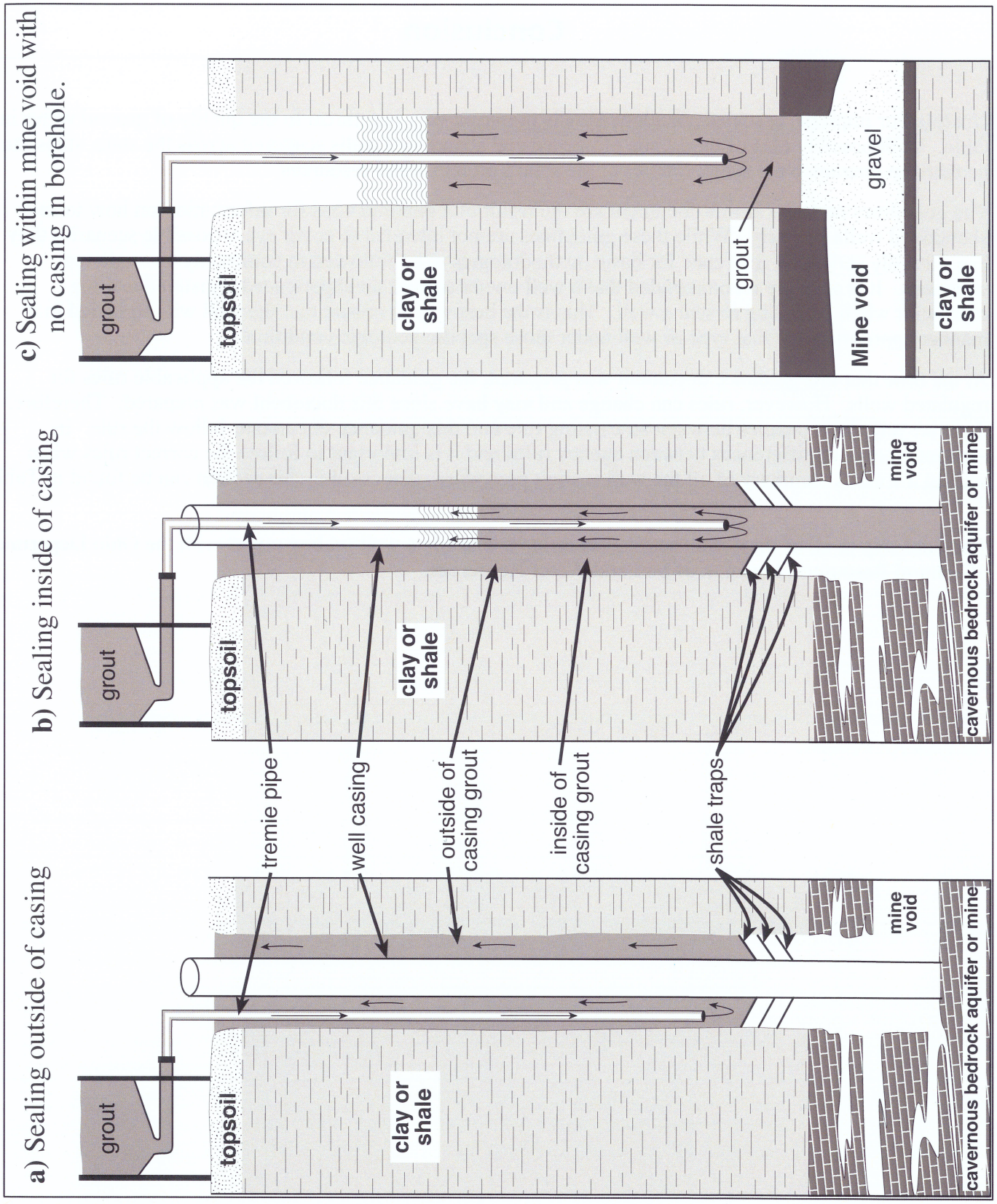

Figure 19. Sealing procedures for wells penetrating fractured or cavernous formations. a) Casing has been installed to the bottom of the borehole with three shale traps installed a few feet above the top of the void(s). Pressure grouting is occurring in the annular space. b) Pressure grouting inside the casing is occurring. c) The void has been filled with gravel up into the borehole and pressure grouting of the borehole is in process.

Conclusion

Unsealed or improperly sealed abandoned wells present a very real threat to the quality of ground water in Ohio. With possibly tens of thousands of unused and abandoned wells scattered across the state, steps must be taken to guarantee the future quality of the state's ground water resources.

The guidelines outlined in this document are the result of a genuine need for information on how to seal abandoned wells properly. While these guidelines are not intended to cover every possible scenario, they can certainly serve as a reference for basic methodologies to be followed in commonly encountered situations. It is strongly recommended that a well owner consult an experienced registered drilling contractor when preparing to seal a well. This is the best way to ensure that the well will be sealed in a manner appropriate for that type of well under those specific geologic conditions.

At the time that this guidance document was prepared, the guidance followed the applicable rules for regulated wells. However, rules can change and may have since this document was prepared. Therefore, if there are any discrepancies between an existing rule and this guidance document, follow the rule. In addition, there are differences between agency rules and it is important to follow the correct rules when sealing a well. A summary of all the well sealing procedures discussed in this section can be found in Table 9.

The final step in all of these well sealing procedures is to file a well sealing report with the Ohio Department of Natural Resources, Division of Soil and Water Resources.

Table 9. Summary of recommended well sealing materials and procedures.

WELL TYPE	MATERIALS									METHOD OF INSTALLATION
	Clean Fill		Concrete	Neat Cement	Cement-Bentonite mix	Coarse grade Bentonite[2]		Bentonite Slurry	Bentonite Granular	
	Gravel and/or Sand	Clay				Chips	Pellets			
Unknown construction	No	No	No	Yes	Yes	No	No	Yes	No	Slurry must be pressure grouted from bottom to top.
Dug Well	Yes[1]	Yes	Yes	No	Yes	Yes	Yes	No	Yes[9]	Material may be poured into well. A 2-foot layer of concrete, cement, or bentonite is required at 13-15 feet below land surface.
Bucket Auger	Yes[1]	Yes	Yes	No	Yes	Yes	Yes	No	Yes[9]	Material may be poured into well. A 2-foot layer of concrete, cement, or bentonite is required at 13-15 feet below land surface.
Driven	No	No	No	Yes	Yes	Yes[2]	Yes[2]	Yes	No	Slurry must be pressure grouted; coarse-grade bentonite must be slow poured.
Small Diameter (<2 in)	No	No	No	Yes	Yes	Yes[2]	Yes[2]	Yes	No	Slurry must be pressure grouted; coarse grade bentonite must be slow-poured.
Wells into a single aquifer	Yes[3]	No	No	Yes	Yes	Yes[2]	Yes[2]	Yes	Yes[10]	Gravel may be poured, slurry must be pressure grouted; coarse-grade bentonite must be slow-poured.
Wells through multiple aquifers	Yes[1]	No	No	Yes	Yes	Yes	Yes	Yes	No	Install clean fill in aquifer zone(s) only and cement or bentonite in confining zones and above uppermost aquifer to the surface.
Wells into flowing artesian aquifers	Yes[4]	No	Yes	Yes[6]	Yes[6]	Yes[6]	Yes[6]	Yes[6]	No	Use gravel to stop or greatly reduce the flow. If flow cannot be stopped, pump concrete into well.
Wells into fractured/cavernous aquifers	Yes[11]	No	Yes	Yes[7]	Yes[7]	Yes[7]	Yes[7]	Yes[7]	No	Use gravel to bridge fractured/cavernous zone only. Slurry must be pressure grouted.
Wells into mine voids	Yes[5]	No	Yes	Yes[8]	Yes[8]	Yes[8]	Yes[8]	Yes[8]	No	Use large gravel in mine void area.

1. In aquifer zone only
2. Coarse grade bentonite must be poured slowly over a wire mesh screen and into the well at a rate no faster than 3 minutes per 50 pound bag. Requires periodic tamping
3. To top of aquifer. The rest of the well should be filled to the surface with cement or bentonite
4. To slow the flow to allow grouting to proceed
5. In mine void area only
6. If flowing conditions have been stopped
7. From top of fractured/cavernous zone to the land surface
8. From top of mine void to the land surface
9. Use for 1-foot layer at the 3-4 foot level below grade
10. Dry hole and less than 25 feet deep. Must be periodically hydrated.
11. Can be used to fill fractured or cavernous zones

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Glossary

Annular space - the space between the well casing and the borehole wall.

Aquifer - a geological formation, part of a formation, or group of formations that is capable of yielding a significant amount of water to a well or spring.

Artesian – a well condition when a confining layer overlies the aquifer, which causes the water level in the well to rise above the top of the aquifer. If the confining pressures are great enough, the water level could rise above the land surface, creating a flowing artesian well.

Atmospheric pressure - the pressure on the earth's surface caused by the weight of the earth's atmosphere.

Auger - is a drilling device, or drill bit, that usually includes a rotating helical screw blade called a "*flighting*" to act as a screw conveyor to remove the drilled out material. The rotation of the blade causes the material to move out of the hole being drilled.

Bailing - the use of a bucket, or rigid tube or pipe with a valve to remove fluid volumes or debris and cuttings from a well.

Bentonite - a plastic, colloidal clay composed predominantly of sodium montmorillonite which has an extensive ability to absorb water and swell in volume.

Borehole - a hole in the earth made by a drill; the uncased drill hole from the surface to the bottom of the well.

Bridging - the action of sealing material to get stuck in the well or borehole before it gets to the bottom, which creates open voids. Fine particles can bridge at the static water level due to surface tension of the water. Any sealing material can bridge when it is poured too quickly.

Bucket auger - a cylindrical bucket that has auger-type cutting blades on the bottom. The bucket fills up as the auger is turned and pushed into the ground.

Cement - complex, finely-ground kiln-fired calcium silicate which, when mixed with water, forms a slurry which will harden in the borehole to form an effective seal.

Cistern - a large receptacle used for storing water, especially an underground tank in which rainwater is collected.

Concrete - a mixture of neat cement, an aggregate, and water.

Confining layer - a body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers.

Confined aquifer - an aquifer bounded above and below by beds of distinctly lower permeability than that of the aquifer itself and which contains groundwater under pressure greater than that of the atmosphere. This term is synonymous with the term "artesian aquifer."

Consolidated - lithified geologic materials. In Ohio, these materials constitute formations such as sandstone, limestone, and shale.

Cuttings - chips removed from the borehole by a bit in the process of well drilling.

Density - the mass or quantity of a substance per unit of volume, usually expressed in grams per cubic centimeter or pounds per gallon.

Drill rod - the extension rods used to attach the bit to the drilling rig to enable the penetration into the earth.

Drilling bit - a device used on the end of a drilling stem or rod for the purpose of penetrating earth formations. Drilling bits are usually made of a hardened material so as to last an extended period of time.

Drilling mud - a special mixture of clay, water, and chemical additives pumped down hole through the drill pipe and drill bit. The mud is used to lubricate and cool the bit and to float cuttings to the surface for removal.

Drilling tools - general term associated with all equipment used in the drilling process. Tools, bits, rods, stems, etc.

Dug well - a well excavated into a generally shallow, unconsolidated aquifer in which the side walls may be supported by material other than standard weight steel casing.

Filter pack - siliceous, well-rounded, clean, and uniform sand or gravel that is placed between the borehole wall and the well screen to prevent formation material from entering through the screen.

Fire clay - a term applied to a range of refractory clays used in the manufacture of ceramics, especially fire brick . Fire clay is made up of natural argillaceous materials, mostly kaolinite group clays, along with fine-grained micas and quartz , and may also contain organic matter and sulfur compounds.

Flowing well - a water well in which ground water normally flows over the top of the well casing

Formation - a body of consolidated or unconsolidated rock characterized by a degree of lithologic homogeneity which is prevailingly, but not necessarily, tabular and is mappable on the earth's surface or traceable in the subsurface.

Gel strength - a measure of internal structural strength. It is an indication of a fluid's ability to support suspended particles when the fluid is at rest. Gel strength is caused by the physical alignment of positive and negative charges on the surface of the clay particles in solution.

Geologic conditions - the distribution, types, and structural features of earth materials present in any given area.

Geotechnical boring - borings installed to determine the geological and engineering properties of subsurface soils.

Geothermal Extraction Well – a well that is used to extract water from an aquifer for the intended use of heating or cooling a building

Geothermal Return Well – a well completed in an aquifer that is used to pump water into after the water is used to heat or cool a building. The water temperature is the only change that has occurred to the water. This type of well is classified as a Class V injection well and is regulated by the Ohio EPA.

Ground water - any water below the surface of the earth in a zone of saturation.

Grout - as used in these guidelines, grout is a fluid mixture of water and cement or water and bentonite that is of a consistency to be pumped through a small-diameter pipe.

Hollow-stem auger - the auger flights are welded onto larger diameter pipe with a cutting head mounted at the bottom. A plug is inserted into the hollow center of the cutter head to prevent soil from coming up inside the auger.

Hydrated - the incorporation of water into the chemical composition of mineral.

Hydraulic head - the height of the free surface of a body of water above a given subsurface point; a reflection of the ground water level plus the pressure head.

Hydrogeologic conditions - the occurrence, distribution, and quality of subsurface water within consolidated and/or unconsolidated earth materials in a given area.

Karst - landscape formed from the dissolution of soluble rocks such as limestone. Sinkholes are a common karst feature.

Mesh - one of the openings in a screen or sieve. The value of the mesh is usually given as the number of openings per linear inch.

Microannulus - for the purpose of this guidance document the term means the space between the sealing material and the casing and/or the formation. This is caused by the shrinkage of the sealing material.

Monitoring well - any excavation that is drilled, cored, bored, washed, driven, dug, jetted, or otherwise constructed for the purpose of extracting groundwater for physical, chemical, or biological testing, or for the purpose of determining the quantity or static level of ground water on a continuing basis.

Mud balance - a scale that measures a specific volume of grout slurry (density) and is expressed in pounds per gallon.

Non-potable well - any well that is used for the provision of water other than for human consumption. Non-potable wells include, but are not limited to, wells used to provide water for irrigation, non-contact cooling water, water for use in commercial and industrial processes, and water for use in dedicated open-loop geothermal heating and cooling systems. (Private water system and public water system wells are potable wells.)

Packer - a rubber or inflatable device used to temporarily or permanently seal off a portion of the borehole, annular space or well casing

Paleokarst - a karstified rock or area that has been buried by later sediments. Most of the voids or caves have been filled by the later sediments.

Permeability - the capacity of a porous rock, sediment, or soil for transmitting fluid; a measure of the relative ease of fluid flow across a pressure gradient often expressed in centimeters per second or feet per day.

Piezometer – generally a small-diameter non-pumping well used to measure the elevation of the water table or potentiometric surface

Pitless adaptor - a device or an assembly of parts which permits water to pass through the casing or extension thereof; provides access to the well and to the parts of the water system within the well; and provides for the transportation of the water and the protection of the well and water therein from surface or near surface contaminants.

Pitless unit - an assembly which extends the upper end of casing to above grade and prevents the entrance of contaminants into the well, to conduct water from the well, to protect water from freezing or extremes of temperature and to allow access to the well and components of the pumping equipment.

Plasticity - the capability of being deformed permanently without rupture.

Pore - a tiny opening, usually microscopic, in consolidated or unconsolidated materials.

Potentiometric surface - a hypothetical surface representing the level to which groundwater would rise if not trapped in a confined aquifer. The potentiometric surface is equivalent to the water table in an unconfined aquifer

Portland cement - fine powder produced by pulverizing clinkers consisting of at least 2/3 by mass hydraulic calcium silicates and the remainder consisting of aluminum- and iron-containing clinker phases with calcium sulfate added to control the set time.

Private water system - any water system, other than a public water system, for the provision of water for human consumption, if the system has fewer than 15 service connections and does not regularly serve an average of at least 25 individuals daily at least 60 days each year.

Public water system - any water system that has 15 or more service connections and regularly serves at least 25 individuals daily at least 60 days each year

Ranney collector well – a large diameter vertical reinforced concrete shaft (caisson) with horizontal lateral well screens projected out into a sand and gravel aquifer. These laterals are typically over 200 feet and extend under a river or lake in an effort to induce recharge from the surface water body.

Recharge - the processes by which water is absorbed and is added to the saturation zone, either directly into a formation, or indirectly by way of another formation.

Saturated zone - the portion of consolidated or unconsolidated materials in which all of the pore space is occupied by water.

Shale trap - flexible rubber cone-shaped packer attached to the outside of the well casing that is designed to prevent material such as a grout seal from passing below it.

Static water level - the measured distance from the established ground surface to the water surface in a well that is neither being pumped nor under the influence of pumping nor flowing under artesian pressure.

Stratigraphy - the arrangement of consolidated and unconsolidated strata.

Table drive - the revolving or spinning section of the drill floor that provides power to turn the drill string in a clockwise direction to facilitate the process of drilling a borehole.

Test boring - a boring designed to obtain information on ground water quality and/or geological and hydrogeological conditions.

Unconsolidated - not lithified but loose, soft geologic materials. Alluvium, soil, gravel, clay, and overburden are some of the terms used to describe a formation consisting of unconsolidated materials.

Underground injection well - wells used to place fluids underground for storage or disposal. These wells are divided into six classes based on the well use: Class I wells inject hazardous wastes, industrial non-hazardous liquids, or municipal wastewater for disposal. Class II wells inject brines and other fluids associated with oil and gas production, and hydrocarbons for storage. Class III wells inject fluids associated with solution mining of minerals. Class VI wells inject carbon dioxide for long term storage. Class I, II, III and VI wells sealing plans specific to each well. Class IV wells are banned unless authorized under a federal or state ground water remediation project. Class V All injection wells not included in Classes I-IV. In general, Class V wells inject non-hazardous fluids and are typically shallow, on-site disposal systems.

Viscosity - the property of a fluid or semi-liquid to offer internal resistance to flow.

Well - any excavation, regardless of design or method of construction, created for any of the following purposes: (1) removing ground water from or recharging water into an aquifer; (2) determining the quantity, quality, level, or movement of ground water in or the stratigraphy of an aquifer; and (3) removing or exchanging heat from ground water.

Well log and drilling report - the official Ohio report that is required to be submitted to the ODNR for the purpose of documenting geologic formations that were encountered during the drilling along with the well construction and pumping test information

Well casing - an impervious, durable pipe placed in a well to prevent the walls from caving and to seal off surface drainage or undesirable water, gas, or other fluids, and prevent their entering the well.

Well screen - a machine-slotted or wire-wrapped portion of casing used to stabilize the sides of the borehole, prevent the movement of fine-grained material into the well, and allow the maximum amount of water to enter the well with a minimum of resistance.

Well Sealing Report - the official Ohio report that is required to be submitted to ODNR when a well is sealed for the purpose of documenting the sealing materials and methods used

Yield - the quantity of water which may flow or be pumped from the well per unit of time.

Appendix 1

Contact Agencies

Ohio Department of Agriculture, Division of Plant Health, Pesticide Regulation Section

The Ohio Department of Agriculture (ODA) does not currently provide routine well analysis for pesticides; however, the Pesticide Regulation Section of ODA will sample any well where it is suspected that the use of a pesticide may have contaminated the well. To protect sample integrity, they must be collected by an ODA inspector. Samples are then analyzed at the ODA laboratory in Reynoldsburg. If a water sample is positive for a pesticide, the Pesticide Regulation Section will investigate to determine how the well was contaminated. The ODA will advise the well owner on how to clean up the well, and, if necessary, take appropriate enforcement action under Ohio Pesticide Law. The Ohio Department of Agriculture can be contacted at 614-728-6200.

Ohio Department of Agriculture, Division of Livestock Environmental Permitting (DLEP)

The Division of Livestock Environmental Permitting (DLEP) regulates and enforces state laws and rules for large livestock farms in Ohio. This regulatory program issues Permits to Install (PTI) and Permits to Operate (PTO) to livestock operations classified as Concentrated Animal Feeding Facilities (CAFF). The ODA-DLEP rules are contained in Chapter 901 of the Ohio Administrative Code (OAC) and cover the following areas: siting criteria, geological evaluations and design of new manure storage structures, manure management plans, groundwater sampling and monitoring, insect and rodent control plans, plans for the disposal of dead livestock, emergency response plans, operating record requirements, inspections, closure plans, enforcement (penalties, fines), and public participation. The Ohio Department of Agriculture can be contacted at 614-728-6200.

Ohio Department of Commerce, Division of State Fire Marshal, Bureau of Underground Storage Tank Regulations (BUSTR)

One of BUSTR's responsibilities is to supervise the investigation and cleanup of suspected releases from to protect human health and preserve the environment for the citizens of Ohio. Monitoring wells have been installed at sites around Ohio as part of these investigations and BUSTR should be contacted with any questions prior to their sealing. If a release from a regulated underground storage tanks is suspected of contaminating a water well, they should be contacted at 1-800-686-2878 before sealing the well.

Ohio Department of Commerce, Bureau of Building Standards

Ohio Board of Building Standards administers the rules covering the design, installation, and testing of geothermal heating and cooling piping systems, heating, ventilation, and HVAC equipment for non-residential buildings (Ohio Administrative Code § 4101:2 - Ohio Mechanical Code) and the rules covering the design, installation, and testing of geothermal heating and cooling piping systems serving residential buildings (Ohio Administrative Code § 4101:8 - The Residential Code of Ohio). Permits may be required prior to the removal of piping before sealing an open-loop geothermal heating and cooling system well.

Ohio Department of Health, Division of Prevention

For information on specific regulatory requirements and permits for sealing private wells, or for questions about possible contamination with substances other than pesticides or petroleum products, or to determine the registration status of a private water system contractor (i.e. drilling contractor or pump installers) contact the local health department or the Ohio Department of Health, Private Water System Program (PWSP) at 614-644-7558.

Ohio Department of Natural Resources, Division of Mineral Resources Management

The Division of Mineral Resources Management regulates the abandonment of coal and industrial minerals test borings through the permitting process under the Ohio Revised Code Chapter 1513 and 1514. Most borings are mined through during the removal of the coal or industrial mineral. Those borings that are not removed by mining are required to be properly sealed using procedures approved by the Division. The Division also recommends that the coal operator properly seal any original private water supply wells that are replaced by a new well drilled as a result of a water supply replacement order by the Chief. The Division investigates any ground water contamination or diminution complaints related to coal and industrial minerals mining activities. The contact phone number is 614-265-6633.

Ohio Department of Natural Resources, Division of Oil & Gas Resources

Personnel in the Groundwater Protection Section of the Division investigate ground water contamination cases when oil and gas operations are the suspected cause. If there is reason to believe that an unsealed, unused well on a property is an oil or gas well, the Division also has an Idle and Orphan Well Program that addresses the need to seal abandoned oil and gas wells. For more information on these two programs, contact the Division's Central Office at 614-265-6922.

Ohio Department of Natural Resources, Division of Soil and Water Resources

The Ohio Revised Code, Section 1521.05, requires that a well sealing report be filed with the Division of Soil and Water Resources for all wells sealed in the State of Ohio. Copies of the well sealing report can be obtained from the Division's website or by calling 614-265-6740. The Division also collects well log and drilling reports required to be filed by drilling contractors for wells drilled across the state. This authority also comes from Section 1521.05 of the Ohio Revised Code. Requests for copies of well log and drilling reports on file can be made by calling 614-265-6740.

Ohio Environmental Protection Agency, Division of Drinking and Ground Waters

The Ohio Revised Code 6111.42 gives the Ohio EPA authority to prescribe regulations for the drilling, operation, maintenance, and sealing of abandoned wells as deemed necessary by the director to prevent the contamination of underground waters in the state, except that such regulations do not apply to non-public potable wells. Currently, the Ohio EPA, Division of Drinking and Ground Waters, has regulations for the sealing of public water supply wells (OAC 3745-9-10) and for wells used for the purpose of injecting fluids into the ground (OAC 3745-34-07, 60, and 36). Sealing of monitoring wells is generally handled by the Division that has regulatory authority over the site/facility. For information on specific regulatory requirements for public drinking water wells or for injection wells, the Division of Drinking and Ground Waters should be contacted at 614-644-2752.

The Ohio EPA has no regulations/requirements for a person to report contamination in their private well. Reporting of ground water contamination is only required if an entity is monitoring ground water in accordance with hazardous or solid waste rules. In general, the Ohio EPA will not respond to a request to evaluate a contaminated private well unless the local or state health department requests assistance in investigating the source of the problem. However, this will not affect how the well should be sealed, but may affect when it is sealed if additional investigation is initiated.

An exception to this occurs if the well was used to inject fluid waste. If it was used as an injection well, the owner/operator must contact the Division of Drinking and Ground Waters, Underground Injection Control Unit (U.I.C.) of the Ohio EPA at 614-644-2752. Specific requirements must be followed for the sealing of injection wells.

Appendix 2

Existing State Regulations for Sealing Water Wells

Private water systems – regulated by ODH and Local Health Departments
OAC 3701-28 - http://codes.ohio.gov/oac/3701-28

Public and Non-potable wells – regulated by Ohio EPA
OAC 3745-9 - http://codes.ohio.gov/oac/3745-9-10

Industrial Mineral exploration borings – regulated by ODNR – Mineral Resources Management
OAC 1501:14 - http://codes.ohio.gov/oac/1501%3A14

Coal Exploratory Holes – regulated by ODNR- Mineral Resources Management
OAC 1501:13 - http://codes.ohio.gov/oac/1501%3A13-13

Concentrated Animal Feeding Facility test borings or wells – regulated by ODA
OAC 901:10-2 - http://codes.ohio.gov/oac/901%3A10-2

Class V UIC wells – regulated by Ohio EPA - Division of Drinking and Ground Waters
OAC 3745-34 - http://codes.ohio.gov/oac/3745-34

Filing a well sealing report – regulated by ODNR- Soil and Water Resources
ORC 1521.05 http://codes.ohio.gov/orc/1521.05

Appendix 3

Cost Considerations

Although there are many factors not discussed below that can impact the final cost of sealing a well, these considerations can be important details for helping a well owner obtain a helpful and accurate estimate.

Determining the cost for sealing a well begins with preparing information prior to performing a sealing project. The original use of the well may determine the contractor qualifications required for sealing the well. Knowing the diameter, depth, and original construction method of the well is helpful in beginning the process of estimating costs. Knowing whether the pumping equipment has been removed or will require removal can be a minor or significant part of the cost depending upon the size or type of pumping system. Investigating the details of the well to be sealed can often be obtained from well logs or by measuring the depth and diameter of the well. It may not be possible to know the final depth of the well until the pumping equipment or obstructions are removed from the well. Special care should be exercised before any large diameter well is measured to ensure safety of life and property. It may be recommended to have this part of the investigation performed by a registered drilling contractor with experience in large diameter well sealing.

Knowing the regulatory requirements along with collecting the well information can help obtain knowledgeable estimates to determine which contractor to hire for sealing the well. Certain wells such as Private Water System wells have sealing permit costs which vary from county to county.

Logistics of mobilizing equipment in a difficult to reach area or a well located inside a basement or structure can impact the labor or material costs for sealing a well. Wells commonly sealed in Ohio are smaller diameter wells originally drilled with cable tool or rotary drilling equipment. The typical project involves the removal of pumping equipment by hand pulling or using mechanical methods such as a hoist truck. A final measurement would take place to confirm expected construction details and for logging information required on the sealing report. If everything complies with regulatory requirements, course grade bentonite can be poured in by using proper hand methods or by pressure grouting a bentonite slurry using a tremie pipe. An excavation would be performed around the sealed well to allow the termination of the casing to the required depth. Large diameter wells including hand dug wells often involve additional equipment such as dump trucks, excavation equipment, excavators and loaders. The amount of materials required can usually be determined prior to beginning the sealing project for cost estimate and project planning purposes. Access paths to the well may be required if materials such as cement are specified for the sealing project.

Occasionally special sealing conditions are encountered that can affect the cost of sealing a well. A well with high chlorides may require cement or concrete which would be more expensive than if just bentonite were used. A well that has an exposed mineshaft may require additional materials for bridging or shale traps or baskets installed for creating a structure to support the sealing material. State regulations may require certain types of constructed wells to be over-drilled or excavated to certain depths for proper sealing. A registered drilling contractor with experience in your unique well sealing conditions should be consulted.

The final use of the well site such as a driveway or road can cause the requirement of certain sealing materials which can increase costs. Backfilling with materials to match native materials or whatever else is required for future use completes the onsite sealing project.

Using the information obtained through measurements and materials used, a well sealing report can then be filed with the proper regulatory authorities and ODNR.

Appendix 4

List of Acronyms

ANSI/NSF – American National Standards Institute/National Science Foundation

ASTM - American Society for Testing and Materials (now known as ASTM International)

API - American Petroleum Institute

BUSTR - Bureau of Underground Storage Tank Regulations

DP - Direct Push

PVC - polyvinyl chloride

OEPA - Ohio Environmental Protection Agency

OEPA-DDAGW - Ohio Environmental Protection Agency – Division of Drinking and Ground Waters

OEPA-DERR - Ohio Environmental Protection Agency – Division of Environmental Response and Revitalization

OEPA-DMWM - Ohio Environmental Protection Agency – Division of Materials and Waste Management

OEPA-DSW - Ohio Environmental Protection Agency – Division of Surface Water

OAC - Ohio Administrative Code

ODA - Ohio Department of Agriculture

ODH - Ohio Department of Health

ODNR - Ohio Department of Natural Resources

ODNR-DGS - Ohio Department of Natural Resources –Division of Geological Survey

ODNR-DOGR - Ohio Department of Natural Resources –Division of Oil and Gas Resources

ODNR-DMRM - Ohio Department of Natural Resources –Division of Mineral Resources Management

ODNR-DSWR - Ohio Department of Natural Resources –Division of Soil and Water Resources

ORC - Ohio Revised Code

PPM - parts per million

SCCGW - State Coordinating Committee on Ground Water

UIC - Underground Injection Control

USGS-OWSC - United States Geological Survey - Ohio Water Science Center

APPENDIX B

OHIO DEPARTMENT OF NATURAL RESOURCES WELL SEALING REPORT

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FIELD USE ONLY
WELL SEALING REPORT
DO NOT FILE. NOT AN OFFICIAL RECORD.

DNR 7810.12e-f

Page____ of____ for this record.

Job Number:

Notes:

LOCATION

County _____ Township _____ Section No. _____ Lot No. _____

Owner _____

Address of Well Location _____

City _____ Zip Code _____

Well Location Description (120 Characters) _____

Location of Well in either:

State Plane N ☐ S ☐ X _____ +/- _____ ft. Y _____ +/- _____ ft.

OR

Latitude/Longitude Latitude _____ Longitude _____

Elevation of Well _____ +/- _____ ft. Datum Plane: ☐ NAD27 ☐ NAD83

Source of Coordinates: ☐ GPS ☐ Survey ☐ Other _____

Source of Elevation: ☐ GPS ☐ Survey ☐ Other _____

WELL IDENTIFICATION ODNR Well Log Number _____ Project Well ID _____

MEASURED CONSTRUCTION DETAILS

Date of measurements _____

Depth of Well _____ ft. Static Water Level _____ ft.

Borehole Depth _____ ft. Borehole Diameter _____ in.

Casing Diameter _____ in. Casing Length _____ ft. Casing Type _____

SEALING PROCEDURE

Placement:	Sealing Material	Volume/Weight Used Units Required	Placement Method
From _____ ft. To _____ ft.			
From _____ ft. To _____ ft.			
From _____ ft. To _____ ft.			
From _____ ft. To _____ ft.			

Condition of Casing _____ Was Casing Removed? ☐ Yes or ☐ No (check one)

If casing **Not Removed**, was it Perforated? ☐ Yes or ☐ No (check one) Perforations: From _____ ft. To _____ ft.

Date Sealing Performed _____

Comments/Reason for Sealing

CONTRACTOR

Name _____ ODH Registration # _____

Address _____

City/State/Zip _____

APPENDIX C
TGM CHAPTER 9, SEALING ABANDONED MONITORING WELLS AND BOREHOLES

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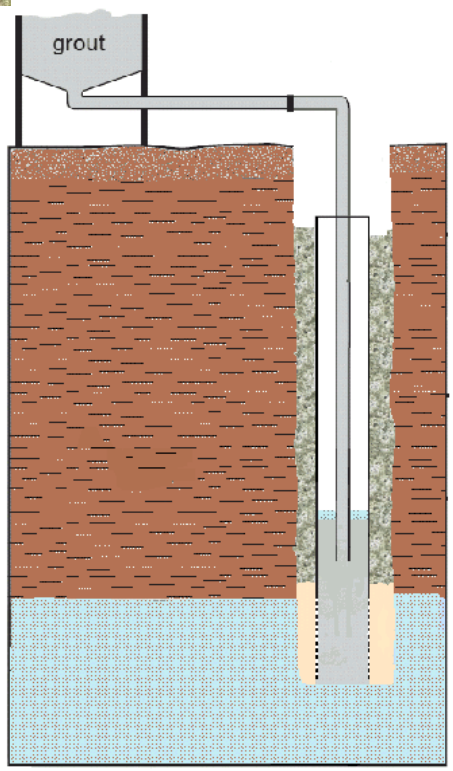
State of Ohio
Environmental Protection Agency

Division of Drinking and Ground Waters

Technical Guidance Manual for Ground Water Investigations

Chapter 9

Sealing Abandoned Monitoring Wells and Boreholes



February 2009

Governor : Ted Strickand
Director : Chris Korleski

TECHNICAL GUIDANCE MANUAL FOR GROUND WATER INVESTIGATIONS

CHAPTER 9

SEALING ABANDONED MONITORING WELLS AND BOREHOLES

October 2009
Revision 2

Ohio Environmental Protection Agency
Division of Drinking and Ground Waters
P.O. Box 1049 50 W. Town Street, Suite 700
Columbus, Ohio 43216-1049
Phone: 614-644-2752
http://www.epa.state.oh.us/ddagw/

PREFACE

The subject of this document is techniques to characterize hydrogeology beneath a site. It is part of a series of chapters incorporated in Ohio EPA's *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring* (TGM), which was originally published in 1995. DDAGW now maintains this guidance as a series of chapters rather than as an individual manual. These chapters can be obtained at http://www.epa.state.oh.us/ddagw/tgmweb.aspx.

The TGM identifies technical considerations for performing hydrogeologic investigations and ground water monitoring at potential or known ground water pollution sources. The purpose of the guidance is to enhance consistency within the Agency and inform the regulated community of the Agency's technical recommendations and the basis for them. In Ohio, the authority over pollution sources is shared among various Ohio EPA divisions, including the Emergency and Remedial Response (DERR), Hazardous Waste Management (DHWM), Solid and Infectious Waste (DSIWM), and Surface Water (DSW), as well as other state and local agencies. DDAGW provides technical support to these divisions.

Ohio EPA utilizes ***guidance*** to aid regulators and the regulated community in meeting laws, rules, regulations and policy. Guidance outlines recommended practices and explains their rationale. Note that the term implies no enforcement authority. The Agency may not require an entity to follow methods recommended by this or any other guidance document. It may, however, require an entity to demonstrate that an alternate method produces data and information that meet the pertinent requirements. Ohio EPA recognizes that inflexibility in the language and/or interpretation of guidance can lead to the adoption of inappropriate measures, delay, and inefficiency. The procedures used to meet requirements usually should be tailored to the specific needs and circumstances of the individual site, project, and applicable regulatory program, and should not comprise a rigid step-by-step approach that is utilized in all situations.

ACKNOWEDGMENTS

This guidance was developed by Ohio EPA's Division of Drinking and Ground Waters (DDAGW). The following are acknowledged.

Lisa Koenig, DDAGW-CO had primary responsibility for researching and writing this chapter in 1995 and completing this updated version.

Jeff Patzke, DDAGW-CO who served as editor and project coordinator the Technical Guidance Manual.

Jeff Martin, DDAGW-CO, **Rich Bendula**, DDAGW-SWDO, and **Ralph Baker**, DDAGW-NWDO, and **Eric Sainey**, DERR-CO provided technical input to the updated version.

The Ohio EPA would also like to thank the numerous people who provided input during the development of the 1995 document. The comments and recommendations from the DDAGW-District Offices, and other Ohio EPA Divisions, State and Federal Agencies, private consultants, and regulated community were greatly appreciated.

TECHNICAL CHANGES FROM FEBRUARY 2005

The Ohio EPA Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring (TGM) was finalized in 1995. This document represents an update to Chapter 9 (Monitoring Well and Borehole Abandonment) of the 1995 TGM.

No major changes were made. Some clarification was added for when disinfection of a well/borehole is needed prior to sealing.

TABLE OF CONTENTS

CHAPTER 9
SEALING ABANDONED MONITORING WELLS AND BOREHOLES

Boreholes that are not completed as monitoring wells and monitoring wells that no longer are being sampled or used for ground water level measurements are considered abandoned and should be sealed properly. Proper sealing is necessary to: 1) prevent poor quality water from one saturated zone entering another, 2) prevent contamination of the ground water by surface contaminants, 3) restore an aquifer to as close to its original condition as possible, 4) eliminate physical hazards, and 5) reduce potential for future liability. A suitable program should be designed and implemented to meet these objectives. This guidance document provides recommendations on sealing materials, procedures to appropriately seal an abandoned well/borehole and documentation of sealing activities. The sealing material and method depends on: 1) the design and construction of the well/borehole, 2) hydrogeologic conditions, 3) the chemical environment, 4) safety hazards and 5) disposal of contaminated materials removed. In general, sealing should consist either of a method for well removal and simultaneous grouting of the borehole with bentonite, neat cement, or a bentonite/cement mixture, or a method for grouting in-place that ensures complete sealing. Additional guidance on sealing of all types of wells can be found in the "State of Ohio Technical Guidance For Sealing Unused Wells" (SCCGW, 1996).

SEALING MATERIALS

The chosen sealing material should:

- Not react with contaminants, ground water, or geologic materials.
- Have a hydraulic conductivity comparable to or lower than the in-situ material.
- Form a tight bond with the borehole wall and well casing.
- Be resistant to cracking and/or shrinking.
- Be of sufficient structural strength to withstand subsurface pressures.
- Be capable of being placed at the appropriate depth.

Chapter 7 (Monitoring Well Design and Installation) should be consulted for details on different types of sealants and their application. No single material exhibits all of the desirable characteristics. Therefore, every situation should be evaluated carefully to determine the appropriate choice. Generally, materials used are comprised of concrete, neat cement, or sodium bentonite.

Most wells completed in unconsolidated formations or non-creviced rock may be satisfactorily sealed with neat cement or bentonite. Wells that penetrate limestone or other creviced or channeled rock formations should be filled with concrete grout or neat cement to ensure seal permanence. The use of fine-grained materials to seal creviced rock may not be desirable because the materials might be displaced by flow of water through crevices (American Water Works Association, 1984). Neat cement or sodium bentonite should be used for sealing an abandoned well/borehole below the water table (Gordon and Koch, 1988). Above the water table, bentonite should be utilized. Sodium bentonite chips or pellets placed above the water table require addition of water during sealing. Neat cement may shrink if placed above the water table.

A common sealing practice is to use a bentonite-cement mixture. Some have recommended a two to six weight percent of bentonite mixed with neat cement to reduce shrinkage. However, this may actually increase shrinking as it ties up water that would be incorporated in the cement. In addition, bentonite can not compensate for shrinkage, as much of the sodium associated with bentonite mixed into a cement slurry is replaced by calcium due to ion exchange. Calcium bentonite has little or no expansive capacity (Smith, 1994). Therefore, cement-bentonite sealants should be used with care (Christman et al., 2002; Edil et al., 1992).

At no time should a borehole or well be backfilled with cuttings or with any materials of unknown integrity. However, in some geologic environments, such as coarse gravel, where excessive loss of sealing materials may occur, or when grout may affect the water quality of nearby monitoring wells, clean sand or gravel or crushed rock in conjunction with regular materials can be used (Gordon and Koch, 1988; Kraemer et al., 1991).

PROCEDURES
PLANNING

Careful review should be conducted prior to sealing abandoning monitoring wells. This may include:

- Review of records pertaining to well construction and repair or modifications.
- Review of analytical chemical data for soil and ground water.
- Review of the hydrogeologic/geologic characteristics in the vicinity of the well.
- Current conditions of the well, such as, total depth, amount of siltation, etc.

If a well is to be left in place, borehole geophysical techniques may be helpful in determining its integrity. This may include caliper logs to measure inside diameter; television logs to identify casing breaks, screen size, etc.; gamma logs to verify geologic information; cement bond logs to determine if the casing is firmly attached to the grout; flow logs to determine if vertical flow occurs within the casing; and hydraulic integrity tests to determine if the casing is intact (ASTM, D5299-99). For additional information on downhole logs, see Chapter

Prior to the sealing of monitoring wells, it is recommended that a work plan detailing the procedures/methods be submitted to the appropriate regulatory authority.[1] The information should include:

- Reasons for sealing.
- Identification and location coordinates.
- Casing diameter and material.
- Screen material, length, and depth.
- Total depth.
- Geologic materials opposite well screen.
- Drilling log and construction diagrams.

---

[1]If a regulated entity is conducting a hydrogeologic investigation or a ground water monitoring program, a ~~well sealing~~ work plan should be submitted prior to initiating the program. In this situation, a separate workplan is not necessary.

- Type and concentrations of contaminants present[2], if any.
- Procedure for disposal of any contaminated media.
- Method for sealing.
- Type of sealing material.
- An estimation of the volume of sealing material needed.
- Measures to protect the health and safety of individuals.

FIELD PROCEDURE

Monitoring wells have often been sealed by pulling the surface casing where possible, followed by pouring cement or bentonite into the hole. This procedure is inappropriate, especially if the construction of the well is unknown or the well intake spans more than one saturated zone. Incomplete seals may form due to bridging. Additionally, the procedure has little effect on the filter pack, which may allow communication between saturated zones.

The following basic procedure is recommended for sealing monitoring wells and boreholes. Steps 1 and 2 are not necessary for sealing of exploratory boreholes. It should be understood that no single method and material are suitable for all situations. Site-specific characteristics may merit modifications or procedures not discussed below. Additional information can be found in the references listed.

1. Inspect the well and remove any obstacles (i.e., pumps, pressure lines, other debris, etc.) that may interfere with the placement and performance of the sealing material. If necessary, a camera survey can help to identify the depth and construction of the well if this information is not known. The outer protective casing should be removed.

2. When the annular seal is inadequate, the filter pack connects two or more water bearing zones, water is flowing from around the outside of the casing, or when construction details are not known, the casing, screen, annular seal and filter pack should be removed. The casing and well screen can be removed by pulling or bumping the casing, overdrilling around the casing using a hollow stem auger, or drilling out the well using a solid stem auger or rotary bit (see Table 9.1). The method used should depend on the type, length, and diameter of the casing, conditions of the annular seal, and site geology. Aller et al. (1991) and ASTM 5299-99 provided a discussion on various removal techniques. The borehole should be overdrilled using a bit with a diameter at least 1.5 times greater than the original diameter of the borehole. Drilling should be slightly deeper than the original depth to assure complete removal. To achieve an effective seal, the borehole should be cleared of any excess mud filtercake.

   In some instances, such as when safety problems occur or when dealing with large diameter wells, casing removal can be difficult. If circumstances prevent complete removal of casing and screen, then the following procedure can be used (based on Renz, 1989):

[2]If contamination was detected or suspected in the original well or boring, appropriate health and safety requirements should be followed.

a. The well can be filled with clean (ANS/NSF 61[3]) disinfected sand to one foot above the screen in the event that the screened area is adjacent to a highly permeable formation.

b. One foot of bentonite chips/pellets can be placed above the screen in a manner that prevents bridging (i.e., through a tremie pipe or by tamping after installation). (Note: Chips are recommended below the water table because they will sink, whereas pellets will often float to the water table.)

c. The chips/pellets should be hydrated, if placed above the water table.

d. To allow the sealant to permeate and be effective, the casing should be perforated to one foot above the bentonite seal either by splitting it vertically (synthetic casing) or by making horizontal cuts every two feet with a retractable blade (steel casing).

Since the primary purpose of sealing is to eliminate vertical fluid movement, it is recommended that the casing and screen be removed and the boring be overdrilled to remove the annular seal and filter pack. However, monitoring wells can be sealed in-place when the construction details are known, the annular seal is intact, and the filter pack does not cross more than one ground water zone.

Table 9.1 Techniques for casing removal.

TECHNIQUE	***METHOD***
Pulling or bumping	Use a rig to pull out the well casing; this may be appropriate only for steel casing since plastic/Teflon casing may break.
Overdrilling	Drill around the well using the well casing as a guide, then pull out the casing. This method is limited by well diameter due to the high torque required to turn large diameter augers.
Drilling through well	Use a solid stem or rotary bit to drill the casing out. This can be done only with plastic/Teflon well material. It can be difficult to retrieve the cutting.

3. Where evidence of microbiological growth is present, a monitoring well may need to be disinfected. However, before disinfecting, an evaluation as to whether this would affect water quality monitoring results in the proximity should be made.

   When needed, wells should be disinfected by slowly wetting the circumference of the well/borehole with the disinfection solution by using a tremie pipe starting from the bottom

[3] NSF/ANSI Standard 61: Drinking Water System Components -- Health Effects are both American National Standards, which means that the NSF Standards and the processes used to develop them conform to ANSI's requirements for voluntary consensus standards (http://www.nsf.org/business/water_distribution/standards.asp?program=WaterDistributionSys).

of the well and working upwards to assure that all sides are wetted by the solution. The solution should be well mixed within the well/borehole and purged before sealing with grout. Contact of disinfectant with bentonite should be avoided. The bentonite grout will not seal properly if it comes into contact with the disinfection solution. The disinfectant should:

- Have a concentration in the water column of approximately fifty milligrams per liter (mg/L) total chlorine, but no more than 100 mg/L.

- Have standard ANSI/NSF 60 certification. Standard ANSI/NSF 60 refers to "Standard ANSI/NSF 60, Drinking Water Treatment Chemicals - Health Effects", February 9, 2001, Document Number NSF/ANSI 60-2001 (NSF Web Site).

4. The borehole should be pressure grouted using a tremie pipe as the drilling stem is removed. The sealant should be applied in one continuous procedure to prevent segregation, dilution, and bridging (Aller et al., 1991). The pipe should be in constant contact with the sealant to prevent air pockets from forming. The borehole should be sealed from the bottom up to the frost line (approximately two to three feet from the surface). The overflowing grout should be regularly evaluated as it reaches the surface. When the observed material is similar to that being pumped in, this stage of the sealing is considered complete. Wells sealed in-situ should be sealed from the bottom up to approximately three feet from the surface.

   Small diameter wells or boreholes (<2 inches) may present special challenges. A small diameter (3/4 inch) grout pipe can be used; however, high pumping pressures or less viscous materials may be necessary (ASTM D5299). Grouting machines are available for use with small diameter wells. A grouting machine reduces problems of bridging and incomplete seals associated with adding materials from the ground surface.

   When sealing wells that have two or more saturated zones or in flowing wells, it may be necessary to use a packer assembly. An inflatable packer can be placed at the top of the producing water zone to stop or restrict flow. The borehole can be sealed by pressure grouting from the bottom of the hole to the top of the packer. The packer can then be deflated and the grouting process continued.

   If dry sealant is introduced by gravity pouring, care must be taken that bridging does not occur. This can be accomplished by slowly adding the grout and stopping periodically (e.g., every five feet) to measure, tamp the grout and add water to hydrate. The amount of added water should be in accordance with manufacturer specifications. Coarse grade or bentonite pellets should be poured over a wire mesh to remove fines.

5. The grout plug should be inspected 24 hours after installation to check for settling; grout should be added if needed. If the well is sealed in-place, the casing should be cut off approximately three feet below ground level and a PVC or stainless steel cap should be emplaced. The boring should be grouted to within two to three feet from the surface with appropriate material. Monitoring wells sealed in-place should be marked with a piece of metal to allow for location by a metal detector or magnetometer (Aller et al., 1991).

6. The remaining area above the plug should be completed in a manner that is compatible with the site. For example, its top can be covered with one to two feet of soil if vegetative growth is desired. If the area is to be surfaced, then the final seal can be completed with cement or concrete.

7. Proper sealing of monitoring wells/boreholes should be documented and reported to the Ohio EPA division regulating the site. The information should include, at a minimum:

   Identification (e.g., registration number, location, owner, and any other features).

   - Well construction details.
   - Date, time, person responsible, and contractor/consultant performing the work.
   - Authority under which sealing was performed.
   - Procedures and materials used (including predicted volume of grout, volume of grout used, and an explanation if any discrepancy exists between these values).
   - Method/procedures for disposal of any contaminated materials. (Disposal of any contaminated material must be in accordance with any federal, state, or local regulations.)

Additionally, Ohio Revised Code 1521.05(B)(9) requires that a well sealing report be filed with the Ohio Department of Natural Resources (ODNR). Figure 9.1 is an example of the form. It can be obtained from ODNR, Division of Water (614-265-6739).

WATER WELL SEALING REPORT
(For Abandoned or Unused Wells)
OHIO DEPARTMENT OF NATURAL RESOURCES
Division of Water, Ground Water Resources Section
1939 Fountain Square Drive
Columbus, Ohio 43224-1360

LOCATION

County _____ Township _____ Section _____
Property Owner _____
Address of Property _____
Location: _____ miles _____ (n, e, s, w) of _____ (nearest intersection)
on the _____ (n, e, s, w) side of _____ (road name)

ORIGINAL WELL

ODNR Well Log Number _____ Copy attached? Yes or No (circle one)

MEASURED CONSTRUCTION DETAILS Date of measurements _____

Depth of Well _____ Static Water Level _____
Size of Casing _____ Length of casing _____
Well Condition _____

SEALING PROCEDURE

Method of Placement _____

			Sealing Material	Volume
Placement:	From _____	To _____	_____	_____
	From _____	To _____	_____	_____
	From _____	To _____	_____	_____

Was Casing Removed? Yes or No (circle one)
Condition of Casing _____
Perforations: From _____ To _____
From _____ To _____
Date Sealing Performed _____
Reason(s) for Sealing _____

CONTRACTOR

Name _____ ODH Registration # _____
Address _____
City/State/Zip _____ Signature _____

DNR 7810.93 **SUBMIT COMPLETED FORM TO ODNR-DIVISION OF WATER**

Figure 9.1 ODNR form for reporting well abandonment procedures.

(Contact ODNR, Division of Water for Form. 614-265-6739).

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APPENDIX D
WELL ABANDONMENT ACCESS ROUTES

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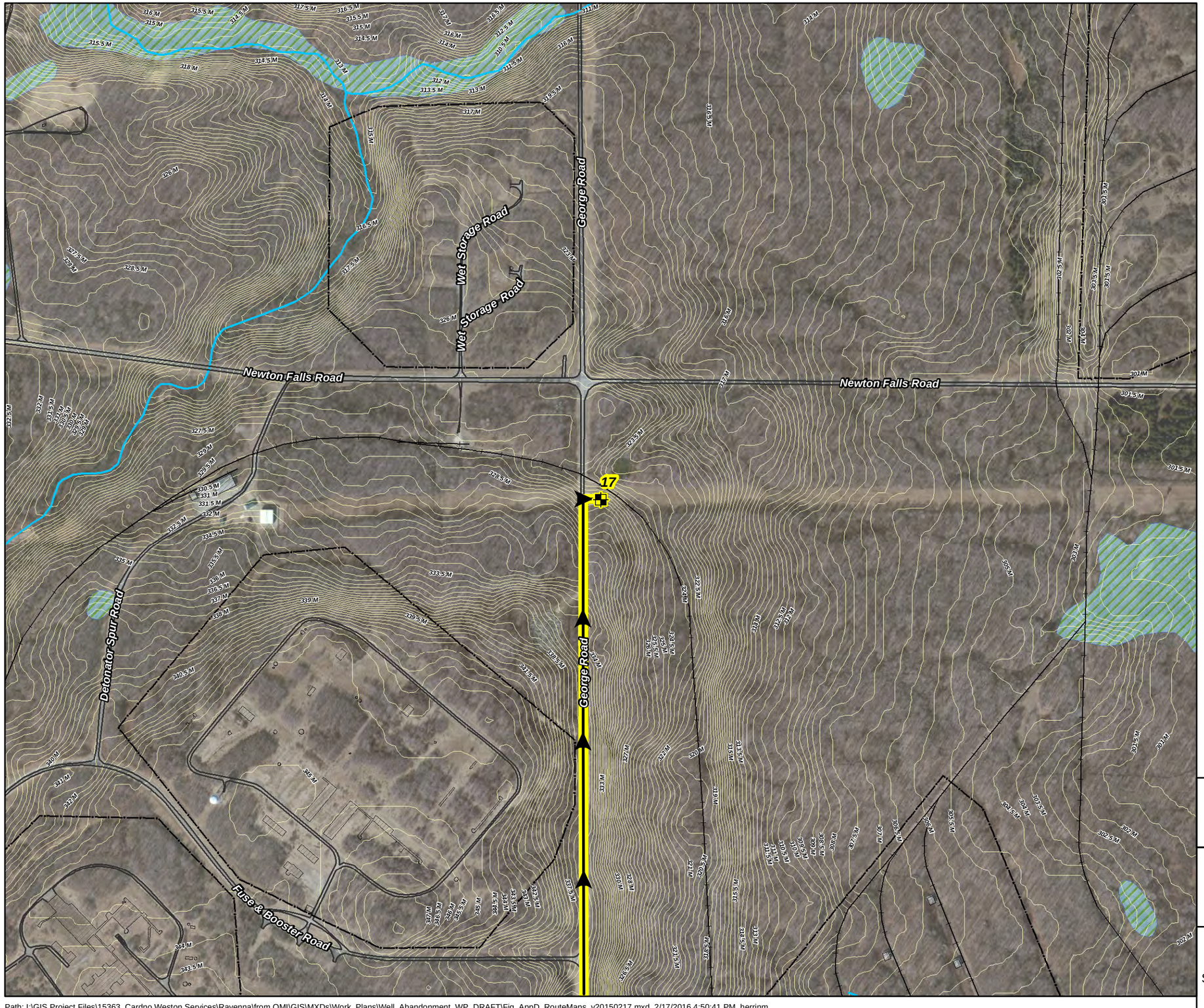

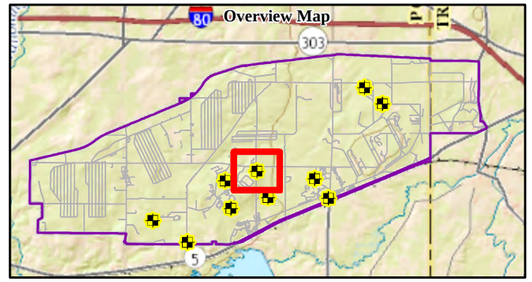

Legend

- Former Groundwater Production Well to be Abandoned by JV Team
- Proposed Route
- Elevation Contour Line (0.5m from USDA)
- Fenceline
- Railroad
- Roads
- Streams
- Water Bodies
- Wetland Area (from the National Wetland Inventory)
- Site Specific Wetland Areas
- Buildings
- Camp Ravenna Property Line

Notes:
- Preferred route will be identified with OHARNG natural resource manager.
- Basemap Source: ESRI Map Service - USGS National Map

N

0 250 500 750 1,000 Feet

1:6,000
NAD83 UTM Zone 17N

TEC-Weston Joint Venture

GROUNDWATER PRODUCTION WELLS ACCESS PATH - #17

Groundwater and Environmental Investigation Services for RVAAP-66 Facility-wide Groundwater
Former RVAAP/Camp Ravenna
Ravenna, Ohio

Figure: D-1

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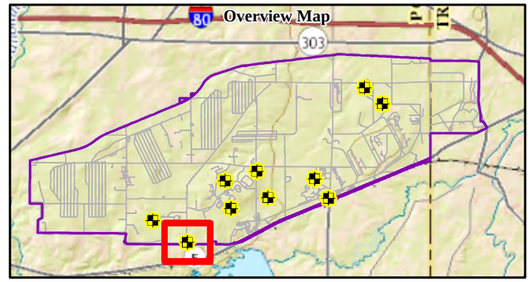

Legend

- Former Groundwater Production Well to be Abandoned by JV Team
- Proposed Route
- Elevation Contour Line (0.5m from USDA)
- Fenceline
- Railroad
- Roads
- Streams
- Water Bodies
- Wetland Area (from the National Wetland Inventory)
- Site Specific Wetland Areas
- Buildings
- Camp Ravenna Property Line

Notes:
- Preferred route will be identified with OHARNG natural resource manager.
- Basemap Source: ESRI Map Service - USGS National Map

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NAD83 UTM Zone 17N

TEC-Weston Joint Venture

GROUNDWATER PRODUCTION WELLS ACCESS PATH - #18

Groundwater and Environmental Investigation Services for RVAAP-66 Facility-wide Groundwater
Former RVAAP/Camp Ravenna
Ravenna, Ohio

Figure: D-2

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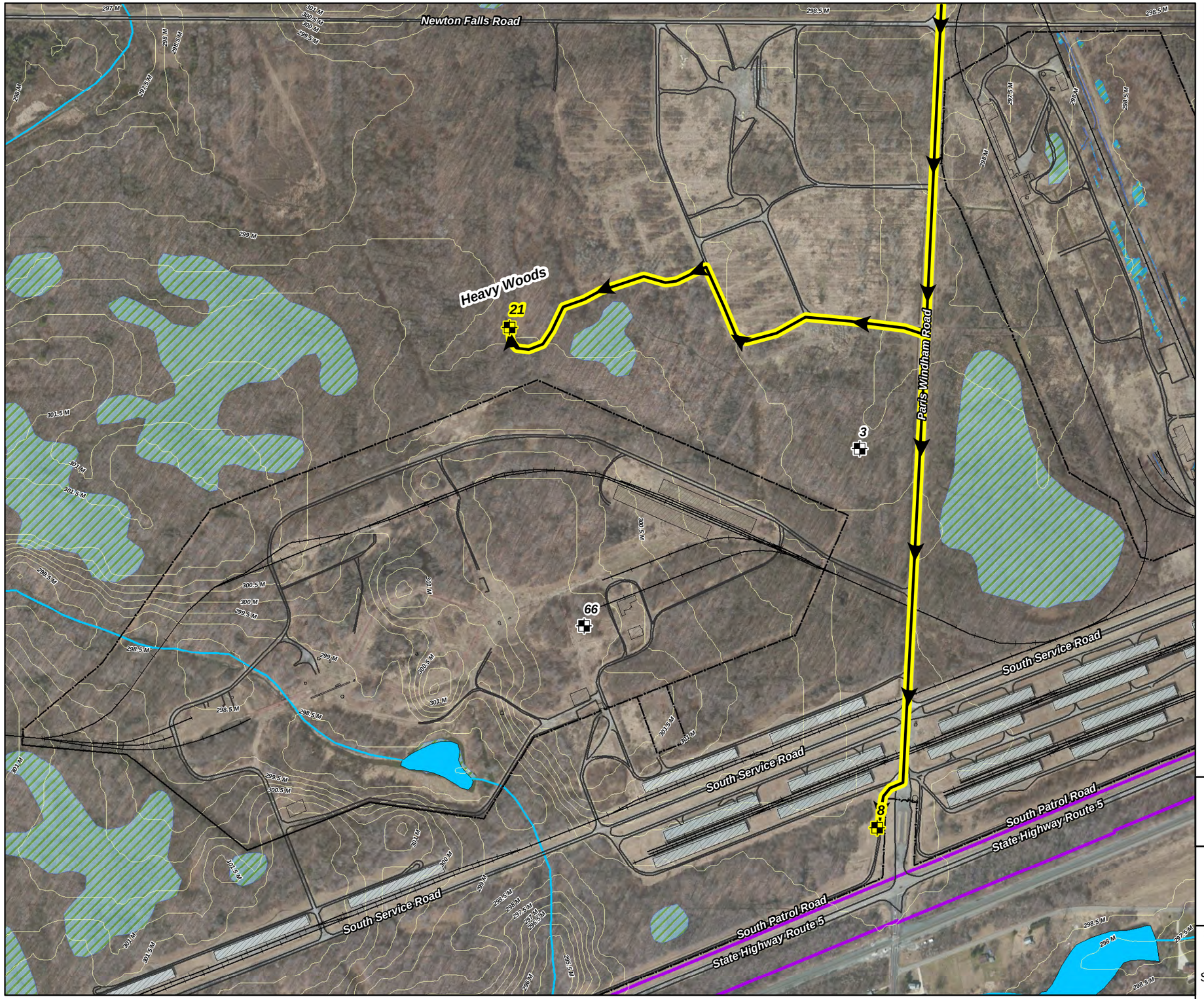

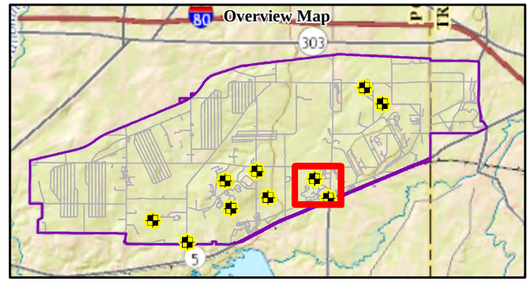

Legend

- Former Groundwater Production Well to be Abandoned by JV Team
- Former Groundwater Production Well to be Abandoned by Others
- Proposed Route
- Elevation Contour Line (0.5m from USDA)
- Fenceline
- Railroad
- Roads
- Streams
- Water Bodies
- Wetland Area (from the National Wetland Inventory)
- Site Specific Wetland Areas
- Buildings
- Camp Ravenna Property Line

Notes:
- Preferred route will be identified with OHARNG natural resource manager.
- Basemap Source: ESRI Map Service - USGS National Map

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Cardno TEC | WESTON SOLUTIONS
TEC-Weston Joint Venture

GROUNDWATER PRODUCTION WELLS ACCESS PATH - #8 AND #21
Groundwater and Environmental Investigation Services for RVAAP-66 Facility-wide Groundwater
Former RVAAP/Camp Ravenna
Ravenna, Ohio

Figure: D-3

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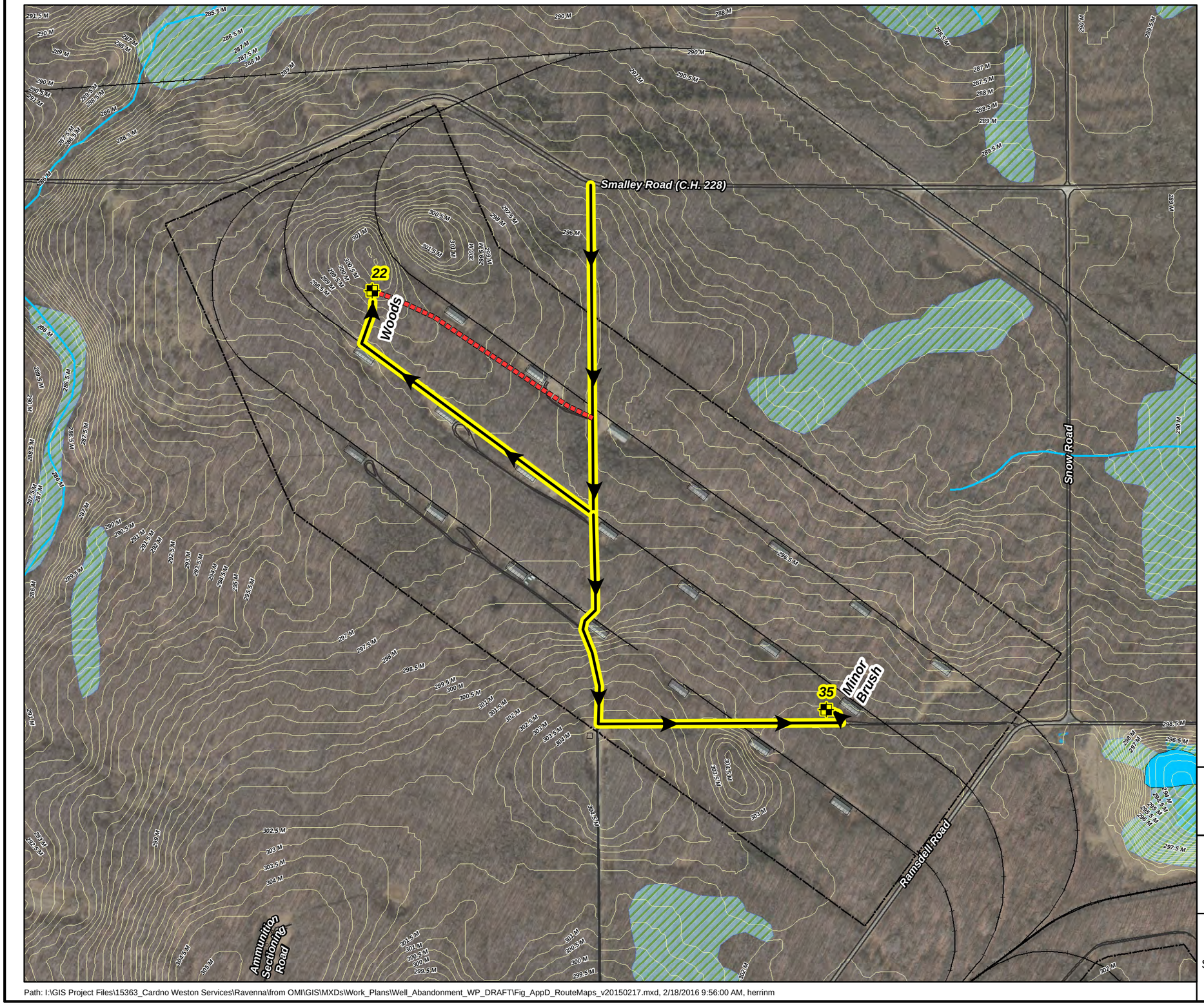

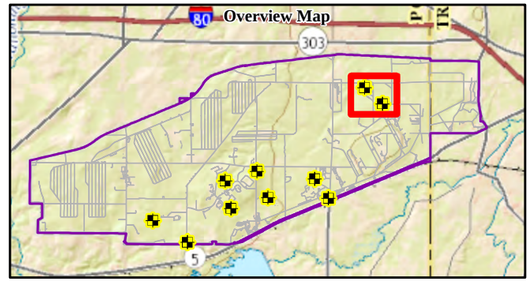

Legend

- Former Groundwater Production Well to be Abandoned by JV Team
- Proposed Route
- Potential Alternate Access
- Elevation Contour Line (0.5m from USDA)
- Fenceline
- Railroad
- Roads
- Streams
- Water Bodies
- Wetland Area (from the National Wetland Inventory)
- Site Specific Wetland Areas
- Buildings
- Camp Ravenna Property Line

Notes:
- Preferred route will be identified with OHARNG natural resource manager.
- Basemap Source: ESRI Map Service - USGS National Map

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NAD83 UTM Zone 17N

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GROUNDWATER PRODUCTION WELLS ACCESS PATH - #22 AND #35

Groundwater and Environmental Investigation Services for RVAAP-66 Facility-wide Groundwater
Former RVAAP/Camp Ravenna
Ravenna, Ohio

Figure: D-4

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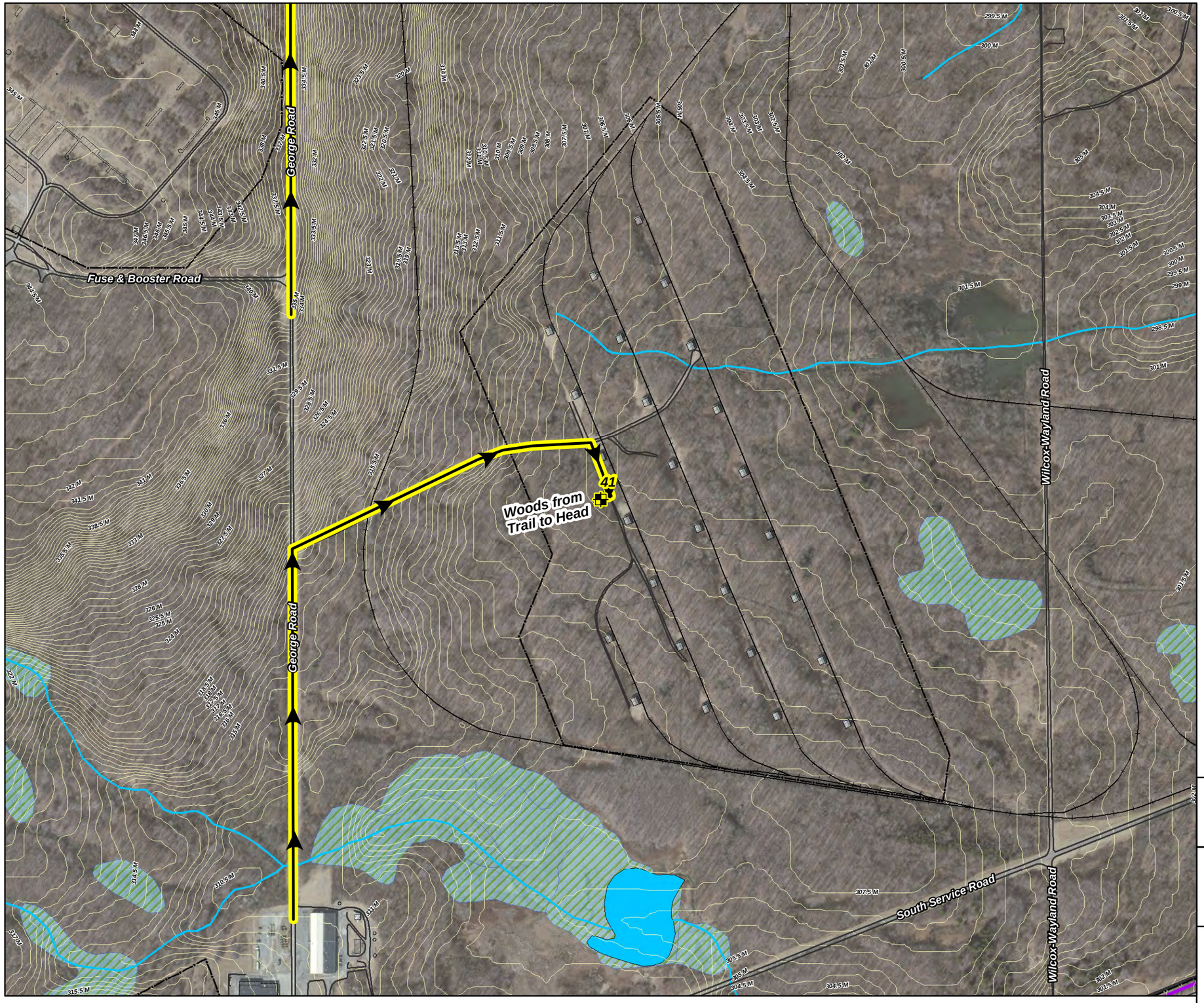

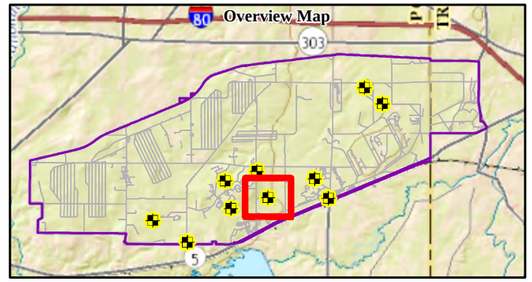

Legend

- Former Groundwater Production Well to be Abandoned by JV Team
- Proposed Route
- Elevation Contour Line (0.5m from USDA)
- Fenceline
- Railroad
- Roads
- Streams
- Water Bodies
- Wetland Area (from the National Wetland Inventory)
- Site Specific Wetland Areas
- Buildings
- Camp Ravenna Property Line

Notes:
- Preferred route will be identified with OHARNG natural resource manager.
- Basemap Source: ESRI Map Service - USGS National Map

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TEC-Weston Joint Venture

GROUNDWATER PRODUCTION WELLS ACCESS PATH - #41

Groundwater and Environmental Investigation Services for RVAAP-66 Facility-Wide Groundwater Former RVAAP/Camp Ravenna Ravenna, Ohio

Figure: D-5

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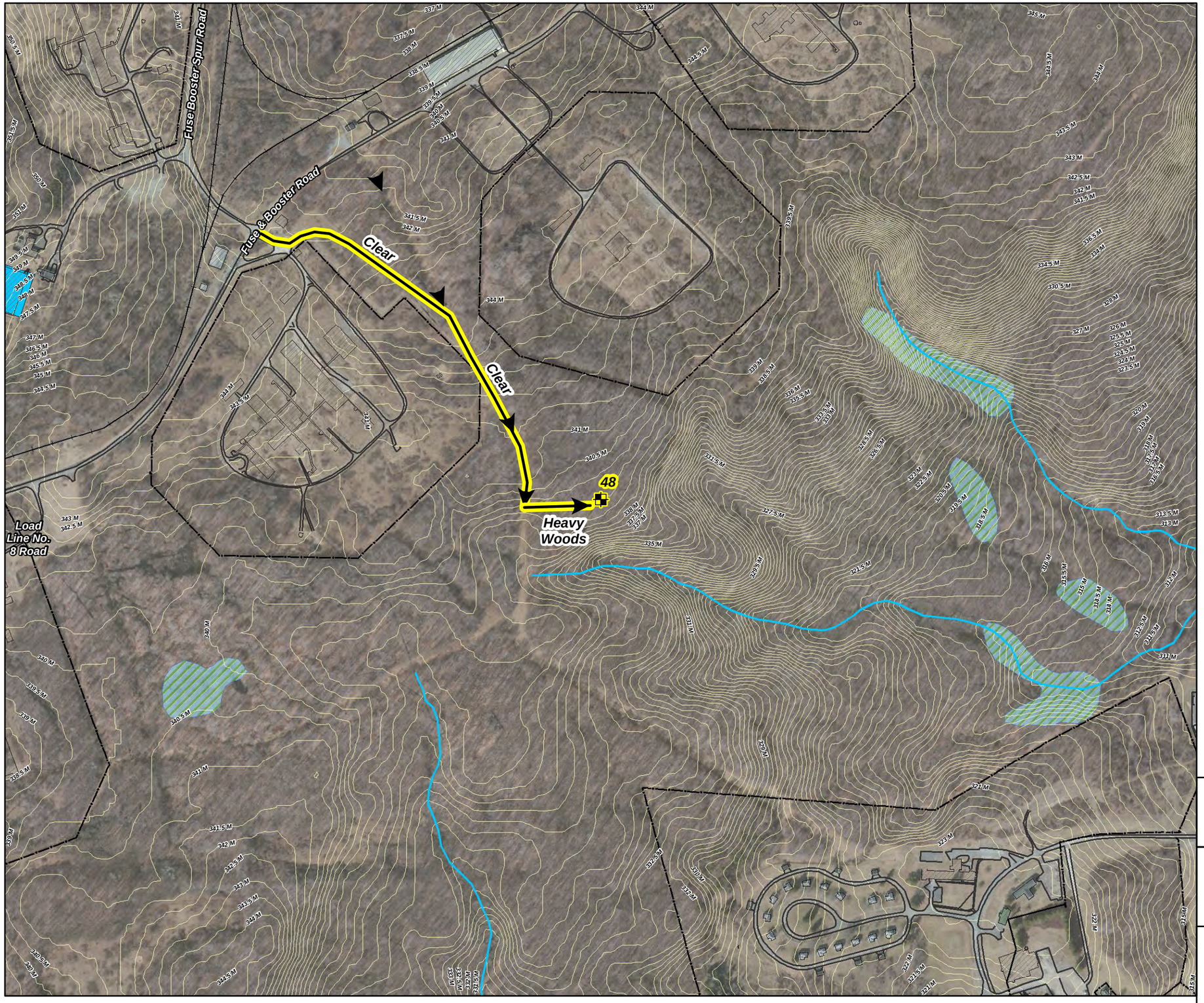

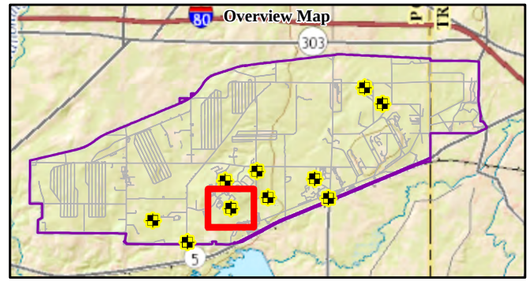

Legend

- Former Groundwater Production Well to be Abandoned by JV Team
- Proposed Route
- Elevation Contour Line (0.5m from USDA)
- Fenceline
- Railroad
- Roads
- Streams
- Water Bodies
- Wetland Area (from the National Wetland Inventory)
- Site Specific Wetland Areas
- Buildings
- Camp Ravenna Property Line

Notes:
- Preferred route will be identified with OHARNG natural resource manager.
- Basemap Source: ESRI Map Service - USGS National Map

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NAD83 UTM Zone 17N

TEC-Weston Joint Venture

GROUNDWATER PRODUCTION WELLS ACCESS PATH - #48

Groundwater and Environmental Investigation Services for RVAAP-66 Facility-Wide Groundwater Former RVAAP/Camp Ravenna Ravenna, Ohio

Figure: D-6

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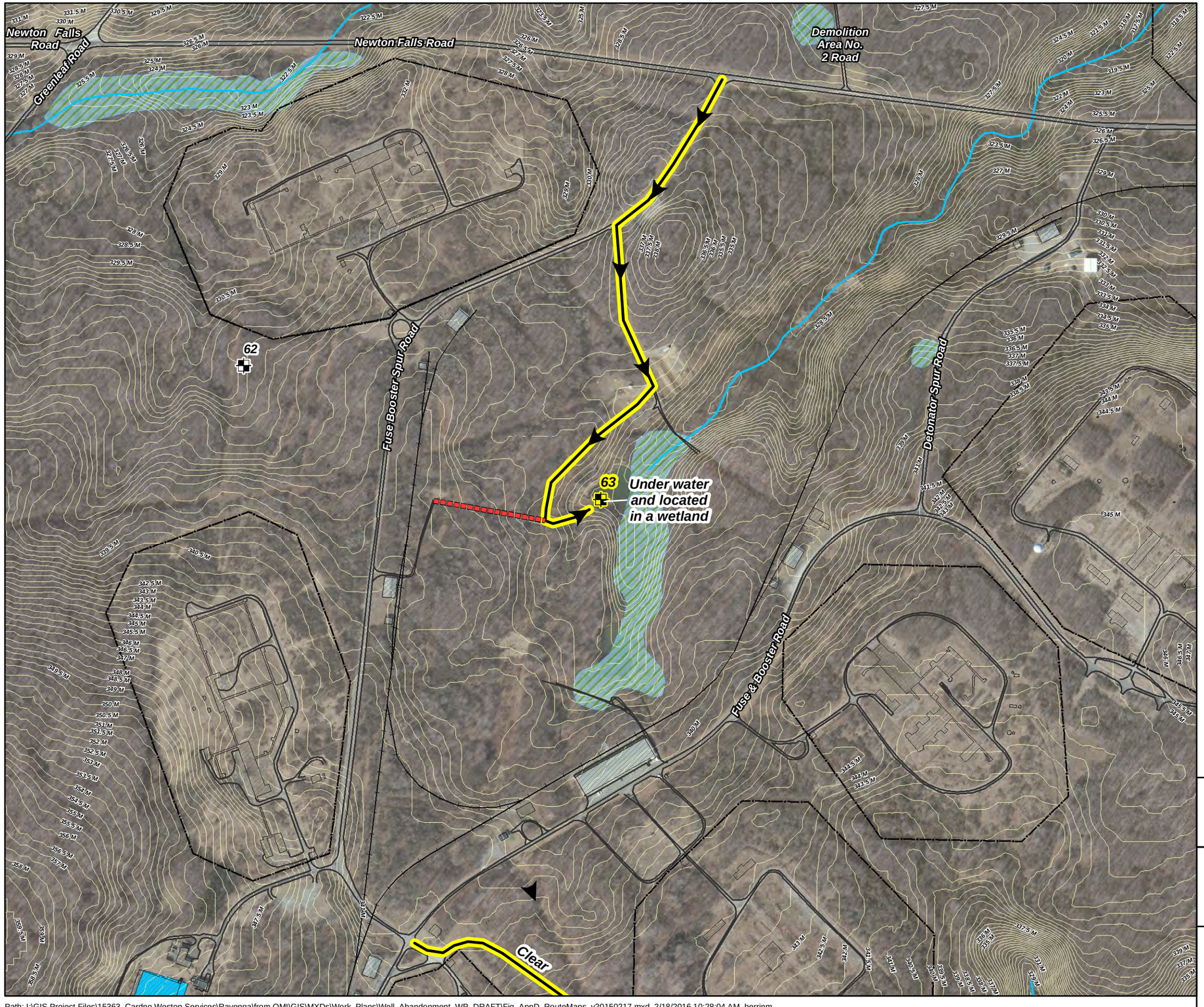

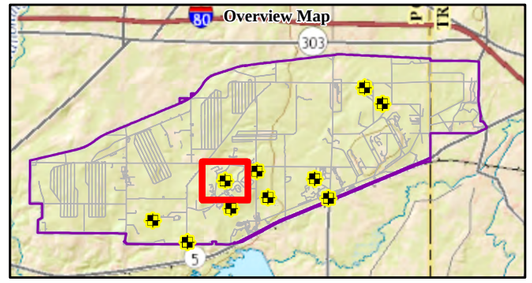

Legend

- Former Groundwater Production Well to be Abandoned by JV Team
- Former Groundwater Production Well to be Abandoned by Others
- Proposed Route
- Potential Alternate Access
- Elevation Contour Line (0.5m from USDA)
- Fenceline
- Railroad
- Roads
- Streams
- Water Bodies
- Wetland Area (from the National Wetland Inventory)
- Site Specific Wetland Areas
- Buildings
- Camp Ravenna Property Line

Notes:
- Foot Traffic only in Wetland
- Preferred route will be identified with OHARNG natural resource manager.
- Basemap Sources: ESRI Map Services - World_Imagery and USGSTopo

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GROUNDWATER PRODUCTION WELLS ACCESS PATH - #63

Groundwater and Environmental Investigation Services for RVAAP-66 Facility-Wide Groundwater Former RVAAP/Camp Ravenna
Ravenna, Ohio

Figure: D-7

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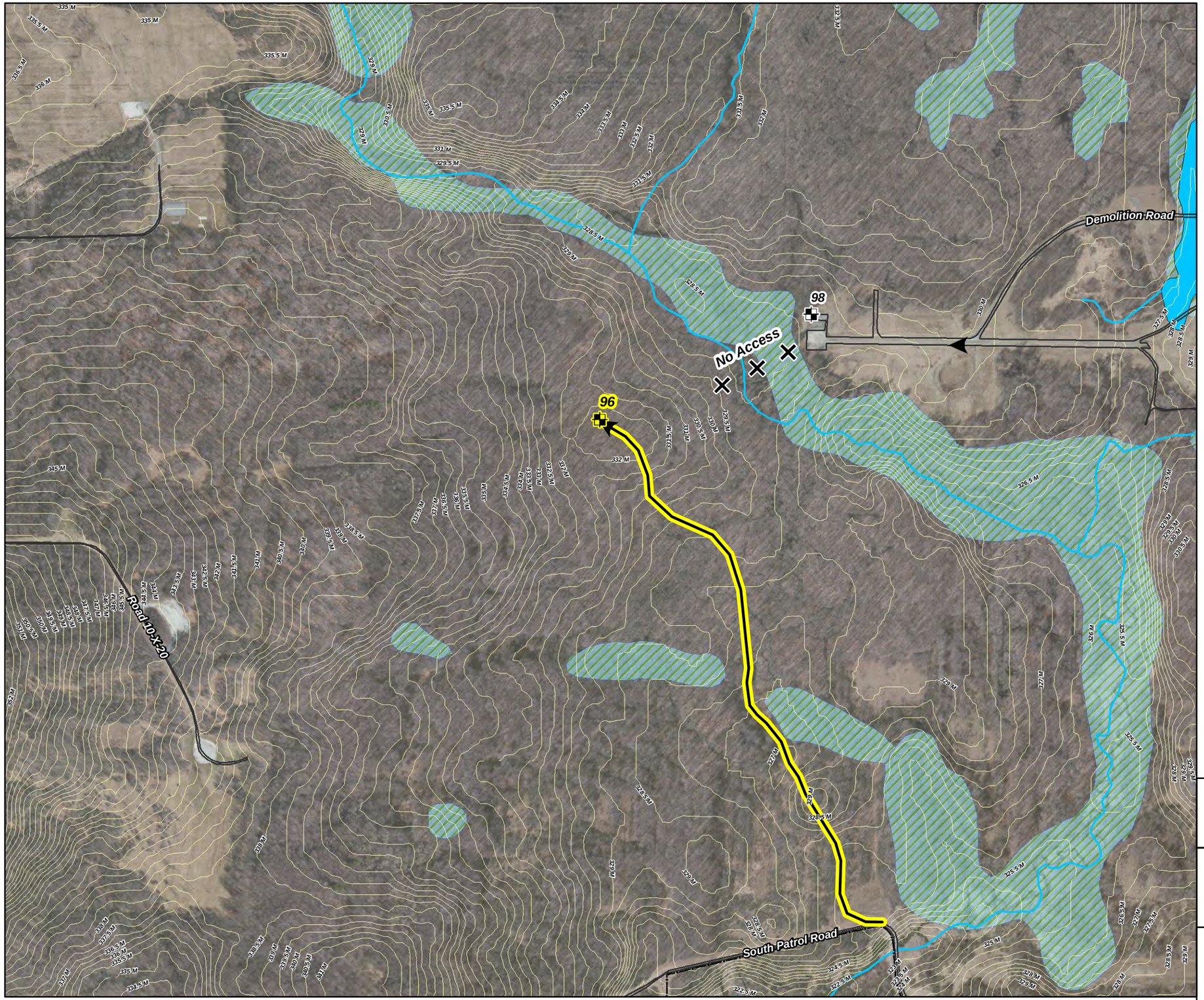

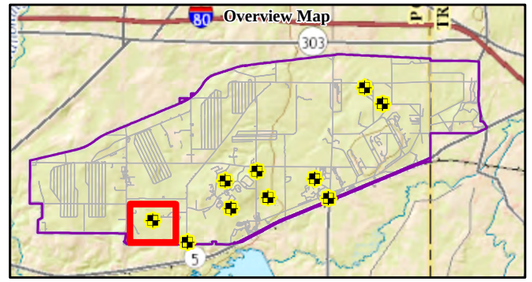

Legend

- Former Groundwater Production Well to be Abandoned by JV Team
- Former Groundwater Production Well to be Abandoned by Others
- Proposed Route
- Elevation Contour Line (0.5m from USDA)
- Fenceline
- Railroad
- Roads
- Streams
- Water Bodies
- Wetland Area (from the National Wetland Inventory)
- Site Specific Wetland Areas
- Buildings
- Camp Ravenna Property Line

Notes:
- Preferred route will be identified with OHARNG natural resource manager.
- Basemap Source: ESRI Map Service - USGS National Map

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NAD83 UTM Zone 17N

TEC-Weston Joint Venture

GROUNDWATER PRODUCTION WELLS ACCESS PATH - #96

Groundwater and Environmental Investigation Services for RVAAP-66 Facility-Wide Groundwater Former RVAAP/Camp Ravenna Ravenna, Ohio

Figure: D-8

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APPENDIX E
CAMP RAVENNA JOINT MILITARY TRAINING CENTER CONTRACTOR GUIDELINES

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OHARNG Procedures for Inadvertent Discovery of Cultural Materials at Camp Ravenna Joint Military Training Center (taken from OHARNG ICRMP and modified for CRJMTC)

Contact(s): Kim Ludt, OHARNG Cultural Resources Manager, 614-336-6569
(Alternate contact, CRJMTC Environmental Office, 614-336-6568/6136)
CRJMTC Range Control 614-336-6041 or MARCS radio Channel #1

Scope: This Standard Operating Procedure (SOP) outlines the steps to be taken upon inadvertent discovery of human remains or artifacts at Camp Ravenna Joint Military Training Center (CRJMTC) during construction, demolition, training events, or other ground disturbing activities. If archaeological surveys or excavations become necessary as a result of the inadvertent discovery, they must be conducted by a person meeting the Secretary of Interior's professional qualification standards for archaeology. Anyone who does not meet these standards and engages in any excavations, including probing during metal detecting, shall be considered to be looting the cultural resources of CRJMTC and subject to prosecution under ARPA. This SOP is intended for all OHARNG personnel, contractors and users of CRJMTC.

Statutory Reference(s):

- Native American Graves Protection and Repatriation Act (NAGPRA) and its implementing regulation (43 CFR 10)
- Archaeological Resources Protection Act (ARPA)
- National Historic Preservation Act (NHPA) and its implementing regulation (36 CFR 800).

Procedures: In the event that artifacts or human remains are encountered, the ground disturbing activity should stop immediately and the following steps should be followed.

- Report any observations or discoveries of artifacts or human remains immediately to CRJMTC Range Control (614-336-6041 or MARCS radio Channel #1). Range Control will immediately notify the OHARNG Cultural Resources Manager (CRM)/CRJMTC Environmental Office.
- The Range Control or the CRM will secure any artifacts or human remains, as appropriate. If human remains are suspected, they are not to be disturbed and Range Control will promptly notify Ohio State Highway Patrol or Federal Bureau of Investigation, as appropriate.
- The CRM and Range Control will take measures to protect the location from further disturbance until appropriate parties are notified.
- If a concentration of artifacts or a burial site is identified as the source of materials discovered, the CRM will make arrangements for site recordation and stabilization, in consultation with the OHPO and any interested Native American tribes.
- Once the site has been cleared by the CRM and CRJMTC Range Control, the activity may resume. Depending on the findings, activities may be cleared to resume in 48 hours or up to 6 months.

THE ADJUTANT GENERAL'S DEPARTMENT
CAMP RAVENNA JOINT MILITARY TRAINING CENTER
1438 State Route 534 SW
Newton Falls, OH 44444

2 April 2014

RE: Camp Ravenna/Former Ravenna Army Ammunition Plant (RVAAP)
Portage and Trumbull Counties, Ohio
Update to Procedures to Follow as Related to the RVAAP Restoration Program due to the Accountability Transfer of the Remaining Property from BRACD to the ARNG/OHARNG

To: RVAAP Restoration Program Stakeholders and Contractors

Accountability for the remaining acreage of the former RVAAP has been transferred from the Base Realignment and Closure Division (BRACD) to the United States Property and Fiscal Office (USP&FO) for Ohio. The entire facility (all acreage) is now part of Camp Ravenna and licensed to the Ohio Army National Guard (OHARNG) for use as a military training site. With this transition, the OHARNG/Army National Guard (ARNG) has assumed responsibility for management of the RVAAP restoration program. The RVAAP restoration program is now part of the larger OHARNG environmental program, and as such, needs to be synchronized with the OHARNG environmental program requirements and Camp Ravenna operational policies and procedures. This letter is to advise you of the environmental program and operational policies and procedures applicable to you as an Army stakeholder and/or contractor involved in the RVAAP restoration program. Our hope is to facilitate a smooth transition. Items addressed in this letter include the following:

- Access procedures to Camp Ravenna/former RVAAP;
- Emergency/Spill procedure for Camp Ravenna/former RVAAP;
- Waste management procedures at Camp Ravenna/former RVAAP;
- Hazardous materials management procedures at Camp Ravenna/former RVAAP;
- Use of Building 1036 and job trailers at Camp Ravenna/former RVAAP;
- Revision to the general facility description in restoration documents; and
- Revisions to shipping address and document distribution.

1. <u>Access Procedures for Camp Ravenna/Former RVAAP</u>

The protocol for access is developed and implemented by the Camp Ravenna headquarters staff and may change depending upon the security level. The current procedure for restoration Army stakeholders, contractors, the Ohio Environmental Protection Agency (Ohio EPA), and any other restoration related visitors to Camp Ravenna is provided in Attachment A and summarized below.

- Request access to Camp Ravenna through Vista Sciences (Rebecca Haney, cc Gail Harris, Al Brillinger) at least 48 hours in advance on the access request form.
- Vista Sciences will confer with the Camp Ravenna Environmental Office (CR-ENV) to confirm the access request is valid.
- Vista Sciences will forward the access request form to the appropriate Camp Ravenna military security staff for approval.

- Camp Ravenna military security staff will approve or deny the request and forward it back to Vista Sciences. If approved, the Camp Ravenna military security staff will send the access form to the applicable gate at Camp Ravenna.
- Vista Sciences will inform access request submitter that the request has been approved.

At no time will contractors be granted access without prior approval by the Camp Ravenna Operations Office. Contractor work schedules must coincide with Camp Ravenna duty days and hours (Monday through Friday, 7:30AM-4:30PM). Extended work schedules must be approved by the Camp Ravenna Environmental Office (Restoration Program and/or Environmental Supervisor) and coordinated and approved by Operations, at least 48 hours prior to the intended start date. Federal holidays will not be approved as a normal work days. Please note: Any work outside of normal duty hours, weekends or holidays must be preapproved by Camp Ravenna.

2. Emergency/Spill Procedure for Camp Ravenna/Former RVAAP

The protocol for emergency procedures is developed and implemented by the Camp Ravenna headquarters staff. The procedure for spills at Camp Ravenna is developed and implemented by the Camp Ravenna Environmental Office in coordination with the Camp Ravenna headquarters staff and in accordance with latest version of the Camp Ravenna Integrated Contingency Plan (ICP or Spill Plan). Please note that the Camp Ravenna ICP/Spill Plan was updated and finalized in January 2014. The current procedure for Army stakeholders, contractors, the Ohio EPA, and any other restoration related visitors to Camp Ravenna is summarized below.

- In the event of an emergency or spill, contact Camp Ravenna Range Control at (614)336-6041.
- Range Control will contact the applicable emergency services which will be dispatched from Trumbull or Portage County depending on the location of the emergency.
- For spills (any time), follow the procedure and telephone notification on the Camp Ravenna First Responder form provided in Attachment B.
- For non-spill emergencies outside Camp Ravenna regular duty hours, dial 911 and ask for the Ravenna, Ohio emergency dispatch.

3. Waste Management Procedures for Camp Ravenna/Former RVAAP

All waste generated by the restoration program will now be managed by the OHARNG (Camp Ravenna Environmental Office). Katie Tait, with support from Vista Sciences (Brad Kline), will be the main contacts for the waste program at Camp Ravenna. Due to the transition from BRACD to OHARNG, procedures for waste management at the facility have changed. Changes are summarized below.

- All waste must be managed in accordance with the Camp Ravenna Waste Management Guidelines- Restoration Waste (see Attachment C)
- All waste must be inspected by the contractor who generated the waste on a weekly basis using the Camp Ravenna Waste Inspection form. Inspection forms must be submitted to Brad Kline (with cc to Katie Tait) on a weekly basis. If the contractor chooses to use Vista for weekly waste inspections, the contractor must work out the logistics and details with Vista including payment for services. Weekly waste inspections for contractor waste is not a government funded task under the Vista support contract.
- All waste profiles must be reviewed and signed by Katie Tait. The alternate for signature (in Katie Tait's absence) is Tim Morgan.
- All manifests must be reviewed and signed by Katie Tait prior to any waste leaving the facility. The alternate for signature is Tim Morgan or Kevin Sedlak (nonhazardous waste only).

- A waste sample must be collected within 10 days of generation of any waste. Analytical results for all waste must be submitted to the OHARNG/ARNG (Katie Tait, Kevin Sedlak) and Vista Sciences (Brad Kline) as soon as received by the contractor. Waiting to submit the analytical results with the IDW report is not acceptable (too much time elapses between sampling and IDW report generation and we must be expedient if the waste is determined to be hazardous).
- All hazardous waste must be removed from the facility within 90 days of generation and all nonhazardous waste must be removed from the facility within 120 days of generation. Any other disposal timeframes must be discussed and approved by the Camp Ravenna Environmental Office.
- A drum label in accordance with the Facility-wide Sampling and Analysis Plan (FWSAP) must be used to label the drum/container prior to sampling and as soon as waste is added to the drum/container. A Pending Analysis label may be used after a waste sample is collected. Use of a Pending Analysis label shall not exceed 20 days. An applicable waste label must be placed on waste containers within 7 days (1 week) of receiving the analytical results determining the waste type.
- All contractor waste must be staged at Building 1036 (nonhazardous) or Building 1047 (hazardous). All other waste storage locations must be approved by the Camp Ravenna Environmental Office prior to use.
- All empty drums that are not in use must be properly labeled as 'Empty'.
- Contractor waste stored onsite is to be tracked and logged in the Waste Binder on the appropriate Container Log within Building 1036 and 1047. When restoration waste is added to the storage area, Vista Sciences (Brad Kline) must be contacted and made aware of the newly added waste.
- The contractor is responsible for ensuring that all waste is ready for transport (proper containerization, labeling, paperwork, etc.) offsite prior to waste transport.

4. Hazardous Materials Management Procedures for Camp Ravenna/Former RVAAP

Hazardous materials may be brought onsite for applicable restoration purposes during the duration of the field work. Any hazardous materials brought onsite must be identified in the contractor's project work plan and on an inventory prior to work. The contractor is required to properly manage all hazardous materials while onsite, including but not limited to, having an inventory and Safety Data Sheets (SDSs) of materials, properly inspecting materials, properly storing on secondary containment, having spill supplies and the first responder form on hand, and having properly labeled materials. Hazardous materials must be removed and taken offsite by the contractor at the end of each field work episode. The OHARNG/ARNG is not responsible for disposing of or managing contractor hazardous materials. The Camp Ravenna Environmental Office must approve any long term storage of hazardous materials. All hazardous materials utilized during field work in Building 1036 are to be stored in the hazardous material lockers offered by OHARNG in Building 1036. All hazardous materials approved by Camp Ravenna Environmental Office for long term storage and the hazardous materials lockers are strictly managed (compatibility, SDS, containers labeled, shelves numbered, inventoried, inspected, etc.) in accordance with the OHARNG requirements. The contractor is required to comply with these requirements.

5. Use of Building 1036 and Work Trailers at Camp Ravenna/Former RVAAP

- If a contractor would like to use Building 1036, the contractor must contact Vista Sciences in the Camp Ravenna Environmental Office for building keys and access.
- All work trailer locations must be approved by Camp Ravenna prior to staging onsite.

6. Revision to General Facility Description in Restoration Documents

The following is a revision to the general facility description as it pertains to the restoration program Please use this description as applicable in all restoration documents.

The former Ravenna Army Ammunition Plant (RVAAP), now known as the Camp Ravenna Joint Military Training Center (Camp Ravenna), located in northeastern Ohio within Portage and Trumbull counties, is approximately three (3) miles east/northeast of the City of Ravenna and one (1) mile north/northwest of the City of Newton Falls. The facility is approximately 11 miles long and 3.5 miles wide. The facility is bounded by State Route 5, the Michael J. Kirwan Reservoir, and the CSX System Railroad to the south; Garret, McCormick, and Berry Roads to the west; the Norfolk Southern Railroad to the north; and State Route 534 to the east. In addition, the facility is surrounded by the communities of Windham, Garrettsville, Charlestown, and Wayland.

Administrative accountability for the entire 21,683-acre facility has been transferred to the United States Property and Fiscal Office (USP&FO) for Ohio and the property subsequently licensed to the OHARNG for use as a military training site, Camp Ravenna. The RVAAP restoration program involves cleanup of former production/operational areas throughout the facility related to former activities conducted under the RVAAP.

7. Revisions to Document Shipping Addresses and Document Distribution

For Preliminary Draft, Draft and Final Documents – OHARNG/ARNG
Send one (1) electronic copy of report to:
Army National Guard
Attn: Brett Merkel
ARNG-ILE Cleanup
111 South George Mason Drive
Arlington VA 22203

Send one (1) hardcopy and one (1) electronic copy of report to:
Camp Ravenna Environmental Office
Attn: Katie Tait/Kevin Sedlak
1438 State Route 534 SW
Newton Falls OH 44444

Send two (2) electronic copies and two (2) hardcopies of report to:
Camp Ravenna Environmental Office
Attn: RVAAP Administrative Records Manager (Gail Harris)
1438 State Route 534 SW
Newton Falls OH 44444

For Draft and Final Documents – Ohio EPA
Vista Sciences will send an email to the Ohio EPA Project Manger with the cover letter and attached document (not to include appendices for size purposes) with a cc to Nancy Zikmanis, Justin Burke, and Rod Beals.

One (1) hardcopy and three (3) electronic copies of the report (with all appendices included) will be sent to the Ohio EPA Project Manager at the Ohio EPA NEDO office along with the cover letter. If the document is too large for email submittal, then one (1) additional electronic copy will be sent to Justin Burke at the Ohio EPA Columbus office.

As we work through this transition, there are likely to be additional updates and changes to programs and policies that impact the RVAAP Restoration Program. We will do our best to keep all stakeholders informed and appreciate your patience during this process. If you have any questions or need additional information, please do not hesitate to contact Ms. Kathryn Tait, OHARNG Environmental Specialist 2, at kathryn.s.tait.nfg@mail.mil or (614)336-6136 or Mr. Kevin Sedlak, ARNG Restoration Project Manager, at kevin.m.sedlak.ctr@mail.mil or (614)336-6000 ext 2053.

Sincerely,

Timothy M. Morgan
Fort Ohio Environmental Supervisor

Cc: Kathryn Tait, OHARNG
Kevin Sedlak, ARNG
Brett Merkel, ARNG
Glen Beckham, USACE
Allan Brillinger, Vista Sciences
Nancy Zikmanis/Rod Beals, Ohio EPA

Attachments
Attachment A – Restoration Contractor Access Packet
Attachment B – Camp Ravenna First Responder Form
Attachment C – Camp Ravenna Waste Management Guidelines

Attachment A

CAMP RAVENNA JOINT MILITARY TRAINING CENTER (CRJMTC) RESTORATION CONTRACTOR INFORMATION

MARCH 2014

TABLE OF CONTENTS

INSTALLATION ACCESS

The Camp Ravenna Joint Military Training Center (CRJMTC) is a restricted access Ohio Army National Guard training installation. Due to the inherent risks involved with military training, access to the facility is controlled. All personnel enter and exit CRJMTC through either the Main or East entry gates (see attached map), and upon arrival, are required to present a valid, state-issued identification card to installation security officers.

Civilian personnel must be granted access, in writing, by the Camp Ravenna Operations office. For Restoration Contractors and non-OHARNG government personnel this approval will be coordinated by Vista Sciences Corporation (VSC) who will collect and submit access requests to Camp Ravenna Operations. VSC will confirm with the Camp Ravenna Environmental Office to ensure the access rosters are valid prior to submitting them to Operations for approval.

Requests for access must be submitted no later than 48 hours prior (two business days) to the desired arrival time. **At no time will contractors be granted access without prior approval by the Camp Ravenna Operations Office. Contractor work schedules must coincide with CRJMTC duty days and hours (Monday through Friday, 7:30AM-4:30PM).**

Extended work schedules must be approved by the Camp Ravenna Environmental Office (Restoration Program and/or Environmental Supervisor) and coordinated and approved by Operations, at least 48 hours prior to the intended start date. **Federal Holidays will not be approved as a normal work days.**

EMPLOYEE ROSTERS

Restoration contractors, subcontractors and non-OHARNG government personnel that require access to CRJMTC are required to submit employee rosters no later than one week prior to the scheduled project start date. Employee rosters, at a minimum, will include:

a. The first and last names of all employees requiring access
b. Site foreman's name and on-site phone number (for emergency notification)
c. Contractor's business office address, phone number, and email address
d. CRJMTC Project title, e.g. "WBG Remedial Investigation"
e. Anticipated dates access will be required, e.g. "08/12/2010 – 10/11/2010"

Employee rosters, once approved by Camp Ravenna Operations, will be forwarded to the guard post at the appropriate entry gate. Contractors must maintain accurate employee rosters and forward all updated rosters to VSC as necessary. Each updated and approved employee roster supersedes all previously submitted rosters.

DELIVERIES

All material deliveries (including FedEx/UPS packages) for contractors or subcontractors must be approved by Camp Ravenna Operations. Access requests for deliveries will be submitted via VSC no later than 24 hours prior (one business day) to the anticipated delivery date and must include:

a. The shipping company or supplier's name
b. Driver's name
c. CRJMTC Project title
d. Date or dates of delivery
e. Contractor or subcontractor on site point of contact, e.g. "XYZ Construction, Phil Hammer, (777) 888-9999

Depending on the location of the project site, contractors may be required to provide a vehicle escort to facilitate the movement of materials from the entry gate to the project site.

Contractors working on the **WEST** side (utilizing the State Route 5 **Main** entry gate) of the installation will provide delivery companies with the following address using the provided format:

Contractor/Subcontractor Name, Attn: Site Foreman's Name
CRJMTC Project Title
8451 State Route 5
Ravenna, Ohio 44266

Contractors working on the **EAST** side (utilizing the State Route 534 **East** entry gate) of the installation will provide delivery companies with the following address using the provided format:

Contractor/Subcontractor Name, Attn: Site Foreman's Name
CRJMTC Project Title
1438 State Route 534 Southwest
Newton Falls, Ohio 44444

CRJMTC employees and security personnel will at no time sign for or receive any packages addressed to contractors. Deliveries to CRJMTC during non-business hours or the weekend will not be granted access unless an extended work schedule has been approved and arrangement made for off-hour deliveries.

ACCESS CONTACT INFORMATION

All access related correspondence should be submitted on company letterhead or on the Camp Ravenna Contractor Access Form (see attached example). A confirmation email will be sent after the request has been processed.

Access Requests and Employee Rosters must be submitted by email to **each** the following VSC personnel:

NAME	EMAIL	OFFICE PHONE
Becky Haney	rebecca.haney@vistasciences.com	(330) 872-8010
Gail Harris	gail.harris3@us.army.mil	(330) 872-8003
Al Brillinger	allan.brillinger@vistasciences.com	(330) 872-8009

In the event you need to contact the Camp Ravenna Environmental Office directly, the contacts are below. Do not submit restoration project access rosters directly to the Camp Ravenna Environmental Office unless you are directed to do so.

NAME	EMAIL	OFFICE PHONE
Kevin Sedlak	kevin.m.sedlak.ctr@mail.mil	(614) 336-6000 ext 2053
Katie Tait	kathryn.s.tait.nfg@mail.mil	(614) 336-6136
Tim Morgan	timothy.m.morgan.nfg@mail.mil	(614) 336-6568

RESTRICTIONS

Contractors/non-OHARNG government personnel working on CRJMTC are responsible for ensuring all employees travel to and from the work site on the prescribed route (as briefed during the pre-construction meeting). Unlike some military installations, CRJMTC does not offer amenities such as fuel stations, convenience stores, public restrooms or restaurants. **Sightseeing, camping, hiking, fishing, trapping, hunting, ATV use and off-roading are strictly prohibited.**

Camp Ravenna is a "Forbidden Carry Zone" (as defined by Ohio's Concealed Carry Laws) and contractors are strictly prohibited from bringing weapons onto the installation. All vehicles entering and exiting the installation are subject to search.

Security guards are not authorized to grant access to any unannounced visitors, subcontractors, contractors or service personnel without permission from Camp Ravenna Operations.

The use or possession of alcohol or other illegal substances (in accordance with state and federal laws) is strictly prohibited on Camp Ravenna.

Ohio is a "Smoke-free Workplace" state. Smoking is prohibited inside all CRJMTC buildings.

VEHICLE SAFETY

The speed limit on CRJMTC is 35 MPH (during daylight hours) & 25 MPH (during hours of darkness) on all roads unless otherwise posted and 10 MPH when passing military personnel traveling on foot. Everyone is required to wear seatbelts at all times when the manufacturer (according to State law) provides such equipment. Drivers must have a valid state issued driver's license on their person while operating a vehicle on CRJMTC. The use of headphones or earphones, for the purpose of listening to music, is prohibited. This does not negate wearing hearing protection where conditions or vehicles require their use. Cell phone use, by the driver of a moving vehicle, is prohibited unless a "hands free" device is utilized. **Gross negligence with regard to vehicle safety will not be tolerated and may result in the loss of driving privileges on Camp Ravenna.**

UNEXPLODED ORDNANCE (UXO)

Camp Ravenna, formerly known as the Ravenna Army Ammunition Plant or "Ravenna Arsenal," produced ammunition for the US military during World War II, the Korean War and the Vietnam War. As a result, some UXO has been discovered by contracted service personnel. Any individual who finds any item resembling artillery projectiles, fuses, casings or other ordnance on post must immediately consider it as unexploded ordnance (UXO). **Do not touch or move the suspected UXO.** Report the incident immediately to the CRJMTC Range Control by telephone at (614) 336-6041 or contact the Main Gate at (330) 358-2017. CRJMTC personnel will take immediate action to secure the area and ensure proper disposal of the suspected UXO.

ACTIONS IF UXO IS FOUND

a. Seal off the area from other personnel
b. Initiate necessary protective and evacuation measures
c. Mark the entrance to the UXO area using easily identifiable markings (do not mark the ordnance).

d. Notify CRJMTC Range Control or Gate Guards immediately by telephone with the description of item. **DO NOT touch the suspected UXO!**
e. Show CRJMTC personnel the location of the item
f. Render such assistance as may be required in support of EOD operations

INADVERTENT DISCOVERY OF CULTURAL MATERIALS

- Report any observations or discoveries of artifacts or human remains immediately to CRJMTC Range Control (614) 336-6041. Range Control will immediately notify the CRJMTC Environmental Office & OHARNG Cultural Resources Manager (CRM).
- CRJMTC Range Control or the CRM will secure the artifacts or discovery site, as appropriate. If human remains are suspected, they are not to be disturbed and Range Control will promptly notify Ohio State Highway Patrol or Federal Bureau of Investigation, as appropriate.
- The CRM and Range Control will take measures to protect the location from further disturbance until appropriate parties are notified.
- If a concentration of artifacts or a burial site is identified as the source of materials discovered, the CRM will make arrangements for site recordation and stabilization, in consultation with the Ohio Historic Preservation Office and any interested Native American tribes.
- Once the site has been cleared by the CRM and CRJMTC Range Control, the activity may resume. Depending on the findings, activities may be cleared to resume in 48 hours or up to 6 months.

FOR EMERGENCY RESPONSE ON THE "WEST SIDE" (PORTAGE COUNTY):

- **For a spill emergency implement the Camp Ravenna Emergency Spill Notification IAW the Camp Ravenna First Responder Form.**
- **For non-spill emergencies from 0730-1630, Monday through Friday, contact CRJMTC Range Control by telephone at (614) 336-6041**
- **For non-spill emergencies outside CRJMTC duty hours, dial 911 and ask for the Ravenna, Ohio emergency dispatch.**
- State your emergency and location.
- Outside of CRJTMC duty hours, the Main Gate guard shack (330) 358-2017 should be notified so they can assist in the process (open the gate, direct vehicles).
- During CRJMTC duty hours, Range Control will contact the appropriate dispatch for emergency response and help guide units to your location.
- If the patient can be moved, transporting the patient to the nearest Medical Transfer Point, or EMS entrance gate (North Gate or Main Gate) will expedite the medical evacuation process.

- If the patient cannot be moved, post a signal person (time and resource permitting) at the nearest major intersection/road/medical transfer to help guide emergency vehicles.
- Medical Transfer Points are located throughout the installation. These predetermined points assist first responders in locating injured personnel.

DIRECTIONS TO ROBINSON MEMORIAL HOSPITAL:

- Exit the Main gate. Take State Route 5 west 7.2 miles to the junction of Routes 14 and 44 north. You will be at a stop light next to a McDonalds/BP.
- Turn right onto Routes 14/44 north.
- Go 2.4 miles to North Chestnut Street. You will pass a light at the intersection of Route 88 and will be at a second light at the intersection where Route 14 goes straight and Route 44 splits to the right and goes north, you need to be in the left lane at this intersection, to turn left (south) on North Chestnut Street.
- After turn, get into the right lane. The hospital entrance is 2/10ths of a mile on your right.
- Follow the signs to the Emergency Room.
- Robinson Memorial Patient Information (330) 297-2448

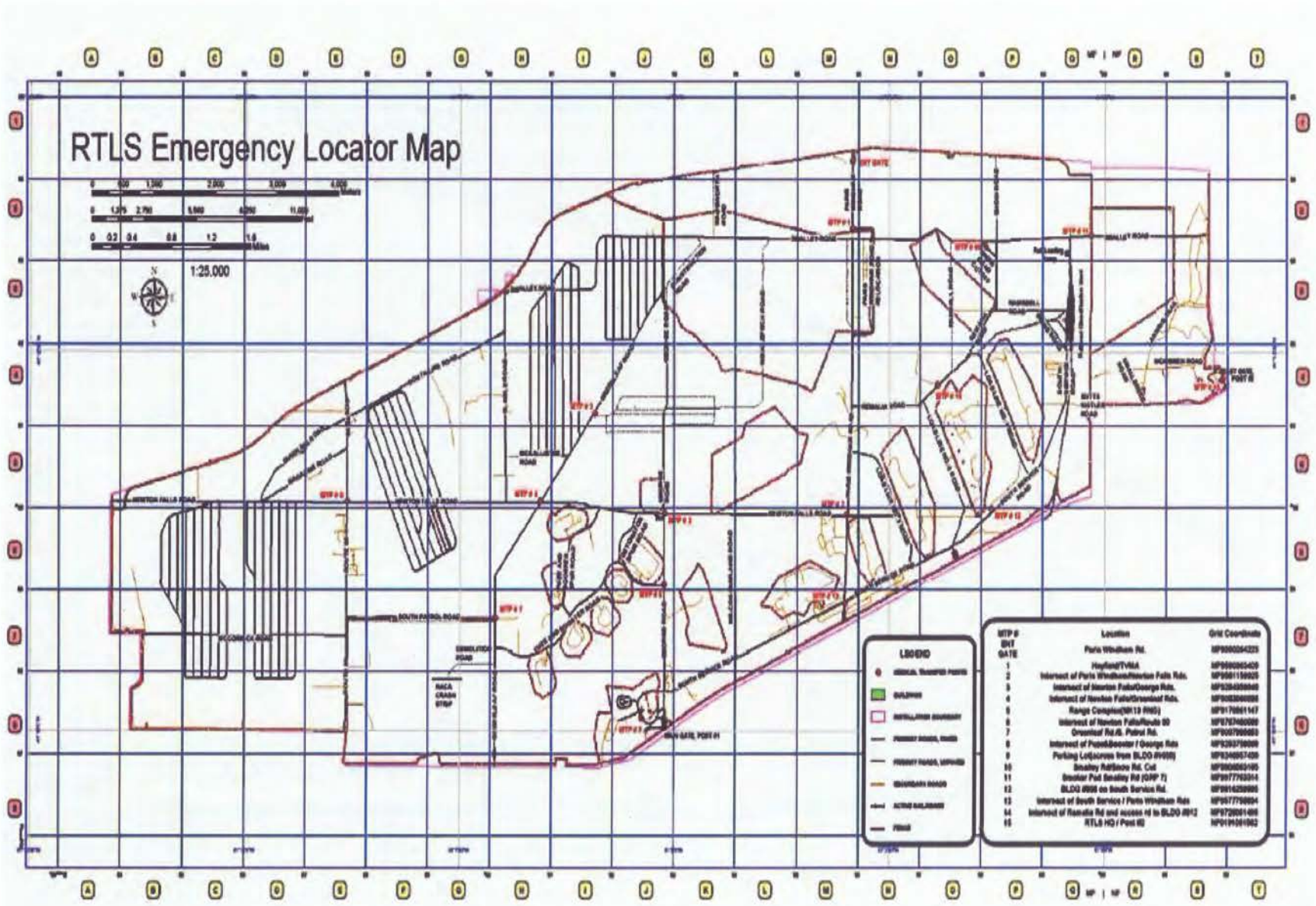
FOR EMERGENCY RESPONSE ON THE EAST SIDE (TRUMBULL COUNTY):

- **For a spill emergency implement the Camp Ravenna Emergency Spill Notification IAW the Camp Ravenna First Responder Form.**
- **For non-spill emergencies from 0730-1630, Monday through Friday, contact CRJMTC Range Control by telephone at (614) 336-6041**
- **For non-spill emergencies outside CRJMTC duty hours, call 911 and ask for the Trumbull County (Ohio) dispatch.**
- State your emergency and location.
- Outside of CRJTMC duty hours, the East Gate guard shack (614) 336-6399 should be notified so they can assist in the process (open the gate, direct vehicles).
- During CRJMTC duty hours, Range Control will contact the appropriate dispatch for emergency response and help guide units to your location.
- If the patient can be moved, transporting the patient to the nearest Medical Transfer Point, or EMS entrance gate (East Gate) will expedite the medical evacuation process.

- If the patient cannot be moved, post a signal person (time and resource permitting) at the nearest major intersection/road/medical transfer to help guide emergency vehicles.
- Medical Transfer Points are located throughout the installation. These predetermined points assist first responders in locating injured personnel.

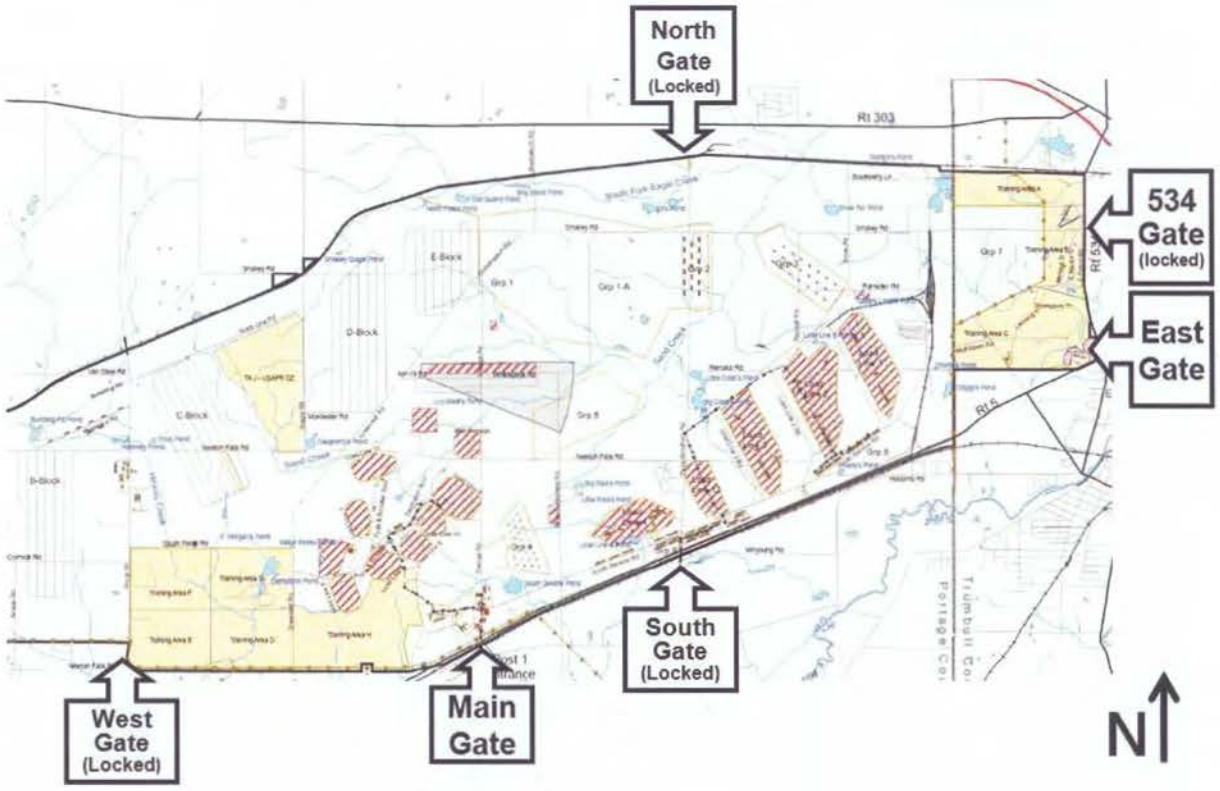
DIRECTIONS TO ROBINSON MEMORIAL HOSPITAL:

- Exit the East Gate. Turn right onto Route 534 and go 300 feet to the first stop light at the intersection of Route 534 and Route 5. Take State Route 5 west 12.4 miles to the junction of Routes 14 and 44 north. You will be at a stop light next to a McDonalds/BP.
- Turn right onto Routes 14/44 north.
- Go 2.4 miles to North Chestnut Street. You will pass a light at the intersection of Route 88 and will be at a second light at the intersection where Route 14 goes straight and Route 44 splits to the right and goes north, you need to be in the left lane at this intersection, to turn left or south on North Chestnut Street.
- After turning get into the right lane. The hospital entrance is 2/10ths of a mile on your right.
- Follow the signs to the Emergency Room.
- Robinson Memorial Patient Information (330) 297-2448


RTLS Emergency Locator Map
1:25,000
LEGEND
MTP # / INT GATE
Location
Grid Coordinate

MAP TO ROBINSON MEMORIAL HOSPITAL

CRJMTC ACCESS GATES



CAMP RAVENNA

Joint Military Training Center

1438 State Route 534 Southwest
Newton Falls, Ohio 44444
(614) 336-6041

RESTORATION CONTRACTOR ACCESS REQUEST FORM

COMPANY NAME:	
STREET ADDRESS:	
CITY, STATE, ZIP:	
POC NAME:	
PHONE:	

PROJECT NAME/AREA OF WORK:	

PERSONNEL REQUIRING ACCESS TO FACILITY:

LAST NAME	FIRST NAME	CELL PHONE #	LIC. PLATE #

START DATE:		**END DATE:**	

CRJMTC APPROVAL:	

signature name rank date

CRJMTC ENV PROJECT POC/PHONE:	

ESCORT REQUIRED? _____ YES _____ NO

GATE #1_____ GATE #2_____ page___ of ____

PLEASE EMAIL COMPLETED FORM TO: VSC Points of Contact

IMPORTANT TELEPHONE NUMBERS	
Range Control Desk	**(614) 336-6041**
Range Control Cell	(614) 202-5783
CRJMTC HQ Fax	(614) 336-6796
Range and Operations	
CPT Yates	(614) 336-6193
SGM Finnegin	(614) 336-8934
SFC Fowler	(614) 336-6133
SFC Welker	(614) 336-6793
SFC Baucum	(614) 336-6562
Engineer Section	
CPT Dunlap	(614) 336-6567
SGM Garloch	(614) 336-6795
Logistics	
MAJ Saphore	(614) 336-6790
SFC Bosley	(614) 336-6791
Security	
Main Gate (West Side)	(330) 358-2017
East Gate	(614) 336-6399
Environmental Office	
Tim Morgan	(614) 336-6568
Katie Tait	(614) 336-6136
Kim Ludt	(614) 336-6569
Kevin Sedlak	(614) 336-6000 ext 2053

DISCUSSION

Most contractor-related access issues are due to a failure to provide CRJMTC with the proper access requests or a failure to provide delivery/service personnel with the correct information.

Due to poor road conditions on Camp Ravenna, "carpooling" is encouraged, in order to prevent unnecessary damage to privately owned vehicles (POVs). Employees working on the West side of CRJMTC may park their POVs in the parking lot located outside the Main Gate.

Employee rosters and access requests have expiration dates, and any warranty work that occurs after the project has been completed requires the submission of a separate access request.

Please keep in mind, at any given time the installation may have several construction projects underway. Taking the necessary steps to avoid confusion will help alleviate congestion around the access gates and prevent delays.

Know your worksite surroundings. **Take note of the nearest road intersection, Medical Transfer Point, firing range or training area and ensure all site employees know where they are and what actions to take in the event of an emergency.** If you don't know, ask someone from Environmental or Range Control for help.

Some CRJMTC worksites are co-located or near training areas/firing ranges and therefore require (daily) Range Control authorizations (via phone) prior to entry/occupation. Your CRJMTC point of contact will advise when these requirements exist.

Attachment B

FIRST RESPONDER REPORTING FORM
(Print all information)

Collect as much of the information on the top half of this form as possible before making initial notification. Complete the top and bottom of the form before turning in to Camp Ravenna.

Name of individual reporting spill: _____

When did the spill occur (Date and Time)? _____

Spill Location (Building or area name / number, indoors or out; if vehicle involved, type and bumper number):

_____

What was spilled? _____ **How much was spilled?** _____

Rate at which material is currently spilling. _____

Extent of spill travel? _____

Did the spill reach water (ditch, creek, stream, pond, well head)? _____

Number of injured personnel and type injuries, if applicable. _____

Do you need the Fire Department to respond to protect life, property, and environment? _____

Unit: _____ **State:** _____ **Report Date & Time:** _____

On Scene Coordinator Name and Grade: _____ **Phone:** _____

How did the spill occur (be specific). _____

_____

What remedial action was taken? _____

_____

Was soil and absorbent material generated? _____ **How much?** _____

What is the location of the soil and absorbents? _____

Was the Environmental Office contacted (yes or No, date and time)? _____

Who did you talk to in the Environmental Office? _____

Was the site cleared by the Env. Office (Yes or No, date and time)? _____

Who cleared the site (name and grade, date and time)? _____

Initial information is critical. Get as much information as you can, but don't hesitate to make the initial notification if a spill is moving or worsening rapidly!

This form must be completed for all releases and turned-in to Camp Ravenna Range Control within 24 hours.

FIRST RESPONDER SPILL/RELEASE RESPONSE ACTIONS

Units or contractors performing training or other operations at Camp Ravenna shall be responsible for adhering to the provisions identified in the Camp Ravenna Integrated Contingency Plans (ICP). A copy of the ICP may be obtained from the Camp Ravenna Environmental Supervisor. Following discovery of a spill (any size), the procedures outlined below shall be executed where applicable:

1. **If necessary, initiate evacuation of the immediate area.**
2. **Notify Camp Ravenna Range Control via two-way radio or by calling (614) 336-6041, and report information contained on the "First Responder Reporting Form" if it is known or can reasonably be determined. This form has been copied on the opposite side of this page. If Range Control cannot be reached, contact a Camp Ravenna OSC (listed below).**
3. **Stop spill flow when possible without undue risk of personal injury.**
4. **If trained, contain the spill using available spill response equipment or techniques.**
5. **Make spill scene OFF LIMITS to unauthorized personnel.**
6. **Restrict all sources of ignition when flammable substances are involved.**
7. **Report to the OSC upon his/her arrival to the scene.**
8. **Turn in a completed copy of the Camp Ravenna First Responder Form to Camp Ravenna Range Control for ALL releases, even ones cleaned up by the reporter.**

TELEPHONE NUMBER

When **Camp Ravenna Range Control** is ***not available*, the Camp Ravenna OSC *must be contacted* by the discoverer/first responder following a release if it is in water, at or above a reportable quantity (25 gallons or more of POL), a hazardous or extremely hazardous substance, a hazardous waste, or involves fire, explosion, or is otherwise a major incident.**

NAME	JOB TITLE	OFFICE	24 HOUR
Camp Ravenna Range Control	Operations and Training	(614)336-6041	(614) 202-5783
Tim Morgan (Primary OSC)	Environmental Supervisor	(614)336-6568	(330)322-7098
Brad Kline (Alternate OSC)	Environmental Specialist	(614)336-4918	Contact Alternate
Katie Tait (Alternate OSC)	Environmental Specialist	(614)336-6136	Contact Alternate
Joint Forces Command (Alternate POC)	OHARNG Emergency Center	(888)637-9053	(888)637-9053

Off-site (from Camp Ravenna area code 614 phones)

Ravenna Dispatch 9-1-330 296-6486

SEE REVERSE FOR FIRST RESPONDER REPORTING FORM

Attachment C

CAMP RAVENNA WASTE MANAGEMENT GUIDELINES

PURPOSE: Guidelines to be followed by contractors working at Camp Ravenna Joint Military Training Center who are generating/shipping Hazardous, Non-Hazardous, Special or Universal Waste.

POLICY: The policy at Camp Ravenna is to comply with all local, state, federal and installation requirements. Contractor is responsible for waste minimization and is required to recycle materials if possible.

Restoration Program POC: Katie Tait (614) 336-6136 Military & Non-Restoration POC: Brad Kline (614) 336-4918

Coordination:

- Coordinate all waste generation and shipments with the appropriate Camp Ravenna POC listed above or the Environmental Supervisor in their absence at (614) 336-6568.
- Notify Camp Ravenna POC prior to waste sampling for characterization. Details about sampling activities must be included (i.e., number of sample, analyticals, etc.).
- All Hazardous and Non-Hazardous waste management storage locations must be pre-approved prior to generation.
- Ensure all labels include: Date, Contractor, and Waste Type.
- When contractors have waste onsite, a weekly Inspection inventory must be completed and submitted to the appropriate POC in the Camp Ravenna environmental office.
- All wastes shall be tracked and logged throughout the duration of the project. Contractor will provide Camp Ravenna POC with a monthly rollup report of all waste and recycled streams generated by no later than the 10th day of the following month.

Hazardous Waste Treatment, Storage and Disposal Facilities and Waste Haulers: Contractors are required to utilize hazardous waste haulers and Treatment, Storage, and Disposal Facilities on the latest Defense Reutilization Marketing Office (DRMO) approved list. The current qualified waste hauler and TSDF list can be viewed by following the "Qualified Facilities" and "Qualified Transporters" links found on the DLA Hazardous Waste Disposal Homepage, http://www.dispositionservices.dla.mil/newenv/hwdisposal.shtml.

Hazardous or Non-Hazardous manifest form, the following must be included:

- Military and non-restoration operations waste Site Name = Camp Ravenna Joint Military Training Center. Mailing and Site address: Camp Ravenna ENV, 1438 State Route 534 SW, Newton Falls, Ohio 44444, (614) 336-4918. Ohio EPA ID # – OHD981192925.
- Restoration Program waste Site Name = Former Ravenna Army Ammunition Plant. Mailing address is same as address above. Site address: 8451 State Route 5, Ravenna, Ohio 44266, (614) 336-6136. Ohio EPA ID # – OH5210020736.
- Contractor's shipping Hazardous Waste must provide a Land Disposal Restriction (LDR) in accordance with 40 CFR Part 268.
- Profiling:
  - The required shipping documentation (i.e. waste profile and executive summary of lab reports (if available)) need to be submitted to appropriate Camp Ravenna POC or designee(s) for approval and signature prior to shipping.
  - Results of characterization must be submitted to appropriate Camp Ravenna POC within 30 days after collecting sample.
- Manifests - Hazardous and Non-Hazardous:
  - The waste carrier/transporter provides appropriate manifest to the contractor.
  - The contractor is required to:
    - Ensure that Camp Ravenna POC or designee(s) is available to sign the manifest on the scheduled day of shipment;
    - Verify that each manifest is properly completed and signed by Camp Ravenna POC or designee(s);
    - Provide the Generator copy of the manifest to Camp Ravenna POC or designee(s); and
    - Ensure that the original Generator copy of the manifest signed by the treatment storage disposal facility is returned to Camp Ravenna within 30 days of the shipping date for Hazardous and Non-Hazardous Waste.
    - The use of a Bill of Lading, in lieu of a waste manifest, must be approved by the Camp Ravenna environmental office.

All satellite accumulation storage sites and containers will comply with 40CFR 262.34(c)(1):

- Any material that is subject to Hazardous Waste Manifest Requirements of the US Environmental Protection Agency must comply with 40 CFR Part 262.
- From the time any waste is placed in a satellite storage container, proper labeling must be on the container (proper labeling includes date, contractors name and product type).
- Pending analysis label is to be used from the time the sample is taken until the results are received.
- In no case will waste labeled pending analysis exceed 45 days.

All Camp Ravenna Hazardous and Non-Hazardous records are maintained at the Camp Ravenna environmental office, point of contacts are Katie Tait at (614) 336-6136 and Brad Kline at (614) 336-4918.

CAMP RAVENNA WEEKLY NON-HAZARDOUS & HAZARDOUS WASTE INSPECTION/INVENTORY SHEET

Contractor: _____ **Month:** _____ **Year:** _____ **Waste Description:** _____

Container Nos. _____

	WEEK 1	WEEK 2	WEEK 3	WEEK 4
	Date: **Time:**	**Date:** **Time:**	**Date:** **Time:**	**Date:** **Time:**
Point of Contact (Name / Number)				
Project Name:				
Contracting Agency and POC:				
Waste Determination: Pending Analysis, Hazardous, Non-Hazardous, etc.				
*Location on installation:				
Date Generated:				
Projected date of disposal:				
Non-Haz, Satellite, 90 day storage area				
Waste generation site:				
Number of Containers (size / type):				
Condition of Container:				
Containers closed, no loose lids, no loose bungs?	yes / no	yes / no	yes / no	yes / no
Waste labeled properly and visible (40 CFR 262.34 (c) (1):	yes / no	yes / no	yes / no	yes / no
Secondary containment	yes / no	yes / no	yes / no	yes / no
Incompatibles stored together?	yes / no	yes / no	yes / no	yes / no
Any spills?	yes / no	yes / no	yes / no	yes / no
Spill kit available?	yes / no	yes / no	yes / no	yes / no
Fire extinguisher present and charged?	yes / no	yes / no	yes / no	yes / no
Containers grounded if ignitables?	yes / no / na	yes / no / na	yes / no / na	yes / no / na
Emergency notification form/info present?	yes / no	yes / no	yes / no	yes / no
Container log binder present?	yes / no	yes / no	yes / no	yes / no
Signs posted if required?	yes / no	yes / no	yes / no	yes / no
Photo's submitted	yes / no	yes / no	yes / no	yes / no
Printed Name:				
Signature:				

This form is required for Non-Hazardous and Hazardous waste including PCB and special waste.

CONTRACTORS ARE REQUIRED TO SUBMIT THIS FORM WEEKLY TO THE CAMP RAVENNA ENV OFFFICE WHEN WASTE IS STORED ON SITE.

CONTRACTORS ARE ENCOURAGED TO INCLUDE PHOTOS WITH EACH WEEKLY INSPECTION SHEET WHEN WASTE IS STORED ON SITE.

*Draw detailed map showing location of waste within the site.

APPENDIX F
STORMWATER INSPECTION FORM

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Stormwater Inspection Sheet

Silt Fence
A silt fence will be constructed at the perimeter of a disturbed area > 15 square meters (m^2). Its use is limited to small drainage areas on relatively flat slopes or around small soil storage piles. It will not be used where runoff is concentrated in a ditch, pipe or through streams. The silt fence will be capable of pooling runoff so that sediment can settle out of suspension. Silt fence will be installed within 7 days of first grubbing the wellhead area it controls.

Inspection Checklist

Inspections will be conducted weekly basis or as necessary (within 24 hours a 0.5" or greater rainfall event).

GENERAL INSPECTION INFORMATION

Site Inspection Date: _____ Inspector Name: _____

Location: _____

Storm Events of the Last 7 Days

Storm Event	Storm Event Time	Storm Event Duration	Total Rainfall Amount	Discharge Occur? (Y/N)

Weather Information at the Time of Inspection

Temperature _____ Climate (Sunny, Cloudy, Rain)? _____
Is Storm Water Being Discharged? _____

SILT FENCE INSPECTION

Key things to look for

Y/N

1. ____ Is the fence at least 4" to 6" into the ground?
2. ____ Is the trench backfilled to prevent runoff from cutting underneath the fence?
3. ____ Is the fence pulled tight so it won't sag when water builds up behind it?
4. ____ Are the ends brought upslope of the rest of the fence so as to prevent runoff from going around the ends?

5. ____ Is the fence placed on a level contour? If not, the fence will only act as a diversion.
6. ____ Have all the gaps and tears in the fence been eliminated?
7. ____ Is the fence controlling an appropriate drainage area?

TEMPORARY STABILIZATION

Key things to look for

Y/N

1. ____ Are there any areas of the site that are disturbed, but will likely lie dormant for over 14 days?
2. ____ Have all dormant, disturbed areas been temporarily stabilized in their entireties?
3. ____ Have disturbed areas outside the silt fence been seeded or mulched?
4. ____ Have soil stockpiles that will sit for over 14 days been stabilized?
5. ____ Has seed and mulch been applied at the proper rate? In general, seed is applied at 3 to 5 lbs per 1000 sq ft and straw mulch is applied at 2-3 bales per 1000 sq ft.
6. ____ Has seed or mulch blown away? If so, repair?

PERMANENT STABILIZATION

Key things to look for

Y/N

1. ____Are any areas at final grade?
2. ____Has the soil been properly prepared to accept permanent seeding?
3. ____Has seed and mulch been applied at the appropriate rate?
4. ____If rainfall has been inadequate, are seeded areas being watered?
5. ____For sites with steep slopes or fill areas, is runoff from the top of the site conveyed to the bottom of the slope or fill area in a controlled manner so as not to cause erosion?

Note areas where repairs or maintenance is needed or where this practice needs to be applied:

APPENDIX G

WEEKLY WASTE INVENTORY AND CONTAINER LOG SHEETS

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CAMP RAVENNA WEEKLY NON-HAZARDOUS & HAZARDOUS WASTE INSPECTION/INVENTORY SHEET

Contractor: _____ Month: _____ Year: _____ Waste Description: _____

Container Nos. _____

	WEEK 1	WEEK 2	WEEK 3	WEEK 4
	Date: **Time:**	**Date:** **Time:**	**Date:** **Time:**	**Date:** **Time:**
Point of Contact (Name / Number)				
Project Name:				
Contracting Agency and POC:				
Waste Determination: Pending Analysis, Hazardous, Non-Hazardous, etc.				
*Location on installation:				
Date Generated:				
Projected date of disposal:				
Non-Haz, Satellite, 90 day storage area				
Waste generation site:				
Number of Containers (size / type):				
Condition of Container:				
Containers closed, no loose lids, no loose bungs?	yes / no	yes / no	yes / no	yes / no
Waste labeled properly and visible (40 CFR 262.34 (c) (1):	yes / no	yes / no	yes / no	yes / no
Secondary containment	yes / no	yes / no	yes / no	yes / no
Incompatibles stored together?	yes / no	yes / no	yes / no	yes / no
Any spills?	yes / no	yes / no	yes / no	yes / no
Spill kit available?	yes / no	yes / no	yes / no	yes / no
Fire extinguisher present and charged?	yes / no	yes / no	yes / no	yes / no
Containers grounded if ignitables?	yes / no / na	yes / no / na	yes / no / na	yes / no / na
Emergency notification form/info present?	yes / no	yes / no	yes / no	yes / no
Container log binder present?	yes / no	yes / no	yes / no	yes / no
Signs posted if required?	yes / no	yes / no	yes / no	yes / no
Photo's submitted	yes / no	yes / no	yes / no	yes / no
Printed Name:				
Signature:				

This form is required for Non-Hazardous and Hazardous waste including PCB and special waste.

CONTRACTORS ARE REQUIRED TO SUBMIT THIS FORM WEEKLY TO THE CAMP RAVENNA ENV OFFFICE WHEN WASTE IS STORED ON SITE.

CONTRACTORS ARE ENCOURAGED TO INCLUDE PHOTOS WITH EACH WEEKLY INSPECTION SHEET WHEN WASTE IS STORED ON SITE.

*Draw detailed map showing location of waste within the site.

CONTAINER LOG

Container No. (1) _____ **Page ___ of ___**

Satellite Accumulation Area ☐ Generator Accumulation Area ☐

Date (2)	Material Name (3)	Quantity Added (4)	Cumulative Quantity (5)	Person Adding Material (6)

(When 55 gals total reached, must move from SAA within 3 calendar days.)
Date Container Transferred to Generator Accumulation Area _____

Materials shipped offsite date: _____

(1) Container ID Number (e.g., FC-FMS#1-2)

(2) Date when waste was added to container

(3) Name of waste added (e.g., Diesel Fuel)

(4) For items such as filters, note the number of items. For liquids, note the number of gallons.

(5) The total quantity of items of number of gallons currently in the container.

(6) The name of the person adding the waste.

LOCATION OR PROJECT SITE	PICKUP DATE	TYPE - HW/NONHAZ/ RECYCLE/ SCRAP/ UNIVERSAL WASTE ETC.	SPECIFIC WASTE TYPE (Concrete/ demo debris/ metal/ paint/ etc)	WASTE CHARACTERIZATION PERFORMED ? Y/N/NA	WASTE PROFILE? Y/N/NA	MANIFEST/ SHIPPING DOCUMENT #	WASTE AMT/ TOTAL - LBS/ TONS/ GALLONS	TRANSPORTER	DISPOSAL/ RECYCLE FACILITY	MANIFEST/ SHIPPING DOCUMENT REVIEWED AND APPROVED BY OHARNG - Y/N	WASTE INSPECTIONS PERFORMED - Y/N/NA

APPENDIX H

BACKFILL SOURCES APPROVAL AND SAMPLE RESULTS

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Building 1200/Anchor Test Area Backfill Sample Results

Sample Id	CAS Number	Background Criteria	Screening Level(HQ=.1, Risk=1E-6)	Screening Level Source	B12bf-060-0015-SO	B12bf-060M-0014-SO
Date					**09/11/14**	**09/11/14**
Analyte						
Metals						
Aluminum	7429-90-5	17700	7380	RFC	NR	6400
Antimony	7440-36-0	0.96	2.82	RFC	NR	0.13 J
Arsenic	7440-38-2	15.4	0.425	RFA	NR	7.4
Barium	7440-39-3	88.4	1413	RFC	NR	46 J
Beryllium	7440-41-7	0.88	16	RSL	NR	0.38 J
Cadmium	7440-43-9	0	6.41	RFC	NR	<0.35 UJ
Calcium	7440-70-2	15800	1000000	RDA	NR	1700
Chromium	7440-47-3	17.4	8147	RFC	NR	15 J
Cobalt	7440-48-4	10.4	131	RFC	NR	6.4
Copper	7440-50-8	17.7	311	RFC	NR	7.4
Iron	7439-89-6	23100	180000	RDA	NR	14000
Lead	7439-92-1	26.1	400	RSL	NR	17
Magnesium	7439-95-4	3030	1000000	RDA	NR	1200
Manganese	7439-96-5	1450	293	RFC	NR	590
Nickel	7440-02-0	21.1	155	RFC	NR	11 J
Potassium	7440-09-7	927	1000000	RDA	NR	370
Selenium	7782-49-2	1.4	39	RSL	NR	1.4
Silver	7440-22-4	0	38.6	RFC	NR	0.038 J
Sodium	7440-23-5	123	1000000	RDA	NR	71 J
Thallium	7440-28-0	0	0.612	RFC	NR	<0.35 UJ
Vanadium	7440-62-2	31.1	44.9	RFC	NR	15
Zinc	7440-66-6	61.8	2321	RFC	NR	33 J
Organics - Explosives						
1,3,5-Trinitrobenzene	99-35-4		225	RFC	NR	<0.05 U
1,3-Dinitrobenzene	99-65-0		0.765	RFC	NR	<0.05 U
2,4,6-Trinitrotoluene	118-96-7		3.65	RFC	NR	<0.05 U
2,4-Dinitrotoluene	121-14-2		0.753	RFA	NR	<0.05 U
2,6-Dinitrotoluene	606-20-2		0.769	RFA	NR	<0.05 U
2-Amino-4,6-Dinitrotoluene	35572-78-2		1.54	RFC	NR	<0.05 U
2-Nitrotoluene	88-72-2		3.88	RFC	NR	<0.05 U
3-Nitrotoluene	99-08-1		0.62	RSL	NR	<0.05 U
4-Amino-2,6-Dinitrotoluene	19406-51-0		1.54	RFC	NR	<0.05 U
4-Nitrotoluene	99-99-0		52.5	RFC	NR	<0.05 U
HMX	2691-41-0		359	RFC	NR	<0.05 U
Nitrobenzene	98-95-3		5.1	RSL	NR	<0.05 U
Nitrocellulose	9004-70-0		18000000	RSL	NR	<1.8 U
Nitroglycerin	55-63-0		52.5	RFC	NR	<0.25 U
Nitroguanidine	556-88-7		620	RSL	NR	<0.039 U
PETN	78-11-5		12	RSL	NR	0.04 J
RDX	121-82-4		8.03	RFC	NR	<0.05 U
Tetryl	479-45-8		12	RSL	NR	<0.05 U
Organics - Semivolatile						
1,2,4-Trichlorobenzene	120-82-1		5.8	RSL	NR	<0.043 U

Building 1200/Anchor Test Area Backfill Sample Results

Sample Id Date Analyte	CAS Number	Background Criteria	Screening Level(HQ=.1, Risk=1E-6)	Screening Level Source	B12bf-060-0015-SO 09/11/14	B12bf-060M-0014-SO 09/11/14
1,2-Dichlorobenzene	95-50-1		180	RSL	NR	<0.086 U
1,3-Dichlorobenzene	541-73-1			NR	NR	<0.086 U
1,4-Dichlorobenzene	106-46-7		2.6	RSL	NR	<0.086 U
2,4,5-Trichlorophenol	95-95-4		620	RSL	NR	<0.17 U
2,4,6-Trichlorophenol	88-06-2		6.2	RSL	NR	<0.086 UJ
2,4-Dichlorophenol	120-83-2		18	RSL	NR	<0.17 U
2,4-Dimethylphenol	105-67-9		120	RSL	NR	<0.17 U
2,4-Dinitrophenol	51-28-5		12	RSL	NR	<0.17 U
2-Chloronaphthalene	91-58-7		630	RSL	NR	<0.0043 U
2-Chlorophenol	95-57-8		39	RSL	NR	<0.086 U
2-Methyl-4,6-dinitrophenol	534-52-1		0.49	RSL	NR	<0.086 U
2-Methylnaphthalene	91-57-6		30.6	RFC	NR	0.011 J
2-Methylphenol	95-48-7		310	RSL	NR	<0.17 U
2-Nitrobenzenamine	88-74-4		61	RSL	NR	<0.086 U
2-Nitrophenol	88-75-5			NR	NR	<0.086 U
3+4-Methylphenol	15831-10-4		620	RSL	NR	<0.17 U
3,3'-Dichlorobenzidine	91-94-1		1.2	RSL	NR	<0.17 U
3-Nitrobenzenamine	99-09-2			NR	NR	<0.17 U
4-Bromophenyl phenyl ether	101-55-3			NR	NR	<0.086 U
4-Chloro-3-methylphenol	59-50-7		620	RSL	NR	<0.17 U
4-Chlorobenzenamine	106-47-8		2.7	RSL	NR	<0.17 U
4-Chlorophenyl phenyl ether	7005-72-3			NR	NR	<0.086 U
4-Nitrobenzenamine	100-01-6		25	RSL	NR	<0.17 U
4-Nitrophenol	100-02-7		61.2	RFC	NR	<0.17 U
Acenaphthene	83-32-9		350	RSL	NR	<0.0085 U
Acenaphthylene	208-96-8		170	RSL	NR	<0.0043 U
Anthracene	120-12-7		1700	RSL	NR	0.013 J
Benz(a)anthracene	56-55-3		0.221	RFA	NR	0.084
Benzenemethanol	100-51-6		620	RSL	NR	<0.17 U
Benzo(a)pyrene	50-32-8		0.022	RFA	NR	0.11 *
Benzo(b)fluoranthene	205-99-2		0.221	RFA	NR	0.16
Benzo(ghi)perylene	191-24-2		170	RSL	NR	0.12
Benzo(k)fluoranthene	207-08-9		2.21	RFA	NR	0.086
Benzoic acid	65-85-0		25000	RSL	NR	0.2 J
Bis(2-chloroethoxy)methane	111-91-1		23	RFC	NR	<0.17 U
Bis(2-chloroethyl) ether	111-44-4		0.23	RSL	NR	<0.0085 U
Bis(2-chloroisopropyl) ether	108-60-1		4.9	RSL	NR	<0.086 U
Bis(2-ethylhexyl)phthalate	117-81-7		38	RSL	NR	<0.086 U
Butyl benzyl phthalate	85-68-7		280	RSL	NR	<0.086 U
Carbazole	86-74-8		44.6	RFC	NR	<0.086 U
Chrysene	218-01-9		22.1	RFA	NR	0.11
Di-n-butyl phthalate	84-74-2		620	RSL	NR	<0.086 U
Di-n-octylphthalate	117-84-0		62	RSL	NR	<0.086 U
Dibenz(a,h)anthracene	53-70-3		0.022	RFA	NR	<0.0085 U

Building 1200/Anchor Test Area Backfill Sample Results

Sample Id Date Analyte	CAS Number	Background Criteria	Screening Level(HQ=.1, Risk=1E-6)	Screening Level Source	B12bf-060-0015-SO 09/11/14	B12bf-060M-0014-SO 09/11/14
Dibenzofuran	132-64-9		15.3	RFC	NR	<0.0085 U
Diethyl phthalate	84-66-2		4900	RSL	NR	<0.086 U
Dimethyl phthalate	131-11-3			NR	NR	<0.086 U
Fluoranthene	206-44-0		163	RFC	NR	0.2
Fluorene	86-73-7		243	RFC	NR	<0.0085 U
Hexachlorobenzene	118-74-1		0.33	RSL	NR	<0.0085 U
Hexachlorobutadiene	87-68-3		6.2	RSL	NR	<0.086 U
Hexachlorocyclopentadiene	77-47-4		37	RSL	NR	<0.086 U
Hexachloroethane	67-72-1		4.3	RSL	NR	<0.086 U
Indeno(1,2,3-cd)pyrene	193-39-5		0.221	RFA	NR	0.096
Isophorone	78-59-1		560	RSL	NR	<0.086 U
N-Nitroso-di-n-propylamine	621-64-7		0.12	RFC	NR	<0.086 U
N-Nitrosodiphenylamine	86-30-6		110	RSL	NR	<0.086 U
Naphthalene	91-20-3		122	RFC	NR	0.0093 J
Pentachlorophenol	87-86-5		2.12	RFA	NR	<0.086 U
Phenanthrene	85-01-8		170	RSL	NR	0.066
Phenol	108-95-2		1800	RSL	NR	<0.086 U
Pyrene	129-00-0		122	RFC	NR	0.16
Organics - Pesticide/PCB						
4,4'-DDD	72-54-8		2.2	RSL	NR	<0.0017 U
4,4'-DDE	72-55-9		2.63	RFC	NR	0.0011 J
4,4'-DDT	50-29-3		1.9	RSL	NR	<0.0017 U
Aldrin	309-00-2		0.053	RFC	NR	<0.0017 U
Dieldrin	60-57-1		0.056	RFC	NR	<0.0017 U
Endosulfan I	959-98-8		37	RSL	NR	<0.0017 U
Endosulfan II	33213-65-9		37	RSL	NR	<0.0017 U
Endosulfan sulfate	1031-07-8		37	RSL	NR	<0.0017 U
Endrin	72-20-8		1.12	RFC	NR	<0.0017 U
Endrin aldehyde	7421-93-4		1.8	RSL	NR	<0.0017 U
Endrin ketone	53494-70-5		1.8	RSL	NR	<0.0017 U
Heptachlor	76-44-8		0.198	RFC	NR	<0.0017 U
Heptachlor epoxide	1024-57-3		0.098	RFC	NR	<0.0017 U
Lindane	58-89-9		0.56	RSL	NR	0.003 J
Methoxychlor	72-43-5		31	RSL	NR	<0.0033 U
Toxaphene	8001-35-2		0.48	RSL	NR	<0.034 U
alpha-BHC	319-84-6		0.085	RSL	NR	0.0049 J
alpha-Chlordane	5103-71-9		1.8	RSL	NR	<0.0017 U
beta-BHC	319-85-7		0.496	RFC	NR	0.0023 J
delta-BHC	319-86-8			NR	NR	<0.0017 U
gamma-Chlordane	5103-74-2		1.8	RSL	NR	0.0019 J
Organics - Volatile						
1,1,1-Trichloroethane	71-55-6		640	RSL	<0.0012 U	NR
1,1,2,2-Tetrachloroethane	79-34-5		0.6	RSL	<0.0012 UJ	NR
1,1,2-Trichloroethane	79-00-5		0.15	RSL	<0.0012 U	NR

Building 1200/Anchor Test Area Backfill Sample Results

Sample Id Date Analyte	CAS Number	Background Criteria	Screening Level(HQ=.1, Risk=1E-6)	Screening Level Source	B12bf-060-0015-SO 09/11/14	B12bf-060M-0014-SO 09/11/14
1,1-Dichloroethane	75-34-3		3.6	RSL	<0.0012 U	NR
1,1-Dichloroethene	75-35-4		23	RSL	<0.0012 U	NR
1,2-Dibromoethane	106-93-4		0.036	RSL	<0.0012 UJ	NR
1,2-Dichloroethane	107-06-2		0.46	RSL	<0.0012 U	NR
1,2-Dichloroethene	540-59-0			NR	<0.0024 U	NR
1,2-Dichloropropane	78-87-5		1	RSL	<0.0024 U	NR
2-Butanone	78-93-3		2700	RSL	<0.0047 U	NR
2-Hexanone	591-78-6		20	RSL	<0.0012 U	NR
4-Methyl-2-pentanone	108-10-1		530	RSL	<0.0012 U	NR
Acetone	67-64-1		6100	RSL	<0.018 UJ	NR
Benzene	71-43-2		1.2	RSL	<0.00059 UJ	NR
Bromochloromethane	74-97-5		15	RSL	<0.0024 U	NR
Bromodichloromethane	75-27-4		0.29	RSL	<0.00059 UJ	NR
Bromoform	75-25-2		67	RSL	<0.0012 U	NR
Bromomethane	74-83-9		0.68	RSL	<0.0012 U	NR
Carbon disulfide	75-15-0		77	RSL	<0.0012 U	NR
Carbon tetrachloride	56-23-5		0.65	RSL	<0.0012 U	NR
Chlorobenzene	108-90-7		28	RSL	<0.0012 UJ	NR
Chloroethane	75-00-3		1400	RSL	<0.0012 U	NR
Chloroform	67-66-3		0.32	RSL	<0.00059 U	NR
Chloromethane	74-87-3		11	RSL	<0.00059 U	NR
Dibromochloromethane	124-48-1		0.73	RSL	<0.0012 UJ	NR
Ethylbenzene	100-41-4		5.8	RSL	<0.00059 UJ	NR
Methylene chloride	75-09-2		35	RSL	<0.0024 U	NR
Styrene	100-42-5		600	RSL	<0.00059 UJ	NR
Tetrachloroethene	127-18-4		8.1	RSL	<0.0012 UJ	NR
Toluene	108-88-3		490	RSL	<0.00059 UJ	NR
Trichloroethene	79-01-6		0.41	RSL	<0.0012 UJ	NR
Vinyl chloride	75-01-4		0.059	RSL	<0.0012 U	NR
Xylenes, total	1330-20-7		58	RSL	<0.0024 U	NR
cis-1,3-Dichloropropene	10061-01-5		1.8	RSL	<0.0012 UJ	NR
trans-1,3-Dichloropropene	10061-02-6		1.8	RSL	<0.0012 U	NR

*- Exceeds screening level
NR- not reported
U-not detected
UJ-not detected, reporting limit estimated
J- estimated
RFC-Resident Farmer Child
RFA-Resident Farmer Adult
RDA-Recommended dail allowance for nutrient
RSL-EPA Regional Screening Level for resident for soil (May 2014)