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Appendix A

Geophysical Reports
Centredale Manor (Woonasquatucket River) Site
North Providence, Rhode Island
September 1999

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21 June 1999

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GSA Raritan Depot
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W.O. No. 03347-144-001-4013

Dear JoAnn:

Please find enclosed a copy of the revised Report for the geophysical surveys that we conducted at the Centredale Manor Site, between 6 and 9 April 1999. Should you have any questions or comments or require additional information, please do not hesitate to contact me at 610-701-7256.

Very truly yours,

ROY F. WESTON, INC.

John A. Williams Jr., P.G.
Technical Manager
Geosciences Department

JAW/jaw

Enclosure

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21 June 1999

Mr. Ted Bazenas
U.S. EPA/On-Scene Coordinator
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W.O. No. 03347-144-001-4013

Dear Ted:

Please find enclosed a copy of the revised Report for the geophysical surveys that we conducted at the Centredale Manor Site. between 6 and 9 April 1999. Should you have any questions or comments or require additional information. please do not hesitate to contact me at 610-701-7256.

Very truly yours.

ROY F. WESTON. INC.

John A. Williams Jr.. P.G.
Technical Manager
Geosciences Department

JAW/jaw

Enclosure

DATE: 17 June 1999

TO: JoAnn Camacho, U.S. EPA/ERTC Work Assignment Manager

THROUGH: Amanda Daly, REAC Task Leader

FROM: John Williams, WESTON

SUBJECT: GEOPHYSICAL INVESTIGATION REPORT, CENTREDALE MANOR SITE, PROVIDENCE, RHODE ISLAND for EPA REGION II, EDISON, NEW JERSEY (WORK ASSIGNMENT 3-428)

INTRODUCTION

In February 1999 REAC performed a comprehensive geophysical investigation for the EPA, Region II, at the Centredale Manor Facility in Providence, Rhode Island. Results of that investigation (submitted to EPA 12 March 1999) provided information related to the substructure of the site and identified several anomalous areas potentially associated with (reported) buried materials. In April 1999 a "follow-up" geophysical survey was undertaken to help further define the extent of those anomalous areas and to complete surveying at other portions of the facility not covered during the previous investigation.

This report provides a description of the applied geophysical techniques, a presentation of the data, and a discussion of results and conclusions for both survey periods. A site index map showing the locations of the respective survey areas is shown in Figure 1. Contour plots for the EM-31 and EM-61 data, and GPR plots are included in Attachments A and B respectively. The *February 1999, Geophysical Survey* Trip Report is provided in Attachment C, and is summarized in the following subsection.

PREVIOUS GEOPHYSICAL INVESTIGATION (February 1999)

The initial geophysical investigation was conducted by REAC during the week of 15 February 1999. For this investigation, four distinct zones requiring geophysical surveying were established. They include the North Grid, Central Grid, South Parking Lot, and South Grid Areas (see Figure 1). The objective of the investigation was to locate possible buried waste containers (e.g., 55-gallon drums). Two EM techniques, time-domain (TDEM) and frequency-domain (FEM), were preformed at the four areas described above. TDEM was conducted using a Geonics, Ltd. EM-61™ metal detector and FEM was conducted using a Geonics, Ltd. EM-31™ terrain conductivity meter.

A total of 44 anomalies were identified from the geophysical data collected in each of the four zones (see Figure 2). These anomalies are summarized in Table 1 of the *February 1999, Geophysical Survey* Trip Report in attachment C. Of particular interest were "possible pipes or targets" (anomalies 1, 2, and 3) in the *North Grid* Area and possible trenches (anomalies 20 and 21) located in the *Central Grid* Area. In addition, a possible buried tank/disposal area south of *the South Parking Lot* (anomalies 33 and 36) and anomalies 43 and 44 in the *South Grid* area were identified. Numerous other single targets, debris, pipes, and buried power-lines throughout the entire site were also reported.

FOLLOW-UP GEOPHYSICAL INVESTIGATION (April 1999)

In April 1999 a "follow-up" geophysical survey was undertaken to help further define the extent of the anomalies described above and to complete surveying at other portions of Centredale Manor not covered during the previous investigation. The follow-up surveys were performed to scan the North, Central and South Grid Areas, as well as portions of the property west along the Woonasquatucket River and the wooded area south of the southernmost parking lot (see Figure 1). The follow-up surveys were conducted using a complement of Electromagnetic (EM) Terrain Conductivity Methods (EM-31 and EM-61) and Ground Penetrating Radar (GPR).

METHODOLOGY

Surveys Grids

Reference grids (shown in Figures 1 and 3) were established at the site in order to provide a means of surface control during the data collection. The field data obtained at the site, along with existing monuments and surface features, were referenced to the grid coordinate system.

Metallic surface debris and other cultural features that potentially affected the EM survey were noted and later compared to the geophysical results.

Electromagnetic (EM) Surveys

EM surveys were preformed using a Geonics, Ltd. EM-61™ metal detector and a Geonics, Ltd. EM-31™ terrain conductivity meter. The TD EM-61 instrument transmits a pulse (instead of a fixed frequency like the EM-31). In general, the instruments measure a radiated signal from conductive materials or objects after a transmitted pulse has been induced. Output from the EM-61 and EM-31 were used to provide information regarding the location and approximate mass and depth of buried metallic conductors. In addition, the EM-31 provided information regarding the soil conductivity, which was used to interpret the composition and structure of the subsurface at the Centredale Manor Site. The EM surveys were performed using the following procedures.

Prior to conducting the surveys, the instrument was calibrated in accordance with the instrument operating manual. The EM-61 survey was performed in the "wheel" mode, while the EM-31 survey was performed in the walking mode. Both surveys were conducted along the same pre-established grid lines (transects) using constant line spacing.

For each instrument the measurements were digitally recorded and stored in memory in an Omni Data Logger™ as the operator traversed each line. Data were collected at approximate 0.5 to 1.5-foot intervals for the EM-61 and 2.5 to 5-foot intervals for the EM-31. Data sets from both instruments were downloaded from the data logger to a field computer. The computer-generated output files were formatted, then compared against the random QA/QC readings recorded in the field logbook.

Conductivity contour plots (presented in attachment A) were prepared from the field data using Oasis montaj™ contour plotting software. Prior to evaluating potential subsurface features, the cultural features identified on the surface (e.g., surface debris) were plotted. This process allowed the geophysicist to note anomalous readings coincident with these surface features. Intense EM anomalies coincident with the cultural features may occasionally interfere or mask buried features. As a result, buried features may go undetected at these locations. The contour plots were interpreted with regard to site soil characteristics, site-specific geology, and the suspected presence of buried waste materials. The results of the EM surveys are presented and discussed below.

Ground Penetrating Radar (GPR) Surveys

GPR surveys were conducted at the four previously described areas of the Centredale Site between 6 and 9 April 1999. The surveys were preformed using a Geophysical Surveys Systems, Inc. Subsurface Interface Radar™ (SIR) System 10A model. The System 10A consists of a control/display unit, mainframe/data storage unit, microcomputer, thermal printer, and a 300 or 500 megahertz (MHz) antenna. The System 10A automatically displays, processes, and records cross sectional profiles of the subsurface. Depth of penetration is site-specific and is dependent upon the electrical characteristics of the site materials and the frequency of the transmitter, therefore a site-specific calibration was conducted.

Prior to conducting the surveys, the instrument was calibrated in accordance with the instrument operating manual. The GPR was field-calibrated using an averaged dielectric constant for the survey medium. Surveying was accomplished by traversing each area (see Figure 3) with a 500 MHz antenna along the pre-established grid lines at 10 to 25-foot

intervals. The product of the GPR survey was a series of real-time subsurface field profiles (provided in Attachment B). The profile plots were interpreted with regard to site soil characteristics, site-specific geology, and the suspected presence of buried waste materials. The results of the EM surveys are presented and discussed below.

RESULTS

Anomalies (subsurface conductors) identified by the EM-31 are characterized by negative and positive excursions in the background measurements. In the EM-61, these features are characterized by variable metallic responses in the upper and lower instrument sensors and are expressed in terms of milli-volts (mV). Information provided by both EM instruments, and the ground penetrating radar was used to provide the following interpretation of the subsurface characteristics in each of the four surveyed areas.

North Grid Area

The North Grid encompasses the area east of Brook Village Apartments and the *North Parking Lot* situated south of Brook Village Apartments (see Figure 1). During the February 1999 investigation, EM-31 surveys were completed in the east area. At the time, the presence of vehicles in the *North Parking Lot* precluded the use of electromagnetic or magnetic techniques. The area was subsequently surveyed in April 1999, when the vehicles were removed. The results of each survey are discussed below.

East Area

Three anomalies (1, 2, and 3) were identified from the February 1999 EM-31 survey (see Figure 2). They are described in the February 1999 trip report (see attachment C), as possible pipes or targets at depths to 5 feet. These three anomalies were the focus for the GPR surveys conducted in this area in April 1999. Radar scans were conducted over each of the four anomalies. The radar scans (shown in attachment B) are referenced to the grid coordinate and include transect 15N, 35E through 60E, and 300N through 350N. Of particular interest, is transects 35E, which bisect the three anomalies. The dark vertical strip in the profile, where the signatures are absent, indicates that the signal was attenuated by a shallower structure. It was confirmed, both by field observation and discussions with Brook Village Apartment maintenance personnel, that the structure is a buried concrete electrical vault. The pipe-like EM-31 responses of the three anomalies (1, 2, and 3) identified from both the February 1999 and GPR signatures correspond to the buried electrical vault and associated buried utilities. In addition, a GPR signature consistent with that of a buried pipeline was identified in several profiles located immediately adjacent to the walkway.

North Parking Lot

Annotated EM contour plots for the *North Parking Lot* are shown in Figure s 4 through 7 (see attachment A). EM anomalies identified in the Figures are summarized, along with interpretations, in Table 1. Ten significant EM anomalies were identified in the EM-31 and EM-61 plots of the North Parking Lot. Four were attributed to known cultural features including, an underground storage tank, two reinforced concrete slabs, several "staged" surface drums (containing drill materials) and a vehicle. The remaining six (numbered from *A1* to *A6*) in Figures 4 through 7, appear as highs or lows at various levels from background. As seen in Figures 4 and 5, the most prominent anomaly, *A1*, is an area of high conductivity appearing as an elongated feature, coincident with the 25W traverse. This feature extends, south to north, from approximately grid node 125N to 225N.

Radar scans of the subsurface collected in the *North Parking Lot* are compiled in attachment B. For discussion purposes refer to Figure 8 which represents a typical radar scan of the parking lot. This figure depicts a scan of the subsurface along the 150 N line, running east to west, from grid node 40E to 90W. Included is an interpretive stratigraphic cross section to assist the reader in making the associations between the reflective layers clearly evident in the radar scans and the physical descriptions of the materials provided in site boring logs. The X-axis

represents horizontal distance (in feet) along the ground surface. The Y-axis represents the travel-time (from 0 to 60 nanoseconds, ns) of the pulsed radar signal and depth below ground surface (bgs) based on the velocities of those travel times.

The GPR profile and accompanying stratigraphic cross section shown in Figure 8 displays a sequence of stratified layers as described in the boring logs obtained by Goldman Environmental (GEC) in March 1999. The undulating reflective layer shown in red, and occurring in the upper 1 - 1.5 feet, represents the base of the sub-grade material (crushed gravel) underlying the asphalt parking surface. Beneath this layer is a zone described as fine to coarse (f-c) sands, some medium to coarse gravel and mixed fill. These materials appear in the profile as a darkened or reflection free area, from 1 to approximately 3.5 feet bgs. Underlying this layer is a zone of reflective materials characterized in the profile by high amplitude (blue and yellow), spiky (chaotic) signatures. This deeper zone extends from 20 to 50 ns or 3.5 to >8 feet bgs and may in fact be the mixture of coarse fill and alluvial deposits of the paleo-channel. The most reflective feature shown in the radar scan is the blue horizontal layer occurring between 6 to 6.5 feet bgs. The boring logs describe a thin layer of wet black silt/ash in the split spoon sample collected from this depth. Static water levels were measured at between 6 to 7.5 feet bgs in the borings drilled in this area.

Central Grid Area

The Central Grid includes the *Central Parking Lot* situated north of Centredale Manor and the adjacent West Area bordered by the Woonasquatucket River (see Figure 1). During the February 1999 investigation, EM-31 surveys were completed in the West Area. At that time, the presence of vehicles in the *Central Parking Lot* precluded the use of electromagnetic or magnetic techniques. This area was subsequently resurveyed, in April 1999, when the vehicles were removed. The results of each survey are discussed below.

Central Parking Lot

The EM-61 contour plots for the Central Parking Lot are shown in Figure s 9 and 10. Potential buried anomalies numbered *A7, A8,* and *A9* were grouped into clusters for easier identification. As shown in Figure 9, several anomalies were identified that were associated with known cultural features. These include several buried utilities (confirmed by utility plans), a reinforced concrete walkway, a fire hydrant and several light poles. The remaining anomalies appear as highs or lows at various levels from background. They are summarized along with the EM interpretations in Table 1.

EM anomalies *A8* and *A9* were scanned using the GPR. Cross sectional profiles of the subsurface (see attachment B) of the Central Parking Lot were collected traversing the anomaly areas along parallel and perpendicular grid lines. No boring logs were available for the area to provide a baseline reference for the GPR interpretation. Profiles for transects 80E, 90E and 100E (see attachment B) show a highly reflective dipping structure with well-defined lateral and vertical boundaries. This feature closely correlates with the northernmost anomaly of cluster *A9* that is located at 150S by 90E. The upper shallow layer is interpreted to represent the shallow mixed fill materials. The reflective zone observed beneath grid node 150S is characterized in the profile by high amplitude (blue and white), chaotic signatures. Similar to the profiles collected in the North Parking Lot, this zone extends from 20 to 45 ns or 4.5 to >10 feet bgs. The deposition of this structure is undetermined; it may be alluvial or anthropogenic (i.e. fill or construction related).

West Area (Adjacent to Woonasquatucket River)

Four anomalies (14, 17, 20, and 21) were identified from the February 1999 EM-31 survey (see Figure 2). They are described in table one of the trip report (see attachment C). Anomalies 14 and 17 are described as possible pipes or targets, and 20 and 21 as possible trenches/disposal areas. Individual EM-31 profiles that were collected in February were re-evaluated and a composite view of selected profiles was developed (see Figure 11). This figure shows the response curves for the EM-31 (quadrature and in-phase) and EM-61 (bottom coil and differential) data for the

80W, 90W, 100W, and 110W lines collected from 900S to 550S adjacent to Woonasquatucket River. While the inphase, bottom coil, and differential data provide information associated with buried metallic materials, the quadrature data yields information pertaining to the apparent conductivity of the underlying sediments. Historically, the depositional conditions in this area are highly variable and complex. As a result, the lithologic character and the permeability of the deposits change abruptly from place to place within short distances. By stacking the profiles as seen in Figure 11, pronounced or site wide trends can be developed to improve the geologic interpretation of this area. For the 80W, 90W, 100W, and 110W lines the most prominent trend occurs in the apparent conductivity or quadrature component. Conductivities decrease abruptly, by as much as 20 mS/m along portions of the data plot. While the conductivity values across the area range from 10 to 30 mS/m lower values (under 10 ms/m) are typical of sands and gravels. The lenticular trend of the feature identified in Figure 11 is consistent with that of paleo-channel deposits.

GPR surveys were performed in this area in April 1999. Radar scans were conducted over each of the anomalies. The scans (shown in attachment B) are referenced to the grid coordinates and include transects 120S through 350S and 0W through 100W. Of particular interest, are transects 250S through 350S, which bisect the anomalous areas. In general, the upper portions of the profile (0 to 20ns) appear as darkened or less reflective material, from 1 to approximately 3.5 feet bgs. Underlying this layer is a zone of reflective materials characterized in the profile by high amplitude (blue and yellow), spiky (chaotic) signatures. Consistent with other areas of the site, this deeper zone extends from 20 to 50 ns or 3.5 to >8 feet bgs and may in fact be the mixture of coarse fill and alluvial deposits of the paleo-channel.

South Parking Lot

The EM-61 contour plots for the South Parking Lot are shown in Figures 12 and 13. Potential buried anomalies are numbered from *A10* to *A12* for easy identification. Several buried conductors which were associated to known cultural features including buried electric and water utilities (confirmed by utility plans), a fire hydrant and several light poles. The three significant anomalies (*A10* to *A12)* appear as highs or lows at various levels from background. They are summarized along with the EM interpretations in Table 1. Anomalies *A10* and *A11* depict two small clusters of individual or localized anomalies. *A12* represents the most dramatic anomaly identified across the entire site. Peak signals response range from 75 mV to greater than 800 mV. The source of the anomaly appears diffuse and widespread and the approximate lateral extent is 80 feet N/S by 120 feet E/W.

The GPR profiles show a well-defined layer of reflective buried materials that correlate with the lateral boundaries of EM anomaly *A12*. Similar to the profiles collected in the Central Parking Lot, the radar signatures appear as high amplitude (blue and white), chaotic signatures. The layer extends vertically from approximately 3.5 to >10 feet bgs. The deposition of this layer is undetermined. The high intensities of the peak EM signals and the GPR signature characteristics indicate that it is probably anthropogenic (i.e. mixed metallic fill or construction debris). Based on these findings this area is deemed to have the highest potential for containing buried *bulk* metallic materials.

South Grid Area

The EM-31 conductivity and in-phase contour plots for the South Grid Area, located south of the South Parking Lot are shown in Figure s 14 and 15. The most significant feature identified in this area (*A13)* is depicted on Figure 15 as a strong negative in-phase response (>-25 ppt). The location and orientation of *A13* suggest that the source is an extension of anomaly *A12*. GPR signature characteristics are consistent with those identified in the adjacent South Parking Lot. It is highly probable that the underlying source is consistent with those described above.

The two anomalies identified during the February 1999 survey (43 and 44, see Figure 2) appear as minor excursions in the EM-31 profiles (see attachment C Trip Report, Appendix D, south grid profiles - 75E and 100E). Based the EM characteristics and visual field observations conducted during the April 1999 investigation these anomalies

were attributed to the remnants of three individual crushed 55-gallon drum carcasses on the ground surface. The EM data indicates no metallic debris buried in upper 12 to 15 feet, the effective depth of the instrument, in this area.

TABLE 1
CENTREDALE MANOR SITE
GEOPHYSICAL SURVEY RESULTS SUMMARY
North Parking Lot Survey Results

SURVEY COVERAGE: Approx. 40,000 sq. ft.-actual coverage
Sample Density:
EM-31 5ft/station x 10 ft/transect
EM-61 0.5-1 ft/station x 5 ft/transect
Number of GPR Transects: 16

SIGNIFICANT EM ANOMALIES IDENTIFIED

Anomaly	Coordinates (Grid node)	Interpreted Anomaly Identity	Comments
A1	135N to 215N/ 15 W to 35W	Indicative of buried conductor. Possible utility or extents of mixed fill. Consistent with ferrous "rusty" band and ash described in borings B3 and B5	Linear conductive feature trending N to S between 25W and 30 W lines. Rapid excursions in the EM31 (conductivity >75 mS/m) and (in-phase >10 ppt) response define linear anomaly. Minimal response in EM-61 does not suggest bulk metallic fill material.
A2	15N/35W	Localized Anomaly, moderate potential of small buried metallic source.	Well-defined negative in-phase response EM-31.
A3	25S/20W	Localized Anomaly; moderate potential of small buried metallic source.	Well-defined strong negative in-phase response EM31.
A4	100S/85W	Localized Anomaly; moderate potential of small buried metallic source.	Moderate response on EM31 in-phase measurement
A5	50W trending N 110S to 10S	Anomaly symmetrical along the survey line; trend suggest buried utility	Linear conductive feature trending N to S between 45W and 50W lines. Rapid excursions in the EM61 (>100 mV) and (in-phase >10 ppt) response define linear anomaly.
A6	10N/55W	Conductive materials. Possible extents of mixed fill. Ferrous "rusty" band and ash described in soil borings B3 and B5	Defuse conductive feature. Moderate EM61 response (differential >50 mV) and slight EM-31 response (in-phase >2 ppt) defines anomaly.

TABLE 1
CENTREDALE MANOR SITE
Geophysical Survey Results Summary
(Continued)

Central Parking Lot Survey Results

SURVEY COVERAGE: Approx. 37,500 sq. ft.-actual coverage
Sample Density:
EM-61 2.5 ft/station x 10 ft/transect
Number of GPR Transects: 15

SIGNIFICANT EM ANOMALIES IDENTIFIED

Anomaly	Coordinates (Grid node)	Interpreted Anomaly Identity	Comments
A7	See fig 7 plot	Localized clustered anomalies moderate potential of small buried metallic source.	Well-defined discriminate targets with peak EM-61 signal responses in excess of 180 mV.
A8		Localized clustered anomalies moderate potential of small buried metallic source.	Well-defined discriminate targets with peak EM-61 signal responses ranging from 50 to 180 mV.
A9		Localized clustered anomalies moderate potential of small buried metallic source.	Well-defined discriminate targets with peak EM-61 signal responses ranging from 50 to 180 mV. Northern most anomaly defined by GPR. Southernmost anomaly diffuse.

TABLE 1
CENTREDALE MANOR SITE
Geophysical Survey Results Summary
(Continued)

South Parking Lot Survey Results

SURVEY COVERAGE: Approx. 37,800 sq. ft.-actual coverage
Sample Density:
EM-61 0.5-1.0 ft/station x 5 ft/transect
Number of GPR Transects: 21

SIGNIFICANT EM ANOMALIES IDENTIFIED

Anomaly	Coordinates (Grid node)	Interpreted Anomaly Identity	Comments
A10	281540N/ 331765E	Localized discrete anomaly; moderate potential of small buried metallic source.	Well-defined discriminate target with peak EM-61 signal responses in excess of 800 mV.
A11	281545N/ 331730E	Localized clustered anomalies; moderate potential of small buried metallic source.	Well-defined discriminate targets with peak EM-61 signal responses in excess of 200 mV.
A12	(See fig.10) (Approx. lateral extent is 80 feet N/S by 120 feet E/W.)	Deposition undetermined. Probably anthropogenic (i.e. mixed metallic fill or construction debris). Deemed to have the highest potential for buried *bulk* metallic materials	Peak EM signals response range from 75 mV to greater than 800 mV. The source of the anomaly appears diffuse and widespread. GPR profiles show well-defined layer of reflective materials that correlate with the lateral boundaries of EM anomaly.

TABLE 1
CENTREDALE MANOR SITE
Geophysical Survey Results Summary
(Continued)

South Grid Wooded Area
Survey Results

SURVEY COVERAGE: Approx. 3,500 linear ft.
Sample Density:
EM-61 5 ft/station x 25 ft/transect
Number of GPR Transects: 9

SIGNIFICANT EM ANOMALIES IDENTIFIED

Anomaly	Coordinates (Grid node)	Interpreted Anomaly Identity	Comments
A13	Extension of anomaly *A12*	Probable that the underlying source is consistent with *A12*. Anthropogenic (i.e. mixed metallic fill or construction debris). Deemed to have high potential for buried *bulk* metallic materials	Strong negative in-phase response >-25 ppt. GPR signature characteristics are consistent with those identified at anomaly *A12* in the adjacent South Parking Lot

Conclusions and Recommendations

Several buried cultural features (i.e. subsurface utilities) were identified across the four surveyed areas. These features were confirmed by utility drawings or associated surface features such as fire hydrants or electrical appurtenances. In addition, a total of 13 significant undetermined EM anomalies were identified. Based on the EM anomaly and the GPR signature characteristics, it is probable that these features are anthropogenic (i.e. mixed metallic fill or construction debris). Anomalies *A12* and *A13*, located in the South Parking Lot, are deemed to have the highest potential for containing buried *bulk* metallic materials. Depending upon the findings of soil and water chemistry sampling, further consideration should be given to physically characterizing the anomalies.

Although a comprehensive geologic analysis of the GPR data was not scoped some stratigraphic trends were identified. The GPR cross sectional profiles collected in the North Parking Lot depicted a sequence of stratified materials reflecting a meandering lateral trend. The trend identified on the GPR profiles, (coupled with the EM data and soil boring information) suggest a natural layer, possibly the buried remnants (alluvial deposits) of a paleo-channel. Depending upon the findings of the water chemistry sampling, further consideration should be given to mapping/modeling the radar data, as these zones may reflect preferred groundwater pathways.

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