DES Waste Management Division
29 Hazen Drive; PO Box 95
Concord, NH 03302-0095

WORK PLAN
SUPPLEMENTAL HYDROGEOLOGIC INVESTIGATION – PHASE I
GROUNDWATER MANAGEMENT ZONE DELINEATION
AND WATER SUPPLY INVESTIGATION
DARTMOUTH COLLEGE, RENNIE FARM SITE
HANOVER CENTER ROAD
HANOVER, NEW HAMPSHIRE
NHDES SITE NO. 201111109, DES PROJECT NO. 277737

Prepared For:
Dartmouth College Office of Environmental Health and Safety
37 Dewey Field Road, Suite 6216
Hanover, NH 03755
Phone Number: (603) 646-0235
RP Contact Name: Mr. Michael D. Cimis
Assistant Director of Environmental Health & Safety
RP Contact Email: Michael.D.Cimis@Dartmouth.EDU

Prepared By:
GZA GeoEnvironmental, Inc.
5 Commerce Park North, Suite 201
Bedford, New Hampshire 03110
Phone Number: (603) 232-8732
Contact Name: Mr. James M. Wieck, P.G.
Contact Email: James.wieck@gza.com
GZA Project No. 04.0190030.01

GZA GeoEnvironmental, Inc.

Digitally signed by GZA GeoEnvironmental, Inc.
DN: cn=GZA GeoEnvironmental, Inc., o=GZA GeoEnvironmental, Inc., ou, email=karen.reed@gza.com, c=US
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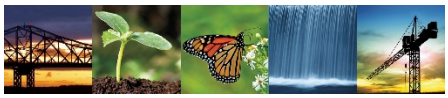

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GEOTECHNICAL
ENVIRONMENTAL
ECOLOGICAL
WATER
CONSTRUCTION MANAGEMENT

5 Commerce Park North
Suite 201
Bedford, NH 03110
603.623.3600
603.624.9463 Fax

www.gza.com

VIA EMAIL

December 2, 2015
File No. 04.0190030.01

Mr. Paul Rydel
Waste Management Division
New Hampshire Department of Environmental Services
29 Hazen Drive, P.O. Box 95
Concord, New Hampshire 03301

Re: Work Plan
Supplemental Hydrogeologic Investigation – Phase I
Groundwater Management Zone Delineation and Water Supply Investigation
Dartmouth College, Rennie Farm Site
Hanover, New Hampshire
NHDES Site No. 201111109, DES Project No. 277737

Dear Mr. Rydel:

On behalf of Dartmouth College (Dartmouth), GZA has prepared this work plan describing proposed supplemental hydrogeologic investigation activities associated with the Rennie Farm Site (Site) for review and comment by the New Hampshire Department of Environmental Services (NHDES). Based on the results of recent off-site water supply well sampling, 1,4-dioxane is present beyond the Site boundaries in groundwater within fractured bedrock at concentrations exceeding the New Hampshire Ambient Groundwater Quality Standard (NH AGQS) for 1,4-dioxane (3 micrograms per liter [ug/L]). Off-site water supply well sampling and results are described in GZA's letter report[1] dated November 11, 2015.

Due to the exceedance of NH AGQS beyond the Site boundary, supplemental hydrogeologic investigations are necessary to evaluate the potential for the presence of human and environmental receptors, and further delineate the extent of 1,4-dioxane. The primary tasks included in the proposed supplemental hydrogeologic investigation were discussed during our November 16, 2015 meeting at NHDES's offices in Concord. As we discussed during our meeting, the proposed hydrogeologic investigation activities have been organized into two phases of work due to the complexity groundwater flow within fractured bedrock groundwater systems and the properties of 1,4-dioxane. The first phase of supplemental investigation is focused on the further characterization of the fractured bedrock groundwater system beneath and immediately east of the Site, with the overall objective of providing hydrogeologic data needed regarding potential contaminant flow paths to select locations for the installation of wells downgradient of the Site.

[1] Letter report by GZA titled "*Letter Report, Off-Site Water Supply Well Sampling, Dartmouth College, Rennie Farm Site, Hanover Center Road, Hanover, New Hampshire, NHDES Site No. 201111109, DES Project No. 277737.*"

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The second phase of the supplemental investigation is focused on the installation and sampling of bedrock groundwater monitoring wells downgradient of the Site, with the overall objective of delineating the extent of 1,4-dioxane and establishing compliance monitoring locations in support of the preparation of an application for Groundwater Management Permit (GMP). This work plan describes the proposed tasks included in Phase I of the supplemental investigation. At the conclusion of Phase I of the investigation, a report will be prepared including recommendations for installation of the Phase II monitoring wells, and further activities necessary to provide the data needed to prepare an application for GMP.

As noted in GZA's letter report dated November 11, 2015, a point-of-entry (POE) treatment system has been installed at 9 Rennie Road to remove 1,4-dioxane from the water supply. The POE treatment system is intended as an interim means of providing the owners of 9 Rennie Road with a source of water meeting NH AGQS. Dartmouth intends to develop and operate a public water supply system to provide a permanent replacement water supply for the owners of 9 Rennie Road. Certain tasks included in Phase I of the proposed supplemental investigation have been selected, as noted below, to evaluate the potential for the transport of 1,4-dioxane toward the proposed location for the alternate water supply (see **Figure 1**).

WORK PLAN

This section describes the proposed activities included in Phase I of the investigation. Specific Phase I objectives include:

1. Characterization of the bedrock fracture fabric within the vicinity of the identified 1,4-dioxane impacted area;
2. Identification and evaluation of 1,4-dioxane transport pathways beneath the Rennie Farm property and downgradient off-site areas relative to potential human and environmental receptors;
3. Source area characterization;
4. Monthly evaluation of 1,4-dioxane concentrations at selected monitoring locations; and
5. Evaluation of the potential for groundwater flow and 1,4-dioxane transport to the proposed water supply well location south of the source area.

Access to existing bedrock water supply wells at 7 and 9 Rennie Road and to properties identified on the Town of Hanover Tax Map as Map 16, Lot 7 and Map 13, Lots 17, 18, 19, and 81 will be needed to complete certain tasks as described below. The proposed work will be completed as allowed by access.

The following describe the proposed tasks.

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TASK 1 – EXPANDED BEDROCK MAPPING, LINEAMENT EVALUATION, AND WELL INVENTORY

This task builds on the previous bedrock structural mapping completed by GZA, expanding the area included in the survey to the entire Rennie Farm property and the off-site downgradient properties identified on Hanover Tax Map 16 (Lot 7) and on Hanover Tax Map 13 (Lots 17, 18, 19, and 81). The expanded bedrock mapping area is illustrated on **Figure 1**. The objective of the expanded survey is to provide bedrock structural information within and surrounding the potential area of 1,4-dioxane transport, as currently understood.

As allowed by access, bedrock outcrops will be identified within the expanded bedrock mapping area by a traverse of the area on foot. The approximate locations of bedrock outcrops will be illustrated on an air-photograph-based figure. Identified bedrock outcrops will be observed for the presence of fractures and the lithology identified. The orientation of representative fractures will be measured and recorded, and the recorded measurements will be summarized using descriptive statistics and illustrated using fracture orientation stereonets.

Lineaments will be identified within the general area shown on **Figure 1** and illustrated on an air-photograph-based figure with similar extents as **Figure 1**. The New Hampshire Well Board records available on the NHDES OneStop Webgeographic system will be reviewed for wells within the area shown on **Figure 1**, which includes the area surrounding the remedial excavation to a radius of approximately 1.0 mile, and the area downgradient of the area surrounding the excavation to New Hampshire Route 10. Well owner, type, depth, and yield will be summarized in a table and the locations of the wells illustrated on an air photograph based figure.

TASK 2 – GEOPHYSICAL SURVEY

Surficial geophysical surveys of the area illustrated on **Figure 1** are proposed to identify areas within bedrock with relatively higher concentrations of fractures (areas of higher fracture density). The methods proposed include Very Low Frequency electromagnetic (VLF-EM) and electrical resistivity imaging (ERI) methods. The VLF-EM data will be acquired along a series of roughly north-south parallel traverses of the survey area spaced approximately 300 feet apart, with a total of approximately 15,000 linear feet. The ERI data will be acquired along four to five approximately 900-foot-long traverses of the survey area totaling approximately 4,000 linear feet. The ERI traverses will be selected based on the results of the VLF-EM survey.

The VLF-EM survey will be performed by Hager-Richter Geoscience, Inc. (Hager- Richter) using an IRIS T-VLF system or equivalent equipment. The ERI survey will be performed by Hager-Richter using an AGI Super Sting R8 IP system.

The results of the VLF-EM and ERI surveys will be used to produce cross-sectional depictions of relative fracture density. The cross-sectional depictions will be used along with the expanded bedrock geologic mapping described in *Task 1* and borehole geophysical logging described in *Task 4* to characterize the bedrock fracture system beneath the Site. Collectively, the results of

these tasks will be used to further evaluate the flow of groundwater and transport of 1,4-dioxane associated with the Site in fractured bedrock.

TASK 3 – WATER QUALITY MONITORING

Water quality monitoring of selected established and proposed sampling locations is proposed to provide 1,4-dioxane concentration data necessary to evaluate temporal and spatial trends in 1,4-dioxane concentration. Proposed established monitoring locations include: GZ-2, GZ-3, GZ-9L, GZ-10L, on-site "dug well," Stream-1, and the water supply wells at 7 and 9 Rennie Road. One or more of the bedrock groundwater monitoring wells described in *Task 6* (GZ-9D, GZ-12L, GZ-13L, GZ-14L, GZ-15D, and GZ-16D) and up to two proposed off-site surface water sampling locations (Stream-2 and Stream-3) may also be included in the monitoring program. The decision to include the proposed sampling locations within sampling program will be based on the results of the initial and confirmatory sampling rounds collected as described in *Task 6*, and/or location relative to groundwater flow from the source area. The locations of the existing monitoring locations, proposed surface water monitoring locations, and proposed bedrock groundwater monitoring wells are illustrated on **Figure 1**.

An approximate one month sampling frequency will initially be used for each of the sampling locations; however, GZA anticipates that sampling frequencies will be decreased as temporal concentration trends are evaluated and understood. GZA also anticipates that the water quality monitoring program will be continued until a monitoring program is established under a GMP. Groundwater monitoring wells will be purged prior to sampling, and purged groundwater discharged to the ground surface. Water supply wells will be sampled following a 20-minute purge of water from the well, and purging water from any additional piping as appropriate. Water quality samples will be collected in accordance with State of New Hampshire Code of Administrative Rules Env-Or 610.02 (Sampling and Analysis), and submitted for laboratory analysis of 1,4-dioxane using low level analytical methods (EPA Method 8260 Selective Ion Method [SIM]).

Treatment system midpoint and effluent (treated water) samples will be collected from the POE treatment system at 7 Rennie Road on a monthly frequency, as necessary to evaluate the performance of the treatment system. Midpoint and effluent samples will be analyzed for 1,4-dioxane using low level analytical methods (EPA Method 8260 SIM).

TASK 4 – BOREHOLE GEOPHYSICAL LOGGING

Geophysical logging of the boreholes of existing bedrock water supply wells at 7 and 9 Rennie Road, and two proposed bedrock boreholes described in *Task 6* (GZ-15D and GZ-16D) is proposed to provide data regarding the locations and orientations of fractures intersecting the boreholes and identify potential water-bearing fractures. The borehole geophysical data will be used along with the fracture fabric information, and the results of the expanded bedrock mapping and surficial geophysical surveys to refine our understanding of the bedrock fracture system and further develop the conceptual site model.

Borehole geophysical logging will include the following methods:

- Fluid temperature and conductivity/resistivity;
- Optical televiewer;
- Acoustic televiewer and acoustic caliper; and
- Heat Pulse Flow Meter under ambient and pumping conditions

For the existing water supply wells, the property owner's submersible well pumps and related down-well plumbing and wiring will be removed to allow logging of the well, and placed back in the well following the completion of the logging. The removal and replacement of the property owner's down-well equipment will be performed by a New Hampshire Licensed Pump Installer. The Pump Installer will also establish temporary water supplies to the residences during the logging program.

The depths of the wells are not known and will be measured during the logging process.

GZA anticipates that the process of logging the bedrock water supply wells will be completed in approximately one week.

TASK 5 – WATER SUPPLY WELL PACKER ZONE SAMPLING

Based on the detection of 1,4-dioxane in groundwater samples collected from the existing bedrock water supply well at 9 Rennie Road, GZA proposes collection of water quality samples from selected vertical intervals within the well to identify the location of the fracture of fractures transmitting 1,4-dioxane to the well. The inflatable packers will be used to collect the samples from selected vertical zones within the borehole.

Water-bearing fractures or fracture zones will be identified within the bedrock borehole based on the results of the borehole geophysical logging of the well described in *Task 3*. The number and depth of the sampling zones will be based on the depth of the well and vertical location of water-bearing fractures. The packer assembly will be used to isolate specific borehole zones for sample collection. One packer will be located above the fracture/fracture zone and one packer will be located below the fracture/fracture zone, creating an isolated zone that straddles the desired fracture. A section of perforated pipe (well screen) connects the two packers. The perforated pipe is attached to threaded polyvinyl chloride (PVC) or steel riser pipe which extends to the ground surface and provides isolated access to the target fracture zone.

Once the packer assembly is lowered to the desired sample depth, the packers are inflated to a pressure sufficient to isolate the sample zone (typically 200 to 400 pounds per square inch). After the zone is sealed, purging and sampling of the zone will be accomplished using a submersible Grundfos Redi-Flow 2 pump. During sampling, water levels will be monitored inside and outside the packer riser to monitor drawdown and test the effectiveness of the packer seal.

Groundwater samples will be collected for analysis of 1,4-dioxane using low level analytical methods (EPA Method 8260 SIM).

The intent of the schedule is to perform the packer zone sampling immediately following the borehole geophysical logging to minimize the disruption to the homeowner.

TASK 6 – BEDROCK WELL INSTALLATION AND SAMPLING

Installation and sampling of supplemental bedrock groundwater monitoring wells is proposed to provide additional 1,4-dioxane concentration data needed to evaluate the distribution and transport of 1,4-dioxane within the fractured bedrock groundwater system. Drilling and monitoring well installation methods will be consistent with previous phases of work at the Site and consistent with Env-Or 610.04 (Groundwater Monitoring Wells). The approximate locations of the proposed supplemental bedrock monitoring wells are illustrated on **Figure 1**. Proposed wells and objectives include:

Source Area (GZ-12L and GZ-13L)

Installation of two shallow bedrock wells (screened in upper 2 to 7 feet of bedrock) within the former remedial excavation/source area are proposed to provide water quality monitoring locations represented of conditions directly beneath the source area. 1,4-dioxane concentration data are needed from the source area to evaluate the residual mass of 1,4-dioxane and potential need for supplemental source remediation.

The boring will be advanced in overburden using hollow stem auger drilling methods, and soil samples collected continuously to the top of bedrock. Soil samples will be screened in the field by a GZA field geologist or engineer. Soil jar headspace screening methods will be used to screen soil samples for total volatile organic compounds (VOCs) using a photoionization detector. Up to two soil samples may be selected from each of the borings for laboratory analysis of VOCs using Environmental Protection Agency (EPA) Method 8260B, including low level analysis for 1,4-dioxane using EPA Method 8260B SIM.

Downgradient Deeper Bedrock (GZ-9D)

GZA proposes installation of a supplemental bedrock groundwater monitoring well (GZ-9D) proximate to the existing GZ-9U/GZ-9L couplet. The objective is to construct a groundwater sampling well at a greater depth than GZ-9L to evaluate the vertical distribution of 1,4-dioxane in bedrock groundwater beneath the location of maximum 1,4-dioxane concentration in shallow bedrock. Top of bedrock was encountered at a depth of 15 feet below ground surface and well GZ-9L is screened within bedrock at a depth of approximately 37.5 feet to 42.5 feet. The proposed screen depth for GZ-9D is from approximately 90 feet to 100 feet below ground surface. The actual screen depth will be based on the drilling conditions encountered, but is intended to be approximately 50 feet below the screen interval of GZ-9L. Based on the location of the proposed

well and results of soil sampling during the installation of wells GZ-9U and GZ-9L, soil samples will not be collected during drilling of well GZ-9D.

Downgradient Site Boundary (GZ-14L)

GZA proposes the installation of one monitoring well in the estimated direction of 1,4-dioxane transport on the downgradient Site boundary. The objective of this monitoring well is to provide a sampling location to collect water quality samples necessary to further evaluate the spatial temporal distribution of 1,4-dioxane. The proposed well will be screened in the upper 25 feet of competent bedrock, with the intent of being similarly constructed to GZ-9L.

Sidegradient Southern Site Area (GZ-15L and GZ-16L)

Two wells consisting of open 6-inch-diameter boreholes are proposed to be installed south of the excavation/source area. The intent of these boreholes is to provide water quality and hydraulic head monitoring locations between the excavation/source area and the proposed location of a water supply well to be installed to provide an alternate source of water for the residence at 9 Rennie Road. The depth of the well will be determined based on results of preceding tasks and the planned depth of the proposed water supply well.

The boreholes will also be logged using geophysical borehole methods as described in *Task 4*.

Well Development, Survey, and Sampling

Each of proposed bedrock groundwater monitoring wells constructed with 2-inch inner-diameter (ID) PVC screen and riser sections will be developed by GZA using manual inertia pump and surge block methods. The two proposed 6-inch ID open-hole bedrock wells will be developed by over pumping using an electric submersible pump.

The location and reference point elevations of each of the proposed bedrock wells will be surveyed by a New Hampshire Licensed surveyor.

Each of the proposed sampling locations will be sampled a minimum of two weeks after installation (initial sampling round), and resampled after a further minimum two week period (confirmatory sampling round). Sampling and analytical methods will be as described in *Task 3*, with the exception that the two proposed 6-inch ID open hole bedrock wells will be purged and sampled using an electric submersible pump.

TASK 7 – DATA EVALUATION AND REPORTING

Data collected during the completion of *Task 1* through *Task 6* will evaluated relative to the project and task objectives. The work performed, results, and GZA's conclusions and recommendation will be summarized in a report. The report will include figures and tables summarizing the data collected and will include a 3-dimensional graphical summary of

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information illustrating the bedrock fracture fabric. The report will include an updated conceptual site model and recommendations, including a work plan, for Phase II of the supplemental investigation.

We trust that the information included herein meets the needs of the NHDES. We appreciate your review of this letter and work plan and look forward to receiving your comments. Should you have any questions, please do not hesitate to contact Mr. James M. Wieck at 603-232-8732.

Very truly yours,

GZA GEOENVIRONMENTAL, INC.

James M. Wieck, P.G.
Senior Project Manager

Steven R. Lamb, P.G., C.G.W.P.
Principal

Ronald A. Breton, P.E.
Senior Principal, Consultant/Reviewer

JMW/RAB/SRL:kr
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Attachment: Figure

cc: Maureen O'Leary, PhD, MBA, CBSP, Dartmouth College
Mr. Michael D. Cimis, CIH, CHMM, Dartmouth College
Ellen Arnold, Esq.

FIGURE

LEGEND:

- ACTIVE DUG WELL
- ABANDONED DUG WELL
  - RED CIRCLE INDICATES WELL SAMPLED DURING INITIAL AND/OR CONFIRMATORY OFF SITE WATER QUALITY SAMPLING ROUND
  - BLUE CIRCLE INDICATES PROPERTY OWNER HAS REQUEST SAMPLING OF WELL, SAMPLING PLANNED
- WATER SUPPLY WELL
- GZ-1 — GROUNDWATER MONITORING WELL
- GZ-14D — POTENTIAL PHASE I PROPOSED BEDROCK GROUNDWATER QUALITY COMPLIANCE MONITORING LOCATION
- SPRING
- SURFACE WATER QUALITY MONITORING LOCATION
- INTERMITTENT/PERENNIAL STREAM; ARROW INDICATES DIRECTION OF SURFACE WATER FLOW
- APPROXIMATE PROPERTY BOUNDARY
- INFERRED DIRECTION OF GROUNDWATER FLOW BASED ON 1, 4 - DIOXANE DISTRIBUTION IN GROUNDWATER
- LOCATION OF INTERMITTENT STREAM
- 1000 — APPROXIMATE GROUND SURFACE ELEVATION CONTOURS
- APPROXIMATE LIMITS OF SURFICIAL GEOPHYSICAL SURVEY
- LOCATION OF POTENTIAL WATER SUPPLY LINE (LOCATION SHOWN PRELIMINARY AND APPROXIMATE)

GENERAL NOTES:

1) 2010-2011 1-FT COLOR AERIAL PHOTOS FOR THE TOWN OF HANOVER WERE OBTAINED FROM THE NH GRANIT NEW HAMPSHIRE STATEWIDE GIS CLEARINGHOUSE.
2) APPROXIMATE PROPERTY BOUNDARIES BASED ON REVIEW OF TOWN OF HANOVER, NEW HAMPSHIRE TAX MAP 13, 15, AND 16, DATED APRIL 1, 2015.
3) LOCATIONS OF MONITORING WELLS, DUG WELL, AND ONSITE INTERMITTENT STREAM BASED ON SURVEYS BY WSP TRANSPORATION AND INFRASTRUCTURE ON OCTOBER 14, 2014 AND JUNE 1, 2015.

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SCALE IN FEET

NO.	ISSUE / DESCRIPTION	BY	DATE

SUPPLEMENTAL HYDROGEOLOGIC INVESTIGATION
DARTMOUTH COLLEGE, RENNIE FARM SITE
HANOVER, NEW HAMPSHIRE
NHDES SITE NO. 201111109, PROJECT NO. 277737

GROUNDWATER MANAGEMENT ZONE DELINEATION INVESTIGATION SUMMARY

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com		PREPARED FOR: DARTMOUTH COLLEGE	
PROJ MGR: JMW	REVIEWED BY: TWK	CHECKED BY: RAB	FIG 1
DESIGNED BY: JMW	DRAWN BY: MJD	SCALE: 1 inch = 250 feet	
DATE: 11-24-2015	PROJECT NO. 04.0190030.01	REVISION NO.	

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