nationalgrid

Katherine Vater
Project Manager
Site Investigation and Remediation

September 24, 2015

Mr. William Wu
Environmental Engineer
New York State Department of Environmental Conservation
Division of Environmental Remediation
Remedial Bureau C, 11th Floor
625 Broadway
Albany, NY 12233

Re: Final Supplemental Remedial Investigation Work Plan (ARCADIS, September 14, 2015), and NYSDEC Approval Letter dated September 15, 2015
Former Dangman Park Manufactured Gas Plant Site - Property Redevelopment
Brooklyn, New York
NYSDEC Site No. 224047
Index # A2-0552-0606

Dear Mr. Wu:

This letter transmits two printed and electronic copies on CD of National Grid's final Supplemental Remedial Investigation Work Plan for the Former Dangman Park Manufactured Gas Plant (MGP) Site in Brooklyn, New York.

Your September 15, 2015 letter approved the September 14, 2015 Pre-Design Investigation Work Plan prepared by ARCADIS, with comments. One of your comments was that the title of the work plan shall be changed from "Pre-Design Investigation (PDI) Work Plan" to "Supplemental Remedial Investigation (RI) Work Plan". Accordingly, the enclosed document will hereinafter be identified as the Supplemental RI Work Plan.

A copy of your letter is included with all copies of the Supplemental RI Work Plan.

A copy of the Supplemental RI Work Plan will be placed in the document repository (Community Board 13).

If you have any questions or require any additional information, please contact me at (608) 826-3663 or at katherine.vater@nationalgrid.com.

Sincerely,

Katherine Vater

Katherine Vater
Project Manager

Enclosure – Supplemental RI Work Plan (ARCADIS, September 14, 2015)

cc: Albert DeMarco, NYSDOH
Linda Sullivan, Esq., National Grid
Bonnie Barnett, Esq., Drinker Biddle and Reath LLP
Megan Miller, P.E., ARCADIS
M. Cathy Geraci, ARCADIS

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Division of Environmental Remediation, Remedial Bureau C
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September 15, 2015

Ms. Katherine Vater
Project Manager
National Grid – Site Investigation and Remediation
287 Maspeth Ave
Brooklyn, NY 11211-1703

Dear Ms. Vater:

Re: K – Dangman Park MGP
Kings County, site no. 224047
Pre-Design Investigation (PDI) Work Plan (ARCADIS, September 14, 2015)

The New York State Department of Environmental Conservation (the Department) and the New York State Department of Health (NYSDOH) have reviewed the referenced work plan. The work plan is hereby approved with the following modifications:

1) The Department understands the difficulty in extending test pits in narrow spaces in a partially vacated structure. The Department reserves the right to require test pits to confirm the locations of the gas holders after the soil boring task, after the structure becomes more available for excavating test pits.
2) The title of the work plan shall be changed from “Pre-Design Investigation (PDI) Work Plan” to “Supplemental Remedial Investigation (RI) Work Plan”

In accordance with the Order on Consent and 6NYCRR 375-1.6(d), please indicate within 15 days whether you accept the Department’s modified work plan. Please ensure that all copies of the final work plan include this approval letter, and place copies of the work plan in the document repositories.

Please contact me with any questions via email at william.wu@dec.ny.gov, or via phone at (518) 402-9662.

Sincerely,

William Wu

William Wu
Environmental Engineer 1
Remedial Bureau C
Division of Environmental Remediation

ec: G. Cross, NYSDEC
A. DeMarco, NYSDOH
J. Deming, NYSDOH
M. Miller, ARCADIS of New York, Inc.
S. Feldman, ARCADIS of New York, Inc.
C. Keen, ARCADIS of New York, Inc.
C. Geraci, ARCADIS of New York, Inc.

Katherine Vater
Project Manager
Site Investigation and Remediation

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September 14, 2015

Mr. William Wu
Environmental Engineer
New York State Department of Environmental Conservation
Division of Environmental Remediation
Remedial Bureau C, 11th Floor
625 Broadway
Albany, NY 12233

Re: Former Dangman Park Manufactured Gas Plant Site - Property Redevelopment
Pre-Design Investigation
Brooklyn, New York
NYSDEC Site No. 224047
Index # A2-0552-0606

Dear Mr. Wu:

Enclosed is the Pre-Design Investigation Work Plan for the former Dangman Park Manufactured Gas Plant (MGP) Site (the "Site"). The Work Plan was originally submitted to the New York State Department of Environmental Conservation (NYSDEC) on August 10, 2015, and has been revised to include the Community Air Monitoring Plan (CAMP) submitted by National Grid to NYSDEC on September 9, 2015. The CAMP was developed to address one of comments presented in your August 17, 2015 e-mail. National Grid provided responses to each of those comments in a September 9, 2015 e-mail (copy of that e-mail, including the associated building photographs, is provided as Attachment A).

This letter was also originally provided to NYSDEC on August 10, 2015 and has been revised to include the aforementioned responses to comments and to update the anticipated start date for the PDI field work. No other changes have been made to the PDI Work Plan or this letter.

Accordingly, this letter is also provided as a follow up to our recent conversations and the meeting on July 7, 2015 among representatives of the New York State Department of Environmental Conservation (NYSDEC), National Grid, and 450 Neptune Associates, LLC (the Owner), the owner of a parcel (Block 7273, Lot 1) within the Site. During the July 7 meeting, an update of activities related to the Owner's redevelopment of that parcel was discussed and the Owner stated that currently vacant tenant spaces inside the eastern portion of the existing shopping center building will be made accessible in the near-term for implementation of the pre-design investigation (PDI) field activities. The eastern portion of the area immediately in front (north) of the shopping center building (shopping center sidewalk) will also be made accessible by the Owner.

As agreed during the meeting, PDI activities are required to evaluate the distribution (if any) of mobile MGP-related non-aqueous phase liquid (NAPL) beneath the areas of the shopping center building described above. Within the areas to be investigated during the PDI are portions of the approximate locations of the three former gas holders, as well as the area immediately downgradient. These areas were not accessible during the Site Characterization (SC) and Remedial Investigation (RI) which delineated the nature and extent of MGP-related impacts for the Site. The proposed scope for the PDI activities is detailed in the attached work plan that was prepared with input from the Owner. As detailed therein, the proposed PDI scope initially includes the following activities:

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- Gauging for the absence/presence of NAPL in the eleven (11) existing monitoring wells located proximate to and within the extent of NAPL that was delineated in the RI Report based on the observations of tar in the soil borings drilled during the SC and RI. As presented in the RI Report, no NAPL has been observed in any of the monitoring wells. These existing monitoring wells will be gauged to confirm Site conditions; and

- Drilling and logging twelve (12) soil borings to be strategically located based on the approximate locations of the three former gas holders and the conceptual site model established for the Site in the NYSDEC-approved Remedial Investigation Report (RI Report; ARCADIS, 2014). If substantial quantities of mobile NAPL are identified during these activities, the proposed PDI scope presented in the attached work plan also identifies that one or more of the following activities may also be conducted:

- Excavating test pits using air-knife/vacuum excavation to further assess the presence of former MGP structures;

- Collecting soil samples for laboratory analysis to preliminarily evaluate off-site treatment/disposal options and/or obtain geotechnical information for design purposes;

- Conducting a hydrogeologic investigation to further characterize aquifer parameters (i.e., transmissivity and specific yield) and NAPL mobility; and

- Drilling additional soil borings.

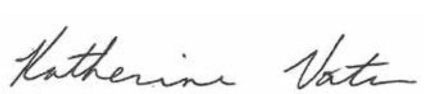
The scope of these additional PDI activities (if any) will depend on PDI field observations and concurrence between National Grid and the NYSDEC.

As we have discussed, the PDI field activities are anticipated to commence on September 21, 2015.

National Grid appreciates NYSDEC's efforts to move this project forward as expeditiously as possible, including participating in the July 7 meeting and providing, at your discretion, an on-site inspector during the PDI field activities. We look forward to continuing to maintain the open lines of communication and our next meeting to discuss the results of the PDI and next steps. National Grid will coordinate with the NYSDEC and the Owner to schedule the meeting once the PDI field activities are underway.

If you have any questions or require any additional information, please contact me at (608) 826-3663 or at katherine.vater@nationalgrid.com.

Sincerely,



Katherine Vater
Project Manager

Enclosure - PDI Work Plan (ARCADIS, September 2015)

Attachment A - Responses to Comments and Associated Photographs of Building

cc: Gardiner Cross, NYSDEC
Albert DeMarco, NYSDOH
Jennifer Coghlan, Esq., Sive, Paget & Riesel PC
Andrew Prophete, National Grid
Linda Sullivan, Esq., National Grid
Bonnie Barnett, Esq., Drinker Biddle and Reath LLP
Megan Miller, P.E., ARCADIS
M. Cathy Geraci, ARCADIS

Attachment A

Responses to Comments and Associated Photographs of Building

From: Vater, Katherine
Sent: Wednesday, September 09, 2015 5:10 PM
To: Wu, William (DEC)
Subject: RE: Dangman Park - Building Investigation Work Plan

William -

Here is the response to the questions related below on the below referenced site and Pre-Design Investigation Work Plan, dated August 10, 2015.

Please let me know if there are any outstanding questions. Your review and prompt consideration is appreciated, we are tentatively scheduled to start this work the middle of next week.

Thank you,
Katherine

1. Have the current tenants in the on-site building been notified of the proposed work and how it will be conducted both inside and outside of the building?

Notices have been prepared identifying the PDI field activities that will be conducted both inside and outside of the shopping center building and will be sent out in advance of the field work.

2. Will the current tenant businesses be open to the public during the work proposed in the PDI?

The shopping center will be open to the public during work. However, all drilling, subsurface work and subsurface material handling areas will be in private areas, not open to the public (i.e., either in unoccupied former tenant spaces or within a restricted area to be created using, for example temporary fencing, and caution tape to separate the work areas from the public). All drilling tasks will be completed inside the unoccupied tenant spaces, where the public cannot access the work. The exterior work is limited to monitoring well gauging, which will be restricted from public access, and equipment staging/storage.

3. More information needs to be provided about the tenant partitions and ceiling structure. Specifically, are the ceiling drop ceiling or open air ceiling where airflow between each tenant space could occur?

The tenant spaces are each individualized and are separated by firewalls from floor to ceiling to eliminate linkage between tenant spaces. These walls go all the way up to the roof decking and are not open above the drop ceiling line. Photographs representing typical construction showing the walls connecting to the ceiling infrastructure are attached. During the Property Owner's preparation of the vacant tenant spaces for PDI implementation, the partitions for the adjacent occupied tenant spaces (i.e., Eastern Chinese Restaurant, Apple Bank and Capital One) were visually inspected by the Property Owner for small penetration(s) and the penetrations (if any) will be securely covered with a plastic covering. Therefore, airflow between unoccupied tenant spaces where the PDI work will be completed and occupied tenant spaces is not anticipated.

4. More information needs to be provided on the HVAC and air handling units. Specifically, how will they prevent any potential vapors or dust from leaving the work area space and reaching other tenant spaces?

Each individual tenant space has its own independent HVAC system (Trane units) with tenant specific make-up air and distribution ductwork. There is no HVAC interaction between tenant spaces.

As an added precaution, HVAC system intakes within work areas will be temporarily blocked or the HVAC system temporarily disabled to prevent any inflow of dust or vapors from work zones. During drilling, dust control measures will be employed to minimize dust generation (e.g., water misting, etc.). With regard to vapors, real-time air monitoring will be performed during drilling activities and work will be stopped if monitoring indicates a potential concern consistent with regard to the limits and standards in the Site Health and Safety Plan (Arcadis HASP) and the revised CAMP (attached, see question 5 below) (Arcadis, 2015).

5. The current site community air monitoring plan (CAMP) would not be protective of public health for the building occupants as proposed. This CAMP is intended for outdoors and the nearby community. The proposed workplan proposes most of the work for inside the structure where individuals not associated with this remedial work could possibly be stationed or visiting. A site specific CAMP for indoor exposure should be submitted to NYSDOH for review.

A revised site specific CAMP has been prepared and is attached (Arcadis, 2015).

6. Since workers not associated with the remedial activities and visitors/customers may be entering the building while the indoor work has commenced, an evacuation plan needs to be developed in the case of a high level odor issue.

PDI activities will only occur in unoccupied, vacant tenant spaces which are disconnected and inaccessible to "visitors/customers". Workers not associated with the investigative activities (no remedial activities are planned, only activities approved in the PDI Work Plan will be conducted) and visitors/customers will not be entering or working in the tenant spaces included in the investigation. The unoccupied portions of the building where work will be conducted will be restricted and not accessible by the public. Workers and visitors/customers may be in the adjacent tenant spaces. To address NYSDOH's concern in the case of a high level odor issue, each tenant will be provided an update of the existing emergency response plan which includes evacuation instructions in the event of a condition at the site warranting evacuation. The basis of the evacuation plan is for National Grid's contractor and/or the property owner's representative to go door-to-door to make an announcement if required. Given the small area of the site, this is the most effective communication method if there is an unexpected condition at the site.

Katherine Vater, PE (WI)
Project Manager
Site Investigation and Remediation
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Fleet Services Building/Administrative Office
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From: Wu, William (DEC) [william.wu@dec.ny.gov]
Sent: Monday, August 17, 2015 9:25 AM
To: Vater, Katherine
Subject: RE: Dangman Park - Building Investigation Work Plan

Hello Katherine,

Re: K – Dangman Park MGP, site no. 224047

The Department of Health offers these comments on the PDI work plan:

1. Have the current tenants in the on-site building been notified of the proposed work and how it will be conducted both inside and outside of the building?

2. Will the current tenant businesses be open to the public during the work proposed in the PDI?

3. More information needs to be provided about the tenant partitions and ceiling structure. Specifically, are the ceiling drop ceiling or open air ceiling where airflow between each tenant space could occur?

4. More information needs to be provided on the HVAC and air handling units. Specifically, how will they prevent any potential vapors or dust from leaving the work area space and reaching other tenant spaces?

5. The current site community air monitoring plan (CAMP) would not be protective of public health for the building occupants as proposed. This CAMP is intended for outdoors and the nearby community. The proposed workplan proposes most of the work for inside the structure where individuals not associated with this remedial work could possibly be stationed or visiting. A site specific CAMP for indoor exposure should be submitted to NYSDOH for review.

6. Since workers not associated with the remedial activities and visitors/customers may be entering the building while the indoor work has commenced, an evacuation plan needs to be developed in the case of a high level odor issue.

Please give me a call to discuss as to how to incorporate these comments into a revised PDI work plan.

All the best,

William Wu
Environmental Engineer 1, Division of Environmental Remediation

New York State Department of Environmental Conservation
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www.dec.ny.gov | |

Property Owner’s Photographs of Existing Shopping Center Building Firewall Construction and HVAC Unit Details

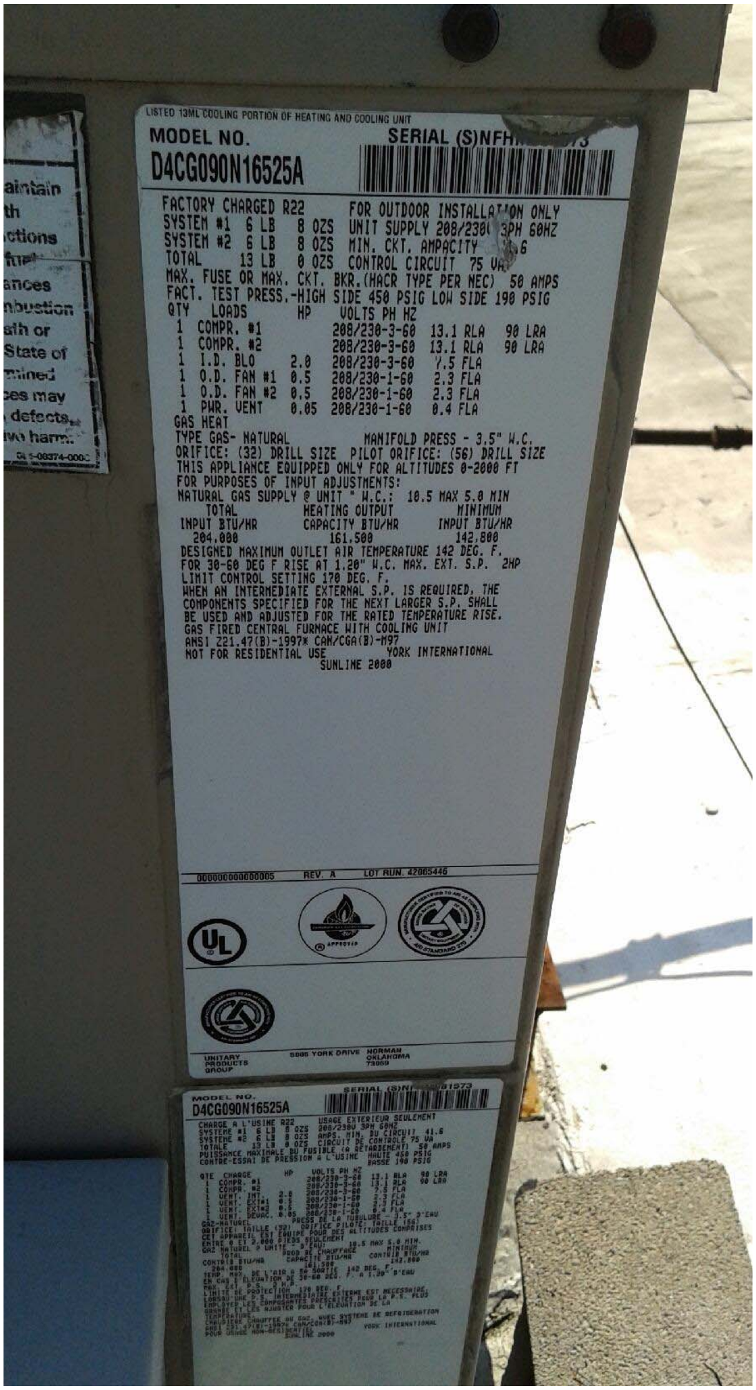
Firewall Construction

Firewall Construction

Property Owner's Photographs of Existing Shopping Center Building Firewall Construction and HVAC Unit Details

Firewall Construction

Property Owner’s Photographs of Existing Shopping Center Building Firewall Construction and HVAC Unit Details



HVAC Unit - Details

Property Owner's Photographs of Existing Shopping Center Building Firewall Construction and HVAC Unit Details

HVAC Unit - Trane

ARCADIS of New York, Inc.
6723 Towpath Road
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Tel 315 446 9120
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ENVIRONMENT

Ms. Katherine Vater
Project Manager
National Grid
287 Maspeth Avenue
Brooklyn, New York 11211

Subject:
Former Dangman Park Manufactured Gas Plant Site - Property Redevelopment Pre-Design Investigation Work Plan
Brooklyn, New York
NYSDEC Site No. 224047
Index # A2-0552-0606

Date:
September 14, 2015

Contact:
Megan A. Miller, P.E.

Phone:
315.671.9422

Email:
Megan.Miller@arcadis.com

Our ref:
B0036704.0001

Dear Ms. Vater:

This letter presents the scope of pre-design investigation (PDI) activities required because of the planned redevelopment on Block 7273, Lot 1 by 450 Neptune Associates, LLC (the Owner), the owner of that lot within the former Dangman Park Manufactured Gas Plant (MGP) Site (the Site). PDI field activities are required to evaluate the distribution (if any) of mobile MGP-related non-aqueous phase liquid (NAPL) beneath four (4) currently vacant tenant spaces inside the eastern portion of the existing shopping center building, and along the eastern portion of the area immediately in front (north) of the building (shopping center sidewalk), as these areas will be made accessible in the near-term by the Owner (Figure 1). Following approval from the New York State Department of Environmental Conservation (NYSDEC), ARCADIS will conduct the proposed PDI activities on behalf of National Grid.

The Brooklyn Union Gas Company d/b/a National Grid NY (National Grid) is responsible for the investigation, and if necessary, remediation of MGP impacts identified at the Site.

Within these areas to be investigated during the PDI are portions of the approximate locations of the three former gas holders, as well as the area immediately downgradient. These areas were not accessible during the Site Characterization (SC) and Remedial Investigation (RI), which delineated the nature and extent of MGP-related impacts for the Site. At minimum, the PDI activities will include the following activities:

- PDI Task 1: Utility Identification
- PDI Task 2: Survey
- PDI Task 3: NAPL Gauging at Existing Monitoring Wells

- PDI Task 4: Soil Borings
- PDI Task 5: PDI Documentation

If substantial quantities of mobile NAPL are identified during these activities, one or more of the following activities may also be conducted:

- Excavating test pits using air-knife/vacuum excavation to further assess the presence of former MGP structures;
- Collecting soil samples for laboratory analysis to preliminarily evaluate off-site treatment/disposal options and/or obtain geotechnical information for design purposes;
- Conducting a hydrogeologic investigation to further characterize aquifer parameters (i.e., transmissivity and specific yield) and NAPL mobility; and
- Drilling additional soil borings.

The scope of these additional PDI activities (if any) will depend on PDI field observations and concurrence between National Grid and the NYSDEC.

Methodologies and protocols to be followed during implementation of the PDI activities are presented in the Field Sampling Plan (FSP) that is included in the Remedial Investigation Work Plan (RI Work Plan) (ARCADIS, 2011) and standard operating procedures (Attachment A). Analytical procedures and requirements to be followed for the laboratory analysis of samples (if any) collected during the PDI activities are presented in the Quality Assurance Project Plan (QAPP) (ARCADIS, 2011).

Health and safety protocols to be followed by field personnel during investigation activities are presented in the Health and Safety Plan (HASP) (ARCADIS, 2011) that will be updated as necessary prior to commencement of the field activities. Community air monitoring procedures to be followed during PDI activities are presented in the Community Air Monitoring Plan (CAMP) (Attachment B).

Work-zone air monitoring and dust, vapor, and odor control measures, including foaming as needed, will be performed during the PDI field activities. Based on air monitoring and visual assessment during intrusive and material handling activities, nuisance odors (if any) will be controlled and particle and volatile organic vapor levels will be maintained below the action levels identified in the HASP and CAMP. Odor control methods to be employed during the PDI field activities include those identified in the CAMP (e.g., containerizing drill cuttings in 55-gallon drums with the cover secure), as well as foaming (as needed). As further described under PDI Task

4, the drums of wastes generated during the PDI activities will be temporarily stored on-site at a location determined with the Owner, until transportation is arranged for off-site treatment/disposal.

A description of the five (5) tasks associated with the PDI is presented below, followed by a discussion of the anticipated PDI schedule.

PDI Task 1 – Utility Identification

Prior to implementing intrusive PDI activities, the following activities will be conducted to identify overhead and subsurface utilities/structures at and in the immediate vicinity of the PDI areas:

- Reviewing detailed site utility plans, if available from the property owners.
- Performing a detailed visual site inspection.
- Verifying that the proposed soil boring locations are accessible (Figure 1).
- Contacting New York 811 to identify and mark the location of underground utilities at and in the immediate vicinity of the PDI areas.
- Utilizing a private utility locating service to identify and mark the location of underground utilities at and in the immediate vicinity of the PDI areas. Private utility locating will be conducted by the Owner in conjunction with National Grid and ARCADIS prior to the PDI activities.
- Obtaining and reviewing utility providers' utility location figures.

PDI Task 2 – Survey

Field survey activities will be performed as part of the PDI by a New York State-licensed Land Surveyor. The survey activities will be performed to field-identify and mark proposed PDI soil boring locations based on coordinates obtained from mapping (to allow soil borings to be positioned in relation to the approximate location of the former MGP structures, as shown on Figure 1).

Most of the survey work is anticipated to be performed prior to implementation of intrusive PDI field activities. Follow-up survey work will be performed, as needed, to document final soil boring locations (if adjustments to the proposed locations were made based on field conditions encountered during the PDI), and to document test pit locations (if any) and locations of subsurface structures encountered (if any).

PDI Task 3 – NAPL Gauging at Existing Monitoring Wells

As presented in the RI Report, no NAPL has been observed in the monitoring wells. The last round of NAPL gauging was conducted at the Site in March 2012 as part of the RI. To confirm Site conditions, NAPL gauging will be conducted during the PDI in the eleven (11) existing monitoring wells located proximate to and within the extent of NAPL. These monitoring wells are identified on Figure 1. At each of these monitoring wells, field personnel will measure depth to water, depth to bottom of the monitoring well, and NAPL thickness (if present). To facilitate/expedite PDI implementation, this task may be conducted concurrently with PDI Task 2 - Survey.

PDI Task 4 – Soil Borings

As part of the PDI, a minimum of twelve (12) soil borings (PDI-1 through PDI-12) will be drilled and logged to achieve the following objectives: 1) determine the distribution of mobile NAPL (if any); and 2) assess the potential subsurface presence of former MGP structures (and other structures). As shown on Figure 1, these soil borings are to be strategically located based on the approximate locations of the three former gas holders and the conceptual site model established for the Site in the NYSDEC-approved Remedial Investigation Report (ARCADIS, 2014).

The PDI soil boring locations will be adjusted, as needed, based on the locations of subsurface utilities as identified under PDI Work Task 1, accessibility for the drill rig given the narrow width of the four (4) currently vacant tenant spaces shown on Figure 1, and subsurface conditions encountered in the field. All drilling locations will be hand augered/hand dug, and/or air-knifed to a depth of 5 feet below land surface (ft bls).

The soil borings will be drilled to a target depth of 30 ft bls. If evidence of mobile NAPL is observed at a depth of 30 ft bls, the boring will continue beyond 30 ft bls to a depth approximately 5 feet deeper than the observed impacts to determine the vertical extent of mobile NAPL. If the foundation of a former gas holder is encountered, the foundation may be penetrated, depending on field observations and in consultation with NYSDEC, if necessary to evaluate the distribution of mobile NAPL. Field data will be used to determine the actual depth of each soil boring.

The soil borings will be drilled using sonic drilling methods. A short-mast configuration (approximately 11.5-foot high mast) for a mini-sonic rig will be used inside the shopping center building; continuous soil sampling will be performed using a 2-foot long, 4-inch diameter core barrel. Soil recovered from each sample interval will be visually characterized for color, texture, and moisture content as described in the National Grid Field Descriptions of Samples for Former Manufactured Gas Plant (MGP) Sites (Appendix B [FSP] of the RI Work Plan). The presence (if any) of visible staining, NAPL, and obvious odors will be noted and the soil will be field screened with a photoionization detector (PID). If NAPL is encountered in any of the soil borings, the DNAPL Contingency Plan provided in Appendix A of the RI Work Plan will be implemented to limit the potential for remobilization and downward migration of DNAPL.

Upon completion, the borings will be tremie-grouted to the surface using a cement-bentonite grout and the surface restored with cement. Soil cuttings and other investigation-derived waste (IDW) (e.g., plastic sheeting, decontamination water, etc.) will be segregated by waste type and placed in appropriate waste containers (e.g., Department of Transportation (DOT)-approved 55-gallon steel drums). Composite samples of the soil cuttings and water will be submitted to a laboratory for waste characterization analyses, and the wastes will be transported for off-site treatment/disposal based on the characterization data.

PDI Task 5 – PDI Documentation

As discussed during the July 7, 2015 meeting among representatives of the NYSDEC, the Owner, and National Grid, the PDI results will initially be presented in the draft figures and tables described below to facilitate a subsequent meeting and future decision making for the Site on an expedited basis.

- Updated figures showing the surveyed locations of soil borings and test pits (if any) completed as part of the PDI, and locations of subsurface structures (if any) identified.

- Updated and new cross-sections showing NAPL impacts using the Colors for National Grid Impacts, National Grid Colors – Brooklyn, consistent with the RI Report. As detailed in ARCADIS' MGP Colors for Impacts comparison memorandum included in the RI Report, the National Grid system evaluates NAPL mobility similar to the NYSDEC system.

- Tables summarizing PDI locations, results of the NAPL gauging conducted at existing monitoring wells, and intervals where NAPL (if any) was encountered in the soil borings.

- Soil boring logs.

The content and format of the PDI documentation submittal to the NYSDEC will be determined upon completion of the PDI, with concurrence between National Grid and the NYSDEC.

PDI Schedule

Intrusive PDI field activities are anticipated to commence in late September 2015, pending NYSDEC's approval of the PDI scope and completion of necessary accommodations by the Owner to the shopping center building for drilling within and near the building. In an effort to facilitate these building accommodations and expedite the PDI implementation schedule, Task 1: Utility Identification and Task 2: Survey may be conducted prior to NYSDEC's written approval. Following NYSDEC-approval, we understand that National Grid will notify the NYSDEC at least seven (7) days in advance of the scheduled date for commencement of the intrusive PDI field activities.

The PDI field activities are estimated to take (at minimum) approximately three weeks based on an estimated one (1) soil boring drilled per day. This estimate is based on the limited working spaces inside the shopping center building and the short-mast configuration required to drill inside involves collecting soil cores in 2-foot intervals instead of 5-foot intervals.

The PDI results will initially be presented in draft figures and tables (described under Task 5) for an upcoming meeting among representatives from the NYSDEC, the Owner, and National Grid to facilitate interpretation of results and discussions on future decision making for the Site on an expedited basis. This meeting is anticipated to occur shortly after completion of the PDI.

Please do not hesitate to contact me or Cathy Geraci if you have any questions or require additional information.

Sincerely,

ARCADIS of New York, Inc.

Megan Miller

Megan A. Miller, P.E.
Vice President

Copies:
Steven Feldman, ARCADIS
Christopher Keen, ARCADIS
Cathy Geraci, ARCADIS
Bonnie Barnett, Esq., Drinker, Biddle and Reath
Linda Sullivan, Esq., National Grid

Attachments:
Figure 1, Proposed Pre-Design Investigation Locations

Attachment A, Standard Operating Procedures

- Test Pit Excavation
- Slug Test Methods
- Pumping Test
- Specific Capacity Testing and Data Reduction

Attachment B, Community Air Monitoring Plan

References:

ARCADIS. 2011. Remedial Investigation Work Plan, Former Dangman Park Manufactured Gas Plant Site, Brooklyn, New York, Site No. 224047, Index # A2-0552-0606. September 2011.

ARCADIS. 2014. Remedial Investigation Report, Former Dangman Park Manufactured Gas Plant Site, Brooklyn, New York, Site No. 224047, Index # A2-0552-0606. July 2014.

ARCADIS

Figures

CITY:(Reqd) DIV/GROUP:(Reqd) DB:(Reqd) LD:(Opt) PIC:(Opt) PM:(Reqd) TM:(Opt) LYR:(Opt)ON=*;OFF=*REF*
G:\ENVCAD\SYRACUSE\ACT\B0036704\0001\01010\36704B01.dwg LAYOUT: 1 SAVED: 8/7/2015 10:59 AM ACADVER: 19.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: ---- PLOTTED: 8/10/2015 9:22 AM BY: SANCHEZ, ADRIAN
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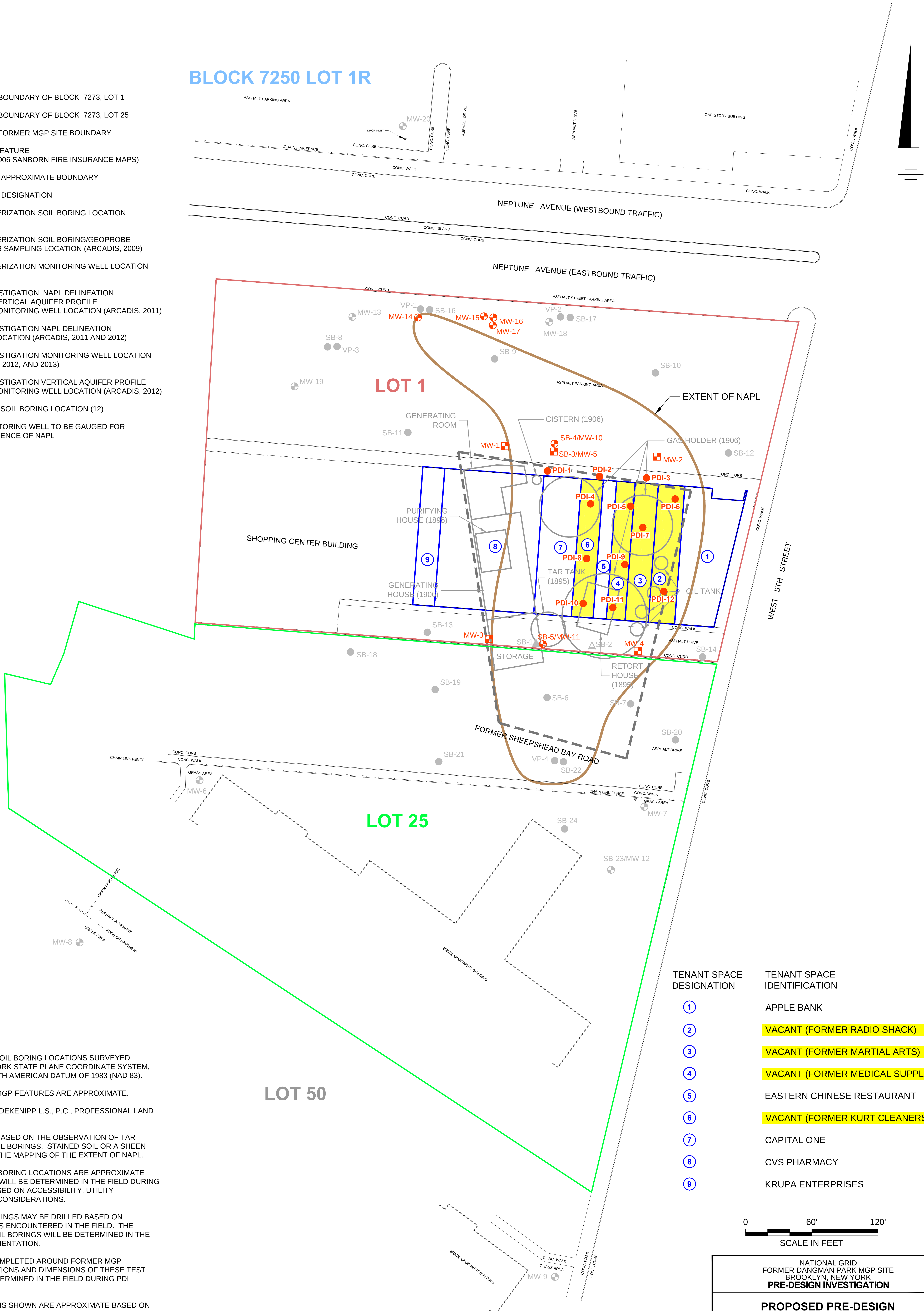
LEGEND:

- APPROXIMATE BOUNDARY OF BLOCK 7273, LOT 1
- APPROXIMATE BOUNDARY OF BLOCK 7273, LOT 25
- APPROXIMATE FORMER MGP SITE BOUNDARY
- FORMER MGP FEATURE (1895 AND/OR 1906 SANBORN FIRE INSURANCE MAPS)
- TENANT SPACE APPROXIMATE BOUNDARY
- 1 TENANT SPACE DESIGNATION
- SB-1 SITE CHARACTERIZATION SOIL BORING LOCATION (ARCADIS, 2009)
- SB-2 SITE CHARACTERIZATION SOIL BORING/GEOPROBE GROUNDWATER SAMPLING LOCATION (ARCADIS, 2009)
- MW-1 SITE CHARACTERIZATION MONITORING WELL LOCATION (ARCADIS, 2009)
- SB-7 REMEDIAL INVESTIGATION NAPL DELINEATION SOIL BORING/VERTICAL AQUIFER PROFILE TEMPORARY MONITORING WELL LOCATION (ARCADIS, 2011)
- SB-8 REMEDIAL INVESTIGATION NAPL DELINEATION SOIL BORING LOCATION (ARCADIS, 2011 AND 2012)
- MW-6 REMEDIAL INVESTIGATION MONITORING WELL LOCATION (ARCADIS, 2011, 2012, AND 2013)
- VP-1 REMEDIAL INVESTIGATION VERTICAL AQUIFER PROFILE TEMPORARY MONITORING WELL LOCATION (ARCADIS, 2012)
- PDI-1 PROPOSED PDI SOIL BORING LOCATION (12)
- MW-1 / MW-11 EXISTING MONITORING WELL TO BE GAUGED FOR ABSENCE/PRESENCE OF NAPL



0 60' 120'
SCALE IN FEET

TENANT SPACE DESIGNATION	TENANT SPACE IDENTIFICATION
1	APPLE BANK
2	VACANT (FORMER RADIO SHACK)
3	VACANT (FORMER MARTIAL ARTS)
4	VACANT (FORMER MEDICAL SUPPLY)
5	EASTERN CHINESE RESTAURANT
6	VACANT (FORMER KURT CLEANERS)
7	CAPITAL ONE
8	CVS PHARMACY
9	KRUPA ENTERPRISES

NOTES:

1. MONITORING WELL AND SOIL BORING LOCATIONS SURVEYED RELATIVE TO THE NEW YORK STATE PLANE COORDINATE SYSTEM, LONG ISLAND ZONE, NORTH AMERICAN DATUM OF 1983 (NAD 83).
2. LOCATIONS OF FORMER MGP FEATURES ARE APPROXIMATE.
3. BASE MAP BY DONALD G. DEKENIPP L.S., P.C., PROFESSIONAL LAND SURVEYOR.
4. THE EXTENT OF NAPL IS BASED ON THE OBSERVATION OF TAR AND/OR BLEBS IN THE SOIL BORINGS. STAINED SOIL OR A SHEEN WERE NOT INCLUDED IN THE MAPPING OF THE EXTENT OF NAPL.
5. ALL PROPOSED PDI SOIL BORING LOCATIONS ARE APPROXIMATE AND ACTUAL LOCATIONS WILL BE DETERMINED IN THE FIELD DURING PDI IMPLEMENTATION BASED ON ACCESSIBILITY, UTILITY LOCATIONS, AND OTHER CONSIDERATIONS.
6. ADDITIONAL PDI SOIL BORINGS MAY BE DRILLED BASED ON SUBSURFACE CONDITIONS ENCOUNTERED IN THE FIELD. THE LOCATIONS OF THESE SOIL BORINGS WILL BE DETERMINED IN THE FIELD DURING PDI IMPLEMENTATION.
7. PDI TEST PITS MAY BE COMPLETED AROUND FORMER MGP STRUCTURES. THE LOCATIONS AND DIMENSIONS OF THESE TEST PITS (IF ANY) WILL BE DETERMINED IN THE FIELD DURING PDI IMPLEMENTATION.
8. TENANT SPACE LOCATIONS SHOWN ARE APPROXIMATE BASED ON INFORMATION OBTAINED BY ARCADIS DURING THE SITE CHARACTERIZATION; LOCATIONS WEST OF KRUPA ENTERPRISES (#9) ARE NOT SHOWN. THESE LOCATIONS ARE CURRENTLY BEING CONFIRMED BY THE PROPERTY OWNER.

NATIONAL GRID
FORMER DANGMAN PARK MGP SITE
BROOKLYN, NEW YORK
PRE-DESIGN INVESTIGATION

PROPOSED PRE-DESIGN INVESTIGATION LOCATIONS

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FIGURE
1

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Attachment A

Standard Operating Procedures

- Test Pit Excavation
- Slug Test Methods
- Pumping Test
- Specific Capacity Testing and Data Reduction

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Infrastructure, environment, facilities

Imagine the result

Test Pit Excavation (NON-ENTRY)

Rev. #: 2

Rev Date: May 28, 2008

Approval Signatures

Prepared by: Andrew Karnik Date: 5/28/2008

Reviewed by: Michael J Gefell Date: 5/28/2008
(Technical Expert)

I. Scope and Application

This SOP outlines policies and procedures for the advancement of test-pits using rubber-tire or track-mounted backhoes. For all work activities conducted by ARCADIS involving test pits or other excavations, ARCADIS staff will refer to and comply with ARCADIS HS Procedure No. ARC HSCS005, Excavation and Trenching. Test pits will be excavated using a decontaminated, rubber-tired backhoe or track-hoe as appropriate. Test pits may be performed based on the need to identify subsurface structures, facilitate the collection of soil samples and provide larger-scale subsurface characterization than allowed using soil borings. Personnel should stand upwind of the excavation area to the extent possible. Continuous air monitoring may be conducted as indicated in the site Health and Safety Plan (HASP). Excavating will be conducted at the selected locations that have been cleared for utilities until significant source materials, groundwater, or bedrock is encountered, or the purpose of the test pit has been met, or the physical limits of the backhoe have been reached. Test pit materials will be visually observed and described with respect to depth. Samples may be collected for laboratory or geotechnical analyses. Photographs of the test pits and excavated materials should be taken for future reference.

II. Personnel Qualifications

ARCADIS personnel overseeing, directing, or supervising the sampling portion of the test pit activities will have a minimum of 6 months of previous related experience under the supervision of an experienced (2 years) oversight person and at a minimum a 4-year degree (Bachelors) in environmental sciences, engineering, hydrogeology, or geology, and have completed health and safety training as required by OSHA Regulation 29 CFR 1910.120 (HAZWOPER). Personnel will also have completed any client-specific training as may be required. If the test pit is excavated by ARCADIS personnel, a competent person as defined by ARC HSCS005 will be on-site at all times.

If the test pit is excavated by a subcontractor, the subcontractor will provide the competent person per OSHA 1926.32(f). The excavation subcontractor will maintain all appropriate licenses and/or certifications as required by the State and Municipality. The equipment operator and any assistants working on site will, prior to beginning work, have completed all health and safety and other training as may be required by ARCADIS and the client.

III. Equipment List

The following equipment will be available, as required, during test pitting:

- rubber-tired (or track-mounted) backhoe in good working order;
- flame ionization detector (FID) and/or photoionization detector (PID), and/or other colorimetric;
- sample containers and forms;
- daily field log and/or field notebook;
- supplies and equipment to comply with site- and client-specific health and safety procedures;
- stainless steel shovel, scoop, hand auger, or trowel;
- digital camera;
- polyethylene sheeting; and
- ground stakes.

IV. Cautions

Water used for decontamination of excavation equipment will be of a quality acceptable for project objectives. Testing of water supply should be considered.

Work may be conducted on or in proximity to steep terrain. Site-specific health and safety issues will be thoroughly reviewed by all site personnel prior to beginning work.

V. Health and Safety Considerations

A site-specific Health and Safety Plan (HASP) meeting client requirements will be prepared along with Job Safety Analyses (JSAs) that outline the H&S hazards and controls for conducting the test pit activities. Project staff will review and be familiar with these plans and JSAs prior to work. These documents will detail the excavation safety requirements per ARC HSCS005. In addition, underground and above ground utilities will be located and cleared per ARCADIS H&S Procedure ARC HSFS019 – Utility Location.

VI. Procedures

Where necessary to characterize soil conditions, soil samples will be collected from the backhoe bucket, either directly or with a decontaminated stainless steel scoop or trowel.

Samples should be homogenized, if appropriate.

Material removed from the test pits during excavation will be placed on polyethylene sheeting. Visually clean soils will be segregated from soils that may contain source materials. Soils meeting field screening or laboratory analytical criteria may be placed back into the excavation. Soils not meeting screening or laboratory analytical criteria will be managed on site as described in the *Waste Management* section below. For sites that cannot be fully secured, clean fill will be available to backfill excavations immediately upon completion of test pits. To facilitate surveying, the location of the test pits will be marked with stakes after they have been backfilled. Stakes should be placed at the ends of the test pit and at any significant bend or corner, as appropriate.

VII. Waste Management

All water generated during decontamination procedures will be collected and contained onsite in 55-gallon drums or a temporary frac-tank pending laboratory analysis and appropriate disposal.

Personal protective equipment (such as gloves, disposable clothing, and other disposable equipment) resulting from personnel cleaning procedures and soil sampling/handling activities will be placed in plastic bags. These bags will be transferred into appropriately labeled 55-gallon drums for appropriate disposal.

Depending on volume generated, soil materials will be placed in sealed 55-gallon steel drums or stockpiled on site (placed on and covered by plastic sheeting). The material will be analyzed to determine the appropriate disposal method.

VIII. Data Recording and Management

The supervising geologist/engineer/scientist will be responsible for documenting activities using a daily field log to record all relevant information in a clear and concise format. As an alternative, a bound field notebook may be used at the discretion of field personnel to document field activities. Where appropriate, photographs will be taken to supplement written notes. The record of test pitting will include:

- start and finish dates of excavating;

- name and location of project;
- project number, client, and site location;
- sample number and depths;
- depth to water;
- observations of soil type/characteristics and lithology;
- documentation of any elevated organic vapor emissions;
- names of Contractor's personnel, inspectors, or other people onsite; and
- weather conditions.

IX. Quality Assurance

Equipment will be cleaned prior to use onsite. At the discretion of the ARCADIS Project Manager or field geologist/engineer/scientist, equipment may be decontaminated between each test pit location, and prior to leaving the site. All equipment and associated tools that may have come in contact with contaminated soils and/or waste materials will be cleaned with high-pressure steam cleaning equipment using a potable water source. More detailed equipment cleaning procedures are provided in the HASP.

X. References

United States Department of Labor. 1989. Occupational Safety & Health Administration (OSHA), Title 29 Code of Federal Regulations (CFR)Part 1926.651 Subpart P Excavations, .54 Federal Register (FR) 45959, October 31, 1989 and 59 FR 40730, Aug. 9, 1994.

ARCADIS HS Procedure No. ARC HSCS005, Excavation and Trenching, 12 May 2008.

ARCADIS H&S Procedure ARC HSFS019 – Utility Location, 22 February 2008

Slug Test Methods – Standard Operating Procedures

STANDARD OPERATING PROCEDURE FOR PNEUMATIC SLUG TESTS

I. Scope and Application

Pneumatic slug tests are conducted by sealing the well head and applying air pressure to depress the water level, with fully submerged well screens. As detailed below, the well screen must remain below the water level throughout the pneumatic slug test. During the test, as air pressure is increased in the well, the water level falls until the water pressure and the air pressure return to equilibrium. After the water level is stable, air is released from the sealed well head by opening an air release valve. The water level recovery is a rising head slug test and produces very high quality data with little interference. A pressure transducer is used to monitor and record the change of the water level in the well during the pneumatic slug test.

II. Equipment List

1. Personal protective equipment, as required by the site Health and Safety Plan.
2. Pneumatic slug test manifold.
3. Pressure transducer and cable.
4. Pressure transducer software.
5. Air pressurization source (compressed or pump) and appropriate hoses.
6. Leak prevention supplies (Teflon pipe sealant, plumbers putty or similar product).
7. Laptop computer.
8. Water level meter.
9. Measuring tape.
10. Decontamination equipment.
11. Slug test field form.
12. Field notebook.
13. Waterproof marker.

III. Procedure

1. Decontaminate all down-well equipment: pressure transducer and cable, water level meter.
2. Measure depth to water and well total depth. Determine the water column length.
3. Review the well construction log to determine screened interval and depth to bottom. If the well screen is not fully submerged, the well cannot be tested with the pneumatic method.
4. Attach the pneumatic slug test manifold onto the top of the well casing. Tighten the rubber connector to ensure an airtight seal.
5. Place the pressure transducer at the proper depth (deep enough to accommodate initial change in head but no deeper than six inches above the well bottom) by measuring the location where the transducer cable will be secured to the compression connector. Also ensure to not exceed the transducer pressure range. Tighten the cable seal by hand to seal the connection to the transducer cable.
6. Program the pressure transducer to record water levels at the following suggested frequencies. Note that the lithologic descriptions and datalogger memory should be used to select the highest measurement frequency possible.
   a. In hydrologic settings where high hydraulic conductivity is expected, water levels should be measured at 0.5 second intervals, or the highest frequency available. This measurement frequency should be selected for gravels and sands.
   b. In hydrologic settings where low hydraulic conductivity is expected, water levels should be measured at 1 to 2 second intervals. This measurement frequency should be selected for silts and clays.

7. View the measured water level in real time on the laptop computer. Wait for the water levels to stabilize. Note that temperature fluctuations on the pressure transducer will affect measured water levels (i.e. temperature differences between the above surface and groundwater environments).
8. Close the air release valve.
9. Close the inlet air valve with the pressure regulator closed.
10. Verify incoming pressure is less than safe operating pressure of manifold pressure regulator (<40 psi is necessary) before attaching air hose (not applicable for hand pump).
11. Attach air hose and open regulator to verify incoming pressure (not applicable for hand pump).
12. Close regulator and open the inlet air valve.
13. Slowly open the pressure regulator to pressurize well head and depress water level a sufficient distance without lowering the head below the top of the well screen (2.31 feet of water is equal to 1 psi). Keep the rule of thumb of 1 to 3 feet displacement and follow best practices with 2 duplicate tests and a third test with double the displacement. Larger displacements may be appropriate for high conductivity formations. Begin with a low pressure and gradually increase the pressure in order to obtain the desired displacement and do not over pressurize the well (do not exceed ~2 psi). If using a hand pump, pressurize well head with pump with regulator open.
14. Close the regulator and leak check the system with leak detection fluid and fix any leaks. If the leak is very slow, or down the well, the regulator may be used to maintain a constant pressure head.
15. Check the pressure transducer response and air pressure to verify system is stable. This may take a period of time as the pressure transducer is equalizing to both the pressurized atmosphere in the well and the displaced water column (see below figure). Stabilization is reached once the pressure returns to near the original pressure. If it is stable proceed to the next step, if not check the seals.
16. Record a baseline pressure for a minimum three minutes. Record data on the field form.
17. Close inlet valve and quickly open the release valve to initiate the test.
18. Allow sufficient time for water level to recover to static level. If completing one test, then 80% recovery is sufficient. Duplicate tests are highly recommended and the next test should be completed after the first test has recovered to greater than 95%. A third test at a displacement of twice the initial is recommended.
19. Save all data files to the laptop and backup flash drive.
20. Finalize any field notes.
21. Review the data collected to determine the reasonableness of the preliminary results. The observation of apparently anomalous results will be discussed with senior project staff prior to proceeding. The water level record for each test should show static conditions, pressurization of the well column, and the recovery response. Make notes on the field form and notebook concerning any irregularities.
22. Decontaminate all down-well equipment.

STANDARD OPERATING PROCEDURE FOR BAILDOWN SLUG TESTS

I. Scope and Application

The use of a bailer to remove a volume of water (slug) is used to complete rising-head tests. A bailer removes water from a well in a near-instantaneous manner. The water level response is observed using a pressure transducer.

II. Equipment List

The following materials will be available, as required, during slug testing using a bailer:

1. Personal protective equipment, as required by the site Health and Safety Plan.
2. Bailers of known size/capacity.
3. Pressure transducer and barologger.
4. Pressure transducer software.
5. Laptop computer.
6. Rope.
7. Water level meter.
8. Measuring tape.
9. Spring-loaded clamps.
10. Decontamination equipment.
11. Slug test field form.
12. Field notebook.
13. Waterproof marker.

III. Procedure

1. Select a bailer according to a target initial displacement using the table below. A general guideline is that initial displacements are between 1 and 3 feet, but should depend on the anticipated response (i.e. larger initial displacements should be chosen for formations with high hydraulic conductivity, smaller initial displacements can be used for formations with low hydraulic conductivity).

Bailer Volume (gal)	Bailer Volume (ml)	Casing Diameter (in)	Theoretical Initial Displacement (ft)
0.25	946	2	1.56
0.5	1893	2	3.13
1	3785	2	6.25
0.5	1893	4	0.77
1	3785	4	1.54
2	7570	4	3.08
1	3785	6	0.68
2	7570	6	1.36
3	11355	6	2.04

Notes:
gal = gallons,
U.S. liquid

ml = milliliters

in = inches

ft = feet

2. Decontaminate all down-well equipment: pressure transducer and cable, rope or cable, water level meter.
3. Open well and allow enough time for the water level to equilibrate to atmospheric conditions.
4. Measure depth to water and well total depth. Total depth should be taken using a weighted tag line. Determine the water column length.
5. Review the well construction log to determine screened interval and depth to bottom.
6. Program the pressure transducer to record water levels at the following suggested frequencies. Note that the lithologic descriptions and datalogger memory should be used to select the highest measurement frequency possible.
   a. In hydrologic settings where high hydraulic conductivity is expected, water levels should be measured at 0.5 second intervals, or the highest frequency available. This measurement frequency should be selected for gravels and sands.
   b. In hydrologic settings where low hydraulic conductivity is expected, water levels should be measured at 1 to 2 second intervals. This measurement frequency should be selected for silts and clays.
7. Program the barologger to record barometric pressure at the same interval as the pressure transducers measuring water levels. The barologger should be placed in the headspace of an adjacent well.
8. Install the pressure transducer deep enough within the water column to not interfere with the testing equipment (remember not to exceed the PSI range of the transducer). Do not install closer than 6 inches above the well bottom. Remember to use measurements and not the well bottom as silt can clog the pressure transducer. Clamp the pressure transducer cable to the well casing or other static object.
9. View the measured water level in real time on the laptop computer or use water level meter. Wait for the water levels to stabilize. Note that temperature fluctuations on the pressure transducer will affect measured water levels (i.e. temperature differences between the above surface and groundwater environments).
10. Measure the bailer and rope assembly length and mark the rope at a length as follows:
    Rope Mark #1 = Depth to Potentiometric Surface from TOC
    Rope Mark #2 = Depth to Potentiometric Surface from TOC + Length of Slug + Safety Factor
    (Safety Factor = 10% of the Length of Slug)
    When deployed, this will ensure that the bailer is fully submerged. If a sufficient water column is not available to obtain a full bailer, measure the volume removed upon removal.
11. Slowly insert the bailer into the well and stop just above the potentiometric surface rope mark #1.
12. With slack in the rope and the bailer being suspended above the water column, lower the bailer and place the rope mark #2 at the top of casing. Clamp the non-bailer end of the rope to a static object to keep in place.
13. Wait for water level to equilibrate using response from the laptop computer or from water level meter.
14. Quickly remove the bailer from the water column and carefully pull it to surface. Pour the removed water into an empty bucket.
15. Observe the water level response on the laptop computer and/or measure depth to water, being careful not to interfere with the pressure transducer cable. Several manual depth to water measurements should be made throughout the test.
16. Allow sufficient time for water level to recover to static level. If completing one test, then 80% recovery is sufficient. Duplicate tests are highly recommended and the next test should be completed after the first test has recovered to greater than 95%. A third test at a displacement of twice the initial is recommended.
17. Measure the volume of water removed by the bailer that was poured into the empty bucket using a graduated cylinder.
18. Repeat steps 10 and 15.

19. Repeat rising-head slug tests for data reproducibility. If possible, complete a third test with a bailer or multiple bailers connected in series that equates to twice the volume as the original.
20. Save all data files to the laptop, backup on flash drive and finalize any field notes.
21. Review the data collected to determine the reasonableness of the preliminary results. The observation of apparently anomalous results will be discussed with senior project staff prior to additional testing or leaving the field site. The water level record for each test should show static conditions, the insertion or removal of the slug(s), and the water level response. Make notes on the field form and notebook concerning any irregularities.
22. Decontaminate all down-well equipment.

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Slug Test Log

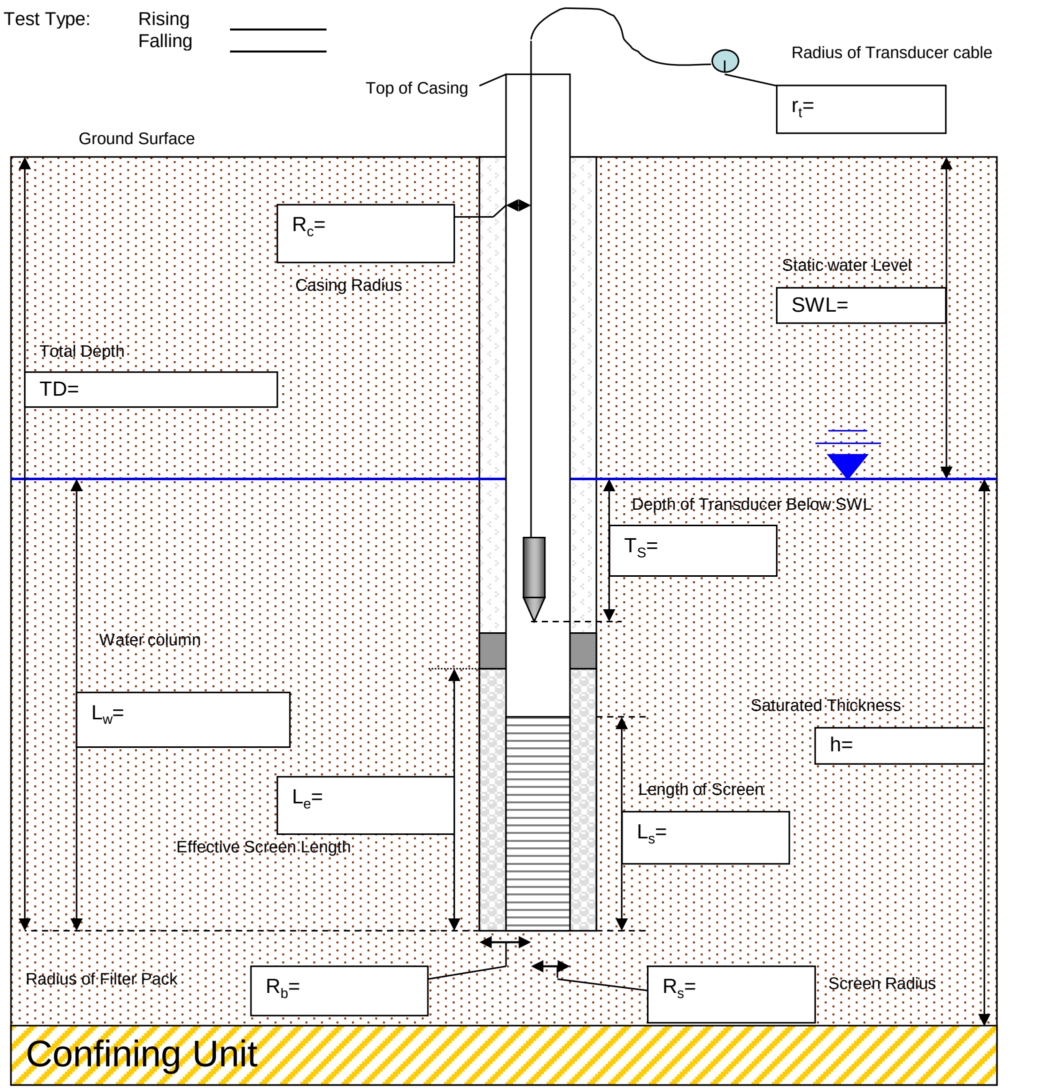
Site Name: ______________________ Project No: ______________________ Page: ____ of ____

Well No: ______________ Prepared By: ______________ Date: ______________ Time: __________

Completed By: ______________________

Test Type: Rising __________

Falling __________



TEST DATA

Number of Tests: ______ Data File Name: ______ Data File Location: ______

Pressure Transducer SN:

Test Number: ______
Slug Volume: ______
Rising or Falling Head Test? ______
T_S Baseline: ______ Baseline Pressure Reading: ______
H_o: ______ Max. Displacement Pressure Reading: ______
Test Duration: ______

Manual Depth to Water Measurements:

Time	Depth to Water

NOTES:

H_o Initial change in head at instant the slug test is started
r_t Radius of transducer cable (can be ignored if less than 1/8 inch)
T_S Depth of transducer below static water level

THEORETICAL HEAD CHANGE

Slug Volume (gallon)	Slug Volume (ml)	Well Casing Diameter (inches)	Theoretical Initial Displacement (feet)
0.25	946	2	1.56
0.5	1893	2	3.13
1	3785	2	6.25
0.5	1893	4	0.77
1	3785	4	1.54
2	7570	4	3.08
1	3785	6	0.68
2	7570	6	1.36
3	11355	6	2.04

WELL PARAMETERS REQUIRED FOR CALCULATING HYDRAULIC CONDUCTIVITY

L_e Effective screen length, including the sand pack
L_s True screen length
L_w Length of water column in Well (TD-SWL)
R_s Screen radius
R_b Radius of filter Pack or borehole
R_c Casing radius
r_t Radius of the transducer cable
T_s Depth the transducer is submerged below the SWL
SWL Static water level
TD Total depth of well/screen from reference point
h Saturated thickness of aquifer
H_o Initial head change at instant the slug test is started.
Aquifer Type Confined or unconfined

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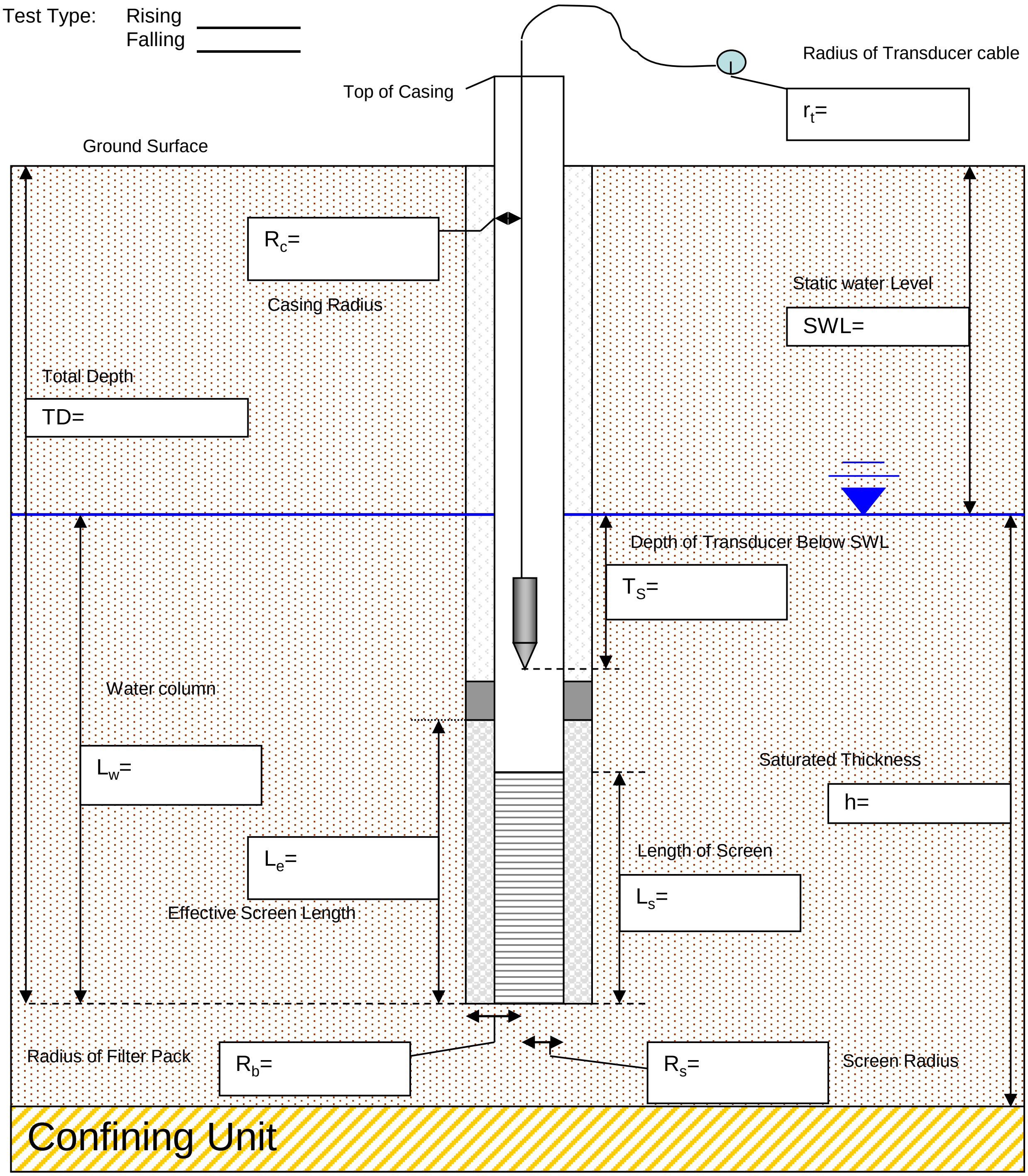
Pneumatic Slug Test Log

Site Name: ______________________ Project No: ______________________ Page: ____ of ____

Well No: ______________ Prepared By: ______________ Date: ______________ Time: __________

Completed By: ______________________

Test Type: Rising __________
Falling __________



ARCADIS

Pneumatic Slug Test Log

Site Name: ______________________ Project No: ______________________ Page: ____ of ____

Well No: ______________ Prepared By: ______________ Date: ______________ Time: __________

TESTS

Number of Tests: ________ Data File Name: ______________ Data File Location: ______________

Input Pressure: ________ Pressure Transducer SN: ______________ r_t: ______

Test: __________ T_S Baseline: __________ Pressure Reading: __________

H_o: __________ Test Start ______ Test End __________

Test: __________ T_S Baseline: __________ Pressure Reading: __________

H_o: __________ Test Start ______ Test End __________

Test: __________ T_S Baseline: __________ Pressure Reading: __________

H_o: __________ Test Start ______ Test End __________

Notes:

H_o	Initial change in head at instant the slug test is started
r_t	Radius of transducer cable
T_S	Depth of transducer below static water level

Theoretical Change in Head - 2.307 feet = 1 psi

(Feet)	**(psi)**	**(Feet)**	**(psi)**	**(Feet)**	**(psi)**
0.50	**0.22**	**1.50**	**0.65**	**2.50**	**1.08**
0.75	**0.33**	**1.75**	**0.76**	**2.75**	**1.19**
1.00	**0.43**	**2.00**	**0.87**	**3.00**	**1.30**
1.25	**0.54**	**2.25**	**0.98**	**3.25**	**1.41**

Well Parameters Required for Calculating Hydraulic Conductivity

L_e	Effective screen length, including the sand pack
L_s	True screen length
L_w	Length of water column in Well (TD-SWL)
R_s	Screen radius
R_b	Radius of filter Pack or borehole
R_c	Casing radius
r_t	Radius of the transducer cable
T_s	Depth the transducer is submerged below the SWL
SWL	Static water level
TD	Total depth of well/screen from reference point
h	Saturated thickness of aquifer
H_o	Initial head change at instant the slug test is started.
Aquifer Type	Confined or unconfined

Infrastructure, environment, facilities

Imagine the result

PUMPING TEST
STANDARD OPERATING PROCEUDRES

Rev. #: 01

Rev Date: September 2008

Approval Signatures

Prepared by: ______________________________ Date: September 29, 2008

Reviewed by: ______________________________ Date: September 29, 2008

(Technical Expert)

I. Test Design

In general conventional hydraulic testing is conducted to provide answers to questions related to water supply problems. Tests are conducted over longer periods of time and provide estimates of hydraulic conductivity values averaged over large aquifer volumes. These tests tend to underestimate the highest hydraulic conductivity values and overestimate the lowest.

When conducting tests for remediation hydrogeology purposes it is important to indentify aquifer heterogeneities which ultimately control the transport of contaminants and reagents distribution within the aquifer. Short-term tests may help identify particular depositional elements and hydraulic conductivity trends and variability associated with facies changes in the aquifer. Data collected from short-term test can then be correlated with detailed hydrostratigraphic information to assist in the development of conceptual site models that describe the transport of contaminants and distribution of reagents.

1. Understand Aquifer Conditions

An aquifer (or permeable zone) pumping test is conducted in order to determine the hydraulic properties (transmissivity, hydraulic conductivity, storage coefficient, leakage, boundaries, anisotropy) of a water-bearing zone or system (including confining beds). Proper design of a pumping test requires a general understanding of the potential hydrologic system prior to the test, so that suitable data are collected to evaluate system parameters. The designer of the test must first develop an appropriate set of assumptions (conceptual model), either taken from previous tests in the immediate area or from well logs and an assessment of the site features that can affect the test (soil or rock types, depth to water, surface- water bodies, existing wells, storm drains). This conceptual model will then help the designer anticipate the necessary design factors such as: number of wells, depth and placement of wells; pumping rate(s); frequency of water-level measurements; and length of pumping. These factors will help the designer determine from the test results the effects of recharge and restrictive boundaries, aquifer geometry, secondary porosity effects (fractures, solution channels), the nature and extent of potentially confining layers, and aquifer interconnections.

2. Estimate Aquifer Parameters

Although the objective of a pumping test is to determine the principal aquifer parameters, the conceptual model requires a prediction of some of these parameters for the design process (i.e., observation well number and spacing requires approximate transmissivity and storage coefficient values). Hydraulic conductivity may be estimated from textural or hydraulic testing of aquifer materials in the laboratory, or from data collected and observations made during drilling or well development (see Driscoll, 1986). Considerable experience is needed to apply these methods for anything but preliminary estimating purposes. Therefore, use as many approaches as possible when making these estimates and remember that they are only estimates. Be ready to adjust preliminary estimates as more information becomes available throughout the process.

For larger tests (and thus larger pumping wells), potential casing storage effects and well (friction and formation) loss may need to be calculated prior to the test. Also, optimum pump size may need to be calculated. These will require an estimate of specific capacity, which is the well discharge rate per unit of drawdown measured at a given time. Specific capacity is typically determined from a step-drawdown test. An added benefit to conducting a step-drawdown test is the graphical results can also be used to calculate transmissivity (but not storage coefficient) in addition to well losses (see Section B.9).

3. Locate the Pumped Well

At many sites, the pumping well location is predetermined because an existing well suits the needs of the test, or the hydraulic properties of a specific location must be measured. If the pumping well location can be selected with relative freedom, the following criteria can be used as a guide for its installation:

a) where the hydrogeology represents the area of interest;

b) proximity to existing wells that could be used as observation wells (see guidelines 5, 6 and 7 below);

c) within the targeted contaminant plume whenever possible;

d) outside the contaminant plume if the system is areally homogeneous (or nearly so) and pumping of contaminated water poses an insurmountable problem;

e) away from groundwater system boundaries (assuming their approximate position is known) when the test purpose is solely to measure aquifer storage and transmission properties;

f) close to groundwater system boundaries (assuming their approximate position is known) when requiring boundary location, orientation (both positive and negative boundaries), or degree of connection (positive boundaries);

g) away from surface features that could obscure the data (for example, surface-water bodies) and away from areas subject to heavy-equipment traffic (i.e., railways and highways) that would put unpredictable stress on the aquifer, unless desiring specific information about the interrelationship of the groundwater system and surface features;

h) away from other producing wells that may not be shut down and may affect test data; and

i) where the site is safely and easily accessible to equipment and personnel.

Although these guidelines generally support test success, strictly adhering to them may produce conflicting test designs. Resolving these design conflicts requires good judgment based on a clear understanding of the test priorities and an appropriate knowledge of the local groundwater system.

4. Design the Pumped Well

a) The casing must accommodate the pump used for the test and allow ample additional space for measuring equipment.

b) The pumped well should be as efficient as possible through sound drilling practices, installation, and construction. A wire-wrapped screen and site-specific filter pack, designed from a sieve analysis, should be used to reduce factors that will mask true aquifer response.

c) If possible, a stilling pipe should be installed in the pumped well for making water- level measurements. The stilling pipe will dampen water-level fluctuations caused by pump vibration, eliminate measurement errors associated with cascading water, and isolate pressure transducers from pressure transients near the pump intake.

d) Generally, the screen in the pumped well should fully penetrate the tested zone to eliminate the complicated data analysis and interpretation required to correct for partial penetration effects (induced vertical flow component in addition to radial flow), with the following two exceptions:

   1) if the screen would form a conduit capable of transmitting chemicals from a contaminated horizon to a clean horizon; or

   2) when attempting to determine an aquifer's vertical anisotropy (ratio of vertical to horizontal hydraulic conductivity). This determination is necessary if remediation well capture zones will not affect the full thickness of the aquifer.

For these two conditions, the pumped well should only penetrate the contaminated portion of the aquifer. In addition, cost considerations may limit full penetration of the tested zone.

e) The pumped well must be fully developed to maximize the pumping rate from wells with limited available drawdown, simplify data interpretation and assure that no additional development occurs during the test.

f) Often, pumping wells are later used as monitoring or recovery wells. Such wells should be designed according to the requirements of the particular application without compromising the aforementioned standards for pumped wells.

5. Determine the Number of Observation Wells

Observation wells help quantify the size, shape, position, and rate of change of the cone of depression formed by pumping, making it possible to determine aquifer parameters. Adding wells increases the amount and accuracy of information acquired, and improves confidence in the data. The number of observation wells selected, however, must balance the information needs with the cost of constructing them.

Without observation wells, only transient analysis (time-drawdown) methods may be used to determine aquifer properties, and only transmissivity and hydraulic conductivity can be determined. A single observation well makes it possible to determine storage coefficient, but data analysis is still restricted to transient methods. Two or more observation wells permit the use of distance-drawdown methods of analysis, greatly improving the accuracy of aquifer parameter estimates. Distance-drawdown analysis is especially important whenever transient analysis methods are apt to produce erroneous results, as often occurs in unconfined aquifers, tight sediments, leaky aquifers, and aquifers with boundaries near the pumped well. Therefore, when possible, use at least two observation wells during a pumping test. Determining parameters such as leakage/delayed yield and anisotropy usually require more than two observation wells.

6. Design the Observation Wells

a) The observation well diameter must be large enough to accommodate instrumentation used to measure water levels and small enough that the volume of water in the well does not cause a time lag in responding to aquifer drawdown changes.

b) Unlike the pumped well, observation wells need not be highly efficient, just open enough to reflect pressure changes that occur in the aquifer. Thus, inexpensive construction materials such as slotted screens may be used (unless they will be used later as monitoring, recovery, or injection wells). Yet, to accurately represent the potentiometric changes that may differ vertically in the aquifer, the well intake must be open to the aquifer from top to bottom. This objective can be achieved with moderate well development. Techniques such as surging and bailing, which provide modestly effective development, can be used.

c) Generally, observation well screens should be fully penetrating to eliminate complications in data interpretation caused by partial penetration. As with the pumping well, the exceptions to this rule are:

   1) Avoid fully penetrating screens where they would create a conduit capable of spreading contamination;

2) Use short screens to assess vertical anisotropy at discrete elevations in the aquifer.

Short screens are appropriate for observation wells installed in aquitards that are being used to assess connectivity, recharge, or delayed yield factors.

As stated above, fully penetrating wells will simplify the data analysis because hydraulic theory for fully penetrating systems is simpler than that for partially penetrating ones. Theory also predicts that, for a confined aquifer, an observation well will show fully penetrating response if either it or the pumped well is fully penetrating. That is, in theory, both need not be fully penetrating --it is sufficient that just one or the other be fully penetrating to observe the simplified fully-penetrating response. In practice, however, it is preferable that both the pumped well and the observation well be fully penetrating, if possible. In aquifers where hydraulic conductivity varies substantially with depth, it is possible that a fully penetrating response would not actually occur unless both the pumped well and observation well were fully penetrating.

7. Situate the Observation Wells

a) Lateral Distribution

When using two observation wells, they should be positioned along a straight line radiating from the well. Accurately assessing horizontal anisotropy or near-well boundaries requires three pairs or sets of observation wells positioned along three different lines emanating from the well. If the principal axis of anisotropy is known, two sets of observation wells will suffice, one along the principal direction of anisotropy and one perpendicular to it. For example, if a fractured rock aquifer is known to be more permeable north-south than east-west, one set of two or more observation wells would be installed on a line north (or south) of the pumped well and another set along a line east (or west) of the pumped well.

In theory, single wells placed on three different lines emanating from the pumped well are sufficient to assess horizontal anisotropy. In practice, however, other heterogeneities can influence drawdown readings enough to bias the calculated anisotropy if just a single well is used along each line. Therefore, it is preferable to use pairs of wells whenever possible.

b) Well Spacing

Observation wells along a particular line from the pumped well should be spaced logarithmically with the distance to each successive observation well approximately double that to the preceding well. For example, three observation wells may be placed at distances of 10 ft, 20 ft, and 40 ft from the pumped well, or 50 ft, 100 ft, and 200 ft from the pumped well.

There are advantages and disadvantages to locating observation wells either near to, or far from, the pumped well. Distance drawdown analysis methods tend to integrate aquifer properties over the area spanned by the observation wells, so distant wells tend to yield aquifer parameters representative of a broad area of aquifer. At great distances, however, wells may exhibit drawdowns so small that they are difficult to measure accurately or analyze confidently. On the other hand, observation wells installed near the pumped well show more substantial drawdown but tend to reveal aquifer properties on a smaller scale. Situating observation wells, therefore, depends on the type of information required. For contamination investigations of small plumes, closely spaced observation wells provide satisfactory data.

The data set will be more reliable if substantial drawdowns can be attained in the observation wells. This is accomplished by maximizing the flow rate and locating the observation wells sufficiently close to the pumped well. As a rule of thumb, the distance from the pumped well to the nearest observation well should not exceed the square root of the expected radius of influence of the pumped well. R can be determined from:

$$R = \sqrt{\frac{0.04Tt}{S}}$$

where

R = radius of influence in ft

T = estimated transmissivity in ft^2/day

t = pumping test duration in days

S = storage coefficient

For example, in tight sediments, if the expected radius of influence is less than 100 ft, at least one observation well should be located within 10ft of the pumped well.

Be aware that the oft-repeated recommendation to locate the nearest observation well one or two aquifer thicknesses from the pumped well is actually a generalization (not entirely correct) for locating partially-penetrating observation wells away from a partially-penetrating pumping well. The actual radial distance for a partially-penetrating observation well must take into account anisotropy, as follows:

$$r = \frac{1.5b}{\sqrt{\frac{K_z}{K_{xy}}}}$$

where

r = radius from pumping well

b = thickness of aquifer

K_z = vertical hydraulic conductivity

K_{xy} = horizontal hydraulic conductivity

In most instances, and especially in unconfined or tight sediments, use closely spaced observation wells and eliminate partial penetration effects by using fully penetrating wells, or compensate for partial penetration effects by determining the anisotropy of the aquifer.

c) Vertical Distribution of Observation Wells

Generally, make sure that observation well screens are located in the pumped aquifer and fully penetrate it. To determine vertical anisotropy, however, screens must only partially penetrate the aquifer. For this determination, install observation wells in pairs at the same location, with one well screened in the pumped interval and the other screened in an unpumped interval of the aquifer to get a three-dimensional view of the pressure reductions caused by pumping.

If pumping is expected to induce leakage across an aquitard and if the leakance must be determined, place one or two piezometers in the aquitard to assess the magnitude of the drawdown, if any, created by the pumped well. Aquitard-monitoring wells should have short screens approximately centered in the aquitard, to keep the screen as far as possible from the top and bottom of the aquitard. Ideally, an aquitard observation well should be drilled at the same location as an observation well completed in the pumped aquifer.

8. Establish the Pumping Test Duration

a) The duration of pumping tests can range from a few hours to a few weeks depending upon the nature of the formation and the type of information required. For example, in highly transmissive confined sediments, if only near-well transmissivity must be known, a 2-hour test might suffice. However, to acquire information about boundaries or leakage, or if sediments are tight or unconfined, a much longer test is required. The preliminary test of the pumped well (Section B.9) will help in planning the test length.

b) For confined aquifers, a test duration of 24 to 48 hours will generally provide the information required.

c) Longer tests are required for unconfined aquifers because the cone of depression expands more slowly and delayed-drainage effects retard the response of the aquifer to pumping. Plan to conduct pumping tests in unconfined aquifers for 3 days or longer.

d) If leakage effects among aquifers must be determined, a longer test is appropriate. For example, under confined conditions, it may be desirable to extend the test to two or three days.

e) Economics may dictate curtailing the length of the pumping test if treating or storing pumped water is expensive. If water disposal is inexpensive, however, it makes sense to extend the test because the cost of the additional pumping and monitoring required is generally nominal.

9. Select the Appropriate Flow Rate and Measurement Device

a) The objective of the pumping test is to stress the aquifer sufficiently to obtain a meaningful, measurable response. Generally, the magnitude of the drawdown response in most observation wells is small. Thus, in most aquifer tests, design the well and pump intake in such a way that a sufficient stress is placed on the aquifer system that can be measured at a distance.

b) Select the pumping rate on the basis of a preliminary test (such as a step-drawdown test, Section B.9) so that the rate can be sustained by the pump for the duration of the test. The rate should not be so large that the water level is drawn down into the screen area, causing cascading effects and entrained air; under no circumstances should the water level be drawn down to the water entry of the pump or tail pipe.

c) Small variations in the discharge rate create large errors in the calculation of aquifer parameters. Therefore, sustaining a constant discharge rate is more important than knowing the exact rate with great accuracy. Accordingly, maintain the flow rate as closely as practical to a constant value, usually within ±1 percent or less. This can be achieved only if the flow rate can be measured precisely and adjusted easily as needed.

d) Always operate the pump against a partially closed valve so that, as drawdown increases during the test, a compensating reduction in back pressure is achieved by gradually opening the valve. The correct valve and flow measurement method are critical to this requirement. Select a valve that can be opened or closed in tiny increments to ease flow-rate control. A ball valve that opens fully or closes fully with a single 90-degree turn of a handle is undesirable because careful adjustments are difficult to achieve. A better choice is a gate valve that requires several 360-degree turns to open or close.

e) Flow measurement devices are typically based on three principles; head-type (orifice, venturi), velocity-type (magnetic, ultrasonic), and displacement-type (rotor, paddlewheel). Measurement devices/methods for a pumping test, in order of preference, are as follows:

1) Orifice weir with manometer (see Driscoll, pg 537): This is the best method of measuring the flow rate because it is precise, allows instantaneous reading of the flow rate so that adjustments can be made readily, and is relatively "low-tech". While most orifice weirs accommodate higher flow rates, small-scale versions can be made for flows as small as a few gallons per minute. Such custom-made meters can be calibrated easily in the field with a bucket and stop watch. Installing a totalizing meter in line with and upstream from the orifice weir provides assurance that the total discharge for the test is calculated accurately. After completing the test, total discharge volume is divided by test duration to determine average flow rate.

2) Instantaneous (ultrasonic) flow meter: non-invasive, can be equipped with a data logger. Some meters may not respond properly when pumping sediment-laden water or two-phase fluids like hydrocarbons and water.

3) Paddlewheel totalizing meter: shows total volume pumped. When using this type of meter, flow rate must be determined by taking consecutive readings and dividing by the time between them. Accuracy may vary from one meter to another. Also may not respond properly when pumping sediment-laden water or two-phase fluids. Meter inaccuracy at low flow rates can be allayed by installing a flow restrictor (such as manufactured by Clack Corporation) upstream of the meter. The restrictor creates enough back pressure on the pumping unit to minimize flow rate fluctuations.

4) Bucket, or other container of known volume, and stop watch. For low flows, this procedure is about as accurate as any for determining the flow rate. It also serves as a reliable calibration tool for other flow measurement devices.

Other methods of measuring flow rate involve using various types of weirs, flumes, and open-discharge pipes generally do not provide the precision required for controlling the flow rate during a constant-rate pumping test.

10. Select the Pump

a) The pump used must have sufficient capacity to maintain the required discharge throughout the constant-rate portion of the test and to produce the various flow rates required for the step-drawdown test.

b) The pump should be capable of delivering the planned discharge rate at pressures substantially higher than the apparent nominal pressure required to lift water to the surface and overcome friction losses in the piping system. Pumping against a high head such as 60 to 100 psi tends to reduce discharge rate variations. It also permits operating the pump against a partially closed valve, creating additional head to help minimize flow-rate fluctuations during the test.

c) Submersible or turbine pumps driven by electric motors are ideal for conducting pumping tests because (barring spikes or storms) they run at nearly constant rates, producing generally uniform flow. Turbine pumps driven by gasoline or diesel engines, however, cause greater flow-rate variations because engine output can vary with fuel mixture, and air temperature and pressure.

d) The pump should be equipped with a check valve so that water in the column pipe and discharge pipes doesn't siphon back into the well following pump shut off. This prevents a sudden charge of water from obscuring the early recovery data and making analysis more difficult.

11. Plan for Pumped Water Disposal

a) Discharge pumped water so that pumped aquifer zones are not recharged. To accomplish this, pipe water to nearby storm or sanitary sewers, or lined surface-water bodies. If these options are not available, arrange to spread the discharge water on the ground sufficiently far from the pumping test site so that infiltration will not affect the test results.

b) If the water quality is such that direct discharge is not permitted, treatment may be necessary. Occasionally, water treatment facilities are already available on site. Alternatively, it may be possible to arrange for temporary treatment equipment just for the pumping test. If disposal during the test is not possible, the fluid can be discharged to containers such as frac tanks temporarily. Provisions must be made for the appropriate number and size of containers to handle the volume of water pumped during well development, step-drawdown testing, and constant-rate testing, plus a safety margin.

c) Discharge water must be disposed according to all applicable laws and regu1ations. Contact the governing agencies to determine which restrictions apply.

d) ARCADIS should not be responsible for signing manifests and should not "take possession" of discharged water.

12. Check for Casing Storage

Casing storage effects will render useless the early time/drawdown data from pumping tests. The larger the well diameter and the lower the specific capacity, the longer casing storage effects persist. Data recorded before casing storage effects end (at t_c) cannot be analyzed by any method.

The duration of the casing-storage affected portion of the test can be estimated as follows:

$$t_c = \frac{0.6\left(D^2 - d^2\right)}{Q/s}$$

where

t_c = duration of casing storage effect ('critical time'), in minutes

D = inside diameter of well casing, in inches

d = outside diameter of pump column pipe, in inches

Q = flow rate, in gpm

s = expected drawdown in the pumped well, in ft

Before conducting the test, it is important to estimate t_c. If the value is large, take steps to minimize storage effects if possible. For example, a packer may be installed with the pump column pipe to keep the water standing in the well casing from being removed from the well. If this is done, the packer must be specially designed to permit measurement of the hydraulic pressure in the well just under the packer. Alternatively, it may be possible to install ballast material alongside the column pipe to take up space and reduce the volume of water stored in the casing. For example, a 3.5-inch OD PVC pipe run alongside the column pipe in a low-yielding, 4-inch well, can reduce the duration of casing storage effects by 75 percent.

To demonstrate the significance of casing storage, a 4-inch test well in tight sediments with 1.25-inch column pipe producing 2 gpm with 30 ft of drawdown results in the following calculation:

$$t_c = \frac{0.6\left(4.026^2 - 1.66^2\right)}{2/30}$$

= 121 minutes

Thus, the first two hours of test data from this well cannot be analyzed.

In filter-packed wells, if water in the filter pack can drain quickly into the well (such as in wells that are screened across the water table), the equation for t_c must be modified to account for filter pack storage. The accomplish this, the term

$$D^2 - d^2$$

is replaced by

$$\left(D^2 - d^2\right) + S_y\left(B_d^{\ 2} - C_d^{\ 2}\right)$$

where

B_d = diameter of borehole, in inches

C_d = outside diameter of casing, in inches

S_y = short-term specific yield of filter pack material --approximately 0.1 or 0.15

II. Pretest Activities

a) Unless installed specifically for the test, sound all wells for use in the test to verify well depth. (Do not use water level meters for this purpose, because some meters have probes that leak and trap water when subjected to excessive pressure.) Also, if adequate connection to the aquifer is suspect, conduct a slug test (either 'in' or 'out' - attempt to change the water level by at least 2 feet) in the observation wells. If the water-level response is too sluggish or no response is apparent, redevelop the well.

b) Label all wells (temporarily, if necessary) for quick and easy identification throughout the test.

c) Unless previously verified, measure the distance of all observation wells from the pumping well to the nearest foot.

2. Select Appropriate Water Level Measuring Devices

a) Pressure Transducers and Data Logger Combination

Transducers connected to electronic data loggers provide rapid water-level measurements with accuracy and ease. Some electronic data loggers (i.e., Hermit) collect and store data from a number of input channels (downhole pressure transducers plus atmospheric pressure) to provide water-level measurements in multiple within several hundred feet radius of the data logger, while others consist of a single logging transducer (i.e., Troll™, Levelogger™). Typical loggers take readings at preprogrammed linear or logarithmic intervals. If desired, data can be transferred to a personal computer for processing.

Small-diameter transducers (typically 0.5 to 0.75 in) are available that cover a range of pressures. Because they yield readings accurate to a percentage of their pressure range (usually about ±0.1 percent of the range in the center of that range, and ±0.2 percent near the limits) transducers that span a wide pressure range have lower absolute accuracies than those that span a narrow range. For example, a typical transducer with a 5 psi range detects water-level changes over a 11.6 ft with an accuracy of ±0.01 ft, whereas, a transducer with a 15 psi range detects changes over a 34.7 ft with an accuracy of ±0.03 ft. Thus, to ensure the greatest accuracy, select the transducer with the pressure range that most closely encompasses the anticipated drawdown or water-level change. Furthermore, confirm transducer water-level measurements throughout a test by manually taking regular water-level readings with a water level meter.

Caution: To prevent transducer malfunction, do not submerge transducers in excess of their operating range.

b) Water Level Meters, Interface Probes

These devices provide quick and easy water-level measurements with reasonable accuracy. They employ a sensor that is lowered into a well on the end of a marked cable (typically imprinted in feet and hundredths of a foot). When the sensor contacts water, a circuit is completed, activating a light, audio signal, ammeter, or digital display in the cable reel or housing. However, because the measurements are manual, the speed of readings cannot match those of a pressure transducer with a data logger. Thus, a water level meter is most useful in taking correlative, manual measurements in wells as a backup and for data checking, as well as measuring wells outside the active observation well network.

When appropriate, one water level meter should be used to take readings in all wells. If more than one meter is used to make site-wide water-level measurements, record the serial numbers and make comparison measurements within a single well to calibrate to a common standard.

c) Wetted Steel Tape

When using a steel tape, attach a weight to the bottom, wipe dry and coat the lower 2 to 3 feet with carpenter's chalk or water-soluble ink from a felt-tip marker, lower the tape into the well until part of the coated section extends below the water level, hold one of the major division (e.g., foot) markings at the predetermined measuring point, and record this reading. After withdrawal, read the wetted line on the coated section to the nearest 0.01 ft. Subtract this reading from the mark held at the measuring point; the difference is the actual depth to water.

A wetted steel tape is accurate and reliable, and is useful to verify and calibrate readings from other instruments. The procedure, however, is more time-consuming than others, limiting its usefulness during the early portion of pumping test when many rapid measurements are required. Furthermore, the approximate depth to water must be known in advance to ensure that part of the chalked section is submerged to produce the wetted line.

3. Verify Measuring Device Accuracy

Test pressure transducers and data logger readings using a bucket or barrel filled with water. Submerge each transducer, accurately measure the water head above the transducer, and compare the measurement to the data-logger reading. Check transducer response to changing heads by raising the transducer a certain distance, observing the change in the datalogger reading, and then measuring the distance with a standard steel tape. Water level meters should be in good working condition and calibrated, ensuring there are no breaks or splices in the cable.

4. Establish a Reference Point for Measuring Water Levels

At each well, establish and clearly mark the position of the selected reference point (often the north side, top of the casing). Determine the elevation of this point, record it, and state how this elevation was determined. This elevation point is important to establish the position of the piezometric surface, so it must be determined accurately.

5. Record Background Water Levels

To establish local trends, measure groundwater levels in all test wells and on-site surface water levels at regular intervals for several days before pumping any of the test wells. Although two days preceding the test may be enough (this meets the standards of some regulators), ideally the period of time should be at least equal to the length of the pumping test (three days to a week is optimum). Unless extreme variations are expected, such as significantly increased stream discharge in response to off-site precipitation, only surface water bodies within the radius of influence of the pumping well need to be monitored. A well outside the radius of influence may provide valuable information about water-level trends if monitored before, during, and after the pumping test. In areas that could be influenced by tidal fluctuations, collect information regarding local tidal variations before, during, and after the test.

If levels in the zones to be monitored during the test might be affected by pumping of other nearby wells, gather information about the discharge rates and operating times of those wells. Also, monitor water levels for a sufficient period before the test to evaluate the influence of nearby wells. Water-level monitoring should be done far enough in advance to allow time to negotiate with well owners and take appropriate action. If possible, arrange to have nearby wells shut down or pumped at a constant rate to ease data interpretation.

6. Record Barometric Pressure

Atmospheric-pressure changes can cause water level changes in confined or semi-confined aquifers, leading to erroneous conclusions about aquifer parameters. To correct for these changes, the barometric efficiency of each appropriate aquifer must be determined. Aquifer barometric efficiency (BE), a ratio of aquifer head change to atmospheric pressure change, can be calculated using:

$$BE = \left(\frac{\Delta h}{\Delta B_p}\right) 100\%$$

where

BE = barometric efficiency, in percent

Δh = change in water level resulting from change in atmospheric pressure, in feet

ΔB_p, = change in atmospheric pressure, in feet of water

To measure atmospheric pressure changes, either ensure that the dataloggers being used also measure barometric pressure, or obtain data from a nearby source. Barometric pressure must be recorded throughout the background water-level-measurement period and throughout the test. Ideally, barometric pressure and water-level measurements should be made during a time of significant atmospheric pressure change so their relationship can be more easily correlated.

Logging transducers with vented cables (e.g.: Troll, miniTroll) already account for barometric pressure and no additional adjustment is required.

7. Install a Rain Gauge

Heavy precipitation can cause a significant water-table rise in shallow aquifers. Note that rainfall data from nearby weather stations or airports may not be representative, because precipitation patterns may vary greatly over short distances. Therefore, when testing shallow aquifers, a rain gauge should be installed at the test site and monitored during rainfall. Keep in mind that storm sewers can channel large volumes of water rapidly to shallow aquifers.

8. Set-up: Remaining Equipment Required for Test

a) Keep sensitive electronic equipment away from devices that generate significant magnetic fields. For example, do not place data loggers near electric power generators or electric pump motors. Likewise, radio signals may cause dataloggers or computers to malfunction.

b) Secure data logger and transducer cables at the well head to prevent movement that would affect measurements. Mark a reference point on transducer cables and check regularly to detect slippage.

c) Provide adequate lighting for night readings.

d) Identify all equipment to be used in the test that will affect data. For example, describe (by serial number or otherwise) the pump, any isolation packers, water level meters, data loggers, rain gauges, barometers, flow meters, buckets or volumetric containers, watches, and steel tapes used.

e) Consider having backups for key equipment such as data loggers, generators, water level meters, etc.

9. Perform a Job Safety Analysis

To ensure that everyone is aware of the hazards associated with the work, and that each person knows his/her responsibilities during the preliminary and full-scale test, run through a JSA of the test before the start of pumping.

10. Conduct a Preliminary Pumping (Step-Drawdown) Test

Conduct a short-term preliminary test of the pumping well to estimate the hydraulic properties of the aquifer, estimate the duration of the test, and establish a pumping rate. A step-drawdown test is the most efficient preliminary test to use. If other constraints determine flow rate and the flow rate is sustainable, a step test is unnecessary.

The concept of step-drawdown testing in wells was first developed by Jacob (1947). He proposed that drawdown in a well has two components: formation loss (laminar, proportional to the discharge), and well loss (turbulent, proportional approximately to the square of the discharge). Jacob outlined a multiple-step drawdown test where discharge was increased at specific times, as if pumping of the well was held constant and additional wells were introduced at corresponding increases in pumping rates. Rorbaugh (1953) later noted that Jacob's assumption of second-order turbulent flow did not take into account that turbulence at low rates of discharge is not fully developed. Thus the exponent for turbulent flow should be expressed as an unknown constant. Taking this into consideration, the arithmetically-plotted results of a step-drawdown test can be used to select the discharge rate for a pumping test, determine drawdown for a given pumping rate and optimum pump depth, and even (with some minor calculations) estimate the transmissivity of the formation prior to the test. (This is also a good test for reliability of the flow meter.)

a) Select the pumping rates for the step-drawdown test based on:

   1) production capability estimates made during well development,

   2) prior pumping information,

   3) slug test data (for small wells), or

   4) a brief, preliminary rate test.

Step tests are most commonly run with three steps at 33, 67 and 100 percent or four steps at 25, 50, 75, and 100 percent of the anticipated maximum rate. Sometimes a step is added at 133 percent for a three-step test or 125 percent for a four-step test and the first step is dropped.

b) Conduct the step test, pumping at each level for 30 to 60 minutes. It is important to run the initial step long enough to establish that the effects of well storage have dissipated, with the remaining steps run for the same duration as the initial step. Although standard practice is to allow a recovery period after each step, practical experience shows that these individual recoveries are not necessary.

c) At the end of the step test, mark the setting of the discharge control valve corresponding to the flow rate for the full-scale pumping test. Secure the valve in that position with wire or tape to prevent inadvertent changes.

d) Allow sufficient time after completion for drawdown to return to static level. Although the time may vary, allow at least one day of recovery after the step-drawdown test has been completed before starting the constant-rate test.

11. Synchronize Watches

Just before the constant-rate test, watches and other time-measurement devices (i.e., dataloggers) should be synchronized so that the time of each reading, electronic and manual, can be referenced to the exact minute and hour that pumping started.

III. CONDUCTING THE TEST

1. Record Information

a) Use appropriate data forms

b) Record all required background information on logs before beginning the test

c) Record time as military (24-hour) time.

d) Ensure that everyone taking manual water-level measurements understands the units of measurement on the device or devices they will use.

2. Keep Pertinent Well Construction Details at Hand

To evaluate data plotted during the test, it may be necessary to have access to well construction information, such as the following:

- Lithologic logs;
- Well depths;
- Screen lengths
- Screen type (slotted, wrapped, opening size)
- Filter pack thickness and length
- Pumped well diameter
- Pump characteristics (performance, unit dimensions)
- Pump setting depth
- Topographic maps

3. Start the Test

a) Check all wells to confirm that water is at static level. Record the time since last pumping.

b) Make sure all field personnel are aware of predetermined starting time.

c) Start the pump and timing devices simultaneously. Use both an audible and visible signal to indicate the start of the test, especially if the distance between the pumped well and observation wells is large.

4. Measure Drawdown at Established Times

The widespread use of data loggers with extended memory precludes the older standard of using logarithmic time measurements. However, remember that rapid-frequency readings are needed early in the test in order to observe early effects of pumping and formation storage, plus effects of well construction. Water level measurements should be taken at least every five seconds.

Early time data are of greater importance when conducting pumping tests to identify aquifer heterogeneities and should be collected at short time intervals (< 1 sec) and considered as part of the pumping test analysis. Large data files can be generated and may need to be manipulated with text editors prior to importing data to other software such as Excel.

For manual observation well readings, the following schedule is suggested:

Elapsed Time	Interval Between (minutes) Measurements (minutes)
0-5	1
5-15	2
15-60	5
60-120	10
120-300	30
300-1440	60
1440-end of test	240

Drawdown readings are sometimes difficult to record at the exact time required by the above schedules. If the designated time for a drawdown reading is missed, take a reading anyway and record the actual time. However, try to follow the established schedule as closely as possible to ease data plotting. Use the following table as a guideline for time measurement accuracy.

5. Check the Flow Measuring Device

Unrecorded fluctuations of pumped well discharge rate can make the test data difficult to interpret. Measure and record discharge every 5 minutes during the beginning of the test. When discharge becomes stable, reduce the frequency to hourly checks.

As water levels decline, the discharge rate may decrease, thus requiring adjustment. Whenever adjusting the flow rate, record water levels in the pumped well before and after each adjustment.

6. Monitor Fuel Levels

When using liquid-fuel-driven engines or generators, monitor and refill fuel tanks as needed to prevent premature termination of the test.

7. Plot Data to Evaluate Trends and Catch Aberrations

a) Begin to tabulate and graph the elapsed time, discharge rate, and pumped well drawdown as early as possible in the test, usually after the first hour of testing.

b) Prepare a plot of the log of drawdown (log10s) versus the log of the ratio of time since pumping started to the square of the distance from the pumped well to the observation well (log10t/r2) on arithmetic graph paper and maintain during the test. Compare this data to basic type curves to detect deviations that may be due to discharge variations or other changes in field conditions that need to be documented. A portable computer and printer ease this plotting for tests with many wells.

c) Keep the plots current throughout the test. This information supports informed, intelligent decisions about test progress and may signal anomalies such as equipment malfunctions or unacceptable flow rate variations. Analysis of these plots may suggest that more data is needed to substantiate conclusions about the groundwater system.

8. Collect Groundwater Samples and Measure Field Parameters

Samples of discharge water may provide valuable information about the nature of aquifer water quality as it changes during the pumping test. Depending on the site conditions, samples collected regularly throughout the test may signal proximity to a contaminant source, connection with surface water bodies, or other contributors to water quality change. The number of water samples needed and the frequency and time of their collection depends on both nearness to suspected or known water quality influences and the test budget.

9. Verify Measuring Device Accuracy

Recheck the accuracy of hand-held electronic water-level sounders before starting the recovery portion of the test. During pumping and recovery, check transducer accuracy periodically with reliable manual devices. Every hour or few hours is sufficient for most tests.

10. Measure Water Levels during the Recovery Phase at Established Times

Recovery of water levels following the pumping phase should be measured immediately upon pump shut down and recorded for a period of time equal to the pumping time, or until the water levels have reached 95 percent of the initial, pre-pumping static water level. Use the same drawdown measurement schedule that was used during pumping. A check valve should be used to prevent backflow of water in the riser pipe into the well, which could result in unreliable recovery data.

Recovery phase data may be easier to analyze because no discharge fluctuations occur, and pump-induced turbulence is not a concern in the pumping well. However, note that typically the calculated transmissivity from the pumping phase will be lower than that of the recovery phase due to the added turbulence and vertical flow components during pumping.

11. Record Observation of Pertinent Phenomena

Record any unusual events occurring just before or during the test that may affect test data, such as:

- Weather changes
- Heavy equipment (trains, etc.) passing through area
- Operation times of other wells
- Changes in pumping rate
- Equipment problems, and
- Earthquakes

IV. POST-TEST PROCEDURES

1. Document the "As-Built" Configuration of the Test

Describe the configuration of the test, the observation well locations versus the pumping well, water discharge, outside influences detected during the test, and any modifications to the original plan.

2. Verify Timing Device Agreement and Measuring Device Accuracy

Compare all clocks, watches, and data recorders for agreement and note any discrepancies, identifying the devices and where they were used. Compare manual measurements to datalogger measurements within wells to confirm accuracy of measuring devices.

3. Sound the Pumped Well

Determine if any aquifer material accumulated in the pumped well during the test. Sand or other material accumulating in the well during the test progressively blocks screen areas, reducing the effective aquifer penetration. If the effect of this condition is not taken into account, aquifer parameters calculated from test data will be wrong. Gradually decreasing aquifer penetration in a pumped well significantly complicates test data analysis. The wisest strategy, therefore, is to prevent infilling of screens by sufficient development of the pumped well.

4. Decontaminate All Equipment Contacting Site Groundwater and Soil

Use appropriate decontamination procedures.

5. Monitor Background Information as Long as Possible

If possible, continue to monitor groundwater levels, surface water levels, and barometric pressure data for several days after test completion. This information may reveal trends or relationships undetected before or during the test.

V. SPECIAL CONSIDERATIONS

1. Wells Containing Floating Nonaqueous Phase Liquids

It is best to use pressure transducers to measure water levels in wells containing floating product such as gasoline. Contact with floating product, however, may make transducers and cable unsuitable for future use. Thus, include the cost of replacing transducers (and perhaps cable) when calculating pumping test budgets. Otherwise, protect each transducer and cable assembly by encasing it in plastic tubing or pipe. Be sure that each protected transducer still can respond accurately to any pressure changes.

As an alternative to pressure transducers, make manual measurements (using a interface probe) of both the fuel level and water level individually. Then correct the observed thickness of floating product by its density to arrive at an effective pumping level. Measure product density in the field using a simple density balance (such as drilling fluid balance) or consult an appropriate API table. This manual procedure will work, but takes time and introduces additional measurement and computation errors.

2. Fill Materials

Occasionally, pumping tests are conducted in or adjacent to fill materials. In these circumstances, it is essential that the nature of the fill and possible extremes in heterogeneity be understood and incorporated into the design of the pumping test so that the resulting data set can provide the required information.

3. Karst and Cavernous Aquifers

Flow through the fractures and conduits within a karst aquifer system ranges from conduit to diffuse. Conduit flow describes flow through dissolution channels with velocities commonly high and turbulent. (The presence of conduits typically requires a dual-porosity model for characterization). Diffuse flow, on the other hand, refers to a slow, mostly laminar to slightly turbulent flow through a series of small, discrete pathways that are being enlarged through dissolution. Karst aquifers do not lend themselves to conventional pumping test layout, procedures, and analysis because flow can be dominated by discrete channels. The discrete nature of high-conductivity zones can range several orders of magnitude and thus hydraulic conductivity values vary according to the scale of measurement, from local to regional. Interpretation of pumping tests must take into consideration the portion of the aquifer being tested.

Additional background investigations may need to be conducted before a pumping test is conducted, in order to predict the connectivity of the wells within the test network. This may include borehole and surface geophysics, tracer (natural and introduced) testing, spring flow and water chemistry analysis, slug testing, and lineament analysis.

4. Fractured Aquifers

The challenge to conducting a pumping test within a fractured-rock aquifer is the continuity of fractures can vary significantly within an area and affect its ability to provide water in a consistent manner. Many fractured aquifers also exhibit a preferred permeability direction based on predominant fracture orientations. Recharge may also vary seasonally and cause production problems in low flow periods (low water level and low recharge). During these periods excessive drawdown may occur. Typically, sources completed in bedrock composed of shale, basalt, granite or any consolidated material can have fractured flow concerns.

For these aquifer systems, although a conventional pumping test approach is generally appropriate, more observation wells will be required to determine the anisotropy and to discern both near-well and distant responses. Also, step-drawdown test data provide valuable information in fractured aquifers because flow near the well in fractured aquifers may be mostly turbulent.

VI. REFERENCES

ASTM D4050, *Standard Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems*. ASTM 04-08, Soil and Rock.

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Specific Capacity Testing and Data Reduction

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Approval Signatures

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I. Scope and Application

Specific-capacity testing is a field method used to estimate the transmissivity of a saturated geologic medium surrounding the screened or open interval of a well. A specific-capacity test involves pumping groundwater from a well at a constant rate and quantifying the pumping rate and magnitude of drawdown inside the tested well after a known duration of pumping. Specific-capacity tests are also referred to as single-well pumping tests or constant-rate tests.

The transmissivity is calculated based on the pumping rate and drawdown measured inside the pumped well. Time-drawdown analysis can be performed with a semilog data plot to estimated transmissivity (Driscoll, 1986). Alternatively, an iterative calculation can be performed based on the pumping duration, the effective radius of the well, and storativity of the formation.

If the thickness of the effective water-bearing zone transmitting groundwater to the well intake is assumed to be approximately equal to the length of the intake, the hydraulic conductivity (K) can be estimated by dividing the transmissivity by the length of the intake.

II. Personnel Qualifications

Specific-capacity tests will be performed by persons who have been trained in the proper usage of pumping and water-level measurement equipment under the guidance of an experienced field geologist, engineer, or technician.

III. Equipment List

The equipment needed for specific-capacity testing includes:

- health and safety equipment, as required in the site Health and Safety Plan (HASP);
- cleaning equipment;
- pump (preferably submersible) capable of pumping at a controlled rate between a fraction of one gallon per minute (gpm) and several gpm, equipped with discharge line;
- power source for the pump;
- calibrated in-line totalizing flow meter or two calibrated buckets;

- stopwatch;
- electronic water-level indicator; and
- field notebook.

IV. Cautions

Wells and piezometers have different water-yielding characteristics as a function of their screen lengths, depth below the water table, and geologic materials in which they are installed. During the first minute of pumping, the water level should be continuously monitored and the pumping rate adjusted to avoid pumping the well dry. Additional cautionary statements pertinent to data reduction are included in Section I. Allowing discharge water to infiltrate next to the well can impact the test results and should be avoided.

V. Health and Safety Considerations

Field activities associated with specific-capacity testing will be performed in accordance with a site-specific HASP, a copy of which will be present on-site during such activities.

VI. Procedures

Pre-Test Set-Up

Prior to installing the pump into the well to be tested, the static water level inside the well is measured to the nearest 0.01 foot relative to a specified datum at the top of the well using the electronic water-level indicator. The water level and the time of measurement are recorded in the field notebook. The water level is measured again several minutes after the initial measurement. This measurement and time are also recorded. This procedure is repeated until two consecutive measurements are identical, indicating approximately static conditions. The static depth-to-water is recorded.

The pump is installed inserted into the well to at least 10 feet below the static water level, or within approximately 1 foot of the bottom of the well if the initial water column in the well is less than 11 feet. The depth of the pump intake below the static water level (indicating the length of the pre-test water column above the pump) is recorded. After the pump is installed inserted (but prior to pumping), the water level in the well is monitored until it has returned to within 0.01 foot of the static water level.

Test Procedures

The specific-capacity test is performed as follows:

1. Hold the water-level probe in the well just above the static water level. If an in-line totalizing flow meter is used, record the pre-test volume measurement in the field notebook. If no in-line flow meter is available, place the end of the discharge line into one of the two calibrated buckets. Record the total volumetric capacity of each bucket.

2. Simultaneously start the pump and stopwatch. Record the start time.

3. Immediately begin monitoring the water level in the well. If the water level inside the test well declines rapidly, quickly reduce the pumping rate to a slower, constant rate. To avoid pumping the well "dry" during the test, the drawdown after one minute of pumping should be less than or equal to 20% of the height of the pre-pumping water column above the pump. All pumping rate adjustments should be completed within 1 or 2 minutes of the start of pumping, after which no adjustment should be made other than minor adjustments that may be necessary to maintain a steady pumping rate.

4. Continue to pump for at least 20 minutes, recording the water level in the well at least once every 3 minutes during pumping. If an in-line flow meter is used, record the volume measurement on the totalizer gauge approximately every 2 minutes during the test. If calibrated buckets are used to measure the pumping rate, record the time at which the bucket reaches the known volumetric capacity of the bucket. Transfer the discharge line to the other (empty) calibrated bucket and record the time when it becomes full. Repeat this procedure for the duration of the test.

5. The specific-capacity test is complete after at least 20 minutes of pumping have elapsed. A longer pumping period is not necessary to estimate transmissivity from the test. However, increasing the length of the test may further increase the reliability of the resulting transmissivity estimate. Immediately before termination of pumping, record the final water-level measurement plus the time of the measurement.

6. Recovery data may be collected following pumping. Such data are highly recommended if the test well is in a location that may be tidally influenced. Also, recovery data provide backup data that may be used to estimate transmissivity. To collect recovery data, measure and record water level data according to the same schedule as used during pumping.

7. Calculate and record the total volume of groundwater removed from the well during the test and the total duration of the test. Divide the total volume (in gallons) by the total pumping duration (in minutes) to calculate and record the average test pumping rate (in gpm).

VII. Waste Management

Water generated during specific capacity testing will be placed in containers, if required per State or local regulations. Containerized waste will be managed and disposed of properly.

VIII. Data Recording and Management

Data from a specific-capacity test are reduced to a transmissivity estimate for the water-bearing formation surrounding the intake of the tested well. The transmissivity may be estimated using a single-well time-drawdown method with multiple drawdown measurements, or else using a specific-capacity procedure with one drawdown measurement. These options are described below.

Time-Drawdown Method

The time-drawdown method of analyzing transmissivity requires graphical data evaluation, but has several advantages. The method does not require an estimate of the formation storativity and the results are not influenced by well efficiency.

Plot the measured drawdown data (measurements in feet on Y-axis) versus the pumping time (minutes, logarithmic scale on X-axis). The semilog data plot typically shows an abrupt initial drawdown at early time, followed by a straight-line trend of data points. Draw a line through the straight-line trend of data points and extend the line through at least one complete log cycle (e.g., 10 to 100 minutes). The data points need not extend through the entire interval of the drawn line. The drawn line is extended to cover at least one complete log cycle for ease in data analysis. Determine the drawdown change (• s) over one log cycle of time for the line drawdown through the straight-line trend in the data points. The value of transmissivity can be solved using the following equation (Driscoll, 1986):

$$T = 264\, Q \,/ \triangle s,$$

where:

T = transmissivity of the water-bearing zone surrounding the intake of the tested well (gallons per day per foot);

Q = pumping rate during the period of the straight-line trend in data points (gpm); and

$\triangle s$ = drawdown change over one log cycle (ft).

Single Drawdown Measurement Method

This method is relatively easy to use, but it requires an estimate of the formation storativity and the results can be influenced by well efficiency. The transmissivity can be estimated using a single drawdown measurement via the following equation (Walton, 1962):

$$\frac{Q}{s} = \frac{T}{\left[264\log\left(\frac{Tt}{2{,}693 r_w{}^2 S}\right) - 65.5\right]}$$

Q/s = specific capacity of the well in gpm per foot

Q = average test pumping rate (gpm)

s = drawdown measured inside of tested well after a known duration of pumping (ft)

T = transmissivity of the water-bearing zone surrounding the intake of the tested well (gallons per day per foot)

S = estimated storativity of the aquifer

r_w = effective radius of the well (ft)

t = time between the start of pumping and the time when the drawdown was measured (minutes)

The value of T can be solved iteratively using a specific-capacity test data reduction computer program. If the well screen is surrounded by a sand pack that may be assumed to be substantially more permeable than the formation, the effective radius of the well is taken to be that of the borehole.

The value of S may be estimated without introducing serious error into the results. For confined aquifers, S should be estimated as 0.0001. For unconfined aquifers, the short-term storativity may be comparable to that of a confined aquifer. Only after a protracted pumping duration (several hours or more) does the storativity begin to approximate the aquifer-specific yield of approximately 0.2 to 0.3 (Nwankwor et al., 1984). In the calculation of transmissivity from a specific-capacity test of less than several hours duration, an estimated storativity value of 0.01 can be used.

To obtain an estimate of the K of the water-bearing zone that transmits groundwater to the well, the calculated transmissivity value may be divided by the estimated thickness of the water-bearing zone. In a stratified formation in which the horizontal K may be expected to greatly exceed the vertical K, the thickness of the water-bearing zone may be estimated as the length of the well intake to obtain an estimate of the K immediately surrounding the well intake.

Cautionary Considerations

It should be noted that the above-listed methods are based on the modified non-equilibrium equation. According to Kruseman and de Ridder (1990), these methods are useful provided that:

$$u = \frac{r^2 s}{4Tt}$$

r = effective well radius
S = storativity
T = transmissivity of the test zone (formation interval adjacent to saturated sand pack)
t = the pumping duration

Following data analysis, the value of u should be calculated to confirm that the above condition is satisfied. If u > 0.15, then a different K test method should be employed. These cases are rare when using drawdown data from the pumped well, because the radius is a small number. The S value used in this calculation can be selected on previous site-specific pumping test results using observation well data, or else estimated as described in the previous subsection.

In circumstances when the pumping rate is low (e.g., less than 1 gpm) and the drawdown is high or occurs within the sand pack, the water removed from the well and sand pack storage should be calculated and subtracted from the pumped volume to estimate the volume of water produced by the formation. The volume of water produced by the formation should be divided by the pumping duration to obtain an effective pumping rate for use in calculating T and K.

In situations where the water level in the test well may be influenced by tidal fluctuations, drawdown and recovery data should both be measured and recorded on the same schedule. In these cases, to correct for potential tidal influence, calculate the average magnitude of the drawdown and recovery measured for the same duration during either pumping or drawdown. For example, if the pumping period lasted 30 minutes, calculate the average of the drawdown at 30 minutes and the magnitude of recovery that occurred during the first 30 minutes after shutting off the pump. This average value accounts for the tidal influence assuming that the rate of tidal change was approximately equal during the drawdown and recovery periods, and it should be considered the “effective drawdown” for use in the specific capacity method of Walton (1962). This correction should be useful in many situations, but may not adequately address tidal impacts if the drawdown due to pumping is small compared to the magnitude of the tidal influence. In these cases, it may be necessary to induce more drawdown during the test and/or time the test to coincide with slack tide conditions.

IX. Quality Assurance

QA Quality assurance calculations must be reviewed by a qualified hydrogeologist. Calculations will be provided with backup documentation, such as raw data and graphs of the data.

X. References

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Attachment B

Community Air Monitoring Plan

1. Introduction

On behalf of Brooklyn Union Gas Company d/b/a National Grid NY (National Grid), ARCADIS has prepared this Community Air Monitoring Plan (CAMP) as a component of the Pre-Design Investigation (PDI) Work Plan for the former Dangman Park Manufactured Gas Plant (MGP) site (Site) located at 486 Neptune Avenue, Brooklyn, New York. The intent of this PDI CAMP is to provide procedures to protect individuals inside the existing shopping center building from potential airborne releases of constituents of concern and nuisance odors during PDI field activities.

As detailed in the PDI Work Plan, field activities will be conducted to evaluate the distribution (if any) of mobile MGP-related non-aqueous phase liquid (NAPL) beneath currently vacant tenant spaces inside the eastern portion of the existing shopping center building, and along the eastern portion of the area immediately in front (north) of the building (shopping center sidewalk).

The planned intrusive (i.e., below land surface) PDI activities are nine (9) soil borings to be drilled inside the shopping center building and three (3) to be drilled immediately outside (i.e., north facing store frontage) the eastern portion of the building. These drilling activities, including pre-clearing each borehole location using non-mechanical means to a depth of 5 feet below land surface and collecting continuous subsurface soil samples during drilling, have the potential to generate localized impacts to air quality. Additional details regarding the scope of the PDI activities are provided in the PDI Work Plan, including a figure showing the investigation locations.

Community air monitoring procedures to be followed during outdoor PDI activities are presented in the CAMP included in the New York State Department of Environmental Conservation (NYSDEC)-approved September 2011 RI Work Plan prepared by ARCADIS (hereinafter referred to as the “RI CAMP”). The RI CAMP provides procedures to protect the downwind communities from potential airborne releases of constituents of concern during outdoor PDI activities. The RI CAMP is cited herein and/or text copied where appropriate for use during intrusive PDI activities conducted inside the shopping center building.

2. Air/Odor Emissions and Control Measures

Air emissions control and fugitive dust suppression procedures and measures will be used during the intrusive PDI activities to limit the potential for air/odor emissions inside the shopping center building. Air monitoring will be conducted as described in Section 3.

During the PDI drilling activities, the following work procedures (at minimum) will be implemented that will serve to minimize the potential for dust, vapor and odor generation inside the shopping center building:

- The drill rig will be equipped with a catalytic convertor on the engine exhaust and metal duct work will be used to convey the exhaust outside the shopping center building.
- Large fans will be used (as appropriate) to exhaust air within the work area and induce ventilation.
- The drill rig will be set up on a large sheet of plastic that will be pulled up around the drill rig.
- Each soil core collected during drilling will be extruded into a plastic sleeve and carried outside the building where it will be opened, inspected, and logged by the ARCADIS geologist. When finished, the ARCADIS geologist will place the soil core (and plastic sleeve) into a 55-gallon steel drum and secure the cover. As further described in the PDI Work Plan, the drums of wastes generated during the PDI activities will be temporarily stored on-site at a location until transportation is arranged for off-site treatment/disposal.
- Upon completion of a boring, the borehole will be tremie-grouted to the surface using a cement-bentonite grout.
- If a boring is not completed before the end of the work day, the borehole location will be appropriately covered using securely anchored plastic sheeting.

Additionally, odor and dust control measures will be available during the PDI and used when (if) necessary. The following dust and odor suppression measures may be used during the PDI activities, depending upon specific circumstances and air monitoring results:

- Water spray
- Plastic sheeting (for covering drill cuttings, etc.)
- Containerize drill cuttings in 55-gallon drums with the cover secured
- Use vapor suppressant foams or sprays, such as BioSolve® PinkWater® concentrate combined on-site with clean water to create a minimum 3% solution (1 part BioSolve® PinkWater® concentrate to 33 parts water).

Odor and dust control measures will be implemented based on visual or olfactory observations, and the results of airborne particulate and volatile organic compound (VOC) monitoring identified herein.

3. CAMP and HASP Air Monitoring

Real-time air monitoring will be implemented during the PDI for VOCs and particulate matter. A community air monitoring location will be established at each PDI equipment entry/exit point to the shopping center building (if these points are open to the exterior during the performance of intrusive PDI activities inside the shopping center building). Additionally, work-zone air monitoring will be conducted in accordance with the Health and Safety Plan (HASP) that is included in the NYSDEC-approved RI Work Plan and will be updated as necessary prior to commencement of the PDI field activities. The work-zone monitoring will be conducted in accordance with the HASP at the borehole where the drilling is occurring, which would be the point of generation for odors and VOC emissions (if any) during the PDI activities.

The total VOC and particulate matter action levels identified in the HASP for a Level D work zone (no respiratory protection) are less than or equal to the RI CAMP action levels, and therefore would be protective of potential receptors outside of the work zone. The HASP action level table (Table 3 - Airborne Contaminant Action Levels) is attached for reference. As specified in the HASP, if the Level D action levels are exceeded (e.g., 5 parts per million [ppm] total VOCs and 100 micrograms per cubic meter [$\mu g/m^3$] particulate matter above background) the intrusive work will stop and required contacts will be notified. Monitoring will continue and additional mitigation measures (described in Section 2) will be employed to abate emissions. Field investigation techniques will also be evaluated and modified, if necessary and appropriate. Intrusive activities may resume if the total VOC or particulate matter level exceedance readily decreases (through observation of instantaneous readings) below the respective Level D action level. As identified in the HASP, exceedances of these action levels are not anticipated.

Based on the Level D action levels specified in the HASP, mitigation measures will be initiated when (if) any of the following occur during the PDI intrusive work: presence of nuisance odors; presence of visible dust; total VOC readings sustained in the work breathing zone at concentrations greater than 0.5 ppm above background; or particulate matter readings above background. Details for additional monitoring requirements for the work breathing zone (e.g., using a secondary monitoring device to screen for presence of benzene) are provided in the HASP.

Based on the work zone air monitoring data described above and community air monitoring data described in the following subsections, along with visual and olfactory observations during intrusive and material handling activities, nuisance odors (if any) will be controlled and particulate and volatile organic vapor levels will be maintained below the action levels identified in the both the HASP (for Level D) and the RI CAMP.

The monitoring requirements, action levels, and instrument calibration requirements for the community air monitoring locations are provided in the following subsections (all of which are consistent with the RI CAMP).

3.1 CAMP Monitoring

As identified above, a community air monitoring location will be established at each PDI equipment entry/exit point to the shopping center building (if these points are open to the exterior during the performance of intrusive PDI activities inside the shopping center building). As required by the New York State Department of Health (NYSDOH) guidance for community air monitoring and as presented in the RI CAMP, VOCs will be monitored continuously at community air monitoring locations with instrumentation that is equipped with electronic data-logging capabilities. Because real-time monitors for polycyclic aromatic hydrocarbons (PAHs) do not exist, the real-time VOC monitoring equipment will also serve as surrogate monitoring equipment for PAH emissions. A photoionization detector (PID) (MiniRAE 2000 [or equivalent]) will be used to conduct the real-time VOC and PAH monitoring. All 15-minute readings will be recorded by the equipment's electronic data-logging system; any instantaneous readings collected to facilitate activity decisions will be recorded in the field logbook.

Similarly, particulate matter will be monitored continuously at community air monitoring locations with instrumentation that is equipped with electronic data-logging capabilities. A particulate monitor (Thermo Scientific personal DataRAM pDR-1500 [or equivalent]) will be used to conduct the real-time monitoring of particulate matter less than 10 microns in size (PM-10). All 15-minute readings will be recorded by the equipment's electronic data-logging system; any instantaneous readings collected to facilitate activity decisions will be recorded in the field logbook.

Fugitive dust migration is not expected during drilling but nevertheless it will be visually assessed during all intrusive work activities, and reasonable dust suppression techniques will be used (as necessary) during any Site activities that may generate fugitive dust. Fugitive dust control measures are discussed in Section 2 of this CAMP.

3.2 CAMP Action Levels

The action levels provided below are from the RI CAMP and are to be used to initiate response actions, if necessary, based on real-time monitoring data obtained from a community air monitoring location. As noted above, these CAMP action levels will be used in addition to those specified in the HASP for a Level D work zone (no respiratory protection).

3.2.1 Action Levels for VOCs and PAHs

As outlined in the NYSDOH CAMP guidance document, if the ambient air concentration of total VOCs at a community air monitoring location exceeds 5 ppm above background for the 15-minute average, intrusive Site activities will be temporarily halted while monitoring continues and additional mitigation measures are implemented to abate the VOC emissions. Field investigation techniques will also be evaluated and modified, if necessary and appropriate.

If the total VOC concentration readily decreases (through observation of instantaneous readings) below 5 ppm above background, then intrusive Site activities can resume with continuous monitoring.

3.2.2 Action Levels for PM-10

As required by the NYSDOH guidance, if the ambient air concentration of PM-10 at community air monitoring locations is noted at levels in excess of 100 $\mu g/m^3$ above background, or if visible dust is observed, intrusive Site activities will be temporarily halted. The source of the elevated PM-10 concentration will be identified, corrective actions to reduce or abate the emissions will be undertaken, and air monitoring will be continued. Work may continue following the implementation of dust suppression techniques provided the PM-10 levels do not exceed 150 $\mu g/m^3$ above background.

If, after implementation of dust suppression techniques, PM-10 levels are greater than 150 $\mu g/m^3$ above background, work must be stopped and Site activities must be re-evaluated. Work may only resume provided that the dust suppression measures and other controls are successful in reducing PM-10 levels to less than 150 $\mu g/m^3$ above background and in preventing visible dust from leaving the Site.

If the ambient air concentration of PM-10 is above 150 µg/m^3 above background, the intrusive Site activities must cease and emissions control measures must be implemented.

3.3 Instrument Calibration

Calibration of the VOC (PID) and PM-10 (particulate monitor) monitoring instrumentation will be performed in accordance with each of the equipment manufacturer's calibration and quality assurance requirements. The VOC and PM-10 monitoring instrumentation will be calibrated at least daily, and calibrations will be recorded in the field activity logbook.

4. CAMP Monitoring Schedule and Data Collection and Reporting

This section presents the monitoring schedule and data collection and reporting requirements, as presented in the RI CAMP.

4.1 Monitoring Schedule

If PDI equipment entry/exit points to the shopping center building are open to the exterior during the performance of intrusive PDI activities inside the shopping center building, a community air monitoring location will be established at each of these points. Real-time VOC and PM-10 monitoring at community air monitoring locations will be performed continuously during intrusive activities.

4.2 Data Collection and Reporting

Air monitoring data will be collected continuously by the VOC and PM-10 monitoring equipment by an electronic data-logging system. The data management software will be set up so that instantaneous observed readings are recorded by the electronic data acquisition system and averaged over 15-minute time periods. All readings will be recorded and archived, and will be available for review by NYSDOH and NYSDEC personnel.

Attachment

Table 3 (Airborne Contamination Action Levels) from the September 2011 Remedial Investigation Work Plan prepared by ARCADIS

Table 3. Airborne Contaminant Action Levels

Parameter	Reading	Action
Total Organic Vapors (measured with a PID)[1]	0 ppm to ≤ 0.5 ppm	Normal operations; continue hourly breathing zone monitoring.
	> 0.5 ppm to < 5 ppm	Increase monitoring frequency to every 15 minutes. Use secondary monitoring device to screen for the presence of benzene (see below).
	≥ 5 ppm to ≤ 10 ppm	Upgrade to Level C PPE; continue screening for benzene.
	> 10 ppm	Stop work; investigate cause of reading.
Benzene (from colorimetric tube)	≥ 0.5 ppm to 10 ppm	Upgrade to Level C PPE.
	> 10 ppm	Stop work; investigate cause of reading.
Total Particulates (measured with a personal DataRAM)[2]	0 to 0.100 mg/m^3 above background	Normal operations.
	> 0.100 mg/m^3 above background	Initiate wetting of work area to control dust, upgrade to Level C if dust control measures do not control dust within 15 minutes. Monitor downwind impacts.
	> 0.150 mg/m^3 in breathing zone or at downwind perimeter of work area	Stop work, investigate cause of reading, and ventilate area.
Oxygen	≤ 19.5%	Stop work, evacuate work area, investigate cause of reading, and ventilate area.
	> 19.5% to < 23.5%	Normal operations.
	≥ 23.5%	Stop work, evacuate work area, investigate cause of reading, and ventilate area.
Carbon Monoxide	0 ppm to ≤ 20 ppm	Normal operations.
	> 20 ppm	Stop work, evacuate work area, investigate cause of reading, and ventilate area.
Hydrogen Sulfide	0 ppm to ≤ 5 ppm	Normal operations.
	> 5 ppm	Stop work, evacuate work area, investigate cause of reading, and ventilate area.
Flammable Vapors (LEL)	< 10% LEL	Normal operations.
	≥ 10% LEL	Stop work, ventilate area, investigate source of vapors.

Notes:

1) Readings for Total Organic Vapors are at breathing zone height, measured with a calibrated PID.
2) Readings for particulates are for results measured with a calibrated personal DataRAM. Dust sampling instruments provide "total dust" levels, and do not differentiate between contaminated and non-contaminated dust particulates. Dust action levels are based upon total dust and not respirable dust levels.

*Note – Use of respiratory protection is not anticipated or planned. If exposure monitoring readings in the **breathing zone** are above action levels, work is to stop and the PM and CHSR informed. Engineering controls such as modifying work and ventilation may be considered. PM and CHSR must concur before respirators will be utilized and respirators will be considered a last resort.*