Delaware Geological Survey
State of Delaware
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# Delaware NGWMN YR2023-2025 Technical Report

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## Introduction

The Delaware Geological Survey (DGS) staff have completed the tasks necessary for Delaware's participation in the National Ground Water Monitoring Network (NGWMN) under the terms of the competitive program and agreement #G23AC00296 with the U.S. Geological Survey (USGS). This work addresses the following objectives:

- **2A**: Maintenance of the IT, web services infrastructure, and data provided to the NGWMN portal
- **4**: Well maintenance
- **6**: Purchase equipment to support continuous water-level data collection

This final report documents the work completed.

## Objective 2A Support Persistent Data Services

Maintain web services connections to the NGWMN Portal

Through previous USGS-funded projects, DGS developed an infrastructure to transmit data to the NGWMN portal (**Figure 1**). All field-collected data — including well metadata, water levels, and water quality — are stored in an internal Oracle database. This system is secured behind an IT firewall and optimized to support DGS daily operations and data editing.

A second database, running the PostgreSQL system, is located in a web-accessible environment and optimized for public data distribution and web services. Records from the Oracle database are migrated to the PostgreSQL database daily, or on demand as needed.

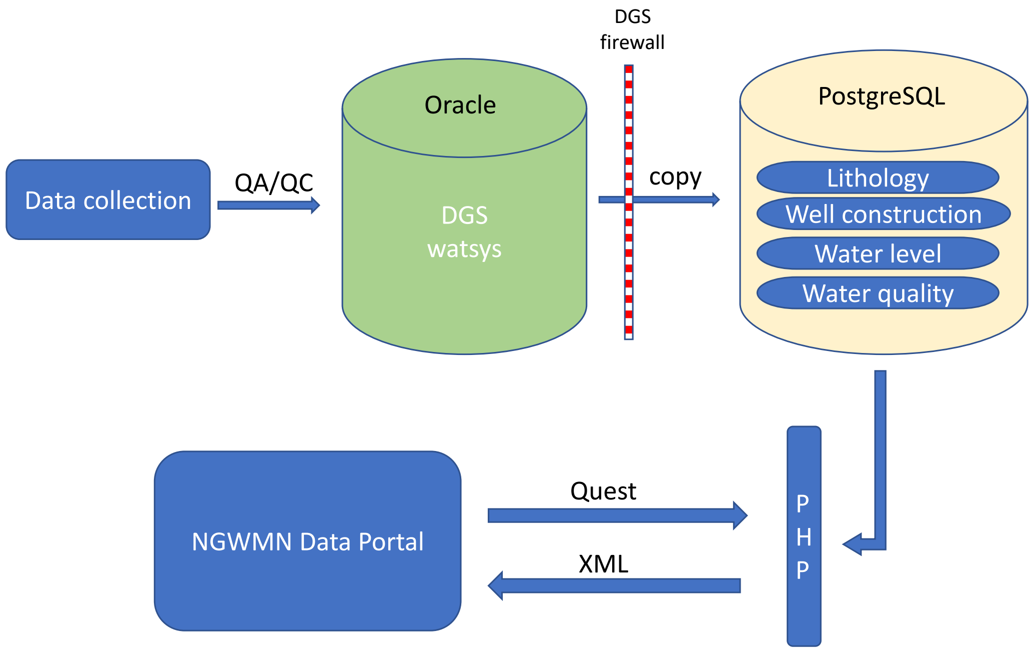


**Figure 1**. Schematic representation of the IT infrastructure that transmits data between DGS and NGWMN data portal.

Four types of data (water levels, water quality, lithology, and well construction) required by NGWMN are made available through a set of web services. These services are streamed to users through URL requests that can be accessed manually via a web browser, or programmatically through scripts. Responses are formatted as XML, a structured and flexible format well suited for machine-to-machine communication, including data exchange between the NGWMN portal server and the DGS database.

We successfully maintained our web services as proposed by updating Apache, PHP, and OpenSSL to their latest versions on the server that connects to the NGWMN portal. These updates enhanced the security of our hosting environment while ensuring uninterrupted access to the portal.

DGS staff regularly use the USGS online dashboard (https://www.usgs.gov/apps/ngwmndatamonitoring/provider/DGS) to monitor data transfers between NGWMN and our server. Additionally, we periodically perform spot checks on water-level and water-quality displays for selected wells.

Update of Well Registry

During the performance period, well Fc51-28 was dropped from the NGWMN after the owner reclassified it as a pumping well. The site remains in the registry, but its display function has been deactivated. Metadata for the deactivated well is provided in **Table 1**.

**Table 1.** Metadata for the well removed from NGWMN

| Site ID | Principal Aquifer | Local Aquifer | Well Depth (feet) | WL Network? | WQ Network? | Record Period |
|---|---|---|---|---|---|---|
| DGS: Fc51-28 | North Atlantic Coastal Plain | Rancocas | 128 | Yes | No | 1996-2023 |

As of the date of this report, there are 57 water-level monitoring wells and 23 water-quality monitoring wells in the NGWMN. Their locations are shown in **Figure 2**. Readers are referred to the NGWMN portal for the most current data and metadata on DGS sites in the NGWMN.

New data collections and methods used

DGS continues to use the standard operating procedures (SOPs) documented during the first year of participation in the NGWMN for well registry, water-level, and water-quality data collection. Water-level SOPs are those from Andres et al. (2018), and data management SOPs are summarized in **Appendix A**. Water-quality SOPs for wells sampled by DGS are those from Andres et al. (2023). SOPs for wells sampled by the Delaware Solid Waste Authority are provided in **Appendix B**.

## Objective 4 Well maintenance

Field work description

Well redevelopment was conducted at 19 selected wells during the project period. One well originally included in the maintenance list (Fc51-28) was removed after being reclassified as a pumping well; well Hd25-10 was redeveloped in its place. Locations of the redeveloped wells are shown in **Figure 2**.

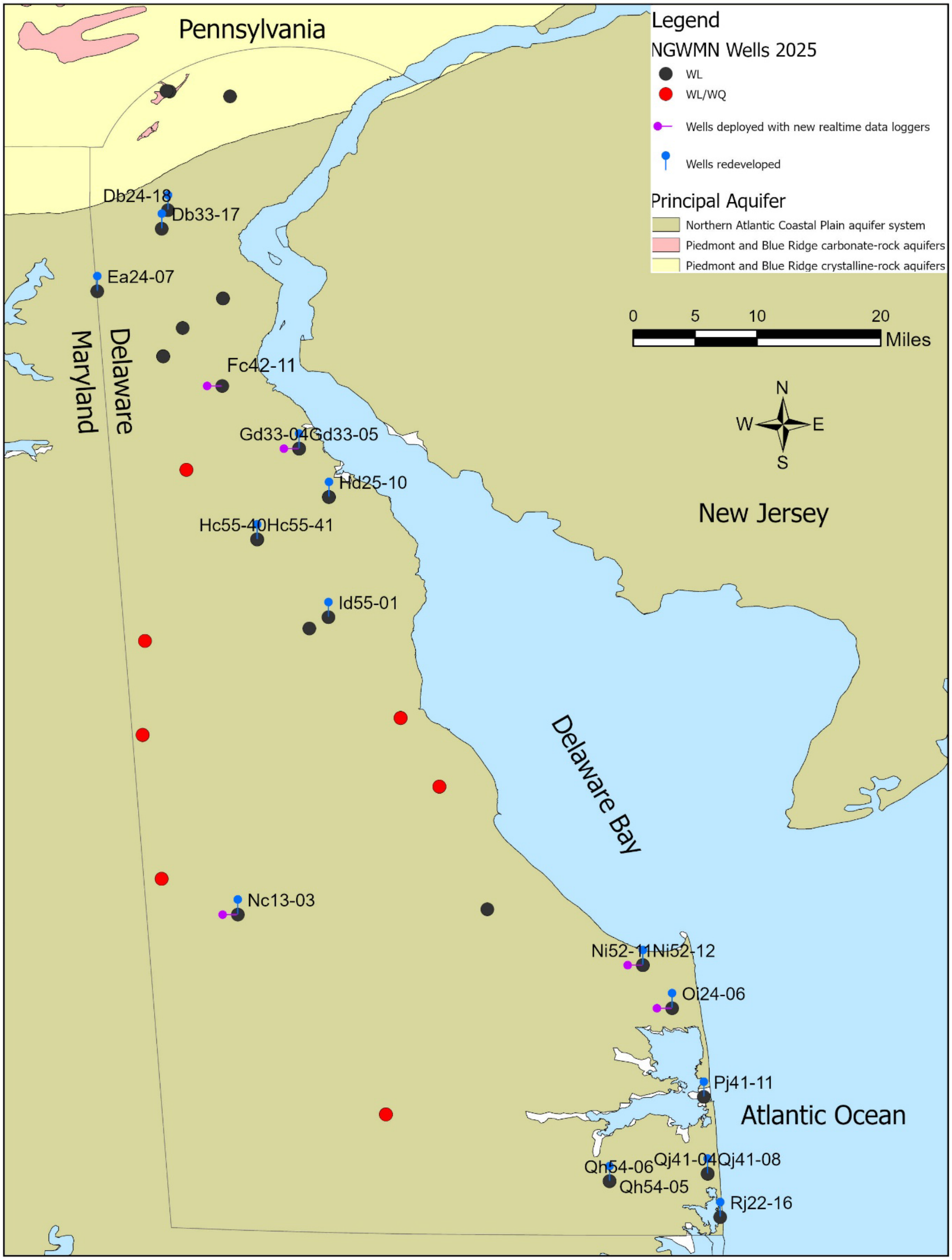


**Figure 2**. Locations of the 2025 NGWMN wells, with labels noting wells that were redeveloped or where new loggers were deployed

Each well was redeveloped using a combination of compressed air-lift surging and pumping. Compressed air was supplied through a high-pressure hose (up to 300 feet long) directed to the well screen or its upper section. Pumping was carried out for 30 to 120 minutes, or until the discharge water appeared clear and free of sediment. During this process, several jetting cycles were created by intermittently switching the air supply on and off. A typical onsite pumping setup is shown in **Figure 3**.

Video inspections were conducted before and after redevelopment using a Dual-Scan micro GeoVISION Borehole Camera system (Marks Products Inc.). The most common issues observed included clogged screen slots, sediment accumulation at the bottom of the wells, and the presence of foreign objects. No visible casing damage was detected.

Slug tests were performed before and after redevelopment. Two sizes of custom-made PVC slugs (2.5 ft × 2 3/8 in and 3 ft × 1 in) were used, depending on casing dimensions. Each slug was inserted and removed three times per well. Water-level responses were recorded using an In-Situ L700 pressure transducer with a minimum logging interval of 0.25 seconds.

Slug test data were analyzed with AquiferTest software (Waterloo Hydrogeologic). Hydraulic conductivity was estimated using the Bouwer & Rice, Hvorslev, or Butler HiK analytical methods, as appropriate.

In general, connectivity between monitoring wells and surrounding aquifers improved following redevelopment. This was supported by visibly cleaner well screens observed during downhole video inspections, as well as increases in estimated hydraulic conductivity. However, performance varied among wells. For instance, well Hc55-41 was pumped for one hour, during which a large amount of iron rust was removed from the bottom of the screen. As a result, hydraulic conductivity increased from 35 ft/d to more than 400 ft/d.

In contrast, redevelopment was less effective in some deep wells (>500 feet), particularly low-yield wells such as Nc13-03 and Hd25-10. Limited effectiveness in these cases likely reflects insufficient groundwater flow through the well screen, reducing the flushing and surging action needed to remove fine sediments and biofouling. In such wells, extended redevelopment or alternative methods may be required to achieve meaningful improvements.

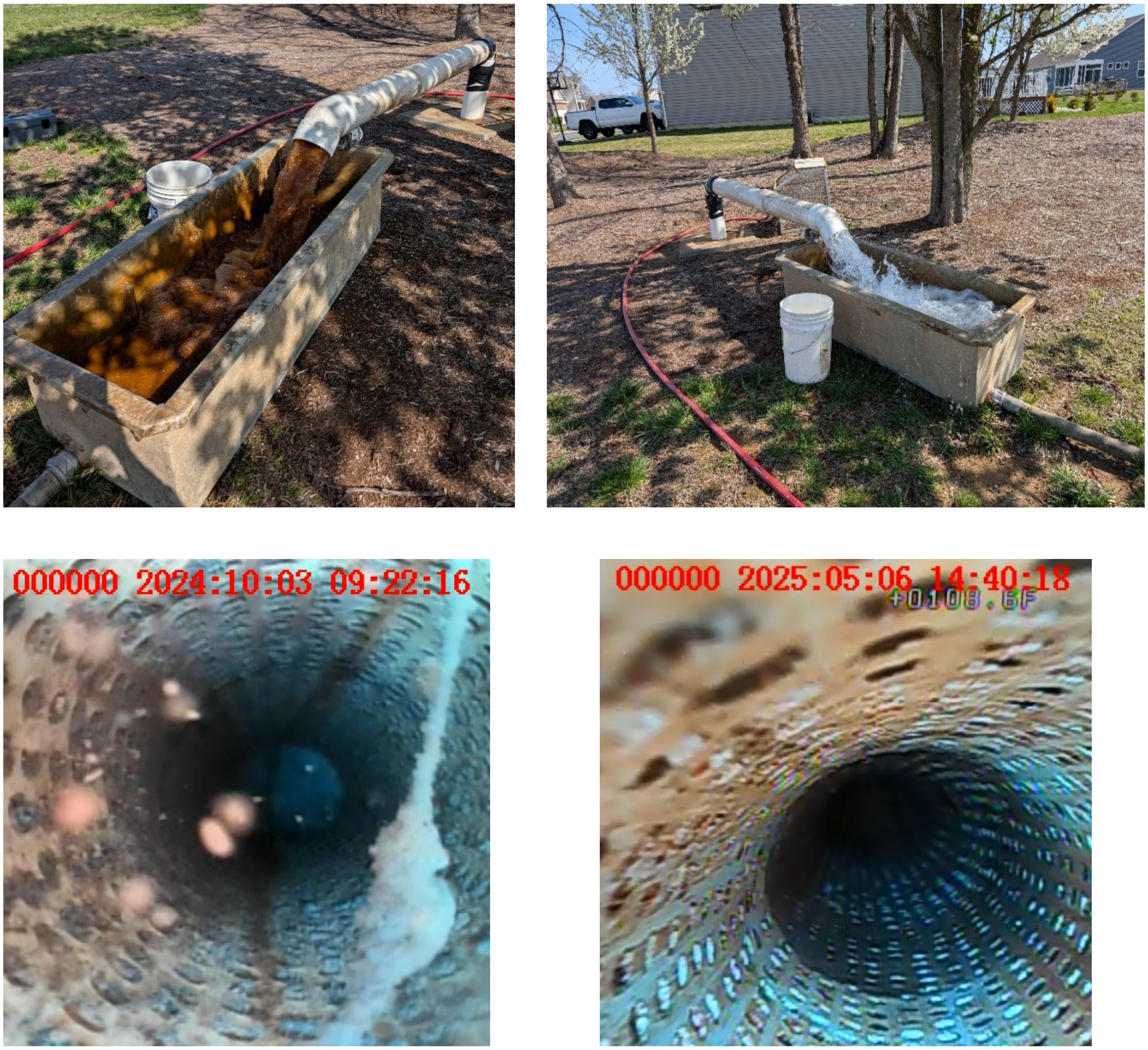


**Figure 3**. Redevelopment of well Hc55-41. The top two images show the change in pumped watercolor between the first 5 minutes and after 30 minutes. The bottom two images show the well screen condition captured by a borehole camera, before and after redevelopment.

**Table 2** summarizes the results of the well redevelopment and maintenance activities.

**Table 2**. Summary of well mainainence during the project period

| NGWMN Site ID | Well information | | | Date Redeveloped | Horizontal Conductivity $K_h$ (ft/d, post redevelopment) | Change of $K_h$ * | Video inspection results |
|---|---|---|---|---|---|---|---|
| | Screen material | Well Diameter (inch) | Screen Depth (ft bls) | | | | |
| DGS: Db24-18 | PVC | 2 | 9-19 | 5/7/2025 | 9.0 | Significant | Well screen is less obstructed |
| DGS: Db33-17 | Steel | 2 | 185-189 | 4/30/2024 | 48.3 | Noticeable | |
| DGS: Ea24-07 | PVC | 2 | 332-352 | 4/30/2024 | 20.5 | Noticeable | |
| DGS: Gd33-04 | Steel | 6 | 394.8-427.4 | 3/19/2025 | 1.4 | Unchanged | Well screen is less obstructed |
| DGS: Gd33-05 | Steel | 4 | 627.8-660 | 3/19/2025 | 8.9 | Noticeable | Well screen is less obstructed |
| DGS: Hc55-40 | PVC | 6 | 201-251 | 4/2/2025 | 0.2 | Noticeable | No visible change |
| DGS: Hc55-41 | PVC | 4.5 | 107-112 | 4/2/2025 | 459.3 | Significant | Less sediment on well sides. Well screen is less obstructed. Less sediment at bottom of well |
| DGS: Hd25-10 | PVC | 2 | 520-530 | 3/19/2025 | Too slow to recover | | Well screen is less obstructed |
| DGS: Id55-01 | Steel | 2.5 | 329-349 | 7/11/2024 | 26.1 | Noticeable | Well screen is less obstructed |

| NGWMN Site ID | Well information | | | Date Redeveloped | Horizontal Conductivity $K_h$ (ft/d, post redevelopment) | Change of $K_h$ * | Video inspection results |
|---|---|---|---|---|---|---|---|
| | Screen material | Well Diameter (inch) | Screen Depth (ft bls) | | | | |
| DGS: Nc13-03 | Steel | 4 | 620-630 | 3/18/2025 | 0.2 | Unchanged | Well screen is less obstructed |
| DGS: Ni52-11 | PVC | 4 | 145-155 | 3/18/2025 | 20.8 | Significant | Fewer sediment aggregates visible |
| DGS: Ni52-12 | PVC | 4 | 70-80 | 3/18/2025 | 341.5 | Noticeable | Well sides are cleaner |
| DGS: Oi24-06 | PVC | 4 | 230-250 | 3/18/2025 | 139.3 | Unchanged | Well screen is less obstructed |
| DGS: Pj41-11 | PVC | 4 | 208-218 | 3/18/2025 | 264.7 | Significant | Well screen is less obstructed |
| DGS: Qh54-05 | PVC | 2 | 229-232 | 7/30/2024 | 86.7 | Noticeable | |
| DGS: Qh54-06 | PVC | 2 | 144-148 | 7/30/2024 | 184 | Unchanged | |
| DGS: Qj41-04 | PVC | 4 | 370-400 | 12/1/2024 | 28.1 | Noticeable | Well screen is less obstructed |
| DGS: Qj41-08 | PVC | 2 | 200-210 | 12/1/2024 | 399.0 | Unchanged | |

* An increase in hydraulic conductivity of more than 50% is considered a significant change, an increase of 10–50% is considered noticeable, and a change of less than 10% is regarded as unchanged.

### Objective 6 Purchase equipment to support continuous water-level data collection

As planned, six data loggers with telemetry service were successfully purchased and installed at selected wells. Each logger records water levels at 15-minute intervals, and the daily averaged data are now available through the NGWMN. Table 3 summarizes the real-time logger installations and results.

**Table 3**. List of wells where real time data loggers were installed

| NGMWN Site No | USGS Principal Aquifer | Well Depth (ft bls) | DTW Range(ft) | Date Installed |
|---|---|---|---|---|
| DGS: Fc42-11 | NACP | 260 | 46.41-73.42 | 12/11/2023 |
| DGS: Gd33-04 | NACP | 427 | 13.06-20.55 | 1/23/2024 |
| DGS: Nc13-03 | NACP | 630 | 69.9-108.99 | 3/27/2024 |
| DGS: Ni52-11 | NACP | 155 | 7.97-11.92 | 7/23/2024 |
| DGS: Ni52-12 | NACP | 80 | 6.1-11.78 | 7/23/2024 |
| DGS: Oi24-06 | NACP | 250 | 16.48-22.49 | 4/23/2024 |

## References Cited

Andres, A.S., He, C., and McKenna, T.E., 2018, Groundwater monitoring procedures part 1: equipment and procedures for manual and automated field measurement of groundwater levels in dedicated monitoring wells: Delaware Geological Survey Open File Report No. 51.

Andres, A.S., McQuiggan, R.W., He, C., and McKenna, T.E., 2023, Kent County groundwater monitoring project: results of hydrogeological studies: Delaware Geological Survey Report of Investigations No. 85.

**Appendix A**. Groundwater Level Data Collection and Processing

## 1. Introduction

This document outlines the processing of manually and electronically collected groundwater level data from field data collection to final data approval and publishing online.

## 2. Field data collection

DGS staff members collect groundwater level data using widely accepted procedures and practices (Andres et al., 2018), which were adapted to Delaware conditions from published methods (Holmes, et al., 2001; Cunningham and Schalk, 2011), interactions with staff of the USGS, consulting firms, and other state agencies. The standard operating procedure (SOP), which covers manual measurements and deployment and operation of dataloggers, and in-field data management tasks, has been documented and governs our program.

## 3. Data Management and Security

All data were entered into the DGS master database through an in-house groundwater database management tool (GWDBM). The GWDBM tool integrates entry, visualization and approval of data into one user-friendly interface. Built-in security and quality control processes significantly facilitate efficiency and reduces potential errors. This tool incorporates a password protected three-level authority scheme to protect the database from unintended or improper modifications. At Level 0, a "*Visitor*" can only display/query existing data. At Level 1, a "*User"* can input field and electronically logged data and edit provisional data. At Level 2, an "*Administrator"* can edit and approve any data.

### *3.1 Field measurement processing*

The depth to water (DTW, feet), date and time (Eastern Standard Time) of measurement, as well as staff name, measuring point datum (top of casing, ground surface or other), and measuring device are entered into GWDBM by the staff. When prompted by the user, GWDBM uploads the data to the master water level data table and assigns a status of "P" (provisional), and displays new and existing data in a graph.

*3.2 Electronic data processing*

Upon returning from the field, electronically collected (e.g., transducer/datalogger instruments) groundwater level data needs to be processed before loading into database. Figure 1 shows the major steps of data processing within GWDBM. GWDBM plots new and historic data in one hydrograph, helping the user visually check and correct for offset and gaps in the record, and to identify instrument malfunction. GWDBM also compares manual and electronic measurements to calculate and correct for instrument drift over time and data are provisionally accepted when there is less than 0.5 feet difference between manually and electronically measured data. Daily averaged groundwater level will be calculated for days having more than 72 provisionally accepted 15-minute interval measurements and uploaded to the master database as along with associated metadata. All the original files of electronically collected data are archived for future referral.

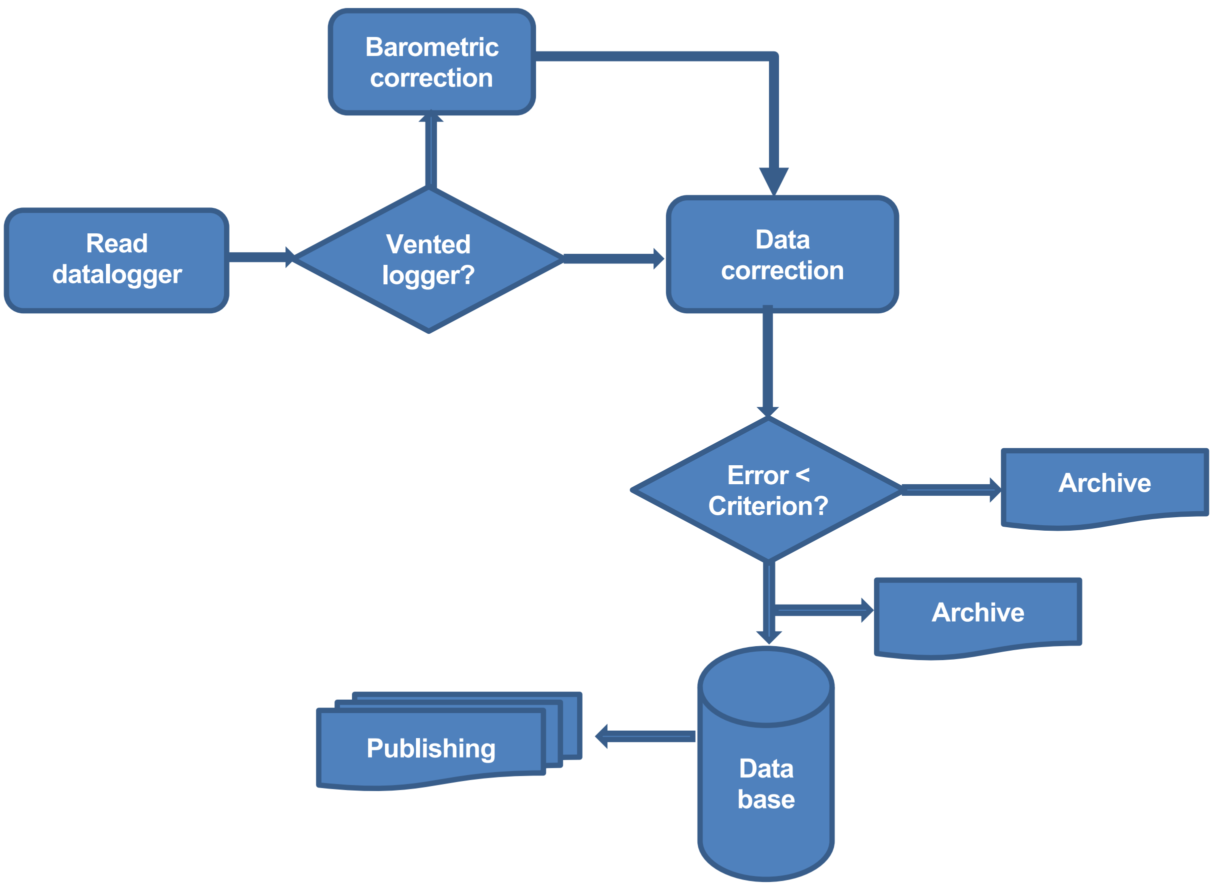


*Figure 1. Flow chart of electronic data processing at DGS.*

**4. Data approval and publishing**

Provisional data are evaluated and assigned a status of accepted or estimated within six months of being uploaded to the master database. The waiting period allows the data to be compared with subsequently collected data. For electronically collected data, the primary criteria for assigning the status are presence or absence of gaps in the electronic or manual measurement records, evidence of instrument malfunction, and the magnitude of the difference between manual and electronic measurements.

Manually measured data are assigned a status of accepted when they fit expected trends and agree with coeval electronically measured data and a status of estimated if there may be questions about the measurement but no clear evidence to reject the data. The criteria for evaluating the accuracy of electronically measured data may differ depending on whether they are collected by vented (gauge) or non-vented (absolute) instruments. For both types of instruments, data are assigned a status of estimated when a manual measurement was not recorded at the beginning or the end of the instrument deployment period.

- From vented instruments - Data are accepted when there is less than 0.05 feet difference between manually and electronically measured water levels. Data are assigned a status of estimated when the difference is between 0.05 and 0.5 feet.

- From non-vented instruments – Data are accepted when there is less than 0.1 feet difference between manually and electronically measured water levels. Data are assigned a status of estimated when the difference is between 0.1 and 0.5 feet.

Groundwater levels, including provisional data, from wells having 100 or more water level observations can be accessed through the DGS public website http://www.dgs.udel.edu.

## References Cited

Andres, A.S., He, C., and McKenna, T.E., 2018, Groundwater monitoring procedures part 1: equipment and procedures for manual and automated field measurement of groundwater levels in dedicated monitoring wells: Delaware Geological Survey Open File Report No. 51.

Cunningham, W.L., and Schalk, C.W., compilers, 2011, Groundwater technical procedures of the U.S. Geological Survey: U.S. Geological Survey Techniques and Methods 1–A1, 151

Holmes Jr, R.R., Terrio, P.J., Harris, M.A., and Mills, P.C. 2001, Introduction to field methods for hydrologic and environmental studies: U.S. Geological Survey Open-File Report 2001-50.

**Appendix B.** Delaware Solid Waste Authority groundwater level and sample collection procedures (DSWA, written communication)

## Groundwater Sample Collection Procedures

Background: Implementation of Slow Purge Method

In October of 1991, the United States Environmental Protection Agency (USEPA) promulgated new regulations under RCRA called the "Solid Waste Disposal Facility Criteria - 40 CFR-258". These regulations present the minimum criteria that owners and operators of municipal solid waste landfill units must meet for protection of the surrounding environment. Some of the criteria covered in this document include:

1. Design
2. Operation
3. Closure
4. Post closure care
5. Monitoring
6. Record keeping
7. Financial Assurance

Although this document explains what criteria owners and operators have to meet to be in compliance with these regulations, the document does not present details concerning the selection and implementation of methodologies to meet compliance.

In 1992, a draft of the "Technical Manual for Solid Waste Disposal Facility Criteria - 40 CFR-258" was released to the State Governments for comment. This DRAFT technical manual discusses methods for selection of sites, materials, testing requirements, acceptance testing, sampling protocols, and monitoring requirements.

Review of this DRAFT technical manual, by the Delaware Department of Natural Resources and Environmental Control (DNREC) and the Delaware Solid Waste Authority (DSWA), raised questions concerning the benefits of implementing certain sampling protocols put forth within the document. Both Agencies felt that upgrading the current groundwater monitoring systems with dedicated equipment necessary to comply with these protocols would:

1. Add excessive and unnecessary costs to the current Environmental Monitoring Program.
2. Increase the time necessary for sample collection.
3. Not yield fully representative samples.

Due to the presence of fine sands, silts, and clays in the aquifers being monitored at all Delaware Solid Waste Authority solid waste management centers, DSWA has implemented a "Common Sense" approach for the collection and preparation of groundwater samples for analysis. Using guidance provided by DNREC, in 1993, DSWA began using slow-purge or micro-purge techniques to collect groundwater samples. These techniques or sampling protocols were implemented to accomplish the following:

1. Reduce the heavy pieces of field equipment, purge pumps, steam cleaners, and generators needed to purge wells and decontaminate equipment;
2. Reduce the number of wells being sampled;
3. Eliminate hand bailing;
4. Significantly reduce time spent purging wells;
5. Reduce or eliminate field filtering as required by 40 CFR-258;

Both the DNREC and the DSWA understand that these methods may vary significantly from many of the currently accepted methods. However, the hydrogeologic conditions that exist on the Delmarva Peninsula (and many other locations where the primary aquifers were formed by weathering and tidal deposition) make certain requirements of 40 CFR-258 difficult to meet without modification.

## I. Monitoring

Groundwater samples shall be analyzed in accordance with the schedules set forth in DSWA's Monitoring Plans. Sample collection, preservation, Chain-of-Custody, labeling, shipment, and equipment decontamination, shall follow the same procedures as outlined in this Plan.

## II. Analytical Methodology

All samples shall be collected and analyzed using the methods provided in the following publications:

1. SW-846 (Most Recent Edition) to be used first;
2. 40 CFR-136 (Most Recent Edition) to be used only if methods are not available in A above;
3. Standard Methods (Most Recent Edition) to be used only if methods are not available in A or B above;
4. Other methods as jointly approved by DSWA and DNREC to be used only if methods are not available in A, B, or C above.

## III. Well Head Protection/Security

Well heads at all DSWA facilities meet or exceed the standards set forth in *DNREC's Delaware Regulations Governing the Construction and Use of Wells*. All monitoring wells are constructed of PVC or stainless steel with protective outer steel casings and locking caps. Additionally, most DSWA wells have additional outer protective casings made of concrete or steel, or concrete pads enclosed by bollards as shown in Figure 2 on Page 12 of this Plan. All protective steel casings have been outfitted with a locking cap, are kept locked using tamper resistant, hardened steel or brass locks. All locks at the major landfill facilities are keyed alike.

IV. Well Construction

All DSWA wells have been constructed and installed in a manner consistent with the existing specifications required by DNREC at the time of construction.

V. Well Locations

The inner well casings of all GMWs being monitored at DSWA facilities have been surveyed by a land surveyor licensed in the State of Delaware. All groundwater monitoring wells have been tied in to the National Geodetic Vertical Datum and Delaware State Coordinate plane using standard land surveying practices. At the time of this plan the coordinate systems being used are the 1927 Delaware State Plane coordinate system and 1929 National Geodetic Vertical Datum.

VI. Well Modifications for Current Sampling Protocols

A. No modifications have been made to groundwater monitoring wells with average DTWs greater than 25 feet.
B. All wells with an average DTW of 25 feet or less have been modified through the installation of a 3/16" Teflon™ tube extending the entire length of the casing and screen. The tube is plugged at the lower end to prevent uptake of solids during sampling, and is solid except for a liberally perforated 2-3 foot section located at mid screen of the well casing. The tube is secured to the outer steel casing by way of nylon cord and straps as shown in Figure 3 on Page 13 of this Plan.

VII. Sample Collection Procedures

The following presents the methods by which DSWA collects or has its Environmental Monitoring Contractors collect groundwater samples from DSWA solid waste management centers. It is believed that these methods allow for uniform sampling of the aquifers without drawing in fine sediments from the surrounding aquifer, or disturbing sediments present in the well casings.

A. Field Preparation: Mobilization/Demobilization

The following outlines those procedures DSWA requires of its environmental monitoring contractors for preparation for the sampling of groundwater at the DSWA facilities:

1. Standard QA/QC required by the monitoring contractor include:
   a. External audits through certification programs;

b. External audits through acceptance of blind samples and round robin testing;
c. Internal audits through splitting samples and shipping samples to other local and regional laboratories;
d. Performance audits of all laboratory personnel and stations.

2. Many times, the bottles used by a contractor for sample collection, shipment, and storage are purchased pre-cleaned and (some with preservatives added) by an independent company. However, all sampling and field equipment is usually cleaned and maintained by the contractor. Therefore, as a part of standard quality checks, all bottle shipments should be tested by the contracted monitoring company on a routine basis for contamination. If the monitoring company elects to clean their own bottles, quality checks should be standard protocol, and should be run on every lot washed. As a minimum, the following should be done prior to any bottles going into the field:
   a. Fresh disposable Nitrile gloves should be worn whenever handling the glassware (prior to and after cleaning);
   b. All labels should be affixed to the bottles prior to issuance to field crews;
   c. All sample preservatives that can be placed in bottles prior to sample collection should be done so before the bottles are issued to the field crews. The type and amount of preservative should be placed on the label immediately prior to or after addition to the bottle;
   d. Specific analytes and sample locations should be placed on the labels in indelible ink prior to the bottles leaving the laboratory. Note that all caps for volatile organic samples should be screwed down tightly prior to labeling to eliminate any airborne volatile contaminants from the label glues or ink from indelible markers, pens, or type.

3. Preparation of field equipment should include the following:
   a. Cleaning of all manual sampling equipment should include the following procedures:
      1. A general rinse with water to remove debris and solids.
      2. An Alconox Wash.
      3. Sterile rinses with deionized/distilled water.
      4. Acid Wash.
      5. Sterile rinses with Deionized/distilled water.
      6. Hexane Wash.
      7. 3 sterile rinses with deionized/distilled water.

      All acids and chemical rinses used should be GCMS grade or better. The field sampling crew is required to carry the necessary chemicals and deionized/distilled water into the field in order to clean any materials that may become contaminated during sampling.

   b. All pumps and field meters should be cleaned and calibrated prior to each monitoring event using chemicals and standard procedures recommended by the manufacturer. The equipment should undergo the same protocols when it is returned to the lab.

c. Maintenance and parts replacement should be performed as required by the manufacturers suggested schedule.
d. The monitoring company is required to retain records of maintenance and calibration certification. These records are periodically checked by the DSWA.
e. All field equipment should be inspected and tested for proper operation prior to being sent into the field.
f. The sampling crew is required to carry duplicates of all major pieces of sampling equipment.

## VIII. Groundwater Sample Collection

### A. General

During all phases of groundwater monitoring at DSWA facilities, field sampling crews are required to:

1. Sign the Visitor's Log and enter their time of arrival at the Administration Building or Weigh Station. If needed, request an escort to the location where the samples are to be collected.
2. The Contractor shall be responsible for the health of its employees. The Contractor shall designate an individual in their organization as the "Safety Coordinator" for the site.
   The Safety Coordinator shall evaluate the sites to determine what safety equipment is required, and shall what measures of procedures should be followed by the field crew. The Safety Coordinator shall develop a Health and Safety Plan (HASP) delineating these. The Contractor shall be responsible for ensuring compliance with the HASP. The Contractor shall submit the HASP to DSWA within two (2) weeks prior to commencement of monitoring activities.

   3. A **minimum of** one pair of Nitrile gloves (two are recommended) are to be used while handling equipment and all phases of the collection, preparation, and shipment of samples. Gloves are changed between monitoring locations. (e.g. gloves are changed prior to sample collections and after equipment decontamination.) This insures minimal opportunity for contamination through handling of samples and equipment by operators.

3. At least one member of the sampling crew collecting samples at DSWA facilities shall carry the following valid certifications:
   a. 40 hour OSHA Emergency Response Program
   b. First Aid and CPR.
4. All monitoring events must be overseen by an individual with a minimum of three years field experience in the collection, preparation, and shipping of groundwater samples.

5. The monitoring company shall conduct annual audits of the procedures and equipment being used by their field crews.
6. DSWA shall conduct random inspections of the field crews sampling protocols during each monitoring event.

B. <u>Gauging</u>

Prior to the collection of any groundwater samples from a DSWA facility, the field sampling crew is required to measure the static groundwater levels to 1/100 of a foot in all groundwater monitoring wells on site. The contractor is required to use an electronic water level indicator dedicated specifically for this purpose. The inner well casings of all groundwater monitoring wells being monitored at DSWA facilities have been surveyed by a land surveyor licensed in the State of Delaware. Each is marked with a reference point that is tied into the National Geodetic Vertical Datum (NGVD). All depth to water readings are to be measured from these reference points.

The following procedures are used by environmental monitoring contractor's field sampling crews for gauging the groundwater monitoring wells prior to collection of samples from DSWA facilities:

1. The following protocols are to be used by the field sampling crew whenever groundwater elevations are taken:

   a. All measurements at a DSWA site are to be taken on the same day.
   b. All GMWs are to be inspected externally and internally for damage, and notations of physical well inspection entered in the field log prior to and after opening the well casing.
   c. Well casings are to be re-locked after measurements have been completed on the well.
   d. Measurements are to be taken from a reference point marked on the inner casing.
   e. A minimum of three measurements are to taken from each well. The location of the well and the three measurements are to be recorded in a field log along with the time and date. These readings are to be averaged. The average of these measurements will be used for:

      1. Mapping the potentiometric head elevations of each aquifer.
      2. Tracking groundwater elevation fluctuations in the aquifers.
      3. Calculating the flow directions and hydraulic gradients of the aquifers.
      4. Entry into a data base for engineering applications as well as possible fate-transport modeling.

2. Between each well being sampled, the field sampling crew is required to rinse the electronic water level indicator thoroughly with deionized-distilled water. If

any procedural or well contamination is suspected, the field sampling crew is required to use the following protocols to decontaminate the water level indicator:

a. A general rinse with water to remove debris and solids.
b. An Alconox Wash.
c. Sterile rinses with deionized/distilled water.
d. Acid Wash.
e. Sterile rinses with deionized/distilled water.
f. Hexane Wash.
g. 3 sterile rinses with deionized/distilled water.

C. Purging

After all wells have been gauged, the field sampling crew is to use the following procedures to collect the groundwater samples:

1. For wells with depth to water measurements (DTWs) equal to or less than 25 feet:

   The field sampling crew attaches a sterile piece of silicone tubing to the Teflon™ tube installed in the well. The sample crew attaches a fresh piece of dedicated Teflon™ tubing between the outflow of the peristaltic pump and a decontaminated flow-through sample chamber. The sample chamber contains the following probes and meters:

   a. pH
   b. Dissolved Oxygen
   c. Temperature
   d. Specific Conductance
   e. Oxidation/Reduction Potential
   f. Turbidity (measured initially at the outflow from the sample cell.)

2. For wells with DTWs greater than 25 feet:

   The field sampling crew lowers the pump head of an adjustable speed low flow pump down to the middle of the GMW screen and ties off, clips off, or sets the brake on the hose spool to maintain the preferred depth. The sample crew affixes a piece of Teflon™ tubing between the outlet of the pump and a decontaminated flow-through sample chamber. The sample chamber contains the following probes and meters:

   a. pH
   b. Dissolved Oxygen
   c. Temperature
   d. Specific Conductance
   e. Oxidation/Reduction Potential

f. Turbidity is also measured initially at the outflow from the sample cell.

3. The field sampling crew begins the purge by recording the following:

   a. Date
   b. Start Time
   c. Location
   d. Location Description:

      1. Well Diameter
      2. Casing Type
      3. Top of Casing
      4. Depth of Well
      5. Depth to Water
      6. Standing Water in Casing
      7. Land Surface Elevation (if necessary)
      8. Sample Methods (Grab, Bailer, Pump, etc...)

4. The field sampling crew starts the purge at a flow rate of 1L/Min or less, and records the following in the field log:

   a. The flow rate setting of the peristaltic pump.
   b. Initial pH
   c. Initial Dissolved Oxygen
   d. Initial Temperature
   e. Initial Specific Conductance
   f. Initial Oxidation/Reduction Potential
   g. Initial Turbidity

   Stabilization of these indicator analytes (except Turbidity) is indicative of uniform water being drawn in from the aquifer. Therefore, the well is considered purged after stabilization has occurred. The field sampling crew is required to purge at least 5 minutes, and no longer than 10 minutes at each sampling point.

5. After purging is complete, the field sampling crew records the following in the field log.

   a. Final pH
   b. Final Dissolved Oxygen
   c. Final Temperature
   d. Final Specific Conductance
   e. Final Oxidation/Reduction Potential
   f. Final Turbidity
   g. Stop time of purge
   h. Total amount of water purged (Gallons), and the number of well volumes removed

i. Any problems encountered during purging including:

1. Mechanical problems/calibration problems.
2. Any strange color, clarity, or odor problems with the samples.
3. Any notes on problems with the wells such as the presence of roots, or gravel pack in the wells, or damage to the well and casing.

D. Well Closeout

1. Upon completion of sampling, the field crew is to rinse off the well plug or expansion cap prior to replacement in the inner casing, replace or close the outer protective well lid, and re-lock the well.
2. The field crew shall use decontamination procedures recommended by the equipment manufacturer.

3. Readings from all equipment are verified 3X before final acceptance. If readings cannot be verified, re-calibration is required. If re-calibration does not result in verification, the monitoring company is required to switch to the back-up meter. Although they are generally done more frequently, calibration checks are required every three samples for most field meters.

*Note: If the monitoring event only requires field analytes, instruments, sample cells, and sample tubes may be decontaminated between GMWs by flushing thoroughly with deionized- distilled water. All pump heads, and hosing of the variable speed pump must be thoroughly rinsed with deionized-distilled water between monitoring points.*

IX. Groundwater Monitoring Well Sampling

If the monitoring event requires indicators or indicators/DNREC Supplemental Analysis for Groundwater Samples to be collected, the sample crew is required to use fresh or decontaminated/dedicated sample tubing in the peristaltic pump. Low flow variable speed pumps must undergo decontamination procedures recommended by the manufacturer. All sample cells are to be decontaminated using the procedures described in VII.A.3.a. above.

The following procedures are to be used by the field sampling crew to collect samples from DSWA GMW wells during a monitoring event that requires indicators or indicator/DNREC Supplemental Analysis for Groundwater Samples analysis to be run on GMW samples:

A. After purging is completed, the field sampling crew shall collect Volatile and Semi-Volatile Organic samples using the peristaltic pump or variable speed pump at a flow rate of 100 mL/Min or less. This is done to insure that: Volatile Organic Compounds (VOCs) are not stripped from the samples.

B. Samples can be collected directly into the bottles, however no contact is allowed between sample bottle or tubing from the pump. VOC vials are to be checked for air entrainment. If air entrainment occurs, the sample shall be retaken. After the VOC and Semi-Volatile Organic samples have been collected, the field crew can increase the flow rate of the pump to expedite the sampling of the remaining sample types which could include:

1. Heavy Metals and Indicator Metals
2. Cyanide
3. Sulfate and Chloride
4. Nitrate and Ammonia
5. Radionuclides
6. All other analytes of interest

The Metals fraction of the samples is to be collected after the Volatile and Semi volatile samples have been collected. Metals samples are the only type of sample that will be considered for filtration. Filtration of Metal samples is to be used as a last resort, and will only be allowed under the following conditions:

1. The turbidity of the sample is >10 NTU's.
2. Reduction in flow rates fail to decrease the Turbidity below 10 NTU's.

If filtration is necessary, the field crew are required to filter the samples through a 0.45 micron mesh cellulose or glass fiber filter.

C. After the sample is collected, the field crew is to record the flow rate of the peristaltic pump in the field logs.
D. After collection of each type of sample is completed, the field crew is required to add any preservatives not added during the bottle prep.
E. Labels affixed to any extra bottles that were not prepared in the laboratory, shall be filled out in indelible ink. Each label is to include the following information:

1. Customer Name or Identification
2. Facility Location
3. Sample Collection Location
4. Time
5. Date
6. Analysis Required
7. Preservatives Used
8. Flow rates used for sample collection.
9. Name of Person that collected the sample.
10. Analytes being analyzed for.

F. After the labels are completed, all samples are to be wrapped in bubble wrap, and placed in shipping boxes containing ice, dry ice, or freezer packs, and preserved at 4° C for shipment.

G. Chain of Custody forms (COC's) are to be filled out with the same information listed above. Each time the sample is transferred, the sample must have a signature of the individual who releases the sample, and one for the individual who receives the sample.

H. The field sampling crew then packages the samples and hand delivers, or ships by overnight express to the contracted analytical laboratory for testing.

I. As the samples arrive at the laboratory, they are to be logged into a laboratory information system where:

1. They are given sample identification numbers (This number is to be noted on the COC).
2. Their pH and Specific conductance is measured and noted on the COC.
3. They are stored or dispersed to the various laboratory stations for analysis.

J. After the samples are logged in, copies of all completed Field Data Sheets and Field logs are to be e-mailed to the DSWA via internet in upon completion of the monitoring event.

X. Quality Assurance/Quality Control

As a minimum, during each monitoring event, the following QA/QC samples are collected, or prepared and analyzed for the analytes required by State Permits/Regulatory Requirements and Federal Requirements under 40 CFR-258.

- Trip Blanks: One per sampling day per facility
- Field Blanks: One per sampling day per facility
- Laboratory Duplicates: One per 10 samples analyzed
- Surrogate Standards: One per sample set
- Surrogate Spike: One per 20 samples
- Lab Method Blanks: One per sample set This analysis is done to insure:

1. Procedures or equipment being used in the sampling, preparation, and shipment train do not cause degradation of the samples.
2. Procedures or equipment being used in the analysis train do not cause degradation of the samples.
3. Samples are not contaminated through outside sources.
4. Methods being used for analysis are conducive to the sample matrix.

XI. Supply Disposal

Non-hazardous expendable supplies and equipment used in the collection of samples can be disposed of at the small load collection station prior to the sampling team leaving the site. Unused or excess sample that has not contacted sample preservatives can be disposed of at the sample location. Disposal of hazardous expendable supplies such as excess preservatives are to be taken back to the laboratory by the sampling team for proper disposal.

Prior to leaving the facility, the field sampling crew will sign out of the facility by entering their exit time in the "Visitor's Log" at the Administration Building or Weigh Station, after which they must leave the facility.

XII. Reporting

Results of analysis and discussion of the groundwater monitoring activities shall be included and discussed in the first quarterly groundwater monitoring report generated following reception of the groundwater monitoring data. The CIL historical groundwater monitoring database will be transferred to the Solid and Hazardous Waste Section of the Delaware Department of Natural Resources and Environmental Control by way of electronic media or direct file transfer on a quarterly basis.

As a final note, the environmental monitoring contractor and contracted laboratory providing analysis of samples is/are required to retain all field and laboratory records in hard copy format for a minimum of five years, with magnetic media storage for thirty years.