Award Number: G16AC00023

Agency Name: Delaware Geological Survey

Title: Delaware NGWMN

A.Scott Andres, asandres@udel.edu, 302-831-2833
John Callahan, john.callahan@udel.edu, 302-831-2833
Changming He, hchm@udel.edu, 302-831-2833
Thomas E. McKenna, mckennat@udel.edu, 302-831-2833
David Wunsch, dwunsch@udel.edu, 302-831-2833
Affiliation: Delaware Geological Survey, University of Delaware, 257 Academy St, Newark, DE 19716

Term: Jan. 6, 2016 to Dec. 31, 2016

Date: December 20, 2016

DELAWARE NGWMN PARTICIPATION REPORT

Delaware Geological Survey (DGS) staff have completed the tasks necessary for Delaware participation in the National Ground Water Monitoring Network (NGWMN) under the terms of the non-competitive program. This work included site selection, quality control of site, subnetwork, monitoring category, and well metadata provided to the NGWMN well registry, as well as the development and testing of web services needed to establish DGS as a server node in the NGWMN portal system. This final report documents the work.

Site Selection Methods

DGS selected wells for water-level monitoring from its long-standing groundwater monitoring network. DGS currently measures water levels as part of routine network activities and special projects in 123 wells representing three principal aquifers: North Atlantic Coastal Plain aquifer system (USGS code S100NATLCP), Piedmont and Blue Ridge Carbonate Rocks (USGS code N400PDMBRC), and Piedmont and Blue Ridge Crystalline Rocks (USGS code M400PDMBRX) - incorporating 13 major and local aquifers. More than 20 sites have nested monitoring wells completed in multiple, layered aquifers to allow calculation of the potential for vertical flow between aquifers. Construction details are known for all of these wells and nearly all have both lithologic and downhole geophysical logs. More than 100 monitoring wells have 10 or more years of water level record. Sites from this monitoring network were considered for addition to the NGWMN for water levels. Wells with less than five years of data were not considered as candidate sites.

DGS has conducted and participated in numerous ground and surface water quality studies (e.g., Andres, 1991; Baxter and Talley, 1996; Sims et al., 1996; Blaier and Baxter, 2000; Ullman et al., 2002, 2007; Andres and Sims, 2013) but funding limitations have stymied efforts to sustain a continuous monitoring program. Through cooperative work with other state agencies we evaluated long-term quality monitoring programs in the state to determine which ones generate data that meet the requirements for inclusion in the NGWMN and may be receptive to a cooperative relationship where DGS acquires data, manages those data within DGS systems, and provides data to the NGWMN portal.

Delaware Solid Waste Authority (DSWA) has operated a water-quality and level monitoring program at several facilities since the 1980s in support of permitting and permit compliance. The permitting process requires adherence to quality assurance and performance plans (QUAPP) for well construction, sampling, sample handling and preservation, laboratory analyses, chain-of –custody, data management, and reporting (Daniel Fluman, personal communication, 2016). Multiple aquifers are monitored with nested or clustered wells. DGS staff conducted geophysical logging and hydraulic testing at these facilities in cooperation with DSWA and have routinely harvested and used water level data from DSWA. DGS operates real-time water level monitoring wells at two DSWA facilities. This previous work provided sufficient experience to be confident in the wells and data from DSWA. In turn, DSWA is confident that their data have value to the NGWMN. Background wells were identified from groundwater elevation contour maps and a well cluster was selected from each of two DSWA facilities.

DGS project members met multiple times to review all water level and water quality data and metadata associated with candidate wells and to select candidate wells. Wells selected (Table 1, Figure 1) have adequate period of record and are distributed with respect to locations, coverage from all three of principal aquifers present in Delaware and partial coverage for 13 local aquifers. The wells selected include both unconfined and confined settings, and where possible span updip to downdip transects within a local aquifer. Several of the sites have nested monitoring wells completed in multiple, layered aquifers to allow calculation of the potential for vertical flow between aquifers and assessment of water quality differences between aquifers at the same site.

Subnetworks (background, suspect, known) and Monitoring Categories (trend, surveillance, special)

Because of Delaware's small size, intensive agricultural and urban development, and reliance on groundwater for water supply, all candidate wells for level monitoring fall into the "known change" or "suspected change" subnetwork categories. In future years, newer monitoring wells, located within large forested tracts, and constructed to monitor water-table level fluctuations will have a long enough record to be added to the NGWMN and will likely meet "background" subnetwork requirements. The "known change" subnetwork was assigned to wells by DGS project members after reviewing hydrographs for indication of pumping influences such as long-term downward trends, heads less than 0 feet (NAVD 88), or daily/weekly level variations that exceed seasonal and annual fluctuations reported in the past (Johnston, 1973; Talley, 1978, 1988; Andres and Martin, 2005; Martin and Andres, 2008). Wells not placed into the "known change" subnetwork are placed in the "suspected change" subnetwork.

All wells selected from the Delaware Groundwater Network for the level network of NGWMN fit the "Trend" monitoring category as they have a minimum of monthly measurements for greater than five years. Daily mean water-levels are reported for wells equipped with automated level instruments.

Review of water-quality data from DSWA wells found no long-term trends that would indicate groundwater contamination has occurred. Nonetheless, DSWA wells selected for the quality network were placed into the "suspected change" subnetwork because they are located near solid waste management facilities where operations may impact water quality in the future. Sampling frequencies and periods of records for DSWA wells meet the requirements to be included in the "Trend" category for water quality.

Web Services

For each of the Delaware wells selected for participation in the NGWMN, observational data are made available through a set of web services, corresponding to the four types of data categories (i.e., water levels, water quality, lithology, and well construction). The web services are streamed to the user through a URL request that can be accessed manually via a web browser or by scripting or programming languages. Responses to each request are formatted as XML, a structured customizable format ideal for machine-to-machine communication, particularly relevant for the data exchange between the NGWMN data portal server and DGS database. Example URL requests and corresponding XML returned output for each of the four web services are included in following paragraphs.

Because the URL requests are stateless and continuously available, the central NGWMN server can pull data extracts from DGS as needed. Using web services in this way separates, technologically and by responsible agency, the tasks of data extraction and data visualization. Several documents were reviewed in order to provide the appropriate information and format required by the web service, including the "NGWMN Tip Sheet on Minimum Data Requirements for Candidate Sites", the "NGWMN Tip Sheet on Developing Web Services for the Network", and the national framework report (Subcommittee on Ground Water, 2013).

In order to develop the web services, the first step was to map table field names in internal DGS databases to required elements in the web services. This worked well when the required web service data elements were a simple one-to-one match of a single field in the DGS database to a single field in the NGWMN portal, such as the well ID. However, some of the web service data elements required manipulation of the DGS table values before they could be returned in the web service. For example, in the water level web service, an estimate of the accuracy of each water level measurement is required to be returned as the element waterLevelAccuracy. This accuracy estimate is not stored with the DGS database directly but rather is dependent on the measuring device used (steel tape, data logger, etc.), which is stored in the database. Another example is the date and time of the observation, used in both the water level and water quality web services. Dates and times are stored in separate fields and different formats within the DGS database and must be combined and converted to ISO 8601 format to adhere to the recommendations for the NGWMN data portal before that information can be returned in the web service.

The web services were developed under contract by GreenWing Solutions (Wilmington, DE) using the PHP programming language. Modifications were made to the contractor-supplied code by DGS staff after receiving NGWMN portal staff feedback. PHP was chosen based on the existing skillset of DGS staff, its wide adoption, available technical support (especially helpful regarding future server maintenance and potential changes to web service requirements), its many available functions ideal to database extraction and distribution in XML format, and no up-front financial cost (PHP is free and open source software). DGS stores internal well information in Oracle and Postgres databases. As each URL request comes in, PHP structures the necessary SQL statements, extracts the field data values from the database tables, performs any necessary intermediate data manipulation required to meet the web service specifications, and exports the resultant data in XML format.

Site identification in the URL request is defined as an internal unique well ID value, noted as the parameter “DGSID.” These unique values are also listed in the NGWMN Well Registry. DGSID values have been in use within DGS for several decades. The structure of the DGSID value begins with two alphabetic characters and by two numeric values, depicting the location of the well within a 5 arc-minute block within the state. This combination is separated by a hyphen, “-“, and followed by a sequential value that designates the number of wells located within that block. More details on the DGSID naming convention can be found in Talley and Windish (1984).

Several measures were adopted to prevent abuse of the system. The parameters of each URL request (e.g., DGSID) are checked to conform to its expected structure (i.e., number of characters, format of character sequence). This minimizes the threat of database-related attacks, such as SQL injection. To minimize load on the server/database and potential bandwidth issues, a maximum of 500 records can be returned per query. Additionally, a maximum of 400 separate queries in any 30-day interval can be performed per IP address to minimize abuse from any single particular user. URL requests are denied if the number of queries is above that limit. Each request is archived and relevant logging tables are pruned to prevent large amounts of extraneous records being stored.

Below are example URL requests and XML-formatted output for each web service. These examples contain the minimum data elements, as described in the NGWMN tip sheets and national framework document for groundwater monitoring in the US, and represent the data values, format, and XML structure in place through production web services at the time of writing this report.

1. Well Construction web service:

URL Request: http://www.dgs.udel.edu/sites/ngwmn/well_construction.php?dgsid=Bc43-01

XML Output:


```
<Response>
   <SiteID>Bc43-01</SiteID>
   <OpenTop>8.5</OpenTop>
   <OpenBot>163.5</OpenBot>
   <ScreenIntervalUnits>FT</ScreenIntervalUnits>
   <OpenMatCode>N</OpenMatCode>
   <OpenMaterial>None</OpenMaterial>
   <CaseTop>-0.96</CaseTop>
   <CaseBot>8.50</CaseBot>
   <CasingIntervalUnits>FT</CasingIntervalUnits>
   <CasingMatCode>S</CasingMatCode>
   <CasingMaterial>Steel</CasingMaterial>
   <OpenDia>6.00</OpenDia>
   <ScreenDiameterUnits>IN</ScreenDiameterUnits>
   <CaseDia>6.00</CaseDia>
   <CasingDiameterUnits>IN</CasingDiameterUnits>
</Response>
```


2. Water Level web service:

URL Request: http://www.dgs.udel.edu/sites/ngwmn/well_waterlevels.php?dgsid=Bc43-01

XML Output:


```
<Response>
   <WaterLevel>
      <SiteID>Bc43-01</SiteID>
      <Date>07/11/2016</Date>
      <Time>1206</Time>
      <TimeZone>EST</TimeZone>
      <DateTimeISO>2016-07-11T12:06:00-04:00</DateTimeISO>
      <WaterLevel>25.10</WaterLevel>
      <WaterLevelUnit>FT</WaterLevelUnit>
      <WaterAccuracy>0.05 ft</WaterAccuracy>
      <WaterLevelStatus>Static</WaterLevelStatus>
```

```
      &lt;WaterLevelDevice&gt;M-Scope&lt;/WaterLevelDevice&gt;
   &lt;/WaterLevel&gt;
   &lt;WaterLevel&gt;
      &lt;SiteID&gt;Bc43-01&lt;/SiteID&gt;
      &lt;Date&gt;07/10/2016&lt;/Date&gt;
      &lt;Time&gt;00:00&lt;/Time&gt;
      &lt;TimeZone&gt;EST&lt;/TimeZone&gt;
      &lt;DateTimeISO&gt;2016-07-10T00:00:00-04:00&lt;/DateTimeISO&gt;
      &lt;WaterLevel&gt;25.09&lt;/WaterLevel&gt;
      &lt;WaterLevelUnit&gt;FT&lt;/WaterLevelUnit&gt;
      &lt;WaterAccuracy&gt;0.02 ft&lt;/WaterAccuracy&gt;
      &lt;WaterLevelStatus&gt;Static&lt;/WaterLevelStatus&gt;
      &lt;WaterLevelDevice&gt;digital data logger&lt;/WaterLevelDevice&gt;
      &lt;ChemimcalClassificationSystem/&gt;
   &lt;/WaterLevel&gt;
  ...
&lt;/Response&gt;
```

3. Lithology web service:

URL Request: http://www.dgs.udel.edu/sites/ngwmn/well_lithology.php?dgsid=Og44-03

XML Output:

```
&lt;Response&gt;
   &lt;LithologyLayer&gt;
         &lt;SiteID&gt;Og44-03&lt;/SiteID&gt;
         &lt;ID&gt;46043&lt;/ID&gt;
         &lt;StartDepth&gt;0&lt;/StartDepth&gt;
         &lt;StartDepthUnits&gt;Feet&lt;/StartDepthUnits&gt;
         &lt;StopDepth&gt;0.20&lt;/StopDepth&gt;
         &lt;StopDepthUnits&gt;Feet&lt;/StopDepthUnits&gt;
         &lt;Description&gt;topsoil, fine sand, silt&lt;/Description&gt;
         &lt;ObservationMethod&gt;Direct Observation&lt;/ObservationMethod&gt;
   &lt;/LithologyLayer&gt;
   &lt;LithologyLayer&gt;
         &lt;SiteID&gt;Og44-03&lt;/SiteID&gt;
         &lt;ID&gt;46044&lt;/ID&gt;
         &lt;StartDepth&gt;0.20&lt;/StartDepth&gt;
         &lt;StartDepthUnits&gt;Feet&lt;/StartDepthUnits&gt;
         &lt;StopDepth&gt;3.50&lt;/StopDepth&gt;
         &lt;StopDepthUnits&gt;Feet&lt;/StopDepthUnits&gt;
         &lt;Description&gt;sand; trace: silt&lt;/Description&gt;
         &lt;ObservationMethod&gt;Direct Observation&lt;/ObservationMethod&gt;
   &lt;/LithologyLayer&gt;
   &lt;LithologyLayer&gt;
         &lt;SiteID&gt;Og44-03&lt;/SiteID&gt;
```

<ID>46045</ID>
<StartDepth>3.50</StartDepth>
<StartDepthUnits>Feet</StartDepthUnits>
<StopDepth>5.50</StopDepth>
<StopDepthUnits>Feet</StopDepthUnits>
<Description>sand; silty</Description>
<ObservationMethod>Direct Observation</ObservationMethod>
</LithologyLayer>
<LithologyLayer>
<SiteID>Og44-03</SiteID>
<ID>46046</ID>
<StartDepth>4.50</StartDepth>
<StartDepthUnits>Feet</StartDepthUnits>
<StopDepth>5.50</StopDepth>
<StopDepthUnits>Feet</StopDepthUnits>
<Description>sand, silt</Description>
<ObservationMethod>Direct Observation</ObservationMethod>
</LithologyLayer>
<LithologyLayer>
<SiteID>Og44-03</SiteID>
<ID>46047</ID>
<StartDepth>5.50</StartDepth>
<StartDepthUnits>Feet</StartDepthUnits>
<StopDepth>9.50</StopDepth>
<StopDepthUnits>Feet</StopDepthUnits>
<Description>
; interbed: sand, fine to coarse sand; slightly silty;
trace: clay
</Description>
<ObservationMethod>Direct Observation</ObservationMethod>
</LithologyLayer>
<LithologyLayer>
<SiteID>Og44-03</SiteID>
<ID>46048</ID>
<StartDepth>9.50</StartDepth>
<StartDepthUnits>Feet</StartDepthUnits>
<StopDepth>19.00</StopDepth>
<StopDepthUnits>Feet</StopDepthUnits>
<Description>
sand, medium to fine sand; silty; trace: granule, coarse
sand
</Description>
<ObservationMethod>Direct Observation</ObservationMethod>
</LithologyLayer>
<LithologyLayer>
<SiteID>Og44-03</SiteID>
<ID>46049</ID>
<StartDepth>19.00</StartDepth>
<StartDepthUnits>Feet</StartDepthUnits>
<StopDepth>25.00</StopDepth>
<StopDepthUnits>Feet</StopDepthUnits>

```
        &lt;Description&gt;sand; silty; trace: silt,
        granule&lt;/Description&gt;
        &lt;ObservationMethod&gt;Direct Observation&lt;/ObservationMethod&gt;
   &lt;/LithologyLayer&gt;
&lt;/Response&gt;
```

4. Water Quality web service:

URL Request: http://www.dgs.udel.edu/sites/ngwmn/well_waterquality.php?dgsid=Pe54-13

XML Output:

```
&lt;Response&gt;
   &lt;WaterQuality&gt;
        &lt;SiteID&gt;Pe54-03&lt;/SiteID&gt;
        &lt;TestID&gt;04/07/2016Pe54-03SC&lt;/TestID&gt;
        &lt;SampleID&gt;04/07/2016Pe54-03&lt;/SampleID&gt;
        &lt;SampleDate&gt;04/07/2016&lt;/SampleDate&gt;
        &lt;SampleTime&gt;00:00&lt;/SampleTime&gt;
        &lt;TimeZone&gt;EST&lt;/TimeZone&gt;
        &lt;DateTimeISO&gt;2016-11-09T00:00:00-05:00&lt;/DateTimeISO&gt;
        &lt;AnalyteName&gt;Specific Conductance&lt;/AnalyteName&gt;
        &lt;AnalyteValue&gt;53.000&lt;/AnalyteValue&gt;
        &lt;ParameterUnit&gt;uS&lt;/ParameterUnit&gt;
        &lt;SampleFraction&gt;DISSOLVED&lt;/SampleFraction&gt;
        &lt;Method&gt;EPA120.1&lt;/Method&gt;
        &lt;MethodName&gt;Spec. Cond. by meter&lt;/MethodName&gt;
        &lt;ChemicalClassificationSystem&gt;CASRN</ChemicalClassification
        System>
        &lt;ChemicalIdentificationNumber&gt;SC</ChemicalIdentificationNum
        ber>
        &lt;AnalyticalMethodSystem&gt;USEPA&lt;/AnalyticalMethodSystem&gt;
   &lt;/WaterQuality&gt;
   &lt;WaterQuality&gt;
        &lt;SiteID&gt;Pe54-03&lt;/SiteID&gt;
        &lt;TestID&gt;04/07/2016Pe54-03TE&lt;/TestID&gt;
        &lt;SampleID&gt;04/07/2016Pe54-03&lt;/SampleID&gt;
        &lt;SampleDate&gt;04/07/2016&lt;/SampleDate&gt;
        &lt;SampleTime&gt;00:00&lt;/SampleTime&gt;
        &lt;TimeZone&gt;EST&lt;/TimeZone&gt;
        &lt;DateTimeISO&gt;2016-11-09T00:00:00-05:00&lt;/DateTimeISO&gt;
        &lt;AnalyteName&gt;Temperature, Degrees C&lt;/AnalyteName&gt;
        &lt;AnalyteValue&gt;13.440&lt;/AnalyteValue&gt;
        &lt;ParameterUnit&gt;DC&lt;/ParameterUnit&gt;
        &lt;SampleFraction&gt;DISSOLVED&lt;/SampleFraction&gt;
        &lt;Method&gt;EPA170.1&lt;/Method&gt;
```

```
        &lt;MethodName&gt;Temperature&lt;/MethodName&gt;
        &lt;ChemicalClassificationSystem/&gt;
        &lt;ChemicalIdentificationNumber/&gt;
        &lt;AnalyticalMethodSystem&gt;USEPA&lt;/AnalyticalMethodSystem&gt;
    &lt;/WaterQuality&gt;
    ...
&lt;/Response&gt;
```

Data-collection and data-management procedures

NGWMN Well Registry
Wells were added to the NGWMN registry and edited with the portal-provided form. The well registry viewer was used for initial checks of consistency between the registry and DGS internal data systems. Content of files generated by the "download csv" function of the portal form were compared to data extracted from DGS internal systems with automated comparisons. Inconsistencies were identified and edited as needed to ensure information in the well registry is correct.

Water Level Standard Operating Procedure
DGS has a written Standard Operating Procedure (SOP) for water level monitoring (DGS, in review) that is summarized here as Appendix A. Data management protocols for water-level data were first documented by Talley and Windish (1984). This document is available from the DGS website (www.dgs.udel.edu). The addition of automated measurements with dataloggers has created the need for additional data management processes and metadata, which are described in Appendix A. All of the metadata elements required by NGWMN are included in DGS web services.

Water Quality SOP
Water quality data added to NGWMN was acquired from DSWA. A document summarizing sampling protocols used by DSWA (DSWA, undated) is included as Appendix B. The DSWA monitoring program is conducted to satisfy regulatory and permitting requirements.

Data management protocols for water quality data were first documented by Talley and Windish (1984). This document is available from the DGS website (www.dgs.udel.edu). Talley and Windish (1984) provided a vocabulary of generic identifiers of chemical testing methods. Since that time, specific citations of standard testing methods have been added to the DGS internal database and are included in DGS web services. NGWMN-required metadata elements (i.e., CASRN, chemical system name) that were not included in Talley and Windish (1984) have been added to the DGS internal database so that all of the metadata elements required by NGWMN are included in DGS web services.

References Cited

Andres, A.S., 1991, Results of the Coastal Sussex County, Delaware Ground-Water Quality Survey: Delaware Geological Survey Report of Investigations No. 49.

Andres, A.S., and Sims, J. T., 2013, Assessing potential impacts of wastewater rapid infiltration basins on groundwater quality: A Delaware case study, Journal of Environmental Quality, v. 42 p. 391-404.

Andres, A.S. and Martin, M.J., 2005, Estimation of the Water Table for the Inland Bays Watershed, Delaware: Delaware Geological Survey Report of Investigation No. 68

Baxter, S.J. and Talley, J.H., 1996, Design, development, and implementation of a ground-water quality monitoring network in southern New Castle County, Delaware phase I - data collection and analysis: unpublished report to New Castle County Water Resources Agency.

Blaier, S.C and Baxter, S.J., 2000, The Occurrence and Distribution of Several Agricultural Pesticides in Delaware's Shallow Ground Water: Delaware Geological Survey Report of Investigations No. 61.

DSWA, undated, Groundwater sample collection procedures: unpublished Delaware Solid Waste Authority document, Dover, DE, 11 p.

Johnston, R.H., 1973, Hydrology of the Columbia (Pleistocene) Deposits of Delaware: An Appraisal of a Regional Water-Table Aquifer: Delaware Geological Survey Bulletin No. 14

Martin, M.J. and Andres, A.S., 2008, Analysis and Summary of Water-Table Maps for the Delaware Coastal Plain: Delaware Geological Survey Report of Investigation No. 73

Sims, J. T., Andres, A. S., Denver, J. M., and Gangloff, W, J., 1996, Assessing the impact of agricultural drainage on ground and surface waters in Delaware: University of Delaware Department of Plant and Soil Science unpublished report to DNREC.

Subcommittee on Ground Water, 2013, A national framework for ground-water monitoring in the United States: Advisory Committee on Water Information.

Talley, J.H., 1978, Ground-Water Levels in Delaware July, 1966 - December, 1977: Delaware Geological Survey Report of Investigation No. 30

Talley, J.H., 1988, Ground-Water Levels in Delaware January 1978 - December 1987: Delaware Geological Survey Report of Investigation No. 44

Talley, J.H. and Windish, D.C., 1984, Instructions for Preparation of Delaware Geological Survey Data Base Schedules: Delaware Geological Survey Special Publication No. 11

Ullman, W.J., Andres, A.S., Scudlark, J.R., and Savidge, K.B., 2002, Storm-Water and Base-Flow Sampling and Analysis in the Delaware Inland Bays Preliminary Report of Findings 1998-2000: Delaware Geological Survey Open File Report No. 44.

Ullman, W.J., Andres, A.S., Scudlark, J.R., and Savidge, K.B., 2007, Storm-Water and Base-Flow Sampling and Analysis in the Nanticoke River Watershed: Preliminary Report of Findings 2002-2004: Delaware Geological Survey Open File Report No. 46.

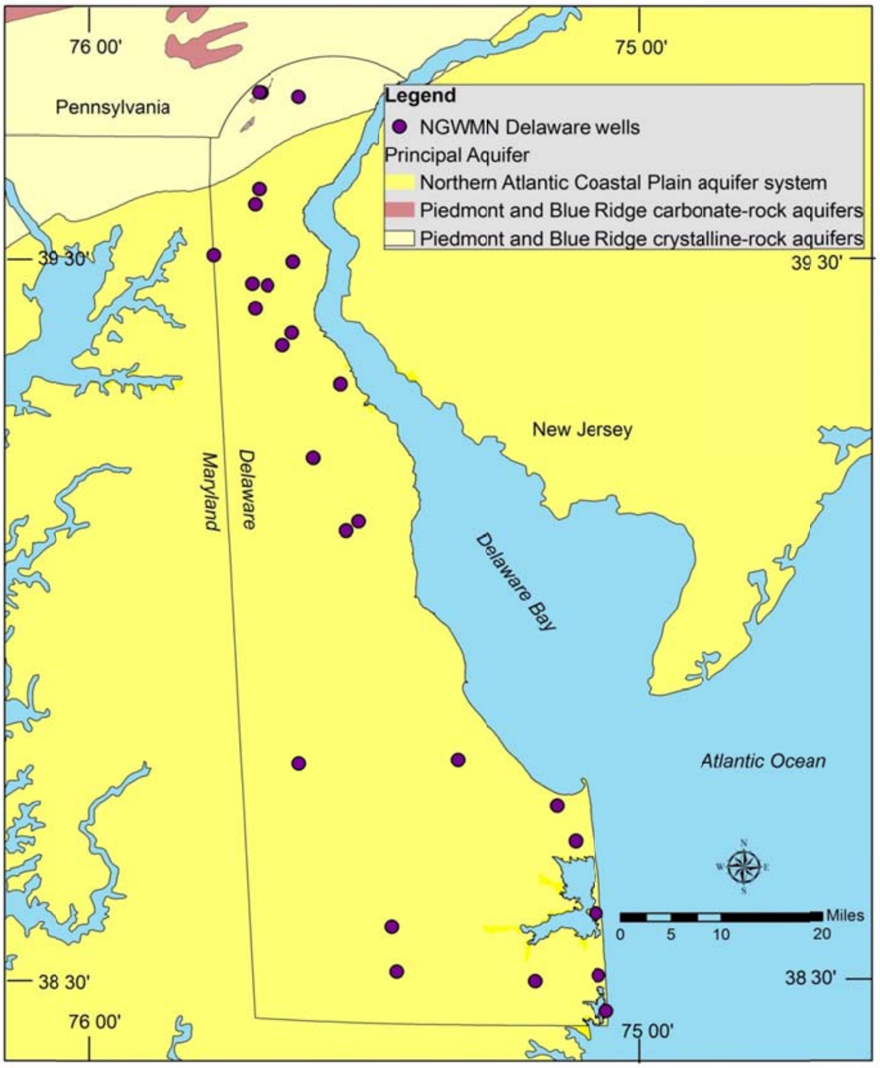

Figure 1. Map showing locations of wells in Delaware selected by the DGS for NGWMN. The wells are monitoring three principal aquifers and 13 local aquifers and cover unconfined and confined conditions. Many sites have multiple wells that are screened in different aquifers.

Table 1. Delaware wells selected for National Ground Water Monitoring Network. All sites are wells in the State of Delaware and are in the Delaware Groundwater Network. "baseline" is a column in the data entry form signifying 5+ years of data.

Site No	Site Name	County	National Aquifer	Local Aquifer	Aquifer Type	Latitude (decimal degrees NAD83)	Longitude (decimal degrees NAD83)	Altitude (ft NAVD88)	Well Depth (ft)	Water-Level Subnetwork
Wells in the WATER LEVEL NETWORK (All are dedicated monitoring wells within the NGWN monitoring category "trend" and are "baseline" wells).										
Bb34-34	Hockessin Fire	New Castle	N400PDMBRC*	Cockeysville Marble	CONFINED	39.787396	-75.695618	260.14	298	Known
Bb34-40	Swift Park	New Castle	N400PDMBRC	Cockeysville Marble	UNCONFINED	39.787959	-75.69929	253.41	59.6	Known
Bc43-01	Greenville	New Castle	N400PDMBRX**	Wissahickon	UNCONFINED	39.78170881	-75.62504789	340.22	163.5	Suspected
Db24-18	Frogtown	New Castle	S100NATLCP^	Columbia	UNCONFINED	39.64867873	-75.69749105	78.03	19	Suspected
Db33-17	Becks Pond	New Castle	S100NATLCP	Potomac Lower Zone	CONFINED	39.62691013	-75.70478201	49.32	189	Known
Ea24-07	Denny Road	New Castle	S100NATLCP	Potomac Lower Zone	CONFINED	39.55398332	-75.7801092	44.55	352	Known
Eb53-33	Sealand	New Castle	S100NATLCP	Mt. Laurel	CONFINED	39.51346225	-75.7094495	67.72	84	Suspected
Eb55-09	Emerson Farm	New Castle	S100NATLCP	Potomac Upper Zone	CONFINED	39.51106416	-75.6804278	57.08	420	Known
Ec32-03	South St Georges	New Castle	S100NATLCP	Potomac Upper Zone	CONFINED	39.54552505	-75.63329438	9.48	348	Known
Fb23-38	Water Farm 2	New Castle	S100NATLCP	Columbia-Rancocas	UNCONFINED	39.47793973	-75.70317041	64.99	59.4	Suspected

Table 1. Delaware wells selected for National Ground Water Monitoring Network. All sites are wells in the State of Delaware and are in the Delaware Groundwater Network. "baseline" is a column in the data entry form signifying 5+ years of data.

Site No	Site Name	County	National Aquifer	Local Aquifer	Aquifer Type	Latitude (decimal degrees NAD83)	Longitude (decimal degrees NAD83)	Altitude (ft NAVD88)	Well Depth (ft)	Water-Level Subnetwork
Wells in the WATER LEVEL NETWORK (All are dedicated monitoring wells within the NGWN monitoring category "trend" and are "baseline" wells).										
Fc42-11	Water Farm 1	New Castle	S100NATLCP	Mt. Laurel	CONFINED	39.44332828	-75.634097	50.71	260	Known
Fc51-28	Fieldsboro	New Castle	S100NATLCP	Rancocas	CONFINED	39.42547327	-75.65148213	52.41	127	Known
Gd33-04	Deakyneville	New Castle	S100NATLCP	Mt. Laurel	CONFINED	39.3701127	-75.54437081	19.51	427	Known
Gd33-05	Deakyneville	New Castle	S100NATLCP	Magothy	CONFINED	39.36999582	-75.54431651	18.62	660	Known
Hc55-40	Garrisons Lake	Kent	S100NATLCP	Piney Point	CONFINED	39.26390005	-75.59322369	46.1	251	Known
Hc55-41	Garrisons Lake	Kent	S100NATLCP	Cheswold	CONFINED	39.26410123	-75.5935314	45.4	112	Known
Id55-01	White Oak Rd	Kent	S100NATLCP	Piney Point	CONFINED	39.17312882	-75.50997813	24.96	349	Known
Jd14-01	Division St	Kent	S100NATLCP	Cheswold	CONFINED	39.15996944	-75.53247181	37.75	227	Known
Ec32-07	South St Georges	New Castle	S100NATLCP	Potomac Lower Zone	CONFINED	39.54544281	-75.63334019	10.38	596	Known

Table 1. Delaware wells selected for National Ground Water Monitoring Network. All sites are wells in the State of Delaware and are in the Delaware Groundwater Network. "baseline" is a column in the data entry form signifying 5+ years of data.

Site No	Site Name	County	National Aquifer	Local Aquifer	Aquifer Type	Latitude (decimal degrees NAD83)	Longitude (decimal degrees NAD83)	Altitude (ft NAVD88)	Well Depth (ft)	Water-Level Subnetwork
Wells in the WATER LEVEL NETWORK (All are dedicated monitoring wells within the NGWN monitoring category "trend" and are "baseline" wells).										
Nc13-03	Greenwood	Sussex	S100NATLCP	Piney Point	CONFINED	38.8256855	-75.61596343	64.25	630	Known
Ng11-37	Jefferson Crossroads	Sussex	S100NATLCP	Columbia	UNCONFINED	38.83194413	-75.32442159	24.11	16	Suspected
Ni52-11	Lewes Railroad Park	Sussex	S100NATLCP	Pocomoke	CONFINED	38.76666385	-75.14266054	14.82	155	Suspected
Ni52-12	Lewes Railroad Park	Sussex	S100NATLCP	Columbia	CONFINED	38.76666027	-75.14264442	15.51	80	Suspected
Oi24-06	Rehoboth Beach	Sussex	S100NATLCP	Manokin	CONFINED	38.71630864	-75.10848495	23.08	250	Suspected
Pj41-11	DSSP	Sussex	S100NATLCP	Pocomoke	CONFINED	38.61280427	-75.07136432	9.17	218	Suspected
Qe44-01	Trap Pond	Sussex	S100NATLCP	Columbia	UNCONFINED	38.52764927	-75.43354813	49.2	26	Known
Qh54-05	Pyle Center A	Sussex	S100NATLCP	Manokin	CONFINED	38.51423967	-75.18155272	26.5	232	Suspected

Table 1. Delaware wells selected for National Ground Water Monitoring Network. All sites are wells in the State of Delaware and are in the Delaware Groundwater Network. "baseline" is a column in the data entry form signifying 5+ years of data.

Site No	Site Name	County	National Aquifer	Local Aquifer	Aquifer Type	Latitude (decimal degrees NAD83)	Longitude (decimal degrees NAD83)	Altitude (ft NAVD88)	Well Depth (ft)	Water-Level Subnetwork
Wells in the WATER LEVEL NETWORK (All are dedicated monitoring wells within the NGWN monitoring category "trend" and are "baseline" wells).										
Qh54-06	Pyle Center A	Sussex	S100NATLCP	Pocomoke	CONFINED	38.51423967	-75.18155272	26.5	148	Suspected
Qh55-03	Pyle Center B	Sussex	S100NATLCP	Columbia	UNCONFINED	38.51426933	-75.18160441	25.8	18	Known
Qj41-04	Sea Colony	Sussex	S100NATLCP	Manokin	CONFINED	38.52298135	-75.0669151	7.43	400	Known
Qj41-08	Sea Colony	Sussex	S100NATLCP	Pocomoke	CONFINED	38.52302191	-75.06691858	7.37	210	Known
Rj22-16	Fenwick Island	Sussex	S100NATLCP	Manokin	CONFINED	38.47225774	-75.05220717	6.78	420	Known
Wells in the WATER LEVEL AND WATER QUALITY NETWORK (All are dedicated monitoring wells within the monitoring categories"trend" and "baseline" for both level and quality and are in the NGWMN Water Quality Subnetwork "suspected.")										
Pe54-03	SSWMC	Sussex	S100NATLCP	Manokin	CONFINED	38.59228906	-75.44281278	52.38	130	Suspected
Pe54-16	SSWMC	Sussex	S100NATLCP	Columbia	UNCONFINED	38.59228906	-75.44281278	52.23	35	Suspected

Table 1. Delaware wells selected for National Ground Water Monitoring Network. All sites are wells in the State of Delaware and are in the Delaware Groundwater Network. "baseline" is a column in the data entry form signifying 5+ years of data.										
Site No	Site Name	County	National Aquifer	Local Aquifer	Aquifer Type	Latitude (decimal degrees NAD83)	Longitude (decimal degrees NAD83)	Altitude (ft NAVD88)	Well Depth (ft)	Water-Level Subnetwork
Wells in the WATER LEVEL NETWORK (All are dedicated monitoring wells within the NGWN monitoring category "trend" and are "baseline" wells).										
Pe54-50	SSWMC	Sussex	S100NATLCP	Columbia	UNCONFINED	38.59224585	-75.44279989	52.12	63	Suspected
Notes										
* Piedmont and Blue Ridge carbonate-rock aquifers										
** Piedmont and Blue Ridge crystalline-rock aquifers										
^ Northern Atlantic Coastal Plain aquifer system S100NATLCP										

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, 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.

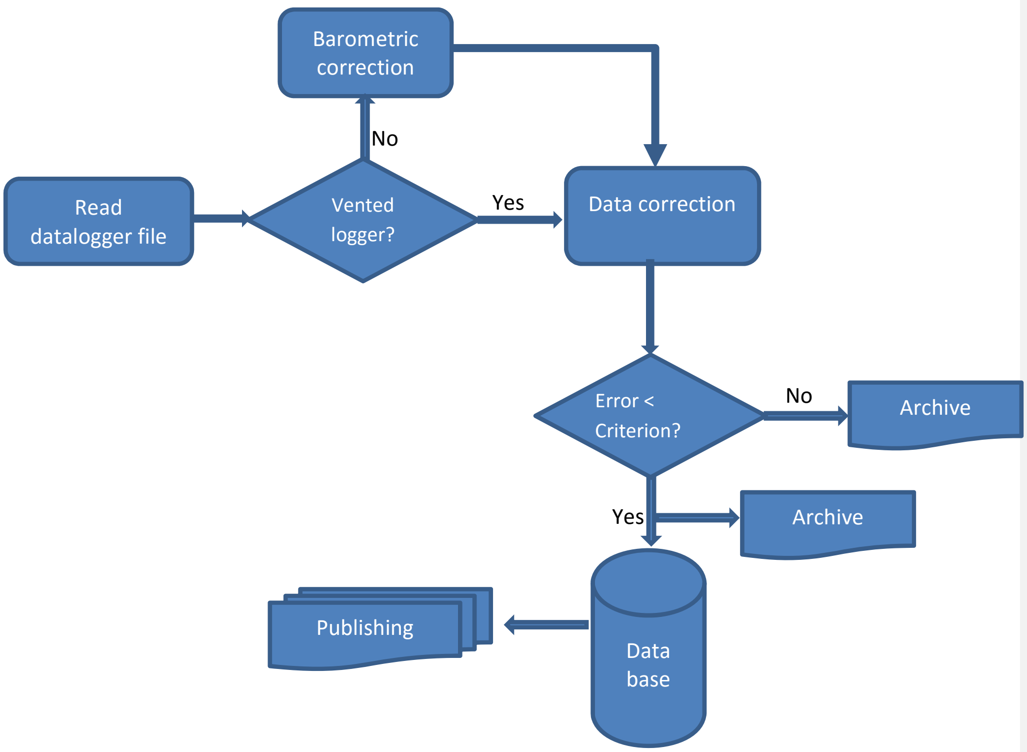

Figure 1. Flow chart of electronic data processing at DGS.

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

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.

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

Appendix B. Delaware Solid Waste Authority Groundwater sample collection procedures

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. <u>Monitoring</u>

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. <u>Analytical Methodology</u>

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.

Comment [TEM1]: No figure in here.

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.
4. 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.
5. 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.
6. The monitoring company shall conduct annual audits of the procedures and equipment being used by their field crews.
7. DSWA shall conduct random inspections of the field crews sampling protocols during each monitoring event.

B. Gauging

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. <u>Purging</u>

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. <u>Well Closeout</u>

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.

XII. 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.

XIII. 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.