



Guidelines for Preparing a Groundwater Sampling and Analysis Plan

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1. Introduction

1.1 Purpose of This Document

This document offers technical guidance to help owners and operators of municipal solid waste (MSW) Type I landfills develop a groundwater sampling and analysis plan (GWSAP) for their facility. A GWSAP is required by MSW management regulations in Title 30, Texas Administrative Code (30 TAC), sections [330.63\(f\)](#) and [330.405 through 330.415](#), which conform to federal Resource Conservation and Recovery Act, Subtitle D rules for groundwater monitoring and corrective action in Title 40, Code of Federal Regulations, [Part 258](#), Subpart E.

The goal of a GWSAP is to establish appropriate methods for sampling and analysis that will yield accurate results for evaluating groundwater conditions at a facility. These guidelines focus on the practices that are most common and easiest to implement, and do not supersede rules.

1.2 Establishing a GWSAP

A GWSAP is a formal document that is part of a facility permit; it must be included in a permit application as part of the Site Development Plan [30 TAC [330.63\(f\)](#)]. You may make changes to an approved GWSAP through a permit modification if the changes are minor and do not substantially alter the permit conditions and do not reduce the capability of your facility to protect human health and the environment [30 TAC [305.70\(d\)](#)]. If you want to make changes that do not meet the eligibility criteria for a modification, these changes must be proposed through a permit amendment.

1.3 Responsibility for Groundwater Monitoring

You, as the owner or operator of a landfill, have primary responsibility for the collection and analysis of groundwater samples and the interpretation and reporting of the results. All reports must contain valid data and be complete, accurate, and clear in their presentation.

2. Groundwater Sampling

2.1 Preliminary Work

2.1.1 Well Inspection

The GWSAP should include procedures directing the sampler to inspect the integrity of each monitoring well before purging and sampling each well. At a minimum, the sampler should do all the following:

- Check casing, concrete pad, protective collar, and protective barriers for cracks, fissures, or damage (by equipment, animals, vandalism, or other cause).
- Check that the lid of the protective collar has a lock, that the lock is functional, and that the lid was locked when the sampler visited the well.
- Check that the well cap is present on the top of the well casing. If the well is flush-mounted (casing is in a ground-level vault and is not above ground level), check that the well cap and lid to the vault are both watertight. Any water present inside a flush-mounted well vault should be removed before removing the well cap.
- Note the proximity of the well to potential sources of contamination, including facility roads.
- Avoid using organic sprays or other potential contaminants to remove any insects found on or in the casing, or organic lubricants on well components such as hinges and locks.

2.1.2 Water-Level Measurements

The GWSAP should specify that the depth-measuring equipment will be calibrated regularly, and that the calibration will be documented. The GWSAP should state that before purging a well, or as otherwise indicated, the sampler will do all the following:

- Measure the depth to water every event, and measure the depth to the bottom of the well at least every two years.
 - Take all depth measurements from a permanent, clearly marked and identifiable reference point, or datum. The datum is typically a notch or a point marked with permanent marker at the top of the well casing, and must be documented on the Monitor Well Data Sheet for each well.
 - Record depths to the nearest hundredth of a foot.
- Decontaminate the water level indicator probe before use in each well.
- Include in the field log any indication of organic compounds that have formed a liquid separate from the groundwater.
- Calculate the elevation of the water level with respect to mean sea level and report to the nearest hundredth of a foot after water-level measurements are taken.

2.2 Well Purging

2.2.1 Purging Options

Your GWSAP should specify which method(s) of purging will be used and the reasons for selecting the method(s). No single purge method may be appropriate for all the monitoring wells at a facility. Variables such as well diameter, depth to water, pH, and total dissolved solids content should be considered when determining which purge method(s) to use.

For wells that have significant levels of total dissolved solids, low-flow purging may be an appropriate method.

Some technologies, such as passive samplers, do not require the well to be purged prior to sampling.

Your GWSAP should provide sufficient details about the chosen purge methods so that samplers can implement methods correctly and consistently.

In the following subsections of this document, we identify and describe several common purge methods, with guidelines for their implementation.

2.2.1.1 Low-Flow Purging

A widely used method of well purging is low-flow purging, which involves removal of well water in a manner that minimizes drawdown, turbidity, and disturbances to the aquifer. The goal is to ensure the collection of representative groundwater samples. This guidance is generally based on the United States Environmental Protection Agency (EPA) publication *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures* (April 1996).

The following procedures should be implemented during low-flow purging:

- Place the pump intake in the middle of the screened interval to avoid mixing formation water with sediments in the well bottom or overlying stagnant water within the well casing. We suggest the use of dedicated purging and sampling devices. If non-dedicated equipment is used, it must be decontaminated between wells to prevent cross-contamination.
- Limit low-flow purging to wells that exhibit no continuous drawdown under sustained pumping.
- Measure and record water levels before pumping.
- Initiate purging and adjust flow to a rate that results in a minimal (<0.1 m [<0.33 feet]) well drawdown. This goal may be difficult to achieve under some circumstances, and may require adjustment based on site-specific conditions. If the minimal drawdown exceeds 0.1 m, but remains stable, continue purging.

Purge rates for low-flow purging are typically in the range of 0.1 to 0.5 liters (L)/min. A higher purge rate may be acceptable, but must be determined at each well location. Purge rates should ideally be equivalent to the well recharge rate at the pump intake. Pumping rates that result in minimal drawdown in one well at a facility could be too high for another well at the same facility.

Water level should be monitored in each well and purge rate adjusted to minimize drawdown. Also, water levels and purge rates should be recorded every three to five minutes during purging, and upon completion of sampling. Determine the optimum pumping rate for each well, and record this information for future reference.

The minimum well-purge volume should be at least 2 pump and tubing volumes.

Water quality indicator parameters should be continuously monitored during purging, preferably with a flow-through cell. Stabilization of parameters such as pH, specific conductance, dissolved oxygen (DO), oxidation-reduction potential (ORP), temperature, and turbidity should be used to determine when stagnant casing water has been purged and formation water is available for sampling. A minimum subset should include pH, specific conductance, and either turbidity or DO. Measurements should be recorded every 3 to 5 minutes. Temperature and pH are not helpful in distinguishing between formation water and stagnant casing water, but are still important for data interpretation. Stabilization is considered achieved when all the parameters are within the following ranges for three successive readings:

- ± 0.1 units for pH
- $\pm 3\%$ for specific conductance
- ± 10 millivolts for ORP
- $\pm 10\%$ for turbidity and DO

2.2.1.2 Purging with a Non-Low-Flow Pump

If you cannot meet the criteria for low-flow purging, then purging with electric, or air-operated pumps at higher speeds is acceptable.

The GWSAP should specify the type of pump that will be used, based on what will be most effective. Pumps and tubing should be limited to those made of stainless steel, Teflon[®], or other resistant materials.

You should use positive-pressure displacement bladder pumps or other types of pumps that are designed to prevent air from contacting the water and to minimize aeration in the well, to help prevent the loss of volatile constituents that are being monitored.

The following procedures should be implemented when purging by a non-low-flow method:

- Make sure that each well has a clean, dedicated pump and tubing installed to minimize cross-contamination between wells.

If separate pumping equipment is not dedicated to each well, the non-dedicated sampling equipment must be decontaminated between wells. The final rinse in the decontamination process should be done with laboratory reagent-grade water. If commercial distilled water is used instead for the final rinse, a sample of the water should be analyzed for volatile organic compounds (VOCs) at each event, to ensure that any VOCs in the commercial distilled water are known and can be factored into the evaluation of the analytical results.

- Calculate the volume of water in each well using the following equation:

$$V = 0.041 d^2h$$

where:

V = volume of water, in gallons

d = diameter of well casing, in inches

h = length of water column (total well depth minus depth to water, measured during preliminary work stage of sampling event), in feet

0.041 = conversion factor = well-casing diameter squared \div $4 \times \pi$ (well cross-sectional area, in inches) \div 144 square inches per square foot \times 7.4805 gallons per cubic foot

- After the preliminary work has been done and a well is ready to be purged, assemble the pump, hoses, and safety chain or rope, and lower the pump into the well. To avoid stirring up accumulated sediments at the bottom of the well, set the pump level at least 3 to 5 feet from the bottom of the well, if possible; however, also make sure that the pump is deep enough in the water column so that it does not run dry, which could damage it.
- Make connections between the pump and the control box, if you are using an air-lift or bladder pump.
- Attach a flow meter to the outlet hose to measure the volume of water purged. Alternatively, a graduated bucket or container with marks can be used to measure volumes.
- Next, attach the power supply if required, and begin purging the well. The well should be purged at a rate low enough to prevent groundwater that is recharging the well from cascading down the sides of the well, if possible.
If the pumping rate exceeds the well recharge rate and the water discharge rate from the pump decreases or stops, lower the pump deeper into the water column in the well or reduce the pumping rate to decrease well drawdown, and then continue pumping. If you are using an air-lift or bladder pump, be sure to adjust the flow rate to prevent violent jolting of the hose as the sample is drawn in.
- Continue purging until the desired volume has been purged, unless the well goes dry before the purging process is completed.

2.2.1.3 Purging with a Bailer

If pumping is not an option, you can use bailers to purge the well. Bailers should have a bottom-emptying device that allows the bailer to be emptied slowly with minimum aeration of the sample. When purging with a bailer, you should also take extra care to avoid introducing contaminants to the water in the well. You should use disposable gloves, a new pair for each well, to avoid cross-contamination.

Because of the ease of stirring up accumulated sediments at the bottom of the well, purging should be done in ways that will minimize turbidity. Bailers should be lowered gently, not dropped, to a foot or two above the bottom of the screen, allowed to sit for several seconds, and then pulled slowly and steadily up to the surface. As was indicated regarding purging with a pump, purging and recovery should continue until

at least three casing volumes have been removed or the well goes dry. The well should then be allowed to recover.

2.2.2 No-Purge Technique

If a well is to be sampled using a passive method, purging may not be necessary. Passive groundwater sampling involves deploying a sampling device, appropriate for the constituents being monitored, in a well and leaving it there for a predetermined period before retrieving it to collect the sample.

2.2.3 Storage and Disposal of Purge Water and Excess Sample Water

Your GWSAP should specify how purge water and excess sample water will be managed and disposed of.

2.2.3.1 Storing Purge Water and Excess Sample Water

You should store purge water and excess sample water in a properly labeled drum or container until the analytical results have been received and a proper disposal method has been selected. All the disposable sampling equipment (such as tubing or bailers) and supplies (such as gloves) should be containerized separately from the purge water.

2.2.3.2 Disposing of Uncontaminated Water

If the analytical results indicate that constituents are at or below background concentrations, purge water and excess sample water may be applied to the unsaturated soil on-site or discharged to surface water, if an authorization is not required.

2.2.3.3 Disposing of Contaminated Water

If constituents are above background concentrations, the water is considered contaminated.

Your GWSAP should specify which methods will be used for disposing of groundwater that is contaminated or for which analyses have not yet been received. The following methods are allowed:

- Place in the landfill leachate collection system via storage tanks, accessible risers, evaporation ponds, or other access points, and manage in the same manner as leachate.
- Place in the landfill gas condensate storage tanks and manage in the same manner as condensate.
- Solidify at a liquid waste processing operation at the facility and dispose of in landfill.
- Transport off-site or discharge to an authorized wastewater treatment facility, or liquid waste processing facility, if the water quality is acceptable to the receiving facility.

If test results indicate levels of contaminants that cause the water to be classified as hazardous, the water must be properly transported and disposed of at a hazardous-waste facility.

2.2.4 Records and Documentation of Well Purging

You should record in a field log all the data that is collected before and during purging. This data should include all of the following:

- Sampler's name.
- Date and time.
- Outdoor temperature and weather conditions.
- Initial depth to water, measured well depth, and calculated height and volume of the water column.
- Desired well volume to purge (for example, three casing volumes).
- Purge-discharge rate, if known, and purge duration (elapsed time).
- Volume of water actually purged from a well.
- Low-flow parameter readings, if a low-flow method is used.
- Well inspection results.
- Any other pertinent information.

2.3 Sample Collection

2.3.1 General Considerations

Your GWSAP needs to contain sufficient detail for personnel to correctly collect, pack, and send the samples. Physical or chemical changes can occur in groundwater samples if inappropriate or inadequate sampling devices, collection procedures, preservatives, temperature controls, or shipping methods are used.

2.3.1.1 Timing and Sequence of Sampling

The elapsed time between purging and sample collection should be as short as possible, to avoid temporal variations in water levels and water chemistry. Preferably, sampling should be done within 24 hours of purging.

You should measure the water level in each well again before sampling to determine whether there is enough water for sampling, especially if the well went dry during purging. Where possible, you should allow the water level in a well to recover to 90 percent of the level that existed prior to purging, before collecting a sample. To allow wells that purged dry to recover sufficiently to sample, or suspended sediments to settle, you may have to wait several hours or several days between purging and sampling.

Allow up to seven days recovery time after purging a well before determining that the well is dry or has not recharged sufficiently to sample. If after seven days a slowly recharging well has not recovered sufficiently for a complete set of samples, you

should collect a partial set of samples in the order specified in the GWSAP, or in another order if warranted by conditions and data needs, until no more samples for the set can be collected.

If contamination is known to be present in one or more wells at an MSW landfill, you should begin the sampling at the well that is known to be the least contaminated and end with the most contaminated well. Where no contamination is known, the order should generally be from the well with the highest water-level elevation to the one with the lowest elevation (that is, from upgradient to downgradient) for wells screened in the same water-bearing unit.

2.3.1.2 Cleaning and Decontaminating Field Equipment

If you use non-dedicated sampling devices, you should clean and decontaminate them using appropriate procedures before sampling each well. Do not reuse sample bottles, bailer rope, rubber hoses, or disposable gloves. If a bailer is used, we recommend a bottom-emptying device, because it allows the bailer to be emptied slowly from the bottom, reducing turbulence and aeration, which could alter sample chemistry.

2.3.1.3 Calibrating Field Equipment

Field equipment, including devices for measuring water levels and water quality indicator parameters, must be calibrated in accordance with the manufacturer's instructions prior to sampling.

2.3.1.4 Water Quality Indicator Parameters

Before sample collection begins, you should again measure and record water quality indicator parameters—including pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature, and turbidity—in addition to the measurements you made during purging.

2.3.1.5 Sample Filtering

Filtering of samples in the field is not allowed [30 TAC [330.405\(c\)](#)].

2.3.2 Sample-Collection Methods

Your GWSAP should include both the preferred and alternative sampling methods that might be used at a facility. Low-flow purging and sampling is the recommended sampling method because it controls turbidity and delivers higher-quality samples. However, non-low-flow pumps, bailers, and passive (no-purge) samplers are also acceptable methods.

When using pumps for sampling, the pumping rate in a well should be the same or less than the purging rate in that well, and should be sufficiently low to minimize sample aeration.

Information about passive samplers is available in the publication *Protocol for Use of Five Passive Samplers to Sample for a Variety of Contaminants in Groundwater* (February 2007), a publication of the Interstate Technology Regulatory Council (ITRC).

2.3.3 Sample Volumes and Sampling Containers

The volume of samples and types of sample containers needed depends on the constituents to be analyzed. EPA recommendations include:

- For volatile organic compounds (VOCs), use two 40 ml glass vials (or lab-specified alternate quantity or size) with special caps with Teflon[®] septa, pre-preserved by the lab. The septum must be correctly placed, with the Teflon[®] side toward the sample (shiny side away from the sample).
- For semivolatile organic compounds (SVOCs), use a one-liter glass container.
- For metals, use laboratory-provided polyethylene or glass containers that already contain the necessary preservatives.
- For other inorganic constituents, use laboratory-provided polyethylene or glass containers (preservatives generally are not used, except for samples to be analyzed for ammonia).

2.3.4 Sample-Collection Procedure

2.3.4.1 Cleanliness

To prevent contamination, keep clean equipment on top of plastic sheeting and not in direct contact with the ground. You should check the area around the sampling point for possible sources of air contamination, particularly when sampling for VOCs. Note any potential impacts in the field log.

You should collect all water samples as close to the wellhead as practical. Do not allow the sampling device to touch the sampling container, but hold the two as close to each other as possible, to reduce aeration.

Generally, you should discard the first portion of water taken from a well during sampling. This is done to help eliminate any non-representative water that may be present at the top of the water column.

Water removed during sampling and not utilized must be handled in the same way as purge water.

2.3.4.2 Filling Sample Containers

Fill sample containers in the following order, according to volatilization sensitivity (from most to least volatile):

- VOCs
- SVOCs
- Metals
- Other Inorganic Constituents

When filling containers for VOC samples, allow the water stream to flow down the inner wall of the vial to minimize formation of air bubbles. Overflow the containers slightly so that the vial has a positive meniscus. Screw the caps on carefully to avoid

leaving any air space in the vials. If an air bubble forms in the bottle, do not open the bottle to remove it, but collect an additional, separate sample.

If you use bailers for sampling, discard the first part of the sample to remove any sludge or suspended solids, then fill both VOC vials from a single bailer to minimize differences in the samples.

2.3.4.3 Labeling Sample Containers

You must label all sample containers for identification purposes. The labels should include information such as sample number (with the well number as part of the sample number), site identification, analysis to be performed, preservatives used, date and time of sample collection, and name of sampler. You should write the information on the label with permanent ink and, if necessary, cover the label with transparent tape to protect the written data.

2.3.5 Quality Control Samples

We recommend that you use trip blanks, field blanks, equipment blanks, and field duplicate samples for quality control (QC), as they can help determine whether samples have been contaminated from other sources. Typical collecting frequencies are as follows:

Typical Collecting Frequencies for Blanks

Type of Blank	Collection Frequency
Trip Blanks	One for each sampling event
Field Blanks	One per day, or one for every 10 wells sampled, whichever is greater
Equipment Blanks	One per day or sampling event
Field Duplicates	One for every 20 wells sampled, with at least one per sampling event

The various types of QC samples are described below.

- **Trip Blanks.** A trip blank is a laboratory-prepared sample of reagent-grade or distilled water provided with a set of sample jars that is transported to and from the site in the same manner as the sample containers. The purpose of the trip blank is to determine if any of the sample bottles or collected samples have been contaminated before or during sampling, or if sample shipment, handling, and storage have had an impact on the integrity of the sample.
- **Field Blanks.** A field blank is prepared in the field by pouring laboratory reagent-grade or distilled water into clean sample containers opened in the field, then returned with the samples to the laboratory for analysis. It is used to check for incorrect sampling procedures or airborne contaminants at the sample-collection point. It is appropriate to collect the field blanks when sampling downgradient wells. If a well is contaminated, a field blank collected close to the contaminated

well, in addition to the regular field blank, may help determine if there are other contaminant sources in the area of the well.

- **Equipment Blanks.** An equipment blank is a sample of laboratory reagent-grade or distilled water run through the well-sampling equipment in the same manner as the actual groundwater sample, to determine the effectiveness of the procedures for equipment decontamination.
- **Field Duplicates.** Analysis of field duplicate samples provides a check on the precision of the laboratory techniques. Field duplicates are two samples taken at the same time from the same well, and from the same bailer, if bailers are used. Field duplicates are labeled differently so that the laboratory is unaware that the samples are duplicates.

You should label duplicate samples as you would regular samples, but with a sample name such as “Dup-1,” “Dup-2,” and so on, and with the sample time omitted, so there is no way for the laboratory to know which well the duplicate sample is from. The information about which well the duplicate is from should be written in the field log book.

2.3.6 Chain-of-Custody Documentation

A suitable chain-of-custody (COC) document must accompany the samples at every step from field to laboratory and must be signed by each party (except commercial transporters) handling the samples, from the sampler to the laboratory representative. Usually laboratories provide their blank COC forms with the empty sample-bottle shipment. Proper COC procedures are essential to ensure sample integrity and to provide legally and technically defensible data.

The person collecting the sample starts the COC procedure and fills in all the required information on the COC document, such as sample name, collection date and time, and requested analyses. Individuals relinquishing and receiving the samples should sign, date, and note the time of transfer on the COC document. A completed COC document should be placed inside a sealed plastic bag to prevent the ice or water in the cooler from damaging it. Mailed packages should have tracking numbers to allow for locating shipments.

2.3.7 Sample Storage and Transport

All samples should be kept cold, ideally at $4^{\circ}\text{C} \pm 2^{\circ}$, and transported to the laboratory as soon as possible, preferably within 48 hours of sampling. You should wrap the samples, put them in resealable plastic bags, and place them in a hard-sided ice chest or other insulated container packed with sufficient ice or refreezable materials to keep them at the ideal temperature. **You should not use dry ice to chill the samples because the samples could freeze and break their containers.**

If the samples are to be shipped, they should be kept chilled with ice that is double-bagged in resealable plastic bags while sampling is occurring. Then, just before shipping, the sampler should pour out the excess melt water, and add more ice, if necessary. Coolers can also be kept cold with frozen packages of refreezable materials such as “blue ice.” The samples, blanks, and COC documents need to be well packed in the insulated cooler, with as little extra air space as possible, utilizing ice bags, foam,

or bubble wrap to add padding, then thoroughly sealed with shipping tape. Flimsy, expanded-foam or soft-sided ice chests are *not* suitable for shipping.

2.3.8 Documentation of Sampling

Your GWSAP should require that all information related to a sampling event be recorded in a bound, permanent field log book or equivalent. All the entries in the log book should be legible and made in black, permanent ink. Entry errors should be crossed out with a single line, dated, and initialed by the person making the corrections. An essential practice is to record sufficient information so that the sampling situation can be reconstructed without relying on the sampler's memory. Location, date, time, weather conditions, name and identity of sampling personnel, all field measurements including numerical values and units, comments about the integrity of the well, and so on should be recorded. Because the field log book may be the only acceptable record for legal purposes, it should be protected and kept in a safe place.

3. Groundwater Analysis

3.1 Laboratory Accreditation

General provisions as well as accreditation and certification requirements for environmental testing laboratories are specified in 30 TAC, [Chapter 25](#). All environmental testing laboratories must be accredited in accordance with 30 TAC, Chapter 25 (except as provided in 30 TAC [25.6](#)), if the laboratory provides analytical data that is used for a TCEQ decision relating to a (1) permit, (2) authorization, (3) compliance action, (4) enforcement action, (5) corrective action, (6) characterization of an environmental process or condition, or (7) assessment of an environmental process or condition.

3.2 Groundwater Sampling and Analysis Requirements

In accordance with 30 TAC [330.405 through 330.415](#), a groundwater monitoring program must include consistent sampling and analysis procedures that are designed to ensure results that provide an accurate representation of groundwater quality at the background and point-of-compliance wells.

3.3 Constituents Required for Detection Monitoring

In accordance with 30 TAC [330.419](#), unless otherwise specified, you, the owner or operator of a facility, must sample and analyze for the constituents listed in [Appendix I](#) to 40 CFR, Part 258, in all groundwater monitoring wells.

In certain cases, the TCEQ may delete any of the constituents listed in Appendix I, and allow facilities to establish an alternative list of inorganic indicator constituents (in place of the constituents listed in Appendix I), if the alternative list ensures a reliable indication of releases from the landfill to the groundwater. We may also add constituents to the list, if they are expected to be in or derived from the waste contained in the landfill or if they are likely to provide a useful indication of releases from the landfill.

3.4 Test Methods

You must also ensure that groundwater samples are analyzed using analytical methods that accurately measure hazardous constituents and other monitoring parameters in groundwater samples. The following two publications identify and describe analytical methods that are acceptable for groundwater monitoring: [Test Methods for Evaluating Solid Waste](#) (a publication of the EPA; also known as SW-846; as revised), and [Standard Methods for the Examination of Water and Wastewater](#) (a joint publication of the American Public Health Association, the American Water Works Association, and the Water Environment Federation; as revised). Any alternative inorganic constituents chosen for detection monitoring can be analyzed by the methods described in either of these two references.

3.5 Reporting Analytical Results

The TCEQ requires that analytical results for groundwater samples from MSW Type I landfill groundwater monitoring wells be reported using a practical quantitation limit (PQL).

Title 30 TAC [330.405\(f\)\(5\)](#) requires that any statistical method used to evaluate groundwater monitoring data shall account for data below the limit of detection with one or more statistical procedures that are protective of human health and the environment, and that any PQL that is used in the statistical method be the lowest concentration level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions.

3.5.1 MSW Benchmark PQLs and Laboratory PQLs

You may report sample results using either laboratory PQLs MSW benchmark PQLs (listed in a letter to MSW landfill owners and operators, dated May 25, 2010; the letter is available at www.tceq.texas.gov/goto/msw-pqls).

Once you have established a method and PQL for a constituent at a facility, you should continue to use the same method and PQL for future analyses. A PQL may be modified if a different test method is used for a constituent, or if the designated PQL cannot be achieved.

PQLs must be equal to or below the groundwater protection standards established for each constituent, unless an alternative PQL is approved by the TCEQ.

3.5.2 Reporting Estimated Results below the PQLs

The MSW rules do not address estimated constituent concentrations (typically flagged in laboratory reports by the letter “J”). The EPA document *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (March 2009) (*Unified Guidance*) specifies that J-flagged sample results represent concentrations that are detected but not quantified, and should be treated as valid measurements for statistical purposes only.

3.5.3 Acceptance Limits for Quality Control Samples

Quality control samples are used to determine precision (how repeatable a measurement is) and bias (how close the result is to the actual value). Each analysis has associated acceptance limits. Quality control results that are outside acceptance limits for a constituent and method should be flagged by the laboratory, with an explanation of any problems encountered by the laboratory, including any corrective actions attempted to resolve the analytical problems. Groundwater sample results associated with quality control results that are outside acceptance limits may still be used, but should be flagged. You, the owner or operator of a facility, must review all data and ensure that the laboratory has performed all required quality assurance and quality control activities, and documented any problems and corrective actions associated with an analysis. The laboratory must maintain all records in accordance with the requirements of the National Environmental Laboratory Accreditation Conference (NELAC).

3.6 Text to Include in GWSAP

The following text should be included in a GWSAP.

Practical Quantitation Limit

30 TAC 330.405(f)(5) defines the practical quantitation limit (PQL) as the lowest concentration level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions.

For each constituent listed in 40 CFR, Part 258, Appendix I or Appendix II, or for each groundwater parameter that has a groundwater protection standard (GWPS), the laboratory will demonstrate that the method and procedure used in the analysis can attain a PQL at or below the GWPS.

Laboratory quality control samples will meet the precision and accuracy data-quality objectives that are listed in the table below.

Table 1. Measurement-Quality Objectives

Chemical of Concern	Precision (% RSD)	Accuracy (% recovery)
Metals	10	70-130
Volatiles	20	50-150
Semivolatiles	30	50-150

The laboratory will report non-detected results as less than the value of the PQL.

When the limits for precision and accuracy listed in Table 1 cannot be met, the owner or operator will submit information to support a recommendation for using alternative precision and accuracy limits.

Laboratory Case Narrative

All analytical data submitted under the requirements of this permit will be examined by the owner or operator to ensure that the data-quality objectives are considered and met prior to submittal for the commission's review. The owner or operator will determine if the results for a sample are accurate and complete. The quality control results, supporting data, and data review by the laboratory must be included when the owner or operator reviews the data. The owner or operator will report any anomalies that were identified in the laboratory case-narrative summary.

The owner or operator will ensure that the laboratory documents and reports all problems and anomalies associated with the analysis. If analysis of the data indicates that the data fails to meet quality control goals, the owner or operator will determine if the data is usable. If the owner or operator determines that the analytical data may be used, all problems and corrective action that the laboratory identified during the analysis will be included in the report submitted to the TCEQ.

A Laboratory Case Narrative (LCN) for all problems and anomalies observed will be submitted by the owner or operator. The LCN will provide the following information:

- 1. The exact number of samples, constituents analyzed, and sample matrices.*
- 2. The name of the laboratory performing analyses. If more than one laboratory is used, all laboratories will be identified in the case narrative.*
- 3. Explanation of each failed precision and accuracy measurement determined to be outside of the laboratory or method control limits.*
- 4. Explanation if the failed precision and accuracy measurements cause a positive or negative bias on the results.*
- 5. Identification and explanation of problems associated with the sample results, along with the limitations on data usability.*
- 6. When appropriate and when requested, a statement on the estimated uncertainty of analytical results of the samples.*
- 7. A statement of compliance or noncompliance with data-quality objectives. Holding-time exceedances and matrix interferences must be identified. Dilutions must be identified, and if dilutions are necessary, they must be done to the smallest dilution possible to effectively minimize matrix interferences and bring the sample into control for analysis.*
- 8. Identification of all applicable quality assurance and quality control samples that will require special attention by the reviewer.*

Other Information

In addition to the LCN, a laboratory report will include the following:

- 1. A table identifying the field-sample name with the sample identification in the laboratory report.*
- 2. Chain of custody.*
- 3. For each sample, a report (certificate of analysis) of the constituents analyzed, the analytical methods, and the laboratory PQLs.*
- 4. A release statement provided by the laboratory, with the following wording: "I am responsible for the release of this laboratory data package. This data package has been reviewed by the laboratory and is complete and technically compliant with the requirements of the methods used, except where noted by the laboratory in the attached exception reports. By my signature below, I affirm to the best of my knowledge that all problems or anomalies that were observed by the laboratory as having the potential to affect the quality of the data have been identified by the laboratory in the Laboratory Review Checklist, and no information or data have been knowingly withheld that would affect the quality of the data."*

If an in-house laboratory is used, the laboratory release statement must also include the following: "This laboratory is an in-house laboratory controlled by the person responding to the rule. The official signing the cover page of the rule-required report in which these data are used is responsible for releasing this data package and is by signature affirming that the above release statement is true."

5. An *MSW Laboratory Review Checklist (LRC)*. For every “exception report”—a response of “No,” “NA,” or “NR”—on the checklist, the permittee will ensure that the laboratory provides a detailed description of the exception in the summary of the LCN.

4. Statistical Evaluation of Monitoring Data

4.1 Regulatory Requirements

Under the rules in 30 TAC 330.405(e) and (f), statistical evaluation of analytical results from groundwater samples is required to determine if landfill activities have affected groundwater quality. Statistical procedures provide an objective way for characterizing analytical results and making decisions, including: establishing background groundwater quality, determining if changes in groundwater quality are significant, and determining if constituents of concern are above or below groundwater protection standards and whether corrective action is needed.

Any statistical method used to evaluate data must be appropriate for the distribution of tested constituents. It may not be possible to specify statistical methods until at least a few background samples have been taken. Therefore, your GWSAP should identify the methods that might be used, and explain how it will be decided which methods to use once the data has been collected.

The *Unified Guidance* offers information about selecting and using various statistical methods.

4.2 Establishing and Updating Background

The background data for a facility should reflect groundwater quality that has not been affected by a landfill. These conditions could range from an uncontaminated aquifer to a historically contaminated site. A minimum of four background samples are needed to establish limits for any statistical test. However, eight background samples are recommended. Generally, the background sample size should be as large as feasible.

A facility may establish background limits for a well using data collected earlier from that well, and then compare detection monitoring results from that well to the earlier background (*intrawell* comparison), provided that the earlier data from the well represent background groundwater quality not affected by waste-management activities. If background values are not available from a well or if the well is already affected by waste-management activities, then detection monitoring results from the well will need to be compared to background from upgradient wells (in the absence of spatial variation) or other wells that are not affected (*interwell* comparison).

Background limits should be periodically reviewed and updated as necessary with valid semiannual detection monitoring results that are representative of background groundwater quality not affected by landfill activities. You should update intrawell background data once every two years, when at least 4 new measurements are available.

4.2.1 Assumptions for Statistical Tests

4.2.1.1 Statistical Independence

Allowing as much time as possible to pass between sampling events is the best way to achieve statistical independence. But you must draw a balance between collecting a sufficient number of samples from a given well over a specified time period, and ensuring that the samples are statistically independent. The time between samples will depend on the hydrogeological conditions and groundwater flow velocity.

4.2.1.2 Normality of Data and Selecting Parametric or Nonparametric Methods

Most statistical methods used for the evaluation of groundwater monitoring results from MSW Type I landfills are based on the assumption that the population from which the data are taken is normally distributed. These methods also apply to data from a population that has been transformed by mathematical manipulations into a normal distribution. In that case, the data are treated statistically after the appropriate transformation.

If the data are not normally distributed, either raw or transformed, then nonparametric statistical methods that do not require or assume normality can be used.

4.2.2 Spatial Variation and Selecting Interwell or Intrawell Comparisons

Each monitored constituent should be evaluated for evidence of spatial variation. When possible, results from a facility should be evaluated using intrawell comparisons, to avoid statistical complications due to natural spatial variation at a site. If background data for a well are not available, interwell comparisons will be necessary. At some sites, a mixture of statistical approaches may be used: interwell tests for some constituents and intrawell tests for others.

4.2.3 Outliers

Unusual values in a data set are considered outliers. Outliers in sample results can be due to several factors, including measurement errors, laboratory errors, clerical errors, and contaminated samples. Statistical calculations are required to determine if a sample result is a statistical outlier. The *Unified Guidance* recommends generally not to remove outliers unless some basis for a likely error can be identified. However, the *Unified Guidance* also recommends removing extreme values (unusual-looking, high-magnitude measurements) in background data sets even if the reason for the extreme values is not known. Removal of statistically identified outliers should be based on technical information or knowledge that can support that decision.

4.2.4 Trends

An assumption about background is that background samples come from a background population with a stable mean and variance that does not vary significantly through time. Data that show a trend of increasing or decreasing

concentrations may violate this assumption. The proper handling of trends in background depends on the cause of the trend. For newly installed monitoring wells, it may be necessary to discard initially collected observations and wait for the aquifer or well construction materials to stabilize.

4.2.5 Non-Detects

Samples with values below the laboratory quantitation limit or other reporting limit (RL) are called “non-detects.” The actual concentration of a constituent reported as non-detect may be anywhere between zero and the reporting limit.

When using parametric statistical tests, the *Unified Guidance* recommends that one-half of the RL be used in place of non-detects for calculations.

If the proportion of non-detects exceeds certain thresholds, nonparametric tests should be used.

When all data are non-detect, a nonparametric prediction limit should be used, with the RL as the limit. If a constituent has never been detected in groundwater at a site, or has not been detected recently, it may be evaluated using the “double-quantification rule” (DQR, described later in this document).

4.3 Site-Wide False Positive Rates and Statistical Power

False positives are results that are from the background population, but exceed the background statistical limit. Statistical power refers to the ability of a test to identify real increases above background.

The *Unified Guidance* recommends two statistical performance criteria that are fundamental to good design of a detection monitoring program:

- Application of an annual cumulative Site-Wide False Positive Rate (SWFPR) design target, suggested at **10 percent per year** (5 percent for each of two semiannual sampling events).
- Use of **EPA power curves** to gauge the cumulative annual ability of any individual test to detect contaminated groundwater when it exists.

The SWFPR is a function of the number of constituents, number of wells, number of annual evaluations, and the type of verification resampling program. The greater the number of constituents, the greater the likelihood of false positives. It is recommended that constituents *not historically detected* in background *not be included in SWFPR* computations.

The *Unified Guidance* recommends a power (the y axis of the power diagram) of at least 55 to 60 percent when concentration levels are 3 standard deviations (SD, the x axis of the power diagram) above the background mean, and at least 80 to 85 percent at 4 SD.

4.4 Statistically Significant Increases during Detection Monitoring

During detection monitoring, a statistically significant increase (SSI) is declared when the concentration of a constituent increases above its background limit and, if resampling is elected by the facility, is verified by resampling. An SSI triggers assessment monitoring, unless it is demonstrated that a source other than a landfill caused the contamination, or that the SSI resulted from error in sampling, analysis, or statistical evaluation, or from natural variation in groundwater quality [30 TAC 330.407(b)(3)].

4.5 Statistical Tests

Prediction limits, control charts, and confidence intervals are statistical tools that are commonly used to evaluate sample data from landfills. Prediction limits and control charts are used for evaluating detection monitoring results. Confidence intervals are used to evaluate results during assessment monitoring and corrective action.

An alternative method—the “double quantification rule”—is available for evaluating results for constituents that have never been detected or that have not been detected in a long time.

Verification resampling will almost always be needed to maintain adequate statistical power and minimize the overall false-positive rate for detection monitoring programs. Therefore, it is important to outline a resampling strategy prior to beginning detection monitoring.

4.5.1 Prediction Limits

Prediction limits provide an estimate of an interval that will include values of future measurements based on previous measurements, with a given level of confidence. The previous measurements may be background data for either a group of wells (interwell comparison) or a single well (intrawell comparison). For parametric prediction limits, background data should be either normal or normalized by using a transformation (e.g., the natural logarithm) and should not exhibit trends and should not include statistical outliers. All possible outliers should be examined to determine whether a cause is known. If a transformation is used, the resulting limit should be back-transformed to the original units. When normality cannot be justified, a nonparametric limit should be computed. The largest or second-largest value in a background data set is usually selected as a non-parametric limit.

4.5.2 Control Charts

Combined Shewhart-CUSUM control charts are an alternative test to prediction limits in detection monitoring. This control chart assesses two statistics at one time: the Shewhart portion works somewhat like a prediction limit and compares each new measurement against a control limit, whereas the CUSUM portion tracks the cumulative sum of how much each measurement exceeds a threshold level. In practice, both the control limit and CUSUM limit can be set to the same value. A statistical exceedance is declared if either the new measurement or the CUSUM exceeds the limit.

To use the Shewhart-CUSUM control chart for analysis, the original or transformed data must be (1) normally distributed, (2) independent, (3) generally above detection limits, and (4) represent groundwater quality not affected by a landfill.

4.5.3 Trend Tests

The *Unified Guidance* suggests trend tests as an alternative to prediction limits when the data are not amenable to prediction limits. Also, a trend test can be used for historically contaminated wells, where uncontaminated data cannot be collected. For most constituents, a trend test will have one of three outcomes: (1) a statistically significant decreasing trend, which indicates that water quality may be improving; (2) an insignificant trend, which indicates that water quality is staying the same; or (3) a statistically significant increasing trend, which indicates that water quality may be getting worse.

4.5.4 Double Quantification Rule (DQR)

The *Unified Guidance* recommends using the Double Quantification rule (DQR) for constituents not historically detected. Constituents that have not been detected in the background samples are not subject to formal statistics and should not be included in Site-Wide False Positive Rate (SWFPR) computations. If a constituent has been detected for two consecutive semiannual sampling events, it should be treated as an SSI and added to SWFPR computations.

4.5.5 Verification Resampling

In a detection monitoring program that incorporates verification resampling, an SSI is not declared unless the resample or resamples also exceed the background limit. The exceedance detected in the initial sample may be referred to as an “initial exceedance.”

Verification resampling should be conducted to verify or disconfirm an initial exceedance. If a constituent in an original sample from a well exceeds its statistical limit, then one or more resamples are collected from that well and evaluated. A statistical test utilizing resampling is not complete until all necessary resamples have been evaluated.

Prediction limits are well suited for retesting. Typical retesting strategies are to allow for one resample for constituents evaluated using a parametric method with eight background measurements, or two resamples for constituents evaluated using a nonparametric method with eight background measurements. If the retesting strategy involves one resample, the initial exceedance is disconfirmed if the constituent concentration in the resample does not exceed the prediction limit (pass one of one resample). If the retesting strategy involves two resamples, the initial exceedance is disconfirmed if the constituent concentration in the first or second resample does not exceed the prediction limit (pass one of two resamples); if the first resample passes, the second resample does not need to be taken.

A resampling strategy ordinarily should not be changed from event to event; however, it can be periodically reevaluated and changed as necessary during a background update, which would include new sample results since the previous background evaluation, and may include new wells or changes to the list of constituents monitored.

4.5.6 Confidence Intervals for Assessment Monitoring and Corrective Action Monitoring

The *Unified Guidance* recommends the use of confidence intervals for evaluating results during assessment monitoring and corrective action monitoring. A confidence interval should be constructed using at least four measurements. For a site conducting semiannual monitoring, the four samples would include the sample from the current event and the samples from the three preceding semiannual events (spanning a period of one and a half years).

During assessment monitoring, the lower confidence limit (LCL) for each constituent is compared against its GWPS to determine if a constituent is present at a statistically significant level above its GWPS. If an LCL exceeds a GWPS, corrective action is triggered, unless it is demonstrated that the statistically significant level resulted from error in sampling, analysis, statistical evaluation, or from natural variation in groundwater quality.

During corrective action monitoring, the upper confidence limit (UCL) for each constituent is compared against its GWPS to determine if a constituent remains at a statistically significant level above its GWPS. A remedy under corrective action is considered complete when the UCLs for all assessment constituents have not exceeded GWPSs for a period of three consecutive years.

5. Monitoring Frequency and Reporting Requirements

5.1 Background Monitoring [30 TAC 330.407(a)(1)]

Background refers to the data set representing groundwater quality that has not been affected by leakage from a landfill. You must collect a minimum of eight statistically independent samples quarterly from each background and point-of-compliance well and analyze them for the constituents listed in [Appendix I](#) of 40 CFR, Part 258. After the facility completes background monitoring, it must evaluate the background data to ensure that the data are representative of background groundwater quality.

You may update background data sets every two years with semiannual monitoring results (at least four measurements) that are demonstrated to be representative of background groundwater quality. You must submit background evaluation reports (BER), as well as background updates, to the TCEQ for review and approval. You should provide the Site-Wide False Positive Rate and Statistical Power for a proposed background data set and statistical evaluation plan in each BER.

5.2 Detection Monitoring [30 TAC 330.407]

After the completion of background monitoring, you must sample all monitoring wells on a semiannual basis unless another sampling schedule is approved by the TCEQ. The monitoring requirements will continue throughout the active life of the landfill and the post-closure care period. The goal of detection monitoring is to identify changes in groundwater chemistry that may indicate a release from the landfill.

Changes in groundwater chemistry are identified by statistically comparing the detection monitoring result for each constituent in each well to the established background statistical limit for that constituent. No later than 60 days after each sampling event, the facility must determine if there has been an initial exceedance over the background limit for any tested constituent. If an initial exceedance is determined at the point of compliance, the facility must notify the TCEQ and any local pollution agency with jurisdiction that has requested to be notified, in writing within 14 days. (The term “initial exceedance” refers to a monitoring result that exceeds a statistical limit but has not yet been verified by resampling.)

5.2.1 Verification Resampling [30 TAC 330.407(b)]

If an initial exceedance over a background limit is determined, the owner or operator may conduct verification resampling and submit the results within 60 days of the initial exceedance determination. The verification resampling results will confirm or disprove the initial exceedance. If an initial exceedance is verified, an SSI is declared and assessment monitoring is triggered unless an “alternate source demonstration” is submitted and approved. If a verification resample does not confirm an exceedance, routine detection monitoring may continue.

5.2.2 "Alternate Source Demonstration" [30 TAC 330.407(b)(3)]

If a statistically significant increase over a background limit of any tested constituent at any monitoring well has occurred and the owner or operator has reasonable cause to think that a source other than a landfill caused the contamination or that the statistically significant increase resulted from error in sampling, analysis, or statistical evaluation, or from natural variation in groundwater quality, then the owner or operator may submit a report providing documentation to this effect. The report is commonly referred to as an "alternate source demonstration (ASD)," but may be a demonstration of an error or of natural variation, instead of a source other than the landfill.

An owner or operator pursuing an ASD must first notify the executive director of the TCEQ (and any local pollution agency with jurisdiction that has requested to be notified) in writing, within 14 days of determining an SSI over a background limit, that the owner or operator intends to make the demonstration. The ASD must be submitted within 90 days of determining an SSI.

If the ASD is satisfactory to the executive director, the facility may continue detection monitoring. If the ASD is not satisfactory, the owner or operator must proceed with assessment monitoring.

5.3 Assessment Monitoring [30 TAC 330.409]

Assessment monitoring is required if a facility determines there has been an SSI over a background limit for one or more of the constituents. Within 90 days of determining that an SSI has occurred, the owner or operator must sample and analyze each affected well and the two wells adjacent to each affected well for the full set of constituents listed in [Appendix II](#) to 40 CFR, Part 258. After sampling for the full set of Appendix II constituents, the executive director may delete any of the Appendix II constituents.

If any new constituents are detected in the well as a result of the Appendix II analysis, a background limit must be established for the additional constituents. This background level consists of four statistically independent samples from each background well.

If the concentration of any Appendix II constituent is above its respective background limit, but below its GWPS, the facility must continue assessment monitoring. If the concentrations of all Appendix II constituents are shown to be at or below background values for two consecutive sampling events, the owner or operator may return the well to detection monitoring status, after notifying the executive director and receiving approval.

If any Appendix II constituents were detected at statistically significant levels above the groundwater protection standard, the facility must notify the executive director and appropriate local government officials within seven days of the determination.

The owner or operator will also need to characterize the nature and extent of the release, notify in writing all persons that own or occupy the land that directly overlies any part of the plume of contamination, and initiate an assessment of corrective measures within 90 days of the notice to the executive director.

5.4 Assessment of Corrective Measures [30 TAC 330.411]

Within 90 days of finding that any of the 40 CFR, Part 258, [Appendix II](#), constituents have been detected at a statistically significant level above a GWPS, the owner or operator shall initiate an assessment of corrective measures. This assessment must be completed within 180 days of initiating the assessment.

The assessment must analyze the effectiveness of potential corrective measures, including performance, reliability, ease of implementation, and potential impacts. The assessment should also discuss the control of exposure to residual contamination, time required to begin and complete the remedy, costs of remedy implementation, and institutional requirements such as state or local permit requirements that may substantially affect implementation of the remedy or remedies.

Prior to selecting a remedy, the owner or operator must discuss the results of the assessment of corrective measures in a public meeting with interested and affected parties. The facility will arrange the meeting and provide notice in accordance with the provisions of 30 TAC [39.501\(e\)\(3\)](#).

5.4.1 Selection of Remedy [30 TAC 330.413]

Within 30 days of completing the assessment of corrective measures, the facility must select a remedy and submit a report to the TCEQ for review and approval. The report must describe the remedy or remedies proposed for selection and the way it or they meet the remedy standards in 30 TAC [330.413\(b\)](#).

5.4.2 Implementation of the Corrective Action [30 TAC 330.415]

A facility must implement a corrective action groundwater monitoring program following the schedule specified for the selected remedy. The corrective action is considered complete when the concentrations of all constituents are shown to be at or below GWPSs for a period of three consecutive years.

5.5 Reporting Requirements

5.5.1 Annual Detection Monitoring Report

The results from detection monitoring events must be submitted to the TCEQ in an annual report within 90 days after the last groundwater monitoring event in a calendar year at a facility. The last groundwater monitoring event refers to a second semiannual event.

An annual detection monitoring report should include the following information:

- A discussion regarding SSIs during the calendar year and a summary of the statistical calculations.
- A summary of the groundwater monitoring events with the monitoring status of each well.

- Results of all groundwater monitoring, resampling, and analytical work produced during the sampling events for the year, including all of the following:
 - groundwater sampling results on form TCEQ-0312
 - background statistical limits and statistical analyses
 - a laboratory case narrative and [laboratory review checklist](#)
 - the chain of custody for the samples
- A contour map of piezometric groundwater levels and groundwater flow direction for each sampling event. The map should include all background wells and point-of-compliance wells.
- Recommendations for any changes or updates to the background data set or the monitoring program for the facility.
- Any other items requested by the executive director.

The entire laboratory report, which includes the laboratory quality assurance information and quality control data, and laboratory analytical data, may be provided electronically in a PDF file on a CD.

5.5.2 Semiannual Report

Although the MSW rules do not require a semiannual monitoring report, the executive director encourages owners or operators to submit a semiannual report covering the first half of the calendar year, within 74 days after the first semiannual event. If a semiannual monitoring report was submitted, the annual report should not duplicate information that was provided in the semiannual report (such as [TCEQ-0312](#), forms, results of statistical evaluations, and laboratory checklist), but should include a summary of the semiannual report.

5.5.3 Assessment Monitoring Report

The results from assessment monitoring events must be submitted no later than 60 days after each sampling event. In addition, an annual assessment monitoring report must be submitted within 60 days after the second semiannual groundwater monitoring event at a facility. The report must include a statement documenting whether any constituent was present at a statistically significant level above a GWPS during the calendar year.

5.5.4 Corrective Action Report

If a facility is performing corrective action, an annual corrective action report must be submitted by March 1 of each year.

5.5.5 Additional Information about Reporting

The TCEQ suggests submitting semiannual reports after the first semiannual groundwater monitoring event and annual reports after the second semiannual groundwater monitoring event. Assessment monitoring reports may be combined with detection monitoring reports.

Further information about meeting the reporting requirements for groundwater monitoring [30 TAC 330.405 through 330.409] is provided in the document *Guidelines for Groundwater Monitoring Reports*, available on the TCEQ website at www.tceq.texas.gov/permitting/waste_permits/msw_permits/msw_gwmon_coract.html.