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Monitoring wells will be constructed using 2-in diameter, flush-threaded PVC casing. The screen length will be up to 5 ft with continuous slot openings of 0.010 in and a PVC plug on the bottom of the screen. The annular space around the screen will be back-filled with silt free silica sand (WB 40 grade) to a height no more than 2 ft above the top of the screen. A minimum 2-ft thick seal of hydrated bentonite will be placed above the sand pack. The remaining annular space will be filled with a cement bentonite grout placed with a tremie pipe. The PVC riser will be covered with a lockable, watertight PVC cap. A 4-in diameter galvanized steel, locking, protective casing will be installed at the surface with a concrete anchor and runoff diversion apron.

Once installed, the grout will be allowed a minimum of 24 hr to cure after which time the well will be developed. Well development will be performed using the pump and surge method. A minimum of five casing volumes will be removed from the well or until the well is pumped to dryness.

5.1.5 Monitoring Well Abandonment Procedures

This procedure will be used for abandoning of monitoring wells at the Coldwater Road Landfill Facility. MDEQ approval is required prior to performing monitoring well abandoning. The wells will be abandoned in accordance with Part 111 Rule 299.9612 (1)(b), methods outlined in this Plan, or per an approved work plan. Two methods may be used in accordance with this Rule to abandon a well. The first method involves over drilling and removal of the well materials and pressure backfilling the open hole with a cement/bentonite grout. The second method involves using a tremie pipe to pressure inject the cement/bentonite grout mixture into the well with the well materials left in place.

The preferred method for abandoning deep double-cased wells is to leave the well materials in place, except for the above ground riser and protective casing, and pressure grouting the well from the bottom to ground surface. The method for abandoning shallow wells will be determined by a geologist. The geologist will review monitoring well construction details and soil boring logs to assess whether the well intersects more than one water-bearing unit. The well will either be over drilled, well materials removed and filled with a cement bentonite grout or filled in place with a cement bentonite grout. Above ground materials (riser and protective casing) will be removed to approximately 2 ft below grade.

These procedures were implemented to abandon two wells (MW-25 and MW-26) at the conclusion of four quarters of sampling in which analytical data indicated four quarters of results below the groundwater/ surface water interface criteria. The MDEQ issued a letter dated September 7, 1999, approving the termination of groundwater sampling of these wells and approved the abandoning of these wells. The wells were abandoned in accordance with the above discussion for shallow wells by removing well materials and cement/grouting the hole.

These procedures were also implemented in the abandonment of monitoring wells B-14, B-29 and B-30 as approved by the MDEQ in their letter dated April 9, 2008. Monitoring well B-14 was over-drilled and the borehole was grouted because of the longer than normal sand pack. Wells B-29 and B-30 were pressure grouted in place.

5.1.6 Benchmark and Monitoring Well Top of Casing Surveying

The top of casing elevations will be established by a licensed land surveyor for new monitoring wells installed in accordance with Section 5.1.4 following installation and prior to their use for the construction of groundwater contour maps for the site. As part of this surveying effort the benchmark or benchmarks (a.k.a., witnesses) utilized to provide control for the top of casing elevation survey will be inspected and surveyed.

In addition, the benchmark(s) and the top of casing elevations for the wells that are part of the groundwater monitoring program, which currently include the following 13 wells: B-2D, B-7, B-9, B-18A, B-19A, B-19Ar, B-20D, B-21D, B-22D, B-23Dr, B-24r, B-27D, and B-28 will be re-surveyed by a licensed land surveyor at a minimum frequency of once every five years. The new top of casing elevations will be utilized in the construction of groundwater contour maps subsequent to the re-surveying event.

5.2 ANALYTICAL PROCEDURES AND SAMPLING FREQUENCY

Groundwater sampling is currently conducted semi-annually, but is subject to change with MDEQ approval.

Groundwater samples will be analyzed for pH, specific conductivity, total organic carbon (TOC), total organic halogen (TOH), and dissolved copper, nickel, zinc, and chromium. In addition, one set of samples per year will also be analyzed for the standard list of parameters specified in 40 CFR Part 265, which includes; chloride, sodium, dissolved iron and manganese, phenols, sulfate, cyanide, and volatile organic compounds. Analytical methods and sampling frequencies are provided in Table 4. Sample handling information is included on Table 5.

5.3 GROUNDWATER SAMPLING PROCEDURES

5.3.1 Groundwater Sampling

Samples will be collected after each well has been purged and field parameters measured. Water sample portions will be filtered and/or preserved in accordance with 40 CFR 136 as promulgated by USEPA on October 26, 1984. The filtered sample portions will be filtered through a disposable 0.45-micron filter in the field. Pre-preserved (with HNO^3) sample containers will be provided by the laboratory for appropriate sample parameter analysis. Purging, field parameter measurements, and sampling procedures are described in detail in the following sections.

5.3.2 Well Purging

The water standing in a well prior to sampling may not be representative of in situ groundwater quality. The "Low Stress/Low Flow" purging and sampling method will be utilized to purge the well to allow representative water from the formation to replace the standing water within the sampling zone of the well (*i.e.*, within the well screen). Purging will be conducted using a submersible or peristaltic pump. During purging, specific conductivity, pH, temperature, oxidation-reduction potential (ORP), dissolved oxygen (DO) and turbidity measurements will be monitored and recorded approximately every 5 minutes to document stable conditions. A steady state flow rate (typically between 100 and 500 ml/minute) should be maintained that results in a drawdown of 0.3 ft or less, and care should be taken to avoid the entrainment of air in the pump intake. Adjustments to the pumping rate and the resulting water level (*i.e.* drawdown) will be recorded after each adjustment.

If drawdowns of 0.3 ft or less cannot be maintained because of the permeability of the formation at a particular well location, "ultra-low flow" purge techniques will be employed. Ultra-low flow purge rates are rates below 100 ml/min. However, if ultra-low flow purging still results in the well purging "dry," the well will be allowed to recharge and the sample will be collected as soon as sufficient water is present to obtain the necessary sample volume.

5.3.3 Field Parameter Measurement

Analyses for specific conductivity, pH, temperature, oxidation-reduction potential (ORP), dissolved oxygen (DO) and turbidity will be completed in the field during purging and prior to sampling of the well using field multi-parameter meters and flow-through cells.

Field meters to be used during purging (*i.e.*, multi-meters capable of measuring specific conductivity, pH, temperature, ORP, DO and possibly turbidity [turbidity may be monitored by a separate meter if necessary]) will be checked for proper calibration and precision using appropriate buffer solutions in accordance with the manufacturers recommendations. The preparation date of standard solutions will be clearly marked on each of the containers to be taken into the field. Calibration records for each meter will be recorded in the dedicated field notebook for the facility. Entries will include problems potentially experienced with the meter, corrective measures taken, battery replacement dates, when the meter was used and the operator.

5.3.4 Procedures for Sampling Wells

Prior to groundwater sampling, an inspection will be performed on each well. The inspection will include:

- Inspecting the concrete pad for cracks
- Inspecting the protective steel cover
- Inspecting the integrity of the PVC well casing (to the extent possible)

- Inspecting the well caps
- Inspecting the well identification markings to confirm they are legible (if illegible, re-mark)
- Inspecting the locks to assess whether they are in good working condition.

Results of the well inspection will be documented on the Groundwater Sampling Log (Appendix C) for each well. If the inspection indicates repairs are required, these will be performed prior to the next sampling event. Corrective actions implemented to repair well(s) will also be documented on the Groundwater Sampling Log and/or the field notebook for the facility.

Groundwater purging and sampling data will be recorded on the Groundwater Sampling Log.

The procedure for sampling the monitoring wells is as follows:

1) Sampling equipment will first be decontaminated prior to each use by the following protocol:
   - Scrub equipment thoroughly in a low-sudsing detergent solution (*e.g.*, Alconox). Pump low-sudsing detergent solution through submersible pump for approximately 5 minutes, if utilized
   - Rinse equipment thoroughly with distilled water, and pump distilled water through submersible pump, if utilized
   - Wrap equipment in plastic for handling and/or storage until next use
   - Decontamination of disposable tubing, if used, will not be necessary
2) An electric water level probe will be used to measure the depth from the top of the casing to the top of water to the nearest 0.01-ft. The measurement will be recorded in a dedicated field notebook and Groundwater Sampling Log
3) Measure the depth from the top of casing to the bottom of the well for the initial sampling event
4) Slowly lower the pump and/or tubing into the well positioning the pump intake at the mid-point of the well screen taking care to minimize disturbing the well.
5) Purge the well using low-flow purging techniques utilizing a submersible or peristaltic pump. During purging, measure the specific conductivity, pH, temperature, ORP, DO and turbidity and recorded approximately every 5 minutes to document stable conditions. The parameters will be considered stable once the readings are within ±3 percent for specific conductivity and temperature, ±0.1 units for pH, ±10 millivolts for ORP, and ±10 percent for DO and turbidity.
6) Verify that drawdowns of 0.3 ft or less are maintained and make adjustments as necessary. Record drawdown measurements and note adjustments in pumping rates as necessary on the Groundwater Sampling Log. If drawdowns of 0.3 ft or less cannot be maintained utilize ultra-low flow purge techniques. However, if ultra-low flow purging still results in the well purging "dry," allowed the well to recharge and the sample will be collected as soon as sufficient water is present to obtain the necessary sample volume.
7) Obtain a sample for chemical analyses immediately upon stabilization of field parameter measurements. Field filter the sample for dissolved metals using a 0.45-micron filter prior to preserving with acid. Samples are to be collected in the order of volatility as follows: TOC/TOX (or VOCs) and dissolved metals.

Either a decontaminated submersible pump or peristaltic pump (for shallow wells only) may be utilized to purge each well. If a submersible pump is utilized in the purging process, then it will be decontaminated prior to and after sampling each well. Sampling equipment must be protected from the ground surface by a clean plastic sheet laid around the work area. Water from purging will not be containerized.

Monitoring wells that consistently have final turbidity values of greater than 10 NTU after low flow sampling for at least three consecutive sampling events will be redeveloped unless previously redeveloped within the last three years. Wells will be redeveloped in accordance with the March 17, 2008 letter to the MDEQ as approved via e-mail on March 19, 2008 (Exhibit 4).

5.4 SAMPLE PRESERVATION

Sample bottles will be labeled with sample identification, collection date and time, filtration/preservative status. Sample bottles will be filled and capped securely and immediately preserved (if required) and stored at 4 degrees Celsius in a cooler.

The cooler and samples will be prepared for shipment or transport by the following procedure:

1) Prepare cooler(s) for shipment.
   - Tape drain(s) of cooler shut
   - Place mailing label with laboratory address on top of cooler(s).
2) Arrange sample containers in a manner to prevent potential sample container breakage.
3) Confirm the bottle labels are completed correctly. Place clear tape over bottle labels to prevent moisture accumulation from causing the label to peel off.
4) Seal sample containers within plastic zip-lock bags to prevent packing material from contacting samples.
5) Place packing material at the bottom of the cooler to act as a cushion for the sample containers.
6) Fill remaining spaces with packing material.
7) Confirm containers are firmly packed in cooler.
8) If ice is required to preserve the samples, cubes should be repackaged in double zip-lock bags, and placed on top of the packing material.
9) Sign COC form (or obtain signature) and indicate the time and date it was relinquished to Federal Express or other carrier, as appropriate.
10) Separate copies of COC forms. Seal proper copies within a large zip-lock bag and tape to inside lid of cooler. Retain copies of forms in-house.
11) Close lid and latch.
12) Tape cooler shut on both ends, making several complete revolutions with strapping tape.
13) Relinquish to Federal Express or other courier service. Retain airbill receipt for project records (Note: Samples will be shipped for "NEXT DAY" delivery).

If samples are delivered directly to the laboratory by the sampling team, the packaging/shipping requirements may be omitted. COC procedures, however, must be strictly maintained.

5.5 SAMPLE MANAGEMENT AND CHAIN-OF-CUSTODY

COC procedures document the history of sample containers and samples from the time of preparation of sample containers through sample collection, shipment, and analysis. A sample is considered in custody if:

- The sample is in the sampler's physical possession
- The sample is secured by the sampler to prevent tampering
- The sample is secured by the sampler employee in an area that is restricted to authorized personnel

To maintain a record of sample collection, transfer between personnel, shipment, and receipt by the laboratory, a COC record will be completed for each sample at each sampling location. Each time the samples are transferred, signatures of the person relinquishing and receiving the samples, as well as the date and time, will be documented. A blank example COC record is provided in Appendix D.

Parallel field notebook and COC records will be maintained. Recorded information will include:

- Sampling Location
- Time and Date
- Sampling Method
- Method of Preservation

Additionally, the field notebook will also include information on weather conditions, depth to water, TD of the well, field parameter and instrument calibration records and other useful or pertinent information. The notebook will be kept at the facility or with their designated contractor.

5.6 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) MEASURES

Field QA/QC procedures will consist of collecting one equipment blank (if reusable equipment is used) and one duplicate sample (one additional sample from one of the wells) for each sampling event. The duplicate sample will be assigned a separate sample identification and submitted to the laboratory "blind".

The procedure for collecting an equipment blank will be to pass distilled water through the decontaminated sampling device into a laboratory-supplied sample bottles. An equipment blank sample will not be required if disposable sampling equipment is used.

5.7. REPORTING REQUIREMENTS

5.7.1. Submittals

A semi-annual, unless an alternative frequency is approved by MDEQ, and annual report will be issued summarizing the monitoring data. Each submittal will consist of:

- Preparation of a potentiometric surface contour map based on representative groundwater surface elevations from each well
- Confirmation of groundwater flow direction(s) from that map
- Documentation of sampling and procedures, COCs and groundwater sampling logs
- Analytical results from laboratory analyses and field measurements
- Statistical testing of pH and specific conductance and dissolved metals as compared with historical measurements. The statistical analysis and control charts will be reported in each report submittal.
- Summary of field and analytical QA/QC data and usability of the data generated.
- Tables summarizing analytical results.

The semi-annual report, unless an alternative frequency is approved by MDEQ, will be submitted to the MDEQ no later than September 1st and the annual report will be submitted no later than March 1st of the following year. A certification statement in compliance with 40 CFR 270.11 will be included with each report submittal.

5.7.2 Statistical Evaluations

Standard RCRA requirements include performing a statistical evaluation of indicator parameters for each round of sampling to determine if there has been a statistically significant increase (or pH decrease) over background. Statistical evaluations used at this site included both the CABF t-test and the Average Replicate t-test for evaluating changes in indicator parameters. During the interim status detection monitoring, a number of indicator parameters consistently tested positive *(i.e.*, a statistically significant increase over background) for various wells including the background well. Subsequent groundwater quality assessment work showed that the standard statistical evaluation approaches are not appropriate for site conditions, therefore, resulting in a high number of false positives.

To mitigate this problem during post-closure monitoring, RACER will use Shewart control charts to analyze the detection monitoring groundwater quality data. The use of control charts for RCRA monitoring is an approved alternative by USEPA (USEPA, 1992). Parameters to undergo statistical analysis will be pH, specific conductance and dissolved copper, nickel, chromium, and zinc.

For replacement wells new to the current monitoring well network sampled, a background data-set will be developed. In accordance with USEPA guidance, the background data-set will include 8 quarters of sample analysis for use in subsequent statistical analysis (1992. *USEPA Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance*. Office of Solid Waste.).

However, assigning a constant value (*i.e.*, one half the detection limit) to non-detects in the baseline data set compromises the underlying assumptions of the control charts, therefore, non-detect background data for the vaults were replaced using a bounding method or randomized replacement method as described in our April 21, 2006 letter to MDEQ (Exhibit 1), which was approved by the MDEQ in their May 19, 2006 response letter (Exhibit 2). In general, this involves randomly selecting a number between zero and the detection limit 10,000 times for each non-detect background result and utilizing the mean of the randomized values to replace the non-detect value.

Originally (1995) the methodology discussed and recommended in the paper by Sparks and Flatman (1991) was used to set up and operate the control charts. This procedure involves the simultaneous use of Shewart and CUSUM charts. The Shewart charts detect medium to large shifts in the mean of a random Gaussian process. The CUSUM charts detect small shifts in the mean of a Gaussian process. However, the CUSUM control charts are no longer plotted because the high sensitivity of the CUSUM control charts causes too many false positive outcomes, which persist for long periods of time. The Shewart control charts allow the detection of changes in indicator parameters that are tailored to the individual differences seen in each parameter at each leak detection vault.

Shewart charts are fairly robust with respect to the assumption of normality (Gaussian distribution) if the data comes from sampling a random quantity that has a symmetric distribution.

It is assumed that the analytical data from the monitoring wells is normally distributed. However, environmental data are frequently non-normally distributed and control charts that are produced under the assumption of normality are still a useful tool when the data has a non-normal distribution (Gilbert, 1987). Control charts are not used to make precise probability statements, but are used as a guide for when investigative action needs to be taken; therefore, use of a symmetrizing transformation, such as the log or square root, on the original data is unnecessary. [2]

As recommended in the USEPA guidance, the Shewart charts will use 4.5 limits and the two-in-a-row rule. The limits for pH differences will be two-sided; all other parameters will have one-sided limits. The two-in-a-row rule used in this application specifies that if a chart control limit is exceeded, the monitoring well in question will be re-sampled. A critical exceedance will be deemed to have occurred if the 4.5 limit is also exceeded on the resample. This is also consistent with requirements using the standard statistical evaluation methods. This provides reasonable protection against outliers due to trace level analytical chemistry errors. Occasional large errors in trace level analysis of environmental samples are possible. Furthermore, outliers as identified utilizing the Grubbs test, or other appropriate test, may be removed from the data if a valid demonstration as to why a datum is an outlier can be made and is approved for removal by the MDEQ. A request to remove an outlier will be made to the MDEQ prior to its removal, and the MDEQ will evaluate the request and either approve or deny the removal of the outlier.

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[2] Gilbert, Richard O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold Company Limited, New York, New York.

Following each semi-annual sampling event, the monitoring well data will be entered into Microsoft® Excel spreadsheet. RACER will use this software to perform the computations and to produce the plots. Each plot will include a print out of chart parameters used in its construction and will both highlight and list points that trigger an out-of-control indication.

A decision tree (Exhibit 3) was developed to guide the evaluation of the monitoring well data to avoid unnecessary re-sampling events, while maintaining the essential purpose of the monitoring program – identifying potential leaks from the landfill. The decision tree will guide the evaluation of the monitoring data, MDEQ notification and re-sampling events.

If there is a Shewart control limit exceedance (*i.e.*, an out-of-control parameter) and this is not an historical exceedance of the control limit, then the MDEQ will be notified immediately and the well will be re-sampled for the parameter exceeding the control limit. If the Shewart control limit is not exceeded or the exceedance is a historical (*i.e.*, continuing) exceedance caused by an earlier result, then the data will be plotted as discussed below.

The data will also be plotted on a simple chart to visually identify whether an increasing trend is observable, and a comparison of the four metals monitored on a semi-annual basis will be made to see if more than one metal concentration is increasing in a similar pattern or spiked in concentration at the same time. If both of the above evaluations result in a null (*i.e.*, negative) hypothesis (no exceedances and no spikes or trends), then the semi-annual or annual monitoring report will be submitted to the MDEQ with a discussion of the statistical and graphical analysis used to conclude that no impact to groundwater (*i.e.*, leak from the landfill) has occurred, and routine semi-annual monitoring will continue for that monitoring well.

If two or more metals spiked at the same time at a concentration greater than their respective mean concentrations (as calculated on the statistical analysis spreadsheets), plus one standard deviation (*i.e.*, a spike is confirmed), or there is a consistent observable increasing trend in the data over a four sampling event period, then the semi-annual or annual monitoring report containing the confirmed spike or consistent trend will be submitted to the MDEQ with a summary of the preliminary evaluation and a notification that further evaluation will be conducted.

The further evaluation will include plotting all of the indicator parameter data (*i.e.*, pH, conductivity, temperature, chromium, copper nickel and zinc) for the monitoring well in question and the associated leak detection vault and sump closest to the well in linear and log scales so a detailed comparison of the concentrations can be evaluated. The concentrations of the different parameters will be compared and contrasted for the well data, then the vault and sump data and finally between the well and the vault and sump data to evaluate whether spikes and/or trends in the data are observable such as a matching rise or fall in parameter concentrations or spikes in well, vault and sump data. However, re-sampling will not be conducted.

If upon further evaluation the detection indicates a potential leak from the landfill, the MDEQ will be immediately notified and the results of the further evaluation will be summarized in a letter report and submitted to the MDEQ within 60 days following the submittal of the corresponding semi-annual or annual monitoring report containing the exceedance, and the leak detection system will be further evaluated and corrective measures may need to be taken. In addition, a Work Plan will be prepared to evaluate liner integrity or other options as appropriate. This Work Plan will be prepared and submitted to the MDEQ within 60 days of confirmation of the potential leak from the landfill. Following completion of the investigation or corrective actions, a Professional Engineer certified report will be submitted to the MDEQ.

If the further evaluation does not indicate a leak from the landfill, then the results of the further evaluation will be summarized in a letter report and submitted to the MDEQ within 60 days following the submittal of the corresponding semi-annual or annual monitoring report containing the exceedance and routine semi-annual monitoring will be continued.