

APPENDIX L

DEVELOPMENT OF OPERATIONAL PARAMETERS FOR SVE SYSTEM

Development of Operational Parameters for SVE System

Page-Trowbridge Ranch Landfill

Pinal County, Arizona

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DEVELOPMENT OF OPERATIONAL PARAMETERS FOR SVE SYSTEM

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Pinal County, Arizona

1.0 INTRODUCTION

AMEC Environment & Infrastructure (AMEC) prepared this document for the University of Arizona (UA) in regard to the Resource Conservation and Recovery Act (RCRA) Part B permit application for the Page-Trowbridge Ranch Landfill (Landfill). The purpose of this document is to present the methodology and results of developing operational parameters for the existing soil vapor extraction (SVE) system at the Landfill. The operational parameters for the SVE system are incorporated into the Expanded Groundwater Detection Monitoring Plan for the Landfill and the Operation and Maintenance Manual for the SVE system (O&M Manual).

2.0 BACKGROUND

The existing SVE system, consisting of two SVE wells (SGS-Well and SGD-Well) and an activated carbon vapor treatment system, was installed at the Landfill in June 2006 as an interim measure. Typically, soil vapor is extracted from well SGS-Well, while air is injected at well SGD-Well. The SVE system is powered by solar panels, and therefore operates for an average of 10 hours each day throughout a year. Details of the SVE system are presented in the O&M Manual. The SVE system operated infrequently between June 2006 and November 2006, stopped operating in June 2007 due to mechanical problems, and resumed operation in November 2008 after repairs were made. Operating the SVE system is not required by the current RCRA permit issued by the Arizona Department of Environmental Quality (ADEQ) on November 6, 2001. ADEQ has requested that, during the permit renewal process, UA evaluate whether continued operation of the SVE system is necessary and if so, incorporate operational parameters in the RCRA permit renewal application.

On May 2, 2011, AMEC, on behalf of UA, submitted a memorandum to ADEQ to propose an approach to developing operational parameters for the SVE system, which consists of using an existing three-dimensional (3D) numerical vapor flow and transport model to assess SVE operational parameters. ADEQ provided their comments on the proposed approach via email on May 10, 2011. ADEQ agreed with the overall approach of using the numerical model to develop operational parameters, but expressed concerns that any changes to the model may result in conflicting conclusions from previous modeling work. A conference call was held between the Arizona State Risk Management (State Risk), UA, ADEQ, and AMEC on May 17, 2011 to discuss ADEQ's comments. On June 6, 2011, AMEC submitted to ADEQ a second memorandum that described the model validation results and provided a list of proposed predictive simulation runs. State Risk, UA, ADEQ, and AMEC

held a conference call on June 7, 2011 to review ADEQ's comments on the June 6 memorandum. ADEQ's comments on both memorandums were addressed to the extent possible in the modeling work. This report was first submitted with the RCRA permit application in July 2011. ADEQ provided comments on the submitted report in a letter dated November 10, 2011. University of Arizona and AMEC discussed these comments with ADEQ during a meeting on November 21, 2011. ADEQ provided additional comments in the Request for Additional Information dated April 12, 2012. These comments are addressed in this report to the extent possible.

3.0 NUMERICAL MODEL AND MODEL VALIDATION

3.1 NUMERICAL MODEL

Development and calibration of the existing 3D vapor flow and transport model is described in the Interim Measures Investigation Report (Hydro Geo Chem, Inc. [HGC], 2004). The 3D numerical model (HGC's model) was developed by HGC using the MODFLOW-SURFACT code (Hydrogeologic, 1996), which is a comprehensive, block-centered finite difference code based on the United States Geologic Survey modular groundwater flow code MODFLOW (McDonald and Harbaugh, 1988). MODFLOW-SURFACT offers a variety of enhanced simulation capabilities, including soil vapor flow and contaminant transport in vapor phase. The horizontal domain of the three-dimensional model covers a 3,000 acre area (12,000 ft by 12,000 ft) centered on the Landfill. The vertical domain covers the vadose zone between ground surface and water table. Trichlorofluoromethane (Freon-11) was used as indicator volatile organic compound (VOC) during calibration. This compound has the highest concentrations in soil vapor samples, and also has one of the highest Henry's Law constants among the VOCs detected in soil vapor. HGC calibrated their model assuming that the vapor concentrations at the two landfill units, Units A and B, remained constant between 1968 and 2003.

Electronic files for the HGC's model were provided to AMEC by HGC (Tucson, Arizona) in the form of Groundwater Vistas (GWV) file, which is a commercial graphical user interface for MODFLOW family of models (Environmental Simulations, Inc., Reinholds, Pennsylvania). Groundwater Vistas (Version 5.43 Build 4) continues to be used as graphical user interface for this work. The GWV file for Simulation 7 in the Interim Measures Investigation Report (HGC, 2004) was used as the starting point for this work, because this scenario simulates one shallow extraction well and one deeper injection well, same as current SVE operation. As requested by ADEQ, no attempt was made to re-evaluate or re-calibrate HGC's model. Instead, HGC's model was validated to verify its ability to reasonably simulate vapor flow and VOC transport under advection-dominated conditions as a result of SVE operation. This is important because prior model calibration was based on analytical data collected under diffusion-dominated conditions prior to SVE operation. Following validation, the model is used to develop operational parameters for the SVE system through predictive simulations.

During model validation and predictive simulations, model domain, grid cell size, number of grid cells, number of layers, layer thickness, and flow and transport parameters remain the same as HGC's model. Table 1 presents the layer thickness and bottom elevation of each layer. Layer 1 is used to represent a constant head boundary at atmospheric pressure. The constant head boundary condition in layer 1 remains unchanged in model validation and predictive simulations. Layer 2 is used to prescribe concentration boundary conditions to represent sources of VOCs. The concentration boundary condition in layer 2 is varied in model validation and prediction simulations. Table 1 also presents the zone number for flow and transport parameters for each layer. Table 2 presents the hydraulic conductivity and corresponding intrinsic permeability values for each zone. Same as HGC's model, parameter value is assumed to be uniform within each layer. Instead of a fixed time step size, MODFLOW-SURFACT's automatic time-stepping (ATO) package is used to control time step size, which varies through simulation depending on how easy convergence is obtained.

HGC's model began with an initial concentration of zero everywhere in the subsurface, and simulated VOC diffusion through a 35-year period (between 1968 and 2003). The simulated concentrations at the end of HGC's model calibration (i.e. end of 2003) were used as the initial concentrations for model validation, which simulates 2004 through 2010. The simulated concentrations at the end of model validation (i.e. end of 2010) were used for predictive simulations.

Same as previous modeling effort, the models described in this report consider only the flow of vapor and contaminant transport in the vapor phase through advection and diffusion. Liquid flow and contaminant transport in the liquid phase are beyond the scope of the modeling work described in this report.

3.2 MODEL VALIDATION

Freon-11 continues to be used as indicator VOC in model validation. The following changes were made to HGC's model:

- The simulation period is set to between January 2004 and November 2010.
- Initial concentrations are set to simulated concentration distribution at the end of HGC's model calibration (December 2003). The initial concentrations for model validation are plotted in plan view (Figure 1A) and in cross-sections (Figure 1B).
- Wells SGS-Well and SGD-Well are represented using the MODFLOW-SURFACT WEL package; the WEL package for well SGS-Well is active in layers 7, 10, and 11, while the WEL package for well SGD-Well is active in layers 20 through 27. Although the screen interval of SGS-Well corresponds to layers 6 through 11, as shown in Table 1, layers 6, 8, and 9 are in silt unit, while layers 7, 10, and 11 are in sand unit. Because it is expected that extracted vapor mainly comes from the sand unit, extraction rate is distributed to layers 7, 10, and 11.

- Extraction and injection rates for each period are set to the average extraction and injection rates based on SVE operation records, by dividing cumulative volumes by elapsed time; therefore, the extraction and injection rates used in the model take into account that the SVE system only operates during a portion of a day. The extraction and injection rates are evenly distributed between layers where WEL package is active. The extraction and injection rates (in standard cubic feet per minute [scfm]) used in the model are presented in Table 3.

The validation targets are Freon-11 concentrations in soil vapor samples collected from soil vapor monitoring points as well as SVE system influent between December 2003 and November 2010. Most soil vapor samples were collected while the SVE system was operating. Because of the inherent variability in VOC measurements in soil vapor, attention is paid to whether the model can reproduce the magnitude and general trends of the observed data, rather than matching each data point. Similar approach has been used in other studies (Stauffer et al., 2007).

The only parameters that were adjusted during model validation are the constant concentration boundary conditions in layer 2. Horizontally, layer 2 is divided into three areas: footprint of Unit A, footprint of Unit B, and remaining area outside landfill footprint. In HGC's model, non-zero constant concentrations were specified for Unit A and Unit B through model calibration. During model validation, it is discovered that if the constant concentrations for Unit A and Unit B remain unchanged from HGC's model, the simulated concentrations at the monitoring points and in SVE influent poorly match the observed data, and are generally over-predicted (Figure 2). On the other hand, assigning a value of zero to source concentrations at Unit A and Unit B through the validation period leads to a better match to the validation targets (Figure 2). Assuming zero source concentrations in model validation also gives a better match to the amounts of Freon-11 removed from SGS-well based on SVE operation records, as presented in Table 4.

It should be noted that the use of constant source concentrations and zero source concentrations are both approximations for the process of VOC release from landfill waste. For example, constant source concentrations have been used by other modeling studies (e.g. Stauffer et al., 2007) to represent slow release of VOC vapor from waste. In reality, it is unlikely for the rate of VOC release to remain constant over decades or decrease to zero over a short period of time. Therefore, the need to adjust source concentrations to zero during model validation should be interpreted as suggesting that the rate of VOC release from waste is likely decreasing over time.

It is also noted that the match between simulated and observed concentrations at well SGD-DP are not as good as the other monitoring points. This is likely due to subsurface heterogeneity that is not captured by the model. As described in the HGC (2004), the model was constructed as a representative soil column from ground surface to water table. Subsurface conditions (e.g. water

content, porosity) in the vicinity of SGD-DP that differs from what is represented in the model likely contribute to such discrepancies between simulated and observed data.

In summary, the 3D numerical model is able to reasonably reproduce the behavior of VOC concentrations in vadose zone at various depths under advection-dominated condition as a result of SVE operation, requiring only adjustment to the source concentrations. Based on the model validation, the 3D model is considered appropriate to use for developing operational parameters for the SVE system.

HGC's model uses non-zero constant source concentrations for Unit A and Unit B to simulate the diffusion of Freon-11 from the landfill to the vadose zone over 35 years (1968 through 2003). The simulated concentrations at the end of HGC's model simulation (i.e. for December 2003) are used as initial concentrations for the validation model (2004 through 2010), which simulates the advective transport and diffusion of Freon-11 between 2004 and 2010. In the validation model, source concentrations are specified as zero in order to match the trends of observed data. The simulated concentrations at the end of model validation (i.e. end of 2010) are used as initial concentrations for predictive simulations. However, source concentrations are not specified as zero in predictive simulations.

It is recognized that due to advection flux of soil vapor, the simulated concentrations at the end of model validation are likely lower than vapor concentrations that would be in equilibrium with solid and liquid phases. If the SVE system were not operating at the end of the validation period, the vapor extraction and air injection would be deactivated in the validation model to allow the vapor concentrations to reach "equilibrium" with solid and liquid phases. However, since the SVE system has been operating until the end of validation period, the "equilibrium" vapor concentrations would not be appropriate to use as initial concentrations for predictive simulations, as they would not represent the actual subsurface conditions.

4.0 APPROACHES TO DEVELOPING SVE OPERATIONAL PARAMETERS

Based on discussions with ADEQ, because of the potential for existing VOCs in vadose zone soil vapor to migrate downward, the SVE system is expected to continue operating for the time being to control downward migration of VOCs in soil vapor. In addition, ADEQ would like to have some thresholds established such that additional actions can be implemented to assess whether groundwater is being protected. The operational parameters for the SVE system include:

- Minimum operation requirements, including
 - Minimum extraction/injection rates; and

- Maximum length of shutdown;
- Operation strategy; and
- Thresholds for implementing additional actions.

The model used for predictive simulations is identical to the validated 3D numerical model, except that the following parameters are adjusted to address each individual scenario.

- Simulation period
- Source locations and concentrations
- Extraction and injection rates

4.1 MINIMUM OPERATION REQUIREMENTS

The approach to developing the minimum operation requirements is to adjust operational parameters in the numerical model and assess the SVE system's effectiveness in (1) protecting groundwater quality and (2) detecting new releases in the landfill. Freon-11 continues to be used as indicator VOC in these predictive simulations.

4.1.1 EFFECTIVENESS IN PROTECTING GROUNDWATER QUALITY

To assess whether operating the SVE system at the minimum requirements is protective of groundwater quality, the simulated Freon-11 concentrations in soil vapor at a few virtual monitoring points above groundwater table are compared to a vapor concentration that is indicative of potential impact to groundwater quality. The virtual monitoring points are located at distances between 0 and approximately 1000 feet from the landfill units on all four directions (Figure 3). The virtual monitoring points are located in the bottom layer between 620 and 645 feet bgs. Therefore, simulated concentrations at the virtual monitoring points represent the average concentrations within 25 ft immediately above water table.

The Freon-11 vapor concentration used to assess protectiveness of groundwater is calculated based on the water quality standards for the COCs and their percentage mass in soil vapor used in the Preliminary Screening Risk Assessment (HGC, 2005), as presented in Table 5. Water quality standards include Arizona Water Quality Standards (AWQS) and State of California maximum contaminant levels (MCLs). Because Freon-11 does not have an AWQS, the California MCL of 150 µg/L is used. For each COC, for example chloroform, its water quality standard (100 µg/L) is first converted to a chloroform vapor concentration of 15 mg/m³ using its Henry's law constant. The vapor concentration is then converted to a Freon-11 vapor concentration of 24 mg/m³ based on percentage mass. This approach is considered conservative because it does not take into account dilution of VOCs in groundwater as a result of mixing in groundwater. In other words, even if pore water that

enters groundwater contains COCs at concentrations equal to their water quality standards, the concentrations in groundwater will likely be lower than water quality standards because the COCs would be diluted in the groundwater mixing zone.

As shown in Table 5, the lowest Freon-11 vapor concentration that corresponds to pore water concentrations of the COCs equal to their water quality standards is 24 mg/m^3 . The simulated vapor concentrations at the virtual monitoring points from the predictive simulations are compared to this value to assess their effectiveness in protecting groundwater quality. This value of 24 mg/m^3 is conservatively low because the percentage mass of Freon-11 in deep vadose zone (e.g. SGD-DP) is around 90%, higher than the 53.8% used in Table 5. For example, using a percentage mass of 90% for Freon-11 and a percentage mass of 4% for chloroform, an aqueous phase chloroform concentration of $100 \text{ } \mu\text{g/L}$ corresponds to a Freon-11 vapor concentration of 350 mg/m^3 , instead of 24 mg/m^3 . It should be stressed that the Freon-11 concentration of 24 mg/m^3 is for the purpose of comparing the effectiveness of simulated SVE operations, and should not be interpreted as a compliance limit.

4.1.2 EFFECTIVENESS IN DETECTING NEW RELEASES

To assess whether operating the SVE system at the minimum requirements will be effective in detecting new releases in the landfill, a remote release is simulated by assigning a constant concentration boundary condition to one model cell in the southwestern corner of Unit B. This location is selected because it is furthest away from the extraction well SGS-Well. The simulated remote release is located in Unit B because:

- Waste disposal at Unit B commenced earlier than Unit A (late 1960s versus 1982).
- Unit A is lined and received containerized waste only, whereas Unit B is mostly unlined and had received direct disposal of waste.

Freon-11 continues to be used as the indicator COC. In order to simulate a release that potentially impact groundwater quality, the source concentration is set at $5,188,000 \text{ mg/m}^3$, which corresponds to Freon-11's saturated vapor concentration. The simulated concentrations at the end of model validation are used as initial concentrations. The simulation is run for 100 years. The following simulation outputs are obtained for 10, 25, 50, and 100 years after release commences:

- Concentrations at each monitoring point;
- Concentrations at SGS-Well to represent SVE influent; and
- Highest concentration in each layer.

These concentrations are plotted against time. Because using Freon-11's saturated vapor concentration as source concentration invalidates the percentage mass assumption, the indicator

concentration of 24 mg/m^3 , as described in Section 4.1.1, is no longer appropriate. Instead, the equilibrium soil vapor concentration to Freon-11's water quality standard (as in Table 5), 596 mg/m^3 , is used as the indicator for groundwater quality impact. If concentration signals are detected at the monitoring points or in the SVE influent much sooner than the concentration in the bottom layer (i.e. within 25 ft of water table) approach a concentration of 596 mg/m^3 , operating the SVE system at the minimum requirements is deemed effective in detecting new releases.

It should be noted that the intent of this simulation is not to evaluate under what scenarios groundwater quality may be impacted or to develop mitigation measures. Rather, the purpose is to assess when the SVE system is operating at the minimum requirements, whether the existing soil vapor monitoring points and SVE influent will be able to detect a release at a remote location before impact to groundwater quality occurs. Although the simulated scenario may result in potential impact to groundwater quality, the simulated release represents an extreme condition that is not likely to be encountered in reality.

4.2 OPERATION STRATEGY

As the SVE system is designed, well SGD-Well can be used as either an air injection well or a vapor extraction well, while well SGS-Well can only be used as a vapor extraction well. The SVE system has two operation modes: extraction-injection mode where soil vapor is extracted at SGS-Well and air is injected at SGD-Well, and extraction-extraction mode where both wells are used for vapor extraction. Currently, extraction-injection mode is the long-term operation strategy for the SVE system. Minimum operation requirements have been developed for the extraction-injection mode, as described in Section 4.1. It needs to be determined whether extraction-extraction mode is a viable long-term operation strategy, and if so, what the minimum operation requirements are.

The same simulation for assessing effectiveness of detecting remote releases (Section 4.1.2) is performed, except that SGD-Well is used for vapor extraction, instead of air injection, at the same rate as the minimum operation requirements. The same simulation outputs are obtained, including:

- Concentrations at each monitoring point;
- Concentrations at SGS-Well and SGD-Well; and
- Highest concentration in each layer.

The highest concentrations in each layer are plotted against depth over time to provide indications of how fast VOCs migrate toward groundwater. The highest concentrations in the bottom layer (within 25 ft of water table) are also plotted over time. These plots are compared with similar plots for the extraction-injection mode. If the extraction-extraction mode will result in slower migration of VOCs toward groundwater or lower concentrations above water table, it will be considered a viable long-term operation strategy.

4.3 THRESHOLDS FOR IMPLEMENTING ADDITIONAL ACTIONS.

The intended function of thresholds for additional actions is to initiate actions to investigate whether groundwater quality may be impacted, and, if necessary, to implement further actions to prevent such impact. Therefore, thresholds are developed based on scenarios of substantial releases that may potentially impact groundwater quality. Thresholds are constituent-specific and monitoring point-specific. Numeric threshold values are developed for the seven COCs listed in Table 5 at each monitoring point and in SVE influent. Predictive simulations are used to develop thresholds for all locations except SGD-DP. Because model validation results (Figure 2) suggest that the model underpredicts concentrations at SGD-DP, the model cannot be relied upon to develop thresholds for SGD-DP. Instead, the thresholds for SGD-MP, which is at an adjacent location and at a shallower depth than SGD-DP, are used for SGD-DP. Because SGD-DP is located at a deeper depth than the other monitoring points, COCs that reach SGD-DP from the landfill would have left concentration signals at the shallower monitoring points and in the SVE influent. Therefore, it is expected that decisions on implementing additional actions will be primarily based on whether thresholds at shallower monitoring points and in the SVE influent are exceeded; therefore, setting thresholds at SGD-DP the same as SGD-MP will not compromise their intended function. In addition, soil vapor samples are collected from groundwater monitoring wells MW-2 and MW-5, which are screened across water table. The thresholds at MW-2 and MW-5 are set at soil vapor concentrations in equilibrium to their water quality standards.

The approach to predictive simulations is to assign constant concentration boundary to Unit B to simulate a source and use simulated concentration signals at the monitoring points as the thresholds. Concentration signals at a monitoring point depend on source strength (e.g. the lower the source concentration is, the weaker the signal is), source area (e.g. the smaller the source area is, the weaker the signal is), as well as source location (e.g. the further away the source is, the weaker the signal is). The source concentrations are assigned in order to simulate substantial release scenarios that the thresholds are intended to address. The constant concentration at source is set at equilibrium vapor concentrations either with groundwater protection level (GPL) or, when calculated GPL is higher than soil saturation limit, with soil saturation limit. GPLs are calculated following ADEQ's guidance document (ADEQ, 1996). The chemical properties used in GPL calculations and the calculated GPLs are presented in Table 6. The default inputs in ADEQ's GPL workbook are used, except depth of incorporation, depth to groundwater, and chemical properties for Freon-11, which are not in the GPL workbook. The GPL calculations are included in Attachment 1. The calculated GPLs are higher than soil saturation limits for all the COCs except methylene chloride. The constant source concentration is set as the equilibrium vapor concentration with the lesser values between GPL and soil saturation limit.

The source area and location are assigned in order to capture substantial release scenarios. If constant concentration boundary is assigned to the whole footprint of Unit B, all the monitoring points will likely see strong concentration signals. However, it would not address the scenarios where the source is distant from some monitoring points. Therefore, Unit B is divided into six portions (Figure 11A) labeled southwest (SW), northeast (NE), southwest (SE), northwest (NW), middle-south (S), and middle-north (N). Constant concentration boundary condition is assigned to one individual portion at a time to obtain concentration signals in response to smaller source areas at various locations. Because simulation results suggest that the assigned source concentrations over one sixth of the footprint do not result in potential groundwater quality impact when thresholds at monitoring points are reached (Section 5.6), assigning the same source concentrations over smaller footprint is not expected to lead to groundwater quality impact. Therefore, Unit B is not divided into smaller portions for threshold development.

For Freon-11, the simulated concentrations at the end of model validation are used as initial concentrations. For the other COCs, because simulated concentrations are not available from model validation, their initial concentrations are assigned at zero across the model domain. The COC's properties (soil distribution coefficient, Henry's law constant, and solubility), as in Table 6, are used in the model.

5.0 PREDICTIVE SIMULATION RESULTS

5.1 MINIMUM RATES OF SOIL VAPOR EXTRACTION AND AIR INJECTION

The simulations are run for a period of 100 years, using the end concentration distribution from the validated model as initial concentration. The same constant source concentrations as in HGC's model are assigned to simulate an ongoing release at historical levels. The following three sets of extraction and injection rates are evaluated.

- A. Extraction rate of 37 scfm and injection rate of 15 scfm, respectively, which are the average flow rates between February and July 2009.
- B. Extraction rate of 18.5 and injection rate of 7.5 scfm, respectively, which are 50% of the average flow rates between February and July 2009.
- C. Extraction rate of 9.25 and injection rate of 3.75 scfm, respectively, which are 25% of the average flow rates between February and July 2009.

Scenario A corresponds to the current operation where the SVE system operates for 10 hours each day throughout a year, whereas Scenarios B and C correspond to operating for 5 hours and 2.5 hours each day throughout a year, respectively.

The simulated concentrations at the virtual monitoring points above groundwater table, as shown on Figure 4, are all well below the concentration of 24 mg/m^3 calculated in Section 4.1. Because of the air injection at SGD-Well, concentrations at virtual monitoring points closer to the landfill (hence closer to the injection well) may be lower than virtual monitoring points further from the landfill. For example, simulated concentrations at MWS-1, which is closer to the air injection well than MWS-2, are lower than those at MWS-2, even though MWS-1 is closer to the landfill than MWS-2. This is because the simulated concentrations at MWS-1 are affected to a greater extent by the injected air than MWS-2.

The difference in simulated concentrations between using Scenario C and Scenario A is less than 3.5 mg/m^3 , indicating that using extraction/injection rates of 9.25 and 3.75 scfm is as protective of groundwater quality as using flow rates of 37 and 15 scfm. Figures 5A and 5B illustrate the simulated pressure responses, as a percentage of the vacuum at the extraction well (for shallow vadose zone) or as a percentage of the pressure at the injection well (for deep vadose zone), around Unit A and Unit B using flow rates of 9.25 and 3.75 scfm (i.e. 25% of the average flow rates between February and July 2009). These results indicate that soil vapor extraction using flow rates of 9.25 and 3.75 scfm will create pressure responses around both landfill units.

Therefore, the extraction/injection rates of 9.25 and 3.75 scfm are proposed as the minimum rate requirements. It should be noted that operating the SVE system at higher extraction/injection rates than these minimum requirements would have the benefits of detecting new releases sooner, if a new release occurs. The above simulations assume that the extraction and injection wells operate at the minimum rates each day. Section 5.2 evaluates how long a shutdown can be allowed while maintaining the minimum extraction/injection rates.

5.2 MAXIMUM LENGTH OF SHUTDOWN

Various combinations of shutdown and operation periods, such as “three months off, one month on” and “nine months off, three months on”, are experimented to identify the maximum length of shutdown within a twelve-month period. The extraction/injection rates in the “on” months are set at 37 and 15 scfm, respectively, so that the twelve-month averages are equal to the minimum rates identified above. The simulations are run for a period of 100 years, using the end concentration distribution from the validation model as initial concentration. The constant source concentrations in HGC’s model are assigned to the two landfill units to simulate an ongoing release at historical levels.

The simulated results for the “nine months off, three months on” scenario are shown in Figure 6 and compared to Scenario C described in Section 5.1. Within each twelve-month period, the extraction and injection rates are set to zero for nine months, followed by being set at 37 and 15 scfm for three months. The results show that running the SVE system for at least three months during a twelve-

month period will keep the vapor concentrations above groundwater table at the same levels as running the SVE system at 9.25 and 3.75 scfm without shutdowns.

Therefore, the minimum operation requirements are for the SVE system to operate for a minimum of three months within a twelve-month period, with annual average extraction and injection rates (total extraction/injection volume divided by total elapsed time) at or above 9.2 and 3.75 scfm, respectively.

5.3 UNCERTAINTY ANALYSIS

The simulations described above assume that the source concentrations are the same as the calibrated source concentrations. This is considered a reasonable assumption, given that the rate of VOC release from the Landfill appears to be decreasing based on model validation (Section 3). Nevertheless, to address the inherent uncertainty in the rate of VOC release in the future, simulations described in Sections 5.1 and 5.2 are repeated with the assumption that the source concentrations are twice the calibrated source concentrations, which simulates a greater VOC release.

The simulated concentration plots for these two cases are shown in Figure 7 and 8, respectively. The two lines in each plot start at the same initial values, even though source concentrations are different. This is because the starting values are determined by the prescribed initial concentrations just above water table, and are not affected by the assumed source concentrations near ground surface. Doubling the source concentrations results in little change in the simulated vapor concentrations above groundwater table. Therefore, the conclusions from Sections 5.1 and 5.2 remain unchanged. Overall, the predictive simulations described in Sections 5.1, 5.2, and 5.3 are considered conservative for the following reasons:

- Source concentrations are assumed to remain constant in the future, whereas the rate of VOC release is expected to decrease over as the finite amount of VOCs is gradually depleted.
- It is assumed that no degradation of VOCs in the vadose zone occurs, whereas VOCs may undergo chemical or microbial degradation.
- The Freon-11 vapor concentration of 24 mg/m^3 as indication of impact to groundwater quality does not account for dilution in the groundwater mixing zone, which would reduce VOC concentrations in groundwater.

5.4 EFFECTIVENESS IN DETECTING REMOTE RELEASES

The simulation is run for a period of 100 years, using the end concentration distribution from the validation model as initial concentration. The source concentration at the remote release location is set at $5,188,000 \text{ mg/m}^3$, which corresponds to Freon-11's saturated vapor concentration. The extraction/injection rates alternate between 0 scfm for nine months and 37 scfm (extraction) and 15 scfm (injection) for three months, which are the minimum operation requirements.

The simulation results are shown in Figure 9. These results suggest that: (1) for potential impact to groundwater quality to occur, source concentrations in the landfill need to be at elevated levels that are sustained over long period of time (e.g. longer than 10 to 20 years); and (2) all existing monitoring points and the SVE influent will detect a sharp increase in soil vapor concentrations at least 10 years before potential impact to groundwater quality may occur. Therefore, these results suggest that the existing monitoring points and SVE influent can be used to monitor release at a remote location within the landfill.

5.5 OPERATION STRATEGY

The simulations are set up the same way as above, except that both SGS-Well and SGD-Well are extraction wells, with extraction rates alternating between 0 for nine months and 37 scfm (SGS-Well) and 15 scfm (SGD-Well) for three months.

The results are shown on Figure 10. Comparison of simulated concentrations in Figures 9 and 10 suggests that the vacuum created by operating SGD-Well in extraction mode will result in faster downward migration of VOCs in the shallow vadose zone toward the water table, and will likely speed up impact to groundwater quality, instead of slowing or preventing such impacts. Therefore, operating both SGS-Well and SGD-Well in extraction mode is not a viable long-term operation strategy. The operation strategy section in the O&M Manual has been revised accordingly. However, operating SGD-Well may be useful on a short-term basis under certain conditions. Such decisions will need to be made on a case-by-case basis.

5.6 THRESHOLDS FOR IMPLEMENTING ADDITIONAL ACTIONS

Simulations are performed for each of the seven COCs listed in Table 5. The simulations are run for 100 years. Initial concentrations and specified source concentrations are explained in Section 4.3. The extraction/injection rates alternate between 0 scfm for nine months and 37 scfm (extraction) and 15 scfm (injection) for three months, which are the minimum operation requirements.

Simulated concentrations at monitoring points (except SGD-DP) and in SVE influent are obtained from model outputs. For each COC, simulated concentrations at a monitoring point from multiple simulations are plotted over time on the same graph. Figures 11A and 11B show the results for Freon-11. The graph for each monitoring point contains six curves, each of which represents the source being located in a different portion of Unit B (e.g. NW, SE, SW, NE, S, and N). These graphs suggest that (1) the concentration responses to release at a monitoring point vary with location of the source; (2) concentrations at monitoring point have a sharp rise and reach a plateau in about 20 years. The weakest response, as indicated by the lowest plot in a graph, is of interest for threshold development because it represents the least obvious signal at a monitoring point. Therefore, the thresholds should be established based on the lowest plateau concentration. Because substantial release needs to be detected earlier than when the concentrations at monitoring points reach plateau, the threshold should

be lower than plateau concentration. It is proposed to use 10% of the lowest plateau concentration as threshold. As shown in Figures 11A and 11B, the thresholds are typically detected within the first five to 10 years of release. Operating the SVE system beyond the minimum requirements would reduce the time for the thresholds to be detected at the monitoring points, if substantial releases occur.

Figures 11A and 11B suggest that the weakest responses occur at SGS-Well and SGS-SP when the source is in the southwest corner, and weakest responses occur at SGD-SP and SGD-MP when the source is in the northeast corner. Therefore, for the other COCs, simulations are only performed with sources in the southwest (SW) and northeast (NEW) portions of Unit B. The COC's properties (soil distribution coefficient, Henry's law constant, and solubility), as in Table 6, are used in the model. Hence, the proposed thresholds for SGS-Well and SGS-SP are 10% of the plateau concentrations with the source in the southwest portion; the proposed thresholds for SGD-SP and SGD-MP are 10% of the plateau concentrations with the source in the northeast portion. The simulated concentrations at the monitoring points for the other COCs are presented in Figures 12 through 17. The proposed thresholds are presented in Table 7. Simulation results suggest that when the thresholds are reached, the simulated concentrations at the water table are below the levels that potentially impact groundwater quality.

Detecting concentrations at monitoring points or in the SVE influent above their threshold levels does not necessarily indicate that an impact to groundwater quality is imminent or that saturated vapor concentrations are present in the landfill units. The intent of the additional actions is to collect more data to assess whether groundwater is still being protected. . When the concentrations of one of these VOCs exceed their thresholds and a statistically significant upward trend (using the Mann-Kendall test or equivalent method) is present, UA will take the following actions:

- Immediately contact the analytical laboratory to confirm the results and perform data quality control review and validation.
- Within one week of verifying the analytical results, inspect the system and verify that the system operation has been meeting the minimum operation requirements.
- If there have been no system upsets and the system has been operating normally, perform monthly sampling at all soil vapor monitoring points for three consecutive months.
- If data from the three monthly sampling events confirm the exceedance of thresholds and the upward trend, UA will consult with ADEQ about further actions and submit a Response Action Plan within approximately three months. These further actions may include:
 - a. Change SVE operation such that the SVE system at higher extraction/injection rates.
 - b. Enhancement or modification of the existing SVE system to allow vapor extraction from additional locations or vertical zones;

- c. Perform shallow soil gas survey to investigate locations of potential release.
- d. Install additional soil vapor monitoring or extraction/injection well.

6.0 OPERATIONAL PARAMETERS FOR SVE SYSTEM

Based on the simulation work described in Section 5, the operational parameters for the SVE system are summarized below.

- The SVE system shall operate for a minimum of three months within a twelve-month period. Annual average extraction and injection rates (total extraction/injection volume divided by total elapsed time) shall be or above 9.2 and 3.75 scfm, respectively. The SVE system may be operated in a pulsed mode.
- Operating the SVE system in extraction-extraction mode is not a viable long-term operation strategy. Extraction-extraction mode may be considered for short-term operation under certain conditions. Such decisions need to be made on a case-by-case basis.
- When detected concentrations for VOCs exceed the thresholds in Table 7 and a statistically significant upward trend is present, the proposed additional actions shall be initiated. When the SVE system is in pulsed operation, sufficient time shall be allowed for the vadose zone to return to equilibrium before SVE influent sampling results are compared to the thresholds.

UA intend to operate the SVE system to meet or exceed the operational parameters described above.

7.0 LIMITATIONS

This report has been prepared by AMEC for the exclusive use of the University of Arizona as it pertains to the above-mentioned property. It has not been prepared for use by other parties. AMEC's professional services were performed using the degree of care and skill ordinarily exercised under similar circumstances by other engineers, geologists, and scientists practicing in this field. No other warranty, express or implied, is made as to the professional advice in this report. Any use of, or reliance on, this report by a third party shall be at such party's sole risk.

The conclusions and recommendations in this report are based on information provided to AMEC by the University of Arizona. Such information includes data collected by others and a numerical model developed and calibrated by others, which forms the basis of the simulation work described in this report. Therefore, our conclusions and recommendations may be subject to reassessment and modification, if warranted, as additional information becomes available.

8.0 REFERENCES

Arizona Department of Environmental Quality (ADEQ), 1996, A Screening Method to Determine Soil Concentrations Protective of Groundwater Quality, September.

Hydro Geo Chem (HGC), 2004, Interim Measures Investigation Report, June 8.

HGC, 2005, Preliminary Screening Risk Assessment, January 20.

HGC, 2009a, Memorandum: Monthly SVE Operation Report – July 2009, August 10.

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HydroGeoLogic, Inc., 1996, MODFLOW-SURFACT software (version 3) Documentation, Herndon, VA.

McDonald M.G., and A.W. Harbaugh, 1988. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, USGS Techniques of Water-Resources Investigations, Book 6, Chapter A1. Washington. United States Government Printing Office.

Stauffer, P.H., J.K., Hopkins, T. Anderson, and J.A. Vrugt, 2007, Soil Vapor Extraction Pilot Test at Technical Area 54, Material Disposal Area L: Numerical Modeling in Support of Decision Analysis, Los Alamos National Laboratory Report, LA-UR-07-4890, 47 pages, July 11.

TABLES

Table 1
Layering of Numerical Model
Development of SVE Operational Parameters
RCRA Part B Post Closure Permit Renewal
Page-Trowbridge Ranch Landfill

Model Layer Number	Layer Bottom Elevation (ft amsl)	Layer Thickness (ft)	Stratigraphic Unit	Parameter Zone Number
1	3631	1	Ground Surface	1
2	3630	1	Upper Silt	1
3	3605	25		1
4	3580	25		1
5	3555	25		1
6	3530	25		1
7	3505	25	Upper Sand	2
8	3482	23	Middle Silt	1
9	3459	23		1
10	3437	22	Middle Sand	1
11	3414	23		2
12	3387	27	Lower Silt	2
13	3362	25		3
14	3337	25		3
15	3312	25		3
16	3287	25		3
17	3262	25		3
18	3237	25		3
19	3212	25		3
20	3187	25		3
21	3161	26	Lower Sand	4
22	3136	25		4
23	3111	25		4
24	3086	25		4
25	3061	25		4
26	3036	25		4
27	3011	25		4
28	2986	25		4

Notets:

Reproduced from Hydro Geo Chem (HGC), 2004, Interim Measures Investigation Report, June 8.

ft = feet

ft amsl = feet above mean sea level

Table 2
Permeability Values in Numerical Model
Development of SVE Operational Parameters
RCRA Part B Post Closure Permit Renewal
Page-Trowbridge Ranch Landfill

Parameter Zone Number	Horizontal Hydraulic Conductivity (ft/day)	Vertical Hydraulic Conductivity (ft/day)	Intrinsic Horizontal Permeability (darcies)	Intrinsic Vertical Permeability (darcies)
1	382	38.2	137	14
2	200	7.36	72	3
3	58.5	5.85	21	2
4	4.09	3.9	1	1

Notes:

Intrinsic permeability is related to hydraulic conductivity by the following equation:

$$k = \frac{K \times \mu}{\rho \times g}$$

k = intrinsic permeability

K = hydraulic conductivity

μ = dynamic viscosity of water

ρ = density of water

g = gravitational acceleration

ft = feet

darcies = 10^{-12} m^2

Table 3
Extraction and Injection Rates in Validation Model
Development of SVE Operational Parameters
RCRA Part B Post Closure Permit Renewal
Page-Trowbridge Ranch Landfill

Validation Period	Extraction Rate at SGS-Well (scfm)	Injection Rate at SGD-Well (scfm)
12/30/2003 to 11/17/2008 ^a	0	0
11/18/2008 to 1/7/2009 ^b	29	11
1/8/2009 to 2/2/2009	0	0
2/2/2009 to 7/9/2009 ^b	37	15
7/10/2009 to 10/14/2009	0	0
10/15/2009 to 11/2/2010 ^{c,d}	37	15

Notes:

- a. SVE operated infrequently between June 2006 and April 2007; assume rate of zero.
- b. Extraction and injection rates were calculated from operation records (HGC, 2009a; HGC, 2009b) by dividing cumulative volume by elapsed time.
- c. Exact restart date is unavailable; assume October 15, 2009.
- d. Operation records unavailable at time of report preparation; assume same as between February and July 2009.

Table 4
Comparison of Freon-11 Mass Removal in Model Validation
Development of SVE Operational Parameters
RCRA Part B Post Closure Permit Renewal
Page-Trowbridge Ranch Landfill

Validation Period	Cumulative Freon-11 Mass Removed Based on SVE Operation Records (lbs)^{a,b}	Simulated Freon-11 Mass Removed Assuming Zero Source Concentrations (lbs)^c	Simulated Freon-11 Mass Removed Assuming Constant Source Concentrations (lbs)^c
11/17/2008 to 1/7/2009	47	51	67
11/17/2008 to 7/10/2009	293	225	350
11/17/2008 to 11/2/2010	428	498	968

Notes:

- a. lbs = pounds
- b. Calculated from operation records by multiplying Freon-11 concentrations in SVE influent samples with cumulative extracted volumes.
- c. Obtained from transport mass budget in MODFLOW-SURFACT output files.

Table 5
Soil Vapor Concentrations Corresponding to Water Quality Standards
Development of SVE Operational Parameters
RCRA Part B Post Closure Permit Renewal
Page-Trowbridge Ranch Landfill

COC	Percentage Mass ^a	Water Quality Standard ^b (µg/L)	Henry's Law Constant (unitless)	Calculated Soil Vapor Concentration based on Henry's Law Constant (mg/m ³)	Corresponding Freon-11 Vapor Concentration based on Percentage Mass (mg/m ³)
Carbon Tetrachloride	2.6%	5	1.13	5.65	117
Chloroform	34.0%	80 ^c	0.15	12	24
1,1-Dichloroethene	0.5%	7	1.07	7.49	806
Methylene Chloride	0.2%	5	0.13	0.67	179
Tetrachloroethene	2.5%	5	0.72	3.62	78
Trichloroethene	2.2%	5	0.40	2.02	49
Freon-11	53.8%	150 ^d	3.97	596	596

Notes:

- a. Percentage mass as in Table 2 of the Preliminary Screening Risk Assessment (HGC, 2005)
- b. AWQS unless noted otherwise
- c. AWQS for total trihalomethane
- d. California MCL

Table 6. Chemical Properties Used inr GPL Calculation and Calculuated GPL Values
Development of SVE Operational Parameters
RCRA Part B Post Closure Permit Renewal
Page-Trowbridge Ranch Landfill

Compound	Properties ^{1,2,3,4}				Water Quality Standard ⁵	Calculated GPL ⁶	Soil Saturation Concentration ⁶	Source Soil Concentration ⁷	Source Soil Vapor Concentration ⁸
	Solubility	Henry's Law Constant	Organic Carbon Partition Coefficient (Koc)	Soil Distribution Coefficient (Kd)					
	(mg/L)	(unitless)	(L/kg)	(m ³ /mg)	(µg/L)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/m ³)
Carbon tetrachloride	790	1.25	174	6.96E-10	5	12705.26	766.50	766.50	987500
Chloroform	7900	0.15	39.8	1.59E-10	80	46144.20	1743.82	1743.82	1185000
1,1-Dichloroethene (1,1-DCE)	2300	1.07	58.9	2.36E-10	7	7168.61	1092.59	1092.59	2461000
Methylene chloride	13200	0.09	11.7	4.68E-11	5	713.45	1276.37	713.45	662576
Tetrachloroethene (PCE)	200	0.754	155	6.20E-10	5	11683.17	159.67	159.67	150800
Trichloroethene (TCE)	1100	0.422	166	6.64E-10	5	15388.79	855.95	855.95	464200
Trichlorofluoromethane (Freon-11)	1100	4	160	6.40E-10	150	466845.21	1590.63	1590.63	4400000

Notes:

1. Property values are obtained from ADEQ's GPL workbook, except for Freon-11.
2. Property values for Freon-11 are obtained from U.S. EPA Region IX Preliminary Remediation Goals (PRGs) guidance document (2004).
3. $K_d = K_{oc} \cdot f_{oc}$. f_{oc} is the fraction of organic content equal to 0.004 based on site data.
4. Default values in the ADEQ's GPL workbook are used for free-air diffusion coefficient (7000 cm²/day) and aqueous diffusion coefficient (0.7 cm²/day).
5. Water quality standards are Arizona aquifer water quality standards (AQWS), except Freon-11 which is California maximum contaminant levels (MCLs).
6. GPLs and soil saturation concentrations are calculated using ADEQ's GPL workbook.
7. Assumed source soil concentration is equal to the lesser value between calculated GPL and soil saturation concentration.
8. Assumed source soil vapor concentration is the soil vapor concentration in equilibrium with the assumed source soil concentration, as calculated using ADEQ's GPL workbook.

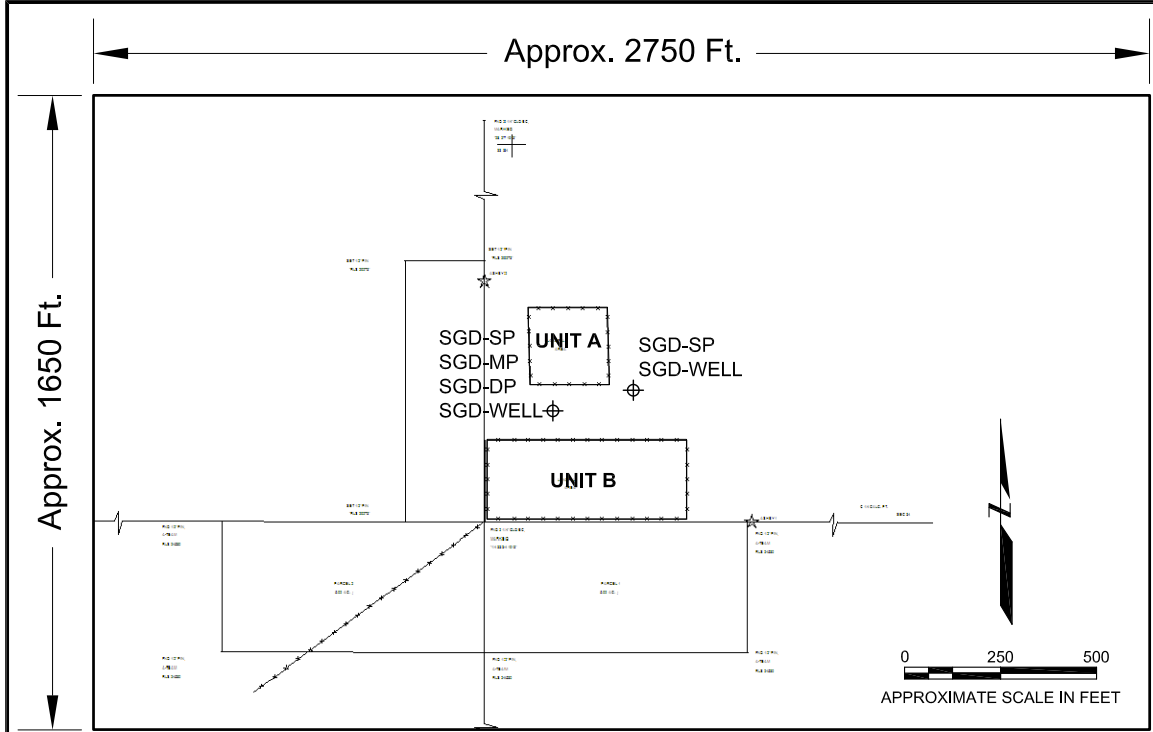
Table 7
Proposed Thresholds for Additional Actions
Development of SVE Operational Parameters
RCRA Part B Post Closure Permit Renewal
Page-Trowbridge Ranch Landfill

Compound	SGS-Well/SVE Influent		SGS-SP		SGD-SP		SGD-MP		SGD-DP	MW-2	MW-5
	Lowest Simulated Plateau Concentration	Proposed Threshdhold	Lowest Simulated Plateau Concentration	Proposed Threshdhold	Lowest Simulated Plateau Concentration	Proposed Threshdhold	Lowest Simulated Plateau Concentration	Proposed Threshdhold	Proposed Threshdhold	Proposed Threshdhold	Proposed Threshdhold
Carbon tetrachloride	8500	850	4500	450	1800	180	1300	130	130	6	6
Chloroform	9000	900	4800	480	2100	210	1400	140	140	12	12
1,1-Dichloroethene (1,1-DCE)	21600	2160	11500	1150	4700	470	3400	340	340	7	7
Methylene chloride	5300	530	2800	280	1200	120	800	80	80	1	1
Tetrachloroethene (PCE)	1300	130	700	70	300	30	200	20	20	4	4
Trichloroethene (TCE)	3300	330	1800	180	800	80	500	50	50	2	2
Trichlorofluoromethane (Freon-11)	38700	3870	20600	2060	8600	860	6400	640	640	596	596

Notes:

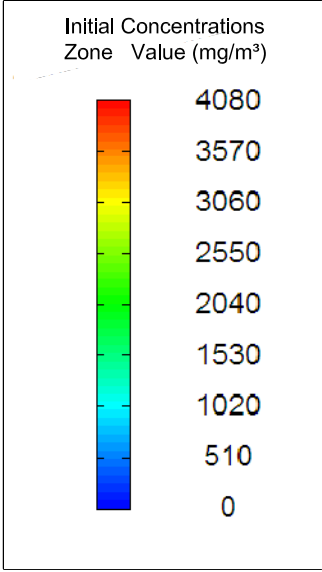
1. All concentrations are in mg/m³
2. Proposed thresholds are calculated as 10% of lowest plateau concentration, except SGD-DP.
3. Proposed thresholds for SGD-MP are used for SGD-DP.
4. Proposed thresholds for MW-2 and MW-5 are set at soil vapor concentrations in equilibrium to water quality standards.

FIGURES



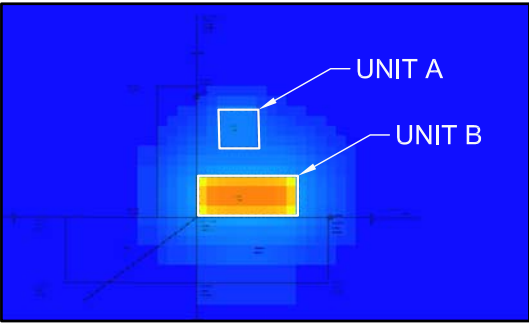
PLAN VIEW

COLOR SCALE

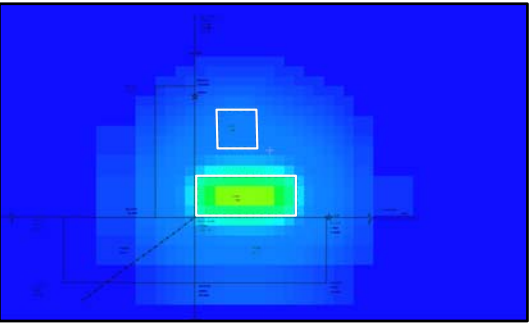


EXPLANATIONS:

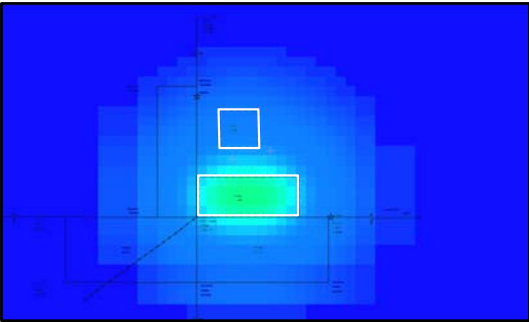
ft = feet
bgs = below ground surface
mg = milligram
m³ = cubic meter



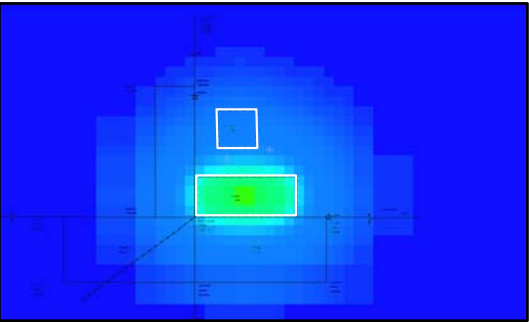
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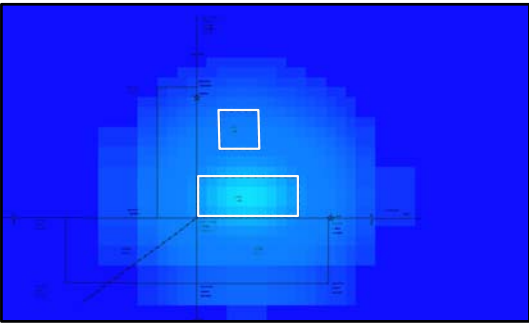
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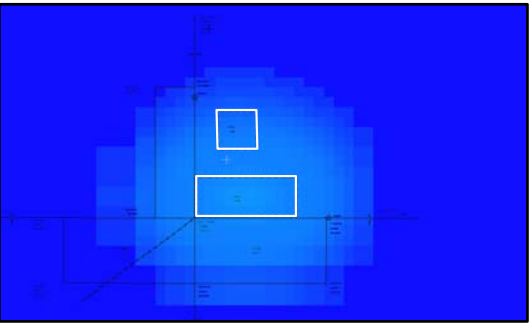
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(Depth = 217 ft bgs)



LAYER 7
(Depth = 126 ft bgs)

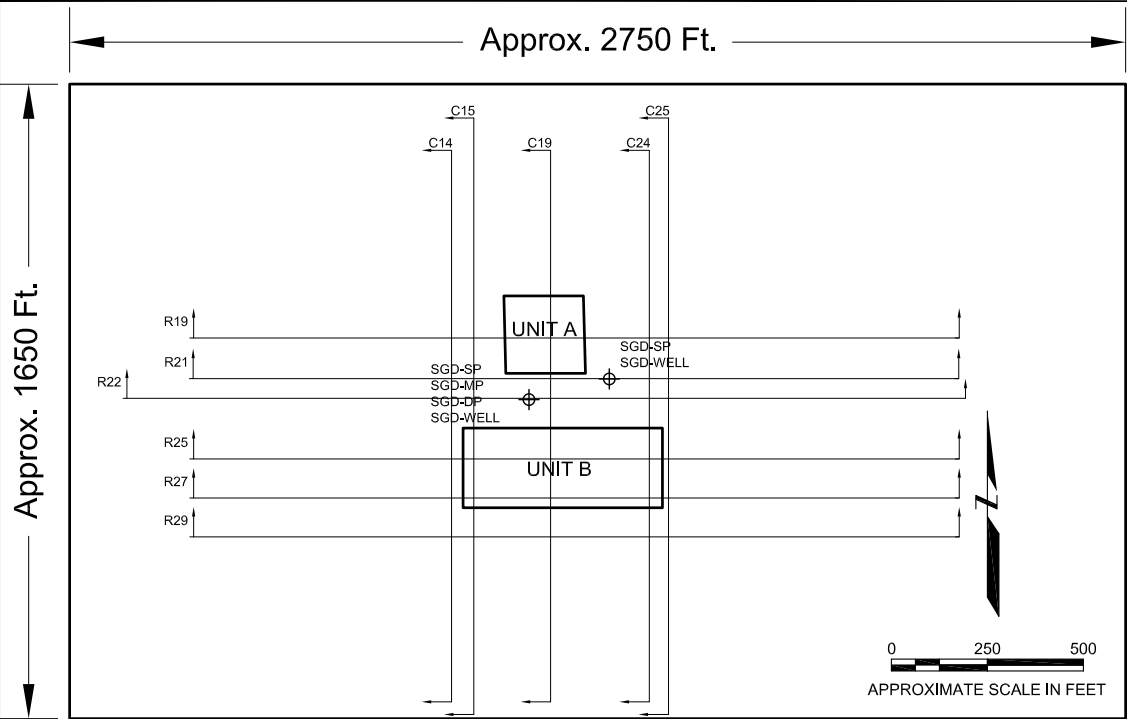


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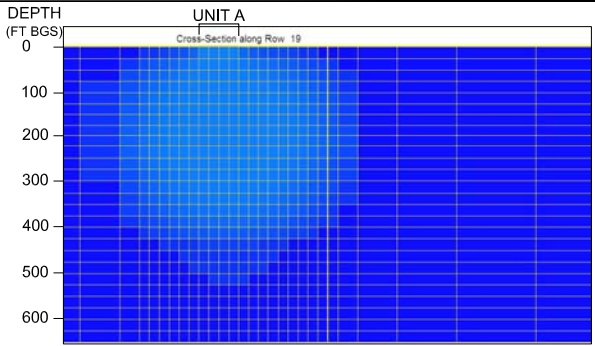


LAYER 16
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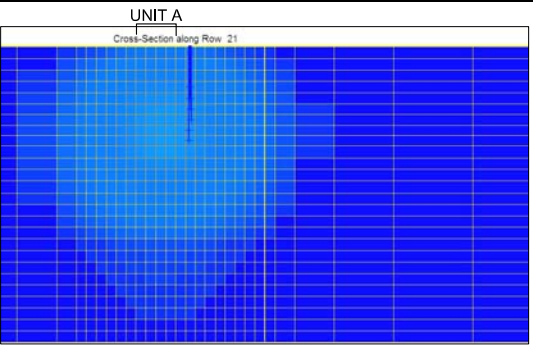
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				CHK'D BY:		PROJECT NO:
		MZ	PROJECT NO.			
		DATUM:	TITLE	REV. NO.:		
PROJECTION:	INITIAL CONCENTRATIONS FOR MODEL VALIDATION PLAN VIEW	A				
SCALE:		FIGURE No.				
AS SHOWN		FIGURE 1A				



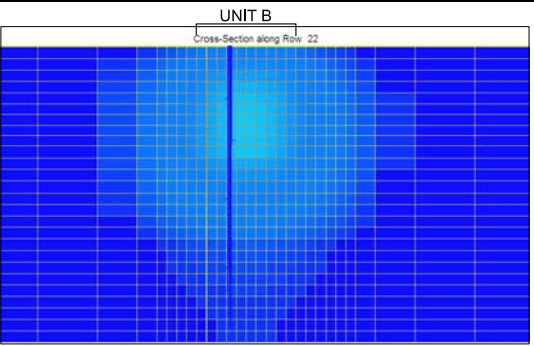
LOCATIONS OF CROSS-SECTIONS



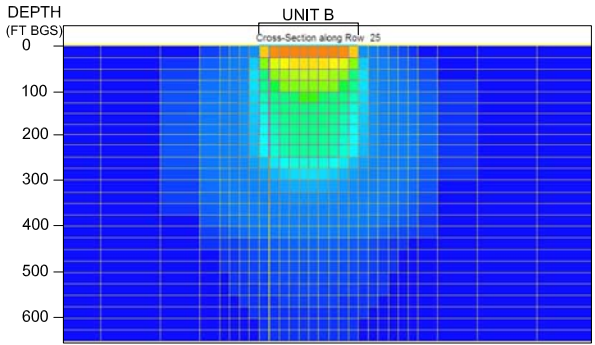
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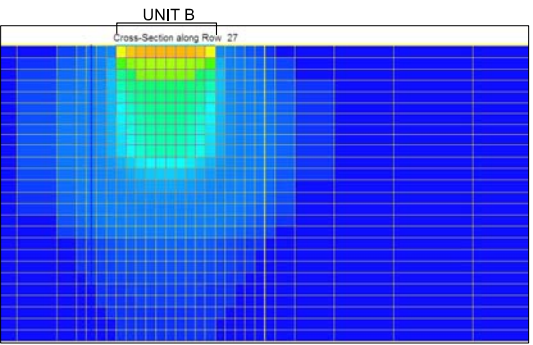
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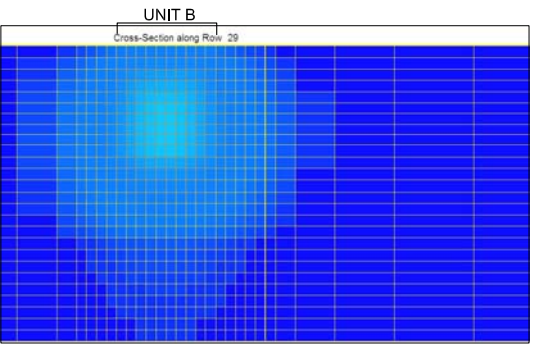
ROW 22



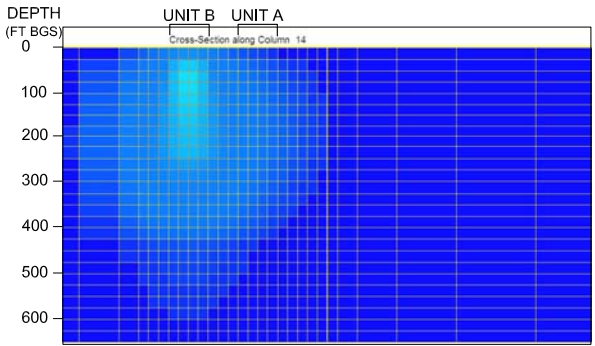
ROW 25



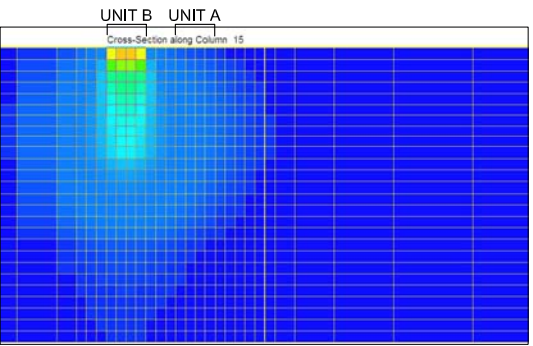
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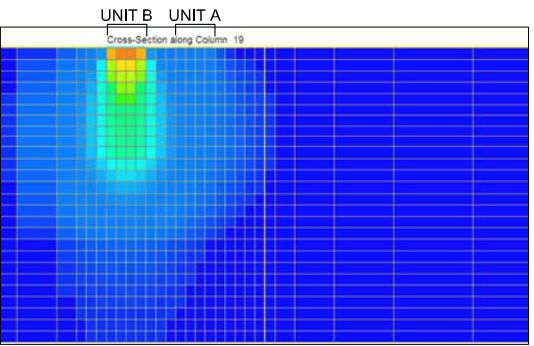
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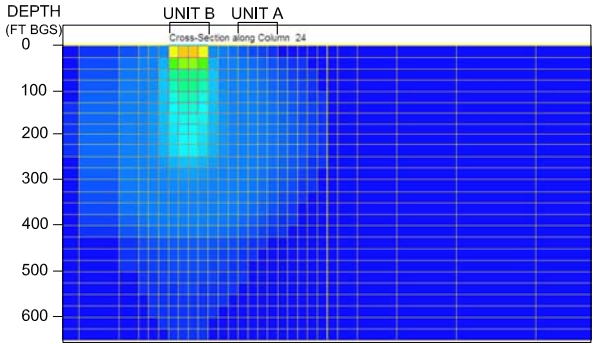
COLUMN 14



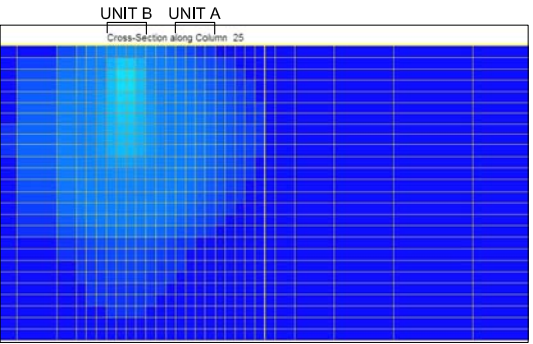
COLUMN 15



COLUMN 19



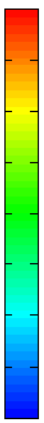
COLUMN 24



COLUMN 25

COLOR SCALE

Initial Concentrations
Zone Value (mg/m³)



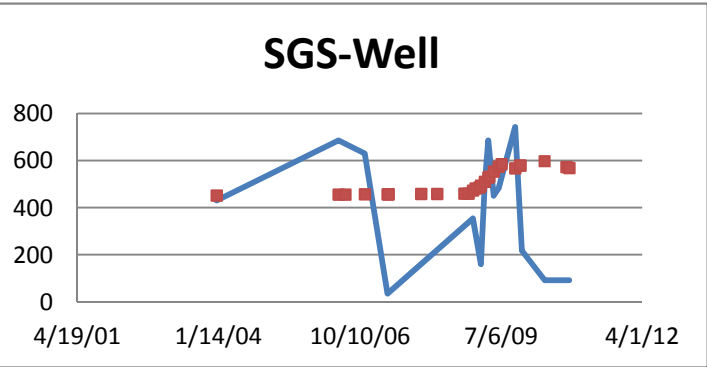
4080
3570
3060
2550
2040
1530
1020
510
0

EXPLANATIONS:

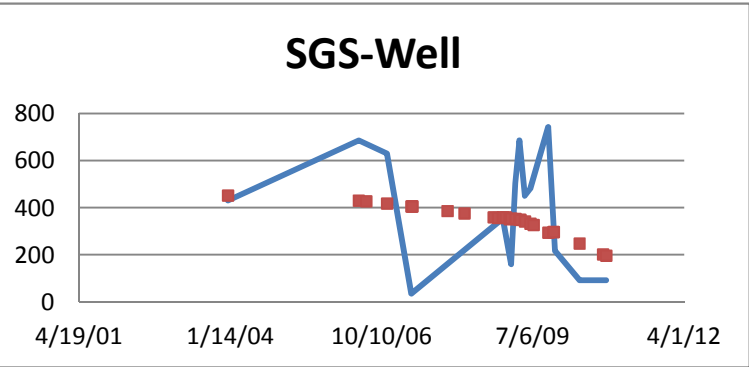
ft = feet
bgs = below ground surface
mg = milligram
m³ = cubic meter

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		AMEC Environment & Infrastructure 4600 East Washington Street, Suite 600 Phoenix, AZ 85034		DATUM:		TITLE INITIAL CONCENTRATIONS FOR MODEL VALIDATION CROSS SECTIONS	PROJECT NO.
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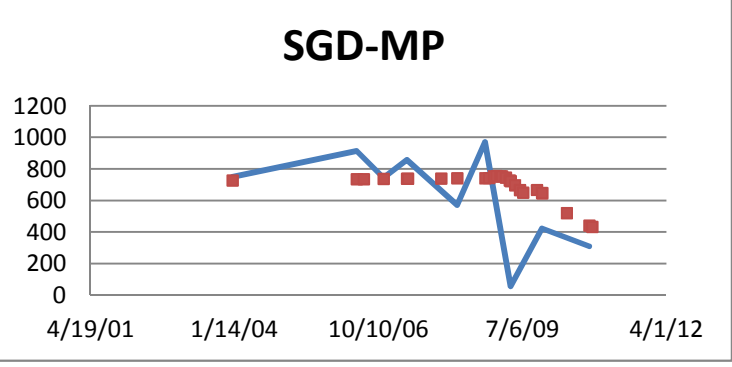
Constant Source Concentration Unchanged



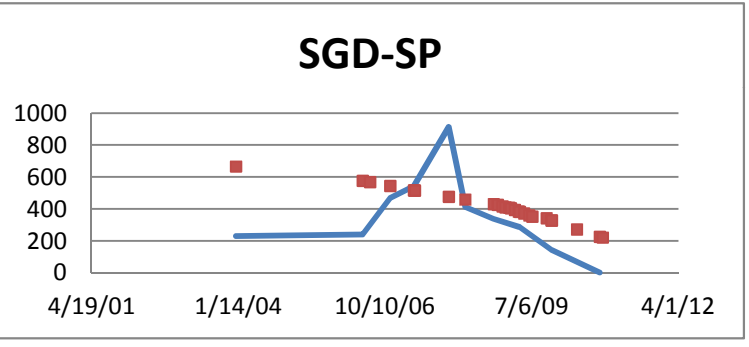
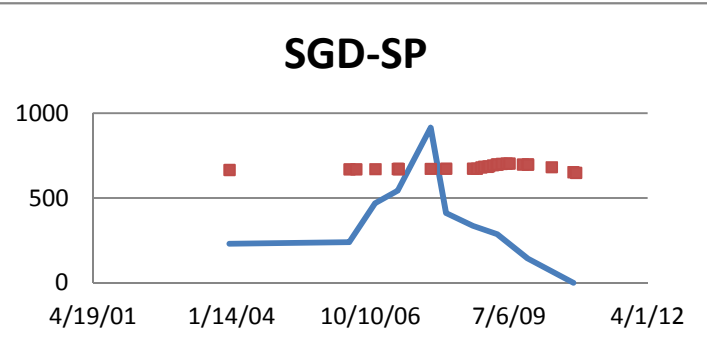
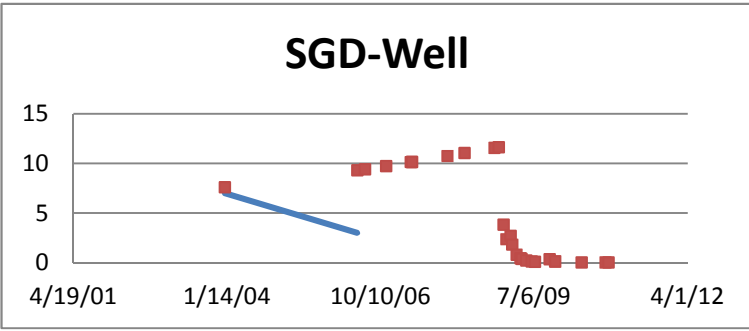
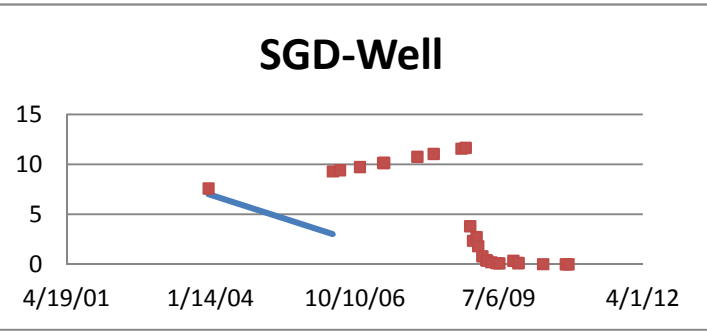
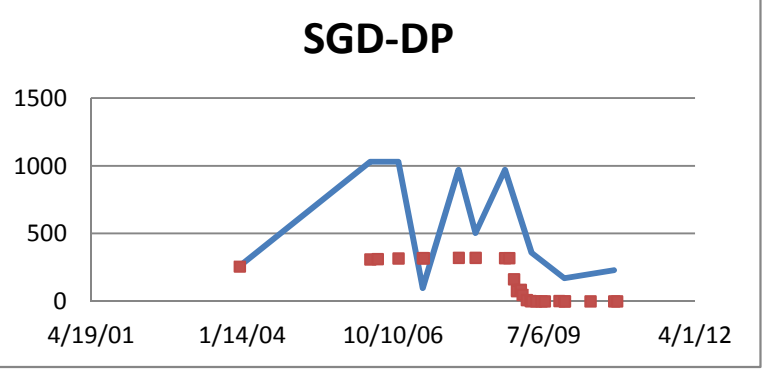
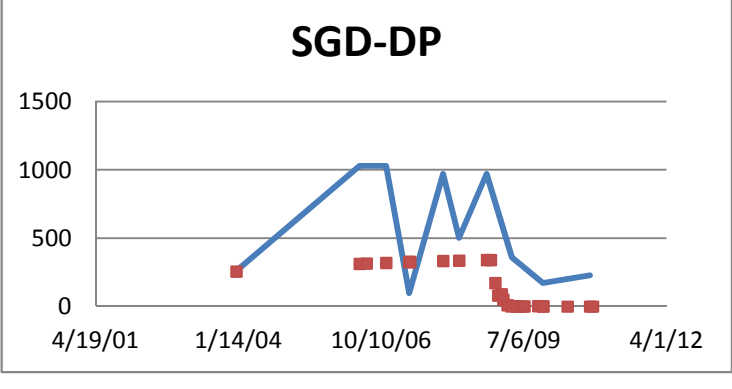
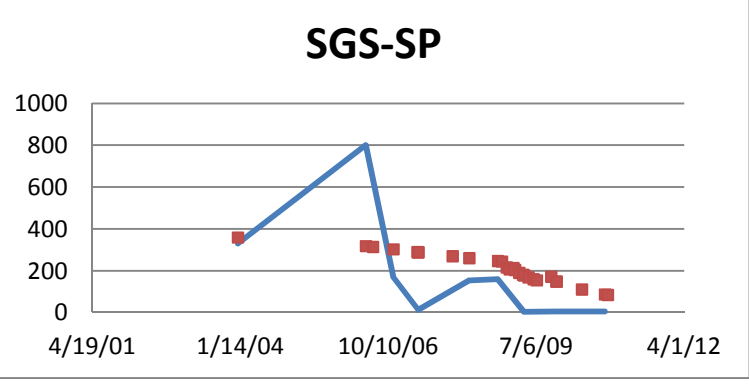
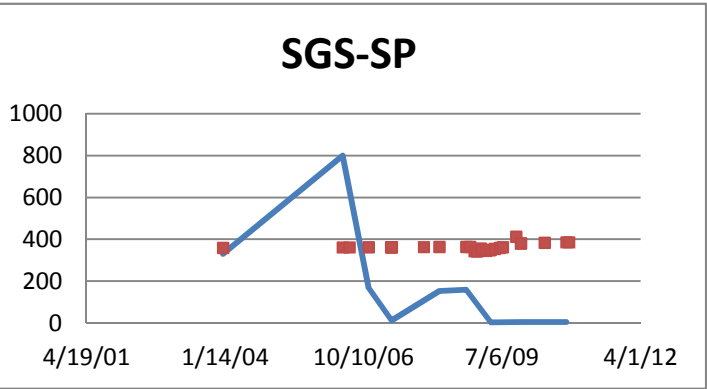
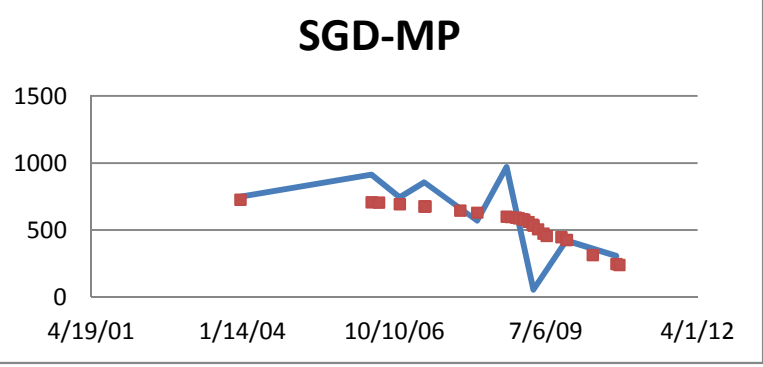
Source Concentrations Equal to Zero



Constant Source Concentration Unchanged



Source Concentrations Equal to Zero



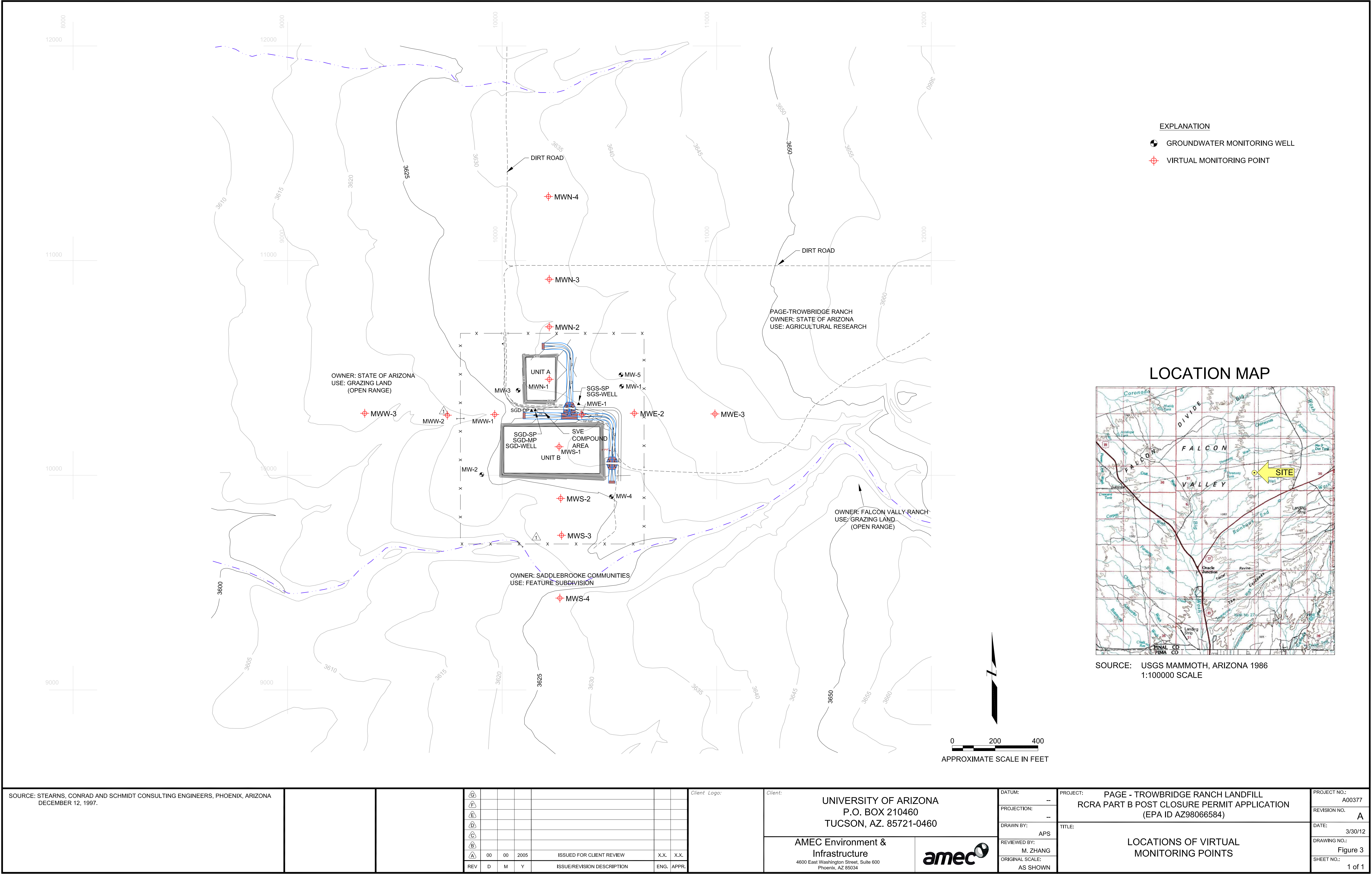
Explanations:

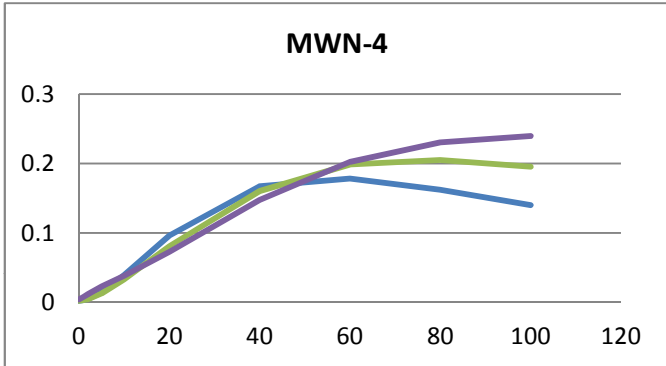
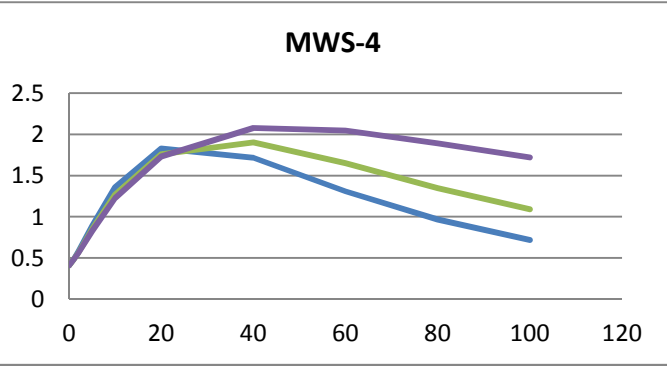
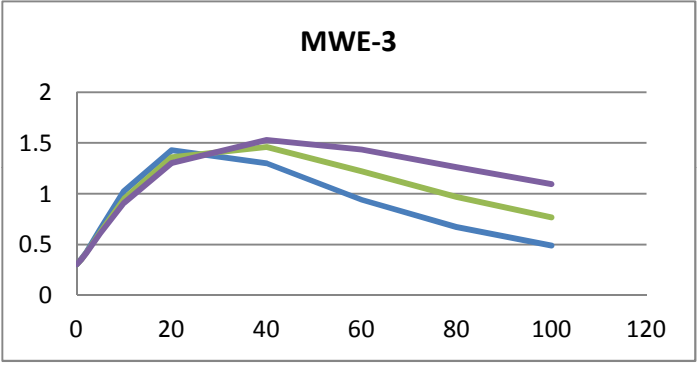
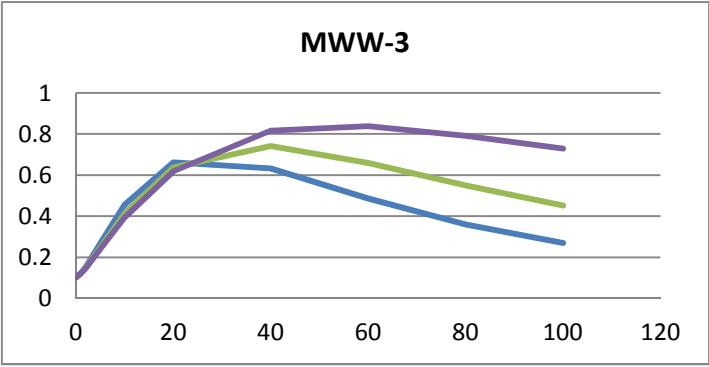
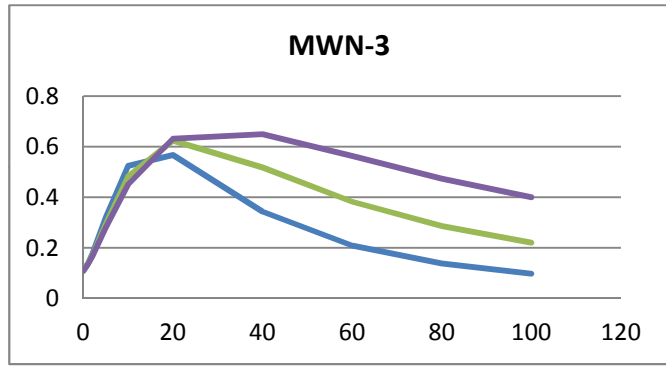
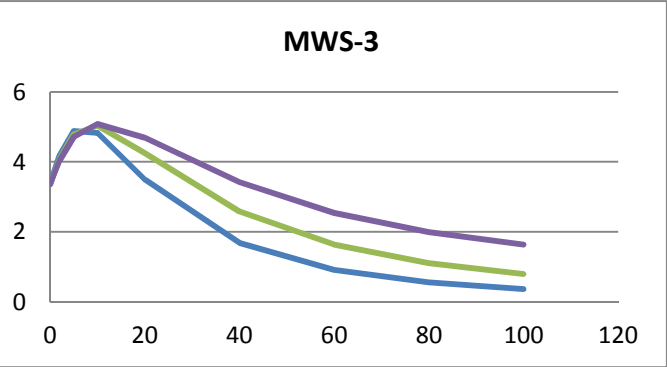
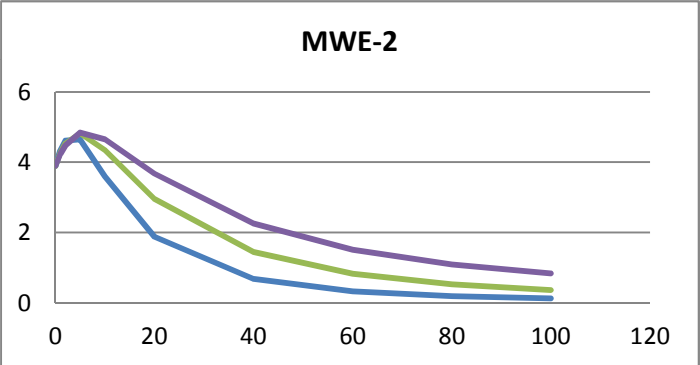
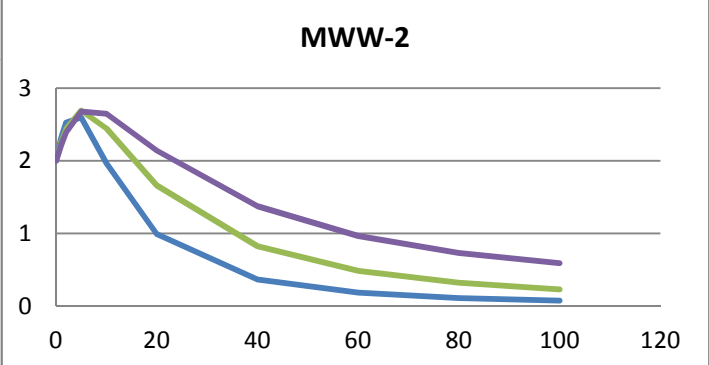
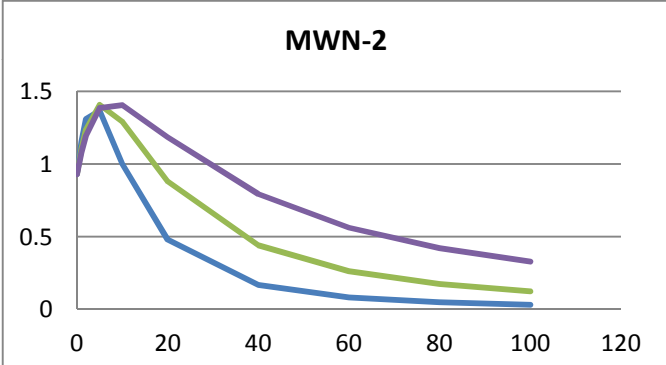
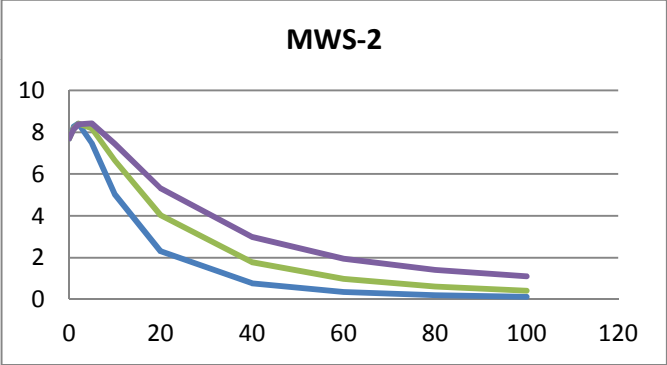
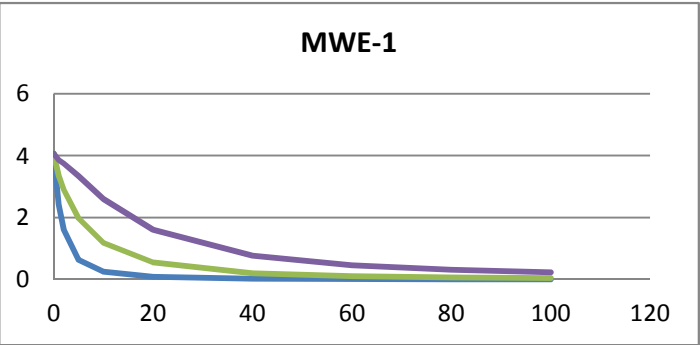
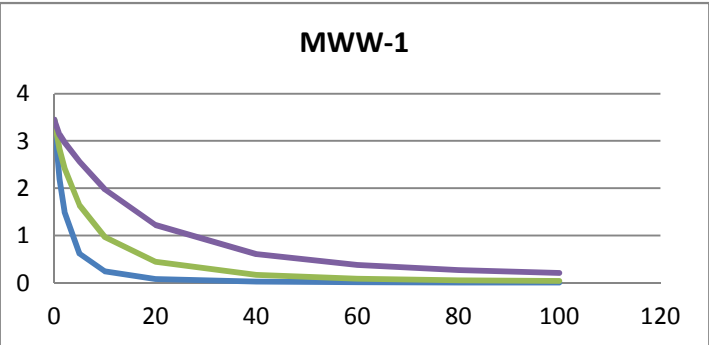
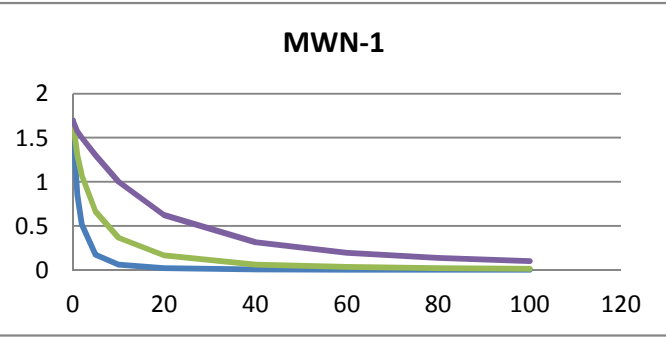
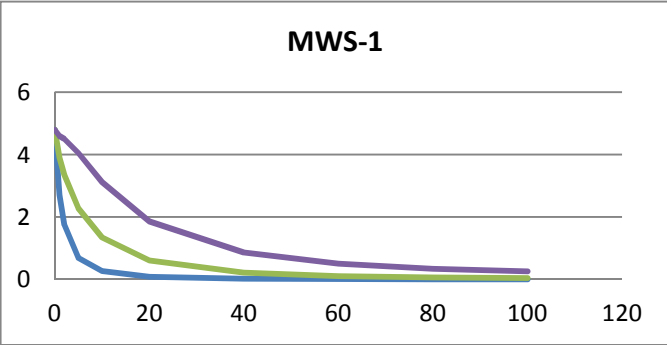
Red - simulated concentrations
Blue - observed concentrations
X axis - date
Y axis - Freon-11 concentration in mg/m³

MODEL VALIDATION RESULTS

By: MZ Date: 06/17/11 Project No.: 1420112012



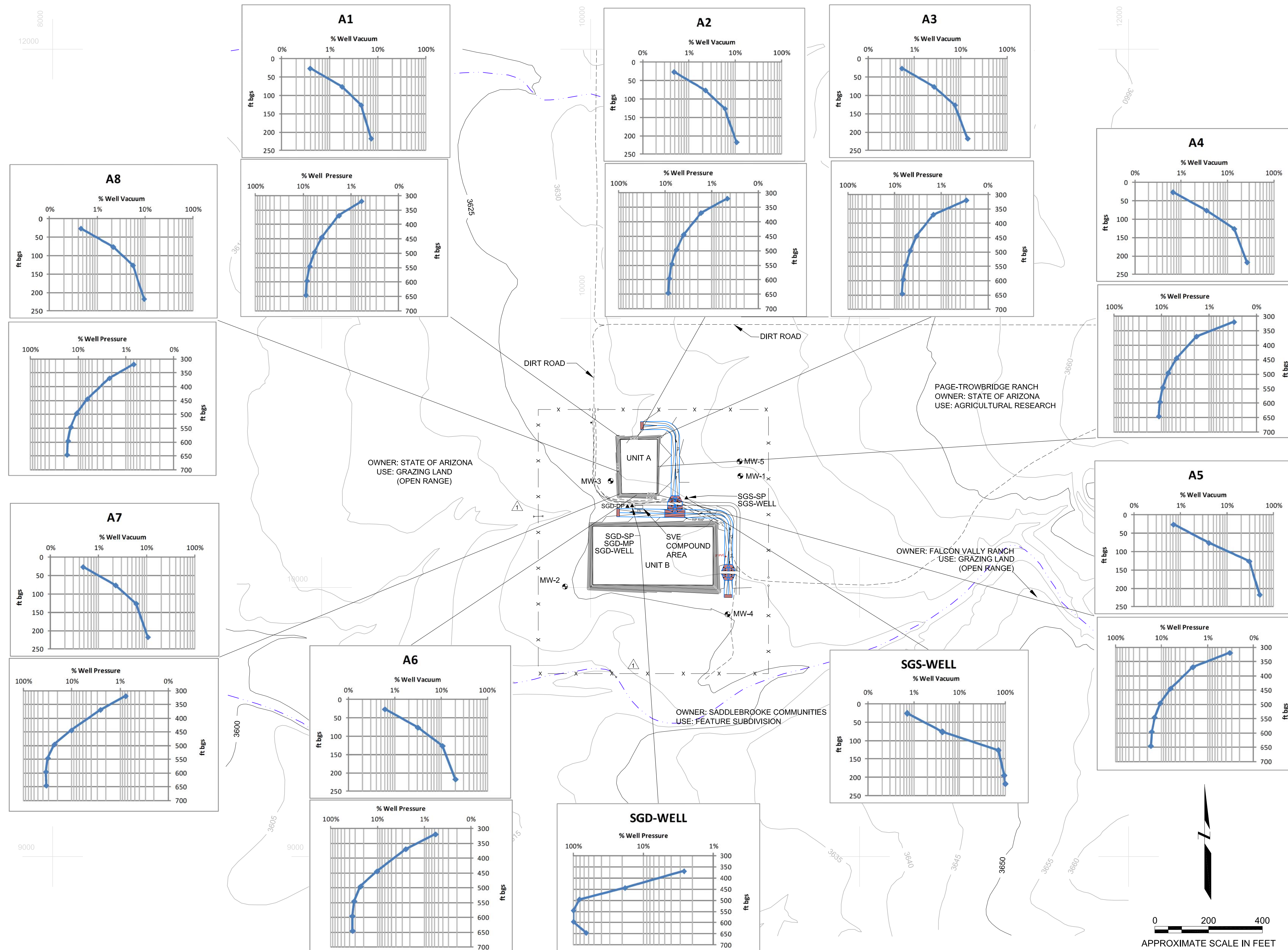




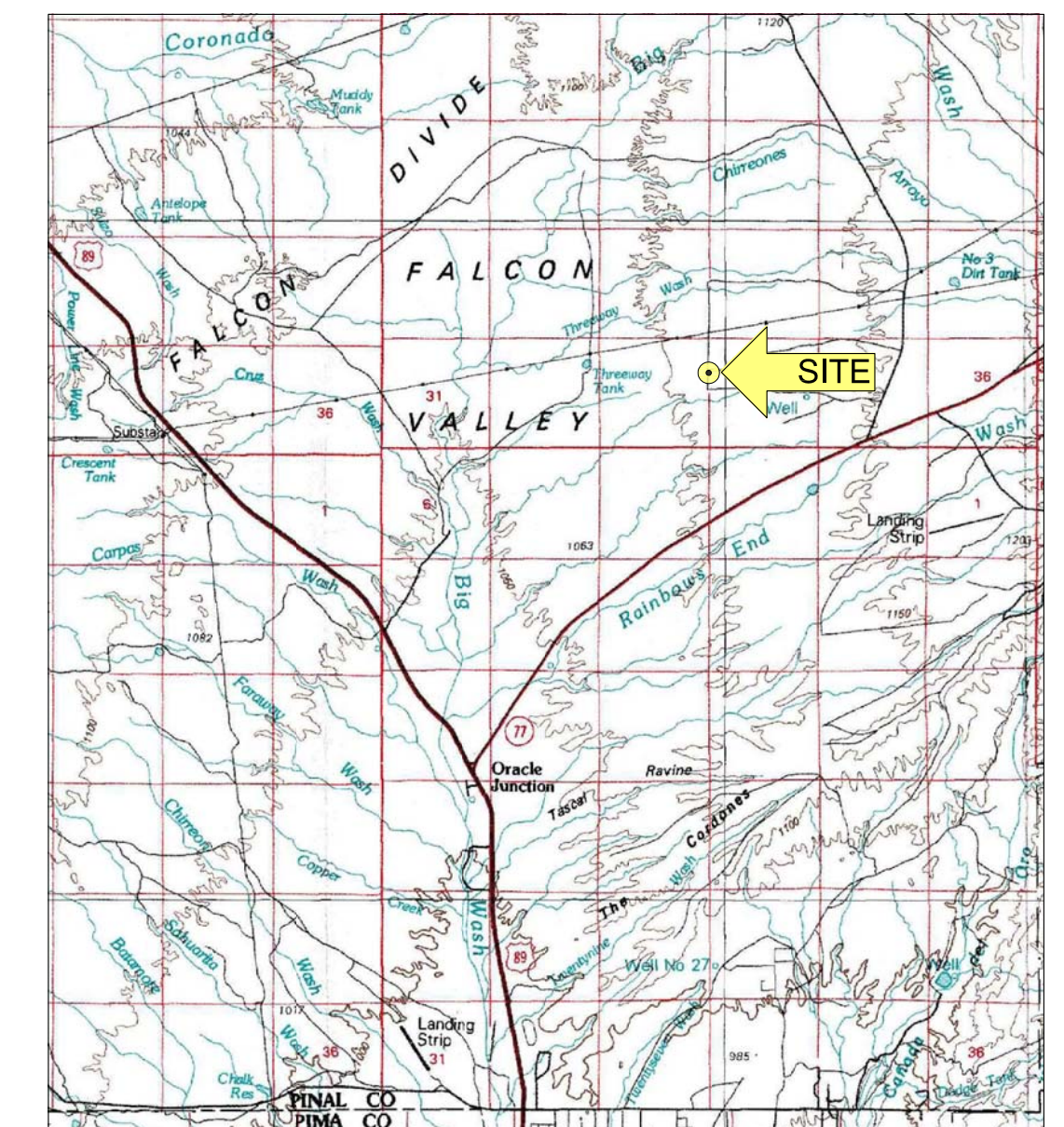
Explanations:

Blue - simulated concentrations using extraction rate of 37 scfm and injection rate of 15 scfm
Green - simulated concentrations using extraction rate of 18.5 and injection rate of 7.5 scfm
Magenta - simulated concentrations using extraction rate of 9.25 and injection rate of 3.75 scfm
X axis - years
Y axis - Freon-11 concentration in mg/m³

SIMULATED SOILVAPOR CONCENTRATIONS
WITHIN 25 FT OF WATER TABLE AT VARIOUS
EXTRACTION/INJECTION RATES



LOCATION MAP



SOURCE: USGS MAMMOTH, ARIZONA 1986
1:100000 SCALE

ft bgs = FEET BELOW GROUND SURFACE

Ⓐ						
Ⓑ						
Ⓒ						
Ⓓ						
Ⓔ						
Ⓕ						
Ⓖ						
Ⓗ						
REV	D	M	Y	ISSUE/REVISION DESCRIPTION		ENG. APPR.

Client Logo:

Client:

UNIVERSITY OF ARIZONA
P.O. BOX 210460
TUCSON, AZ. 85721-0460

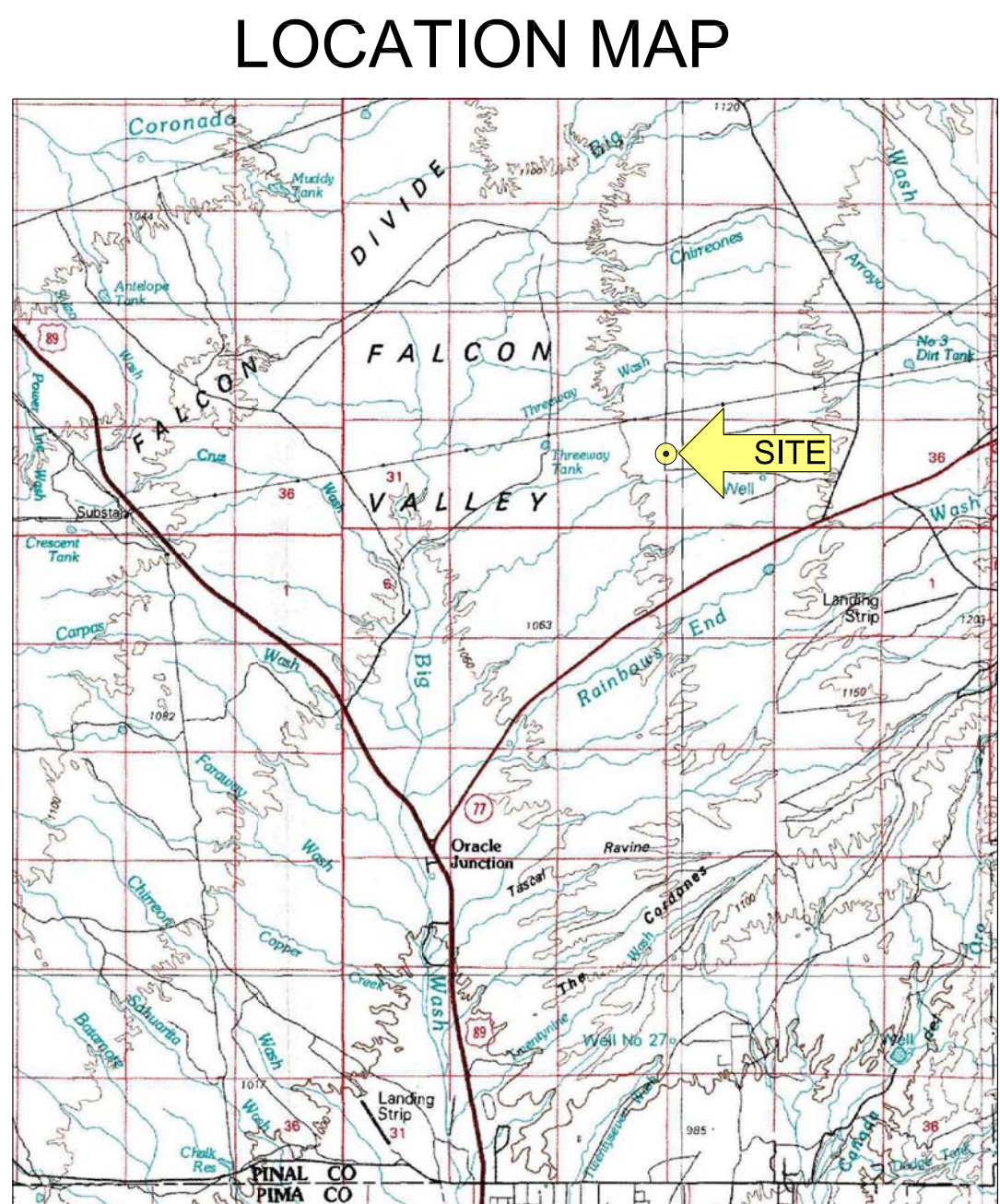
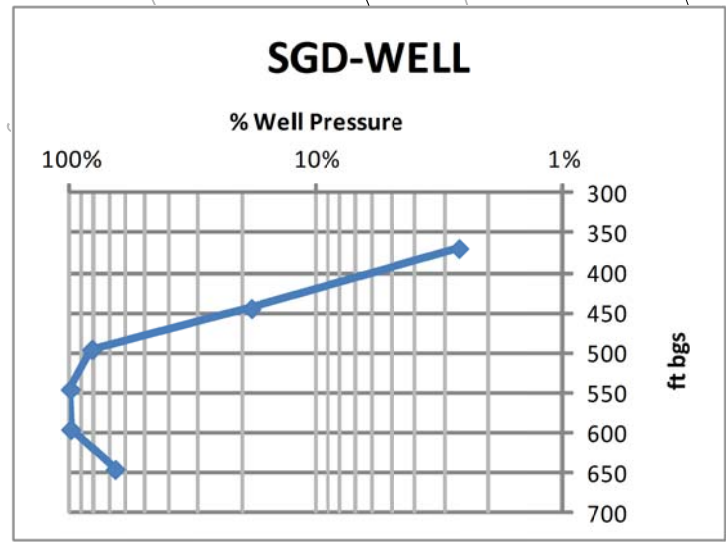
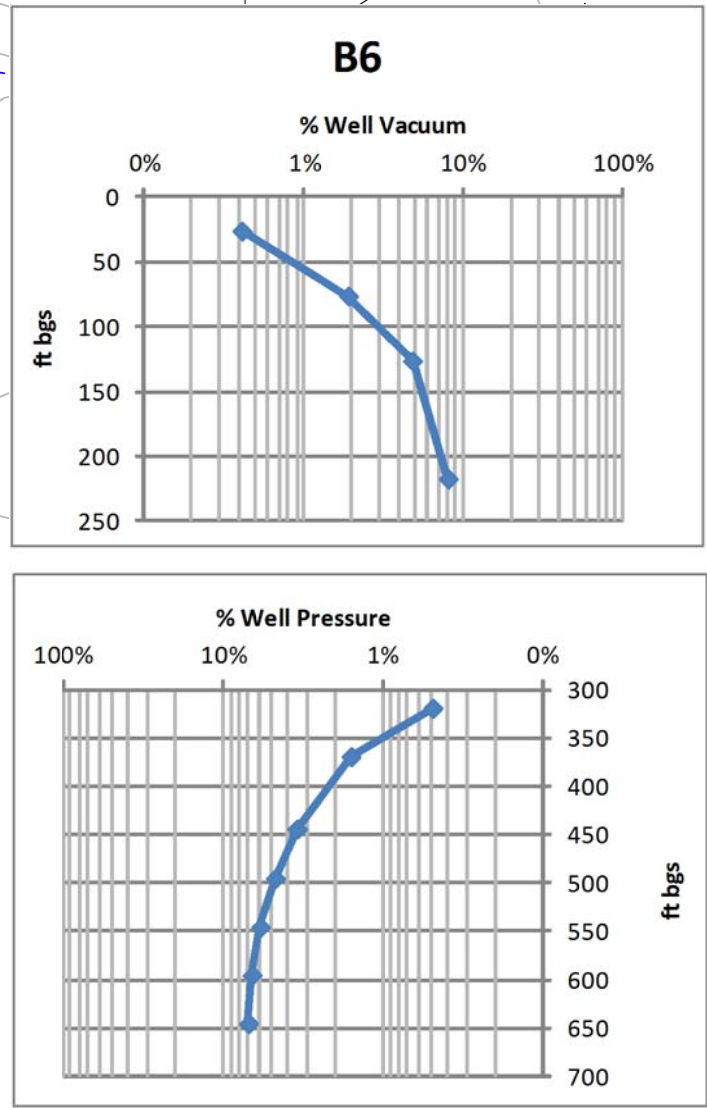
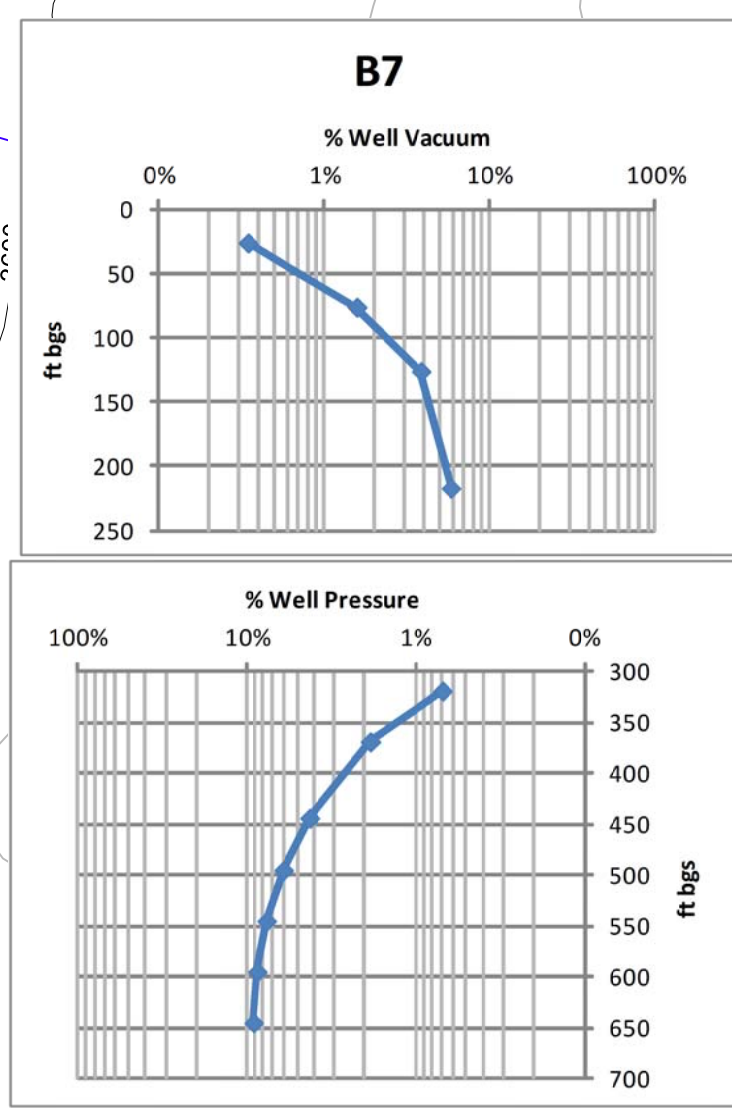
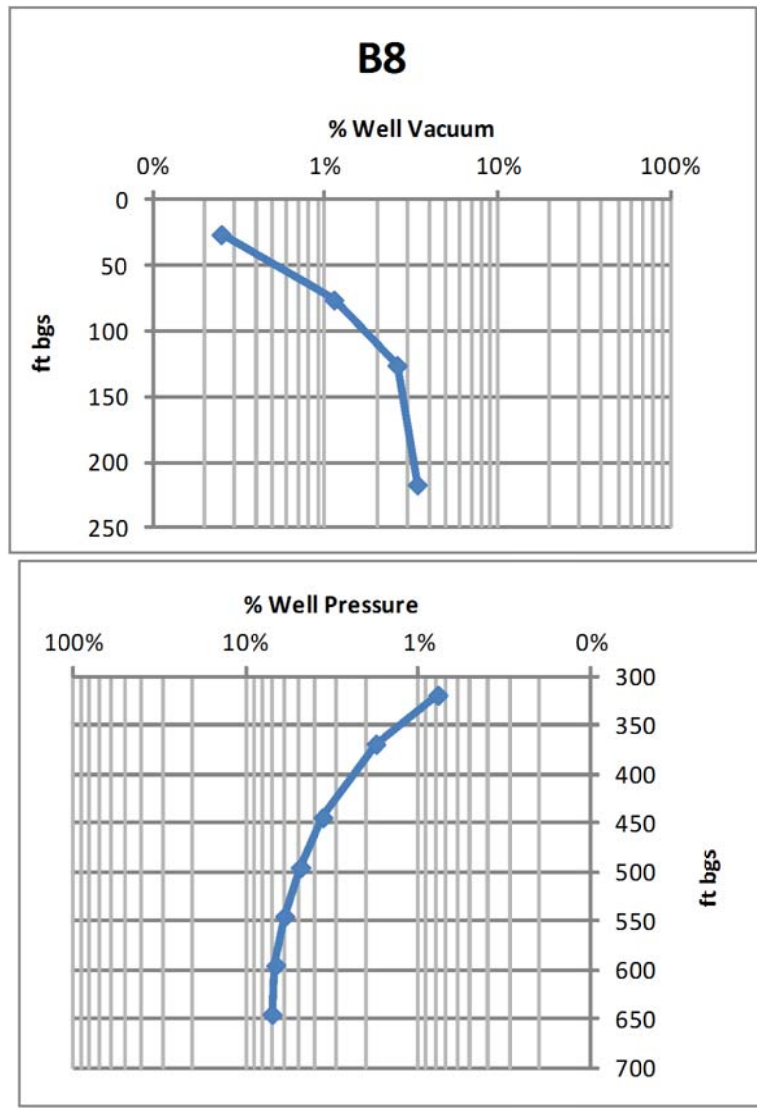
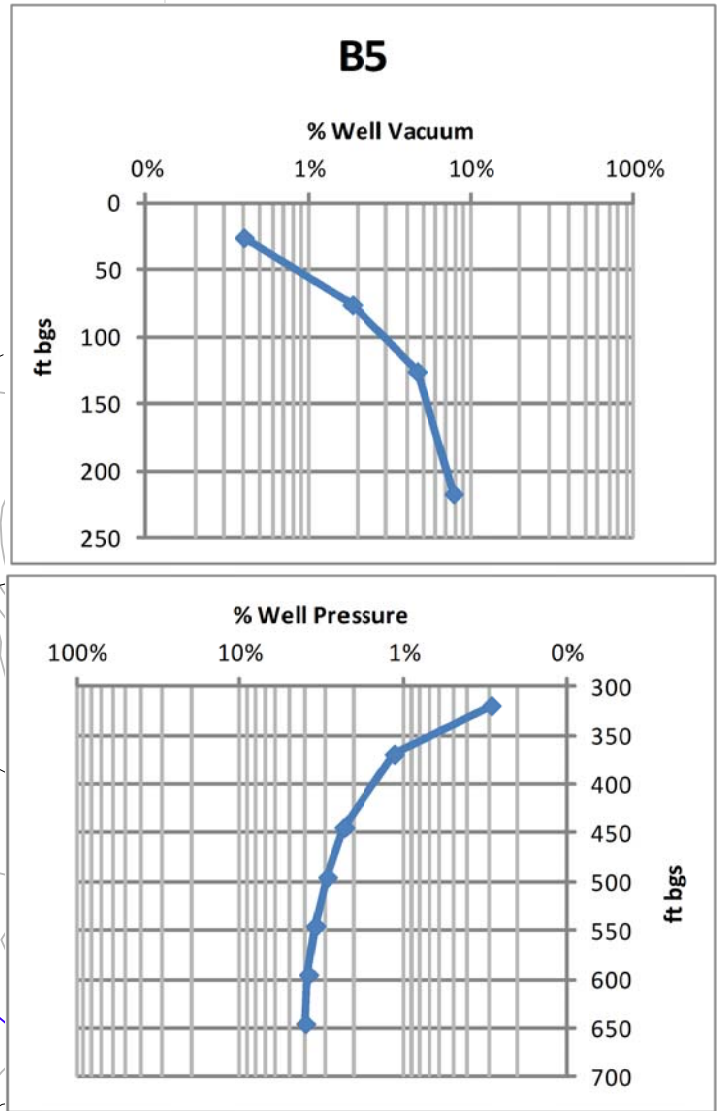
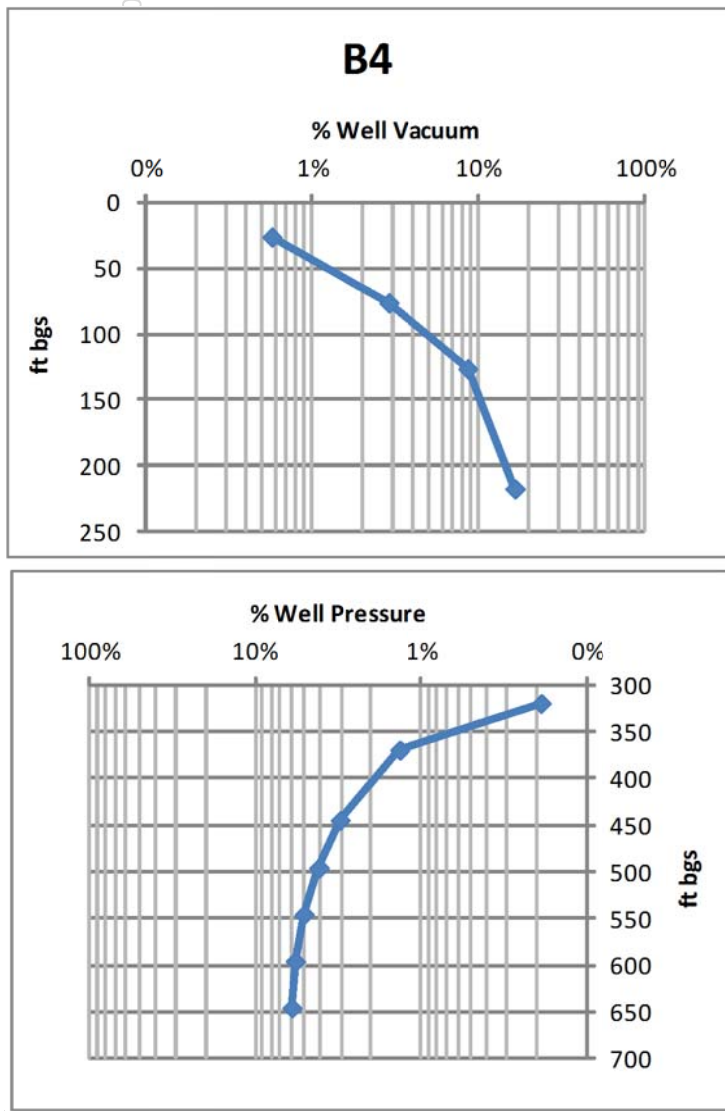
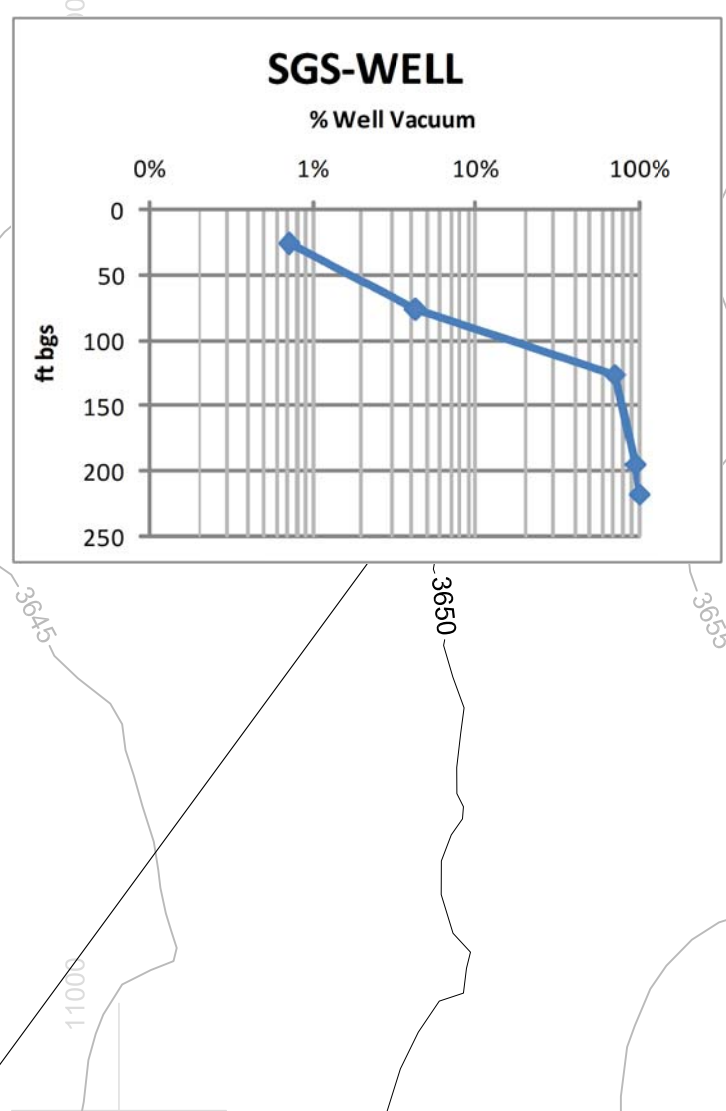
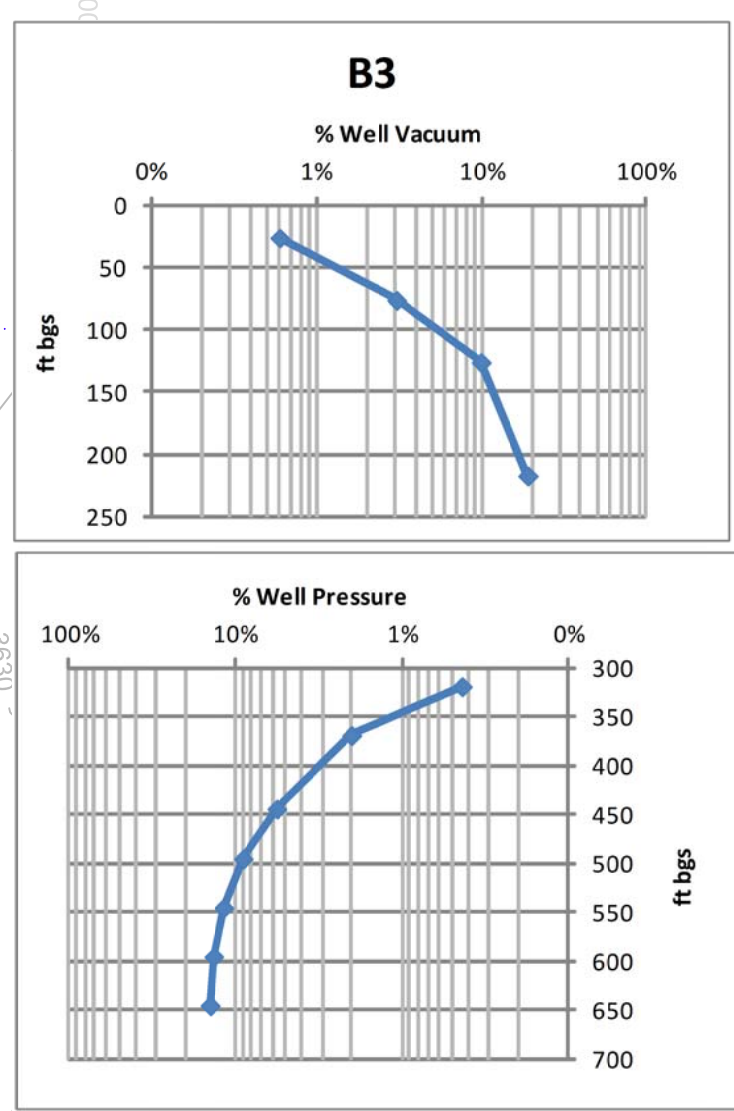
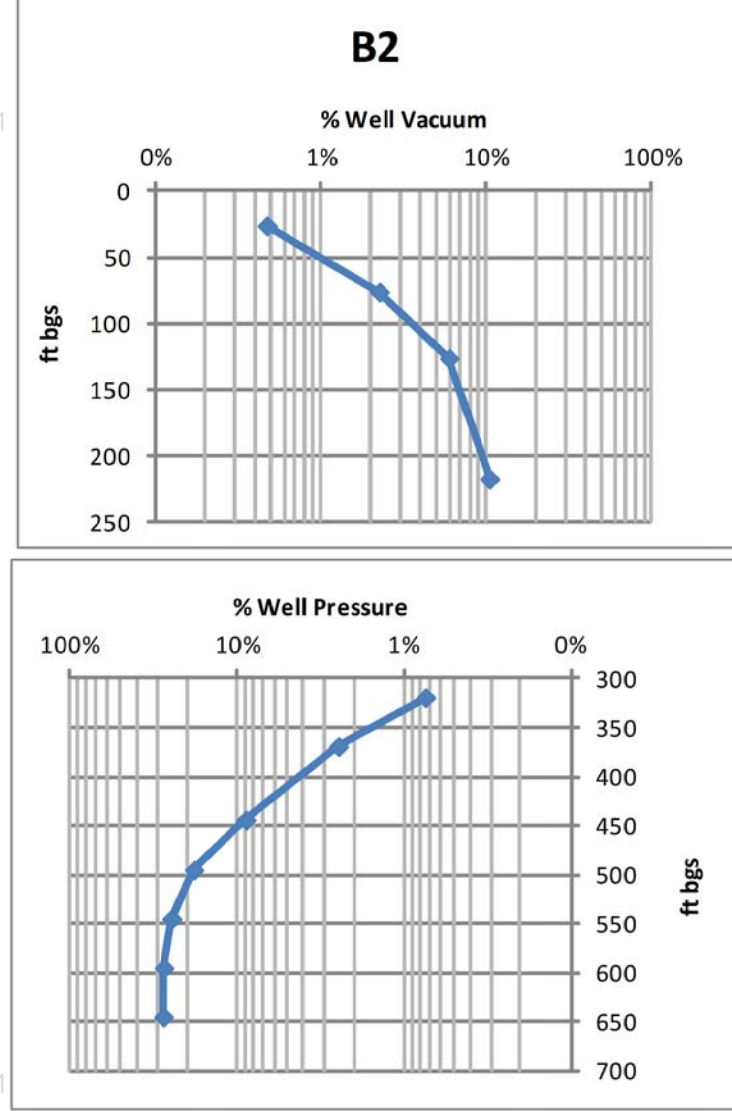
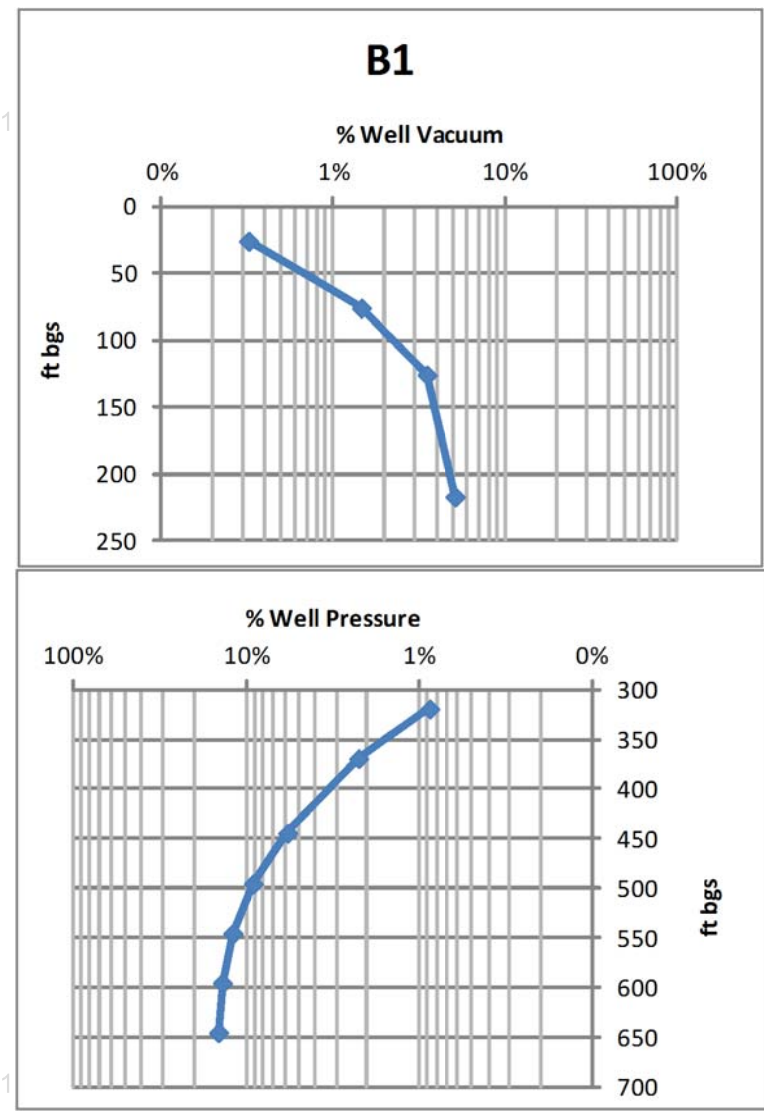
AMEC Environment & Infrastructure
4600 East Washington Street, Suite 600
Phoenix, AZ 85034



DATUM:	—
PROJECTION:	—
DRAWN BY:	MDS
REVIEWED BY:	M. ZHANG
ORIGINAL SCALE:	AS SHOWN

PROJECT: PAGE - TROWBRIDGE RANCH LANDFILL
RCRA PART B POST CLOSURE PERMIT APPLICATION
(EPA ID AZ98066584)

TITLE: SIMULATED PRESSURE RESPONSES AT EXTRACTION / INJECTION RATES OF 9.25 AND 3.75 SCFM AROUND UNIT A



SOURCE: USGS MAMMOTH, ARIZONA 1986
1:100000 SCALE

ft bgs = FEET BELOW GROUND SURFACE

0 200 400
APPROXIMATE SCALE IN FEET

REV	D	M	Y	ISSUE/REVISION DESCRIPTION	ENG. APPR.

Client Logo:

Client:

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P.O. BOX 210460
TUCSON, AZ. 85721-0460

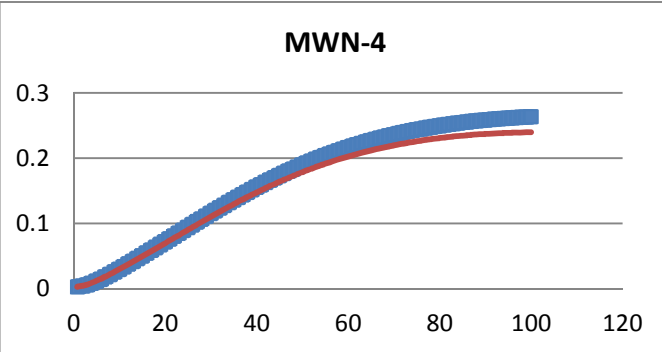
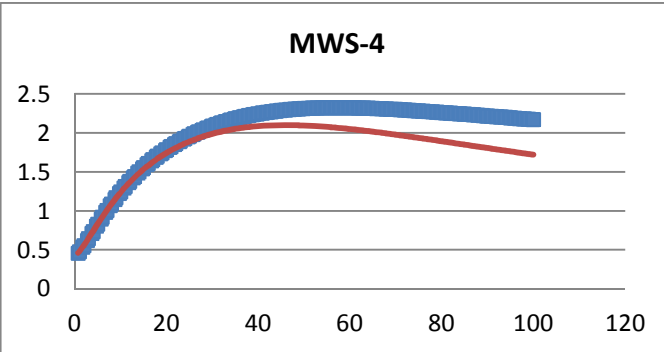
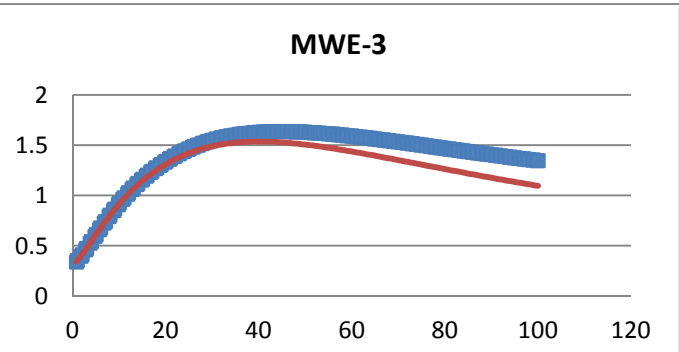
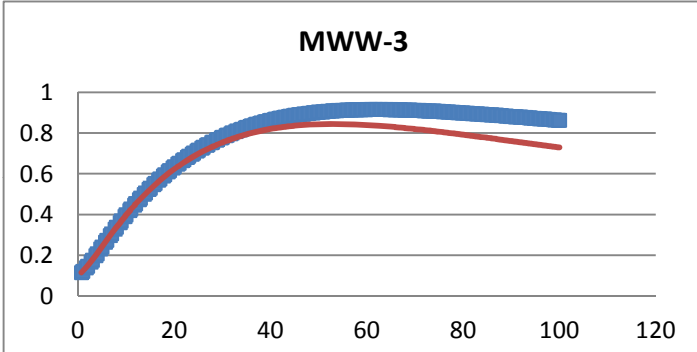
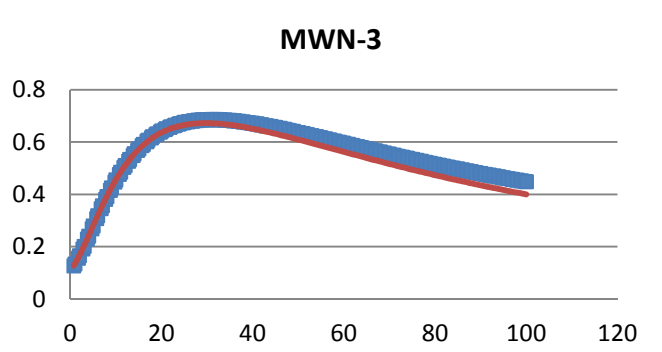
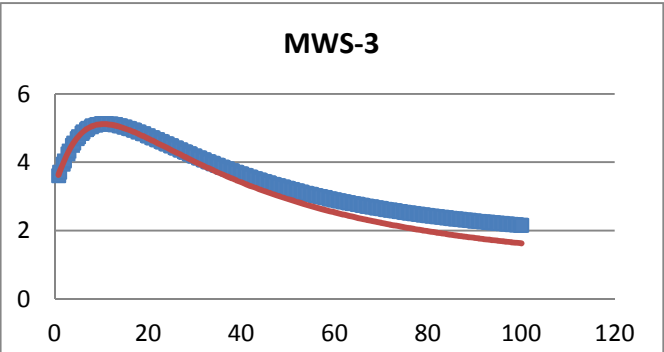
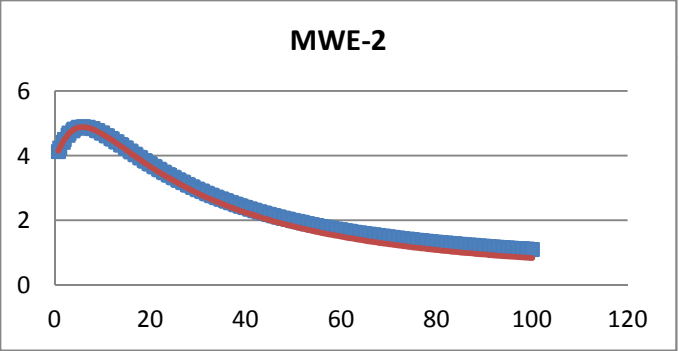
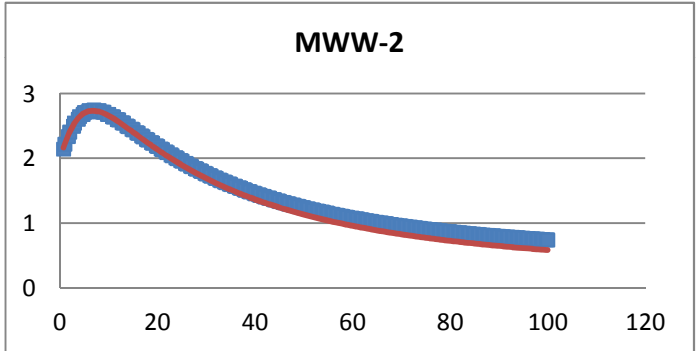
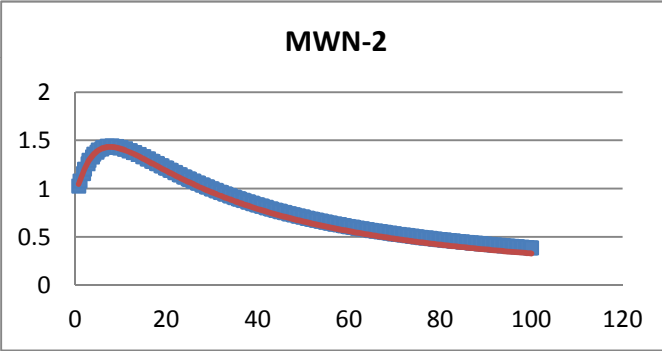
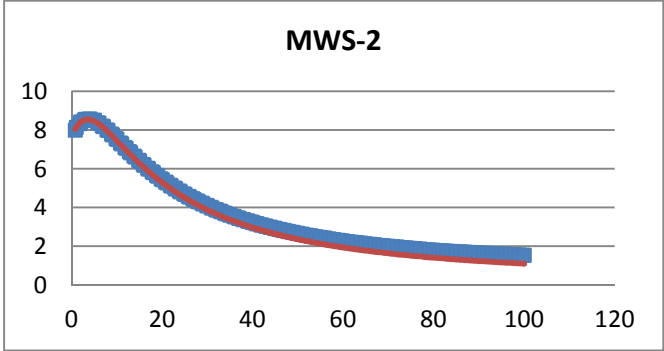
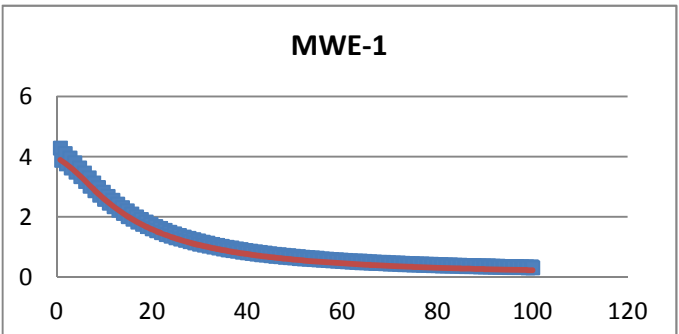
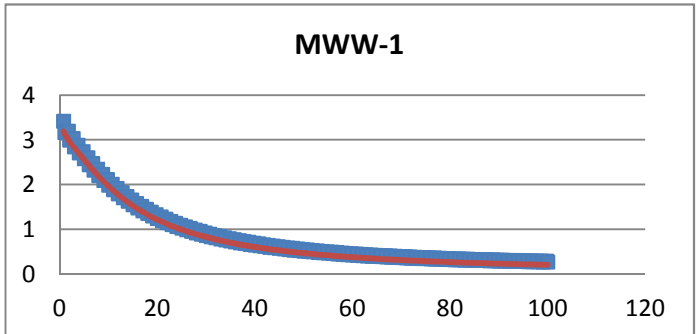
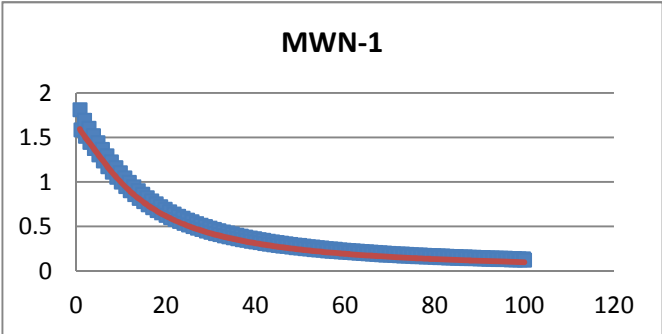
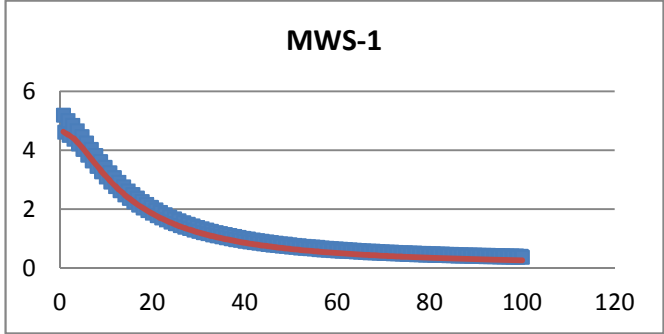
AMEC Environment & Infrastructure
4600 East Washington Street, Suite 600
Phoenix, AZ 85034



DATUM:	---
PROJECTION:	---
DRAWN BY:	MDS
REVIEWED BY:	M. ZHANG
ORIGINAL SCALE:	AS SHOWN

PROJECT:	PAGE - TROWBRIDGE RANCH LANDFILL RCRA PART B POST CLOSURE PERMIT APPLICATION (EPA ID AZ98066584)	PROJECT NO.: A00377
TITLE:	SIMULATED PRESSURE RESPONSES AT EXTRACTION / INJECTION RATES OF 9.25 AND 3.75 SCFM AROUND UNIT B	REVISION NO.: A
DATE:	3/30/12	DRAWING NO.: Figure 5B
SHEET NO.:	1 of 1	

S:\AMEC\Office\Temp\11201\CAD\PTBL RCRA MP\Locations\Graphs BY_C03812.dwg - Figure 5B - Mar. 30, 2012 10:36am - adam.schenberg



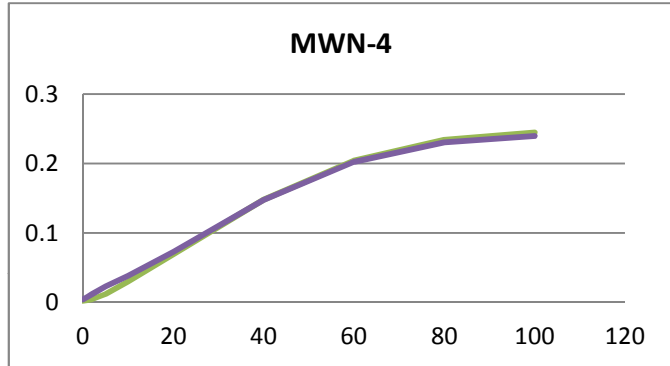
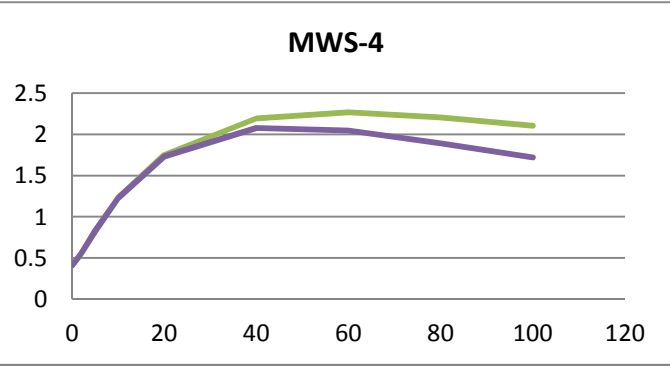
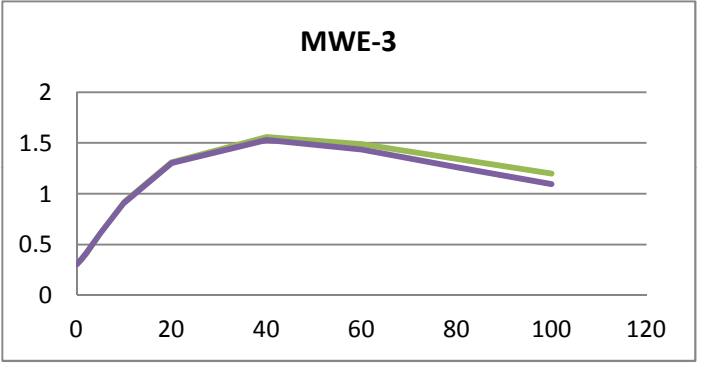
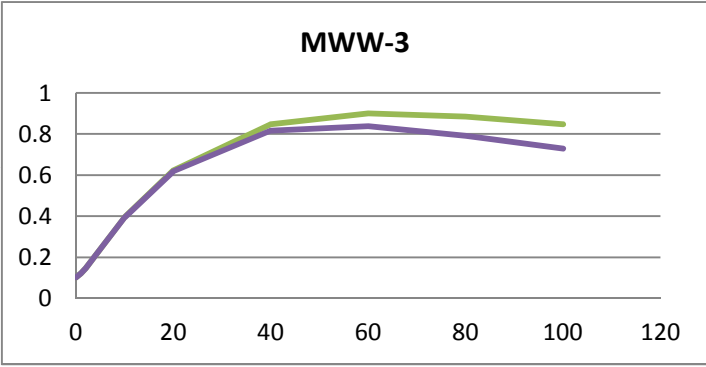
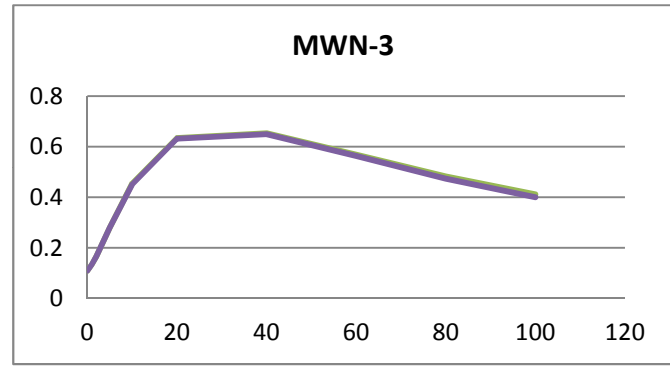
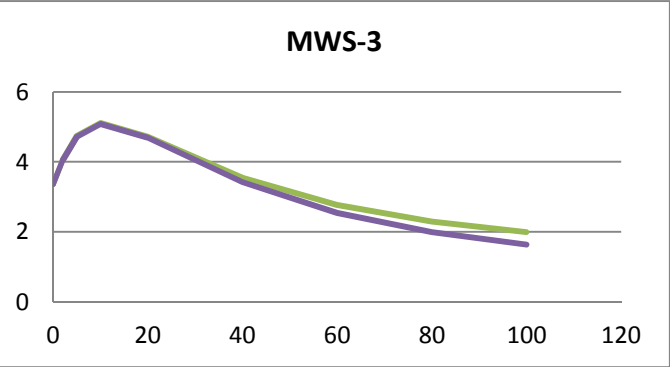
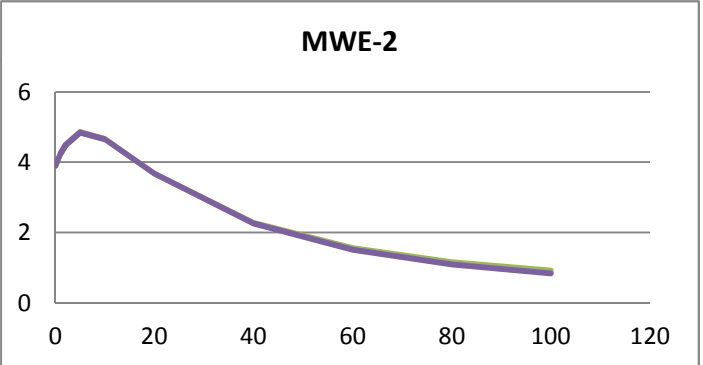
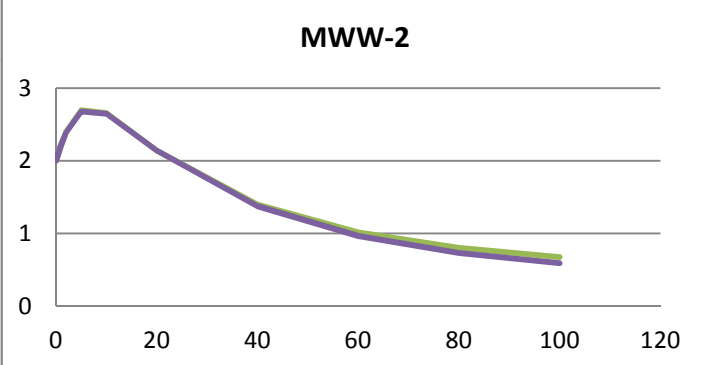
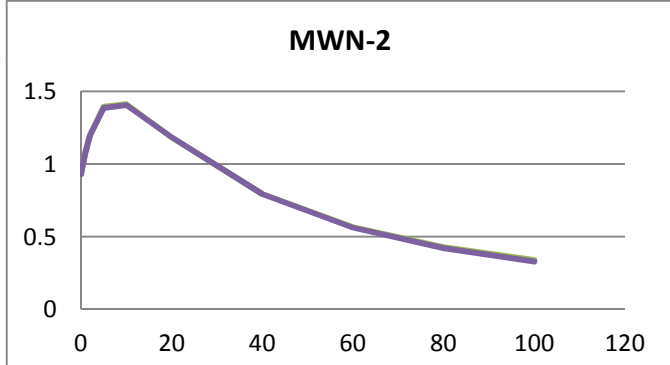
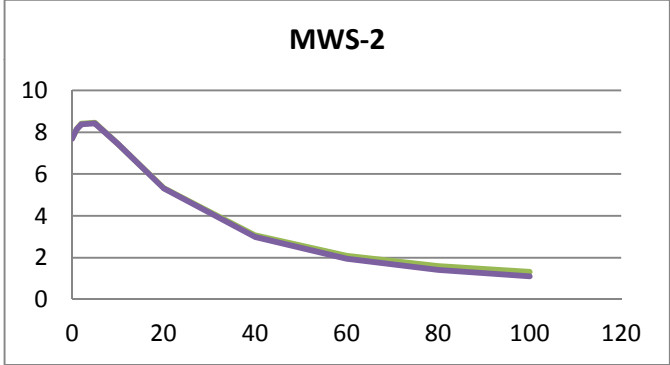
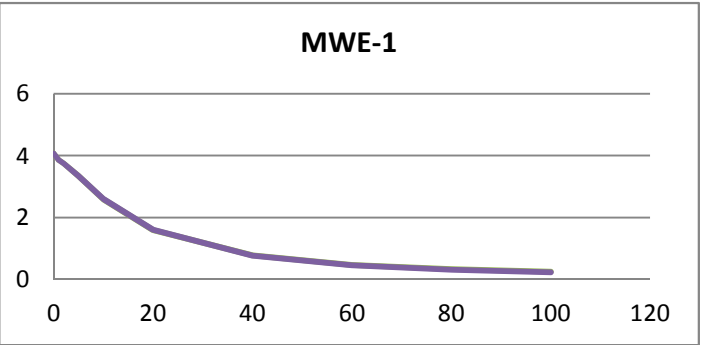
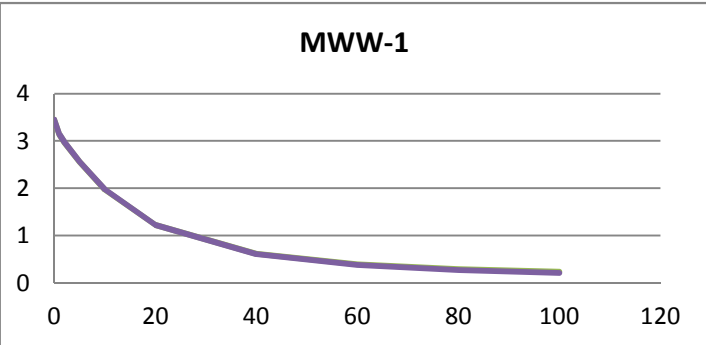
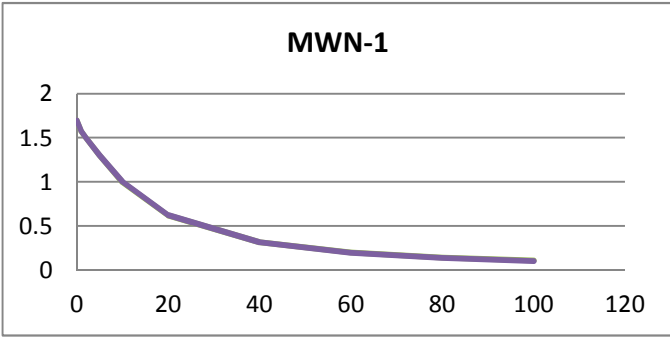
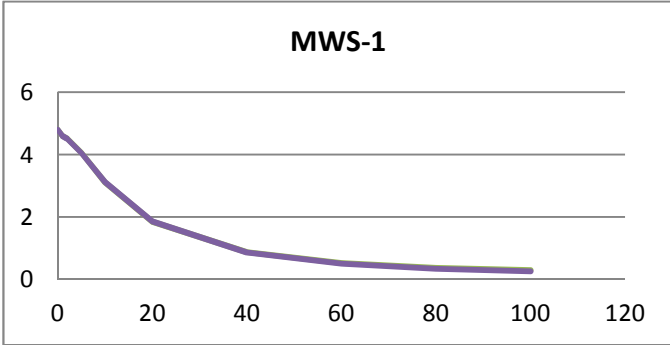
Explanations:

Red - simulated concentrations assuming no shutdown
Blue - simulated concentrations assuming nine-month shutdown during each twelve-month period
X axis - years
Y axis - Freon-11 concentration in mg/m³

SIMULATED SOIL VAPOR CONCENTRATIONS WITHIN 25 FT OF WATER TABLE - EXTRACTION/INJECTION RATES OF 9.25 SCFM AND 15 SCFM ON "NINE MONTHS OFF, THREE MONTHS ON" SCHEDULE

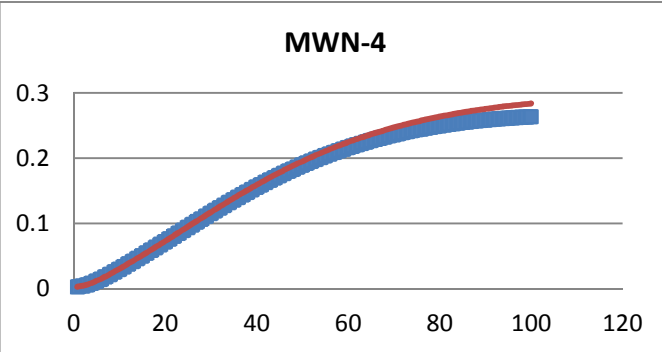
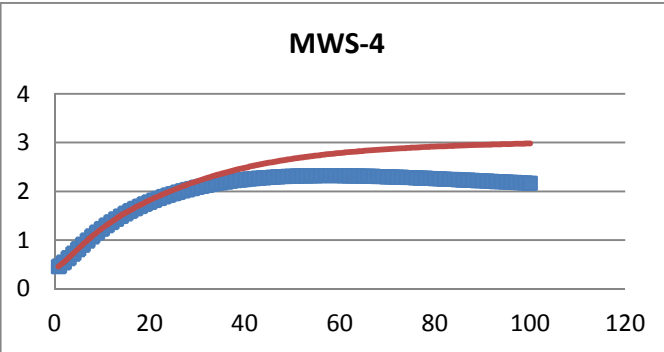
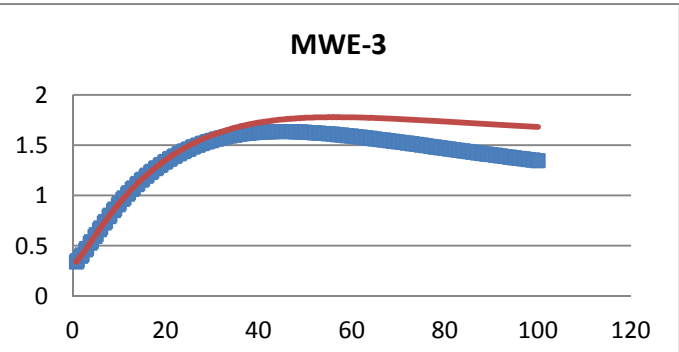
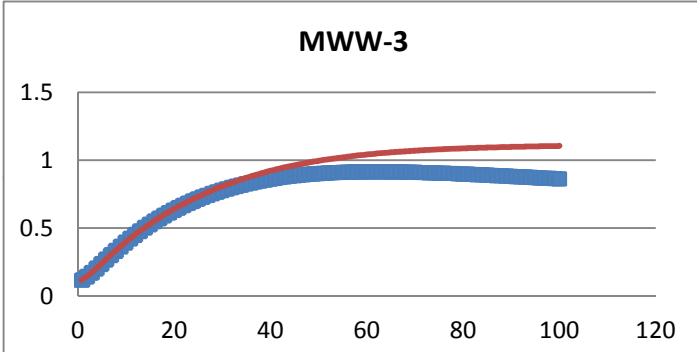
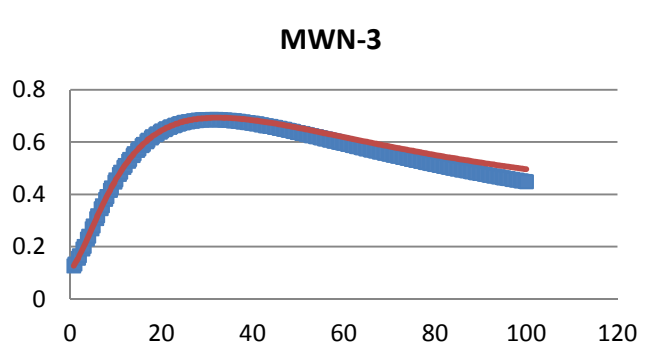
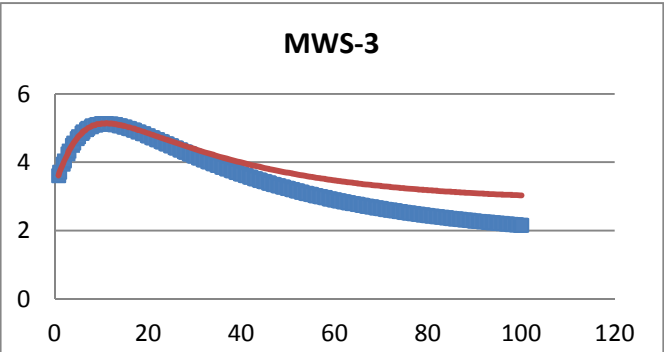
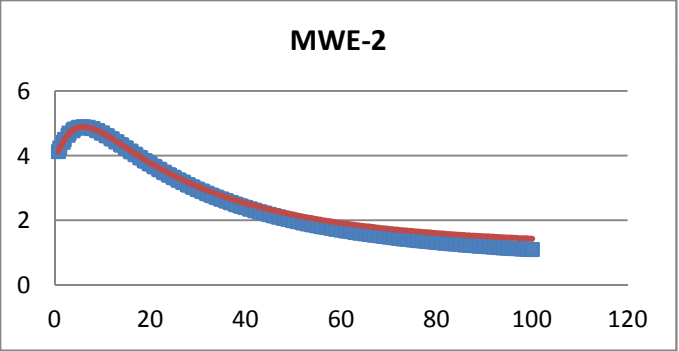
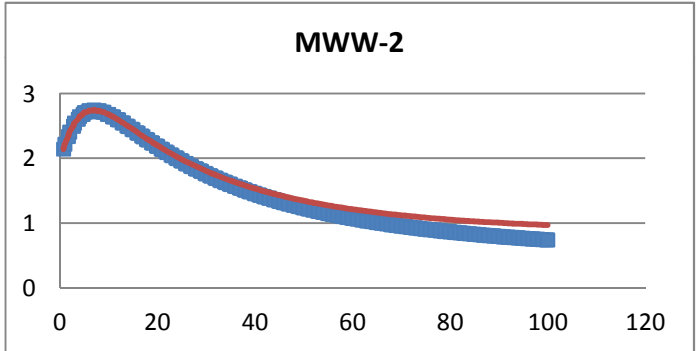
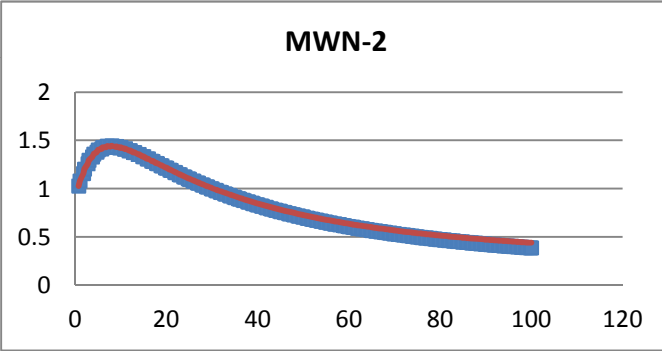
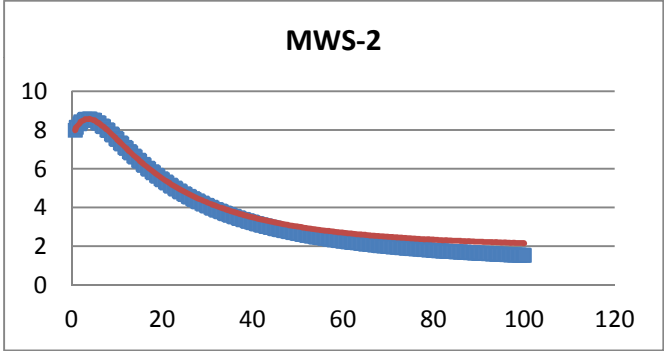
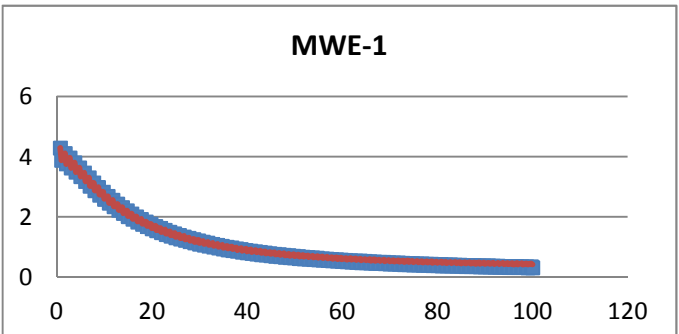
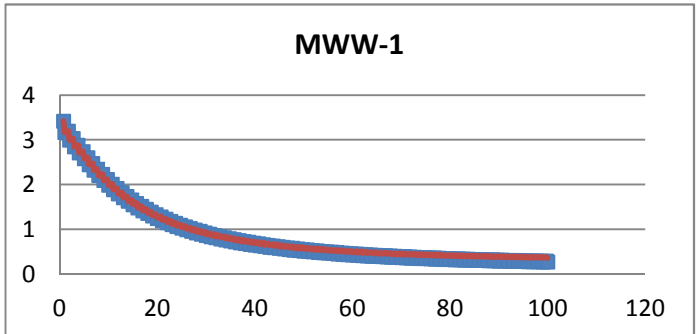
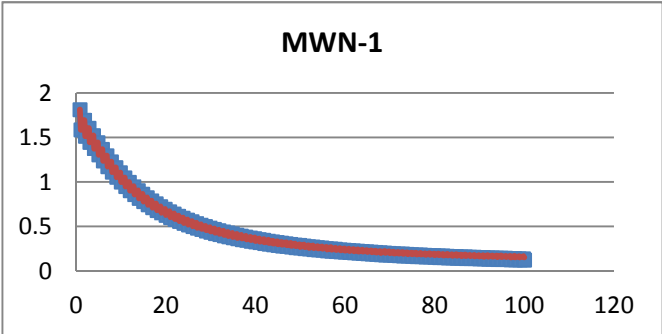
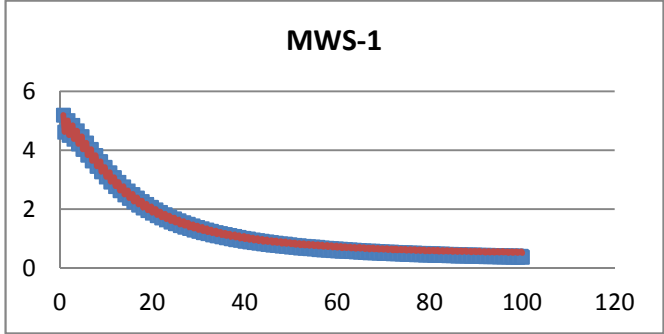
By: MZ Date: 06/28/11 Project No.: 1420112012





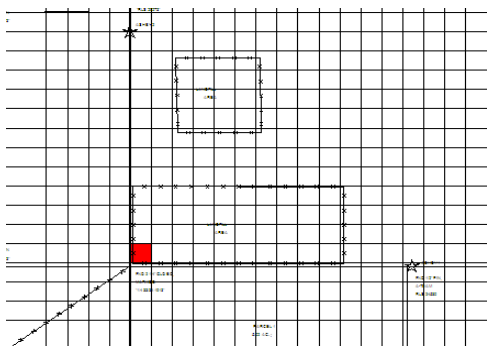
Explanations:

Green - simulated concentrations assuming source concentrations equal to twice the calibrated values
Magenta - simulated concentrations assuming source concentrations equal to the calibrated values
X axis - years
Y axis - Freon-11 concentration in mg/m³

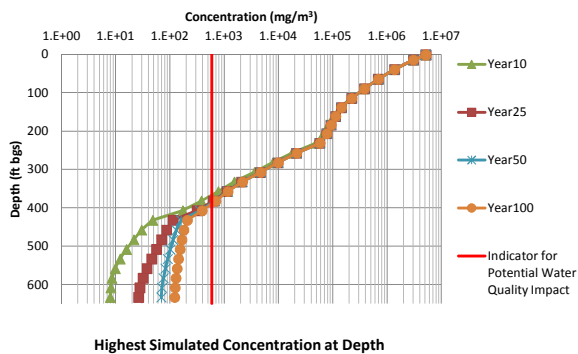


Explanations:

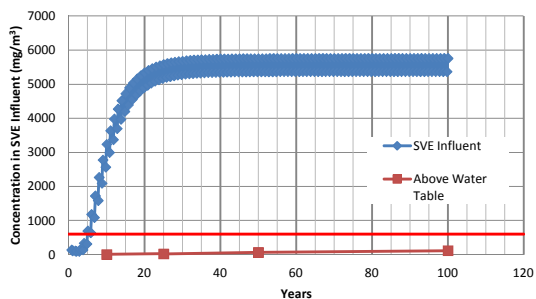
Red - simulated concentrations assuming source concentrations equal to twice the calibrated values
Blue - simulated concentrations assuming source concentrations equal to the calibrated valules
X axis - years
Y axis - Freon-11 concentration in mg/m³



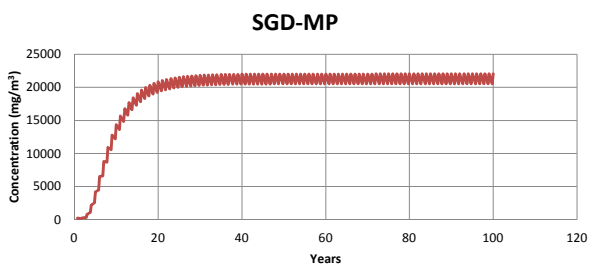
Remote Release in Southwest Corner of Landfill Unit B



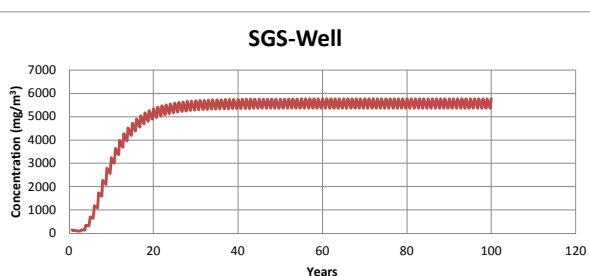
Highest Simulated Concentration at Depth



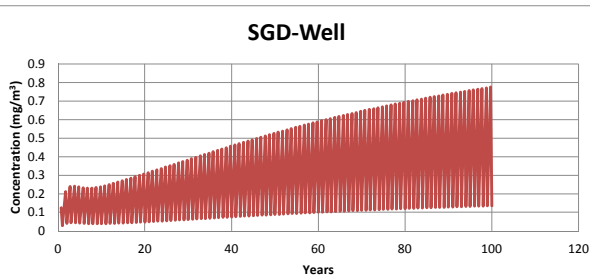
Concentrations in SVE Influent and Soil Vapor above Water Table



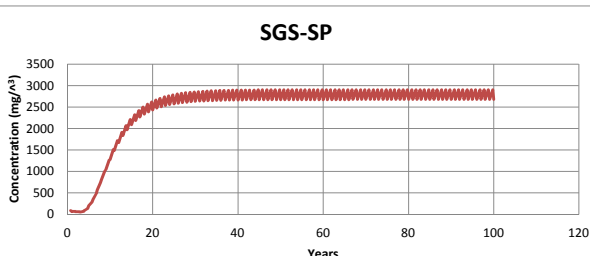
SGD-MP



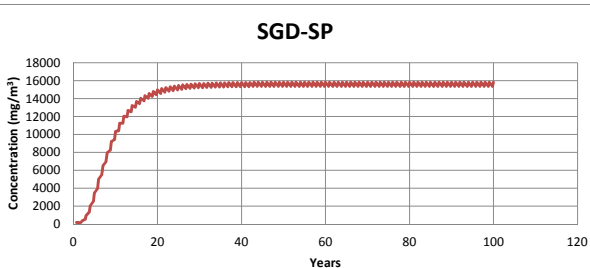
SGS-Well



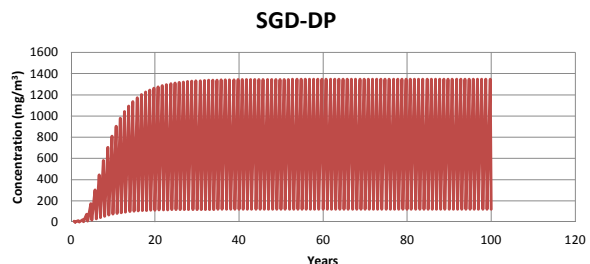
SGD-Well



SGS-SP



SGD-SP



SGD-DP

Explanation:

1. SGS-Well is in extraction mode. SGD-Well is in injection mode.
2. SGS-Well and SGD-Well are operating on a schedule of nine-month off & three-month on.
3. When in operation, SGS-Well and SGD-Well are operating at time-averaged extraction/injection rates of 37 and 15 scfm, respectively.
3. All concentrations plotted are for Freon-11 in unit of mg/m^3 .
4. A simulated release occurs at year zero in the southwest corner of landfill Unit B.



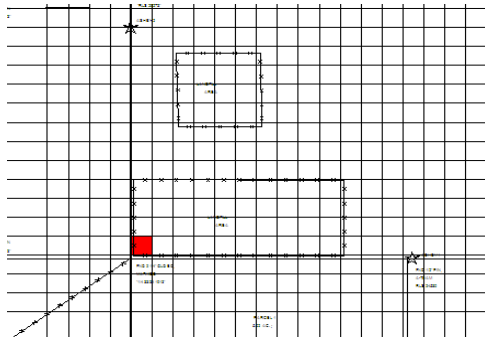
Project: 1420112012

By: MZ

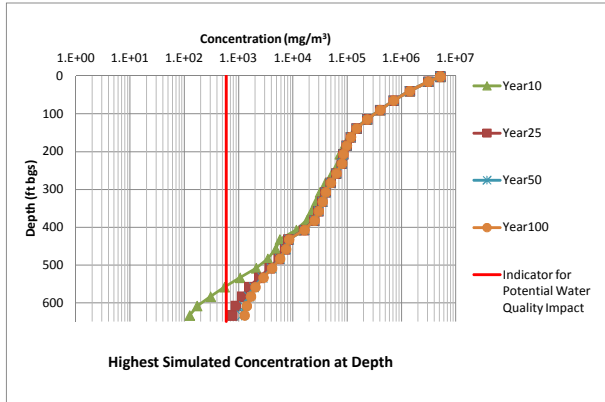
Date: 04/20/12

Figure 9

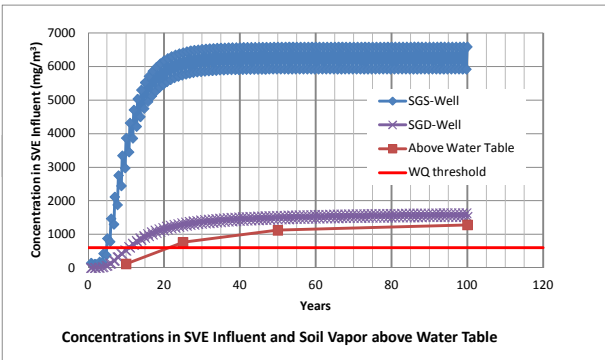
Simulated Concentrations at Monitoring Points and in SVE Influent for Remote Release with SGS-Well in Extraction Mode and SGD-Well in Injection Mode



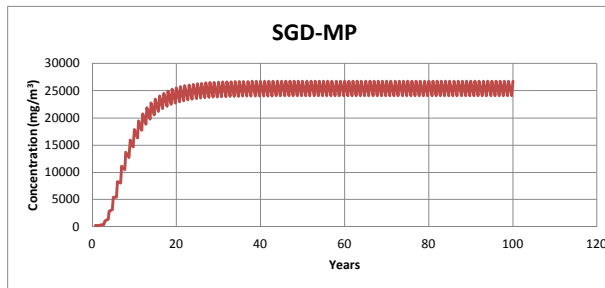
Remote Release in Southwest Corner of Landfill Unit B



Highest Simulated Concentration at Depth



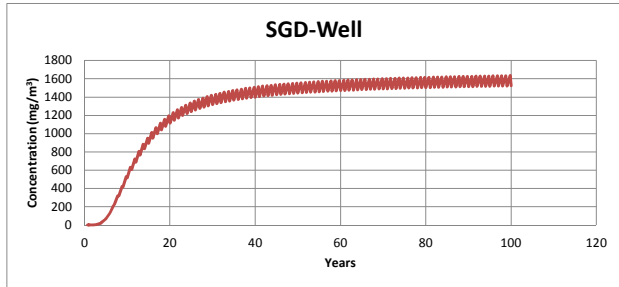
Concentrations in SVE Influent and Soil Vapor above Water Table



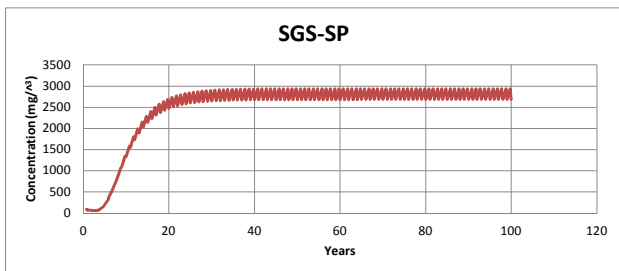
SGD-MP



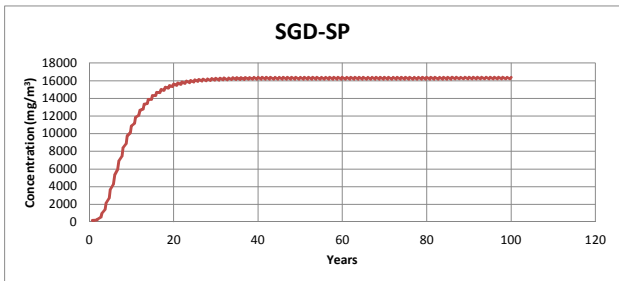
SGS-Well



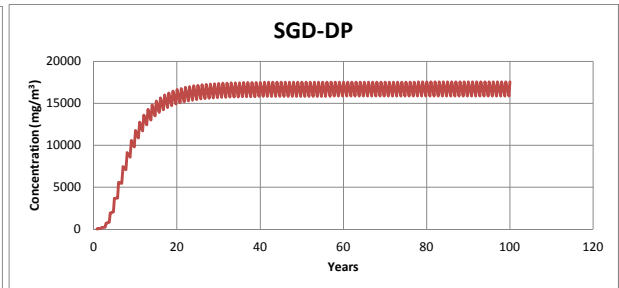
SGD-Well



SGS-SP



SGD-SP



SGD-DP

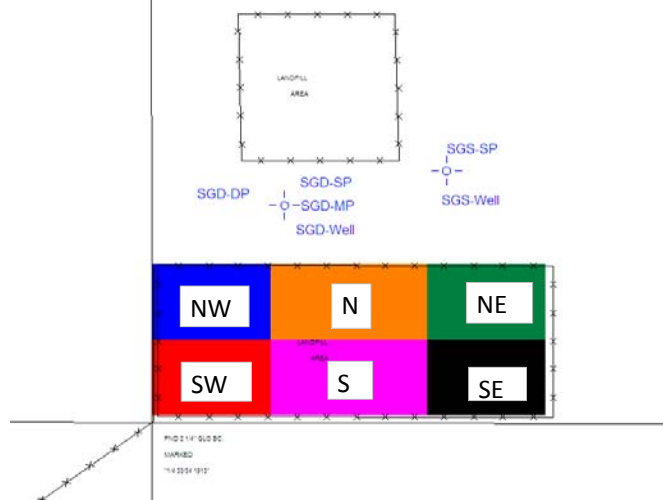
Explanation:

1. Both SGS-Well and SGD-Well are in extraction mode.
2. SGS-Well and SGD-Well are operating on a schedule of nine-month off & three-month on.
3. When in operation, SGS-Well and SGD-Well are operating at time-averaged extraction rates of 37 and 15 scfm, respectively.
4. All concentrations plotted are for Freon-11 in unit of mg/m^3 .
5. A simulated release occurs at year zero in the southwest corner of landfill Unit B.

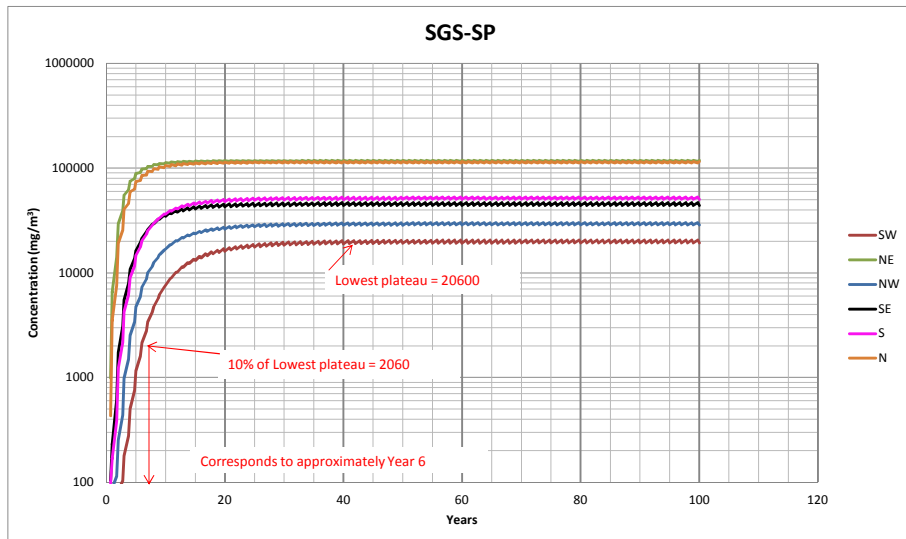
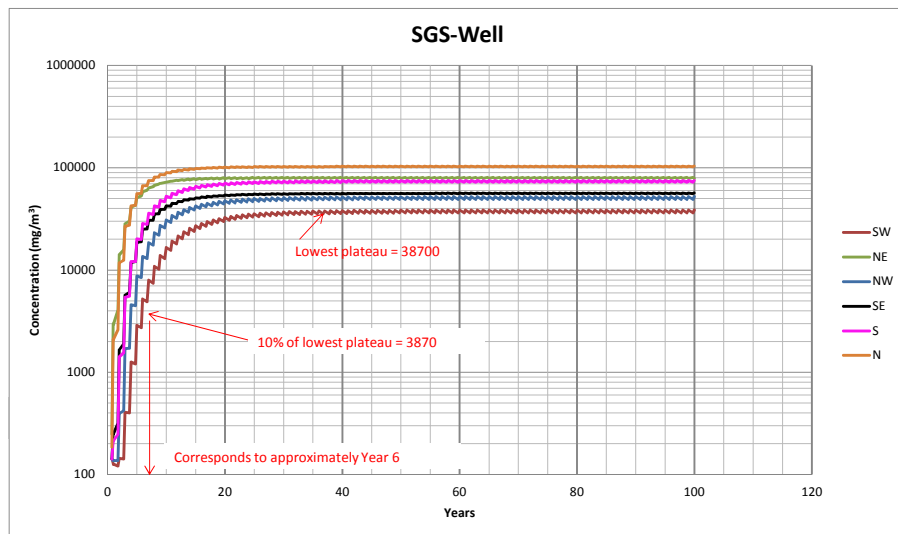


Project: 1420112012
By: MZ
Date: 04/20/12

Figure 10
Simulated Concentrations at Monitoring Points and in SVE Influent for
Remote Release with Both SGS-Well and SGD-Well in Extraction Mode



Locations of Simulated Releases in Unit B



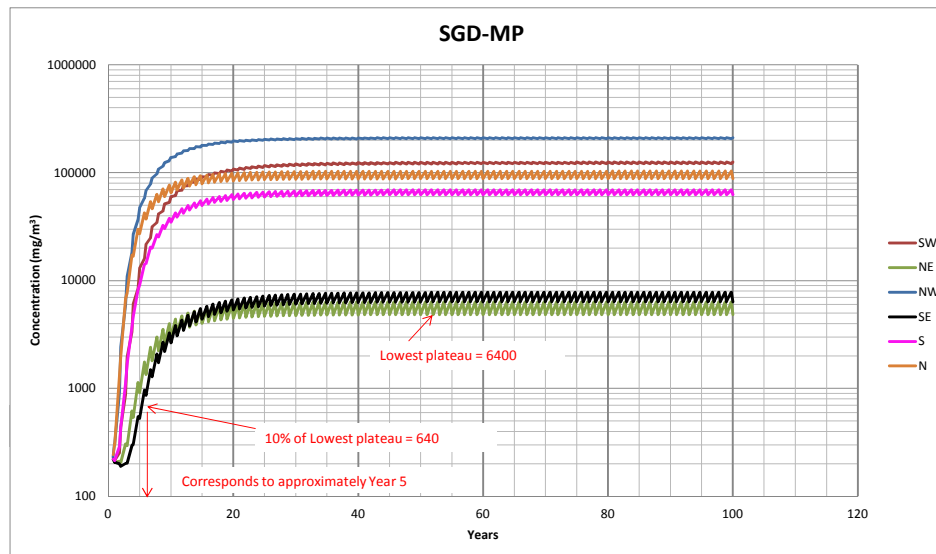
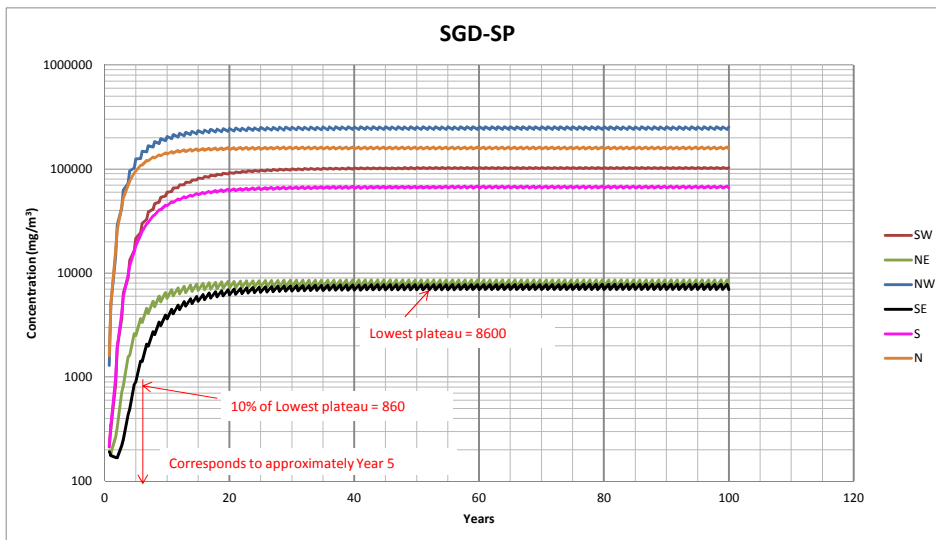
Project: 1420112012

By: MZ

Date: 03/27/12

Figure 11A

Simulated Freon-11 Concentrations at SGS-Well and SGS-SP with SVE Operating at Minimum Operational Parameters



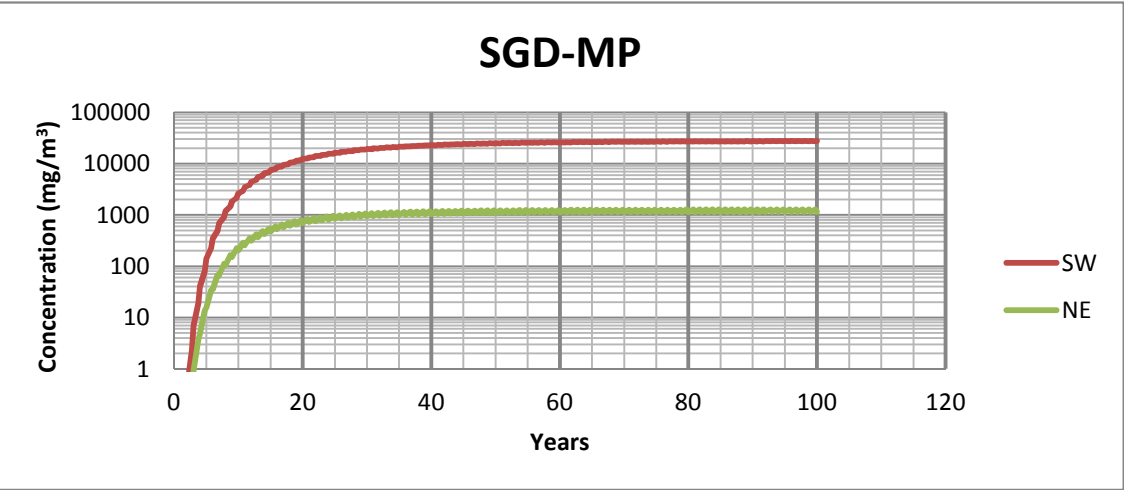
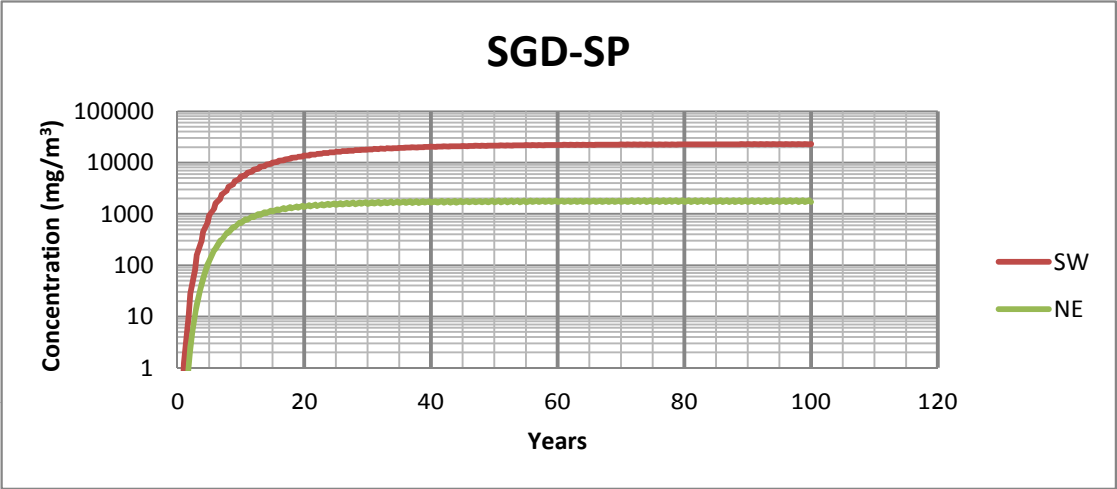
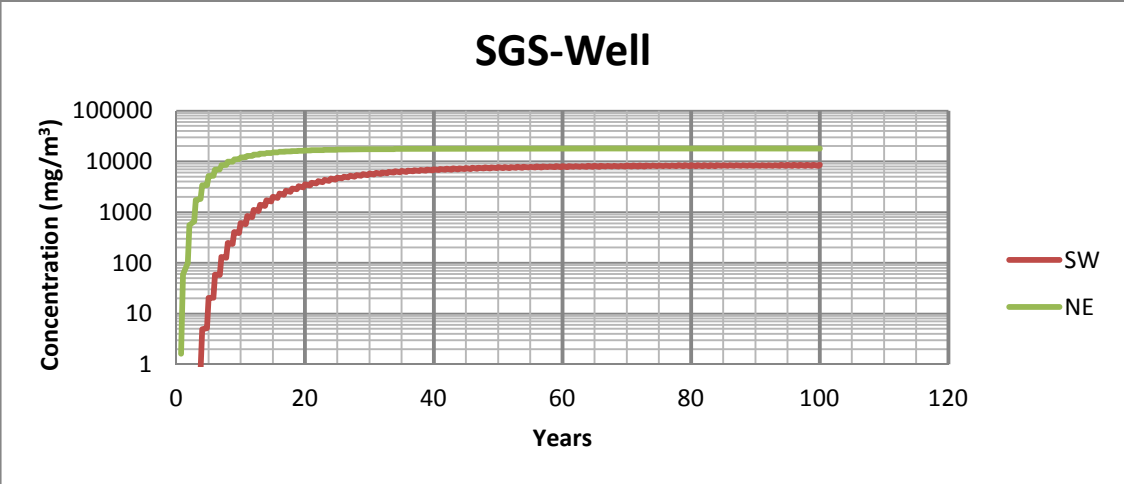
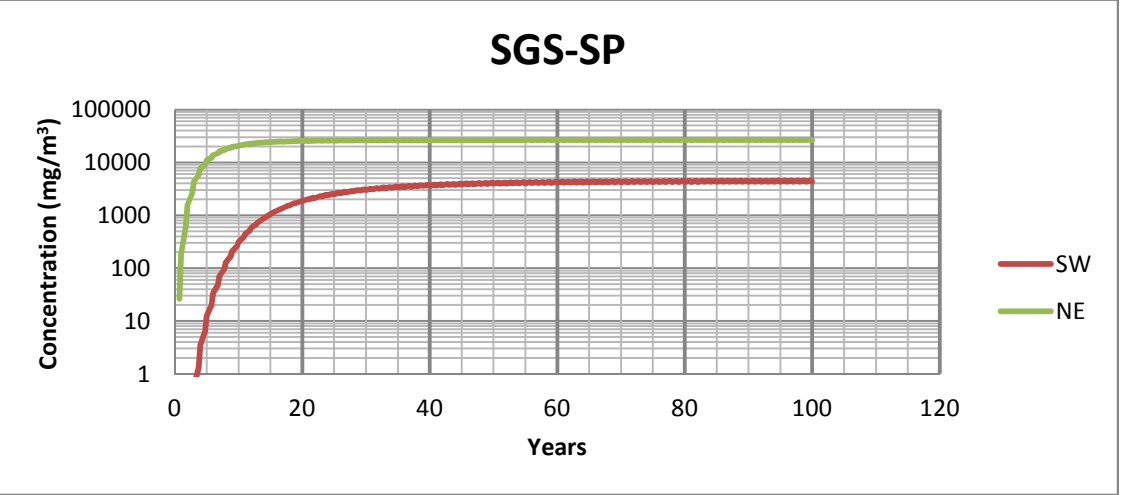
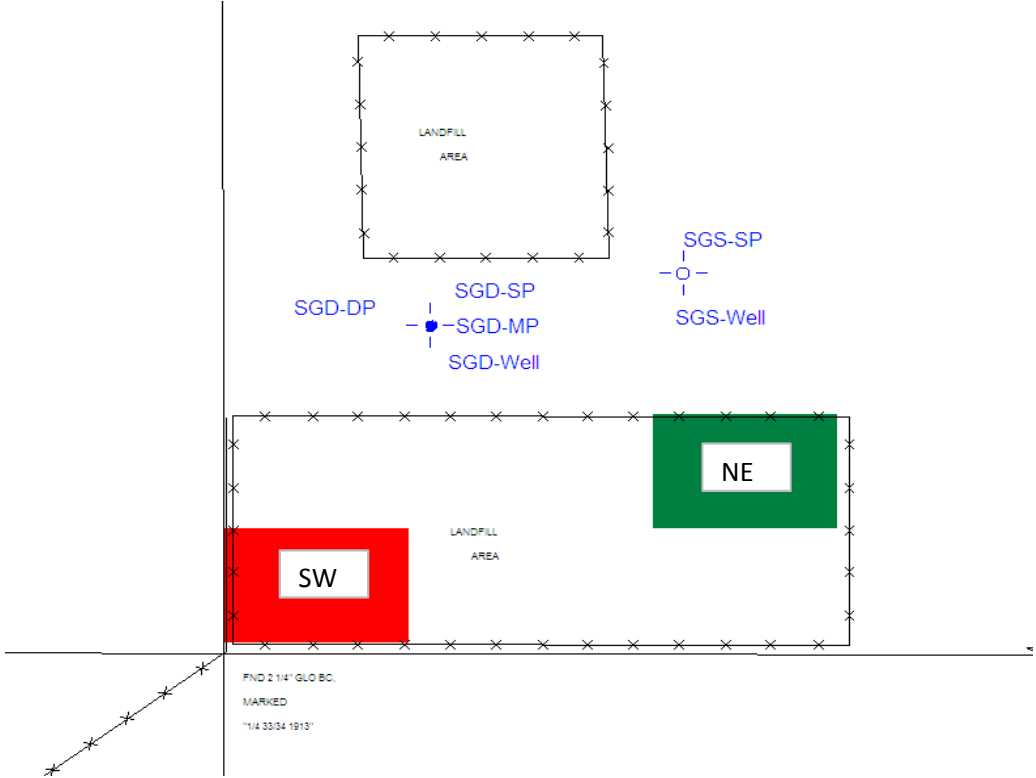
Project: 1420112012

By: MZ

Date: 03/27/12

Figure 11B

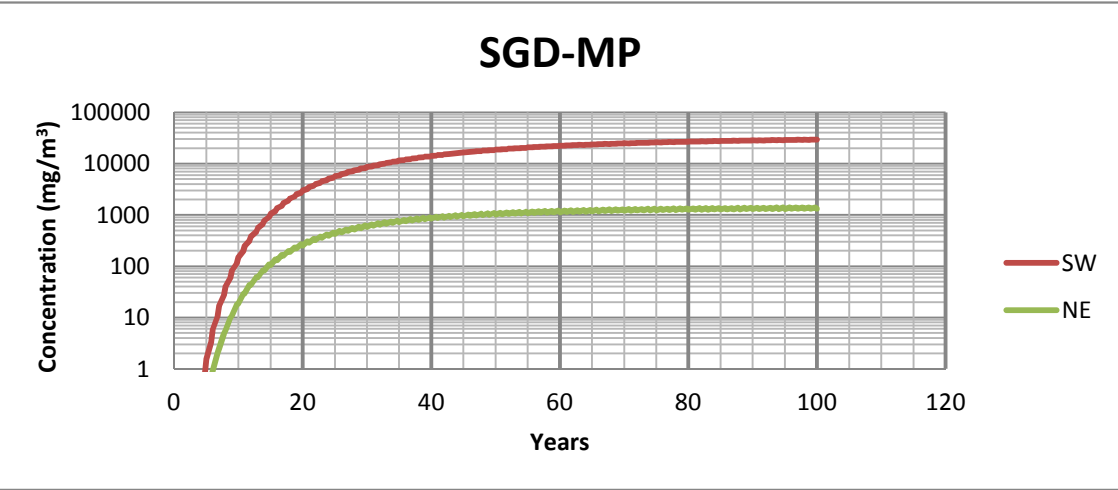
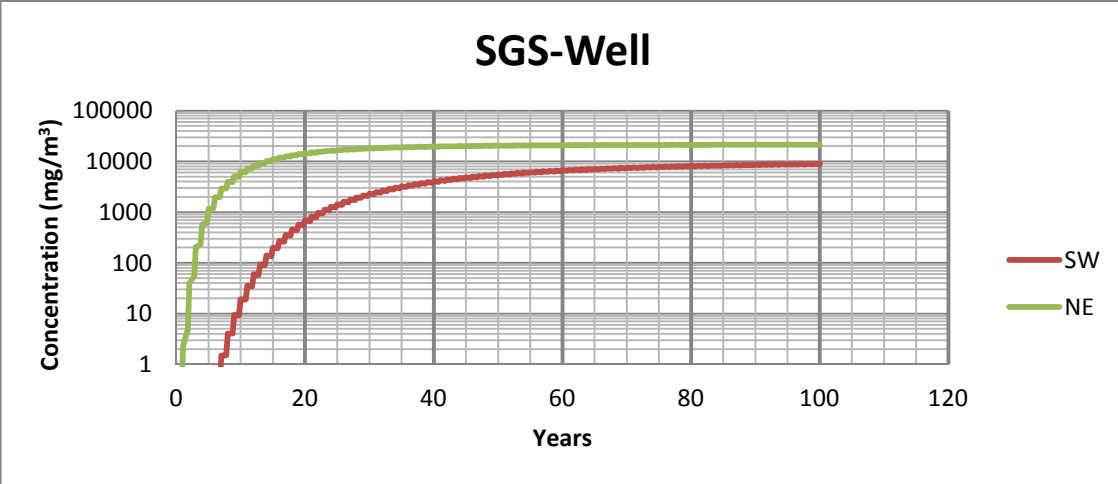
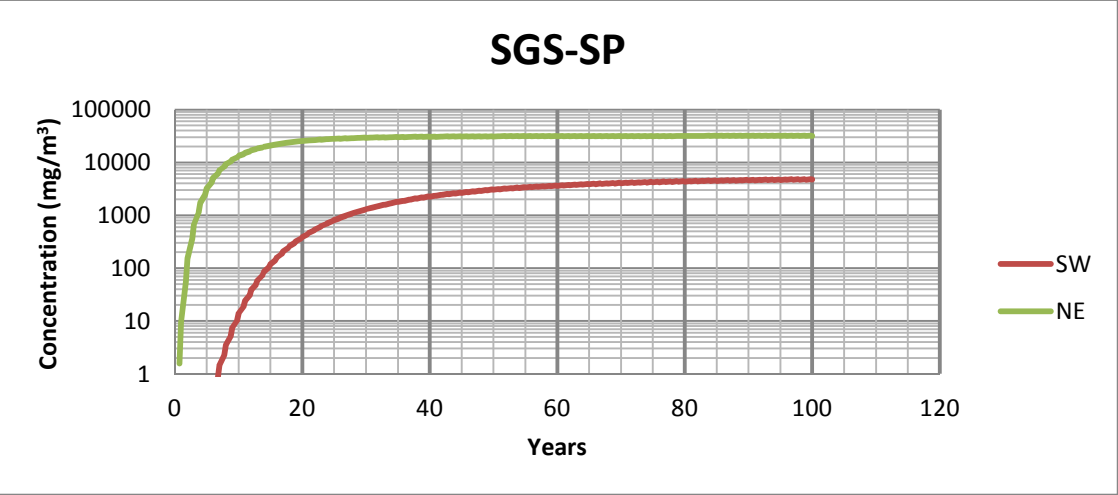
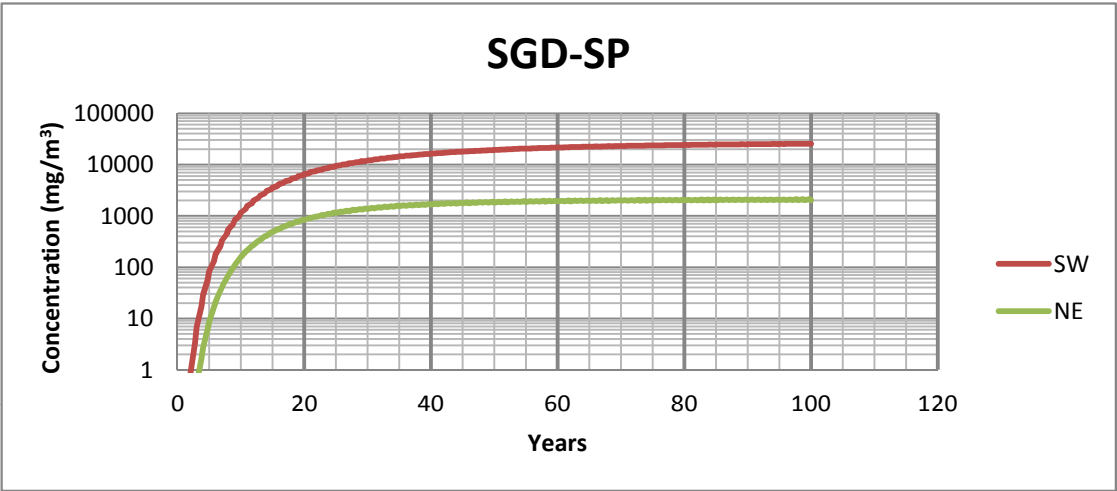
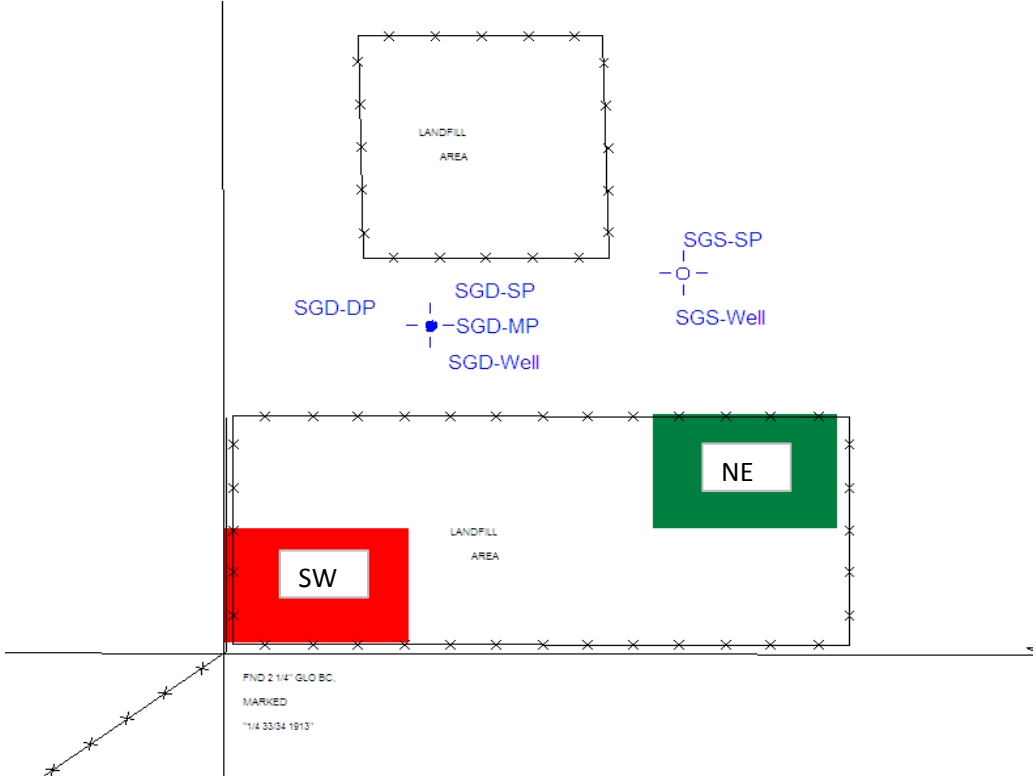
Simulated Freon-11 Concentrations at SGD-SP and SGD-MP with SVE Operating at Minimum Operational Parameters



SIMULATED CARBON TETRACHLORIDE
CONCENTRATIONS AT MONITORING POINTS AND
IN SVE INFLUENT WITH SVE OPERATING AT
MINIMUM OPERATIONAL PARAMETERS

By: MZ Date: 03/28/12 Project No.: 1420112012

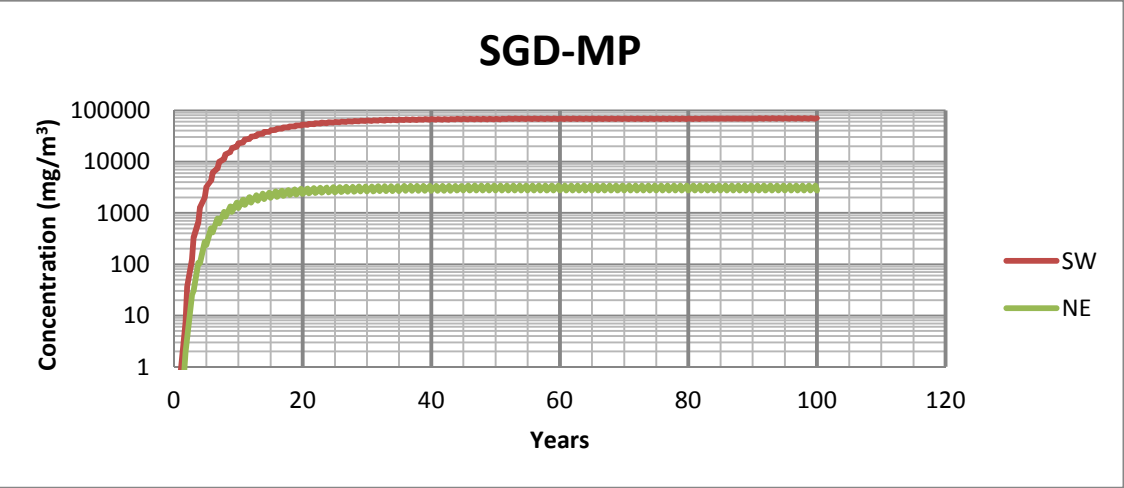
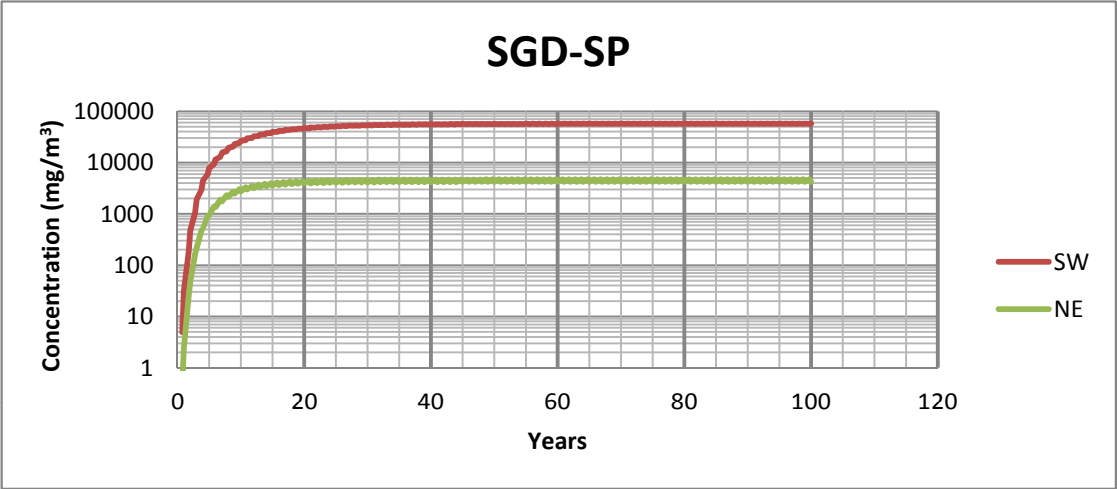
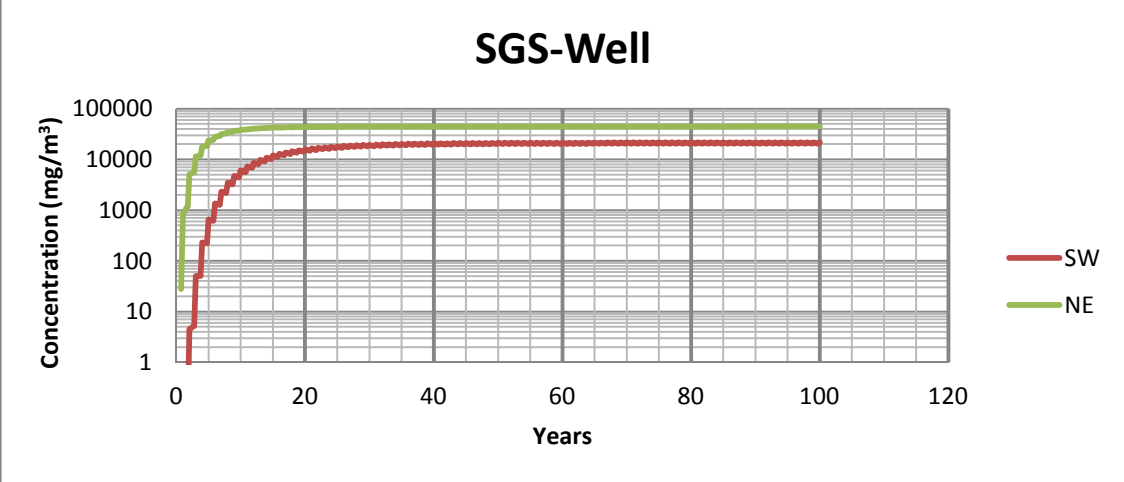
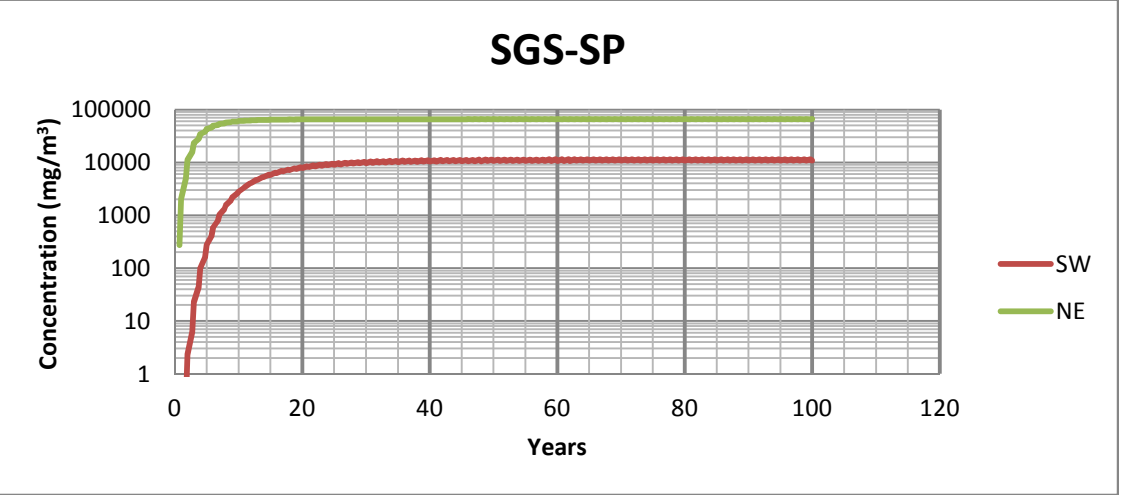
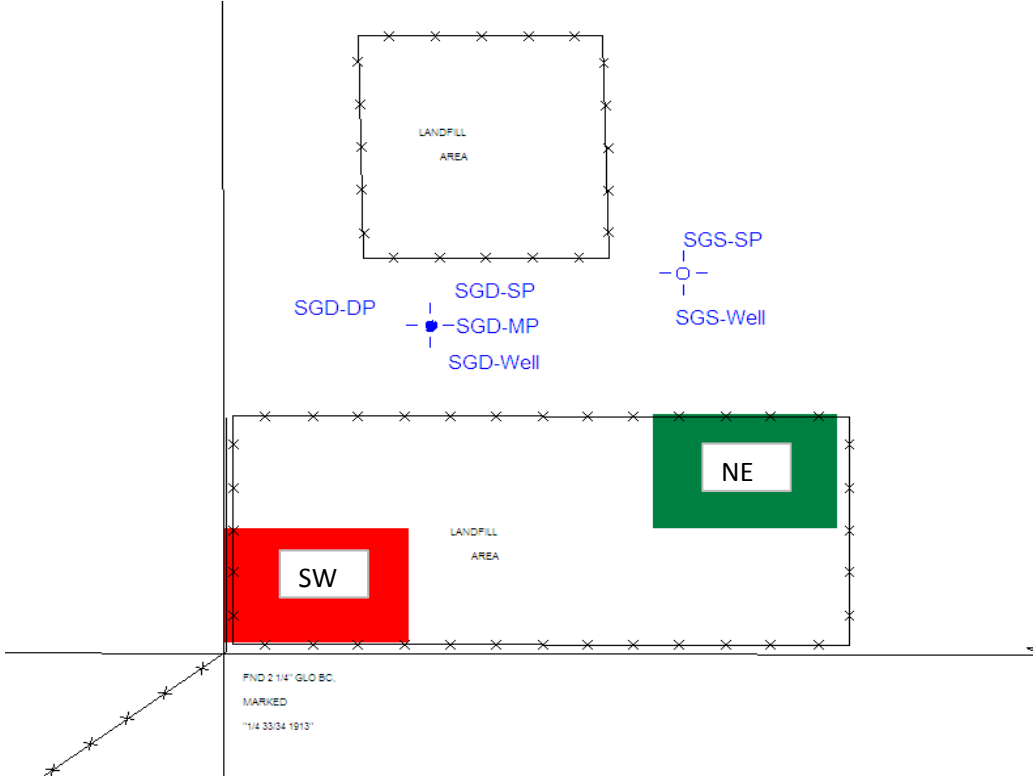




SIMULATED CHLOROFORM CONCENTRATIONS AT MONITORING POINTS AND IN SVE INFLUENT WITH SVE OPERATING AT MINIMUM OPERATIONAL PARAMETERS

By: MZ Date: 03/28/12 Project No.: 1420112012

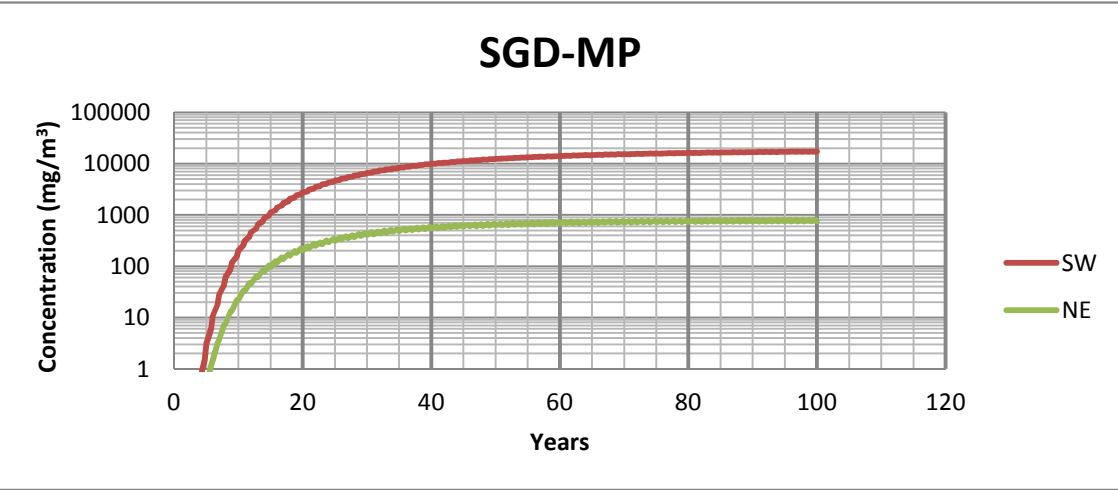
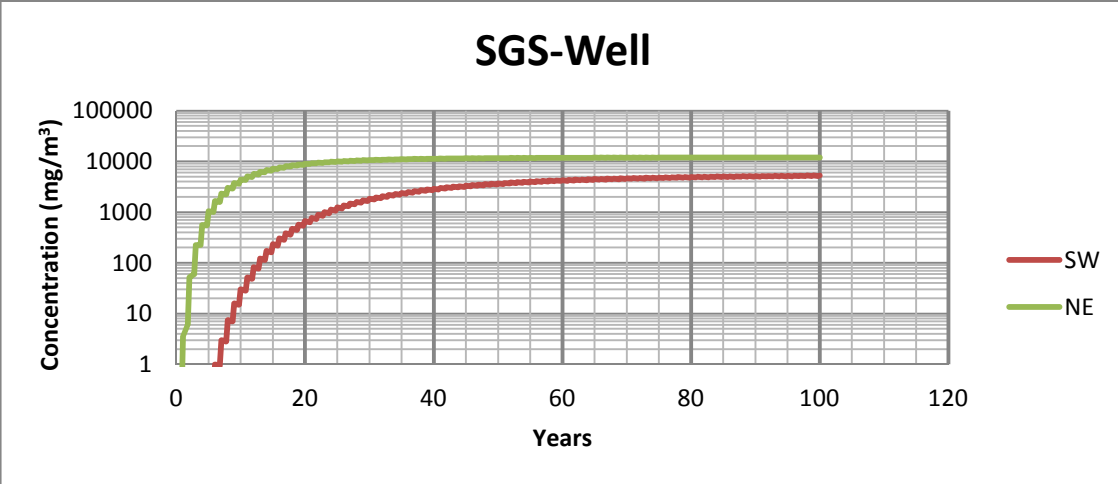
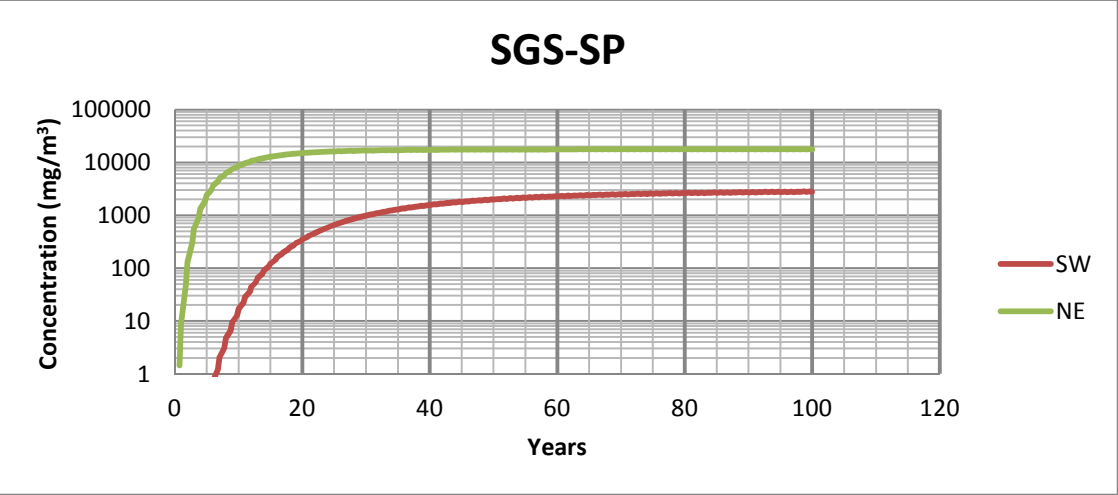
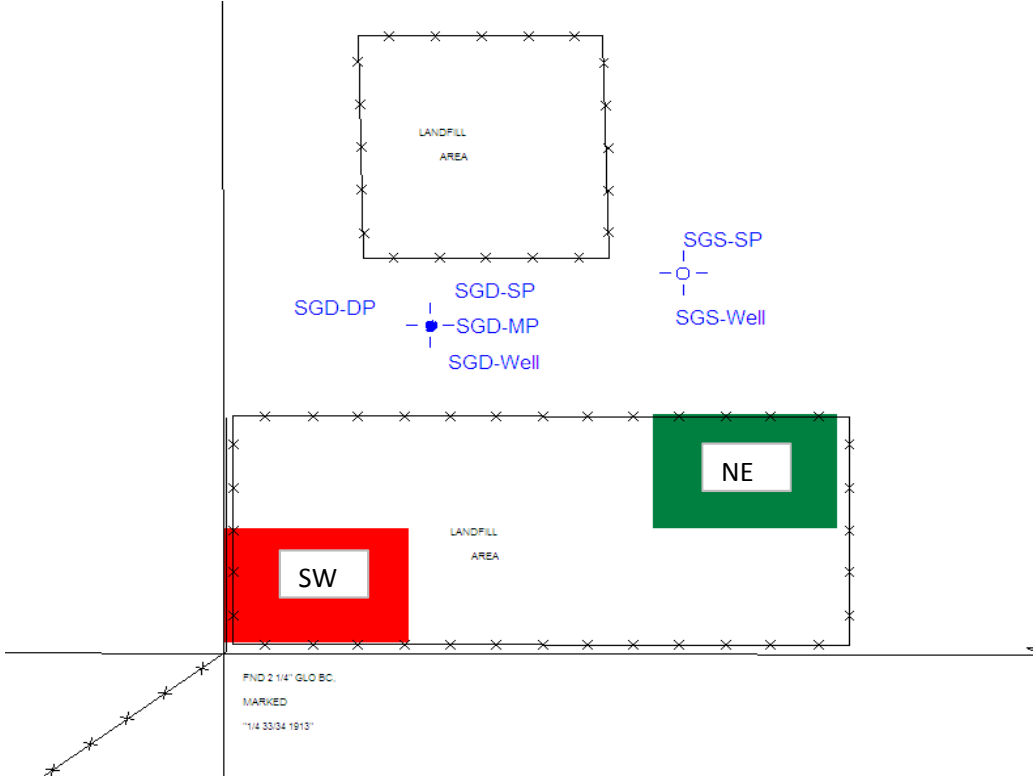




SIMULATED 1,1-DICHLOROETHENE
CONCENTRATIONS AT MONITORING POINTS AND
IN SVE INFLUENT WITH SVE OPERATING AT
MINIMUM OPERATIONAL PARAMETERS

By: MZ Date: 03/28/12 Project No.: 1420112012

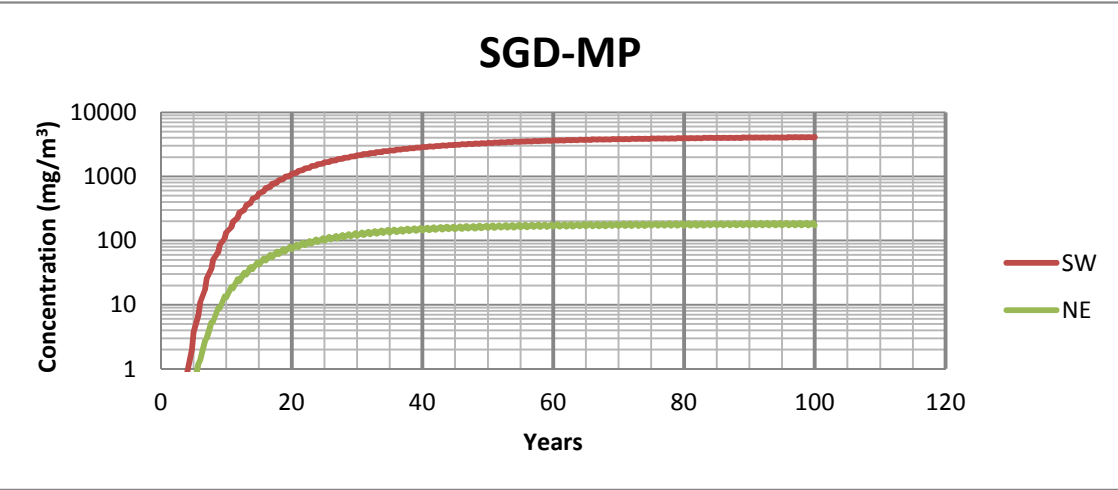
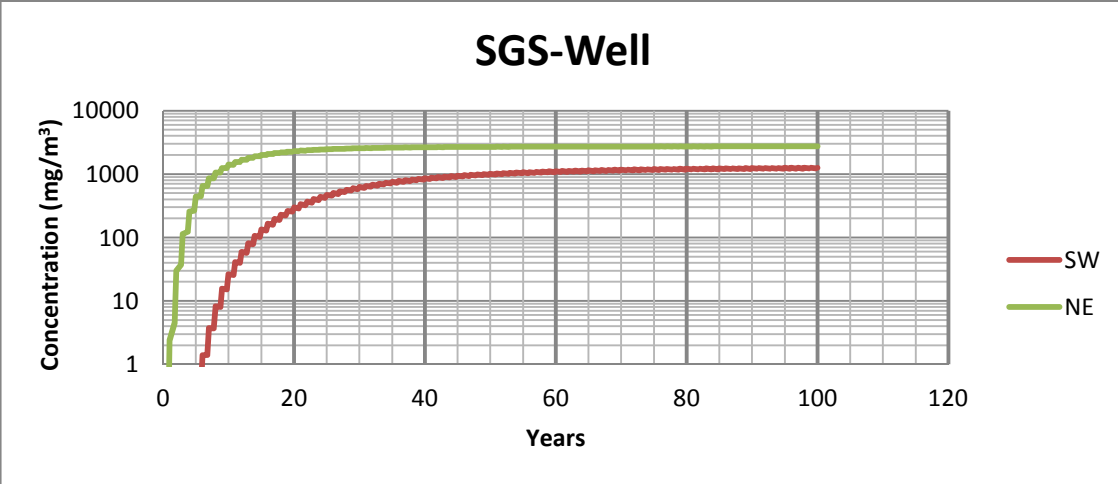
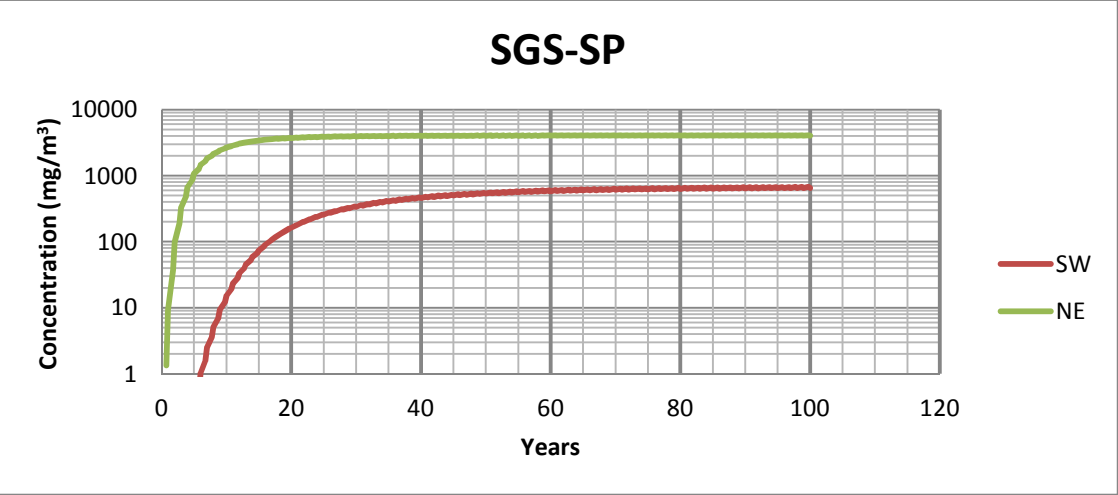
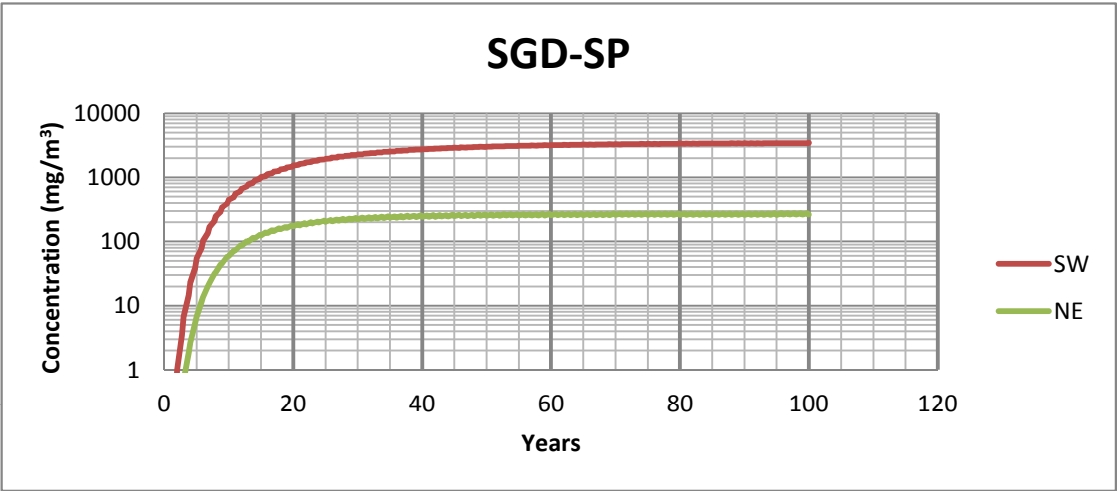
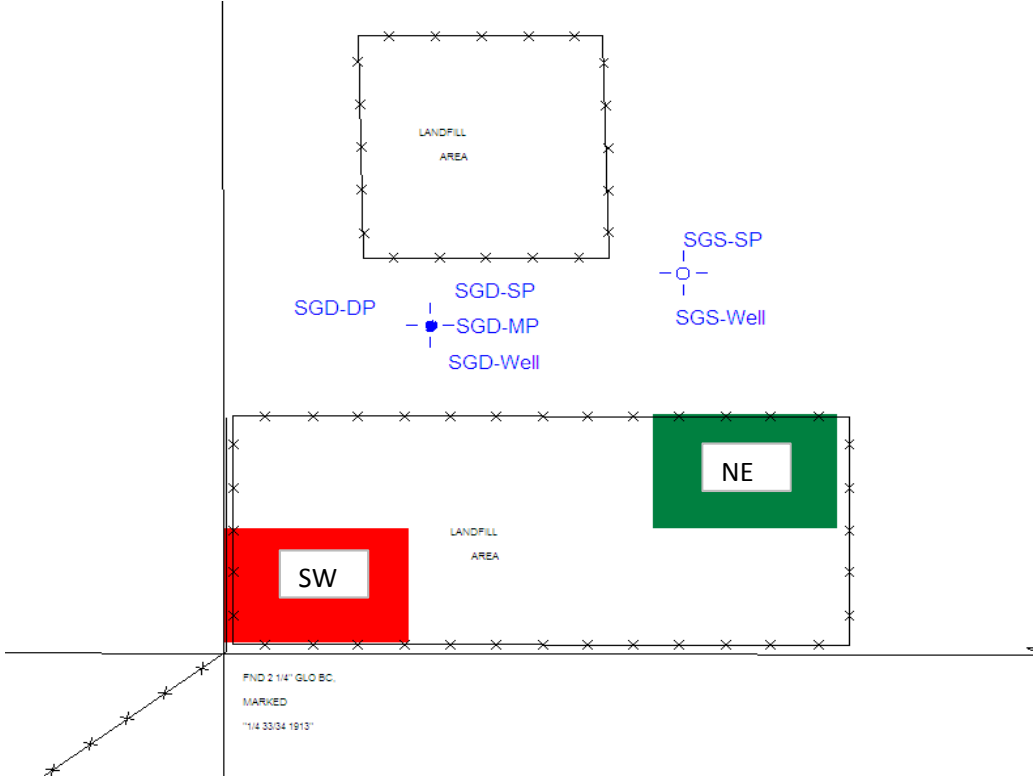




SIMULATED METHYLENE CHLORIDE
CONCENTRATIONS AT MONITORING POINTS AND
IN SVE INFLUENT WITH SVE OPERATING AT
MINIMUM OPERATIONAL PARAMETERS

By: MZ Date: 03/28/12 Project No.: 1420112012

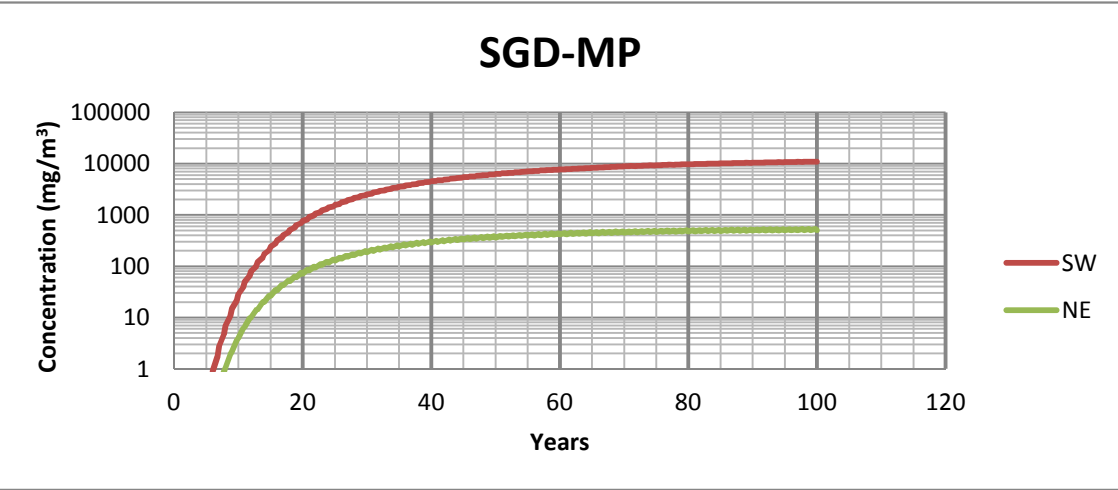
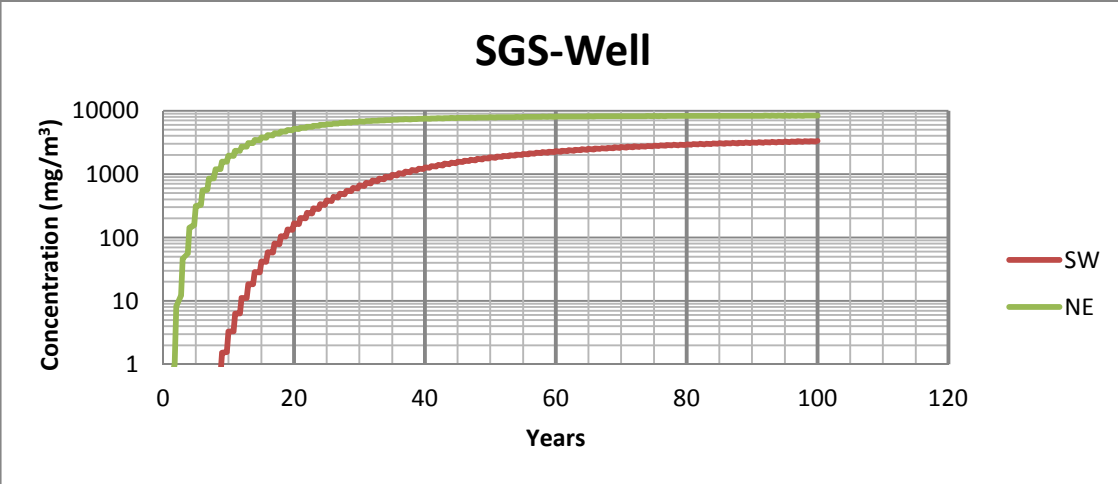
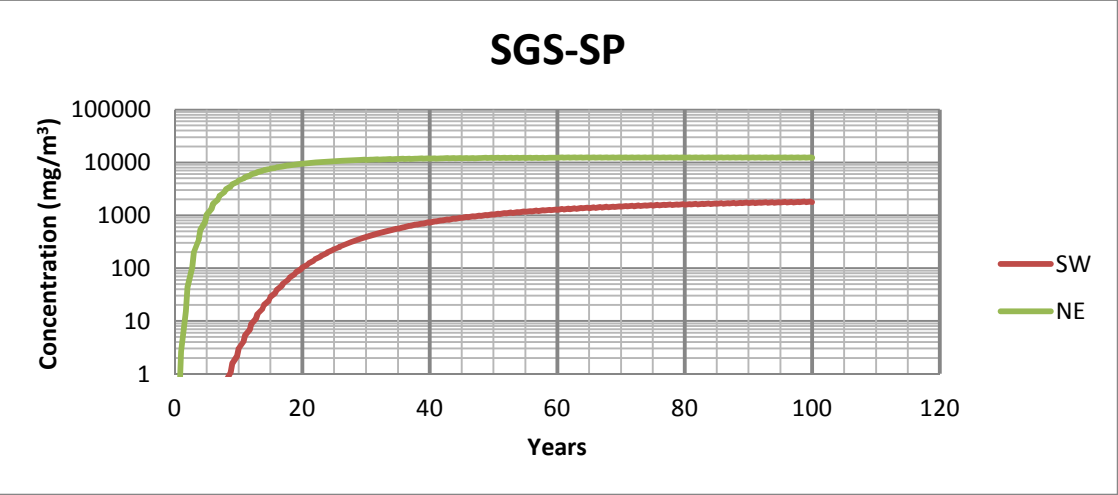
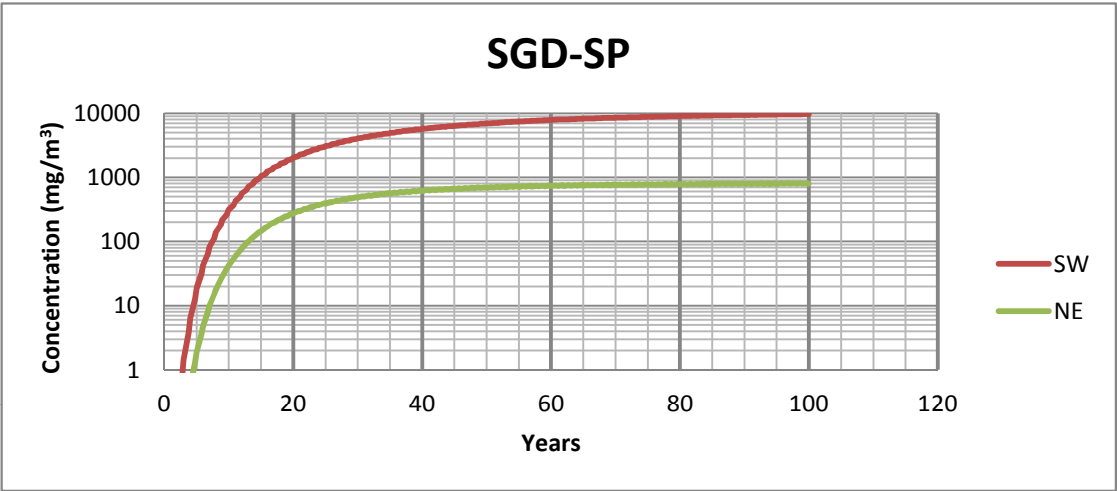
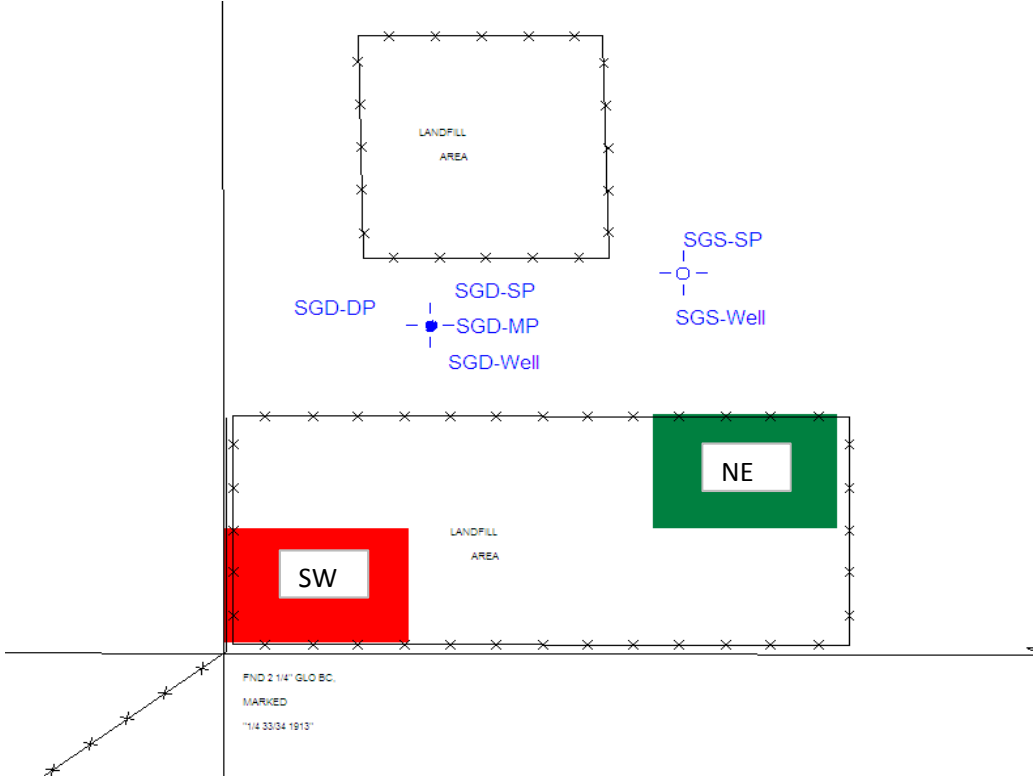




SIMULATED TETRACHLOROETHENE
CONCENTRATIONS AT MONITORING POINTS AND
IN SVE INFLUENT WITH SVE OPERATING AT
MINIMUM OPERATIONAL PARAMETERS

By: MZ Date: 03/28/12 Project No.: 1420112012





SIMULATED TRICHLOROETHENE
CONCENTRATIONS AT MONITORING POINTS AND
IN SVE INFLUENT WITH SVE OPERATING AT
MINIMUM OPERATIONAL PARAMETERS

By: MZ Date: 03/28/12 Project No.: 1420112012



ATTACHMENT 1

Groundwater Protection Level (GPL) Calculations

8/12/2008

Model Inputs

Select chemical name from drop down list

Ct = Initial total soil contamination, ug/kg (ug/kg = (ug/l)/Pb)

Kh (dimensionless)

S (water solubility, mg/l)

Koc (L/Kg)

T1/2 (d) (vadose zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

T1/2 (d) (groundwater zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

Select Soil Type from drop down list

Φ (total porosity)

(minimum GPL default = .25)

Pb (g/cm³) (dry bulk density)

(minimum GPL default = 1.5)

foc (vadose zone)

(minimum GPL default = .001)

foc (aquifer)

Dg^a (cm²/d) (gaseous diffusion coefficient)

(7000 = default)

D1^w (cm²/d) (liquid diffusion coefficient)

(.7 = default)

d(diffusion layer thickness,cm)

(.5 = default)

θ (vol/vol)= moisture content

(minimum GPL default = .15)

Jw (water flux- cm/d)

(minimum GPL default = .007)

time step (days) vary until output graphs shows complete curve, Jury 1 solution)

L (cm)(depth of incorporation- Jury 1 solution)

Z -cm(depth to water, or depth of interest, Jury 1 solution)

depth profile time (d), Jury 2 solution)

total vadose zone depth (cm, Jury 2 solution)

Distance to compliance point (Sc) (meters)

(minimum GPL default = 30)

Release width (w) (meters)

(minimum GPL default = 10)

Well screen interval (s) (meters)

(minimum GPL default = 8.2)

Water Quality Standard (ug/l)- see note regarding standard

Groundwater velocity (cm/d) (actual velocity not Darcy velocity)

(minimum GPL default = 10)

Infiltration rate outside of source area (cm/d)

(minimum GPL default = .007)

Calculation values

100
1.25
790
174
100000
100000

0.375
1.66
0.004
0.004
7000
0.7
0.5
0.054
0.007
2000
457.2
19812
3650
5000
30
10
8.2
5
10
0.007

Data Enter

Carbon tetrachloride
100
4
1100
160
100000
100000
Sand

0.25
1.5
0.004
0.004
7000
7.00E-01
0.5
0.15
0.007
2000
457.2
19812
3650
5000
30
10
8.2
150
10
0.007

Run GPL

Carbon tetrachloride

GPL (mg/kg) = 12705.26

Saturation conc. (mg/kg) 766.50

GPL exceeds saturation, discuss with specific ADEQ Program

GPL based upon Aquifer Water Quality Standard

8/12/2008

Model Inputs

Select chemical name from drop down list

Ct = Initial total soil contamination, ug/kg (ug/kg = (ug/l)/Pb)

Kh (dimensionless)

S (water solubility, mg/l)

Koc (L/Kg)

T1/2 (d) (vadose zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

T1/2 (d) (groundwater zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

Select Soil Type from drop down list

Φ (total porosity)

(minimum GPL default = .25)

Pb (g/cm³) (dry bulk density)

(minimum GPL default = 1.5)

foc (vadose zone)

(minimum GPL default = .001)

foc (aquifer)

Dg^a (cm²/d) (gaseous diffusion coefficient)

(7000 = default)

D1^w (cm²/d) (liquid diffusion coefficient)

(.7 = default)

d(diffusion layer thickness,cm)

(.5 = default)

θ (vol/vol)= moisture content

(minimum GPL default = .15)

Jw (water flux- cm/d)

(minimum GPL default = .007)

time step (days) vary until output graphs shows complete curve, Jury 1 solution)

L (cm)(depth of incorporation- Jury 1 solution)

Z -cm(depth to water, or depth of interest, Jury 1 solution)

depth profile time (d), Jury 2 solution)

total vadose zone depth (cm, Jury 2 solution)

Distance to compliance point (Sc) (meters)

(minimum GPL default = 30)

Release width (w) (meters)

(minimum GPL default = 10)

Well screen interval (s) (meters)

(minimum GPL default = 8.2)

Water Quality Standard (ug/l)- see note regarding standard

Groundwater velocity (cm/d) (actual velocity not Darcy velocity)

(minimum GPL default = 10)

Infiltration rate outside of source area (cm/d)

(minimum GPL default = .007)

Calculation values

100
0.15
7900
39.8
100000
100000

0.375
1.66
0.004
0.004
7000
0.7
0.5
0.054
0.007
2000
457.2
19812
3650
5000
30
10
8.2
80
10
0.007

Data Enter

Chloroform
100
4
1100
160
100000
100000
Sand

0.25
1.5
0.004
0.004
7000
7.00E-01
0.5
0.15
0.007
2000
457.2
19812
3650
5000
30
10
8.2
150
10
0.007

Run GPL

Chloroform

GPL (mg/kg) = 46144.20

Saturation conc. (mg/kg) 1743.82

GPL exceeds saturation, discuss with specific ADEQ Program

GPL based upon Aquifer Water Quality Standard

8/12/2008

Model Inputs

Select chemical name from drop down list

Ct = Initial total soil contamination, ug/kg (ug/kg = (ug/l)/Pb)

Kh (dimensionless)

S (water solubility, mg/l)

Koc (L/Kg)

T1/2 (d) (vadose zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

T1/2 (d) (groundwater zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

Select Soil Type from drop down list

Φ (total porosity)

(minimum GPL default = .25)

Pb (g/cm³) (dry bulk density)

(minimum GPL default = 1.5)

foc (vadose zone)

(minimum GPL default = .001)

foc (aquifer)

Dg^a (cm²/d) (gaseous diffusion coefficient)

(7000 = default)

D1^w (cm²/d) (liquid diffusion coefficient)

(.7 = default)

d(diffusion layer thickness,cm)

(.5 = default)

θ (vol/vol)= moisture content

(minimum GPL default = .15)

Jw (water flux- cm/d)

(minimum GPL default = .007)

time step (days) vary until output graphs shows complete curve, Jury 1 solution)

L (cm)(depth of incorporation- Jury 1 solution)

Z -cm(depth to water, or depth of interest, Jury 1 solution)

depth profile time (d), Jury 2 solution)

total vadose zone depth (cm, Jury 2 solution)

Distance to compliance point (Sc) (meters)

(minimum GPL default = 30)

Release width (w) (meters)

(minimum GPL default = 10)

Well screen interval (s) (meters)

(minimum GPL default = 8.2)

Water Quality Standard (ug/l)- see note regarding standard

Groundwater velocity (cm/d) (actual velocity not Darcy velocity)

(minimum GPL default = 10)

Infiltration rate outside of source area (cm/d)

(minimum GPL default = .007)

Calculation values

100
1.07
2300
58.9
100000
100000

0.375
1.66
0.004
0.004
7000
0.7
0.5
0.054
0.007
2000
457.2
19812
3650
5000
30
10
8.2
7
10
0.007

Data Enter

1,1-Dichloroethylene(DCE)
100
4
1100
160
100000
100000
Sand

0.25
1.5
0.004
0.004
7000
7.00E-01
0.5
0.15
0.007
2000
457.2
19812
3650
5000
30
10
8.2
150
10
0.007

Run GPL

1,1-Dichloroethylene(DCE)

GPL (mg/kg) = 7168.61

Saturation conc. (mg/kg) 1092.59

GPL exceeds saturation, discuss with specific ADEQ Program

GPL based upon Aquifer Water Quality Standard

8/12/2008

Model Inputs

Select chemical name from drop down list

Ct = Initial total soil contamination, ug/kg (ug/kg = (ug/l)/Pb)

Kh (dimensionless)

S (water solubility, mg/l)

Koc (L/Kg)

T1/2 (d) (vadose zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

T1/2 (d) (groundwater zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

Select Soil Type from drop down list

Φ (total porosity)

(minimum GPL default = .25)

Pb (g/cm³) (dry bulk density)

(minimum GPL default = 1.5)

foc (vadose zone)

(minimum GPL default = .001)

foc (aquifer)

Dg^a (cm²/d) (gaseous diffusion coefficient)

(7000 = default)

D1^w (cm²/d) (liquid diffusion coefficient)

(.7 = default)

d(diffusion layer thickness,cm)

(.5 = default)

θ (vol/vol)= moisture content

(minimum GPL default = .15)

Jw (water flux- cm/d)

(minimum GPL default = .007)

time step (days) vary until output graphs shows complete curve, Jury 1 solution)

L (cm)(depth of incorporation- Jury 1 solution)

Z -cm(depth to water, or depth of interest, Jury 1 solution)

depth profile time (d), Jury 2 solution)

total vadose zone depth (cm, Jury 2 solution)

Distance to compliance point (Sc) (meters)

(minimum GPL default = 30)

Release width (w) (meters)

(minimum GPL default = 10)

Well screen interval (s) (meters)

(minimum GPL default = 8.2)

Water Quality Standard (ug/l)- see note regarding standard

Groundwater velocity (cm/d) (actual velocity not Darcy velocity)

(minimum GPL default = 10)

Infiltration rate outside of source area (cm/d)

(minimum GPL default = .007)

Calculation values

100
0.0898
13200
11.7
100000
100000

0.375
1.66
0.004
0.004
7000
0.7
0.5
0.054
0.007
2000
457.2
19812
3650
5000
30
10
8.2
4.3
10
0.007

Data Enter

Methylene chloride
100
4
1100
160
100000
100000
Sand

0.25
1.5
0.004
0.004
7000
7.00E-01
0.5
0.15
0.007
2000
457.2
19812
3650
5000
30
10
8.2
150
10
0.007

Run GPL

Methylene chloride

GPL (mg/kg) = 713.45
Saturation conc. (mg/kg) 1276.37

GPL based upon risk based water quality standard

8/12/2008

Model Inputs

Select chemical name from drop down list

Ct = Initial total soil contamination, ug/kg (ug/kg = (ug/l)/Pb)

Kh (dimensionless)

S (water solubility, mg/l)

Koc (L/Kg)

T1/2 (d) (vadose zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

T1/2 (d) (groundwater zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

Select Soil Type from drop down list

Φ (total porosity)

(minimum GPL default = .25)

Pb (g/cm³) (dry bulk density)

(minimum GPL default = 1.5)

foc (vadose zone)

(minimum GPL default = .001)

foc (aquifer)

Dg^a (cm²/d) (gaseous diffusion coefficient)

(7000 = default)

D1^w (cm²/d) (liquid diffusion coefficient)

(.7 = default)

d(diffusion layer thickness,cm)

(.5 = default)

θ (vol/vol)= moisture content

(minimum GPL default = .15)

Jw (water flux- cm/d)

(minimum GPL default = .007)

time step (days) vary until output graphs shows complete curve, Jury 1 solution)

L (cm)(depth of incorporation- Jury 1 solution)

Z -cm(depth to water, or depth of interest, Jury 1 solution)

depth profile time (d), Jury 2 solution)

total vadose zone depth (cm, Jury 2 solution)

Distance to compliance point (Sc) (meters)

(minimum GPL default = 30)

Release width (w) (meters)

(minimum GPL default = 10)

Well screen interval (s) (meters)

(minimum GPL default = 8.2)

Water Quality Standard (ug/l)- see note regarding standard

Groundwater velocity (cm/d) (actual velocity not Darcy velocity)

(minimum GPL default = 10)

Infiltration rate outside of source area (cm/d)

(minimum GPL default = .007)

Calculation values

100
0.754
200
155
100000
100000

0.375
1.66
0.004
0.004
7000
0.7
0.5
0.054
0.007
1500
457.2
19812
3650
5000
30
10
8.2
5
10
0.007

Data Enter

Tetrachloroethylene (PCE)
100
4
1100
160
100000
100000
Sand

0.25
1.5
0.004
0.004
7000
7.00E-01
0.5
0.15
0.007
1500
457.2
19812
3650
5000
30
10
8.2
150
10
0.007

Run GPL

Tetrachloroethylene (PCE)

GPL (mg/kg) = 11683.17

Saturation conc. (mg/kg) 159.67

GPL exceeds saturation, discuss with specific ADEQ Program

GPL based upon Aquifer Water Quality Standard

8/12/2008

Model Inputs

Select chemical name from drop down list

Ct = Initial total soil contamination, ug/kg (ug/kg = (ug/l)/Pb)

Kh (dimensionless)

S (water solubility, mg/l)

Koc (L/Kg)

T1/2 (d) (vadose zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

T1/2 (d) (groundwater zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

Select Soil Type from drop down list

Φ (total porosity)

(minimum GPL default = .25)

Pb (g/cm³) (dry bulk density)

(minimum GPL default = 1.5)

foc (vadose zone)

(minimum GPL default = .001)

foc (aquifer)

Dg^a (cm²/d) (gaseous diffusion coefficient)

(7000 = default)

D1^w (cm²/d) (liquid diffusion coefficient)

(.7 = default)

d(diffusion layer thickness,cm)

(.5 = default)

θ (vol/vol)= moisture content

(minimum GPL default = .15)

Jw (water flux- cm/d)

(minimum GPL default = .007)

time step (days) vary until output graphs shows complete curve, Jury 1 solution)

L (cm)(depth of incorporation- Jury 1 solution)

Z -cm(depth to water, or depth of interest, Jury 1 solution)

depth profile time (d), Jury 2 solution)

total vadose zone depth (cm, Jury 2 solution)

Distance to compliance point (Sc) (meters)

(minimum GPL default = 30)

Release width (w) (meters)

(minimum GPL default = 10)

Well screen interval (s) (meters)

(minimum GPL default = 8.2)

Water Quality Standard (ug/l)- see note regarding standard

Groundwater velocity (cm/d) (actual velocity not Darcy velocity)

(minimum GPL default = 10)

Infiltration rate outside of source area (cm/d)

(minimum GPL default = .007)

Calculation values

100
0.422
1100
166
100000
100000

0.375
1.66
0.004
0.004
7000
0.7
0.5
0.054
0.007
2000
457.2
19812
3650
5000
30
10
8.2
5
10
0.007

Data Enter

Trichloroethylene (TCE)
100
4
1100
160
100000
100000
Sand

0.25
1.5
0.004
0.004
7000
7.00E-01
0.5
0.15
0.007
2000
457.2
19812
3650
5000
30
10
8.2
150
10
0.007

Run GPL

Trichloroethylene (TCE)

GPL (mg/kg) = 15388.79

Saturation conc. (mg/kg) 855.95

GPL exceeds saturation, discuss with specific ADEQ Program

GPL based upon Aquifer Water Quality Standard

8/12/2008

Model Inputs

Select chemical name from drop down list

Ct = Initial total soil contamination, ug/kg (ug/kg = (ug/l)/Pb)

Kh (dimensionless)

S (water solubility, mg/l)

Koc (L/Kg)

T1/2 (d) (vadose zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

T1/2 (d) (groundwater zone) (enter 100,000 if no biodegradation, 1000 for BTEX)

Select Soil Type from drop down list

Φ (total porosity)

(minimum GPL default = .25)

Pb (g/cm³) (dry bulk density)

(minimum GPL default = 1.5)

foc (vadose zone)

(minimum GPL default = .001)

foc (aquifer)

Dg^a (cm²/d) (gaseous diffusion coefficient)

(7000 = default)

D1^w (cm²/d) (liquid diffusion coefficient)

(.7 = default)

d(diffusion layer thickness,cm)

(.5 = default)

θ (vol/vol)= moisture content

(minimum GPL default = .15)

Jw (water flux- cm/d)

(minimum GPL default = .007)

time step (days) vary until output graphs shows complete curve, Jury 1 solution)

L (cm)(depth of incorporation- Jury 1 solution)

Z -cm(depth to water, or depth of interest, Jury 1 solution)

depth profile time (d), Jury 2 solution)

total vadose zone depth (cm, Jury 2 solution)

Distance to compliance point (Sc) (meters)

(minimum GPL default = 30)

Release width (w) (meters)

(minimum GPL default = 10)

Well screen interval (s) (meters)

(minimum GPL default = 8.2)

Water Quality Standard (ug/l)- see note regarding standard

Groundwater velocity (cm/d) (actual velocity not Darcy velocity)

(minimum GPL default = 10)

Infiltration rate outside of source area (cm/d)

(minimum GPL default = .007)

Calculation values

100
4
1100
160
100000
100000

0.375
1.66
0.004
0.004
7000
0.7
0.5
0.054
0.007
1500
457.2
19812
3650
5000
30
10
8.2
150
10
0.007

Data Enter

Enter chemical properties
100
4
1100
160
100000
100000
Sand

0.25
1.5
0.004
0.004
7000
7.00E-01
0.5
0.15
0.007
1500
457.2
19812
3650
5000
30
10
8.2
150
10
0.007

Run GPL

Enter chemical properties

GPL (mg/kg) = 466845.21

Saturation conc. (mg/kg) 1590.63

GPL exceeds saturation, discuss with specific ADEQ Program

GPL based upon risk based water quality standard