Northwest Pipe Company

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August 23, 2016

Mr. Jim Orr, R.G.
Oregon Department of Environmental Quality
Northwest Regional Office
Suite 600
700 NE Multnomah St.
Portland, OR 97232

Dear Mr. Orr:

RE: Response to DEQ Comment Letters dated 01/19/2016 and 02/18/2016 pertaining to Northwest Pipe Company's Supplemental Groundwater Sampling and Data Evaluation Work Plan.

This letter presents Northwest Pipe Company's (NWP's) response to the DEQ letters and EPA comments referenced above, which were included in the 01/19/2016 DEQ letter, all regarding NWP's 12/18/2016 *Supplemental Groundwater Sampling and Data Evaluation Work Plan* (Work Plan).

NWP, DEQ, and EPA met on 01/25/16 to discuss the agencies' comments and resolve any remaining issues. After the meeting, DEQ provided a written summary on 02/18/2016 of the group's resolution of the issues along with additional comments and requests for more work.

The results of the discussion from the January meeting and the additional comments and requests from DEQ are referenced in the responses in this letter. Where text from DEQ's 02/18/2016 letter is included, the source is noted.

In the following text, agency comments are presented in italic font and NWP's response in regular font.

Comments and Responses

DEQ Comments

DEQ Comment 1: *Page 1, Background, Last paragraph*

The Plan conclusion that the there is an offsite source to the east-northeast is not supported by current data compared to an onsite source. This issue was discussed in previous comments and our teleconference. The proposed work will address groundwater contamination potentially migrating to the river but will not provide information regarding offsite sources of contamination. DEQ considers the groundwater plume to be from NWP based on the current monitoring data. NWP may propose additional work to evaluate contributions from offsite sources.

Response: Comment noted.

DEQ Comment 2: *Page 2, Scope of Work*

The Plan states that the work will confirm hydraulic characteristics (flow direction and magnitude of gradient). DEQ is concerned that existing survey

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information is not sufficient to accurately determine well elevations between NWP and the Terminal 4 wells. DEQ requests that a new survey be performed to provide accurate information for well elevations tied to a common datum by a licensed land surveyor.

Response: NWP has confirmed that both the Port's monitoring wells and NWP's monitoring wells were surveyed by an Oregon-licensed land surveyor to a common datum: the National Geodetic Vertical Datum of 1929, 1947 adjustment, with a vertical precision of 0.01 foot.

In our January 25th meeting, DEQ explained its concern as being more related to potential settlement and measuring point elevation change over the years since the wells were installed rather than to a datum question. Accordingly, NWP agrees to have an Oregon-licensed land surveyor determine and mark measuring point elevations on each of the wells involved in the proposed scope of work.

DEQ Comment 3: Page 2, Well Redevelopment

The Plan states that the wells will be redeveloped by raising and lowering the pump between pumping cycles. DEQ recommends that a surge block and submersible pump be used to effectively develop the wells that are proposed for sampling. In addition, please define the criteria used by the hydrologist to determine if well development is complete. Please provide copies of all monitoring well logs to provide information regarding well construction and subsurface materials. DEQ Groundwater Monitoring Well Drilling, Construction, and Decommissioning 1992 guidance is recommended for the Plan and may be found at http://www.deq.state.or.us/lg/pubs/ docs/tanks/GroundwaterMonitoring WellDrilling.pdf.

Response: DEQ's guidance for monitoring well construction notes that a pump is among the devices that may be used to induce reverse flow across the well screen during development, consistent with the approach proposed in the draft work plan. The guidance states:

> *"Develop the entire vertical screened interval using surge blocks, bailers, pumps, or other equipment which frequently reverses the flow of water through the well screen and prevents bridging of formation or filter pack particles."*

As agreed during the meeting, however, NWP added a surge block to the equipment to be used during well development. The hydrogeologist observing well development activities will consider development complete when the visible clarity of the water ceases to improve with continued development efforts.

The reason monitoring water quality parameters during well development is sometimes advised is because of water quality alteration that may occur during well installation (such as use of water, air, or drilling mud during borehole

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advancement). Among the objectives of developing a newly-installed well is to remove the water quality effects of well installation to the extent reasonably possible. The wells involved in this work have been in place for a decade or more and have had ample time for any lingering effects of well installation to have dissipated. Regardless, in response to DEQ request, after the combination of more aggressive surging and pumping has concluded, the pump will be operated at an approximate constant rate and pH, specific conductance, and turbidity will be measured in the pump discharge until three successive measurements, each made at least 5 minutes after the previous measurement, meet the stabilization criteria noted for these parameters in Table 1 of the work plan.

As requested by DEQ, copies of well logs have been appended to the revised work plan.

DEQ Comment 4: *Page 3, Aquifer Testing*

Please evaluate the slug testing data to determine if well recovery indicates that this method is sufficient to provide accurate data. Each well should have well efficiency reported with the aquifer testing results.

DEQ 02/18/2016 Comment Letter with Additional Requests: *DEQ withdraws the request that well efficiency be reported with the slug testing results.*

Response: Slug test data will be evaluated for possible skin or filter pack effects and the results of this evaluation will be noted in the document reporting slug test results. As discussed in the January 25th meeting, quantitative estimates of well efficiency are not provided by slug testing results. However, the rate of water level recovery will be documented for each well and the relative ranking of the tested wells noted.

DEQ Comment 5: *Page 4, Well Redevelopment [Groundwater Sampling]*

The bulleted list of measurement to supplement biochemical indicator is missing carbon dioxide and methane. Please add carbon dioxide/methane and all constituents needed to complete EPA Technical Protocol for Evaluating Natural Attenuation.

Response: In response to this comment, NWP has reviewed the guidance and adjusted the analytical program to more closely match the guidance, including analysis for carbon dioxide and methane. Because of the scoring approach used in Table 2.3 of EPA's *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water,* not analyzing for certain specialty constituents is actually conservative, as the cumulative effect of the remaining constituents would have to be overwhelmingly consistent with conditions conducive to reductive dechlorination for a site score to fit into either an "adequate evidence" or a "strong evidence" category for reductive dechlorination. Consequently, the approach for evaluating site conditions in

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the context of natural attenuation of chlorinated solvents in the draft work plan is more conservative than it would be with additional analytical constituents. However, both methane and carbon dioxide have been included in response to DEQ comments.

DEQ Comment 6: *Page 4, Groundwater Sampling*

The Plan proposed six monitoring well sampling locations and. two quarterly sampling events. DEQ requests the addition of T-4-MW-23 and T-4-MW-9 to the six proposed wells for sampling and that there are four quarterly sampling events for all eight monitoring wells for all parameters (chemicals of interest and natural attenuation parameters).

Response: NWP agrees to add the two additional wells to the sampling program, pending Port of Portland approval for access, and also agrees to add two additional quarters to the sampling schedule. However, as discussed in the meeting, Northwest Pipe anticipates that volatile organic compounds (VOCs) will be analyzed during each quarter but that after two quarters of analysis, the data will be reviewed and the utility and value of continuing to analyze for indicators of natural attenuation will be evaluated. If appropriate, rationale for a revised analytical program will be proposed at that time, either suspending analysis for natural attenuation indicators, or focusing the analysis on certain wells.

DEQ Comment 7: *Page 5, Well Purging and Sampling*

The Plan presents a sampling order that does not consider the concentrations observed in MW-5 and MW-6. DEQ requests that well gauging, well development, and sampling be performed in the following order: T-4-MW-9, T-4-MW-03S, T-4-MW-22, T-4-MW-23, MW-3, MW-4, MW-5, and MW-6.

Response: The order of wells visited for water level measurement, well development, and sampling will be, in sequential order from first to last, as follows:

First	T4S1MW-09
	T4S1MW-03s
	T4S1MW-22
	T4S1MW-23
	MW-02
	MW-03
	MW-01
	MW-04
	MW-05
Last	MW-06

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DEQ Comment 8: *Page 5, Well Purging and Sampling*

Please sample turbidity at the inlet of the flow through chamber in order to collect a representative sample. In addition, it is recommended by EPA guidance, that Teflon or Teflon- lined polyethylene tubing is used for collection of groundwater samples to prevent leaching of contaminants. DEQ requests the use of Teflon or Teflon-lined tubing to sample ground water.

Response: Turbidity will be measured prior to the inlet of the flow-through cell. Either polytetrafluoroethylene (PTFE), of which Teflon is a trade name, tubing or PTFE-lined polyethylene tubing will be used for sampling.

DEQ Comment 9: *Page 8, Data Analysis and Reporting*

Please provide a more precise description for what data distribution will switch from Bouwer and Rice to an alternative method.

Response: DEQ's comment reflects a misunderstanding of the work plan. The work plan states that other analytical methods, such as the Hvorselv method, may be used **in addition** to the Bouwer and Rice method. The work plan does not propose to "switch" from Bouwer and Rice; but acknowledges that alternate analytical methods exist and that these may be used to supplement the proposed Bouwer and Rice analysis to provide additional insight into the response of wells to testing.

DEQ Comment 10: *Page 8, Data Analysis and Reporting*
DEQ request that copies of field log books are included in data submittals and that preliminary reports to DEQ be submitted within 60 days of the report of analytical results.

Response: Scanned copies of groundwater sampling data sheets will be included in data submittals, and these preliminary results will be submitted to DEQ within 60 calendar days of receiving validated analytical results.

DEQ Comment 11: *Table 2, Analytical Methods*

DEQ requests that Table 2 include the reporting limits compared to the Draft PRG screening levels (July 2015). Please discuss any analytical detection limit exceedances compared to Draft PRGs and why a more precise method is not used.

Response: Preliminary remediation goals (PRGs) selected from Table 2.2-1 of the Draft Final Portland Harbor RI/FS Feasibility Study (CDM Smith, 2016) are included in Table 2 for use as screening values, as indicted during the January 25th meeting with DEQ. Note, despite selecting the analytical method with the lowest method reporting limit (MRL), the MRL for vinyl chloride is still above the Portland Harbor PRG. However, the method detection limit (MDL) is below the Portland Harbor PRG. The MDL is the minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results. Results below the MRL, but above the MDL, will be "J" flagged indicating they are estimated.

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These results will provide a reliable indication of whether vinyl chloride is present above the Portland Harbor PRGs.

DEQ 02/18/2016 Comment Letter with Additional Requests: *In addition to the above review comments and resolutions, DEQ requests that drawdown and recovery data from wells be collected during development. This information should be evaluated to determine differences in water production from the wells.*

Response: The work plan has been modified to state that water levels in the well undergoing development will be measured using an electronic water level indicator periodically during well development.

DEQ 02/18/2016 Comment Letter with Additional Requests: *Well logs should also be evaluated to determine if the selected wells for slug testing are representative of site conditions.*

Response: An evaluation of the well logs associated with these wells confirms that the selected wells are completed in the unconfined shallow aquifer. The wells represent a range of subsurface conditions and sufficient spatial coverage of the various segments of the potential flow path to Slip 1. Well logs are included in Appendix A.

DEQ 02/18/2016 Comment Letter with Additional Requests: *DEQ requests that the NWP team consider this well development data prior to finalizing the selection of wells for slug testing and provide their assessment to DEQ for review and confirmation prior to conducting the slug tests.*

DEQ understands that the slug tests are planned to obtain a more site specific conductivity value to update the fate and transport model previously developed by NWP. DEQ believes it is important to note that the fate and transport model will continue to have substantial uncertainty and that DEQ will primarily look to the distribution of contaminant concentrations observed in monitoring wells as the primary line of evidence for contaminant fate and transport.

Response: Upon completion of well redevelopment, an assessment will be made of the well development data to justify the selection of wells for slug testing. This assessment will include an evaluation of the drawdown and recovery data from the redeveloped wells to confirm the wells selected for slug testing represent aquifer conditions. Data assessment and justification of selected wells will be provided to DEQ by email for review. Slug testing will occur one week after the data assessment and justification is provided to DEQ unless DEQ objects.

EPA General Comments

EPA General Comment 1: *One of the key objectives of the Work Plan is to evaluate the fate and transport of the VOC plume data from the proposed two sampling events using the BIOCHLOR model and compare the output of the model to the BIOCHLOR model from previous sampling events. The Work Plan states (Section 1.1) that the BIOCHLOR modeling from the 2005 event predicted groundwater discharge to the Willamette River at concentrations below the levels of concern. EPA has not*

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reviewed the referenced report of this modeling effort prepared by CH2M in 2005 and, therefore, cannot evaluate or comment on the analysis. A copy of this report should be provided to EPA so that this analysis may be reviewed.

Response: NWP will provide a scanned version of the report pages that relate to the BIOCHLOR modeling work completed in 2005. As discussed in the meeting, the remaining elements of the report have been superseded by the March 2015 RI/SCE report, which has been previously provided to EPA.

EPA General Comment 2: *Additional groundwater monitoring beyond the two sampling events proposed in the Work Plan is necessary to statistically document time concentration trends. After the first two monitoring events, concentration data should be evaluated at each monitoring point as evidence for identifying whether the concentrations are decreasing, stable, or increasing.*

Response: In response to DEQ's request, four quarterly sampling events will be completed. EPA clarified in the January 25, 2016 meeting that statistical analysis was not required.

EPA General Comment 3: *The Work Plan states that well construction logs will be obtained for T4S1MW-22 and T4S1MW-03s to determine if groundwater from these wells is representative of samples taken from the shallow aquifer. The Work Plan also states that if the wells are found to be non-conducive to collecting samples in the shallow aquifer, then DEQ will be informed. Due to the undefined VOC plume extent extending from the NW Pipe property downgradient onto the T4 property, sampling T4S1MW-22 and T4S1MW-03s is critical to the source control evaluation. An alternative plan should be in place in case these wells are not conducive to shallow aquifer testing so that the downgradient extent of the VOC plume can be confirmed and data can be collected to determine whether the plume is reaching the Willamette River.*

Response: The well logs have been located and NWP has confirmed that the wells included in this proposed sampling program are screened in the same shallow fill aquifer. Accordingly, no alternative plan is necessary. The well logs are included in the final work plan.

EPA Specific Comments

EPA Specific Comment 1: *Page 1, Section 1.1, last paragraph - This Work Plan states that changes in concentrations of VOCs (both parent compounds and degradation products) suggest that VOCs are migrating onto the NW Pipe facility from an offsite area to the east-northeast. As stated in previous comments on the RI/SCE, EPA does not agree that there is sufficient data to support this determination. In the teleconference in November 2015, NW Pipe presented a groundwater contour map that showed that the gradient is essentially flat in the area between MW-05 and MW-06. Based on the low gradient, historic pooling of stormwater in this area, formerly unpaved areas in the area between MW-05 and MW-06, other transport processes may have resulted in VOC concentrations at MW-05.*

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Changes in condition at the site, such as increasing and decreasing water levels, increased pooling and stormwater infiltration could cause contaminant migration leading to increased concentrations at MW-05. Lacking groundwater monitoring wells between MW-05 and the east-northeast end of the property, it is not possible to evaluate potential offsite contributions to the VOC plume at the NW Pipe property.

Response: Comment noted. As discussed in the meeting, the storm water pooling referenced by EPA was a temporary phenomenon starting in the Fall of 2009 created by roadway and storm water drainage infrastructure construction being undertaken by the City of Portland along North Burgard Road near the NWP facility. This work was completed and the run-on and pooling of offsite stormwater is no longer occurring. The temporary pooling condition caused by this road work started several years after the change in concentration was observed at MW-5 in September 2005 and cannot logically be concluded to be a cause of the change.

EPA Specific Comment 2: *Page 2, Section 2.1, first paragraph -The criteria that the hydrogeologist will use to determine when well development is complete should be defined in this work plan.*

Response: The hydrogeologist observing well development activities will consider development complete when the visible clarity of the water ceases to improve with continued development efforts.

In addition, in response to DEQ request, after the combination of more aggressive surging and pumping has concluded, the pump will be operated at an approximate constant rate and pH, specific conductance, and turbidity will be measured in the pump discharge until three successive measurements, each made at least 5 minutes after the previous measurement, meet the stabilization criteria noted for these parameters in Table 1 of the work plan.

EPA Specific Comment 3: *Page 4, Section 2.3.2, second paragraph -The bulleted list of measurements to supplement biochemical indicators of anaerobic biodegradation measured in 2005 is missing carbon dioxide and methane. These constituents are needed to complete EPA's Technical Protocol for Evaluating Natural Attenuation worksheet. EPA recommends including all relevant constituents evaluated in the worksheet.*

Response: In response to this comment, NWP has reviewed the guidance and adjusted the analytical program to more closely match the guidance, including analysis for carbon dioxide and methane. Because of the scoring approach used in Table 2.3 of EPA's *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water,* not analyzing for certain specialty constituents is actually conservative, as the cumulative effect of the remaining constituents would have to be overwhelmingly consistent with conditions conducive to reductive dechlorination for a site score to fit into either an "adequate evidence" or a "strong evidence" category for reductive dechlorination. Consequently, the approach for evaluating site conditions in the context of natural attenuation of chlorinated solvents in the draft work plan is more conservative than it would be

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with additional analytical constituents. However, in response to DEQ comments, methane and carbon dioxide have been added to the proposed list of analysis in the work plan.

EPA Specific Comment 4: *Page 4, Section 2.3.3, third paragraph -EPA recommends that sampling for the geochemical indicators be conducted during the wet and dry season sampling events to determine seasonal variation and potential effect on natural attenuation.*

Response: In response to a comment from DEQ, NWP has agreed to add two additional quarters to the sampling schedule. However, as discussed in the meeting, NWP anticipates that volatile organic compounds (VOCs) will be analyzed during each quarter but that after two quarters of analysis, the data will be reviewed and the utility and value of continuing to analyze for indicators of natural attenuation will be evaluated. If appropriate, a revised analytical program will be proposed at that time, either suspending analysis for natural attenuation indicators, or focusing the analysis on certain wells.

EPA Specific Comment 5: *Page 5, Section 2.3.3, third paragraph -Text states that wells will be sampled in order from expected lowest concentrations to expected highest concentration to avoid cross contamination, with the following prescribed sequence: T4S1MW-03s, T4S1MW-22, MW-03, MW-01, MW-04, MW-06, and MW-05. Although PCE was slightly higher in concentration in MW-05 than MW-06 in 2007, the degradation products were much more elevated in MW-06 than MW-05, see table below:*

VOCs	*MW-05 (mg/L)*	*MW-06 (mg/L)*
PCE	*1.4*	*1.2*
TCE	*0.078*	*0.47*
c-1,2-DCE	*0.34*	*0.64*
VC	*0.00028*	*0.0031*

The elevated degradation products in MW-06 vs. MW-05 indicates that MW-06 is more likely to induce cross over contamination if sampled first. Considering this, EPA recommends that the sample order be revised as follows: T4S1MW-03s, T4S1MW-22, MW-03, MW-01, MW-04, MW-05, and MW-06.

The order of work at each well is of greater importance for the non-sampling activities, including water level gauging, well development, and slug testing, which involve placement of non-dedicated equipment in the well. Water level gauging and well development should be conducted in the above sequence to minimize potential cross contamination.

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Response: The order of wells visited for water level measurement, well development, slug testing (if applicable), and sampling will be, in sequential order from first to last, as follows:

First	T4S1MW-09
	T4S1MW-03s
	T4S1MW-22
	T4S1MW-23
	MW-02
	MW-03
	MW-01
	MW-04
	MW-05
Last	MW-06

EPA Specific Comment 6: *Page 5, Section 2.3.3, third paragraph -EPA guidance recommends Teflon or Teflon-lined polyethylene tubing be used for collection of groundwater samples that include analysis of VOCs. Teflon prevents potential leaching of contaminants from the tubing into the sample that could cause interference with analytical procedures.*

Response: Either polytetrafluoroethylene (PTFE), of which Teflon is a trade name, tubing or PTFE-lined polyethylene tubing will be used for sampling.

EPA Specific Comment 7: *Page 5, Section 2.3.3, fifth paragraph -The text states that turbidity samples will be collected from the flow through chamber. The flow through cell for a multi-probe acts as a settling chamber and typically the turbidity is lower in the effluent than the influent. EPA recommends measuring turbidity at the influent of the flow-through cell rather than the effluent so that the sample turbidity is more representative of the groundwater being sampled.*

Response: Turbidity will be measured prior to the inlet of the flow-through cell.

EPA Specific Comment 8: *Table 2 -The reporting limit for VOCs is listed as 0.5 µg/L with the exception of PCE, which has a reporting limit listed as 0.1 µg/L. Portland Harbor PRGs for PCE, TCE, and vinyl chloride (VC) are 0.2, 1.4, and 0.02 µg/L respectively. In 2007, VC in some wells were below the reporting limit of 1 µg/L; therefore, it is unclear if these wells were below the PRG. A more sensitive analytical method is targeted for PCE in this work plan to be able to report concentrations below the PRG, but not for VC. If there is a reason a more sensitive analytical method is not being used for VC, it needs to be stated in the text.*

Response: Vinyl chloride will be analyzed with the EPA method SW8260SIM with a method reporting limit of 0.05 µg/L. Table 2 has been revised in the final work plan to reflect this change. See response to DEQ comment 11 for additional clarification.

EPA Specific Comment 9: *Page 8, Section 3.0, bullet 2 -Text states that the aquifer test data will be analyzed by the Bouwer and Rice method and, depending on the data distribution, may be supplemented with other methods. Earlier in the Work Plan, on Page 3, Section 2.2, last paragraph, the text states that the aquifer test will be*

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analyzed by another standard method based on CH2M hydrogeologist's opinion. The text needs to state precisely what data distribution metric will trigger a switch from the Bouwer and Rice method to an alternative method and why.

Response: EPA's comment reflects a misunderstanding of the work plan. The work plan states that other analytical methods, such as the Hvorselv method, may be used **in addition to** the Bouwer and Rice method. The work plan does not propose to "switch" from Bouwer and Rice; but acknowledges that alternate analytical methods exist and that these may be used to supplement the proposed Bouwer and Rice analysis to provide additional insight into the response of wells to testing.

EPA Editorial Comments

EPA Editorial Comment 1: *Page 5, Section 2.3.3, third paragraph - Wells in text MW-01 through MW-06 do not match the labels in Figure 1 or from RI/SCE, MW-01 through MW-06. Please adjust label naming structure to be consistent.*

Response: Labels have been revised to be consistent.

EPA Editorial Comment 2: *Figure 1 - Well labels in figure T-4-MW-22 and T-4-MW-03s do not match labels in text of the Work Plan, T4S1MW-22 and T4S1MW-03s. Text or Figure labels should be adjusted to match.*

Response: Labels have been revised to be consistent.

Closing

The revised work plan is included along with this response to comments and includes revisions to incorporate the comment responses provided herein. If you have any questions regarding the responses presented in this letter, please do not hesitate to contact Stephanie Heldt-Sheller of Northwest Pipe Company at sheldtsheller@nwpipe.com or Ken Shump of CH2M at ken.shump@ch2m.com.

Sincerely,

Stephanie Heldt-Sheller
Northwest Pipe Company
Corporate Environmental Manager

C: Eva DeMaria/EPA
Sean Sheldrake/EPA

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Mike Merchant/Black Helterline LLP
Ken Shump/CH2M
Gretchen Gee/CH2M

Enclosure: CH2M Technical Memorandum entitled *Final Supplemental Groundwater Sampling and Data Evaluation, Northwest Pipe Company, Portland, Oregon ECSI #138*

TECHNICAL MEMORANDUM

Final Supplemental Groundwater Sampling and Data Evaluation Northwest Pipe Company, Portland, Oregon ECSI #138

PREPARED FOR:	Stephanie Heldt-Sheller/Northwest Pipe Company Dave Bennett/Northwest Pipe Company
COPY TO:	Tim Whitson/Northwest Pipe Company Claudia Powers/Ater Wynne LLP Mike Merchant/Black Helterline LLP
PREPARED BY:	Gretchen Gee/CH2M Ken Shump/CH2M
DATE:	August 23, 2016

1.0 Introduction

This work plan has been developed to address additional groundwater sampling work required by the Oregon Department of Environmental Quality (DEQ) and Region 10 of the Environmental Protection Agency (EPA) following review of Northwest Pipe Company's Remedial Investigation and Source Control Evaluation (RI/SCE) report (CH2M 2015). The objective of the work described in this work plan is to generate updated groundwater quality information to supplement the existing data set and help inform the source control decision for groundwater at the site.

The focus of this work is shallow groundwater at and downgradient of the Southeast Area of the Northwest Pipe Company site in Portland, Oregon (Figure 1).

1.1 Background

As part of the site characterization work for the facility, sampling work for soil and groundwater, with analysis for volatile organic compounds (VOCs), was completed from 2001 through 2007 (CH2M 2015). A total of six groundwater monitoring wells were installed and sampled in the Southeast Area of the Northwest Pipe Portland facility. The principal VOCs detected were the chlorinated solvents tetrachloroethene (PCE) and its breakdown products trichloroethene (TCE), cis-1,2-dichloeoethene (c-1,2-DCE) and vinyl chloride (VC) (in addition to being a breakdown product of PCE, TCE also is a commercial solvent and its presence may be attributable to use of solvents containing TCE). No additional investigation of this area had been requested by DEQ until August of 2015, in response to EPA's comments.

The Northwest Pipe Company monitoring wells are completed in an unconfined aquifer located within hydraulic fill (dredged river sediment) placed over the mudflats that formerly characterized the site vicinity during the late 1930s and early 1940s. Groundwater in the shallow fill aquifer flows generally south-southwest in the Southeast Area of the site.

As part of the characterization work, the potential for natural attenuation via microbially-mediated reductive dechlorination of the VOCs detected at the site was evaluated. Using analysis of geochemical indicators of reductive dechlorination, the site was determined to have strong evidence for anaerobic biodegradation (reductive dechlorination) of chlorinated organic compounds (CH2M 2005, EPA 1998). Using the BIOCHLOR model (EPA 2002), transport and degradation of VOCs from the Southeast Area was predicted to yield concentrations below the levels of concern evaluated prior to discharge to the Willamette River (CH2M 2005).

However, changes in concentration and the relative preponderance of parent compounds and degradation products suggest that, VOCs also have migrated onto the Northwest Pipe facility from the offsite area to the east-northeast, based on data from monitoring well MW-05. This well (MW-05) is located close to the upgradient property line of Northwest Pipe.

1.2 Objective

The objective of this work is to provide supplemental data to help inform the source control determination for the Northwest Pipe Company Portland facility. The work consists of the following elements:

1. Further demonstrate plume stability or decreasing trend in concentration and natural attenuation of VOCs in groundwater, by collecting groundwater samples in monitoring wells at and downgradient of the Southeast Area and compare them to concentrations documented in past work
2. Collect and evaluate appropriate geochemical data to further demonstrate by comparison to previous work, that site conditions are favorable for natural reductive dechlorination of VOCs
3. Confirm groundwater flow conditions on the Northwest Pipe property including flow direction, horizontal hydraulic conductivity, and horizontal hydraulic gradient, to further demonstrate plume stability and allow natural attenuation to be evaluated
4. Evaluate the fate and transport of VOCs using the BIOCHLOR model (EPA 2002) and compare these results to previous BIOCHLOR modeling in order to assess the results against the draft preliminary remediation goals

2.0 Scope of Work

The scope of work for this data collection effort consists of aquifer testing and groundwater sampling in the Southeast Area of the site and at selected Port of Portland wells offsite and potentially downgradient of the Northwest Pipe facility. Aquifer testing is intended to provide additional site-specific information on aquifer hydraulic characteristics to expand the understanding of the groundwater flow velocity at the site. Groundwater elevations calculated from depth to water measurements made in conjunction with groundwater sampling will confirm the hydraulic gradient (flow direction and magnitude of gradient). Groundwater sampling for VOCs will provide the agency-requested updated data to show plume stability, decrease trending, and natural attenuation. Sampling a second time for geochemical indicators of natural attenuation will provide further evidence of site conditions favorable for natural enhanced reductive dechlorination.

2.1 Well Survey

Both the Port of Portland’s monitoring wells and Northwest Pipe’s monitoring wells were surveyed by an Oregon-licensed land surveyor to a common datum: the National Geodetic Vertical Datum of 1929 (NGVD29), 1947 adjustment, with a vertical precision of 0.01 foot. However, in response to DEQ’s concern that the wells may have been subject to potential settlement and measuring point elevation change over the years since the wells were installed, the wells will be resurveyed to determine and mark measuring point elevations. Wells to be used in this monitoring program (see Section 2.4.1) will be resurveyed prior to beginning groundwater investigation activities by an Oregon-licensed land surveyor to the NDGV29, 1947 adjustment, with a vertical precision of 0.01 foot.

2.2 Well Redevelopment

The wells planned for sampling (see Section 2.4.1) will be redeveloped to confirm they are not plugged, silted in, or otherwise unable to yield representative groundwater samples. Redevelopment will consist of using a decontaminated submersible pump (such as a Grundfos Redi-Flo), surge block, and bailer to surge and pump the wells and confirm their ability to yield water. During pumping and between pumping cycles, the pump will be raised and lowered along the well screen to promote surging and flow reversal across different portions of the well screen. In addition, a surge block will be used to induce reverse flow across the well screen during development. Total well depth will be measured before and after redevelopment to confirm the well screen is not silted in. If necessary and if possible, a bailer will be used to suspend and remove settled silt to the degree necessary to allow the well to be sampled. Water levels in the well undergoing development will be measured using an electronic water level indicator periodically during well development. Well development will be considered complete when the visible clarity of the water ceases to improve with continued development efforts. After the combination of more aggressive surging and pumping has concluded, the pump will be operated at an approximate constant rate and a multi-parameter meter (see Section 2.4.3) will be used to measure pH, specific conductance, and turbidity in the pump discharge until three successive measurements, each made at least 5 minutes after the previous measurement, meet the stabilization criteria noted for these parameters in Table 1 (Section 2.4.3). Well development water and any silt removed from the wells will be stored in steel drums that will be transported to a designated staging area on the Northwest Pipe facility and managed as described in Section 2.4.5.

Upon completion of well redevelopment, an assessment will be made of the water level observations made during well development to confirm the selection of wells for slug testing. This assessment will include an evaluation of the drawdown and recovery data from the redeveloped wells to confirm the wells selected for slug testing represent aquifer conditions. Data assessment and justification of selected wells will be provided to DEQ via email for review. Slug testing will occur one week after the data assessment and justification is provided to DEQ unless DEQ objects.

2.3 Aquifer Testing

The hydraulic conductivity of the shallow aquifer will be estimated based on interpretation of single-well rising head tests, commonly referred to as slug-withdrawal tests, performed on three of the six monitoring wells on the Northwest Pipe property (MW-05, MW-06, and MW-03) and two of the offsite wells to be sampled as part of this work (Port of Portland monitoring wells T4S1MW-22 and T4S1MW-03s, assuming that Northwest Pipe will be able to obtain permission from the Port of Portland to access its monitoring wells). These wells are located as follows:

- Near the upgradient boundary of the Southeast Area (MW-05)
- In the central part of the Southeast Area (MW-06)
- Near the downgradient edge of the Southeast Area (MW-03)
- Near the upgradient edge of the Port of Portland Terminal 4, along the potential flow path (T4S1MW-22)
- Near the discharge point for groundwater from the Port's property at Slip 1 (T4S1MW-03s)

An evaluation of the well logs associated with these wells confirms that the selected wells are completed in the unconfined shallow aquifer. The wells represent a range of subsurface conditions and sufficient spatial coverage of the various segments of the potential flow path to Slip 1. Well logs are included in Appendix A. The list of wells to be tested may be modified as noted in Section 2.2 after well development information is available. The equipment required for the test includes a water pressure transducer and digital data logger (In-Situ Mini-Troll™ or equivalent), a manual electronic water level indicator, and a decontaminated solid slug consisting of weighted PVC pipe with closed ends. The slug will be decontaminated with detergent wash and a distilled water rinse before each use in a well and the cord used at each well will be new, to be discarded and replaced after use at each well.

The approach for performing the slug withdrawal test is as follows:

1. Decontaminate slug and water level indicator as needed.
2. Install water pressure transducer and digital data logger (In-Situ Mini-Troll™ or equivalent). Synchronize the data logger clocks and program the data logger to record the height of the water column above the pressure sensor. Measure depth to groundwater manually as the data logger is set up so that the continuous water-level measurements taken by the loggers are referenced to the appropriate datum. Manually recorded data pertaining to the test will be reported in the field notes.
3. Lower the slug into the water column and wait until the water level has stabilized to static conditions.
4. Rapidly remove the slug making sure not to disturb the transducer cable.
5. At the moment of volume removal, assigned time zero, measure and record the depth to water and the time. Supplement transducer readings with periodic manual water level measurements. Depths should be measured to the nearest 0.01 foot.
6. Continue measuring and recording depth-time measurements until the water level returns sufficiently to analyze.

Slug test data will be analyzed with the method provided by Bouwer and Rice (1976) and Bouwer (1989). Another standard method (such as the 1951 Hvorslev method [EPA 1994]) may be selected and used in addition to the Bouwer and Rice method if, in the CH2M hydrogeologist's opinion, the observed data distribution suggests it would provide useful information. Slug test data will be evaluated for possible skin or filter pack effects and the results of this evaluation will be noted in the document reporting slug test results. In addition, the rate of water level recovery will be documented for each well and the relative ranking of the tested wells noted.

2.4 Groundwater Sampling

2.4.1 Sampling Locations

The proposed groundwater sample locations are displayed on Figure 1. The sampling program will consist of six Northwest Pipe Company monitoring wells in the Southeast Area, MW-01 through MW-06, and four Port of Portland monitoring wells (T4S1MW-23, T4S1MW-22, T4S1MW-09, and T4S1MW-03s), assuming that Northwest Pipe will be able to obtain permission from the Port of Portland to access its monitoring wells. Well completion logs for the selected wells are included in Appendix A.

2.4.2 Sampling Events and Proposed Analysis

As required by DEQ, four quarterly sampling events will be completed to characterize possible seasonal effects on groundwater quality. Sampling will occur no sooner than 2 weeks after redevelopment and slug testing, to reduce the potential that those activities could influence the laboratory analytical results.

The primary objective of the sampling is to characterize current VOC concentrations in groundwater. Consequently, sample sets described in this work plan will be analyzed for VOCs. In addition, the wells will be analyzed for the following selected geochemical indicators, which are commonly used to evaluate the potential for natural attenuation (EPA 1998), to supplement the measurements made in 2005:

- Dissolved oxygen (DO) – field measurement
- Oxidation-reduction potential (ORP) – field measurement
- Temperature – field measurement
- pH – field measurement
- Dissolved iron
- Chloride
- Sulfate
- Nitrate
- Total organic carbon
- Methane
- Carbon dioxide

These constituents represent the overall chemistry of the aquifer, which typically varies over a narrow range. Concentrations of constituents that are increased under conditions favorable to reductive dechlorination would be well above reporting limits, minimizing sensitivity to small changes that parameters experience at very low concentrations near reporting limits. After two quarters of analysis, the data will be reviewed and the utility and value of continuing to analyze for indicators of natural attenuation will be evaluated. If appropriate, rationale for a revised analytical program will be proposed at that time, either suspending analysis for natural attenuation indicators, or focusing the analysis on certain wells.

2.4.3 Sampling Methods

Groundwater samples will be collected using low-flow, also known as low-stress, sampling techniques. The following sections describe the procedures, documentation, and sample handling procedures to be followed during this work.

Pre-sampling groundwater level measurements

Prior to sampling, the depth to groundwater will be measured in each of the wells to be sampled, as well as other accessible monitoring wells on the Port's property, prior to initiating purging and sampling activities. An electronic water level indicator with an audible alarm and a cable marked in 0.01-foot increments will be used for the measurements. Before use, and between wells, the wetted portion of the water level indicator tip will be decontaminated using a distilled water rinse. If the wells are sealed with an airtight cap, 20 to 30 minutes will be provided to allow pressure to equilibrate after the cap is released and before water levels are measured. Measurements will be repeated until consecutive readings are within 0.01 foot.

Well purging and sampling

Purging and sampling will be conducted using a peristaltic pump with new disposable polytetrafluoroethylene (PTFE) (Teflon) tubing or PTFE-lined polyethylene tubing and new disposable silicone head tubing at each well (EPA 1998). The peristaltic pump will be powered by either a car battery or generator. Should a generator be used, it will be located downwind of sampling activities at sufficient distance and gloves will be changed following any contact with the generator to prevent sample contamination. To further reduce the potential for cross-contamination, wells will be purged and sampled in order of expected lowest to highest concentrations of VOCs. For the first sampling event, the recommended sequence will be as follows:

First	T4S1MW-09
	T4S1MW-03s
	T4S1MW-22
	T4S1MW-23
	MW-02
	MW-03
	MW-01
	MW-04
	MW-05
Last	MW-06

The well sequence for the subsequent sampling events will be determined using laboratory results of VOC concentrations from the first sampling event.

Prior to beginning purging at a well, the static, pre-purging water level will be measured with a water level indicator and recorded. The pump intake will be set within the middle of the screened interval and the drawdown will be kept as low as reasonably possible (target of 0.33 foot) using flow rates in the range of 0.1 to 0.3 liter per minute. Purge water will be directed into 5-gallon buckets with fitted lids, which will be emptied into one or more 55-gallon labeled, steel drums with lids. The initial measurements of pH, specific conductance, dissolved oxygen, turbidity, and temperature of the purge water will be observed and recorded in the field logbook and/or sampling log for the well. Subsequent readings will be noted after removal of approximately 1 well casing volume, and then at a frequency of approximately every 5 minutes until water quality parameters have stabilized; defined as three successive measurements within the target criteria listed in Table 1.

Water quality parameters will be measured inline using a YSI 556 multiparameter water quality meter or similar instrument with a flow-through cell to monitor pH, oxidation-reduction potential (ORP), specific conductance, dissolved oxygen (DO), and temperature. A separate turbidity meter, HACH 2100Q or similar instrument, will be used to record turbidity readings prior to the inlet of the flow-through cell. Field meters will be calibrated following the manufacturer’s specifications at the start of each day of sampling. The results of this calibration will be noted in the field notebook.

Table 1. Stabilization Criteria for Water Quality Parameters
Supplemental Groundwater Sampling and Data Evaluation
Northwest Pipe Company Portland Plant

Parameter	Target Stabilization Criteria
pH	+/- 0.1 pH units
Specific Conductance	+/- 3% µS/cm
ORP	+/- 10 millivolts
Turbidity	+/- 10% NTUs (when turbidity is greater than 10 NTUs)
DO	+/- 0.3 mg/L

Notes:

ORP = oxidation-reduction potential
DO = dissolved oxygen
µS/cm = microSiemens per centimeter
mV = millivolts
NTU = nephelometric turbidity units
mg/L = milligrams per liter

After the field parameters have stabilized during purging, the in-line flow cell will be disconnected and the well will be sampled. The elapsed time between stabilization of field parameters and the beginning of sampling will be as short as reasonably possible to minimize potential changes in water quality after field parameter values have been documented. Samples will be placed in laboratory-provided containers previously prepared with the appropriate preservative, if necessary, by the analytical laboratory. Field personnel will replace nitrile gloves with new pair prior to sample collection and change gloves between sample locations to reduce the potential for cross-contamination. The pumping rate used for sample collection will be approximately 0.1 liter per minute or less.

For wells to be analyzed for both VOCs and geochemical parameters, VOC samples will be collected first. VOC vials will be filled in such a way as to minimize the volatilization of VOCs and dilution or loss of laboratory-provided sample preservative. The pumped water will be directed to run down the inside wall of the sample bottle to minimize splashing, bottles will not be overfilled, and no air bubbles or headspace will remain in vials upon completion of filling.

Samples for iron analysis will be field-filtered using a new, disposable 0.45-micron in-line filter to remove artificial turbidity, if any, that could bias sample results. The other sample containers listed in Table 2 will be filled in accordance with the sample handling procedures listed in the section below.

Sample Handling and Quality Assurance

The selected laboratory will provide the required sample containers. The analytical laboratory will add preservatives, as needed, prior to shipping the sample containers to the field. The laboratory, upon receipt of the samples, will verify the adequacy of preservation and will add additional preservative, if necessary.

Trip blanks will be analyzed for VOCs and included at a rate of 1 per sample cooler (that is, 1 per event). Because disposable sample equipment will be used, no equipment blank is necessary. One blind sample duplicate (labeled MW-100) will be analyzed for each sample event.

Sample preservation efforts will commence at the time of sample collection and will continue until analyses are performed. After filling, sample containers will be placed promptly in an insulated cooler with ice to maintain sample temperature at or below 4 degrees Celsius (°C). The ice will be double bagged in plastic storage bags. Coolers will be kept out of direct sunlight. The temperature of the samples will be documented upon receipt at the laboratory.

A chain of custody (COC) form will be completed for each sampling event. The original copy will be provided to the laboratory with the sample shipping cooler, and a copy will be retained in the field documentation files. The coolers containing the samples will be sealed with a custody seal any time the coolers are not in an individual's possession or view before shipping. The custody seals will be signed and dated by a sampling team member.

Samples will be hand delivered or shipped by overnight express carrier for delivery to the analytical laboratory. Samples will be shipped for laboratory receipt and analyses within specific holding times.

Field Documentation

Standard field information [typically weather conditions, personnel onsite, equipment calibration, sample information and location, and field observations], any deviations from the work plan, and the reason for deviations will be recorded daily in a field logbook. In addition, general observations of samples and field parameter measurements will be documented in the field logbook and/or the groundwater sampling worksheets.

Sample labels will be filled out using waterproof ink. At a minimum, each label will contain the following information:

- Sample identification code (i.e., MW06-122015-0)

    - Well ID and sample date (MMDDYY)
- Date and time of sample collection
- Sampler's signature or initials

2.4.4 Laboratory Analysis

Samples will be submitted to the Applied Sciences Laboratory for analysis:

Applied Sciences Laboratory (ASL)
1100 NE Circle Blvd, Suite 300
Corvallis, OR 97330-3538
(541) 768-3120

The laboratory will be requested to provide results using standard turnaround time; generally 2 to 4 weeks depending on laboratory sample volume. The sample containers, preservative requirements, and maximum holding times for individual analyses are shown in Table 2. ASL is certified under the National Environmental Laboratory Accreditation Program (NELAP) as well as the Oregon Environmental Laboratory Accreditation Program (ORELAP).

Preliminary remediation goals (PRGs) selected from Table 2.2-1 of the Draft Final Portland Harbor RI/FS Feasibility Study (CDM Smith, 2016) are included in Table 2 for use as screening values, as indicted during the January 25th meeting with DEQ. Note, despite selecting the analytical method with the lowest method reporting limit (MRL), the MRL for vinyl chloride is still above the Portland Harbor PRG. However, the method detection limit (MDL) is below the Portland Harbor PRG. The MDL is the minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results. Results below the MRL, but above the MDL, will be "J" flagged indicating they are estimated. These results will provide a reliable indication of whether vinyl chloride is present above the Portland Harbor PRGs.

Table 2. Sample Containers, Holding Times, and Analytical Methods
Supplemental Groundwater Sampling and Data Evaluation
Northwest Pipe Company Portland Plant

Analysis	Method	Container Size	Container Type	Preservative	Holding Time	Screening Values[2] (μg/L)	Method Detection Limit (μg/L)	Method Reporting Limit (μg/L)
TCE	SW8260C	(3) 40 mL VOA vials	Glass VOA vials	HCl	14 days	0.6	0.15	0.5
c-1,2-DCE						9.9	0.15	0.5
VC[1]	SW8260SIM	(3) 40 mL VOA vials	Glass VOA vials	HCl	14 days	0.02	0.0047	0.05
PCE[1]						0.2	To be determined during analysis	0.1
Fe [3]	E200.7	250 mL – field filtered	HDPE	HNO_3	180 days	--	10	100
Cl	E300.0	(1) 250 mL	HDPE	None, 4°C	28 days	--	29	200
SO_4	E300.0				28 days	--	32	200
NO_3	E353.2				48 hours	--	2.8	10
TOC	SM5310	(1) 250 mL	HDPE	H_2SO_4	28 days	--	200	500
Methane	RSK175	(3) 40 mL VOA vials	Glass VOA vials	None, 4°C	14 days	--	0.055	1
Carbon Dioxide							39.8	100

Notes:
[1] To achieve lower reporting limits, PCE and VC will be analyzed separately with method SW8260SIM.
[2] Screening values are selected from Table 2.2-1 of the Draft Final Portland Harbor RI/FS Feasibility Study (CDM Smith, 2016). Values were selected from remedial action objectives (RAOs 4 and 8) associated with migration of contaminated groundwater. If more than one PRG was specified, the numerically smaller value was selected.
[3] dissolved iron (Fe); field-filtered
°C = degrees Celsius.
μg/L = microgram per liter
mL = milliliter
HDPE = high-density polyethylene
-- = Not applicable

2.4.5 Investigation-Derived Waste Management

Purge water and any suspended silt from well redevelopment, sampling activities, and equipment decontamination water will be contained, labeled, and temporarily stored in a designated location at the Northwest Pipe facility. It is anticipated that up to five 55-gallon drums will be needed to store purge water generated during the work described in this work plan with up to one additional drum per well to contain well redevelopment water. Drums will be labeled and covered with lids. The drums will be disposed of by Northwest Pipe through a commercial wastewater treatment service as part of its routine waste management procedures. Tubing, gloves, and other solid waste will be managed by Northwest Pipe as solid waste along with other site solid waste from the site.

2.4.6 Health and Safety

Sampling by CH2M staff will be conducted according to the site health and safety plan consistent with 29 CFR 1910, which calls for modified Level D personal protective equipment to be worn during sampling activities (safety glasses with side shields, steel-toed boots, disposable nitrile gloves, and safety vest).

3.0 Data Analysis and Reporting

Following the completion of the aquifer testing and the receipt of laboratory data, the following analyses will be performed:

- Analyze aquifer test data using the Bouwer and Rice method, supplemented with another standard method depending on data distribution, to document aquifer hydraulic conductivity.
- Generate groundwater contour maps for each measurement event to document flow direction and magnitude of hydraulic gradient.
- Tabulate VOC data and geochemical data.
- Update time-concentration plots for PCE, TCE, cis-1,2-DCE, and VC.
- Evaluate data with the BIOCHLOR spreadsheet model, a screening model that simulates the remediation by natural attenuation of dissolved solvents, including a sensitivity analysis of selected input parameters and a comparison of the output results with Portland Harbor draft PRGs.

Data and results of the analysis will be provided to DEQ and EPA in the form of a technical memorandum that will subsequently be incorporated into a final RI/SCE report (either by attaching or by incorporating into the text itself).

As requested by DEQ, CH2M will provide preliminary result updates via email after results are received from each sample event and validated by data quality review. Scanned copies of groundwater sampling data sheets will be included in data submittals, and these preliminary results will be submitted to DEQ within 60 calendar days of receiving validated analytical results.

4.0 References

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Figure 1
Groundwater Sample Locations
Northwest Pipe Company
Portland, Oregon

LEGEND

- Existing Monitoring Well Selected for Sampling
- Existing Monitoring Well
- Northwest Pipe Property Boundary

N

0 100 200 300 400
Feet

ch2m

\\PDXFPP01\PROJ\NORTHWESTPIPECOMPANY\485880PORTHARBSUP\GIS\MAPFILES\2015\FIGURE1_SAMPLINGLOCATIONS.MXD GGEE 2/11/2016 9:48:28 AM

Appendix A

Northwest Pipe Wells

Table 5-3
Construction Summary of Groundwater Monitoring Wells
Northwest Pipe Company - Portland, Oregon

Well ID	Installation Date	Total Depth [a]	Casing Diameter (inches) [b]	Borehole Diameter (inches)	Screen Length (feet)	Screened Interval [a]	Top of Filter Pack [a]	MPE [c]	GSE [d]	Screened Material	Comments
MW-1	07/23/03	25	2-inch	6	10	14 to 24	12.5	32.02	32.39	Medium to fine sand	Backfilled from 27 ft bgs.
MW-2	07/23/03	22	2-inch	6	10	10.5 to 20.5	9	29.05	29.35	Medium to fine sand	Backfilled from 23 ft bgs.
MW-3	07/24/03	26	2-inch	6	10	14.5 to 24.5	13	30.54	30.78	Medium to fine sand	Backfilled from 27 ft bgs.
MW-4	08/06/04	27	2-inch	6	10	16.5 to 26.5	14	31.51	32.08	Sand w/ silt. Medium to fine sand	Backfilled from 29 ft bgs.
MW-5	08/06/04	28	2-inch	6	10	17.5 to 27.5	16	31.76	32.17	Sand w/ silt.	Backfilled from 30 ft bgs.
MW-6	12/20/04	29	2-inch	6	10	18.5 to 28.5	16.5			Medium to fine sand	No Survey
MW-7	05/31/12	18	2-inch	4	10	17 to 7	6	26.37	26.79	Medium to fine sand	Installed with direct push
MW-8	05/31/12	17	2-inch	4	10	17 to 7	6	26.36	26.88	Medium to fine sand	Installed with direct push
MW-9	05/31/12	17	2-inch	4	10	17 to 7	6	25.75	26.17	Medium to fine sand	Installed with direct push

Notes:
[a] Feet below ground surface (ft bgs).
[b] Casing and screen constructed with flush-threaded Schedule 40 polyvinyl chloride with 0.010-inch machine-slotted screen.
[c] MPE = Measuring point elevation, feet City of Portland Vertical Datum (COP).
Monitoring wells MW-1 through MW-3 were resurveyed on August 20, 2004. Elevations confirmed from original survey effort conducted during 2003.
[d] GSE = Ground surface elevation, feet COP.

CH2MHILL

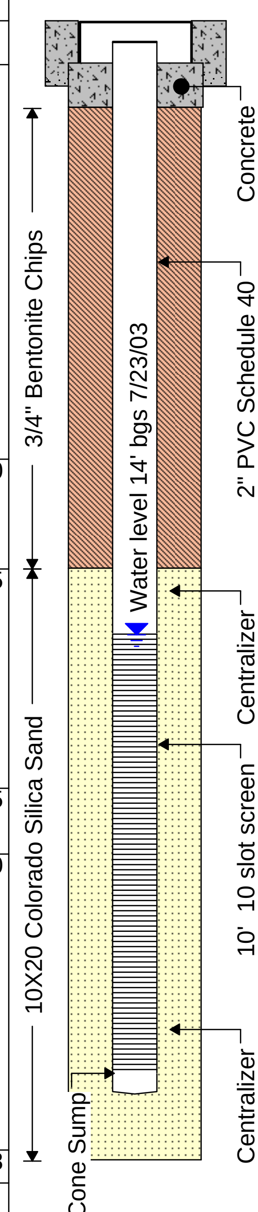
Well Number: MW-1

Client: Northwest Pipe Company
Project: Groundwater Investigation
Location: North Portland
Project Number: 161844.A0.ZZ

Driller: Geo-Tech Explorations
Drilling Method: Hollow Stem Auger
Sampling Method: Split Spoon
Logged by: Pat Heins
Start/Finish Date: 7/23/03

Depth (ft)	Sample	Sample Type	Recovery (ft)	STP (6"-6"-6")	PID (ppm)	Soil Description	Depth / Elev
						Ground Surface	
0						**Asphalt**	0.0
						GP/SW-SM 3/4" gravel with well graded sand, light brown, dry, medium to fine grain sand	
	1	SS	.5	8-13-17	0.8	**SP** Poorly graded sand, light brown, moist, medium to fine grain sand	
5	2	SS	1	6-8-9	1.6		
	3	SS	1	4-4-5	0.8		
10	4	SS	.75	4-4-4	0.7	**SM** Silty sand, light brown, moist, fine grain sand	10.0
	5	SS	1	3-4-5	6.8	**SP** Poorly graded sand, light brown, saturated, medium to fine grain sand	12.5
15	6	SS	1	2-2-3			
	7	SS	.75	3-3-6	6.5	**SP/GP** Poorly graded sand with 3/4" well weathered gravel, light brown, saturated (small piece of wood fiber)	17.5
20	8	SS	1	2-6-6	8.4	**SP** Poorly graded sand, dark gray, saturated, medium to fine grain sand	19.0
	9	SS	1	3-3-6	3.0		
25	10	SS	1.5	3-5-8	8.5	**ML** Silt, dark gray, moist	25.8
						End of Log	
30							

Well Completion Details



Comments

- Heavy duty Sherwood flush mount monument
- Ground elevation: 31.01' (NGVD '29)
- Top of well casing elevation: 30.64' (NGVD '29)
- OWRD Well ID Number: L58982
- Start Card Number: 156646
- Encountered fair amount of heaving at ~20'bgs. Water added to auger stem seems to
- Water came from driller's rig, filled from Tualatin City water.

CH2MHILL

Well Number: MW-2

Sheet: 1 of 1

Client: Northwest Pipe Company
Project: Groundwater Investigation
Location: North Portland
Project Number: 161844.A0.ZZ

Driller: Geo-Tech Explorations
Drilling Method: Hollow Stem Auger
Sampling Method: Split Spoon
Logged by: Pat Heins
Start/Finish Date: 7/23/03

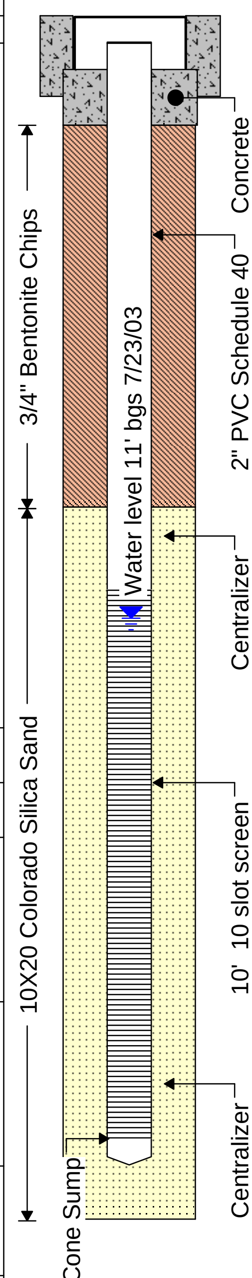
Sample Info

Sample	Sample Type	Recovery (ft)	STP (6"-6"-6")	PID (ppm)
1	SS	1	6-6-9	2.3
2	SS	1	4-4-5	1.8
3	SS	1.5	6-7-6	3.4
4	SS	1	3-4-4	
5	SS	1	4-4-8	1.7
6	SS	1	1-4-4	3.5
7	SS	1	4-4-8	1.0
8	SS	.75	1-1-2	2.5
9	SS	1.5	0-1-3	

Soil Description

Depth / Elev	Soil Description
	Ground Surface
0.0	**Asphalt**
	SP Poorly graded sand, light brown, moist, medium to fine grain sand
13.0	**SP** Poorly graded sand, light brown, saturated, medium to fine grain sand
14.0	
15.0	**SP** Poorly graded sand, gray, saturated, medium to fine grain sand
	SW-SM/GP 3/4" gravel well weathered with well graded sand, gray, saturated
18.0	**SP** Poorly graded sand, dark gray, saturated, medium to fine grain sand
21.0	**ML** Silt, gray, moist (bottom 4" brown mottled rust color), firm, medium plasticity
23.0	End of Log

Well Completion Details



Comments

- Heavy duty Sherwood flush mount monument
- Ground elevation: 27.97' (NGVD '29)
- Top of well casing elevation: 27.67' (NGVD '29)
- OWRD Well ID Number: L58983
- Start Card Number: 156647
- Encountered fair amount of heaving at ~16' bgs. Water added to auger stem to reduce heave.
- Water came from driller's rig, filled from Tualatin City water.

CH2MHILL

Well Number: MW-3

Sheet: 1 of 1

Client: Northwest Pipe Company
Project: Groundwater Investigation
Location: North Portland
Project Number: 161844.A0.ZZ

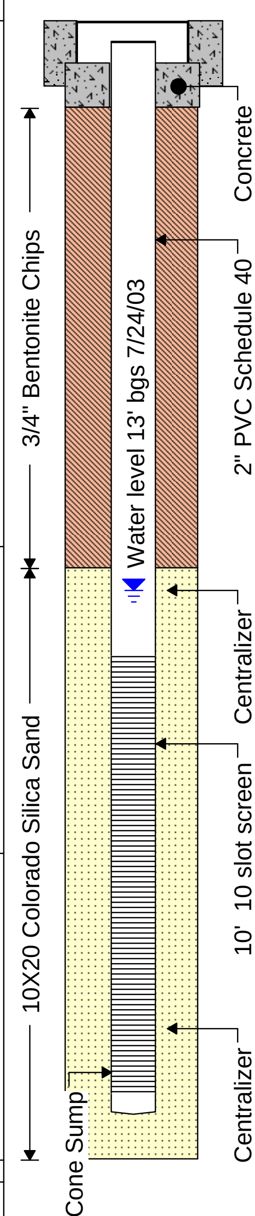
Driller: Geo-Tech Explorations
Drilling Method: Hollow Stem Auger
Sampling Method: Split Spoon
Logged by: Pat Heins
Start/Finish Date: 7/24/03

Sample	Sample Type	Recovery (ft)	STP (6"-6"-6")	PID (ppm)
1	SS	1	4-9-7	0.4
2	SS	.66	5-7-6	0.6
3	SS	1.25	4-6-6	0.3
4	SS	1	3-5-5	0.2
5	SS	1	2-4-6	0.4
6	SS	1.5	3-3-4	0.3
7	SS	1.5	5-7-7	0.7
8	SS	1.5	3-3-5	0.4
9	SS	0	2-2-3	
10	SS	1.5	2-2-2	0.6

Depth / Elev	Soil Description
	Ground Surface
0.0	**Asphalt**
	SP Poorly graded sand, light brown, moist, medium to fine grain sand
12.0	**SP** Poorly graded sand, light brown, saturated, medium to fine grain sand
19.0	**SP** Poorly graded sand, gray, saturated, medium to fine grain sand
26.0	**ML** Silt, gray, moist (root material), firm, medium plasticity
	End of Log

Depth (ft): 0, 5, 10, 15, 20, 25, 30

Well Completion Details



Comments

- Heavy duty Sherwood flush mount monument
- Ground elevation: 29.40' (NGVD '29)
- Top of well casing elevation: 29.16' (NGVD '29)
- Start Card Number: 156648
- OWRD Well ID Number: L58987
- Encountered fair amount of heaving at ~20' bgs. Water added to auger stem to reduce .
- Water came from driller's rig, filled from Tualatin City water.
- Standard split spoon, no return, changed to 3" OD split spoon, no return

CH2MHILL

Well Number: MW-4

Client: Northwest Pipe
Project: Monitoring Wells 2004
Location: North Portland
Project Number: 161844.04.ZZ

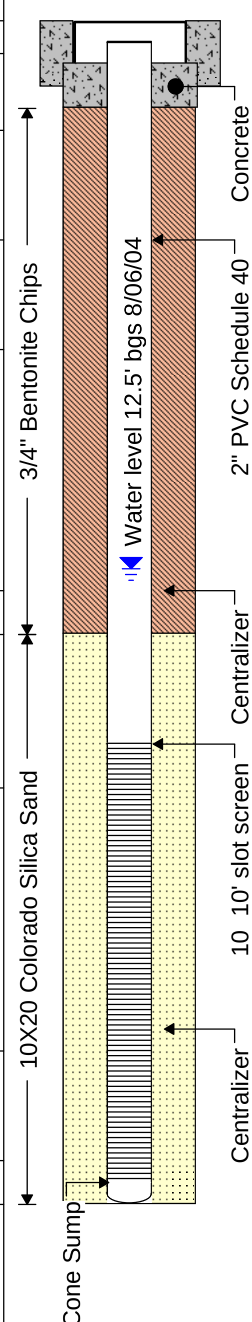
Driller: Geo-Tech Explorations
Drilling Method: HSA CME
Sampling Method: Split Spoon
Logged by: C. Augustine
Start/Finish Date: 8/06/2004

Sample Info

Sample	Sample Type	Recovery (ft)	STP (6"-6"-6")	PID (ppm)
1	SS	1	4-5-6	1.0
2	SS	1.3	4-5-5	2.4
3	SS	1.4	2-3-5	3.2
4	SS	1.5	2-3-3	1.9
5	SS	1.5	2-2-3	1.6
6	SS	1.5	3-3-4	4.0
7	SS	1.5	3-3-4	3.9
8	SS	1.5	1-1-1	3.9
9	SS	1.3	2-2-3	2.4
10	SS	1.5	1-1-1	2.0
11	SS	1.5	3	

Depth / Elev	Soil Description
	Ground Surface
0.0	**Asphalt**
	SP Poorly graded SAND, orange-brown, dry, loose, medium grained sand, some fine - coarse
2.5	**SP** Poorly graded SAND with gravel, orange, dry, loose, medium sand, some fine gravel
5.0	**SP** Poorly graded SAND, orange-brown, dry, loose, fine to medium grained sand, some fine gravel 1/2"-3/4" in 5.0-5.5 feet layer
7.5	**SP** Poorly graded SAND, orange-brown, moist, loose, fine grained sand, some silt
13.0	**OL** Organic SILT composed of woody vegetation with sand, gray, moist, firm, low plasticity
17.5	**SM** SILTY SAND, dark brown, wet, soft fine grained sand
	SM Sand with Silt, dark orange-brown to brown, wet, soft, fine-medium sand, with wood.
23.5	**SM** Poorly graded SAND with SILT, gray, wet, soft Fine sand
26.0	**ML** SILT, grey, wet, firm, medium plasticity, low to no dilatancy
	End of Log

Well Completion Details



Comments

- -Heavy-duty Sherwood flush mount monument
- -Ground elevation: 30.70' (NGVD '29)
- -Top of well casing elevation: 30.13' (NGVD '29)
- OWRD Well ID Number: L67930
- Start Card number: 167488
- Driller reports heaving at ~17 feet bgs, added water to stabilize the borehole

CH2MHILL

Well Number: MW-5

Client: Northwest Pipe
Project: Monitoring Wells 2004
Location: North Portland
Project Number: 161844.04.ZZ

Driller: Geo-Tech Explorations
Drilling Method: HSA CME
Sampling Method: Split Spoon
Logged by: C. Augustine
Start/Finish Date: 8/06/2004

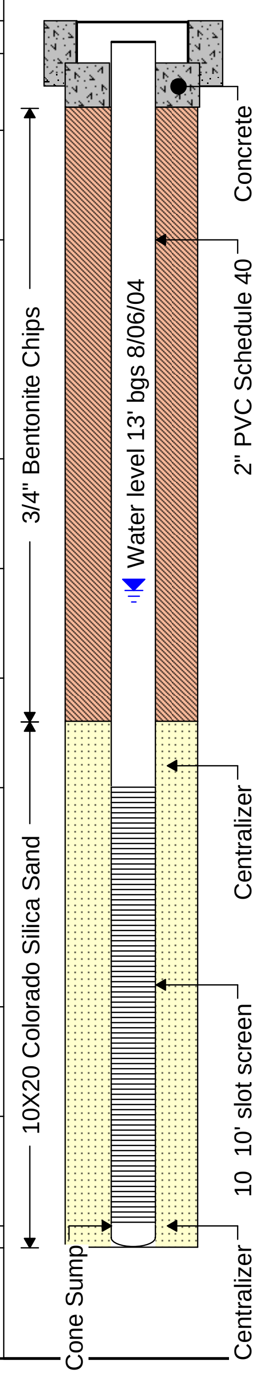
Depth (ft): 0, 5, 10, 15, 20, 25, 30

Sample	Sample Type	Recovery (ft)	STP (6"-6"-6")	PID (ppm)
1	SS	1.5	9-9-8	14.2
2	SS	1.2	5-6-9	5.2
3	SS	1.5	3-4-5	2.4
4	SS	1.5	4-5-5	2.0
5	SS	1.5	4-4-4	6.1
6	SS	1.5	3-5-6	
7	SS	1.5	4-5-6	1.0
8	SS	1.5	2-5-7	1.0
9	SS	1.5	4-6-8	2.0
10	SS	1.5	3-3-4	1.2
11	SS	1.5	1-1-1	

Ground Surface

Depth / Elev	Soil Description
0.0	**Asphalt**
	SP Poorly graded SAND, orange-brown, dry, loose, fine -med grained san, some gravel up to 1-inch
2.5	**SP** Poorly graded SAND with gravel, orange, dry, loose fine - medium sand, gravel up to 1/2 inch in upper 6 inches of sample
5.0	**SP** Poorly graded SAND", orange-brown, dry, loose Fine to medium grained sand
10.0	**SP** Poorly graded SAND, orange-brown, moist, loose Fine to medium grained sand
12.5	**SP/SM** Poorly graded SAND with Silt, orange, moist, loose Fine-medium grained sand
15.0	**ML** SILT, orange brown to grey, moist, soft, low to no plasticity in upper 6-inches Poorly graded SAND, dark brown, wet, loose, fine to medium sand, some silt
17.5	**SP** Poorly Graded Sand, dark orange-brown to brown, wet, soft, some silt
22.5	**SP/SM** Poorly graded SAND with SILT, orange brown to gray wet, very soft
25.0	**SP** Poorly graded SAND, orange brown to grey, wet, soft, some silt in lower 6-inches
27.5	

Well Completion Details



Comments

-Heavy-duty Sherwood flush mount monument

-Ground elevation: 30.79' (NGVD '29)

-Top of well casing elevation: 30.38' (NGVD '29)

OWRD Well ID Number: L67931

Start Card number:167489

Driller reports heaving at ~17 feet bgs, added water to stabilize the borehole

CH2MHILL

Well Number: MW-6

Sheet: 1 of 1

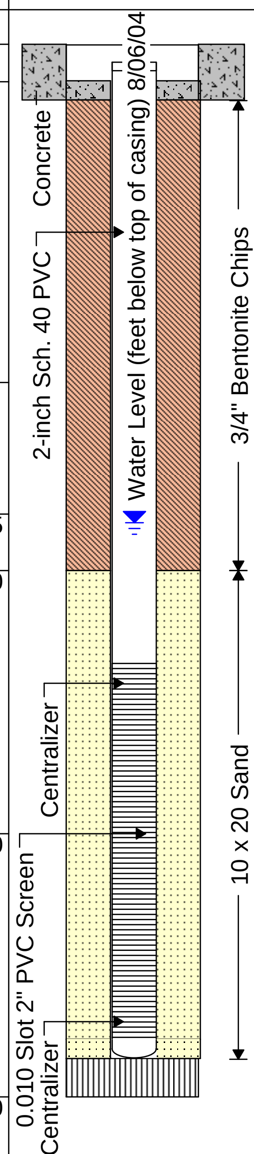
Driller: Geotech
Client: Northwest Pipe
Drilling Method: Hollow Stem Auger Mobile B59
Project: Geoprobe/MW install
Sampling Method: Split Spoon
Location: near GP112
Logged by: Chris Augustine
Project Number: 161844.A0.ZZ
Start/Finish Date: 12/20/2004

Sample	Sample Type	Recovery (ft)	STP (6"-6"-6")	PID (ppm)	Comments
SS1	SS	1.0	5-10-9	0.2	No sheen, no odor
SS2	SS	1.0	3-7-9	0.2	No sheen, no odor
SS3	SS	0	5-7-8	0.2	No sheen, no odor
SS4	SS	1.5	3-5-5	0.4	No sheen, no odor
SS5	SS	1.5	4-6-6	2.1	No sheen, no odor
					Water Encountered @14.0 feet
SS6	SS	1.5	3-5-8	0.7	No sheen, no odor
SS7	SS	1.5	4-5-5	20.8	No sheen, no odor
SS8	SS	1.5	2-4-8	0.8	No sheen, no odor
SS9	SS	1.5	3-4-5	0.0	No sheen, no odor
SS10	SS	1.5	1-2-2	0.2	No sheen, no odor
SS11	SS	1.5	1-2-2	0.0	No sheen, no odor
SS12	SS	1.5	1-2-2	0.0	No sheen, no odor

Soil Description	Depth / Elev
Ground Surface	
Asphalt overlying 3/4 " gravel	0.0
SP Poorly graded SAND, brown, dry to moist, loose, trace silt (<10%)	
SP-SM Sand with silt, brown, moist, loose, silt <10%	9.0
SM Silty SAND, brown, moist to wet, loose	12.5
SP Poorly graded SAND, brown, wet, loose, trace silt	14.0
SM Silty Sand, grey, wet, loose, sand fine, silt 15%	21.0
ML SILT, grey brown, wet,firm, low to medium plasticity, no dilatancy, trace fine sand	28.0
End of Log	30.5

Depth (ft): 0, 5, 10, 15, 20, 25, 30, 35

Well Completion Details



Port of Portland Wells

TABLE C-1
WELL CONSTRUCTION DETAILS

REMEDIAL INVESTIGATION
PORT OF PORTLAND - TERMINAL 4 SLIP 1

Well ID	Completion Date	Operating Unit	Northing	Easting	Screen Interval (ft bgs)	Sandpack Interval (ft bgs)	Bentonite Seal/Backfill (ft bgs)	Total Depth of Boring (ft bgs)
T4S1MW-01s	4/6/2004	OU1	715157.7	7618979.3	25-35	24-35	0.5-24	35
T4S1MW-02s	4/8/2004	OU1	714999.8	7621229	20-30	19-30	0.5-19	30
T4S1MW-03s	4/6/2004	OU1	714749.8	7620500.8	20-30	19-30	0.5-19	30
T4S1MW-07	4/5/2004	OU1	714952.7	7618940.6	29-39	28-39	0.5-28	40
T4S1MW-08	4/7/2004	OU1	714907.7	7619696.7	20-30	19-30	0.5-19	30
T4S1MW-17	4/7/2004	OU1	715070.4	7620055.6	17-27	16-27	0.5-16	27
T4S1MW-19	9/10/2004	OU1	715121.3	7621556.7	22-32	20-35	1-20	35
T4S1MW-22	8/24/2004	OU1	715327.7	7621108.5	13-23	11-30	1-11	30
T4S1MW-23	8/24/2004	OU1	715368.4	7620360.1	15-25	13-30	1-13	30
T4S1MW-24	8/24/2004	OU1	715419.1	7619301.4	20-29.5	17-30	1-18	30
T4S1MW-26	9/7/2005	OU1	714886.2	7620070.6	15-25	13-25	3-13	25
T4S1MW-04s	3/29/2004	OU2	714009.9	7619894	33-43	32-43	0.5-32	43
T4S1MW-09	4/7/2004	OU2	714627.9	7620525.8	20-30	19-30	0.5-19	30
T4S1MW-10	4/7/2004	OU2	714471.7	7620519.9	10-20	9-20	0.5-9	20
T4S1MW-11	3/30/2004	OU2	714223.3	7620492.2	17-27	16-27	0.5-16	30
T4S1MW-12	3/30/2004	OU2	714247.9	7619783	30-40	29-40	0.5-29	40
T4S1MW-13	4/1/2004	OU2	714225.7	7619281.2	30-35	29-35	0.5-29	35
T4S1MW-14	4/1/2004	OU2	714031.6	7619687.1	24-29	23-29	0.5-23	50
T4S1MW-15	3/29/2004	OU2	713644.7	7619834.2	30-40	29-40	0.5-29	40
T4S1MW-16	3/29/2004	OU2	713565.2	7620296.1	22-27	20-27	0.5-20	35
T4S1MW-18	4/6/2004	OU2	715140.6	7619354.3	27-32	26-32	0.5-26	35
T4S1MW-20	8/25/2004	OU2	714335.7	7621441.4	15-25	13-30	1-13	30
T4S1MW-21	8/25/2004	OU2	713826.0	7621247.3	15-25	13-30	1-13	30
T4S1MW-25	9/7/2005	OU2	714520.1	7620895.8	10-20	8.5-20	3-8.5	20

Notes:
1. Vertical Datum: NGVD 29 (47) UNITS: U.S. Survey Feet (ft)
2. Horizontal Datum: NAD 83 (98) UNITS: International Feet
3. bgs = Below ground surface.

Key to Exploration Logs
Phase I Data Summary Report
T4 S1 Upland Facility Remedial Investigation

Sample Description

Classification of soils in this report is based on visual field and laboratory observations which include density/consistency, moisture condition, grain size, and plasticity estimates and should not be construed to imply field nor laboratory testing unless presented herein. Visual-manual classification methods of ASTM D 2488 were used as an identification guide.

Soil descriptions consist of the following:
Density/consistency, moisture, color, minor constituents, MAJOR CONSTITUENT, additional remarks.

Density/Consistency

Soil density/consistency in borings is related primarily to the Standard Penetration Resistance.
Soil density/consistency in test pits is estimated based on visual observation and is presented parenthetically on the test pit logs.

SAND or GRAVEL Density	Standard Penetration Resistance (N) in Blows/Foot	SILT or CLAY Consistency	Standard Penetration Resistance (N) in Blows/Foot	Approximate Shear Strength in TSF
Very loose	0 - 4	Very soft	0 - 2	<0.125
Loose	4 - 10	Soft	2 - 4	0.125 - 0.25
Medium dense	10 - 30	Medium stiff	4 - 8	0.25 - 0.5
Dense	30 - 50	Stiff	8 - 15	0.5 - 1.0
Very dense	>50	Very stiff	15 - 30	1.0 - 2.0
		Hard	>30	>2.0

Moisture

Dry	Little perceptible moisture
Damp	Some perceptible moisture, probably below optimum
Moist	Probably near optimum moisture content
Wet	Much perceptible moisture, probably above optimum

Minor Constituents

	Estimated Percentage
Not identified in description	0 - 5
Slightly (clayey, silty, etc.)	5 - 12
Clayey, silty, sandy, gravelly	12 - 30
Very (clayey, silty, etc.)	30 - 50

Legends

Sampling Test Symbols

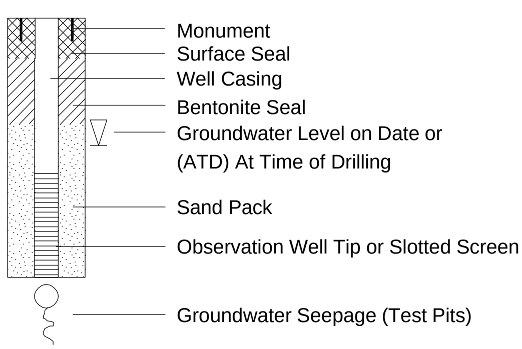
BORING SAMPLES

- Split Spoon
- Tube (Shelby, Push Probe)
- Cuttings
- Core Run
- * No Sample Recovery
- P Tube Pushed, Not Driven

TEST PIT SAMPLES

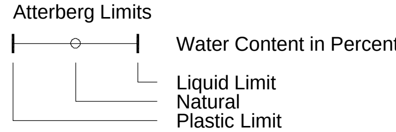
- Grab (Jar)
- Bag
- Shelby Tube

Groundwater Observations



Test Symbols

NS	No Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
TCD	Triaxial Consolidated Drained
QU	Unconfined Compression
DS	Direct Shear
K	Permeability
PP	Pocket Penetrometer Approximate Compressive Strength in TSF
TV	Torvane Approximate Shear Strength in TSF
CBR	California Bearing Ratio
MD	Moisture Density Relationship
AL	Atterberg Limits



PID	Photoionization Detector Reading
CA	Chemical Analysis
DT	In Situ Density Test

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15533-00 *4/04*

Figure B-1

Monitoring Well Log MW-03s

Phase I Data Summary Report

T4 S1 Upland Facility Remedial Investigation

Soil Descriptions

Base material.

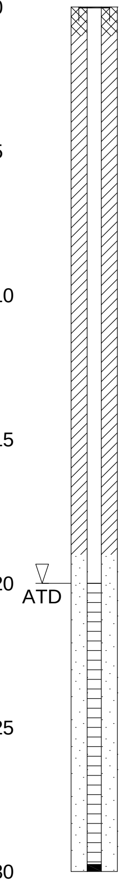
Dark brown, poorly graded, medium SAND.

Becomes wet.

Grades to very dark gray.

Bottom of Boring at 30.0 Feet.
Completed 4/06/04.

Ground Surface Elevation = 33.25 Feet.
Top of Casing Elevation = 32.79 Feet.



Sample	Field Tests and (PID)
MC-1	(2.0)
MC-2	(11)
MC-3	(9.0)
MC-4	(4.0)
MC-5	(4.0)
MC-6	(4.5)

Depth in Feet: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

1. Refer to Figure B-1 for explanation of descriptions and symbols.
2. Descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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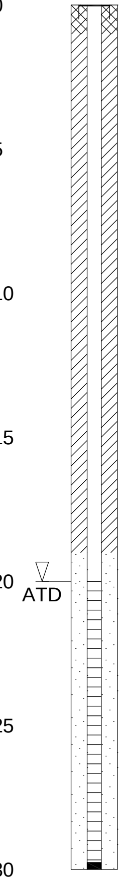
Figure B-4

Monitoring Well Log MW-09
Phase I Data Summary Report
T4 S1 Upland Facility Remedial Investigation

Soil Descriptions	Depth in Feet	Sample	Field Tests and (PID)
Fill material.	0		
Dark brown, poorly graded, medium SAND.		MC-1	(0)
	5	MC-2	(2.0)
	10	MC-3	(1.0)
	15	MC-4	(5.0)
Becomes wet.	20	MC-5	(3.0)
	25	MC-6	(10.0)
Dark brown, moist, sandy SILT with organic material at contact.			
Bottom of Boring at 30.0 Feet. Completed 4/04/04.	30		
Ground Surface Elevation = 33.67 Feet. Top of Casing Elevation = 33.35 Feet.	35		
	40		
	45		
	50		



1. Refer to Figure B-1 for explanation of descriptions and symbols.
2. Descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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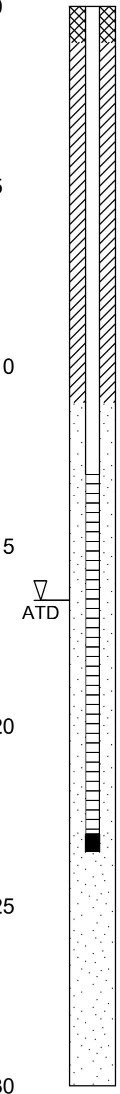
15533-00 4/04

Figure B-8

Boring Log and Construction Data for Monitoring Well MW-22

Soil Descriptions	Depth in Feet	Sample	Field Tests and (PID)
GRAVEL.	0		
(Medium dense), damp, brown SAND.			
(Medium stiff), damp, brown SILT.			
(Medium dense), damp, brown SAND.			NS (<5)
	5		NS (<5)
	10		
Becomes gray.			NS (<5)
	15		
Becomes wet.			NS (<5)
	20		NS (<5)
(Medium stiff), wet, gray, slightly sandy SILT.			
	25		NS (<5)
Bottom of Boring at 30.0 Feet. Completed 8/24/04.	30		
Start Card #167539. Well ID L73504. Inside Diameter of PVC: 2-Inches.			
	35		
	40		



1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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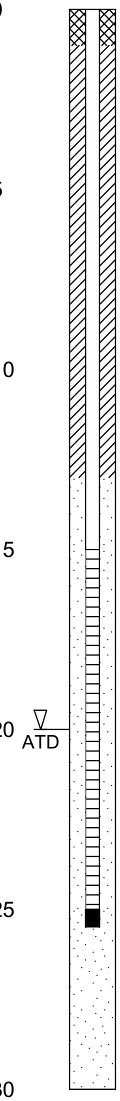
15533-00 *8/04*

Figure A-83

Boring Log and Construction Data for Monitoring Well MW-23

Soil Descriptions	Depth in Feet	Sample	Field Tests and (PID)
Asphalt concrete over (dense), damp, brown, silty, sandy GRAVEL.	0		
(Medium dense), damp, brown SAND.	2.5		NS (<5)
	7.5		NS (<5)
	12.5		NS (<5)
Silt lens.	17.5		NS (<5)
Becomes wet.	20		
Thin SILT lenses.			
Becomes gray.	22.5		NS (<5)
Becomes black.	25		
	27.5		NS (<5)
Bottom of Boring at 30.0 Feet. Completed 8/24/04.	30		
Start Card #167540. Well ID L73505. Inside Diameter of PVC: 2-Inches.			



BORING LOG 1553300 A- (MWS).GPJ HC OREGON.GDT 3/16/05

1. Refer to Figure A-1 for explanation of descriptions and symbols.
2. Descriptions and stratum lines are interpretive and actual changes may be gradual.
3. Groundwater level, if indicated, is at time of drilling (ATD) or for date specified. Level may vary with time.

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15533-00 *8/04*

Figure A-84

Remedial Investigation/Source Control Evaluation Report Northwest Pipe Company Portland Facility

Prepared for

Northwest Pipe Company
12005 North Burgard Road
Portland, Oregon
ECSI No. 138

December 2005

Prepared by

CH2MHILL

Printed on Recycled and Recyclable Paper

PDX/050540026.DOC1

PAHs detected above the reporting limits in storm water samples during the RI/SCE sampling are naphthalene, acenaphthylene, anenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo (a) anthracene, chrysene, benzo (b) fluoranthene, benzo (k) fluoranthene, indeno (1,2,3-cd) pyrene, dibenzo (a,h) anthracene, and benzo (g,h,i) perylene.

Oil and grease were detected in the storm water samples at concentrations that are considered normal for an industrial site and below NPDES benchmark levels. TSS were detected at concentrations that are considered normal for storm water.

3.2.2 Groundwater

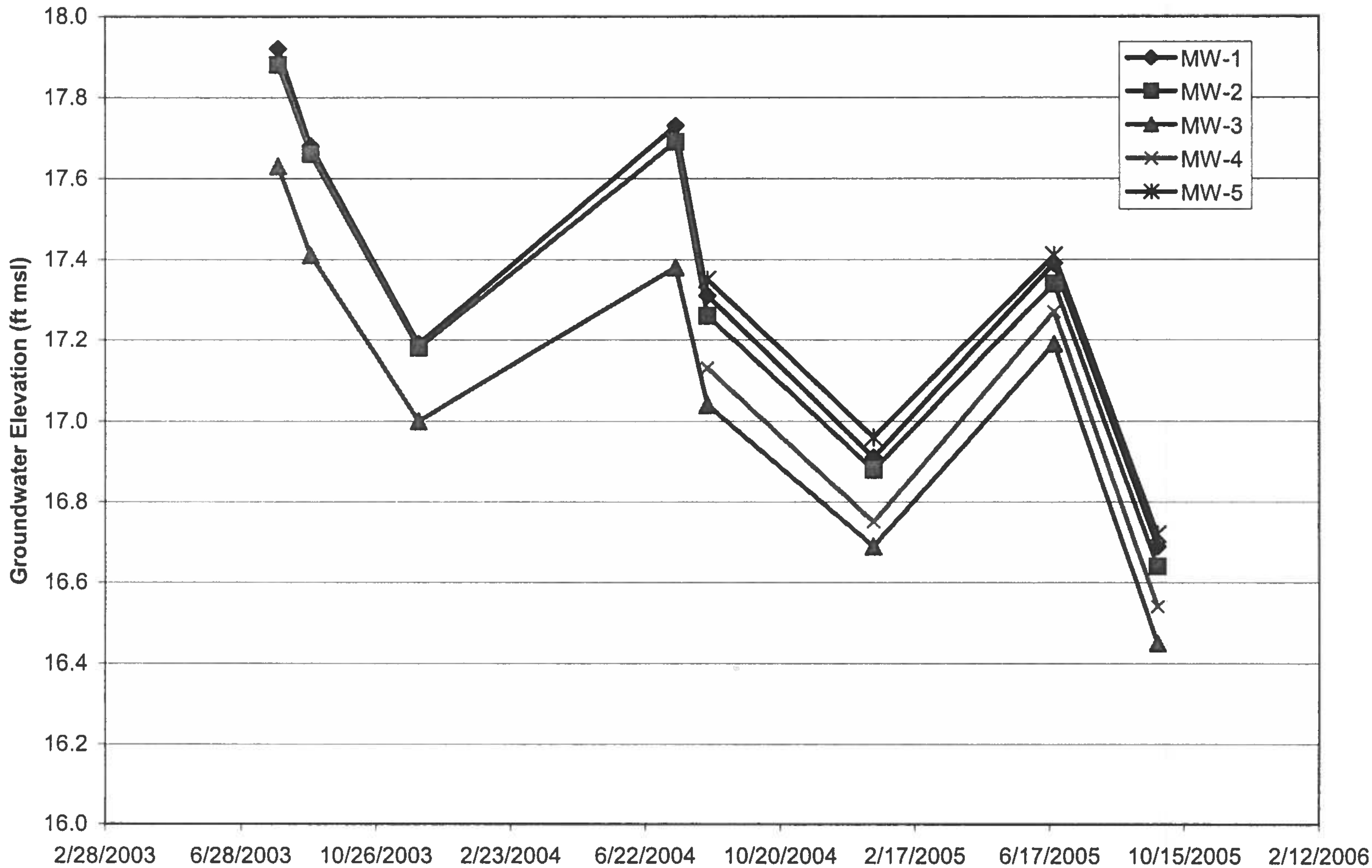
Table 2-5 summarizes the analytical results for VOCs detected during the June 2005 and September 2005 groundwater monitoring events, as well as historic VOC detections in the monitoring wells. VOCs detected above the reporting limits in the monitoring well samples during the RI/SCE sampling are PCE and its breakdown products TCE, c-1,2-DCE, t-1,2-DCE, 1,1-DCE, and vinyl chloride. Other VOCs, including 1,1-DCA, toluene, benzene, and chloromethane, were not detected during the RI/SCE sampling events. Acetone, which is a common laboratory contaminant, was detected in the samples collected from MW-2 and MW-3 during the September 2005 monitoring event.

Figure 2-6 shows the distribution of VOCs in groundwater in the Southeast Area, using PCE as an indicator of the presence of VOCs. This figure includes all Geoprobe borings in the Southeast Area and data for the most recent (September 2005) groundwater monitoring event. The monitoring well data show a spatial distribution of VOCs similar to that indicated by the Geoprobe data collected to date: the highest concentrations of PCE have been detected near MW-6 and MW-1, with lower concentrations detected both upgradient (MW-5) and downgradient (MW-3 and MW-4) of these wells. MW-2, located west of GP-1 and GP-2, defines the approximate westward extent of VOCs in groundwater.

Water levels measured during the June 2005 and September 2005 monitoring events are summarized in Table 2-7. As shown in Figure 3-3, water levels measured during the September 2005 monitoring event were lower than during previous monitoring events, although the relative water levels stayed consistent with all previous measurements. Consistent with previous events, the groundwater flow direction during both the June 2005 and September 2005 monitoring events was slightly west of due south, at a hydraulic gradient of 0.00072 ft/ft and 0.00085 ft/ft, respectively. Figure 3-4 presents the groundwater elevation contours based on water levels measured during the September 21, 2005, monitoring event.

Reductive dechlorination is the most important process for natural biodegradation of chlorinated solvents, including PCE, TCE, trans-1,2-DCE, and vinyl chloride. In reductive dechlorination, chlorine atoms are successively removed from the chlorinated hydrocarbon and are replaced by hydrogen atoms. The removal of the chlorine atoms occurs as anaerobic microorganisms obtain energy by transferring electrons from electron donors (such as naturally occurring organic matter) to electron acceptors, such as DO, nitrate, ferric iron ($Fe2+$), sulfate, carbon dioxide, and chlorinated aliphatic hydrocarbons such as PCE, TCE, DCE, and vinyl chloride.

Figure 3-3
Groundwater Levels in Southeast Area Monitoring Wells



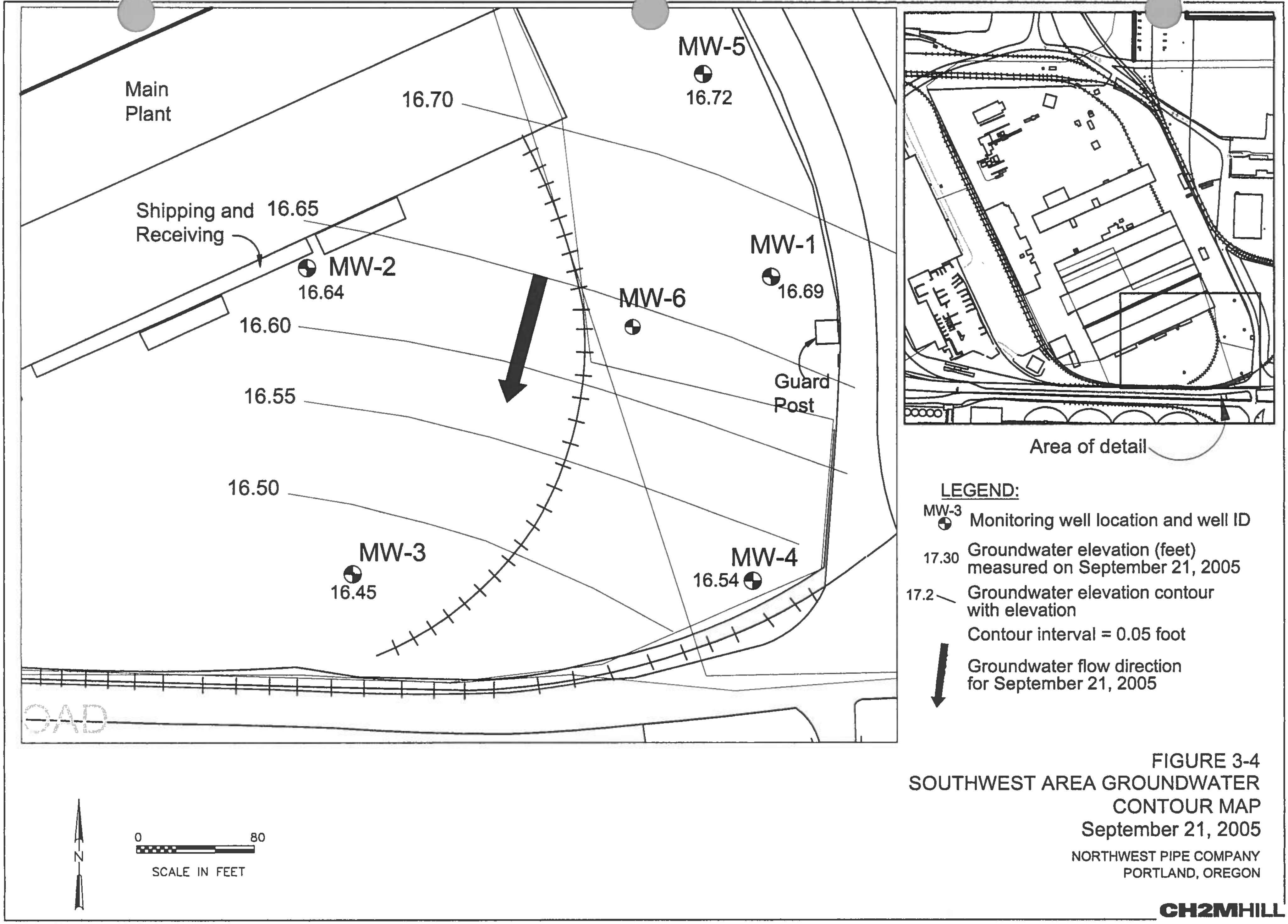


FIGURE 3-4
SOUTHWEST AREA GROUNDWATER CONTOUR MAP
September 21, 2005

NORTHWEST PIPE COMPANY
PORTLAND, OREGON

CH2MHILL

After DO is consumed, the anaerobic microorganisms preferentially use additional electron acceptors in the following order of preference: nitrate, Fe2+, sulfate, and, finally, carbon dioxide. Reductive dechlorination is most effective in the range corresponding to sulfate reduction and methanogenesis (which occurs through the reduction of carbon dioxide). Groundwater chemistry indicative that sulfate-reducing or methanogenic conditions exist includes:

- Low DO concentrations, typically less than 0.5 mg/L
- Low ORP, typically less than 50 mV and preferable below -100 mV
- Low concentrations of nitrate, typically less than 1 mg/L
- The presence of ferrous iron (Fe3+), which results from the reduction of Fe2+, at concentrations greater than 1 mg/L

Table 2-8 presents field parameters measured during collection of groundwater samples. DO and ORP levels measured at site monitoring wells (typically below 0.20 mg/L and -100 mV, respectively) indicate that reducing conditions are present throughout the Southeast Area. Additionally, the pH (which ranged from 6.1 to 7.1 standard units) is within the range amenable to microorganism survival and the alkalinity (which ranged from 120 to 192 mg/L) is sufficient for buffering the pH against acids produced during biodegradation.

Table 2-9 presents other natural attenuation parameters analyzed during the RI/SCE: nitrate, iron, manganese, sulfate, carbon dioxide, methane, chloride, and TOC. Combining these data with the field parameter data described above and the record of chlorinated solvent data from monitoring well samples (Table 2-5), it is possible to evaluate whether site conditions are consistent with reductive dechlorination of chlorinated solvents. EPA (1998) developed a screening worksheet for evaluating the potential for reductive dechlorination based on geochemical conditions. Table 3-4 contains the worksheet, along with scores assigned to the Northwest Pipe facility based on available monitoring well data. The total score of 24 for the Northwest Pipe facility falls within the "strong evidence" category identified by EPA (1998) for chlorinated solvent degradation via reductive dechlorination, indicating that geochemical conditions at the site are conducive to reductive dechlorination and consistent with the observed limited migration of chlorinated solvents.

Additional evidence that demonstrates that reductive dechlorination is occurring is found in the presence of PCE and TCE daughter products, such as trans-1,2-DCE, cis-1,2-DCE, 1,1,-DCE, and vinyl chloride in the shallow groundwater. The presence of cis-1,2-DCE as a more common breakdown product (compared to trans-1,2-DCE and 1,1-DCE) has been shown to be indicative of reductive dechlorination through biodegradation (EPA, 1998). Moreover, the elevated chloride concentrations in MW-6 compared to cross-gradient background conditions in MW-2 are consistent with chloride production from reductive dechlorination.

TABLE 3-4
Analytical Parameters and Weighting for Preliminary Screening for Anaerobic Biodegradation Processes
Northwest Pipe Company, Portland Oregon

Analysis	Concentration in Most Contaminated Zone	Interpretation	Value	Northwest Pipe Score[a]
Oxygen	< 0.5 mg/L	Tolerated; suppresses the reductive pathway at higher concentrations	3	3
Nitrate	< 1 mg/L	At higher concentrations, may compete with reductive pathway	2	2
Iron II	> 1 mg/L	Reductive pathway possible	3	3
Sulfate	< 20 mg/L	At higher concentrations, may compete with reductive pathway	2	2
Sulfide	> 1 mg/L	Reductive pathway possible	3	ND[b]
Methane	> 0.5 mg/L	Ultimate reductive daughter product	3	3
Oxidation reduction potential	< 50 millivolts	Reductive pathway likely	2	2
pH	5 < pH < 9	Optimal range for reductive pathway	0	0
TOC	> 20 mg/L	Carbon and energy source; drives dechlorination; can be natural or anthropogenic	2	0
Temperature	> 20°C	At T > 20°C, biochemical process is accelerated	1	0
Carbon dioxide	> 2x background	Ultimate oxidative daughter product	1	1
Alkalinity	> 2x background	Results from interaction between CO_2 and aquifer minerals	1	0
Chloride	> 2x background	Daughter product of organic chlorine	2	2
Hydrogen	> 1 nM	Reductive pathway possible	3	ND
TCE		Daughter product of PCE	2[c]	2
DCE		Daughter product of TCE	2[c]	2
VC		Daughter product of DCE	2[c]	2
		Total Score for Northwest Pipe Facility		**24**

[a] Using data from MW-2 as indicative of background conditions and MW-1, MW-4, and MW-6 as representative of the most contaminated zone.
[b] ND = Not determined. Assigned a value of zero although the actual value, if data were available, may be higher.
[c] Points awarded only if it can be shown that the compound is a daughter product (i.e., not a constituent of the source material). The presence of TCE and further breakdown products, combined with the limited migration distance away from the area of highest concentration, indicate that TCE, DCE, and VC are breakdown products.

3.2.3 Soil

Table 3-5 summarizes the analytical results for PCBs detected during the RI/SCE soil sampling effort. Four surface soil samples were collected from the former transformer area and analyzed for a suite of PCBs. PCB Aroclors detected above the reporting limit during the RI/SCE sampling are Aroclor-1254 and Aroclor-1260. Aroclors-1016, -1221, -1232, -1242, and -1248 were not detected above the reporting limit during the 2005 sampling effort.

3.3 Hydrogeologic Conceptual Site Model

A hydrogeologic conceptual site model (CSM) has been developed to assist in evaluating potential exposure pathways for VOCs in groundwater identified in the southeast portion (near the Southeast Area [Area 1] and Area 13) of the Northwest Pipe facility. In accordance with the American Society of Testing and Materials (ASTM) Standard Guide E1689-95, this CSM:

1. Identifies the constituents of potential concern and the potential source areas of the constituents
2. Establishes the background concentrations for the constituents
3. Identifies the potential migration and exposure pathways for constituents in groundwater beneath the site

The CSM was developed based on review of soil and groundwater investigation data collected at the site.

3.3.1 Site Hydrogeology

The site is underlain by two principal horizons in the upper 100 feet—a shallow sand interval from the surface to approximately 26 feet bgs, composed of fine to medium-grained sand with occasional intervals of silty sand (interpreted to be hydraulic fill generated from dredging activities prior to Northwest Pipe's presence at the site) underlain by a thick deposit of fine-grained silt with infrequent sandier silt intervals (interpreted to be native alluvium deposited in a low-energy environment), from approximately 26 feet to at least 120 feet bgs.

The shallow sand interval is the uppermost water-bearing zone at the site, with a depth to groundwater of approximately 14 feet bgs. The underlying silt horizon is a confining layer that separates the shallow water-bearing zone from a deeper coarse sand and gravel aquifer that is tapped by the onsite production well at a depth of 198 to 203 feet bgs. Figure 3-5 presents a cross-section depicting the subsurface profile in the Southeast Area of the site to a depth of 120 feet (the depth of deep GP-112), including the concentrations of PCE detected in samples from the area.

Table 3-6 presents the estimates of transmissivity and hydraulic conductivity for the shallow aquifer calculated using ASTM Method D 5472-93. Details regarding these calculations are provided in Appendix A of the RI/SCE Workplan (CH2M HILL, 2005). Hydraulic conductivity estimates varied from 2.6 feet/day (ft/d) to 28 ft/d, with higher conductivity values estimated for MW-1 and MW-6 (28 and 19 ft/d, respectively), and lower conductivity

Table 3-6

Summary of Transmissivity and Hydraulic Conductivity Estimates for Shallow Aquifer

Northwest Pipe Company - Portland, Oregon

Well ID	Depth of Screened Interval a			Saturated Aquifer Thickness (ft msl)	Drawdown During Purging (ft)	Average Flow Rate During Purging (gpm)	Estimated Aquifer Transmissivity (ft2/day)	Estimated Hydraulic Conductivity (ft/day)
MW-1	14	to	24	14.21	0.10	0.19	400	28
MW-2	10.5	to	20.5	14.18	0.91	0.22	37	2.6
MW-3	14.5	to	24.5	13.99	0.77	0.21	43	3.1
MW-4	16.5	to	26.5	14.05	0.52	0.24	80	5.6
MW-6	18.5	to	28.5	14.00	0.15	0.20	270	19

Notes:

Refer to Figure 4-3 for well locations.

A storativity value of 0.15 was assumed in the estimation of transmissivity. Assuming storativity values of 0.10 and 0.20 result in less than a 10% increase or decrease in the estimated value for aquifer transmissivity/conductivity.

values estimated for downgradient wells (MW-3 and MW-4, 3.1 and 5.6 ft/d, respectively). A hydraulic conductivity of 2.6 ft/d was estimated from data measured at MW-2. Although the hydraulic conductivity at MW-5 could not be quantitatively evaluated because drawdown was minimal at this well, the minimal drawdown indicates that the hydraulic conductivity near MW-5 is apparently greater than at the other monitoring wells. Based on these results, the relative hydraulic conductivity of the shallow water-bearing zone decreases from an upgradient to downgradient direction. This apparent southward decrease in hydraulic conductivity is accompanied by a slight increase in hydraulic gradient, described below.

Groundwater levels have been measured on eight occasions since July 2003. As shown in Figure 3-3, the relative water levels in site monitoring wells have remained consistent for each set of measurements. Figure 3-4 presents the groundwater level contours based on water levels measured during the September 21, 2005, monitoring event. During all monitoring events, the groundwater flow direction in the Southeast Area has been slightly west of due south (similar to that shown in Figure 3-4). The hydraulic gradient across the Southeast Area has ranged from 0.00072 ft/ft to 0.0015 ft/ft, with an average gradient of 0.0010 ft/ft. Table 3-6 summarizes the hydraulic gradient estimated for all previous groundwater level monitoring events. Closer examination of the contour map indicates that the hydraulic gradient in the northern portion of the Southeast Area, near MW-5, is lower than the gradient in the southern portion of the Southeast Area, near MW-3, MW-4, and MW-6. This spatial variation in gradient correlates well with the apparent spatial variation in hydraulic conductivity described above.

The groundwater flow velocity at the site can be estimated using a modified form of Darcy's Law:

$$v = K \bullet i / n_e$$

where:

v = groundwater seepage velocity in ft/d
K = hydraulic conductivity (ft/d)
i = hydraulic gradient (unitless)
n_e = effective porosity (unitless)

Using an average hydraulic gradient across the Southeast Area of 0.001, an average hydraulic conductivity for MW-3 and MW-4 of 4.4 ft/d, and an assumed effective porosity of 0.2, the average groundwater seepage velocity of groundwater migrating offsite to the south is estimated to be 0.022 ft/d, or approximately 8 feet per year.

3.3.2 Chemicals of Potential Concern

As shown in Table 2-5, the constituents of potential concern present above the reporting limits in the monitoring well samples are PCE and its breakdown products: TCE, c-1,2-DCE, t-1,2-DCE, 1,1-DCE, and vinyl chloride. Other VOCs (1,1-DCA, toluene, benzene, and chloromethane) have been detected below the reporting limit at estimated concentrations during previous monitoring events, although these VOCs were not detected during the most recent (January 2005) monitoring event. Chloroform and acetone, which are common

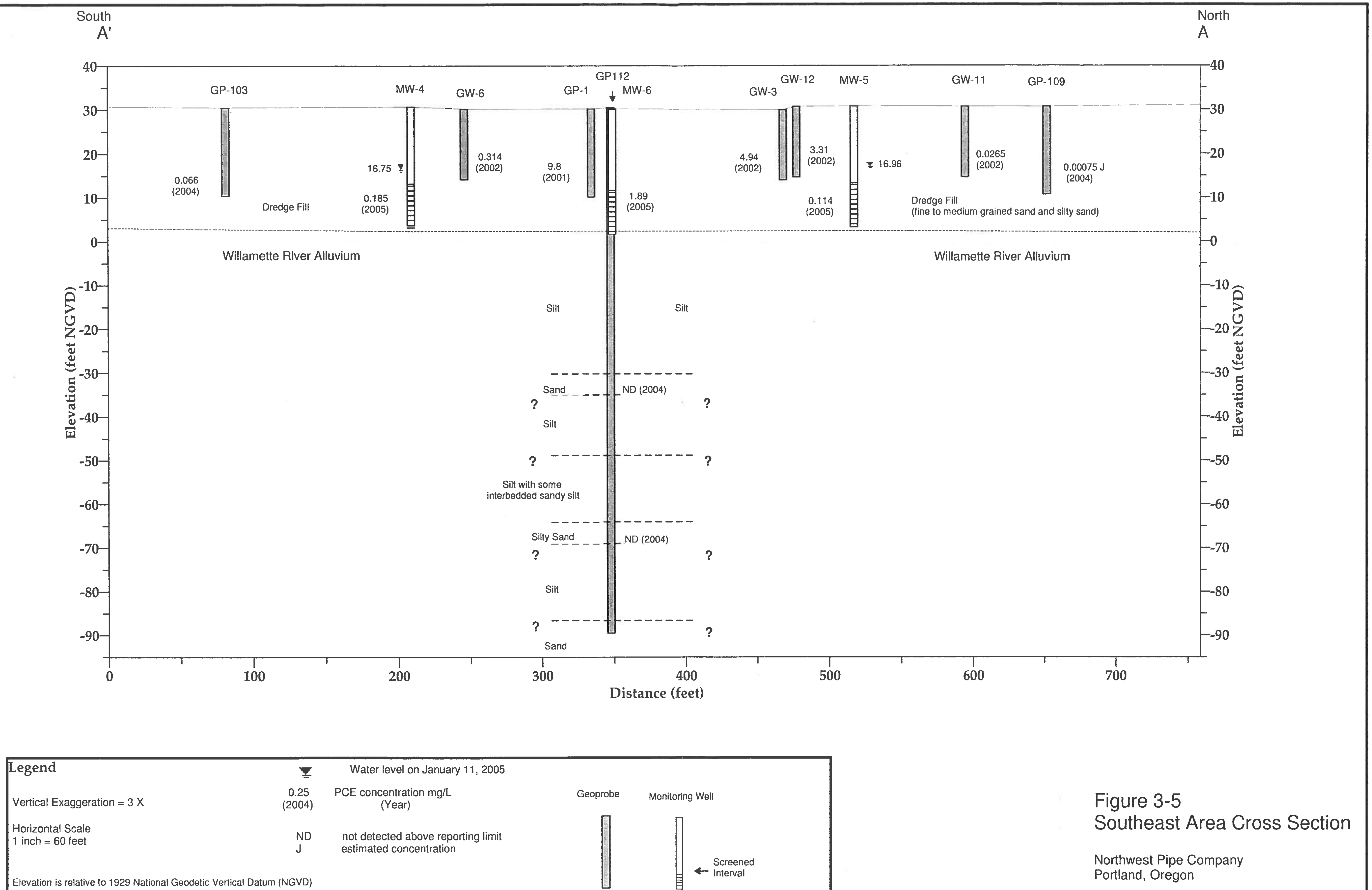


Figure 3-5
Southeast Area Cross Section

Northwest Pipe Company
Portland, Oregon

CH2MHILL

laboratory contaminants, were detected in samples collected from MW-6 during the January 2005 monitoring event.

3.3.3 Potential Contaminant Source Areas and Background Areas

The distribution of PCE in groundwater for the Southeast Area of the site, using PCE as an indicator of the presence of VOCs, is shown in Figure 2-6. This figure includes all Geoprobe borings in the Southeast Area and data from the most recent groundwater monitoring event. The monitoring well data show a spatial distribution of VOCs similar to that indicated by the Geoprobe data collected to date: the highest concentrations of PCE have been detected near MW-6 and MW-1, with lower concentrations detected both upgradient (MW-5) and downgradient (MW-3 and MW-4) of these wells. As during previous events, MW-2 defines the approximate westward extent of VOCs in groundwater.

Because of the 95-foot-thick silt confining layer that underlies the shallow water-bearing zone, vertical migration of VOCs into the underlying aquifer is unlikely. Data from deep groundwater samples collected from sandier intervals within the confining layer (at 62 and 96 feet) did not contain VOCs, confirming that downward migration of VOCs has not occurred in the Southeast Area.

The source area for the observed VOCs in groundwater at the Northwest Pipe facility is uncertain. As described above, low concentrations of PCE and occasional detections of PCE biodegradation products have been found at most locations where shallow groundwater has been sampled and analyzed for VOCs. As indicated in Table 2-6, these low-level concentrations generally can be characterized as being less than 0.005 mg/L. In the Southeast Area, however, higher concentrations have been detected, ranging up to 9.8 mg/L in a 2001 Geoprobe sample (GP-1) and up to 1.96 mg/L in a 2005 monitoring well sample from the same location (MW-6). DEQ (2002a) has suggested that these elevated concentrations of PCE may be associated with an onsite source area near the location of GP-1. However, given the consistent southerly groundwater flow direction and the presence of elevated concentrations of VOCs on the upgradient property line (3.31 mg/L in Geoprobe sample GW-12) and 250 feet upgradient of GP-1 at offsite Geoprobe sampling location GP-108 (0.021 mg/L), the presence of a source of VOCs upgradient and offsite from the Southeast Area is indicated by the existing data.

3.3.4 Evaluation of Shallow Groundwater Discharge to Surface Water Pathway

Because the shallow aquifer is not a source of drinking water in the area (see Section 4.0), the potential receptors that may be exposed to shallow groundwater are hypothetical ecological receptors that use local surface water for habitat. Based on the observed, consistent flow direction, the nearest location where groundwater may discharge surface water would be at the Terminal 4 Slip 1, which is located approximately 1,000 feet downgradient of the Southeast Area of the Northwest Pipe facility.

To evaluate the ability of VOCs in groundwater to migrate downgradient at sufficient concentrations that would pose a risk to ecological receptors, groundwater flow and the transport of constituents of interest were evaluated using EPA's BIOCHLOR model (EPA, 2000). BIOCHLOR simulates the reductive dechlorination process (the dominant biotransformation process for chlorinated organic compounds at most sites), and was developed to assist in assessing the potential for downgradient migration of dissolved chlorinated solvents in groundwater. Reductive dechlorination occurs under anaerobic conditions. Field monitoring data collected during groundwater monitoring at Northwest Pipe confirm that anaerobic conditions are present in shallow groundwater beneath the site, and the presence of chlorinated solvent degradation products is consistent with reductive dechlorination as an active process, reducing the concentration and migration potential for chlorinated solvents in shallow groundwater.

BIOCHLOR is based on the Domenico analytical solute transport model, which assumes a uniform groundwater flow field. In addition to biotransformation, BIOCHLOR includes the ability to simulate three-dimensional dispersion and adsorption onto aquifer organic carbon. Literature values for organic carbon partition coefficient and first-order biodegradation decay constants were used in the BIOCHLOR evaluation. Other parameters used by the model were based on site-specific data (gradient, hydraulic conductivity, fractional organic carbon content, and VOC concentrations), and assumed values (porosity, dispersivity, source area width). The input parameters used in the BIOCHLOR evaluation are summarized in Table 3-7.

Within BIOCHLOR, the source area is represented as a cross-sectional area (with a specified width and depth) that is oriented perpendicular to the flow field, and through which groundwater enters the model at the assigned source area concentration. For the BIOCHLOR model, it was assumed that the width of the source zone was 90 feet, based on review of the elevated concentration area identified in the Southeast Area. As a conservative assumption, the vertical distribution of VOC in the source area was assumed to equal the full saturated thickness of the shallow aquifer (14 feet).

Source area concentrations for PCE and breakdown products assigned to the model are the average concentrations as measured in groundwater samples collected from Geoprobes GP-1, GP-2, and MW-6 as shown in Tables 2-2 and 2-5. This is also a conservative assumption, as the monitoring well concentrations at MW-6 are less than one-half of the average concentration used for the source zone in the BIOCHLOR modeling. All simulations also assumed that concentrations within the simulated source area remained constant for the full duration of the simulation. This also is a conservative assumption because concentrations within the source area would be expected to decrease as mass migrates away from the simulated source area and subsequently degrades. Model results for concentrations after 1,000 years (which was found by iteration to be well beyond the time-frame for steady-state conditions) were utilized for the analysis, as this conservative assumption results in maximum predicted concentrations at the downgradient discharge location.

Table 3-7
BIOCHLOR Input Parameters for Base Case
Northwest Pipe Company - Portland, Oregon

Input Parameter	Value(s)	Comments
Hydrogeologic Data		
Hydraulic Conductivity	0.00155 cm/sec	average hydraulic conductivity estimated at downgradient wells (4.4 ft day)
gradient	0.001 [unitless]	average gradient
effective porosity	0.2 [unitless]	typical value
seepage velocity	8.0 ft/year	calculated from above parameters
longitudinal dispersivity	50 ft	Conservatively assumed to be 5% of the distance to the discharge point, which is within the upper half of the range of acceptable values for dispersivity estimates for a migration distance of 1,000 feet (EPA 2000)
transverse dispersivity	5 ft	assumed to be 10% of longitudinal dispersivity
aquifer bulk density	1.7 kg/L	default value for soil
organic carbon partition coefficient	1.93 mg/kg	calculated from reported values for chlorinated solvents (EPA, 2000)
fraction organic carbon	0.000843 [unitless]	average of 3 shallow aquifer formation samples collected in boring for MW-6
Biotransformation Data		
PCE to TCE	0.1 per year	calibration to observed concentrations
TCE to DCE	0.48 per year	calibration to observed concentrations
DCE to vinyl chloride	0.6 per year	calibration to observed concentrations
vinyl chloride to ethene	1.39 per year	calibration to observed concentrations
Source Data		
PCE concentration in source zone	5.63 mg/L	average concentration of samples collected at GP-1, GP-2, and most recent MW-6 sample
TCE concentration in source zone	1.13 mg/L	average concentration of samples collected at GP-1, GP-2, and most recent MW-6 sample
DCE concentration in source zone	0.99 mg/L	average concentration of samples collected at GP-1, GP-2, and most recent MW-6 sample
vinyl chloride concentration in source zone	0 mg/L	average concentration of samples collected at GP-1, GP-2, and most recent MW-6 sample
source area width	90 feet	based on field observations
source area depth	14 feet	assumed to extend over full saturated thickness of aquifer

First-order biodegradation constants were identified by calibrating the model to concentrations at observed downgradient locations. Data included for the model calibration included Geoprobes GW-6, GW-7, and GP-102, which are directly downgradient of Geoprobes GP-1, GP-2, and MW-6. Figures presenting the model-simulated concentrations with increasing distance from the source, along with the output and input screens from BIOCHLOR simulations for PCE, TCE, and total DCE (total DCE is the sum of cis-1,2-DCE, trans-1,2-DCE, and 1,1,-DCE) are included in Appendix B. These figures present the model-simulated concentrations with increasing distance from the source area along the centerline axis of the simulated plume—the location where concentrations would be highest. At any given distance downgradient, concentrations decrease with increasing distance from the centerline of the plume.

In addition to the calibrated model simulation, several sensitivity simulations were also conducted to assess the effect of variations in modeling parameters on predicted downgradient concentrations. Simulations for the sensitivity analysis included:

- Simulations to assess the effect of increased and decreased biodegradation rates on downgradient concentrations. The simulation with decreased degradation rates utilized rates equal to the lowest field value consistent with some, though very slow, biodegradation identified in a literature review of rate constants (Aronson and Howard, 1997) for sites where biodegradation is occurring (0.07 per year, 0.05 per year, 0.18 per year, and 0.12 per year for PCE, TCE, DCE, and vinyl chloride, respectively). The simulation with increased degradation rates utilized rates (0.56 per year, 0.48 per year, 1.74 per year, and 1.39 per year for PCE to TCE, TCE to DCE, DCE to vinyl chloride, and vinyl chloride to ethane, respectively) equal to the average of the median field value and the lowest rates identified in a literature review of rate constants (Aronson and Howard, 1997).
- Assessing the effect of increased and decreased seepage velocity on downgradient concentrations. Seepage velocities (which are calculated from hydraulic conductivity, effective porosity, and hydraulic gradients) were increased and decreased by 50 percent, which results in seepage velocities of 12 feet/year and 4 feet/year, respectively.
- Assessing the effect of source area size on downgradient concentrations. Source area size was increased to 120 feet and decreased to 60 feet for the sensitivity simulations. For these simulations, the thickness of the source area was maintained at 14 feet—the full saturated thickness of the shallow aquifer.
- Assessing the effect of increased and decreased dispersivity values on downgradient concentrations. The horizontal and transverse dispersivity values were increased to 100 feet and 10 feet, respectively, and decreased to 25 feet and 2.5 feet, respectively.

Table 3-8 summarizes the BIOCHLOR simulated concentrations at the downgradient discharge location for the calibrated model and the sensitivity simulations. Using the conservative assumptions described above, BIOCHLOR predicted that VOCs would not reach surface water at concentrations above screening values for the calibrated model. It is important to note that, in addition to the conservative input parameters used in the BIOCHLOR modeling, the comparison against screening levels was against predicted plume "centerline" concentrations. The centerline represents the highest possible concentration downgradient of a source area. Concentrations on either side of the centerline are lower, and the average concentration discharging to the slip along the plume front would be substantially less than the centerline concentrations. Consequently, using centerline concentrations for the comparison against screening levels adds another layer of conservatism to the analysis.

Simulated concentrations for all constituents at the downgradient discharge location met screening levels for the sensitivity simulations with increased degradation rates, increased source area, decreased source area, increased dispersivity, decreased dispersivity, and decreased seepage velocity. Screening criteria was exceeded for only two of the sensitivity simulations: the simulations with decreased degradation rates and increased seepage velocity. In most cases, the simulated concentrations only slightly exceeded the screening criteria. The exception to this was for TCE and vinyl chloride for the simulation that utilized decreased degradation rates. This sensitivity simulation is highly conservative, because it also yields simulated concentrations that are much greater (for all VOC constituents) than indicated by the field monitoring data collected for the site. For this reason, although this sensitivity analysis provides insight into how predictions vary when input parameters are varied, its results are extreme and do not represent actual conditions. In summary, the analysis indicates that the concentrations of VOCs detected at the Northwest Pipe facility do not pose a risk to potential receptors to surface water.

3.3.5 Preferential Pathway Assessment of Underground Utilities

As part of the RI/SCE investigation, an evaluation of potential preferential pathways associated with underground utilities located near the Southeast Area was completed. Typical groundwater elevations in this area are approximately 17 feet relative to the 1929 National Geodetic Vertical Datum (NGVD). For the purpose of this discussion, all elevations have been adjusted to the 1929 NGVD. Figure 3-6 shows the locations of underground utilities, which are discussed as follows.

3.3.5.1 Storm Water Lines

Four storm water conveyance lines are located near the Southeast Area, two from the Northwest Pipe storm water system and two from the Schnitzer Investment Corporation storm water system as shown in Figure 3-1. Northwest Pipe storm water lines leave the site near sampling points No. 3 and No. 4 located 6 feet bgs (24 feet NGVD), and 5 feet bgs (25 feet NGVD), respectively. Given these pipe elevations and the understanding that the storm water system flows by gravity, any upgradient portions of the storm water lines would be at a higher elevation than where they leave the site. Because they lie well above the elevation of groundwater (which averages 17 feet NGVD), the storm water lines are not a preferential pathway for groundwater.

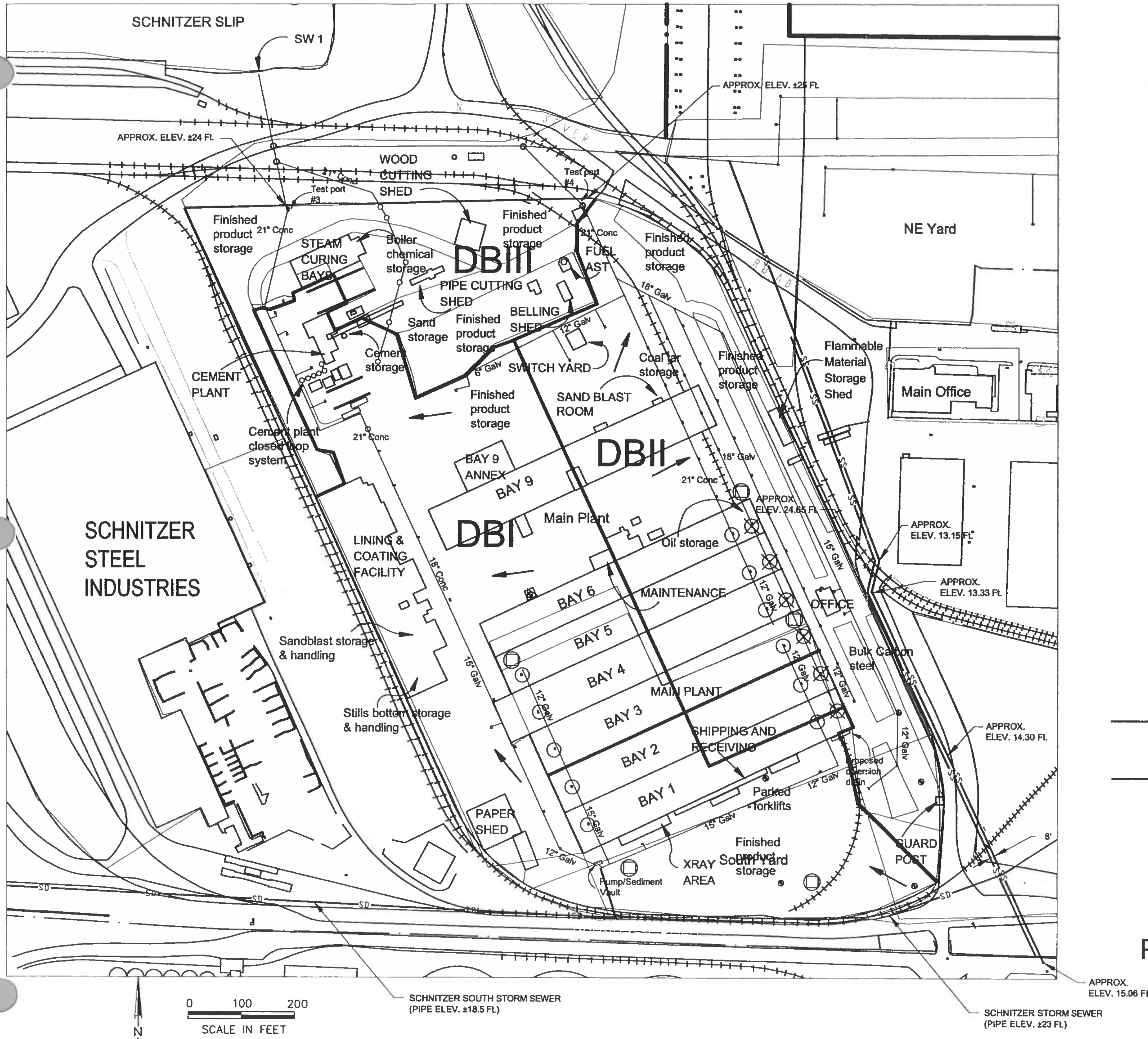
Table 3-8
BIOCHLOR Simulated Concentrations at Downgradient Discharge Point

Constituent	Screening Criteria	Calbrated Model	Sensitivity Simulations			
			Increased Degradation Rates	Decreased Degradation Rates	Increased Source Area	Decreased Source Area
PCE	0.00010	0.000048	0.0000000	**0.00040**	0.000064	0.000032
TCE	0.000028	0.000010	0.0000000	**0.0047**	0.000013	0.0000067
Total DCE	0.061	0.0000059	0.0000000	0.0013	0.0000079	0.0000039
VC	0.000020	0.0000021	0.0000000	**0.0019**	0.0000028	0.0000014

Constituent	Screening Criteria	Calbrated Model	Sensitivity Simulations			
			Increased Dispersivity	Decreased Dispersivity	Increased Velocity	Decreased Velocity
PCE	0.00010	0.000048	0.00010	0.000026	**0.00051**	0.00000014
TCE	0.000028	0.000010	0.000022	0.0000055	**0.00011**	0.0000000
Total DCE	0.061	0.0000059	0.000013	0.0000033	0.000063	0.0000000
VC	0.000020	0.0000021	0.0000044	0.0000011	**0.000022**	0.0000000

Notes:
Screening criteria are EPA Region IX PRGs for tap water
Screening criterion for Total DCE is 0.061 mg/L, which is the lowest screening criteria for any DCE constituent.
Predicted concentrations exceeding screening criteria are shown in **bold**.

Dec 29, 2005



LEGEND

- SCRAP METAL RECYCLING BINS
- SEALED CATCH BASINS
- CATCH BASINS PLANNED TO BE SEALED
- PRODUCTION WELL
- SURFACE WATER FLOW DIRECTION
- SW 1 — STORMWATER OUT FALL (OUTFALL 18)
- STORMWATER CATCH BASIN
- SAMPLING PORT
- 12" Galv — 12" GALVANIZED STEEL PIPE
- 21" Conc — 21" CONCRETE PIPE
- DRAINAGE BASIN DIVIDE (APPROXIMATE)
- APPROXIMATE LOCATION OF UNDERGROUND STORM DRAIN
- APPROXIMATE AREA OF PERVIOUS SURFACES
- DB — DRAINAGE BASIN
- NPS — NON-POINT SOURCE
- —SS— SANITARY SEWER LINE
- —SD— STORM DRAIN LINE

FIGURE 3-6
PREFERENTIAL PATHWAY EVALUATION

NORTHWEST PIPE COMPANY
PORTLAND, OREGON

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Two Schnitzer Investment Corporation storm water conveyance lines are located to the south of the site. One is located southwest and the other is southeast of the affected groundwater in the Southeast Area. The pipe running to the southwest is 18 inches in diameter, with a depth of 9 feet bgs or elevation of approximately 18.5 feet MSL. A second line, located to the southeast, is a 12-inch-diameter steel pipe located at a depth of 7 feet bgs or an elevation of approximately 23 feet MSL. Because they lie above the average groundwater elevation, these lines are not a preferential pathway for groundwater.

3.3.5.2 Water Mains

Data from the City of Portland Water Bureau shows a hydrant near the affected groundwater in the Southeast Area. Additional hydrants and water mains are located to the northeast of the site. According to the City, the mains are buried approximately 2.5 to 3 feet bgs or approximately 27 to 27.5 feet MSL. Because of their shallow depth and northeast location, these pipelines are not a preferential pathway for groundwater.

3.3.5.3 Sanitary Sewer

Two parallel sewer lines are located east of the affected groundwater in the Southeast Area, approximately 50 feet east of MW-5. According to the City of Portland, Bureau of Environmental Service drawings, one of the pipes is a pressurized sanitary line, located approximately 6.5 feet bgs or 23.5 feet MSL. The other is a gravity-flow sanitary sewer line, with an invert elevation ranging from approximately 15 feet bgs (15 feet MSL) to 17 feet bgs (13 feet MSL). The pipeline originates from the access road to the Port of Portland former grain facility and flows by gravity to the north approximately 1,200 feet to a pump station. No pipe bedding information was available from the City of Portland. Although the invert of this pipeline is likely below the water table (typical groundwater elevations are approximately 17 feet MSL), given the limited length of this sewer line, the permeable nature of the surrounding soil, the location of the sewer east of elevated concentrations of VOCs in the Southeast Area, and its termination point of approximately 300 feet downgradient of the Southeast Area, this pipeline is not a preferential groundwater pathway.

3.3.5.4 Natural Gas Lines

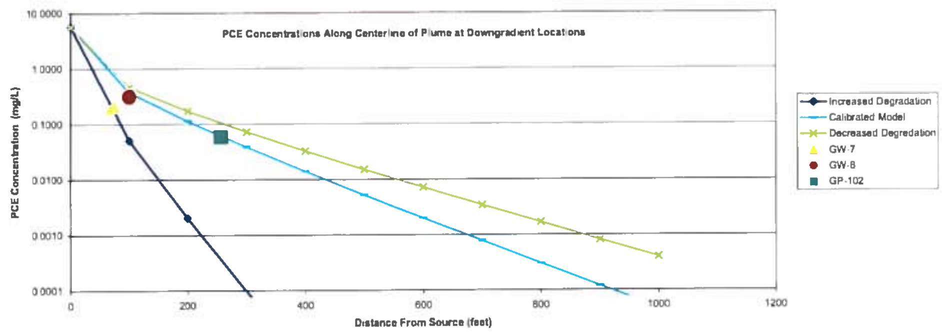
According to Northwest Natural Gas, standard natural gas service lines (1-inch-diameter) are buried 18 inches bgs. On average, main lines are buried approximately 30 inches bgs; they are typically 1.25-inch pipe. If any high-pressure lines are installed, they are usually placed 4 to 5 feet bgs. The site has some natural gas pipelines associated with it. However, the gas pipelines lie to the east of the affected groundwater in the Southeast Area. Because of their shallow burial depth, these pipelines are not a preferential pathway for groundwater.

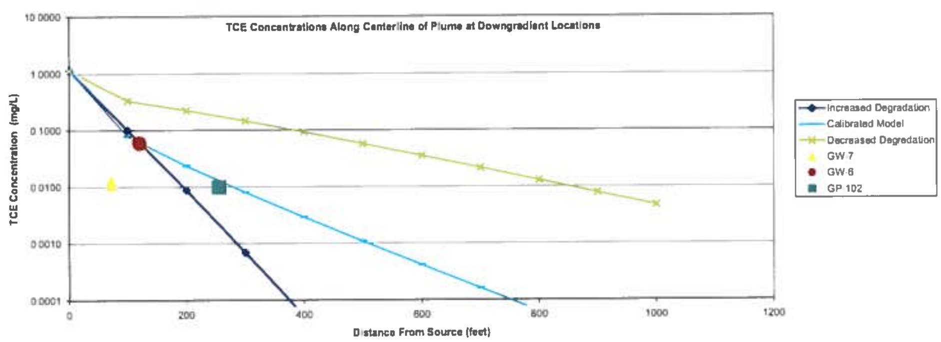
APPENDIX B

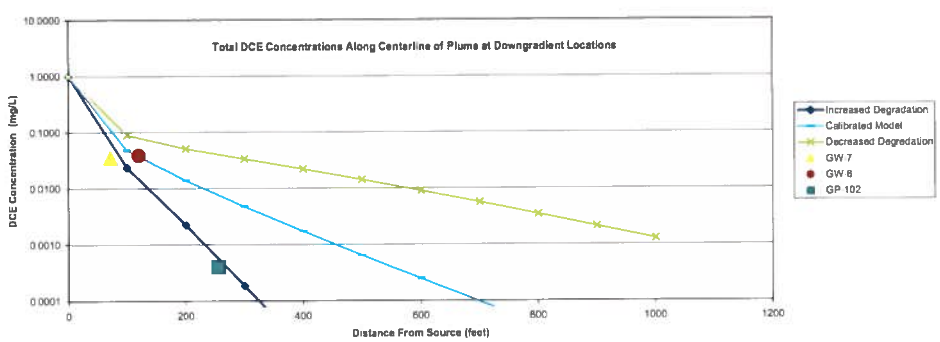
BIOCHLOR Modeling Data

Figures

Sensitivity to Degradation Rates







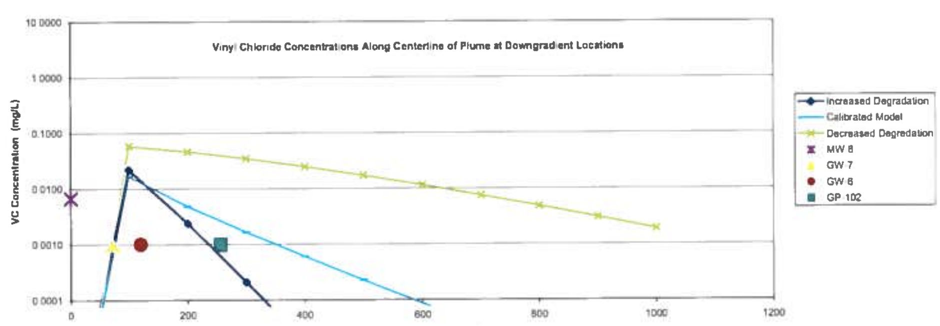


Figure B-1
Sensitivity to Degradation Rates
Northwest Pipe Company
Portland, Oregon

Sensitivity to Source Area Width

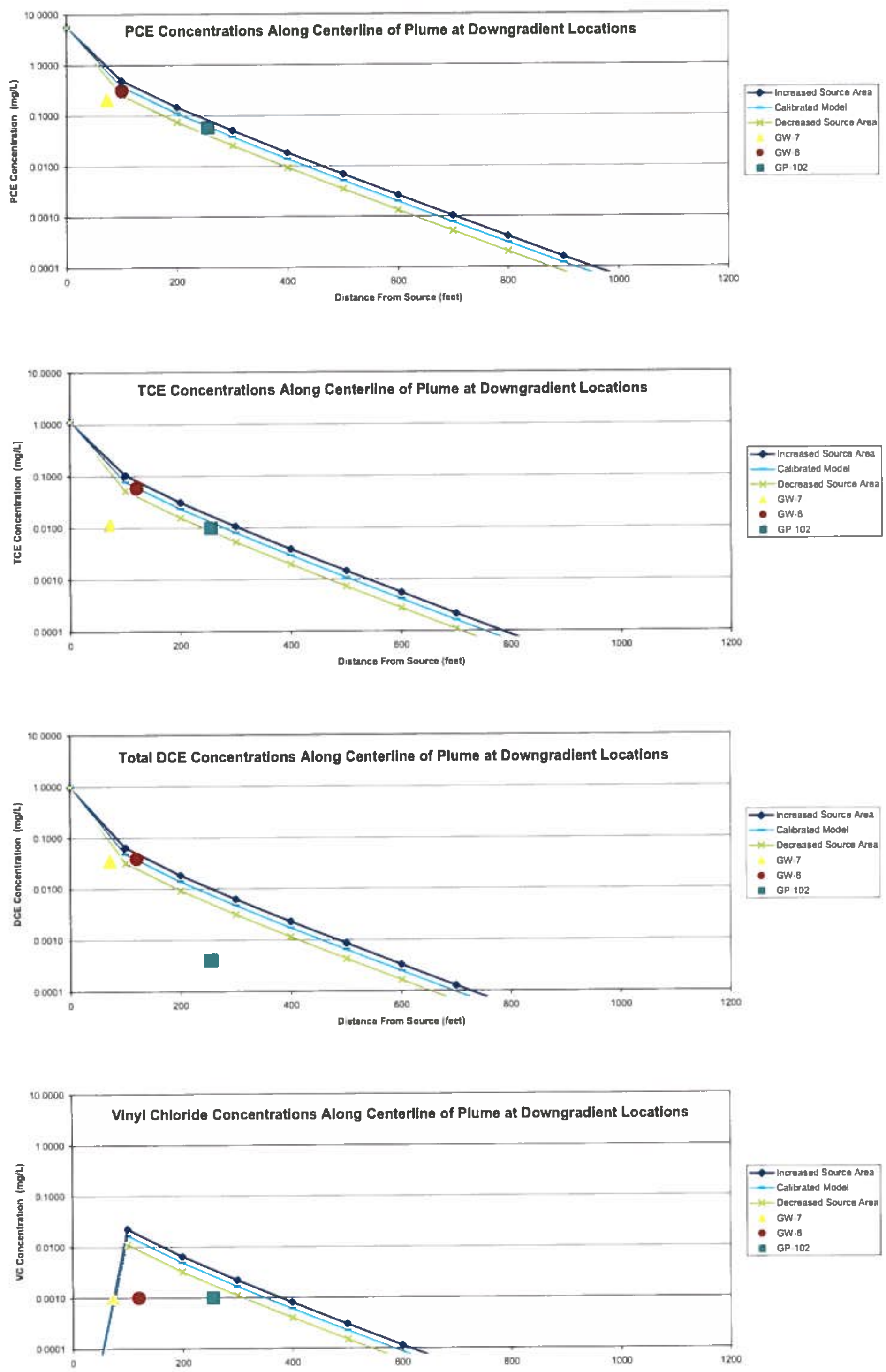


Figure B-2
Sensitivity to Source Area Size
Northwest Pipe Company
Portland, Oregon

Sensitivity to Dispersivity

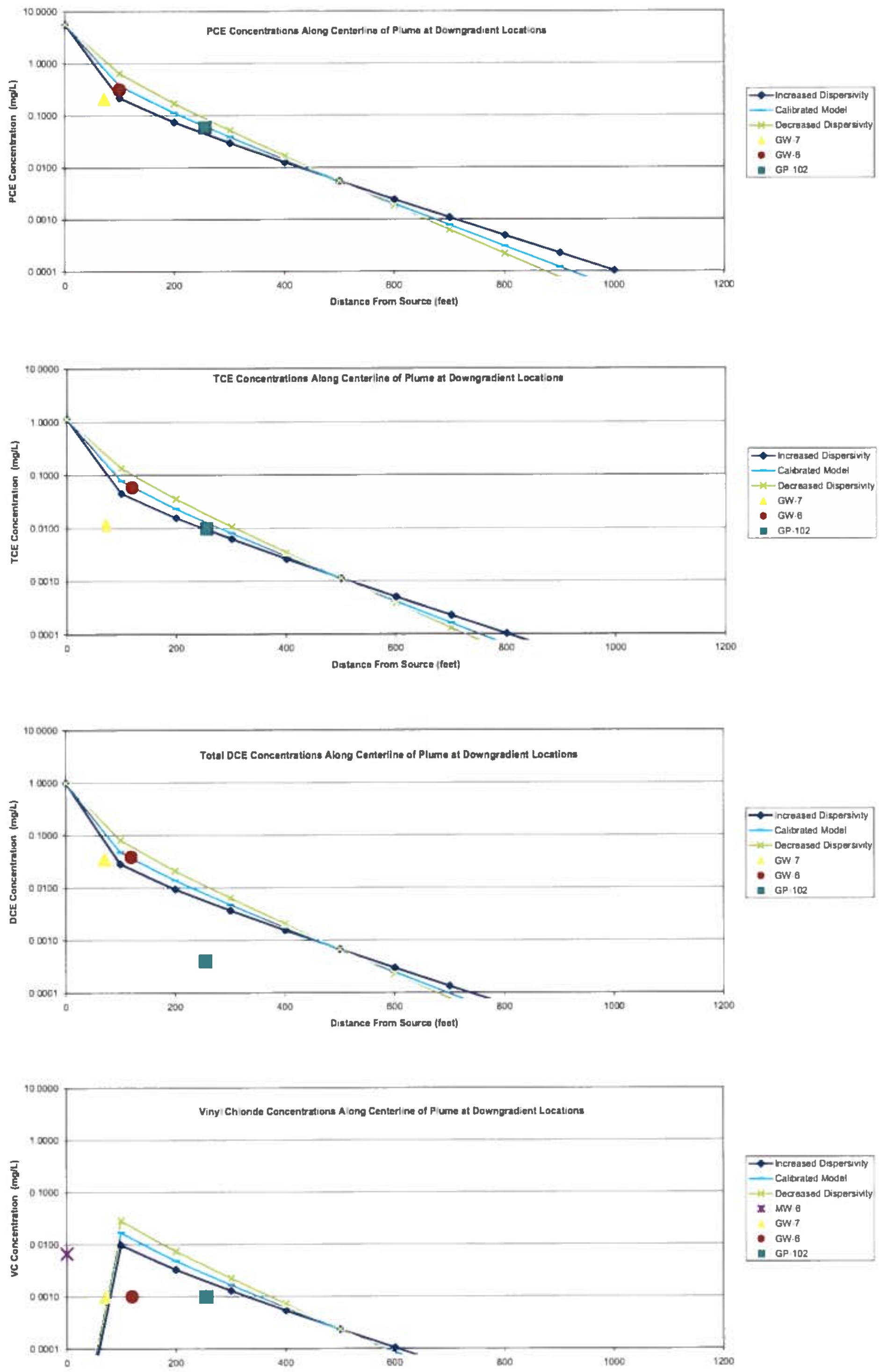
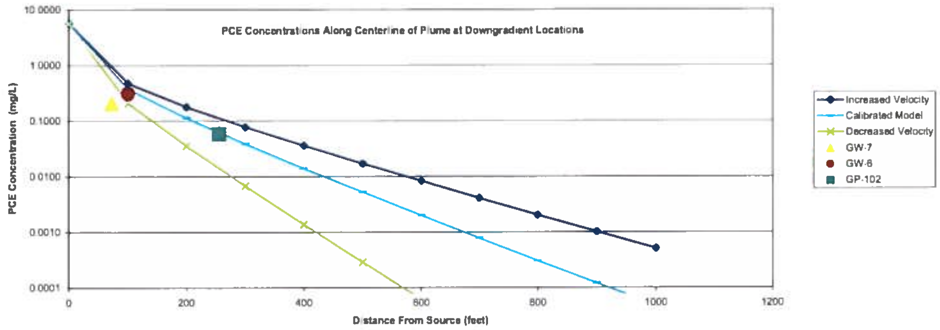
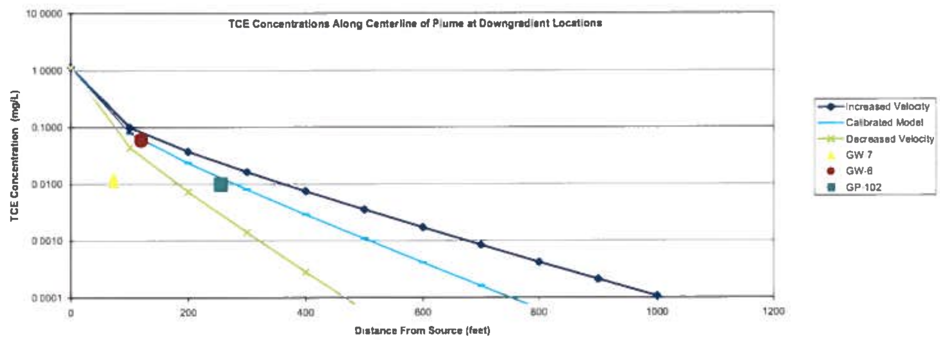
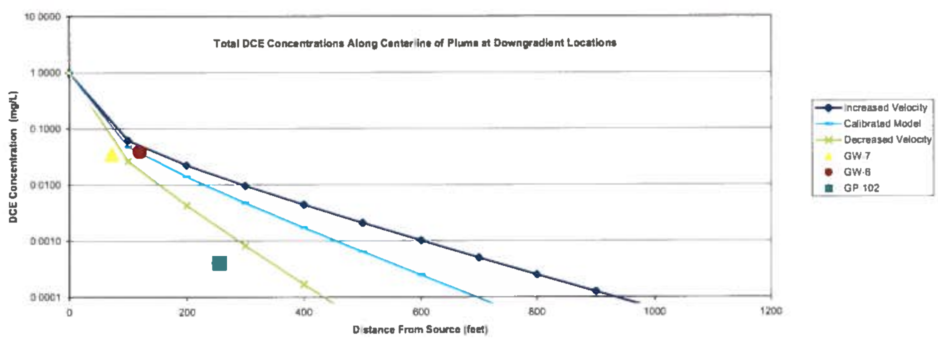


Figure B-3
Sensitivity to Dispersivity
Northwest Pipe Company
Portland, Oregon

Sensitivity to Seepage Velocity







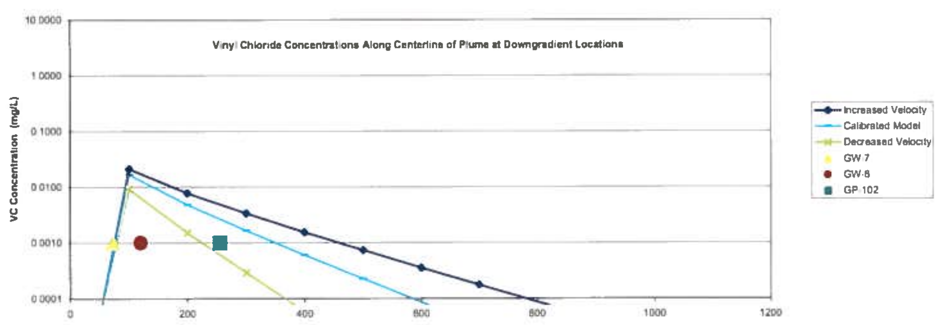


Figure B-4
Sensitivity to Seepage Velocity
Northwest Pipe Company
Portland, Oregon

Model Simulations

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel '97

Run Name
NW Pipe
Southeast Area

Data Input Instructions:

115 → 1. Enter value directly....or
or 0.02 → 2. Calculate by filling in gray cells. Press Enter, then C
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	8.0	(ft/yr)
or			
Hydraulic Conductivity	K	1.6E-03	(cm/sec)
Hydraulic Gradient	i	0.001	(ft/ft)
Effective Porosity	n	0.2	(-)

2. DISPERSION

Alpha x*	50	(ft)
(Alpha y) / (Alpha x)*	5	(-)
(Alpha z) / (Alpha x)*	2.E-05	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.7	(kg/L)		
FractionOrganicCarbon, foc	8.4E-4	(-)		
Partition Coefficient	Koc		R	
PCE	426	(L/kg)	4.05	(-)
TCE	130	(L/kg)	1.93	(-)
DCE	125	(L/kg)	1.90	(-)
VC	30	(L/kg)	1.21	(-)
ETH	302	(L/kg)	3.16	(-)
Common R (used in model)* =			1.93	

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	0.100		0.79
TCE → DCE	0.480		0.74
DCE → VC	0.700		0.64
VC → ETH	1.390		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL

Simulation Time*	1000	(yr)
Modeled Area Width*	500	(ft)
Modeled Area Length*	1000	(ft)
Zone 1 Length*	1000	(ft)
Zone 2 Length*	0	(ft)

L, W
Zone 2= L - Zone 1

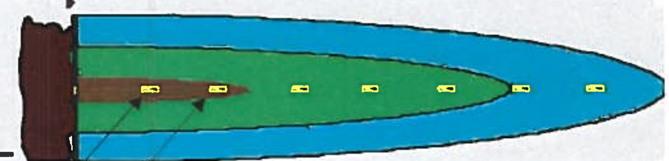
6. SOURCE DATA TYPE: Continuous Single Planar

Source Options

Source Thickness in Sat. Zone* 14 (ft)

	Y1	
Width* (ft)	90	
Conc. (mg/L)*	C1	k_s^* (1/yr)
PCE	5.63	0
TCE	1.13	0
DCE	.99	0
VC	.0	0
ETH	0	0

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations



View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.314	.059	.208								
TCE Conc. (mg/L)	.059	.01	.012								
DCE Conc. (mg/L)	.039	.0	.035								
VC Conc. (mg/L)	.001	.001	.001								
ETH Conc. (mg/L)	0.0	.0	.0								
Distance from Source (ft)	120	255	72								
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:

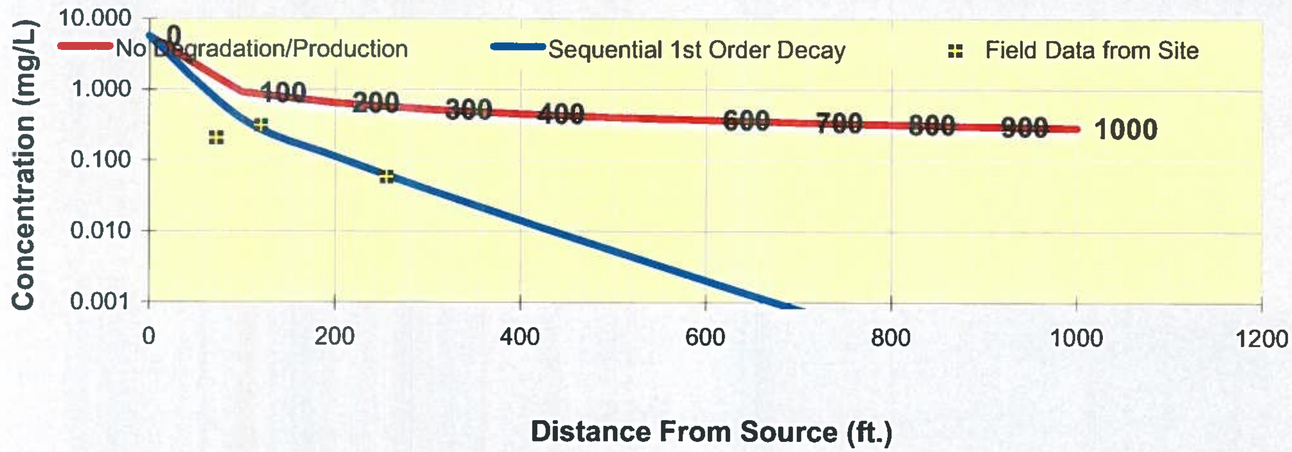
RUN CENTERLINE | RUN ARRAY | Help | Restore Formulas | RESET | SEE OUTPUT | Paste Example

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

PCE

	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	5.630	0.898	0.637	0.521	0.451	0.404	0.369	0.341	0.319	0.301	0.286
Biotransformation	5.6300	0.376	0.112	0.038	0.014	0.005	0.002	0.001	0.000	0.000	0.000

	Monitoring Well Locations (ft)										
	120	255	72								
Field Data from Site	0.314	0.059	0.208								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

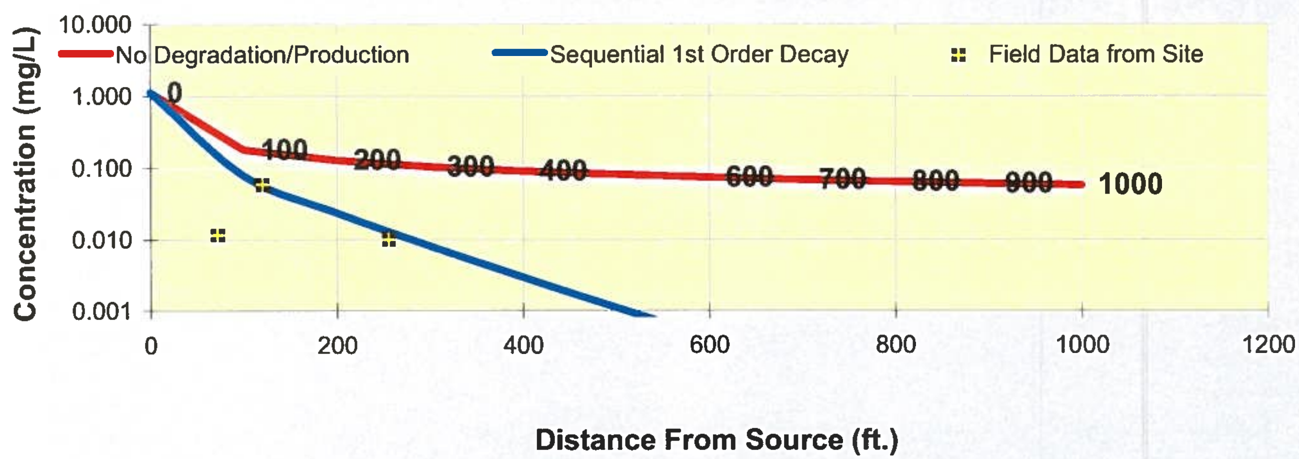
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

TCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	1.130	0.180	0.128	0.105	0.091	0.081	0.074	0.069	0.064	0.060	0.057
Biotransformation	1.1300	0.078	0.023	0.008	0.003	0.001	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.059	0.010	0.012								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time: *1,000.0 Years*

Log ⟺ Linear

Return to Input

To All

To Array

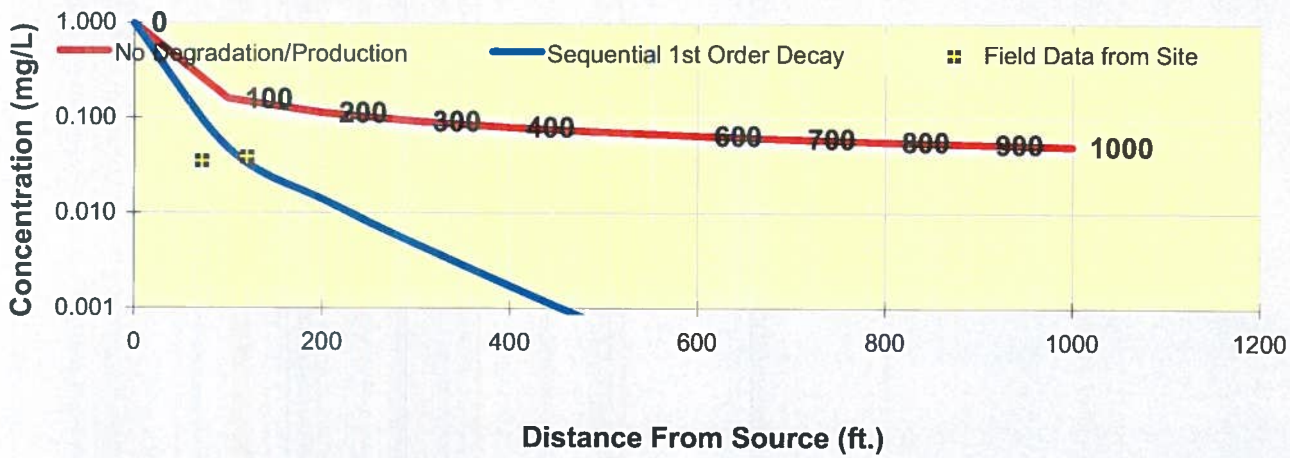
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

DCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.990	0.158	0.112	0.092	0.079	0.071	0.065	0.060	0.056	0.053	0.050
Biotransformation	0.9900	0.048	0.014	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.039	0.000	0.035								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

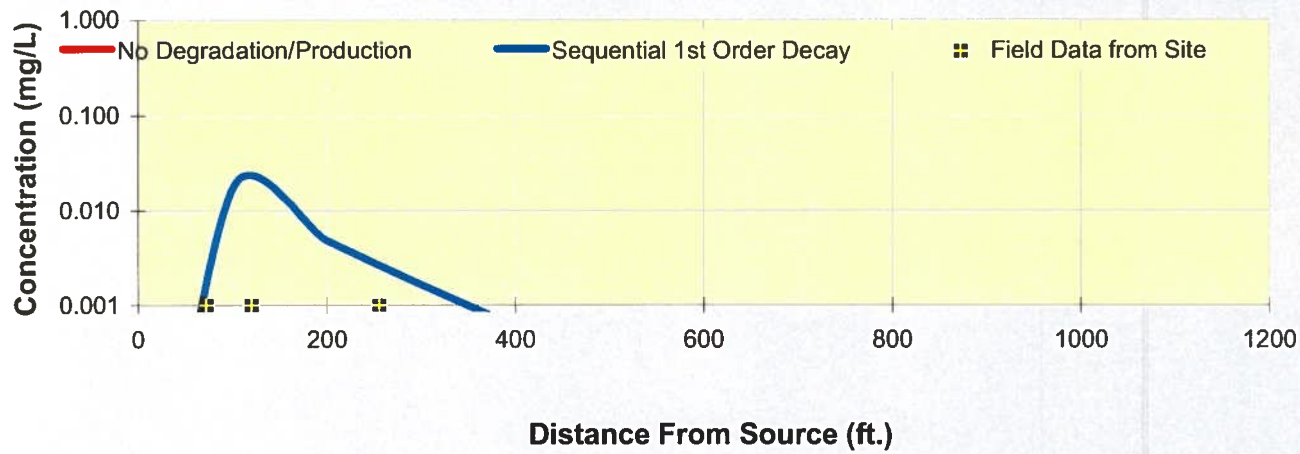
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

VC	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.017	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.001	0.001	0.001								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel '97

NW Pipe
Southeast Area
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
or 0.02 → 2. Calculate by filling in gray cells. Press Enter, then (C)
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	8.0	(ft/yr)
or			
Hydraulic Conductivity	K	1.6E-03	(cm/sec)
Hydraulic Gradient	i	0.001	(ft/ft)
Effective Porosity	n	0.2	(-)

2. DISPERSION

Alpha x*	25	(ft)
(Alpha y) / (Alpha x)*	2.5	(-)
(Alpha z) / (Alpha x)*	2.E-05	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.7	(kg/L)
FractionOrganicCarbon, foc	8.4E-4	(-)

Partition Coefficient	Koc		R	
PCE	426	(L/kg)	4.05	(-)
TCE	130	(L/kg)	1.93	(-)
DCE	125	(L/kg)	1.90	(-)
VC	30	(L/kg)	1.21	(-)
ETH	302	(L/kg)	3.16	(-)

Common R (used in model)* = 1.93

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

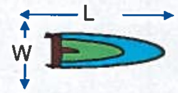
Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	0.100		0.79
TCE → DCE	0.480		0.74
DCE → VC	0.700		0.64
VC → ETH	1.390		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL

Simulation Time*	1000	(yr)
Modeled Area Width*	500	(ft)
Modeled Area Length*	1000	(ft)
Zone 1 Length*	1000	(ft)
Zone 2 Length*	0	(ft)



Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Continuous Single Planar

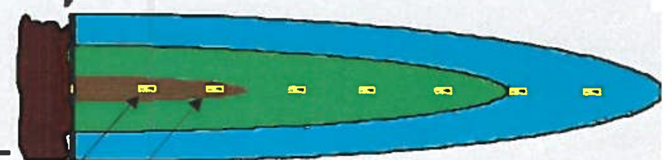
Source Options

Source Thickness in Sat. Zone* 14 (ft)

Width* (ft) Y1: 90

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	5.63	0
TCE	1.13	0
DCE	.99	0
VC	.0	0
ETH	0	0

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations



View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

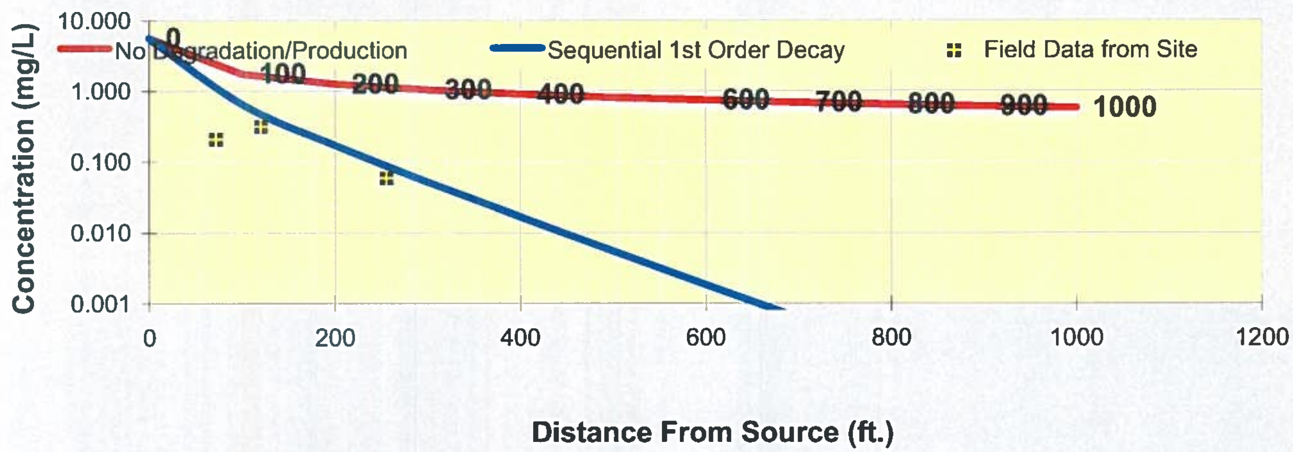
PCE Conc. (mg/L)	.314	.059	.208
TCE Conc. (mg/L)	.059	.01	.012
DCE Conc. (mg/L)	.039	.0	.035
VC Conc. (mg/L)	.001	.001	.001
ETH Conc. (mg/L)	0.0	.0	.0
Distance from Source (ft)	120	255	72
Date Data Collected			

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | Restore Formulas | RESET | SEE OUTPUT | Paste Example

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

PCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	5.630	1.760	1.261	1.035	0.898	0.804	0.735	0.681	0.637	0.601	0.570
Biotransformation	5.6300	0.649	0.171	0.052	0.017	0.005	0.002	0.001	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
	120	255	72								
Field Data from Site	0.314	0.059	0.208								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:
1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

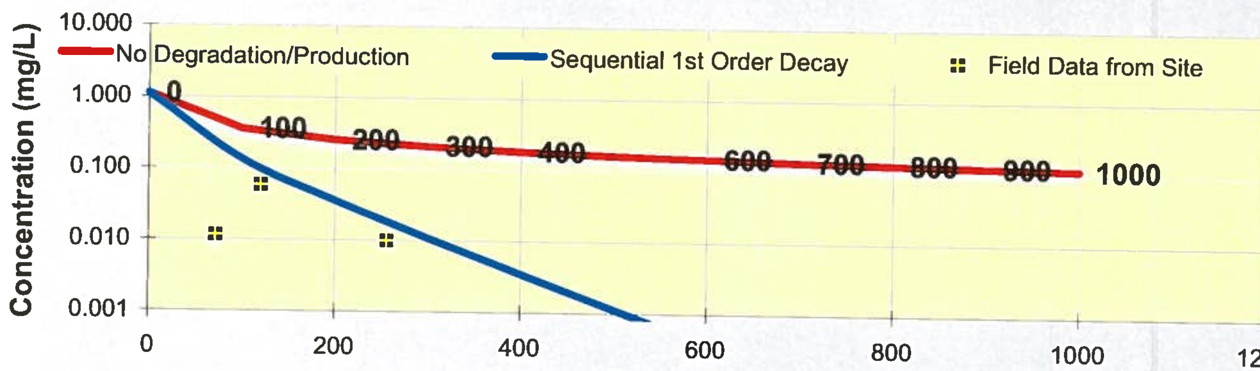
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

TCE — Distance from Source (ft)

TCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	1.130	0.353	0.253	0.208	0.180	0.161	0.147	0.137	0.128	0.121	0.114
Biotransformation	1.1300	0.135	0.036	0.011	0.003	0.001	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.059	0.010	0.012								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time: 1,000.0 Years

Log ⟺ Linear

Return to Input

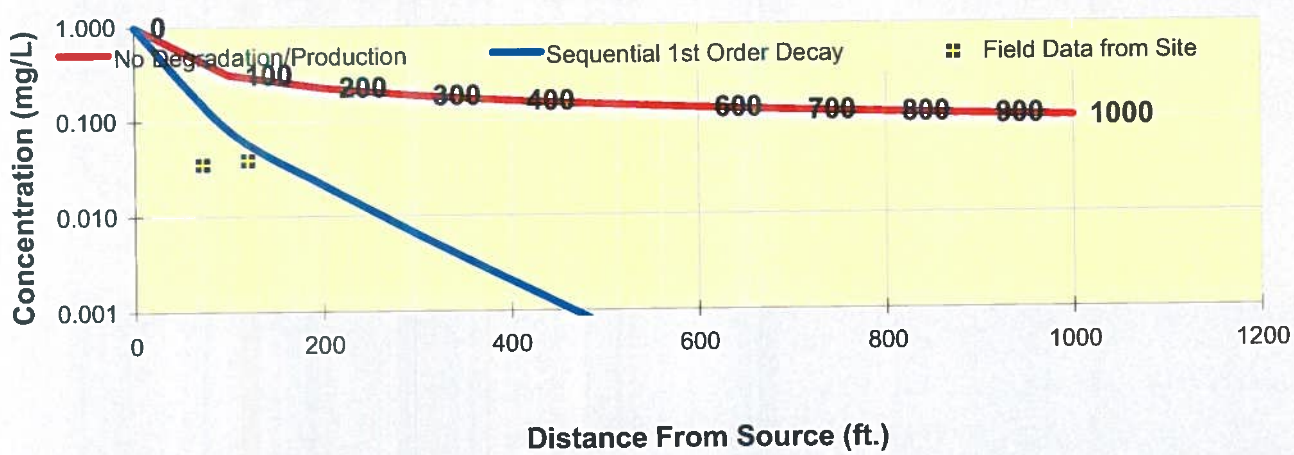
To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

DCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.990	0.310	0.222	0.182	0.158	0.141	0.129	0.120	0.112	0.106	0.100
Biotransformation	0.9900	0.081	0.021	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000

	Monitoring Well Locations (ft)										
	120	255	72								
Field Data from Site	0.039	0.000	0.035								



See PCE | See TCE | See DCE | See VC | See ETH

Prepare Animation

Time: 1,000.0 Years

Log ⟺ Linear

Return to Input | To All | To Array

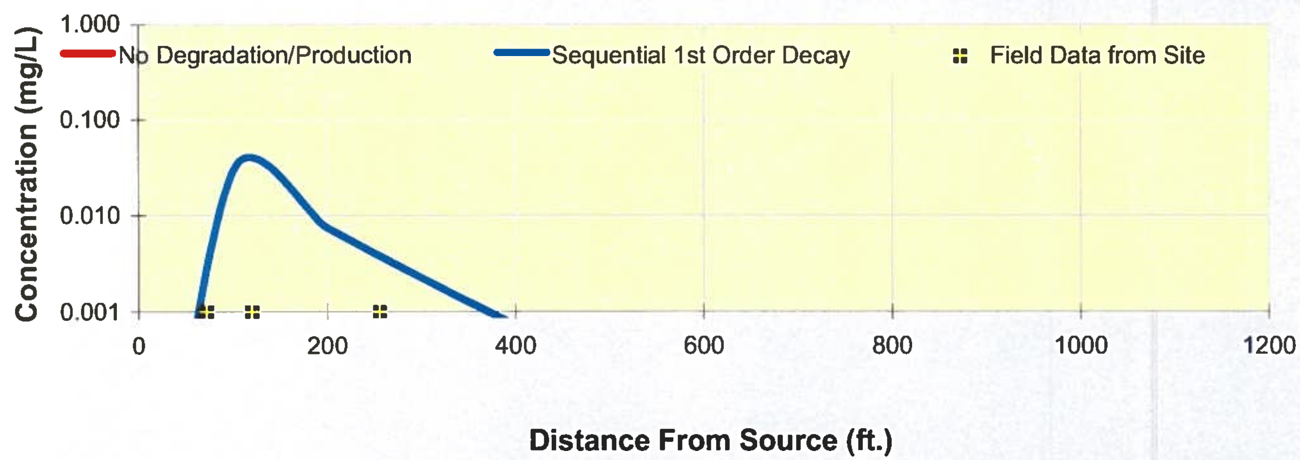
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

VC	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.028	0.007	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.001	0.001	0.001								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel '97

NW Pipe
Southeast Area
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
or ↗ 2. Calculate by filling in gray
0.02 cells. Press Enter, then (C)
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	8.0	(ft/yr)
or			
Hydraulic Conductivity	K	1.6E-03	(cm/sec)
Hydraulic Gradient	i	0.001	(ft/ft)
Effective Porosity	n	0.2	(-)

2. DISPERSION

Alpha x*	50	(ft)
(Alpha y) / (Alpha x)*	5	(-)
(Alpha z) / (Alpha x)*	2.E-05	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R
or

Soil Bulk Density, rho	1.7	(kg/L)		
FractionOrganicCarbon, foc	8.4E-4	(-)		
Partition Coefficient	Koc			
PCE	426	(L/kg)	4.05	(-)
TCE	130	(L/kg)	1.93	(-)
DCE	125	(L/kg)	1.90	(-)
VC	30	(L/kg)	1.21	(-)
ETH	302	(L/kg)	3.16	(-)
Common R (used in model)* =			1.93	

4. BIOTRANSFORMATION

-1st Order Decay Coefficient*

Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	0.070		0.79
TCE → DCE	0.050		0.74
DCE → VC	0.180		0.64
VC → ETH	0.120		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL

Simulation Time*	1000	(yr)
Modeled Area Width*	500	(ft)
Modeled Area Length*	1000	(ft)
Zone 1 Length*	1000	(ft)
Zone 2 Length*	0	(ft)

L W
Zone 2= L - Zone 1

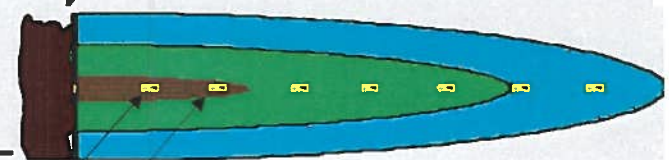
6. SOURCE DATA

TYPE: Continuous
Single Planar

Source Options

Source Thickness in Sat. Zone* 14 (ft)

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations



View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

	Y1	
Width* (ft)	90	
Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	5.63	0
TCE	1.13	0
DCE	.99	0
VC	.0	0
ETH	0	0

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.314	.059	.208
TCE Conc. (mg/L)	.059	.01	.012
DCE Conc. (mg/L)	.039	.0	.035
VC Conc. (mg/L)	.001	.001	.001
ETH Conc. (mg/L)	0.0	.0	.0
Distance from Source (ft)	120	255	72
Date Data Collected			

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | Restore Formulas | RESET | SEE OUTPUT | Paste Example

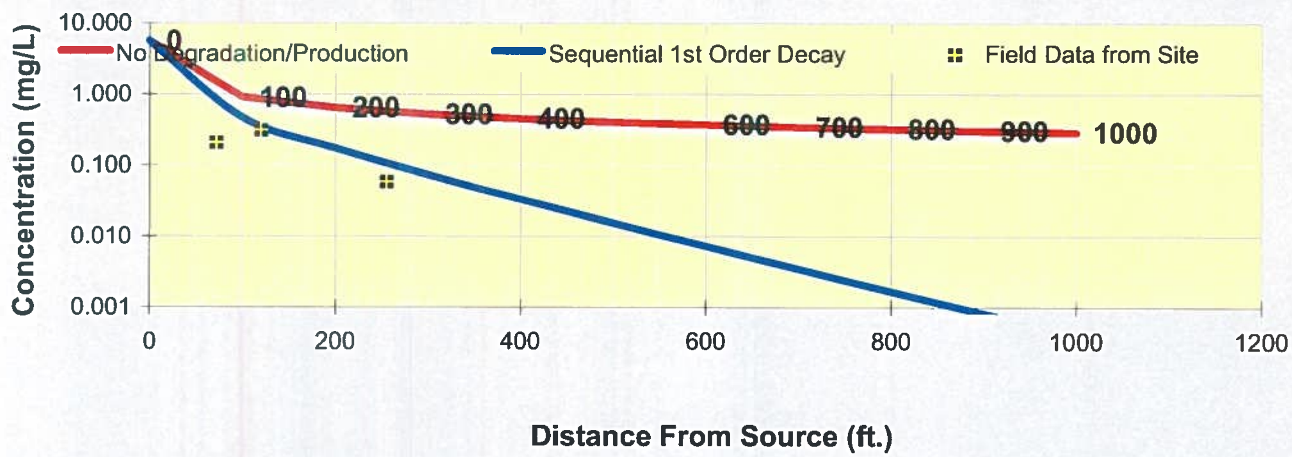
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

PCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	5.630	0.898	0.637	0.521	0.451	0.404	0.369	0.341	0.319	0.301	0.286
Biotransformation	5.6300	0.465	0.171	0.073	0.033	0.015	0.007	0.003	0.002	0.001	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.314	0.059	0.208								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

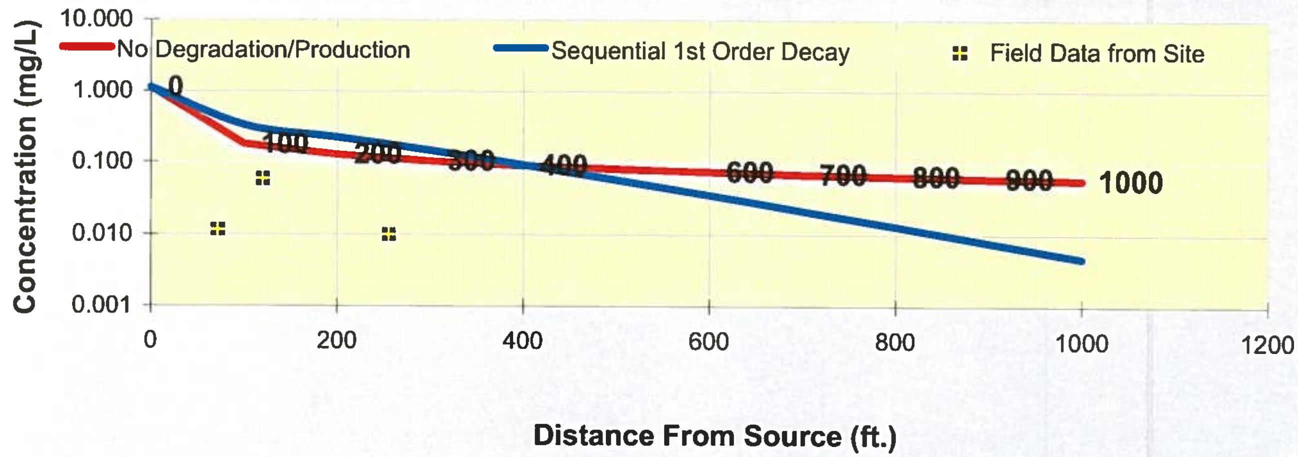
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

TCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	1.130	0.180	0.128	0.105	0.091	0.081	0.074	0.069	0.064	0.060	0.057
Biotransformation	1.1300	0.331	0.224	0.146	0.092	0.057	0.035	0.021	0.013	0.008	0.005

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.059	0.010	0.012								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

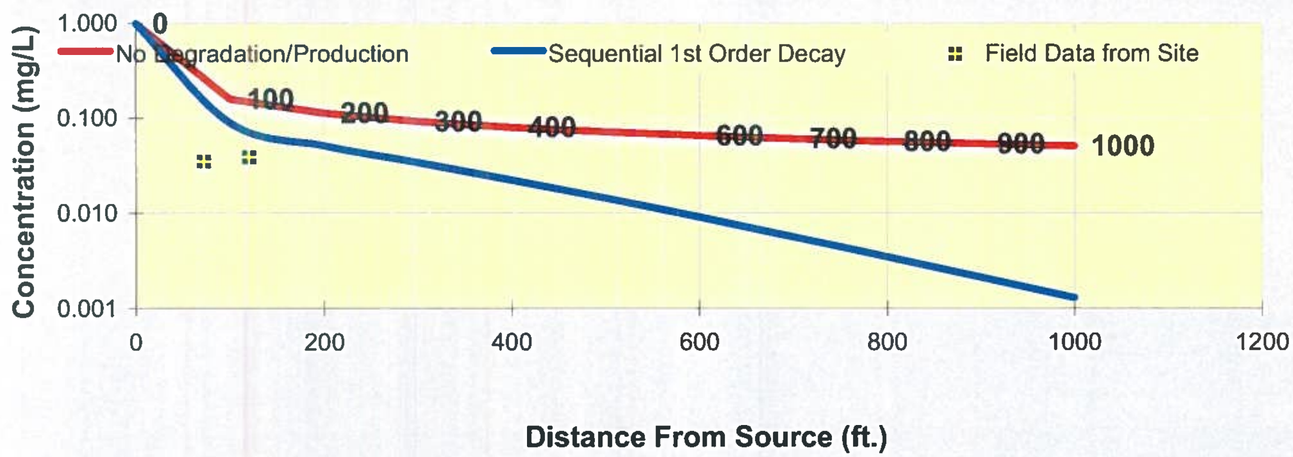
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

DCE

Distance from Source (ft)	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.990	0.158	0.112	0.092	0.079	0.071	0.065	0.060	0.056	0.053	0.050
Biotransformation	0.9900	0.089	0.050	0.033	0.022	0.014	0.009	0.006	0.003	0.002	0.001

Monitoring Well Locations (ft)

Monitoring Well Locations (ft)	120	255	72								
Field Data from Site	0.039	0.000	0.035								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

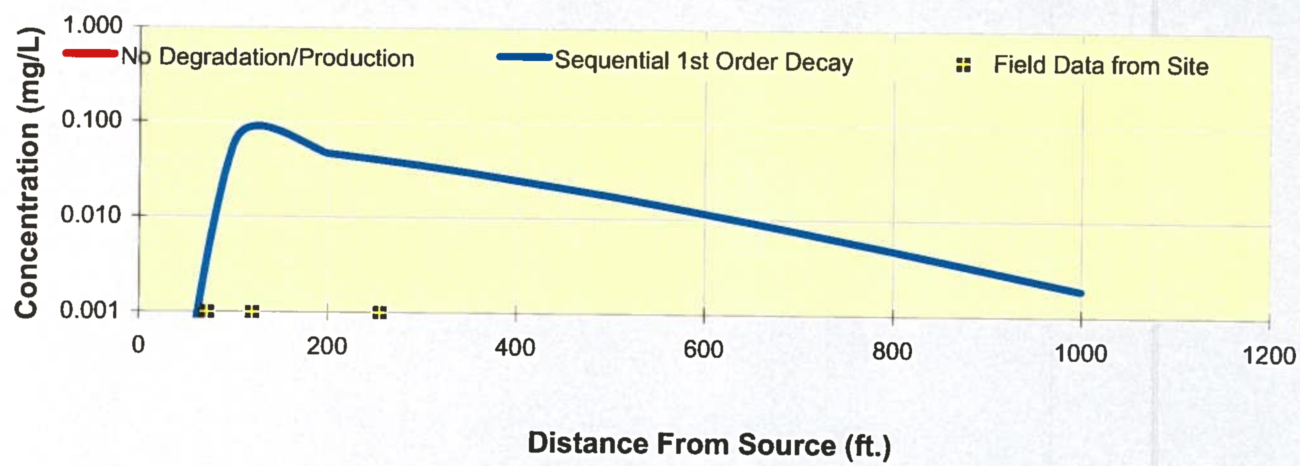
To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

VC

Distance from Source (ft)	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.058	0.047	0.035	0.025	0.017	0.012	0.008	0.005	0.003	0.002

Monitoring Well Locations (ft)	120	255	72								
Field Data from Site	0.001	0.001	0.001								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time: 1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel '97

Run Name
NW Pipe
Southeast Area

Data Input Instructions:

115 → 1. Enter value directly....or
↑ or ↗ 2. Calculate by filling in gray
0.02 cells. Press Enter, then (C)
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	8.0	(ft/yr)
or			
Hydraulic Conductivity	K	1.6E-03	(cm/sec)
Hydraulic Gradient	i	0.001	(ft/ft)
Effective Porosity	n	0.2	(-)

2. DISPERSION

Alpha x*	50	(ft)
(Alpha y) / (Alpha x)*	5	(-)
(Alpha z) / (Alpha x)*	2.E-05	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.7	(kg/L)
FractionOrganicCarbon, foc	8.4E-4	(-)

Partition Coefficient	Koc		R	
PCE	426	(L/kg)	4.05	(-)
TCE	130	(L/kg)	1.93	(-)
DCE	125	(L/kg)	1.90	(-)
VC	30	(L/kg)	1.21	(-)
ETH	302	(L/kg)	3.16	(-)

Common R (used in model)* = 1.93

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

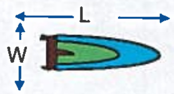
Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	0.100		0.79
TCE → DCE	0.480		0.74
DCE → VC	0.700		0.64
VC → ETH	1.390		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL

Simulation Time*	1000	(yr)
Modeled Area Width*	500	(ft)
Modeled Area Length*	1000	(ft)
Zone 1 Length*	1000	(ft)
Zone 2 Length*	0	(ft)



Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Continuous Single Planar

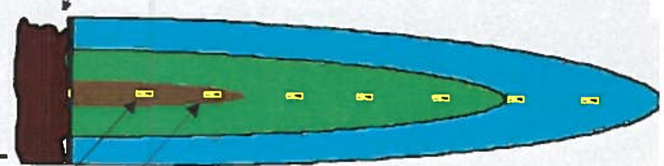
Source Options

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

Source Thickness in Sat. Zone* 14 (ft)

Width* (ft) Y1: 60

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	5.63	0
TCE	1.13	0
DCE	.99	0
VC	.0	0
ETH	0	0



View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.314	.059	.208								
TCE Conc. (mg/L)	.059	.01	.012								
DCE Conc. (mg/L)	.039	.0	.035								
VC Conc. (mg/L)	.001	.001	.001								
ETH Conc. (mg/L)	0.0	.0	.0								
Distance from Source (ft)	120	255	72								
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | SEE OUTPUT | Restore Formulas | Paste Example | RESET

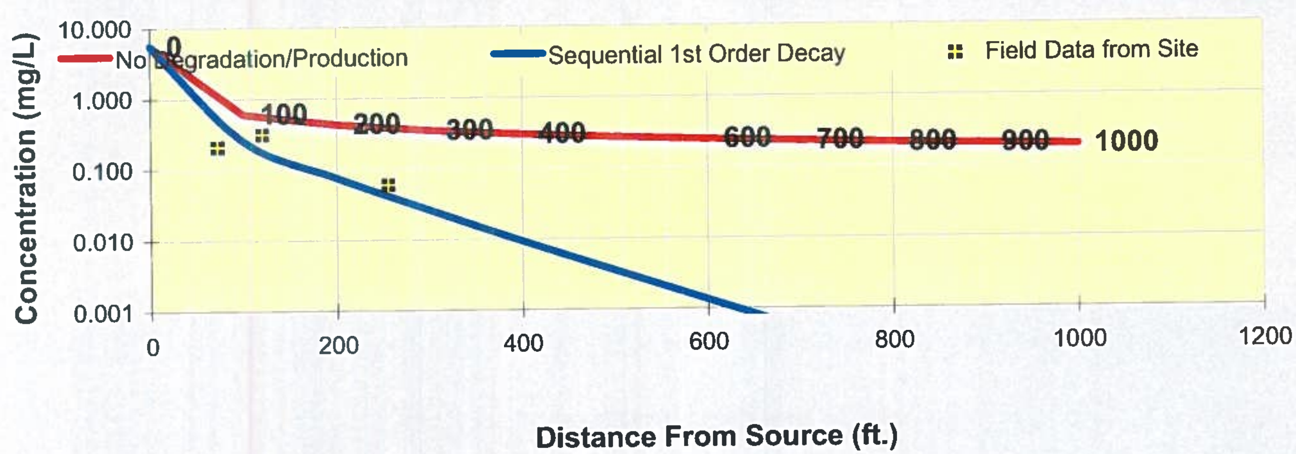
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

PCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	5.630	0.601	0.426	0.348	0.301	0.269	0.246	0.228	0.213	0.201	0.191
Biotransformation	5.6300	0.252	0.075	0.026	0.009	0.003	0.001	0.001	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.314	0.059	0.208								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time: 1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

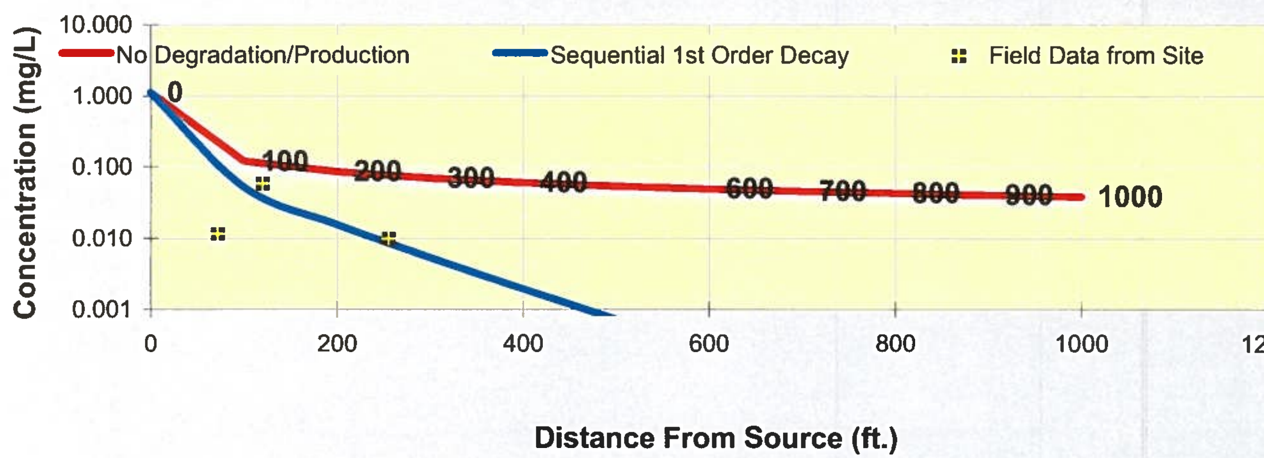
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

TCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	1.130	0.121	0.085	0.070	0.060	0.054	0.049	0.046	0.043	0.040	0.038
Biotransformation	1.1300	0.052	0.016	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.059	0.010	0.012								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

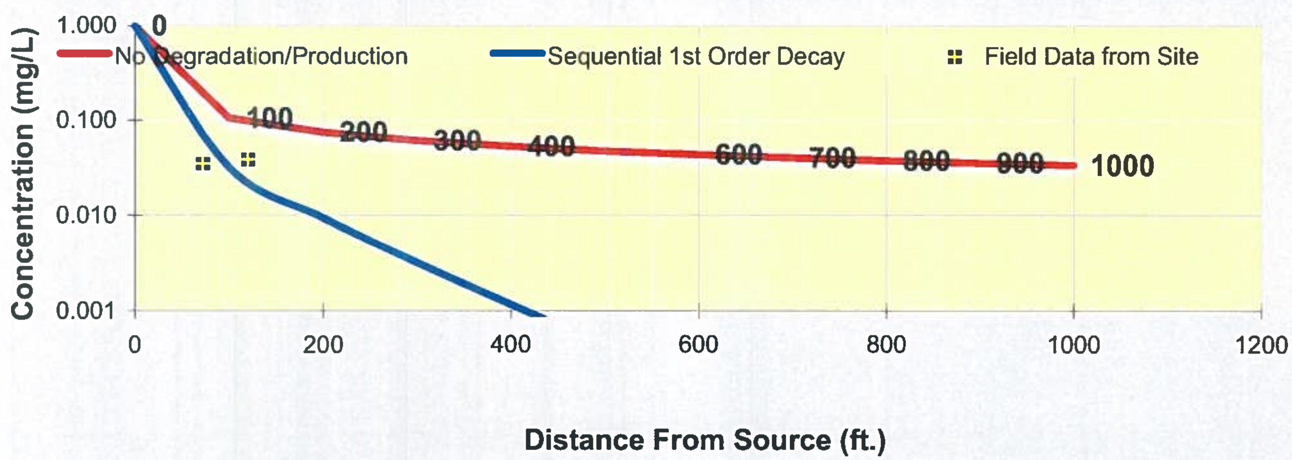
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

DCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.990	0.106	0.075	0.061	0.053	0.047	0.043	0.040	0.037	0.035	0.034
Biotransformation	0.9900	0.032	0.009	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.039	0.000	0.035								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

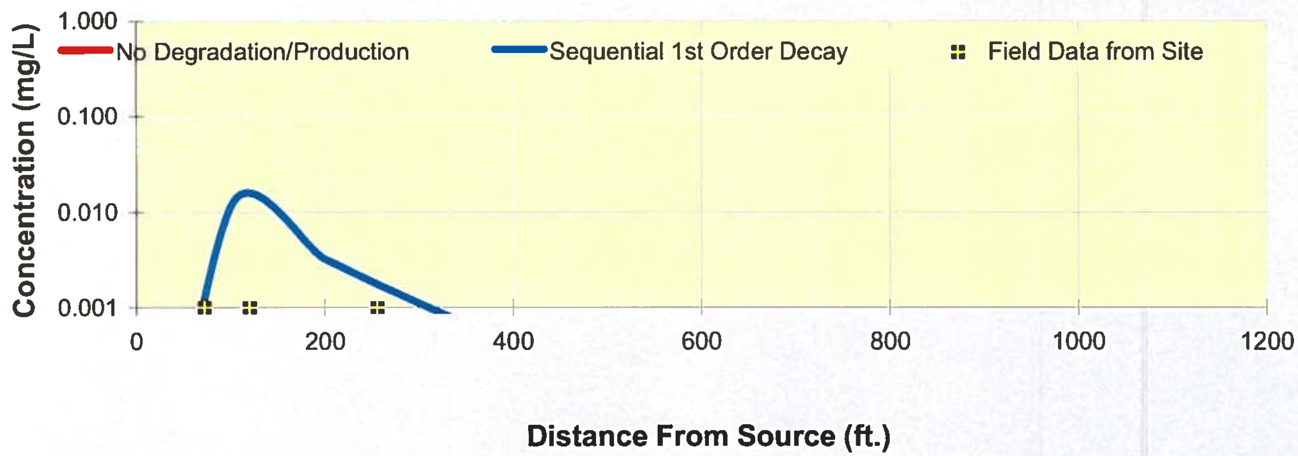
VC

Distance from Source (ft)

	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.011	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.001	0.001	0.001								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel '97

NW Pipe
Southeast Area
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
or
0.02 → 2. Calculate by filling in gray cells. Press Enter, then (C)
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	12.0	(ft/yr)
or			
Hydraulic Conductivity	K		(cm/sec)
Hydraulic Gradient	i		(ft/ft)
Effective Porosity	n	0.2	(-)

2. DISPERSION

Alpha x*	50	(ft)
(Alpha y) / (Alpha x)*	5	(-)
(Alpha z) / (Alpha x)*	2.E-05	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R
or
Soil Bulk Density, rho 1.7 (kg/L)
FractionOrganicCarbon, foc 8.4E-4 (-)

Partition Coefficient	Koc		R	
PCE	426	(L/kg)	4.05	(-)
TCE	130	(L/kg)	1.93	(-)
DCE	125	(L/kg)	1.90	(-)
VC	30	(L/kg)	1.21	(-)
ETH	302	(L/kg)	3.16	(-)
Common R (used in model)* =			1.93	

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

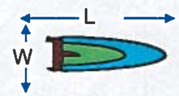
Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	0.100		0.79
TCE → DCE	0.480		0.74
DCE → VC	0.700		0.64
VC → ETH	1.390		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL

Simulation Time*	1000	(yr)
Modeled Area Width*	500	(ft)
Modeled Area Length*	1000	(ft)
Zone 1 Length*	1000	(ft)
Zone 2 Length*	0	(ft)



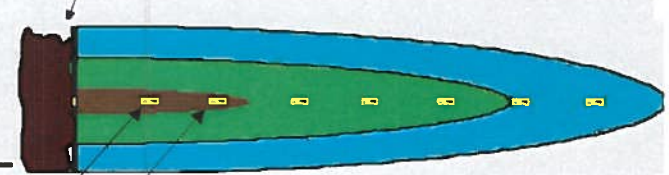
Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Continuous Single Planar

Source Options

Source Thickness in Sat. Zone* 14 (ft)

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations



View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

	Y1	
Width* (ft)	90	
Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	5.63	0
TCE	1.13	0
DCE	.99	0
VC	.0	0
ETH	0	0

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.314	.059	.208								
TCE Conc. (mg/L)	.059	.01	.012								
DCE Conc. (mg/L)	.039	.0	.035								
VC Conc. (mg/L)	.001	.001	.001								
ETH Conc. (mg/L)	0.0	.0	.0								
Distance from Source (ft)	120	255	72								
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:

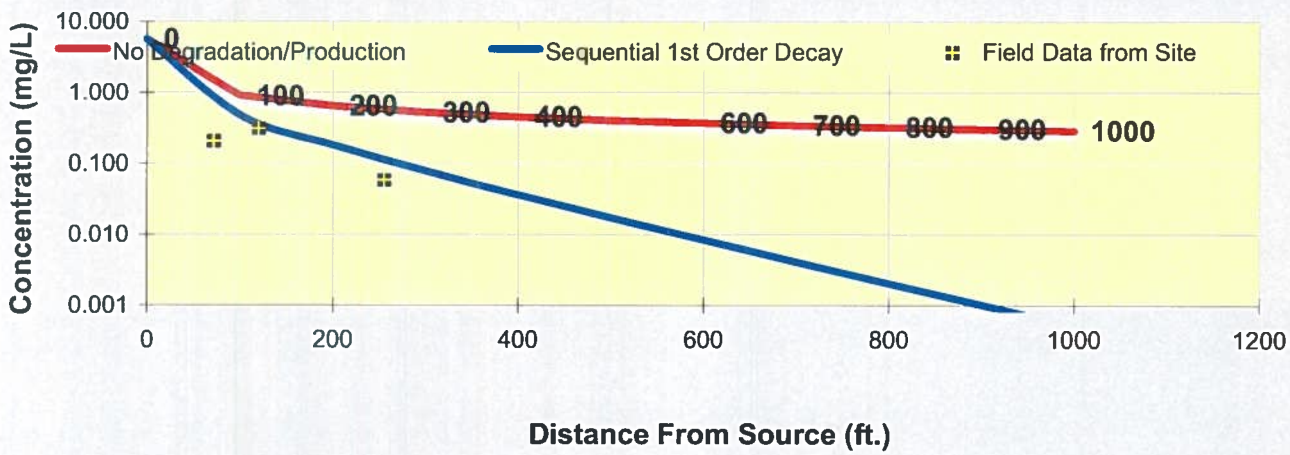
RUN CENTERLINE | RUN ARRAY | Help | Restore Formulas | RESET | SEE OUTPUT | Paste Example

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

PCE

	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	5.630	0.898	0.637	0.521	0.451	0.404	0.369	0.341	0.319	0.301	0.286
Biotransformation	5.6300	0.477	0.180	0.078	0.036	0.017	0.008	0.004	0.002	0.001	0.001

	Monitoring Well Locations (ft)										
	120	255	72								
Field Data from Site	0.314	0.059	0.208								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time: *1,000.0 Years*

Log ⟺ Linear

Return to Input

To All

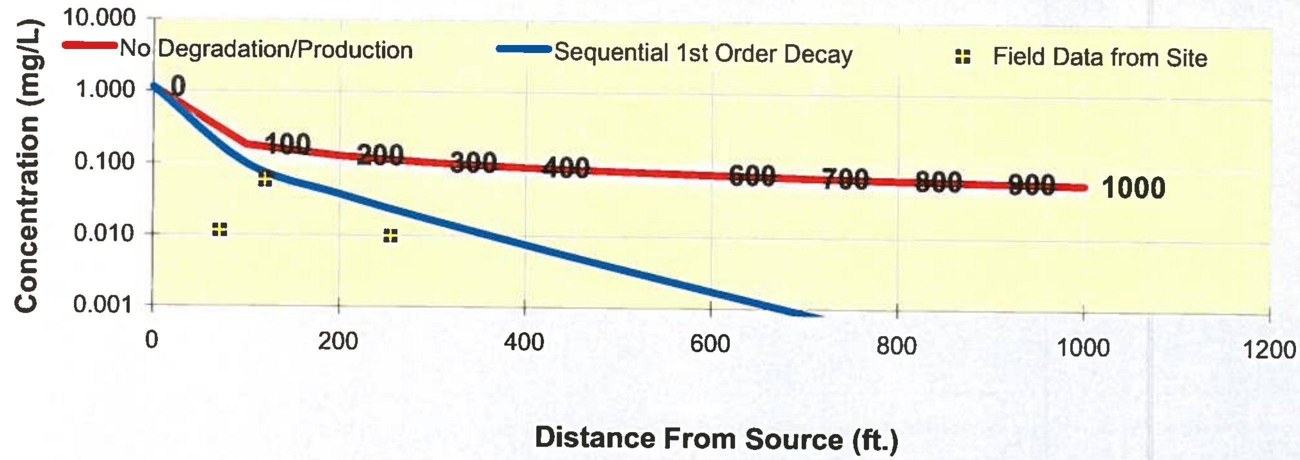
To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

TCE

Distance from Source (ft)	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	1.130	0.180	0.128	0.105	0.091	0.081	0.074	0.069	0.064	0.060	0.057
Biotransformation	1.1300	0.099	0.037	0.016	0.008	0.004	0.002	0.001	0.000	0.000	0.000

Monitoring Well Locations (ft)	120	255	72								
Field Data from Site	0.059	0.010	0.012								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

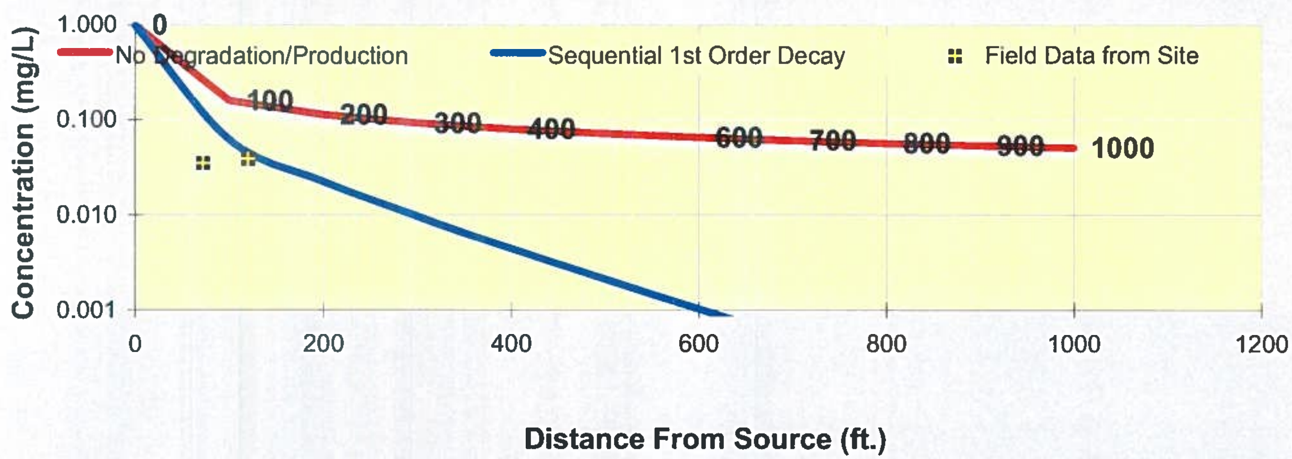
DCE

Distance from Source (ft)

DCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.990	0.158	0.112	0.092	0.079	0.071	0.065	0.060	0.056	0.053	0.050
Biotransformation	0.9900	0.062	0.022	0.010	0.004	0.002	0.001	0.001	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.039	0.000	0.035								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

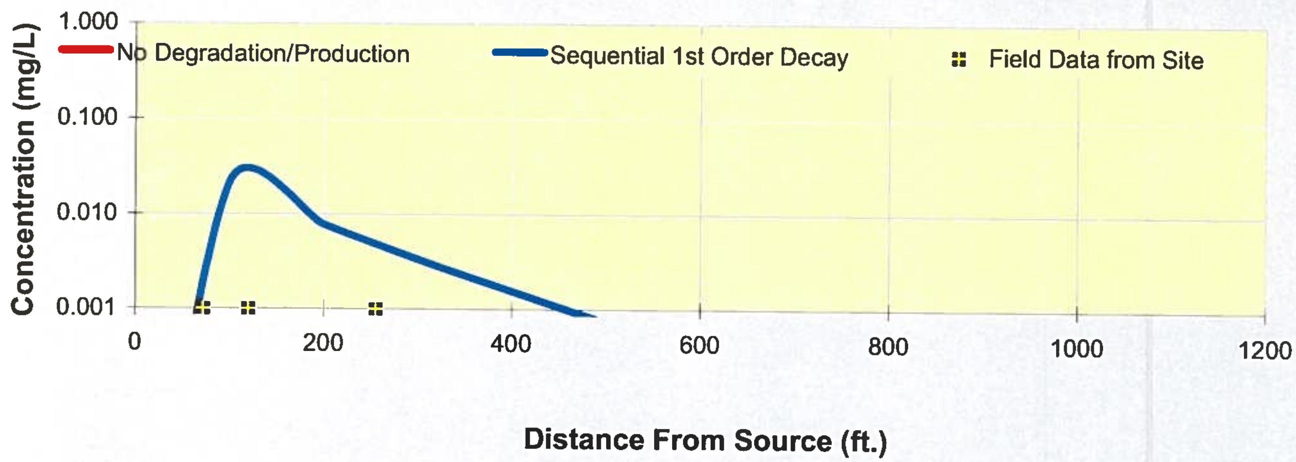
To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

VC

Distance from Source (ft)	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.021	0.008	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)	120	255	72								
Field Data from Site	0.001	0.001	0.001								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel '97

NW Pipe
Southeast Area
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
or 2. Calculate by filling in gray
0.02 cells. Press Enter, then C
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	8.0	(ft/yr)
or			
Hydraulic Conductivity	K	1.6E-03	(cm/sec)
Hydraulic Gradient	i	0.001	(ft/ft)
Effective Porosity	n	0.2	(-)

2. DISPERSION

Alpha x*	100	(ft)
(Alpha y) / (Alpha x)*	10	(-)
(Alpha z) / (Alpha x)*	2.E-05	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.7	(kg/L)		
FractionOrganicCarbon, foc	8.4E-4	(-)		
Partition Coefficient	Koc			
PCE	426	(L/kg)	4.05	(-)
TCE	130	(L/kg)	1.93	(-)
DCE	125	(L/kg)	1.90	(-)
VC	30	(L/kg)	1.21	(-)
ETH	302	(L/kg)	3.16	(-)
Common R (used in model)* =			1.93	

4. BIOTRANSFORMATION

-1st Order Decay Coefficient*

Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	0.100		0.79
TCE → DCE	0.480		0.74
DCE → VC	0.700		0.64
VC → ETH	1.390		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL

Simulation Time*	1000	(yr)
Modeled Area Width*	500	(ft)
Modeled Area Length*	1000	(ft)
Zone 1 Length*	1000	(ft)
Zone 2 Length*	0	(ft)

Zone 2= L - Zone 1

6. SOURCE DATA

TYPE: Continuous Single Planar

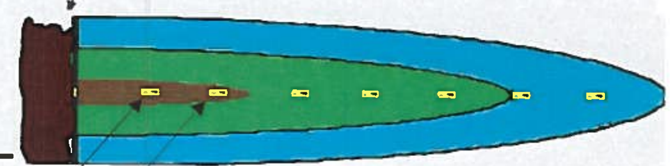
Source Options

Source Thickness in Sat. Zone* 14 (ft)

	Y1
Width* (ft)	90

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	5.63	0
TCE	1.13	0
DCE	.99	0
VC	.0	0
ETH	0	0

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations



View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.314	.059	.208
TCE Conc. (mg/L)	.059	.01	.012
DCE Conc. (mg/L)	.039	.0	.035
VC Conc. (mg/L)	.001	.001	.001
ETH Conc. (mg/L)	0.0	.0	.0
Distance from Source (ft)	120	255	72
Date Data Collected			

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | SEE OUTPUT | Restore Formulas | Paste Example | RESET

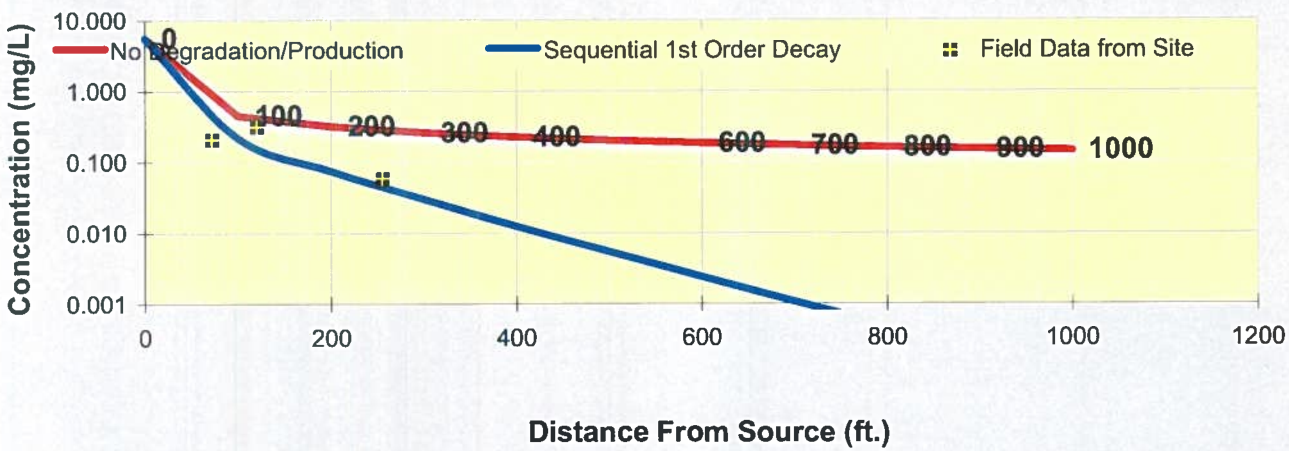
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

PCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	5.630	0.451	0.319	0.261	0.226	0.202	0.184	0.171	0.160	0.151	0.143
Biotransformation	5.6300	0.219	0.075	0.030	0.013	0.005	0.002	0.001	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.314	0.059	0.208								



See PCE | See TCE | See DCE | See VC | See ETH

Prepare Animation

Time: *1,000.0 Years*

Log ⟺ Linear

Return to Input | To All | To Array

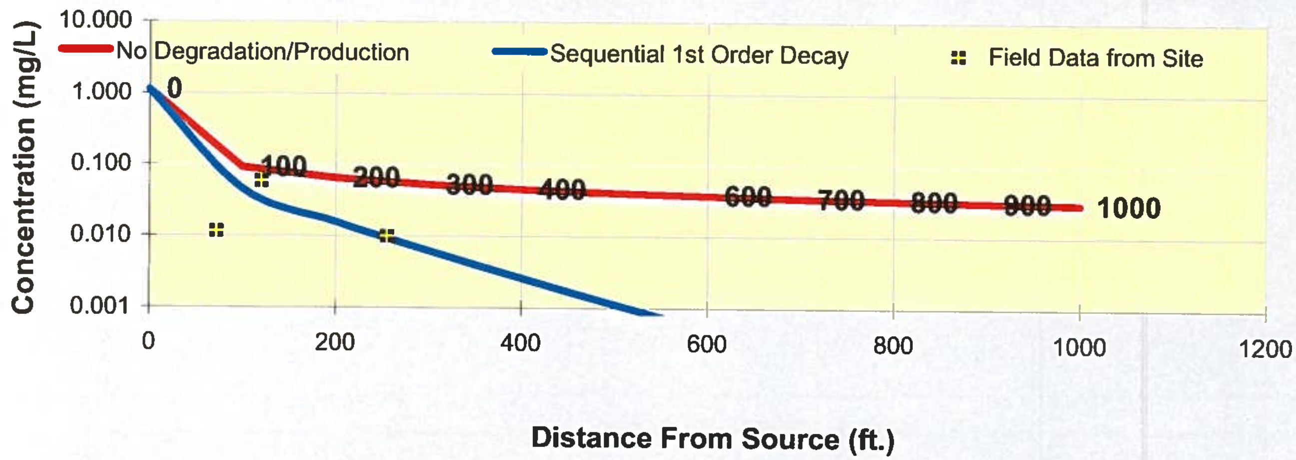
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

TCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	1.130	0.091	0.064	0.052	0.045	0.041	0.037	0.034	0.032	0.030	0.029
Biotransformation	1.1300	0.045	0.016	0.006	0.003	0.001	0.001	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.059	0.010	0.012								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time: *1,000.0 Years*

Log ⟺ Linear

Return to Input

To All

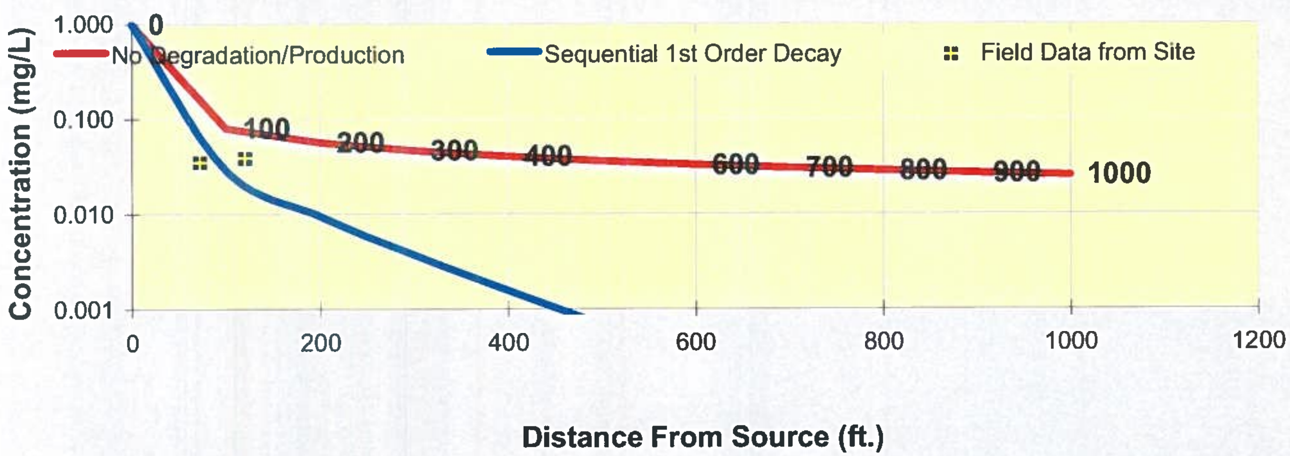
To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

DCE

	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.990	0.079	0.056	0.046	0.040	0.036	0.032	0.030	0.028	0.026	0.025
Biotransformation	0.9900	0.029	0.009	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000

	Monitoring Well Locations (ft)										
	120	255	72								
Field Data from Site	0.039	0.000	0.035								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

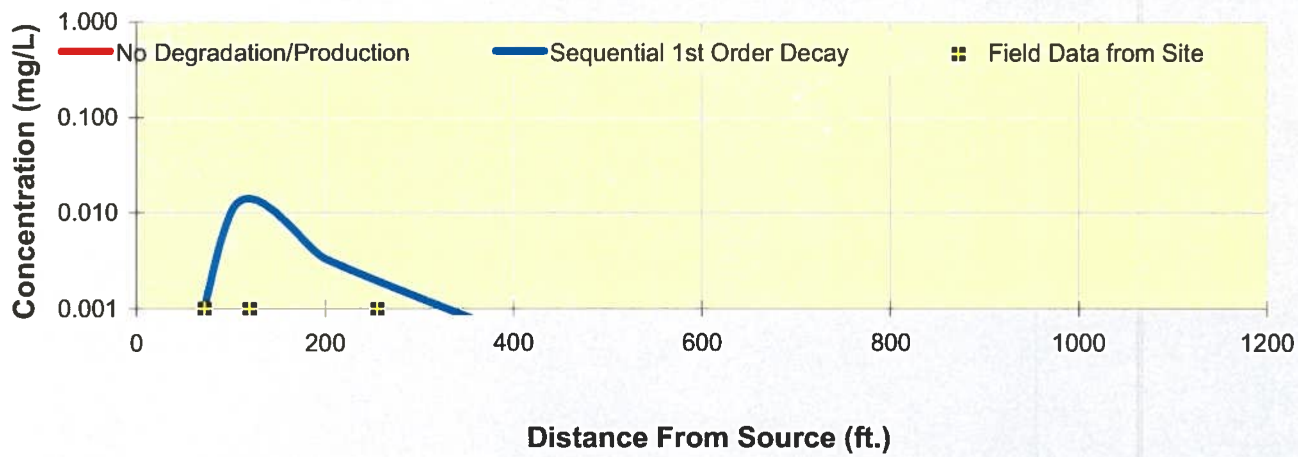
To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

VC	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.010	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000

	Monitoring Well Locations (ft)										
	120	255	72								
Field Data from Site	0.001	0.001	0.001								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel '97

Run Name
NW Pipe
Southeast Area

Data Input Instructions:

115 → 1. Enter value directly....or
or 2. Calculate by filling in gray
0.02 cells. Press Enter, then C
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	8.0	(ft/yr)
or			
Hydraulic Conductivity	K	1.6E-03	(cm/sec)
Hydraulic Gradient	i	0.001	(ft/ft)
Effective Porosity	n	0.2	(-)

2. DISPERSION

Alpha x*	50	(ft)	Calc. Alpha x
(Alpha y) / (Alpha x)*	5	(-)	
(Alpha z) / (Alpha x)*	2.E-05	(-)	

3. ADSORPTION

Retardation Factor* → R
or

Soil Bulk Density, rho	1.7	(kg/L)		
FractionOrganicCarbon, foc	8.4E-4	(-)		
Partition Coefficient	Koc			
PCE	426	(L/kg)	4.05	(-)
TCE	130	(L/kg)	1.93	(-)
DCE	125	(L/kg)	1.90	(-)
VC	30	(L/kg)	1.21	(-)
ETH	302	(L/kg)	3.16	(-)
Common R (used in model)* =			1.93	

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

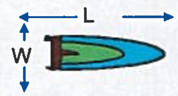
Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	0.560		0.79
TCE → DCE	0.480		0.74
DCE → VC	1.740		0.64
VC → ETH	1.390		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL

Simulation Time*	1000	(yr)
Modeled Area Width*	500	(ft)
Modeled Area Length*	1000	(ft)
Zone 1 Length*	1000	(ft)
Zone 2 Length*	0	(ft)



Zone 2= L - Zone 1

6. SOURCE DATA TYPE: Continuous Single Planar

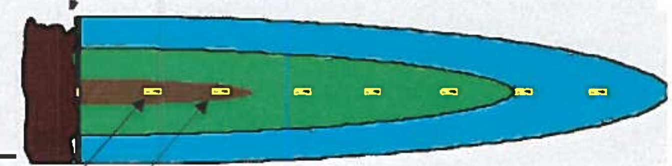
Source Options

Source Thickness in Sat. Zone* 14 (ft)

Y1
Width* (ft) 90

Conc. (mg/L)*	C1	k_s^* (1/yr)
PCE	5.63	0
TCE	1.13	0
DCE	.99	0
VC	.0	0
ETH	0	0

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations



View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

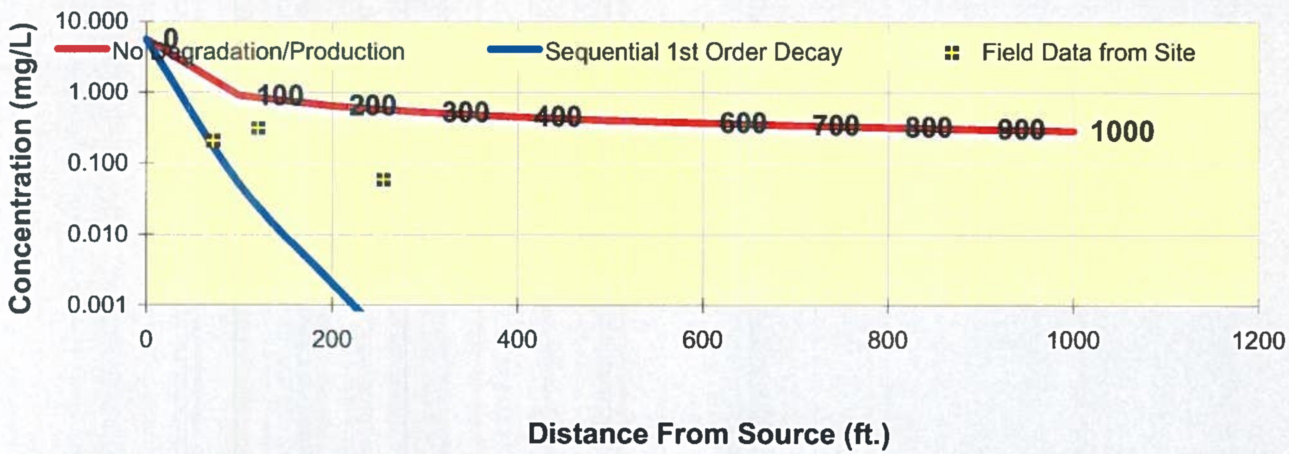
PCE Conc. (mg/L)	.314	.059	.208								
TCE Conc. (mg/L)	.059	.01	.012								
DCE Conc. (mg/L)	.039	.0	.035								
VC Conc. (mg/L)	.001	.001	.001								
ETH Conc. (mg/L)	0.0	.0	.0								
Distance from Source (ft)	120	255	72								
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | Restore Formulas | RESET | SEE OUTPUT | Paste Example

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

PCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	5.630	0.898	0.637	0.521	0.451	0.404	0.369	0.341	0.319	0.301	0.286
Biotransformation	5.6300	0.051	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Monitoring Well Locations (ft)	120	255	72								
Field Data from Site	0.314	0.059	0.208								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

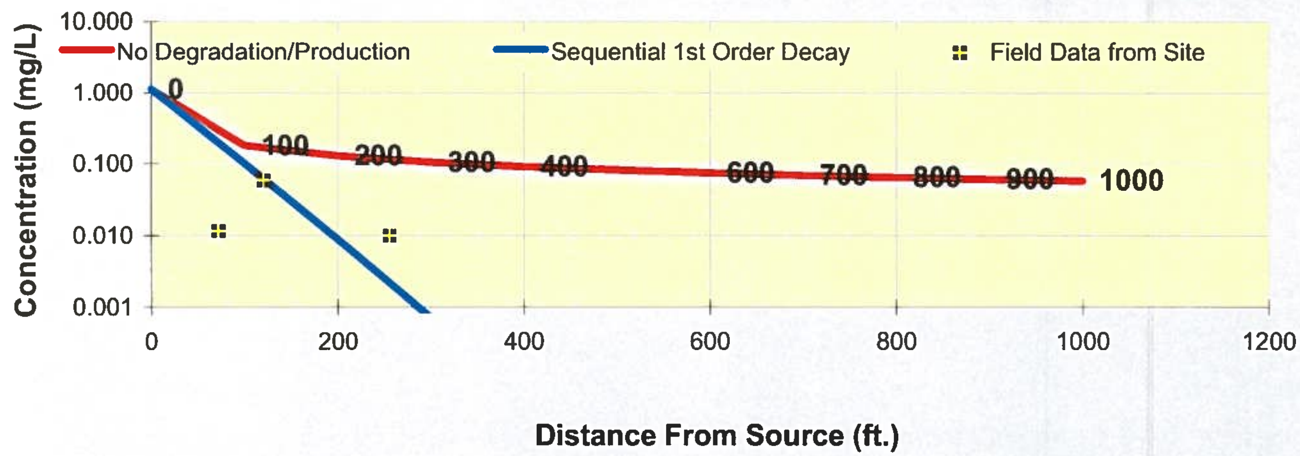
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

TCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	1.130	0.180	0.128	0.105	0.091	0.081	0.074	0.069	0.064	0.060	0.057
Biotransformation	1.1300	0.100	0.009	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.059	0.010	0.012								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

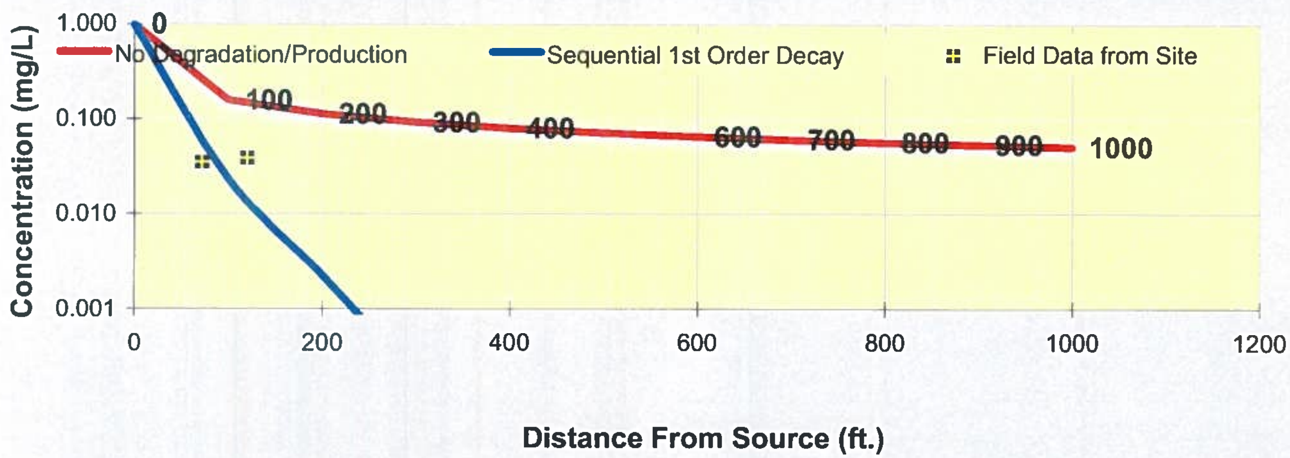
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

DCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.990	0.158	0.112	0.092	0.079	0.071	0.065	0.060	0.056	0.053	0.050
Biotransformation	0.9900	0.023	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.039	0.000	0.035								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

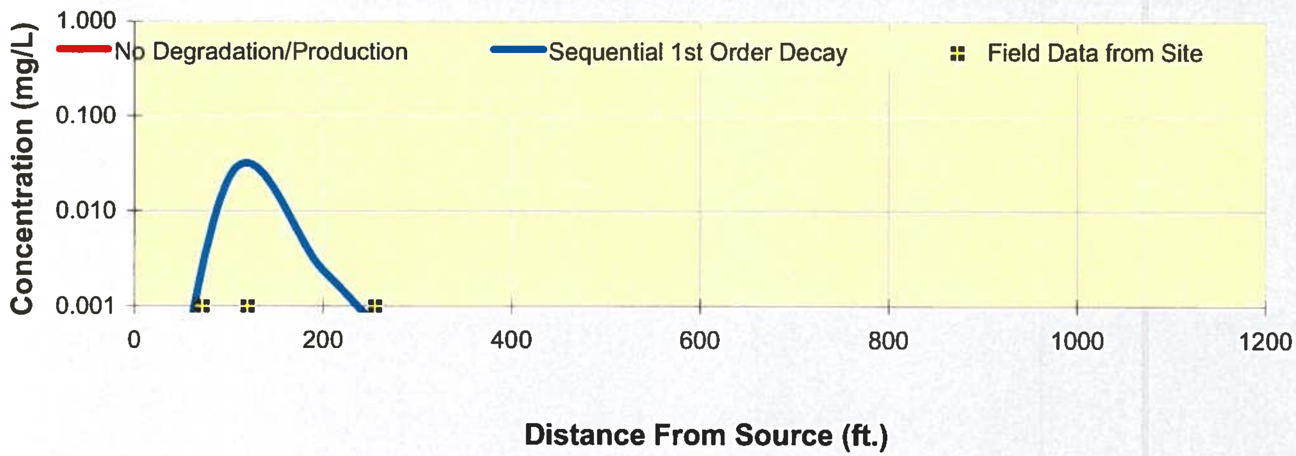
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

VC	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.022	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.001	0.001	0.001								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel '97

NW Pipe
Southeast Area
Run Name

Data Input Instructions:

115 → 1. Enter value directly....or
or 2. Calculate by filling in gray
0.02 cells. Press Enter, then C
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	8.0	(ft/yr)
or			
Hydraulic Conductivity	K	1.6E-03	(cm/sec)
Hydraulic Gradient	i	0.001	(ft/ft)
Effective Porosity	n	0.2	(-)

2. DISPERSION

Alpha x*	50	(ft)
(Alpha y) / (Alpha x)*	5	(-)
(Alpha z) / (Alpha x)*	2.E-05	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.7	(kg/L)		
FractionOrganicCarbon, foc	8.4E-4	(-)		
Partition Coefficient	Koc		R	
PCE	426	(L/kg)	4.05	(-)
TCE	130	(L/kg)	1.93	(-)
DCE	125	(L/kg)	1.90	(-)
VC	30	(L/kg)	1.21	(-)
ETH	302	(L/kg)	3.16	(-)

Common R (used in model)* = 1.93

4. BIOTRANSFORMATION -1st Order Decay Coefficient*

Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	0.100		0.79
TCE → DCE	0.480		0.74
DCE → VC	0.700		0.64
VC → ETH	1.390		0.45

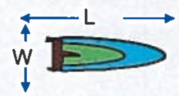
Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL

Simulation Time*	1000	(yr)
Modeled Area Width*	500	(ft)
Modeled Area Length*	1000	(ft)
Zone 1 Length*	1000	(ft)
Zone 2 Length*	0	(ft)

Zone 2= L - Zone 1



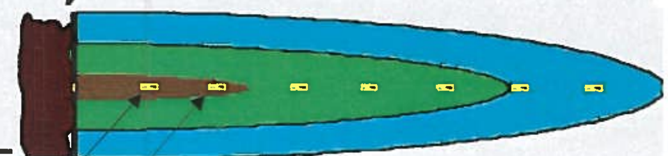
6. SOURCE DATA TYPE: Continuous Single Planar

Source Options

Source Thickness in Sat. Zone* 14 (ft)

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations

	Y1	
Width* (ft)	120	
Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	5.63	0
TCE	1.13	0
DCE	.99	0
VC	.0	0
ETH	0	0



View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

PCE Conc. (mg/L)	.314	.059	.208								
TCE Conc. (mg/L)	.059	.01	.012								
DCE Conc. (mg/L)	.039	.0	.035								
VC Conc. (mg/L)	.001	.001	.001								
ETH Conc. (mg/L)	0.0	.0	.0								
Distance from Source (ft)	120	255	72								
Date Data Collected											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | Restore Formulas | RESET | SEE OUTPUT | Paste Example

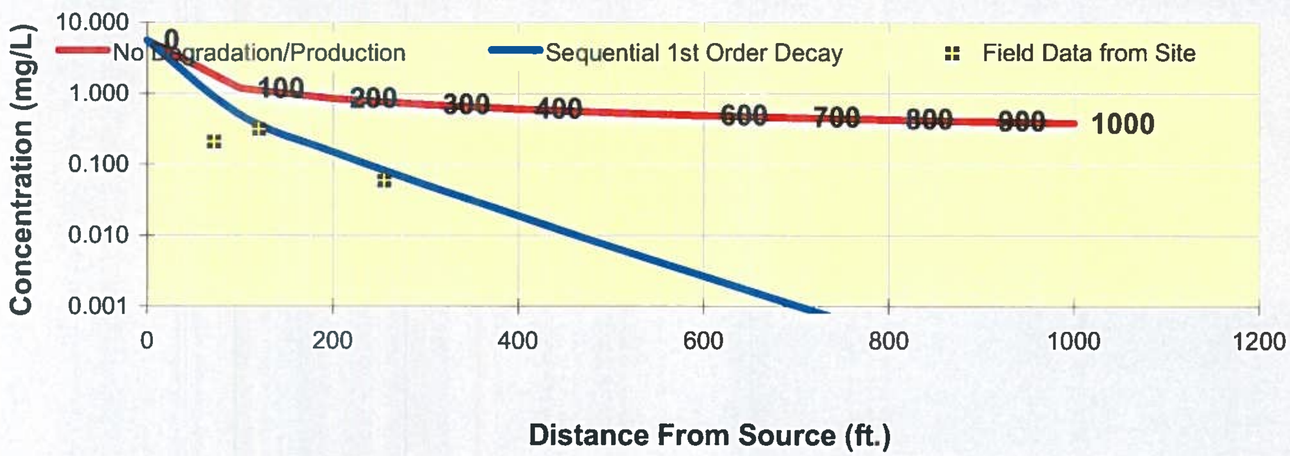
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

PCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	5.630	1.191	0.847	0.693	0.601	0.538	0.491	0.455	0.426	0.401	0.381
Biotransformation	5.6300	0.499	0.149	0.051	0.019	0.007	0.003	0.001	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.314	0.059	0.208								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

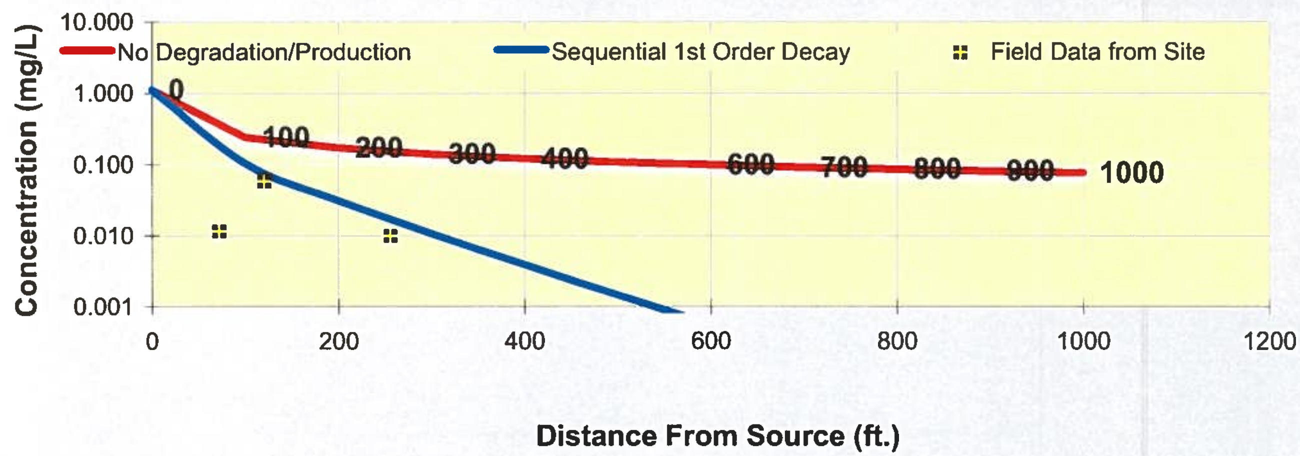
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

TCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	1.130	0.239	0.170	0.139	0.121	0.108	0.099	0.091	0.085	0.081	0.076
Biotransformation	1.1300	0.104	0.031	0.011	0.004	0.001	0.001	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.059	0.010	0.012								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

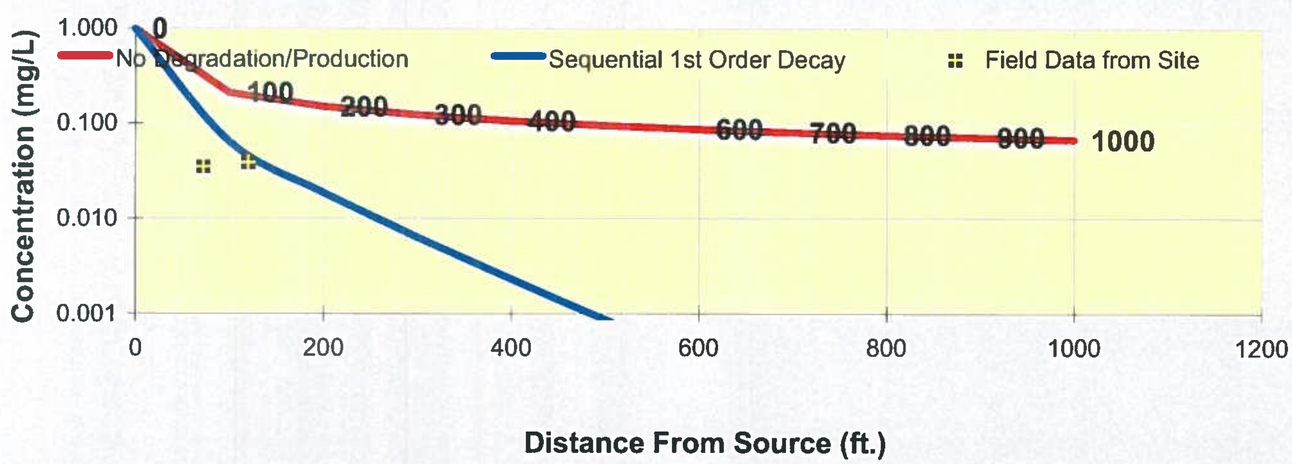
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

DCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.990	0.209	0.149	0.122	0.106	0.095	0.086	0.080	0.075	0.071	0.067
Biotransformation	0.9900	0.063	0.018	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.039	0.000	0.035								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time: 1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

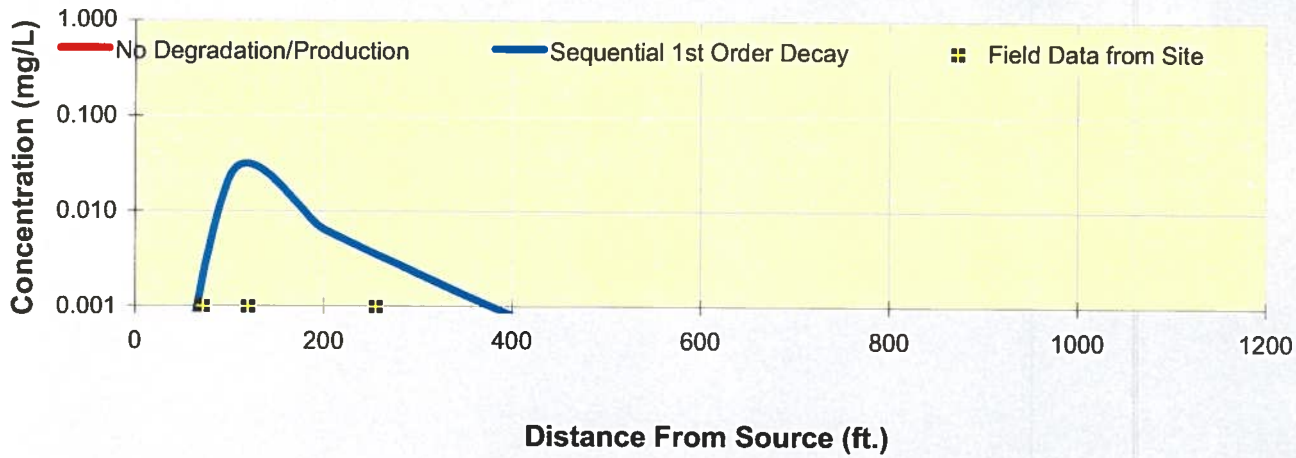
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

VC	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.022	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.001	0.001	0.001								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

To All

To Array

BIOCHLOR Natural Attenuation Decision Support System

Version 2.2
Excel '97

Run Name
NW Pipe
Southeast Area

Data Input Instructions:

115 → 1. Enter value directly....or
or 0.02 → 2. Calculate by filling in gray cells. Press Enter, then C
(To restore formulas, hit "Restore Formulas" button)
Variable* → Data used directly in model.

Test if Biotransformation is Occurring → Natural Attenuation Screening Protocol

TYPE OF CHLORINATED SOLVENT: Ethenes ● Ethanes ○

1. ADVECTION

Seepage Velocity*	Vs	12.0	(ft/yr)
or			
Hydraulic Conductivity	K		(cm/sec)
Hydraulic Gradient	i		(ft/ft)
Effective Porosity	n	0.2	(-)

2. DISPERSION

Alpha x*	50	(ft)
(Alpha y) / (Alpha x)*	5	(-)
(Alpha z) / (Alpha x)*	2.E-05	(-)

Calc. Alpha x

3. ADSORPTION

Retardation Factor* → R

or

Soil Bulk Density, rho	1.7	(kg/L)		
FractionOrganicCarbon, foc	8.4E-4	(-)		
Partition Coefficient	Koc		R	
PCE	426	(L/kg)	4.05	(-)
TCE	130	(L/kg)	1.93	(-)
DCE	125	(L/kg)	1.90	(-)
VC	30	(L/kg)	1.21	(-)
ETH	302	(L/kg)	3.16	(-)
Common R (used in model)* =			1.93	

4. BIOTRANSFORMATION

-1st Order Decay Coefficient*

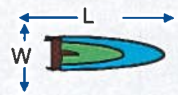
Zone 1	λ (1/yr)	half-life (yrs)	Yield
PCE → TCE	0.100		0.79
TCE → DCE	0.480		0.74
DCE → VC	0.700		0.64
VC → ETH	1.390		0.45

Zone 2	λ (1/yr)	half-life (yrs)
PCE → TCE	0.000	
TCE → DCE	0.000	
DCE → VC	0.000	
VC → ETH	0.000	

λ HELP

5. GENERAL

Simulation Time*	1000	(yr)
Modeled Area Width*	500	(ft)
Modeled Area Length*	1000	(ft)
Zone 1 Length*	1000	(ft)
Zone 2 Length*	0	(ft)



Zone 2= L - Zone 1

6. SOURCE DATA

TYPE: Continuous Single Planar

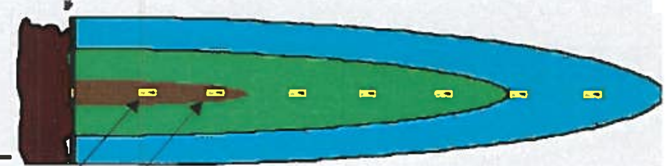
Source Options

Source Thickness in Sat. Zone* 14 (ft)

	Y1
Width* (ft)	90

Conc. (mg/L)*	C1	k_s* (1/yr)
PCE	5.63	0
TCE	1.13	0
DCE	.99	0
VC	.0	0
ETH	0	0

Vertical Plane Source: Determine Source Well Location and Input Solvent Concentrations



View of Plume Looking Down

Observed Centerline Conc. at Monitoring Wells

7. FIELD DATA FOR COMPARISON

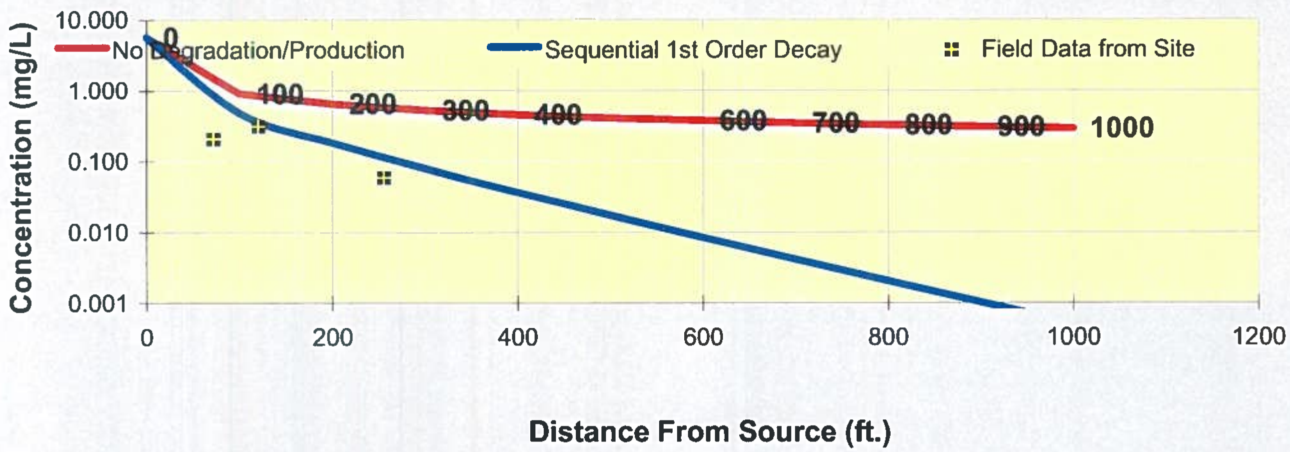
PCE Conc. (mg/L)	.314	.059	.208									
TCE Conc. (mg/L)	.059	.01	.012									
DCE Conc. (mg/L)	.039	.0	.035									
VC Conc. (mg/L)	.001	.001	.001									
ETH Conc. (mg/L)	0.0	.0	.0									
Distance from Source (ft)	120	255	72									
Date Data Collected												

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE | RUN ARRAY | Help | Restore Formulas | RESET | SEE OUTPUT | Paste Example

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

PCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	5.630	0.898	0.637	0.521	0.451	0.404	0.369	0.341	0.319	0.301	0.286
Biotransformation	5.6300	0.477	0.180	0.078	0.036	0.017	0.008	0.004	0.002	0.001	0.001
	Monitoring Well Locations (ft)										
	120	255	72								
Field Data from Site	0.314	0.059	0.208								



Prepare Animation

Time:
1,000.0 Years
Log ⟺ Linear

Return to Input

To All

To Array

See PCE

See TCE

See DCE

See VC

See ETH

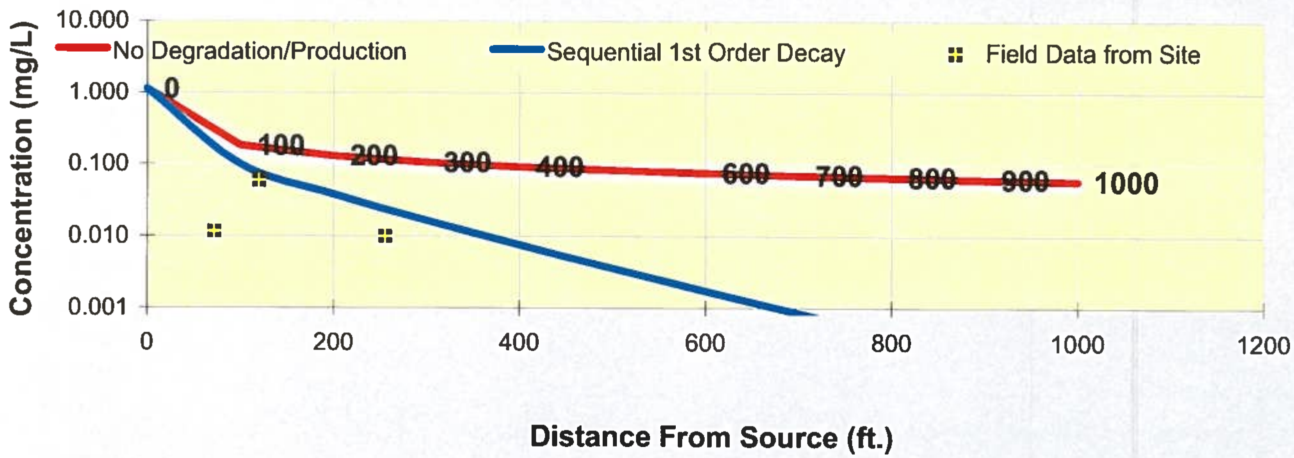
DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

Distance from Source (ft)

TCE	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	1.130	0.180	0.128	0.105	0.091	0.081	0.074	0.069	0.064	0.060	0.057
Biotransformation	1.1300	0.099	0.037	0.016	0.008	0.004	0.002	0.001	0.000	0.000	0.000

Monitoring Well Locations (ft)

	120	255	72								
Field Data from Site	0.059	0.010	0.012								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

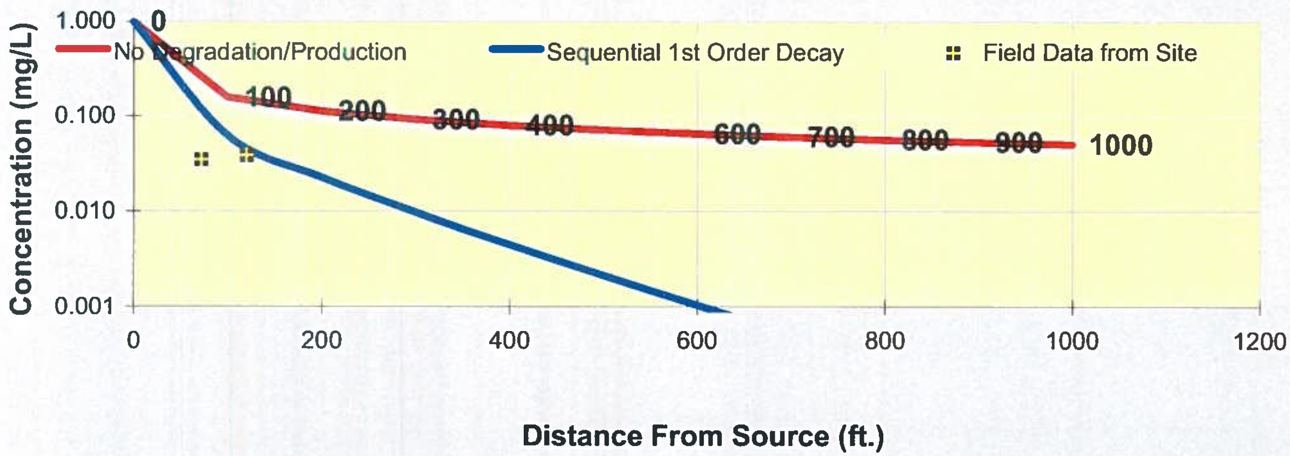
To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

DCE	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.990	0.158	0.112	0.092	0.079	0.071	0.065	0.060	0.056	0.053	0.050
Biotransformation	0.9900	0.062	0.022	0.010	0.004	0.002	0.001	0.001	0.000	0.000	0.000

	Monitoring Well Locations (ft)										
	120	255	72								
Field Data from Site	0.039	0.000	0.035								



See PCE

See TCE

See DCE

See VC

See ETH

Prepare Animation

Time:

1,000.0 Years

Log ⟺ Linear

Return to Input

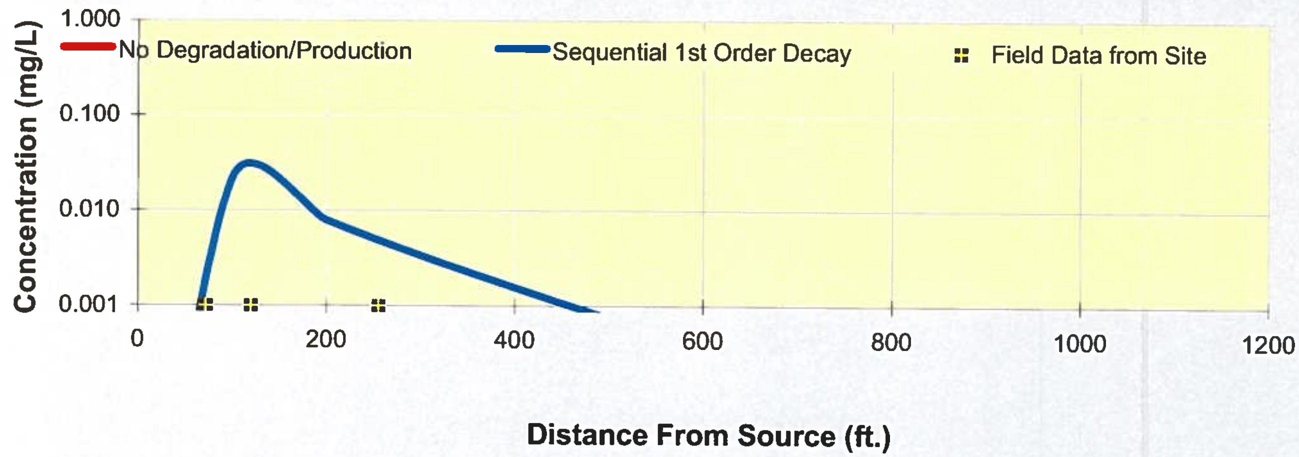
To All

To Array

DISSOLVED CHLORINATED SOLVENT CONCENTRATIONS ALONG PLUME CENTERLINE (mg/L) at Z=0

VC

	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Biotransformation	0.0000	0.021	0.008	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000
	Monitoring Well Locations (ft)										
	120	255	72								
Field Data from Site	0.001	0.001	0.001								



See PCE | See TCE | See DCE | See VC | See ETH

Prepare Animation

Time:
1,000.0 Years
Log ⟺ Linear

Return to Input | To All | To Array