ESTCP

USER GUIDE

Training for Environmental Monitoring Performance Optimization (TEMPO)

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14. ABSTRACT
The TEMPO (Training for Environmental Monitoring Performance Optimization) Training Tool is an interactive training tool that gives users a hands-on experience in contaminant site investigation through examination of virtual sites. It is aimed at supporting learning and skills development for two training modules including a Site Investigation module for improving investigation skills for conceptual site model development and a Long-Term Monitoring module for improving the design of cost-effective monitoring programs for Long-Term compliance. TEMPO is accessible online and consists of a graphical user interface that allows end users to undertake real-time training on these modules and for seven different virtual sites with varying complexity in geology and contaminant distribution. Users have the ability to investigate the selected virtual site by deploying an array of both conventional and advanced investigation tools including boreholes and MW installations, Membrane Interface Probe (MIP) and Dye-enhanced Laser Induced Fluorescence (DYE-LIF), and soil and groundwater analytical sampling. TEMPO tracks the costs of the investigation or monitoring programs in real-time and allows the user to evaluate their results to the true, known model of the virtual site, balancing cost with uncertainty and value of information. The user can assess their performance against the true results and monitor improvement with multiple attempts at each site.
The goal of the TEMPO program is to provide a training instrument for students, early career contaminated site specialists and site management personnel to improve abilities in site investigations for remedial designs that are not under- or over- scoped and aid in the review of sampling programs.

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ACRONYMS AND ABBREVIATIONS

cm/s	centimeter per second
DOC	dissolved organic carbon
DYE-LIF	Dye-enhanced Laser Induced Fluorescence
EC	electricalconductivity
ECD	electron capture
ESTCP	Environmental Security Technology Certification Program
foc	fraction of organic carbon
ft/d	feet/day
GIS	Geographical Information Systems
g/g	grams per gram
GUI	Graphical User Interface
K	hydraulic conductivity
LTM	long-term monitoring
mg/kg	milligram per kilogram
mg/L	milligram/liter
MIP	Membrane Interface Probe
Mm	millimhos per centimeter
mmhos/cm	millivolts
mV	millivolts
ORP	oxidation-reduction potential
PID	photoionization
rRNA	ribosomal ribonucleic acid
TEMPO	Training for Environmental Monitoring Performance Optimization
TOC	Total organic carbon
SVOC	semi- volatile organic carbon
V	volts
VOC	volatile organic carbon
VSD	virtual site
µg/kg	microgram/ kilogram
µg/L	microgram/liter
% RE	% relative emission

INTRODUCTION

The TEMPO (Training for Environmental Monitoring Performance Optimization) Training Tool is an interactive training tool that gives users a hands-on experience in contaminant site investigation through examination of virtual sites. It is aimed at supporting learning and skills development for two training modules including a Site Investigation module for improving investigation skills for conceptual site model development and a Long-Term Monitoring module for improving the design of cost-effective monitoring programs for Long-Term compliance. TEMPO is accessible online and consists of a graphical user interface that allows end users to undertake real-time training on these modules and for seven different virtual sites with varying complexity in geology and contaminant distribution. Users have the ability to investigate the selected virtual site by deploying an array of both conventional and advanced investigation tools including boreholes and MW installations, Membrane Interface Probe (MIP) and Dye-enhanced Laser Induced Fluorescence (DYE-LIF), and soil and groundwater analytical sampling. TEMPO tracks the costs of the investigation or monitoring programs in real-time and allows the user to evaluate their results to the true, known model of the virtual site, balancing cost with uncertainty and value of information. The user can assess their performance against the true results and monitor improvement with multiple attempts at each site.

The goal of the TEMPO program is to provide a training instrument for students, early career contaminated site specialists and site management personnel to improve abilities in site investigations for remedial designs that are not under- or over- scoped and aid in the review of sampling programs.

TEMPO Learning Objectives:

- Develop site investigation skills through engagement with conceptual site models of virtual sites with varying complexity in geology and contaminant distribution.
- Contrast the application of conventional and advanced investigation tools for the treatment of virtual sites.
- Enhance the ability to design cost-effective monitoring programs for compliance.
- Utilize the evaluation of performance against true results to improve abilities in site investigations for remedial designs.

1.0 CONTRINUTORS

The TEMPO training tool was developed under funding from the Department of Defense, Environmental Security Technology Certification Program (ESTCP) project # ER-201566 by Geosyntec Consultants Inc. and Queen's University.

2.0 BACKGROUND

TEMPO has two modules: Site Investigation and Long-Term Monitoring. TEMPO consists of seven different virtual sites (VSD) with varying complexity in geology and contaminant distribution. The first three VSDs are learning modules (VSD1 through VSD3) for site investigation. VSD1 through VSD3 may be repeated multiple times so that the user can experiment and attempt to improve their score. VSD4 is created to be a test VSD and may not be repeated multiple times. The Long-Term Monitoring module comprises temporal monitoring data at three different sites (VSD5 through VSD7) and will focus on improving the users' skill at selecting long-term monitoring locations.

3.0 LICENSE AND USE AGREEMENT

TEMPO is a free-use software. There are no limitations or license agreements for the use of TEMPO.

4.0 SYSTEM REQUIREMENTS

TEMPO was developed using the ESRI ArcGIS for Desktop Platform (ArcGIS) and contains an integrated user interface and associated automation. TEMPO can be used on any computer running Windows XP or greater and through the following browsers: Firefox, Microsoft Edge, and Google Chrome. **Microsoft Internet Explorer does not support the use of TEMPO.**

5.0 USING TEMPO

5.1 ACCESSING TEMPO

To begin using TEMPO, navigate to and open the website http://www.build-a-csm.com. Select the blue 'Open TEMPO' box to enter the program. A login screen will appear as in Figure 1. Enter a username and select the site VSD that you would like to train on. Click the green 'Login' button to begin. The username is only required so that a user can return to their work in progress. E-mail addresses are recommended as usernames since they guarantee uniqueness. There is no security on TEMPO. User data will be deleted after a certain period of inactivity (minimum of 6 months), depending on the total number of users of TEMPO. All work in TEMPO is maintained (saved) under the username and may be exported to pdf or Excel-compatible files.

Figure 1. Accessing the Login Screen

5.2 UNDERSTANDING THE DIFFERENT MODULES

TEMPO contains two different training modules. The first is targeted at increasing the skills of the user in site investigation and conceptual site model design and contains 4 different sites (VSDs 1 to 4). It is suggested that the VSDs be examined in sequence as the complexity of the sites increase from VSD1 to VSD3. VSD4 is an "assessment" site and can only be examined once. The second module is aimed at allowing the user to explore optimizing long-term monitoring programs at contaminate sites. VSDs 5 to 7 present the user with very large data sets (both spatially and temporally) that require reduction in cost and complexity while maintaining an effective monitoring program to assess risk to receptors and monitor remediation performance. There is no increasing complexity between VSDs 5 to 7 and they can be attempted in any order.

6.0 SITE INVESTIGATION MODULE

The default view will be a Graphical User Interface (GUI) that uses Geographical Information Systems (GIS) technology. An aerial image of the VSD selected will open automatically (example of VSD1 is shown in Figure 2).

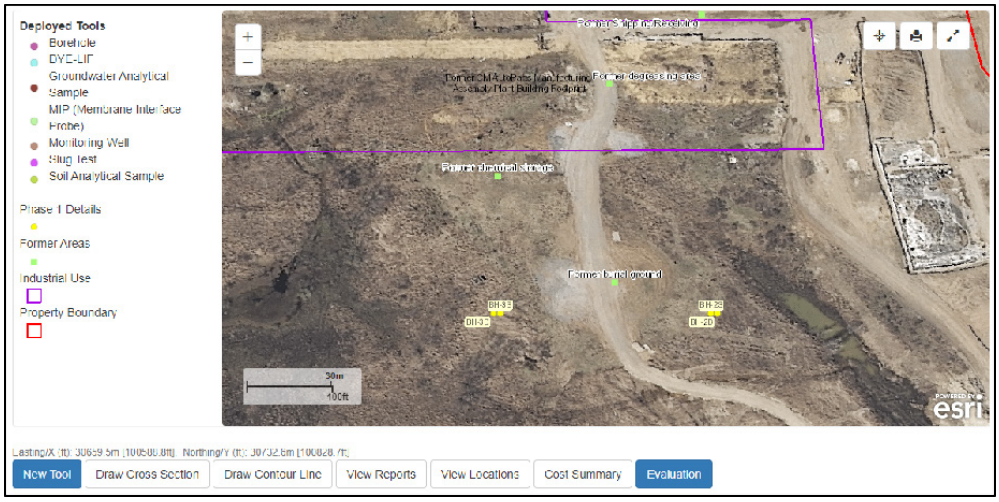


Figure 2. Default View

Along the left side of the GUI, there will be a legend of tool location markers:

- Boreholes
- DYE-LIF (Dye-enhanced Laser Induced Fluorescence)
- Groundwater Analytical Sample
- MIP (Membrane Interface Probe)
- Monitoring Well
- Slug Test
- Soil Analytical Sample

Markers are also included for locations that were part of previous investigations andoutlines exist for areas of interest, for example:

- Phase 1 Details
- Former Areas (of importance at the site)
- Industrial Use (area)
- Property Boundary

6.1 OTHER FEATURES

Along the top left of the main GUI, there are three sources of additional information:

- User's Guide (this document)
- Phase 1 Report (summary of historical investigations)
- Calculators (handy tools for performing site investigation calculations)

6.2 USING THE TOOL—OVERVIEW

Along the bottom left of the main GUI, there are seven actions (Figure 3) a user can take.

Figure 3. Options for User Action

Whilst using TEMPO, the user should be aware that some of the reports take up to 30 seconds to generate. Users should wait until the screen is completely loaded before selecting further commands.

6.2.1 New Tool

Click on the 'New Tool' button (Figure 3). A data entry menu will pop up allowing the user to enter information to select which type of tool is desired (see screen shot in Figure 4).

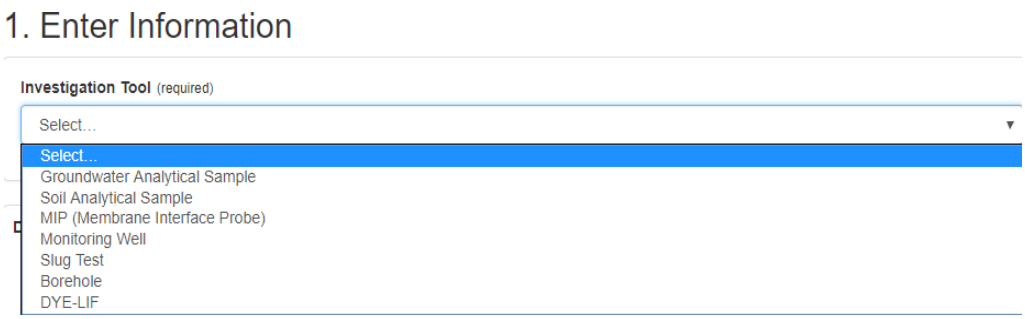


Figure 4. Tool Options

The options are:

- Groundwater Analytical Sample
- Soil Analytical Sample
- MIP (Membrane Interface Probe)
- Monitoring Well
- Slug Test
- Borehole
- DYE-LIF

Tip

For sampling, well installation or a slug test theuser is required to select theborehole tool first (i.e., you can't do the action without first having created/drilled a borehole).

After a tool is selected, the user is prompted to enter details specific to that tool (more information provided in the 'Using the tool—specific details' section below), and to select a location on the map to identify the location. This can be done by either specifying easting and northing coordinates in feet, or by clicking the 'set location' button and subsequently clicking and dragging the blue chevron to the desired location on the map. Once the blue chevron is in the desired location select 'submit entry' under the '3. Complete Form' options (Figure 5).

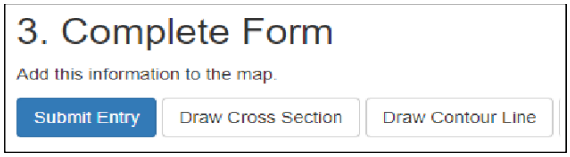


Figure 5. Form Completion Options

After the entry loads, a pop-up will appear (Figure 6) indicating that the entry was submitted. Click 'Close'. Note: tools will load into a new tab automatically. The pop-upindicated in Figure 6 will be on the original tab.

Figure 6. Submittal Confirmation

6.2.2 Draw Cross Section

TEMPO includes the ability to draw cross sections along a user-specified line. Selecting 'Draw Cross Section' opens a pop-up (Figure 7) asking for a Cross Section Name and an 'offset' that is the perpendicular distance from the line where existing information will be mapped to the cross section (all information within the offset distance will be treated as being on the actual cross section line).

Figure 7. Cross Section Information Box

After entering the information, the cross-section line is specified by left-clicking and drawing a line on the map. The line can contain multiple segments (does not have to be a straight line). Each segment is defined by an additional left click of the mouse. The cross-section line is completed by a double left click (Figure 8).

Figure 8. Completed Cross Section Line

To view the cross-section, left click on the line. To expand the view, select '(Click Here for Expanded View)'. This will open the cross-section in a new tab.

6.2.3 Draw Contour Line

TEMPO includes the ability to draw parameter contour lines based on the data gathered during the site investigation process. Data can be reviewed either by looking at the tool reports or left clicking on a tool location and selecting the data of interest at that location (e.g., soil analytical samples).

To draw a contour line, select 'Draw Contour Line', which will open a new pop-up (Figure 9). Contour lines can be generated for water levels, groundwater concentrations, or soil concentrations.

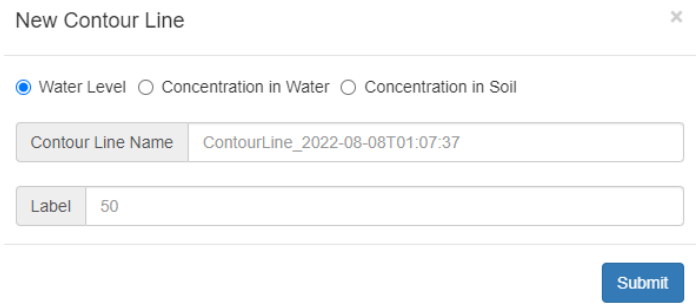


Figure 9. New Contour Line Information Box

Contours lines are drawn by holding down the left button on the mouse and moving the cursor around the map. Contour lines are completed by releasing the left button on the mouse.

6.2.4 View Reports

When the 'View Reports' button is selected, the user will be brought to a separatebrowser page (Figure 1 0) called 'Your Report Library'. The library includes reports for all previously investigated data as well as current investigations. Selecting a hyperlink in the 'Report URL' column will load the report into a new tab in the browser. Some reports allow for the data to be exported to an Excel-compatible csv file (slug tests,DYE-LIF, MIP, Analytical Samples).

Your Report Library

Tool Name	Date Appended	Report URL	CSV Export
Borehole	11/2/2016 10:02:51 AM	BH-1D	
Borehole	11/2/2016 10:02:51 AM	BH-1S	
Borehole	11/2/2016 10:02:51 AM	BH-2D	
Borehole	11/2/2016 10:02:51 AM	BH-2S	
Borehole	11/2/2016 10:02:51 AM	BH-3D	
Borehole	11/2/2016 10:02:51 AM	BH-3S	
Borehole	11/2/2016 10:02:51 AM	BH-4D	
Borehole	11/2/2016 10:02:51 AM	BH-4S	
Monitoring Well	12/8/2016 9:01:10 AM	MW-1D	
Monitoring Well	12/8/2016 9:01:10 AM	MW-1S	
Monitoring Well	12/8/2016 9:01:10 AM	MW-2D	
Monitoring Well	12/8/2016 9:01:10 AM	MW-2S	
Monitoring Well	12/8/2016 9:01:10 AM	MW-3D	
Monitoring Well	12/8/2016 9:01:10 AM	MW-3S	
Monitoring Well	12/8/2016 9:01:10 AM	MW-4D	
Monitoring Well	12/8/2016 9:01:10 AM	MW-4S	
Slug Test	12/8/2016 1:11:25 PM	MW-1D-SlugTest	Export CSV
Borehole	8/7/2022 8:27:04 PM	BHNew1	
MIP (Membrane Interface Probe)	8/7/2022 8:27:26 PM	MIP1	Export CSV
DYE-LIF	8/7/2022 8:27:54 PM	DYE1	Export CSV
Soil Analytical Sample	8/7/2022 8:28:16 PM	SS1	Export CSV

Figure 10. Your Report Library

Left click on the 'Report URL' or 'CSV Export' of the data set you wish to view. The data will open in another tab. Alternatively, the user can right click on these links elect to 'open link in new tab', 'open link in new window' or to 'save link as'. Sometimes the data takes up to a minute to load depending on connection speed, complexity of the request, and total number of users in the system. Refrain from clicking additional commands while the data is loading.

Once the data is open in the new tab, new window, or from the saved file location as applicable, the data can be saved or printed with a right-click on the data sheet and selecting 'save as' or 'print' if the user wishes to retain the data. Electing 'print' will, by default, print the output to a pdf file, and will then prompt the user to 'save as' in the location they desire. The user may also elect to return to the 'view report library' at any time during the completion of the Site Investigation module to view the data again.

6.2.5 View Locations

When the 'View Locations' button is selected, the user will be brought to a separate browser page (Figure 11) called 'Your Deployed Locations'. The sheet provides details (type of tool used (i.e., borehole, monitoring well), sample ID (ID), start depth and end depth in feet, X and Y coordinate data, and date and time that the tool was deployed) about all investigation locations.

Your Deployed Locations

Tool	ID	Start Depth	End Depth	X-Coord	Y-Coord	Date Deployed
Borehole	BH-01	0	50	null	null	2017-05-02 15:26:47.860000
Borehole	BH-02	0	100	null	null	2017-05-02 15:27:57.640000
Borehole	BH-03	0	50	null	null	2017-05-04 15:42:41.363000
Borehole	BH-1D	0	90.35	200986	200872	2016-11-02 10:02:51.983000
Borehole	BH-1S	0	40.97	200978	200872	2016-11-02 10:02:51.983000
Borehole	BH-2D	0	90.35	200781	200860	2016-11-02 10:02:51.983000
Borehole	BH-2S	0	40.97	200774	200860	2016-11-02 10:02:51.983000
Borehole	BH-3D	0	90.35	200781	200494	2016-11-02 10:02:51.983000
Borehole	BH-3S	0	40.97	200774	200494	2016-11-02 10:02:51.983000

Figure 11. Your Deployed Locations

To return to the TEMPO tool, the user needs to re-open the tab labelled 'TEMPO', which will still be showing the main GUI.

6.2.6 Cost Summary

Selecting the 'Cost Summary' button will provide the total costs of the investigation to date. Note that this option is not available until at least one tool has been deployed. An example output is shown in Figure 12. Costs were developed as industry averages at the time of the development of TEMPO (2020) and are not updated over time. This allows for standard comparisons with other users over the history of use of TEMPO.

Total Cost

Tool	Tool Count	Tool Category	Tool Expense	Labour Category	Labour Expense
Borehole	1	Sonic Drilling	$8,405.00	Labor - Drilling oversight/logging	$500.00
DYE-LIF	1	DYE-LIF	$8,550.00	Labor - Drilling oversight/logging	$675.00
Groundwater Analytical Sample	5	Anions - EPA 300/9056	$300.00	No Labor	$0.00
Groundwater Analytical Sample	7	Dissolved hydrocarbon gases	$490.00	No Labor	$0.00
Groundwater Analytical Sample	5	Gene-Trac® Dhb*	$250.00	No Labor	$0.00
Groundwater Analytical Sample	5	Gene-Trac® Dhc*	$250.00	No Labor	$0.00
Groundwater Analytical Sample	5	Gene-Trac® Dhg*	$250.00	No Labor	$0.00
Groundwater Analytical Sample	5	Gene-Trac® Universal*	$250.00	No Labor	$0.00
Groundwater Analytical Sample	5	Gene-Trac® VC*	$250.00	No Labor	$0.00
Groundwater Analytical Sample	5	Microbial DNA extraction	$1,375.00	No Labor	$0.00
Groundwater Analytical Sample	21	Monitoring Well	$1,080.00	Labor - Groundwater sampling	$3,150.00
Groundwater Analytical Sample	5	Multiparameter Test	$360.00	Labor - Groundwater sampling	$750.00
Groundwater Analytical Sample	37	Sample Shipment	$400.00	Sample Shipment	$150.00
Groundwater Analytical Sample	5	SVOC analysis	$600.00	No Labor	$0.00
Groundwater Analytical Sample	5	TOC	$150.00	Analyte	$0.00
Groundwater Analytical Sample	5	Total metals	$500.00	No Labor	$0.00
Groundwater Analytical Sample	5	VOC analysis	$300.00	No Labor	$0.00
MIP (Membrane Interface Probe)	1	MIP/MiHPT	$4,075.00	Labor - Drilling oversight/logging	$375.00
Monitoring Well	1	Monitoring Well Install	$440.00	Labor - Well install oversight	$312.50
		Total Expense:	**$28,275.00**	**Total Labor:**	**$5,912.50**
			GRAND TOTAL:	**$34,187.50**	

Figure 12. Investigation Cost Estimate

6.2.7 Evaluation

When the user believes they have enough data to sufficiently characterize the site, the usermay choose to evaluate their work. Click on the 'Evaluation' button on the bottom of the main GUI page. A warning will appear (Figure 13) notifying the user that they will no longer be able to add additional tools to the investigation if they proceed. To continue and be evaluated, click 'Proceed'.

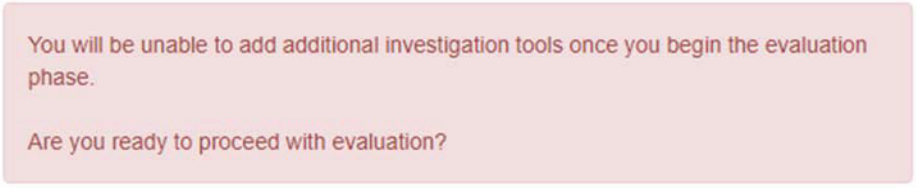


Figure 13. Evaluation Warning

The user will be directed to a new evaluation interface page where they will be given toolswith which to complete their evaluations. These include site geology, site hydrogeology, contaminant source zones, contaminant plumes and mass discharge as shown in Figure 14. More detailed information on each of the evaluation tools is included in Section 5 'evaluating the data – specific details'. The user should make themselves familiar with Section 5 before beginning their site investigation such that they can ensure the appropriate data is collected to allow for their CSM to be evaluated.

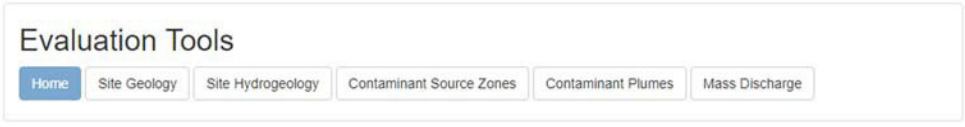


Figure 14. Evaluation Tool Options

A TEMPO splash page will be created when the modules are complete, which will containlinks to the TEMPO login (where you are starting from now) and downloadable guidance documents.

6.3 USING THE TOOL – SPECIFIC DETAILS

The tools below are described in order of their appearance in the 'New-Tool' drop-down menu, however there are certain tools that need to be deployed before others can be used. All tools (except the MIP and DYE-LIF) require that a borehole be created first. A groundwater analytical sample requires that both a borehole and a monitoring well in that borehole be installed. If the user thinks about the installation and sampling process logically, the sample tools available at each stage should be clear. If the user attempts to use a tool for which the required precursors have not been completed, an error message will pop up indicating the type of data that is required before that tool can be utilized. A few details about each tool are described below.

6.3.1 Groundwater Analytical Sample (Figure 15)

This tool requires both a borehole and a monitoring well to be created prior to obtaining analytical data. If a monitoring well has not yet been created, an error message will appear indicating these requirements to the user; 'This tool requires a monitoring well'. The user may request analyses of dissolved hydrocarbon gases, total metals, anions, multiparameter meter, total organic carbon, volatile organic carbon (VOC), semi- volatile organic carbon (SVOC) and Gene-Trac®. Multiple analyses may be selected at the same time. Examples of the outputs provided are given in the 'Examples of data output' section under 'Groundwater and Soil Analytical data'.

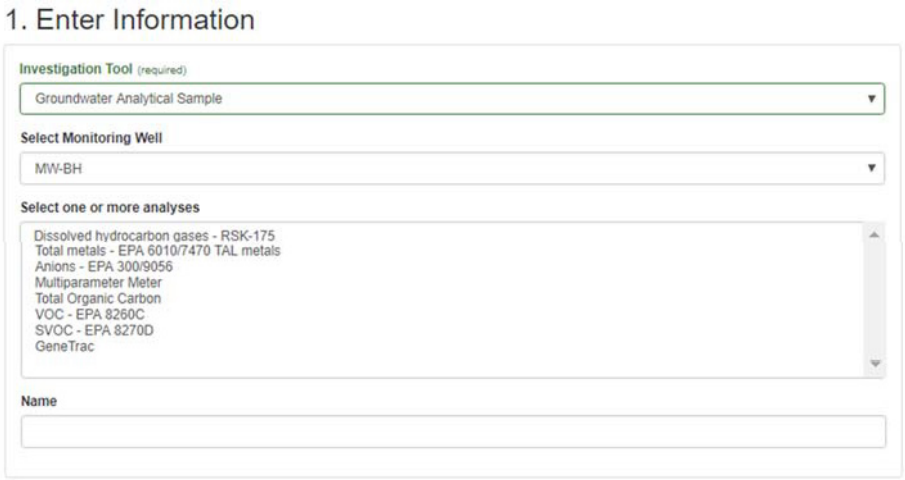


Figure 15. Groundwater Analyses Options

6.3.2 Soil Analytical Sample (Figure 16)

This tool requires a borehole to have been created. If a borehole has not yet been created, an error message will appear indicating these requirements to the user; 'This tool requires a borehole'.

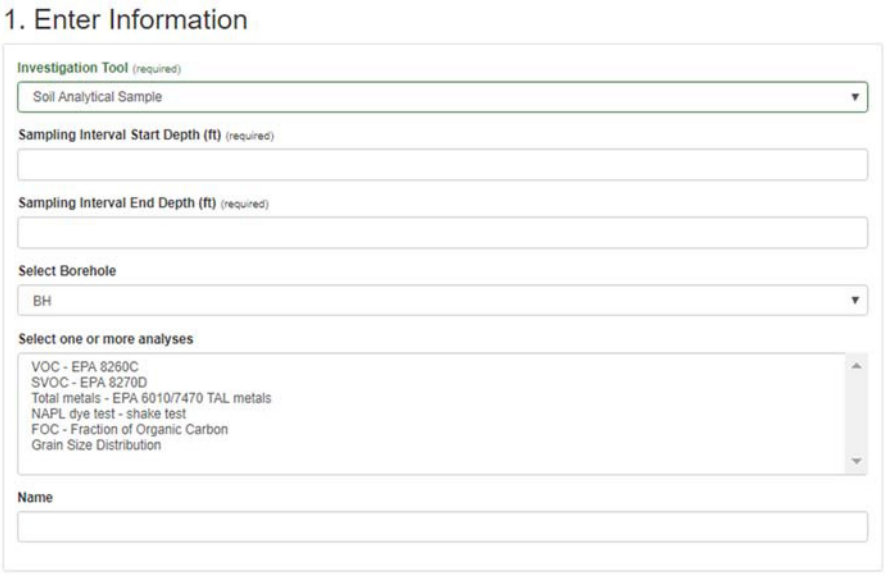


Figure 16. Soil Analyses Options

6.3.3 MIP (Membrane Interface Probe) (Figure 17)

A MIP is a direct push logging technology that is used to locate volatile organic compounds in the subsurface. Additional information can be found at the clu-in website (www.clu-in.org). This tool does not require a borehole to have been created prior to its use. However, it does require that a unique location name be provided.

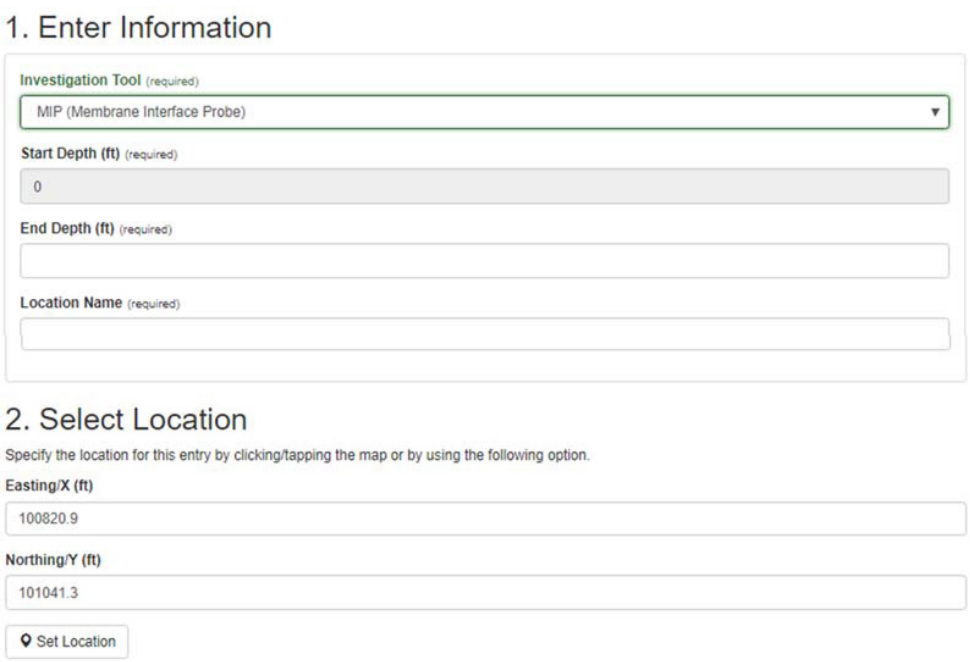


Figure 17. MIP Options

6.3.4 Monitoring Well (Figure 18)

This tool requires a borehole to already have been created. The minimum screen length allowed is 0.5 ft. If a borehole has not yet been created, an error messagewill appear indicating these requirements to the user; 'This tool requires a borehole'.

Figure 18. Monitoring Well Options

6.3.5 Slug Tests

This tool requires both a borehole and a monitoring well to already have been created. If a monitoring well has not yet been created, an error message will appear indicatingthese requirements to the user; 'This tool requires a monitoring well'. A slug test is an aquifer test where water is quickly added or removed from a groundwater monitoring well and the charge in hydraulic head is monitored through time, to determine the near-well aquifer characteristics. Additional details can be found on the clu-in website (www.clu-in.org).

6.3.6 Borehole (Figure 19)

The user must enter the 'end depth' in feet and unique location names for eachborehole created.

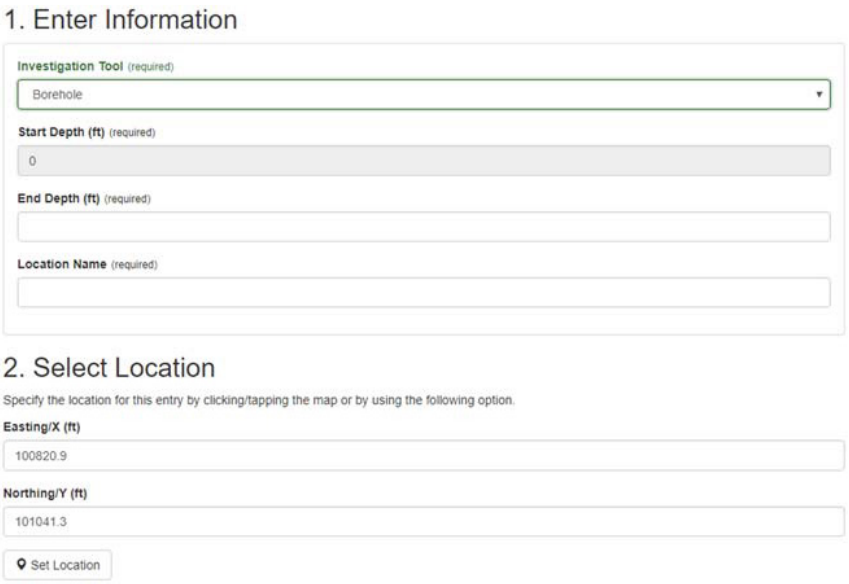


Figure 19. Borehole Options

6.3.7 DYE-LIF (Figure 20)

The DYE-LIF tool is a direct push profiling tool that injects a hydrophobic fluorescent dye into a formation that partitions into DNAPL and allows for its identification. Additional information can be found in ESTCP project ER-201121. This tool, like a MIP, requires the selection of a location and specification of depth interval.

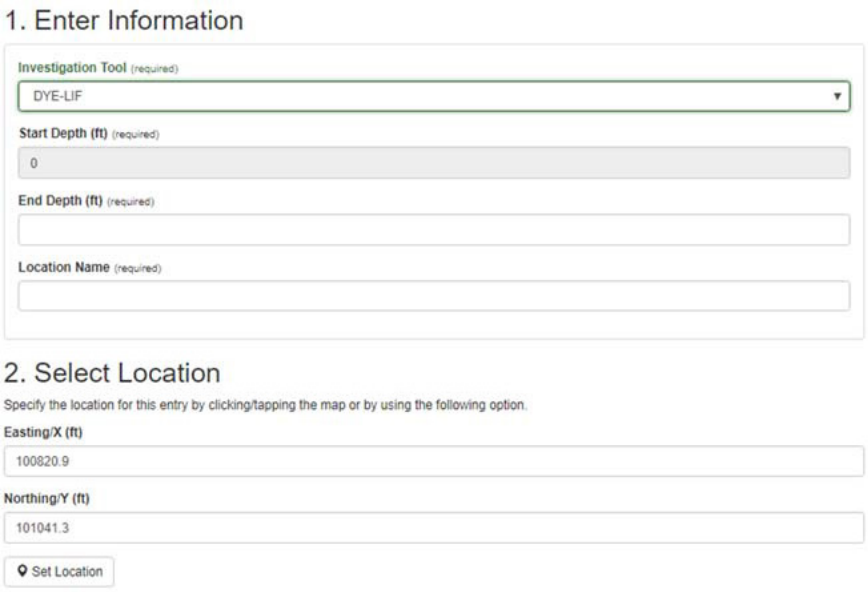


Figure 20. DYE-LIF Options

7.0 BUILDING THE CSM

The key output in the site investigation module is a CSM of the VSD being investigated. Five components are involved in building and evaluating the CSM within TEMPO (Figure 21). The user proceeds through the site investigation process for each VSD, obtaining data through the investigation tools that will be used in constructing the CSM for the site and at the point where the user feels confident enough data has been collected and has undertaken some interpretation, the user can have their CSM evaluated against the "true" CSM. The process of parameterizing the required CSM components for evaluation is described in the following sections and it is highly recommended the user familiarize themselves with the following prior to beginning their site investigation (such that investigations are targeted at producing data to address the required components of the CSM within TEMPO).

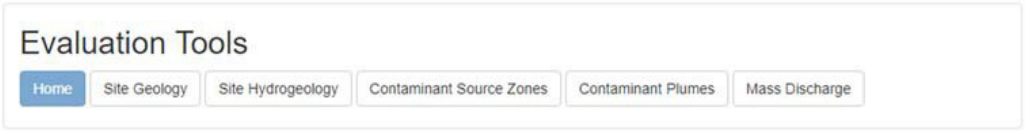


Figure 21. Evaluation Tool Options

7.1 SITE GEOLOGY

The CSM requires a depiction of the aquitards at the site. Two cross-sections are required, one north-south and one east-west. These cross-sections are pre-defined and located along the western and southern sides of the footprint of the source zones(s) at the site. Actual cross-section locations are not shown prior to evaluation as that would provide information on the source portion of the CSM and undermine the authenticity of the process. Any borehole logs created during the site investigation will be displayed in the pre-defined cross-sections for identification of the aquitards using the following approach:

1. Click on the cross-section to start the outline of an aquitard.
2. Double click to complete drawing.
3. Press [ESC] to cancel drawing.
4. [Optional] Double click on completed aquitard(s) to edit shape.
5. [Optional] Use [CTRL] or [CMD] + click on aquitard to delete aquitard from map.

When the user double clicks the aquitard, a pop-up is generated (Figure 22) to let the user know that the entry has been successfully submitted.

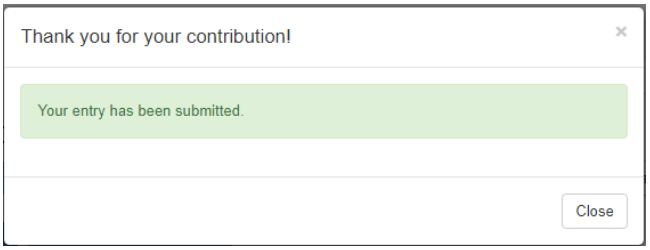


Figure 22. Submittal Confirmation

Click ‘close’ on the pop-up. Make sure to complete both the east-to-west and north-to-south cross-sections.

7.2 SITE HYDROGEOLOGY

In this section (Figure 23), the user will need to enter the approximate hydraulic and vertical gradients across the site in ft/ft and the groundwater Darcy Flux across the site in ft/year.

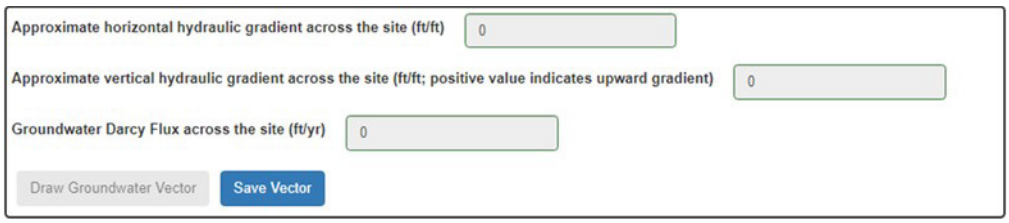


Figure 23. Hydraulic and Vertical Gradients

The user drags the pushpin on the map in the direction of the groundwater gradient, then clicks the ‘Save Vector’ button to submit the entry. After submission, the vector may be deleted and redrawn if desired. When the user saves the vector, a pop-up is generated tolet the user know that the entry has been successfully submitted.

7.3 CONTAMINANT SOURCE ZONE

Another key component of the CSM is identification of the footprint, vertical distribution, and total contaminant mass in any source zone(s) at the site. Selecting ‘Contaminant Source Zones’ from the Evaluation Tools menu will pop up the information entry box presented in Figure 24.

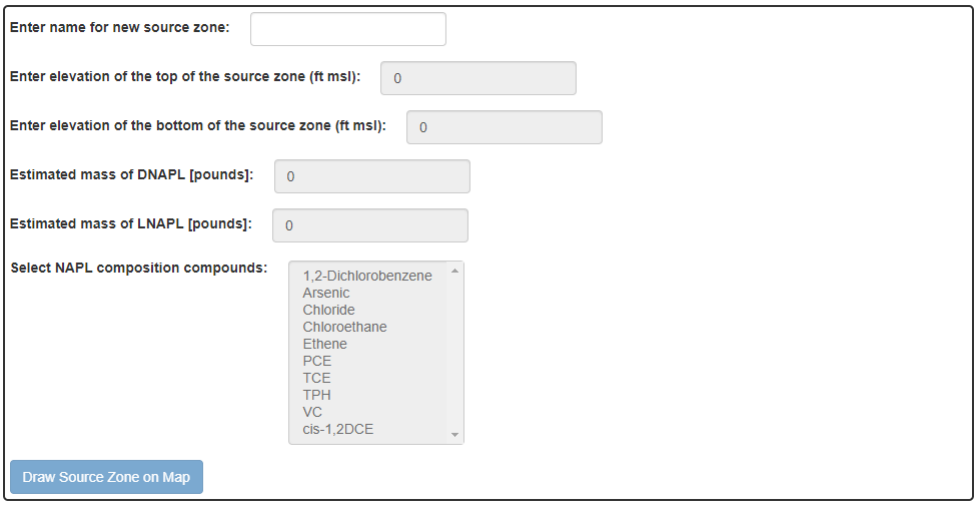


Figure 24. Parameter Entry Window for Contaminant Source Zones

There is the possibility to define up to 2 source zones, identified as shallow and deep. Note that the naming is simply for differentiation; source zones could be at identical elevations but in different planar locations.

Each source zone requires a unique name as well as identification of its top and bottom elevation. The total estimated NAPL mass (DNAPL or LNAPL) is required to be entered as well as the compounds within the source. Following entry of the required data, the source zone footprint can be drawn on the map using the same approach as for drawing aquitards in the Site Geology evaluation section.

Data gathered during the site investigation will be displayed on the map to aid in the drawing of source zone footprints. All tool reports generated during the site investigation process are available by selecting the 'View Reports' button located below the map.

7.4 CONTAMINANT PLUMES

A plume footprint is required to be drawn for each of the contaminants identified as present as a source within the source zone(s). In addition to the footprint an estimate of the top and bottom elevations of each plume is required. The plume footprint should be to the 5 ug/L contour and if the plume is at steady state, then this should also be indicated (Figure 25).

Figure 25. Parameter Entry Window for Groundwater Plumes

The process for drawing a plume footprint is identical to the process for drawing a source zone footprint.

7.5 MASS DISCHARGE

The final component of the CSM is an estimate of mass discharge (Figure 26) of contaminants from the source zone(s) at the downgradient edge of the source zone(s). Site investigation data should be planned to allow for an estimate of this parameter.

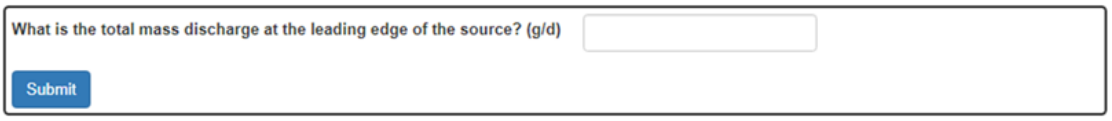


Figure 26. Estimated Mass Discharge

7.6 CALCULATORS

Four calculators (Mass Flux, Maximum Soil Concentration, Groundwater Velocity, Retardation) are incorporated into TEMPO to aid in common calculations that are performed when creating a CSM and to assist in developing quantitative aspects of the CSM. Calculators are accessed through a link at the top left of each page in TEMPO. Mathematical descriptions of the calculators are provided with each calculator and additional references are provided under the "Tools and Resources" page accessed from the main page.

7.7 EVALUATION

When the user is satisfied with their entries in the CSM components return to the Home tab and click 'Submit evaluation'. A pop-up (Figure 27) will confirm that the user intends to submit their evaluation for scoring.

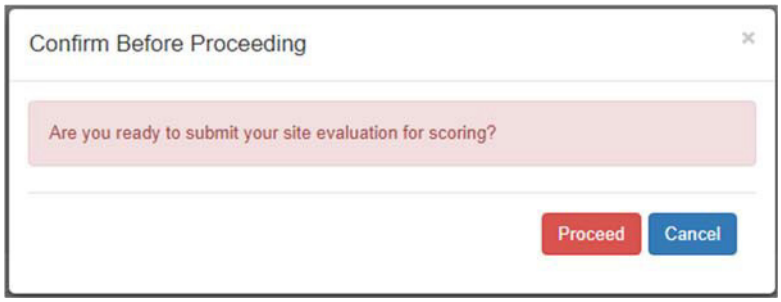


Figure 27. Confirmation Before Proceeding

When the user clicks 'Proceed' the evaluation is submitted for scoring, and a comparison is provided in the form of percent error (along the y-axis) to the true values of the CSM components calculated with perfect information of the underlying model (Figure 28). Current CSM estimates are plotted as large orange circles, withprevious estimates (for the same VSD) plotted as smaller orange circles. A selection of other estimates from other users are provided as smaller gray circles. The importance of the magnitude of errors is site and parameter specific and understanding is a function of experience. In general scoring +/- 30% should be considered an excellent outcome. Additional reading on CSM parameter error and its importance can be found in the final report for TEMPO's parent project (DIVER, SERDP ER-21313).

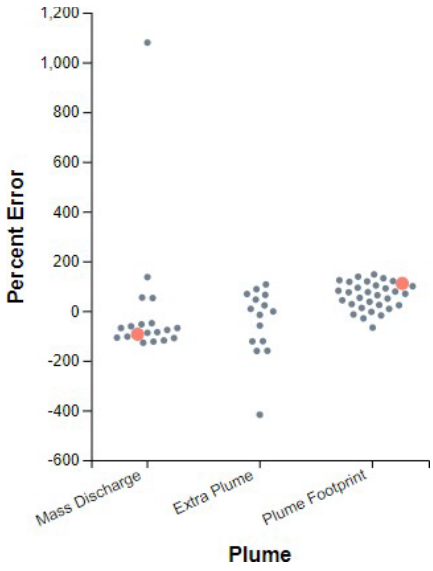


Figure 28. Evaluation Scoring

For VSDs 1 through 3, the user may return to the login page and repeat the processagain (all site investigation data is erased) to improve their site characterization score (i.e., by reducing the % error). VSD4 is considered a testing module and may only be evaluated once per username.

8.0 EXAMPLES OF DATA OUTPUT

8.1 MONITORING WELLS AND BOREHOLE LOGS

Monitoring well and borehole log outputs are similar in that thegeology data obtained from the borehole log is recorded alongthe left-hand side in each output (Figure 29). Monitoring well logs have theaddition of 'monitoring well description', which identifies wherethe screen was placed, and 'water level'. The water level, which identifies the depth to water measurement in the monitoring well, is indicated by a black triangle pointing downwards. The exact measurement is also recorded in the header of the log.

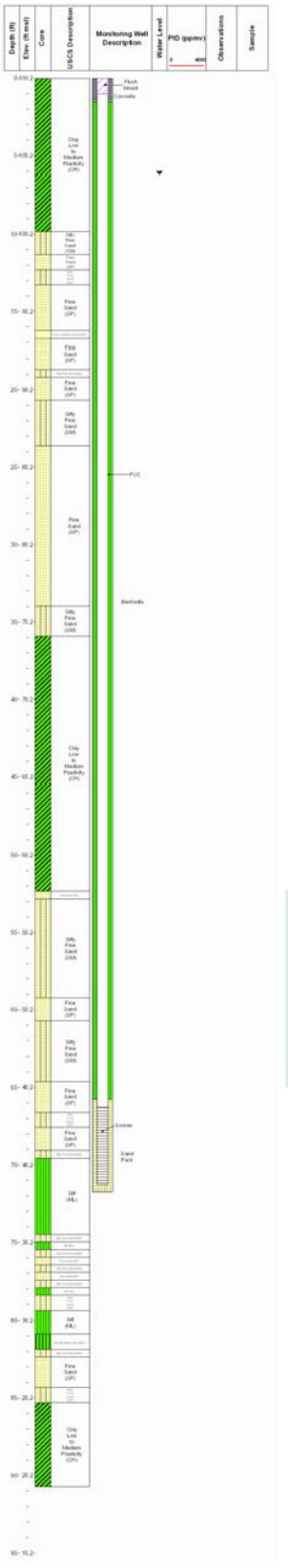


Figure 29. Monitoring Well and Borehole Log Output

8.2 GROUNDWATER AND SOIL ANALYTICAL DATA

8.2.1 Dissolved Gasses (Figure 30)

Dissolved Hydrogen Gases data is reported using RSK test method 175 for groundwater data. Data reported are constituent, result, and reporting limit in milligram/liter (mg/L) and date analyzed. Alkalinity, specific conductance, and total dissolved solids data are also providedas part of this output.

Constituent	Result	Report Limit	Date Analyzed
Alkalinity, Bicarbonate (as CaCO3) - M2320 B			**mg/L as CaCO3**
Bicarbonate	1149.8	2	10/09/2017
Carbonate	2.1	2	10/09/2017
Dissolved Gases by RSK-175 (GC)			**mg/L**
Acetylene	ND	0.01	10/09/2017
Ethane	ND	0.01	10/09/2017
Ethene	ND	0.01	10/09/2017
Hydrogen	ND	1E-08	10/09/2017
Methane	ND	0.01	10/09/2017
n-butane	ND	0.01	10/09/2017
Oxygen	4.3	0.01	10/09/2017
Propane	ND	0.01	10/09/2017
Propene	ND	0.01	10/09/2017
Propyne	ND	0.01	10/09/2017
Specific Conductance - Standard Method 2510 B-201			**mmhos/cm**
Specific Conductance	1.7	0.01	10/09/2017
Total Dissolved Solids - SM 2540 C-2011			**mg/L**
Total Dissolved Solids (Residue,Fiterable)	1151.9	10	10/09/2017

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B- Analyte Detected in The Associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated value between MDL and PQL
E - Estimated value exceeds calibration curve

D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference
TNTC - Too numerous to count

Figure 30. Dissolved Gasses Data Output

8.2.2 Total Metals (Figure 31)

Total metals data are reported using EPA test method 6010/7470 TAL metals. This is an option for both groundwater and soil. Data reported are constituent, result, and reporting limit in mg/L (for groundwater) or milligram per kilogram (mg/kg) (for soil) and date analyzed. Alkalinity, specific conductance, and total dissolved solids data are also providedas part of the groundwater output.

Constituent	Result	Report Limit	Date Analyzed
Alkalinity, Bicarbonate (as CaCO3) - M2320 B			**mg/L as CaCO3**
Bicarbonate	1149.8	2	10/09/2017
Carbonate	2.1	2	10/09/2017
Metals by Method 6010 (ICP-AES),Total			**mg/L**
Calcium	111.4	0.5	10/09/2017
Iron	0.2	0.05	10/09/2017
Magnesium	55.9	0.1	10/09/2017
Manganese	0.4	0.01	10/09/2017
Potassium	19.4	2	10/09/2017
Sodium	210.0	0.5	10/09/2017
Specific Conductance - Standard Method 2510 B-201			**mmhos/cm**
Specific Conductance	2.3	0.01	10/09/2017
Total Dissolved Solids - SM 2540 C-2011			**mg/L**
Total Dissolved Solids (Residue,Fiterable)	1549.2	10	10/09/2017

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B- Analyte Detected in The Associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated value between MDL and PQL
E - Estimated value exceeds calibration curve

D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference
TNTC - Too numerous to count

Figure 31. Total Metals Data Output

8.2.3 Anions (Figure 32)

Anions data is reported using EPA test method 300/9056. Data reported are constituent,result, and reporting limit in mg/L and date analyzed. Alkalinity, specific conductance, and total dissolved solids data are also provided as part of this output.

Constituent	Result	Report Limit	Date Analyzed
Alkalinity, Bicarbonate (as CaCO3) - M2320 B			**mg/L as CaCO3**
Bicarbonate	1149.8	2	10/09/2017
Carbonate	2.1	2	10/09/2017
Anions by Ion Chromatography by Method 300/9056			**mg/L**
Ammonia	ND	0.1	10/09/2017
Chloride	56.8	0.2	10/09/2017
Nitrate	0.3	0.05	10/09/2017
Nitrite	ND	0.05	10/09/2017
Sulfate	90.0	0.2	10/09/2017
Specific Conductance - Standard Method 2510 B-201			**mmhos/cm**
Specific Conductance	1.9	0.01	10/09/2017
Total Dissolved Solids - SM 2540 C-2011			**mg/L**
Total Dissolved Solids (Residue,Fiterable)	1299.0	10	10/09/2017

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B- Analyte Detected in The Associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated value between MDL and PQL
E - Estimated value exceeds calibration curve
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference
TNTC - Too numerous to count

Figure 32. Anions Data Output

8.2.4 Multiparameter Meter (Figure 33)

Multiparameter meter groundwater data reported are sample ID, analysis date, sample matrix, pH in standard units, electrical conductivity in millimhos per centimeter (mmhos/cm), dissolved oxygen in mg/L, and oxidation-reduction potential (ORP) in millivolts (mV).

Sample id	Analysis Date	Sample Matrix	pH	Electrical Conductivity (mmhos/cm)	Dissolved Oxygen (mg/L)	ORP (mV)
MW-BH-multi	10/09/2017	Water	6.97	1.72	4.28	298.74

Notes:
mmhos/cm - millimhos per centimeter
ft bgs - feet below ground surface
ORP - Oxidation-Reduction Potential
mV - millivolts
mg/L - milligrams per litre

Figure 33. Multiparameter Meter Data Output

8.2.5 Total Organic Carbon (Figure 34)

Total organic carbon (TOC) groundwater data reported are sample ID, analysis date, sample matrix, reporting limit, TOC, and dissolved organic carbon (DOC) in mg/L.

Sample id	Analysis Date	Sample Matrix	Report Limit (mg/L)	TOC (mg/L)	Dissolved Organic Carbon (mg/L)
MW-BH-TOC	10/09/2017	Water	1	1.87	1.88

Notes:
ft bgs - feet below ground surface
mg/L - milligrams per litre

Figure 34. TOC Data Output

8.2.6 GENE-TRAC® (Figure 35)

Gene-Trac® groundwater data reported are sample ID, Gene-Trac® test, sample matrix, andGene-Trac® data in ribosomal ribonucleic acid (rRNA) gene copies/Liter.

Sample id	Test	GWA id	Sample Matrix	Gene Trac Dhc (16S rRNA gene copies/L)
MW-BH-Gene	Gene-Trac Dhc	DHC-1	Water	ND

Sample id	Test	GWA id	Sample Matrix	Gene Trac Dhb (16S rRNA gene copies/L)
MW-BH-Gene	Gene-Trac Dhb	DHB-1	Water	ND

Sample id	Test	GWA id	Sample Matrix	Gene Trac VC (16S rRNA gene copies/L)
MW-BH-Gene	Gene-Trac VC	VC-1	Water	ND

Notes:
ND - Not detected. The quantitation limit is 2 x 10^3 gene copies/litre.
Analyst: AL Reviewed By HG

Qualifiers:
ND/U - Not Detected at the Reporting Limit
B- Analyte Detected in The Associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated value between MDL and PQL
E - Estimated value exceeds calibration curve
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference
TNTC - Too numerous to count

Figure 35. Gene-Trac® Data Output

8.2.7 Volatile Organic Compound and Semi-volatile Organic Compound (Figures 36 and 37)

Volatile organic compound (VOC) and semi-volatile organic compound (SVOC) data reported are constituent, date analyzed, result, and reporting limit in microgram/liter (µg/L)for groundwater and in microgram/ kilogram (µg/kg) for soil. Alkalinity, specific conductance, and total dissolved solids data are also provided as part of the groundwater output.

Groundwater Analysis Report

Client Sample ID: MW-BH-VOC
Lab Sample ID: MW-BH-VOC

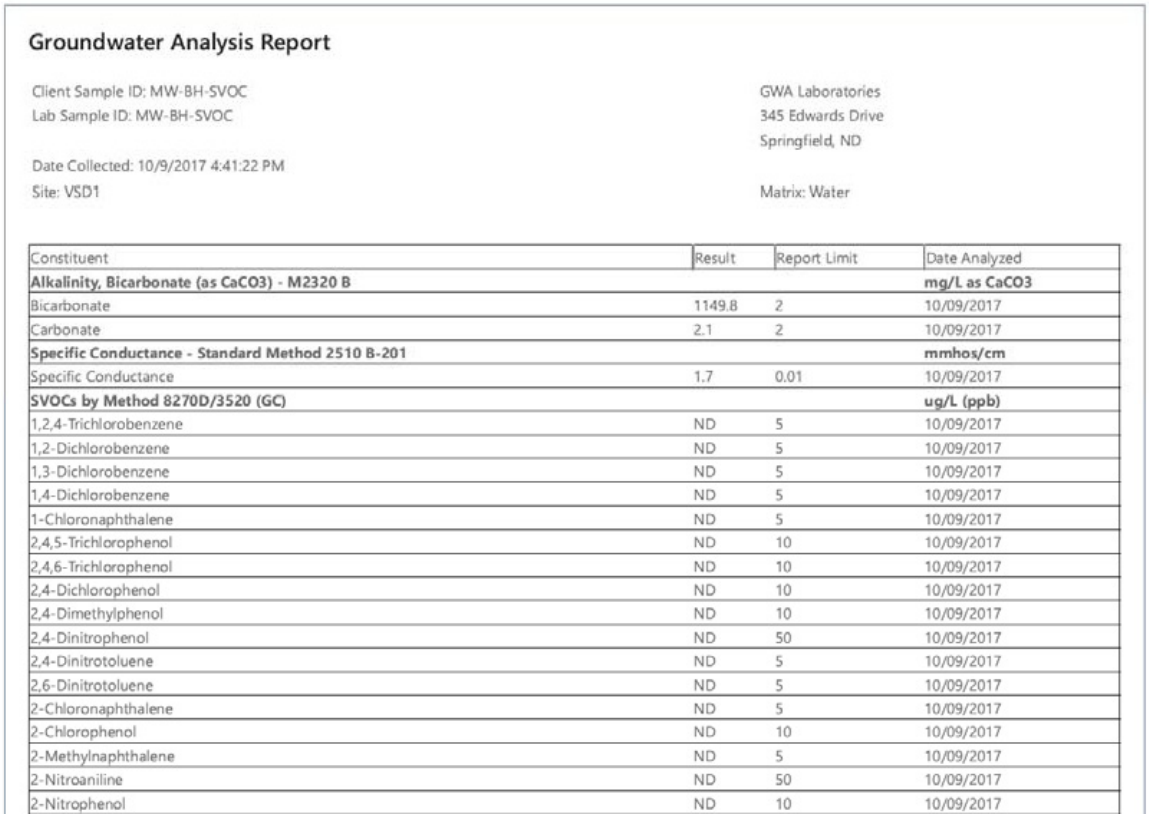
Date Collected: 10/9/2017 4:40:06 PM
Site: VSD1

GWA Laboratories
345 Edwards Drive
Springfield, ND

Matrix: Water

Constituent	Result	Report Limit	Date Analyzed
Alkalinity, Bicarbonate (as CaCO3) - M2320 B			**mg/L as CaCO3**
Bicarbonate	1149.8	2	10/09/2017
Carbonate	2.1	2	10/09/2017
Specific Conductance - Standard Method 2510 B-201			**mmhos/cm**
Specific Conductance	1.7	0.01	10/09/2017
Total Dissolved Solids - SM 2540 C-2011			**mg/L**
Total Dissolved Solids (Residue,Fiterable)	1151.9	10	10/09/2017
VOCs by Method 8260C/5030 (GC)			**ug/L (ppb)**
1,1,1,2-Tetrachloroethane	ND	1	10/09/2017
1,1,1-Trichloroethane	ND	3	10/09/2017
1,1,2,2-Tetrachloroethane	ND	1	10/09/2017
1,1,2-Trichloroethane	ND	1	10/09/2017
1,1-Dichloroethane	ND	7	10/09/2017
1,1-Dichloroethene	ND	7	10/09/2017
1,2,3,4-Diepoxybutane	ND	1	10/09/2017
1,2,3-Trichloropropane	ND	1	10/09/2017
1,2,4-Trichlorobenzene	ND	3	10/09/2017
1,2-Dibromoethane	ND	1	10/09/2017
1,2-Dichlorobenzene	ND	2	10/09/2017
1,2-Dichloroethane	ND	3	10/09/2017

Figure 36. VOC Data Output, Partial



Groundwater Analysis Report

Client Sample ID: MW-BH-SVOC
Lab Sample ID: MW-BH-SVOC

Date Collected: 10/9/2017 4:41:22 PM
Site: VSD1

GWA Laboratories
345 Edwards Drive
Springfield, ND

Matrix: Water

Constituent	Result	Report Limit	Date Analyzed
Alkalinity, Bicarbonate (as CaCO3) - M2320 B			**mg/L as CaCO3**
Bicarbonate	1149.8	2	10/09/2017
Carbonate	2.1	2	10/09/2017
Specific Conductance - Standard Method 2510 B-201			**mmhos/cm**
Specific Conductance	1.7	0.01	10/09/2017
SVOCs by Method 8270D/3520 (GC)			**ug/L (ppb)**
1,2,4-Trichlorobenzene	ND	5	10/09/2017
1,2-Dichlorobenzene	ND	5	10/09/2017
1,3-Dichlorobenzene	ND	5	10/09/2017
1,4-Dichlorobenzene	ND	5	10/09/2017
1-Chloronaphthalene	ND	5	10/09/2017
2,4,5-Trichlorophenol	ND	10	10/09/2017
2,4,6-Trichlorophenol	ND	10	10/09/2017
2,4-Dichlorophenol	ND	10	10/09/2017
2,4-Dimethylphenol	ND	10	10/09/2017
2,4-Dinitrophenol	ND	50	10/09/2017
2,4-Dinitrotoluene	ND	5	10/09/2017
2,6-Dinitrotoluene	ND	5	10/09/2017
2-Chloronaphthalene	ND	5	10/09/2017
2-Chlorophenol	ND	10	10/09/2017
2-Methylnaphthalene	ND	5	10/09/2017
2-Nitroaniline	ND	50	10/09/2017
2-Nitrophenol	ND	10	10/09/2017

Figure 37. SVOC Data Output, Partial

8.2.8 NAPL Dye Test (Figure 38)

Shake test soil data reported are sample ID, sample depth in ft below ground surface (bgs),analysis date, sample matrix, and the hydrophobic dye tests results/observations.

Sample id	Sample Depth (ft bgs)	Analysis Date	Sample Matrix	Dye Test Results/ Observations
BH-5_NAPL_dye	67.5	10/09/2017	Soil	Negative

Notes:
ft bgs - feet below ground surface

Figure 38. NAPL Dye Test Data Output

8.2.9 Fraction of Organic Carbon (Figure 39)

Fraction of organic carbon (foc) soil data reported are sample ID, sample depth in ft bgs, analysis date, sample matrix, TOC in mg/kg and fraction organic carbon in grams per gram (g/g).

Sample id	Sample Depth (ft bgs)	Analysis Date	Sample Matrix	Total Organic Carbon (mg/kg)	Fraction Organic Carbon (g/g)
BH-5_FOC	67.5	10/09/2017	Soil	3709.25	0.00370925

Notes:
ft bgs - feet below ground surface
foc - fraction of organic carbon

Figure 39. FOC Soil Data Output

8.2.10 Grain Size Distribution (Figure 40)

Soil data grain size distribution data presented in the form of a graph with % finer particleson the y-axis and the particle size along the x-axis.

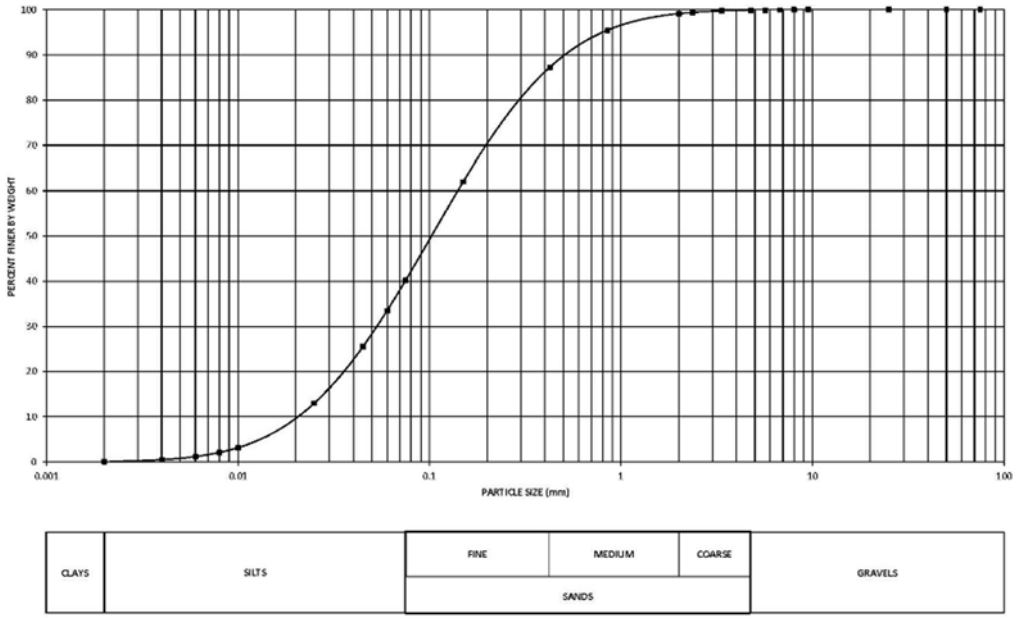


Figure 40. Grain Size Distribution Data

8.3 MIP DATA (FIGURE 41)

In the MIP logs, both depth in feet, and elevation in feet above mean sea level (amsl) are recorded along the Y-axis. Four measurements are recorded on the MIP logs. These are electron capture (ECD) in volts (V), photoionization (PID) in V, electricalconductivity (EC) in milliSiemens/ meter (mS/m), and estimated hydraulic conductivity (K) in feet/day (ft/d).

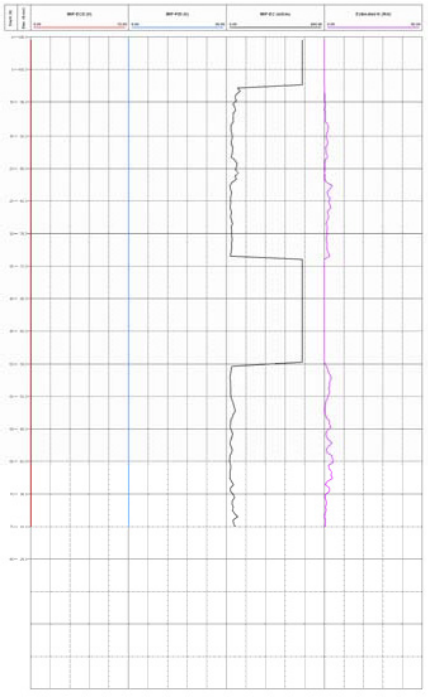


Figure 41. MIP Log Output

8.4 SLUG TEST DATA (FIGURE 42)

The data provided from a slug test are the top and bottom depth in feet (of the screen in the monitoring well) and hydraulic conductivity as calculated in centimeter/second (cm/s).

Slug Test

Monitoring Well	Top Depth	Bottom Depth	Hydraulic Conductivity (cm/s)
MW-1D	66.25	71.25	0.0008
MW-1S	20.35	25.35	0.00168
MW-2D	63.4	68.4	0.00076
MW-2S	17.45	22.45	0.00105
MW-3D	63.5	68.5	0.00065
MW-3S	17.55	22.55	0.00062
MW-4D	62.95	67.95	0.00271
MW-4S	16.98	21.98	0.00322

Notes:
Slug Dimensions: Length = 3.00 ft, Diameter = 1.50 in
Pressure transducer accuracy: +/- 3mm

Figure 42. Slug Test Data Output

8.5 DYE-LIF DATA (FIGURE 43)

In the DYE-LIF logs, both depth in feet, and elevation in ft amsl are recorded along the Y-axis. The signal in % relative emission (% RE) is provided on the right-hand side of the output as a red line.

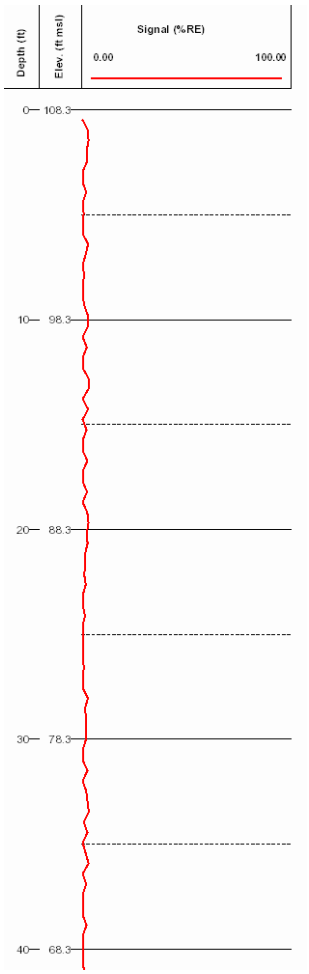


Figure 43. DYE-LIF Log Output

9.0 LONG-TERM MONITORING MODULE

The long-term monitoring (LTM) module is intended to allow users to gain experience in the optimization of monitoring programs at sites following remediation or under a monitored natural attenuation approach. There are 3 sites (VSD5 through VSD7) that have undergone site investigation and remediation and are in a current long-term monitoring program.

The starting GUI for the LTM module is shown in Figure 44. There are 3 components to the GUI:

- A map of the site showing the existing monitoring infrastructure
- A data information panel
- A graphical output panel showing concentration versus time for selected analytes at selected wells

Figure 44. Long-term Monitoring GUI

Site background data (and this user manual) are available as hyperlinks in the top left of the GUI. Background data includes a site history document as well as borehole and monitoring well logs for the site.

At the start of the optimization process, monitoring data is available to a certain date (e.g., 2015 for VSD5). The user is required to examine the historical data and to select monitoring wells to carry forward for long-term monitoring (LTM plan). The regulatory drivers for each site are provided in the site history document and should be used to guide the selection of monitoring into the future. For example, in VSD5 the only identified receptors at the site involve the river to the north where groundwater discharges. The risk-based criteria for the site are provided in the site history document and should be used to design a monitoring plan that provides early warning if the receptor is at risk.

In addition to the monitoring program providing indications that the risk-based criteria may be exceeded at the receptor, the possibility exists that the remediation was not entirely successful and the monitoring program should also include wells that may indicate that the remediation was not successful at meeting the remediation performance criteria (e.g., a portion of the source zone was "missed" by the thermal remedy in VSD5 and continues to act as a source to the groundwater plume).

The selection of long-term monitoring locations should be based on (amongst others):

- Monitoring impacts to receptors
- Monitoring the "success" of the remediation program
- Providing data for assessment of passive approach such as monitored natural attenuation

The user will have 2 opportunities to refine the LTM plan (i.e., if the first attempt is not satisfactory to the user wells can be added or deleted in a second attempt).

9.1 INTERROGATING THE HISTORICAL DATA

To examine the historical data at a monitoring location the monitoring well is selected in the map (Figure 45), the constituent of interest is selected from the list (Figure 46), and the yellow 'View Well Data' button is clicked. The historical data for the selected constituent at the selected monitoring well is then displayed in the graph at the bottom of the page (Figure 47). Many of the monitoring locations contain multi-level wells. Individual wells can be selected by using the arrow (e.g., '1 of 4') at the bottom of the pop-up window.

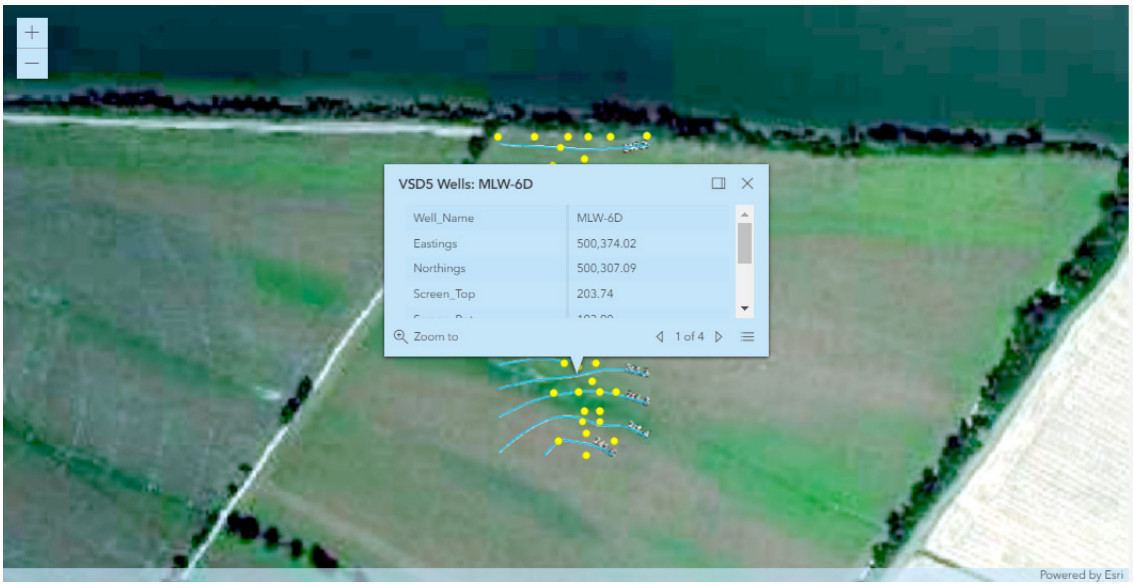


Figure 45. Monitoring Well Selection

Figure 46. Constituent of Interest Selection

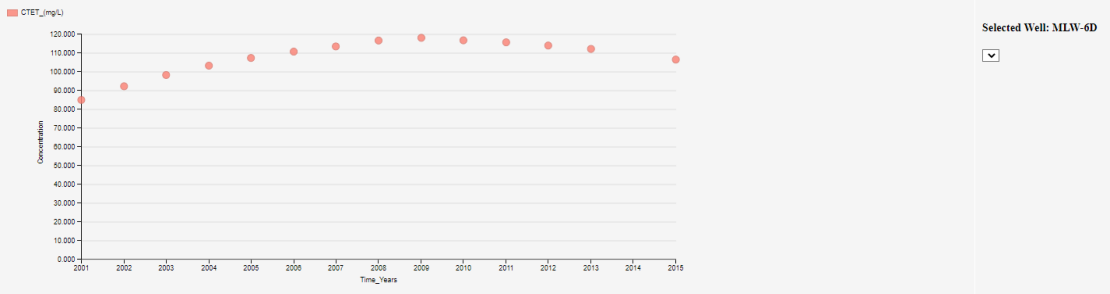


Figure 47. Graphical Output

9.2 DEVELOPING THE LTM PLAN

If a well is to be added to the proposed LTM plan, then it is added by selecting the blue 'Add Well to Monitoring Plan' button. This will cause the well to be highlighted red in the map and be added to the 'Currently selected Wells' window in the data information portion of the GUI (Figure 48).

Figure 48. Adding Wells to the LTM Plan

Once all the wells have been added to the proposed LTM plan select the green 'Submit Monitoring Plan' button (Figure 49).

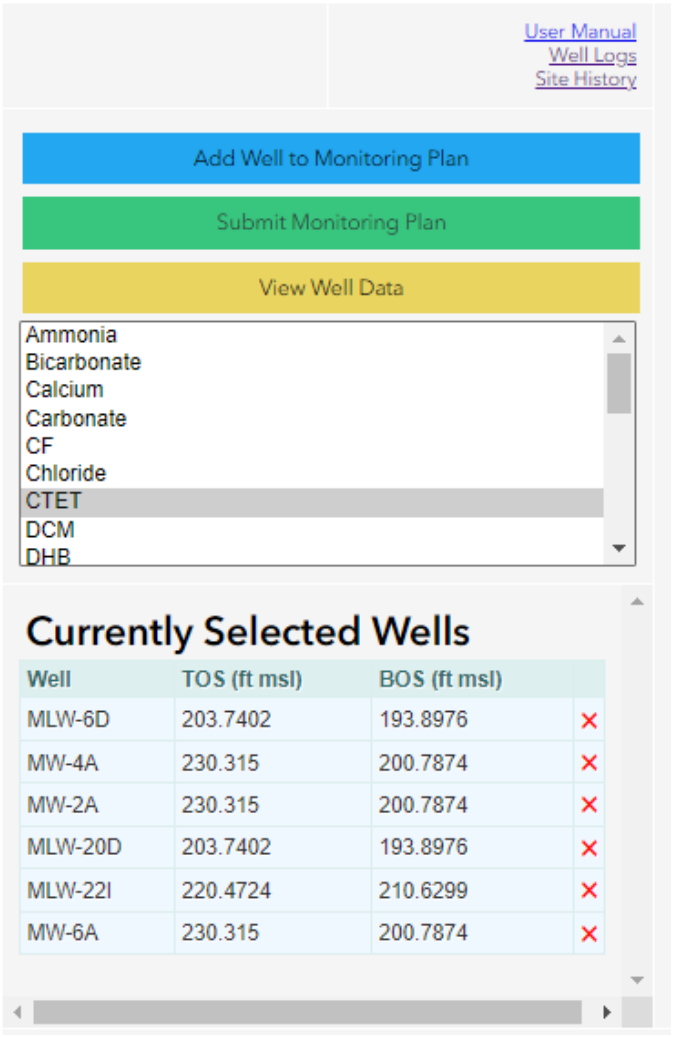


Figure 49. Proposed LTM Plan

Following submission of the LTM plan, additional data will become available in the graphical display window (Figure 50—note data is now available to 2019).

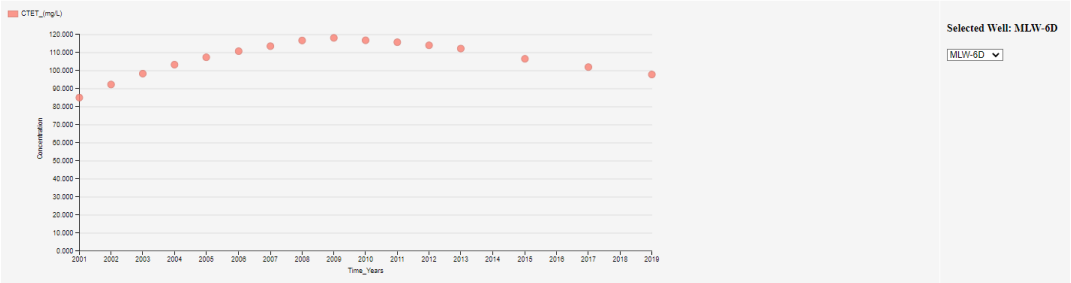


Figure 50. Additional Data Availability Under LTM Plan

Data for different wells in the LTM plan can be quickly viewed by selecting the toggle at the top right of the graphical display window (Figure 50).

Following user consideration of the additional data now available at monitoring wells in the LTM plan, a second attempt can be made at refining the LTM plan. The process is the same as the first monitoring well selection process, however newly added wells are now highlighted purple in the map (Figure 51).

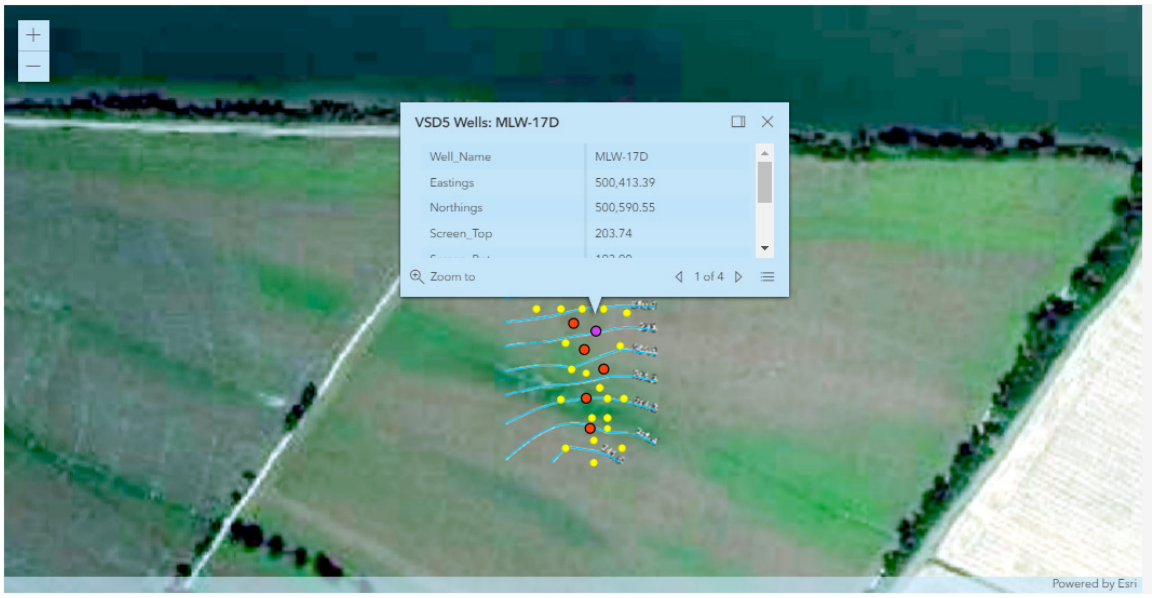


Figure 51. Wells Selected in the Second Attempt

Following submission of the second attempt (which is the final attempt allowed in TEMPO) data into the future is now viewable in the graphical display window (Figure 52).

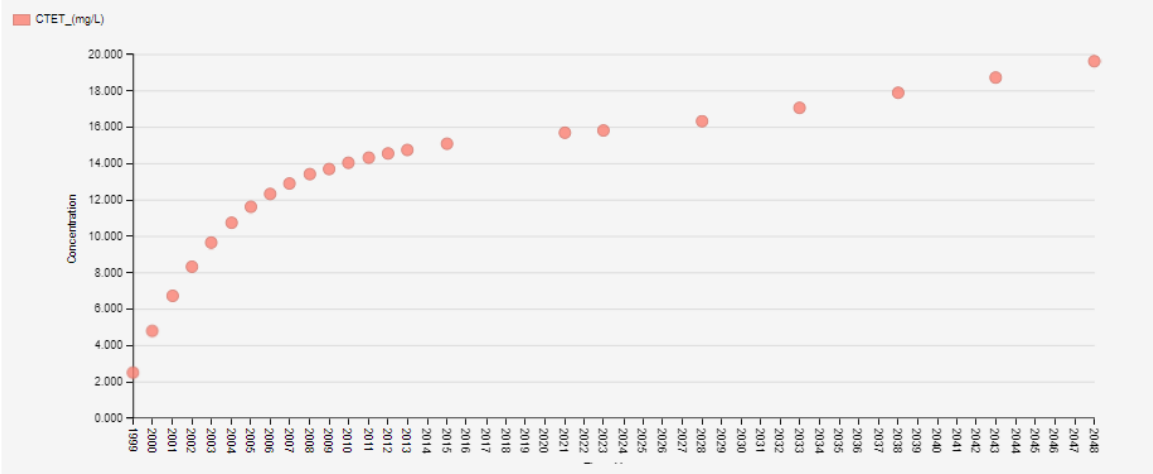


Figure 52. Future Data Following Second LTM Plan Attempt

It is clear that the monitoring well data shown in Figure 52 indicates a continuing source of CTET at the site and is potentially an indicator that the remediation goals were not met at the site and there will be a future risk to receptors in the river.

Optimization of a LTM plan requires experience, an understanding of the science of contaminant fate and transport (e.g., consideration of attenuation, degradation, geologic controls on flow, and other factors) and a deep dive into the large data sets available. Resources to assist the user with this process are available from the 'Tools and Resources' section accessed from the main page.

Although there is no "right" answer to the LTM plan for each site (it is possible that different combinations could fulfill the objectives) an indication of an appropriate LTM plan for each site (based on access to perfect information) can be viewed following submission of the second attempt by selecting the 'Master Solution' button in the top left of the GUI.

The final Beta release of TEMPO is available at:

www.build-a-csm.com