



Groundwater Sensitivity TOOLKIT

Users Guide Version 1.0

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GROUNDWATER SENSITIVITY TOOLKIT

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APPENDIX A: GROUNDWATER SENSITIVITY LOGIC DESIGN

Disclaimer: The Groundwater Sensitivity Toolkit is made available on an as-is basis without guarantee or warranty of any kind, express or implied. The authors and reviewers accept no liability resulting from the use of the toolkit or its documentation. Implementation of the toolkit and interpretation of the results are the sole responsibility of the user.

FOREWORD

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ABOUT THE GROUNDWATER SENSITIVITY TOOLKIT

The Groundwater Sensitivity Toolkit was designed to help site managers, water purveyors and regulators evaluate the sensitivity of a groundwater resource to a potential release at a particular site. This screening tool cannot anticipate all factors that may affect groundwater sensitivity at a given site. Therefore managers, purveyors, and regulators may need to consider other factors as well.

The toolkit examines three aspects of sensitivity:

- Natural Sensitivity
- Receptor Vulnerability
- Resource Value

The user enters in site-specific information about the site, and the Toolkit returns a three-section "scorecard" addressing the three aspects of sensitivity. This scorecard may be used to prioritize and categorize the sites in a catalog.

The Groundwater Sensitivity Toolkit was developed for the American Petroleum Institute and the California MTBE Research Partnership by Groundwater Services, Inc.

QUICK START

MINIMUM SYSTEM REQUIREMENTS

The Groundwater Sensitivity Toolkit may be used on a computer system running Windows 98/NT/2000/XP and Microsoft Excel™ 97SR-1/2000/XP. A minimum of 64 MB of system memory, 25 MB of free disk space and virtual memory is required.

INSTALLATION

The Groundwater Sensitivity Toolkit is distributed as a self-extracting ZIP file, Setup.exe, containing the following files:

Sensitivity.xls	Sensitivitytoolkit
Sensitivity.ch	Help file
Readme.txt	Readme
CaseStudy.xls	Case Study example file

The user will be prompted to specify the directory to which to extract the files. By default, the zip file will extract to c:\Sensitivity. Extracting the program into another folder should not cause any problems, although the user may want to check with the network administrator before attempting to install all of it on a central server. A sample help file, the Microsoft Excel file, together, and to maintain the original names. In addition, the user may also want to set the Sensitivity.xls to read-only to minimize the chance of corruption of macros during use.

DATA INPUT AND OUTPUT

The toolkit was designed to run under Microsoft Excel™ with Visual Basic for Applications (VBA). Input values are entered into spreadsheets and navigation among the cells on each individual input screen can be performed using the arrow keys or the mouse, just as with any spreadsheet. The individual screens of the toolkit may be printed using the buttons provided or by using the "Print" command (Ctrl+P) command in Microsoft Excel's "File" menu.

ON-LINE HELP

Each input and output screen is described in detail in this manual and in the on-line help text. To access on-line help for a particular input section, click on the help buttons located throughout the software.

TECHNICAL SUPPORT

Limited technical support related to compatibility issues for the Groundwater Sensitivity Toolkit is available from GSI via phone at 713-522-6300, fax via 713-522-8010, or email at gwsensitivitytoolkit@listserve.api.org. Please be sure to include contact information, the version of the toolkit, and the version of Microsoft Windows/Office that you are using.

INTRODUCTION

PURPOSE

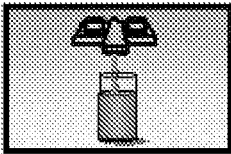
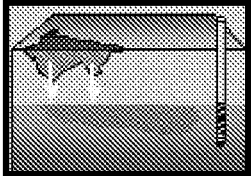
Groundwater sensitivity is a key consideration in the development and implementation of appropriate corrective actions at potential release sites, such as leaking underground storage tanks, landfills, and other sources. Experience shows that actual impacts on critical water supply resources have occurred at a relatively small number of sites. Due to the risk of potential exposure, these high-sensitivity sites should warrant a large percentage of the available public and private resources for release prevention, assessment, and remediation.

However, practical, site-specific measures of groundwater sensitivity may not be sufficiently considered in release prevention efforts and the development of remediation goals. As a result, low sensitivity and high sensitivity sites may be frequently treated as equivalent concerns. This results in an inefficient allocation of available remediation/prevention dollars.

The Groundwater Sensitivity Toolkit is a decision support expert system that allows a user to enter site-specific parameters to generate a scorecard for that site. This scorecard, when compared to the scores for other sites in a portfolio, gives the decision-maker insight into how resources should be allocated amongst the portfolio.

METHOD

This scorecard is based on three separate but related issues for a site:

Resource Value 	Importance of the groundwater to water purveyors, municipalities, domestic groundwater users, or natural systems.
Receptor Vulnerability 	Impact of a release to groundwater to existing (not potential) receptors who are using groundwater from any hydrogeological unit.
Natural Sensitivity 	Effectiveness of natural factors (such as the depth to water, soil type, etc.) in preventing a release at this location from impacting groundwater.

A user may enter data for up to three aquifers for a site. For each aquifer, a HIGH, MEDIUM, or LOW score is determined for each of the three issues. The results may be printed out, and the project may be saved to a data file for later revision.

MAIN SCREEN

The main screen serves as the central point for the toolkit. It is the launch point to all other sections of the toolkit and is the place where general information about the project, such as name, location, date, and aquifer names is entered. The main screen is also the place in the toolkit where the user may create, load, and save data input files.

Main Screen

The Groundwater Sensitivity Tool Kit can help you determine how sensitive groundwater is to a potential release from a particular site (such as a gasoline service station, landfill, or other source)*. It evaluates sensitivity on the basis of resource value, receptor vulnerability, and natural sensitivity. Enter the requested data on this page and on subsequent pages to determine if the groundwater sensitivity is High, Medium, or Low.

1. Enter Project Information

Site Name:
 Location:
 Compl. By:
 Date: Job ID:

2. Deeper Hydrogeologic Units*

Are there one or more deeper water-bearing units (not including aquitards or confining units)? ☐ Yes ☐ No

3. Name of Hydrogeologic Units*

enter name to continue:
 First Encountered Water-Bearing Unit:

* enter water bearing units only, do not enter aquitards or confining units

4. Evaluation Steps

Click on each button and enter required data. When the first three buttons are complete, click on the Results button.

RESOURCE VALUE

RECEPTOR VULNERABILITY

NATURAL SENSITIVITY

RESULTS

INSTRUCTIONS

- ☒ Data Incomplete
- ☒ Data Complete
- ☐ Enter Data Here
- ☐ Calculated Value (do not enter data)

PROJECT INFORMATION

Basic site and project information is entered here and will be displayed on all input and output screens for easy identification and recordkeeping.

DEEPER HYDROGEOLOGIC UNITS

This question asks if there are multiple units under consideration. Click yes if there are multiple units, or if the unit under consideration has overlying hydrogeologic units.

NAME OF HYDROGEOLOGIC UNITS

The toolkit permits the user to enter information for up to three hydrogeologic units. This is where you may enter a name for the unit. For sites where there is only one unit of interest, the user can enter information for the Top Unit only. Entering a name into either the Middle or Bottom Unit spaces will display the buttons for that unit in the Evaluation Steps section.

EVALUATION STEPS

The buttons located on the Evaluation Steps screen provide a gateway for all other input pages in the project. By default, the buttons for the middle and bottom units are hidden. To display the other two units, a name must be entered in the Hydrogeologic Units section.

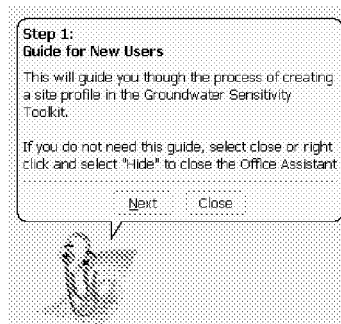
COMMANDS

- **New Site:** Clear all input values, resets options for the current project, and resets any default values. If the current data set is not saved, a message will prompt the user to either save or discard any changes.
- **Load Site:** Loads the input values and options for a previously saved project data set. If the current project data set is not saved, a message will prompt the user to either save or discard any changes.
- **Save Site:** Saves all input values and options for the current data set as a separate Microsoft Excel™ workbook (a .xls file). Saved data files do not have to be in a directory as application files for the Groundwater Sensitivity Toolkit.

Note: Workbooks created by this method are formatted for use with the Sensitivity Toolkit. Editing the files should only be done with the Sensitivity Toolkit and attempting to change the files manually in Microsoft Excel™ may corrupt the file.

- **Quit:** Quits the Groundwater Sensitivity Toolkit.
- **Print Page:** Opens the Print Preview for the sheet and allows the user to print the sheet.
- **New User:** Opens the Office Assistant to guide first-time users. This option only works for users of Office 2000 and XP.

New User Guide



RESOURCE VALUE

The Resource Value is an indication of the potential a water-bearing unit has for becoming a usable water supply or a resource to support natural systems.

Determine Resource Value: Shallow Aquifer



Resource Value is how important the groundwater in this unit is or potentially is to water purveyors, municipalities, domestic groundwater users, or natural systems. Answer these questions to determine if resource value is high, medium, or low.

REGULATORY USE

1. Answer YES only if both of the following statements are true, otherwise, answer NO:

a) Groundwater use at this location is precluded by some type of existing regulatory restriction.

b) There is no groundwater discharge to a high- or moderate-value surface water within 2500 ft* of this location.

2. Is the water-bearing unit a sole-source aquifer or does the unit serve an area with no alternative supply? (no if unknown)

3. Is the unit currently being used? (are there any drinking water wells screened in the unit within 2500 ft*?) (no if unknown)

4. Is there a publically available water development plan indicating that the aquifer will be used, or can it be reasonably anticipated to be used in the future?

RESOURCE USABILITY

5. Evaluate the potential for future use of water based on well yield, quality, and water resource planning information.

Instructions: Use calculators to estimate well yield and impact of water quality.

WELL YIELD CALCULATOR

Hydraulic cond.(K) cm/sec

Aquifer thickness (b) ft

Confining head (h_c) ft
(enter 0 for an unconfined aquifer)

Estimated Well Yield (Q)^{*} gpd

Picture

Resource value based on yield:

WATER QUALITY CALCULATOR

Total Dissolved Solids (C_{TDS}) mgd

Regional Contam. > MCL?

Yes
No

Resource value based on quality:

* Use calculated value, or override by entering your own well yield.

Site Name:

Location:

Compl. By:

Job ID:

Return to Main Menu

Print Page Clear Values Help

RESULT:

Resource Value

NOT COMPLETE

The first four questions address any policy-based usage of this aquifer. In the toolkit, policy-based considerations override the engineering considerations when determining resource value for an aquifer. The fifth question, in two parts, addresses the two major limitations on water production from an aquifer.

POLICY QUESTIONS

1. If groundwater use is precluded by some type of regulation or law (such as a no-pumping rule) then the Resource Value is defined as LOW as it is not usable for a resource water-supply purposes.
2. If the water-bearing unit is a sole-source aquifer as defined by federal or state regulations, then the Resource Value is defined as HIGH as the water-bearing unit is a vital water supply resource.
3. If the water-bearing unit is currently being used in the vicinity of the site of interest, then the Resource Value is considered HIGH as it is a usable water supply resource. For the purposes of this software, the software development committee used a distance of 2500 ft to determine if water supply wells (either domestic, municipal, irrigation, or industrial) that are screened in the water-bearing unit have the potential for being affected by the site of interest. This distance was based on general experience about the potential conservative (high-end) length of contaminant plumes.
4. If there is a formally adopted water supply plan (adopted by regulatory body such as a city, county, regional planning board, state, etc.) that indicates that the unit may be used as a

drinking water supply in the near future (i.e., within a few years), then the Resource Value is automatically upgraded to MEDIUM.

RESOURCE USABILITY: Well Yield

Determination of well yield addresses the ability of a unit to produce water and is a primary concern when deciding if a water-bearing unit with no production or policy information has the potential to become a water supply resource. The well yield is determined from calculations based on hydraulic conductivity, aquifer thickness, and confining head. The software development committee developed the following rules to define Resource Value as a function of well yield based on regulatory approaches used in several states:

Well Yield	Resource Value Rating
above 144000 gpd (100 gpm)	HIGH
between 200 and 144000 gpd	MEDIUM
less than 200 gpd	LOW

RESOURCE USABILITY: Water Quality

The quality of water in an aquifer is another primary concern that determines resource value. Total dissolved solids (TDS) adversely affect aquifer quality, and any water produced from a high TDS aquifer often precludes use of a groundwater resource as a water supply.

Water Quality	Resource Value Rating
TDS below 500 mg/L	HIGH
TDS between 500 and 3000 mg/L	MEDIUM
TDS above 3000 mg/L	LOW

In addition, the software asks the user if a regional contaminant (such as nitrate) is above the MCL (either secondary or primary) is then the Resource Value is defined as being LOW. Examples of regional contaminants include nitrate, radium, coliform, and some wide-scale man-made contaminants (wide-scale means not from a particular site of interest). In many cases, the regional contaminant will come from diffuse non-point sources rather than from a particular site.

The Resource Value addresses the potential of usage for that aquifer, and considerations regarding the aquifer proximity to surface water bodies or other discharge points to another unit are addressed in other sections of the toolkit.

The final Resource Value is the lower of the two usability criteria unless the answer to question 4 is "yes," in which case the software automatically upgrades the value to at least a MEDIUM.

RESOURCE TO SUPPORT NATURAL SYSTEMS

Many of the criteria above are related to drinking water supply issues. For the purposes of this general planning software, the software development committee is assuming that resource value related to water supply issues will be a good estimate in most cases for the value of a water-bearing unit to natural systems.

RECEPTOR VULNERABILITY

The Receptor Vulnerability section addresses the impact of a release to groundwater to existing (not potential) receptors that are using groundwater from any hydrogeological unit. An aquifer may be affected by horizontal migration of a contaminant to the extraction point, or by vertical migration from a shallower unit.

Two key points are:

1. Analysis of vertical vulnerability will not be needed for the shallowest water-bearing unit, as there is no water-bearing unit above it.
2. The main receptor vulnerability screen allows the user to start with either vertical or horizontal vulnerability, but it is recommended that the user begin by addressing vertical vulnerability first, if there is an upper water-bearing unit above the water-bearing unit of interest.

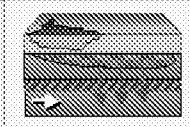
Note that this has been designed by the software development committee to be a conservative analysis and will tend to over predict the risk to existing receptors from an actual or potential release from the site of interest.

Determine Existing Receptor Vulnerability: Middle Unit

Existing receptor vulnerability is how much of a threat a release to groundwater to existing (not potential) receptors who are using groundwater from any hydrogeological unit (not just the one being evaluated). Click on the buttons below to determine if existing wells or planned wells at or near this location have high, medium, or low vulnerability to a release.

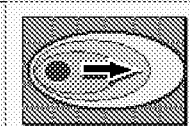
Is there a potential for vertical migration into this unit from an overlying unit?

Vertical Migration



Is there a potential for horizontal migration in this unit?

Horizontal Migration



RESULT:

Receptor Vulnerability

NOT COMPLETE

Site Name:

Location:

Compl. By:

Job ID:

Return to Main Menu

Print Page

Help

VERTICAL VULNERABILITY

The Vertical Vulnerability section addresses the potential for the vertical migration of contaminants from a shallower water-bearing unit to the unit of interest. The toolkit addresses the case in which groundwater from an upper aquifer can seep through an aquitard (confining layer) or an artificial penetration to affect the water-bearing unit of interest. Factors that are related to how easily contaminants can travel through the vadose (unsaturated) zone are handled in the Natural Sensitivity section of the software.

The vertical transport section examines transport occurring in the following scenario: The unit of interest may receive contaminated groundwater from an upper water-bearing unit by either: 1) groundwater flow through an aquitard or through an artificial penetration (such as an inadequately sealed well or a well that has been screened across multiple units).

Receptor Vulnerability

Answer these questions to determine if there is a potential for vertical migration from a shallow unit to this unit.



VERTICAL MIGRATION POTENTIAL
Hydrogeologic Guidance

1. Do data from continuous cores show 50 ft or more of homogeneous, continuous, fine-grained material (clay or shale) over the ultimate area of a plume from the site with no artificial penetrations between the upper unit and lower unit, and wells in this deeper unit?

Yes No

Planning Level Calculation: Artificial Penetrations

3. Is there a potential for an artificial penetration within the area of ultimate extent of the upper plume?

Yes No

4. Enter data and answer the questions below:

Planning Level Calculations: Aquitards

2. Enter data and answer the questions below:

See graphic of flow through aquitard

Parameter	Value	Units
Potentiometric Surface Elevation of this aquifer (H _{thisunit})		ft
Horizontal Hydraulic gradient of this unit (I _{thisunit})		ft/ft
Hydraulic conductivity of this unit (K _{thisunit})		cm/sec
Horizontal Darcy velocity (V _{thisunit}) in this unit		ft/yr
Mixing zone thickness in this unit (δ _u)		ft
Potentiometric Surface Elevation of upper aquifer (H _{upper})		ft
Concentration in the upper unit (C _{u,avg})		mg/L
Ultimate length of plume in upper unit (L _u)		ft
Thickness of aquitard (b _{aquitard})		ft
Vertical Hydraulic conductivity to this unit (K _{vert})		cm/sec
Vertical Hydraulic gradient in aquifer (I _{vert})		ft/ft
Vertical Darcy velocity (V _v) through aquitard		ft/yr
Resulting mass flow entering this unit		mg/L/ft/yr
Resulting concentration in this unit		mg/L
Is this concentration greater than the regulatory limit?	Yes No	

See graphic of flow through penetration

Parameter	Value	Units
Potentiometric Surface Elevation of this aquifer (H _{thisunit})		ft
Hydraulic gradient of this unit (I _{thisunit})		ft/ft
Hydraulic conductivity of this unit (K _{thisunit})		cm/sec
Mixing zone width in this unit (W _u)		ft
Mixing zone thickness in this unit (δ _u)		ft
Concentration in the upper unit (C _{u,avg})		mg/L
Potentiometric Surface Elevation of upper aquifer (H _{upper})		ft
Thickness of aquitard (b)		ft
Vertical Hydraulic gradient in aquifer (I _{vert})		ft/ft
Hydraulic conductivity of material in penetration or annulus (K _a)		cm/sec
Cross section area of penetration (A _p)		ft ²
Downward flow through penetration (Q _d)		ft/yr
Darcy Velocity of this unit		ft/yr
Resulting concentration in this unit		mg/L
Is this concentration greater than the regulatory limit?	Yes No	

Go to Receptor Vulnerability Main Screen

Go to Part 2: Horizontal Vulnerability

Vertical Vulnerability: --
Horizontal Vulnerability: --
Receptor Vulnerability: **NOT COMPLETE**

Site Name: _____
Location: _____
Compl. By: _____
Job ID: _____

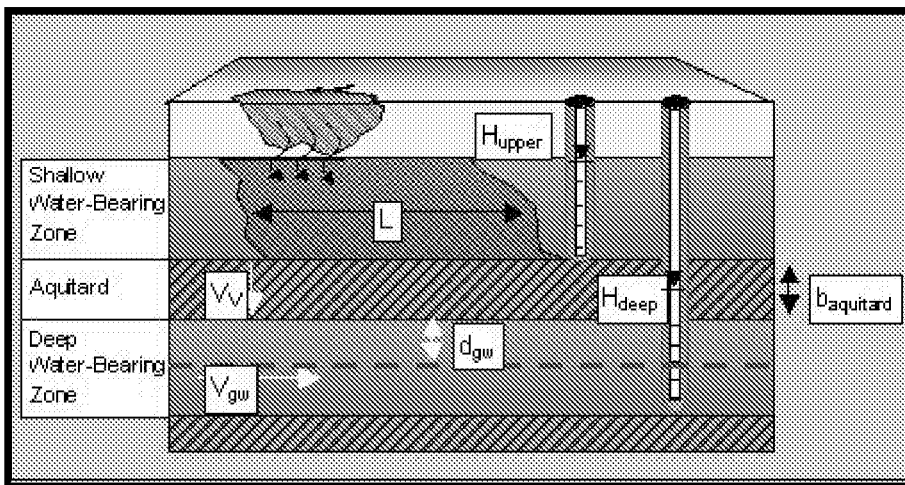
Return to Main Menu

Print Page Clear Values Help

Four main questions are asked in this section. Questions 1 and 3 are general questions regarding the possibility of transport via aquitard transport or artificial penetration, respectively. Questions 2 and 4 provide the user with supporting calculations to determine if the aquifer could be negatively impacted by a release to an upper unit through aquitard transport or artificial penetration. The user should understand that a "no" answer for either 1 or 3 determine if the calculations in 2 or 4, respectively, are performed.

Aquitards

A contaminant in an upper water-bearing unit may reach a lower water-bearing unit by transport through an aquitard.

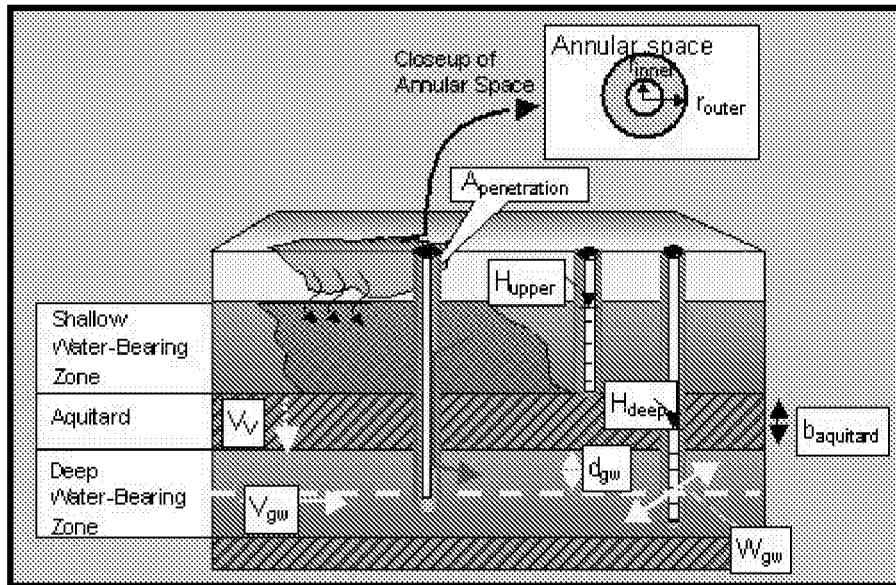


The first question is designed to rule out potential transport through aquitards if there is strong hydrogeologic/stratigraphic information that the aquitard is likely to prevent vertical transport to this water-bearing unit. The second question provides a quantitative tool to estimate the resulting concentration in this water-bearing unit after groundwater migrating from the upper water-bearing unit through the aquitard mixes with groundwater in this water-bearing unit. This calculation is based on potentiometric level, aquifer thickness, concentration in the contaminated unit, mixing layer thickness, and ultimate length of plume in the upper unit. The equations used in this calculation may be viewed by clicking the "See graphic of flow-through aquitard" button.

Once the concentration has been calculated, the user may compare the lower unit concentration to the MCL or other relevant regulatory standard to answer Question 2. Mass flux information associated with transport through the aquitard is also provided.

Artificial Penetrations

A contaminant in an upper water-bearing unit may reach this water-bearing unit by flowing through an artificial penetration. Examples of artificial penetrations include poorly sealed wells or wells screened across units.



The third and fourth equations address the potential for contamination to flow through an artificial penetration to a lower unit. The fourth equation calculates the concentration in the lower unit based on penetration cross sectional area, mixing zone, concentration, potentiometric level, and hydraulic conductivity. The equations used in this calculation may be viewed by clicking the "See graphic of flow-through penetration" button.

Once the concentration has been calculated, the user may compare the lower unit concentration to the MCL or other relevant regulatory standard to answer Question 4. Mass flux information associated with transport through the artificial penetration is also provided.

HORIZONTAL VULNERABILITY

Horizontal Vulnerability addresses the potential for horizontal migration from a site of interest to a well. The first two questions address the possibility of transport to a public water supply, while the remaining questions determine the capture zone and travel time to a water supply well in the vicinity of the site.

Receptor Vulnerability **Shallow Aquifer**

Answer these questions to determine if there is a potential for horizontal migration to an existing receptor. When the box in the "Go to Receptor Vulnerability: Main Screen" button is green, go back to the Receptor Vulnerability Main Screen to see the final result.

HORIZONTAL MIGRATION POTENTIAL

Location-Based Evidence

1. Is the location a potential MTBE source within 2500 ft of a current or potential municipal drinking water well in the same unit in any direction, or within 2500 ft upgradient from a current or potential domestic water well in the same unit, or within 2500 ft of sensitive surface water receiving groundwater discharge? ☐ Yes ☒ No

2. Is location on fractured bedrock geology or karst geology that is used as public water supply within 2 miles? ☐ Yes ☒ No

Planning-Level Calculation - Capture Zone

3. Enter data or answer questions below for up to four wells that are either screened in this unit or can pull water from this unit.

Well ID	Y distance from center flowline to location	X dist. upgradient (negative) from well to loc.	Pumping rate of well (Q)	Hydraulic conductivity of unit (K)	Saturated thickness of unit (b)	Hydraulic gradient of unit (G)	Groundwater Darcy velocity (V _G)	Is the site in the capture cone?	Effective porosity (n _e)	Travel time from site to well (t _T)
1										
2										
3										
4										

Click to display details for this well

Horizontal Migration Result

Click to display details for this well

Site Name:

Location:

Compl. Dt:

Job ID:

Vertical Vulnerability: n/a

Horizontal Vulnerability: n/a

Receptor Vulnerability: NOT COMPLETE

Go to Receptor Vulnerability Main Screen

Return to Main Menu

Print Page **Clear Values** **Help**

For Question 1, the software development committee has utilized a distance of 2500 ft to help users decide if there is a municipal water supply well or discharge point close enough to the site of interest that the well might be threatened by a potential release. To answer "yes" to Question 1, the well must be screened in the water-bearing unit that is being analyzed. If a discharge point is being considered, then the site of interest must be located upgradient of the discharge point. Note that 2500 ft is used as an example plume length for a recalcitrant compound. The user may elect to use 1200 ft if the constituent of concern is known to degrade significantly in groundwater or otherwise use a distance that represents the longest plume length for the constituent in concern in that area, assuming that the plume used for reference has stabilized.

For Question 2, the user should indicate if the site of interest is located near a fractured bedrock or karst water-bearing unit that is being used for a water supply. This question was adapted from California's "Guidelines for Investigation and Cleanup of MTBE and Other Oxygenates, 2001."

Question 3 permits the user to enter data for up to four wells to determine if a plume emanating from the site of interest lies within the capture zone of the well. The capture zone is determined individually for each well, and collective drawdown from a group of wells is not considered in this calculator. The user may view the capture zone for an individual well by clicking the radio buttons below the input column for that well.