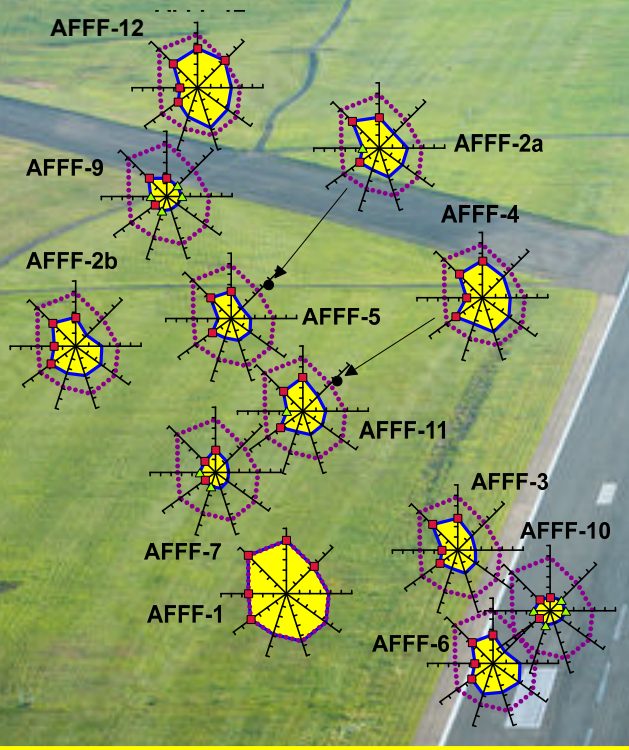
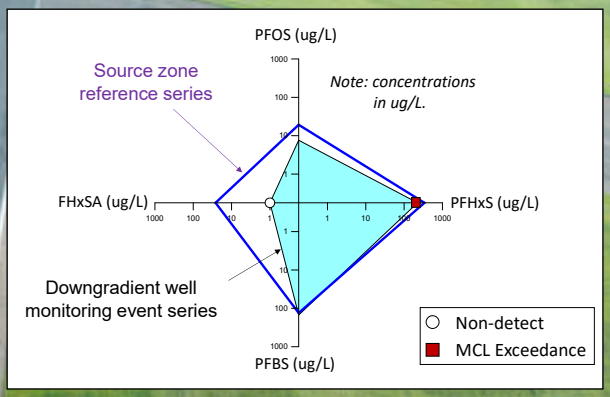
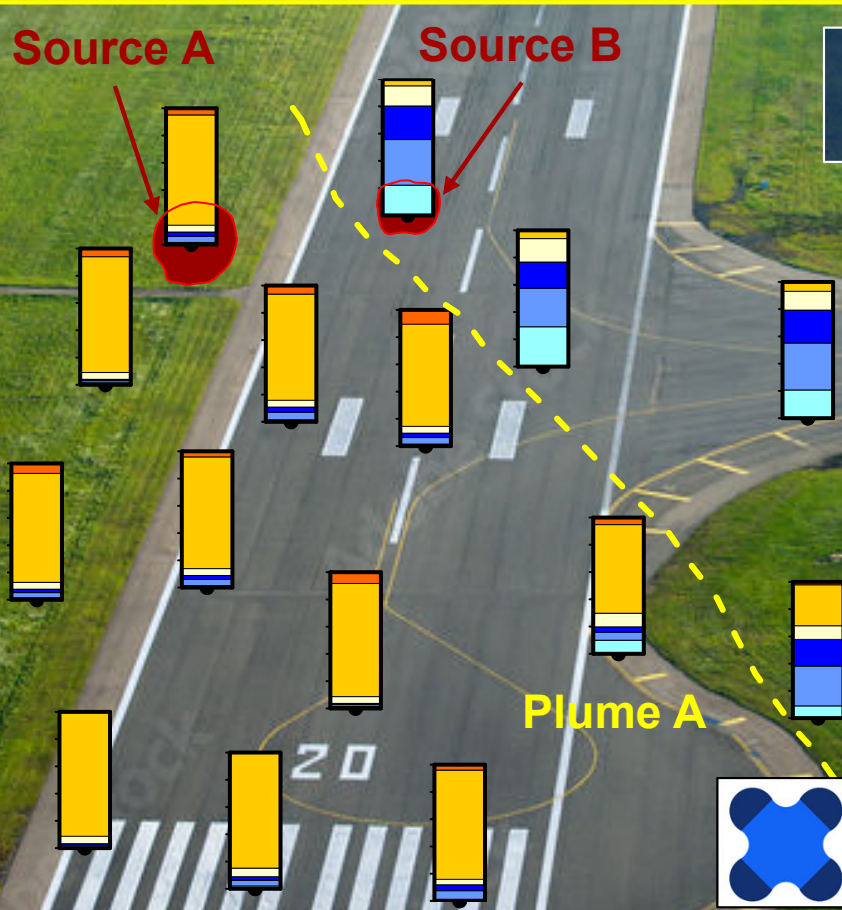
Visual PFAS™ Users Guide (v1.1.1)

Improving Conceptual Models for PFAS Site Characterization, Remediation, and Forensic Analysis

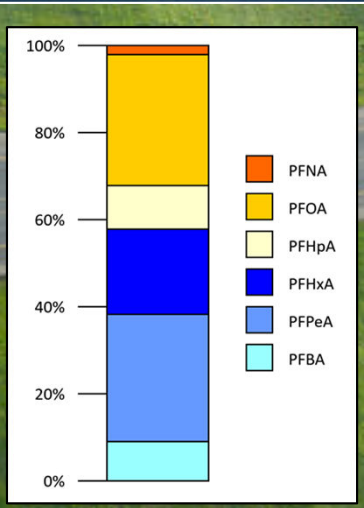


Radial Diagram Maps Strengthen Conceptual Models and Communication Strategies





Stacked Bar Maps for Source Forensics



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Visual PFAS™

Version 1.1.1 Users Guide

Developed by

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January 20, 2025

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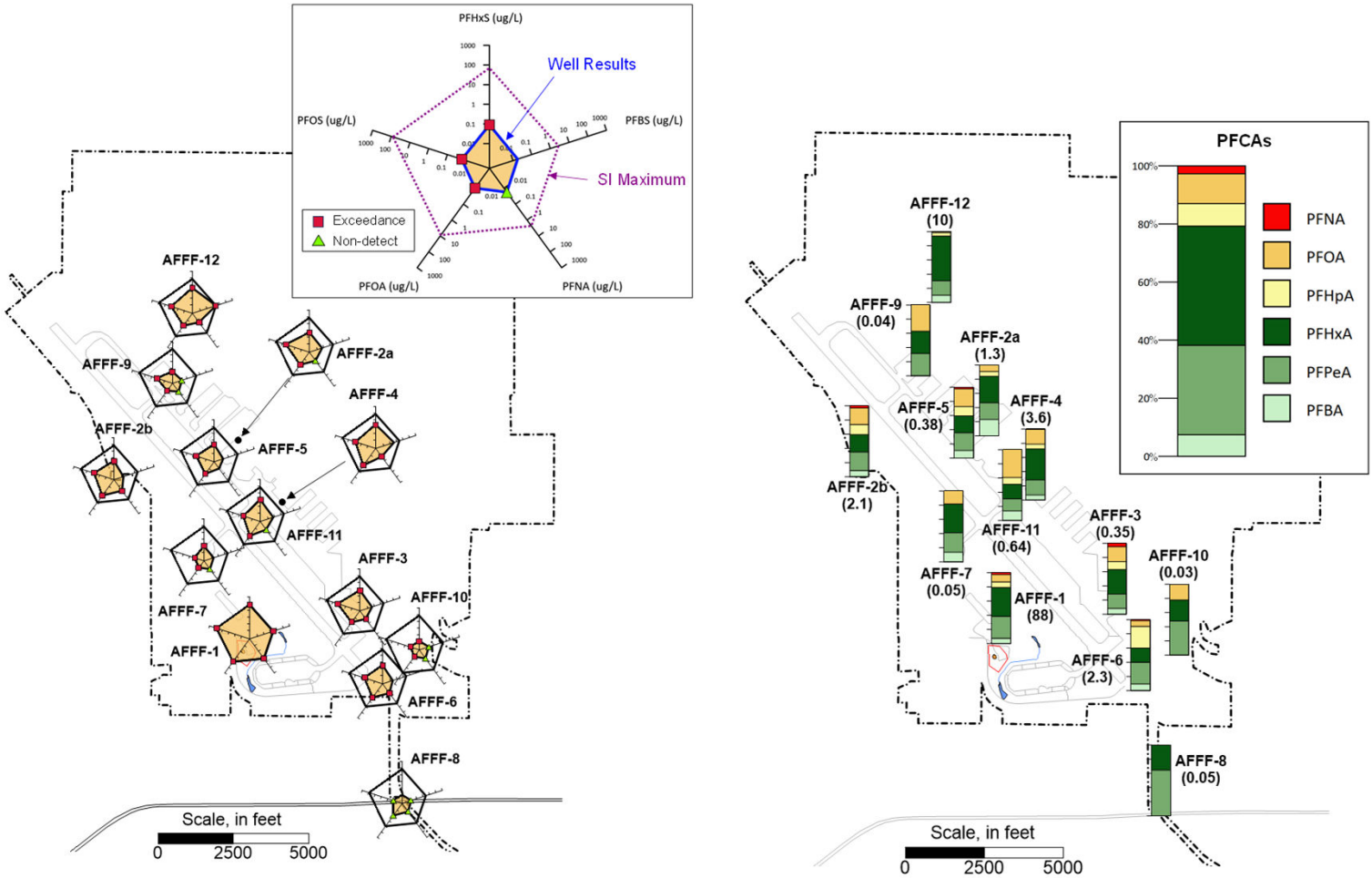

Reference: Carey et al. (2025) visualization of PFAS trends at AFFF source areas across a South Dakota Air Force Base.

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January 20, 2025

1.1 Introduction to Visual PFAS™

Visual PFAS™ has been developed with specialized functionality for constructing radial diagram and stacked bar maps, with a focus on supporting PFAS site characterization, remediation performance monitoring, and forensic assessments. The tools in Visual PFAS™ are also applicable to a wide range of other chemicals including chlorinated solvents, petroleum hydrocarbons, metals, geochemical/redox indicators, and radionuclides.

Visual PFAS™ Applications

Visual PFAS™ has been designed with an easy-to-use interface that provides powerful flexibility when it comes to preparing radial diagram and stacked bar maps. The types of visual aids that may be prepared using Visual PFAS™ are ideal for:

- Easily identifying where regulated PFAS exceed criteria on a single site map
- Delineating a PFAS groundwater plume
- Comparing short vs long-chain PFAS at each monitoring well
- Evaluating precursor transformations to regulated and other PFAAs
- Visualizing PFAA attenuation along a groundwater flow path
- Comparing site concentrations to background
- Summarizing TOP assay results overlaid on a site map
- Monitoring PFAS remediation performance
- Source differentiation forensic assessments

Benefits of Using Visual PFAS™

The benefits associated with using Visual PFAS™ for evaluating your site include:

- Prepare effective and powerful visual aids in minutes
- Save time and reduce the cost of analyzing PFAS data
- Impress clients with improved conceptual models and demonstrative visual aids
- Improve communication with non-technical stakeholders
- Develop more persuasive forensic assessments
- Anyone in an office can use this software - no need to tie up specialized graphics support to evaluate PFAS trends, and no need to purchase multiple licenses for use by multiple people at an office location

1.2 Software Overview

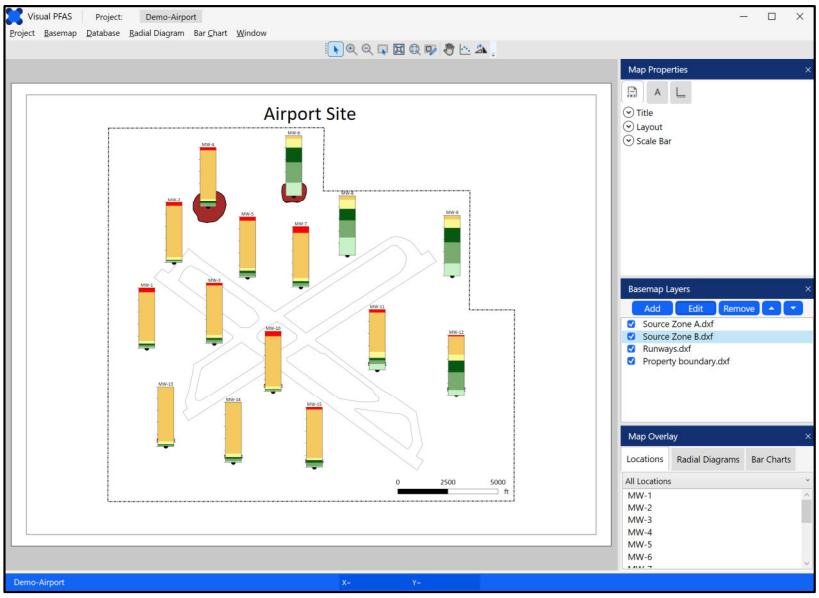
Preparation of the project dataset to be imported into Visual PFASTM is done outside of the software using custom programs already in use by each organization (see Chapter 2). Visual PFAS™ provides a wide range of tools for:

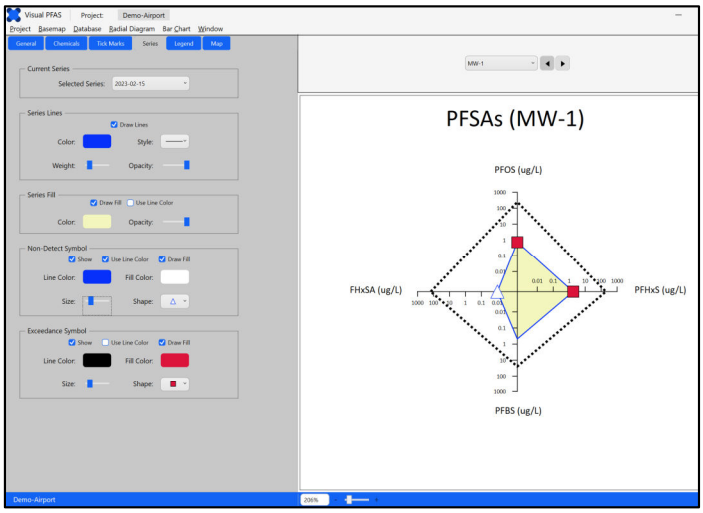
- Preparing a site basemap with imported layers to provide an underlay for radial diagram and stacked bar maps (see Chapter 3);
- Constructing radial diagram maps where the axes represent either measured concentrations or chemical ratios (see Chapter 4); and
- Constructing stacked bar maps to visualize the relative proportion of different chemicals across source areas or along a groundwater flow path (see Chapter 5).

Visual aids constructed using Visual PFAS™ may be printed to a physical printer or a PDF file, exported to various image formats, and/or exported to native files which may be imported into common mapping software including GIS, CAD, or Surfer. For example, Visual PFAS™ maps may be exported to images and then combined and further refined in Microsoft PowerPoint in preparation for a presentation, or imported these images may be directly imported into the body of a report.

Visual PFAS™ has been developed using a similar framework to a previous radial diagram mapping product (SEQUENCE) which was first developed over 25 years ago, with a focus on evaluating natural and enhanced attenuation of chlorinated solvents. A simpler version of this program was also called Visual Bio™.

The main goal of Visual PFAS™ is to increase the range of tools available for analyzing PFAS trends in groundwater, soil, surface water, and sediment samples. With dozens of PFAS constituents now being analyzed with EPA Method 1633, there is a strong need for visualization tools to help assess and then communicate the results of these sampling programs.





1.2.1 Software Licensing

Visual PFAS™ comes with a site license, which means that anyone working permanently at the office location which purchased Visual PFAS™ is free to use the software with the site license. There is no restriction on the number of users who can use Visual PFAS™ at that office location.

It is forbidden for anyone to distribute Visual PFAS™ to users, offices, and/or organizations outside of the purchasing office location. For example, it is forbidden to store or install Visual PFAS™ on a server which may be accessed from outside of that office location. It is also forbidden to transfer or distribute Visual PFAS™ electronically. Copies of Visual PFAS™ may be provided only to employees who work permanently at the purchasing office location via external hard drive or USB.

A Visual PFAS™ license will last in perpetuity; these licenses do not expire, and there are no annual maintenance agreement or subscription fees. Periodic email technical support is available for up to a one-year period with each site license. Future software upgrades will be available for optional purchase, typically on an annual basis.

1.2.2 Installation Requirements

Requirements for using Visual PFAS™ include Microsoft Windows version 10 or 11; and installation of the .NET Framework version 4.8 or higher. The .NET Framework is typically pre-installed with Windows 10 and 11.

1.2.3 Users Guide Organization

The Visual PFAS™ Users Guide contains detailed descriptions of various features and methods for using these tools. A step-by-step tutorial is provided throughout the Users Guide to illustrate all aspects of Visual PFAS™. Map layers and a complete import dataset are provided with the tutorial example project, and may be found in the Visual PFAS™ installatio package provided at the time of purchase (i.e., in the **Demo-Airport Project Files** folder). Remaining chapters in this Users Guide include:

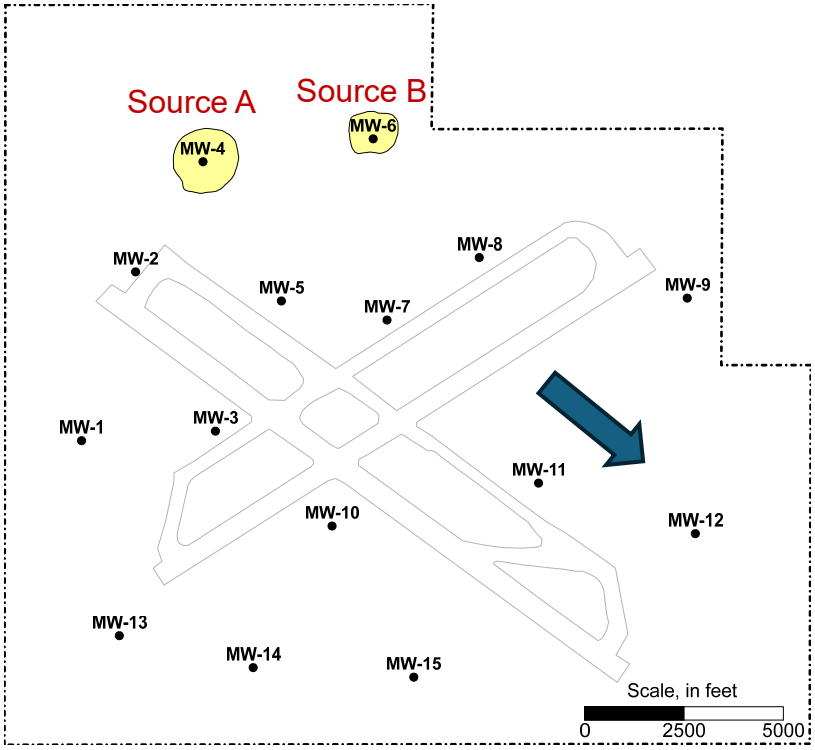
- Chapter 2 – Creating A Project and Importing A Dataset (including detailed format specifications for project datasets to be imported into Visual PFAS™);
- Chapter 3 – Creating A Basemap;
- Chapter 4 – Creating Radial Diagrams; and
- Chapter 5 – Creating Stacked Bar Maps.

1.3 Tutorial Example Project

The tutorial presented in this Users Guide is based on a hypothetical *Demo-Airport* project example. A complete import dataset is provided with the software installation files for set-up to import into Visual PFAS™. (The process used to import this dataset is discussed in Section 2.4.) The *Demo-Airport* site example has the following characteristics:

- Two AFFF-impacted source areas:
    - Source A represents the former fire training area (former FTA) where legacy AFFF products, based on long-chain constituents including a mix of sulfonates (PFSAs) and carboxylates (PFCAs), were used in an unlined pit; and
    - Source B is the location of the current FTA where modern AFFF products are used, resulting in predominantly short-chain PFCAs impacts to groundwater with smaller releases than those that occurred at the former FTA.
- Fifteen monitoring wells (MW-1 through MW-15, inclusive) with eleven wells screened in the shallow zone and four wells screened in the deeper zone of the main aquifer at the site.
- Two recent PFAS groundwater monitoring events where samples were collected at the 15 monitoring wells in February and August, 2023.
- Groundwater flow direction is from the northwest to the southeast.

The site basemap showing the source area and monitoring well locations is presented below, including the direction of groundwater flow downgradient from the source areas.



The February 2023 monitoring event results for this example site are presented below for perfluorinated carboxylates (PFCAs) and perfluorinated sulfonates (PFSAs). The August 2023 monitoring event sample results included in the dataset are similar to the February 2023 event results. (The February 2023 event is used to support the tutorial provided in all Chapters of the Users Guide.)

February 2023 PFCA Monitoring Event Results

Location	Total PFCAs (ug/L)	PFBA (ug/L)	PFPeA (ug/L)	PFHxA (ug/L)	PFHpA (ug/L)	PFOA (ug/L)	PFNA
MW-1	0.4	0.006	0.015	0.01	0.02	0.32	0.029
MW-2	0.6	0.009	0.009	0.006	0.03	0.51	0.036
MW-3	8	0.12	0.36	0.234	0.4	6.56	0.328
MW-4	96	1.44	4.4	2.94	4.8	77.76	4.7
MW-5	45	0.66	2.5	1.7	2.25	35.1	2.808
MW-6	5	1.125	1.7	1.25	0.75	0.25	-0.001
MW-7	38	0.57	1.82	1.22	1.9	28.5	3.99
MW-8	1	0.289	0.28	0.19	0.17	0.06	-0.001
MW-9	0.057	0.012	0.02	0.014	0.008	0.004	-0.001
MW-10	5	0.075	0.066	0.044	0.25	4.15	0.415
MW-11	14	1.4	0.82	0.55	1.4	9.1	0.728
MW-12	12	1.08	3.5	2.34	1.2	3.6	0.252
MW-13	0.09	-0.001	0.002	0.001	0.005	0.084	-0.001
MW-14	0.19	0.004	0.008	0.005	0.012	0.162	-0.001
MW-15	3	0.036	0.19	0.13	0.12	2.4	0.12

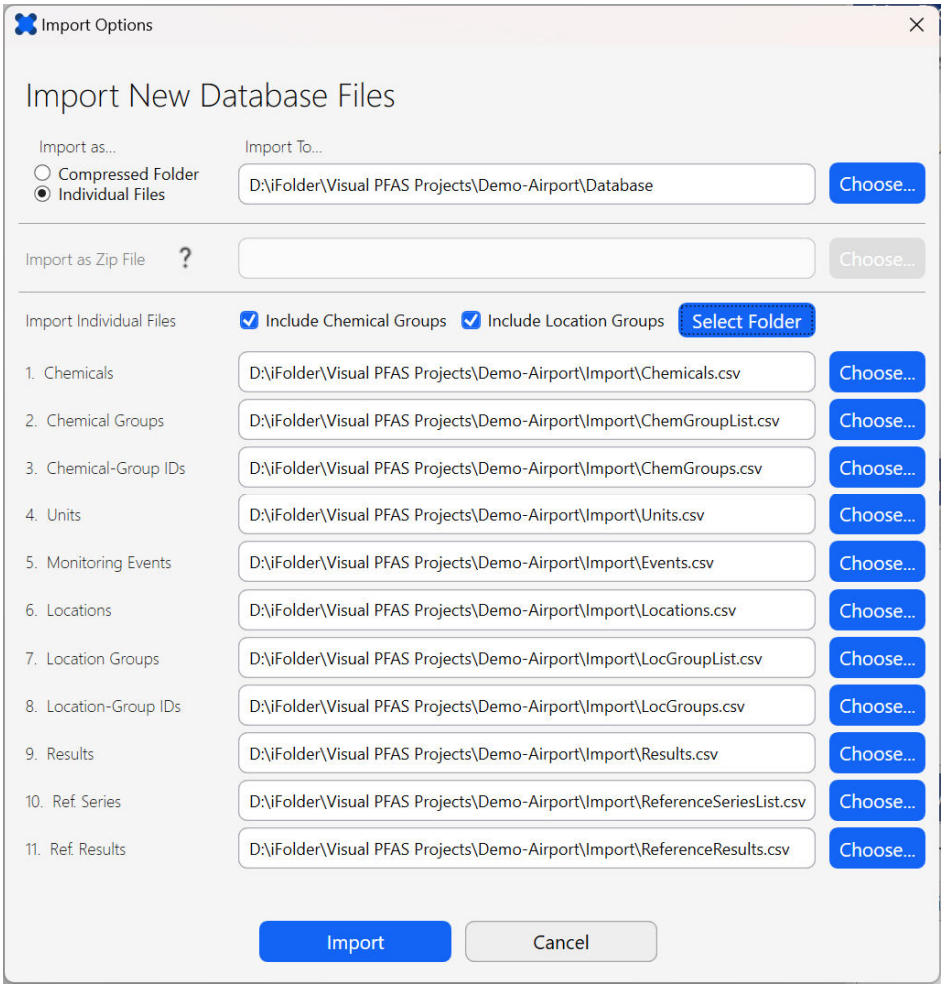
February 2023 PFSAs Monitoring Event Results

Location	Total PFSAs (ug/L)	PFBS (ug/L)	PFHxS (ug/L)	PFOS (ug/L)	FHxSA (ug/L)
MW-1	3	0.49	1.8	0.7331	-0.001
MW-2	4.5	0.69	2.7	1.03875	0.1
MW-3	60	9.51	36.25	14.26	0.4
MW-4	725	25	300	250	150
MW-5	509	4	410	85	10
MW-6	0.5	0.10	0.25	0.1506	-0.001
MW-7	287	41.60	176	62.4	7
MW-8	0.3	0.06	0.15	0.0906	-0.001
MW-9	0.2	0.04	0.09	0.0666	-0.001
MW-10	12	2.15	6.6	3.231	0.015
MW-11	50	10.77	23	16.158	0.07
MW-12	10	2.00	5	3.0006	-0.001
MW-13	0.68	0.12	0.39	0.1744125	-0.001
MW-14	0.6	0.12	0.3	0.1806	-0.001
MW-15	3	0.56	1.59	0.8466	-0.001

Visual PFAS™
Users Guide:

Creating A Project and Importing the Dataset

Chapter 2



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2.1 Introduction to Visual PFAS Projects

Visual PFAS™ input and output files are stored within a project-specific folder. Each new project that you work on with Visual PFAS™ will have its own folder, with six sub-folders that are created automatically by Visual PFAS™ when each new project folder is created. The names of these six project sub-folders created by Visual PFAS™ are:

- **Basemaps** – stores basemaps created users (*.vpmap) using Visual PFAS™. Projects may include one site-wide basemap, and possibly maps with smaller areas of focus at larger sites. The basemaps are used as underlays for radial diagram or stacked bar maps.
- **Map Layers** – contain polyline and/or polygon files that may be added as individual layers to the basemap, including GIS shapefiles (*.shp), CAD dxf files (*.dxf), and Surfer boundary line files (*.bln).
- **Import** – contains the dataset tables in comma-delimited (*.csv) files which are to be imported into the Visual PFAS™ project database. These dataset import files have strict format requirements which are discussed further in Section 2.3.
- **Database** – this is a read-only folder that contains the project database files that are created by Visual PFAS™ after users import the *.csv dataset table files. It is important that users do not change or move/delete files in this **Database** folder.
- **RD Properties** – contains radial diagram property files (*.rd) which are used to construct radial diagram maps. These property files contain all the look-and-feel properties for radial diagrams, as well as lists of applicable site locations, reference and monitoring event series, and chemicals associated with each axis.
- **Bar Charts** – contains stacked bar property files (*.bar) which are used to construct stacked bar maps. These property files contain all properties associated with a stacked bar map, including lists of applicable site locations, monitoring events, and chemicals. Reports created by Visual PFAS™ with stacked bar statistics for each location are produced automatically and stored in this folder as well.

Users can create additional sub-folders in these project folders, such as an Export sub-folder to store images and other files exported from Visual PFAS™.

Notes:

1. It is strongly recommended that users do not create a new project within an existing project folder. This may result in deletion of prior work.
2. It may be beneficial to create multiple instances of a project with different project folders e.g., one for working with groundwater data, the other for working with soil data (see Section 2.5).

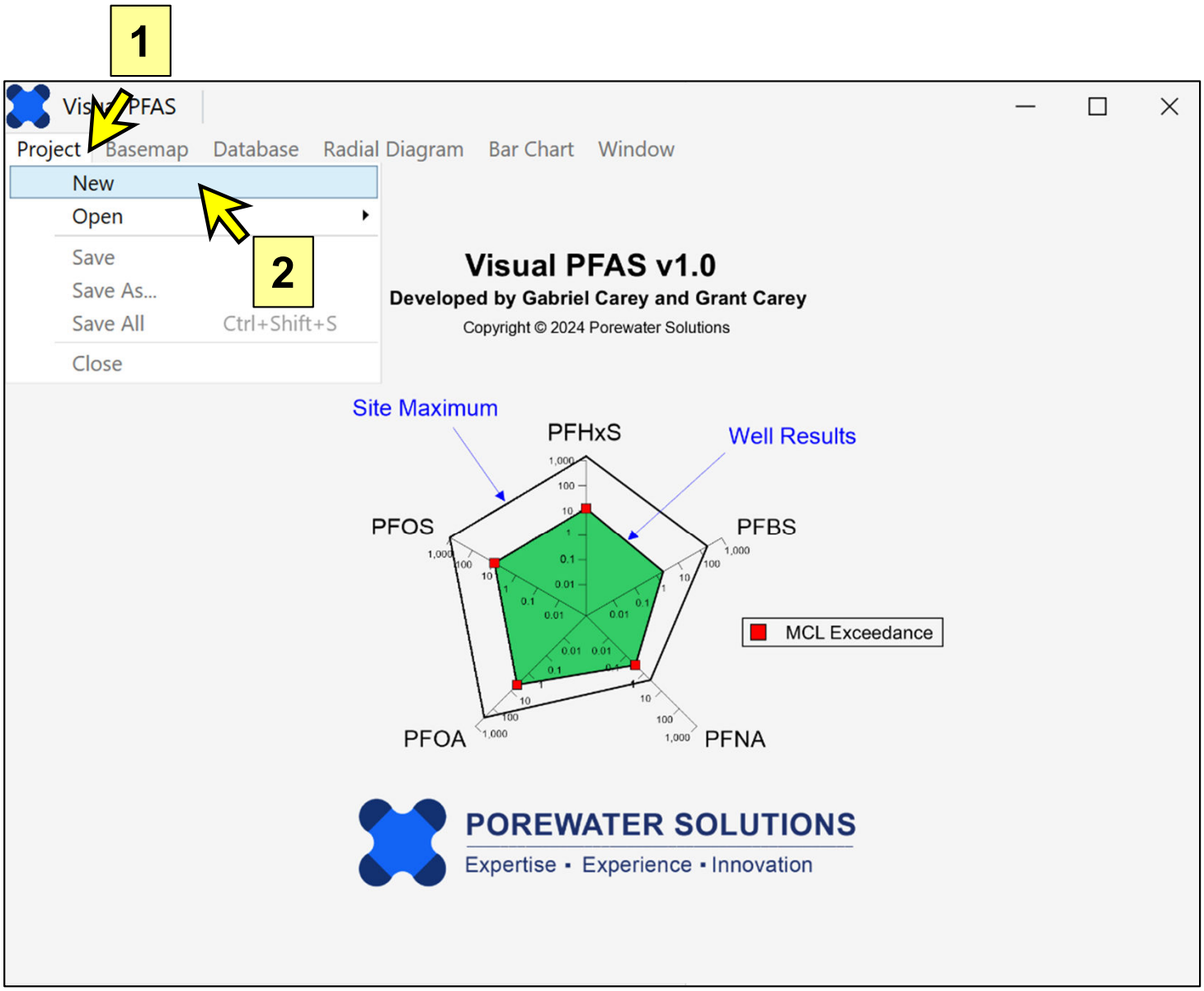
2.2 Creating or Opening a Project

When opening Visual PFAS™ for the first time, the software splash screen will be displayed (see example below) because there have been no projects created yet.

To create a new project, click the **Project** menu (see "1" below) and select **New** (see "2" below).

Notes:

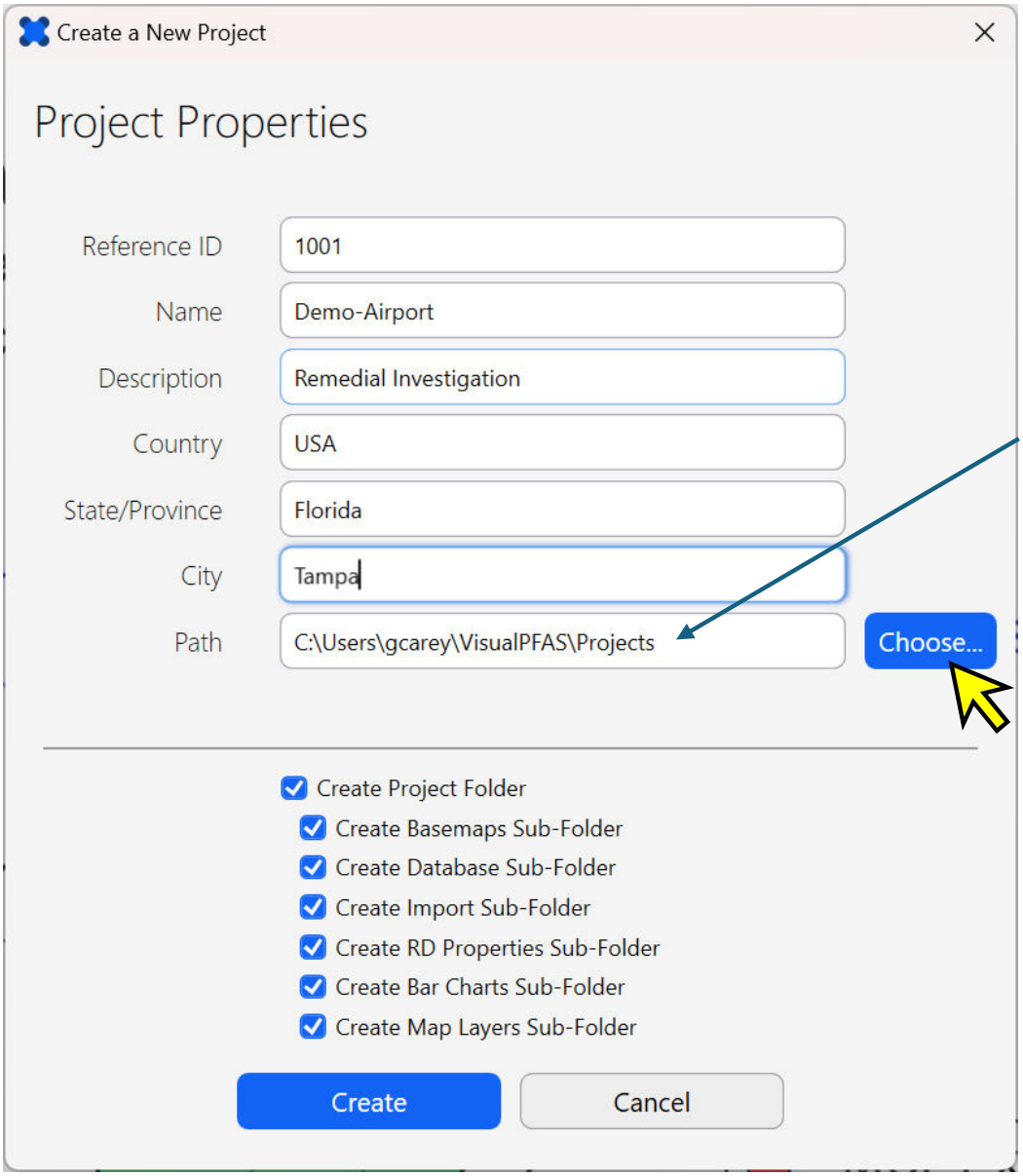
1. Visual PFAS™ will automatically maintain a log of projects that have recently been opened, and the program will provide you with a short-cut to recently opened projects if you decide to open a different project.
2. When starting Visual PFAS™ after a previous session, the most recently used project will be opened automatically. You can close this project and open a different project.



For this tutorial, fill out the information below. When creating a new project, Visual PFAS™ will automatically create a project-specific folder with the same name as the project name, at a location specified by the user.

In the example below, the project name is *Demo-Airport*. A project folder with this same name will be created at the **Path** specified below, along with the project sub-folders shown at the bottom of the dialog box.

To change the path where the project folder is to be located, click the **Choose** button as shown by the yellow arrow below, and select the folder under which the new project main folder will be created.



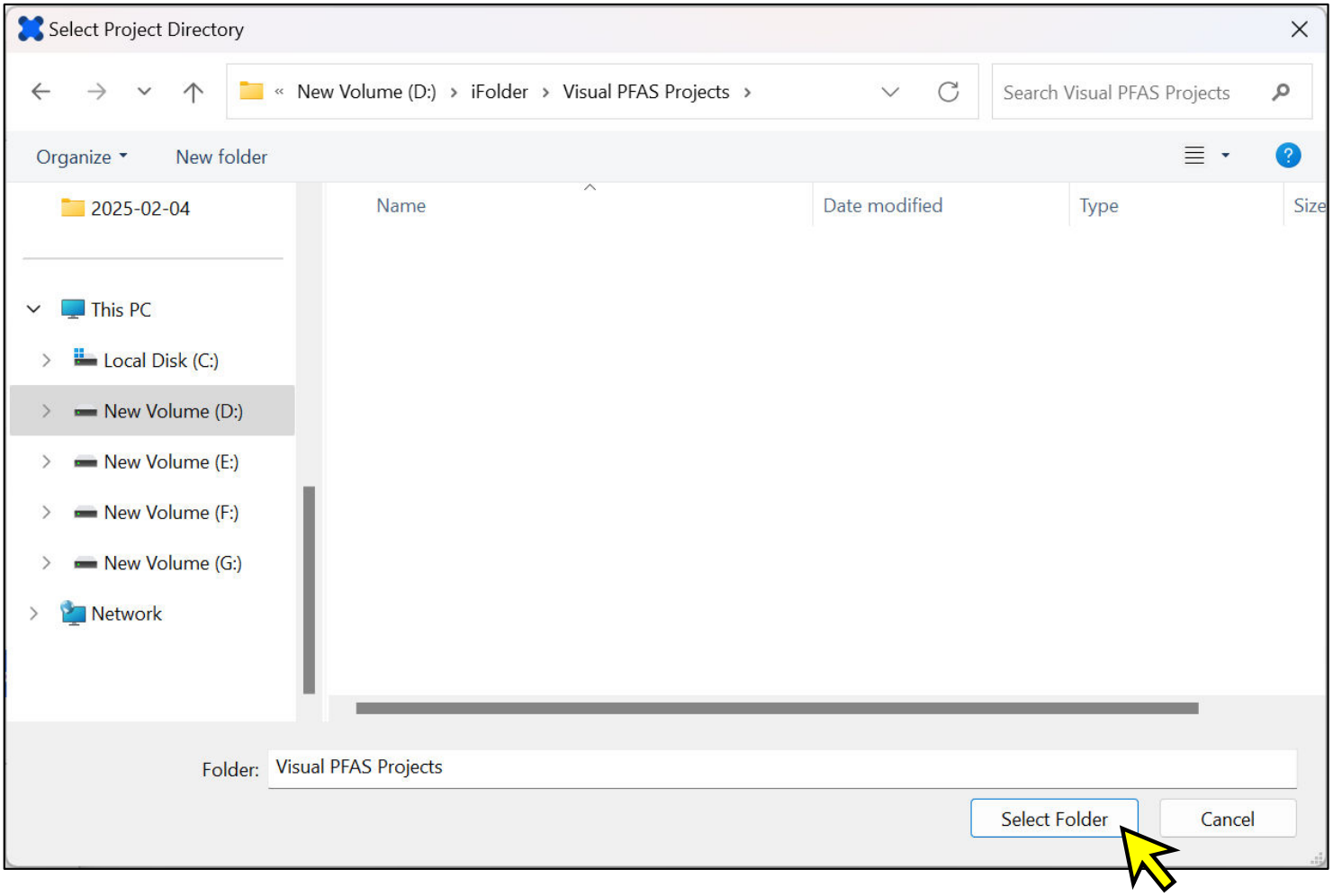
Default user path

For this example, we prepared a new folder called “Visual PFAS Projects” on a local hard drive. You can identify a different location where the *Demo-Airport* project folder is to be created.

Once you have identified the folder location under which the new project folder will be created, click **Select Folder** at the bottom of the window as shown below.

Notes:

1. In this step, you are selecting an existing folder. Visual PFAS™ will create the new project folder under the folder you select. In this example, we have created an overall folder to house all Visual PFAS™ Projects. You can take a different approach and store the project files under an already-existing project-specific folder.
2. You are not specifying the name of the project folder here, only the existing folder under which the new project folder will be created. The name of the new project folder will automatically be specified to be the same as the project name: *Demo-Airport*.

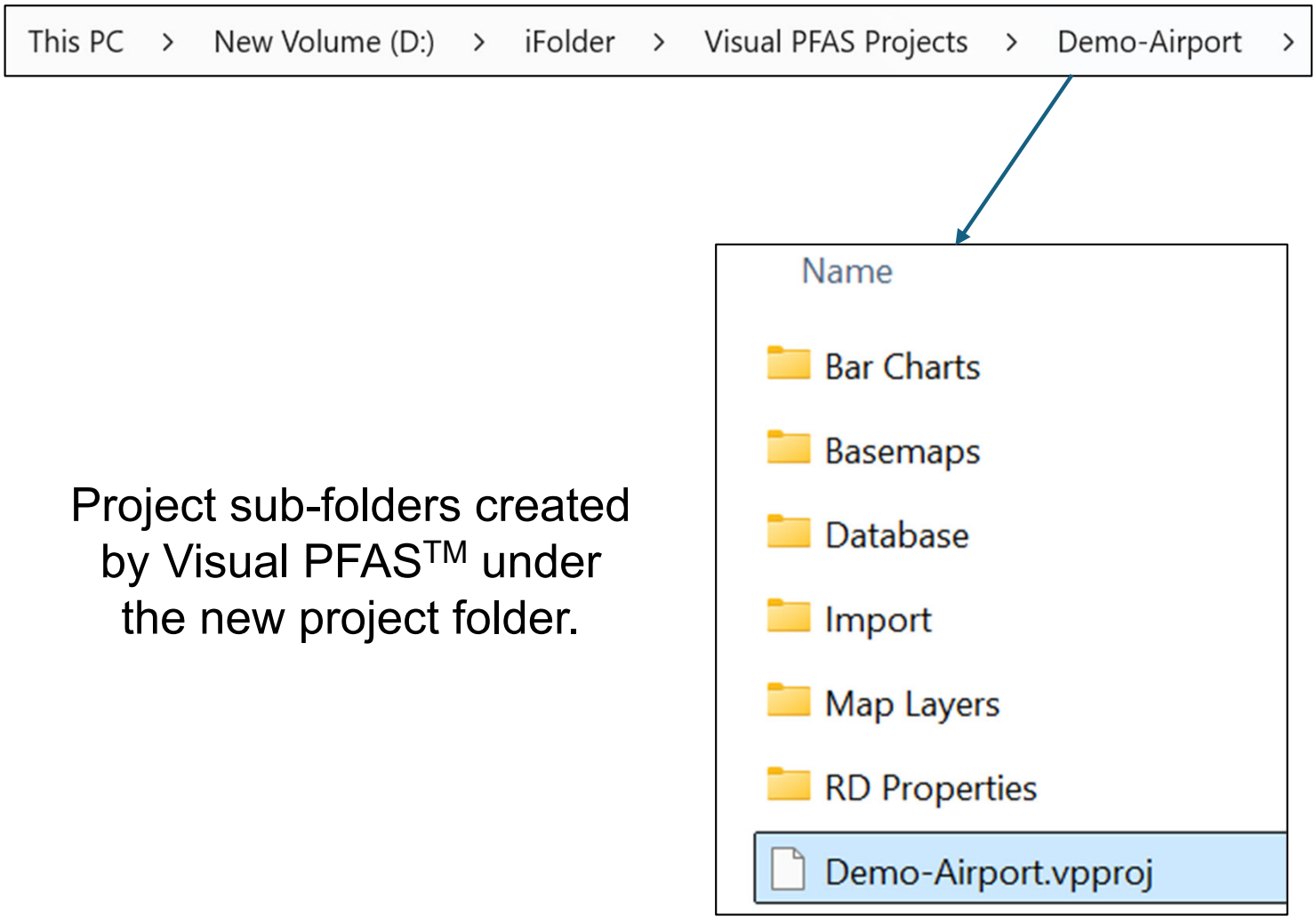


Once you have selected the path for where to create the new project folder, you will return to the Project Properties dialog box (see image on p. 2.4). Click the blue **Create** button to create the new project folder.

Visual PFAS™ will create a new project file with a *.vpproj extension under the new project folder, where the name of the file is the same as the project name: **Demo-Airport.vpproj**. This project file is stored directly under the main project folder, and it stores the basic project information entered on p. 2.4. This project file will also store the path and name of the most recent basemap, radial diagram, and stacked bar input files created or opened with this project.

The project sub-folders shown below are created automatically by Visual PFAS™ when a new project is first created. Users may add additional sub-folders and files at any time, but the names of these default sub-folders should not be modified.

Note: Users do not have to do anything with the project file after a project is opened. Visual PFAS™ saves the names of recently opened files automatically to this project file. Do not try to open or edit this file outside of Visual PFAS™.

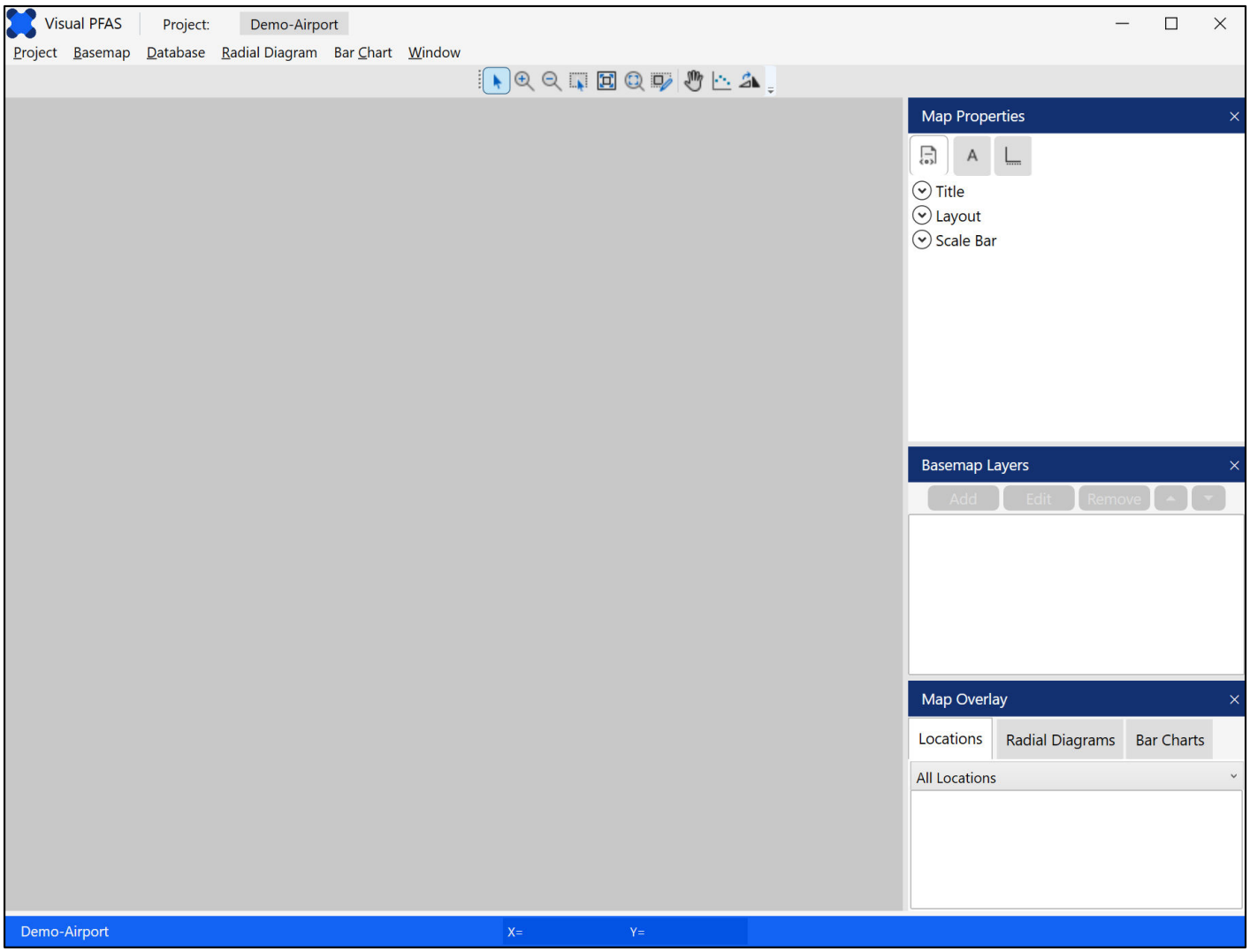


Project sub-folders created by Visual PFAS™ under the new project folder.

After the new project has been created, the project basemap window will be displayed. No basemaps have been created yet so the basemap screen is blank. (see gray are in the image below)

The project database has not been imported yet, so no locations are shown in the list at the bottom-right in the Map Overlay section.

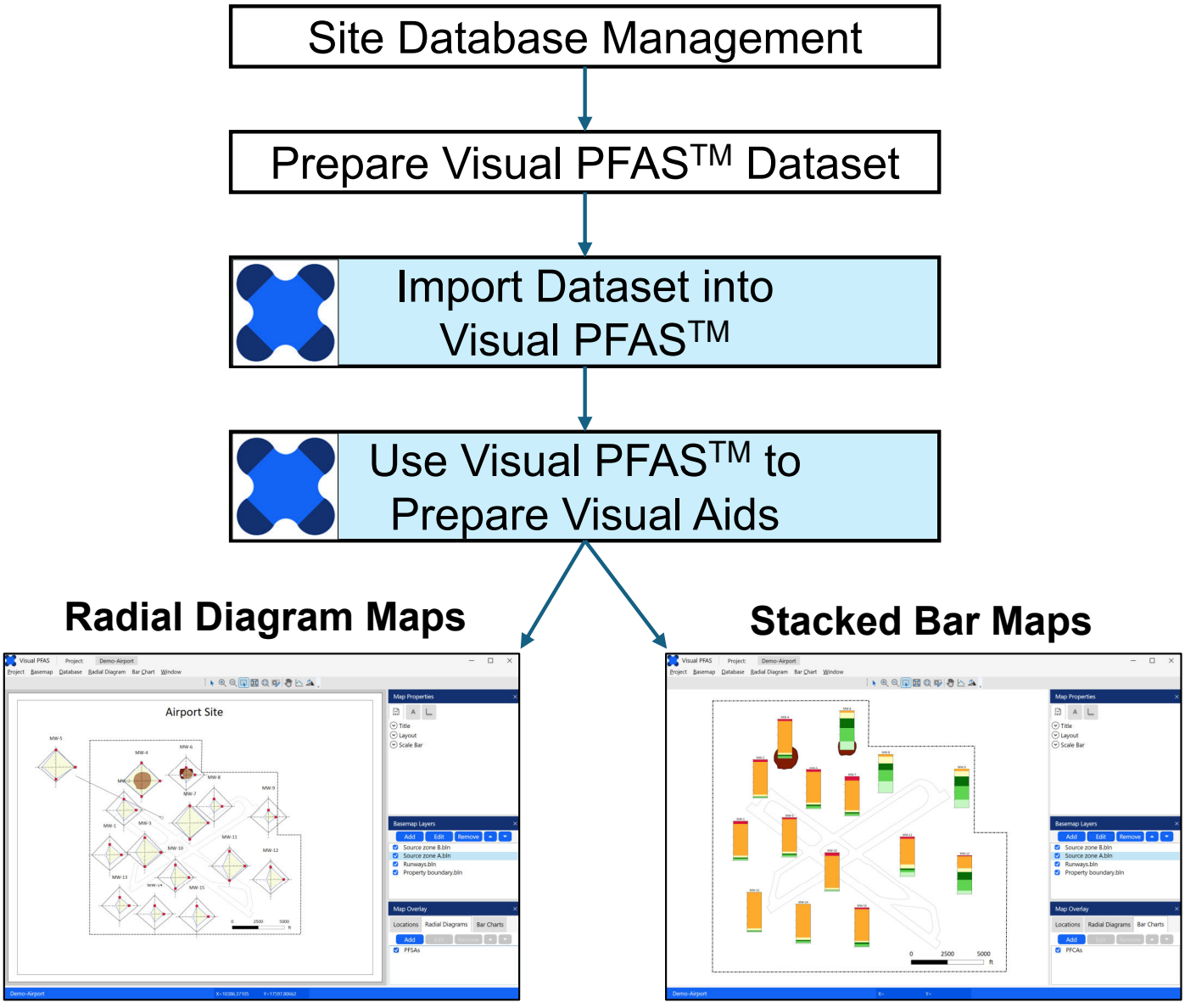
The next two sections will describe the project database format and how to import a dataset. Chapter 3 provides a tutorial for creating the project basemap.



2.3 Imported Dataset Format

Visual PFAS™ provides users with an easy-to-use interface for constructing visual aids that support site characterization, forensic analyses, and remediation performance monitoring assessments. An overall environmental database for a contaminated site typically includes a large array of information that are more extensive than what Visual PFAS™ needs. It is recognized that organizations use a wide range of specialized methods and software tools for managing the overall site database.

For that reason, Visual PFAS™ is intentionally not a data management tool; it is expected that users will conduct data management activities outside of Visual PFAS™, and then import a prepared dataset into Visual PFAS™. The dataset to be imported into Visual PFAS™ is focused on chemical analytical data, and will typically constitute only a subset of the overall site database. The figure below illustrates the general processes involved with using Visual PFAS™.



The current version of Visual PFAS™ is focused on plotting radial diagrams and stacked bar maps that convey chemical analytical results for water-based media including groundwater, surface water, and porewater. Refer to Section 2.5 for a simple workaround for preparing radial diagram and stacked bar map visual aids based on a soil and/or sediment analytical dataset.

The dataset to be imported into Visual PFAS™ consists of a series of 11 comma-delimited (*.csv) tables that are summarized below.

Visual PFAS™ Comma-Delimited Import Tables

Table No.	Filename	Description
Chemical Lists and Properties		
1	Chemicals.csv	Chemical names and default concentration units
2	ChemGroupList.csv	List of chemical groups
3	ChemGroups.csv	List of chemicals associated with each chemical group
Concentration Units List and Conversion Factors		
4	Units.csv	List of concentration units and conversion factors
Location Lists and Coordinates		
5	Locations.csv	Location names and coordinates
6	LocGroupList.csv	List of location groups
7	LocGroups.csv	List of locations associated with each location group
Monitoring Events List and Analytical Results		
8	Events.csv	List of monitoring event series
9	Results.csv	Chemical sample results
Reference Series List and Results		
10	ReferenceSeriesList.csv	List of reference series
11	ReferenceResults.csv	Reference Series chemical results

The list of fields and required formats for each of these 11 comma-delimited table are described in Sections 2.3.1 through 2.3.11. These tables can easily be edited using Microsoft Excel which opens and saves comma delimited (*.csv) files.

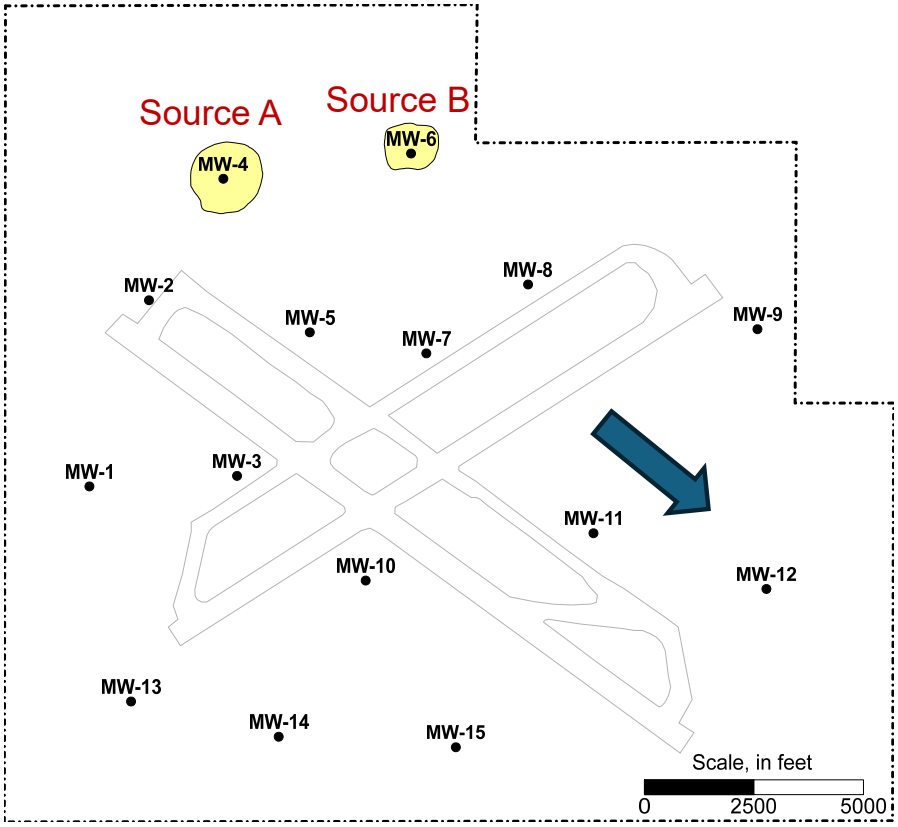
Note: The following are strict rules required for the import dataset table formats:

1. Include the same number of fields in the tables as shown in Sections 2.3.1 to 2.3.11;
2. First row is always a header row;
3. All eleven *.csv tables, with the exact filenames shown here, need to be in one folder or one zip file, and contain at least one row after the header row;
4. Follow the specifications in Sections 2.3.1 to 2.3.11 about fields requiring integer or real numbers, or character strings.
5. Do not leave table cells blank, values are required in every cell in the populated rows.
6. Do not use character strings with “,” since these are comma-delimited files, even if the strings are in quotes. E.g., use 111-TCA instead of 1,1,1-TCA as a chemical name.

The tutorial presented in this Users Guide based on the *Demo-Airport* example includes a complete dataset which has been set-up to import into Visual PFAS™. (The process used to import this dataset is discussed in Section 2.4.) The *Demo-Airport* hypothetical site example has the following characteristics:

- Two AFFF-impacted source areas:
    - Source A represents the former fire training area (former FTA) where legacy AFFF products based on long-chain constituents including a mix of sulfonates (PFSAs) and carboxylates (PFCAs) were used in an unlined pit; and
    - Source B is the location of the current FTA where modern AFFF products are used, resulting in predominantly short-chain PFCAs impacts to groundwater with smaller releases than the former FTA.
- Fifteen monitoring wells (MW-1 through MW-15, inclusive) with eleven wells screened in the shallow zone and four wells screened in the deeper zone of the main aquifer at the site.
- Two recent PFAS groundwater monitoring events where samples were collected at the 15 monitoring wells in February and August, 2023.
- Groundwater flow direction is from the northwest to the southeast.

The site basemap showing the source area and monitoring well locations is presented below, including the direction of groundwater flow downgradient from the source areas.



2.3.1 Chemicals.csv Table Format

The 7 fields required for this import table are described in the table below, and the *Demo-Airport* example table is presented on the next page.

Notes on this table format:

- Project chemical lists should be kept relatively small, since this list is used to populate various dropdown lists for chemical selection. i.e., it's easier to select from a list of 30 chemicals than from a list of 300 chemicals.
- Chemical type and molecular weight are not currently used in Visual PFAS™, but these fields do require values to be populated prior to the import process.
- As shown in the example on the next page, you can create a chemical name for various total concentrations if these are to be represented in radial diagrams or stacked bars. You would need to calculate these total concentrations and enter these values in the Results.csv table prior to importing the dataset into Visual PFAS™.
- For TOP assays, you may want to create a second monitoring event to represent the total concentrations measured during the assay for various PFCAs, using the original chemical IDs for PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, etc. (see Section 2.3.9 for a more detailed description of how to include TOP assay results.)
- Do not use "," in chemical names because these are comma-delimited files
- ID numbers and sort IDs to not have to be in order, and do not have to contiguous series of numbers
- Default units are used to set the initial units for radial diagram axes, but are not required to be used in the imported **Results.csv** or **ReferenceResults.csv** files
- Enter "-1" in the Criterion field for chemicals that do not have cleanup criteria. This flag tells Visual PFASTM that there are no applicable criterion for these chemicals. Users may still enter a criterion manually when preparing radial diagrams (see Chapter 4).

Table 1 - Chemicals.csv: Chemical names and default concentration units

Field No.	Field	Description	Variable Type	Comments
1.1	ChemID	Chemical ID No.	Integer	
1.2	ChemSName	Chemical short name	Character (25 max)	
1.3	DefUnitID	Chemical default concentration unit ID No.	Integer	ID number of default units (e.g., 1=ug/L)
1.4	ChemType	Chemical type	Integer	Not currently used, set to 1
1.5	ChemSortID	Chemical sorting order	Integer	Order for populating drop-down lists
1.6	ChemMW	Molecular weight (g/mol)	Real	Not currently used (-1 if not available)
1.7	Criterion	Default cleanup criterion in default concentration units	Real	Default cleanup criterion (-1 if not applicable)

Demo-Airport Example Table

ChemID	ChemSname	DefUnitID	ChemType	ChemSortID	ChemMW	Criterion
3	PFBA	1	1	1	214.04	-1
4	PFPeA	1	1	2	264.05	-1
5	PFHxA	1	1	3	314.05	-1
6	PFHpA	1	1	4	364.06	-1
7	PFOA	1	1	5	414.07	0.004
8	PFNA	1	1	6	464.08	0.01
9	PFDA	1	1	7	514.08	-1
10	PFBS	1	1	8	300.1	2
23	PFPeS	1	1	9	350.11	-1
11	PFHxS	1	1	10	400.11	0.01
24	PFHpS	1	1	11	450.12	-1
12	PFOS	1	1	12	500.13	0.004
25	4:2 FtS	1	1	13	350.13	-1
21	6:2 FtS	1	1	14	428.16	-1
22	8:2 FtS	1	1	15	545.22	-1
15	FHxSA	1	1	16	400.12	-1
27	FOSA	1	1	17	499.15	-1
1	Total PFCAs	1	1	18	-1	-1
2	Total PFSAs	1	1	19	-1	-1
14	Total_FtS	1	1	20	-1	-1
13	Total Precursors	1	1	21	-1	-1
16	Top-PFBA	1	1	22	214.04	-1
17	Top-PFPeA	1	1	23	264.05	-1
18	Top-PFHxA	1	1	24	314.05	-1
19	Top-PFHpA	1	1	25	364.06	-1
20	Top-PFOA	1	1	26	414.07	-1
26	Top-PFNA	1	1	27	464.08	-1

2.3.2 ChemGroupList.csv Table Format

The 3 fields required for this import table are described in the table below, and the *Demo-Airport* example table is presented at the bottom of the page.

Notes on this table format:

- Chemical groups are used to create smaller lists of chemicals to select from

Table 2 - ChemGroupList.csv: List of chemical groups				
Field No.	**Field**	**Description**	**Variable Type**	**Comments**
2.1	ChemGrpID	Chemical group ID No.	Integer	
2.2	ChemGrpName	Chemical group name	Character (25 max)	
2.3	ChemGrpSortID	Chemical group sorting order	Integer	Order for populating drop-down lists

Demo-Airport Example Table

ChemGrpID	ChemGrpName	ChemGrpSortID
1	PFCAs	1
2	PFSAs	2
3	Precursors	3
4	Top Assay	5
5	Regulated	4

2.3.3 ChemGroups.csv Table Format

The 2 fields required for this import table are described in the table below, and the *Demo-Airport* example table is presented at the bottom of the page.

Notes on this table format:

- This table lists the chemical ID numbers associated with each chemical group listed in **ChemGroupList.csv**
- All chemical groups listed in **ChemGroupList.csv** must be listed in this table with at least one chemical associated with each group.

Table 3 - ChemGroups.csv: List of chemicals associated with each chemical group

Field No.	Field	Description	Variable Type	Comments
3.1	ChemGrpID	Chemical group ID No.	Integer	
3.2	ChemID	Chemical ID No. associated with chemical group	Integer	

Demo-Airport Example Table

ChemGrpID	ChemID
1	3
1	4
1	5
1	6
1	7
1	8
1	9
2	10
2	23
2	11
2	24
2	12
3	15
3	27
3	25
3	21
3	22
4	12
4	11
4	10
4	7
4	8
5	16
5	17
5	18
5	19
5	20
5	26

2.3.4 Units.csv Table Format

The 6 fields required for this import table are described in the table below, and the *Demo-Airport* example table is presented at the bottom of the page.

Notes on this table format:

- The units table lists the names and conversion factors for water sample concentrations. A simple workaround for representing soil and/or sediment sample results in radial diagrams or stacked bar maps is discussed in Section 2.5.
- All units associated with a single matrix (e.g., water) must have the same reference unit ID. In the example shown at the bottom of the page, the reference units are mg/L (i.e., UnitID=2) for all rows in the **Units.csv** table.
- The unit conversion factor represents the multiplier to be used to convert from the current units to the reference units. For example, the unit conversion factor for ug/L is 0.001 to convert from ug/L to mg/L.
- The monitoring event **Results.csv** and **ReferenceResults.csv** tables include specification of the units ID number for each result i.e., each row in these tables. Visual PFAS™ will automatically convert units from the imported dataset to represent the user-specified units for each radial diagram axis.

Table 4 - Units.csv: List of concentration units and conversion factors

Field No.	Field	Description	Variable Type	Comments
4.1	UnitID	Unit ID No.	Integer	
4.2	UnitName	Unit name	Character (20 max)	
4.3	UnitConv	Multiplier to confirm from current units to reference units	Real	e.g., UnitConv = 0.001 when current units are ug/L, and the reference units are mg/L
4.4	RefUnitID	Reference unit ID No.	Integer	
4.5	UnitType	Unit type	Integer	Not current used, set to 1
4.6	UnitSortID	Unit sorting order	Integer	Order for populating drop-down lists

Demo-Airport Example Table

UnitID	UnitName	UnitConv	RefUnitID	UnitType	UnitSortID
1	ug/L	0.001	2	1	2
2	mg/L	1	2	1	3
3	ng/L	1.00E-06	2	1	1
4	g/L	1000	2	1	4
5	Kg/L	1.00E+06	2	1	5

2.3.5 Locations.csv Table Format

The 5 fields required for this import table are described in the table below, and the *Demo-Airport* example table is presented at the bottom of the page.

Notes on this table format:

- This table lists all locations which may be used to plot radial diagrams or stacked bars on a map.
- It is possible to show other locations on the site basemap even if they are not used for plotting radial diagrams; in this case, these locations should be listed in locations.csv even if no analytical results are included for these locations in the monitoring event **Results.csv** table.

Table 5 - Locations.csv: Location names and coordinates

Field No.	Field	Description	Variable Type	Comments
5.1	LocID	Location ID No.	Integer	
5.2	LocName	Location name	Character (20 max)	
5.3	Easting	Location easting coordinate in map units	Real	Map units (e.g., feet or meters) must be consistent for
5.4	Northing	Location northing coordinate in map units	Real	all locations and basemap layer files
5.5	LocSortID	Location list sorting order	Integer	Order for populating drop-down lists

Demo-Airport Example Table

LocID	LocName	Easting	Northing	LocSortID
1	MW-1	-5172.7	6397.6	1
2	MW-2	-3812.8	10657.6	2
3	MW-3	-1803.2	6638.3	3
4	MW-4	-2116	13437.4	4
5	MW-5	-142.5	9923.5	5
6	MW-6	2167.9	14015.1	6
7	MW-7	2516.9	9442.2	7
8	MW-8	4839.5	11018.6	8
9	MW-9	10074.2	9995.8	9
10	MW-10	1133	4243.5	10
11	MW-11	6331.7	5326.6	11
12	MW-12	10278.8	4051	12
13	MW-13	-4222	1475.7	13
14	MW-14	-852.5	669.5	14
15	MW-15	3190.8	428.8	15

2.3.6 LocGroupList.csv Table Format

The 3 fields required for this import table are described in the table below, and the *Demo-Airport* example table is presented at the bottom of the page.

Notes on this table format:

- This table lists the names of location groups which may be used to filter down the list of available locations to select from. i.e., it's easier to select from a group of 30 wells than from a list of 300 available wells at a site.
- The sort ID reflects the order at which the locations are shown in selection boxes. This allows you to sort the location names alphanumerically. For example, if you were to sort the list alphabetically based on well names, then MW-10 will appear before MW-2, MW-3, etc. in a well list. Using the sort IDs, you can arrange to have the wells sorted based on their alphanumeric ID values e.g., so MW-2, MW-3, etc. appear in the displayed selection list before MW-10.

Table 6 - LocGroupList.csv: List of location groups

Field No.	Field	Description	Variable Type	Comments
6.1	LocGrpID	Location group ID No.	Integer	Examples of well groups could be shallow and deep, and/ or monitoring and extraction wells
6.2	LocGrpName	Location group name	Character (25 max)	
6.3	LocGrpSortID	Location group sorting ID	Integer	Order for populating drop-down list

Demo-Airport Example Table

LocGrpID	LocGrpName	LocGrpSortID
1	Shallow	1
2	Deep	2

2.3.7 LocGroups.csv Table Format

The 2 fields required for this import table are described in the table below, and the *Demo-Airport* example table is presented at the bottom of the page.

Notes on this table format:

- This table lists the location ID numbers associated with each location group specified in **LocGroupList.csv**
- All groups listed in LocGroupList.csv must be listed with at least one location in this table.

Table 7 -LocGroups.csv: List of locations associated with each location group

Field No.	Field	Description	Variable Type	Comments
7.1	LocGrpID	Location group ID No.	Integer	
7.2	LocID	Location ID No. associated with location group	Integer	

Demo-Airport Example Table

LocGrpID	LocID
1	1
1	2
1	4
1	5
1	6
1	7
1	8
1	10
1	12
1	13
1	15
2	3
2	9
2	11
2	14

2.3.8 Events.csv Table Format

The 4 fields required for this import table are described in the table below, and the *Demo-Airport* example table is presented at the bottom of the page.

Notes on this table format:

- This table lists the monitoring events which may be used as separate data series on a radial diagram map or used to prepare stacked bar maps.
- Do not enter dates or event names that contain a comma, this will cause an error because these are comma-delimited files (even if the dates or names are in quotes in the csv table)
- This table is also used to represent depth or elevation intervals for plotting soil and/or sediment results – refer to Section 2.5 for more details.
- The sort ID field governs the order at which monitoring events are listed in selection boxes. Events are not sorted chronologically based on the date.

Table 8 - Events.csv: List of monitoring event series

Field No.	Field	Description	Variable Type	Comments
8.1	EventID	Monitoring event ID No.	Integer	
8.2	EventDate	Monitoring event date	Character (15 max)	Example format: YYYY-MM-DD (format not required; date is not currently used)
8.3	EventName	Monitoring event name	Character (25 max)	Event name presented in event lists
8.4	EventSortID	Monitoring event sorting order	Integer	Order for populating drop-down list (by date)

Demo-Airport Example Table

EventID	EventDate	EventName	EventSortID
1	2023-02-15	2023-02-15	1
2	2023-08-21	2023-08-21	2

2.3.9 Results.csv Table Format

The 7 fields required for this import table are described in the table on the next page, as well as an excerpt from the *Demo-Airport* example table.

Notes on this table format:

- This table represents monitoring event chemical analytical results to be used as well-specific data series in radial diagrams and stacked bar maps
- The location, monitoring event, and chemical ID numbers listed in the first three fields must correspond to entries in **Locations.csv, Events.csv, and Chemicals.csv**
- Enter one row in the table for each available analytical result
- If results are not available for a specific chemical in a monitoring event, do not include a row entry in the **Results.csv** file for this chemical/event.
- A result of zero for a concentration is invalid and will cause an error. You must enter a non-zero value for chemical analytical results.
- Non-detect results are represented as negative values, where the negative means it's a non-detect, and the absolute value of the result is the method detection limit (MDL) or more generally, the detection limit to be represented on radial diagrams. (see the example table on the next page.) Reporting limits can be entered as the detection limit as an alternative to the MDL.
- If you are entering data into the table from a historic report which only lists ND without a detection limit, you cannot enter zero. You can enter an arbitrarily low value if you are confident that the detection limit was relatively low (e.g., -0.001 or -0.01 ug/L).
- Top Assay results may be entered as follows:
    - For the monitoring event, enter the results for the non-TOP sample analyses for PFCAs such as PFBA, PFPeA, PFHxA, PFHpA, PFOA, and PFNA. These values represent the groundwater concentrations prior to the performance of the TOP assay and are assigned to the specific monitoring event.
    - To represent the total TOP assay results (i.e., total PFCA species measured in the assay), create a new monitoring event so that these total measured assay results can be represented as a second data series on radial diagrams, or on stacked bar maps. The chemicals are the same (PFBA, PFPeA, etc.) as the pre-assay chemicals.
    - For a stacked bar map representing the *increase* in PFCAs measured in the TOP assay, create new rows in the Chemicals.csv list to account for the measured increases (e.g., chemical name Top-PFBA to represent ΔPFBA which is the observed increase in PFBA after the TOP assay, and similarly for other relevant PFCAs). These results should be saved in the original monitoring event – there is no need to create a second event to represent TOP assay results if you are plotting the *increase* or change in PFCAs instead of the *total*. You must assign a non-detect value if the increase is zero or negative in the TOP assay relative to the non-assay sample results.

Table 9 - Results.csv: Chemical sample results				
Field No.	**Field**	**Description**	**Variable Type**	**Comments**
9.1	LocID	Result Location ID No.	Integer	
9.2	EventID	Result Event ID No.	Integer	
9.3	ChemID	Result Chemical ID No.	Integer	
9.4	ResultVal	Result value	Real	Result is detected if value is positive; a negative result represents a non-detect, where the absolute value is the detection limit
9.5	UnitID	Concentration units ID No.	Integer	
9.6	ResultType	Result type	Integer	Not currently used, set to 1
9.7	ResultMatrix	Result matrix ID No.	Integer	Not currently used, set to 1

Handling Duplicate Sample Results: It is recommended that you have only one row for results unique to each location, monitoring event, and chemical analyte. This could be the average or maximum result, for example. If multiple results are presented as multiple rows in the Results.csv table, then the last result read during the import process (i.e., lowest applicable row in the table) will be used. As shown below and on the next page, you can sort these on Location-Event-Chemical-Result fields so that the lowest applicable row is the maximum result.

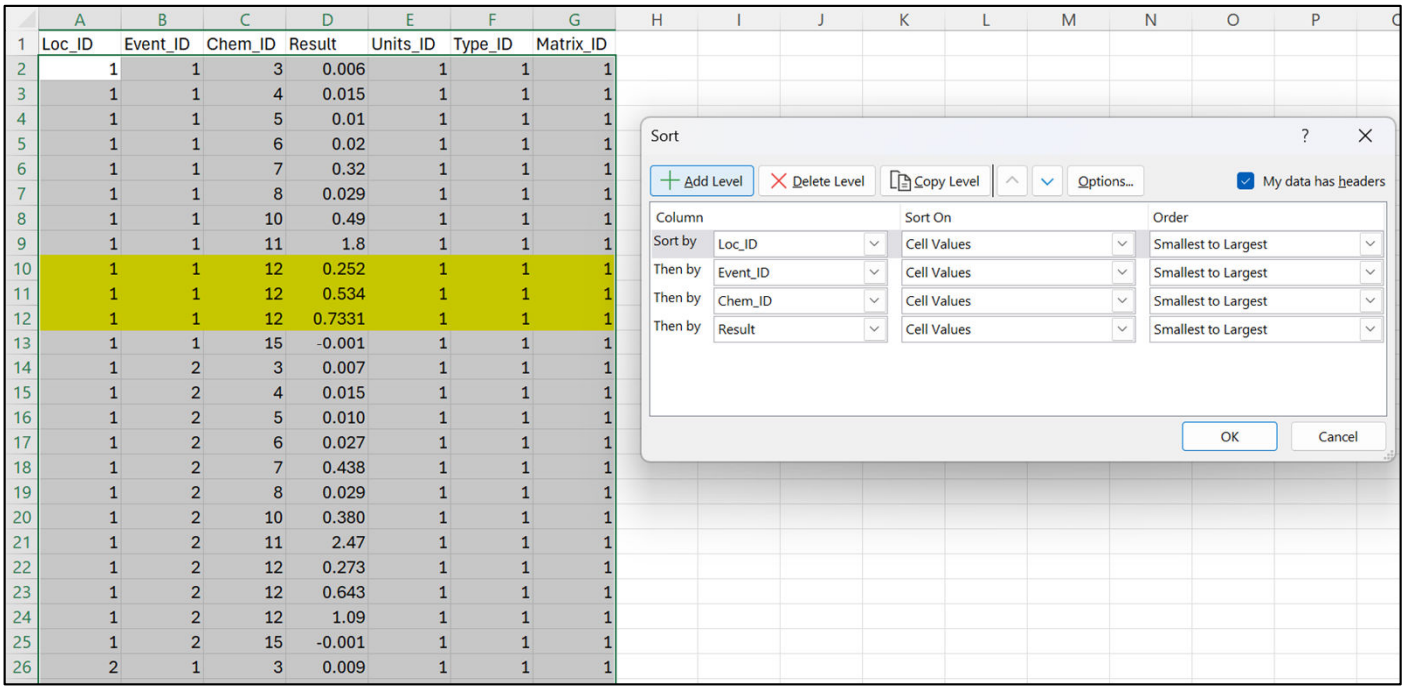
Demo-Airport Example Table

LocID	EventID	ChemID	ResultVal	UnitID	ResultType	ResultMatrix
1	1	3	0.006	1	1	1
1	1	4	0.015	1	1	1
1	1	5	0.01	1	1	1
1	1	6	0.02	1	1	1
1	1	7	0.32	1	1	1
1	1	8	0.029	1	1	1
1	1	10	0.49	1	1	1
1	1	11	1.8	1	1	1
1	1	12	0.252	1	1	1
1	1	12	0.534	1	1	1
1	1	12	0.7331	1	1	1
1	1	15	-0.001	1	1	1
1	2	3	0.007	1	1	1
1	2	4	0.015	1	1	1
1	2	5	0.01	1	1	1
1	2	6	0.027	1	1	1
1	2	7	0.438	1	1	1
1	2	8	0.029	1	1	1
1	2	10	0.38	1	1	1
1	2	11	2.47	1	1	1
1	2	12	0.273	1	1	1
1	2	12	0.643	1	1	1
1	2	12	1.09	1	1	1
1	2	15	-0.001	1	1	1
2	1	3	0.009	1	1	1

In this example with multiple results, the lowest row with a result of 0.7331 ug/L will be used in Visual PFAS™.

The example below shows how the **Results.csv** table can be sorted so that the maximum result with duplicate or triplicate samples is the lowest applicable row in the table for each unique combination of location-event-chemical analyte.

If it is desired to use the average concentration, then that calculation must be done outside of Visual PFAS™. In this case, only a single row with the average analyte concentration would be included for each location-event-chemical in the **Results.csv** table. Averaging concentrations will need to take into account how to handle a mix of non-detect and detected results for duplicate samples.



	A	B	C	D	E	F	G
1	Loc_ID	Event_ID	Chem_ID	Result	Units_ID	Type_ID	Matrix_ID
2	1	1	3	0.006	1	1	1
3	1	1	4	0.015	1	1	1
4	1	1	5	0.01	1	1	1
5	1	1	6	0.02	1	1	1
6	1	1	7	0.32	1	1	1
7	1	1	8	0.029	1	1	1
8	1	1	10	0.49	1	1	1
9	1	1	11	1.8	1	1	1
10	1	1	12	0.252	1	1	1
11	1	1	12	0.534	1	1	1
12	1	1	12	0.7331	1	1	1
13	1	1	15	-0.001	1	1	1
14	1	2	3	0.007	1	1	1
15	1	2	4	0.015	1	1	1
16	1	2	5	0.010	1	1	1
17	1	2	6	0.027	1	1	1
18	1	2	7	0.438	1	1	1
19	1	2	8	0.029	1	1	1
20	1	2	10	0.380	1	1	1
21	1	2	11	2.47	1	1	1
22	1	2	12	0.273	1	1	1
23	1	2	12	0.643	1	1	1
24	1	2	12	1.09	1	1	1
25	1	2	15	-0.001	1	1	1
26	2	1	3	0.009	1	1	1

2.3.10 ReferenceSeriesList.csv Table Format

The 3 fields required for this import table are described in the table below, and the *Demo-Airport* example table is presented at the bottom of the page.

Notes on this table format:

- This table includes a list of reference series which are to be available for plotting with radial diagrams.
- Reference series are plotted using uniform results across all locations at a site. Examples of reference series include background or maximum source concentrations.
- In the *Demo-Airport* example dataset, the reference series represents the Source A concentrations because this source (former FTA where an unlined burn pit was used) has higher PFAS concentrations than Source B (current FTA with a lined burn pit).
- At least one reference series needs to be entered into this table, even if it's not used on radial diagrams.

Note: Large sites may have more than one set of PFAS background concentrations. It is possible to have more than one background reference series listed as reference series (e.g., north and south background reference series). One radial diagram properties file would be created specific to one of these two background reference series. Both sets of radial diagrams (i.e., one with a north background reference series, the other with locations using the south background series) can be overlaid on the site basemap simultaneously simply by adding each radial diagram map as a separate layer to the basemap. (See Section 4.8 in Chapter 4 for more information on how to add radial diagrams to the site basemap.)

Table 10 - ReferenceSeriesList.csv: List of reference series

Field No.	Field	Description	Variable Type	Comments
10.1	RefSeriesID	Reference series ID No.	Integer	
10.2	RefSeriesName	Reference series name	Character (25 max)	
10.3	RefSeriesSortID	Reference series sorting order	Integer	Order for populating drop-down list

Demo-Airport Example Table

RefSeriesID	RefSeriesName	RefSeriesSortID
1	Source A	1

2.3.11 ReferenceResults.csv Table Format

The 6 fields required for this import table are described in the table below, and the *Demo-Airport* example table is presented at the bottom of the page.

Notes on this table format:

- This table lists the chemical analytical results for each reference series listed in the **ReferenceSeriesList.csv** table discussed in Section 2.3.10.
- The fields in this table are generally similar to those in the **Results.csv** table. Refer to the corresponding notes in Section 2.3.9, particularly with respect to entering negative values to represent non-detects (where the absolute value of the result is the detection limit).
- Only one row in the table should be used to represent each chemical analyte in the reference series.

Table 11 - ReferenceResults.csv: Reference Series chemical results

Field No.	Field	Description	Variable Type	Comments
11.1	RefSeriesID	Reference series ID No.	Integer	
11.2	ChemID	Chemical ID No.	Integer	
11.3	ResultVal	Reference series result value	Real	If negative value for UnitType()=1 --> not detected, value=detection limit
11.4	UnitID	Unit ID No.	Integer	
11.5	ResultType	Result type	Integer	Not currently used, set to 1
11.6	ResultMatrix	Result matrix	Integer	Not currently used, set to 1

Demo-Airport Example Table

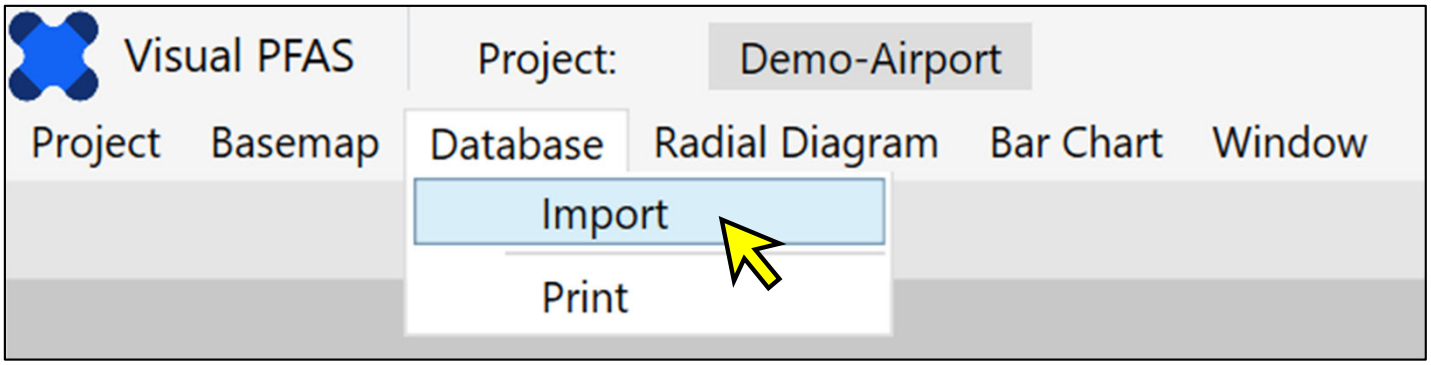
RefSeriesID	ChemID	ResultVal	UnitID	ResultType	ResultMatrix
1	3	1.44	1	1	1
1	4	4.4	1	1	1
1	5	2.94	1	1	1
1	6	4.8	1	1	1
1	7	77.8	1	1	1
1	8	4.7	1	1	1
1	10	25	1	1	1
1	11	200	1	1	1
1	12	250	1	1	1
1	15	150	1	1	1

2.4 Importing the Dataset

After creating a new project, the next step is to import the 11 project dataset tables described in Section 2.3. Click on the **Database** option in the top menu bar and then click **Import** to start this process (see arrow below).

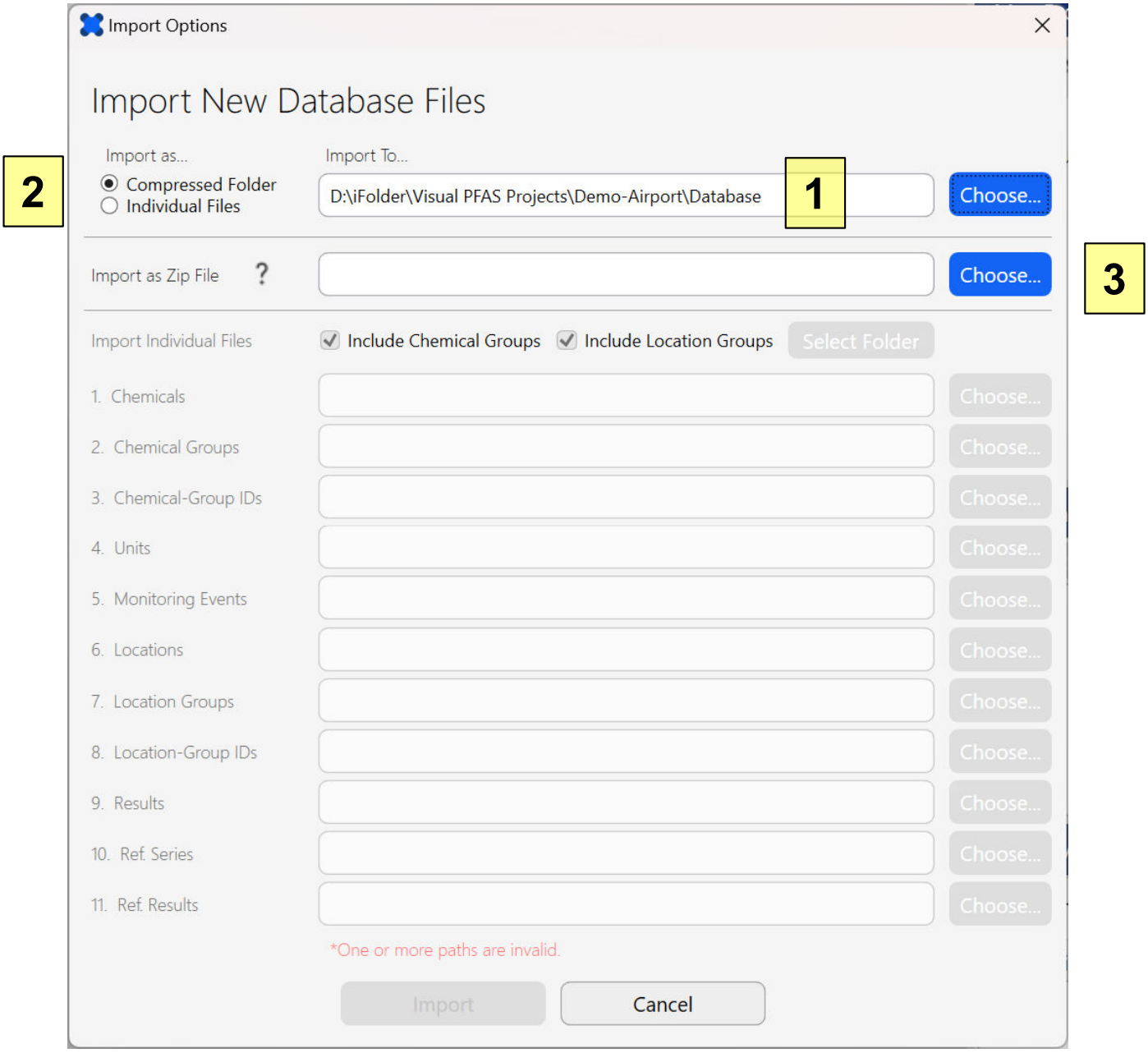
Notes:

1. This import process only needs to be done once. During the import process, Visual PFAS™ will conduct a QA/QC to verify that the import data tables are properly formatted. Error messages will be displayed if there is a problem with the formatting of any of these tables. Import errors should be corrected before proceeding.
2. After the import process has been completed, the imported dataset tables will be copied to the **Database** folder as read-only, with the same names as the eleven csv files previously imported. Do not change or move/delete the files in the **Database** folder.
3. It is possible to print the contents of all tables in the **Database** folder to a single csv report file, to verify the content of the database after the import process. To print a database "report", select the Print option in the **Database** menu (see image below).
4. Visual PFAS™ will automatically read the dataset files in the **Database** folder each time it is re-opened.
5. If any of the eleven dataset files (*.csv) are changed in the **Import** folder, then these changes will only be adopted after re-importing the dataset.
6. Visual PFAS™ tracks the path of the project folder and the corresponding sub-folders (e.g., Basemap, Database, Import, etc.). It is possible to copy a **Project** folder to another location, in which case you will need to re-import the dataset again.



The pop-up menu below shows two options for importing the dataset files to the default **Database** folder (see "1" below) for the project :

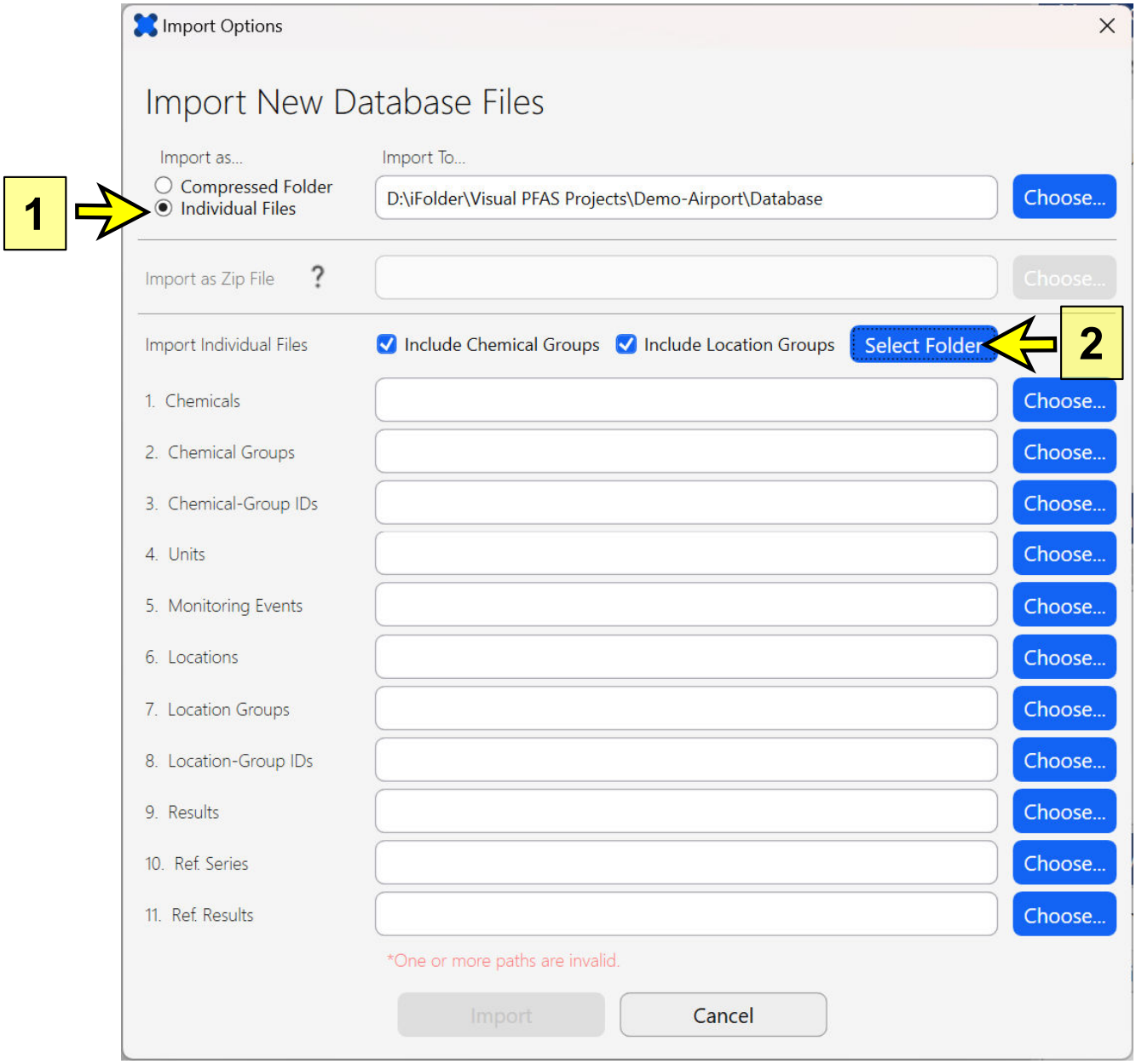
1. Import the tables contained in a compressed folder (i.e., zip file) – see selection at "2" below. If this option is selected, then Visual PFAS™ will automatically read the 11 csv files from the specified zip file. The zip filename and path are specified by clicking the Choose button (see "3" below); OR
2. Import the 11 csv files directly from a sub-folder (see next page).



Selecting Import from Individual (csv) Files

To specify that the 11 csv files will be read from a sub-folder instead of a zipped file:

1. Click the “Individual Files” button (see “1” below); and
2. Click the Select Folder button (see “2” below).

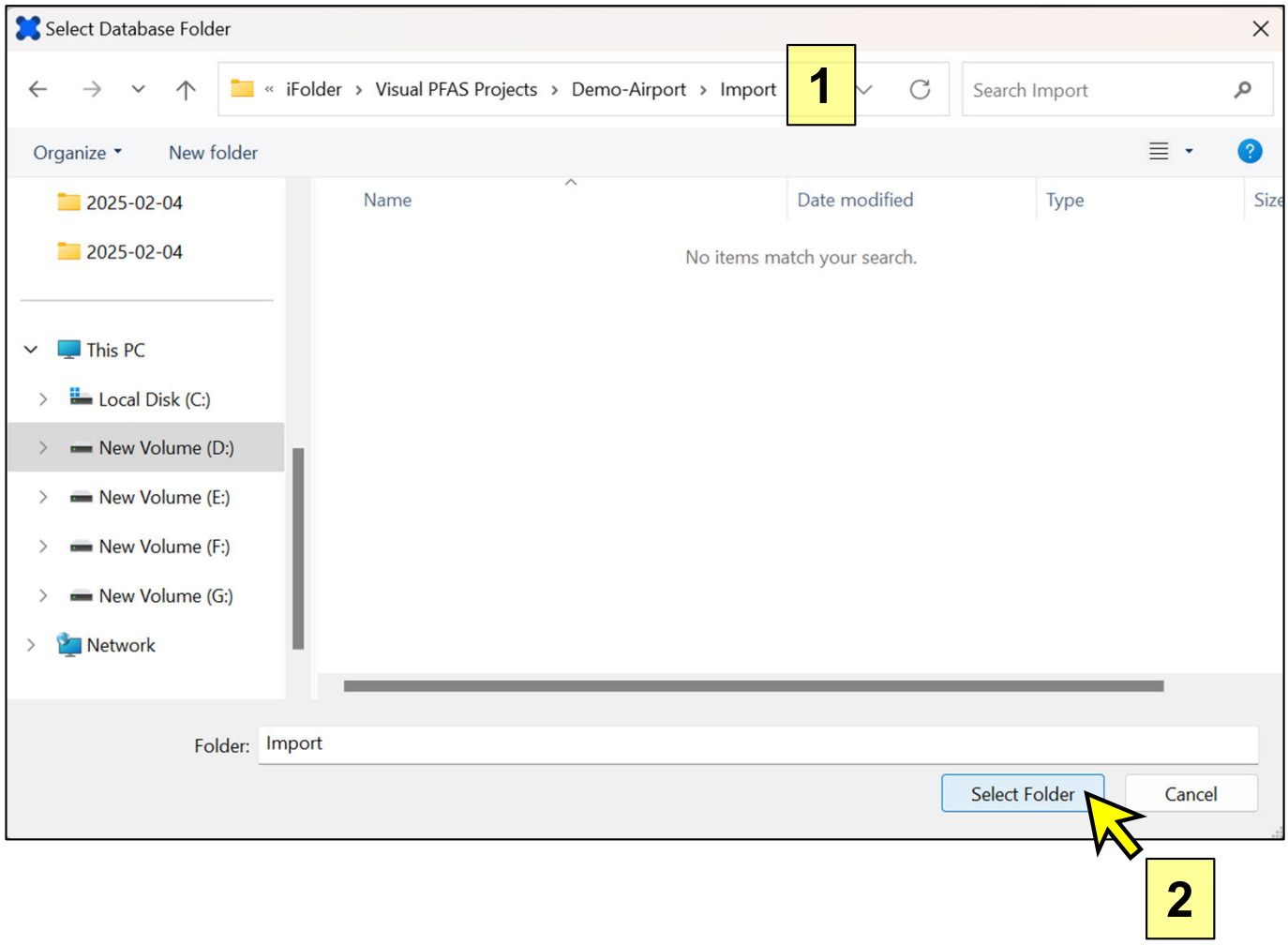


After pressing the **Select Folder** button, the dialog box below will appear.

Using the path bar at the top of the dialog box (see "1" below), navigate to the location of the Import folder containing the project dataset. The default sub-folder will be the **Import** folder under the Visual PFAS™ main **Project** folder that was created when the new project was started (see Section 2.1).

You won't see the csv files in this dialog box because you are only selecting the folder, not an actual file.

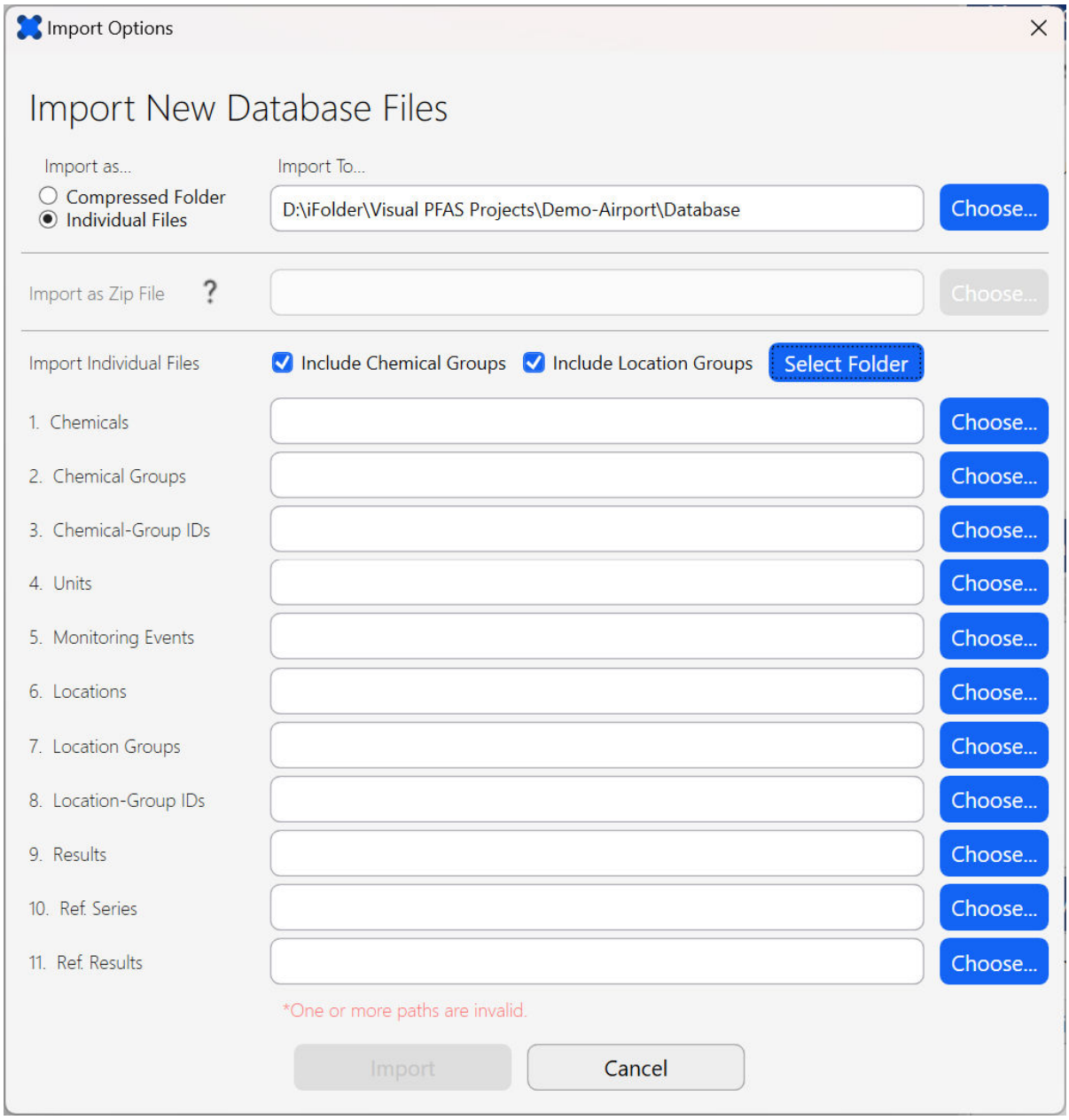
Once the **Import** folder path has been specified, click the **Select Folder** button to save this change (see "2" below).



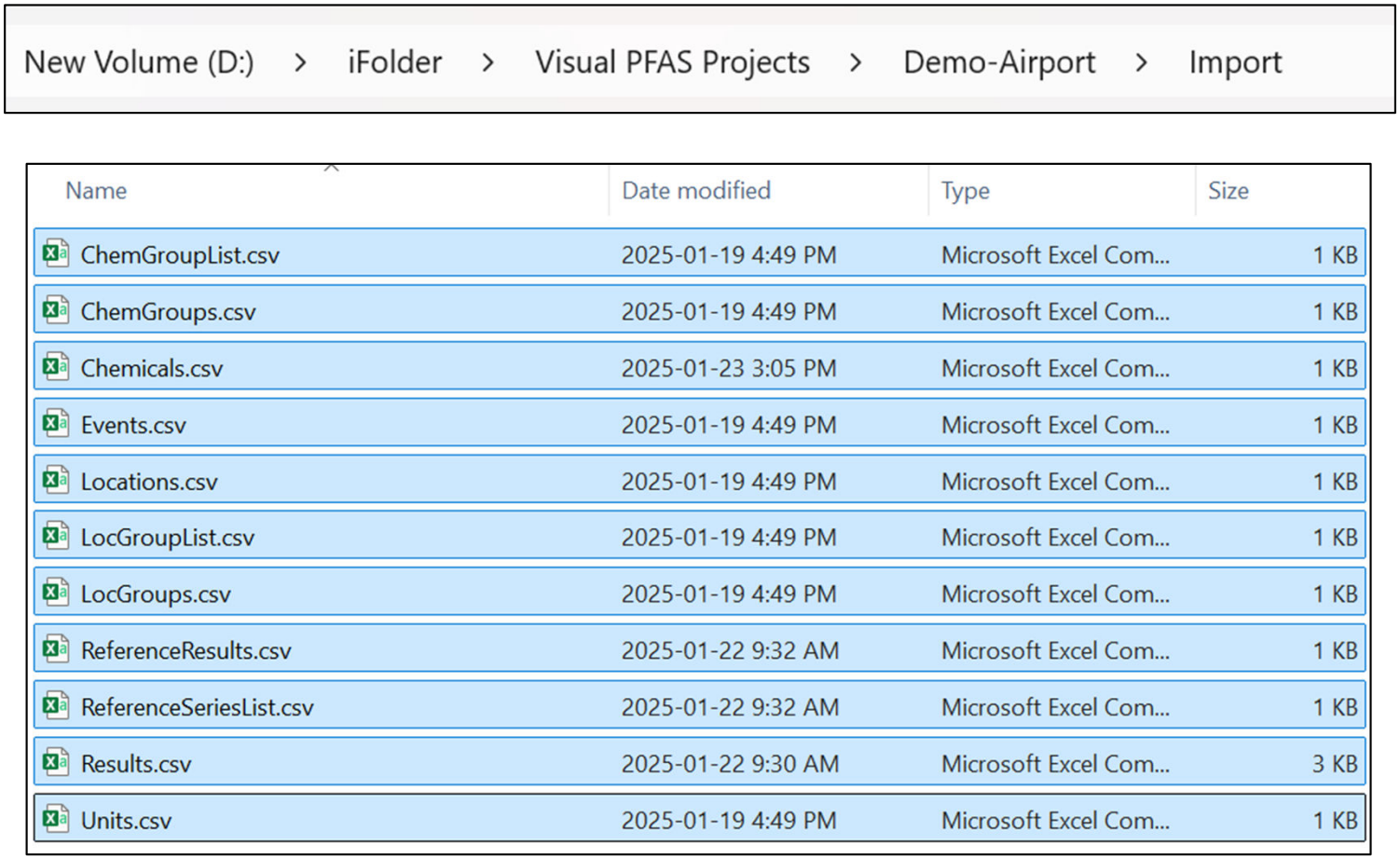
Once you've specified the **Import** folder path, you should see the path and names of all 11 csv files for the import dataset listed in the window below.

If you are not seeing the names of these files listed, as shown below, it means that the csv files were not found in the selected Import folder. This is also noted with the "One or more paths are invalid" error message shown in red font at the both of the image below.

In our case, the project **Import** files have not yet been copied into the Import folder as part of this tutorial. The *Demo-Airport* dataset csv files are provided with the Visual PFAS™ install files in a separate folder. (see the Visual PFAS™ Quick Install Guide for the location of this tutorial folder)

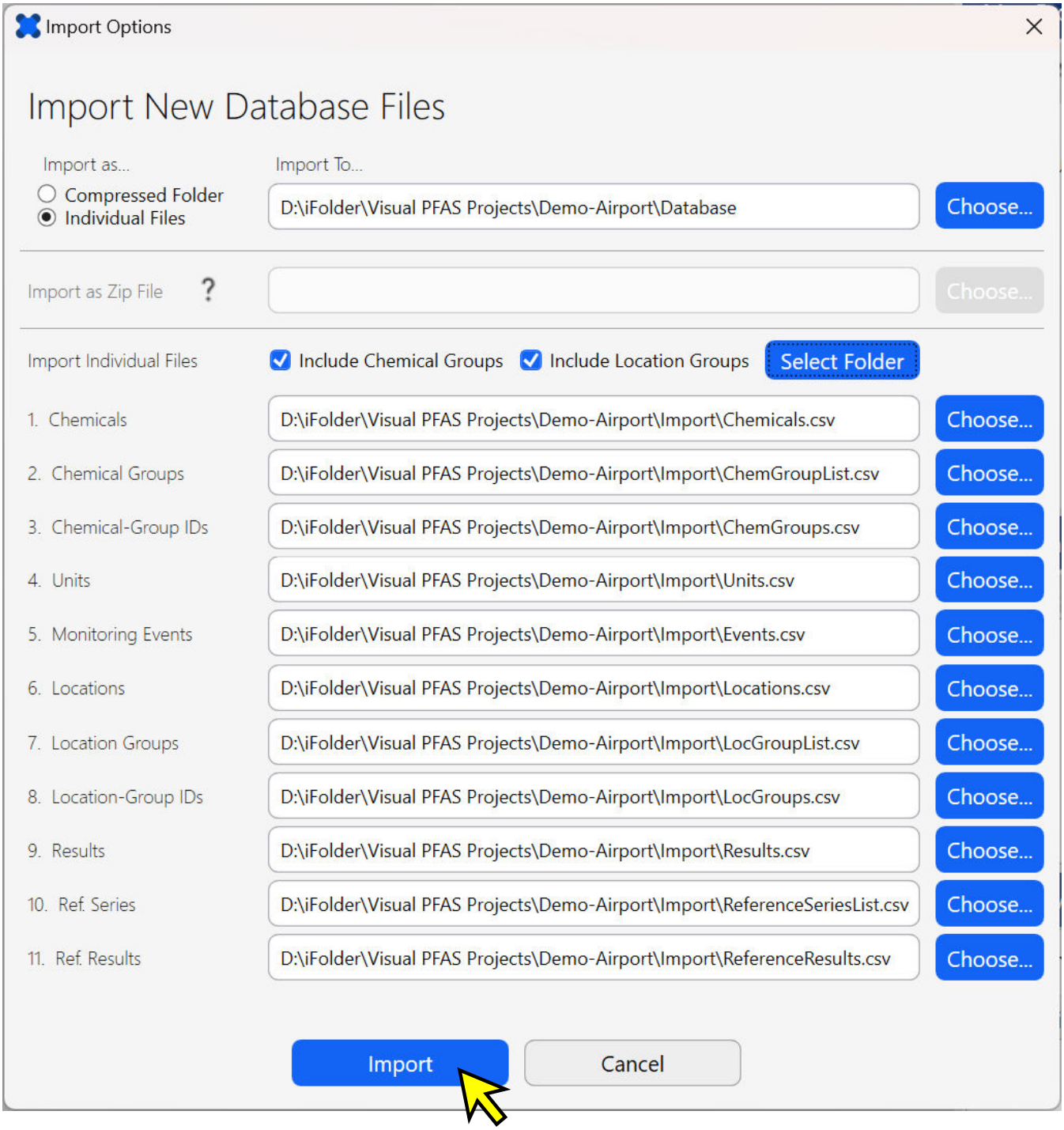


The next step in the tutorial is to copy the *Demo-Airport* dataset csv files to the project Import folder. An example path is shown below, along with the list of import csv table files that should be copied from the Visual PFAS™ install folder to the project **Import** sub-folder. (This step is conducted using Windows Explorer, outside of Visual PFAS™.)



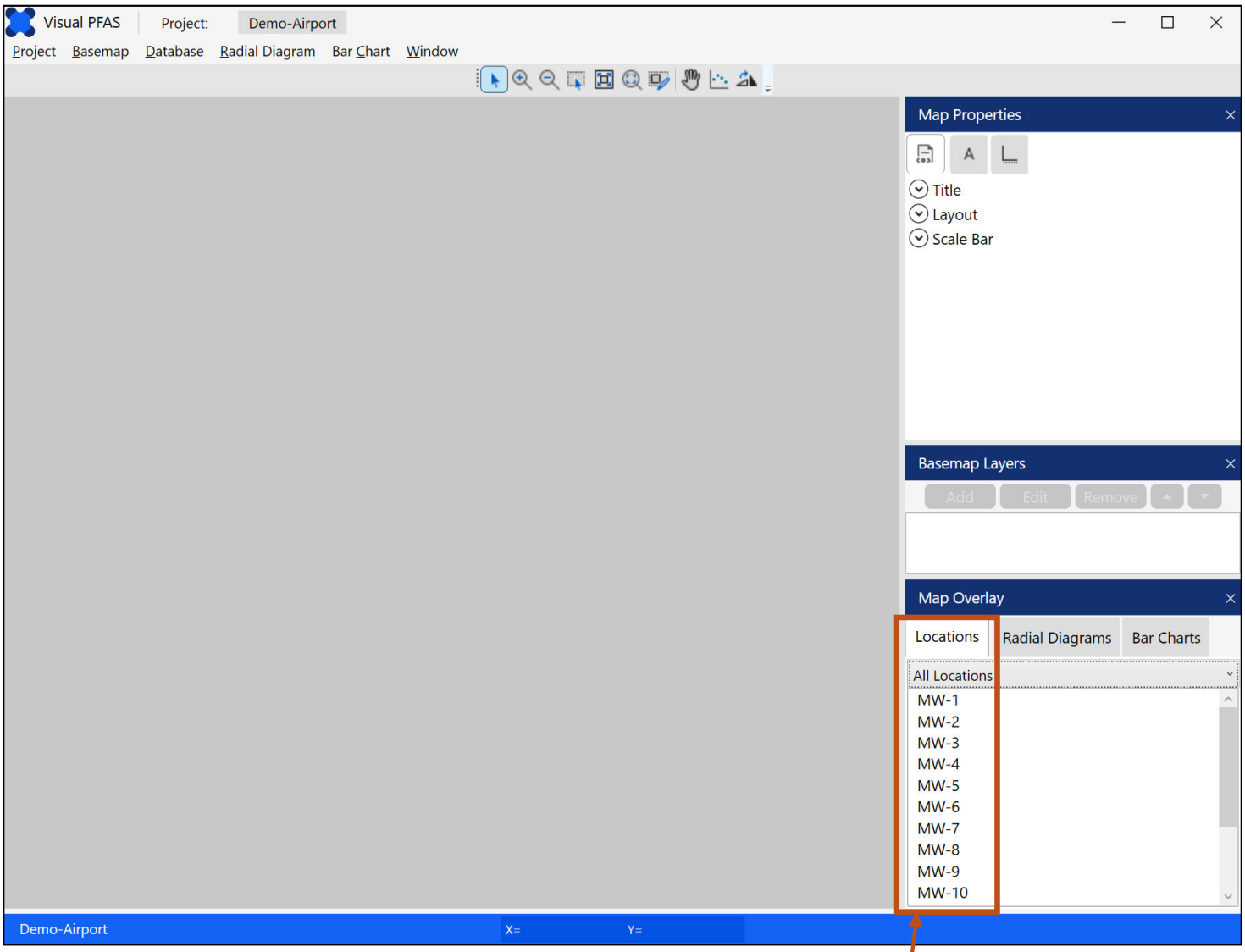
After copying the csv files into the target Import sub-folder, re-select the **Import** sub-folder using the steps shown previously on p. 2.27 to 2.28.

Now when you return to the dialog box below, you will see the paths and filenames for all 11 comma-delimited csv files shown as depicted below. Click the Import button (see arrow below) to import the dataset into Visual PFAS™. If any errors are displayed during the automatic QA/QC process that Visual PFAS™ conducts during this import step, these errors should be corrected and the dataset re-imported before proceeding.



Once you've successfully imported the dataset, the monitoring well locations will be listed in the Map Overlay section of the basemap as shown below.

The well locations are not shown yet on the basemap because a basemap hasn't been created yet as part of this tutorial. See Chapter 3 for the tutorial steps to create a basemap and display selected well locations.



Locations are listed after database imported

2.5 Importing A Soil/Sediment Dataset for Visualization

The current version of Visual PFAS™ is generally focused on preparing visual aids based on groundwater monitoring results. However, it is possible to plot soil and/or sediment sample results using the same visualization tools.

The main difference between groundwater and soil samples is that groundwater samples are associated with a single monitoring location (i.e., single screened horizon); whereas soil borings will typically have multiple sampling intervals associated with each location. It is true that nested wells have multiple screens, although in this case each well screen would be assigned to a different location in the dataset (e.g., MW-1S and MW-1D would be listed as separate locations in the **Locations.csv** table).

When using radial diagrams or stacked bar maps to visualize soil or sediment data on a plan view map of a site, the monitoring events list (**Events.csv**) can be re-purposed to become a list of sampling horizons based on user-specified depth or elevation target intervals. For example, let's say that you wanted to plot one or multiple maps to represent soil concentration trends for the following depth intervals: a) 0-2 feet below ground surface (ft bgs); b) 2-10 ft bgs; 10-20 ft bgs; and d) 20 to 40 ft bgs. (In this example, the site water table is at a depth of 40 ft bgs.)

A simple workaround with Visual PFAS™ is to create a new project folder and a new dataset (separate from your groundwater sample folder and dataset), to represent soil and/or sediment sample results. In this new dataset, the monitoring events list would list the four depth intervals as Event Names instead of four monitoring events. (It is assumed that you would plot soil sample results from all available site characterization events, or you could use a subset of investigations – this dataset compilation is done outside of Visual PFAS™, so you have flexibility about which data to include in the import dataset.)

The Events.csv file would have four rows below the header with the following EventNames:

- 0 to 2 ft bgs
- 2 to 10 ft bgs
- 10 to 20 ft bgs
- 20 to 40 ft bgs

Each of these depth intervals becomes a separate data series that can be represented on a radial diagram or in a stacked bar map. For example, you can plot all four data series (i.e., depth intervals) on a single radial diagram at each soil boring location, to visually assess how PFAS concentrations change with depth on a single map. The main difference between soil and groundwater visualization using radial diagrams is that with soil, each event or data series represents a distinct depth (or elevation) horizon; and with groundwater each series represents a different monitoring event.

Visual PFAS™ currently has hardwired concentration units for a water matrix (e.g., ng/L, ug/L, mg/L, etc.). When using Visual PFAS™ to represent soil or sediment sample results, you can use the same water units as if they were solid concentrations. For example, use ng/L to represent solid concentrations in ng/kg; use ug/L units to represent sample results in ug/kg; etc.

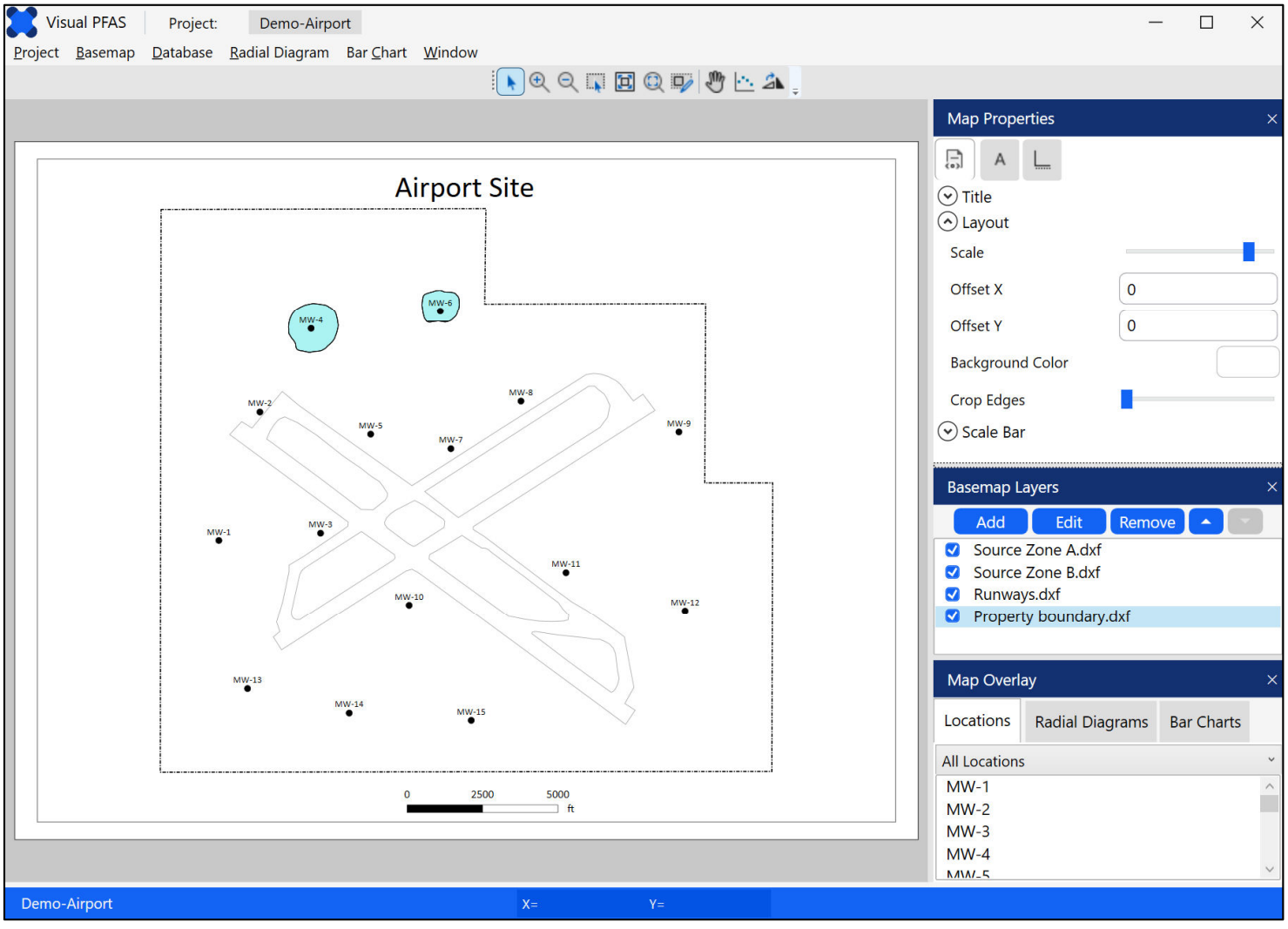
So the **Units.csv** file will still have the same water concentration units; and your **Results.csv** and **ReferenceResults.csv** will have the same Unit IDs that correspond to ng, ug, mg, etc. in the solid units. For example, if a soil sample result was 1.2 ug/kg, the UnitID assigned to that sample result would be 1 in the **Results.csv** table, which is consistent with units of ug/L in the **Units.csv** table. The unit conversion factors are the same for soil and water concentrations in this case.

A future version of Visual PFAS™ will include solid concentration units (e.g., ng/kg, ug/kg, mg/kg, etc.) as another option in the **Units.csv** table.

Visual PFAS™
Users Guide:

Creating A Basemap

Chapter 3



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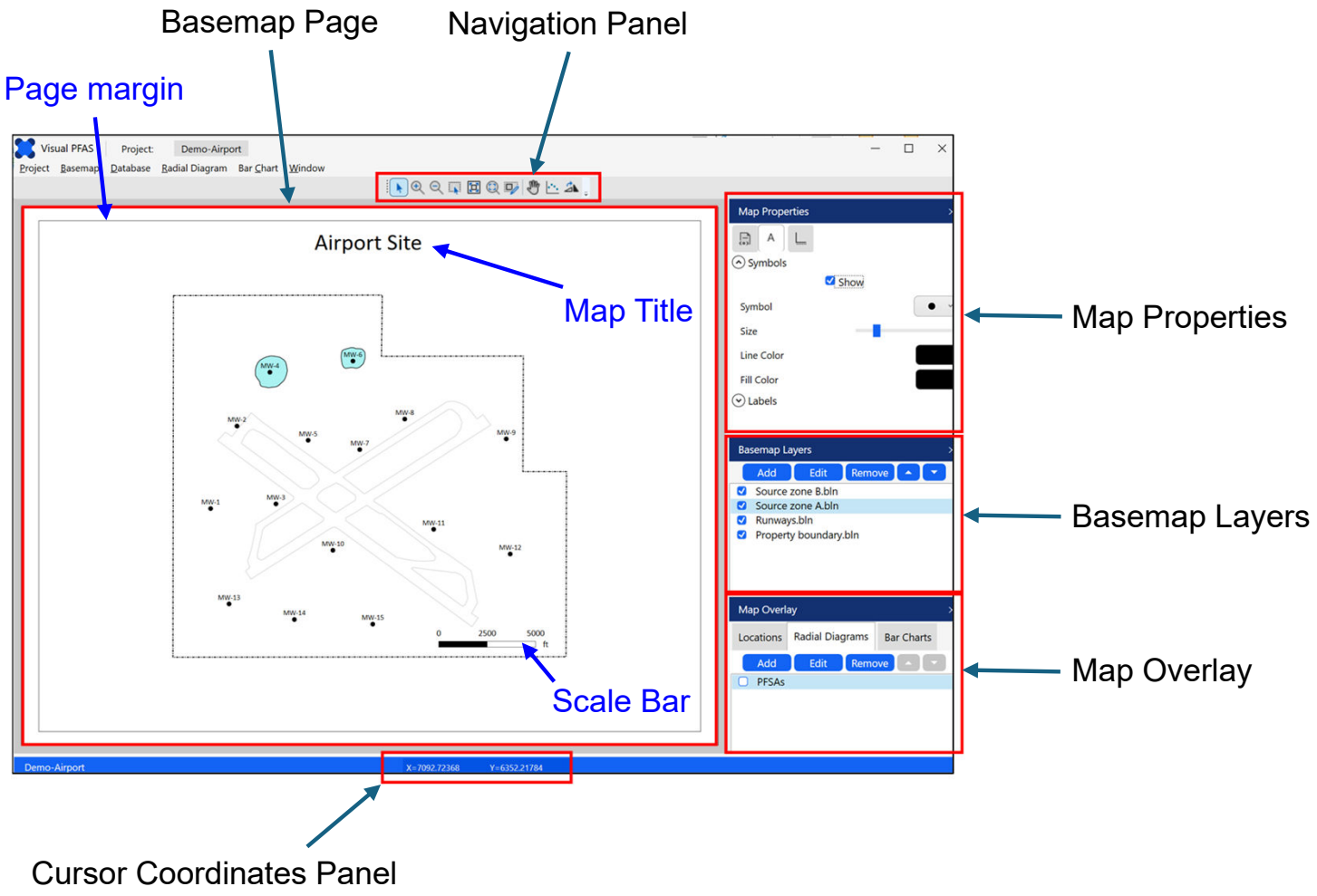
3.1 Introduction to Visual PFAS™ Basemaps

Visual PFAS™ basemaps allow users to import polyline or polygon layer files in shapefile, CAD dxf, or Surfer boundary line (bln) format. The main purpose of these basemaps is to provide a simple platform for determining which locations to include in radial diagram and stacked bar maps, and for viewing the final radial diagram and stacked bar maps.

A number of options are provided in Visual PFAS™ for adjusting the look of the basemap; however, Visual PFAS™ is not intended to replace more sophisticated programs for preparing basemaps and final report figures such as GIS, CAD, or Surfer. The final radial diagram and stacked bar figures may be exported as images for further editing in other software (e.g., PowerPoint for making presentations), and as vector files that can be imported to GIS, CAD, or Surfer for editing figures in specialized templates that most companies use for preparing reports.

The main components of the Visual PFAS™ **Basemap Window** are shown below, and include the Basemap Page (letter size in portrait or landscape), a Navigation Panel, Map Properties, Basemap Layers, Map Overlays, and a Cursor Coordinates Panel. These components are discussed further below.



The general functionality of each component in the Basemap window includes:

- **Basemap Page** – portrait or landscape view (letter size at 8.5” x 11”) of the basemap with options for including a basemap title, a scale bar, easting and northing coordinate axes, basemap layers, symbols to illustrate select locations (e.g., all locations in the dataset or only the locations in a specific location group), and eventually radial diagram and stacked bar maps.
- **Navigation Panel** – various buttons to facilitate zooming in and out, panning, entering custom basemap extents, toggling between portrait and landscape page views, and digitizing points.
- **Map Properties** – allows users to change a number of properties related to the basemap title, size (i.e., scale) of the basemap layers on the page, scale bar, location symbols and labels, and easting and northing coordinate axes around the edges of the basemap.
- **Basemap Layers** – Addition, editing, or removal of polyline and polygon layers (e.g., site property boundary, source areas, surface water tributaries, roads, etc.). Layers may be added in *.shp, *.dxf, and/or *.bln format.
- **Map Overlays** – Several tabs that facilitate selection of a location group for showing symbols on the basemap (or selecting all locations); adding radial diagram layers and editing key features such as the radial diagram axis lengths from the basemap window; and adding stacked bar layers and editing key features such as the height and width of the stacked bars from the basemap window.
- **Cursor Coordinates Panel** – illustration of easting and northing (i.e., X and Y) coordinates of the cursor location on the basemap.

The tutorial for creating and editing a basemap is based on the project started in Chapter 2 of this Users Guide. It is assumed that the project dataset has already been imported per the steps described in Chapter 2, although users have the option of importing the initial dataset (or a revised dataset) at any time while using Visual PFAS™.

The process for constructing radial diagram and stacked bar maps, or editing features related to these maps from the basemap window, are described in Chapters 4 and 5, respectively.

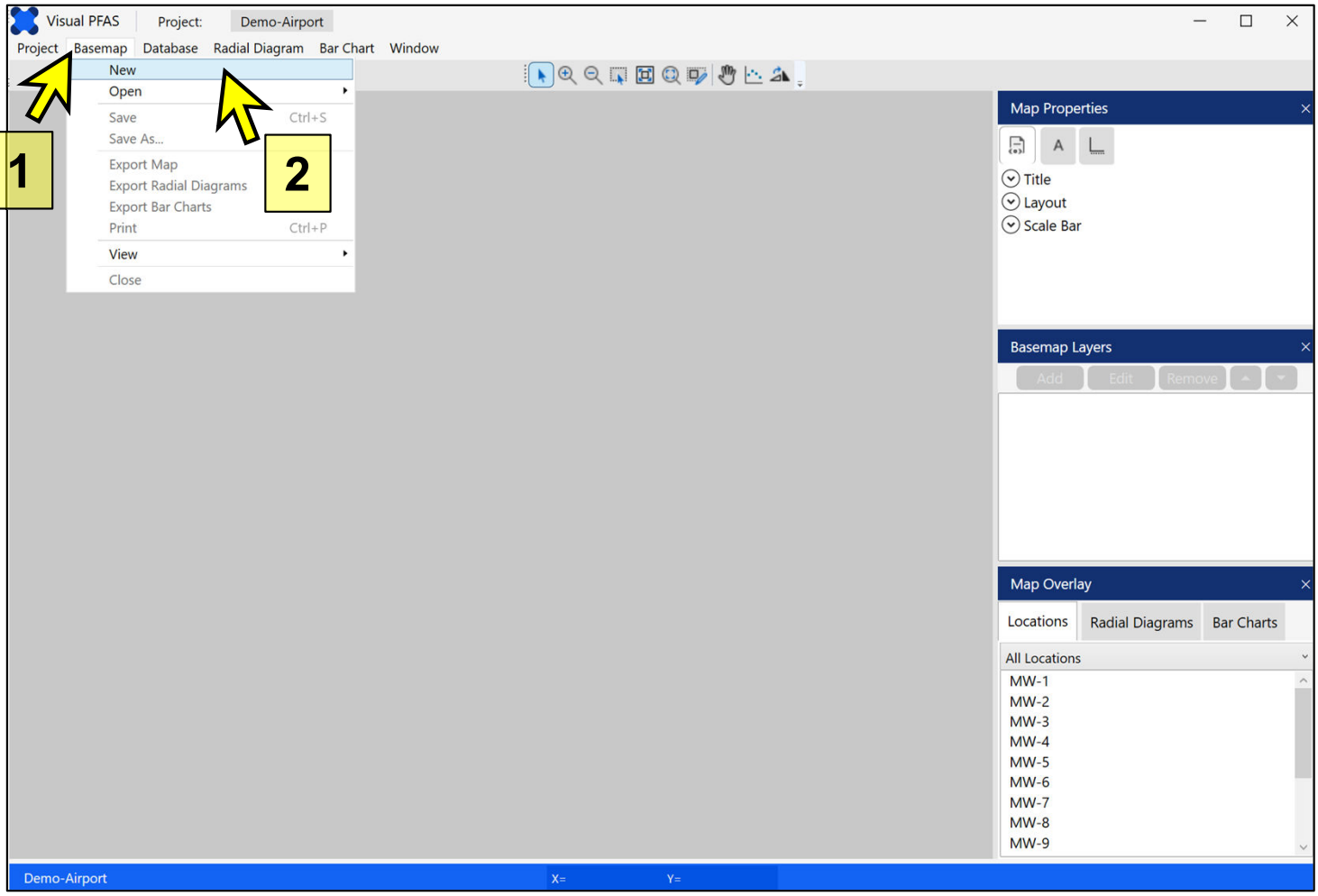
3.2 Creating A New Basemap

The window below shows where the tutorial left off at the end of Chapter 2, after importing the project dataset with location and chemical analytical data. The list of monitoring well locations is shown in the **Map Overlay** section at the bottom-right of the image below.

To start the creation of a new basemap, click the **Basemap** option from the main menu (see "1" below) and then select **New** (see "2" below).

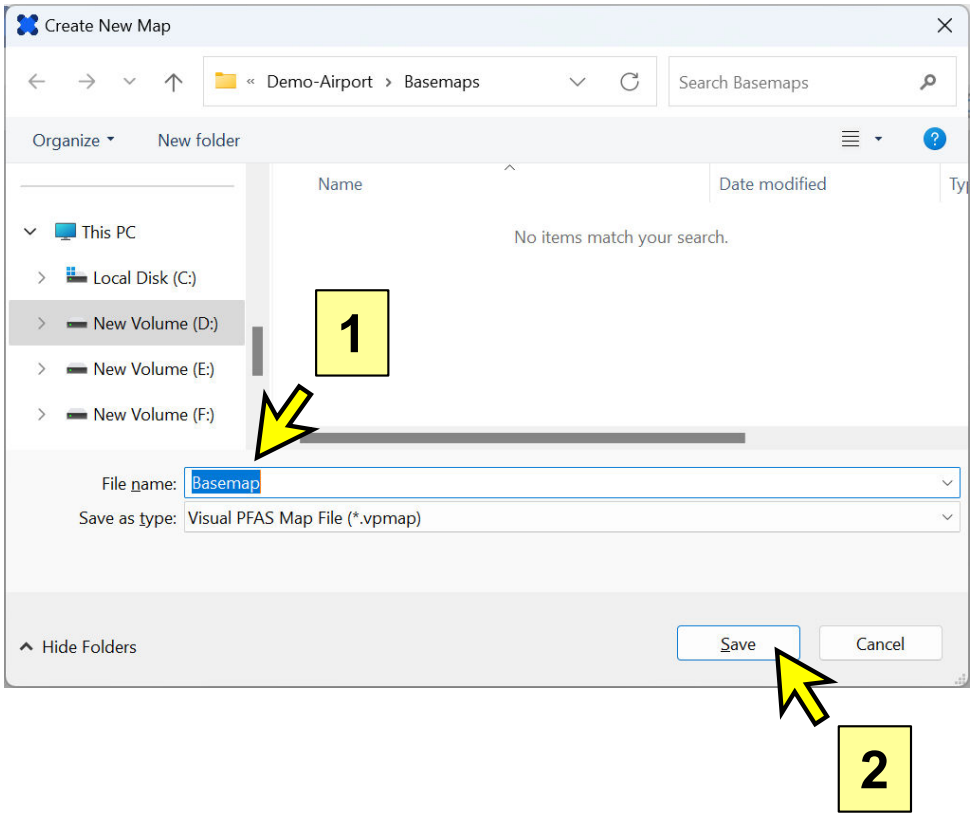
Notes:

1. As shown in the menu options below, users have the option to save a basemap, to Save As a new basemap file, export, print, toggle on/off the Map Properties, Basemap Layers and Map Overlay components on the right side of the window, and to close a basemap.
2. For large sites with many monitoring wells or soil borings, it may be beneficial to create one site-wide basemap, and then to create multiple basemaps with a more zoomed-in (i.e., local) scale of certain areas. Radial diagram and stacked bar maps can also be created either with all site locations, or a subset of locations from a specific area.



After selecting the **New** basemap option, the dialog box shown below will pop-up. Visual PFAS™ will automatically select the **Basemaps** sub-folder under the **Project** folder for the destination of the new basemap file to be created with a *.vpmap extension. This basemap file stores all of the properties that users select during the basemap editing process. Users should not attempt to open this file outside of Visual PFAS™.

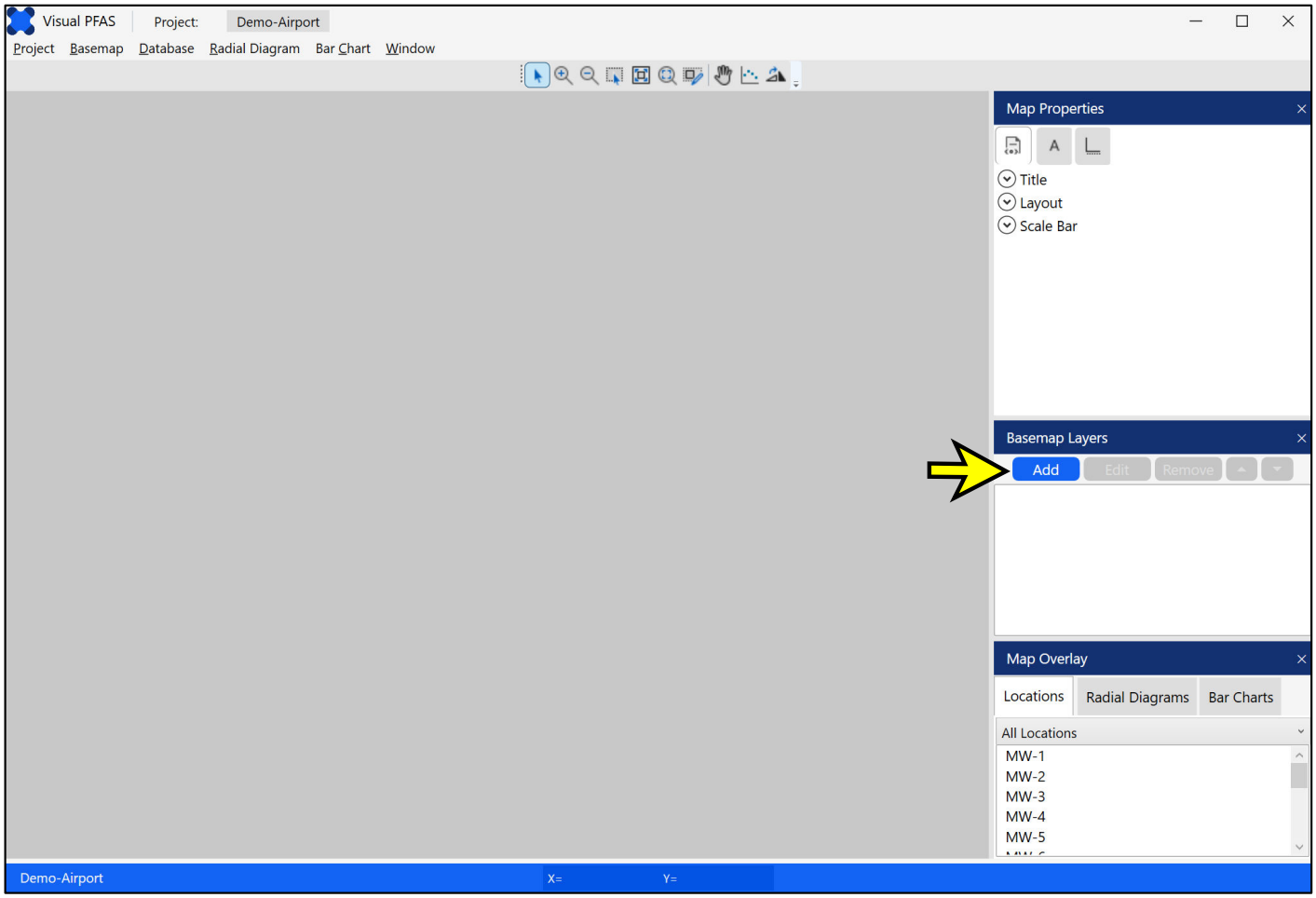
Enter the name of the basemap file to be created: *Basemap (*shown at "1" below). Then click the **Save** button (see "2" below) to return to the basemap window.



3.3 Adding Basemap Layers

After creating the new basemap properties file, the only change to the basemap window shown below is that now the **Add** button in the Basemap Layers component has changed to blue (see arrow below, which means that the Add basemap layers option has now been enabled.

Note: When a button in Visual PFAS™ changes from being grayed out to blue, it means that the button has been enabled so users can now click on the button to enact a function.

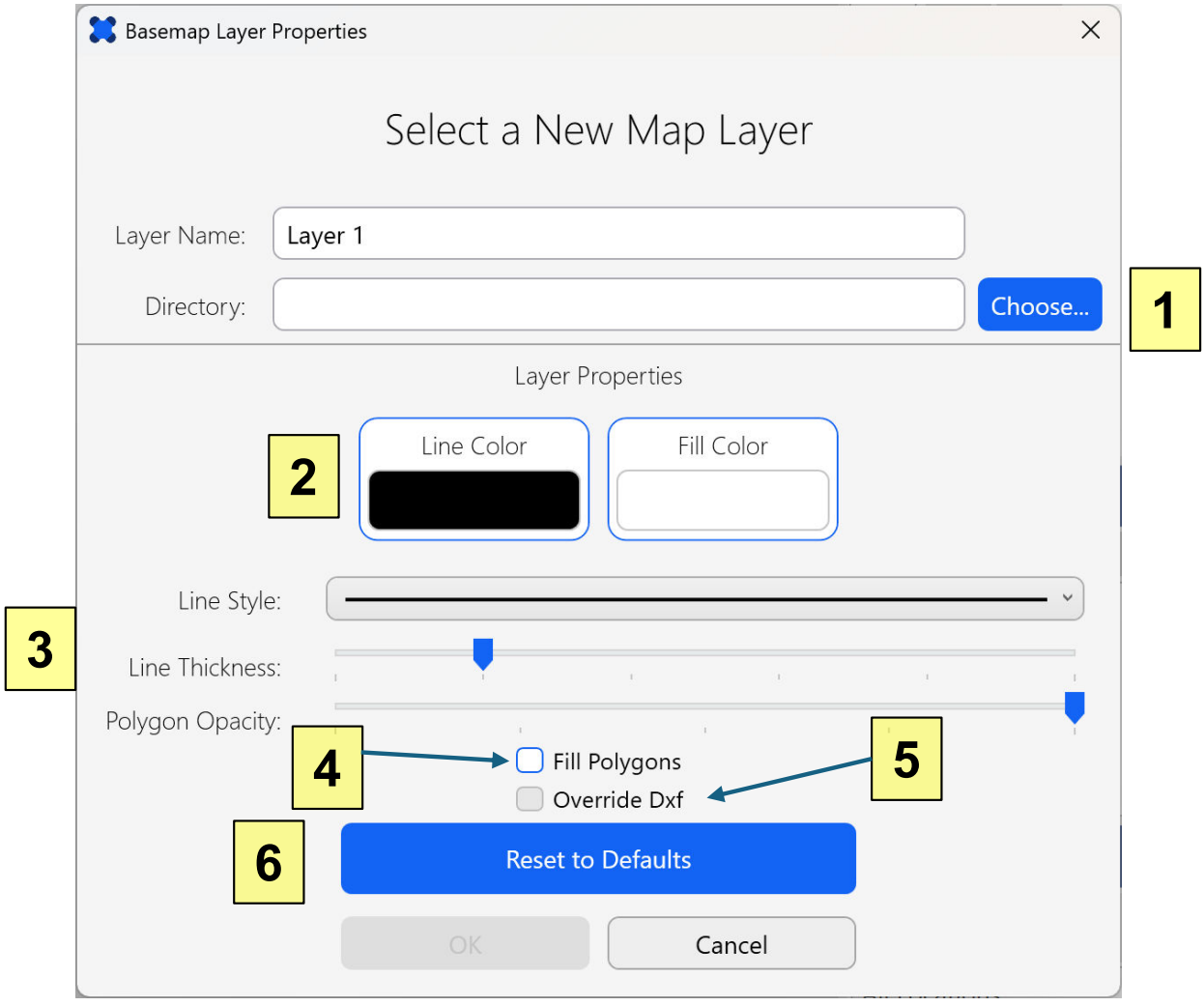


The next step in the tutorial is to add several map layers. The Visual PFAS™ installation package comes with a folder containing four *Demo-Airport* map layers in dxf format: Property boundary, runways, Source zone A, and Source zone B. Copy these map layer dxf files into the **Map Layers** sub-folder under the *Demo-Airport* **Project** folder.

Once you have copied over these four map layer dxf files to the **Map Layers** sub-folder (see the *Visual PFAS™ Quick Installation Guide* for more information), click the **Add** button to start adding layers to the basemap.

After clicking the Add button, the Basemap Layer Properties window will pop-up (see below). This is where users can specify the path and filename of a layer containing polylines and/or polygons to the basemap. Visual PFAS™ will automatically recognize polygons as polylines that start and end at the same coordinates. The additional feature associated with polygons relative to polylines is the option to add color fill to polygons contained in a layer. Properties which may be specified for a layer (with corresponding numeric labels in the image below) include:

1. Pathname and filename of layer to add (dxf, shapefile, or Surfer bln format);
2. Line color and optional fill color for polygons;
3. Line style, line thickness, and polygon opacity (100% opacity is solid and is equivalent to 0% transparency; using <100% opacity allows objects below a filled polygon to be visible);
4. Fill polygons checkbox (to toggle the fill option on/off);
5. Override dxf – enabled if a dxf file is added. This option allows users to overwrite line and fill properties contained in a layer dxf file; and
6. Reset to default line and fill properties.



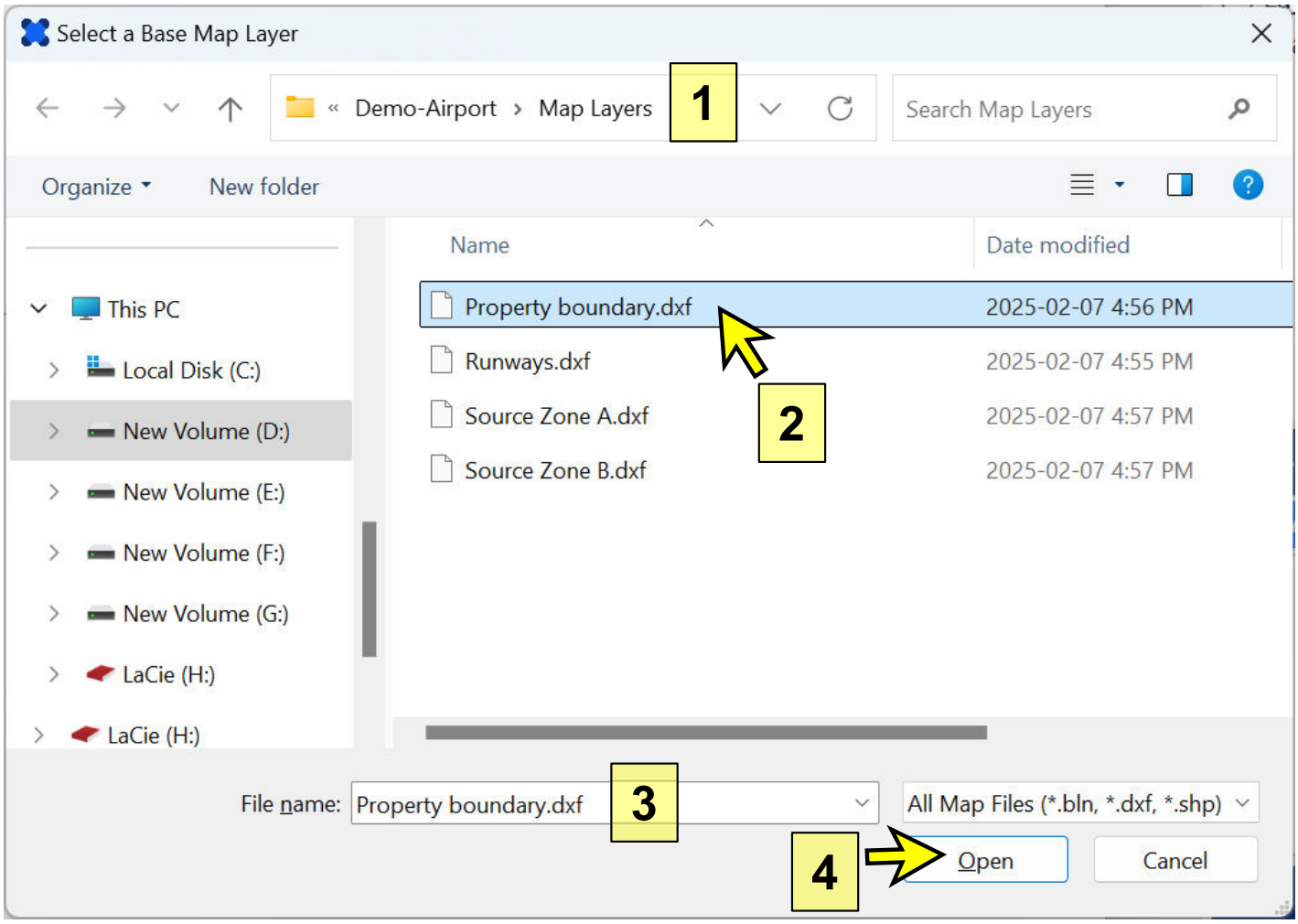
The next step in the tutorial is to add four basemap layers in dxf format. Start by clicking the **Choose** button in the **Basemap Layer Properties** window shown on the previous page. This will cause a file dialog box to appear. The default folder used by Visual PFAS™ is the **Map Layers** sub-folder in the **Project** folder (see "1" below).

Click once on the **Property boundary.dxf** shown in the list (see "2" below). The filename will be added in the textbox at "3" below.

Click the **Open** button to select this layer file to be added to the basemap and you will return to the Basemap Layer Properties window.

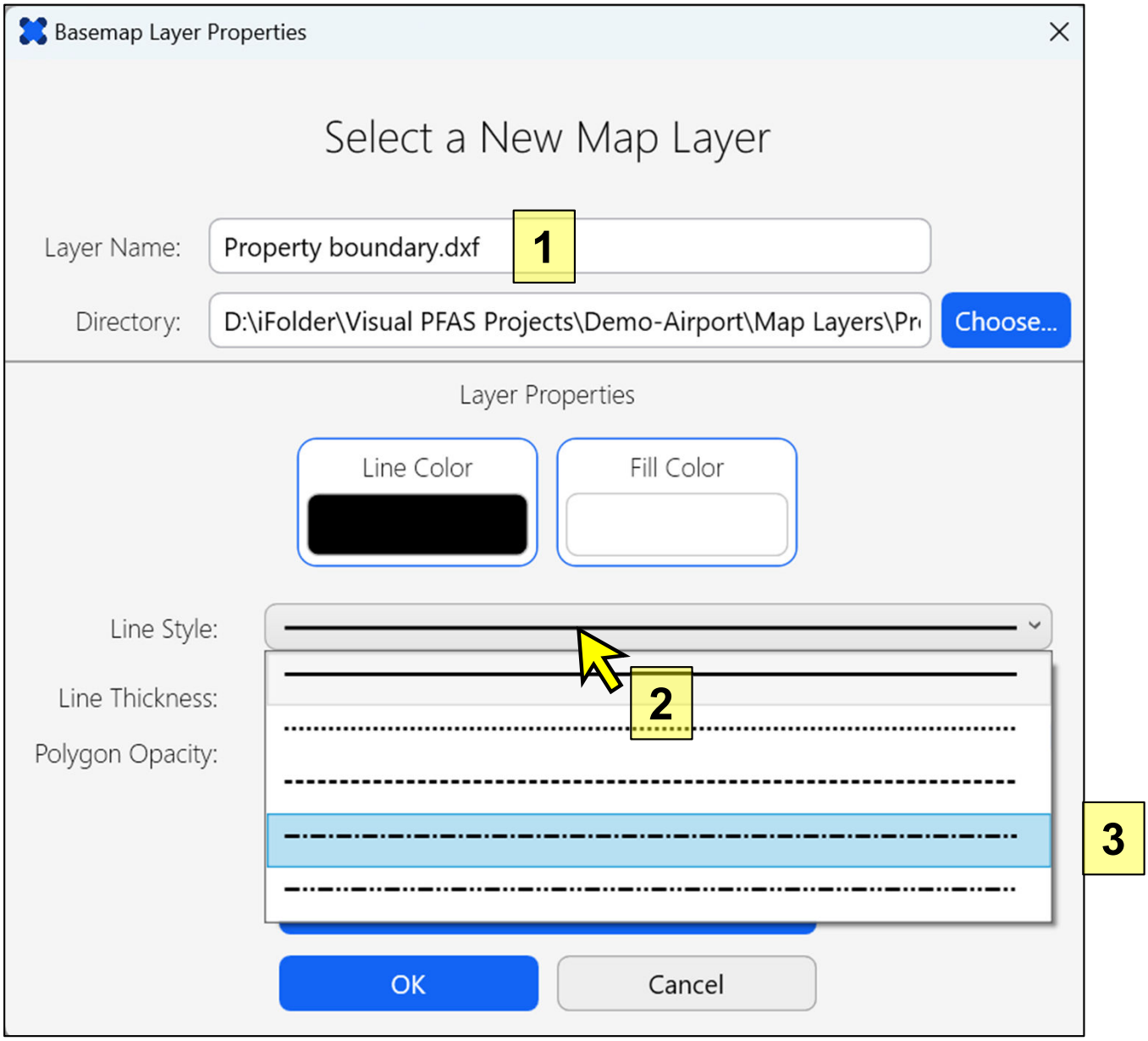
Notes:

1. If you don't see the four dxf files shown below in this folder, then you need to copy these layer files from the Demo-Airport files that came with the Visual PFAS™ installation files. See the instructions at the bottom of page 3.6 or in the *Quick Installation Guide*.
2. You can only select one layer file at a time to add to the basemap.



The layer name will be automatically populated with the filename (see "1" below). This layer name will appear in the list of layers associated with the basemap. You can change this layer name here – the name does not have to be the same as the filename.

Click on the line style dropdown box (see "2" below) and select the dash-dot style typically associated with property boundaries (see "3" below).



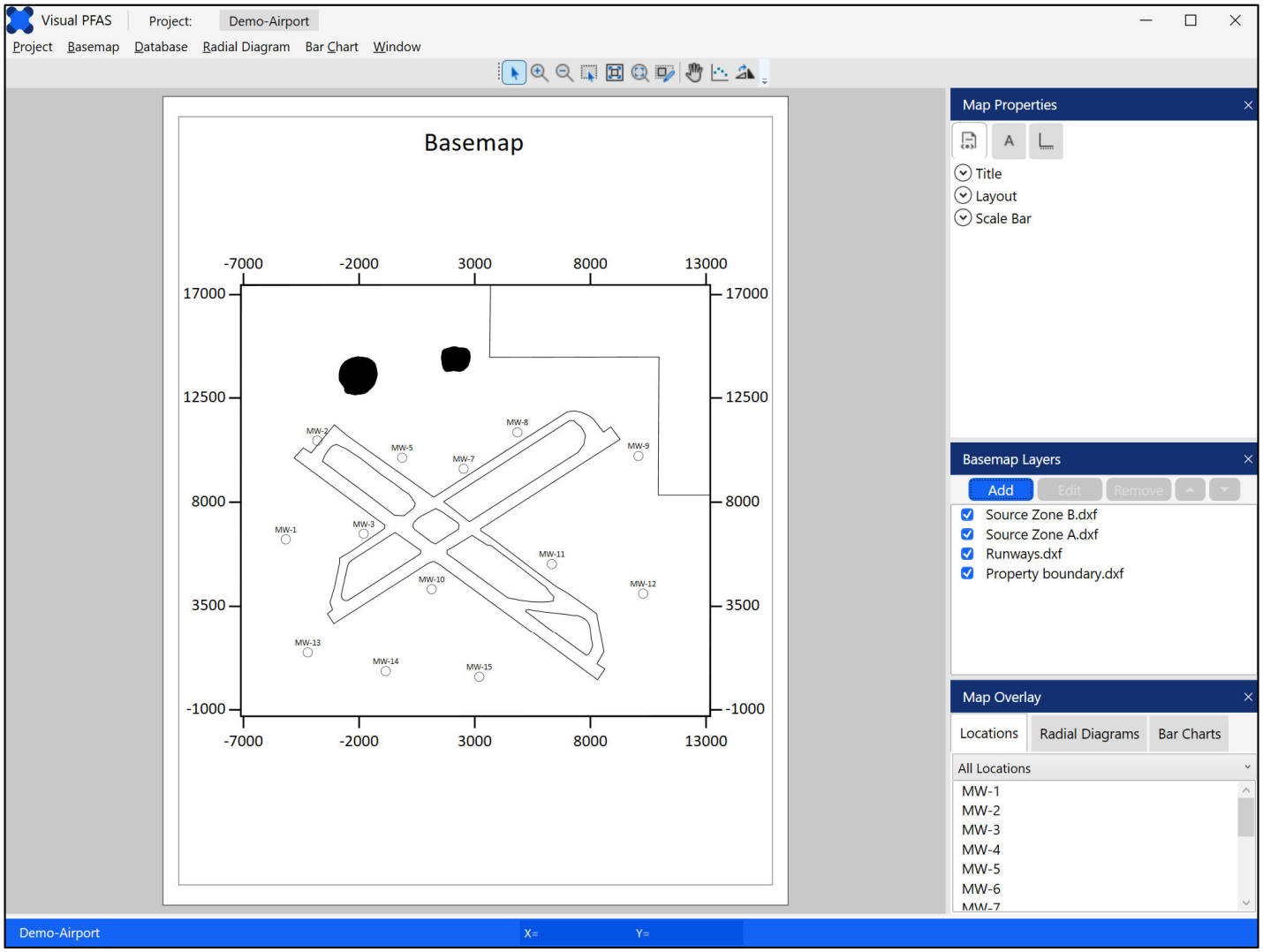
Change the line thickness by moving the scale to the middle as shown below.

Finally, click the **OK** button to save this layer to the basemap.

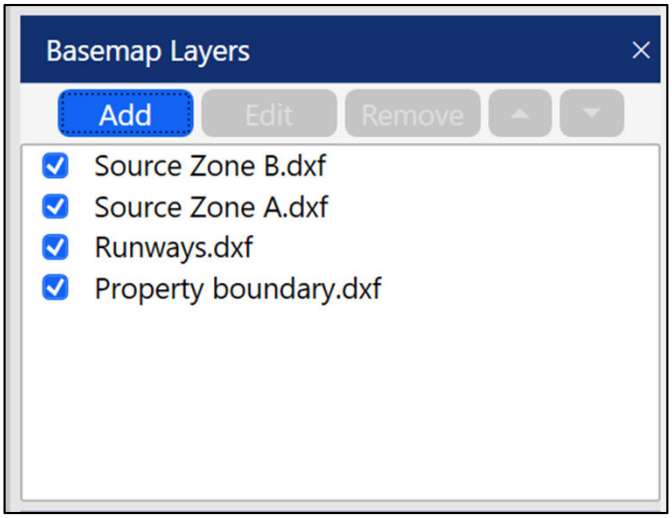
Repeat the steps to **Add** layers to the basemap three times, to add the remaining three dxf layer files (runways and source zones A and B). The basemap window should look like the image below after adding all four layers to the basemap. All four layers are now shown in the **Basemap Layers** section to the right of the basemap page.

Monitoring well locations are now shown on the basemap with symbols and labels. The easting and northing axes are added by default, and are currently covering a portion of the property boundary layer. We will toggle these axes off a little later in the tutorial.

You will also see that the two source area layers are shown with black fill. This is the default associated with the dxf files that we just added to the basemap. We will change this later in the tutorial as well.

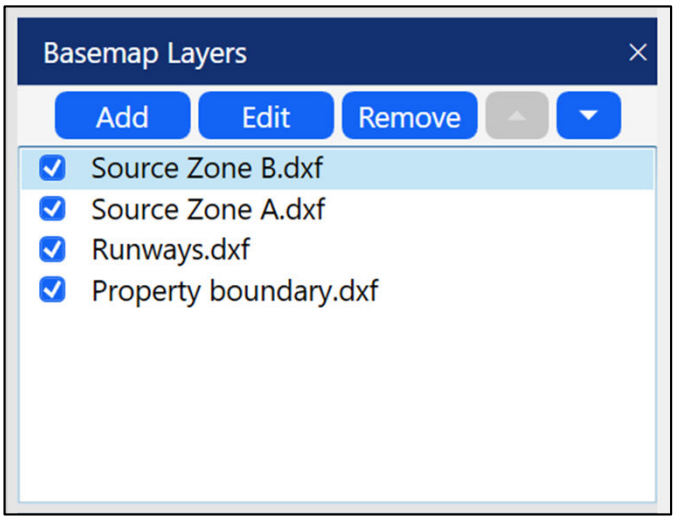


In the Basemap Layers section to the right of the basemap, you will see that the **Add** button is shown in blue at the top of this section, but the other buttons above the layers list are still grayed out (i.e., disabled).



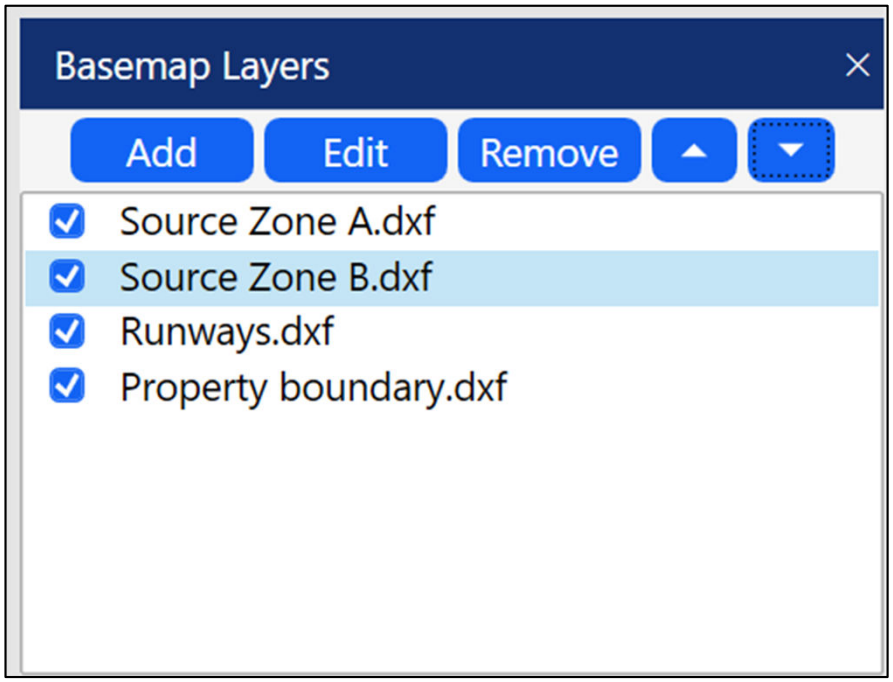
Click on the Source Zone B layer in the list; this will cause this layer to be highlighted in blue as the current layer, and the Edit, Remove, and down-arrow buttons will change to blue. (see image below)

The Edit button allows you to edit the properties for this layer (e.g., line and fill properties). The Remove button deletes this layer from the basemap. The directional arrow buttons (up or down) allow you to change the order of layers in the list. The up-arrow button is still disabled because you have selected the first item in the list, and thus cannot move this layer further up.

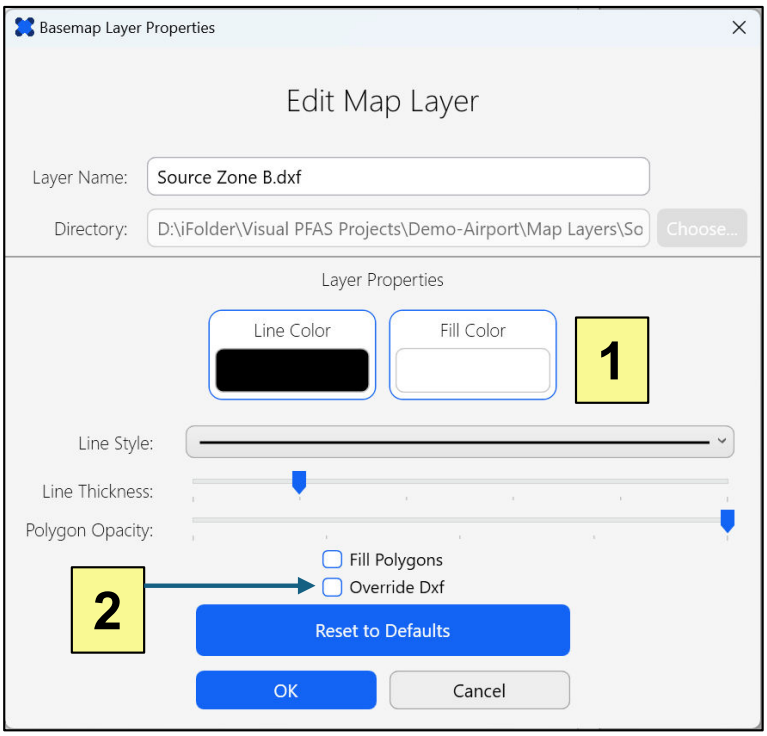


Click the  button to move the Source Zone B layer below Source Zone A in the basemap layers list.

The basemap layers list will now look like the image below.



Note: The order of basemap layers in this list will influence how layers are shown when they overlap on the basemap. The layer shown at the top of the list will be shown above all other layers which intersect with this layer on the basemap. You can change the priority for which layers are plotted where they intersect by moving layers up or down in the list.



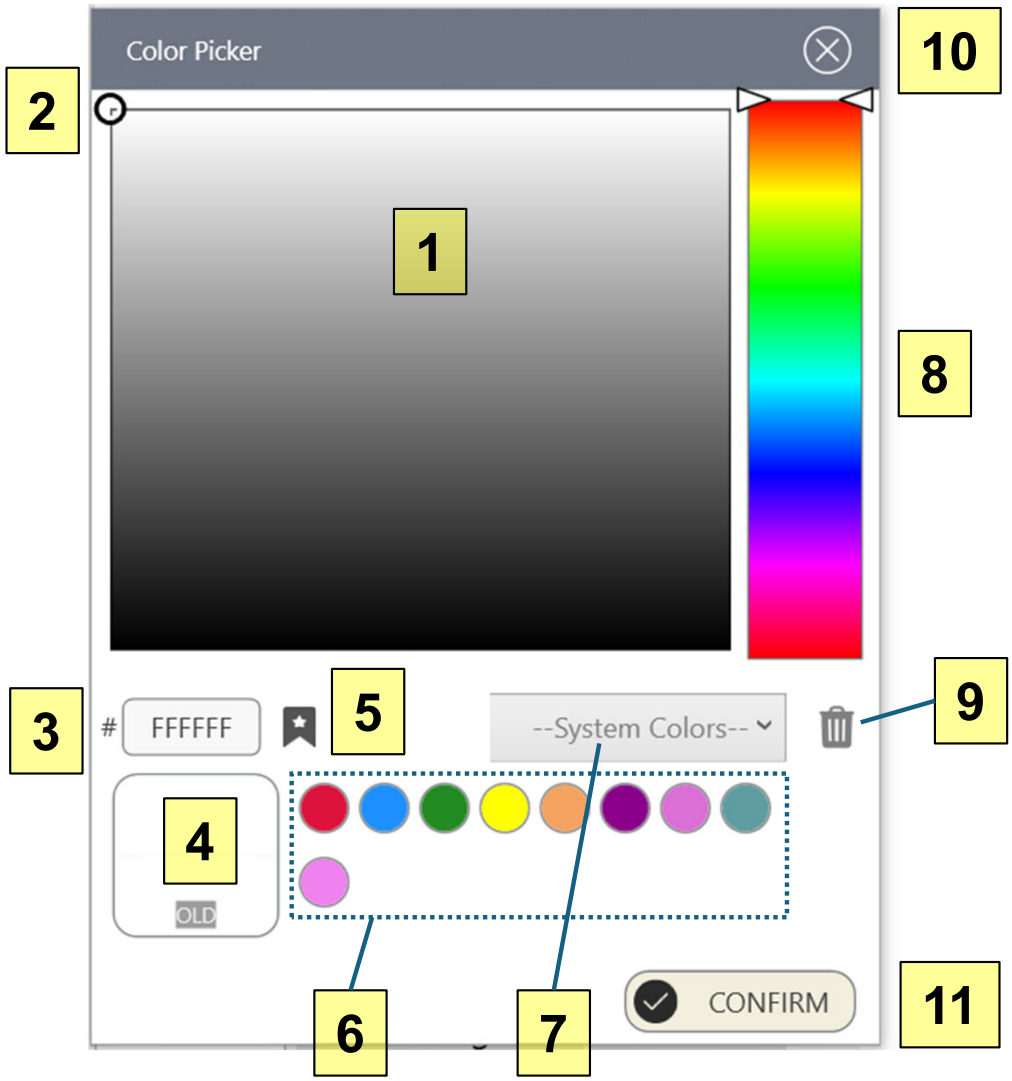
Click the **Edit** button to change the properties for Source Zone B which is highlighted as the current layer. As shown on page 3.10, the source zone layers currently both have black fill based on the properties in the imported dxf files. The fill color is shown in the image on the left as white (see "1"), but the Override DXF button (see "2") is unchecked so this white fill color is not plotted.

Click the fill color button to change the color of the Source Zone B fill. This will automatically override the DXF fill property.

3.3.1 Changing Color Properties

Components of the color dialog box that correspond to the numeric labels shown below:

1. Color palette – click anywhere in the palette to choose the new color.
2. Color selection – the old color (white) is in the top-left of the color palette.
3. The hexadecimal code for the current color selection.
4. Old color (shown in the lower half) and new color (shown in the upper half) – the upper half will change when a new color is selected.
5. Add currently selected color to the Favorites list for quick selection in the future.
6. Favorite colors – click on one to select the new color.
7. System Colors – pre-selected colors shown in a long dropdown list.
8. Color scale bar – click on this to change the color palette.
9. Delete last Favorite color selected.
10. Cancel the selection of a new color, keep the previous color.
11. Confirm saving the new color and close the color dialog box.

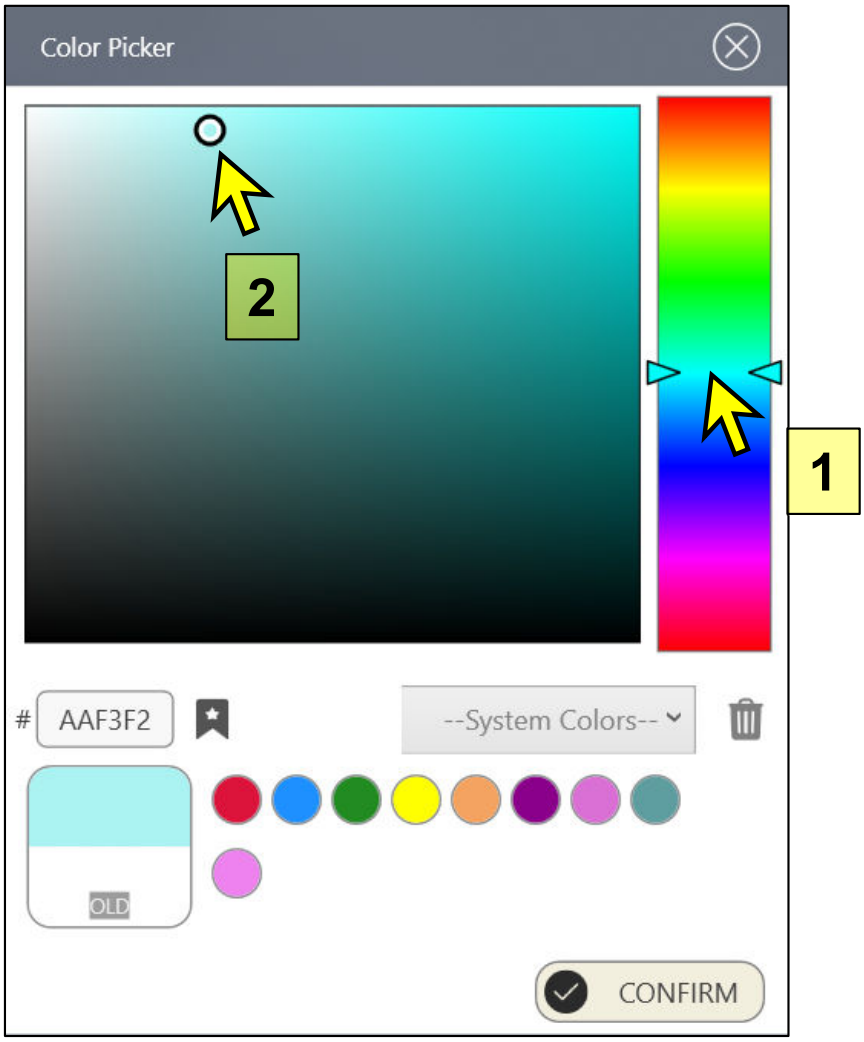


To select blue for the source zone fill color:

- Click on blue in the color scale bar (see “1” below);
- Click around the top left portion for a lighter blue (see “2” below). You don’t have to match the exact color shown below with the hexadecimal code of #AAF3F2.

Notes:

1. You cannot enter the hexadecimal code directly to change the color, this box only shows the code of the selected color. (“#” below for the hexadecimal code, or see “3” in the image on the previous page).
2. You can, however, enter the RGB code to specify an exact color using the step as shown on the next page.
3. There are a number of online color conversion utilities available to convert between hexadecimal and RGB colors. This allows you to calculate the RGB of a color selected using the palette or system colors, so you can specify this exact same color for other basemap layers.



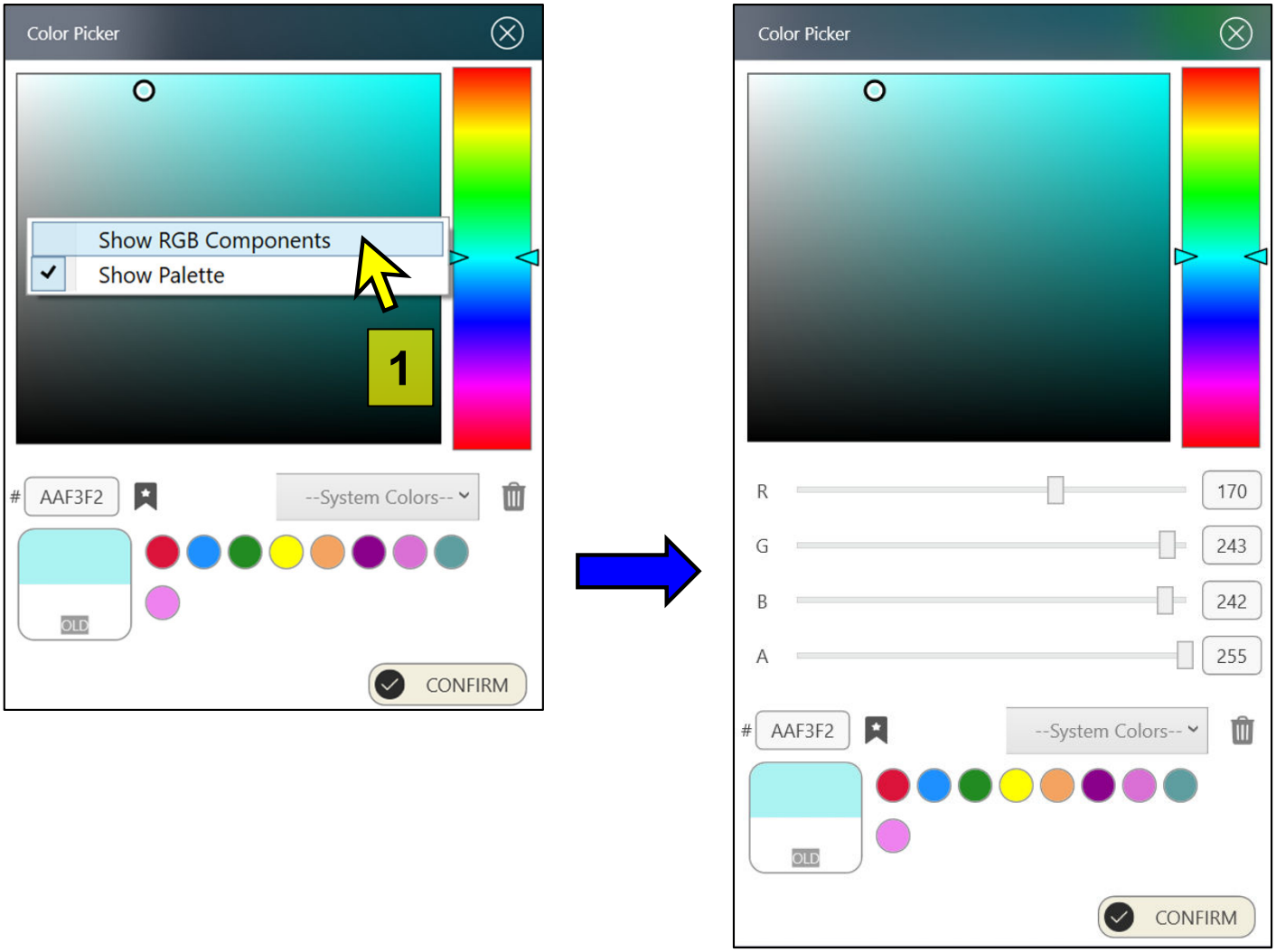
To view the RGB color that corresponds to the selected color with hexadecimal code #AAF3F2, right-click anywhere on the color palette and the pop-up menu shown in the image on the left below will appear.

Select **Show RGB Components** from the pop-up menu (see "1" below on the left). The color dialog box will change to the image shown on the right, where the selected RGB color is shown to have the RGB color code of 170, 243, 242. The **A** line shown in the image on the right (below RGB) represents opacity, which is currently shown as 100% (i.e., a value of 255 in a scale of 0 to 255). This is equivalent to a transparency of 0%. To add transparency to a line or polygon fill color, change the opacity to be below 255.

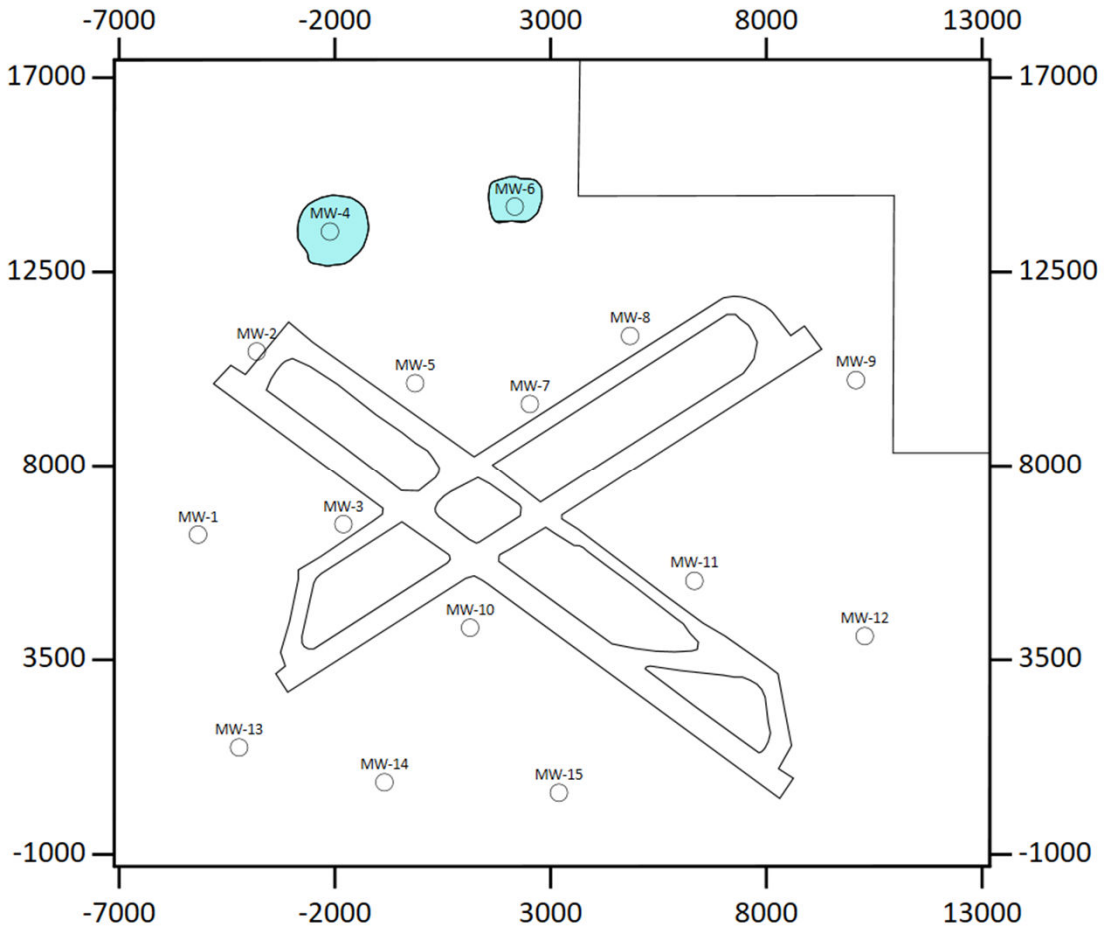
In the image on the right, you can change the R, G, B, or A (opacity) by either sliding the scroll bars to the left or right; or you can enter the values of R, G, B, and/or A in the text boxes shown to the right of the respective scroll bars.

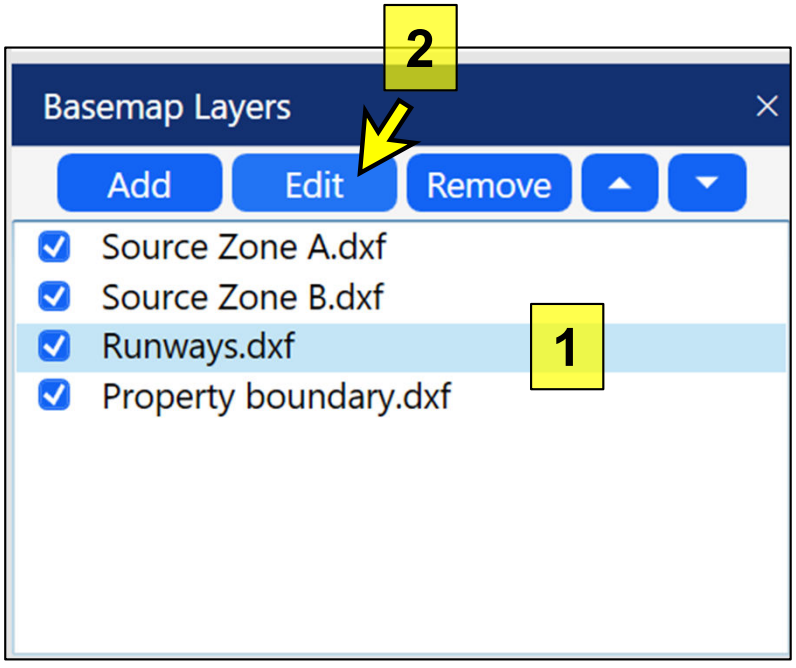
Press confirm to save the selected color for the fill at Source Zone B.

Then repeat these steps to enter the RGB code of 170, 243, 242 for the color fill in Source Zone A.



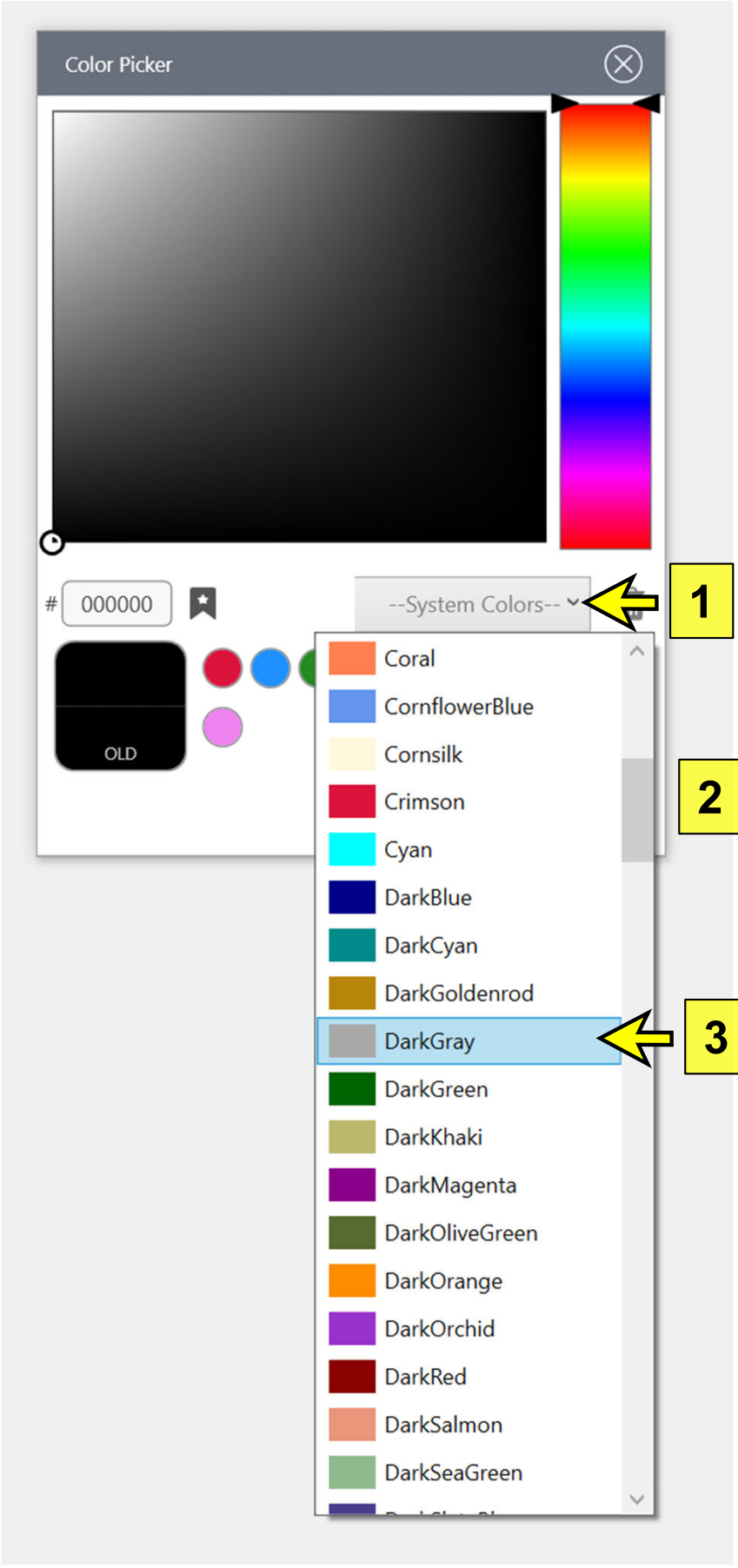
Once you've selected light blue to be the color fill for Source Zones A and B, your basemap should look like the one below. Now we can see that there are two locations shown in the center of each of these source zones (MW-4 is in Source Zone A and MW-6 is in Source Zone B).





Next we'll change the color for the runways so they are a little less prominent; we need the basemap as a reference, but we don't want the basemap layers to overwhelm the map when showing radial diagram and stacked bar maps later.

Click on the *Runways.dxf* layer in the **Basemap Layers** list as shown on the left (see "1", and click the **Edit** button (see "2").



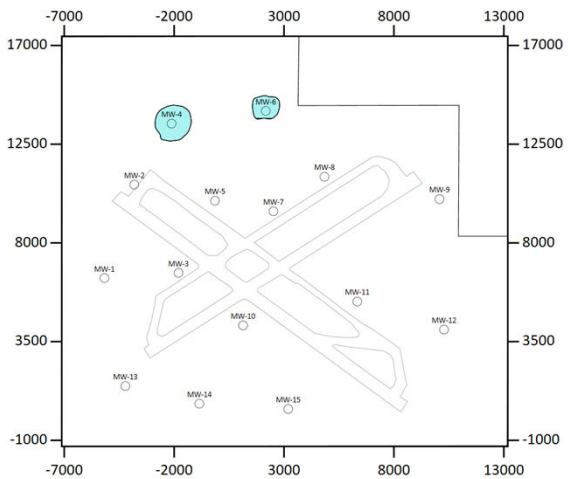
In the **Basemap Layer Properties** window, click on the **Line Color** which is currently shown as black.

In the **Color Dialog Box**, click on **System Colors** (see "1" at left), scroll down the list of colors using the scroll bar (see "2") or mouse wheel, and select *DarkGray* (see "3").

Click **Confirm** to save this color in the color dialog box.

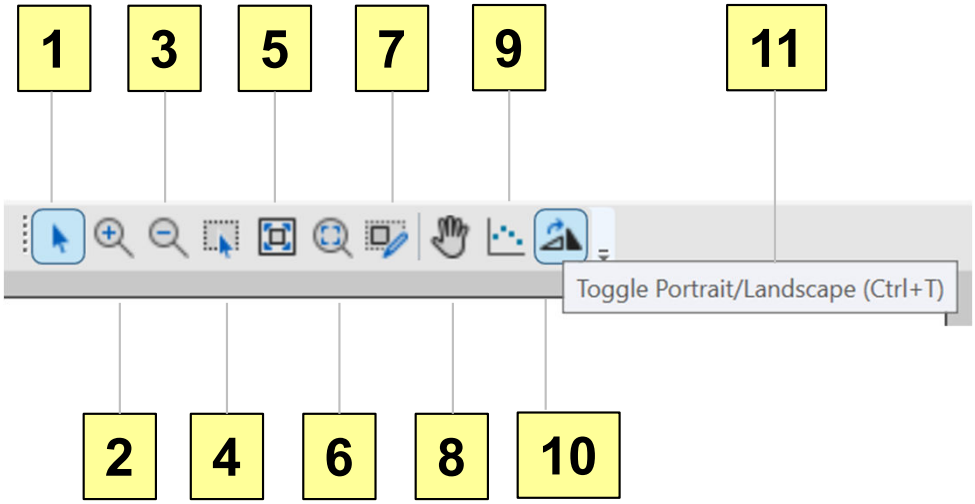
Then click **OK** from the **Basemap Layer Properties** window to save this change.

The basemap will now show the runways with a less intense color as shown below.



3.4 Navigation Panel

The Navigation Panel is positioned directly above the basemap (see page 3.2). Icons included in the Navigation Panel are shown in the image below.

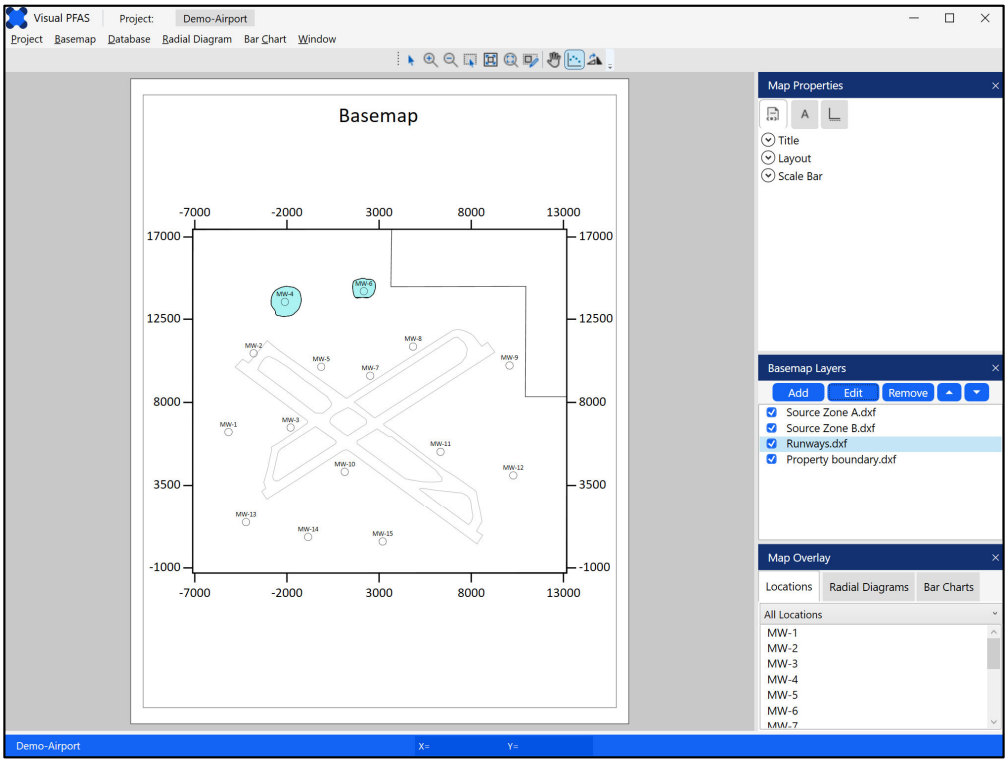


These icons are described below with numbering that corresponds to the labels in the image above.

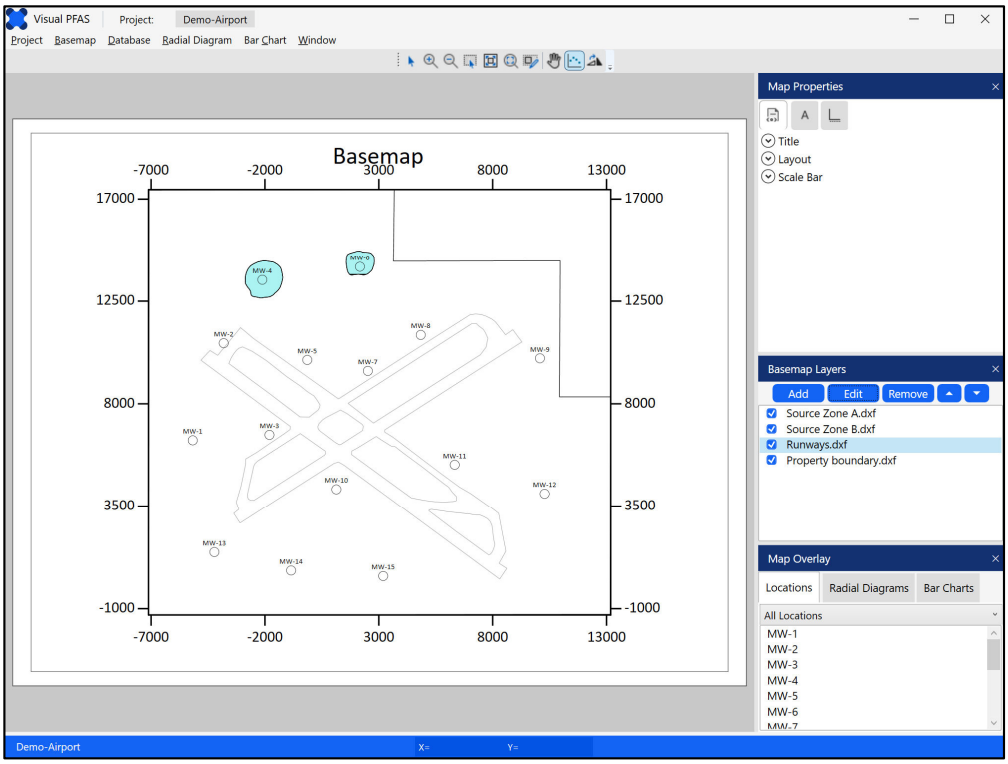
1. Return cursor to its normal function (e.g., after zooming in or out)
2. Zoom-in at the location clicked
3. Zoom-out at the location clicked
4. Zoom-in to rectangle drawn by user: left-click and hold the left mouse button down when the cursor is at one corner of the target rectangle, then drag the mouse to the opposite corner of the rectangle and release the left mouse button
5. Zoom to map extents (i.e., the outer extends of the basemap layers)
6. Zoom to page extents
7. Enter custom map extents
8. Pan: Click the pan icon to enter pan mode, move the cursor to the center of the location you want to view, click and hold the left mouse button down while dragging the map to the target location, then release the left mouse button.
9. Digitize easting and northing coordinates at select points on the basemap: Click the icon, then move the cursor to a target point and click and release the left mouse button to digitize the coordinates. The coordinates will be saved to the clipboard when you press the OK button after digitizing (one point at a time).
10. Toggle between portrait and landscape for the basemap page.
11. Example of an icon label that is shown when the cursor hovers over the icon.

Click the Portrait / Landscape toggle icon (see arrow at left).

Basemap Window: Page in Portrait

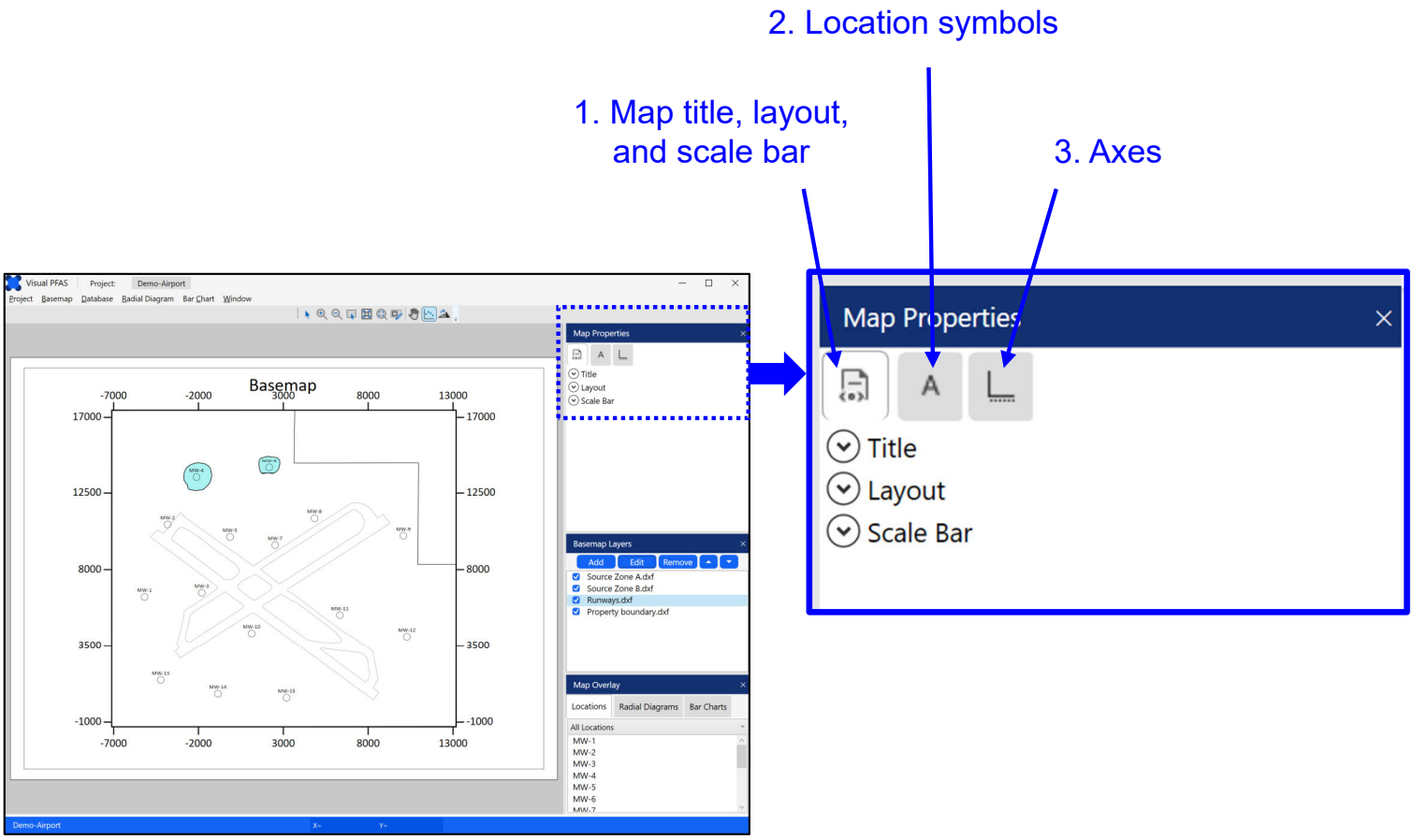


Basemap Window: Page in Landscape



3.5 Map Properties

The **Map Properties** section is positioned at the top-right of the **Basemap Window** (see below).



Components of the Map Properties section include:

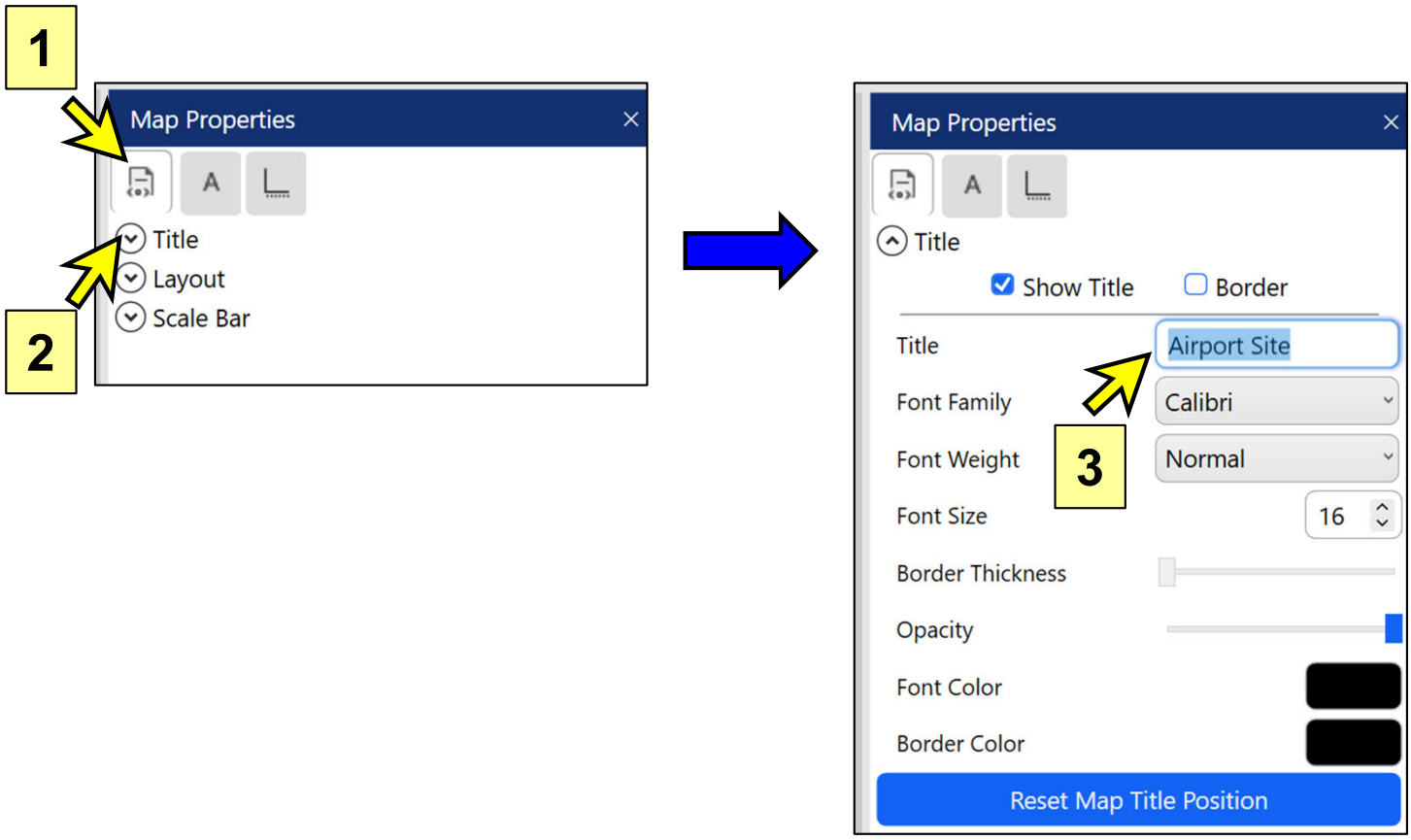
1. **Map title, layout, and scale bar properties** – including show/hide toggles for the map title and scale bar, font properties, and the layout of the map on the Basemap Page (e.g., change scale to make the map smaller or larger on the page), and style and properties of the scale bar.
2. **Location symbols** – change properties of location symbols and labels including show/hide options; symbol shape, size, line color, fill color; and location label font size, style, and color.
3. **Axes** – toggle axes on/off, change major and minor tick mark scales, and label fonts.

3.5.1 Map Title, Layout, and Scale Bar

Click on the **Map Properties** first tab at the left (see "1" below). This tab supports changes to properties for the map title, layout on the page, and the scale bar.

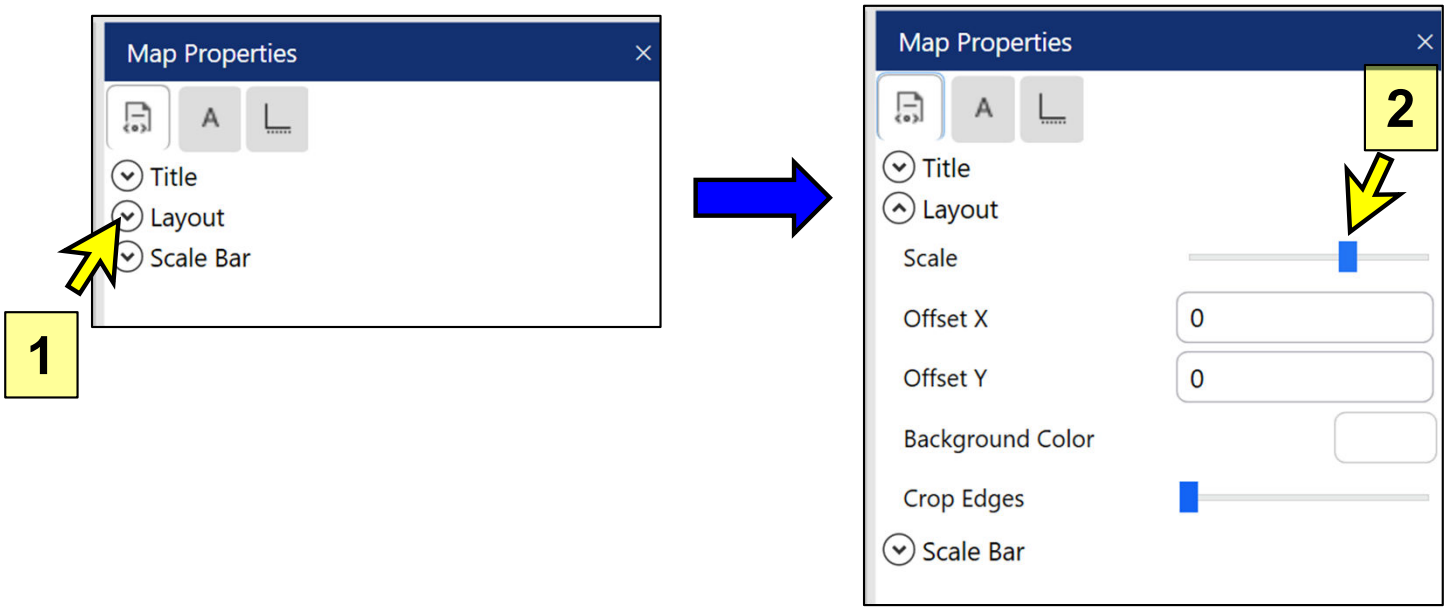
Click the down-arrow to the left of **Title** to expand the map title properties (see "2" below). The down-arrow next to **Title** will change to an up-arrow after it's clicked, and the title properties will now be visible as shown in the image on the right.

Change the map title from the default which is the same as the basemap filename to *Airport Site* (see "3" below).

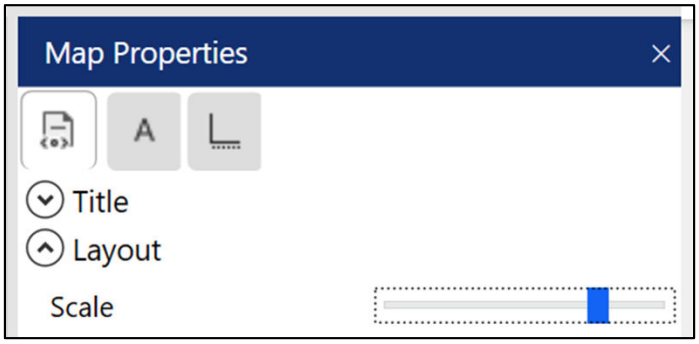


Click the up-arrow next to Title so it changes to a down-arrow and the title properties are no longer shown (similar to the left image above).

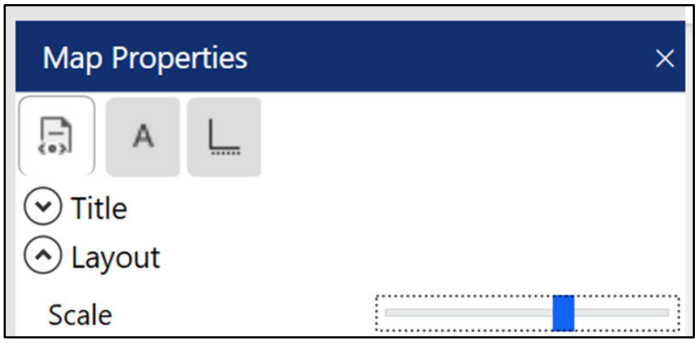
Click the down-arrow next to Layout to show the layout properties (see "1" below on the left). Move the scale scroll bar to the left, to make the basemap extents smaller on the Basemap Page (see "2" below on the right). The influence of this change in scale is shown in the respective Basemap Page images shown below.



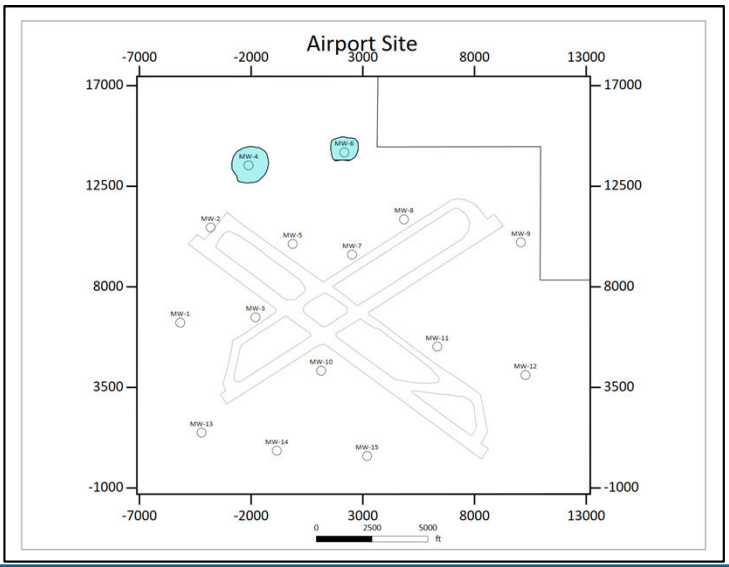
Initial Scale



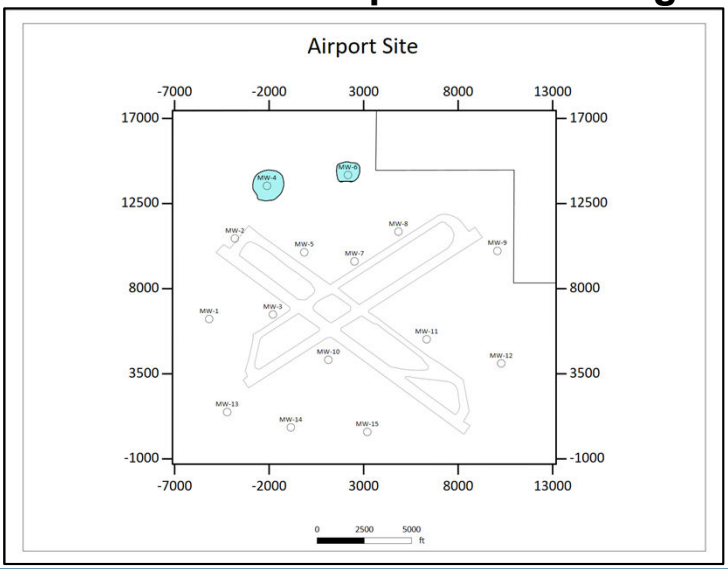
Reduced Scale



Initial Basemap Extent on Page



Reduced Basemap Extent on Page



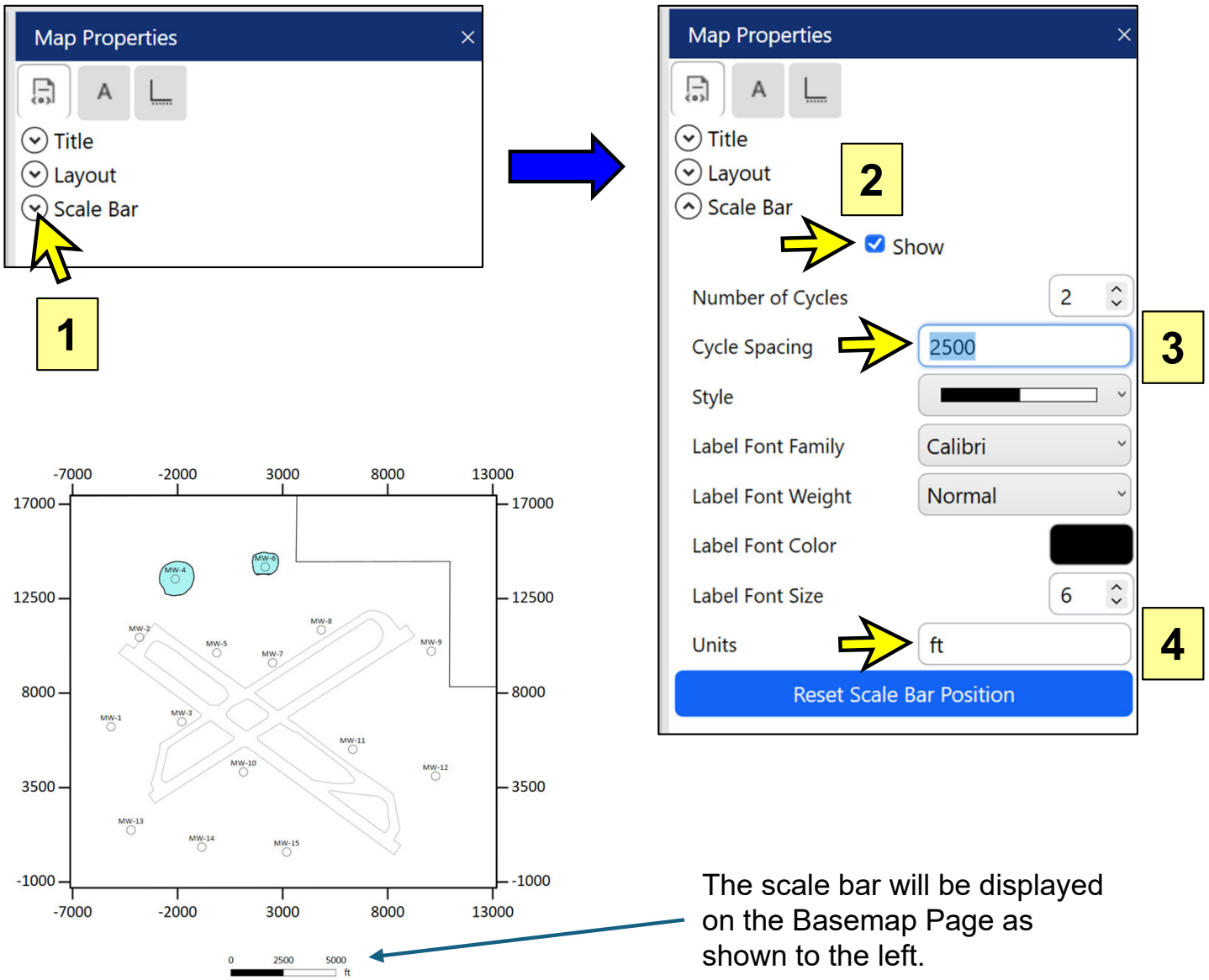
Click the up-arrow next to **Layout** to hide these properties, and then click the down-arrow next to **Scale Bar** to show these properties (see "1" below on the left).

The scale bar properties are shown in the image below on the right, including whether to show or hide the scale bar, number of cycles in the scale bar, style, label font properties including size, and the text to show for the units next to the scale bar.

Update the scale properties as follows:

- Click the **Show** checkbox to show the scale bar on the map (see "2" below on right)
- Change **Cycle Spacing** from the default of 1000 to 2500 (see "3" below)
- View **Style** options in the dropdown list and select the style that you prefer
- Insert the length **Units** "ft" in the textbox (see "4" below).

Then click the up-arrow next to **Scale Bar** to hide these properties.



The scale bar will be displayed on the Basemap Page as shown to the left.

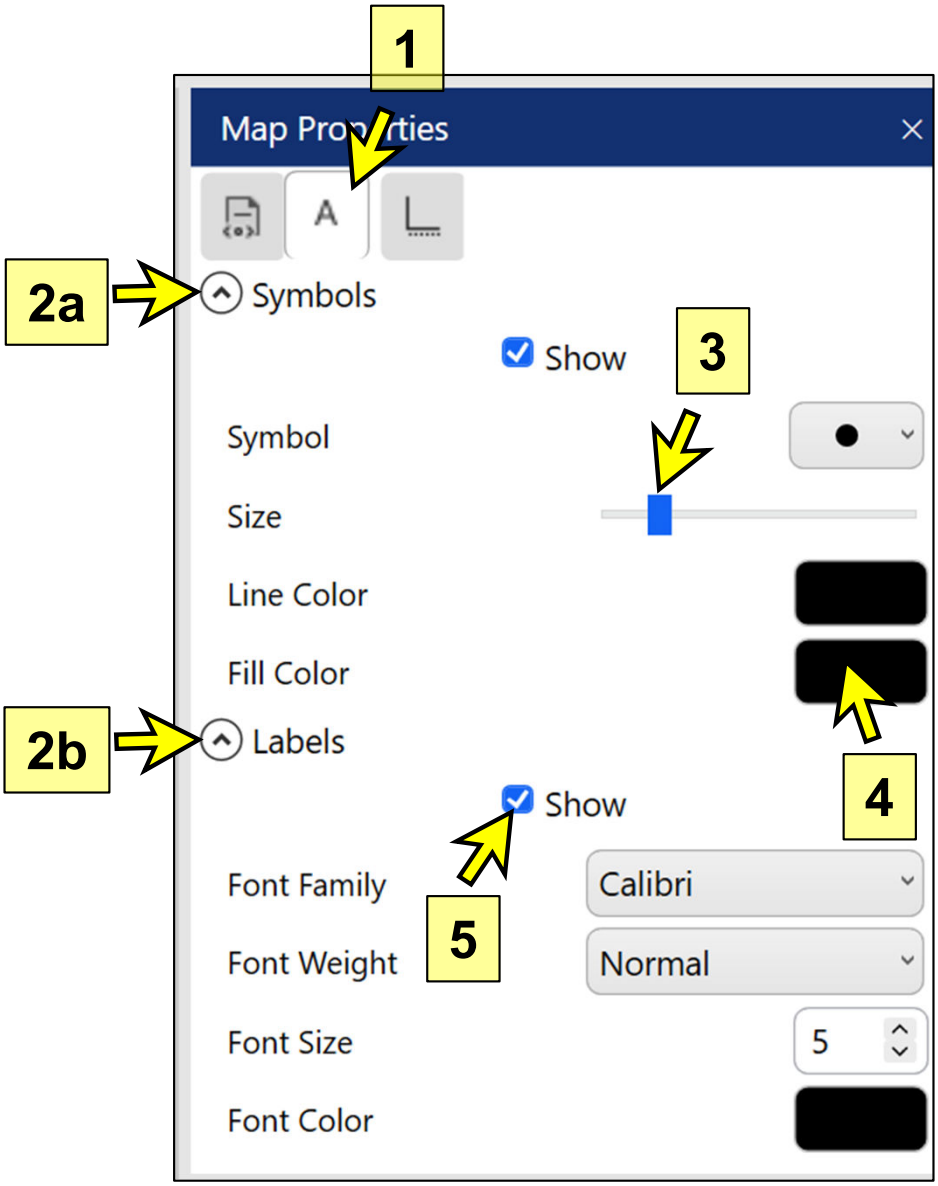
Click the **A** tab at the top of the **Map Properties** section (see "1" below) to select location symbol and label properties.

Click the **down-arrow** next to **Symbols** (see "2a") and then click the **down-arrow** next to **Labels** (see "2b") to show properties for both categories as shown below.

Make the following changes to the location symbol and label properties:

1. Move the symbol **Size** scroll bar to the left (see "3" below), similar to the magnitude shown below, to reduce the size of the location symbols on the basemap.
2. Click on the **Fill Color** box (see "4" below), select **System Colors** in the **Color Dialog Box**, and then select *Black* from the dropdown list of system colors. Click **Confirm** to close the Color Dialog Box.
3. Confirm that the **Labels Show** box is checked on (see "5") to show the location labels.

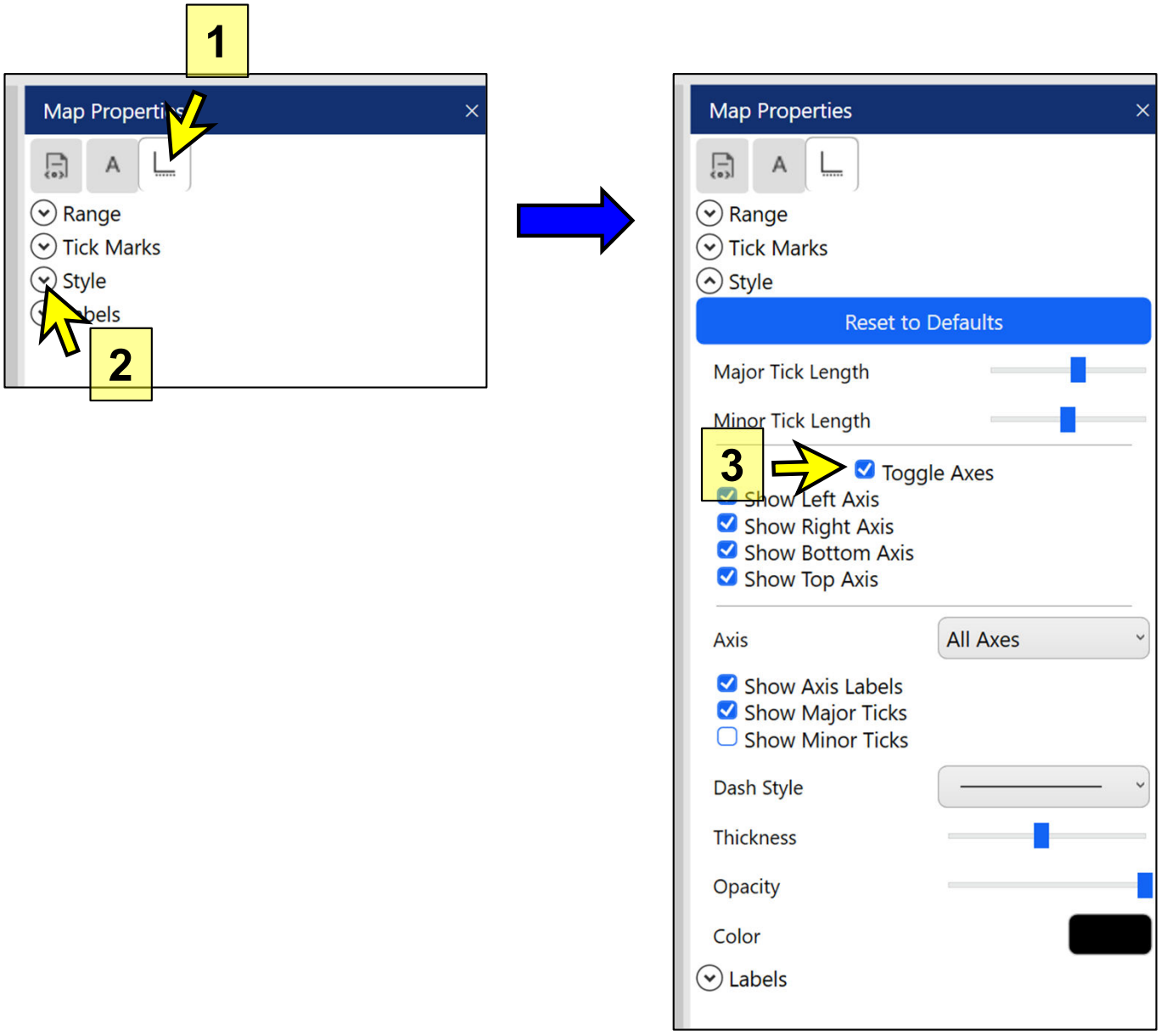
Click the **up-arrows** next to **Symbols** and **Labels** to hide both categories of properties.



Click the **Axis** tab (see "1" below) at the top of the Map Properties section to work on properties for the easting and northing coordinate axes.

Click the **down-arrow** next to **Style** (see "2" below) to show axis style properties.

Turn off the **Toggle Axes** checkbox (i.e., not checked) to hide all four easting and northing coordinate axes.



When you hide the coordinate axes, you will be able to view the entire extent of the property boundary (which was previously partially hidden under the coordinate axes).

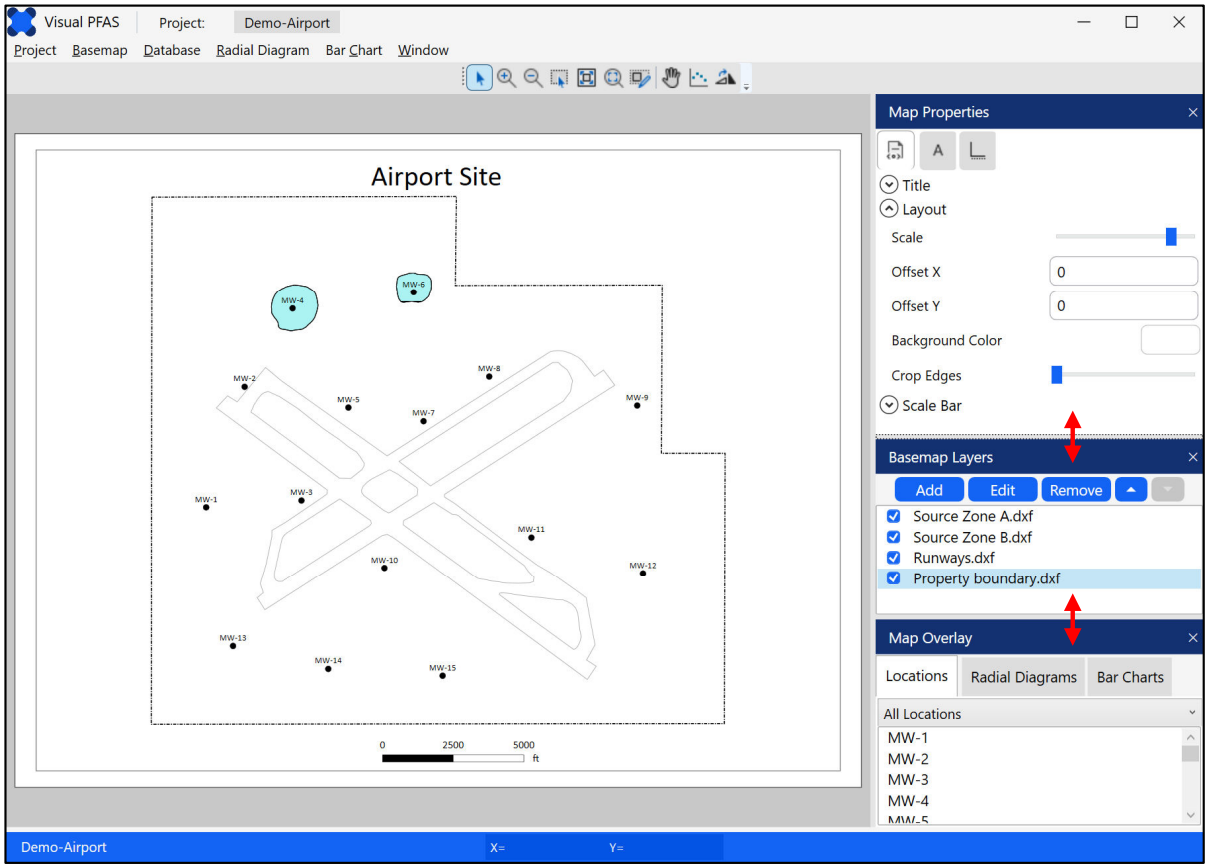
You can also now increase the scale of the map on the Basemap Page. Click the left tab under Map Properties, click the down-arrow next to Layout, and increase the scale of the map so that it is larger on the Basemap Page (similar to the scale shown on the next page).

The Basemap Window should now look like the image below.

Note: The horizontal dividing lines between the sections to the right of the Basemap Page can be moved up or down. This allows you to change the height of each of these three sections (i.e., Map Properties, Basemap Layers, and Map Overlay) to accommodate long lists if your screen resolution is sufficiently large. (The Visual PFAS™ default window size is relatively small to accommodate laptop display screens.)

To move these dividing lines up or down, hover the cursor directly over the dividing line so that it changes from a single arrowhead cursor to a vertical line with arrowheads on both sides (see red arrows below – the red color is used for illustrative purposes only, the actual cursor will be black when in the sliding mode).

When the cursor is in this double-arrowhead mode, click the left mouse button and hold it down, then drag the horizontal dividing line up or down. Release the left mouse button when you have completed moving the divider.

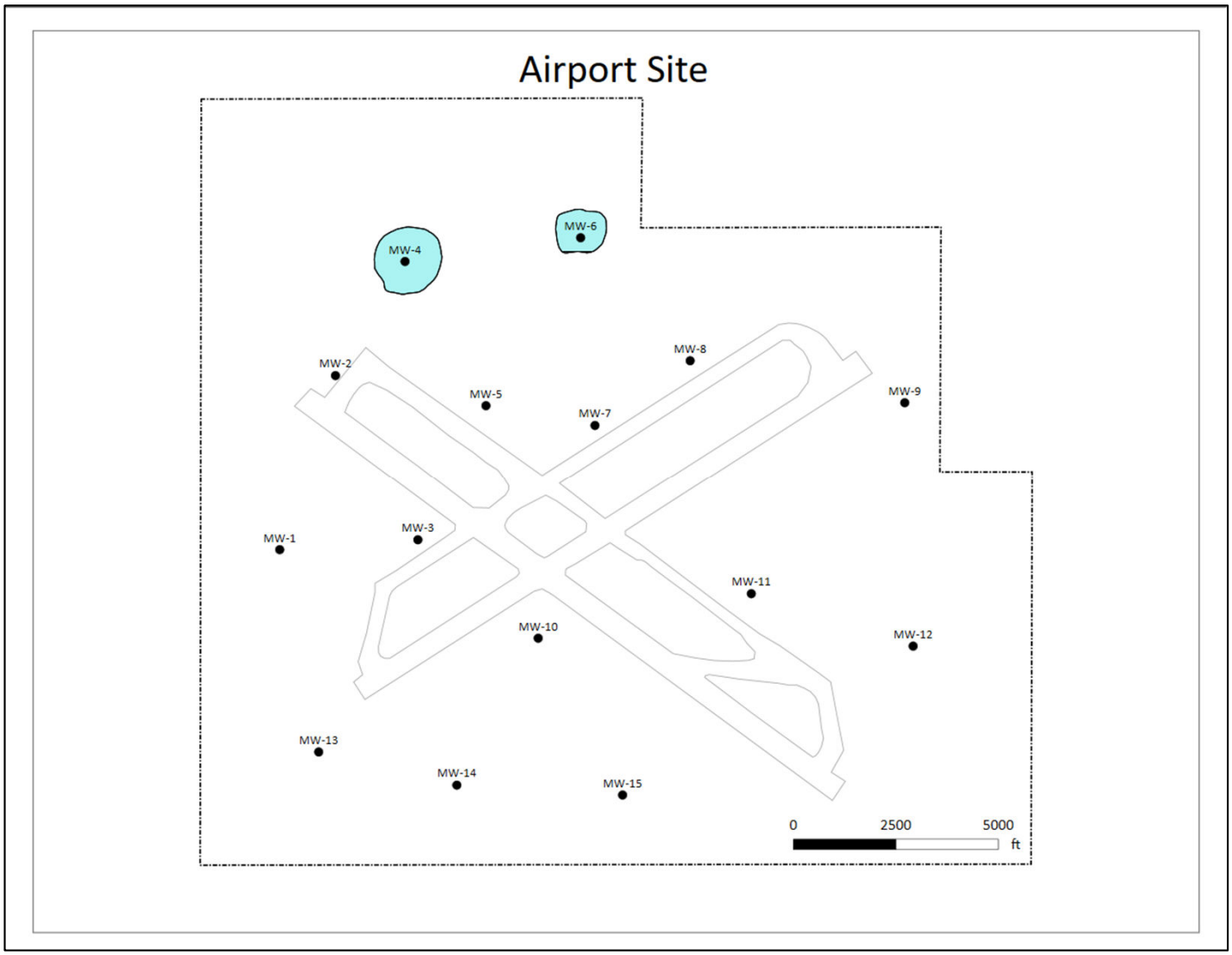


Dividers between property sections can be moved up or down.

3.5.2 Moving the Map Title and Scale Bar

Both the **Map Title** and **Scale Bar** are moveable. These may be moved at any time by double-clicking the left mouse button over one of these objects and holding the mouse button down on the 2nd click; then dragging the object until the object is in the desired position; and then releasing the left mouse button.

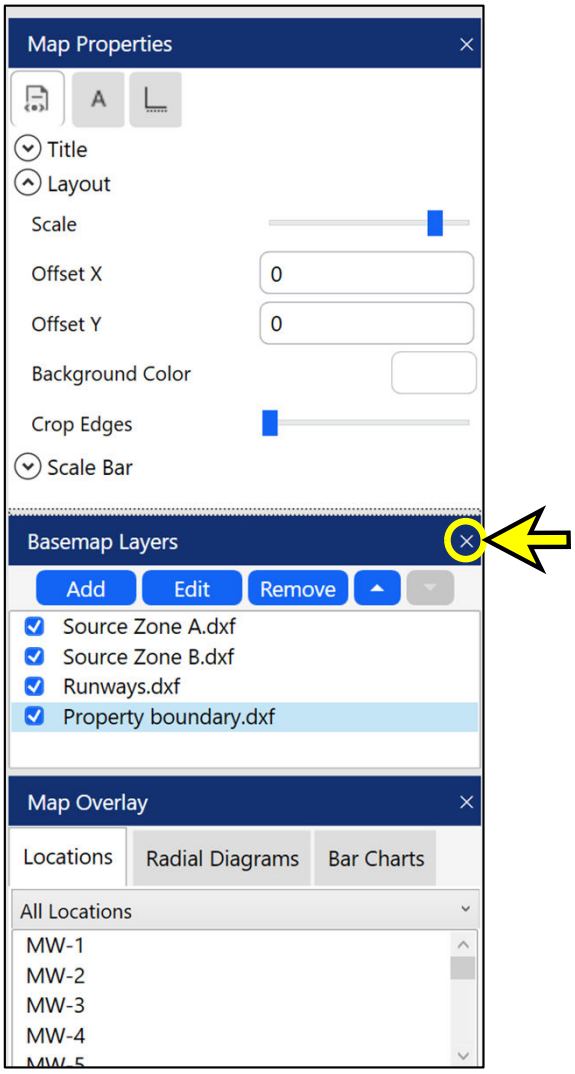
You can practise this by hovering the mouse cursor over the scale bar, double clicking and holding the left mouse button, and moving the scale bar to be inside the lower-right area of the site property line. (see example below for the moved scale bar)



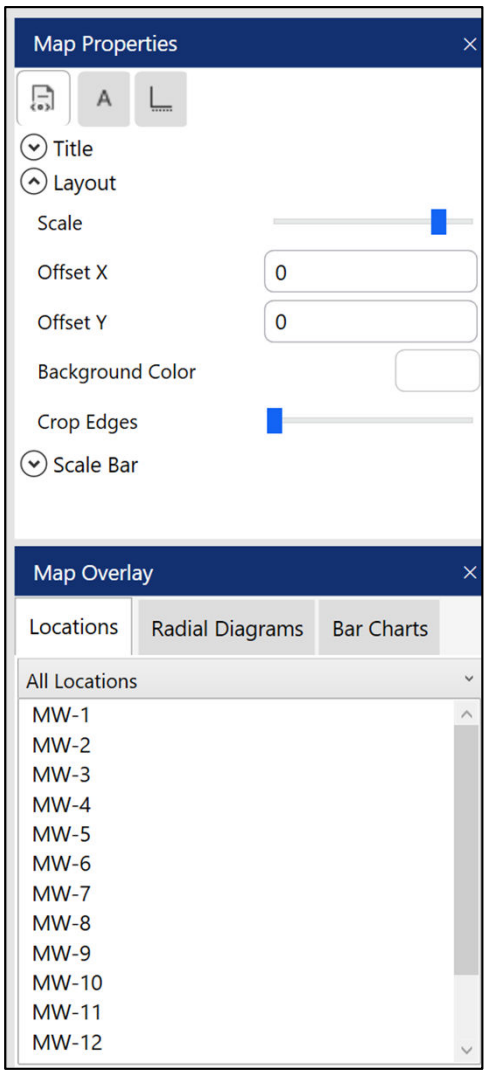
3.5.3 Viewing the Property Windows

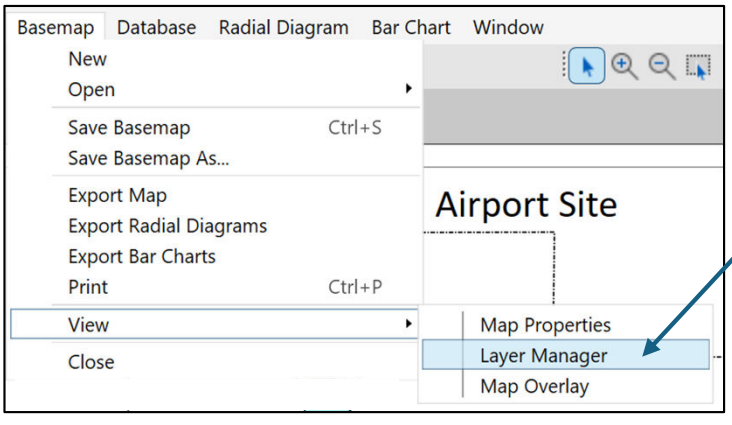
Any of the three property windows to the right of the **Basemap Page** may be closed by clicking on the **X** at the top right of the respective property windows. The example below on the left shows all three property windows just prior to closing the **Basemap Layers** window. The image on the right shows the effect of hiding the Basemap Layers window.

Show all 3 Property Windows



Show 2 Property Windows





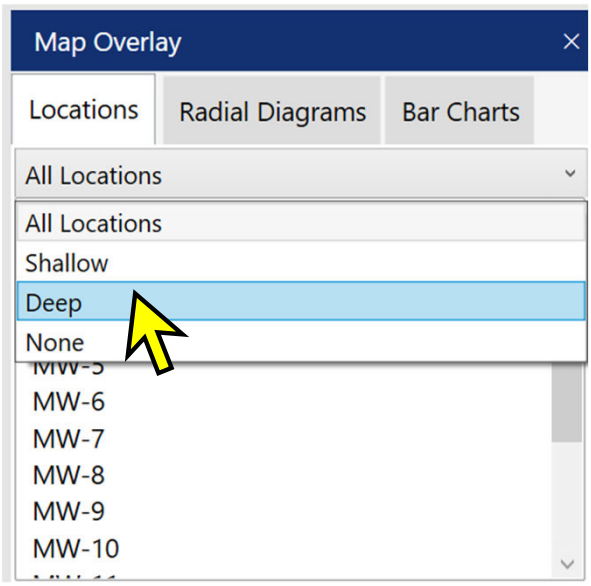
To show a previously closed property window, Click the **Basemap** main menu option, click **View**, and then click on the applicable property window to open it. The image on the left shows the Basemap Layers window being re-opened. The same layers list will be displayed as was shown previously before the Basemap Layers window had been closed.

3.6 Viewing Location Groups

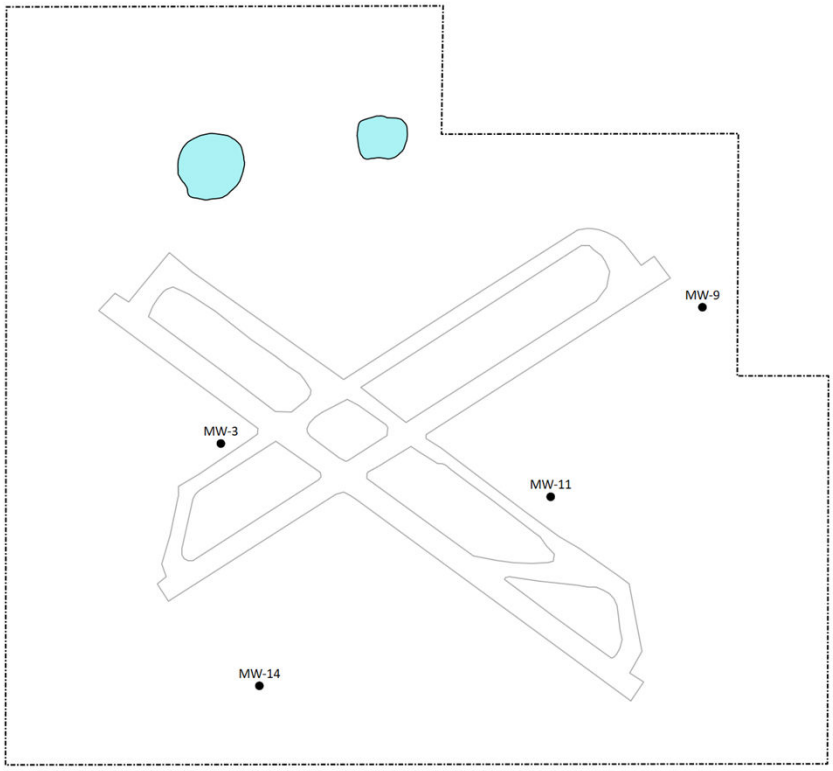
The **Map Overlay** section contains a location group dropdown box where either the user can select to see only locations from a specific location group identified in the imported dataset, or all locations if the location group selected is “None”.

As discussed in Chapter 2 (Sections 2.3 and 2.3.5 through 2.3.7), there are two location groups identified in the imported dataset for the *Demo-Airport* project: Shallow and Deep monitoring wells. If no location groups are selected, then all 15 monitoring well locations will be displayed on the basemap. If Shallow wells are selected, then 11 well locations will be displayed. If Deep wells are selected as the location group (e.g., see image on left below), then four well locations will be shown as demonstrated below (MW-3, MW-9, MW-11, and MW-14) as demonstrated in the image on the right below.

Selection of Deep location group



Basemap showing Deep monitoring wells

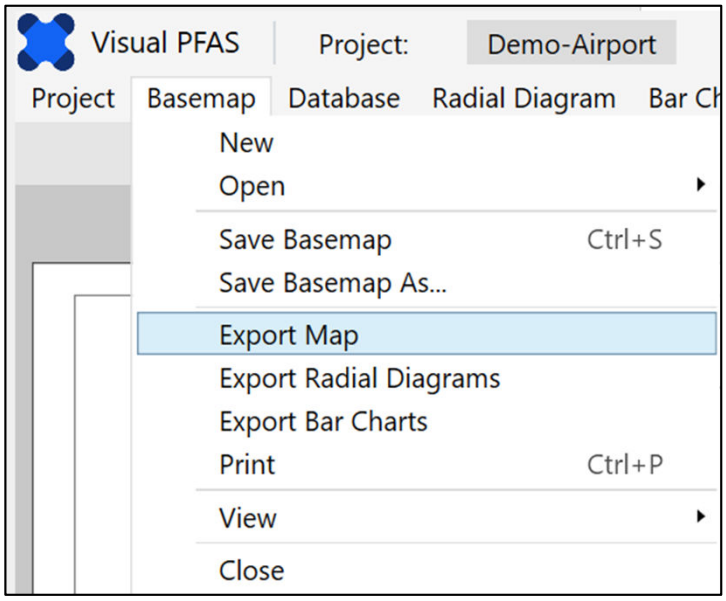


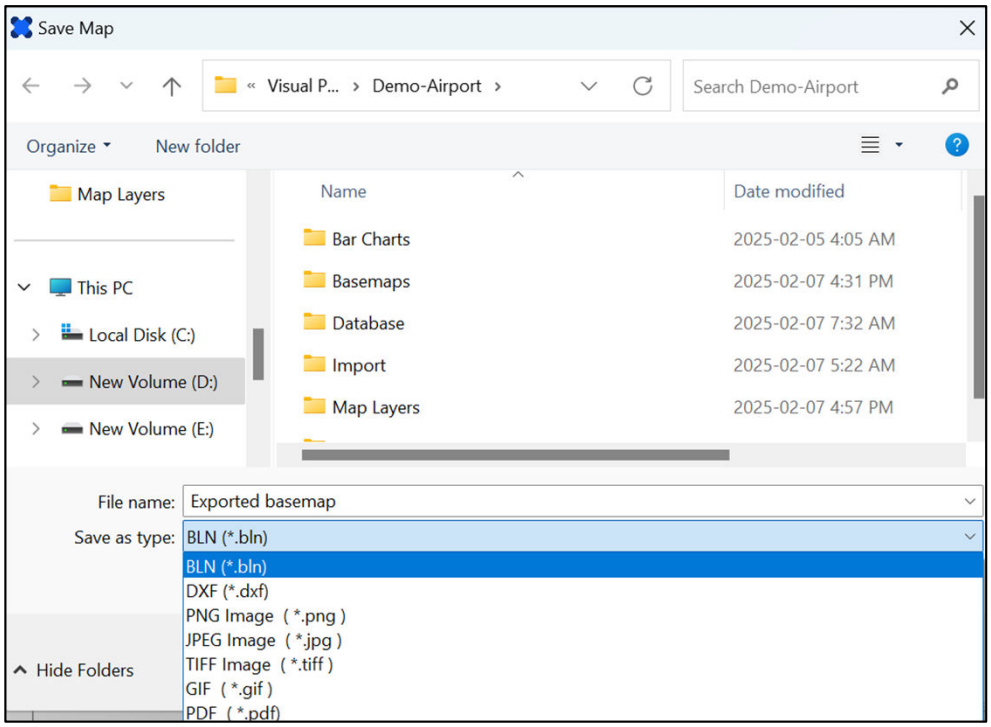
Update the basemap to show all monitoring wells by selecting None as the location group before proceeding.

3.7 Print or Export Basemap

Users have the option to export the basemap to a pdf file, or an image file format such as png, jpeg, tiff, or giff. Basemaps can also be exported as combined polylines and polygons to a single file in dxf or Surfer bln format. To export a basemap, click on the Basemap main menu option, click Export Map, enter the filename into the file dialog box and select the type that the file should be saved as. (see example below)

To print a basemap to a physical printer, select the Print option from the Basemap main menu and then choose the printer the same way you would for printing any other type of document. For basemaps ploted in landscape in Visual PFAS™, select the Landscape option for the physical printer.

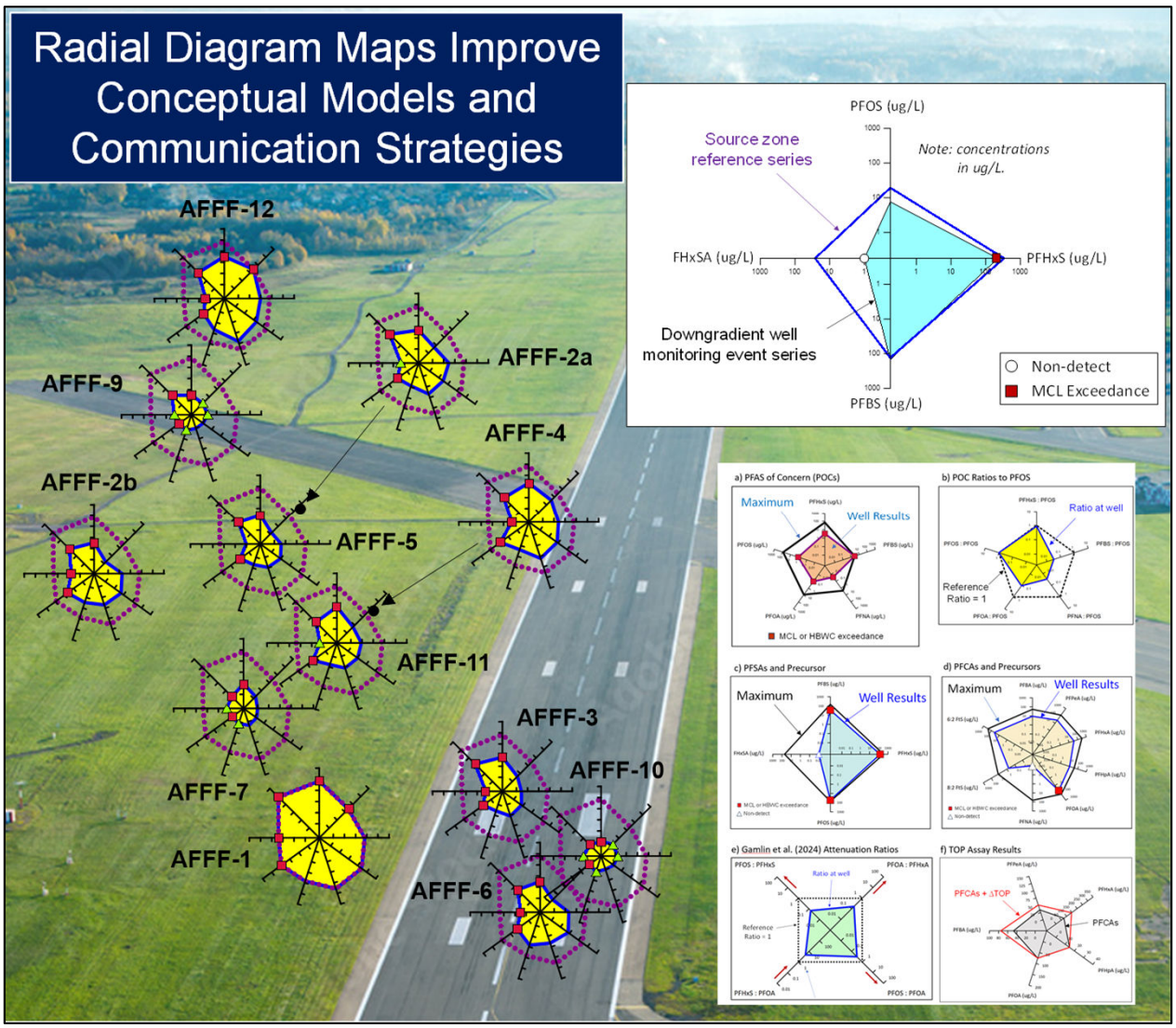




Visual PFAS™
Users Guide:

Creating Radial Diagrams

Chapter 4



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4.1 Introduction

Laboratory analysis of PFAS in groundwater and soil samples now include results for up to 40 PFAS (i.e, precursors and PFAAs) when the analysis is conducted using EPA Method 1633. The large number of analytes associated with each soil and groundwater sample poses a major challenge for data analysis, and for communicating the results of site characterization to a non-technical audience. Radial diagrams represent a simple visualization approach which is ideal for viewing trends for between 5 and 10 PFAS constituents on a single map.

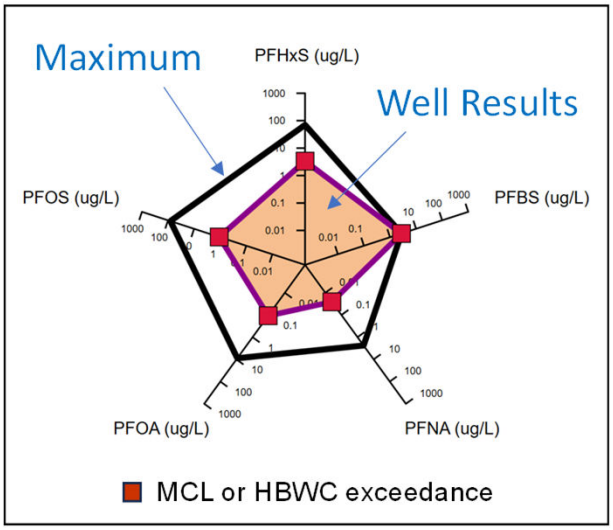
Radial diagrams may be used to support the following types PFAS site characterization, forensic, and remediation performance monitoring assessments:

- Source zone and groundwater plume delineation;
- Precursor biotransformation to corresponding PFAAs along a flow path;
- PFAS attenuation along a groundwater flow path due to precursor biodegradation, dispersion, and/or forward attenuation into silt/clay layers.
- Distribution of PFAS ratios within and downgradient of source areas;
- Redox zone delineation (e.g., aerobic, moderately anaerobic, and strongly anaerobic) to support a precursor biotransformation analysis;
- TOP assay results along a flow path to determine the maximum potential for PFAA increases due to future precursor transformations;
- Temporal changes due to remediation, or due to expanding or receding plumes;
- Source differentiation and forensic analysis of contributions from multiple sites to a commingled plume; and
- Visual comparison of background levels to PFAS at various site monitoring wells.

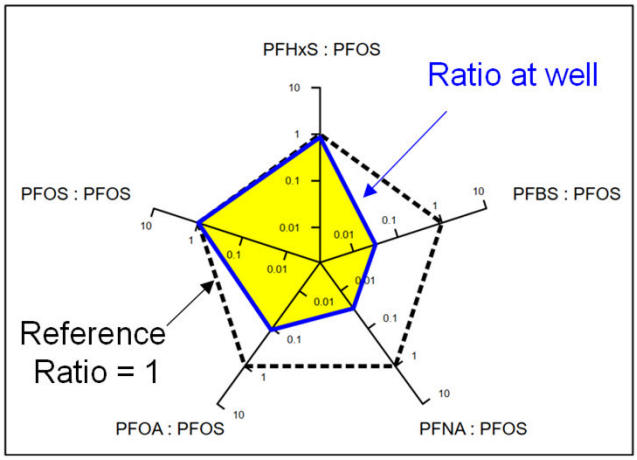
Radial diagram visual aids are capable of illustrating spatial and/or temporal distributions of multiple PFAS species on a single map, which is particularly useful given the need to assess both intra-well and inter-well trends for PFAS in the source area and within a downgradient plume. Carey et al. (2025) document a detailed case study which demonstrates how radial diagram and stacked bar maps may be used to support site characterization and source forensic assessments at an AFFF-impacted site in South Dakota. Carey et al. (1996, 1999, 2003) demonstrate several other case study examples of how radial diagrams may be used to support analogous applications for chlorinated solvents and petroleum hydrocarbons. Carey et al. (1996, 1999, 2003) also demonstrate case study examples of how specialized redox radial diagrams can be used to delineate between aerobic, moderately anaerobic, and strongly anaerobic zones in groundwater, which is important for evaluating where precursors may be biodegrading to regulated PFAAs.

Carey et al. (2025) examples of the types of radial diagrams used to characterize the South Dakota AFFF-impacted site are shown below, using both concentrations and PFAS ratios.

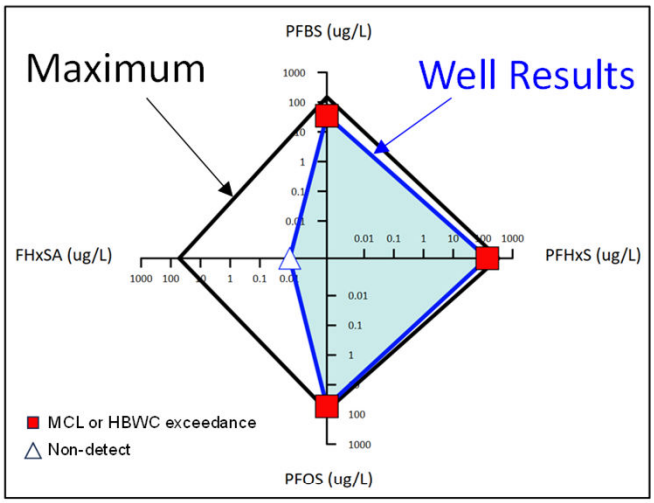
a) PFAS of Concern (POCs)



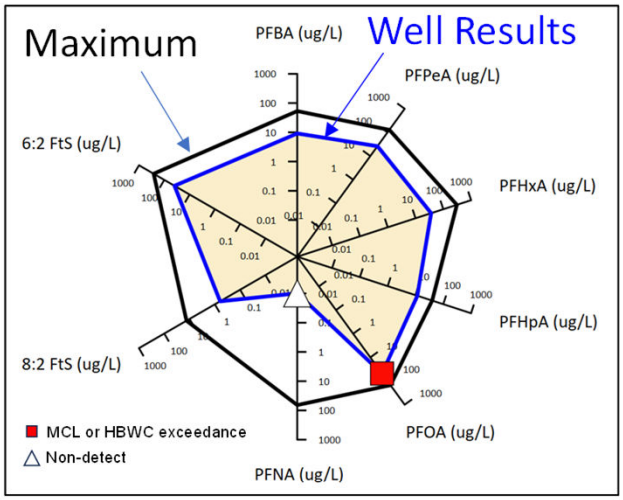
b) POC Ratios to PFOS



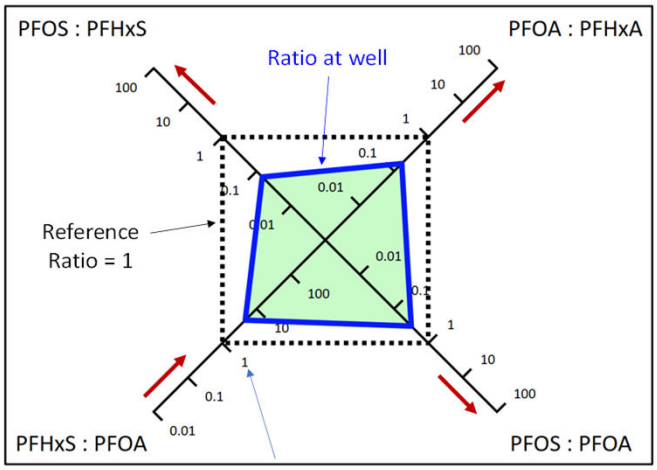
c) PFSAs and Precursor



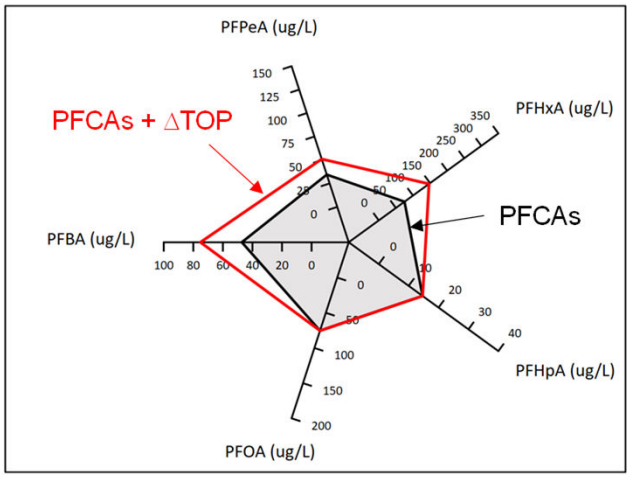
d) PFCAs and Precursors



e) Gamlin et al. (2024) Attenuation Ratios



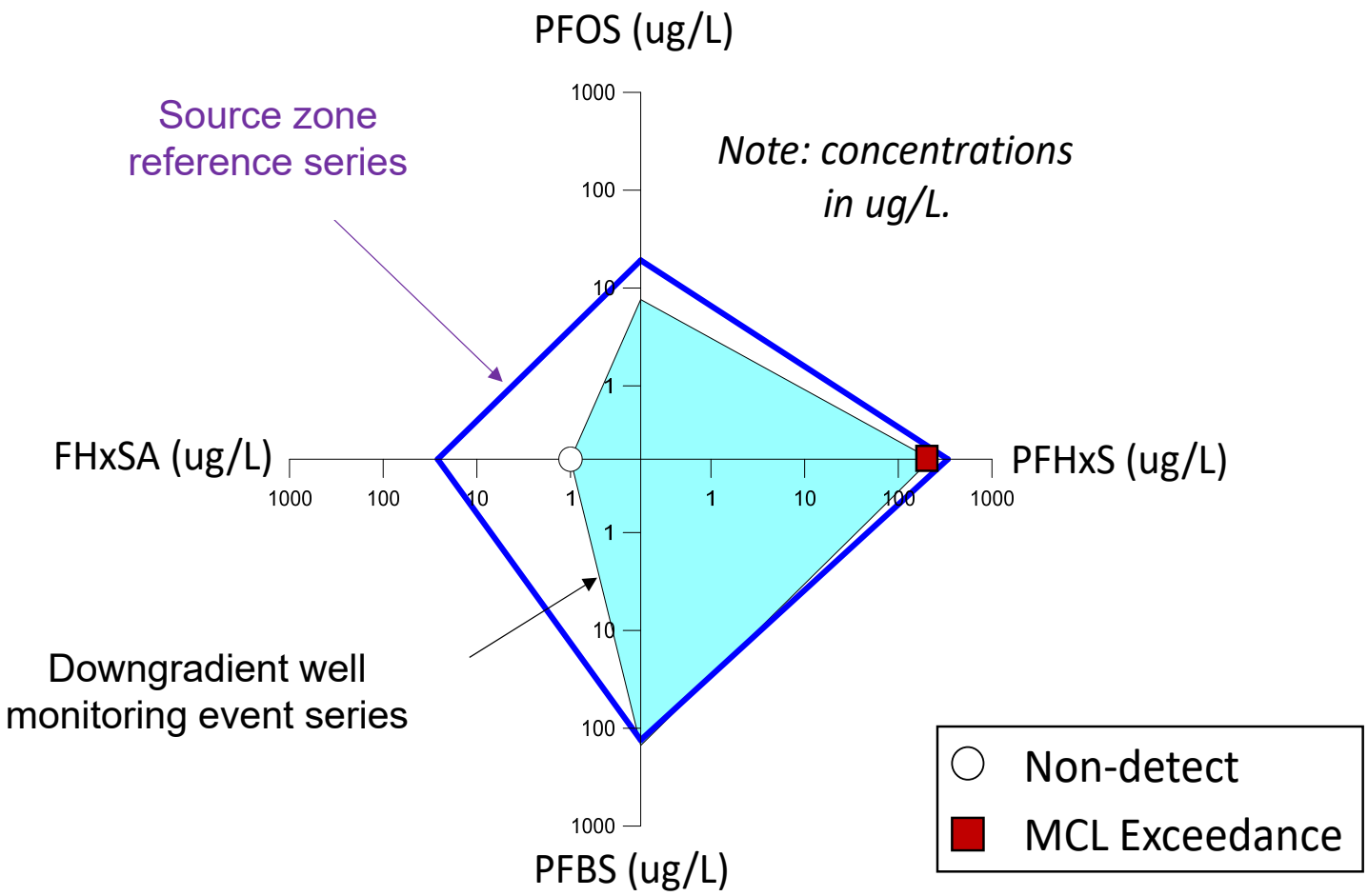
f) TOP Assay Results



Components of a Radial Diagram

The radial diagram below shows an example that includes axes to represent three sulfonates (PFOS, PFHxS, and PFBS); and FHxSA which is a precursor that may biodegrade to PFHxS under aerobic conditions. The PFAA axes are sequenced in order of chain length which facilitates a relatively quickly visual comparison of long vs. short-chain concentrations at each well location. In this example, a **reference series** is shown to represent the maximum source zone concentrations, and results for a single **monitoring event series** at a downgradient well are shown with the data series with blue fill. When these radial diagrams are plotted at individual well locations on a site map, the well-specific series will change at each well location. The reference series (e.g., maximum source zone concentrations) will be uniform across all wells.

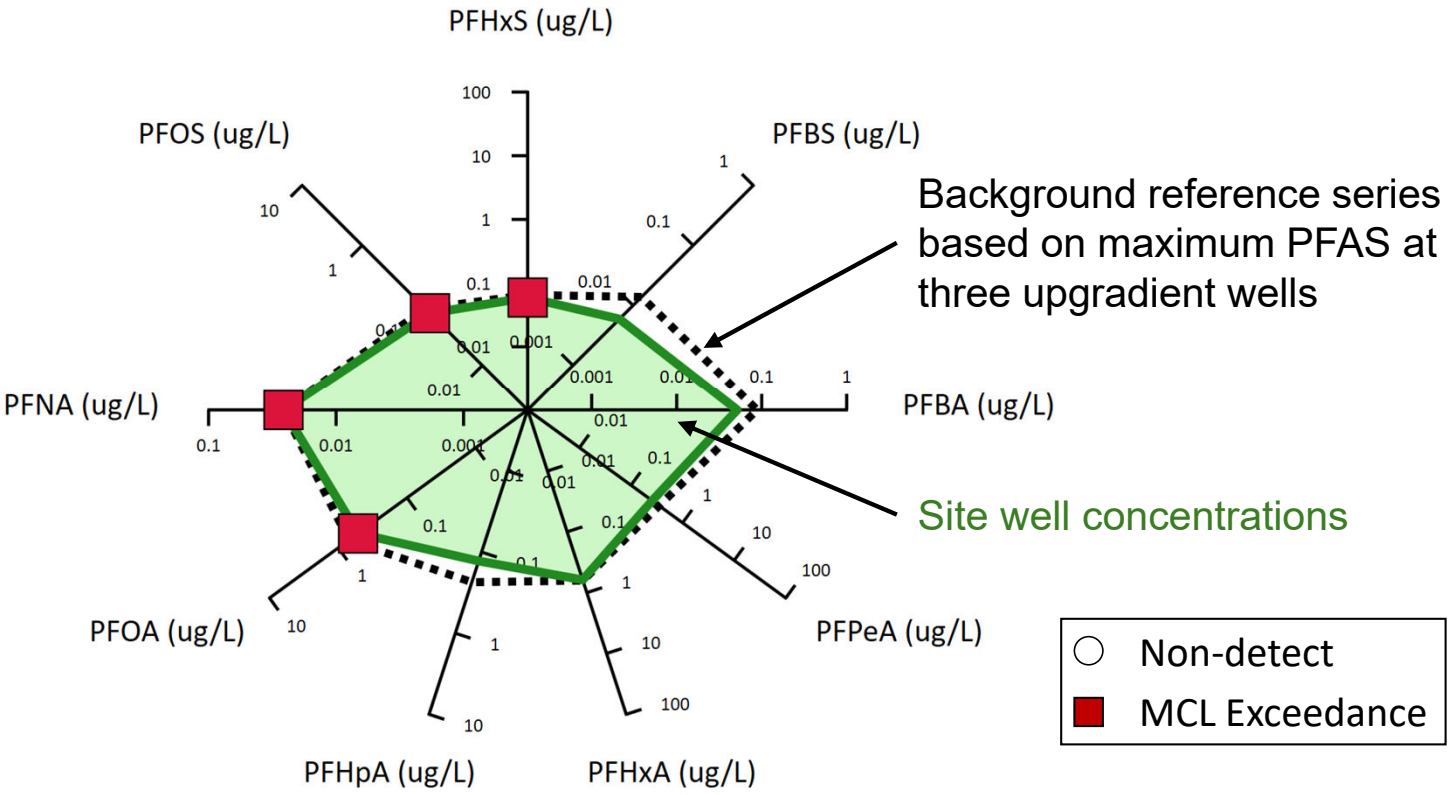
The purpose of including a reference series on the radial diagram, in addition to the well-specific concentrations for a specific monitoring event, is to allow for more effective visualization of changes in well concentrations with distance downgradient from a source zone. It is easier to visualize the size of the gap between the reference series and the well-specific monitoring event series, than trying to visually measure changes in the size of well-specific series in radial diagrams overlaid onto a site map. This will be demonstrated further in the radial diagram map discussion below.



The radial diagram example shown on the previous page indicates that the FHxSA concentration at the downgradient well has declined about 1.5 orders of magnitude relative to the maximum source zone concentration, and PFOS has declined close to half an order of magnitude. The distance between one pair of tick marks on an axis represents an order of magnitude change in concentration when the axis is plotted using a logarithmic scale. So changes in concentration with radial diagrams may be visually estimated by interpolating the number of tick marks between the reference and monitoring event series. In this example from the South Dakota AFFF-impacted site, there has been relatively little change in PFHxS and PFBS concentrations between the source zone and the downgradient well location.

The radial diagram shown on the previous page also demonstrates the use of symbols for representing MCL or other cleanup criteria exceedances, or to represent non-detects. Including symbols to identify cleanup criteria exceedances, with multiple regulated PFAS constituents shown on a site radial diagram map, facilitates delineation of the extent of exceedances and the corresponding plume boundary.

The radial diagram below shows a different example where background concentrations are used as the site-wide reference series to facilitate an evaluation of which wells at a site have similar concentrations to background.



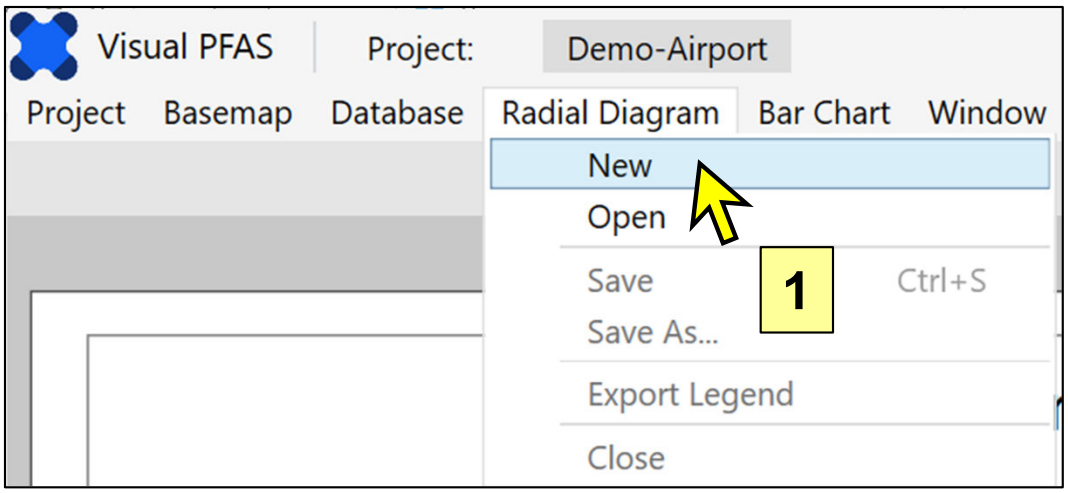
Chapter 4 in the Visual PFAS™ Users Guide provides a hands-on tutorial with step-by-step instructions for creating a radial diagram map using the example Airport Site discussed in Chapter 1. Specialized features and options available in Visual PFAS™ for creating radial diagrams are illustrated in this chapter.

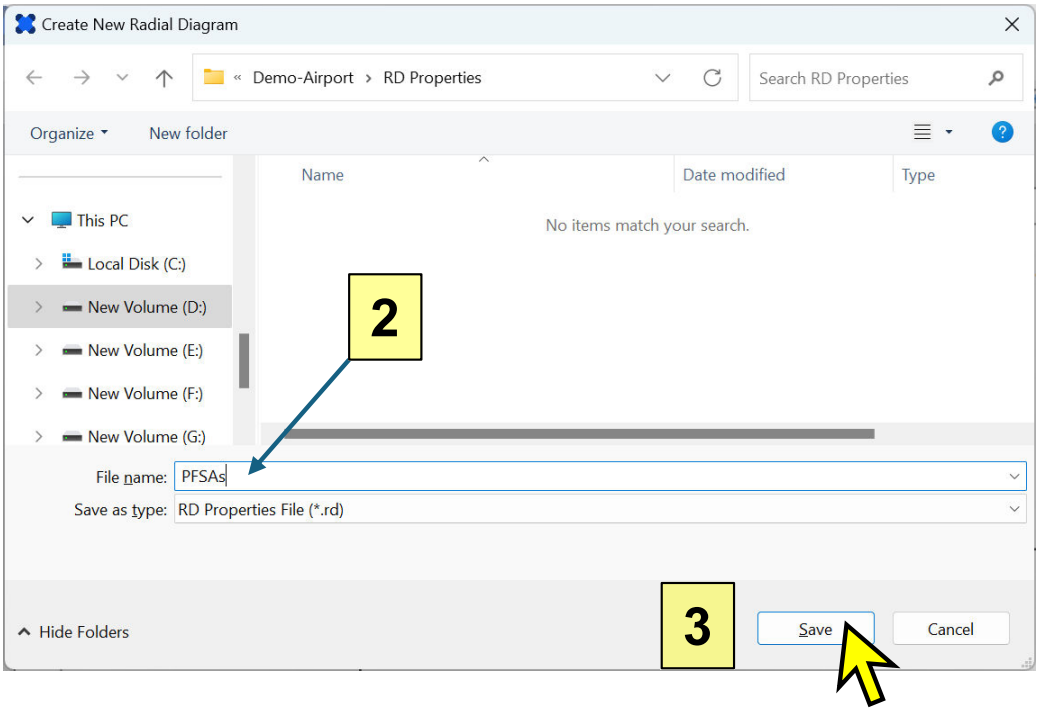
4.1.1 Creating a new radial diagram properties file

Each radial diagram map will have its own properties file that specifies the axis properties, which chemicals are to be represented on each axis, what data series and symbols to plot, and the overall look and feel of the radial diagram legend.

Once the legend has been finalized, then the radial diagrams are overlaid onto the site basemap, and additional iterations may be needed at that time to refine the length of radial diagram axes, series colors, line thicknesses, series fill, symbol sizes, etc.

To start, let's create a new radial diagram properties file. Click the **Radial Diagram** menu option, select **New** (see "1" below), and then enter the name of the radial diagram properties to create: *PFSAs* (see "2" below). The radial diagram properties file has an extension of *.rd, and by default these files are stored in the **RD Properties** sub-folder under the project folder.

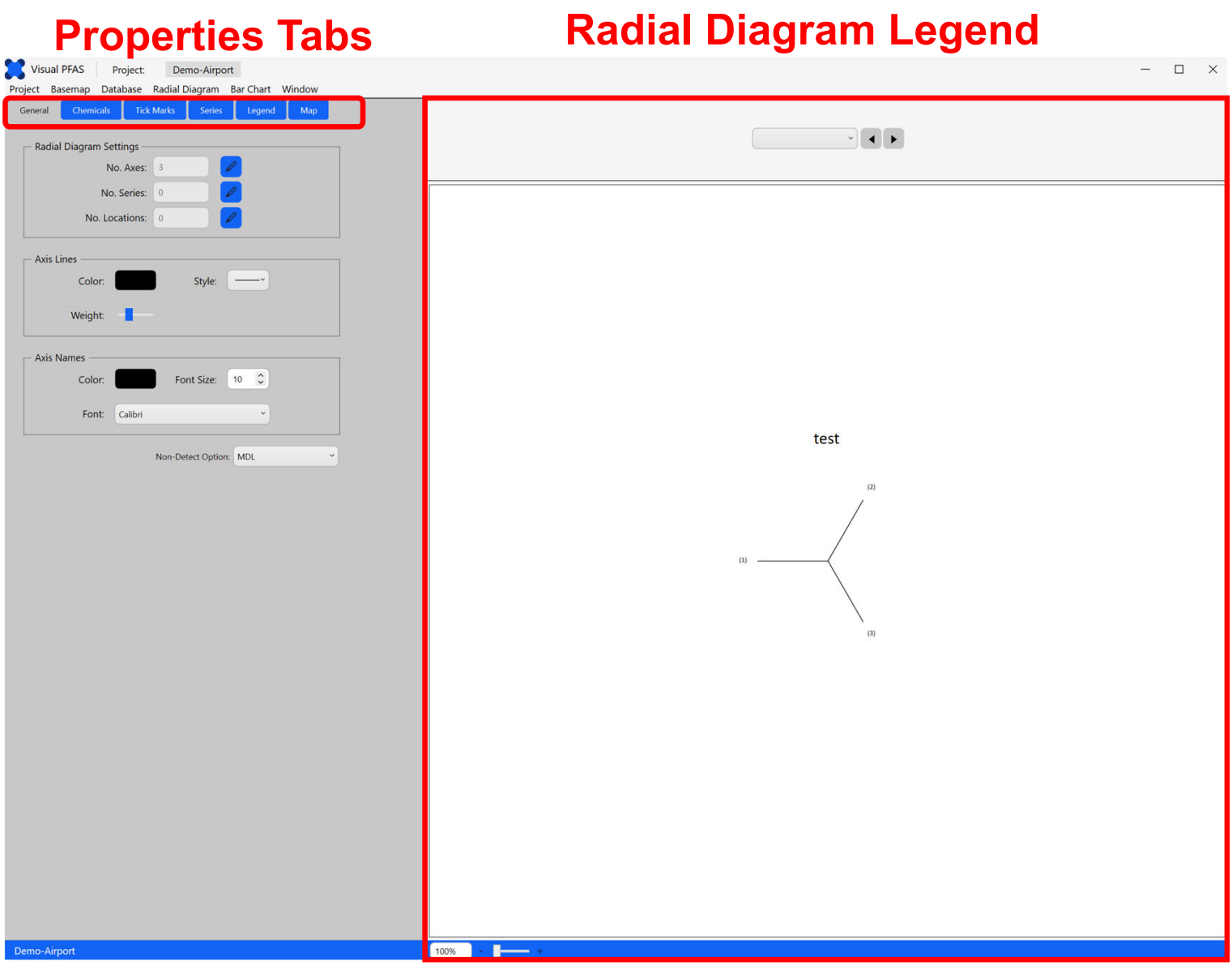




The image below shows what appears after a new radial diagram properties file has been created. The left part of the screen is where users can modify various properties of radial diagrams by clicking on the tabs at the top. The **General** tab is first selected by default when a new radial diagram file is created. This is where users can specify properties for each axis in the radial diagram, select reference and monitoring event series, the locations at which radial diagrams will be shown on the basemap, and the axis line and label properties. Other tabs facilitate user specification of properties for Chemicals, Tick Marks, Series, the legend, and the radial diagram map.

By default, radial diagrams will have three axes when the properties file is first created. The radial diagram legend is shown on the right side of the image below. The radial diagram legend can be re-sized using the scroll bar at the bottom of the legend – this allows you to re-size the legend based on the size of your window.

The top part of the legend allows you to scroll through locations once they have been selected.



4.2 General Properties

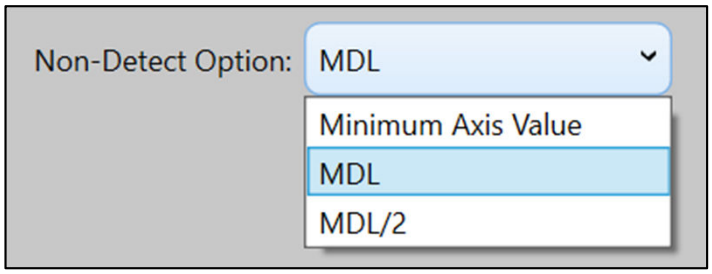
General properties for a radial diagram map include:

1. Number of axes, and which chemicals are to be represented on each axis;
2. Number and selection of reference and/or monitoring event series;
3. Number of locations at which radial diagrams will be shown on the map;
4. Axis line properties (color, style, and thickness or weight);
5. Axis name (i.e., label) properties (color, font size, and font style); and
6. Option of how to plot non-detect results on the radial diagrams. The default option is to plot non-detect results at the method detection limit (MDL) on the radial diagram axis.

The locations of these three groups of properties are identified in the image below.

> Note: Non-detect chemical concentrations are represented by negative values in the Results.csv file with the project database, where the value represents the MDL. For example, a result of -0.3 ug/L in the Results.csv file for a chemical represents a non-detect where the MDL is 0.3 ug/L.

Note: There are three **Non-Detect Options** for plotting non-detect values on radial diagrams: i) at the MDL; ii) at one-half of the MDL; or iii) at the minimum axis range. If the MDL is less than the minimum axis range, then the radial diagram series will be plotted at the minimum axis range.



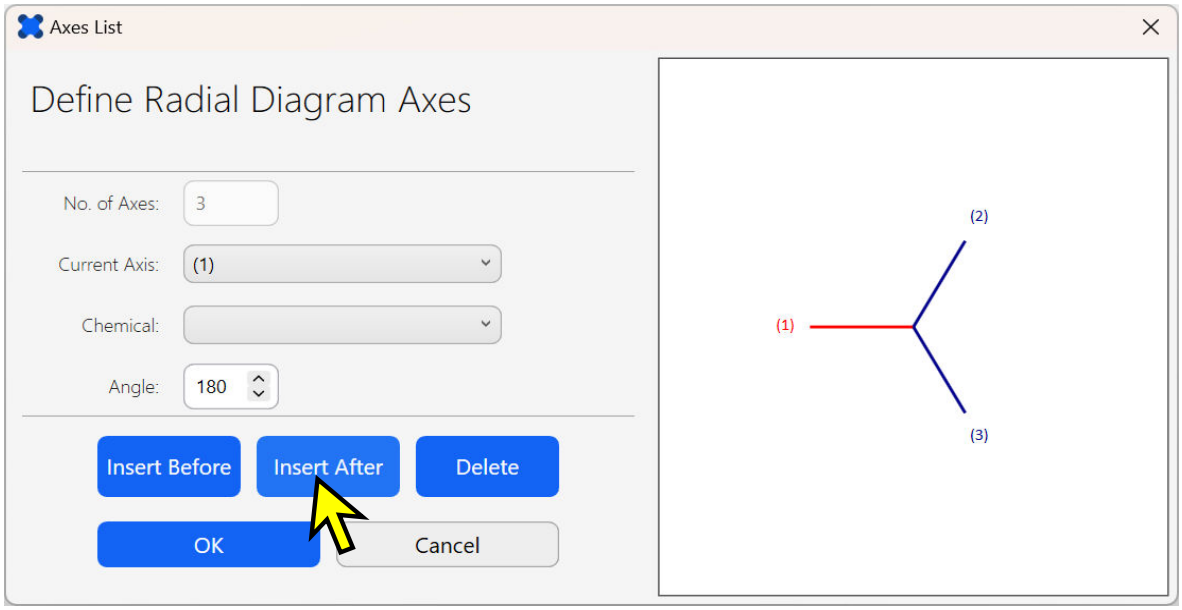
This dropdown box shows the available options for plotting non-detect results on radial diagrams.

4.2.1 Number of Axes, Chemical Selection, and Axis Angles

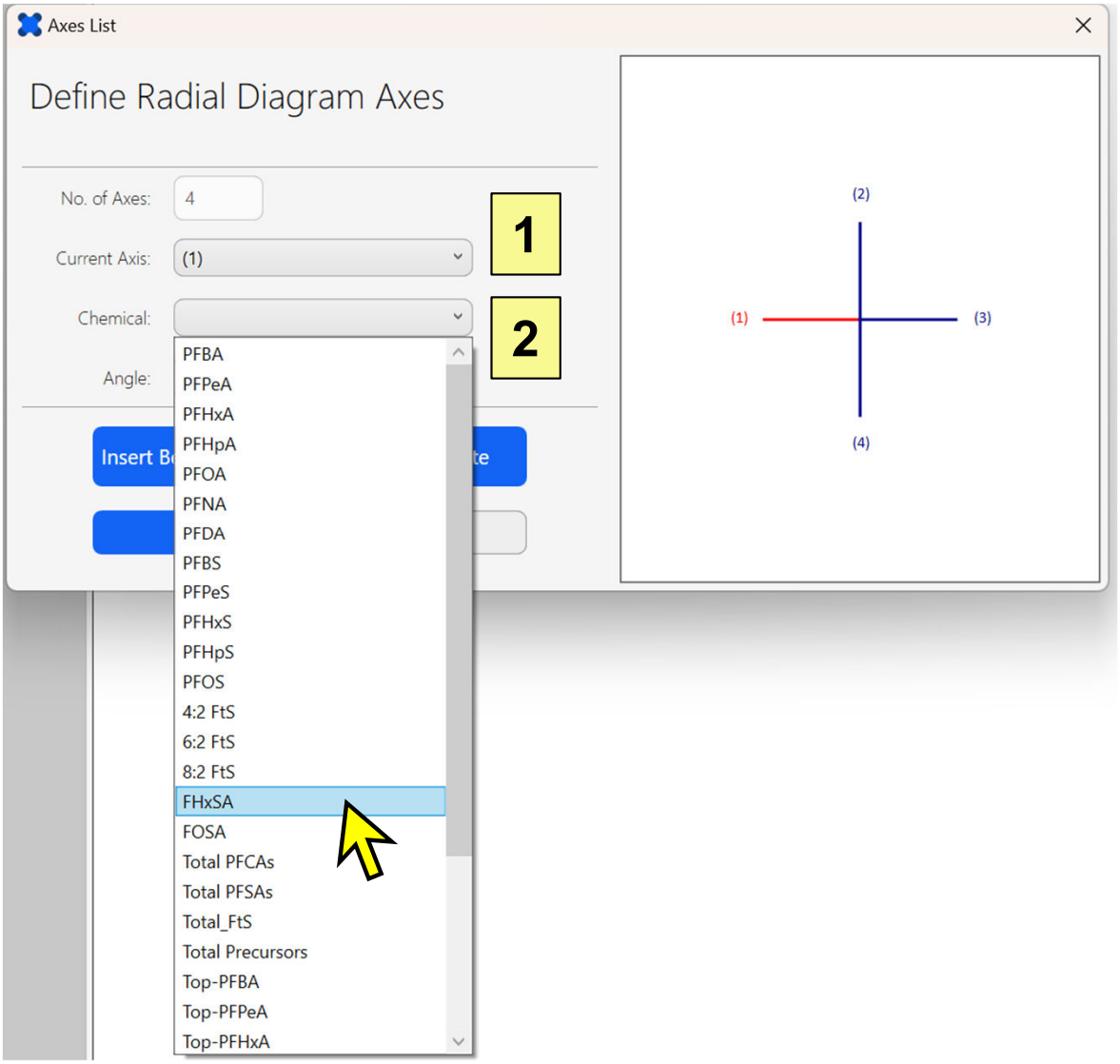
To start editing the radial diagram properties, click the pencil (i.e., **Edit**) icon next to the **No. of Axes** textbox, which currently states that there are three axes. (see "1" on previous page)

A pop-up window will then be displayed with the default 3-axis radial diagram. The current axis is shown with the red line in the legend (see image below). Any changes such as specifying the chemical, changing the axis angle, or deleting an axis will be made to the current axis selected. You can change the current axis using the corresponding dropdown box. Before a chemical is selected for an axis, the current axis is shown as the axis number. Once a chemical has been selected for an axis, then the axis label in the **Current Axis** dropdown box will be replaced with the chemical name.

For this tutorial we want to use a 4-axis radial diagram to represent: a) the precursor FHxSA which is known to degrade to PFHxS; and b) three sulfonates (PFOS, PFHxS, and PFBS). To add a fourth axis, click the **Insert After** button as shown with the yellow cursor in the image below.



1. After inserting the new axis, the current axis selected will be Axis No. 2. Click the **Current Axis** dropdown box and select (see "1" below) to make the first axis the current axis.
2. Next, click on the **Chemical** dropdown list and select *FHxSA*. The chemicals listed in the dropdown box are from the list of chemicals that were imported into the project database with the **Chemicals.csv** file. The order of chemicals in the dropdown box is based on the Sort_ID field in Chemicals.csv.



After specification of FHxSA for Axis No. 1, repeat the process for selecting chemicals for each axis as follows:

- Make Axis No. 2 the current axis and select *PFOS* from the **Chemical** dropdown box.
- Make Axis No. 3 the current axis and select *PFHxS* from the **Chemical** dropdown box.
- Make Axis No. 4 the current axis and select *PFBS* from the **Chemical** dropdown box.

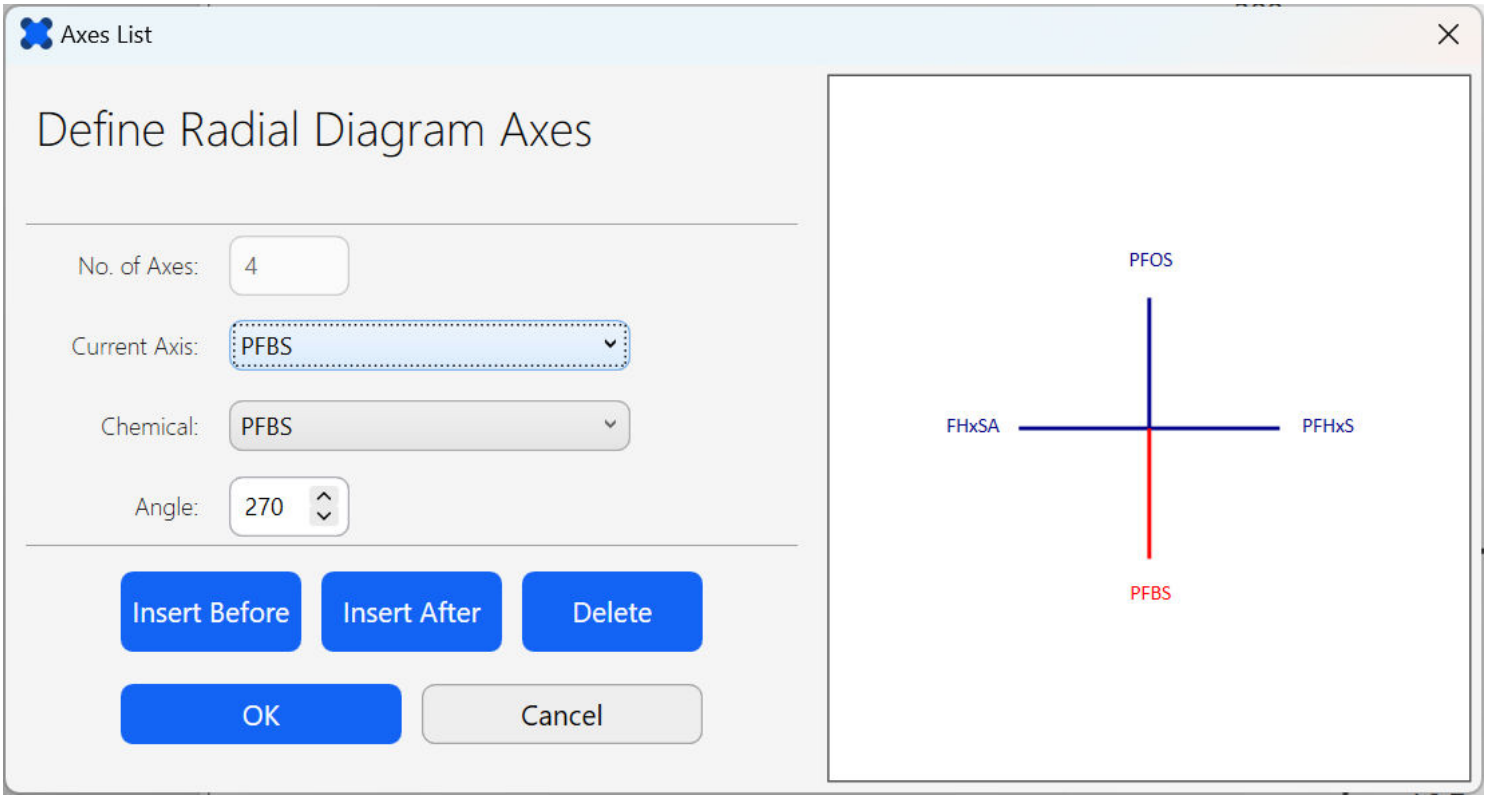
The corresponding legend for these four axes and chemicals is shown in the image below.

You have the option of modifying the angles for each axis by selecting a current axis, and then changing the value of the angle shown in the **Angle** textbox, or using the up or down arrows on the right of this textbox to make incremental changes in the angle. The legend on the right of the image below will be updated based on the new axis angle each time you make a change.

For this tutorial we will keep the default axis angles.

Click the **OK** button to save your changes and go back to the **General** tab.

> **Note:** The default angle for Axis 1 is 180 degrees. The default angle for all other axes is based on the assumption of uniform angles between all axes of the radial diagram, keeping Axis No. 1 angle at 180 degrees as the default.



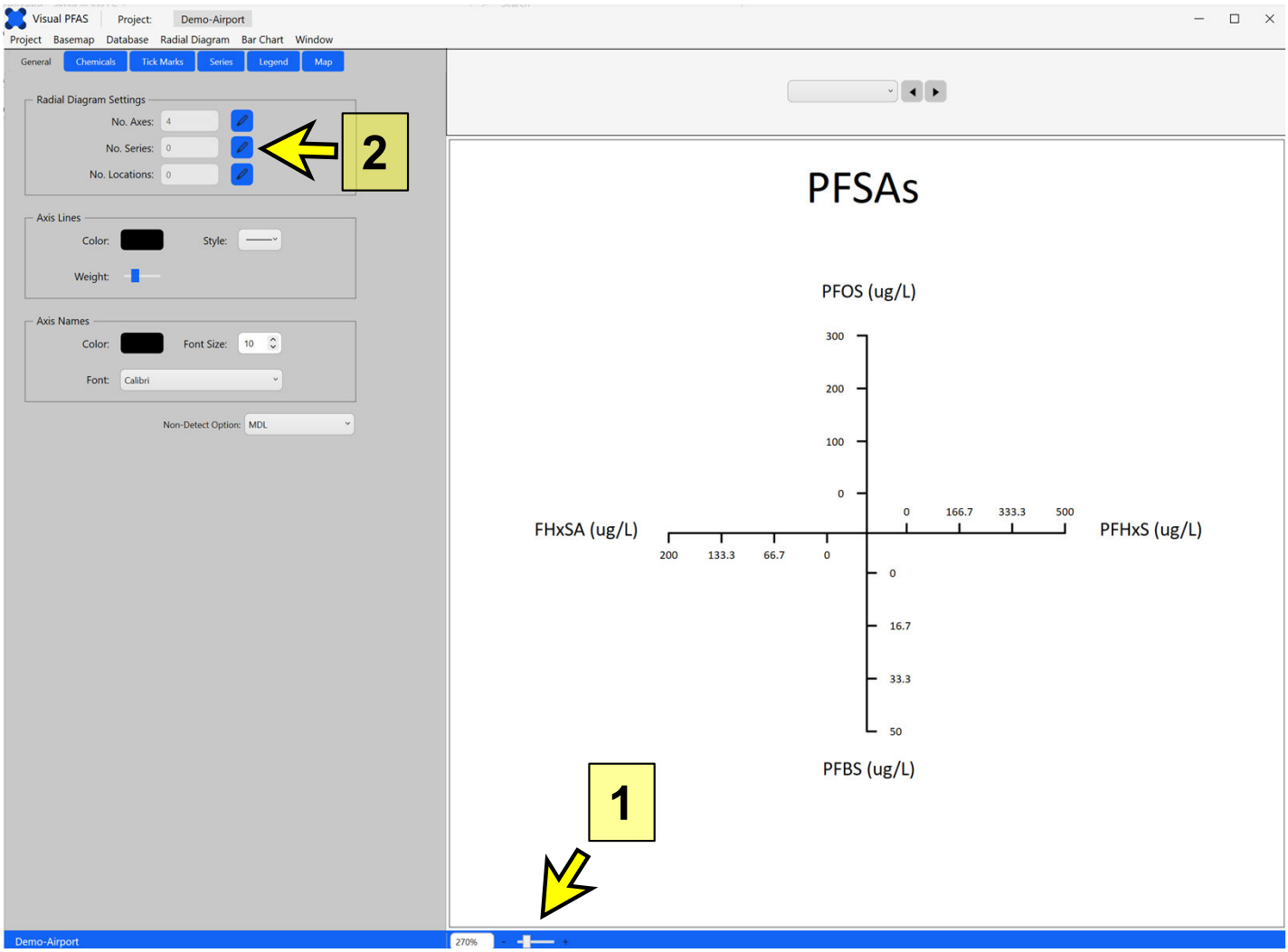
After exiting the pop-up window, you will see the window below where the radial diagram legend has now been updated to show the chemical names associated with each axis, and the default concentration units (ug/L) that are specified separately for each chemical in the **Chemicals.csv** file imported into the project database earlier.

Visual PFAS™ will search the chemical concentrations in the project database to automatically define the minimum and maximum axis ranges and major tick mark scales for each chemical, as shown in the radial diagram legend below. The default for each axis is arithmetic scale, and this is easily changed to log scale as we discuss a little later in this tutorial. Axis ranges and tick marks can also be changed as shown later.

The size of the radial diagram in the legend is dependent on each user's screen resolution and monitor size. The size of the radial diagram can be easily increased by moving the scroll bar indicated at "1" in the image below. Click and hold this scroll bar to the right to make the radial diagram a little larger in the legend.

4.2.2 Number of Reference and Monitoring Event Series

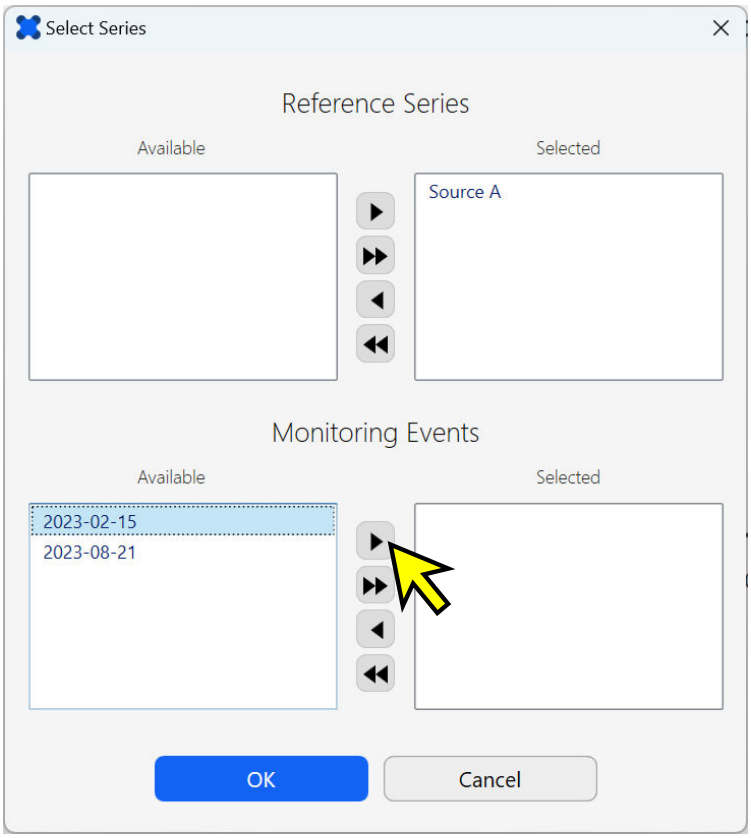
The next step in the tutorial is to click the **Edit** icon to the right of the **No. Series** textbox (see "2" below).

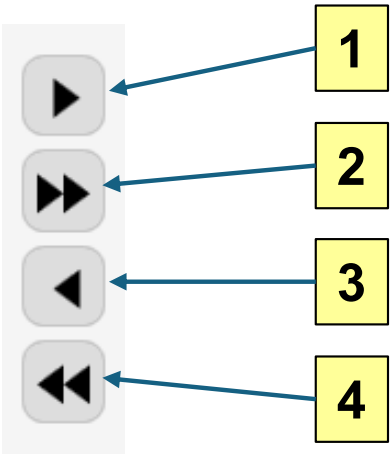


A pop-up window will appear (see below), allowing you to add reference and/or monitoring event series. The **Available** series are shown on the left side of the window based on data in the project database. To move a reference or monitoring event series from the **Available** side to the **Selected** side, you can either: a) double-click on the series in the **Available** side which will automatically move it to the **Selected** side; or click on it once in the Available side so that it is highlighted in blue, and then press the single right arrow (#1 button below) to move it to the selected side. The opposite is done to move a series from the **Selected** side back to the **Available** (i.e., unselected) side. The double arrows (#2 and #4 below) are used to move all series from one side to the other.

Note: You can highlight more than one item at a time in the Available or Selected lists by holding the SHIFT key to highlight a contiguous block of items, or by holding the CTRL key to highlight non-contiguous items in the list.

The image below shows that the *2023-02-15* monitoring event has been clicked on once (i.e., based on the blue highlighting shown below). In this case, click the single right-arrow to move this event to the **Selected** side. For this tutorial, select the *Source A* reference series and the *2023-02-15* monitoring event series to show on the radial diagrams, then press the **OK** button at the bottom of the window. All well radial diagrams will have the same Source A reference series, and each radial diagram will show the well-specific monitoring event concentrations.





Button functionality:

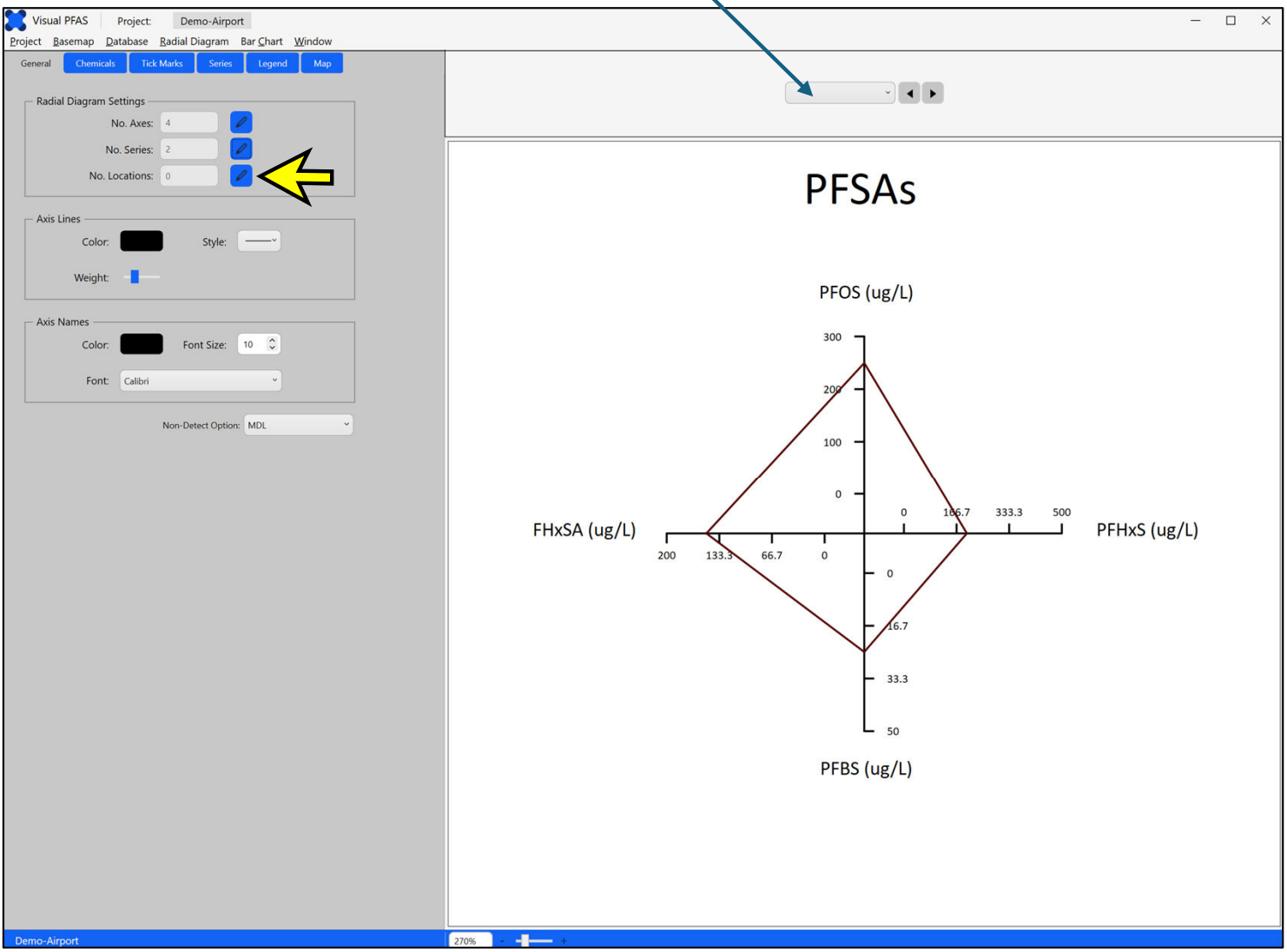
1. Move highlighted items to the **Selected** list;
2. Move all Available items to the **Selected** list;
3. Remove highlighted items from the **Selected** list back to the **Available** list;
4. Remove all items from the **Selected** list back to the **Available** list.

4.2.3 Select Locations to Plot Radial Diagrams

After selecting the two series in the previous step, the image below shows what will be displayed. Only the Source A reference series is shown because well locations for the monitoring event series haven't been selected yet. Radial diagram series have randomly assigned colors initially, which you can easily change (i.e., similar to how Excel creates random initial colors for chart series).

Click the **Edit** icon next to the **No. Locations** textbox to select monitoring well locations where radial diagrams will be plotted on the basemap.

Note: The dropdown box displayed above the radial diagram legend will include selected monitoring well locations (see next step in the tutorial). This allows you to select a specific well to review with a single radial diagram, and you can press the right and left arrows to cycle through radial diagrams for all selected monitoring wells.

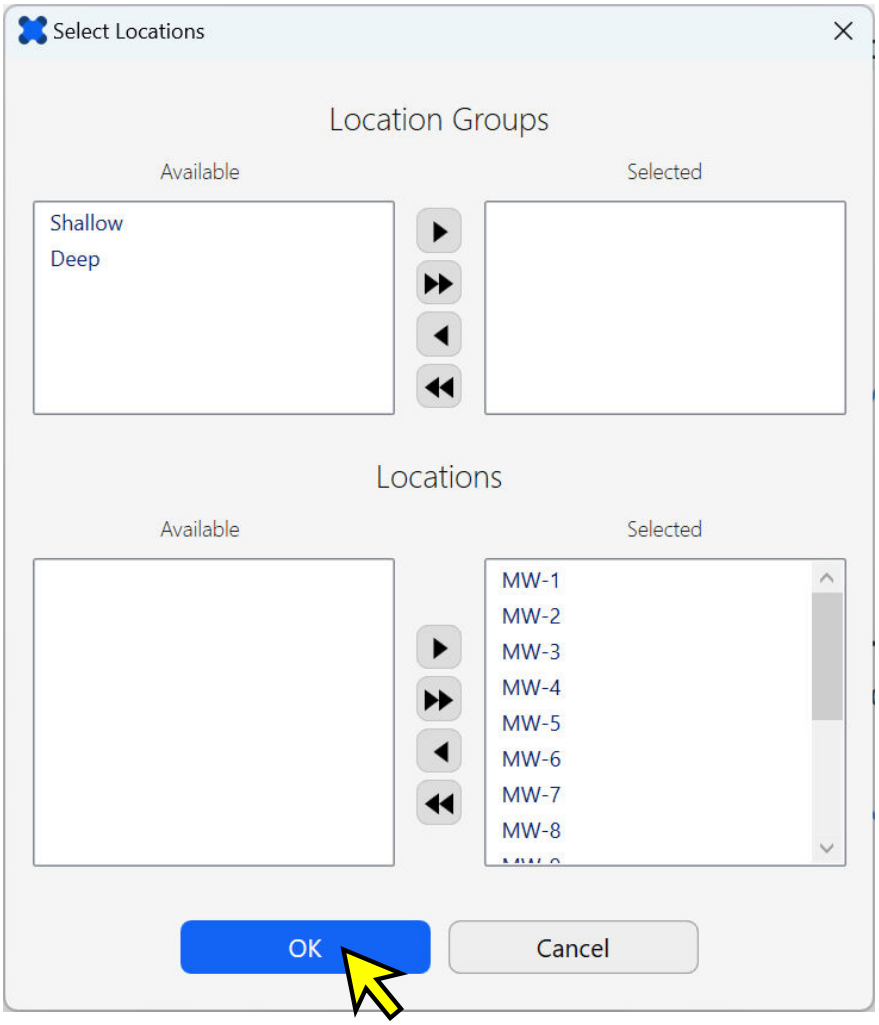


The project database for the Airport Site has two groups of locations: shallow and deep monitoring wells. Specifying groups of wells allows you to quickly filter a large list of site monitoring wells to a smaller list with only those wells that you want to select for plotting radial diagrams.

For example, if you select the *Shallow* location group by double-clicking on it to move it to the **Selected** side, then the list of **Available** locations in the lower list will be reduced to include only 11 shallow monitoring wells. Or if you selected the *Deep* location group, then only four monitoring wells would be included in the **Available** locations list.

In this tutorial, we will plot radial diagrams at all 15 monitoring well locations as a simple demonstration. (At other sites, it may be advisable to create separate radial diagram maps for shallow and deep monitoring wells.) So you will not select either of the location groups shown in the top list.

To select all 15 monitoring well locations, click the ▶▶ button and press OK to close the pop-up window.



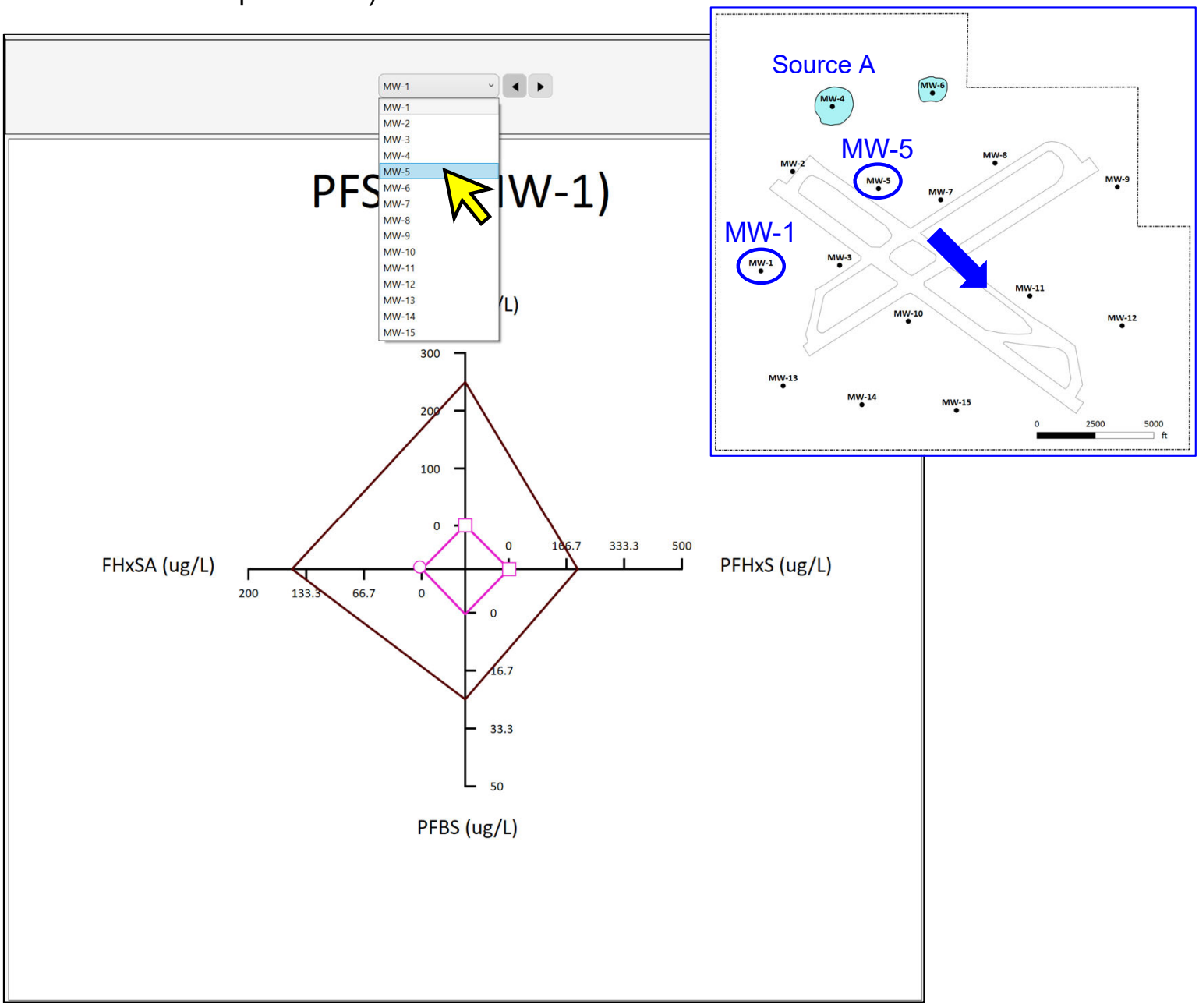
Note: The order for displaying monitoring wells in the **Available** and **Selected** lists is based on the Sort_ID field in the Locations.csv file with the project database.

This allows users to sort wells numerically (e.g., so MW-2 is shown ahead of MW-10 in the well list).

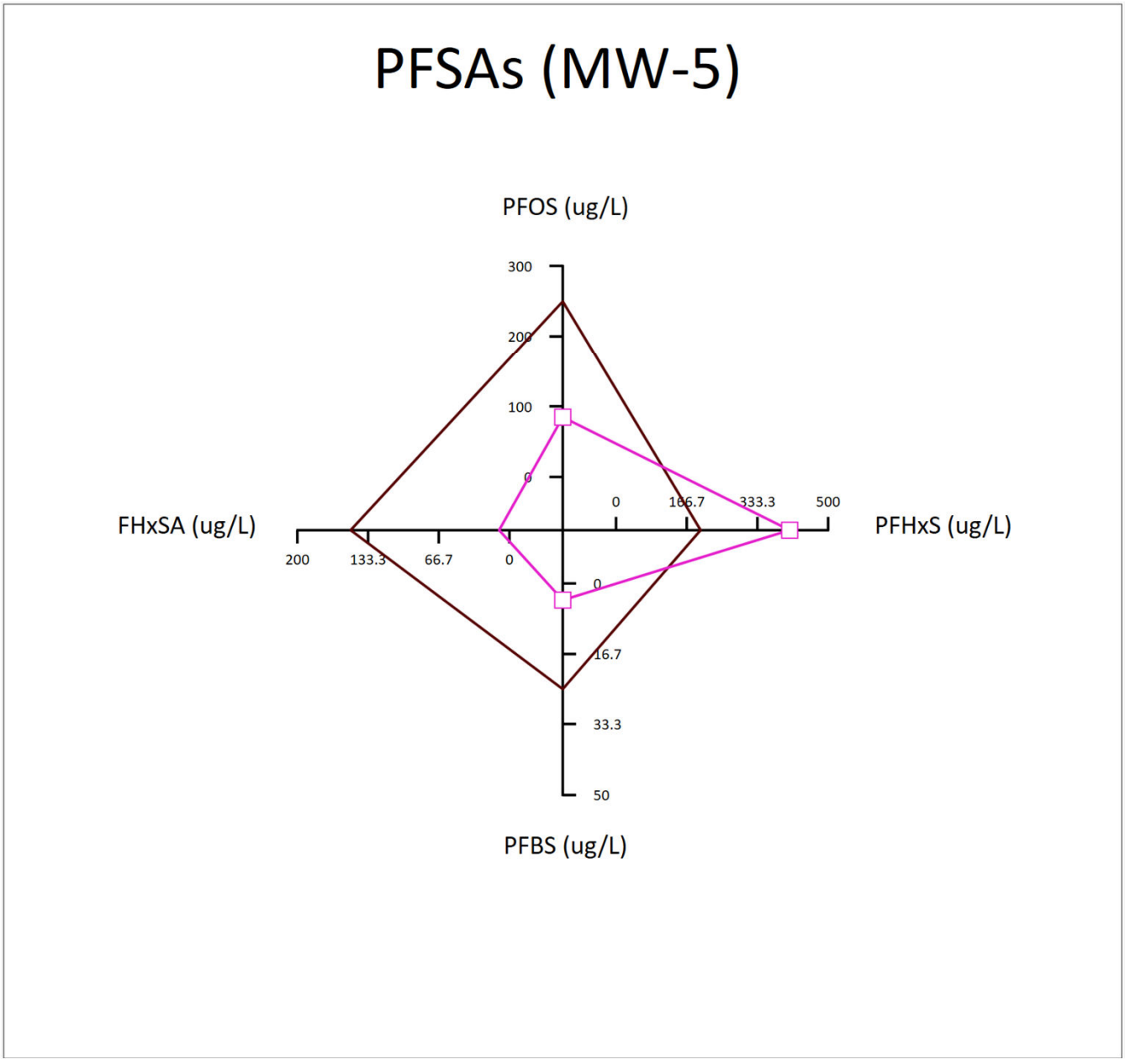
Now that monitoring well locations have been selected, both the reference and monitoring event series will be shown for the first well in the selected list (i.e., MW-1).

Recall that the reference series (red) represents the concentrations at Source A where sulfonates and FHxSA are high. The image below shows that sulfonate and FHxSA concentrations at MW-1 (pink series) are much lower than at Source A. MW-1 is cross-gradient from the source, so it is located on the fringe of the plume. This is why PFAS concentrations are much lower at MW-1 than at the source area. (see inset map below)

Monitoring well MW-5 is directly downgradient of Source A. To view the radial diagram for MW-5, click on the selected locations drop-down list above the legend, move your cursor so it is at the MW-5 location in the list, and click once. (see image below which shows the initial radial diagram for MW-1 and the subsequent selection of MW-5 in the locations dropdown list.)



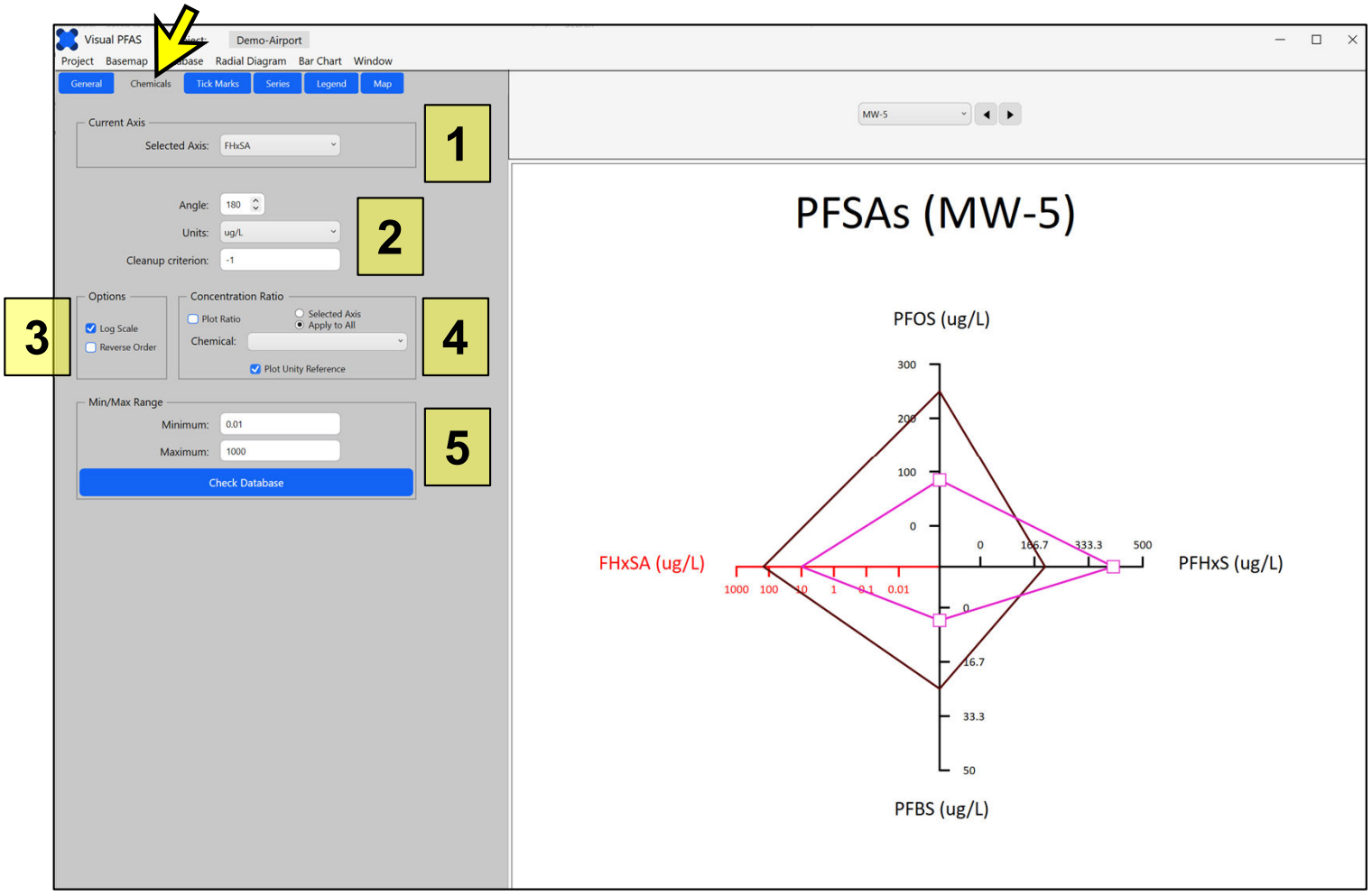
The radial diagram for monitoring well MW-5 is shown below. The red reference series represents the Source A concentrations, and the pink data series represents MW-5 concentrations downgradient from Source A. The decrease in FHxSA concentration between Source A and the downgradient monitoring well indicates that the precursor FHxSA is biodegrading, which is consistent with aerobic conditions in groundwater. PFHxS is shown to be increasing between Source A and MW-5 because PFHxS is a daughter product of FHxSA that is biodegrading. Both PFOS and PFBS are shown to be decreasing between Source A and MW-5, which indicates that neither of these two sulfonates are being produced at significant rates downgradient of the source area. Concentrations for these two species are declining along the flow path between Source A and MW-5, due to plume dispersion and/or forward diffusion into silt or clay layers in the aquifer. The increase in PFHxS indicates that the transformation of FHxSA to PFHxS is occurring at a higher rate than the attenuation caused by dispersion or diffusion.



4.3 Chemical Properties

Click on the **Chemicals** tab to change axis properties for the radial diagram. The numeric labels on the image below correspond to:

1. Selection of current axis (shown by the red line and red chemical label font in the legend) – any changes to axis properties will be made only to the current axis.
2. Axis angle, concentration units, and cleanup criterion (-1 if not applicable)
3. Toggle on/off for log scale, or to reverse the direction of increasing concentration on the axis. The minimum concentration range is by default near the origin of the radial diagram; this can be reversed to occur on the outer extent of the axis, which is useful when plotting redox indicators)
4. Change an axis from a concentration to a ratio; and
5. Checking the project database for the minimum and maximum detected concentrations and method detection limits (MDLs).



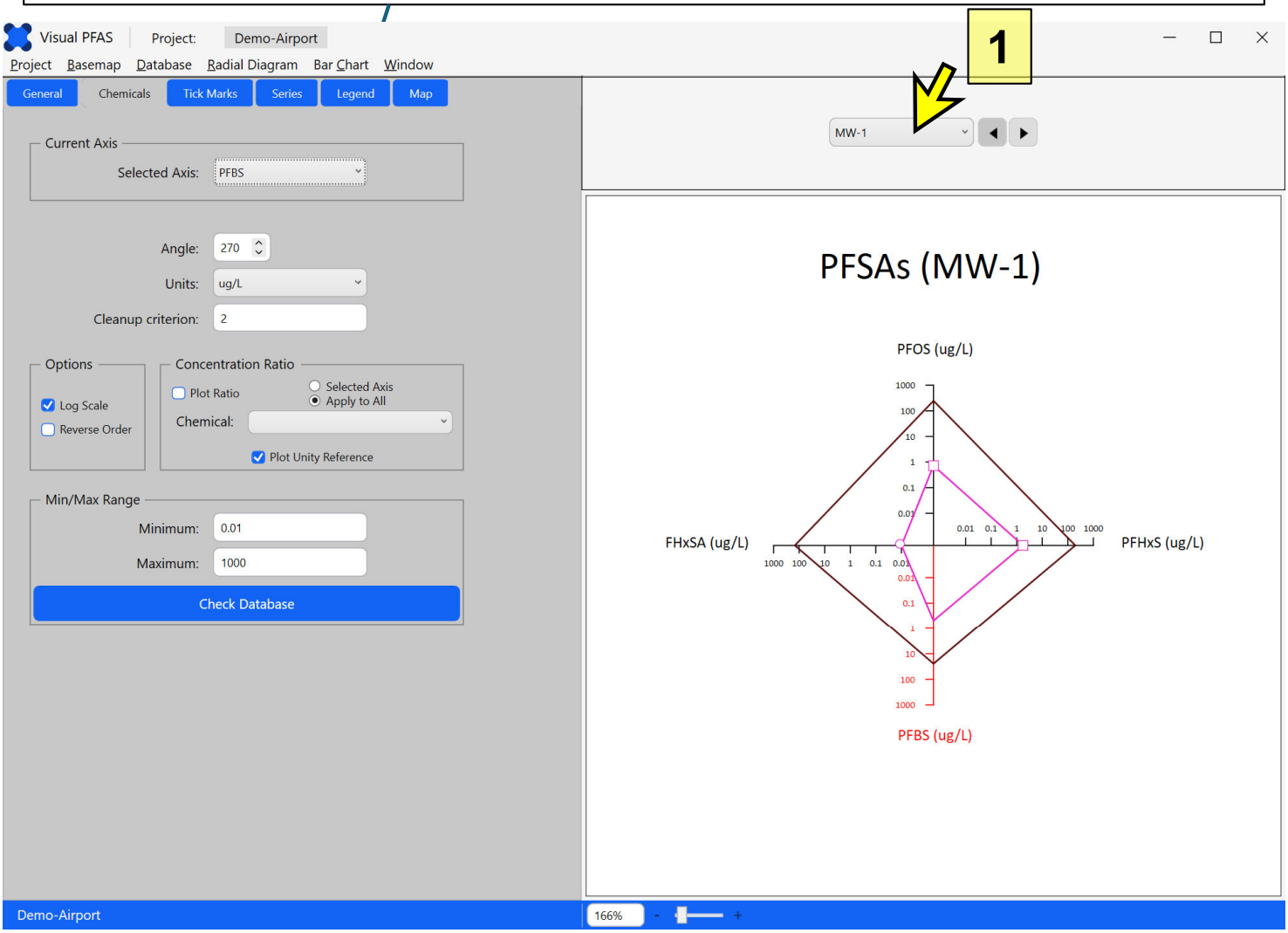
For the tutorial, switch to MW-1 (see "1") and change all four radial diagram axes to log scale which is typical for PFAS sites where concentrations vary by orders of magnitude:

i) Select FHxSA as the current axis if it's not already selected (see the dropdown box at "1" in the image on the previous page.

ii) Check the "Log Scale" option shown at the "3" label on the previous page. The axis ranges will change automatically based on the minimum and maximum project concentrations for FHxSA. You can change the minimum or maximum range for each axis by entering new values in the text boxes at the bottom of the properties section. (see "5" on previous page).

iii) Repeat steps i) and ii) for each of the remaining three axes (PFOS, PFHxS, and PFBS). The image below shows the updated radial diagram legend with all four axes now using log scale.

Note: The default units selected for each chemical axis (ug/L in this example) are based on the default units specified in the Chemicals.csv file which was imported into the project database. Database results and axis ranges are automatically updated to reflect the selected units for each axis.

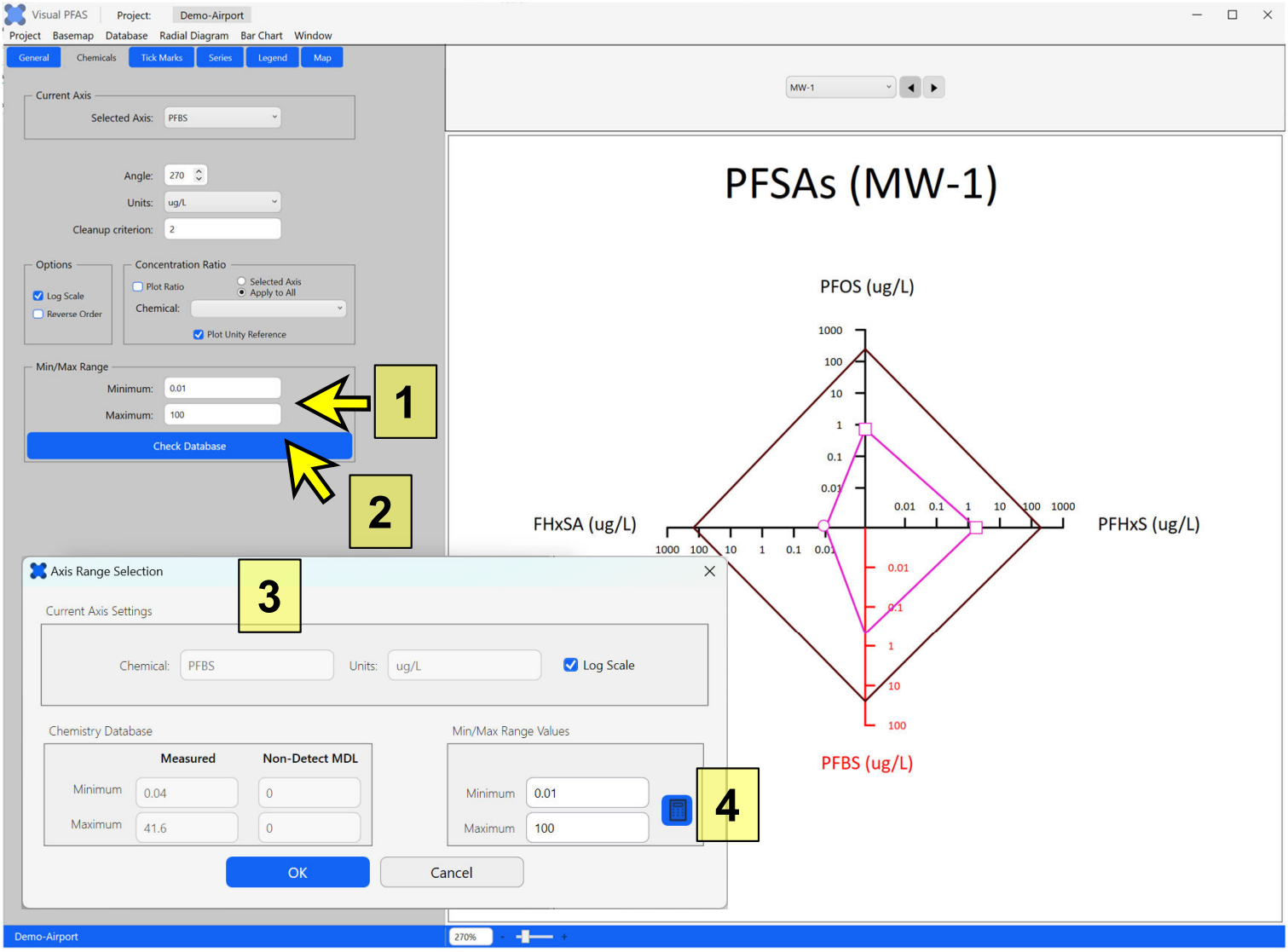


As discussed above, you can change the axis minimum or maximum ranges by entering new values in the textboxes at "1" below.

You can also check the range of project concentrations for the chemical at the current axis by pressing "Check Database" at "2" below. The **Axis Range Selection** pop-up window will appear (see "3" below), which lists the minimum and maximum concentrations for detected (i.e., measured) and non-detect (MDL) results.

You can update the minimum and maximum axis ranges with the textboxes on the right of this pop-up window, or you can re-calculate the axis default ranges (based on database min/max values for this chemical) by pressing the calculator icon at "4" below.

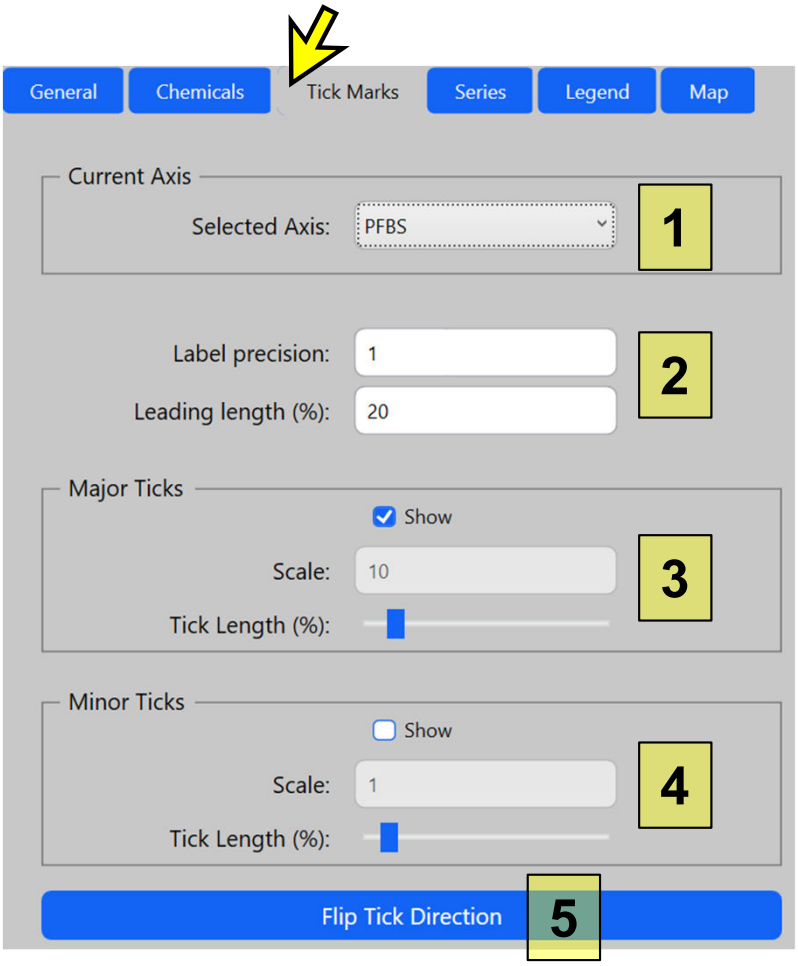
Note that Visual PFAS™ automatically converts project concentrations to the selected concentration units when the database stores values in different concentration units.



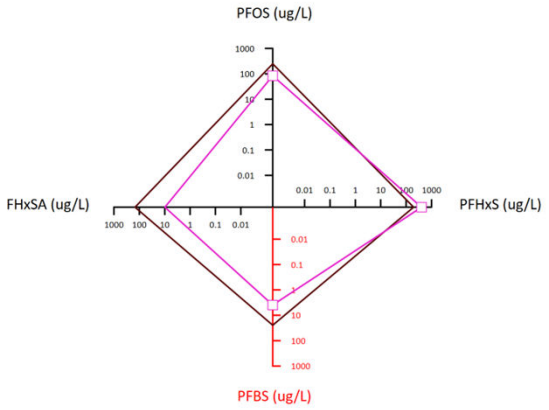
4.4 Tick Mark Properties

Click on the **Tick Marks** tab to view tick mark properties. There are several options for changing tick marks corresponding to "1" through "4" in the image below.

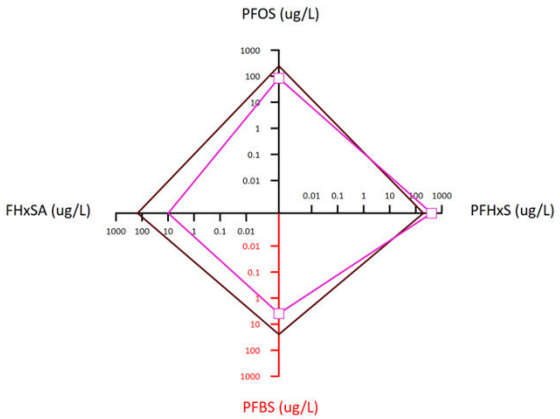
1. Select Current Axis (as shown by the red line and red chemical label in the legend).
2. Update the axis tick mark label precision (i.e., number of decimal places). This only applies for axes that are based on arithmetic scale, not for log scale). The leading length can also be modified – this is the distance on the current axis between the centroid of the radial diagram, and the first tick mark on the axis next to the centroid. By default, this leading length is specified to be 20% of the total axis length.
3. Major tick marks – can toggle on/off by clicking the *Show* checkbox. If the axis is based on arithmetic scale, you can change the scale of the major ticks which is the interval (in concentration units) at which the major tick marks are plotted. You can also change the length of the major tick marks by clicking on the scroll bar, holding it while moving to the left or right to change the tick mark length.
4. Minor tick marks – same options as major tick marks.
5. Clicking the **Flip Tick Direction** button will plot the tick marks on the opposite side of the axis. See the different tick locations on the PFBS axis below.



1. Default tick directions



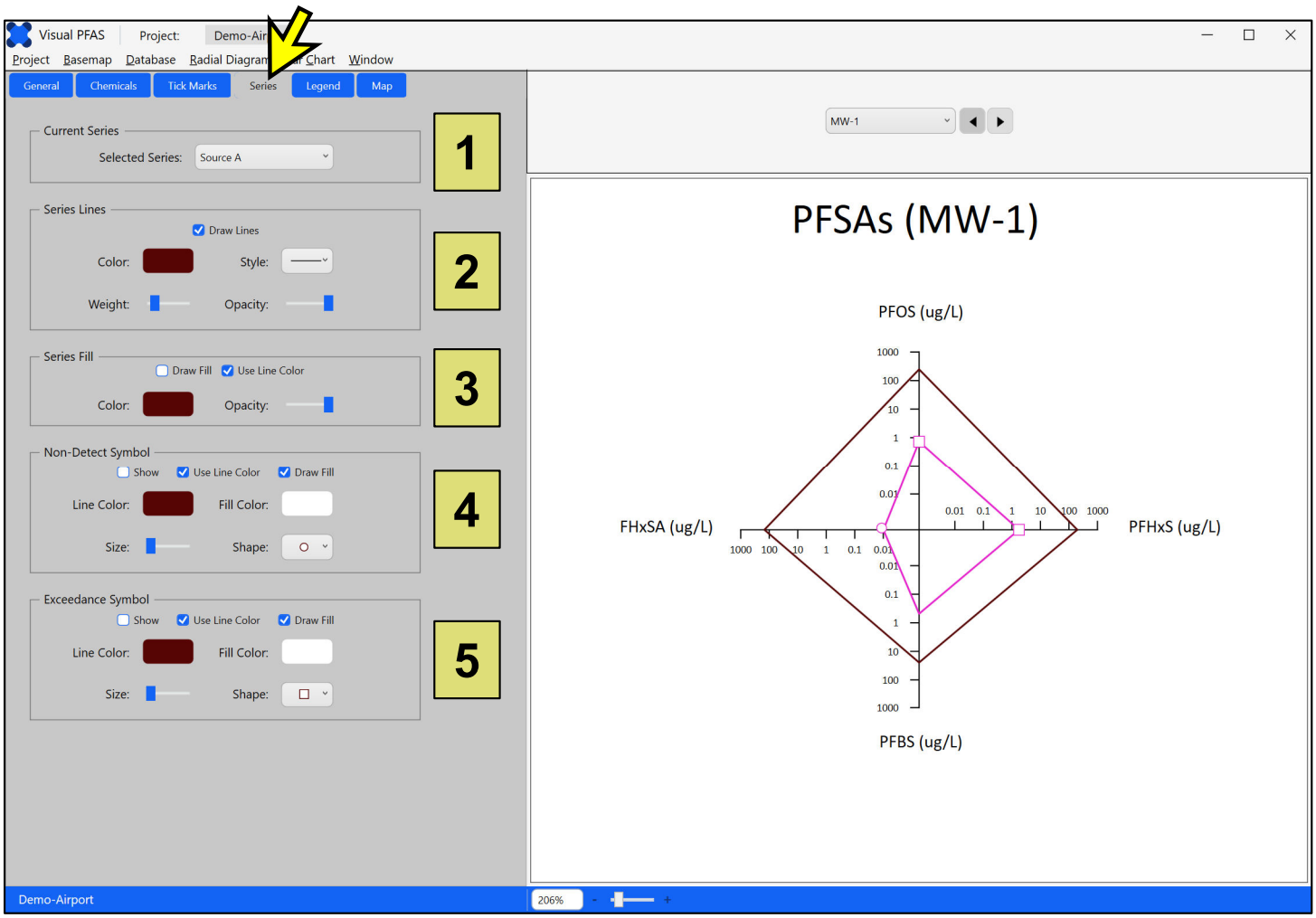
2. Flipped tick direction for PFBS axis



4.5 Series Properties

Click on the **Series** tab to view the series properties. There are several options for changing series properties corresponding to "1" through "5" in the image below.

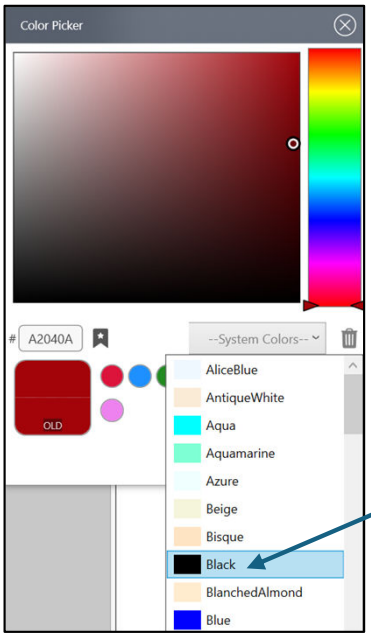
1. Select the current series. (Note – ignore "Unity Reference" series in the dropdown list unless ratios are being plotted, in which case a unity reference series is optionally plotted at Ratio=1)
2. Revise series lines: Draw checkbox, color, style, weight, and opacity (which is the opposite of transparency).
3. Revise series fill: Draw checkbox, use same color as series lines checkbox, color, and opacity.
4. Non-detect symbols: show checkbox, and various options for line and fill color, symbol size, and symbol shape.
5. Exceedance symbols (plotted on an axis when the result exceeds the applicable cleanup criterion): show checkbox, and various options for line and fill color, symbol size, and symbol shape.



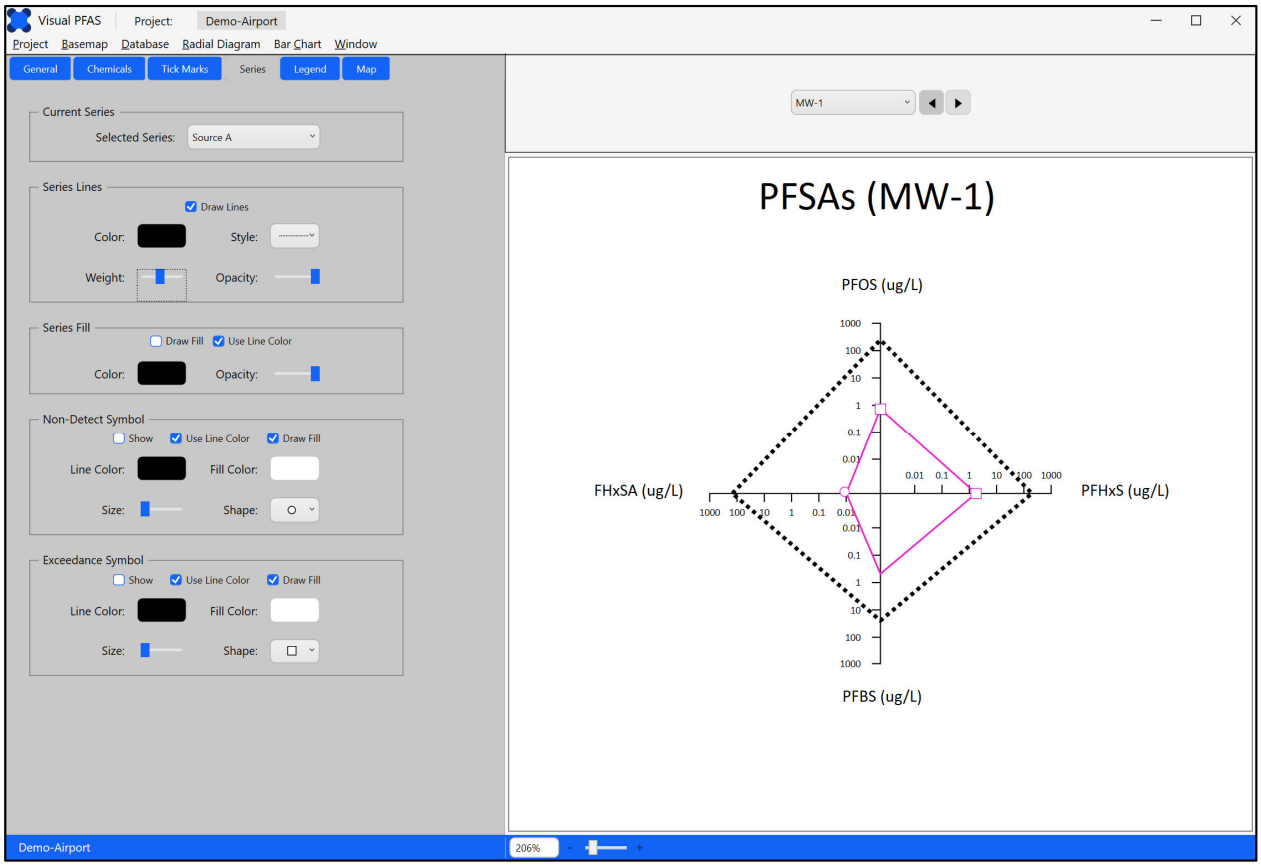
For the tutorial, first select the Source A reference series if it's not already selected.

Then change the series line color to black, change the style to a dotted line, and increase the thickness (i.e., weight) of the series line as shown below.

Note: Non-detect or exceedance symbols are typically not plotted with a reference series.



Select black from the system colors dropdown menu



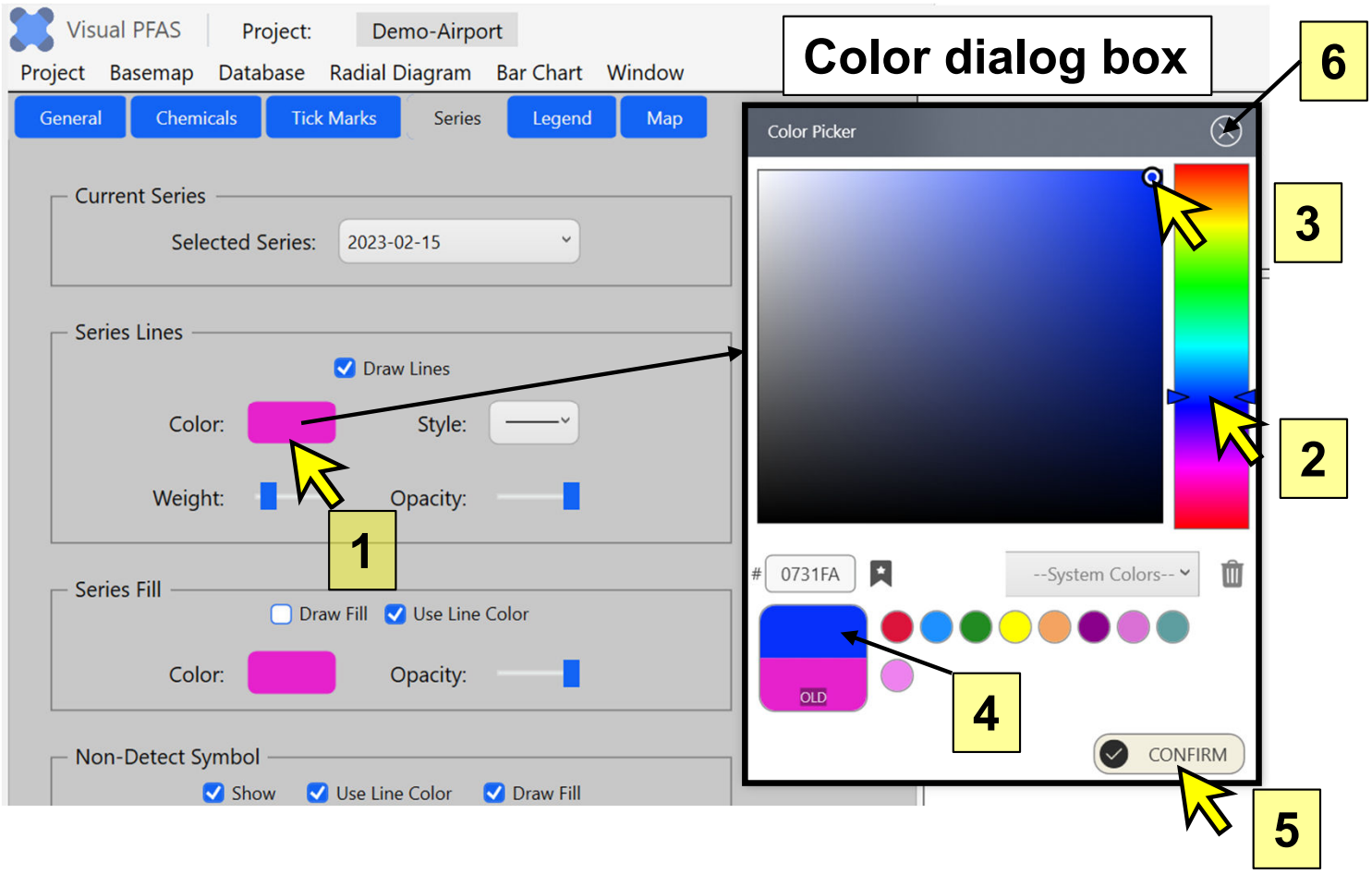
The next step in the tutorial is to change the monitoring event series as follows:

i) Select the **2023-02-15** monitoring event series from the dropdown list.

ii) Change the line color to blue:

1. Click the line color box (see “1” below) to pop-up the color dialog box.
2. Click on blue in the scale bar at the right of the color dialog box (see “2”).
3. Click in the top right corner of the color palette (see “3”).
4. Now that a new line color has been selected, this color will be shown as the new selection (see “4”).
5. To save the line color change, click the Confirm button at the bottom-right of the color dialog box (see “5”). The line color box will automatically be updated with the new selected color for the series line.

Note: To cancel the selection of a new color and retain the original color selection, click the “x” icon at the top-right of the color dialog box (see “6”). This will close the color dialog box without changing the color.



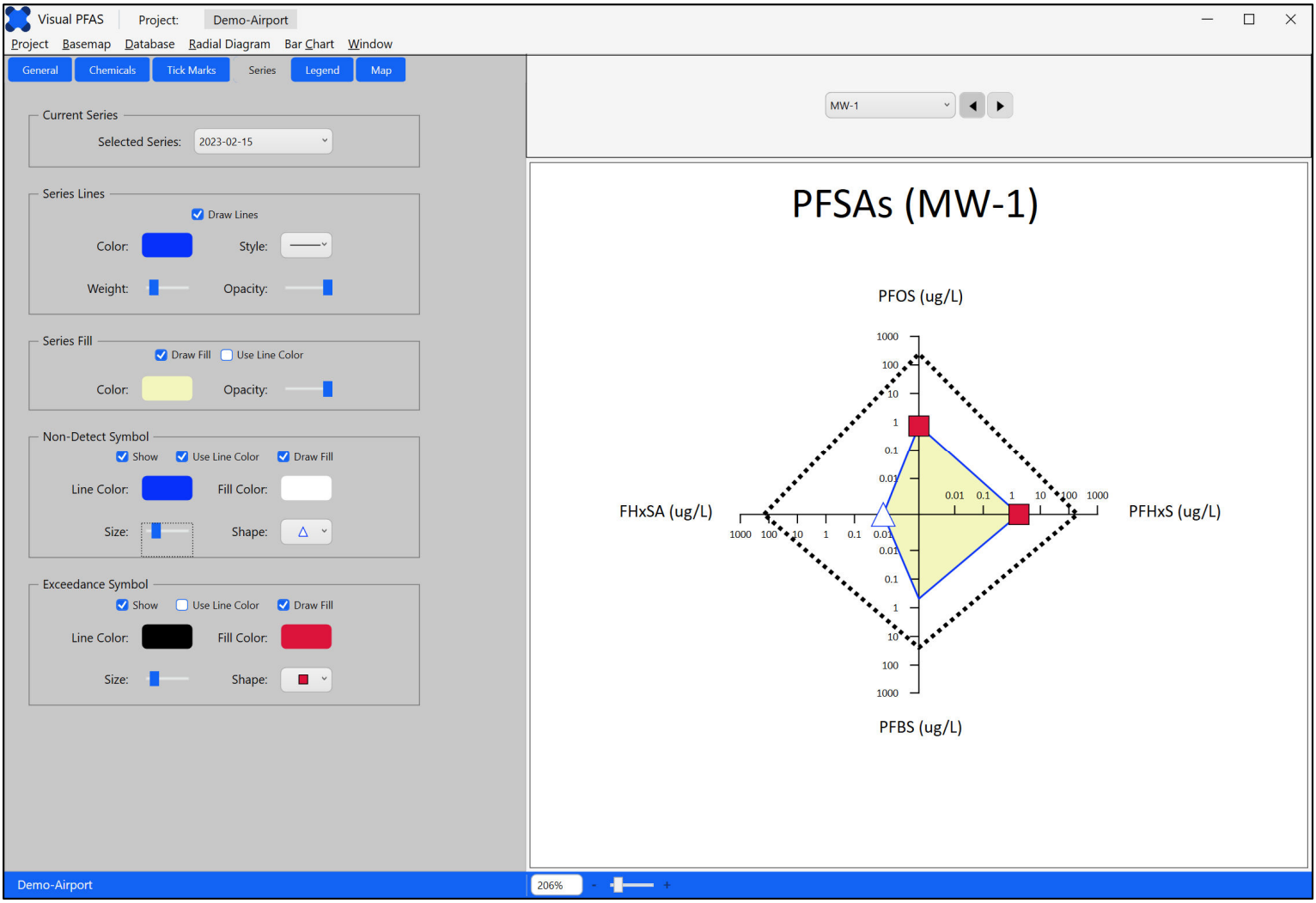
After updating the series line color, you will see that the series fill and symbol line colors will automatically change to the series line color. That's because the default is to have these colors be the same as the series line color – see the **Use Line Color** checkbox for each of these properties.

For the tutorial, change the series fill and symbol properties as follows:

i) Change the series fill to a light yellow color. Once the series fill color has been changed, the **Draw Fill** checkbox will automatically be toggled on. You can turn off the series fill by toggling **Draw Fill** off.

ii) Change the non-detect symbol to a triangle, and increase the size as shown below.

iii) Change the exceedance line color to black, change the fill color to red, and increase the size as shown below.

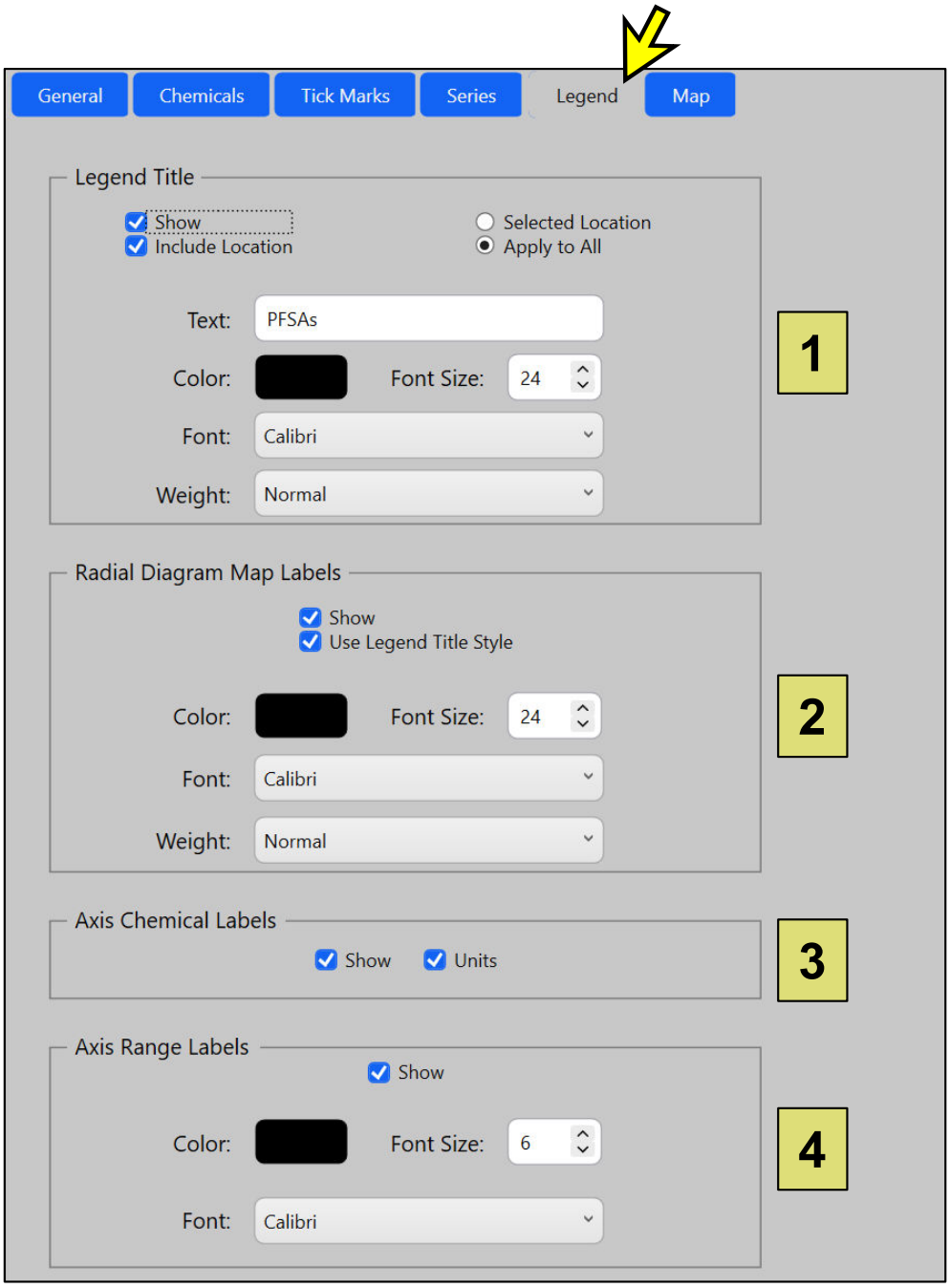


4.6 Legend Properties

Click on the **Legend** tab to view legend properties related to:

1. Legend title shown above the radial diagram;
2. Radial diagram map labels (i.e., location names) that are optionally shown above each well radial diagram when radial diagrams are overlaid on the project basemap;
3. Axis chemical labels on the legend; and
4. Axis range labels.

Try changing various legend properties to see how the plot is updated.

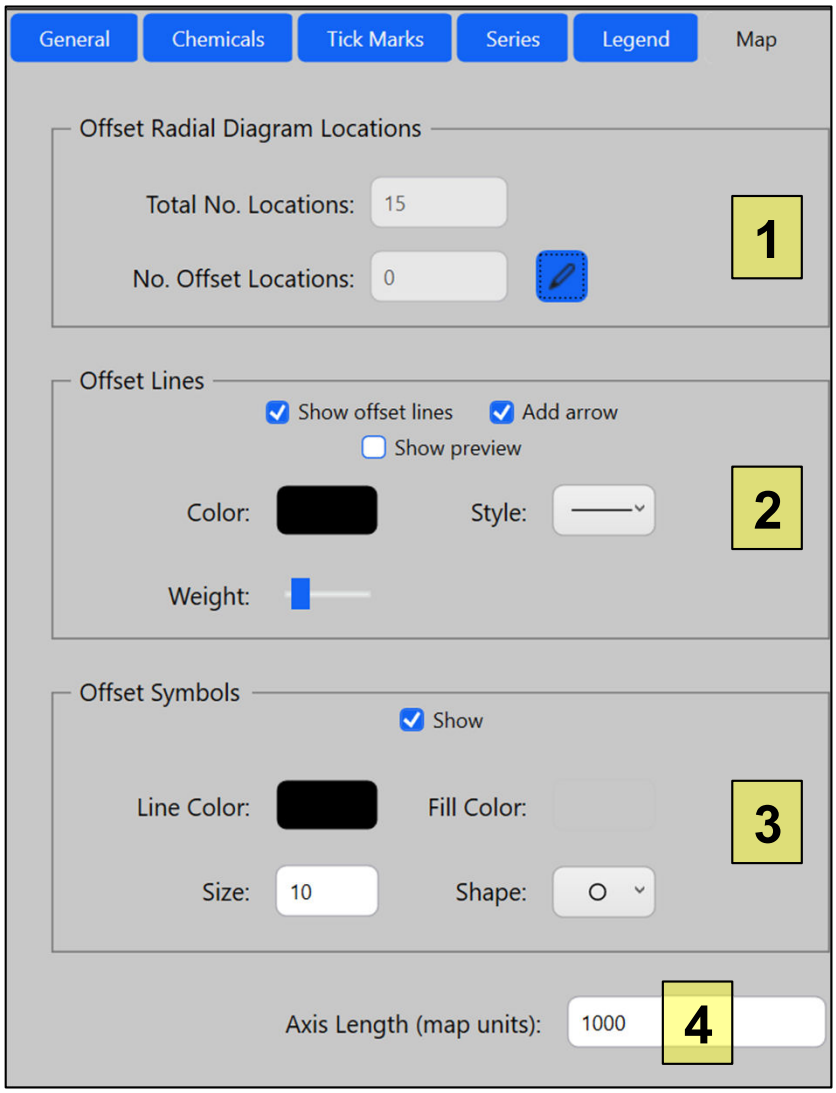


4.7 Map Properties

Click on the **Map** tab to view map properties related to:

1. Offset radial diagrams from the original locations, to avoid overlapping of radial diagrams at locations that are adjacent to each other. (An example of this process is provided later in this tutorial.)
2. Offset lines (or arrows) that are optionally shown between the offset radial diagram, and the original location.
3. Offset symbols which are plotted to show the original location(s) that have been offset to avoid overlap with adjacent locations.
    - The symbol size is in map units. If offset symbols do not appear to be shown on the basemap, it may be that this size is too small. The size should reflect the symbol size in map units (e.g., feet or meters).

4. Axis length in map units (e.g., feet or meters). This will govern the size of the radial diagram axes on the map. **Change the length to 1000 in the textbox at "4" below.**



Note: Determining the final axis lengths will depend on the distance between locations where radial diagrams are plotted. For example, if two locations are situated 100 ft apart, then axis lengths of 50 ft or less will ensure that these radial diagrams will not overlap.

It will typically take a few iterations to get the sizes adjusted to a preferred level for axis lengths and offset symbol sizes.

The series symbols are proportional to the axis length, so increasing the axis length in a radial diagram will increase the series symbol sizeson the map automatically.

All radial diagram axes have a uniform length.

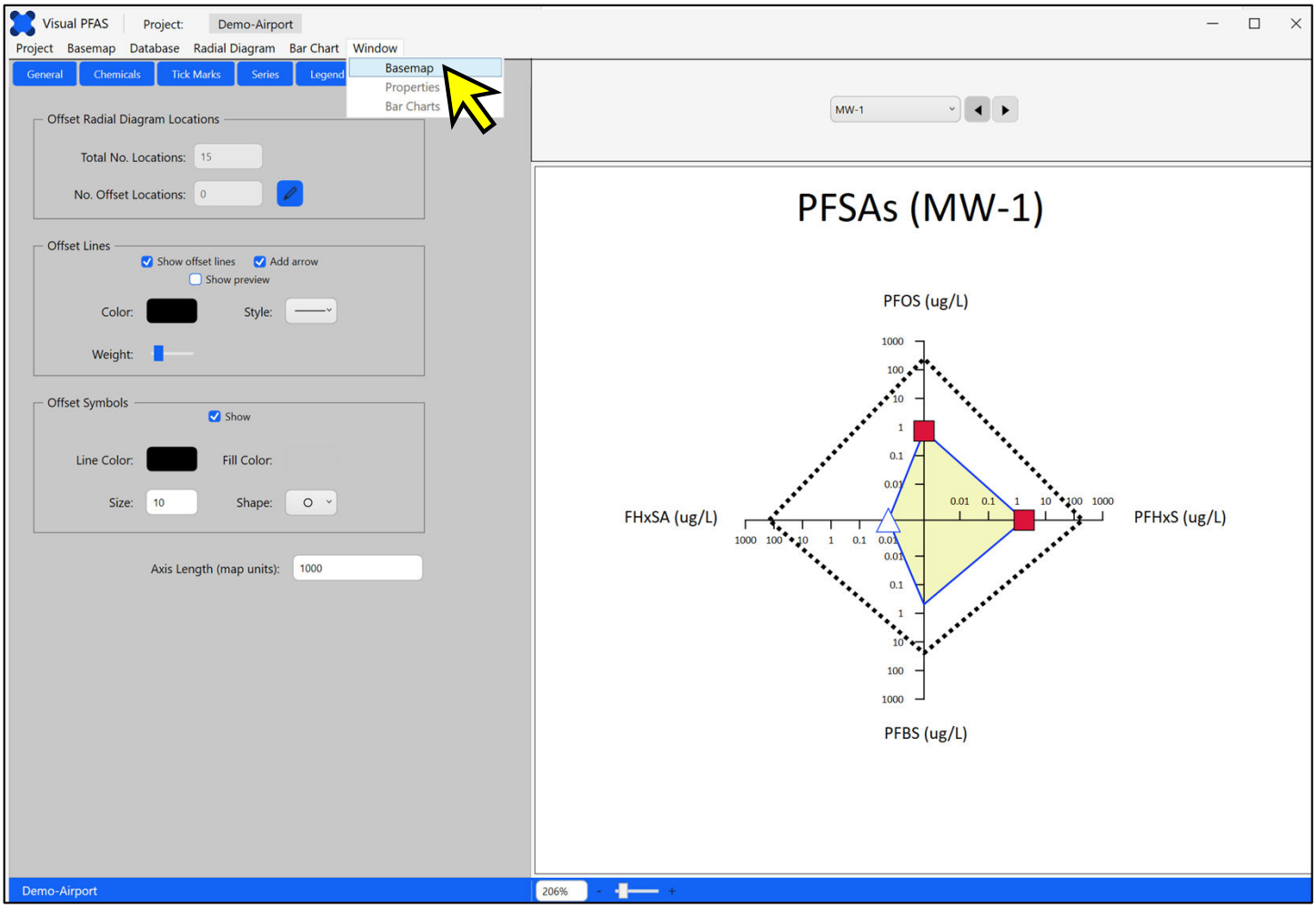
4.8 Iterating Between the Basemap and Radial Diagram Properties

The next step is to overlay the radial diagrams on the site basemap. The typical process is to move back-and-forth between viewing the radial diagrams on the basemap, and then adjusting various radial diagram properties (e.g., series line weights, fill colors, axis lengths, radial diagram location label font size, etc.)

First save the radial diagram properties by selecting **Radial Diagram** from the top menu bar and clicking on **Save**.

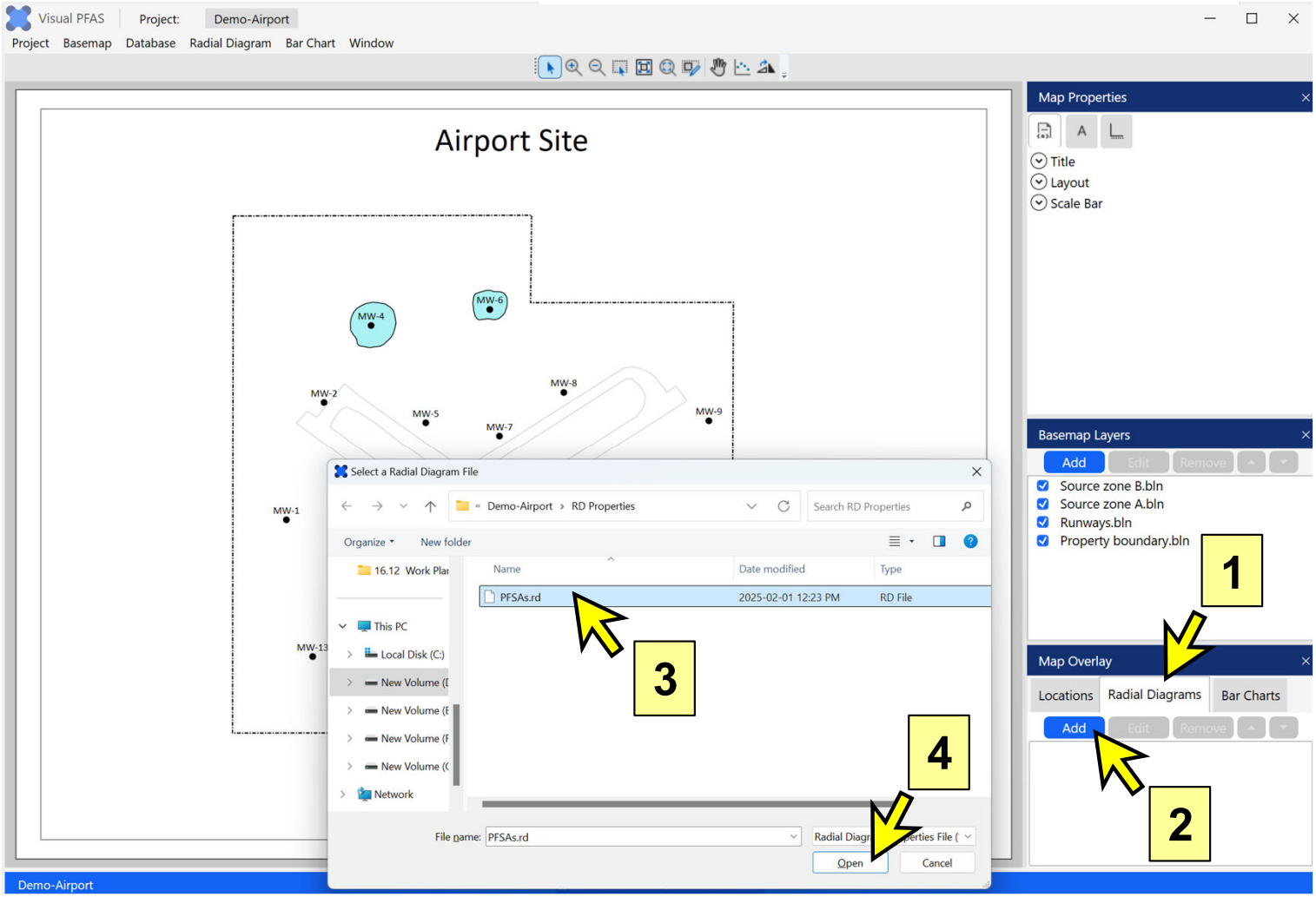
To switch between the **Basemap** and radial diagram **Properties** options, use the **Window** option in the top menu bar send click on **Basemap** to return to the site basemap window (see arrow in image below). This is where you can overlay the radial diagrams on the basemap.

Note: Auto-save is used to save radial diagram properties on a regular basis. Still, it's good practice to use the menu Save option periodically to ensure that your changes are saved. When Visual PFAS™ is closed and then opened again, the software will remember which radial diagram properties file was open last, and will automatically open that properties file again, as well as the site basemap.

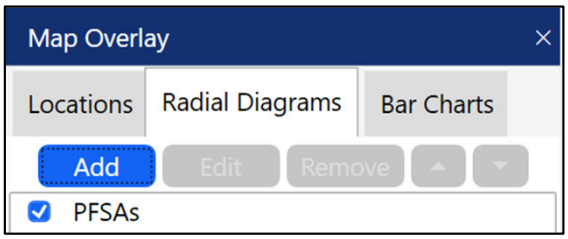


The map overlay options at the bottom right is where you can add radial diagrams as an overlay layer on the basemap. Follow these steps which correspond to the numeric labels below, to plot the radial diagrams:

1. Click on the **Radial Diagrams** tab in **Map Overlay**. At first no radial diagram maps have been added as layers so none will be shown.
2. Click the **Add** button to add a layer with radial diagrams.
3. A pop-up window will appear where you can select the *PFSAs.rd* radial diagram properties file to add as a layer. Select the *PFSAs.rd* file that you just finished saving (see "3"). Visual PFAS™ uses the "RD Properties" sub-folder under the project folder as the default for where these radial diagram properties files are saved.
4. Click the **Open** button to add this radial diagram map as another layer in the basemap.

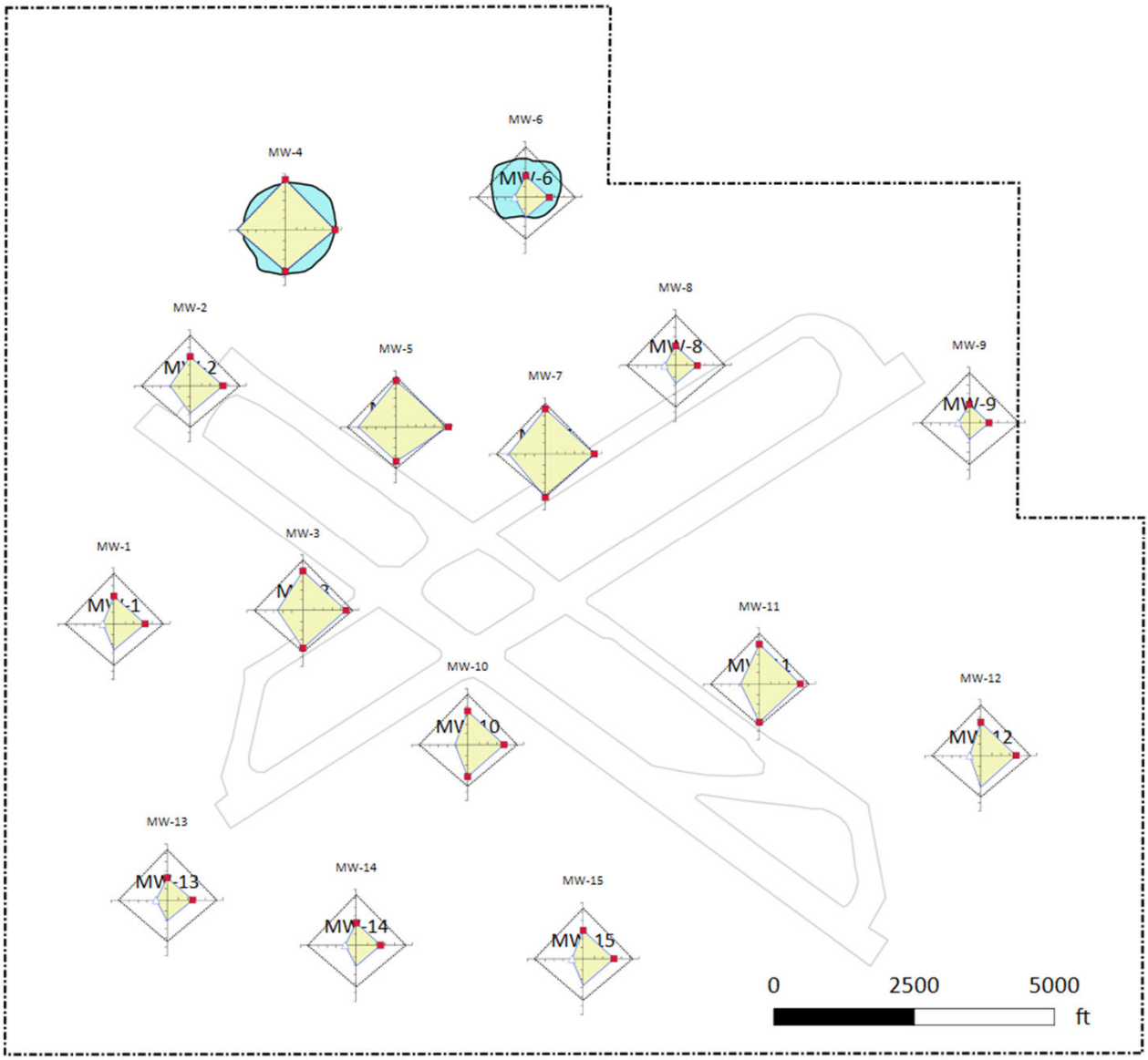


After adding the PFSAs radial diagrams, your Map Overlay window should look like the one on the right. The checkbox is used to show or hide a radial diagram overlay or layer.



You can add multiple radial diagram layers, and either show all at the same time or view one at a time. This allows you to prepare different types of radial diagrams for different well locations if that helps with a site evaluation.

Your radial diagram map should look like the one below after adding this layer to the basemap. You can see that there's a lot of space between radial diagrams, so we can increase the axis length to make the radial diagrams larger. This will help you to better visualize trends at and between wells.



Fortunately, it's a simple matter to edit the axis length without having to go back to the radial diagram properties window. There is an edit feature that allows you to change the axis length while in this basemap window. (All radial diagram axes have a uniform length which is based on map units like feet or meters.)

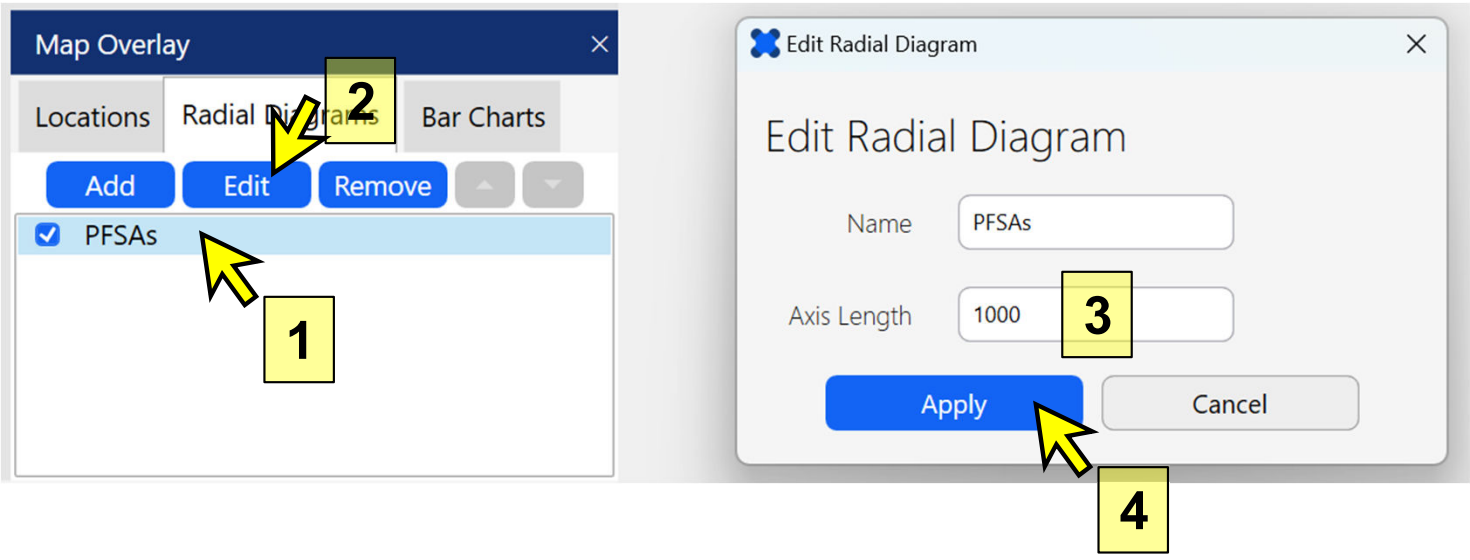
First, click on the line where the *PFSAs* layer is shown (see "1" below) in the **Map Overlay** section. Clicking on this row will cause the row to be highlighted in light blue, meaning you have selected this layer to be the current layer.

Now that a radial diagram layer has been selected, the **Edit** button will change to blue meaning that it is now enabled so you can make changes to the highlighted layer.

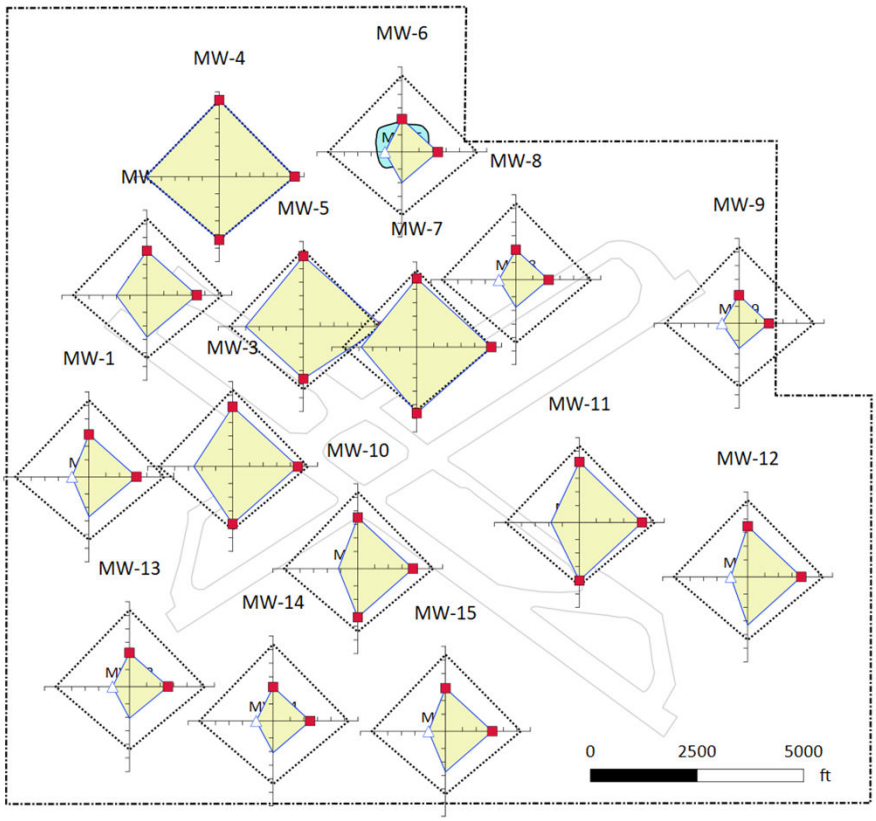
Click the edit button (see "2" below). An **Edit Radial Diagram** dialog box will pop-up. You have the option of changing the name of the layer that's shown. (The radial diagram layer name does not need to be the same as the radial diagram properties filename.)

You can also change the axis length. For this tutorial, change the Axis Length from 1000 to 2000 (see "3" below), and then click the Apply button to register this change (see "4" below).

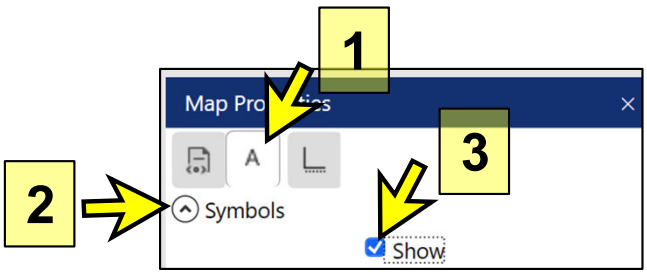
The radial diagram map will now be redrawn using this longer axis length of 2000 ft.



The radial diagrams are now easier to interpret because each diagram is twice the size of the original version (see image below). This makes it easier to count the number of tick marks (i.e., number of orders of magnitude) between the reference series and the monitoring event series at different well locations. This process allows you to identify order of magnitude changes between the source areas and downgradient wells along the flowpath, or cross-gradient from the main flow paths.



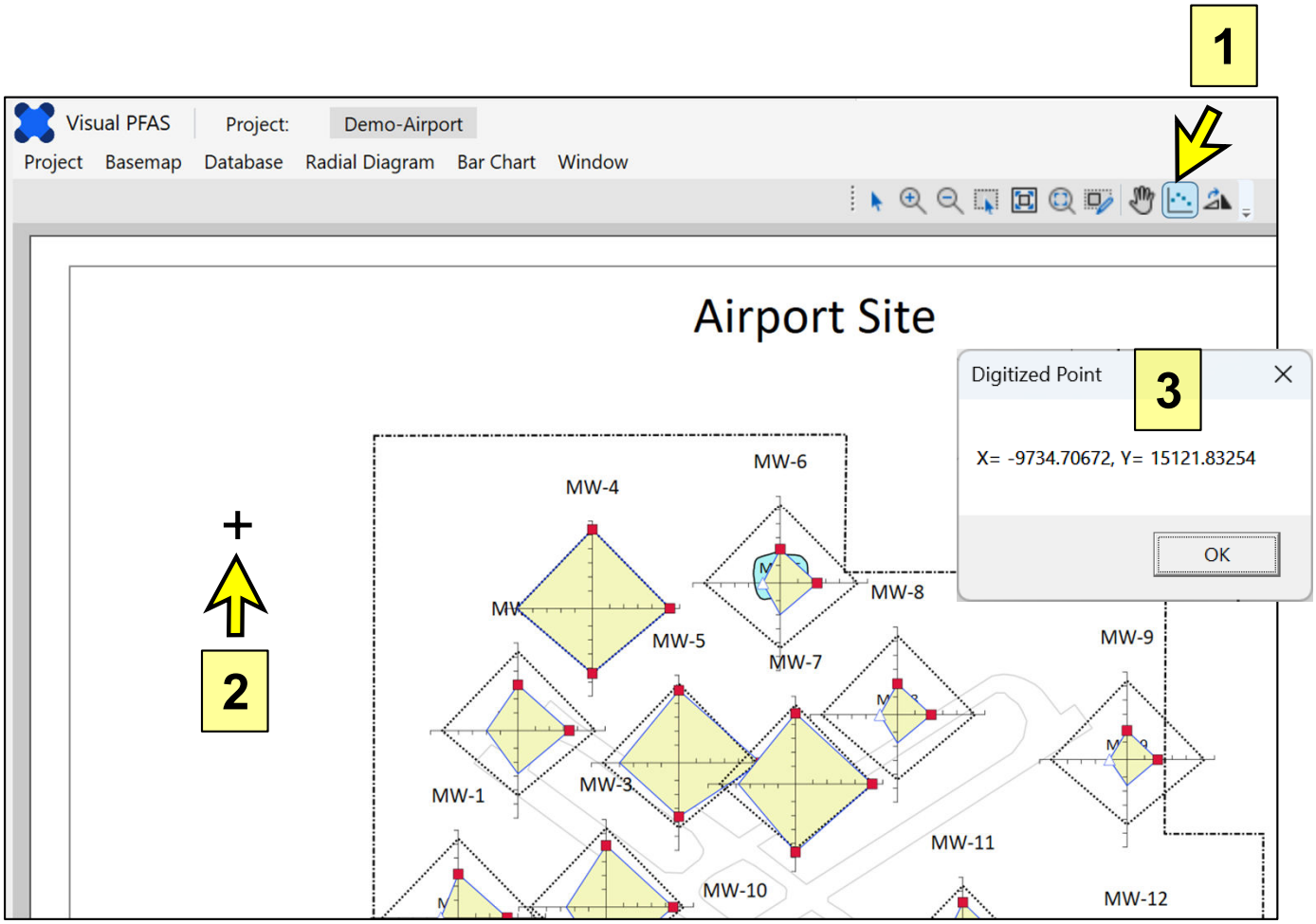
If you look closely at the image above, you'll see that the original basemap location symbols and labels are still shown as a layer below the radial diagrams. (see p. 4.26 for the basemap location symbols and labels.) Since we don't need this underlying locations layer when the radial diagrams are shown, you can turn off the location symbols in the Map Properties section (top-right of the basemap window) by following the steps shown in the image below.



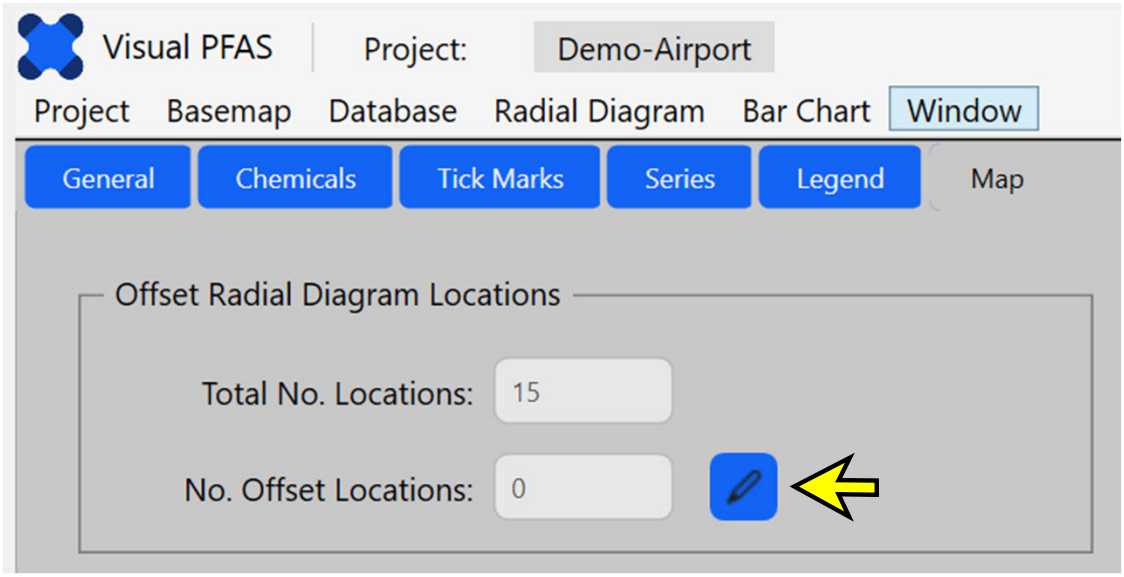
1. Click the A tab for location symbols.
2. Click the Symbols arrow to show related options.
3. Click the Show checkbox to toggle off symbols. This will hide the location symbols and labels.

Inspection of the radial diagram map on the previous page indicates that there is a small amount of overlap between radial diagrams for monitoring wells MW-5 and MW-7. To offset the MW-5 radial diagram to mitigate this overlap:

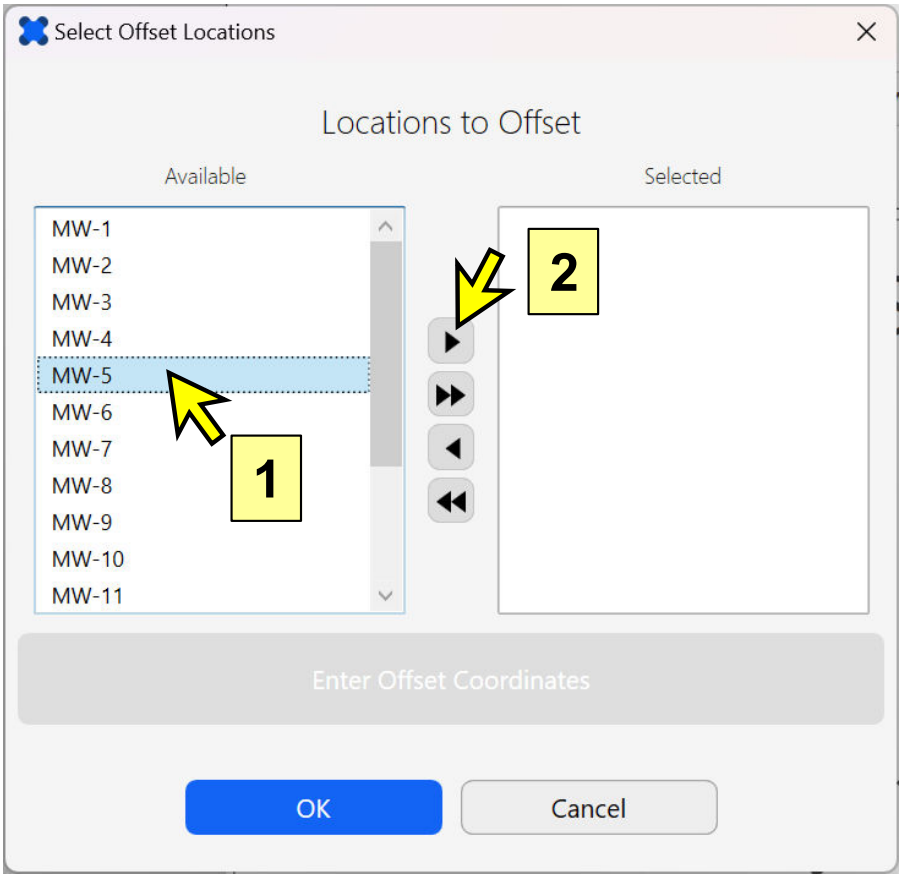
1. Click the **Digitize icon** in the top basemap menu bar (see "1" below). The cursor will change to a "+" symbol.
2. Move the cursor to the location shown northwest of MW-5 and click once to register the location – this will digitize the easting, northing (x,y) coordinates (see "2" below).
3. After clicking at the digitized location, the **Digitized Point** dialog box will pop-up to show the digitized coordinates for that point (see "3" below). Click the **OK** button which will save these coordinates to the clipboard.
4. To offset the MW-5 radial diagram from the original well location, select the **Window → Properties** menu to return to the radial diagram properties, and click the **Map** tab in the radial diagram properties window.



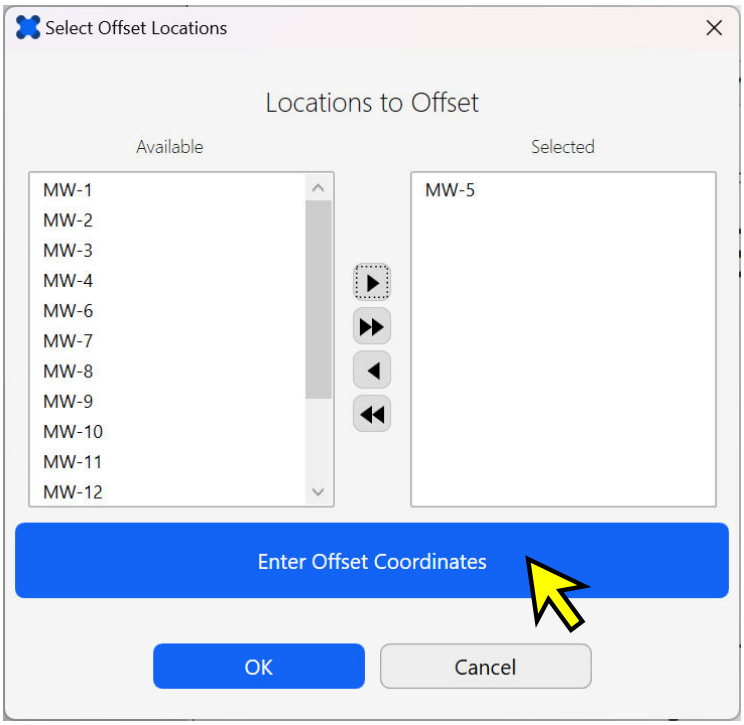
To specify which well(s) should have offset radial diagrams, click on the **Edit** icon shown for **No. Offset Locations** (see arrow below). This will open-up the **Select Offset Locations** dialog box shown at the bottom of the page.



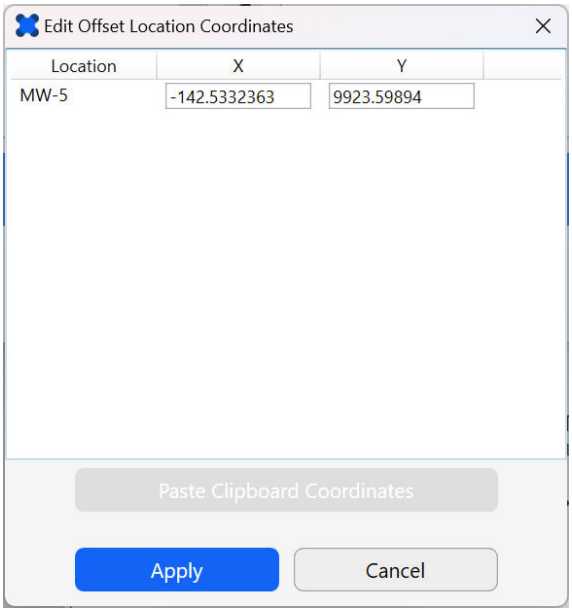
Click on MW-5 in the Available list so that it is highlighted in blue (see "1" below). Then click on the single right-arrow (see "2" below) to move this well from the Available to the Selected List.



Once MW-5 has been moved to the Selected list, the **Enter Offset Coordinates** button will change to blue meaning that it is now enabled because at least one offset location has been selected. Click the **Enter Offset Coordinates** button to open-up the dialog box where offset coordinates can be pasted or entered manually.



The Edit Offset Location Coordinates dialog box will pop-up (see image below) with at least one (or multiple) locations to have offset radial diagrams (see image below).

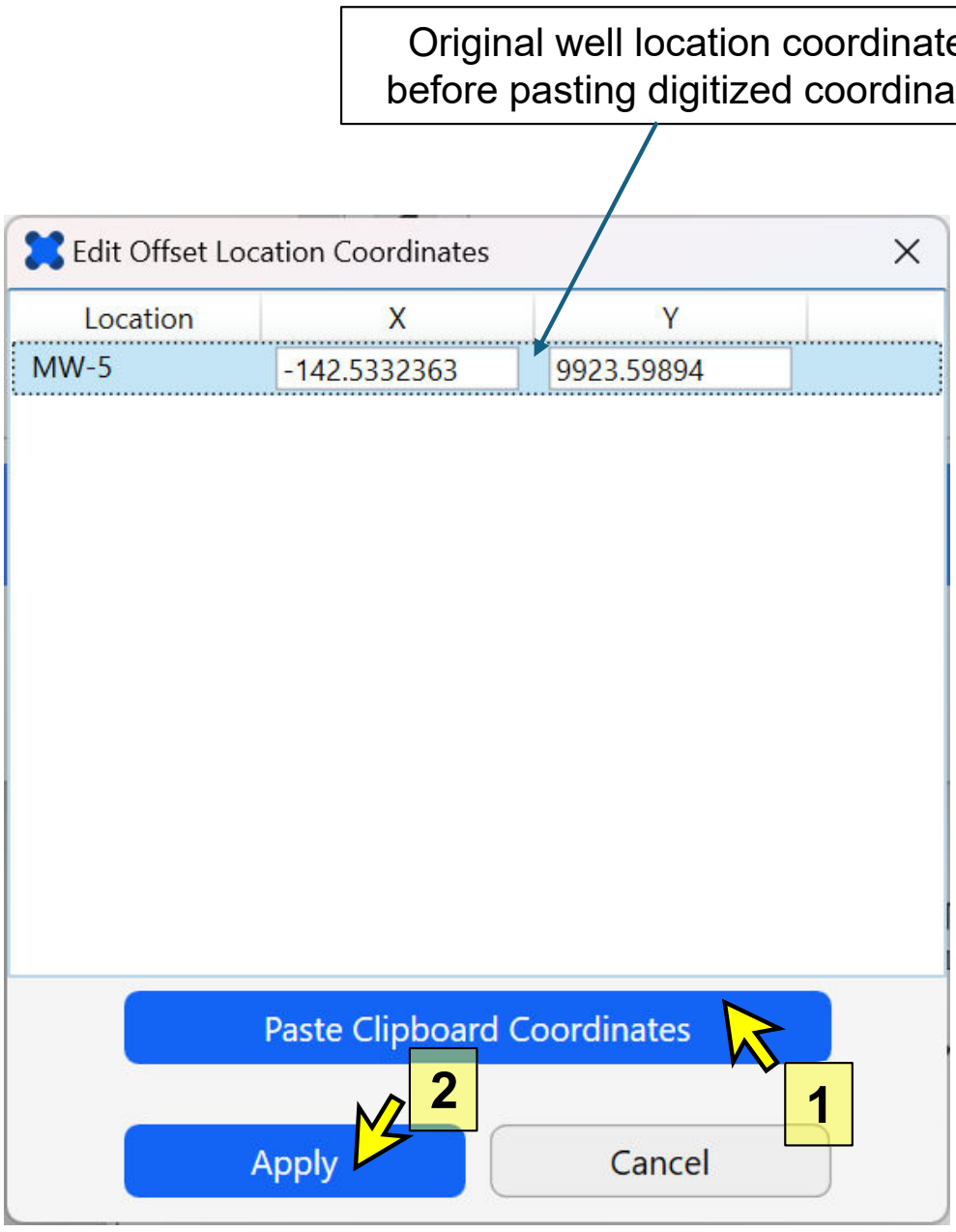


Click on the row in the table with the MW-5 location so that this row becomes highlighted in blue. Now that a row has been highlighted, the **Paste Clipboard Coordinates** button will change to blue meaning that it is now enabled.

The image below shows the original well location coordinates for MW-5 (x=-142.5 ft and y=9923.6 ft). After pressing the **Paste Clipboard Coordinates** button (see "1" below), the x and y coordinates will automatically be changed to the digitized point coordinates from the basemap. (Our digitized point coordinates are shown in the image on page 4.30 – see "3" label in this image.)

After the coordinates have been pasted, click the Apply button to register this new offset location for the MW-5 radial diagram (see "2" below).

The click the OK button on the Select Offset Locations window to save your changes.

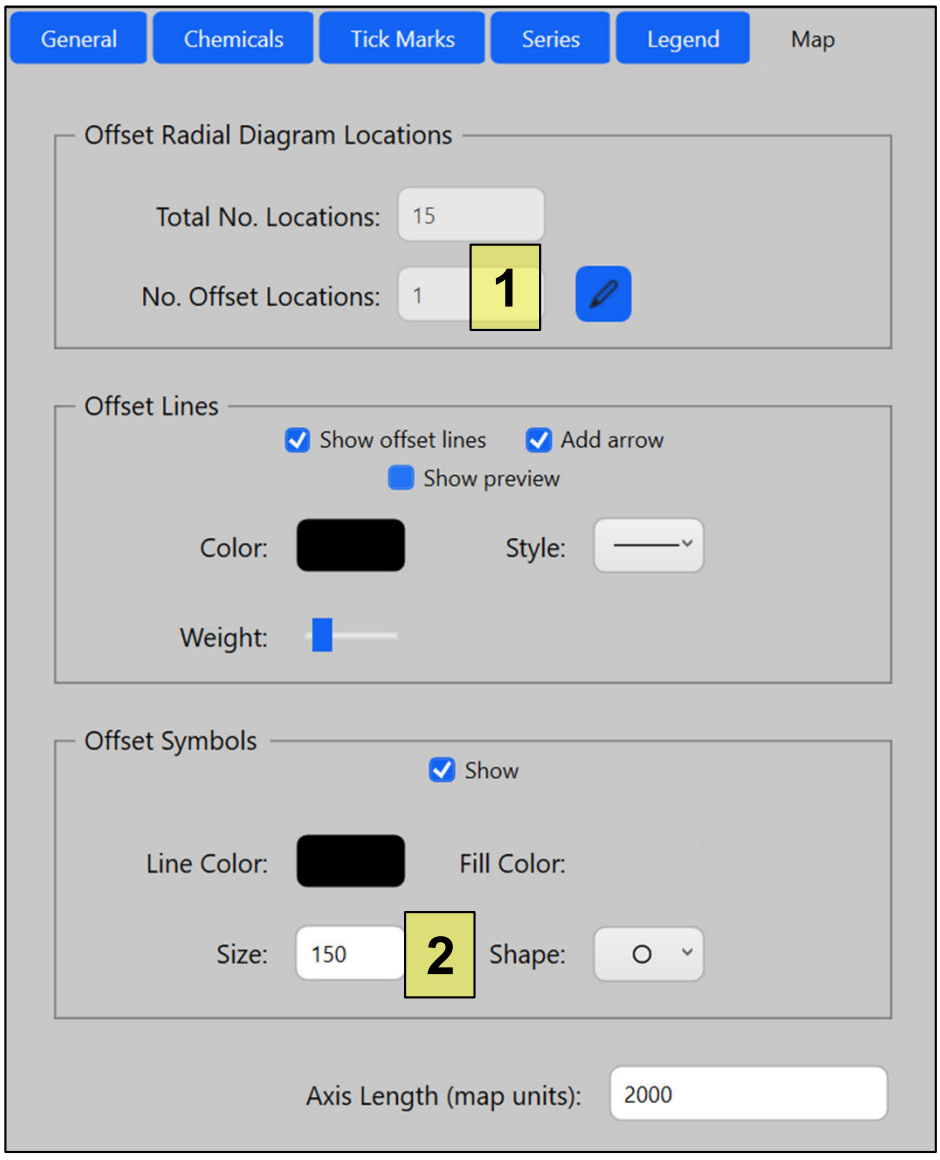


Note: An alternative to using the copy-paste method for entering offset location coordinates, is to simply write down the x,y coordinates after digitizing, and then to enter these coordinates manually using the dialog box shown to the left.

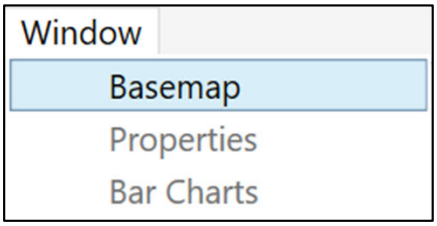
After closing the **Select Offset Locations** window, the **No. Offset Locations** will change to 1 to reflect the new offset saved for monitoring well MW-5 (see "1" below).

An optional offset symbol will be shown at the original MW-5 location (i.e., the location before the offset), and an optional line or arrow will be shown between the offset radial diagram and this original location. The respective checkboxes can turn these on/off.

The default symbol size is 10 map units, which will be too small to see for the basemap in this example tutorial. Change the symbol size to 150 map units (i.e., ft) as shown in "2" below.

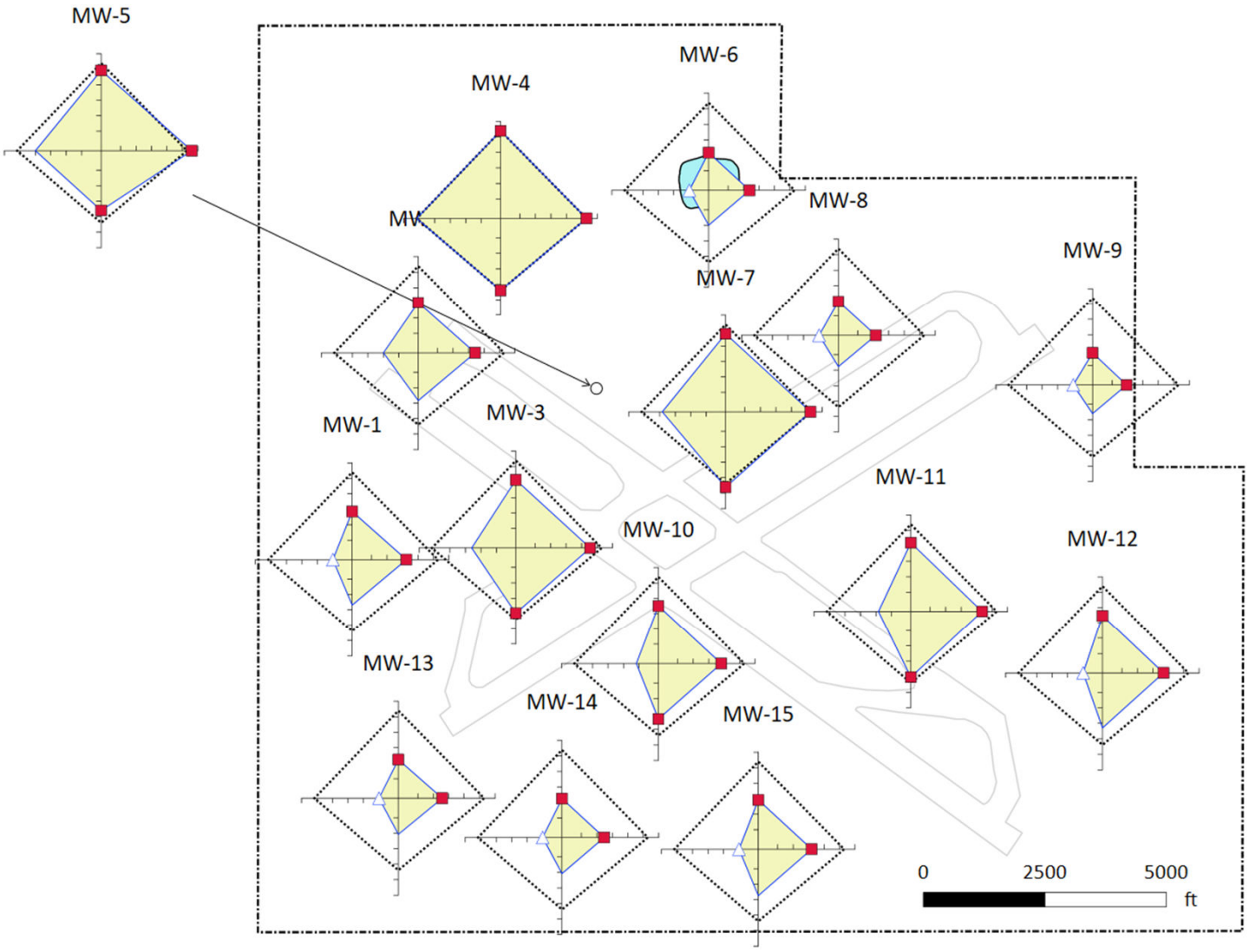


Then using the **Window** option in the top menu bar, select **Basemap** to return to the basemap to view the updated radial diagram map.



The updated radial diagram map, with the MW-5 offset radial diagram, is shown below. You can easily re-digitize the MW-5 location if you want to move it to a different location and then re-paste the digitized offset coordinates using the same steps discussed previously.

> **Note:** The offset line arrowhead size is proportional to the offset symbol size.

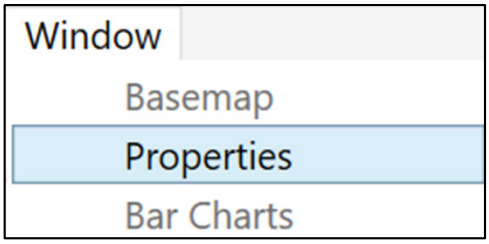


Let's make one more change to illustrate another option for visualizing these radial diagrams as a layer on the site basemap.

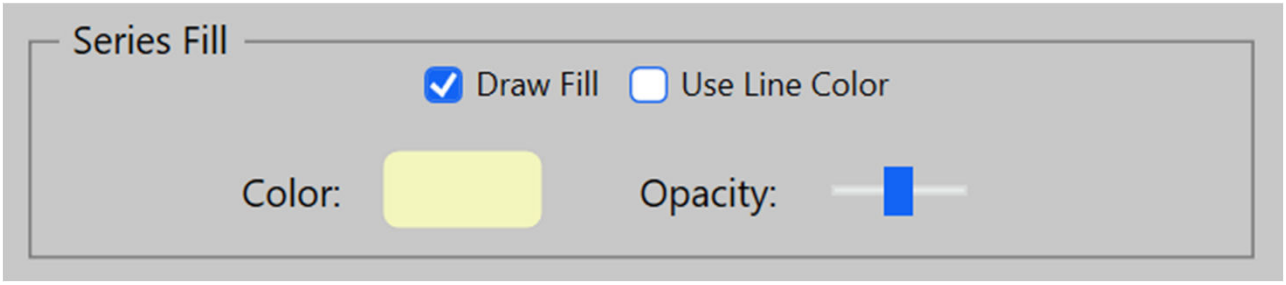
Using a solid color (i.e., 100% opacity or 0% transparency), the radial diagram for monitoring well MW-4 overlies the Source A basemap layer which isn't visible. And Source B is just shown around the edges of the filled monitoring even series for MW-6.

The next step will be to assign a 50% opacity/transparency to the event series fill so that underlying basemap ayers can be seen.

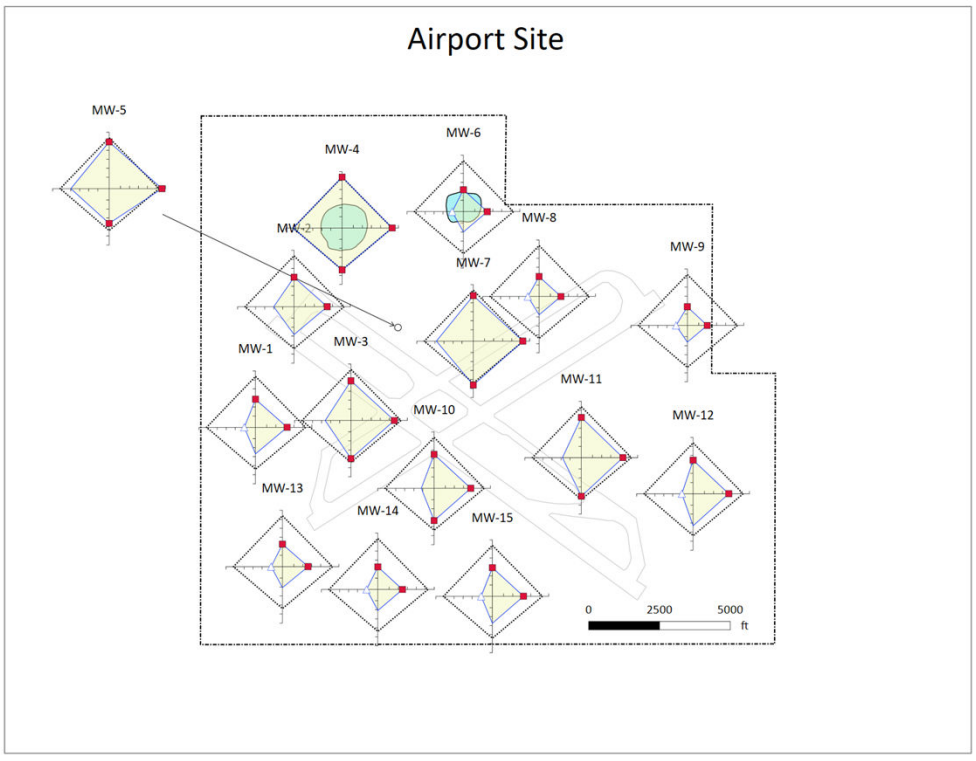
Using the **Window** option in the top menu bar, select **Properties** to return to the radial diagram properties, and click on the **Series** tab.



Make sure that the *2023-02-15* monitoring event series is selected as the current series in the top dropdown list. Then change the **Opacity** for the series fill to be at about a 50% level as shown in the image below. This will increase the transparency of the series fill, so that basemap layers under the radial diagram layer can be seen.



Then use the **Window → Basemap** option to return to the basemap window and the updated radial diagrams (see below). You can now see the full outlines for Sources A and B below the radial diagrams for monitoring wells MW-4 and MW-6, respectively.



Note: Using exceedance symbols allows you to clearly identify where PFAS of Concern are exceeding cleanup criteria across a site.

This tutorial demonstrates that it is a relatively simple process to create a radial diagram map. Some iteration will probably be needed to update properties like series line and fill colors, symbol properties, location labels, opacity, and basemap layer properties.

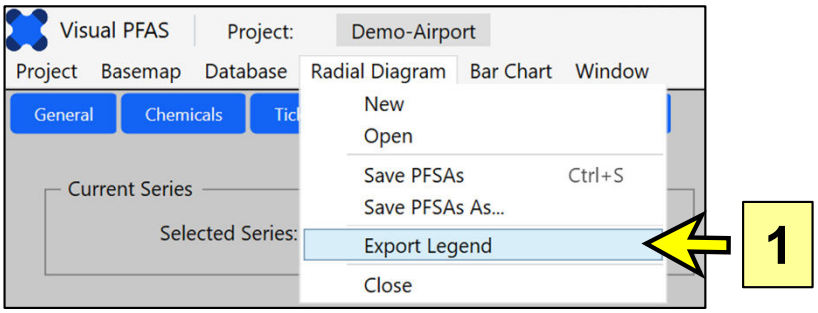
4.9 Exporting Radial Diagram Legends and Maps

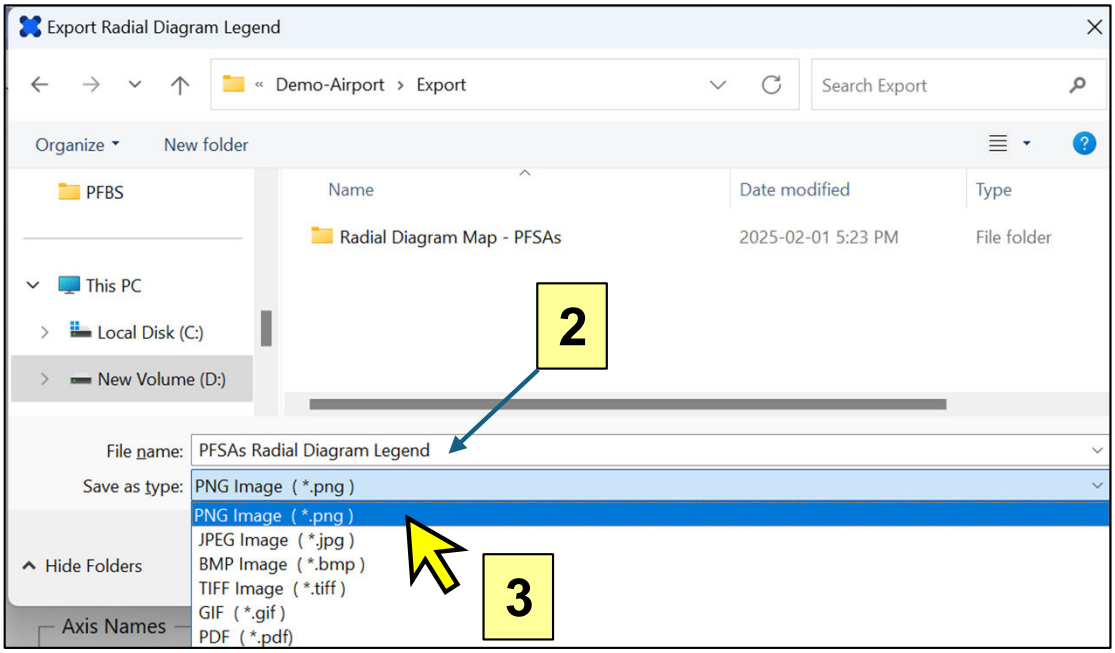
Once the radial diagram map has been completed, the final product may be exported in several types of formats:

1. The radial diagram legend may be exported as a pdf file, or as one of five possible image files: png, jpeg, bmp, tiff, or gif format.
2. A radial diagram map may also be exported as a pdf file or the same five types of image files. Alternatively, a radial diagram map including symbols may be exported in native format so that these files may be opened in GIS or CAD (dxf format), or Surfer (bln format). Exceedance, non-detect, offset symbols are saved as x,y text (dat) files which may be posted in GIS, CAD, or Surfer.

This allows you to create final report figures or presentations using Visual PFAS™ figures directly, or to quickly re-create these figures in GIS, CAD, or Surfer using the exported polyline, polygon, and symbol posting files. This allows you to easily iterate through different figure versions using Visual PFAS™, and then to use more sophisticated software for making final report figures in your company template.

To export the radial diagram legend as a pdf or image format, go to the radial diagram **Properties** window and select the **Export Legend** menu option (see "1") as shown below. Then, then identify the folder, filename (see "2"), and file type for the export (see "3" below).

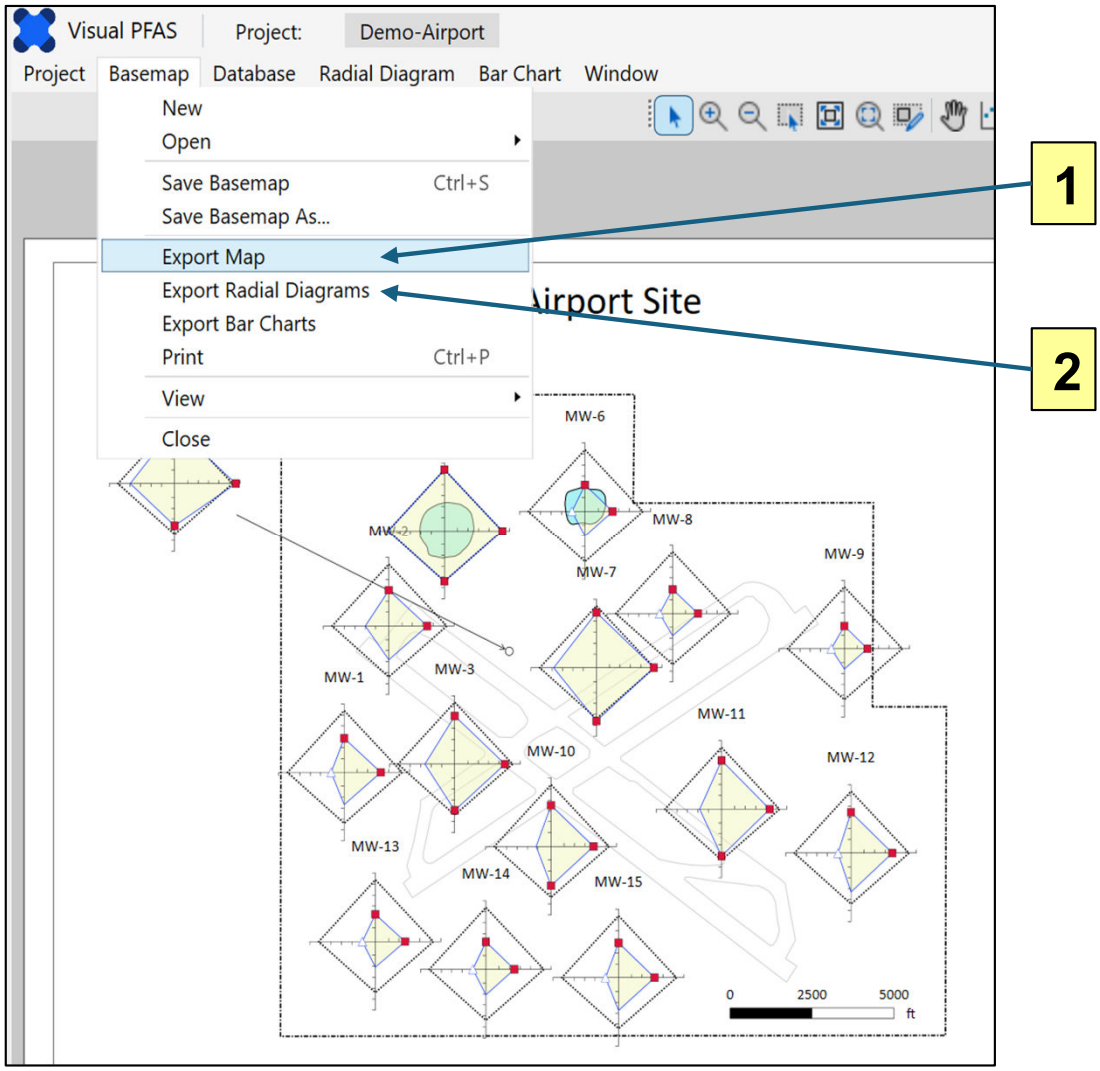




There are two options for exporting the basemap: i) as a pdf or image file that includes both the underlying basemap and the radial diagrams; or ii) as separate polyline/polygon (dxf or bln) files, and symbol x,y coordinate (dat) files so that these figures can be re-created in software typically used to make final report figures (e.g., GIS, CAD, or Surfer).

To export the combined basemap and radial diagrams as a pdf or image file, select the **Export Map** option under the **Basemap** menu (see "1" below). The five image file type options are the same as those shown for the radial diagram legend on the previous page. Exporting the map as a pdf or image file will present the radial diagram map (including all basemap layers, the basemap title, and scale bar or axes) as the map is shown on the page in the basemap window. Image files can be loaded directly into reports, or additional customization can be done using PowerPoint to create final images for inserting into a report or presentation.

Alternatively, you may export the radial diagram layer as separate files for polylines, polygons and symbols (bln/dxf for lines and polygons, and dat for symbol coordinates) which can then be imported into GIS, CAD, or Surfer for further processing as final figures. In this case, select the **Export Radial Diagrams** option in the **Basemap** menu (see "2" below).

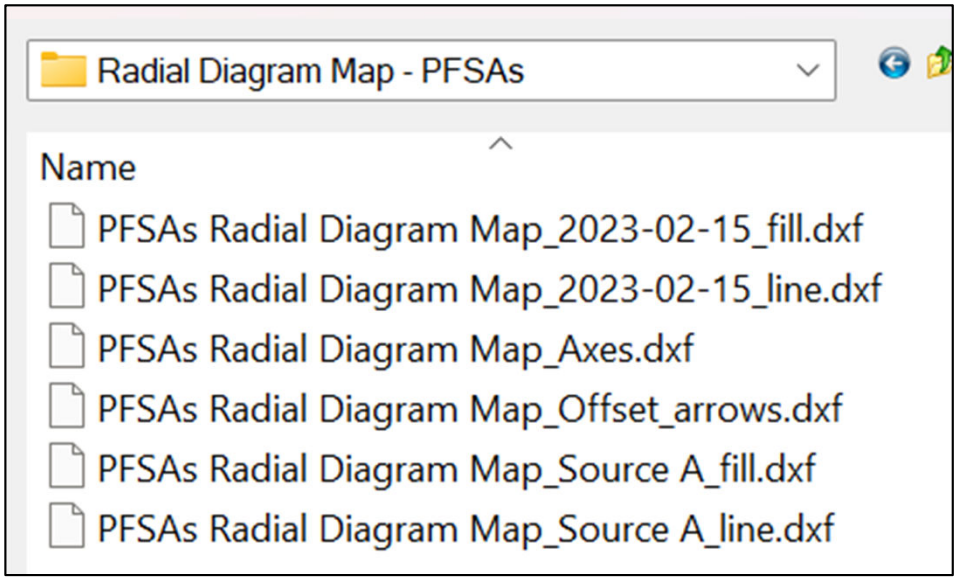


When exporting only the radial diagram layer (i.e., without the underlying basemap layers), separate files are created for: a) axis lines with tick marks; b) series lines and polygons (one set of files for each series); c) offset arrow lines that point from the offset radial diagram(s) to the original location; d) exceedance symbol coordinates; e) non-detect symbol coordinates; and offset symbol coordinates at the original location(s).

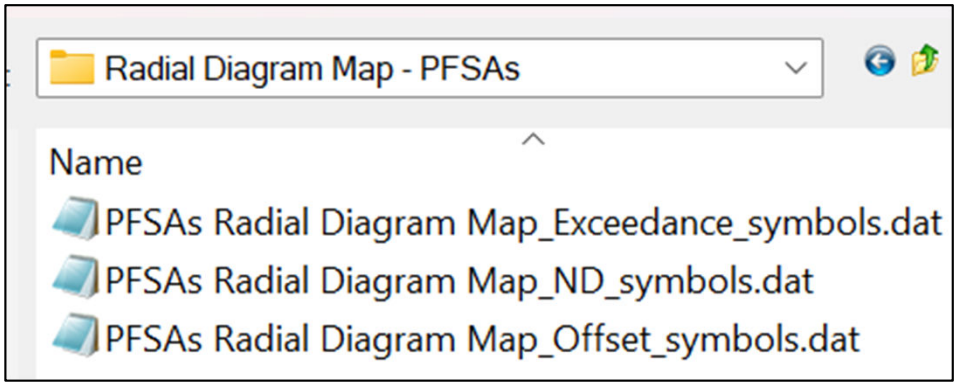
Each of these polyline/polygon (dxf or bln) and symbol dat files can then be imported into GIS, CAD, or Surfer as separate layers. Each polyline/polygon layer may be assigned distinct properties for line color, weight, and fill. The symbols may be posted at the assigned coordinates using symbol properties such as shapes, sizes, and colors that are assigned or changed in the software that is being used to process the final report figures.

Examples of polyline/polygon and symbol files created for the PFSAs radial diagram layer that was prepared as part of this tutorial are shown below. Users have the option of selecting either dxf or bln format for the polyline/polygon files.

Examples of two radial diagram figures from the Carey et al. (2025) journal paper, which documents a case study for a South Dakota Air Force Base, are shown on the next few pages. These examples demonstrate how legends may be added to radial diagram maps and how custom labels can be added using common third party graphics software.

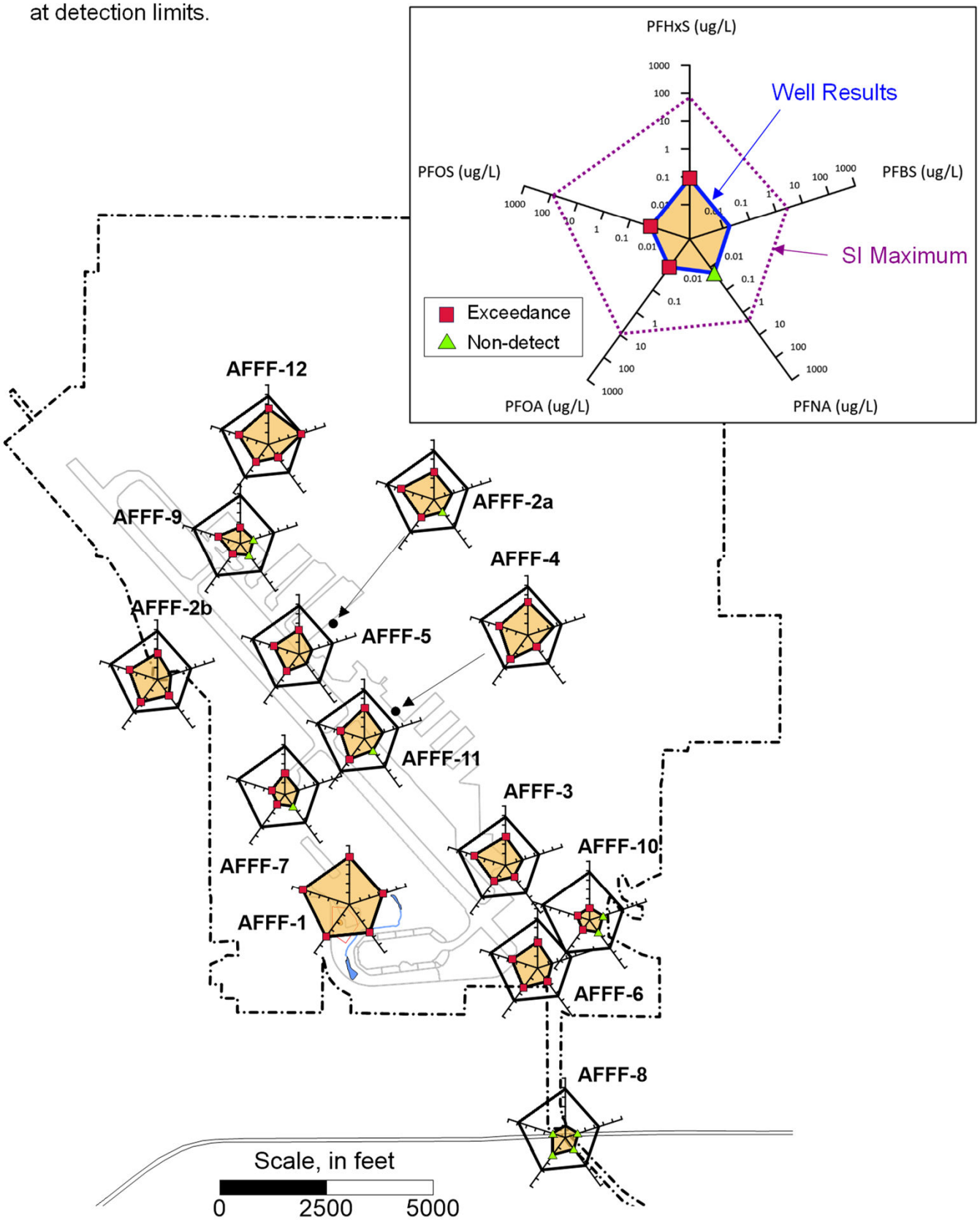


Radial diagram polyline / polygon layer files

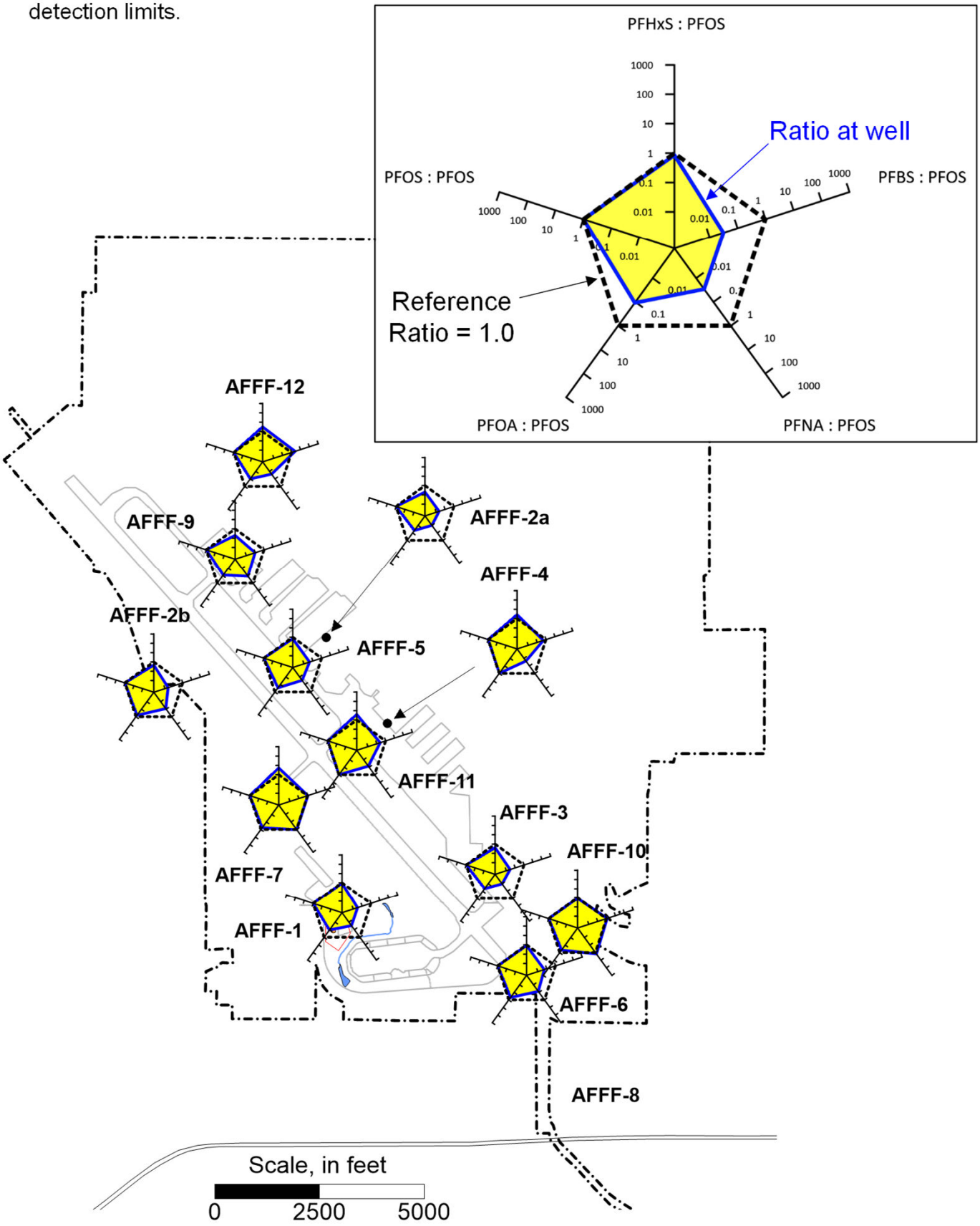


Radial diagram symbol coordinate files

Carey et al. (2025) Figure 2. PFAS of Concern (POCs) radial diagrams at AFFF source areas with PFSAs in the upper portion (PFOS, PFHxS, and PFBS) and PFCAs in the lower portion (PFNA and PFOA). Exceedance symbols are based on EPA maximum contaminant levels (MCLs), or EPA health-based water concentrations for PFBS. Non-detects are plotted at detection limits.



Carey et al. (2025) Figure 3 . PFAS of Concern (POC) radial diagrams at AFFF source areas with ratios to PFOS. PFSAs are in the upper portion (PFOS, PFHxS, and PFBS) and PFCAs are in the lower portion (PFNA and PFOA). Non-detect POC ratios are based on detection limits.



References

Carey, G.R., R. Krebs, G.T. Carey, M. Rebeiro-Tunstall, J. Duncan, G.N. Carey, and K. Rooney, 2024, Visualizing PFAS Trends at a South Dakota AFFF-Impacted Site, in submittal to Remediation Journal.

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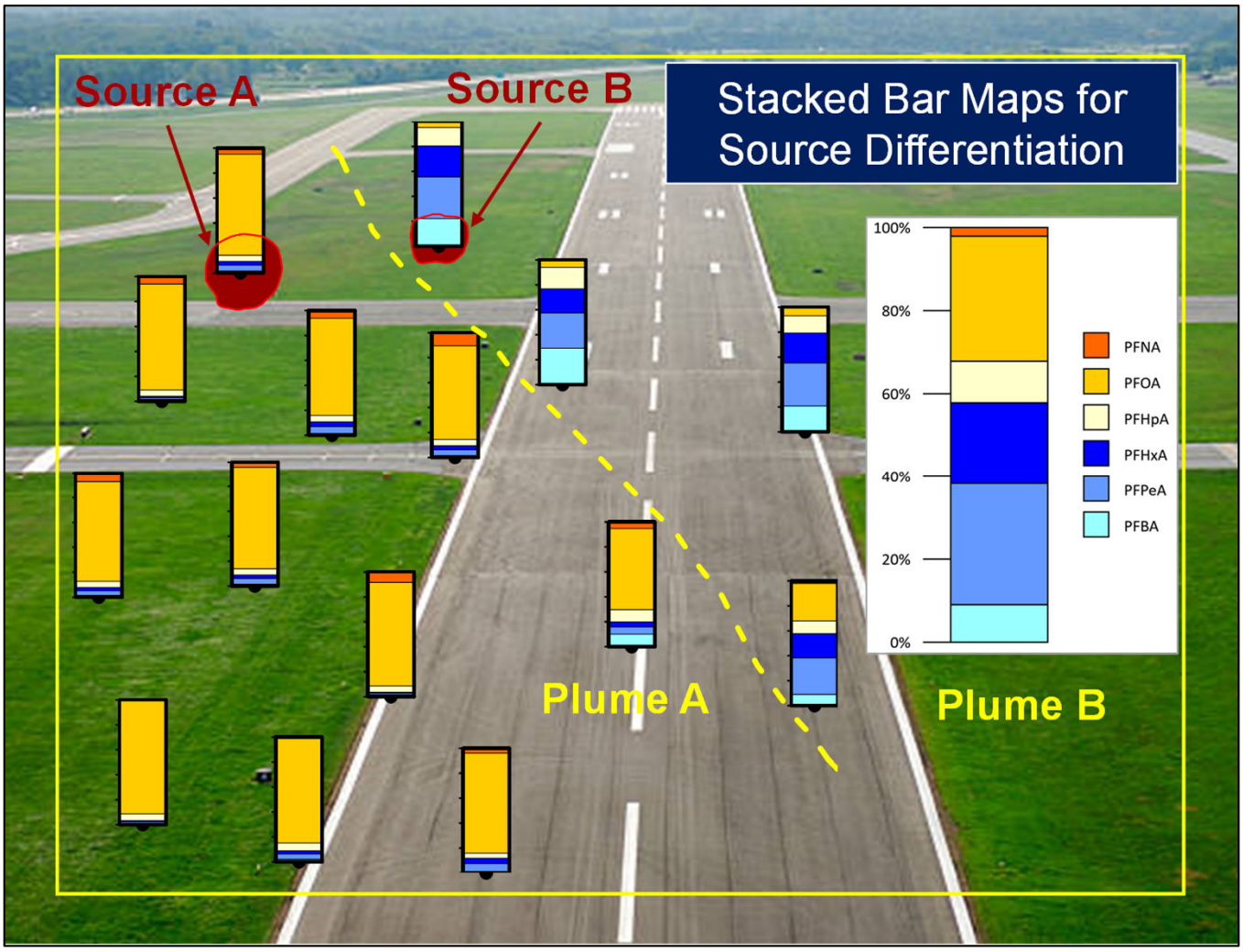
Visual PFAS™
Users Guide:

Stacked Bar Maps

Chapter 5



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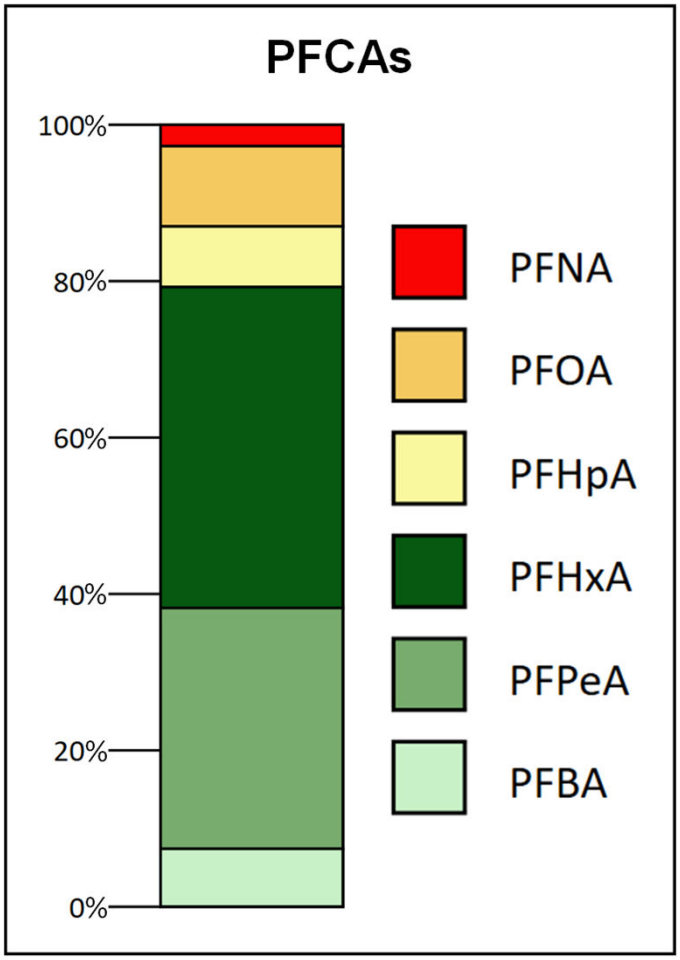
January 20, 2025

5.1 Introduction

Creating stacked bar charts in Microsoft Excel is a typical approach for evaluating PFAS trends. Visual PFAS™ takes this one step further by facilitating the plotting of stacked bar charts as overlays on a site map. Bar charts are placed at monitoring locations where groundwater, porewater, soil, or sediment samples were collected. This provides a powerful tool for users to conduct a more comprehensive spatial analysis of stacked bar trends across a site, or as a comparison of data extending over multiple sites.

An example of a simple stacked bar legend showing relative concentrations of short-chain and long-chain perfluorinated carboxylates (i.e., PFCAs) is shown below. Chemicals in the stacked bar include (in order of shortest to longest chain length): PFBA, PFPeA, PFHxA, PFHpA, PFOA, and PFNA. The stacked bar represents the proportion i.e., percent (X_i) of each chemical concentration relative to the total concentration of represented chemicals at a monitoring well location. In this manner, the stacked bar will always have a range of 0 to 100%.

Stacked bars are calculated using analytical results from a sample collected at a monitoring location during a single monitoring event. The equations used to construct this stacked bar are shown below.



The individual proportion of chemical *i* in the stacked bar is calculating using:

$$p_i = \frac{C_i}{\sum_{k=1}^{n} C_k}$$

where:

i and k = are chemical indices in order from the bottom to the top in the bar
p_i = proportion of chemical *i* relative to total
C_i = concentration of chemical *i*
n = number of chemicals in stacked bar

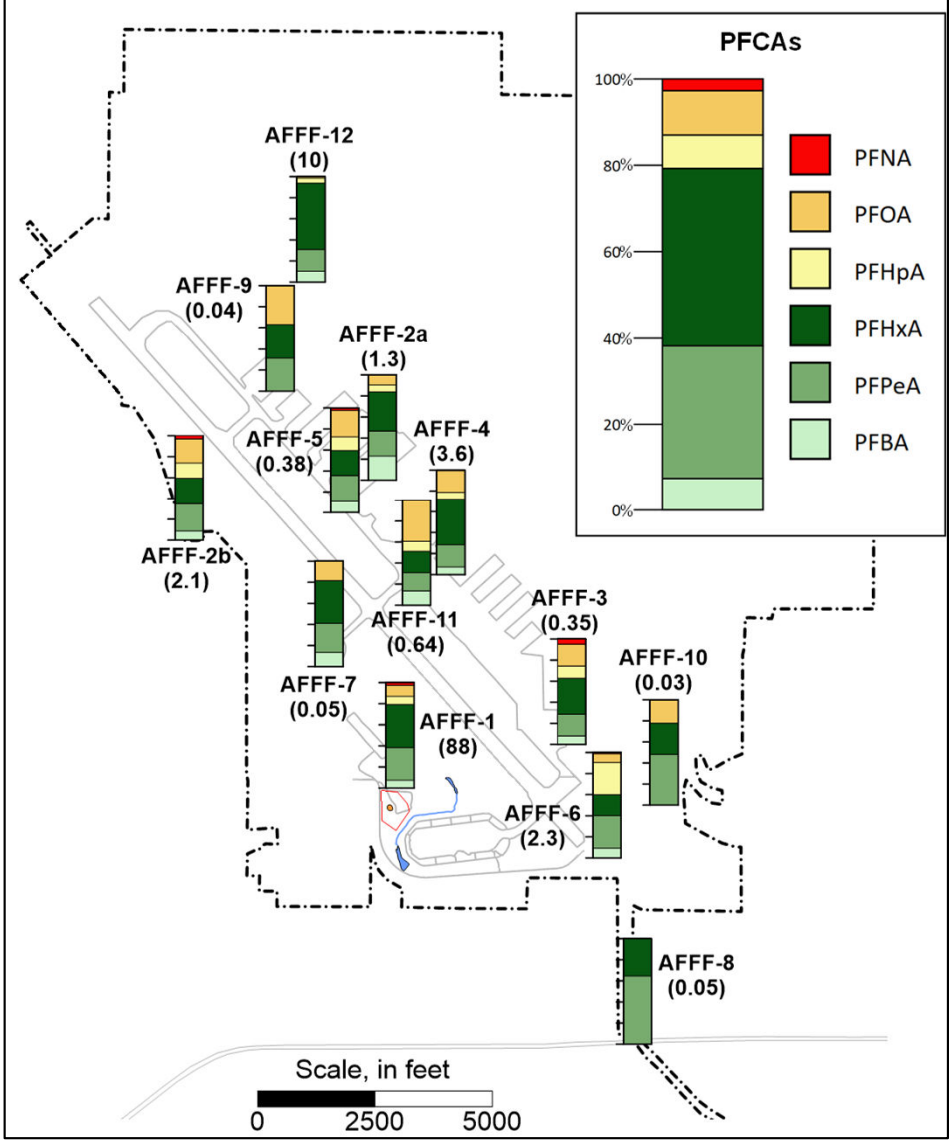
The cumulative proportion or percent (*Xi*) for *i* = 2 through *n* is determined using:

$$X_i = \sum_{j=1}^{i-1} p_j + \frac{C_i}{\sum_{k=1}^{n} C_k}$$

In Visual PFAS™, stacked bar legends are first created by the user with a specified sequence of chemicals such as the PFCAs example shown on the previous page. Then the stacked bars at each monitoring location are overlaid on the site basemap (see Chapter 2 for instructions on how to create a site basemap). The tutorial shown in the following sections provides a hands-on example using the **Demo-Airport** project for creating a stacked bar map.

Carey et al. (2025) present a case study that includes the use of stacked bar maps for visualizing PFAS trends between AFFF source areas at a South Dakota Air Force Base. The figure below shows an example from this case study where a PFCAs stacked bar map was used to differentiate between the use of legacy and modern AFFF products across various AFFF source areas at the base. (Send an email to gcarey@porewater.com to request a copy of this paper.)

Figure 4. Stacked bar map representing PFCAs at AFFF source areas. Shaded bar intervals represent the proportion of PFBA, PFPeA, PFHxA, PFHpA, PFOA, and PFNA to the sum of these six PFCAs. Values in brackets below each source area label represent the sum of these PFCAs in units of ug/L.

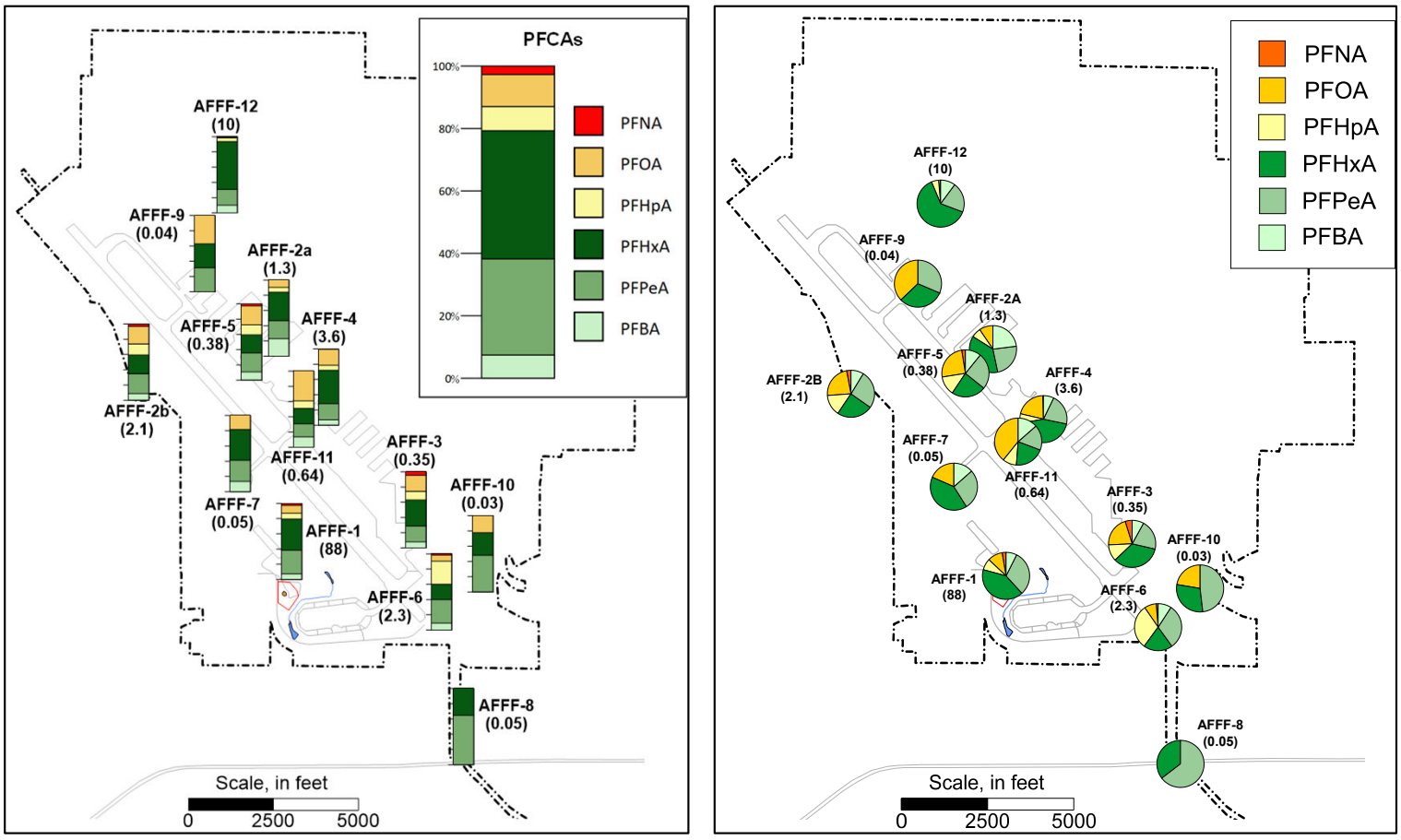


Note: Visual PFAS™ provides the option to show tick marks on stacked bars at each monitoring location. This facilitates estimation of the relative proportion of each chemical at each location.

Carey et al. (2025) conducted a side-by-side comparison of stacked bar and pie chart maps (see figures below), and noted the following three advantages associated with the use of stacked bars to represent proportional PFAS distributions:

1. It is easier to estimate the relative proportion of individual chemicals with stacked bars at each monitoring location, particularly when tick marks are shown to the left of the stacked bars. (There are no corresponding tick marks available to help with estimating the proportion of each species in pie charts.)
2. The stacked bars better convey the linear progression in chain length from C4 to C9 (i.e. from bottom-up in each stacked bar). The pies also show a progression in chain length in a clockwise direction, although the relative change in chain length concentrations is less evident in pie charts when compared to the stacked bar representation.
3. The stacked bars are also more effective for visualizing relative similarities and differences in PFAS concentrations between well locations.

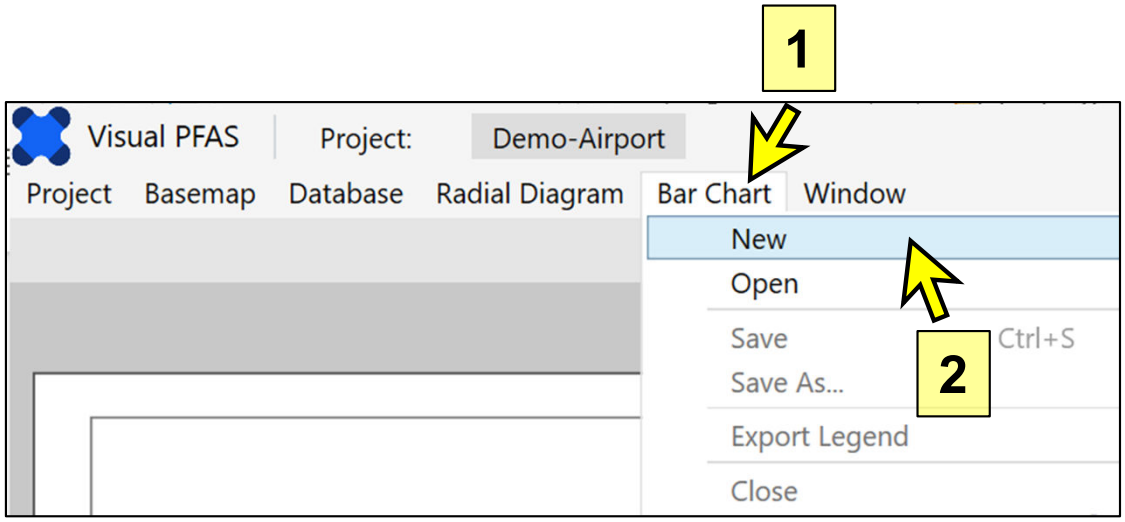
Comparison of Stacked Bar and Pie Maps



5.2 Creating a New Stacked Bar Map

To start the process of creating a new stacked bar map:

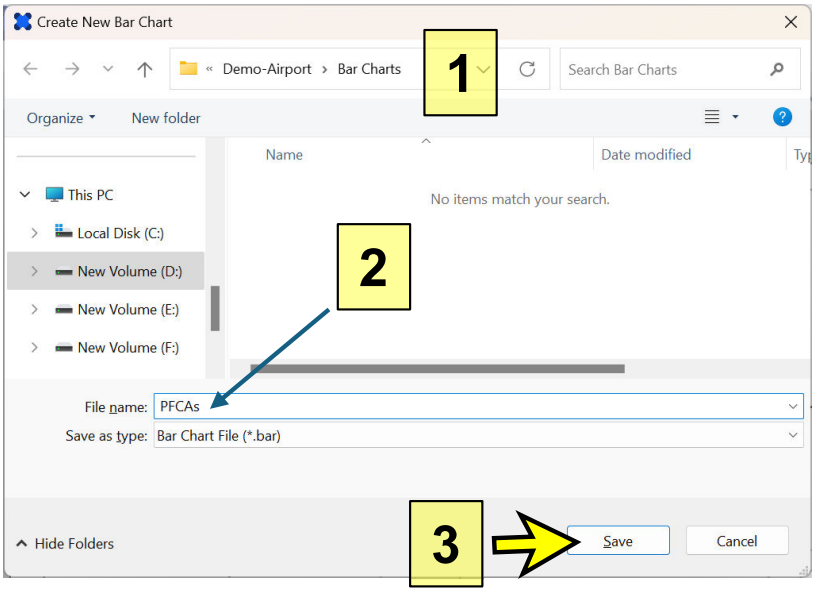
1. Click on **Bar Chart** in the main menu bar (see "1" below); and
2. Click on **New** to create a stacked bar properties file (see "2" below).



Visual PFAS™ will use the **Bar Charts** sub-folder under the **Demo-Airport** project folder as the default location for stacked bar property files (*.bar extension). (see "1" below)

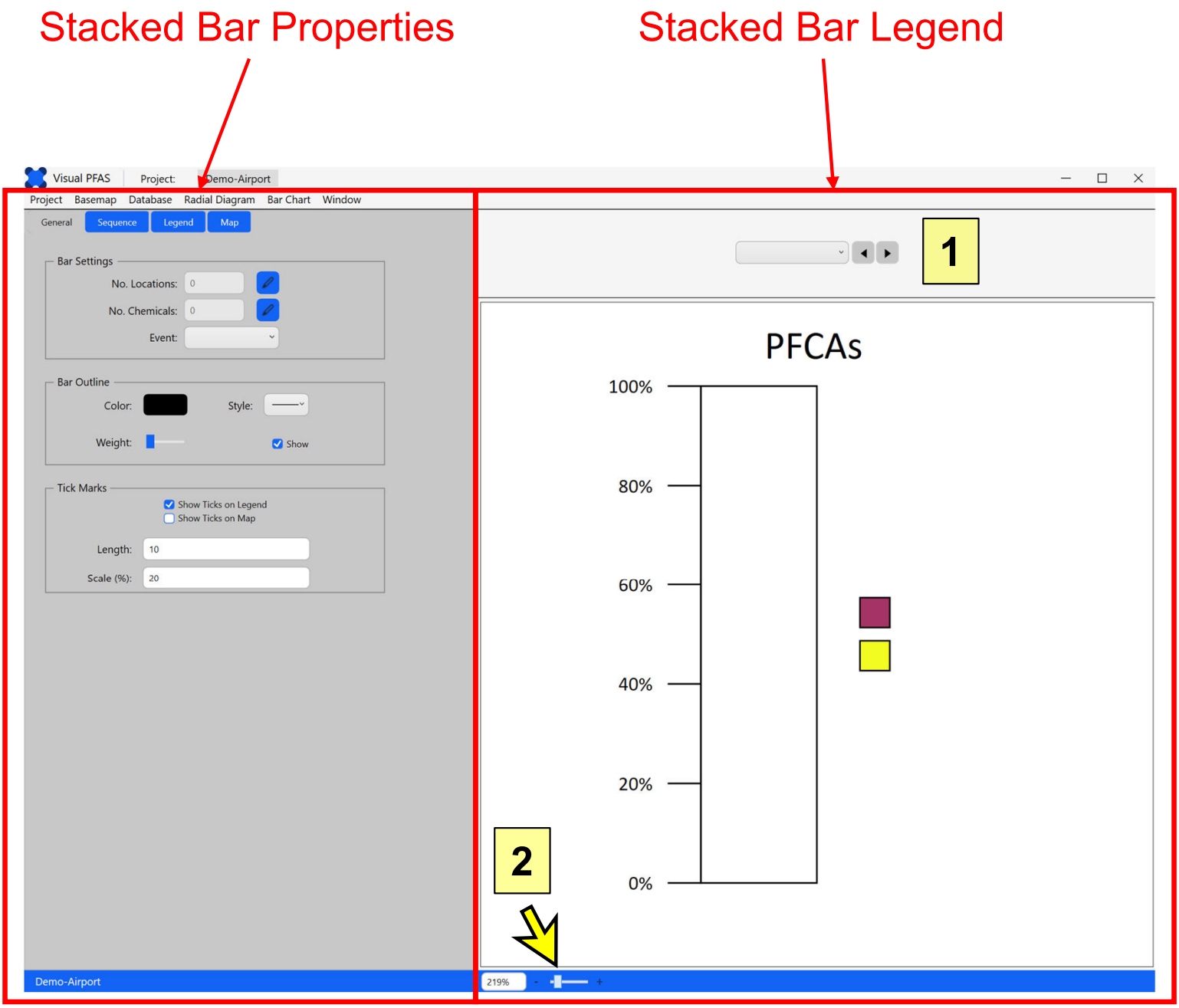
Enter the new stacked bar property filename: *PFCAs* (see "2" below). Then Click the **Save** button to create this new property file.

> **Note:** Users should not attempt to open these *.bar files outside of Visual PFAS™ as it may result in file corruption.



Upon creating a new property file, the stacked bar window below will appear as shown below with two components: Stacked Bar Properties on the left, and the Stacked Bar Legend on the right. There are no colors shown in the legend yet because we have not yet entered the list of chemicals, monitoring locations, and the monitoring event to use for the stacked bar as part of this tutorial. When selected, users can cycle through monitoring locations to view changes in the stacked bars between locations (see "1" below).

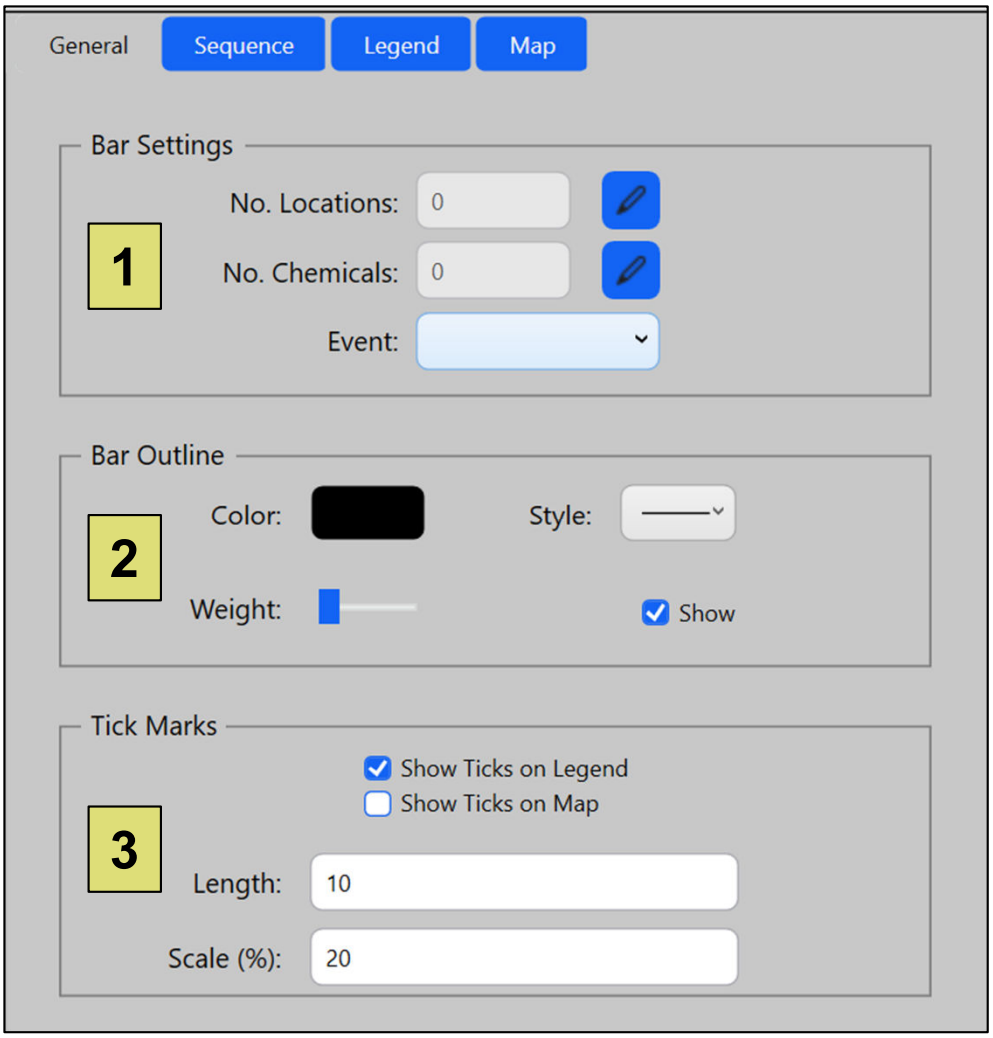
The stacked bar in the legend will initially appear as small on the screen to allow for small display screens. You can increase the size of the stacked bar by scrolling the size bar at the bottom of the legend (see "2" below).



5.3 General Properties

General properties for stacked bar maps are listed below, where the number coincides with the labels shown on the image below representing initial default settings for stacked bar maps.

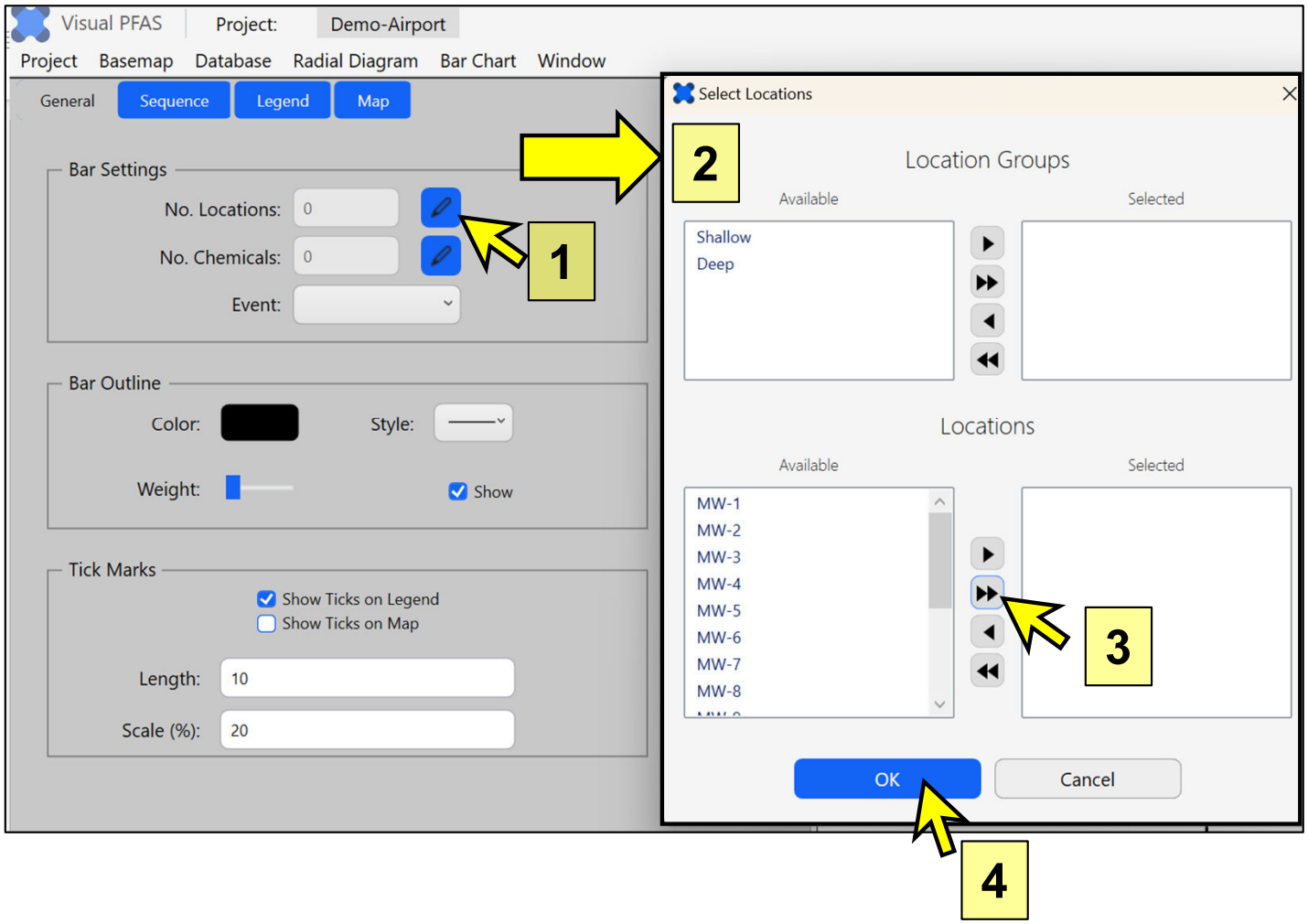
1. **Bar Settings** – including specification of:
    - Monitoring well or soil boring locations at which stacked bars will be shown on the basemap;
    - Chemicals to represent in the stacked bar; and
    - The monitoring event to be used for determining chemical concentrations in the project database.
2. **Bar Outline** properties (e.g., line color, style, weight, and show/hide); and
3. **Bar Tick Mark** properties (e.g., show/hide in legend; show/hide on map; length in map units; and tick mark scale i.e., intervals).



5.3.1 Selecting Monitoring Locations

To select all site monitoring wells for this tutorial:

1. Click the **Edit** icon next to No. Locations (see "1" below).
2. The **Select Locations** window will pop-up (see "2" below). This is where you select which well locations will have stacked bars shown on the basemap. (See pages 4.13 to 4.15 in Chapter 4 with more information on how to select locations and use location groups in this window.)
3. Click the ⏩ button to move all monitoring well locations from the **Available** list to the **Selected** list (see "3" below).
4. Click OK to close the Select Locations window (see "4" below).



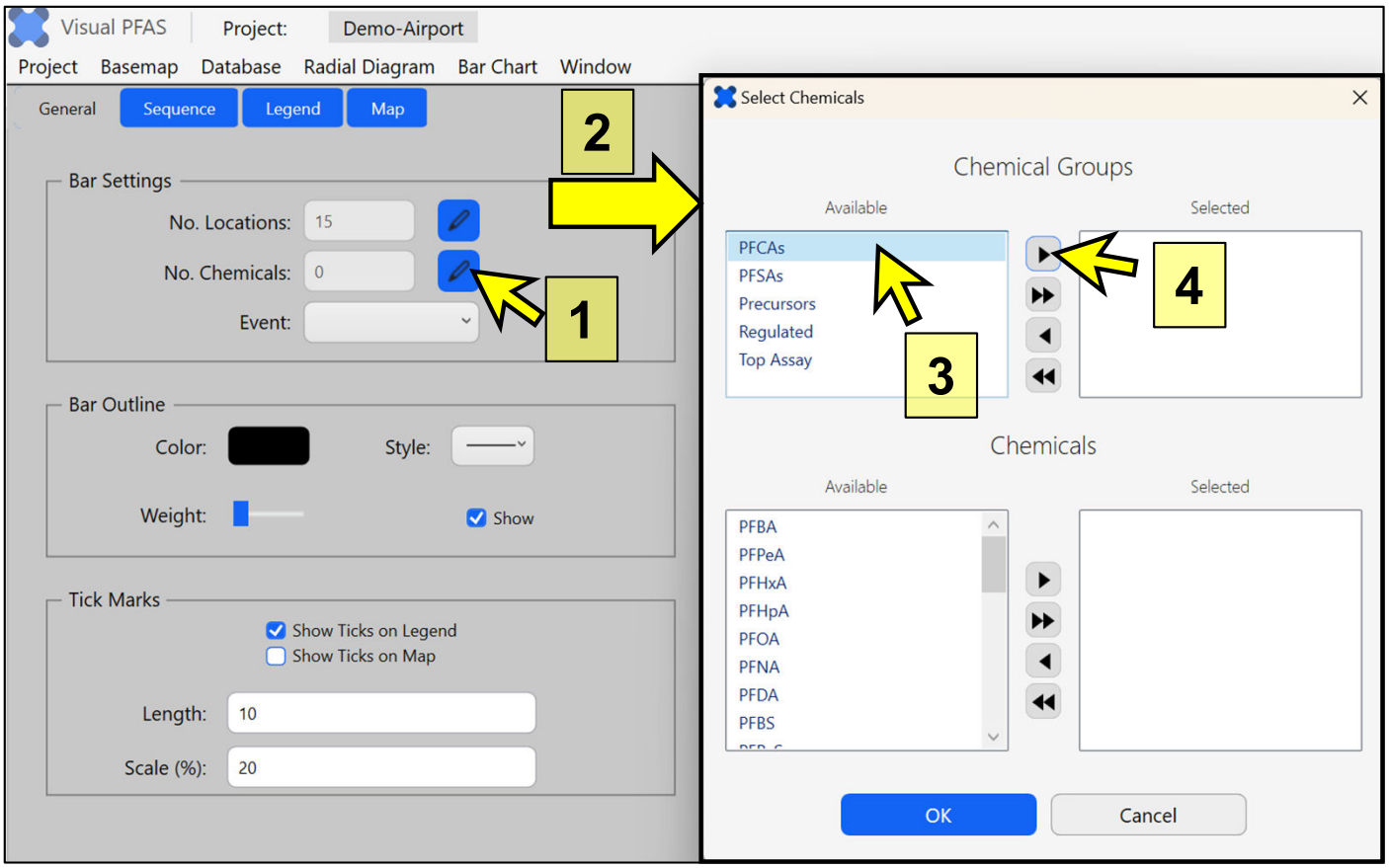
After closing the Selection Locations window, the No. Locations textbox will change to 15 as shown in the image on the left.

5.3.2 Selecting Chemicals

To select the chemicals to be represented in the stacked bar:

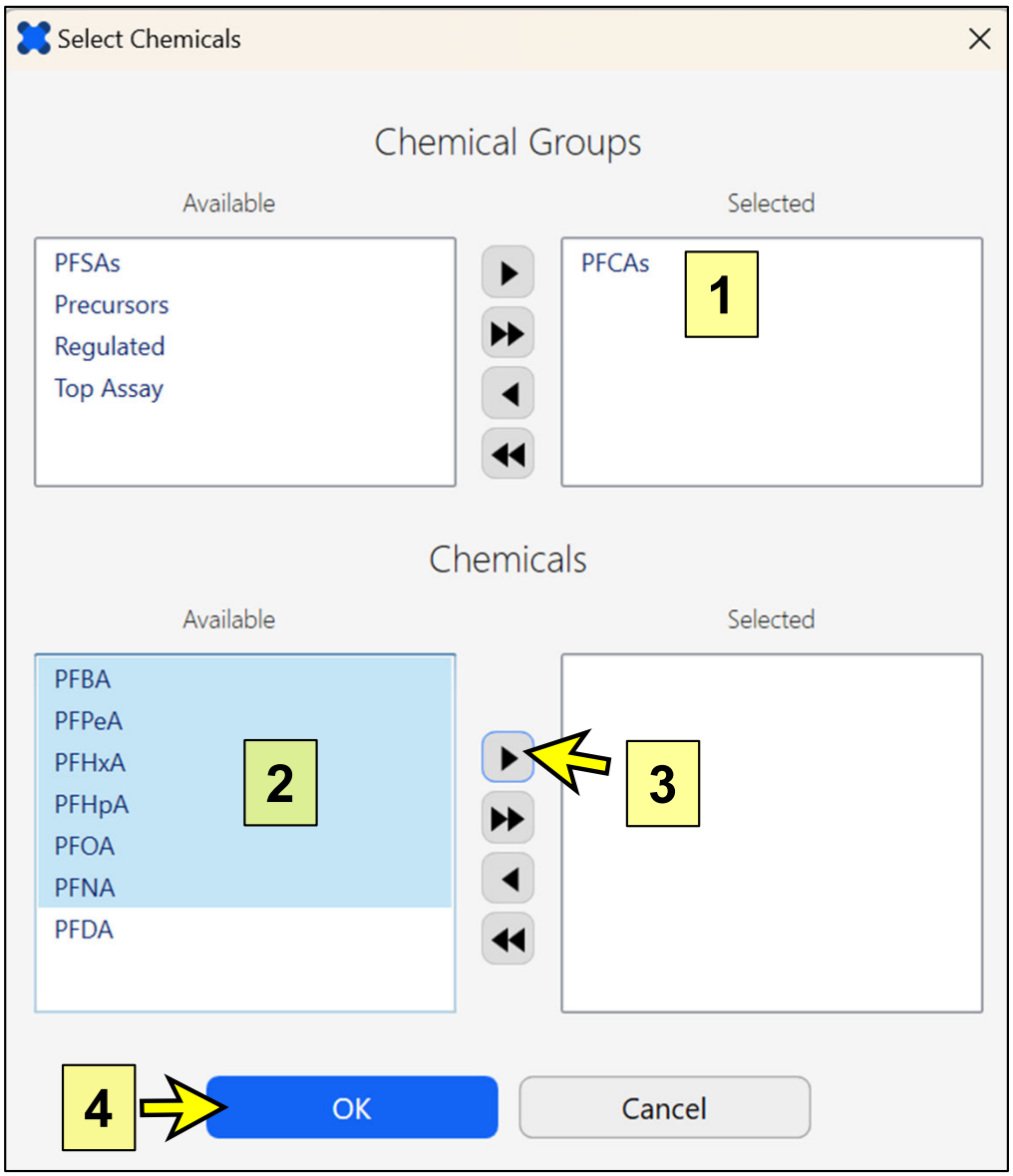
1. Click the **Edit** icon next to No. Chemicals (see "1" below).
2. The **Select Chemicals** window will pop-up (see "2" below). This is where you select which chemicals are to be included in the stacked bars.
3. Click on PFCAs in the Available Chemical Group list, so this row is highlighted in blue (see "3" below).
4. Click the ▶ button associated with the Chemical Groups lists to move this group from the **Available** list to the **Selected** list (see "4" below).

> **Note:** The order of chemicals selected does not matter at this point – you will specify the sequence for chemicals in the stacked bar later in the tutorial.



After selecting PFCAs as the chemical group (see "1" below), the list of **Available** chemicals will be filtered to only show the chemicals that are included in this group. For the stacked bar in this tutorial, we want to select the first six PFCAs in the **Available** list (see "2" below) because PFDA typically has lower concentrations at AFFF-impacted sites.

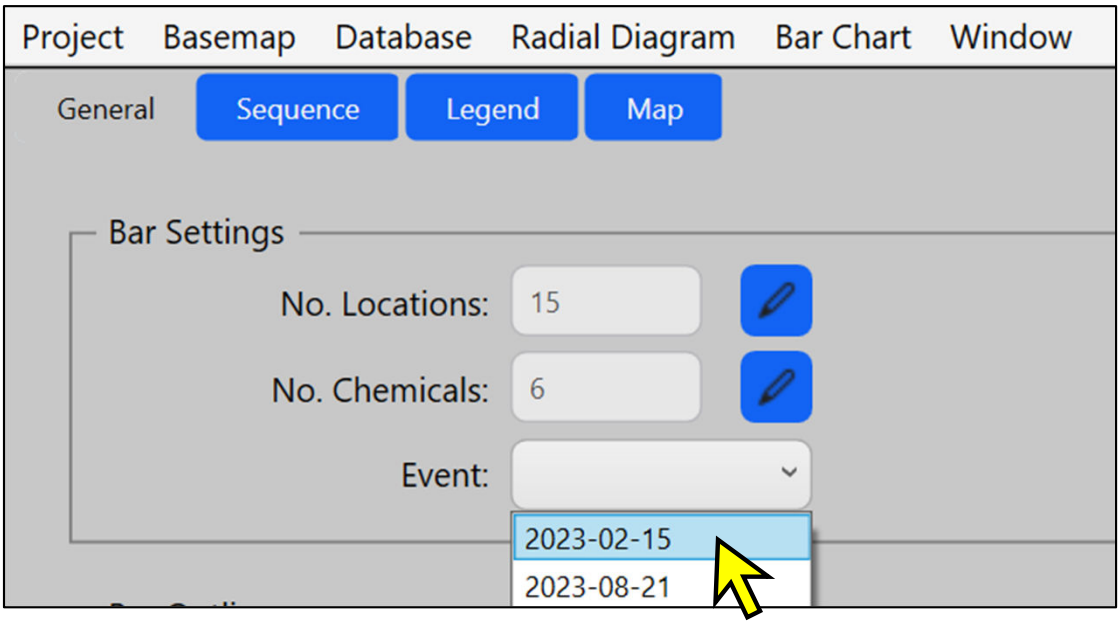
To select six of the seven PFCAs, click on *PFBA* and then hold the shift key before clicking PFNA (and then release the shift key). This will select all chemicals between *PFBA* and *PFNA* in the **Available** list as shown with the blue highlighting below (see "2"). Then click the ▸ button to move these chemicals to the **Selected** list (see "3" below), and click **OK** to save the selection (see "4" below).



5.3.3 Selecting the Monitoring Event

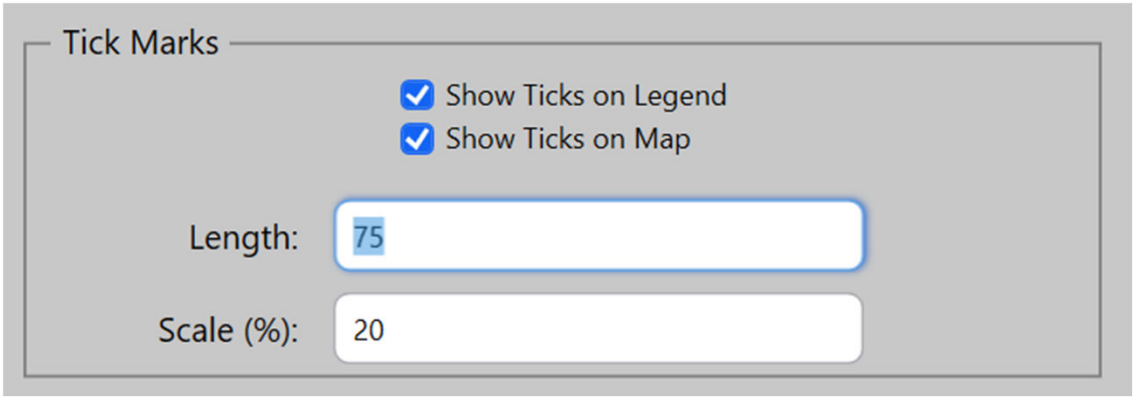
After selecting the chemicals, the No. Chemicals textbox will change automatically to 6.

To select the monitoring event, click on the Event dropdown box and select the 2023-02-15 event from the list (see arrow below).



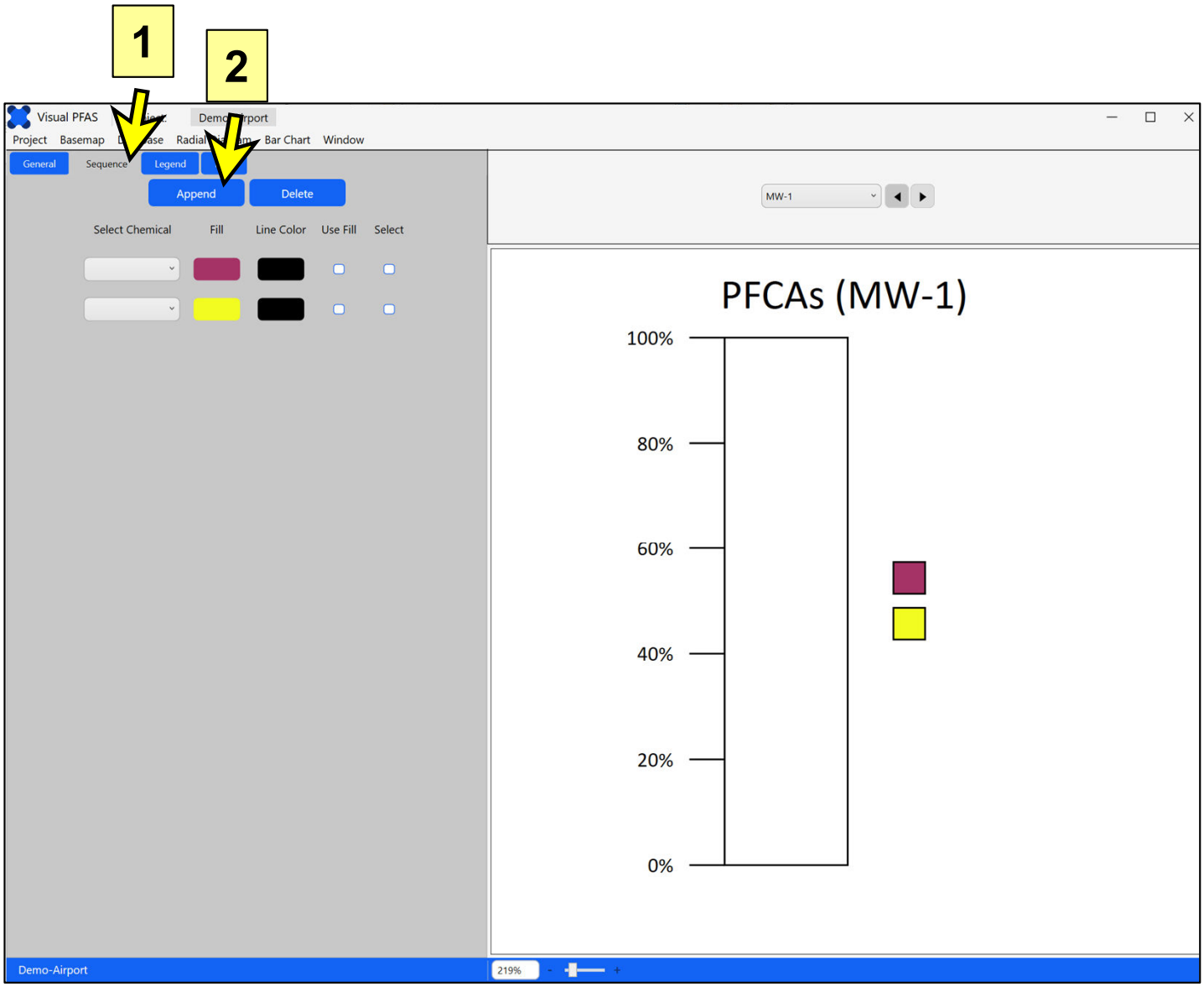
To finish the specification of general properties, click the Show Ticks on Map checkbox to turn this on (i.e., with a checkmark showing) and change the tick mark length to 75 map units as shown below.

The tick mark length needs to be sufficiently large on the basemap that it will be seen when viewing the site basemap. It may take several iterations to find the tick mark length (in map units) that works best.



5.4 Chemical Sequence Properties

The next step is to specify the order of chemicals that are to be represented in the stacked bar. The image below shows what you will see when first clicking on the **Sequence** tab (see "1" below), prior to the specification of chemicals.

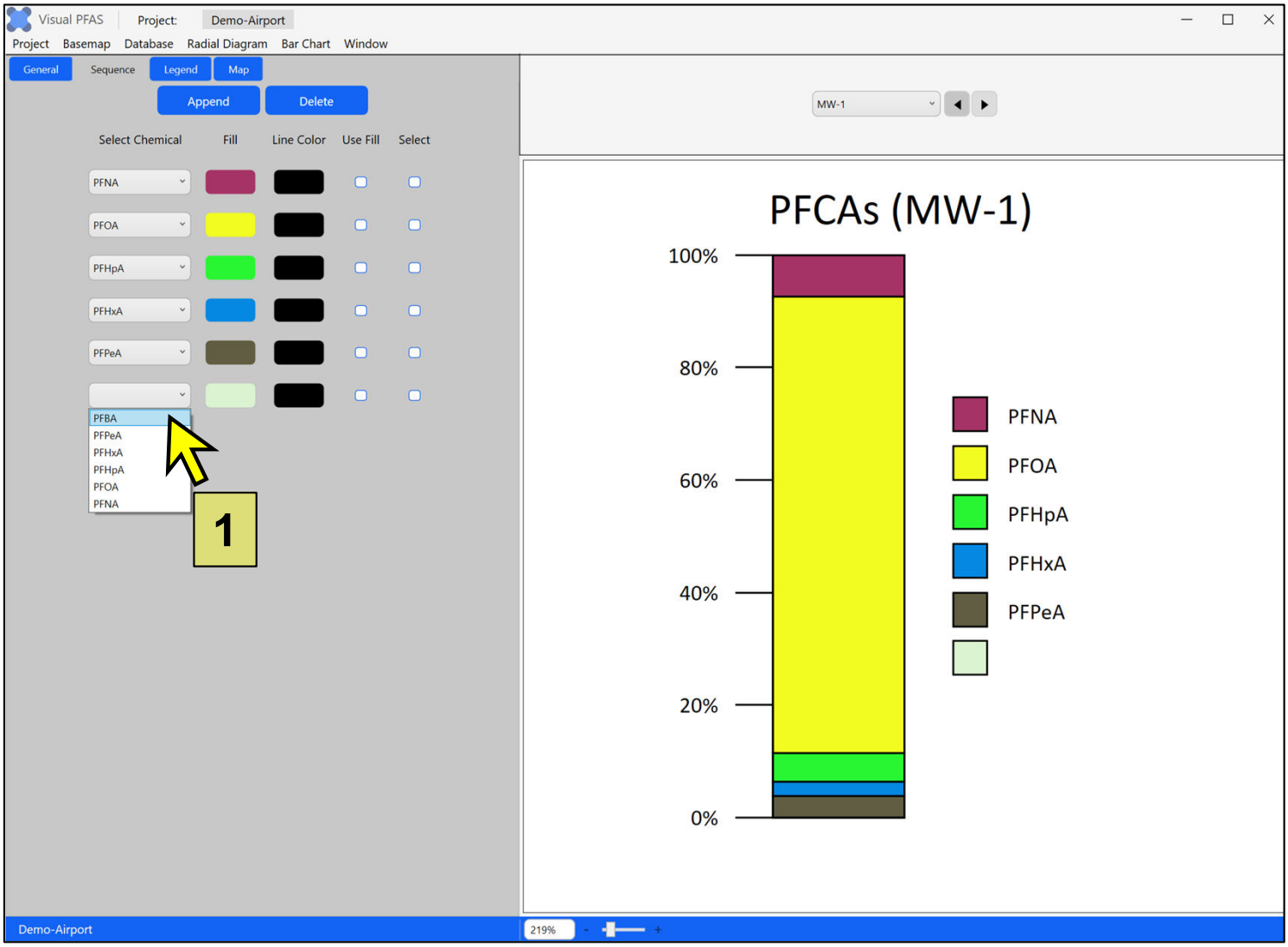


Then click the **Append** button (see "2" above) four times, so that there is a total of six dropdown boxes shown. Colors will be randomly picked for each of these six chemical series, similar to the approach used in Microsoft Excel when data series are added to a chart.

Chemical dropdown boxes are used to selecting each the six chemicals from the list previously specified in Section 5.3.2. The dropdown boxes are listed in a top-down sequence corresponding to the chemicals to be shown in top-down order in the stacked bar.

Click on the upper-most chemical dropdown box and select *PFNA*. This is the chemical that will be shown at the top of the stacked bar.

Then proceed sequentially down the list from top to bottom, selecting in the order of longest to shortest chain length after PFNA: PFOA, PFHpA, PFHxA, PFPeA, and PFBA (see "1" below).



After specifying the sequence of chemicals for the stacked bar, the next step is to specify fill colors for each chemical interval. (The default line color is black.)

Using the color dialog box functions described in Section 3.3.1 of Chapter 3, specify the following RGB fill colors for the six chemicals top-down order in the stacked bar:

- PFNA: 250, 3, 3
- PFOA: 244, 202, 96
- PFHpA: 250, 248, 148
- PFHxA: 7, 88, 17
- PFPeA: 120, 172, 110
- PFBA: 200, 241, 199

RGB color codes

Note: As discussed in Section 3.3.1, RGB colors may be specified by right-clicking in the color palette of the color selection window, then clicking the RGB menu option, and finally, entering the RGB color codes directly.

Note: Using a black line color is typical in stacked bars so that each chemical interval is easier to see on a site map. Users can change the line color if desired, including specifying that the line color is the same as the fill color. To specify that the chemical interval line color is to be the same as the fill color, click the **Use Fill** checkbox to turn on this option. The line color will automatically change to be the same as the fill color.

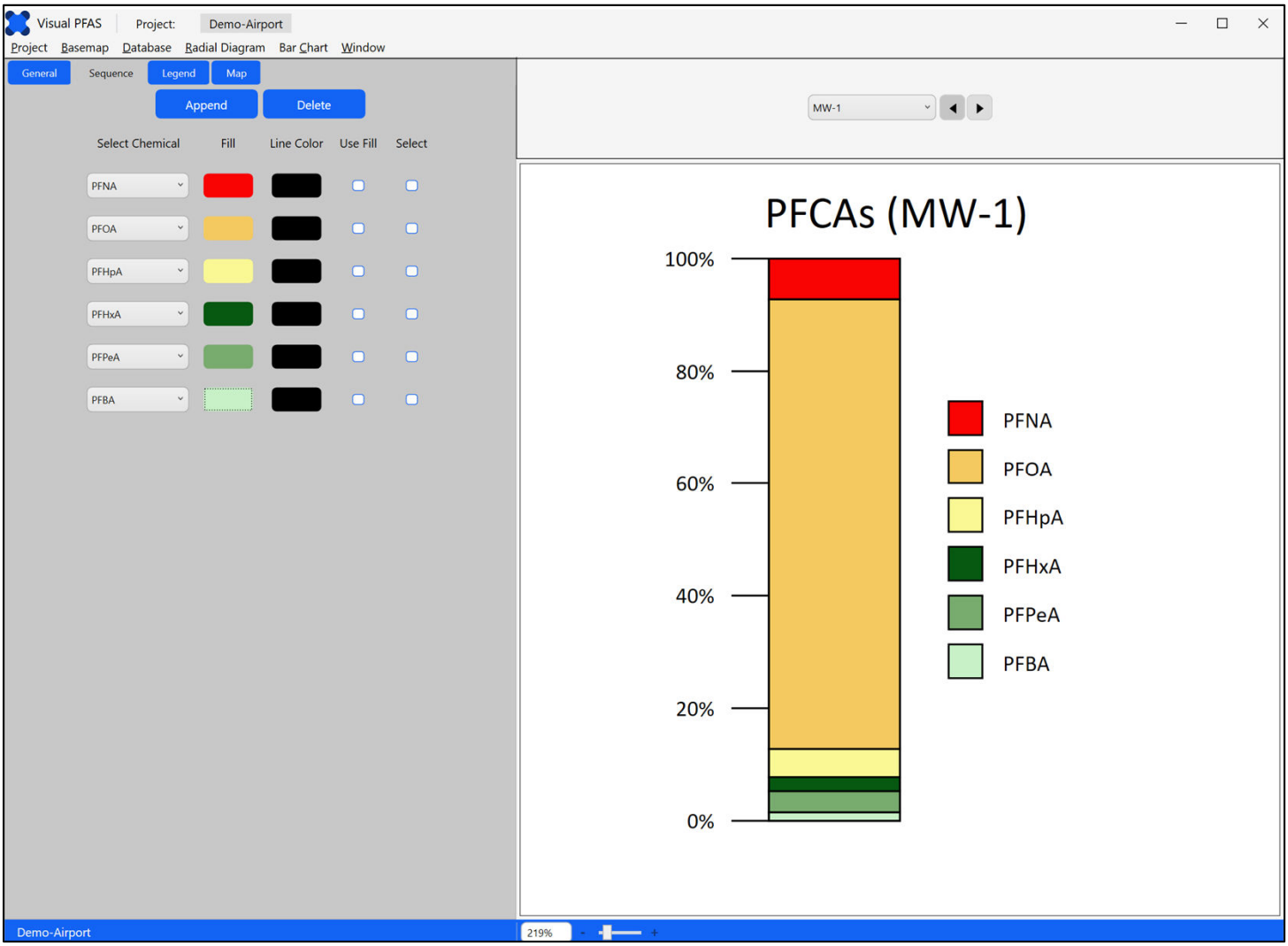
If the fill color is changed, then this **Use Fill** checkbox will automatically be switched off so that the line color does not change unless you click this checkbox again.

Using the RGB color codes specified on the previous page, the stacked bar for MW-1 will look like the bar in the image below.

Note how the short-chain PFCAs were all assigned a green shade (from light to dark for shortest to longest chain of these three species). The long-chain PFCAs were assigned shades of yellow, orange and red from lightest to darkest for shortest to longest chain.

Using grouped colors like this helps to more quickly distinguish between total short- and long-chain PFAS concentrations in stacked bar maps.

Note: Users can click the monitoring location dropdown box at the top of the stacked bar legend to change which location is shown in the legend. Alternatively, users can use the right or left arrows next to the location dropdown box to cycle forwards or backwards through the list of selected monitoring locations in the legend. This provides a quick and simple approach for viewing stacked bars separately for each monitoring location before plotting these on the basemap.



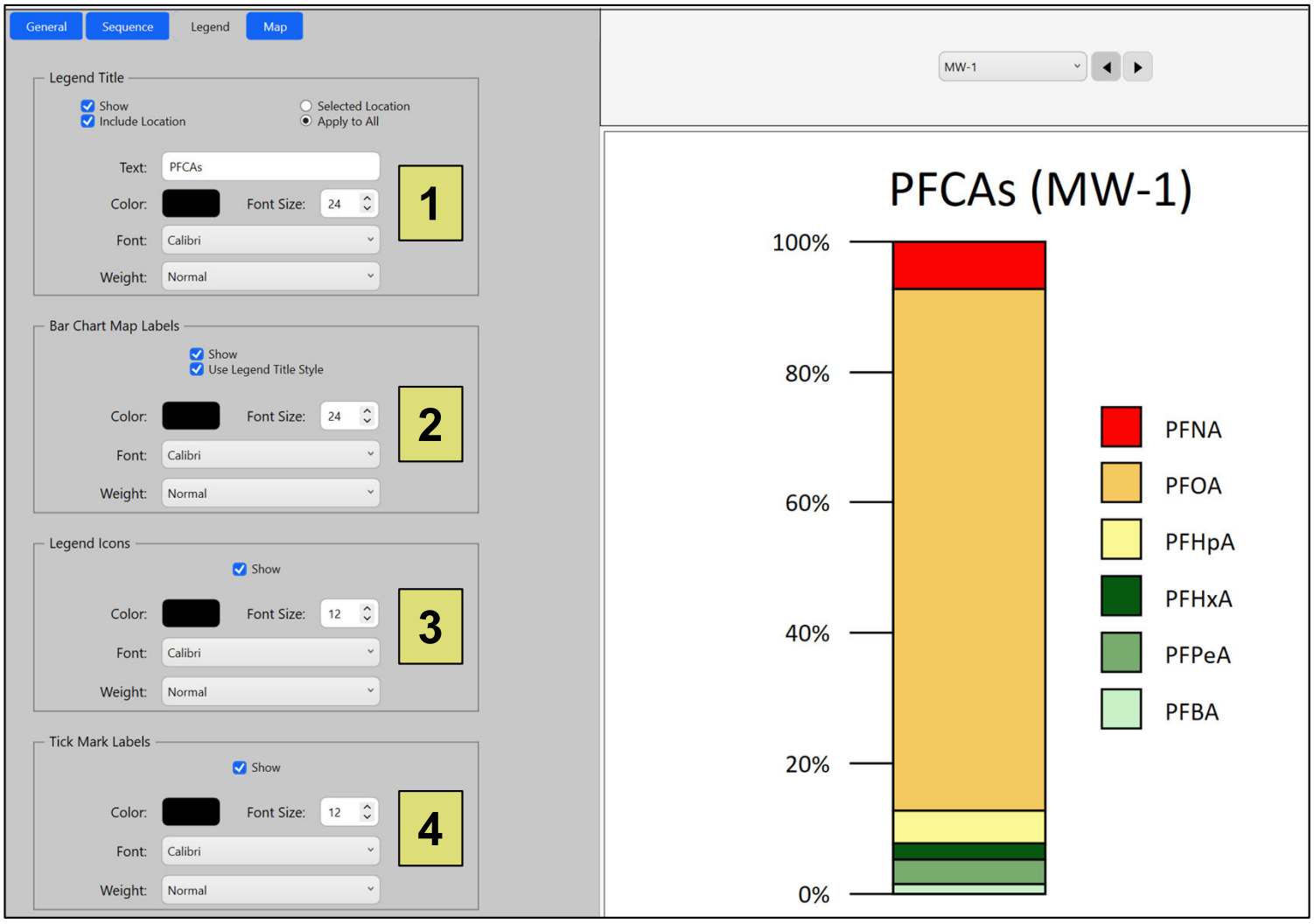
5.5 Legend Properties

Legend properties include options for the features listed below, which correspond to the numeric labels shown on the image at the bottom of the page:

1. Changing the appearance of the legend title;
2. Showing location labels above each stacked bar on the basemap, and properties associated with the labels such as font color, size, style, and weight;
3. Showing the color intervals legend and font properties; and
4. Tick mark labels (show/hide and font properties).

You can try changing some of these legend properties to view the corresponding effects on the legend appearance.

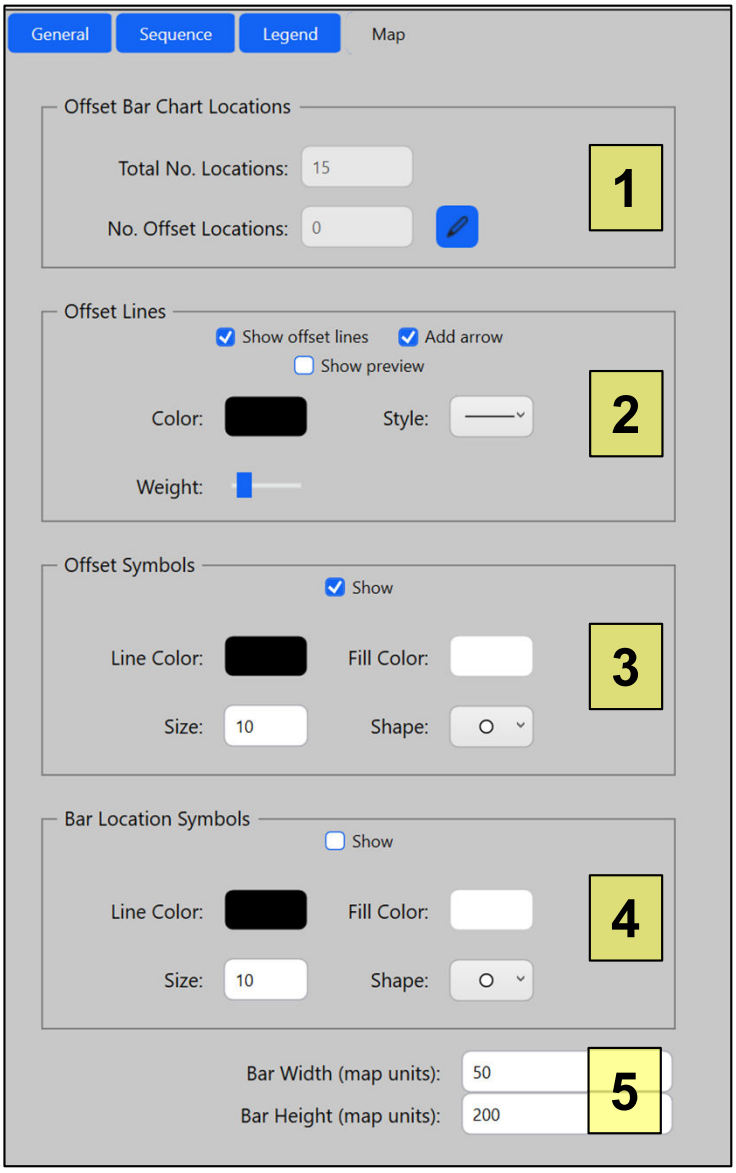
Note: Changing the Bar Chart Map Labels (see "2" below) will only affect the labels shown on the stacked bar basemap; these changes will not be reflected in the legend.



5.6 Map Properties

Click on the **Map** tab to view map properties related to the following categories which correspond to the numeric labels shown in the image below.

1. **Offset Bar Chart Locations** from the original locations, to avoid overlapping of bars at locations that are adjacent to each other.
2. **Offset Lines** (or arrows) that are optionally shown between the offset bar(s) and the original location(s).
3. **Offset Symbols** which are plotted to show the original location(s) that have been offset to avoid overlap with adjacent locations.
    - The symbol size is in map units. If offset symbols do not appear to be shown on the basemap, it may be that this size is too small. The size should reflect the symbol size in map units (e.g., feet or meters).



4. Bar location symbols which are optionally shown at the bottom of each stacked bar on the basemap, to illustrate that the monitoring location is at the bottom-center of each stacked bar.

Offsetting stacked bars is based on the same process described in Chapter 4 for offsetting radial diagram locations (see p. 4.33 to 4.38 for a tutorial example).

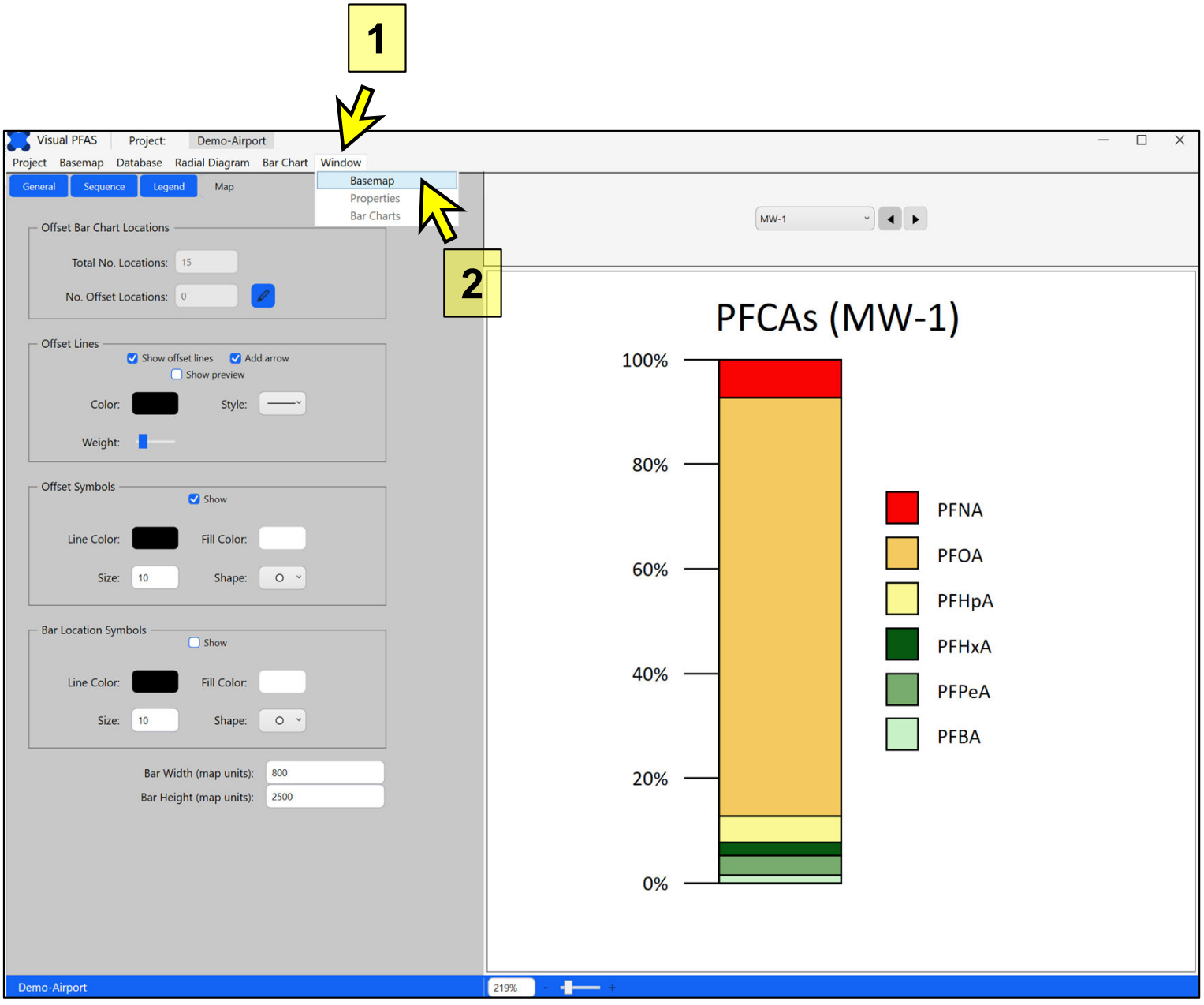
The width and height of the bar (in map units) are shown at “5” in the image on the left. The bar width and height can also be changed from the basemap window directly, which reduces the number of iterations required to go back-and-forth between the stacked bar basemap and property windows.

For this tutorial, change the bar width to 800 ft (map units) and the bar height to 2500 ft at “5” on the left.

5.7 Viewing the Stacked Bar Map

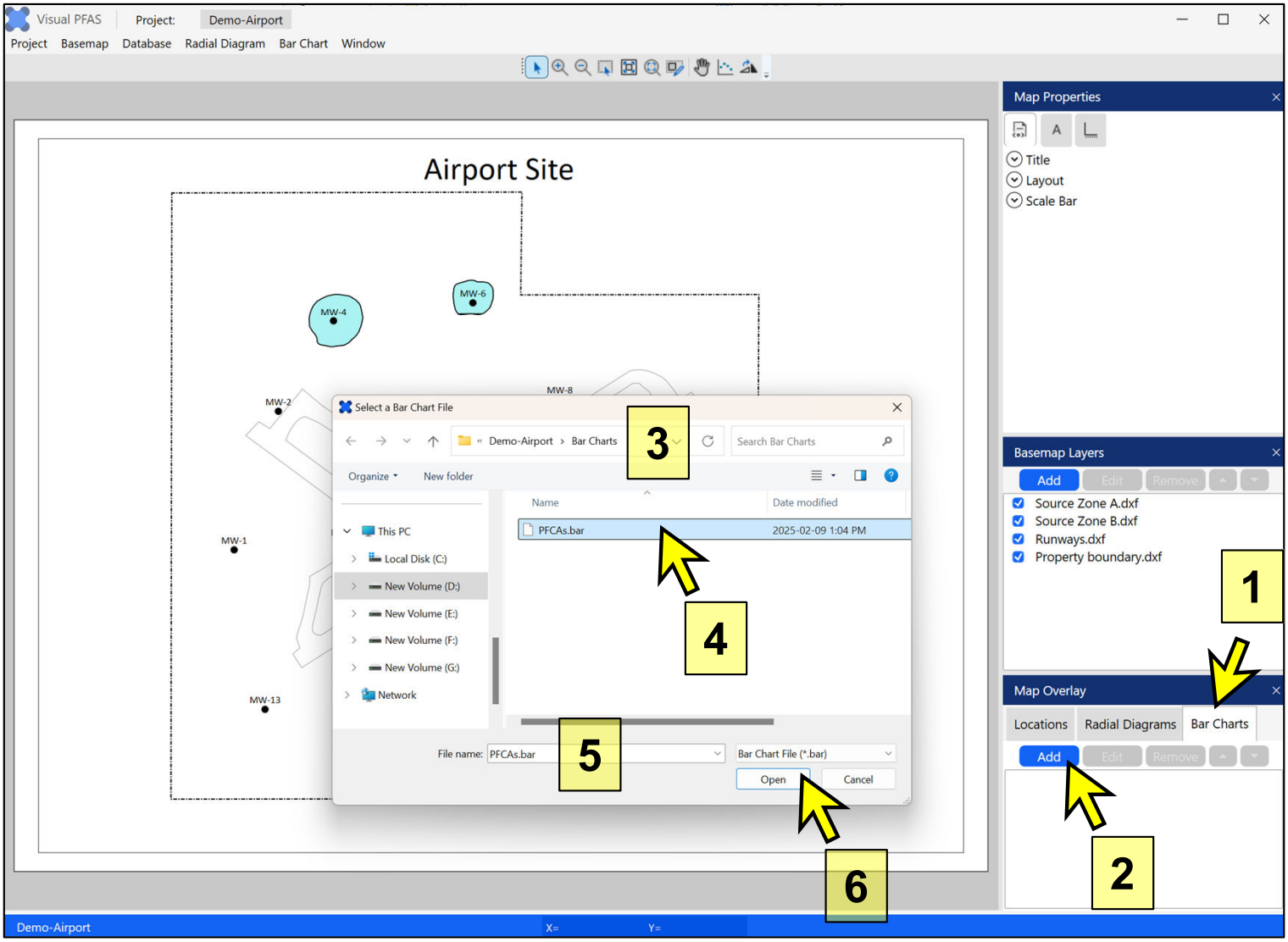
While Visual PFAS™ does incorporate an Auto-save function, it is good practise to save the properties during an editing session. This is done by clicking on the **Bar Chart** menu option at the top and clicking **Save** *PFCAs*.

Now we're ready to plot the stacked bar layer on the site basemap. Click the **Window** option at the top menu (see "1" below and click the **Basemap** menu option (see "2" below) . This allows you to switch to the **Basemap Window**. You can also do the reverse process to return to the **Bar Chart Window** shown below.



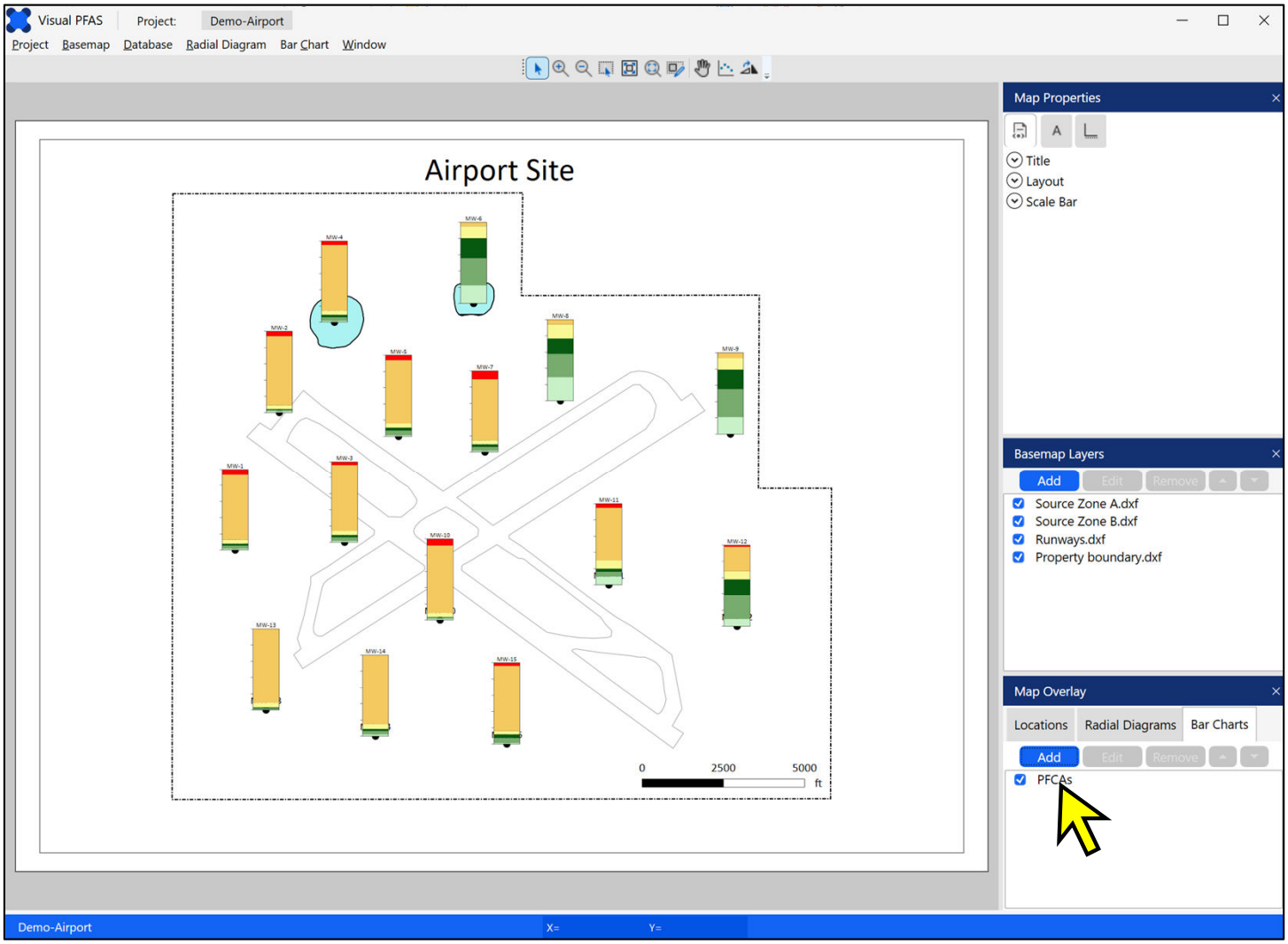
From the **Basemap Window**, click on the **Bar Charts** tab in the **Map Overlay** section at the bottom-right of the window (see “1” below). Then click the Add button to overlay a stacked bar layer on the basemap (see “2” below).

A file explorer window will pop-up and will automatically show the available stacked bar property files in the **Bar Charts** sub-folder (see “3” below) under the current project folder. Click on the *PFCAs.bar* file just created in the previous section of this tutorial (see “4” below); this will automatically fill the **File name** text box below (see “5”). Then click **Open** to add this stacked bar layer as an overlay to the basemap (see “6” below).

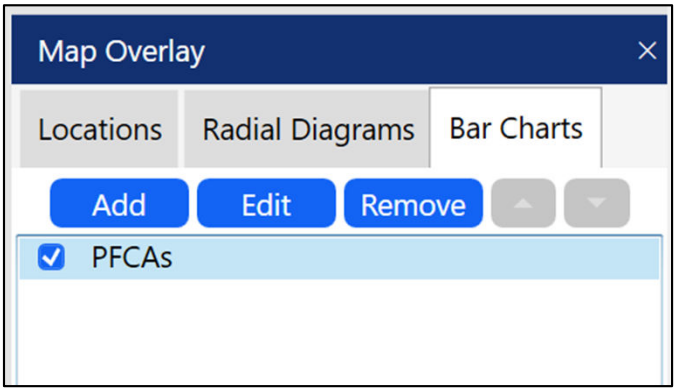


The Basemap Window will now show the stacked bar layer (see below).

To edit several stacked bar properties from this window, click on the PFCAs stacked bar layer in the Map Overlay section (see arrow below).



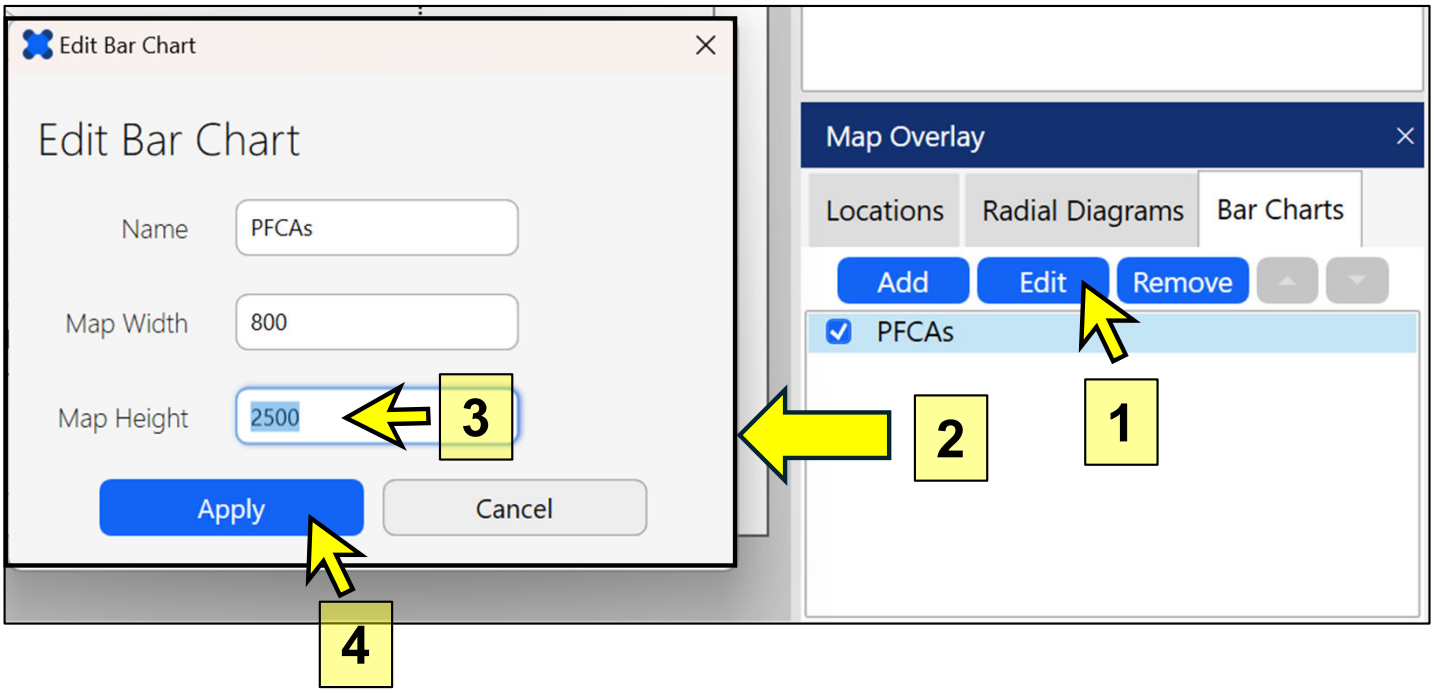
Once you have selected PFCAs as the current stacked bar layer, the **Edit** and **Remove** buttons change to blue from being grayed out, as shown below. This means that the **Edit** and **Remove** buttons are now enabled because a stacked bar layer has been selected.



Click the **Edit** button (see "1" below), which will cause the **Edit Bar Chart** window to pop-up (see "2"). This allows you to quickly change the bar width and/or height and see the effects immediately on the basemap after making the change. In this manner, you can avoid having to return to the Bar Charts Window, making the change on that form, and then using the Window menu to return back to the Basemap Window.

Select the original height defined (2500) as shown at "3" below, and change this to 3000 so that the bar height will increase slightly. Larger bars on the map make it easier to visualize trends between monitoring locations and source areas. It may take several iterations to finalize the bar height and width for a site basemap.

Click Apply to save this change (see "4" below). The stacked bar layer on the basemap will change immediately to reflect this new height.



5.8 Printing and Exporting Stacked Bar Maps

The stacked bar map **Print** and **Export** options are the same as those described previously for basemaps (see Section 3.7), and for radial diagrams (see Section 4.9).

When printing a basemap to PDF or a printer, it will include any stacked bar and/or radial diagram layers currently shown on the basemap. The same applies if a basemap is exported to an image or PDF file.

When exporting stacked bar maps to a CAD DXF or Surfer bln file, only the stacked bar layer will be exported to the respective file type. Separate DXF or bln files will be created for the stacked bar outline and bar tick marks, and one file will be exported to represent each chemical series. This allows users to import these files as different layers to CAD, GIS, or Surfer and apply different line and/or polygon properties to each. Offset location symbols (if applicable) will be saved to an x,y text file (*.dat).

The stacked bar legend can be exported separately to an image file or PDF by choosing the Bar Chart → Export Legend menu option. The exported stacked bar basemap and legend can be combined using software such as Microsoft PowerPoint for making a presentation or final report figure.