THE W2 ANIMATOR – USER MANUAL

TABLE OF CONTENTS

General Information and Installation

About the W2 Animator

The W2 Animator, or W2Anim for short, is an interactive Perl script that allows the user to explore and visualize output from the CE-QUAL-W2 (Wells, 2025) two-dimensional flow and water-quality model as well as measured data from limnological profiles and time series. Several W2Anim visualizations can be animated to view data and model results over time. All graphs are created on a "drawing canvas" that can be annotated with text, shapes, lines, and images. Everything on the canvas can be exported as encapsulated PostScript, and optionally in PDF or raster image formats (PNG, GIF, JPG, BMP, PPM, TGA, TIFF) or as a video file (AVI, FLV, GIF, MOV, MP4).

A number of different graph types are supported, including:

- Vertical profiles of measured parameters over time,
- Vertical profiles of model results over time,
- Vertical profile matrix plots of modeled and measured parameters,
- Longitudinal slices of model results through the model domain over time,
- Modeled water-level plots for a longitudinal reach over time,
- Time/distance maps of model results,
- Vertical withdrawal zones at dam outlets, computed from measured data,
- Vertical withdrawal zones from model output,
- Measured time series, and
- Modeled time series.

More graph types and features will continue to be added with future releases.

Latest Version

The most recent version of The W2 Animator can be found on its GitHub page at https://github.com/sarounds/w2anim/releases/latest.

License

Installation

The W2 Animator is written in Perl with the Tcl/Tk toolkit, and therefore requires the user to have both Perl and Tcl installed with the proper modules. Detailed instructions for installing Perl and Tcl on a Windows machine are given below. Once Perl and Tcl are installed and any helper programs also are installed, the W2Anim package may be downloaded from its home on GitHub and unzipped to any appropriate location on the user's computer. Running The W2 Animator is as simple as starting the *w2anim.pl* script. Windows users may double-click on that script file from the Windows File Explorer, or a Perl command window may be started and the *w2anim.pl* script initiated from there.

Installation of Perl and Tcl

Both Perl and Tcl must be installed, along with several required modules of those interpreters. Tcl is needed because the Tk module in Perl is not up to date, whereas the Tcl/Tk module *is* up to date. The W2 Animator requires version 8.6 of Tk to build and use all of the features of its user interface, and the Tcl/Tk module utilizes version 8.6 or later of Tk.

These instructions describe how to install the Strawberry Perl and ActiveTcl distributions of Perl and Tcl, respectively, on a 64-bit Windows system. If you wish to install different distributions of these languages, feel free, but the instructions here are specific to Strawberry Perl and ActiveTcl. The W2 Animator should work on multiple operating systems, but you may need different source distributions of Perl and Tcl to make it work on each operating system.

Step 1. Install Strawberry Perl

Strawberry Perl is a free distribution of Perl for Windows that is designed to be as close as possible to the Perl environments on unix systems. Strawberry Perl is free and available at https://strawberryperl.com/. Download the installer for your system and install it as you would normally install any Windows program. I am using version 5.42.0.1 (64-bit) of Strawberry Perl, which is the current version as of this writing, to my system at C:\Perl\Strawberry\. Previously, I had used version 5.32.1.1 (64-bit) of Strawberry Perl with great success.

Step 2. Install ActiveTcl

ActiveState provides packages for several useful languages. I signed up for a free account at ActiveState (https://www.activestate.com/products/tcl/). I downloaded the most-recent standard and recommended Tcl package for Windows, which is version 8.6.14.0000 (64-bit), built on 8-Oct-2024. You can find that package at https://platform.activestate.com/ActiveState/TclTk-RecommendedVersion/distributions. Previously, I had successfully used version 8.6.12.0000 (64-bit), but that version is no longer available from ActiveState. Install the Tcl package as you would any Windows program. I installed my package to C:\Tcl\ActiveTcl\.

It is likely that you will need to make a few edits to one file in the Tcl package after installation. In the file:

C:\Tcl\ActiveTcl\lib\tclConfig.sh

I found six lines that the installer did not properly complete. Here are the 6 lines, where I commented out the first line in the pair (with a leading #), copied it to the second line and edited the second line to have the correct path and syntax:

```
#TCL_PREFIX='C:\TEMP\ActiveState----------------------------------------please-run-the-install-script----------------------------------------'
TCL_PREFIX='C:\Tcl\ActiveTcl'

#TCL_EXEC_PREFIX='C:\TEMP\ActiveState----------------------------------------please-run-the-install-script----------------------------------------\bin'
TCL_EXEC_PREFIX='C:\Tcl\ActiveTcl\bin'

#TCL_LIB_SPEC='C:\TEMP\ActiveState----------------------------------------please-run-the-install-script----------------------------------------\lib\tcl86t.lib'
TCL_LIB_SPEC='-LC:\Tcl\ActiveTcl\lib\tcl86t.lib'

#TCL_INCLUDE_SPEC='-IC:\TEMP\ActiveState----------------------------------------please-run-the-install-script----------------------------------------\include'
TCL_INCLUDE_SPEC='-IC:\Tcl\ActiveTcl\include'

#TCL_STUB_LIB_SPEC='-LC:\TEMP\ActiveState----------------------------------------please-run-the-install-script----------------------------------------\lib tclstub86.lib'
TCL_STUB_LIB_SPEC='-LC:\Tcl\ActiveTcl\lib tclstub86.lib'

#TCL_STUB_LIB_PATH='C:\TEMP\ActiveState----------------------------------------please-run-the-install-script----------------------------------------\lib\tclstub86.lib'
TCL_STUB_LIB_PATH='C:\Tcl\ActiveTcl\lib\tclstub86.lib'
```

With these modifications to the tclConfig.sh file, Strawberry Perl will be able to download and properly compile the Perl Tkx module, which is an interface to the Tcl/Tk package. Without these modifications, the Tkx interface in Perl to Tcl/Tk will not be available and The W2 Animator program will not run properly.

Step 3. Modify the System PATH (optional, but useful)

I found it useful to modify the Windows system PATH. The installer for ActiveTcl unnecessarily puts its folder at the top of the PATH list, whereas Strawberry Perl puts its entries at the bottom of the system PATH. To modify your Windows system PATH, click the Start menu and select Settings. Then type “system path” into the search bar. On Windows, you need to be Administrator to modify the system PATH. You may need to enlist the assistance of your system administrator to complete some of these instructions.

I moved the three entries for Strawberry Perl up to the top, before the Tcl path, as follows:

```
C:\Perl\Strawberry\c\bin
C:\Perl\Strawberry\perl\site\bin
C:\Perl\Strawberry\perl\bin
C:\Tcl\ActiveTcl\bin
```

Step 4. Install Required Perl Modules

The W2 Animator requires several additional Perl modules to be installed. This is a common task and is fairly simple to carry out. Start by opening Strawberry Perl's text interface. Check the Start menu for a new item—it is probably labeled “Perl (command line).” I added a shortcut to my taskbar for future use.

New modules can be installed in Strawberry Perl, and indeed in most Perl distributions, by using the “cpanm” command. It's really simple, but pay attention to the messages it prints to the screen. If you have problems, you should be able to find a “build.log” file in C:\Users\your_user_name\.cpanm\ that will be more verbose. You will also find more build logs under C:\Users\your_user_name\.cpanm\work\.

Running as Administrator (I don't know if this is necessary), I started by installing the Perl Tkx module with:

```
cpanm Tkx
```

This module is small and quick to install, but it requires the Tcl module as a dependency, and so will install the Tcl module as well. The Tcl/Tk module is used for creating user interfaces. As a result, you will see many different windows popping up as various tests are generated and run. Do not be alarmed, as this is normal.

Other Perl modules that you will need, and their installation commands:

```
cpanm Tkx::ROText
cpanm Tkx::Scrolled
cpanm Proc::Background
cpanm File::Find::Object
cpanm Math::Bezier
cpanm Win32::GUI
```

If you have any problems installing any of these modules, which may happen if some automated tests fail, you may need to force the installation, such as:

```
cpanm Win32::GUI --force
```

As an aside, The W2 Animator does not need Perl's Tk module to be installed, but if you are using Perl for some other programs, you may want the Tk module. A known bug in the Perl Tk module makes its installation difficult with the latest packages. To install the Perl Tk module, you need to point cpanm to a different repository that has a "patched" package with some fixes:

```
cpanm https://github.com/StrawberryPerl/Perl-Dist-
            Strawberry/releases/download/patched_cpan_modules/Tk-804.036_001.tar.gz --force
```

Installation of the Perl Tk module, however, is optional and not needed for W2Anim.

All of the other modules required by The W2 Animator should already be part of the standard distribution of Strawberry Perl. For example, the Math::Trig and Imager modules are already installed.

Finally, when I was using Strawberry Perl version 5.32.1.1, I found one error in its Tcl module, which has since been fixed. If you are using an older version of Perl, you may need to edit the file at:

C:\Perl\Strawberry\perl\site\lib\Tcl.pm

In that file, find the line that looks like:

```
print "TCL::TRACE_DELETECOMMAND: $interp -> ( $tclname )\n" if TRACE_DELETECOMMAND();
```

This line may be missing a "Tcl::" in front of the final TRACE_DELETECOMMAND. The fixed line should look like:

```
print "TCL::TRACE_DELETECOMMAND: $interp -> ( $tclname )\n" if Tcl::TRACE_DELETECOMMAND();
```

Doing this little edit may be tricky, as the default file permissions for the Tcl.pm file don't include write permissions, even for the owner. I worked around it by changing the file's user write permission while logged in as Administrator in my Cygwin environment and editing the file with vi there. Another user reported that you can open the file in Notepad++, right-click on the file-name tab, and choose the option to clear the ReadOnly flag. You may find another solution.

That's all. You should now have a functioning Strawberry Perl environment with ActiveTcl available to assist.

Installing and Starting The W2 Animator

The W2 Animator does not have its own installation program. You simply need to download the latest code package from GitHub at https://github.com/sarounds/w2anim/releases/latest and unzip that package into whatever directory you choose as the home for The W2 Animator on your computer, such as C:\Data\w2anim on a Windows system. It is your choice; just make sure you have read and write access to that location. Optionally, you may put that folder on the system PATH. When updating or installing for the first time, be sure to update the path in the w2anim.bat file to point to the location on your computer where the W2Anim scripts reside.

Once the scripts and associated files have been unzipped, you can start up The W2 Animator in several different ways:

- Type “w2anim.pl” in a Perl command line window. You may need to be in the directory where the W2anim scripts reside if that folder is not on the system PATH.
- Type “perl w2anim.pl” in any command window. You may need to be in the directory where the W2Anim scripts reside if that folder is not on the system PATH.
- Double-click on the w2anim.pl file from the File Explorer, after any .pl files have been associated with Perl.
- Double-click any W2Anim project file in the File Explorer. See the section Opening a W2Anim Project File with a Double-Click for more information.

If you are running W2Anim under Windows, you may find that Windows has tagged the W2Anim package files as from an unknown publisher. As a result, Windows may attach an “Alternate Data Stream” to the various files that were downloaded, and every file in the unzipped package now may have a Zone.Identifier as part of their Alternate Data Stream. This is not a problem, but it will cause a warning message from Windows to appear each time you run W2Anim, and that can become annoying. The solution is to identify which files (probably all) have that Alternate Data Stream, and then remove that Alternate Data Stream from those files. To do that, follow these instructions:

In a regular Command window:

- Navigate to the proper folder.
- Issue this command:
  dir /r /s |findstr /e ":$DATA"
  That command will recursively find any files that have an Alternate Data Stream and list them.

Then in a PowerShell window:

- Navigate to the proper folder.
- Issue these commands:

  Unblock-File *
  Unblock-File */*
  Unblock-File */*/*

  Finally, go back to the regular Command window and re-issue the dir|findstr command as above to ensure that all of the Alternate Data Streams have been removed.

Helper Programs

Visualizations from The W2 Animator can be exported natively in encapsulated PostScript format. To export visualizations in PDF format or in several types of raster image formats (PNG, GIF, JPG, BMP, PPM, TGA, TIFF), an independent helper program such as Ghostscript must also be installed. Similarly, to export video files in several formats (AVI, FLV, GIF, MOV, MP4), an independent helper program such as FFmpeg must be available. Detailed instructions for obtaining and installing these independent helper programs on a 64-bit Windows machine are given below. Alternate methods are discussed in this manual under Alternate Export Methods.

Ghostscript

Ghostscript is a powerful and commonly used interpreter for the PostScript language and for Portable Document Files (PDFs). Artifex Software maintains and develops the Ghostscript software and has ported it to a number of operating systems including Windows and Linux. As of this writing, the current version is 10.06.0, and that is the version I am using. The source code as well as pre-compiled binaries are available at:

- https://www.ghostscript.com/
- https://www.ghostscript.com/releases/gsdnld.html

Ghostscript is available as open source software under the GNU Affero General Public License.

The important point is that Open Source Ghostscript is free to use. None of the source code has been modified for use with W2Anim, none of the source code has been incorporated into W2Anim, and Ghostscript is not distributed with W2Anim. It is up to the user to decide whether to use Ghostscript in conjunction with W2Anim. If the user wishes to export screenshots or animations from W2Anim, then the user may find it useful to install and use Ghostscript as a helper application to W2Anim. See the Help/Configure menu option in The W2 Animator to ensure that W2Anim knows where Ghostscript is located on your computer.

In Windows, you can install Ghostscript by running the installation executable program as Administrator. I suggest that you install the program under

C:\Program Files\gs\gsxx.xx.xx

where the xx stuff refers to the version number. For example, my installation location is

C:\Program Files\gs\gs10.06.0\

FFmpeg

FFmpeg is a powerful set of tools and libraries for decoding, encoding, translating, and reformatting almost every type of audio and video file. It is free to use and is covered under the GNU General Public License (GPL), version 2 or later. See https://ffmpeg.org/legal.html for more information.

FFmpeg may be used with W2Anim as a helper program to make AVI, FLV, MOV, and MP4 video output files from a series of PNG images. FFmpeg is not needed in order to run or use W2Anim, and it is up to the user to decide whether (or not) to download and install FFmpeg as a helper program. None of the source code of FFmpeg has been incorporated into W2Anim, and FFmpeg is not distributed with W2Anim. If the user wishes

to create certain video output files, then the user may wish to download and install FFmpeg or some other video software to accomplish that task.

FFmpeg tools include:

- ffmpeg— a command line tool to convert multimedia files between various formats
- ffplay— a simple media player
- ffprobe— a simple multimedia stream analyzer

More information and free downloads of the FFmpeg software can be found online at the following URLs:

- https://ffmpeg.org/
- https://ffmpeg.org/about.html
- https://ffmpeg.org/download.html

As of this writing, the current version of FFmpeg is 8.0.1, based on a build from 20-Nov-2025. Compiled packages of FFmpeg are available for Windows at:

- https://www.gyan.dev/ffmpeg/builds/
- https://www.gyan.dev/ffmpeg/builds/ffmpeg-git-full.7z

The compiled package for Windows mentioned above does not come with an installer. To install FFmpeg on your Windows system, create the following directory:

C:\Program Files\FFmpeg\

and then unzip the package so that the following folders exist:

C:\Program Files\FFmpeg\bin
C:\Program Files\FFmpeg\doc
C:\Program Files\FFmpeg\presets

Lastly, you may wish to put the C:\Program Files\FFmpeg\bin folder on the system PATH so that the programs are more easily accessible, but this is not strictly necessary if you use the folders as suggested above and/or provide the appropriate path to the FFmpeg programs to The W2 Animator program under the Help/Configure menu.

Video Files

Video Formats

When used with Ghostscript and FFmpeg, W2Anim can create several types of video output files. Although the smoothest and fastest way to view W2Anim animations is probably within W2Anim itself, you may find it useful to export video files to share with your colleagues or partners. The following video formats are available for export from W2Anim. You can research their advantages and disadvantages yourself, but here is my take:

- **AVI**—Audio Video Interleave format. This is an older video format that is still in use and is compatible with a wide range of video players. Quality is high, but the file size will be larger than MOV or MP4 formats.
- **FLV**—Flash Video format. This format was developed for use with the Adobe Flash player, and often was used for showing videos in web pages. It is provided in case compatibility for older web pages is needed.
- **GIF**—Animated Graphics Interchange Format. Animated GIFs have enjoyed somewhat of a resurgence in popularity for small animations, but this format is not recommended unless you have no other options. W2Anim can create animated GIFs without FFmpeg, but Ghostscript or a similar PostScript interpreter is still needed. This video format restricts the color palette to 256 colors, and compression of the final file is poor compared to other video formats.
- **MOV**—QuickTime movie format. The MOV format was developed by Apple and is compatible with Windows and MacOS systems. It uses the MPEG-4 encoding algorithms and results in smaller file sizes compared to AVI, FLV, and GIF formats.

- **MP4**—MPEG-4 format. The latest MPEG-4 format was derived at one time from the QuickTime movie format. MP4 files are commonly used for modern videos, and file sizes are small compared to the AVI, FLV, and GIF formats. File sizes for MP4 and MOV files created by FFmpeg through W2Anim will be the same.

Video Codecs

Your computer probably already has most of the video codecs required to encode, decode, compress, and decompress the data in video files. If a video player on your system cannot play a particular video file, it may or may not be due to not having the proper codecs installed. Many video players rely on codecs that are compiled into their code, but some rely on libraries installed with the operating system. If you wish to update the codecs on a Windows computer, you may download and install the codecs contained in the "K-Lite Codec Pack Standard" available at https://www.codecguide.com/download_k-lite_codec_pack_standard.htm.

Video Players

Many video players are available, but not all of them can open and play the video files that may be exported by W2Anim with or without FFmpeg as a helper program. Here is a limited list of some video players that may be useful:

- **MPC-HC**: The K-Lite Codec Pack includes a video player program called MPC-HC that can be used to view just about any video file and has some decent user controls.
- **VLC Media Player**: The VLC Media Player also can be used to view just about any video file and comes with its own codecs compiled into the program. This is a very useful video viewer, but I personally don't like the user controls as much as those in some other programs.
- **MPV**: The MPV player works well, but personally I find the user controls of some other players to be more useful.
- **IrfanView**: IrfanView is a powerful image editor program that also can play certain types of video files, depending on the codecs that are installed and known by that program. Give it a try to see if you like it, but recognize that it won't work in all instances, and the user controls are limited.
- **Windows Media Player**: The Windows Media Player still exists, but is no longer under development and has been superceded with other tools in Windows 11. Some types of video files will not play in this older viewer.
- **ffplay**: The video player that comes with the FFmpeg package is simple, but portable, and should work with video files produced by FFmpeg. The user controls are minimal, and most options are invoked from a command line. Still, it may be a useful option in some situations.
- **Woldo's MCI Video File Player**: Despite the fact that this is the oldest and most out-of-date video file player in this list, it can still be made to view the AVI files created by W2Anim in conjunction with FFmpeg. I like the user controls and the fact that the video can be viewed one frame at a time at superspeed in both forward and reverse directions. It's a useful program to have, despite its age and incompatibility with more modern video formats. It may be hard to find a copy of this program online.

SUPPORT

Documentation

This User Manual is the only official documentation for The W2 Animator. It will be continuously updated as time allows and as new features are added.

Updates

The most recent version of The W2 Animator can be found on its GitHub page at https://github.com/sarounds/w2anim/releases/latest. For a list of all of the substantial changes to the program features over time; see the change log at https://github.com/sarounds/w2anim/blob/main/CHANGELOG.md.

Questions and Bug Reports

If you have questions or wish to report a problem with The W2 Animator, please send me an email at roundsstewart@gmail.com. I will try to respond in a timely manner. Alternatively, you can ask questions or report problems directly on the GitHub page for The W2 Animator at https://github.com/sarounds/w2anim.

Supporting W2 Tool Development

Developing The W2 Animator as a data visualization tool has been a hobby and obsession, and I am happy to make it available for free to the W2 user community. Although this software is absolutely free of charge, it is my hope that some users of The W2 Animator, perhaps particularly those who may be using it as part of a business, will choose to independently support higher education in some fashion. Two worthy funds that might be considered are:

- *The CE-QUAL-W2 Model Development Fund (#8610011)* at the Portland State University Foundation, and
- *The Stewart Rounds & Bernadine Bonn Scholarship Fund* at the Oregon State University Foundation.

AUTHORS AND ACKNOWLEDGMENTS

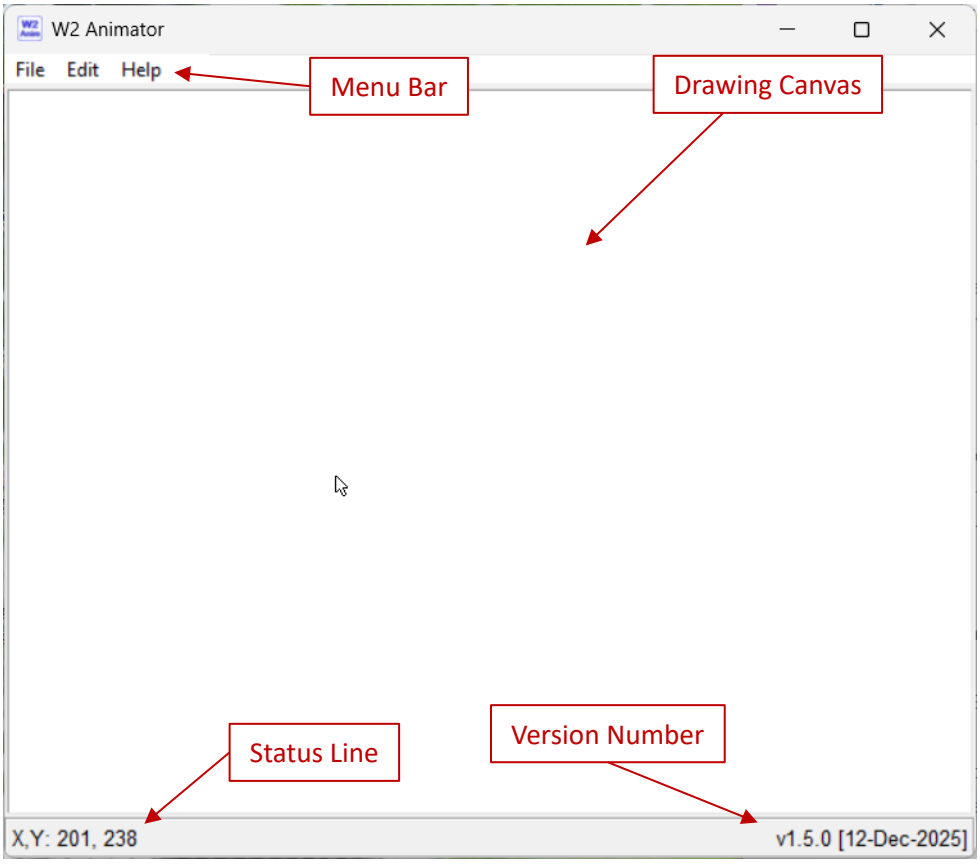
All development on The W2 Animator up to this point has been done by the primary author, Stewart Rounds. The author appreciates all of the work on the Perl base code and various Perl modules by the Perl community. The author also appreciates the pre-release testing done on W2Anim by Laurel Stratton Garvin (Oregon Water Resources Department), Annett Sullivan (U.S. Geological Survey), Scott Wells and Zhonglong Zhang (Portland State University), and Bernadel Garstecki (City of Portland), as well as suggestions submitted by later users.

The author also acknowledges and is thankful to those who have developed useful color schemes that are applied in this program. Several of the color schemes used in The W2 Animator were developed by, or described by, Kenneth Moreland. Seven of the perceptually uniform color schemes are part of the Scientific Colour Maps package produced by Fabio Crameri. All color schemes used in The W2 Animator are free for use and redistribution, and their known developers or copyright holders and licenses are listed here:

- **CoolWarm**: Developed by Kenneth Moreland (public domain; CC0 creative commons)
- **Viridis**: Developed by Eric Firing (public domain; CC0 creative commons)
- **Plasma**: Developed by Stefan van der Walt and Nathaniel Smith (public domain; CC0 creative commons)
- **Inferno**: Developed by Stefan van der Walt and Nathaniel Smith (public domain; CC0 creative commons)
- **BlackBody**: Developer unknown; scheme has been in use for decades (no known claims of intellectual property)
- **Batlow:** Developed and copyrighted by Fabio Crameri (MIT license)
- **Bam:** Developed and copyrighted by Fabio Crameri (MIT license)
- **Cork:** Developed and copyrighted by Fabio Crameri (MIT license)
- **Roma:** Developed and copyrighted by Fabio Crameri (MIT license)
- **Vik:** Developed and copyrighted by Fabio Crameri (MIT license)
- **Oslo:** Developed and copyrighted by Fabio Crameri (MIT license)
- **GrayC:** Developed and copyrighted by Fabio Crameri (MIT license)
- **Kindlmann**: Developed by Kindlmann, Reinhard, and Creem (no known claims of intellectual property)
- **Extended Kindlmann**: Based on scheme developed by Kindlmann, Reinhard, and Creem (no known claims of intellectual property)
- **Turbo**: Copyrighted by Google, LLC. (Apache license, version 2.0)
- **Jet**: Developer unknown. Used in matplotlib. (matplotlib BSD-compatible license)
- **CubeYF**: Developed by Matteo Niccoli (free use and redistribution)
- **Cube1**: Developed by Matteo Niccoli (free use and redistribution)

THE DRAWING CANVAS AND OBJECT DEFAULTS

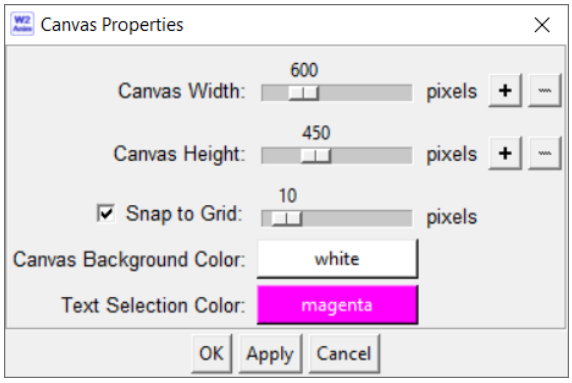
All graphs and annotations in The W2 Animator are drawn or placed on a “drawing canvas” where the location, size, and characteristics of each object are controlled by the user. This approach allows for interactive and efficient generation of visualizations. When first initialized, the W2Anim screen looks something like this:



The status line is used by W2Anim to provide status messages, instructional prompts, and location and size information. In the example above, the status line is showing the X and Y location of the mouse cursor on the drawing canvas in units of pixels, where the upper left of the drawing canvas is the (0,0) point. A canvas that is 600 pixels wide has X pixel coordinates that range from 0 to 599.

The main W2Anim window containing the drawing canvas can be resized by grabbing a window edge or corner with the mouse (hold down the left mouse button) and dragging that edge or corner. Making the window smaller will cause scroll bars to appear. The main window cannot be made larger than the drawing canvas. The size of the drawing canvas is not altered by changing the size of the main window; rather, resizing the window in some cases just makes it easier to fit a visualization on the screen, or makes it easier to work on a large visualization when the user is, for example, using a smaller screen temporarily. The main window cannot be larger than the current screen size, but the drawing canvas can be large (thousands of pixels) in either width or height. A maximum of 20,000 pixels in width or height is imposed by W2Anim, but hopefully no user will ever need so large a canvas.

CANVAS PROPERTIES

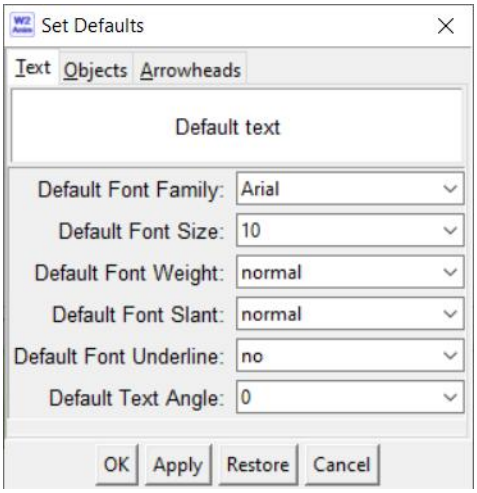


The properties of the drawing canvas can be changed by the user. A Canvas Properties menu (seen at right) is accessed either through the menu bar (Edit/Preferences/Canvas Props) or by right-clicking (or typing Alt-p) while hovering over the canvas and selecting Canvas Props from the pop-up menu.

The maximum canvas width and height are derived from the size of the user's screen. To allow canvas sizes that exceed the screen size, click the + button to expand the scale of the slider. The *Snap to Grid* option is useful because it can facilitate the alignment of objects and graphs when they are first placed on the canvas, or when aligning objects later. By default, the canvas background is white.

When the mouse cursor is hovered over an object on the drawing canvas, W2Anim displays not only the X,Y position of the mouse cursor in the status line, but also the object type. To show that the object under the mouse cursor is ready for selection or editing, the object will be highlighted in some fashion using the "Text Selection Color." For a text object, the text temporarily assumes the selection color. For graph objects, the graph frame temporarily assumes the selection color and its thickness is temporarily incremented by one unit. For shape objects (lines, circles, etc.), the outline of the shape is incremented but no color change occurs. For images, a bounding box is shown.

PROGRAM DEFAULTS

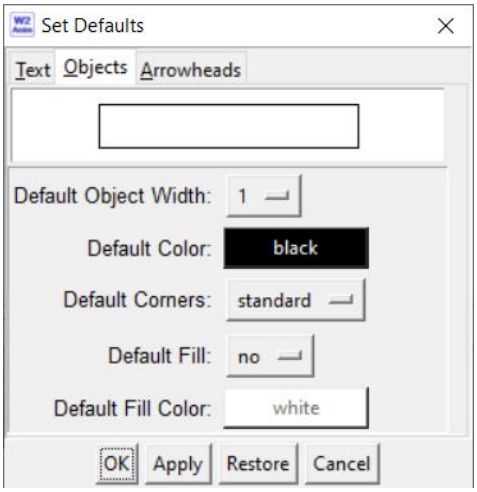


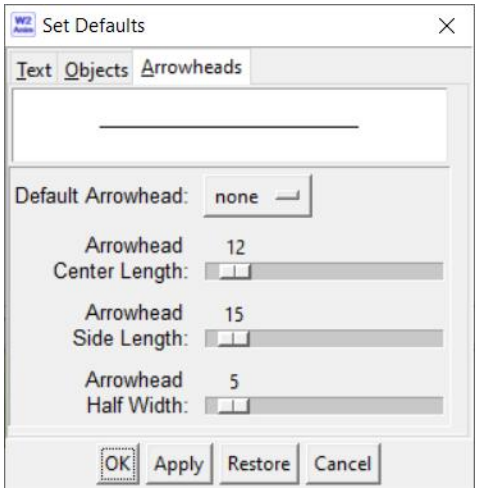
Default properties for text annotations and drawing objects may be set by the user through the menu bar (Edit/Preferences/Defaults) or by right-clicking on the drawing canvas and selecting Defaults.

The default properties of several types of objects may be set through this menu. The user may select any of the Text, Objects, or Arrowheads tabs at the top of the menu, and then set their defaults as desired.

For text, any font that is installed on the user's computer should be available in the drop-down list of the default font family. The preview area at the top of the menu will display the results of the user's choices. Existing text objects will not be affected by a change in the default text properties, but new text objects and the text in new graph objects will use the default font. Choosing "Restore" will reset the defaults back to those used by W2Anim at startup.

For drawing objects such as lines, circles, rectangles, and so forth, some of their default properties may be set from the Objects tab of the Defaults menu. A preview of the object properties is provided at the top of the menu. Line width is an integer value in pixels. Corners for rectangles and diamonds can be standard or rounded; the exact shape of the rounded corner is fixed by the toolkit and cannot be changed. For lines, arrowheads can be set by default for neither, both, or the start or end of the line. The exact shape of the arrowhead is set through a combination of the center length, side length, and half width. Play with those parameters to see what is possible. Note that these are simply system defaults for the next drawing objects that are created. Each object also offers an independent means of editing its properties.





W2ANIM INITIALIZATION FILE

By default, The W2 Animator will begin with canvas dimensions of 600x450 pixels (width x height), a white canvas background, a magenta text selection color, a grid spacing of 10 pixels, and *Snap to Grid* disabled. These program defaults can be overridden through the use of an initialization file named w2anim.ini. Place this file either in the directory where the W2Anim scripts are located, or in the folder from which the W2Anim program is started. If a w2anim.ini file exists in the folder from which W2Anim is started, the program will read that file. Lacking an initialization file there, W2Anim will look for a w2anim.ini file in the directory where the W2Anim scripts are located. If no initialization file exists in those two locations, the program will fall back to its defaults.

A sample w2anim.ini file should exist in the directory where the W2Anim scripts are located, and that file can be copied and/or edited. The format of the key words and values must be followed if the initialization is to work properly. The proper format for a w2anim.ini file is shown below.

```
# W2 Animator initialization file, version 1.5.0 [12-Dec-2025]

==== CANVAS ====
  width:     1200
  height:    600
  color:     white
  text_slct: magenta
  snap2grid: 1
  grid_spac: 10
==== END CANVAS ====

==== FONT DEFAULTS ====
  family:    Arial Narrow
  f_size:    10
  f_weight:  normal
  f_slant:   normal
  f_under:   no
  f_angle:   0
==== END FONT DEFAULTS ====

==== OBJECT DEFAULTS ====
  ob_width:  1
  ob_color:  black
  ob_corner: standard
  ob_fill:   no
  ob_fcolor: white
==== END OBJECT DEFAULTS ====

==== ARROW DEFAULTS ====
  arrow:     none
  center:    12
  side:      15
  halfwidth: 5
==== END ARROW DEFAULTS ====

==== CONFIG ====
  tmp_path:  .\tmp
  gr_path:
  ffmp_path:
==== END CONFIG ====
```

In this case, canvas dimensions of 1200x600 pixels are specified, the canvas background color is white, the text selection color is magenta, the grid spacing is 10 pixels, and *Snap to Grid* is enabled (1=enabled, 0=disabled). The canvas width must be a minimum of 200 pixels, and the canvas height must be at least 150 pixels. Colors may be specified with the format #RRGGBB, where RR, GG, and BB are hex codes for red, green, and blue; for example, the color magenta is identical to #FF00FF. Unrecognized color names will be ignored.

Defaults for text objects are in the next section. The font family entry will be ignored if it does not exist. The default font family will be used as the initial font for text in graph objects. The font size for text objects is restricted to a range of 5-32. The font weight must be “normal” or “bold”. The font slant must be “normal” or “italic”. The font underline must be “yes” or “no”. The font angle must be in the range 0-359.

For object defaults, the width must be in the range 1-10. The corner entry must be “standard” or “rounded”. The object fill must be “yes” or “no”.

The arrow setting must be “none” or “start” or “end” or “both”. The arrowhead center length must be in the range 6-100. The arrowhead side length must be in the range 10-100. The arrowhead half width must be in the range 3-40.

The default temporary space in this example is located in a “tmp” folder off of the directory where the W2Anim scripts reside. An absolute or relative path may be used.

You can specify the path to the helper programs with the gr_path and ffmp_path entries. If the Ghostscript program resides at “C:\Program Files\gs\gs10.06.0\bin\gswin64c.exe” then that is the entry that should be in the w2anim.ini file after the “gr_path:” key word. Similarly, if the FFmpeg program resides on the local system at “C:\Program Files\FFmpeg\bin\ffmpeg.exe” then that is the entry that should follow the “ffmp_path:” key word in the w2anim.ini file. Do not include any quotation marks.

To turn off the use of Ghostscript or FFmpeg, simply enter the word “off” (without the quotation marks) in the w2anim.ini file instead of specifying the path to either of these programs. If no path is specified and the entry is left blank as in the example above, then W2Anim will do its best to find the helper programs upon initialization, and will notify the user if the helper programs are not found.

Menus, Autosave, Undo, and Recent Files

Menus

The W2 Animator interacts with users through a variety of menus. Most of the functions are available through the menu bar at the top left of the main window (File, Edit, Help). New objects and graphs can be created through the Edit/Add Object, Edit/Add Graph, and Edit/Add W2 Graph menu options, or by right-clicking on the drawing canvas and choosing similar options. Opening and saving W2Anim projects is done through options in the File menu. Certain configurations and preferences can be set through the Help/Configuration menu and the Edit/Preferences menu. Explore these menus and read this User Manual to learn more details about this program.

Autosave

Starting with version 1.3.0, W2Anim includes an autosave feature that is turned off by default. To turn on the autosave feature, choose an autosave frequency of 1, 2, 3, 4, 5, 10, or 20 minutes from the File/Autosave menu. Each instance of W2Anim will be associated with two unique autosave file names, using the convention "_autosaveXXXXX.w2a" and "_autosaveXXXXX_2.w2a" where the XXXXX is a random number generated when the program starts. Autosave files may be found in the temporary directory, which is shown or set under the Help/Configure menu. Changing the location of the temporary directory will cause any previously generated autosave files for the current instance of W2Anim to be rewritten and moved to the new directory.

The first autosave file (_autosaveXXXXX.w2a) is generated whenever the autosave routine is scheduled to run, or whenever W2Anim needs to determine whether the current project might need to be saved before exiting, before starting a new project, or before opening a saved project. When the first autosave file is generated, it is compared to the last-saved autosave file (if present) to determine whether any changes have been made. If changes are detected, then the previous (different) autosave file is renamed as the second autosave file. In this way, the two most-recent distinct and different autosaved files are available to the user.

The user may revert to the first autosave file (if it exists) by choosing the "Revert, recent" option from the File/Autosave menu. Alternatively, the user may revert to the second (older) autosave file (if it exists) by choosing the "Revert, previous" option from the File/Autosave menu. Either autosave file also may be loaded by simply opening the appropriate file from the temporary directory. Opening an autosave file or reverting to an autosaved file will not cause any autosaved files to be modified or renamed.

Any autosave files from the current instance of W2Anim will be deleted if W2Anim exits normally. If W2Anim should terminate abnormally, then any autosave files hopefully will be left intact and could be opened later. Any stale autosave files in the temporary directory will be removed upon program startup if they are more than 5 days old. Scheduled autosave operations are not allowed during animation, during the export of output, while saving a file, or while opening a previously saved file.

Undo and Related Safeguards

W2Anim does not have an "undo" feature, but judicious use of the autosave feature can provide a means of recovering from an unintentional change by reverting back to a previous version of the working project. If the user anticipates a need for this sort of safeguard, then the autosave feature should probably be turned on with a frequent interval.

Starting with version 1.3.0, W2Anim will check to see if any unsaved or unmodified objects are on the drawing canvas whenever the user chooses to exit or start a new project or load a previously saved project. If the checks indicate that unsaved objects are present or object properties have been modified, then the user will be asked if they would like to save the current project before moving forward with the indicated operation.

Similarly, if an autosaved project file is loaded, W2Anim will not retain the autosaved file name for the project and the user will be reminded that it would be wise to save the project under a new file name. In this way, the user may be able to avoid some of the easiest ways to unintentionally lose unsaved work.

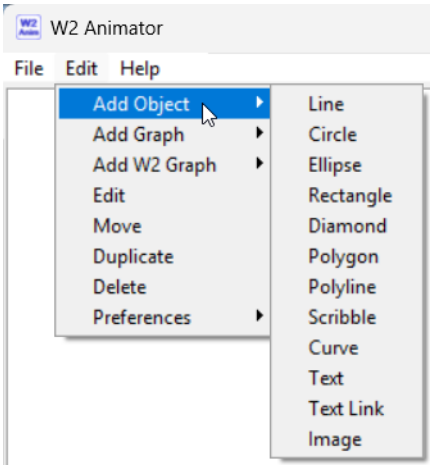
Note that when new features are added to W2Anim, sometimes those features require new entries to the W2Anim saved project files. This means that when a user loads an older W2Anim project file and later wants to exit or start a new project or load a different project file, W2Anim may tell the user that the current project has unsaved changes even when the user made no changes. This is because W2Anim would be adding new lines to the old project file to save some new settings. Saving older project files using the most-recent version of W2Anim will ensure that the most-recent settings associated with new features are saved.

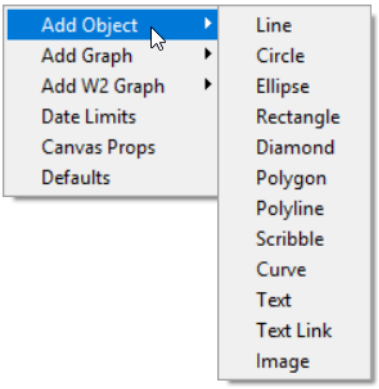
Recent File List

Starting with version 1.3.0, the File menu includes a Recent submenu that allows a user to quickly open one of up to fifteen recently opened W2Anim project files. The last entry in the File/Recent menu, if recent files are listed, is an option to clear the list. Recently opened W2Anim project file names are listed in the order in which they were recently opened (with no duplicates), and saved in the "w2anim_recent.txt" file that is stored in the W2Anim script home directory.

DRAWING OBJECTS

New text annotations, drawing objects, and images may be added to the drawing canvas either through the Edit entry of the menu bar (Edit/Add Object), or by right-clicking (or typing Alt-p) while hovering on the canvas, and then selecting the Add Object option.





ADDING NEW OBJECTS

Lines

When adding a new line, the mouse cursor will change to a crosshair and wait for the user to designate the starting point of the line via a left mouse click. Note that the user can monitor the X,Y location of the mouse cursor on the status line. If *Snap to Grid* is turned on, a small magenta dot will be displayed on the screen at the nearest grid location. After the first click, the status line will show the coordinates of both the starting and potential ending points of the line. A strictly horizontal or vertical line can be forced by holding down the Shift key. A second left click of the mouse ends the line, whereas a right click will abort the creation of the line. If the default line properties include an arrowhead, that feature will be present in the new line.

Circles and Ellipses

When adding a new circle or ellipse, the mouse cursor will change to a crosshair and wait for the user to designate an anchor point for its bounding box. The user can monitor the X,Y location of the mouse cursor with a glance at the status line. If *Snap to Grid* is turned on, a small magenta dot will be displayed on the screen at the nearest grid location. After setting the object's anchor point with a left mouse click, the user moves the mouse to see a circle or ellipse being drawn within a bounding box covered by the anchor point and the mouse cursor position at the opposite corner. Regardless of the *Snap to Grid* setting, the anchor point will be temporarily displayed with a magenta dot. An ellipse can be forced to be a circle by holding down the Shift key. As the mouse is moved, the status line shows the X,Y position of the mouse as well as the width and height of the object being created. Clicking the left mouse button sets the final shape of the circle or ellipse, whereas a right click will abort the creation of the object. New circles and ellipses will have the default line width, outline color, and fill properties, all of which may be edited later.

Rectangles and Diamonds

When adding a rectangle or diamond, the mouse cursor will change to a crosshair and wait for the user to designate an anchor point for its bounding box. The user can monitor the X,Y location of the mouse cursor with a glance at the status line. If *Snap to Grid* is turned on, a small magenta dot will be displayed on the screen at the nearest grid location. After setting the object's anchor point with a left mouse click, the user moves the mouse to see a rectangle or diamond being drawn within a bounding box covered by the anchor point and the

mouse cursor position at the opposite corner. Of course, the bounding box for a rectangle is the rectangle itself. Regardless of the *Snap to Grid* setting, the anchor point will be temporarily displayed with a magenta dot. A rectangle can be forced to be a square by holding down the Shift key; similarly, a diamond will be forced to have equal-length sides if the Shift key is depressed. As the mouse is moved, the status line shows the X,Y position of the mouse as well as the width and height of the object being created. Clicking the left mouse button sets the final shape of the rectangle or diamond, whereas a right click will abort the creation of the object. New rectangles and diamonds will have the default line width, outline color, corners, and fill properties, all of which may be edited later.

Polygons and Polylines

A polygon is a closed shape with at least three sides, whereas a polyline is simply a line with more than one segment and at least three points. Both polygons and polylines are created in a similar way. When adding a polygon or a polyline, the mouse cursor will change to a crosshair and wait for the user to designate the first point of the object. The user can monitor the X,Y location of the mouse cursor with a glance at the status line. If *Snap to Grid* is turned on, a small magenta dot will be displayed on the screen at the nearest grid location. After setting the object's anchor point with a left mouse click, the user moves the mouse to see a line connected between the anchor point and the mouse cursor location. Regardless of the *Snap to Grid* setting, the anchor point will be temporarily displayed with a magenta dot. Holding down the Shift key will force the current line segment of the polygon or polyline to be exactly horizontal or vertical. The status line will continue to show the X,Y position of the mouse cursor, as influenced by the *Snap to Grid* setting.

Points are added to the polygon or polyline by clicking the left mouse button. For a polyline with an arrowhead at its end, the arrowhead will be transferred to the end of the line as new points are added. When the user wishes to add the final point of the polygon or polyline, the left mouse button should be double-clicked to complete the object. Clicking the right mouse button at any point in the process will abort the creation of the object. The new object will have the default line width and line color. Polygons will be given the default fill and fill color, whereas polylines will be given the default arrowhead properties.

Scribbles

A scribble is essentially a polyline that is created by recording the path that the cursor makes while the left mouse button is held down, rather than the more-intentional setting of point coordinates on a polyline through sequential clicks of the left mouse button. As with a polyline, the mouse cursor will change to a crosshair and wait for the user to designate the beginning point of the scribble. A single scribble is completed while the left mouse button is held down. Releasing the left mouse button ends the scribble and makes the canvas ready to start the next scribble. The user must exit "scribble mode" by clicking the right mouse button. In this way, successive objects or quick annotations can be made with the mouse or a stylus on a touch screen.

When each scribble is ended, the set of points is filtered to remove any redundant point locations that are co-linear. Still, the number of points is likely to be large. New scribbles will have the default line width, line color, and arrowhead characteristics.

Curves

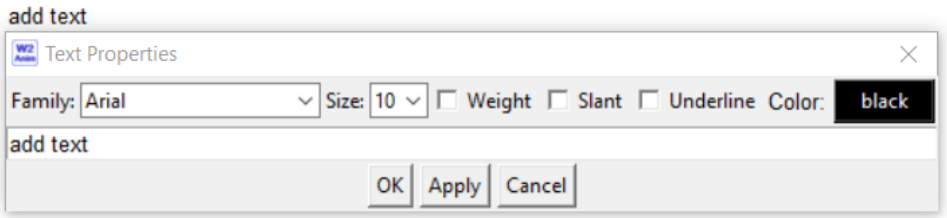
All curve objects in W2Anim are composed of a connected sequence of Bézier curves, which are smooth continuous curves commonly used to depict arcs, curves, or complex shapes in graphics programs. When adding a curve object, the mouse cursor will change to a crosshair and wait for the user to designate the location of the first point on the curve. The user can monitor the X,Y location of the mouse cursor with a glance at the status line. If *Snap to Grid* is turned on, a small magenta dot will be displayed on the screen at the nearest grid location. After setting the curve's anchor point with a left mouse click, the user moves the mouse to a new location for the next point on the curve, which will correspond to an endpoint of a Bézier curve.

Regardless of the *Snap to Grid* setting, the anchor point will be temporarily displayed with a magenta dot. The status line will continue to show the X,Y position of the mouse cursor, as influenced by the *Snap to Grid* setting.

Bézier curve endpoints are added to the curve object with each click of the left mouse button at the desired locations. By default, the first and last Bézier endpoints are designated as "corner" points, and all other Bézier endpoints are designated as "symmetric" points. As endpoints are added with a click of the left mouse button, the designation of the point type can be changed to "corner" by holding down the Shift key while clicking the left mouse button. More details about endpoint types can be found later in this user manual (section Editing Curves). A curve object is completed with a double left-click of the mouse. The curve can be abandoned by clicking the right mouse button.

Text

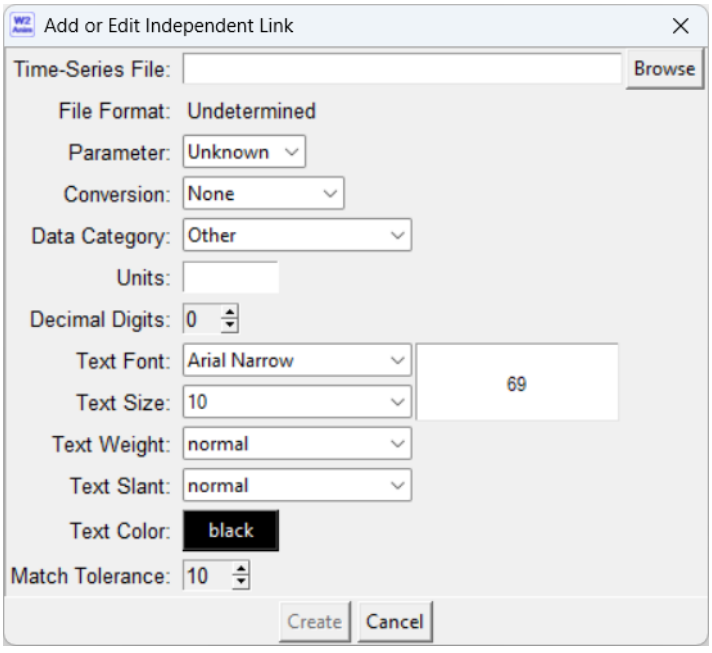
When adding a text object, the mouse cursor changes to the text cursor and waits for the user to choose an anchor point. By default, the anchor for text objects will be at the left side, midway between top and bottom (this is called west, or "w"). The user can monitor the X,Y location of the mouse cursor with a glance at the status line. If *Snap to Grid* is turned on, a small magenta dot will be displayed on the screen at the nearest grid location. After setting the text anchor point with a left mouse click, the text "add text" will be displayed on the drawing canvas in the default font, size, color, weight, slant, underline, and angle.



At this point, the text may be changed in the Text Properties window and its attributes can be changed. Multi-line text is not allowed at this time. Clicking OK or Apply will apply the changes to the text object. The OK button will also remove the menu, whereas the Apply button will retain the menu. Clicking Cancel will abort the creation of the new text object.

Text Links

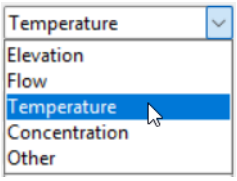
A text link is similar to a text object, but the text itself is drawn from values found in an independent time-series file (not linked to any animated graph), and that text changes as the objects on the drawing canvas are animated. The date/time values in the external time-series file do not affect the master date/times for the animation of W2Anim graphs; when the current date/time for the animation is matched by a date/time in the external file (plus or minus a user-defined tolerance), that value will be displayed in the text link as an W2Anim animation proceeds. This option is only valid and available after at least one animated graph has been added to the drawing canvas.



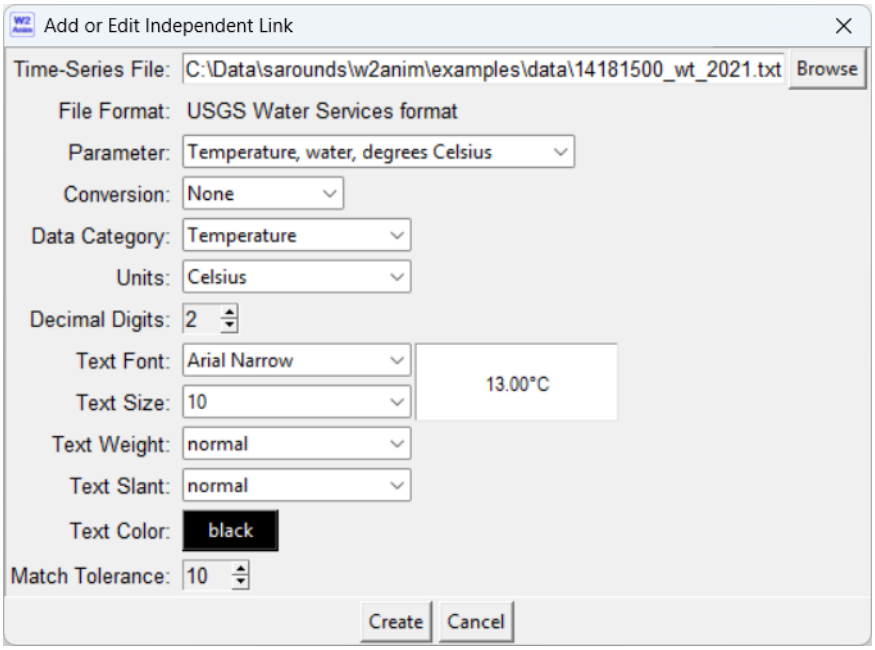
When adding a new text link, the menu at the right is shown. The first step is to designate the time-series file of interest by clicking on the

Browse button and choosing an appropriate file. Once the file is chosen, the file format is determined and the available parameters are shown, as in the menu below and to the right. See the Recognized File Types section of this user manual for a list of file formats that are recognized by W2Anim.

The user next should choose the parameter and its units. Unit choices are facilitated by choosing a Data Category as shown in this drop-down list:



In this example, the water-temperature values will be displayed with two digits after the decimal, as shown in the preview box of the menu. Once created, the user must then position the text link on the drawing canvas.

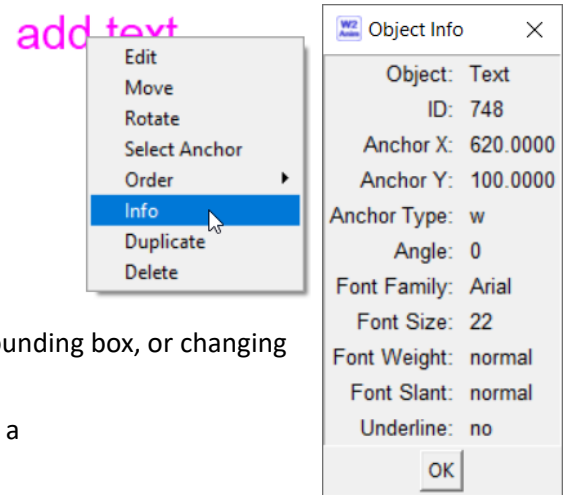


Images

When adding an image, W2Anim first asks the user to choose an image file. Many image formats are valid, including PNG, GIF, JPG, BMP, PPM, TGA, and TIFF. After the image file is chosen, the image will be imported to the center of the drawing canvas and any mouse movement will move the image on the canvas. The status line shows the X,Y location of the anchor point (the upper left corner, by default) and the image's bounding box coordinates. A single left click will place the image at the current coordinates, whereas a right click of the mouse will abort the import of the image.

If the image is too large for the drawing canvas, such as might be the case for an imported photograph, the image will be scaled down until it fits on the canvas before showing its initial placement. The image may be resized and cropped after it is imported and placed on the canvas.

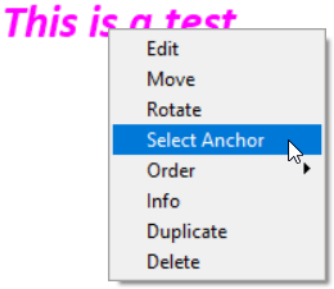
OBJECT ANCHORS



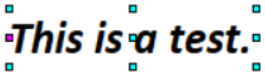
Every object on the drawing canvas has an X,Y anchor position in pixels, where the (0,0) position is at the upper left corner of the canvas. The anchor position is used during move, resize, and rotate operations, and can be used in alignment requests. The current anchor position can be found by hovering the mouse over the object of interest, then right-clicking the mouse and selecting the Info option. Remember that the status line will show the type of object that the mouse is over, and that object will reveal that it is the "selected" object by increasing its outline width, changing its text color, showing a bounding box, or changing the color of its graph frame.

Anchor types for text and image objects are named according to a compass-like naming system:

- w = west (left side, midpoint vertically)
- n = north (top side, midpoint horizontally)
- e = east (right side, midpoint vertically)
- s = south (bottom side, midpoint horizontally)
- nw = northwest (upper left corner)
- ne = northeast (upper right corner)
- se = southeast (lower right corner)
- sw = southwest (lower left corner)
- c = center (midpoint horizontally and vertically)



Object anchors can be chosen from a selection of possible anchors by right-clicking on the object of interest and choosing the Select Anchor option, as shown at the right.

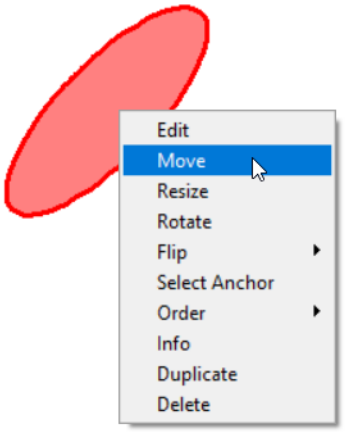


The text object example shown at the right has a "w" or west anchor, as designated by the magenta-filled square at the west position. That example shows what is displayed on the screen when the user chooses the Select Anchor option for this unrotated text object. The user may choose a new anchor by hovering the mouse cursor over any of the cyan-colored anchor points and clicking the left mouse button. Alternatively, the user may exit "select anchor mode" by right-clicking on the mouse.

Lines have potential anchor points only at either end and at their midpoint. Circles, ellipses, rectangles, diamonds, polygons, polylines, scribbles, and curves have potential anchor points at the corners and midpoints of their bounding box as well as in their geometric center. The bounding box used for potential anchor points includes any rotation angle that has been applied to the object. Polygons, polylines, scribbles, and curves also allow anchor points to be chosen at the location of any vertex/point and also at the center point of the smallest circle that bounds all of the points of the object. These various anchor points may be called "point" or "midpoint" or "corner" or "center" or "center_rot" (center of rotation). The exact coordinates are available from the Info option.

MANIPULATING DRAWING OBJECTS

Moving Objects

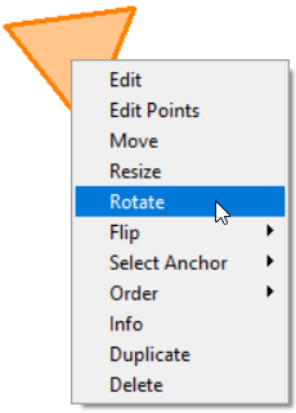


Any object on the drawing canvas can be moved by hovering over it so that it is the "current" object, then right-clicking the mouse (or typing Alt-p) and selecting the Move option. Alternatively, select Edit/Move from the menu bar and then select the item of interest. Once the Move option is selected, the object will move on the canvas as the mouse is moved. If *Snap to Grid* is turned on, the anchor point of the object will be shown with a magenta point. The status line will display the X,Y location of the anchor as well as the coordinates of the object's bounding box. Clicking the left mouse button will confirm the move, whereas clicking the right mouse button will cancel the move.

Note that W2Anim does not allow objects to be moved off of the drawing canvas. Valid moves are only those that cause the entire object to remain on the canvas, even if part of the object was initially not on the canvas. The anchor point is allowed to be moved off of the canvas, as long as the object itself remains on the canvas.

An object also can be moved by selecting it with a left mouse click and then moving it with the arrow keys.

Rotating Objects

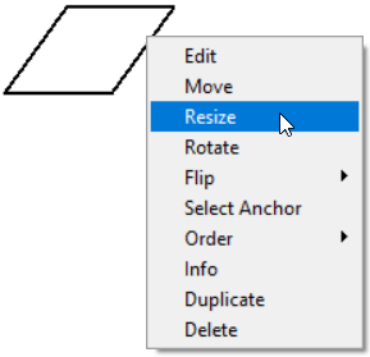


Most drawing objects (ellipses, rectangles, diamonds, polygons, polylines, scribbles, curves, text, and images) can be rotated in W2Anim. It is pointless to try to rotate a circle. W2Anim does not allow single lines to be rotated, but they can be resized, which essentially allows for a different orientation. Graphs in W2Anim are objects, but not included in the list of drawing objects, and are not allowed to be rotated.

To rotate an object, hover the mouse over it, then right click (or type Alt-p) and select the Rotate option. Images provide three choices under the Rotate option: Clockwise 90, Counterclockwise 90, and Free Rotate. If the current rotation angle for an image is nonzero, then a fourth option is presented: To Zero. All rotations are implemented around the object's current anchor point, which will be highlighted with a magenta point when the rotation option is chosen.

In free-rotation mode, as the user moves the mouse on the canvas, the object is rotated to correspond to the angle between the anchor point and the mouse cursor location. The rotation angle is shown in the status line, and is restricted to integer values. Clicking the left mouse button confirms the current rotation, whereas clicking the right mouse button will cancel the current rotation and revert to the previous rotation.

Resizing Objects



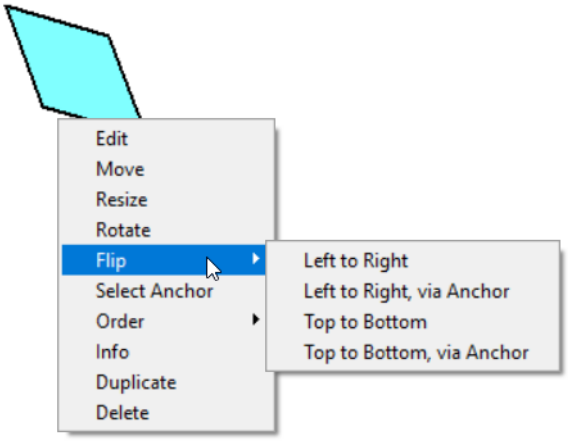
All objects on the drawing canvas in W2Anim, including graphs, can be resized. For text objects, resizing is just a matter of changing the font size, which is implemented under its Edit option. Resizing a line is accomplished by moving the non-anchor point of the line, which redraws the entire line. Resizing an object will always retain the existing anchor point. Resizing an image will retain its existing aspect ratio, after accounting for any cropping. Resizing an object also retains its existing angle of rotation, unless the user removes that rotation.

To resize an object, hover the mouse over it, then right click (or type Alt-p) and select the Resize option. Moving the mouse will cause the object or its bounding box (or the graph frame) to be temporarily resized on the canvas. Holding the Shift key down while resizing with the mouse will cause most objects to have a bounding box with an identical width and height, after accounting for rotation; so, ellipses would look like circles, rectangles and diamonds would look like squares, and so forth. For a line, holding down the Shift key causes the line to be exactly horizontal or vertical. The Shift key has no effect on images, whose aspect ratios (after any cropping) are preserved.

Holding the Ctrl key down while resizing with the mouse will cause any original nonzero rotation angle to revert to zero. The user may also combine the Shift and Ctrl keys, and the effects combine as one would expect.

If an image object has been resized or cropped or flipped or rotated, a Revert option will become available from the pop-up menu. Choosing that option will revert the image to its original size, uncropped and unrotated and unflipped, but honoring its current anchor point.

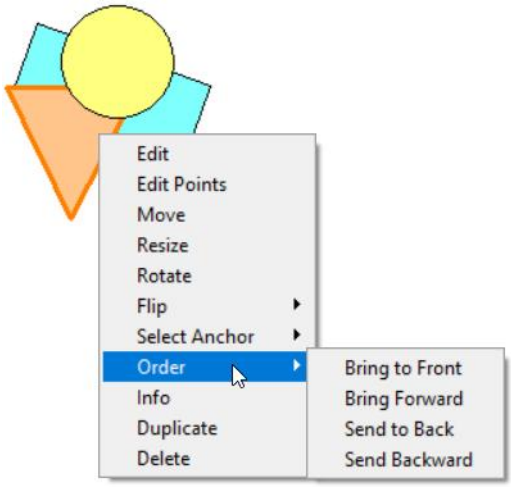
Flipping Objects



W2Anim allows lines, ellipses, rectangles, diamonds, polygons, polylines, scribbles, curves, and images to be flipped vertically or horizontally. The action can be centered on the object's center (Left to Right, Top to Bottom) or relative to its anchor point (Left to Right, via Anchor; Top to Bottom, via Anchor). It is pointless to flip a circle, and W2Anim does not allow text or graphs to be flipped. Note that flipping an object may affect its rotation angle and anchor point designation.

If an image object has been flipped, a Revert option will become available from the pop-up menu (right-click or Alt-p while hovering on the object). Choosing that option will revert the image to its original size, uncropped and unrotated and unflipped, but honoring its current anchor point. Similarly, an Original option will appear in the Flip menu, and choosing that option will cause the image to be restored to its non-flipped state.

Changing the Drawing Order



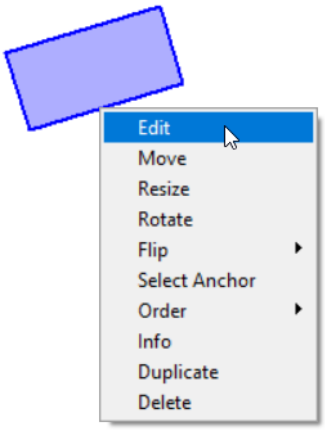
Each object on the drawing canvas is drawn in a specific order, such that objects drawn later in the list are placed in front of earlier objects if the objects overlap. The user can move objects forward and backward in the list. Simply hover the mouse over the object of interest, then right click (or type Alt-p), select the Order option, then the desired order-change option:

- Bring to Front – puts object in front of all other objects
- Bring Forward – move object up one place in drawing order
- Send to Back – pushes object behind all other objects
- Send Backward – move object back one spot in drawing order

If an object is already being drawn last, then the Bring to Front and Bring Forward options will be inactivated. Similarly, if an object is first in the drawing list, the Send to Back and Send Backward options will be inactivated.

Editing Object Properties

The appearance of objects other than images on the canvas can be modified by editing their properties. Start by hovering over the object of interest so that it is the "current" object, then right-click the mouse (or type Alt-p) and select the Edit option. Alternatively, select Edit/Edit from the menu bar and then left-click on the object of interest. Each object type will present a different Object Properties pop-up menu. The following properties may be edited for each object type:

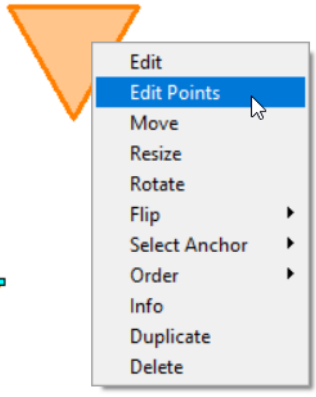


Object Type	Line Width	Line Color	Arrowheads	Arrowhead Center Length	Arrowhead Side Length	Arrowhead Half Width	Fill	Fill Color	Corners	Font Family	Font Size	Font Weight	Font Slant	Font Underline	Font Color
Line	✓	✓	✓	✓	✓	✓									
Circle	✓	✓					✓	✓							
Ellipse	✓	✓					✓	✓							
Rectangle	✓	✓					✓	✓	✓						
Diamond	✓	✓					✓	✓	✓						
Polygon	✓	✓					✓	✓							
Polyline	✓	✓	✓	✓	✓	✓									
Scribble	✓	✓	✓	✓	✓	✓									
Open curve	✓	✓	✓	✓	✓	✓									
Closed curve	✓	✓					✓	✓							
Text										✓	✓	✓	✓	✓	✓

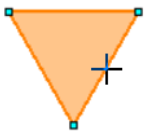
Graph objects have entirely different properties that can be edited, such as those for axes, titles, color schemes, and legends. These properties are described later, in the section on Graph Types.

Adding, Moving, and Deleting Points

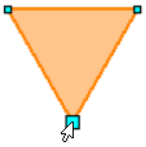
W2Anim allows the user to add, move, or delete points from polygons, polylines, scribbles, and curves. To begin that process, hover over the object of interest so that it is the "current" object, then right-click the mouse (or type Alt-p) and select the Edit Points option. In point-edit mode, each vertex of the polygon, each point on the polyline or scribble, and each Bézier endpoint on the curve will be highlighted with a small cyan-filled square. To exit point-edit mode, click the right mouse button on the canvas.



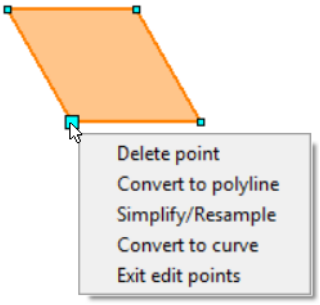
When in point-edit mode, hovering the mouse cursor over any of the lines (or outlines) connecting the points of the polyline, scribble, curve, or polygon changes the mouse cursor to a crosshair, which then allows a new point to be added via a click of the left mouse button. The status bar, in fact, should say "Left click to insert new point…" The newly added point may then be dragged to a new position by holding the left mouse button down while moving the mouse; release the left mouse button to leave the new point at that location.



Moving an existing point is as simple as hovering the mouse cursor over an existing point, holding down the left mouse button, and moving the mouse to drag the point to a new position. (Note that this is a change from versions prior to v1.5.0.) When hovering the mouse over an existing point, the status bar will prompt the user with the message “Left click and drag to move. Right click for menu…”

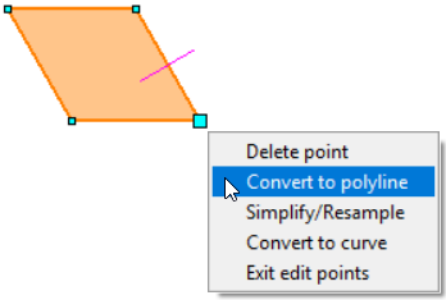


Deleting an existing point must be initiated by hovering the mouse cursor over the point of interest and clicking the right mouse button to bring up the object’s point-edit menu, as shown at the right. The options shown will be specific to the object type. For a polygon, a point cannot be deleted if only three vertices exist. Selecting the “Delete point” option with a left mouse click will delete the point, redraw the object, and remove the menu. Right-click on the canvas to exit point-edit mode, or left-click anywhere but on this menu to remove the menu and remain in point-edit mode.



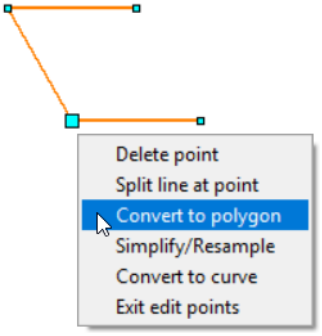
Converting Polygons to Polylines

Any polygon object can be converted to a polyline simply by breaking the outline between any two points. This action can be accomplished by first entering point-edit mode (select Edit Points from the right-click pop-up menu when hovering over a polygon), then hovering over any vertex point of the polygon, right-clicking the mouse and selecting the “Convert to polyline” option. When hovering over that menu option, a magenta line will appear between the two points where the outline of the polygon would be broken, as shown at the right. If that break location is not the desired location, then abort the conversion by left-clicking somewhere off of the menu. Select a different point and try again. Once the polygon has been converted to a polyline, the new object remains in point-edit mode. Note that the new polyline will temporarily retain information about the fill status and fill color of the parent polygon, but that information will not be saved with the polyline in the project file.

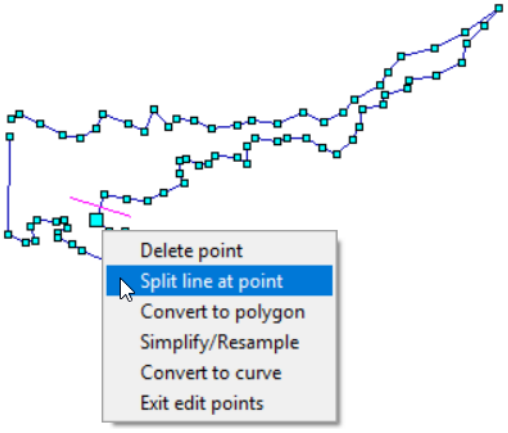


Converting Scribbles or Polylines to Polygons

A polyline or scribble object can be converted to a polygon by connecting the first point to the last point. This action can be accomplished by first entering point-edit mode (select Edit Points from the right-click pop-up menu when hovering over a polyline or scribble), then hovering over any point of the object, right-clicking to bring up the point-edit menu, and selecting the “Convert to polygon” option. This option can be selected from any point of the object. Once the polygon has been created, the new object remains in point-edit mode. Note that the new polygon will temporarily retain information about the arrowhead characteristics of the parent polyline or scribble, but that information will not be saved with the polygon in the project file.

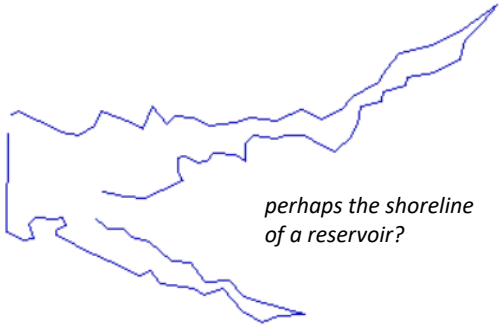


Splitting Polylines, Scribbles, and Curves

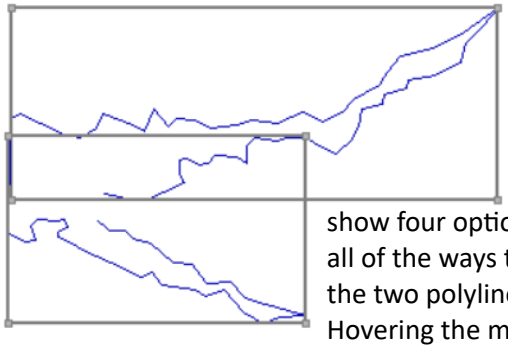


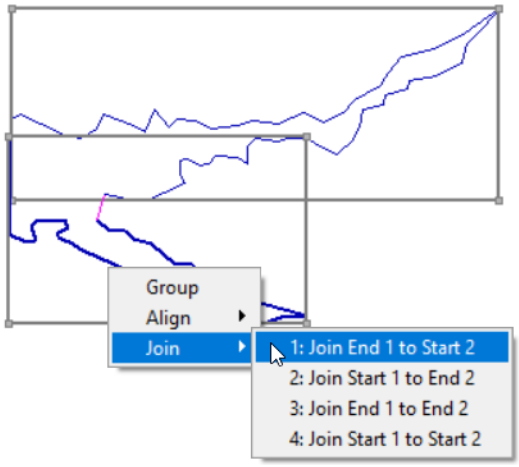
Many complex shapes can be created with polylines, scribbles, and curves. The process of creating such shapes is aided by the ability to split and join these objects. To split a single polyline, scribble, or curve into two such objects, first enter point-edit mode (select Edit Points from the right-click pop-up menu when hovering over a polyline, scribble, or curve), then hover over a point next to the intended split location and right-click to bring up the point-edit menu. Hovering the mouse over the "Split line at point" option will cause a short magenta line to appear between the selected point and an adjacent point, showing the location of the proposed break in the object (see illustration at the right). If that location is acceptable, click the left mouse button or the Enter key to split the line. If a different location is preferable, then left-click somewhere outside of the point-edit menu, select a different point and try again. After the object has been split, the part that includes the selected point will remain active in point-edit mode, and the other part will be a separate object of the same type and characteristics. Note that splitting polylines and scribbles is a simple matter of breaking the object between adjacent points. For curves, the location of the split line will become a new Bézier endpoint.

Joining Two Polylines, Scribbles, or Curves

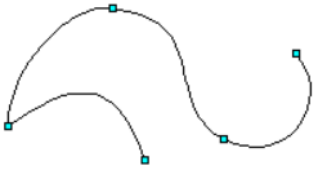


Two polylines, two scribbles, a polyline and a scribble, or two curves can be joined to create a single object of the same type. (Joining a polyline and a scribble will result in a scribble.) For example, the two polylines that were created from the split operation above can be joined again. The two polylines are shown at the right. They can be selected together by holding down the left mouse button and drawing a selection rectangle on the canvas around both of the objects. W2Anim will show bounding boxes in grey around each object to show that they have been selected, as shown at the left. To join the two objects, right-click over one of the objects (not its bounding box, but the object itself) to bring up a pop-up menu as shown to the right. The Join menu will show four options, corresponding to all of the ways that the endpoints of the two polylines can be connected. Hovering the mouse over each menu option will cause a magenta "join line" to appear as a preview. Object 1 is the object from which the pop-up menu was initiated. In this case, the first join option will produce the desired result, and the two polylines will be joined as in the preview once that option is selected with a left mouse click or by hitting the Enter key. After the join operation is completed, the selections are cleared and the joined object is redrawn.



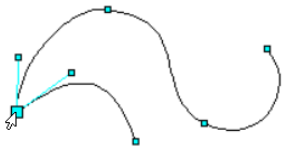


Editing Curves

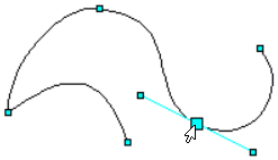


Curve objects are composed of a connected sequence of Bézier curves, and are a powerful means of constructing smooth continuous shapes. Consider the example shown at the right. That curve object is composed of four cubic Bézier curves, where each Bézier curve is located between adjacent pairs of the five endpoints shown by cyan-filled rectangles. The shape of a cubic Bézier curve is controlled by four control points—the two endpoints and two intermediate points that could be called "handles" or just intermediate control points. The angle that each intermediate control point makes relative to its adjacent endpoint, and its distance away from that endpoint, will control the shape of the curve that results.

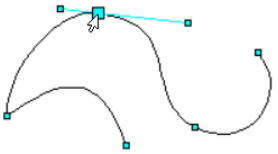
Four types of Bézier endpoints can be assigned in W2Anim:



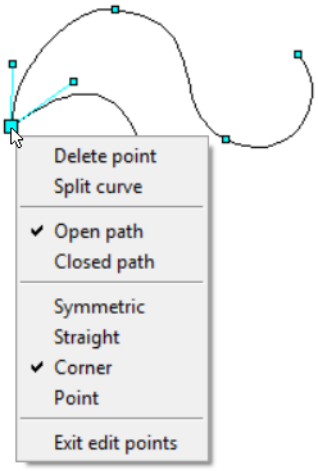
- **Corner.** A corner point has either (a) just one handle because it is the start or end of the curve object, or (b) two handles that are completely independent. The two handles of a corner endpoint may point in different directions and have different distances from that endpoint, as shown at the right. This type of endpoint is often used when a sharp angle is needed, rather than a smooth curve.



- **Symmetric.** A symmetric endpoint has two handles that must point in opposite directions and have identical distances from the endpoint, as shown at the right. This is one of the most common types of endpoints, as it helps to ensure a smooth transition of the curve from one adjacent Bézier curve to the next.



- **Straight.** A straight endpoint also has two handles that must point in opposite directions, but they are not required to have equal distances from the endpoint. An example is shown at the right. A smooth transition from adjacent curves across the endpoint is not guaranteed, but it will appear relatively smooth.
- **Point.** An endpoint of type "point" essentially has no handles, and the adjacent Bézier curves are quadratic rather than cubic, unless of course an adjacent endpoint also has type "point." If a pair of Bézier endpoints are both of type "point," then the connecting curve is linear. Without assigning an endpoint to type "point," a similar result can be achieved by placing the handles quite close to the endpoint.



Bézier endpoint types can be modified while in point-edit mode. Select the "Edit Points" option from the right-click pop-up menu when hovering over a curve, then hover over the Bézier endpoint of interest and right-click to bring up the point-edit menu (shown at right). In this case, the endpoint is a corner point, but the menu allows the user to assign a different type by selecting Symmetric, Straight, or Point. After the change, the curve remains in point-edit mode.

Clicking the left mouse button on a Bézier endpoint will cause its handles (the adjacent intermediate control points), if any, to be revealed. The Bézier endpoints and their handles can be repositioned by hovering over the point of interest, clicking and holding the left mouse button, and dragging the point to a new location. The shape of the affected portions of the curve object will be updated as the point is moved. In this way, the entire curve object may be edited to alter its shape to meet the needs of the user. Remember that W2Anim has no "undo" feature, so the user would be well advised to save the project frequently or make use of the autosave option.

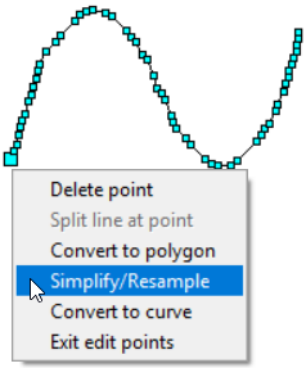
The point-edit menu also includes options to change the curve from an open path to a closed path, or the reverse. Closing the path may be done from any endpoint, whereas opening a closed curve will create a different result depending on where the curve is opened. Only open curves may be split, because creating an open path from a closed path on a curve is essentially a split operation, and a separate option is unnecessary.

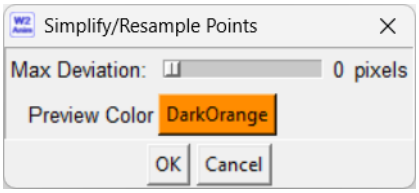
Simplify and Resample

When creating sketches or annotation with the scribble option, the resulting objects may have hundreds of points, even after the automatic removal of redundant co-linear points just after the object is first created. While not necessary, it is often possible to simplify these scribbles through a point-resampling process. Or, perhaps the ultimate aim of the user was to use the scribble option as a first draft of a polyline, and simplification was always part of the plan.

Scribbles, polylines, and polygons all can be simplified and resampled, although scribbles are the most-likely objects to benefit. W2Anim applies the Ramer-Douglas-Peucker algorithm to recursively resample the set of points, subdividing the original and discarding points that are farther than some user-provided threshold from a line segment connecting points that may be kept. The algorithm is fairly simple and efficient, and the results should be easy to understand.

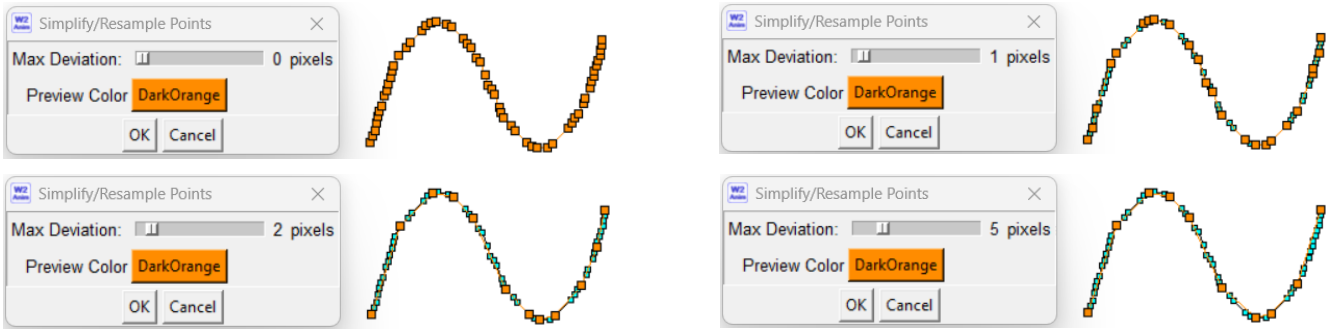
To resample a scribble, polyline, or polygon, it is first necessary to enter point-edit mode by hovering over the object, clicking the right mouse button (or typing Alt-p) and selecting the Edit Points option. Then, hover the mouse over any point and click the right mouse button to bring up the point-edit menu, as shown at the right for a simple scribble. Selecting the Simplify/Resample option will cause the point-edit menu to disappear and the Simplify/Resample Points menu to appear, as shown below.



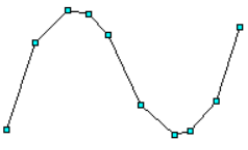


The maximum deviation value is a distance in pixels. Starting with a line drawn from the starting point to the ending point of the object, the perpendicular distances from all of the remaining points to that line are computed. If the point with the maximum distance has a distance larger than the maximum deviation value, then that point is kept and new lines are considered between that point and the starting and ending points. Following that recursive strategy, points are kept or discarded until a new set of points has been identified such that any points whose perpendicular distances were less than the maximum deviation were discarded, and only those whose distances exceeded the threshold were retained.

For the example scribble, some results are shown below with different values of the maximum deviation distance, where the orange points represent those that are retained and the smaller cyan points would be discarded.



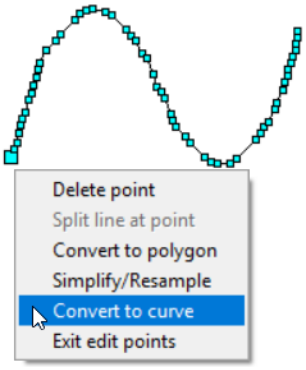
Clicking the OK button will discard the cyan-colored points, retain the preview-colored points, close the menu, redraw the object, and remain in point-edit mode, as depicted to the right. In this case, the number of points in the scribble was decreased from 57 to 10.

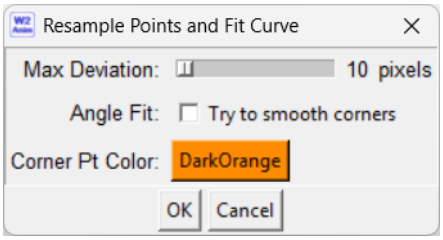


Fitting Polylines, Scribbles, or Polygons to Curves

The conversion of a polyline, scribble, or polygon to a curve object is a two-step process involving the simplification or resampling of the object's points, followed by a curve-fitting process to determine the optimum characteristics of a curve that mimics the shape of the original object. The point-resampling step is useful not only because it might result in fewer Bézier endpoints in the final curve object, but also because the discarded points of the original shape can be used to help fit the final curve.

The "Convert to curve" option is just below the Simplify/Resample option on the point-edit menu, as shown at the right for the same original scribble as from the previous Simplify/Resample section. Selecting the "Convert to curve" option will remove the point-edit menu and bring up the Resample Points and Fit Curve menu as shown below.

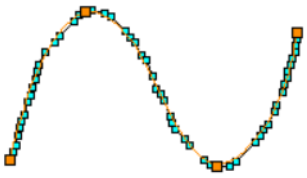


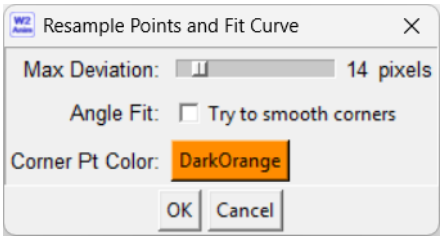


Unlike the Simplify/Resample Points menu in which the maximum deviation value was allowed to range from 0 to 25 pixels, the Resample Points and Fit Curve menu uses a maximum deviation range of 10 to 50. The minimum value of 10 forces some object simplification and hopefully sets aside some points for curve fitting.

Curve Fitting—Part 1

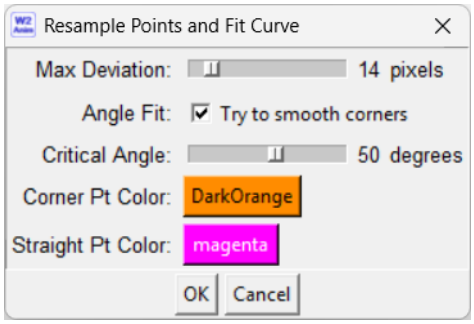
The curve-fitting process can proceed in two steps, where the second step is optional but often useful. With the "Angle Fit" box unchecked, all remaining points of the resampled object are assumed to be corner-type Bézier endpoints. In that way, each Bézier curve that will be fit between pairs of endpoints is independent of adjacent curve sections. In part 1 of the curve-fitting, the shape of each of these independent Bézier curves is optimized by fitting the x,y coordinates of the two intermediate control points for each curve. The best fit is determined by minimizing the sum of the squared distances between any discarded points from the original shape and the corresponding points on the fitted cubic Bézier curve. This minimization is implemented in 4-dimensional space using the downhill simplex method of Nelder and Mead, as described by Press et al. (1989) in section 10.4 of their book on Numerical Recipes; their Fortran code was translated into Perl for application in W2Anim. The example at the right shows that with a maximum deviation value of 14, the number of points is decreased to four, meaning that only three cubic Bézier curves need to be fitted. The resulting fitted curve is shown with the orange line that is plotted on top of the original shape.





Curve Fitting—Part 2

In this example, the fitted curve from part 1 appears to capture the original shape of the scribble pretty well. Remember, however, that all of the Bézier endpoints from part 1 are configured to be corner points, and therefore the curve may not be as smooth at the two middle endpoints as they might be if they were symmetric or straight endpoints. In part 2, the Angle Fit box is checked, and an algorithm is used to re-fit the points to a set of Bézier curves when some of the Bézier corner endpoints are converted to straight points.



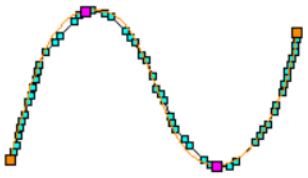
Checking the Angle Fit box causes the Resample Points and Fit Curve menu to change. A new Critical Angle user-set parameter appears, and the Bézier endpoints are now divided into two categories based on their type designation (corner vs. straight). To visualize the point-type differences, different colors are used to display each type. The critical angle parameter is used to determine whether a corner point will be changed to a straight point. If a corner endpoint has two handles, and if the part-1 angles that those handles make relative to their shared endpoint and a common axis are less than the critical angle, then the endpoint type is changed to straight. In other words, if the two handles are close enough to pointing in opposite directions, then the endpoint will change to straight and the handles will be required to point in exactly opposite directions. The use of a straight Bézier endpoint, however, means that the process of fitting a curve on one side of the endpoint will affect the fit of the curve on the other side of the endpoint.

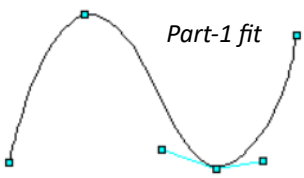
One solution to this interdependency of adjacent curves across straight endpoints would be to fit the entire curve object all at once. Fitting parameters would include the angle of each handle and the distance from each handle to its adjacent endpoint. For straight endpoints, one angle and two distances describe the locations of its two handles. At most, then, a curve object with N Bézier endpoints would have N-2 straight endpoints and 2 corner endpoints, with a total of 3*N-2 unknowns. For our simple example with 4 endpoints, the curve-fitting would require the simultaneous optimization of 10 unknowns, and the number of unknowns would increase substantially with increasing curve complexity. A minimization of a fitting function in (3*N-2)-dimensional space is possible, but is not likely to be robust, as that (3*N-2)-dimensional space probably has many local minima that may not lead the minimization algorithm neatly to a global minimum. During development of W2Anim, this type of simultaneous global minimization was attempted, but it proved to be unreliable.

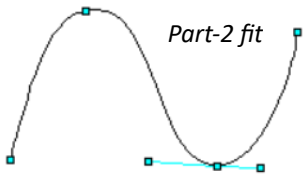
A better solution is to fit the individual Bézier curves one at a time, but to account for the fit dependency on adjacent curves. Fitting each Bézier curve by itself still requires the simultaneous optimization of four fitting parameters: the angles and distances of the intermediate control points (handles) from their adjacent Bézier endpoints. However, the minimization of the sum of the squared distances of the discarded points relative to their locations described by the fitted curve must also include points on adjacent Bézier curves. Inclusion of the fit of adjacent curves is only required if the endpoint is a straight-type point; it is not necessary to consider the adjacent curve on the other side of a corner-type endpoint.

In the part-2 fit, therefore, each curve is fit using the angles and distances of the handles. For straight-type endpoints, the optimized angle for the handle affects the curve shape (and fit) on the opposite side of the straight endpoint, but the distance to the handle on the other side is not allowed to vary during the optimization. Once the fitting routine moves along to the next curve, the fitted angles can again affect the fit of the previous curve, but the fact that the previous curve's fit is included in the minimized fitting function should decrease any disruptions to that previous fit. The process could be iterative, but that would take more time.

For this example, the part-2 fit (at right) looks much the same as that from part 1 because the part-1 fit did a pretty good job of capturing the original shape. However, the use of straight-type endpoints in part 2 does provide a smoother curve shape at those endpoints. Compare the handles at one of the endpoints to see the difference below.







Strategies for Curve Fitting

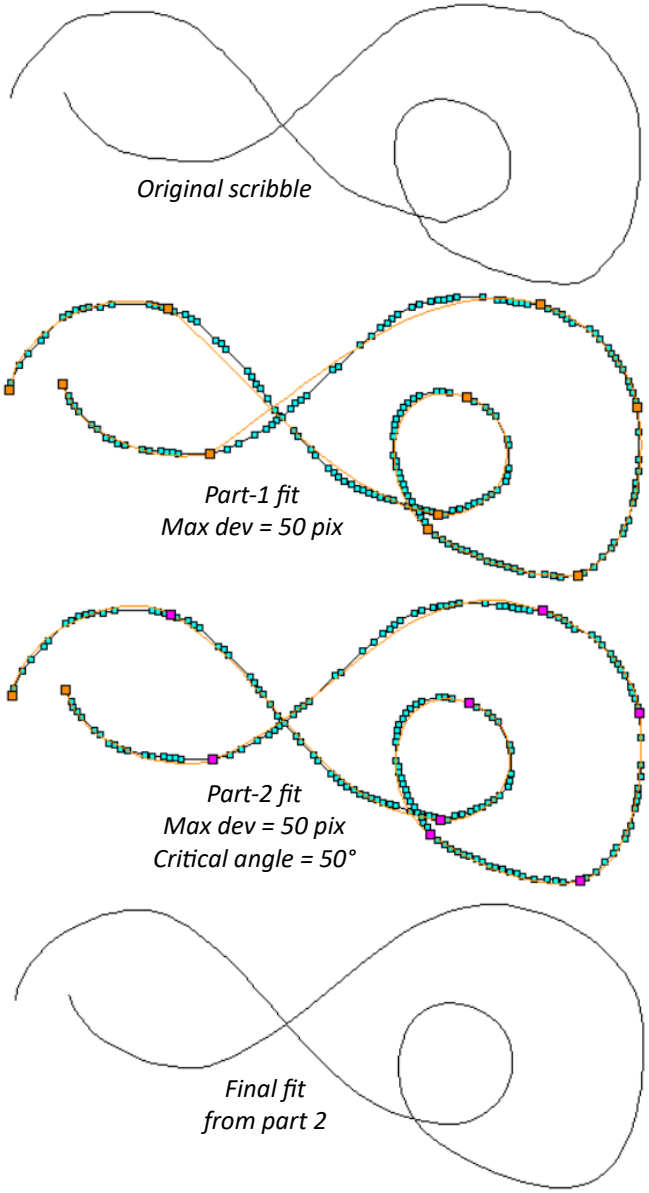
Complex shapes may require more attention to the fitting parameters (part 1 vs part 2, and critical angle) to obtain an acceptable fit to the original shape. For example, consider the scribble shown to the right.

The part-1 curve fit produces a reasonable result when including more endpoints and more individual curves. However, with greater resampling to remove more points (maximum deviation set to 50 pixels), the result from the part-1 curve fit may no longer be as acceptable; see result at right. Some of the corner endpoints do not provide a smooth fit.

Turning on the angle fit to try to add more straight-type endpoints with a part-2 fit produces a better result in this case, even using a maximum deviation setting of 50 pixels; see the part-2 figure at right. The critical angle was left at its default of 50 degrees. All endpoints except the first and last were converted to straight-type points (magenta points), and the resulting curve is smoother at those locations.

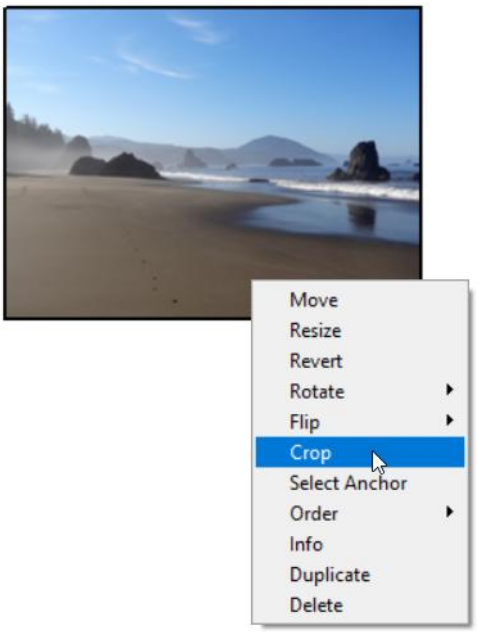
Some compromises may be necessary when converting objects into curves. Preserving the original shape may require more Bézier endpoints. It may be necessary to adjust the maximum deviation setting and the critical angle setting until an acceptable result is obtained.

Alternatively, the user could make a copy of the object, use one copy to fit to a curve, then superimpose the two objects (align to XY anchor, perhaps) and adjust the curve until it reflects the shape of the original object to an acceptable degree. In most cases it is likely that the user will need to adjust the final fitted curve anyway.



Cropping Images

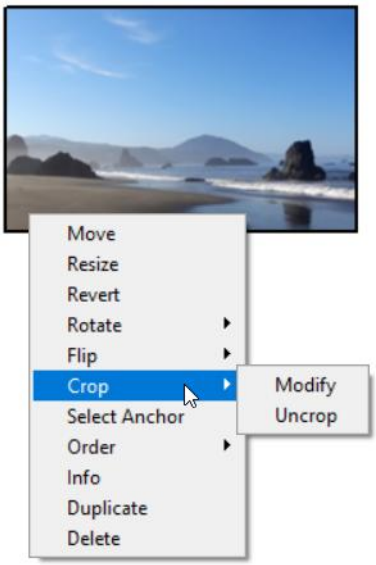
W2Anim allows users to interactively crop imported images. Hover over the image of interest so that it is the "current" object, then right-click the mouse (or type Alt-p) and select the Crop option. In image-crop mode, the current cropping frame will be drawn on the image with a magenta rectangle, with magenta control points at each corner and at the midpoints of each side:



The cropping frame can be altered by clicking the left mouse button while hovering over one of the control points and dragging that control point to the desired location. While the control point is selected and being moved, its size is enlarged. Drag any of the other control points to finalize the desired cropping, then double-click the left mouse button to implement that cropping frame on the selected image. The cropping frame and control points are removed.

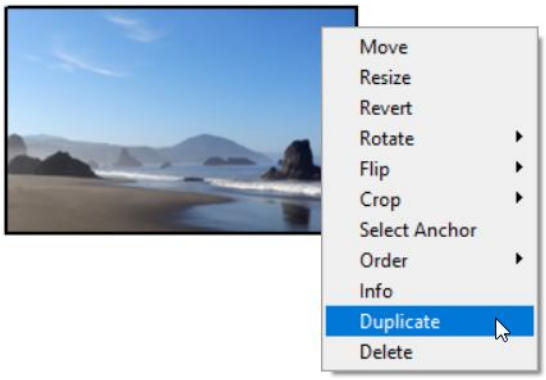
Exit image-crop mode without altering the cropping frame by clicking the right mouse button.

If an image has already been cropped, the Crop option will include two sub-options: Modify and Uncrop. The Modify option will allow the current cropping frame to be altered, whereas the Uncrop option will directly remove any cropping.



An image can be cropped, or its cropping modified, while at any size or rotation angle or after being flipped. Any image that has been resized, cropped, flipped, or rotated will include a Revert option in its pop-up menu (right-click or Alt-p while hovering on the object). Choosing that option will revert the image to its original size, uncropped and unrotated and unflipped, but honoring its current anchor point. Large images that were automatically resized to fit the canvas will include the Revert option, but possibly only because W2Anim had to resize the image because it was larger than the canvas.

Duplicating Objects



Any object on the W2Anim drawing canvas, including graphs, can be duplicated. To duplicate an object, hover over the object of interest so that it is the "current" object, then right-click the mouse (or type Alt-p) and select the Duplicate option. Alternatively, select the Edit/Duplicate option from the menu bar and then left-click on the object to be duplicated. The duplicated object may now be moved to a new location by moving the mouse. The status line shows the X,Y location of the anchor point along with the duplicated object's bounding box coordinates. A single left click will place the new object at its moved coordinates, whereas a right click of the mouse will abort the move, but not the duplication, of the object.

Deleting Objects

Any object on the drawing canvas can be deleted by hovering over the object of interest so that it is the "current" object, then right-clicking the mouse (or typing Alt-p) and selecting the Delete option. Alternatively, select the Edit/Delete option from the menu bar and then left-click on the object to be deleted. When initiating object deletion from the menu bar, the mouse cursor is changed to a skull and cross-bones; that mode can be aborted through a click of the right mouse button. Take care when deleting, as W2Anim has no "undo" feature.

GROUPING OBJECTS

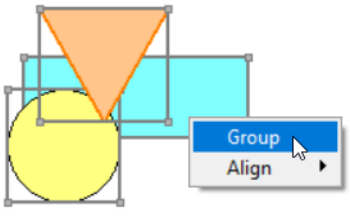
More than one object on the drawing canvas can be selected, and those multiple objects may be moved, aligned, and/or grouped.

Selecting Multiple Objects

Objects may be selected in two different ways:

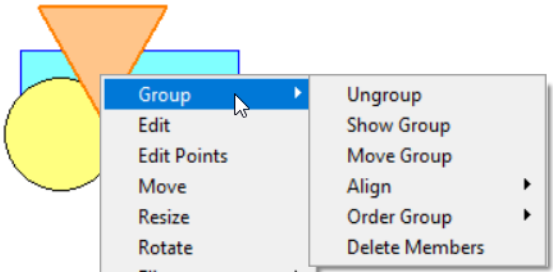
- The user can draw a selection rectangle on the canvas by holding down the left mouse button and dragging it so that the selection rectangle fully encloses the objects of interest. After releasing the left mouse button, selected objects will display their bounding boxes in gray, along with small gray squares at the corners of each bounding box.
- Alternatively, or in addition, individual objects may be selected with a click of the left mouse button. After one or more objects are selected, objects can be added or removed from the selection by clicking the left mouse button while holding down the Shift key.

Grouping Objects



Objects may be assigned to a group by first selecting multiple objects, and then hovering over one of the selected objects and clicking the right mouse button or typing Alt-p and then selecting the Group option. Objects need not be grouped for them to be moved or aligned as a group. It can be useful, however, for certain items in a visualization to be grouped so that they can be moved later as a grouped object.

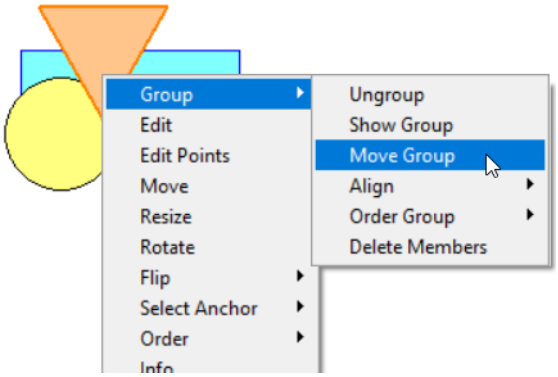
Once a group is assigned, a Group menu option is added to the pop-up menu for each object in the group, as seen at the right. From this menu, the objects may be ungrouped, shown with selection boxes, moved as a group with the mouse, deleted, and aligned in certain ways. In addition, the members of the group may be moved up or down in the drawing order list from the Order Group submenu options.



Moving Multiple Objects

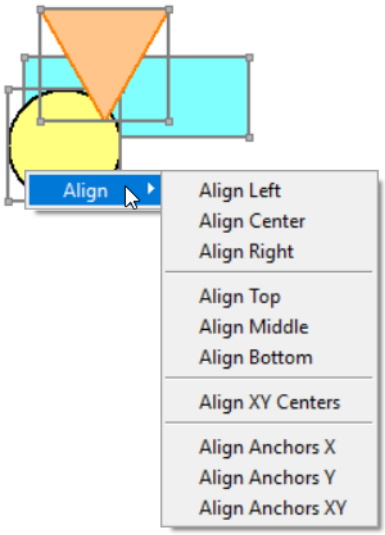
When multiple objects are selected, the only way to move those multiple objects without assigning them to a group is by using the arrow keys on the keyboard. Each use of an arrow key will move the group by only one pixel, unless the *Snap to Grid* option is turned on. With *Snap to Grid* enabled, each depression of an arrow key moves the group's anchor point to the next closest grid node in the direction of movement, where the anchor point for the group is set at the upper left corner of the bounding box for the group.

When objects are assigned to a group, a grouped move can be initiated by hovering over one of the grouped items (it need not be selected), right-clicking the mouse or typing Alt-p, then selecting the Group/Move Group option. At that point, the items in the group will be moved together when the mouse is moved. If *Snap to Grid* is enabled, the group's anchor point at the upper left corner of the group's bounding box will be shown with a small magenta square, and movement of the group will be tied to moves that snap the group's anchor point to the grid. The group move is finalized with a left mouse click, or aborted with a right mouse click.



Aligning Objects

Multiple objects may be aligned in a number of different ways, either by selecting two or more objects and bringing up the Align menu, or by assigning a group and accessing the Align menu through the Group menu. The example at the right shows three selected objects. The Align pop-up menu was activated by hovering over one of the selected objects and clicking the right mouse button (or typing Alt-p).



Alignment is always performed relative to the object that was used to bring up the Align menu. In the example to the right, the Align menu was activated by right-clicking while hovering over the yellow circle. Therefore, alignment actions will be relative to the left, top, center, right, bottom, or the anchor of the yellow circle. The options should be self-explanatory.

If the user wishes to align to an anchor point but has forgotten its location, the position of the anchor point of the reference object may be determined in two different ways. First, the user could right click on the object and choose the Select Anchor option and look for the magenta-highlighted anchor position (left click on a point to select; right click to abort). This may require some iteration for a polygon or polyline, as two different methods of setting anchor points are available for such objects. The second way to determine the location of the anchor point is to right-click on the reference object, select the Info option, and take note of the X,Y anchor position.

Alignment is a great way to ensure that annotations on a visualization are properly placed, or to align graphs or to draw dam schematics and outlet structures and align them to their proper elevations relative to a graph.

GRAPH TYPES

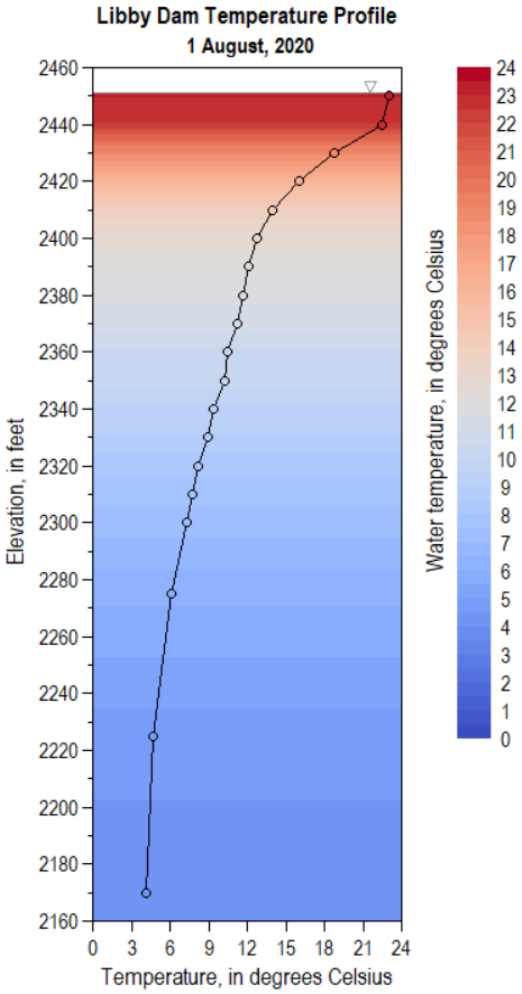
The W2 Animator supports a number of different graph types, including:

- Vertical profiles of measured parameters over time,
- Vertical profiles of model results over time,
- Vertical profile matrix plots of modeled and measured parameters,
- Longitudinal slices of model results through the model domain over time,
- Modeled water-level plots for a longitudinal reach over time,
- Time/distance maps of model results,
- Vertical withdrawal zones at dam outlets, computed from measured data,
- Vertical withdrawal zones from model output,
- Measured time series, and
- Modeled time series.

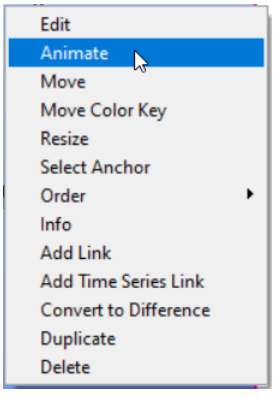
More graph types will continue to be added with future releases. This section describes how each of the graph types is created and used in The W2 Animator.

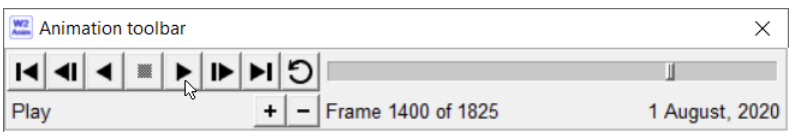
MEASURED VERTICAL PROFILES

Measured vertical profiles of any parameter can be graphed in two different ways—either as a time-indexed profile that can be animated for the available dates, or as a colormap over time. The data can be provided at any time interval, such as daily or hourly, but a more consistent visualization is obtained if the measurement frequency is constant over time. An example of a measured vertical profile graph of water temperature using daily measurements from the U.S. Army Corps of Engineers at Libby Dam in Montana is shown below. In that graph, the vertical profile is shown for one date or date/time, with elevation or depth on the Y axis and a scale for the measured parameter on the X axis. The vertical profile is shown with circles plotted at the measurement elevation or depth and at the measurement values, and with the points connected with lines to show the profile. An optional color-highlighting scheme can be added to emphasize the variation in the parameter value with depth. In this case, a CoolWarm color scheme is used to display temperatures between 0 and 24°C. The measurements are interpolated to vertical increments of 1 ft or less, depending on the number of pixels in the vertical range of the graph.



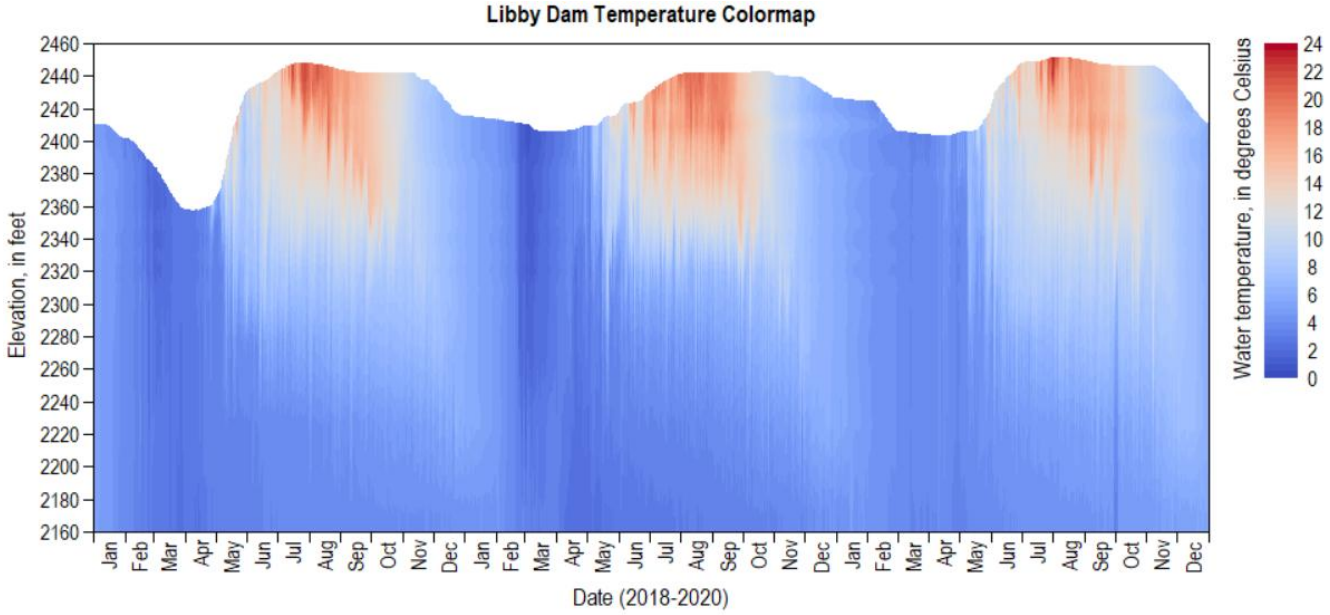
W2Anim can animate this type of vertical profile. Hovering over the graph and clicking the right mouse button (or typing Alt-p) brings up a menu from which the user can choose the Animate option. This brings up the Animation toolbar (below), which allows the user to play the animation forward or backward





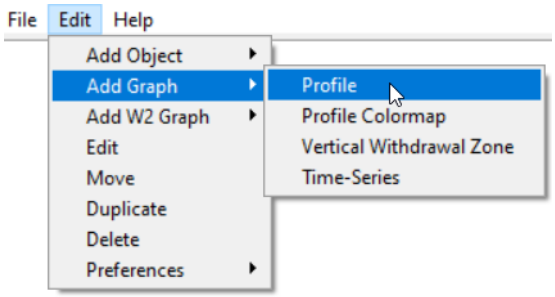
at various speeds, jump to different dates or move forward or backward a frame at a time. The animations in W2Anim are fast and efficient, and allow the user to explore how the vertical profiles change over time.

The W2 Animator can also represent vertical profiles of a measured parameter as a colormap over time. In this type of graph, the X axis is a date/time or Julian Date axis, and the measured vertical profiles are represented as colors according to a chosen color scheme. In the example below, several years of measured vertical temperature profiles at Libby Dam are represented using the CoolWarm color scheme, based on daily data from the U.S. Army Corps of Engineers.



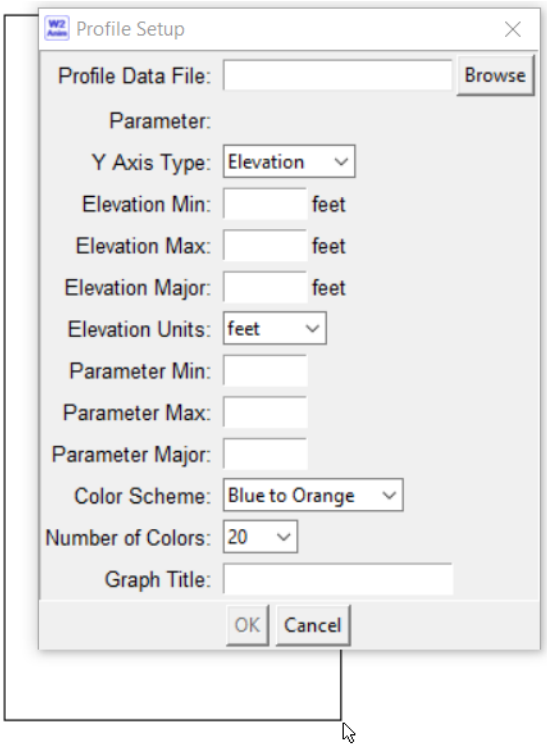
Creating a New Graph

To create a Measured Vertical Profile graph, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at Canvas Properties.



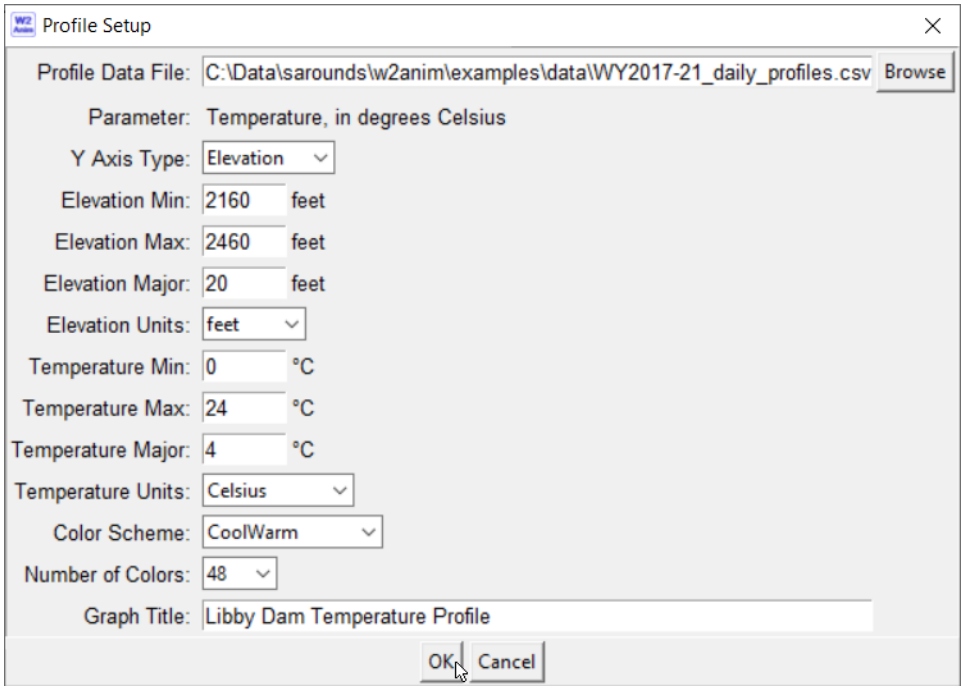
The Measured Vertical Profile graph can be started by choosing the Edit/Add Graph/Profile option from the menu bar, or by right-clicking on the canvas and choosing Add Graph/Profile. If the measured vertical profile colormap is the graph of interest, choose the Profile Colormap option instead. When either of these options is chosen, the mouse cursor becomes a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair also will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the “anchor point” for the graph; a different anchor point location can be set later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the mouse crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the graph frame is set, a new menu will pop up, as seen on the next page.

The only difference in the Profile Setup menu between the vertical profile and the vertical profile colormap graph is that the colormap menu will not ask for a Parameter Major entry. The first step is to browse your file system for a measured vertical profile data file. Find and set that file by clicking on the Browse button and selecting the file from your file system. W2Anim will scan that file for the parameter it contains as well as some initial values for many of the fields in this menu.



At this point, the user may change any of the menu options and select an initial color scheme for highlighting the profile. All of the inputs to this menu can be changed later, with the exception of the profile data file and the parameter. The Y Axis Type is either Elevation or Depth. If Depth is chosen, then the Elevation Max and Major and Units become Depth Max and Major and Units, and the Min option disappears because the minimum depth will be set to zero.

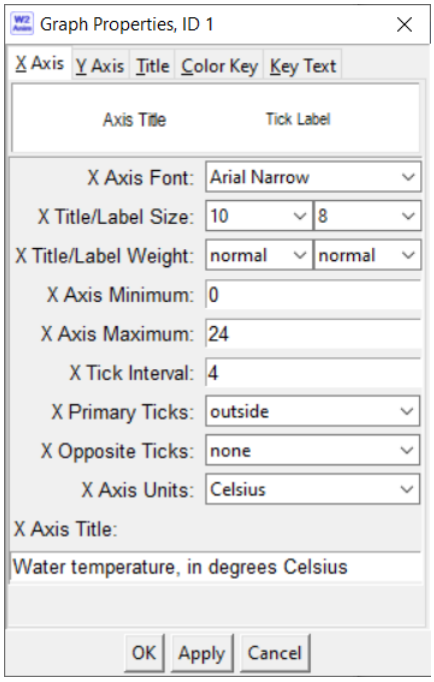
The color scheme input for this menu offers a limited range of options; other choices become available after the graph has been created, and more information on color schemes is available elsewhere in this user manual. For this example, the CoolWarm scheme was chosen with 48 colors because 48 is an even multiple of the parameter value range when a minimum and maximum of 0 and 24, respectively, are chosen. The resulting filled-out menu is shown below.

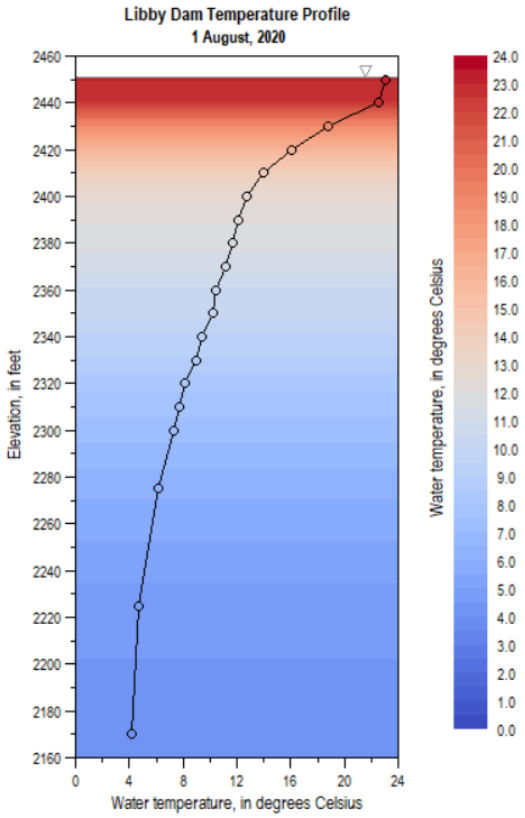


Clicking the OK button will remove the menu and create the graph. Clicking the Cancel button will remove both the menu and the graph. The vertical profile graph created from this example looks similar to the first measured vertical profile graph shown in this section, and is also shown on the next page.

The default font family is set by W2Anim and is likely Helvetica, Arial, or Times, as most computer systems are guaranteed to have one of those. The initial font size for new graphs is scaled according to the size of the graph frame in pixels, but the resulting font size for tick labels typically is in the range of 8 to 11 points, and 2 points larger for axis titles and graph titles. The default font family for graph text can be set by the user in the Program Defaults or by configuring a W2Anim Initialization File.

To edit the characteristics of this new graph, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option. Alternatively, select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown below. For this graph type, five tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, Title, Color Key, and Key Text.

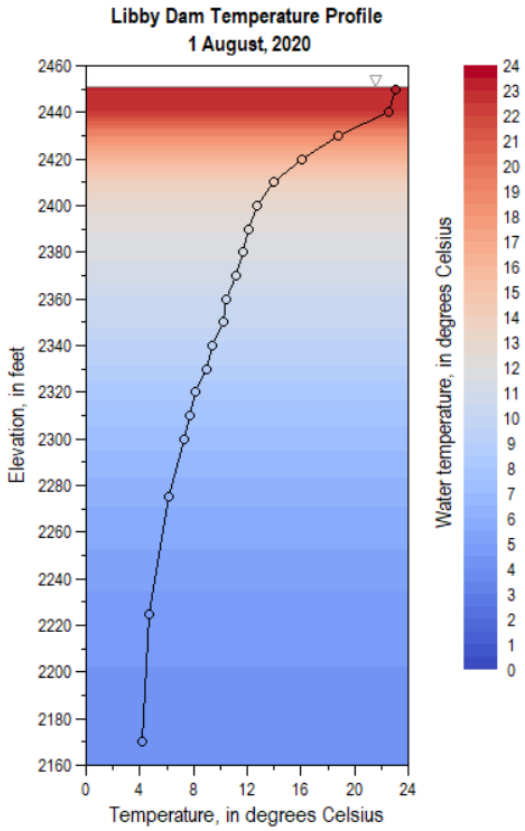


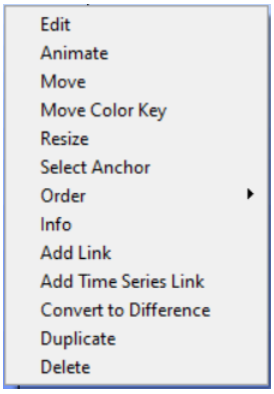


The various options of the Graph Properties menu should be fairly self-explanatory, and therefore will not be discussed in detail here. In general, the user can play with each of the options and observe the result when the Apply button is clicked.

Under the Color Key tab, note that the color key Status can be set to visible, hidden, or inactive. The Inactive option turns off the color highlighting altogether, whereas the Key hidden option simply hides the color key, which is useful if more than one graph with the same color scale is present on the canvas. The Links option allows changes to the color scheme for one graph to cause changes to the color schemes for other graphs on the canvas, either for the same parameter or for the same source data file.

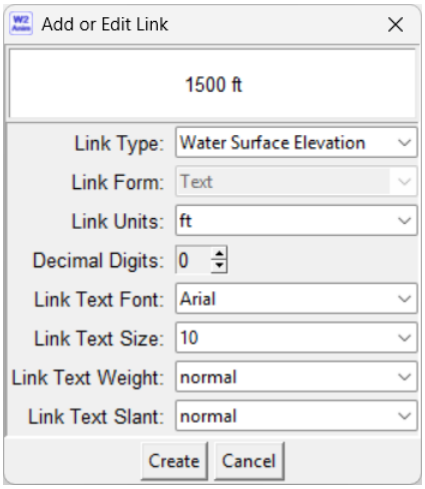
For vertical profile colormaps, the X Axis tab of the Graph Properties menu has different options relating to the date axis. The X Axis can be plotted as a Date/Time axis or as a Julian Date axis; to translate between them, a base year must be set. In Date/Time mode, the X Axis tick labels can be set just to the Year or Month or to a Mon-DD or Mon-DD-YYYY format. In Month mode, the labels will adjust themselves according to how much space is available. After changing font sizes, the X Axis title, and the number of digits after the decimal for the color key, the updated vertical profile graph is shown at the right.





Now that the graph has been created and edited, the user has a number of other options to animate, move, or resize it, select a different anchor point, move it up or down in the drawing order, extract a link or add a linked time-series graph, make a duplicate, or delete it. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu with various options. The entire graph can be moved just like any drawing object, or grouped with other objects and moved as a group. The color key can be moved independently from the graph itself, which can be useful when its default placement is not ideal. At this time, the color key cannot be rotated. The Resize option allows the user to resize the graph frame, where one of the corners is tied to the graph's anchor point; the user may select a different anchor point before resizing. After redrawing the graph frame with the Resize option, the graph will be replotted. Right-clicking during the Resize process will abort the resize action. See the sections on Object Anchors and Manipulating Drawing Objects for more information on many of these options.

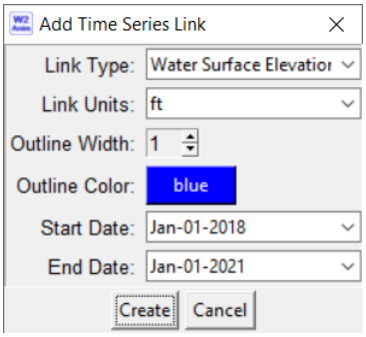
Adding a Link



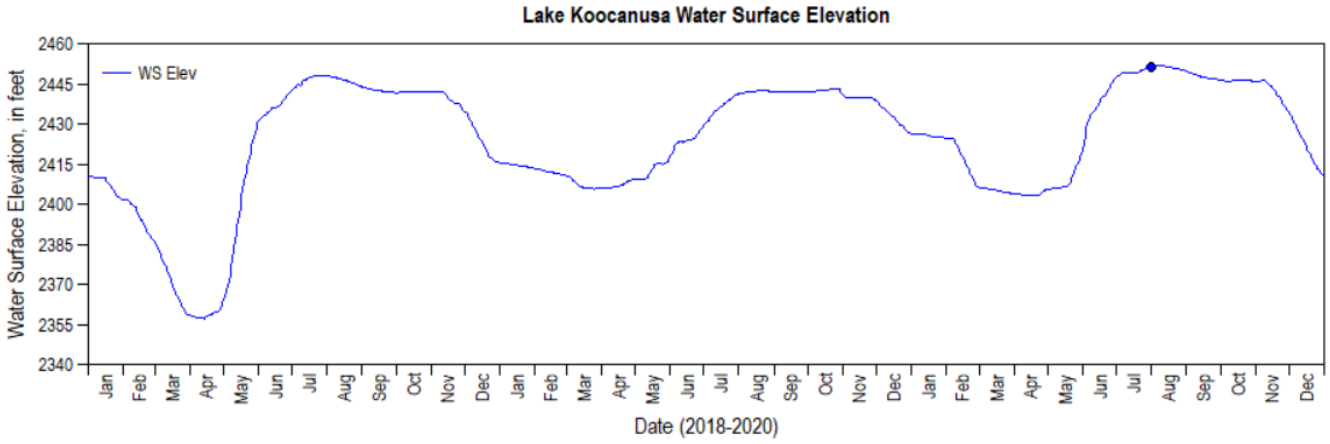
The Measured Vertical Profile graph allows a user to create a linked text object that is tied to the water-surface elevation for the date/time of the profile being depicted. In this way, a linked text object can be placed on or near the graph that shows the current water-surface elevation, and which is continually updated when the graph is animated to show the water-surface elevation on the date tied to the profile being graphed.

After the linked text object is created, it can be moved and its font characteristics can be edited just like any other text object, except that the actual text cannot be changed by the user. The units of measurement and the number of digits after the decimal can be changed later by choosing the Edit Link option from the linked text object's menu.

Adding a Time Series Link

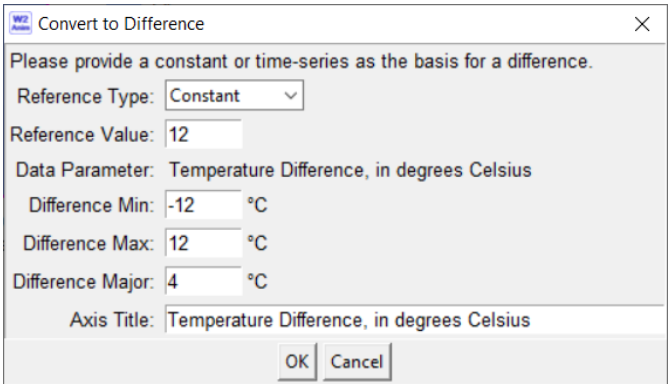


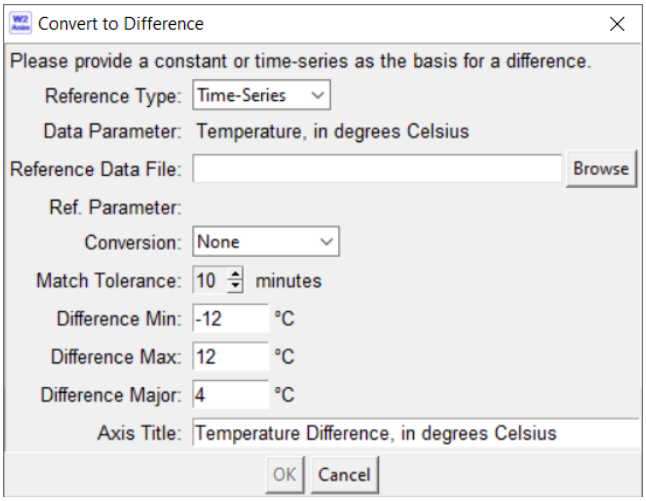
The entire time series of water-surface elevation data associated with the Measured Vertical Profile graph can be linked to a separate time-series graph. Choose the Add Time Series Link option from the pop-up menu, and the Add Time Series Link menu to the right will pop up. Choose the start and end dates and any other options and click the Create button. The mouse cursor changes to a crosshair and the user must draw a frame for the linked time-series graph on the canvas. The result, after a bit of editing, is the graph below. When animated, a circle showing the date of the animation moves along the graph.



Creating a Difference Plot

If a user wishes to visualize the parameter profile values as a difference relative to a constant or relative to a user-supplied time series, the Convert to Difference option can be applied to either the measured Profile or Profile Colormap graph. Choosing this option will bring up a new menu asking for the type of difference, where the menu on the left is for the choice of a difference relative to a constant value, and the menu on the right is for computing differences relative to a time series.



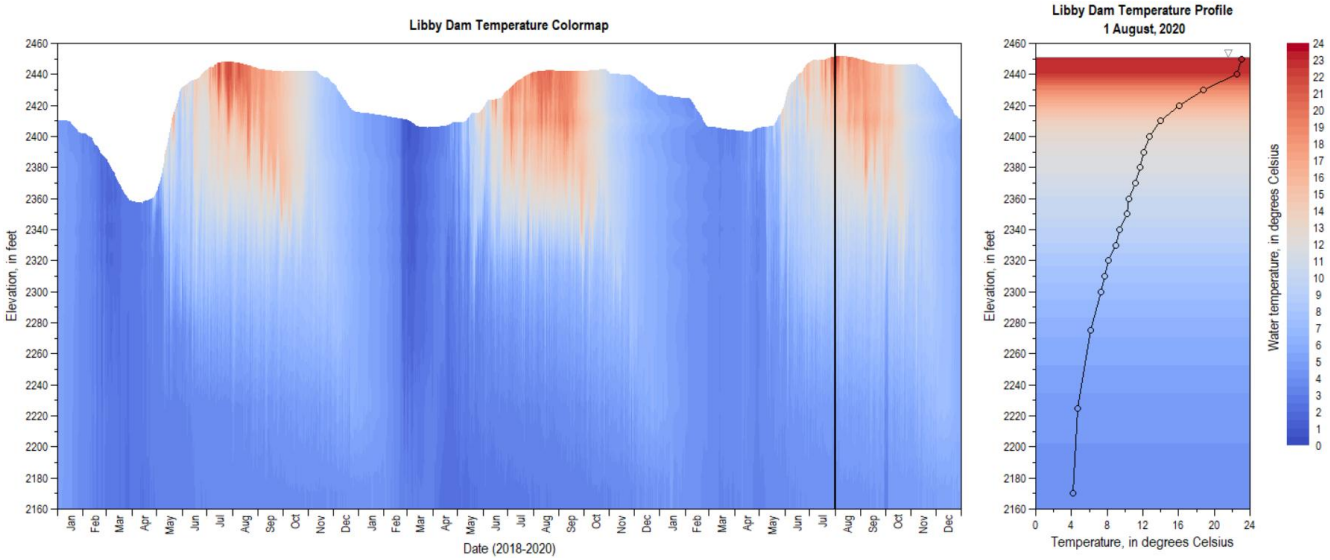


For example, if the goal is to determine how much of the profile might provide more-optimal conditions for a particular aquatic species and a threshold temperature exists to denote the limits of that range, then the profile data could be plotted as a difference relative to that threshold. On the other hand, if the goal is to visualize the heat content of a lake profile relative to the heat content of a stream entering the same reservoir at that time, then a difference relative to a temperature time series of the incoming stream might be of interest. (Thanks to Laurel Stratton Garvin for that idea!)

To compute the difference plot, fill out the fields in the Convert to Difference menu and press the OK button. The user can revert back to the measured parameter profiles later by choosing the Undo Differences option that is available when the profile plot is in difference mode.

Pairing Profiles and Colormaps

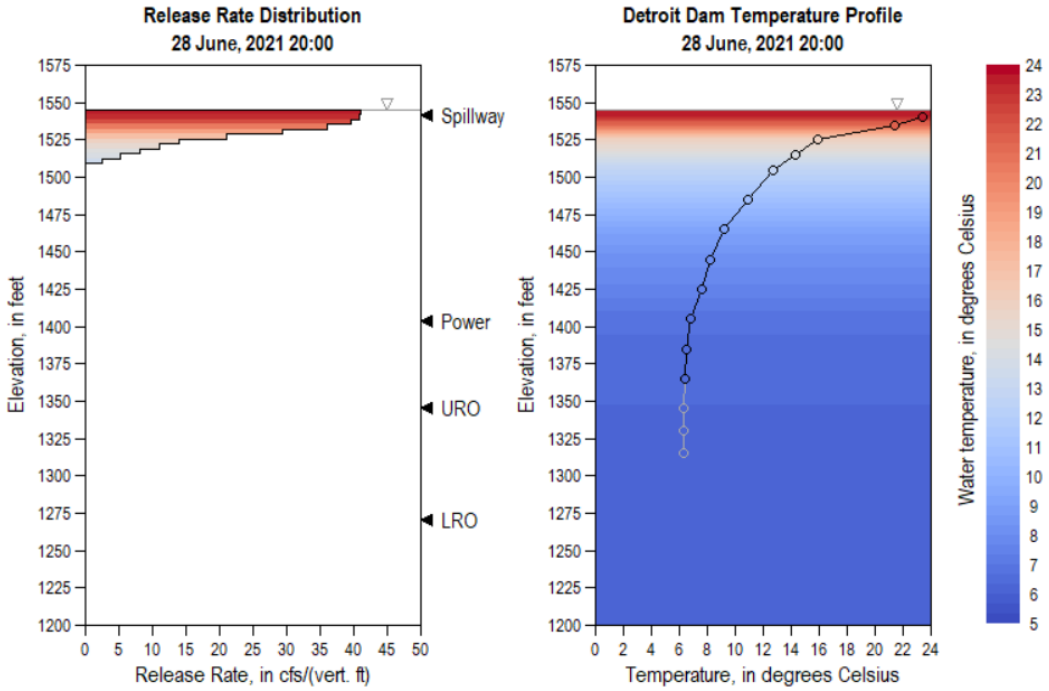
Often it is useful to pair a Measured Vertical Profile graph with a Measured Vertical Profile Colormap because the profile graph is specific to a particular date/time whereas the colormap provides a time-series context. When the profile is animated, a vertical line can be shown on the colormap to denote the current date/time.



VERTICAL WITHDRAWAL ZONES FROM MEASURED DATA

The characteristics of releases from dam outlets depends on many factors, including the elevation or depth and dimensions of the outlet, the release rate, the density profile of the water in the reservoir next to the dam, and the temperature and quality of the water in that profile. When a reservoir is strongly stratified, a release from an outlet located above the thermocline generally draws water from depths above the thermocline. Similarly, a release from an outlet located below the thermocline typically draws water from a range of depths below the thermocline. The range of depths from which water is drawn to the outlet and the amount of water that is drawn from each depth in that range can be calculated based on the factors mentioned above. This release of water from a specific vertical depth range or zone is known as selective withdrawal. The CE-QUAL-W2 model includes algorithms to compute selective withdrawal, and those algorithms have been incorporated into The W2 Animator so that vertical withdrawal zones and the vertical distribution of flows toward dam outlets can be calculated and visualized. The Vertical Withdrawal Zones from Measured Data graph type is a visualization of such withdrawal zones.

To compute vertical withdrawal zones, information about dam outlets and their release rates is needed, along with the vertical density profile in the reservoir. Water density in fresh water is controlled mainly by water temperature, so it is sufficient to provide vertical profiles of water temperature. Finally, to convert horizontal velocities toward dam outlets into flow rates, the width of the reservoir as a function of depth also is needed.

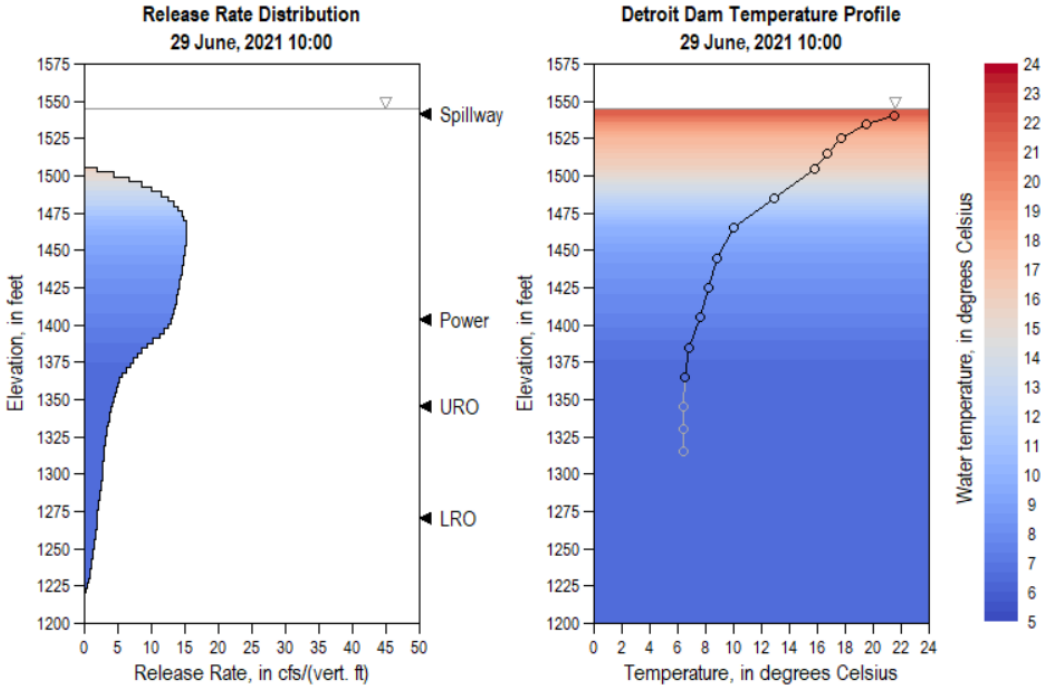


An example of a computed vertical withdrawal zone graph for releases from Detroit Dam's spillway is given at the right, along with a corresponding measured vertical temperature profile at the far right to illustrate the degree of stratification. The vertical distribution of release rates is shown in the graph, in units of ft^3/s per vertical foot, and the temperature of the water being drawn to the spillway is illustrated with the color highlighting. In this example, the spillway release rate was 810 ft^3/s and stratification was strong near the lake surface, resulting in a relatively shallow withdrawal zone and releases that were fairly warm. (Detroit Dam is located on the North Santiam River in western Oregon.)

The user can choose whether to plot the release rate per unit depth ($ft^3/s/ft$ or $m^3/s/m$) or the horizontal velocity (ft/s or m/s) on the X axis. Knowing how much water is drawn from each depth and knowing the water temperature as a function of depth allows W2Anim to also compute the overall temperature of the release through each outlet. Each of the release rates and computed release temperatures can also be linked to objects on the canvas to provide an information-rich visualization.

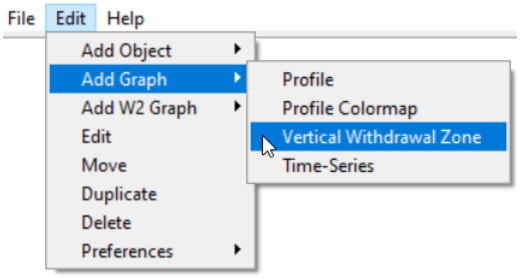
The annotations for the vertical locations of the outlets on the right side of the withdrawal zone graph were manually added using text and polygon objects.

As a contrast to the previous graph in which releases were over the spillway, another example is shown at the right using data from just a few hours later when releases were solely through the power penstocks at Detroit Dam. In this case, the release rate was more than twice as large (2,040 ft^3/s) and the release was from below the thermocline, which caused the vertical withdrawal zone to be much wider, vertically, than in the previous example. Releases from below the thermocline in this instance would be far cooler than those over the spillway. This example also illustrates that with a large enough release rate and a zone of water densities that are not all that different, releases from a single discrete outlet can draw water from a very large range of depths.



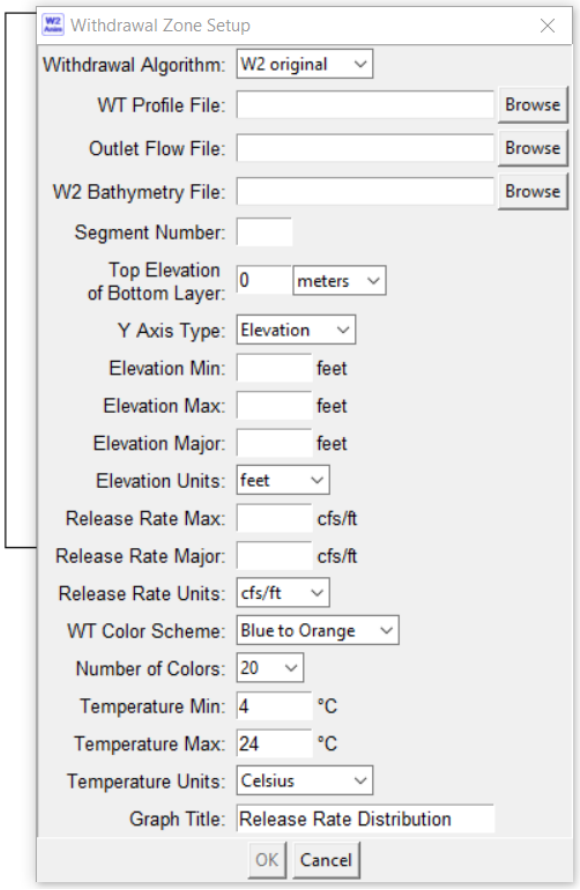
Creating a New Graph

To create a Vertical Withdrawal Zone from Measured Data graph, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by right-clicking on the canvas and choosing the Canvas Props option or by choosing the Edit/Preferences/Canvas Props option from the menu bar. See also the information in this user manual at Canvas Properties.



The Vertical Withdrawal Zone from Measured Data graph can be started by choosing the Edit/Add Graph/Vertical Withdrawal Zone option from the menu bar, or by right-clicking on the canvas and choosing Add Graph/Vertical Withdrawal Zone. The mouse cursor will become a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the "anchor point" for the graph; a different anchor point location can be set later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the mouse crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the graph frame is set, a new menu will pop up, as seen on the next page.

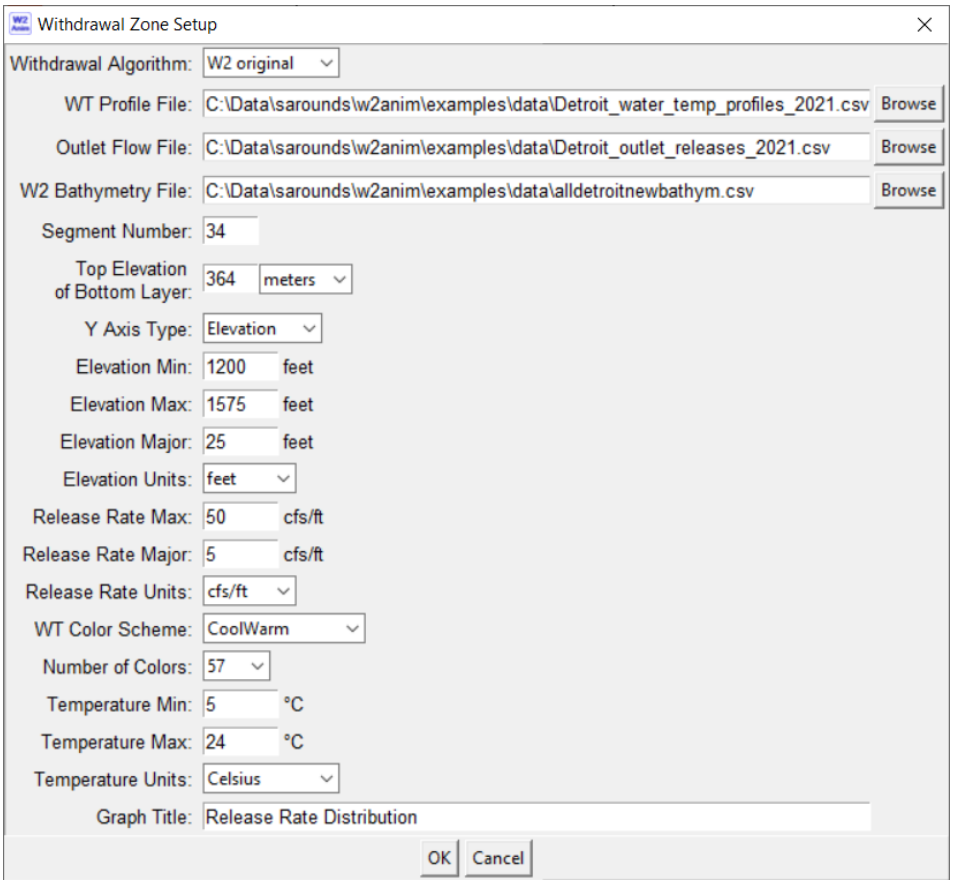
The first step is to determine whether all of the dam outlets may be treated with the original CE-QUAL-W2 selective withdrawal algorithm, or whether one or more has a variable bulkhead configuration such as what is found at Libby Dam. If a Libby-Dam-like outlet is present, the user must choose the Libby Dam option for the Withdrawal Algorithm. More details on that option are provided later.



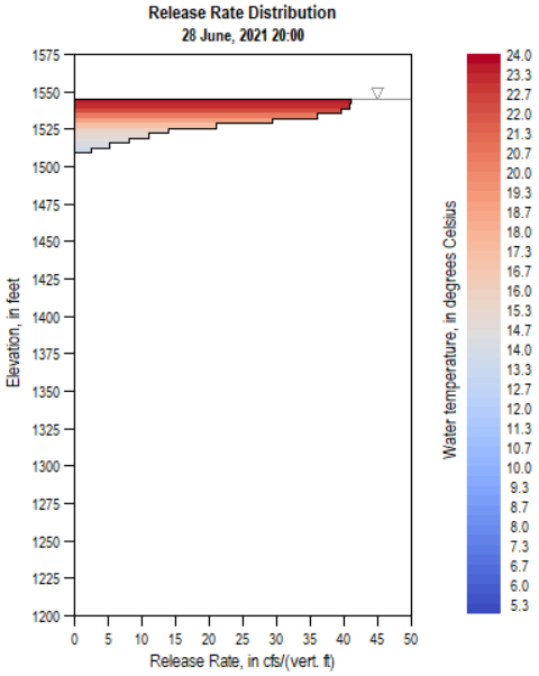
Next, browse your file system for a measured temperature profile data file. Click on the Browse button and select the file from your file system. W2Anim will scan that file for the parameter it contains (Temperature, in this case) as well as suggested initial values for some of the fields in this menu. Similarly, an outlet flow file must be provided; use the Browse button to select that file from your file system. Finally, a CE-QUAL-W2 bathymetry file is required; use the Browse button to find and set that file name. To help W2Anim use the information in the bathymetry file, the user must provide the model segment number that is adjacent to the dam, as well as the elevation of the top of the bottom-most layer in that bathymetry file.

At this point, the rest of the menu inputs and options may be changed or set. An initial color scheme for highlighting the profile should be selected. All of the inputs to this menu can be changed later, with the exception of the withdrawal algorithm and the file names. The Y Axis Type is either Elevation or Depth. If Depth is chosen, then the Elevation Max and Major and Units become Depth Max and Major and Units, and the Min option disappears because the minimum depth is zero.

The color scheme input for this menu offers just a few options; other choices are available after the graph has been created. For this example, the CoolWarm scheme was chosen with 57 colors because 57 is an even multiple of the temperature range when a minimum and maximum of 5 and 24, respectively, are chosen. The resulting filled-out menu is shown to the right.

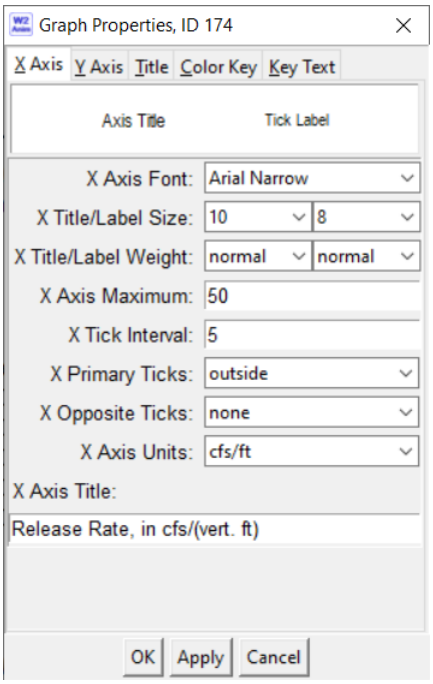


Click the OK button to remove the menu and create the graph. Click the Cancel button to remove both the menu and the graph. The Vertical Withdrawal Zone graph created from this example looks similar to the first example graph shown in this section, and is shown here to the right.



The default font family for graph text can be set in the Program Defaults or by configuring a W2Anim Initialization File. The initial font size for new graphs is scaled according to the size of the graph frame in pixels, but the resulting font size for tick labels typically is in the range of 8 to 11 points, and 2 points larger for axis titles and graph titles.

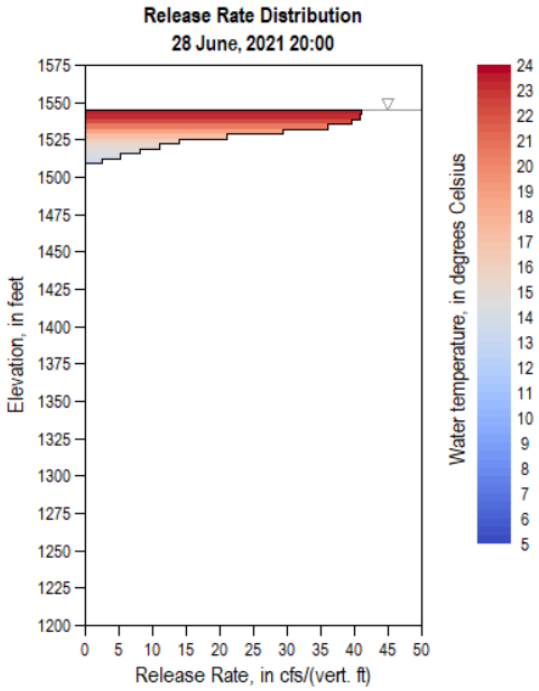
To edit the characteristics of this new graph, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option. Alternatively, select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown below. For this graph type, five tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, Title, Color Key, and Key Text.



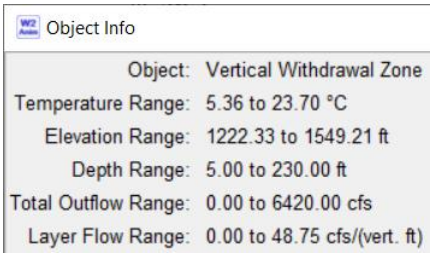
Most options in the Graph Properties menu should be fairly self-explanatory, and therefore are not discussed in detail here. The user is advised to play with the various options and observe the results when the Apply button is clicked.

Under the Color Key tab, the color key Status can be set to visible, hidden, or inactive. The Inactive option turns off the color highlighting altogether, whereas the Key hidden option simply hides the color key, which is useful if more than one graph with the same color scale is present on the canvas. The Links option allows changes to the color scheme for one graph to cause changes to the color schemes for other graphs, either for the same parameter or for the same source data file.

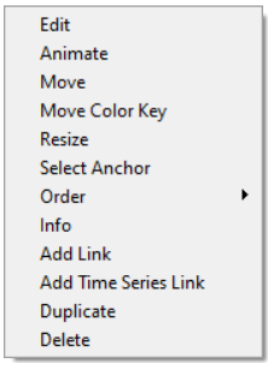
After changing font sizes, the color key cell height, and the number of digits after the decimal for the color key, the updated graph is shown at the right.



Setting the X axis maximum value can be a challenge for the vertical withdrawal graph type, but the limits of the data are available from the Object Info box. Just right-click over the graph, select the Info option, look at the values given for the Layer Flow Range or the Velocity Range, and adjust the X axis maximum value accordingly. Click on Calculate if needed.

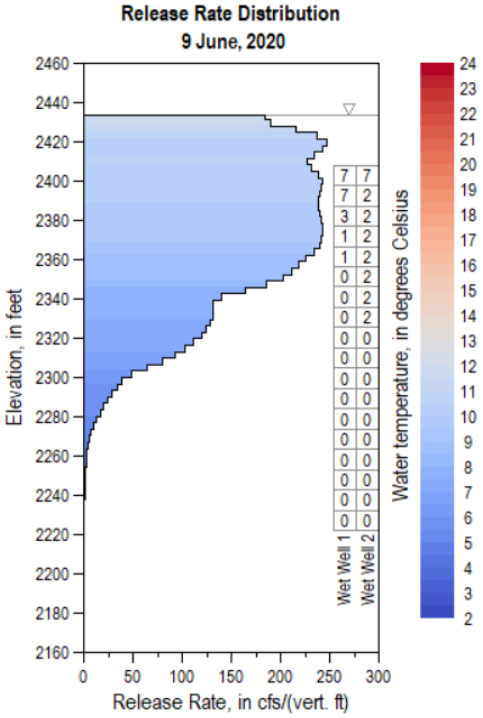


Now that the graph has been created and edited, the user has a number of options to animate, move, or resize it, select a different anchor point, move it up or down in the drawing order, extract a link or add a linked time-series graph, make a duplicate, or delete it. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu with various options. The entire graph can be moved just like any drawing object, or grouped with other objects and moved as a group. The color key can be moved independently from the graph itself, which can be useful when its default placement is not ideal. At this time, the color key cannot be rotated. The Resize option allows the user to resize the graph frame, where one of the corners is tied to the graph's anchor point; the user may select a different anchor point before resizing. After redrawing the graph frame with the Resize option, the graph will be replotted. Right-clicking during the Resize process will abort the resize action. See the sections on Object Anchors and Manipulating Drawing Objects for more information on many of these options.

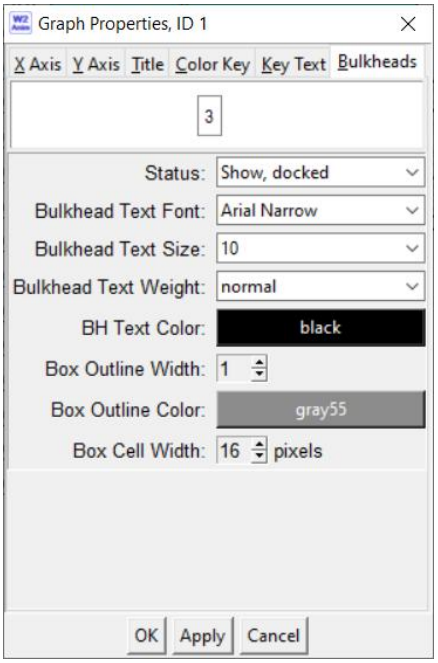


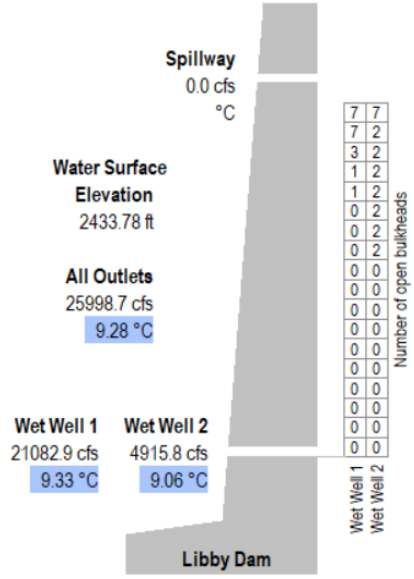
Libby-Dam-Type Outlets

If one or more of the dam outlets has a time-varying bulkhead configuration such as what is used at Libby Dam, then the user must choose the Libby Dam option for the Withdrawal Algorithm and specify the name of a Libby Dam Bulkhead Configuration file. At Libby Dam, flow to the power penstocks is from two different wet wells that are fronted by an array of bulkheads that can be installed or removed to modify the vertical withdrawal zone and thereby the release temperature. Each wet well has 7 vertical slots of up to 18 rows of removable bulkheads. The example at the right shows a vertical withdrawal zone for Libby Dam and also shows the configuration of bulkheads, where the numbers in the diagram are the number of open bulkhead positions in each row for each wet well. The "Wet Well" text at the bottom was added as an annotation.



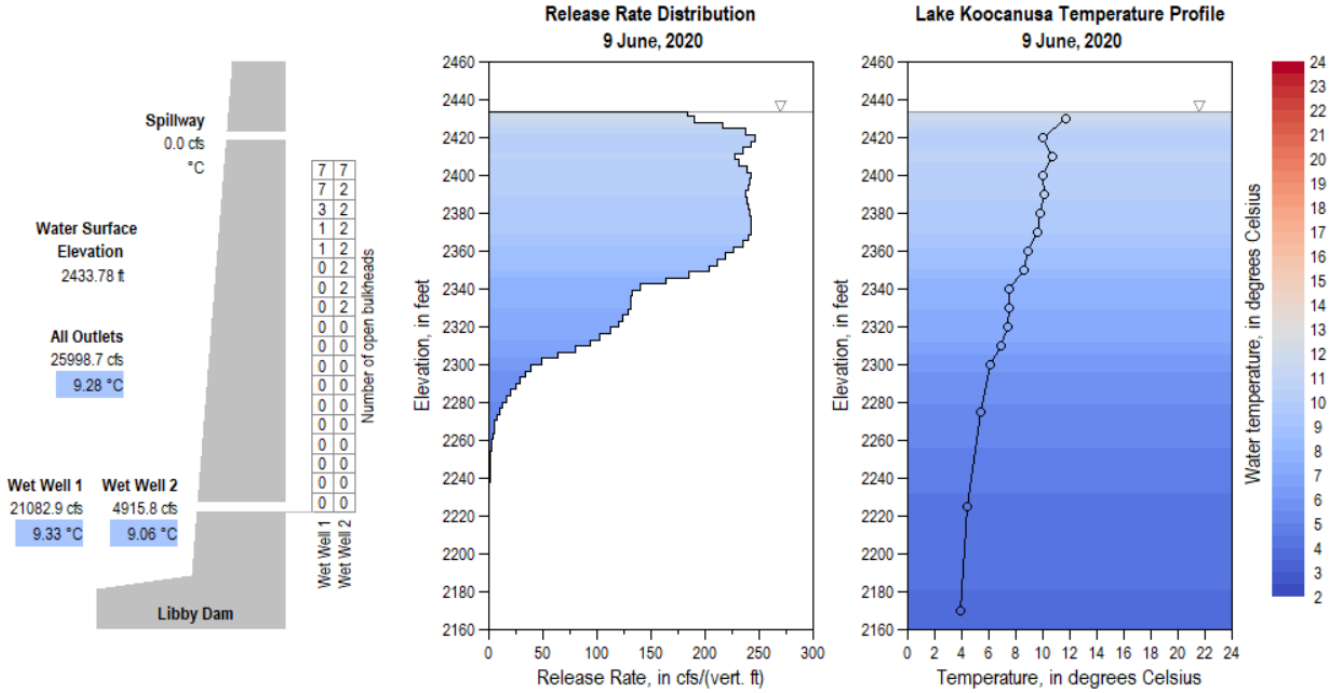
The Graph Properties menu for a Libby-Dam-type withdrawal zone graph includes a Bulkheads tab, which allows the user to show or hide the time-varying bulkhead diagram. When "docked" to the graph, the diagram is pinned to the inner right side of the graph and the rows are shown at their exact depth or elevation. When "undocked" from the graph, the bulkhead diagram may be moved elsewhere on the canvas, perhaps next to a drawing of the dam itself, such as the example shown to the right.





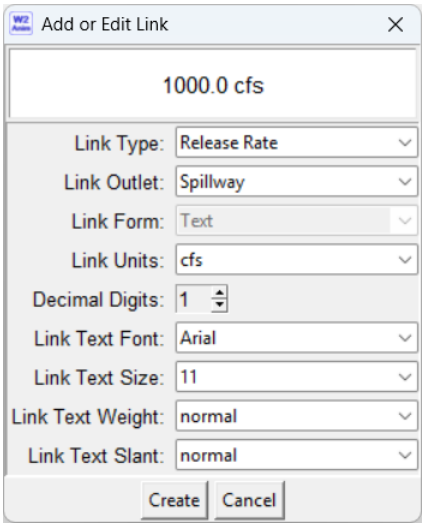
Many of the text objects showing release rates and release temperatures, as well as the filled rectangles showing the release temperature according to a color scale, were added as linked objects. See the next section on Adding a Link.

The example below combines the sketch of the dam, the undocked bulkhead diagram, a Vertical Withdrawal Zone from Measured Data graph, and a Measured Vertical Profile graph for Libby Dam, where both of the graphs have color highlighting based on the measured temperature profile.

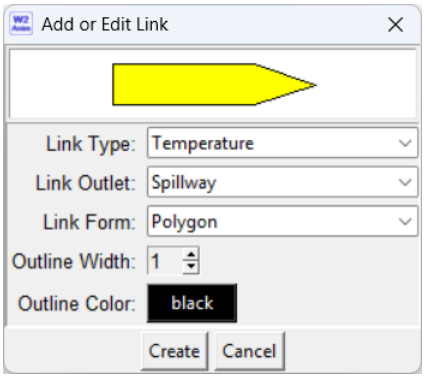


Adding a Link

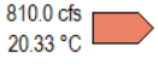
The Vertical Withdrawal Zone from Measured Data graph allows a user to create linked text or graphical objects that are tied to the water-surface elevation or the release rate or release temperature for any or all of the outlets at the date/time of the withdrawal zone being depicted. In this way, linked text objects and color-filled shapes can be placed on or near the graph that show the current water-surface elevation, release rates, and release temperatures, and the text or fill colors would be continually updated when the graph is animated.



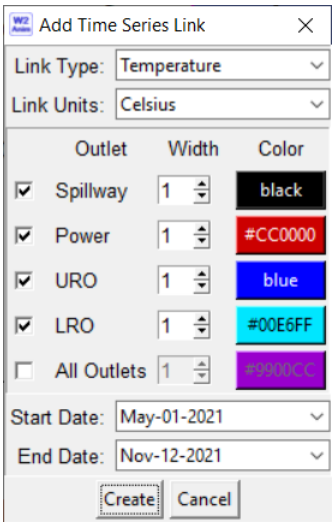
After the linked text object is created, it can be moved and its font characteristics can be edited just like any other text object, except that the actual text cannot be changed by the user. The units of measurement and the number of digits after the decimal can be changed later by choosing the Edit Link option from the linked text object's menu.



For example, the combination of linked text objects and a linked shape shown at the right can be used to annotate results on the canvas in a dynamic manner as the visualization is animated.

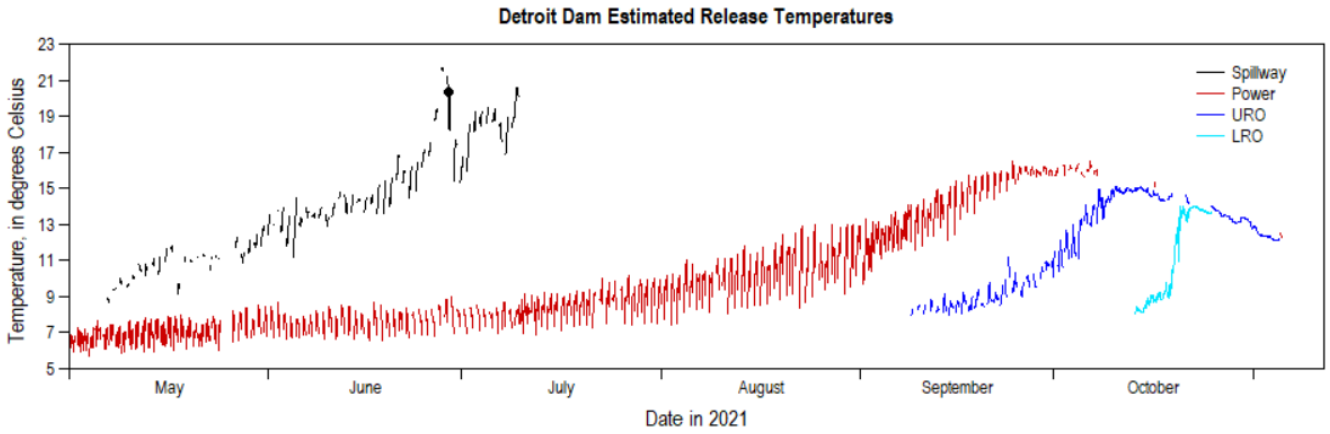


Adding a Time Series Link

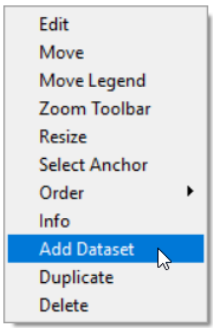


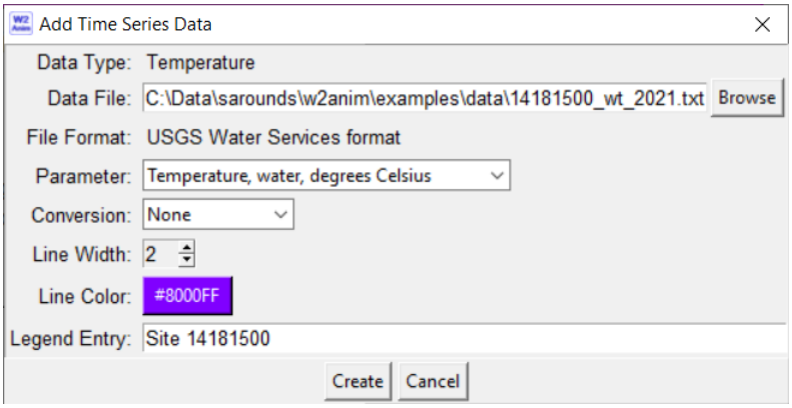
Entire time series of water-surface elevations, release rates, and release temperatures associated with the Vertical Withdrawal Zone graph can be linked to separate time-series graphs. Choose the Add Time Series Link option from the pop-up menu, and the Add Time Series Link menu to the right will pop up. Choose the Link Type (Flow, Temperature, or Water-Surface Elevation), the desired units, the outlets of interest, the start and end dates and any other options and click the Create button. The mouse cursor changes to a crosshair and the user must draw a rectangular frame for the linked time-series graph on the canvas. The result, after a bit of editing, is the graph below. When animated, circles highlighting the linked datasets on the date of the animation will move along the graph for each of the graphed datasets.

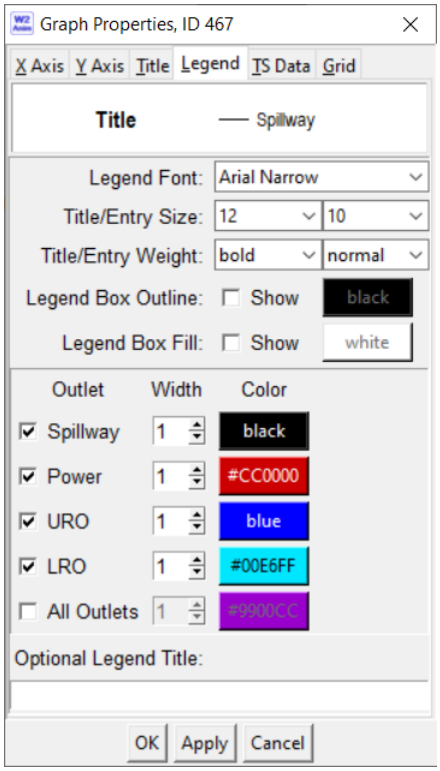
For temperature, W2Anim will need a few moments to pre-calculate the release temperatures prior to creating the linked time-series graph.



The Graph Properties menu (Edit option) for the linked time-series graph has a Legend tab, and may have a TS Data tab if additional datasets have been added to the graph. These tabs allow the user to change line widths and line colors, show or hide each dataset, change the legend font and so forth. Additional datasets may be added to a linked time-series graph by hovering the mouse over the graph and right-clicking (or typing Alt-p) and selecting the Add Dataset option. This brings up the Add Time Series Data menu.

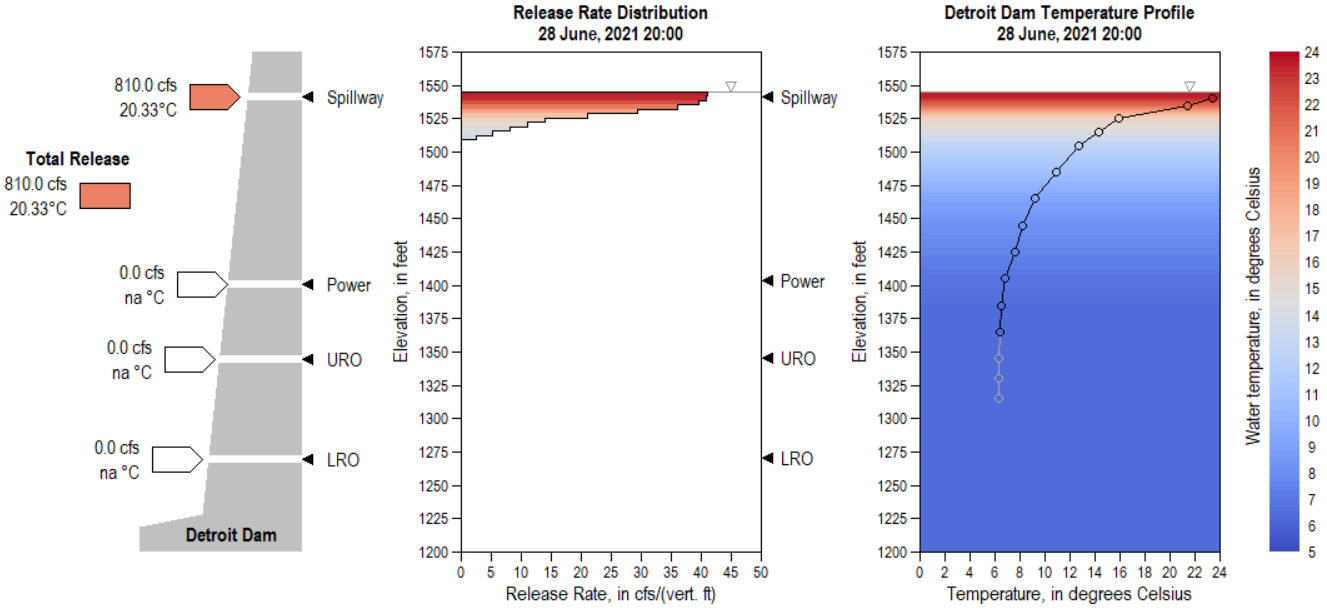


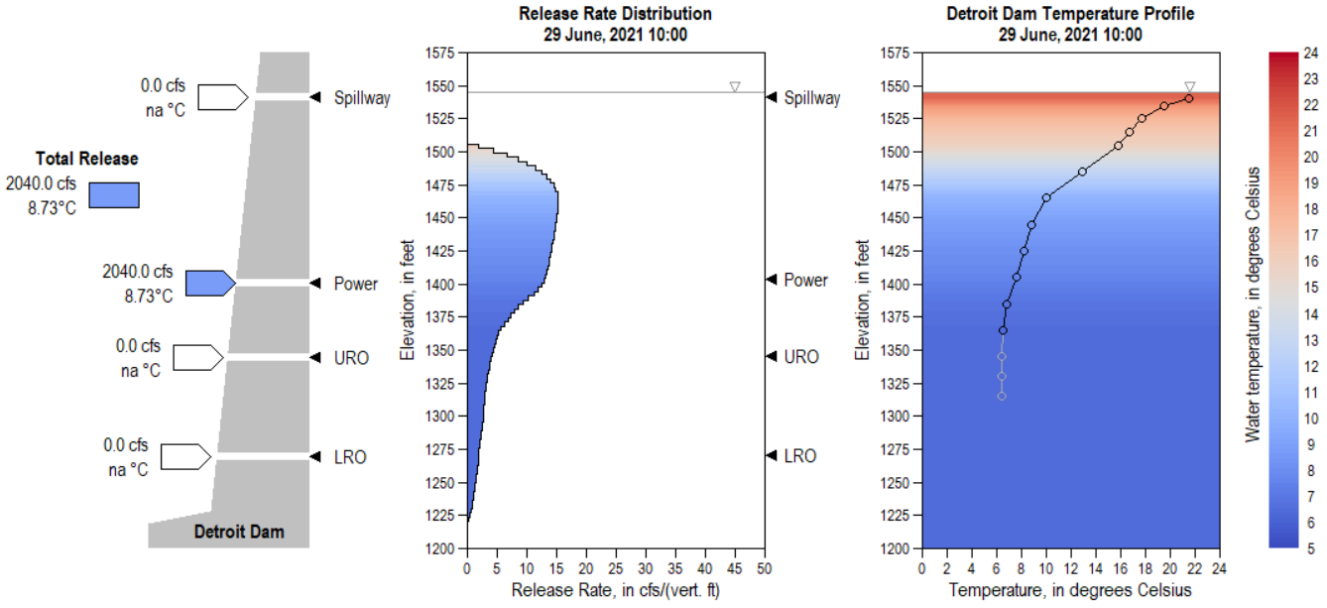




Pairing Multiple Graphs and Drawings

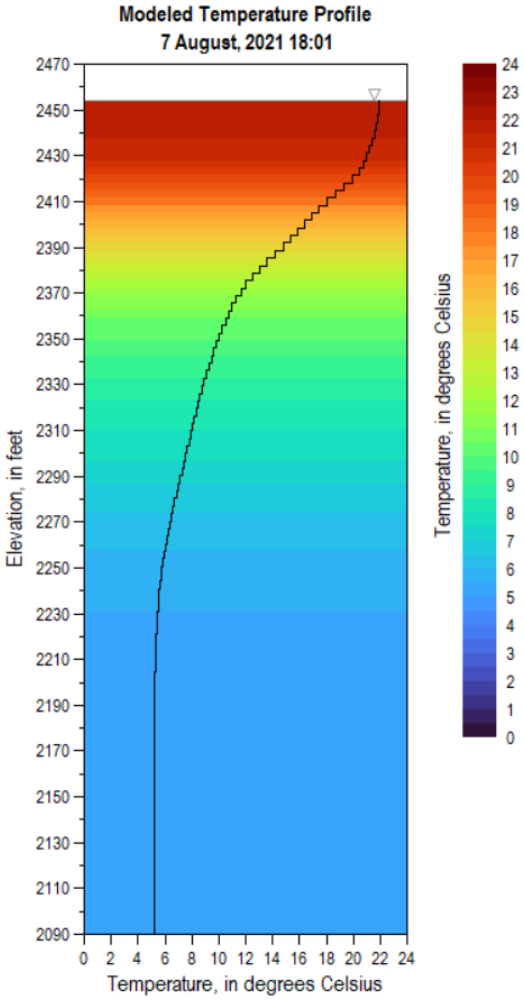
The Vertical Withdrawal Zone from Measured Data graph is perhaps best utilized when paired with a Measured Vertical Profile graph and some creative annotations. For example, the graphs and annotations below were all created in The W2 Animator. The text and triangles at the right side of the withdrawal zone graph are text and polygon objects that were exactly aligned to the appropriate elevations. The sketch of Detroit Dam and its outlets to the left was put together with various text, polygon, and rectangle objects. The release rates and release temperatures from each outlet and from the overall release are all linked objects, such that the text values and fill colors change as the visualization is animated.



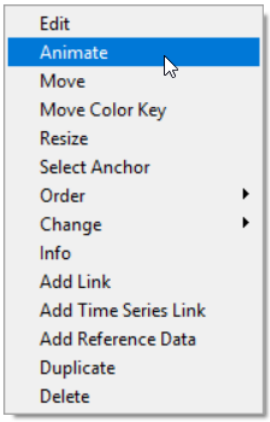


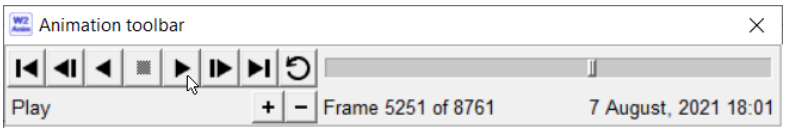
W2 Vertical Profiles

The W2 Vertical Profile graph type is similar to the Measured Vertical Profile graph type except that the profile data are from a CE-QUAL-W2 output file. A few of the extra functions also are different. For example, the W2 Vertical Profile graph is allowed to import measured vertical profiles as a reference dataset, from which goodness-of-fit statistics can be computed. Just as with the measured profile graph, a colormap over time also can be plotted. These graphs are built from W2 spreadsheet, contour, vector, or lake contour output files, and the best results are obtained if the model output frequency is relatively constant over the time period being plotted. The example to the right uses hourly results from a W2 spreadsheet output file, with elevation on the Y axis and temperature on the X axis. These graphs also can be plotted with depth rather than elevation. The vertical profile is shown with a black line, stair-stepped (by default) for each layer in the model. An optional color-highlighting scheme can be added to emphasize the variation in the parameter value with depth. In this case, the Turbo color scheme was used.

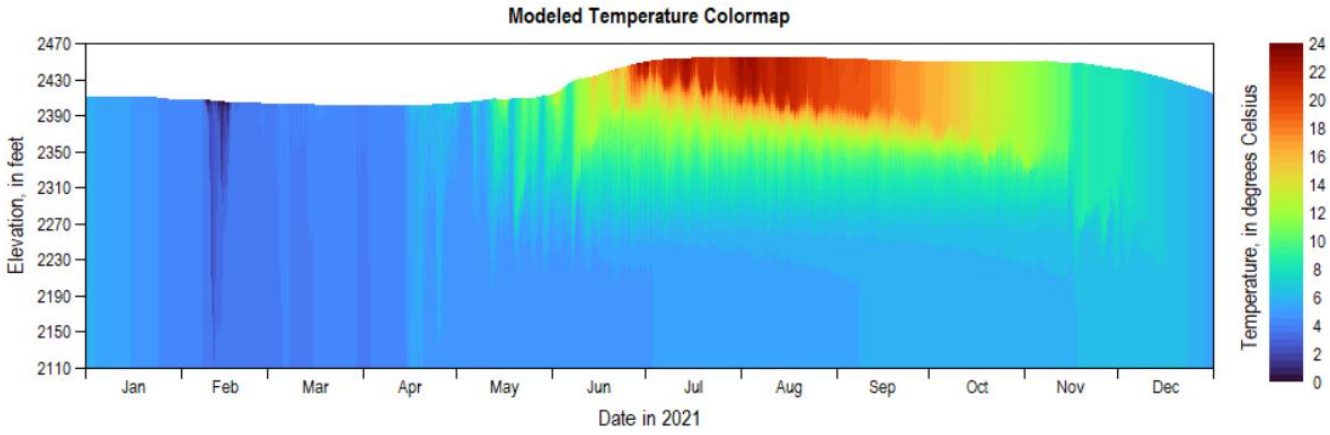


W2Anim can animate this type of vertical profile. Hovering over the graph and clicking the right mouse button (or typing Alt-p) brings up a menu from which the user can choose the Animate option. This brings up the Animation toolbar (below), which allows the user to play the animation forward or backward at various speeds, jump to different dates or move forward or backward a frame at a time. The animations in W2Anim are fast and efficient, and allow the user to explore how the vertical profiles change over time.



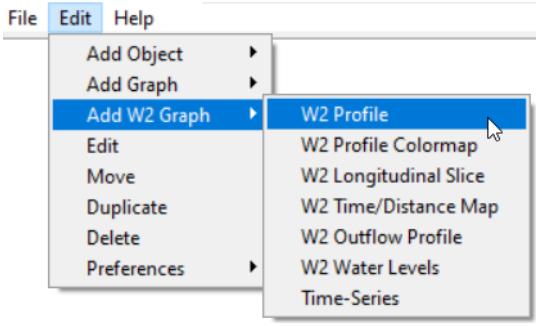


The W2 Animator also can plot W2 vertical profiles as a colormap over time. In this type of graph, the X axis is a date/time or Julian Date axis, and the vertical profiles are represented as colors according to a chosen color scheme. In the example below, temperature profiles are represented using the Turbo color scheme.

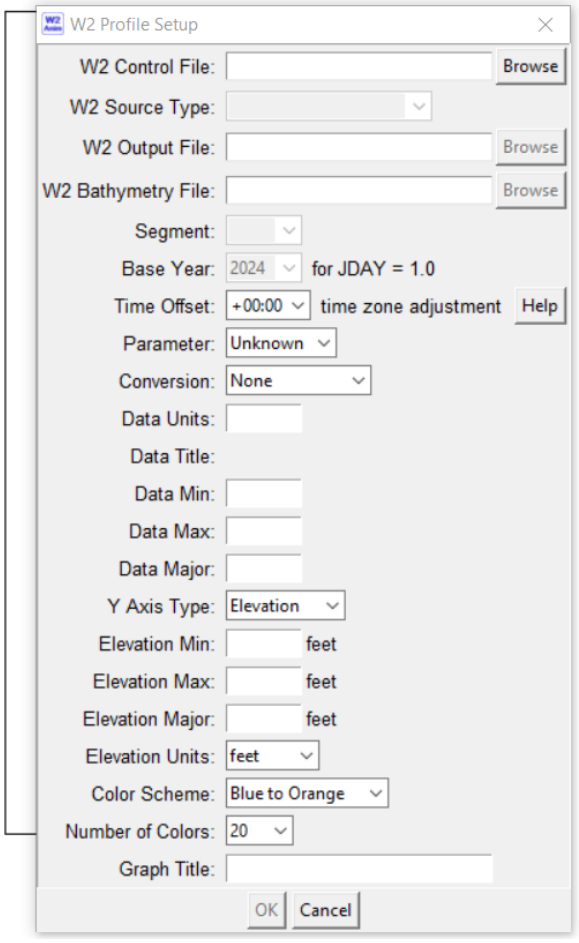


Creating a New Graph

To create a W2 Vertical Profile graph, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at Canvas Properties.



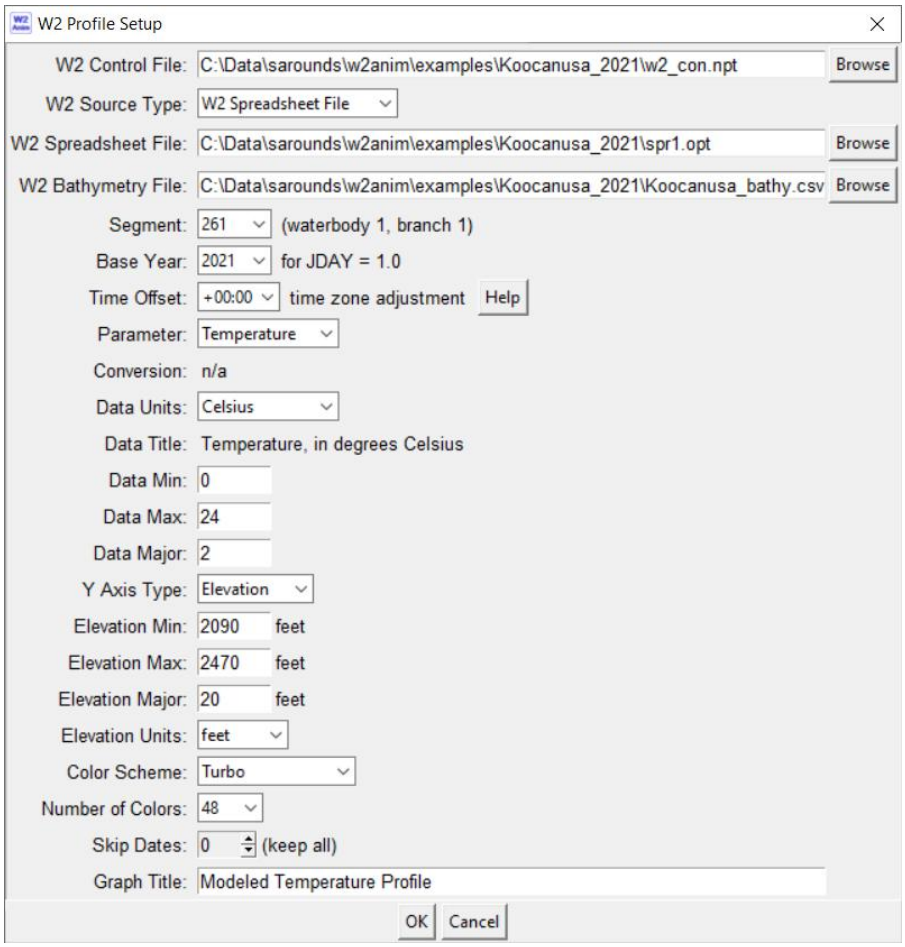
The W2 Vertical Profile graph can be started by choosing the Edit/Add W2 Graph/W2 Profile option from the menu bar. Alternatively, right-click on the canvas and choose the Add W2 Graph/W2 Profile option. If the W2 Vertical Profile Colormap is desired, choose the W2 Profile Colormap option instead. When either of these options is chosen, the mouse cursor becomes a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair also will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the "anchor point" for the graph; a different anchor point can be set later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the frame is set, a new menu will pop up, as seen below.



The only difference in the W2 Profile Setup menu between the W2 Profile and the W2 Profile Colormap graph is that the colormap menu will not ask for a Data Major entry. The first step is to specify a W2 control file. Find and set that file by clicking on the Browse button and selecting the file from your file system. W2Anim will scan that file for model grid parameters and the model year and so forth. Next, choose the W2 spreadsheet, contour, vector, or lake contour option as the source of the profile information and Browse to find and select the appropriate file. For all W2 output file types, W2Anim must read a W2 bathymetry file so that it can properly represent layer elevations. Select the model segment number and the profile parameter from among those available in the W2 output file. The time offset input is for W2 models that were run using a non-local time zone.

At this point, the user needs to set the axis limits and select an initial color scheme for highlighting the profile. The Y Axis Type is either Elevation or Depth. If Depth is chosen, then the Elevation Max and Major and Units become Depth Max and Major and Units, and the Min option disappears because the minimum depth will be set to zero. The color scheme input for this menu offers just a few options; other choices are available after the graph has been created. All inputs to this menu can be changed later, either through editing the graph properties or by choosing to change the segment, parameter, units, or data sources.

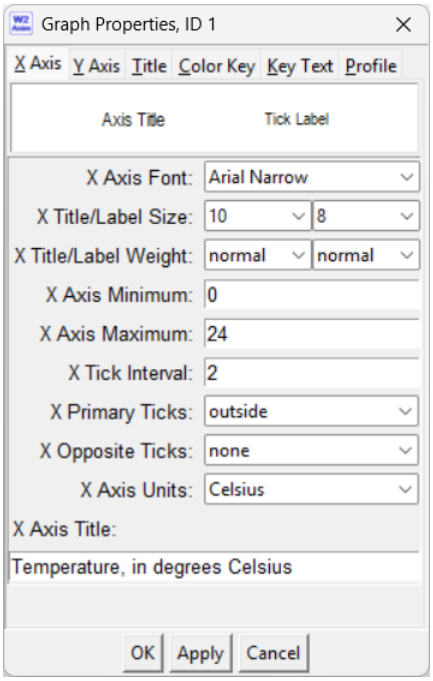
For this example, the Turbo color scheme was chosen with 48 colors because 48 is an even multiple of the temperature range when a minimum and maximum of 0 and 24, respectively, are chosen. The resulting filled-out menu is shown to the right.

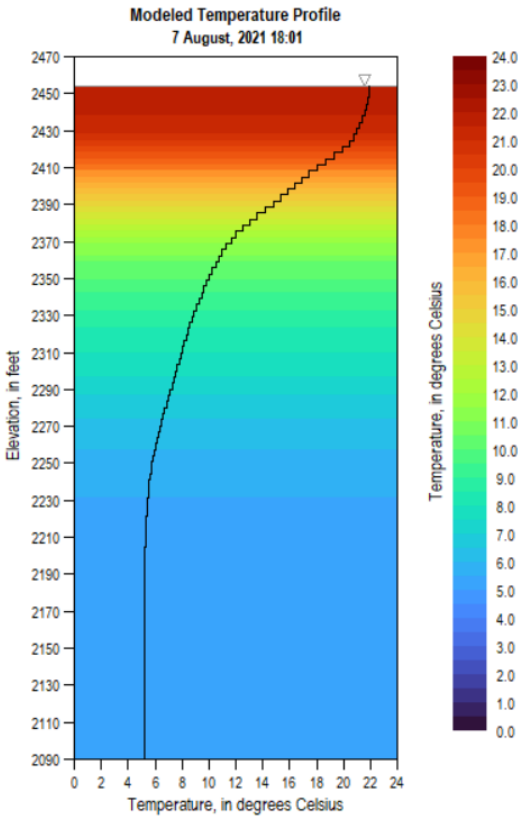


Clicking the OK button will remove the menu and create the graph. Clicking the Cancel button will remove both the menu and the graph. The W2 Vertical Profile graph created from this example looks similar to the first W2 Vertical Profile graph shown in this section, and is also shown below.

The default font family for graph text can be set in the Program Defaults or by configuring a W2Anim Initialization File. The initial font size for new graphs is scaled according to the size of the graph frame in pixels, but the resulting font size for tick labels typically is in the range of 8 to 11 points, and 2 points larger for axis titles and graph titles.

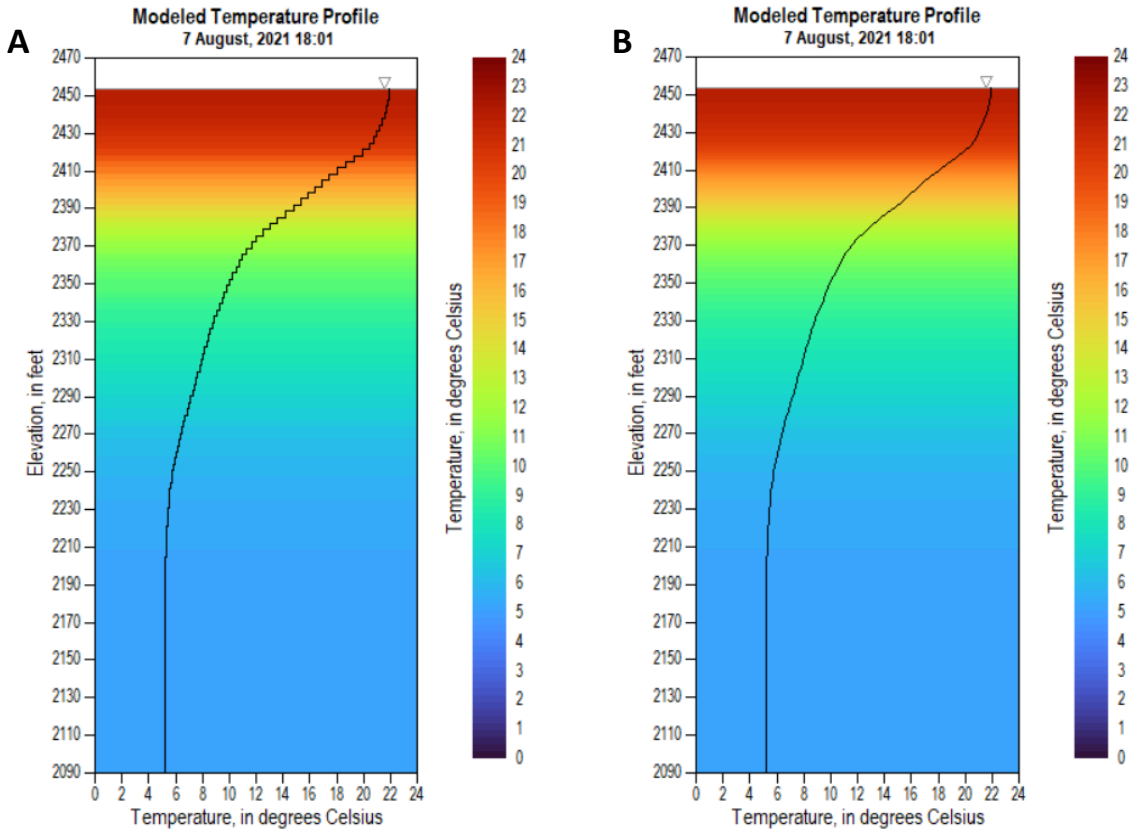
To edit the characteristics of this new graph, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option. Alternatively, select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown at the right. For this graph type, six tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, Title, Color Key, Key Text, and Profile.





The various options of the Graph Properties menu should be fairly self-explanatory, and therefore will not be discussed in detail here. In general, the user can play with each of the options and observe the result when the Apply button is clicked.

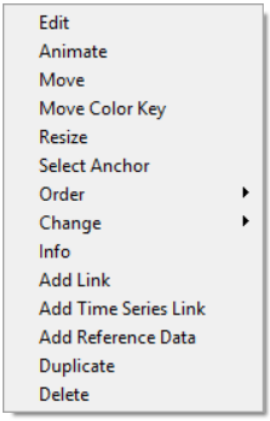
Under the Profile tab, the user can set a vertical interpolation scheme for the color background, and can also show the vertical profile as either a stairstep according to the model layers, or as an interpolated line based on the values from the model layers. The two graphs below show (A) the default stairstep profile and the "By Layer" color highlighting option, and (B) an interpolated profile and the "Max Interpolated" color highlighting option, using 100 colors in the Turbo color scheme. The vertical interpolation options make more of a difference when the W2 layer heights are large. In this example, the layer heights are small relative to the total elevation range.



Under the Color Key tab of the Graph Properties menu, note that the color key Status can be set to visible, hidden, or inactive. The Inactive option turns off the color highlighting altogether, whereas the Key hidden option simply hides the color key, which is useful if more than one graph with the same color scale is present on the canvas. The Links option allows changes to the color scheme for one graph to cause changes to the color schemes for other graphs on the canvas, either for the same parameter or for the same source data file.

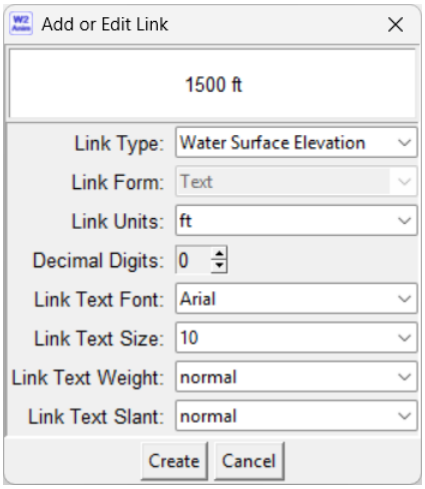
For W2 profile colormaps, the X Axis tab of the Graph Properties menu has different options relating to the date axis. The X Axis can be plotted as a Date/Time axis or as a Julian Date axis; to translate between them, a base year must be set. In Date/Time mode, X Axis tick labels can be set just to the Year or Month or to a Mon-DD or Mon-DD-YYYY format. In Month mode, the labels will adjust themselves according to how much space is available.

Now that the graph has been created and edited, the user has a number of other options to animate, move, or resize it, select a different anchor point, move it up or down in the drawing order, add links or a reference dataset, make a duplicate, or delete it. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu with various options. The entire graph can be moved just like any drawing object, or grouped with other objects and moved as a group. The color key can be moved independently from the graph itself, which can be useful when its default placement is not ideal. At this time, the color key cannot be rotated. The Resize option allows the user to resize the graph frame, where one of the corners is tied to the graph's anchor point; the user may select a different anchor point before resizing. After redrawing the graph frame with the Resize option, the graph will be replotted. Right-clicking during the Resize process will abort the resize action. See the sections on Object Anchors and Manipulating Drawing Objects for more information on many of these options.



Adding a Link

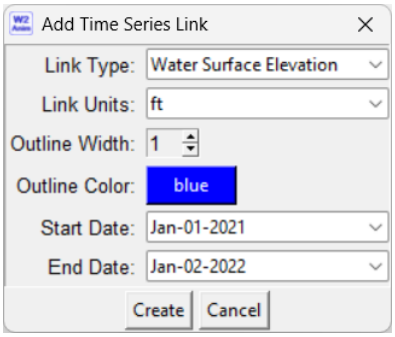
Like the Measured Vertical Profile graph, the W2 Vertical Profile graph allows a user to create a linked text object that is tied to the water-surface elevation for the date/time of the profile being depicted. In this way, a linked text object can be placed on or near the graph that shows the current water-surface elevation, and which is continually updated when the graph is animated to show the water-surface elevation on the date tied to the profile being graphed.

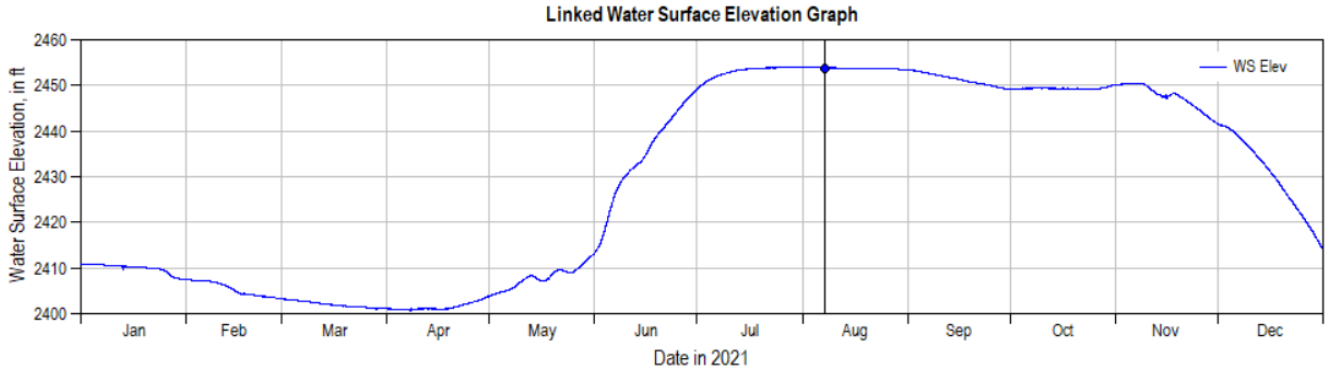


After the linked text object is created, it can be moved and its font characteristics can be edited just like any other text object, except that the actual text cannot be changed by the user. The units of measurement and the number of digits after the decimal can be changed later by choosing the Edit Link option from the linked text object's menu.

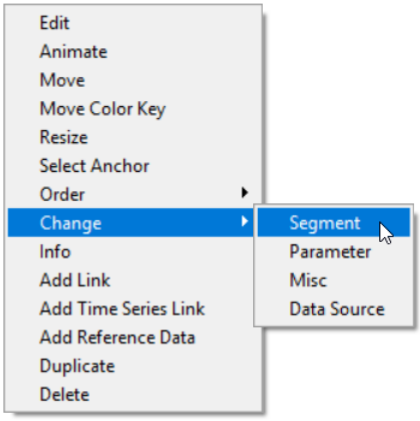
Adding a Time Series Link

The time series of water-surface elevation data associated with the W2 Vertical Profile graph can be linked to a separate time-series graph. Choose the Add Time Series Link option from the pop-up menu, and the Add Time Series Link menu to the right will pop up. Choose the start and end dates and any other options and click the Create button. The mouse cursor changes to a crosshair and the user must draw a frame for the linked time-series graph on the canvas. The result, after a bit of editing, is the graph below. When animated, a circle showing the date of the animation moves along the graph with an optional vertical line showing the current date/time.





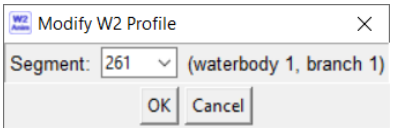
Changing the Segment, Parameter, or Data Source



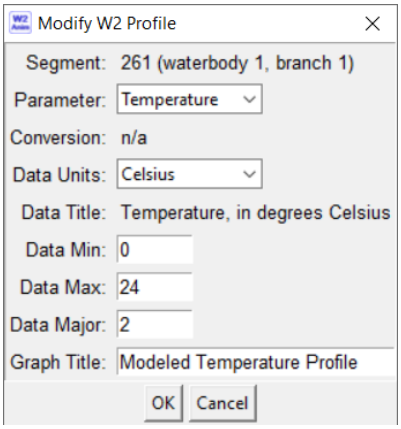
Through the Change submenu (at right), the user can change the model segment, modeled parameter, parameter units, W2 model begin year, a date-skip setting, and/or any of the data source files associated with the profile graph. This feature is handy not only for fixing user mistakes after the graph is originally created, but also for creating multiple similar graphs by duplicating a graph and then changing the model segment, parameter, and/or model output file used in the duplicated graph. In this way, a user can quickly set up an array of profile graphs for a suite of modeled parameters, or perhaps a set of profile graphs for the same parameter at many different locations in the model domain. Options under the Change submenu are slightly different when using a lake contour output file.

The Change submenus should be self-explanatory because they mimic parts of the menu used to create the original profile graph. The menus for the main four options are shown below.

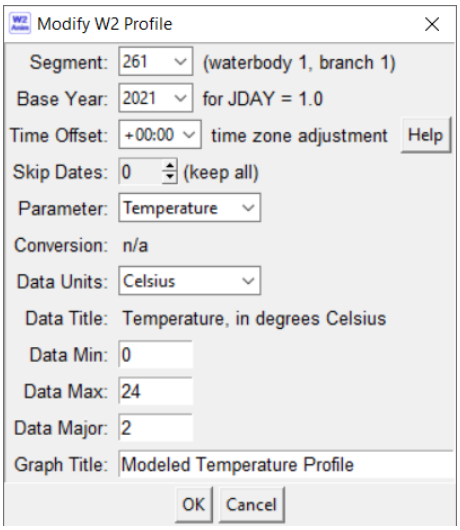
Segment:



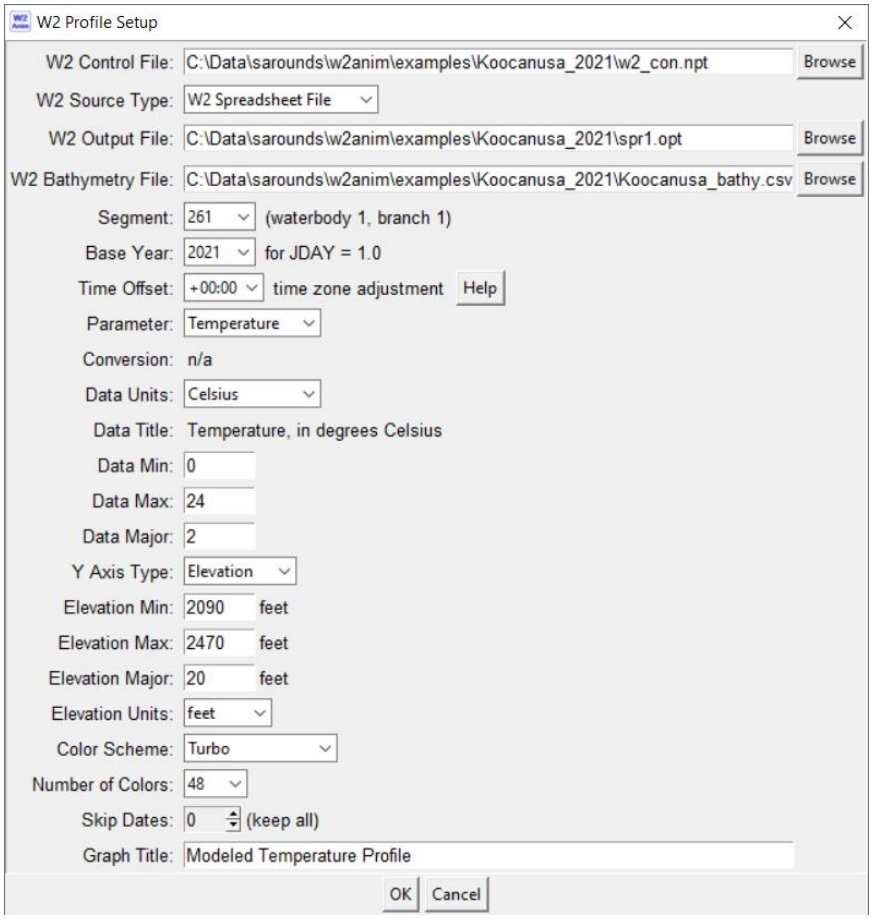
Parameter:



Misc:

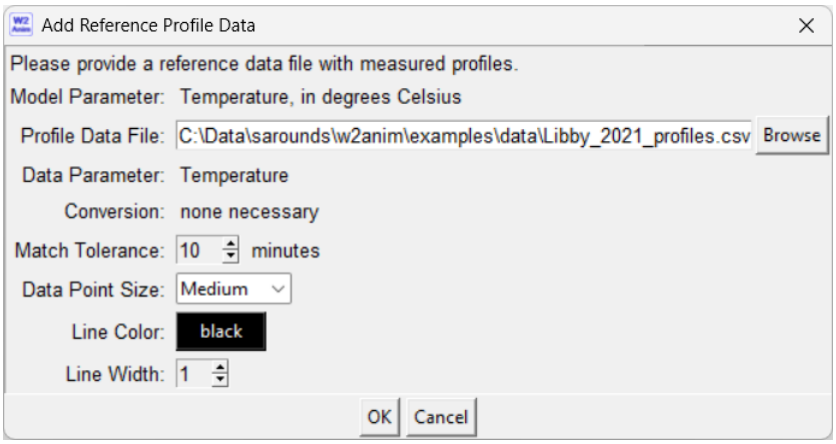


Data Source:

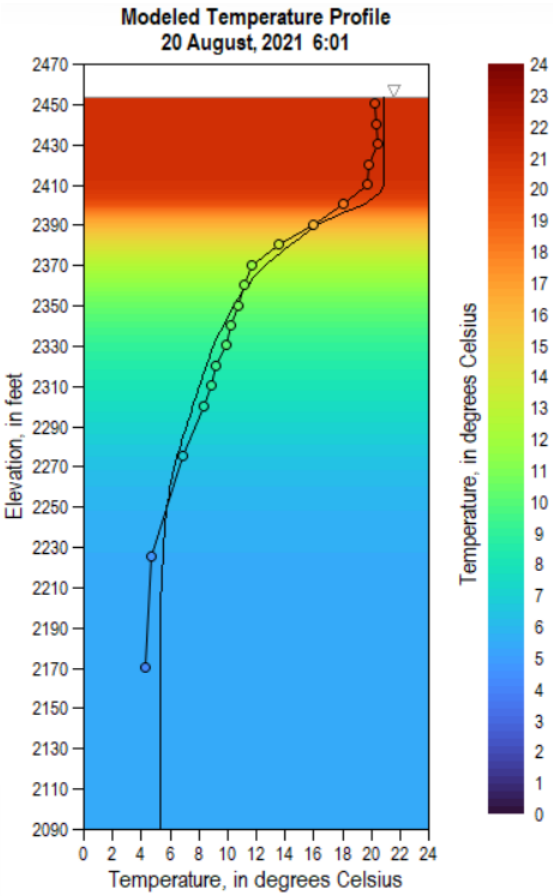


Any substantial change requested from these menus will cause the data file(s) to be re-read and the graph to be re-created. Cancelling the operation or destroying the menu will result in no changes to the graph. Simply changing the data limits (Min/Max/Major) or graph title is not allowed from these menus, as that is best done from the Graph Properties menu. Re-creating the graph will cause any reference profiles to be removed.

Adding Reference Profiles

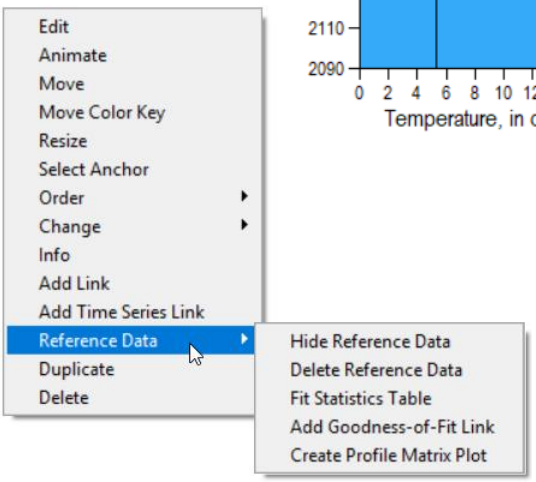


Reference profile data may be added to a W2 Vertical Profile graph so that a comparison can be made between measured and modeled profiles. To add reference data, hover the mouse over the graph and click the right mouse button (or type Alt-p) then select the Add Reference Data option. The Add Reference Profile Data menu will pop up, showing the modeled parameter and prompting the user to provide the name of a data file. The profile data file is expected to be in the same format as the data required for a Measured Vertical Profile graph. W2Anim will scan the data file to confirm that it contains data for the correct parameter. The user can choose the size of the measured data points, the color and line width of the data profile, and the date/time match tolerance, which defaults to 10 minutes. The match tolerance cannot be changed after the reference profiles are added, but the reference data can be deleted and reloaded to modify the match tolerance, if needed. The reference line color, line width, and data-point size may be modified later from the Profile tab of the Graph Properties menu. The resulting comparison of measured and modeled vertical profiles is shown at the right.

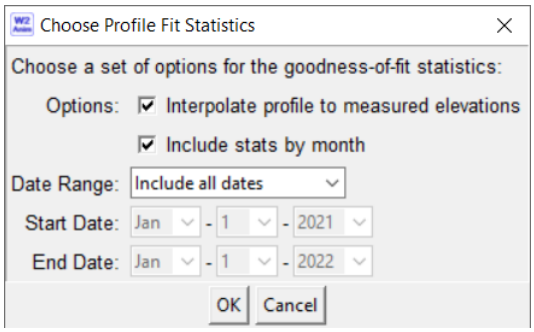


For any modeled date/time, W2Anim will search for and try to plot a measured profile with a date/time that is within the match tolerance. The measured profile is plotted with circles and connecting lines showing the elevation or depth location of each measurement. If color highlighting is turned on, the circles are filled with a color corresponding to the measurement value, whereas the background colors of the graph still correspond to the modeled profile values.

As the profile is animated, both the modeled and measured profiles will be updated. A measured profile will be shown whenever a measured profile is available within the match tolerance of the modeled date/time. The measured profiles can be hidden or deleted by hovering the mouse cursor over the graph, clicking the right mouse button (or typing Alt-p) and selecting the Reference Data option and the Hide Reference Data or Delete Reference Data option.

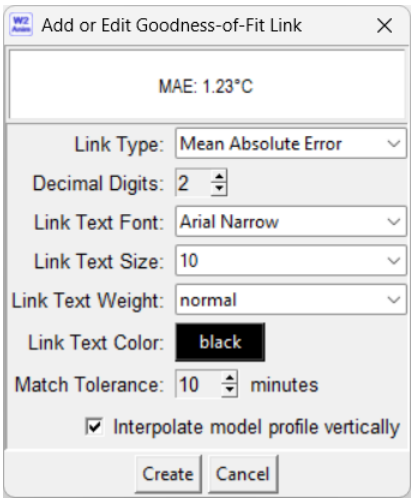


From the Reference Data submenu, the Fit Statistics Table option will bring up a menu (at right) that can be used to compute goodness-of-fit statistics for the comparison of modeled and measured vertical profiles. The user can choose to interpolate the modeled profile to each of the measured elevations or depths, or simply compare each measured point to the value associated with the model layer it falls within. The user can choose to compute the fit statistics by month and/or for a specific date range. The results also will include goodness-of-fit statistics for the modeled water-surface elevation.



The Add Goodness-of-Fit Link option allows the user to create one or more linked text objects that show a goodness-of-fit statistic for the current vertical profile. The menu at the right will appear. The possible link types are Mean Error (ME), Mean Absoute Error (MAE), Root Mean Square Error (RMSE), and Stats Table. Choosing Stats Table will create four linked text objects in a right-justified table that show the number of data pairs being compared (N) along with the ME, MAE, and RMSE, similar to the example at the right. Before creating these linked stat objects, the user can choose the font family, size, weight, and color, the number of digits after the decimal, the match tolerance, and whether the statistics are computed with a vertically interpolated model profile. If no measured profile is available for the current date/time, then each linked object will show an "na" value. After these linked statistic objects are created, they can be moved or edited like any other text object, except that their text is controlled by the graph to which they are linked.

N: 19
ME: 0.21°C
MAE: 0.69°C
RMSE: 0.75°C

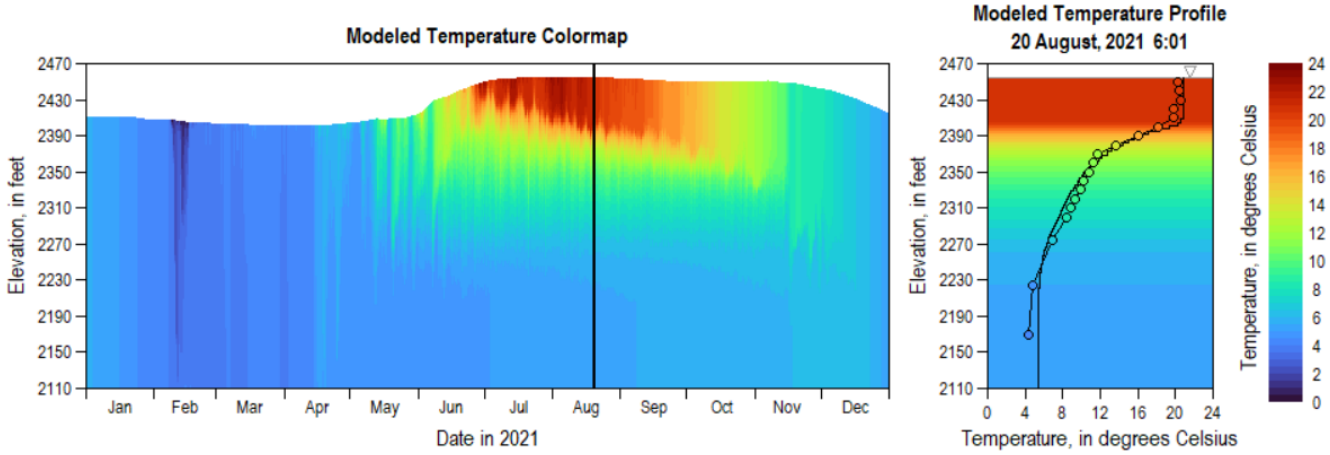


The Create Profile Matrix Plot option from the Reference Data submenu is described in the section titled Vertical Profile Matrix Plots for Modeled and Measured Data.

Note that some extra features are associated with the Animation Toolbar for W2 Vertical Profile graphs that have reference data profiles. Use Shift-Forward and Shift-Backward to manually move from one profile comparison to the next date/time with an available modeled/measured profile comparison.

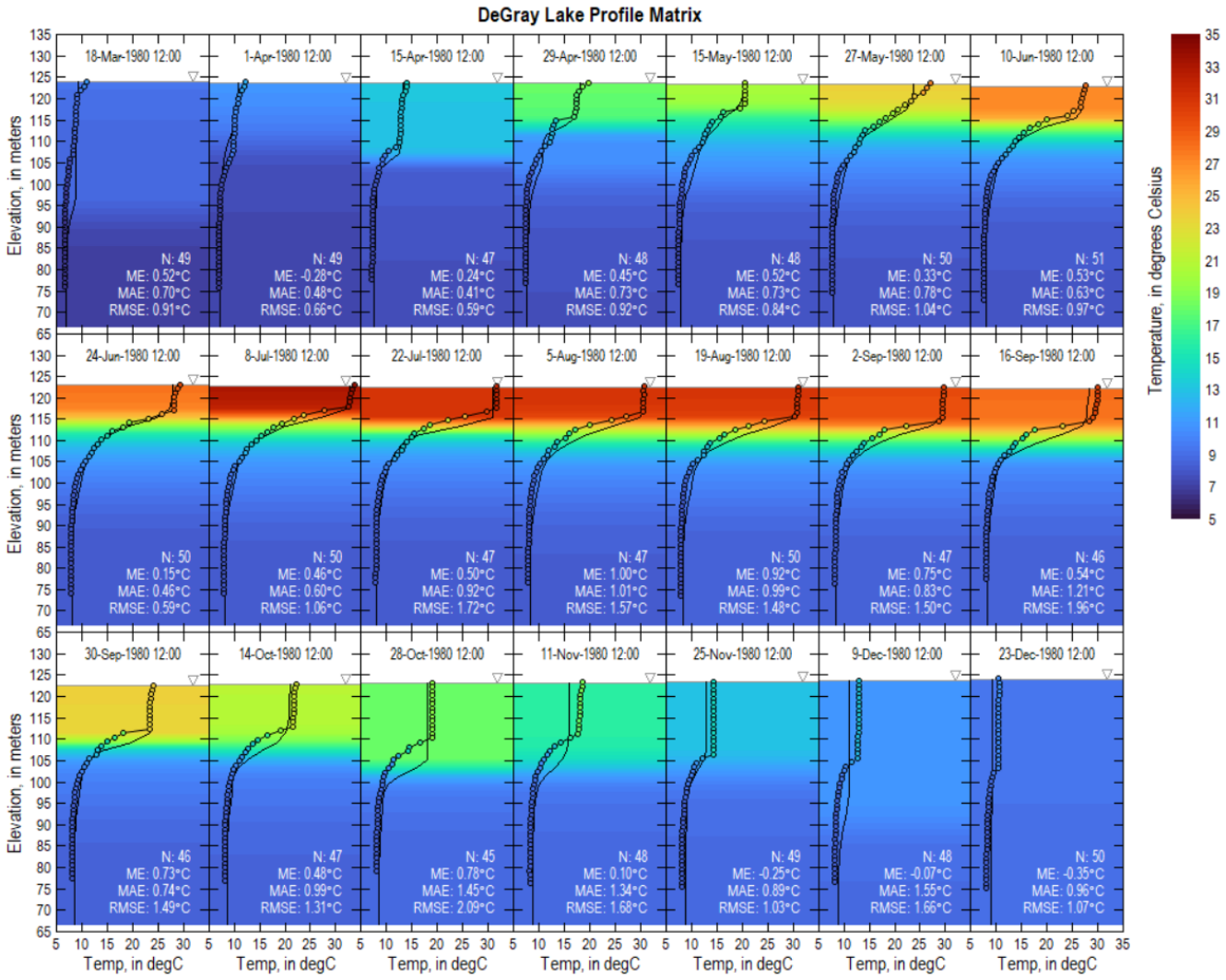
Pairing Profiles and Colormaps

Often it is useful to pair a W2 Vertical Profile graph with a W2 Vertical Profile Colormap because the profile graph is specific to a particular date/time whereas the colormap provides a time-series context. When the profile is animated, a vertical date line can be shown on the colormap to denote the current date/time.



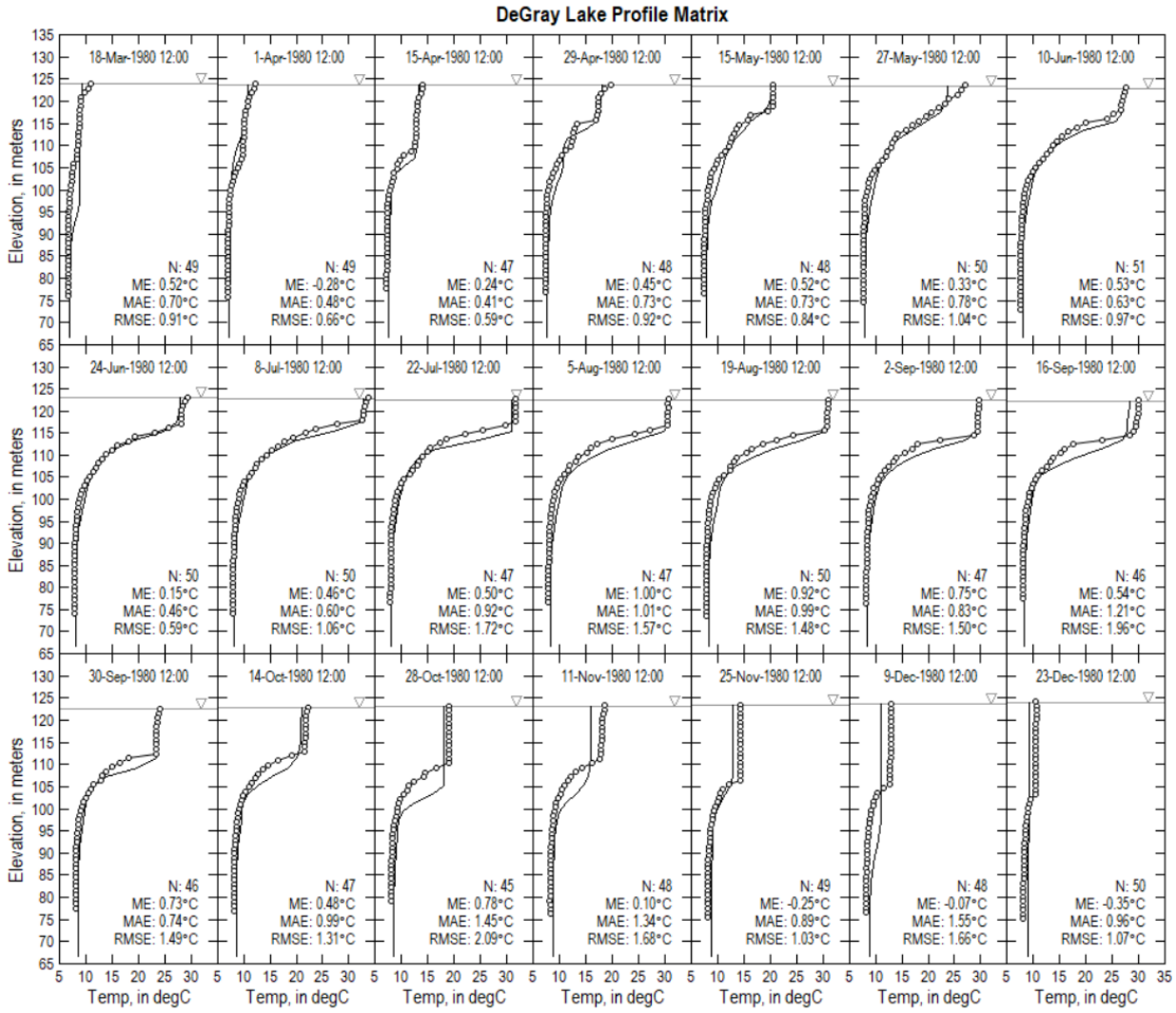
VERTICAL PROFILE MATRIX PLOTS FOR MODELED AND MEASURED DATA

The W2 Vertical Profile graph is an animated graph that shows information only for one date at a time. Often it is advantageous to visualize modeled and measured vertical profiles for a number of dates in separate graphs so that the user can compare the model fit over time at a single location, as in the example matrix below for the often-used DeGray Lake W2 model.



In this example, 21 measured profiles were available for the location near the dam during 1980, and all are shown along with optional goodness-of-fit statistics for each profile. The user can choose the date/times for the profiles of interest to include in the matrix, along with the number of rows and columns in the matrix and the arrangement of the graphs within the matrix. In cases where many more measured profiles are available, it may take longer for the user to choose the exact date/times of interest, but any available subset may be chosen.

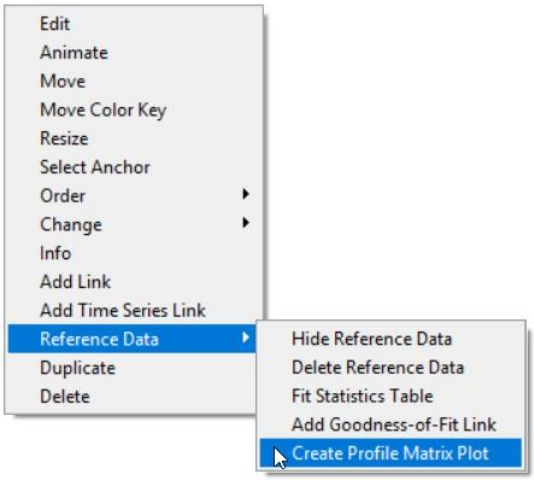
The same matrix also can be plotted without color highlighting, which would result in the matrix on the next page.

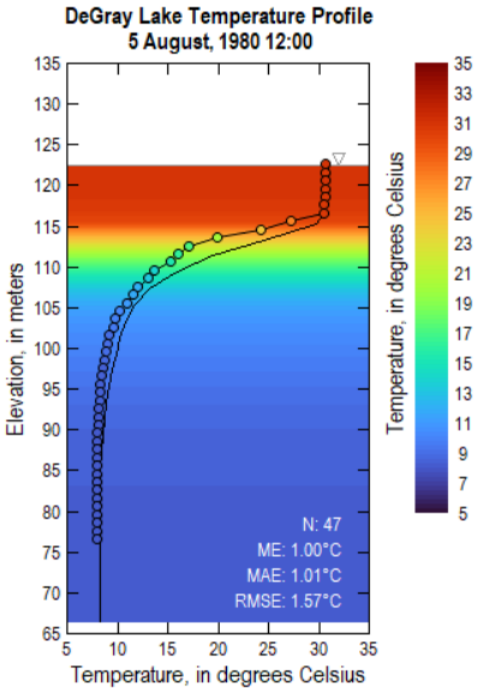


Creating a New Vertical Profile Matrix

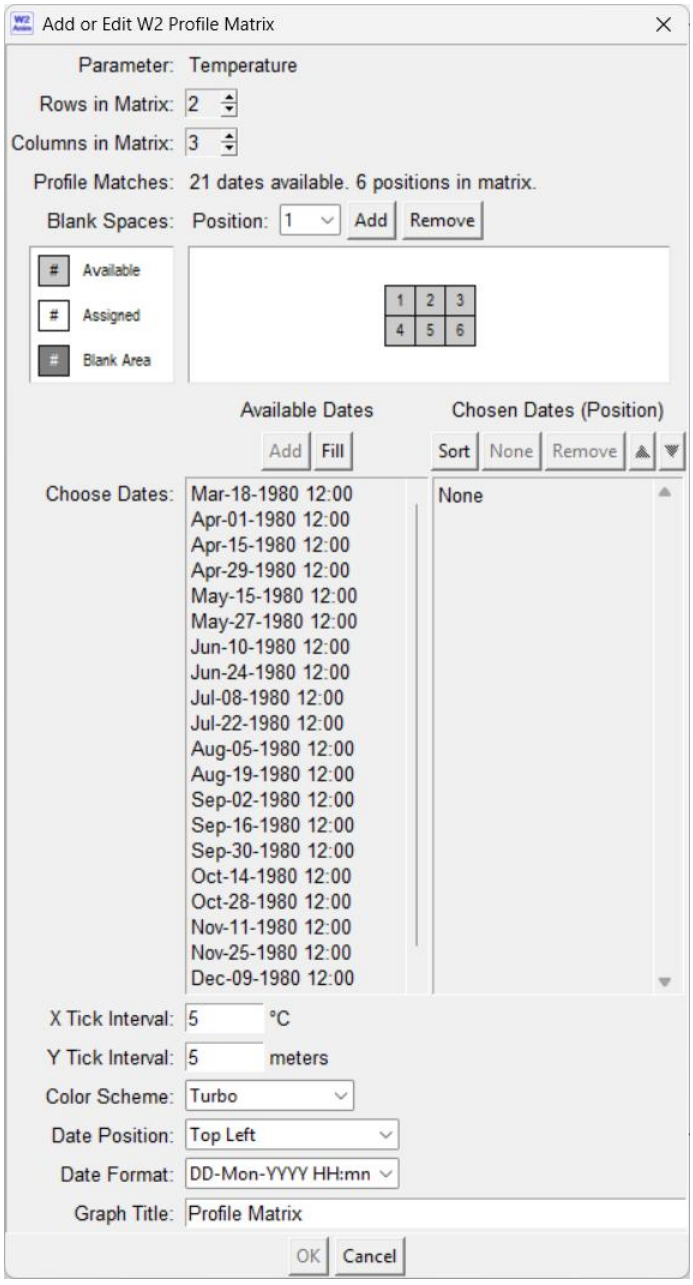
A Vertical Profile Matrix plot cannot be created without first having a W2 Vertical Profile graph that also has one or more measured profiles in a reference dataset. Before creating a matrix plot, it is prudent to ensure that the drawing canvas has sufficient room to hold the matrix plot.

Then, using the DeGray Lake example at the right, a new Vertical Profile Matrix plot can be created by hovering the mouse over the W2 Vertical Profile graph and right-clicking (or typing Alt-p), then choosing the Reference Data submenu and the Create Profile Matrix Plot option.





At this point, the mouse cursor becomes a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new matrix (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the "anchor point" for the matrix; a different anchor point can be set later. Then, move the mouse to a location that specifies the opposite corner of the matrix; W2Anim will draw a rectangle that follows the crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if Snap to Grid is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a matrix of a particular size. Click the left mouse button to set the matrix size. Once the frame is set, a new menu will pop up, as seen below.

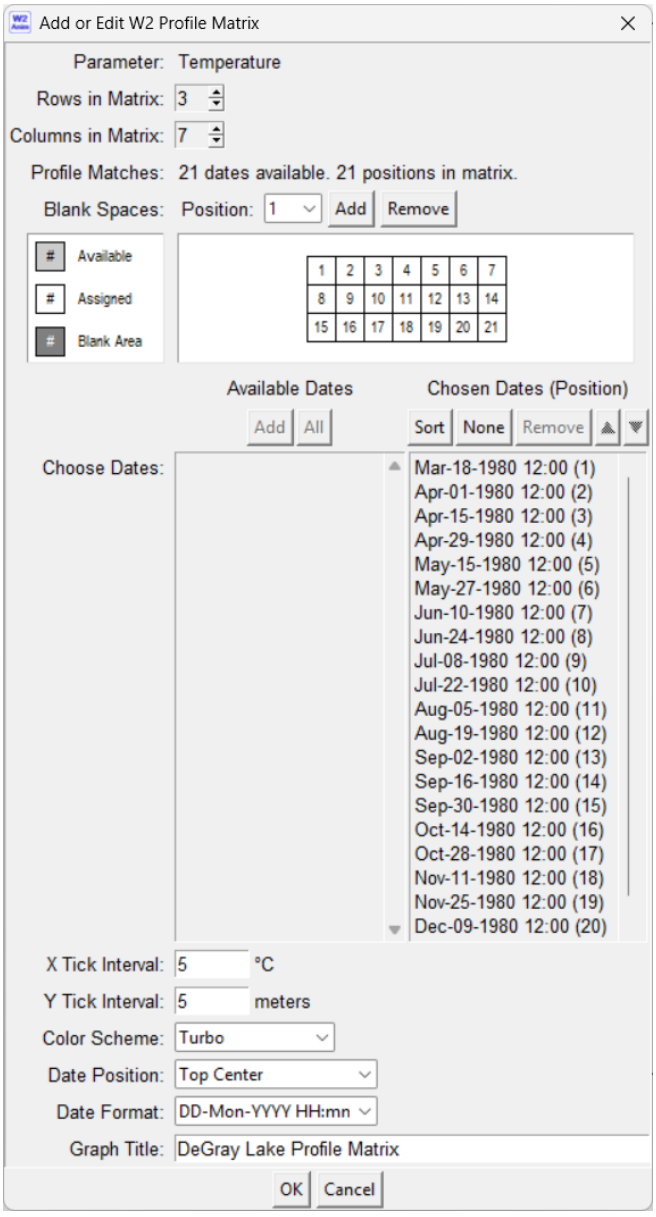


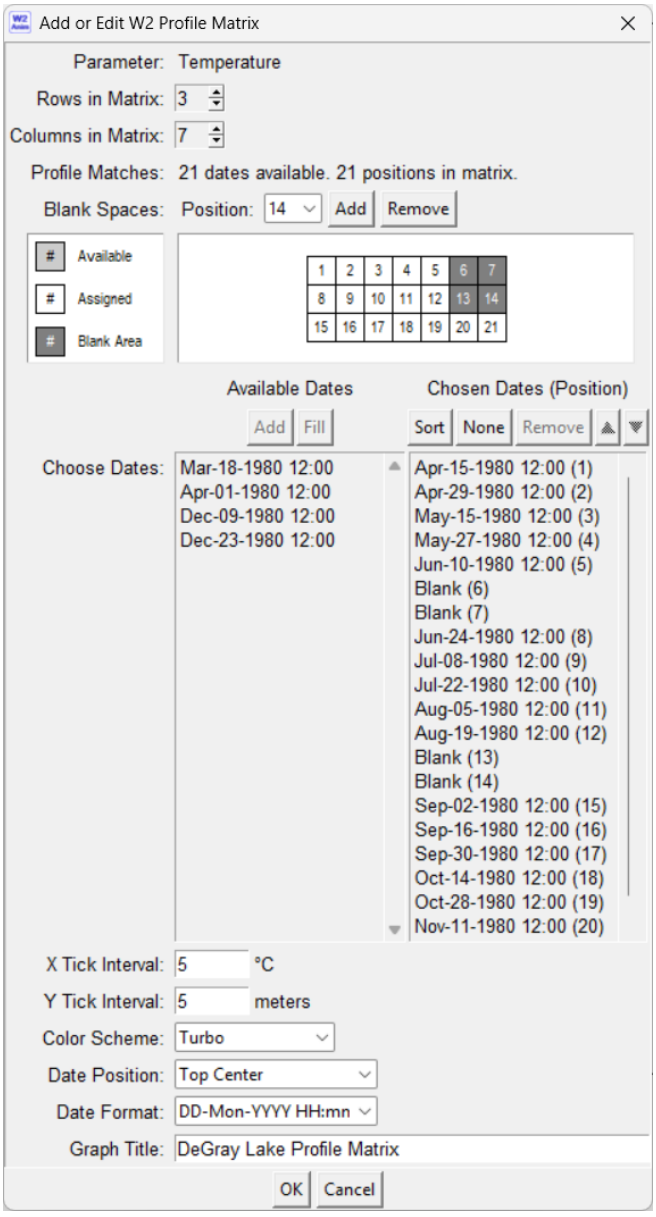
The first task is to set the number of rows and columns in the matrix. By default, new matrices initially have 2 rows and 3 columns. A maximum of 15 rows and 25 columns is allowed. The menu at the right shows a preview of the arrangement of profile plots in the matrix, initially showing that all positions are available. The list of available dates where measured and modeled profiles are within the user-specified match tolerance is shown as a scrollable list under the Available Dates heading. To add a date to the matrix, select a date from among the available dates and click the Add button to move it to the Chosen Dates list on the right. Multiple dates can be chosen by dragging the mouse over the list while holding down the left mouse button. Alternatively, select one date, and choose a range by holding down the Shift key while selecting a second date. Or, select multiple dates by holding down the Ctrl key while selecting dates with the left mouse button. The Chosen Dates list for the matrix also can be filled by clicking on the Fill button, which will populate the list by drawing upon the first available dates. When the available date list holds fewer dates than the available positions in the matrix, the Fill button becomes an All button.

As dates are chosen, they are filled into the matrix from lower numbered positions to higher positions. Once in the Chosen Dates list, a date may be moved among the positions using the Up and Down buttons just to the right of the Remove button. The controls are largely self-explanatory.

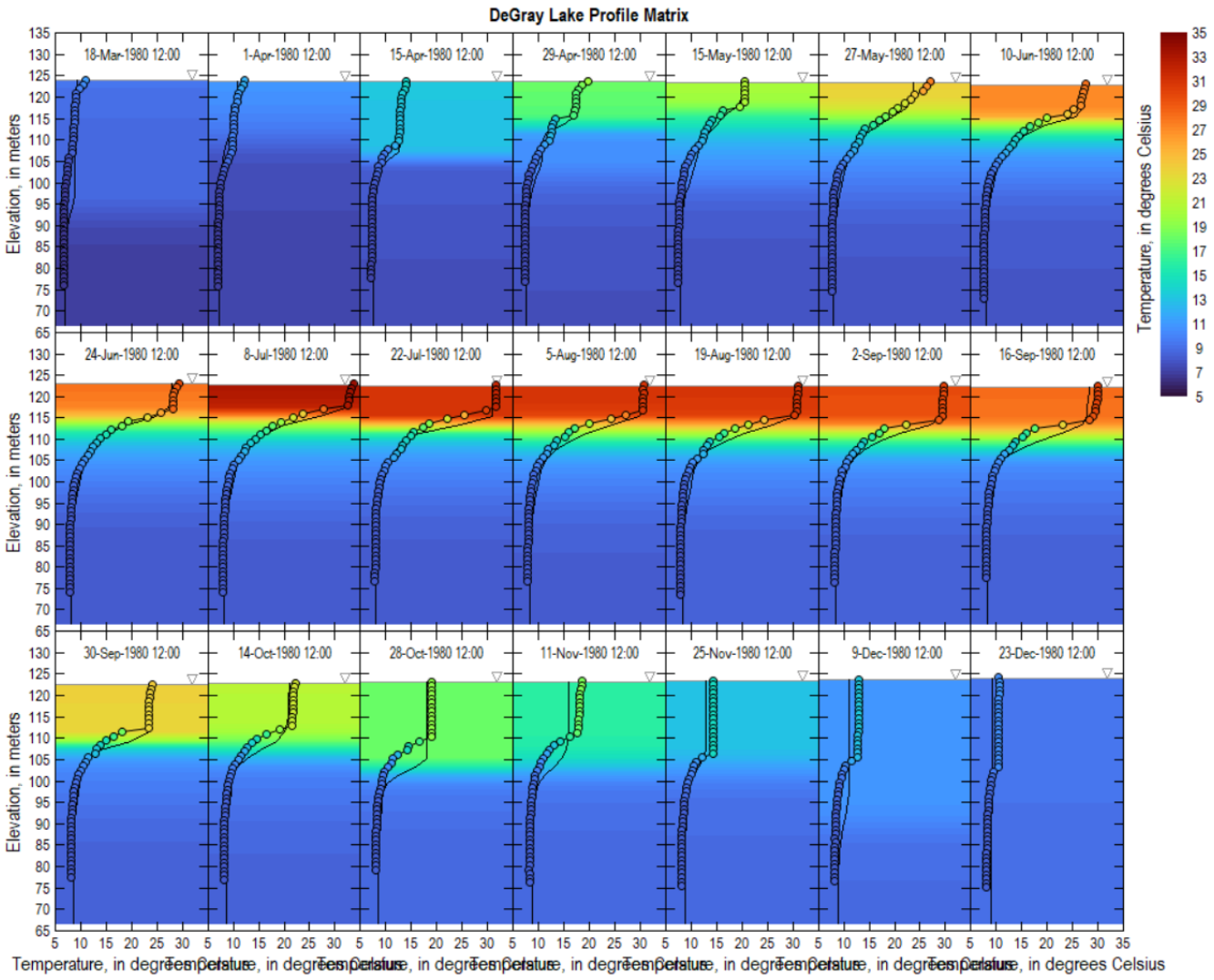
Blank spaces may be inserted into the matrix as desired, either by manually inserting them with the Add and Remove buttons for Blank Spaces, or by moving chosen dates down in the list such that blanks are inserted to fill the gaps. By using blank spaces in the matrix, the user can create a matrix that is not quite rectangular. For example, a corner could be cut out to make space on the drawing canvas to hold the animated W2 Vertical Profile graph that is the parent of the matrix.

The initial menu also allows the user to specify the matrix title, whether a color scheme is to be used, and the location and format of the date for each member of the matrix. Two potential matrix choices are illustrated in the menus below, where the choice on the right carves out a corner of the matrix, perhaps to set aside a space on the canvas for the original W2 Vertical Profile graph.

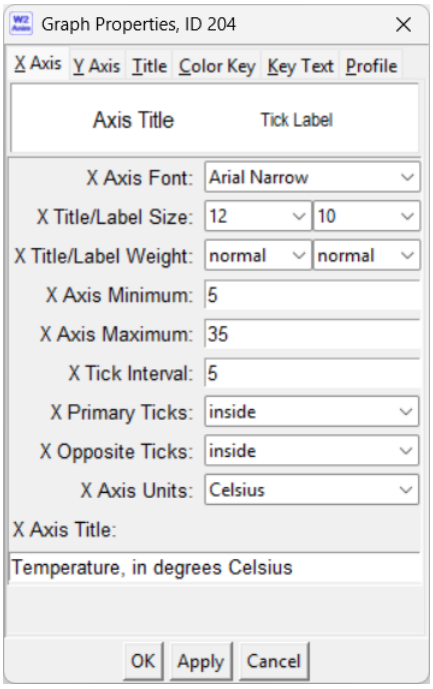




The X and Y tick intervals, along with the color scheme, date position and format, and graph title all can be modified later from the Graph Properties menu. Choosing the configuration on the left above, the example matrix is shown on the next page after the user clicks on the OK button.



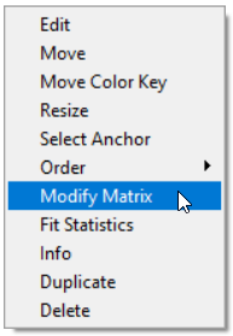
The matrix of plots was created, but the X axis title clearly is too long. Modifications can be made from the Graph Properties menu. To open that menu, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option. Alternatively, select the Edit/Edit option from the menu bar and left click on the matrix. The Graph Properties menu will appear, as shown at the right. For profile matrix plots, six tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, Title, Color Key, Key Text, and Profile.



The Profile tab allows the user to control the vertical interpolation of the modeled profile and the background color scheme, as well as the line colors and widths of the profiles and the size of the circles denoting the measurements. The font, size, weight, color, format, and position of the date labels can be modified from the Title tab.

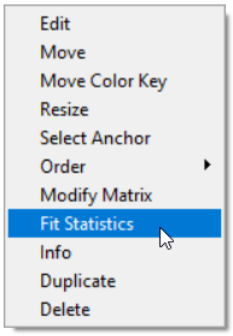
When profile matrix plots are created, axes are created and labelled as appropriate, and axis maxima or minima are clipped, when necessary, if neighboring axis labels would interfere.

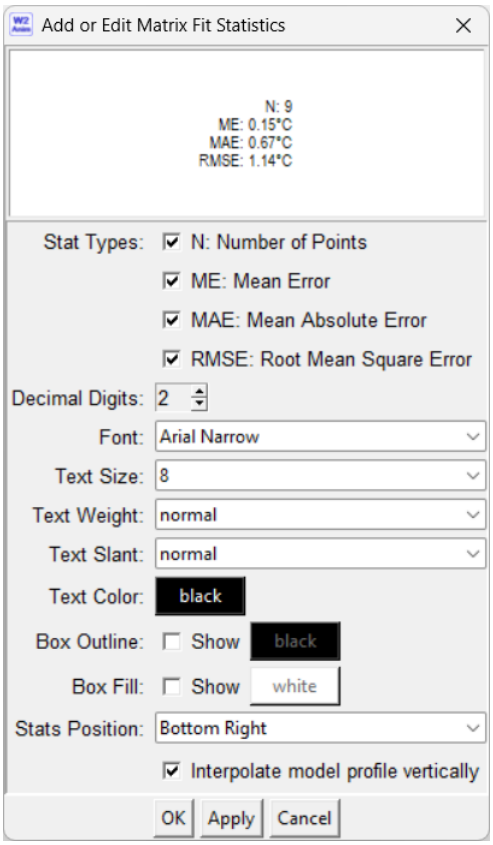
Anytime after creation of the matrix plot, the matrix may be modified by right-clicking over the matrix (or typing Alt-p when hovering over the matrix) and selecting the Modify Matrix option. The Add or Edit W2 Profile Matrix menu will appear as before, although without any options to modify the X or Y tick intervals, color scheme, graph title, or position and format of the date labels, as those options are available from the Graph Properties menu. This menu allows the user to resize the matrix (different number of rows and columns), insert or remove blank positions in the matrix, choose different dates, and modify the order (positioning) of the chosen dates in the matrix.



Adding Fit Statistics

Goodness-of-fit statistics can be added to each profile in the matrix. To add such statistics, right-click over the matrix (or type Alt-p while hovering over the matrix) and select the Fit Statistics option. A new menu will appear, as shown below at left. This menu is used to select the statistics of interest, the number of digits after the decimal to be displayed (for all but N), the font characteristics and optional outline and box fill, and the position on each graph for the placement of the statistics. The user also can choose whether the model profile should be interpolated vertically when matching the vertical position of the measurements in the reference profile.



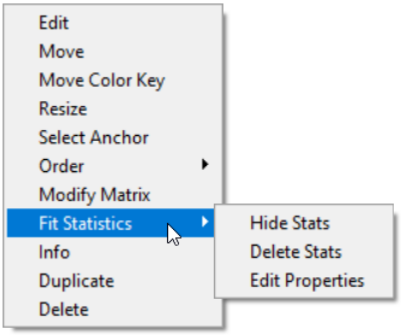


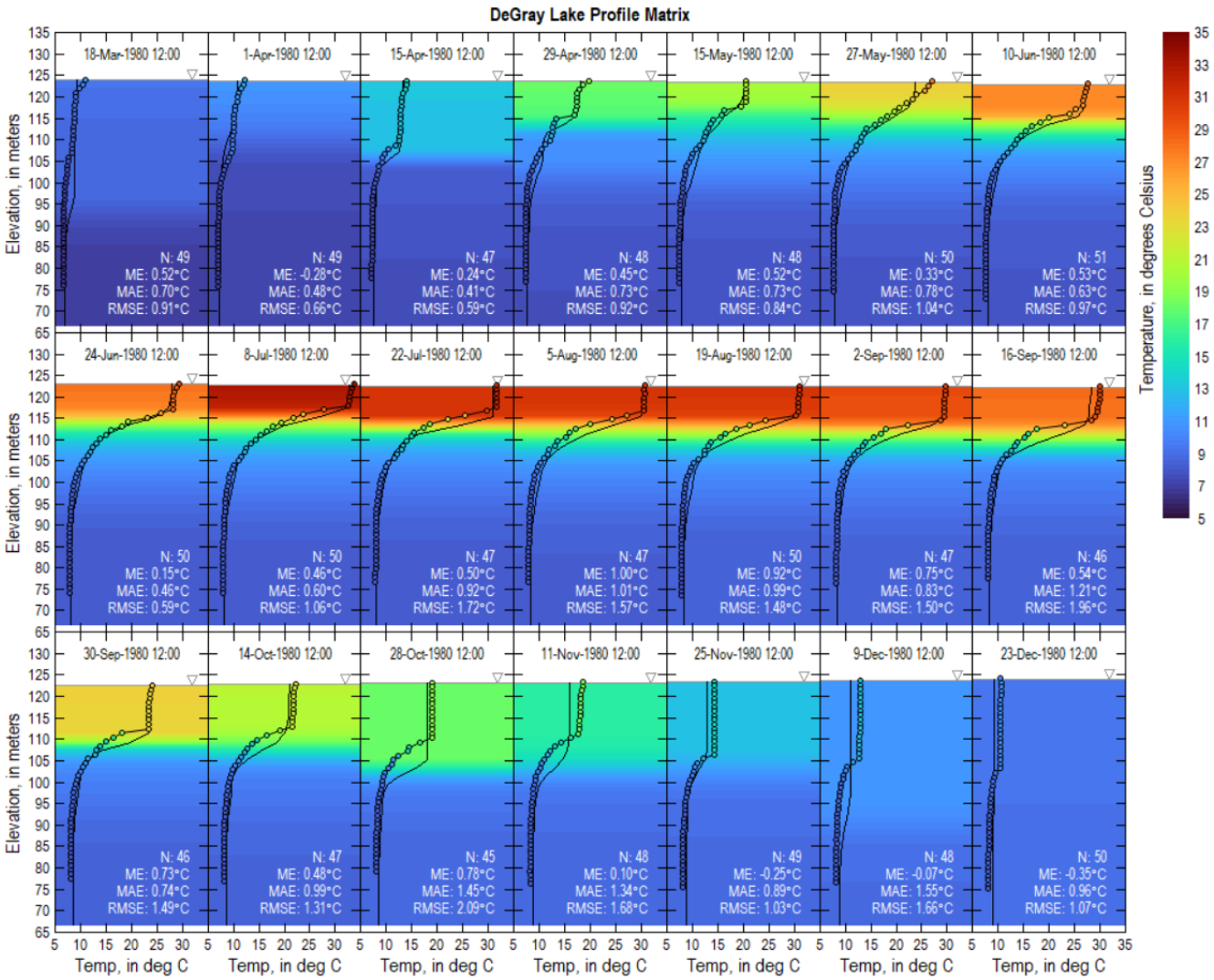
The choice of statistics holds for every graph in the matrix and the statistics will be shown for all of the profiles in the matrix. See the Goodness-of-Fit Statistics section of this user manual for more information.

In this case, it would be wise to change the text color to white, or to turn on the box fill, so as to provide some contrast for the statistics text when shown over the top of the color highlighting for the profile. When the position for the fit statistics is chosen to be the same as that for the date label, the date label takes precedence and the position of the fit statistics will be adjusted slightly to account for the space taken by the date label.

After choosing a white text color and other adjustments from the Graph Properties menu, the resulting profile matrix plot is shown on the next page.

Once the fit statistics have been turned on, they may be hidden or deleted, or their properties modified, by again accessing the Fit Statistics menu, as shown at the right. W2Anim will attempt to ensure that the fit statistics text remains visible when activating or deactivating the vertical profile's color scheme. For example, if the text color of the fit statistics is white with no background box color and the color highlighting is subsequently turned off, W2Anim will change the text color of the fit statistics to black.

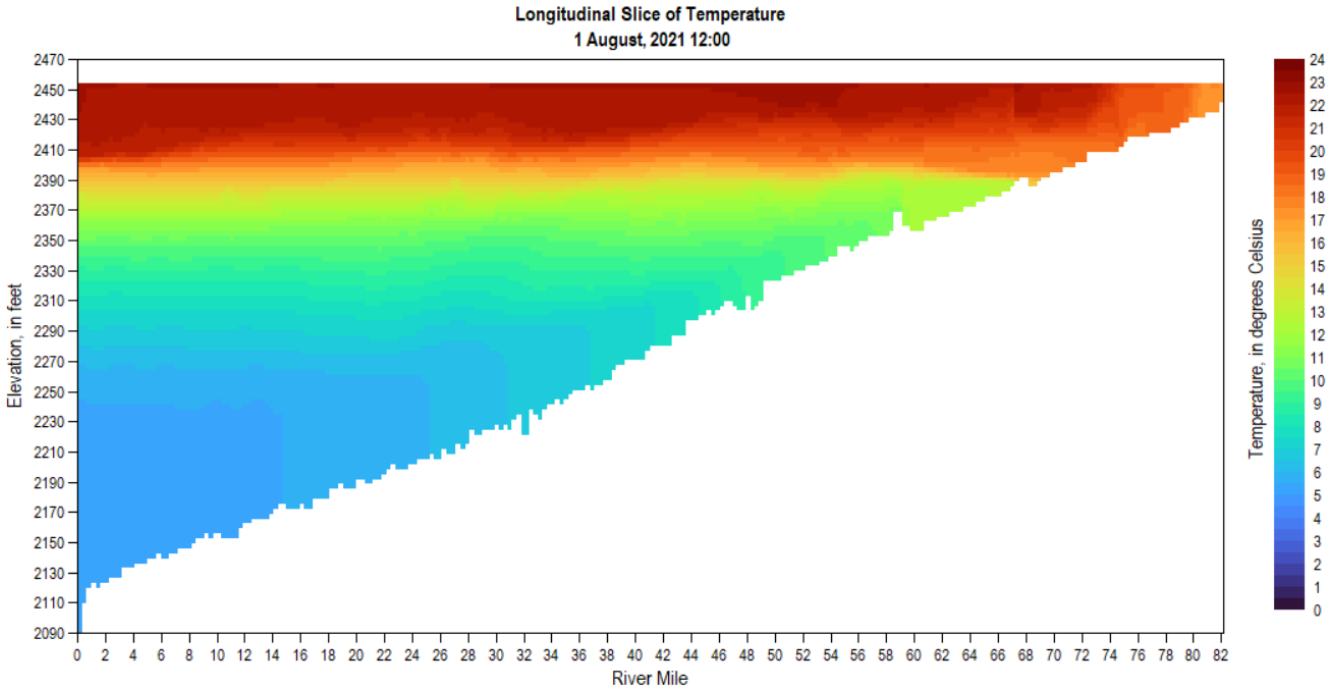




These Vertical Profile Matrix plots are useful for visualizing model results and comparing those results to measured profiles at a single location, but these plots are static objects with no animation. The emphasis in W2Anim is on animation, so it is assumed that the parent W2 Vertical Profile graph will be retained on the drawing canvas after creating a profile matrix. The matrix is still valid, however, even if the parent graph is later deleted. Still, the only way to create such matrix plots is to first create a W2 Vertical Profile graph with reference profiles. At this time, separate matrices can be created for different locations, but each matrix will hold profile plots only for the same location.

W2 Longitudinal Slices

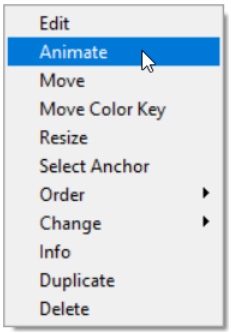
For lakes and reservoirs or any waterbody that stratifies, an animated visualization of modeled conditions along a longitudinal slice through the model domain can be an effective way of discerning spatial and temporal patterns and gaining insights related to important inputs, fluxes, or instream processes. The W2 Animator can read W2 contour and vector output files to create such longitudinal slices. An example slice of modeled water temperature is shown below, using the Turbo color scheme to display the spatial temperature variations.

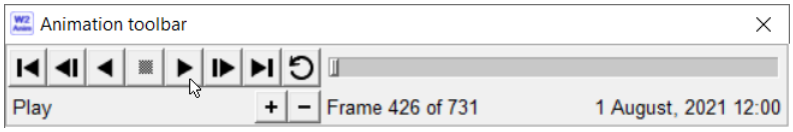


Such longitudinal slices often embody some substantial vertical exaggeration, given that the depths simulated in a CE-QUAL-W2 model typically are small relative to the longitudinal distances. The graph depicted above, for example, has a vertical exaggeration of about 571; that information is available in W2Anim through the Info option from the menu that pops up when the user right-clicks over the graph.

The W2 Longitudinal Slice graph can be plotted with either elevation or depth on the Y axis, river mile or river kilometer on the X axis, and segment number on an optional segment axis along the distance (X) axis. The minimum X axis distance location need not be zero, and the user may set that value to any number. In addition, the slice depiction can be flipped left to right, such that the river miles or kilometers (or segment numbers) are reversed.

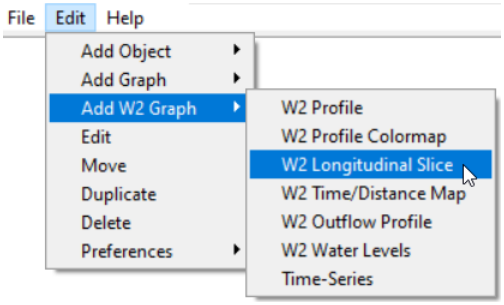
Of course, the longitudinal slices can be animated. Hovering over the graph and clicking the right mouse button (or typing Alt-p) brings up a menu from which the user can choose the Animate option. This brings up the Animation toolbar (below), which allows the user to play the animation forward or backward at various speeds, jump to different dates or move forward or backward a frame at a time. The animations in W2Anim are fast and efficient, and allow the user to explore how the longitudinal slices change over time. For the animations to work properly, the user must allow W2Anim to initially cycle through the available dates so that the slice images can be prepared and stored for quick swapping during animation.



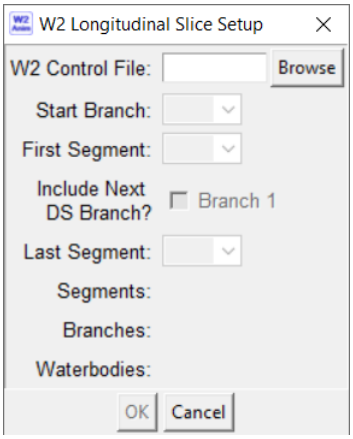


Creating a New Graph

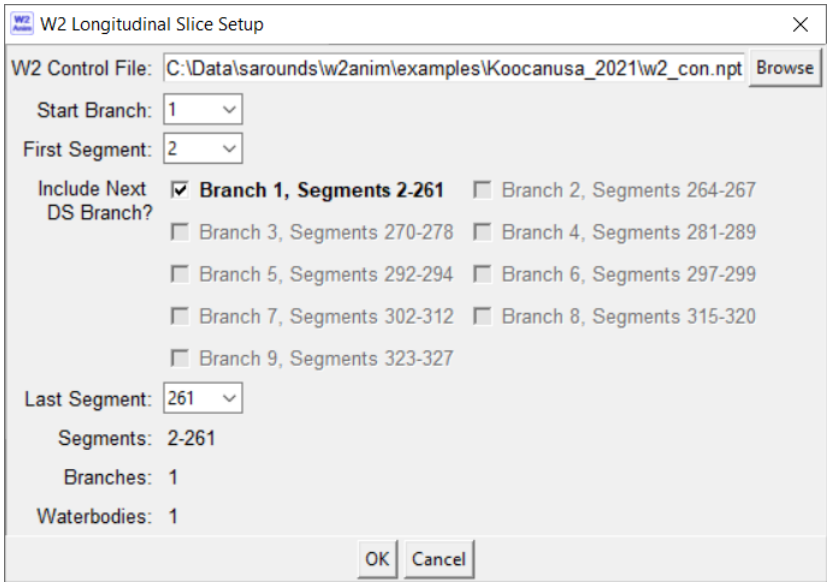
To create a W2 Longitudinal Slice graph, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at Canvas Properties.



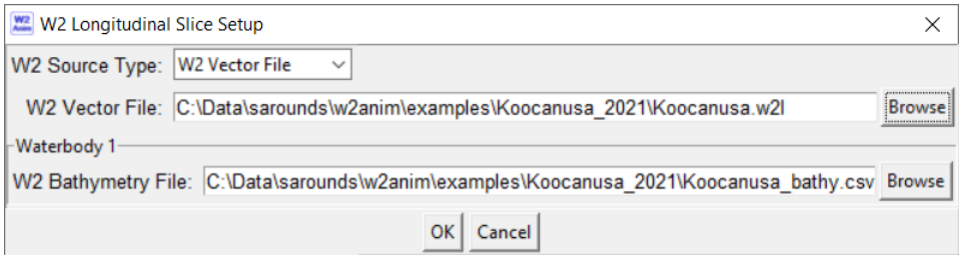
The W2 Longitudinal Slice graph can be started by choosing the Edit/Add W2 Graph/W2 Longitudinal Slice option from the menu bar. Alternatively, right-click on the canvas and choose the Add W2 Graph/W2 Longitudinal Slice option. The mouse cursor will become a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the "anchor point" for the graph; a different anchor point can be set later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the frame is set, a new menu will pop up, as seen at the right.



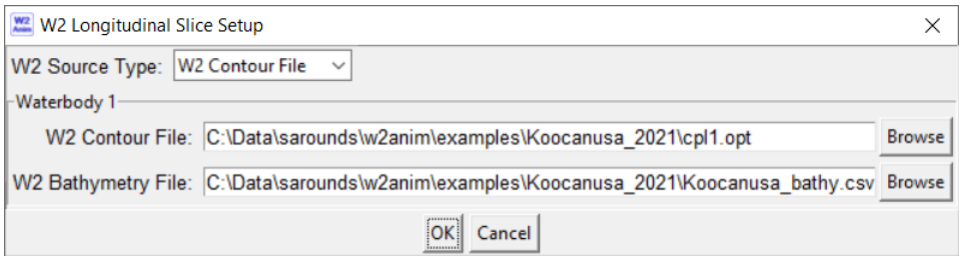
This is the first of three menus that gather the information needed to create a W2 Longitudinal Slice graph. In this first menu, the user starts by specifying a W2 control file, which W2Anim scans for segment, branch, and waterbody parameters. The user next chooses the starting branch and segment number for the upstream end of the slice, then selects the model branches to follow downstream and finally the most-downstream segment for the slice. In the example at the right, the choice was to select segments 2-261 in branch 1 of waterbody 1. Using the information in the control file, W2Anim knows how the various branches are connected, and therefore can provide the user only with options that constitute continuous longitudinal slices from the chosen starting location. Clicking the OK button moves on to the second menu, shown on the next page.



In the second step, the user must choose the source for the slice data, either from one or more W2 contour output files, or from a W2 vector file. When using a W2 vector file for the slice data, it is still necessary to provide the name(s) of any associated bathymetry file(s), as shown in the menu below, even though some bathymetric information is included in the vector file.

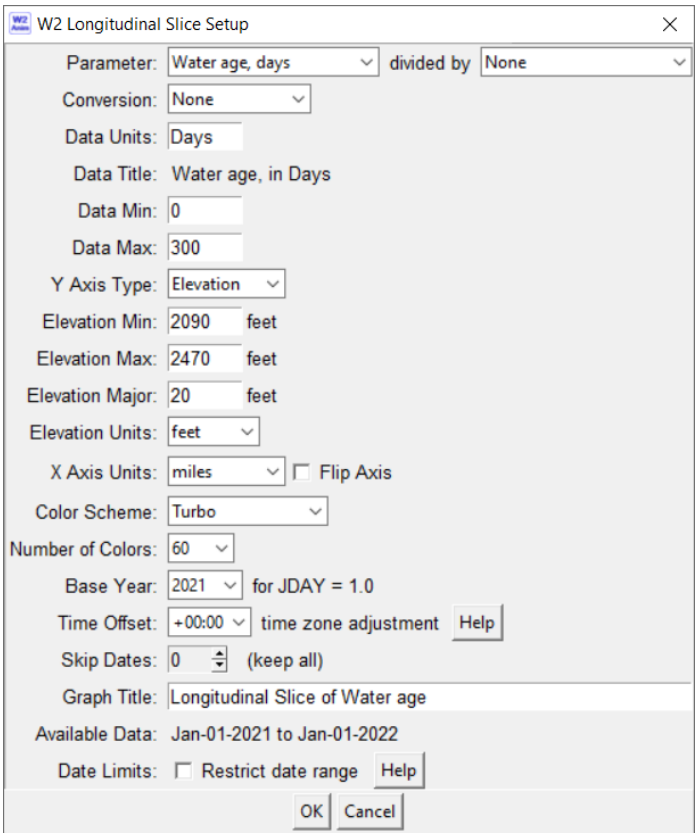


When the source type is set to use a W2 contour output file, the user must provide the names of the W2 contour and bathymetry files for each of the waterbodies included in the longitudinal slice, as shown in the example below.



Clicking the OK button moves on to the third and final input menu. Canceling aborts the graph creation.

The third W2 Longitudinal Slice Setup menu handles the choice of the modeled parameter, axis limits, color scheme, and base year, among other inputs. If the W2 contour or vector output frequency is less than 1.0 (more than one output per day), then the user is offered the choice to skip one or more dates in the source file. Skipping 1 would use every other output date, skipping 2 would use every 3rd date, and so forth. Skipping dates is a trade-off for the slice graph, as more dates provide more frequent detail in the animation, but require more time to process the additional data.



All of the inputs to this third menu can be changed later, either through the Graph Properties or Change menus. The Y Axis Type is either Elevation or Depth. If Depth is chosen, then the Elevation Max and Major and Units become Depth Max and Major and Units, and the Min option disappears because the minimum depth will be set to zero. An option to add a segment-number axis is available only through the Graph Properties menu after the graph has been created.

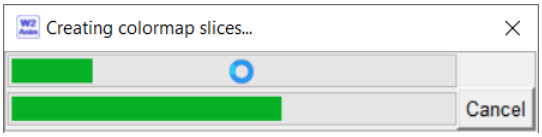
The "Water age" parameter was chosen for this example graph, and its native W2 units are days. Note that any parameter choice other than Velocity, Temperature, Density, or Habitat creates an option to divide the chosen

parameter's value by the value of a different parameter. When tracking heat sources with CE-QUAL-W2, many of the modeled heat-tracking parameters must have their simulated concentration divided by the modeled temperature (see Rounds and Stratton Garvin, 2022). Similarly, if the user wishes to visualize a nitrogen to phosphorus ratio or a dissolved to particulate ratio and both parameters are present in the output file, then this would be possible.

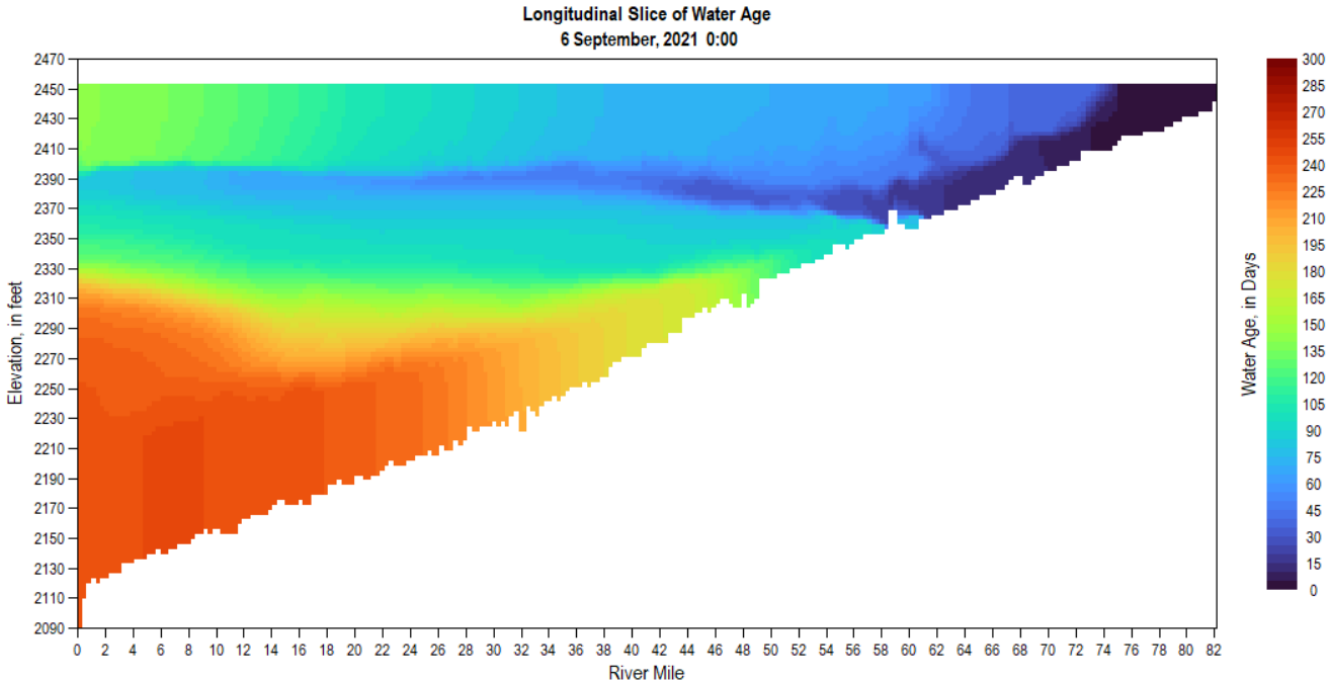
The example simulation was for one year, so a maximum of 300 days was chosen for the water age color scale. The color scheme input for this menu offers just a few options; other choices become available after the graph has been created. For this example, the Turbo scheme was chosen with 60 colors.

If the W2 output file has data for a long time period and the slice graph has a lot of pixels, then in some instances Perl may run out of memory while generating the slice images for each date. This sort of problem should be rare, but in such cases the user may wish to restrict the date range for the W2 Longitudinal Slice plot. Alternatively, if the output file has data for 30 years and the user wishes to examine only the first five, then a date restriction may be useful. Selecting the "Restrict date range" checkbox will bring up inputs for a start and end date. This date restriction can be modified from the Change menu later. The resulting filled-out menu is shown on the previous page.

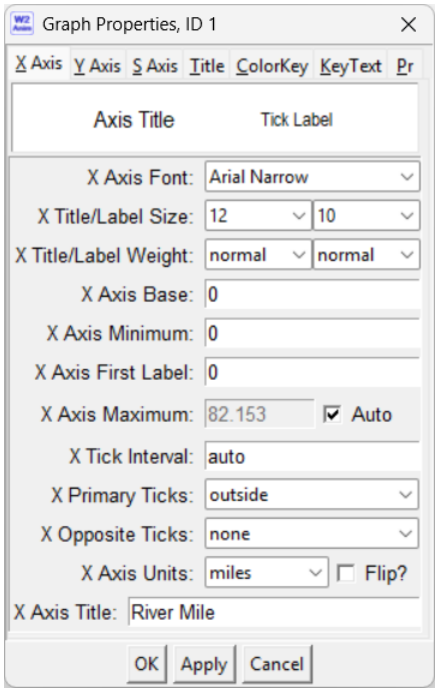
Clicking the OK button will remove the menu and create the graph. Clicking the Cancel button will remove both the menu and the graph. The resulting W2 Longitudinal Slice graph created from this example is shown below. As W2Anim works to create this graph, it must first read the W2 contour or vector output file, evaluate the limits of the data, and then create images of the longitudinal slices for each available date. This takes some time, and W2Anim informs the user of its progress with a two-part progress bar, where the lower bar shows the progress of creating an individual slice for each single date, and the upper bar shows the overall progress of creating all of the required slice images. By pre-computing these slice images, an animation of the longitudinal slices later will be fast and efficient.



Note that the default font family for graph text can be set in the Program Defaults or by configuring a W2Anim Initialization File. The initial font size for new graphs is scaled according to the size of the graph frame, and the resulting font size for tick labels typically is in the range of 8 to 11 points, and 2 points larger for axis and graph titles.

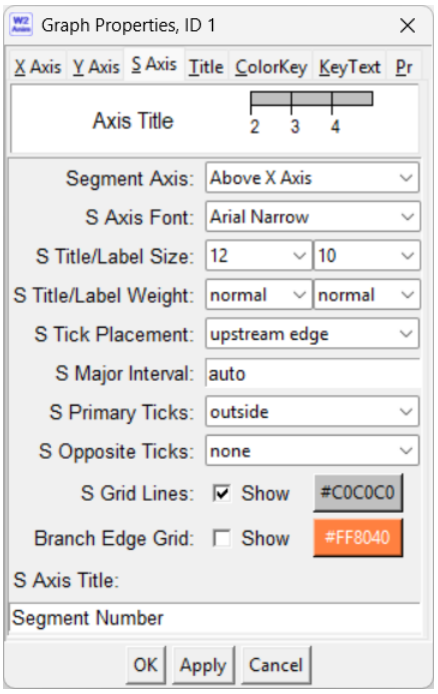


To edit the characteristics of this new graph, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option. Alternatively, select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown at the left. For this graph type, seven tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, S Axis, Title, Color Key, Key Text, and Profile.

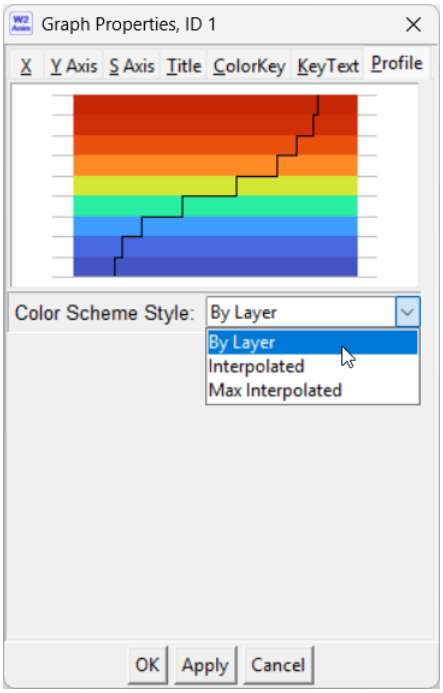


The various options of the Graph Properties menu should be fairly self-explanatory, and therefore most will not be discussed in detail here. In general, the user can play with each of the options and observe the result when the Apply button is clicked. Note in particular the Flip option for the X axis, which will flip the slices left to right. Flipping the precomputed slice images requires some image manipulation, but is less time-consuming than generating all of the slices from scratch.

The base value is a distance that corresponds to the most-downstream location of the chosen reach, and the automatically calculated maximum value is derived from the base value plus the slice's total distance.

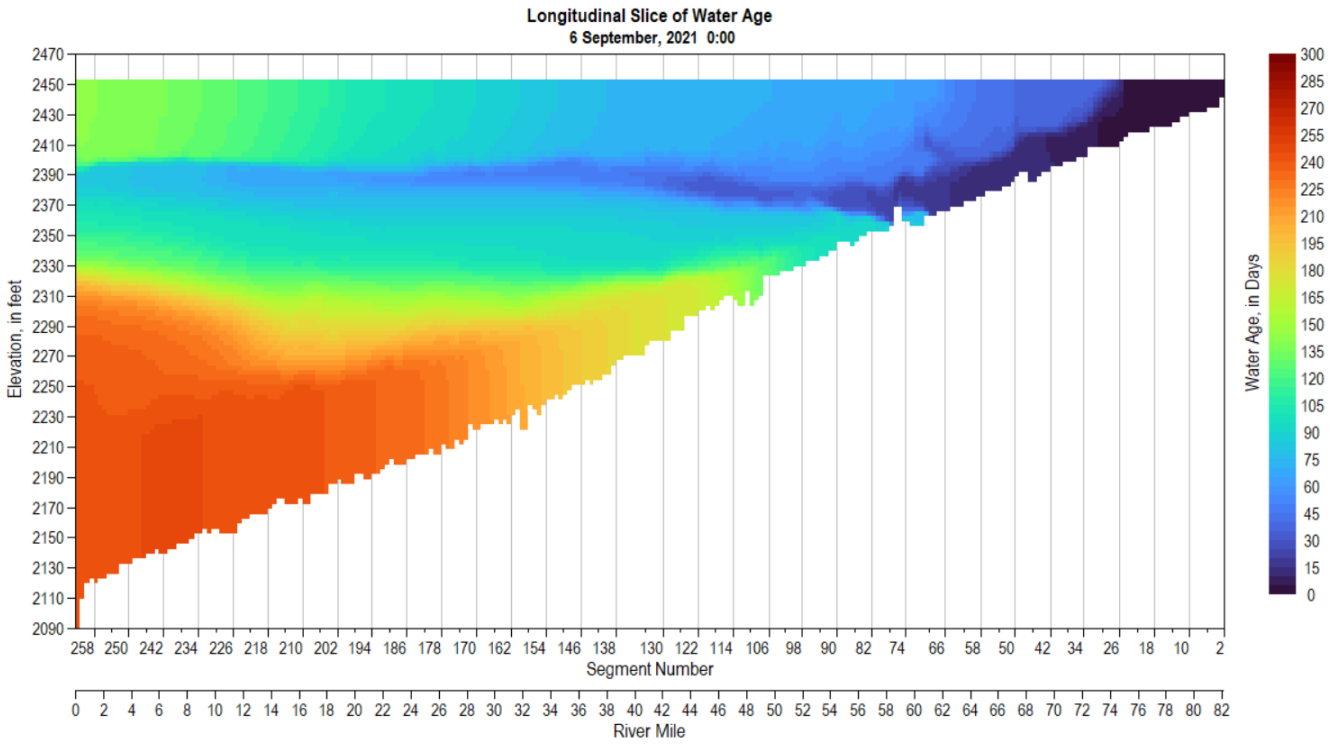


The S Axis (segment axis) tab of the Graph Properties menu is used to create or modify a segment-number axis along the X distance axis of the graph. A segment axis can be placed above or below the X distance axis or can replace the X distance axis. In the example to the right, the choice was made to put a segment axis above the X distance axis. Segment tick marks can be placed at the upstream or downstream edge of a segment or in the segment center. The preview at the top of the menu gives the user an idea of the final appearance. The segment major tick interval can be set to "auto" or to a user-defined number, and minor tick marks will be set automatically. As with other axes, tick marks may be placed on the primary or opposite axis, and potential tick mark styles include inside, outside, cross, or none. Vertical grid lines can be shown at each of the segment tick marks, and optional vertical lines also can be shown at branch boundaries.

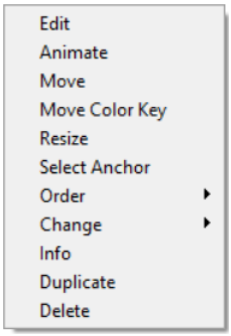


The Profile tab (at the far right) of the Graph Properties menu is used to specify whether the vertical color profile for each segment should be shown with a uniform color for each model layer, interpolated somewhat from the middle to the top and bottom of each model layer, or interpolated to a maximum extent such that vertical zones for each color in the color scheme are interpolated and displayed.

An example W2 Longitudinal Slice graph with a segment axis is shown on the next page.

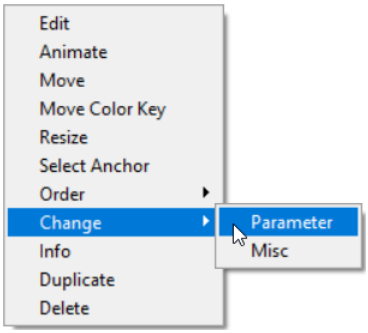


Under the Color Key tab of the Graph Properties menu, note that the color key Status can be set to visible or hidden. The hidden option hides the color key, which is useful if more than one graph with the same color scale is present on the canvas. The Links option allows changes to the color scheme for one graph to cause changes to the color schemes for other graphs on the canvas, either for the same parameter or for the same parameter and source data file.



Now that the graph has been created and edited, the user has a number of other options to animate, move, or resize it, select a different anchor point, move it up or down in the drawing order, make a duplicate, or delete it. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu. The entire graph can be moved just like any drawing object, or grouped with other objects and moved as a group. The color key can be moved independently from the graph itself, which can be useful when its default placement is not ideal. At this time, the color key cannot be rotated. The Resize option allows the user to resize the graph frame, where one of the corners is tied to the graph's anchor point; the user may select a different anchor point before resizing. See the sections on Object Anchors and Manipulating Drawing Objects for more information on many of these options.

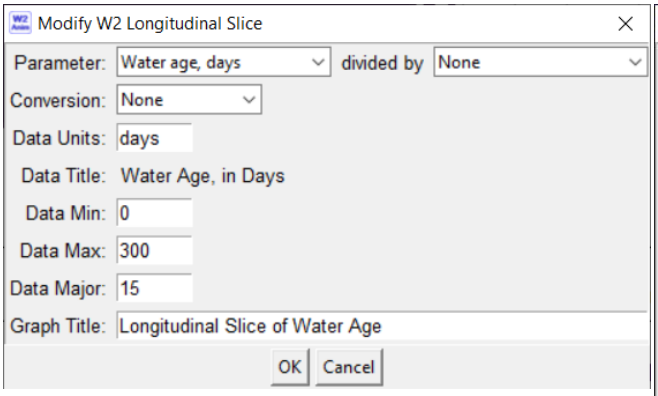
Changing the Parameter or Units



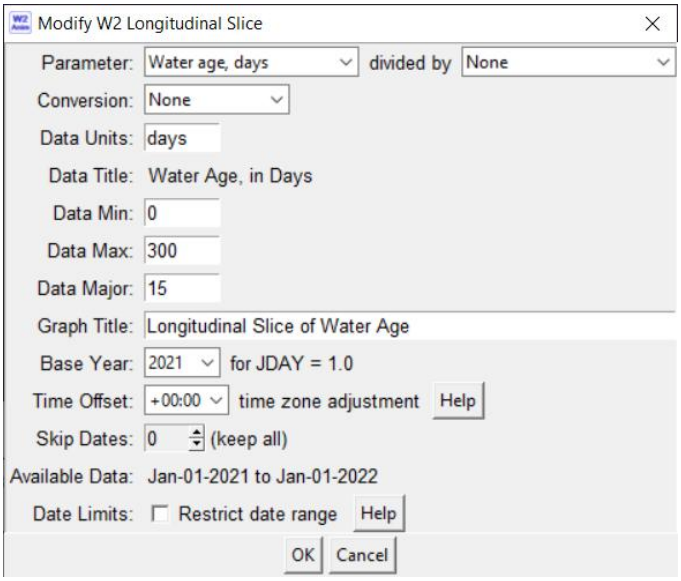
Through the Change submenu (at right), the user can select a different model parameter, parameter units, W2 model begin year, time offset, date-skip setting, or date restriction range. This feature is handy not only for fixing user mistakes after the graph is created, but also for creating multiple slice graphs by duplicating a graph and then changing the model parameter used in the duplicated graph. In this way, a user can quickly set up an array of slice graphs for a suite of modeled parameters. If the user wants a different slice composed of different segments or branches, however, a new slice graph must be created. Choosing a new date range will cause the slice graph to be rebuilt.

The Change submenus should be self-explanatory because they mimic parts of the menu used to create the original slice graph. The menus for the two options are shown below.

Parameter:



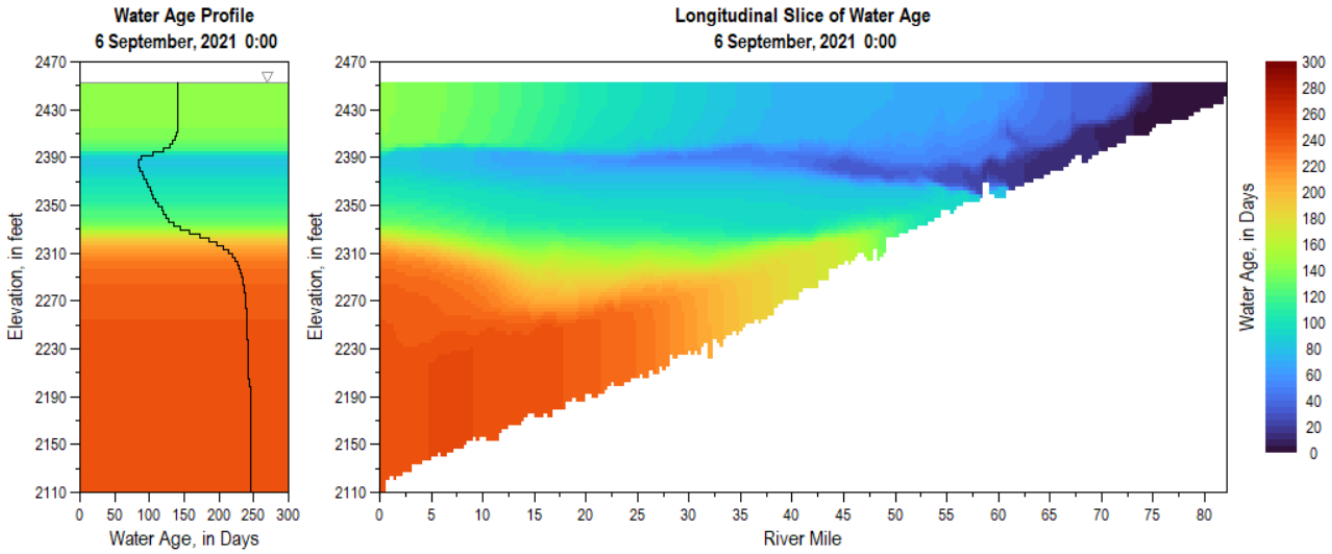
Misc:



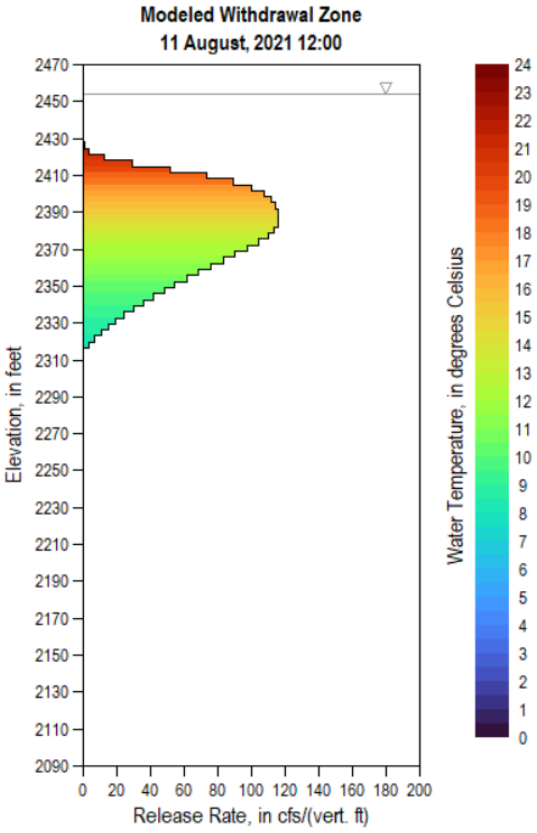
The only difference between the Change Parameter menu and the Change Misc menu for W2 Longitudinal Slice graphs is that the latter allows the user to select a different W2 base year, time offset, date-skip setting, or date range restriction. Any substantial change requested from these menus will cause the data file(s) to be re-read and the graph to be re-created. Cancelling the operation or destroying the menu will result in no changes to the graph. Simply changing data limits (Min/Max) or the graph title is not allowed from these menus, as that is best done from the Graph Properties menu. For W2 Longitudinal Slice plots derived from large data files, modifying the date restriction period can be a good way to prepare animations from a subset of the available data.

Pairing Slices with Profiles

It can be useful to pair a W2 Longitudinal Slice graph with a W2 Vertical Profile graph because the profile graph provides a better depiction of the vertical profile than a vertical line of colored pixels. In the example below, a vertical profile of modeled water age at the downstream-most segment was paired with a longitudinal slice of water age, such that the profile of water age at the downstream end of the slice can be examined in more detail. In this instance, that is also the location of a dam, and the dam affects the depth of water releases from the reservoir, so having more detail on the vertical profile at the dam can be useful. When animation is invoked, both graphs track the changing date/time in a synchronized manner.



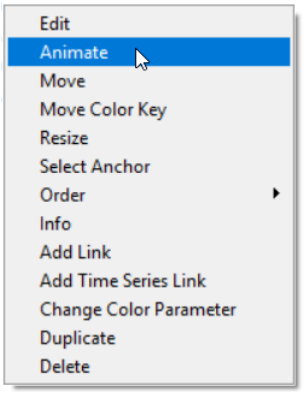
W2 Outflow Profiles

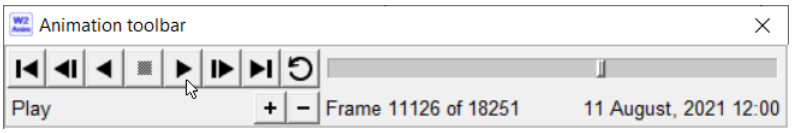


Selective withdrawal is the release of reservoir water from a specific vertical range of depths according to the interplay of the depth and dimensions of a dam outlet, the release rate, and the density profile of water in the reservoir near the outlet. The CE-QUAL-W2 model applies selective withdrawal algorithms to compute the vertical range of depths from which water is drawn to dam outlets and the amount of water that is drawn from each model layer as water moves toward those outlets. The model algorithms generally describe dam outlets as point or line sinks, where each line sink is given an effective width. Recent USGS modifications to CE-QUAL-W2 also allow a time-varying bulkhead configuration such as that constructed at Libby Dam to be part of selective withdrawal computations by using a set of virtual line sinks fronting a common wet well. Other code modifications also created a new W2 Layer Outflow output file that is used by W2Anim to visualize vertical withdrawal zones and the flows toward dam outlets.

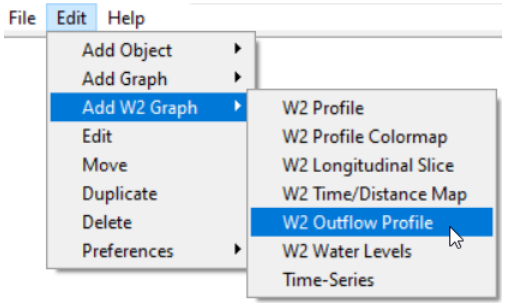
The graph at the right is an example of a W2 Outflow Profile graph as made by The W2 Animator. In that graph, the vertical distribution of flows or velocities toward dam outlets on a particular date is plotted against depth or elevation on the Y axis. The release rate is plotted per unit depth (cfs per vertical foot, or cms per vertical meter). Alternatively, the user can choose to plot the horizontal velocity (ft/s or m/s) toward the dam outlets on the X axis. Optional color highlighting of the model layers can be used to show the characteristics of water in each model layer where water is being drawn to the dam outlets. In this example, water temperature is used for the layer color highlighting according to the Turbo color scheme illustrated to the right of the graph. The water-surface elevation is shown in the example using a gray horizontal line and the universal water-level triangle symbol near the top of the graph.

W2Anim can animate this type of vertical withdrawal zone graph. Hovering over the graph and clicking the right mouse button (or typing Alt-p) brings up a menu from which the user can choose the Animate option. This brings up the Animation toolbar (below), which allows the user to play the animation forward or backward at various speeds, jump to different dates or move forward or backward a frame at a time. The animations in W2Anim are fast and efficient, and allow the user to explore how the vertical withdrawal zones change over time.

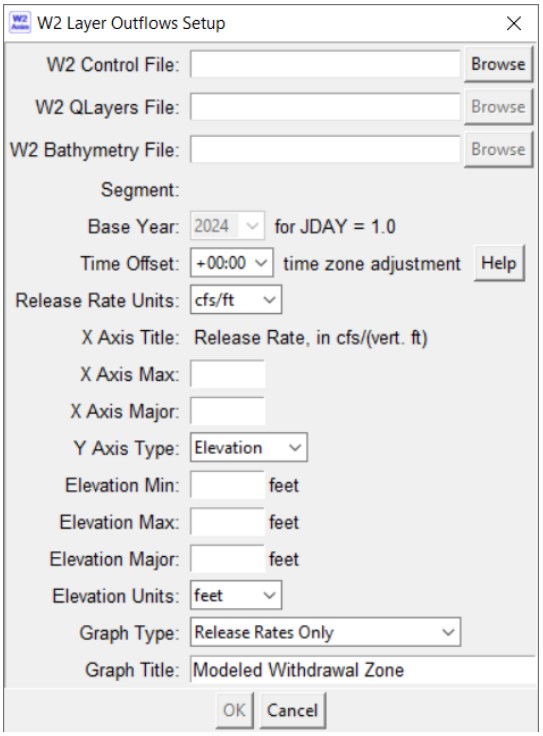




Creating a New Graph



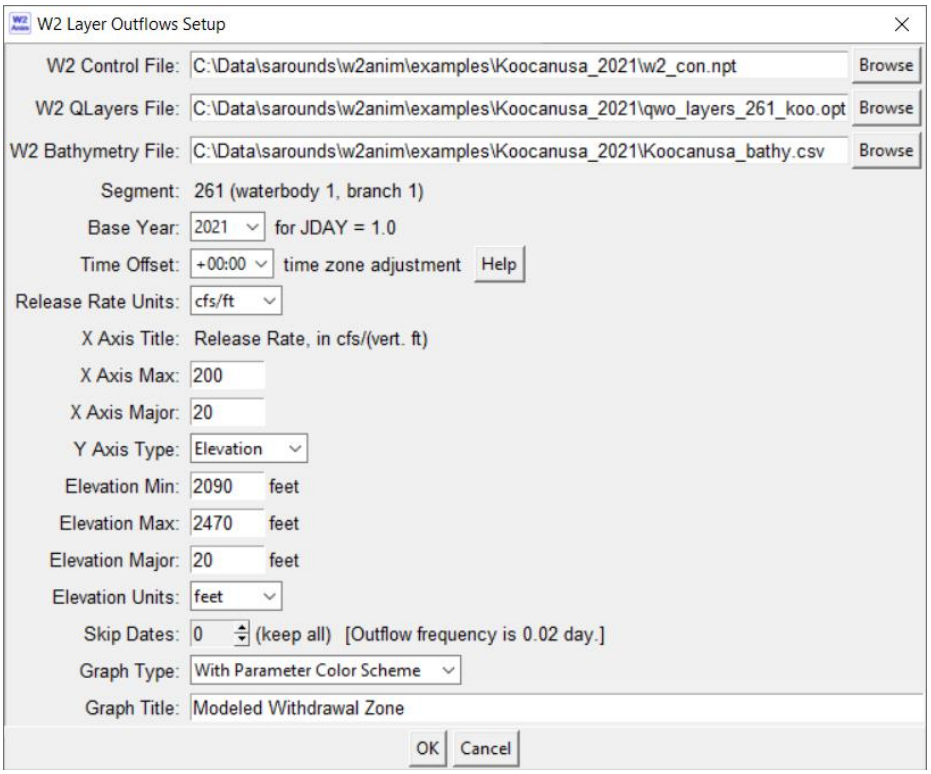
To create a W2 Outflow Profile graph, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at Canvas Properties.



The W2 Outflow Profile graph can be added by choosing the Edit/Add W2 Graph/W2 Outflow Profile option from the menu bar, or by right-clicking on the canvas and choosing Add W2 Graph/W2 Outflow Profile. The mouse cursor will become a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the "anchor point" for the graph; a different anchor point can be set later. Then, move the mouse to specify the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the mouse crosshair location. The status line will show the X,Y crosshair location (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the graph frame is set, a new menu will pop up, as seen at the right.

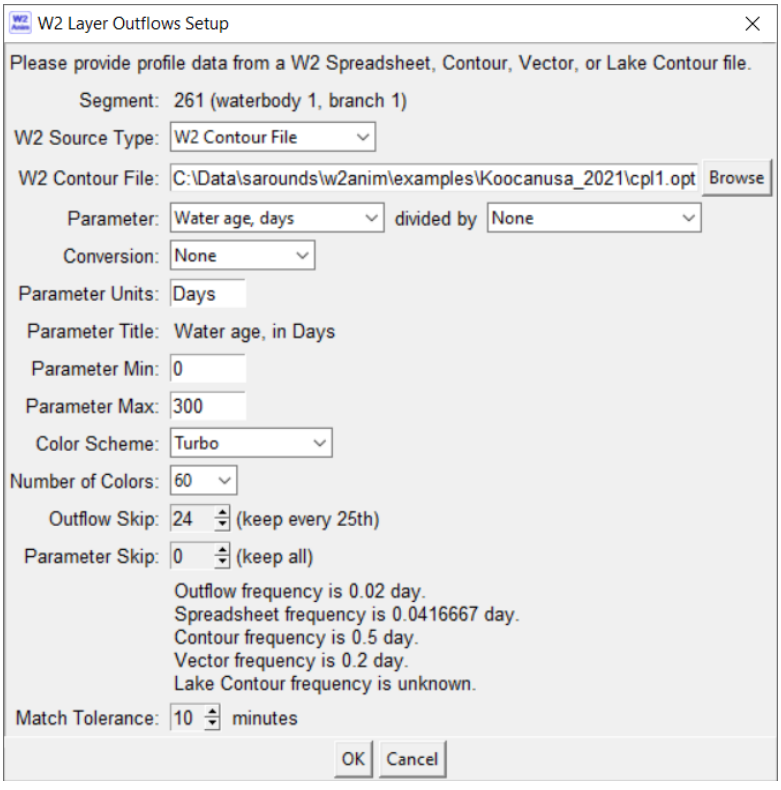
This W2 Layer Outflows Setup menu is the first of two possible menus needed to create the graph; the second is required if the user chooses to include color highlighting with a modeled parameter. The first step is to provide the name of a W2 control file. Click the Browse button to find and select that file. W2Anim will scan the control file for segment, branch, and waterbody details, the begin year, and the frequency of layer outflow output. Next, W2Anim requires the name of the W2 Layer Outflow output file and the W2 bathymetry file.

W2Anim will identify the model segment associated with the layer outflow file and show its value as well as the waterbody and branch number on the menu. Inputs other than the file names, base year, and time offset can be changed after the graph is created. The user often will not know the best X Axis maximum value to specify, but the range of the data can be checked with the Info option after the graph is created. The menu reminds the user of the layer outflow output frequency specified in the W2 control file, and the user can skip every nth date if they choose to do so. In this example, the choice was made to use color highlighting (With Parameter Color Scheme) rather than the Release Rates Only option. The filled-out menu for this example is shown above and to the right.



Clicking the OK button will move on to the second menu. Clicking the Cancel button will remove the menu and abort creation of the graph. In this case, the layer outflow output frequency was 50 times per day (0.02 day), and the choice was to put off a decision on skipping data points until the second menu was filled out.

The second W2 Layer Outflows Setup menu is shown at the right, with its fields filled out for this example. This menu focuses on inputs required to highlight model layers in the graph with colors corresponding to the values of a modeled parameter in W2.



The user must first choose whether the modeled parameter values are to be read from a W2 spreadsheet, contour, vector, or lake contour output file. Both the original and the Tecplot format of the W2 contour file can be read by W2Anim. The user must choose an output file that includes information for the model segment chosen in the previous menu, which is noted near the top of this menu. In this example, the contour file option was chosen. Next, the user must choose the modeled parameter of interest; in this example, “Water age” was chosen. Note that any parameter choice other than Horizontal Velocity, Vertical Velocity, Horizontal Layer Flow,

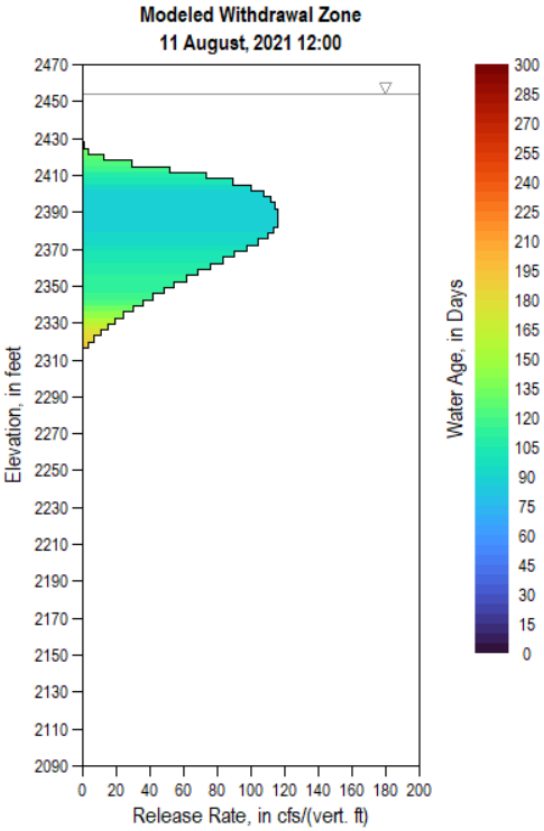
Density, Habitat, or Temperature creates an option to divide the chosen parameter's concentration by the value of a different parameter. When tracking heat sources with CE-QUAL-W2, many of the modeled heat-tracking parameters must have their simulated concentration divided by the modeled temperature (see Rounds and Stratton Garvin, 2022). Similarly, if the user wanted to visualize a nitrogen to phosphorus ratio or a dissolved to particulate ratio and both parameters were present in the spreadsheet or contour or vector output file, then this capability in W2Anim could be useful.

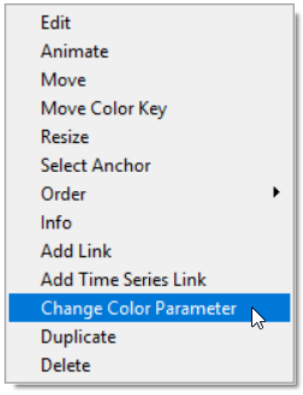
The example simulation was for one year, so a maximum of 300 days was chosen for the water age color scale. The color scheme input for this menu offers just a few options; other choices become available after the graph has been created. For this example, the Turbo scheme was chosen with 60 colors.

To ensure that the model output used for color highlighting is synchronized with the model output for layer outflows, it is important to pay attention to the output frequencies of the different output files. In this example, the layer outflow output frequency was 0.02 day (50 points per day) whereas the contour output frequency was 0.5 day (twice a day). To ensure that each date of the graph in an animated time series has color-highlighting information, the outflow skip input was set to 24 so that every 25th point was used, which corresponds to twice a day, the same output frequency as that used for the contour output file. Finally, to help line up output dates, a date match tolerance input value is available. The color highlighting information will be used as long as that information is available at a date that is within the match tolerance window of the dates on which layer outflow information is available. The default is 10 minutes.

If color highlighting with a W2 spreadsheet output file were used instead of a W2 contour, vector, or lake contour output file, then the date skipping and match tolerance would be somewhat different. The spreadsheet output frequency in this case was hourly. One option would be to retain the outflow skip input of 24 and also use a parameter skip input of 11, which would make them synchronized at twice a day. Alternatively, both the outflow skip and parameter skip inputs could be set to zero and the match tolerance value could be pushed up to 30 minutes. In that case, every outflow date would always be within 30 minutes of an hourly output date for the spreadsheet output file, and therefore each graph in the animation would have color highlighting. These choices in the end come down to what sort of animation frequency the user wishes to have in the final visualization.

Clicking the OK button causes W2Anim to begin the process of creating the graph. It first reads the input files, which may take a bit of time if the files are large. A progress bar may be shown. After the files are read, the graph is created. After editing some font sizes, the example graph at the right was obtained.

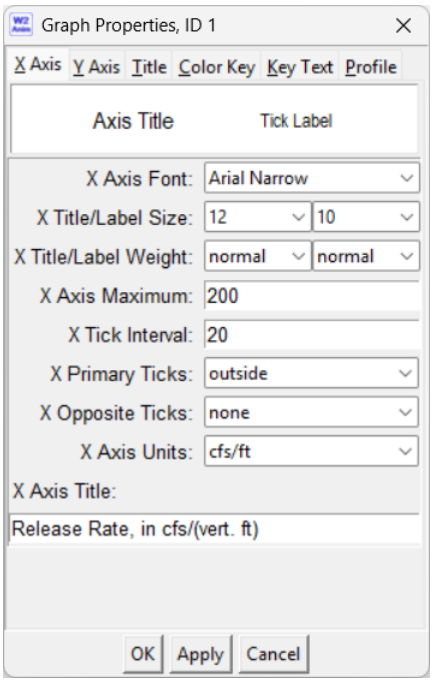




The color-highlighting parameter can be changed after the W2 Outflow Profile graph is created. To select a different parameter, hover the mouse over the graph, right click (or type Alt-p) and select the Change Color Parameter option. The second W2 Layer Outflows Setup menu will appear, and the user can fill out the menu as described above. If the Release Rates Only option was selected at the time of graph creation, then the pop-up menu would have an option called Add Color Parameter. Once a color-highlighting parameter is added to a

W2 Outflow Profile graph, it cannot be removed, but color-scheme highlighting can be inactivated through the Graph Properties menu.

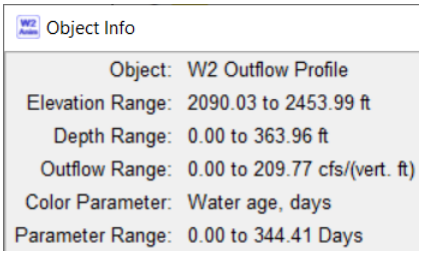
The default font family for graph text can be set in the Program Defaults or by configuring a W2Anim Initialization File. The initial font size for new graphs is scaled according to the size of the graph frame, and the resulting font size for tick labels typically is in the range of 8 to 11 points, and 2 points larger for axis titles and graph titles.



To edit the graph properties, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option, or select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown at the right. For this graph type, six tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, Title, Color Key, Key Text, and Profile. If no color highlighting was chosen, the Color Key, Key Text, and Profile tabs would be absent.

The options of the Graph Properties menu are fairly self-explanatory, and therefore will not be discussed in detail here. In general, the user can play with each of the options and observe the result when the Apply button is clicked. Under the Color Key tab, note that the color key Status can be set to visible, hidden, or inactive. The Inactive option turns off the color highlighting altogether, whereas the Key hidden option simply hides the color key, which is useful if more than one graph with the same color scale is present on the canvas. The Links option allows changes to the color scheme for one graph to cause changes to the color schemes for other graphs on the canvas, either for the same parameter or for the same parameter and source data file.

The Profile tab of the Graph Properties menu is used to specify whether the parameter color highlighting should be shown with a uniform color for each model layer, interpolated somewhat from the middle to the top and bottom of each model layer, or interpolated to a maximum extent such that vertical zones for each color in the color scheme are interpolated and displayed.

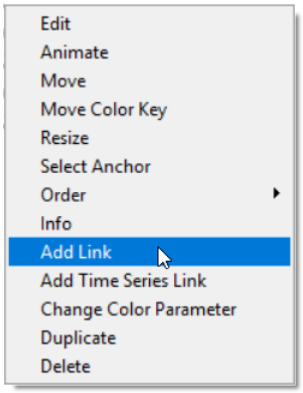


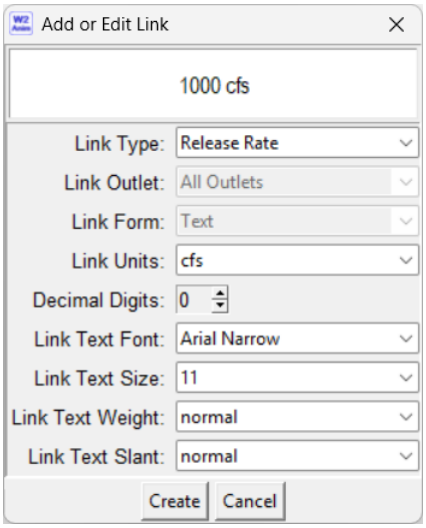
Setting the X axis maximum value can be a challenge for a W2 Layer Outflow graph, but the limits of the data are available from the Object Info box. Right-click over the graph, select the Info option, examine the Outflow Range (see partial information box at right), and adjust the X axis maximum value accordingly.

Now that the graph has been created and edited, the user has a number of other options to animate, move, or resize it, select a different anchor point, move it up or down in the drawing order, add links, choose a different color-highlighting parameter, make a duplicate, or delete the graph. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu. The entire graph can be moved just like any drawing object, or grouped with other objects and moved as a group. The color key can be moved independently from the graph itself if its placement is not ideal. The Resize option allows the user to resize the graph frame, where one of the corners is tied to the graph's anchor point; the user may select a different anchor point before resizing. See the sections on Object Anchors and Manipulating Drawing Objects for more information on many of these options.

Adding a Link

The W2 Outflow Profile graph allows a user to create a linked text object that is tied to the water-surface elevation or the total release rate for the date/time of the outflow zone being depicted. In this way, a linked text object can be placed on or near the graph that shows the current water-surface elevation or total release rate, and which is continually updated when the graph is animated to show those values on the date tied to the profile being graphed.

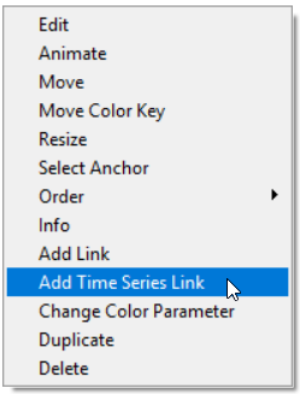


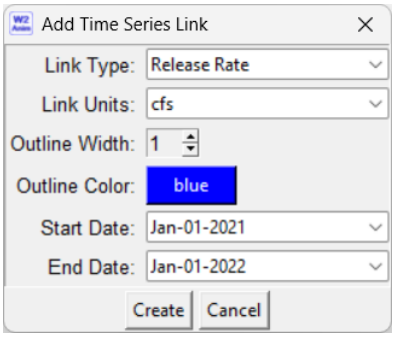


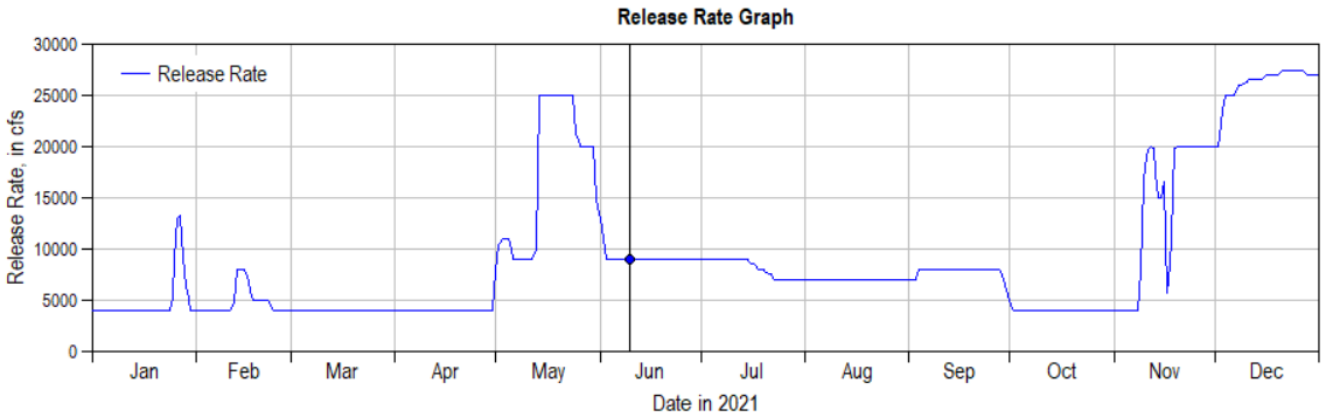
After the linked text object is created, it can be moved and its font characteristics can be edited just like any other text object, except that the actual text cannot be changed by the user. The units of measurement and the number of digits after the decimal can be modified by choosing the Edit Link option from the linked text object's menu.

Adding a Time Series Link

The time series of water-surface elevation or total release rate data associated with a W2 Outflow Profile graph can be linked to a separate time-series graph. Choose the Add Time Series Link option from the pop-up menu, and the Add Time Series Link menu to the left will pop up. Choose the start and end dates and any other options and click the Create button. The mouse cursor changes to a crosshair and the user must draw a frame for the linked time-series graph on the canvas. The result, after a bit of editing, is the graph below. When animated, a circle showing the date of the animation moves along the graph with an optional vertical line showing the current date/time. This graph is tied (linked) to the W2 Outflow Profile graph, and would be automatically deleted if the user were to delete the W2 Outflow Profile graph to which it is linked.



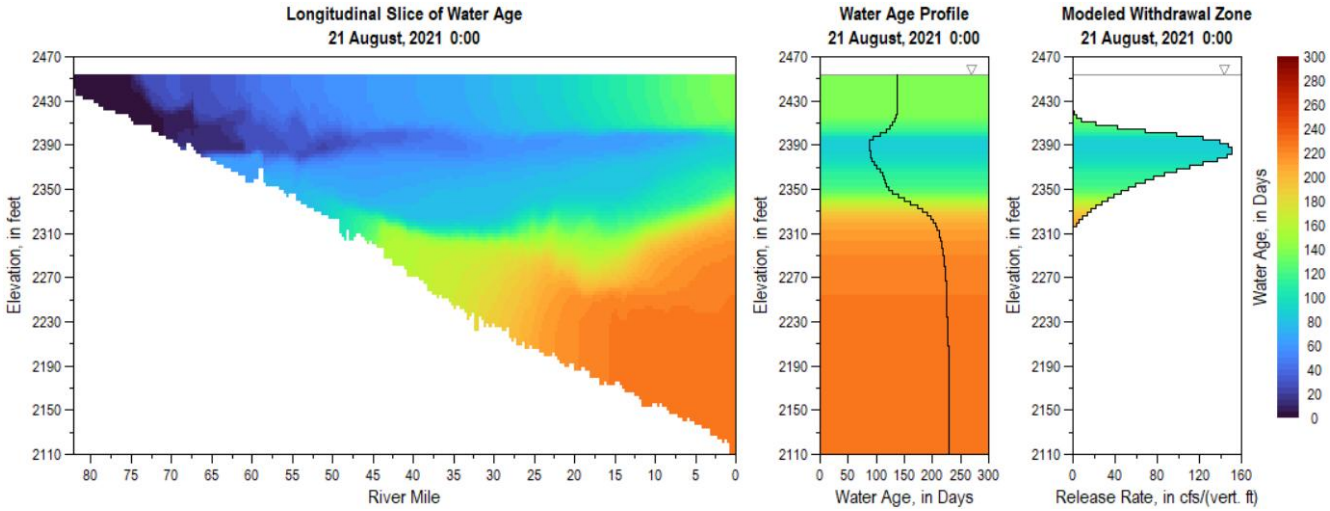




Pairing Outflow Profiles with Other Graphs

The W2 Outflow Profile graph is probably most useful when paired with a W2 Longitudinal Slice graph and/or a W2 Vertical Profile graph. The vertical profile or longitudinal slice graphs provide a visualization of conditions throughout the water column, whereas the outflow profile is focused on the water being released through dam outlets, which may have characteristics that are quite different than water at different depths in the profile.

In the example below, three graph types are used to show water age along a longitudinal slice through a large reservoir, with more detail in a vertical profile at the most-downstream model segment, and finally in an outflow profile that illustrates the vertical withdrawal zone and the conditions being exported via dam releases. The conditions shown are for late August when the waterbody is strongly stratified and releases are from a location somewhat high in the water column, such that water in the hypolimnion is generally not released downstream and continues to get older. Water entering the upstream portion of the reservoir is new to the model (lower water age) and cooler than water near the surface of the reservoir, so it sinks to find its place in the reservoir's density profile. Enough water is displaced along that flow line through summer that the younger water appears to be transported through the metalimnion and directly toward the dam outlet. Indeed, the model shows that releases are definitely younger than water at the surface or in the hypolimnion. This sort of visualization clearly shows patterns of water transport that might be hard to discern otherwise. When animation is invoked, all three graphs track the changing date/time in a synchronized manner.

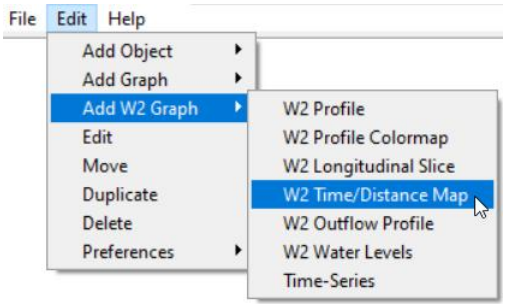


W2 Time/Distance Maps

For river systems, a date/time versus distance graph showing results as a function of color can be a powerful way to visualize spatial and temporal patterns. These types of plots also can be used to show differences in two different parameter values, or parameter differences from two different model scenarios. Multiple plots can be created to show longitudinal space/time variations along a river corridor that spans multiple model domains.

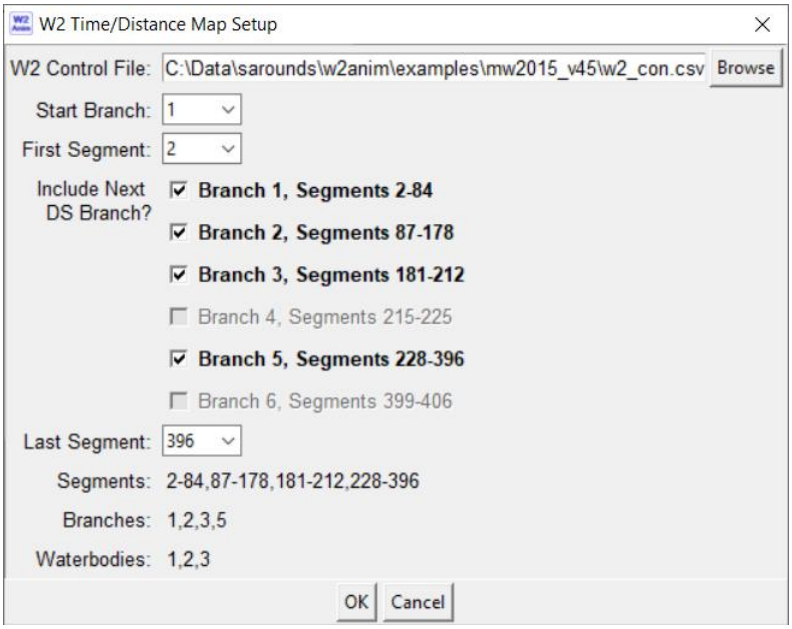
Creating a New Graph

To create a W2 Time/Distance Map, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at Canvas Properties.



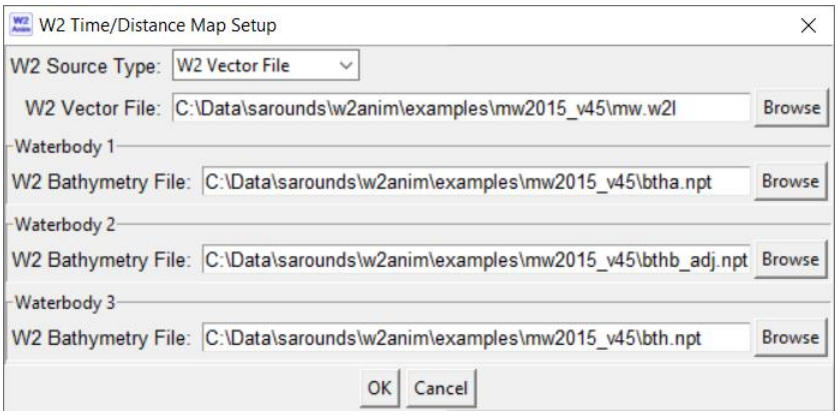
A W2 Time/Distance Map can be started by choosing the Edit/Add W2 Graph/"W2 Time/Distance Map" option from the menu bar, or by right-clicking on the canvas and choosing Add W2 Graph/ "W2 Time/Distance Map." The mouse cursor will become a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the "anchor point" for the graph; a different anchor point location can be set later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the mouse crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the graph frame is set, a new menu will pop up, as seen below.

This first setup menu is identical to the first menu in the creation of a W2 Longitudinal Slice graph, and is the first of three menus needed to create a W2 Time/Distance Map. In this first menu, the user starts by specifying a W2 control file, which W2Anim scans for segment, branch, and waterbody parameters. W2Anim uses the information from the control file to determine how model branches connect, and the menu is interactive, allowing only choices that comprise an upstream to downstream pathway. The user must choose the starting branch and segment number for the upstream end of the map, then select the model branches to follow downstream and finally the most-downstream segment. In the example at the right, the choice was to select all of the segments in branch 1 and to follow that downstream through branches 2, 3, and 5. The chosen segments, branches, and waterbodies are listed at the bottom of the menu.

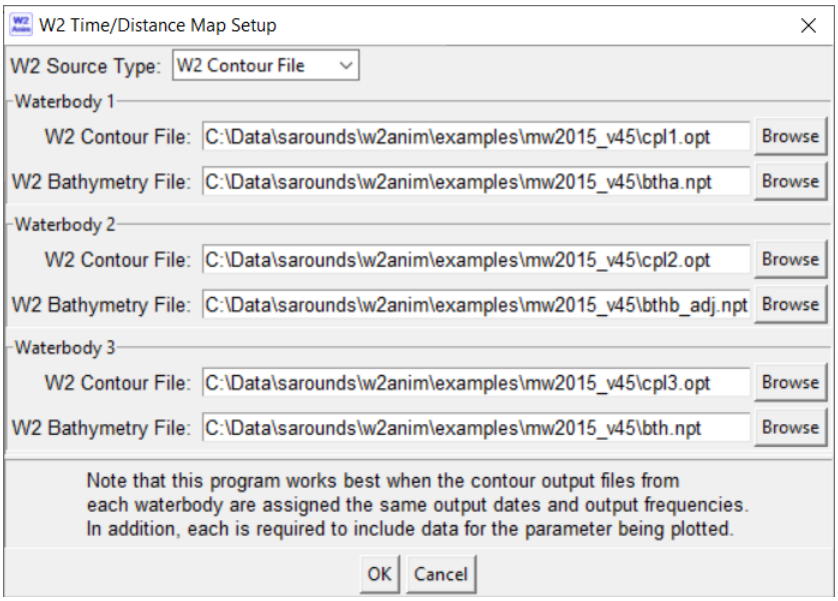


Clicking the OK button moves on to the second menu. In this second step, the user must choose the source for the time/distance data from one or more W2 contour output files, from a W2 vector file, from one or more W2 River Contour output files, or from a custom W2 SurfTemp, VolTemp, or FlowTemp output file. The SurfTemp, VolTemp, and FlowTemp output files are available from a customized USGS edition of CE-QUAL-W2; these output files include results from every segment in the model and contain either surface values, volume-weighted averages, or flow-weighted averages.

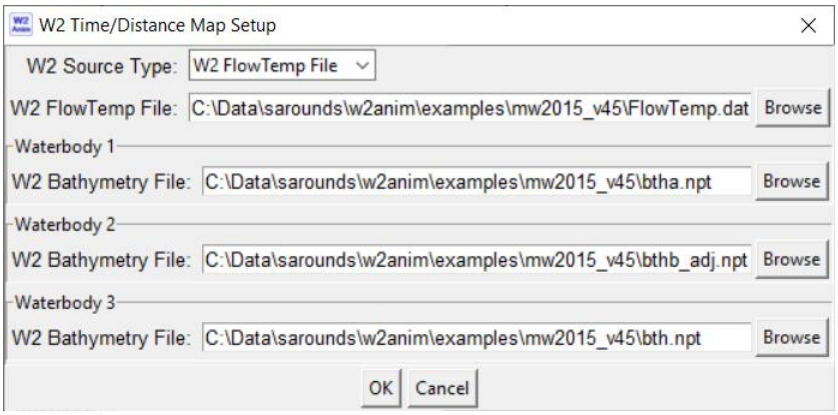
When choosing a W2 vector file for the time/distance data, it is still necessary to provide the associated bathymetry file(s), as shown in the menu to the right. Although the vector output file includes some bathymetric data, those data are not necessarily correct for sloping branches; therefore, W2Anim must read the bathymetry file(s).



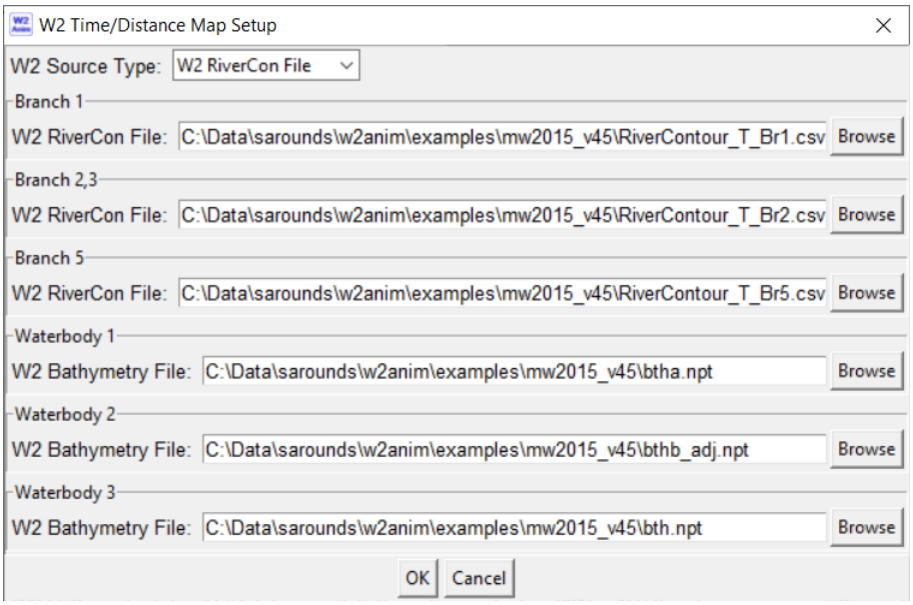
When the source type is set to use a W2 contour output file, the user must provide the names of the W2 contour and bathymetry files for each of the waterbodies included in the time/distance plot, as shown in the menu to the right. The menu indicates the waterbodies for the required files.



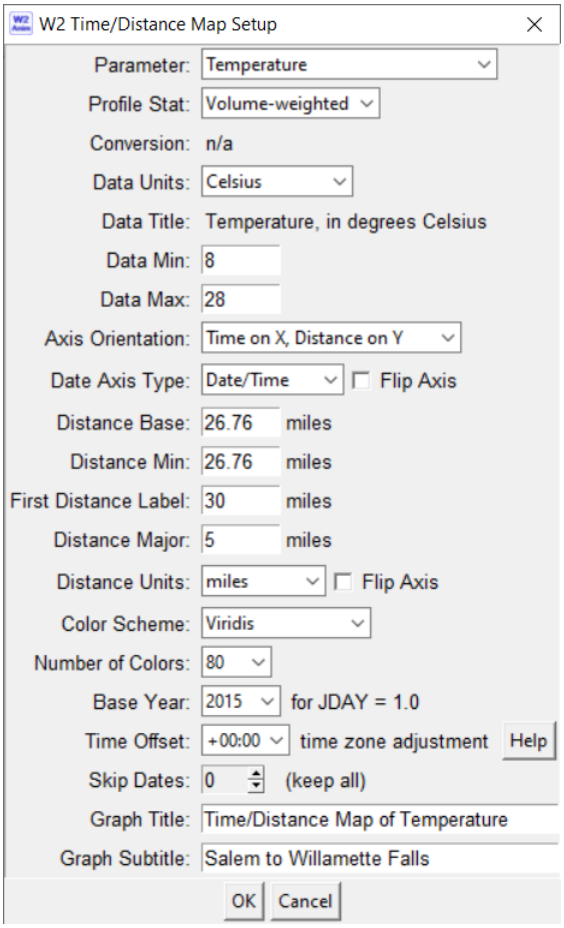
When the source type is set to use a W2 SurfTemp, VolTemp, or FlowTemp file, only one such file is required because it contains results from every segment in the model. The bathymetry files are required so that the model can compute downstream distances from the segment lengths. In the example at the right, a flow-weighted vertical average was chosen through the use of the W2 FlowTemp file. Remember that these *Temp files are custom outputs from a USGS version of CE-QUAL-W2.



W2Anim also can use the W2 River Contour output file format for time/distance plots. Both formats 1 and 2 are honored by W2Anim, but it is important for the starting date and output frequency to be identical for each River Contour output file. The menu at the right provides input fields for all of the model branches used in the plot, even though some River Contour files may contain output from multiple branches in a single waterbody. In the example at the right, the second River Contour file contained output from branches 2 and 3, and the menu identified that content after a quick scan of the output file.



Clicking the OK button takes the user to the third and final setup menu for the W2 Time/Distance Map, shown at the right, where the user can choose the desired parameter and set the profile statistic and many other characteristics for the plot. Most of these settings can be changed later.



In this example, the W2 contour output was used, and several parameter choices were available. The contour output includes sufficient information to choose either the surface value or to compute a volume-weighted vertical average value for each date and location in the time/distance plot. A flow-weighted vertical average is available only from the custom W2 FlowTemp output.

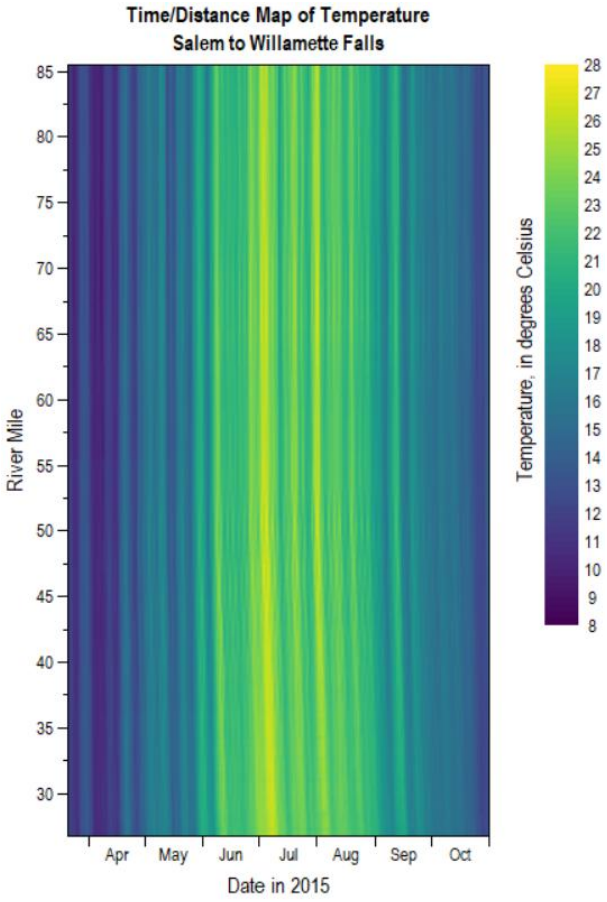
When using the W2 River Contour output option, CE-QUAL-W2 at this time only includes one parameter in each output file (either water temperature or dissolved oxygen concentration) and includes only the surface value, so the parameter and profile statistic cannot be changed when using this type of output file.

As is the case with all W2 plots in W2Anim, some modeled parameters can be divided by the values of other modeled parameters. When using the USGS custom heat-tracking features of CE-QUAL-W2, the output for certain parameters sometimes must be divided by the water temperature to compute the desired result. This feature also allows the user to dream up and plot other potentially useful ratios from model output.

W2 Time/Distance Maps can be created with time on the X or Y axis. By default, time marches forward to the right on an X axis, and from top to bottom on a Y axis, but this default can be “flipped.” Similarly, distance by default proceeds downstream to the right on an X axis, or top to bottom on a Y axis, and also can be flipped. Time can be shown as either a date or a Julian Date.

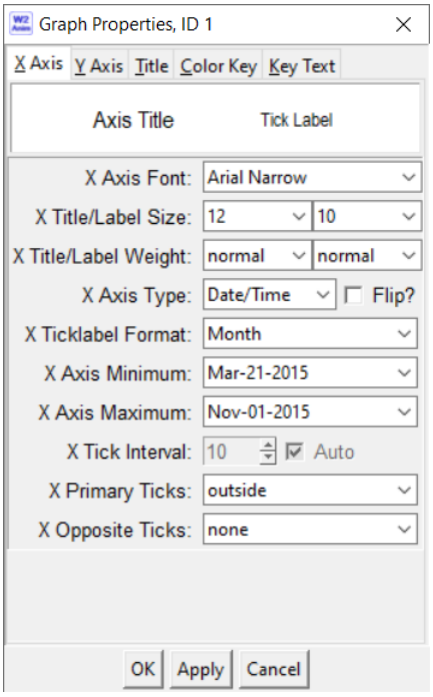
In this menu, it may be useful to specify distance base and minimum values that are different from the first labeled distance tick mark. In this case, the most downstream distance location (the "base" value) was at river mile 26.76, but the first labeled tick mark was set to 30 miles.

After clicking on the OK button, W2Anim will read the output files, perform any unit conversions or other required computations, and find the date, distance, and parameter limits from the available data. The resulting W2 Time/Distance Map for this example is shown at the right.

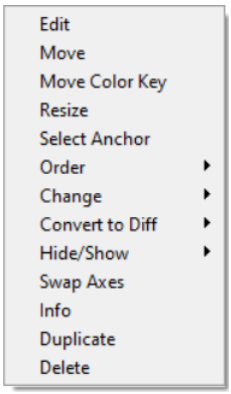


The default font for graph text can be set in the Program Defaults or by configuring a W2Anim Initialization File. The initial font size for new graphs is scaled according to the size of the graph frame, and the resulting font size for tick labels typically is in the range of 8 to 11 points, and 2 points larger for axis titles and graph titles.

To edit the characteristics of this new graph, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option. Alternatively, select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown below. For this graph type, five tabs are shown at the top of the menu to control aspects of the X Axis, Y Axis, Title, Color Key, and Key Text.

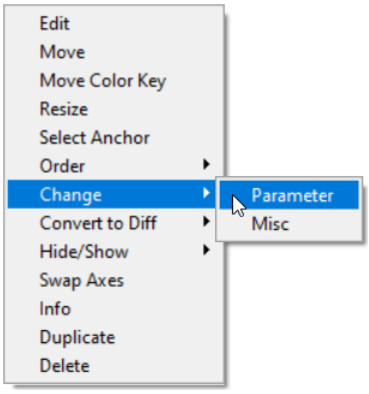


The options of the Graph Properties menu should be self-explanatory, and therefore will not be discussed in detail here. In general, the user can play with each of the options and observe the result when the Apply button is clicked. Under the Color Key tab, note that the color key Status can be set to visible or hidden. The hidden option hides the color key, which is useful if more than one graph with the same color scale is present on the canvas. The Links option allows changes to the color scheme for one graph to cause changes to the color schemes for other graphs on the canvas, either for the same parameter or for the same parameter and source data file.



Now that the graph has been created and edited, the user has a number of other options to move, resize, select a different anchor point, move it up or down in the drawing order, make a duplicate, or delete it. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu. The entire graph can be moved just like any drawing object, or grouped with other objects and moved as a group. The time and distance axes may be swapped (X vs Y) using the Swap Axes option. The color key can be moved independently from the graph itself, which can be useful when its default placement is not ideal. At this time, the color key cannot be rotated. The Resize option allows the user to resize the graph frame relative to the graph's anchor point; the user may select a different anchor point before resizing. See the sections on Object Anchors and Manipulating Drawing Objects for more information on many of these options.

Changing the Parameter or Skip Date

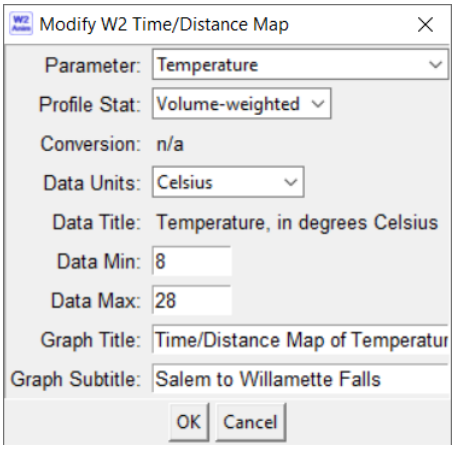


Through the Change submenu (at right), the user can select a different model parameter, parameter units, W2 model begin year, time offset, and/or a date-skip setting. This feature is handy not only for fixing user mistakes after the plot is created, but also for creating multiple time/distance maps by duplicating a graph and then changing the model parameter used in the duplicated map. In this way, a user could quickly set up an array of time/distance maps for a suite of modeled parameters. If the user wants a plot composed of different segments or branches, however, a new time/distance map must be created. The Change submenu is not available when using W2 River Contour output files because such files contain only one parameter.

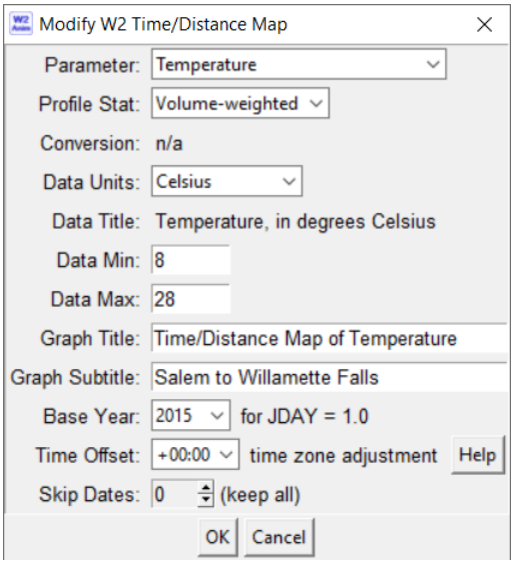
The Change submenus should be self-explanatory because they mimic parts of the menu used to create the original W2 Time/Distance Map. The menus for the two options are shown below.

The only difference between the Change Parameter menu and the Change Misc menu is that the latter allows the user to select a different W2 base year, time offset, and/or date-skip setting. Any substantial change requested from these menus will cause the data file(s) to be re-read and the graph to be re-created. Cancelling the operation or destroying the menu will result in no changes to the graph. Simply changing data limits (Min/Max) or the graph titles is not allowed from these menus, as that is best done from the Graph Properties menu.

Parameter:

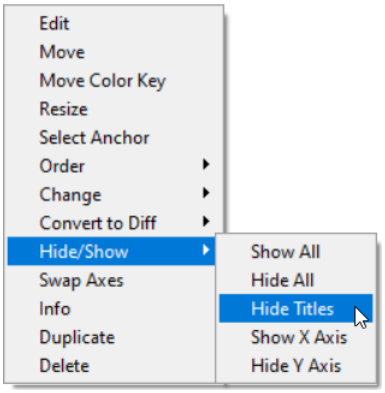


Misc:



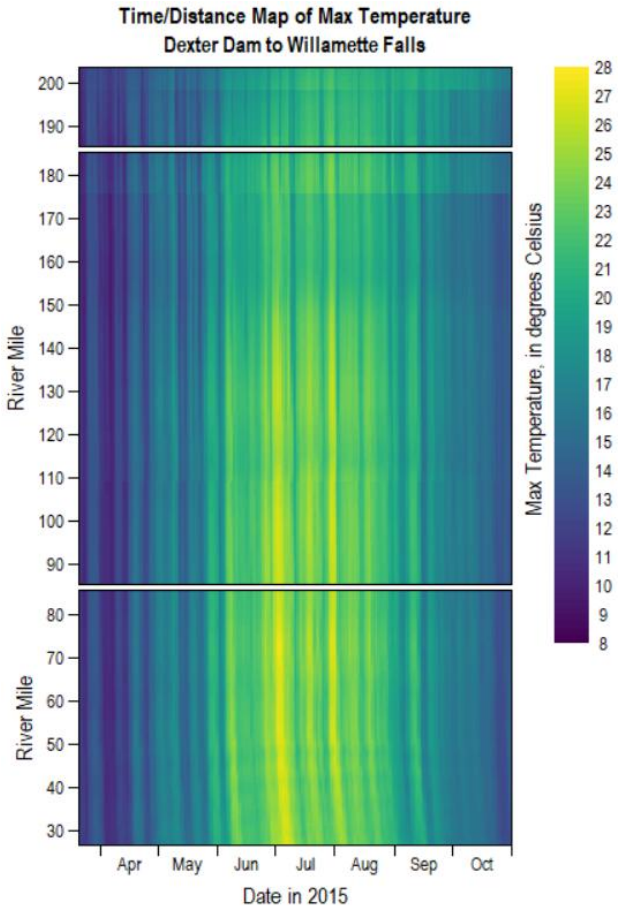
Combining Plots from Multiple Models

When multiple W2 models are used to simulate flow and transport through various reaches of a river system, it may be useful to combine multiple W2 Time/Distance Maps to visualize spatial and temporal variations through the entire system. W2Anim helps to make such multiple-model maps possible by allowing the titles and axes of each time/distance map to be shown or hidden according to the wishes of the user.



Right-clicking on any W2 Time/Distance Map (or typing Alt-p while hovering over such a map) brings up the options menu, and the Hide/Show submenu allows the user to choose whether titles or axes are hidden. The example menu at the right shows an instance where the X axis, with all of its tick marks and labels, is already hidden.

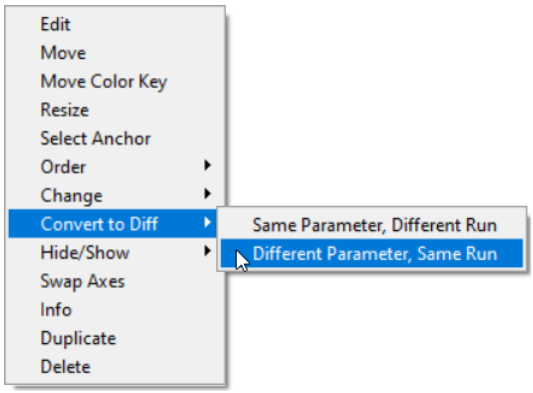
An example using three W2 Time/Distance Maps to illustrate spatial and temporal variations in daily maximum temperature along the Willamette River in western Oregon is shown at the right. (The USGS custom SurfTemp and FlowTemp output files were used to obtain the daily maximum temperatures.) In this instance, the top two maps have their X axes hidden, and the lower two maps have their titles hidden. Each plot uses the same X axis limits and the same color scheme, but the color keys for two of the plots are hidden.



It is important when displaying multiple time/distance maps in this way to scale the distance dimension of each plot so that each map uses the same ratio of river distance to display pixels. In this example, the middle plot is 300 pixels in height and spans 99.778 river miles. The lower plot spans 58.738 river miles, and therefore was configured to be 58.738 x 300/99.778 = 176.6, or 177 pixels in height. Similarly, the top plot spans 18.378 river miles, and therefore was configured to be 55 pixels in height. The longitudinal distances are easy to find in the Object Info box; just right-click over a graph, select the Info option, and find the values given for Distance Range and Height. Resize the plot with *Snap to Grid* turned off, and monitor the plot size in the status bar while resizing to set the desired plot height or width. If the X axis was used for distance, then the widths would be scaled as opposed to the heights. The scaled maps can be positioned with a small gap, as shown in the example, or with edges that touch each other. See the sections in this manual on Moving Objects and Aligning Objects for more information on moving and positioning objects.

Creating a Difference Plot

Once a W2 Time/Distance Map has been created, a difference plot can be created by subtracting results from another dataset. The second dataset can be for (1) the same parameter from a different model scenario, or (2) a different parameter from the same model run, as indicated in the option menu to the right.

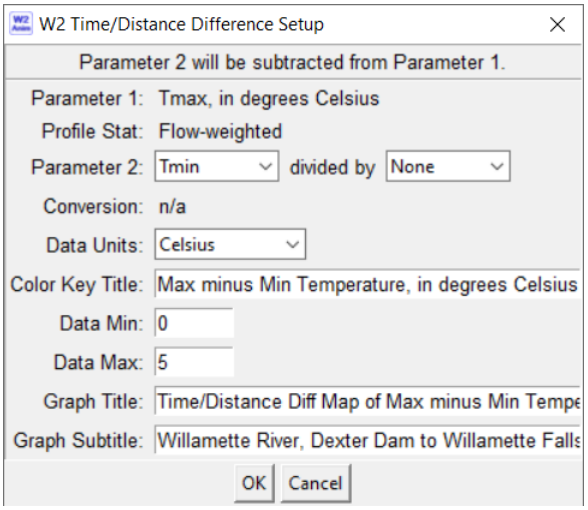


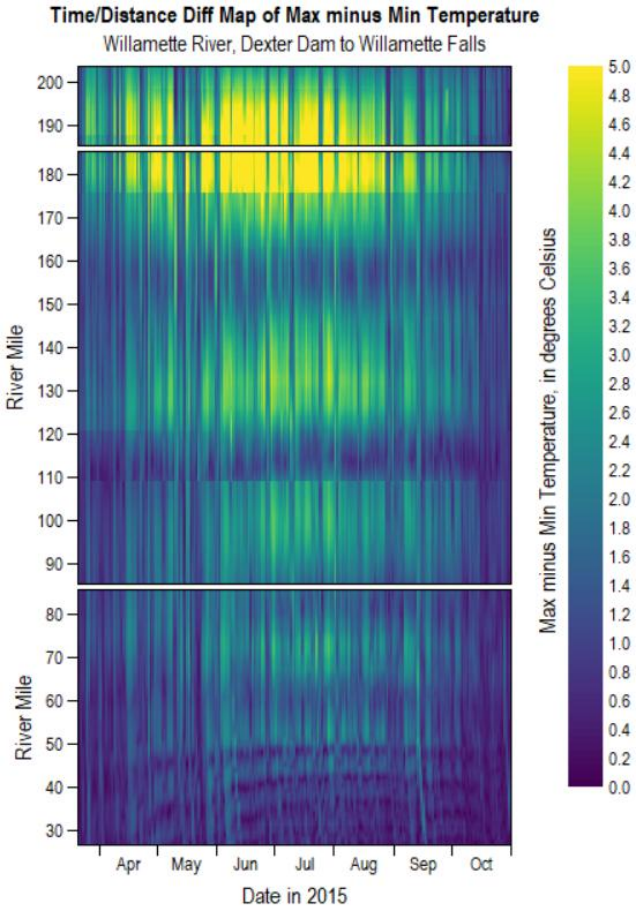
When choosing the same parameter from a different run, the second dataset can be from a different source file type, as long as the other source type can support the same profile statistic. Regardless, the W2 output file must be from a model that uses the same model grid.

When choosing a different parameter from the same model run, W2Anim requires the use of the same source file. As a result, the “Different Parameter, Same Run” option is not available when a time/distance plot is created from W2 River Contour output files, as those files only contain one parameter.

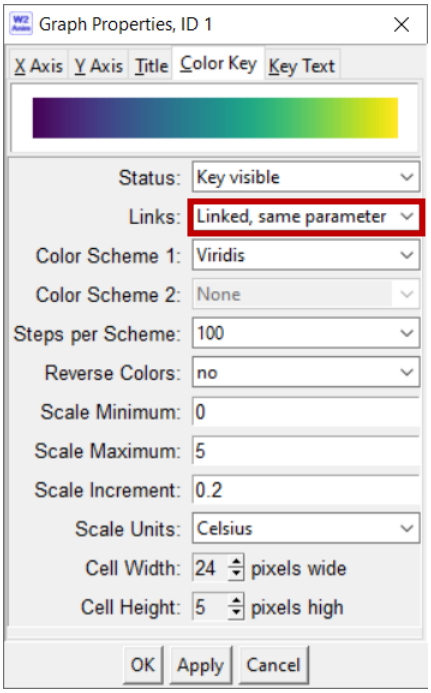
Different Parameter, Same Run

When choosing the “Different Parameter, Same Run” option, a difference setup menu will appear, as shown below. The menu reminds the user of the first parameter and profile statistic, and prompts the user to choose the second parameter, any unit conversion, numeric plotting limits for the computed difference, and any modifications to the graph titles and color key title. In this example, the daily minimum temperature (Tmin) was subtracted from the daily maximum temperature (Tmax). The color scale was reconfigured to run from 0 to 5 degrees Celsius, and the titles were adjusted to denote the appropriate difference. The resulting difference maps, after repeating the process for all three plots in the example, is shown below on the right.



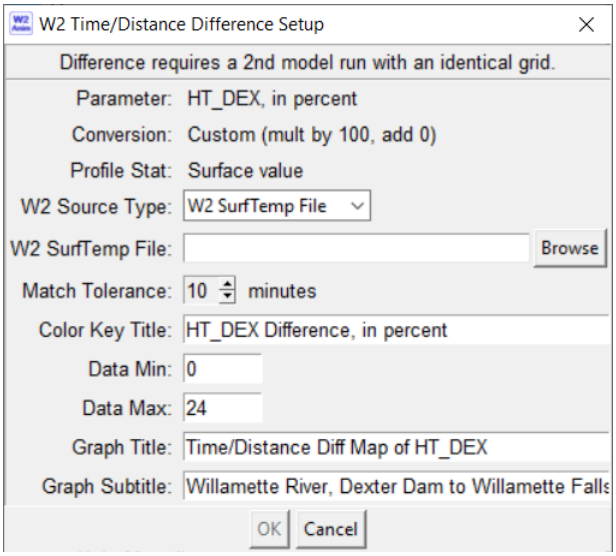


When multiple plots are intended to use the same color scheme, it is useful to link the color schemes in the Graph Properties menu as shown below with the red rectangle. When specifying such a link, a change to the color scheme of one plot will cause the same change to occur in other plots that use the same parameter combination.

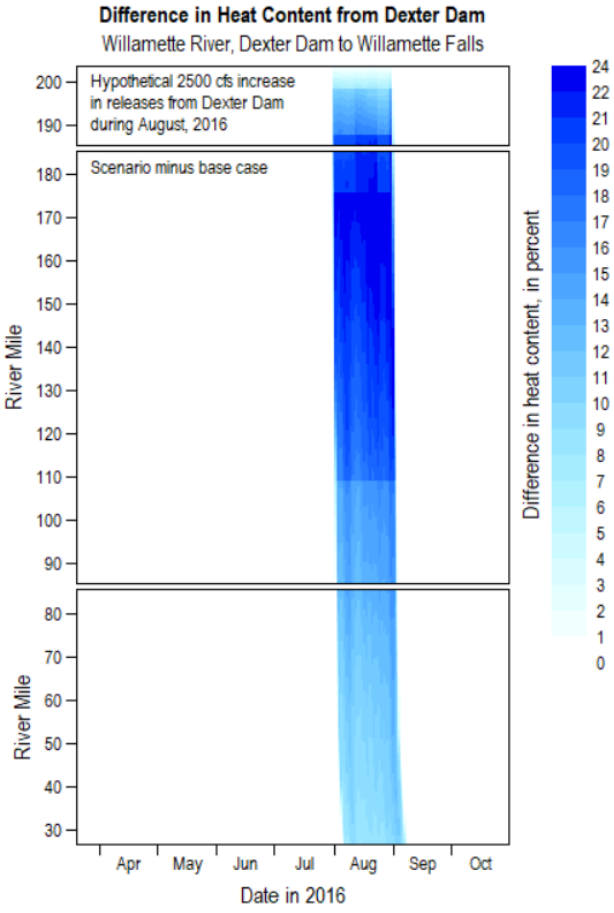


Same Parameter, Different Run

When choosing the "Same Parameter, Different Run" option, a difference setup menu will appear, as shown to the right. The menu reminds the user of the chosen parameter and profile statistic, and prompts the user to choose a source type and source file(s) that contains data for the chosen parameter from a different model run. To help account for any differences in output frequency, a match tolerance can be set by the user to ensure that W2Anim can align the date/time markers of the two datasets. Finally, the user is prompted for the numeric plotting limits for the computed difference and any modifications to the graph titles and color key title.

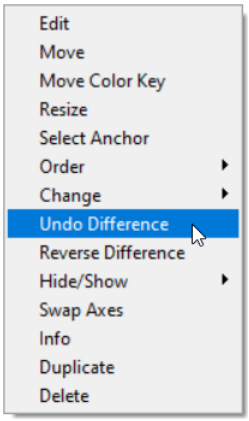


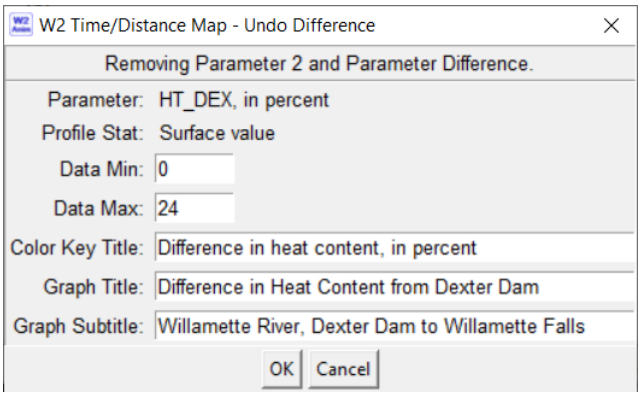
In this example, a generic tracer was used to track the heat content associated with releases from Dexter Dam on the Middle Fork Willamette River, and track that heat downstream in the Willamette River in western Oregon through three different W2 models. A customized USGS edition of CE-QUAL-W2 was used to track the heat, as documented by Rounds and Stratton Garvin (2022). The three W2 Time/Distance Maps shown at the right represent the difference in heat content sourced from Dexter Dam as simulated by two scenarios. Results from a base case were subtracted from results in which Dexter Dam releases were hypothetically increased by 2,500 ft^3/s during August. As a result, travel times were decreased, and heat content in the river was replaced less quickly by environmental heat fluxes across the air/water surface.



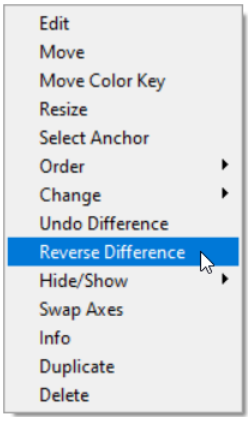
In the custom SurfTemp or FlowTemp output files, heat content from various sources is output as a fraction, so a multiplier of 100 was applied in a custom unit conversion in W2Anim to express the results as a percentage. A white-to-blue color scheme was used so that any differences less than 1 percent show up as white, which allows the more-significant differences to be highlighted with various shades of blue. The resulting plot is similar to the one published as figure 19D in the report by Rounds and Stratton Garvin (2022).

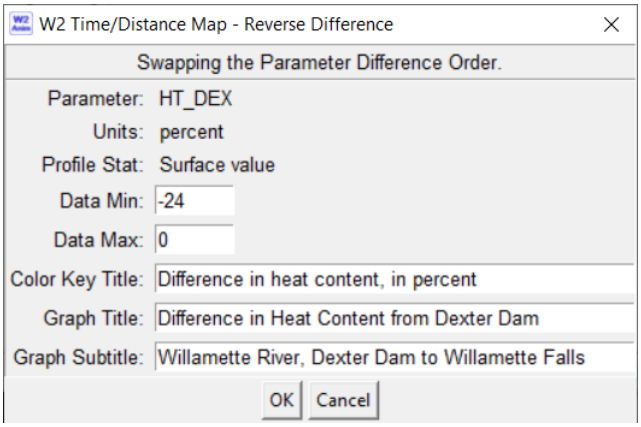
Reverting and Reversing Differences



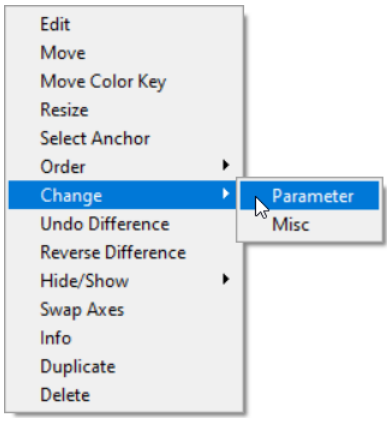


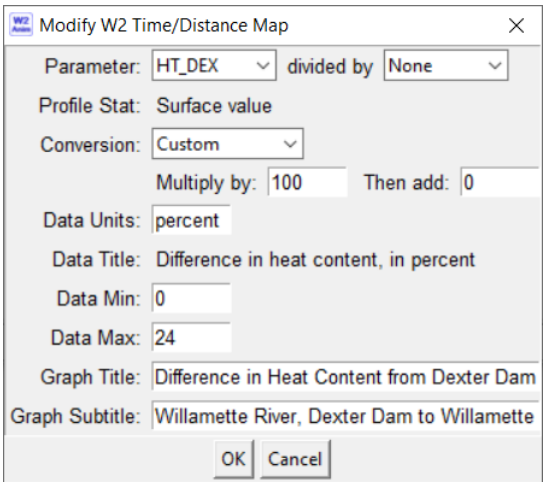
Once a W2 Time/Distance Map has been converted into a difference plot, the user has several options to undo, reverse, or modify those differences. All such options are available from the options menu, accessed by right-clicking on the graph of interest or typing Alt-p while hovering over the graph. The "Undo Difference" option allows the user to eliminate the difference and revert to a map of values from the original dataset. Choosing that option will open a menu (above, right) that allows the user to refine the limits of the color scheme as well as the titles for the graph and color key. Clicking OK will proceed, whereas clicking Cancel will abort the operation and preserve the original difference map.





The "Reverse Difference" option allows the user to reverse the computed differences, such that positive differences become negative and vice versa. Choosing this option will open a menu (shown at right) that allows the user to refine the limits of the color scheme and edit the titles of the graph and color key. W2Anim will populate the initial data limits in the menu based on the non-reversed values. Clicking OK will proceed, whereas clicking Cancel will abort the operation and preserve the original difference map.



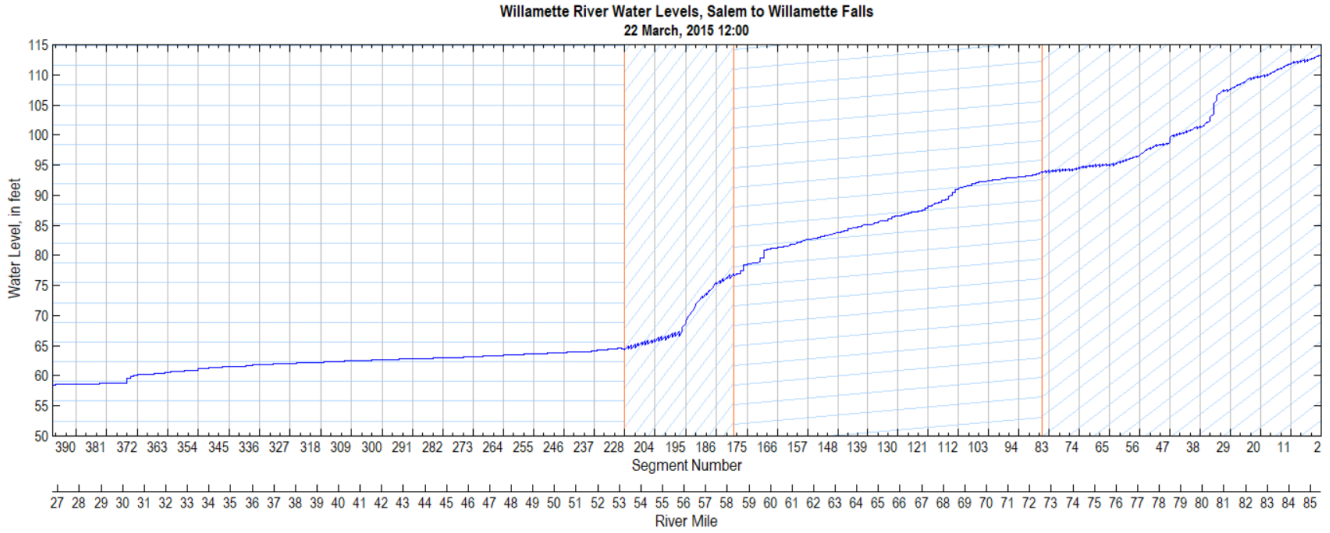


Even when a difference has been computed, the first parameter of a "Different Parameter, Same Run" difference or the only parameter of a "Same Parameter, Different Run" difference can be changed. Select the Change submenu as described earlier in the section Changing the Parameter or Skip Date and use that menu (shown at the far right) to select a different parameter.

W2 Water Levels Plot

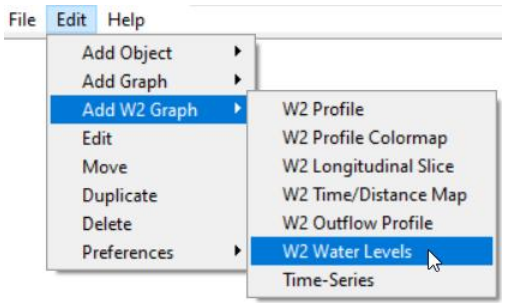
Examination of an animated water-level plot for a longitudinal model reach can be an excellent means of refining model branch slopes to match modeled water-level slopes, analyzing the effects of wind speed and direction on surface waves and seiching, and determining the location and severity of any oscillations or anomalies in modeled water levels. Modeled water levels also can be examined and animated through the use of W2 Longitudinal Slice plots in W2Anim, but the W2 Water Levels plots provide a more detailed examination of the modeled water levels.

An example W2 Water Levels plot is shown below for a W2 model of the middle Willamette River from Salem, Oregon, to Willamette Falls. The modeled water levels are shown in dark blue, traversing four model branches whose boundaries are shown with vertical light orange lines. Segment boundaries are shown with vertical light gray lines every nine segments along with both a segment axis and a distance axis along the X coordinates. Layer boundaries are shown with light blue lines, illustrating the slopes used to represent the model branches. In this case, the water levels are shown with a stair-stepped representation where the water level in each segment is given the slope of the branch. This type of graph can be animated in the same way as other animated graphs in W2Anim.



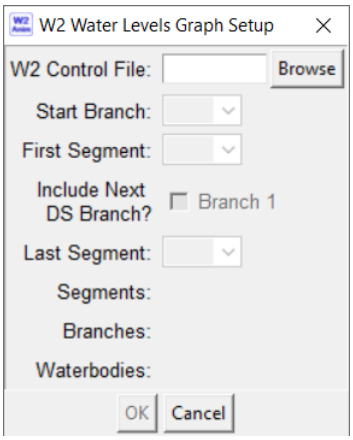
Creating a New Graph

To create a W2 Water Levels plot, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at Canvas Properties.

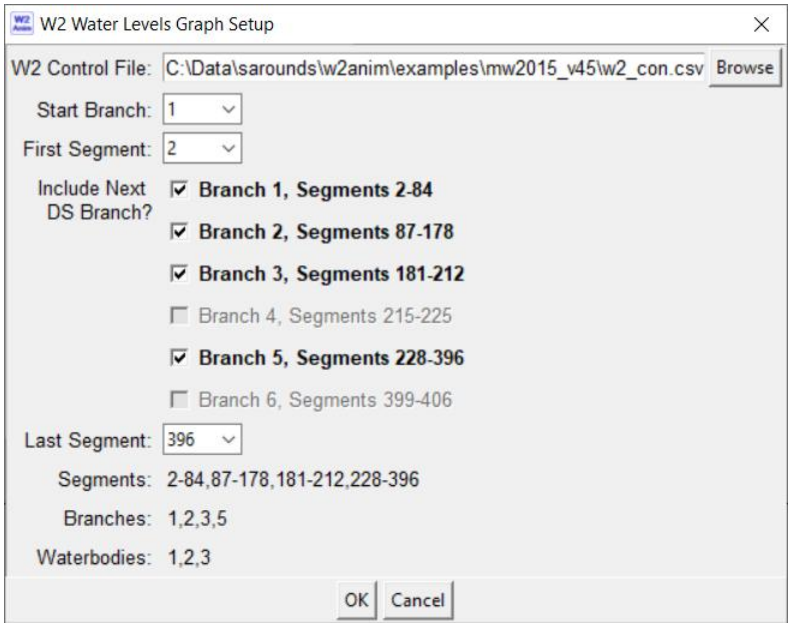


The W2 Water Levels plot can be started by choosing the Edit/Add W2 Graph/W2 Water Levels option from the menu bar. Alternatively, right-click on the canvas and choose the Add W2 Graph/W2 Water Levels option. The mouse cursor will become a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the "anchor point" for the graph; a different anchor point can be set later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will

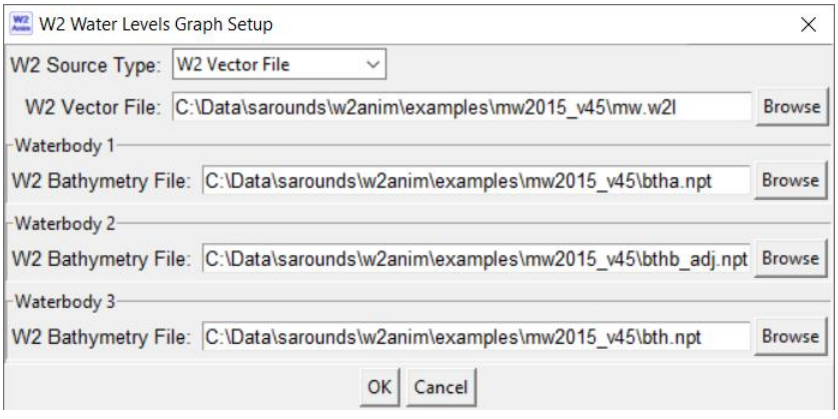
draw a rectangle that follows the crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the frame is set, a new menu will pop up, as seen at the right.



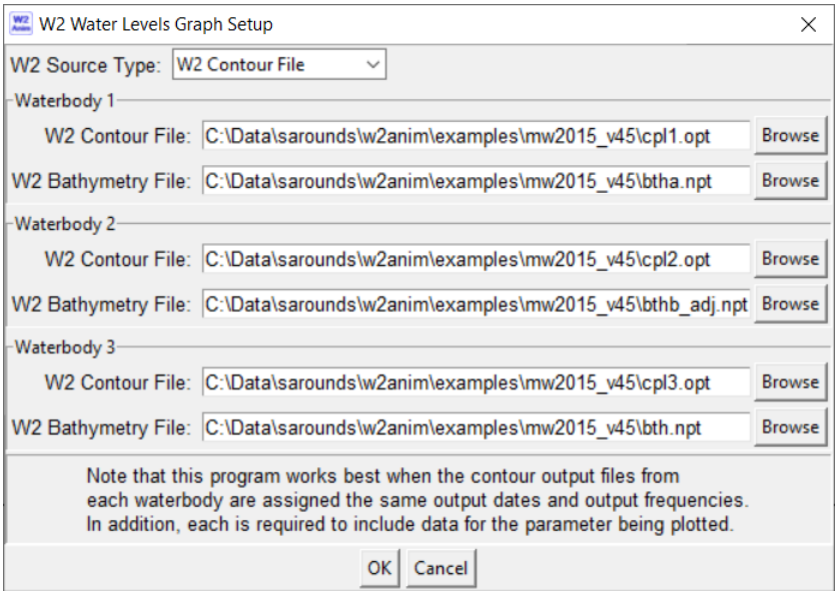
This is the first of three menus that gather the information needed to create a W2 Water Levels plot. In this first menu, the user starts by specifying a W2 control file, which W2Anim scans for segment, branch, and waterbody parameters. The user next chooses the starting branch and segment number for the upstream end of the slice, then selects the model branches to follow downstream and finally the most-downstream segment to set the longitudinal reach of interest. In the example at the right, the choice was to select segments 2-84, 87-178, 181-212, and 228-396 in branches 1, 2, 3, and 5 and waterbodies 1, 2, and 3. W2Anim knows from the control file how the model branches connect, and offers active checkboxes only for those branches that connect in a downstream direction. In this case, filling out the menu was as simple as selecting the checkboxes for branches 1, 2, 3, and 5. Clicking the OK button moves on to the second menu, where the file names of W2 output file(s) and bathymetric input files are specified.



In the second input menu, the user must choose the source for the water-level data, from one or more W2 contour output files, from a W2 vector file, or from a W2 water-level output file. When using a W2 vector file as a water-level input, it is still necessary to provide the name(s) of any associated bathymetry file(s), as shown in the menu at the right, even though some bathymetric information is included in the vector file.

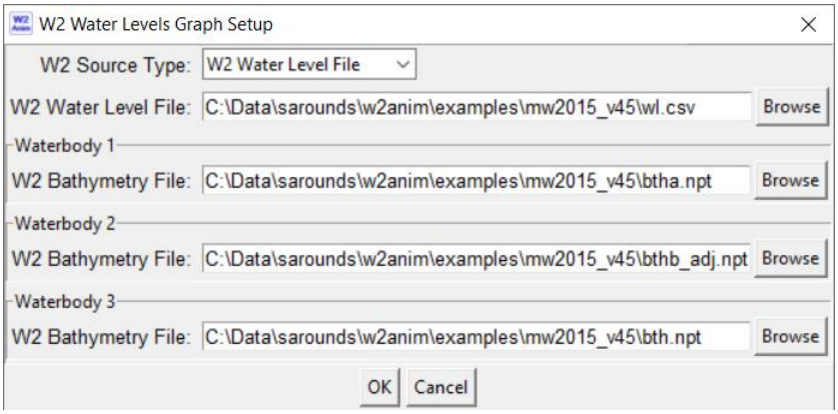


When the source type is set to use a W2 contour output file, the user must provide the names of the W2 contour and bathymetry files for each of the waterbodies included in the chosen longitudinal reach, as shown in the example at the right.



Similarly, if the source type is set to use a W2 Water Level output file, the user must provide the names of the W2 bathymetry files for each of the waterbodies included in the chosen longitudinal reach, as shown at the right.

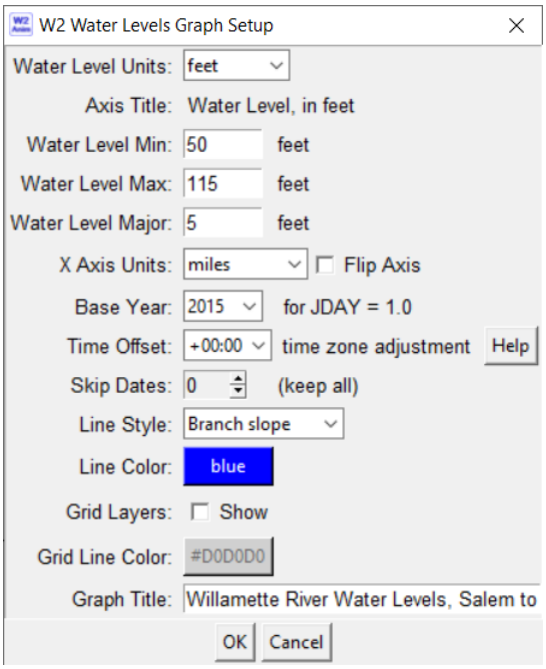
Clicking the OK button moves on to the third and final input menu. Canceling aborts the creation of the graph.

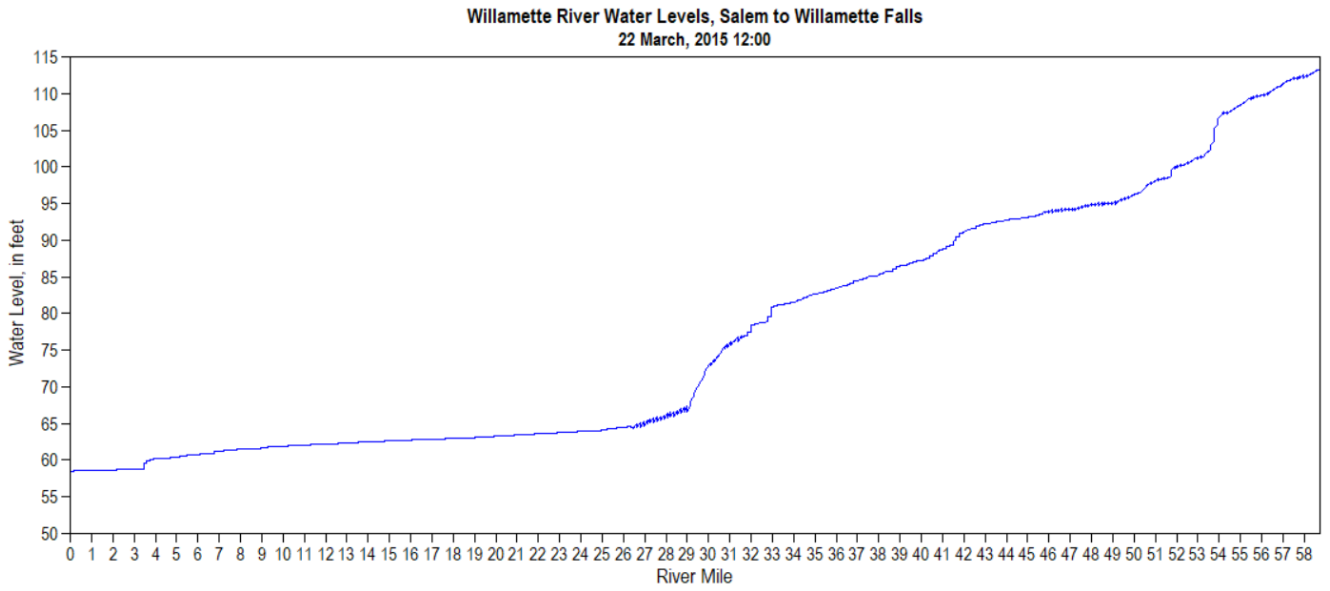


The third W2 Water Levels Setup menu handles the choice of elevation axis limits and units (feet or meters), distance units (miles or kilometers), base year, time offset, line style and color, and grid layer display. If the chosen W2 output file frequency is less than 1.0 (more than one output per day), then the user is offered the choice to skip one or more dates in the source file. Skipping 1 would use every other output date, skipping 2 would use every 3rd date, and so forth. Skipping dates simply allows the user to tailor the amount of information displayed in the resulting animation.

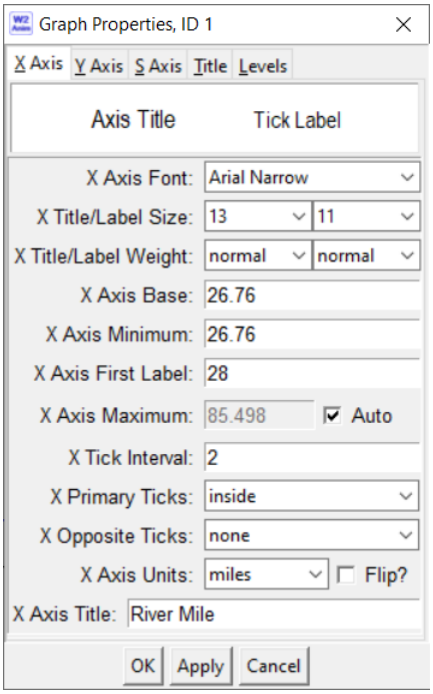
The water levels for each segment can be plotted either as a stair-stepped flat surface, a line interpolated from the mid-distance point of each segment, or as a stair-stepped line using the slope of the segment's branch. In the example at the right, a blue line stair-stepped with the branch slope was chosen.

All of the inputs to this third menu can be changed later, either through the Graph Properties or Change menus. An option to add a segment-number axis is available only through the Graph Properties menu after the graph has been created. The resulting water-level plot is shown on the next page.



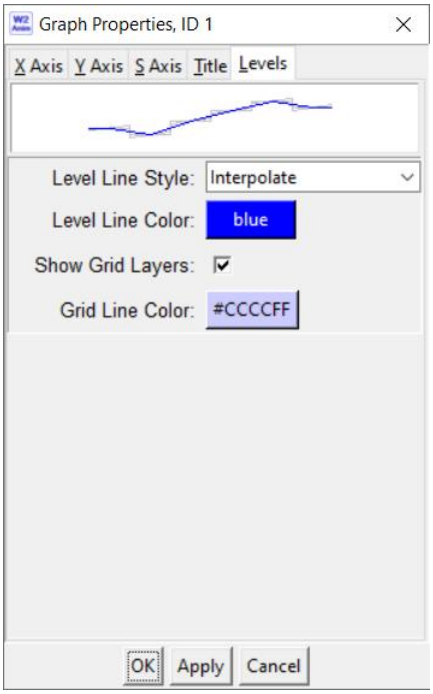


This example graph displays the data, but the baseline river mile for the downstream-most location needs to be modified, and the graph itself can be augmented with some additional features showing segment, branch, and layer boundaries. These attributes can be modified from the Graph Properties menu.



To access the Graph Properties menu, hover the mouse over the graph, right click (or type Alt-p) and select the Edit option. Alternatively, select the Edit/Edit option from the menu bar and left click on this new graph. The Graph Properties menu will appear, as shown at the left (modified). For this graph type, five tabs are shown across the top of the menu to control aspects of the X Axis, Y Axis, S Axis, Title, and Levels.

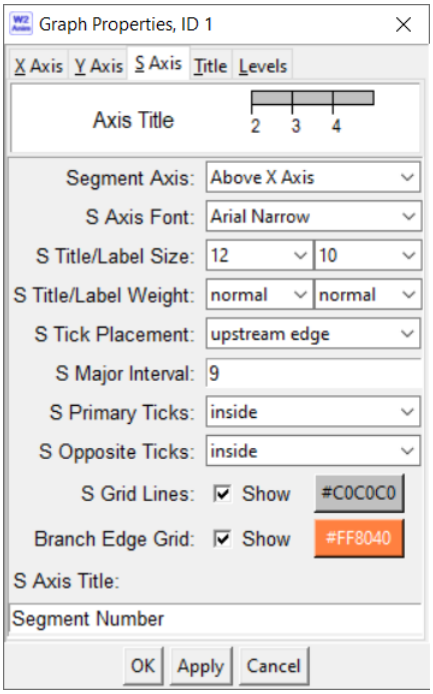
The various options of the Graph Properties menu should be fairly self-explanatory, and therefore most will not be discussed in detail here. In general, the user can play with each of the options and observe the result when the Apply button is clicked. Note in particular the Flip option for the X axis, which will flip the distance axis left to right, and the fact that tick marks for the primary and opposite X axes can be placed on the inside or outside, crossing the axis bar, or omitted altogether.



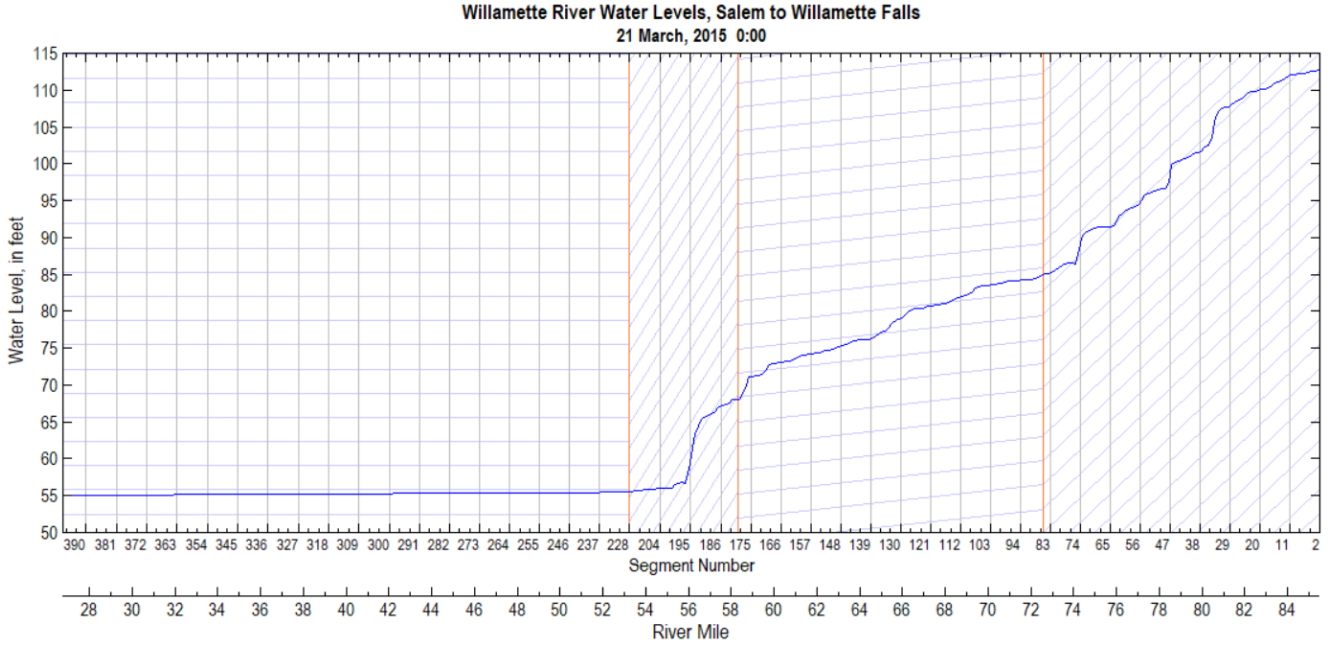
The X axis base value is a distance that corresponds to the most-downstream location of the chosen reach, and the automatically calculated maximum value is derived from the base value plus the slice's total distance. In this case the base value was set to 26.76 miles.

On the Levels tab of the Graph Properties menu (at right), the style and color of the water-level line can be modified, and grid lines for the layer boundaries can be activated and given a user-defined color. In this case, the Interpolate option was chosen and a light-blue layer boundary was chosen.

The S Axis (segment axis) tab of the Graph Properties menu is used to create or modify a segment-number axis along the X distance axis of the graph. A segment axis can be placed above or below the X distance axis or can replace the X distance axis. In the example at the right, the choice was made to put a segment axis above the X distance axis. Segment tick marks can be placed at the upstream or downstream edge of a segment or in the segment center. The preview at the top of the menu gives the user an idea of the final appearance. The segment major tick interval can be set to "auto" or to a user-defined number, and minor tick marks will be set automatically. As with other axes, tick marks may be placed on the primary or opposite axis, and potential tick mark styles include inside, outside, cross, or none. Vertical grid lines can be shown at each of the labeled segment tick marks, and optional vertical lines can also be shown at branch boundaries.

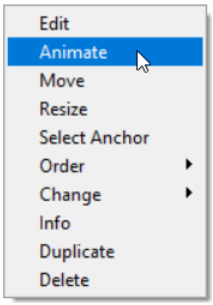


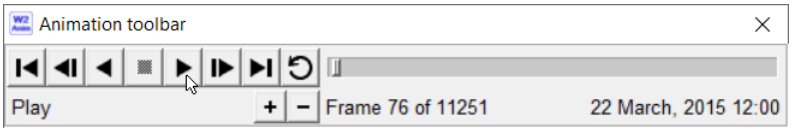
After making these changes, the example W2 Water Levels plot is shown below.



This W2 Water Level plot has substantially more information than the original plot. The light-orange lines indicate branch boundaries, and each of the four branches for this river reach were modeled with different slopes. By animating the graph and examining the degree of agreement between the water-surface slope and the layer slope in each branch, the user can obtain some useful feedback regarding the potential need to refine the slope of a particular branch. In this case, it appears that the slope of the third branch from the left is probably too shallow, and the second branch from the left might benefit from being broken into two branches with different slopes.

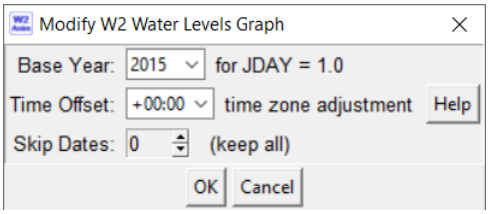
As with other animated graphs, the W2 Water Levels plots can be animated. Hovering over the graph and clicking the right mouse button (or typing Alt-p) brings up a menu from which the user can choose the Animate option. This brings up the Animation toolbar (below), which allows the user to play the animation forward or backward at various speeds, jump to different dates or move forward or backward a frame at a time. The animations in W2Anim are fast and efficient, and allow the user to explore how the water levels in a reach change over time.

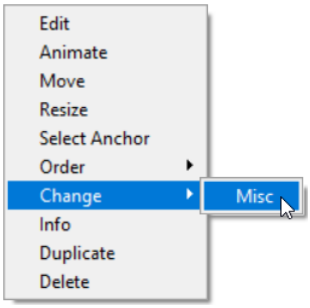




Changing the Base Year, Time Offset, and Skip Date

Through the Change submenu (at right), the user can select a different model base year, time offset, or date-skip setting, as seen below.



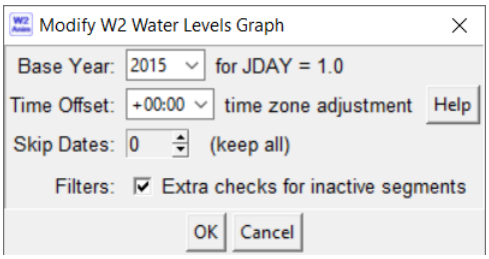


Inactive Segment Detection

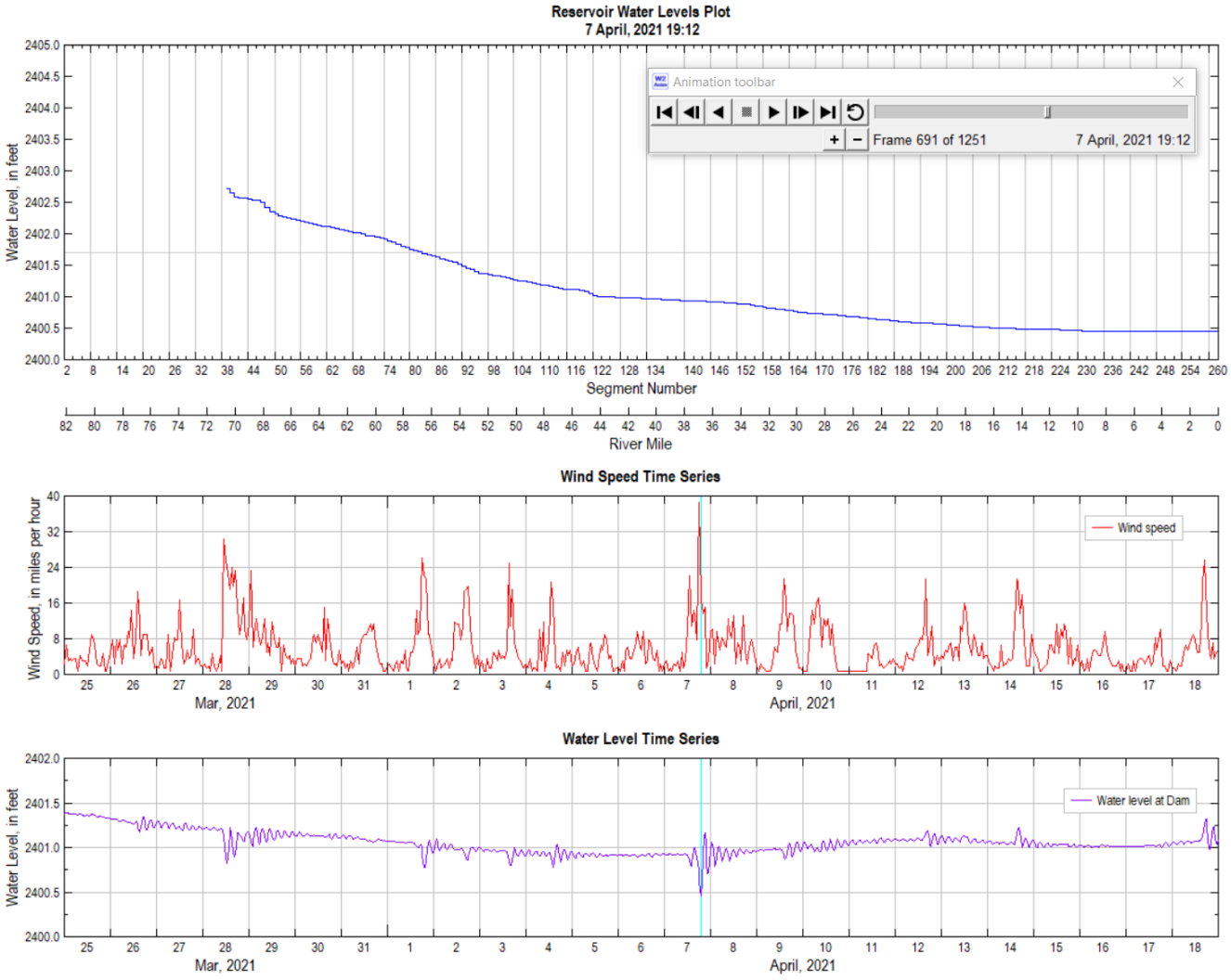
For some CE-QUAL-W2 models, often for reservoirs, a decrease in the modeled water-surface elevation can cause the water surface to drop below the bottom of some segments at the upstream end of certain branches. When these model branches have a slope of zero, W2 will inactivate these upstream segments and translate the upstream boundary condition to the most-upstream segment that remains active. The W2 contour and vector output files have sufficient information in them for W2Anim to determine which segments of a zero-slope branch may be inactive, but the W2 water-level output file (typically wl.opt or wl.csv) may or may not have specific information for W2Anim to determine whether a segment is inactive.

More-recent versions of CE-QUAL-W2 include a -999 value in the water-level output file as an inactive-segment indicator, and W2Anim will recognize that value and omit any such tagged segments from a W2 Water Levels plot. Lacking that -999 value, in certain situations W2Anim will attempt to determine whether segments in a W2 water-level output file are inactive by evaluating the water-level values for each segment over time. This inactive-segment detection is applied only for zero-slope branches that have an upstream flow boundary (UHS = 0 in the W2 control file), because a model that includes a zero-slope branch with an upstream head boundary is less likely to have inactive segments at the upstream end, and branches with a non-zero slope never have inactive segments in CE-QUAL-W2. The inactive-segment detection method is turned off if any -999 values are found in the water-level output file. The method will label a segment as inactive if its branch slope is zero, the branch has an upstream flow boundary condition (UHS = 0), no -999 values have been detected in the W2 water-level output file, no active segment has been detected in the same branch upstream, a comparison of the current water level with the previous water level for that segment shows no change, and comparisons of the current water level with the three next most-recent but previous water levels (if within 0.08 days) for the same segment also show no change. The W2 water-level output file shows modeled water levels to the nearest 0.001 meter (1 millimeter), so some change would typically be expected in the output except during very stable flow, wind, or water-level conditions.

This inactive-segment detection algorithm is not perfect, and W2Anim users are encouraged to use a recent version of CE-QUAL-W2 that includes the -999 output value for inactive model segments. If a W2Anim user wishes to turn off the inactive-segment detection, that can be done through the Change menu. For a W2 Water Levels plot that was generated from a W2 water-level output file using segments from a zero-slope branch, the Change menu looks like the example menu at the right.



When evaluating the effects of wind on waves and seiching in a reservoir, it may be advantageous to combine an animated W2 Water Levels plot with one or more time-series plots (described in the next section). In the example below, high winds on certain dates that also were aligned with the longitudinal axis of a long reservoir caused surface waters in the reservoir to be pushed upstream and caused water-level waves to bounce back and forth in the reservoir over short time periods. The example below shows how modeled water levels increased at the upstream end of the reservoir when exposed to a near 40 mile/hour wind in the upstream direction. The time-series plots include vertical date lines showing the date during the animation.



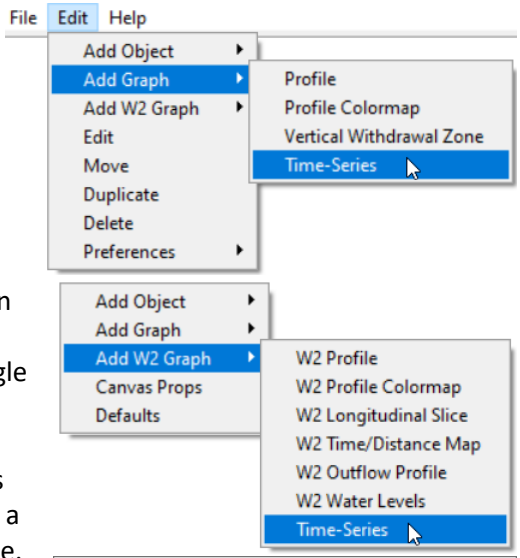
TIME-SERIES GRAPHS

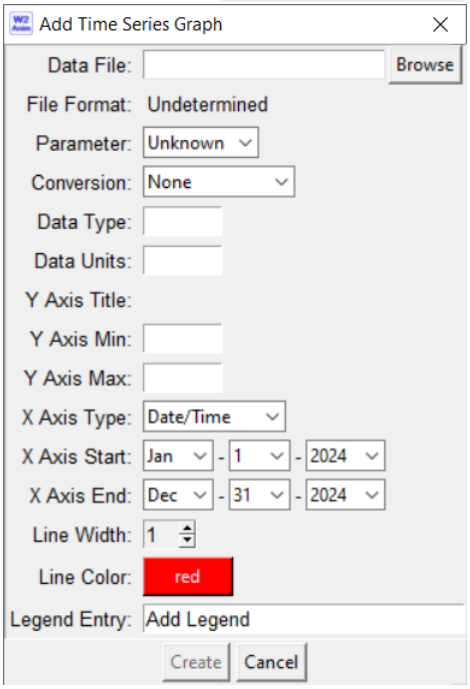
The W2 Animator can make general time-series graphs from many different types of time-series input files. See the Recognized File Types section for a list of file types that are recognized by W2Anim. Most input and output files from CE-QUAL-W2 have time-series datasets that can be read and plotted by W2Anim, along with many publicly available time-series formats from USGS, USACE, and others.

Creating a New Graph

To create a new Time-Series graph, start by ensuring that the drawing canvas is initialized to the desired size (for example, 1450x650 pixels) and that *Snap to Grid* is enabled or disabled according to your wishes. These canvas properties are set either by choosing the Edit/Preferences/Canvas Props option from the menu bar, or by right-clicking on the canvas and choosing the Canvas Props option. See also the information in this user manual at Canvas Properties.

A Time-Series graph can be created by choosing Edit/Add Graph/Time-Series or Edit/Add W2 Graph/Time-Series option from the menu bar. Alternatively, right-click on the canvas and choose the Add Graph/Time-Series or Add W2 Graph/Time-Series option. These choices all lead to the same graph type. When any of these options is chosen, the mouse cursor becomes a crosshair. If *Snap to Grid* is enabled, the nearest grid node to the crosshair will be highlighted with a magenta point. Move the crosshair cursor to the location of a corner of the new graph frame (check the status message in the lower left corner for the crosshair coordinates) and click the left mouse button to set the location of that corner. That first corner becomes the anchor point for the graph; a different anchor point can be selected later. Then, move the mouse to a location that specifies the opposite corner of the graph frame; W2Anim will draw a rectangle that follows the crosshair location. The status line will show the X,Y location of the mouse (or the nearest grid node if *Snap to Grid* is enabled) as well as the width and height of the graph frame in pixels as the mouse is moved, so that the user can create a graph frame of a particular size. Click the left mouse button to set the graph frame size. Once the frame is set, a new menu will pop up, as seen at the right.



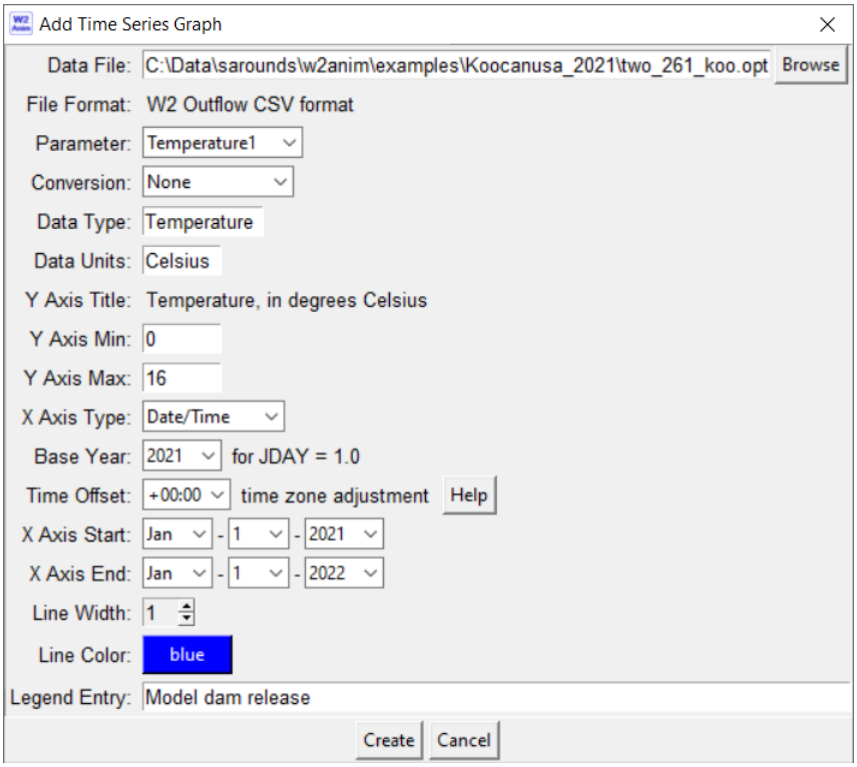


Start by providing W2Anim with the name of a time-series data file. Click the Browse button to find and select the file containing the first dataset. The program will scan that file in an attempt to identify its format and determine whether it is a recognized file type. If the file is recognized, W2Anim will try to create a list of parameters contained in the file so that the user may choose one. Some file types provide detailed parameter names, while others provide almost no information, which may result in a list of generic parameter names.

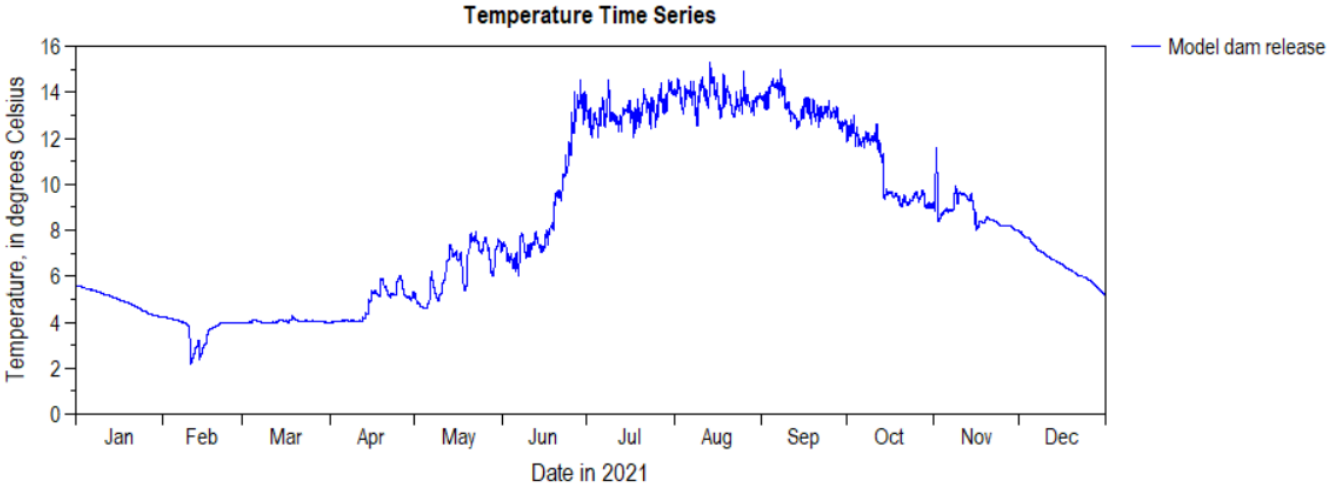
The user should make an attempt to be familiar with the units of the time-series parameter of interest in the data file, so that those input units can either be converted to different units, or just so that the information can be provided to W2Anim. A number of unit-conversion filters are available, along with a custom filter that allows the user to input a multiplicative factor and an additive factor, which covers many possible unit conversion equations. The Data Type input (for example, Temperature) cannot be changed later, but it serves mainly as a

reminder to the user when additional datasets are added. Currently, only one Y axis is possible in the Time-Series graph type, so only one type of parameter may be plotted at a time.

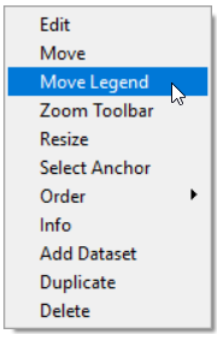
Either a “Date/Time” or “Julian Date” X Axis Type can be chosen, and a Base Year must be chosen for certain combinations of file formats and axis types. Most of the inputs in this menu can be changed later, but the user should pay particular attention to the Base Year input for time-series files that specify only the Julian Date, because W2Anim will convert the Julian Date to a date/time for internal use, and that date/time index cannot be changed later, other than by removing the dataset and adding it back again with a different Base Year.



For this example, a W2 outflow temperature file was selected for the first time-series dataset, and the menu to the right shows the rest of the inputs. The resulting time-series graph is shown below.

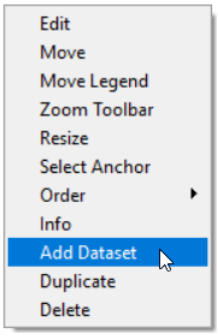


The legend entry can be moved independently from the graph itself. Hover the mouse over the graph and right-click (or type Alt-p) and select the Move Legend option. The legend then can be moved by the mouse to a different position. If *Snap to Grid* is enabled, then a magenta anchor point for the legend will be shown. Left click the mouse to establish the new legend position; note that the legend position is an offset relative to the upper right corner of the graph frame, so resizing the time-series graph may also move the legend position in such a way that it may need to be repositioned again.

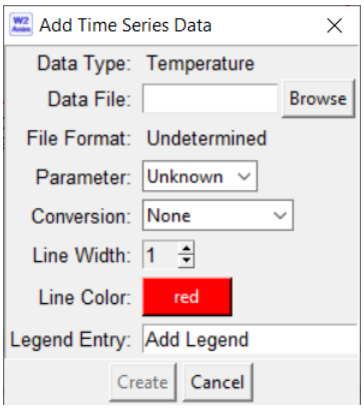


As with other graph types, the option menu to the right shows that the graph may be edited, moved, resized, duplicated, and deleted. A new anchor point for the graph may be selected, and the graph may be moved up or down in the drawing order. Information about the graph and the range of its datasets can be displayed. Finally, additional datasets may be added to the graph.

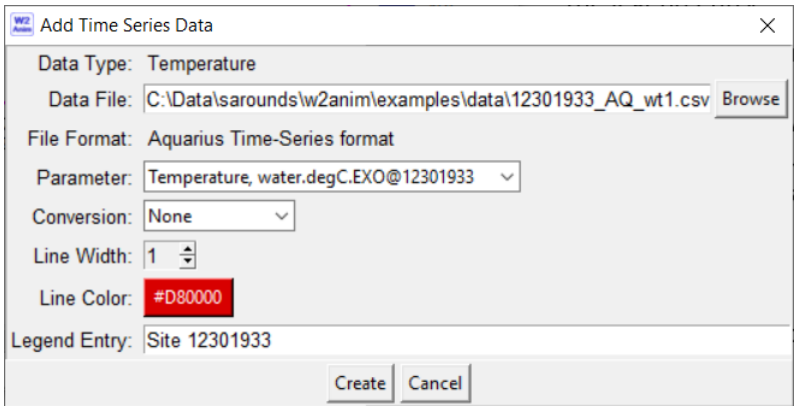
Adding More Datasets



Additional datasets can be added to a Time-Series or Linked Time-Series graph by hovering the mouse over the graph and clicking the right mouse button (or typing Alt-p) and selecting the Add Dataset option. These time-series graphs can only display one Y axis at this time, so any new datasets should be such that they can be plotted with the graph's existing Y axis. Selecting the Add Dataset option brings up the Add Time Series Data menu, as seen below.

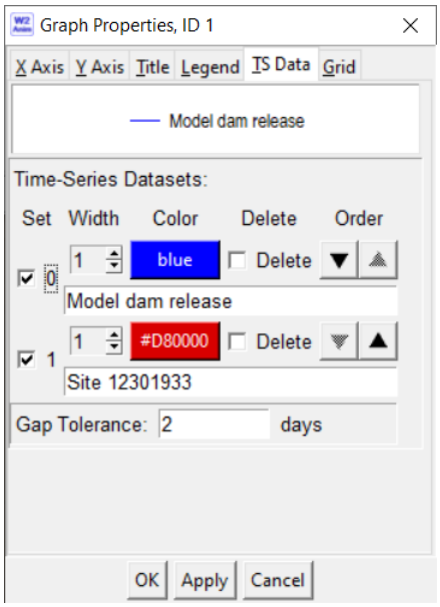


As a reminder, the menu displays the current data type assigned to the time-series graph, then prompts the user to find and choose another time-series dataset by clicking the Browse button to find and specify a file name. When the file is selected, W2Anim will scan the file (just as it did for the initial dataset) to try to identify its format and determine whether it is a recognized file type. If the file is recognized, W2Anim will try to create a list of parameters contained in the file so that the user may choose one. Some file formats provide descriptive parameter names, while others provide almost no information. Once the parameter is selected, the user should determine whether its units need to be converted. A number of unit-conversion filters are available, along with a custom filter that allows the user to input a multiplicative factor and an additive factor, which covers many possible unit conversion equations. Finally, the user should choose a line width and line color and specify a legend entry. W2Anim will not accept "Add Legend" or an empty string for the legend entry.



For this example, a measured temperature time-series was specified from a location not far from the downstream end of the model. The filled-out menu is shown at the right. Most of the parameters of the time-series graph can be modified through the Graph Properties menu, which is activated by hovering the mouse over the graph and clicking the right mouse button (or typing Alt-p) and selecting the Edit option. Alternatively, select the Edit/Edit option from the menu bar and then click the left mouse button when hovering the mouse over the graph of interest. The Graph Properties menu for this time-series graph is shown on the next page.

The Graph Properties menu for Time-Series graphs has six tabs across the top of the menu to control aspects of the X Axis, Y Axis, Title, Legend, the time-series data (TS Data), and an optional Grid. Most options in this menu should be fairly self-explanatory, and therefore are not discussed in detail here. The user is advised to play with the various options and observe the results when the Apply button is clicked.

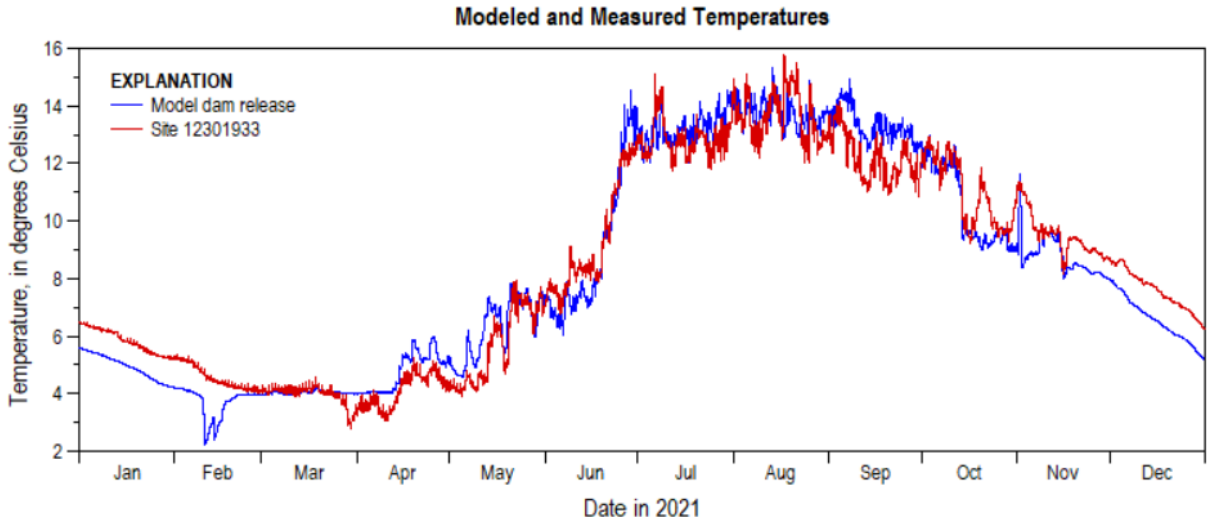


The line width, line color, legend entry, and order of plotting for each time-series dataset can be modified from the TS Data tab of the Graph Properties menu. The triangular Order buttons are used to move a dataset up or down in the list, where the datasets are plotted in list order from top to bottom. Any dataset may be hidden by unchecking the checkbox next to the dataset number at the left of each entry, and shown again by checking the box. Nothing happens until the OK or Apply button is clicked. If the Delete box is checked, then the dataset will be removed after the OK or Apply button is clicked. W2Anim has no Undo function at this time, so be sure that you really want to delete a dataset before clicking OK or Apply. The dataset can always be added back through the Add Dataset menu option. Note that Legend Title (on the Legend tab) is optional.

A gap tolerance value can be set for a Time-Series graph such that any date/time gap exceeding the gap tolerance will break the line between adjacent points. When a data point has gaps exceeding the tolerance on both sides, the point is plotted with a small rectangle. An entire time series can be plotted with points rather than a line if the gap tolerance is sufficiently small, such as zero, but be careful because doing so with a large dataset will cause the user interface to slow considerably (because so many objects for the points will have been created). The default gap tolerance is 2 days, and can be changed from the Graph Properties menu in the TS Data tab.

If grid lines are turned on (Grid tab of Graph Properties menu) and the legend is moved inside the graph frame, the user may wish to turn on the border outline and fill for the legend box. The colors of the legend box border and fill may be set by the user. These various attributes are controlled from the Legend tab of the Graph Properties menu.

After changing a few font sizes and moving the legend inside the graph frame, the example Time-Series graph is shown below.

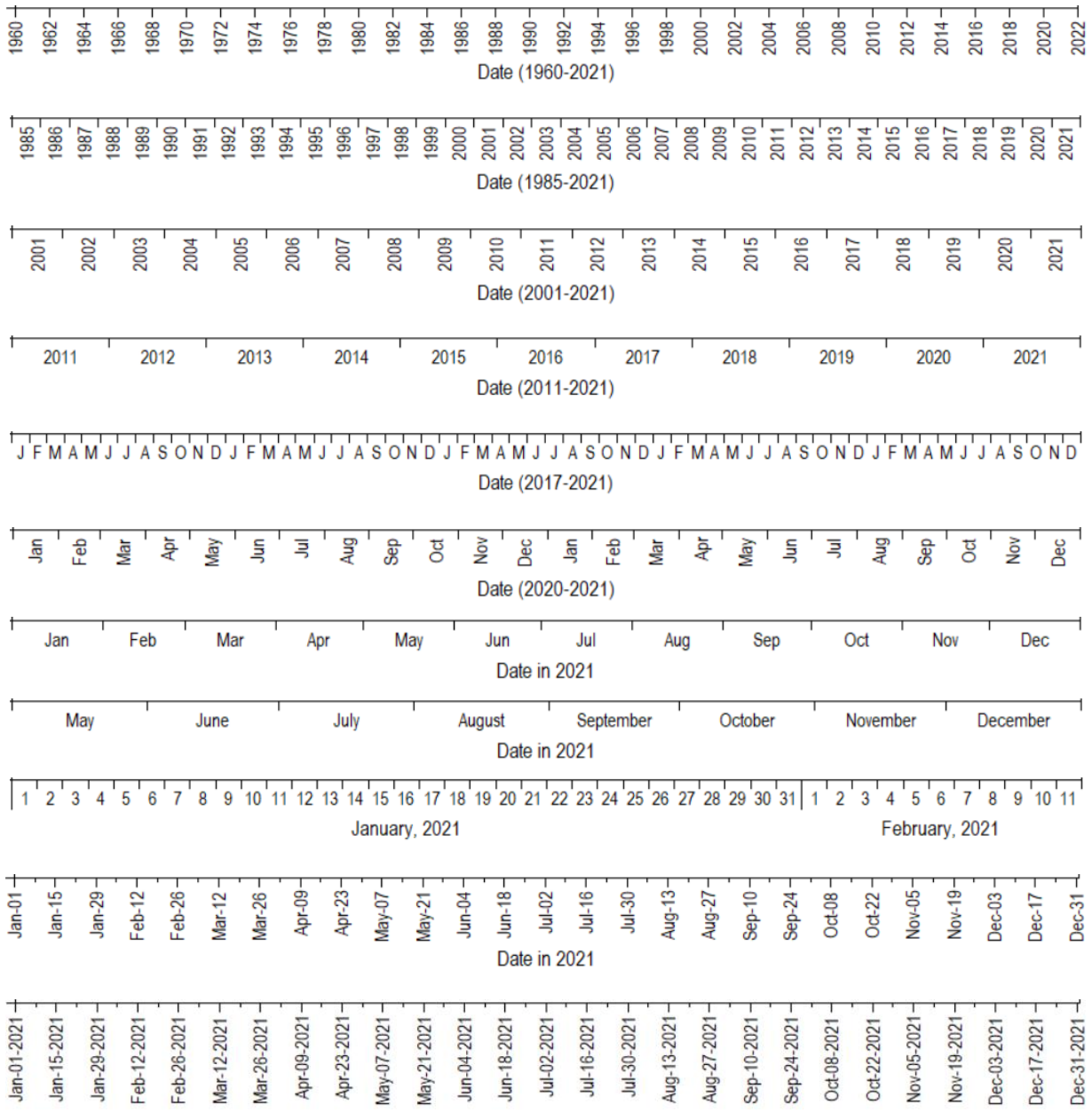


X Axis Formats

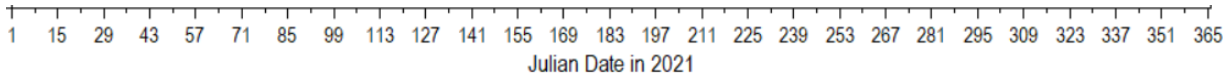
Any X axis that is a date axis can have several different formats. In Date/Time mode, the axis will show calendar dates with one of four formats:

- Year: In this format, the year is displayed between or at year-boundary tick marks. When showing the year, the format will adjust automatically according to how much space is available.
- Month: In this format, the month name is displayed between or at month-boundary tick marks. When showing the month name, the format will adjust automatically according to how much space is available, either spelling out the entire month name, shortening it to one or three letters, or rotating the three-letter abbreviation. The font size affects these determinations. If sufficient room is available, the day of the month also will be plotted between tick marks for each day.
- Mon-DD or Mon-DD-YYYY: In these modes, the dates are shown in Mon-DD or Mon-DD-YYYY format next to the major tick marks.

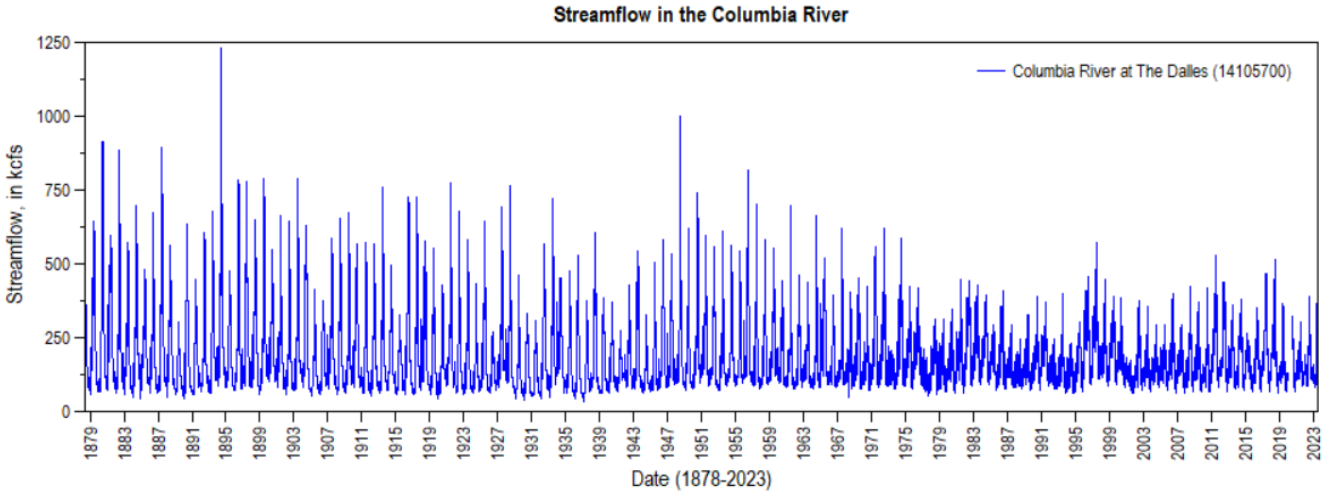
Examples of different Date/Time axis formats are shown below:



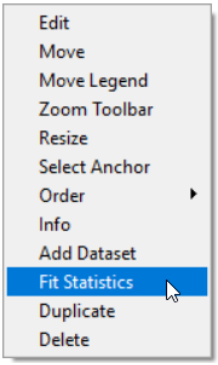
When the X axis is in Julian Date mode, the X axis is numeric and the values displayed depend on the specified base year.



With the Year format, long time-series datasets can be plotted. Daily mean streamflow data are plotted below for Jun-01-1878 through Jun-09-2023 from the Columbia River at The Dalles station (USGS gage 14105700).



Because the Time-Series graph type may often be used to compare modeled and measured time-series datasets, a goodness-of-fit option becomes available if at least two datasets are included in the graph. Hover over the graph and right-click (or type Alt-p) and select the Fit Statistics option. A menu will appear (see below, right), prompting the user to select the test dataset and a reference dataset. See the Goodness-of-Fit Statistics section of this User Manual for more details.




TS Goodness-of-Fit Statistics

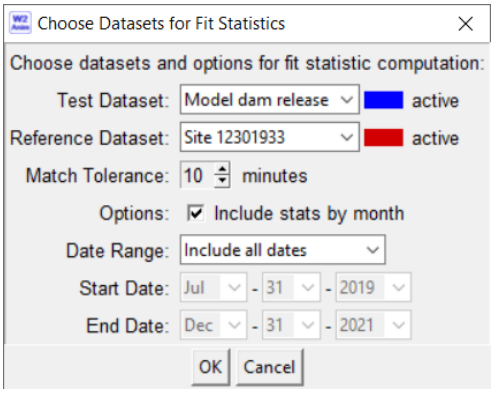
Goodness-of-Fit Statistics
Test: Model dam release
Reference: Site 12301933

	n	Mean Error	Mean Absolute Error	Root Mean Squared Error
All*	18208	-0.1108	0.7445	0.8995
Jan	1547	-0.9000	0.9000	0.9019
Feb	1398	-0.8511	0.8511	1.0362
Mar	1548	0.0560	0.1970	0.3250
Apr	1498	0.6768	0.6769	0.7180
May	1550	0.6343	0.7054	0.8858
Jun	1498	-0.2819	0.7041	0.8526
Jul	1531	0.3453	0.5784	0.7245
Aug	1550	0.1108	0.7095	0.8693
Sep	1498	1.1753	1.1812	1.2814
Oct	1543	-0.5091	0.6190	0.8305
Nov	1497	-0.7732	0.7889	1.0103
Dec	1550	-1.0419	1.0419	1.0487

*All = All available dates

OK Save

The "test" dataset in this case would be the model results, and the reference dataset would be the measured data. The menu shows the user what line colors are associated with the chosen datasets, as well as whether they are shown (active) or hidden. Computations are only done on test/reference data pairs where a reference value can be found within the match tolerance of the date/time of the test value. The statistics can be computed by month, and the user can also choose a date range.



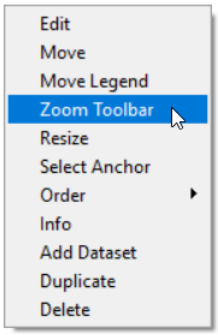
After clicking the OK button, W2Anim computes the goodness-of-fit statistics and pops up the results in a new window (see example at left). The legend entries for the test and reference datasets are noted in the header. Fit statistics are computed for the user-specified date range or for the entire time period where test and reference data are available for comparison, and also may be computed by month. The results can be saved to a text file by clicking the Save button.

Linked Time-Series Graphs

At this time, linked time-series graphs can be created only from existing Measured Vertical Profile graphs, Vertical Withdrawal Zone from Measured Data graphs, W2 Vertical Profile graphs, and W2 Outflow Profile graphs. The creation and use of these linked time-series graphs are explained with their parent graph types in the sections on Measured Vertical Profile graphs, Vertical Withdrawal Zone from Measured Data graphs, W2 Vertical Profile graphs, and W2 Outflow Profile graphs. Additional time-series datasets can be added to linked time-series graphs. See the Time-Series graph description for more information on adding datasets to time-series graphs.

The Zoom Toolbar

The X and Y axis limits and major tick spacing for each graph in W2Anim can be modified from the Graph Properties menu. For Time-Series graphs, however, the Zoom toolbar also is available and provides some quick shortcuts to change the axis limits. Hover over any Time-Series graph and right-click (or type Alt-p) and select the Zoom Toolbar option. The function of each button on the Zoom toolbar can be discerned by hovering the mouse over a button and reading the text that appears in the lower left corner of the toolbar. The following is a list of the features of the Zoom toolbar:



Zoom buttons

Message area

Zoom in	Zoom out	Zoom to Full Extent
Zoom in, X only	Zoom out, X only	Zoom to X Full Extent
Zoom in, Y only	Zoom out, Y only	Zoom to Y Full Extent

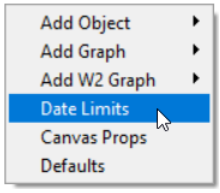
Clicking on any of the “zoom in” buttons will turn the mouse cursor into a crosshair, and the message area on the toolbar will prompt the user to draw a zoom box (for “zoom in”) or a zoom bar (for a zoom in just the X or Y direction) on any time-series graph. To create a zoom box or zoom bar, click and hold the left mouse button on a starting point within the graph frame and drag to the final point before releasing the mouse button. Alternatively, click the right mouse button to abort the action, or click on a different zoom button to choose to zoom in a different manner.

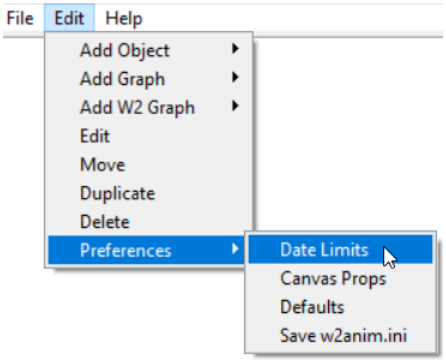
After clicking on any of the “zoom out” or “zoom to full extent” buttons, the mouse cursor will become a hand pointer, and the message area will prompt the user to choose a time-series graph for that zoom action. Clicking on a time-series graph implements the zoom action; clicking the right mouse button aborts the action. Zooming out in the X direction is limited to the range of the available non-hidden data, whereas the user can zoom out in the Y direction without limit. Zooming outward attempts to expand the axis limits by roughly 25 percent in each direction, with some constraints. Computing new Y axis limits may result in a compromise between the actual zoom-to value and a more-rounded value. Zooming to full extent will modify the X and Y axis limits to show the full range of all visible datasets; hidden datasets are ignored.

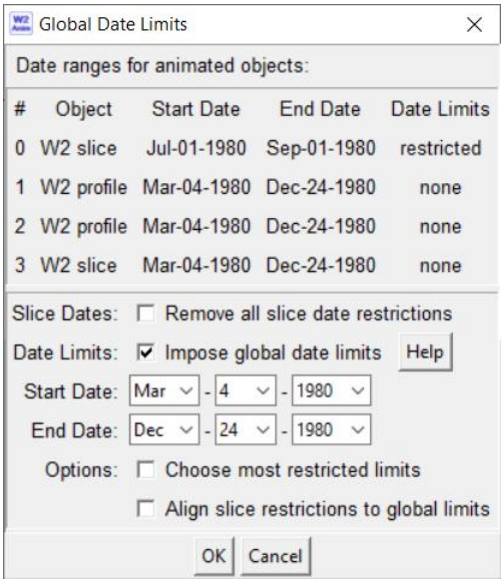
GLOBAL DATE LIMITS

Each of the animated graphs in W2Anim retains its own datasets that are indexed to the date and time from its associated data files. The data files for each animated graph, however, will not necessarily have the same set of dates. For the purpose of animation, therefore, W2Anim uses a global list of dates derived from all of the animated graphs that are present on the canvas, and that global date list is automatically pruned and sorted such that any dates within 5 minutes of one another are deemed to be redundant and are removed. During animation, each animated graph is updated using the nearest date/time that is within about 10 minutes of the current date/time from the global list.

By default, W2Anim uses the entire global date list for animation. Because W2 Longitudinal Slice graphs can have restricted date limits, however, the user also can place limits on the global dates list for the purpose of animation. Imposing limits on the global date list does not affect the data associated with any of the animated graphs, and the global date list is easily rebuilt if new date limits are chosen or if the global date limits are removed. To impose global date limits, choose the Date Limits option either from the Edit/Preferences menu or from the pop-up menu that appears when right-clicking (or typing Alt-p) when the mouse is hovering over no objects on the background canvas. The Date Limits option in the Edit/Preferences menu is only active when at least one animated graph is present on the canvas.







The Global Date Limits menu is shown at the left. The top part of the menu lists all animated graph objects that are currently on the canvas, including their type, their start and end dates, and whether any date restrictions have been imposed (for W2 slice plots). The bottom part of the menu allows the user to impose or change the global date limits, and also allows the user to either remove any date restrictions imposed on W2 slice plots, or to align W2 slice date restrictions to the imposed global date limits. Some parts of this menu will not appear if no W2 Longitudinal Slice plots are present on the canvas. If the various animated graphs have different date limits, the "Choose most restricted limits" option will impose global date limits that have the latest start date and the earliest end date from the available date ranges of the animated graphs.

When global date limits are imposed, the global date list will be truncated at the imposed start and end dates, the date/time indices for animation will be updated, and the Animation toolbar (if present) will be rebuilt. If any date restrictions for W2 Longitudinal Slice plots are modified, then the data files for those plots will be re-read and those graphs will be rebuilt. Clicking OK will cause the lower part of the menu to be wiped clean to make room for a set of messages to inform the user as to the status of the steps involved in rebuilding graphs or rebuilding the global date list.

Setting global date limits will cause a new section to be saved to the W2Anim project file. That optional section is described in the W2Anim Project File Format section of this User Manual.

MODEL AND DATA FILES

MEASURED VERTICAL PROFILES

For the Measured Vertical Profile (profile and colormap) and for the Vertical Withdrawal Zone from Measured Data graph types, a data file of measured vertical profiles must be provided, and in the latter case it must be for water temperature. The format of these measured vertical profile files is straightforward, with a time-series of water-surface elevations and parameter values at given elevations or depths, along with some headers providing key metadata. These are text files and are expected to be comma-delimited. The header information consists of pairs of fields, with a key word in the first field and a value in the second field. The expected key words and values are given in the table below, where some flexibility in the key words is possible when the measured profiles are for water temperature.

Key Word	Possible Values
DataType	*ProfileData* or *TemperatureProfile*
Parameter	parameter name, such as *Temperature*
ElevOrDepth	*Elevation* or *Depth*
ElevUnits	*ft* or *foot* or *feet* or *m* or *meter* or *meters*
InputUnits (or InputDegrees)	parameter units (or *Celsius* or *Fahrenheit)*
Ytype	*Elevation* or *Depth*
Yunits	*ft* or *foot* or *feet* or *m* or *meter* or *meters*
Ymin	suggested Y axis minimum value
Ymax	suggested Y axis maximum value
Ymajor	suggested Y axis major spacing
ParmUnits (or WTunits)	parameter units (or *Celsius* or *Fahrenheit)*
ParmMin (or WTmin)	suggested parameter axis minimum value
ParmMax (or WTmax)	suggested parameter axis maximum value
ParmMajor (or WTmajor)	suggested parameter axis major spacing

The Parameter line can be skipped if the parameter is temperature and the value TemperatureProfile is used for the DataType. The ElevOrDepth line tells W2Anim whether to expect profiles at fixed elevations or at specific depths. The ElevUnits line tells W2Anim the units associated with the input elevations or depths. Similarly, the InputUnits (or InputDegrees) line tells the program which input units to expect for the measured profile values. For temperature, W2Anim will store the data internally in degrees Celsius, but it must be told what units to expect for the data. The rest of the lines (Ytype, etc.) are used by W2Anim as suggestions to the user when a new graph is being created, and the values provided here are used as initial values in the program's interface.

After these header lines, the next line must have the key word ElevationOrDepth in the first field. The second field is ignored but typically may contain the word "Surface." The rest of the fields on this line are numeric and are the elevations or depths at which the profile data are measured. For example, if the measurements were made at fixed elevations, this line might look something like:

ElevationOrDepth,Surface,2450,2440,2430,2420,2410,2400,2390,2380,2370,2360,2350,2340,2330,2320,2310,2300,2275,2225,2170

and if the measurements were made at fixed depths, the line might look something like:

ElevationOrDepth,Surface,5,10,20,30,40,60,80,100,120,140,160,180,200e,215e,230e

Note that the second example includes several depths with an "e" at the end, which marks those depths as containing estimated data. Estimated profile points are plotted with a different color, and it can be useful to include estimates in some cases.

After the line containing ElevationOrDepth, the rest of the file contains the profile data. The first column is expected to contain a date or a date/time, where the following date formats are valid:

MM-DD-YYYY, YYYY-MM-DD, Mon-DD-YYYY, DD-Mon-YYYY, or YYYYMMDD

where the "-" separator may also be a "/". The first digit of a numeric month or day can be dropped if it is zero, except for the YYYYMMDD format. The date need not include a time for data that are daily. For date/time formats, all of the date formats are still valid, but the hour and minute are appended. The YYYYMMDDHHmm format has no punctuation, or the HHmm can be separated from the YYYYMMDD with a space, tab, or a capital letter T. All other recognized date/time formats separate the date from the time with a space, tab, or a capital

letter T. Then, the hour and minute are given with a format of either HHmm or HH:mm, where the first digit of the hour may be dropped if it is zero.

The second field is expected to be the measured water-surface elevation, in the expected units (see the ElevUnits line). The rest of the fields are expected to be the measured parameter values at the corresponding elevations or depths and in the expected units (see the InputUnits line). If any data points are missing, the text "na" (without quotation marks) is used as a placeholder to be ignored. Therefore, some data lines for a file containing daily temperature profiles in Fahrenheit at fixed elevations might look something like:

```
ElevationOrDepth,Surface,2450,2440,2430,2420,2410,2400,2390,2380,2370,2360,2350,2340,2330,2320,2310,2300,2275,2225,2170
10/1/2020,2446.49,na,58.49,58.60,58.14,59.44,58.36,58.54,59.08,58.96,58.83,55.81,54.57,53.65,51.70,49.25,46.52,42.90,39.21,37.70
10/2/2020,2446.42,na,58.01,58.20,57.81,59.11,58.04,58.23,58.74,57.41,55.84,54.29,52.43,50.71,48.41,45.35,43.55,41.71,39.20,37.98
10/3/2020,2446.33,na,57.83,57.95,57.51,58.77,57.68,57.73,57.80,56.78,55.15,54.00,51.76,48.45,44.80,43.26,42.48,41.11,38.77,37.64
10/4/2020,2446.13,na,57.53,57.66,57.10,58.40,57.32,57.48,57.77,56.75,55.45,53.13,48.54,45.31,43.98,43.53,42.83,41.41,39.02,37.83
10/5/2020,2446.04,na,59.35,59.24,58.85,60.14,58.81,58.59,57.96,55.14,52.92,51.80,50.37,49.75,48.59,47.58,46.85,44.71,41.47,40.15
10/6/2020,2446.01,na,59.14,59.28,58.69,60.01,58.03,56.39,55.58,53.15,52.09,50.60,49.17,48.39,47.49,47.13,46.45,45.32,41.43,40.22
10/7/2020,2445.98,na,59.83,59.09,58.59,59.62,57.91,56.97,56.44,53.98,52.75,51.83,50.41,49.39,48.27,47.39,46.86,45.58,42.28,40.34
10/8/2020,2446.00,na,59.06,59.03,58.51,59.20,57.18,56.13,54.78,53.01,51.82,50.64,48.96,48.28,47.40,47.14,46.42,45.03,41.68,40.18
10/9/2020,2445.98,na,59.24,59.20,58.40,59.28,57.86,56.90,55.88,53.94,52.62,51.58,50.33,49.39,48.27,47.73,47.11,45.75,42.88,40.36
10/10/2020,2446.00,na,58.34,58.49,58.11,58.96,57.63,55.96,54.85,53.07,51.84,51.02,49.52,48.72,47.88,47.29,46.53,45.55,41.71,40.16
```

Note the "na" values for the 2450 elevation when the water-surface elevation is less than 2450. Alternatively, some lines for a file containing hourly temperature profiles in Celsius at fixed depths might look something like:

```
ElevationOrDepth,Surface,5,10,20,30,40,60,80,100,120,140,160,180,200e,215e,230e
5/1/2021 0:00,1537.30,9.82,9.25,8.81,8.37,8.1,7.83,7.41,6.84,6.57,6.07,5.6,5.46,5.43,5.43,5.43
5/1/2021 1:00,1537.39,9.63,9.01,8.59,8.33,8.22,7.67,7.28,6.95,6.4,6.01,5.66,5.51,5.47,5.47,5.47
5/1/2021 2:00,1537.46,9.74,9.01,8.53,8.35,8.15,7.55,7.31,6.78,6.34,5.99,5.87,5.61,5.55,5.55,5.55
5/1/2021 3:00,1537.53,9.53,8.99,8.53,8.34,8.18,7.66,7.29,6.53,6.29,6.1,5.89,5.61,5.54,5.54,5.54
5/1/2021 4:00,1537.63,9.47,8.89,8.51,8.39,8.23,7.65,7.15,6.61,6.34,6.15,5.97,5.65,5.57,5.57,5.57
5/1/2021 5:00,1537.69,9.53,8.66,8.42,8.37,8.23,7.6,7.2,6.61,6.23,6.07,5.89,5.73,5.69,5.69,5.69
5/1/2021 6:00,1537.71,9.47,8.77,8.5,8.38,8.14,7.69,7.19,6.68,6.27,6.02,5.8,5.58,5.53,5.53,5.53
5/1/2021 7:00,1537.73,9.42,8.63,8.55,8.41,8.09,7.62,7.18,6.58,6.26,5.99,5.73,5.56,5.52,5.52,5.52
5/1/2021 8:00,1537.76,9.48,8.79,8.64,8.33,8.11,7.57,7.12,6.42,6.26,6.01,5.72,5.59,5.56,5.56,5.56
5/1/2021 9:00,1537.77,9.52,8.76,8.53,8.2,8.09,7.44,7,6.47,6.08,6.04,5.77,5.58,5.53,5.53,5.53
5/1/2021 10:00,1537.80,9.75,8.69,8.4,8.21,7.97,7.42,7.01,6.53,6.08,6.06,5.83,5.6,5.54,5.54,5.54
```

This file format also is used for measured reference profile data that can be added to a W2 Vertical Profile graph so that measured and modeled vertical profiles can be compared and goodness-of-fit statistics computed. Note that if all of the measured water-surface elevations are missing (na), the Measured Vertical Profile or Vertical Withdrawal Zone graph can still be produced if the measured profiles are provided at fixed depths and the graph uses a Depth Y axis. Without the water-surface elevation data, however, a fixed-elevation vertical profile or vertical withdrawal zone graph cannot be produced because W2Anim has no way of determining the location of the water surface. The code has been written to be as flexible as possible, but sometimes the measured water-surface elevation is required; therefore, if no measurements of the water-surface elevation are available, the user will need to estimate those values somehow in order to produce the graph of interest.

MEASURED DAM RELEASE RATES

The Vertical Withdrawal Zone from Measured Data graph type requires release flow-rate data from each of the dam outlets for which withdrawal zones are being calculated. The format of these measured dam release-rate files is straightforward, with a time-series of release rates for each outlet along with some headers providing key metadata. These are text files and are expected to be comma-delimited. The header information consists of pairs of fields, with a key word in the first field and a value in the second field. The expected key words and values are given in the table to the right.

Key Word	Possible Values
DataType	*ReleaseRates*
ElevUnits	*ft* or *foot* or *feet* or *m* or *meter* or *meters*
LineWidthUnits	*ft* or *foot* or *feet* or *m* or *meter* or *meters*
InputFlowUnits	*cfs* or *cubic feet per second* or *cms* or *cubic meters per second*
NumOutlets	number of dam outlets
Algorithm	*LibbyDam* or *W2orig*, specified for each outlet, comma-delimited
OutletName	name of each outlet, comma-delimited
CenterlineElev	centerline elevation of each outlet, comma-delimited
OutletType	sink type, *Line* or *Point*, for each outlet, comma-delimited
LineWidth	line width of Line outlets, for each outlet, comma-delimited
TopLayerLimit	W2 model layer that is the top limit for withdrawal zone (default is 2)
BottomLayerLimit	W2 model layer number that is bottom limit for withdrawal zone (default is bottom-most possible layer)
FlowUnits	suggested units for plot, *cfs/ft* or *cms/m* or *ft/s* or *m/s*
FlowMax	suggested maximum outflow axis value
FlowMajor	suggested major outflow axis spacing

The ElevUnits line gives the units for the outlet centerline elevations, and the LineWidthUnits line provides the units to expect for the input line widths. The InputFlowUnits line tells the program which input units to expect for the measured release rates. W2Anim will store elevation and line-width information in meters and release rates in m^3/s, but it must be told what units to expect for those data. The NumOutlets line tells W2Anim how many outlets to expect. The Algorithm line specifies either LibbyDam or W2orig as an algorithm for computing the vertical withdrawal zone for each outlet. The code LibbyDam or W2orig must be specified for each of the outlets, with commas separating each entry. Similarly, the name of each outlet is given on the OutletName line, with each name separated by a comma; the outlet names are used in graph legends and in the W2Anim interface. The CenterlineElev line provides the centerline elevations of each outlet in a comma-delimited list; this input is ignored for outlets using the LibbyDam algorithm. The OutletType designates each outlet as either a Line sink or a Point sink in a comma-delimited list. The LineWidth line gives the effective outlet line widths for those outlets designated as line sinks. The TopLayerLimit and BottomLayerLimit lines specify CE-QUAL-W2 model layer numbers that are used to limit the extent of the vertical withdrawal zone; this is an option in the W2 model and the user must provide a W2 bathymetry file as input, so it makes sense to offer a similar vertical limit option here. The rest of the lines (FlowUnits, FlowMax, and FlowMajor) are used by W2Anim as suggestions to the user when a new graph is being created, and the values provided here are used as initial values in the program's interface.

The LibbyDam outlet algorithm is new and only available in a USGS modification of CE-QUAL-W2 based on versions 4.2 or 4.5. The documentation for that new algorithm will be published by USGS soon as part of a study on the Kootenai River in Montana. Libby Dam routes most of its releases through four hydropower generators that take water from the bottom of a wet well that is fronted by a grid of bulkheads whose configuration changes over the course of a year. The LibbyDam algorithm used in W2Anim is identical to the algorithm that USGS has added to the CE-QUAL-W2 model. In that algorithm, virtual line-sink outlets are used to mimic the flow through open bulkhead positions at various elevations, and the flow through each virtual outlet is estimated iteratively based on an algorithm proposed by Howington (1990). The full USGS report will be referenced when published.

After the header lines, the next line in the release-rate file must have the key word DateTime in the first field, and the names of the various outlets in the rest of the fields. The rest of the lines in the file provide a time series of release rates from each named outlet, with a date or date/time in the first field. As with the measured vertical profile data files, the following date formats are valid:

MM-DD-YYYY, YYYY-MM-DD, Mon-DD-YYYY, DD-Mon-YYYY, or YYYYMMDD

where the "-" separator may also be a "/". The first digit of a numeric month or day can be dropped if it is zero, except for the YYYYMMDD format. The date need not include a time for data that are daily. For date/time formats, all of the date formats are still valid, but the hour and minute are appended. The YYYYMMDDHHmm format has no punctuation, or the HHmm can be separated from the YYYYMMDD with a space, tab, or a capital letter T. All other recognized date/time formats separate the date from the time with a space, tab, or a capital letter T. Then, the hour and minute are given with a format of either HHmm or HH:mm, where the first digit of the hour may be dropped if it is zero.

If daily release rates are specified for three outlets, this part of the file might look something like:

```
DateTime,Wet Well 1,Wet Well 2,Spillway
1/1/2021,180.7,0,0
1/2/2021,113.8,0,0
1/3/2021,113.8,0,0
1/4/2021,113.3,0,0
1/5/2021,113.3,0,0
1/6/2021,113.3,0,0
1/7/2021,113.3,0,0
1/8/2021,113.3,0,0
1/9/2021,113.3,0,0
```

Similarly, if hourly release rates were specified for four outlets, the file might look something like:

```
DateTime,Spillway,Power,URO,LRO
5/1/2021 0:00,0,0,0,0
5/1/2021 1:00,0,0,0,0
5/1/2021 2:00,0,0,0,0
5/1/2021 3:00,0,0,0,0
5/1/2021 4:00,0,0,0,0
5/1/2021 5:00,0,100,0,0
5/1/2021 6:00,0,2230,0,0
5/1/2021 7:00,0,2350,0,0
5/1/2021 8:00,0,2350,0,0
5/1/2021 9:00,0,2350,0,0
```

LIBBY DAM BULKHEAD CONFIGURATION

If the user is creating a Vertical Withdrawal Zone from Measured Data graph in W2Anim and wishes to assign one or more of the outlets to the LibbyDam withdrawal algorithm, then a Libby Dam Bulkhead Configuration file is required to provide the time-varying configuration of the bulkheads fronting one or more of the dam outlets. The format of a bulkhead configuration file is fairly simple, with a time-series of open bulkhead positions for each outlet along with some headers providing key metadata. These are text files and are expected to be comma-delimited. The header information consists of pairs of fields, with key words in the first field and a value or values in the succeeding fields. The expected key words and values are given in the table to the right.

Key Word	Possible Values
Wet Wells	number of outlets using the LibbyDam algorithm
WW Names	names of outlets using LibbyDam algorithm, comma-delimited
Bulkhead Slots	columns of bulkheads fronting each outlet, comma-delimited
Bulkhead Rows	number of rows of bulkheads
Bulkhead Width	width of a bulkhead, then units (*ft*,*foot*,*feet*,*m*,*meter*,*meters*)
Bulkhead Height	height of a bulkhead, then units (*ft*,*foot*,*feet*,*m*,*meter*,*meters*)
Baseline Elevation	elevation of the bottom of the bulkhead array, then units (*ft*,*foot*,*feet*,*m*,*meter*,*meters*)
Baseline Head Loss Coef	value of smallest head-loss coefficient, assigned to bottom-most virtual outlet
Head Loss Increment	amount to increment the head-loss coefficient for each virtual outlets above the bottom-most virtual outlet

The “Wet Wells” key-word line specifies the number of outlets using the LibbyDam algorithm. The “WW Names” line specifies the outlet names that are using the LibbyDam algorithm; these names should match those specified in the release-rates file. The “Bulkhead Slots” line specifies the number of vertical columns of bulkheads fronting each wet well; when more than one outlet uses the LibbyDam algorithm, specify the number of columns for each outlet in a comma-delimited list. The “Bulkhead Rows” line specifies the number of rows of bulkheads fronting each wet well, where the program assumes that if more than one outlet is of the LibbyDam type, they all have the same number of bulkhead rows; if that is not the case, just specify the larger number. The “Bulkhead Width” line provides the effective width of an individual bulkhead in the second field and the units of measurement (*ft* or *foot* or *feet* or *m* or *meter* or *meters*) in the third field. The “Bulkhead Height” line gives the height of an individual bulkhead in the second field and the units of measurement (*ft* or *foot* or *feet* or *m* or *meter* or *meters*) in the third field. The “Baseline Elevation” line tells W2Anim the elevation of the bottom of the bulkhead array (bottom of the bottom row) in the second field and the units of measurement (*ft* or *foot* or *feet* or *m* or *meter* or *meters*) in the third field. The “Baseline Head Loss Coef” line gives the value of the baseline head-loss coefficient used in Howington’s algorithm (dimensionless); this baseline value is assigned to the lowest-elevation virtual outlet that has a non-zero width. A good default value might be 0.5. The ”Head Loss Increment” line gives the value that the head-loss coefficient for a virtual outlet should be incremented for each virtual outlet above the bottom-most virtual outlet. A good default value might be 0.2. In this way, if four virtual outlets are used to describe four discrete openings in a bulkhead array at different elevations, the bottom-most virtual outlet would be assigned a head-loss coefficient of 0.5, and the next three virtual outlets above would be assigned head-loss coefficients of 0.7, 0.9, and 1.1. The research documented by Howington (1990) states that (1) it is extremely difficult to measure or otherwise theoretically obtain an accurate value for a head-loss coefficient for outlets bordering a common wet well, and (2) the relative difference in magnitudes of the head-loss coefficients is often more important than the absolute magnitudes of the coefficients, depending on the overall release rate. The head-loss coefficients are calibration parameters, but they may not affect the results substantially.

The next couple of lines may contain some header information that is ignored, but is eventually followed by a time series of the number of open bulkhead positions in each row for each outlet that is using the LibbyDam withdrawal algorithm. The first column contains a date or date/time, and the second column contains a Julian Date representation of the date. The Julian Date field is ignored. As with previous files described in this section, the following date formats are valid:

MM-DD-YYYY, YYYY-MM-DD, Mon-DD-YYYY, DD-Mon-YYYY, or YYYYMMDD

where the “-“ separator may also be a “/”. The first digit of a numeric month or day can be dropped if it is zero, except for the YYYYMMDD format. The date need not include a time for data that are daily. For date/time formats, all of the date formats are still valid, but the hour and minute are appended. The YYYYMMDDHHmm format has no punctuation, or the HHmm can be separated from the YYYYMMDD with a space, tab, or a capital letter T. All other recognized date/time formats separate the date from the time with a space, tab, or a capital letter T. Then, the hour and minute are given with a format of either HHmm or HH:mm, where the first digit of the hour may be dropped if it is zero.

The following is an example showing the number of open bulkhead positions for two Libby-Dam-type outlets that each have 7 slots of bulkheads arranged in 18 rows:

```
,,Number of missing bulkheads or blocks in each row of each wet well (row 1 is lowest)
Bulkhead configuration,,Wet Well #1,,,,,,,,,,,,,,,,,,Wet Well #2,,,,,,,,,,,,,,,,,,
Date,JDAY,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
01/01/2020 00:00,  1.000,2,2,2,2,2,2,2,2,2,4,4,4,6,6,7,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
04/14/2020 12:00,105.500,0,1,1,1,1,1,1,1,1,4,4,4,6,6,7,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
04/21/2020 12:00,112.500,0,0,0,0,0,0,0,0,0,4,4,4,6,6,7,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
05/19/2020 12:00,140.500,0,0,0,0,0,0,0,0,0,0,0,0,2,6,7,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
06/08/2020 12:00,160.500,0,0,0,0,0,0,0,0,0,0,0,0,1,1,3,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
06/09/2020 12:00,161.500,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
06/29/2020 12:00,181.500,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
10/20/2020 12:00,294.500,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
10/22/2020 12:00,296.500,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
10/26/2020 12:00,300.500,0,0,1,1,1,1,1,1,1,1,1,1,1,1,1,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
10/27/2020 12:00,301.500,0,1,1,1,1,1,1,1,1,1,1,1,1,2,2,2,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
10/28/2020 12:00,302.500,0,1,1,1,1,1,1,1,1,1,2,3,3,3,3,4,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
10/29/2020 12:00,303.500,0,1,1,1,1,1,1,1,1,1,3,4,4,4,4,4,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
11/02/2020 12:00,307.500,0,1,1,1,1,1,1,1,1,1,5,5,5,6,6,7,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
11/03/2020 12:00,308.500,0,1,2,2,2,2,2,2,2,2,5,5,5,6,6,7,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
11/04/2020 12:00,309.500,1,2,2,3,3,3,3,3,3,3,5,5,5,6,6,7,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
11/09/2020 12:00,314.500,2,3,3,3,3,4,4,4,4,4,5,5,5,6,6,7,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
11/10/2020 12:00,315.500,2,3,4,4,4,4,4,4,4,4,4,5,5,5,6,6,7,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
11/16/2020 12:00,321.500,3,4,4,4,4,4,4,4,4,4,4,5,5,5,6,6,7,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
01/01/2021 00:00,367.000,3,4,4,4,4,4,4,4,4,4,5,5,5,6,6,7,7,7,0,0,0,0,0,0,0,0,0,0,2,2,2,2,2,2,2,7
```

The first three lines above are ignored, but the third line shows that each outlet is assigned 18 columns of input corresponding to the 18 rows of bulkheads, where row 1 is the lowest and row 18 is at the top. The time series then gives the number of open bulkhead positions in each row of the bulkhead array on the given date. In this case, with each outlet fronted by 7 slots or columns of bulkhead positions, the maximum number of open bulkheads in any row is 7. In addition, because the bulkheads stack on top of each other in their slots, the number of open bulkhead positions cannot decrease as the row index increases. A value of 0 means that all 7 bulkheads are installed for that row and no flow is possible through a virtual outlet at that elevation. In contrast, a value of 3 means that three bulkheads are missing in that row, and a value of 7 means that no bulkheads are installed in that row.

The format of this Libby Dam Bulkhead Configuration file is slightly different than that used with CE-QUAL-W2.

W2 Layer Outflow File

Modifications were made to USGS edition 9 of version 4.2, USGS edition 1 of version 4.5, and to the 14-Jul-2023 public release of version 4.5 of CE-QUAL-W2 to produce a new kind of output file that contains layer-specific outflow rates for a user-specified segment location. This W2 Layer Outflow file is tied to the WDO (withdrawal output) capability in CE-QUAL-W2, which has several lines in the W2 control file just before the restart output lines. This W2 Layer Outflow is tied to the WDO output dates, output frequencies, and segment locations. The new layer outflow file is named with the pattern *qwo_layers_XXX_BASE* where the XXX is the segment number and BASE is the user-specified output file name for WDO output. This W2 Layer Outflow file is needed by W2Anim to create the W2 Vertical Withdrawal Zone graph type.

The W2 Layer Outflow file contains the following header lines:

```
Flow layers file for segment XXX
Output is JDAY, total outflow, WS elev, and layer outflows starting w/ layer 2
JDAY,Q(m3/s),ELWS(m),LayerFlows(m3/s)
```

where the XXX in the first line is replaced with the segment number. Following those lines are model outputs in comma-separated format, where the first field is the Julian Date, the second field is the total outflow rate (m^3/s) for that model segment, the third field is the water-surface elevation (m) for the segment of interest, and the rest of the fields are the layer-specific outflow rates (m^3/s) for each layer of that model segment, starting with layer 2 and proceeding to the bottom-most active layer.

RECOGNIZED FILE TYPES

Data File Formats

The following types of time-series data files are recognized by and can be read by The W2 Animator:

- USGS Water Services time-series files (rdb format)
- USGS Aquarius database exported time-series files*
- USGS getData format time-series files*
- USGS Data Grapher table files
- USACE Dataquery 2.0 time-series files
- Generic csv format

*Some of these file types may not be available to users outside of the U.S. Geological Survey (USGS).

For a time-series data file that is recognized to have a generic csv format, W2Anim will try to extract a list of available parameter names from a comma-delimited header line that begins with “DateTime”, “Date”, or “Date/Time”. For this type of time-series file, the following missing value codes are recognized:

na, NA, -99, -999, or the empty string

W2 Model Files

The following types of CE-QUAL-W2 model files can be read and recognized by The W2 Animator:

- W2 Control file (up to the WDO input, both original and csv format)
- W2 Bathymetry file (both the original and csv format)
- W2 Spreadsheet output file
- W2 Contour output file (both original and Tecplot-style)
- W2 Vector (w2l) output file (DSI linkage file)
- W2 River Contour output file
- W2 Lake Contour output file
- W2 input time-series files (column format or csv)
- W2 TSR format
- W2 Outflow csv format (including structure withdrawal output files)
- W2 Water Level (wl) format
- W2 Heat Fluxes output file*
- W2 Daily *Temp.dat format*
- W2 Subdaily *Temp2.dat format*
- W2 Layer Outflow csv format

*Several of these file types are from a customized USGS version of the CE-QUAL-W2 model.

On-The-Fly Unit Conversions

When creating some new graphs and when reading new time-series files, W2Anim often provides an option to convert the input values from one unit system to another. The following unit-conversion options are available:

- None
- degC to degF (Celsius to Fahrenheit)
- degF to degC (Fahrenheit to Celsius)
- m to ft (meters to feet)
- ft to m (feet to meters)
- cms to cfs (cubic meters per second to cubic feet per second)
- cfs to cms (cubic feet per second to cubic meters per second)
- cfs to kcfs (cubic feet per second to thousands of cubic feet per second)
- mg/L to µg/L (milligrams per liter to micrograms per liter)
- µg/L to mg/L (micrograms per liter to milligrams per liter)
- days to hours
- hours to days
- Custom

For the Custom option, the user can specify a multiplicative factor and an additive factor, such that:

$$V_n = mV_o + a$$

where:

V_n is the converted value in the new units,
V_o is the original value,
m is the multiplicative conversion factor, and
a is the additive conversion factor.

Conversion from degrees Celsius to degrees Fahrenheit, for example, can be accomplished either by choosing that option from the list, or by choosing the Custom conversion option with a multiplicative factor of 1.8 and an additive factor of 32. In the saved W2Anim project file, this custom conversion type would be denoted as “Custom,1.8,32” without the quotation marks.

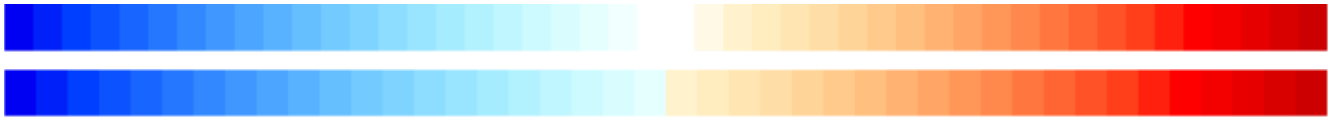
COLOR SCHEMES

Two categories of color schemes for highlighting data patterns are implemented in The W2 Animator. In the first category, single or double diverging color ramps are blended together with a discrete number of colors. In the second category, publicly available and commonly used colormaps are used to derive a user-specified color scheme with the requested number of discrete colors.

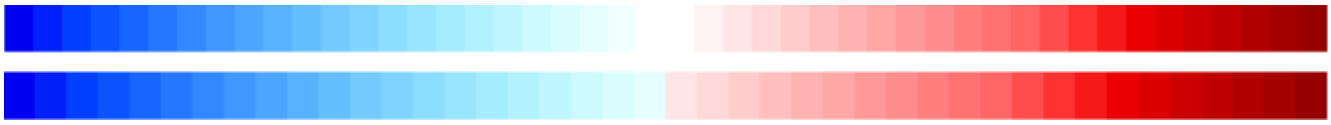
SIMPLE COLOR RAMPS

The user can choose a single color ramp (chosen color to white) or a blended two-color ramp (one color towards white and then towards the second color). These color schemes have a limited number of discrete colors because each color scheme is relatively simple and composed of only a couple dozen base color steps. For a single-color ramp, the user can choose either 8, 9, 10, 11, 12, 15, 17, 19, 21, or 23 discrete colors. The ramps using fewer colors are the result of skipping every other color and reducing the use of white and colors near white. For a two-color ramp, the number of available colors is essentially doubled, as the same number of colors is applied to each color ramp, but the user specifies only the number of colors for a single-color ramp. The base colors used for these color schemes are blue, orange, red, green, magenta, and brown. The blue to orange or blue to red two-color ramps are useful for water temperature. The color ramps can be reversed by the user. Here are some examples:

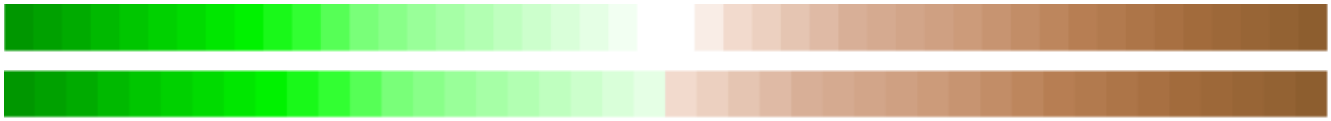
Blue to Orange



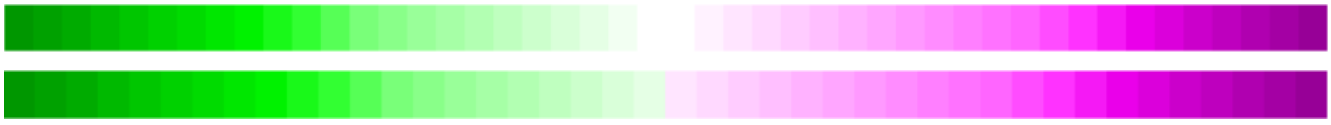
Blue to Red



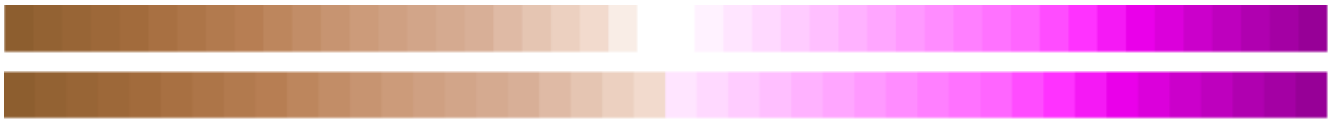
Green to Brown



Green to Magenta



Brown to Magenta



NAMED COLORMAPS

In addition to the simple color ramps, W2Anim offers a set of widely used colormaps developed by others. In these named colormaps, 256 index colors are used as the basis for interpolation and W2Anim allows the user to choose between 8 and 100 discrete colors drawn from the base colors. All color schemes used in W2Anim are free for use and redistribution, and their developers and any license agreements are listed below.

CoolWarm

The CoolWarm color scheme is a blue-to-red diverging colormap with a smooth light gray transition in the middle. Diverging colormaps do not present perceptual issues or problems related to color-blindness. This colormap was developed by Kenneth Moreland and is free for others to use, modify, and redistribute (public domain; CC0 creative commons). See https://www.kennethmoreland.com/color-advice/ for more information on this and some other color schemes. The CoolWarm colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

Turbo

The Turbo color scheme is a rainbow-like colormap that was designed to be more perceptually uniform than previous rainbow colormaps. The Turbo colormap is copyrighted (2019) by Google LLC under version 2.0 of the Apache license, which allows for free, unlimited public use, modification, and redistribution. The Turbo colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

Jet

The Jet color scheme is representative of the classic rainbow colormap, which has been widely criticized for not being perceptually uniform and for issues related to color-blindness. It is included in W2Anim simply because some users may like it. The developer of the Jet colormap is unknown, but it is widely available and believed to be free to use, modify, and redistribute. The Jet colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

Viridis

The Viridis color scheme is a perceptually uniform colormap with increasing luminance progressing from blue through green to yellow. This colormap was developed by Eric Firing and is free to use, modify, and redistribute (public domain; CC0 creative commons). The Viridis colormap is shown here with 100 discrete colors interpolated from its 256 index colors. See https://github.com/BIDS/colormap/blob/master/colormaps.py.

Plasma

The Plasma color scheme is a perceptually uniform colormap with increasing luminance progressing from blue through purple to yellow. This colormap was developed by Stefan van der Walt and Nathaniel Smith and is free to use, modify, and redistribute (public domain; CC0 creative commons). The Plasma colormap is shown here with 100 discrete colors interpolated from its 256 index colors. See https://github.com/BIDS/colormap/blob/master/colormaps.py.

BlackBody

The BlackBody color scheme is a perceptually uniform colormap with increasing brightness progressing from black through orange to yellow. The codes for this colormap were obtained from Kenneth Moreland at https://www.kennethmoreland.com/color-advice/. The BlackBody colormap has been in use for decades and the developer is unknown, with no known claims of intellectual property. It is shown here with 100 discrete colors interpolated from its 256 index colors.

Inferno

The Inferno color scheme is a perceptually uniform colormap with increasing luminance that is similar to the BlackBody colormap but with some additional purple hues. This colormap was developed by Stefan van der Walt and Nathaniel Smith and is free to use, modify, and redistribute (public domain; CC0 creative commons). The Inferno colormap is shown here with 100 discrete colors interpolated from its 256 index colors. See https://github.com/BIDS/colormap/blob/master/colormaps.py.

Batlow

The Batlow color scheme is a perceptually uniform sequential-gradient colormap that varies from dark blue through green-brown to pink and was designed to be readable by color-vision deficient and color-blind people, even when printed in black and white. This colormap was developed by Fabio Crameri as part of his Scientific Color Maps package, which is free to use, modify, and redistribute (MIT license). The Batlow colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

Oslo

The Oslo color scheme is a perceptually uniform sequential-gradient colormap that varies from black through blue to gray and was designed to be readable by color-vision deficient and color-blind people, even when printed in black and white. This colormap was developed by Fabio Crameri as part of his Scientific Color Maps package, which is free to use, modify, and redistribute (MIT license). The Oslo colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

GrayC

The GrayC color scheme is a perceptually uniform sequential-gradient colormap that varies from black through gray to white and was designed to be readable by color-vision deficient and color-blind people. This colormap was developed by Fabio Crameri as part of his Scientific Color Maps package, which is free to use, modify, and redistribute (MIT license). The GrayC colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

Bam

The Bam color scheme is a perceptually uniform diverging-gradient colormap that varies from deep magenta through gray to dark green and was designed to be readable by color-vision deficient and color-blind people, even when printed in black and white. This colormap was developed by Fabio Crameri as part of his Scientific Color Maps package, which is free to use, modify, and redistribute (MIT license). The Bam colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

Cork

The Cork color scheme is a perceptually uniform diverging-gradient colormap that varies from dark blue through gray to dark green and was designed to be readable by color-vision deficient and color-blind people, even when printed in black and white. This colormap was developed by Fabio Crameri as part of his Scientific Color Maps package, which is free to use, modify, and redistribute (MIT license). The Cork colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

Roma

The Roma color scheme is a perceptually uniform diverging-gradient colormap that varies from dark orange to blue and was designed to be readable by color-vision deficient and color-blind people, even when printed in black and white. This colormap was developed by Fabio Crameri as part of his Scientific Color Maps package, which is free to use, modify, and redistribute (MIT license). The Roma colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

Vik

The Vik color scheme is a perceptually uniform diverging-gradient colormap that varies from dark blue through gray to dark red and was designed to be readable by color-vision deficient and color-blind people, even when printed in black and white. This colormap was developed by Fabio Crameri as part of his Scientific Color Maps package, which is free to use, modify, and redistribute (MIT license). The Vik colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

Kindlmann

The Kindlmann color scheme is essentially a rainbow-type colormap with the colors adjusted for increasing luminance, thus making it more perceptually viable. The colormap was first proposed by Kindlmann, Reinhard, and Creem and is free to use, modify, and redistribute (no known claims of intellectual property). The codes for this colormap were obtained from Kenneth Moreland at https://www.kennethmoreland.com/color-advice/. The Kindlmann colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

Extended Kindlmann

The Extended Kindlmann color scheme modifies the Kindlmann colormap to add more hues and make the yellows more like pink. The resulting colormap retains an increasing brightness. The colormap is free to use, modify, and redistribute (no known claims of intellectual property). The codes for this colormap were obtained from Kenneth Moreland at https://www.kennethmoreland.com/color-advice/. The Extended Kindlmann colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

CubeYF

The CubeYF color scheme is a perceptually improved rainbow-like colormap created by Matteo Niccoli and available for free use and redistribution. The CubeYF colormap is shown here with 100 discrete colors interpolated from its 256 index colors.

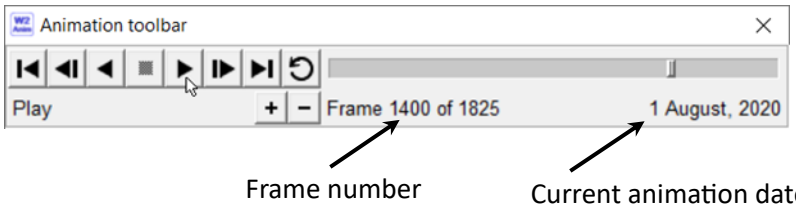
Cube1

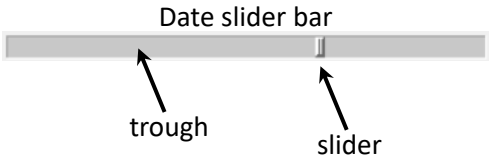
The Cube1 color scheme is another rainbow-like colormap created by Matteo Niccoli and available for free use and redistribution. Compared to CubeYF, Cube1 has more red hues at the high end, but slightly deviates from 100% perceptuality. CubeYF is shown here with 100 discrete colors interpolated from its 256 index colors.

ANIMATIONS AND EXPORTING VISUALIZATIONS

THE ANIMATION TOOLBAR

One of the major goals in creating The W2 Animator was to allow users to produce visualizations of data and model results that could then be animated over time. Several of the current graph types in W2Anim can be animated. To use the animation features, a user first must bring up the Animation toolbar. That toolbar is activated by hovering the mouse cursor over any graph that can be animated, clicking the right mouse button (or typing Alt-p), and choosing the Animate option. The Animation toolbar is a compact set of tools in a pop-up window; most of the tools and icons should be familiar to users, but the function of each button can be discerned by hovering the mouse over a button and reading the text that appears in the lower left corner of the toolbar. The following is a list of the features of the Animation toolbar:





- Go to first frame
- Step backward one frame
- Reverse (play backwards)
- Stop
- Play
- Pause
- Step forward one frame
- Go to last frame
- Repeat toggle
- Play faster (decrease frame delay by 0.1 second, or increase skip-date value)
- Play slower (increase frame delay by 0.1 second, or decrease skip-date value)

The step forward and step backward buttons may be held down to repeat the operation in rapid succession. After pressing either Play or Reverse, the button is replaced by the Pause button and the Stop button is activated. Pressing Pause or Stop reverts the Play or Reverse button to its original image. When the Repeat toggle is activated, the animation date will cycle from the last date to the first date when playing in the forward direction, or from the first date to the last date when playing in reverse.

The slider bar may be dragged left or right with the left mouse button and the animation will run forward or backward to follow the date. Clicking the left mouse button in the trough to the left of the slider bar is the equivalent of one step backward. Clicking the left mouse button in the trough to the right of the slider bar is the equivalent of one step forward. Holding the left mouse button down in the trough to the left or right of the slider bar will repeat the step forward or backward. Clicking the right mouse button anywhere in the slider bar's trough will immediately jump to that date position. Dragging the right mouse button anywhere along the trough will animate the visualization forward or backward according to the date position on the slider bar.

Holding the Ctrl key down and clicking the left mouse button in the trough to the left of the slider bar will move the slider bar to the far left. Holding the Ctrl key down and clicking the left mouse button in the trough to the right of the slider bar will move the slider bar to the far right.

When one or more W2 Vertical Profile graphs are present and they have reference measured profiles loaded and active, the user can move among the dates with paired modeled/measured profiles by holding down the Shift key and clicking on the Step Forward or Step Backward buttons. This is useful when the measured profiles are limited to a subset of the total dates in the animation timeline.

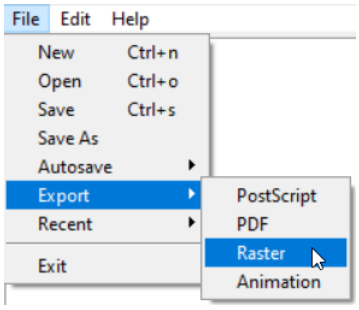
In addition, when at least 100 dates are present in the animation timeline, the user can alter the speed of the animation by holding down the Shift key and clicking on either the Faster or the Slower button to change the skip-date value. The default value is 1, meaning that the animation will move forward (or backward) by one date index when playing (or reversing). If hundreds or thousands of dates exist in the animation timeline and an animation is proceeding very slowly relative to the date range, even with a short delay between frames, then using a larger skip-date value may be useful when viewing an animation. If the time interval between animation dates is constant, then an animation of model output at hourly output intervals, for example, can be sped up to show only animated results at noon, say, by starting the animation at noon and setting the skip date to 24.

Each of the tools in the Animation toolbar can also be invoked with the keyboard. Hit the Tab key on the keyboard to move the focus from one item in the toolbar to the next. Type Shift-Tab to reverse the movement of the focus from one item to the previous item. When the focus is on one of the buttons, pressing the space bar will “press” the button once. When the focus is on the Step Forward or Step Backward button, holding the space bar down will cause the button to be invoked repeatedly (be careful with this, as it might mess things up). When the focus is on the slider bar, pressing the Up or Left arrow key will step backward; pressing the Down or Right arrow key will step forward. Pressing the Home key moves the slider to the far left. Pressing the End key moves the slider to the far right. Holding the Ctrl key down while pressing the Up or Left button will move the slider bar to the left by $1/10^{th}$ of the number of frames. Similarly, holding the Ctrl key down while pressing the Down or Right button will move the slider bar to the right by $1/10^{th}$ of the number of frames.

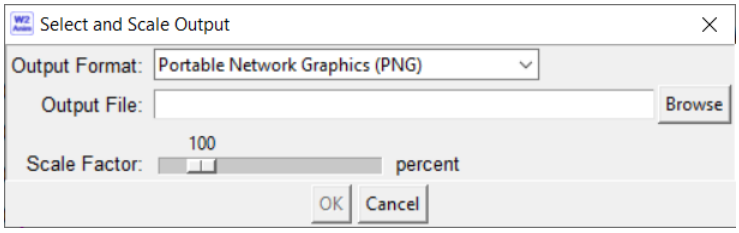
The special functions for the W2 Vertical Profile graphs (Shift-StepForward and Shift-StepBackward) are also possible with the keyboard. Just move the focus to the correct key, hold down the Shift key and then the space bar at the same time. Similarly, the skip-date value can also be changed with keystrokes using the Shift-Faster and Shift-Slower combinations (when at least 100 frames are present in the animation).

If the Animation toolbar is visible when a new animated graph is added to the canvas or when global date limits are added or modified, the available date/time list for animation will be regenerated and the Animation toolbar may be refreshed automatically if the number of frames changes.

Exporting Canvas Snapshots

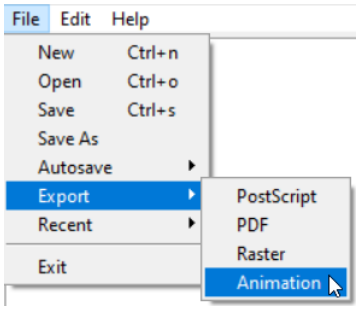


All objects on the drawing canvas can be exported to an Encapsulated PostScript (EPS) file, which in turn can be printed or imported to another program. If Ghostscript is installed as a helper program, then W2Anim will use Ghostscript to convert the EPS output to either a Portable Document Format (PDF) file or to a raster image file in any of several formats (PNG, GIF, JPG, BMP, PPM, TGA, TIFF). To export a canvas snapshot, use the menu bar to select the File/Export menu and select the PostScript, PDF, or Raster option. The PDF and Raster options will only be active if Ghostscript has been installed and W2Anim was able to find it; see the menu for helper programs under the Help/Configure menu.

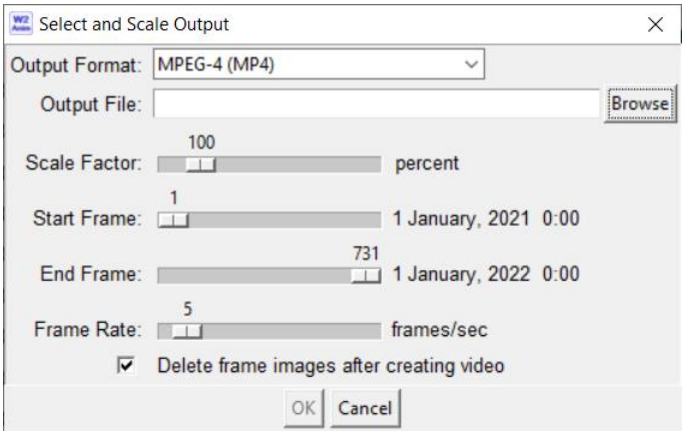


When exporting a raster image, the user must choose the file format, the file name, and a scale factor. On some high-resolution screens, the user may have to increase the scale factor above 100% to create a graphic the same size as what is seen on the W2Anim canvas.

Exporting Video Files



If any of the animated graph types are present on the drawing canvas, and if both Ghostscript and FFmpeg have been installed as helper programs, then W2Anim can be used to export a video file of the animated graphs. Everything on the drawing canvas will be included in the video. To create the video, W2Anim will draw the items on the canvas for the first specified date, export an EPS file, use Ghostscript to create a PNG image, and then move on to the next date to create the next image for the video. Once all of the user-specified frames of the video have been created in a temporary space, W2Anim will use FFmpeg to stitch the frames together to create the video in the user-specified video format (AVI, FLV, GIF, MOV, MP4).



On high-resolution computer screens, the user may have to specify a scale factor greater than 100% to reproduce the size of the canvas in W2Anim. If the user wishes to create the same video in more than one format, uncheck the box to delete the frame images, and the second video file can be created immediately after the first by using the same frame images.

Note that the skip-date value set with the Animation toolbar has no effect on exported video files. To speed up an exported video, the user must choose a higher frame rate.

ALTERNATE EXPORT METHODS

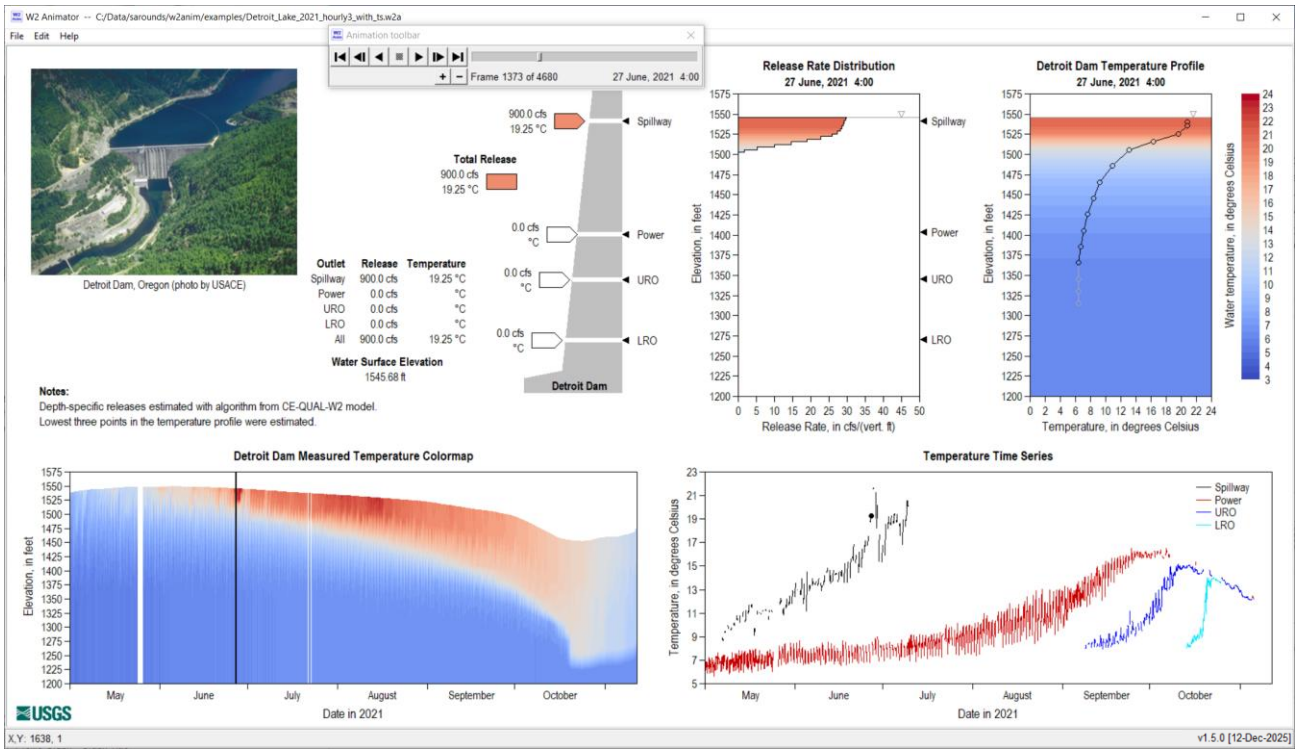
For those who cannot or choose not to install the W2Anim helper programs, the native export option from W2Anim will be limited to a static encapsulated PostScript output format. Other methods can be employed, however, to capture screenshots and the animations displayed by W2Anim. Adept users will be able to find and use these other methods and programs; just a few are mentioned here.

Screenshots

On a Windows-based computer, many options are available to capture a screenshot of the W2Anim canvas. For example, one can simply make the W2Anim canvas visible and then press the Alt-PrtScn keys on the keyboard, which copies a screenshot to the Windows clipboard. From there, the image may be pasted into any of a variety of Windows document-processing or graphics programs such as IrfanView or Word or PowerPoint. Some programs like Irfanview also have their own screen capture ability (see the Options/Capture menu option in Irfanview). Windows 10 and 11 have the Snipping Tool (or Snipping mode) for screen captures. Windows also has the built-in Xbox Game Bar (or Game Bar) for capturing screenshots. Given the number of built-in options to capture screenshots in Windows, along with a large number of free programs with such capabilities, W2Anim users should be able to create static images from W2Anim visualizations with ease, even without using the W2Anim helper programs.

Video Capture

Exporting W2Anim animations directly to video files with the help of Ghostscript and FFmpeg is probably the easiest option, but other methods can be applied to capture W2Anim animations to video files. On a Windows-based computer, for example, the built-in Xbox Game Bar (or Game Bar) can be used to capture video from the user's computer screen. Just bring up the W2Anim visualization, start up a video capture session with the Game Bar, and begin animating the W2Anim visualization. When finished, stop the video capture. Easy instructions can be found online, or some simple shortcuts can be found under the Game Bar topic in the Windows Settings. Under Windows 11, the Snipping Tool also allows for video capture. Other programs for video capture are also available online, but the author of W2Anim cannot endorse any at this time.



GOODNESS-OF-FIT STATISTICS

W2Anim can compute several goodness-of-fit statistics to compare measured and modeled vertical profiles or measured and modeled time-series. The goodness-of-fit statistics are always reported relative to the model dataset, such that a positive computed mean error, for example, implies a positive overall bias in the model results. The statistics are computed and reported for the entire time period of comparison as well as for each month of the comparison. The following statistics and parameters are computed:

Mean Error: $ME = \frac{1}{n}\sum(v_m - v_r)$

Mean Absolute Error: $MAE = \frac{1}{n}\sum|v_m - v_r|$

Root Mean Squared Error: $RMSE = \sqrt{\frac{1}{n}\sum(v_m - v_r)^2}$

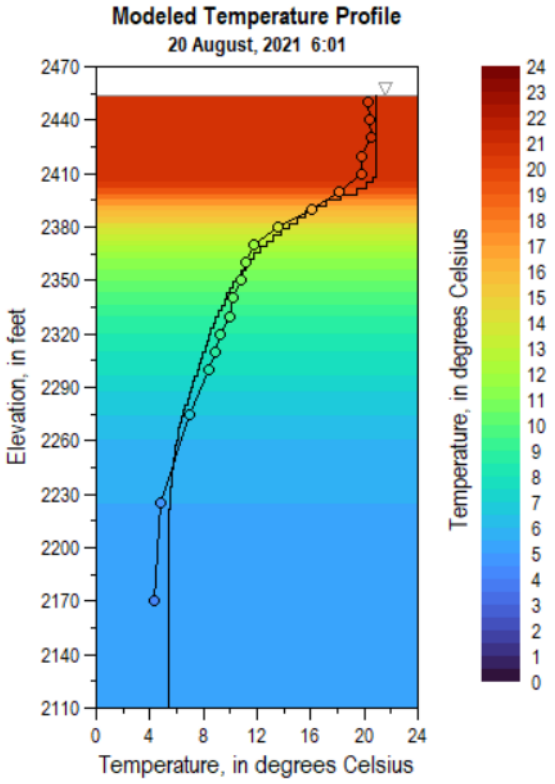
where:

ME	is the mean error,	n	is the number of comparisons,
MAE	is the mean absolute error,	v_m	is a modeled value,
RMSE	is the root mean squared error, and	v_r	is a reference value.

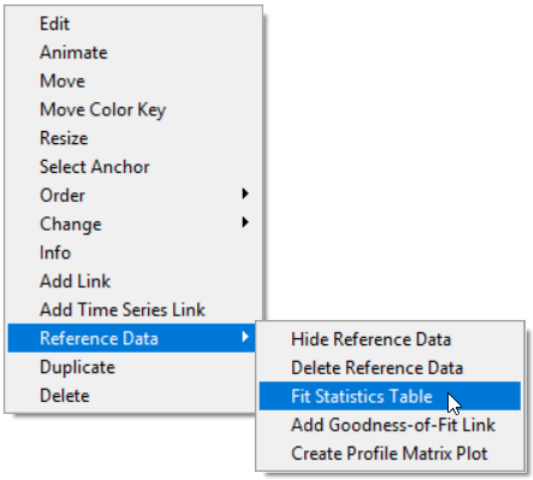
When including a comparison in each statistic, a reference value must be found within some user-specified tolerance of the date/time of the modeled value; the default value is 10 minutes. When comparing vertical profiles, the modeled value for comparison to a measured value is either (1) taken from the model layer that encompasses the depth or elevation of the measured value's location, or (2) interpolated to the elevation or depth of the measured value.

STATISTICS FOR W2 VERTICAL PROFILE GRAPHS

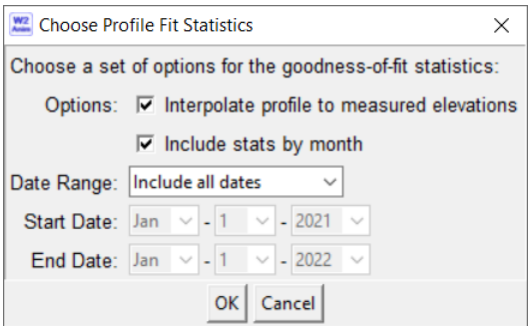
W2Anim allows a reference dataset to be plotted alongside model results in a W2 Vertical Profile graph, such as in the example at the right. The points represent a measured vertical profile of water temperature, whereas the solid stair-stepped line and the color highlighting represent the modeled temperatures.



To compute goodness-of-fit statistics for these modeled temperature profiles, hover the mouse over the graph and right-click (or type Alt-p) to bring up the menu, then choose the Reference Data/Fit Statistics Table option.



Choosing the Fit Statistics Table option will bring up a menu (seen at the right) that allows the user to choose whether the model profile will be vertically interpolated to each measured depth or elevation, or whether the comparison is made simply with the modeled value from the layer in which the measured point falls. The user also can choose whether to compute the fit statistics by month, and whether to calculate the statistics only for a certain range of dates.



Clicking on the OK button causes W2Anim to compute the goodness-of-fit statistics and pop up a new window with the results, as shown at the right for the interpolated option. Fit statistics for the profile are reported for the aggregate total of comparison points and also as mean fit statistics generated from each profile. In the example at the right, 139,964 point comparisons were made and a total of 8,503 profiles were compared.

Profile Goodness-of-Fit Statistics (Vertically Interpolated)

	Goodness-of-Fit Statistics Temperature (Celsius)				Mean Fit Statistics By Profile Temperature (Celsius)				Goodness-of-Fit Statistics Water-Surface Elevation (feet)			
	n	Mean Error	Mean Absolute Error	Root Mean Squared Error	n	Mean Error	Mean Absolute Error	Root Mean Squared Error	n	Mean Error	Mean Absolute Error	Root Mean Squared Error
All*	139964	0.2174	0.7661	1.0118	8503	0.2019	0.7566	0.9032	8601	-0.1022	0.1236	0.1757
Jan	10699	-0.5737	0.5748	0.5919	731	-0.5739	0.5750	0.5911	744	0.0332	0.0623	0.0998
Feb	9338	-0.5646	0.6769	0.9367	667	-0.5646	0.6769	0.7216	672	-0.1076	0.1148	0.1503
Mar	10408	0.4437	0.4547	0.5702	744	0.4436	0.4546	0.4861	744	-0.1631	0.1631	0.1665
Apr	9226	0.7802	0.8042	0.8967	659	0.7802	0.8042	0.8786	720	-0.1994	0.1997	0.2079
May	10466	0.6133	0.9239	1.1544	739	0.6185	0.9251	1.0698	740	-0.2601	0.2608	0.2806
Jun	12049	0.2513	0.7794	1.0909	711	0.2430	0.7722	1.0047	711	-0.3760	0.3760	0.3946
Jul	13766	0.7000	1.0191	1.4639	726	0.6996	1.0191	1.4058	727	-0.0956	0.0967	0.1122
Aug	13772	0.5841	0.8859	1.2551	725	0.5840	0.8858	1.2132	734	-0.0002	0.0321	0.0407
Sep	13401	0.6490	0.9670	1.1988	713	0.6482	0.9667	1.1767	713	0.0019	0.0224	0.0278
Oct	12610	0.3078	0.6859	0.8145	700	0.3081	0.6860	0.8004	704	-0.0018	0.0294	0.0416
Nov	13138	-0.2572	0.5581	0.6931	718	-0.2602	0.5601	0.6768	718	-0.0246	0.0739	0.1043
Dec	11091	-0.5686	0.7546	0.8016	670	-0.5728	0.7563	0.7999	674	-0.0285	0.0451	0.0589

Modeled profiles were vertically interpolated to match the measured vertical profile measurement points for each comparison.
*All = All available dates.

OK Save

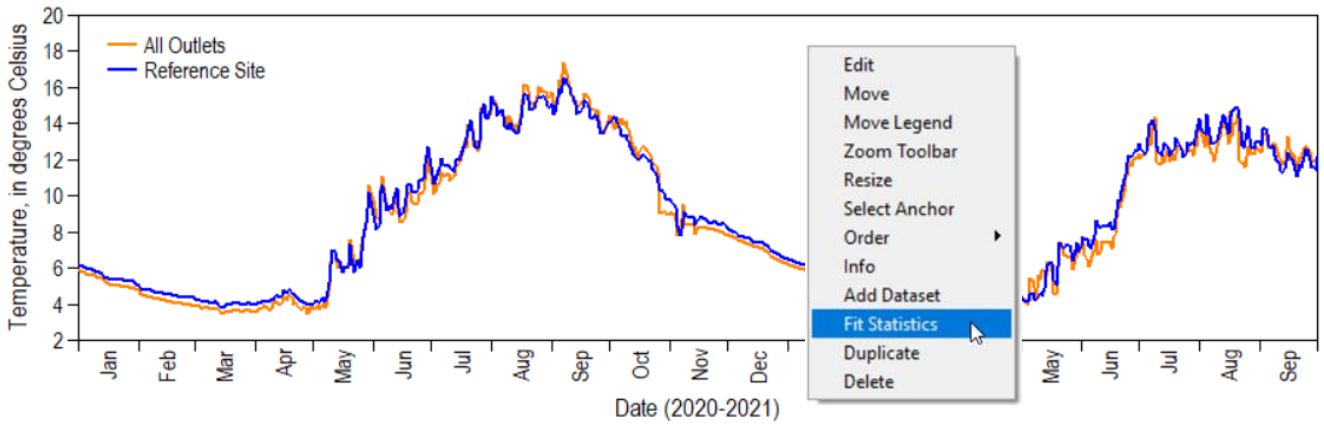
The fit statistics are computed for both the profile data as well as the modeled and measured water-surface elevations (if measured water-surface elevations are available). The fit statistics are reported in the units currently being used in the visualization; in this example, that was degrees Celsius for temperature and feet for water-surface elevation.

The goodness-of-fit statistics are reported for the chosen date range, and also optionally by month. For the vertical profiles, each comparison of a model result to a measurement adds to the total number of comparisons (n), which explains why the n value for the temperature points is so much larger than the n value for the profiles or for the water-surface elevation statistics. In this example, some measured profiles were missing, which explains why the number of profiles compared (8503) is less than the number of water-surface elevations compared (8601).

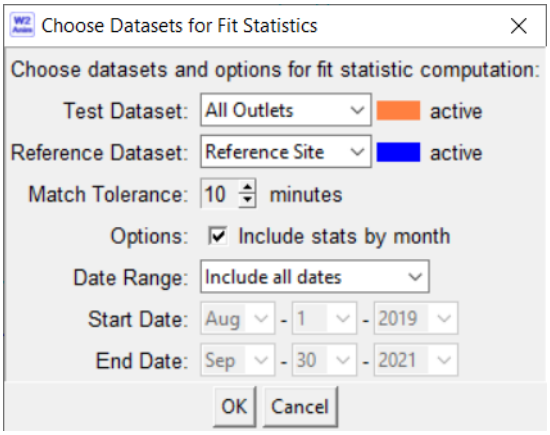
The results can be saved to a text file by clicking on the Save button. The table for the non-interpolated fit statistics is similar, but with a different message denoting the method of calculation. When a date range is specified by the user, that date range is also echoed to the reporting window and to the saved file.

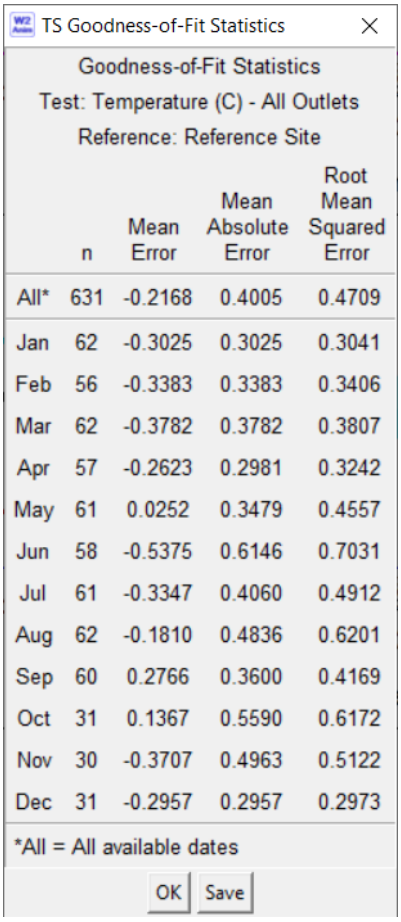
STATISTICS FOR TIME-SERIES GRAPHS

For time-series graphs, the user may generate goodness-of-fit statistics between any two time-series datasets present in the graph, but of course this option is meant to compare model results to a reference measurement dataset. Hover over the graph and click the right mouse button (or type Alt-p) to bring up the menu, then select the Fit Statistics option:



The next step is to choose the datasets for the comparison. The "test" dataset could be the model results, and the reference dataset could be the measured time series. For convenience, the menu shows the user what line colors are associated with the chosen datasets, as well as whether they are shown (active) or hidden.





Computations are only done on test/reference data pairs where a reference value can be found within the match tolerance of the date/time of the test value.

The user may specify a specific date range for the calculation of goodness-of-fit statistics, and whether the fit statistics should be computed by month. After clicking the OK button, W2Anim computes the goodness-of-fit statistics and shows the results in a new window, as show to the right. The legend entries for the test and reference datasets are noted in the header. As with the vertical profiles, fit statistics are computed for the user-specified date range, and also optionally by month. The results can be saved to a text file by clicking the Save button. When a date range is specified by the user, that date range is echoed to the reporting window and to the saved file.

W2Anim Project Files

Any visualization created in W2Anim can be recreated later by saving its input sources and object characteristics in a W2Anim project file. Previously saved project files may be opened from the menu bar under the File/Open option or by typing Ctrl-o. Loading a saved project will discard any objects that were on the drawing canvas prior to the load.

Opening a W2Anim Project File with a Double-Click

The Windows operating system allows users to open files and their associated programs by double-clicking on the file of interest in the File Explorer. Similar capabilities are built into the graphical user interfaces of other operating systems. Under Windows, saved W2Anim project files can be opened in The W2 Animator through the File Explorer by associating files with the ".w2a" file-name extension with the w2anim.bat Windows batch file. My copy of w2anim.bat is located at C:\Data\sarounds\w2anim and contains just one line:

```
C:\Data\sarounds\w2anim\w2anim.pl %*
```

You will want to edit your copy to provide the proper path to your w2anim.pl file. To create the proper association between ".w2a" files and the w2anim.bat Windows batch file, follow these steps:

Windows 10:

- Open the Windows File Explorer.
- In the File Explorer, navigate to any folder containing a saved W2Anim project file, such as the examples folder that was provided with the W2Anim scripts.
- Find a file with the .w2a file-name extension, right-click on it, and choose "Open with…".
- A menu should pop up with a question such as "How do you want to open this file?"
- Check the box next to "Always use this app to open .w2a files".
- Under "Other options" click on the "More apps" link.
- Scroll down and choose the "Look for another app on this PC" option.
- An "Open with…" dialogue box will appear. Navigate to the folder where the W2Anim scripts reside on your computer, then choose the "w2anim.bat" file.

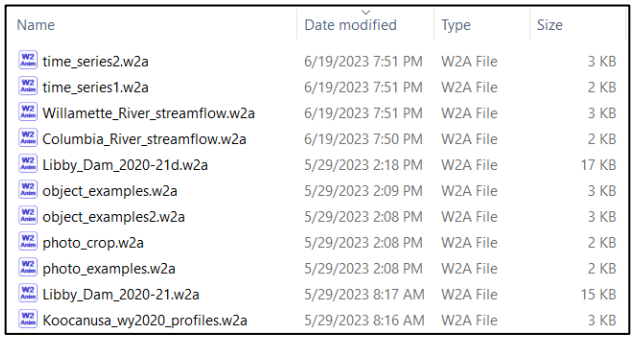
Windows 11:

- Open the Windows File Explorer.
- In the File Explorer, navigate to any folder containing a saved W2Anim project file, such as the examples folder that was provided with the W2Anim scripts.
- Find a file with the .w2a file-name extension, right-click on it, and choose "Open with…".
- If some file associations are already defined, you may need to choose the "Choose another app…" option.
- A menu should pop up with a list of programs that may or may not include a default app.
- Scroll down to the bottom of the list of apps and click on the link for "Choose an app on your PC".
- An "Open with…" dialogue box will appear. Navigate to the folder where the W2Anim scripts reside on your computer, then choose the "w2anim.bat" file.
- Finally, select the w2anim.bat option in the list of apps and click on the "Always" button.

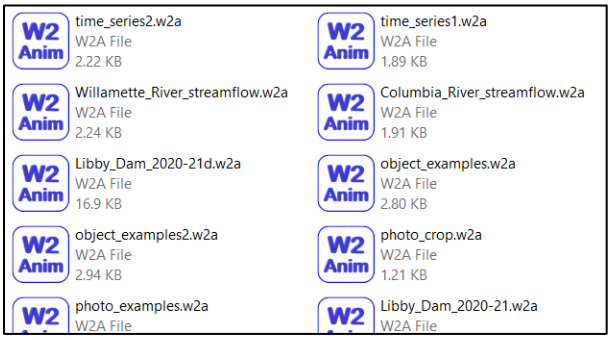
As soon as you choose w2anim.bat as the program to associate with your .w2a files (W2Anim project files), Windows will run the w2anim.bat batch file to open W2Anim and load the project file on which you had originally right-clicked. You can close that instance of W2Anim at this point. Now you should be able to double-click on any .w2a in the File Explorer, and Windows should open up that saved project file in W2Anim.

Associating an Icon with W2Anim in the File Explorer

Even if you are successful in associating the w2anim.bat batch file with all .w2a files in the File Explorer, Windows doesn't know that we have an icon file to associate with w2anim.bat. To make that association, you either need to find and run a separate program (several are available from the internet) or you need to edit the Windows registry, and the required registry edits require Administrator privileges. If you are successful in associating the w2anim.ico icon file with the .w2a file type in the Windows registry, the icon used in the File Explorer will identify .w2a files as W2Anim project files. Here are a couple screenshots from the File Explorer:



Name	Date modified	Type	Size
time_series2.w2a	6/19/2023 7:51 PM	W2A File	3 KB
time_series1.w2a	6/19/2023 7:51 PM	W2A File	2 KB
Willamette_River_streamflow.w2a	6/19/2023 7:51 PM	W2A File	3 KB
Columbia_River_streamflow.w2a	6/19/2023 7:50 PM	W2A File	2 KB
Libby_Dam_2020-21d.w2a	5/29/2023 2:18 PM	W2A File	17 KB
object_examples.w2a	5/29/2023 2:09 PM	W2A File	3 KB
object_examples2.w2a	5/29/2023 2:08 PM	W2A File	3 KB
photo_crop.w2a	5/29/2023 2:08 PM	W2A File	2 KB
photo_examples.w2a	5/29/2023 2:08 PM	W2A File	2 KB
Libby_Dam_2020-21.w2a	5/29/2023 8:17 AM	W2A File	15 KB
Koocanusa_wy2020_profiles.w2a	5/29/2023 8:16 AM	W2A File	3 KB



To tell Windows how to associate a "DefaultIcon" in the Windows registry with .w2a files and then to use that icon, several steps may be required:

- Edit the Windows registry.
- Clear and reset the thumbnail cache in Windows. (optional?)
- Remove the current icon cache in Windows and reboot. (optional?)
- Force Windows to rebuild the icon cache database.

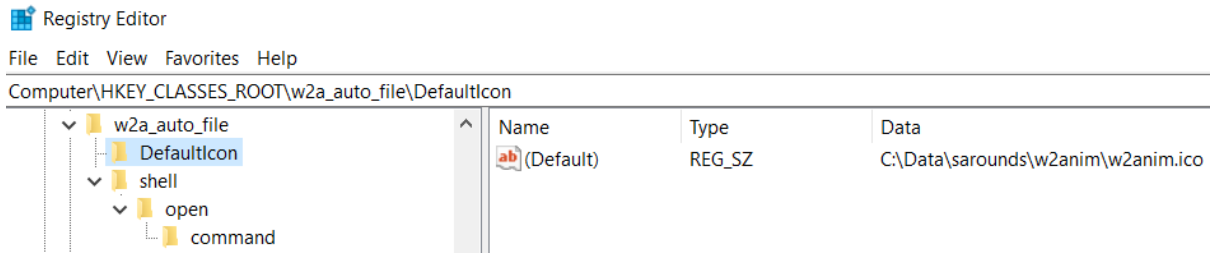
Each step can be done easily enough, but some steps require Administrator access and the user must be careful and pay attention to details. Here are some instructions that you may choose to follow. I followed these steps for Windows 10 and it worked well, but do so at your own risk.

Edit the Windows Registry

This is the tough part, but it is straightforward, so just focus and proceed. Do the following:

- Type "regedit" into the Windows search bar, and it should find the Windows registry editor. You'll need to either find and click on the "Run as administrator" option or you will need to right-click on the program name and choose the "Run as administrator" option. You'll probably need to provide the proper credentials.
- In the registry editor, scroll all the way up to the top of the folder tree on the left side and find the HKEY_CLASSES_ROOT folder. Expand that part of the tree and find the entry for ".w2a". Just one key is likely to be there, and it probably refers to "w2a_auto_file". That's good.
- Now, keep scrolling down the folder tree, well into the program names, until you find the entry for "w2a_auto_file". The list should be in alphabetical order, and it is likely that the w2a_auto_file has a subfolder named "shell". If you were to look in that part of the tree, you would find shell/open/command folders and the command folder would include an entry with a path name to the w2anim.bat file that you specified in the earlier part of this section of the manual.
- You need to add a new registry key under "w2a_auto_file". Right-click on the "w2a_auto_file" entry in the folder tree on the left-hand side of the registry editor, and choose "New" and "Key". The system will create what looks like a new folder under w2a_auto_file; type in a name of "DefaultIcon".
- Now that you have a DefaultIcon key under w2a_auto_file, you need to set the value of that key. Left-click on the DefaultIcon key on the left-hand side, then notice the entry on the right-hand side, which should show one line. Double-click on the "(Default)" entry. The registry editor will pop up a menu and you should

be able to type in a path to the w2anim.ico file that resides in the same folder as your W2Anim scripts. An example for my computer is shown below:



At this point, you should be able to simply close the registry editor. You have made the required change!

Clear and Reset the Thumbnail Cache in Windows

For Windows 10, you may choose to follow the instructions at: https://www.tenforums.com/tutorials/5655-clear-reset-thumbnail-cache-windows-10-a.html. The Disk Cleanup menu is activated by right-clicking on Drive C: in the File Explorer, choosing the Properties option, then clicking on the "Disk Cleanup" button. From there, choose the "Thumbnails" category and click the OK button.

Remove the Current Icon Cache in Windows and Reboot

For Windows 10, you may choose to follow the instructions at: https://www.tenforums.com/tutorials/5645-rebuild-icon-cache-windows-10-a.html. The instructions there can be boiled down to the following steps. Open a command window and enter the following five commands exactly as written, and one at a time. These commands will terminate your File Explorer program, then delete the icon cache database and the File Explorer's icon cache.

```
ie4uinit.exe -show
taskkill /IM explorer.exe /F
DEL /A /Q "%localappdata%\IconCache.db"
DEL /A /F /Q "%localappdata%\Microsoft\Windows\Explorer\iconcache*"
shutdown /r /f /t 00
```

After the last command above, your computer will reboot.

Force Windows to Rebuild the Icon Cache

After rebooting, you need to force Windows to rebuild its icon cache database. The easiest way to do this is to change one of the default programs in the Windows Settings, and then change it back. That process invokes the program that will rebuild the icon cache. For Windows 10:

- Open the Windows Settings utility, either by typing "settings" into the Windows search bar, or by clicking on the Start icon (lower left of task bar) and selecting the icon shaped like a gear.
- Choose the "Apps" category, then the "Default apps" subject from the left-hand side.
- The easiest way to change a default is to select the "Photo viewer" app. Windows will bring up a menu with a list of potential programs. Remember the default, and choose a different option.
- After Windows sets the default program to that other app for viewing photos, just re-select the Photo viewer app and change it back to its original default. This action causes Windows to rebuild the icon cache database.

In Windows 11, the steps are similar, but the menus are a bit different.

- Enter the Settings program, then choose the Apps category.
- Choose "Default Apps" and then enter ".png" in the field for "Set a default for a file type or link type". The selection just below should now be fore the Photos app or some program that is the default app for opening PNG files.

- Click on that app name and you should be given an opportunity to change the default app for opening PNG files. Remember the default, and choose a different option.
- After Windows sets the default program to that other app for viewing PNG files, just re-select the default app for PNGs and change it back to its original default. This action should cause Windows to rebuild the icon cache database. You may or may not want to reboot.

At this point, if all went well, your Windows File Explorer should recognize the W2Anim icon for .w2a files. Of course, none of this icon stuff is required to make W2Anim run, but it is useful to have the W2Anim icon associated with W2Anim project files and to see that icon in the File Explorer.

W2ANIM PROJECT FILE FORMAT

The W2Anim project file is a simple text file that contains all of the information required to recreate a previously created visualization. By default, W2Anim project files have a ".w2a" file name extension. The characteristics of the canvas as well as each object on the canvas are saved in the W2Anim project file. All file names in the project file are saved with file paths relative to the location of the project file. Therefore, W2Anim project files can be moved to a different directory on a computer and they will still be properly read as long as the files they reference are also moved so that the relative path names are still valid.

The experienced W2Anim user will be able to decipher many of the saved parameters in W2Anim project files, such that previously saved visualizations can be adapted for, or used as templates for, new visualizations or updates with different model outputs.

Each W2Anim project file begins with a header that specifies when the file was created or updated along with the version of W2Anim that created the file. Those lines are followed by a section specifying canvas parameters, such as:

```
==== CANVAS ====
  width:     2000
  height:    750
  color:     white
  text_slct: magenta
  snap2grid: 1
  grid_spac: 10
==== END CANVAS ====
```

The width and height of the canvas and the grid spacing are specified in pixels. W2Anim uses the RGB (Red Green Blue) color model, and colors are saved with names defined and standardized by the X Consortium (rgb.txt,v 10.41 94/02/20 18:39:36 rws Exp). See the color names and RGB codes in the w2anim_rgb.pl source file if you need to track down a particular color name. Colors also can be expressed as an RGB hex code in #RRGGBB format ("red" would be #FF0000). *Snap to Grid* is either 1 (enabled) or 0 (disabled).

Following the Canvas section in the W2Anim project file is an optional section describing the potential presence of global date limits on any animated objects. That optional section might look like the following:

```
==== DATE LIMITS ====
  gdt_begin: Jun-01-2020
  gdt_end:   Aug-31-2020
==== END DATE LIMITS ====
```

The gdt_begin key word designates the global start date in Mon-DD-YYYY format, and the gdt_end key word designates the global end date in Mon-DD-YYYY format. If no global date restrictions are present, then this entire section will not be present in the W2Anim project file.

Following the Canvas and optional Date Limits sections in the W2Anim project file is a potentially lengthy section describing each of the objects drawn on the canvas. The objects are saved in "drawing order," where the first object in the list is drawn first, such that later objects could be drawn on top of previously drawn objects. The object list starts with the line:

```
==== OBJECTS ====  From lowest to highest
```

and ends with the line:

```
==== END OBJECTS ====
```

Within the objects section, the description of each object starts with a line denoting the object type and ends with a line that includes the word “end” and the object type. Object types include the following:

line, circle, ellipse, rectangle, diamond, polygon, polyline, text, image, graph

For example, a section of the W2Anim project file that describes a “rectangle” object would include the following lines:

```
rectangle
  …a bunch of lines documenting certain parameters of the rectangle…
end rectangle
```

KEY WORDS AND PARAMETERS IN W2ANIM PROJECT FILES

The following is an attempt to document the various parameters used in W2Anim project files. The key words are subject to change in later versions, but an attempt will be made to avoid such changes for backward compatibility.

Canvas

width	canvas width, in pixels, starting at 0 and ranging to width-1
height	canvas height, in pixels, starting at 0 and ranging to height-1
color	background canvas color name or RGB code
text_slct	color name or RGB code for text selection and graph frame selection
snap2grid	snap to grid option, where 1 is enabled and 0 is disabled
grid_spac	grid spacing, in pixels

Date Limits *(optional section, not present if global date limits are not set)*

gdt_begin	global start date in Mon-DD-YYYY format
gdt_end	global end date in Mon-DD-YYYY format

Line Objects

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center
anchor	anchor point type (point, midpoint)
color	line color name or RGB code
width	line width, in pixels
arrow	arrowhead code: 0=none, 1=start, 2=end, 3=both
ahd1	arrowhead center length
ahd2	arrowhead side length
ahd3	arrowhead half width
coordlist	comma-separated list of the X,Y coordinates of the two points of the line, in pixels

Circle Objects

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center

anchor	anchor point type (corner, midpoint, center)
color	outline color name or RGB code
width	outline width, in pixels
fill	enable fill, where 1 is enabled and 0 is disabled
fillcolor	color name or RGB code for the fill color
coordlist	comma-separated list of the X,Y coordinates of the two opposite corners of the circle's bounding box, in pixels

Ellipse Objects

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center
anchor	anchor point type (corner, midpoint, center)
color	outline color name or RGB code
width	outline width, in pixels
fill	enable fill, where 1 is enabled and 0 is disabled
fillcolor	color name or RGB code for the fill color
angle	rotation angle, in degrees counterclockwise starting from east
hw	half width, in pixels
hh	half height, in pixels

Rectangle and Diamond Objects

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center
anchor	anchor point type (corner, midpoint, center)
color	outline color name or RGB code
width	outline width, in pixels
fill	enable fill, where 1 is enabled and 0 is disabled
fillcolor	color name or RGB code for the fill color
angle	rotation angle, in degrees counterclockwise starting from east
smooth	code for smoothed corners, where 1 is enabled and 0 is disabled
coordlist	comma-separated list of the X,Y coordinates of the four corners of the rectangle, in pixels

Polygon Objects

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center
anchor	anchor point type (point, corner, midpoint, center, center_rot)
color	outline color name or RGB code
width	outline width, in pixels
fill	enable fill, where 1 is enabled and 0 is disabled
fillcolor	color name or RGB code for the fill color
angle	rotation angle, in degrees counterclockwise starting from east
coordlist	comma-separated list of the X,Y coordinates of the vertices of the polygon, in pixels

Polyline and Scribble Objects

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center
anchor	anchor point type (point, corner, midpoint, center, center_rot)
color	line color name or RGB code
width	line width, in pixels
angle	rotation angle, in degrees counterclockwise starting from east
arrow	arrowhead code: 0=none, 1=start, 2=end, 3=both
ahd1	arrowhead center length
ahd2	arrowhead side length
ahd3	arrowhead half width
coordlist	comma-separated list of the X,Y coordinates of the points along the line, in pixels

Curve Objects

x	X location of anchor point
y	Y location of anchor point
xc	X location of object center
yc	Y location of object center
anchor	anchor point type (point, corner, midpoint, center, center_rot)
color	line color name or RGB code
width	line width, in pixels
angle	rotation angle, in degrees counterclockwise starting from east
curv_fill	enable fill, for closed curves, where 1 is enabled and 0 is disabled
fillcolor	color name or RGB code for the fill color, for closed curves
arrow	arrowhead code: 0=none, 1=start, 2=end, 3=both, for open curves
ahd1	arrowhead center length, for open curves
ahd2	arrowhead side length, for open curves
ahd3	arrowhead half width, for open curves
curv_form	code denoting the curve form (“open” for open curves, and “closed” for closed curves)
ctrl_pts	comma-separated list of the X,Y coordinates of all control points along the curve, in pixels
pt_types	space-separated list of the Bézier endpoint types (corner, symmetric, straight, point)

Text Objects

text	The desired string of text. No need for quotation marks.
x	X location of anchor point
y	Y location of anchor point
anchor	anchor point type (w, nw, n, ne, e, se, s, sw, center)
color	color name or RGB code for text color
family	font family name, such as Arial or Calibri
size	font size, in points
weight	text code for font weight (bold, normal)
slant	numeric code for font slant (1=italic, 0=normal)
underline	numeric code for font underline (1=enabled, 0=disabled)
angle	rotation angle, in degrees counterclockwise starting from east

Image Objects

x	X location of anchor point
y	Y location of anchor point
anchor	anchor point type (w, nw, n, ne, e, se, s, sw, center)
angle	rotation angle, in degrees counterclockwise starting from east
crop	comma-separated list of crop fraction factors for left, right, top, and bottom, where 0.0 means no cropping from that side, and the sum of the left and right crop factors and the sum of the top and bottom crop factors cannot be as large as 1.0
scale	numeric multiplier for scaling the image, where 1.0 means no scaling
flip	flip type code: none, h=left to right, v=top to bottom, vh=left to right and top to bottom
file	relative path and file name of the image

Linked Objects

Several types of objects can be linked to time-series values generated from certain graph types. The types of objects that can be linked to a graph time series are text, circle, ellipse, rectangle, diamond, and polygon. When a link is present, the following lines are added to the W2Anim project file for those linked objects:

ln_gnum	graph number to which the object is linked
ln_type	link parameter type (Water Surface Elevation, Release Rate, Temperature)
ln_outlet	link outlet name (outlet names specified in flow file, or All Outlets)
ln_form	link form (Text, Circle, Ellipse, Rectangle, Diamond, Polygon)
ln_units	link units (such as ft, m, cfs, cms, Celsius, Fahrenheit)
ln_digits	number of digits after the decimal in a text link

If the linked object is text showing a goodness-of-fit statistic, then the properties of the linked object are slightly different, as follows:

ln_gnum	graph number to which the object is linked
ln_form	link form (“stat” is the only option here)
ln_type	link statistic type (n, me, mae, rmse)
ln_tol	number of minutes to allow (plus or minus) as a window to match dates between the modeled and measured vertical profiles, for computation of a goodness-of-fit statistic
ln_interp	code denoting whether the model profile is to be vertically interpolated to the depth or elevation of a point in the measured profile (0=no, 1=yes)
ln_digits	number of digits to display after the decimal (0 for type “n”)

Independent Linked Text Objects

A special set of text objects also may be linked to external independent time-series files rather than to time-series values from certain graph types. These objects are classified as text objects, but include the following lines to describe the independent link:

src_file	relative path and file name for the independent external time-series file
src_type	the type of time-series file (see Recognized File Types)
src_lines	number of lines to read in the source file, for purposes of making a progress bar
ctype	unit conversion choice (see Unit Conversions)
parm	the measured parameter name, such as *Temperature*
byear	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year (required only for source types that begin with “W2 “)
tz_offset	time offset to convert model time to local standard time (default: +00:00; required only for source types that begin with “W2 “)

seg	model segment number (required only for source types that begin with "W2 ", and optional for some file types)
data_type	a category for the linked data (Elevation, Flow, Temperature, Concentration, Other)
ln_units	units for the linked values
ln_digits	number of digits to display after the decimal
ln_tol	number of minutes to allow (plus or minus) as a window to match dates between each master animation date and the available dates in the independent time-series file

Graph Objects

The various graph objects are distinguished from each other by codes associated with the "meta" key word, which for convenience and clarity is the first item listed in the W2Anim project file for a graph object.

Measured Vertical Profile

This graph type plots elevation or depth on the Y axis and the value of a measured parameter on the X axis. Graphs are plotted for a particular date, and can be animated over time.

meta	data_profile
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center
yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
src_file	relative path and file name of the data file containing measured vertical profiles over time
parm	the measured parameter name, such as *Temperature*
parmunits	parameter units; *Celsius* or *Fahrenheit* when parameter is *Temperature*
prof_type	profile type (standard, difference)
add_cs	code to enable a color highlighting scheme (1=enable, 0=disable)
cs_hide	code to hide the color scheme legend (1=hide, 0=show)
cs_link	code linking color scheme to other graphs (0=none, 1=same data file, 2=same parameter)
cscheme1	name of first color ramp, or name of the color scheme
cscheme2	name of second color ramp, or None
ncolors	number of colors in the color scheme or for each color ramp
cs_rev	code to reverse the color scheme (0=disabled, 1=enabled)
cs_min	minimum parameter value for the color-highlighting scheme
cs_max	maximum parameter value for the color-highlighting scheme
cs_major	scale interval used for color scheme legend (number, or "auto")
cs_width	width of each color swatch in the color key legend, in pixels
cs_height	height of each color swatch in the color key legend, in pixels
xleg_off	X distance offset for left edge of color legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of color legend, in pixels from the top edge of the graph frame
keyfont	font family used for text on the color key legend
keytitle	title text for the color key legend
kt_size	font size for the title text of the color key legend, in points
kt_weight	font weight for the title text of the color key legend (normal, bold)

kn_size	font size for the number scale of the color key legend, in points
kn_weight	font weight for the number scale of the color key legend (normal, bold)
kn_digits	number of digits after the decimal for the number scale of the color key legend
xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum parameter value for the X axis
xmax	maximum parameter value for the X axis
xmajor	major tick label spacing for the X axis
xpr_tics	tick mark style for the primary X axis (outside, inside, cross, none)
xop_tics	tick mark style for the opposite X axis (outside, inside, cross, none)
ytype	Y axis type (Elevation, Depth)
yunits	Y axis units (feet, meters)
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum elevation or depth value for the Y axis
ymax	maximum elevation or depth value for the Y axis
ymajor	major tick label spacing for the Y axis
ypr_tics	tick mark style for the primary Y axis (outside, inside, cross, none)
yop_tics	tick mark style for the opposite Y axis (outside, inside, cross, none)
gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gs_size	graph subtitle font size, in points
gs_weight	graph subtitle font weight (normal, bold)

If the profile type (prof_type) is set to “difference” then several other key words are required. For a difference profile with a constant reference value, the parameters are:

dref_type	difference type (Constant)
dref_val	the constant reference value (a number)

For a difference profile with a time-series reference value, the parameters are:

dref_type	difference type (Time-Series)
dref_file	file name of the reference time series
dref_ftyp	file type code for the reference time series (see Recognized File Types)
dref_line	number of data lines in reference time-series file
dref_parm	chosen parameter name in the time-series input file
dref_ctyp	unit conversion choice (see Unit Conversions)
dref_tol	number of minutes to allow (plus or minus) as a window to match dates between the measured and reference time series
dref_byr	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year, used only for W2 time-series file types

dref_tzof	time offset to convert model time to local standard time (default: +00:00), used only for W2 time-series file types

Measured Vertical Profile Colormap

This graph type plots elevation or depth on the Y axis and time on the X axis. Values of the measured parameter are represented with a color scheme in vertical profiles, where the measured profiles are interpolated to vertical increments of 1 foot or less.

The key words and parameters used for this graph type are the same as those for the Measured Vertical Profile, except for the following:

meta	data_profile_cmap
xmin	minimum date (Mon-DD-YYYY) or Julian date value for the X axis
xmax	maximum date (Mon-DD-YYYY) or Julian date value for the X axis
xtype	X axis type (Date/Time, Julian Date)
base_yr	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
datefmt	date format for Date/Time axis (Year, Month, Mon-DD, Mon-DD-YYYY)
dateline	code denoting the presence of a vertical line at the animation date (0=off, 1=on)
datelinec	color of the optional vertical dateline

In addition, the key word add_cs is not needed because a color scheme is always used, and the key words gs_size and gs_weight are not used for this graph type because it does not have a graph subtitle.

Vertical Withdrawal Zone from Measured Data

This graph type plots elevation or depth on the Y axis and a depth- or elevation-specific horizontal velocity or flow rate per unit height in a vertical withdrawal zone next to a set of dam outlets. The key words and parameters used for this graph type have many in common with those from the Measured Vertical Profile. Additional or modified key words and parameters are as follows:

meta	vert_wd_zone
wt_file	relative path and file name of the data file containing measured vertical temperature profiles over time
flow_file	relative path and file name of a data file containing time-series of release rates from each of the dam outlets
bth_file	relative path and file name of a CE-QUAL-W2 bathymetry file that is relevant for describing the bathymetry next to the dam
wd_alg	code for the withdrawal algorithm to use (W2 original, Libby Dam)
seg	model segment number that is next to the dam
elbot	elevation of the top of the bottom-most layer in the W2 bathymetry file
cs_min	minimum temperature value for the color-highlighting scheme
cs_max	maximum temperature value for the color-highlighting scheme
qunits	X axis flow-like units (cfs/ft, cms/m, ft/s, m/s)
wt_units	water temperature units (Celsius, Fahrenheit)

Key words from the Measured Vertical Profile graph that are not used for the Vertical Withdrawal Zone include the following:

src_file, parm, parmunits, prof_type

as well as all of the key words associated with the difference profile type (prof_type):

dref_type, dref_val, dref_file, dref_ftyp, dref_line, dref_parm, dref_ctyp, dref_tol, dref_byr, dref_tzof

If the withdrawal algorithm (wd_alg) code is set to “Libby Dam,” then a few additional lines are expected to bring in information and parameters on the variable bulkhead configurations:

lbc_file	relative path and file name of a Libby-Dam-type bulkhead configuration time-series file
bh_show	code denoting whether the bulkhead configuration is shown on the graph (1=yes, 0=no)
bh_docked	code denoting whether the bulkhead diagram is "docked" to the graph or has been repositioned to an alternate location by the user (0=no, 1=yes)
bh_xpos	X pixel location of upper left corner of bulkhead diagram
bh_ypos	Y pixel location of upper left corner of bulkhead diagram
bh_font	font family used in the bulkhead diagram
bh_size	font size used in bulkhead diagram, in points
bh_weight	font weight used in bulkhead diagram (normal, bold)
bh_tcolor	color name or RGB code for text color in bulkhead diagram
bh_bwidth	line width for box grid in bulkhead diagram
bh_bcolor	color name or RGB code for lines in box grid of bulkhead diagram
bh_bcellw	box cell width in bulkhead diagram, in pixels
bh_bcellh	box cell height in bulkhead diagram, in pixels

W2 Vertical Profile

This graph type plots elevation or depth on the Y axis and the value of a modeled parameter on the X axis. Graphs are plotted for a particular date, and can be animated over time. For completeness, all of the key words and parameters for the W2 Vertical Profile graph are as follows:

meta	w2_profile
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center
yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
con_file	relative path and file name of a CE-QUAL-W2 control file
bth_file	relative path and file name of a CE-QUAL-W2 bathymetry file
src_type	type of W2 output file used (W2 Spreadsheet File, W2 Contour File, W2 Vector File, or W2 Lake Contour File)
src_file	relative path and file name of a CE-QUAL-W2 spreadsheet, contour, vector, or lake contour file
src_lines	number of lines to read in the source file, for purposes of making a progress bar (omitted for a W2 vector file, where the progress bar uses the file size in bytes)
tplot	code denoting whether a W2 contour file uses the Tecplot format (0=no, 1=yes) (omitted for W2 spreadsheet, vector, and lake contour source files)
parm	the modeled parameter name, such as *Temperature*
parm_div	name of a modeled parameter name to divide into the chosen parameter, or None
parmunits	parameter units; *Celsius* or *Fahrenheit* when parameter is *Temperature*
ctype	unit conversion choice (see Unit Conversions)
seg	model segment number of interest for the vertical profile
byear	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
tz_offset	time offset to convert model time to local standard time (default: +00:00)
jd_skip	number of dates in the output file to skip (0=none, 1=every other, etc.)

add_cs	code to enable a color highlighting scheme (1=enable, 0=disable)
cs_hide	code to hide the color scheme legend (1=hide, 0=show)
cs_link	code linking color scheme to other graphs (0=none, 1=same data file, 2=same parameter)
cscheme1	name of first color ramp, or name of the color scheme
cscheme2	name of second color ramp, or None
ncolors	number of colors in the color scheme or for each color ramp
cs_rev	code to reverse the color scheme (0=disabled, 1=enabled)
cs_min	minimum parameter value for the color-highlighting scheme
cs_max	maximum parameter value for the color-highlighting scheme
cs_major	scale interval used for color scheme legend (number, or “auto”)
cs_width	width of each color swatch in the color key legend, in pixels
cs_height	height of each color swatch in the color key legend, in pixels
xleg_off	X distance offset for left edge of color legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of color legend, in pixels from the top edge of the graph frame
keyfont	font family used for text on the color key legend
keytitle	title text for the color key legend
kt_size	font size for the title text of the color key legend, in points
kt_weight	font weight for the title text of the color key legend (normal, bold)
kn_size	font size for the number scale of the color key legend, in points
kn_weight	font weight for the number scale of the color key legend (normal, bold)
kn_digits	number of digits after the decimal for the number scale of the color key legend
pr_style	style for the modeled profile line (Stairstep, Interpolated)
pr_linec	line color name or RGB code for the modeled profile line
pr_linew	line width for the modeled profile line (1 or 2)
pc_style	style for the modeled color scheme (By Layer, Interpolated, Max Interpolation)
xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum parameter value for the X axis
xmax	maximum parameter value for the X axis
xmajor	major tick label spacing for the X axis
xpr_tics	tick mark style for the primary X axis (outside, inside, cross, none)
xop_tics	tick mark style for the opposite X axis (outside, inside, cross, none)
ytype	Y axis type (Elevation, Depth)
yunits	Y axis units (feet, meters)
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum elevation or depth value for the Y axis
ymax	maximum elevation or depth value for the Y axis
ymajor	major tick label spacing for the Y axis
ypr_tics	tick mark style for the primary Y axis (outside, inside, cross, none)
yop_tics	tick mark style for the opposite Y axis (outside, inside, cross, none)
gtitle	graph title text

gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gs_size	graph subtitle font size, in points
gs_weight	graph subtitle font weight (normal, bold)

If reference measured profiles are provided, then the following key words are also given:

ref_file	relative path and file name for the reference profile data file
ref_ctype	unit conversion choice for the reference profile data (see Unit Conversions)
ref_tol	match tolerance in minutes for the reference profile data
ref_color	color name or RGB code for the reference profile line
ref_size	code denoting the size of the measured data points (Small, Medium, Large, Extra Large)
ref_linew	line width for the measured reference profiles (1 or 2)
ref_hide	code to hide the reference profiles (1=hide, 0=show)

W2 Vertical Profile Colormap

This graph type plots elevation or depth on the Y axis and time on the X axis. Values of the modeled parameter are represented with a color scheme in vertical profiles, where the modeled values are displayed for each active cell in the profile.

The key words and parameters used for this graph type are the same as those for the W2 Vertical Profile, except for the following:

meta	w2_profile_cmap
xmin	minimum date (Mon-DD-YYYY) or Julian date value for the X axis
xmax	maximum date (Mon-DD-YYYY) or Julian date value for the X axis
xtype	X axis type (Date/Time, Julian Date)
base_yr	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
datefmt	date format for Date/Time axis (Year, Month, Mon-DD, Mon-DD-YYYY)
dateline	code denoting the presence of a vertical line at the animation date (0=off, 1=on)
datelinec	color of the optional vertical dateline

In addition, the key word add_cs is not needed because a color scheme is always used, and the key words gs_size and gs_weight are not used for this graph type because it does not have a graph subtitle.

Vertical Profile Matrix

This graph type contains a matrix of rows and columns containing plots of date-matched modeled and measured vertical profiles, all derived at some point from a W2 Vertical Profile graph that had at least one measured vertical profile in a reference dataset.

The key words and parameters for this graph type are similar to those used for the W2 Vertical Profile, and are as follows:

meta	w2_profile_matrix
gnum	graph number, used internally for links
x	X location of anchor point for matrix
y	Y location of anchor point for matrix
xc	X location of matrix center
yc	Y location of matrix center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frames (black)
width	line width for graph frames, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately

coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the matrix, in pixels
con_file	relative path and file name of a CE-QUAL-W2 control file
bth_file	relative path and file name of a CE-QUAL-W2 bathymetry file
src_type	type of W2 output file used (W2 Spreadsheet File, W2 Contour File, W2 Vector File, or W2 Lake Contour File)
src_file	relative path and file name of a CE-QUAL-W2 spreadsheet, contour, vector, or lake contour file
src_lines	number of lines to read in the source file, for purposes of making a progress bar (omitted for a W2 vector file, where the progress bar uses the file size in bytes)
tplot	code denoting whether a W2 contour file uses the Tecplot format (0=no, 1=yes) (omitted for W2 spreadsheet, vector, and lake contour source files)
parm	the modeled parameter name, such as *Temperature*
parm_div	name of a modeled parameter name to divide into the chosen parameter, or None
parmunits	parameter units; *Celsius* or *Fahrenheit* when parameter is *Temperature*
ctype	unit conversion choice (see Unit Conversions)
seg	model segment number of interest for the vertical profile
byear	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
tz_offset	time offset to convert model time to local standard time (default: +00:00)
jd_skip	number of dates in the output file to skip (0=none, 1=every other, etc.)
matrix	number of rows and columns, in RxC format where R=rows and C=columns
pr_gnum	graph number of the parent W2 Vertical Profile graph, or blank if that graph does not exist
pr_dates	space-delimited list of dates to include in the matrix (each using YYYYMMDDHHmm format)
blanks	space-delimited list of codes denoting whether the position in the matrix is blank or filled with a profile graph, where 1=blank and 0=filled
add_cs	code to enable a color highlighting scheme (1=enable, 0=disable)
cs_hide	code to hide the color scheme legend (1=hide, 0=show)
cs_link	code linking color scheme to other graphs (0=none, 1=same data file, 2=same parameter)
cscheme1	name of first color ramp, or name of the color scheme
cscheme2	name of second color ramp, or None
ncolors	number of colors in the color scheme or for each color ramp
cs_rev	code to reverse the color scheme (0=disabled, 1=enabled)
cs_min	minimum parameter value for the color-highlighting scheme
cs_max	maximum parameter value for the color-highlighting scheme
cs_major	scale interval used for color scheme legend (number, or “auto”)
cs_width	width of each color swatch in the color key legend, in pixels
cs_height	height of each color swatch in the color key legend, in pixels
xleg_off	X distance offset for left edge of color legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of color legend, in pixels from the top edge of the graph frame
keyfont	font family used for text on the color key legend
keytitle	title text for the color key legend
kt_size	font size for the title text of the color key legend, in points
kt_weight	font weight for the title text of the color key legend (normal, bold)
kn_size	font size for the number scale of the color key legend, in points
kn_weight	font weight for the number scale of the color key legend (normal, bold)
kn_digits	number of digits after the decimal for the number scale of the color key legend
pr_style	style for the modeled profile lines (Stairstep, Interpolated)
pr_linec	line color name or RGB code for the modeled profile lines
pr_linew	line width for the modeled profile lines (1 or 2)
pc_style	style for the modeled color scheme (By Layer, Interpolated, Max Interpolation)

xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum parameter value for the X axis
xmax	maximum parameter value for the X axis
xmajor	major tick label spacing for the X axis
xpr_tics	tick mark style for the primary X axis (outside, inside, cross, none)
xop_tics	tick mark style for the opposite X axis (outside, inside, cross, none)
ytype	Y axis type (Elevation, Depth)
yunits	Y axis units (feet, meters)
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum elevation or depth value for the Y axis
ymax	maximum elevation or depth value for the Y axis
ymajor	major tick label spacing for the Y axis
ypr_tics	tick mark style for the primary Y axis (outside, inside, cross, none)
yop_tics	tick mark style for the opposite Y axis (outside, inside, cross, none)
gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gs_size	graph date label font size, in points
gs_weight	graph date label font weight (normal, bold)
gs_pos	position for date label (Top Left, Top Center, Top Right, Middle Left, Middle Right, Bottom Left, Bottom Center, Bottom Right)
gs_fmt	format for date label (DD-Mon-YYYY HH:mm, DD Mon, YYYY HH:mm, Mon DD, YYYY HH:mm, MM/DD/YYYY HH:mm, MM-DD-YYYY HH:mm)
gs_color	color name or RGB code for the date label
gs_edge	code denoting whether the date label box should have a border (0=off, 1=on)
gs_edgec	color of the date label box border
gs_fill	code denoting whether the date label box should be filled with color (0=off, 1=on)
gs_fillc	color of the filled date label box
ref_file	relative path and file name for the reference profile data file
ref_ctype	unit conversion choice for the reference profile data (see Unit Conversions)
ref_tol	match tolerance in minutes for the reference profile data
ref_color	color name or RGB code for the reference profile line
ref_size	code denoting the size of the measured data points (Small, Medium, Large, Extra Large)
ref_linew	line width for the measured reference profiles (1 or 2)
ref_hide	code to hide the reference profiles (always 0=show)
ms_stats	code denoting whether goodness-of-fit statistics are computed and shown (1=show, 0=none)
ms_types	space-delimited list of goodness-of-fit statistics to include (N ME MAE RMSE)
ms_digits	number of digits to display after the decimal for the fit statistics (except for N)

ms_interp	code denoting whether to vertically interpolate the modeled profiles when computing the fit statistics (1=yes, 0=no)
ms_font	font family for the fit statistics text
ms_size	font size, in points, for the fit statistics text
ms_weight	font weight for the fit statistics text (normal, bold)
ms_slant	font slant code for the fit statistics text (1=italic, 0=normal)
ms_color	color name or RGB code for the color of the statistics text
ms_edge	code denoting whether the statistics box should have a border (0=off, 1=on)
ms_edgec	color of the statistics box border
ms_fill	code denoting whether the statistics box should be filled with color (0=off, 1=on)
ms_fillc	color of the filled statistics box
ms_pos	position for goodness-of-fit statistics (Top Left, Top Center, Top Right, Middle Left, Middle Right, Bottom Left, Bottom Center, Bottom Right)

W2 Longitudinal Slice

This graph type plots elevation or depth on the Y axis and longitudinal distance on the X axis. Values of the modeled parameter throughout a longitudinal slice through the model domain are represented with a color scheme, where the modeled values are displayed for all active cells in the chosen longitudinal slice. For completeness, all of the key words and parameters for the W2 Longitudinal Slice graph are as follows:

meta	w2_slice
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center
yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
con_file	relative path and file name of a CE-QUAL-W2 control file
src_type	type of W2 output file used (W2 Contour File, W2 Vector File)
w2l_file	file name of W2 vector file, if vector input source type is used (omitted when using W2 contour file as input)
cpl_info	three values: file index number, Tecplot code, and number of lines to read in the contour file. The Tecplot code is 0 for a non-Tecplot contour file and 1 for a Tecplot-style contour file. If more than one contour file must be read, more than one line with the cpl_info, cpl_files, and bth_files key words will be present. (omitted when using W2 vector file as input)
cpl_files	two values: file index number, and relative path and name of a CE-QUAL-W2 contour file (omitted when using W2 vector file as input)
bth_files	two values: file index number, and relative path and name of a CE-QUAL-W2 bathymetry file
seg_list	text string showing the segments included in the longitudinal slice
wb_list	text string showing the waterbodies included in the longitudinal slice
parm	the modeled parameter name, such as *Temperature*
parm_div	name of a modeled parameter name to divide into the chosen parameter, or None
parmunits	parameter units; *Celsius* or *Fahrenheit* when parameter is *Temperature*
ctype	unit conversion choice (see Unit Conversions)

byear	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
tz_offset	time offset to convert model time to local standard time (default: +00:00)
jd_skip	number of dates in the contour file to skip (0=none, 1=every other, etc.)
dt_limits	code designating whether date restrictions are in place (1=yes, 0=no)
dt_begin	begin date for date restrictions, if present (Mon-DD-YYYY format); absent if dt_limits = 0
dt_end	end date for date restrictions, if present (Mon-DD-YYYY format); absent if dt_limits = 0
cs_hide	code to hide the color scheme legend (1=hide, 0=show)
cs_link	code linking color scheme to other graphs (0=none, 1=same data file, 2=same parameter)
cscheme1	name of first color ramp, or name of the color scheme
cscheme2	name of second color ramp, or None
ncolors	number of colors in the color scheme or for each color ramp
cs_rev	code to reverse the color scheme (0=disabled, 1=enabled)
cs_min	minimum parameter value for the color-highlighting scheme
cs_max	maximum parameter value for the color-highlighting scheme
cs_major	scale interval used for color scheme legend (number, or “auto”)
cs_width	width of each color swatch in the color key legend, in pixels
cs_height	height of each color swatch in the color key legend, in pixels
xleg_off	X distance offset for left edge of color legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of color legend, in pixels from the top edge of the graph frame
keyfont	font family used for text on the color key legend
keytitle	title text for the color key legend
kt_size	font size for the title text of the color key legend, in points
kt_weight	font weight for the title text of the color key legend (normal, bold)
kn_size	font size for the number scale of the color key legend, in points
kn_weight	font weight for the number scale of the color key legend (normal, bold)
kn_digits	number of digits after the decimal for the number scale of the color key legend
pc_style	style for the modeled color scheme (By Layer, Interpolated, Max Interpolation)
xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum longitudinal distance value for the X axis
xmax	maximum longitudinal distance value for the X axis
xmajor	major tick label spacing for the X axis, or “auto”
xpr_tics	tick mark style for the primary X axis (outside, inside, cross, none)
xop_tics	tick mark style for the opposite X axis (outside, inside, cross, none)
xmax_auto	code denoting whether the maximum value for the X axis should be calculated from the X axis base value and the slice’s total distance (0=no, 1=yes)
xbase	X axis value corresponding to most-downstream location of the chosen reach
xfirst	value for the first major tick mark on the X axis
xflip	code denoting whether the X axis should be flipped (0=no, 1=yes)
xunits	X axis units (miles, kilometers)
ytype	Y axis type (Elevation, Depth)
yunits	Y axis units (feet, meters)
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)

yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum elevation or depth value for the Y axis
ymax	maximum elevation or depth value for the Y axis
ymajor	major tick label spacing for the Y axis
ypr_tics	tick mark style for the primary Y axis (outside, inside, cross, none)
yop_tics	tick mark style for the opposite Y axis (outside, inside, cross, none)
stype	segment axis type (none, above, below, replace)
sfont	segment axis font family
st_size	segment axis title font size, in points
st_weight	segment axis title font weight (normal, bold)
sl_size	segment axis label font size, in points
sl_weight	segment axis label font weight (normal, bold)
stic_loc	segment axis tick mark location (upstream edge, center, downstream edge)
smajor	segment axis major tick label spacing, or “auto”
spr_tics	tick mark style for the primary Segment axis (outside, inside, cross, none)
sop_tics	tick mark style for the opposite Segment axis (outside, inside, cross, none)
sgrid	segment axis vertical grid lines at major tick label spacing (0=off, 1=on)
sgrid_col	segment axis vertical grid line color at major tick label spacing
bgrid	segment axis vertical grid lines at branch boundaries (0=off, 1=on)
bgrid_col	segment axis vertical grid line color at branch boundaries
stitle	segment axis title text
gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gs_size	graph subtitle font size, in points
gs_weight	graph subtitle font weight (normal, bold)

W2 Outflow Profile

This graph type plots elevation or depth on the Y axis and a depth- or elevation-specific horizontal velocity or flow rate per unit height in a modeled vertical withdrawal zone next to a set of dam outlets. For completeness, all of the key words and parameters for the W2 Outflow Profile graph are as follows:

meta	w2_outflow
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center
yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
con_file	relative path and file name of a CE-QUAL-W2 control file
bth_file	relative path and file name of a CE-QUAL-W2 bathymetry file
qla_file	relative path and file name of a CE-QUAL-W2 “qlayers” output file
qla_lines	number of lines to read in the qlayers file, for purposes of making a progress bar

seg	model segment number of interest for the vertical profile
byear	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
tz_offset	time offset to convert model time to local standard time (default: +00:00)
jd_skip	number of dates in the qlayers output file to skip (0=none, 1=every other, etc.)
qla_parm	code denoting whether a modeled parameter is used for color highlighting (0=no, 1=yes)
src_type	type of W2 output file used for color highlighting (W2 Spreadsheet File, W2 Contour File, W2 Vector File, or W2 Lake Contour File)
src_file	relative path and file name of a CE-QUAL-W2 spreadsheet, contour, vector, or lake contour file
src_lines	number of lines to read in the source file, for purposes of making a progress bar (omitted for a W2 vector file, where the progress bar uses the file size in bytes)
tplot	code denoting whether a W2 contour file uses the Tecplot format (0=no, 1=yes) (omitted for the W2 spreadsheet, vector, and lake contour source types)
parm	the modeled parameter name for color highlighting, such as *Temperature*
parm_div	name of a modeled parameter name to divide into the chosen parameter, or None
parmunits	parameter units; *Celsius* or *Fahrenheit* when parameter is *Temperature*
ctype	unit conversion choice for the color highlight parameter (see Unit Conversions)
parm_skip	number of dates in the parameter output file to skip (0=none, 1=every other, etc.)
match_tol	number of minutes to allow (plus or minus) as a window to match dates between the qlayers input and the parameter highlighting input
add_cs	code to enable a color highlighting scheme (1=enable, 0=disable)
cs_hide	code to hide the color scheme legend (1=hide, 0=show)
cs_link	code linking color scheme to other graphs (0=none, 1=same data file, 2=same parameter)
cscheme1	name of first color ramp, or name of the color scheme
cscheme2	name of second color ramp, or None
ncolors	number of colors in the color scheme or for each color ramp
cs_rev	code to reverse the color scheme (0=disabled, 1=enabled)
cs_min	minimum parameter value for the color-highlighting scheme
cs_max	maximum parameter value for the color-highlighting scheme
cs_major	scale interval used for color scheme legend (number, or “auto”)
cs_width	width of each color swatch in the color key legend, in pixels
cs_height	height of each color swatch in the color key legend, in pixels
xleg_off	X distance offset for left edge of color legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of color legend, in pixels from the top edge of the graph frame
keyfont	font family used for text on the color key legend
keytitle	title text for the color key legend
kt_size	font size for the title text of the color key legend, in points
kt_weight	font weight for the title text of the color key legend (normal, bold)
kn_size	font size for the number scale of the color key legend, in points
kn_weight	font weight for the number scale of the color key legend (normal, bold)
kn_digits	number of digits after the decimal for the number scale of the color key legend
pc_style	style for the modeled color scheme (By Layer, Interpolated, Max Interpolation)
xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum parameter value for the X axis
xmax	maximum parameter value for the X axis

xmajor	major tick label spacing for the X axis
xpr_tics	tick mark style for the primary X axis (outside, inside, cross, none)
xop_tics	tick mark style for the opposite X axis (outside, inside, cross, none)
qunits	X axis flow-like units (cfs/ft, cms/m, ft/s, m/s)
ytype	Y axis type (Elevation, Depth)
yunits	Y axis units (feet, meters)
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum elevation or depth value for the Y axis
ymax	maximum elevation or depth value for the Y axis
ymajor	major tick label spacing for the Y axis
ypr_tics	tick mark style for the primary Y axis (outside, inside, cross, none)
yop_tics	tick mark style for the opposite Y axis (outside, inside, cross, none)
gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gs_size	graph subtitle font size, in points
gs_weight	graph subtitle font weight (normal, bold)

W2 Time/Distance Map

This graph type plots date/time on one axis and longitudinal distance on the other axis, then uses colors from a color scale to represent the values of a W2 modeled parameter or parameter difference. All of the key words and parameters for the W2 Time/Distance Map are as follows:

meta	w2_tdmap
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center
yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
map_type	the type of time/distance map (standard, parmdiff, filediff) The code is parmdiff for a difference plot using “Different Parameter, Same Run.” The code is filediff for a difference plot using “Same Parameter, Different Run.”
con_file	relative path and file name of a CE-QUAL-W2 control file
src_type	type of W2 output file used for plotting data (W2 Contour File, W2 Vector File, W2 River Contour File, W2 SurfTemp File, W2 VolTemp File, or W2 FlowTemp File)
w2l_file	file name of W2 vector file, if vector input source type is used
src_file	file name of a W2 SurfTemp, W2 VolTemp, or W2 FlowTemp output file, if any of these sources is used as input

src_lines number of lines to read in the source file, for purposes of making a progress bar
(used here only for SurfTemp, VolTemp, and FlowTemp source files)

cpl_info three values: file index number, Tecplot code, and number of lines to read in the contour file. The Tecplot code is 0 for a non-Tecplot contour file and 1 for a Tecplot-style contour file. If more than one contour file must be read, more than one line with the cpl_info, cpl_files, and bth_files key words will be present.
(omitted when not using W2 contour file as input)

cpl_files two values: file index number, and relative path and name of a CE-QUAL-W2 contour file
(omitted when not using W2 contour file as input)

riv_info three values: file index number, starting branch number, and number of lines to read in the river contour file. If more than one river contour file must be read, more than one line with the riv_info and riv_files key words will be present.
(omitted when not using W2 river contour file as input)

riv_files two values: file index number, and relative path and name of a CE-QUAL-W2 river contour file
(omitted when not using W2 river contour file as input)

bth_files two values: file index number, and relative path and name of a CE-QUAL-W2 bathymetry file. A bathymetry file is needed for each W2 waterbody that is included.

src_type2 type of W2 output file used as a second input source for plotting differences (W2 Contour File, W2 Vector File, W2 River Contour File, W2 SurfTemp File, W2 VolTemp File, or W2 FlowTemp File)
(used only when map_type is filediff)

match_tol number of minutes to allow (plus or minus) as a window to match dates between the first and second datasets for plotting differences
(used only when map_type is filediff)

w2l_file2 file name of W2 vector file for second source input for plotting differences, if vector input source type is used for that second input file
(used only when map_type is filediff)

src_file2 file name of a W2 SurfTemp, W2 VolTemp, or W2 FlowTemp output file for second source input for plotting differences, if any of these sources is used for that second input file
(used only when map_type is filediff)

src_line2 number of lines to read in the file for second source input for plotting differences, for purposes of making a progress bar
(used here only for SurfTemp, VolTemp, and FlowTemp source files)
(used only when map_type is filediff)

cpl_info2 three values: file index number, Tecplot code, and number of lines to read in the contour file if a contour file is used for second source input for difference plots. The Tecplot code is 0 for a non-Tecplot contour file and 1 for a Tecplot-style contour file. If more than one contour file must be read, more than one line with the cpl_info2 and cpl_file2 key words will be present.
(omitted when not using W2 contour file as input for second source inputs)
(used only when map_type is filediff)

cpl_file2 two values: file index number, and relative path and name of a CE-QUAL-W2 contour file if a contour file is used for second source input for difference plots
(omitted when not using W2 contour file as input for second source inputs)
(used only when map_type is filediff)

riv_info2 three values: file index number, starting branch number, and number of lines to read in the river contour file if a river contour file is used for second source input for difference plots. If more than one river contour file must be read, more than one line with the riv_info2 and riv_file2 key words will be present.

	(omitted when not using W2 river contour file as input for second source inputs) (used only when map_type is filediff)
riv_file2	two values: file index number, and relative path and name of a CE-QUAL-W2 river contour file if a river contour file is used for second source input for difference plots (omitted when not using W2 river contour file as input for second source inputs) (used only when map_type is filediff)
seg_list	text string showing the segments included in the time/distance map
wb_list	text string showing the waterbodies included in the time/distance map
parm	the modeled parameter name, such as *Temperature*
parm_div	name of a modeled parameter name to divide into the chosen parameter, or None
ctype	unit conversion choice (see Unit Conversions)
parm2	the second modeled parameter name, such as *Temperature* (used only when map_type is parmdiff)
parm2_div	name of a modeled parameter name to divide into the second chosen parameter, or None (used only when map_type is parmdiff)
ctype2	unit conversion choice for second parameter (see Unit Conversions) (used only when map_type is parmdiff)
diff_swap	code to reverse the order of a calculated parameter difference (0=no, 1=yes) (used only when map_type is parmdiff or filediff)
parmunits	parameter units; *Celsius* or *Fahrenheit* when parameter is *Temperature*
prof_stat	profile statistic (Surface value, Volume-weighted, Flow-weighted) The Flow-weighted statistic currently is only available for W2 FlowTemp output files. The W2 river contour file only contains surface values.
byear	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
tz_offset	time offset to convert model time to local standard time (default: +00:00)
jd_skip	number of dates in the input source file to skip (0=none, 1=every other, etc.)
cs_hide	code to hide the color scheme legend (1=hide, 0=show)
cs_link	code linking color scheme to other graphs (0=none, 1=same data file, 2=same parameter)
cscheme1	name of first color ramp, or name of the color scheme
cscheme2	name of second color ramp, or None
ncolors	number of colors in the color scheme or for each color ramp
cs_rev	code to reverse the color scheme (0=disabled, 1=enabled)
cs_min	minimum parameter value for the color scheme
cs_max	maximum parameter value for the color scheme
cs_major	scale interval used for color scheme legend (number, or “auto”)
cs_width	width of each color swatch in the color key legend, in pixels
cs_height	height of each color swatch in the color key legend, in pixels
xleg_off	X distance offset for left edge of color legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of color legend, in pixels from the top edge of the graph frame
keyfont	font family used for text on the color key legend
keytitle	title text for the color key legend
kt_size	font size for the title text of the color key legend, in points
kt_weight	font weight for the title text of the color key legend (normal, bold)
kn_size	font size for the number scale of the color key legend, in points
kn_weight	font weight for the number scale of the color key legend (normal, bold)
kn_digits	number of digits after the decimal for the number scale of the color key legend
date_axis	code denoting which axis is the date/time axis (X or Y)
ttitle	date/time axis title text
tfont	date/time axis font family
tt_size	date/time axis title font size, in points

tt_weight	date/time axis title font weight (normal, bold)
tl_size	date/time axis tick label font size, in points
tl_weight	date/time axis tick label font weight (normal, bold)
tmin	minimum date (Mon-DD-YYYY) or Julian date value for the date/time axis
tmax	maximum date (Mon-DD-YYYY) or Julian date value for the date/time axis
tmajor	major tick label spacing for the date/time axis, in days, or “auto”
tpr_tics	tick mark style for the primary date/time axis (outside, inside, cross, none)
top_tics	tick mark style for the opposite date/time axis (outside, inside, cross, none)
ttype	date/time axis type (Date/Time, Julian Date)
tflip	code for flipping the date/time axis (0=no, 1=yes)
base_yr	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
datefmt	date format for a Date/Time axis (Year, Month, Mon-DD, Mon-DD-YYYY)
dtitle	distance axis title text
dfont	distance axis font family
dt_size	distance axis title font size, in points
dt_weight	distance axis title font weight (normal, bold)
dl_size	distance axis tick label font size, in points
dl_weight	distance axis tick label font weight (normal, bold)
dbase	distance axis value corresponding to most-downstream location of the chosen reach
dmin	minimum value for the distance axis
dmax	maximum value for the distance axis
dmax_auto	code denoting whether the maximum value for the distance axis should be calculated from the minimum distance value and the map’s total distance (0=no, 1=yes)
dfirst	value for the first major tick mark on the distance axis
dmajor	major tick label spacing for the distance axis (number, or “auto”)
dpr_tics	tick mark style for the primary distance axis (outside, inside, cross, none)
dop_tics	tick mark style for the opposite distance axis (outside, inside, cross, none)
dflip	code for flipping the distance axis (0=no, 1=yes)
dunits	distance axis units (miles, kilometers)
gtitle	graph title text
gstitle	graph subtitle text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gs_size	graph subtitle font size, in points
gs_weight	graph subtitle font weight (normal, bold)
hidetitle	code denoting whether to hide the graph title and subtitle (0=no, 1=yes)
hidetaxis	code denoting whether to hide the date/time axis (0=no, 1=yes)
hidedaxis	code denoting whether to hide the distance axis (0=no, 1=yes)

W2 Water Levels Plot

This graph type plots elevation on the Y axis and longitudinal distance on the X axis to display a plot of the modeled water level for the chosen reach. All of the key words and parameters for the W2 Water Levels Plot are as follows:

meta	w2_wlevels
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center

yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
con_file	relative path and file name of a CE-QUAL-W2 control file
src_type	type of W2 output file used (W2 Contour File, W2 Vector File, W2 Water Level File)
w2l_file	file name of W2 vector file, if vector input source type is used (omitted when using W2 contour or W2 water level file as input)
cpl_info	three values: file index number, Tecplot code, and number of lines to read in the contour file. The Tecplot code is 0 for a non-Tecplot contour file and 1 for a Tecplot-style contour file. If more than one contour file must be read, more than one line with the cpl_info, cpl_files, and bth_files key words will be present. (omitted when using W2 vector or W2 water level file as input)
cpl_files	two values: file index number, and relative path and name of a CE-QUAL-W2 contour file (omitted when using W2 vector or W2 water level file as input)
wl_file	file name of W2 water level file (often wl.opt or wl.csv) (omitted when using W2 contour or W2 vector file as input)
wl_lines	number of lines to read in the W2 water level file, for purposes of making a progress bar (omitted when using W2 contour or W2 vector file as input)
bth_files	two values: file index number, and relative path and name of a CE-QUAL-W2 bathymetry file
seg_list	text string showing the segments included in the longitudinal slice
wb_list	text string showing the waterbodies included in the longitudinal slice
byear	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
tz_offset	time offset to convert model time to local standard time (default: +00:00)
jd_skip	number of dates in the input source file to skip (0=none, 1=every other, etc.)
extra_chk	code to designate whether extra checks are made on a W2 water level file to determine whether segments are inactive (0=off, 1=on)
xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum longitudinal distance value for the X axis
xmax	maximum longitudinal distance value for the X axis
xmajor	major tick label spacing for the X axis, or “auto”
xpr_tics	tick mark style for the primary X axis (outside, inside, cross, none)
xop_tics	tick mark style for the opposite X axis (outside, inside, cross, none)
xmax_auto	code denoting whether the maximum value for the X axis should be calculated from the X axis base value and the reach’s total distance (0=no, 1=yes)
xbase	X axis value corresponding to most-downstream location of the chosen reach
xfirst	value for the first major tick mark on the X axis
xflip	code denoting whether the X axis should be flipped (0=no, 1=yes)
xunits	X axis units (miles, kilometers)
yunits	Y axis elevation units (feet, meters)
ytitle	Y axis title text
yfont	Y axis font family

yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum elevation value for the Y axis
ymax	maximum elevation value for the Y axis
ymajor	major tick label spacing for the Y axis
ypr_tics	tick mark style for the primary Y axis (outside, inside, cross, none)
yop_tics	tick mark style for the opposite Y axis (outside, inside, cross, none)
stype	segment axis type (none, above, below, replace)
sfont	segment axis font family
st_size	segment axis title font size, in points
st_weight	segment axis title font weight (normal, bold)
sl_size	segment axis label font size, in points
sl_weight	segment axis label font weight (normal, bold)
stic_loc	segment axis tick mark location (upstream edge, center, downstream edge)
smajor	segment axis major tick label spacing, or “auto”
spr_tics	tick mark style for the primary Segment axis (outside, inside, cross, none)
sop_tics	tick mark style for the opposite Segment axis (outside, inside, cross, none)
sgrid	segment axis vertical grid lines at major tick label spacing (0=off, 1=on)
sgrid_col	segment axis vertical grid line color at major tick label spacing
bgrid	segment axis vertical grid lines at branch boundaries (0=off, 1=on)
bgrid_col	segment axis vertical grid line color at branch boundaries
stitle	segment axis title text
gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gs_size	graph subtitle font size, in points
gs_weight	graph subtitle font weight (normal, bold)
wl_color	color of the line showing the water-level elevations for the chosen reach
wl_style	style of water-level elevation line (Flat surface, Interpolate, Branch slope)
wl_grid	code denoting whether grid layer boundaries will be plotted (0=off, 1=on)
wl_gridc	color of the lines showing the grid layer boundaries

Time-Series Graph

This graph type plots a parameter value on the Y axis and time on the X axis. The key words and parameters for the Time-Series graph are as follows:

meta	time_series
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center
yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately

coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum date (Mon-DD-YYYY) or Julian date value for the X axis
xmax	maximum date (Mon-DD-YYYY) or Julian date value for the X axis
xmajor	major tick label spacing for the X axis, or “auto”
xpr_tics	tick mark style for the primary X axis (outside, inside, cross, none)
xop_tics	tick mark style for the opposite X axis (outside, inside, cross, none)
xtype	X axis type (Date/Time, Julian Date)
base_yr	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
datefmt	date format for Date/Time axis (Year, Month, Mon-DD, Mon-DD-YYYY)
dateline	code denoting the presence of a vertical line at the animation date (0=off, 1=on)
datelinec	color of the optional vertical dateline
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum parameter value for the Y axis
ymax	maximum parameter value for the Y axis
ymajor	major tick label spacing for the Y axis
ypr_tics	tick mark style for the primary Y axis (outside, inside, cross, none)
yop_tics	tick mark style for the opposite Y axis (outside, inside, cross, none)
gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gridx	code to enable vertical grid lines (1=enable, 0=disable)
gridy	code to enable horizontal grid lines (1=enable, 0=disable)
gridwidth	width of any enabled grid lines (default is 1 pixel)
gridcolor	color of any enabled grid lines (default is #C0C0C0, a light gray)
leg_title	legend title text (can be blank)
legfont	legend font family
lt_size	legend title font size, in points
lt_weight	legend title font weight (normal, bold)
le_size	legend entry font size, in points
le_weight	legend entry font weight (normal, bold)
le_edge	code denoting whether the legend box should have a border (0=off, 1=on)
le_edgec	color of the legend box border
le_fill	code denoting whether the legend box should be filled with color (0=off, 1=on)
le_fillc	color of the filled legend box
xleg_off	X distance offset for left edge of legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of legend, in pixels from the top edge of the graph frame
gap_tol	gap tolerance for breaking the lines of time-series datasets (default is 2.0 days)

ts_type	time-series parameter type (user specified)
ts_units	time-series parameter units; *Celsius* or *Fahrenheit* when parameter is *Temperature*

The rest of the key words and parameters for a time-series graph each start with a dataset number (beginning with zero) as the first parameter, followed by a comma and the second parameter value. These key words and parameters are repeated as often as necessary to include all of the datasets that are included in the graph.

add_data	set number, relative path and file name of time-series data file
add_ftype	set number, file type code (see Recognized File Types)
add_ctype	set number, unit conversion choice (see Unit Conversions)
add_parm	set number, parameter name choice from input file
add_show	set number, code denoting whether dataset is shown (1) or hidden (0)
add_width	set number, line width in pixels
add_color	set number, color name or RGB code for the line color
add_text	set number, legend text for the dataset
add_byear	set number, base year for which a JDAY of 1.0 equals the start of Jan-01 on that year, or “n/a”
add_tzoff	set number, time offset (default: +00:00), only for W2 time-series file types
add_seg	set number, model segment number of interest for the input data, or “n/a”

Linked Time-Series Graph

Four of the W2Anim graph types (Measured Vertical Profile, Vertical Withdrawal Zone from Measured Data, W2 Vertical Profile, W2 Outflow Profile) allow for a time-series graph to be created and linked to one of the time-series datasets associated with the original graph. These linked time-series graphs are similar to a regular time-series graph, but have at least one dataset that is linked to another graph.

This graph type plots a parameter value on the Y axis and time on the X axis. The key words and parameters for the Linked Time-Series graph are as follows:

meta	linked_time_series
gnum	graph number, used internally for links
x	X location of anchor point for graph frame
y	Y location of anchor point for graph frame
xc	X location of graph frame center
yc	Y location of graph frame center
anchor	anchor point type (corner, midpoint, center)
color	line color name or RGB code for graph frame (black)
width	line width for graph frame, in pixels (1)
fill	graph frame fill disabled (0); graph frames are filled with white separately
coordlist	comma-separated list of the X,Y coordinates of the upper left and lower right corners of the graph frame, in pixels
xtitle	X axis title text
xfont	X axis font family
xt_size	X axis title font size, in points
xt_weight	X axis title font weight (normal, bold)
xl_size	X axis tick label font size, in points
xl_weight	X axis tick label font weight (normal, bold)
xmin	minimum date (Mon-DD-YYYY) or Julian date value for the X axis
xmax	maximum date (Mon-DD-YYYY) or Julian date value for the X axis
xmajor	major tick label spacing for the X axis, or “auto”
xpr_tics	tick mark style for the primary X axis (outside, inside, cross, none)
xop_tics	tick mark style for the opposite X axis (outside, inside, cross, none)
xtype	X axis type (Date/Time, Julian Date)

base_yr	base year for which a Julian date of 1.0 equals the start of Jan-01 on that year
datefmt	date format for Date/Time axis (Year, Month, Mon-DD, Mon-DD-YYYY)
dateline	code denoting the presence of a vertical line at the animation date (0=off, 1=on)
datelinec	color of the optional vertical dateline
ytitle	Y axis title text
yfont	Y axis font family
yt_size	Y axis title font size, in points
yt_weight	Y axis title font weight (normal, bold)
yl_size	Y axis tick label font size, in points
yl_weight	Y axis tick label font weight (normal, bold)
ymin	minimum parameter value for the Y axis
ymax	maximum parameter value for the Y axis
ymajor	major tick label spacing for the Y axis
ypr_tics	tick mark style for the primary Y axis (outside, inside, cross, none)
yop_tics	tick mark style for the opposite Y axis (outside, inside, cross, none)
gtitle	graph title text
gtfont	graph title font family
gt_size	graph title font size, in points
gt_weight	graph title font weight (normal, bold)
gridx	code to enable vertical grid lines (1=enable, 0=disable)
gridy	code to enable horizontal grid lines (1=enable, 0=disable)
gridwidth	width of any enabled grid lines (default is 1 pixel)
gridcolor	color of any enabled grid lines (default is #C0C0C0, a light gray)
leg_title	legend title text (can be blank)
legfont	legend font family
lt_size	legend title font size, in points
lt_weight	legend title font weight (normal, bold)
le_size	legend entry font size, in points
le_weight	legend entry font weight (normal, bold)
le_edge	code denoting whether the legend box should have a border (0=off, 1=on)
le_edgec	color of the legend box border
le_fill	code denoting whether the legend box should be filled with color (0=off, 1=on)
le_fillc	color of the filled legend box
xleg_off	X distance offset for left edge of legend, in pixels from the right edge of the graph frame
yleg_off	Y distance offset for top edge of legend, in pixels from the top edge of the graph frame
gap_tol	gap tolerance for breaking the lines of time-series datasets (default is 2.0 days)
ts_gnum	graph number to which the linked time-series graph is linked
ts_type	time-series parameter type (determined by the linked parameter)
ts_units	time-series parameter units; specified when link is created
ts_show	comma-separated list of codes for each outlet, and All Outlets, denoting whether each dataset is shown (1) or hidden (0); ignored for Water Surface Elevation
ts_width	comma-separated list of line widths for each outlet, and All Outlets, in pixels; only the first entry is used for Water Surface Elevation
ts_color	comma-separated list of line color names or RGB codes for each outlet, and All Outlets; only the first entry is used for Water Surface Elevation

The rest of the key words and parameters for a linked time-series graph are only relevant if the user has added extra time-series datasets to the linked time-series graph. Each of these lines starts with a dataset number (beginning with the next dataset number after accounting for the outlets and All Outlets) as the first parameter,

followed by a comma and the second parameter value. These key words and parameters are repeated as often as necessary to include all of the added datasets that are included in the graph.

add_data	set number, relative path and file name of time-series data file
add_ftype	set number, file type code (see Recognized File Types)
add_ctype	set number, unit conversion choice (see Unit Conversions)
add_parm	set number, parameter name choice from input file
add_show	set number, code denoting whether dataset is shown (1) or hidden (0)
add_width	set number, line width in pixels
add_color	set number, color name or RGB code for the line color
add_text	set number, legend text for the dataset
add_byear	set number, base year for which a JDAY of 1.0 equals the start of Jan-01 on that year, or “n/a”
add_tzoff	set number, time offset (default: +00:00), only for W2 time-series file types
add_seg	set number, model segment number of interest for the input data, or “n/a”

REFERENCES CITED

Howington, S.E., 1990, Simultaneous, multiple-level withdrawal from a density stratified reservoir: U.S. Army Corps of Engineers Technical Report W-90-1, 68 p. plus appendix, accessed October 30, 2022, at https://erdc-library.erdc.dren.mil/jspui/handle/11681/4366.

Press, W.H., Flannery, B.P., Teukolsky, S.A., and Vetterling, W.T., 1989, Numerical Recipes—The Art of Scientific Computing (FORTRAN version): Cambridge University Press, New York, 702 p.

Rounds, S.A., and Stratton Garvin, L.E., 2022, Tracking heat in the Willamette River system, Oregon: U.S. Geological Survey Scientific Investigations Report 2022–5006, 47 p., https://doi.org/10.3133/sir20225006.

Wells, S.A., 2025, CE-QUAL-W2: A two-dimensional, laterally averaged, hydrodynamic and water quality model, version 4.5, User Manual, Department of Civil and Environmental Engineering, Portland State University, Portland, OR [variously paged].

Wikipedia contributors, 2025, Bézier curve: Wikipedia, The Free Encyclopedia, accessed December 12, 2025 at https://en.wikipedia.org/wiki/B%C3%A9zier_curve.

Wikipedia contributors, 2025, Ramer–Douglas–Peucker algorithm: Wikipedia, The Free Encyclopedia, accessed December 12, 2025 at https://en.wikipedia.org/wiki/Ramer%E2%80%93Douglas%E2%80%93Peucker_algorithm.