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HYDROLOGY OF JACOB'S WELL SPRING

A tutorial for using HydroDesktop to discover and access water data

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Distribution

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Table of Contents

Introduction	1
About Jacob’s Well Spring	1
Goals and Objectives	3
Computer and Data Requirements	3
Participating in the Open Source Community	4
Exercise Procedure	5
Getting To Know HydroDesktop	5
Creating a Project	7
Searching for Hydrologic Data	8
Selecting Data for Download	11
Downloading Data	14
Visualizing Time Series Data	14
Searching for Additional Data	16
Labeling Features	18
Adding Data to a Theme	19
Exporting Data	21
Advanced: Analysis with R	23
Installing R	23
Enabling the HydroR Plug-in	23
Plotting a Graph with R	24
Analyzing Flow in Jacob’s Well Spring	25
Appendix A: R Scripts	28
Script 1: Preparing Inputs for Flow Analysis	28
Script 2: Computing Surface Water Flow Fraction	28
References	30

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INTRODUCTION

CUAHSI-HIS enables sharing of water data

The Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) Hydrologic Information Systems project (CUAHSI-HIS) has devoted itself to improving access to time series of water data. Towards that end, CUAHSI-HIS has developed standards for sharing data that make it easier to ask for water data and interpret what comes back from a given data source. CUAHSI-HIS also maintains a catalog of data available from organizations that use CUAHSI-HIS standards, essentially serving as a search engine for water data. The result is a universal mechanism for accessing time series data, greatly simplifying the typically laborious task of getting the data you need to do your analysis. But how do people who are unfamiliar with CUAHSI-HIS standards use this system? That's where HydroDesktop comes in.

HydroDesktop uses CUAHSI-HIS to help you find water data

HydroDesktop is a free and open source Geographic Information Systems (GIS) application that helps you discover, use, and manage hydrologic time series data published with CUAHSI-HIS. It handles the details of how to work with CUAHSI-HIS so that you don't have to. HydroDesktop includes data query, download, visualization, graphing, analysis and modeling capabilities. The result is a spatially-enabled system that facilitates the aggregation of observational data describing the water environment.

Let's use HydroDesktop to learn about Jacob's Well Spring

This document presents an exercise that shows how to use HydroDesktop to find water data for Jacob's Well Spring in Texas. With some simple analysis, you will compare characteristics of this groundwater-dominated system with those of a nearby river. During the exercise, you will learn about some of the most commonly-used tools in HydroDesktop.

Related Links:

HydroDesktop - <http://hydrodesktop.codeplex.com/>

CUAHSI Hydrologic Information System - <http://his.cuahsi.org/>

ABOUT JACOB'S WELL SPRING

The underwater cave known as Jacob's Well emerges in Hays County, Texas, at Jacob's Well Spring where it serves as one of the primary sources of water for Cypress Creek, which later flows into the Blanco River. The clear, crisp water cools down many Texans as it moves through the Blue Hole swimming area near Wimberley, Texas. This karst spring has been impacted in recent years by development in Hays County and increasing demands on the Middle Trinity Aquifer (Davidson, 2008).



Figure 1 Jacob's Well Spring (San Marcos Local News, 2009)

In 2005, a monitoring station was installed at Jacob's Well Spring 18 meters below the ground surface, reporting flow and temperature conditions at 15-minute intervals. The data for this station are accessible via the US Geological Survey's National Water Information System (USGS NWIS).

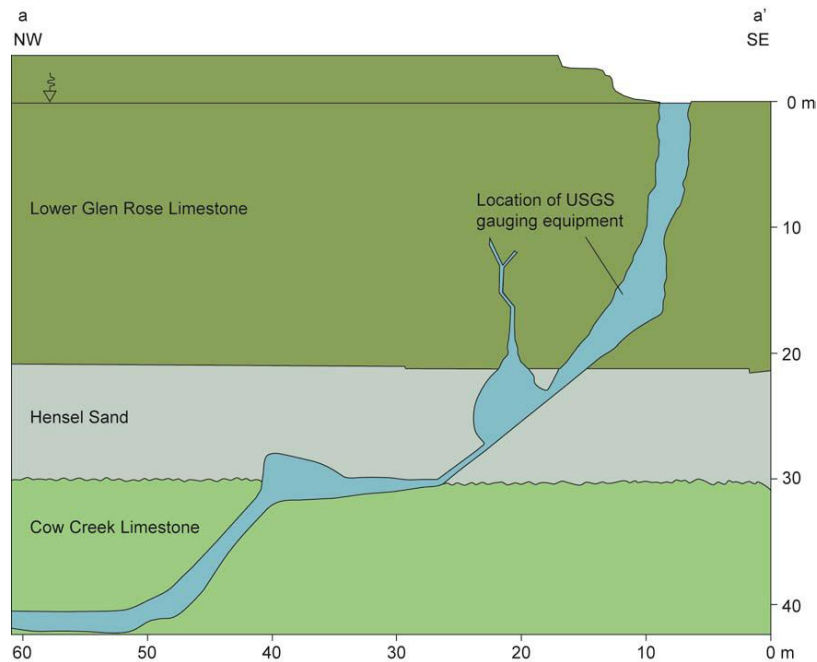


Figure 2 Cross-sectional diagram of Jacob's Well (Davidson, 2008)



Figure 3 Jacob's Well Spring Monitoring Station (United States Geological Survey, 2007)

For more information about the spring, please read the 2008 Masters thesis of Sarah Cain Davidson from The University of Texas at Austin.

GOALS AND OBJECTIVES

The goal of this exercise is to introduce you to the tools and functions available in HydroDesktop that allow you to search for and synthesize hydrologic time series data in an area of interest. This exercise will teach you how to find and obtain data for Jacob's Well Spring in Texas and compare data characteristics using the analysis capabilities of HydroDesktop.

Objectives for this exercise include:

- Find streamflow and temperature data for Jacob's Well Spring in Texas.
- Identify useful time series and download them.
- Visualize time series data in graphs.
- Export time series data for use in other programs.

COMPUTER AND DATA REQUIREMENTS

At the time of this writing, HydroDesktop is still in beta stages, and thus changes are made frequently to fix bugs and enhance the software. Therefore, it is recommended that you install the version of HydroDesktop that was used to prepare this exercise: **Version 1.1 Beta 294**. This version is only compatible with a Windows operating system such as **Windows XP or Windows 7**. You will also need an Internet connection since you will be accessing online resources to download time series data.

To install HydroDesktop:

1. In a Web browser, navigate to <http://hydrodesktop.codeplex.com/>.
2. Click the **Downloads** link near the top left of the page.

3. Find the link for the **1.1 Beta 294** installer and click it.
4. Read the license and agree to it.
5. Save and run the installer, accepting all defaults. The installer will guide you through the rest.

This document contains an advanced section after the conclusion of the main exercise. This section uses a software environment called R to analyze time series data. If you want to execute the procedure in the advanced section, you will need to install R. Instructions are in the advanced section.

PARTICIPATING IN THE OPEN SOURCE COMMUNITY

HydroDesktop is an open source product, which means that anyone can see the source code used to create the program and contribute to its development. Even if you aren't a programmer, you can still participate in the discussion forums and post bugs or feature requests in the issue tracker.

The home for HydroDesktop is on CodePlex, a Web site for open source software. To add to the discussions or post a bug, you must first register for your free CodePlex account. Once you have a CodePlex account, you can log in at <http://hydrodesktop.codeplex.com/> and start contributing. The community is really what drives open source software development, so this is an exciting opportunity to make your voice heard.

You are encouraged to provide feedback on any issue or problem you may encounter throughout this exercise. Feel free to utilize online resources such as the issue tracker on the HydroDesktop Web site when providing feedback. In this exercise you'll learn how to access these resources directly through HydroDesktop.

EXERCISE PROCEDURE

Suppose you live in Hays County in Texas, and for years you have enjoyed taking a dip in the Blue Hole swimming area along Cypress Creek during hot Texas summers. As population growth and increased groundwater pumping threaten Jacob's Well Spring, the primary source of water for Cypress Creek, you decide to learn more about this valuable resource. In this exercise, you'll use HydroDesktop to find temperature data and see how it compares to a nearby river.

IMPORTANT

At the time of this writing, HydroDesktop is still in the beta stages of software development and thus still contains bugs. We are working hard to fix these bugs, but you may want to closely and carefully follow the exercise procedure in the mean time in order to minimize bugs encountered.

GETTING TO KNOW HYDRODESKTOP

Let's open HydroDesktop and get to know its user interface.

1. Open HydroDesktop (Start | All Programs | CUAHSI HIS | HydroDesktop | HydroDesktop).
2. Take a moment to explore the user interface.

As you can see, HydroDesktop looks much like a typical GIS interface. It supports complex layer symbologies, access to online map services, and custom programmed tools and plugins. It even comes with some basemap shapefile data which are already added to the map. What sets HydroDesktop apart from other GIS applications, is the ability to query for hydrologic time series data.

Notice that HydroDesktop presents many of its controls on a ribbon, much like modern versions of Microsoft Office. The ribbon is organized into tabs which contain groups of buttons and tools. There is also an orb for accessing basic functions like saving and printing.

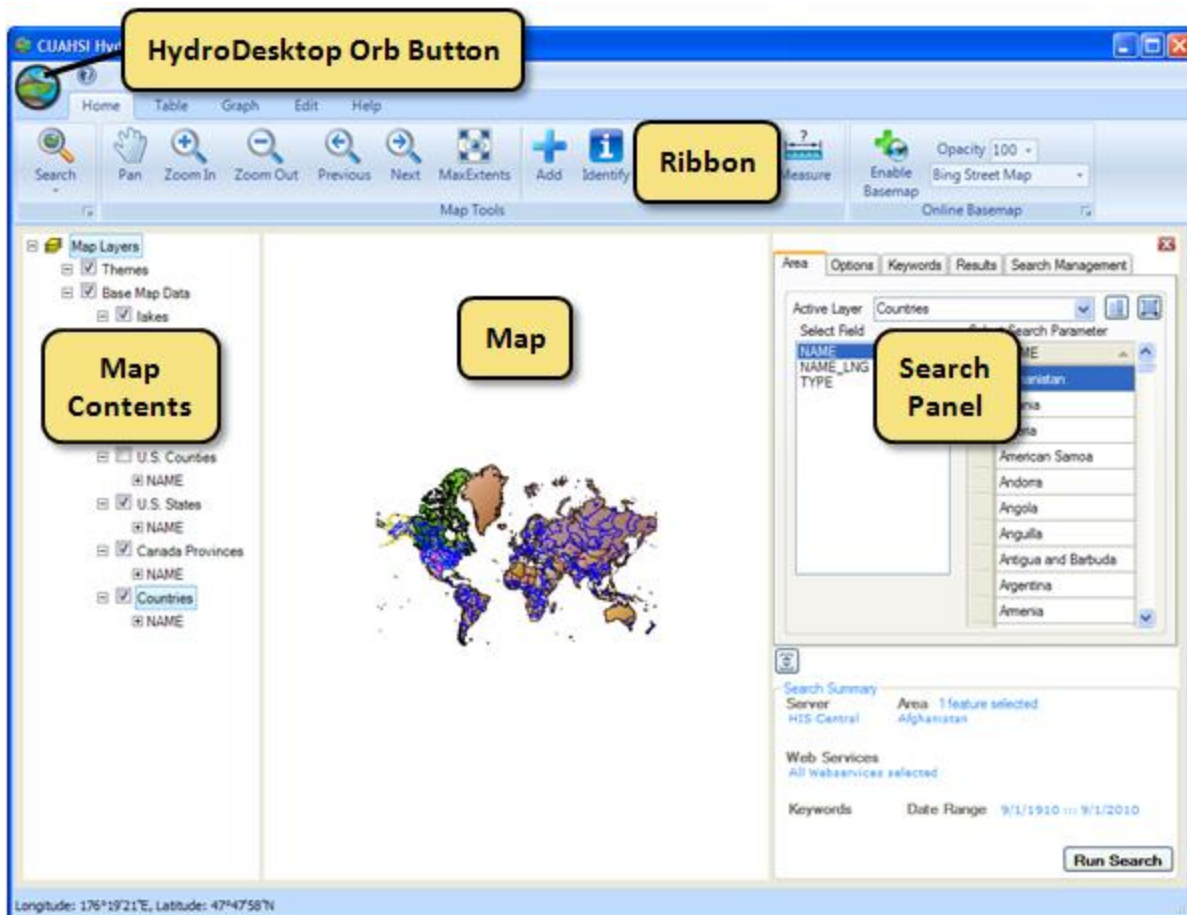


Figure 4 HydroDesktop User Interface

If you have comments or issues as you work through this exercise, you can find helpful resources on the Help tab. The buttons on this tab let you view documentation, jump to the discussion forums or issue tracker, email for help, or submit a comment.

3. Click the **Help** tab in the ribbon to view the buttons available on that tab.
4. Click the **Issues** button to open the issue tracker on the HydroDesktop Web site.



Figure 5 Using the Help Tab To Open the Issue Tracker

5. Close the Issue Tracker Web page.

CREATING A PROJECT

HydroDesktop manages your work within *projects*. A HydroDesktop project file (.hdprj) contains information about what geospatial layers you have in your map and how those layers are symbolized. These layers are stored in shapefiles, a widely available GIS data format. The shapefiles such as state boundaries that are included with HydroDesktop are located in its installation folder, e.g.,
C:\Program Files\CUAHSI HIS\HydroDesktop\maps\BaseData-MercatorSphere.

The HydroDesktop project file also connects your work to a database (.sqlite file) where temporal data are stored. This is where the time series data that you download through HydroDesktop is saved. A relational database is much more efficient at storing time series data than shapefiles, and HydroDesktop uses a free database called SQLite for this purpose.

You can create projects to organize your work, and you can save the project so that you can open it again later. When you first open HydroDesktop, it sets up a clean map and loads the default system database. In order to better manage the work in this exercise, you will create a new project and database.

To create a new project and database:

1. Click the **HydroDesktop Orb** button.
2. In the **Orb** menu, click **New Project**.



Figure 6 Creating a New Project

3. Choose a location to save your project such as your desktop.
4. Name the project "Jacob's Well Spring" and then click **Save**. Click **Yes** if prompted about overwriting the database.

HydroDesktop will notify you that the project was created successfully. The text in the title bar of the HydroDesktop window should now include the name of your project. HydroDesktop has also created a database for your project named "Jacob's Well Spring.sqlite." This database is saved in the same location as your project file.

You are now ready to work within your newly created project and database. To save your project after performing some work, click on the **Save Project** button in the **Orb** menu. To open a project, click on the **Open Project** button in the **Orb** menu.

SEARCHING FOR HYDROLOGIC DATA

When searching for data in HydroDesktop, you can specify the following filters: region of interest, time period of interest, data source and variables of interest. HydroDesktop then searches the CUAHSI-HIS national catalog of known time series data to find locations of time series that match your search. Locations of time series data that match your search are presented in the map. These results include information that HydroDesktop can use to connect to each individual data provider for data access. You can further filter the results and then choose which data you want to actually download and store in your database.

When you save data to your database, it is stored as a theme. A *theme* is a collection of hydrologic time series data that share a common relationship. A theme can be anything from a geographic space (e.g., Texas, Colorado) to a hydrologic event (e.g., flood, hurricane) to a combination of both (e.g., Texas Flood). Simply put, a theme organizes a collection of related time series. HydroDesktop can save data to a new theme or append data to an existing theme. The workflow for finding data and saving it to a theme is shown in Figure 7.

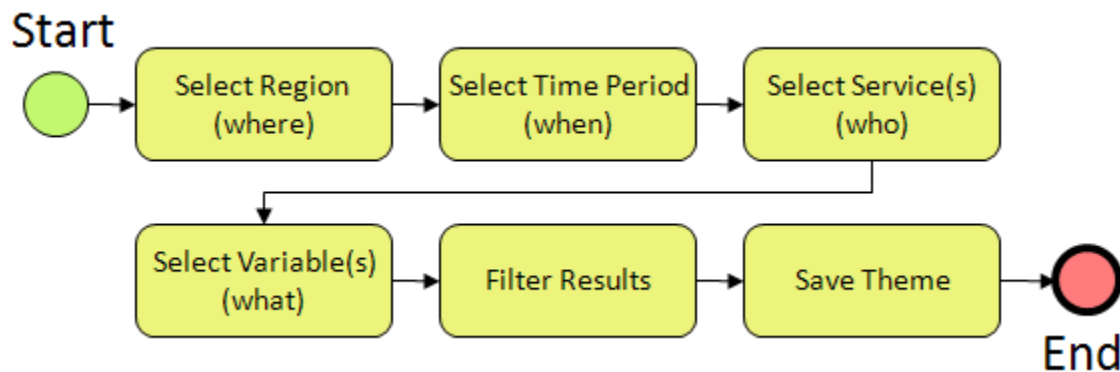


Figure 7 Workflow for Searching for Hydrologic Data

In this exercise, you will locate streamflow and temperature data for one water year near Jacob's Well Spring. The county boundary for Hays County is included in the U.S. Counties layer that is already in the map. You'll use this boundary to restrict the area being searched.

1. Click the **Home** tab in the ribbon to activate it.
2. In the **Search Panel** on the right, under the **Area** tab, choose **U.S. Counties** in the list of Active Layers. The map zooms to the extent of this layer while the Search Panel shows the fields in this layer.
3. Under **Select Search Parameter**, scroll through the names until you find Hays, TX. Click **Hays, TX** to select it. The map zooms to the county and highlights it in blue.

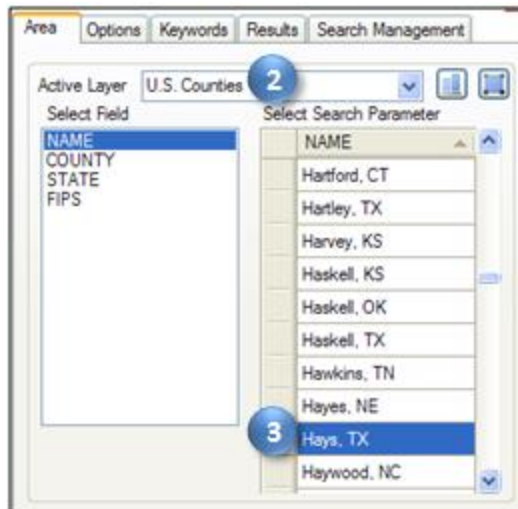



Figure 8 Choosing a Search Area

Tip

As you build your query, the current search parameters are shown in the Search Summary at the bottom of the Search Panel. To give yourself more room to work, you can hide the Search Summary by clicking the Hide Search Summary button . Click the button again to show the Search Summary once it is hidden.

Next you will tell HydroDesktop the date range of time series that you want. For this exercise, search for data available in the 2010 water year (i.e., 10/1/2009 to 9/30/2010).

4. In the **Search Panel**, click the **Options** tab to activate it.
5. Specify a **Start Date** of **10/1/2009** and an **End Date** of **9/30/2010**. You can click and type the numbers in directly, or you can click the drop down arrow next to the date to open an interactive calendar.

Tip

On the Options tab, you can also select specific Web services (i.e., data sources) to query. The default is to search all Web services.

Next you will tell HydroDesktop what hydrologic variables you want. To help you in this regard, HydroDesktop employs a list of official CUAHSI-HIS keywords for hydrologic variables. Data providers use this list when registering with CUAHSI-HIS. This is a lot easier than typing whatever term the data provider may be using internally. For example, the USGS uses the term “00060” to describe streamflow.

6. In the **Search Panel**, click the **Keywords** tab to activate it.
7. Start typing “streamflow” in the **Keywords** text box. The list of keywords automatically selects keywords that match your search.
8. Click **Streamflow** in the list of keywords.

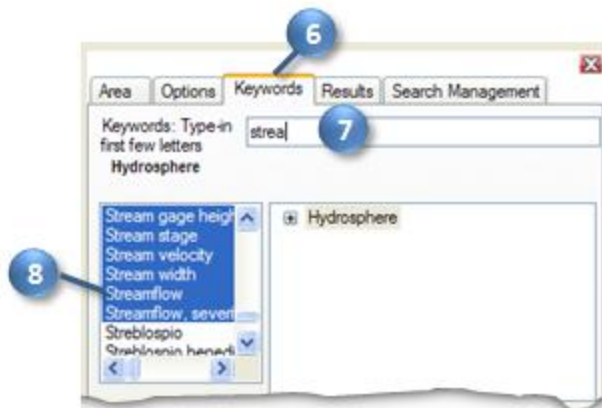



Figure 9 Choosing a Hydrologic Variable Keyword to Search

When you click Streamflow, the keyword list automatically jumps to the term “Discharge, stream.” It just so happens that “Discharge, stream” is the official keyword for what we think of as streamflow. However, the keyword list also includes synonyms like “streamflow” to make it easier to find the variable you’re after. To the right of the keyword list, you can see where stream discharge fits within the overall hierarchy of hydrologic variables.

Now that you’ve identified the right keyword, you’ll tell HydroDesktop to add that keyword to the list of variables for which it will search.

9. In the **Search Panel**, Click the **Add** button  to add “Discharge, stream” into the Selected Keywords box.

Now you will repeat the process to add the water temperature keyword.

10. In the **Keywords** text box, start typing “temperature.”
11. Click **Temperature, water** in the list of keywords.
12. In the **Search Panel**, click the **Add** button to add “Temperature, water” into the Selected Keywords box.

With search parameters set, you will now tell HydroDesktop to run the search for data.

13. In the Search Panel, click **Run Search**.

When you run a search, HydroDesktop asks the CUAHSI-HIS national catalog for descriptions of time series that match your search criteria. At this point, your software is using a remote online resource and bringing back data to display in your map. After HydroDesktop has finished searching for time series, it displays the locations of time series that fit your search in a map layer called “Search Results.” Note that there will be several “dots” at a single location in the map if the site represented by a given dot measures more than one time series that matches your search. In other words, each dot in the map represents a time series of data. Different symbols for the dots indicate different data sources.



Figure 10 Locations of Streamflow and Water Temperature Observations in Hays County, TX

While the search may have seemed fast, remember that your map is only showing where time series of interest are located, and that you haven't actually downloaded any time series values yet. Now you can begin to refine these search results to locate time series that you actually want to download and save to your database.

SELECTING DATA FOR DOWNLOAD

To help you identify time series of interest, HydroDesktop includes data and tools to give you a spatial context for the data. One of these is the ability to display online basemaps from ESRI, Bing, and OpenStreetMap. These are beautiful cartographic maps cached at multiple scales which are accessed in real time as you move around in the HydroDesktop map. For this exercise, you will enable the ESRI Hydro Basemap. This map shows rivers and watershed boundaries in the USA.

To enable the ESRI Hydro Basemap:

1. On the **Home** tab in the ribbon, find the **Online Basemap** group. Click the drop down list of basemaps and choose **ESRI Hydro Base Map**.
2. Select an opacity of **70** so that you can see some of the map layers under the basemap.
3. Click **Enable Basemap**.



Figure 11 Enabling an Online Basemap

In addition to providing spatial context, you can see that this basemap can help you produce a more aesthetically pleasing printed map.

For this exercise, you will work with the sites and variables shown in Table 1. You will select the features that represent these time series so that HydroDesktop knows which time series you want to download. These time series are located at or near Jacob's Well Spring.

Table 1 Selected Time Series in the San Marcos River Basin

DataSource	SiteName	VarName
NWISDV	Blanco Rv nr Kyle, TX	Discharge, cubic feet per second, , DataType=Average
NWISDV	Jacobs Well Spg nr Wimberley, TX	Discharge, cubic feet per second, , DataType=Average
NWISDV	Jacobs Well Spg nr Wimberley, TX	Temperature, water, degrees Celsius, , DataType=Average
NWISDV	Blanco Rv at Halifax Rch nr Kyle, TX	Temperature, water, degrees Celsius, , DataType=Average

To select time series for download:

1. In the **Map Contents** on the left, right-click on the **Search Results** layer name and click **View Attributes**.

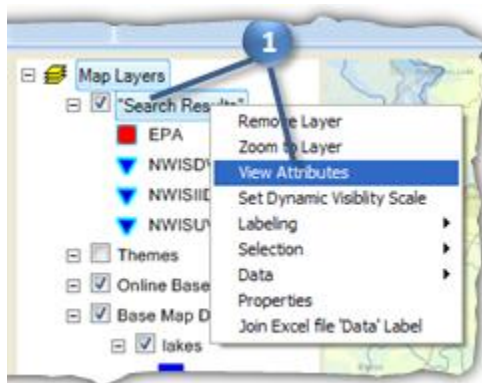


Figure 12 Viewing the Search Results Layer Attributes

The Attribute Table Editor opens showing you descriptions of time series in the Search Results layer. You can scroll through the table and resize columns to see the information. Some key columns to note are:

- **DataSource** – The search results include time series from different Web services, as indicated by the abbreviation for the service in this column.
- **SiteName** – The name of the monitoring point where the time series is recorded.
- **VarName** – The name of the variable represented by the time series.
- **DataType** – Some sites report several statistics of data. For example, at Jacob's Well Spring, you can find minimum, maximum, and average streamflow values computed on daily time step.
- **StartDate, EndDate, ValueCount** – These fields give you sense of the overall period of record for a time series and the number of values for its entire period of record.

As indicated in Table 1, you will focus on average streamflow and temperature for Jacob's Well Spring, and you'll also choose a couple of time series from nearby sites for comparison. Since the period of interest is one water year, you'll choose time series from the US Geological Survey's NWISDV service, which provides data on a daily time step. That is a decent temporal resolution for initial explorations of the data.

2. In the **Attribute Table Editor**, use the values in the **DataSource**, **SiteName** and **VarName** columns to locate rows that match the values in Table 1. While holding down the CTRL key, left click on these rows to select them.

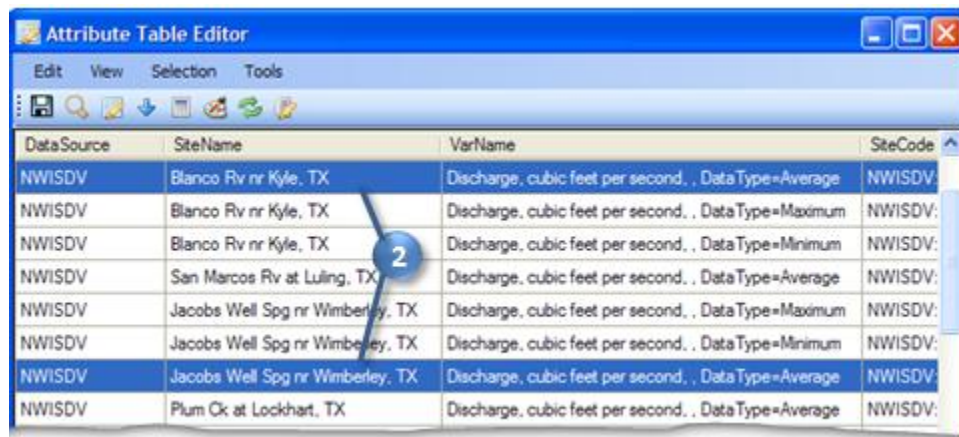


Figure 13 Selecting Time Series for Download

3. Close the Attribute Table Editor.

HydroDesktop currently has a bug where you must refresh the table within the Search panel in order for it to recognize the feature selection. This can be accomplished simply by clicking between the field names in the table as if you were going to resize the field widths. **Be careful to not click the field names themselves or click any rows within the table, or else you may lose your selection.**

4. In the **Search Panel**, under the **Results** tab, click between one pair of field names in the table as if you were going to resize the field widths.

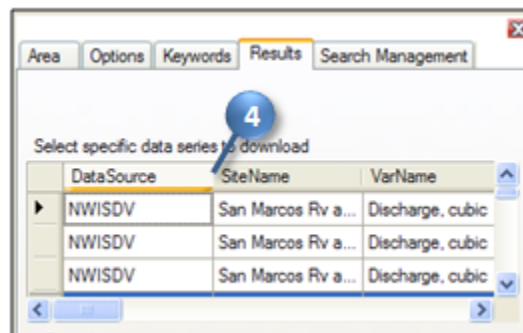


Figure 14 Refreshing the Selection

With the items properly selected, you are ready to download the data.

DOWNLOADING DATA

Recall that when you save data, it is organized into a Theme and stored in the database associated with your HydroDesktop project. You'll now download the data that you selected.

To download data:

1. In the **Search Panel**, in the **Results** tab, type "Hays County Data" in the **New Theme** text box, and make sure New Theme is selected.
2. Click **Download Data**.

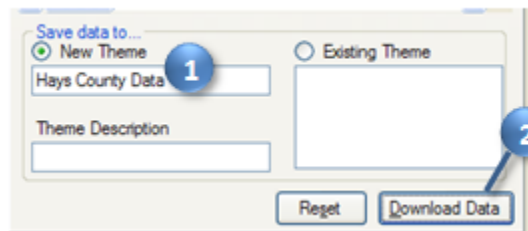


Figure 15 Saving a Theme

At this point, HydroDesktop connects to the data source associated with each time series you selected in the map, requests the time series, and stores the data in your new theme. Once the download is complete, the new theme is shown under the Themes group in the Map Contents. If you create additional themes, they will also appear in the Themes group.

Now that you've downloaded the data, you can view the data in both tabular and graph form.

VISUALIZING TIME SERIES DATA

HydroDesktop takes a series-centric view of temporal data, meaning that it provides access to the data at the time series level. An example of a time series is all of the temperature values measured at a certain point on the Blanco River. Let's take a look at the time series that you just downloaded.

To visualize time series data in HydroDesktop:

1. Click the **Graph** tab in the ribbon to activate it.

On the left you will see a list of all the time series in your database. You could use filters to restrict the time series that are shown, but you only retrieved a handful in this exercise so it's fine to leave the default view.

2. Click to place a check next to **Temperature at the Blanco River at Halifax Ranch**.

From the graph you can see how the temperature in the water changes with the seasons throughout the year. Now let's compare this time series with the one for Jacob's Well Spring.

- Place a check next to **Temperature at Jacob's Well Spring**.

HydroDesktop allows you to visualize multiple time series on the same graph. The plot axes automatically adjust to fit your data. In this example, there is a dramatic difference between the two temperature time series. The one for Jacob's Well Spring shows much less variation throughout the year than the one for the Blanco River at Halifax Ranch.

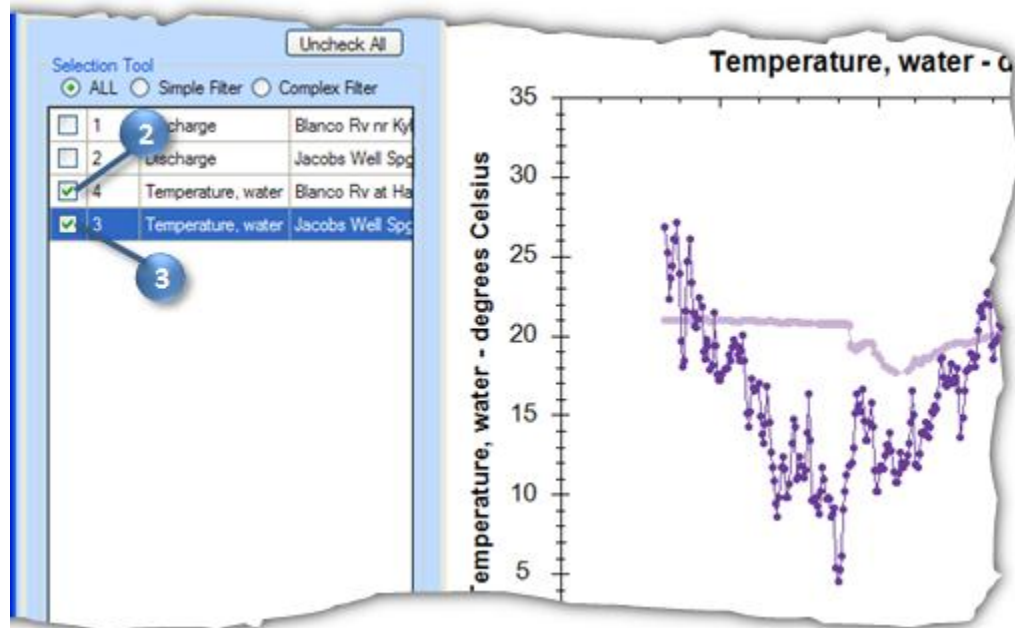


Figure 16 Comparing Temperature Time Series

- In the ribbon, click **Probability** to show a probability plot of the data, further illustrating the difference between the two time series.
- Click **Time Series** to restore the time series view.

The dramatic difference in the shapes of the two time series plots is caused by the source of water for these two rivers. The Blanco River at Halifax Ranch is largely a surface water system while Jacob's Well Springs is fueled by groundwater. While the groundwater system does maintain a much more steady temperature than the surface water system, notice how jumps still exist, such as the sudden decrease in temperature in mid-January, 2010. Let's plot flow on this graph to see why this might be happening.

- Place a check next to **Discharge at Jacob's Well Spring**.

Notice the sharp increase in streamflow around the same time that the water temperature dropped. It seems like the system is experiencing a large influx of surface water, which is colder than the groundwater in the winter. Similarly, you can see an increase in streamflow in late summer, 2010, which results in an increase in water temperature.

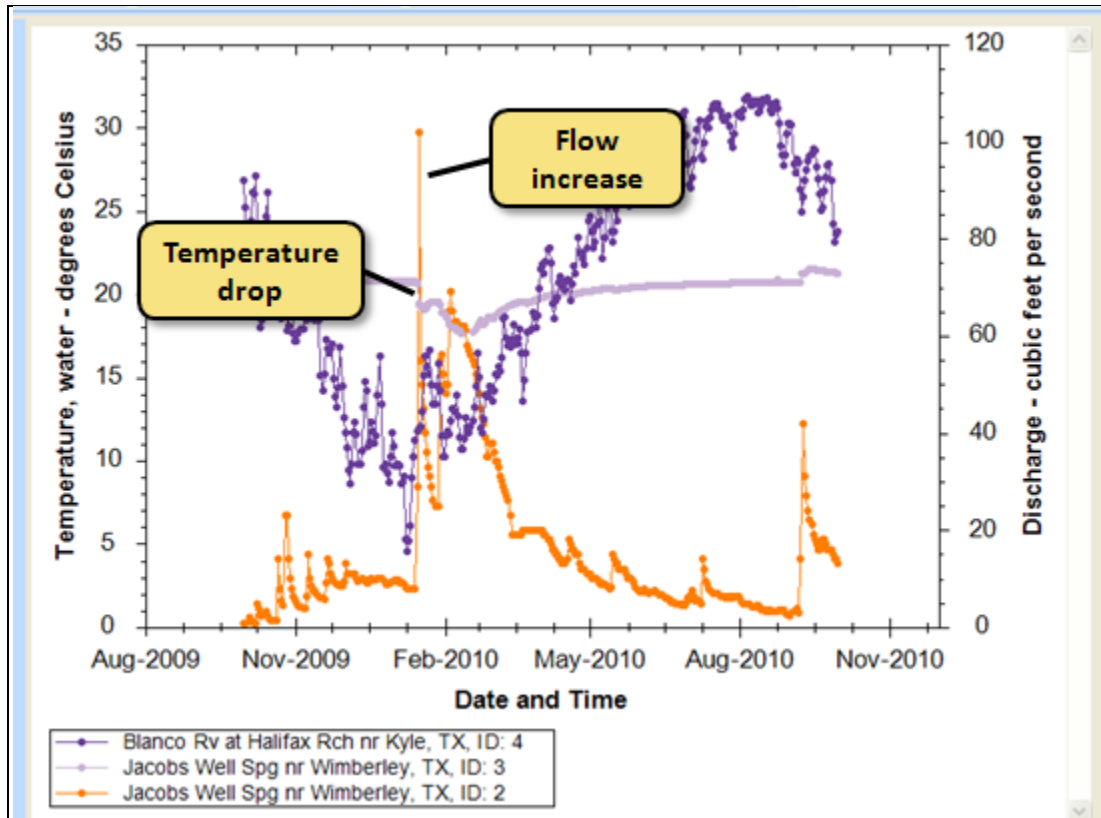


Figure 17 Examining Changes in Flow and Temperature

7. Uncheck the two temperature time series, and place a check next to **Discharge at the Blanco River near Kyle**.

The flow of the Blanco River dwarfs that of Jacob's Well Spring, but you can still see increases in flow in the Blanco River at about the same time as those observed in the spring. Also notice the 4000 cfs flow in September, 2010. This flow is the result of tropical storm Hermine as it swept through Texas.

SEARCHING FOR ADDITIONAL DATA

At this point, it might be nice to see precipitation data in the area for this water year. You can append this data to your current theme by performing another search. In this exercise, you'll search for daily precipitation data. To demonstrate how to choose a particular data source for a search, you will select to search for precipitation data from the National Weather Service.

1. Click the **Home** tab in the ribbon to activate it.
2. In the **Search Panel**, under the **Options** tab, click the **Show Web Service Selection Panel** checkbox.
3. Click **Select None**.
4. In the list of services, place a check next to **NWS-WGRFC Daily Multi-sensor Precipitation Estimates**. This service provides precipitation data from the National Weather Service West Gulf River Forecast Center.

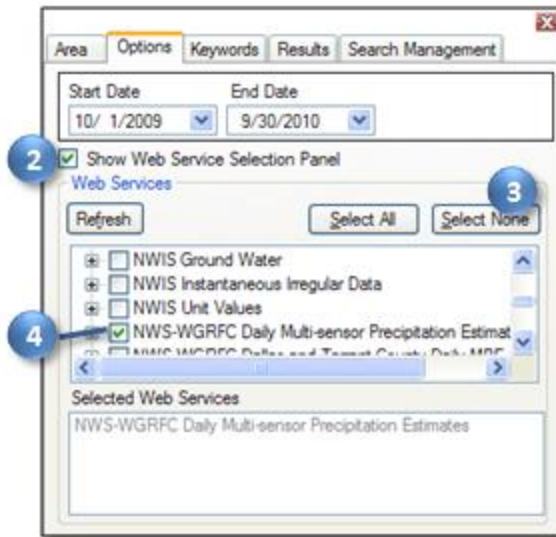


Figure 18 Selecting a Single Service to Search


5. In the **Search Panel**, click the **Keywords** tab to activate it.
6. In the Selected Keywords list, select all keywords from the previous search.
7. Click the Remove button  to remove those keywords from the search.



Figure 19 Removing Keywords from a Search

8. In the **Keywords** text box, start typing “precipitation.”
9. Click **Precipitation** in the list of keywords.
10. In the **Search Panel**, click the **Add** button to add “Precipitation” into the Selected Keywords box.
11. In the Search Panel, click **Run Search**.

When the search finishes, Hays County may be covered by a bunch of dots. These dots represent the centroids of NEXRAD HRAP cells. In other words, this Web service provides discrete point locations where you can basically sample this gridded rainfall dataset. Each of these points is like a virtual rain gauge. For this exercise, you’ll just pick one near Jacob’s Well Spring.

LABELING FEATURES

To identify Jacob's Well Spring, you'll add labels to the map.

1. In the Map Layers, right-click on the **Hays County Data** layer name and click **Labeling | Label Setup**.

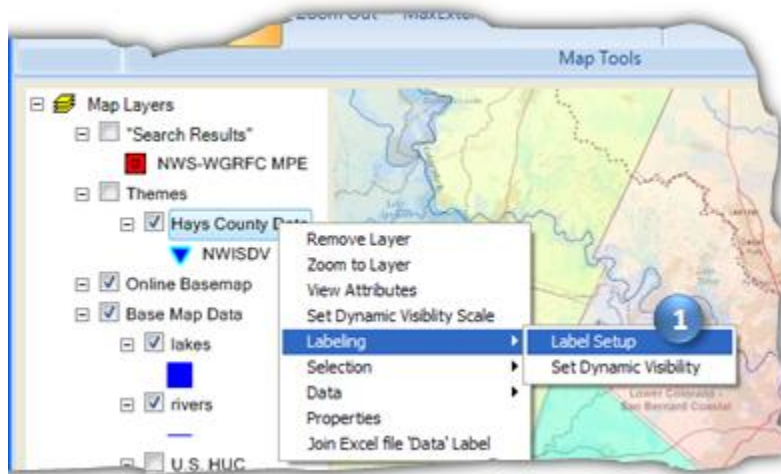


Figure 20 Accessing Label Setup

2. In the Feature Labeler dialog, in the list of Field Names, double-click **SiteName** to use that field for the labels.

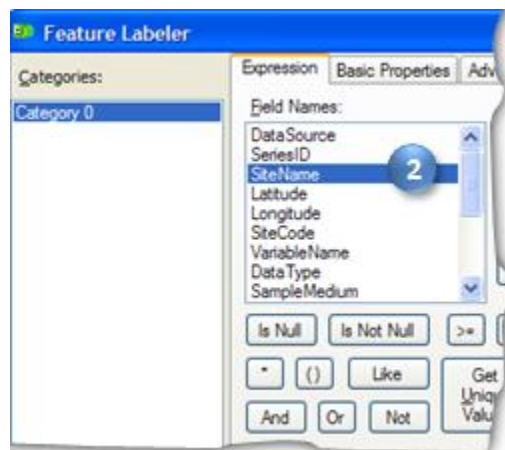


Figure 21 Choosing a Field for Labels

3. Click **Apply**, and then click **OK**. Your map should now be labeled according to the settings you have just chosen. To more easily see the labels, you'll turn off the search results layer.
4. In the **Map Layers**, uncheck **Search Results** to temporarily hide that layer. You should now be able to see dots representing the streamflow and temperature time series that you already downloaded.



Figure 22 Labeling USGS Sites

ADDING DATA TO A THEME

Now that you can easily see the location of Jacob's Well Spring, you will zoom into it and choose nearby precipitation time series to download.

1. Click the **Zoom In** tool to activate it.
2. In the map, click and drag to draw a box just around the locations of time series you have already downloaded. The map zooms in to this area.



Figure 23 Zooming in to the Study Area

3. In the **Map Layers**, check **Search Results** to show that layer.
4. In the ribbon, click the **Select** tool to activate it.
5. In the **Map Layers**, make sure the **Search Results** layer is selected. The Select tool works with the selected layer in the list of map layers.
6. Draw a box around one or more precipitation sites to select time series for download.
7. In the **Search Panel**, in the **Results** tab, select **Hays County Data** in the **Existing Theme** text box.
8. Click **Download Data**.

The precipitation data are added to your theme. Now let's view the results.

9. Click the **Graph** tab.
10. Plot a graph with one of the **precipitation** time series you just downloaded and **Discharge from Jacob's Well Spring**. Notice how quickly Jacob's Well Spring responds to rainfall events.

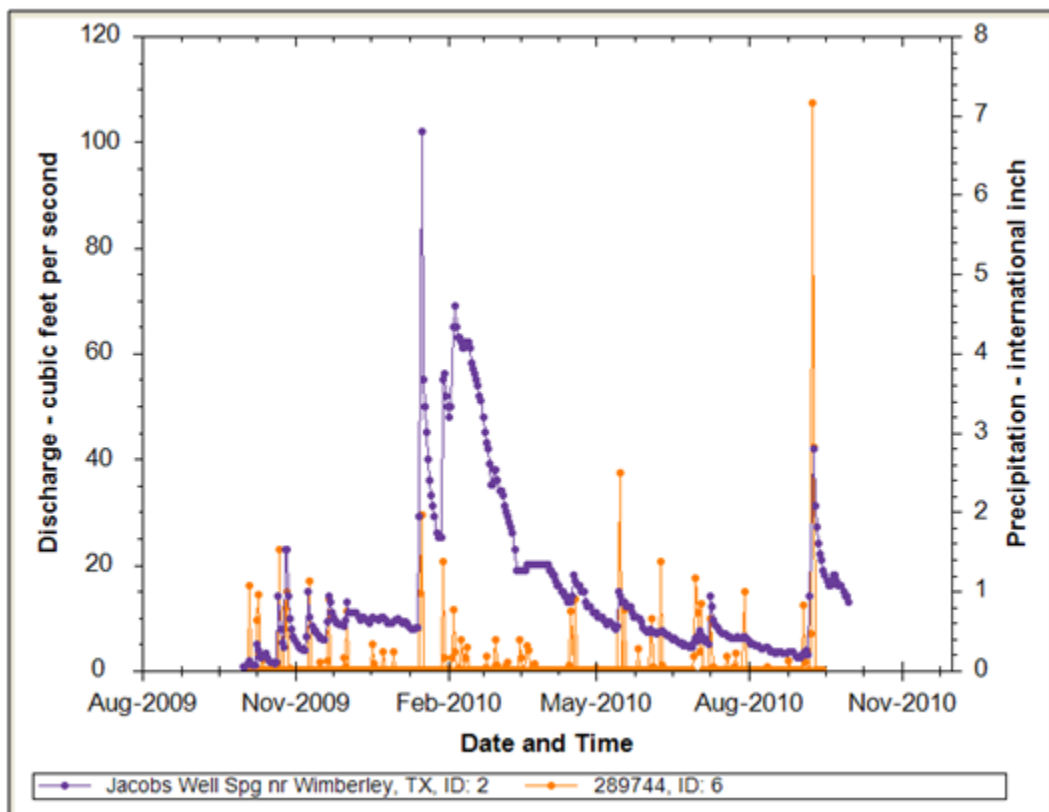


Figure 24 Rainfall and Streamflow at Jacob's Well Spring

While HydroDesktop does contain additional analysis capabilities, it can also export data to a text file for use in other programs.

EXPORTING DATA

HydroDesktop can export data to a variety of output file types for further study and analysis. For example, you can export individual time series by placing a check next to them and then right-clicking them in Table or Graph view. For this exercise, you will export all time series for an entire theme.

To export time series data for a theme:

1. Click the **Table** tab in the ribbon to activate it.
2. In the **Data Export** group, click **Export**.

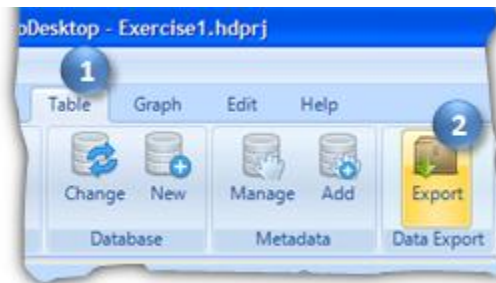


Figure 25 Exporting Data

This tool exports all data in a theme to a delimited text file. In the Export To Text File dialog, notice that your theme name is already selected by default. You can also control the fields that are included in the export and choose a delimiter. For this exercise, you will accept all defaults to produce a comma delimited text file.

3. In the **Export To Text File** dialog, specify the output file location and name.
4. Click **Export Data**.
5. Close the **Export To Text File** dialog when it is finished.

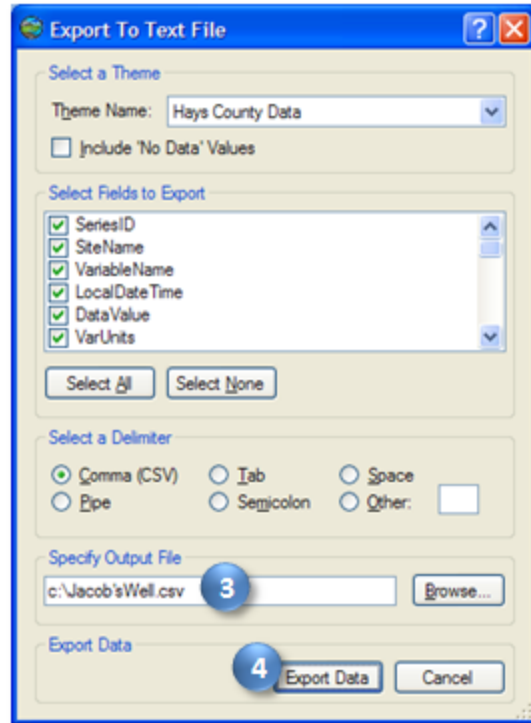


Figure 26 Setting Export Options

6. Find the file on your computer and open it to verify that the data were exported.

Congratulations! With your theme data in hand, you have completed the exercise and learned how to use HydroDesktop to discover and access water data. Feel free to experiment with other functionality such as creating and printing a map, and be sure to give feedback using the Help tab. This concludes the main portion of the exercise. For an example of more advanced analysis, continue with the section below to learn how to use the R statistical environment with HydroDesktop.

ADVANCED: ANALYSIS WITH R

The work above has illustrated temperature, precipitation and discharge data and suggested that variations in temperature in Jacob's Well Spring may be related to the mixing of surface and subsurface water sources. In this section, you will use the HydroR plug-in in HydroDesktop to explore this phenomenon. The HydroR plug-in provides an interface between HydroDesktop and the free R statistical software environment.

INSTALLING R

R is a separate project from HydroDesktop, so you will need to install it if it is not already installed on your computer. It is not included with the HydroDesktop installation.

To install R:

1. In a Web browser, navigate to <http://www.r-project.org/>.
2. Click the **download R** link.
3. Click the link for a download site near your current location.
4. Click the link for your operating system (most likely Windows if you are using HydroDesktop).
5. Click the link for the **base** installation.
6. Click the link to **Download R**.
7. Run the setup file and follow the instructions to complete the installation.

ENABLING THE HYDROR PLUG-IN

Once R is installed, you will need to enable the HydroR plug-in in HydroDesktop.

To enable the HydroR plug-in:

1. Click the **HydroDesktop Orb** button.
2. In the **Orb** menu, click **Extensions**. In the extensions list, click **HydroR**. This adds a HydroR tab to the ribbon. You may have to hover the mouse on and off of Extensions to make the list open.
3. Click the **HydroR** tab in the ribbon to activate it.
4. In the **HydroR** tab, click **Start R**.
5. If prompted for the path to R.exe, enter the path where it was installed on your computer. Note that R may include more than one R.exe file. The one you typically need is in the **bin\i386** folder, as in C:\Program Files\R\R-2.12.0\bin\i386\R.exe. Click **OK** once the path is entered. HydroDesktop will remember this path the next time you use the HydroR extension.
6. HydroDesktop needs some additional R libraries. If you are using the HydroR extension for the first time, you may be prompted for a CRAN mirror to download these libraries. Select the mirror closest to your location and click **OK**. The appropriate libraries are downloaded automatically.

R should now start and give you a blank R script in the top panel and R Console in the bottom panel. Standard R commands can be entered in the R Console. HydroR makes it easy to provide R access to the data you have downloaded with HydroDesktop using the buttons on the ribbon in the HydroR tab.

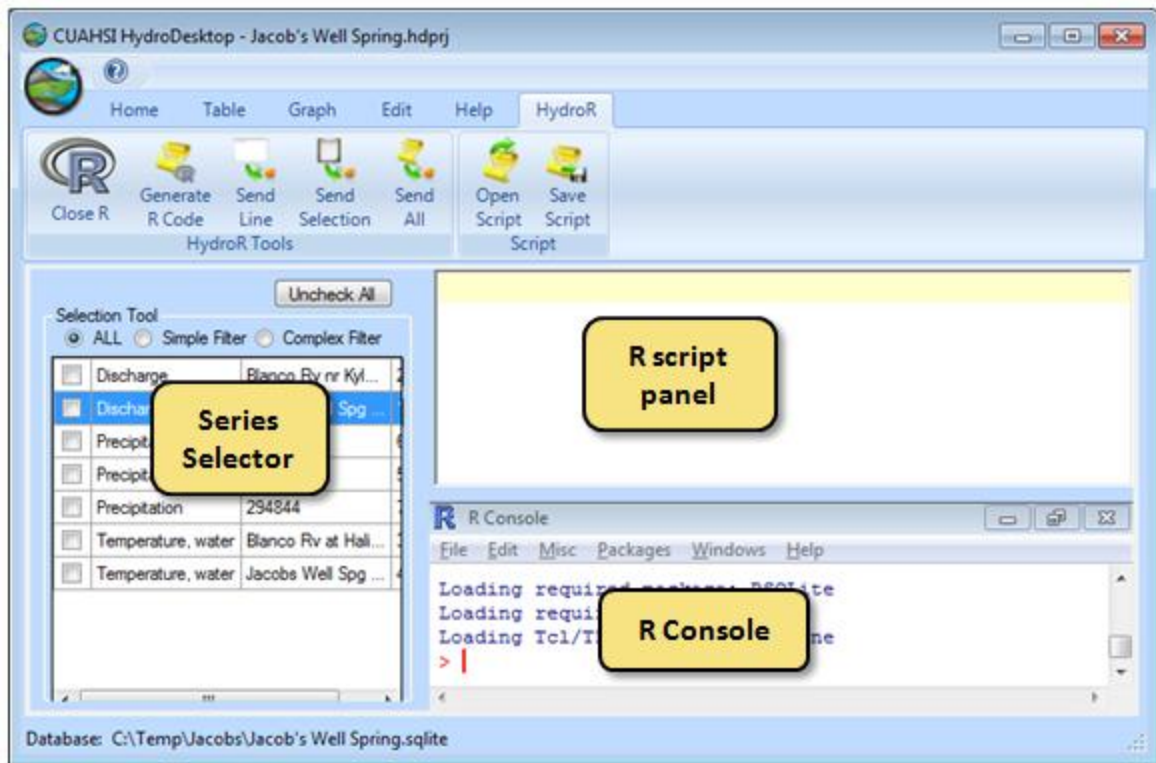


Figure 27 HydroR Layout

PLOTTING A GRAPH WITH R

To get familiar with how HydroR works, you'll plot a hydrograph for Jacob's Well Spring.

To plot a graph in HydroR:

1. In the **HydroR** tab, in the list of time series on the left, select a time series that you would like to import as a data frame into R. For this exercise, select **discharge at Jacob's Well Spring**.
2. In the ribbon, click **Generate R code**. The R code to get the selected data series is entered into the script.
3. Click **Send All**. This sends the script text to the console and executes it. The result is an object named **data0**, which contains a list of R data frames.
4. In the **R Console**, enter **labels(data0)** to see a list of data frames that make up data0.

These data frames are basically tables from your HydroDesktop database. The key table we're interested in for this exercise is the DataValues table.

5. To see the first six rows of DataValues, in the **R Console**, enter **head(data0\$DataValues)** (R is case sensitive, so type the command exactly as it appears in this text). You may have to scroll up in the R Console to see the full result.

You'll use the LocalDateTime and DataValue columns to provide data for the graph.

6. To make it easier to access this streamflow time series, in the **R Console**, enter `Q.jacobs=data0$DataValues`. This assigns the DataValues data frame to a variable named **Q.jacobs**.
7. In the **R Console**, enter `plot(Q.jacobs$LocalDateTime,Q.jacobs$DataValue,type="l")` (the type is a lower case L, not a one). A time series plot of the data should appear in an R graphics window, demonstrating that the full capability of R is available to work with the data that has been imported.

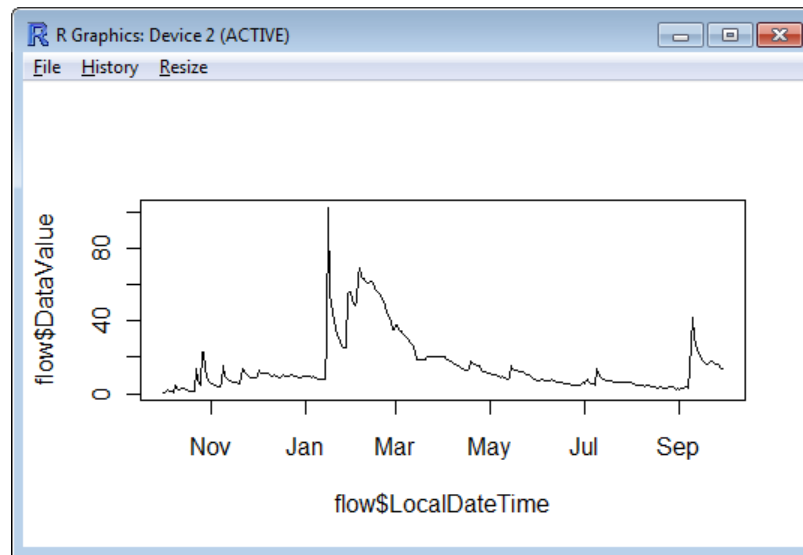


Figure 28 Jacob's Well Spring Hydrograph Plotted Using R

Let's add a title to this graph.

8. In the **R Console**, enter `data0$Variable` to see all attributes for the Variable table.
9. In the **R Console**, enter `title(data0$Variable$VariableName)` to add the variable name as the title for the plot.
10. After verifying that the title was added, close the R graphics window showing the graph.

ANALYZING FLOW IN JACOB'S WELL SPRING

Let's use mixing theory to estimate the fractions of Jacob's Well Spring flow that are from the surface and subsurface based on temperature. Assume the surface source has temperature equal to the temperature in Blanco River. Assume groundwater source is at a fixed temperature. The following equations then apply.

$$\text{Energy Balance: } QT = Q_1T_1 + Q_2T_2$$

$$\text{Mass Balance: } Q = Q_1 + Q_2$$

where Q is discharge in Jacob's Well Spring, T is Temperature in Jacob's Well Spring, T_1 is the temperature of the surface source (assumed equal to Blanco River temperature), and T_2 is the temperature of the subsurface source (assumed constant and taken as the average of last 60 days). Q_1 and Q_2 are the unknown discharge contributions

from surface and subsurface sources respectively. Two linear equations, two unknowns can be easily solved (see your high school algebra book). The solution is

$$Q_1/Q = (T-T_2)/(T_1-T_2)$$

The R scripts in Appendix A use data from HydroDesktop to solve this equation. You'll assign the relevant time series to simple variable names and then use the R scripts to plot a graph representing the amount of flow in Jacob's Well Spring inferred as coming from the surface.

To use the R scripts to compute fractional flow:

1. In the same manner that you created the Q.jacobs variable above and assigned it to be the discharge at Jacob's Well Spring, create and assign the following R variables (remember, the variable names are case sensitive). In other words, for each variable, clear the R script panel, select a series, generate the R code, send it to R, and assign the variable in the R Console.
 - a. Q.blanco – Discharge at the Blanco River near Kyle
 - b. t.jacobs – Water temperature at Jacob's Well Spring
 - c. t.blanco – Water temperature at the Blanco River at Halifax Ranch

IMPORTANT

You may encounter a bug when generating R code for water temperature at Jacob's Well Spring. In the R script panel, if the endDate is not "2010-09-30" then edit the script to use "2010-09-30" before sending the script to the R Console.

2. Enter **Script 1** found in Appendix A into the **R Console** to execute the script. This script prepares inputs for the analysis and plots graphs of the input temperature and flow.
3. Once you have reviewed the graphs of temperature and streamflow generated by Script 1, close the two R Graphics Windows containing the graphs.
4. Enter **Script 2** found in Appendix A into the **R Console** to execute the script. This script smooths the temperature time series and then performs the analysis to determine the fraction of flow in Jacob's Well Spring from surface water.

The resulting graphs show smoothed temperature time series and the portion of flow in Jacob's Well Spring inferred to be from the surface (the red line in the graph). Note that the analysis requires differences between the assumed groundwater temperature and surface water temperature, so the graph will be missing segments when those temperatures are nearly the same.

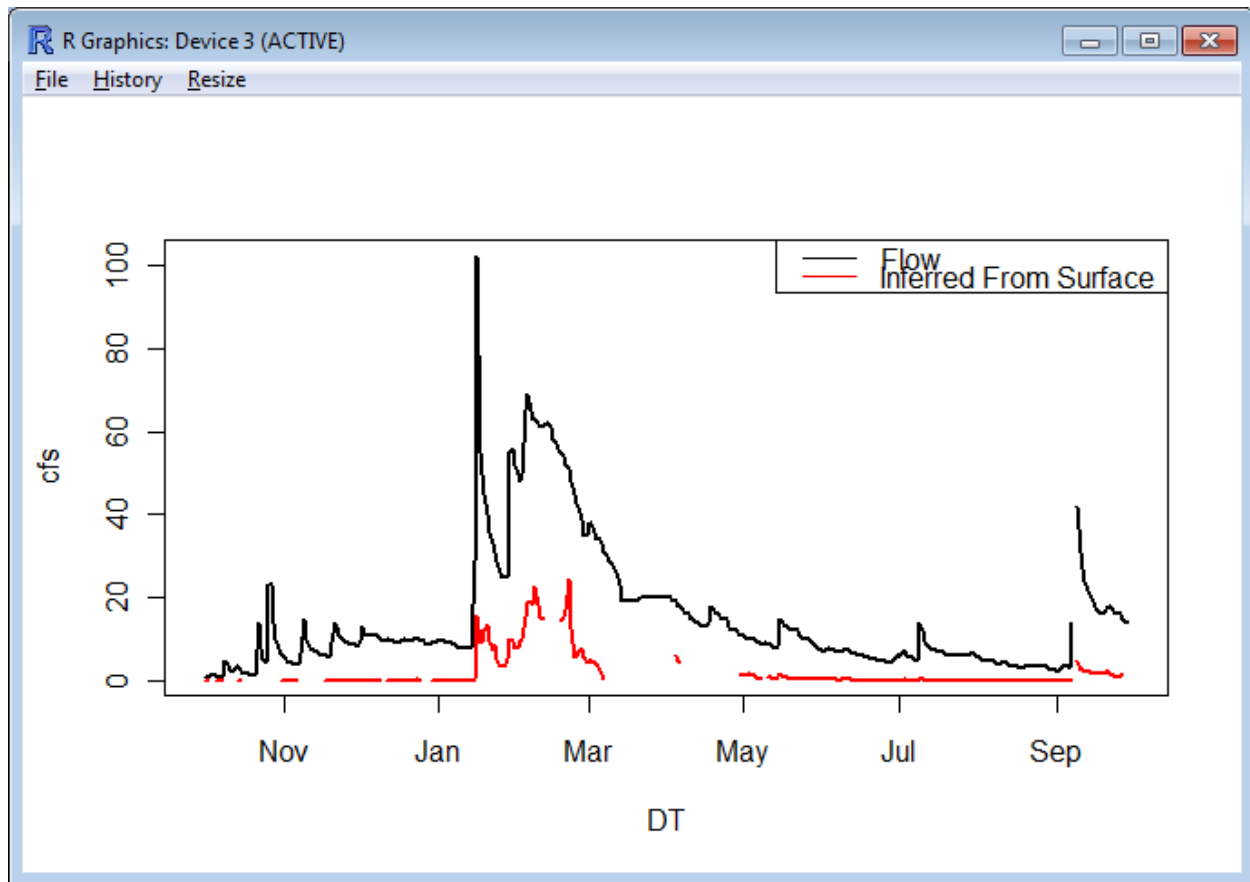


Figure 29 Fractional Flow in Jacob's Well Spring

Congratulations! You have completed the exercise and seen how advanced analysis environments such as R can be integrated into HydroDesktop using the power of plug-ins. This concludes the advanced portion of the exercise.

APPENDIX A: R SCRIPTS

SCRIPT 1: PREPARING INPUTS FOR FLOW ANALYSIS

```
# SCRIPT 1: PREPARING INPUTS FOR FLOW ANALYSIS

# This code plots input time series of flow and temperature.
# The code assumes the following variables have already been set to
# the DataValues data frame for these time series:
#   Q.jacobs - Discharge at Jacob's Well Spring
#   Q.blanco - Discharge at the Blanco River near Kyle
#   t.jacobs - Water temperature at Jacob's Well Spring
#   t.blanco - Water temperature at the Blanco River at Halifax Ranch
# The code handles intermittent missing values

# Start one day earlier because queries seem to be based on UTC
DT = seq(from=as.Date("2009-09-30"), to=as.Date("2010-09-30"), by=1)
ind=match(t.blanco$LocalDateTime, DT)
T1=rep(NA, length(DT))
T1[ind]= t.blanco$DataValue

ind=match(t.jacobs$LocalDateTime, DT)
T=rep(NA, length(DT))
T[ind]=t.jacobs$DataValue
T2 = T[1] # The first value

ind=match(Q.jacobs$LocalDateTime, DT)
Q=rep(NA, length(DT))
Q[ind] = Q.jacobs$DataValue
plot(DT, T1, type="l", ylab="T")
lines(DT, T, col=2)
legend("bottomright", c("T Blanco", "T Jacobs"), col=c(1, 2), lty=1)
windows()
plot(DT, Q, type="l")
```

SCRIPT 2: COMPUTING SURFACE WATER FLOW FRACTION

```
# SCRIPT 2: COMPUTING SURFACE WATER FLOW FRACTION

# This script solves the equation  $Q_1/Q = (T-T_2)/(T_1-T_2)$ 
# and plots a graph showing the portion of flow inferred
# to be directly from surface water sources in Jacob's
# Well Spring.
# Before running this script, you must run SCRIPT 1:
# PREPARING INPUTS FOR FLOW ANALYSIS

# Smoothing Blanco River temperature data using lowess
ind=!is.na(T1) # array indices of unmissing values
T1l<-lowess(DT[ind], T1[ind], f=0.1)
plot(DT, T1, type="l", ylab="Degrees C")
lines(T1l, col=2)
lines(DT, T, col=3)
legend("bottomright", c("Blanco T", "Smoothed Blanco T", "Jacobs
T"), col=c(1:3), lty=1)
```



```

title("Temperatures")

# Match the dates of the output for use in calculations
ind=match(T11$x,DT)
T1s=rep(NA,length(DT))
T1s[ind]=T11$y

# For results to be reasonable T1 and T2 have to be different.
# Only evaluate answers when T1 and T2 differ by at least 3 degrees
# Also only accept positive answers

# Calculate T2 as average over last 60 days
T2p=c(rep(T[1],59),T)
T2=rep(NA,length(DT))
for(i in 1:length(DT)) T2[i]=mean(T2p[i:(i+59)],na.rm="True")

Q1f=(T-T2)/(T1-T2) # apply the mixing solution equation
# eliminate answers when temperature difference is less than 3
indna=abs(T1-T2)<3
Q1f[indna]=NA
indna=Q1f< -0.05 # eliminate large negative values
Q1f[indna]=NA

# Plot the results
windows()
plot(DT,Q,type="l",ylab="cfs",lwd=2)
lines(DT,Q*Q1f,col=2,lwd=2)
legend("topright",c("Flow","Inferred From Surface"),lty=1,col=c(1,2))
title("Jacobs Well Discharge")

```

REFERENCES

- Davidson, S. C. (2008). *Hydrogeological characterization of baseflow to Jacob's Well spring, Hays County, Texas* (Master's thesis). Retrieved November 2, 2010, from Hays Trinity Groundwater Conservation District Web site: http://haysgroundwater.com/files/Documents/Davidson-08_thesis_Cypress_Crk_Jacobs_Well.pdf.
- San Marcos Local News. (2009, March 10). Jacobs Well area to hold incorporation vote. Retrieved November 2, 2010, from San Marcos Local News Web site: <http://www.newstreamz.com/2009/03/10/area-around-jacobs-well-to-hold-incorporation-election/>.
- United States Geological Survey. (2007, March 26). National Surface Water Conference and Hydroacoustics Workshop. Retrieved November 1, 2010, from United States Geological Survey Web site: http://water.usgs.gov/osw/images/2007_photos/Hydroacoustics.html.