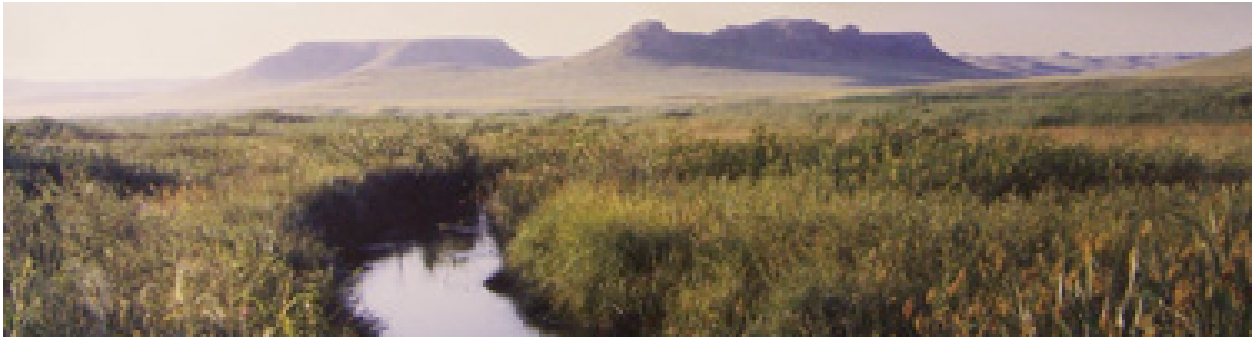


Groundwater Elevation Monitoring at Agate Fossil Beds National Monument, Rationale and Standard Procedures

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LONG-TERM GROUNDWATER MONITORING PLAN

AGATE FOSSIL BEDS NATIONAL MONUMENT

Summary

Groundwater levels will be monitored at three wells using pressure transducers and water level loggers. The well sites were chosen based on availability of existing wells. No new monitoring wells were constructed and none are planned. Data collection and analyses will be a collaborative effort of staff at Agate Fossil Beds, Scotts Bluff National Monument, and the Water Resources Division.

Background

Agate Fossil Beds National Monument is in central Sioux County, in northwestern Nebraska, in the unglaciated High Plains physiographic province (Figure 1). The park is in the Niobrara River Valley about 40 miles north of Scottsbluff. The park preserves a unique unglaciated area of the High Plains. Wetlands stretch out from the river and meet terraces that lead to breaks and buttes. The buttes contain fossil remains, providing important information about the life of mammals in the Miocene Era, 19-22 million years ago. Once part of "Captain" James H. Cook's Agate Springs Ranch, the fossil beds are an important source of Miocene epoch mammal fossils. Cook's ranch was also a gathering place for Chief Red Cloud and other Oglala Lakota (Sioux) Indian people.

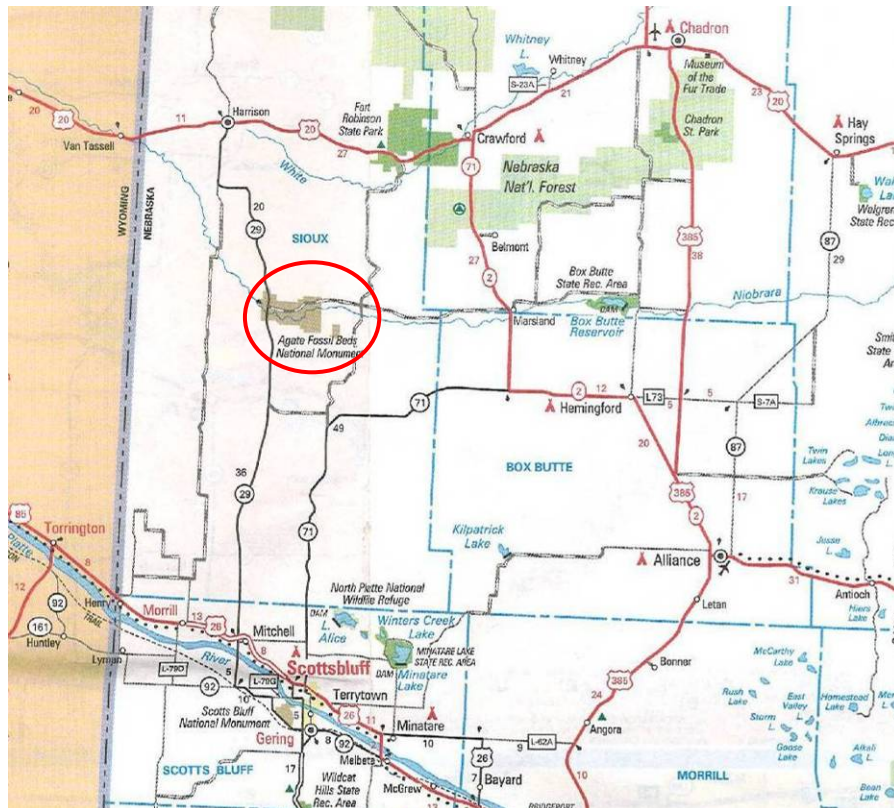


Figure 1. Location of Agate Fossil Beds in western Nebraska.

Agate Fossil Beds National Monument is a small park unit with only 2,700 acres of federally managed land included in the 3050 acres within the park's legislative boundary (Figure 2). Particularly notable is the privately-owned land in the northeast part of the authorized park boundary. This area is an irrigated field and with an irrigation well immediately adjacent to the park's maintenance and housing areas, as shown on Figure 2.

Water resources at Agate Fossil Beds are dominated by the Niobrara River, which flows from west to east through the middle of the park. Groundwater in the alluvium adjacent to the river is closely interconnected with surface water in the river. The alluvium is a buffer to streamflow, accepting recharge during periods of high streamflow and slowly releasing the water from storage during periods of low streamflow.

Stream flow diversions and groundwater pumping upstream of the park reduces streamflow through the park by an unknown amount. Additional groundwater pumping for irrigation from wells immediately downstream of the park may deplete groundwater and streamflow near the eastern boundary of the park.

Geology and Groundwater Resources

The geology and groundwater resources of Agate Fossil Beds and the surrounding area are described by Bradley (1956). Site-specific hydrogeologic conditions are provided in unpublished USGS reports prepared in conjunction with construction of the park's original water supply well in 1967 (Emery, 1966).

The Niobrara River valley is underlain by up to 50 feet of alluvium. The alluvium overlies sand and silt sediments belonging to the Arikaree Group. In general, groundwater in the alluvium along the river is closely interconnected with surface water flow in the river. Water table elevations in the alluvium are thought to mimic stream elevations, with a slight gradient toward the river. Flooding creates opportunities for recharge by infiltration of surface water over large flooded areas, followed by subsequent drainage of the shallow alluvial groundwater to the river. Rainfall and snowmelt provide another source of recharge to the shallow alluvial aquifer. There is a small component of groundwater flow toward the river. Discharge of groundwater to the river maintains baseflow in the stream and generally causes streamflow to increase in the downstream direction. Much of the groundwater in the alluvium probably remains in the alluvium, flowing downstream as a slow-moving underground river. The alluvium acts as a buffer to streamflow, accepting large quantities of recharge during wet periods and slowly releasing the water to the stream during dry periods.

Groundwater in the underlying sediments of the Arikaree Group is recharged by infiltration of rainfall on upland areas. Even though rainfall is low in the area, sandy soils allow rapid infiltration of water, resulting in significant recharge to underlying geologic formations. Figure 3 (Plate 1 from Bradley, 1956) illustrates the hydrology of the Niobrara River valley in the vicinity of Agate Fossil Beds.

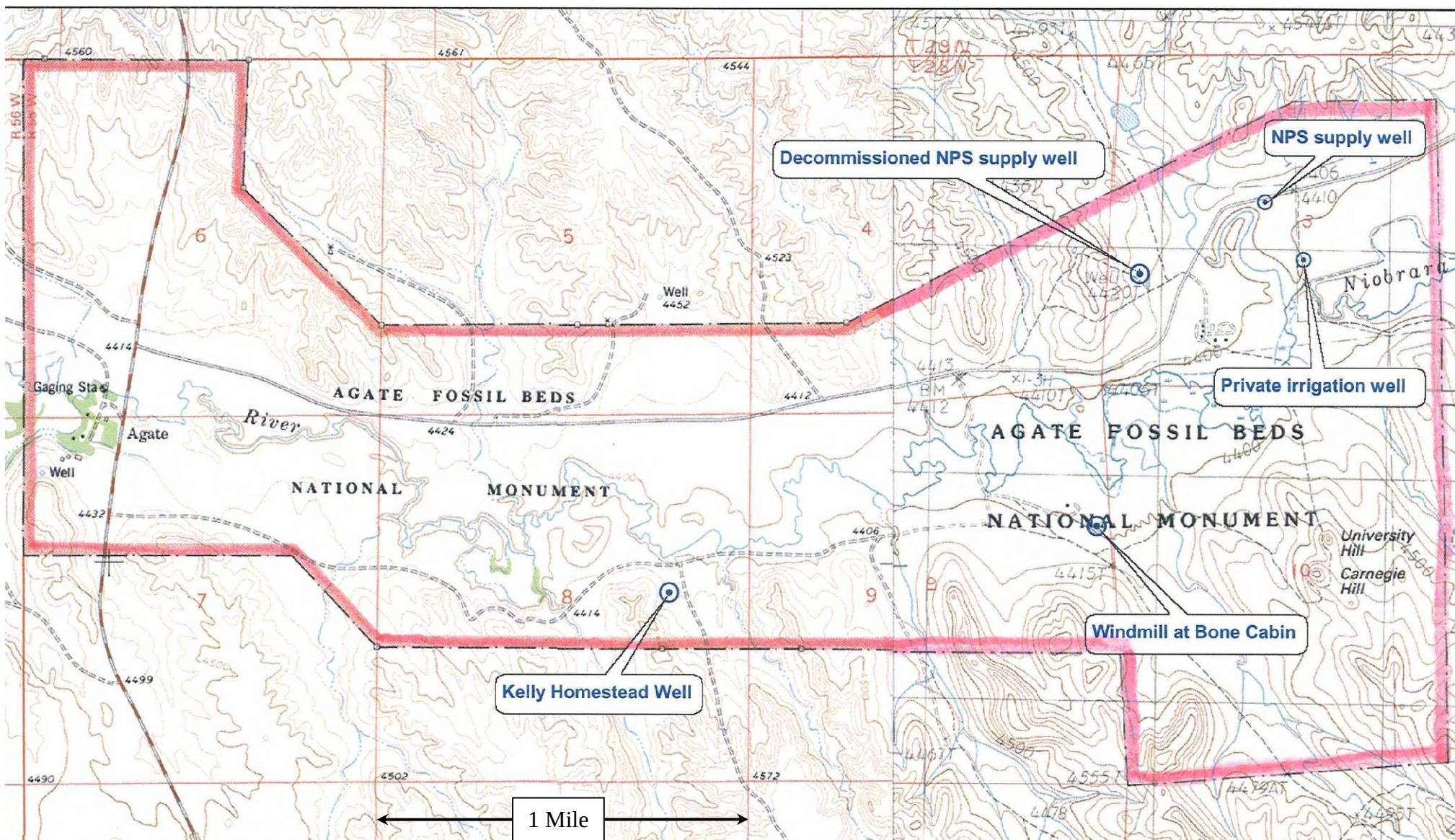


Figure 2. Authorized boundary of Agate Fossil Beds and location of wells discussed in this report.

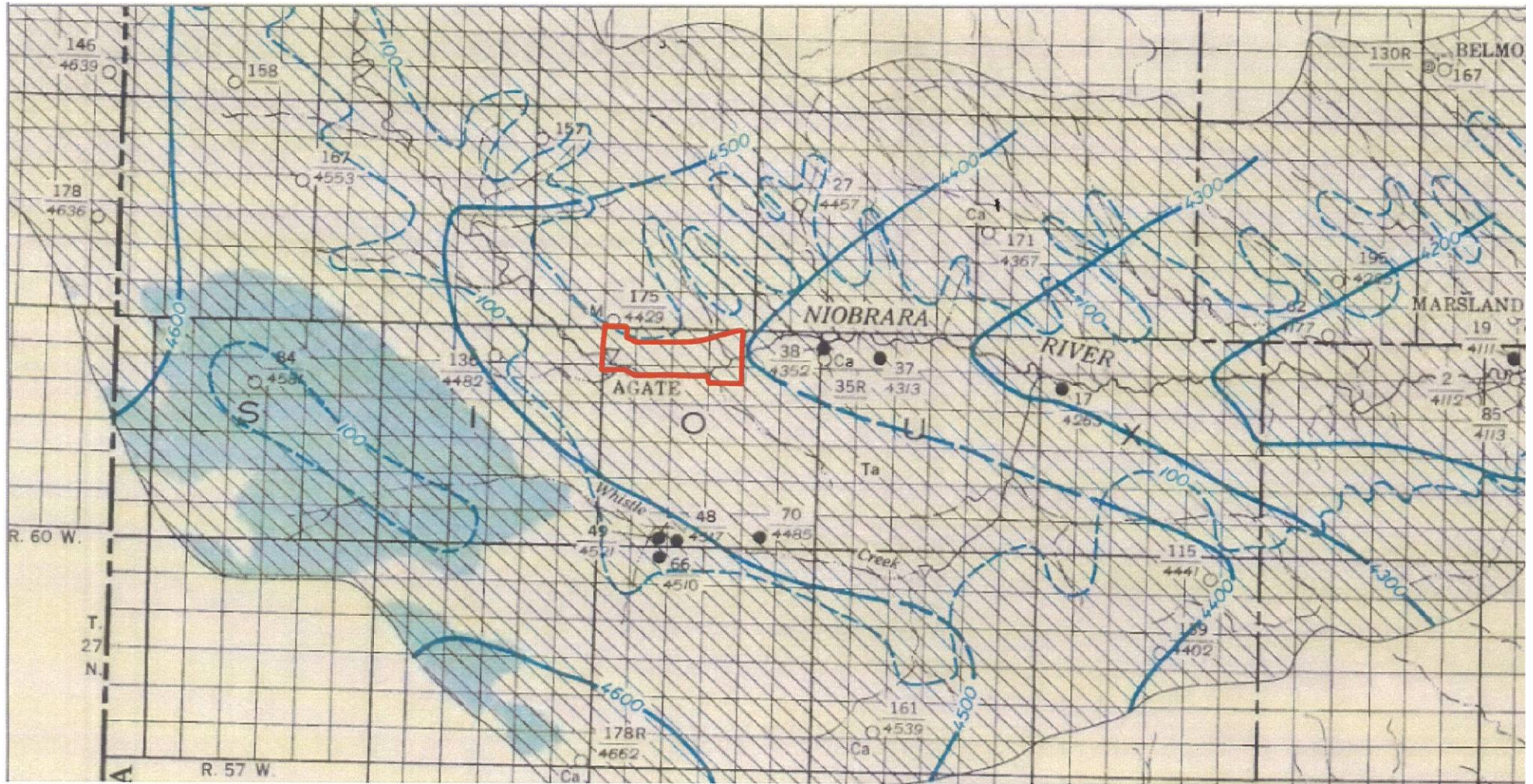


Figure 3. Hydrology of the Niobrara River Valley in the vicinity of Agate Fossil Beds National Monument, (Plate 1 from Bradley, 1956)

The blue dashed line labeled “100” shows the extent of the area (generally the river valley) where it is less than 100 feet to the water table. The contour lines labeled “4300, 4400, 4500” etc. show the elevation of the water table. The red line is the park boundary.

In August 2002, a series of streamflow measurements were made along the length of the river through the park in an attempt to identify areas of significant groundwater inflow into the river. The data were inconclusive in identifying the location of significant springs or seeps. The extreme drought conditions of the summer of 2002 may have contributed to the lack of significant groundwater flow to the stream. Alternatively, groundwater inflow to the river under baseflow conditions may be insignificant over the four miles encompassed by the park.

The park's water supply wells and nearby irrigation wells are constructed into the Arikaree Group, generally to a depth of 100-200 feet. Yields of 100-1000 gpm are common for wells constructed in the Arikaree Group.

Water levels in the parks potable supply well were measured periodically by park maintenance staff from December 2002 to April 2005 and then again in the summer of 2006 (Figure 4). The well is located west of the maintenance building. Water levels fluctuate about 5 feet seasonally. In the winter, the depth to water is about 25 feet below ground surface. In summer the water level drops to about 31-32 feet below ground surface. We do not know how much of this seasonal decline is due to local groundwater pumping (from the irrigation well on adjacent property to the east of the maintenance shop and park housing or from the park's water supply well) vs. how much is natural seasonal fluctuation.

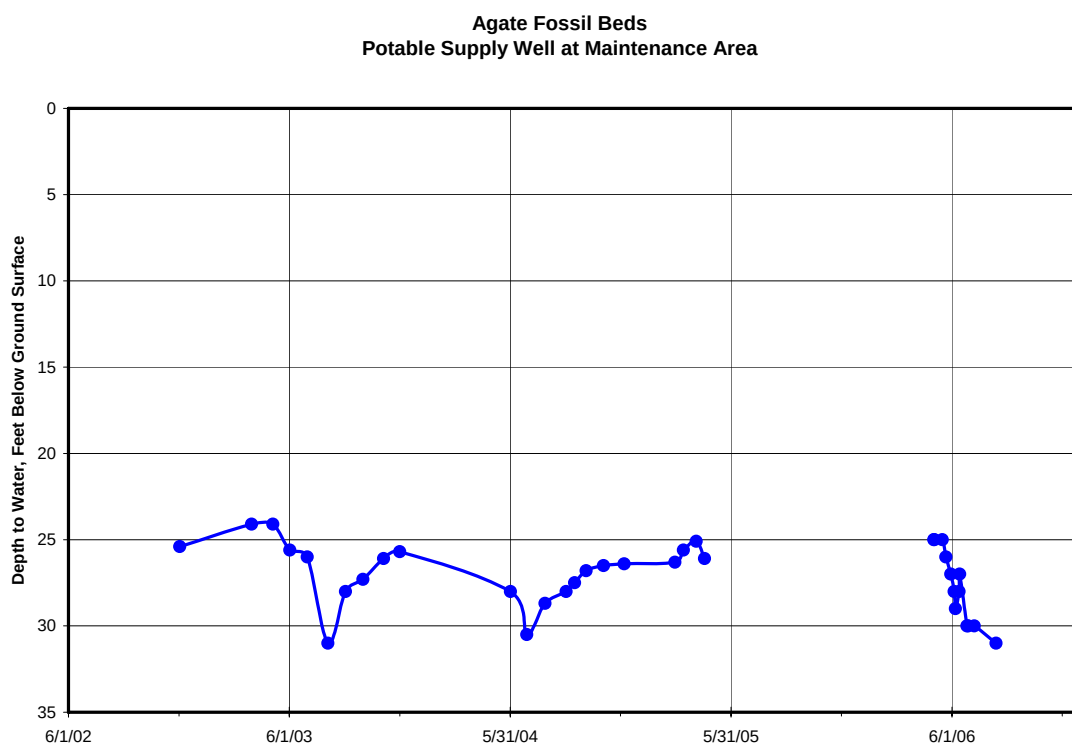


Figure 4. Water level in the park's potable water supply well near the maintenance shop.

Objectives

The objectives for the groundwater level monitoring program are twofold. One is to obtain long-term data on the levels of the groundwater within the park to determine natural fluctuations in response to weather cycles such as drought or wet periods. Second, by having an understanding of the natural fluctuations of the groundwater, we can assess the affects of pumping groundwater from nearby wells.

General Monitoring Protocol

The National Park Service Northern Great Plains Inventory and Monitoring Program purchased three HOBO® U20 water level loggers for use at Agate Fossil Beds National Monument, to enable the park to establish a long-term groundwater monitoring program. Three sites will be monitored during this study, the park's decommissioned water supply well, the windmill well at the Bone Cabin, and an unused well at the old Kelly Homestead (Figure 2). These sites were chosen because there are existing wells at the sites. Physical characteristics of the wells are provided in Table 1.

	Total Depth	Screened Interval	Geological Formation	Depth to Water
Decommissioned Supply Well	239'	139-239'	Arikaree	40'
Bone Cabin Well		---	Alluvium and Arikaree	9'
Kelly Homestead Well	60'	---	Arikaree	50'

Table 1. Groundwater level monitoring wells at Agate Fossil Beds National Monument

The water level loggers are programmed to obtain a reading every 30 minutes. Data are downloaded at approximately 2-3 month intervals. At that time the depth to water in each well is measured manually to obtain confirmation of the accuracy of the water level logger readings and to provide an "anchor" point for the dataset.

The HOBO® U20 Water Level logger is not vented to compensate for changes in the barometric pressure. Originally, we planned to obtain barometric pressure data from one of the weather stations at the park, but none of the weather stations include a barometer. We attempted to use barometric pressure data from National Weather Service stations at Chadorn and Alliance, NE and Torrington, WY to remove the effects of barometric pressure changes from the total pressure measured by the water level loggers. Data from NWS stations did not provide adequate resolution. A fourth HOBO® U20 Water Level logger was purchased and installed in the Kelly Homestead Well at a depth about 3 feet below ground surface. This logger measures only barometric pressure and provides a record of barometric pressure for use with the HOBOWare® Barometric Compensation Data Assistant software.

The three water level loggers that monitor water levels in the monitoring wells were originally deployed on Oct. 13, 2006. The barometric pressure logger was deployed on Aug. 15, 2007.

The data are collected, processed, and maintained by park staff with assistance from a hydrologist with NPS Water Resources Division.

Data from the water level loggers will be processed by the Onset HOBOWare® Pro Software. Updates to the software will be obtained on an “as it comes out” basis. The updates are free of charge from their website (<http://www.1800loggers.com/support/software>).

Monitoring Procedure

Procedures for programming and downloading data from the water level loggers are contained in the user guides and will not be repeated here. The programs are fairly simple to use and operate by user-friendly graphical user interface (GUI) screens. The water level loggers should be programmed to take a measurement at half hour intervals. Water level loggers can be programmed and data downloaded either in the office, or by taking a laptop computer to the field and doing it at each well site.

Depth to water must be measured at each well every time the water level logger is retrieved. Measurements should be made from the measuring point as described for each monitoring well on the field data sheets. The field tech will record the depth to water below the measuring point (usually the top of the well casing) on the field data sheets, the date and time of the measurement, and the date and time that the water level logger was retrieved and deployed.

After downloading, the data must be processed to compensate for fluctuations of barometric pressure. Detailed instructions for the barometric compensation process are provided in the “Procedure” document that accompanies this report.

Analysis and Thresholds

Analysis of the data will be conducted by a hydrologist with NPS Water Resources Division. The data obtained from this project shall be shared with other agencies such as the USGS and State of Nebraska, who are actively monitoring the regional groundwater conditions.

Being that it is a natural phenomenon; no thresholds will be established for natural fluctuations of the groundwater. However, determining the natural fluctuation is crucial for determining thresholds for fluctuations caused by pumping of adjacent wells. Once additional data is obtained the park can determine natural fluctuations and develop thresholds for fluctuations from groundwater pumping.

References

Bradley, Edward, 1956, *Geology and Ground-Water Resources of the Upper Niobrara River Basin, Nebraska and Wyoming*, U.S. Geological Survey Water-Supply Paper 1368, 67 pp.

Emery, Phillip A., 1966, *Reconnaissance Survey of the Geology and Ground-Water Resources of the Proposed Agate Fossil Beds National Monument, Sioux County, Nebraska*, U. S. Geological Survey unpublished report, 4 pp.

Martin, Larry, 2005, *Hydrology of Agate Fossil Beds National Monument, Nebraska*, National Park Service, Water Resources Division Technical Report NPS/NRWRD/NRTR-2005/327, 7 pp plus figure, table, and appendices.

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Procedure for Operating HOB0® U20 Water Level Loggers and Data Management

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Procedure for Operating HOB0® U20 Water Level Loggers and Data Management

Agate Fossil Beds National Monument

Short Summary

1. Program data loggers to record data every 30 minutes. “Launch” the water level logger. The water level logger will begin logging data at 30 minute intervals.
2. Install data logger in the well and make a manual water level measurement.
3. Forget about it for a couple of months.
4. When retrieving data loggers, measure the water level in the well and then retrieve the water level logger from the well.
5. Take the water level logger back to the office and download data to a computer.
6. Go back to the top of this list.

“Launching” a Water level logger

General Information

The internal clock in the water level logger is synchronized with your computer when you connect them. Check the computer clock (lower right corner of the screen) to make certain the computer clock is correct before connecting the logger to the computer.

From the “Launch Logger” popup window

The description should be the serial number of the water level logger and the well where it is deployed. Valid options for serial numbers and wells are;

1028663 Kelly Homestead
1028661 Bone Cabin Windmill
1028692 Decommissioned NPS Well
1146281 Barometric Pressure

(The barometric pressure logger is installed in the Kelly Homestead Well.)

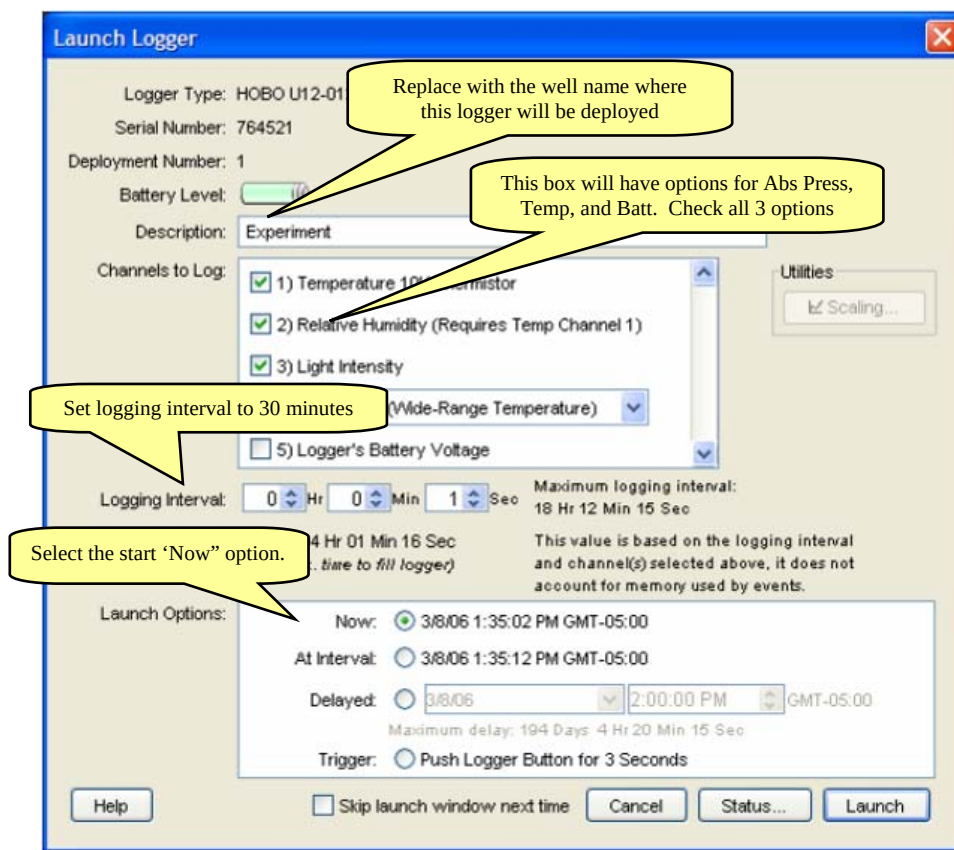
Matching, and double-checking, the serial number and well name will help insure that water level loggers end up in the correct monitoring well. The description will show up as the default file name in the popup window when the data are downloaded and saved. When the data are downloaded and saved, the default file name should be appended with the date in the format “mmm-dd-yy”. For example a data file name might be, “1028663 Kelly Homestead Dec-24-07”.

Deployment of the data logger in the well and associated water level measurements should occur when the water level in the well is stable, i.e., the well is not currently being pumped or recovering from recent pumping. If a water level measurement is made when the well is being pumped, that fact should be noted on the field data sheets and entered as a note in any computer files containing that measurement. The Bone Cabin Windmill is the only well equipped with a pump at this time. It would be good practice to disengage the pumping mechanism the day

before the water level logger is retrieved (or at least a couple of hours prior to retrieval) to ensure that the last several records of water level data are representative of non-pumping water level conditions.

Setup and Programming Data Loggers

1. Open the HOBOWare® Pro software program. Connect the water level logger to the computer via the USB port and cable.
2. Click the Launch icon  on the toolbar. This displays the logger's Launch window which looks similar to the following window.

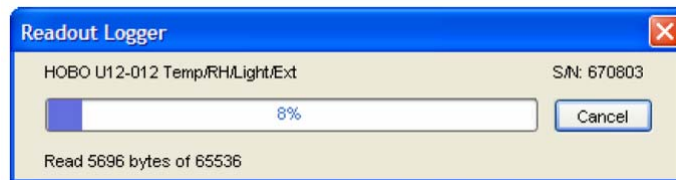


3. Review the default settings and change them as follows:
 - a. Check the boxes to log all 3 available channels;
Abs Press, Temp, and Batt.
 - b. Set the logging interval for 30 minutes
 - c. Set the "Launch Options" to start "Now".

The water level logger will begin measuring and recording data at 30 minute intervals. We chose the start "Now" option because it's not important that the measurements be made at any particular time, or synchronized with other measurements. There will likely be a few recorded events prior to placing the logger in the well (because of travel time between the office and deployment of the water level logger in the well), but they can be easily deleted in the future.

Retrieval and Downloading data

1. Go to the well site. Measure the water level in the well. Since the water level in the well changes slowly, this measurement can be used to calibrate the last recorded data from the water level logger. The worst-case scenario is that the field measurement of the water level in the well and the data recorded by the water level logger will be a half hour apart.
2. Remove the water level logger and return to the office.
3. Connect the logger to the computer.
4. Click the Stop icon  on the toolbar, or choose **Stop** from the Device menu.
5. Click the Readout icon  on the toolbar, or choose **Readout** from the Device menu.
6. Wait while the data are read from the logger. This usually takes only a few seconds.



7. HOBOWare® Pro prompts you to save the data. Save it to the folder designated as the repository for groundwater level monitoring data. By default, the file is saved with the extension of .hobo. Refer to the discussion on naming convention on page 1 of this document. The file name should be of the format; S/N, Well Name, Date. e.g., **1028661 Bone Cabin Windmill Aug-15-07**.
8. Do **NOT** save the data as a “project” at this time.

At this point, the data have been downloaded and saved in a file on the computer. The water level logger can be “Launched”, i.e., restarted and taken to the field for deployment in a monitoring well. The remainder of the data processing and archiving, as described in this document, can be done later.

Barometric Compensation

The HOBO® U20 water level loggers used at AGFO record total pressure. This includes both atmospheric pressure and water pressure (water pressure varies depending on the height of the water table above the pressure transducer. The effects of barometric pressure fluctuation must be subtracted from the total pressure recorded by the logger to obtain the water pressure component. There is an option to perform this correction that becomes available from the HOBOWare® Pro software when a .hobo data file is opened. Double-clicking on a file name will open a Plot Setup dialog box with the options for running the barometric compensation at the bottom part of the dialog box.

Plot Setup

Description: 1028661 - Bone Cabin Windmill Well

Select Series to Plot

Series	Measurement	Units
☒ 1	Abs Pres	psi
☒ 2	Temp	°F
☐ 3	Batt	V

Select Internal Logger Events to Plot

Event	Event Type	Units
☒ 1	Coupler Detached	
☒ 2	Coupler Attached	
☒ 3	Host Connected	
☒ 4	Stopped	
☒ 5	End Of File	

Offset from GMT (+/- 13.0 hours, 0 = GMT) -6

Data Assistants

- Barometric Compensation Assistant

Buttons: Process..., What's This?, Manage..., Load..., Help, Cancel, Plot

Click the **Process** button to proceed to the next step.

1. Select the option to derive fluid density from the temperature channel.

Barometric Compensation Assistant

Fluid Density

- ☐ Fresh Water (62.428 lb/ft³)
- ☐ Salt Water (63.989 lb/ft³)
- ☐ Brackish Water (63.052 lb/ft³)
- ☐ Manual Input lb/ft³
- ☒ Derived From Temp. Channel, assuming fresh water

Barometric Compensation Parameters

☒ Use a Reference Water Level

Reference Water Level:

Reference Time:

3

Barometric Datafile:

When using a reference water level, there is no need to enter a constant barometric pressure

Constant Barometric Pressure:

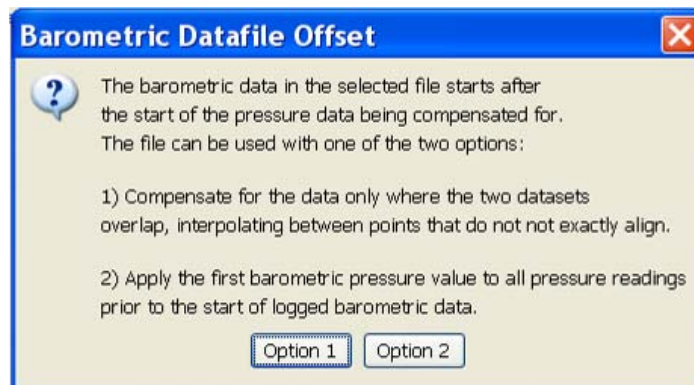
Resultant Series Name:

User Notes:

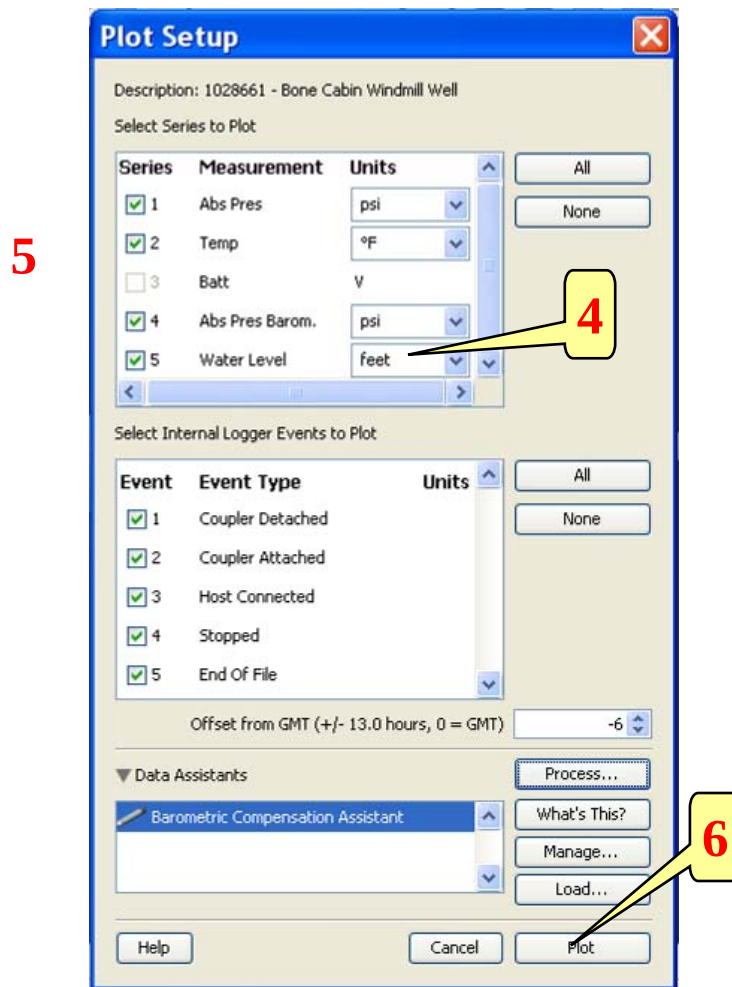
Buttons: Help, Cancel, Create New Series

2. Check the box to use a reference water level and enter the depth to water from the measuring point, usually the top of the well casing. Then select the date & time from the “Reference Time” box that most closely matches the date & time of the water level measurement. Do NOT select one of the anomalous values at the beginning or end of the dataset (usually 2 or 3 values at the beginning or end). The anomalous values are data that were recorded either before the logger was placed in the well or after the logger was removed from the well. Use a reference time that has a pressure value that seems to be representative of most of the data. In this example, the recording of total pressure of 14.902 at 1:05 p.m. on Oct. 10 coincides with a water level measurement of 40.2 feet below the top of the well casing. Enter the value as negative 40.2 because the water level was below the measuring point.
3. Select the data file containing the barometric data that corresponds to the time period for the data from the monitoring well.
4. Accept the default of **Water Level** for the resultant series name and click the **Create New Series** button.

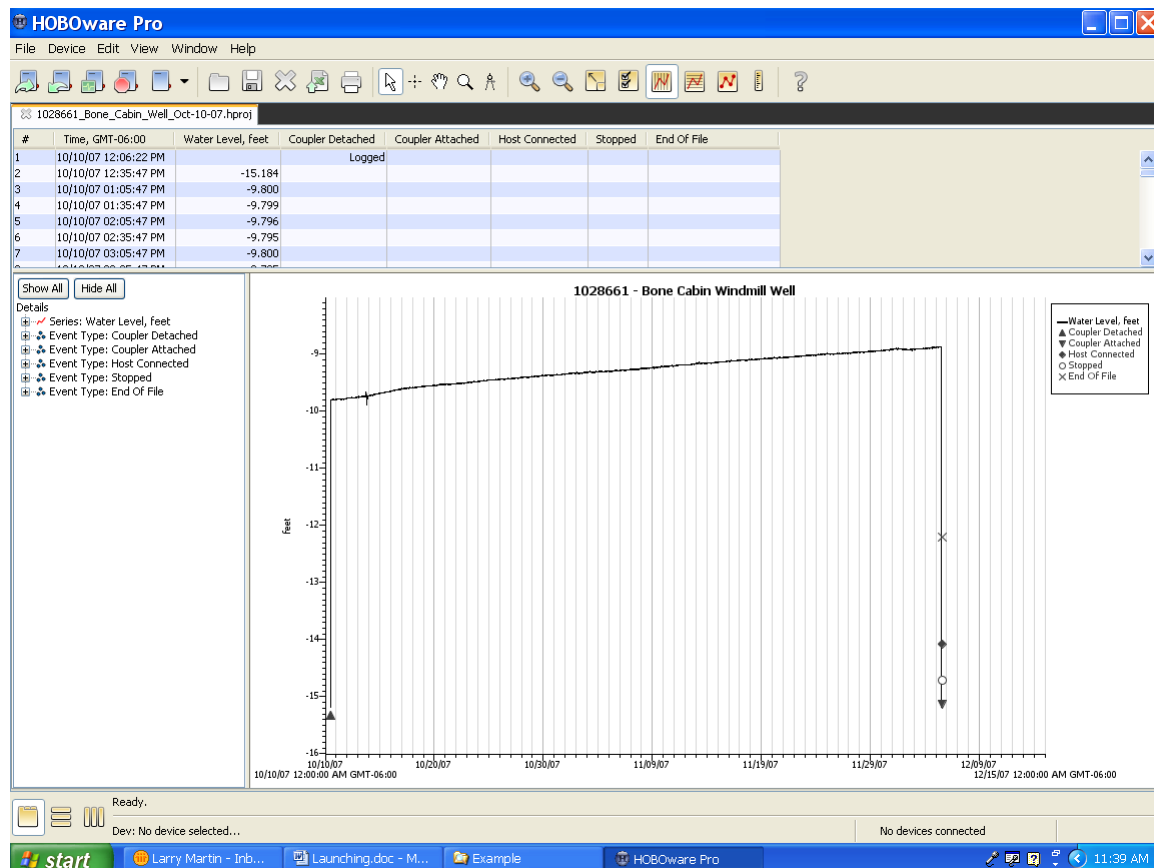
If you get the following popup box, choose **Option 1**. This may occur if the water level logger and the barometric pressure logger do not have exactly the same start and stop times.



A new popup window will appear; “**Plot Setup**”.



4. The barometric compensation program produces a new series of data; Water Level.
5. Uncheck the other series (Abs Pres, Temp, Batt, and Abs Pres Barom) so that the new plot will have only the water level series plotted. Otherwise it gets too cluttered and the resultant Excel worksheet will contain lots of extra columns that you don't need. You can always go back to the original data file to obtain this information.
6. Click on the Plot button at the bottom of the box to get a new plot of the corrected water level data.

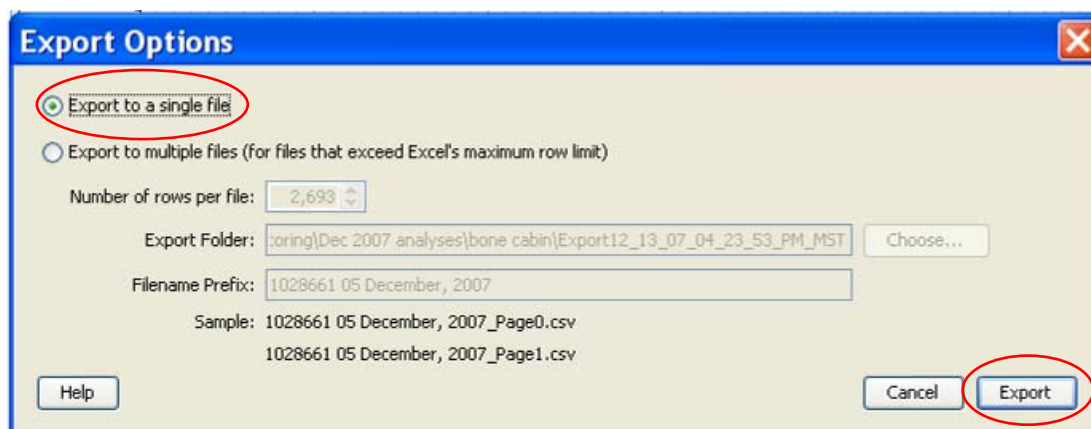


The lower part of this screen shot is a plot of the new, corrected water level series. The upper part is a data file similar to an Excel spreadsheet. You can scroll through the data file by using the slider bar on the right side of the spreadsheet. There are usually a couple of erroneous recordings at the beginning and end of the data file, representing recording events before the logger was placed in the well or after the logger was removed from the well.

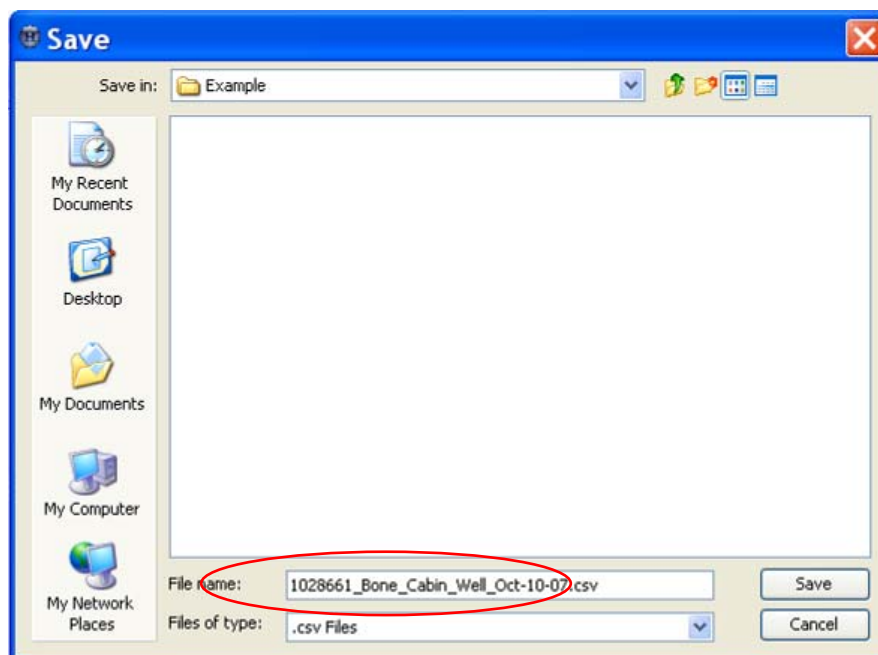
In this example, the water level was gradually rising from about -9.8 feet on October 10 to -8.8 feet on December 5.

Exporting and archiving data

Use the Export Data Button  to export the data to an Excel worksheet in .csv format (.csv is the only format option allowed by HOBOWare® Pro). Choose the option to **Export to a single file** and then click the **Export** button.

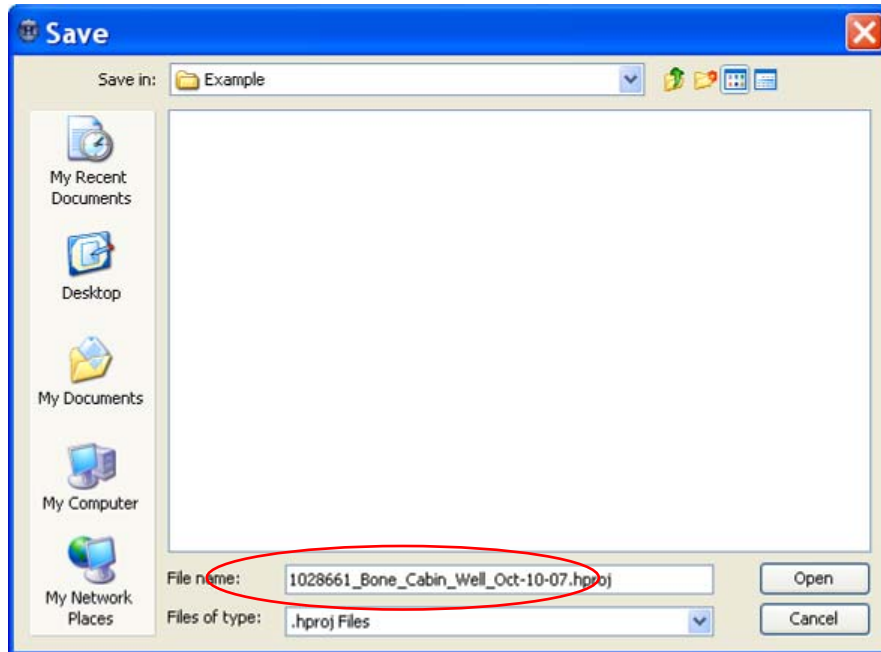


Enter the file name according to the naming convention as stated earlier (S/N, Well name, End date of data file). Be certain that you have specified the proper location (pathway) of the folder where the file is to be stored. (Look at the “Save In” box at the top of the window.)



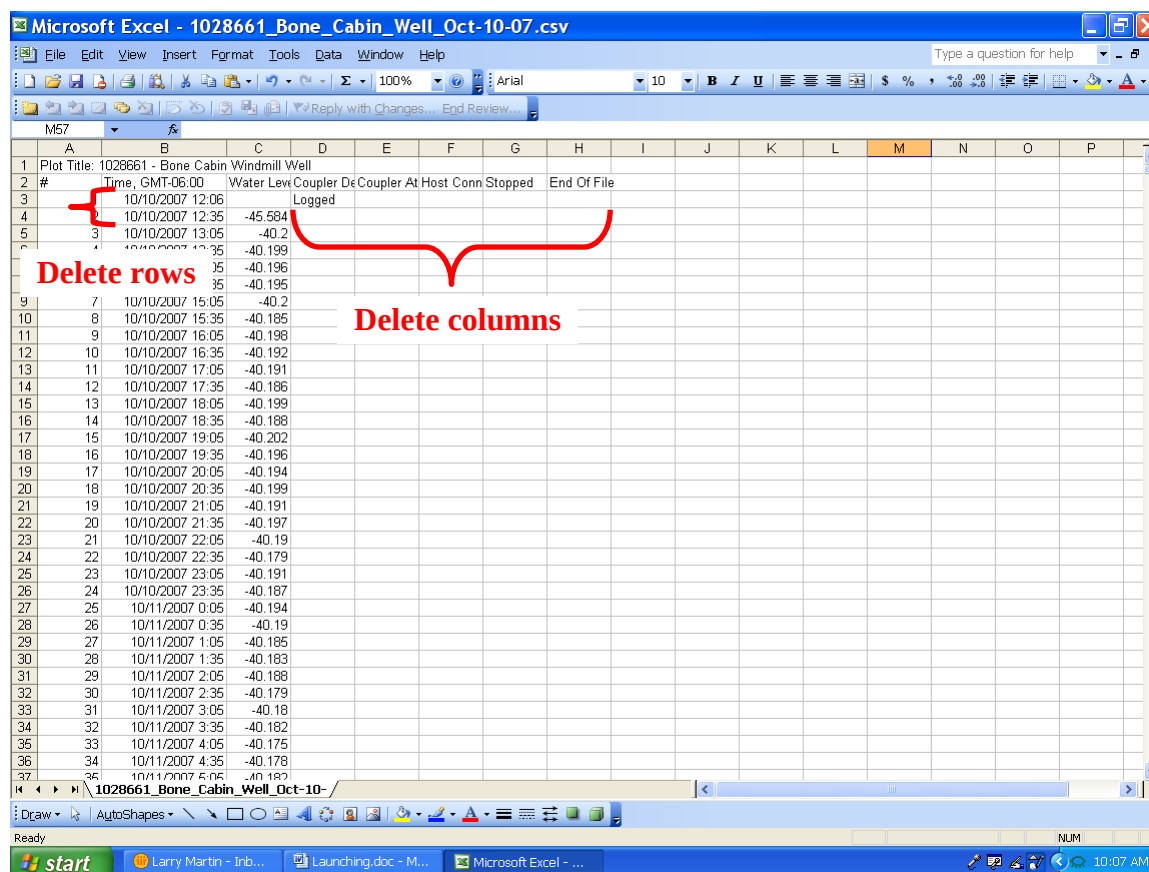
The last step using the HOBOWare® Pro software is to save your work as a “project” file (to distinguish it from the data file). The project file will contain the data after compensation for variations of barometric pressure. The original data file (.hobo) is retained in its original form

and format; containing the raw data. Click on the Save Project icon  or use the drop down menus and select **File, Save Project**. Enter the file name as per the naming convention (S/N, Well Name, End Date of file) and use the default file extension of **.hproj**. Be certain that you have specified the proper location (pathway) of the folder where the file is to be stored. (Look at the “Save In” box at the top of the window.)



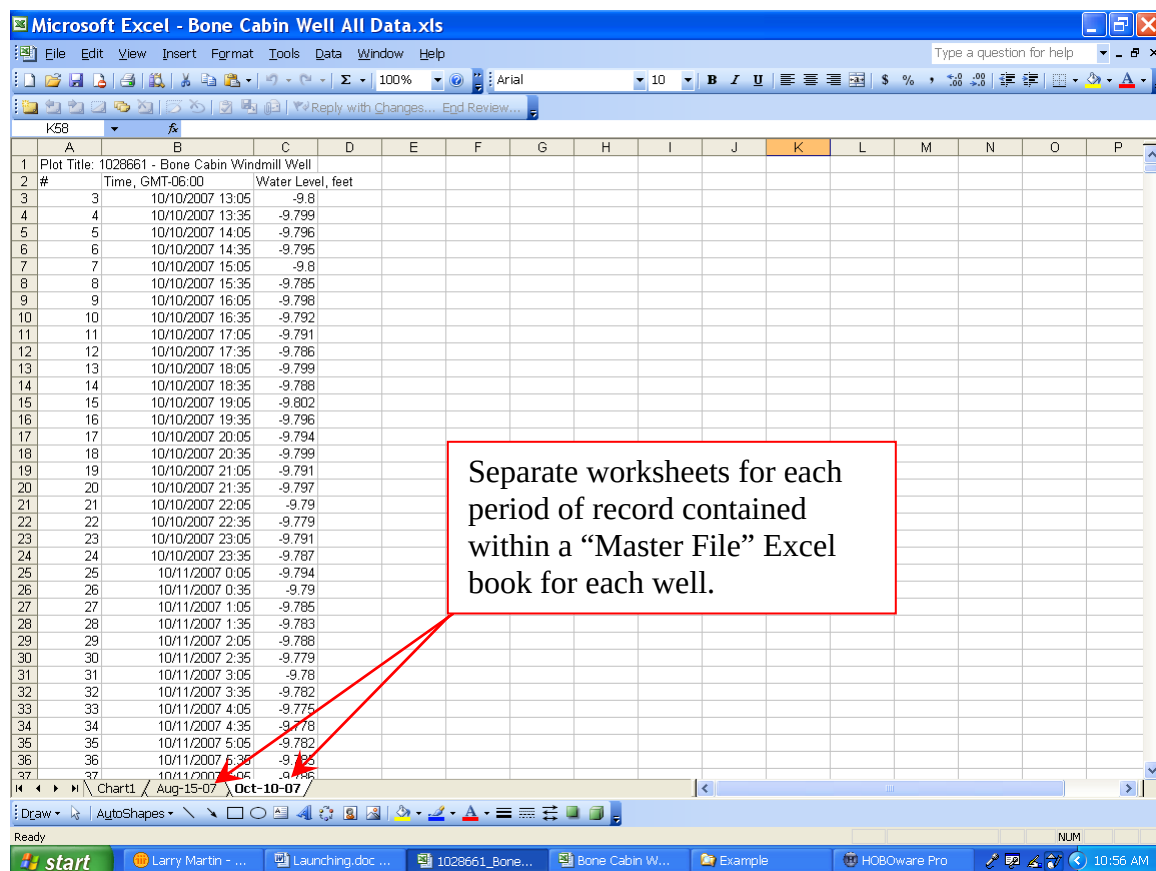
Importing the .csv file into Excel, making graphs, and archiving data.

The .csv file can be opened and manipulated as any other Excel worksheet. The file contains information regarding start and stop times for the data logger in columns D-H. Delete these columns. There will be a couple rows of data at the start and end of the file that contain water levels that are obviously much different than the water levels recorded when the logger is in the well. These data are from recording events that occurred between the time the logger was programmed and “launched” in the office and when it was installed in the well. The anomalous data at the end of the file are from recording events after the logger was removed from the well and before it was stopped to download data in the office. Delete the rows containing anomalous data at the top and bottom of the file. Save the file in .csv format.

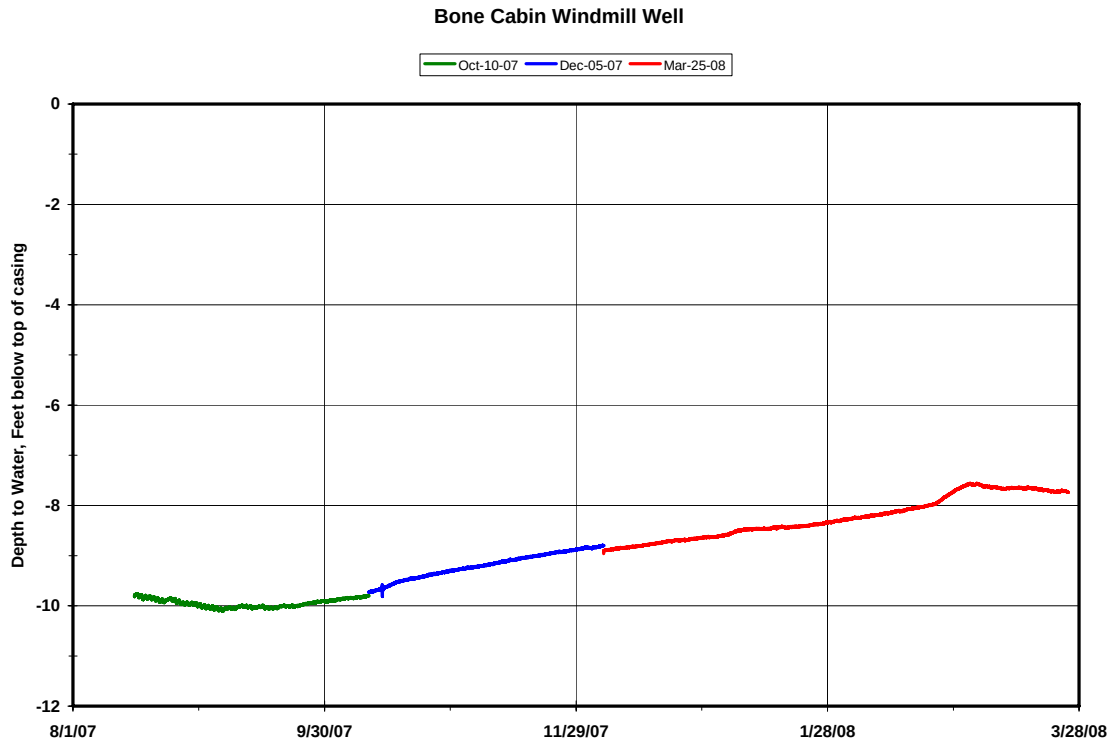


Copy the worksheet to another Excel book which should contain a separate worksheet for each recording period, as shown on the following page. This new book will be the master list containing separate worksheets for each period of record. After the worksheet has been copied to the master list book, rename the worksheet with the date of the end of that recording period.

Use the *Edit, Move or Copy Sheet*, commands from the drop down menus at the top toolbar in Excel. From the popup window, select the “**Book**” that you want to copy the worksheet to and the location of the worksheet relative to other worksheets in that book. Check the “*Create a Copy*” box to create a copy of the worksheet at the new location, otherwise it will be moved and no longer exist in its original location.



A chart can be created using the data from each recording interval as a separate time series. In the following example, the line graph of each series is plotted with a different color.



Daylight Saving Time

The internal clock in the water level loggers does not automatically adjust to the time changes associated with the start and end of daylight saving time. The water level loggers should be retrieved, data downloaded, and the internal clocks should be reset by syncing with the computer's internal clock soon after the time change in the spring and fall (2nd Sunday in March and 1st Sunday in November). That will minimize the amount of data that are offset by one hour from the "clock" time.

When the data are downloaded, the header for the time column will state what the time is relative to Greenwich Mean Time. Mountain Daylight Saving Time is -6 hours GMT. Mountain Standard Time is -7 hours GMT.

No effort will be made to adjust the time in the data files; the ".hobo" files, the ".csv" files, or the Excel spreadsheets. If there was some reason this level of accuracy was needed, it could be done for the particular dataset in question. There will be a one hour differential between the recorded time and actual local clock time for the couple of weeks before/after the time change until the datalogger is next connected to the computer and its internal clock is reset.

Barometric Pressure Effects

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**Effect of Barometric Pressure Fluctuation On Data Recorded
With An Unvented HOBO® U20 Water Level Logger
Agate Fossil Beds National Monument**

Water levels in three wells at Agate Fossil Beds National Monument have been monitored since October 2006 with a HOBO® U20 water level logger. This paper provides examples of the raw data, effect of barometric pressure changes, and water level corrections for barometric pressure changes.

There are many manufacturers of water level sensors and loggers. They all operate by the same basic principle. As water level in a well rises/falls, the pressure on the sensor at a fixed location in a well increases/decreases. It's the same basic principle that causes a person to feel greater pressure on their eardrum when diving into a swimming pool; greater pressure at greater depths.

Water level sensors are either vented or unvented. Vented sensors have a bundle of cables from the sensor to the top of the well. The electrical cables allow communication between the sensor and a laptop computer, allowing retrieval of data and reprogramming of the data logger without removing it from the well. Vented sensors also have a small diameter vent tube running from the sensor to the end of the cable at the top of the well. Barometric pressure changes are transmitted through the vent tube to the sensor, providing compensation for barometric pressure changes. Unvented sensors are generally suspended in a well by a cable. They must be removed from the well to retrieve data and reprogram the data logger. Unvented sensors measure total pressure, both barometric pressure and pressure changes due to water level changes. Data from unvented sensors must be adjusted to remove the effects of barometric pressure changes; producing a dataset that represents the pressure change associated only with water level changes. The water level loggers at Agate Fossil Beds National Monument are unvented.

Figure 1 shows an example of raw data from water level sensors at Agate Fossil Beds. The sensor placed deep in the well, below the water level, measures total pressure; the combined effect of barometric pressure and water level pressure. It should be apparent that most of the variability seen in the record for total pressure is due to fluctuations of barometric pressure. Barometric pressure changes need to be subtracted from total pressure to get the pressure due to water level changes.

In the simplest case, the water level sensor and the barometric pressure sensor would both take a reading at exactly the same time and the water level pressure could be obtained by simply subtracting one value from the other. Measurements are rarely recorded at the same time. Fortunately, the HOBOWare® Pro software will do the interpolation between barometric pressure readings and compute the correction to apply to water level readings that are not simultaneous with barometric pressure readings.

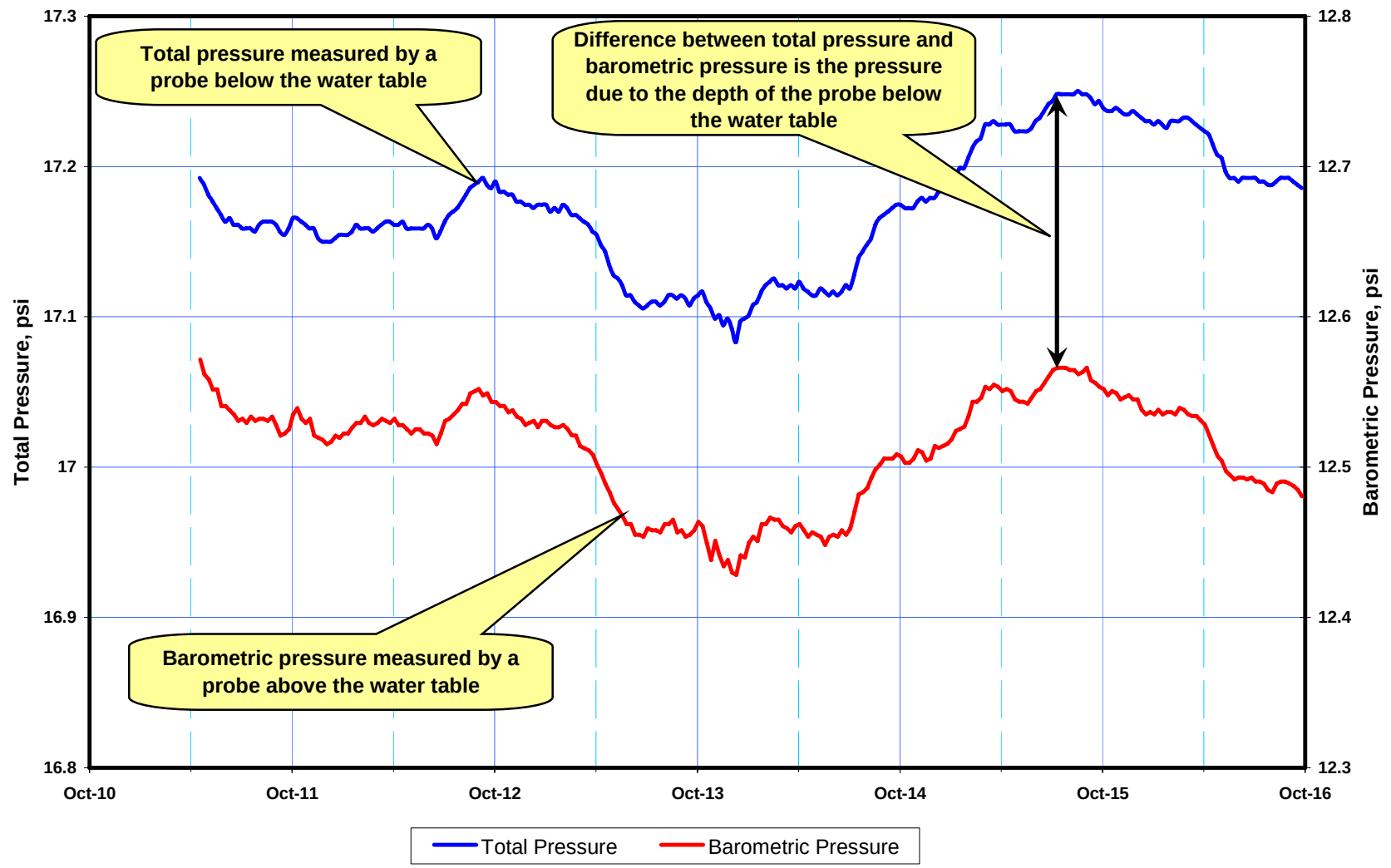
Figure 2 shows the dataset after correcting for variations of barometric pressure. The data are plotted as both psi and the equivalent feet of water. The conversion factor is dependent on the temperature (and therefore density) of the water, but is approximately 1 psi = 2.31 feet water. The small fluctuations are on the order of ± 0.01 feet. The data plot would appear as a straight line if the range of the y-axis was larger. The two different y-axes are offset from one another so that the plotted lines are offset.

Figure 3 shows the total pressure (barometric + water level) as measured by a water level logger in the well. Figure 3 also shows the water level pressure after correcting for barometric pressure fluctuation. The graph has greatly expanded y-axes to maximize visualization of the variability. If the range of the y-axis was 5 feet or more, the graph of water level pressure would appear to be a nearly straight line. The water level gradually rises about 0.2 feet over the 5½ days shown in the graph on Figure 3.

Figure 4 shows the raw data (total pressure) and the corrected water level for this monitoring well for the period between data downloads from early-October to early-December 2007. The y-axes for both sets of data are an equivalent range, i.e., 5 feet = 2.16 psi. The graph shows the difference between the total pressure measured by the unvented pressure transducer and the actual water level data following correction for fluctuations of barometric pressure.

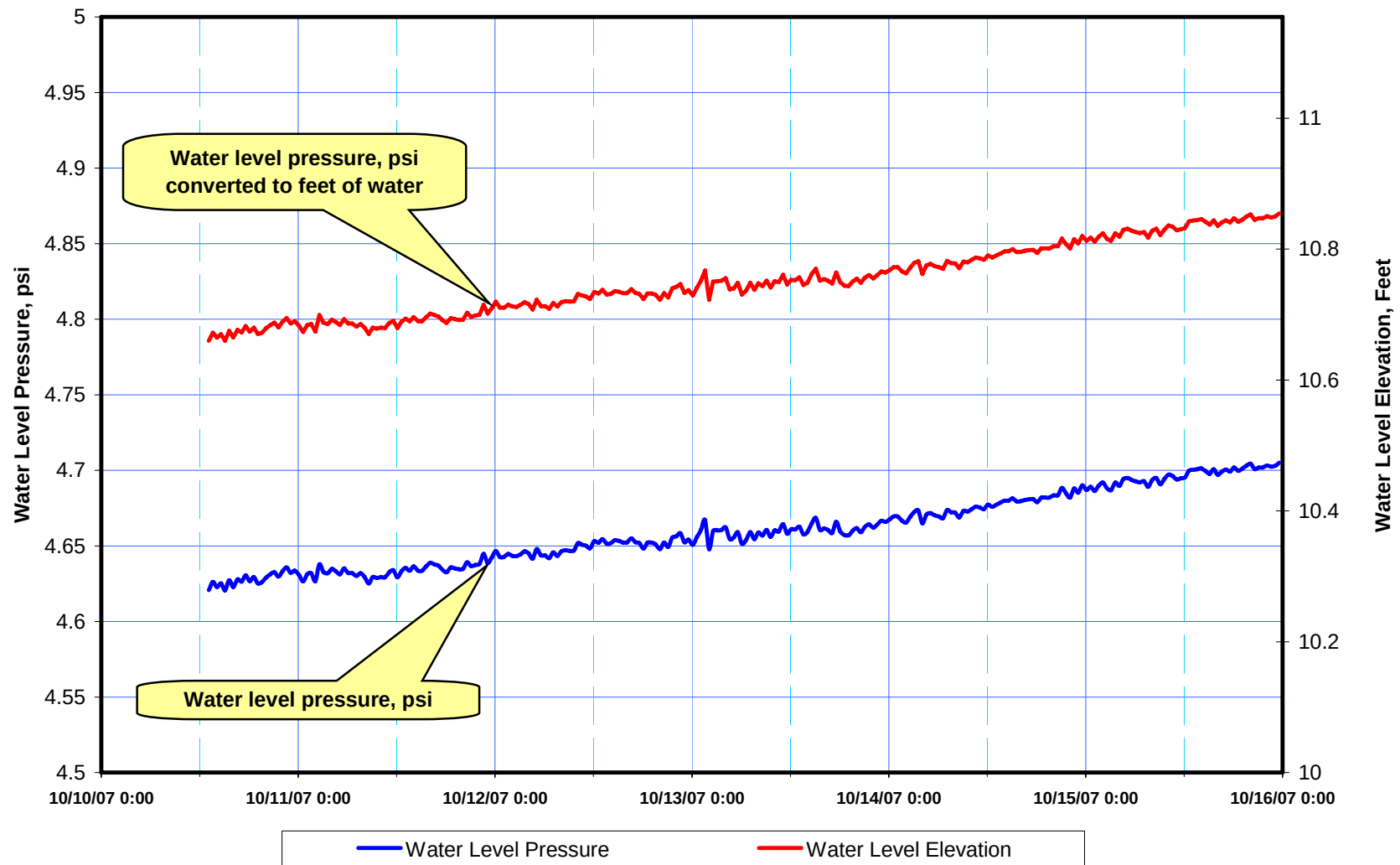
Decommissioned NPS Supply Well
Agate Fossil Beds National Monument

Figure 1



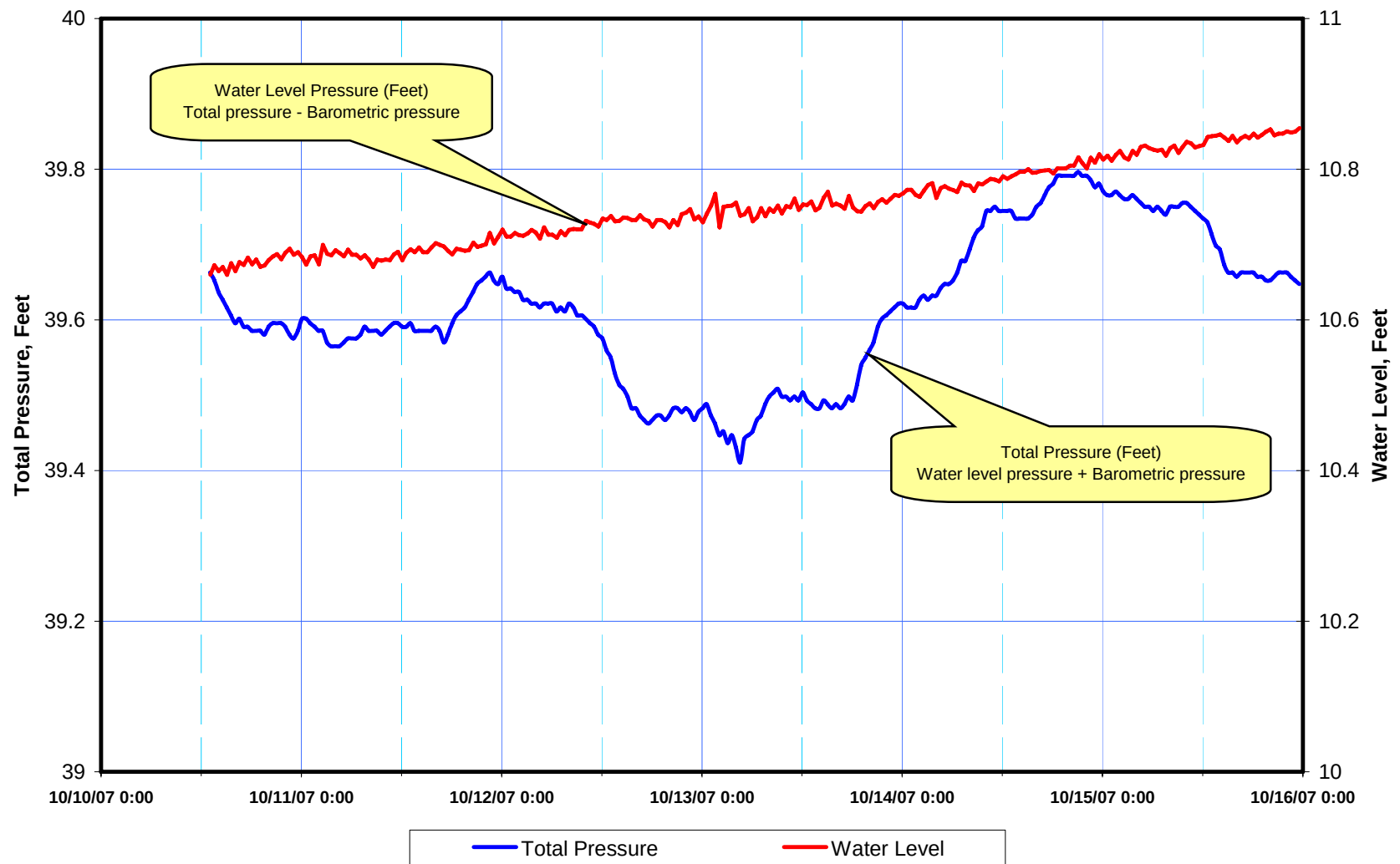
Decommissioned NPS Supply Well
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Figure 2



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Figure 3



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Field Data Sheets

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Agate Fossil Beds National Monument Ground Water Level Monitoring

Kelly Homestead Well, SN: 1028663

Date mm/dd/yy	Time (24 h)			Water Level (to top of casing)		Observer(s)	Notes
	Retrieved	Launched	Deployed	Depth (ft)	Time		
10/13/06		10:00	10:48	50.66	10:48	L.Martin, R.Manasek, T.Trapp	Cable length: 57.1 feet.
11/08/06	14:40			50.49	14:40	Shiny, T. Trapp	
11/09/06		12:00	13:50	50.50	13:52	Shiny, T. Trapp	
11/29/06	11:57	13:00		50.34	11:56	R. Manasek, T. Trapp	
11/29/06		14:00	15:47	50.36	15:44	Lil Morava, T. Trapp	
03/05/07	13:01	15:00	16:16	unk		R. Manasek	
04/20/07	11:29	16:00	13:09	49.60		R. Manasek	
06/14/07	10:41	11:58	12:31	50.20		R. Manasek, Thad Carr	
08/15/07	9:22	13:45	14:15	51.10		R. Manasek, L. Morava	Datalogger S/N 1146281 deployed for the first time to measure barometric data.
10/10/07	10:38	12:07	13:03	50.70	10:37	R. Manasek	
12/05/07	10:43	12:08	13:53	56.30	10:43	R. Manasek	The well appears to have gone dry. The Solinst never sounded and was dry upon retrieval. It became slack at 56.7 feet.
03/25/08	11:56	12:55	15:03	49.52	11:56	R. Manasek	All of the Solinst's cable extended with no slack and did not sound. Upon drawing back up it sounded at 49.52 feet. Go figure.
05/19/08	12:43:00	14:30	15:23	49.72		R.Manasek, L.Martin, P.Miller	

Agate Fossil Beds National Monument Ground Water Level Monitoring

Bone Cabin Windmill Well, SN: 1028661

Date mm/dd/yy	Time (24 h)			Water Level (to top of casing)		Observer(s)	Notes
	Retrieved	Launched	Deployed	Depth (ft)	Time		
10/13/06		10:00	11:50	9.35	11:35	L.Martin, R.Manasek, T.Trapp	Cable length: 15.5 feet from top of casing.
11/08/06	14:10			9.08	14:10	Shiny, T. Trapp	
11/09/06		12:00	13:22	9.09	13:24	Shiny, T. Trapp	
11/29/06	11:35			8.72	11:34	R. Manasek, T. Trapp	
11/29/06		14:00	15:23	8.73	15:21	Lil Morava, T. Trapp	
03/05/07	12:41	15:12	16:34	unk	N/A	R. Manasek	
04/20/07	11:10	12:03	12:53	15.50		R. Manasek	
06/14/07	11:02	12:06	12:47	11.10		R. Manasek, Thad Carr	
08/15/07	9:37	13:42	14:42	13.50	14:42	R. Manasek, L. Morava	
10/10/07	10:57	12:05	12:48	9.80	12:04	R. Manasek	
12/05/07	10:22	12:12	13:38	8.80	10:22	R. Manasek	
03/25/08	11:36	12:50	14:31	7.74	11:36	R. Manasek	
05/19/08	13:13	14:34	15:42	7.86		R.Manasek, L.Martin, P.Miller	

Agate Fossil Beds National Monument Ground Water Level Monitoring

Decommissioned Park Supply Well, SN: 1028692

Date mm/dd/yy	Time (24 h)			Water Level (to top of casing)		Observer(s)	Notes
	Retrieved	Launched	Deployed	Depth (ft)	Time		
10/13/06		11:00		39.57	10:00	L.Martin, R.Manasek, T.Trapp	Cable length: 50.2 feet.
11/08/06	13:40			38.98	13:40	Shiny, T. Trapp	Lots of iron deposits on cable and logger.
11/09/06			11:45	38.96	12:05	Shiny, T. Trapp	
11/29/06	11:18			38.45	11:17	R. Manasek, T. Trapp	
11/29/06			14:57	38.47	14:53	Lil Morava, T. Trapp	
03/05/07	12:10	15:10	15:10	unk		R. Manasek	Depth meter's weights fell off the cable to the bottom of the well.
04/20/07	10:49	12:16	12:16	37.10	11:45	R. Manasek	
06/14/07	11:33	12:10	12:59	38.50		R. Manasek, Thad Carr	Lots of iron deposits on cable and the top of logger.
08/15/07	9:48	13:49	14:48	41.60	14:48	R. Manasek, L. Morava	
10/10/07	11:13	12:04	12:40	50.20	11:12	R. Manasek	
12/05/07	10:07	12:15	13:28	38.75	10:07	R. Manasek	
03/25/08	11:23	12:57	14:18	37.40	11:23	R. Manasek	
05/19/08	13:26	14:34	15:51	37.57		R.Manasek, L.Martin, P.Miller	

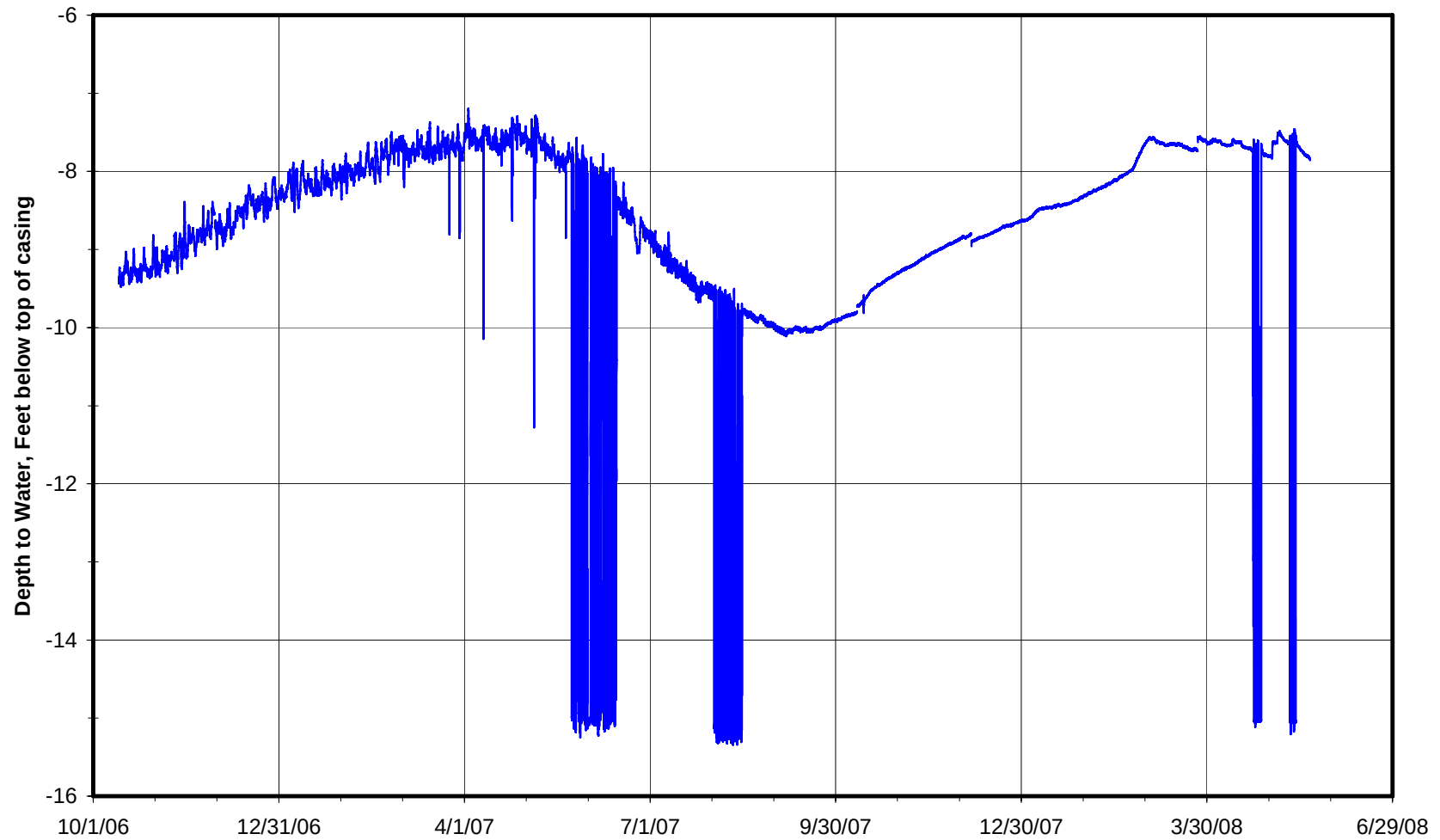
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Examples of Groundwater Hydrographs

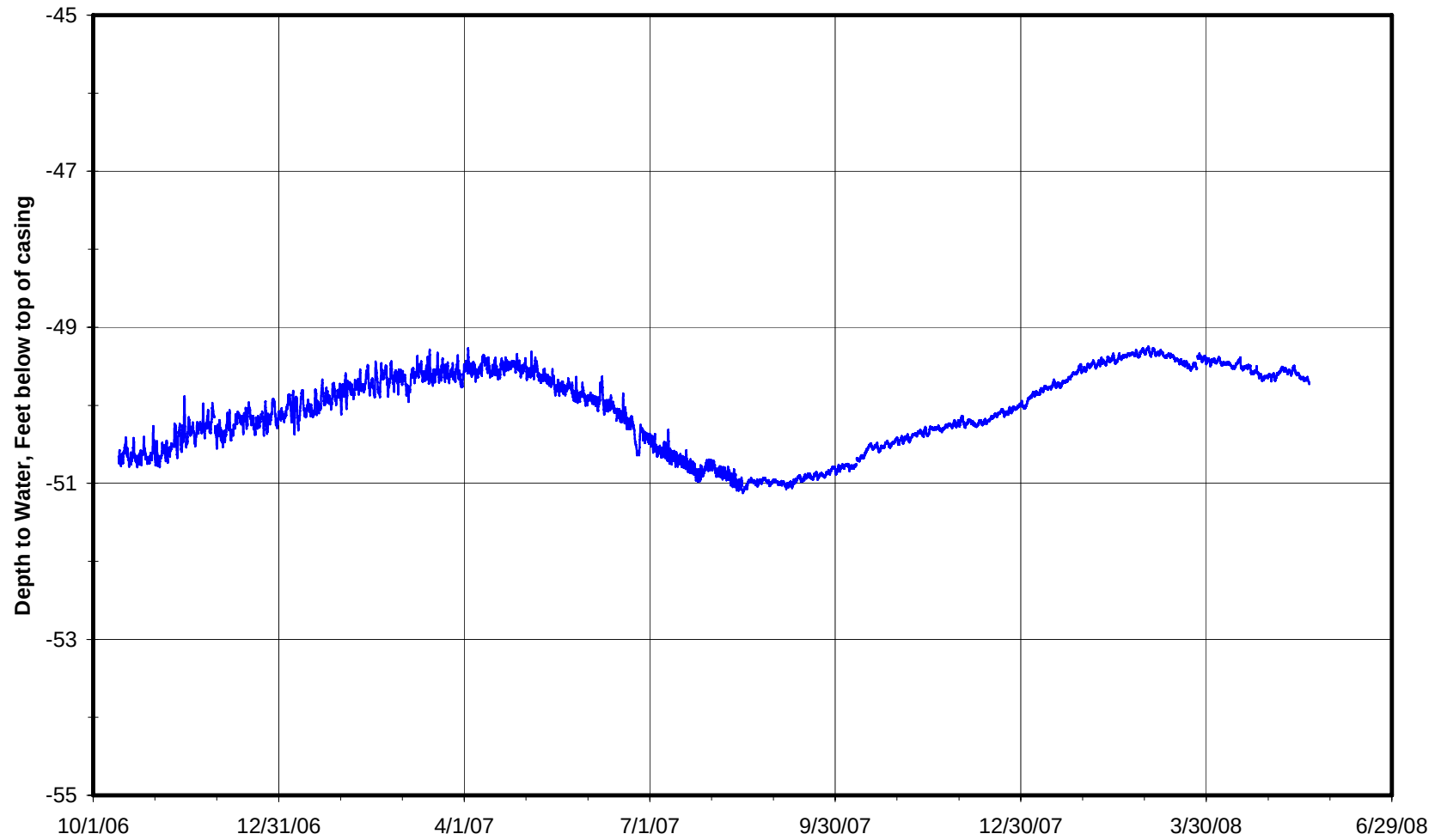
October 13, 2006 to May 19, 2008

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**Bone Cabin Windmill Well
Agate Fossil Beds National Monument**



Kelly Homestead Well
Agate Fossil Beds National Monument



**Decommissioned Park Supply Well
Agate Fossil Beds National Monument**

