COVER PAGE

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AGENCY NAME:	Arizona Department of Water Resources
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Overview of Work

The Arizona Department of Water Resources (ADWR) performed work necessary to become a new data provider with the USGS National Ground-Water Monitoring Network (NGWMN) per Cooperative Agreement Number: G16AC00367, for the grant period 10/1/2016 – 9/30/2018.

As a new data provider, the following work was conducted:

- Select and classify sites for the NGWMN;
- Provide required data elements for selected sites;
- Populate the NGWMN Well Registry with site and network information;
- Connect agency databases to the NGWMN Portal using web services; and
- Document field and data management practices.

The selection and classification of a hand full of real-time continuous and discrete monitoring well-sites, per NGWMN (aka Network) guidelines; provide documentation describing the site selection and classification processes; setup of web services and mapping data; and establish a connection between ADWR database and NGWMN using web services were tasks completed to become a new data provider to the Network.

ADWR added five well sites to the USGS Network-Portal providing well registry, well construction, lithology, and water level data (see Figure 1.). Three of the five sites are within the Colorado Plateau principal aquifers, the other two within the Basin and Range basin-fill aquifers. Three sites provide daily water levels and two sites provide quarterly measurements.

This technical report summarizes work performed and results obtained during the grant period.

Existing Water-Level Network

With the establishment of the ADWR in 1980, ADWR assumed lead responsibility from the U.S. Geological Survey (USGS) for the collection of groundwater levels in wells statewide. ADWR's groundwater monitoring program serves to monitor the state's groundwater resources as directed by the Groundwater Management Act of 1980 (the Act). The Act ultimately formed five Active Management Areas (AMAs) and three Irrigation Non-Expansion Areas (INAs) in addition to designating 53 groundwater basins within the state.

ADWR staff adopted and follows all USGS data collection protocols for well and spring site inventories, water-levels, water quality, and well discharge measurements. This provides ADWR data instant compatibility with all USGS historical data. A copy of the USGS Ground Water Site Inventory (GWSI) database was received in the 1980s which ADWR staff has continually maintained and updated by ongoing field investigations and through the statewide network of water level sites (ADWR GWSI): https://gisweb.azwater.gov/waterresourcedata/GWSI.aspx.

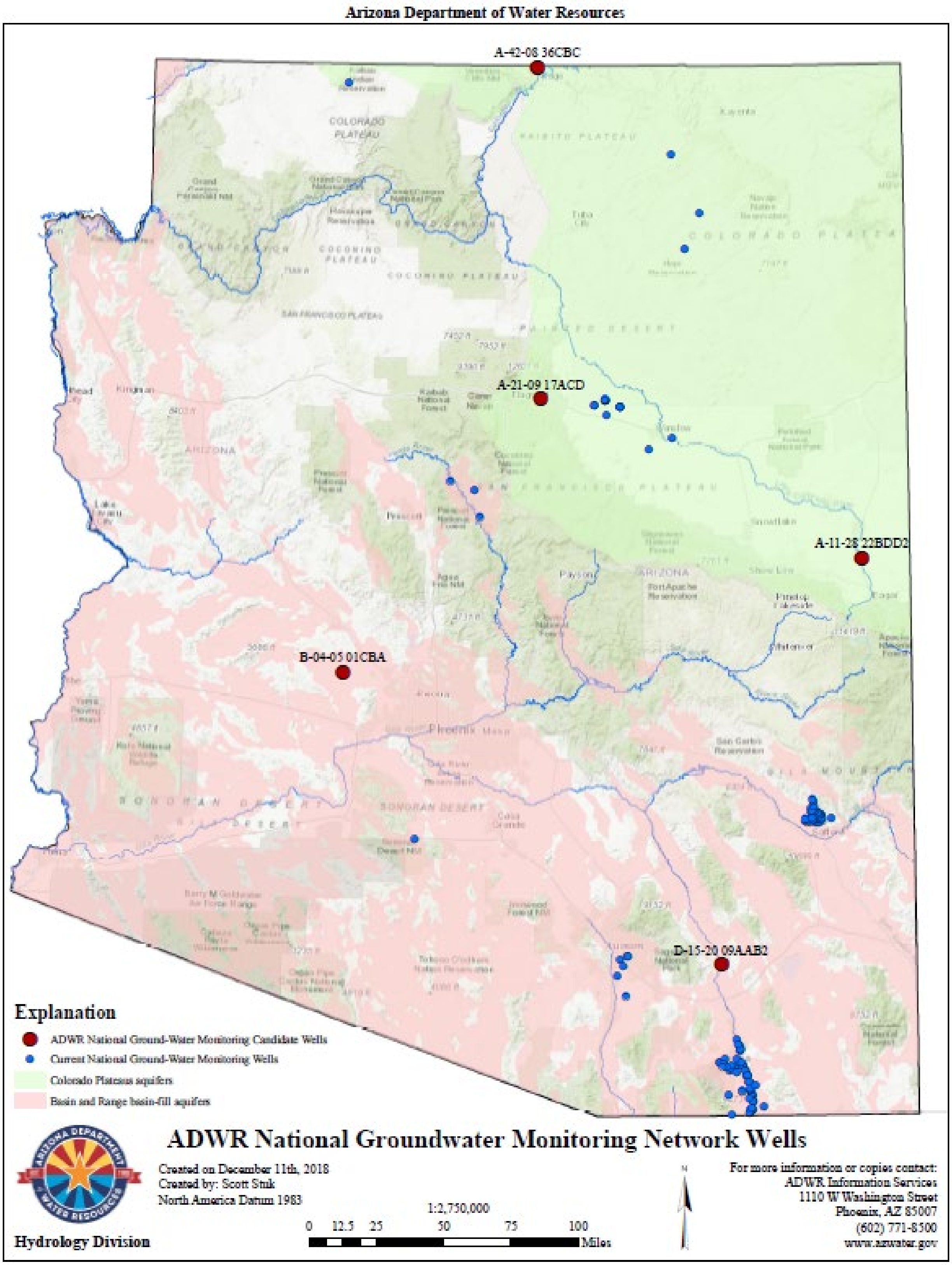


Figure 1. ADWR National Ground Water Monitoring Network (NGWMN) wells.

ADWR has two primary Oracle databases: 1) as discussed above, ADWR GWSI consists of over 40,000 wells – including cadastral and GPS locations, current and historical water-level measurements and associated information relating to those wells, and 2) the ADWR well registry database, known as WELLS55, required by statute to contain owner-supplied and driller information of wells of record:
https://gisweb.azwater.gov/waterresourcedata/WellRegistry.aspx.

ADWR currently monitors statewide groundwater levels at more than 1,450 wells on an annual basis. Most of these well sites were originally chosen by the USGS and have measurements dating back into the 1940s to 1960s. ADWR also monitors water levels in about 100 wells on a semi-annual basis, more than 50 wells quarterly, 17 wells monthly and approximately 120 wells on a continuous basis with about 75 on real-time telemetry.

ADWR also collects water levels within critical groundwater basins annually during what is known as "basin sweeps". A basin sweep is an extensive data collection effort within a specific groundwater basin to measure water levels both spatially and vertically within basin aquifers to provide a comprehensive picture of the groundwater system. An AMA or INA basin sweep occurs once every five years, with other basin sweeps completed as needed. Using these data, ADWR produces various reports like Groundwater Level Change - Open File Reports (OFR) and various Hydrologic Monitoring Reports (HMR). These and other reports can be viewed here: https://new.azwater.gov/hydrology/e-library.

Principal or major aquifers (as defined by the U.S. Geological Survey, 1995) monitored by ADWR include:

- **Basin and Range aquifers** (Basin-fill aquifers and Basin carbonite-rock aquifers); and
- **Colorado Plateau aquifers** (Mesa Verde aquifer, Dakota-Glen Canyon aquifer system, and Coconino-De Chelly aquifer).

Description of Site Selection Criteria and Process

Candidate monitoring well sites within principal or major aquifers were considered for potential inclusion in the Network based on the site selection criteria generally described within the Framework document and "tip sheets", (SOGW, 2013):
https://acwi.gov/sogw/ngwmn_framework_report_july2013.pdf.

Wells within ADWR's existing water level network were evaluated per principal aquifer: Basin and Range basin-fill, Basin and Range carbonate-rock, or Colorado Plateau;

- A review of the frequency of water-level data collection and the period of record.
- A review of all available data for each site was made. Preference was given to sites that have available the minimum data elements found in the Framework document.
- Principal or National aquifer codes for these wells were assigned (see Table 1.).

Table 1. Wells selected within ADWR's existing water level network for NGWMN.

National Ground-Water Monitoring Network - ADWR Water Level Sites (November 2018)					
Site Name	National Aquifer Name	Local Aquifer Name	Monitoring Frequency	Period of Record (non-Daily)	(non-Daily) WL Count
A-11-28 22BDD2 [TEP M-6]	Colorado Plateaus (N300C0PLTS)	Coconino Sandstone (310CCNN)	Daily	1/22/1985 - 5/25/2017	92
A-42-08 36CBC [OW 8]	Colorado Plateaus (N300C0PLTS)	Navajo Sandstone (220NVJO)	**Annual	6/23/1964 - 10/24/2016	354
A-21-09 17ACD [WINONA RA]	Colorado Plateaus (N300C0PLTS)	Supai Formation (310SUP)	Quarterly	6/1/1972 - 1/18/2017	35
B-04-05 01CBA [DR-6]	Basin and Range -Basin Fill (N100BSNRGB)	Basin Fill - Lower (121BSFLL)	Daily	10/21/1987 - 2/23/2017	84
D-15-20 09AAB2 [3 LINKS RANCH]	Basin and Range -Basin Fill (N100BSNRGB)	Basin Fill - Upper (112BSFLU)	Daily	11/26/1990 - 6/1/2017	36

** Quarterly as of 7/2018

ADWR water level monitoring sites have historically been selected to provide spatial distribution or coverage within a groundwater basin and to assess vertical gradients where possible. ADWR measures water levels in a wide variety of well types including irrigation, stock, domestic, municipalities, monitor, and unused. Generally, wells that had been selected for "index" well designation (wells that are measured at least annually, with many being measured more frequently) are based on guidelines developed by the USGS Office of Ground Water for the Collection of Basic Records (CBR) Program.

Minimum criteria for monitoring well selection can include:

- Open to a single, known aquifer category (i.e. Principal, Secondary, Local and/or Hydrogeologic Unit).
- Known well construction, including total depth.
- Minimally affected by pumping or nearby pumping and likely to remain so.
- Unaffected by irrigation, canals, and other potential sources of artificial recharge.
- High probability of long-term monitoring for the foreseeable future.
- Well has never gone dry and low probability of going dry due to well construction and aquifer parameters (exceptions may apply to wells used for specific monitoring purposes such as compliance or short-term objectives).
- Up to-date and accurate well site inventory.
- Prior record of water levels exists from sources ADWR, USGS, or BOR and, or has been used in previous hydrologic studies or other published works.
- Lithologic and/or geophysical logs available.

Please note the selection criteria may vary for ADWR GWSI Index wells depending on area specific monitoring objectives. For example, a well may be selected to monitor confined conditions versus unconfined for specific regional data needs. Others may include, but are not limited to, drought specific wells, recharge monitoring wells, flood/event monitoring wells, etc.

Site Classification of Subnetworks and Monitoring Categories

Monitoring categories and subnetworks for sites with sufficient period of record were reviewed per Framework document Monitoring Categories "tip sheets", (SOGW, 2013). All five ADWR Network wells (wells within the USGS Network that ADWR is providing data) are measured frequently, each least annually, therefore falling into the "trend" monitoring category (see Table 1., Table 2.). Three well sites are measured daily by continuous automated water level devices (pressure transducers), one is measured on a quarterly basis by a calibrated water level sounder and one was measured on an annual basis which has now been rescheduled to quarterly measurements also made by a calibrated water level sounder.

Review of hydrographs and well logs (geologic, geophysical, and, or driller) provided the data necessary to determine both monitoring and subnetwork categories and aquifer type determinations. Documented changes are observed within two of the Colorado Plateaus aquifers wells. Suspected changes are observed in the both Colorado Plateaus aquifers and Basin and Range - Basin Fill aquifer wells.

Table 2. Monitoring categories and subnetworks for selected ADWR wells for NGWMN.

National Ground-Water Monitoring Network - ADWR Water Level Sites (November 2018)			
Site Name	Water Level Network		Aquifer Type
	Subnetwork Category	Monitoring Category	
A-11-28 22BDD2 [TEP M-6]	Documented Changes	Trend	Confined
A-42-08 36CBC [OW 8]	Documented Changes	Trend	Unconfined
A-21-09 17ACD [WINONA RA]	Suspected Changes	Trend	Unconfined
B-04-05 01CBA [DR-6]	Suspected Changes	Trend	Confined
D-15-20 09AAB2 [3 LINKS RANCH]	Suspected Changes or Background	Trend	Unconfined

Field Techniques for Water-Level Measurements

ADWR's data collection procedures are consistent with the standards outlined in Appendix 5 of the Framework Document (SOGW, 2013), Field Practices for Ground-Water Data Collection. ADWR's original groundwater level monitoring program was patterned after the USGS management practices, collection protocols, standards, and techniques, specifically Garber and Koopman (1968) and Mann (1980). A copy of Mann's "Operational guidelines for measuring ground-water levels - Arizona District" is provided in Appendix I.

Today, ADWR continues to model field techniques for water level measurements and water level monitoring practices after the USGS (Taylor and Alley, 2001 and Cunningham and Schalk, 2011). ADWR groundwater level data collection protocols and methods, and field techniques for water level measurements, are documented in the ADWR Field Service Section Training Manual which is undergoing final update and revision. Appendix II contains a draft version of the Training Manual.

Presently, ADWR uses commercial electric tapes, graduated steel tapes, electric sounders, and a variety of pressure transducers, bubblers, and float recorders with shaft encoders for groundwater-level measuring instruments. All water-level measuring devices are calibrated annually if not more often by a dedicated steel calibration tape that is always kept in the office as a reference; the frequency of their calibration varies depending upon the instrument. See Appendix II for additional water-level measurement techniques.

Description of Data Quality and Quality Assurance Processes

All field collected data are entered into ADWR's GWSI database with application-built data quality checks into the data entry screens. ADWR is working to update both versions of ADWR GWSI Database Handbook (ADWR, 2007) and ADWR GWSI User's Guide (ADWR, 2008) which are provided in Appendix III.

Data are quality controlled by standardized field methods and procedures designed to identify anomalous measurements or data. Once all data are entered into ADWR GWSI, information is further reviewed by established protocol for consistency with previous water level trends. Water level change error reports are sent to the Section Manager, Supervisor and GWSI database administrator for review and verification for previous water levels greater than set parameters.

Other SOPs such as well site inventory validations and unable to measure procedures are documented with the Field Service Section Training Manual (see Appendix II).

Web Services - Minimum Data Elements

All well construction, water level, and lithology data contained within ADWR's GWSI database are provided to the Network using web services described below. ADWR has an enterprise in-house application that allows the collection and maintenance of the monitoring data. The infrastructure uses Oracle 12c database on the back-end and both Window-based and web-based client systems. The windows-based application is software written in Delphi and ADWR web applications are ASP.NET C# developments. In addition, ADWR has a GIS back-end database on ESRI´s Spatial Database Engine (SDE) and front-end application developed with MVC. ADWR currently has a web infrastructure in place that allows data sharing using web services. The security for this infrastructure is provided by the State of Arizona firewall as well as ADWR´s firewall. All ADWR data are provided to the NGWMN by this mechanism (see Figure 2.).

ADWR's GWSI Oracle database holds the construction and water level data needed for the services. ADWR's LOGS Oracle database contains the lithology data, aquifer and other water-bearing or hydrogeologic unit information from well logs needed for the services. ADWR already provides data to other entities using web services though Simple Object Access Protocol (SOAP); the web service is called ADWRDataWebService. SOAP, an XML-based messaging protocol defines a set of rules for structuring messages that can be used for simple one-way messaging but are particularly useful for performing RPC-style (Remote Procedure Call) request-response dialogues.

The service has 4 methods that provide data for a specific site, they are:

Screening Data GetNGWMNScreenData(string site)
Water Level GetNGWMNWaterLevelsData(string site)
CasingGetNGWMNCasingData(string site)
LithologyGetNGWMNLithologyData(string site)

Each method runs a live query against ADWR's Oracle databases and returns the data. The NGWMN adds our data in the following map: https://cida.usgs.gov/ngwmn/index.jsp.

Intranet Server Specifications include the following:

- Server: Windows Server 2008 Enterprise
  - Code Location:E:\developers\ADWR Data\ADWRDataWebService
  - IIS:Version:6
    - Site:AzWater
    - Application:ADWRDataWebService
  - Data software:Oracle client
- Software: Visual Studio 2017, coded in C# and utilizing the SOAP protocol.
- Database: Oracle 12: ADWR Database Structure

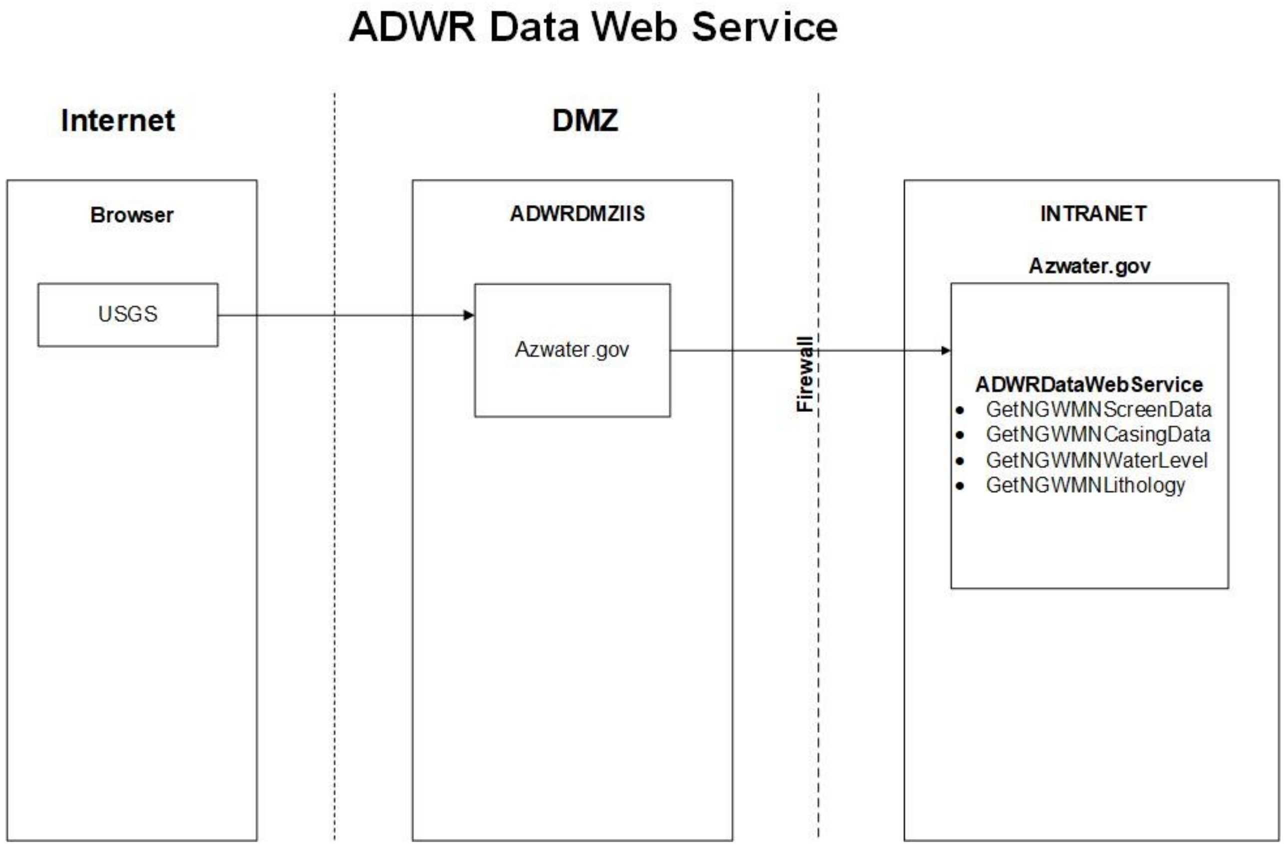
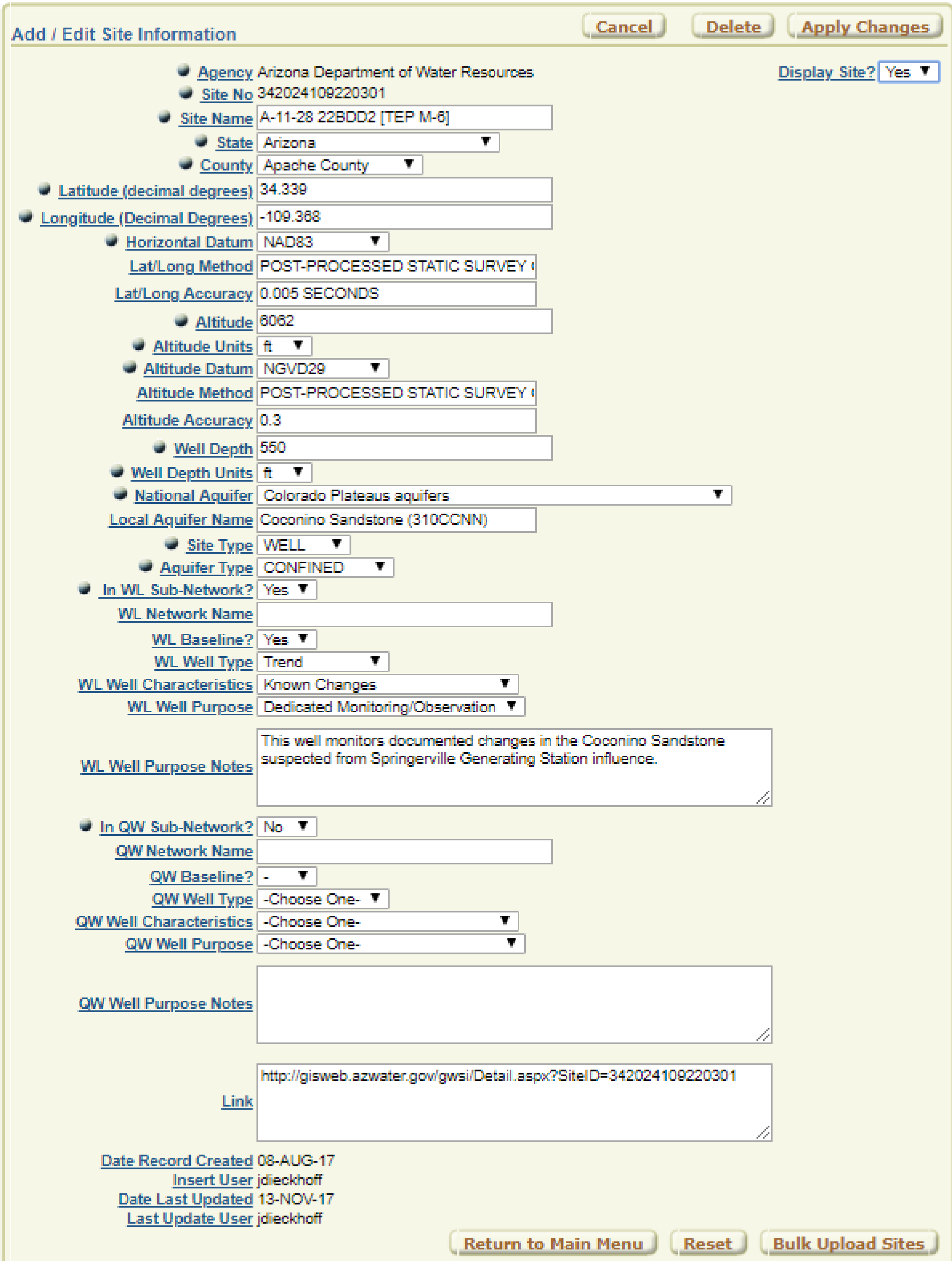


Figure 2. ADWR web service data flow.

As discussed in the Existing Water-Level Network section, ADWR adopted all original data collection procedures from the USGS including the same protocol for establishing a new site from Minimum Data Elements for Site Schedules. Minimum data elements for ADWR Network selected wells were provided to the data portal through the online Well Registry or linked using web services using the tip sheet on populating the Well Registry.

For example, a screen shot of the Add/Edit Site Information screen of the Well Registry for well completed within the Coconino Sandstone Local aquifer of the Colorado Plateaus National aquifer, A-11-28 22BDD2 [TEP M-6], shows the Minimum Data Elements “entered directly into a table in the Portal database which contains Site information called the ‘Well Registry’”, (see Figure 3).



Add / Edit Site Information

Cancel | Delete | Apply Changes

Display Site? Yes

Agency	Arizona Department of Water Resources
Site No	342024109220301
Site Name	A-11-28 22BDD2 [TEP M-6]
State	Arizona
County	Apache County
Latitude (decimal degrees)	34.339
Longitude (Decimal Degrees)	-109.368
Horizontal Datum	NAD83
Lat/Long Method	POST-PROCESSED STATIC SURVEY (
Lat/Long Accuracy	0.005 SECONDS
Altitude	6062
Altitude Units	ft
Altitude Datum	NGVD29
Altitude Method	POST-PROCESSED STATIC SURVEY (
Altitude Accuracy	0.3
Well Depth	550
Well Depth Units	ft
National Aquifer	Colorado Plateaus aquifers
Local Aquifer Name	Coconino Sandstone (310CCNN)
Site Type	WELL
Aquifer Type	CONFINED
In WL Sub-Network?	Yes
WL Network Name	
WL Baseline?	Yes
WL Well Type	Trend
WL Well Characteristics	Known Changes
WL Well Purpose	Dedicated Monitoring/Observation
WL Well Purpose Notes	This well monitors documented changes in the Coconino Sandstone suspected from Springerville Generating Station influence.
In QW Sub-Network?	No
QW Network Name	
QW Baseline?	-
QW Well Type	-Choose One-
QW Well Characteristics	-Choose One-
QW Well Purpose	-Choose One-
QW Well Purpose Notes	
Link	http://gisweb.azwater.gov/gwsi/Detail.aspx?SiteID=342024109220301
Date Record Created	08-AUG-17
Insert User	jdieckhoff
Date Last Updated	13-NOV-17
Last Update User	jdieckhoff

Return to Main Menu | Reset | Bulk Upload Sites

Figure 3. Minimum Data Elements entered directly into a table in the Portal database which contains site information called the Well Registry.

For the same well, A-11-28 22BDD2 [TEP M-6], the Minimum Data Elements were entered by the following web services script:

Water Levels WebServices Query

```sql
select 'ADWR' “AgencyCd", s.site_well_site_id "SiteNo", trunc(l.wlwa_measurement_date)
"MeasurementDate", m.code_description "MeasurementMethod", d.code_description "Source", null
"OriginalParameter", 'Down' "Original Direction", 'ft' "Original Unit",
to_char(l.wlwa_depth_to_water,'9,999.99') "Original Value", r.code_description "Remarks",
to_char(l.wlwa_depth_to_water,'9,999.99') "DTW Below Land Surface", m.accuracy
"WaterLevelAccuracy", 'ft' "Accuracy Unit"
from sites s, ww_levels l, mm_codes m, data_sources d, mr_codes r
where s.site_well_site_id = l.wlwa_site_well_site_id
  and l.wlwa_source_code = d.code_entry
  and l.wlwa_method_code = m.code_entry
  and l.wlwa_remark_code = r.code_entry(+)
  and l.wlwa_depth_to_water is not null
  and s.site_well_site_id =  <site>
 union
select 'ADWR' "AgencyCd", s.site_well_site_id "SiteNo", trunc(t.measurement_date)
"MeasurementDate", m.code_description "MeasurementMethod", d.code_description "Source", null
"OriginalParameter", 'Down' "Original Direction", 'ft' "Original Unit",
to_char(avg(t.depth_to_water),'9,999.99') "Original Value", r.code_description "Remarks",
to_char(avg(t.depth_to_water),'9,999.99') "DTW Below Land Surface", m.accuracy
"WaterLevelAccuracy", 'ft' "Accuracy Unit"
from sites s, transducer_levels t, mm_codes m, data_sources d, mr_codes r
where s.site_well_site_id = t.well_site_id
  and t.source_code = d.code_entry
  and t.method_code = m.code_entry
  and t.remark_code = r.code_entry(+)
  and s.site_well_site_id = <site>
  and t.depth_to_water is not null
group by s.site_well_site_id, trunc(t.measurement_date), m.code_description, d.code_description,
r.code_description, m.accuracy
```

Casing WebService Query

```sql
select 'ADWR' "AgencyCd", s.site_well_site_id "SiteNo", c.case_top "CasingDepthFrom",
nvl2(c.case_top, 'Feet', null) "CasingFromUnit", c.case_bottom "CasingDepthTo",
nvl2(c.case_bottom, 'Feet', null) "CasingDepthToUnit", cf.code_description "CasingMaterial",
c.case_diameter "CasingDiameter", 'Inches' "CasingDiameterUnit"
from sites s, well_completions w, casing_completions c, casing_finishes cf
where s.site_well_site_id = w.wlco_site_well_site_id
  and w.wlco_site_well_site_id = c.case_wlcomp_site_well_site_id(+)
  and w.wlco_id = c.case_wlcomp_id(+)
  and c.case_finish_code = cf.code_entry(+)
  and s.site_well_site_id = <site>
 order by s.site_well_site_id
```

Screen WebService Query

```
select 'ADWR' "AgencyCd", s.site_well_site_id "SiteNo", p.perf_top "ScreenDepthFrom",
    nvl2(p.perf_top,'Feet',null) "ScreenDepthFromUnit", p.perf_bottom "ScreenDepthTo",
    nvl2(p.perf_bottom,'Feet',null) "ScreenDepthToUnit", p.perf_width "HoleSize",
    nvl2(p.perf_width,'Inches',null) "HoleSizeUnit", pt.code_description "ScreenMaterial",
    p.perf_diameter "ScreenDiameter", nvl2(p.perf_diameter,'Inches',null) "ScreenDiameterUnit"
from sites s, well_completions w, perforation_completions p, perforation_types pt, screen_materials sm
where s.site_well_site_id = w.wlco_site_well_site_id
  and w.wlco_site_well_site_id = p.perf_wlcomp_site_well_site_id(+)
  and w.wlco_id = p.perf_wlcomp_id(+)
  and p.perf_type_code = pt.code_entry(+)
  and p.perf_material_code = sm.code_entry(+)
  and s.site_well_site_id = <site>
 order by s.site_well_site_id
```

Lithology WebService Query

```
select 'ADWR' "AgencyCd", s.site_well_site_id "SiteNo", dl.code "LithologyId", dl.description
"LithologyDescription", 'UNKNOWN' "ObservationMethod", l.top_dbls "LithologyDepthFrom", l.bot_dbls
"LithologyDepthTo", 'ft' "DepthUnit"
from sites s, LOGS.LOG_EVENTS le, LOGS.layers l, logs.cd_drillers_log dl
where s.site_well_reg_id = le.well_id
  and le.id = l.log_event_id
  and l.drl_code = dl.code
  and s.site_well_site_id = <site>
```

Notes on Sites Missing Required Data Elements

Currently one ADWR Network well site in the Basin and Range-Basin Fill aquifer is missing a well log (D-15-20 09AAB2). Well depth has been determined by a depth measurement using an ADWR sounder, and geologic inference has been made as to principal and local aquifer from surrounding well logs.

One ADWR Network well site in the Colorado Plateaus aquifer is missing detailed lithology and a well log (A-42-08 36CBC); however, during the next grant cycle the U.S. Bureau of Reclamation Office (BOR) will be contacted regarding missing well log information, as they oversaw completion of the well in 1959. Existing well construction data such as casing, screen, diameter and well depth are contained within ADWR GWSI as sourced from USGS.

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APPENDIX I

Operational Guidelines for Measuring Ground-Water Levels (Mann, 1980)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OPERATIONAL GUIDELINES FOR MEASURING GROUND-WATER LEVELS—ARIZONA DISTRICT

By

Larry J. Mann

For Administrative Use Only

Tucson, Arizona
May 1982

CONTENTS

Illustrations

METHODS OF WATER-LEVEL MEASUREMENT

The electric sounder and graduated steel tape are the two main ground-water level measuring devices used in the Arizona District. These devices primarily are used to measure the depth to water in a well on a periodic basis, i.e., monthly or annually. Water-level fluctuations resulting from barometric pressure changes, seasonal changes in recharge rates, the effect of pumping wells, etc., are more easily measured using water-level recorders or pressure transducers. A discussion of measuring devices is provided in TWRI Book 8, Chapter A1—"Methods of Measuring Water Levels in Deep Wells,"—and National Handbook of Recommended Methods for Water-Data Acquisition, Chapter 2. Moreover, the sections that follow assume that the user is familiar with the types of equipment being discussed; if not, he or she should consult the subdistrict's lead ground-water technician or hydrologist or immediate supervisor.

Both methods of measuring ground-water levels—an electric sounder and graduated steel tape—have certain advantages and disadvantages depending mainly on site conditions. For the most part, however, the electric sounder is a more reliable and simpler method of measuring the depth to water than a steel tape. The reasons are as follows:

1. In wells with cascading water, it is imperative that an electric sounder with a shielded probe be used to measure the depth to water. Cascading water greatly affects the accuracy and reliability of steel-tape measurements; most measurements are worthless.

2. In wells for which the depth to water and well depth are unknown, use of an electric sounder eliminates the time consuming and frustrating method described in "Precaution 3" of the section entitled "Graduated Steel Tape."

3. Steel-tape measurements require two or more times in and out of the well to check the measurement. In places where the depth to water is several hundred feet, a lot of time and effort is spent to obtain an accurate measurement.

4. In wells equipped with electric-powered submersible pumps, a tape may cut through the insulation on the electric power wires. This is a safety hazard and could lead to electrocution or to pump failure.

5. Steel tapes are inordinately expensive when compared to sounding wire and much more difficult to repair in the field when they are broken.

In general, steel tapes should only be used for measuring the depth to water in wells where: use of an electric sounder is not feasible owing to access, i.e., hole into well bore is too small for a sounder and cannot be enlarged with a drill; to set the datum on a recorder; cascading water does not exist; to record the oil level (see "Precaution 6" in section entitled "Electric Sounder"); the water level is shallow and visible; or there is a small diameter access line—such as a one-half inch airline—that extends from land surface to below the water level.

Electric Sounder

Electric sounders are perhaps the most versatile of water-level measurement devices. They are small and portable, simple to operate and repair in the field, and easily used by one person. Most electric sounders in the Arizona District consist of an aluminum reel that will hold 1,000-2,000 ft of 22-gauge insulated sounding wire, a battery-powered water-level indicating meter, a water-level probe, and a ground wire. In its simplest description, the water-level probe is attached to and lowered down a well by the sounding wire. The sounding wire is connected through the reel and a brush system to the water-level indicating meter, which is, in turn, grounded to the well casing or pump column. When the probe enters the water an electrical circuit is completed, and the meter will give a steady reading.

The depth to water in a well is equal to the combined length of the sounding wire and probe at the point at which the needle on the meter is deflected. The sounding wire usually is calibrated using a steel tape and marked at 100- and 50-foot intervals; markings at 25-foot intervals are optional. When the water level is between two marks, a steel tape is used to measure from the nearest point of the line that the level was measured. The sounding wire can be marked using different methods:

1. Three-quarter inch plastic tape wrapped tightly around the wire;
2. Water-resistant markers similar to felt-tip pens; and
3. Paint or fingernail polish.

Although the type and the interval of markings are largely dependent on personal preference of the field person, the following policies and guidelines are hereby proposed in order to establish consistency from office to office and within a specific office.

1. A bound equipment book will be prepared and kept current for each sounder. The contents of the book will include the following:

    (a) The type and color of marks used on the sounding wire.

    (b) The interval(s) at which the sounding wire is marked.

    (c) A record showing the date, person(s), and method used to calibrate, check the calibration, or recalibrate the marks. In general, the calibration of the sounding wire and probe should be spot checked: prior to a field trip in which the sounder will be extensively used; at least once daily; after replacing a probe;

immediately after being "hung-up"—to document whether the sounding wire was stretched; and anytime the field person questions its accuracy, e.g., if the depth-to-water measurement is inconsistent with the trend defined by previous measurements.

(d) The date, person(s), and changes that were made to the length of the sounding wire or probe.

2. It is suggested that the sounding wire be marked at least at 50-foot intervals; marks at 25-foot intervals are optional.

3. The 100-foot marks on the sounding wire should be obviously recognizable and distinguishable from 0.0 ft to 300 ft. It is suggested that the following scheme be used for 100-300 ft and then reused or recycled for 400 to 600 ft, 700 to 900 ft, and so on. (See example on next page.) Two marks should be used to designate 50-foot intervals; if 25-foot intervals are opted for, they should be designated by a single mark. There is also a question of using other marking systems. For example, some personnel prefer to mark the sounding wire in the same manner as a cableway is marked, e.g., each 100-foot mark is unique. On 500- to 2,000-foot long sounding wires, this system is impractical. The main problem being that the entire wire has to be remarked if part of the wire is lost and replacement wire is not available. Secondly, several more marks have to be replaced when the wire is recalibrated. Once again, whatever marking system is used should be clearly defined in the equipment book that accompanies the instrument.

4. Each office in the District has its own type of water-level probes, which were designed to best fit their needs. Each probe should be constructed so that the contact is shielded and will not come in contact with the casing or pump column. The shield can also serve to eliminate the effects of cascading water.

5. The point of reference for the actual footage designated by a specific mark will be the center of the mark; the yellow marks help protect the specific marks on a sounder, so we use the C/L (center line) as the absolute point. An alternative is to use the extreme end of the first mark nearest to the probe. The method used should be thoroughly described in the equipment book. An advantage to using the extreme end of the marks as a reference point, is that if there is stretch in the sounding line all that needs to be done to recalibrate is to replace the end mark; most often the stretch will be a few tenths of a foot.

Distance	Marking	*Color of marking
0.0	-	R
25 (optional)	-	Y
50	- -	Y/Y
75	-	Y
100	- - -	Y/R/Y
150	- -	Y/Y
200	- - - -	Y/R/R/Y
250	- -	Y/Y
300	- - - - -	Y/R/R/R/Y
350	- -	Y/Y
400	- - -	Y/R/Y
450	- -	Y/Y
500	- - - -	Y/R/R/Y
550	- -	Y/Y
600	- - - - -	Y/R/R/R/Y

*Color of marking: R, red; Y, yellow

Reference point for measurements: C/L (center line): - ↓C/L - -   - - ↓C/L - -

or

Extreme end: Reel → - - - ↓ → Probe.

6. The 0.0-foot mark should be clearly marked and distinguishable from other marks on the sounding line. Because the 0.0 mark usually is above the probe, the distance from the mark to the end of the probe should be measured and noted in the equipment book. This distance—usually referred to as the tare—is commonly between 2 and 5 ft and must be added to the length of the sounder line when computing the depth to water.

Some field persons prefer to set a reference mark at a predetermined footage, say 5 ft, and adjust the length of the probe so that the contact on the probe is at 0.0 ft. This is permissible as long as the practice is fully documented in the equipment book.

<u>Precautions</u>.-- 1. If the field person is unfamiliar with a particular electric sounder, verify markings on sounding wire, and the length of the water-level probe, and record the information in the equipment book.

2. If length of wire has changed because of stretching and use, replace it with new wire rather than remark it; two sets of marks are confusing to the user and, if the amount of stretch is a significant factor, the wire probably is weakened and subject to breaking.

3. Always carry a spare battery and several spare probes.

4. Always attach probe so that the point at which it is attached is "the weakest link in the chain." It is better to lose a probe than to lose several hundred feet of wire down a well.

5. When using an electric sounder, keep the reel sitting on a clean dry area such as a 2-foot long, 2-inch by 12-inch lumber, and do not let the reel touch any metal around the well. Many reels short out when set on damp ground or touch the casing.

6. Oil-lubricated turbine pumps typically have an oil film on top of the water. Care should be taken that the oil does not foul the water-level probe as it passes through the oil before entering the water. If several feet of oil is on the surface, it is better to use a steel tape and record the oil level rather than record the water level at the base of the "oil plug." For example, assuming that there is 10 ft of oil, the surface of the oil will be within 1.4 ft of the "true water level;" the oil-water contact on the other hand will be 8.6 ft deeper than the "true water level." To adjust the depth-to-water measurement for the effect of the oil column, the height of the oil column must be determined. The top of the column can usually be measured with a steel tape and the oil-water contact with an electric sounder; an alternate method of measuring the oil-water contact is to use a steel tape and a water-sensing paste that undergoes a permanent color change when wetted. The height of the oil column is multiplied by 0.86 to obtain the height of a water column of

equivalent weight; although this coefficient ranges from 0.85 to 0.88, depending on the type of oil, 0.86 represents an average value for oils typically used to lubricate turbine pumps. The height of the water column is then subtracted from the depth to the oil-water contact.

For example:

Depth to top of oil =	132.6 ft
Depth to oil-water contact =	147.3 ft
Height of oil column - 147.3 minus 132.6 =	14.7 ft
Height of oil column times 0.86 =	12.6 ft
Depth to oil-water contact minus 12.6 ft =	134.7 ft
Depth to water adjusted for the effect of the oil column =	134.7 ft

An example of how data should be entered in the field notes is shown on figure 1.

7. Except for sites where a film of oil or other debris on the water precludes it, the probe should be submersed and the water-level reading taken as the probe is removed from the water. This insures that the sounding wire is as straight as possible and sags are minimal. Sag can sometimes account for a 1- to 2-foot error in water level especially in crooked wells or in wells with debris in the water.

8. An ideal way to check the calibration of a sounding line is to first measure the depth to water in a well with the sounder, then make a verification measurement with a steel tape; this assumes that there is no cascading water. If the sounding wire is properly calibrated, the difference between the two measurements should be less than 0.1 ft per 100 ft of depth to water. Calibration checks of this nature should be documented in the equipment book.

9. When lowering or removing the sounding wire and probe down the well, it should be done very slowly so that "tight" spots can be detected. When lowering, the "tight" spots should be noted so that care can be taken when removing the line. A second advantage to slowly lowering or removing the sounding wire and probe, is that it gives the field person the opportunity to inspect the markings and determine whether they have slipped or need repair or replacement; for example, plastic tape has a tendency to slip on the sounding wire especially if the marks contact oil which is often present on the water surface in wells equipped with oil-lubricated turbine pumps.

10. The sounding wire can gently be popped in the well as a check to see if it is hanging freely.

11. Always measure the distance from the tip of the probe to the 0.0-foot marker before sounding for a water level. The probe may be lost while retrieving the sounding wire from the well; the measurement is then useless.

FORM NO. 9—1904—E
Revised September 1980

U.S. DEPT. OF INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
WATER-LEVEL DATA

WELL NO. A-10-20 30ABC(2)
MP HEIGHT 2.0 ft above LS
SHV area

Site Ident. No 341234111123401   R=234 *   T= A *

Example	235 DATE	237 WATER LEVEL (BELOW LSD)	238 STATUS	239 METHOD	HOLD	CUT	DEPTH BELOW MP	REMARKS	DATE PUNCHED	DATE ENTERED
Example 1: Steel tape					100.0	-12.5	87.5	No oil; L. Mann		
	9/10/1982	85.5		S	95.0	-7.5	87.5			
	/ /									
	/ /									
Example 2: Combination				V	113.7	+1.4	115.1	Trace of oil; unadjusted		
	9/20/1982	113.0	R	S	118.0	-3.0	115.0	for oil – L. Mann		
	/ /									
	/ /									
Example 3: Sounder	9/30/1982	113.1	S	V	113.7	+1.4	115.1	No oil detected; double		
								checked measurement – L. Mann		
	/ /									
Example 4: Oil correction				S	150.0	-17.4	132.6	Top of oil		
				V	141.3	+6.0	147.3	Oil-water contact		
					147.3 - 132.6 = 14.7 ;		14.7 × 0.86 = 12.6			
	11/31/198	132.7	R	S	147.3 - 12.6 =		134.7	b/w MP – L. Mann		
	/ /									
	/ /									
	/ /									
	/ /									
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	/ /									
	/ /									
	/ /									
	/ /									
	/ /									

-7-

MEASURING POINT
R=320 *   T= (A) D M *
add, delete, modify

M.P. Begin Date 321 # 9/10/1982 *
M.P. End Date 322 / /
M.P. Height 323 2.0 *
M.P. Remark 324 TOP OF CASING 2.0 FT ABV LAND SURFACE

Method of Measurement 239 – A B C E G H L M N R S T V Z
airline, analog, calibrated airline, estimated, pressure gage, calibrated pressure gage, geophysical logs, manometer, non-recording gage, reported, steel tape, electric tape, calibrated electric tape, other

Site Status 238 – D E F G H I J N O P R S T V W X Z
dry, recently flowing, flowing, nearby flowing, nearby recently flowing, injector, injector site monitor, plugged, obstruction, pumping, recently pumped, nearby pumping, nearby recently pumped, foreign substance, surface water, well destroyed, affected by surface water site, other

12. The sounding wire should be reeled into and out of the well and not be allowed to accumulate on the ground; the reasons are nearly the same as those discussed for the use of a steel tape (see "Precaution 2" in section entitled "Graduated Steel Tape").

Graduated Steel Tape

The graduated steel surveyor's tape has long been used to measure the depth to water in wells. Steel tapes are available in lengths up to 500 ft, although some as much as 2,000 foot long have been specially made. In the day-to-day use of a steel tape, lengths over 800 to 1,000 ft are cumbersome and awkward to use even with special reels and other associated equipment.

The depth to water in a well is measured by inserting the tape in an opening in the top of the casing, base of turbine pump, or plate covering the casing that gives direct access to the inside of the casing. The tape is lowered through the opening to a predetermined footage so that the lower few feet of tape are submerged in water. The lower part—20 to 50 ft—of tape is usually coated with a substance such as carpenters chalk or water-sensing paste that exhibits a marked color change when wetted. The depth to water is calculated by subtracting the length of wet tape from the predetermined footage.

Precautions.-- 1. A small weight of 2 to 4 oz should be attached to the end of the tape prior to inserting the tape in the well. The weight serves three purposes: (a) First, it makes the tape hang straight by removing minor bends and kinks; (b) in the event that the water surface is covered by floating debris, such as oil, sludge, and fine trash, a weighted tape will more easily penetrate the debris than will a nonweighted tape; and (c) the added weight will aid the field person in "feeling" his or her way down the well.

The weight can be attached in one of two ways. It can be attached to the ring on the end of the tape that is standard on most tapes, or the ring can be removed and a hole drilled or punched in the end of the tape. The weight is attached to the tape by a fine wire or nylon string, which will easily break if the weight is bound up by an obstruction. The weight can be considered expendable, but the tape should not be.

2. The tape is always spooled directly from the reel into the well—a few feet at a time—back onto the reel and never allowed to accumulate on the ground. This precaution serves three functions: (a) By inserting the tape a few feet at a time, the field person can monitor the weight of the suspended tape and, thereby, detect whether the tape is hanging freely or the hole is obstructed; (b) the possibility of kinking the tape is minimal; and (c) if the tape accumulates on the ground, it can be a tripping hazard, come in contact with an electrical circuit, or interfere with the operation of equipment at the well site.

3. Depth-to-water measurements in wells that previously have not been measured and for which the depth of the well is not known should be done with great care and caution. The tape should be inserted a few feet at a time and to regular intervals such as 50 or 100 ft. For example, lower the tape 50 to 100 ft and remove it to check if water was encountered. On a second trial, lower the tape an additional 50 to 100 ft and remove it again. Repeat this additive process until water is detected on the tape. The length of tape lowered in the well is left up to the discretion and "common sense" of the field person, but under no conditions should it be lowered at intervals exceeding 100 ft. This practice will minimize the likelihood of getting the tape "balled-up" or "bound-up" in the well. Once the depth to water is measured using this process, a second measurement will be made and recorded using the knowledge gained from the first measurement.

4. In wells in which the depth to water is more than about 200 ft, carpenter's chalk tends to dry out as the tape is removed from the well; the result is an erroneous measurement or none at all. The chalked interval of the tape should be closely scrutinized for the possibility of the chalk drying out. If the chalk dries too quickly, alternate methods can be used to measure the depth to water, e.g., replace the chalk with the water-sensing paste or use of an electric sounder.

5. If the chalk appears to be spotty and it is difficult to detect the wet interval, an alternate method should be used to measure the depth to water. The most common conditions that lead to "spotty" tapes are cascading water and condensation on the inside of the casing.

6. All steel tapes should periodically be inspected for kinks, worn spots, and other conditions that would affect the reliability and accuracy of measurements or the likelihood of the tape breaking while suspended in a well. If practical the tape should be repaired, otherwise it should be replaced.

7. Each field person should securely attach the steel tape to the reel so that the tape cannot accidently separate from the reel and be lost down a well.

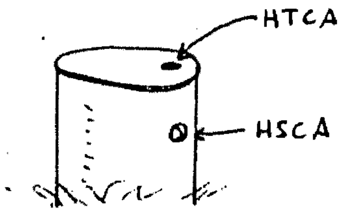
Recording of Water-Level Data

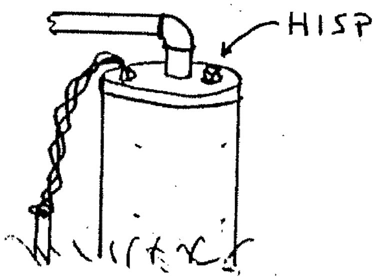
The accuracy to which the depth to water can be measured is largely dependent on field conditions. In general, the depth to water can be measured to ±0.1 ft per 100 ft with either the steel tape or electric-sounder method. The measurements should be recorded on the field sheet to the nearest 0.1 ft; this implies that the measurement is accurate to the nearest 1 ft. On the other hand if the measurement is recorded to the 0.01 ft, this implies that the measurement is accurate to the nearest 0.1 ft. Because of many unknown field conditions, such as alignment and crookedness of the well and the expansion and contraction of steel tapes and sounding wire, accuracies of less than 0.1 ft are usually not obtainable and, therefore, should not be implied by recording the depth to water to the nearest 0.01 ft.

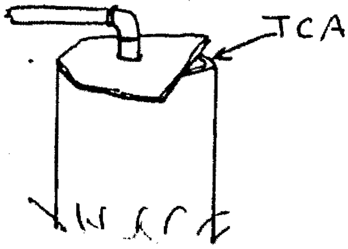
When entering the depth to water on the field sheet, it should be obvious which method was used to make the measurement. Several codes have been devised to indicate the "method of measurement." (See figure 1.) If a steel tape was used, an "S" should be coded. If an electric sounder was used, a "V"—code for a calibrated electric tape—should be coded. The code for an electric tape—"T" implies the tape is uncalibrated—should be used only if an unmarked sounder was used to measure the water level and the length of sounder wire was measured using a steel tape once the wire was removed from the well.

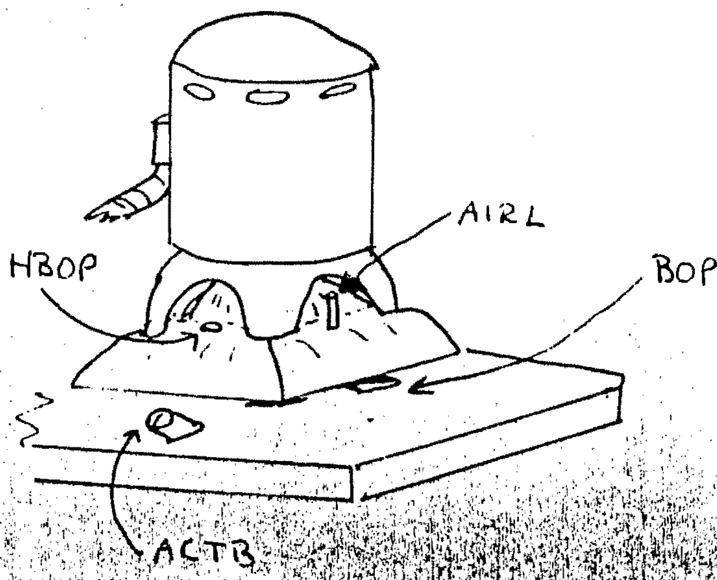
In most instances, the depth to water is measured to the nearest 0.1 ft and verified by a second measurement. The field notes should clearly indicate that the measurement was verified and the method used to obtain both measurements. However, only the measurement that is deemed as being most accurate by the field person will be entered into the water-level file. Examples of the field notes are shown on figure 1.

HTCA, W	Hole in top of casing, west side
HSCA, N	Hole in side of casing, north side
TCA, SE	Top of casing, southeast side
HBOP, S	Hole in pump base, south side
BOP, N	Access under base of pump, north side
ACTB, S	Measuring (access) tube, south side
AIRL, S	Airline, south side
HISP, NE	Hole in submersible cap plate, northeast side









APPENDIX II

ADWR Field Service Section Training Manual

(Draft November 2018)

ARIZONA DEPARTMENT OF WATER RESOURCES

Field Services Training Manual

Prepared by
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PROTECTING
ARIZONA'S WATER SUPPLIES
for ITS NEXT CENTURY

Hydrology Division
Field Services Section
2018

Revised July 2018

CONTENTS

ACKNOWLEDGEMENTS

For many years, the Field Services Section (FSS) staff relied on an instructional manual prepared by Ron Stulik. At the time (1983), Ron was a Water Resource Specialist at Field Services. Ron had spent many years at the United States Geological Survey (USGS) doing data collection. Ron helped pattern Field Services Section after the data collection units of the USGS. All of us who knew Ron, worked with him, and were trained by him can be thankful for his influence. Ron taught us to do a hard job, and to do it in a concise, professional manner. Much of the fine reputation our Unit now enjoys is in no small way due to the efforts of Ron Stulik.

Ron's manual was largely based on USGS memos written in 1982 by Larry Mann (see Mann, 1982). For years we simply referred to the manual as the "Field Services Bible". New technology has made much of the "old" manual obsolete, but the message of the original – such as attention to detail, pride in what we do, and dedication to a worthy endeavor – will never change.

This new training manual draws generously from the efforts of Ron Stulik and Larry Mann, and the protocols they developed. New innovations have made our work easier in the post-2000 era. However, it is my hope that the commitment to excellence that we inherited will be conveyed in this new manual.

Chapter I

INTRODUCTION

The Arizona Department of Water Resources (ADWR) has been in existence since 1980. Before we became an agency, we were known as the Arizona Water Commission (a much smaller group), which was a part of the Arizona State Land Department. The FSS, formerly known as Basic Data, has been the data collection arm of ADWR since the beginning. The unit was patterned after similar data collection units in the USGS. We adopted all data collection protocols from the USGS, including field inventories, water-level measurements, discharge measurements, automated groundwater monitoring measurement and land subsidence surveying. This enabled the data that we collected to have instant compatibility with all USGS historical data.

Personnel from the FSS, which include hydrologists and water resource specialists, perform many tasks. In the field, we measure water levels in wells, measure discharge from pumping wells, measure stream flows, maintain a collection of transducers, inventory wells for our database and collect elevation and gravity data to monitor land subsidence throughout Arizona. Also, hydrologists of the FSS produce the Hydrologic Map Series (HMS) reports, Hydrologic Monitoring Reports (HMR) and the Water Level Change Map Series (WLCMS) reports, which show groundwater conditions statewide.

The FSS maintains a statewide network of about 1800 index wells which are used to monitor water levels. Discrete water-level measurements are taken at all of these wells on an annual, semiannual or quarterly basis. Approximately 125 wells are continuously monitored with digital pressure transducers, shaft encoders, and bubblers. Many of the automated sites are equipped with GOES radios, which transmit water-level data to ADWR via satellite.

The FSS also maintains the Groundwater Site Inventory (GWSI) database. GWSI is a field verified database consisting of thousands of wells – including cadastral and GPS locations, current and historical water-level measurements and numerous associated data relating to those wells (see Arizona Department of Water Resources, 2007).

This manual is intended to introduce the new employee to the "how and why" of what we do, but it is also intended to serve as a reference manual for both new and experienced employees. The procedures outlined in these pages are the "tried and true" methods which have been perfected over the years. To become a skilled field hydrologist or field technician takes time, you must gain experience in the field, and for this there is no substitute. However, before you can work in the field, it is imperative that you have the proper knowledge and introduction into how and why we collect data. This manual is intended to provide FSS employees with the necessary techniques and understanding to facilitate the accurate collection of data. It is hoped that it will become a valuable reference for both new and experienced FSS personnel.

The following performance skills checklist (Table 1) is a tool for the employee and their supervisor to plan their training needs. Not all employees will receive all the training. This checklist is primarily intended to assure the employee has the necessary training to successfully complete their immediate assignments, but it also intended to be used to plan career development. All employees in FSS that do field work are required to be trained in each of the listed field skills. Computer skills and specialized skills will be taught to the employee as needed.

Table 1: Field Services Section Skills Checklist

Field Skills	Computer Skills	Specialized Skills
☐ GPS	☐ Understanding GWIS	☐ Sounder Probe Construction
☐ Well Location	☐ ArcGIS	☐ Sounder/Tape Calibration
☐ Well Inventory	☐ Access & Excel	☐ Discharge Measurements
☐ Water-Level Measurements	☐ GPS & All Topos	☐ Water Level Measurements
☐ Safety	☐ ArcMap in the Field	☐ Automated Sites Download
☐ First Aid		☐ Automated Site Installation
☐ Dealing with the Public		☐ GPS Survey Measurements
☐ 4 x 4 Vehicle Training		☐ Gravimeter Measurements
		☐ Streamflow Measurements

____________________________ ____________________________

Employee Signature/Date Supervisor Signature/Date

Chapter II

DATA

The primary responsibility of FSS is the collection of groundwater related data. The data that we collect is critical to the planning and protection of Arizona's groundwater resources. But, what exactly is groundwater data? The evaluation of the groundwater resources of an area should include such things as an assessment of the amount of water available, the depth to the water, the conditions under which it occurs, the quality of the water, the past and present uses of the water, and the effects of past and present water use. Much of this can be determined by collecting well data, water levels and water samples from existing wells within the area. An individual well owner may know the depth to water, production figures, water quality, and pumping effects of his own well, but only an area-wide compilation of these data from numerous wells can determine the groundwater conditions of an entire basin. The collection and compilation of this data is our responsibility.

What Kind of Data Do We Collect?
We collect several different types of data including water levels, well discharge measurements, streamflow measurements, various types of location and physical (inventory) well information, and USGS grade GPS/elevation measurements in select areas. Each of these data types will be discussed in detail in subsequent chapters of this manual.

Why Do We Collect Data?
To assure Arizona's continued growth and prosperity, our State lawmakers enacted the 1980 Groundwater Management Act. At the very heart of this Act is the management and conservation of Arizona's groundwater resources. To effectively execute this mandate would require vast amounts of information on the physical condition and make-up of Arizona's groundwater; past, present and future. Before 1980, the USGS was Arizona's groundwater data collection authority. After the 1980 Groundwater Management Act, the responsibility of groundwater data collection was inherited by the newly formed ADWR (specifically the FSS).

How is the Data Used?
We use the data to publish our HMS reports, HMR, and WLCMS reports. HMS reports contain maps and associated text describing the hydrogeology of a given groundwater basin. The maps show depth to water, contours of water table elevation, water level changes, flow **direction** of the groundwater, approximate boundaries of the main and sometimes lesser water bearing units (aquifers) in the basin, and water quality information. These published reports are a compilation and interpretation of the hydrologic data we have collected. HMR and WLCMS reports can be published for each

basin, by AMA or on a statewide basis. The maps from both series are made for public and FSS staff use.

Other uses of the data we collect include but are not restricted to the preparation of groundwater models, numerous types of map construction, development of annual water budgets, determination of assured water supply, growth and development planning for both urban and rural communities and resource management (especially critical during drought conditions).

Who Uses the Data?
Aside from the ADWR, our data is used by a wide spectrum of professionals and non-professionals. Our data is used by other government agencies (on the federal, state and local levels), numerous municipalities and power providers, construction companies, consultants, attorneys, universities and students, developers and realtors, farmers, ranchers and land owners, drillers, and the general public.

Sales of real estate can frequently be dependent on the verification of the adequacy of the water supply. This information is not only valuable to sellers, but to buyers as well. Industries contemplating location within the state are generally concerned about the availability and suitability of the groundwater. Industries requiring large amounts of water are advised against locating in areas where water use is already in excess of recharge thereby protecting interests of both the industry and the existing water users. Well owners whose historically adequate water supply suddenly becomes inadequate may suspect that new use or overuse by nearby users is causing the problem and may seek relief through the legal system. In such a case, retained attorneys and consultants could make use of our publications and historical data. Banks often require certificates of adequacy before granting loans on land. Drillers are frequent users of our depth to water maps, especially in areas where they have not previously drilled.

Construction interests commonly need to know depth to water information (especially where deep basements or underground parking is planned). The list goes on and on. Environmental impact studies, the pollution of an aquifer and the resultant potential heath concerns require vast amounts of current and historical groundwater data. It is extremely important to know the depth of pollutants and which direction the contaminant (plume) is moving, when an aquifer is found to be contaminated and before the clean-up can begin. Water is important everywhere, but in an arid state like Arizona, it is vital that we be good managers and custodians of our groundwater. The problem is exacerbated by the almost uncontrolled growth and subsequent development the state is currently experiencing. Arizona now finds itself in the throes of an extended drought, and the data we collect is invaluable in assessing the drought's impact.

Where Do We Collect the Data?
We collect data throughout the State of Arizona, with the exception of most Indian reservations, (where we work only with the approval of the individual Tribal Councils). It is our responsibility to provide current groundwater data for most parts of the state. We are just as responsible to the citizens of Willcox, Snowflake, Sonoita and San Simon as

we are to those who live in Phoenix and Tucson. We are kept busy, but with the knowledge that we are being responsive to needs of all the people of Arizona and hopeful that our data will play an important part in securing Arizona's future.

The Importance of Quality Control

Without quality control, there can be questions regarding the integrity of the data. Incorrect data can result in misleading conclusions, inaccurate maps, models, management and ultimately in a loss of confidence in the unit. The job we do is important, and the data we collect is vital if the Department is to manage Arizona's groundwater resources properly. It is therefore imperative that we do the utmost to insure accuracy. First, the data must always be collected according to protocol with properly calibrated equipment. This however, is only half the job. The data, once collected, must be entered into the GWSI database (see Arizona Department of Water Resources, 2008b). Great care must be taken when entering data, as this process can introduce many errors. Data entry accuracy in any business has always been a function of the diligence of those entering the data. It is extremely easy to misplace a decimal, or invert two numbers. It can easily happen, even to the most experienced of personnel. To combat this type of error, we have always used "field data sheets" which are filled out immediately after the data is collected. It is imperative for FSS personnel to double-check every measurement, correctly document their findings and relate it to previous measurement in order to find drastic changes, or possibly incorrect measurements. This type of double check should eliminate most field generated errors. When entering data into GWSI, if a water level differs from the previous water level by more that 10 feet, the computer automatically generates a warning. These types of checks are extremely important if we are to uphold the integrity of our database. It is not realistic to think that our database is perfect. Sometimes errors are made, however, it remains our goal to be diligent with our data collection, data entry and quality control as we strive to keep our database as accurate as possible.

Chapter III

NAVIGATION

Navigation is defined as the ability to control one's course. Perhaps the most important aspect of field work, regardless of the discipline, is knowing where you are. If you don't know where you are; any subsequent data that you collect is useless. Not to mention the fact that in Arizona's harsh summer climate, the result of becoming lost or disoriented can be fatal. For these reasons, it is extremely important that field personnel know "where they are". To this end, it is necessary that all field personnel are well acquainted with and become fluent with all of the navigational tools at our disposal.

It seems improbable that a trained Earth scientist could somehow be confused about where they are. However, as unlikely as it sounds, it can happen; and we have had to discard a considerable amount of data, simply because the "location of collection" could not be verified.

Maps

For decades, field hydrologists have used maps to guide them to well sites. Maps have traditionally been the only navigational medium available for field work. There are several types of maps at our disposal. We use road maps to guide us, in our travels, throughout the state. The road maps are scaled at 1:1,000,000 (1" = 16 miles). By using road maps, we can traverse the state and usually reach the general area we are looking for (i.e., assignment area). We also use another set of road/topographic maps. This set of maps is called the *Arizona Atlas & Gazetteer*. These maps are scaled at 1:250,000 (1" = 4 miles), and they offer a more detailed view, than the previously mentioned road maps.

When looking for a particular area, a map with greater detail must be used; these maps are known as Quadrangles or "topographic maps". These maps are prepared by the U.S. Geological Survey. A Quadrangle map covers four sided areas bounded by parallels of latitude and meridians of longitude. Quadrangle size is given in minutes or degrees. Work assignments (or working areas), are usually assigned by Quadrangles. That is, an individual is responsible for all the wells found within the area covered by a given Quadrangle. The first Quadrangles used by our office were the 15' maps, (15 minutes of latitude and 15 minutes of longitude). These maps are scaled at 1:62,000 (1" ≈ 1 mile). Most of the older 15' maps have now been replaced by 7½' maps, (7½ minutes of latitude and 7½ minutes of longitude). These maps are much more detailed than the 15' maps and are almost exclusively used for our field assignments. They are scaled at 1:24,000 (1" = 2,000 ft.).

Global Positioning System (GPS) Units

The advent of the GPS unit has greatly improved our ability to locate or orient ourselves in the field. Briefly, the GPS unit communicates with any one of numerous GPS satellites (in geosynchronous orbit), to tell the operator the current latitude and longitude of his/her position. By mounting the GPS unit in your field vehicle, your corrected latitude and longitude will continuously be displayed as you drive. Considering the fact that we work with maps delineated in degrees of latitude and longitude, the value of such an instrument is obvious. At any given time, you can pinpoint your location on the particular map you are working. This is extremely important as we commonly operate in areas where there are no discernable roads. We occasionally must go cross-country, or travel up washes, as it is the only way to get to an old abandoned well site. It is easy to become disoriented in these types of situations. However, with a functioning GPS unit, becoming lost is no longer an issue.

<u>Horizontal Datums</u>

Please take the time needed to determine how to set the horizontal datum. FSS will be collecting all latitude and longitude (in degrees-minutes-seconds format) in NAD27.

Laptops and PenTabs

Portable computers have made the life of the field hydrologist easier yet. The benefit of having your computer-housed database in the field with you is clear, but modern technology has again made field navigation easier. Some trucks are all outfitted with custom mounts to accommodate a laptop. These mounts allow us to see the screen of the computer as we travel (very similar to the arrangement in police cars). Our computers are downloaded with a software called *All Topo Maps: Arizona*. This software makes available (in electronic form), all the 7½ minute topographic Quadrangles in Arizona. The map upon which an individual is working can then be displayed on the computer screen. By attaching the GPS unit to the computer, the field person can follow his/her movements within their assigned area. An ArcMap project on your laptop will also have similar capabilities. This innovation should prevent field personnel from ever being lost or disoriented.

This arrangement also allows you to establish retraceable waypoints, or to program the latitude and longitude of a particular well(s). The GPS will then lead you to the desired well, as you follow your movements on the screen of the computer.

The new technology has certainly simplified field navigation, however it is not without its potential pitfalls. The most common of which is a difficulty seeing the screen of the computer in the bright Arizona sun. Another source of potential trouble arises when an individual spends a little too much time staring at the computer screen, and not enough time watching where they are going. You would be amazed how quickly you can drive into serious trouble (even at <5mph). The backcountry is loaded with ditches, washes, holes, cactuses, trees, posts, barbed wire fences, and occasionally mud. All these things have the potential to “ruin your day”. The worst-case scenario would be gazing at your computer screen while driving on a road or highway and drifting across the center line. **Always exercise care and caution when navigating with the computer and watch where you are going!**

While off-road navigation with the GPS and computer have certainly simplified the lives of FSS staff, to become completely reliant upon these innovations, is to invite trouble. Both the GPS and laptops are sensitive electronic instruments and they can fail in the heat of an Arizona summer, or due to the “beating” they take in the backcountry. Should such a failure occur, the ability to read and be proficient with Quadrangle maps can at the very least allow you to continue your work assignment. The ability to read and fully understand a topographic Quadrangle map could save your life.

For this reason, it is mandatory that all field personnel be trained to read and interpret topographic maps and learn to navigate using them. This was the method used by field hydrologists for decades, and it is still a virtually foolproof way to navigate in the field. If for any reason your computer fails (and it eventually will), you must rely on your maps to navigate, and complete your assignment. Ultimately, your field maps may be the only navigational tool left to you, so make sure you have learned how to use them.

Summary

If you are well versed in the use of all methods of field navigation, you should never become disoriented in the field. Should your computer “go down”, you can use the GPS to determine the latitude and longitude of your position. By plotting that point on the 7½ minute map, you can locate your position on the map. You may not know exactly where you are, but you won’t be lost. If you can read and interpret the topographic Quadrangle maps, you can still navigate, even if your GPS should fail.

Our computer, GPS, and topographic Quadrangle maps are the tools of navigation. They all have their positives and negatives, but without them, we are truly lost.

Chapter IV

WELL LOCATION

Before a well can be properly inventoried (see Chapter IV), it must first be located and identified. Each well in the GWSI has two unique identifiers; a site identification number (site ID) and a cadastral location (local ID). This chapter will deal with the protocols involved in locating and naming a well.

Site Identification Number
A site identification number or site ID is a unique 15-digit number assigned to one, and only one well. It is based on the latitude and longitude of the well in question. Once a site identification number has been assigned to a well, it is **never** changed for any reason.

In the interest of historical continuity, a bit of digression is necessary. The latitude and longitude of any well was originally determined by locating the well on a topographic Quadrangle (either 7½ minute or 15 minute), preferably a 7½ minute map, because of the greater detail. Some wells are already located and printed on the maps, with an associated well elevation. In this case, location of the well is already done, however, latitude and longitude still must be determined. Very few wells are pre-located on the maps, so it became the job of the field hydrologist to actually locate the well and mark its position on the map. This is not a difficult task, but it requires patience and a great deal of attention to detail. Once the well is located (and when back in the office), the latitude and longitude of the well can be determined. This determination is made using a transparent interpolation grid. By overlaying the map with the grid, and properly aligning it, the latitude and longitude of a particular well can be determined. There are two separate grids; one for 7½ minute maps, and one for 15 minute maps.

Well location became much easier and accurate with the development of orthophoto quads. The orthophoto quads are essentially aerial photos of the exact area covered by a given 7½ minute topographic Quadrangle and they are in nearly all cases, much more current. They are overlain with an imprinted latitude and longitude grid. The orthophoto quads became an immediate and invaluable tool for well location and subsequent latitude/longitude determination. Using orthophotos in the field made well location much easier. You could often see individual wells on the photo, and when you couldn't clearly see them, the well could usually be located by spotting trees, bushes, or other noticeable nearby features. The orthophotos greatly increased the certainty of accurate well location. Once located, a straight pin was used to make a pinhole in the photo at the determined location of the well. Once located on the photo, there was a permanent record of the well's location regardless of what future changes might be made in the area. Using the same transparent interpolation grids, the latitude and longitude of the individual wells (pinholes) could be determined. Once locations are determined, the appropriate notations are made on the back of the photo, at the proper pinhole.

So far, we have talked about latitude and longitude determination. As previously stated, the site identification number is based on the latitude and longitude of the well. The latitude (ex. 32º 45’ 15”) and the longitude (ex. 109º 15’ 31”) are combined to form the first part of the site ID. For example, the above hypothetical locations become 3245151091531. The suffix (01) is added to indicate that there is only one well at this location. In other words, the official site ID of this hypothetical well becomes 324515109153101. There are rare occasions when more than one well or perhaps a piezometer nest is located at a particular latitude and longitude. In the case of two wells, (01) is attached to the oldest well, and (02) to the younger of the two. Generally, piezometer nests house 3 wells and the suffixes (01, 02, & 03) are attached, based on criteria such as depth, drilling order, etc.

When this unique site identification number is established for a site (well), it is never changed and all pertinent data in the database (GWSI), will be referenced to that number. It should be noted that the site ID, once determined, becomes an identifier, and should **not** be used as a locator. The thinking behind this is, that for any number of reasons, errors can be made when establishing the site ID. Numbers in the latitude or longitude can be transposed, or incorrectly recorded. The latitude or longitude may have been incorrectly determined in the first place, however those incorrect numbers become the basis for the site ID of the well. Making a simple transcribing error such as 108º instead of the actual 109º, would place the well miles from its actual location if you were using the site ID as a locator. You can easily see how using the site identification number as the location of the well could lead to problems. In many cases, the site ID is spot on to the actual latitude/longitudinal location, but it cannot be assumed, and is therefore not to be used as a locator.

Many years have passed since the previously mentioned methods were used to determine latitude and longitude of a well site. Portable (hand held) GPS units have replaced the old methods and are now exclusively used to determine the location of wells. The GPS is placed on the well and after stabilizing the location is saved. However, even though the GPS unit will, when properly used, give you an extremely accurate latitude and longitude, transcribing errors can still occur. For this reason, we still **never** use the site identification number as a locator.

Cadastral Location

When the physical location of a given well is determined, based on its latitude and longitude, a cadastral location [ex. (A-03-04) 25abc2] can be assigned. The well numbers and letters (cadastral location) used by the FSS , as well as the USGS, are in accordance with the U.S. Bureau of Land Management’s system of land subdivision (Cadastral system). The land survey in Arizona is based on the Gila and Salt River meridian and baseline, which divide the State into four quadrants. These quadrants are designated counterclockwise by the capital letters; A, B, C and D. All land north and east of the point of origin is in A quadrant. The land north and west is in B quadrant.

The land south and west is in C quadrant and that south and east is in D quadrant. The first two digits of a well location indicates the Township, the second two digits, the Range, and the fifth and sixth refer to the Section in which the well is located. The lowercase letters a, b, c, and d after the section number indicates the well location within the section. The first letter denotes a 160-acre tract, the second the 40-acre tract, and the third the 10-acre tract. These letters are also assigned in a counterclockwise direction, beginning in the northeast quarter. In the example, well (A-03-04) 25abc2 is read as being located in the SW¼, of the NW¼, of the NE¼ of Section 25, Township 03 north, Range 04 east. If there is more than one well in a given 10-acre location, then numbers (ex. 1,2,3) are added as a suffix, in chronological order if known, with the oldest well being designated (1), and so on in order of age. If the chronologic order can't be determined, then the order will be arbitrary. A suffix number will not be used at all if only one well exists in the 10-acre tract, (for more information on the Cadastral system see Arizona Department of Water Resources, 2007).

Once the well is accurately located (using GPS generated data) on the proper 7½ minute topographic Quadrangle, the cadastral location can be determined by overlaying a transparent locator. This is a multiple scale locator which can be used to name all wells located within the Gila and Salt River meridian and baseline system.

Unlike the site identification number, the cadastral number is a locator, and can be changed if found to be incorrectly designated. With the benefit of GPS units and proper quality control, there should be very few newly generated erroneous well locations.

Whether you are attempting to assign a cadastral location to a well, or determine a site identification number, multiple wells in a given 10-acre location can be a source of confusion. As previously stated, suffixes are added to additional wells. In instances of more than one well within a 10-acre tract, it is unlikely that both the latitude and the longitude for each would be the same, especially now that we are using GPS units which report to the nearest tenth of a second. Therefore, the latitude and/or longitude for each well within a 10-acre tract should reflect a difference, either north-south or east-west, relative to one another. Although it might not seem important at the time of location, a photograph should be taken and a sketch should be drawn (on the back of the inventory sheet, see Chapter V), showing the location of each well in relation to the other. In following years, attempts to duplicate water level measurements or water quality samples could be confused by the absence (destruction) of one or more of the wells at a single location. Perhaps the only way of identifying a remaining well or wells would be a photograph and/or a sketch of the original wells and some permanent landmarks.

Chapter V

WELL INVENTORY

The early part of any basin investigation involves a very important phase called the well inventory. Well inventory consists of the collection of information pertaining to individual wells. The inventory is conducted by the field personnel of the FSS. The first step in the well inventory is the determination of the location of the well (covered in detail in Chapter III).

When conducting an inventory, a **well inventory form** is filled out (Figure 2). This form, when properly filled out, will contain all pertinent "field" information regarding that individual well. This data will eventually be entered into the GWSI database, and the inventory form will be placed in the permanent well file along with all other pertinent data regarding that particular well.

An obvious question might be, "How do we find all these wells?" Many wells are pre-marked on the topographic Quadrangle maps. When working in a given area, visual observation will yield many other wells not shown on the topographic maps. You can sometimes find potential well locations by carefully inspecting the orthophoto maps. You should always visit old homesteads. From a lofty vantage point use binoculars to scan the area, looking for dirt mounds, old broken-down windmills, casing laying on the ground, old cable and isolated power poles. Ask ranchers, farmers, foremen, drillers and land tenants if they know of any old abandoned wells in the area, or any newly drilled wells. Search the GWSI for old wells entered by the USGS; wells that have not been visited by ADWR staff.

Basin and Date

When a new well is found, the first thing the field person does is record the date and the appropriate ADWR groundwater basin and sub-basin. The date that the inventory is conducted is extremely important. The inventory form will become an official State document, and without a date it is of diminished value. So always fill out the current date first.

Site ID

This is the only data line that should **never** be filled out in the field. As previously stated in Chapter III, this unique 15-digit number is to be determined in the office. The site ID data line is only used for new wells (those not in GWSI).

Well Location
Again, this information and the way it is derived was covered in detail in Chapter III. This information can be filled in, if known, at the time of inventory. If there is confusion regarding multiple wells in a given 10-acre tract, the proper suffix number can more easily be determined when back in the office. In the office you would have access to driller's logs, GWSI, and 55-file information.

55 Number
This is a number assigned to registered wells, by ADWR. Unless you receive this information from the owner at the time of inventory, you would have no definitive way of obtaining it in the field. You should never match a 55 number to a well unless you are sure that the two belong together. It is better not to match a 55 number to a well, than to attach the wrong number to a well. This can best be accomplished in the office. **Since many wells are not registered, it is important to realize that some wells will not have a 55-number.**

Latitude and Longitude
Now that we have the benefit of GPS units, this information should always be filled out in the field. The first thing you do when you arrive at a well is to turn on the GPS and set it somewhere on the well. When the unit has stabilized (it can take a minute or two for the unit to acquire a satellite signal and become stable), you save the information in the GPS unit. It will be saved as a waypoint (ex. 045). You then record the latitude/longitude values and the waypoint number on the Inventory Sheet. This allows you to quality control your latitude/longitude values when back in the office (before you enter the data into GWSI).

Topographic Quadrangle
This information is simply the full name and scale of the topographic Quadrangle map where you are working, (ex. Green Valley 7½').

Topographic Setting
Fill in the description of the topographic setting where the well is located, (ex. valley flat, undulating, stream channel, hillside, etc.). See ADWR, 2006 for a list of topographic settings.

Altitude
Fill in the altitude as determined from the topographic Quadrangle map. Some wells have a surveyed value on the map. This value should be used when available. Otherwise you must interpolate the altitude of the well site. Before assigning an altitude value, you should scan the area to be sure that the well isn't located in a high or a low that isn't obvious on the topographic map. If this happens to be the case, adjust the interpolation accordingly. After recording the altitude, also record the accuracy (± ½ the contour interval). Altitude should always be determined while in the field, never in the office.

Water Use/Site Use
Note the water use and any pertinent factors that might affect the use. If the use is irrigation, you might note approximate number of acres irrigated, type of crop being irrigated, whether a sprinkler system, center pivot, or if gravity flow is used. If the use is domestic, try to note the number of families being served, number of houses or trailers, or if the use is public supply you might ask the number of accounts being served or the annual pumpage. The essential information is the actual water use, i.e. irrigation, domestic, public supply, stock, recreational, industrial, etc.

Pump Type/ HP/ Power Type
Note the type of pump such as turbine, submersible, piston (windmill or Jenson), etc. If the pump is a turbine, you will see a data plate somewhere on the side of pump. The horsepower of the pump will be listed on this plate. If the pump is a submersible, the horsepower will be shown on the starter box. Power types include; electric, gasoline, diesel, natural gas, wind, etc. If the well is, or was used for irrigation, check for indications of previous different power sources, such as natural gas mounts near a well that is now electric. This type of information is helpful in tracing historic pumpage data or in matching current wells to old wells.

Meter Number
The meter number assigned to the meter by the utility company is what you should record, rather than the meter manufacturer's serial number. The number you want is usually on a plate inside the glass meter housing on an electric meter and on a metal tab riveted to the cubic feet meter on a natural gas meter. These meter numbers are the key to identification of power use records, both past and present, and in the case of irrigation wells are extremely important. They are also frequently the only clue to matching old records to new records. It should also be noted whether the meter belongs to SRP, TGE, APS, etc., if known. In the case of domestic or public supply wells, the meter number is not nearly as important, but it should be noted and recorded if it is readily available.

Driller
If known, the drillers name is recorded (or it may be added later using a drillers log). This information would probably come from the owner.

Construction Method
This information is generally taken from a driller's log, and unless the owner provides the information, you would most likely never have this information in the field.

Date Drilled
Again, an owner can often supply this data. Sometimes the date is scratched into the concrete pad. There are many things that can be learned by being a "good detective" in the field.

Depth of Well
This is also data that generally will come from the driller's log if available. However, many owners may have this information. This information may be scratched into the concrete pad, so always check the pad carefully.

Casing Diameter
This is absolutely necessary information. You should never leave the well site without measuring the diameter of the well casing. This information can be vital when matching new well data to historical well data.

Casing Length
This information comes from Driller's logs and it is unlikely you will ever get this information when performing a well inventory.

Casing Circumference
There are times when you can't physically get a measure of diameter (due to pump sitting on top of casing, etc.), however you may be able to measure the circumference of the casing. Record this information, because the diameter can be calculated from the circumference.

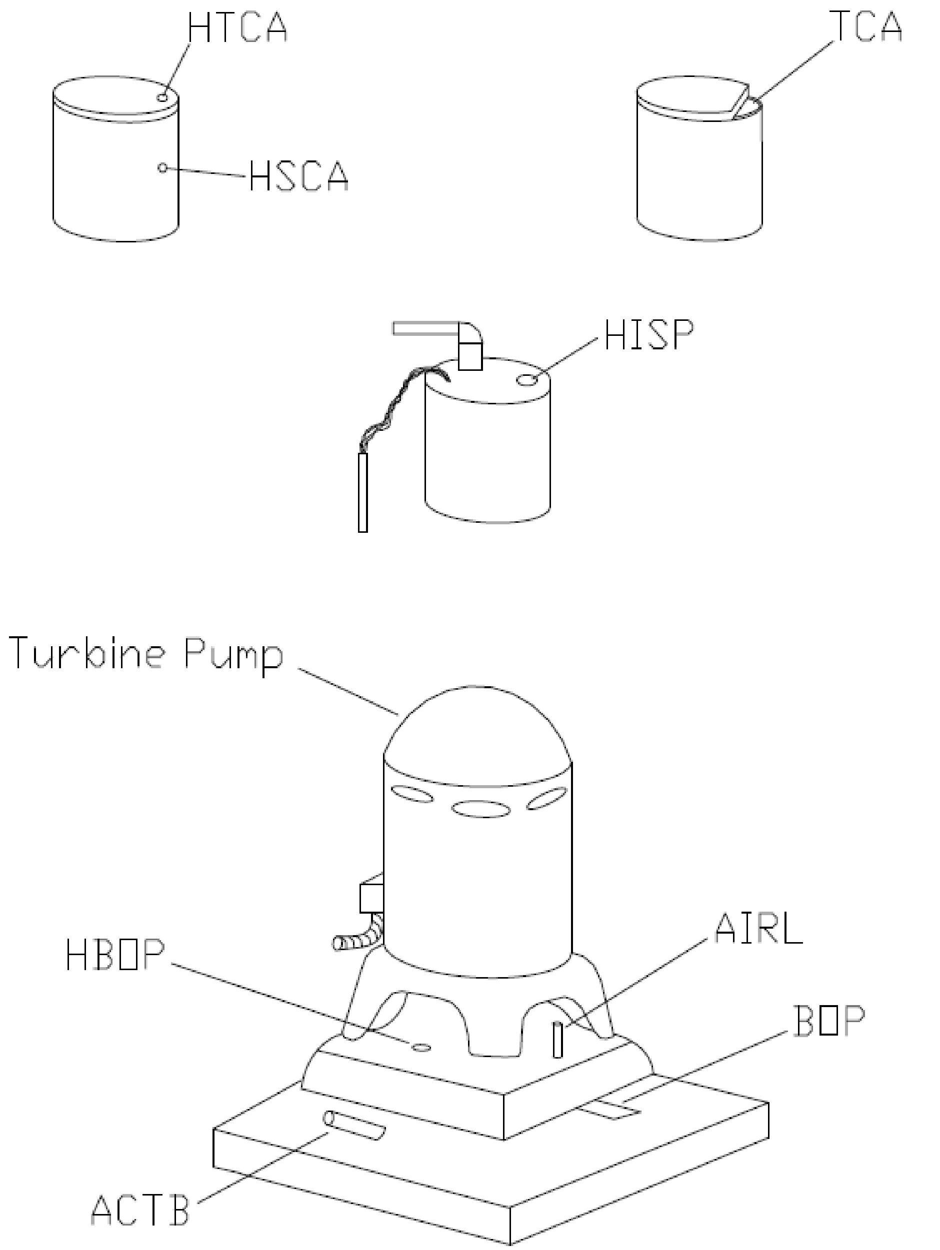
Owner
If known, the well owner's name is recorded.

Log
Generally, you will not have access to a log in the field, unless the owner lets you see their copy, or if they give you a copy.

Depth to Water below Measuring Point and Remarks
The number that you record here is the measured depth below the measuring point. **Note** this number (depth) is **not** the water level unless the measuring point height is 0.0' (see Chapter VI, Water Level Measurement). Be sure to associate any measurement remakes, and include them on your form (pumping, cascading etc.)

Measuring Point Description
This is the physical description of the location of the point where access for the sounder probe or steel tape was gained. Examples might be the top of casing, hole in pump base, a crack between wood timbers, slot between pump base and casing, hole in submersible pump plate, etc. Meaningful abbreviations, such as TCA for top of casing, HBOP for hole in base of pump and HISP for hole in submersible pump plate are generally used. See Figure 1 for a full list of access descriptions and abbreviations. Frequently, more than one access hole is available and sometimes when only one of several access holes allows access to the water table, it becomes necessary to identify which point should be used for the current and all future measurements. An example might be a hole in pump base, west side (HBOP,w), or slot under pump base, northeast corner (BOP,ne), etc. Some pumps have completely enclosed pump bases with the only access holes hidden inside. Some of these pumps have a plate which is held in

place by four screws. By removing the screws, the plate can be removed and access may be gained, (always replace the plate when you are finished). Inspect pump installations carefully for access, especially when the measurement is badly needed.



HTCA, w	Hole in top of casing, west side
HSCA, n	Hole in side of casing, north side
TCA, se	Top of casing, southeast side
HBOP, s	Hole in pump base, south side
BOP, n	Access under base of pump, north side
ACTB, s	Access (measuring) tube, south side
HISP, ne	Hole in submersible cap plate, northeast side
AIRL, w	Airline, west side
STB	Sounding tube (PVC)

Figure 1: Measuring Point (Access Hole) Descriptions.

The access hole in the pump base may be filled with debris (by digging around with a long screw driver or metal rod, the access hole can often be found). Sometimes you may find a slot between the concrete pad and the pump base or a small crack between the top of the casing and the plate that covers the casing. It is incumbent upon each field person to fully inspect the pump for possible access holes. Look carefully and take your time, you will often find an access hole where you didn't originally see one. **Note!** We often measure wells that have been measured before. When this is the case, **always try to use the same access hole from which the previous measurement was made.** This information is available in GWSI or on the water level printouts we always carry in the field. If this is impossible, you must try to find another access hole, accurately describe it, and note the reason for the change. This is extremely important!

Measuring Point Height above Land Surface Datum (LSD)
This is the measured height (rounded to the nearest 0.5'), from land surface to the point of access (access hole). If you are measuring a well that has been previously measured, use the same measuring point height as previous. This information will be available in GWSI, or on the water level printouts that we always carry in the field. The only exception to this rule would be an actual physical change to the pump or pump base, or the need to use an alternate access hole, due to blockage, etc.

Method of Measuring
You record the type of instrument that you used to make the water level measurement. In nearly all cases, this will be either the sounder (V) or the steel tape (S). The exception would be an electric tape (T), which is used for measuring water levels in sounding tubes at transducer sites.

Sketch
If there is more than one well at the site, or if the well is hard to find, always draw a sketch on the back of the inventory sheet. Always use a north arrow, note landmarks, trees, power poles, etc., and measure distances so that subsequent inquiries may easily be solved.

Field Checked By
Always print your name at the bottom of the field inventory sheet. The well inventory form is one of the most important documents that field hydrologists and technicians use while conducting an investigation. The accurate reporting of all possible data can be of incalculable value a year, two years, or maybe even ten years down the road. Always be diligent and thorough in your investigation. If something seems important, write it down.

ADWR BASIC DATA SITE INVENTORY SHEET

GWSI SITE ID: ____________________ LOCAL ID: ____________________

DATE INVENTORIED: ____________________ 55 REG ID: ____________________

LATITUDE / LONGITUDE (NAD 27): ____________________

ACCURACY:__________ SOURCE:__________ METHOD:__________

TOPO QUADRANGLE: ____________________ UNSURVEYED: ☐

MAP SCALE:__________ CONTOUR INTERVAL: __________ TOPO SETTING: __________

ALTITUDE (NGVD29): __________

SOURCE:__________ METHOD:__________ ALTITUDE ACCURACY:__________

ADWR BASIN / SUB – BASIN: __________ / __________

USGS BASIN: __________ STATE: __________ COUNTY: __________

SITE USE: ____________________ WATER USE: ____________________

PUMP TYPE / HP / POWER TYPE, SOURCE, Co.: ____________________METER#:__________

CASING DIAMETER (IN) / MATERIAL: ____________________

WELL / SITE COMMENT: ☐

OWNER FIRST:____________________OWNER LAST:____________________

CONTACT INFORMATION: ____________________

SITE ADDRESS ____________________

OTHER SITE IDS / SOURCE: ____________________

M.P. DESCRIPTION / HEIGHT (LSD): ____________________

DEPTH TO WATER BELOW M.P.__________ DEPTH TO WATER B.L.S. __________

METHOD:__________ REMARK:____________________

WATER LEVEL COMMENT: ☐

Figure 2: Well Inventory Form

PICTURES: Y N PICTURE INFO: ____

SKETCH

HAS REGISTRATION ID BEEN RESEARCHED? Y N

FIELD CHECKED BY: ______________________

ENTERED INTO GWSI DATE: ______________________

ENTERED BY (INITIALS): ______________________

VALIDATED BY: __________ DATE: __________

ADWR BASIC DATA SITE INVENTORY SHEET Revised: 6/03/2016 By: JMD N:\Basic Data\DOCS\Form Docs\Field Inventory Sheet V3.0

Figure 2: Well Inventory Form

Validation Instructions for Site Inventory Sheets

Validator: Mark in red all corrections on site inventory sheet. Mark in pencil all fields needed to be checked by staff. Once the inventory sheet has been reviewed, if there are corrections to be made in GWSI or info to be checked, return the sheet to field staff. They will make any corrections needed in GWSI and return the Inventory Sheet to you for review once again. Once all corrections have been made, then initial-date in the Validated By space at end of the sheet.

General Instructions:

- ❑ Check that all information (fields) on Inventory Sheet match what is in GWSI. For ex., check that the lat/long on the Inventory Sheet is typed the same in GWSI; do this for everything.
- ❑ Check all Site Detail fields for consistency and reasonability on all tabs.
- ❑ Check the cadastral format in GWSI is correct; no extra spaces or missing – dashes, etc.
- ❑ Check that GWSI Report and any imaged records are attached to Inventory Sheet before filing in Master File.

Specific Instructions:

- ❑ Check that the latitude/longitude on the Sheet matches what's in GWSI.
- ❑ Check Local ID (cadastral) and compare with topo map well mark; is the cadastral correct based on topo map check?
- ❑ Check 55 Reg ID matched correctly? Is 55 imaged record attached?
- ❑ Check other fields and see if they make sense such as Accuracy and Methods are reasonable.
- ❑ Is the Altitude reasonable and does it match what's in GWSI?
- ❑ Does the Water and Site Use match the Sheet?
- ❑ Right Basin, State, County?
- ❑ Check Source is correct.

- ❑ Check Lift Tab- entered correctly?
- ❑ Check Owner Tab is entered correctly.
- ❑ Check Site Names Tab if Other Site is filled out on Sheet.
- ❑ Check WM Points Tab if MP is filled out.
- ❑ Check WW Levels Tab if water level is filled out on Sheet.
- ❑ Check Images Tab if Pictures is marked Y on Sheet.
- ❑ Check MISC form Drillers Tab is completed if known.
- ❑ Check COMP form and Well, Borehole, Casing, Perforation tabs are filled out correctly from attached driller's report/log.
- ❑ Check MISC form and Site Inventories tab is filled out correctly using this format: Inventoried By: Last Name, Initial For example (Perez, MK)

Chapter VI

DISCRETE WATER-LEVEL MEASUREMENTS

Water levels are the measurement of the distance from the land surface down to the top of the water table. The collection of high-quality water-level data is dependent upon specific measurement techniques and the use of properly maintained and calibrated equipment. In a non-pumping well, these measurements are called static levels. In a pumping well, the resultant measurement is called a pumping level. The vast majority of the water levels we collect are static levels, but pumping levels are important, and we do, at times, measure pumping levels. In this chapter, it will be assumed that all the methodology discussed will pertain to static water levels. There are three instruments that we use to measure water levels: the electric tape, the steel tape, and the electric sounder. They all have strengths and limitations. Electric tapes and steel tapes are usually more precise than electric sounders, but electric sounders are generally more robust than steel tapes, and steel tapes are generally more robust than electric tapes.

Steel Tape

The first 20 feet of our steel tapes are graduated in hundredths of a foot. It is this part of the tape that is used to determine the water level. Before the tape is inserted into the well opening, a small weight is attached to the end of the tape and the graduated part is coated with chalk. The depth to water is obtained by lowering the tape to a predetermined footage so that the lower few feet of tape are submerged in the water. The tape is quickly removed from the well and the water level is determined by subtracting the length of wet tape from the predetermined footage (amount of tape lowered into the well).

Example	100.00’	(tape lowered into well)
	-9.15’	(length of wet tape)
	90.85’	(depth to water)

If the general depth to water is not known, trial and error will be necessary before an initial water level can be determined. Once the initial water level is established, the measurement must be re-done until repeatable. All water levels obtained with the steel tape must be repeated to insure accuracy.

Steel tapes are often used when the use of an electric tape or sounder is not feasible. Examples include wells where the access hole is too small to accommodate the probe (of the sounder). The steel tape can be slipped into small openings and cracks that the electric sounder would never fit into. The steel tape is also used to obtain an oil measurement. Another common application for the steel tape is to obtain water levels in shallow wells where the water table can be seen.

The steel tapes that we use are 500-foot tapes as well as 250-foot tapes, so an obvious limitation is that we can't measure a water level that is greater than 500 feet. Another disadvantage of the steel tape is that it cannot be used when cascading water is present in the well casing because the chalk will be removed. When the water level is deep, a lot of time and energy can be spent obtaining an accurate measurement. In wells equipped with electric-powered submersible pumps, a steel tape may cut through the insulation on the electric power wires. This is a safety hazard, which could result in a severe shock, electrocution, and/or pump failure. Using the steel tape to measure deep water levels in equipped wells is discouraged. The tape may become wedged or hung-up. Pulling on the tape can result in a break, which renders an expensive instrument worthless. Should such a break occur, the broken part of the tape may fall down the casing of the well and become entangled in the pump bowls. This can result in pump failure. To sum up, the steel tape, like all tools has its limitations, but when used properly, in the appropriate application, there should be no reluctance to use it. The steel tape is an invaluable tool, and an irreplaceable part of the field hydrologist's arsenal.

Electric Tape

Electric tapes are used on the transducer project and are used only in wells with sounding tubes and in shallow wells were the water table is visible. Four electric tapes manufactured by Waterline Envirotech LTD are available for use – two 500-foot tapes and two 1500-foot tapes. These tapes have two stainless steel electrodes that complete an electric circuit when they are in water (Figure 3). The first electrode to contact the water is the stainless-steel tip, and the second electrode to contact the water is the stainless-steel tubing. The circuit is completed when the bottom of the tubing contacts the water. When this happens, a buzzer and/or LED is activated to indicate the water level has been contacted. Moving the probe fractionally up and down, while noting the selected indicator, usually allows measurements to be precisely determined to the nearest 0.01 foot.

<u>Function Switch</u>

This switch has four settings: off, test, LED, and buzzer. When not in use the setting should be in the off position. The test position allows you to test the charge of the battery and the function of the electronic circuitry. When set to LED, the LED light will be activated when the circuit is complete. When set to buzzer, the buzzer will be activated when the circuit is complete.

<u>Sensitivity Switch</u>

The "LO" position is used for high salinity water. The "HI" position is used for very pure water.

<u>Battery</u>

The tapes require a 9-volt battery to operate. When not in use, turn the function switch to off to keep the battery from draining.

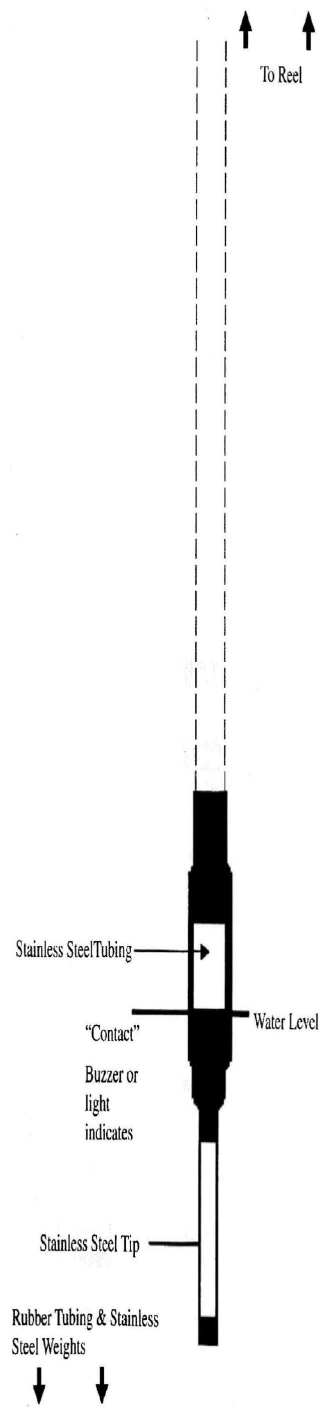


Figure 3: Electric Tape

Operation

1) Before inserting the probe into a well, the function switch should be set to test; this activates the LED and buzzer. If this does not work, then turn the sensitivity switch to HI and try again. If it still doesn't work, then replace the battery and try again.
2) Clean the electrodes. It is common to have a thin film of dirt form on the electrodes that may make it impossible for the electric circuit to be completed when the electrodes are in water.
3) Select the preferred indication. For most users and applications this will be buzzer. Occasionally, because of noise such as traffic at a busy intersection, it is hard to hear the buzzer and it may be easier to set the indicator to LED.
4) Set the sensitivity to HI.
5) Gently lower the tape into the sounding tube. Never let the electric tape free fall; when the free fall stops the weight of the tape may cause it to be permanently stretched and damaged. This is important because electric tapes do not have the tensile strength of our sounders. It is easy to permanently damage an electric tape by stretching it.
6) When the indicator is activated, then slowly reduce the sensitivity until the indicator is just deactivated, then increase the sensitivity about ¼ turn. This is generally an ideal setting to get precise measurements. If the sensitivity is too high, it is easy to get false readings when the stainless-steel tubing contacts condensation on the side of the sounding tube. If the sensitivity is too low, it is possible to have the stainless-steel tubing in the water without the indicator being activated.
7) Raise and lower the tape by small increments and observe the indicator until the measurements are precise to about 0.01 foot. If this does not seem possible then raise or lower the sensitivity by about ¼ turn and try again until the desired precision is attained.
8) Turn the function switch to off and neatly rewind the tape.

Troubleshooting

Installing a fresh battery will eliminate most problems.

1) Continuous signal
    i. Thoroughly clean and dry the electrodes.
    ii. Check the sensitivity setting.
    iii. Inspect the electrodes and tape for damage which might cause a short.
2) No signal
    i. Make sure the function switch is in the correct mode.
    ii. Set the sensitivity to HI.
    iii. Inspect the tape for damage.

Electric Sounder
The electric sounders used by the FSS consist of an all aluminum reel that can hold in excess of 2000 feet of 22-guage insulated (military communication wire) wire, a battery-powered meter box, a probe and a ground wire. The probe is attached to the sounding wire, which is connected through the reel and a brush system to the meter box, which is connected to ground. When the probe enters the water, an electrical circuit is completed and a deflection is indicated on the meter box. When using an electric sounder, water levels are generally measured to a precision of about 0.1 foot.

The Calibrated Wire
The sounder wire is calibrated using a steel tape and marked at 25-foot intervals using different colored three-quarter inch plastic tape. The 100-foot marks on the sounder wire are an obviously recognizable and distinguishable sequence from 0 to 300 ft. The same sequence is repeated for the interval from 400 to 600 ft., from 700 to 900 ft., from 1000 to 1200 ft., and so on for the entire length of sounder wire used. The following scheme must be followed.

Distance	Color
0	Blue
25	White
50	Yellow
75	White
100	Red
125	White
150	Yellow
175	White
200	Red Red
225	White
250	Yellow
275	White
300	Red Red Red

The above 300-foot sequence is repeated and marked the same way for each additional 300 feet of sounder wire used.

All sounding wire is marked at 25-foot intervals, and the reference point for measurements is **always the down hole side of the down hole mark**.

All sounders are numbered, and a companion equipment book is kept with the sounder. The equipment book is kept current for each sounder. The contents of the book include the sounder calibration form (Figure 4). This form must be completed for each calibration of all sounders.

SOUNDER CALIBRATION

SOUNDER # ____________________________

DATE ____________________________

YOUR NAME ____________________________

HELPERS
NAME ____________________________

DID YOU CHECK CALIBRATION MARKS ON FLOOR? YES NO
(BEFORE YOU CALIBRATED SOUNDING WIRE)

WHAT CHANGES DID YOU MAKE TO SOUNDER # _______

_______ ONLY A CALIBRATION CHECK

_______ ADD WIRE, HOW MUCH DID YOU ADD? _________FT.

_______ REMOVE WIRE, HOW MUCH REMOVED? _________ FT.

HOW MUCH TOTAL WIRE IS NOW ON YOUR SOUNDER? _________FT.

DID YOU FOLLOW THE PROPER PROTOCOL WHEN
MARKING THE SOUNDING WIRE? YES NO NA

If NO, why? ____

0.0 Blue
25.0 White
50.0 Yellow
75.0 White
100.0 Red
(1 Red for 100', 2 Reds for 200', 3 Reds for 300', repeat for each 300' sequence)

____
Your Signature

____
Helpers signature

Figure 4: Sounder Calibration Form

The Probe

The sounder probe used by ADWR is designed to minimize measurement errors caused by cascading water. Cascading water is not always obvious by sound. A number of assumedly accurate water level measurements made with steel tapes by the USGS during the late 1950's and early 1960's were later found to be inaccurate due to cascading water. A probe was developed to solve this problem.

At FSS, we use a very similar probe to the original design developed by the USGS. We use a 16" length of 3/8" vinyl PVC tubing, a 24" length of 18 gauge insulated wire, #7 steel shot and ½" lengths of plastic tubing (plugs), to construct our probes, (Figure 5). When first packed, the vinyl tubing will be curved and need to be straightened. This can be accomplished in several steps:

- First, the probes should be massaged to tightly pack the shot into the bottom of the probe; this will leave more room at the top of the probe to add additional shot.
- Second, heating the probe with a hair dryer can take some of the curvature out of the probe.
- Third, packing the probes tightly together into bundles with rubber bands and leaving them to rest for a few days can help straighten the probes.
- Fourth, inspect the probes to make sure they are ready to use.
    1) First, make sure the probe is tightly packed with shot. A good way to make sure the probes are tightly packed is to hold them upright and tap the bottom end of the probe onto a desk top. If the probes are not tightly packed, there will be room at the top of the probe to add additional shot.
    2) Finally, make sure the wire tip is not protruding from the vinyl tubing. New employees should work closely with their supervisor to make sure that their probes are being constructed properly.

The probes are designed so that a ¾" to 1" shroud (of PVC vinyl) protects the bare wire at the tip of the probe, and thereby eliminating false readings on the meter box. This simple, but effective development has made it possible to accurately measure thousands of water levels in wells where cascading water is present. One of the advantages of this probe is that it is designed to be disposable. It is attached to the sounder wire in such a way as to be the "weakest link in the chain". If it becomes hung-up while removing the sounding wire from the well; it will pull off with a simple pull on the wire. It is far better to lose one probe than to potentially lose hundreds of feet of wire down a well. After the sounder has been strung with calibrated wire, a probe is attached and the tare (including length of probe) is accurately measured and recorded in the equipment book.

PROBE SPECIFICATIONS

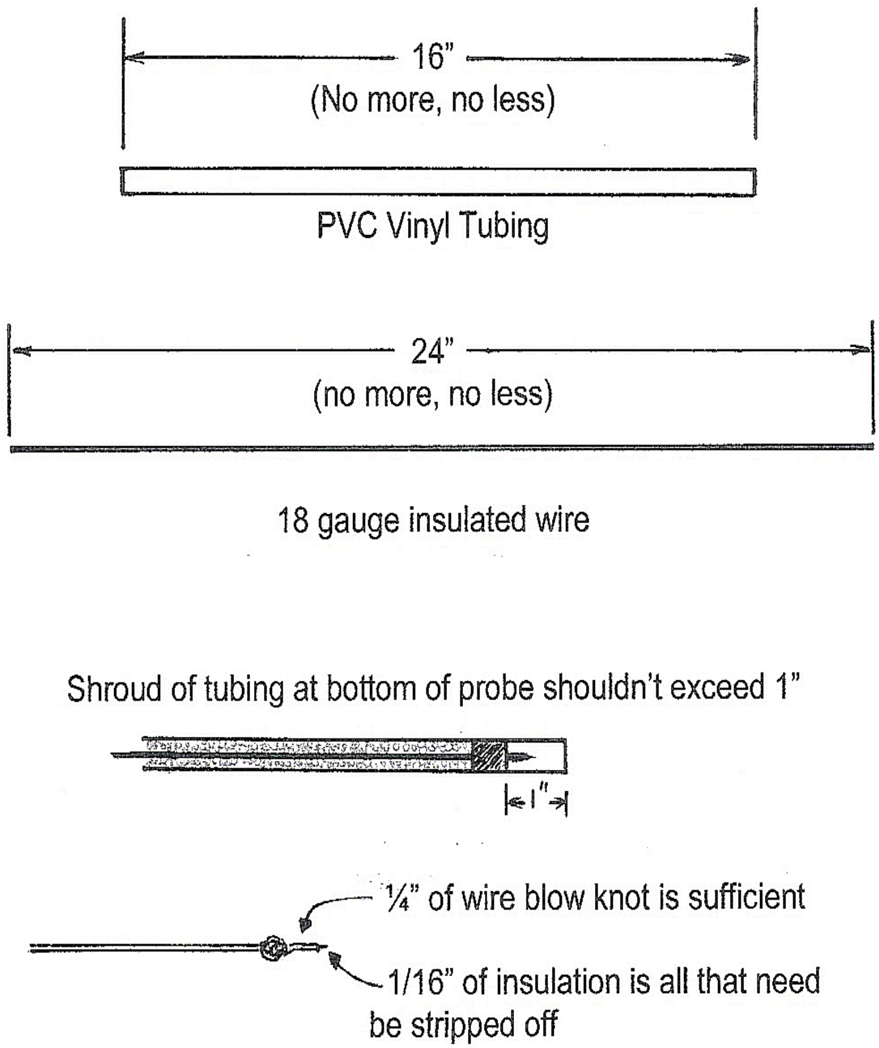


Figure 5: Probe Specifications

Operation

A measurement may be obtained once the probe has been lowered into the water. At this point, an electrical circuit will have been completed and the needle on the meter will be deflected. The sounding wire is very slowly pulled out of the water until the circuit is broken. This can be noted by watching the needle, (when it falls, the circuit is broken, meaning the probe is no longer in the water). By very slowly lowering and raising the sounding wire, the surface of the water table can be pinpointed. **Note!** The point from which you measure is **always** determined coming out of the water, **never** going into the water. By measuring from this point on the wire to the nearest 25-foot mark, an offset distance can be calculated by either adding (if the measured point is above the closest 25-foot mark), or by subtracting (if the measured point is below the closest 25-foot mark). The offset distance and tare are added to obtain the depth to water measurement. The measurement is then repeated to insure a precision of about 0.1 foot. The measuring point is generally above the land surface. If this is the case, by subtracting the height of the measuring point from the depth to water that has just been determined, you will obtain an accurate measurement of the depth to water below land surface at that particular well, (if below land surface, you add the measuring point distance).

When using an electric sounder, always keep the unit sitting on a dry area. If you are working in wet weather, carry some dry wood to sit the sounder on. Do not let the sounder touch any metal around the well. Sounders can short out when touching the well casing or being set on wet ground.

When lowering or removing the sounding wire and probe in a well, it should be done very slowly so that “tight spots” can be noticed and negotiated. When lowering, the “tight spots” are noted so that care can be taken when removing the sounding wire. A second advantage of slowing lowering the sounding wire and probe is that it gives the field person the opportunity to inspect the markings on the wire and determine whether they may have slipped and/or need repair or replacement. **Note!** Tape can slip after repeated use or become susceptible to slippage after coming in contact with oil.

A good general practice is to gently “snap” the sounding wire every 50’ when lowering it into a well. This will allow the operator to tell if the probe is hanging free, or if it is hung-up. **Note!** Always know the length of the tare, before sounding for a water level. This is important because the probe may be lost while retrieving the sounding wire. Sounding wire should be reeled into and out of the well and not allowed to accumulate on the ground. This can easily lead to tangles and kinks (which lead to weak spots), in the sounding wire.

Oil Measurements

Oil-lubricated turbine pumps typically have an oil film on top of the water column. Care should be taken that the oil does not foul the probe as it passes through the oil before entering the water. If several feet of oil floats on the surface of the water, it is better to use a steel tape and record the oil level, rather than record the water level at the base of the "oil column". For example, assuming that there is ten feet of oil, the upper surface of the oil will be within 1.4 feet of the true water level; the oil-water contact on the other hand will be 8.6 feet deeper that the true water level. However, it is possible to obtain a much more accurate water level when dealing with an oil-water interface. To adjust the depth to water measurement for the effect of the oil column, the height of the oil column must be determined. The top of the column can generally be measured with a steel tape and the oil-water contact can be measured with an electric sounder. By subtracting the depth of the oil measurement from the depth of the oil-water contact measurement, you can determine the height of the oil column. The height of the oil column is then multiplied by 0.86 (constant), to obtain the height of a water column of equivalent weight. Although this coefficient ranges from 0.85 to 0.88, depending on the type of oil, 0.86 represents an average value for oils typically used to lubricate turbine pumps. The height of the water column is then subtracted from the depth to the oil-water contact. For example:

Depth to top of oil (using steel tape) =	132.6 ft.
Depth to oil-water contact (using sounder) =	147.3 ft.
Height of oil column	
147.3 ft. - 132.6 ft. =	14.7 ft.
Height of oil column X 0.86 =	12.6 ft.
Depth to oil-water contact	
minus 12.6 ft. =	134.7 ft.
Depth to water adjusted for the	
Effect of the oil column =	**134.7 ft.**

Recording of Water-Level Data

When recording depth to water data, it is extremely important that the date and type of instrument used is recorded. The code for steel tape is "S", "T" for electric tape, and "V" for electric sounder. Other data that must be accurately recorded is the description of the measuring point and the height of the measuring point above/below the land surface. Unless there have been physical changes to the measuring point since the last measurement, you should always use that which was previously used for continuity.

Decontamination of Probes and Tapes

Water-level measuring instruments can become contaminated after use. It is good practice to clean the equipment regularly. All parts of the equipment that come into contact with the well water should be cleaned. Oil and grease can be easily cleaned using soapy water. Biological microbes can be killed using a dilute bleach solution. For wells used for drinking water, it is required that the equipment be cleaned before taking the measurement. A dilute bleach solution that is at least 1-part bleach per 10 parts tap water is acceptable to spray onto the equipment, then rinsed using a spray bottle of tap water. For wells that are located within areas of known contamination, all parts of the equipment that have come into contact with the well water must be cleaned immediately after the measurement using Alconox and then rinsed with tap water. The wash water from contaminated sites must be collected and handled in accordance with federal, state, and local laws or regulations.

Calibration

Water level measuring instruments require periodic calibration. The frequency of their calibration varies depending upon the instrument. The steel and electric tapes should be calibrated no less than once per year. The electric sounder should have a full calibration once a year, with a simple field calibration taking place daily, when the instrument is in constant use.

One **dedicated steel calibration tape is kept in the office at all times** as a reference. This tape is never used to measure water levels in wells. It is used as a “standard” for the calibration checks of all the other tapes and sounders.

At the time a sounder is strung, you are in effect performing the initial calibration. Once checked, the sounding wire is marked by variously colored 3M plastic tape. A new 25’ calibration table is now in use as opposed to traditional methods. The measured and calibrated edge of the tape is the down hole (probe) end of the sounding wire. The sequence for marking the sounder wire shall always be the same. That sequence is described earlier in this chapter.

A **master calibration book** and the reference steel tape are kept by the FSS Supervisor. Each time a sounder is strung, re-strung, has wire added, or is simply checked for calibration; the sounder number, the date, and the amount of wire added, and the names of the staff members performing the calibration is recorded in the book (Figure 6).

When working in the field, there is a simple field calibration that should be performed daily or at any time that the user has reason to believe that his or her sounder may be out-of-calibration. For example, if you think the length of wire has changed due to extended use, or because of applying extended tension to wire has become hung during retrieval. An “easy to measure” well should be selected that is representative of the general water levels in the area you are working. Attach a small lead weight to the end of the steel tape and make a water level measurement. Repeat the measurement to assure accuracy. You then measure the well with the electric sounder. If the sounding wire is properly calibrated, the difference between the two measurements should be less than 0.1 foot per 100 feet of depth to water. Record the time, date, and depth to water of the steel tape and the sounder in the **equipment book**, of the sounder you are using.

Anytime a new probe is attached, you immediately measure the new tare, the distance between the down hole edge of the blue tape, and the exposed tip of wire in the shroud of the probe. This is in effect a mini-calibration and should be recorded on a piece of paper somewhere in your vehicle or tool bag. This “tare” will be added to the total length of your measurement. Record the length of the new tare, along with the date and time. This provides you with an accurate reference, until a new probe is attached, at which time the procedure is repeated. By recording this measurement, you are assuring that you will never forget the tare.

The reference steel tape is used to check the calibration of other steel tapes and electric tapes. This calibration technique is taken directly from Oregon District Ground-Water Technical Note No. 3, (see United States Geological Survey, 2003). An unobstructed area with a flat surface is needed to lay out the tapes. We currently use the same 25' calibration table. The reference tape needs to be secure at both ends using appropriate hardware. Secure both ends of the tape and apply 20 pounds of tension. Unreel the field tape and align the zero marks of the two tapes and secure the field tape applying 20 pounds of tension. It is critical to apply the correct tension. Straighten and align tapes as needed with the tapes as close together as possible. Record observations at intervals no greater than 25% of the entire length of tape (100-foot intervals should suffice). At each observation point on the master tape, record the field tapes values. Compute the interval and the cumulative difference between the master tape and the field tape. Determine the accuracy standard for the tape. For example, steel field tape measurements should be within +/-0.01% of the master tape value, therefore there should be differences of no more than +/-0.005 feet (0.0001 ft. X 50 ft.) for each 50-foot interval, or twice the values for 100-foot intervals. Attempt to isolate the location of any discrepancies exceeding the standard to within an interval equal to 5% of the overall tape length. For example, 5% of a 200-foot length would be 10 feet; if a difference exceeding 0.005 feet was found in the 50 to 100-foot interval, check measurements should be made at 10-foot intervals from 50 to 100 feet to try and isolate the part of the tape where the 0.005 difference is located if possible. Release tension on tapes and rewind onto reels and fill out check sheets and record findings in the **master calibration book**, (Figure 6) If the tape is found to be within acceptable tolerances, the date for the next check is recorded and the tape may be released for further field use. If the instrument failed to meet the accuracy standard, a determination by FSS supervisor will determine whether the instrument should be repaired or retired.

ADWR/FIELD SERVICES SECTION
SOUNDER CALIBRATION CHECK SHEET

Inspected by:	Field Instrument/ID #	Date

Sounder Reading	Reference Reading	Cumulative Difference		Sounder Reading	Reference Reading	Cumulative Difference
0.0	0.00	0.00				
25.0				625.0		
50.0				650.0		
75.0				675.0		
100.0				700.0		
125.0				725.0		
150.0				750.0		
175.0				775.0		
200.0				800.0		
225.0				825.0		
250.0				850.0		
275.0				875.0		
300.0	0.00			900.0	0.00	
325.0				925.0		
350.0				950.0		
375.0				975.0		
400.0				1000.0		
425.0				1025.0		
450.0				1050.0		
475.0				1075.0		
500.0				1100.0		
525.0				1125.0		
550.0				1150.0		
575.0				1175.0		
600.0	0.00			1200.0	0.00	

COMMENTS, RECOMMENDATIONS & CALCULATIONS:

ADWR/FIELD SERVICES SECTION
SOUNDER CALIBRATION CHECK SHEET

Inspected by:	Field Instrument/ID #	Date

Sounder Reading	Reference Reading	Cumulative Difference		Sounder Reading	Reference Reading	Cumulative Difference
1225.0				1825.0		
1250.0				1850.0		
1275.0				1875.0		
1300.0				1900.0		
1325.0				1925.0		
1350.0				1950.0		
1375.0				1975.0		
1400.0				2000.0		
1425.0				2025.0		
1450.0				2050.0		
1475.0				2075.0		
1500.0	0.00			2100.0	0.00	
1525.0				2125.0		
1550.0				2150.0		
1575.0				2175.0		
1600.0				2200.0		
1625.0				2225.0		
1650.0				2250.0		
1675.0				2275.0		
1700.0				2300.0		
1725.0				2325.0		
1750.0				2350.0		
1775.0				2375.0		
1800.0	0.00			2400.0	0.00	

COMMENTS, RECOMMENDATIONS & CALCULATIONS:

ADWR/FIELD SERVICES SECTION
TAPE CALIBRATION SHEET

Inspected by:	Field Instrument/ID #	Date

1. Steel Tape Range 500 **Ft.**
2. Planned check Interval 100 **Ft.**
3. Accuracy Standard for Steel Tape 0.01 **%**
4. Discrepancy Tolerance .005 **Ft.**
5. Discrepancy Check Internal 25 **Ft. ≤ 5% of Full Range**

Check Instrument Reading	Field Instrument Reading	Cumulative Difference	Interval Difference	NOTES
0.0	0.00	0.00	0.00	
50.00				
100.0				
150.0				
200.0				
250.0				
300.0				
350.0				
400.0				
450.0				
500.0				

General Condition of Instrument: ☐ Excellent ☐ Good ☐ Fair ☐ Poor

COMMENTS, RECOMMENDATIONS & CALCULATIONS:

Figure 6: Tape Calibration Sheet

Chapter VII

AUTOMATED WATER-LEVEL MEASUREMENTS

The Statewide Automated Groundwater Monitoring Program was established to improve our understanding of water supplies in areas lacking groundwater data throughout the state. The program manages and maintains over 120 automated groundwater monitoring sites in Arizona, utilizing automated devices that record water levels on a predefined frequency on a continuous basis.

Automated sites gather data primarily using pressure transducers, but also utilize shaft encoders and bubblers. Groundwater levels are typically collected four times daily, with data being stored on-site using data loggers. Many automated sites are also equipped with GOES (Geostationary Operational Environmental Satellite) radio transmitters. Those sites transmit data daily using a satellite telemetry system, providing near real-time measurements. All automated sites are visited three times per year to download data, confirm the water levels with a manual measurement, and perform any needed site maintenance (such as replacing desiccant). Once the data are confirmed, they are uploaded to ADWR's GWSI database.

The following sections describe how to use, program, and maintain the transducers, shaft encoders, bubblers, data loggers, and GOES transmitters to collect automated water level measurements. For DH-21 operating instructions, see ADWR, 2008a.

Transducer Program Troubleshooting Checklist

Item’s typically brought to the site when troubleshooting and repairing a site include:

- Battery
- GOES radio and serial cable
- Data logger
- Bus plate
- Transducer
- Handheld GPS
- Ladder
- Multimeter
- Solar panel
- GPS unit for sites with a DA or DASE GOES radio
- Compass
- Data card
- Various tools

☐ If data logger won’t turn on:

- Check power connections to see if any are loose and check power toggle switch to make sure it is working.

- If connections are fine, then disconnect power cable from data logger and attach to a new data logger. If new data logger powers up, then check battery voltage. If battery voltage is fine, then you need to replace data logger. If battery voltage is very low or if new data logger does not turn on, then you have a power issue.

- If you have a power issue, then use volt meter to check voltage coming off solar panel. In direct sunlight the solar panel should provide around 18.5 volts. If solar panel is not providing significant voltage, then panel may need to be replaced (very rare).

- If solar panel is ok, then check voltage coming out of solar regulator. This voltage should be between 12 and 14.5 volts with solar panel in direct sunlight. If not, then voltage regulator needs to be replaced. In doing this it is easiest to replace entire bus plate, if present. This would also rule out a bad bus strip as the problem.

- When replacing voltage regulator/bus plate also replace battery and bring battery back to office and try to recharge it.

- If voltage regulator/bus plate is ok, then replace battery.

☐ If data logger turns on but site is not transmitting data:

- Check all connections to GOES radio to see if any are loose.
- Use data logger to check GOES time and compare it to time on handheld GPS. Remember that goes time is in Greenwich Mean Time (GMT), which is 7 hours ahead of Arizona time. Adjust if needed on a SE radio.
- If GOES time is incorrect or all zeros on a site with a DA or DASE radio, then try turning GOES mode from Timed to Off and then back to Timed to see if GOES time can be reinstated (may take up to 15 minutes). If not, then replace GOES radio. If a new DA or DASE radio is used and GOES time still can't be established, then GPS might be bad and would require replacement.
- Check GOES PDT address, report time, GOES channel, and baud rate to see if they are correct. This information is on first page for each site in Index Book.
- Check angle of GOES antenna. Should be pointing up 45 degrees and at an azimuth of approximately 217 degrees.
- If all GOES settings and time are ok, and the antenna angle is correct, then replace GOES radio.
- If data logger can't communicate with GOES radio at all, then replace GOES radio. If data logger still can't communicate with GOES radio, then try replacing data logger.
- If doing all above does not work, try replacing GOES antenna (very rare that this is the problem).

☐ If data logger turns on, but transducer is providing PSI or temperatures of zero:

- Check transducer connections to data logger and within top of dry air cell.
- Check battery voltages, if voltage to data logger is too low it may allow data logger to operate but not be providing enough power for transducer to operate. If voltage is low, then troubleshoot and fix voltage problem (see earlier explanation for this).
- Power up a new data logger and attach it to transducer. If it allows transducer to provide reasonable PSI and temperature values, then data logger may need to be replaced. If PSI and temperature are still reading zeros, then transducer needs to be replaced.

☐ If data logger turns on and transducer is providing PSI and temperatures that aren't zero, but the water level is significantly wrong from what was measured discretely then transducer may need to be replaced or water level tape is malfunctioning.

- Try using a backup water level tape (i.e. use the 1,500-foot tape instead of the 500-foot tape), if available. If water levels do not agree, then you might have a low battery in the water level tape. Replace battery and try again. If battery is replaced and water levels still don't agree, then you might have a malfunctioning water level tape.

If water levels between the two tapes agree then replace transducer and bring old transducer to office for cleaning and subsequent testing. Sometimes removing the screen on the transducer and cleaning it will fix transducer and allow it to operate correctly. However, this transducer should be put on test bed and tested for a long period of time prior to reinstalling into a well. **Transducer Program H-500XL or H-522+ with V4.4 or later firmware Download Instructions**

1) To download data, turn on data logger and insert USB stick into USB slot or data card into PCMCIA slot.

2) Scroll down on data logger screen using the down arrow until you get to "Data Options", then hit the right arrow. Hit the down arrow at 'Enter Device Mode' prompt.

3) Scroll down to 'Copy Files' and hit right arrow. Scroll down to 'Copy .NEW to USB?' if using USB or 'Copy .NEW to Card?' and hit enter.

4) While downloading watch the screen on the data logger and pay attention to how many kilobytes the .New file is. File should be around 40 kilobytes if site was last downloaded six months ago, or approximately 6 to 7 kilobytes per month of data. After the first download of the .New file, the data logger will ask if it should erase the .New file. Hit the escape button as you don't want to erase the .New file until after you have downloaded it to two PCMCIA cards or USB sticks.

5) If .New file appears to be too small, then use the up arrow on the data logger to scroll up to the selection above which says 'Copy All to Card?' or 'Copy All to USB Dev' and hit enter. This will copy all data that is stored on the data logger to the card or USB stick.

6) Whether you download just the .New file or download all the data, make sure that you download it two times using separate PCMCIA cards or USB sticks. This is done in case a card goes bad so you have a backup of the data.

7) When done downloading the .New file for the second time hit enter when the data logger asks if it should erase the .New file. This will erase the .NEW file and will start a new .NEW file that will include data to be downloaded during the next download run.

8) Once done downloading data, take a water level relative to the well's monitoring point (i.e. top of sounding tube) and then calculate the depth to water below the

site's benchmark (i.e. add or subtract the height of the monitoring point above or below the benchmark) .

9) Compare this water level to the water level that the transducer is reading. To find the water level that the transducer is reading keep hitting escape until you get to the beginning of the data logger menu tree. Once there, scroll down using the down arrows until you get to the depth to water that the instrument is reading (called "DTW"). Then hit the enter button and the instrument will take a current water level. If this water level is off by more than 0.02 feet, then the water level needs to be adjusted. If not, you are done.

10) To adjust the water level, scroll down from the initial screen to the "Sensor Input Setup" selection and hit the right arrow. Scroll down to 'SDI12 Task Options' and hit the right arrow key. Hit the right arrow key again at 'SDI12 Tasks Table' to get to 'Value 1' with a water level next to it in brackets. Hit the enter key and use the arrows to adjust the water level to what you measured in the well and hit enter.

11) Once the water level has been set, keep hitting the escape button until you get back to the beginning of the menu tree. Then scroll down and check the water level, as described earlier, to make sure it is consistent with the value you measured.

12) If the water level is the same, you are done. If not, go back and enter the water level again until you get it changed to the correct water level.

Transducer Program H-310/H-500XL, Shaft Encoder/H-500XL, and Bubbler/H-350XL Download Instructions

1) To download data from all three systems, turn on data logger and insert data card into PCMCIA slot on data logger.

2) Scroll down on data logger screen using the down arrow until you get to "Data Options", then hit the right arrow.

3) The data logger will perform a memory test. Once done, hit the down arrow and the data logger will perform a test on the data card. When done, hit the down arrow until you get to "Copy .New to Card?" and hit enter.

4) While downloading watch the screen on the data logger and pay attention to how many kilobytes the .New file is. File should be around 40 kilobytes if site was last downloaded six months ago, or approximately 6 to 7 kilobytes per month of data. After the first download of the .New file, the data logger will ask if it should erase the .New file. Hit the escape button as you don't want to erase the .New file until after you have downloaded it to two PCMCIA cards.

5) If .New file appears to be too small, then use the up arrow on the data logger to scroll up to the selection above which says “Copy Data to Card?” and hit enter. This will copy all data that is stored on the data logger to the card.

6) Whether you download just the .New file or download all the data, make sure that you download it two times using separate PCMCIA cards. This is done in case a card goes bad so you have a backup of the data.

7) When done downloading the .New file for the second time hit enter when the data logger asks if it should erase the .New file. This will erase the .New file and will start a new .New file that will include data to be downloaded during the next download run.

8) Once done downloading data, take a water level relative to the well’s monitoring point (i.e. top of sounding tube) and then calculate the depth to water below the site’s benchmark (i.e. add or subtract the height of the monitoring point above or below the benchmark) .

9) Compare this water level to the water level that the transducer is reading. To find the water level that the transducer is reading keep hitting escape until you get to the beginning of the data logger menu tree. Once there, scroll down using the down arrows until you get to the depth to water that the instrument is reading (called “DTW” on the H-310/H-500 XL and the shaft encoder and H-500XL and called “Stage” on the bubbler/H-350XL system). Then hit the enter button and the instrument will take a current water level. If this water level is off by more than 0.02 feet, then the water level needs to be adjusted. If not, you are done.

10) To adjust the water level, scroll down from the initial screen to the “Sensor Input Setup” selection and hit the right arrow.

11) For a H-310/H-500XL system, you will see a selection that says “Remote Stage Setup”. Hit the right arrow and then hit the down arrow until you are at a screen that says “Rem Stage” with a water level next to it in brackets. Hit the enter key and use the arrows to adjust the water level to what you measured in the well and hit enter.

12) For a bubbler/H-350XL system, you will see a selection that says “Stage Setup”. Hit the right arrow and then hit the down arrow until you are at a screen that says “Stage” with a water level next to it in brackets. Hit the enter key and use the arrows to adjust the water level to what you measured in the well and hit enter.

13) For a shaft encoder/H-500XL system, scroll down to the very last selection which will be called H-330 Setup and hit the right arrow button. Then make sure the SDI-12 Test address is set to [1] and hit the down arrow. The screen will say H330 Stage with a water level next to it in brackets. Hit the enter key and use the arrows to adjust the water level to what you measured in the well and hit enter.

14) Once the water level has been set, keep hitting the escape button until you get back to the beginning of the menu tree. Then scroll down and check the water level, as described earlier, to make sure it is consistent with the value you measured.

15) If the water level is the same you are done, if not, go back and enter the water level again until you get it changed to the correct water level.

Transducer Program Downloads and Operation and Maintenance Checklist

- Download data to two data cards or to computer (DH-21) and ensure that all data since last download has been included in the .NEW file. If it seems that some data is missing, then download all data (see downloading instructions if unclear how to perform this step).

- Delete .NEW file for sites with H-500XL or H-350XL data loggers. DH-21 sites will automatically delete .NEW file following download (see downloading instructions if unclear how to perform this step).

- Check battery voltage. If battery voltage is in the low 11-volt range, then view logged data and check to see if solar panel is really dirty. If solar panel is really dirty use water to clean it off. If battery voltages are falling below 11 volts overnight on the logged data and the solar panel was fairly clean, then replace battery.

- Check GOES time on sites with SE radios using time on handheld GPS unit. If GOES time is off by even a second, adjust time. Remember GOES time is in Greenwich Mean Time (GMT) which is 7 hours ahead of Arizona time. GOES time can be found on the data logger by scrolling down to “Output Options” then hitting the right arrow, then scrolling down to “GOES Options”, then hitting the right arrow, then scrolling down to “GOES Time” which will have the time next to it in brackets. Then hit enter and use the arrows to adjust the time. Then use the handheld GPS and hit enter again when the time you entered, and the GPS time match up and the GOES clock will start up. Make sure the times match up, if not repeat until they do.

- Take water level in well using electric sounder and calculate depth below land surface by factoring in the monitoring point height above or below the benchmark. Record these numbers in Index Book.

- Use data logger to measure what water level the automated device is reading. Record this value in comments section of Index Book (see downloading instructions if unclear how to perform this step).

- Compare discrete and automated water levels and adjust automated device to the discrete water level if difference is greater than 0.02 feet (see downloading instructions if unclear how to perform this step).

- Record what water level you reset automated device to in the comments section of Index Book. If you did not change the water level, then write “no reset” in book.

- Check desiccant, replace if pink or starting to turn pink.

- Make sure that scanning is turned on in data logger prior to leaving site. This is especially important for DH-21 sites as you need to turn scanning off in order to download data.

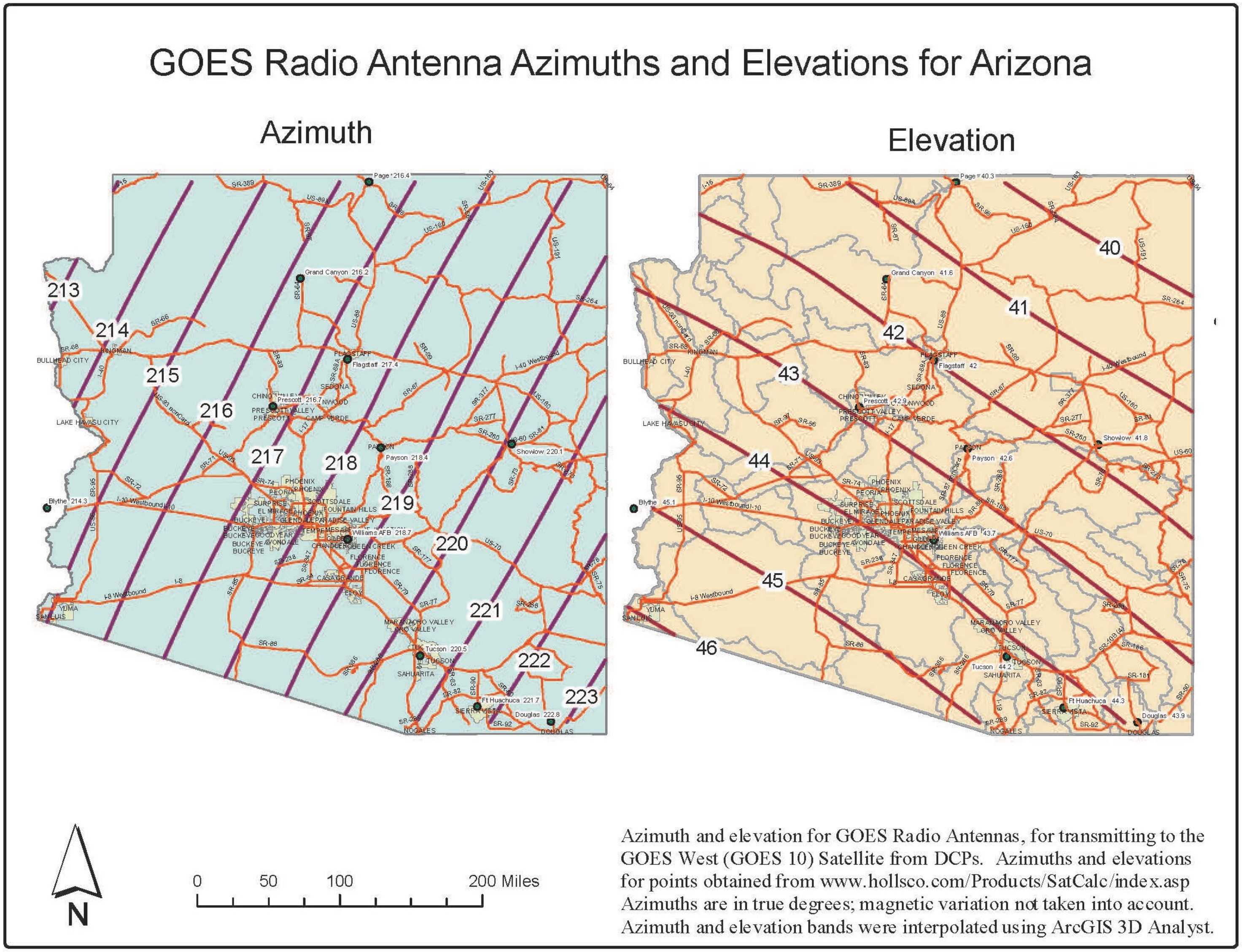


Figure 7. Azimuth and elevation for GOES Radio Antennas.

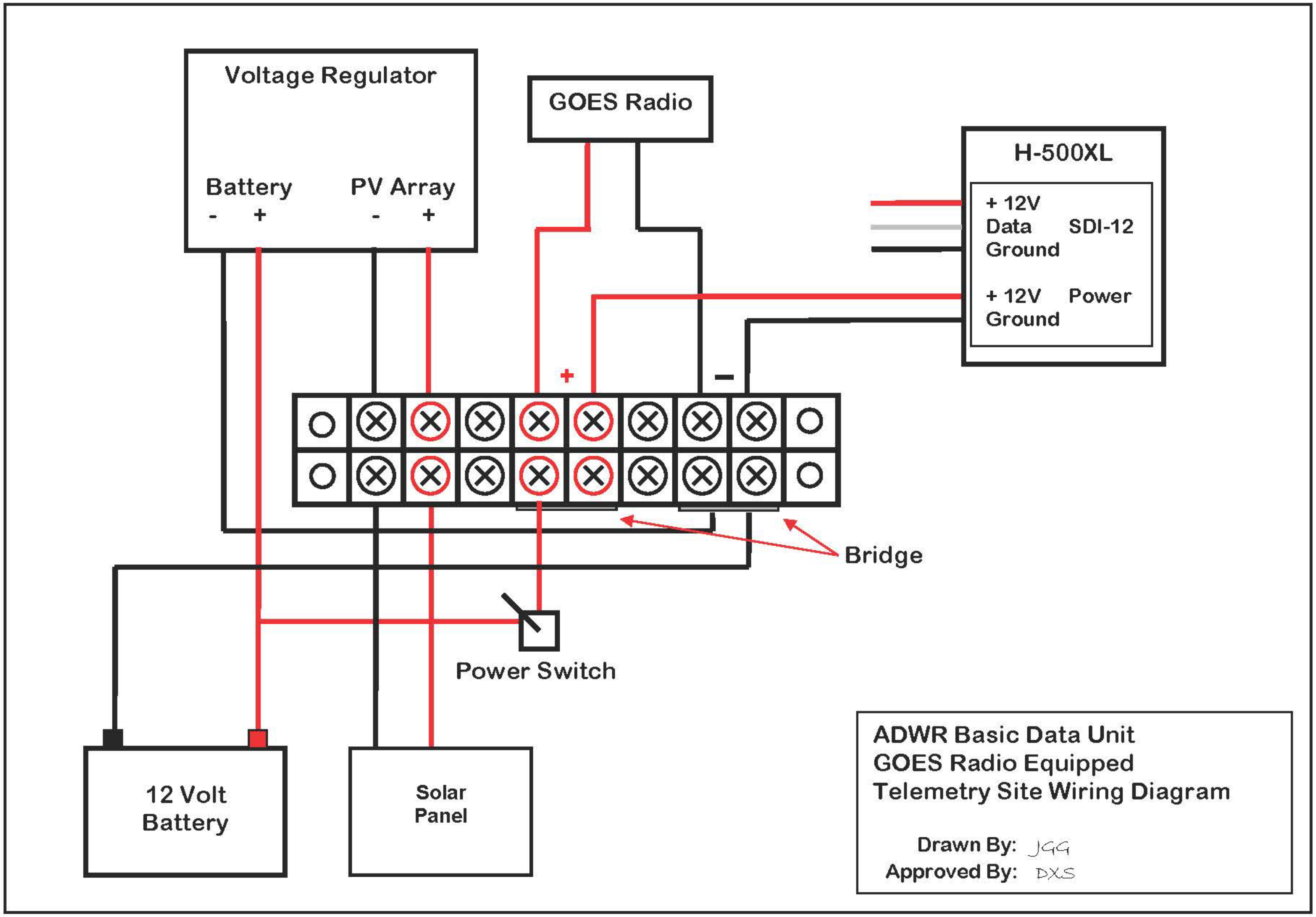


Figure 8. Telemetry Site Wiring Diagram.

Chapter VIII

WELL-DISCHARGE MEASUREMENTS

Measuring the discharge of pumping wells has constituted a significant portion of historic groundwater data collection in Arizona. The USGS began measuring well discharge in the 1940's. The vast majority of those measurements were made on agricultural irrigation wells, since they accounted for more than 90% of the groundwater withdrawal in the state. The results were combined with groundwater withdrawal data supplied by irrigation districts, municipalities, industries, private water companies and military installations to determine annual withdrawal in the state. The amount and distribution of annual withdrawal is an extremely important parameter in the assessment of a state's water resources, whether it is for planning, development or modeling purposes.

The Groundwater Act of 1980 stipulated that persons who withdraw groundwater from a non-exempt well in an Active Management Area (AMA) or an Irrigation Non-expansion Area (INA) are required to use an approved water-measuring device to monitor and annually report the quantities withdrawn. The Act further stipulated that withdrawals of groundwater for domestic use from wells having a pump with a maximum capacity of not more than 35 gallon-per-minute are considered exempt from monitoring and reporting annual withdrawal. These stipulations created a need for measuring the discharge of pumping wells that are now part of the duties of the FSS. Although annual groundwater withdrawal in the AMA's and INA's can now be ascertained from the annual reports required by the Act, periodic discharge measurements to validate the accuracy of approved measuring devices are necessary. When questions arise by the individual AMA's as to the exempt or non-exempt status of wells, discharge measurements by the FSS are the deciding factor.

The Cox Flow Meter and the Control-o-tron were at one time used by the FSS to measure discharge, however the primary instrument now used to determine a well's discharge rate is the Fuji Portable Ultrasonic Flowmeter. This instrument can measure the flow rate in a non-evasive manner from outside the discharge pipe. Because the Fuji unit is small and lightweight, it can easily be adapted to most well sites. Once the section of pipe has been selected where the measurement will be made, the discharge measurement is completed by first measuring the outside diameter of the pipe as well as the pipe wall thickness (there is an instrument that determines this measurement), and the type of pipe material that the pumping groundwater is flowing through. This information is entered directly into the Fuji Flowmeter which then calculates the cross-sectional area of the inside of the pipe and displays the distance that the transducers need to be separated when attached to the outside of the pipe. Once the transducers are attached with the correct spacing, the instantaneous discharge is displayed as gallons-per-minute as well as an integrated flow rate in total gallons. If possible, the flow discharge measurement is read over a 6 to 10-minute time period to minimize any possible varying flow rates by the pump. The Fuji Flowmeter can be used on pipes that range from ½ inch to 72 inches in diameter with an accuracy of 1 to 2%.

ARIZONA DEPARTMENT OF WATER RESOURCES

Well Discharge Field Report

Site ID__________________ Quad______________

Well Loc.__________________ WR No.__________ Power Acct#__________ Date__________ Time in______ Time out__________

Observers______________________________________ Lift Type__________ HP______ Line Pressure__________ Lbs/Sq In_x 2.31 = __________

Air Temp_____ °C Water Temp______ °C Sample pH_____ Est GPM__________ Owner__________________________________

Pumping Lift__________below MP MP__________Ft above/below LSD Address__________________________________

Permission Obtained From____________________ Title______________ How______ Town______________________Zip__________

MEASURING DEVICE DATA	ADWR MEASUREMENTS
______________________________ Make & Model Needle Reading______________ x 60 _____ = ______________GPM Seconds Totalizer Readings End______________Ac. Ft. ______Min. ________Sec. Begin______________Ac. Ft. ______________ x 325851 x 60 = ______________GPM Seconds End______________Gallons________Min.________Sec. Begin______________Gallons ______________ x 60 = ______________GPM Seconds	Method: Pitot Tube__________ Diameter (ID)________In. Yoke______ Area________Sq. In. Pipe Full________ How Determined__________ Rod Reading_______ Q______________GPM Measurement Rated______ Cox Extension: In. Of Water______________Manometer______________ Method: Fuji Portaflow Sensor Mount **V** or **Z** Circumference__ __ . __ __ Ft. ________In. Diameter(OD) __ __ . __ __ In Thickness **0.**__ __ __ In. Pipe Material____________ Signal Intensity____ Transducer Spacing __ __ . __ __ __In. Lining______________________ Trans. Voltage **Standard** / **2X** / **4X** / **8X** Totalizer Readings End__________Units Time____________Min.__________Sec. Begin________Units ______________ x 60 ______________ = ______________GPM Seconds
ENERGY DATA Power Type Elec. Ngas. Other Company__________ Meter No.______________ ______Rev. Disc.________Sec. Cu. Ft. 1Rev. Disc.______________Sec. Dedicated______________ Kh______ Kr______ K__________ F______________ K Revs. KWH = 19550 x __________ x __________ = __________ Ac. Ft. x Q Secs. RPM __________ Cu. Ft. F Therms = 195500 x __________ x __________ = __________ Ac. Ft. x Q Seconds	Method: Weir______________ Dimensions______________ Rod or Staff Read______________ Q______________GPM Measurement Rated______________ Method: Volumetric________________________GPM IVT Can, Vertical Cylinder, Horizontal Tank, Stock Tank, Etc. See attached Sheets Measurement Rated______________ Field Checked By ____________ Calculations Checked By__________ Notes:

Method: Current Meter No. Observer

Station	Width	Depth	Obs Depth	Vel' Point	Vel' Mean	Area	Q (cfs)

Checked By__________ Cfs x 448.8 = __________GPM

Water HP = Q x Head / 3960 = __________

Input HP = K x Revs. / Seconds x 4.83 = __________

Input HP = Cu. Ft. x F / Seconds x 1414 = __________

Overall Efficiency = Water HP / Input HP x 100 = __________%

Sheet Checked By__________Date__________

Owner notified By__________Date__________

Posted in Power Records By__________Date__________

Coded By__________Date__________

Entered in System By__________Date__________

Sheet__________ of __________Sheets

SKETCH

FLOW DISCHARGE

T | Seq. No. | Date Measured

Discharge | Source | Method of Measurement

Production Level | Source | Method of Measurement

LIFT DATA

T | Seq. No. | Date Measured

Lift | Power | Meter Number | Power Co. | Horsepower

Account Number | Divider | Source | Method

WATER LEVEL DATA

T | Seq No. | Date Measured

Water Level | Method | Remark | Source

MEASURING POINT

T | Date Established | MP Height | MP Description

Chapter IX

STREAMFLOW MEASUREMENTS

In 2007 the FSS, using USGS standards, was asked to begin streamflow measurement on two separate rivers in the state. The first being the Santa Cruz River which flows north through the Satan Cruz AMA from Nogales toward Tucson. The second being the Verde River which originates near Paulden, Arizona and flows through the Verde Valley Basin south into Phoenix. Though the purpose of each project remains separate, the discharge measurements in both rivers are generally taken within the same week on a quarterly basis.

Measurement of Discharge
The discharge or rate of flow of a stream is the quantity of water flowing past a cross section of the stream in a unit of time. The unit in which discharge is usually expressed is cubic foot per second, which is contracted into second-foot. A second-foot of water is defined as the quantity flowing through a cross section 1 square foot in area at a velocity of 1 foot per second. The procedure of measuring the area of a cross section of a stream and the velocity of flow past the section is known as the velocity-area method of measuring discharge. The product obtained by multiplying the area of the cross-section by the velocity constitutes a discharge measurement for that area (Buchanan et al., 1969).

The velocity of water may be measured either directly or indirectly, depending on the method employed. A direct method consists in observing the rate of travel of a float or a chemical placed in the stream. An indirect method consists either in the measurement of the slope of the water surface from which the velocity is computed by means of a slope-velocity formula or in the use of an instrument to measure the velocity of flow within a selected section. Discharge measurements are classified according to the method used in measuring velocity. The most common method used by the USGS for measuring discharge in a stream is the mechanical current-meter method. In this method, the stream channel cross section is divided into numerous vertical subsections. In each subsection, the area is obtained by measuring the width and depth of the subsection, and the water velocity is determined using a current-meter. The discharge in each subsection is computed by multiplying the subsection area by the measured velocity. The total discharge is then computed by summing the discharge of each subsection. ADWR has adopted the same methods as the USGS to complete any streamflow project.

Meter Types
To complete these stream discharge measurements field staff are equipped with two types of devices, the Marsh McBirney and the SonTek FlowTracker. The Marsh McBirney provides the hydrologist with an instantaneous velocity at each vertical within

a cross-section. The total discharge is calculated by hand after a sufficient number of verticals are taken. More commonly used by FSS Staff, and many other entities, is the SonTek FlowTracker. This device will calculate total discharge and all other cross-section information automatically at the ended of the measuring period

Completing a Wading Measurement

Before making a wading measurement, the hydrologist should examine various cross sections near the gage to find the one most suitable for this type of measurement. With the measuring section selected and the equipment assembled, the next step is to span the measuring section with a tag line at right angles to the direction of the streamflow. Any unnecessary deviation should be avoided by careful placing of the line. While placing the tag line, the hydrologist should obtain a general idea of the proper spacing of verticals by observing the total width of the section and the character of the stream bed.

After the tag line is placed, the actual discharge measurement has begun. The edge of the water in reference to a marker on the line and the bank from which the measurement is started (whether left or right bank, looking downstream) are recorded. The rod is then placed in a perpendicular position in the first selected vertical and the depth observed. If the depth in the vertical is 1.5 feet or greater, the two-point method should be used. If the depth is less than 1.5 feet the method used will depend largely upon the type of current-meter, the depth of the water, and the roughness of the stream bed. The performance of current-meters in water of shallow depths has been investigated by the USGS at the National Hydraulic Laboratory of the National Bureau of Standards. The results indicate that the 0.6-depth method should be used for depths between 0.5 foot and 1.5 feet and that the 0.5-depth method should be used for depths less than 0.5 foot.

It appears that coefficients other than unity may be necessary for current-meter measurements in very shallow depths for two reasons: First, the distribution of velocity in a vertical may be such that the actual velocity at the point of observation is not the mean for the vertical as, for instance, an observation at 0.5 of the depth; and second, the registration of the current-meter may be affected by its proximity to the water surface or the stream bed. Sometimes the errors from those two sources may be of opposite sign and therefore compensating. Under other circumstances the errors may be of the same sign, or may be predominantly of one sign, and therefore not compensating. As a result of the investigations mentioned above, coefficients have been determined for use with observations of velocities in shallow depths (Buchanan et al., 1969).

In wading measurements, the engineer should stand in a position that least affects the velocity of the water passing the current-meter. Field and laboratory studies conducted by the Hydraulic Laboratory Committee of the USGS indicate that the position of the hydrologist least affecting the accuracy of a discharge measurement by wading may be described as follows: With the meter rod at the tag-line and facing the bank with the water flowing against the side of his leg, the engineer, should stand from 1 to 3 inches downstream from the tag-line and 18 inches or more from the meter rod. If facing the left bank, they will naturally hold the meter rod with their left hand; if facing the right bank, they will hold it with their right hand. The results of the investigation show that no coefficient for position need be applied if this position is used. The hydrologist can maintain a standing position 18 inches or more from the meter rod with a reasonable degree of comfort and at that distance can also give proper attention to the current-meter.

Care should be taken to keep the rod in a vertical position and the meter parallel to the direction of flow while the velocity is being observed. If the flow is not at right angles to the tag-line, the amount by which the angle deviates from 90° or the angle coefficient for that difference should be recorded. This angle coefficient, which is the cosine of the angle of difference, may be determined using an angle chart or a protractor held in proper alinement with the tag-line while the "angle-coefficient line" that corresponds most nearly to the direction of the flow is being observed on the chart or protractor. Upon completion of the necessary observations at the first measuring point, a similar procedure is followed successively at each of the remaining verticals.

If the velocity at the edge of the water is not zero, it is customary to estimate this velocity as a percentage of the velocity measured at the first vertical or measuring point. In order that no appreciable error may be introduced into the total measurement as a result of such estimates, care should be taken to space the verticals so that the flow in the section bordering the edge of water is extremely small in comparison with the total flow. Furthermore, it should be kept in mind that the vertical-shaft cup-type meter tends either to under register or to over register when used close to a vertical wall or bank where the velocity is nonuniform, the direction of deviation depending on whether the bank or wall is to the right or left of the meter, looking downstream.

Two-Point Method

In the two-point method of measuring velocities, observations are made in each vertical at 0.2 and 0.8 of the depth below the surface. The average of these two observations is taken as the mean velocity in the vertical.

The two-point method is based on many studies of actual observations and on the theory that the vertical velocity curve corresponds to part of a parabola with axis horizontal at the point of highest velocity, for which it may be mathematically demonstrated that the average of the velocities at 0.2114 and 0.7886 of the depth is equivalent to the mean velocity. Studies of many vertical velocity curves made for different depths, velocities, and conditions of stream bed support this theory. Experience has shown that this method gives more consistent and accurate results than any of the other methods, except the vertical velocity curve method when it is used under measuring conditions of constant stage and steady flow. Because of the support given the two-point method by both theory and practice, it is generally used by the USGS in current-meter measurements of discharge.

There are, however, a few situations where correct results are not obtainable using the two-point method. One situation relates to the use of the vertical-shaft cup-type current-meter, which under registers near the surface and near the bed of the stream, so that for shallow depths a coefficient greater than unity may be required. The coefficient may vary with both depth and velocity. With the cup-type meter it is generally not advisable to use the two-point method in depths of less than about 2.0 feet unless a coefficient is applied. Occasionally, conditions may necessitate the application of a coefficient less than unity to obtain the correct discharge, as for example in deep water immediately above a dam where the measuring section is sloping upward. Before any coefficient is applied, however, its applicability should be thoroughly established by vertical velocity curves for the entire range of conditions covered by the measurement or by such other data as are available (Buchanan et al., 1969).

Sixth-Tenths-Depth Method

In the 0.6-depth method an observation of velocity is made in each of the selected verticals at 0.6 of the depth below the surface. This method is based on the theory that the vertical velocity curve corresponds to part of a parabola with the maximum abscissa within the upper third of the ordinate representing the depth. On this basis, the mean abscissa lies between 0.58 and 0.67 of the depth below the surface. If the maximum abscissa is in the upper fourth of the measured depth, the 0.6-depth ordinate is very nearly the mean. Although a large percentage of velocity curves that have been studied indicate that the mean velocity in the vertical is at approximately 0.6 of the depth below the surface, experience on certain streams, particularly those of great depths or with smooth beds, has shown that the results obtained by this method tend to be slightly greater than those obtained by the two-point method. Under those circumstances it is possible that the maximum abscissa for several of the selected verticals in the measuring section may be more than one-fourth of the depth below the surface. Laboratory investigations of performance of current-meters in water of shallow depth indicate that vertical-axis cup-type current-meters when used at 0.6 of the depth give results that are too small (requiring coefficients greater than unity) for velocities of 0.3 foot per second and less and where depths are 0.5 foot or less.

Although the 0.6-depth method generally gives fairly satisfactory results, nevertheless as the variations of individual observations may be somewhat greater than those shown by the two-point method it is used by the USGS only if the two-point method is found impracticable because of insufficient depth or for other reasons such as a rough stream bed or aquatic growth (Buchanan et al., 1969).

Chapter X

GEOPHYSICS & SURVEYING UNIT

The Geophysics/Surveying Unit's primary purpose is to gather, process and interpret land subsidence and aquifer storage in order to aid the ADWR in better management of the State's water resources. The data are gathered by using survey-grade Global Positioning System (GPS) equipment, gravity meters, and Synthetic Aperture Radar (SAR) satellites. The data consist primarily of GPS positions and elevations at discrete points, absolute and relative gravity values at discrete points for depth to bedrock and aquifer storage modeling, and broad swaths of SAR data that cover several critical areas of the State.

The primary programs supported by the Unit are the Land Subsidence Monitoring Program, the Aquifer Storage Monitoring Program, and Depth-to-Bedrock Modeling Projects. In addition, the Geophysics/Surveying Unit has performed surveys and supplied data to a wide variety of ADWR programs.

In the past, the Geophysics/Surveying Unit has worked collaboratively with numerous outside groups to perform projects that aid ADWR in a variety of efforts, including: water resource management, required survey-grade GPS measurements, gravity measurements, and/or the collection, processing, and interpretation of InSAR data. These efforts are mutually beneficial to a great many organizations, including: AZGS, Flood Control District of Maricopa County, State Land, CAP, SRP and more.

Trimble R8 GNSS Receiver Operating Instructions

To Check the Bluetooth Connection:

Press the windows button on the survey controller (the top left button on the TSC2 controller)

Click “settings”

Click the “Connection” tab at the bottom of the screen

Click “Wireless Manager”

If Bluetooth is off, just click on the Bluetooth line and the Bluetooth will turn on.

Click done after the Bluetooth shows up as “on”

Close the setting window by clicking on the “x” at the upper right corner of the screen

You should now be back in the main menu of the surveying software

Tripod and Receiver Set Up:

Verify the survey monument with the stamping to ensure you are surveying the correct survey monument.

Set up the center leg of the tripod to the 2-meter mark.

Set up and level the tripod on the survey monument (depends on survey monument). Try to have the two, hand-adjustable tripod legs on the south side of the center tripod leg.

Remove the brass receiver mount from the top of the tripod by loosening the holding screw.

Screw the brass receiver mount into the bottom of the receiver.

Plug the external power chord into the receiver by lining up the red dot and the red line on the power port.

Place the receiver on top of the tripod and tighten the holding screw for the brass receiver mount.

Re-check the level on tripod and re-level if necessary. Be sure to tighten the screw on the third tripod leg.

Changing the Receiver Between Rover and Base Mode:

Select the Instrument Tab

Select the GNSS Functions Tab

Select the Bluetooth Tab

If you want the receiver in rover mode, select the rover serial number from the drop-down menu for the GNSS rover and select none for the GNSS base.

If you want the receiver in base mode, select the base serial number from the drop-down menu for the GNSS base and select none for the GNSS rover.

After you make your selections, changing between rover and base mode, hit the accept button at the bottom right corner.

It might take a few minutes for the receiver to change modes, but you'll know when it has been completed when all the buttons (position, receiver status, etc.) are illuminated again on the GNSS functions screen

Starting GNSS Survey:

Turn on the TSC2 survey controller/handheld (Only push the green power button for a second. Holding it down more than a few seconds will reset the controller.)

Connect the external power cables for the receiver to the battery.

Wait for the receiver to connect to the handheld.

Once the receiver is connected to the handheld, select the Measure tab.

Select the Fast Static Tab. Select Start Base Receiver.

Enter in the Point name (e.g. FRESH) and click okay for the error message regarding entering GPS coordinates after the survey after you enter the point name.

Make sure the Height of the Antenna is 2.0 meters (or the height of the tripod labeled on the center adjustable pole) and that the measured to bottom of tripod is selected.

Select the Measure button at the bottom right of the screen. Click OK for the message that the Base has started.

Survey for four hours or whatever pre-determined time (use a stop watch and/or record the starting time of the survey on the GPS session sheet).

Enter the PDOP and number of satellites on the form in 30-minute increments.

To check the name of the file for the current survey, select the Instruments tab, select the Receiver Files tab, and the file with the T0A by it is the current file that is being created.

To check your current position, select the Instruments tab and select the Position Tab

Turn the controller off when you aren't using it to check the PDOP or start/end the survey.

Once the four hours is completed, select the measure tab, select the fast static tab, and select End GNSS base survey.

Select Yes to power down the GPS receiver. Turn the controller off (Only push the green power button for a second. Holding it down more than a few seconds will reset the controller.)

Put the GPS receiver and controller back in the case, break down the tripod, and move to your next point.

At the end of the day, download the receiver using the Trimble Data Transfer program and place the files in a folder on your laptop

Rename both the .T01 and the .DAT files, so the Point name and date (using YYYYMMDD) is at the beginning of each file name (e.g. X479_20180201_19940371)

Typical GNSS Survey Setup

Scintrex CG-3M Operating Instructions

Taking a Field Measurement:

Setting up Excel Gravity Data Entry Form

Open the Excel Gravity Data Entry Form and rename it to the Date (yyyymmdd) followed by the name of the gravity loop or base tie and gravimeter. For example, 20161206_Loop1_NewMeter, or 20161206_Loop1_CG5, or 20161206_PHXAA_PHXAB_BaseTie

Setting up the tripod and gravimeter

Set up the tripod so that the level bubble is oriented to the north. The two adjustable legs should be on the southern and western-most points. The tripod leg with the spacer is always on the top right (northeast). Never adjust the top right leg and make sure it is hand tightened against the spacer. After you set up the tripod, very carefully and very gently place the gravimeter on the tripod.

Changing the Gravimeter Mode (If needed)

Press the Aux button twice. Scroll to the Autograv setup screen and press enter. Scroll to the mode screen. Press enter and then scroll to the appropriate gravimeter mode (none, fld grav, or cycling) and press enter. For collecting data in the field, be sure to scroll to the fld grav and then press enter. Press Aux twice to leave this screen.

Changing the Time (If needed)

Press the Aux button twice. Scroll to the Initialize screen and press enter. Scroll to the time screen. Press enter and then follow the screen by entering HH, then MM, then SS, then YY, MM, and DD and press enter. Press the Aux button twice to leave the time screen.

Changing the Enter the lat/long

CG-3M Gravimeter Screen/Menu

Press the Aux button twice and use the arrow keys to scroll to the Autograv setup screen and press enter. Then scroll until you see Deg Long to change the Longitude. Press the enter button and then enter the decimal longitude to one decimal place (for example 112.1) and press enter. To change the latitude, scroll up to the Deg Lat and press enter. Enter the latitude to two decimal places (for example 33.45) and press enter. Press the Aux button twice to leave the time screen.

Leveling the gravimeter


CG-3M Tripod Setup

Press the Aux button twice and then press the start button. The autograv adjust screen will appear with the X and Y tilt. You always need to adjust the Y tilt first by using the upper left tripod adjustment knob. If the Y value is too negative, turn the knob to the left or counter clockwise. If the Y value is too positive, turn the knob to the right or clockwise. Adjust the Y until it is between +/-2. Next adjust the X tilt by using the bottom tripod adjustment knob. If the X value is too positive, turn the bottom knob to the left or counter clockwise. If the X value is too negative, turn the knob to the right or clockwise. Adjust the X until it is between +/-2. Doublecheck that both X and Y tilt are between +/-2 and make any necessary adjustments. Let the gravimeter sit and stabilize for one minute.

Taking a measurement


CG-3M Gravimeter Setup

After the gravimeter has stabilized for one minute, press the Aux button twice. Press the start button and confirm that the levels are still good (X and Y are within +/- 2). Press the start button again for the measurement to begin. The measurement takes around 60 seconds. While the gravimeter is making the measurement, remain as still as possible, and shield the gravimeter from the sun and/or wind with your body. The gravimeter will pick up the vibrations from any operator movements, as well as other environmental noise like traffic or wind. Also, direct sun on the tripod will affect the gravimeter's level. Record the station number, name, and any comments on the excel gravimeter form on the Microsoft Surface Pro during the measurement. As the measurement is ending, be sure to record the SD value on the form. When the measurement is complete, the final gravimeter value will appear. Enter the final gravity value on the form press the record button to record the value. In rare cases, you may not want to record the measurement. If you don't want to record the measurement, press the start button to start a new measurement without recording it. If you want to cancel taking a measurement at any time while you are at the leveling screen, press the Aux button a few times. If you want to cancel taking a measurement at any time while a measurement is recording, press the start button again and the measurement will stop. Don't record the measurement by pressing the start button again.

Be sure to take a minimum of two measurements at each location. Continue to take a measurement until the final two measurements are within 0.003 mGal of each other. When starting each field day, take a minimum of five measurements at the gravity base station and continue taking measurements until the final two measurements are within 0.003 mGal of each other.

Gravity Looping Procedure

CG-3M Gravimeter Setup

The gravimeter is a relative gravimeter and will drift during the gravity survey. To account for the drift, gravity loops must be completed. Start each day off by measuring the gravity base station first. You will take five measurements at the gravity base station and continue taking measurements until the last two measurements are within 0.003 mGal. After you measure the gravity base station, move to the first gravity station and take a minimum of two measurements and continue taking measurements until the final two measurements are within 0.003 mGal of each other. Move to the next gravity station and repeat these steps. Once all the gravity stations have the first set of measurements, return to the gravity base station (to close out the first loop) and take a minimum of three measurements and continue taking measurements until the final two measurements are within 0.003 mGal of each other.

After you measure the gravity base station for the second time, move to the first gravity station and repeat the procedure of collecting measurements at all the gravity stations. Once all the gravity stations have the second set of measurements, return to the gravity base station (to close out the second loop) and take a minimum of three measurements and continue taking measurements until the final two measurements are within 0.003 mGal of each other.

At this point review the results worksheet on the gravity spreadsheet and see if the differences between loops 1 and 2 for the gravity stations are within 0.005 mGal of each other. If not, repeat a third loop of measurements ONLY for those stations that have differences that are greater than 0.005mGal. After the third loop of measurements is completed, including the gravity base station, review the results and see if differences between loops 1 and 3, and loops 2 and 3 are within 0.005mGal for the stations measured in the third loop. If not, those gravity stations will need to be measured a fourth time if time permits. Otherwise, measure those gravity stations another day with a minimum of two gravity loops.

When completing gravity base ties, take a minimum of five measurements for all the base stations. For example, a PHXAA and PHXCC base-time would have five measurements each time at PHXAA and PHXCC for each gravity loop.

All gravity stations must be measured a minimum of two times using two gravity loops.

Returning to the Office:

Set up the gravimeter:

Set the tripod up and carefully place the gravimeter on the tripod. Plug the gravimeter into the external power supply. Remove the battery compartment cover. Level the gravimeter.

Downloading the gravimeter:

Plug the serial/parallel cable into the laptop and the gravimeter. Open the command line on the laptop and type:

cd /

cd idump

idump mm_dd_yy.NEW com1 2400 no 8 1 s

(for example: idump 11_23_16.NEW com1 2400 no 8 1 s)

The idump window will then appear within the command line screen. Go to the gravimeter and press the Aux button twice on the gravimeter and scroll to the Output page and press enter and then press start. The data will then start to be dumped onto the laptop and you will see it appear on the command line screen on the laptop. Let the data download. If it's just a field day of gravity data, it will only take a few minutes. If it's a few days to a week worth of drift data, it will take around an hour to download. When no more data is scrolling across the command line screen the data dump is completed. Hit the ESC key on the laptop and then type exit. The command line will disappear. Copy the file onto N:\SUBSIDEN\ASM PHOENIX AMA\PHX AMA GRAVITY\Phoenix AMA Gravity 2016

Open the idump file in excel. When the text import wizard appears, select fixed width, and scroll down to row 15 and change the start import at row value to 15 and click next. Insert break lines in between all the columns where break lines don't already exist. Copy and paste the Grav., SD., and Time values into the form. Copy the file onto N:\SUBSIDEN\ASM PHOENIX AMA\PHX AMA GRAVITY\Phoenix AMA Gravity 2016

Erasing the memory:

Confirm that the dump file is on the laptop before erasing the gravimeter memory. Press the Aux button and scroll to the Initialize screen, press enter and then scroll to the memory screen. Press enter and then press start. The memory will be erased, and you will know it's done when it says 100%. Press Aux twice to return to the main menu.

Setting up for a Drift Measurement (If needed):

Press the Aux button twice. Scroll to the Autograv setup screen and press enter. Scroll to the mode screen. Press enter and then scroll to the appropriate gravimeter mode (none, fld grav, or cycling) and press enter. For drift measurements, be sure to scroll to cycling and then press enter. Press Aux twice to leave this screen.

Be sure the memory is cleared on the gravimeter (see erasing the memory above).

Level the gravimeter and then start the measurement. There will be nothing to record during the drift measurement. The gravimeter will continuously be taking a measurement every five minutes until it is stopped or runs out of memory. The drift measurement usually last anywhere between 3 to 9 days.

Changing the Drift Value (If needed)

Press the Aux button twice. Scroll to the Autograv setup screen and press enter. Scroll to the drift screen. Press enter and scroll to the drift date. Press enter and then enter again to change the drift date. Next, change the drift value. Scroll to the drift value. Write down the drift value and then calculate the new drift value by adding the drift correction value to the drift value. (For example, Drift Value 0.251 + Drift Correction value -0.008 = 0.243 New Drift Value). Press the enter button and then enter in the new drift value (0.243 in the example) and press enter. Press Aux twice to leave this screen.

GPS STATION OBSERVATION SHEET

Project Name:____________________________________ Project Number(WO#):________

STATION INFORMATION

Station Name ___________________________

4 Letter Station ID __ __ __ __

Lat: __ __ __°__ __'__ __"N
Long: __ __ __°__ __'__ __"W
Elevation: __ __ __ __ . __ meters/feet

WEATHER

	START	MID	END
Temp. (F/C)			
Wind (mph)			
Cloud Cover			

OBSERVATION INFORMATION

Operator: Last Name: ______________________First Name: _________________________

File name: __ __ __ __-__ __ __-__ Session : __

Start:	Date:__ __/__ __/__ __	Julian: __ __ __		
	Time: Local __ __:__ __am/pm	24H __ __:__ __	U.T.C: __ __:__ __	
Finish:	Date:__ __/__ __/__ __	Julian: __ __ __		
	Time: Local __ __:__ __ am/pm	24H __ __:__ __	U.T.C: __ __:__ __	

EQUIPMENT CONFIGURATION

Logged Data in (Data Collector / Receiver) Equipment Name/Number: ________________
Receiver Type ____
Antenna Type ____

Antenna Measurement __.__ __ __ meters / feet true / uncorrected

Check Plumb
- ☐ Begin
- ☐ Mid
- ☐ End

MONUMENT DESCRIPTION

Monument type and description ____
Monument stamping or tag number: ____

STATION INFORMATION

Monument sketch	Remarks (Comment on any potential problems)

Time	PDOP	# SV

Chapter XI

DEALING WITH THE PUBLIC

Without the cooperation of the well owners of Arizona, we would effectively be out of the data business. We rely on the well owners to allow us access to their property and to their wells. This access and any subsequent information we receive is totally voluntary on the part of the owners, and yet without it, most groundwater studies would be impossible. FSS staff have worked hard to gain the respect of the land owners, well operators and the general public. This respect is not something just given, it is something earned, and we constantly strive to maintain that relationship and trust.

The keyword when working with the public is **respect**. It is incumbent upon each member of our staff to show respect to any land owner. After all, we are a guest on their property. The law provides for us to enter private property; to obtain permission, and nothing else. Unless these are your intentions, you may well be trespassing, and you may incur the wrath of an angry rancher or farmer, and be asked to exit, posthaste. Due to vandalism, disregard for No Trespassing signs and the potential for legal issues, many land owners have become very sensitive to unauthorized people "nosing" around their property.

When obtaining permission to enter anyone's property, present yourself in the best possible way. If you have to go to a public office, don't show up at the end of the day in your dirty clothes. It is far better to approach these types of situations first thing in the morning, when you would be much more presentable. Many people judge us by first impression, and as the old saying goes, "You only get one chance to make a first impression". If you are requesting permission from a rancher, farmer or rural landowner; approach their homes respectfully. Nearly all rural roads are dirt, so drive slowly, raising as little dust as possible. If you must open a gate to get in; once through, get out and close the gate. Many land owners have animals freely roaming their land and just because you don't see them at the time, doesn't mean they aren't there. **Always respect a closed gate** (open it to pass through and immediately close it). If the owner is not around, ask to see the foreman or someone in charge.

Some owners have no problem with our visits to their property, but some take great exception to our presence. Regardless of their disposition, they deserve to have their permission sought in a courteous way. Many owners will ask why the government wants information about their well or the groundwater beneath their property? What are we going to do with the data? Why do we need to collect the data? Are we going to use the information against them? They may see our presence as an intrusion into their privacy. However, when presented with such owners, we need to explain, as best we can, that our request to measure a well is strictly for scientific and resource assessment purposes that will benefit all well owners in the area. It may help to mention that you are a taxpayer just like them, and that you are a scientist, not a bureaucrat.

Ultimately, it is up to you to try to answer their questions succinctly, in a very polite way, and hopefully to sway their opinion. This means being informed on the water issues of the area and being well versed with exactly what it is you are doing and why you are doing it, (see Chapter I). You should explain why it is beneficial to know the groundwater conditions of the area in which they live. You may even be asked to leave the property and yelled at, but if you do a good job of explaining your (our) interest in their well, chances are you are going to be granted permission most of the time.

If you get permission from one rancher, sometimes passing that information on to his neighbor will carry some weight. If an owner requests information on their well, give them copies of the data that we collect from their wells, and encourage them to visit our online database to access historical records, or submit a public records request. If we have a publication on the area, direct them to our website for further information. If time allows, show the owner where his land is on the map and how to interpret the information. Offer to come back when it is more convenient for them, especially if there are many gates that need to be unlocked. Very seldom will the ranchers offer to give you a key, more than likely they will want to accompany you. If they do give you *carte blanche* to their property, don't ever exceed your stated business. Close all gates, especially near windmills, as cattle are often nearby. The last thing you want to have to do is tell the rancher you let some of his cattle out, (however, if this should be the case, or if you damage anything while on the property, you must report the loss immediately).

Be willing to make an appointment with the land owner. They are busy people, and we need to try to accommodate them. Other than being well informed and respectful, most of our interaction with the public is simple common sense. Treat people the way you would want to be treated. Try to put yourself in their position. To whom would you grant access to your land?

Never measure a well without permission. We won't get permission to measure every well we find; these wells may not be measured. Some owners simply can't be found, and many others are absentee owners. Occasionally, determining the actual owner is impossible. Many wells are obviously abandoned or unused, but these wells may not be measured without permission.

If you see someone (even if they are not the owner), tell them who you are and what you are doing. Offer to show them your State ID or give them a business card. When in farm country, it is extremely difficult to tell which farmer owns which well. The important thing is to try. If there is a home, a barn, or an equipment shelter where people are gathered, stop and ask questions about who owns which wells. Make the effort. Make yourself known, so people are at ease with you, and what you are doing.

Never jump a fence to measure a well, unless you know it to be permissible. **Never** make a discharge measurement without permission. **Never** start or turn-off someone's well. **Never** enter Indian lands for the purpose of conducting any investigation without prior approval. Indian reservations are considered sovereign nations and are administered by the U.S. Bureau of Indian Affairs. We, as employees of the State of Arizona are considered to be trespassing if we conduct any type of water resource investigation without approval of the Tribal Council.

The overlying theme of all this is that the best source of hydrologic data in any area is the existing wells, and their owners. Cooperation between owners and department personnel provide an avenue to data and information that are mutually beneficial. It is of the utmost importance that we do all we can to nurture this valuable relationship.

Chapter XII

SAFETY

It is difficult to over emphasize the value of safety. When it comes to safety, doing little things can pay big dividends. We work in climate extremes and are often exposed to the denizens of the desert (i.e. bees, scorpions, black widows, rattlesnakes, etc.). You should always be aware of the potential dangers to which you are exposed. The intent of this chapter is to alert the FSS personnel to the potential dangers of field work. Doing what we can to prevent accidents is important, but accidents will occasionally occur. While great lengths can be taken to prevent an unfortunate accident or injury, it may well be how **you** react, after an accident or injury that makes the difference.

Vehicle Safety
Each of our trucks are assigned to an individual staff member. That is to say that nearly every time you go into the field, you will be in the same vehicle. All of our trucks are maintained by the Arizona Department of Transportation (ADOT). We and Fleet Management are responsible for seeing to it that the trucks are serviced regularly (by ADOT). They maintain the integrity of the mechanics of the vehicle. We are responsible for making sure the truck is equipped with the proper safety equipment. You should become well acquainted with the location of the jack, and how to use it. You should carry several small (6”), pieces of 2”x4” or 4”x4” wood to set the jack on (if you have a flat tire or get stuck in the mud, these pieces of wood may come in very handy). Always maintain a complete set of tools. In the case of a break down, you may have to perform some maintenance to get your vehicle back to town, or at least out to the main road. The following is a list of some of the safety equipment your truck should always be equipped with.

1. Well stocked first-aid kit
2. Fire extinguisher
3. A nylon tow-strap
4. A shovel
5. An axe
6. Jumper cables
7. A portable air pump, and/or 2 cans of pressurized quick fix tire repair
8. At least 2 gallons of water
9. Flashlight (and extra batteries)

When you return from the field each day, you should do a quick inspection of the tires (a low tire could be the result of a slow leak). Check the ground under the engine, looking for any leaking fluids. If you should notice leaking fluids or tires, the situation needs to be addressed immediately, so you can get back out in the field the following morning.

Worse yet, would be to ignore or not notice the leaks and become stranded somewhere far from help.

When operating a state vehicle always obey all traffic laws and speed limits. Remember that while 65mph may be lawful and safe on a dry highway, it can be anything but safe on a wet slippery road. Slow down when conditions dictate. Don't drive into muddy areas without first getting out of the truck and checking the conditions. One quick minute of your time may save you hours of digging or walking for help. **There is no substitute for common sense.**

Personal Safety

The degree to which an individual may go to ensure personal safety, is indeed a personal choice. However, there are some very basic and general precautions that all field personnel should take to protect themselves. The first thing any field person should understand is that the Sonoran Desert can be a very unforgiving place. There are temperature extremes, dangerous insects, reptiles, a myriad of thorned plants and cacti, the potential for flash floods, and very little help when you are in need. So, as previously stated, the way you prepare yourself for and react to adversity may well save you a lot of heartache.

We do most of our field work in the Fall/Winter/Spring months, however there are many times you will be in the field during the Summer months. There is no way a person can really be immune to the extreme heat of an Arizona summer day. Even if you've spent your entire life in Arizona, the heat can kill you just as certainly as it can a person who has only been here a week. Don't be arrogant and think you are immune to the heat. You must always respect the heat and do all you can to protect yourself from it. General precautions include, starting early in the morning, before the heat of the day. You can have most of a day's work done by 2:00 PM, if you get an early start. So simply avoiding the heat is the number one thing you can do. If the job you are doing requires that you stay out longer, be prepared. Always drink plenty of water. Have plenty of extra drinkable water (at least 2 gallons). This will not only sustain you, but if your truck overheats, you may have to add water to the radiator. Stay in your truck as much as possible (shelter from the sun as well as air conditioning). So unless the work you are doing absolutely requires you to be outside, stay in the truck. Even a parked truck with the engine off (no AC), will give you shelter from the sun, but maintain ventilation, by opening a window. Use protective clothing. Wear light colored shirts (long sleeve shirts are better than the best sun block), long pants and leather field boots (preferably some that offer ankle protection and steel toes). If you wear a short sleeve shirt, use plenty of sun block. Never wear shorts and sneakers into the field. Wear a hat at all times (the larger the brim, the more protection from the sun). Know the symptoms of heat exhaustion. If caught in the Arizona sun for too long you will most likely suffer heat cramps or heat exhaustion as a precursor to heatstroke, so those are the most important symptoms for you to recognize. Heat cramps are associated with heavy sweating and painful spasms in the legs and/or abdomen. The symptoms of heat exhaustion include an overall feeling of weakness and profuse sweating. The skin feels cool and clammy and an individual's pulse becomes unsteady. Vomiting may occur, or possible fainting. If you ever recognize these symptoms or general dizziness and headaches in a fellow worker, or yourself, there is still time but you must act quickly. It may well save a life. Get yourself or fellow worker to some shade or a cooler area (air-conditioned truck). Sit down and rest, slowly drink cool water if available. If an individual's symptoms have progressed to extremely high body temperature, with hot dry skin, rapid pulse and possible unconsciousness, or if the lesser symptoms haven't rapidly improved, seek medical attention immediately. **Waiting, or being indecisive can result in death. Don't mess with heat stroke, it's a real killer.**

As previously stated, Field Services does the largest percentage of its fieldwork in the Fall/Winter/Spring months. While the heat is generally not a factor in these months, the cold can be the source of some difficult field conditions, especially when working in the northern and southeastern parts of the state. It is not uncommon for us to work in cold rain, sleet and occasionally in snow. Warm clothes, good leather boots, gloves and a hat are necessary to protect us from the elements. It is far better to dress in layers, than to wear a large bulky coat. By layering, you have the option to dress lighter as the daytime temperatures rise. Good rain gear is also a necessity (either a rain slicker or "pancho"). The ability to stay dry, when working in cold weather, is very important. Cold weather also presents a different set of driving conditions. You must drive in accordance with the conditions. It is quite common for Field Services staff to drive on wet and muddy roads, or occasionally in snow. Fog is another common occurrence in the Winter months. The fog usually burns off, as the daytime temperature rises, but proper caution must be exercised when driving in the fog. Wet roads, rain, snow and fog all present problems, but these conditions can be overcome by **slowing down**, staying on paved roads as much as possible and driving with your lights on. Know your limitations as a driver, and never exceed your ability. Continually test your brakes in wet weather, and never exceed your vehicles ability to safely stop.

Desert dust storms present problems as well. Blowing dust can literally cut visibility to near zero. This situation is especially prevalent on Interstate 10 (between Phoenix and Tucson). This area supports a great deal of farming, and when combined with high speed driving on the Interstate, a very dangerous situation can be produced. Should you ever encounter these conditions; pull safely (as far off the road as you can get) off the road or highway, stop your vehicle and **turn your lights <u>off</u>**. Many people believe that you should keep your lights on, so other drivers can see you. However, in a no visibility situation, other drivers might see your lights and try to follow you. The results could be fatal.

Wear your leather work gloves anytime you are working, or handling tools. **Don't** ever stick your hand into something you haven't looked into first, and even after you have looked, play it safe and keep your gloves on. Dark, relatively cool places are ideal refuges for black widows and brown recluse spiders, scorpions and sometimes a rattlesnake. If you have to dig around in the base of a pump, use a long screw driver or metal rod. Don't use your hands. Anytime you are walking in the field, keep your eye on the ground in front of you. When walking through tall grass or weeds, move slowly, and if possible, use a long stick to prod the grass ahead of you. The department can provide you with snake guards that protect your lower ankles from bites. Better the stick arouses a rattlesnake, than your foot. In the mornings, rattlesnakes like to sun themselves out in the open, so be vigilant. Listen for the characteristic “rattling” warning of an angered rattlesnake, and if you should ever hear it, stop immediately. A rattlesnake strikes at motion, so your best option is to freeze until you determine where the snake is. A rattlesnake bite, while generally not fatal, can make you wish you were dead. Most rattlesnake bites occur on the hands, wrist, feet or ankle area. High top leather boots and leather gloves may well save you from the misery of a snake bite. Should you ever sustain a rattlesnake bite, do your best to stay calm and immediately drive to the nearest emergency medical facility, if your ability to drive is impaired, call 911 or an emergency contact. This holds true for black widow and brown recluse spider bites, and scorpion or bee (if allergic) stings.

Watch for wasp nests and bee hives. You must now assume that all honey bees in Arizona are of the ”Africanized” variety. They regularly make hives in well casings and their presence is not always obvious, so be vigilant. They don’t have to be provoked, if they feel you are too close, they will attack. Their attack is relentless, and your only real retreat is to your truck. Staff members have been chased for a quarter mile by attacking bees. If you are allergic to bee stings, it is imperative that you carry a bee sting kit with you in the field. Even if you are not allergic, a bee sting kit is a good idea and should be part of the first aid kit.

General Safety Tips

Perhaps the most important thing a field person can do is to keep their eyes open, be observant, pay attention to the task at hand and don’t “daydream”. Look around and expect the unexpected. Beware of open well casings. Don’t step on large pieces of plywood lying on the ground. The wood may be partially rotted and covering a 20’’ well casing. When looking under large pieces of wood, use a stick or metal rod to flip the wood over. Don’t use your hands, as rattlesnakes often take refuge under wood, old blankets, or rugs. Be careful around windmill towers. It is very easy to knock yourself senseless on the metal crossbars of a windmill tower. Don’t try to measure wells if there is lightening anywhere near. Be careful around pumping wells, especially natural gas wells. Natural gas pumps are driven by a very rapidly rotating drive shaft. Stay clear of the drive shaft, as loose clothing or hair can easily get wrapped around the shaft, resulting in severe injury, or perhaps worse. When working around noisy pumps; for the purpose of obtaining pumping levels, or discharge measurements, hearing protection is advised. Respirators are also advised for very dusty work sites, or for use in sheds. Watch for nails sticking up through old boards. It is very easy for a nail to penetrate the sole of a shoe or to scratch yourself on barbed wire, so a current tetanus shot is highly recommended.

When approaching an owner’s home, you are often first met by any number of dogs. Some dogs are very friendly, some are not. Unfortunately, you can’t always tell the friendly ones from the unfriendly ones. Generally, when the owner hears his/her dogs barking, they will investigate the cause, and call their dogs off. At this point, you can approach the owner. If the owner doesn’t appear, you may choose not to get out of the truck. Sometimes a gentle honk on the horn will bring the owner out, (excessive honking will only irritate the owner and lessen your chances of measuring his wells). As a general rule, always leave the truck door open when you approach the owner's house. Dogs can often appear suddenly and your ability to get back into the truck quickly can spare you the pain of a dog bite.

In addition to a couple of gallons of spare water, it is always a good idea to take a small ice chest (filled with drinking water or Gatorade), into the field. Another handy item to take to the field on an everyday basis, is a small knapsack. If you should become stranded and have to walk, the knapsack will allow you to carry your drinking water, GPS unit, maps, binoculars, first aid items and cell phone, while allowing you to keep your hands free. It is much easier to walk over rugged terrain if your hands are free. If you become stranded, but know where you are, and you can reach help by walking, then this is the best plan of action. If you are hopelessly lost, it is always best to stay with your vehicle and wait for help to find you.

In addition to these precautions, field services staff are equipped with a SPOT device. Each SPOT device provides location-based messaging and emergency notification technology that allows you to communicate from remote locations, where cell phone service may not be available. Your SPOT device can send staff and supervisors a pre-determined message with your current location, notifying them you may need assistance (truck stuck or flat tire). It is also capable of notifying local emergency services of your location and that you are in need of immediate, life threatening help. The operating instructions for the SPOT GEN3 device are included in the manual.

As your day in the field comes to a close, it is important to notify your supervisor that you have safely arrive back at your hotel room or at home. If your supervisor does not hear from you by a set time, they may call, text or email you questioning your safety. **DON'T FORGET TO CHECK IN**.

Fieldwork presents many challenges, but if an individual is observant and mindful of common safety procedures and barring any unforeseen calamities, their time in the field should be just as safe and productive as a day in the office.

SAFETY CHECKLIST FOR FIELDWORK

Nearest Emergency Medical Care Facility

Area #1 Address:___________________________

Phone# :___________________________

Area#2 Address:___________________________

Phone# :___________________________

Area#3 Address:___________________________

Phone# :___________________________

Do You Have ?

____First aid kit (+bee sting)
____Fire extinguisher
____Nylon tow strap
____Shovel
____Jumper cables
____Extra water
____Quick fix tire repair
____SPOT device
____Cell phone
____Knapsack
____Binoculars
____Hearing protection
____Respirator
____GPS
____Maps
____Hardhat

Should you receive one of the following:

- Injury (cuts, broken bones, etc)
- Toxic contamination
- Scorpion sting
- Black Widow or Brown Recluse spider bite
- Bee stings (if allergic)
- Rattlesnake bite
- Dog or other animal bite
- Heat cramps/exhaustion/stroke
- Other emergency

If able

Note: Time of event__________ AM, PM

Phone ahead to nearest medical facility: Tell them where you are and ask for instruction on how best to treat the injury until you can get there.

Remember: Try to stay calm; haste can cause further injury or accidents while driving for help.

NOTE! Fill out this form and keep it handy when you travel

SPOT Generation 3 Device Operating Instructions

TO TURN SPOT ON: Simply locate the Power button on the upper left corner of the device, press and hold the button; lights will illuminate.
TO TURN SPOT OFF: Press and hold the Power button until the Power light blinks rapidly.
TO CONSERVE POWER: Your SPOT unit **will automatically** turn off after one hour of inactivity unless the unit is being line powered.

PLACEMENT OF YOUR SPOT

The placement of your SPOT can make a difference. For best reception, **always keep the logo pointed towards the sky** (the satellite antenna is located under the logo).

GPS

The GPS light notifies you whether SPOT is able to see the GPS satellites and obtain a GPS location.

- Green – The GPS light blinks green if SPOT sees the GPS satellites and is looking for/has found your GPS location.
- Red – The GPS light blinks red if SPOT cannot see the GPS satellites and /or cannot find your GPS location. If the GPS light blinks red, you should move to a location with a clearer view of the sky.

USING THE CHECK IN OR CUSTOM MESSAGE FUNCTION

Press and hold the Check In or Custom Message button until the function light blinks green. The GPS light will blink green when SPOT sees the GPS satellites and will continue blinking while obtaining your GPS location.

Once your GPS location is obtained, SPOT sends your message with GPS location. The GPS light and Message Sending light will both blink green. The message is sent three times over a 20-minute period to the SPOT network - this is to ensure maximum reliability in getting your message out. Only one message will be sent to your contacts.

The Message Sending light continues to blink green until the next scheduled message or until the mode ends.

If no GPS signal is found, the GPS light will blink red. If possible, you should move to a location with a clearer view of the sky. SPOT will keep looking for your GPS location for up to 4 minutes. If no GPS location is found in 4 minutes, SPOT does not send your message. To try again, simply press and hold the function button. If the message does not send, the Message Sending light will blink red.

TO CANCEL

You can end the transmission of a Check In or Custom Message by pressing and holding the function button until the light blinks red. This action does not cancel any message already transmitted.

USING THE HELP FUNCTION

To send a Help message, open the protective flap then press and hold the Help button until the light blinks green. The GPS light will blink green when SPOT sees the GPS satellites and while obtaining your GPS location.

Once your GPS location is obtained, SPOT sends your Help message with GPS location every five minutes for one hour. The GPS light and Message Sending light will both blink green.

The Message Sending light continues to blink green until the next scheduled message or until the mode ends.

If no GPS signal is found, the GPS light will blink red. If possible, you should move to a location with a clearer view of the sky. SPOT will keep looking for your GPS location for up to 4 minutes. If no GPS location is found in 4 minutes, SPOT sends your message without GPS location; the GPS light will blink red and the Message Sending light will blink green in unison.

TO CANCEL

Press and hold the Help button until the Help light blinks red. Leave SPOT on while the Help cancel message is sent, turning off your SPOT DOES NOT cancel the Help message. When it is finished, the Message Sending light will blink green indicating it has sent the cancel message.

USING THE S.O.S. FUNCTION

To send an S.O.S. alert, open the protective flap then press and hold the S.O.S. button until the function light blinks green. The GPS light will blink green when SPOT sees the GPS satellites and while obtaining your GPS location.

Once your GPS location is obtained, SPOT sends your S.O.S. message with GPS location. The GPS light and Message Sending light will both blink green.

The Message Sending light continues to blink green until the next scheduled message to notify you that your most recent message was transmitted.

If no GPS signal is found, the GPS light will blink red. If possible, you should move to a location with a clearer view of the sky. The first message will be sent within one minute after activation with or without your GPS location. For all subsequent messages, SPOT will keep looking for your GPS location for up to 4 minutes. The S.O.S. message will send every 5 minutes (with or without GPS) until cancelled or the power source runs out.

TO CANCEL S.O.S.

Press and hold the S.O.S. button until the light blinks red. Let SPOT work until the S.O.S. button stops blinking red to finish sending the cancellation message. The Message Sending light will blink green indicating it has sent the cancel message. Turning off your SPOT while in S.O.S. mode DOES NOT send an S.O.S. cancel message.

MESSAGE INDICATORS

For all functions, SPOT lets you know what it is doing.

INDICATOR	BLINKING GREEN	BLINKING RED
GPS	Searching for GPS signal	GPS location fix failed, move to a new location
Message Sending	Message transmission schedule in progress	Last message was not sent
Check In or Custom Message	Message sequence in progress	Message sequence has been cancelled
Help	SPOT in Help/SPOT S.O.V. mode	Help/SPOT S.O.V. has been cancelled
S.O.S.	S.O.S. is engaged	S.O.S. has been cancelled
Tracking	SPOT in Track mode	Track sequence has been cancelled
Power	On	Low battery

Chapter XIII

GWSI & ACCESSING GWSI WITH MICROSOFT ACCESS

The GWSI database is ADWR's main repository for accurate, state-wide groundwater and well data. GWSI consists of field data collected and verified by personnel from the ADWR's Field Services Section or the USGS. The information in GWSI is constantly updated and added to by ongoing field investigations. In addition to normal field investigations, ADWR conducts a state-wide water level monitoring program that annually measures water levels in approximately 1800 wells, which are located throughout the state. Along with using the application to access information, data can also be queried by using Microsoft Access. More information on using the GWSI application and Microsoft Access can be found in the GWSI Manual (see Arizona Department of Water Resources, 2008b).

Chapter XIV

MAKING MAPS WITH ARCGIS

In recent years FSS has become a more frequent user of ArcGIS. ArcGIS is a platform for organizations to create, manage, share, and analyze spatial data. It consists of server components, mobile and desktop applications, and developer tools. This platform can be deployed on-premises or in the cloud (Amazon, Azure) with ArcGIS Enterprise, or used via ArcGIS Online which is hosted and managed by ESRI. Our most commonly used applications are ArcGIS Pro and ArcMap. They are part of ArcGIS Desktop suite and allow users to publish and manage data and maps in conjunction with ArcGIS Online and ArcGIS Enterprise. These desktop tools also excel at detailed and sophisticated analysis and can be extended and scripted with various tools. For an overview of the capabilities of ArcGIS Desktop, visit the ArcGIS Desktop website.

In the FSS, ArcMap is commonly used for navigational purposes and to display database information that may be related to a well you are visiting or a well nearby. ArcMap can toggle between different layers of spatial data that contain a variety of information that may be necessary to get you where you need to go, or to answer questions that you may encounter in the field. The Department will assign you a laptop along with a GPS unit that can connect to your computer. Once ArcGIS Desktop is installed on your computer you can begin the process of adding the needed project files to your laptop. Following this process will allow you to work without an active internet or network connection. This is an extremely useful tool, specifically when conducting a ‘Basin Sweep’. It allows access to imagery that might not otherwise be available without a connection. You will likely still be assigned a topo map packet, in case any technical errors should arise.

ARCMAP IN THE FIELD

Before using ArcMap in the field, be sure to check out a license using “ArcGIS Administrator” **while connected to the network in the office.**

1) Open ArcGIS Administrator
2) Click “Borrow/Return”
3) Select “Desktop Basic”
4) Select “OK”

Installing Imagery

5) On your laptop C: Drive create a folder titled < “ArcGIS Data”
6) In the “ArcGIS Data” folder, create a folder titled < “ArcMap”
7) On the N: Drive visit the following link
   N:\SUBSIDEN\ArcGisData\ArcMap

8) Copy the “LayerNAIP” folder and paste it in the “ArcMap” folder previously created on your C: Drive.
9) Copy the “NAIP2010” folder and paste it in the “ArcMap” folder previously created on your C: Drive.
10) THIS WILL TAKE A WHILE – PLUG YOUR COMPUTER IN

Installing Your Arc Project/Updating Your Arc Project

1) Navigate to the “Basic Data” folder on the N: Drive
2) Copy the “GIS_FieldWork” folder and paste it on your C: Drive in the “ArcGIS Data” folder
3) Open the “GIS_FieldWork” folder and open “ArcProject_Field_Work_MapPack” and begin selecting layers you want to use
4) To add imagery, navigate to the LayerNAIP folder in your ArcMap Catalog. (Imagery is broken up in to sections throughout the state, select the degree of Latitude and Longitude you are working in to display imagery.

Using Your GPS

1) Connect your GPS to your computer
2) In ArcMap navigate to the “Customize” Tab
3) Select “Toolbars” and Scroll down to “GPS”
4) Select the “GPS” dropdown in the toolbar and click “GPS Connection Setup”
5) In the “GPS Connection Setup” Window, select “Detect GPS port”
6) Your GPS should be recognized by your computer, select “OK”
7) On your GPS Toolbar click the “Open Connection” button, then click the “Pan to GPS Position”
8) Your location should now be visible on your project.

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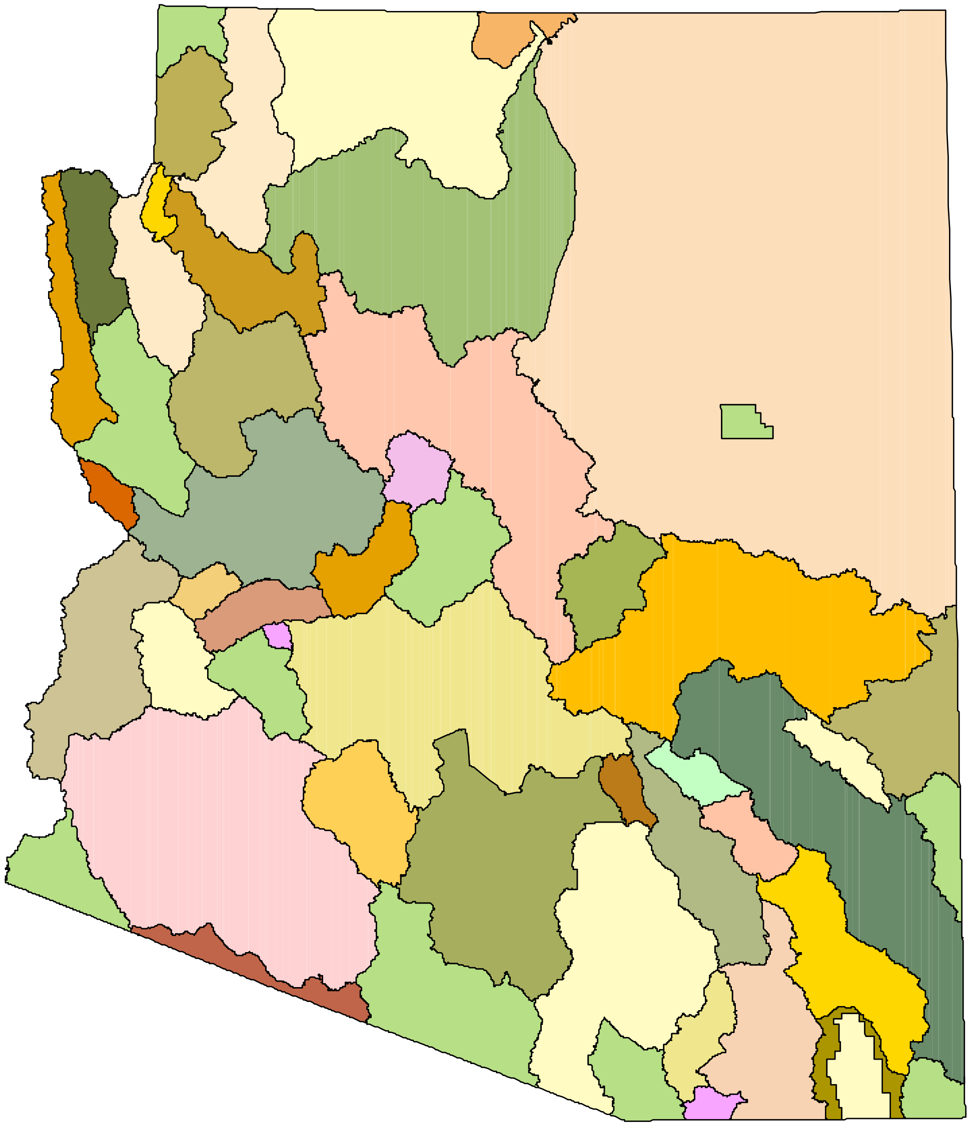
APPENDIX III

ADWR GWSI Database Handbook and User's Guide

ARIZONA DEPARTMENT OF WATER RESOURCES



GROUNDWATER SITE INVENTORY (GWSI) DATABASE HANDBOOK

ARIZONA
DEPARTMENT
OF WATER
RESOURCES

HYDROLOGY DIVISION

2007

Table Of Contents

Appendices:

List of Figures

Groundwater Site Inventory (GWSI) Database

Introduction

The Groundwater Site Inventory (GWSI) database is ADWR's main repository for state-wide groundwater data. The GWSI consists of field-verified data regarding wells and springs collected by personnel from Hydrology Division's Basic Data Section, the U.S. Geological Survey, and other co-operating agencies. The information in GWSI is constantly being updated by ongoing field investigations and through a state-wide network of water level and water quality monitoring sites.

This handbook has been developed for use by both the Basic Data section and other Department personnel. With the Department's move to a PC based client–server network, the data in GWSI have become more readily available to everyone within the Department. This handbook has been developed to help department personnel understand the GWSI database system, the data available in the system, and how the different data tables in the system can be used to extract meaningful information from the GWSI.

The GWSI data resides in 17 separate Oracle data tables, with each table containing a unique set of data. For example, the SITES data table contains the cadastral location (township, range, section, and quarter, quarter, quarter section), latitude/longitude, site elevation, well use, well depth, and other general information for each GWSI site. There are also a number of other tables in the GWSI folder. These tables contain letter codes associated with fields in the main GWSI data tables and other data related to the GWSI system. A full list of the main GWSI data tables along with a brief description of the data they contain is presented below.

Each data site in GWSI is assigned a unique 15-character identification number, the SITE ID, which is a common field in all the GWSI data tables. All the information available for a specific site can be obtained by using the SITE ID number. Site specific information can be accessed by using either the Oracle Application Forms or a relational database query tool such as Oracle Browser, Access, or Paradox. The SITES data table is the main data table in the GWSI system and can be linked to other GWSI tables using the SITE ID when using a relation database query tools. Data in any of the GWSI tables can be retrieved for any given geographic area using the townships and ranges, groundwater area designations, latitudes and longitudes, or UTM coordinates located in the SITES data table. In addition to the data tables there is an Oracle view, the TRS View, that can be used to aid in designing queries based on a sites township, range, and section.

Listed below are the main GWSI data table and a general description of the information available in each table. The main body of this report presents each data table and lists each field in the table, then the acceptable codes for each field are listed and explained.

Table Name	**Table Discription**
Sites	General Location Data, Well Depth, Well Altitude, and Water Use Data
Well_Completions	Well Construction and Finish Data, Driller's Name, and Completion Date
Bore_Completions	Bore Hole Data
Casing_Completions	Well Casing Data
Perforation_Completions	Well Casing Perforation Data
Flowing_Discharges	Flowing Discharge Data – for flowing wells and springs
Pumping_Discharges	Instantaneous Pumped Discharges from Wells
Well_Lifts	Well Lift (Pump) Data
Well_Logs	Well Log Data
Well_Owners	Well Ownership Data
Owner_Site_Names	Other Well Identification Data
Remarks	Pertinent Notes about Site
Site_Inventories	Personnel who Inventoried Site
Spring_Names	Name of Spring and other Data Pertaining to the Spring (if Site is a Spring)
WW_Levels	Historic Water Level Measurements
WQ_Report	Water Quality Data
WM_Points	Well Measurement Height and Location point
TRS	Oracle View with Local Id broken into Quadrant, Township, and Range – used for queries based on township and range.

Sites Data Table (SITES**)**

The SITES Data Table is used for recording general information about the site, including location information, general well construction, and well use information. The Sites data table is the main table in the GWSI system. All other GWSI tables are linked to it by the Site Id field.

Site Identification Number (Site_Well_Site_Id)

This field contains the 15-digit identification number assigned to the site. The SITE ID contains no blanks or alphabetic characters. It is used as a unique identification number that allows users to link records in the SITES data table with records in other GWSI data tables. By linking across to other GWSI data tables all the data for one specific site can be retrieved.

Although the Site Identification Number is derived initially from the latitude and longitude of the site, the number is a unique identifier and not a locator. It cannot be too strongly emphasized that the site identification number, once assigned, is a pure number and has no locational significance. The site identification number never changes once it is established except under unusual conditions.

The site identification number is assigned by locating the site on the best available map or orthophoto as accurately as possible. Using appropriate locational techniques, the latitude and longitude of the point on the map that represents the site is determined. The location of this point is always scaled to the nearest second of latitude and longitude, even if there is doubt as to the exact location of the site or the accuracy of the map. The first six digits of the site identification number are the value of the latitude, the seventh through thirteenth digits are the value of the longitude, and the value 01 is used for the fourteenth and fifteenth numbers. Leading zeros are used if the value of the minutes, or seconds of the latitude or longitude is less than 10, for example, 01, 02, ...09. No blanks or alphabetic letters are to be used in the Site Id. The site identification number usually ends in 01; however, in rare instances sequential numbers such as, 00, 02, 03, ..., have been assigned to these last two digits. Generally, this happens when more than one well occupies the same latitude and longitude. Some sites have longitude and latitude determined by Global Positioning Satellites (GPS) equipment. Sites with longitude and latitude assigned by GPS are coded according.

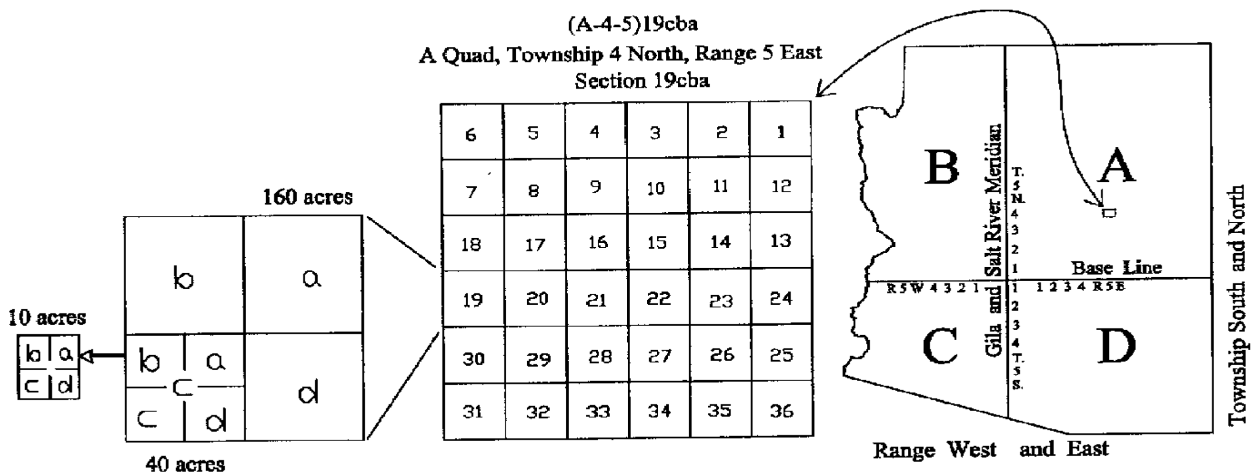
Cadastral Location (Site_Local_Id)

This is a 20 character-long site location based on the U. S. Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River Baseline and Meridian, which divides the state into four quadrants. These quadrants are designated **A**, **B**, **C**, and **D** in a counterclockwise direction starting in the upper right hand corner (Figure 1). All land with north *Townships* and east *Ranges* are in the **A** quadrant, north *Townships* and west *Ranges* in the **B** quadrant , south *Townships* and west *Ranges* in the **C** quadrant, and south *Townships* and east *Ranges* in the **D** quadrant. The first number in the cadastral location is the *Township*, the second is the *Range*, and the third is the *Section* in which the site is located. The letters following the section number indicate the well location within the section. The first letter indicates the 160-acre quarter section, the second letter the 40-acre quarter-quarter section, and the third letter the 10-acre quarter-quarter-quarter section. These letters are also assigned in a counterclockwise direction, beginning with the northeast quarter of the section. For example, a well with the cadastral location **D-04-05 16CAA** is located in *Township* 4 South, *Range* 5 East, *Section* 16 in the southwest quarter section, the northeast quarter-quarter section, and the northeast quarter-quarter-quarter section. Leading zeros are included in the township, range, and section numbers. If more than one well or site is located within a 10-acre tract, consecutive numbers beginning with 1 are added as suffixes with the oldest known well labeled as 1.

Oversized sections occur in several areas of the state. If a section is more than a mile in the north/south or east/west dimension, the excess area is considered a part of that section and has the same section number. A control corner is established for the section on the section corner that is closest to the center of the township (see Figures 2a and 2b). The oversized section is divided so that a full square-mile unit is adjacent to the control corner, the rest of the section is considered a separate unit of land. Appropriate N, S, E, W, or X letters are assigned to the separate units of land depending on where they lie in relation to the full square-mile land unit.

The well numbers and letters used by the Geological Survey in Arizona are in accordance with the Bureau of Land Management's system of land subdivision. The land survey in Arizona is based on the Gila and Salt River meridian and base lines, which divide the state into four quadrants. These quadrants are designated counter clockwise by the capital letters A, B, C, and D. All land north and east of the point of origin is in A quadrant, that north and west is in B quadrant, that south and west in C quadrant, and that south and east in D quadrant. The first digit of a well number indicates the township, the second the range, and the third the section in which the well is situates The lowercase letters a, b, c, and d after the section number indicate the well location within the section. The first letter denotes a particular 160-acre tract, the second the 40-acre tract, and the third the 10-acre tract. These letters are also assigned in a counter clockwise direction, beginning in the north east quarter. If the location is known within the 10-acre tract, three lowercase letters are shown in the well number. In the example shown in figure 2, well number (A-4-5) 19cba designates the well as being in the SWI/4 NW1/4 NEl/4 sec.19, T. 4 N., R. 5 E. Where there is more than one well within a 1 0-acre tract, consecutive numbers beginning with 1 are added as suffixes.

When a section is more than 1 mile in any dimension, the section numbers applies as usual. The oversized section is divided so that a full square-mile unit of the section is adjacent to a normal section within the appropriate N., S., E., or W. letters are assigned to the units, depending upon where they lie in relation to the full square-mile unit. A well would be designated as shown in figure 2 with the appropriate letter following the section number in which the well is located.



FICURE 2. -- WELL NUMBERING SYSTEM IN ARIZONA.

Figure 1 – Arizona Well numbering System

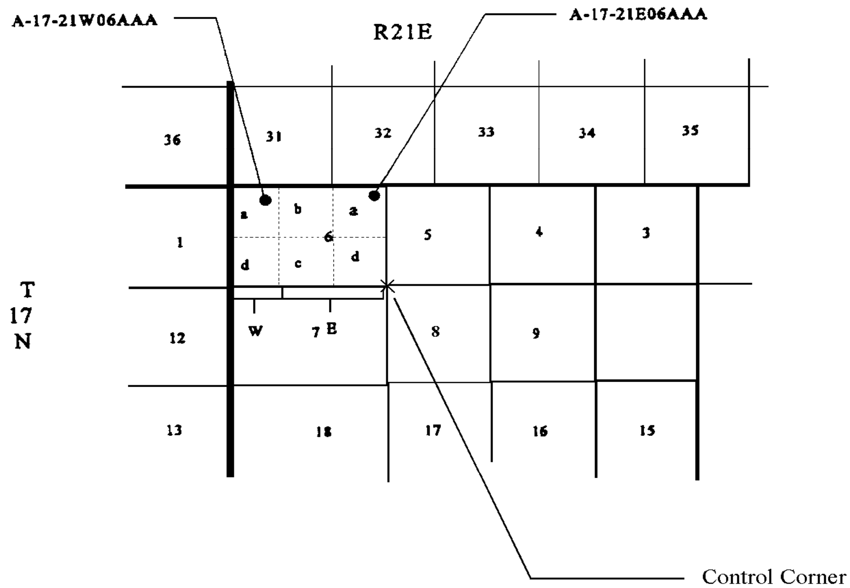


Figure 2a. Cadastral location of over-sized section in on direction.

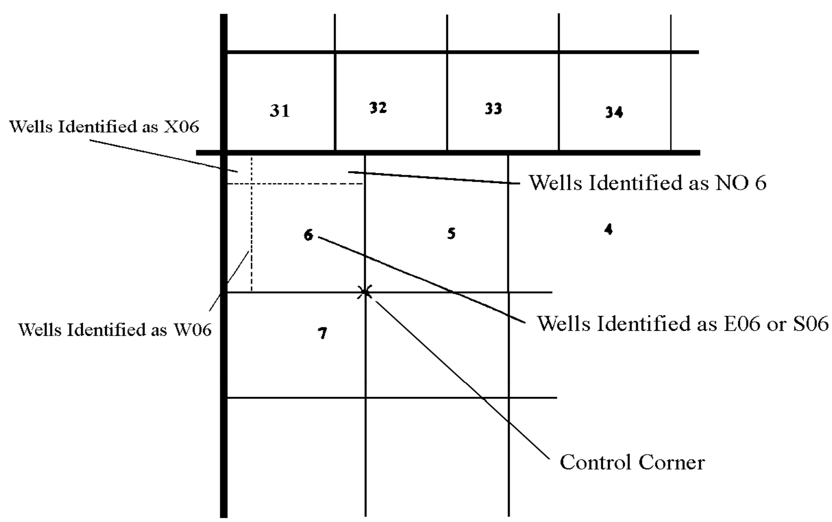


Figure 2b. Cadastra locatons for over-sized sections in two directions.

Figure 2. Cadastral locations for over-sized sections in Arizona.

For example, in Figure 2a, the section is over-sized in only one direction (East-West). Well A-17-21E06AAA is in the northeast quarter, of the northeast quarter, of the northeast quarter, of the *eastern* unit of Section 6, Township 17 North, Range 21 East. The well location is determined by placing the lower right hand corner of the map locator on the control corner and reading the location within the full-sized section of land. The location of well A-17-21W06AAA is determined by moving the lower right hand corner of the map locator to the lower right hand corner of the *western* unit of Section 6 and reading the location within the over-sized unit of land (Figure 2a). Sections that are over-sized in the north-south direction use the same general procedure.

Figure 2b illustrates how wells are identified for sections that are over-sized in both east-west and north-south directions. Wells in the full section can be identified as being in either the *eastern* or *southern* unit of Section 6. A well located in the unit of land north of the full section are in the *northern* unit, and a well located in the unit of land to the west of the full unit is in the *western* unit of section six. A well in the small unit of land to the *north* and *west* of the full section uses an X as identifier, for example, X06 (Figure 2b).

Some areas of the state have half townships and half ranges. Half township and half ranges are designated by the letter **H** following the township or range. In some areas of the state survey lines have not been established. Sites in these areas have the suffix UNSURV in the last six spaces of the LOCAL ID field to indicate that the location is in an unsurveyed area. The cadastral location of a site in an unsurveyed area may not be as accurate as in a surveyed area and may only be identified to the 160 or 40 – acre location. Listed below are examples of some typical cadastral locations:

A-09-12 19ADD2	A-10H05 06ACD
D-05-04N27CDD	B-24-12 13BA UNSURV

A different numbering system is used to locate GWSI sites on the Navajo and Hopi Indian Reservations. The Navajo Indian Reservation is divided into 17 administrative districts, numbered 1 to 5 and 7 to 18, and the Hopi Indian Reservation comprises District 6. The Reservation is further divided into 15-minute quadrangles arbitrarily numbered from 1 to 151 starting in the northeast corner of the area and numbering consecutively in a row from east to west. Within the 15-minute quadrangle a site is located in miles south and west from the northeast corner of the quadrangle. The first two numbers in the well number represent the district, the next three numbers are the quadrangle, the decimal numbers are miles west by (X) miles south of the northeast corner of the quadrangle. For example, the site identified as 02 021-05.28X10.68 identifies a well that is in district 2, quadrangle 21, and is 5.28 miles west by 10.68 miles south of the northeast corner of the map.

GWSI sites located in California, New Mexico, Nevada, and Utah use different baselines and meridians. Cadastral identifications for non-Arizona GWSI sites are presented in Appendix D. The complete list of land net meridians is listed below. Some land in Arizona falls in the California Survey because changes in the Colorado River have left parts of California on the Arizona side of the river.

<u>Land Net Meridian</u> (Site_Meridian)

This field records the land net meridian that is used to establish the Local Id or cadastral location of the site. In general all sites located in Arizona, except those on the Navajo and Hopi Indian Reservation, use the Gila and Salt River Meridian and Baseline. There are six meridian codes in GWSI. They are:

B - San Bernardino Meridian and Baseline
D - Mount Diablo Meridian and Baseline
G - Gila and Salt River Meridian and Baseline
N - Navajo Meridian and Baseline
P - New Mexico Principal Meridian and Baseline
S - Salt Lake Meridian and Baseline

<u>Site Type</u> (Site_Type_Code_Entry)

This field is used to describe what is at the location of the site. Generally ADWR is interested only in wells and springs, however, several different types of sites have been entered in the past. The site codes and their descriptions are listed below.

C - Collector or Ranney type well.

D - Drain dug to intercept the water table or potentiometric surface to either lower the water table or serve as a water supply.

E - Excavation

M - Multiple Wells. Used for well fields consisting of a group of wells that are pumped through a single header and for which little or no data are available.

S - Spring

T - Tunnel or Shaft. Tunnel, shaft, or mine from which groundwater is obtained.

W - Well. For single wells other than wells of the collector or Ranney type.

<u>Reliability</u> (Site_Rely_Code_Entry)

This field is used to describe the reliability of the data available for the site.

C - Field Checked. The data have been field checked by the reporting agency.

L - Location Not Accurate. Location of the latitude and/or longitude is not accurate.

M - Minimal Data. Used when modifying an existing record when the investigator is unsure if the site has been field checked.

U - Unchecked. The data have not been field checked by the reporting agency, but the reporting agency considers the data reliable.

<u>Topo Setting</u> (Site_Toposet_Code_Entry)

The Topographic Setting field contains codes that best describe the topographic setting of the area in which the site is located. (Figure 3).

* - Undetermined

A - Alluvial Fan. Refers to a slopping mass of material, shaped like an open fan or cone, deposited by a stream or wash at a place where it issues from a narrow mountain valley onto a plain or broad valley.

B - Playa. Refers to a dried-up, vegetation-free, flat-floored area composed of thin, evenly stratified sheets of fine clay, silt, or sand, that represents the bottom of a shallow, enclosed or undrained desert lake basin in which water accumulates and is quickly evaporated, usually leaving deposits of soluble salts.

C - Stream Channel. Refers to the bed in which a natural stream of water runs. The stream may be perennial, intermittent, or ephemeral. The term includes washes, arroyos, and coulees.

D - Depression. Refers to an area that has no external surface drainage. Depressions can range from a few acres to several square miles and should be considered local features. Do not use for regional features such as the large closed basins found in the Basin and Range province, or on the undulating surface of glacial drift (use undulating).

E - Dunes. Refers to mounds or ridges of windblown, or eolian sand. This term should not be used for an isolated mound unless it has a rather extensive area and is of hydrologic significance to the site.

F - Flat. Refers to a flat surface that may be part of a larger feature, such as an upland flat, mesa or plateau, coastal plain, lake plain, or pediment. Terraces and valley flats, which are special varieties of flat surfaces, are classified separately.

G - Floodplain. Refers to the surface or strip of relatively smooth land adjacent to a river channel, constructed by the present river in its existing flow regime and covered with water when the river overflows its banks at flood stage.

H - Hilltop. A hilltop is the upper part of a hill or ridge above a well-defined break in slope.

K - Sink. A sinkhole is a special type of depression that results from the dissolving of soluble rock (salt, gypsum, limestone) and the subsequent collapse of the earth into the solution cavity.

L - Lake. This code stands for any inland body of water where the ground may be saturated, or water may stand above the land surface for a period of time.

M - Mangrove Swamp. Refers to a tropical or subtropical marine swamp containing abundant mangrove trees.

P - Pediment. Refers to a plain of combined erosional material that forms at the foot of a mountain range.

S - Hillside. Refers to the sloping side of a hill, i.e., the area between a hilltop and valley flat.

T - Terrace. Refers to an alluvial or marine terrace that is generally a flat surface, usually parallel to but elevated above a stream valley or coast line. Due to the effects of erosion, the terrace surface may not be as smooth as a valley flat, and within the general terrace area there may be undulating areas.

U - Undulating. Refers to topography characteristic of areas which have many small depressions and low mounds. An undulating surface is primarily a depositional feature, not an erosional one. The term should not be used for areas that have a slightly irregular shape due to erosion.

V - Valley Flat. Refers to a low flat area between valley walls and bordering a stream channel. It includes the stream floodplain and, generally, is the flattest area in the valley. A valley flat may have a slight slope towards the main drainage, towards the valley walls, or may be cut by smaller streams. Generally, the valley flat is separated from alluvial terraces or the upland by a pronounced break in slope.

W - Upland Draw. Refers to a small natural drainage or depression, usually dry, on a hillside or upland area.

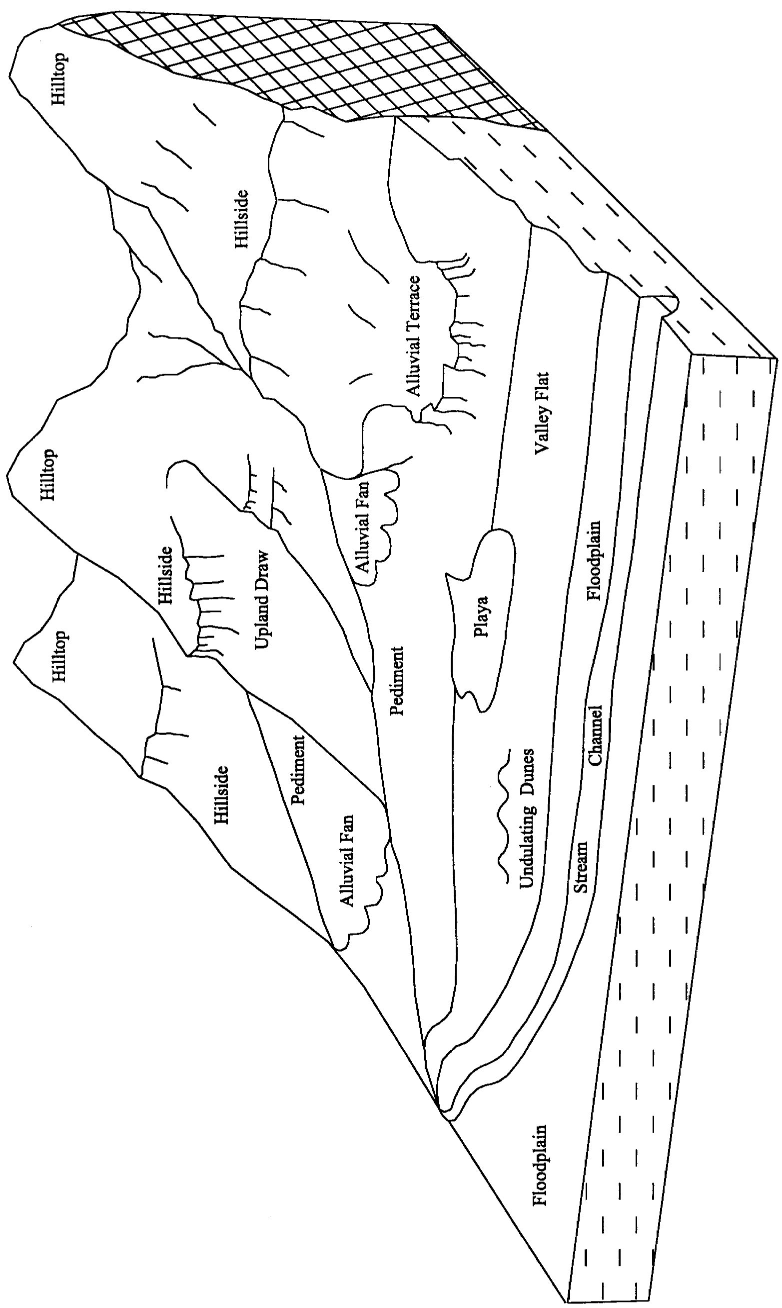


Figure 3. Diagrammatic sketch of Topographic features.

Figure 3. Diagrammatic sketch of Topographic features.

Site Data Source (Site_sisrc_Code)

This field contains the agency making the original field check and initial data entry, usually ADWR or USGS.

ADWR - Arizona Department of Water Resources
USBR - U.S. Bureau of Reclamation
USGS - U.S. Geological Survey

Topographic Quad Name (Site_Tqnam_Quad_Name)

This field contains the name of the U.S. Geological Survey Topographic Quadrangle map on which the site is located. Use the drop-down list to select the proper map name.

Map Scale (Site_Map_Scale)

This field records the scale of the topographic quadrangle map on which the site is located.

ALRIS Quadrangle Number (Site_Quad_No)

This field contains the Arizona Land Resource Information System (ALRIS) number of the topographic quadrangle that the site is located on. ALRIS is supported by the Arizona State Land Department and is based on a row - column grid of all 7.5 minute quadrangle maps that cover a part of the state. The first two numbers represent the column a map is in and the second two numbers are the row the map occupies. ORACLE assigns the ALRIS quadrangle number based on the name that is entered into the Topographic Quadrangle Name field.

Latitude and Longitude (Site_Latit_Degree, Site_Latit_Min, Site_Latit_Sec)
(Site_longit_Degree, Site_longit_Min, Site_longit_Sec)

The three latitude fields and the three longitude fields contain the best available value for the latitude and longitude of the site in degrees, minutes, and seconds. The site is located on an orthophoto and/or best available map in the field. The position of the site may be measured in the field by global positioning system (G.P.S.) equipment if available. The longitude and latitude will be determined from the orthophoto or map by the field person in the office. Each value for the degrees, minutes and seconds should be entered into the appropriate field.

Latitude/Longitude Accuracy (Site_Llaccr_Code)

This field records the accuracy of the latitude/longitude location for the site. If the site cannot be spotted on an orthophoto within 2 seconds, then the field person will indicate the appropriate accuracy. In general a site can be located to within five seconds on a map, Two seconds on an orthophoto with a templet, and one second if it is digitized. The appropriate codes are listed below:

* - Undetermined
2 - The measurement is accurate to + or - two seconds
B - 0.2 Seconds
F - The measurement is accurate to + or - five seconds
G - 0.5 Seconds
M - The measurement is accurate to + or - one minute
R – 0.005 seconds
S - The measurement is accurate to + or - one second
T - The measurement is accurate to + or - ten seconds

Decimal Latitude (Site_Latitude_Decimal)

This field contains the latitude in decimal format of the site which is calculated by ORACLE.

Decimal Longitude (Site_Longit_Decimal)

This field contains the longitude in decimal format of the site which is calculated by ORACLE.

UTM Coordinates (Site_Utm_East, Site_Utm_North)

The two UTM fields contain the Universal Transverse Mercator (UTM) location of the site. The Universal Transverse Mercator system is a special application of the Transverse Mercator map projection. The UTM system divides the globe into sixty (60) zones, each spanning six (6) degrees of longitude. Each UTM zone has a central meridian which divides the zone into two equal parts, three degrees east and three degrees west. The origin of a zone is the central meridian and the equator, all points within a zone are referenced from this point in meters. To eliminate negative values the origin is assigned a false easting value of 500,000 meters; thus Easting values of less than 500,000 meters are located in the east half of a zone and easting values of more than 500,000 meters are located in the west half of a zone. The UTM values for a GWSI site are calculated from the latitude and longitude coordinates and currently are in NAD27, Zone 12.

State Well Registration Number (Site_Well_Reg_Id)

This field contains the State Well Registration (55) number of the well if the site can be positively matched to a registered well. The 55 number is matched with a GWSI well only when the field investigator is absolutely positive that the wells are the same. If there is any doubt about the match, the 55 number is not entered until those doubts are resolved.

Site Altitude (Site_Well_Altitude)

This field contains the altitude of the site in feet above NGVD, precision to two decimals can be coded if available. This value is determined by the person field checking the site.

Method of Altitude Measurement (Site_Altmeth_Code_Entry)

This field records the method used to determine the altitude of the site.

* - Undetermined
A - Altimeter
G – Hand held G.P.S. unit
L - Level or other surveying method
M - from topographic map
R – Survey Grade G.P.S. unit

Altitude Accuracy (Site_Altit_Accuracy)

This field contains the level of accuracy, in feet, of the site altitude. Site altitudes taken from a map are generally accurate to one half the maps contour interval. Sites that are leveled in from a bench mark are considered accurate to within 1.0 foot.

ADWR Basin Codes (Site_Ama_Code_Entry)

This field contains the appropriate letter code for the ADWR groundwater basin or Active Management Area (AMA) in which the site is located. For sites that are in either a subdivided and non-subdivided basin the appropriate basin code is entered into this field. For sites that are in Active Management Areas (AMAs) the appropriate AMA code is entered. Sites that are located in Irrigation Non-Expansion Areas (INAs) have the three letter code of the groundwater basin within which the INA occurs entered in this field, and the three letter INA code entered into the ADWR Sub-basin field. See Appendix A for the appropriate ADWR Basin, Sub-basin, AMA, and INA Codes.

ADWR Sub-basin Codes (Site_Adwbas_Code_Entry)

Many of the ADWR groundwater basins and AMAs are subdivided into smaller sub-basins based on hydrologic conditions. This field contains the appropriate three letter code for the ADWR designated groundwater sub-basin. For sites that are in basins or AMAs with no Sub-basins, i.e., non-subdivided basins, the three letter basin or AMA code is entered into this field. Sites that are located in Irrigation Non-Expansion Areas (INAs) have the three letter INA code entered into this field. See Appendix A which contains the ADWR Basin, Sub-basin, AMA, and INA Codes.

USGS Basin Codes (Site_Usbasn_Code_Entry)

This field contains the appropriate three letter code for the U S Geological Survey groundwater area in which the site is located. See Appendix B which contains the USGS area codes.

State Codes (Site_State_Code)

This field contains the appropriate letter code for the state in which the site is located.

AZ - Arizona	NM - New Mexico	UT - Utah
CA - California	NV - Nevada	
CO - Colorado	SO - Sonora	

County Codes (Site_Cnty_Code)

This field contains the appropriate numeric code for the county in which the site is located.

Arizona

01 - Apache
03 - Cochise
05 - Coconino
07 - Gila
09 - Graham
11 - Greenlee
12 - La Paz
13 – Maricopa
15 – Mohave
17 – Navajo
19 - Pima
21 – Pinal
23 - Santa Cruz
25 - Yavapai
27 – Yuma

New Mexico

03 - Carton
17 - Grant
23 - Hidalgo
31 - McKinley
45 - San Juan
61 - Valencia

Nevada

03 - Clark

Utah

25 - Kane

California

25 - Imperial
65 - Riverside
71- San Bernardino

Colorado

83 - Montezuma

Site Use (Site_Use_1, Site_Use_2, Site_Use_3)

The three Site Use fields contain the appropriate letter codes for the use of the site. SITE_USE1 is the principal use of the site at the time of the last field visit. If the site is used for more than one purpose then the second and third Site Use entries can be coded with the appropriate letter codes.

* - Undetermined

A - Anode. An anode is a hole used as an electrical anode. Included in this category are wells used solely for cathodic protection of pipelines or electronic relays and other installations.

Site Use (cont)

C - Standby, Emergency Supply. This refers to a water supply source that is used only when the principal source of water is unavailable.

D - Drain. Refers to the drainage of surface water underground.

E - Geothermal. A geothermal well is a hole drilled for geothermal energy development. Use this category for dry geothermal wells or wells into which water is injected for heating. For a wet geothermal well, from which water is withdrawn, use W – Withdrawal of water for the site use, and E - Power Generation as the primary use of water.

G - Seismic. A seismic hole is one drilled for seismic exploration. A seismic hole converted for other uses should be coded based on its current use.

H - Heat Reservoir. Refers to a well in which a fluid is circulated in a closed system. Water is neither added nor withdrawn from the well.

M - Mine. A mine includes any tunnel, shaft, or other excavation constructed for minerals extraction.

N - Non-exempt well in AMA/INA

O - Observation - Water Level. An observation well is a well that is used for water level observations. Do not use this category for oil test holes or water-supply wells used only occasionally as observation wells. ADWR state-wide water level monitoring wells are identified by convention with the code O only in the Site_Use_ 2 or Site_Use_3 fields.

P - Oil or Gas. Refers to any well or hole drilled in search of, or for production of, petroleum or gas. This category includes any oil or gas production well, dry hole, core-hole, or injection well drilled for secondary recovery of oil and/or gas. An oil-test hole converted to a water supply hole should be classified as Withdrawal.

Q - Water Quality Monitoring. An observation well is a well that is used for water-quality observations. Do not use this category for oil test-holes or water supply wells used only occasionally as observation wells. ADWR state-wide water quality monitoring wells are identified by convention by the code Q only in the Site_Use_2, or Site_Use_3 fields

R - Recharge. A recharge site is a site constructed for, or converted for, use in replenishing the aquifer. Use this category for wells that are used only to place water into an aquifer.

S - Repressurized. Refers to pumping water into an aquifer in order to increase the pressure in the aquifer for a specific purpose, for example, water flood purposes in an oil field.

T - Test. Refers to either an uncased or temporarily cased hole, that was drilled for water, or for geologic or hydrogeologic testing. The hole may be temporarily equipped with a pump in order to make a pump test, but if the well is developed after testing it is still a test hole. A core hole that is part of mining or quarrying exploration work should be in this class.

U - Unused. Refers to an abandoned site or one for which no use is contemplated. At an abandoned farmstead a domestic, or stock well equipped with a pump may be classed as unused. An irrigation well that is not equipped with a pump, nor used for other reasons, also may be classified unused.

W - Withdrawal. Refers to a site that withdraws water for one of the purposes listed under water use. It includes a dewatering well if the dewatering is accomplished by pumping groundwater.

X - Waste . Refers to a site used to convey industrial waste, domestic sewage, oil-field brine, mine drainage, radioactive waste, or other waste fluid into an underground zone. An oil-test or deep-water well converted to waste disposal should be in this category.

Z - Well Destroyed. Refers to a site that is has been destroyed and is no longer in existence.

Water Use (Site_Water_Use_1, Site_Water_Use_2, Site_Water_Use_3)

The three Water Use fields are used to indicate to what purpose any water withdrawn from the site is used. Use WATER_USE_1 to indicate the principal use of the water from the site. Other uses are entered in the other two water use fields.

* - Undetermined

A - Air Conditioning. Refers to water supplied solely or principally for the heating or cooling of a building. Water used to cool industrial machinery should be coded as Industrial, not as Air Conditioning.

B - Bottling. Refers to the storage of water in bottles and use of the water for potable purposes.

C - Commercial. Refers to use by a business that does not fabricate or produce a product. Filling stations and motels are examples of commercial establishments. If some product is manufactured, assembled, remodeled, or otherwise fabricated, use of water at the plant should be considered as Industrial, even though the water is not used directly in the production and/or manufacture of the product.

D - Dewatering. Refers to water pumped for dewatering a construction or mining site, or to lower the water table for agricultural purposes. In this respect, it differs from a drainage well that is used to drain surface water underground. If the main purpose for which the water is withdrawn is to provide drainage, Dewatering should be indicated even though the water may be discharged into an irrigation ditch and subsequently used to irrigate land.

E - Power. Refers to water withdrawn for the use of generating any type of power.

F - Fire. Refers to the principal use of the water and should be indicated if the site was constructed principally for this purpose, even though the water may be used at times for other purposes.

H - Domestic. Refers to water used to supply household needs, principally for drinking, cooking, washing, and sanitary purposes, but includes watering a lawn and caring for pets. Most domestic wells will be in suburban or farm homes, but wells supplying small quantities of water for domestic purposes to one-room schools, turnpike gates, and similar installations, should also be included in the category.

I - Irrigation. Refers to water used to irrigate cultivated crops. Most irrigation site will supply water for farm crops, but this category should include wells used to water the grounds of schools, industrial plants, cemeteries, or golf courses if more than a small amount is used and that is the sole use of the water.

J - Industrial Cooling. Refers to a well that supplies water used solely for industrial cooling.

K - Mining. Refers to a well that supplies water used solely for mining purposes.

M - Medicinal. Refers to water believed to have therapeutic value. Water may be used for bathing and/or drinking. If used of water is mainly because of its claimed therapeutic value, use this category even if the water is bottled.

N - Industrial. Refers to water used within a plant that manufactures or fabricates a product. The water may or may not be incorporated into the product being manufactured. Industrial water may be used to cool machinery, to provide sanitary facilities, to air condition the plant, or to irrigate the grounds at the plant.

O - Observation. Refers to water that is used for water quality sampling.

P - Public Supply. Refers to water that is pumped and distributed through a network that supplies several homes. Such supplies may be owned by a municipality or community, a water district, or a private water company. If the system supplies five or more homes it should be considered. "Public Supply"; for four or fewer homes classify use as . "Domestic". Wells that supply motels and hotels should be classified as "Commercial". Many public supply wells also supply water for a variety of uses, such as industrial, institutional, and commercial.

Water Use (continued)

Q - Aquaculture. Refers to water used solely for aquaculture, such as fish farms.

R - Recreation. Refers to water discharged into pools, or channels, which are dammed to form pools, that are used for swimming, boating, fishing, ice rinks, or other recreational uses. Also used for wells that irrigate golf courses and parks.

S - Stock. Refers to a well pumped to supply water to livestock.

T - Institution. Refers to water used in the maintenance and operation of institutions such as large schools, universities, hospitals, rest homes, or similar institutions. Owners of the institutions may be individuals, corporations, churches, or government bodies.

U - Unused. Means that water is not being removed from the site for one of the purposes listed above. A test hole, oil or gas well, recharge, drainage, observation, or waste-disposal well will be in the category. Do not use this classification for a stock, irrigation, domestic, or other well during off season or other temporary periods of nonuse.

Z - Other.

Depth of Hole (Site_Hole_Depth)

This field records the total depth to which the hole was drilled in feet, below the land surface datum, even though it may have been plugged back in completing the well. For collector or Ranney-type wells, the depth of the central shaft should be entered. For multiple-well fields, ponds, tunnels, springs, or drains, the field should be blank. If the hole depth is given, all other depths associated with the site will be compared with it for validity.

Depth of Well (Site_Well_Depth)

This field contains the depth of the finished, or cased, portion of the well in feet below land surface datum. The depth of the well is usually taken from the completed well drillers report.

Source of Depth Data (Site_Adwrs_Code)

This field contains the source of the reported depth of a well.

* - Undetermined
A - Arizona Department of Water Resources.
B - U.S. Bureau of Reclamation.
C - Consultant.
D - Driller. Depth taken from a drillers log or report.
E - New Mexico Office of State Engineer.
G - Geologist.
L - Logs.
M - Memory. Depth from owner, driller, or well operator.
O - Owner. Depth reported by well owner.
R - Other Reported. Depth reported by person other than owner, driller, or another governmental agency.
S - U.S. Geological Survey. Depth reported by personnel from the U. S. Geological Survey.
Z - Other. Depth reported by other source. Explain source in Remarks section.

Geological Unit (Site_Geo_Unit)

This field contains an 8-character code that identifies the lithologic unit in which the well is finished. See Appendix C for the appropriate Geological Unit Codes.

Site Creation Date (Site_Create_Date)

This field is filled by ORACLE with the date when the SITES entry was created.

Site Update Date (Site_Update_Date)

This field is filled by ORACLE with the date when information in any of the data tables related to the GWSI site is updated or modified.

Last Action Date (Site_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the SITES data table is changed or modified.

Last Action Operator (Site_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to change or modify any field in the SITES data table.

Valid Entry Dates (Site_Cdate_Valid, Site_Udate_Valid)

The two Valid Entry Date fields contain flags that indicate the accuracy of the dates in the Site Create or Site Update fields. Prior to being loaded into the ORACLE data tables GWSI was located on an IBM mainframe computer. Some of the date fields in the GWSI on IBM mainframe had no month or day values. The ORACLE GWSI date fields would not accept the null date entries when the IBM data were loaded into the ORACLE forms. To get around this problem, values were added to those GWSI entries with null dates. The month field was assigned a value of one (1) if it was empty, and the day field was assigned a value of one (1) if it was empty. The letter code 'M' in the Date Valid field indicates the month value has been assigned and the date is only accurate to the year. The letter code 'D' in the Date Valid field indicates the day value has been added and the date is accurate only to the month. A blank entry indicates that the full date is accurate. Each data table in GWSI that contains date fields will contain a Date Valid field.

Arizona Watershed Codes (Site_Wshd_Code)

This field contains the Arizona Watershed that the site falls in. Watershed codes are listed below

01 - Virgin River
02 - Colorado River
03 - Little Colorado River
04 - Bill Williams River
05 - Verde River
06 - Agua Fria River
07 - Salt River
08 - Upper Gila River
09 - Santa Cruz River
10 - San Simon River
11 - San Pedro River
12 - Willcox Playa
13 - White Water Draw
14 - Rio Yaqui
15 - La Paz

Index Well Book (Site_Indx_Book)

If the site an active index well the number of the index book is entered in this field. It needs to be noted that this field only includes active index wells. Other wells that were index wells and then were removed from the index lines are not noted in this field. Wells that are on the index lines are a good place to start when looking for long-term water level records. However, other wells in the area of interest still need to be checked. A well that has been removed from the index line may still contain a very useful water level history.

Well Completions Data Table (WELL_COMPLETIONS**)**

The Well Completions Data Table is used to record detailed information about the construction of a site that is a well. The information includes the drillers' names, dates of completion, drilling methods, casing finishes, and sources of the data.

Construction Entry Number (Wlco_Id)

Construction data can be entered more than once for a given site, such as when a well is deepened or some other major work is done. Therefore, a unique identifying control number is assigned by Oracle for each construction data entry. The number need not be sequential but needs to be unique for the site. The unique construction number is also assigned to any related construction information that is entered into the Bore Completions, Casing Completions and Perforation Completions Data Tables.

Well Completion Date (Wlco_Completion_Date)

This entry is the date the drilling was completed. If the day or month are not known enter 01 for the month and 01 for the day, and code the appropriate letter is entered into the Date Valid Field.

Method of Construction (Wlco_Drilmth_Code_Entry)

This field describes the method by which the site was constructed. Allowable entries are:

* - Undetermined.

A - Air Rotary. This method uses a stream of air to cool the bit and bring the rock cuttings to the surface.

B - Bored or Augured. This method uses an auger to cut and remove the earth material. The auger may be powered by hand or by machinery.

C - Cable Tool. Refers to a well drilled by the percussion or churn-drill method whereby a heavy drilling tool is raised and lowered with enough force to pulverize the rock. The rock debris is commonly removed from the hole with a bailer.

D - Dug. Hand dug holes are excavated by hand tools or power-driven digging equipment. Caissons, Ranney-type collectors, and galleries belong in this classification even though they may have laterals that are driven or jetted.

H - Hydraulic Rotary. With this method a well is constructed by rotating a length of pipe (drill stem) equipped with a drill bit that cuts or grinds the rocks. Water or drilling mud is pumped down the drilling stem. Cuttings are carried to the surface in the annular space between the drilling stem and the wall of the hole. Note that separate categories are provided for air-rotary and reverse-rotary.

J - Jetted. Jetted wells are excavated by using high velocity streams of water that are pumped through a pipe having a restricted opening or jetting nozzle. For some types of earth material, a cutting bit is attached to the end of the jetting nozzle. The material cut or washed from the hole is carried to the surface in the annular space outside the pipe as in the hydraulic-rotary method.

P - Air Percussion. This method uses a cutting tool powered by compressed air. A rapid percussion effect, coupled with rotary action, is used to drill through the earth material. Compressed air is also used to blow cuttings from the drill hole. Air-percussion drills are generally used in conjunction with air-rotary drilling rigs.

R - Reverse Rotary. This method is similar to the hydraulic rotary method except that the water or drilling mud flows down the annular space between the drilling stem and the walls of the hole and the cuttings are pumped out through the drill stem.

Method of Construction (Cont.)

T - Trenching. Refers to the construction of a sump or open pit from which groundwater may be pumped. Trenching may be done by hand, but more commonly power equipment, such as a bulldozer, power shovel, or back-hoe is used. Ponds and Drains belong in this category.

V - Driven. A well constructed by driving a length of pipe, usually of a small diameter and generally equipped with a sand point, to a desired depth. These wells may be driven by hand or with an air hammer or other power equipment. An essential feature of a driven well is that no earth material is removed as the well is constructed.

W - Drive and Wash. These wells are constructed by driving a small diameter open-ended casing a few feet into the earth and then washing the material inside the casing out with a jet of water. The process is repeated until the well is at the desired depth.

Z - Other. Any other drilling method that may be used. The method may be described in the Remark Field.

Well Finish (Wlco_Wlcase_Code_Entry)

This data field is used to describe the method of finish or the nature of the openings that allow water to enter the well. The allowable codes are listed below.

* - Undetermined

C - Porous Concrete. This is a concrete casing that is pervious enough to allow groundwater to seep into the well.

F - Gravel Pack with Perforations. Refers to a well that has a gravel envelope opposite a casing section with perforations which allows water to enter the well.

G - Gravel Pack with Screen. Refers to a well that has a gravel envelope opposite a commercially available casing section with screening material which allows water to enter the well.

H - Horizontal Gallery. This type of finish is a horizontal-type well in which the screen, slotted pipe, or gravel-filled trench is horizontal. All horizontal wells should be in this class, including Ranney collectors and infiltration galleries.

O - Open Ended. Refers to a well that is cased to the bottom of the hole so that water can enter the well only through the bottom of the hole.

P - Perforated or Slotted. Refers to casing that has had holes punched or slots cut into it to allow water to enter. Do not use this classification if the well has a gravel pack; use F or G, whichever is appropriate.

S - Screened. Refers to commercially available well screen manufactured for the purpose of allowing water to enter the well casing. Common types of screen are wire mesh, wrapped trapezoidal wire, or shutter screen. Do not use this classification if the well also has gravel pack; use G instead.

T - Sand Point. Refers to the screen part of a drive point and usually is part of a driven well.

W - Walled or Shored. Refers to a dug well that has walls that have been shored up with open-jointed fieldstone, brick, tile, concrete blocks, wood cribbing or other material. A dug well that is mostly open hole but has even a few feet of cribbing, corrugated pipe, or other shoring to prevent caving should be in this category. Wells of this type with gravel walls belong in this category, not in the F or G.

X - Open Hole. Refers to a well that has a finished open hole in the aquifer. A well belongs in this classification even if the casing does not actually extend to the geologic unit or zone from which the water is obtained.

Z - Other. Any other drilling method that may be used. The method may be described in the Remark Field.

Source of Construction Data (Wlco_Adwrs_Code)

This field contains the source of the construction data and has the same letter codes as those found in the Sites_Adwrs_Code field in the Sites Data Table. See page 14 for the appropriate letter codes.

Name of Driller (Wlco_Driller_Name)

This field contains the name of the driller or drilling company that constructed the well. For very long company names use meaningful abbreviations as needed to fit the name into the space provided.

Last Action Date (Wlco_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Well Completions data table is changed or modified.

Last Action Operator (Wlco_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Well Completions data table.

Valid Completion Date (Wlco_Valid_Date)

This field contains a flag that indicates the accuracy of the well completion date. See the previous explanation of the Valid Date field.

Bore Hole Completions Data Table (BORE_COMPLETIONS)

The Bore Hole Completions Data Table is used to record specific data describing the drill hole for a well site.

Construction Entry Number (Bore_Wlcomp_Id)

The construction entry is the unique control number assigned by Oracle to well construction data in the Well Completions Data Table. This control number is assigned to the corresponding bore hole construction information.

Bore Hole Interval (Bore_Hole_Interval)

This field contains a sequential number assigned by Oracle to each separate bore hole diameter record for a specific construction entry number. For example, a bore hole that is drilled at 16 inches in diameter from land surface to 500 feet below land surface and then drilled at 12 inches in diameter from 500 feet below land surface to 750 feet below land surface would have two bore hole intervals. The first interval is 0 to 500 feet, the second bore hole interval is 501 to 750 feet. The interval numbers for the bore hole completions data table is assigned sequentially and generally starts from the construction entry number. For example, for a well with a construction entry number of 451384 the first bore hole interval would be assigned 451385, a second bore hole interval would be assigned 451386.

Top of Bore Hole (Bore_Hole_Top)

This is the depth to the point at which the top of a segment of the hole begins in feet below land surface. The first section of the hole begins at zero (0).

Bottom of Bore Hole (Bore_Hole_Bottom)

This is the depth to the bottom of the hole segment, in feet below land surface.

Diameter of the Bore Hole (Bore_Hole_Diameter)

This is the normal diameter of the bit used to drill this section of the hole, or the diameter to which the hole was reamed, in inches. Two decimal places are provided for fractional sizes.

Last Action Date (Wlco_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Bore Completions data table is changed or modified.

Last Action Operator (Wlco_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Bore Completions data table.

Casing Completion Data Table (CASING_COMPLETIONS)

The Casing Completions Data Table describes information about the casing of a well.

Construction Entry Number (Case_Wlcomp_Id)

The construction entry number is the unique control number assigned by Oracle to well construction data in the Well Completions Data Table. This control number is assigned to the corresponding well casing information.

Casing Interval (Case_Interval)

This is a sequential number assigned to each casing diameter for a specific construction entry number. For example, a well that is cased at 16 inches in diameter from land surface to 500 feet below land surface and then cased at 12 inches in diameter from 500 feet below land surface to 750 feet below land surface would have two casing intervals. The first casing interval is 0 to 500 feet, the second casing interval is 500 to 750 feet. The casing interval numbers are assigned sequentially and generally start from the construction entry number.

Top of Casing (Case_Top)

This is the depth to the point at which the top of a casing segment begins in feet below land surface. The first section of casing begins at zero (0).

Bottom of Casing (Case_Bottom)

This is the depth to the bottom of the casing segment, in feet below land surface.

Diameter of the Casing (Case_Diameter)

This is the outside diameter of the casing segment in inches. Two decimal places are provided for fractional sizes.

Casing Material (Case_Material_Code)

This data table indicates the material from which the casing is made. The codes and their meanings are:

* - Undetermined	I - Wrought Iron	T - Tile
B - Brick	M - Other Metal	U - Coated Steel
C - Concrete	P - PVC or Plastic	W - Wood
D - Copper	R - Rock or Stone	Z - Other
G - Galvanized Iron	S - Steel	

Last Action Date (Case_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Casing Completions Data Table is changed or modified.

Last Action Operator (Case_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to change or modify the Casing Completions Data Table.

Perforation Completion Data Table (PERFORATION_COMPLETION)

The Perforation Completion Data Table is used to record information about the openings through which water enters a well.

Construction Entry Number (Perf_Wlcomp_Id)

The construction entry number is the unique control number assigned by Oracle to well construction data in the Well Completions Data Table. This control number is assigned to the corresponding well perforation information.

Perforation Interval (Perf_Interval)

This is a sequential number assigned to each perforation interval for a specific construction entry number. For example, a well that is perforated from 200 feet below land surface to 500 feet below land surface and then perforated from 600 feet below land surface to 750 feet below land surface would have two perforation intervals. The first perforated interval is 200 to 500 feet, the second perforated interval is 600 to 750 feet. The interval numbers are assigned sequentially and generally start from the construction entry number.

Top of perforation (Perf_Top)

This field contains the depth to the point at which the top of a perforated segment begins in feet below land surface.

Bottom of perforation (Perf_Bottom)

This field contains the depth to the bottom of the perforated segment, in feet below land surface.

Diameter of Perforation Casing (Perf_Diameter)

This field records the outside diameter, in inches, of the perforated casing or slotted pipe, the diameter of a screen or the diameter of the hole, if the well is finished as an open hole. Two decimal places are provided for fractional sizes.

Perforation Material (Perf_Material_Code)

This is a code that indicates the type of material from which the screen or other open section is made. The codes and their meanings are:

* - Undetermined	I - Wrought Iron	S - Steel
B - Brass or Bronze	M - Other Metal	T - Tile
C - Concrete	P - PVC or Plastic	Z - Other
G - Galvanized Iron	R - Stainless Steel	

Perforation Type (Perf_Type_Code)

This entry indicates the type of open section that allows groundwater to enter the well. The codes and their meanings are:

* - Undetermined	P - Perforated or Slotted	W - Walled
F - Fracture	R - Wire Wound	X - Open Hole
L - Louvered or Shuttered	S - Screen	Z - Other
M - Mesh	T - Sand Point	

Length of Perforations (Perf_Length)

This field records the long dimension of the perforations or slots, in inches, or the individual openings in the screen or slotted pipe.

Width of Perforations (Perf_Width)

This field records the short dimension of the perforations or slots, or the mesh size of the screen, in inches.

Last Action Date (Perf_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Perforation Completions Data Table is changed or modified.

Last Action Operator (Perf_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Perforation Completions Data Table.

Flowing Discharge Data Table (FLOWING_DISCHARGES)

The Flowing Discharge Data Table is used to record water discharge data or springs that flow naturally. Occasionally data for both flowing and pumped conditions will be collected for the same site. In the event data are collected at a flowing site during natural flow and also while being pumped (to increase discharge or during a time of no natural flow), the pumped data should be entered in the Well Production Data Table.

Discharge Number (Flwd_Id)

Each flowing discharge entry for a site is assigned a unique identifying number by Oracle. The discharge numbers are assigned sequentially starting from the construction entry number and including any sequential numbers already assigned to records in other data tables with the same sites Id.

Measurement Date (Flwd_Measure_Date)

This field records the date on which the discharge was measured. The associated data field Date Valid indicates the accuracy of the measurement date. See the previous explanation of the Valid Date field.

Discharge Rate (Flwd_Discharge_Rate)

This is the discharge rate of the site in gallons per minute. If discharge is determined in other units (such as cfs or other metric units) convert to gallons per minute. Two decimal places are provided for very small discharges.

Discharge Measurement Method (Flwd_Dscmth_Code_Entry)

This is the method by which the discharge was measured. The methods and their codes are:

* - Undetermined	M - Totaling Meter	S - Ultrasonic Transit Time
B - Bailer	O - Orifice Plate	T - Trajectory
C - Current Meter [1]	P - Pitometer	V - Volumetric
E - Estimated	R - Reported	Z - Other
F - Flume		

1 A current meter may be either a propeller-type meter in a discharge pipe, or a induction-type in a channel (e.g. Marsh-McBirney).

Discharge Data Source (Flwd_Datasrc_Code_Entry)

This entry indicates who provided the discharge data. The codes are listed below:

* - Undetermined
A - Arizona Department of Water Resources
B - U.S. Bureau of Reclamation
C - Consultant
D - Driller
E - New Mexico Office of the State Engineer
F - Arizona Public Service
G - University of Arizona
J - Military
L - Arizona State Land Department
M - Bureau of Land Management
O - Owner
R - Other Reported
S - Salt River Project
T - City of Tucson
U - U.S. Geological Survey
Z - Other

Last Action Date (Flwd_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Flowing Discharges data table is changed or modified.

Last Action Operator (Flwd_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Flowing Discharges data table.

Flow Date Valid (Flwd_Date_Valid)

This field contains a flag that indicates the accuracy of the flowing discharge date. See the previous explanation of the Valid Date field.

Pumping Discharge Data Table (PUMPING_DISCHARGE)

The Pumping Discharge Data Table is used to record water levels and discharge data needed to estimate well performance for pumped well sites. Occasionally data for both flowing and pumped conditions will be collected for the same site. In the event data are collected at a flowing site during natural flow and also while being pumped (to increase discharge or during a time of no natural flow), the pumped data should be entered in this Data Table.

Discharge Number (Pmpd_Id)

Each discharge entry for a site is assigned a unique identifying number by Oracle. The discharge numbers are assigned sequentially starting from the construction entry number and including any sequential numbers already assigned to records in other data tables with the same sites Id.

Measurement Date (Pmpd_Measure_Date)

This field records the date on which the discharge was measured. The associated data field Date Valid indicates the accuracy of the pumping discharge measurement date.

Discharge Rate (Pmpd_Discharge_Rate)

This field contains the discharge rate of the site in gallons per minute. If discharge is determined in other units (such as cfs or other metric units) convert to gallons per minute. Two decimal places are provided for very small discharges.

Discharge Measurement Method (Pmpd_Pmpdmth_Code_Entry)

This field records the method by which the discharge was measured. The methods and their codes are the same as for Flowing Discharge Methods and can be found on page 21.

Discharge Data Source (Pmpd_Data_Source)

This field indicates who provided the discharge data. The codes are the same as for Flowing Discharge Source found on page 22.

Production Water Level (Pmpd_Production_Water_Level)

This field records the water level in feet below land surface, while the well was discharging. The difference between this value and the static water level is the production drawdown.

Static Water Level (Pmpd_Static_Water_Level)

This field records the static, or pre-pumping, water level in feet below land surface. If the static water level is above the land surface, the head (if measurable) is preceded by a minus sign (-).

Static Water Level Method (Pmpd_Statmth_Code_Entry)

This field records the code that indicates the method by which the static water level was measured. If the static and production water levels were measured by different methods, record the method considered least accurate. The water level measurement codes are listed below.

* - Undetermined	G - Pressure Gauge	R - Reported
A - Airline	H - Calibrated Pressure Gauge	S - Steel Tape
B - Analog	L - Geophysical Logs	T - Electric Tape
C - Calibrated Airline	M - Manometer	V - Electric Sounder
E - Estimated	N - Non-recording Gauge	Z - Other

Static Water Level Source (Pmpd_Static_Source)

This field contains the code that indicates the source of the static water level measurement. The code letters are the same as for the source of the Flowing Discharge Data Source found on page 22.

Pumping Period (Pmpd_Pumping_Period)

This field contains the length of time, in hours, that the well was pumped prior to the measurement of the production levels. Two decimal points are provided for times less than an hour.

Well Drawdown (Pmpd_Well_Drawdown)

This field contains the drawdown, in feet, of the pumping well (static level - pumping level).

Specific Capacity (Pmpd_Specific_Capacity)

The specific capacity is calculated by Oracle from the Pumping level and the discharge rate.

Last Action Date (Pmpd_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Pumping Discharges data table is changed or modified.

Last Action Operator (Pmpd_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Pumping Discharges data table.

Pumping Date Valid (Flwd_Date_Valid)

This field contains a flag that indicates the accuracy of the Pumping Discharge date. See the previous explanation of the Valid Date field.

Well Lifts Data Table (WELL_LIFTS)

The Well Lifts Data Table contains information about the pump that is used to bring water to the surface at the site.

Lift Number (Wlli_Id)

Each lift entry for a site is assigned a unique identifying number by Oracle that is a sequential variation of the well construction entry number.

Lift Date (Wlli_Entry_Date)

This entry is the date on which the well lift was observed. The associated data field Date Valid indicates whether the date has been modified to be accepted by ORACLE.

Lift Type (Wlli_Type_Code)

This field contains the code for the type of pump or lift that brings water to the surface.

* - Undetermined.

A - Air lift. An air lift is a jet of air pumped below the water table that causes a stream of mixed air and water to flow from the well.

B - Bucket. This type of lift includes a rope and bucket, chain and bucket lifts, and a small bailer lifted by a rope or chain and pulley.

C - Centrifugal. Centrifugal pumps have rotating impellers in a closed chamber that draw the water into the pump. The water is then discharged from the pump, under pressure, by centrifugal force. Centrifugal pumps have a maximum lift of about 25 feet.

J - Jet. Jet pumps have two pipes extending from the pump into the well. One pipe forces air down the well bore under pressure while the other pipe discharges water that has been forced to the surface by the jet.

N - None. The well has no pump.

P - Piston. Piston pumps include the familiar lift and pitcher pumps, reciprocating pumps, and deep-wells with "walking-beam jacks pumps.

R - Rotary. Rotary pumps operate on the principle that direct pressure is created by squeezing water between specially designed runners. A high vacuum is created on the intake side so that a suction lifts the water to the surface. Rotary pumps have a maximum lift of about 25 feet.

S - Submersible. A submersible pump is a special type of turbine pump that is designed to be submerged in water. An electric motor is connected directly to impellers and then submerged in water.

T - Turbine. There are several types of turbine pumps that are designed for either deep or shallow wells. In a turbine pump a series of impellers are placed below the surface of the water and rotated by a vertical shaft connected to a power source at the land surface. The impellers pick up the water and force it to the surface through the pump column. Turbine pumps are capable of lifting large amounts of water at high pressure. Most high capacity public supply, industrial, and irrigation wells use turbine pumps.

U - Unknown. If the pump type is unknown or cannot be identified.

Lift Type (cont.)

V - Not Assigned.

Z - Other. Any lifting device that is not listed above.

Lift Power Type (Wlli_Power_Type)

This field contains the code for the type of power used to power the pump.

* - Undetermined	G - Gasoline	N - Natural Gas
D - Diesel	H - Hand	W - Wind
E - Electric	L - LP Gas	Z - Other

Lift Meter Number (Wlli_Meter_Num)

This field can contain the meter number of the gas or electric meter which records the power consumption of the pump. This information in this field can be used as a cross reference to help identify a well.

Power Company (Wlli_Power_Company)

This field contains a three letter code for the name of the company that provides electrical, natural gas, or other power for the pump. For a complete list use the pull/down menu in the ORACLE forms application.

APS	Arizona Public Service	NAE	Navapache Electric Co-Op
CAL	Calapco	NAV	Navajo Tribal Utility Authority
CIT	Citizens Utility	NEW	Nevada Power Company
COM	City of Mesa	PHS	Public Health Service
DIX	Dixeletta (Utah)	PTU	Papago Tribal Utility
DVE	Duncan Valley Electric Co-Op	RD1	Electrical Dist. RD1 (Roosevelt District
ED1	Electrical District 1	REA	Rual Electrification Administration
ED2	Electrical District 2	SCP	San Carlos Project
ED3	Electrical District 3	SOU	Southern Union Gas
ED4	Electrical District 4	SRP	Salt River Project
ED5	Electrical District 5	SSV	Sulphur Springs Valley Elec. Co-Op
ED7	Electrical District 7	SWG	Southwest Gas
ED8	Electrical District 8	TEP	Tucson Electric and Power
GAR	Garkane Power Association	TGE	Tucson Gas and Electric
GCE	Graham County Electice Co-Op	TR1	Trico Electric Co-Op
IID	Imperial Irrigation District	USB	U.S. Bureau of Reclamation
INT	Interstate Utility	WD1	Elect. District WD1 (Maricopa Water Dist.)
MAG	Magma Gas Company	WEM	Welton Mohawk Irrigation and Power
MEC	Mohave Electric Co-Op	WMIDD	Welton Mohawk Irrigation and Drainage District

Lift Horsepower (Wlli_Horsepower)

This field contains the power rating, in horsepower, of the wells primary power source. Two decimal places are provided for small motors.

Lift Account Number (Wlli_Account_Num)

This field contains the account number under which the power company stores power consumption rates for the site.

Lift Power Divider (Wlli_Divider)

This field contains the pump rating as the unit of power consumed per volume of water lifted. The value should be expressed as kilowall-hours per acre-foot of electricity or therms per acre-feet of water depending on the type of power used by the pump.

<u>Source of Divider Measurement</u> (Wlli_Source_Code)

This field contains the name of the source of the power divider or the rating of the pump as the volume of water lifted per unit of power consumed.

* - Undetermined
A - Arizona Department of Water Resources
B - U S Bureau of Reclamation
C - Consultant
D - Driller
E - New Mexico Office of State Engineer
F - Arizona Public Service
G - University of Arizona
J – Military
L - Arizona State Land Department
M -Bureau of Land Management
O - Owner
R - Other Reported
S - Salt River Project
T - City of Tucson
U - U. S. Geological Survey
W – Wellton-Mohawk Irrigation and Drainage District)
Z - Other

<u>Method of Power Divider Measurement</u> (Wlli_Method_Code)

This field contains the method of the measurement that determined the power divider, or pump rating.

* - Undetermined
O - Old Data
A - Dedicated power meter, instantaneous discharge with approved equipment/method, with static pressure <10 psi
B - Dedicated power meter, instantaneous discharge with approved device with static pressure <10 psi
D - Non-Dedicated power meter, instantaneous discharge with approved equipment/method, with static pressure <10 psi
E - Non-Dedicated power meter, instantaneous discharge with approved device with static pressure <10 psi
P - Dedicated power meter, instantaneous discharge with approved equipment/method, with static pressure > = 10 psi
Q -Dedicated power meter, instantaneous discharge with approved device with static pressure > = 10 psi
R - Non-Dedicated power meter, instantaneous discharge with approved equipment/method, with static pressure > = 10 psi
S - Non-Dedicated power meter, instantaneous discharge with approved device, with static pressure > = 10 psi

<u>Last Action Date</u> (Wlli_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Well Lifts Data table is changed or modified.

<u>Last Action Operator</u> (Wlli_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Well Lifts Data table.

<u>Date Valid</u> (Wlli_Date_Valid)

This field contains a flag that indicates the accuracy of the Well Lifts date. See the previous explanation of the Valid Date field.

Well Log Data Table (WELL_LOGS)

The Well Log Data Table contains information about the types of geophysical and/or other log data available for the site.

Log Type (Wllo_Logty_Code_Entry)

This field contains letter codes for the types of logs that are available for a site.

* - Undetermined	I - Induction	Q - Radioactive
A - Time	J - Gamma Ray	S - Sonic
B - Collar	K - Dipmeter	T - Temperature
C - Caliper	L - Lathering	U - Gamma-Gamma
D - Driller	M - Microlog	V - Fluid Velocity
E - Electric	N - Neutron	X - Core
F - Fluid Conductance	O - U Later	Z - Other
G - Geologist	P - Photo	

Log Start (Wllo_Log_Start)

This field contains the depth to the top of the logged interval in feet below land surface.

Log End (Wllo_Log_End)

This field contains the depth to the bottom of the logged interval in feet below land surface.

Source of Log Data (Wllo_Adwrs_Code)

This fields contains information that indicates who provided the log information. The codes are the same as those found in the Sites_Adwrs_Code field in Sites Data Table found on page 14.

Last Action Date (Wllo_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Well Logs Data table is changed or modified.

Last Action Operator (Wllo_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Well Logs Data Table.

Well Owners Data Table (WELL_OWNERS)

The Well Owners Data Table contains the name of the site owner and the date of their known ownership of the site. It should be emphasized that the last entry in this data table may not be the current owner of the site, but is the owner at the time indicated in the Owner Entry Date Field.

Owner Id (Wlow_Id)

Each ownership entry for a site is assigned a unique identifying number by Oracle that is a sequential variation of the construction entry number.

Owner Entry Date (Wlow_Entry_Date)

This entry is the date that the owner acquired ownership of the site, or the earliest date on which the owner was known to own the site. The associated Date Valid field indicates the accuracy of the Well Owner Entry date

Owners Last Name (Wlow_Last_Name)

This field is used for recording the last name of the well owner.

Owners First Name (Wlow_First_Name)

This field is used for recording the first name of the well owner.

Owners Middle Initial (Wlow_Middle_Initial)

This field contains one (1) space for recording the middle initial of the well owner.

Last Action Date (Wlow_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Well Owners Data Table is changed or modified.

Last Action Operator (Wlow_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Well Owners Data Table.

Date Valid (Wlow_Date_Valid)

This field contains a flag that indicates the accuracy of the Well Owners date. See the previous explanation of the Date Valid Field.

Other Site Id Data Table (OWNER_SITE_NAMES)

The Owner Site Id Data Table contains identifying numbers or names that have been assigned to a site, usually by the site owner. For example, a city or town may assign a number to each of its wells.

Owner Id (Owns_Other_Id)

This field contains spaces for recording the name or number used to by the owner to identify the site.

Assigner (Owns_Assigner)

This field contains thirty (30) spaces for recording the person or organization that assigned the other Id.

Last Action Date (Owns_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Owners Site Name Data Table is changed or modified.

Last Action Operator (Owns_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Owner Site Name Data Table.

Remarks Data Table (REMARKS)

The Remarks data table contains remarks from field investigators that may help clarify data entered in other data tables regarding the site.

Remarks Id (Rem_Id)

Each remarks entry for a site is assigned a unique identifying number by Oracle that is a sequential variation of the construction entry number.

Remarks Date (Rem_Remarks_Date)

This entry is the date that the remarks for the site were recorded. The associated Date Valid field indicates the accuracy of the Remarks Date.

Remarks (Rem_Remarks)

This field contains 40 spaces per line to record remarks used to clarify information associated with the site. More than one line can be used to record the site remarks.

Last Action Date (Rem_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Remarks Data Table is changed or modified.

Last Action Operator (Rem_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to change or modify any field in the Remarks Data Table.

Date Valid (Rem_Date_Valid)

This field contains a flag that indicates the accuracy of the Remarks Date. See the previous explanation of the Date Valid Field.

Site Inventories Data Table (SITE_INVENTORIES)

The Site Inventories Data Table contains information on the date of the site visit and the name of the person who made the site visit.

Site Inventory Id (Siti_Id)

Each site inventory visit is assigned a unique identifying number by Oracle that is a sequential variation of the construction entry number.

Site Inventory Date (Siti_Inventory_Date)

This field records the date that the site was visited. The associated Date Valid field indicates the accuracy of the Inventory Date.

Inventoried By (Siti_Inventoried_by)

This field is used to record the name of the person making the site inventory or visit. (The last name is entered first followed by a space and the first and middle initials, do not include periods or spaces. Examples are listed below.)

BARNES RL   BLACK K   MASON DA   RASCONA S

Last Action Date (Siti_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Site Inventories Data Table is changed or modified.

Last Action Operator (Siti_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to change or modify any field in the Site Inventories Data Table.

Date Valid (Siti_Date_Valid)

This field contains a flag that indicates the accuracy of the Inventory Date. See the previous explanation of the Date Valid Field.

Spring Names Data Table (SPRING_NAMES)

The Spring Names Data Table is used to record the name of flowing springs that have been inventoried. Additional data such as, spring type, flow variability, spring name and any site improvements may also be entered into the record.

Spring Name (Spna_Spring_Name)

This field is used to record the name, if any is given, that has been assigned to the spring.

Permanence (Spna_Spperm_Code_Entry)

This field is used to describe the dependability of the spring flow, if it is known, at the site.

* - Undetermined	P - Perennial
E - Periodic - Ebb and Flow	R - Response to Precipitation
G - Geyser	S - Seasonal
I – Intermittent	Z – Other

Type of Spring (Spna_Sptype_Code_Entry)

This field is used to describe the type of spring found at the site.

* - Undetermined	F - Fracture	P - Perched
A - Artesian	H - Perched or Tubular	R - Perched Seepage
B - Perched or Contact	J - Artesian and Depression	S - Seepage of Filtration
C - Contact	K - Artesian and Seepage	T - Tubular - Cave
D - Depression	L - Fracture and Depression	Z - Other
E - Perched or Depression	O - Perched and Fracture	

Spring Improvements (Spna_imprv_Code_Entry)

This field contains the record of any improvements that have been made to the site to improve, impound or redirect the spring flow.

* - Undetermined	H - Spring House	R - Pipe
B - Boxed Basin	L - Lined	T - Trough
C - Concrete Gallery	N - None	Z - Other
G - Gallery	P - Pond	

Last Action Date (Spna_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Spring Name Data Table is changed or modified.

Last Action Operator (Spna_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Spring Name Data Table.

Water Levels Data Table (WW_LEVELS)

The Water Levels Data Table contains information related to the depth to water at the site. Data that is contained includes, depth to water, water table elevation, measurement date, method of measurement, measurement remarks and source of the water level measurement.

Water Level Id (Wlwa_Id)

Each water level entry for a site is assigned a unique identifying number by Oracle that is a sequencial variation of the construction entry number.

Date Measured (Wlwa_Measurement_Date)

This field records the date that the water level was recorded for the site. The associated Date Valid field indicates the accuracy of the Water Level Measurement Date.

Depth to Water (Wlwa_Depth_To_Water)

This field records the depth to water, in feet, below land surface. Depth to water can be carried out to two decimal places. If the water level is above land surface, enter the water level in feet above land surface preceded by a minus (-) sign. If the head at a flowing site is unknown, if the water level can not be measured, the site is dry, or the well destroyed then this field is left blank and the appropriate code must be placed in the associated Water Level Remarks Code field (Wlwa_Remarks). (By default there can be no 0.00 depth to water.)

Water Level Elevation (Wlwa_Water_Level_Elevation)

This field contains the elevation of the water table above mean sea level datum. This field is calculated by subtracting the depth to water from the well altitude as entered in the Sites Data table. Except for flowing wells water level elevations are blank for records that have no depth to water measurements.

Method of Water Level Measurement (Wlwa_Method Code)

This field contains the code for the method used to measure the depth to water.

* - Undetermined	G - Pressure Gauge	R - Reported
A - Airline	H - Calibrated Pressure Gauge	S - Steel Tape
B - Analog	L - Geophysical Logs	T - Electric Tape
C - Calibrated Airline	M - Manometer	V - Electric Sounder
E - Estimated	N - Non-recording Gauge	Z - Other

Remarks (Wlwwa_Remarks)

This field contains letter codes that describe the status of the site at the time of the water level measurement.

* - Undetermined.

C - Cascading Water. Water was cascading down the well casing from some point above the water table.

D - Dry. The site was dry and no water level was recorded.

E - Recently Flowing. The site had recently been flowing.

F - Flowing. The site was flowing, but no head could be measured (no water level is recorded).

Water Level Remarks (cont)

G - Nearby Flowing. A nearby site was flowing at the time of measurement.

H - Nearby Recently Flowing. A nearby site had recently flowed.

I - Well Injecting. The well was being used to inject water into the aquifer at the time of the measurement attempt. Examples of injection wells are wells used to recharge water into an aquifer.

N - Measurements Discontinued at the site.

O - Obstructed. An obstruction in the well casing prevented a measurement (no water level is recorded).

P - Pumping. The site was being pumped at the time of measurement.

R - Recently Pumped. The site had been pumped recently.

S - Nearby Pumping. A site nearby was being pumped at the time of measurement.

T - Nearby Recently Pumped. A nearby site had recently been pumped.

U - Nearby Injecting. A site nearby was being used to inject water into an aquifer.

V - Foreign Material (Oil). A foreign material, usually oil, was encountered on the surface of the water table.

W - Well Destroyed. The well has been destroyed and no water level is recorded.

X - Surface Water Effects. The water level may be affected by the a nearby surface water site.

Z - Other. Other conditions that may affect the measured water level. (Explain in the Remarks Data Table).

Water Level Source Code (Wlwa_Source_Code)

This field contains letter codes for the source of the water level measurement.

* - Undetermined	L - Arizona State Land Department
A - Arizona Department of Water Resources	M - Bureau of Land Management
B - U. S. Bureau of Reclamation	O - Owner
C - Consultant	R - Other Reported
D - Driller	S - Salt River Project
E - New Mexico Office of State Engineer	T - City of Tucson
F - Arizona Public Service	U - U. S. Geological Survey
G - University of Arizona	W –(Welton Mohawk Irrigation & Drainage District)
J – Military	Z - Other

Last Action Date (Wlwa_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Water Levels Data Table is changed or modified.

Last Action Operator (Wlwa_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Water Levels Data Table.

Date Valid (Wlwa_Date_Valid)

This field contains a flag that indicates the accuracy of the Water Levels Date. See the previous explanation of the Valid Date field.

Water Level Measuring Point Data Table (WM_POINTS)

The Water Level Measuring Point Data Table contains a description of the point used to measure the depth to water in a well.

Water Level Point Id (Welm_Id)

Each water level measuring point entry for a site must have a unique identifying number that is used only once at a site.

Date Measured (Welm_Date_Measured)

This field records the date that the water level measuring point was established for the site. The associated Date Valid field indicates the accuracy of the Measuring Point Date.

Measuring Point Height (Welm_Measure_Point_Height)

This entry is the height above the land surface from which the depth to water measurement was made. If the measurement point is below land surface, the measurement height is preceded by a minus sign (-).

Measuring Point Descriptions (Welm_Mp_Description)

This field contains a description of the point use to measure the depth to water. Listed below and illustrated in Figure 4 are some of the common measuring point descriptions.

HTCA, W - Hole in Top of Casing, West Side
HSCA, N - Hole in Side of Casing, North Side
TCA, SE - Top of Casing, Southeast Side
HBOP, S - Hole in Pump Base, South Side
BOP, N - Access under Base of Pump, North Side
ACTB, S - Measuring (Access) Tube, South Side
AIRL, S - Airline, South Side
HISP, NE - Hole in Submersible Plate, Northeast Side

Last Action Date (Welm_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Measuring Point Data Table is changed or modified.

Last Action Operator (Welm_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Measuring Point Data Table.

Date Valid (Welm_Date_Valid)

This field contains a flag that indicates the accuracy of the Measuring Point Date. See the previous explanation of the Date Valid Field.

Water Quality Reports Data Table (WQ_REPORT)

The Water Quality Data table contains six (6) basic water quality parameters that are gathered by Department personnel during field investigations. The seven parameters are specific conductance, in microsiemens per centimeter at 25 degrees Celsius; fluoride, in milligrams per liter (mg/L); temperature, in degrees Celsius; pH; alkalinity as $CaCO_3$, in milligrams per Liter; and dissolved oxygen, in milligrams per Liter. Not all parameters may have been tested for at any given site and at any given time. Blank data in the water quality fields indicate that the parameter was not tested for at the time of sampling.

Water Quality Id (Watq_Id)

Each water quality measurement entry for a site is assigned a unique identifying number by Oracle that is a sequencial variation of the construction entry number.

Date Measured (Watq_Date_Measured)

This field records the date that the water quality sample was analyzed at the site. The associated Date Valid field indicates the accuracy of the Date Measured.

Specific Conductance (Watq_Specific_Conductance)

Specific conductance is a measure of the electrical conductance of a water sample, and as such, is an indicator of the amount of total dissolved solids (TDS) in a sample. The specific conductance value is reported as microsiemens per centimeter at 25 degrees Celsius.

Fluoride (Watq_Fluoride)

Fluoride is measured to one decimal point in milligrams per liter (mg/L).

Temperature (Watq_Temperatur_Celcius)

Temperature is the water temperature in degrees Celsius (C^{o}) at the time of sampling. The temperature can be entered to one decimal point.

pH (Watq_Ph)

The pH is a measure of the hydrogen activity of the sample. The pH can be entered to one decimal point.

Alkalinity (Watq_Alkalinity)

Alkalinity is a measure of metallic ions, principally calcium and magnesium, in the water sample and is reported as milligrams per liter (mg/l) of calcium carbonate ($CaCO_3$).

Dissolved Oxygen (Watq_Dissolved_Oxygen)

Dissolved oxygen is the measure of the amount of oxygen dissolved in water an is measured in milligrams per Liter.

Last Action Date (Welm_Last_Act_Date)

This field is filled by ORACLE with the date when any field in the Water Quality Data Table is changed or modified.

Last Action Operator (Welm_Last_Act_Oper)

This field is filled by ORACLE with the user id of the last person to modify or change any field in the Water Quality Data Table.

Date Valid (Welm_Date_Valid)

This field contains a flag that indicates the accuracy of the Water Quality Date. See the previous explanation of the Date Valid Field.

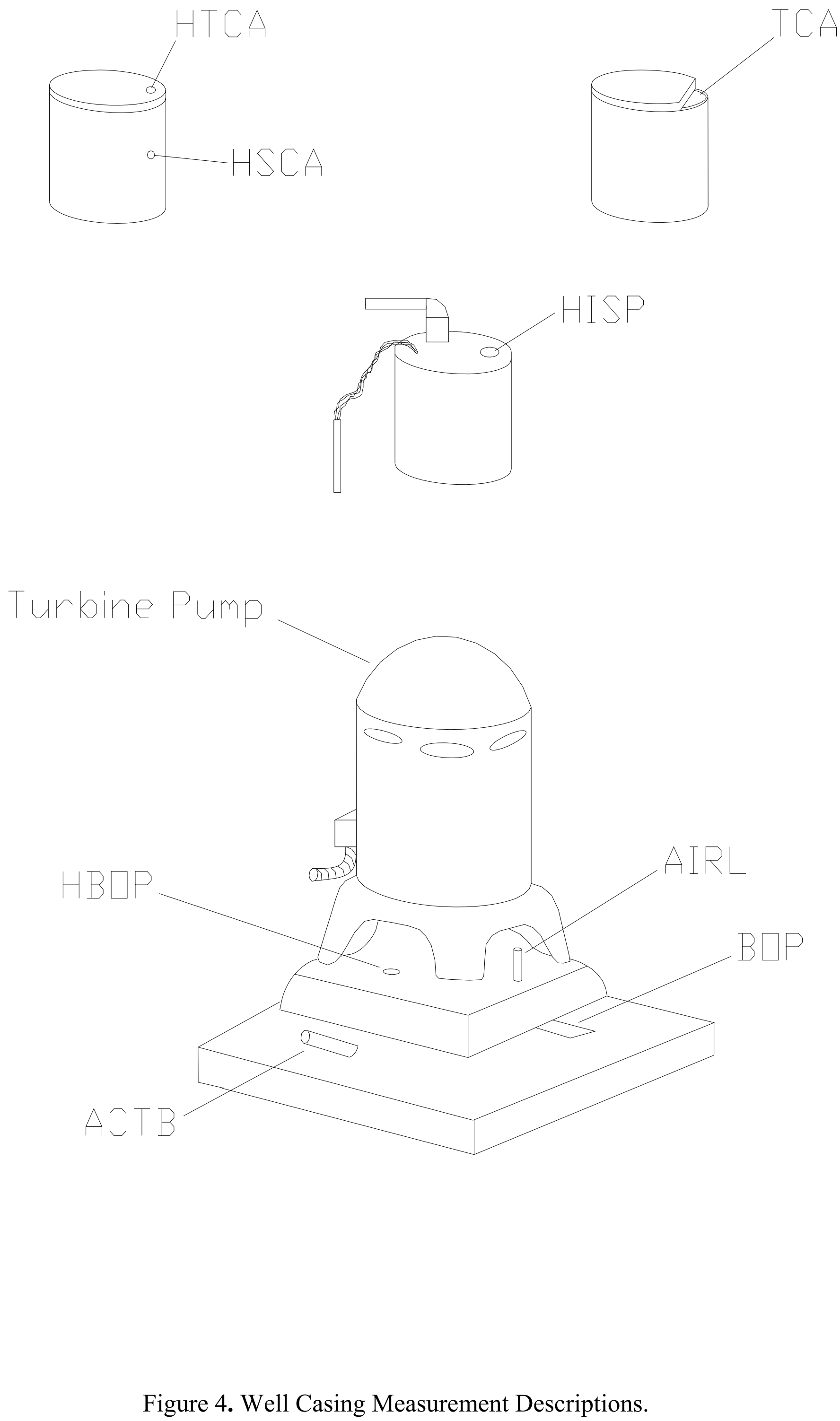


Figure 4**.** Well Casing Measurement Descriptions.

Appendix A : ADWR Groundwater Basin Codes

Listed below are the letter codes used to identify the ADWR Groundwater Basins, Sub-basins and Active Management Areas (AMAs).

ADWR Non-Subdivided Groundwater Basins

Basin Name	Basin Code
Agua Fria	AGF
Aravaipa Canyon	ARA
Bonita Creek	BON
Butler Valley	BUT
Cienega Creek	CCK
Coconino Plateau	COP
Detrital Valley	DET
Donnelly Wash	DON
Douglas	DOU
Dripping Springs Wash	DSW
Duncan Valley	DUN
New Mexico section of Duncan Valley Basin	DNM
Gila Bend	GIL
Grand Wash	GWA
Hualapai Valley	HUA
Kanab Plateau	KAN
Lake Havasu	LKH
Lake Mohave	MHV
Little Colorado River Plateau	LCR
McMullen Valley	MMU
Meadview	MEA
Morenci	MOR
Paria	PAR
Peach Springs	PSC
Ranagras Plain	RAN
Sacramento Valley	SAC
San Bernadino Valley	SBV
San Rafael	SRF
San Simon Wash	SSW
Shivwits Plateau	SHV
Tiger Wash	TIG
Tonto Creek	TON
Upper Hassayampa	UHA
Virgin River	VRG
Western Mexican Drainage	WMD
Willcox	WIL
Yuma	YUM

ADWR Subdivided Groundwater Basins

Basin	Subbasin	Basin Code
Big Sandy		**BIS**
	Fort Rock	FTR
	Wikieup	WIK
Bill Williams		**BWM**
	Alamo Reservoir	ALR
	Burro Creek	BUR
	Clara Peak	CLA
	Santa Maria	SMR
	Skull Valley	SKU
Lower Gila		**LGB**
	Childs Valley	CHV
	Dendora Valley	DEN
	Mohawk-Welton	WEM
Lower San Pedro		**LSP**
	Camp Grant Wash	CGW
	Mammoth	MAM
Parker		**PKB**
	Colorado River Indian Reservation	CRI
	Cibola Valley	CIB
	La Posa Plains	LPC
Safford		**SAF**
	San Carlos Valley	GSK
	San Simon Valley	SSI
	Gila Valley	SAF
Salt River		**SRB**
	Black River	BRB
	White River	WRB
	Salt River Canyon	USR
	Salt River Lakes	SRL
Upper San Pedro		**USP**
	Allen Flat ALF	
	Sierra Vista	SEV
Verde River		**VRB**
	Big Chino	BIC
	Verde Canyon	LVR
	Verde Valley	VER

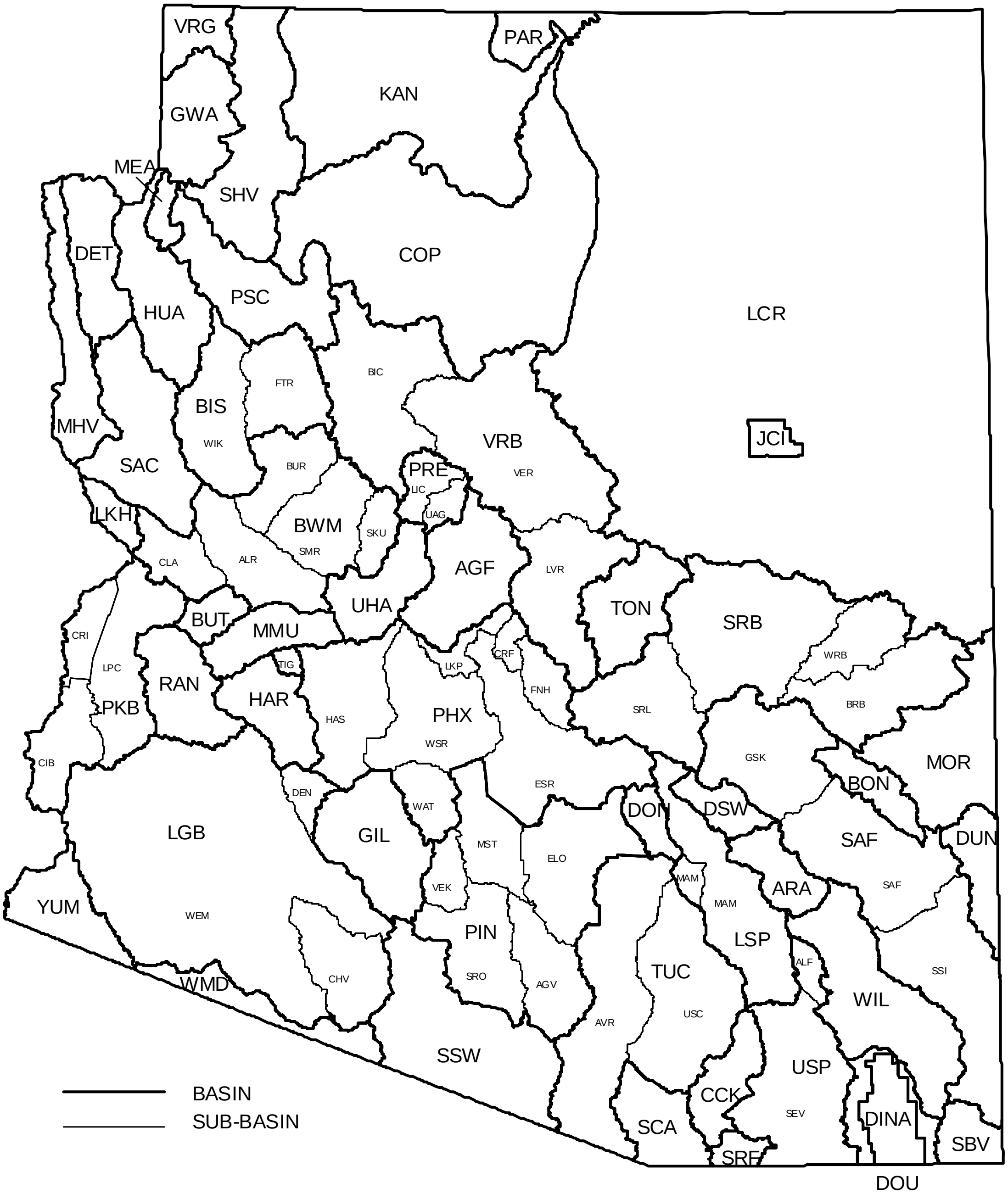


Figure 5. ADWR Groundwater Basins and Subbasins Map.

ADWR Active Management Areas (AMA)

AMA Name	Subbasin	Code
Phoenix AMA		**PHX**
	West Salt River Valley	WSR
	East Salt River Valley	ESR
	Carefree	CRF
	Lake Pleasant	LKP
	Fountain Hills	FNH
	Hassayampa	HAS
	Rainbow Valley	WAT
Pinal AMA		**PIN**
	Aguirre Valley	AGV
	Eloy	ELO
	Maricopa-Stanfield	MST
	Santa Rosa Valley	SRO
	Vekol Valley	VEK
Prescott AMA		**PRE**
	Upper Agua Fria	UAG
	Little Chino Valley	LIC
Santa Cruz AMA		**SCA**
Tucson AMA		**TUC**
	Avra Valley	AVR
	Upper Santa Cruz	USC

ADWR Irrigated Non-Expansion Areas (INA)

INA Name	Code
Douglas INA	DIN
Harquahala INA	HAR
Joseph City INA	JCI

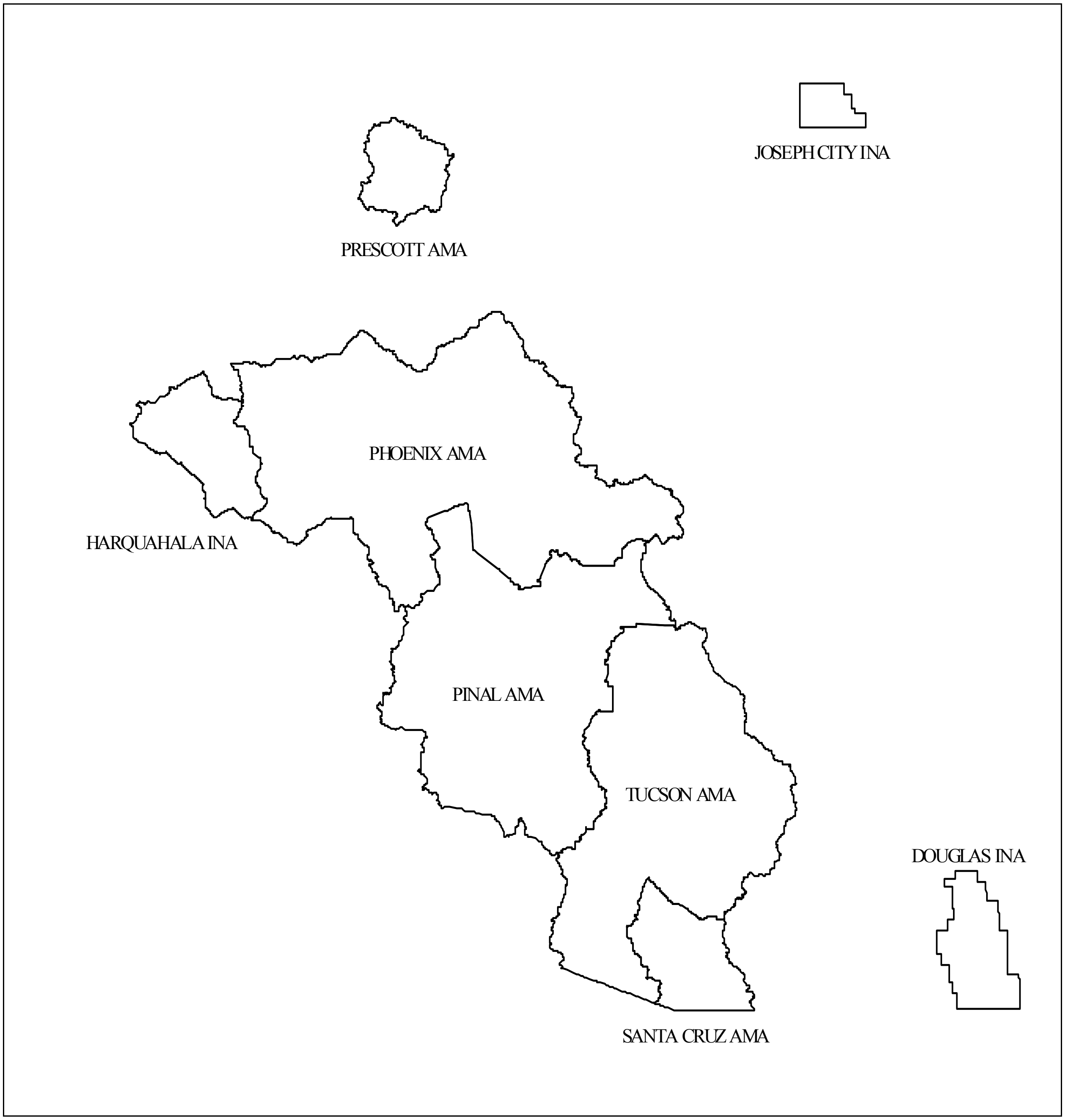


Figure 6 ADWR Active Management Areas and sub-basins Map**.**

Appendix B: U.S. Geological Survey Groundwater Area Codes

Groundwater Site Inventory (GWSI) Database

Listed below are the letter codes used to identify the U.S. Geological Groundwater Areas

Basin Name	Basin Code
Agua Fria Basin	AGF
Altar Valley	ALT
Aravaipa Valley	ARA
Avra Valley	AVR
Big Chino Valley	BIC
Big Sandy Valley	BIS
Bill Williams	BWM
Black Mesa	BLM
Black River Basin	BRB
Bodaway Mesa	BOD
Butler Valley	BUT
Canyon Diablo	CDI
Chevelon	CHV
Chinle	CHN
Coconino Plateau	COP
Colorado River, Hoover Dam to Imperial Dam	CHI
Concho	CON
Douglas Basin	DOU
Duncan Basin	DUN
Gila Bend Basin	GIL
Gila River, Painted Rock Dam to Texas Hill	GRD
Gila River, San Carlos Reservoir to Kelvin	GSK
Gila River, Texas Hill to Dome	GTD
Grand Wash	GRA
Harquahala Plains	HAR
Hassayampa Basin	HAS
Holbrook	HOL
Hopi	HOP
House Rock	HOU
Hualapai Valley	HUA
Kaibito	KAI
Kanab	KAN
Little Chino Valley	LIC
Lower Hassayampa	LHA
Lower San Pedro	LSP
Lower Santa Cruz	LSC
Lower Verde River	LVR
McMullen Valley	MMU
Monument Valley	MNV
New River-Cave Creek	N-C
Peach Springs Canyon	PSC
Puerco-Zuni	PRZ
Ranegras Plain	RAN
Sacramento Valley	SAC
Safford Basin	SAF
Saint Johns	STJ
Salt River Valley	SRV
San Bernardino Valley	SBV

Basin Name	Basin Code
San Francisco Peaks	SFP
San Francisco River Basin	SFR
San Simon Basin	SSI
San Simon Wash	SSW
Shivwits	SHV
Snowflake	SNO
Tonto Basin	TON
Tuba City	TUB
Upper Salt River Basin	USR
Upper San Pedro Basin	USP
Upper Santa Cruz Basin	USC
Upper Verde River	VER
Virgin River	VRG
Waterman Wash	WAT
Western Mexican Drainage	WMD
White Mountains	WHM
White River Basin	WRB
Willcox Basin	WIL
Williamson Valley	WMN
Yuma	YUM

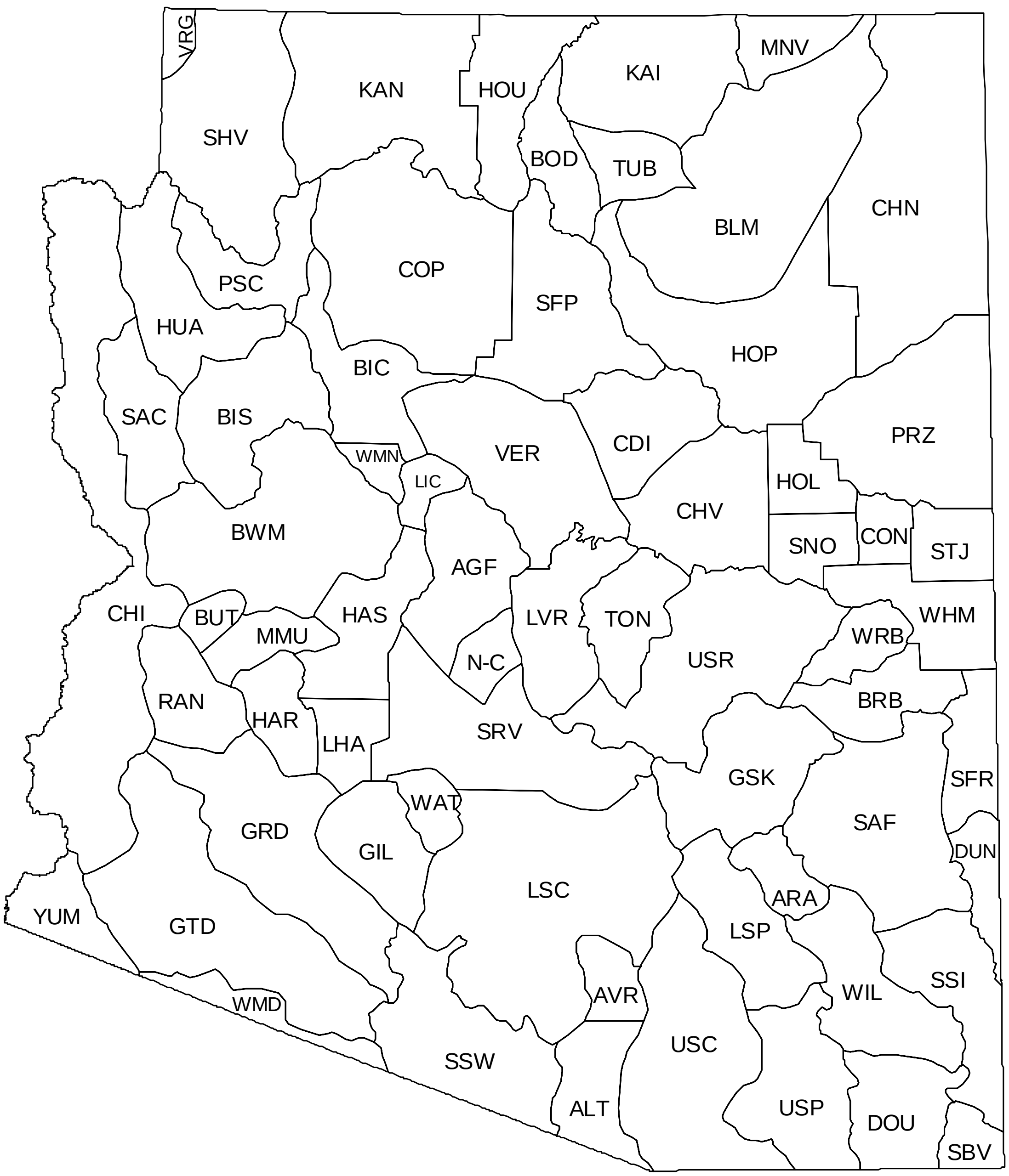


Figure 7. U. S. Geological Survey Groundwater Areas

Appendix C: Geological Unit Codes

Cenozoic

Quaternary

Holocene

Alluvium (Flood-Plain and Stream Channel)	111ALVM

Pleistocene

Basaltic Flows	112BLCF
Basin Fill - Upper, Lower, Undifferentiated	112BSFL
Basin Fill - Upper	112BSFLU
Sand and Gravel - Upper	112SDGVU
Terrace (and Surficial) Deposits	112TRRC

Tertiary

Consolidated Sedimentary Rocks, Tertiary and Mesozoic Undifferentiated	120CDSM
Datil Formation	120DATIL
Felsic Volcanic Rocks	120FCVC
Intrusive Rocks	120IRSV
Mafic Volcanic Rocks	120MFCV
Mafic and Felsic Volcanic Rocks	120MFFV
Sedimentary Rocks	120SDMR
Volcanic Rocks	120VLCC

Pliocene

Bidahochi Formation	121BDHC
Bidahochi Formation - Lower	121BDHCL
Bidahochi Formation - Middle	121BDHCM
Bidahochi Formation - Upper	121BDHCU
Basaltic Flows	121BLCF
Basin Fill - Lower	121BSFLL
Chuska Sandstone	121CHSK
Lower Basin Fill and Miocene Sedimentary Rocks - Undifferentiated	121LBFM

Miocene

Basalt-Andesite Flows	122BLAD
Sedimentary Rocks	122SDMR
Volcanic Breccias, Agglomerates, and Tuffs	122VBAT
Muddy Creek Formation	121MDCK
Verde Formation	121VERD

Tertiary

Oligocene

Felsic Flows or Welded Tuffs	123FFTW
Sedimentary Rocks	123KDMR
Mafic Flows	123MFCF
Volcanic Breccias, Agglomerrates, or Tuffs	123VBAT
Volcanic Rocks	123VLCC

Eocene

Felsic Volcanic Rocks	124FCVC
Mafic Volcanic Rocks	124MFCV
Sedimentary Rocks	124SDMR

Paleocene

Nacimiento Formation	125NCMN
Ojo Alamo Formation	125OJAM

Mesozoic

Felsic Intrusive Rocks	200FCIV
Felsic Volcanic Rocks	200FCVC
Mafic Volcanic Rocks	200MFCV
Mafic Intrusive Rocks	200MFIV
Sedimentary Rocks	200SDMR
Volcanic Rocks	200VLCC

Cretaceous

Upper Cretaceous

Allison Member of Menefee Formation of the Mesaverde Group	211ALSN
Bartlett Barren Member of Crevasse Canyon Formation of the Mesaverde Group	211BRLB
Cliff House Sandstone of the Mesaverde Group	211CLFH
Cleary Coal Member of Menefee Formation of the Mesaverde Group	211CLRY
Crevasse Canyon Formation of the Mesaverde Group	211CRVC
Dilco Coal Member of Crevasse Canyon Formation of the Mesaverde Group	211DLCO
Dalton Sandstone Member of Crevasse Canyon Formation of the Mesaverde Group	211DLTN
Dakota Sandstone	211DOKT
Fruitland Formation	211FRLD
Farmington Sandstone Member of Kirkland Shale	211FRMG
Gallup Sandstone	211GLLP

<u>Mesozoic</u>

<u>Cretaceous</u>

Upper Cretaceous (cont.)

Hosta Tounge of Point Lookout Sandstone of the Mesaverde Group	211HOST
Juana Lopez Member of Mancos Shale	211JLPZ
Kirkland Shale - Upper	211KRLDU
Lewis Shale	211LWIS
Menefee Formation	211MENF
Mulatto Tongue of Mancos Shale	211MLTT
Mancos Sahle	211MNCS
Pictured Cliffs Sandstone	211PCCF
Point Lookout Sandstone	211PNLK
Pescado Tongue of Mancos Shale	211PSCD
Santan Tongue of Mancos Shale	211SATN
Sedimentary Rocks - Undifferentiated	211SDMR
Toreva Formation	211TORV
Wepo Formation	211WEPO
Yale Point Sandstone	211YLPN

Lower Cretaceous

Burro Canyon Formation	217BRCN

<u>Jurassic</u>

Navajo Sandstone	220NVJO

Upper Jurassic

Bluff Sandstone	221BLFF
Brushy Basin Shale Member of Morrison Formation	221BRSB
Carmel Formation	221CRML
Cow Springs Sandstone	221CSPG
Entrada Sandstone	221ENRD
Entrada Sandstone - Lower	221ENRDL
Entrada Sandstone - Middle	221ENRDM
Entrada Sandstone - Upper	221ENRDU
Morrison Formation	221MRSN
Recapture Shale Member of the Morrison Formation	221RCPR
Salt Wash Sandstone Member of the Morrison Formation	221SLWS
Summerville Formation	221SMVL
Todilto Limestone	221TDLT
Westwater Canyon Sandstone Member of the Morrison Formation	221WSRC

<u>Mesozoic</u>

<u>Triassic</u>

Hoskinnini Member of the Moenkopi Formation	230HSKN
Moenkopi Formation	230MNKP

Triassic

Upper Triassic

Church Rock Member of Chinle Formation	231CCRK
Chinle Formation	231CHNL
Correo Sandstone Bed of Petrified Forest Member of Chinle Formation	231CORR
Dinosaur Canyon Sandstone Member of Moenave Formation	231DSRC
Kayenta Formation	231KYNT
Lukachukai Member of Wingate Sandstone	231LKCK
Monitor Butte Member of Chinle Formation	231MNRB
Moenave Formation	231MOONV
Mesa Redondo Member of Chinle Formation	231MRDD
Owl Rock Member of Chinle Formation	231ORCK
Petrified Forest Member - Lower - of Chinle Formation	231PFDFL
Petrified Forest Member - Upper - of Chinle Formation	231PFDFU
Rock Point Member of Wingate Sandstone	231RCKP
Sonsela Sandstone Bed of Petrified Forest Member of Chinle Formation	231SNSL
Springdale Sandstone Member of Moenave Formation	231SPGD
Shinarump Member of Chinle Formation	231SRMP
Wingate Sandstone	231WNGT

Middle Triassic

Holbrook Sandstone Member of Moenkopi Formation	224HLBK

Lower Triassic

Moqui Member of Moenkopi Formation	237MOQU
Wapatki Member of Moenkopi Formation	237WPTK

Paleozoic

Limestone	300LMSN
Quartzite	300QRTZ
Sandstone	300SNDS

Permian

Abo Formation	310ABO
Coconino Formation	310CCNN
Cedar Mesa Sandstine Member of Cutler Formation	310CDRM
Cutler Formation	310CTLR
De Chelly Sandstone	310DCLL
Glorieta Sandstone	310GLRT
Halgaito Tongue of Cutler Formation	310HLGT
Hermit Shale	310HRMT
Kaibab Limestone	310KIBB
Meseta Blanca Sandstone Member of Yeso Formation	310MBLC
Naco Formation	310NACO

<u>Paleozoic</u>

<u>Permian</u> (cont.)

Organ Rock Tongue of Culter Formation	310OGRK
Rico Formation	310RICO
Supai Formation	310SUPI
Supai Fprmation - Lower	310SUPIL
Supai Formation - Middle	310SUPIM
Supai Formation - Upper	310SUPIU
San Ysidro Member of Yeso Formation	310SYDR
Toroweap Formation	310TRWP
Yeso Formation	310YESO

<u>Guadalupian</u>

San Andres Limestone	313SADR

<u>Pennsylvanian</u>

Hermosa Formation	320HRMS
Molas Formation	320MOLS

<u>Mississippian</u>

Redwall Limestone	330RDLL

<u>Devonian</u>

Upper Devonian

Martin Limestone	341MRTN

<u>Cambrian</u>

Middle Cambrian

Bright Angle Shale	374BGAG
Muav Limestone	374MUAV
Tapeats Sandstone	374TPTS

<u>Precambrian</u>

Granitic Gneiss	400GRCG
Granite	400GRNT
Schist	400SCST
Sedimentary Rocks	400SDMR

Appendix D: Non-Arizona Well Identification Systems

Well Numbering System

The local well identification (Local_Id) system for GWSI sites located in California, Colorado, Nevada, New Mexico, and Utah is based on the system of land subdivision used by the Bureau of Land Management. This system uses a surveyed base line and principal meridian from which townships and ranges are located. Townships are located north or south of the base line and ranges are located east or west of the principal meridian. Sections are designated 1 through 36 and are numbered in rows following a serpentine pattern beginning in the northeast corner of a township and ending in the southeast corner of the township. The method of locating sites within a section varies with each state and is described in detail below.

California Well Numbering System

The California well numbering system is based in the San Bernardino Baseline and Meridian. A GWSI site located in California in the *NW*1/4 of the *NE*1/4 of the *NE*1/4 of *Section* 35, *Township* 15 *South*, *Range* 23 *East*, would be identified as **15S/23E-35 Jb**. The number preceding the slash (/) is the township and the letter after the township (**N** or **S**) indicates its position north or south of the San Bernardino Baseline. The number after the slash is the range and the letter following the range (**E** or **W**) indicates its position east or west of the San Bernardino Meridian. The number following hyphen (-) is the section and the two letters following the section number identify the 40-acre and 10-acre subdivisions. The 40-acre subdivisions are identified using the same serpentine pattern used to identify section numbers in a township (Figure 1). Each 40-acre subdivision is assigned a capital letter *A* through *R*, omitting *I* and *O*. The 10-acre tracts are assigned the lowercase letters *a*, *b*, *c*, or *d* in a counter-clockwise direction in the same manner as the 10-acre subdivisions in the Arizona. In some cases a second lowercase letter is added if the 21/2 acre location is known.

Colorado Well Numbering System

The southwestern corner of Colorado, the part closest to Arizona, is part of the New Mexico Baseline and Meridian. The New Mexico Well Numbering System is used and described below.

New Mexico Well Numbering System

The New Mexico well numbering system is based on the New Mexico Principal Baseline and Meridian. The local identifications (Local_Id) based on this well numbering system consists of four parts, each separated by spaces (Figure 2). The first three parts are the township number, the range number, and the section number, respectively. The township number is followed by the letters **N** or **S** to indicate if the township lies north or south of the New Mexico Base Line. The range number is followed by the letters **E** or **W** to indicate if the range lies east or west of the New Mexico Principal Meridian. The letters **T** and **R**, for **T**ownship and **R**ange, are omitted from the GWSI local identification. Hence, a site located in *Township* 29 *South*, *Range* 22 *West*, *Section* 25 would be identified as **29S 22W 25**.

The fourth part of the well identification consists of three numbers that identify the 10-acre tract within the section in which the site is located. The method of numbering the tracts within the section is different that used in Arizona and is shown in Figure 2. The section is divided into four 160-acre quarters, numbered 1, 2, 3, and 4, using a normal reading order from left to right, for the northwest, northeast, southwest and southeast quarters, respectively. Each 160-acre quarter section is subdivided in the same manner to produce the second number, which defines a 40-acre quarter-quarter section. The 40-acre tract is divided in the same manner to produce the third number, which identifies the 10-acre quarter-quarter-quarter section tract. Thus a site in the *NE* 1/4 of the *SE* 1/4 of the *NE* 1/4 *of Section* 25, *Township* 29 *South*, *Range* 22 *West*, would be identified as **29S 22W 25 242**. If multiple sites are located within a 10-acre tract, consecutive letters starting with the letter *a* are added as a suffix, with *a* being the oldest known site.

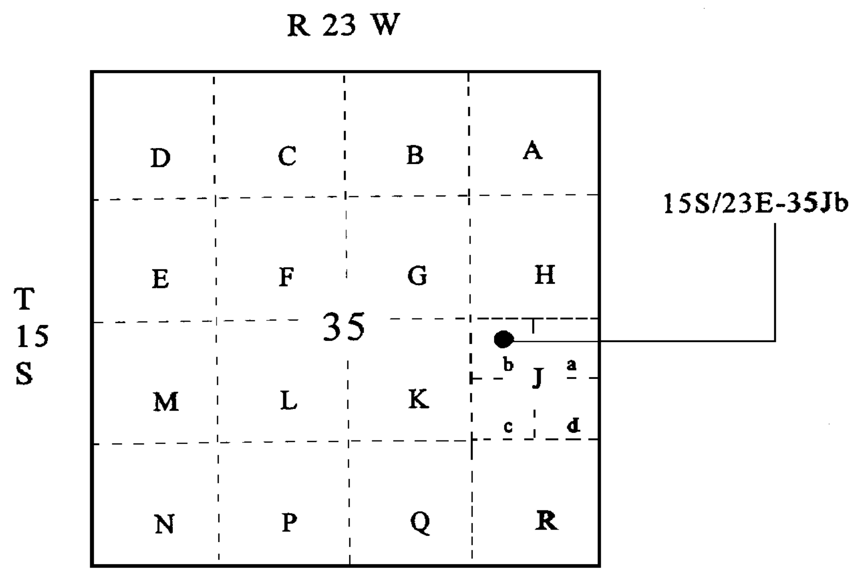


Figure 7. California Well Identification System

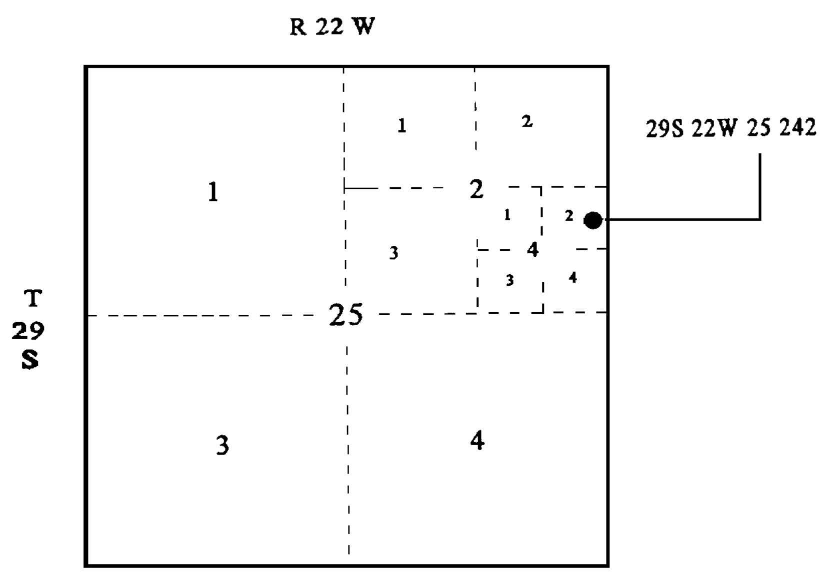


Figure 8. New Mexico Well Identification System

Figure 8. New Mexico Well Location System

Nevada Well Numbering System

GWSI local identifications in Nevada are determined using the Mount Diablo Base Line and Principal Meridian. The subdivision of sections is the same as in Arizona, except that Nevada sections are divided four times to specify the site location to within a 21/2 acre tract. A numerical suffix to denote multiple wells within a section is used just as in Arizona. Letters denoting the township or range location relative to the base line and meridain, **N** or **S** for the township**,** **E** or **W** for the range, precede the township and range numbers. A prefix of three numbers, **222**, is added to identify GWSI wells in Nevada. For example, a site located in the *SW* 1/4 of the *NW* 1/4 of the *SE* 1/4 of the *SE* 1/4 of *Section* 28, *Township* 13 *South*, *Range* 71 *East*, would be identified as **222 S13 E71 28DDBC**.

Utah Well Numbering System

In Utah GWSI site locations are based on the Salt Lake Base Line and Meridian. The method of land subdivision is the same as is used in Arizona. The base line and meridian are used to divide the state into four quadrants, **A**, **B**, **C**, and **D**, starting in the upper right corner (northeast) and moving counter-clockwise to the southeast quadrant. Sections are divided down to quarter-quarter-quarter sections in the same manner as in Arizona. For example, a site located in the *NW* 1/4 of the *NW* 1/4 of the *NW* 1/4 of *Section* 25, *Township* 43 *South*, *Range* 19 *West*, would be identified as **C-43-19 25BBB**.

The well-numbering system used in Utah is based on the Bureau of Land Management’s system of land subdivision. The well – numbering system is familiar to most water users in Utah, and the well number shows the location of the well by quadrant. township, range, section, and position within the section. Well number for most of the State are derived from the Salt Lake Base Line and the Salt Lake Meridian. Well numbers for wells located inside the area of the Utah Base Line and Meridian are designated in the same manner as those based on the Salt Lake Base Line and Meridian, with the addition of the “U” preceding the parentheses. The numbering system is illustrated below in Figure 9.

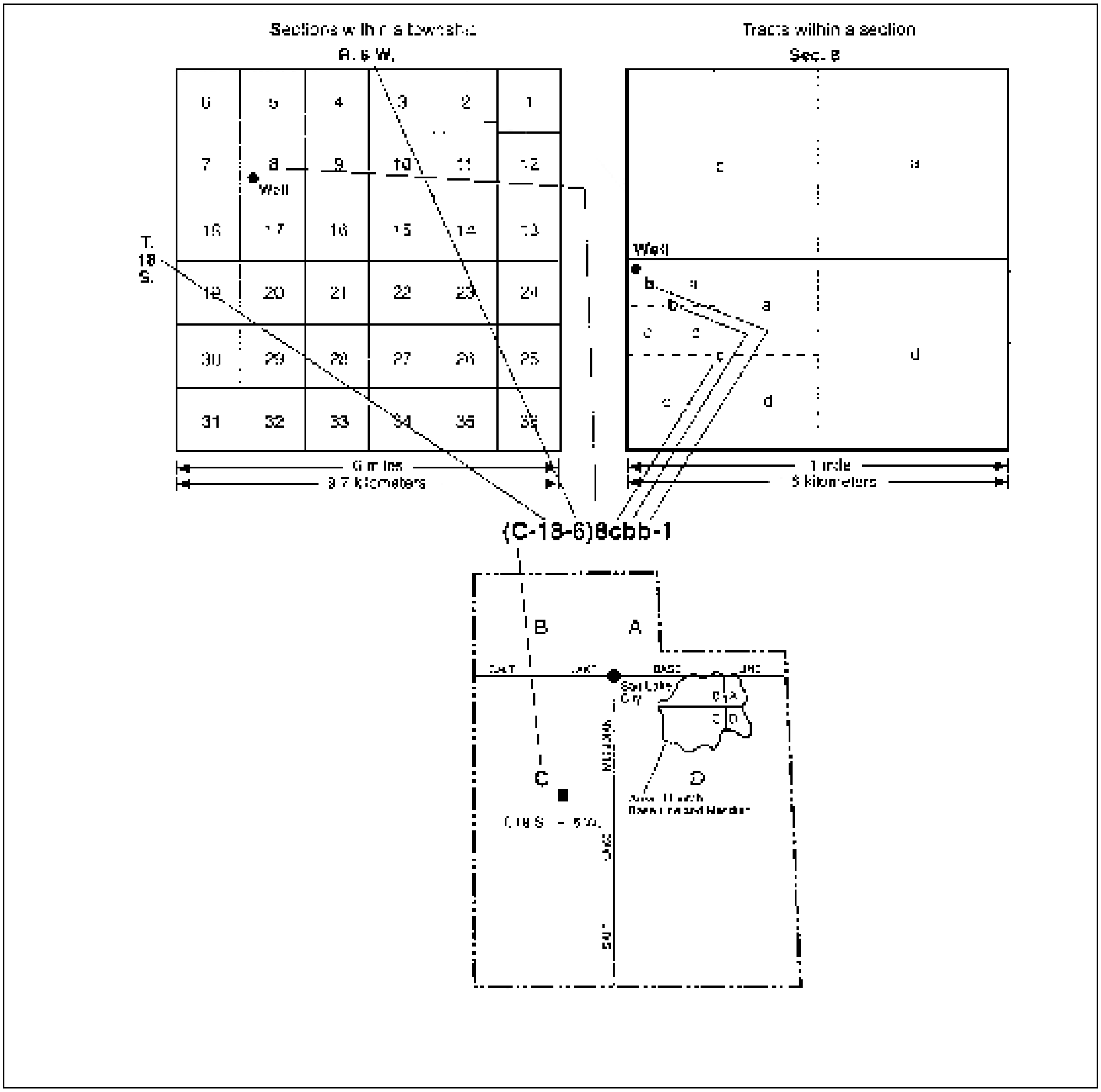


Figure 9. Utah Well Location System

ARIZONA DEPARTMENT OF WATER RESOURCES

PenTab Application User's Guide
Second Edition

Basic Data Unit
2008

1. Introduction

1.1 Purpose

The purpose of this document is to describe the Arizona Department of Water Resources' (ADWR's) PenTab application and its use in collecting groundwater site information.

2. Operational Overview

2.1 Logging On

The PenTab application can be accessed by double clicking on the PenTab icon. The user has the option of connecting to the local database or to the remote database (figure 1).

- To log on to the local database, check the Connect to Local Database box after entering a valid user name and password.
- To log on to the remote database, uncheck the Connect to Local Database box after entering a valid user name and password.

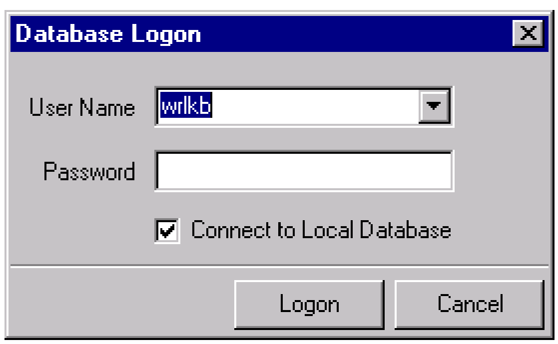
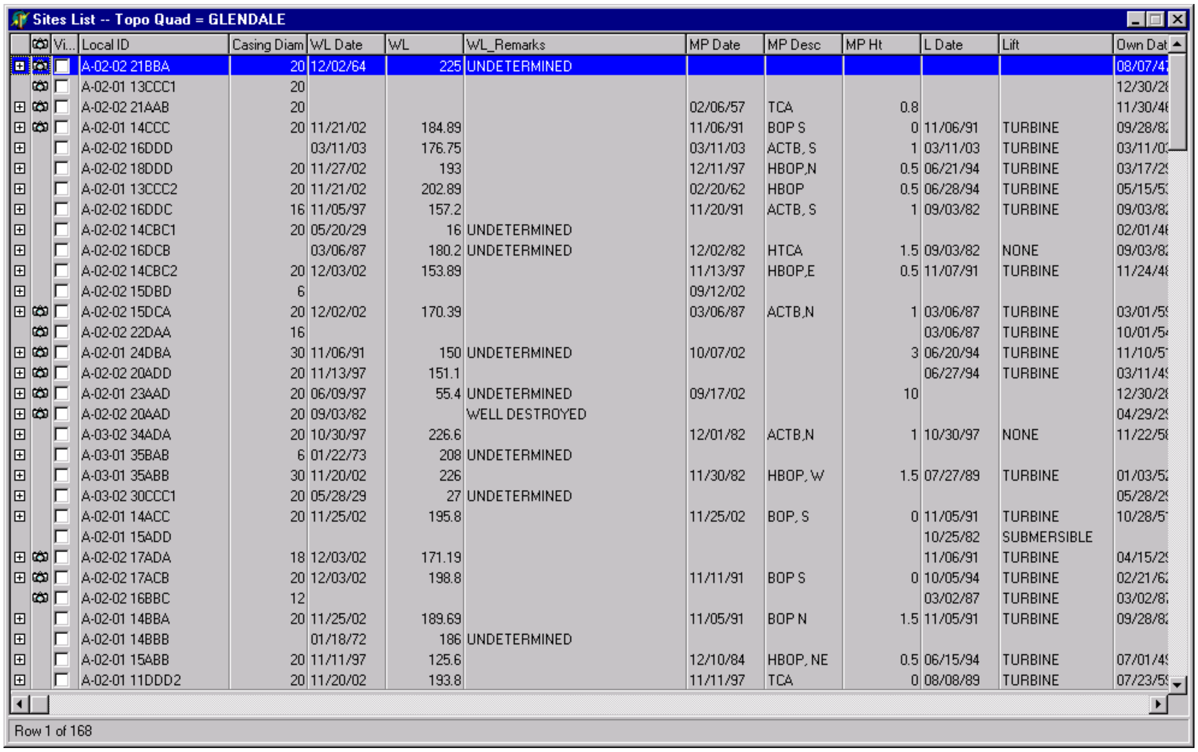


Figure 1

To complete the logon process, click the Logon button.

2.2 The Sites List

The Sites List window is the heart of the PenTab application (figure 2). It displays summary information and serves as the primary mechanism for selecting site records for site report generation, detail viewing, and editing.


Sites List -- Topo Quad = GLENDALE

Local ID	Casing Diam	WL Date	WL	WL_Remarks	MP Date	MP Desc	MP Ht	L Date	Lift	Own Dat
A-02-02 21BBA	20	12/02/64	225	UNDETERMINED						08/07/4
A-02-01 13CCC1	20									12/30/2
A-02-02 21AAB	20				02/06/57	TCA	0.8			11/30/4
A-02-01 14CCC	20	11/21/02	184.89		11/06/91	BOP S	0	11/06/91	TURBINE	09/28/8
A-02-02 16DDD		03/11/03	176.75		03/11/03	ACTB, S	1	03/11/03	TURBINE	03/11/0
A-02-02 18DDD	20	11/27/02	193		12/11/97	HBOP,N	0.5	06/21/94	TURBINE	03/17/2
A-02-01 13CCC2	20	11/21/02	202.89		02/20/62	HBOP	0.5	06/28/94	TURBINE	05/15/5
A-02-02 16DDC	16	11/05/97	157.2		11/20/91	ACTB, S	1	09/03/82	TURBINE	09/03/8
A-02-02 14CBC1	20	05/20/29	16	UNDETERMINED						02/01/4
A-02-02 16DCB		03/06/87	180.2	UNDETERMINED	12/02/82	HTCA	1.5	09/03/82	NONE	09/03/8
A-02-02 14CBC2	20	12/03/02	153.89		11/13/97	HBOP,E	0.5	11/07/91	TURBINE	11/24/4
A-02-02 15DBD	6				09/12/02					
A-02-02 15DCA	20	12/02/02	170.39		03/06/87	ACTB,N	1	03/06/87	TURBINE	03/01/5
A-02-02 22DAA	16							03/06/87	TURBINE	10/01/5
A-02-01 24DBA	30	11/06/91	150	UNDETERMINED	10/07/02		3	06/20/94	TURBINE	11/10/5
A-02-02 20ADD	20	11/13/97	151.1					06/27/94	TURBINE	03/11/4
A-02-01 23AAD	20	06/09/97	55.4	UNDETERMINED	09/17/02		10			12/30/2
A-02-02 20AAD	20	09/03/82		WELL DESTROYED						04/29/2
A-03-02 34ADA	20	10/30/97	226.6		12/01/82	ACTB,N	1	10/30/97	NONE	11/22/5
A-03-01 35BAB	6	01/22/73	208	UNDETERMINED						
A-03-01 35ABB	30	11/20/02	226		11/30/82	HBOP, W	1.5	07/27/89	TURBINE	01/03/5
A-03-02 30CCC1	20	05/28/29	27	UNDETERMINED						05/28/2
A-02-01 14ACC	20	11/25/02	195.8		11/25/02	BOP, S	0	11/05/91	TURBINE	10/28/5
A-02-01 15ADD								10/25/82	SUBMERSIBLE	
A-02-02 17ADA	18	12/03/02	171.19					11/06/91	TURBINE	04/15/2
A-02-02 17ACB	20	12/03/02	198.8		11/11/91	BOP S	0	10/05/94	TURBINE	02/21/6
A-02-02 16BBC	12							03/02/87	TURBINE	03/02/8
A-02-01 14BBA	20	11/25/02	189.69		11/05/91	BOP N	1.5	11/05/91	TURBINE	09/28/8
A-02-01 14BBB		01/18/72	186	UNDETERMINED						
A-02-01 15ABA	20	11/11/97	125.6		12/10/84	HBOP, NE	0.5	06/15/94	TURBINE	07/01/4
A-02-01 11DDD2	20	11/20/02	193.8		11/11/97	TCA	0	08/08/89	TURBINE	07/23/5

Row 1 of 168

Figure 2

The Sites List can be used to determine the date and water level of a site's most recent water level measurement, whether there is an image of the site available, current construction, and ownership information. It can even be used as a high-level planning tool during a data collection project – the user simply indicates whether a site has been visited anytime during a project and whether the data collection process is complete or incomplete and the current status is then reflected in the Sites List.

The Title Bar reflects the query criteria that was used to produce the list. For example, Figure 2 shows a list which was generated by querying for sites which are located in the Glendale topo quad.

2.2.1 Query Sites Tool

The Query Sites tool is used to create a Sites List (figure 3). The user may toggle the Query Sites tool on and off by clicking on the Query button (i.e., magnifying glass button), or by pressing F3.

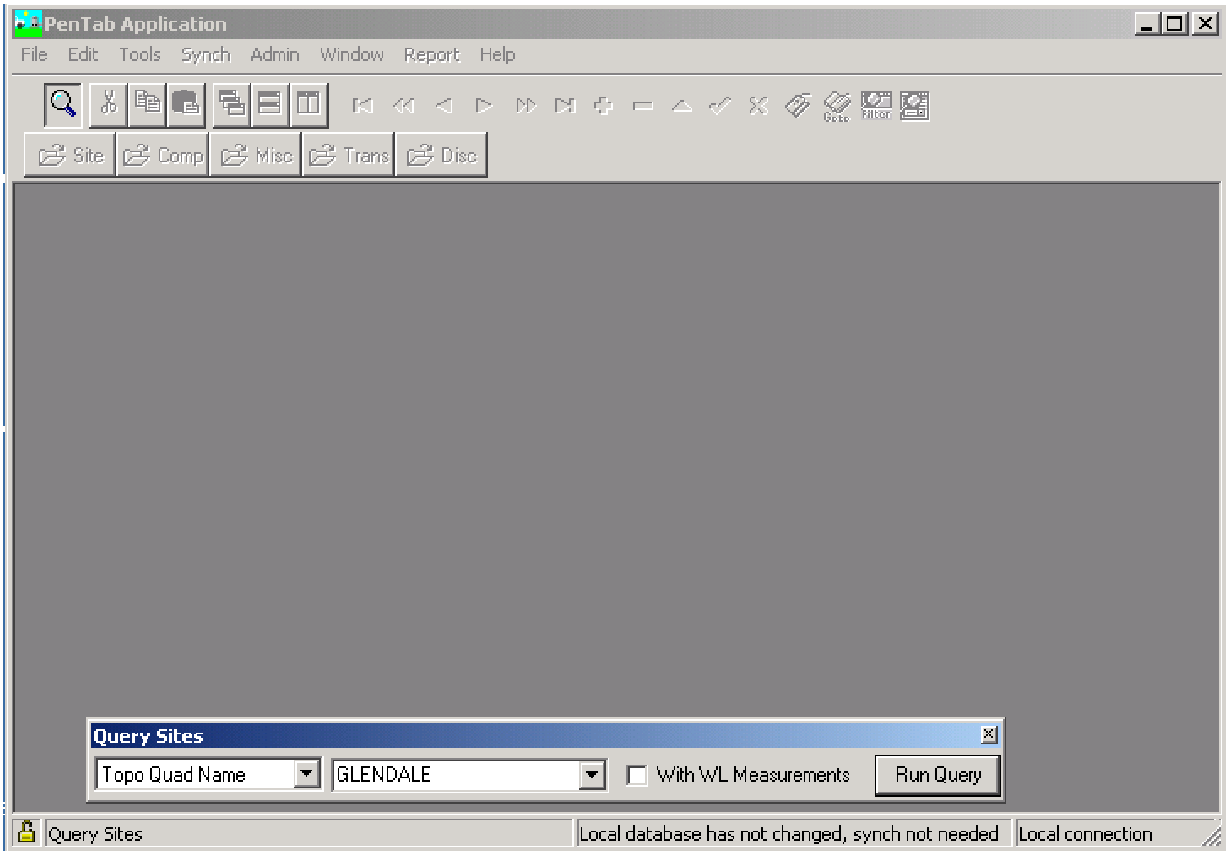


Figure 3

The query categories available for generating a Sites List are as follows:

- Well Registration Number
- Local ID
- Site ID
- Topo Quad Name
- ADWR Basin
- Sub-basin
- Index Line Book

To generate a Sites List, select a query category and a query value in the Query Sites window and then click on the Run Query button. For example, figure 3 illustrates the query criteria for generating a Sites List for the Topo Quad of Glendale.

The Query Sites tool may also be used to refine a query based on water level measurements for a given date range. Simply check the With WL Measurements checkbox and two to three new fields will be displayed. For example, figure 4 illustrates the criteria used to select all sites within the Glendale Topo Quad which have at least one water level measurement that has a measurement date between 01/01/00 and 09/09/02. When the Run Query button is clicked a Sites List is generated.

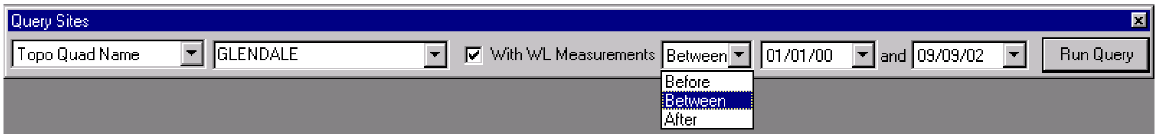


Figure 4

Another method for refining the query criteria using the Query Sites window is to use "%" as a wild card. This is useful when generating a Sites List using a partial well registration number, local ID, or site ID. For example, figure 5 shows the query criteria for selecting all sites located in quadrant A, township 3 and range 1.

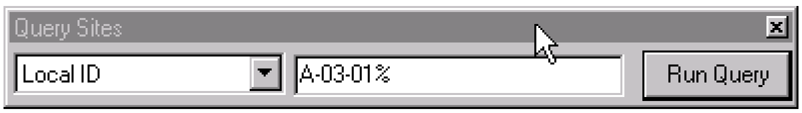


Figure 5

2.2.1.1 Specifying Dates Using the Pop-up Calendar

A pop-up calender can be used to enter the date (figure 6). To view the pop-up calendar in the Query Sites window, check the With WL Measurements box and click on the drop-down lookup list in the date field. The calendar opens with the current date highlighted. To select a different date, click on a day within the month being displayed, or use the right and left arrows to specify a different month, or click on the year and use the up or down arrows to specify a different year. Once the correct date is being displayed, click on it to return the value to the date field.

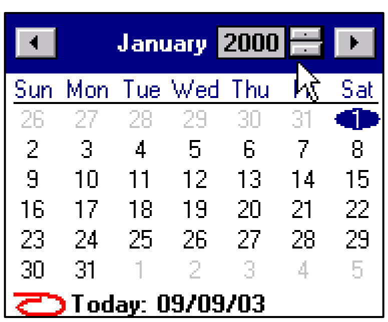


Figure 6

2.2.2 Sorting the Sites List

When the Sites List is first displayed, it is not in any particular sort order, but it can be sorted.

The Sites List may be sorted on the following columns:

- Visited
- Local ID
- Casing Diam
- WL Date
- WL
- MP Date
- MP Desc
- MP Ht
- L Date
- Own Date
- Owner
- Site ID
- Index Book
- Topo Quad Name
- Site Uses
- Water Uses
- Hole Depth
- Well Depth
- Well Registry ID
- ADWR Basin

To sort the Sites List based on one of these columns, simply click on the column header. Clicking on the column header one time will sort the entire list in ascending order. Clicking on the same column a second time will sort the entire list in descending order, and clicking on the same column a third time will return the list to the original, unsorted order. Figure 7 shows a Sites List which is sorted in ascending order based on the Local ID column; notice the small triangle displayed in the right-hand corner of the Local ID header indicating that the list is sorted in ascending order.

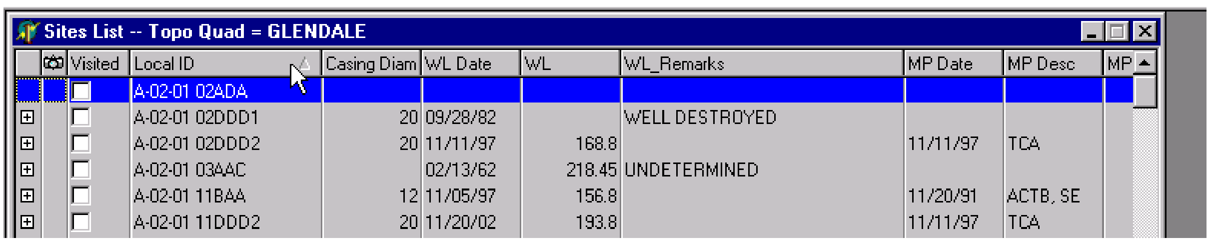


Figure 7

Figure 8 shows the same list sorted in descending order based on the Local ID column; notice that the small triangle in the right-hand corner of the Local ID header now indicates that the list is sorted in descending order.

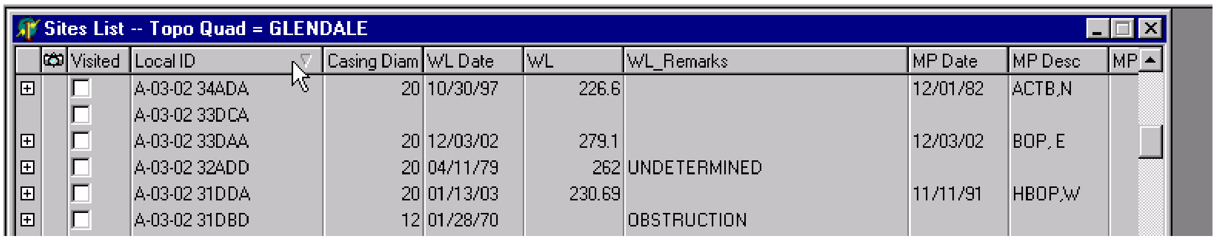


Figure 8

2.2.3 Generating a Site Report

To generate a site report, highlight a site from the Sites List and click on Report in the main menu (figure 9).

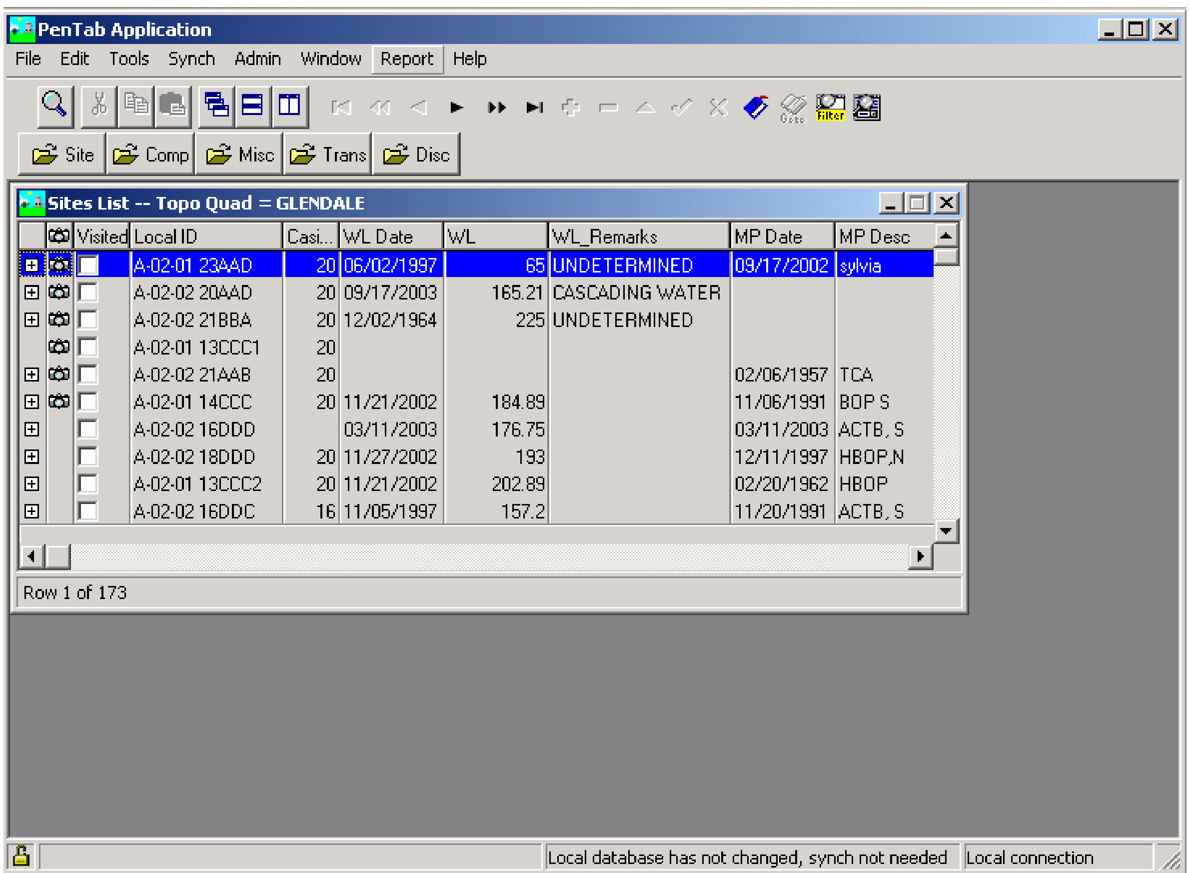


Figure 9

After clicking the Report menu item the Report Destination window appears, allowing the report to be output to a printer or the screen. Printer settings can be selected using the Printer Setup button. Clicking on the Print button will generate the report.

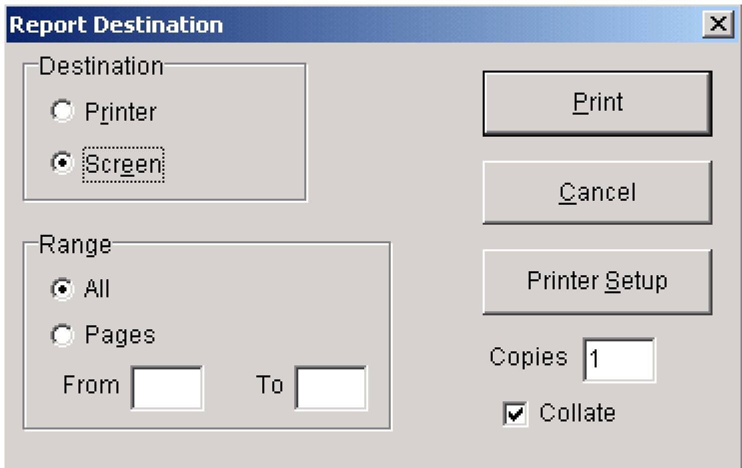


Figure 10

Figure 11 shows a report that was sent to the screen.

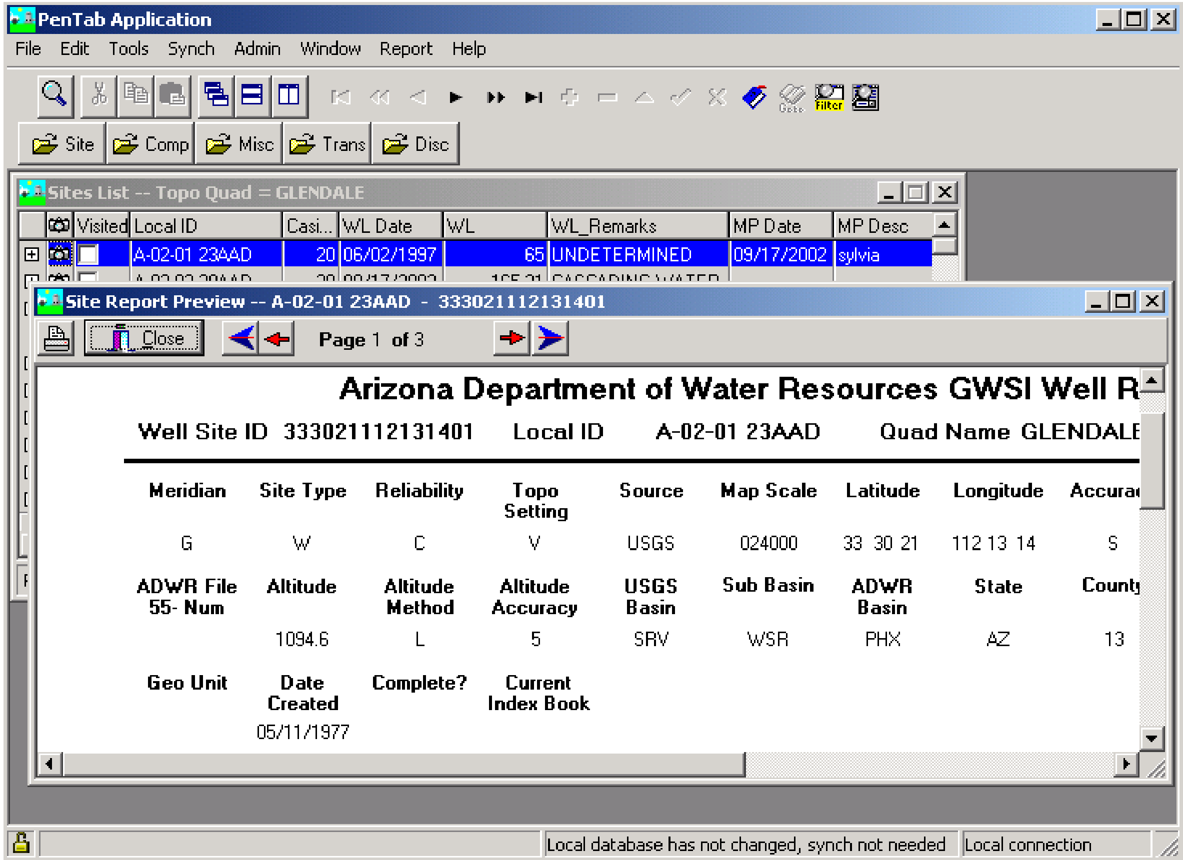


Figure 11

2.3 Detail Windows

To view site information, highlight a site record in the Sites List and click on one of the buttons in the Detail Windows Tool Bar (figure 12).

Figure 12

The Site button opens the Site Details window, which has the following tabs:

- Site Detail
- WWlevels
- WM points
- Lifts
- Owners
- Site Names
- Remarks
- Images
- Hydro Graph

The Comp button opens the Completion Details window, which has the following tabs:

- Well
- Bore Hole
- Casing
- Perforation

The Misc button opens the Miscellaneous Details window, which has the following tabs:

- Site Inventories
- Spring Names
- Wq Reports
- Well Logs

The Trans button opens the Transducer Details window, which has the following tabs:

- Levels
- Field Load
- Telemetry Load
- Hydro Graph

The Disc button opens the Discharge Details window, which has the following tabs:

- Flowing discharges
- Pumping Discharges

2.3.1 Site Details

The Site Details window is used to view, insert, delete, and edit information regarding the details of the site.

2.3.1.1 View Site Details

The Site Details window can be viewed by clicking on the Site button in the Detail Windows Tool Bar (figure 12) or by double clicking on a site record in the Sites List. Details about the site can be viewed by clicking on the tabs, including: Site Detail, WW Levels, WM Points, Lifts, Owners, Site Names, Remarks, Images, and Hydro Graph. Figure 13 shows the Site Detail tab selected.

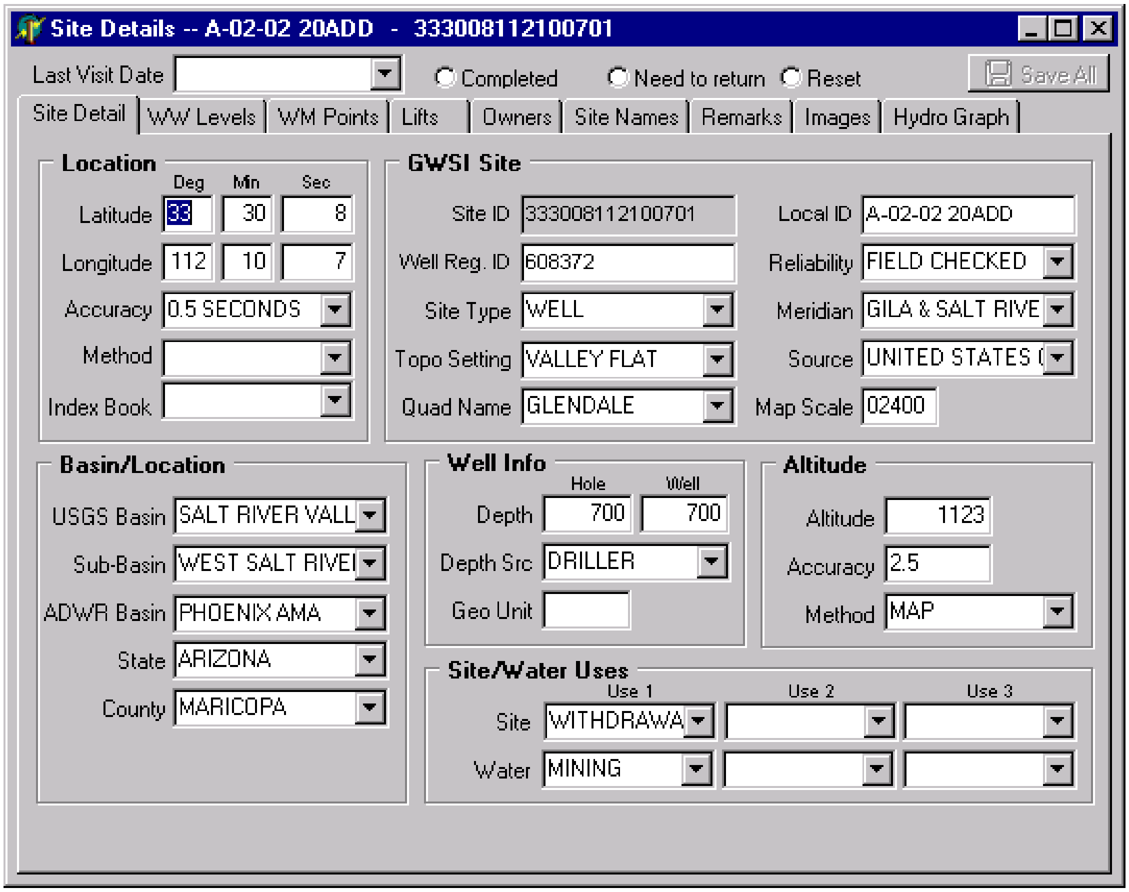


Figure 13

2.3.1.2 Insert a New Site

To insert a new site record, open the Site Details window for any site, click on the Site Detail tab, and click on the Insert new record button in the Navigator Bar (figure 14).

Figure 14

Once the Insert new record button is clicked, "New Site" appears in the title bar and the fields of the Site Detail tab are cleared and are ready for data entry (figure 15).

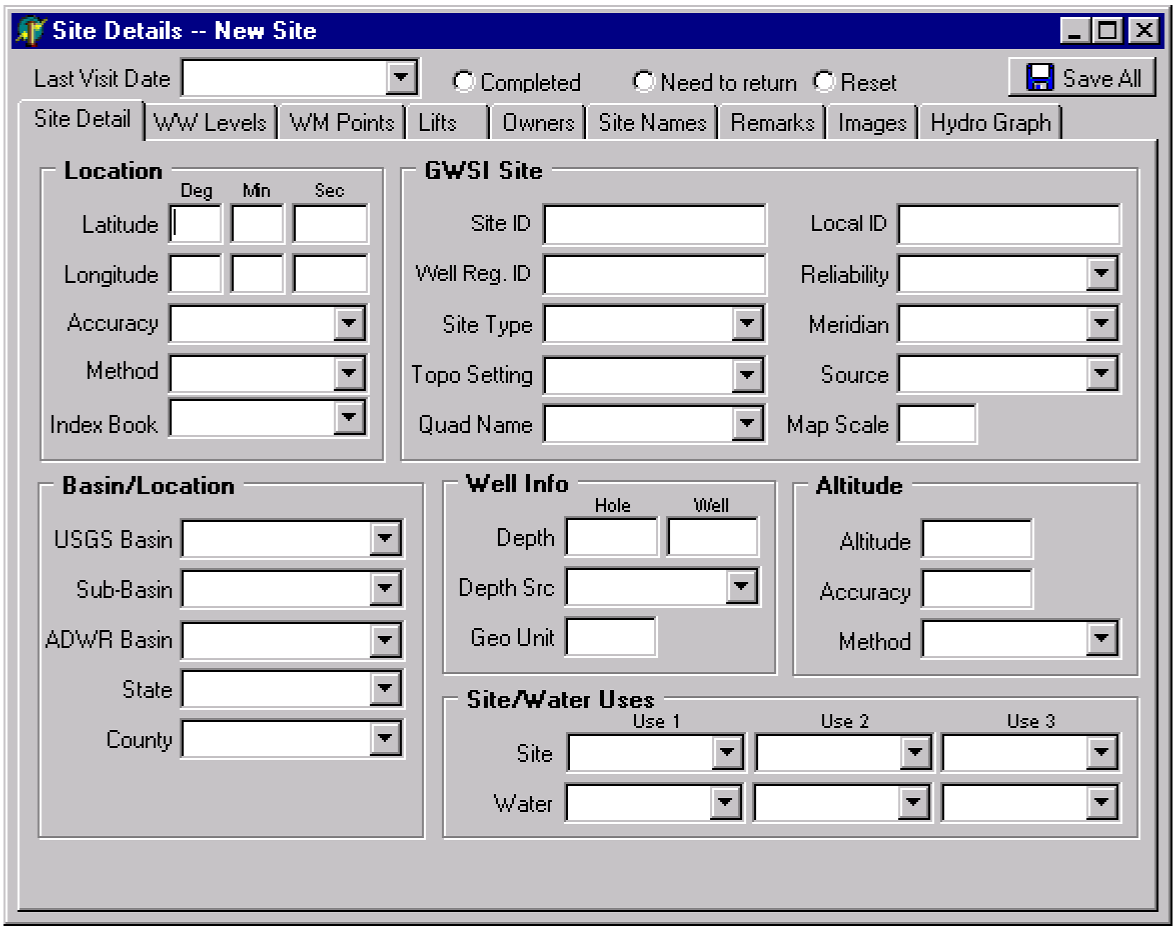


Figure 15

Once the new site information has been entered, it can be saved by clicking on the Save All button located in the upper right-hand corner of the Site Details window (figure 15). It is not necessary that the Save All button be clicked after a record is inserted, updated, or deleted; but it may be good practice when first learning to use the PenTab application.

When the Save All button is clicked, a confirmation screen appears (figure 16).

- Clicking on the yes button will permanently save the data.
- Clicking on the no button will lose all changes made since the last save.
- Clicking on the cancel button will keep the changes made in the window without permanently saving the changes to the database.

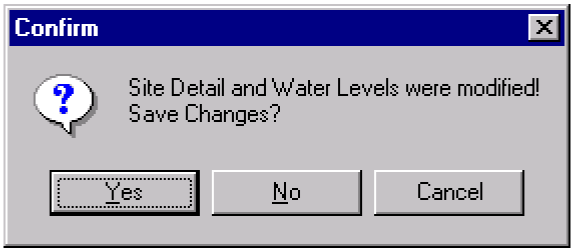


Figure 16

If the site number being inserted already exists in the database, clicking yes to save the changes will cause the Insert conflict window to be displayed (figure 17); it displays a list of similar sites, the current value, and a recommended change. Clicking on the Try Again button will move the new site ID to the Site Details window.

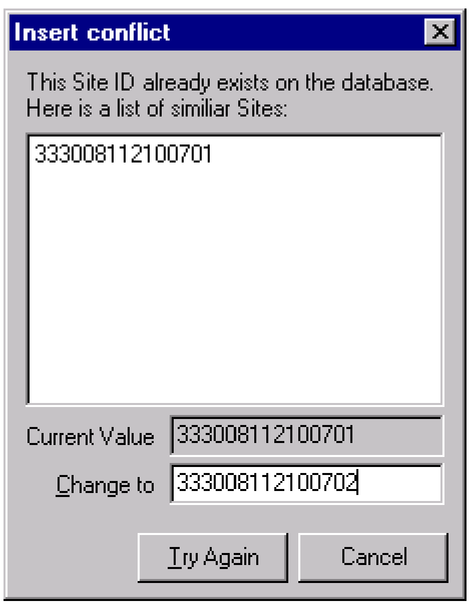


Figure 17

2.3.1.3 Edit an Existing Site

There are two modes of editing: Auto Edit and Manual Edit. The default mode is Manual Edit. When Auto Edit is on, changes can be typed immediately. When Auto Edit is off, it is necessary to click on the Edit current record button on the Navigator Bar (Figure 18) before changes can be typed. Edits are made by placing the cursor in an editable field and typing. Once the data has been edited, click on the Save All button.

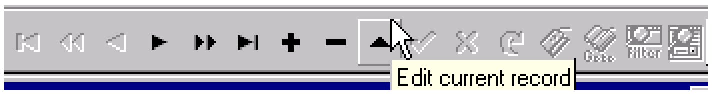


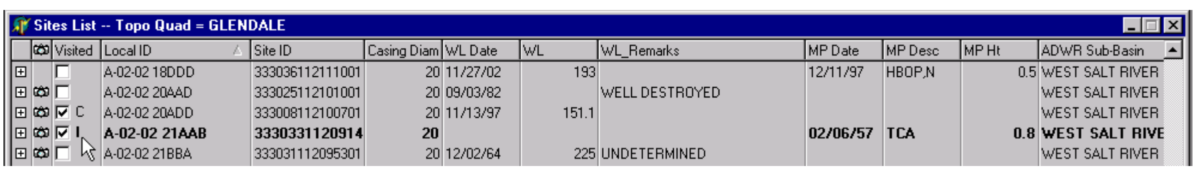
Figure 18

To change edit modes, go to the Main Menu and click on Tools → Preferences → Auto Edit. The Auto Edit menu item acts as a toggle switch – simply click on the menu item to turn Auto Edit on or off.

2.3.1.3.1 Update the Site Visited Flag

The Site Details window includes information for capturing the status of the field visit for a given site; this is just below the title bar. The data collection process at a given site may be marked as Completed or as Needs to return. The Last Visit Date can also be entered field.

Once a radio button has been selected in the Site Details screen, the Visited column in the Sites List is updated. Figure 20 shows two sites which have been visited. Site A-02-02 20ADD was set to Completed as designated by the "C" in the Visited column, and site A-02-02 21AAB was set to Need to Return (i.e., incomplete). In addition to displaying an "I" in the Visited column, sites which have the Need to Return flag set appear in bold font in the Sites List.


Sites List -- Topo Quad = GLENDALE

Visited	Local ID	Site ID	Casing Diam	WL Date	WL	WL_Remarks	MP Date	MP Desc	MP Ht	ADWR Sub-Basin
	A-02-02 18DDD	333036112111001	20	11/27/02	193		12/11/97	HBOP,N	0.5	WEST SALT RIVER
	A-02-02 20AAD	333025112101001	20	09/03/82		WELL DESTROYED				WEST SALT RIVER
C	A-02-02 20ADD	333008112100701	20	11/13/97	151.1					WEST SALT RIVER
I	**A-02-02 21AAB**	**3330331120914**	**20**				**02/06/57**	**TCA**	**0.8**	**WEST SALT RIVE**
	A-02-02 21BBA	333031112095301	20	12/02/64	225	UNDETERMINED				WEST SALT RIVER

Figure 19

2.3.1.4 Delete an Existing Site

To delete a site, open the Site Details window and click on the Delete current record button (-) in the Navigator Bar (figure 20). A message box will be displayed to verify the delete request (figure 21). If the Yes button is clicked, the site record and all records which are associated with the site will be deleted. If the No button is clicked, the delete operation is canceled.

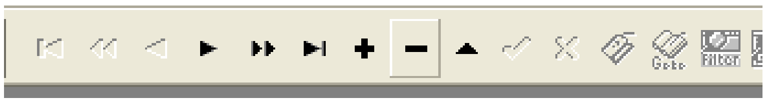


Figure 20

Figure 21

2.3.1.5 View Manual Water Level Measurements

Water level measurements that were collected manually can be viewed by clicking on the WW Levels tab (figure 22).

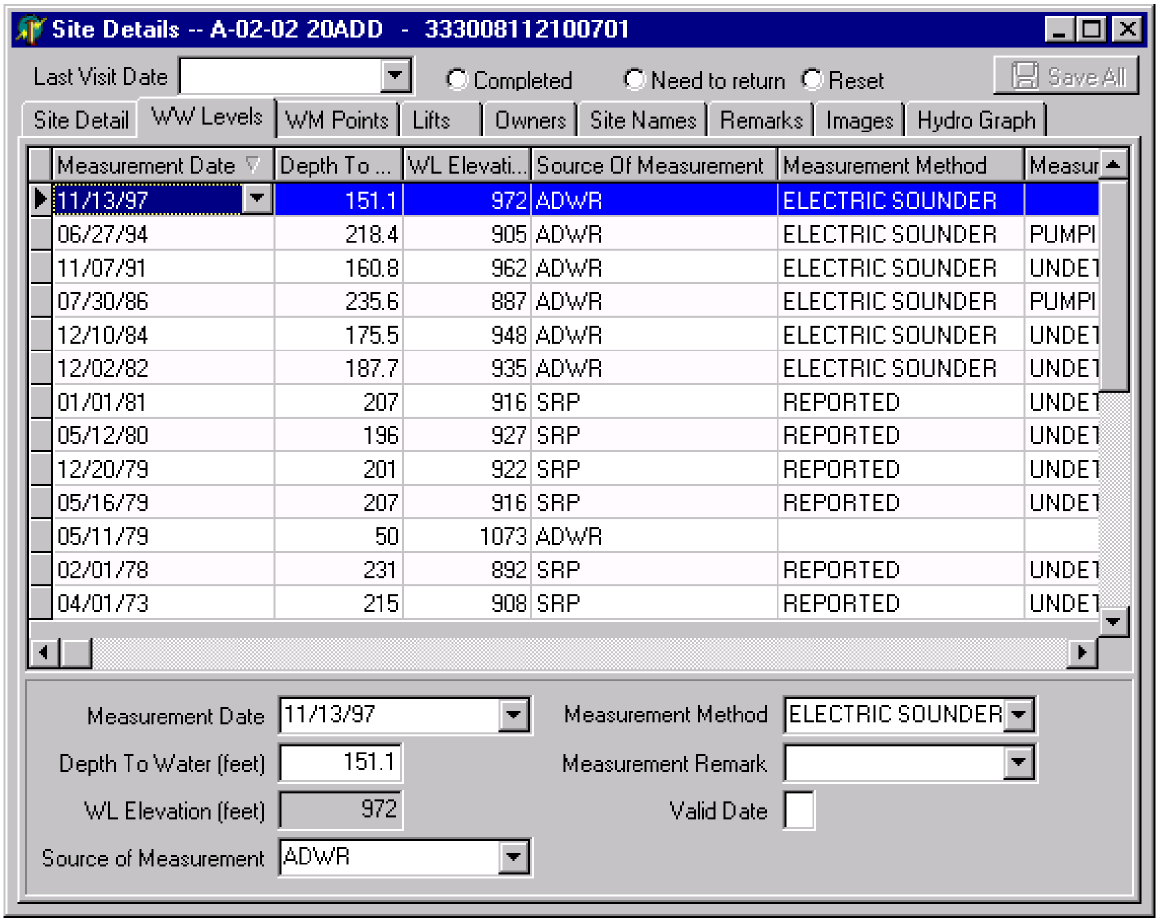


Figure 22

2.3.1.6 Insert a New Manual Water Level Measurement

To insert a new water level measurement, first click on the WW Levels tab (figure 22) and then click on the Insert new record button in the Navigator Bar (figure 23). After the Insert button is clicked, each field on the water level measurement tab will be cleared and will be ready to accept new data. A new water level measurement can be inserted by typing directly into the data grid or by typing in the data fields at the bottom of the window (figure 22).

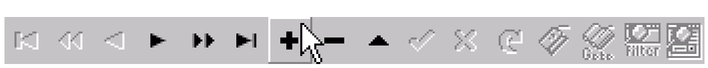


Figure 23

Once all of the data have been entered, click on the Save All button located in the upper right-hand corner of the screen (figure 22).

2.3.1.7 Edit a Manual Water Level Measurement

Manual water level measurement can be edited in the same manner as site information (see section 2.3.1.3).

2.3.1.8 Delete a Manual Water Level Measurement

Manual water level measurements can be deleted in the same manner as site information (see section 2.3.1.4).

2.3.1.9 View Images

The Images tab is used for site images that are in a JPEG (.jpg) file format (figure 24).

Figure 24

Multiple images of a site may be stored and can be viewed by clicking on the Move to Next Record button in the Navigator Bar (figure 25).

Figure 25

2.3.1.10 Insert Images

To insert a new image, first click on the Images tab in the Site Details window and then click on the Insert new record button in the Navigator bar. The Load JPEG Image window will appear (figure 26); navigate to the folder containing the image, highlight the file, and then click on the Open button.

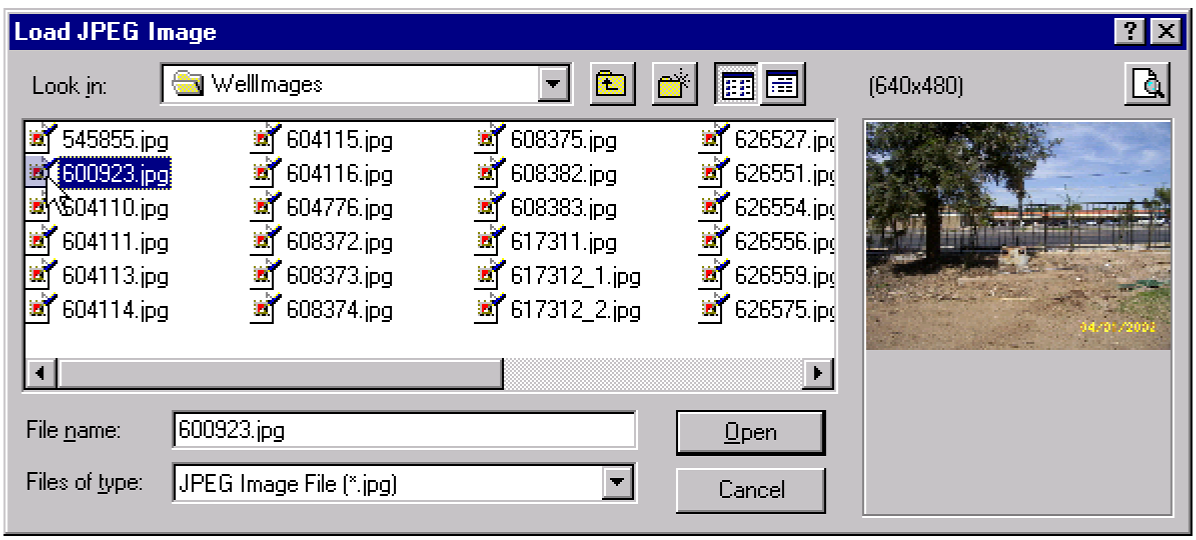


Figure 26

Click on the Save All button to save the new image to the database (figure 27).

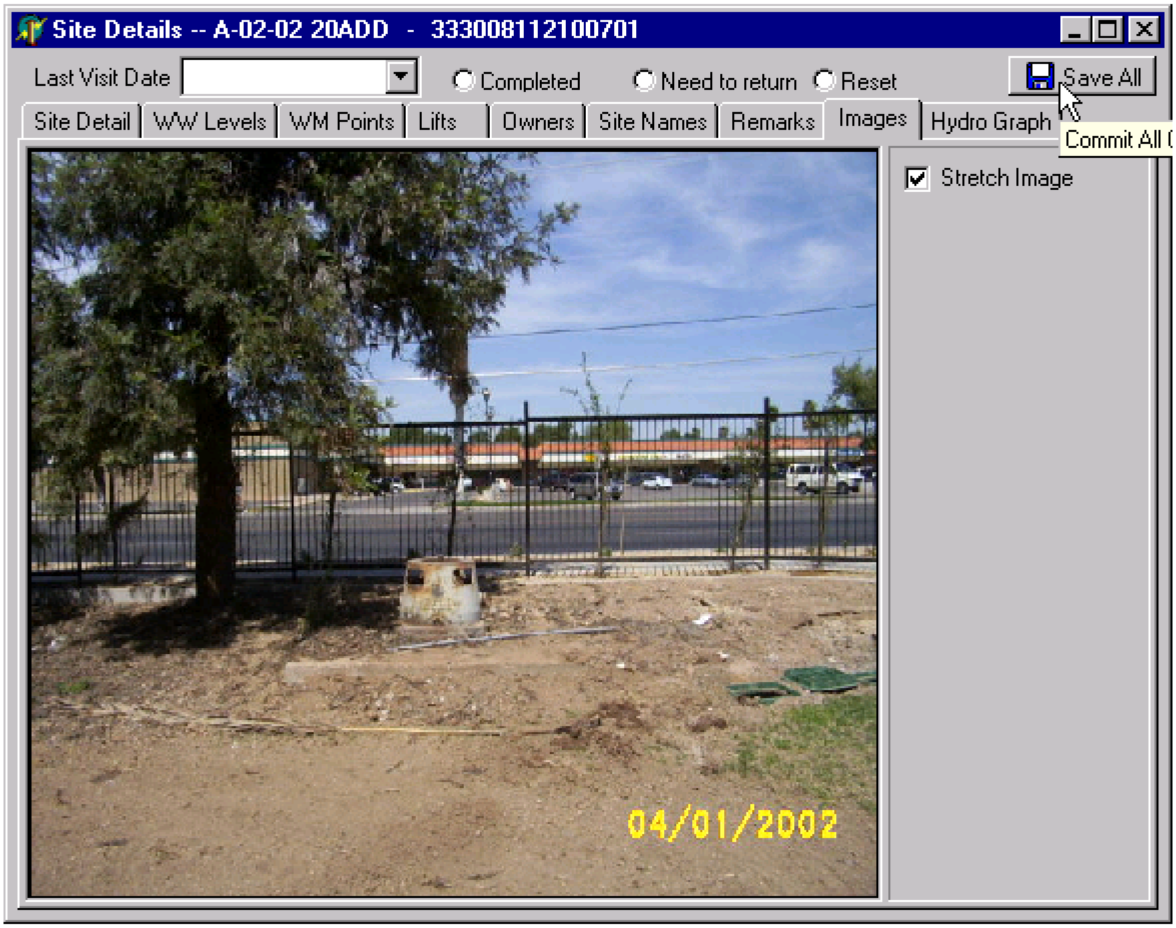


Figure 27

2.3.1.11 Delete Images

Images can be deleted in the same manner as site information (see section 2.3.1.4).

2.3.1.12 View a Hydrograph

The Hydro Graph tab of the Site Details Window displays the manual water level measurements (figure 28).

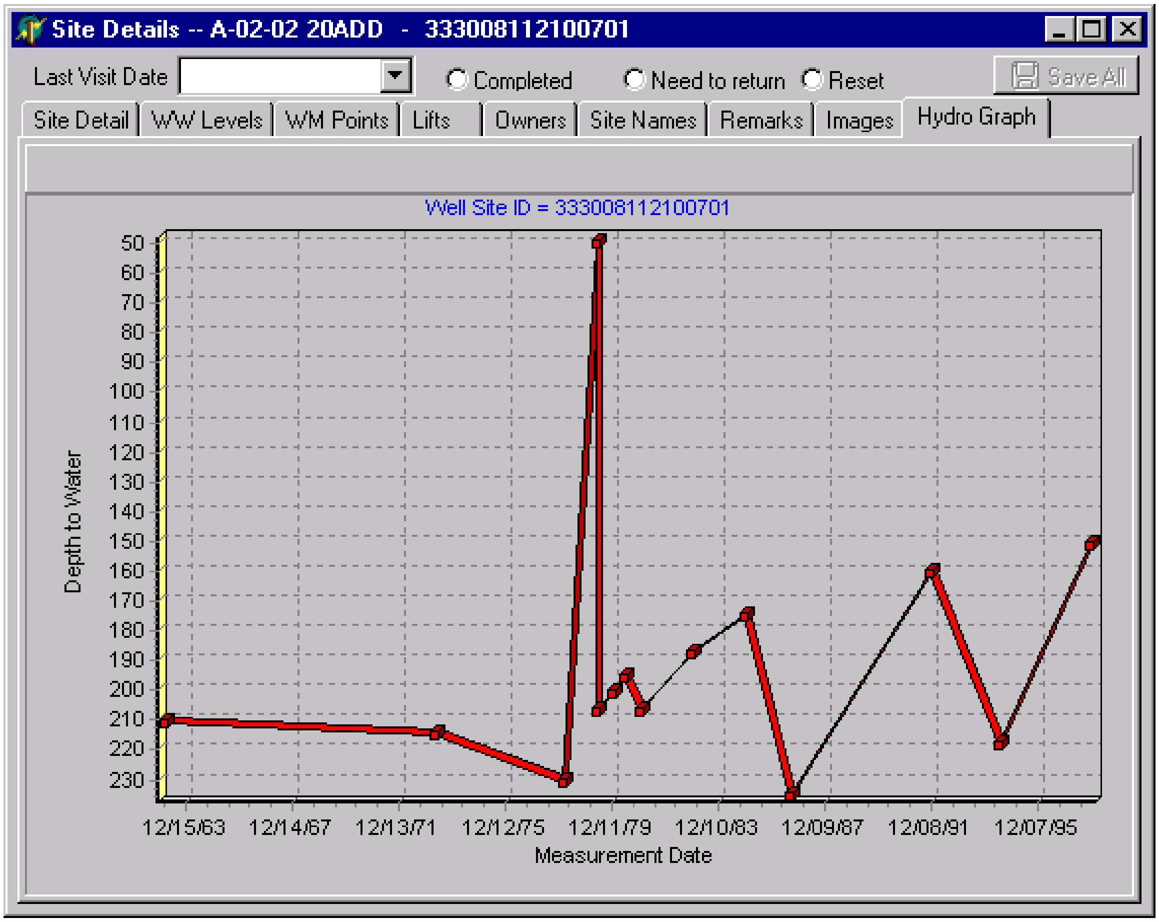


Figure 28

To zoom in on a hydrograph; place the cursor above and to the left of the area of interest, click and hold the left mouse button, and drag the cursor over the area of interest. A white rectangle will be drawn on the screen and forms the zoom boundaries (figure 29).

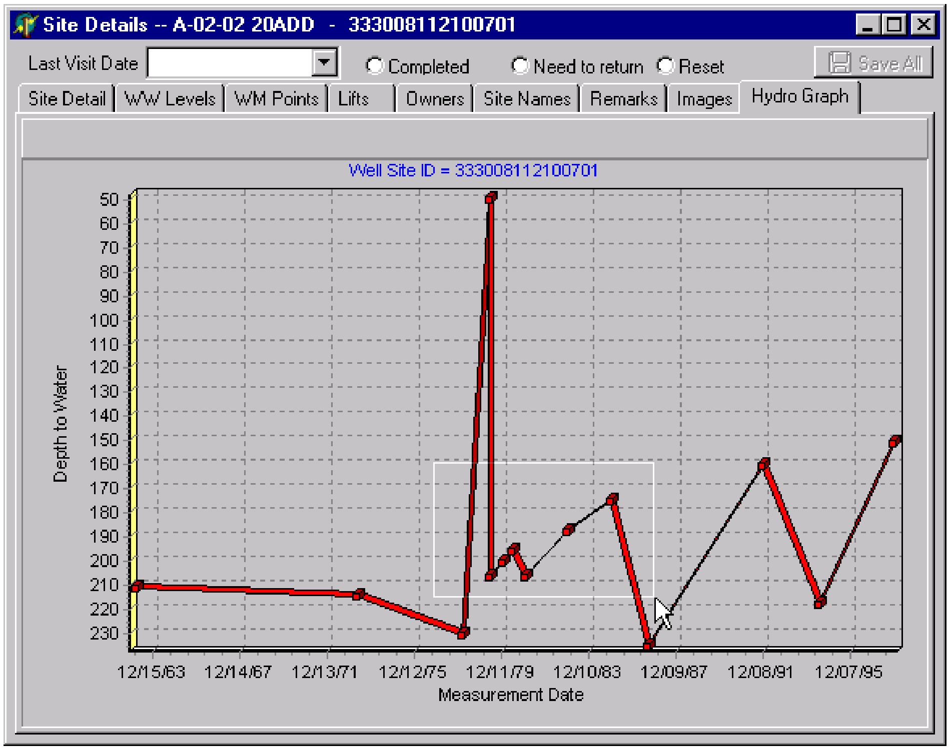


Figure 29

Upon releasing the left mouse button, the area within the white rectangle will be enlarged (figure 30).

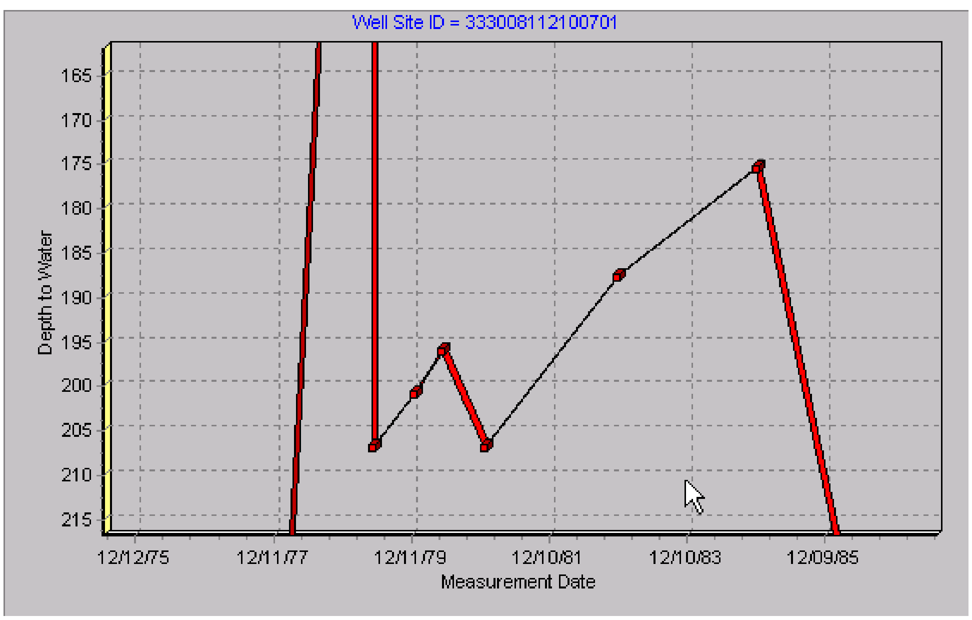


Figure 30

To return to the full extent of the hydrograph; place the cursor anywhere within the screen, click and hold the left mouse button, drag the cursor to the left, and release.

2.3.2 Completion Details

The Completion Details window is used to view, insert, delete, and edit information regarding the details of the well completion. Completion Details can be viewed by clicking on the Comp button in the Detail Windows Tool Bar (figure 12). The tabs in this window include: Well, Bore Hole, Casing, and Perforation. Completion Details can be inserted, edited, and deleted in the same manner as Site Details (see sections 2.3.1.2, 2.3.1.3, and 2.3.1.4).

2.3.3 Miscellaneous Details

The Miscellaneous Details window is used to view, insert, delete, and edit information regarding miscellaneous details of the site. Miscellaneous Details can be viewed by clicking on the Misc button in the Detail Windows Tool Bar (figure 12). The tabs in this window include: Site Inventories, Spring Names, Wq Reports, and Well Logs. Miscellaneous Details can be inserted, edited, and deleted in the same manner as Site Details (see sections 2.3.1.2, 2.3.1.3, and 2.3.1.4).

2.3.4 Automated Monitoring Details

The Transducer Details window is used to view, insert, delete, and edit information regarding automated monitoring data. This includes pressure transducers and shaft encoders.

2.3.4.1 View Transducer Details

The Transducer Details window can be viewed by clicking on the Trans button in the Detail Windows Tool Bar (figure 12). When the Trans button is clicked, a window titled Confirm pops up with the message, “Do you want to see all the Transducer records? If so, it may take a long time for all the records to load.” Click on the yes button to view the transducer data; 10 seconds or more may pass before the data is visible. The tabs in this window include: Levels, Field Load, Telemetry Load, and Hydro Graph (figure 31). When connected to the local database, only the Levels tab can be viewed from the Transducer Details Window and only the most recent record is viewable.

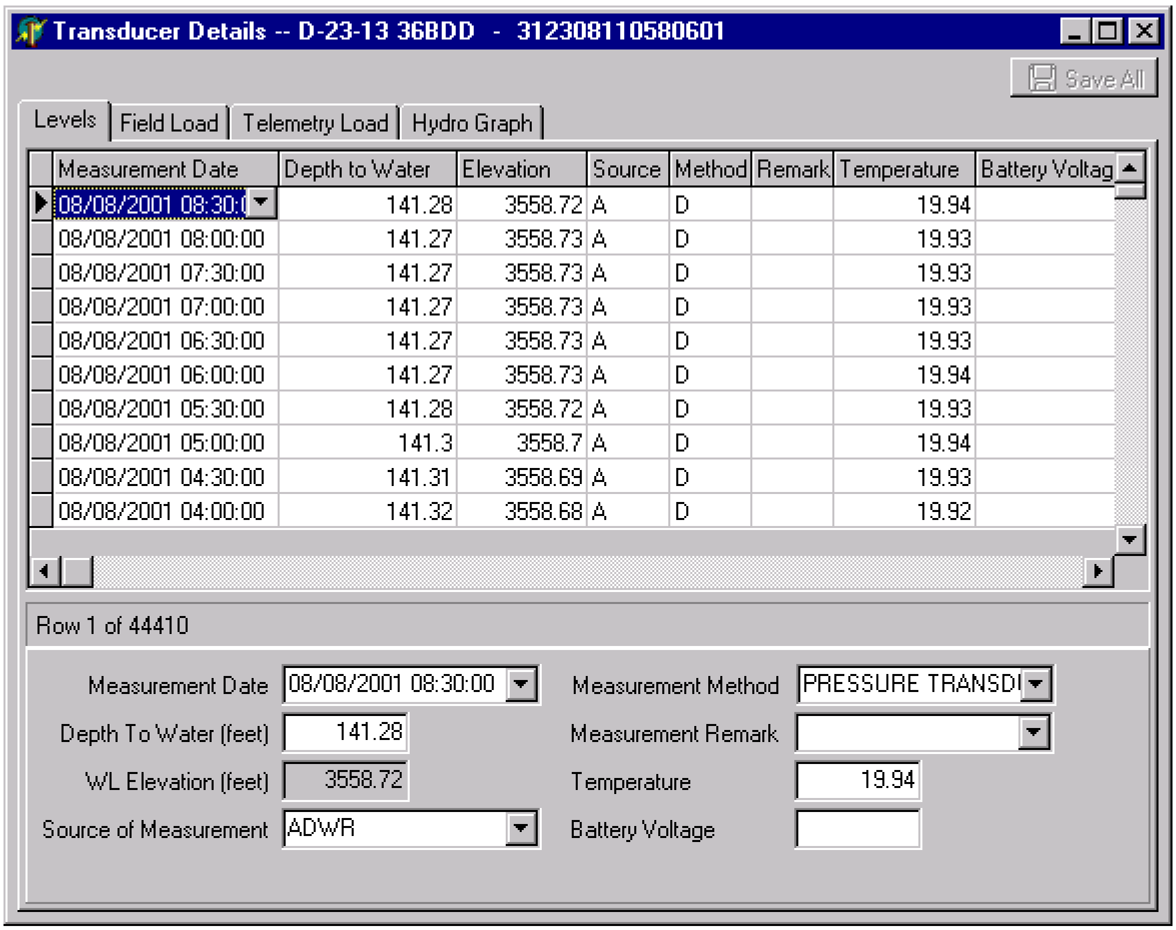


Figure 31

The columns of the tabular data seen from the Levels tab are Measurement Date, Depth to Water, Elevation, Source, Method, Remark, Temperature, and Battery Voltage (figure 31).

Measurement Date includes the time and is in Mountain Standard Time. Presently, all ADWR automated monitoring measurements are recorded in 6 hour increments.

Depth to Water is recorded in units of feet and typically should have a resolution of 0.01 foot. Water level changes of more than 1 foot in a 6 hour interval are rare, and when changes larger than this are observed the possibility that the automated sensor is malfunctioning should be carefully considered.

Elevation is the elevation of the water level and is in units of feet.

The Source of the measurement typically will be ADWR.

The Method of measurement is pressure transducer or shaft encoder.

Temperature is measured by the pressure transducers – not by the shaft encoders – and is recorded in units of Celsius. The recorded resolution typically is 0.1 C. Temperature rarely varies by more than 0.1 C in a monitoring well within a 6 hour interval, so viewing the recorded temperature variations can be helpful in detecting data from malfunctioning pressure transducers.

The battery voltage is in units of Volts and typically has a resolution of 0.1 V. The voltage should be recorded for all automated monitoring measurements. Presently, 12 Volt batteries are utilized at each automated monitoring site. Almost all automated monitoring sites are presently equipped with a solar panel and voltage regulator. Therefore, typical battery voltages will be about 11.0 to 14.5 volts; when the voltage is outside of this range the quality of the measurements should be carefully considered. Some of the pressure transducers originally operated on a 7 volt battery.

The hydrograph can be viewed by clicking on the Hydro Graph tab. The hydrograph of the automated data can be zoomed in on in the same manner as the manual hydrographs (see section 2.3.1.12). Spikes or offsets in the data of a foot or more are often erroneous data and should be carefully reviewed.

2.3.4.2 Load Automated Monitoring Measurements

Automated monitoring measurements may be loaded by users with the necessary system privilege. This privilege can be approved by the Basic Data Unit Supervisor or the Field Services Section Manager.

Files to be loaded need to have a .csv extension. The naming convention for the files is the two letter site code followed by the last 2 digits of the year, two digits for the month, and 2 digits for the day; for example file AE070622.csv was collected at site AE on June 22, 2007. Three types of data files may exist: a file from an H-500XL data logger and H-310 pressure transducer (figure 32), a file from an H-500XL data logger and H-330 shaft encoder (figure 33), and a file from a DH-21 pressure transducer/data logger (figure 34). Notice that there is no header information in figures 32 and 33; it is necessary to remove header information from H-500XL files before they can be successfully loaded. DH-21 files (figure 34), however, have header information and must be retained to be successfully loaded. Data from a DH-21 MUST be saved in Excel before loading.

12/06/06 00:00:00	232.82	24.1	12.6	1
12/06/06 06:00:00	232.69	24.1	12.5	1
12/06/06 12:00:00	232.60	24.1	13.5	1
12/06/06 18:00:00	232.51	24.1	12.9	1

Figure 32

In figure 32, the first column is the date in MM/DD/YY, the second column is Mountain Standard Time in HH:MM:SS, the third column is the depth to water in feet, the fourth column is temperature in Celsius, the fifth column is the battery voltage in volts, and the sixth column is the analog ID. Starting in February 2008, the analog ID was discontinued and replaced by PSI.

08/08/06 12:00:00	241.41	0	13.8	0	39
08/08/06 18:00:00	241.39	0	13.1	0	32
08/09/06 00:00:00	241.38	0	12.8	0	34
08/09/06 06:00:00	241.38	0	12.8	0	34

Figure 33

In figure 33, the first column is the date in MM/DD/YY, the second column is Mountain Standard Time in HH:MM:SS, the third column is depth to water in feet, the fourth column is set to 0, the fifth column is the battery voltage in volts, the sixth column is set to 0, and the seventh column is unknown.

```
WaterLOG Logging Module (All data extracted)
Serial Number : 01650
Extracted     : 10:40:57 03/01/07
Logger Started: 18:00:00 08/29/06
Logging Rate #1 : 06:00:00, Samples :    0
Logging Rate #2 : 06:00:00, Samples :    0
Logging Rate #3 : 06:00:00, Samples :    0
Logging Rate #4 : 06:00:00, Samples :    0
Logging Rate #5 : 06:00:00, Samples :    0
Logging Rate #6 : 06:00:00 (final)
User Notes
 WaterLOG Down Hole Data Sensor/Logger
                From
    Design Analysis Associates, Inc.
   Logan, Utah  84321  (801) 753-2212
Delta Log =           0
Hyper Log =           0
Hyper Divisor =   1

Coefficients  y = b0 + b1*x

Pressure,    b0 =       344.71 ,b1 =      -2.3067 ,Units = Feet
Temperature, b0 =            0 ,b1 =            1 ,Units = Deg C

Date       "Time"     "Day" "Pr(Feet   )" "Tmp(Deg C  )" "Batt. Voltage"
08/29/2006 "18:00:00"  241                      322.1976     19.68     13.5
08/30/2006 "00:00:00"  242                      322.2774     19.66     12.1
08/30/2006 "06:00:00"  242                      322.2948     19.66       12
08/30/2006 "12:00:00"  242                       322.264     19.65     13.4
```

Figure 34

To load the data, place the file on the L drive in the LOADFIELD folder; and from the Transducer Details window, click on the Field Load tab (figure 35). The file(s) to be loaded for the site are listed in the window on the right. Highlight the file to be loaded and enter the date the data was collected. The box "Measure Point If Not 0 (Surface level) can be used if the depth to water measurements are not already relative to land surface. The data source will typically be ADWR. Finally, click on the Load Data button.

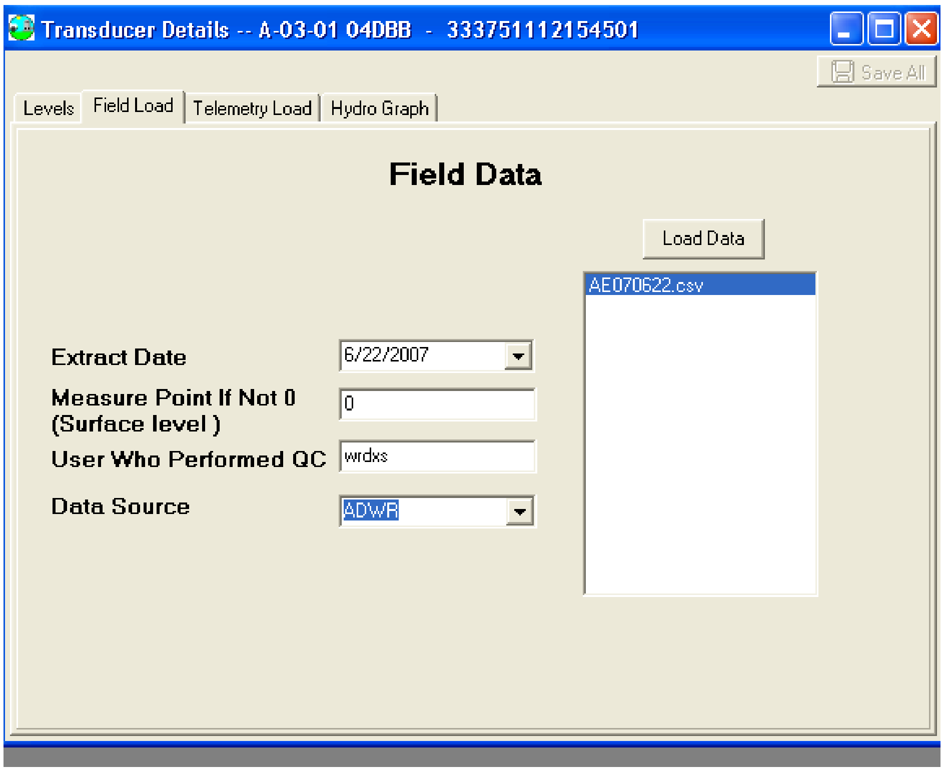


Figure 35

If the data is successfully loaded, a message will appear (figure 36) and the file will be moved to the LOADED folder.

2.3.4.3 Delete a Single Automated Monitoring Record

Single records of automated monitoring sites can be deleted by users with the necessary system privilege. This privilege can be granted by the Transducer Unit Supervisor or the Water Resources Investigations Section Manager. To delete a single record, click anywhere on the row of data to be deleted and then click on the Delete current record button (-) in the Navigator Bar (figure 36). A confirmation window will pop up (figure 37). Clicking on OK will delete the single row of data. Clicking on Cancel will cancel the action.

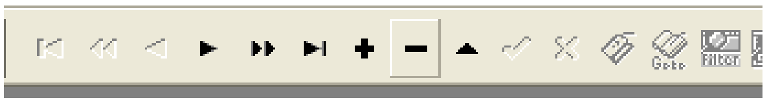


Figure 36

Figure 37

2.3.4.4 Delete a Batch of Transducer Records

An entire batch of automated monitoring data can be deleted by users with the necessary system privilege. This privilege is assigned by ITD and can be granted by the Transducer Unit Supervisor or the Water Resources Investigations Section Manager.

To delete an entire batch of data, it is necessary to determine the site ID, the parameter ID of the data to be deleted, and the extract date. The parameter ID is a unique identifier that is stored in the GWSI_TRANSDUCER_PARAMETERS table. This table can be viewed from the Access transducer database or the Access monitoring database; the site ID is "WELL_SITE_ID," the parameter ID is "ID," and the extract date is the most recent date of the batch of data to be removed.

The Remove Transducer Data window (figure 38) can be accessed by going to the Main Menu and clicking on Admin → Remove Transducer Load.

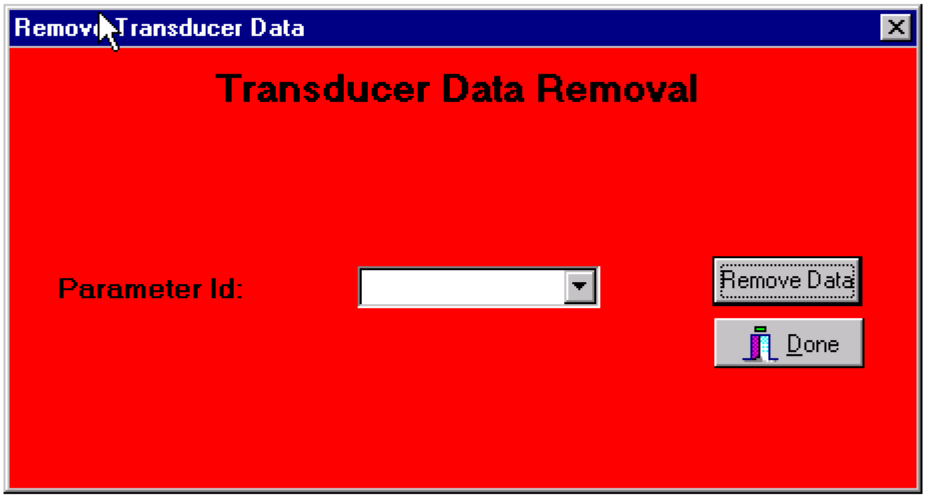


Figure 38

Enter the Parameter ID and press the Remove Data button. The Confirm window will appear with the number of records to be deleted for the site (figure 39).

Figure 39

Pressing the Yes button will continue with the delete operation, and pressing the No button will abort the delete operation. If the delete is successful, a message will appear with 'Level Records DELETED'. Click on the OK button to close the screen. If a problem is encountered then a message with 'Delete aborted, Only an Administrator can delete! If you are the Administrator then contact ITD.'

2.3.5 Discharge Details

The Discharge Details window is used to view, insert, delete, and edit information regarding discharge details of the site. Discharge Details can be viewed by clicking on the Disc button in the Detail Windows Tool Bar (figure 12). The Discharge Details window has the following tabs: Flowing discharges and Pumping Discharges. Discharge Details can be inserted, edited, and deleted in the same manner as Site Details (see sections 2.3.1.2, 2.3.1.3, and 2.3.1.4).

2.4 *User Defined Preferences*

2.4.1 Order of Columns in the Sites List

The Sites List columns may be reordered by clicking on the column header to be moved with the left mouse button and dragging the column header to a new position in the Sites List (figure 40). The columns will remain in this order until further changes are made.

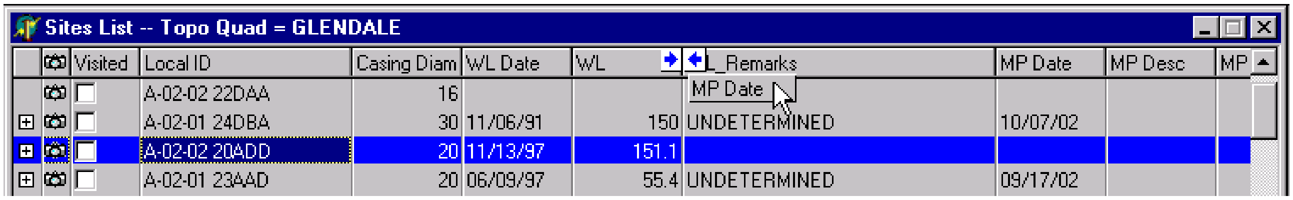


Figure 40

2.4.2 Changing the Start Tab Page

The tab that is first visible when opening a Details window can be changed. To do this, go to the Main Menu and click on Tools → Preferences → Start Tab Page. Select the tab that you first want to see and click on it. A check mark will appear to the left to indicate your selection. Now, when the window is first opened, the selected tab will be visible.

2.4.3 Display Hints

Hints are displayed each time the cursor is moved over a field which contains data or when the cursor is moved over a button on the tool bar. This feature can be turned off. To accomplish this, go to the Main Menu and click on Tools → Preferences → Hints. A check mark next to Hints indicates the item is active and hints will be displayed. By clicking on Hints, the check mark will disappear and hints will not be displayed.

2.4.4 Locking the Application

There may be occasions in which Field Services personnel want to prevent the accidental update of site information (e.g., while traveling to a site, etc). The PenTab application provides a mechanism for accomplishing such a task. Personnel may lock the application one of two ways:

- by clicking on the "lock" icon in the lower left-hand corner of the screen, or
- by going to the **Main Menu** and clicking on **Tools → Lock Application**.

Either of these actions causes a small dialog box to be displayed as illustrated in Figure 46

Figure 41

To unlock the keyboard, click on the **Unlock** button which causes a second button will be displayed.

Figure 42

<u>Immediately</u> click the second button to unlock the keyboard. If the second button is not clicked within a couple of seconds, the first button is redisplayed and personnel must start the process again.

2.5 Changing Your Password

When the PenTab application is first installed on a pentab PC, the passwords for the local database and the remote database will be the same, and it is critical that this relationship remains established in order for the pentab application to function correctly. This requirement, however, should NOT be interpreted to mean that the password cannot be changed. It simply means that when it is necessary to change a password in the ADWR database, it will be necessary for PenTab application users to make the change via the Change Password utility in the PenTab application so that the passwords for the local database and remote database remain the same.

To change a password, personnel must be logged into the remote database. If you are unsure about which database you are currently logged into, look to the bottom right-hand corner of the screen: If you are logged into the remote database you should see your user ID followed by the database name. For example, in figure 43, wrlkb is currently logged into the TEST database.

Figure 43

To change a password, log into the remote database, go to the **Main Menu** and click on the **Tools → Change Password** menu item. When the Change Password menu item is clicked the following dialog box is displayed:

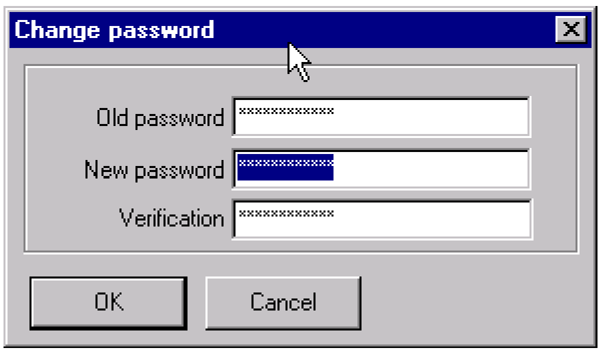


Figure 44

Once the correct information has been entered, click on the **OK** button. If the change was successful, the passwords for both the local database and the remote database will be changed as is illustrated below.

Figure 45

2.6 *Admin Features*

2.6.1 Overwrite Local Data

There will almost never be an occasion in which Field Services personnel will need to use this feature. It is designed as a last ditch effort to correct data problems in the local database.

> **WARNING**: IT IS IMPERATIVE TO UNDERSTAND THAT THIS FEATURE COMPLETELY OVERWRITES THE LOCAL DATA WITH THE DATA FROM THE REMOTE DATABASE WITH ABSOLUTELY NO REGARD TO PENDING CHANGES WHICH MAY CURRENTLY EXIST IN THE LOCAL DATABASE. IF YOU ARE UNSURE ABOUT WHETHER TO USE THIS FEATURE OR NOT, PLEASE CONTACT THE SYSTEM ADMINISTRATOR.

To overwrite the local data, go to the **Main Menu** and click on **Admin → Overwrite Local Data** and the following dialog box will be displayed:

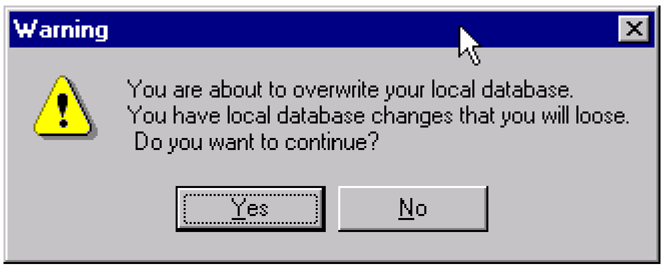


Figure 46

If the **Yes** button is clicked the local data will be overwritten with the data from the remote server. If the **No** button is clicked, the overwrite operation is cancelled.

2.6.2 Refresh Most Recent Transducer

There have been two optimizations incorporated into the PenTab application with respect to transducer generated water level measurements:

1. There is a restriction on the number of transducer water level measurements which are copied to the local database when the Refresh Most Recent Transducer menu item is selected.
   As mentioned earlier in the documentation, when logged into the local database, Field Services personnel do not see the entire list of transducer records for a given (transducer) site. For sites which have a transducer installed, personnel will only see the most recent transducer-generated water level measurement taken for a given site. Limiting the number of transducer records which can be viewed in the local database was done for performance purposes (it would significantly lengthen the amount of time needed to synchronize data between the local database and the remote database).

2. Refreshing of the most recent transducer-generated water level measurement does NOT happen automatically during the data synchronization process.
   Once again because of the volume of data involved, the most recent transducer-generated water level measurement for a given site is refreshed at personnel's discretion (when needed vs. with every data synchronization performed by personnel).

To refresh the most recent transducer-generated water level measurement on the remote server go to the **Main Menu** and click on **Admin → Refresh Most Recent Transducer**. This process may take a minute or two to complete. It should be noted, however, that the most recent transducer information is not copied to the local database until the next synch is performed by Field Services personnel on a given pentab.

2.6.3 Reset Complete Flag

One of the new features of the PenTab application allows Field Services personnel to indicate whether or not a site visit was completed; although it is important to note that it is limited to the current data collection year. The PenTab application does not currently support tracking the status of multiple projects at the same time.

Note: this feature is restricted to individuals with administrative privileges.

To reset the flags go to the **Main Menu** and click on **Admin → Reset Complete Flag**. The following dialog box will be displayed:

Figure 47

If the **Yes** button is clicked, the flags in the remote database will be reset, and if the **No** button is clicked, the reset operation is aborted.

Note: since the PenTab application is limited to tracking a complete flag for one year at a time, it may be most effective to establish a procedure like the following in preparation of a new data collection year:

- Field Services personnel ensure that all local database changes for the current data collection year have been moved (synched) to the remote database
- System administrator/manager resets the complete flag prior to the new year's field work (typically around October of each year).
- Field Services personnel ensure that another synch is performed (even if they have no local changes) before starting the new year's data collection project(s). This will ensure that their respective databases will have all of the complete flags reset in preparation of the new data collection project.

If, for some reason, someone forgets to check-in his/her local database changes before the administrator/manager resets the complete flag, it can still be rectified by Field Services personnel. Field Services personnel must also be responsible for ensuring that before starting a new year's data collection effort, the complete flags are set correctly (i.e., there should be no flags set (in the **Sites List**) to either **C** or **I** (refer to Section2.3.1.3.1). If Field Services personnel follow this procedure, it will still be possible to manually reset the complete flags before starting the new year's project; personnel would simply open each **Site Details** screen and reset the complete flag. Personnel would repeat this process for each site with an incorrect complete flag value.

2.6.4 Backup the Local Database

The PenTab application provides functionality for backing up the local database while out in the field.

2.6.4.1 Hardware Requirements

In order to perform a backup of the local database, each pentab PC must have a PCMCIA (Flash) card installed as the D drive with the following directory structure created: D:\ORACLE\exp. Note: the PCMCIA card must be installed before any other external devices such as a CD drive in order to ensure that this directory structure is available at the time a backup is performed. If this directory structure does not exist at the time that a backup is attempted, an error message will be displayed as illustrated in Figure 48.

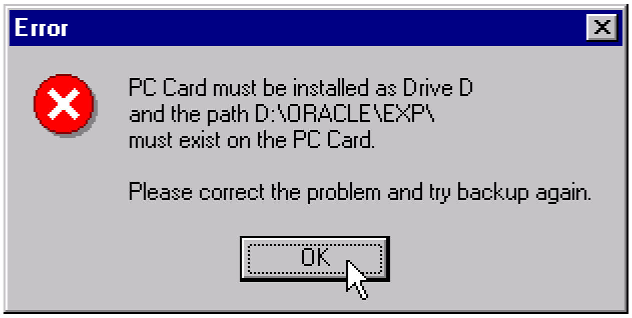


Figure 48

2.6.4.2 Perform Backup

To perform a backup of the local database, go to the **Main Menu** and click on the **Admin → Backup Local Database** menu item.

On average, it takes a couple of minutes to backup the local database.

2.7 Synchronizing the Local Database to the Remote Database

2.7.1 Overview:

During the course of a data collection project, Field Services personnel will be modifying data in the local database (i.e., a copy of the remote/GWSI database), and in order for the modified data, which has been saved in the local database, to be moved to the remote (centralized GWSI) database, personnel must synchronize their local changes with those on the remote database. During the synching process, all pending changes on the local database are moved to the remote database, and, conversely, all changes, which have been made on the remote database since the last time the user performed a synch, will be moved to the user's local database. So after the synching process, Field Services personnel will have the most current data available, at that time, on the local database.

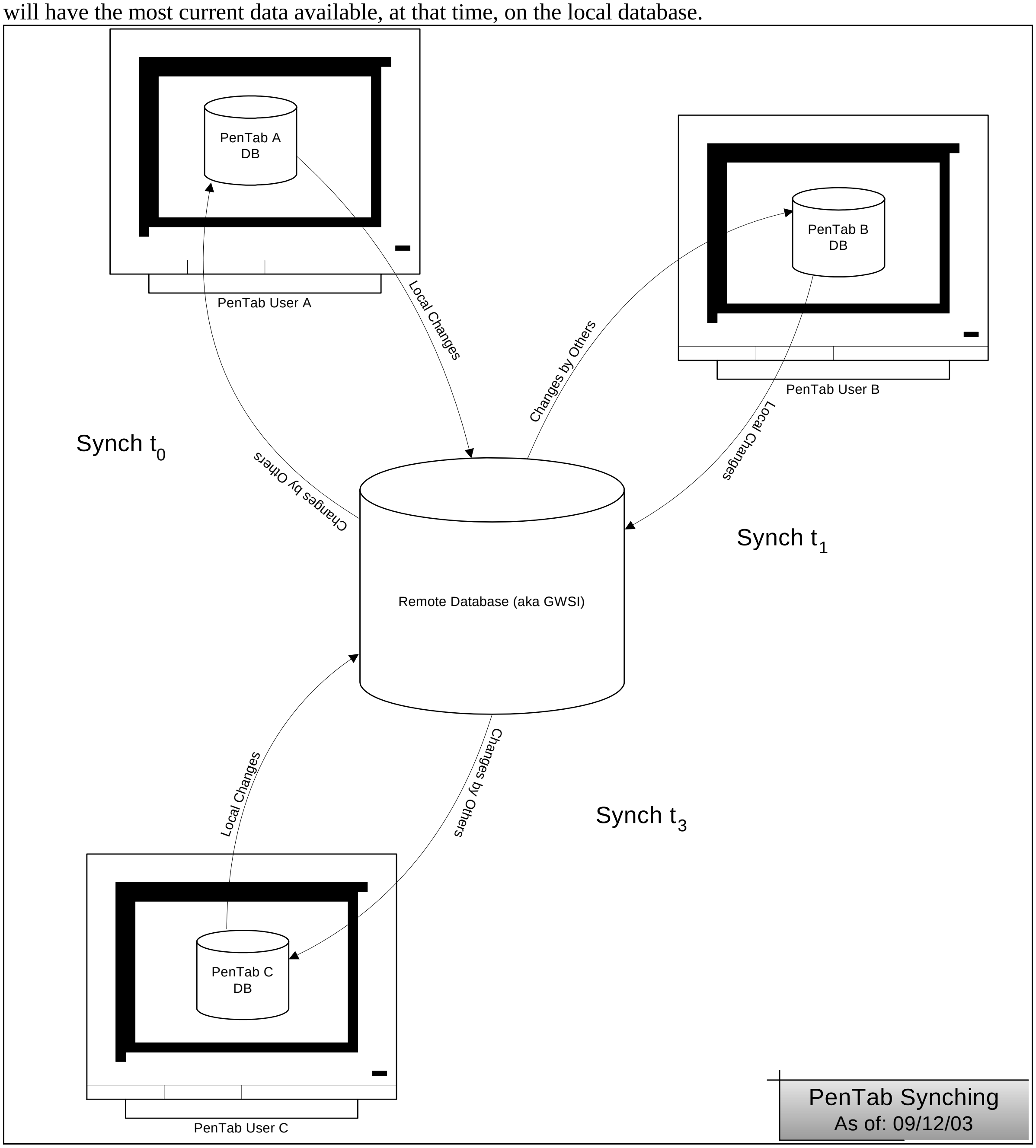


Figure 49

For example, if pentab user A (see Figure 59) synchs at t_0, his data will be moved to the remote server, and he will receive any changes which were made to the remote data since the last time he synched, up to the time of the t_0 synch (i.e., pentab users B and C are synching after pentab user A, so their changes won't be available at t_0). On the other hand, when pentab user B synchs at t_1, he will receive all of pentab user A's changes but not pentab user C's changes and so on. It, therefore, will be important that Field Services personnel recognize that if it's been a while since a synch was performed (on a given pentab) and it becomes necessary to do some field work, that he/she should perform a synch - even if he/she has no local changes pending on his/her pentab. This will ensure that personnel have the most current data available from the remote database before going out into the field.

2.7.1.1 Message Status Bar

When there are no pending changes in the local database, the message displayed at the bottom of the screen reads: "Local database has not changed, synch not needed", as is illustrated in figure 50.

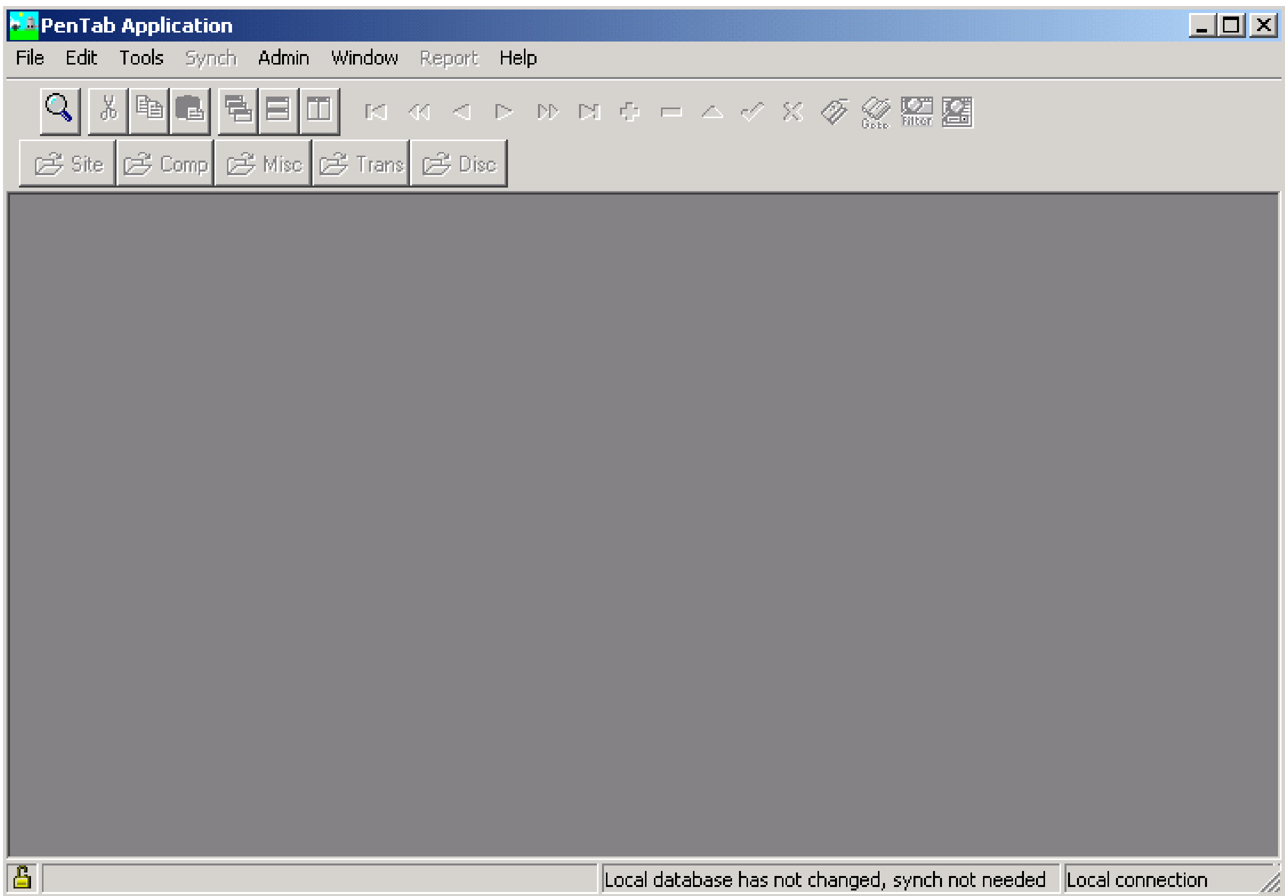


Figure 50

As soon as a change is made to the local data, however, the message will change to read: "Local database has changed, synch needed". The message will remain this way until personnel synchronize the local changes to the remote database; or, until personnel overwrite the local changes with the data from the remote database (see WARNING in Section 2.6.1).

Figure 51

Note: it is crucial to understand that the message displayed in the status bar only reflects the "condition/status" of the data in the local database (i.e., on the pentab PC). It NEVER reflects the condition/status of the data on the remote database. The basic assumption implied is that the remote database always has changes which need to be "pushed out" to the local pentab database (because other PenTab users may be checking in their respective changes to the remote (centralized) database at any time). So, it will be critical that Field Services personnel develop procedures for ensuring that prior to a data collection effort (with the PenTab application), the local database is synchronized with the remote server - even if the message status bar indicates that no changes exist in the local database.

During the synching process the following messages will be displayed in the message status bar:

- "Synching local business tables changes with server."
- then either one of the following:
  - "No conflicts found" or
  - "Conflicts detected"
- "Refreshing local code tables"
- "Refreshing local business tables"
- "Local business tables have been refreshed"
- "Synch completed successfully"

2.7.2 Synchronize Data

In order to perform a synch, Field Services personnel must be connected to ADWR's network. In other words, the pentab PC must be docked at a staff member's desk at ADWR, and the staff member must log in to the Novell network.

Once a connection to ADWR's network has been established by personnel, go to the **Main Menu** and click on **Synch → Synch with Server** and one of two message boxes will be displayed. If the **Synch with Server** menu item is selected and there are no changes in the local database, then the following message box is displayed:

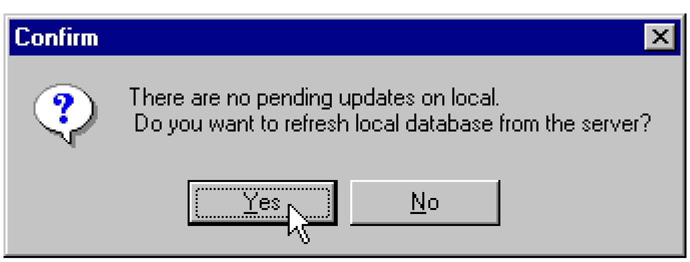


Figure 52

If there are changes in the local database which need to be moved to the remote database, then the following message box will be displayed:

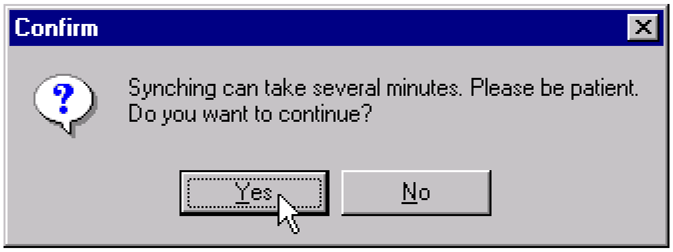


Figure 53

If the **Yes** button is clicked, then the synch process is performed. If the **No** button is clicked, then the synch process is canceled, and no data is moved to or from the remote server.

On average, the synching process takes approximately 4 – 5 minutes, but be aware that performance can be impacted by network activities of other users in ADWR's system, and it may take a little longer at times.

2.8 *Conflict Detection and Resolution*

2.8.1 Overview

During the synching process, the very first step that is performed by the PenTab application is the detection of conflicts as illustrated in the status bar of Figure 54.

Figure 54

A conflict exists when a particular PenTab application user has modified a given record on the local database, attempts to synch, and another user has also modified the copy of that very same record on the remote database (figure 55). This is a conflict that cannot be resolved by the PenTab application – which change is the correct one? Only the PenTab user performing the synch can make this determination.

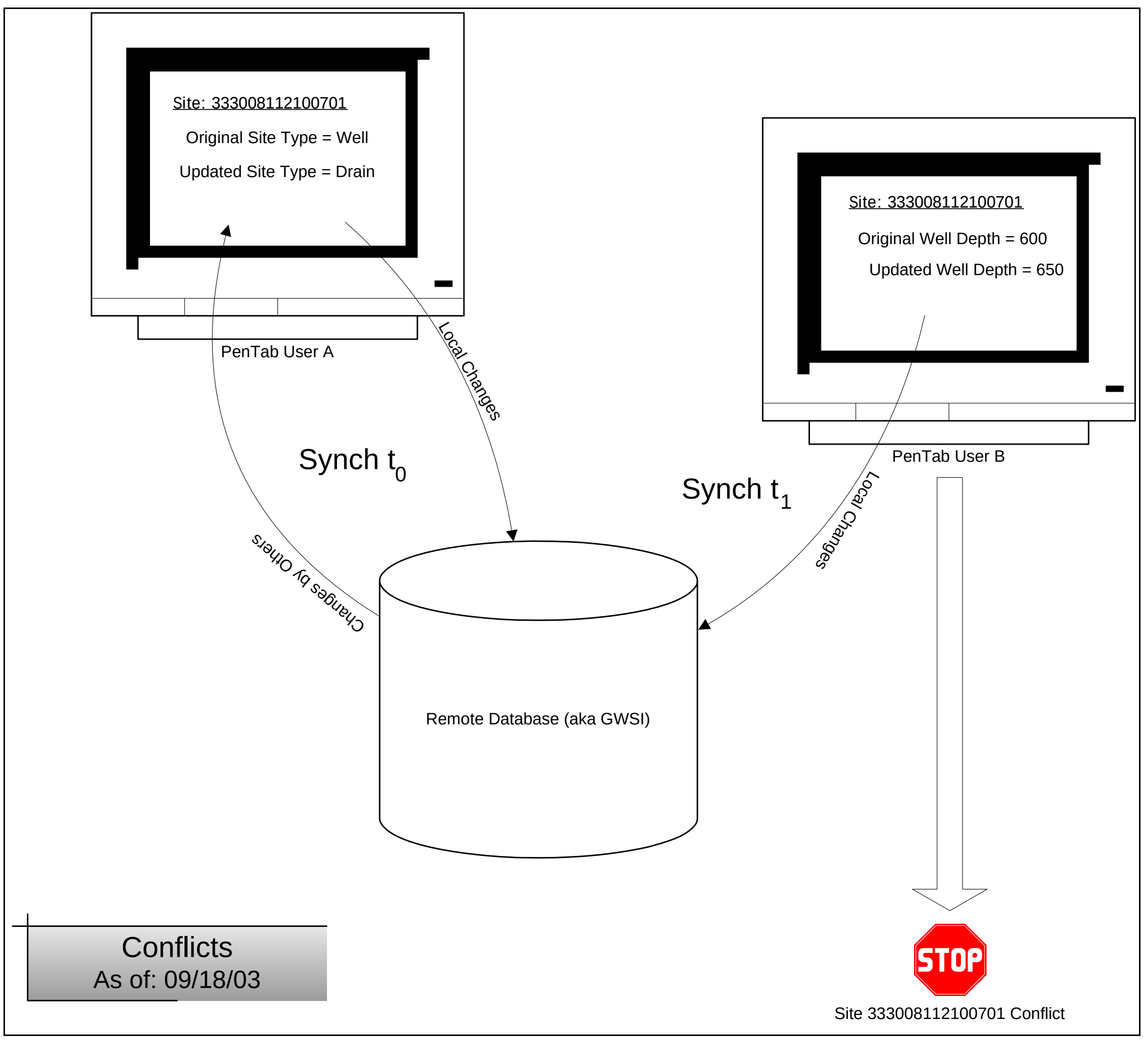


Figure 55

When a conflict is detected during the synching process, the synch operation is canceled, and a message box is displayed:

Figure 56

At this point, personnel cannot proceed with the synching process without resolving all of the conflicts that were detected.

Figure 57 shows an example of a conflict in the site ID 333008112100701 record. When the conflict screen is first opened, it displays all columns which exist in the conflict record. In other words, it shows columns which are in conflict as well as those that are not in conflict. The cursor, however, will be automatically positioned on the first column in which a conflict is detected.

In the example below, the original value of the Well Altitude column (i.e., the value of the column as of the last synch performed) was 1123. The value of the Well Altitude column on wrlkb's pentab is 1123 (i.e., it's the same as when it was last synched, or "checked out", from the remote server, so it can be determined that wrlkb did not modify this particular column on the local database). And, lastly, the value of the Well Altitude column on the remote server is 1150. Which value is correct? Only the person performing the synch can make this determination, and it may involve contacting coworkers before a decision can be made.

Simply stated, the goal of the conflict resolution process is to merge, or consolidate, changes made on the same record which were made by two different people. Choosing a value to keep will be discussed in greater detail in the next few sections.

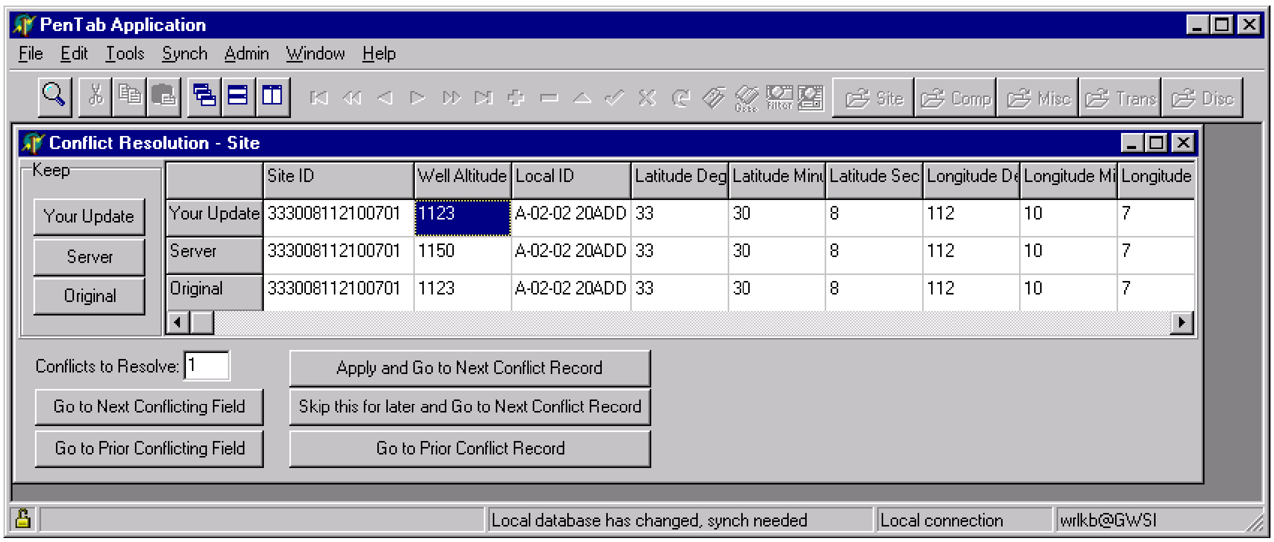


Figure 57

2.8.2 Conflict Resolution Screen Layout

The conflict resolution screen in Figure 64 has three principal areas: the data grid, the navigate and apply buttons, and the change selection (i.e., Keep) buttons.

2.8.2.1 Conflict Data Grid:

The conflict data grid represents 3 views of a given record at the time that the conflict is detected (during the synch process). The rows displayed in the grid are interpreted as follows:.

- of the 3 rows, the top row (**Your Update** line) is probably the most important row during the conflict resolution process. It really serves two purposes: 1) it represents the record as it currently exists (after any changes) on the local database and can therefore be used to compare/evaluate conflicts; and 2) it also serves as the placeholder for the data which will be moved to the remote database during the synching process. In other words, personnel specify which changes to keep by ensuring the correct values are in the first/top row, and when the next synch is performed, it will be these values which get moved to the remote database.
- the middle row (**Server** line) in the data grid represents the record as it currently exists on the remote database.
- the bottom row (**Original** line) in the data grid represents the original snapshot of the record on the local database before any changes were made to the record.

	Site ID	Well Altitude	Local ID	Latitude Deg	Latitude Min	Latitude Sec	Longitude De	Longitude Mi	Longitude
Your Update	333008112100701	1123	A-02-02 20ADD	33	30	8	112	10	7
Server	333008112100701	1150	A-02-02 20ADD	33	30	8	112	10	7
Original	333008112100701	1123	A-02-02 20ADD	33	30	8	112	10	7

Figure 58

For example, in figure 58, the conflict data grid shows a conflict in a site record for site ID 333008112100701 in the Well Altitude column. Notice, as was mentioned previously, that the cursor (field/cell highlighted) is positioned in the Well Altitude column and identifies it as the first conflict in the record.

By comparing the Well Altitude value that currently exists on the local database (first row) to that of the original Well Altitude value (third row), it is easy to see that the conflict was not created because it was edited by the person performing the synch (i.e., the value that currently exists in the local database (1123) still matches the original value (1123)); rather, the conflict exists because someone else made a change to the well altitude value, which was ultimately saved to the remote database. It is up to the person performing the synch to determine what to do about the conflict.

2.8.2.2 Navigate and Apply Buttons:

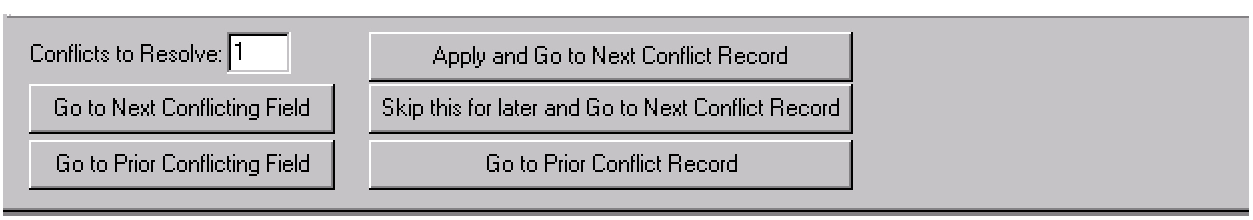


Figure 59

There are two prevailing concepts to understand when navigating through conflicts:

1. A given conflict record may have one or more columns which are in conflict – it depends on the number of fields on the local database which differ from like fields on the remote database.

2. It is also possible for there to be one or more records (each with its respective columns) which have conflicts and need to be resolved before continuing with the synch process.

So, to state another way, the navigate and apply buttons provide mechanisms both for moving from one conflict column to another as well as for moving from one conflict record to another (figure 59). The buttons are as follows:

Go to Next Conflicting Field
Moves the cursor to the right if another column (in the current conflict record) contains data in conflict
Go to Prior Conflicting Field
Moves the cursor to the left if another column (in the current conflict record) contains data in conflict
Apply and Go to Next Conflict Record
Sets a flag which indicates that all conflicts for the current record have been resolved
Skip this for later and Go to Next Conflict Record
Skips the current conflict record and advances to the next conflict record.
Go to Prior Conflict Record
Returns to the previous conflict record (if/when one exists)

The best analogy for understanding this concept is that of a rolodex or a stack of index cards. Just as a rolodex can have many cards nested one behind the other, so, too, can the conflict screen have multiple conflict records which need to be resolved.

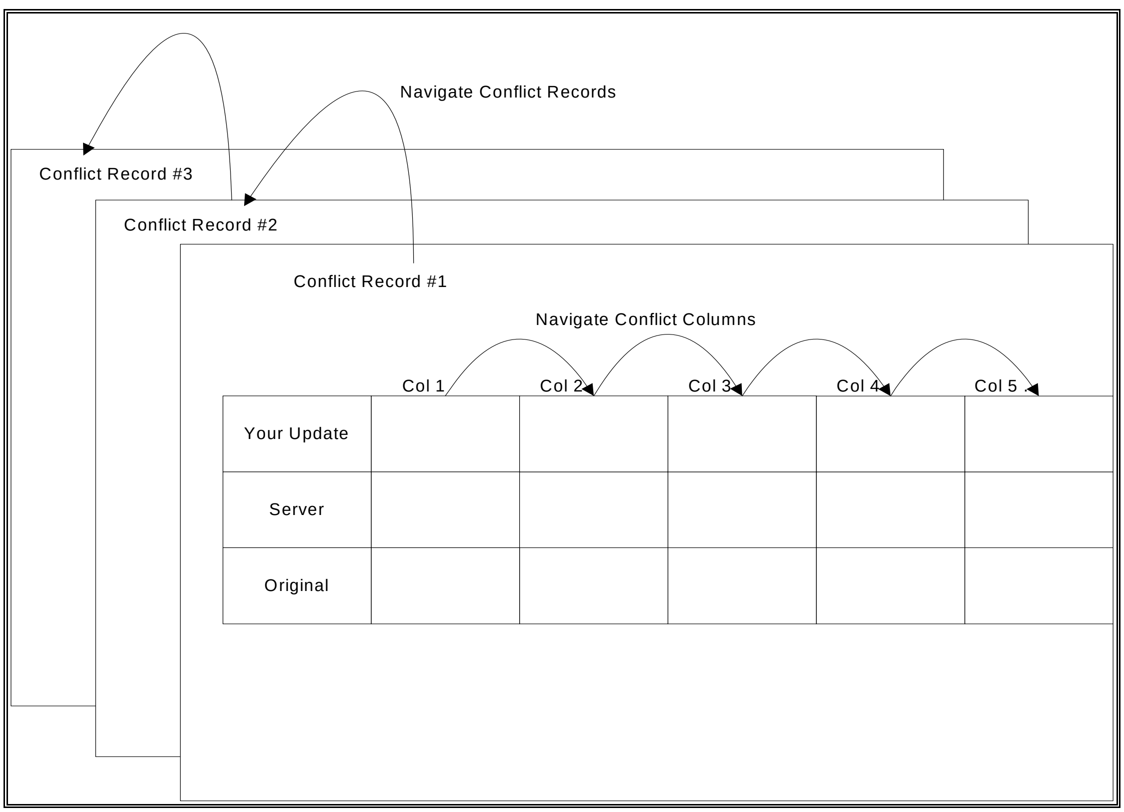


Figure 60

To navigate to the next conflict record (if one exists), click on either the **Apply and Go to Next Conflict Record** button or the **Skip this for later and Go to Next Conflict Record** button.

Note: Field Services personnel may also quickly determine how many conflict records need to be resolved by referring to the **Conflicts to Resolve** field. In Figure 68, there is only one record in conflict; although, in reality, there is no limit to the number of records which may have conflicts.

2.8.2.3 Change Selection Buttons:

Figure 61

Once a conflict has been reviewed/evaluated in the conflict data grid, Field Services personnel must indicate which row represents the correct data to move to the remote database. This is accomplished by clicking on either the **Your Update** button, the **Server** button, or the **Original** button.

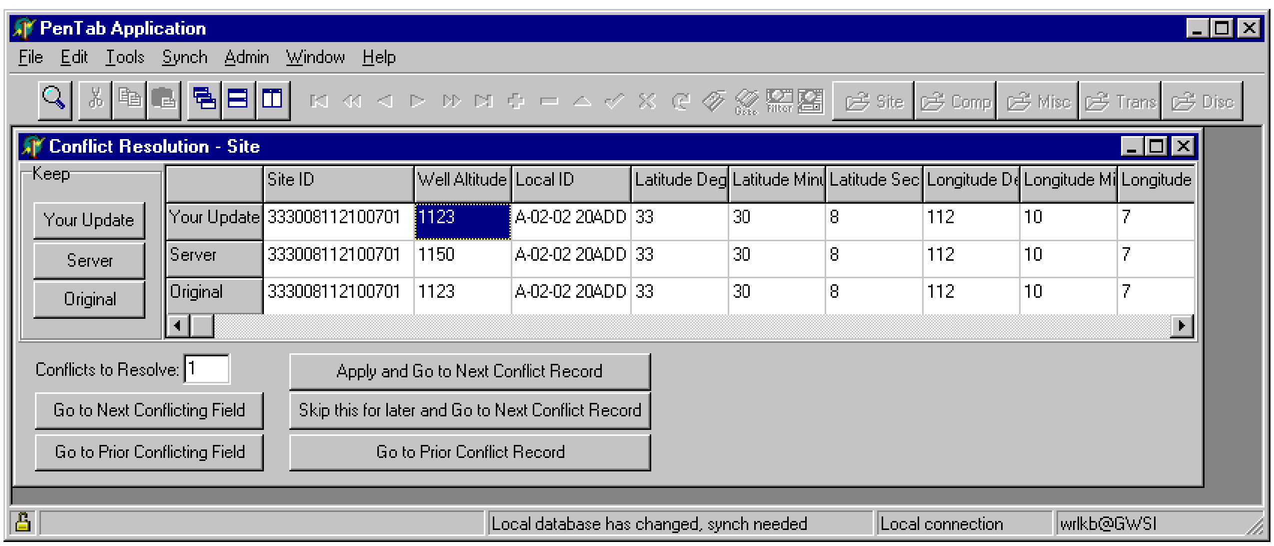


Figure 62

As was discussed in Section 2.8.2.1, only the first row's data will be moved to the remote database during the synch process, and it is the "Keep" buttons which allow Field Services personnel to move data values from either the second row or third row to that of the first. For example, if it was determined that the value on the remote database (1150) was correct, personnel simply need to click on the **Server** button which causes all of the values in the second row to be copied to the top row (e.g., the value of 1150 is copied to the top row) as is illustrated in figure 63.

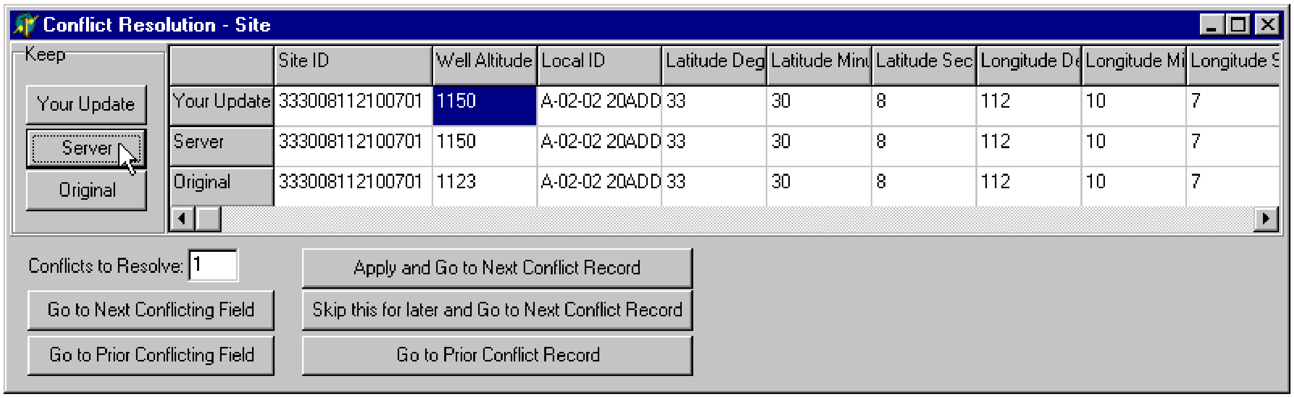


Figure 63

Note: the PenTab application does not require that the "Keep" buttons be used to specify a value in the first row; it also allows a value to be typed directly into the field/cell or allows personnel to double click on a value in the second or third row to move it to the top row, but these options should be used with care. It may be possible to enter an incorrect/inconsistent value when typing a value directly into the top row/cell, or by moving one cell at a time by double clicking. Please see ITD personnel for additional information.

2.8.3 Resolving Conflicts

A prerequisite to viewing conflict information is that a synch be attempted (refer to Section 2.7). Once a synch has been performed and a conflict detected, go to the **Main Menu** and click on **Synch → Conflicts** menu item**.** Figure 74 shows a list of menu items in which one menu item has been enabled (bolded). The fact that the **Sites** menu item is bolded indicates that the conflict was detected for a record which exists in the sites table. There is one menu item for each table in the PenTab (GWSI) database.

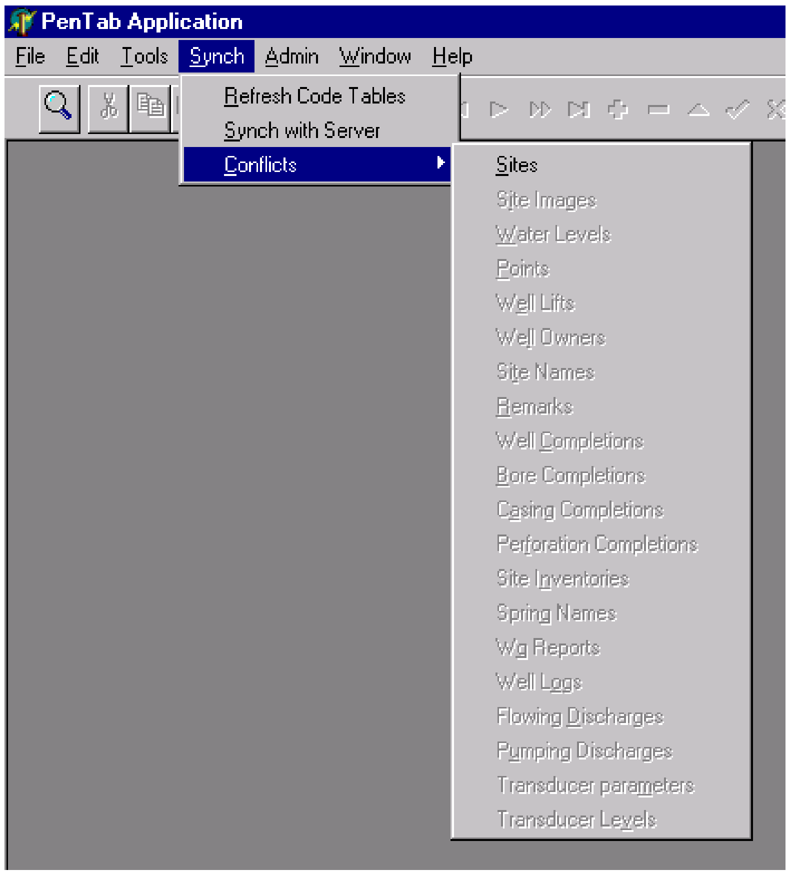


Figure 64

Steps for resolving a conflict:

1. Click on the appropriate (bolded) menu item and the **Conflict Resolution** screen (figure 64) will be displayed.

2. Review <u>ALL</u> columns/cells which are in conflict before trying to move data to the first row.
   Note: this step is strictly procedural in nature, however. If personnel were to click on either the **Server** button or the **Original** button before reviewing all of the outstanding conflicts for the record, it may be possible to move a change (in another column/cell, which isn't currently displayed in the screen) to the top row which personnel didn't intend to move.

3. Ensure that appropriate values are displayed in the top row of the conflict data grid.

4. Click on either one of the following buttons:

- **Apply and Go to Next Conflict Record** button. As mentioned earlier, clicking this button sets a flag which indicates that all conflicts for the current record have been resolved and causes the next conflict record to be displayed (if it exists).
- **Skip this for later and Go to Next Conflict Record** button. Again, as mentioned earlier, clicking this button skips the current conflict record and advances to the next conflict record (if it exists). It should be noted, however, that all conflicts must be resolved before the synch can be performed, so this button simply lets Field Services personnel postpone the resolution process while additional information regarding the conflict is gathered/researched. Personnel must ultimately select the **Apply and Go to Next Conflict Record** button for each conflict record before the synch can be attempted again.

5. If all conflict records have been processed, perform another synch.

   Once the **Apply and Go to Next Conflict Record** button has been clicked for a given conflict record, the conflict is considered to be resolved. If all conflict records have been processed in this manner, personnel may attempt another synch operation.

3. Glossary/Terminology

Conflict - when a particular PenTab user has modified a given record on the local database, attempts to synch, and another user has also modified the copy of that very same record on the remote database.

Local PenTab Database – the database which is used by the PenTab application to capture data while personnel are out in the field, and which physically resides on the pentab PC.

Remote PenTab Database (a.k.a. – GWSI) – the Oracle database, which is used by the PenTab application as the central repository of all GWSI data, which physically resides at ADWR's facility, and is synonymous with the current GWSI database.