Groundwater Level Monitoring Plan for the Sacramento Groundwater Authority CASGEM Well Network

Submitted by
Sacramento Groundwater Authority

December 2011

Introduction

The Sacramento Groundwater Authority (SGA) is a joint powers authority formed in 1998 by agreement between the cities of Citrus Heights, Folsom, and Sacramento and the County of Sacramento to exercise their common police powers to manage the groundwater basin underlying Sacramento County north of the American River. Since its inception, SGA has developed and implemented an active groundwater management program. This program included the development of the first comprehensive groundwater management plan adopted in December 2003 and its subsequent update and re-adoption in December 2008. Additional program elements include the development of a comprehensive data management system for groundwater data, enhancement and recalibration of a regional integrated groundwater/surface water model, establishment of a local water accounting framework that assigns sustainability pumping goals to urban water suppliers overlying the basin, preparation of a recurring basin management report to assess basin conditions through time, and construction of dedicated monitoring wells where past data gaps existed in the basin. Additional information, including the SGA Groundwater Management Plan and Basin Management Report can be found at www.sgah2o.org.

Monitoring Plan Rationale

The monitoring plan was developed to reflect the current level of understanding and management activities in the basin. In essence, a program is now in place that ensures that significant fluctuations in basin groundwater elevations could not occur without being detected or without an appropriate management response to mitigate such conditions.

Principal Aquifer Features

The groundwater resources of Sacramento County have been extensively investigated and reported in DWR Bulletin 118-3, Evaluation of Ground Water Resources: Sacramento County (DWR, 1974). DWR Bulletin 118-3 identifies and describes the various geologic formations that constitute the water-bearing deposits underlying Sacramento County. These formations include an upper, unconfined aquifer system consisting of the Riverbank (formerly known as Victor), and Turlock Lake (formerly known as Fair Oaks), Laguna, and a lower, semi-confined aquifer system consisting primarily of the Mehrten Formation. These formations are shown on Figure 1 and are typically composed of lenses of inter-bedded sand, silt, and clay, interlaced with coarse-grained stream channel deposits. Figure 1 illustrates that these deposits form a wedge that generally thickens from east to west.

Groundwater occurs in unconfined to semi-confined states throughout the North American Subbasin. Semi-confined conditions occur in localized areas; the degree of confinement typically increases with depth below the ground surface. Groundwater in the Riverbank, Turlock Lake, and Laguna Formations (the “upper aquifer”) is typically unconfined. However, due to the heterogeneous nature of the alluvial depositional system, semi-confined conditions can be encountered at shallow depths in the aquifer. The deeper Mehrten Formation (the “lower aquifer”) typically exhibits semi-confined conditions. Provided below is a more detailed description of the water-bearing formation characteristics within the SGA area.

Turlock Lake and Riverbank Formations – Within the SGA area, these Formations, designated Qtl and Qr on Figure 1 overlie the Laguna Formation and have been laid down along the American River downstream of Folsom Dam. These Formations are relatively young (Pleistocene in age) and largely unconsolidated. Formation sediments are primarily derived from decomposed granite and metamorphic rock of the western Sierra (DWR, 1974).

Laguna Formation – The Laguna Formation, designated as Tl on Figure 1, is late Pliocene to early Pleistocene in age and is non-volcanic, comprised of heterogeneous deposits of silt, clay, sands and fine gravels that vary from tan to brown in color. The lower portion of the Laguna Formation often consists of a gradational contact with the Mehrten Formation. The Laguna formation will yield moderate quantities of water to wells screened in fine grained deposits with wells screened in well sorted Laguna granitic sands producing higher yields (DWR, 1974).

Mehrten Formation – The Mehrten Formation designated as Tm on Figure 1, is very different than the overlying Laguna Formation. The Mehrten Formation's gray and black andesitic sands, interbedded with blue to brown clays and gray tuff-breccia sand, are all volcanic in origin in contrast with the tan to brown color non-volcanic sediments of the Laguna Formation. The Mehrten Formation was derived from reworked andesitic volcanic mudflow deposits that are late Miocene to early Pliocene in age. The Mehrten formation can be divided into two different units: the upper sedimentary unit is composed of well sorted black andesitic sands, sometimes with cobbles and boulders, (reported by well drillers as "black sands") and interbedded blue to brown clays; the lower consolidated unit is a hard and very dense gray tuff-breccia (reported by well drillers as "lava"). The Mehrten units range in thickness from 200 to 1,200 feet and form a semi-confined aquifer, which dips toward the west at approximately 1 to 2 degrees. The most resistant beds in the Mehrten are andesite mudflow breccias that form steep cliffs where they are exposed along the lower American River north of Lake Natoma. The Mehrten formation is a major aquifer and provides copious quantities of groundwater to many wells within the North Area Basin. The volcanic sands and gravels yield large quantities of water to wells, while the clays yield little water and the tuff-breccias yield low quantities (DWR, 1974).

Monitoring History in Basin

In 1990, the California Department of Water Resources (DWR) reported that it was monitoring some 124 wells in Sacramento County biannually and cooperators were monitoring an additional 139 wells (DWR, 1990). The oldest monitoring record in that report dated back to 1934 (DWR 1990). While many additional wells were added in the 1940s and 1950s, it appears based on the information in the DWR report that the 1960s saw the greatest increase of systematic monitoring throughout the County. While the wells monitored in any given year vary, the program monitors about two-dozen wells within the SGA area. Beginning in the 1980's, the Ari Force began systematic water level monitoring in conjunction with water quality sampling to assess the extent of contamination at the now former McClellan Air Force Base located in the center of the SGA area. Today, the network includes hundreds of monitoring wells. In the 1990's, the USGS constructed several dedicated monitoring wells that are still being monitored in urban settings as part of the National Water Quality Assessment Program (NAWQA). In the mid-2000's, SGA constructed a dedicated network on eight monitoring wells at locations that lacked data in the SGA area. That network is still being monitored by SGA.

Groundwater Level Trends. Figure 2 shows the locations and hydrographs of selected long-term monitoring wells in the basin. In general, past data shows that in the central portion of the North Area Basin groundwater elevations declined at a rate of nearly 1.5 feet per year from around the 1950s through the mid-1990s. Since the mid-1990s, groundwater elevations have stabilized within the regional cone of depression and, in some cases, groundwater elevations are continuing to increase slightly. This trend is largely due to operational changes as noted later in this section. For purposes of further discussion, the North Area Basin can be divided into three sub-areas.

Western Area. The western portion of the North Area Basin is bounded by the Sacramento River on the west and extends east to approximately the boundary between Natomas Central Mutual Water Company and Rio Linda/Elverta Community Water District (Figure 2). This area is served almost exclusively by surface water. Hydrographs for SWP-216, SWP-261, and SWP-263 show that groundwater elevations range from about five feet below MSL to 20 feet above MSL. The hydrographs show that groundwater elevations have been fairly stable over the period of record, with very modest increases in 2003 and 2004. These wells typically experience only seasonal fluctuations.

Central Area. The central portion of the North Area Basin is bounded roughly on the west by the boundary between Natomas Central Mutual Water Company and Rio Linda/Elverta Community Water District and to the east by a line running approximately along San Juan Avenue (Figure 2). This area currently uses a combination of surface water and groundwater, but has historically relied predominantly on groundwater. Hydrographs for SWP-220, SWP-229, SWP-232, SWP-240, SWP-270, and SWP-276 show that groundwater elevations currently range from about 10 feet above MSL to 40 feet below MSL. The drawdown in these wells over the past 60 years has been in excess of about 70 feet. Groundwater elevations in this area continued to decline every year until around the mid-1990s, when groundwater elevations stabilized due, at least in part, to expanded conjunctive use operations. Groundwater elevations have increased slightly over previous years despite the temporary increase in groundwater extraction in the basin in 2007. This is likely because groundwater for public supply has been reduced in the immediate vicinity of McClellan to help contain the movement of contamination.

Eastern Area. The eastern portion of the North Area Basin extends roughly east of San Juan Avenue to the eastern edge of the basin (Figure 2). This area has historically relied primarily on surface water. Hydrographs for wells SWP-236 and SWP-283 are typically in excess of 100 feet above MSL. Groundwater elevations can be highly varied from one well to another, as the area has rolling topography and the groundwater elevation tends to mimic ground elevations. Hydrographs indicate that groundwater elevations have not changed greatly with time, reflecting the limited use of groundwater in the area. There were no notable changes in recent groundwater elevations.

Groundwater Conditions in the Basin

As discussed above, groundwater conditions in the basin have improved greatly over the past decade. A long-term trend in declining water levels has been eliminated and water levels have exhibited recovery. This is in large part due the efforts on public water suppliers to increase conjunctive use operations through the additional surface water supplies brought into the central part of the basin. Figure 3 shows groundwater extraction by public water suppliers since 1990. This pumping, which accounts for more than 80% of the total pumping in the SGA area, has decreased dramatically resulting in greatly improved groundwater elevations.

Figure 4 shows a groundwater surface elevation map for Spring 2010. This map was produced by downloading water elevation collected by DWR and Sacramento County from the DWR Water Data Library. The map is supplemented by additional data collected by SGA and one of its member agencies, Sacramento Suburban Water District (SSWD). Most of these wells, and additional ones identified in 2011, will be included as part of the proposed CASGEM network for the SGA area.

Selection of Wells for CASGEM Program

There are many factors that were considered in selecting wells for the CASGEM network in the SGA area. These include: prioritizing parts of the basin where pumping is occurring as they are the most likely to exhibit changes; ensuring adequate spatial density of data with an average of about 1 well per 5 square miles over SGA's nearly 200 square-mile management area; maintaining wells that have been monitored for long periods as part of the network, but excluding those exhibiting erratic data through time; including an adequate number of wells near surface water bodies (e.g., along American River) and near the water table to observe how recharge areas are responding to groundwater stresses through time.

Additionally, SGA considered that some of the wells in the DWR/SCWA network will be discontinued through time. Some newly added wells were included that are proximal to these locations should they need to be destroyed. SGA requested that public water suppliers considering destroying existing production wells notify SGA to discuss and evaluate whether the wells could be incorporated into the network now or in the future. Finally, there were several opportunities to monitor multi-completion wells in the basin. These wells were added to observe gradients at varying depths in the basin under various stresses.

Selection of the Monitoring Schedule

Based on the decades of available monitoring in the basin, SGA believes that semi-annual monitoring is appropriate to evaluate long-term groundwater elevation trends. Our program has target data collection dates of April 15 and October 15, with a window of +/- 2 weeks of each of these dates to accommodate inclimate weather conditions and conflicting schedules of the cooperators. These dates were established following coordination meetings with DWR and SCWA monitoring staff in early 2004 to ensure levels are collected in a fairly small window to ensure consistency of data collected. During periods in which unusually high stresses are expected, more frequent monitoring may occur. For example, when SSWD and the City of Sacramento participating in the 2009 State Drought Water Bank, wells were monitored on at least a monthly basis at the beginning of the groundwater exchange pumping and continued until water elevations recovered to pre-exchange levels.

SGA Monitoring Well Network

Based on observed long-term trends, known aquifer characteristics, and future planned groundwater production reported by public water suppliers, SGA is proposing a network that we believe is capable of providing important trend information to overlying basin managers to take actions needed to ensure long-term basin sustainability. The current CASGEM network being proposed by SGA is depicted in Figure 5. The network includes 23 distinct locations, 8 of which have multi-completion wells, for a total of 42 measurements to be collected. Of the wells, 12 will be monitored directly by SGA staff, 23 will be monitored by SSWD staff and reported to SGA, and 7 are monitored by DWR and posted in the WDL. These wells are listed in Table 1 below. Note that while SGA considers this an appropriate network for monitoring the basin, we will likely work with

DWR and SCWA to potentially identify additional wells in the WDL as candidates for inclusion into the SGA CASGEM network.

Within the network, SGA has purposely proposed wells that are in proximity to the existing network of SCWA and DWR. We understand that many of the SCWA and DWR wells are quite old and may be lost through time. If that were to occur, we would be able to maintain a representative network to continue future monitoring.

Table 1. SGA CASGEM Monitoring Well Network

Local Well Designation	State Well Number	Well Use	Depth	Cooperator
AB-3 middle	10N04E27R003M	Observation	500	DWR
AB-3 shallow	10N04E27R004M	Observation	220	DWR
AB-4 shallow	10N04E31M004M	Observation	200	DWR
AB-4 middle-deep	10N04E31M002M	Observation	815	DWR
AB-3 deep	10N04E27R002M	Observation	995	DWR
AB-4 middle-shallow	10N04E31M003M	Observation	410	DWR
AB-4 deep	10N04E31M001M	Observation	1080	DWR
SGA_MW01		Observation	110	SGA
SGA_MW02		Observation	110	SGA
SGA_MW03		Observation	305	SGA
SGA_MW04		Observation	65	SGA
SGA_MW05		Observation	220	SGA
SGA_MW06		Observation	72	SGA
SGA_MW08		Observation	145	SGA
SGA_MW09		Observation	165	SGA
Well 10	09N05E13L002M	Observation	265	SSWD
MW11A		Observation	187	SSWD
MW11B		Observation	278	SSWD
MW11C		Observation	375	SSWD
MW12A		Observation	285	SSWD
MW12B		Observation	385	SSWD
MW12C		Observation	615	SSWD
MW12D		Observation	845	SSWD
MW12E		Observation	1005	SSWD
Well 15	09N06E06A001M	Observation	486	SSWD
Well 54	09N06E20D001M	Observation	550	SSWD
Well 67	09N06E30G001M	Observation	577	SSWD
Well N28	09N06E03C001M	Observation	454	SSWD
Monument (A)		Observation	274	SSWD
Monument (B)		Observation	334	SSWD
Monument (C)		Observation	450	SSWD
Monument (D)		Observation	544	SSWD
Poker (A)		Observation	134	SSWD
Poker (B)		Observation	176	SSWD
Poker (C)		Observation	320	SSWD
Poker (D)		Observation	470	SSWD
North Antelope (A)		Observation	283	SSWD
North Antelope (B)		Observation	473	SSWD
USGS_SGA_001	09N04E13R001M	Observation	52	SGA/USGS
USGS_SGA_002	09N04E23R002M	Observation	48	SGA/USGS
USGS_SGA_003	10N06E27F001M	Observation	198	SGA/USGS
USGS_SGA_004	10N05E13F001M	Observation	166	SGA/USGS

Field Methods

Wells monitored by DWR and SCWA will continue to employ the field methods used as part of their ongoing programs. SGA will consult with SSWD to ensure that appropriate fields methods are employed to include the following:

- Field measurements will be collected within +/- 2 weeks of biannual target date.
- Field measurements will include recording of date, time, name of person collecting data, type of instrument used (e.g., electric sounder, acoustic sounder, steel tape, etc), and any other relevant observations.
- Standard questionable measurement and no measurement codes will be used.
- Field equipment will be cleaned as necessary in between taking measurements, including the use of a 1% bleach solution or use of a chemical wipe followed by a distilled water rinse as recommended for the USGS wells.
- Staff will bring previous measurements to the field when taking measurements for comparison to check reasonableness of data being collected.
- SSWD field measurements will be reviewed by a supervisor prior to being submitted to SGA.
- While none of the wells being monitored by SGA and SSWD are producing wells, staff will observe for any proximal wells that could be pumping and potentially influencing measurements.

SGA will utilize the instructions provided by DWR in its final CASGEM guidelines (DWR, 2010) for establishing reference points and taking water level measurements and will provide these instructions to SSWD staff. SGA and SSWD will use DWR Form 1213 for recording measurements. These instructions and form are included in excerpts from the DWR Guidelines included here as Attachment 1.

Cooperating Agencies

The program will rely on several cooperating agencies. SGA will rely on DWR and SCWA to continue their existing monitoring programs and will rely only on the DWR dedicated monitoring wells at this time. SGA will collect data from its eight monitoring wells and has been granted access by the USGS to collect data from four NAWQA wells. SSWD will collect data from 18 dedicated monitoring wells and 5 former production wells that have been abandoned, but are being maintained for CASGEM monitoring purposes.

References

California Department of Water Resources (DWR). Evaluation of Groundwater Resources: Sacramento County. Bulletin 118-3. July, 1974.

California Department of Water Resources (DWR). Historical Ground Water Levels in Sacramento County. November, 1990.

California Department of Water Resources (DWR). Groundwater Elevation Monitoring Guidelines. December, 2010.

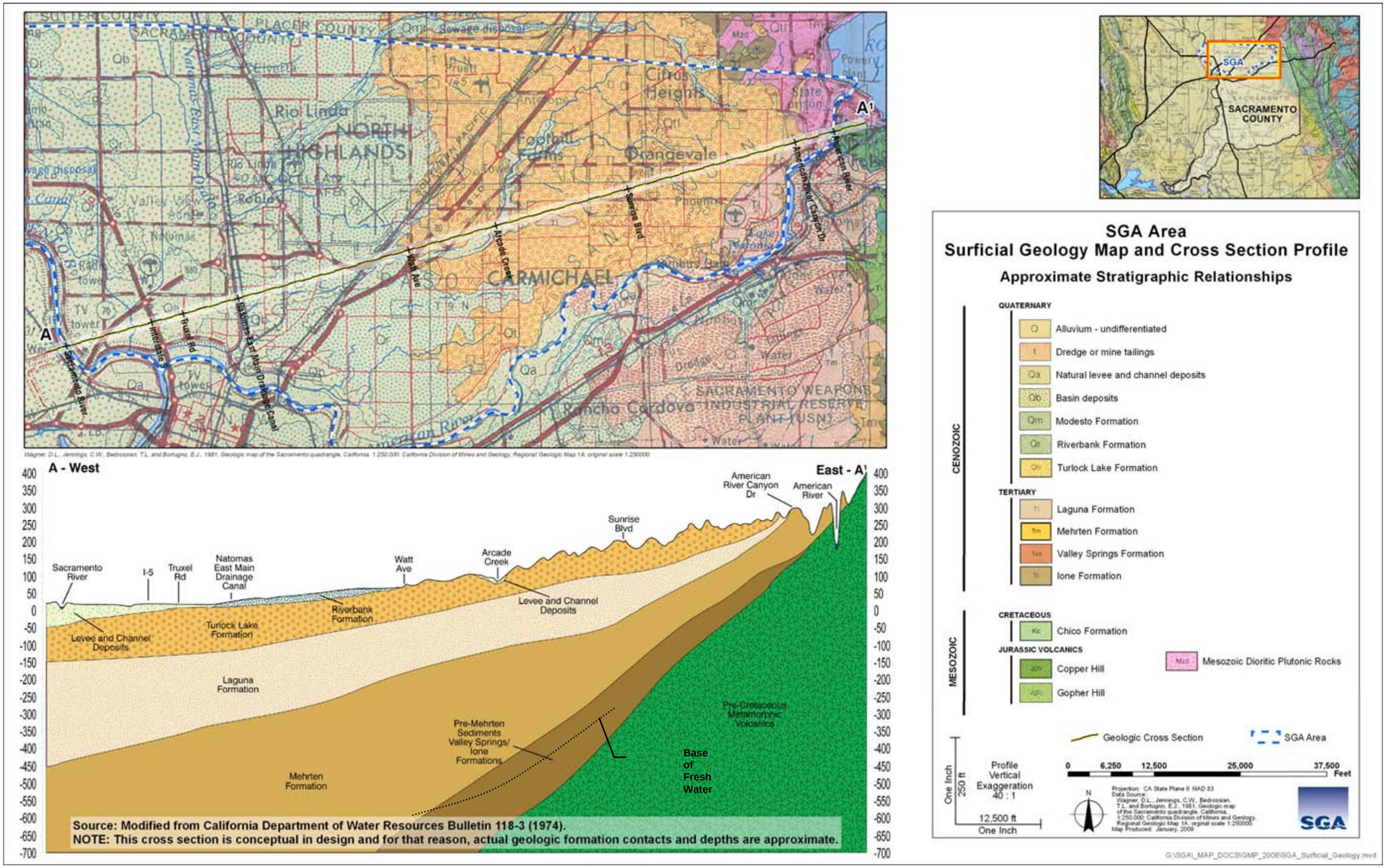

Figure 1. Regional geology and stratigraphy in the SGA area.

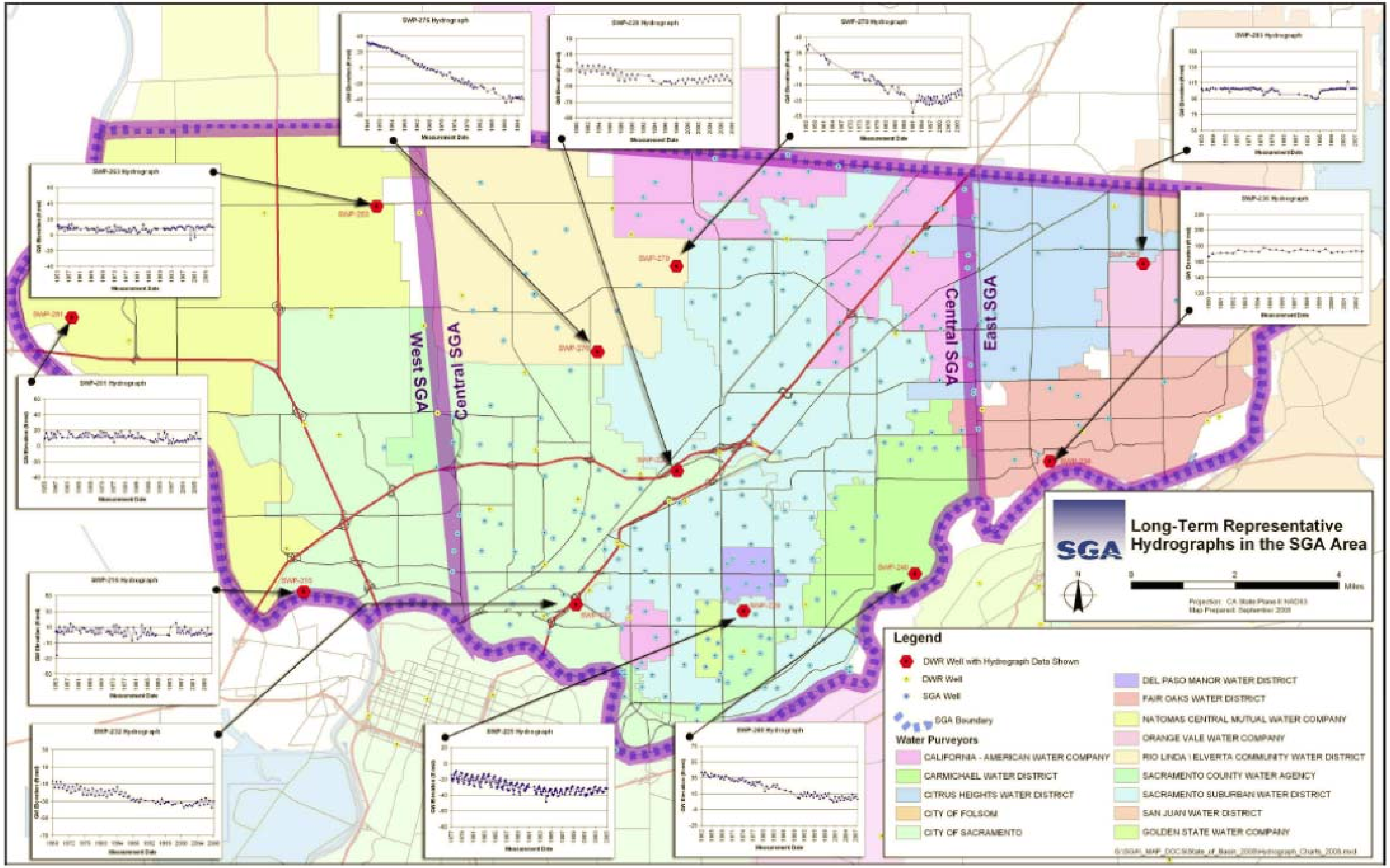

Figure 2. Long-term representative hydrographs in the SGA area.

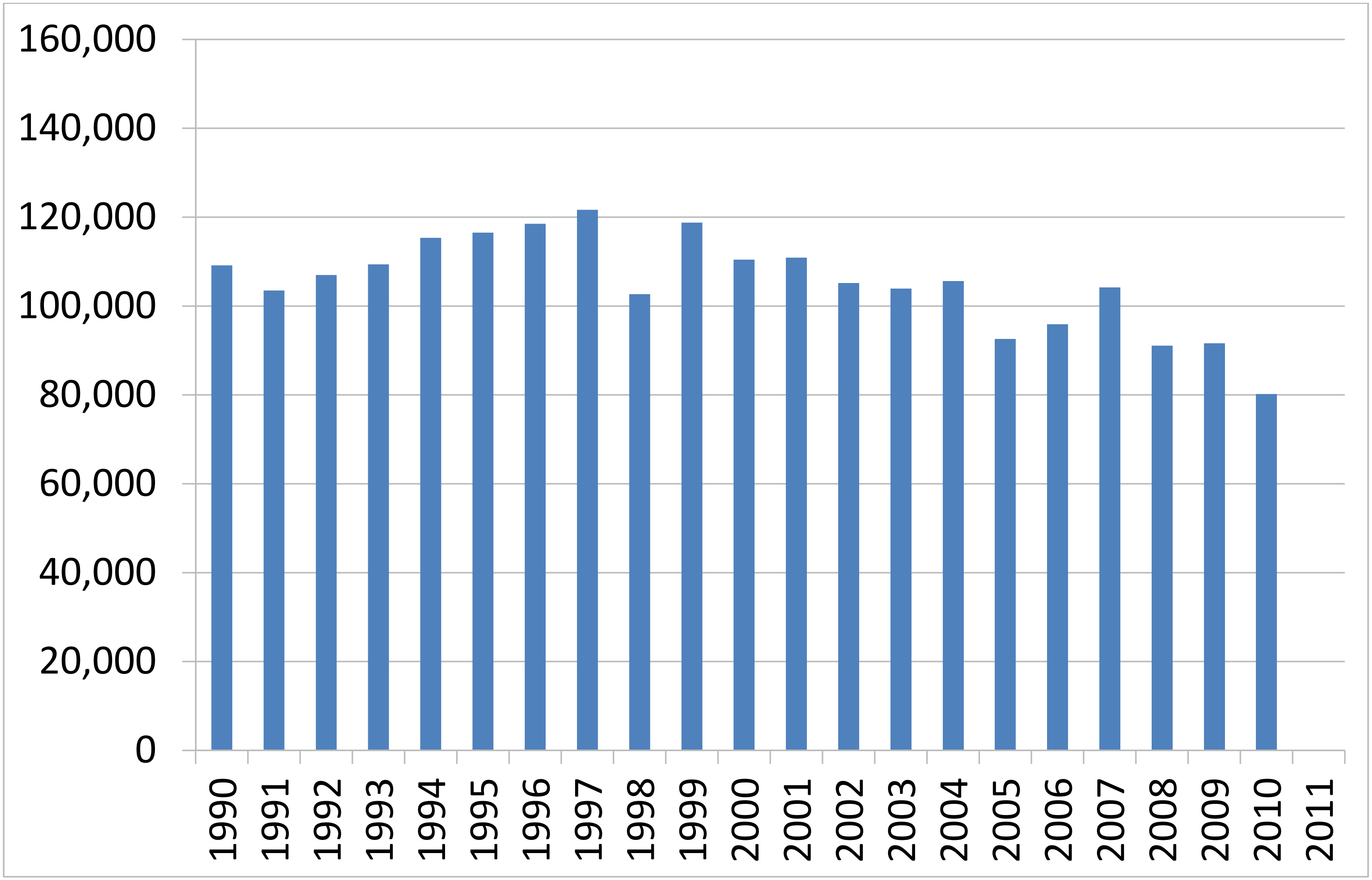

Figure 3. Reported pumping by municipal water purveyors within SGA area.

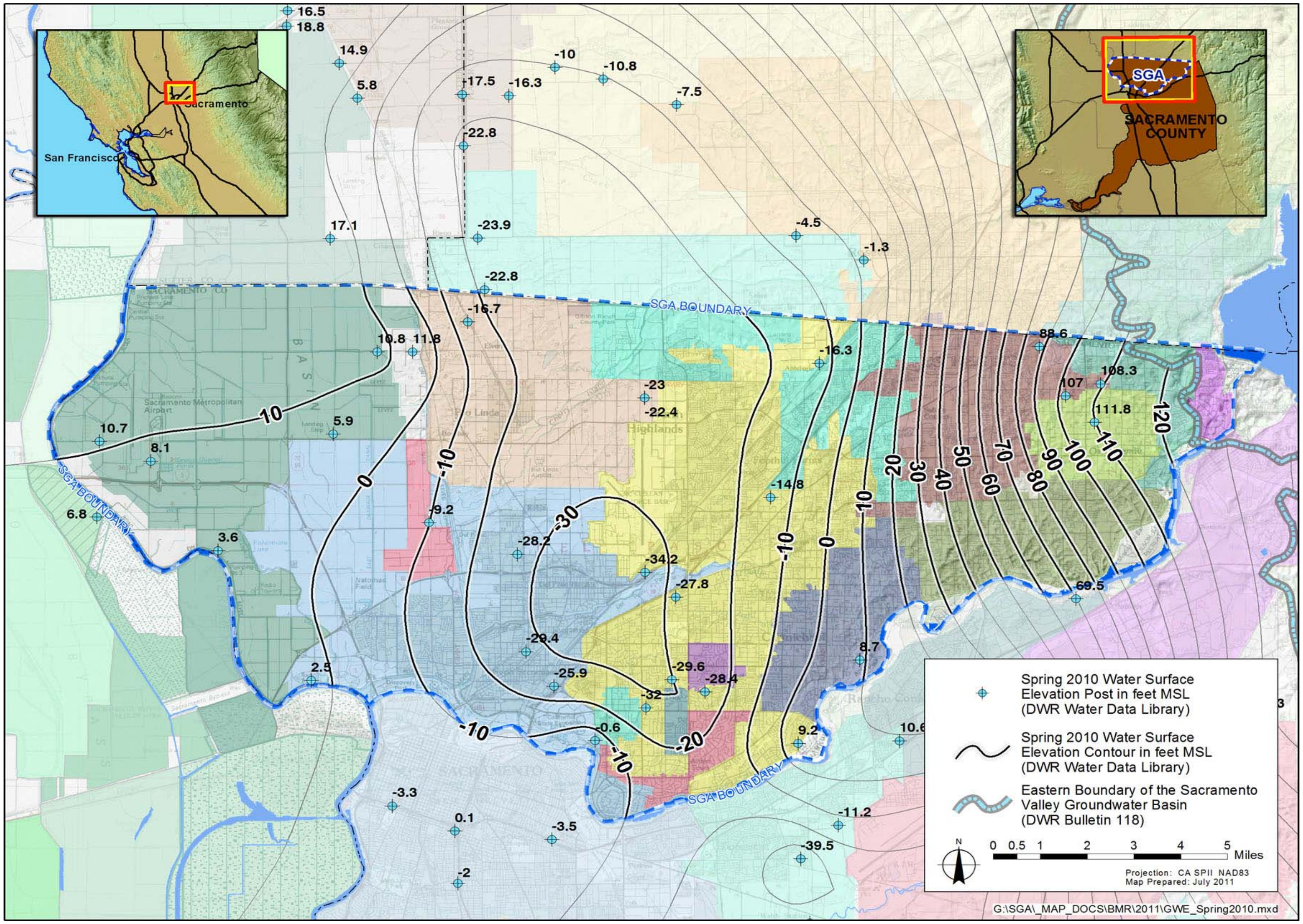

Figure 4. Spring 2010 groundwater elevations in SGA area.

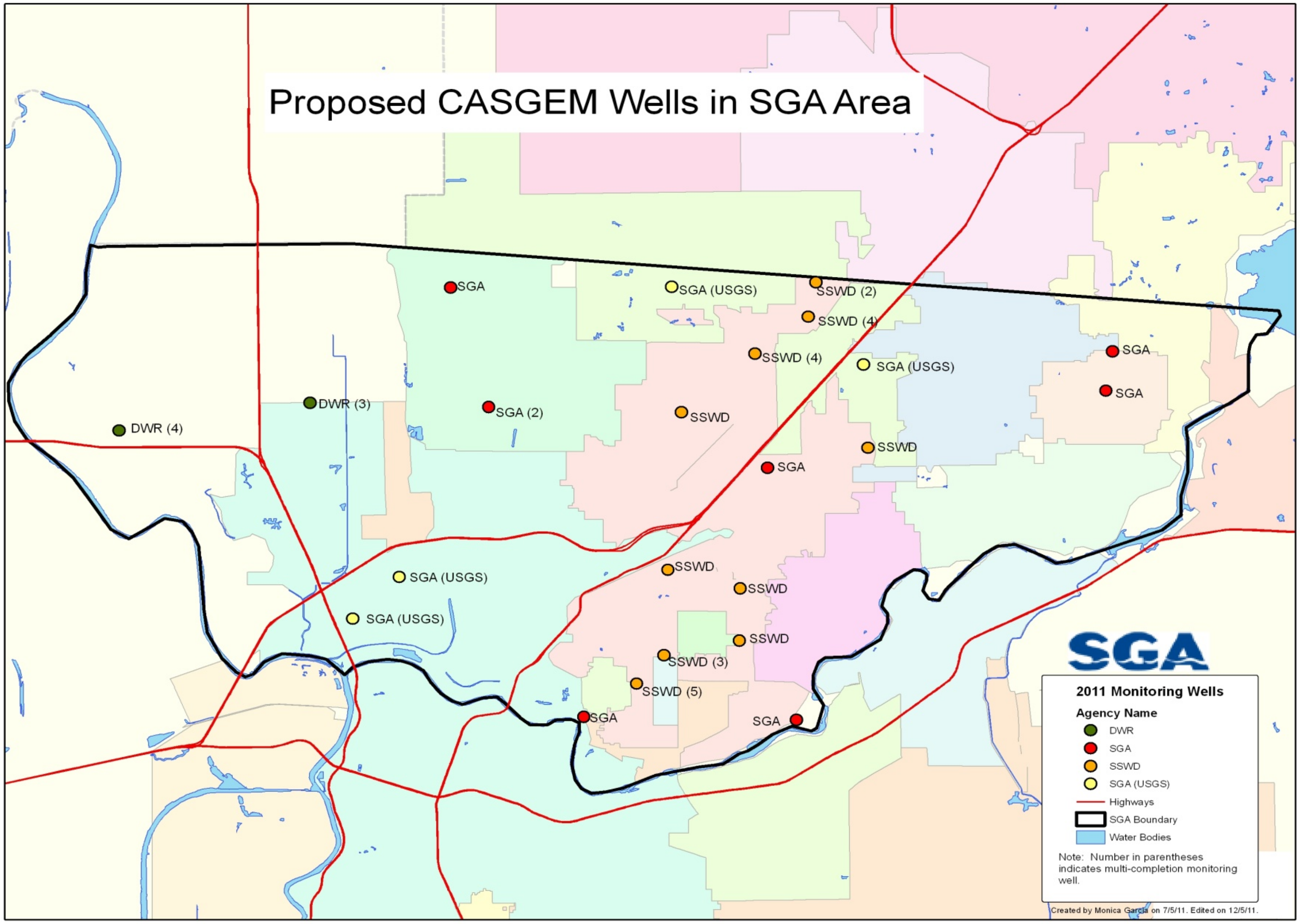

Figure 5. Locations of proposed wells in SGA CASGEM network.

Attachment 1

Excerpts from DWR Guidelines for Establishing Reference Points and Taking Water Level Measurements

Establishing the Reference Point

Water-level measurements from a given well must be referenced to the same datum (the reference point, or RP) to ensure data comparability (see Figure 4). For monitoring wells, the RP should be marked on the top of the well casing. For production wells, the RP will most likely be the top of the access tube or hole to the well casing. The RP must be as permanent as possible and be clearly visible and easily located. It can be marked with a permanent marker, paint, imprinting a mark with a chisel or punch, or by cutting a slot in the top of the casing. In any case, the location of the RP should be clearly described on DWR Form 429 (see Table 3). A photograph of the RP, with clear labeling, should be included in the well folder. In some cases, it may be valuable to establish multiple RPs for a well, depending on the consistent accessibility of the primary RP. In this case, each RP should be clearly described on DWR Form 429 and labeled in the field. The RP should be established with the following coordinate system: horizontal location (decimal latitude and longitude referenced to the North American Datum of 1983; NAD83) and vertical elevation (referenced to the North American Vertical Datum of 1988; NAVD88, in feet).

The land-surface datum (LSD) is established by the person making the initial water-level measurement at the well. The LSD is chosen to represent the average elevation of the ground around the well. Because LSD around a well may change over time, the distance between the RP and LSD should be checked every 3 to 5 years. If appropriate, a concrete well pad or well vault may be chosen as the LSD, since they will be more permanent than the surrounding ground surface.

The elevation of the RP can be determined in several ways: (1) surveying to a benchmark, (2) using a USGS 7.5’ quadrangle map, (3) using a digital elevation model (DEM), or (4) using a global positioning system (GPS). While surveying is the most accurate (± 0.1 ft), it is also the most expensive. Depending on the distance to the nearest benchmark, the cost can be prohibitive. The latitude and longitude of the well can be established accurately using a handheld GPS. From this information, the LSD can be located on a USGS quadrangle and the elevation estimated. However, the accuracy is only about ± one half of the contour interval. Thus, for a contour interval of 5 feet, the accuracy of the elevation estimate would be about ± 2.5 feet. The contour interval of high quality DEMs is currently about 30 feet. Therefore, the accuracy of using

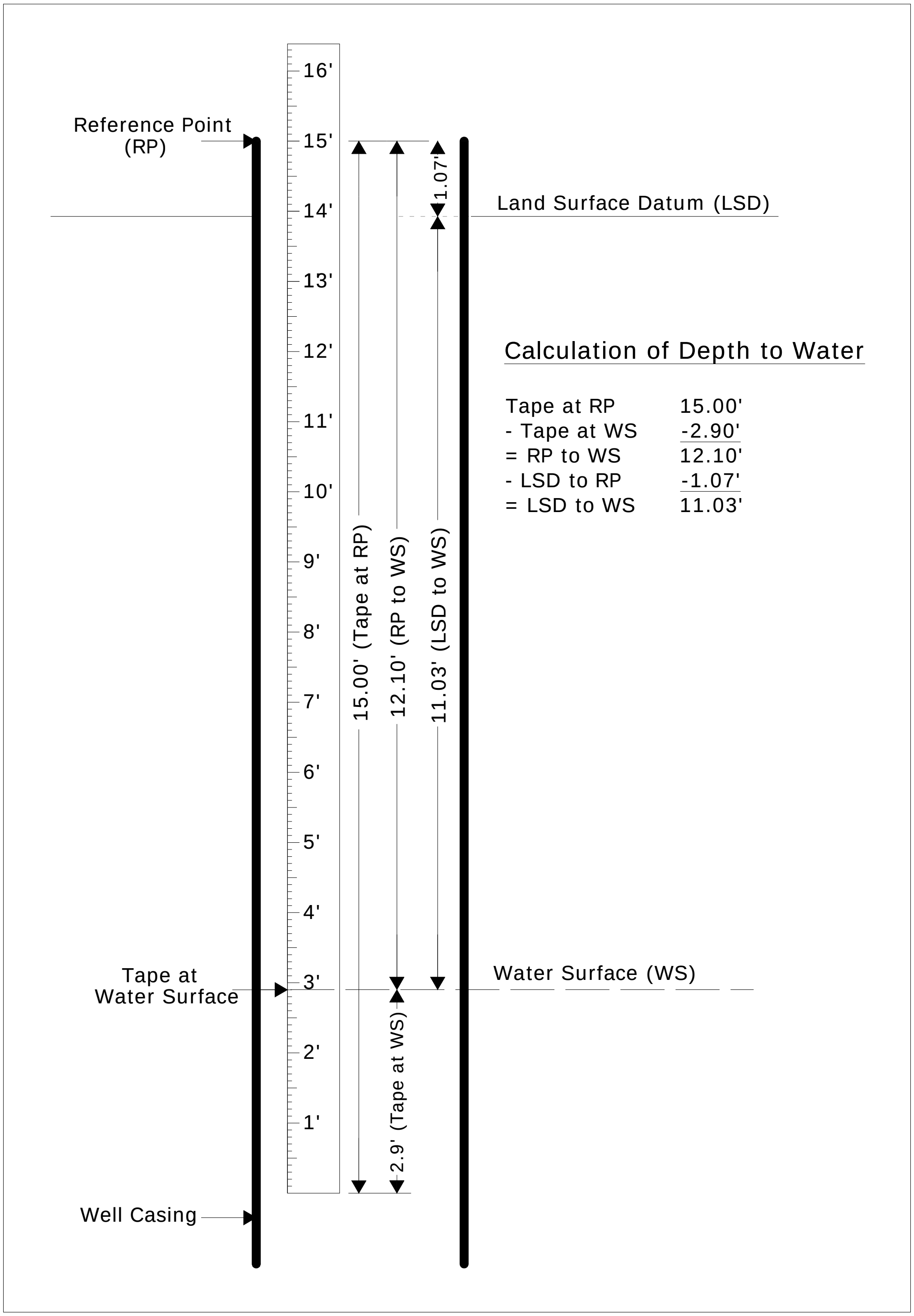

Figure 4. Groundwater-level measurements using a graduated steel tape (modified from U.S. Geological Survey, 2006).

State of California — DEPARTMENT OF WATER RESOURCES — California Natural Resources Agency

WELL DATA

State No. ______________________

District ______________________

OWNER	STATE NO.
ADDRESS	OTHER NO.
TENANT	
ADDRESS	

TYPE OF WELL	☐ SPECIAL STUDIES	☐ MONTHLY	☐ SEMI ANNUAL	☐ WATER QUALITY
LOCATION: COUNTY	BASIN		NO.	

U.S.G.S. QUAD.	QUAD NO.

1/4	1/4 SECTION	TWP.	RGE.	MD ☐ SB BASE & MERIDIAN H ☐

COORDINATES X:	Y:	SOURCE:

DESCRIPTION

REFERENCE POINT DESCRIPTION

WHICH IS	FT.	ABOVE ☐ BELOW ☐	LAND SURFACE.	GROUND ELEVATION	FT.

REFERENCE POINT ELEVATION	FT.	DETERMINED FROM

WELL: USE	CONDITION	DEPTH	FT.
CASING, SIZE	IN.,	PERFORATIONS	

MEASUREMENTS BY:	☐ DWR	☐ USGS	☐ USBR	☐ COUNTY	☐ IRR. DIST.	☐ WATER DIST.	☐ CONS. DIST.

CHIEF AQUIFER: NAME	DEPTH TO TOP AQ.	DEPTH TO BOT. AQ.
TYPE OF MATERIAL	PERM. RATING	THICKNESS
GRAVEL PACKED? ☐ YES ☐ NO	DEPTH TO TOP GR.	DEPTH TO BOT GR.
SUPP. AQUIFER	DEPTH TO TOP AQ.	DEPTH TO BOT. AQ.
DRILLER	DATE DRILLED:	LOG NUMBER:

EQUIPMENT: PUMP, TYPE		MAKE		
SERIAL NO.	SIZE OF DISCHARGE PIPE IN.	WATER ANALYSIS: MIN. (1)	SAN. (2)	H.M. (3)
POWER, KIND	MAKE	WATER LEVELS AVAILABLE: YES (1)	NO	
H.P.	MOTOR SERIAL NO	PERIOD OF RECORD: BEGIN	END	
ELEC. METER NO.	TRANSFORMER NO.	COLLECTING AGENCY:		
YIELD	G.P.M. PUMPING LEVEL FT.	PROD. REC. (1)	PUMP TEST (2)	YIELD (3)

SKETCH (N)	REMARKS
	RECORDED BY:
	DATE:

DWR 429 (Rev. 1/09)

Table 3. General well data form (DWR Form 429).

DEMs to determine the elevation of the LSD is about ± 15 feet. While a handheld GPS unit is not very accurate for determining elevation, more expensive units with the Wide Area Augmentation System can be more accurate. However, GPS readings are subject to environmental conditions, such as weather conditions, overhead vegetative cover, topography, interfering structures, and location. Thus, the most common method of determining the elevation will probably be the use of USGS quadrangles. The method used needs to be identified on DWR Form 429 (Table 3). The important matter is that all measurements at a well use the same RP, as the elevation of that point can be more accurately established at a later date. The equipment and supplies needed for establishing the RP are shown in Table 4.

If possible, establish a clearly displayed reference mark (RM) in a location near the well; for example, a lag bolt set into a nearby telephone pole or set in concrete in the ground. The RM is an arbitrary datum established by permanent marks and is used to check the RP or to re-establish an RP should the original RP be destroyed or need to be changed. Clearly locate the RP and RM on a site sketch that goes into the well folder (see Table 3). Include the distance and bearing between the RP and the RM and the height of the lag bolt above the ground surface. Photograph the site, including the RP and RM locations; draw an arrow to the RP and RM on the photograph(s) using an indelible marker, and place the photos in the well file.

Table 4. Equipment and Supply List

Equipment and supplies needed for (a) all measurements, (b) establishing permanent RP, (c) steel tape method, (d) electric sounding tape method, (e) sonic water-level meter, and (f) automated measurements with pressure transducer.
(a) All measurements
GPS instrument, digital camera, watch, calculator, and maps
General well data form (DWR Form 429; see Table 3)
Pens, ballpoint with non-erasable blue or black ink, for writing on field forms and equipment log books
Well file with previous measurements
Measuring tape, graduated in feet, tenths, and hundredths of feet
Two wrenches with adjustable jaws and other tools for removing well cap
Key(s) for opening locks and clean rags
(b) Establishing a permanent reference point
Steel tape, graduated in feet, tenths, and hundredths of feet
Calibration and maintenance log book for steel tape
Paint (bright color), permanent marker, chisel, punch, and(or) casing-notching tool

Table 4. Equipment and Supply List (continued)

(c) Steel tape method
DWR field form 1213 (see Table 5)
Steel tape, graduated in feet, tenths, and hundredths of feet
Calibration and maintenance log book for steel tape
Weight (stainless steel, iron, or other noncontaminating material – do not use lead)
Strong ring and wire, for attaching weight to end of tape. Wire should be strong enough to hold weight securely, but not as strong as the tape, so that if the weight becomes lodged in the well the tape can still be pulled free.
Carpenters' chalk (blue) or sidewalk chalk
Disinfectant wipes, and deionized or tap water for cleaning tape.
(d) Electric sounding tape method
DWR field form 1213 (see Table 5)
Steel tape, graduated in feet, tenths, and hundredths of feet
An electric tape, double-wired and graduated in feet, tenths, and hundredths of feet, accurate to 0.01 ft. Electric sounding tapes commonly are mounted on a hand-cranked and powered supply reel that contains space for the batteries and some device ("indicator") for signaling when the circuit is closed.
Electric-tape calibration and maintenance log book; manufacturer's instructions.
Disinfectant wipes, and deionized or tap water for cleaning tape.
Replacement batteries, charged.
(e) Sonic water-level meter method
DWR field form 1213 (see Table 5)
Temperature probe with readout and cable
Sonic water-level meter with factory cover plate
Custom sized cover plates for larger well diameters
Replacement batteries
(f) Automated measurements with pressure transducer
Transducer field form (see Figures 1 and 2 in Drost, 2005: http://pubs.usgs.gov/of/2005/1126/pdf/ofr20051126.pdf)
Transducer, data logger, cables, suspension system, and power supply.
Data readout device (i.e., laptop computer loaded with correct software) and data storage modules.
Spare desiccant, and replacement batteries.
Well cover or recorder shelter with key.
Steel tape (with blue carpenters' chalk or sidewalk chalk) or electric sounding tape, both graduated in hundredths of feet.
Tools, including high-impedance (digital) multimeter, connectors, crimping tool, and contact-burnishing tool or artist's eraser.

GUIDELINES FOR MEASURING WATER LEVELS

Monitoring wells typically have a cap on the wellhead. After the cap is removed, the open top of the well is easily accessible for sampling water levels and water quality. If the well is to be sampled for water quality in addition to water level, the water-level measurement should be made before the well is purged. Before discussing the detailed measurement steps for different methods, some guidance is provided on the common issues of well caps, recovery time after pumping, and cascading water in a well.

Well caps are commonly used in monitoring wells to prevent the introduction of foreign materials to the well casing. There are two general types of well caps, vented and unvented. Vented well caps allow air movement between the atmosphere and the well casing. Unvented well caps provide an airtight seal between the atmosphere and the well casing.

In most cases it is preferred to use vented well caps because the movement of air between the atmosphere and the well casing is necessary for normal water level fluctuation in the well. If the cap is not vented the fluctuation of groundwater levels in the well will cause increased or decreased air pressure in the column of air trapped above the water in the casing. The trapped air can prevent free movement of the water in the casing and potentially impact the water level that is measured. Vented caps will allow both air and liquids into the casing so they should not be used for wells where flooding with surface water is anticipated or contamination is likely from surface sources near the well.

Unvented well caps seal the top of the well casing and prevent both air and liquid from getting into the well. They are necessary in areas where it is anticipated that the well will be flooded from surface water sources or where contamination is likely if the casing is not sealed. Because the air above the water in the casing is trapped in the casing and cannot equalize with the atmospheric pressure, normal water level fluctuation may be impeded. When measuring a well with an unvented cap it is necessary to remove the cap and wait for the water level to stabilize. The wait time will vary with many different factors, but if several sequential water-level measurements yield the same value it can be assumed the water level has stabilized.

Unlike monitoring wells, production wells have obstructions in the well unless it is an abandoned production well and the pump has been removed. In addition, the wellhead is not always easily accessible for monitoring water levels. Since pumping from the production wells will create a non-static water level, the water-level measurement should ideally not be made until the water level has returned to static level. However, this recovery time will vary from site to site. Some wells will recover from pumping level to static level within a few hours, while many wells will take much longer to recover. Some wells will recover from pumping level to static level within a few hours, while many wells will take much longer to recover. Thus, as a general recommendation, measurements should not be collected until 24 hours after pumping has ceased, however, site specific

conditions may require deviating from this. The time since pumping should be noted on the field form.

Water may enter a well above the water level, drip or cascade down the inside of the well, and lead to false water level measurements. Sometimes cascading water can be heard dripping or flowing down the well and other times it is discovered when water levels are abnormally shallow and/or difficult to determine. Both steel tapes and electric sounding tapes can give false readings. A steel tape may be wet from the point where water is entering the well making it hard to see the water mark where the tape intersects the water level in the well. An electric sounding tape signal may start and then stop as it is lowered down the well. If this happens, you can lightly shake the tape. The signal often becomes intermittent when water is running down the tape, but remains constant in standing water. On most electric sounding tapes, the sensitivity can be turned down to minimize false readings. It should be noted when a water level measurement is taken from a well with cascading water.

(1) Steel Tape Method

The graduated steel-tape (wetted-tape) procedure is considered to be the most accurate method for measuring water levels in nonflowing wells. A graduated steel tape is commonly marked to 0.01 foot. When measuring deep water levels (>500 ft), thermal expansion and stretch of the steel tape starts to become significant (Garber and Koopman, 1968). The method is most accurate for water levels less than 200 feet below land surface. The equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

- It may be difficult or impossible to get reliable results if water is dripping into the well or condensing on the well casing.
- If the well casing is angled, instead of vertical, the depth to water should be corrected, if possible. This correction should be recorded in the field folder.
- **Check that the tape is not hung up on obstructions.**

Before making a measurement:

1. Maintain the tape in good working condition by periodically checking the tape for rust, breaks, kinks, and possible stretch. Record all calibration and maintenance data associated with the steel tape in a calibration and maintenance log book.

2. If the steel tape is new, be sure that the black sheen on the tape has been dulled so that the tape will retain the chalk.

3. Prepare the field forms (DWR Form 1213; see Table 5). Place any previous measured water-level data for the well into the field folder.

4. Check that the RP is clearly marked on the well and accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

5. In the field, wipe off the lower 5 to 10 feet of the tape with a disinfectant wipe, rinse with de-ionized or tap water, and dry the tape.

6. If possible, attach a weight to the tape that is constructed of stainless steel or other noncontaminating material to protect groundwater quality in the event that the weight is lost in the well. **Do not attach a weight for production wells.**

Making a measurement:

1. If the water level was measured previously at the well, use the previous measurement(s) to estimate the length of tape that should be lowered into the well. Preferably, use measurements that were obtained during the same season of the year.

2. Chalk the lower few feet of the tape by pulling the tape across a piece of blue carpenter's chalk or sidewalk chalk (the wetted chalk mark identifies that part of the tape that was submerged).

3. Slowly lower the weight (for monitoring wells only) and tape into the well to avoid splashing when the bottom end of the tape reaches the water. Develop a feel for the weight of the tape as it is being lowered into the well. A change in this weight will indicate that either the tape is sticking to the side of the casing or has reached the water surface. Continue to lower the end of the tape into the well until the next graduation (a whole foot mark) is at the RP and record this number on DWR Form 1213 (Table 5) next to "Tape at RP" as illustrated on Figure 4.

4. Rapidly bring the tape to the surface before the wetted chalk mark dries and becomes difficult to read. Record the number to the nearest 0.01 foot in the column labeled as "Tape at WS."

5. If an oil layer is present, read the tape at the top of the oil mark to the nearest 0.01 foot and use this value for the "Tape at WS" instead of the wetted chalk mark. Mark an "8" in the QM column of DWR Form 1213 (see Table 5) to indicate a questionable measurement due to oil in the well casing. There are methods to correct for oil, such as the use of a relatively inexpensive water-finding paste. The paste is applied to the lower end of the steel tape and the top of the oil shows as a wet line and the top of the water shows as a distinct color change. Since oil density is about three-quarters that of water, the water level can be estimated by adding three-quarters of the thickness of the oil layer to the oil-water interface elevation (U.S. Geological Survey, 2006).

6. Subtract the “Tape at WS” number from the “Tape at RP” number and record the difference (to the nearest 0.01 ft) as “RP to WS”. This reading is the depth to water below the RP.

7. Wipe and dry off the tape and re-chalk based on the first measurement.

8. Make a second measurement by repeating steps 3 through 5, recording the time of the second measurement on the line below the first measurement (Table 5). The second measurement should be made using a different “Tape at RP” than that used for the first measurement. If the second measurement does not agree with the original within 0.02 of a foot **(0.2 of a foot for production wells)**, make a third measurement, recording this measurement and time on the row below the second measurement with a new time. If more than two readings are taken, record the average of all reasonable readings.

After making a measurement:

1. Clean the exposed portion of the tape using a disinfectant wipe, rinse with de-ionized or tap water, and dry the tape. Do not store a steel tape while dirty or wet.

GROUNDWATER LEVEL DATA FORM
MANUAL MEASUREMENTS

WELL ID NUMBER	WELL NAME	STATE WELL NUMBER	COUNTY	B-118 BASIN OR SUBBASIN	MEASURING AGENCY	LAND SURFACE DATUM (LSD) ELEV.	RP TO LAND SURFACE DATUM (LSD), IN FT	REFERENCE POINT (RP) ELEV.

NO MEASUREMENT (NM)
0. Measurement discontinued
1. Pumping
2. Pump house locked
3. Tape hung up
4. Can't get tape in casing
5. Unable to locate well
6. Well has been destroyed
7. Special
8. Casing leaky or wet
9. Temporarily inaccessible

QUESTIONABLE MEASUREMENT (QM)
0. Caved or deepened
1. Pumping
2. Nearby pump operating
3. Casing leaky or wet
4. Pumped recently
5. Air or pressure gauge measurement
6. Other
7. Recharge operation at or nearby well
8. Oil in casing

MEASUREMENT METHOD (MM)
0. Steel tape
1. Electric sounding tape
2. Other

DATE	TIME	N M	Q M	MM	TAPE at RP	TAPE at WS	RP to WS	LSD to WS	OBS	COMMENTS

[For explanation of terms, see figure 1.]

DWR Form 1213 (modified 6/28/2010) (data for Water Data Library)

Table 5. Groundwater level data form for manual measurements (DWR Form 1213).

(2) Electric Sounding Tape Method

The electric sounding tape procedure for measuring depth to the water surface is especially useful in wells with dripping water or condensation, although there are still precautions needed as noted in the beginning of this section. Other benefits of this method include:

- Easier and quicker than steel tapes, especially with consecutive measurements in deeper wells.
- Better than steel tapes for making measurements in the rain.
- Less chance for cross-contamination of well water than with steel tapes, as there is less tape submerged.

The accuracy of electric sounding tape measurements depends on the type of tape used and whether or not the tape has been stretched out of calibration after use. Tapes that are marked the entire length with feet, tenths, and hundredths of a foot should be read to 0.01 ft. Electric sounding tapes are harder to keep calibrated than are steel tapes. As with steel tapes, electric sounding tapes are most accurate for water levels less than 200 ft below land surface, and thermal expansion and stretch start to become significant factors when measuring deep water levels (>500 ft) (see Garber and Koopman, 1968). Equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

- If the well casing is angled, instead of vertical, the depth to water will have to be corrected, if possible. This correction should be recorded in the field folder.
- **Check that the electric sounding tape is not hung up on an obstruction in the well.**
- The electric sounding tape should be calibrated annually against a steel tape in the field (using monitoring wells only) as follows: Compare water-level measurements made with the electric sounding tape to those made with a steel tape in several wells that span the range of depths to water encountered in the field. The measurements should agree to within ± 0.02 ft. If this accuracy is not met, a correction factor should be applied. All calibration and maintenance data should be recorded in a calibration and maintenance log book for the electric sounding tape.
- **Oil on the surface of the water may interfere with obtaining consistent readings and could damage the electrode probe. If oil is present, switch to a steel tape for the water-level measurement.**
- If using a repaired/spliced tape: see section A4-B-3(b) (page B16) of the NFM (U.S. Geological Survey, 2006).

Before making a measurement:

1. Inspect the electric sounding tape and electrode probe before using it in the field. Check the tape for wear, kinks, frayed electrical connections and possible stretch; the

cable jacket tends to be subject to wear and tear. Test that the battery and replacement batteries are fully charged.

2. Check the distance from the electrode probe’s sensor to the nearest foot marker on the tape, to ensure that this distance puts the sensor at the zero foot point for the tape. If it does not, a correction must be applied to all depth-to-water measurements. Record this in an equipment log book and on the field form.

3. Prepare the field forms (DWR Form 1213; see Table 5) and place any previous measured water-level data for the well into the field folder.

4. After reaching the field site, check that the RP is clearly marked on the well and is accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

5. Check the circuitry of the electric sounding tape before lowering the electrode probe into the well. To determine proper functioning of the tape mechanism, dip the electrode probe into tap water and observe whether the indicator needle, light, and/or beeper (collectively termed the “indicator” in this document) indicate a closed circuit. For an electric sounding tape with multiple indicators (sound and light, for instance), confirm that the indicators operate simultaneously. If they do not operate simultaneously, determine which is the most accurate and use that one.

6. Wipe off the electrode probe and the lower 5 to 10 feet of the tape with a disinfectant wipe, rinse with de-ionized or tap water, and dry.

Making a measurement:

1. If the water level was measured previously at the well, use the previous measurement(s) to estimate the length of tape that should be lowered into the well. Preferably, use measurements that were obtained during the same season of the year.

2. Lower the electrode probe slowly into the well until the indicator shows that the circuit is closed and contact with the water surface is made. Avoid letting the tape rub across the top of the well casing. Place the tip or nail of the index finger on the insulated wire at the RP and read the depth to water to the nearest 0.01 foot. Record this value in the column labeled “Tape at RP”, with the appropriate measurement method code and the date and time of the measurement (see Table 5).

3. Lift the electrode probe slowly up a few feet and make a second measurement by repeating step 2 and record the second measurement with the time in the row below the first measurement in Table 5. Make all readings using the same deflection point on the indicator scale, light intensity, or sound so that water levels will be consistent between measurements. If the second measurement does not agree with the first measurement within 0.02 of a foot **(0.2 of a foot for production wells)**, make a third measurement,

recording this measurement with the time in the row below the second measurement. If more than two readings are taken, record the average of all reasonable readings.

After making a measurement:

1. Wipe down the electrode probe and the section of the tape that was submerged in the well water, using a disinfectant wipe and rinse thoroughly with de-ionized or tap water. Dry the tape and probe and rewind the tape onto the tape reel. Do not rewind or otherwise store a dirty or wet tape.

(3) Sonic Water-Level Meter Method

This meter uses sound waves to measure water levels. It requires an access port that is 5/8 – inch or greater in diameter and measurement of the average air temperature in the well casing. The meter can be used to quickly measure water levels in both monitoring wells and production wells. Also, since this method does not involve contact of a probe with the water, there is no concern over cross contamination between wells. However, the method is not as accurate as the other methods, with a typical accuracy of 0.2 ft for water levels less than 100 ft or 0.2% for water levels greater than 100 ft. Equipment and supplies needed for this method are shown in Table 4.

The following issues should be considered with this method:

- The accuracy of the meter decreases with well diameter and should not be used with well diameters greater than 10 inches.
- An accurate air temperature inside the well casing is necessary so that the variation of sound velocity with air temperature can be accounted for.
- **Obstructions in the well casing can cause erroneous readings, especially if the obstruction is close to half the well diameter or more.**

Before making a measurement:

1. Check the condition of the meter, especially the batteries. Take extra batteries to the field.

2. Take a temperature probe with a readout and 50-ft cable.

3. If open wellheads with diameter greater than the factory cover plate and less than 10 inches will be monitored, fabricate appropriately-sized cover plates using plastic or sheet metal.

4. Prepare the field forms (DWR Form 1213; see Table 5). Place any previous measured water-level data for the well into the field folder.

5. Check that the RP is clearly marked on the well and accurately described in the well file or field folder. If a new RP needs to be established, follow the procedures above.

Making a measurement:

1. If the water level was measured previously at the well, lower the temperature probe to about half that distance in the well casing. Preferably, use measurements that were obtained during the same season of the year.

2. Record this temperature in the comments column of DWR form 1213 (see Table 5). Use this temperature reading to adjust the temperature toggle switch on the sonic meter.

3. Select the appropriate depth range on the sonic meter.

4. For a covered wellhead, insert the meter duct into the access port and push the power-on switch. Record the depth from the readout.

5. For an open wellhead, slip the provided cover plate onto the wellhead to provide a seal. If the cover plate is not large enough, use a fabricated cover plate for diameters up to 10 inches. Record the depth from the readout.

After making a measurement:

1. Make sure the temperature probe and the sonic meter are turned off and put away in their cases.

(4) Pressure Transducer Method

Automated water-level measurements can be made with a pressure transducer attached to a data logger. Care should be taken to choose a pressure transducer that accurately measures the expected range of groundwater levels in a well. Pressure-transducer accuracy decreases linearly with increases in the depth range (also known as pressure rating). A pressure transducer with a depth range of 0 to 10 ft (0 to 4.3 psi) has an accuracy of 0.01 ft while a pressure transducer with a depth range of 0 to 100 ft (0 to 43 psi) has an accuracy of 0.1 ft. But if the measurement range exceeds the depth range of a pressure transducer, it can be damaged. So it is important to have a good idea of the expected range of groundwater levels in a well, and then refer to the manufacturer's specification when selecting a pressure transducer for that well.

Some of the advantages of automated monitoring include:

- No correction is required for angled wells, as pressure transducers only measure vertical water levels.
- A data logger can be left unattended for prolonged periods until data can be downloaded in the field.
- Downloaded data can be imported directly into a spreadsheet or database.

Some of the disadvantages of automated monitoring include:

- It may be necessary to correct the data for instrument drift, hysteresis, temperature effects, and offsets. Most pressure transducers have temperature compensation built-in.
- Pressure transducers operate only in a limited depth range. The unit must be installed in a well in which the water level will not fluctuate outside the operable depth range for the specific pressure transducer selected. Wells with widely fluctuating water levels may be monitored with reduced resolution or may require frequent resetting of the depth of the pressure transducer.
- With some data loggers, previous water-level measurements may be lost if the power fails.

There are two types of pressure transducers available for measuring groundwater levels; non-vented (absolute) and vented (gauged). A non-vented pressure transducer measures absolute pressure, is relative to zero pressure, and responds to atmospheric pressure plus pressure head in a well (see Figure 5). A vented pressure transducer measures gauge pressure, is relative to atmospheric pressure, and only responds to pressure head in a well.

Non-vented pressure transducer data require post processing. Barometric pressure data must be collected at the same time as the absolute pressure data at the well, and subtracted from each absolute pressure data record before the data can be used to calculate groundwater levels. Thus, if a non-vented pressure transducer is used, a barometric pressure transducer will also be needed near the well. This subject is usually covered in more detail by the manufacturer of the pressure transducer. In an area with little topographic relief, a barometer at one site should be sufficient for use by other sites within a certain radius (9 miles reported by Schlumberger http://www.swstechnology.com/ groundwater-monitoring/groundwater-dataloggers/baro-diver and 100 miles reported by Global Water http://www.globalw.com/support/barocomp.html). In an area of significant topographic relief, it would be advisable to have a barometer at each site.

Vented pressure transducers can be programmed so no post processing of the data is necessary. The vent is usually a small tube in the communication cable that runs from the back of the pressure transducer to the top of the well. This vent enables the pressure transducer to cancel the effect of atmospheric pressure and record groundwater level as the distance from the RP to the WS (see Figure 5). However, if the vent is exposed to excessive moisture or submerged in water it can cause failure and damage to the pressure transducer.

The existing well conditions should be considered when deciding which type of pressure transducer to use. Non-vented pressure transducers should be used when the top of a well or its enclosure may at any time be submerged in water. This can happen when artesian conditions have been observed or are likely, the well is completed at or below the LSD, or the well or its enclosure are susceptible to periods of high water. Otherwise, it is advisable to use a vented pressure transducer.

The following guidelines are USGS guidelines from Drost (2005) and Freeman and others (2004) for the use of pressure transducers. These USGS guidelines have not been incorporated as yet in the NFM. The equipment and supplies needed for automated measurements of water level using a pressure transducer are shown in Table 4.

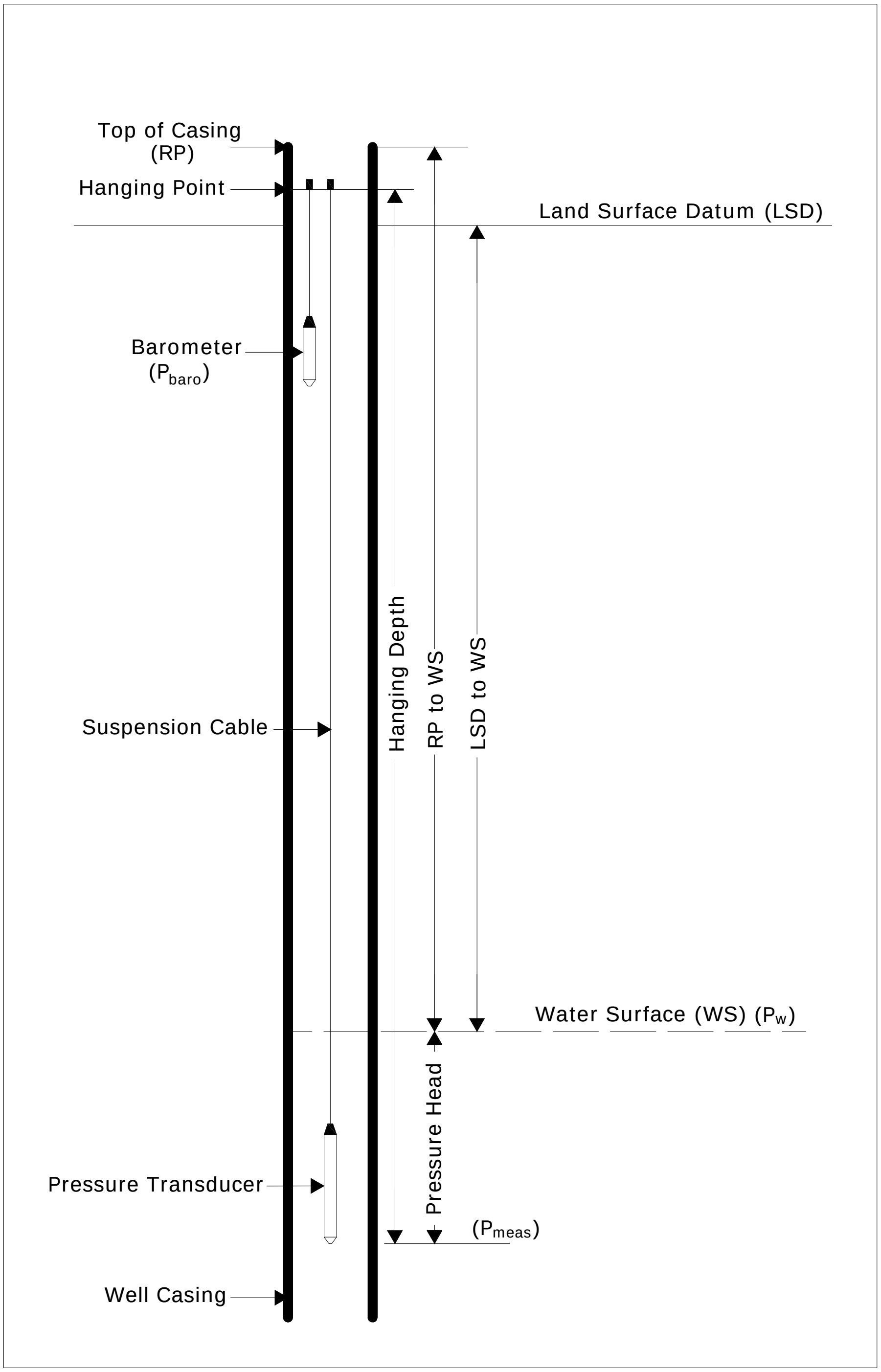

Figure 5. Groundwater-level measurements using a pressure transducer (vented or non-vented) (modified from Drost, 2005).

Before making a measurement:

1. Keep the pressure transducer packaged in its original shipping container until it is installed.

2. Fill out the DWR field form (Table 6), including the type, serial number, and range of measurement device; and what units are being measured (ft, psi).

3. Take a reading from the pressure transducer before placing into the well. For a vented pressure transducer the reading should be zero. For a non-vented pressure transducer the reading should be a positive number equivalent to atmospheric pressure. Configure the units (ft, psi) on a barometric pressure transducer the same as the non-vented pressure transducer. A reading from the barometric pressure transducer should be the same as the non-vented pressure transducer reading.

4. Lower the pressure transducer into the well slowly. Conduct a field calibration of the pressure transducer by raising and lowering it over the anticipated range of water-level fluctuations. Take two readings at each of five intervals, once during the raising and once during the lowering of the pressure transducer. Record the data on the DWR field form (see Table 6). If using a non-vented pressure transducer, take a reading from the barometric pressure transducer at the same time as the other readings.

5. Lower the pressure transducer to the desired depth below the water level (caution: do not exceed the depth range of the pressure transducer).

6. Fasten the cable or suspension system to the well head using tie wraps or a weatherproof strain-relief system. If the vent tube is incorporated in the cable, make sure not to pinch the cable too tightly or the vent tube may be obstructed.

7. Make a permanent mark on the cable at the hanging point, so future slippage, if any, can be determined.

8. Measure the static water level in the well with a steel tape or electric sounding tape. Repeat if measurements are not consistent within 0.02 ft **(0.2 ft for production wells)**.

9. Record the well and RP configuration, with a sketch. Include the RP height above the LSD, the hanging point, and the hanging depth (see Figure 5).

GROUNDWATER LEVEL DATA FORM
VENTED OR NON-VENTED PRESSURE TRANSDUCER WITH DATALOGGER

Station Information						Transducer Information						
Well ID Number	Well Name	State Well Number	County	Bulletin 118 GW Basin or Subbasin	Measuring Agency	Type of Pressure Transducer -- (A) Gauged (vented) or (B) Absolute (non-vented)?	Manufac-turer	Model	Serial Number	PSI Rating	Cable Length	Barometer Serial Number

Datum Measurements (in feet) [Date of Measurements:]

Reference Point (RP) Elevation (MSL) [from DWR Form 429]	RP to Land Surface Datum (LSD)	(1) RP to Hanging Point	(2) Hanging Depth	(3) RP to Pressure Transducer

Manual Readings									Datalogger Readings						Datalogger Servicing			
Date	Time	Obser-ver	NM	QM	MM	(4) Tape at RP	(5) Tape at WS	(6) RP to WS	(7) Transducer pressure (psi)	(8) Barometric pressure (psi)	(9) WS pressure (psi)	(10) WS above transducer (ft)	(11) RP to WS (ft)	Test Name	Download-ed data? (Y/N)	Batt. life left / new batteries? (%; Y/N)	Comments	

These cells only need to be filled out for non-vented transducers (which will have a barometer at the well in addition to the transducer)

Notes about calculated entries in form (referenced by number in cell): (3) = (1) + (2); (6) = (4) - (5) for steel tape; (6) = (4) for electric sounding tape; (9) = (7) - (8) for non-vented transducer; (9) = (7) for vented transducer; (10) = 2.3067 * (9); (11) = (3) - (10) [for explanation of terms, see figure 2]

NM (No Measurement) Codes: 0--Measurement discontinued 1--Pumping 2--Pump house locked 3--Tape hung up 4--Can't get tape in casing 5--Unable to locate well 6--Well has been destroyed 7--Special 8--Casing leaky or wet 9--Temporarily inaccessible

QM (Questionable Measurement) Codes: 0--Caved or deepened 1--Pumping 2--Nearby pump operating 3--Casing leaky or wet 4--Pumped recently 5--Air or pressure gauge measurement 6--Other 7--Recharge operation at or nearby well 8--Oil in casing

MM (Measurement Method) Codes: 0--Steel tape 1--Electric sounding tape 2--Other

DWR Form xxxx (data for Hydstra)

Table 6. Groundwater level data form for vented or non-vented pressure transducer with data logger.

10. Connect the data logger, power supply, and ancillary equipment. Configure the data logger to ensure the channel, scan intervals, units, etc., selected are correct. Activate the data logger. Most data loggers will require a negative slope in order to invert water levels for ground-water applications (i.e., distance from the RP to the WS). If using a non-vented pressure transducer the data logger will not require a negative slope, but atmospheric pressure data will need to be collected by a barometric pressure transducer.

Making a measurement:

1. Retrieve water-level data (to 0.01 ft) using instrument or data logger software. If using a non-vented pressure transducer, retrieve barometric pressure data.

2. Measure the water level with a steel tape or electric sounding tape (to 0.01 ft) and compare the reading with the value recorded by the pressure transducer and data logger. Record the reading and time in the file folder. If using a non-vented pressure transducer, subtract the barometric pressure value from the transducer pressure value to obtain the water level pressure value. The water level pressure can then be multiplied by 2.3067 to convert from psi of pressure to feet of water (Freeman and others, 2004). Report the calculated water level to the nearest 0.01 ft.

3. If the tape and pressure transducer readings differ by more than **(the greater of 0.2 ft or)** two times the accuracy of the specific pressure transducer, raise the pressure transducer out of the water and take a reading to determine if the cable has slipped, or whether the difference is due to drift. The accuracy of a pressure transducer is typically defined as 0.001 times the full scale of the pressure transducer (e.g., a 0 to 100 ft pressure transducer has a full scale of 100 ft). The accuracy of a specific pressure transducer should be specified by the manufacturer's specifications.

4. If drift is significant, recalibrate the pressure transducer as described using a steel tape. If using a non-vented pressure transducer, keep the pressure transducer out of the water and calibrate to the barometric pressure transducer value. If field calibration is not successful, retrieve the transducer and send back to the manufacturer for re-calibration.

5. Use the multimeter (see Table 4) to check the charge on the battery, and the charging current supply to the battery. Check connections to the data logger, and tighten as necessary. Burnish contacts if corrosion is occurring.

6. Replace the desiccant, battery (if necessary), and data module. Verify the data logger channel and scan intervals, document any changes to the data logger program and activate the data logger.

7. If possible, wait until data logger has logged a value, and then check for reasonableness of data.