

Monitoring Protocol for Inclusion in the GSP

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Butte County Department of Water and Resource Conservation

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1 Introduction

1.1 Regulations and Purpose of Monitoring Protocols

This document describes the protocols for the collection, recording, and storage of geologic and hydrologic data for agencies within the Vina, Wyandotte Creek, and Butte Subbasins (Subbasins), to support the implementation of Groundwater Sustainability Plans (GSPs) required by the Sustainable Groundwater Management Act (SGMA). The rationale of monitoring network design and site selection is discussed in the Monitoring Network section of the GSP, which is under development.

Pursuant to §352.2 and §10727.2 of the SGMA Emergency Regulations ^[1], shown below, monitoring protocols for data collection and management must be adopted to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence, and surface water flow and quality. The monitoring protocols described in this document are informed by existing monitoring protocols, when possible, and are intended to provide practical guidance for field personnel in the collection and management of data.

§ 352.2: Monitoring Protocols

Each Plan shall include monitoring protocols adopted by the Agency for data collection and management, as follows:

- (a) Monitoring protocols shall be developed according to best management practices.*
- (b) The Agency may rely on monitoring protocols included as part of the best management practices developed by the Department or may adopt similar monitoring protocols that will yield comparable data.*
- (c) Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan and modified as necessary.*

§ 10727.2 Required Plan Elements

- (f) Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin. The monitoring protocols shall be designed to generate information that promotes efficient and effective groundwater management.*

The establishment of monitoring protocols is closely related to other GSP sections. Subarticle 4 of the GSP Emergency Regulations requires the establishment of a monitoring network that includes monitoring objectives, monitoring protocols, and data reporting requirements. The protocols must allow for the monitoring network to collect ample data to establish seasonal, short-term, and long-term trends in groundwater levels, groundwater quality, inelastic surface subsidence, and surface water flow and quality. In addition, monitoring protocols ensure that the methods used in future data collection – in support of measuring the achievement of sustainability goals or occurrence of undesirable results are consistent with the methods used to establish these metrics.

The boundaries of Vina, Wyandotte Creek, and Butte Subbasins are shown in Figure 1.

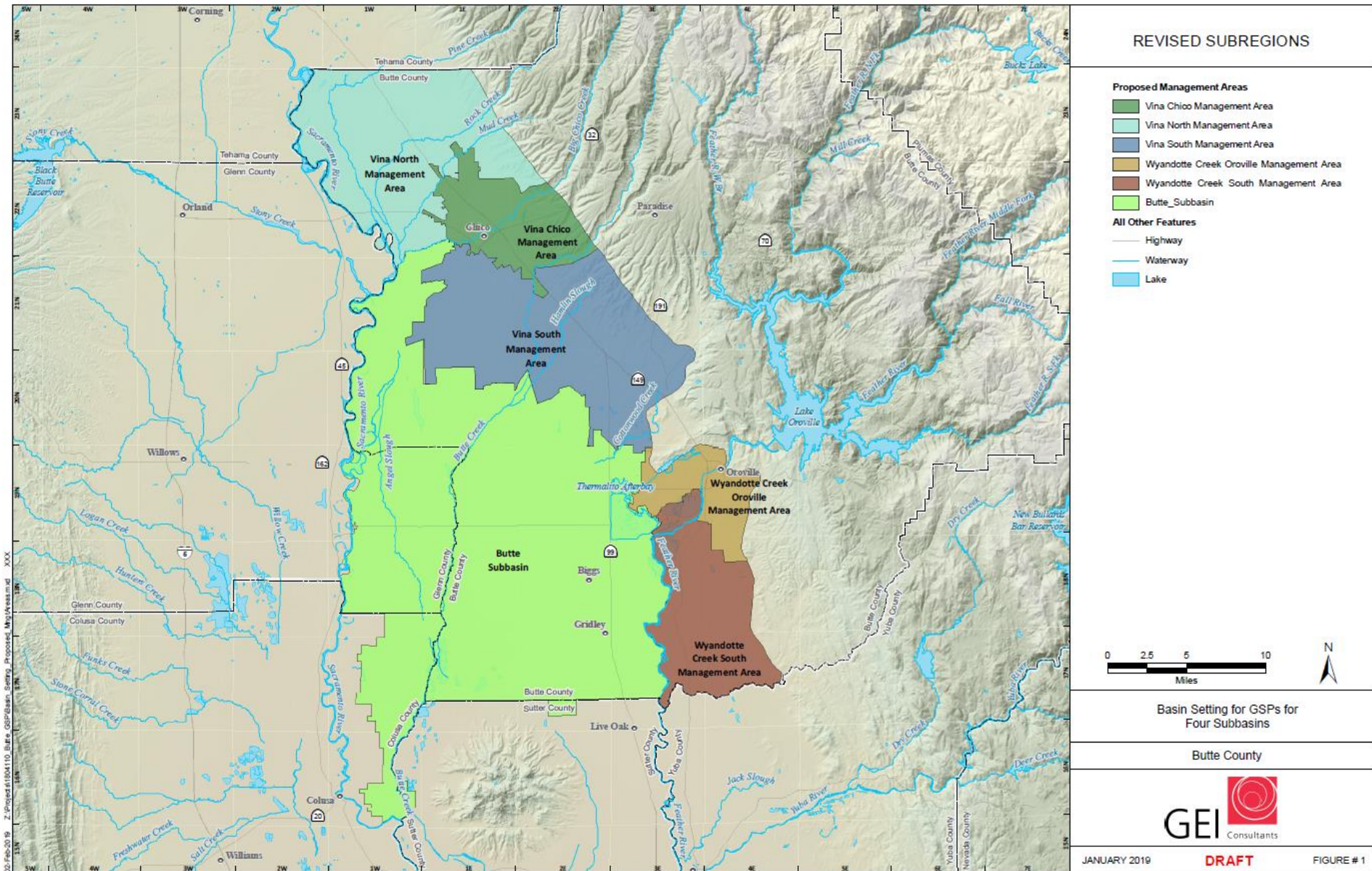


Figure 1. Butte County Subbasins and Neighboring Counties

1.2 Goals and Objectives

The objectives of this monitoring protocol are to establish the purposes for monitoring groundwater, surface water, and subsidence with subbasins, and to set forth standard practices to be widely, and uniformly applied when collecting data from monitoring sites to provide a sound technical foundation for compliance with SGMA. This protocol provides necessary tools and procedures for any GSA to monitor groundwater and surface water conditions within their boundaries.

1.3 Description of Monitoring Protocol Structure

The Department of Water Resources (DWR) recommends that GSAs consider the adoption of existing monitoring protocols when possible. Section 2 – Existing Monitoring Protocol – provides information and background of existing monitoring protocols used by agencies in the Sacramento Valley for each of the following:

- Groundwater Level;
- Water Quality;
- Subsidence, and
- Streamflow.

The adequacy of existing monitoring protocols will then be compared to the benchmarks established in DWR's *Monitoring Protocols, Standards, and Sites: Best Management Practices (BMP)* ^[2] document. Section 3 – Monitoring Protocol for Inclusion in the GSP – provides field personnel with a practical guide to collect and manage groundwater level, water quality, subsidence, and streamflow data. This section will be included as a chapter in the GSP and is adapted from existing monitoring protocols (Section 2) and then altered, as needed, to comply with the *BMP*.

The appendices to this protocol contain procedures or documents that are referenced in Sections 2 and 3.

2 Existing Monitoring Protocols

The Sacramento Valley Groundwater Basin covers an area of 4,900 square miles lying between the Coast Range to the west and the Cascade and Sierra Nevada Ranges to the east and extending from Red Bluff in the north to the Delta in the south. It covers parts of Sacramento, Placer, Solano, Yolo, Yuba, Sutter, Colusa, Tehama, Glenn and Butte counties and is the major source of groundwater in Butte County ^[3]. This monitoring protocol is intended for the Vina, Wyandotte Creek, and Butte Subbasins, which are part of the larger Sacramento Valley Groundwater Basin. Therefore, the protocols discussed in this section are derived from the counties that overlie any of these Subbasins (Butte County, Glenn County, and Colusa County) or agencies that operate within these counties. It should be noted that the Subbasins predominately lie within Butte County and therefore the protocols referenced in this section are often developed by Butte County.

2.1 Groundwater Level: Existing Protocols

Groundwater level monitoring within the Subbasins is well established, with the most comprehensive programs of data collection being performed by Butte, Glenn, and Colusa Counties. Some of this data is currently reported to DWR as part of the CASGEM network. To provide guidance for landowners and other agencies within the subbasins that monitor groundwater level, there are two protocols that are consistently relied upon:

- DWR's *Groundwater Elevation Monitoring Guidelines* (2010) ^[4]
- Glenn County's *Landowner Monitoring Guide* (2011) ^[5]

DWR's *Groundwater Elevation Monitoring Guidelines* provides detailed explanation of network design concepts and field guidelines for CASGEM water level measurements using a steel tape, electric sounding tape, sonic water level meter, or pressure transducer. Glenn County's *Landowner Monitoring Guide* similarly provides a protocol for the spatial and temporal components of monitoring, in addition to field guidelines for the collection and recording of water level data with electric sounding tape and steel tape.

Both the DWR and Glenn County documents provide example templates for data collection, shown in Figures 2 and 3, respectively.

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			QUESTIONABLE MEASUREMENT (QM) 0. Caved or deepened 1. Pumping 2. Nearby pump operating 3. Casing leaky or wet 4. Pumped recently			5. Unable to locate well 6. Well has been destroyed 7. Special 8. Casing leaky or wet 9. Temporarily inaccessible		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.]											

Figure 2. DWR Form 1213 for the Manual Measurement of Groundwater Level

Well Monitoring Form

"Must Have" information:			"Nice to have" information:	
Well Name: <u>Field 05</u>			Well Depth: <u>400 feet</u>	
Well Location/Description: <u>Near shed, green pump</u>			Screened Interval: <u>250-375</u>	
Measurement Point: <u>bolt on north side of casing</u>			Ground Surface Elevation: <u>200</u>	
Well type: <input type="checkbox"/> Domestic <input checked="" type="checkbox"/> Irrigation			Measurement Point Elevation: <u>202.4</u>	
<input type="checkbox"/> Other <input type="checkbox"/> Observation			GPS Coordinates:	
			Other Notes:	

1. Measurement Date	2. Depth to Water (feet)	3. Comments/Questionable Measurement	4. Measurement Point Elevation (feet above sea level)	5. Water Surface Elevation (feet above sea level)
<u>5/3/2013</u>	<u>34.5</u>	<u>none</u>	<u>202.4</u>	<u>167.9</u>
<u>6/4/2013</u>	<u>34.1</u>	<u>none</u>	<u>202.4</u>	<u>168.3</u>
<u>7/4/2013</u>	<u>33.1</u>	<u>none</u>	<u>202.4</u>	<u>169.3</u>
<u>8/1/2013</u>	<u>30.4</u>	<u>none</u>	<u>202.4</u>	<u>172</u>
<u>9/5/2013</u>	<u>31.8</u>	<u>none</u>	<u>202.4</u>	<u>170.6</u>

Figure 3. Glenn County Well Monitoring Form for the Manual Measurement of Groundwater Level

2.2 Water Quality: Existing Protocols

Pursuant to DWR's Best Management Practices for Groundwater Monitoring Protocols, Standards, and Sites (*BMP*) the use of existing water quality data within the basin should be done to the greatest extent possible to achieve the Data Quality Objectives (DQOs) for the Groundwater Sustainability Plan. To ensure that the existing water quality data is collected with the same methods, it is imperative that the data collection in support of GSPs developed within the Vina, Wyandotte Creek, and Butte Subbasins employ the same monitoring protocols. The following documents were consulted to determine the methods used for historical water quality data collection:

- *Groundwater Quality Trend Monitoring Program* (Butte County, 2012) ^[6]
- *Groundwater Quality Monitoring Yearly Process* (Butte County) ^[7]
- *HQd Portable Meter: Users Guide* (Hach, 2017) ^[8]

Each of these documents were created or used by Butte County to provide a protocol that ensures consistent collection of groundwater temperature, groundwater pH, and groundwater electrical conductivity. This water quality monitoring is in response to Butte County Code Chapter 33 and Chapter 33-A.

Together, the *Groundwater Quality Trend Monitoring Program* and *Groundwater Quality Monitoring Yearly Process* establish the objectives of the monitoring program and provide an explanation of the data gathering process. Water quality samples are collected by a Hach HQd Portable Meter, and field staff are required to consult the *HQd Portable Meter: Users Guide* to calibrate and operate the instrument properly.

Additional water quality data is collected within the Subbasins and reported by the Sacramento Valley Water Quality Coalition in response to the Irrigated Lands Regulatory Program. This data updates the Groundwater Quality Assessment Report (GAR) and is compiled from the following sources:

- SWRCB: GeoTracker GAMA geodatabase;
- USGS: NWIS Web Portal, and
- DWR: Water Data Library.

2.3 Subsidence: Existing Protocols

Pursuant of DWR's *BMP* document, land subsidence should be measured based on the USGS guidelines for measuring land subsidence, which were created in response to the most recent California drought. These protocols provided by USGS recommends the use of the following to measure subsidence:

- Interferometric Synthetic Aperture Radar (InSAR);
- Continuous GPS (CGPS);
- Spirit Leveling;
- Extensometers, and
- Piezometers.

Within the Subbasins, both CGPS and extensometers are currently used to measure land subsidence. Additionally, the processing of InSAR data has been completed for a limited period by NASA's Jet Propulsion Laboratory (JPL), which is available to the public through DWR^[9]. Although the USGS guidelines do not list surveying benchmarks, the region has an extensive network of benchmarks – especially along highways – which can be used to monitor relative elevations over time.

2.4 Streamflow: Existing Protocols

Multiple surface water features are located within or form the boundary of the Subbasins. These include:

- Feather River;
- Sacramento River;
- Butte Creek;
- Pine Creek;
- Rock Creek;
- Mud Creek;
- Cottonwood Creek;
- Lake Oroville, and
- Thermalito Afterbay.

Additional waterways are listed and described in the 2016 Water Inventory and Analysis Report^[10]. To monitor streamflow, a network of existing USGS gages and CDEC stations within the Subbasins has been developed. Streamflow measurements from this network are collected and reported in accordance with the procedures outlined in *USGS Water Supply Paper 2175*^[11], which are currently being used by both the USGS and DWR for streamflow monitoring throughout the State. *USGS Water Supply Paper 2175* provides detailed instructions for the measurement of flow with multiple methods, including: stage, current-meter method, moving-boat method, tracer dilution, and miscellaneous methods.

3 Monitoring Protocol for Inclusion in the GSP

This section provides a “how to” manual for field staff that emulates the content and format of DWR’s *BMP* and is informed by applicable existing protocols discussed in Section 2 – Existing Monitoring Protocol. Per the *BMP*, the collection of data should be based on the best available science and applied consistently throughout the subbasin to yield comparable data.

This section will explore the following:

- goals of the monitoring protocol;
- training requirements;
- data and reporting standards, and
- monitoring protocols for each data collection process.

Monitoring for the sustainability indicator of “significant and unreasonable seawater intrusion” into the areas covered by this monitoring protocol is not needed due to the isolation of Butte County and its neighboring counties from the ocean and from estuaries or other saline bodies of water connected to the ocean. The monitoring protocol is intended to address each of the other sustainability indicators.

3.1 Goals of the Monitoring Protocol

The overarching goal of this monitoring protocol is to provide agencies and field personnel with explicit instructions for the data collection, storage, and reporting of data to be included in the development and implementation of the GSPs. The adoption of these protocols allows for neighboring GSPs and, more broadly, GSPs statewide to have comparable data. The protocol will provide agencies the tools necessary to meet monitoring objectives described in the SGMA regulations. This includes the capture of data with a sufficient spatial distribution and temporal frequency to demonstrate short-term, seasonal, and long-term trends in basin conditions for each of the applicable sustainability indicators.

3.1.1 Data Quality and Consistency

To be considered for inclusion in a GSP, data used to monitor sustainability indicators should be held to a quality standard. Quality data comes from a reputable source with known, documented methods of collection. The adoption of statewide and regional protocol allows for comparable data that is held to a similar quality standard.

This monitoring protocol also provides a template for consistent data collection for GSPs. If the quality of previous data collection is adequate, the same methods should be continued for future data collection to allow for accuracy in trend analysis. Where methods deviate, GSPs must be explicit in explaining the methods and potential data gaps.

3.1.2 Standardized Data and Reporting

The following data and reporting standards from §352.4 are relevant to the collection of monitoring data:

- (1) *Water volumes shall be reported in acre-feet.*
- (2) *Surface water flow shall be reported in cubic feet per second and groundwater flow shall be reported in acre-feet per year.*
- (3) *Field measurements of elevations of groundwater, surface water, and land surface shall be measured and reported in feet to an accuracy of at least 0.1 feet relative to NAVD88, or another national standard that is convertible to NAVD88, and the method of measurement described.*
- (4) *Reference point elevations shall be measured and reported in feet to an accuracy of at least 0.5 feet, or the best available information, relative to NAVD88, or another national standard that is convertible to NAVD88, and the method of measurement described.*
- (5) *Geographic locations shall be reported in GPS coordinates by latitude and longitude in decimal degree to five decimal places, to a minimum accuracy of 30 feet, relative to NAD83, or another national standard that is convertible to NAD83.*

Pursuant to §352.4, all monitoring sites must include the following information:

- (1) *A unique site identification number and narrative description of the site location.*
- (2) *A description of the type of monitoring, type of measurement taken, and monitoring frequency.*
- (3) *Location, elevation of the ground surface, and identification and description of the reference point.*
- (4) *A description of the standards used to install the monitoring site. Sites that do not conform to best management practices shall be identified and the nature of the divergence from best management practices described.*

3.2 Training Requirements

Although not discussed in the *BMP*, the monitoring and data collection shall be completed by trained personnel. This monitoring protocol and all field equipment instructions, equipment calibration instructions, safety manuals, and other reference documents discussed in this protocol must be available to all personnel that conduct monitoring or data collection activities. Any laboratory used for water quality analysis must be accredited by the California Environmental Laboratory Accreditation Program.

3.3 Protocols

The GSP Regulations require the use of the protocols discussed in the *BMP*, or the development of similar protocols. Where applicable, the technical protocols described herein are adopted in their entirety and reprinted from the *BMP*, which leverages existing professional standards that are often adopted in various groundwater-related programs. When the protocol deviates from

the *BMP*, explanation for how the alteration or elaboration yields similar data is provided. The protocol for the selection and maintenance of monitoring sites is described in **Section XX – Monitoring Network**. All language that is taken directly from the *BMP* is shown in italics and any changes, additions, or edits are shown in brackets, [].

3.3.1 Groundwater Level: Protocol

The protocol for groundwater level monitoring described in the *BMP* is reprinted below. The field form shown in Figure 2 shall be used to record groundwater level measurements.

Groundwater levels are a fundamental measure of the status of groundwater conditions within a basin. In many cases, relationships of the sustainability indicators may be able to be correlated with groundwater levels. The quality of this data must consider the specific aquifer being monitored and the methodology for collecting these levels.

The following considerations for groundwater level measuring protocols should ensure the following:

- *Groundwater level data are taken from the correct location, well ID, and screen interval depth;*
- *Groundwater level data are accurate and reproducible;*
- *Groundwater level data represent conditions that inform appropriate basin management DQOs;*
- *All salient information is recorded to correct, if necessary, and compare data, and*
- *Data are handled in a way that ensures data integrity.*

General Well Monitoring Information

The following presents considerations for collection of water level data that include regulatory required components as well as those which are recommended.

Groundwater elevation data will form the basis of basin-wide water-table and piezometric maps and should approximate conditions at a discrete period in time. Therefore, all groundwater levels in a basin should be collected within as short a time as possible, preferably within a 1- to 2-week period.

Depth to groundwater must be measured relative to an established Reference Point (RP) on the well casing. The RP is usually identified with a permanent marker, paint spot, or a notch in the lip of the well casing. By convention in open casing monitoring wells, the RP reference point is located on the north side of the well casing. If no mark is apparent, the person performing the measurement should measure the depth to groundwater from the north side of the top of the well casing.

The elevation of the RP of each well must be surveyed to the North American Vertical Datum of 1988 (NAVD88), or a local datum that can be converted to NAVD88 [if not already

surveyed]. The elevation of the RP must be accurate to within 0.5 foot. It is preferable for the RP elevation to be accurate to 0.1 foot or less. Survey grade global navigation satellite system (GNSS) global positioning system (GPS) equipment can achieve similar vertical accuracy when corrected. Guidance for use of GPS can be found at USGS <http://water.usgs.gov/osw/gps/>. Hand-held GPS units likely will not produce reliable vertical elevation measurement accurate enough for the casing elevation consistent with the DQOs and regulatory requirements.

The sampler should remove the appropriate cap, lid, or plug that covers the monitoring access point listening for pressure release. If a release is observed, the measurement should follow a period of time to allow the water level to equilibrate.

Depth to groundwater must be measured to an accuracy of 0.1 foot below the RP. It is preferable to measure depth to groundwater to an accuracy of 0.01 foot. Air lines and acoustic sounders may not provide the required accuracy of 0.1 foot.

The water level meter should be decontaminated after measuring each well by:

1. Using deionized water to rinse the equipment;
2. Washing the equipment with an Alconox solution, then re-rinsing with deionized water;
3. Rinsing with the appropriate solvent type (such as isopropyl alcohol, acetone, or methanol, depending of the equipment's material composition);
4. Rinsing the equipment with deionized water several (at least three) times, and
5. Allowing equipment to dry on a clean surface (i.e. a polyethylene sheet) ^[12].

Measuring Groundwater Levels

Measure depth to water in the well using procedures appropriate for the measuring device. Equipment must be operated and maintained in accordance with manufacturer's instructions. Groundwater levels should be measured to the nearest 0.01 foot relative to the RP.

For measuring wells that are under pressure, allow a period of time for the groundwater levels to stabilize. In these cases, multiple measurements should be collected to ensure the well has reached equilibrium such that no significant changes in water level are observed. Every effort should be made to ensure that a representative stable depth to groundwater is recorded. If a well does not stabilize, the quality of the value should be appropriately qualified as a questionable measurement. In the event that a well is artesian, site specific procedures should be developed to collect accurate information and be protective of safety conditions associated with a pressurized well. In many cases, an extension pipe may be adequate to stabilize head in the well. Record the dimension of the extension and document measurements and configuration.

The sampler should calculate the groundwater elevation as:

$$GWE = RPE - DTW$$

Where:

- *GWE = Groundwater Elevation*
- *RPE = Reference Point Elevation*
- *DTW = Depth to Water*

The sampler must ensure that all measurements are in consistent units of feet, tenths of feet, and hundredths of feet. Measurements and RPEs should not be recorded in feet and inches.

Recording Groundwater Levels

The sampler should record the well identifier, date, time (24-hour format), RPE, height of RP above or below ground surface, DTW, GWE, and comments regarding any factors that may influence the depth to water readings such as weather, nearby irrigation, flooding, potential for tidal influence, or well condition. If there is a questionable measurement or the measurement cannot be obtained, it should be noted.

The sampler should replace any well caps or plugs, and lock any well buildings or covers.

All data should be entered into the data management system (DMS) as soon as possible. Care should be taken to avoid data entry mistakes and the entries should be checked [for quality assurance and quality control.]

Pressure Transducers

Groundwater levels and/or calculated groundwater elevations may be recorded using pressure transducers equipped with data loggers installed in monitoring wells. When installing pressure transducers, care must be exercised to ensure that the data recorded by the transducers is confirmed with hand measurements.

The following general protocols must be followed when installing a pressure transducer in a monitoring well:

- *The sampler must use an electronic sounder or chalked steel tape and follow the protocols listed above to measure the groundwater level and calculate the groundwater elevation in the monitoring well to properly program and reference the installation. It is recommended that transducers record measured groundwater level to conserve data capacity; groundwater elevations can be calculated at a later time after downloading.*
- *The sampler must note the well identifier, the associated transducer serial number, transducer range, transducer accuracy, and cable serial number.*

- *Transducers must be able to record groundwater levels with an accuracy of at least 0.1 foot. Professional judgment should be exercised to ensure that the data being collected is meeting the DQO and that the instrument is capable. Consideration of the battery life, data storage capacity, range of groundwater level fluctuations, and natural pressure drift of the transducers should be included in the evaluation.*
- *The sampler must note whether the pressure transducer uses a vented or non-vented cable for barometric compensation. Vented cables are preferred, but non-vented units provide accurate data if properly corrected for natural barometric pressure changes. This requires the consistent logging of barometric pressures to coincide with measurement intervals.*
- *Follow manufacturer specifications for installation, calibration, data logging intervals, battery life, correction procedure (if non-vented cables used), and anticipated life expectancy to assure that DQOs are being met for the GSP.*
- *Secure the cable to the well head with a well dock or another reliable method. Mark the cable at the elevation of the reference point with tape or an indelible marker. This will allow estimates of future cable slippage.*
- *The transducer data should periodically be checked against hand measured groundwater levels to monitor electronic drift or cable movement. This should happen during routine site visits, at least annually or as necessary to maintain data integrity.*
- *The data should be downloaded as necessary to ensure no data is lost and entered into the basin's DMS following the QA/QC program established for the GSP. Data collected with non-vented data logger cables should be corrected for atmospheric barometric pressure changes, as appropriate. After the sampler is confident that the transducer data have been safely downloaded and stored, the data should be deleted from the data logger to ensure that adequate data logger memory remains.*

3.3.2 Groundwater Quality: Protocol

For monitoring groundwater quality, the *Groundwater Quality Trend Monitoring Program* and *Groundwater Quality Monitoring Yearly Process* provide an explanation of the data gathering process. Water quality samples are collected by a Hach HQd Portable Meter and field staff are required to consult the *HQd Portable Meter: Users Guide* to calibrate and operate the instrument properly.

- *The Groundwater Quality Monitoring Yearly Process provides an overview of the yearly monitoring process, the sampling procedure, and the equipment checklist for field testing.*
- *The Groundwater Quality Trend Monitoring Program outlines general monitoring objectives, parameters to be monitored, and the definition of parameters and their importance. These parameters include Electrical Conductivity/Total Dissolved Solids, pH, and Temperature.*

The County's *Groundwater Quality Monitoring Yearly Process* is presented below and will guide groundwater quality monitoring for evidence of saline intrusion from brackish groundwater, performed for SGMA.

Groundwater Quality Monitoring Yearly Process

1. **3 weeks prior:** Send out initial contact letter to well owners. Follow up with email/phone call to schedule a specific appointment time according to predetermined route. Update contact information
2. Send out/phone reminders to well owners.
3. **Late July/Early August:** Conduct the Field Testing
4. Compile data: enter into excel tables, update summary report.
5. Mail "thank you" letter and preliminary results to well owners.
6. Email summary report to TAC members.
7. Possibly present monitoring results to the Water Commission.
8. Include data in Annual Groundwater Status Report.

Equipment Checklist for Field Testing:

- ✓ Field binder
- ✓ Hach Instrument
- ✓ pH buffer solutions (check expiration date)
- ✓ 2-3 bottles of deionized water (for rinsing probe)
- ✓ Paper towels
- ✓ Sampling bottle
- ✓ Wrench/pliers
- ✓ Camera

Information from the *Groundwater Quality Trend Monitoring Program* that provides relevant background to monitoring under SGMA is summarized below with the document presented in its entirety in Appendix B:

Electrical Conductivity/ Total Dissolved Solids

Degraded water quality is a predominant impact of over utilizing groundwater resources resulting in saline intrusion from among other sources, marine formations underlying freshwater aquifers. In Butte County, the primary freshwater bearing formations include the Tuscan Formation, overlying Alluvium deposits, Basin deposits, and the Riverbank and Modesto formations. A number of marine formations beneath the Tuscan formation make up the underlying saline aquifer system. Increasing salinity in groundwater wells could indicate over utilization of groundwater resources. To ensure sustainable management of local groundwater resources, monitoring efforts need to provide baseline trends related to salinity.

Total dissolved solid (TDS) concentrations are affected by the quantity and types of minerals present in the water. Since soil and rocks release ions into water flowing over or through them,

the geology of the aquifer plays a role in determining the amount and type of ions in solution, and because the concentration of total dissolved solids also determines the electrical conductivity, the two measures are related. Saltwater primarily contains sodium chloride (NaCl), but saline waters can owe their high salinity to a combination of other dissolved ions. The major positively charged ions (cations) are calcium (Ca⁺²), potassium (K⁺) and magnesium (Mg⁺²). The major negatively charged ions (anions) are chloride (Cl⁻), sulfate (SO₄⁻²), carbonate (CO₃⁻²), and bicarbonate (HCO₃⁻). Electrical conductivity is also greatly dependent on temperature, however most meters adjust EC readings to a standard 25°C (77 °F).

pH

pH, by definition, is dependent on the solution's hydrogen ion concentration and is a measure of how acidic or basic the water is. An abundance of hydrogen ions in solution (as indicated by low pH) can change concentrations of other substances present in the water, sometimes to a more or less toxic form. For example, a decrease in pH (below 6) may increase the amount of mercury (or other metals) soluble in water. pH therefore is important because it affects the solubility of substances in solution. The U.S. EPA has identified a desirable pH range of 6.5-8.5 as part of its Secondary Drinking Water Standards. pH is also an important parameter for irrigation water. The pH of the soil affects plant production and acceptable soil pHs vary by plant type. Irrigation water or precipitation can change the pH of the soil over time. Variation in pH can affect plant growth, nutrition, and susceptibility to pests. Nutrients present in the soil may be unavailable to plants due to a pH that is either too high or too low.

Temperature

Temperature is a standard parameter measured when assessing water quality mostly to indicate the point at which water being sampled is representative of aquifer water and not water standing in the well casing. Data is recorded when the temperature, pH and EC from the well stabilizes, typically after purging a minimum of three well volumes. Changes in temperature can also be an indication of other source waters migrating into the aquifer system such as stream seepage or flow from a different aquifer system.

The protocol for groundwater quality monitoring described in the *BMP* is reprinted below. The field form shown in Appendix A shall be used to record groundwater quality measurements.

All analyses should be performed by a laboratory certified under the State Environmental Laboratory Accreditation Program. The specific analytical methods are beyond the scope of this BMP but should be commensurate with other programs evaluating water quality within the basin for comparative purposes.

The following points are general guidance in addition to the techniques presented in the USGS National Field Manual for the Collection of Water Quality Data ^[13].

Standardized protocols include the following:

- *Prior to sampling, the sampler must contact the laboratory to schedule laboratory time, obtain appropriate sample containers, and clarify any sample holding times or sample preservation requirements.*
- *Each well used for groundwater quality monitoring must have a unique identifier. This identifier must appear on the well housing or the well casing to avoid confusion.*
- *In the case of wells with dedicated pumps, samples should be collected at or near the wellhead. Samples should not be collected from storage tanks, at the end of long pipe runs, or after any water treatment.*
- *The sampler should clean the sampling port and/or sampling equipment and the sampling port and/or sampling equipment must be free of any contaminants. The sampler must decontaminate sampling equipment between sampling locations or wells to avoid cross-contamination between samples.*
- *The groundwater elevation in the well should be measured following appropriate protocols described above in the groundwater level measuring protocols.*
- *For any well not equipped with low-flow or passive sampling equipment, an adequate volume of water should be purged from the well to ensure that the groundwater sample is representative of ambient groundwater and not stagnant water in the well casing. Purging three well casing volumes is generally considered adequate. Professional judgment should be used to determine the proper configuration of the sampling equipment with respect to well construction such that a representative ambient groundwater sample is collected. If pumping causes a well to be evacuated (go dry), document the condition and allow well to recover to within 90% of original level prior to sampling. Professional judgment should be exercised as to whether the sample will meet the DQOs and adjusted as necessary.*
- *Field parameters of pH, electrical conductivity, and temperature should be collected for each sample. Field parameters should be evaluated during the purging of the well and should stabilize prior to sampling. Measurements of pH should only be measured in the field, lab pH analysis are typically unachievable due to short hold times. Other parameters, such as oxidation-reduction potential (ORP), dissolved oxygen (DO) (in situ measurements preferable), or turbidity, may also be useful for meeting DQOs of GSP and assessing purge conditions. All field instruments should be calibrated daily and evaluated for drift throughout the day.*
- *Sample containers should be labeled prior to sample collection. The sample label must include: sample ID (often well ID), sample date and time, sample personnel, sample location, preservative used, and analytes and analytical method.*
- *[If possible], samples should be collected under laminar flow conditions. This may require reducing pumping rates prior to sample collection.*
- *Samples should be collected according to appropriate standards such as those listed in the Standard Methods for the Examination of Water and Wastewater, USGS National Field Manual for the Collection of Water Quality Data, or other appropriate guidance.*

The specific sample collection procedure should reflect the type of analysis to be performed and DQOs.

- *All samples requiring preservation must be preserved as soon as practically possible, ideally at the time of sample collection. Ensure that samples are appropriately filtered as recommended for the specific analyte. Entrained solids can be dissolved by preservative leading to inconsistent results of dissolve analytes. Specifically, samples to be analyzed for metals should be field-filtered prior to preservation; do not collect an unfiltered sample in a preserved container.*
- *Samples should be chilled and maintained at 4 °C to prevent degradation of the sample. The laboratory's Quality Assurance Management Plan should detail appropriate chilling and shipping requirements.*
- *Samples must be shipped under chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions.*
- *Instruct the laboratory to use reporting limits that are equal to or less than the applicable DQOs or regional water quality objectives/screening levels.*

Special protocols for low-flow sampling equipment:

- *In addition to the protocols listed above, sampling using low-flow sample equipment should adopt the following protocols derived from EPA's Low-flow (minimal drawdown) ground-water sampling procedures (Puls and Barcelona, 1996 ^[14]). These protocols apply to low-flow sampling equipment that generally pumps between 0.1 and 0.5 liters per minute. These protocols are not intended for bailers.*

Special protocols for passive sampling equipment:

- *In addition to the protocols listed above, passive diffusion samplers should follow protocols set forth in USGS Fact Sheet 088-00 ^[15].*

Note that the protocol for monitoring seawater intrusion (SI) has been excluded from this document, as the Butte County Subbasin and its neighboring counties are inland and thus not expected to require analysis of SI-dependent variables.

3.3.3 Subsidence: Protocol

The protocol for subsidence monitoring described in the *BMP* is reprinted below. Monitoring land surface displacement in the subbasin will rely upon existing and available data.

Evaluating and monitoring inelastic land subsidence can utilize multiple data sources to evaluate the specific conditions and associated causes. To the extent possible, the use of existing data should be utilized. Subsidence can be estimated from numerous techniques, they include: level surveying tied to known stable benchmarks or benchmarks located outside the area being studied for possible subsidence; installing and tracking changes in borehole extensometers; obtaining data from continuous GPS (CGPS) locations, static GPS surveys or

Real-Time-Kinematic (RTK) surveys; or analyzing Interferometric Synthetic Aperture Radar (InSAR) data. No standard procedures exist for collecting data from the potential subsidence monitoring approaches. However, an approach may include:

- *Identification of land subsidence conditions.*
 - *Evaluate existing regional long-term leveling surveys of regional infrastructure, i.e. roadways, railroads, canals, and levees.*
 - *Inspect existing county and State well records where collapse has been noted for well repairs or replacement.*
 - *Determine if significant fine-grained layers are present such that the potential for collapse of the units could occur should there be significant depressurization of the aquifer system.*
 - *Inspect geologic logs and the hydrogeologic conceptual model to aid in identification of specific units of concern.*
 - *Collect regional remote-sensing information such as InSAR, commonly provided by USGS and NASA. Data availability is currently limited, but future resources are being developed.*
- *Monitor regions of suspected subsidence where potential exists.*
 - *Establish CGPS network to evaluate changes in land surface elevation.*
 - *Establish leveling surveys transects to observe changes in land surface elevation.*
 - *Establish extensometer network to observe land subsidence. There are a variety of extensometer designs and they should be selected based on the specific DQOs.*

3.3.4 Streamflow: Protocol

The protocol for streamflow monitoring described in the *BMP* is reprinted below.

Monitoring of streamflow is necessary for incorporation into water budget analysis and for use in evaluation of stream depletions associated with groundwater extractions. The use of existing monitoring locations should be incorporated to the greatest extent possible.

Establishment of new streamflow discharge sites should consider the existing network and the objectives of the new location. Professional judgment should be used to determine the appropriate permitting that may be necessary for the installation of any monitoring locations along surface water bodies. Regular frequent access will be necessary to these sites for the development of ratings curves and maintenance of equipment.

To establish a new streamflow monitoring station special consideration must be made in the field to select an appropriate location for measuring discharge. Once a site is selected, development of a relationship of stream stage to discharge will be necessary to provide continuous estimates of streamflow. Several measurements of discharge at a variety of stream stages will be necessary to develop the ratings curve correlating stage to discharge. The use

of Acoustic Doppler Current Profilers (ADCPs) can provide accurate estimates of discharge in the correct settings. Professional judgment must be exercised to determine the appropriate methodology. Following development of the ratings curve a simple stilling well and pressure transducer with data logger can be used to evaluate stage on a frequent basis.

Streamflow measurements should be collected, analyzed, and reported in accordance with the procedures outlined in USGS Water Supply Paper 2175, Volume 1. – Measurement of Stage Discharge and Volume 2. – Computation of Discharge (USGS 2013). This methodology is currently being used by both the USGS and DWR for existing streamflow monitoring throughout the State.

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Appendix A: Field Forms for Protocols

Appendix B: Groundwater Quality Monitoring Yearly Process and Trend Monitoring Program
