FINAL TECHNICAL REPORT

Provide Persistent Data Services

National Groundwater Monitoring Network

U.S. Geological Survey Cooperative Agreement

Award No. G18AC00087

July 3, 2018 through July 2, 2020
(Extended through June 30, 2021)

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Overview of Work

This technical report was prepared in accordance with a cooperative grant agreement between the United States Geological Survey (USGS) and the Water Replenishment District of Southern California (District or WRD). The tasks described in this report were completed as required in the grant and are associated with the National Groundwater Monitoring Network (NGWMN). The NGWMN program is described further in a document entitled “A National Framework for Ground-Water Monitoring in the United States” dated July 2013 (USGS, 2013).

Grant agreement details are summarized as follows:

Project:	Provide Persistent Data Services
Grant No:	G18AC00087
Period:	07/03/18 to 07/02/20 (Period extended to 06/30/21)

In 1959, WRD was formed by a vote of the people for the purposes of protecting the groundwater resources of two adjudicated groundwater basins in southern Los Angeles County: Central Basin and West Coast Basin (CBWCB). WRD is also the local entity responsible for gathering and reporting water level data for both groundwater basins as part of California’s Statewide Groundwater Elevation Monitoring Program (aka, CASGEM) (WRD, 2011). WRD’s service area is shown below on Figure 1.

Figure 1 – WRD’s Service Area Boundary.

The USGS made available financial support to state or local water-resource agencies to join the NGWMN. The grant funding was organized into five main objectives including 1) support to become a new data provider, 2) support persistent data service from existing data providers, 3) filling data gaps, 4) well maintenance, and 5) well drilling. WRD received grant funding to become a data provider on July 3, 2018.

WRD's initial grant activities primarily focused on selecting representative groundwater monitoring wells for the monitoring network and developing the necessary procedures for staff to report water level and water quality data to the NGWMN. The work associated with these tasks was completed under Grant G18AC00087 with a performance period that originally ended July 2, 2020, but was later extended to June 30, 2021. The results for these tasks are described in this Technical Report.

Existing Groundwater Monitoring Network

For over 25 years, WRD has been studying the groundwater basin in cooperation with the USGS (2003a). Many scientific studies have been completed including the installation of hundreds of deep nested groundwater monitoring wells up a depth of approximately 2,900 feet below ground surface (ft bgs). The regional groundwater monitoring program currently consists of a network of 335 monitoring wells at 60 locations throughout the District (Figure 2).

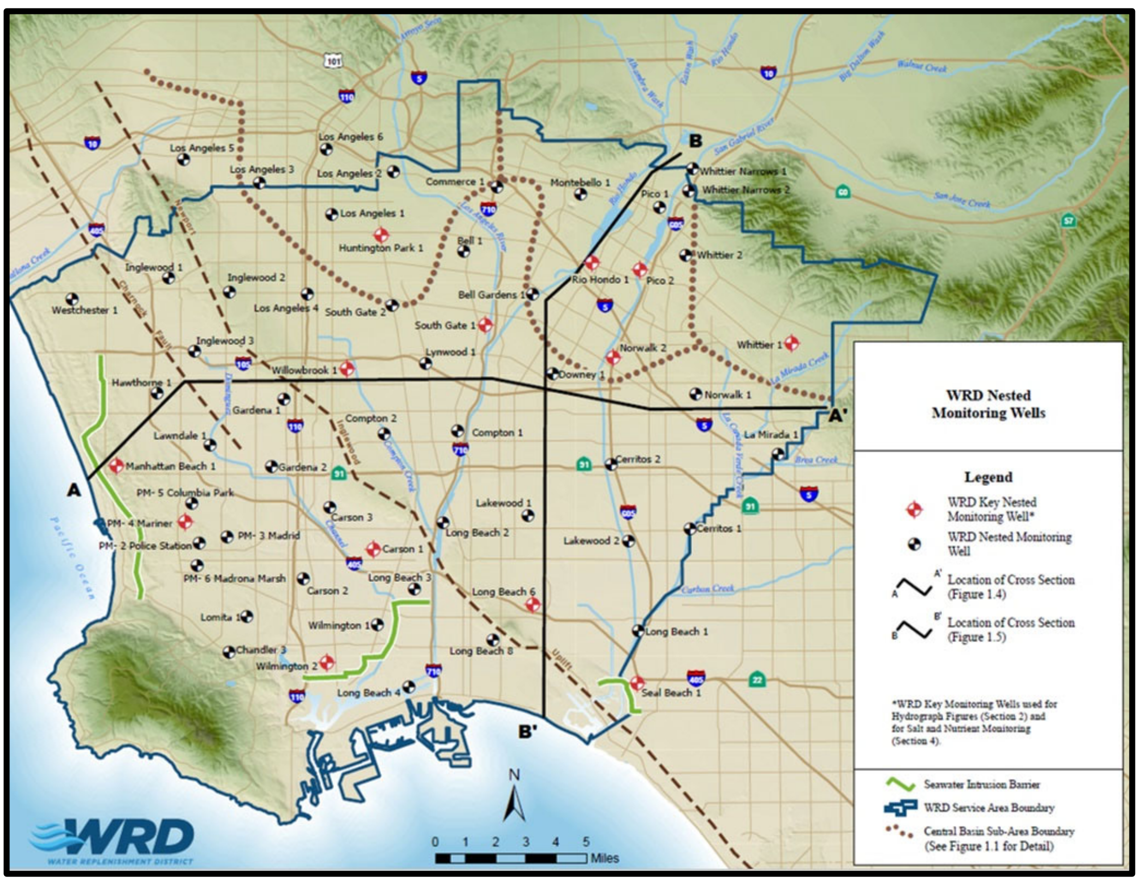
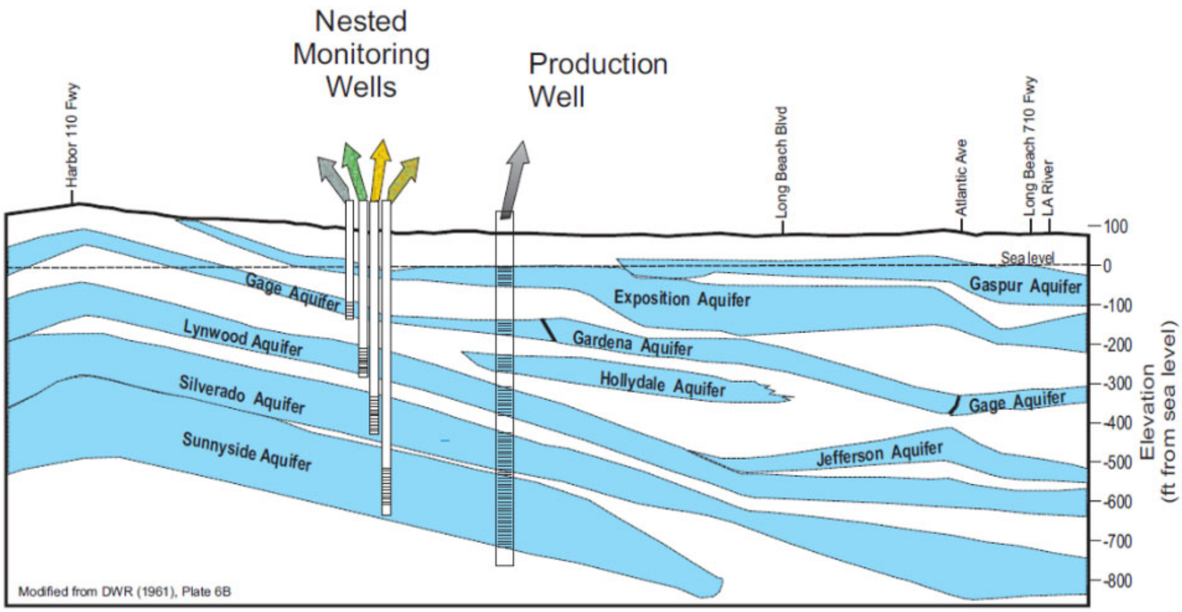


Figure 2 – Groundwater Monitoring Network

Historically, groundwater data was obtained from water supply wells that typically have long screen intervals completed across multiple aquifers resulting in a blended sample making it difficult to evaluate groundwater data from each specific aquifer in the CBWCB. Therefore, WRD and the USGS have spent the past couple decades installing a deep nested groundwater monitoring network to provide a much better dataset as conceptually shown on Figure 3.



Production wells are typically perforated across multiple aquifers producing an average water quality. Nested monitoring wells are screened in a portion of a specific aquifer, providing water quality and water level information for the specific zone.

Figure 3 – Nested Wells vs. Production Wells for Aquifer Specific Data

The basin geology and structures are generally described by the Department of Water Resources (DWR, 1961). The USGS also contributed to the basin interpretations through the development of a groundwater model for the Los Angeles Coastal Plains Aquifers (USGS, 2003a) and more recently using a modern sequence stratigraphic approach (USGS, 2021).

Site Selection

In 2011, WRD conducted a site selection analysis to identify key groundwater monitoring wells representative of groundwater conditions in both basins so long-term groundwater elevation trends could be evaluated across California CASGEM (WRD, 2011). Twenty eight (28) key groundwater monitoring wells were selected to represent groundwater conditions for the CBWCB. The Hopkins Method was used as a guideline to select a representative number of groundwater monitoring wells for each basin based the approximate area of each groundwater basin in square miles (mi^2) and the current pumping volume in acre feet per year (AFY). The CASGEM well density criteria are summarized below in Table 1.

Table 1
Well Density Criteria used for CASGEM

Criteria	Pumping Area (mi^2)	Pumping Amount (AFY)	Well Density (Wells per 100 mi^2)
A	100	>10,000	4.0
B	100	1,000-10,000	2.0
C	100	250-1,000	1.0
D	100	100-250	0.7

Note: Analysis based on Hopkins (1994).

The number of wells selected are summarized as follows:

- Central Basin has a total surface area of approximately 282 mi^2. In 2011, the average annual groundwater production was reportedly around 196,600 AFY. Therefore, 11 groundwater monitoring well locations were selected for monitoring under CASGEM.
- West Coast Basin has a total surface area of approximately 147 mi^2. In 2011, the average annual groundwater production was reportedly around 44,700 AFY. Therefore, 6 groundwater monitoring well locations were selected for monitoring under CASGEM.

The groundwater monitoring wells described above provide sufficient spatial distribution to represent seasonal variability and long-term trends for the CBWCB. However, 11 additional wells were included to account for the large vertical separation and gradient in water levels between the deep and shallower aquifer systems present in the CBWCB. Therefore, 28 groundwater monitoring wells are currently being utilized for monitoring under CASGEM.

In 2018, WRD conducted a second site selection analysis to identify key groundwater monitoring wells for the NGWMN. A smaller subset of groundwater monitoring wells was selected from the existing monitoring network currently used for CASGEM. Seventeen (17) groundwater monitoring wells were selected to best represent water levels and water quality associated with the primary drinking water source in the Upper San Pedro Formation (primarily consisting of the Silverado Aquifer). WRD regularly generates groundwater elevation contour maps for the drinking water aquifer and calculate annual storage changes in the CBWCB. The groundwater monitoring well details are summarized below in Table 1 and are shown below on Figure 4.

Table 1
Well Construction Details

#	Subbasin	State Well Number	WRDID	Well Name	Top of Screen (ft)	Bottom of Screen (ft)	Reference Elevation (ft)
1	West Coast	04S13W09H010S	100031	Carson1_2	740	760	26.86
2	West Coast	03S14W25K009S	101806	Gardena2_3	610	630	29.45
3	West Coast	03S14W17G006S	100890	Hawthorne1_4	400	420	88.98

Table 1
Well Construction Details

#	Subbasin	State Well Number	WRDID	Well Name	Top of Screen (ft)	Bottom of Screen (ft)	Reference Elevation (ft)
4	West Coast	02S14W28M005S	100093	Inglewood1_3	430	450	112.82
5	West Coast	04S14W04Q002S	100039	Mariner_2	500	540	100.38
6	West Coast	04S13W32F003S	100077	Wilmington2_3	540	560	32.30
7	Central	04S11W05P010S	100871	Cerritos1_2	1000	1020	43.10
8	Central	03S12W09J003S	100012	Downey1_3	580	600	99.39
9	Central	02S13W22C001S	100005	HuntingtonPark1_1	890	910	179.44
10	Central	04S13W01N005S	101742	Long Beach2_3	450	470	44.20
11	Central	04S12W21M011S	101795	Long Beach6_4	480	500	34.47
12	Central	02S14W12E005S	102073	LosAngeles3_5	330	350	145.71
13	Central	02S12W10Q008S	101773	Montebello1_4	370	390	193.11
14	Central	03S11W17F002S	101815	Norwalk1_2	990	1010	96.18
15	Central	02S12W26D012S	100067	RioHondo1_4	430	450	146.51
16	Central	03S11W02K006S	101738	Whittier1_4	450	470	217.35
17	Central	03S13W08J002S	100017	Willowbrook1_2	500	520	98.87

Notes:

- Elevations based on The North American Vertical Datum of 1988 (NAVD 88).
- Ft = Feet.

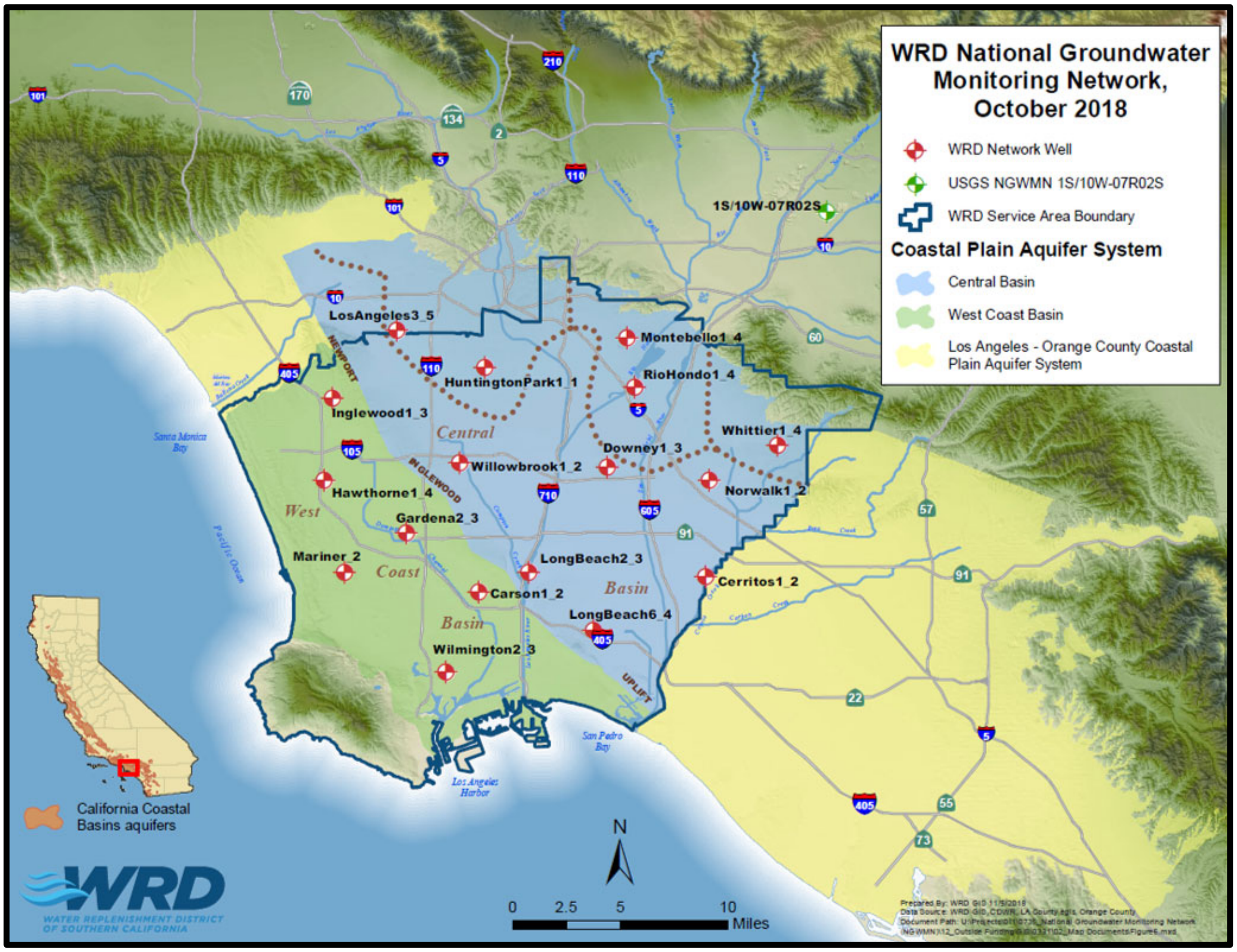


Figure 4 – Groundwater Monitoring Well Network for the NGWMN

Assigning Subnetworks and Monitoring Categories

In general, each monitoring well screen is currently assigned two designations; one based on the original basin interpretations by DWR (1961) and the other based on the more modern sequence stratigraphic interpretation by the USGS (2021). However, for the purposes of this groundwater monitoring program the data provided is generally representative of the primary drinking water source in the Upper San Pedro Formation (primarily consisting of the Silverado Aquifer).

Field Techniques for Groundwater Monitoring

WRD hydrogeologists collect water level and water quality data throughout the year and document the results in an annual Regional Groundwater Monitoring Report. Electronic pressure transducers have been installed in hundreds of key monitoring wells to collect continuous data with four readings recorded each day (or every 6 hours). Monitoring wells are also manually gauged each quarter and pressure transducer data is verified (and corrected if needed) by WRD. Groundwater samples are also collected for laboratory analysis semiannually in the spring generally commencing in February and fall generally commencing in July.

Land Survey

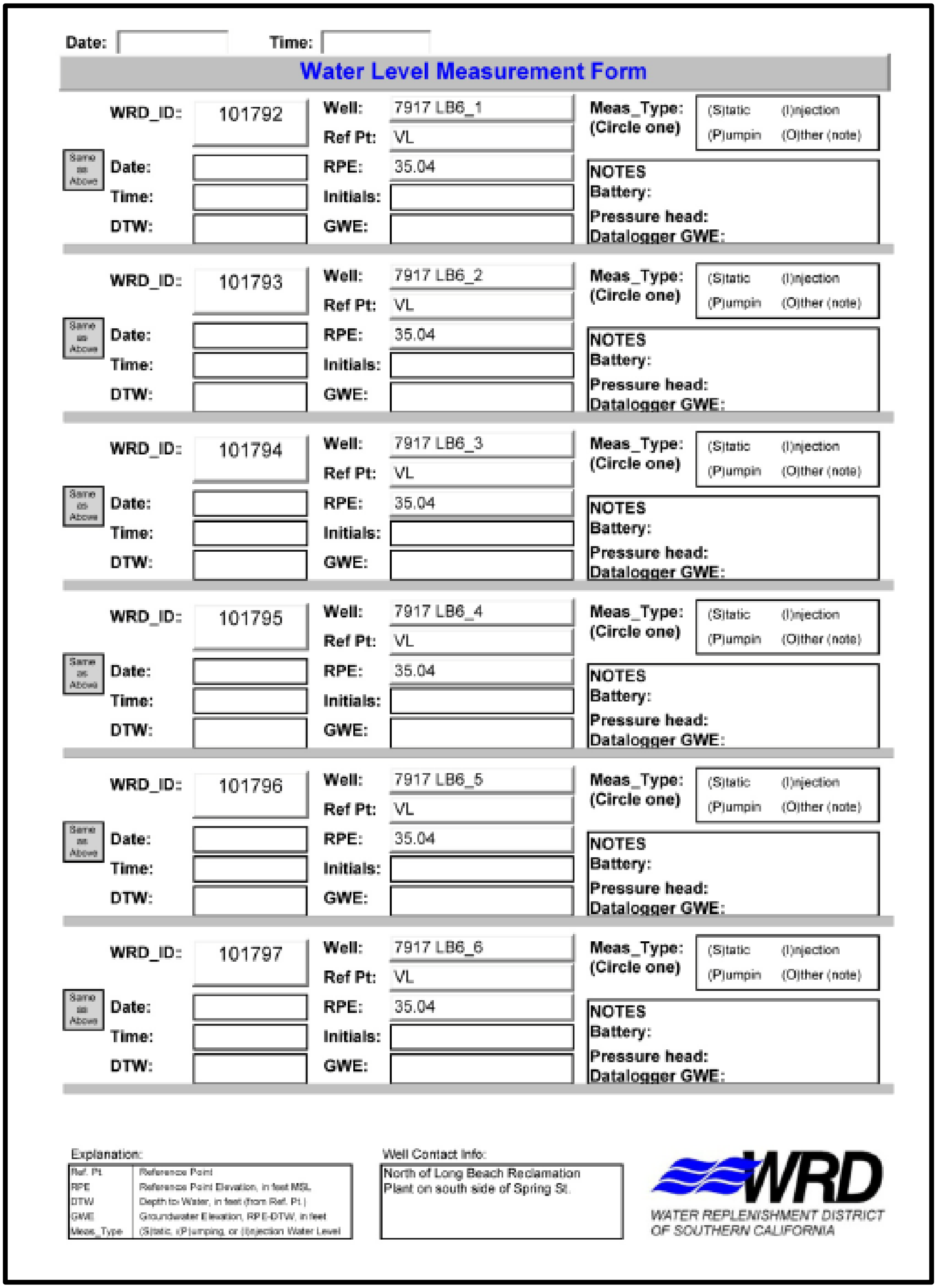
The location of each groundwater monitoring well was recorded by the USGS. A reference point (RP) is etched into the surface of the well vault and surveyed using a Trimble R7 base station receiver, Zephyr geodetic antenna, Seco 2-meter fixed height tripod and TSC-3 data collector, following procedures described by Rydlund and Densmore (USGS, 2012).

Water Levels

The depth to water is measured using an electronic water level meter in each groundwater monitoring well relative to a reference point at the surface (TOS). Measurements are recorded to the nearest 0.01 foot and converted to feet above mean sea level (ft msl). Daily and seasonal variations in water levels are also recorded using electronic pressure transducers as described above. The measurement steps conducted as follows:

1. The water level measurement is read off of a level placed across the well or vault lid at the RP. A bubble indicator signals when the level is horizontal with the RP.
2. The tape is slowly lowered down the well casing until the first beep. The sensitivity control may need to be adjusted until the beep is consistent and clear.
3. The tape is slowly raised and lowered several times to ensure the repeatability of the read.
4. If the readings are variable due to water fluctuations, an average of all readings is used and is noted on the measurement form.
5. The depth-to-water (DTW) is read where the tape meets the bottom of the horizontal level.
6. The depth-to-water measurement is then recorded (along with the date, time and the field person's initials) on the WRD Water Level Measurement Form (Figure 5).
7. The groundwater elevation (GWE) is calculated as RPE-DTW.
8. The measurement type is circled: 1) static 2) pumping 3) injection 4) other. Any anomalies in the water level collection are also recorded on the measurement form in the NOTES field.
9. The tape is reeled up, rinsed and cleaned with distilled or tap water over the entire length of the submerged section of tape. Excess water is wiped off with a clean cloth or paper towel.

WRD staff review the field measurements and if needed, wells are gauged a second time to verify the accuracy of the water level data prior to entering the final water level measurements to the Database Manager. The data is reviewed a second time prior to being published to our on-line hydrograph tool (https://hydrographs.wrd.org/) and uploaded to the NGWMN and CASGEM.



Date: Time:

Water Level Measurement Form

WRD_ID: 101792 | Well: 7917 LB6_1 | Meas_Type: (Circle one) (S)tatic (I)njection (P)umpin (O)ther (note)
Ref Pt: VL
Same as Above | Date: | RPE: 35.04 | NOTES
Time: | Initials: | Battery:
DTW: | GWE: | Pressure head:
Datalogger GWE:

WRD_ID: 101793 | Well: 7917 LB6_2 | Meas_Type: (Circle one) (S)tatic (I)njection (P)umpin (O)ther (note)
Ref Pt: VL
Same as Above | Date: | RPE: 35.04 | NOTES
Time: | Initials: | Battery:
DTW: | GWE: | Pressure head:
Datalogger GWE:

WRD_ID: 101794 | Well: 7917 LB6_3 | Meas_Type: (Circle one) (S)tatic (I)njection (P)umpin (O)ther (note)
Ref Pt: VL
Same as Above | Date: | RPE: 35.04 | NOTES
Time: | Initials: | Battery:
DTW: | GWE: | Pressure head:
Datalogger GWE:

WRD_ID: 101795 | Well: 7917 LB6_4 | Meas_Type: (Circle one) (S)tatic (I)njection (P)umpin (O)ther (note)
Ref Pt: VL
Same as Above | Date: | RPE: 35.04 | NOTES
Time: | Initials: | Battery:
DTW: | GWE: | Pressure head:
Datalogger GWE:

WRD_ID: 101796 | Well: 7917 LB6_5 | Meas_Type: (Circle one) (S)tatic (I)njection (P)umpin (O)ther (note)
Ref Pt: VL
Same as Above | Date: | RPE: 35.04 | NOTES
Time: | Initials: | Battery:
DTW: | GWE: | Pressure head:
Datalogger GWE:

WRD_ID: 101797 | Well: 7917 LB6_6 | Meas_Type: (Circle one) (S)tatic (I)njection (P)umpin (O)ther (note)
Ref Pt: VL
Same as Above | Date: | RPE: 35.04 | NOTES
Time: | Initials: | Battery:
DTW: | GWE: | Pressure head:
Datalogger GWE:

Explanation:

Ref. Pt.	Reference Point
RPE	Reference Point Elevation, in feet MSL
DTW	Depth to Water, in feet (from Ref. Pt.)
GWE	Groundwater Elevation, RPE-DTW, in feet
Meas_Type	(S)tatic, (P)umping, or (I)njection Water Level

Well Contact Info:
North of Long Beach Reclamation Plant on south side of Spring St.

WATER REPLENISHMENT DISTRICT OF SOUTHERN CALIFORNIA

Figure 5 – WRD Water Level Measurement Form

Water Quality

Annually, WRD collects over 600 groundwater samples from its monitoring well network and analyzes them for more than 100 water quality constituents to produce over 60,000 individual data points to help track the water quality in the CBWCB. The groundwater monitoring wells are generally purged of three casing volumes using a submersible pump until field parameters have stabilized for pH, turbidity, temperature, electrical conductivity, dissolved oxygen (DO), and oxidation reduction potential (ORP). The sample bottles are maintained in a chilled cooler until transported via courier under chain-of-custody to an analytical laboratory under contract with WRD.

Ten (10) constituents were selected to represent water quality for various constituent classes in both basins and include naturally occurring constituents (i.e., iron, nitrate, chloride, arsenic, manganese, and total dissolved solids) and key man-made constituents (i.e., perchlorate, hexavalent chromium, trichloroethene, and tetrachloroethene). The groundwater analytical data listed above as well as other constituents is presented in our annual groundwater monitoring report (https://www.wrd.org/reports/regional-groundwater-monitoring-report) and water quality data for the constituents listed above in key monitoring wells are uploaded to the NGWMN.

Minimum Data Elements

WRD established four data services to provide the USGS with (1) well construction casings, (2) well construction screens, (3) water levels and (4) water quality. Due to the architecture of the District's established master records on wells, data on casings and screens were deemed to be best delivered via separate services. The data elements for each service are described below in Table 2.

Table 2
Data Elements

Data Element	Description	Example Value
Well Construction Casings		
SITE_NO*	Unique identifier for each well (common field across all services).	100031
CASING_DEPTH_BEG_VALUE*	The numeric value for the depth to the top of the casing.	0
CASING_DEPTH_END_VALUE	The numeric value for the depth to the bottom of the casing.	740
CASING_DEPTH_UNIT	The unit in which depths are measured.	feet
CASING_DIAMETER_VALUE	The numeric value for the diameter of the casing.	2
CASING_DIAMETER_UNIT	The unit in which casing diameter is measured.	inches
CASING_MATERIAL	The material of the casing.	Blank PVC Schedule 80
DATA_PROVIDED_BY	Data provider for each data record (common field across all services and constant for every record).	WRDSOCAL

Table 2
Data Elements

Data Element	Description	Example Value
Well Construction Screens		
SITE_NO*	Unique identifier for each well (common across all services).	100031
SCREEN_DEPTH_BEG_VALUE*	The numeric value for the depth to the top of the screen.	740
SCREEN_DEPTH_END_VALUE	The numeric value for the depth to the bottom of the screen.	760
SCREEN_DEPTH_UNIT	The unit in which depths are measured.	feet
SCREEN_DIAMETER_VALUE	The numeric value for the diameter of the screen.	2
SCREEN_DIAMETER_UNIT	The unit in which screen diameter is measured.	inches
SCREEN_MATERIAL	The material of the screen.	Slotted PVC Schedule 80
DATA_PROVIDED_BY	Data provider for each data record (common field across all services and constant for every record).	WRDSOCAL
Water Levels		
SITE_NO*	Unique identifier for each well (common field across all services).	100031
MEASURE_DATE*	Date of measurement; field includes time precision, but time of day is absent here and instead presented in the next field.	2021-06-09T00:00:00Z
MEASURE_TIME	Time of measurement.	14:00:00
MEASURE_TIME_ZONE	Descriptive time zone for the recorded date and time of the measurement.	Pacific
DEPTH_TO_WATER_VALUE	The numeric value for the depth to water.	64.05
DEPTH_TO_WATER_UNIT	The unit in which depths are measured.	feet
MEASURE_METHOD	The method by which the measurement was taken.	Transducer
MEASURE_ACCURACY_VALUE	The numeric value for the accuracy of the measurement.	0.01
MEASURE_ACCURACY_UNIT	The unit for the accuracy of the measurement.	feet
DATA_PROVIDED_BY	Data provider for each data record (common field across all services and constant for every record).	WRDSOCAL

Table 2
Data Elements

Data Element	Description	Example Value
Water Quality		
SITE_NUMBER*	Unique identifier for each well (common field across all services).	100031
ACTIVITY_START_DATE	Date of the water quality sample collection.	2021-03-01
ACTIVITY_START_TIME	Time of day of the water quality sample collection.	11:30:00
TIMEZONECODE	The time zone for which the time of day is reported.	PST
CHARACTERISTIC_NAME	The property or substance which is evaluated or enumerated by either a direct field measurement, a direct field observation, or by laboratory analysis of material collected in the field.	Apparent Color
CHARACTERISTIC_STORET	Laboratory assigned alphanumeric code used to track analytes.	00081
MEASURE_VALUE	The reportable measure of the result for the chemical, microbiological or other characteristic being analyzed.	Non-Detect
UNITS	The code that represents the unit for measuring the value.	ACU
DETECTION_LIMIT	Constituent concentration that, when processed through the complete method, produces a signal that is statistically different from a blank.	3
VALUE_TYPE	A name that qualifies the process, which was used in the determination of the result value (e.g. actual, calculated, estimated).	Actual
SAMPLE_FRACTION	The text name of the portion of the sample associated with results obtained from a physically partitioned sample.	Total
METHOD_NAME	The identification number or code assigned by the method publisher.	2120
ANALYTICAL_METHOD_SYSTEM	The title that appears on the method from the method publisher.	SMB
SAMPLE_METHOD_ID	Methodology of sample collection.	Submersible Pump
SAMPLE_METHOD_ID_CONTEXT	Additional information about sampling method.	N/A
SAMPLE_METHOD_NAME	Type of sampling method.	Grab
ACTIVITY_TYPE_CODE	Description of the purpose of conducting WQ monitoring.	Sample-Routine
DATA_PROVIDED_BY	Data provider for each data record (common field across all services and constant for every record).	WRDSOCAL

Note: Asterisk (*) Indicates fields used to form a composite key for unique record identification.

The minimum data elements needed to distinguish unique records in each service are denoted with an asterisk (*) in Table 2. Note that a composite key is required to uniquely identify casings and screens because a well (identified by SITE_NO) can have more than one of each. This was in fact the case for one well in the casing dataset. Having multiple possible blank casing intervals per well serves as another reason to separate casings and screens from a unified well construction data service, which would have one well per record and would then require indefinite fields to accommodate an unknown number of casings for a well (e.g., fields named 1ST_CASING_DEPTH, 2ND_CASING_DEPTH, 3RD_CASING_DEPTH, etc.).

Missing Data Elements

WRD did not identify any missing data elements from the data services created. Many water level records in WRD's master SQL database have been excluded deliberately to provide the data service a more meaningful temporal resolution. Water level data acquired by transducers record four readings per day on average, and the frequency of readings made the data service large while providing more data than would be appropriate for most forms of analysis or visualization, such as hydrographs. WRD staff chose to produce the water levels data service with no more than one record per day. On days where more than one reading was taken, the reading taken closest to 14:00 local time was kept, and the rest excluded. This exclusion was only applied to the data service provided to the USGS and can be modified upon request.

WRD has not yet provided data services for lithology, but may include once data is compiled and cross-walked with USGS web services.

Web Services

New web services were established at WRD for the NGWMN, as no similar services existed prior to this need. The data for the services originate from a SQL Server database, which is protected behind the District's firewall. The data are regularly extracted, transformed, and loaded onto an externally hosted server where they can be accessed publicly in XML format via a custom-built REST API.

The four services can be found at the following URLs, requiring a value for the SITE_NO parameter (SITE_NO 100031 is used as an example here).

- https://data-apps.wrd.org/usgs_ngwmn/usgs_ngwmn_wellconstructioncasing.php?SITE_NO=100031
- https://data-apps.wrd.org/usgs_ngwmn/usgs_ngwmn_wellconstructionscreen.php?SITE_NO=100031
- https://data-apps.wrd.org/usgs_ngwmn/usgs_ngwmn_waterlevel.php?SITE_NO=100031
- https://data-apps.wrd.org/usgs_ngwmn/usgs_ngwmn_waterquality.php?rowid=100031

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