Appendix 5A

County CASGEM Monitoring Plans

CASGEM Monitoring Plan

To meet the requirements of SBX7 6

Submitted by the Glenn County Department of Agriculture

on behalf of the Glenn County Water Advisory Committee

August 2011

Glenn County CASGEM Monitoring Plan

Glenn County has applied to be a monitoring and reporting entity for the geographic area within the boundaries of the county where alluvial groundwater basins identified in Bulletin 118 are located. In 2000, Glenn County adopted a Groundwater Management Plan in where 17 groundwater management sub-areas were identified. For CASGEM, not all sub-basins qualify for monitoring as described in the legislation. Monitoring and reporting will be accomplished through cooperative agreements with all groundwater subareas throughout the County. The cooperating agencies that conduct monitoring will submit the data to Glenn County. The County will submit the monitoring data to Department of Water Resources (DWR). Information on the monitoring plan will be available to the public at www.glenncountywater.org

Monitoring Plan Overview

Groundwater monitoring in Glenn County is currently performed by the DWR. They collect data from 156 groundwater data points, 82 of those are discreet zones from the network of 26 dedicated monitoring wells. For the purposes of CASGEM, monitoring will be from selected zones in the dedicated network and irrigation wells where needed to fill in a monitoring gap. The wells (zones) selected should adequately characterize the basin.

The valley portion of the County is mostly in the Colusa Basin (5-21.52), a small portion in the north is in the Corning Basin (5-21.51) and a small portion in the east is in the West Butte Basin (5-21.58). These areas will be adequately represented in the monitoring network. The western portion of the Colusa Basin has limited water resources development and is considered low priority at this time. There are very few wells in the area and a small population base. No monitoring will occur in this area at this time, but will be reassessed on an as needed basis.

The groundwater sub-basins outside of the valley consist of shallow wells constructed in shale and rock formations and are not considered alluvial, although the basins are listed in Bulletin 118, and will not be included in the monitoring network. There are limited water resources development with minimal yield per well (typically averaging less than 5 gallons per minute), and are considered low priority. These areas include Chrome Town Area (5-61), Elk Creek Area (5-62), Stony Gorge Reservoir (5-88), Squaw Flat (5-89), Stonyford Town Area (5-63), and Funks Creek (5-90).

Cooperating entities with the County consist of:

- Glenn Colusa Irrigation District
- Orland Unit Water Users Association
- Orland/Artois Water District
- Kanawha Water District
- Glide Water District
- Provident Irrigation District

- Princeton-Codora-Glenn Irrigation District
- Western Canal Water District
- Reclamation District 2106
- Reclamation District 1004
- Willow Creek Mutual Water Company

Groundwater elevations in Glenn County fluctuate greatly from north to south and east to west. With the introduction of the Tehama Colusa Canal (TC), land and water use has changed dramatically. The TC service areas, north central and the west side of the County, has shifted from flood irrigation on row crops from surface supplies to micro sprinkler irrigation from groundwater on tree crops. The south and eastern portions of the County continue to be flood irrigated with surface water for rice production, the north eastern and central portion of the County is tree and row crops solely dependent on groundwater. In general, there is approximately 1,000,000 acre feet of water with a 70-30% split of surface water to groundwater applied to 265,000 acres for agricultural purposes in the County.

In 2001, the County and irrigation districts started to install a series of dedicated monitoring wells in areas identified as economically sensitive to groundwater use. Since that time other dedicated monitoring wells have been installed to provide information for aquifer interaction and potential conjunctive use programs.

The dedicated monitoring zones range from shallow (under 100 feet) to deep (over 1000 feet) and well zones selected for CASGEM will take into consideration land and water use in the general area as well as agricultural, municipal, industrial, and domestic demand. In reviewing the data it appears that it makes the most sense to select a dedicated monitoring well from an area of the County and monitor and report all zones available. Having a dedicated monitoring network with a high level of sophistication, should not place an undo burden on the County to over monitor aquifer zones that do not provide for the overall protection of the majority of water users.

The major geologic/aquifer systems of Glenn County consist of the Tehama Formation, the Upper and Lower Tuscan Formations, and the Stony Creek alluvium. All of the dedicated wells have discreet monitoring zones within one or many of the formations. Previous work has indicated a substantial influence of up gradient surface application of water for irrigation and stream flow from Stony Creek provides down gradient groundwater users with an adequate supply for the irrigation season.

Maps

Figure 1 shows the selected dedicated monitoring wells discussed above that will adequately characterize the County's groundwater resources and provides the most comprehensive coverage available.

Schedule

The major groundwater use in the County is for agricultural purposes and follows traditional seasonal trends of spring highs to fall lows over a long period of time. Therefore measurements will be taken from all selected wells in the end of March and in mid-October to coincide with typical pre and post irrigation seasons.

Field Methods

Field methods for the collection and documentation of groundwater elevation data in the County will be standardized and meet all CASGEM basic requirements:

- Reference Point has been established by DWR staff previously
- Measurements will be recorded in a field data book and transferred to an electronic spread sheet and submitted to DWR with the following information:

    1. State Well Number
    2. Date of Measurement
    3. Reference Point Elevation
    4. Land Surface Elevation
    5. Reference Point to Water Surface
    6. Method of Measurement
    7. No measurement and Questionable Measurement Codes (same as DWR Water Data Library)
    8. Agency ID
    9. Comments

  Table 1 is a template of the field data recording form.

- A visual assessment of possible groundwater pumping in surrounding areas will confirm static groundwater conditions
- An electronic well sounder will be the measurement instrument, typically lowered two times at the water surface and compared for consistency

Well Information

Table 2 contains all of the data listed below:

- Map Location Number
- State Well Number
- Use
- Well Completion Type
- Top Perforation
- Bottom Perforation
- Total Depth
- Ground Surface Elevation

- Method of Determining Elevation
- Accuracy of Elevation Method
- Reference Point Elevation
- Reference Point Description (Reference Point is top of casing)
- Well coordinates (decimal lat/long, NAD83)
- Method of determining coordinates
- Accuracy of coordinate method
- Entity Responsible for Monitoring
- Groundwater basin
- Well Completion Report number
- Geologic Formation if known
- Written Description of Well Location
- Additional Comments (if needed)

Written Descriptions of Well Locations Included in Table 2 are as follows:
(numbers correspond to map locations)

1 – Approximately 2 miles south of Highway 162 and ½ mile east of Road Z

2 - Approximately ½ mile north of Road 68 and east of Sac Refuge Boundary

3 - Approximately 2 miles north of Highway 162 and 200 feet east of Road Y

4 - Approximately 1 mile south of Highway 162 and ¼ mile east of Road R

5 - Approximately ¼ mile south of Road 61 at Road SS

6 - Approximately 1 mile south of Road 44 at Road TT

7 - Approximately at the SE intersection of Road 35 and W

8 - Approximately ¼ mile north of Highway 162 and west of Road Pat GCID Canal

9 - Approximately 200 feet north of Road 44 and ¼ mile east of Road WW

10 - Approximately ½ mile south of Road 35 and 50 feet east of Road D

11 - Approximately ½ mile south of Road 24 and 1.5 miles west of Highway 45

12 - Approximately ¼ mile north of Road 25 and ¼ mile west of Road U

13 - Approximately ¼ mile northeast of the intersection of Road 25 and QQ

14 - Approximately ¼ mile north of Road 32 and east of Road WW at the GCID Canal

15 - Approximately ¼ mile north of Road 33 and 500 feet east of Road S

16 - Approximately 1 mile north of Road 30 and 200 feet east of Road M

17 - Approximately 1 mile east of Highway 99 and 50 feet north of Road 33

18 - At the southwest corner of the intersection of Road 25 and Road D

19 - Approximately ¾ mile north of Road 23 on the east side of Highway 45

20 - Approximately 200 feet southeast of the intersection of Capay and 1st Avenues

21 - Approximately ¼ mile south of Road 9 and east of 4th Avenue

22 - Approximately 500 feet east of Road P south of Road 9

23 - Approximately ½ mile east of Road P and 50 feet north of Road 18

24 - Approximately ¼ mile west of Road P and 25 feet south of Road 6

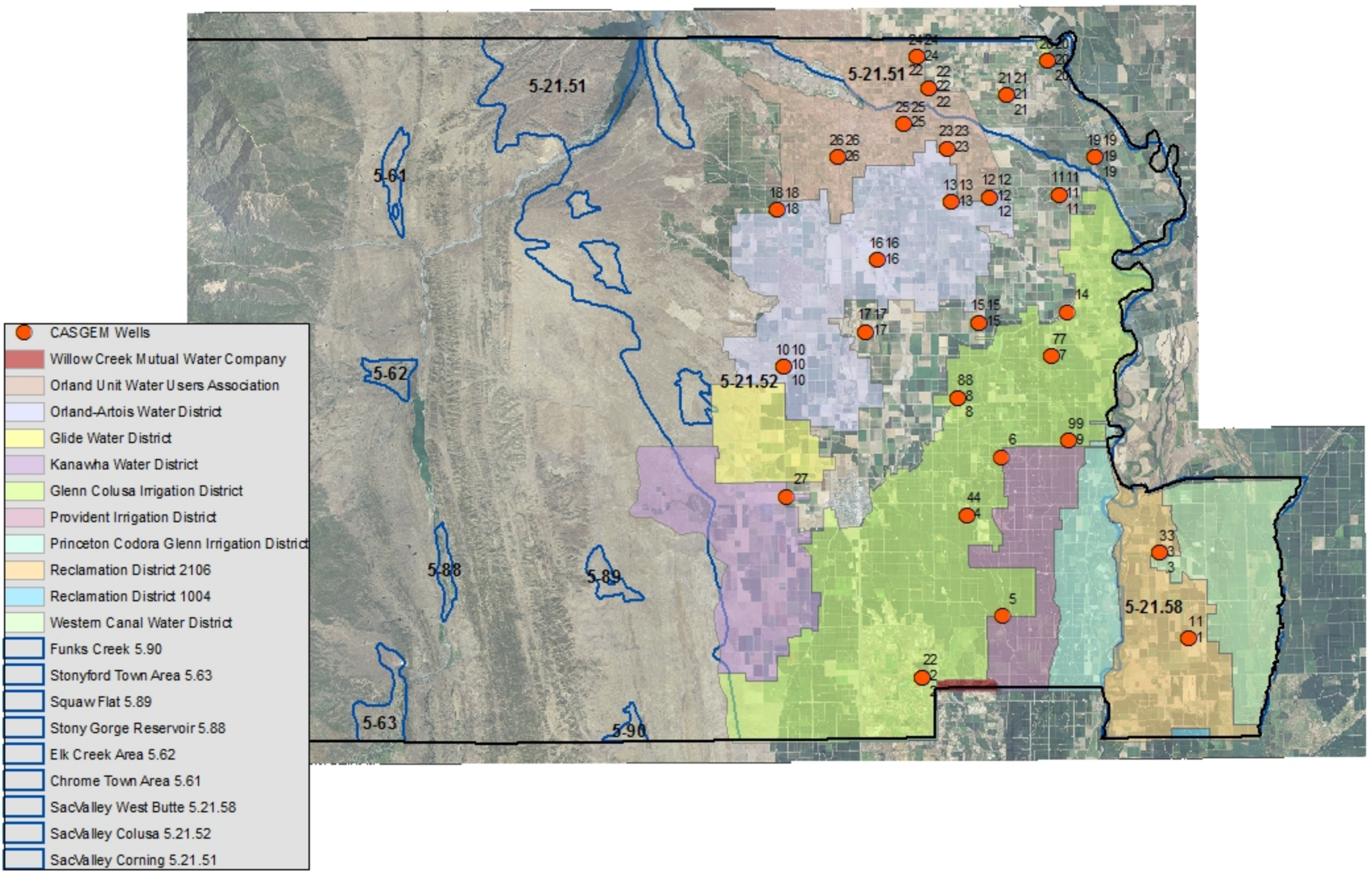
25 - Approximately 1/10 mile east of Road N and 50 feet north of Highway 32

26 - Approximately ¼ mile north of Road 20 and east of Road HH

27 - Approximately ¼ mile north of Highway 162 and 180 feet east of Road D

Figures

Figure 1.
CASGEM Wells Located Within Glenn County



Tables

Table 1.
Glenn County
CASGEM Recording Form

SWN	Date	RP Elev (ft)	Land Surface Elev (ft)	RPWS	Method	NM Code	QM Code	Agency ID	Comments

Table 2.
CASGEM Well Information

Map Location Number	SWN	Use	Status	Well Comp Type	Top Perf	Bottom Perf	Total Depth	GSE	Method Det Elev	Accuracy Elev (ft)	RPE	RP Desc	Datum	Easting	Northing	Units	Zone	Method Det Coordinates	Accuracy Coordinates	Entity	Basin	WCR#	Formation	Written Desc	Additional Comments
1	18N01W02E001M	Observation	active	multi-completion	719	729	760	78.5	surveyed to a benchmark	0.01	80.9	top of casing	NAD83	590918	4366345	meters	10	surveyed to a benchmark	0.01	Glenn Co	West Butte	726833	Tuscan C	Approximately 2 miles south of Highway 162 and ½ mile east of Road Z	
1	18N01W02E002M	Observation	active	multi-completion	450	460	470	78.5	surveyed to a benchmark	0.01	81.3	top of casing	NAD83	590918	4366346	meters	10	surveyed to a benchmark	0.01	Glenn Co	West Butte	726833	Tehama	Approximately 2 miles south of Highway 162 and ½ mile east of Road Z	
1	18N01W02E003M	Observation	active	multi-completion	100	110	120	78.5	surveyed to a benchmark	0.01	81.4	top of casing	NAD83	590918	4366347	meters	10	surveyed to a benchmark	0.01	Glenn Co	West Butte	726833		Approximately 2 miles south of Highway 162 and ½ mile east of Road Z	
2	18N02W18D001M	Observation	active	multi-completion	975	985	1000	80	surveyed to a benchmark	0.01	80.6	top of casing	NAD83	573529	4363826	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	E045412	Tuscan A	Approximately ½ mile north of Road 68 and east of Sac Refuge Boundary	
2	18N02W18D002M	Observation	active	multi-completion	620	680	700	80	surveyed to a benchmark	0.01	81	top of casing	NAD83	573529	4363826	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	E045412	Tuscan C	Approximately ½ mile north of Road 68 and east of Sac Refuge Boundary	
2	18N02W18D003M	Observation	active	multi-completion	510	520	530	80	surveyed to a benchmark	0.01	81.6	top of casing	NAD83	573529	4363826	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	E045412	Tehama	Approximately ½ mile north of Road 68 and east of Sac Refuge Boundary	
2	18N02W18D004M	Observation	active	multi-completion	246	256	266	80	surveyed to a benchmark	0.01	82	top of casing	NAD83	573529	4363826	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	E045412	Tehama	Approximately ½ mile north of Road 68 and east of Sac Refuge Boundary	
3	19N01W22D004M	Observation	active	multi-completion	780	790	820	85	surveyed to a benchmark	0.01	87.3	top of casing	NAD83	589015	4371966	meters	10	surveyed to a benchmark	0.01	Glenn Co	West Butte	816274	Tuscan C	Approximately 2 miles north of Highway 162 and 200 feet east of Road Y	
3	19N01W22D005M	Observation	active	multi-completion	520	530	555	85	surveyed to a benchmark	0.01	87.5	top of casing	NAD83	589015	4371966	meters	10	surveyed to a benchmark	0.01	Glenn Co	West Butte	816274	Tuscan C	Approximately 2 miles north of Highway 162 and 200 feet east of Road Y	
3	19N01W22D006M	Observation	active	multi-completion	340	350	380	85	surveyed to a benchmark	0.01	87.8	top of casing	NAD83	589015	4371966	meters	10	surveyed to a benchmark	0.01	Glenn Co	West Butte	816274	Tuscan	Approximately 2 miles north of Highway 162 and 200 feet east of Road Y	
3	19N01W22D007M	Observation	active	multi-completion	80	90	120	85	surveyed to a benchmark	0.01	88	top of casing	NAD83	589015	4371966	meters	10	surveyed to a benchmark	0.01	Glenn Co	West Butte	816274		Approximately 2 miles north of Highway 162 and 200 feet east of Road Y	
4	19N02W08Q001M	Observation	active	multi-completion	857	877	940	99	surveyed to a benchmark	0.01	103.4	top of casing	NAD83	576381	4374412	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	726952	Tehama	Approximately 1 mile south of Highway 162 and ¼ mile east of Road R	
4	19N02W08Q002M	Observation	active	multi-completion	208	218	228	99	surveyed to a benchmark	0.01	99.8	top of casing	NAD83	576381	4374413	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	726952	Tehama	Approximately 1 mile south of Highway 162 and ¼ mile east of Road R	
4	19N02W08Q003M	Observation	active	multi-completion	77	87	97	99	surveyed to a benchmark	0.01	100.2	top of casing	NAD83	576381	4374414	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	726952	Tehama	Approximately 1 mile south of Highway 162 and ¼ mile east of Road R	
5	19N02W33K001M	Observation	active	single completion	160	260	260	85	surveyed to a benchmark	0.01	85.3	top of casing	NAD83	578711	4367831	meters	10	surveyed to a benchmark	0.01	Provident	Colusa	581475		Approximately ¼ mile south of Road 61 at Road SS	
6	20N02W33B001M	Observation	active	single completion	100	320	320	103	surveyed to a benchmark	0.01	104.6	top of casing	NAD83	578687	4378239	meters	10	surveyed to a benchmark	0.01	Provident	Colusa	3686		Approximately 1 mile south of Road 44 at Road TT	
7	20N02W11A001M	Observation	active	multi-completion	70	90	90	123	surveyed to a benchmark	0.01	123	top of casing	NAD83	581990	4384821	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	3669	Tehama	Approximately at the SE intersection of Road 35 and W	
7	20N02W11A002M	Observation	active	multi-completion	140	160	160	123	surveyed to a benchmark	0.01	123	top of casing	NAD83	581990	4384821	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	3669	Tehama	Approximately at the SE intersection of Road 35 and W	
7	20N02W11A003M	Observation	active	multi-completion	490	510	510	123	surveyed to a benchmark	0.01	123	top of casing	NAD83	581990	4384821	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	3669	Tehama	Approximately at the SE intersection of Road 35 and W	
8	20N02W18R005M	Observation	active	multi-completion	920	980	1000	131.4	surveyed to a benchmark	0.01	132.5	top of casing	NAD83	575826	4382128	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	801448	Tuscan AB	Approximately ¼ mile north of Highway 162 and west of Road Pat GCID Canal	
8	20N02W18R006M	Observation	active	multi-completion	635	655	675	131.4	surveyed to a benchmark	0.01	133	top of casing	NAD83	575826	4382128	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	801448	Tehama	Approximately ¼ mile north of Highway 162 and west of Road Pat GCID Canal	
8	20N02W18R007M	Observation	active	multi-completion	450	526	545	131.4	surveyed to a benchmark	0.01	133.4	top of casing	NAD83	575826	4382128	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	801448	Tehama	Approximately ¼ mile north of Highway 162 and west of Road Pat GCID Canal	
8	20N02W18R008M	Observation	active	multi-completion	140	180	201	131.4	surveyed to a benchmark	0.01	134	top of casing	NAD83	575826	4382128	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	801448		Approximately ¼ mile north of Highway 162 and west of Road Pat GCID Canal	
9	20N02W25F002M	Observation	active	multi-completion	420	470	490	102.2	surveyed to a benchmark	0.01	104.1	top of casing	NAD83	583103	4379315	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	782025	Tehama	Approximately 200 feet north of Road 44 and ¼ mile east of Road WW	
9	20N02W25F003M	Observation	active	multi-completion	190	260	280	102.2	surveyed to a benchmark	0.01	104.6	top of casing	NAD83	583103	4379316	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	782025	Tehama	Approximately 200 feet north of Road 44 and ¼ mile east of Road WW	
9	20N02W25F004M	Observation	active	multi-completion	55	65	85	102.2	surveyed to a benchmark	0.01	105.1	top of casing	NAD83	583103	4379317	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	782025	Tehama	Approximately 200 feet north of Road 44 and ¼ mile east of Road WW	
10	20N03W07E001M	Observation	active	multi-completion	984	1014	1030	179.2	surveyed to a benchmark	0.01	180.8	top of casing	NAD83	564420	4384159	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	E057712	Tehama	Approximately ½ mile south of Road 35 and 50 feet east of Road D	
10	20N03W07E002M	Observation	active	multi-completion	616	636	656	179.2	surveyed to a benchmark	0.01	181.1	top of casing	NAD83	564420	4384159	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	E057712	Tehama	Approximately ½ mile south of Road 35 and 50 feet east of Road D	
10	20N03W07E003M	Observation	active	multi-completion	380	485	505	179.2	surveyed to a benchmark	0.01	181.5	top of casing	NAD83	564420	4384159	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	E057712	Tehama	Approximately ½ mile south of Road 35 and 50 feet east of Road D	
10	20N03W07E004M	Observation	active	multi-completion	118	128	138	179.2	surveyed to a benchmark	0.01	181.8	top of casing	NAD83	564420	4384159	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	E057712	Tehama	Approximately ½ mile south of Road 35 and 50 feet east of Road D	
11	21N02W01F001M	Observation	active	multi-completion	547	557	578	160.9	surveyed to a benchmark	0.01	162.1	top of casing	NAD83	582444	4395389	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	726740	Tuscan C	Approximately ½ mile south of Road 24 and 1.5 miles west of Highway 45	
11	21N02W01F002M	Observation	active	multi-completion	297	307	318	160.8	surveyed to a benchmark	0.01	162.3	top of casing	NAD83	582444	4395390	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	726740	Tehama	Approximately ½ mile south of Road 24 and 1.5 miles west of Highway 45	

Table 2.
CASGEM Well Information

Map Location Number	SWN	Use	Status	Well Comp Type	Top Perf	Bottom Perf	Total Depth	GSE	Method Det Elev	Accuracy Elev (ft)	RPE	RP Desc	Datum	Easting	Northing	Units	Zone	Method Det Coordinates	Accuracy Coordinates	Entity	Basin	WCR#	Formation	Written Desc	Additional Comments
11	21N02W01F003M	Observation	active	multi-completion	109	119	124	161.8	surveyed to a benchmark	0.01	162.8	top of casing	NAD83	582444	4395391	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	726740	Modesto	Approximately ½ mile south of Road 24 and 1.5 miles west of Highway 45	
11	21N02W01F004M	Observation	active	multi-completion	55	65	75	161.9	surveyed to a benchmark	0.01	163.2	top of casing	NAD83	582444	4395392	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	726740	Modesto	Approximately ½ mile south of Road 24 and 1.5 miles west of Highway 45	
12	21N02W04G002M	Observation	active	multi-completion	928	938	948	176	surveyed to a benchmark	0.01	177.8	top of casing	NAD83	577925	4395225	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	E044112	Tuscan B	Approximately ¼ mile north of Road 25 and ¼ mile west of Road U	
12	21N02W04G003M	Observation	active	multi-completion	673.5	703.5	713	176	surveyed to a benchmark	0.01	178.1	top of casing	NAD83	577925	4395225	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	E044112	Tuscan C	Approximately ¼ mile north of Road 25 and ¼ mile west of Road U	
12	21N02W04G004M	Observation	active	multi-completion	165	279	289	176	surveyed to a benchmark	0.01	177.9	top of casing	NAD83	577925	4395225	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	E044112	Tehama	Approximately ¼ mile north of Road 25 and ¼ mile west of Road U	
12	21N02W04G005M	Observation	active	multi-completion	57	67	77	176	surveyed to a benchmark	0.01	178.8	top of casing	NAD83	577925	4395225	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	E044112	Modesto	Approximately ¼ mile north of Road 25 and ¼ mile west of Road U	
13	21N02W05M001M	Observation	active	multi-completion	442	452	473	186.5	surveyed to a benchmark	0.01	188	top of casing	NAD83	575379	4394921	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	801406	Tehama	Approximately ¼ mile northeast of the intersection of Road 25 and QQ	
13	21N02W05M002M	Observation	active	multi-completion	122	132	153	186.5	surveyed to a benchmark	0.01	188.5	top of casing	NAD83	575379	4394921	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	801406	Modesto	Approximately ¼ mile northeast of the intersection of Road 25 and QQ	
13	21N02W05M003M	Observation	active	multi-completion	44	54	75	186.5	surveyed to a benchmark	0.01	189.9	top of casing	NAD83	575379	4394921	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	801406	Modesto	Approximately ¼ mile northeast of the intersection of Road 25 and QQ	
14	21N02W36A002M	Observation	active	single completion	120	140	155	133	surveyed to a benchmark	0.01	133.8	top of casing	NAD83	582979	4387714	meters	10	surveyed to a benchmark	0.01	GCID	Colusa	315497		Approximately ¼ mile north of Road 32 and east of Road WW at the GCID Canal	
15	21N02W33M001M	Observation	active	multi-completion	869	890	974	148.9	surveyed to a benchmark	0.01	151.7	top of casing	NAD83	577199	4387045	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	726724	Tuscan AB	Approximately ¼ mile north of Road 33 and 500 feet east of Road S	
15	21N02W33M002M	Observation	active	multi-completion	540	550	571	148.9	surveyed to a benchmark	0.01	150.6	top of casing	NAD83	577199	4387046	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	726724	Tuscan C	Approximately ¼ mile north of Road 33 and 500 feet east of Road S	
15	21N02W33M003M	Observation	active	multi-completion	140	150	171	148.9	surveyed to a benchmark	0.01	151.3	top of casing	NAD83	577199	4387047	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	726724	Tehama	Approximately ¼ mile north of Road 33 and 500 feet east of Road S	
16	21N03W23D001M	Observation	active	multi-completion	362	372	393.5	202.3	surveyed to a benchmark	0.01	203.4	top of casing	NAD83	570561	4391143	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	801404	Tehama	Approximately 1 mile north of Road 30 and 200 feet east of Road M	
16	21N03W23D002M	Observation	active	multi-completion	142	170	191.5	202.3	surveyed to a benchmark	0.01	204	top of casing	NAD83	570561	4391143	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	801404	Modesto	Approximately 1 mile north of Road 30 and 200 feet east of Road M	
16	21N03W23D003M	Observation	active	multi-completion	42	72	93.5	202.3	surveyed to a benchmark	0.01	204.5	top of casing	NAD83	570561	4391143	meters	10	surveyed to a benchmark	0.01	O/AWD	Colusa	801404	Modesto	Approximately 1 mile north of Road 30 and 200 feet east of Road M	
17	21N03W34Q002M	Observation	active	multi-completion	930	960	980	166.2	surveyed to a benchmark	0.01	167.1	top of casing	NAD83	569764	4386421	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	816224	Tehama	Approximately 1 mile east of Highway 99 and 50 feet north of Road 33	
17	21N03W34Q003M	Observation	active	multi-completion	620	690	721	166.3	surveyed to a benchmark	0.01	167.4	top of casing	NAD83	569764	4386422	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	816224	Tehama	Approximately 1 mile east of Highway 99 and 50 feet north of Road 33	
17	21N03W34Q004M	Observation	active	multi-completion	60	70	108	167.6	surveyed to a benchmark	0.01	163.3	top of casing	NAD83	569764	4386423	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	816224		Approximately 1 mile east of Highway 99 and 50 feet north of Road 33	
18	21N04W12A002M	Observation	active	multi-completion	247	257	278	247.9	surveyed to a benchmark	0.01	249.9	top of casing	NAD83	564019	4394413	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	726739	Tehama	At the southwest corner of the intersection of Road 25 and Road D	
18	21N04W12A003M	Observation	active	multi-completion	955	1050	1070	247.5	surveyed to a benchmark	0.01	250.1	top of casing	NAD83	564009	4394400	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	E0103388	Tehama	At the southwest corner of the intersection of Road 25 and Road D	
18	21N04W12A004M	Observation	active	multi-completion	520	640	659	247.5	surveyed to a benchmark	0.01	249.6	top of casing	NAD83	564009	4394400	meters	10	surveyed to a benchmark	0.01	Glenn Co	Colusa	E0103388	Tehama	At the southwest corner of the intersection of Road 25 and Road D	
19	22N01W29N001M	Observation	active	multi-completion	859	1135	1156	146.3	surveyed to a benchmark	0.01	151	top of casing	NAD83	584796	4397844	meters	10	surveyed to a benchmark	0.01	Glenn Co	Corning	E0103616	Tuscan A	Approximately ¾ mile north of Road 23 on the east side of Highway 45	
19	22N01W29N002M	Observation	active	multi-completion	549	641	661	146.3	surveyed to a benchmark	0.01	150.7	top of casing	NAD83	584796	4397844	meters	10	surveyed to a benchmark	0.01	Glenn Co	Corning	E0103616	Tuscan B/C	Approximately ¾ mile north of Road 23 on the east side of Highway 45	
19	22N01W29N003M	Observation	active	multi-completion	189	380	400	146.3	surveyed to a benchmark	0.01	150	top of casing	NAD83	584796	4397844	meters	10	surveyed to a benchmark	0.01	Glenn Co	Corning	E0103616	Tehama	Approximately ¾ mile north of Road 23 on the east side of Highway 45	
19	22N01W29N004M	Observation	active	multi-completion	89	99	109	146.3	surveyed to a benchmark	0.01	149.1	top of casing	NAD83	584796	4397844	meters	10	surveyed to a benchmark	0.01	Glenn Co	Corning	E0103616	Modesto	Approximately ¾ mile north of Road 23 on the east side of Highway 45	
20	22N02W01N001M	Observation	active	multi-completion	812.75	1050	1060	159.2	surveyed to a benchmark	0.01	161.1	top of casing	NAD83	581674	4404172	meters	10	surveyed to a benchmark	0.01	GCID	Corning	E038764	Tuscan A	Approximately 200 feet southeast of the intersection of Capay and 1st Avenues	
20	22N02W01N002M	Observation	active	multi-completion	698.75	708.75	730	159.2	surveyed to a benchmark	0.01	161.3	top of casing	NAD83	581674	4404172	meters	10	surveyed to a benchmark	0.01	GCID	Corning	E038764	Tehama, Tuscan C	Approximately 200 feet southeast of the intersection of Capay and 1st Avenues	
20	22N02W01N003M	Observation	active	multi-completion	209.25	367.5	440	159.2	surveyed to a benchmark	0.01	161.5	top of casing	NAD83	581674	4404172	meters	10	surveyed to a benchmark	0.01	GCID	Corning	E038764	Tehama	Approximately 200 feet southeast of the intersection of Capay and 1st Avenues	
20	22N02W01N004M	Observation	active	multi-completion	70.6	80.6	108	159.2	surveyed to a benchmark	0.01	161.6	top of casing	NAD83	581674	4404172	meters	10	surveyed to a benchmark	0.01	GCID	Corning	E038764	Stony Creek Alluvium	Approximately 200 feet southeast of the intersection of Capay and 1st Avenues	
21	22N02W15C002M	Observation	active	multi-completion	760	781	880	189.5	surveyed to a benchmark	0.01	194.2	top of casing	NAD83	579035	4401917	meters	10	surveyed to a benchmark	0.01	Glenn Co	Corning	726790	Tuscan A	Approximately ¼ mile south of Road 9 and east of 4th Avenue	

Table 2.
CASGEM Well Information

Map Location Number	SWN	Use	Status	Well Comp Type	Top Perf	Bottom Perf	Total Depth	GSE	Method Det Elev	Accuracy Elev (ft)	RPE	RP Desc	Datum	Easting	Northing	Units	Zone	Method Det Coordinates	Accuracy Coordinates	Entity	Basin	WCR#	Formation	Written Desc	Additional Comments
21	22N02W15C003M	Observation	active	multi-completion	370	380	444	189.2	surveyed to a benchmark	0.01	192	top of casing	NAD83	579035	4401918	meters	10	surveyed to a benchmark	0.01	Glenn Co	Corning	726789	Tuscan B	Approximately ¼ mile south of Road 9 and east of 4th Avenue	
21	22N02W15C004M	Observation	active	multi-completion	210	220	240	189.3	surveyed to a benchmark	0.01	192.3	top of casing	NAD83	579035	4401919	meters	10	surveyed to a benchmark	0.01	Glenn Co	Corning	726789	Tehama	Approximately ¼ mile south of Road 9 and east of 4th Avenue	
21	22N02W15C005M	Observation	active	multi-completion	60	70	90	189.4	surveyed to a benchmark	0.01	192.7	top of casing	NAD83	579035	4401920	meters	10	surveyed to a benchmark	0.01	Glenn Co	Corning	726789	Modesto	Approximately ¼ mile south of Road 9 and east of 4th Avenue	
22	22N02W18C001M	Observation	active	multi-completion	989	1029	1049	221	surveyed to a benchmark	0.01	222.2	top of casing	NAD83	573962	4402387	meters	10	surveyed to a benchmark	0.01	OUWUA	Corning	E044014	Tuscan A	Approximately 500 feet east of Road P south of Road 9	
22	22N02W18C002M	Observation	active	multi-completion	414	434	455	221	surveyed to a benchmark	0.01	222.4	top of casing	NAD83	573962	4402387	meters	10	surveyed to a benchmark	0.01	OUWUA	Corning	E044014	Tuscan BC	Approximately 500 feet east of Road P south of Road 9	
22	22N02W18C003M	Observation	active	multi-completion	165	175	185	221	surveyed to a benchmark	0.01	223.1	top of casing	NAD83	573962	4402387	meters	10	surveyed to a benchmark	0.01	OUWUA	Corning	E044014	Tehama	Approximately 500 feet east of Road P south of Road 9	
22	22N02W18C004M	Observation	active	multi-completion	55	65	75.4	221	surveyed to a benchmark	0.01	223.5	top of casing	NAD83	573962	4402387	meters	10	surveyed to a benchmark	0.01	OUWUA	Corning	E044014	Modesto	Approximately 500 feet east of Road P south of Road 9	
23	22N02W30H002M	Observation	active	multi-completion	850	880	930	202	surveyed to a benchmark	0.01	202.8	top of casing	NAD83	575147	4398437	meters	10	surveyed to a benchmark	0.01	OUWUA	Colusa	726922	Tuscan C	Approximately ½ mile east of Road P and 50 feet north of Road 18	
23	22N02W30H003M	Observation	active	multi-completion	130	260	291	202	surveyed to a benchmark	0.01	201.3	top of casing	NAD83	575147	4398438	meters	10	surveyed to a benchmark	0.01	OUWUA	Colusa	726922	Tehama	Approximately ½ mile east of Road P and 50 feet north of Road 18	
23	22N02W30H004M	Observation	active	multi-completion	45	70	88	202	surveyed to a benchmark	0.01	202	top of casing	NAD83	575147	4398439	meters	10	surveyed to a benchmark	0.01	OUWUA	Colusa	726922	Modesto	Approximately ½ mile east of Road P and 50 feet north of Road 18	
24	22N03W01R001M	Observation	active	multi-completion	470	480	490	226	surveyed to a benchmark	0.01	228.2	top of casing	NAD83	573171	4404425	meters	10	surveyed to a benchmark	0.01	Glenn Co	Corning	726839	Tuscan C	Approximately ¼ mile west of Road P and 25 feet south of Road 6	
24	22N03W01R002M	Observation	active	multi-completion	270	280	290	226	surveyed to a benchmark	0.01	228.5	top of casing	NAD83	573171	4404426	meters	10	surveyed to a benchmark	0.01	Glenn Co	Corning	726839	Tehama	Approximately ¼ mile west of Road P and 25 feet south of Road 6	
24	22N03W01R003M	Observation	active	multi-completion	60	70	80	226	surveyed to a benchmark	0.01	229	top of casing	NAD83	573171	4404427	meters	10	surveyed to a benchmark	0.01	Glenn Co	Corning	726839	Modesto	Approximately ¼ mile west of Road P and 25 feet south of Road 6	
25	22N03W24E001M	Observation	active	multi-completion	800	820	850	230.5	surveyed to a benchmark	0.01	231.7	top of casing	NAD83	572311	4400036	meters	10	surveyed to a benchmark	0.01	OUWUA	Colusa	726923	Tehama	Approximately 1/10 mile east of Road N and 50 feet north of Highway 32	
25	22N03W24E002M	Observation	active	multi-completion	128	178	225	230.5	surveyed to a benchmark	0.01	231.9	top of casing	NAD83	572311	4400037	meters	10	surveyed to a benchmark	0.01	OUWUA	Colusa	726923	Modesto	Approximately 1/10 mile east of Road N and 50 feet north of Highway 32	
25	22N03W24E003M	Observation	active	multi-completion	49	59	81	230.5	surveyed to a benchmark	0.01	232.4	top of casing	NAD83	572311	4400038	meters	10	surveyed to a benchmark	0.01	OUWUA	Colusa	726923	Modesto	Approximately 1/10 mile east of Road N and 50 feet north of Highway 32	
26	22N03W28P001M	Observation	active	multi-completion	390	400	421	255.8	surveyed to a benchmark	0.01	257	top of casing	NAD83	567946	4397861	meters	10	surveyed to a benchmark	0.01	OUWUA	Colusa	801439	Tehama	Approximately ¼ mile north of Road 20 and east of Road HH	
26	22N03W28P002M	Observation	active	multi-completion	270	290	311	255.8	surveyed to a benchmark	0.01	257.5	top of casing	NAD83	567946	4397862	meters	10	surveyed to a benchmark	0.01	OUWUA	Colusa	801439		Approximately ¼ mile north of Road 20 and east of Road HH	
26	22N03W28P003M	Observation	active	multi-completion	30	50	71	255.8	surveyed to a benchmark	0.01	258.1	top of casing	NAD83	567946	4397861	meters	10	surveyed to a benchmark	0.01	OUWUA	Colusa	801439		Approximately ¼ mile north of Road 20 and east of Road HH	
27	19N03W06N002M	Irrigation	active	single completion	90	272	282	154	GPS	unknown	154.3	top of casing	NAD83	564578	4375632	meters	10	GPS	uknown	KWD	Colusa	581432		Approximately 1/4 mile north of Hwy 162 and 180 feet east of Road D	

CASGEM Monitoring Plan

To meet the requirements of SBX7 6

Submitted by the Tehama County Flood Control

And Water Conservation District

September 2011

Tehama County CASGEM Monitoring Plan

The Tehama County Flood Control and Water Conservation District (TCFC&WCD) applied to be a monitoring and reporting entity for the geographic area within the boundaries of the county and for the underlying groundwater basins identified in Bulletin 118. In 1996, TCFC&WCD adopted the Tehama County Coordinated AB3030 Groundwater Management Plan. Implementation of the plan led to the identification of 12 groundwater management sub-areas that were adopted by the TCFC&WCD board in 1998. The TCFC&WCD will monitor groundwater levels as described in the County's AB3030 Groundwater Management Plan and submit the groundwater basin monitoring data obtained by staff to Department of Water Resources (DWR). Information on the monitoring plan is available to the public at http://www.tehamacountypublicworks.ca.gov/Flood/groundwater.htm

Monitoring Plan Overview

Groundwater monitoring in Tehama County is currently performed by the DWR and TCFC&WCD. DWR collects data from approximately 160 groundwater wells in Tehama County. TCFC&WCD collects data from 26 dedicated monitoring wells at eight locations and submits the data to DWR. For the purposes of CASGEM, monitoring data will be collected from wells identified as "Key Wells" in the Tehama County Groundwater Management Plan. The Key Wells are of various use types and depths. Groundwater level measurements in the Key Wells are expected to adequately characterize and document the primary areas of groundwater use within the identified sub-basins. The Tehama Co. CASGEM Monitoring Plan does not involve any cooperating agencies.

Groundwater Sub-basins

The valley portion of Tehama County overlies all or a portion of the following groundwater sub-basins as identified in DWR Bulletin 118.

- Antelope (5-21.54)
- Bend (5-21.53)
- Bowman (5-6.01)
- Colusa (5-21.52)
- Corning (5-21.51)
- Dye Creek (5-21.55)
- Los Molinos (5-21.56)
- Red Bluff (5-21.50)
- Rosewood (5-6.02)
- South Battle Creek (5-6.06)
- Vina (5-21.57)

Bulletin 118 indicates that the Colusa Sub-basin (5-21.52) underlies a very small portion (approximately 1400 acres) of Tehama County. It also shows that the majority of the sub-basin lies within Glenn County. The small portion of the sub-basin that lies within Tehama County is predominantly foot hills and isolated valley areas with very little

groundwater use. The limited amount of irrigated acreage that lies within this sub-basin in Tehama County will be represented by the monitoring plan developed and submitted for CASGEM by Glenn County. Therefore it will not be necessary to include this small area of Tehama County in its monitoring plan to satisfy CASGEM goals.

The Bend Sub-basin (5-21.53) and South Battle Creek Sub-basin (5-6.06) are not currently monitored by DWR or TCFC&WCD. These sparsely populated sub-basins consist largely of foothills and isolated valleys. Groundwater use is relatively limited except in small areas near the Sacramento River and Battle Creek. For the Sacramento Valley portion of these sub-basins, there are fewer than 20 wells located in the South Battle Creek Sub-basin and approximately 180 wells in the Bend Sub-basin. Potential monitoring wells have been identified in the most densely populated portion of the Bend Sub-basin and the South Battle Creek Sub-basin. Cooperative land owners will be sought to obtain monitoring wells in these sub-basins.

The western portions of the Red Bluff Sub-basin (5-21.50) and Corning Sub-basin (5-21.51) are areas of sparse population and low water use in the foothills and isolated valleys. The Rancho Tehama Reserve (pop. 1485 in 2010) has the largest population in these sub-basins. Due to low population and water use in the western portions of these two sub-basins, groundwater monitoring is not necessary in those areas. Groundwater levels in the Sacramento Valley floor portion of these sub-basins are adequately represented by measuring Key Wells in the existing monitoring network.

Groundwater wells in the portions of the groundwater sub-basins lying outside of the Sacramento Valley floor generally consist of shallow wells constructed in shale and rock or lava formations and are not considered alluvial. The portions of the sub-basins lying outside of the Sacramento Valley will not be included in the Tehama County monitoring network because they represent limited water resources development with minimal yield per well (typically averaging less than 5 gallons per minute). Monitoring needs in these areas will be periodically assessed to address significant changes in development.

Land and Water Use Trends

Groundwater elevations in Tehama County vary greatly from north to south and between the foothills and the Sacramento River. Agricultural land use and water use shifted from un-irrigated range and flood irrigation on row crops with surface supplies, to tree crops with drip and micro sprinkler irrigation using groundwater. In the early 1900s most crops were irrigated with surface water. By 2003 two-thirds of the cropland was irrigated with groundwater and cropland had substantially increased. This growth and practice continues today.

Dedicated Monitoring Wells

In 2004, TCFC&WCD began to install a series of dedicated groundwater monitoring wells in areas identified as economically sensitive to groundwater use. Since that time, dedicated monitoring wells at eight locations have been placed in service. These wells

provide access to measure 26 zones. In these dedicated wells, groundwater levels are monitored with pressure transducers and data loggers to attain high frequency data. This information allows evaluation of aquifer interaction and potential conjunctive use programs.

The dedicated monitoring zones range from shallow (under 100 feet) to deep (approximately 1000 feet). Well zones selected for CASGEM take into consideration land and water use in the general area as well as agricultural, municipal, industrial, and domestic demand and well infrastructure to provide for the overall protection of the majority of water users.

Maps

Figure 1 shows the location of the Key Wells discussed above. Key Wells adequately characterize the County's groundwater resources and provide the most comprehensive coverage available.

Schedule

The major groundwater use in the County is for agricultural purposes and follows traditional seasonal trends of high groundwater levels in the spring and declining groundwater levels over an extended period in summer and fall. Therefore two measurements will be taken in the identified wells; one in March or April, and the other in October or November to coincide with the typical pre- and post-irrigation seasons.

Field Methods

Field methods for the collection and documentation of groundwater elevation data in the County will be standardized and meet the following CASGEM basic requirements:

- Reference Points for the Key Wells were previously established by DWR staff and will be used for the CASGEM monitoring.
- Manual measurements will be recorded in a field data book using DWR Form 1213. Automatic measurements of groundwater levels in dedicated monitoring wells will be recorded by a data logger. All measurements will be transferred to an electronic spread sheet and submitted to CASGEM with the following information:

    1. State Well Number
    2. Date of Measurement
    3. Reference Point Elevation
    4. Land Surface Elevation
    5. Reference Point to Water Surface
    6. Method of Measurement
    7. No measurement and/or Questionable Measurement Codes (consistent with DWR Water Data Library codes)

8. Agency ID
9. Comments

- A visual assessment of possible groundwater pumping in surrounding areas will confirm static groundwater conditions
- An electronic well sounder may be used to measure groundwater levels in selected wells. The sounder will typically be lowered two times at the water surface and compared for consistency
- A steel tape measure will be used to measure the domestic and irrigations wells in the monitoring grid.
- Dedicated monitoring wells are equipped with pressure transducers and data loggers and will periodically be calibrated with measurements made using an electronic well sounder or steel tape measure.

Well Information

Table 1 contains the information listed below for each Key Well as required by CASGEM:

- Local well identification name
- State Well Number
- Well coordinates (decimal lat/long, NAD83), as previously determined by DWR
- Groundwater basin or sub-basin name and number per DWR Bulletin 118
- Reference Point Elevation (feet, NAVD88) as previously determined by DWR
- Land surface elevation datum (feet, NAVD88) as previously determined by DWR
- Use of well
- Well Completion Type
- Top Perforation
- Bottom Perforation
- Total Depth of Well
- Additional Comments (if needed)

MAPS

Figure 1 shows the location of the monitoring wells used in the Tehama County CASGEM Monitoring Plan and the sub-basins as identified in DWR Bulletin 118 and the Tehama County Coordinated AB3030 Groundwater Management Plan.

Appendix 5B

Groundwater Level Monitoring Well Summary Table

Table B5-1. Groundwater Level Monitoring Well Summary Table

State Well Number	CASGEM Well Number	Local Well Designation	Well Type	Total Well Depth (feet bgs)	Perforated Interval (feet bgs)	Latitude (NAD 83)	Longitude (NAD 83)	Reference Point Elevation (feet AMSL)	First Measurement Date	Last Measurement Date	Measurment Count
22N01W29N001M-004M	397263N1220105W001	22N01W29N001M	Observation	1204	859 - 1135	39.72627	-122.01052	150.95	1/5/2010	10/15/2019	59
	397263N1220105W002	22N01W29N002M	Observation	670	549 - 641	39.72627	-122.01052	150.68	1/5/2010	10/15/2019	59
	397263N1220105W003	22N01W29N003M	Observation	400	189 - 380	39.72627	-122.01052	149.99	1/5/2010	10/15/2019	59
	397263N1220105W004	22N01W29N004M	Observation	120	89 - 99	39.72627	-122.01052	149.06	1/5/2010	10/15/2019	59
22N02W01N001M-004M	397836N1220461W001	22N02W01N001M	Observation	1100	810 - 1050	39.78356	-122.04614	161.07	8/17/2006	10/15/2019	95
	397836N1220461W002	22N02W01N002M	Observation	730	700 - 710	39.78356	-122.04614	161.31	8/17/2006	10/15/2019	95
	397836N1220461W003	22N02W01N003M	Observation	440	210 - 370	39.78356	-122.04614	161.50	8/17/2006	10/15/2019	96
	397836N1220461W004	22N02W01N004M	Observation	108	70 - 80	39.78356	-122.04614	161.65	2/14/2007	10/15/2019	94
22N02W15C002M-005M	397634N1220771W001	22N02W15C002M	Observation	825	760 - 781	39.76342	-122.07717	192.37	2/18/2003	10/18/2019	149
	397634N1220771W002	22N02W15C003M	Observation	422	370 - 380	39.76344	-122.07716	192.01	2/18/2003	10/18/2019	151
	397634N1220771W003	22N02W15C004M	Observation	258	210 - 220	39.76344	-122.07716	192.25	2/18/2003	10/18/2019	152
	397634N1220771W004	22N02W15C005M	Observation	100	60 - 70	39.76344	-122.07716	192.71	2/18/2003	10/18/2019	150
22N02W18C001M-004M	397682N1221364W001	22N02W18C001M	Observation	1062	841 - 1029	39.76820	-122.13645	224.64	2/14/2007	10/17/2019	65
	397682N1221364W002	22N02W18C002M	Observation	482	414 - 434	39.76820	-122.13645	224.84	2/14/2007	10/17/2019	64
	397682N1221364W003	22N02W18C003M	Observation	188	165 - 175	39.76820	-122.13645	225.54	2/14/2007	10/17/2019	61
	397682N1221364W004	22N02W18C004M	Observation	90	55 - 65	39.76820	-122.13640	225.94	2/14/2007	10/17/2019	62
22N03W01R001M-003M	397866N1221455W001	22N03W01R001M	Observation	515	470 - 480	39.78662	-122.14550	228.17	7/24/2003	10/17/2019	103
	397866N1221455W002	22N03W01R002M	Observation	314	270 - 280	39.78662	-122.14552	228.53	7/24/2003	10/17/2019	101
	397866N1221455W003	22N03W01R003M	Observation	103	60 - 70	39.78662	-122.14552	229.04	7/24/2003	10/17/2019	102
23N02W28N001M-004M	398117N1221020W002	28N01 Deep	Observation	970	910 - 950	39.81170	-122.10200	204.09	10/21/2011	10/15/2019	39
	398117N1221020W003	28N02 Int./Deep	Observation	580	550 - 570	39.81170	-122.10200	204.37	10/21/2011	10/15/2019	39
	398117N1221020W004	28N03 Shallow/Int.	Observation	370	330 - 350	39.81170	-122.10200	204.50	10/21/2011	10/15/2019	39
	398117N1221020W001	28N04 Shallow	Observation	205	100 - 170	39.81167	-122.10200	204.43	10/21/2011	10/15/2019	39
23N03W13C003M-007M	398543N1221535W001	13C03 Deep	Observation	980	900 - 970	39.85430	-122.15350	216.06	5/22/2007	10/15/2019	71
	398543N1221535W002	13C04 Deep Int	Observation	835	815 - 825	39.85430	-122.15350	215.88	5/22/2007	10/15/2019	70
	398543N1221535W003	13C05 Intermediate	Observation	381	345 - 355	39.85430	-122.15350	215.73	5/22/2007	10/15/2019	71
	398543N1221535W004	13C06 Shal/Int	Observation	182	95 - 135	39.85430	-122.15350	215.59	5/22/2007	10/15/2019	71
	398543N1221535W005	13C07 Shallow	Observation	71	25 - 35	39.85430	-122.15350	215.25	5/22/2007	10/15/2019	69

Table B5-1. Groundwater Level Monitoring Well Summary Table

State Well Number	CASGEM Well Number	Local Well Designation	Well Type	Total Well Depth (feet bgs)	Perforated Interval (feet bgs)	Latitude (NAD 83)	Longitude (NAD 83)	Reference Point Elevation (feet AMSL)	First Measurement Date	Last Measurement Date	Measurment Count
23N03W25 M001M-004M	398193N1221590W002	25M01 Deep	Observation	988	965 - 975	39.81925	-122.15900	237.76	10/20/2011	10/15/2019	39
	398193N1221590W003	25M02 Inter/Deep	Observation	513	470 - 500	39.81925	-122.15900	237.68	10/20/2011	10/15/2019	39
	398193N1221590W004	25M03 Shallow/Int.	Observation	262	240 - 250	39.81925	-122.15900	237.48	10/20/2011	10/15/2019	39
	398193N1221590W001	25M04 Shallow	Observation	155	120 - 130	39.81925	-122.15900	237.40	10/20/2011	10/15/2019	39
24N02W29 N003M-004M	398996N1221227W001	29N03 Shallow	Observation	388	200 - 290	39.89962	-122.12275	213.76	6/23/2004	10/15/2019	99
	398996N1221227W002	29N04 Deep	Observation	741	590 - 710	39.89960	-122.12270	213.45	6/23/2004	10/15/2019	100
24N03W29 Q001M-003M	399030N1222246W001	29Q01 Shallow	Observation	372	130 - 360	39.90305	-122.22456	316.18	6/23/2004	10/15/2019	98
	399030N1222246W002	29Q02 Intermediate	Observation	575	490 - 550	39.90305	-122.22456	315.76	6/23/2004	10/15/2019	97
	399030N1222246W003	29Q03 Deep	Observation	844	650 - 710	39.90305	-122.22456	315.40	6/23/2004	10/15/2019	97
21N01W04 N001M	396971N1219893W001	--	Domestic	100	--	39.69710	-121.98930	137.68	8/24/1959	10/15/2019	208
22N01W19 E003M	397501N1220267W001	--	Irrigation	500	80 - 400	39.75002	-122.02669	157.79	9/12/2001	10/16/2019	90
22N01W19 K005M	397475N1220221W001	--	Irrigation	1300	920 - 1230	39.74750	-122.02211	156.58	4/5/2011	10/15/2019	53
22N01W29 K001M	397301N1220022W001	--	Irrigation	150	--	39.73010	-122.00220	144.68	12/13/1973	10/15/2019	164
22N02W02 J001M	397875N1220494W001	--	Irrigation	1350	800 - 1300	39.78745	-122.04941	166.40	2/14/2007	10/16/2019	101
22N02W02 K001M	417895N1210549W002	--	Irrigation	250	80 - 250	39.78953	-122.05494	172.00	3/19/2019	10/15/2019	3
22N02W08 B002M	397829N1221117W001	--	Other	165	--	39.78290	-122.11170	208.43	4/18/1962	10/15/2019	321
22N02W09 L003M	397752N1220970W001	--	Irrigation	550	40 - 536	39.77520	-122.09700	198.12	3/12/1965	10/15/2019	169
22N02W11 Q001M	397687N1220546W001	--	Irrigation	240	12 - 239	39.76867	-122.05468	168.40	8/8/1973	10/15/2019	153
22N02W14 C002M	397646N1220599W001	--	Irrigation	540	180 - 540	39.76460	-122.05990	174.00	9/12/2001	10/17/2019	90
22N02W16 B002M	397674N1220912W002	--	Irrigation	349	150 - 349	39.76740	-122.09122	199.00	8/8/2018	10/15/2019	5
22N02W16 B003M	397668N1220936W002	--	Domestic	163	147 - 163	39.76676	-122.09362	199.50	8/8/2018	10/15/2019	5
22N02W21 D001M	397504N1221000W001	--	Irrigation	90	--	39.75037	-122.10000	202.42	1/31/1923	10/17/2019	405
22N02W22 B001M	397520N1220737W001	--	Irrigation	430	80 - 430	39.75200	-122.07370	187.21	9/12/2001	10/17/2019	103
22N03W03 D001M	397972N1221967W001	--	Domestic	104	90 - 102	39.79720	-122.19670	270.97	8/9/1973	8/1/2016	139
22N03W03 D002M	397974N1221969W001	--	Domestic	200	100 - 200	39.79737	-122.19691	271.07	3/19/2014	10/16/2019	20
22N03W04 E001M	397946N1222138W001	--	Domestic	180	40 - 180	39.79460	-122.21380	285.98	10/9/1963	10/15/2019	139
22N03W05 F002M	397956N1222278W001	--	Irrigation	218	188 - 218	39.79560	-122.22780	298.89	10/4/1979	10/15/2019	92
22N03W06 B001M	397953N1222433W001	--	Domestic	210	195 - 210	39.79527	-122.24339	309.90	5/26/2000	10/16/2019	123
22N03W10 R001M	397697N1221812W001	--	Domestic	131	111 - 131	39.76970	-122.18120	259.46	5/26/2000	10/17/2018	105

Table B5-1. Groundwater Level Monitoring Well Summary Table

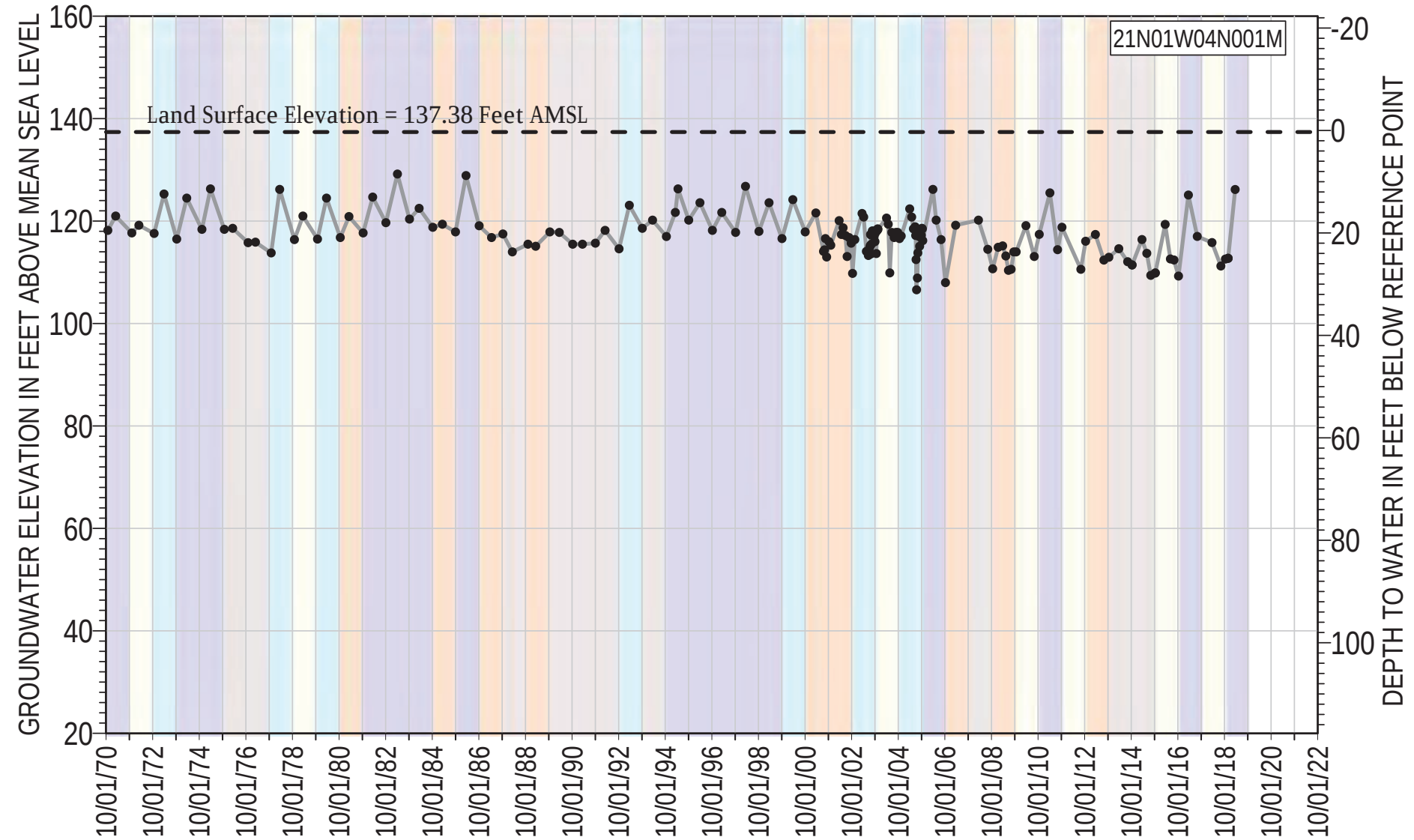
State Well Number	CASGEM Well Number	Local Well Designation	Well Type	Total Well Depth (feet bgs)	Perforated Interval (feet bgs)	Latitude (NAD 83)	Longitude (NAD 83)	Reference Point Elevation (feet AMSL)	First Measurement Date	Last Measurement Date	Measurment Count
22N03W12 Q003M	397705N1221491W001	--	Domestic	124	112 - 123	39.77050	-122.14910	232.94	7/31/1973	10/17/2019	178
23N02W16 B001M	398534N1220963W001	--	Irrigation	120	100 - 120	39.85339	-122.09629	186.53	4/22/1949	10/16/2019	180
23N02W34 A001M	398089N1220677W001	--	Irrigation	130	--	39.80890	-122.06770	172.91	7/22/1949	10/16/2019	175
23N02W34 A003M	398108N1220711W001	--	Irrigation	125	104 - 124	39.81079	-122.07105	171.01	10/13/2000	10/16/2019	67
23N02W34 N001M	397993N1220850W001	--	Industrial	100	70 - 100	39.79930	-122.08500	185.92	5/24/2000	10/16/2019	67
23N03W04 C001M	398813N1222108W001	--	Irrigation	270	140 - 270	39.88130	-122.21080	270.38	8/6/2007	10/11/2011	19
23N03W04 H001M	398804N1221981W001	--	Irrigation	270	200 - 270	39.88039	-122.19808	261.90	10/13/2014	10/16/2019	18
23N03W04 J001M	398743N1221985W001	--	Domestic	195	165 - 195	39.87430	-122.19850	283.48	8/6/2007	3/19/2014	26
23N03W05 G001M	398815N1222225W001	--	Domestic	70	--	39.88150	-122.22250	280.29	4/29/1946	10/16/2019	286
23N03W07 F001M	398662N1222480W002	--	Irrigation	790	240 - 790	39.86618	-122.24796	314.40	10/19/2018	10/18/2019	4
23N03W12 L001M	398623N1221536W001	--	Irrigation	150	45 - 148	39.86230	-122.15360	249.95	1/5/1973	10/16/2019	326
23N03W16 F002M	398511N1222091W001	--	Irrigation	450	110 - 445	39.85103	-122.20916	256.98	3/18/1993	10/18/2019	89
23N03W16 H001M	398493N1222016W001	--	Domestic	150	144 - 150	39.84932	-122.20168	278.08	3/18/1993	10/18/2019	88
23N03W17 R001M	398456N1222199W002	--	Irrigation	720	360 - 720	39.84559	-122.21995	302.50	10/19/2018	10/18/2019	4
23N03W22 Q001M	398260N1221876W001	--	Irrigation	380	--	39.82597	-122.18757	235.97	1/16/1955	10/16/2019	156
23N03W24 A002M	398389N1221442W001	--	Irrigation	200	--	39.83890	-122.14420	208.44	1/7/1941	10/16/2019	180
23N03W24 A003M	398392N1221430W001	--	Domestic	199	180 - 199	39.83915	-122.14301	207.44	5/4/2000	10/16/2019	67
23N04W13 G001M	398527N1222610W001	--	Irrigation	560	--	39.85270	-122.26100	360.71	3/13/1993	10/18/2019	85
24N02W17 A001M	399412N1221040W002	--	Domestic	140	120 - 140	39.94124	-122.10400	212.20	10/19/2018	10/16/2019	4
24N02W20 B001M	399274N1221123W001	--	Domestic	120	100 - 120	39.92745	-122.11234	223.43	5/4/2000	8/2/2019	68
24N02W30 P002M	399021N1221338W001	--	Irrigation	300	120 - 300	39.90210	-122.13380	228.24	10/6/1992	10/15/2019	92
24N03W01 B001M	399711N1221492W001	--	Domestic	68	52 - 64	39.97110	-122.14920	248.44	2/9/1973	8/1/2019	125
24N03W02 R001M	399666N1221647W001	--	Domestic	270	--	39.96665	-122.16465	257.95	3/20/1947	10/14/2019	218
24N03W03 R002M	399586N1221812W001	--	Domestic	132	112 - 132	39.95860	-122.18120	279.46	5/2/2000	10/16/2019	69
24N03W14 B001M	399421N1221676W001	--	Industrial	140	130 - 140	39.94214	-122.16762	294.05	3/6/2001	10/15/2019	69
24N03W16 A001M	399376N1222021W001	--	Irrigation	195	85 - 195	39.93760	-122.20210	290.97	10/28/1947	10/14/2019	178
24N03W17 M001M	399346N1222349W001	--	Domestic	108	100 - 108	39.93460	-122.23490	316.48	2/20/1973	10/18/2019	182
24N03W17 M002M	399346N1222344W001	--	Irrigation	505	315 - 495	39.93458	-122.23443	316.80	10/13/2014	10/18/2019	18
24N03W20 N001M	399174N1222327W001	--	Irrigation	230	69 - 202	39.91740	-122.23270	310.99	2/20/1973	5/11/2009	74

Table B5-1. Groundwater Level Monitoring Well Summary Table

State Well Number	CASGEM Well Number	Local Well Designation	Well Type	Total Well Depth (feet bgs)	Perforated Interval (feet bgs)	Latitude (NAD 83)	Longitude (NAD 83)	Reference Point Elevation (feet AMSL)	First Measurement Date	Last Measurement Date	Measurment Count
24N03W24 E001M	399215N122 1588W001	--	Domestic	224	212 - 220	39.92147	-122.15879	298.45	9/17/2009	10/16/2019	36
24N03W26 K001M	399061N122 1689W001	--	Irrigation	245	103 - 175	39.90609	-122.16893	283.46	11/1/1947	10/15/2019	195
24N03W35 P004M	398881N122 1725W001	--	Irrigation	107	--	39.88810	-122.17250	253.46	4/23/1950	10/16/2019	165
24N03W35 P005M	398851N122 1737W001	--	Domestic	120	100 - 120	39.88510	-122.17370	251.46	5/1/2000	10/16/2019	68
24N04W02 N001M	399591N122 2874W001	--	Domestic	100	30 - 90	39.95910	-122.28740	382.71	5/9/1946	3/12/2008	134
24N04W14 N002M	399305N122 2865W001	--	Domestic	180	--	39.92972	-122.28761	375.52	8/27/1952	10/14/2019	168
24N04W33 P001M	398876N122 3207W001	--	Irrigation	780	250 - 780	39.88760	-122.32070	424.56	5/11/2000	10/14/2019	68
24N04W34 K001M	398893N122 2943W002	--	Irrigation	750	310 - 750	39.88933	-122.29434	421.50	10/19/2018	10/18/2019	4
24N04W34 P001M	398858N122 3011W002	--	Irrigation	535	290 - 475	39.88578	-122.30107	440.10	10/19/2018	10/18/2019	4
24N04W36 G001M	398929N122 2573W002	--	Irrigation	750	320 - 750	39.89290	-122.25731	362.20	10/19/2018	10/18/2019	4
25N02W31 G002M	399820N122 1294W001	--	Irrigation	115	93 - 113	39.98198	-122.12937	223.80	10/19/2012	10/14/2019	24
25N02W31 K001M	399772N122 1277W001	--	Irrigation	520	39 - 520	39.97715	-122.12770	234.00	10/19/2012	10/14/2019	24
25N03W36 H001M	399789N122 1446W001	McCoy	Irrigation	524	--	39.97888	-122.14458	241.00	6/19/2014	10/14/2019	20

Appendix 5C

Groundwater Level Representative Monitoring Point Hydrographs



21N01W04N001M Groundwater Elevation

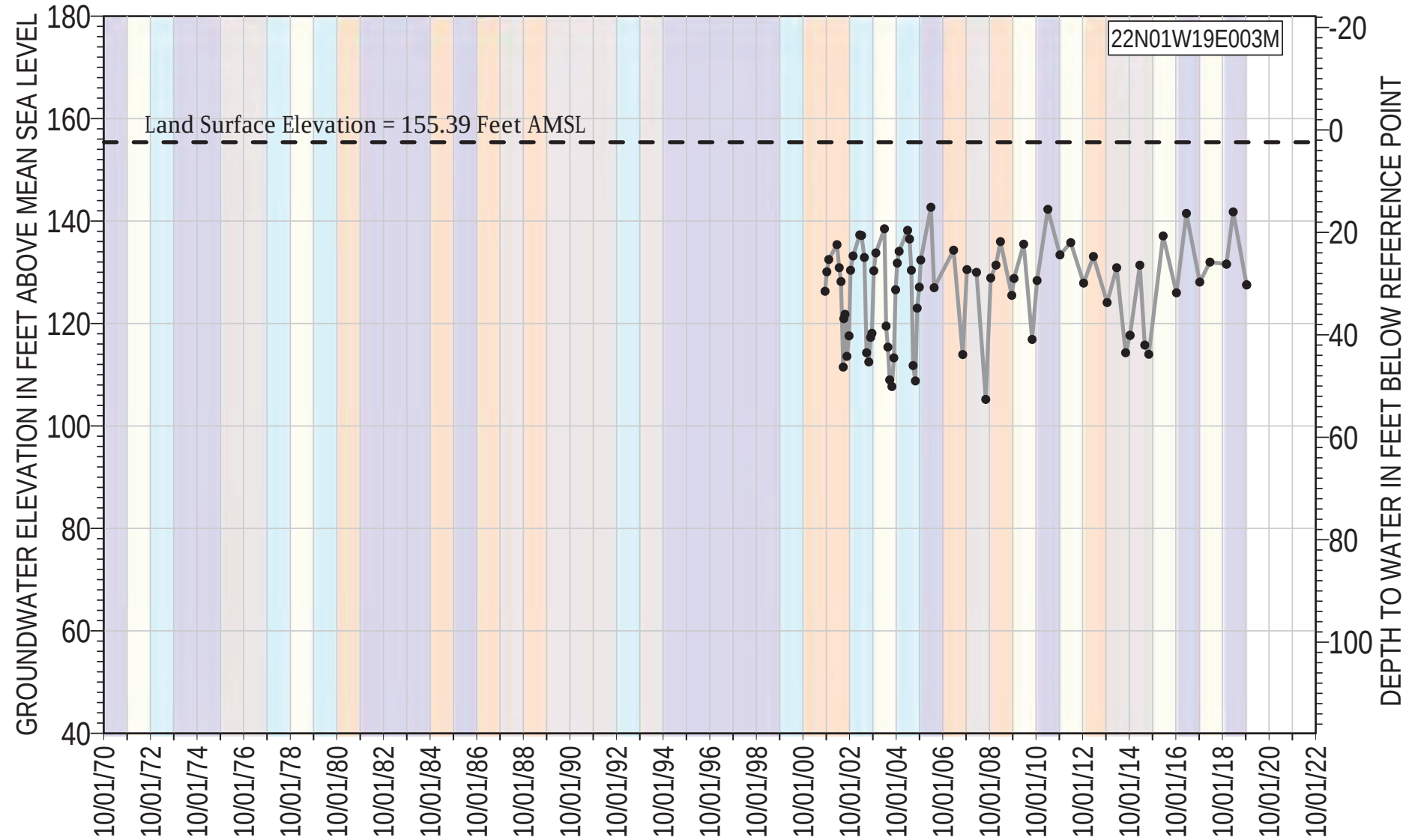
Land Surface Elevation

Reference Point Elevation= 137.68 ft AMSL
Well Type: Domestic
Total Depth: 100 ft bgs
Well Screen Interval= Unknown ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





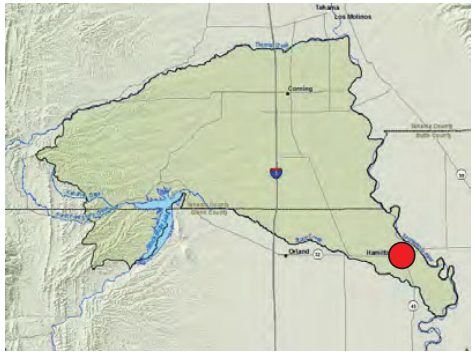
22N01W19E003M Groundwater Elevation

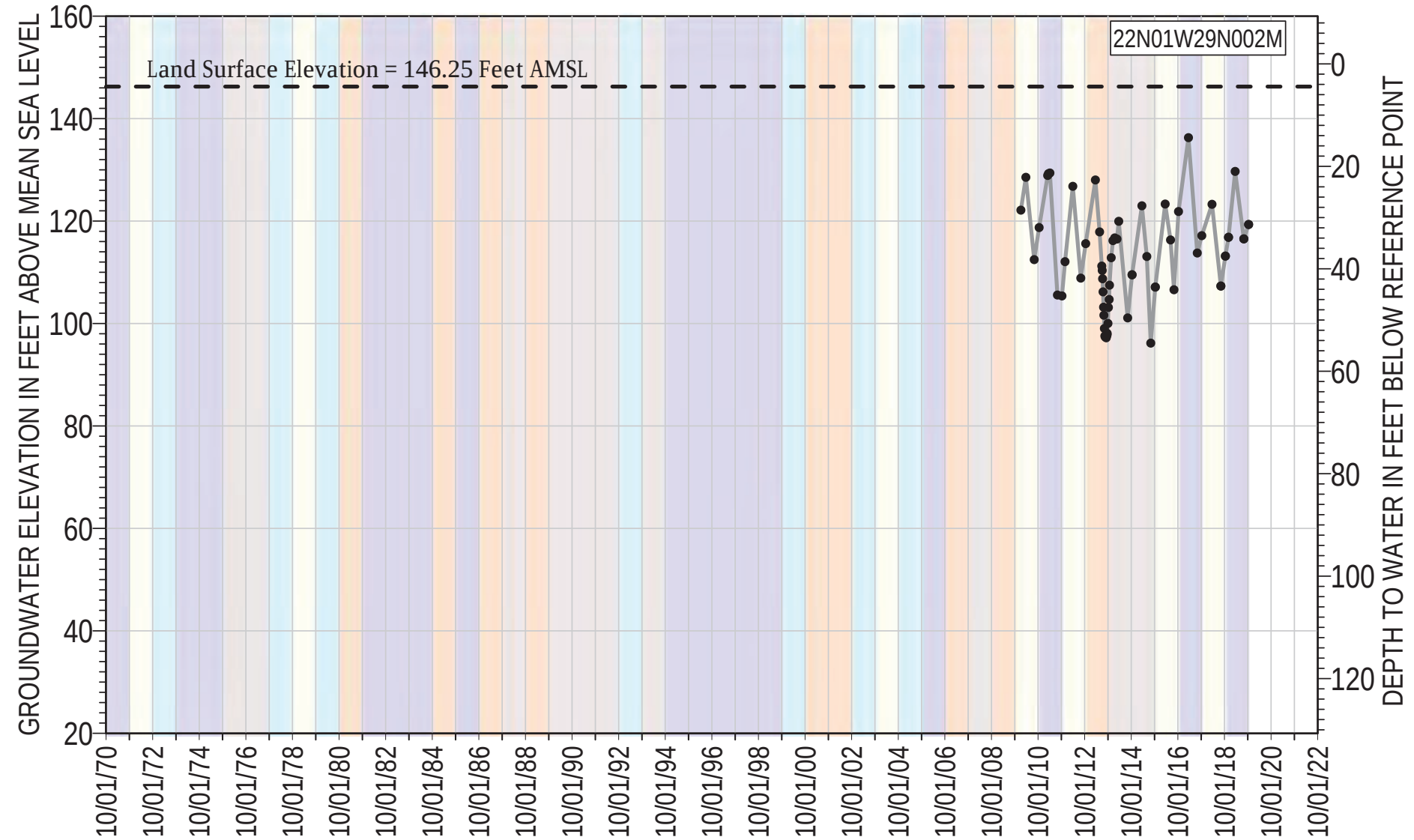
Land Surface Elevation

Reference Point Elevation= 157.79 ft AMSL
Well Type: Irrigation
Total Depth: 500 ft bgs
Well Screen Interval= 80 - 400 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





22N01W29N002M Groundwater Elevation

Land Surface Elevation

Reference Point Elevation= 150.68 ft AMSL

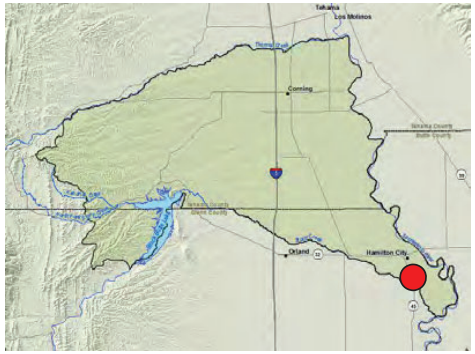
Well Type: Observation

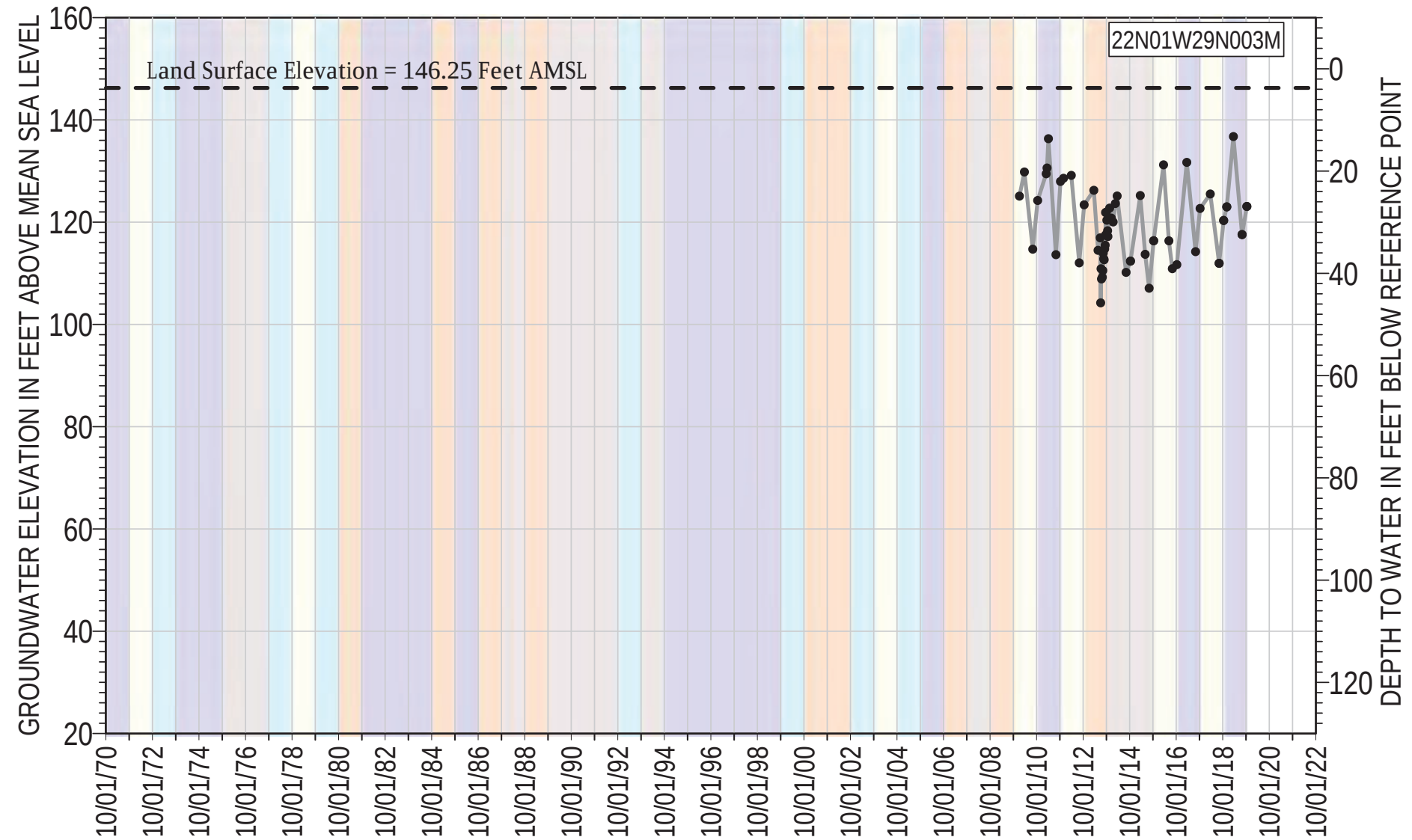
Total Depth: 670 ft bgs

Well Screen Interval= 549 - 641 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





22N01W29N003M Groundwater Elevation

Land Surface Elevation

Reference Point Elevation= 149.99 ft AMSL

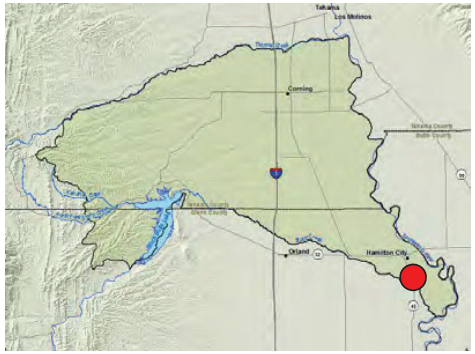
Well Type: Observation

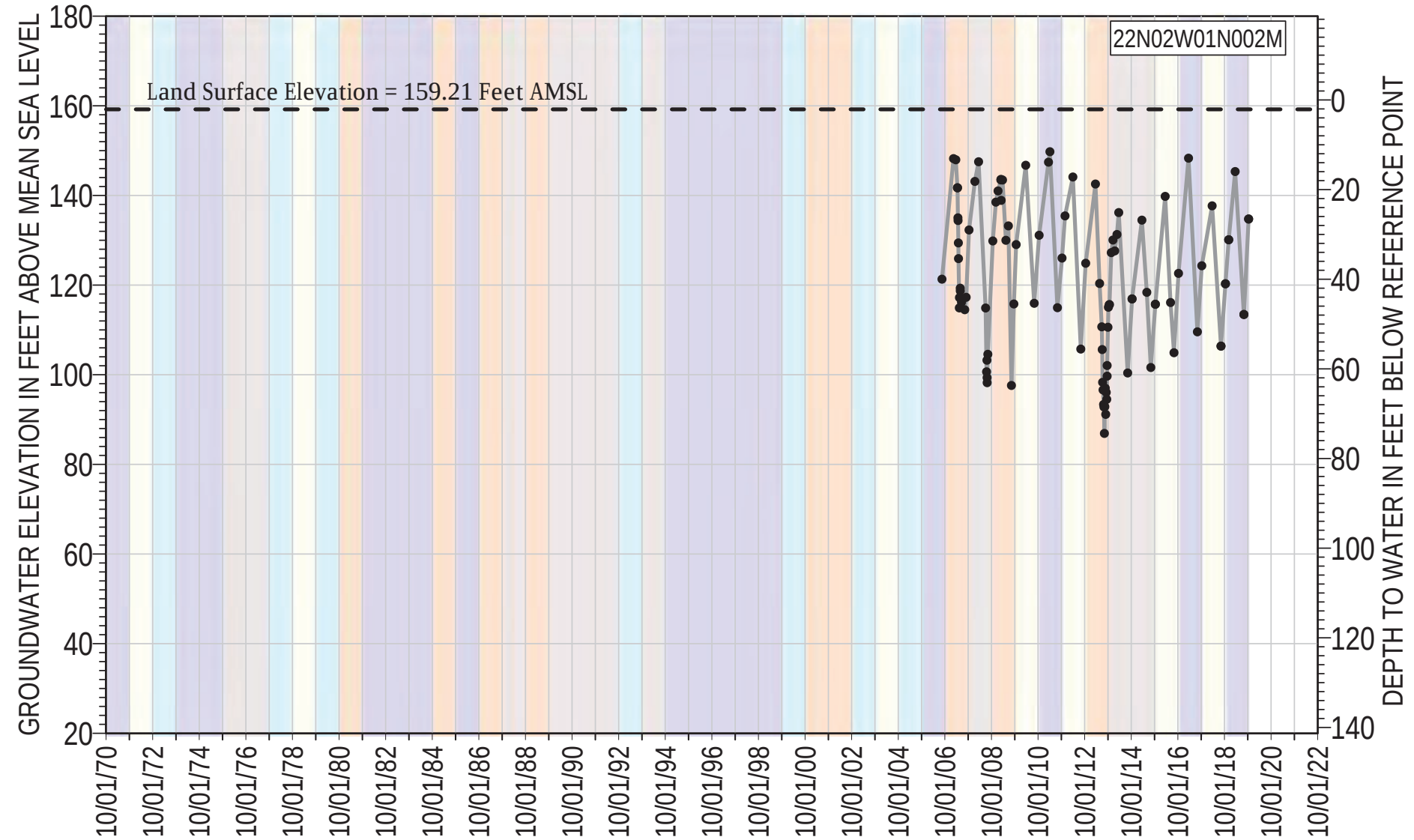
Total Depth: 400 ft bgs

Well Screen Interval= 189 - 380 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





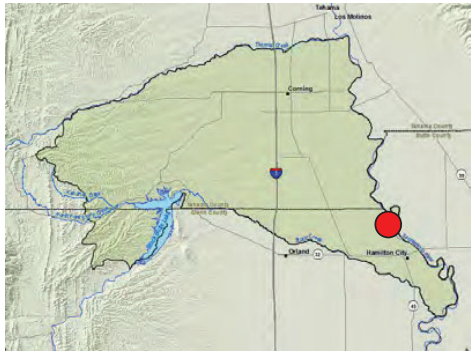
22N02W01N002M Groundwater Elevation

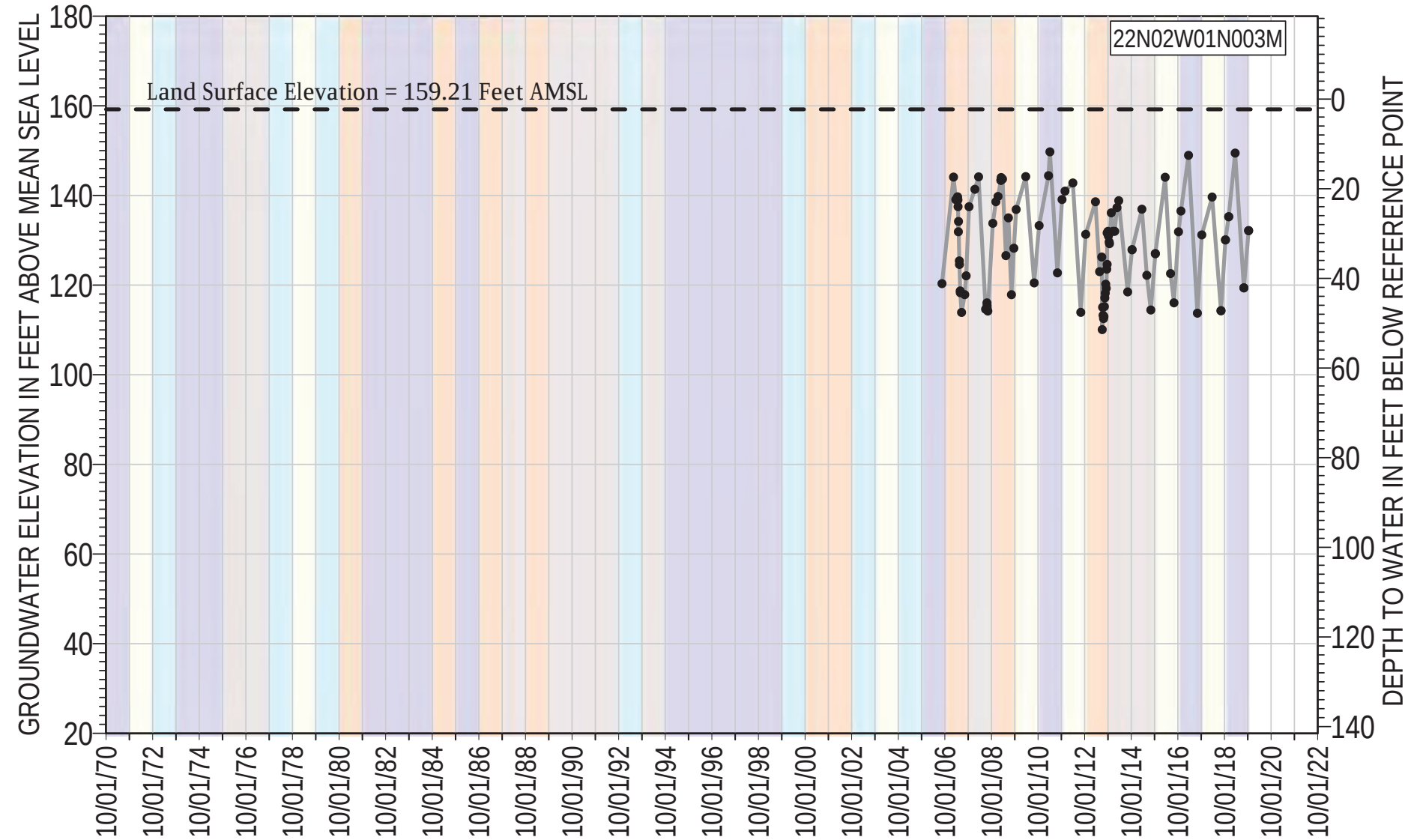
Land Surface Elevation

Reference Point Elevation= 161.305 ft AMSL
Well Type: Observation
Total Depth: 730 ft bgs
Well Screen Interval= 700 - 710 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





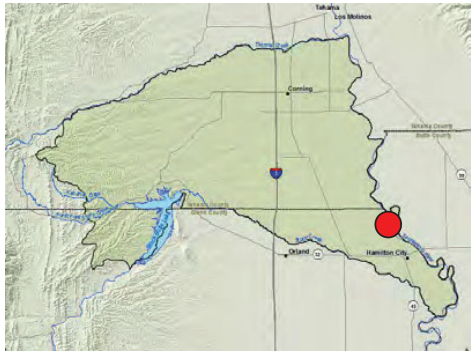
22N02W01N003M Groundwater Elevation

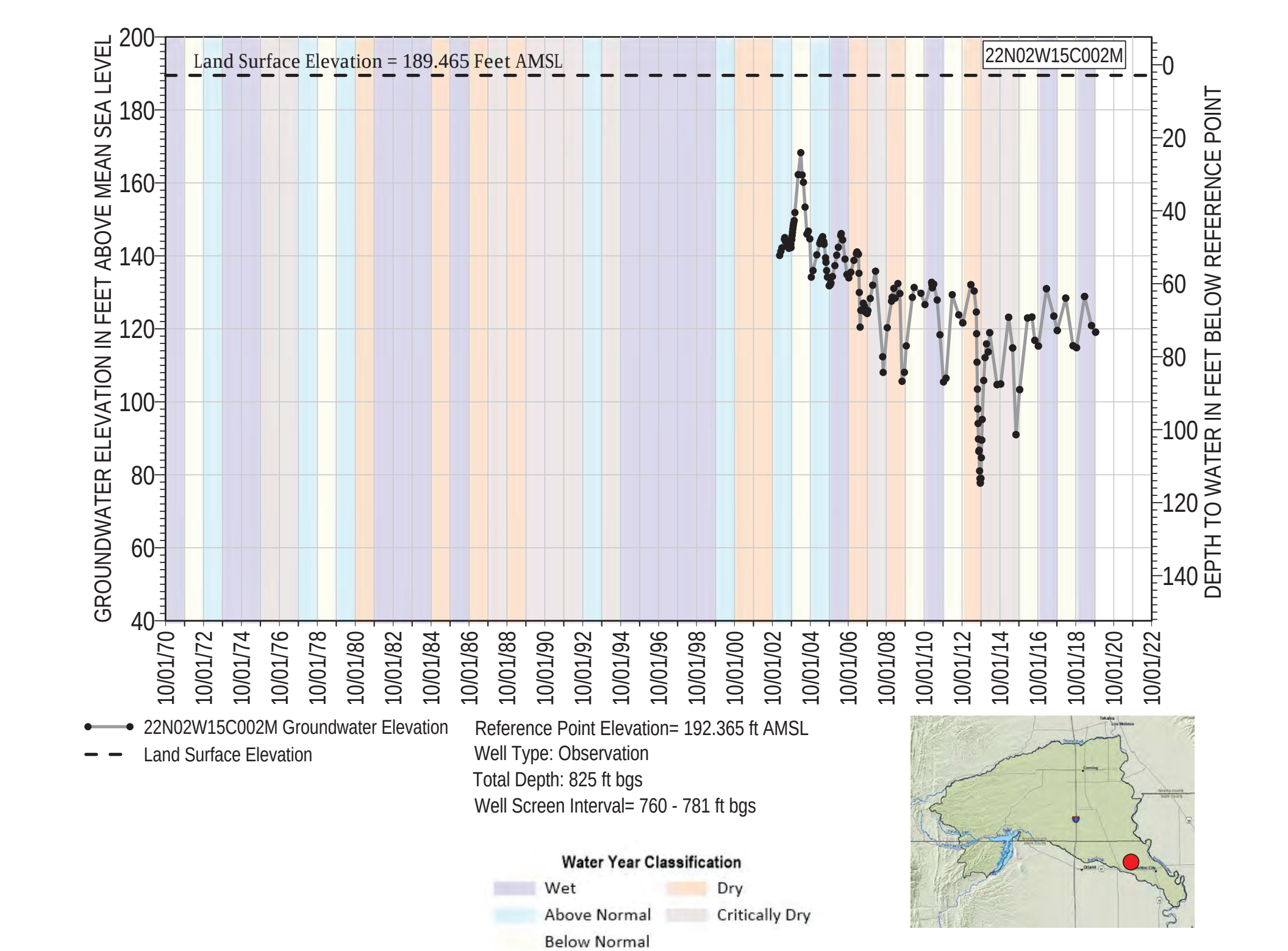
Land Surface Elevation

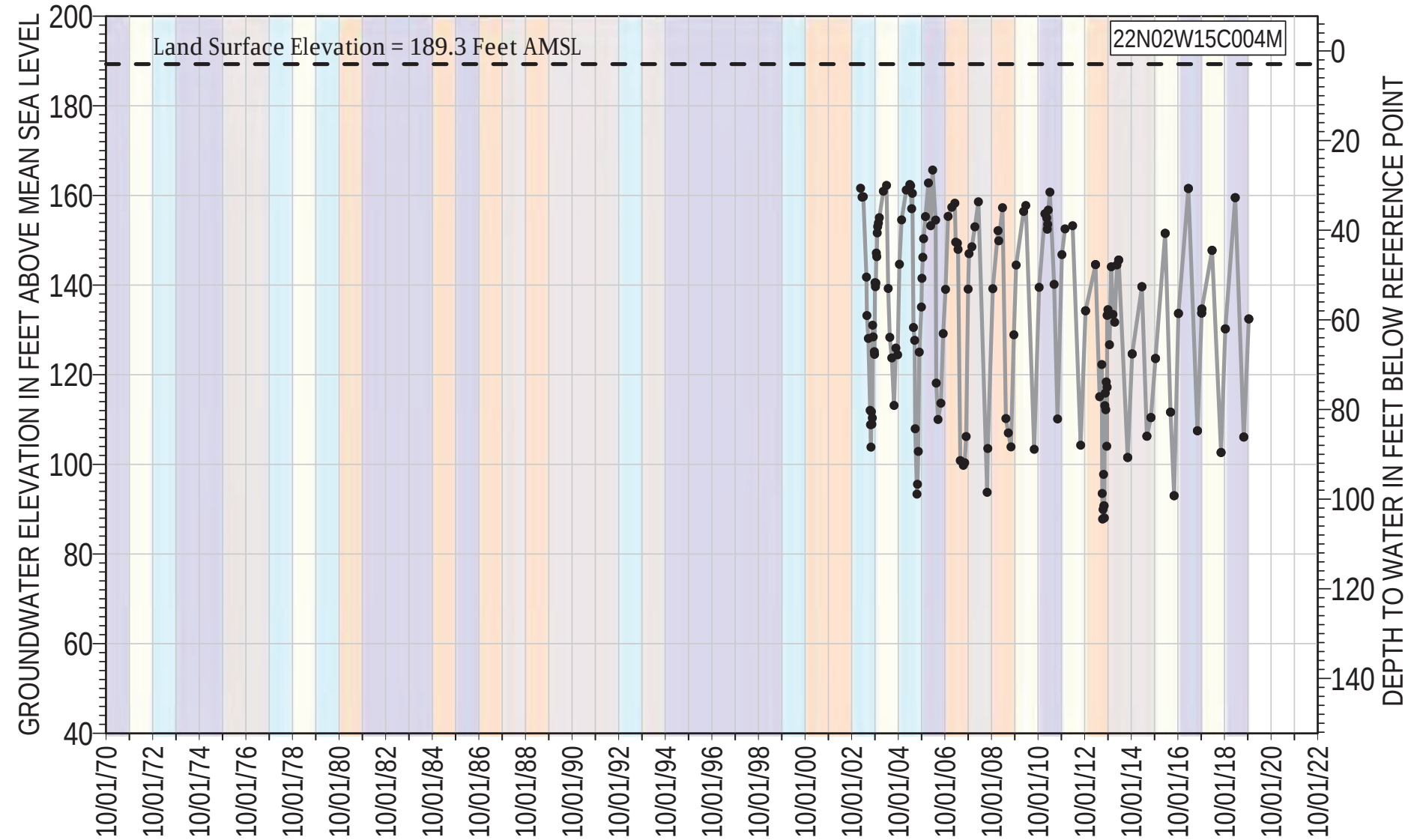
Reference Point Elevation= 161.495 ft AMSL
Well Type: Observation
Total Depth: 440 ft bgs
Well Screen Interval= 210 - 370 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	




Land Surface Elevation = 189.465 Feet AMSL
22N02W15C002M
GROUNDWATER ELEVATION IN FEET ABOVE MEAN SEA LEVEL
DEPTH TO WATER IN FEET BELOW REFERENCE POINT
200
180
160
140
120
100
80
60
40
0
20
40
60
80
100
120
140
10/01/70
10/01/72
10/01/74
10/01/76
10/01/78
10/01/80
10/01/82
10/01/84
10/01/86
10/01/88
10/01/90
10/01/92
10/01/94
10/01/96
10/01/98
10/01/00
10/01/02
10/01/04
10/01/06
10/01/08
10/01/10
10/01/12
10/01/14
10/01/16
10/01/18
10/01/20
10/01/22
22N02W15C002M Groundwater Elevation
Land Surface Elevation
Reference Point Elevation= 192.365 ft AMSL
Well Type: Observation
Total Depth: 825 ft bgs
Well Screen Interval= 760 - 781 ft bgs
Water Year Classification
Wet
Above Normal
Below Normal
Dry
Critically Dry



22N02W15C004M Groundwater Elevation

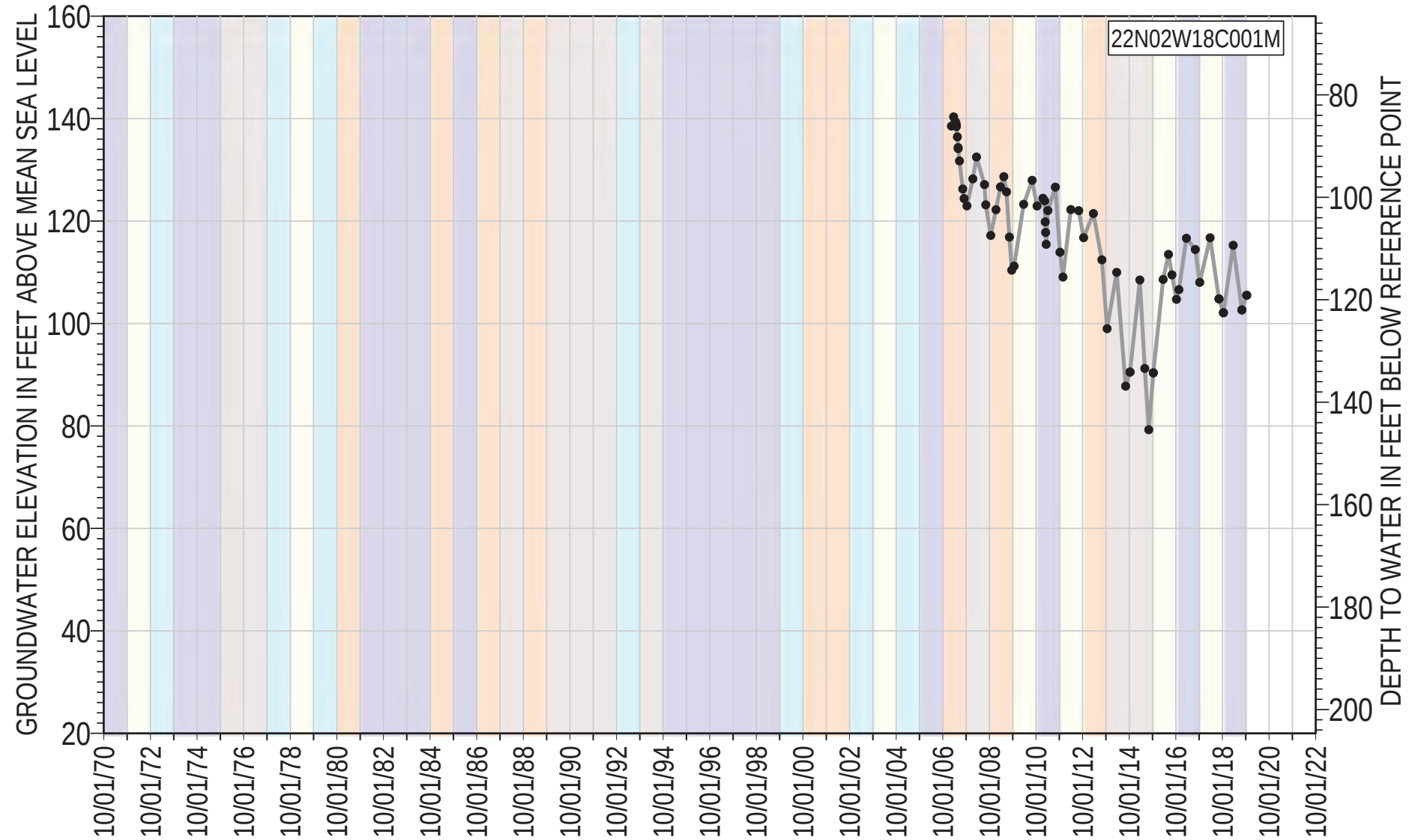
Land Surface Elevation

Reference Point Elevation= 192.245 ft AMSL
Well Type: Observation
Total Depth: 258 ft bgs
Well Screen Interval= 210 - 220 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





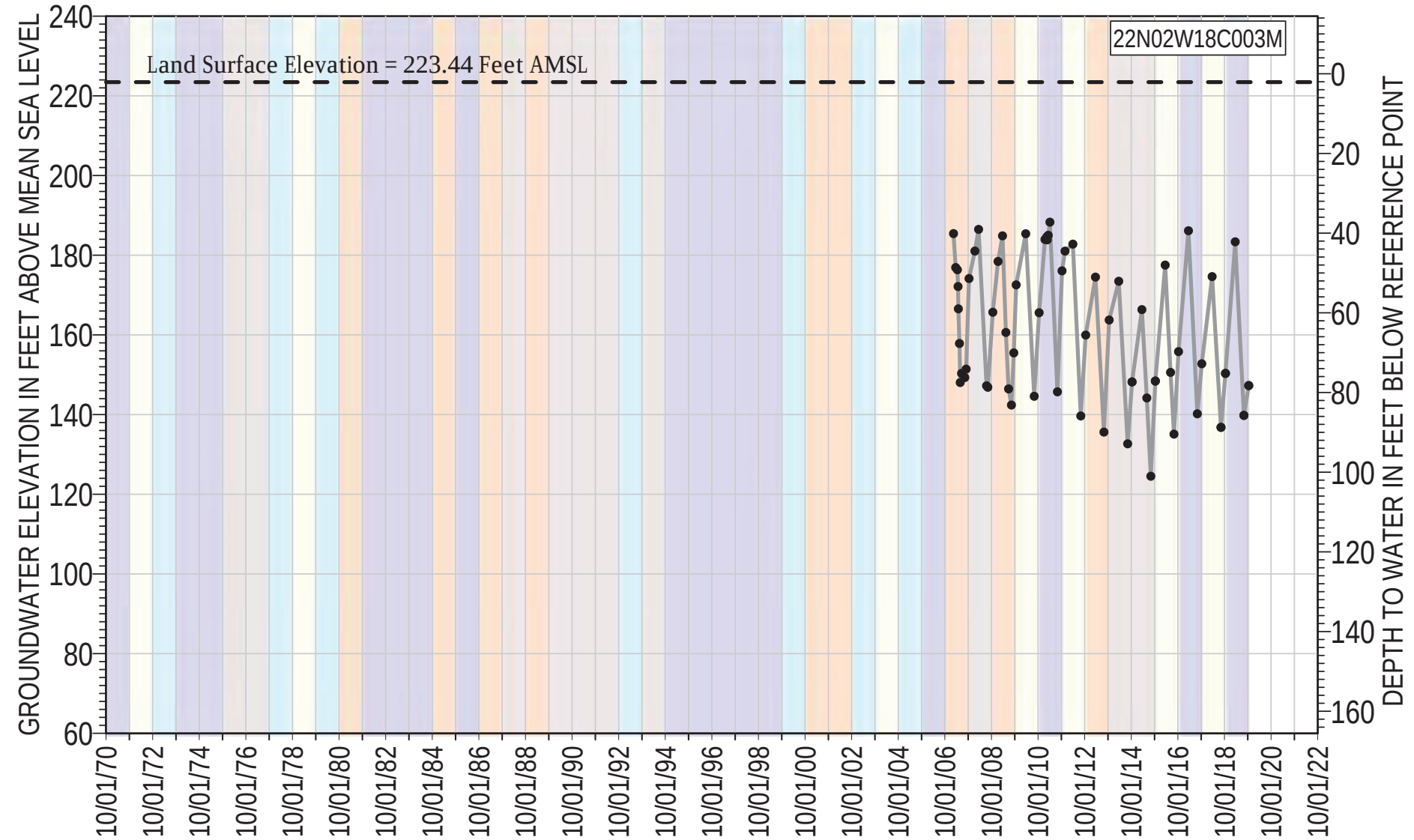
22N02W18C001M Groundwater Elevation

Reference Point Elevation= 224.64 ft AMSL
Well Type: Observation
Total Depth: 1062 ft bgs
Well Screen Interval= 841 - 1029 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





22N02W18C003M Groundwater Elevation

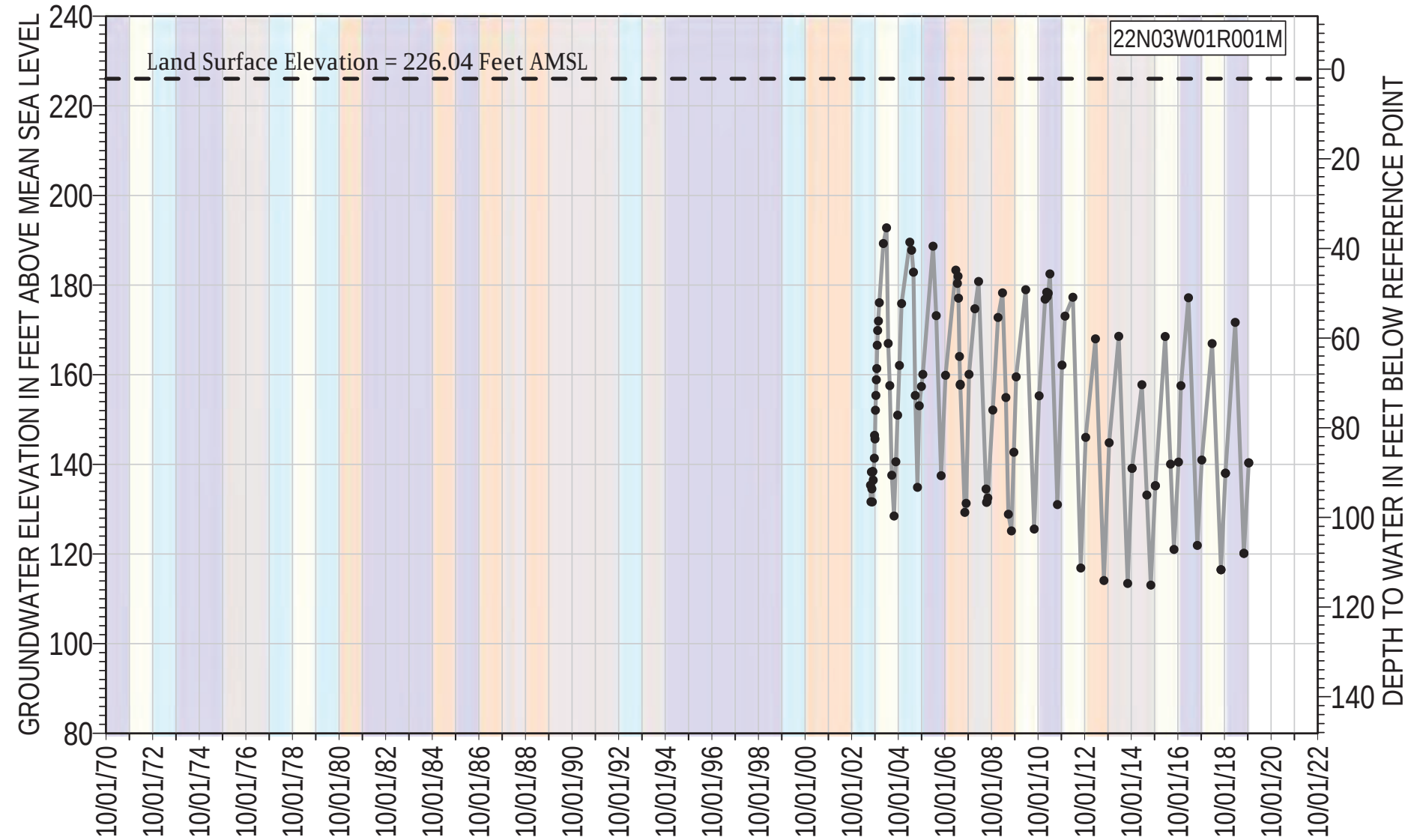
Land Surface Elevation

Reference Point Elevation= 225.54 ft AMSL
Well Type: Observation
Total Depth: 188 ft bgs
Well Screen Interval= 165 - 175 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





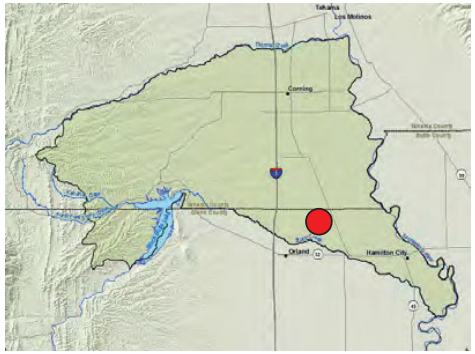
22N03W01R001M Groundwater Elevation

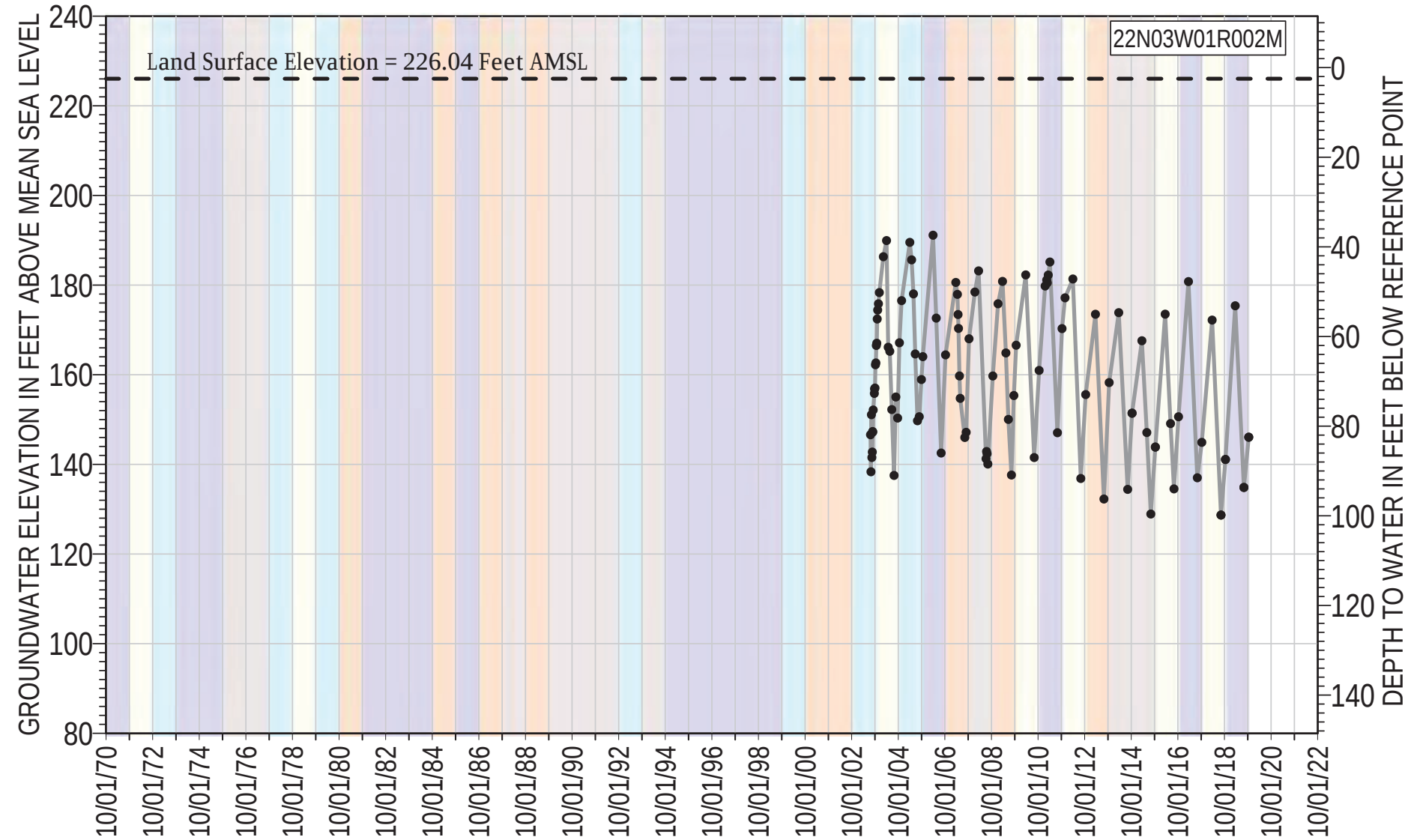
Land Surface Elevation

Reference Point Elevation= 228.174 ft AMSL
Well Type: Observation
Total Depth: 515 ft bgs
Well Screen Interval= 470 - 480 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





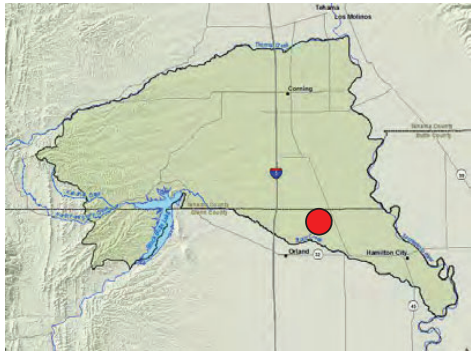
22N03W01R002M Groundwater Elevation

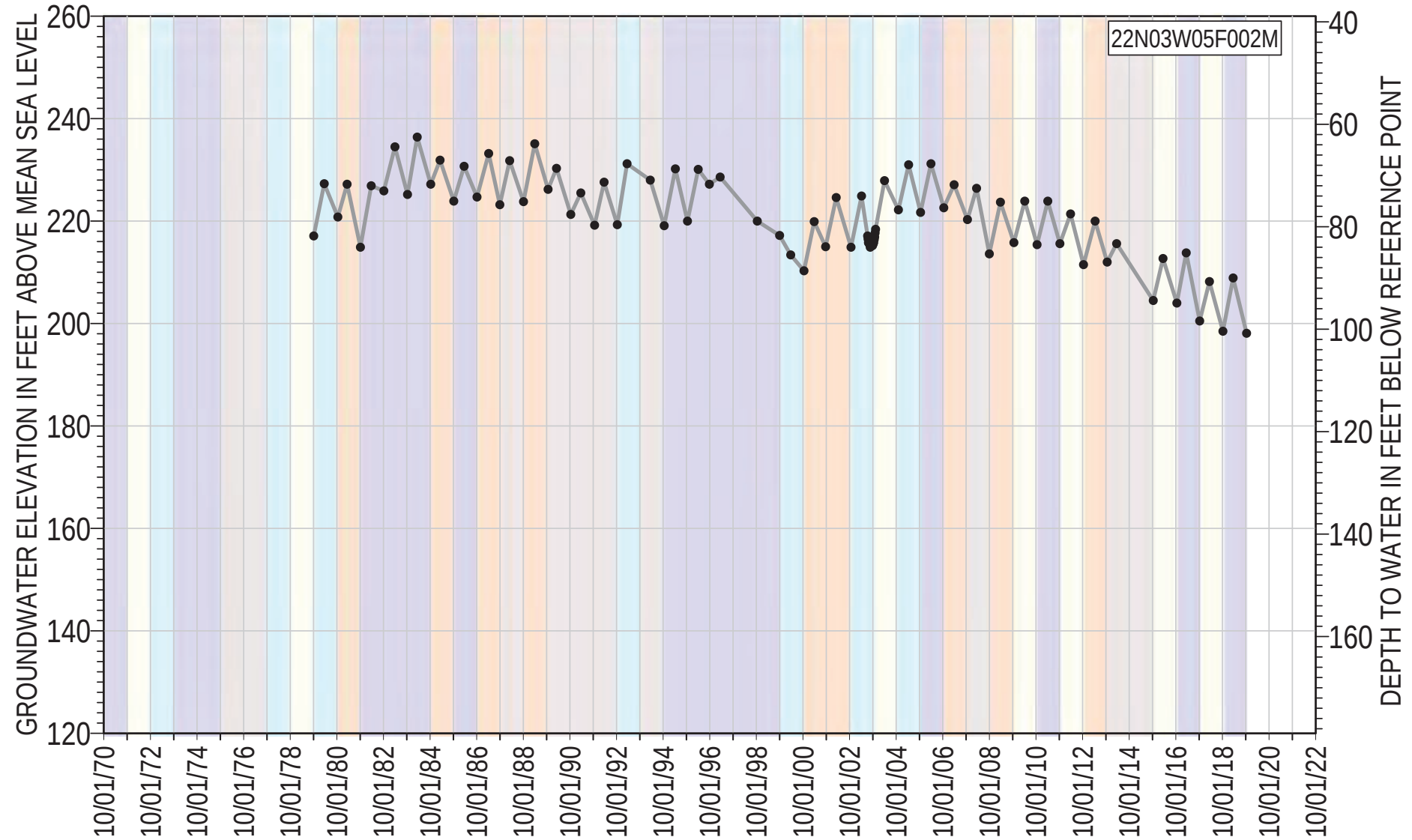
Land Surface Elevation

Reference Point Elevation= 228.529 ft AMSL
Well Type: Observation
Total Depth: 314 ft bgs
Well Screen Interval= 270 - 280 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





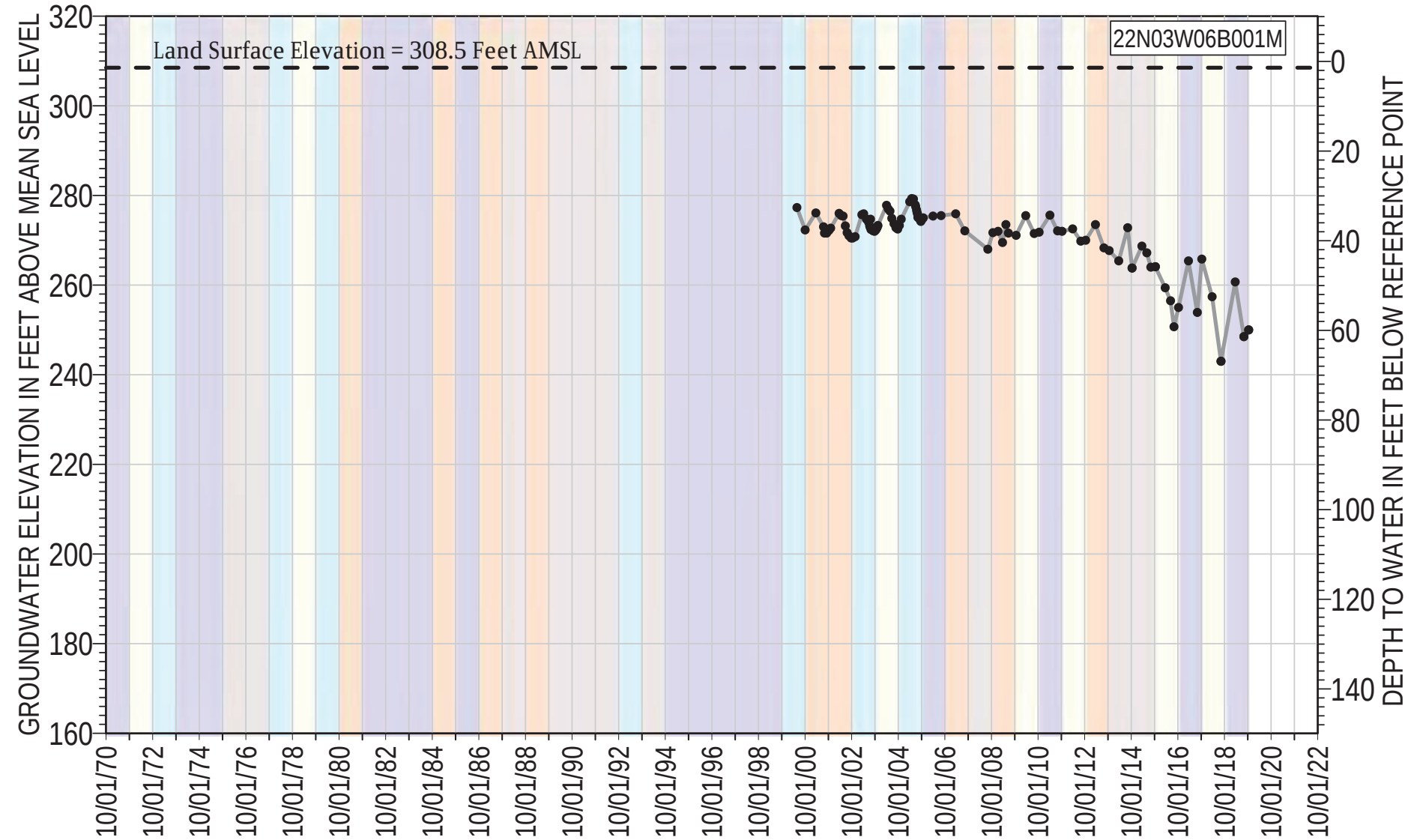
22N03W05F002M Groundwater Elevation

Reference Point Elevation= 298.89 ft AMSL
Well Type: Irrigation
Total Depth: 218 ft bgs
Well Screen Interval= 188 - 218 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





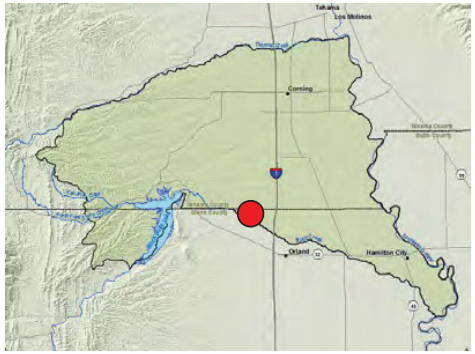
22N03W06B001M Groundwater Elevation

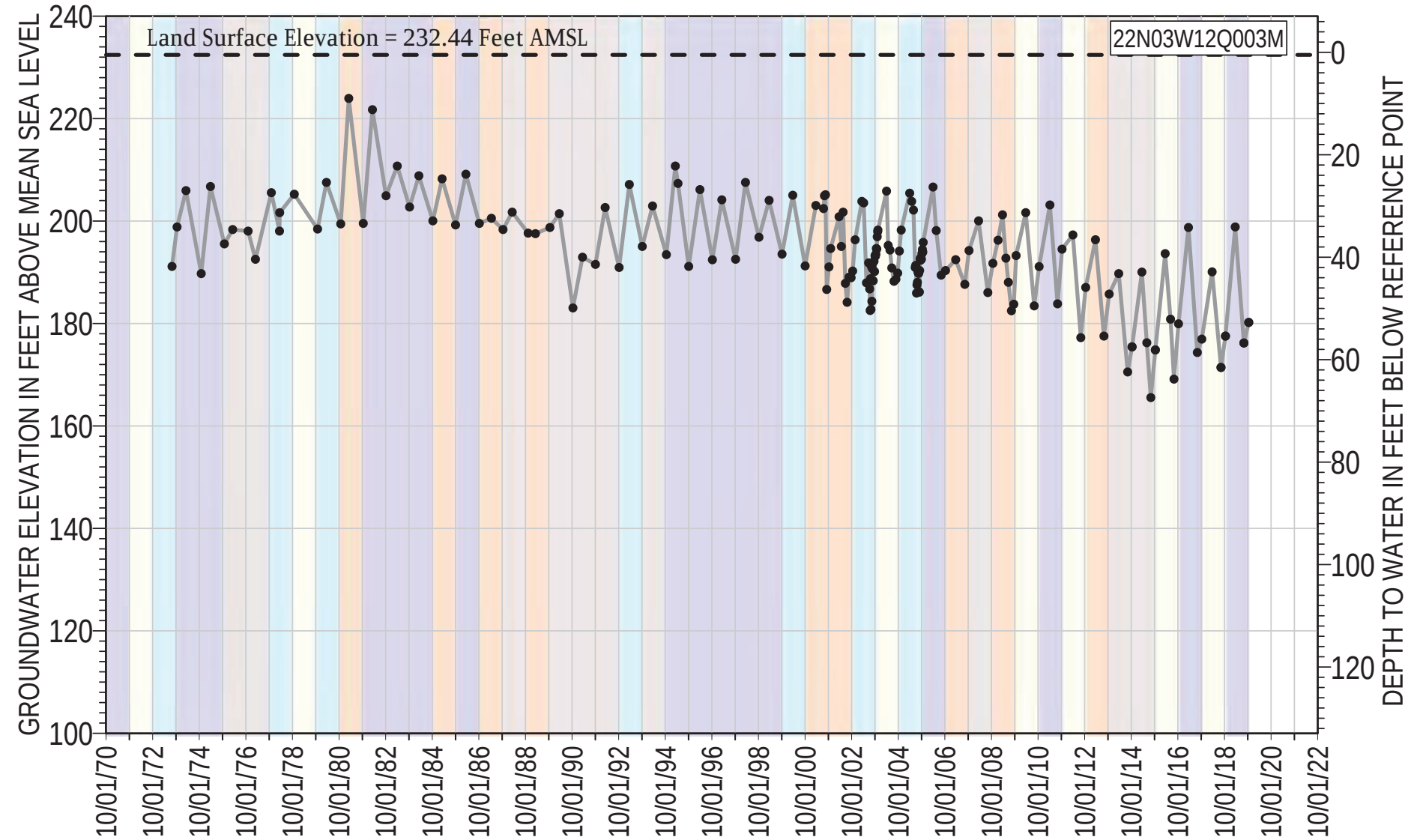
Land Surface Elevation

Reference Point Elevation= 309.9 ft AMSL
Well Type: Domestic
Total Depth: 210 ft bgs
Well Screen Interval= 195 - 210 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





22N03W12Q003M Groundwater Elevation

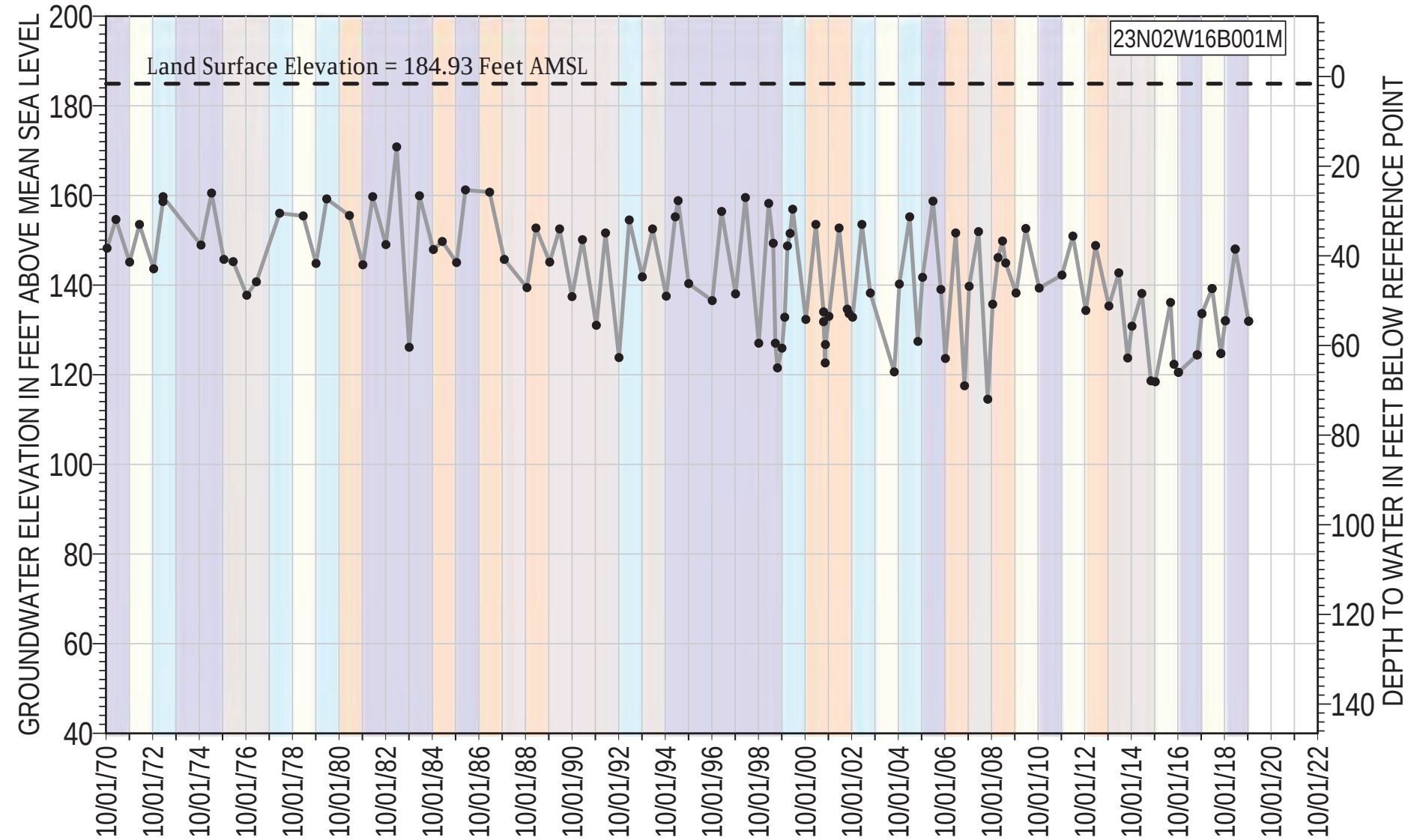
Land Surface Elevation

Reference Point Elevation= 232.94 ft AMSL
Well Type: Domestic
Total Depth: 124 ft bgs
Well Screen Interval= 112 - 123 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





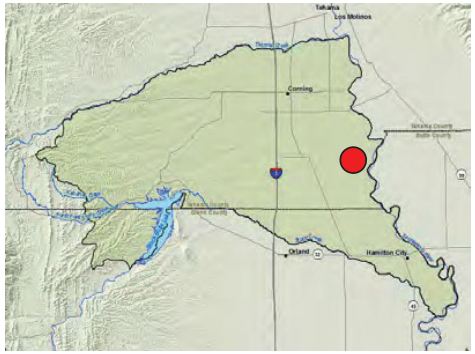
23N02W16B001M Groundwater Elevation

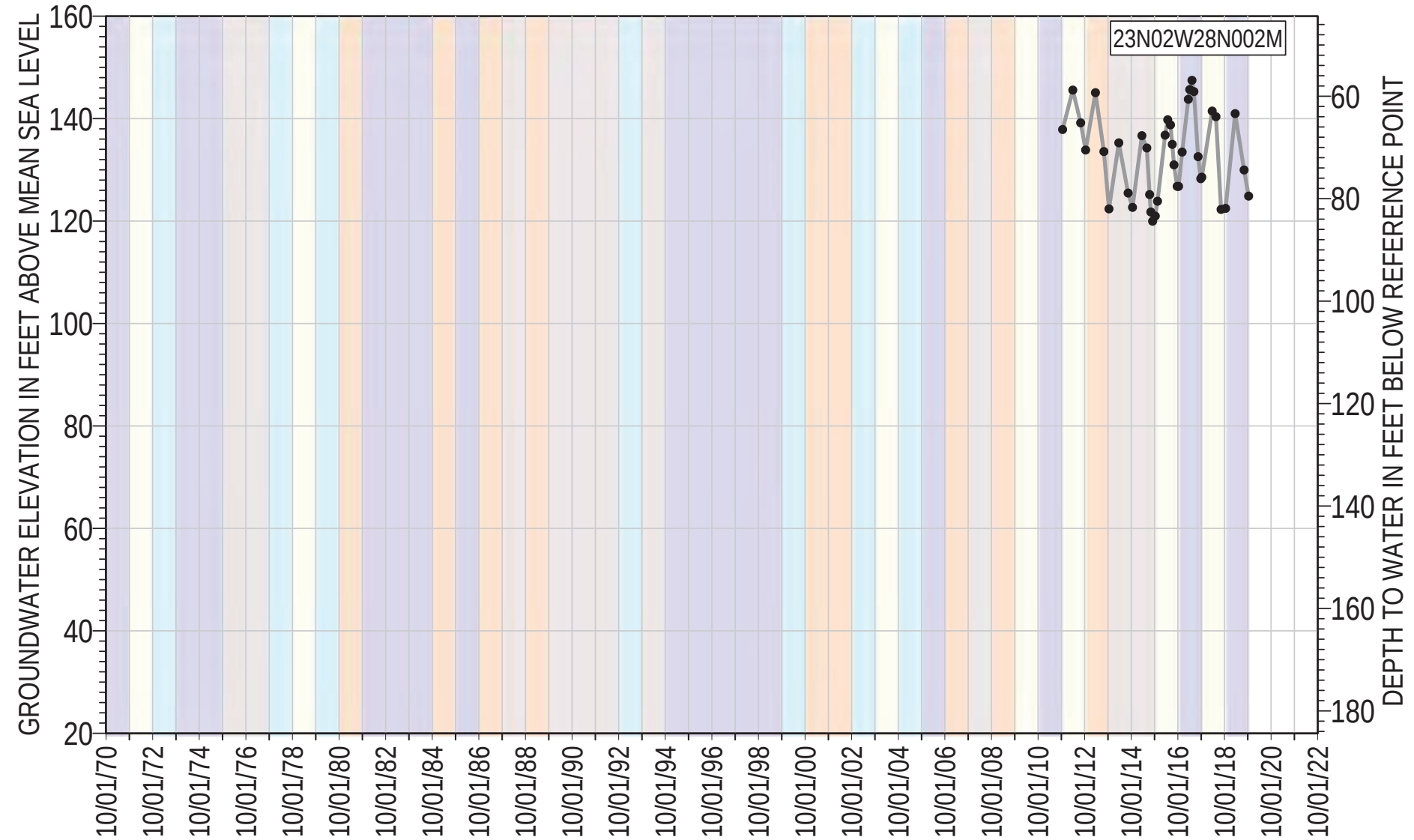
Land Surface Elevation

Reference Point Elevation= 186.53 ft AMSL
Well Type: Irrigation
Total Depth: 120 ft bgs
Well Screen Interval= 100 - 120 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



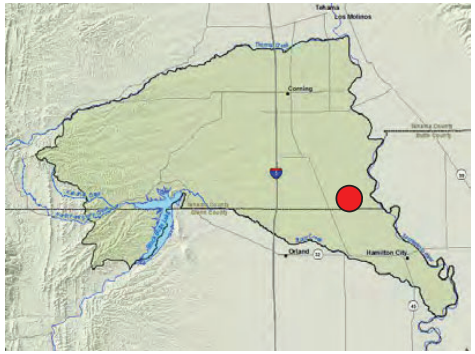


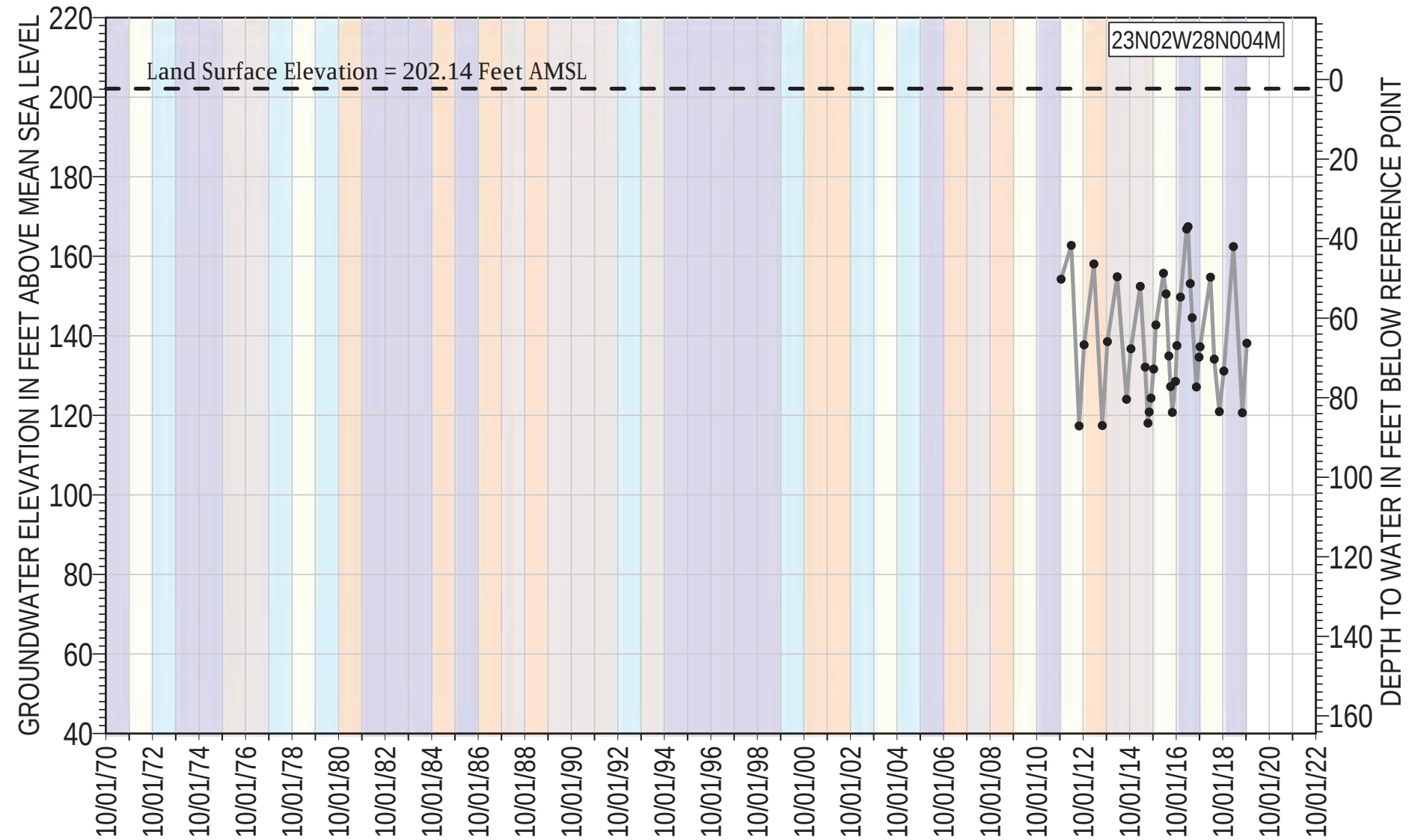
23N02W28N002M Groundwater Elevation

Reference Point Elevation= 204.37 ft AMSL
Well Type: Observation
Total Depth: 580 ft bgs
Well Screen Interval= 550 - 570 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





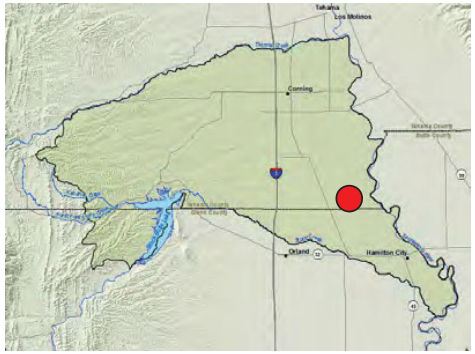
23N02W28N004M Groundwater Elevation

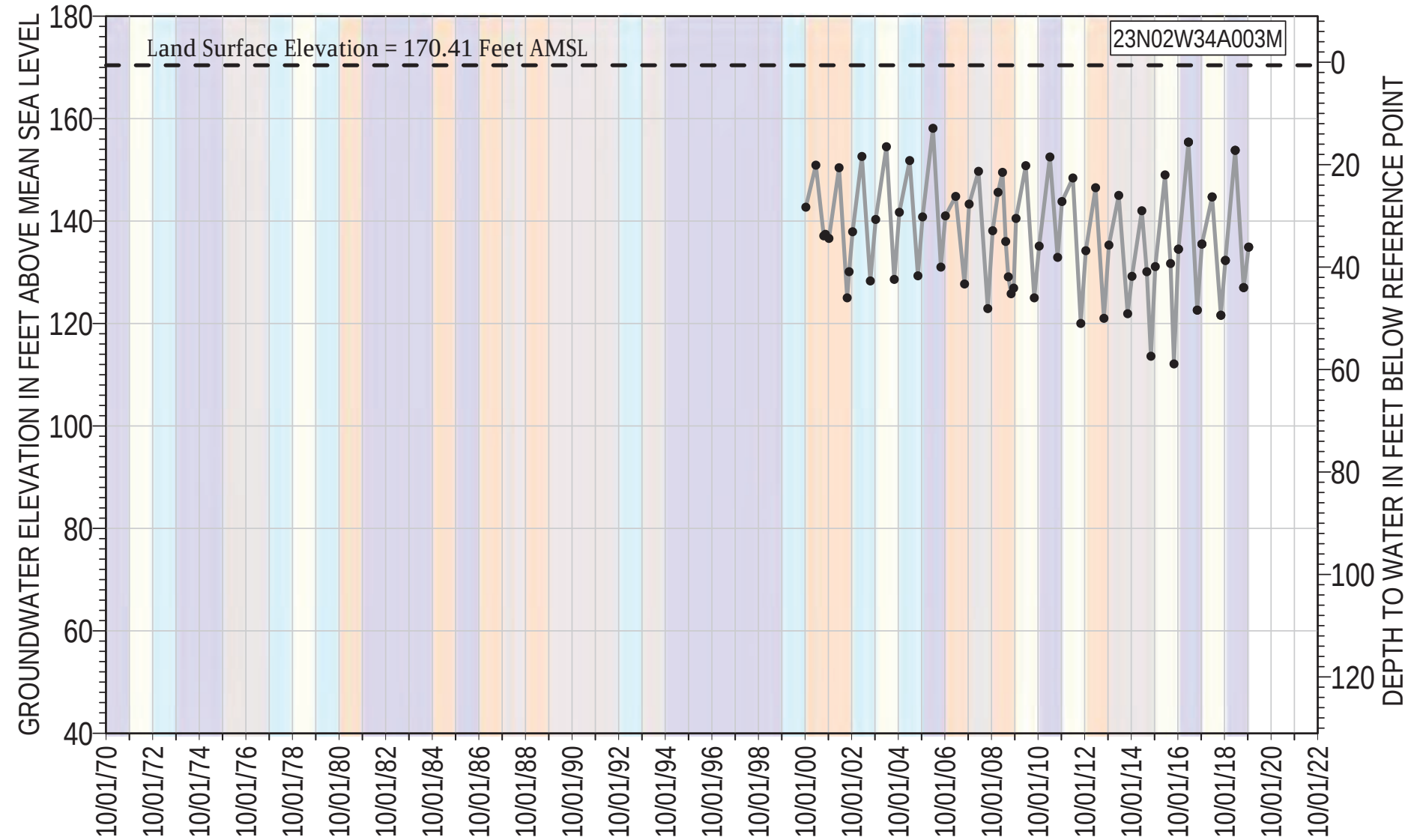
Land Surface Elevation

Reference Point Elevation= 204.43 ft AMSL
Well Type: Observation
Total Depth: 205 ft bgs
Well Screen Interval= 100 - 170 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





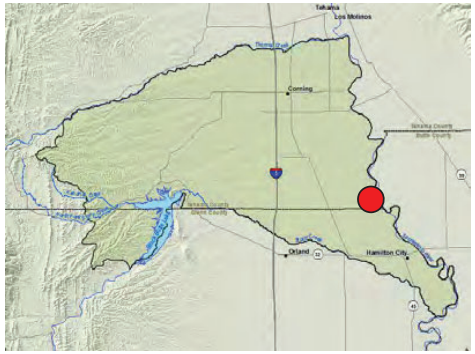
23N02W34A003M Groundwater Elevation

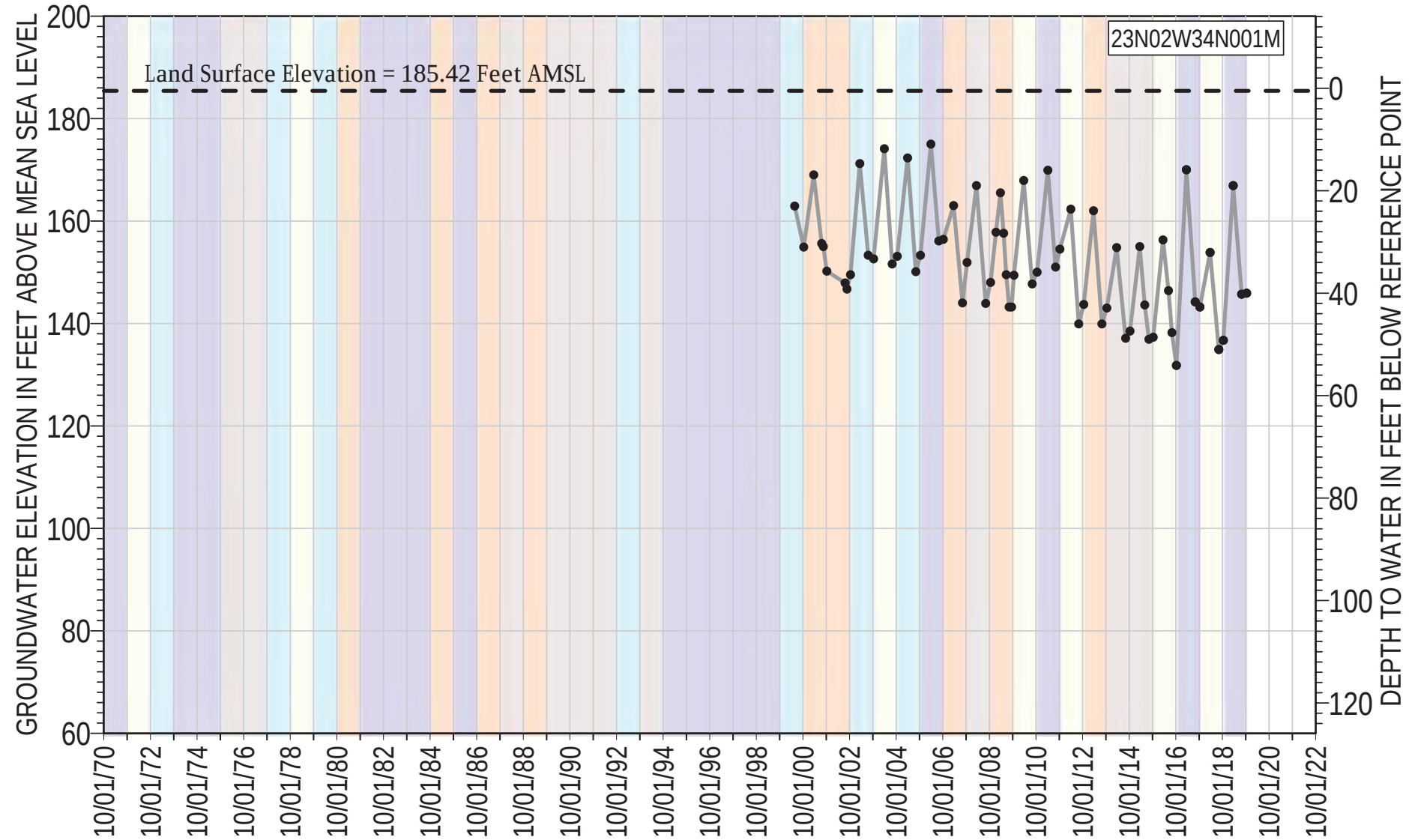
Land Surface Elevation

Reference Point Elevation= 171.01 ft AMSL
Well Type: Irrigation
Total Depth: 125 ft bgs
Well Screen Interval= 104 - 124 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





23N02W34N001M Groundwater Elevation

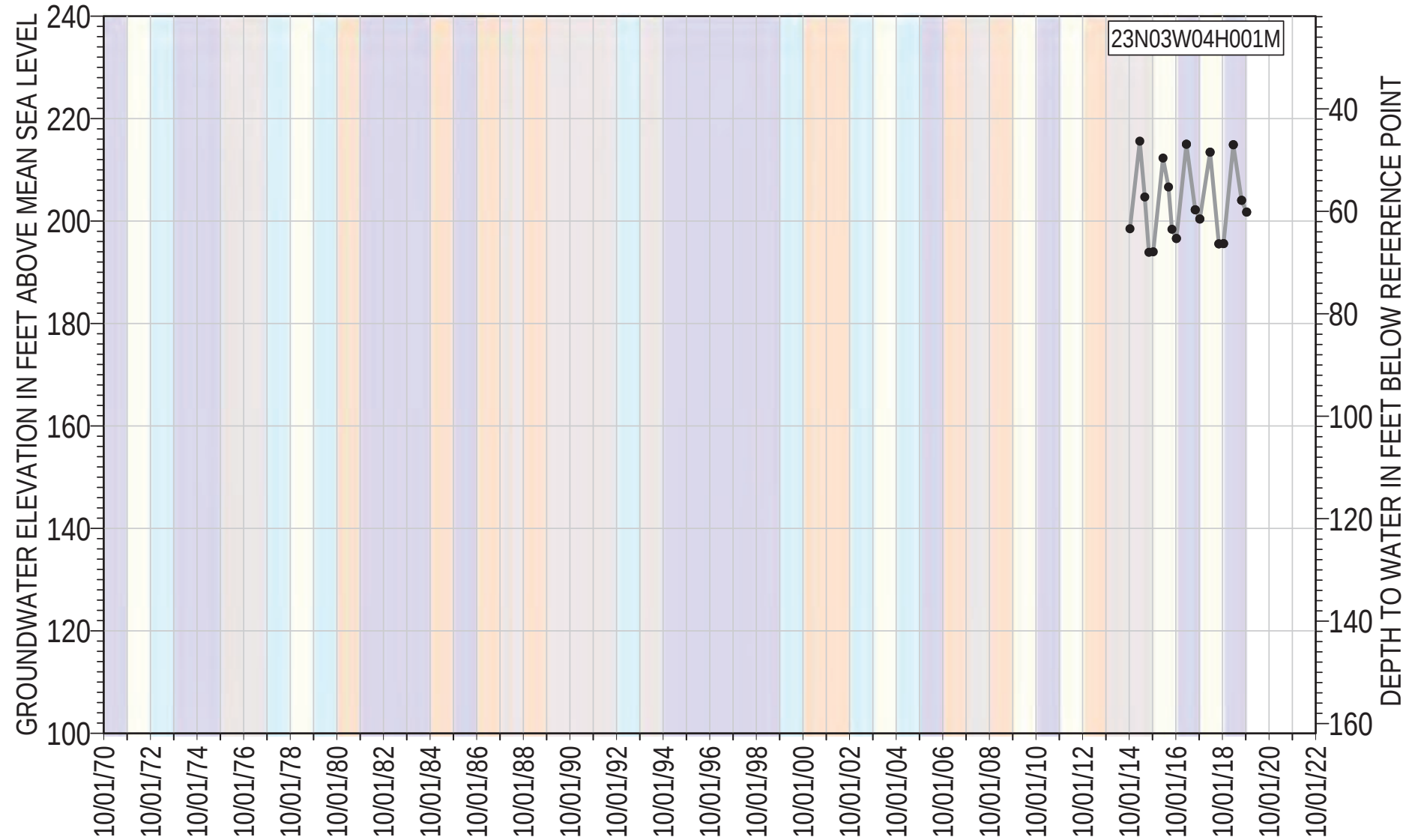
Land Surface Elevation

Reference Point Elevation= 185.92 ft AMSL
Well Type: Industrial
Total Depth: 100 ft bgs
Well Screen Interval= 70 - 100 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





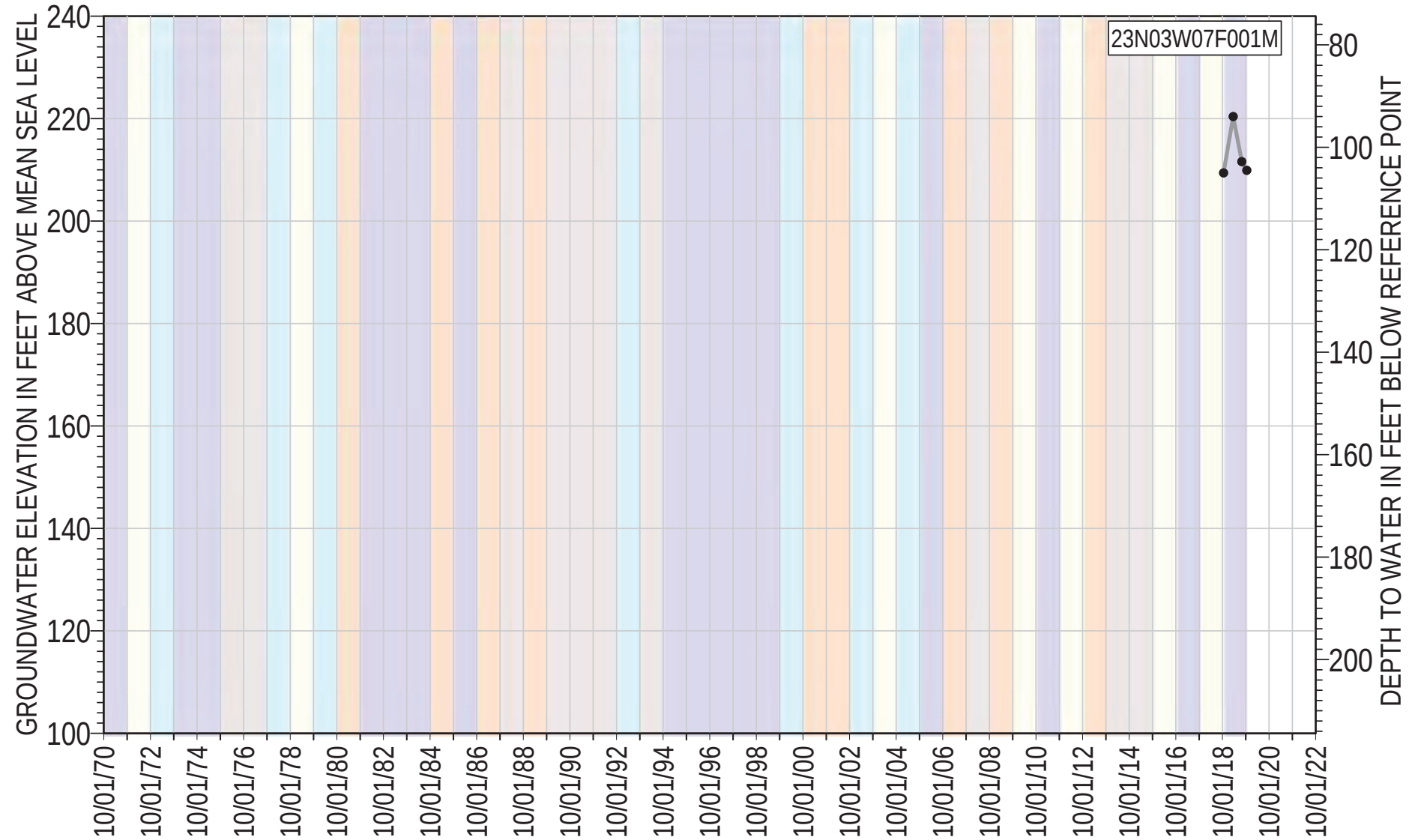
23N03W04H001M Groundwater Elevation

Reference Point Elevation= 261.9 ft AMSL
Well Type: Irrigation
Total Depth: 270 ft bgs
Well Screen Interval= 200 - 270 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



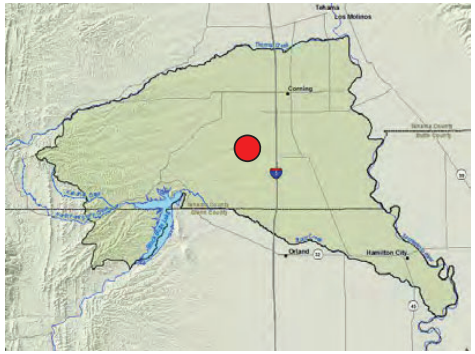


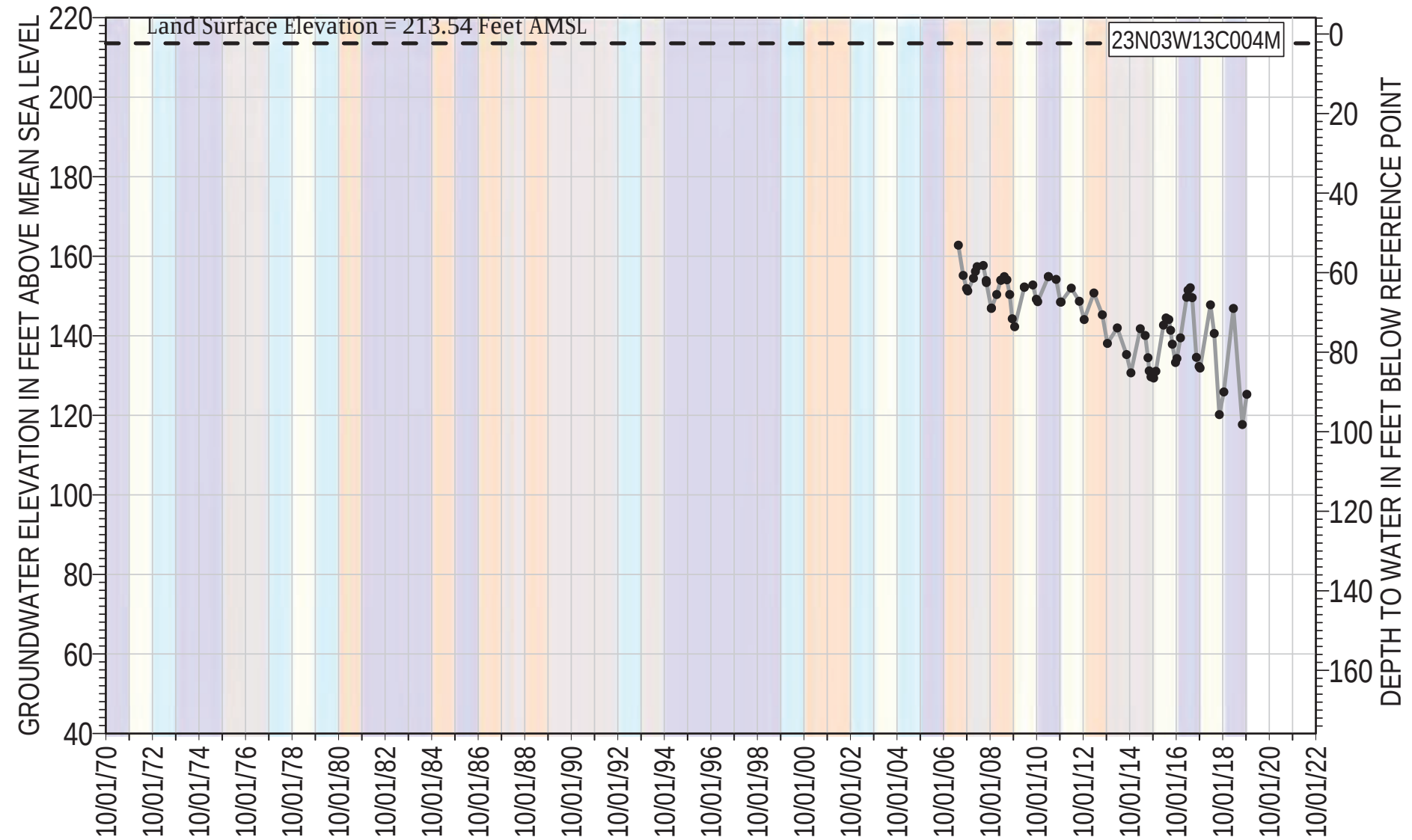
23N03W07F001M Groundwater Elevation

Reference Point Elevation= 314.4 ft AMSL
Well Type: Irrigation
Total Depth: 790 ft bgs
Well Screen Interval= 240 - 790 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





23N03W13C004M Groundwater Elevation

Land Surface Elevation

Reference Point Elevation= 215.88 ft AMSL

Well Type: Observation

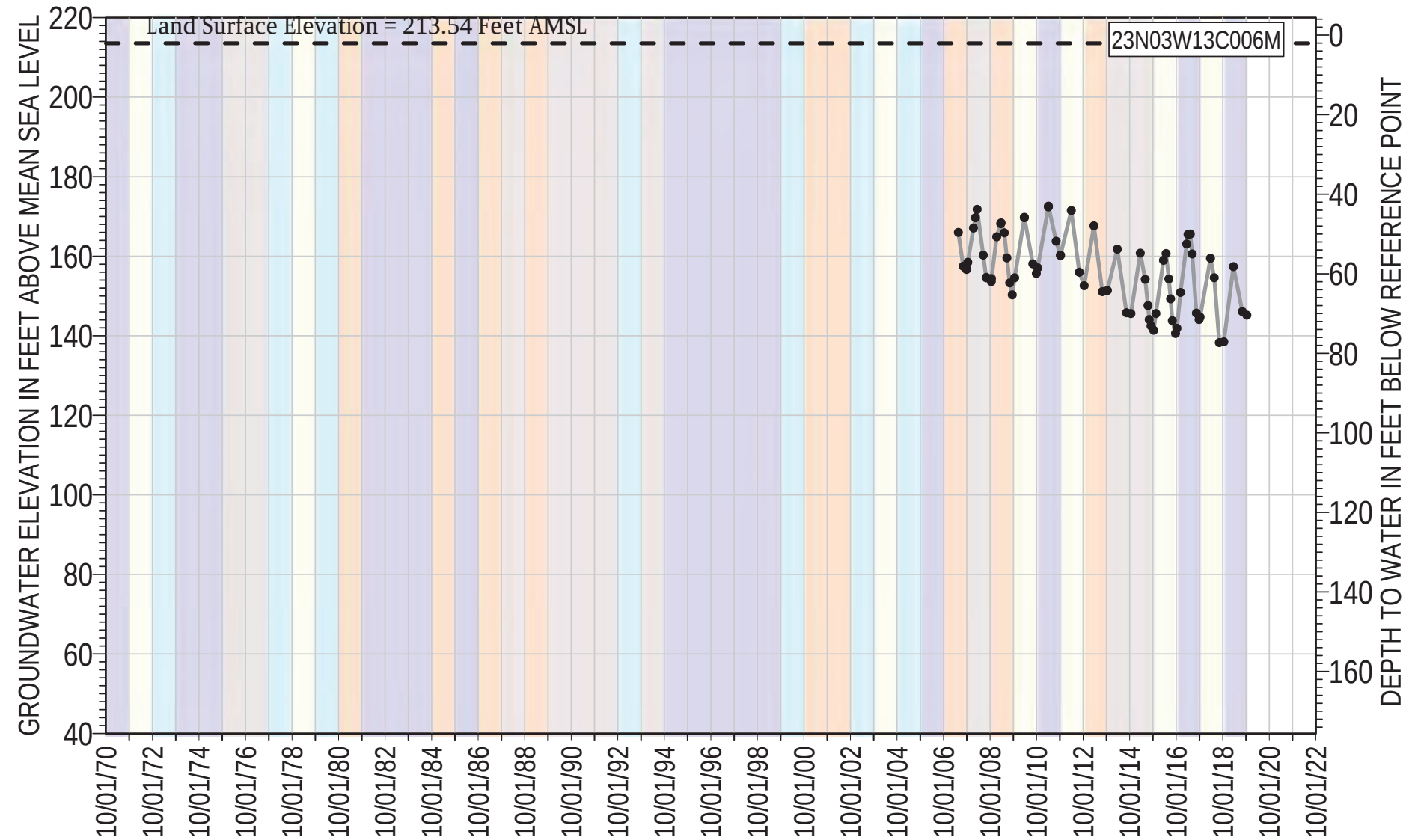
Total Depth: 835 ft bgs

Well Screen Interval= 815 - 825 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





23N03W13C006M Groundwater Elevation

Land Surface Elevation

Reference Point Elevation= 215.59 ft AMSL

Well Type: Observation

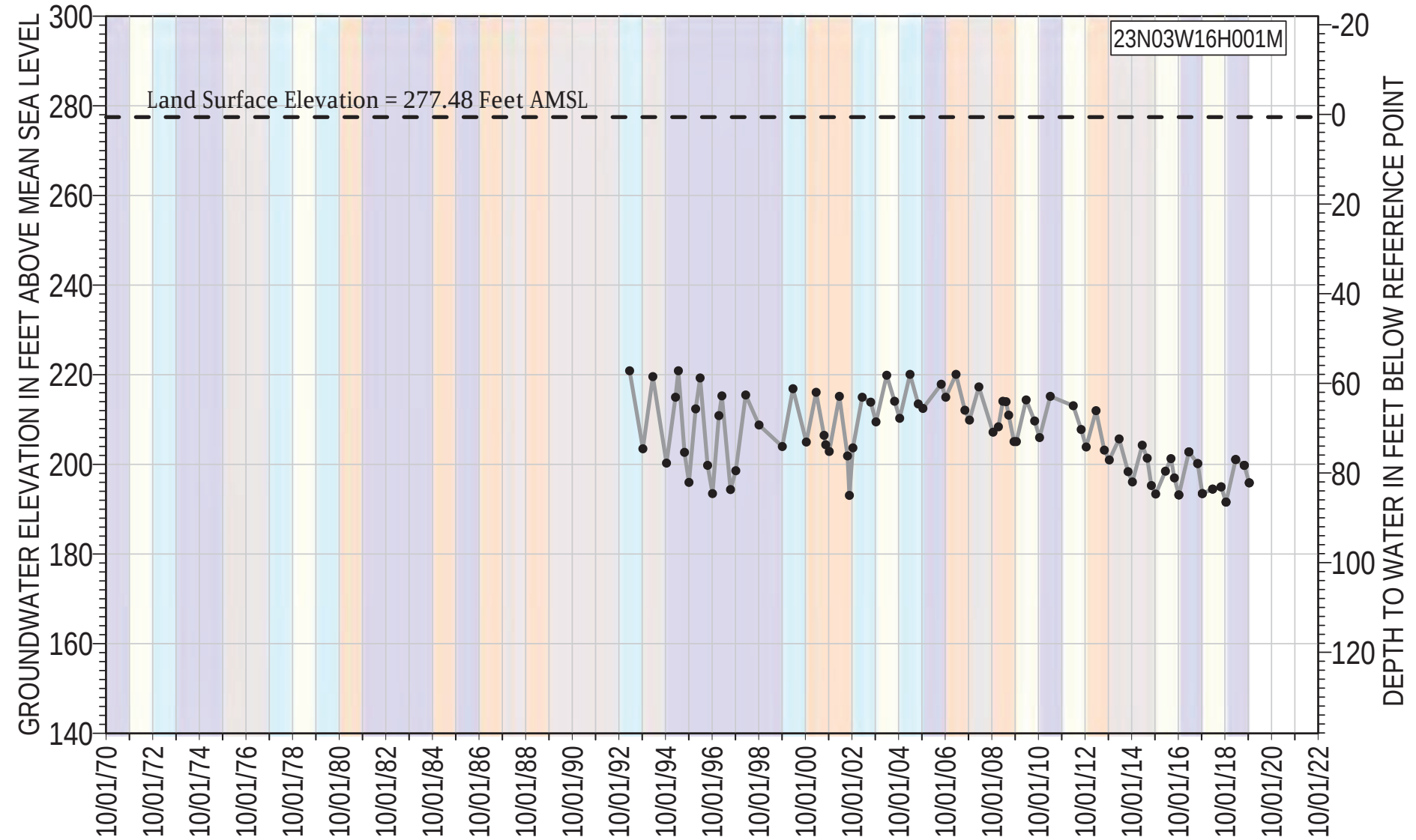
Total Depth: 182 ft bgs

Well Screen Interval= 95 - 135 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





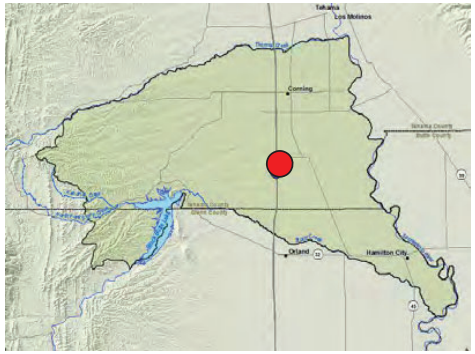
23N03W16H001M Groundwater Elevation

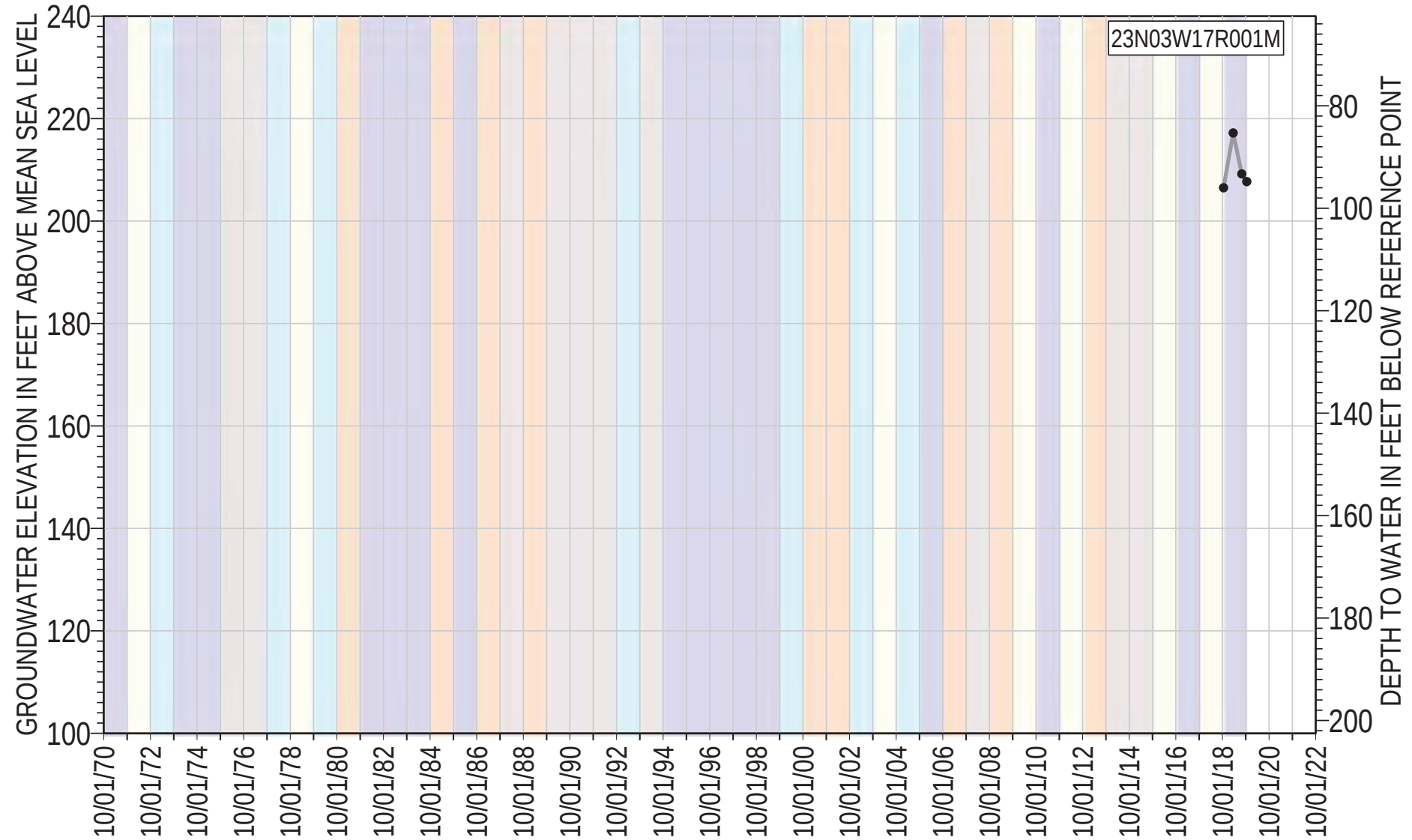
Land Surface Elevation

Reference Point Elevation= 278.08 ft AMSL
Well Type: Domestic
Total Depth: 150 ft bgs
Well Screen Interval= 144 - 150 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



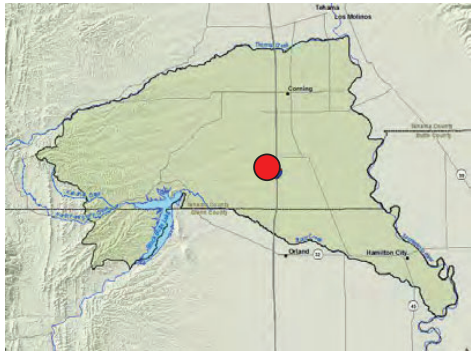


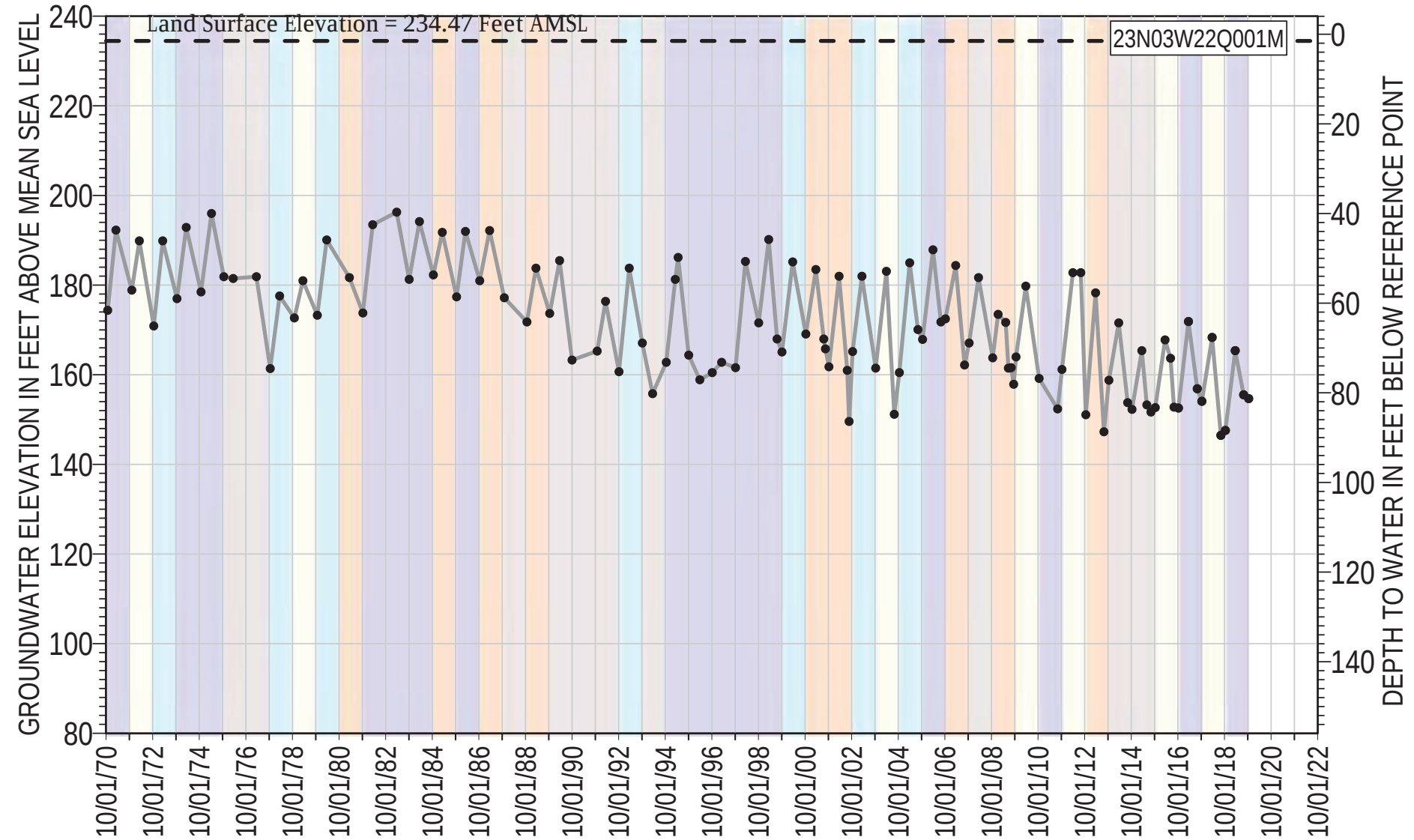
23N03W17R001M Groundwater Elevation

Reference Point Elevation= 302.5 ft AMSL
Well Type: Irrigation
Total Depth: 720 ft bgs
Well Screen Interval= 360 - 720 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





23N03W22Q001M Groundwater Elevation

Land Surface Elevation

Reference Point Elevation= 235.97 ft AMSL

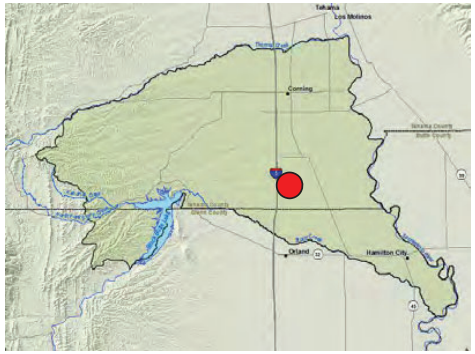
Well Type: Irrigation

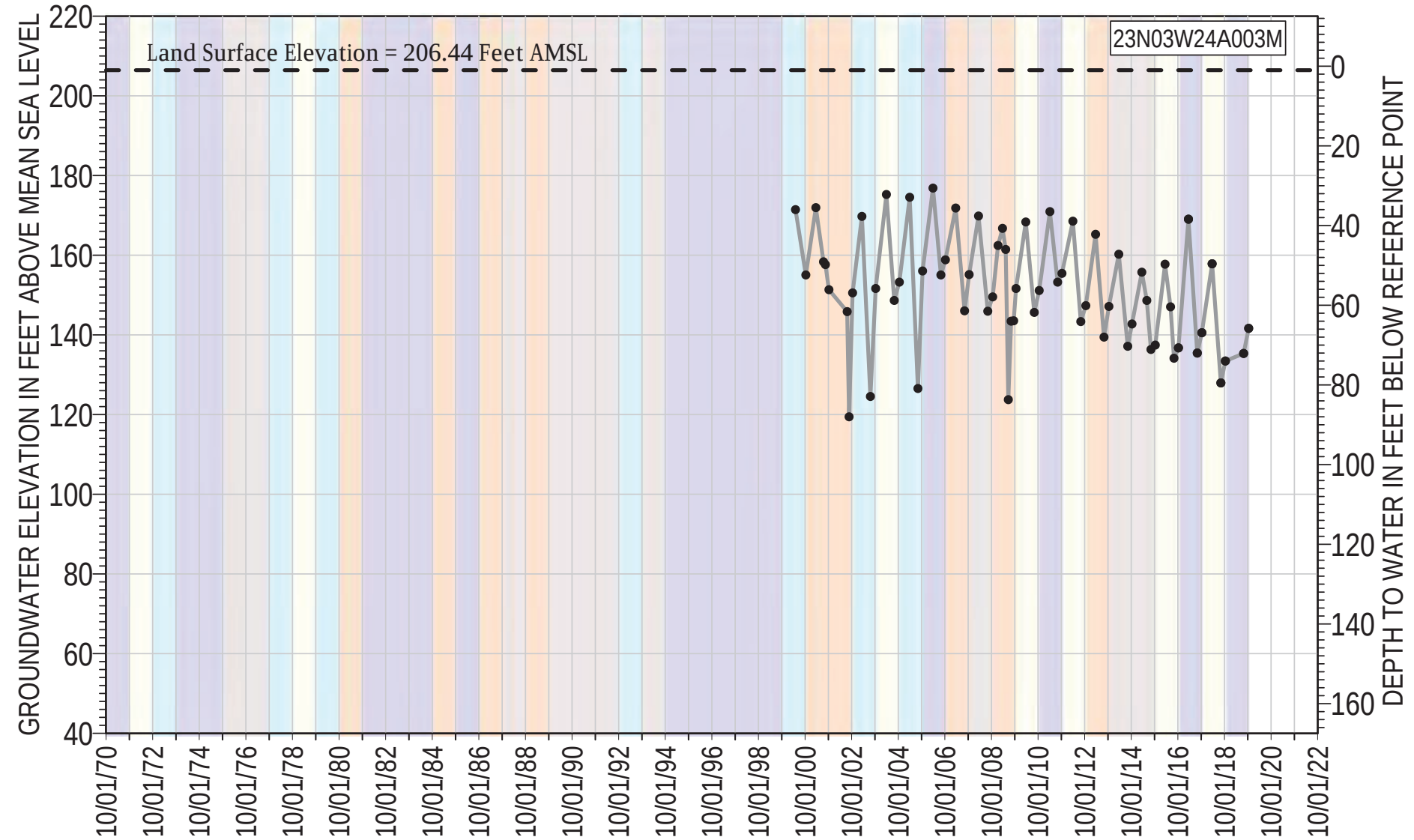
Total Depth: 380 ft bgs

Well Screen Interval= Unknown ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





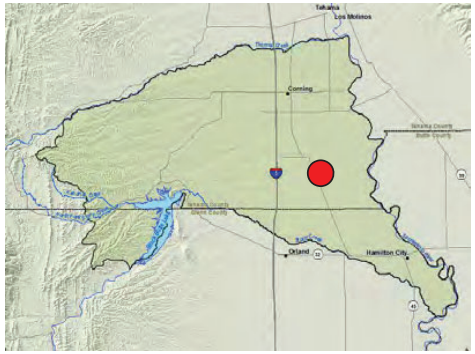
23N03W24A003M Groundwater Elevation

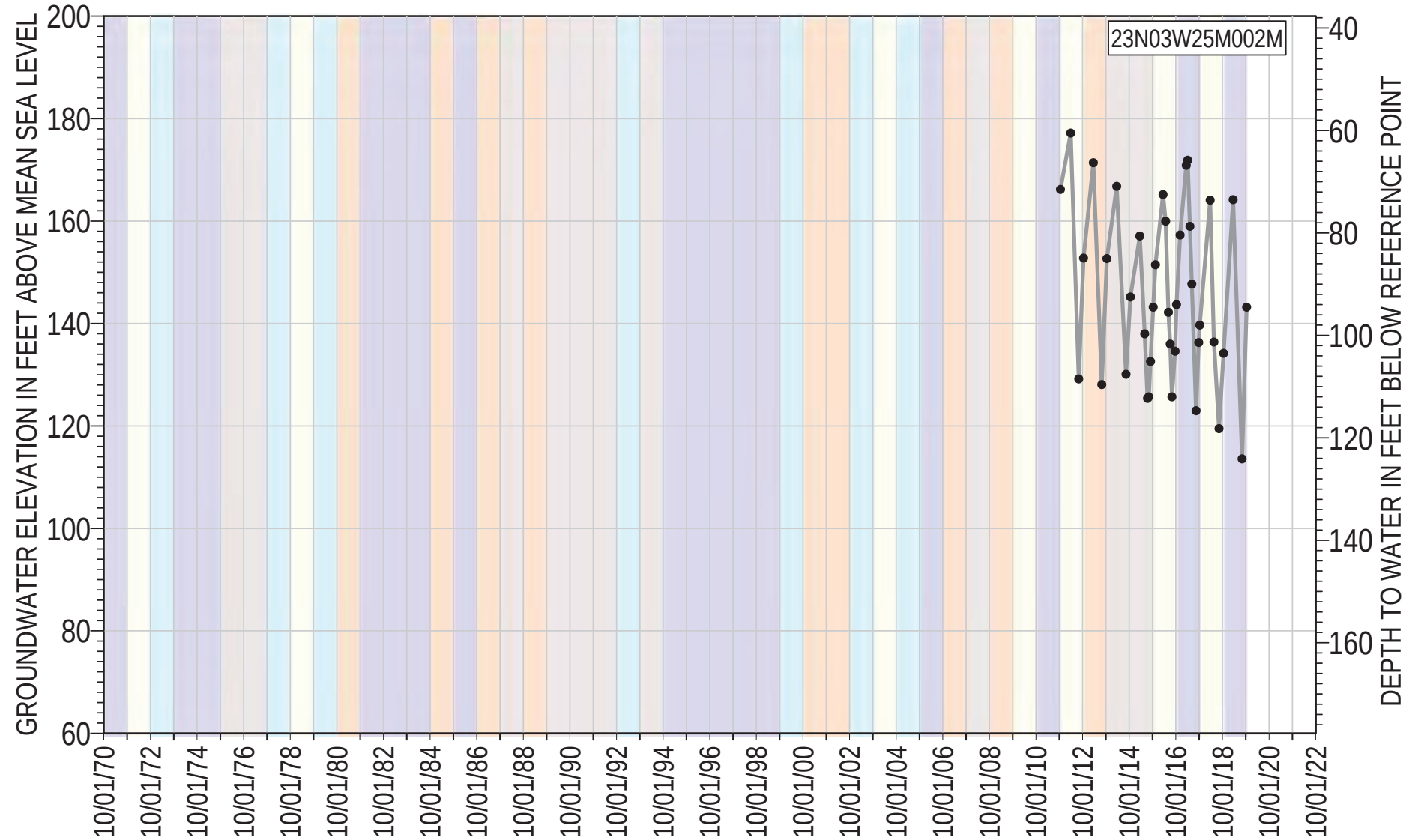
Land Surface Elevation

Reference Point Elevation= 207.44 ft AMSL
Well Type: Domestic
Total Depth: 199 ft bgs
Well Screen Interval= 180 - 199 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



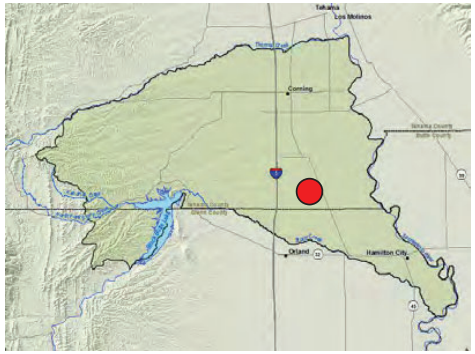


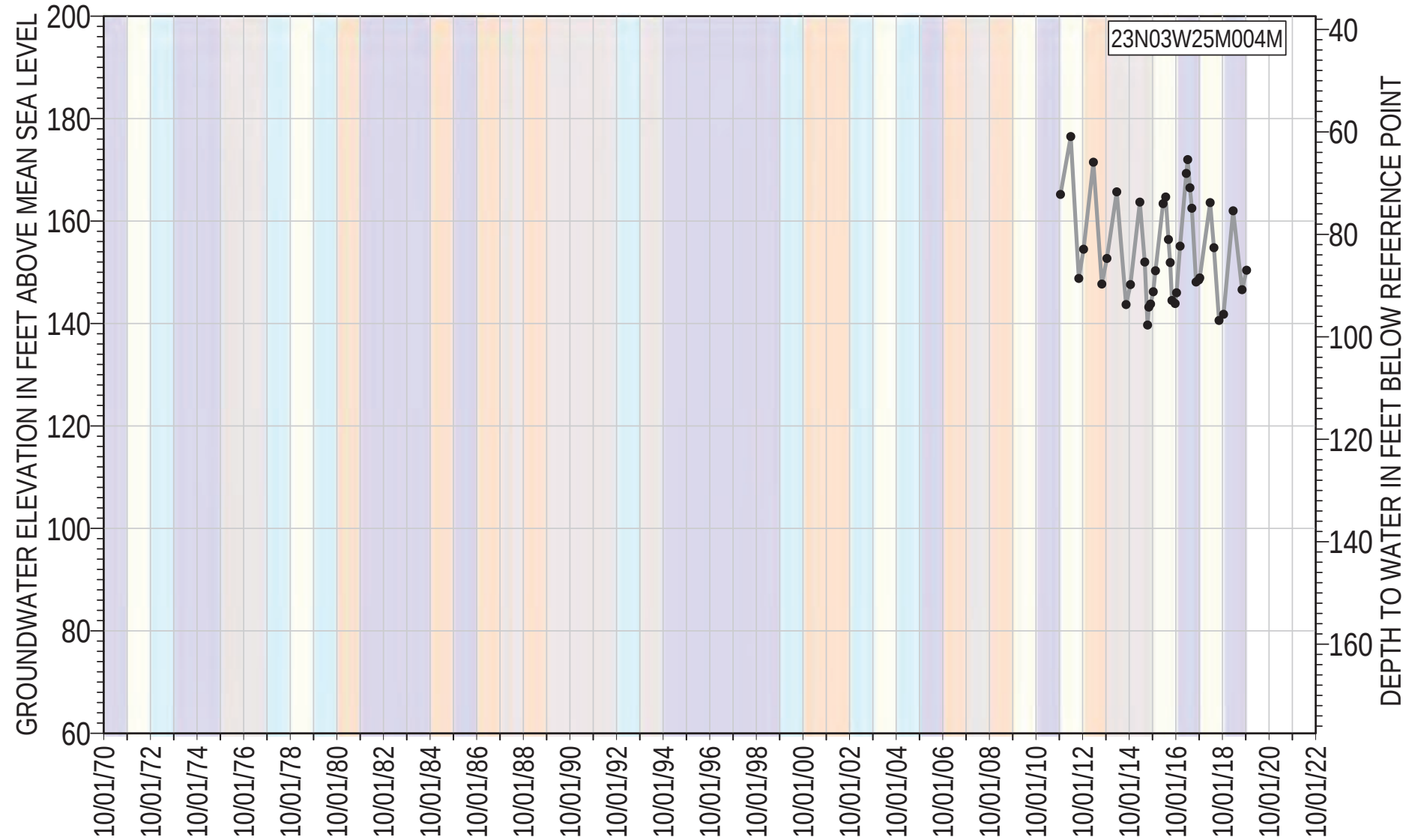
23N03W25M002M Groundwater Elevation

Reference Point Elevation= 237.68 ft AMSL
Well Type: Observation
Total Depth: 513 ft bgs
Well Screen Interval= 470 - 500 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



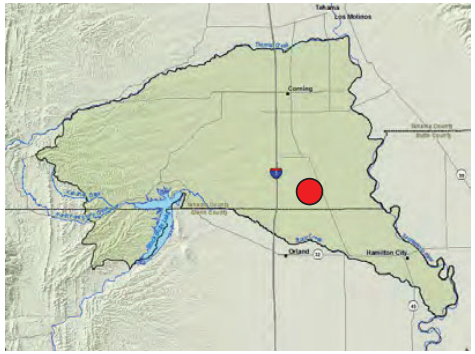


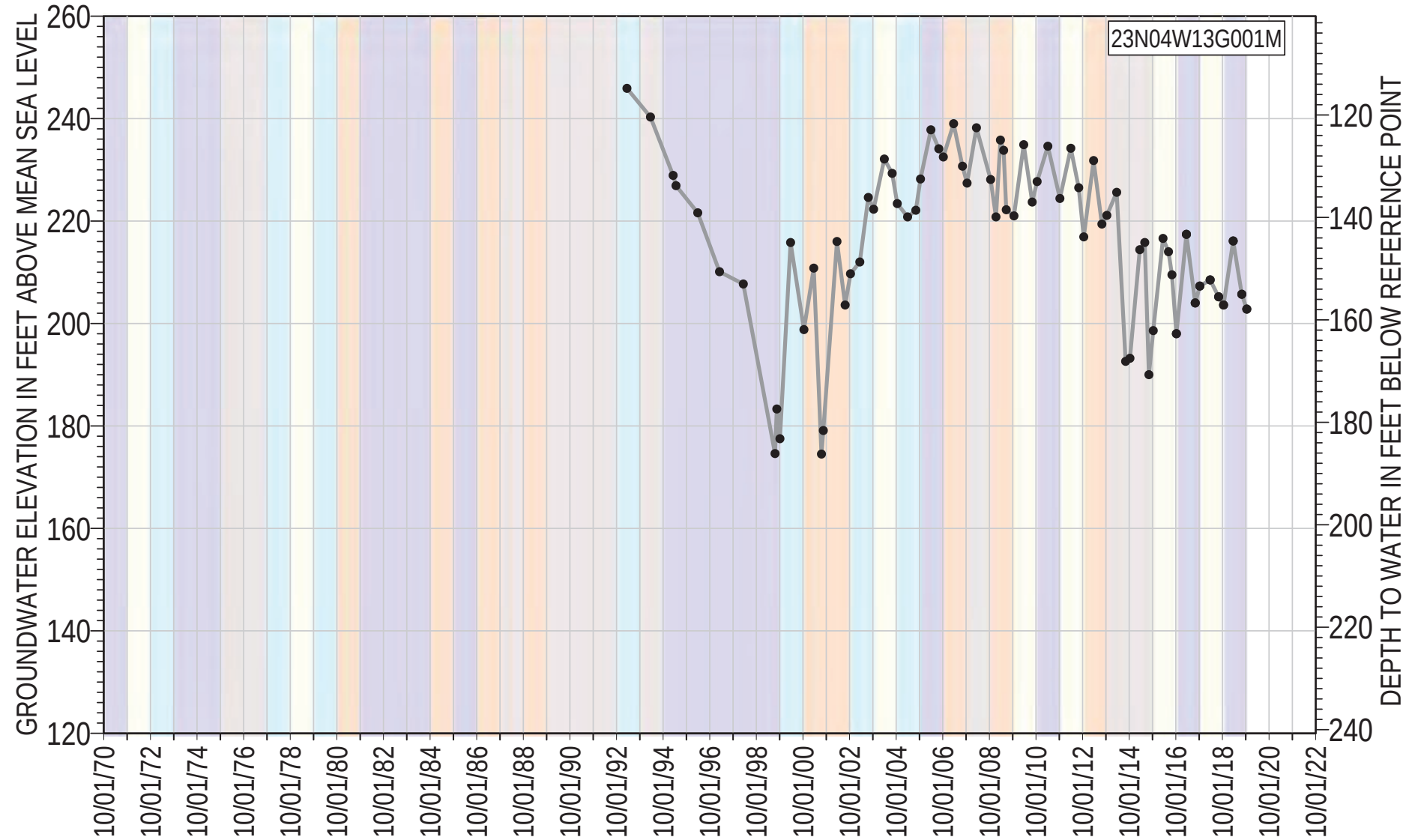
23N03W25M004M Groundwater Elevation

Reference Point Elevation= 237.4 ft AMSL
Well Type: Observation
Total Depth: 155 ft bgs
Well Screen Interval= 120 - 130 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



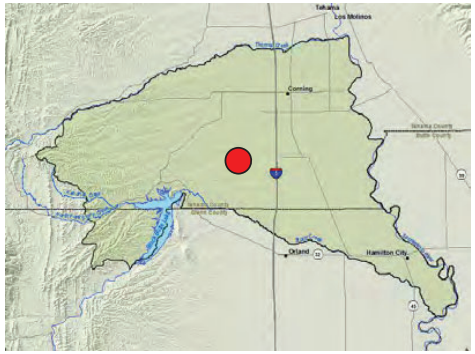


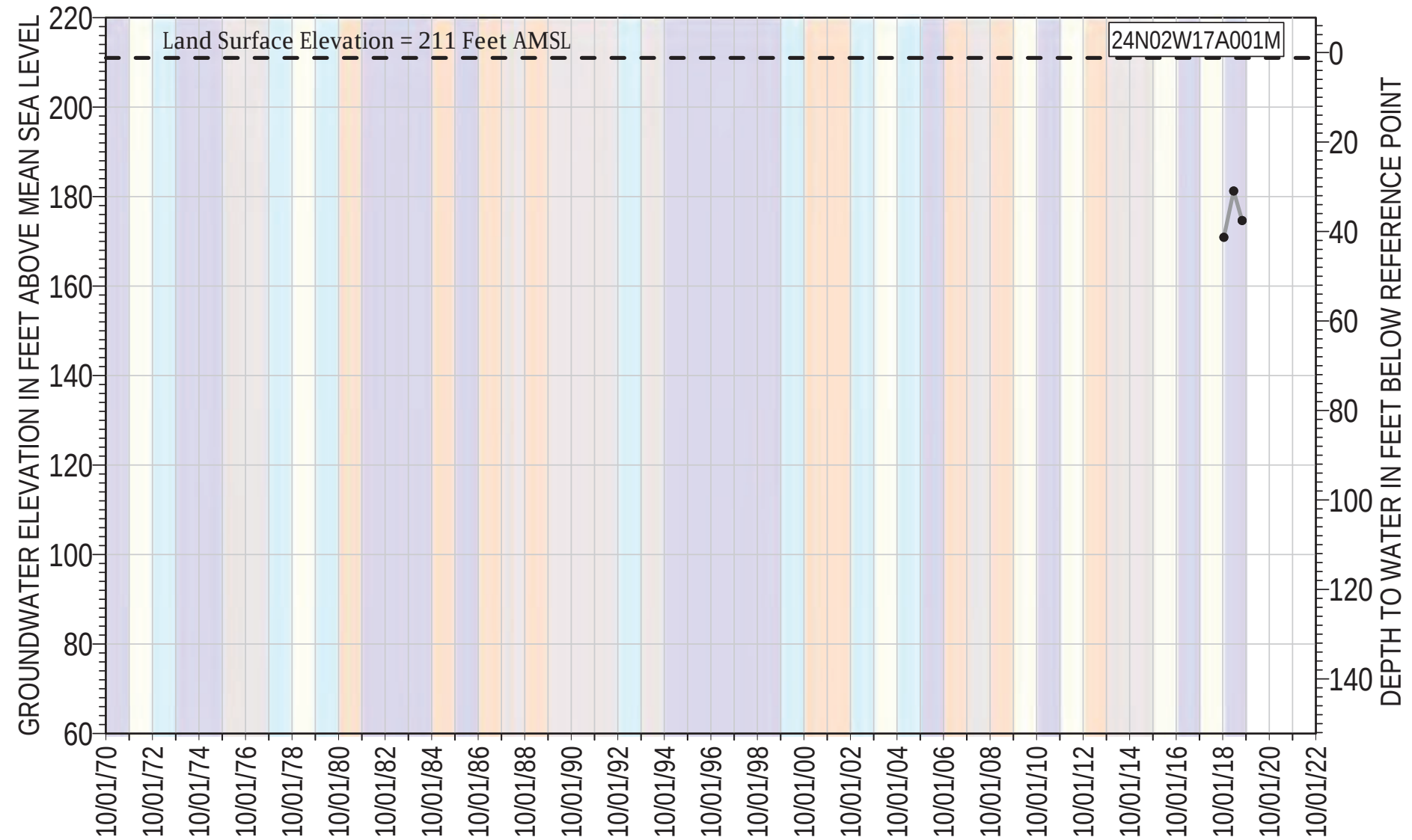
23N04W13G001M Groundwater Elevation

Reference Point Elevation= 360.71 ft AMSL
Well Type: Irrigation
Total Depth: 560 ft bgs
Well Screen Interval= Unknown ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





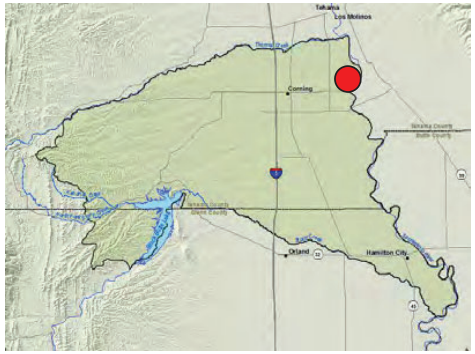
24N02W17A001M Groundwater Elevation

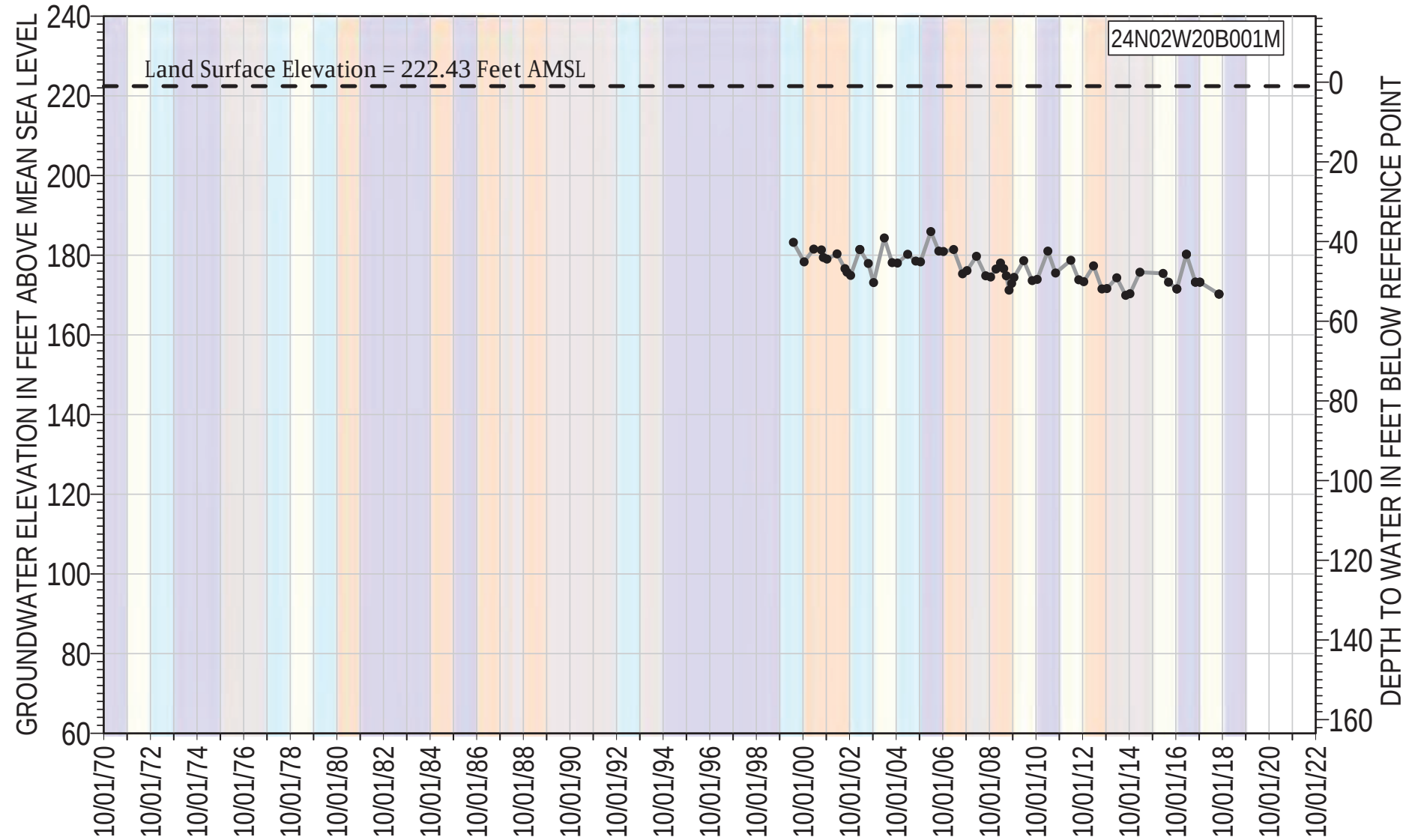
Land Surface Elevation

Reference Point Elevation= 212.2 ft AMSL
Well Type: Domestic
Total Depth: 140 ft bgs
Well Screen Interval= 120 - 140 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





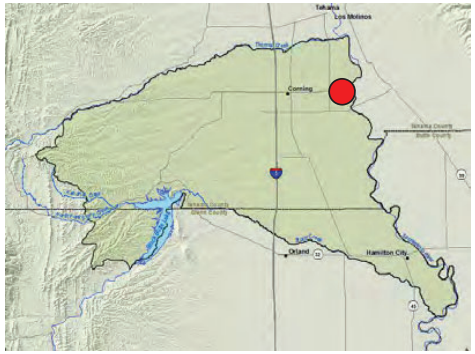
24N02W20B001M Groundwater Elevation

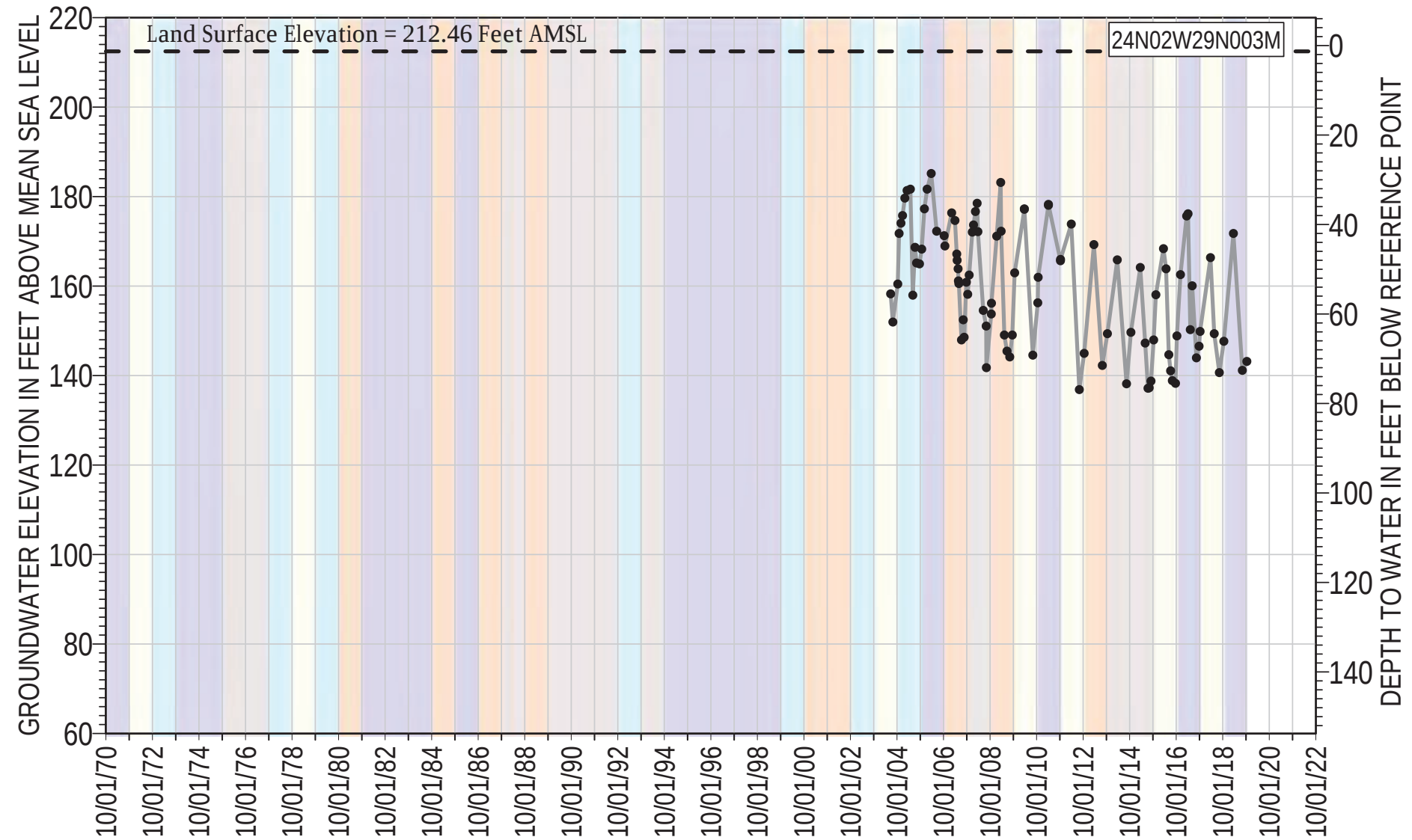
Land Surface Elevation

Reference Point Elevation= 223.43 ft AMSL
Well Type: Domestic
Total Depth: 120 ft bgs
Well Screen Interval= 100 - 120 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





24N02W29N003M Groundwater Elevation

Land Surface Elevation

Reference Point Elevation= 213.76 ft AMSL

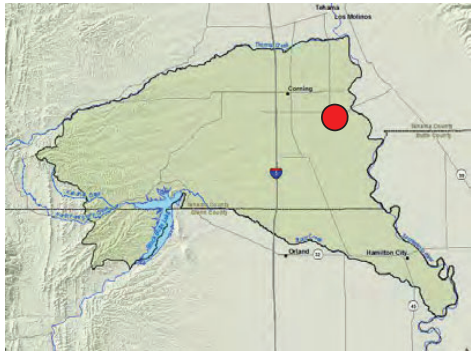
Well Type: Observation

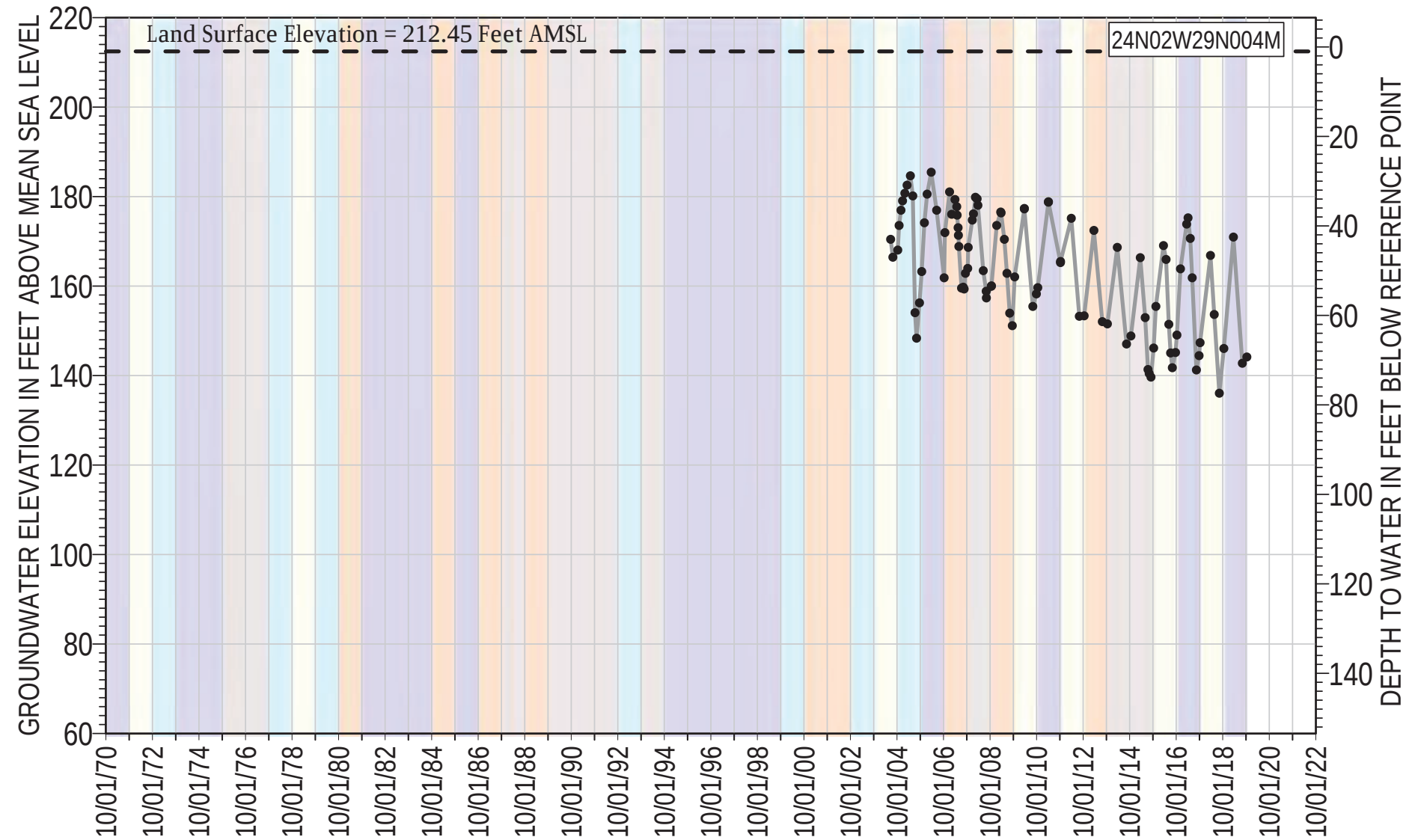
Total Depth: 388 ft bgs

Well Screen Interval= 200 - 290 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





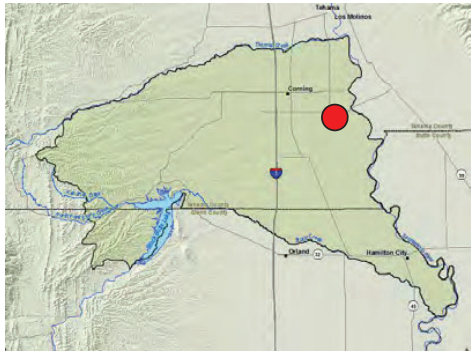
24N02W29N004M Groundwater Elevation

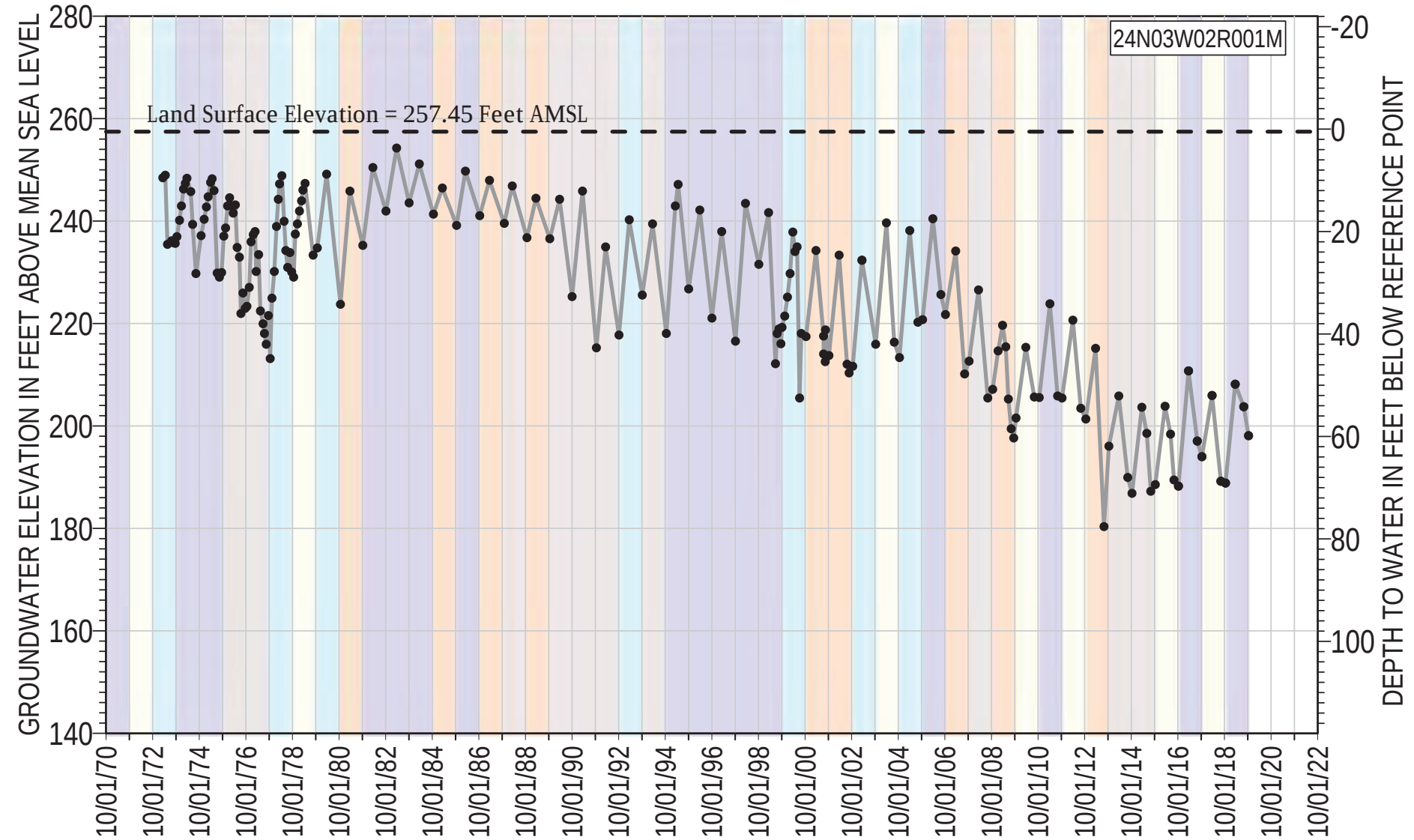
Land Surface Elevation

Reference Point Elevation= 213.448 ft AMSL
Well Type: Observation
Total Depth: 741 ft bgs
Well Screen Interval= 590 - 710 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





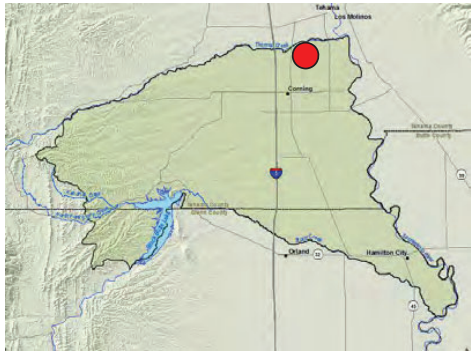
24N03W02R001M Groundwater Elevation

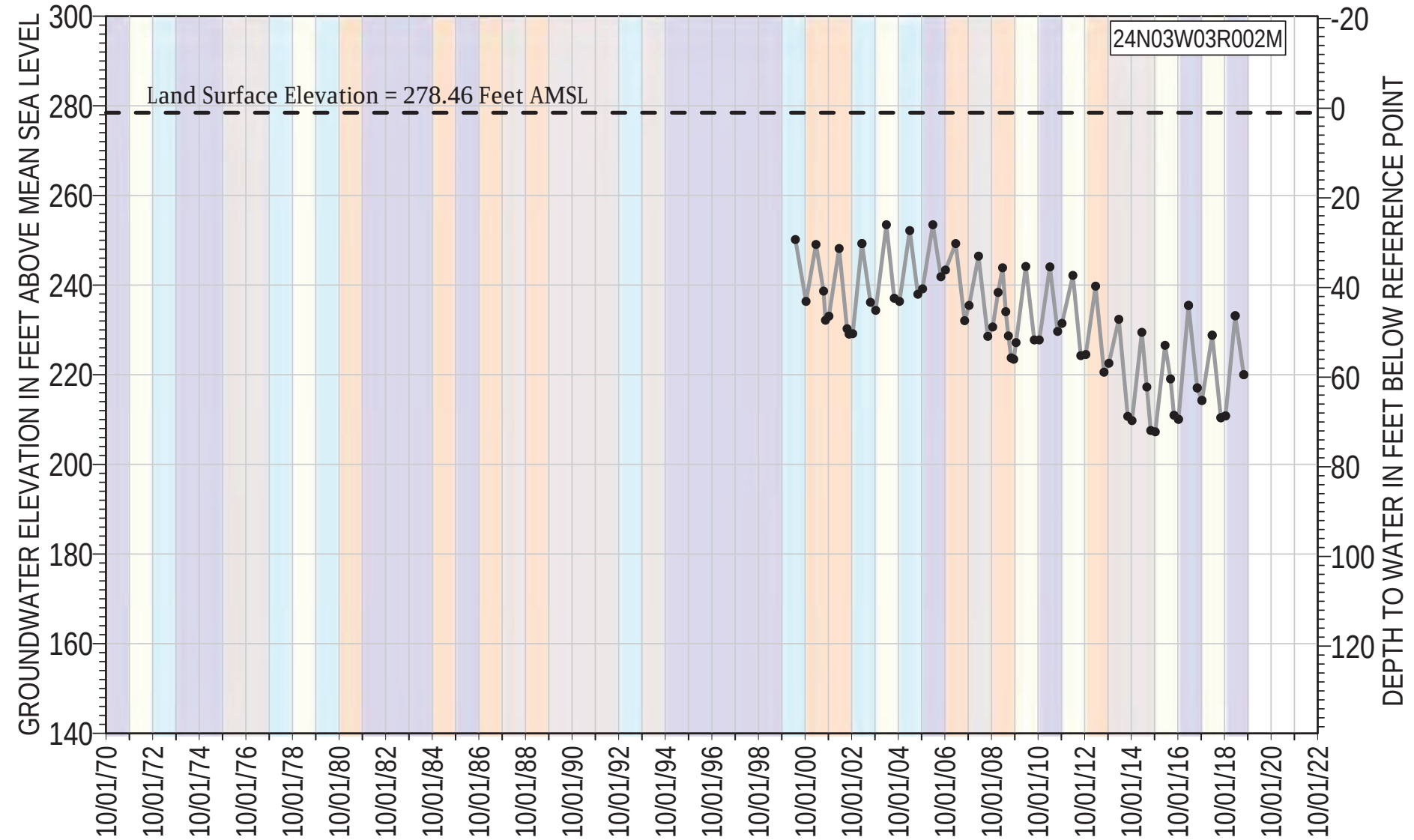
Land Surface Elevation

Reference Point Elevation= 257.95 ft AMSL
Well Type: Domestic
Total Depth: 270 ft bgs
Well Screen Interval= Unknown ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





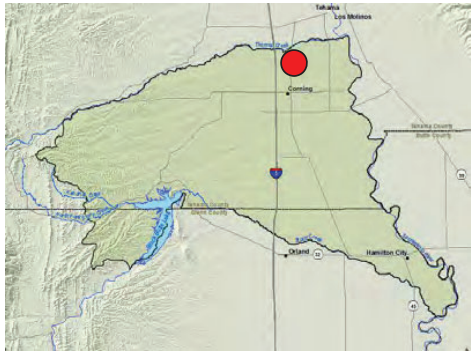
24N03W03R002M Groundwater Elevation

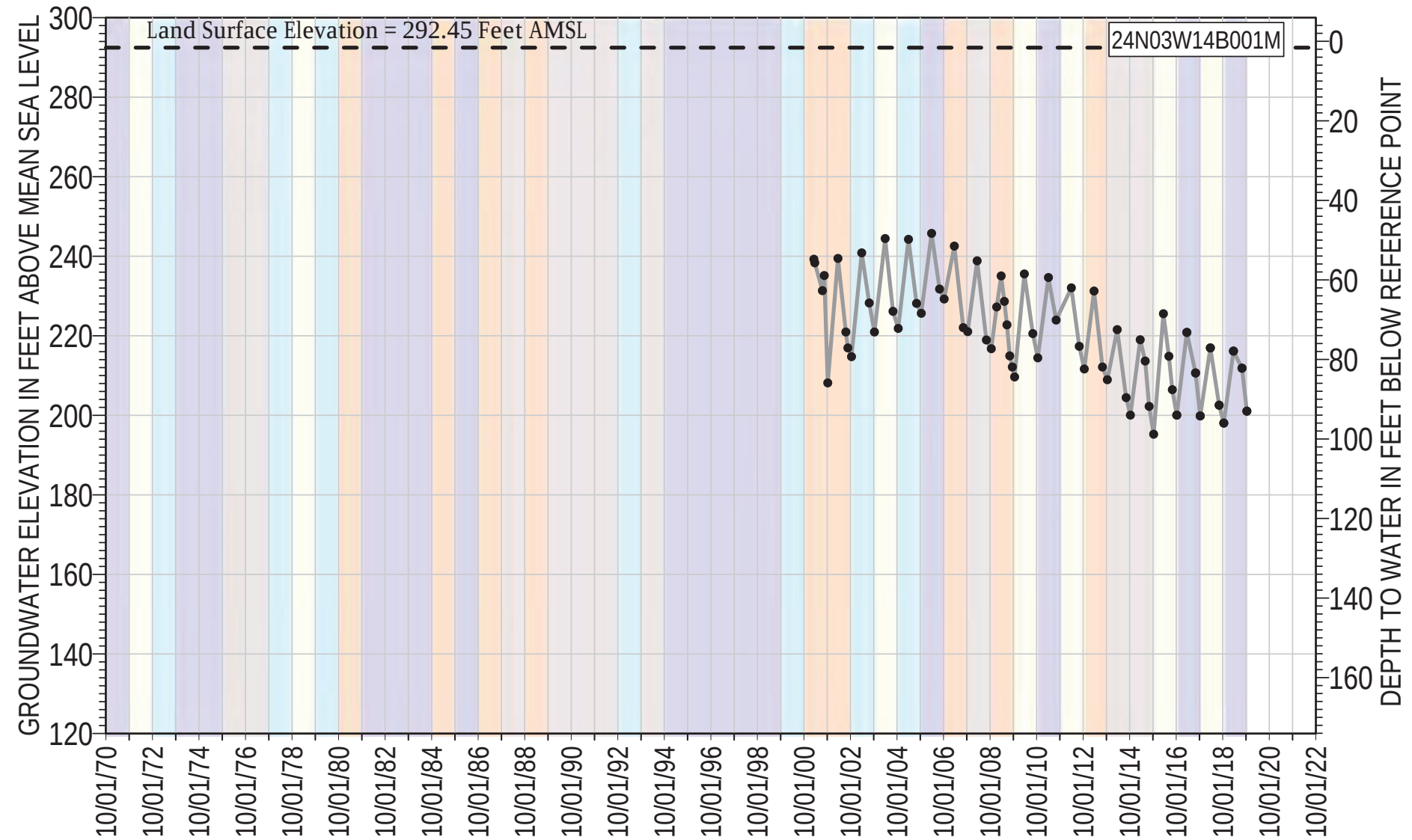
Land Surface Elevation

Reference Point Elevation= 279.46 ft AMSL
Well Type: Domestic
Total Depth: 132 ft bgs
Well Screen Interval= 112 - 132 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





24N03W14B001M Groundwater Elevation

Land Surface Elevation

Reference Point Elevation= 294.05 ft AMSL

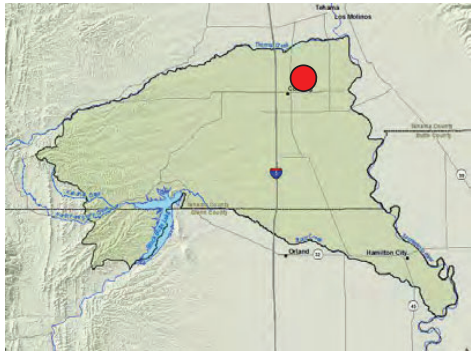
Well Type: Industrial

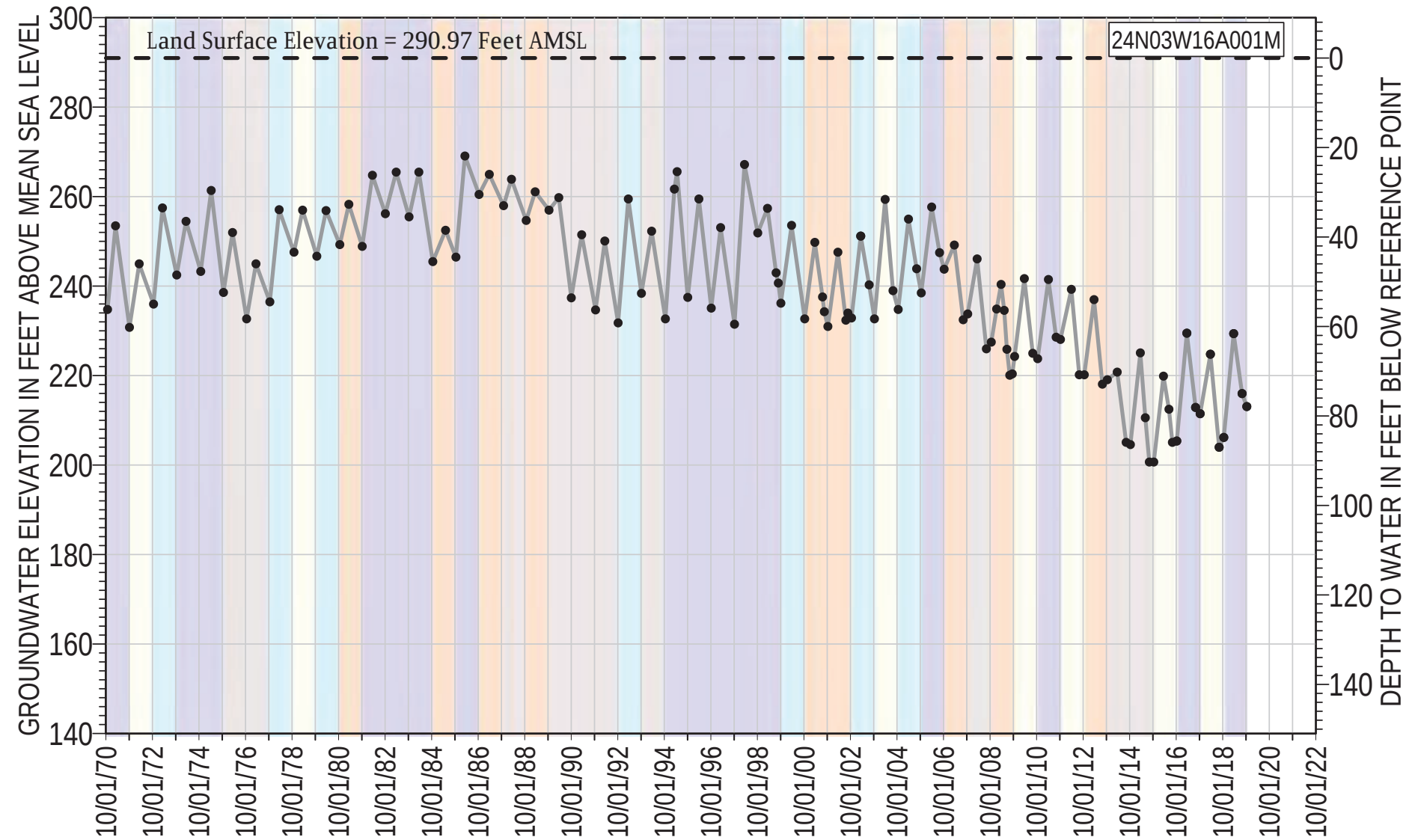
Total Depth: 140 ft bgs

Well Screen Interval= 130 - 140 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





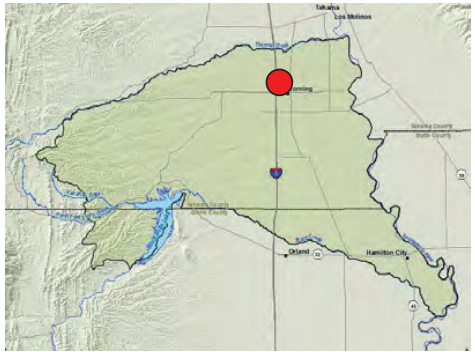
24N03W16A001M Groundwater Elevation

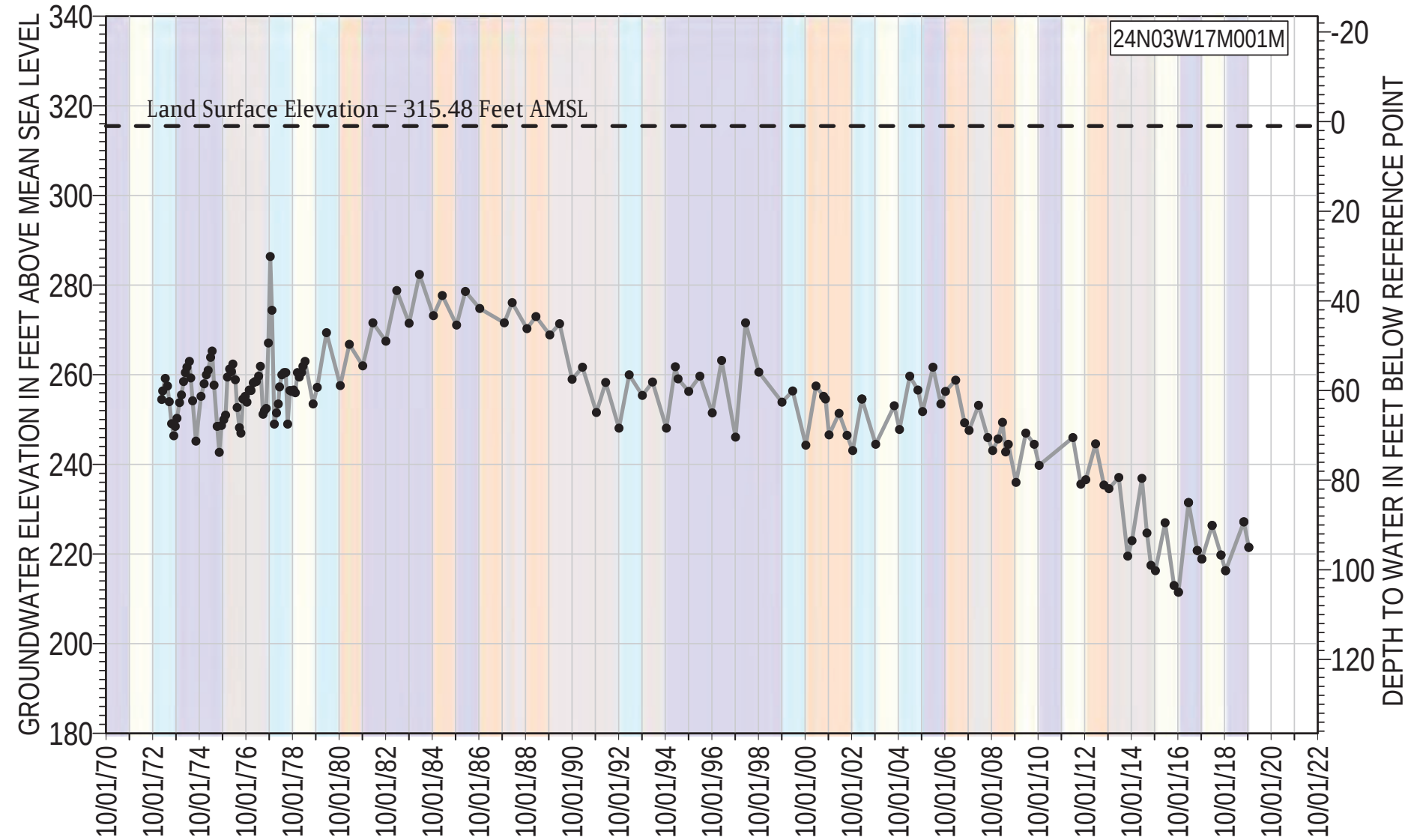
Land Surface Elevation

Reference Point Elevation= 290.97 ft AMSL
Well Type: Irrigation
Total Depth: 195 ft bgs
Well Screen Interval= 85 - 195 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





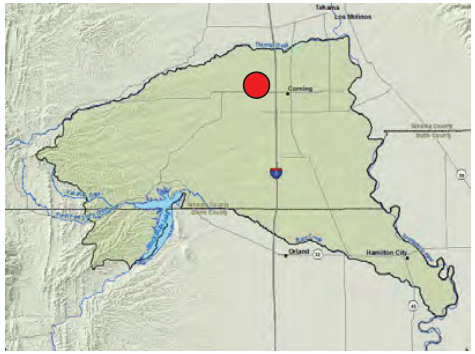
24N03W17M001M Groundwater Elevation

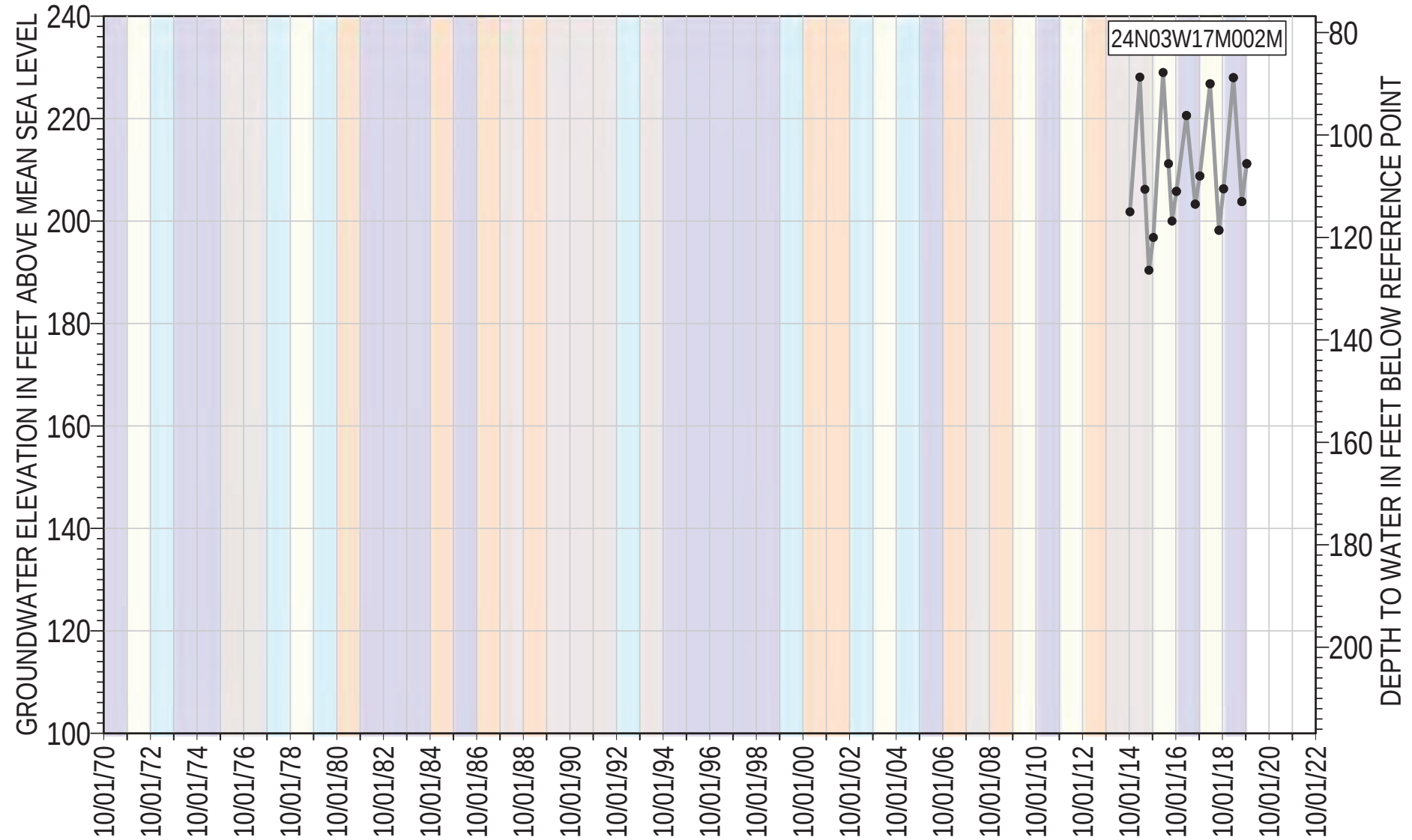
Land Surface Elevation

Reference Point Elevation= 316.48 ft AMSL
Well Type: Domestic
Total Depth: 108 ft bgs
Well Screen Interval= 100 - 108 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



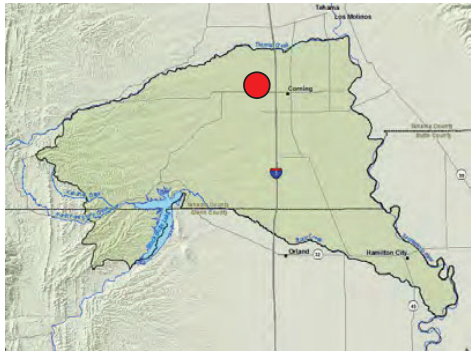


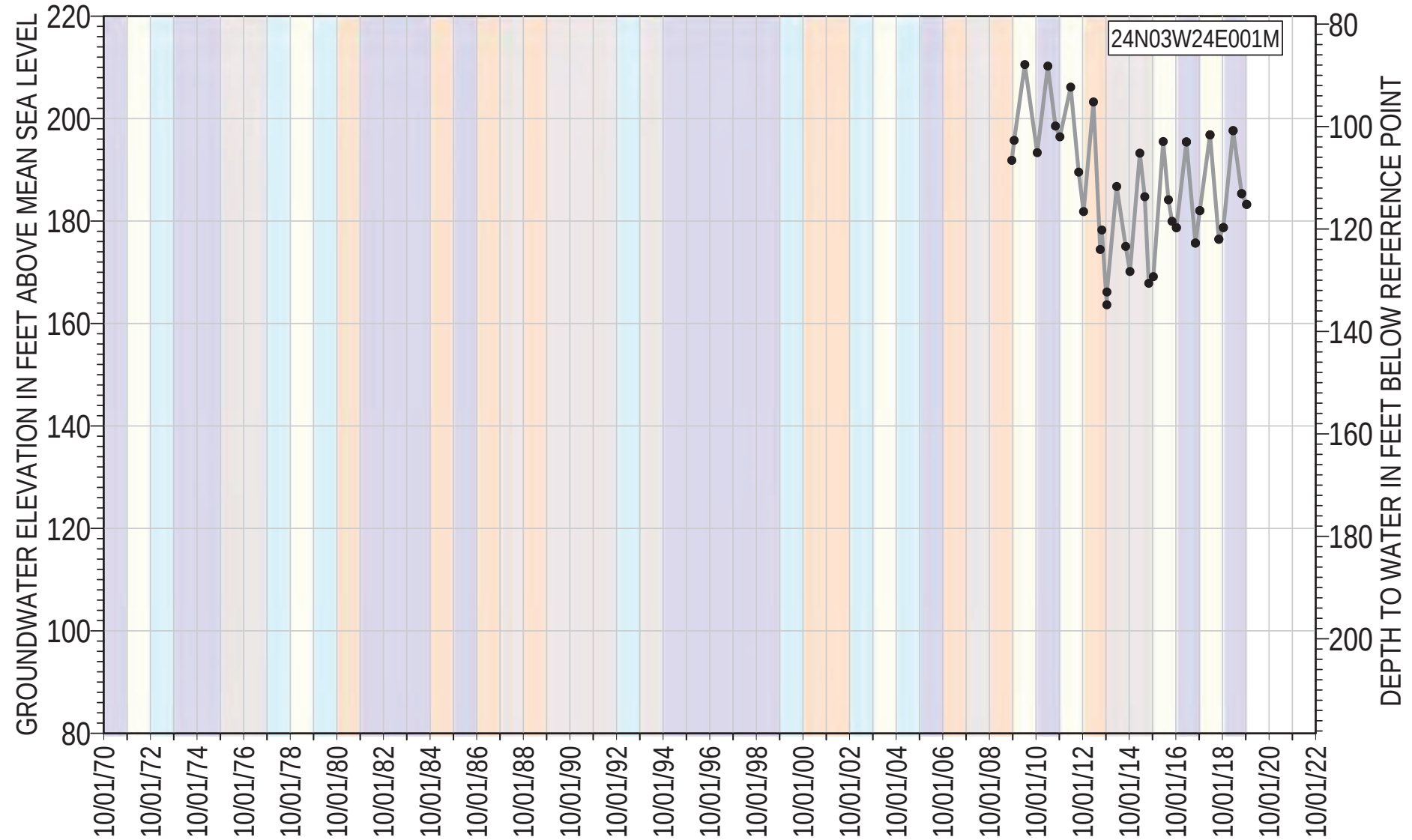
24N03W17M002M Groundwater Elevation

Reference Point Elevation= 316.8 ft AMSL
Well Type: Irrigation
Total Depth: 505 ft bgs
Well Screen Interval= 315 - 495 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



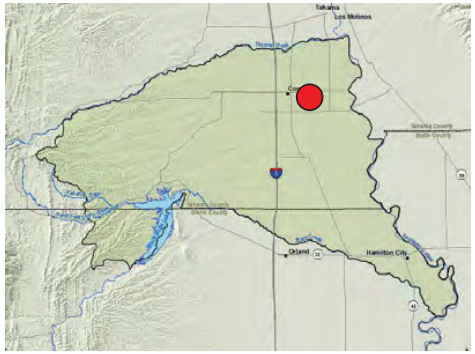


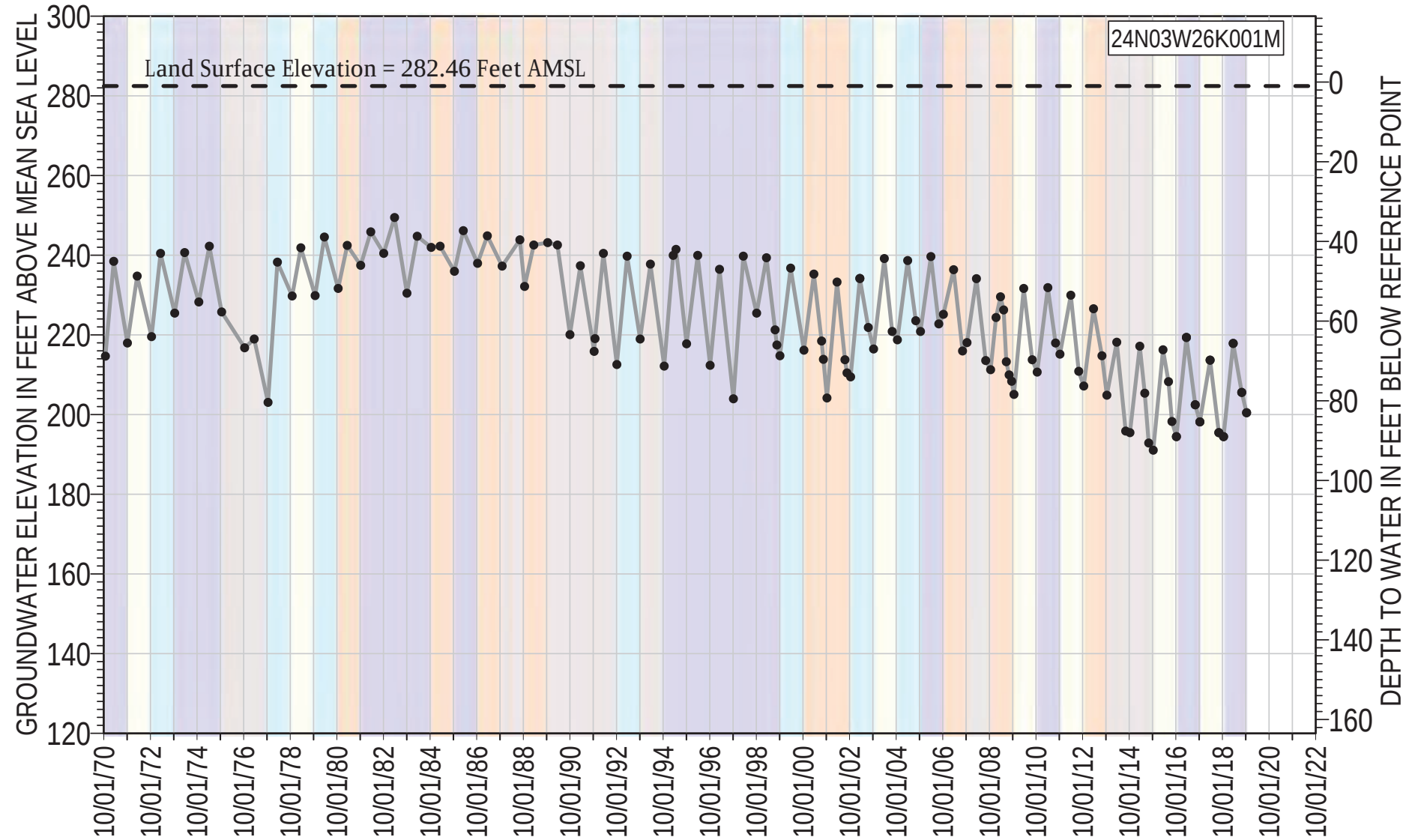
24N03W24E001M Groundwater Elevation

Reference Point Elevation= 298.45 ft AMSL
Well Type: Domestic
Total Depth: 224 ft bgs
Well Screen Interval= 212 - 220 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





24N03W26K001M Groundwater Elevation

Land Surface Elevation

Reference Point Elevation= 283.46 ft AMSL

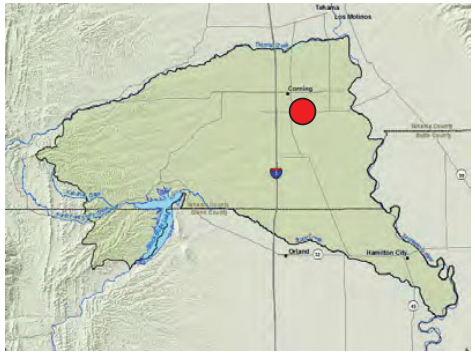
Well Type: Irrigation

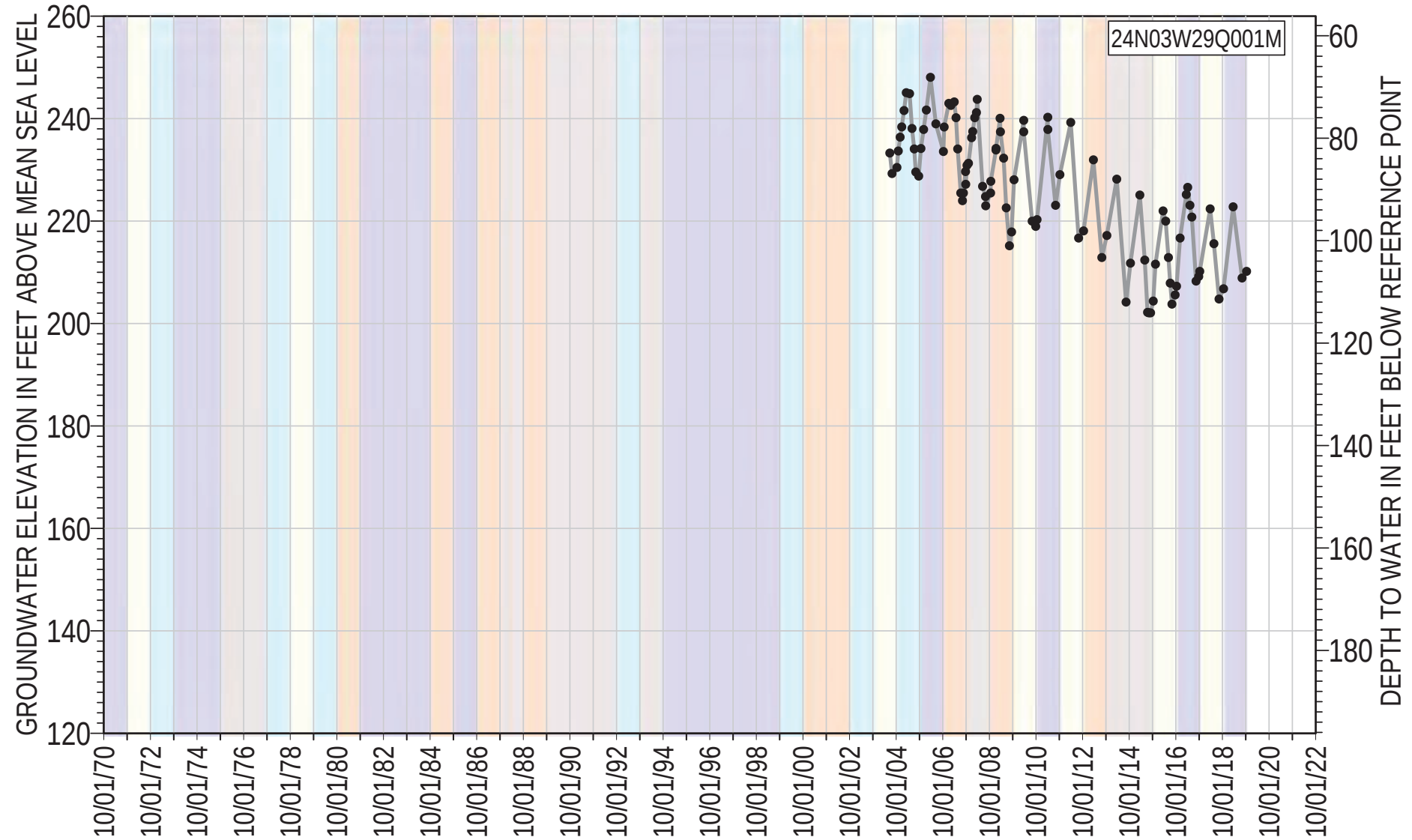
Total Depth: 245 ft bgs

Well Screen Interval= 103 - 175 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



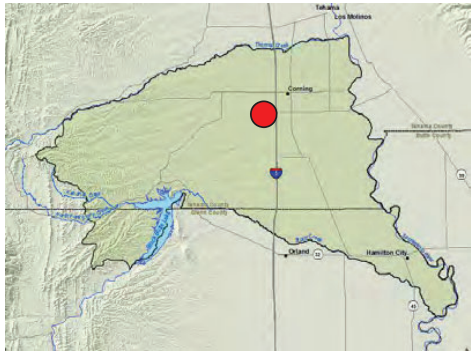


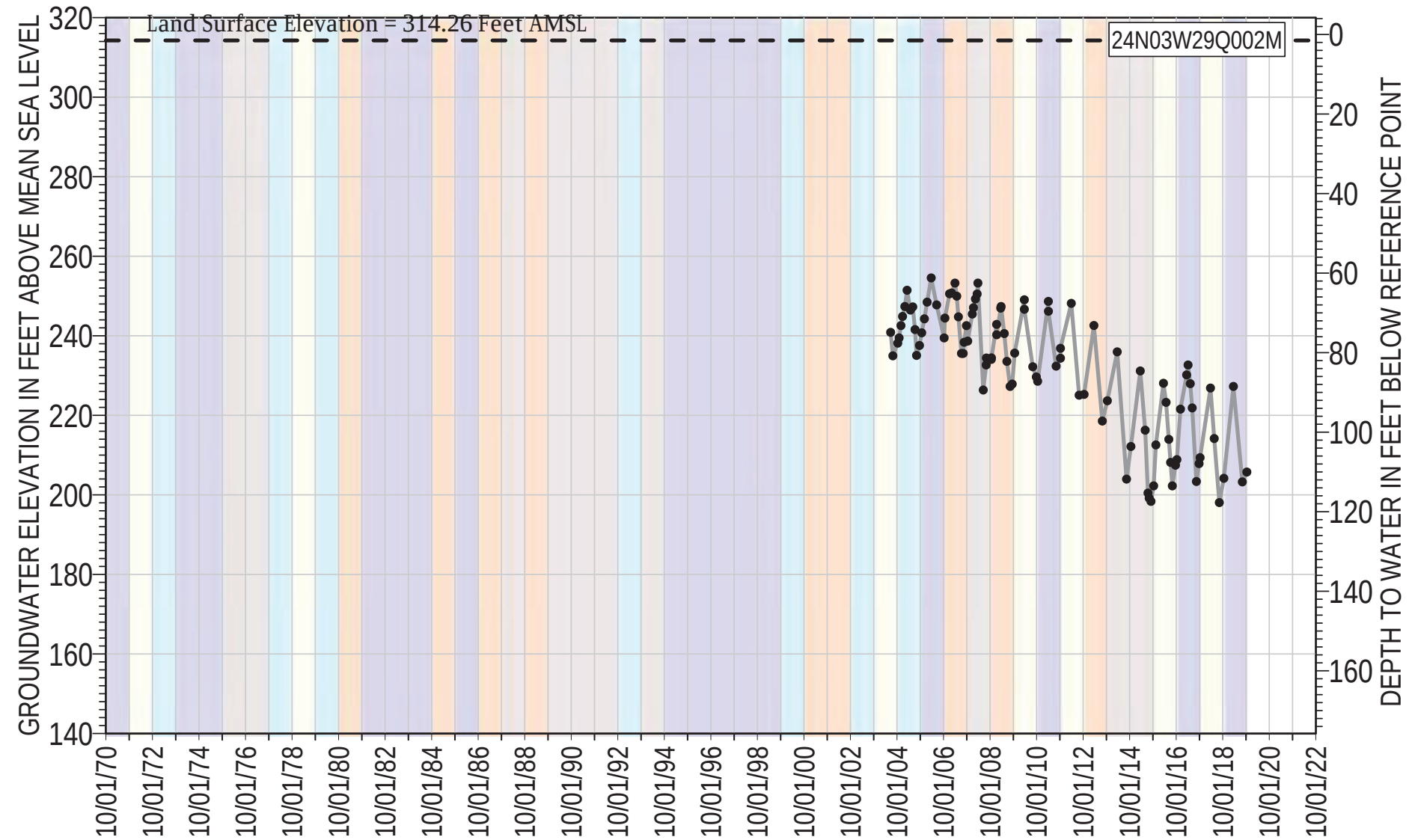
24N03W29Q001M Groundwater Elevation

Reference Point Elevation= 316.176 ft AMSL
Well Type: Observation
Total Depth: 372 ft bgs
Well Screen Interval= 130 - 360 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





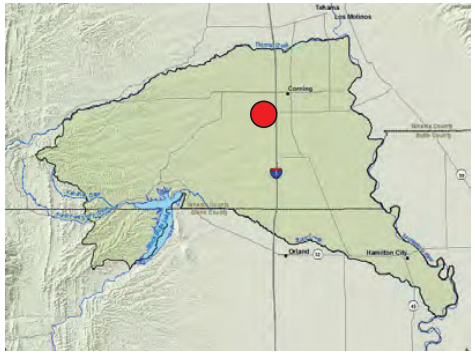
24N03W29Q002M Groundwater Elevation

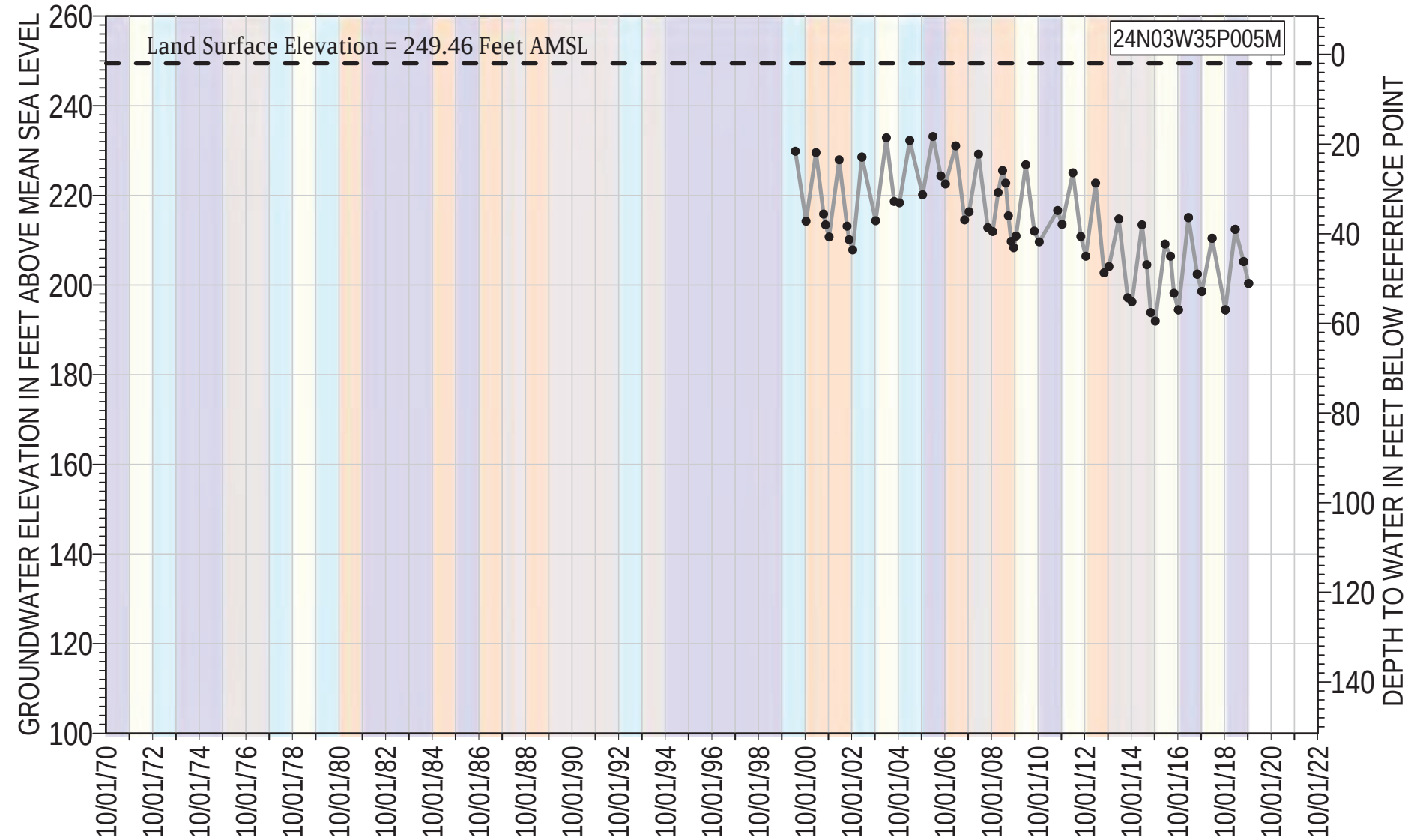
Land Surface Elevation

Reference Point Elevation= 315.763 ft AMSL
Well Type: Observation
Total Depth: 575 ft bgs
Well Screen Interval= 490 - 550 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





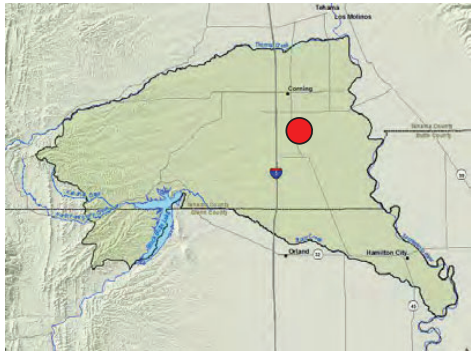
24N03W35P005M Groundwater Elevation

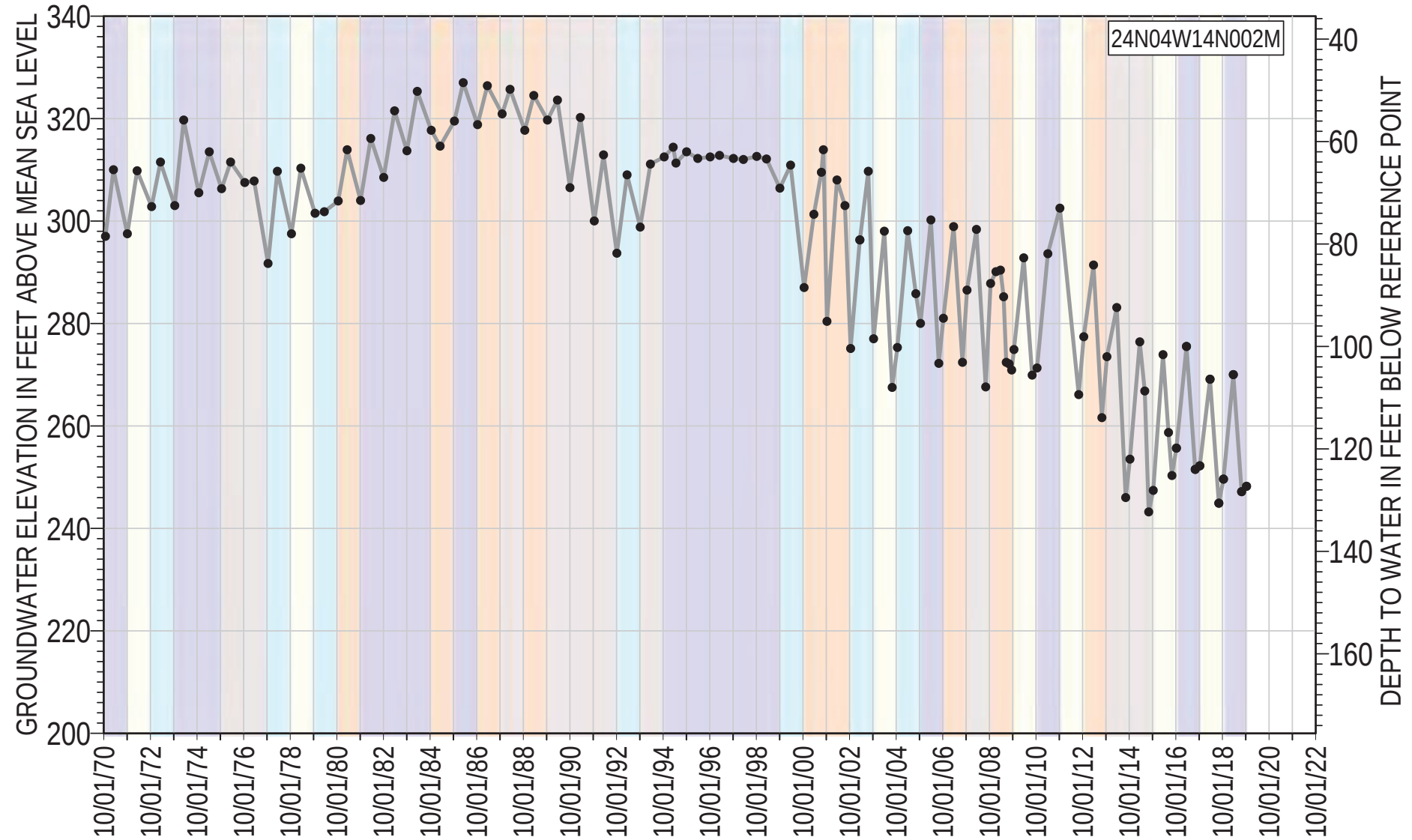
Land Surface Elevation

Reference Point Elevation= 251.46 ft AMSL
Well Type: Domestic
Total Depth: 120 ft bgs
Well Screen Interval= 100 - 120 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



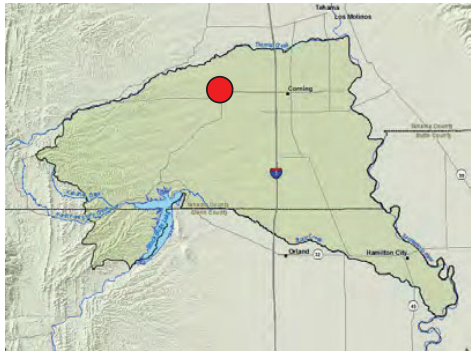


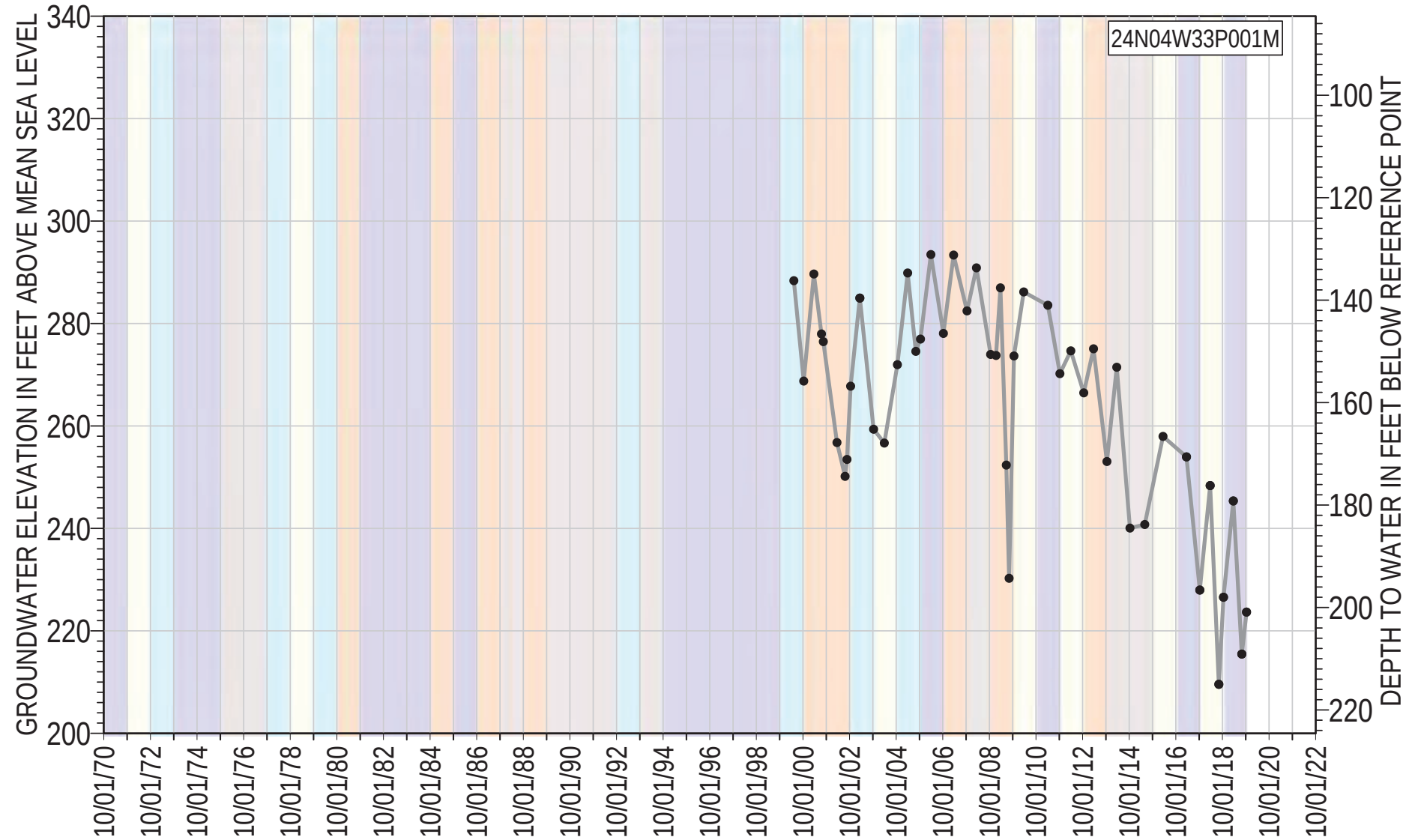
24N04W14N002M Groundwater Elevation

Reference Point Elevation= 375.52 ft AMSL
Well Type: Domestic
Total Depth: 180 ft bgs
Well Screen Interval= Unknown ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



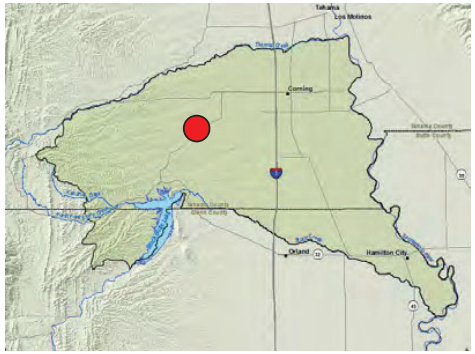


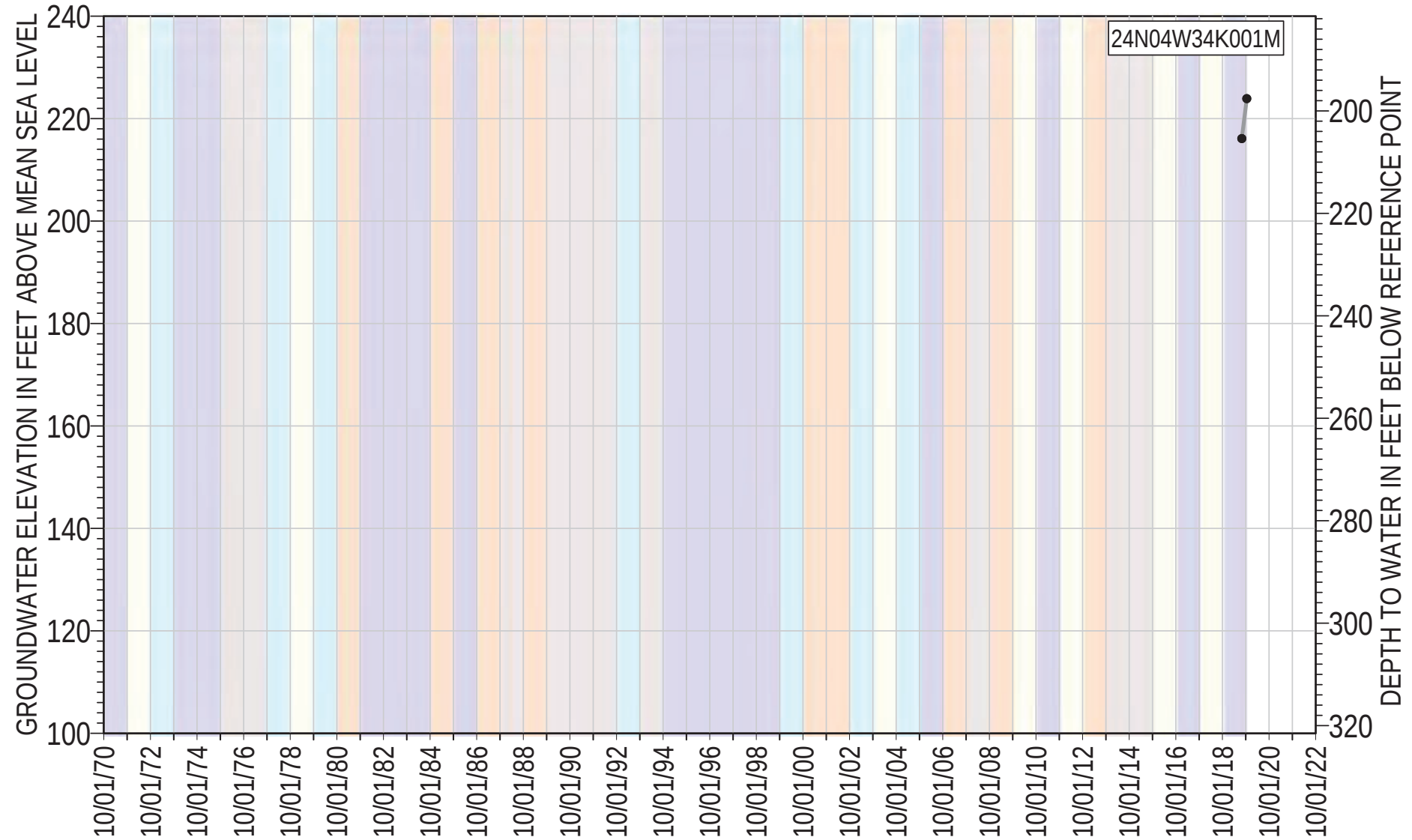
24N04W33P001M Groundwater Elevation

Reference Point Elevation= 424.56 ft AMSL
Well Type: Irrigation
Total Depth: 780 ft bgs
Well Screen Interval= 250 - 780 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



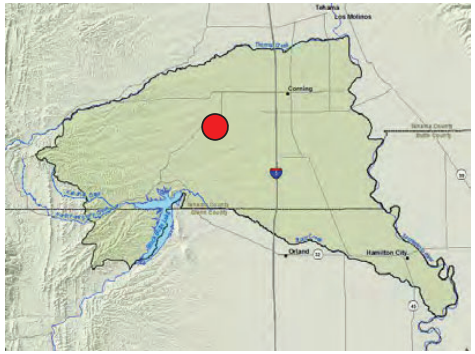


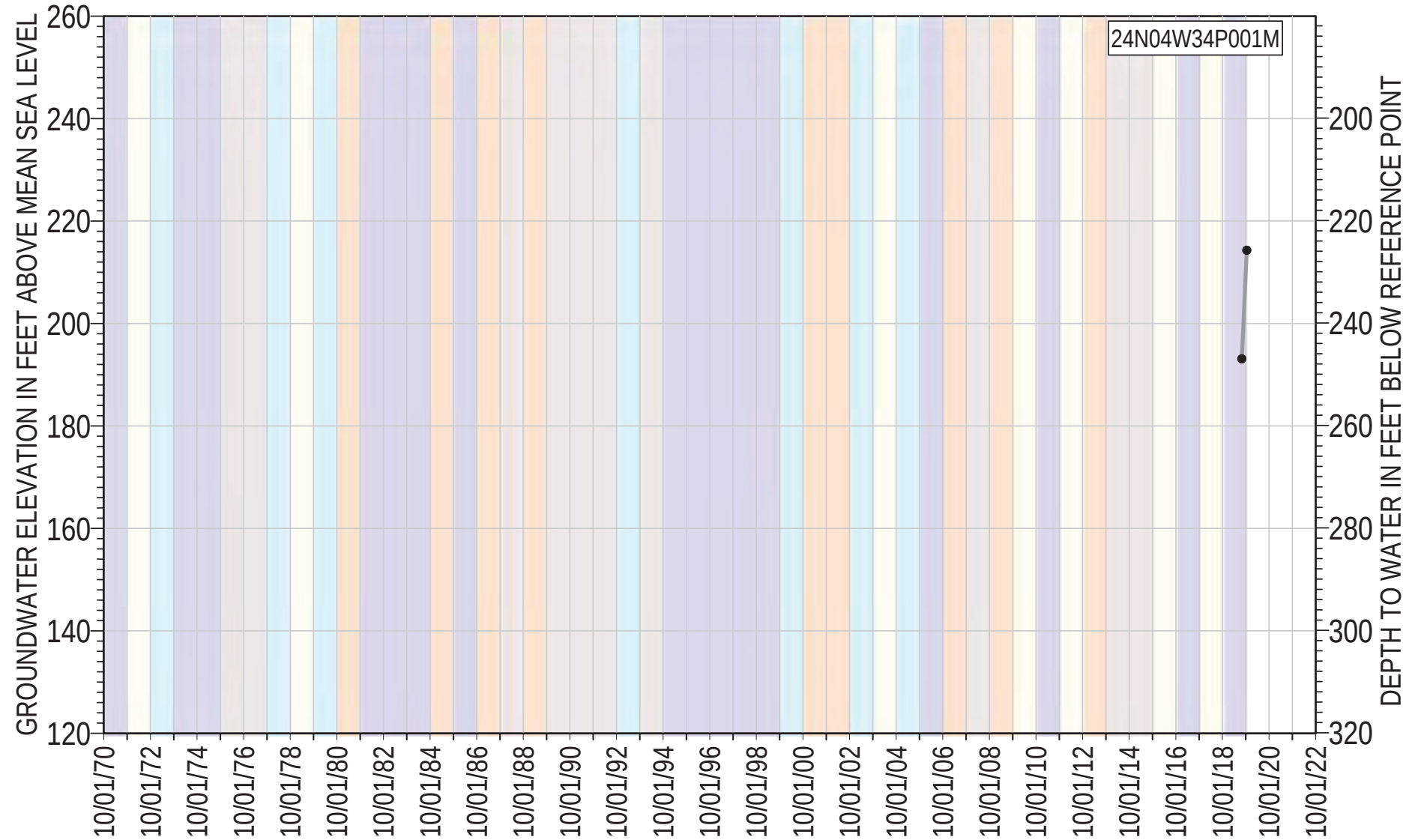
24N04W34K001M Groundwater Elevation

Reference Point Elevation= 421.5 ft AMSL
Well Type: Irrigation
Total Depth: 750 ft bgs
Well Screen Interval= 310 - 750 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



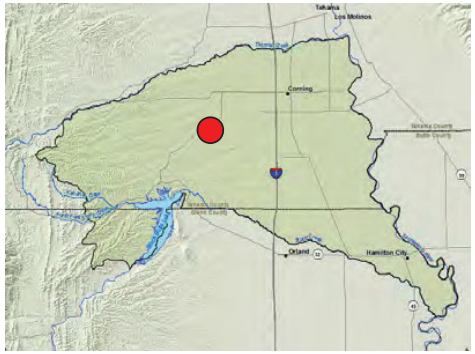


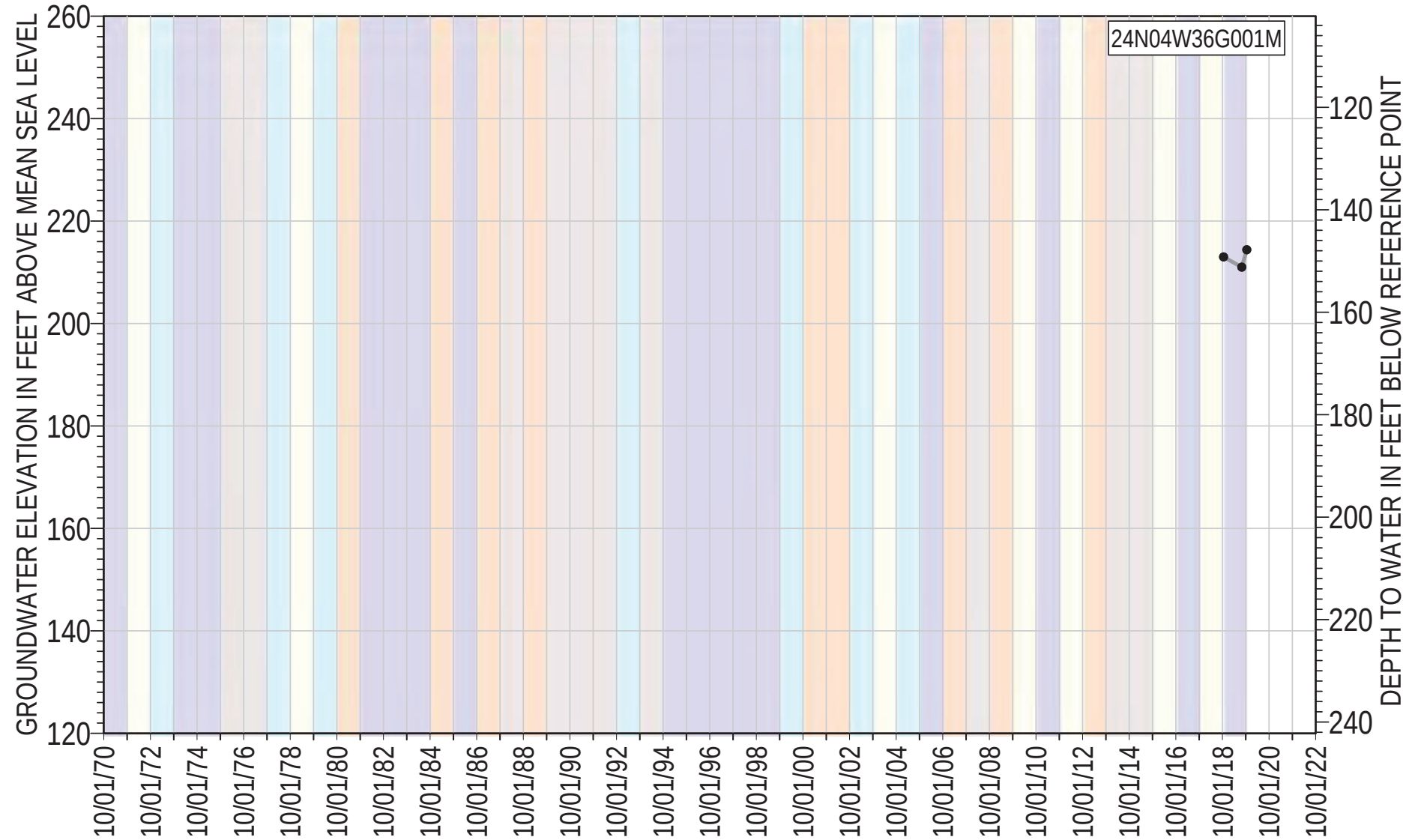
24N04W34P001M Groundwater Elevation

Reference Point Elevation= 440.1 ft AMSL
Well Type: Irrigation
Total Depth: 535 ft bgs
Well Screen Interval= 290 - 475 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



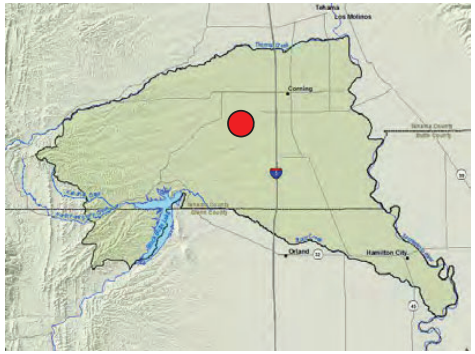


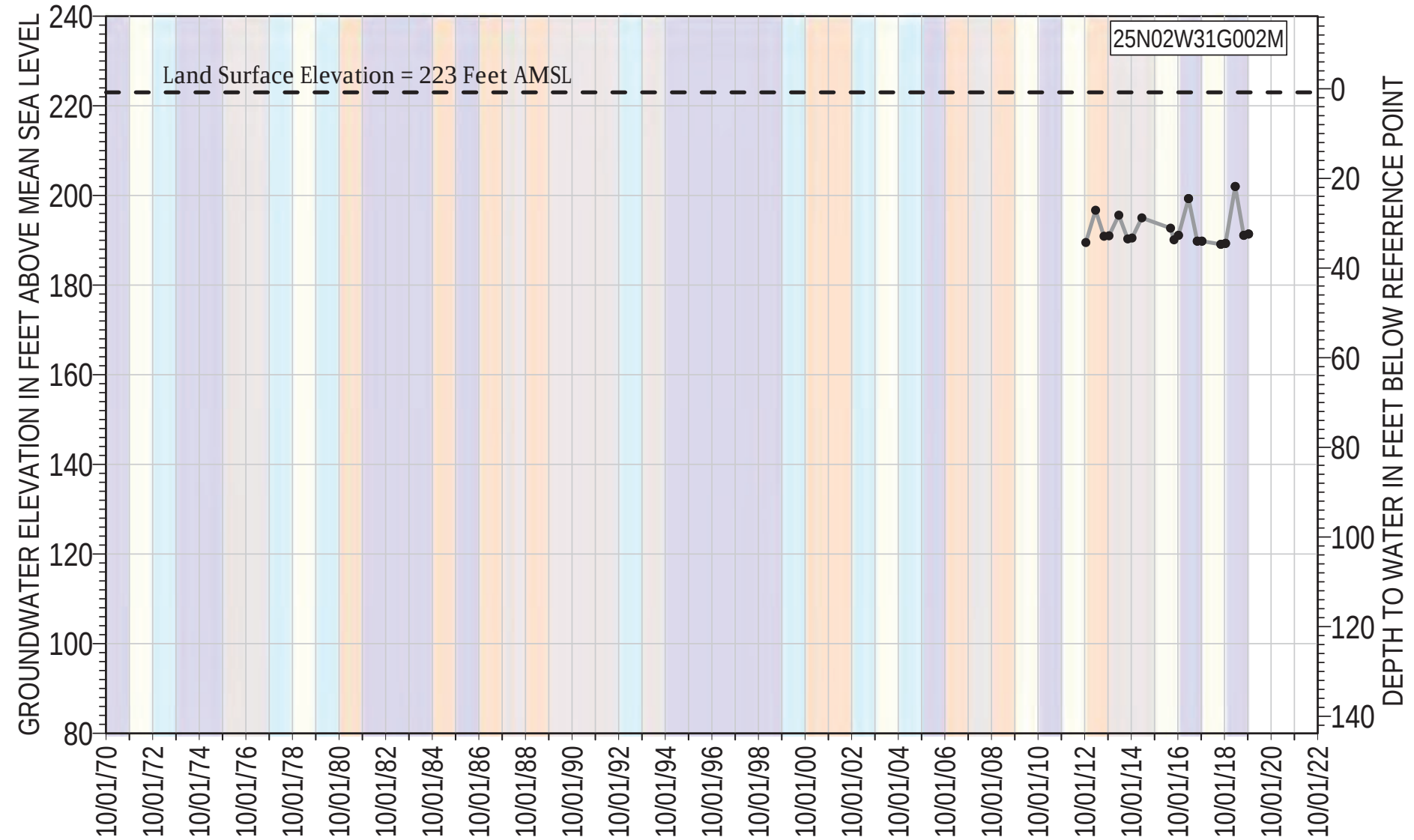
24N04W36G001M Groundwater Elevation

Reference Point Elevation= 362.2 ft AMSL
Well Type: Irrigation
Total Depth: 750 ft bgs
Well Screen Interval= 320 - 750 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





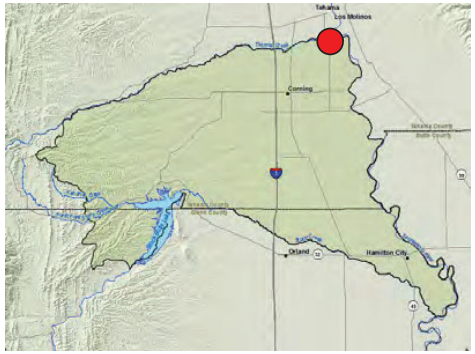
25N02W31G002M Groundwater Elevation

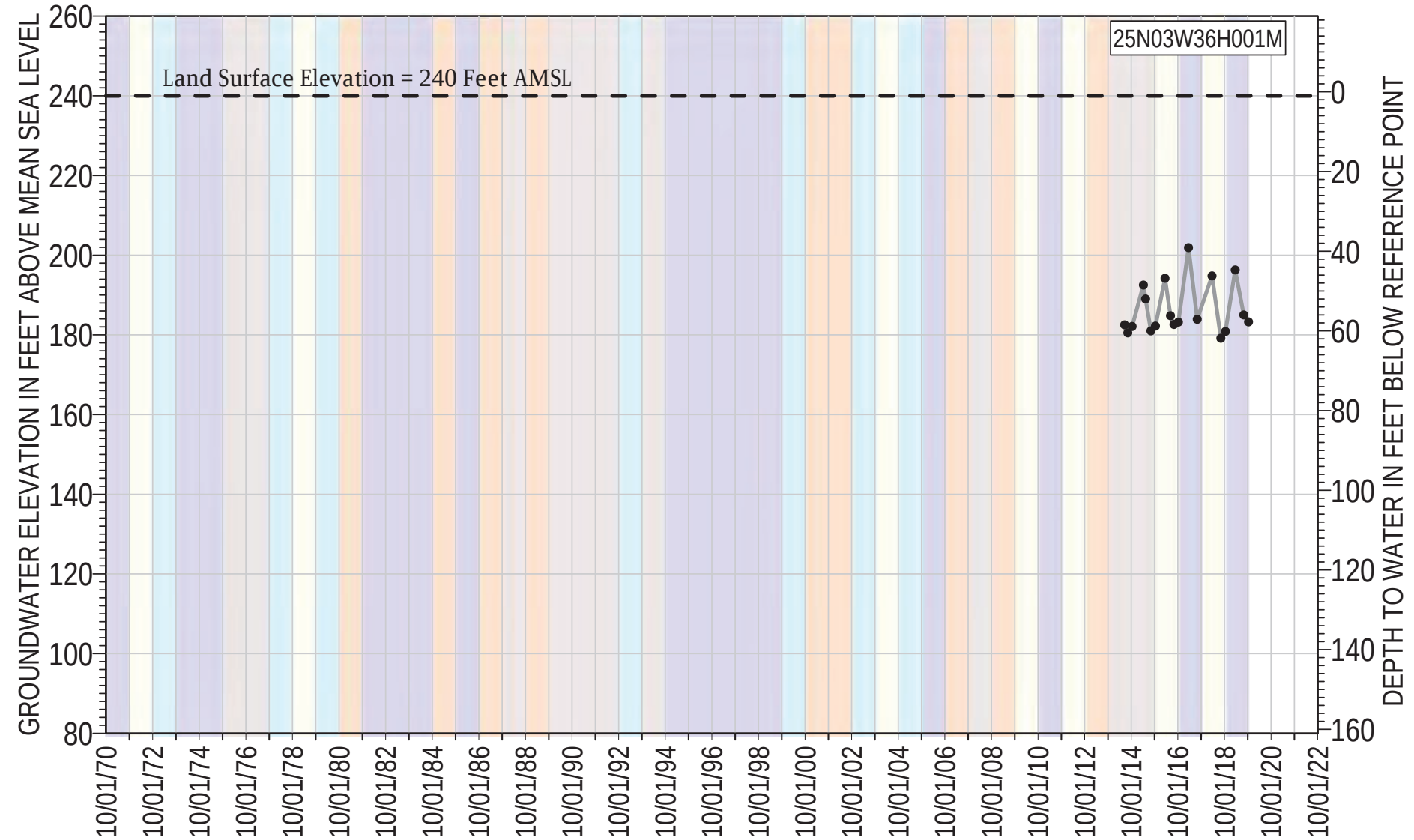
Land Surface Elevation

Reference Point Elevation= 223.8 ft AMSL
Well Type: Irrigation
Total Depth: 115 ft bgs
Well Screen Interval= 93 - 113 ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	





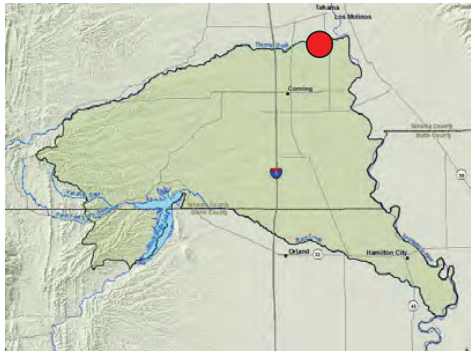
25N03W36H001M Groundwater Elevation

Land Surface Elevation

Reference Point Elevation= 241 ft AMSL
Well Type: Irrigation
Total Depth: 524 ft bgs
Well Screen Interval= Unknown ft bgs

Water Year Classification

Wet	Dry
Above Normal	Critically Dry
Below Normal	



Appendix 5D

Subsidence Monitoring Protocols

State of California
Natural Resources Agency
Department of Water Resources
Division of Integrated Regional Water Management
Northern Region Office

2017 GPS Survey of the Sacramento Valley Subsidence Network

December 2018

Project Manager:
Seth Lawrence, Senior Engineer, WR

Prepared By:
James West, Transportation Surveyor

With Assistance From:
Scott Kennedy, Engineer, WR
Brian Humphrey, Environmental Scientist
Jonathan Stephan, Research Analyst I
Teresa Connor, Supervising Engineer, WR

Technical Information Record (TIR) – NRO-2018-01

This Technical Information Record is primarily a working paper and is subject to revision or replacement. Its primary purpose is to summarize the equipment, procedures, processing, and results of the 2017 survey of the Sacramento Valley Subsidence Network installed in 2008.

Acknowledgements

This important survey project required many hours of field observation over more than 12 weeks using 4 to 10 observers per day. Without the outstanding support and assistance of many State, county, and local agencies, and private entities this project would not have been possible. The California Department of Water Resources would like to acknowledge and thank the following public and private entities for their assistance and support in making this project happen.

- **Butte County**
- **Caltrans**
- **City of Roseville**
- **City of Sacramento**
- **Colusa County**
- **Glenn-Colusa Irrigation District**
- **Glenn County**
- **Natomas Central Mutual Water Company**
- **Placer County**
- **Placer County Water Agency**
- **Reclamation District 108**
- **Sacramento County**
- **Sacramento Central Groundwater Authority**
- **Shasta County**
- **Sutter County**
- **Tehama County**
- **University of California Cooperative Extension**
- **Yolo County Flood Control and Water Conservation District**
- **Yuba County Water Agency**

Certification

I hereby state, all the work performed for this project was done by, or under the direct supervision of, a Licensed Land Surveyor. It is my opinion that the survey control, equipment, procedures, and techniques used for this survey are in conformance with accepted professional survey practice standards.



James R West 12/13/2018

Signature **Date**

James R. West, Transportation Surveyor
Engineering Studies Section
Northern Region Office
Licensed Land Surveyor, L.S. 7660

This technical information record report has been prepared under my direction as the professional engineer in direct responsible charge of the work, in accordance with the provisions of the Professional Engineers Act of the State of California.



12/13/2018

Signature **Date**

Seth W. Lawrence, Senior Engineer, Water Resources
Engineering Studies Section
Northern Region Office
Registered Civil Engineer No. 64213

Table of Contents

Acknowledgements ..... **i**
Certification ..... **ii**
Acronyms and Abbreviations ..... **iv**
Executive Summary ..... **v**
1. Introduction/Background **1**
1.2 Monitoring Network 1
1.3 Equipment and Procedures 1
1.3 Training and Reconnaissance 2
1.4 Safety 4
2. Network Observation and Processing **7**
2.1 Local Network Observations 7
2.2 Primary Network Observations 10
2.3 Baseline Processing 10
2.4 Network Adjustment 12
3. Survey Data Analysis **16**
4. Future Considerations **20**
References **21**

Figures

Figure ES-1 Height Change at Monuments between 2008 and 2017 vi
Figure 1-1 FERR Monument with Tripod in Place 2
Figure 1-2 QR Code and Smartphone Application Screenshot 4
Figure 1-3 Various Safety Concerns at Observation Sites 5
Figure 2-1 Local Network Map 8
Figure 2-2 Primary Network Map 9
Figure 2-3 Hether Ward (Glenn County) at Station Peter and Jerry Peatross (Placer County Water Agency) at Station Hallwood 10
Figure 3-1 Height Change at Stations between 2008 and 2017 17
Figure 3-2 Station WAYN with and without Cover 19

Tables

Table 3-1 Published and Network Ellipsoid Height of CORS 18
Table 3-2 30-Day Average CORS Ellipsoid Height 18

Appendices

Appendix A: Survey Equipment List **A-1**
Appendix B: New Monument Descriptions **B-1**
Appendix C: Observation Schedule **C-1**
Appendix D: List of Observers **D-1**
Appendix E: Combined Fully Constrained Network Adjustment **E-1**
Appendix F: Adjusted Ellipsoid Heights for all Stations **F-1**
Appendix G: Station Ellipsoid Height Changes from 2008 to 2017 ..... **G-1**

Acronyms and Abbreviations

CORS	Continuously Operating Reference Station
CSRC	California Spatial Reference Center
DIRWM	Division of Integrated Regional Water Management
DWR	California Department of Water Resources
GPS	Global Positioning System
ft.	feet
IRWM	Integrated Regional Water Management
InSAR	Interferometric Synthetic Aperture Radar
JPL	Jet Propulsion Laboratory
NAD83	North American Datum of 1983
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
NRO	Northern Region Office
OPUS	Online Positioning User Service
PDOP	Position Dilution of Precision
QR Code	Quick Response Code
RMS	Root Mean Square
Subsidence Network	Sacramento Valley GPS Subsidence Monitoring Network
TBC	Trimble Business Center
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey

Executive Summary

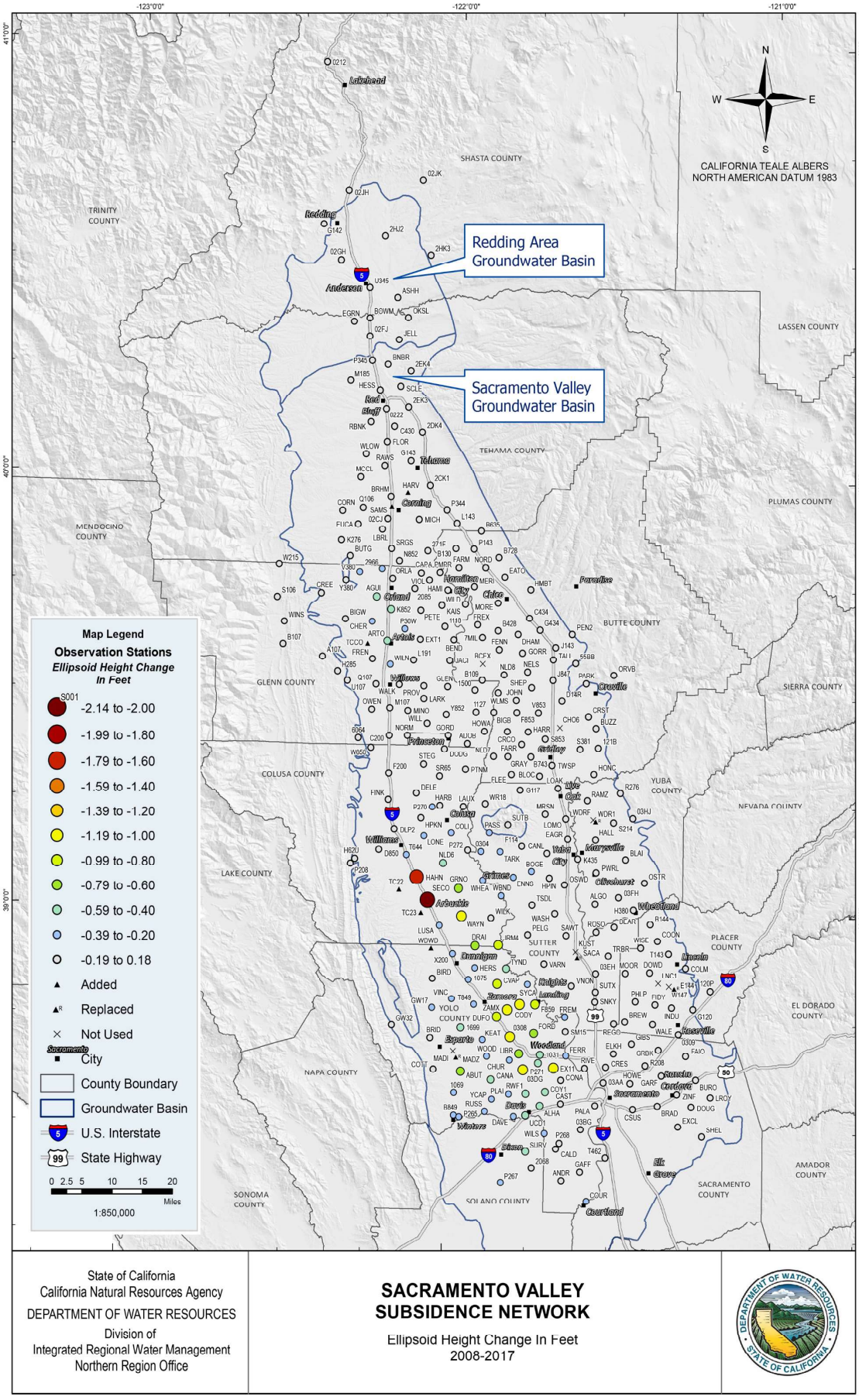
Land subsidence caused by groundwater extraction has occurred historically and continues to occur in portions of the Sacramento Valley. Over many years, the California Department of Water Resources (DWR) has established a subsidence monitoring program that includes field-based monitoring stations (11 extensometers and a Global Positioning System (GPS) network (further explained in this report) and more recently, remotely-sensed data (Interferometric Synthetic Aperture Radar [InSAR]) obtained from NASA and the Jet Propulsion Laboratory (JPL). In 2008, DWR developed a series of survey monuments in the Sacramento Valley to create a subsidence monitoring network. The network encompasses all or part of 11 counties, from Shasta County at the north end of the valley to Solano and Sacramento counties in the south. It includes over 300 benchmarks with an average spacing of 4.3 miles (7 kilometers). During the spring/summer of 2008, DWR along with 25 local, State, and federal partners performed an initial GPS survey of the network to establish a baseline measurement to compare against future surveys. The initial survey was done using National Geodetic Survey standards.

DWR resurveyed the monument network in 2017 with assistance from 19 State, county, and local agencies, and a private entity. The methodology and equipment used was similar to the 2008 survey. Analysis of the results was done to depict the change in height at each monument from 2008 to 2017.

The Arbuckle area (Colusa County) showed the most subsidence with a maximum change of -2.14 feet (ft.). Surrounding stations and InSAR data confirm this result with changes ranging from -0.49 to -1.00 ft. In eastern Yolo County (Zamora to Davis), the largest spatial extent of station declines was observed with several benchmarks showing changes between -0.3 and -1.1 ft. In Glenn County (Artois and Orland area), three stations, ARTO, K852, and AGUI showed changes of -0.59 ft., -0.46 ft., and -0.44 ft., respectively. An area on the south side of the Sutter Buttes showed changes ranging from -0.19 to -0.36 ft. The remainder of the valley shows little change overall. The results of the change between 2008 and 2017 are shown in Figure ES-1.

During the time of the 2017 survey, groundwater levels in the Sacramento Valley were recovering from the severe drought of 2012-16. During the drought, groundwater levels hit historic lows in most wells in the Sacramento Valley with maximum decreases in Glenn and Colusa Counties of 58 ft. and 43 ft., respectively, compared to 2011 pre-drought conditions. During the survey field work in 2017, groundwater levels had recovered about 7 ft. on average since 2015. The period between the two surveys was nine years, and it was not possible to determine when during that time frame the changes shown took place. However, it is likely that the subsidence occurred during the drought in 2012-16 when groundwater levels in many wells reached historic lows due to increased groundwater pumping. To better bracket when changes occur, surveys at a more frequent interval (3-5 years), are recommended. Integrating ground-based subsidence monitoring such as continuous GPS sites and extensometers and remote sensing data, such as InSAR, into the subsidence monitoring network is also recommended.

Figure ES-1 Height Change at Monuments between 2008 and 2017



1. Introduction/Background

It has long been known that pumping large quantities of groundwater in areas with compressible subsurface sediments in California's Central Valley lead to land subsidence (Borchers et al. 2014). DWR is interested in monitoring this phenomenon on a large spatial scale. To assist with this effort, in 2008 the Sacramento Valley GPS Subsidence Monitoring Network (Subsidence Network) was established and an initial survey was conducted (California Department of Water Resources 2008). In 2017, the Subsidence Network was resurveyed. This technical information record report summarizes the equipment, procedures, processing, and results of the 2017 resurvey. The purpose of the 2017 resurvey was to use GPS to resurvey the network to determine if any changes had occurred in the ground-surface elevation since the original survey was performed in 2008, and if so, to what magnitude. DWR's Division of Integrated Regional Water Management (DIRWM) Northern Region Office (NRO) staff led this work with the assistance of 19 State, county, and local agencies, and a private entity. The work was performed between February and December 2017 with funding from DWR's Sustainable Groundwater Management and Future Water Supply programs.

At the time of the 2017 survey, groundwater levels in the Sacramento Valley were recovering from the severe drought of 2012-16. During the drought, groundwater levels hit historic lows in most wells in the Sacramento Valley with maximum decreases in Glenn and Colusa counties of 58 ft. and 43 ft., respectively, compared to 2011 pre-drought conditions. During the survey field work in 2017, groundwater levels had recovered about 7 ft. on average since 2015.

The period between the two surveys was nine years, and it was not possible to determine when in that time frame the changes shown took place. However, it is likely that the subsidence occurred during the drought in 2012-16 when groundwater levels in many wells reached historic lows due to increased groundwater pumping.

1.2 Monitoring Network

In 2008, DWR contracted with Frame Surveying & Mapping to develop a series of survey monuments in the Sacramento Valley, to create a subsidence monitoring network, and to conduct a baseline GPS survey (California Department of Water Resources 2008). DWR resurveyed the monument network in 2017 with assistance from 19 state, county, and local agencies, and private entities to determine the change in elevation at each benchmark in the network.

The network encompasses all or part of 11 counties, from Shasta County at the north end of the valley to Solano and Sacramento Counties in the south. It includes over 300 benchmarks with an average spacing of 4.3 miles (7 kilometers).

Information gathered from the GPS subsidence network is used in conjunction with other sources including groundwater levels to assess the timing and location of land subsidence and help determine a correlation between the amount of groundwater extraction and the subsidence.

1.3 Equipment and Procedures

As with the 2008 network campaign, the procedures for this project followed the National Geodetic Survey (NGS) *Guidelines for Establishing GPS-Derived Ellipsoid Heights* NOAA Technical

Memorandum NOS NGS-58 using the 2-centimeter standards (National Geodetic Survey 1997). Although there are slight deviations from the network design standards for spacing, they are the same deviations that existed in 2008 and the design was accepted and approved by NGS at that time. Other variations from the Technical Memorandum include longer observation times than the minimum requirement and recording data at a higher epoch rate (recording interval). Each of these variations exceeded the guideline requirements. All GPS receivers and antennas used for the survey were dual-frequency, full-wavelength receivers that satisfied the requirements of NGS-58. All tripods used were fixed height, either 2-meter (6.562 ft.) or 1.8-meter (5.905 ft.). Prior to the first observations, the tripods and level bubbles were adjusted to plumb. Because all tripods had either a 3-bubble level plate or a rotating center pole bubble, there was an immediate indicator if the pole was not plumb. Any tripods that were found to be out of plumb during the survey were immediately removed from service until they were readjusted to plumb. A complete list of the equipment used is in Appendix A.

At the FERR station it was necessary to add a 2-foot extension to the tripod for a total of 8.562 ft. (2.61 meters) because the construction of a new water intake structure on the Sacramento River raised the ground surface nearly two feet, putting the monument below the surface by over 2.5 ft. (Figure 1-1).

Figure 1-1 FERR Monument with Tripod in Place



1.3 Training and Reconnaissance

After initial planning, two training sessions were held, one at DWR's Northern Region Office on April 18, 2017, and one at DWR's North Central Region Office on April 20, 2017. These sessions were designed to discuss safety and teach potential observers the process for locating the monuments, operating the survey equipment, and properly filling out the GPS Observation Log. Each observer was given the opportunity to complete a full scenario of setting up the equipment, recording data, and filling out the Observation Log. These sessions helped reduce errors during the survey campaign and revealed some

unanticipated problems. One of the problems identified was that some observers had difficulty reaching the GPS receiver once it was placed atop the 2-meter tripod. To accommodate these situations, 1.8-meter tripods were sometimes used while some observers brought a stable platform, such as a step stool. Fieldwork began in March 2017. The first phase involved finding the monuments and marking them to make it easier for the observers to quickly identify them during the actual survey. It also allowed for identifying if monuments had been destroyed or if conditions such as vegetation growth prevented the monument from being surveyed directly with GPS.

During the first phase, it was discovered that five monuments had been destroyed: BC EXTN 2 (BCEX), Kuster (KUST), Madison (MADI), W1474 (W147), and Woodruff (WDRF). BCEX was in farmland and was damaged by disking equipment. KUST was located on a canal headwall which was removed by Caltrans for construction of a new alignment of Highway 99. MADI had been in farmland and was destroyed by land levelling during the planting of a new orchard. W147 was on a drainage channel headwall which was removed when the adjacent street was widened and improved. And WDRF, which was on an irrigation ditch headwall, was destroyed when the county realigned the road.

To meet the requirements for GPS network design station spacing, other existing monuments, if available, had to be recovered and marked, or new monuments had to be installed. Office and field research found existing monuments as replacements for W147, and MADI, stations E1446 (E144), and Madison Az Mk (MADZ), respectively. BCEX, KUST, and WDRF required that new stations be set. For BCEX, the existing metal rod was bent back into position and the name on the monument cap was changed to include "RESET"; although the original coordinates and elevation as published by NGS cannot still be considered valid, the elevation of the new monument is within a few hundredths of a foot of the original one. For KUST, a brass disk monument, Sacramento Ave (SACA) was set on a new headwall very near the original location of KUST. Unfortunately, there is no known data to relate the original elevation of KUST to the new SACA monument. Similarly, WDRF was also replaced with a new monument, Woodruff Replacement (WDR1), in a headwall; however, there is no data available to compare their elevations. The field location and marking also found that three stations were no longer suitable for GPS observations because of trees blocking the view of the sky; these stations are Gaffney (GAFF), Alhambra (ALHA), and Fremont (FREM). For these locations, temporary points were set for the GPS observations and differential levels were performed to tie the observed location back to the original network.

During the first phase, counties and other agencies were given an opportunity to add monuments to expand or densify the network. Tehama County set two new monuments, Harvest 2017 (HARV) and Samson 2107 (SAMS), to increase the network density in areas of potential subsidence. Glenn County added one monument, Tehama-Colusa Canal 0 (TCC0), to expand the network to the west; it is an existing brass cap monument on a Tehama-Colusa Canal check structure. Colusa County added three stations to the network to expand the network to the west as well. The southernmost monument, Wildwood Bridge (WDWD), is a new monument set on a bridge on Wildwood Road. The other two stations, Tehama-Colusa Canal 22 (TC22) and Tehama-Colusa Canal 23 (TC23), were existing monuments on Tehama-Colusa Canal check structures and their number designates the check structure numbers on the canal. Descriptions or sketches for the locations of all the new monuments are in Appendix B.

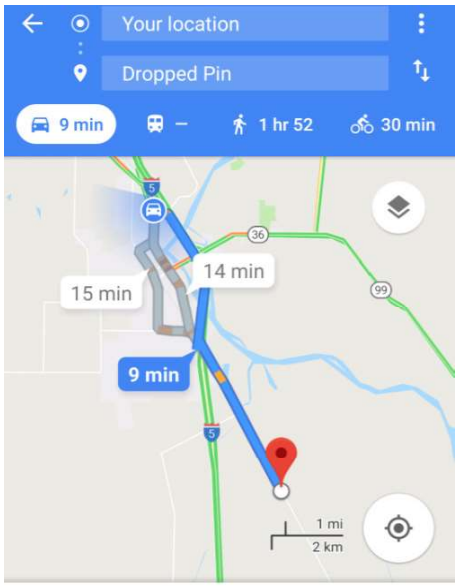
After the network points were found or re-set, one-page summary sheets including the location, description, and a map were created for each station. This was done to provide the observers with an easy

to use reference to access each site. Previously, in 2008, NGS datasheets were used and they can consist of one to eight pages making them cumbersome and difficult to read. For the 2017 resurvey, a Quick Response (QR) Code was created to assist with locating the monuments. The QR Code leverages smartphone technology by quickly enabling the user to access a map and turn-by-turn instructions to the station (Figure 1-2). Although there were a few errors because of road locations relative to the monument, using the QR Code worked well by enabling the observer to quickly access station maps and location information and it reduced the time required to get from station to station.

After completing phase one of the project, monument locating and marking, a plan was developed for surveying the network (phase two of the project). This plan called for ten observers per day with eight-hour work days starting and ending within the vicinity of the network that was being observed that day. To allow for travel time between stations and a lunch break, the plan included four 50-minute surveying sessions per day with one hour of travel time between sessions. Thoughtful consideration of the daily surveying plan, including the number and location of the stations, was necessary to ensure that every observer would be able to conduct their daily surveying sessions without incident and that each station was surveyed in accordance with NGS standards.

Figure 1-2 QR Code and Smartphone Application Screenshot





1.4 Safety

As with all DWR projects, the safety of staff and the public is the highest priority. This project involved numerous hazards including: working along roadways, railroads, and airports, extreme weather conditions including record-breaking heat, biting and stinging insects, poison oak, and rattlesnakes (Figure 1-3). To minimize the risk to the station observers, several actions were taken. Prior to beginning observations each day, safety meetings were held with the observers to discuss the possible hazards and how to lessen the dangers. Because many of the stations are near roadways, traffic was a primary concern. An

encroachment permit was obtained from Caltrans to allow work in the state right-of-way. This permit also provided roadside safety techniques. All observers were provided safety vests, hard hats, and traffic cones. Drinking water was made available to all observers at the beginning of each day.

Figure 1-3 Various Safety Concerns at Observation Sites



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2. Network Observation and Processing

This technical information record report summarizes the surveying results of observing the monuments in the Sacramento Valley to determine how much they have changed since 2008. The following section describes the observation work and the processing of the resulting data.

2.1 Local Network Observations

The Subsidence Network is comprised of two networks referred to as the Local Network and the Primary Base Station Network (Primary Network). The local network includes the stations with an average spacing of 4.3 miles (7 kilometers) (Figure 2-1). The primary network has 24 stations with much larger spacing of 24 miles (40 kilometers) (Figure 2-2). Local observations began on May 2, 2017. The goal was to have ten observers per day to complete the project in a timely manner. Unfortunately, it was not possible to recruit ten daily observers until the final day of observations. In fact, the number of observers changed from week to week, and sometimes from day to day. The average number of observers was seven with some days as few as four. This unplanned variability required the network observation schedule to be re-evaluated and significantly modified each week, which greatly increased the time required to complete the network observations. On June 28, 2017, it was necessary to modify the surveying schedule ad hoc because of a freeway closure due to a vehicle crash, which prevented the observers from reaching their stations. That day the observation schedule was reduced to three sessions. On five other days, the schedule was reduced to three sessions to accommodate for excessive travel times.

During the observation period for the local network, all staff met between 7:00 and 8:00 AM each morning (depending on location) to discuss and plan the day's activities and to distribute survey equipment, observer binders, and safety items as well as to do a safety briefing. At the end of each day, staff met again to collect the equipment and discuss any problems that may have occurred. Each night the files collected in the GPS receiver during the daily observation sessions were downloaded and checked. A complete listing of the observation schedule is provided in Appendix C.

Despite the limited amount of surveying experience of the observers, phase two was completed successfully, and the observers were able to complete their tasks of traveling to the station and locating the monuments, setting up and operating the equipment, and filling out the GPS Observation Logs. As previously stated, individuals from multiple agencies participated in this effort. A complete list of observers is shown in (Appendix D) and without the support of staff from the cooperating agencies, this project could not have been completed. Figure 2-3 shows a couple of the observers set up on stations.

Figure 2-1 Local Network Map

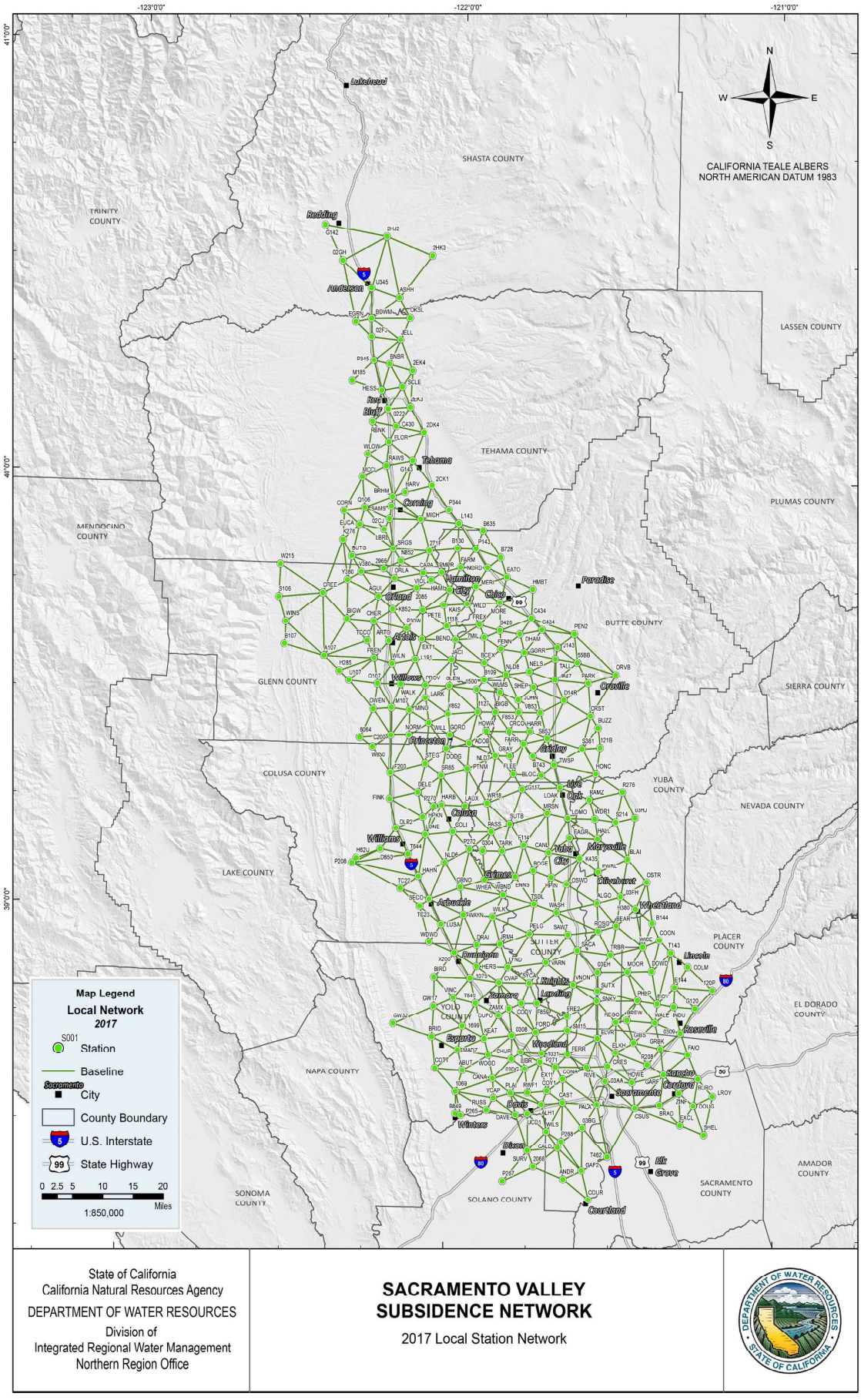


Figure 2-2 Primary Network Map

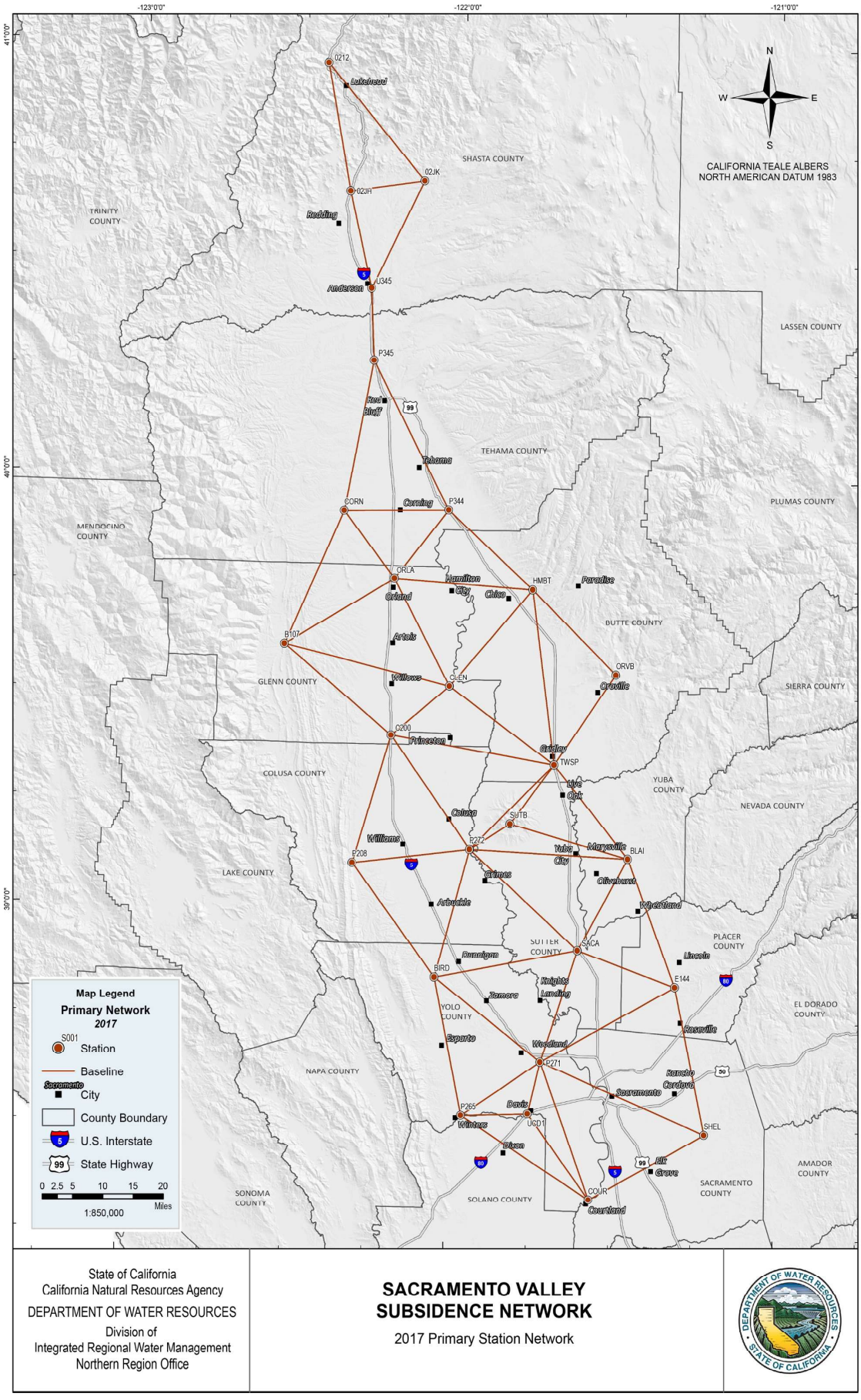


Figure 2-3 Hether Ward (Glenn County) at Station Peter and Jerry Peatross (Placer County Water Agency) at Station Hallwood



2.2 Primary Network Observations

Primary network observations began on August 8, 2017. As with the local network, the monitoring plan included ten observers per day, however the actual number of daily observers was less than ten. This shortage changed the observation plan of the primary network from two sections (northern area and southern area) to three sections; increasing the observation schedule from two weeks to three weeks. For the northern third of the network, staff met at the beginning and end of each day and checked out/in the surveying equipment. Data files were also downloaded and checked nightly. For the other two-thirds of the primary network it was not feasible to meet daily due to increased travel times required to cover the monitoring grid in the central and southern Sacramento Valley. Observers in these areas met at the beginning and end of each week, and the data was downloaded at the end of the week.

During the primary network observations, it was discovered that at station HPGN CA 0212 (0212) a nearby tree had grown large enough to affect the quality of the survey data. Future surveys will require that at station HPGN CA 0212 an offset point with a clear view of the sky be set and differential levels performed.

2.3 Baseline Processing

The third phase of assessing land subsidence with GPS involves processing and analysis of the GPS data, typically referred to as “baseline processing”. A baseline is the measured vector between two GPS receiver antennas. Each baseline for the 2017 survey was processed using Trimble Business Center (TBC) software (version 3.7).

Initially, the processing was accomplished using the broadcast ephemeris. The broadcast ephemeris contains information pertaining to the expected positions of the GPS satellites. After approximately ten

days, the precise ephemeris was published and the baseline processing was done again. The precise ephemeris contains information about the actual locations of the GPS satellites. Generally, the baselines were processed using a 15-degree elevation mask for the satellites; however, some variations were made to account for obstructions at some stations. For this survey, the NGS absolute antenna calibration model was used, as opposed to the relative antenna calibration model used in 2008. The relative antenna model could not be used for this survey because some of the GPS receivers were not calibrated by NGS using the relative model and mixing of antenna models within a survey can lead to significant differences. Although it is known that there is some difference in the computed ellipsoid height difference due to the different antenna calibration models, when NGS was contacted they said the amount of difference cannot be quantified.

For the 2008 campaign, Trimble Geomatics Office software was used to process the baselines. Because of differences between the processing software, including the tropospheric model used during processing, there is a chance that systematic errors or differences can occur between the two sets of data. However, these differences, if they do exist, should be minor and not have a significant effect on the final results.

As per the NGS standards, each baseline within the local network was measured twice under different satellite configurations and atmospheric conditions and after processing using the precise ephemeris, duplicate baselines were compared to make sure they met the 2-centimeter ellipsoid height difference criteria. Additionally, the root-mean-square (RMS) value for each computed baseline must not exceed 1.5 centimeters (0.05 ft.). Only 4.2 percent of the baselines failed the criteria and required re-observation. The schedule for the re-observation is combined with the observation schedule in Appendix C.

The requirements for the primary network are different than those for the local network. Because of the much greater spacing between stations in the primary network, the required observation time is five hours and there are three redundant baselines between stations. And in this case, the ellipsoid height difference for the baselines cannot exceed 5.0 centimeters (0.16 ft.).

One baseline, between stations B1079 (B107) and Glenn (GLEN), slightly exceeded this criterion, however, because baselines processed to adjoining stations from each of these stations did meet the standards, the baseline was accepted. During the primary network adjustment, discussed later, this baseline was a significant outlier and was removed. Although the loss of this baseline is a deviation from the recommended standards, the results of the network adjustment are such that it was not deemed to be a substantial issue. The complete baseline processing report contains over 10,000 pages and is not included in this report but can be made available upon request.

To supplement the bench marks used, any Continuously Operating Reference Station (CORS) in the valley are included in this study and the 2008 study. CORS are fixed locations that continually collect position data, and it is available online. During processing, it was discovered that two CORS used in the 2008 survey could not be used for this 2017 survey. One station, Chico 6 CORS ARP (CHO6), had been decommissioned by the United States Coast Guard and the other station, Lincoln 1 CORS ARP (LNC1), had problems functioning for the majority of 2017. This loss of stations required observations of eleven additional baselines to meet the network requirements. Some of these additional baselines were added as observations during the local network observation schedule and the rest were completed during the re-observation schedule of baselines that did not meet the 2-centimeter criteria.

During processing, it was also discovered that the wrong monument had been measured at station Winslow (WINS). This error occurred because the wrong monument was flagged and marked during phase one. Specifically, the monument for Winslow RM1 had been marked; it is approximately 50 ft. from the WINS monument. To account for this error, differential levelling was performed from Winslow RM1 to WINS to update the elevation for the correct station.

2.4 Network Adjustment

The primary and local network adjustments were performed individually. The adjustments were performed with TBC using a least squares adjustment method; using this method, the sum of the squares of all the weighted residuals is minimized. For the primary network, a minimally constrained adjustment was performed first using station Sutter Buttes CORS Point (SUTB) as the fixed position both horizontally and vertically. This station was held fixed because it is near the center of the network and is very stable. The adjustment statistics showed a network reference factor of 1.00 and an A Priori scalar of 1.49 at the 95% confidence level. From the adjustment, there were only four outliers and two of these were baseline measurements to station 0212, which is understandable given the poor observation conditions that exist at that station due to the overgrown tree. A complete listing of the results of this adjustment are available upon request from NRO. They are not included in this report due to the size of the document. Overall, these statistics indicate there are no significant issues or large errors in the measurements and that the observations form a cohesive network.

Similarly, the local network was first adjusted in the same manner holding SUTB fixed horizontally and vertically. This adjustment produced a network reference factor of 1.00 and a scalar of 1.09 with three outliers. In this case, all the outliers occurred at station Oswald (OSWD) during one observation. Although it is possible that the satellite measurements were the source of the difference, analysis of the three outliers strongly indicate that the tripod was not plumb and was leaning northeasterly. Regardless, these differences were in the ellipsoid distance and azimuth and have little to no effect on the ellipsoid heights which is the focus of this survey. Again, these results indicate a cohesive network with no large errors. The complete results of this minimally constrained adjustment of the local network are available upon request from NRO.

To begin establishing control for the primary network, the five-hour observations from the primary network survey were processed using the NGS program “Online Positioning User Service” (OPUS). OPUS is a program that allows users to upload a GPS file from dual frequency survey grade receivers (like those used in this project) and then computes a position based on three CORS receivers. The computed position is an average of three independent baseline solutions generally, but not always, from the closest CORS. For each passive station in the primary network, the CORS solutions from the three sessions were then averaged for a final value. The solutions provided by the CORS processing are provided in reference to the most current NGS realization of the North American Datum of 1983 (NAD83) which is known as NAD83 (2011).

To keep the end results of the 2017 survey consistent and comparable with the previous survey referencing NAD83 (2007), the OPUS-produced ellipsoid heights were compared to the previously published NAD83 (2011) heights and the difference was then applied to the ellipsoid heights from the 2007 reference. The results for all the stations were then used as constraints in a least-squares adjustment with the measured baselines produced from the primary network survey. The results showed several

significant outliers with the measured baselines indicating that all the CORS solutions could not be correct, or there was a problem with the baselines themselves.

Because the minimally constrained adjustment proved the network to be cohesive, the problem was in some of the positions from the OPUS solutions. To help determine which positions might be in question, at least one session from each primary station was processed to a minimum of three CORS using the July 2, 2017 ellipsoid heights published by the California Spatial Reference Center (CSRC) as constraints. Unlike the OPUS solutions, the CORS selected for processing were chosen to provide strong geometry to the measured station location. These results were then compared to those from the OPUS solutions. Generally, the results from each method should be comparable at about 0.08 ft. (2.4 centimeters). If the results for the computed ellipsoid heights were not within 0.10 ft. (3.0 centimeters) of each other, the OPUS solution was not considered reliable and that station's height was not held fixed. Because of the loss of CORS LNC1 and passive station KUST, their replacement stations E144 and SACA were not held fixed since there was no previous ellipsoid heights available for reference. The results of this process generated the following stations as vertical constraints for the primary network adjustment: 02JK, BIRD, BLAI, COUR, GLEN, ORVB, P208, P265, P271, P345, SHEL, SUTB, TWSP, and U345. For the CORS stations held fixed (ORVB, P208, P265, P271, P345, and SUTB), the ellipsoid height used was computed by taking the difference between the CSRC 2017 NAD83 (2011) ellipsoid values and the 2008 NAD83 (2011) values and then applying that difference to the NAD83 (2007) ellipsoid height.

Because the purpose of this survey was not to produce new horizontal coordinates, only SUTB and U345 were used for horizontal constraints. The results from the fully constrained primary network adjustment yielded good results with a reference factor of 1.00 and an A Priori scalar of 2.44. Of the 162 baselines, there were only two outliers and one of those was to station 0212 which was discussed earlier. The other was a baseline which, although it met the 5-centimeter criteria, had a large difference compared to the other two baselines measured between stations P345 and CORN.

The fixed and adjusted heights from the primary network were then used as constraints for the local network. The fixed adjustment process was a series of iterations of adding points as constraints and then analyzing the results to be sure they fit properly within the structure of the network. From this process, a discrepancy was discovered in the southeast portion of the local network (this is the area where primary stations LNC1 and KUST were lost). When the height of primary station E144 was added as a constraint, it showed an increase in height of the nearest stations and created some outlier observations. Although most of the changes were within the 0.17-foot level of statistical significance, the decision was made to find another source of height control in this area. When the network was first created for the 2008 survey, it was intentionally designed to tie into stable monuments outside the area susceptible to subsidence. Consequently, station G120 on the eastern edge of the network was chosen to provide vertical control for this area and its ellipsoid height was held fixed. This station is set in a rock outcrop and has a stability level A per the NGS which means it is considered "most reliable and expected to hold position/elevation well." With the addition of this station as a final constraint, the local network was then adjusted using the least-squares method.

The final combined network consists of 321 stations, 1,357 occupations (including CORS), and 1,728 baselines. The overall network reference factor is 1.00 with an A Priori Scalar of 1.18. Of the 1,728 baseline measurements, there are only seven outliers (at the 95% confidence level). Of these, only four were in the ellipsoid height difference. Again, these results show that there are no large errors and as

such, the remaining errors are small and random and were properly distributed by the least-squares adjustment. The complete results of the fully constrained adjustment can be found in Appendix E.

Appendix F contains a table of the adjusted ellipsoid heights for all stations in the survey. For existing stations, the record 2008 latitude and longitude is shown; for new and replacement stations, the computed latitude and longitude from the network adjustment is shown.

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3. Survey Data Analysis

The final adjusted ellipsoid heights from the 2017 survey were compared with the computed ellipsoid heights from the 2008 survey. Ellipsoid heights, not orthometric heights (elevations), were used to negate the errors introduced when ellipsoid heights are converted to orthometric heights using a geoid model. The geoid model represents the equipotential surface of the Earth's gravity field. Over time, additional measurements further refine the model and there have been four new models created since the 2008 survey. The use of ellipsoid heights removes the question of which geoid model to use as well as eliminating the errors contained within the model.

With GPS, as with any type of measurement, there is some amount of error. For GPS measurements, the primary sources of error come from signal delays caused by the troposphere and ionosphere, poor satellite geometry (known as Position Dilution of Precision or PDOP), and multi-path where the signals from the satellites reflect off an object before reaching the GPS receiver. Additional errors may occur from clock timing and clock synchronization errors. These errors or "noise," creates an error of uncertainty of approximately 0.17 ft. (5.2 centimeters). Therefore, any change less than 0.17 ft. is not considered statistically significant. The results of the differences for stations that have previously measured ellipsoid heights can be seen in Appendix G and graphically in Figure 3-1.

To validate the results of this survey, additional checks were made to other sources of data. First, a comparison was made to the results of a DWR subsidence survey for Colusa County that was completed in 2016. That network was a small portion of the Subsidence Network and therefore used different stations for constraints (control). Of greatest concern for comparison were stations SECO and HAHN in the Arbuckle area that showed major changes of -2.14 and -1.69 ft., respectively. Also of importance for comparison were two stations that were added for the 2016 Colusa County Survey, TC22 and TC23. Although the surveys were done a year apart and the method of control was different, the comparison showed a difference of only -0.062 ft. for station SECO and -0.049 ft. for station HAHN. The computed ellipsoid heights for stations TC22 and TC23 differed in each survey by only 0.016 ft. and 0.019 ft., respectively. The observation that significant subsidence has occurred in this area is reinforced by the knowledge that a number of nearby wells have suffered collapse or damage in recent years.

Next, a comparison was made to CORS that were not held fixed as part of the primary network adjustment. For these stations, two different comparisons were made. The first was to the height difference as discussed in the primary network portion of the Network Adjustment section. The second was to the height difference computed by the CORS. Each CORS measures its current position several times per day and computes the daily change from its reference height. CORS then publishes the daily average height change as well as the standard deviation for the measurement. For a variety of reasons, the standard deviation may exceed the single day change shown. For this reason, the 30-day average encompassing the observation dates in both 2008 and 2017 were used to determine the change. The results are shown in Tables 3-1 and 3-2.

Figure 3-1 Height Change at Stations between 2008 and 2017

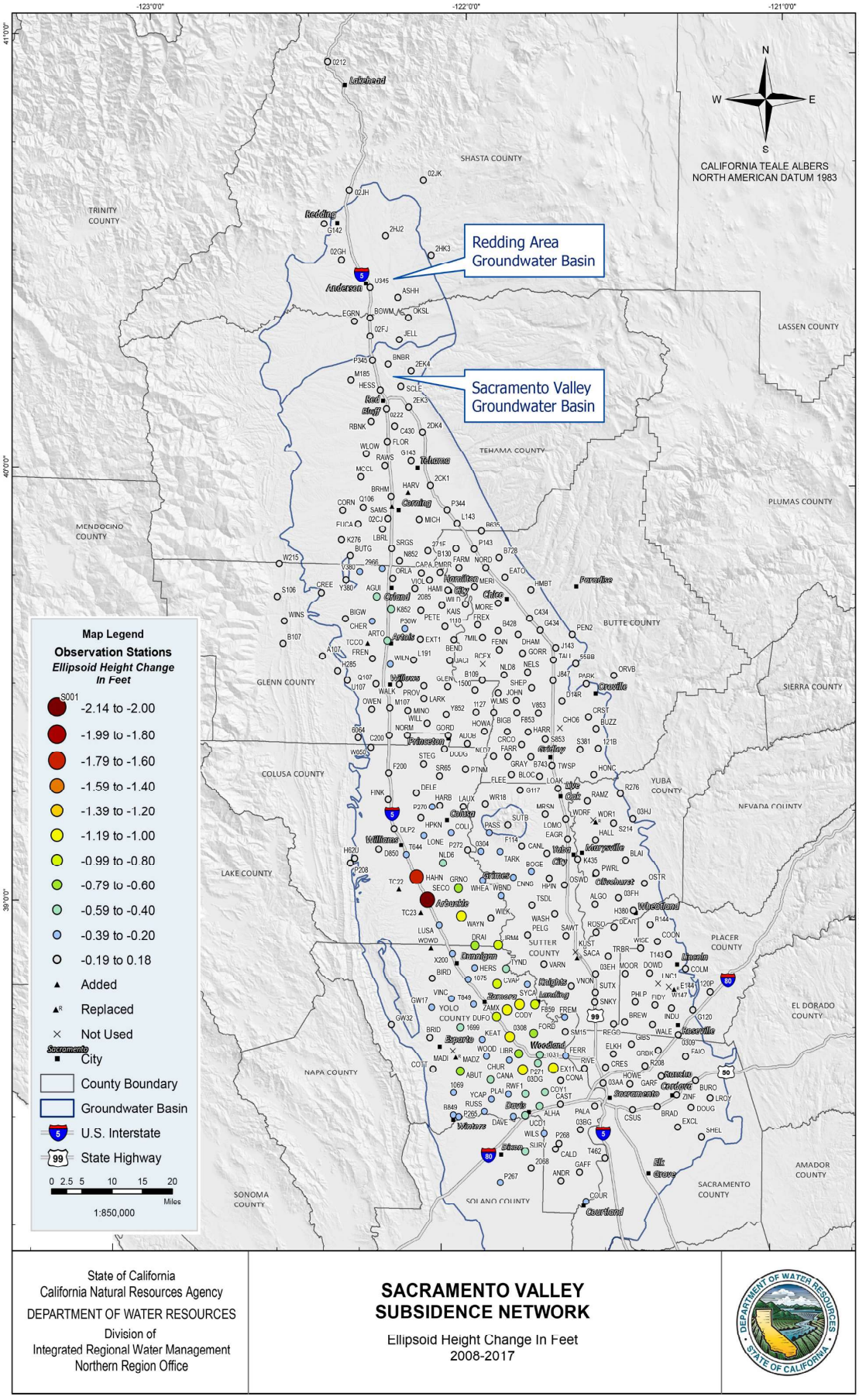


Table 3-1 Published and Network Ellipsoid Height of CORS

4-CH ID	Published 2017 Ellipsoid Height (ft.)	2017 Network Ellipsoid Height (ft.)	Difference (ft.)
267	-55.612	-55.787	0.175
P268	-76.875	-76.887	0.012
P272	-38.101	-38.042	-0.059
P344	164.733	164.748	-0.015
UCD1	-0.142	-0.046	-0.096

Table 3-2 30-Day Average CORS Ellipsoid Height

	30-Day Average in mm (2008)		30 Day Average in mm (2017)		Change 17-08 (mm)	Change 17-08 (ft.)	Measurement change (ft.)	Difference Station-Measurement (ft.)
Station	Measurement	SD	Measurement	SD				
P268	-17.627	5.036	-42.386	5.181	-24.759	-0.081	-0.125	0.044
P272	-16.278	4.698	-29.557	5.378	-13.279	-0.044	-0.129	0.085
UCD1	-71.491	7.836	-191.970	7.907	-120.479	-0.395	-0.558	0.163
P270	-4.281	4.790	-24.685	4.498	-20.404	-0.067	-0.258	0.191
P344	-7.313	5.630	-17.810	5.487	-10.497	-0.034	-0.032	-0.002

Notes:
ft.= feet, mm= millimeter, SD= Standard Deviation
Original data published in millimeters.

Within the Sacramento Valley, the stations SECO and HAHN, in the Arbuckle area, showed the greatest height changes at -2.14 ft. and -1.69 ft. respectively. Three stations immediately to the east and southeast of these also showed declines ranging -0.49 ft. to -1.00 ft. In Yolo County, several stations show a decrease between -0.3 and -1.1 ft. and Yolo County shows the largest spatial extent of stations showing decline. In Glenn County, in the Artois and Orland area, three stations, ARTO, K852, and AGUI show changes of -0.59 ft., -0.46 ft., and -0.44 ft., respectively. There is also an area on the south side of the Sutter Buttes showing a decrease in elevation ranging from -0.19 to -0.36 ft. Only one station showed an increase greater than or equal to the level of statistical significance; station J143 showed an increase in elevation of 0.18 ft. Initially this change was troublesome since the NGS datasheet states this monument has a stability "A" and is in a bedrock outcropping. However, after further investigation it was determined that it is not a bedrock outcropping but rather a pyroclastic rock boulder approximately 2 ft. x 6 ft. in size.

While it is not the purpose of this survey to determine new horizontal coordinates for the monuments, the measured positions were compared to those from the 2008 survey for Quality Assurance/Quality Control (QA/QC) purposes. With only one exception, all the monuments were very near their previous horizontal geographic positions. The one exception was station WAYN, where the horizontal position changed by 0.69 ft. Station WAYN is located on the east levee of the Colusa drain approximately 5.6 miles southeast of Arbuckle. Per the NGS datasheet, this monument is on an aluminum alloy rod that was driven into the ground nearly 20 ft. and originally the monument cap was 0.2 ft. below the monument cover. Today, the monument has lifted the cover off its concrete collar and with the cover removed, is protruding more than 0.25 ft. (Figure 3-2). The measurements and visual inspection indicate that the levee is most likely sloughing and pushing the monument and aluminum alloy rod to the northeast.

Figure 3-2 Station WAYN with and without Cover



4. Future Considerations

Based on the work of the 2017 survey, several lessons were learned and should be considered for the future:

- Monitoring of all types, including GPS, involves looking for spatial and temporal trends in the data. Although the 2008 survey provided a baseline for comparison, there have only been two surveys and thus, only two datasets. As such, it is difficult to say that any trends are occurring since a difference at any location may just be an anomaly in either one of the surveys. The resurveying of the network should occur more frequently to develop a better record from which trends can be determined.
- Because of the spacing of the stations, the loss of even one station creates a large spatial gap. Even if a GPS survey is not performed, the stations should be visited more frequently to make sure the protective markers are still in place. Although they initially had signs indicating to contact the NGS if the monument had to be disturbed, it would be beneficial to have a notice indicating to contact DWR. If DWR is contacted, DWR would have the opportunity to perform differential leveling from the station before it is destroyed so that the relative elevation could be perpetuated for comparison in future surveys.
- To avoid spending unnecessary time during planning, have a firm commitment of the number of observers available before developing an observation schedule.
- The observation data from the 2008 baseline survey, this survey, and subsequent surveys should be kept in a centralized location. Then, the data could all be re-processed using the same baseline processor and adjustment software to eliminate the errors that can be introduced by using different software applications.
- The NGS has an on-line program called OPUS Shared. Just like the OPUS Program, it allows users to submit a survey-grade GPS file for processing with the additional requirement of submitting photographs of the monument and equipment set-up. The solution produced from the OPUS processing is then shared on-line. This site should be monitored on a regular basis for solutions published for monuments that are part of the Sacramento Valley Subsidence Network. Although there is no guarantee that the solution provided properly reflects the equipment used (correct tripod height, for example), the combination of data could be used to find trends indicating potential subsidence and help promote further study in a focused area.

Another part of the OPUS Shared Program is OPUS Projects. This program adds additional visualization and management tools. DWR might want to consider creating a project specific to the monuments within the Subsidence Network. Through outreach and coordination with State and local agencies (Caltrans, county survey offices, and groundwater sustainability agencies for example), a great deal of data could be collected for review and analysis without a large expenditure of time, resources, and money for any one agency.

References

Borchers JW, Grabert VK, Carpenter M, Dalgish B, and Cannon D. 2014. *Land Subsidence from Groundwater Use in California*. Sacramento (CA): California Water Foundation. 193 pp. Viewed online at: https://water.ca.gov/LegacyFiles/waterplan/docs/cwpu2013/Final/vol4/groundwater/13Land_Subsidence_Groundwater_Use.pdf.

California Department of Water Resources. 2008. *Project Report: 2008 California Department of Water Resources and U.S. Bureau of Reclamation, Sacramento Valley GPS Subsidence Project*. Sacramento (CA): California Department of Water Resources. Prepared by Jim Frame and Don D'Onofrio. 49 pp. Viewed online at: https://water.ca.gov/LegacyFiles/groundwater/docs/DWR_USBR_Sacramento_Valley_Subsidence_Report_2008.pdf

National Geodetic Survey. 1997. *Guidelines for Establishing GPS-Derived Ellipsoid Heights*: NOAA Technical Memorandum NOS NGS-58. Silver Spring (MD) NOAA. Viewed online at: https://www.ngs.noaa.gov/PUBS_LIB/NGS-58.html.

DWR Extensometers

Description

Borehole extensometers are a more site specific method of measuring land subsidence. These instruments consist of a pipe or cable anchored at the bottom of a well casing. Pipe or cable extend from the bottom of the well, through geologic layers susceptible to compaction, to the ground surface. The pipe or cable is connected to a recorder that measures the relative distance between the bottom of the bore hole to the ground surface. These instruments are capable of detecting changes in land surface elevation to 1/100th of a foot. When land subsidence and water depth monitoring activities are paired together, hydraulic and mechanical properties of the aquifer system can be determined. DWR monitors 11 extensometers in the Sacramento Valley.

Service/Hosted Location

Download and API @OpenData: https://data.cnra.ca.gov/dataset/wdl-ground-surface-displacement

Guidance

DWR makes no warranties or guarantees - either expressed or implied - as to the completeness, accuracy, or correctness of the data. DWR neither accepts nor assumes liability arising from or for any incorrect, incomplete, or misleading subject data.DWR makes no warranties or guarantees - either expressed or implied - as to the completeness, accuracy, or correctness of the data. DWR neither accepts nor assumes liability arising from or for any incorrect, incomplete, or misleading subject data.

Contact

Water Data Library, wdl@water.ca.gov

TRE ALTAMIRA InSAR Dataset

Description

This dataset represents measurements of vertical ground surface displacement in more than 200 of the high-use and populated groundwater basins across the State of California between January of 2015 and September of 2019. Vertical displacement estimates are derived from Interferometric Synthetic Aperture Radar (InSAR) data that are collected by the European Space Agency (ESA) Sentinel-1A satellite and processed by TRE ALTAMIRA Inc. (TRE), under contract with the California Department of Water Resources (DWR) as part of DWR's SGMA technical assistance to provide important SGMA-relevant data to GSAs for GSP development and implementation. Sentinel-1A InSAR data coverage began in late 2014 for parts of California, and coverage for the entire study area began in June 13, 2015. Included in this dataset are point data that represent average vertical displacement values for 100 meter by 100 meter areas, as well as GIS rasters that were interpolated from the point data; rasters for total vertical displacement relative to June 13, 2015, and rasters for annual vertical displacement rates with earlier coverage for some areas, both in monthly time steps.

Service/Hosted Location

Image Server: https://gis.water.ca.gov/arcgisimg/rest/services/SAR

Download @OpenData: https://data.cnra.ca.gov/dataset/tre-altamira-insar-subsidence

Guidance

This statewide InSAR subsidence dataset was acquired as part of DWR's SGMA technical assistance to provide important SGMA relevant data to GSAs for GSP development and implementation. The dataset is formatted to support the production of maps and graphs that show the extent, cumulative total, and annual rate of land subsidence.

Interferometric Synthetic Aperture Radar (InSAR) is a satellite-based remote sensing technique that measures vertical ground surface displacement changes at high degrees of measurement resolution and spatial detail. TRE processed Sentinel-1A InSAR data over the study area between January 1, 2015 and September 19, 2019 and calibrating them to data from 232 stations of the regional network of Continuous Global Positioning System (CGPS) stations. TRE provided the resulting time series data of vertical displacement values for point

locations on a grid with 100 meter spacing, with values representing averages of vertical displacement measurements within the immediate 100 by 100 meter square areas of each point. Gaps in the spatial coverage of the point data are areas with insufficient data quality. The period of record for the point time series data varies by area, starting as early as January 1, 2015 and as late as June 13, 2015. TRE also provided 2 sets of GIS rasters; annual vertical displacement and total vertical displacement relative to the common start date of June 13, 2015, both in monthly time steps. An Inverse Distance Weighted (IDW) method with a maximum search radius of 500 meter was used to interpolate the rasters from the point data.

Towill Inc. (Towill), also under contract with DWR as part of DWR's SGMA technical assistance, conducted an independent study comparing the InSAR-based vertical displacement point time series data to data from 160 CGPS stations that were not used for calibrating the InSAR data, as well as 21 CGPS stations that were used for calibrating InSAR data in Northern California. The goal of this study was to ground-truth the InSAR results to best available independent data.

The National Standard for Spatial Data Accuracy (NSSDA), developed by the Federal Geographic Data Committee (Document Number FGDC-STD-007.3-1998), offers a well-defined statistic and testing methodology for positional accuracy of geospatial data derived from various surveying methods including satellite remote sensing. The NSSDA is based on comparison of data from the tested dataset to values from an independent source of higher accuracy. For this study, variation in vertical displacement of California's ground surface over time, as measured from interferometric synthetic aperture radar (InSAR) satellites, was statistically compared to available ground based continuous global positioning systems (CGPS) data.

Tested: 16 mm vertical accuracy at 95% confidence level.

As tested by the processes described, this analysis provides statistical evidence that InSAR data accurately measured vertical displacement in California's ground surface to within 16 mm for the period January 1, 2015 through September 19, 2019. This statement of accuracy is based on the assumptions that the number, distribution, and characteristics of CGPS check point locations provide a representative sample of the entire study area and of the entire InSAR dataset, and that the CGPS data constitutes an independent source of higher accuracy. This statement of accuracy applies to the state-wide dataset and may vary for regional or localized area subsets.

The Department of Water Resources makes no warranties, representations or guarantees, either expressed or implied, as to the accuracy, completeness,

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