JANUARY 2022

EAST BAY PLAIN SUBBASIN GROUNDWATER SUSTAINABILITY PLAN APPENDIX 3

PREPARED FOR

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APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

Appendix 3.A. Supporting Data for Groundwater Level SMC

Appendix 3.B. Supporting Data for Groundwater Storage SMC

Appendix 3.C. Supporting Data for Seawater Intrusion SMC

Appendix 3.D. Supporting Data for Land Subsidence SMC

Appendix 3.E. Supporting Data for Groundwater Quality SMC

Appendix 3.F. Supporting Data for Stream Depletion SMC

Appendix 3.G. Supplemental Monitoring Network

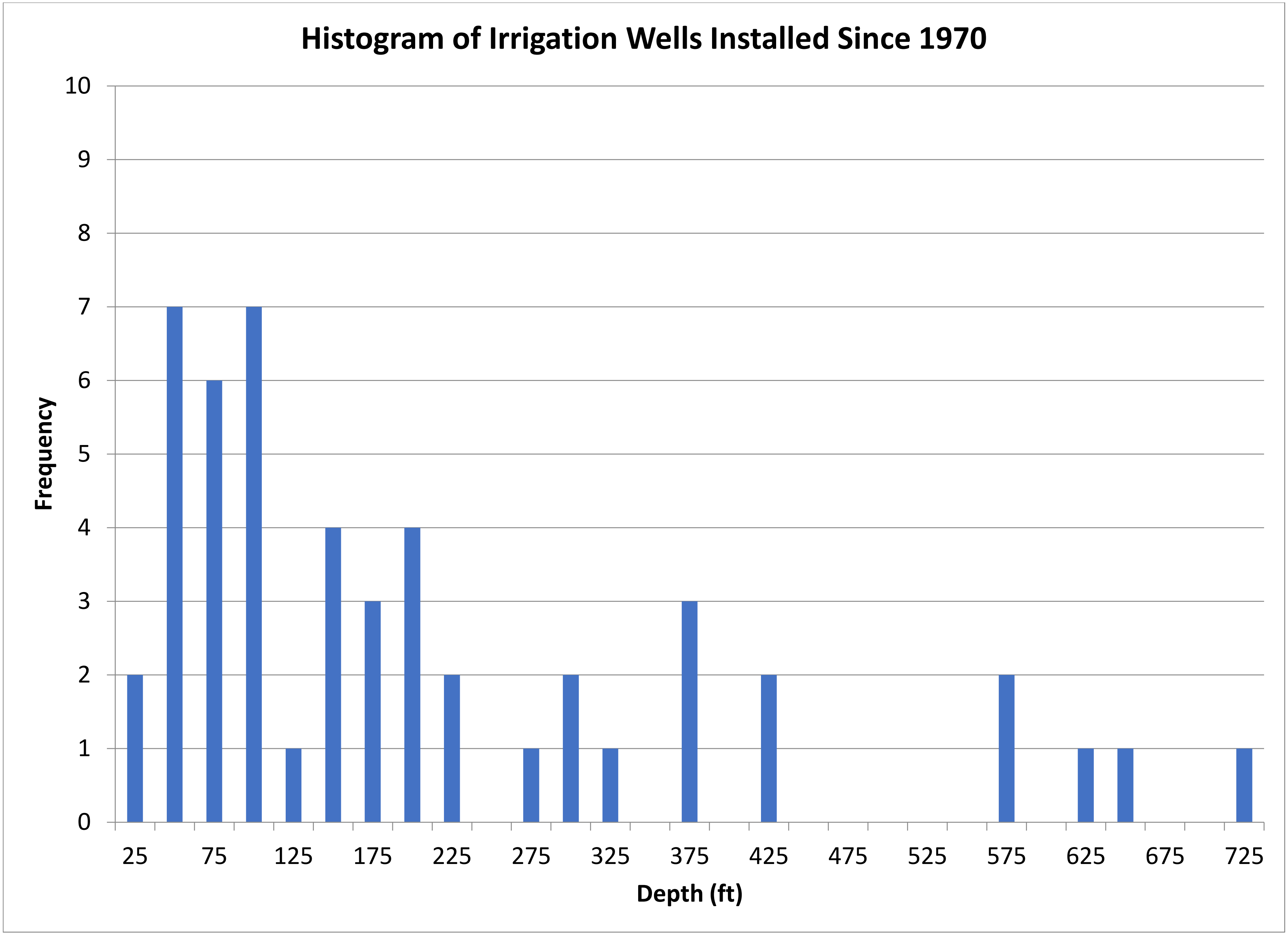
APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

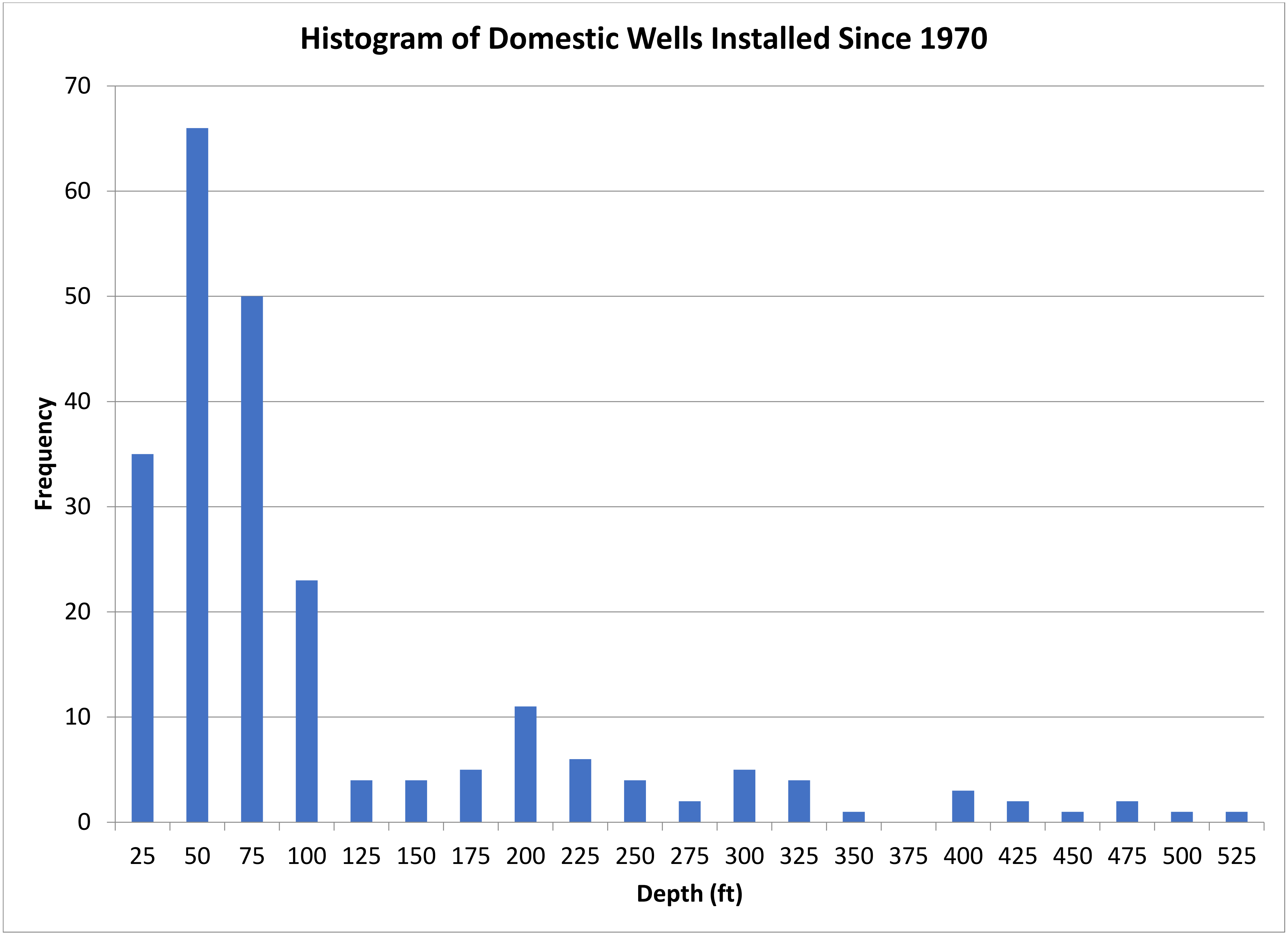
3.A. Supporting Data for Groundwater Level SMC

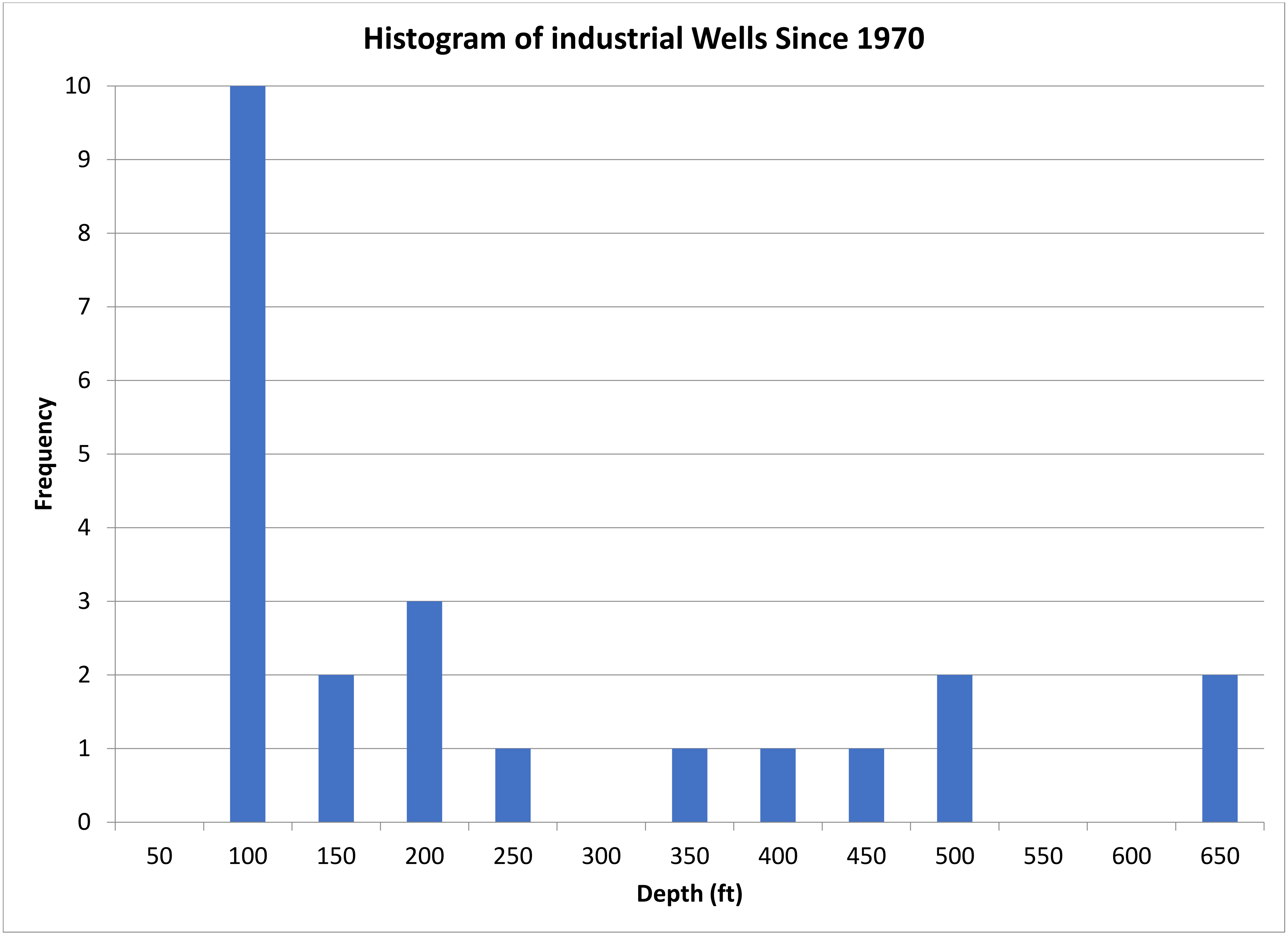
APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.A. Supporting Data for Groundwater Level SMC

3.A.a DWR Well Completion Report Database Summary


Histogram of Irrigation Wells Installed Since 1970
Frequency
0
1
2
3
4
5
6
7
8
9
10
25
75
125
175
225
275
325
375
425
475
525
575
625
675
725
Depth (ft)


Histogram of Domestic Wells Installed Since 1970
Frequency
0
10
20
30
40
50
60
70
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
525
Depth (ft)


Histogram of industrial Wells Since 1970
Frequency
0
1
2
3
4
5
6
7
8
9
10
50
100
150
200
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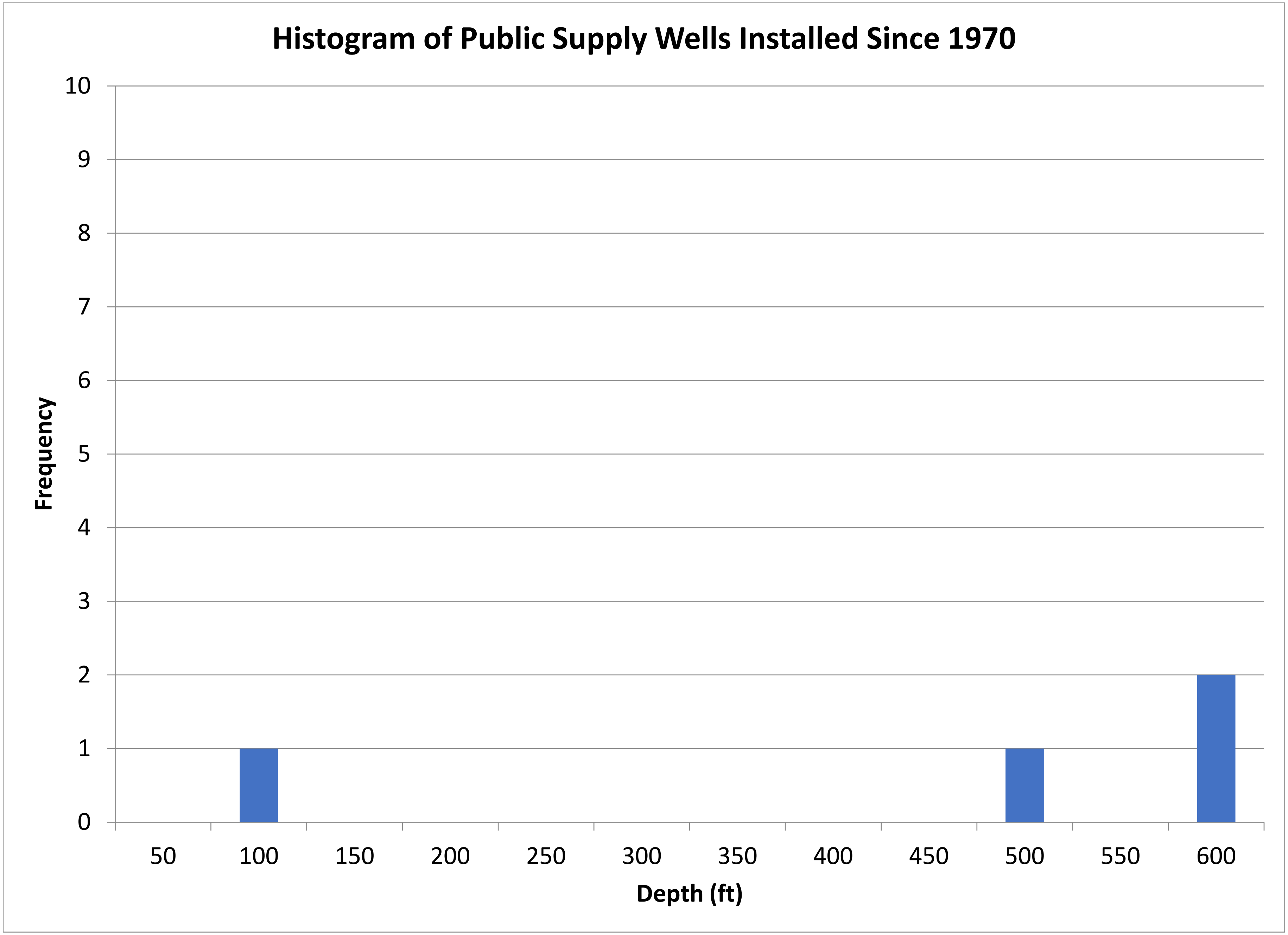
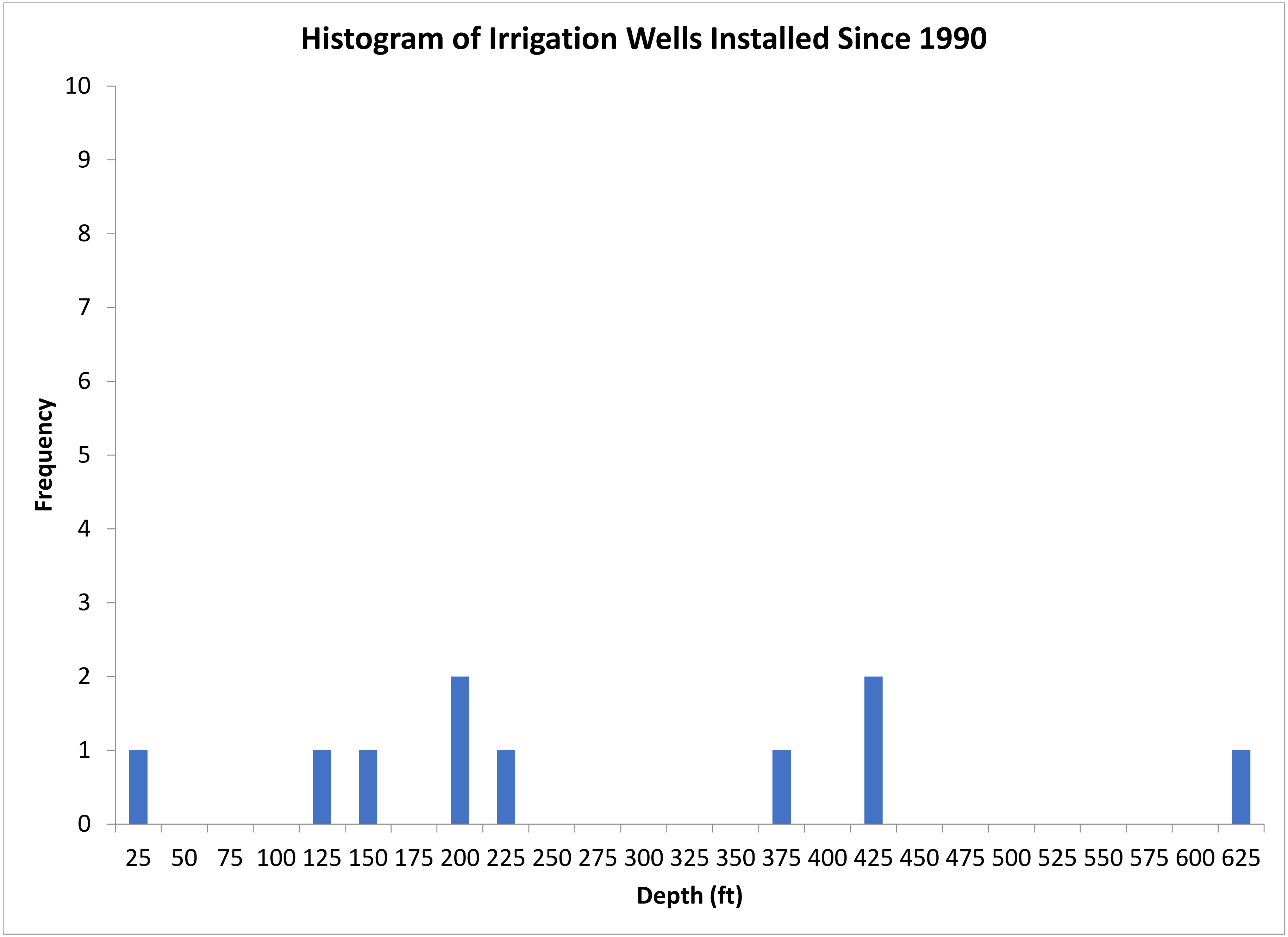
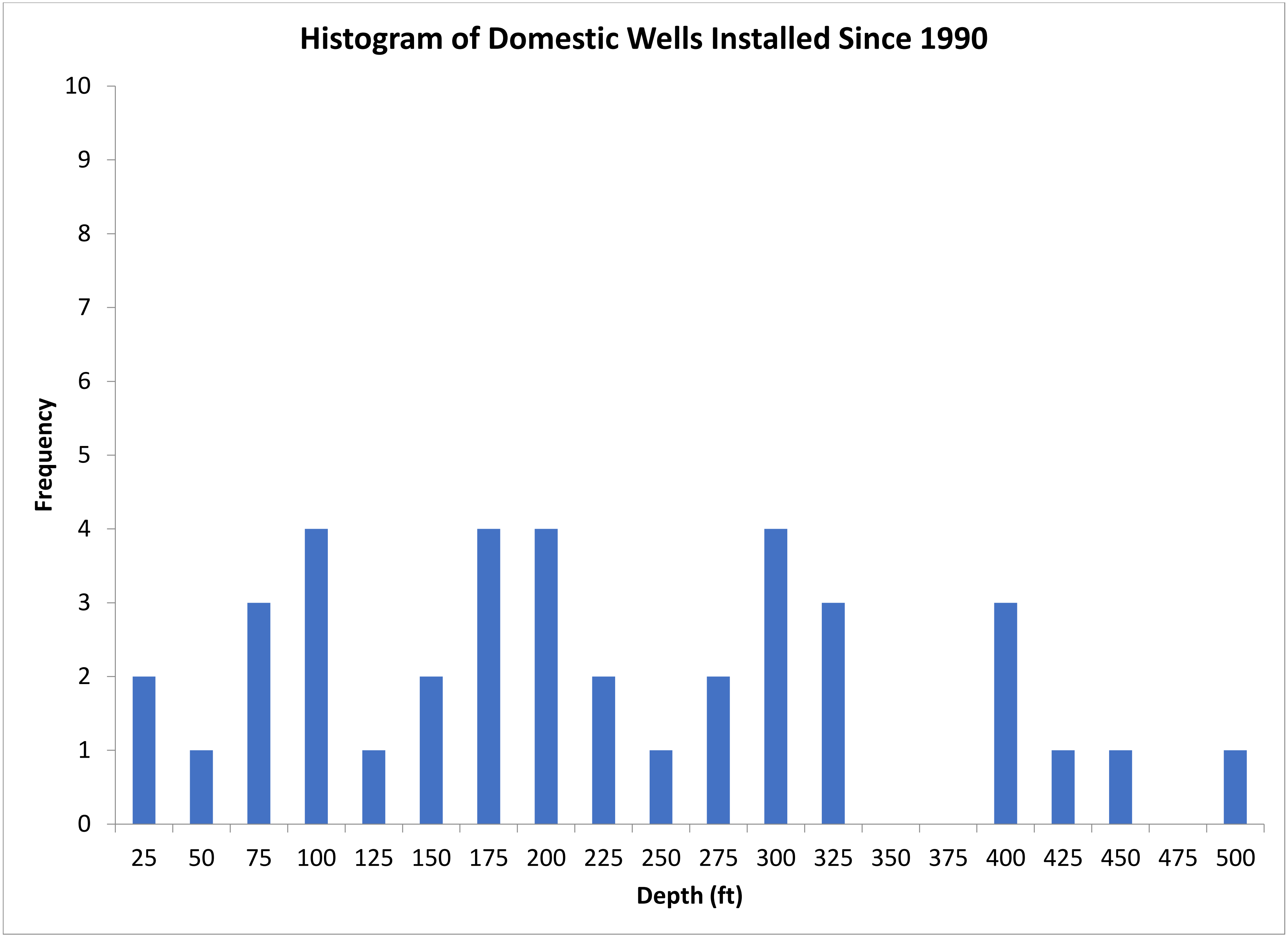
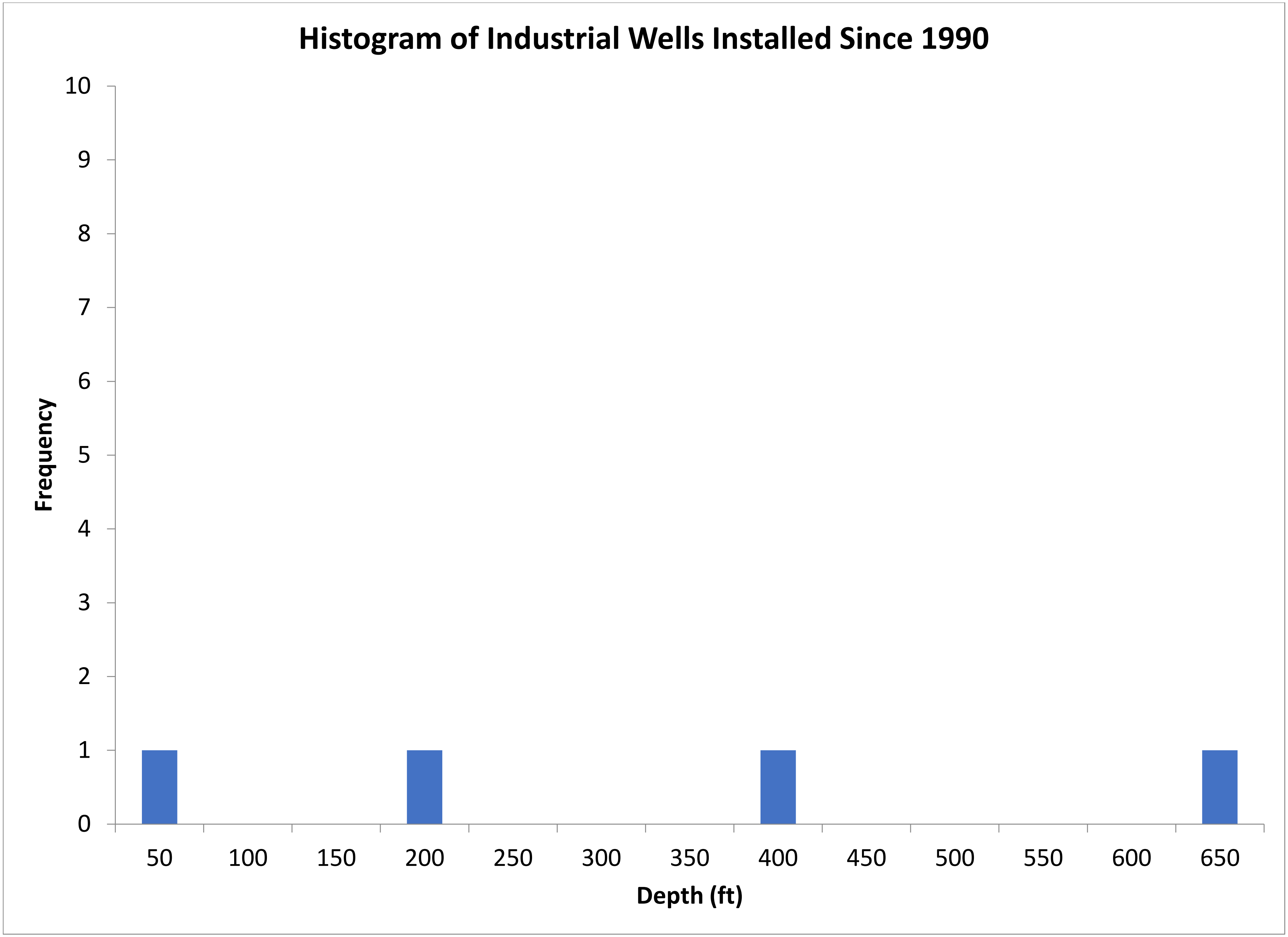
300
350
400
450
500
550
600
650
Depth (ft)


Histogram of Public Supply Wells Installed Since 1970
Frequency
0
1
2
3
4
5
6
7
8
9
10
50
100
150
200
250
300
350
400
450
500
550
600
Depth (ft)

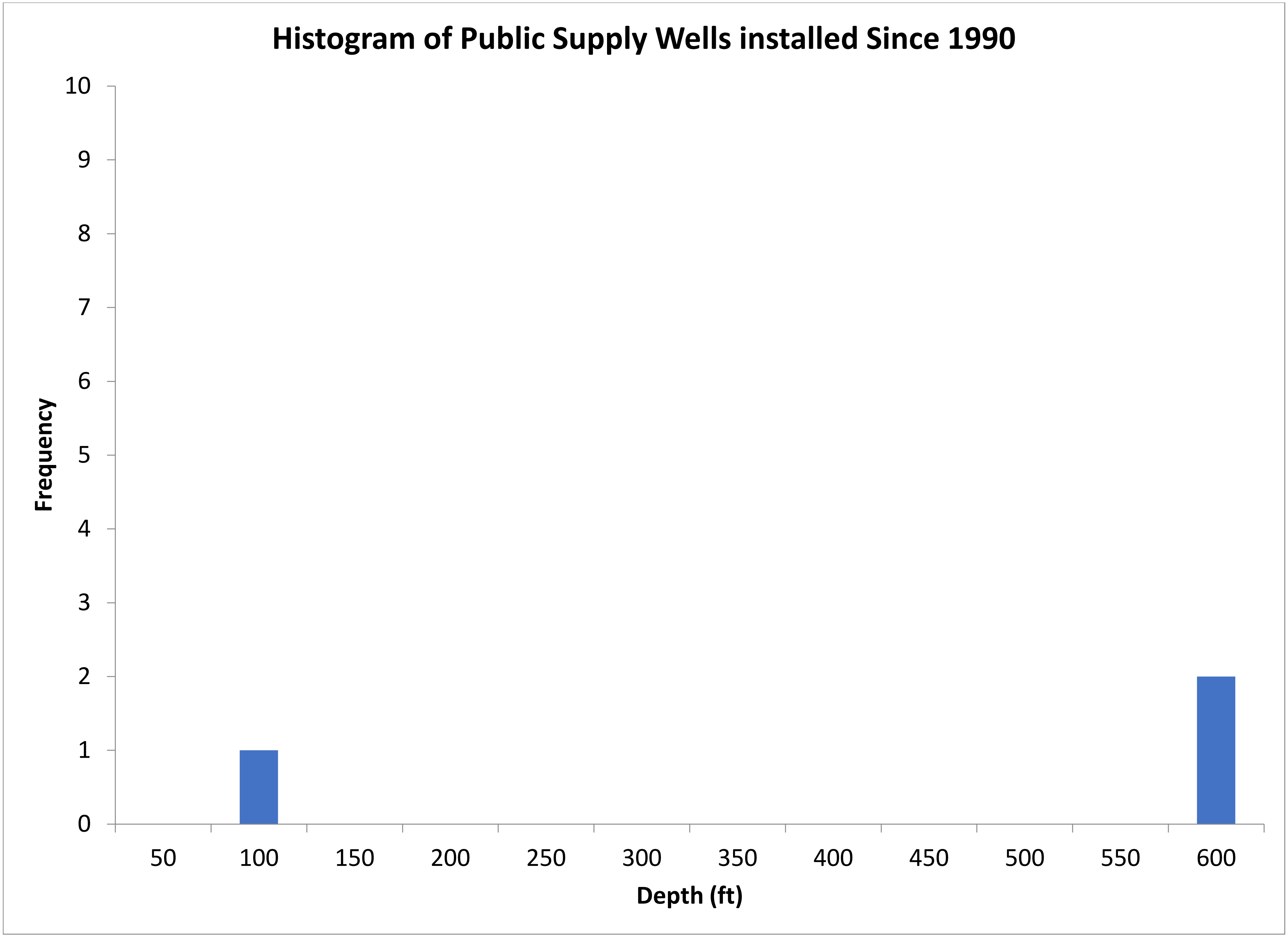


Histogram of Irrigation Wells Installed Since 1990
Frequency
0
1
2
3
4
5
6
7
8
9
10
25 50 75 100 125 150 175 200 225 250 275 300 325 350 375 400 425 450 475 500 525 550 575 600 625
Depth (ft)


Histogram of Domestic Wells Installed Since 1990
Frequency
0
1
2
3
4
5
6
7
8
9
10
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
Depth (ft)



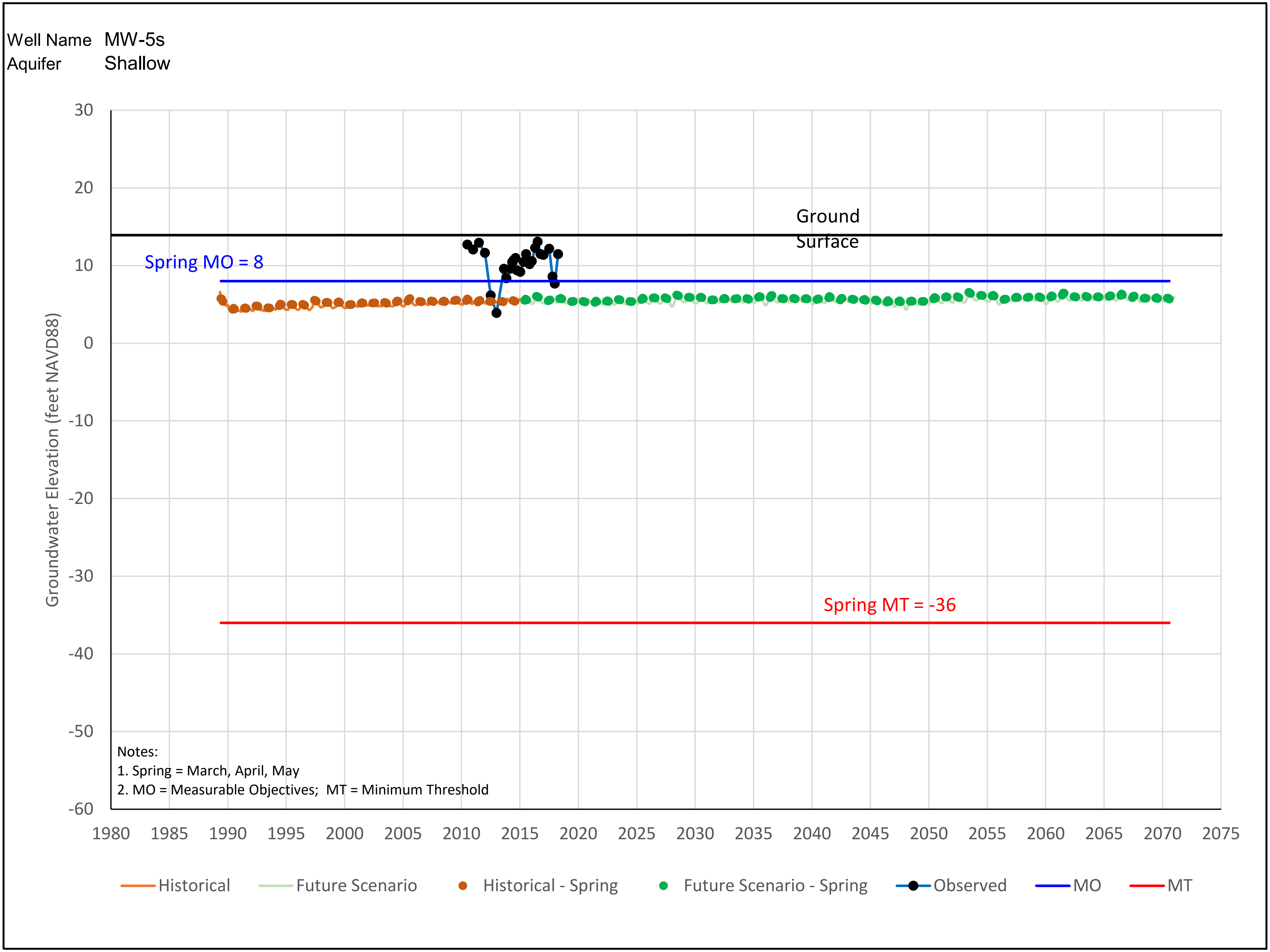
Histogram of Industrial Wells Installed Since 1990
10
9
8
7
6
5
4
3
2
1
0
Frequency
50
100
150
200
250
300
350
400
450
500
550
600
650
Depth (ft)

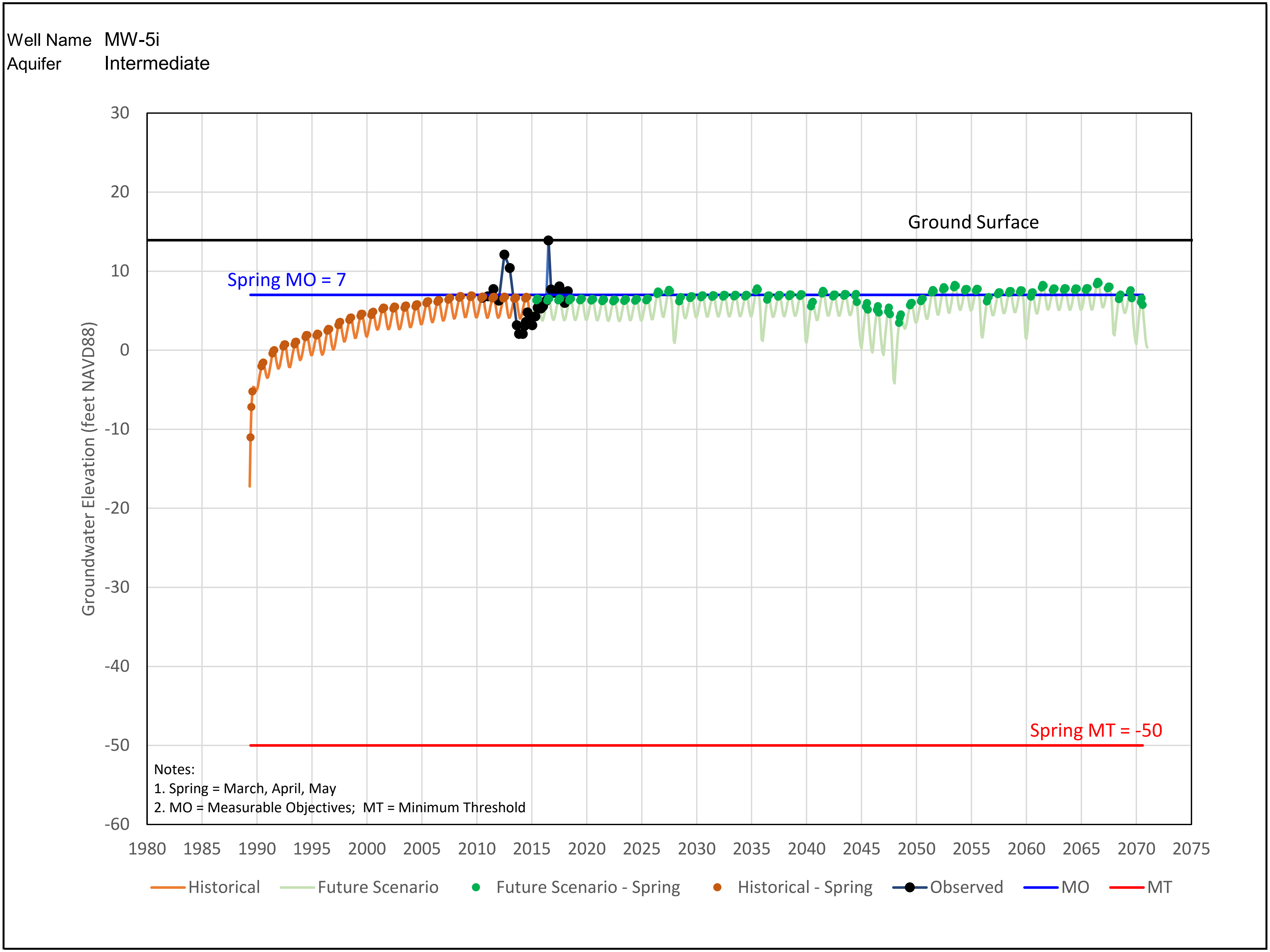

Histogram of Public Supply Wells installed Since 1990
Frequency
0
1
2
3
4
5
6
7
8
9
10
50
100
150
200
250
300
350
400
450
500
550
600
Depth (ft)

APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.A. Supporting Data for Groundwater Level SMC

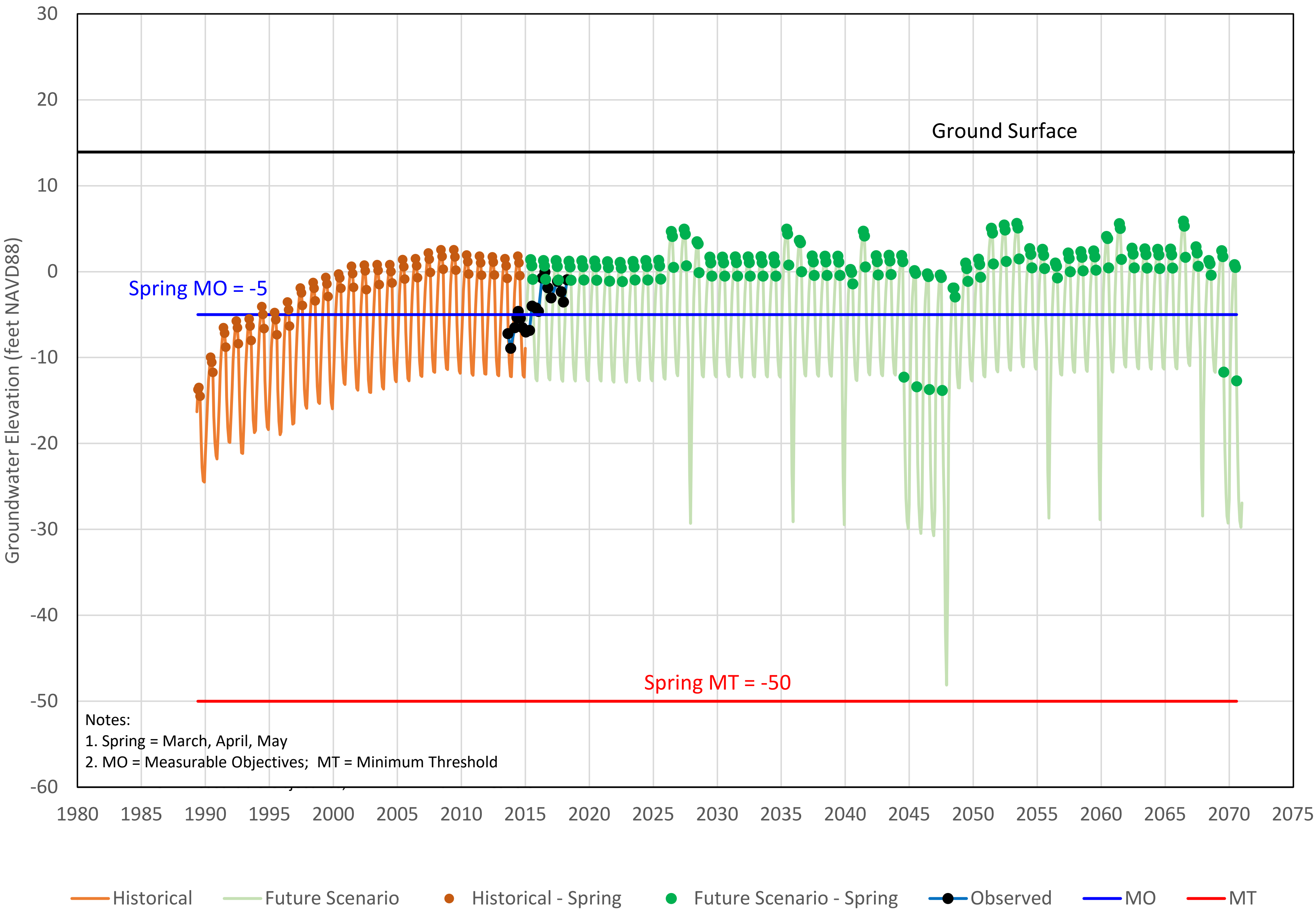
3.A.b Groundwater Level Hydrographs With MT/MO

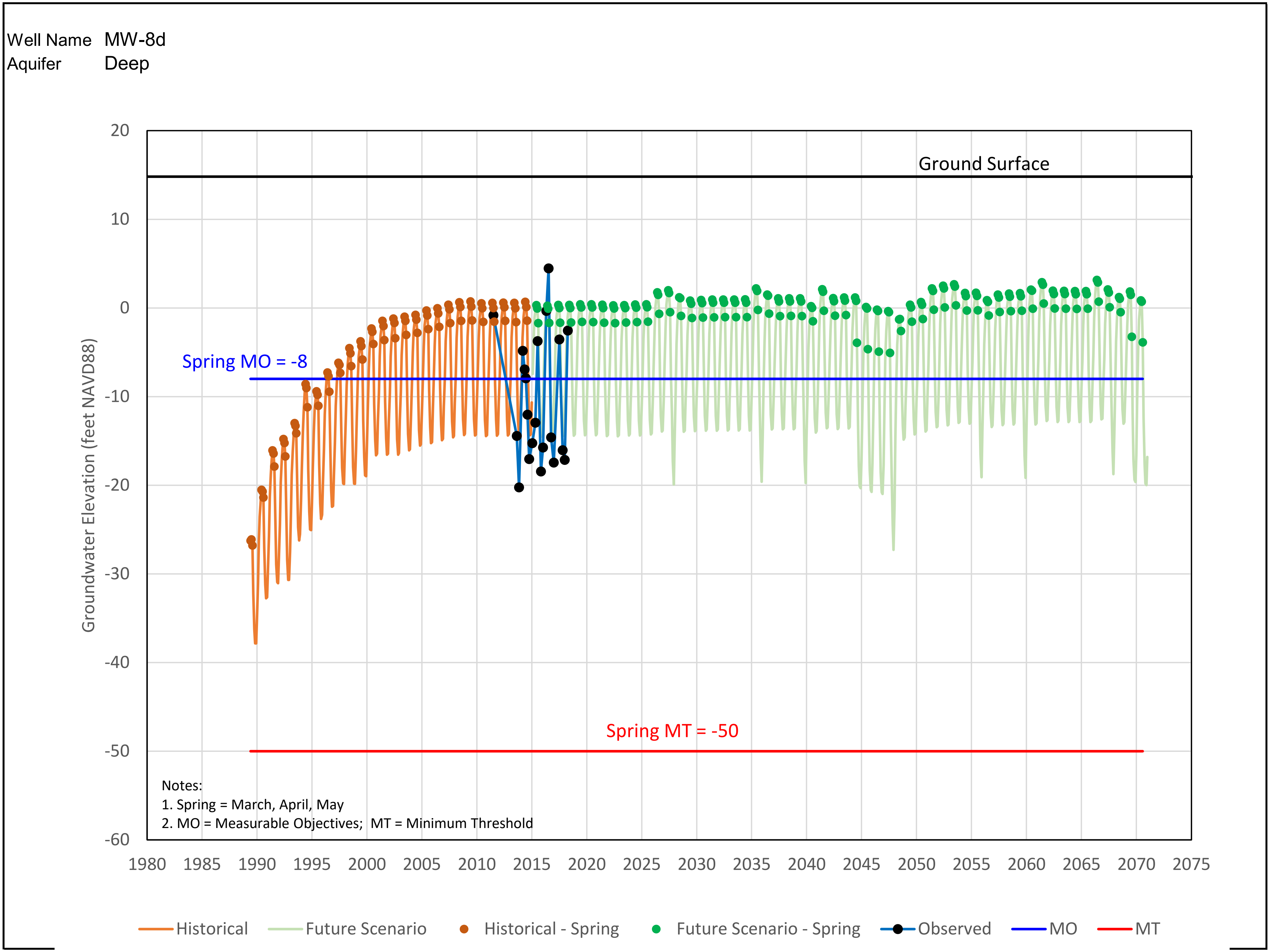

Well Name MW-5s
Aquifer Shallow
Ground Surface
Spring MO = 8
Spring MT = -36
Groundwater Elevation (feet NAVD88)
30
20
10
0
-10
-20
-30
-40
-50
-60
1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
Observed
MO
MT



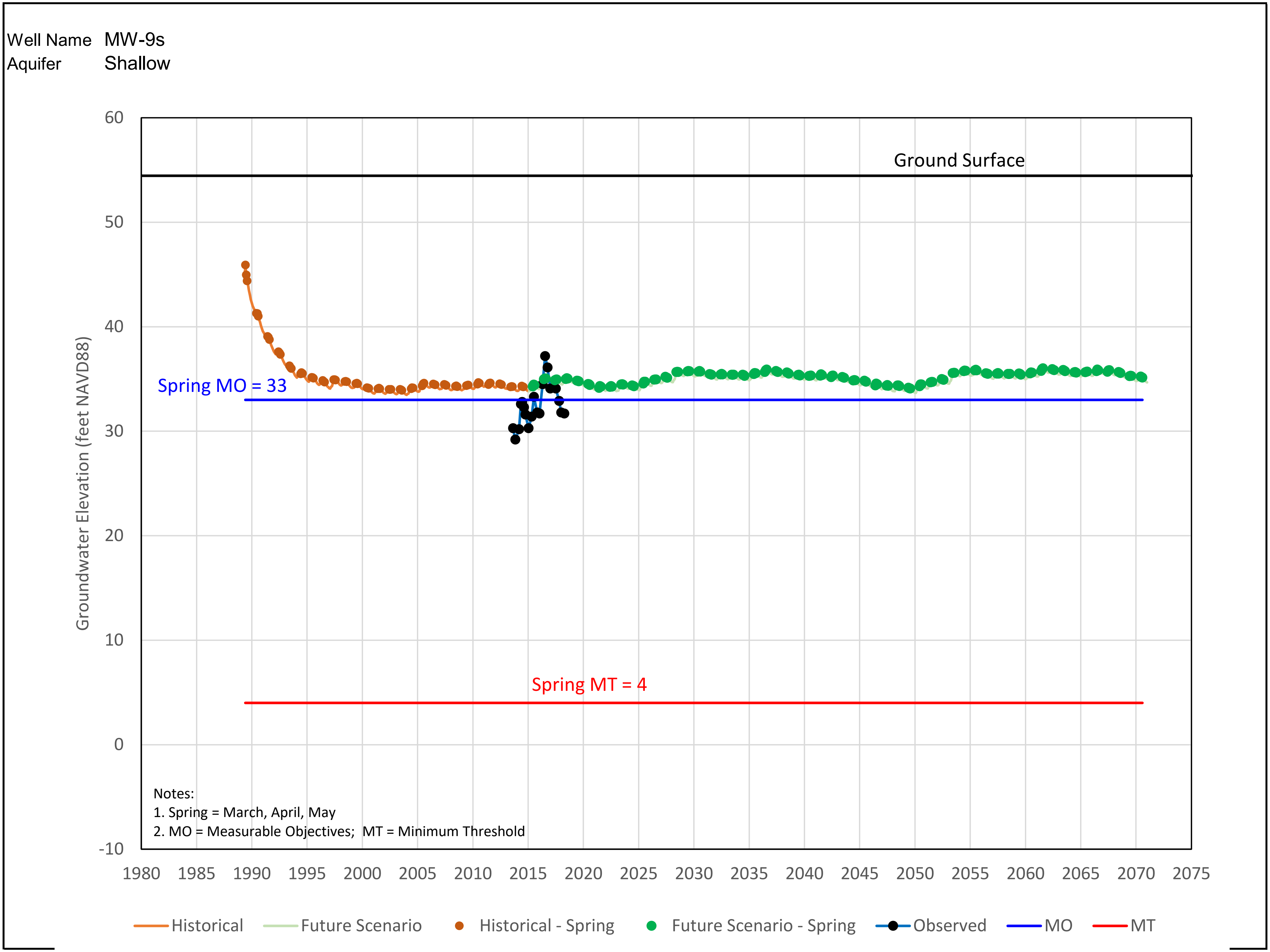
Well Name MW-5i
Aquifer Intermediate
Ground Surface
Spring MO = 7
Spring MT = -50
Groundwater Elevation (feet NAVD88)
30
20
10
0
-10
-20
-30
-40
-50
-60
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Future Scenario - Spring
Historical - Spring
Observed
MO
MT

Well Name MW-5d
Aquifer Deep



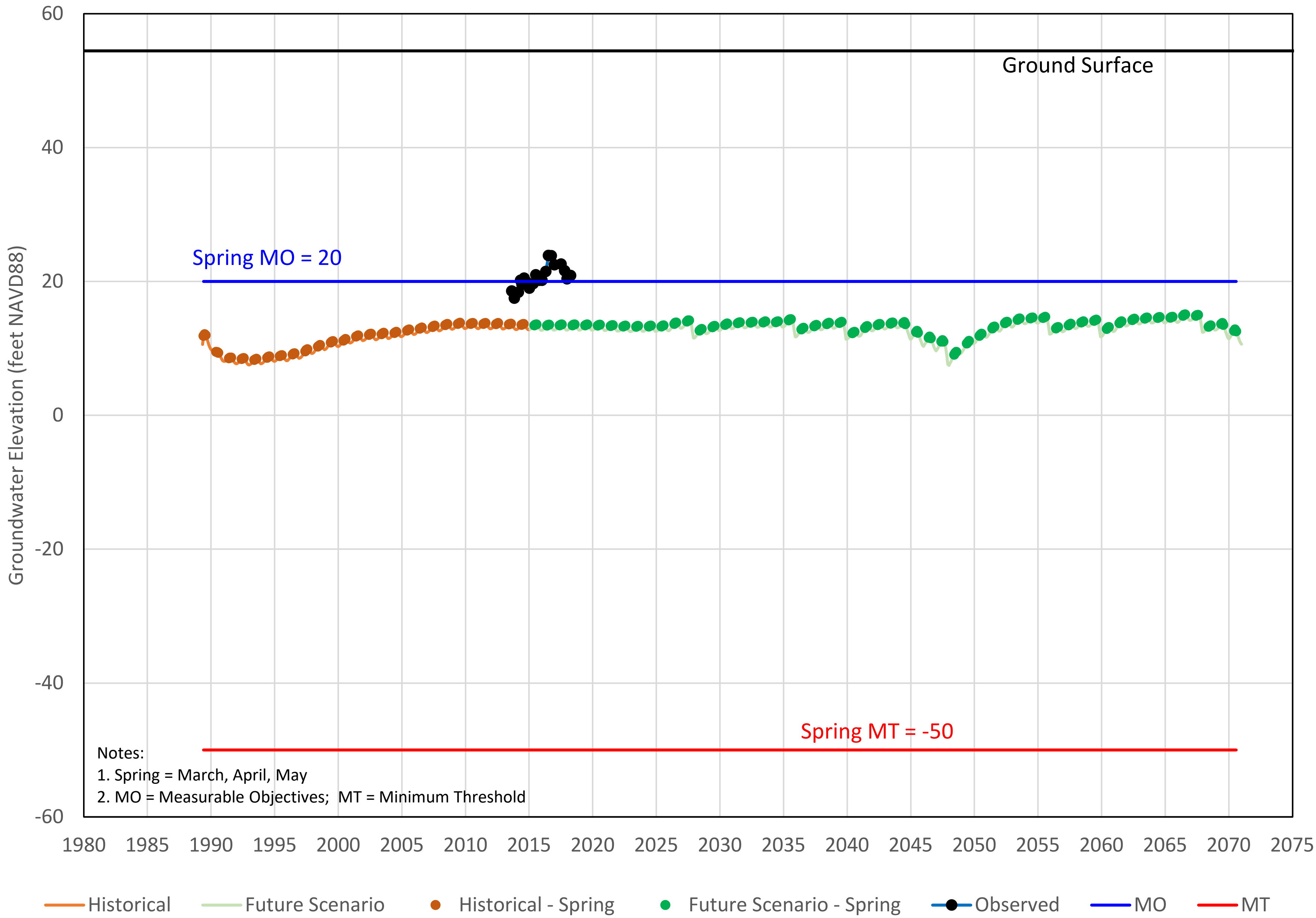


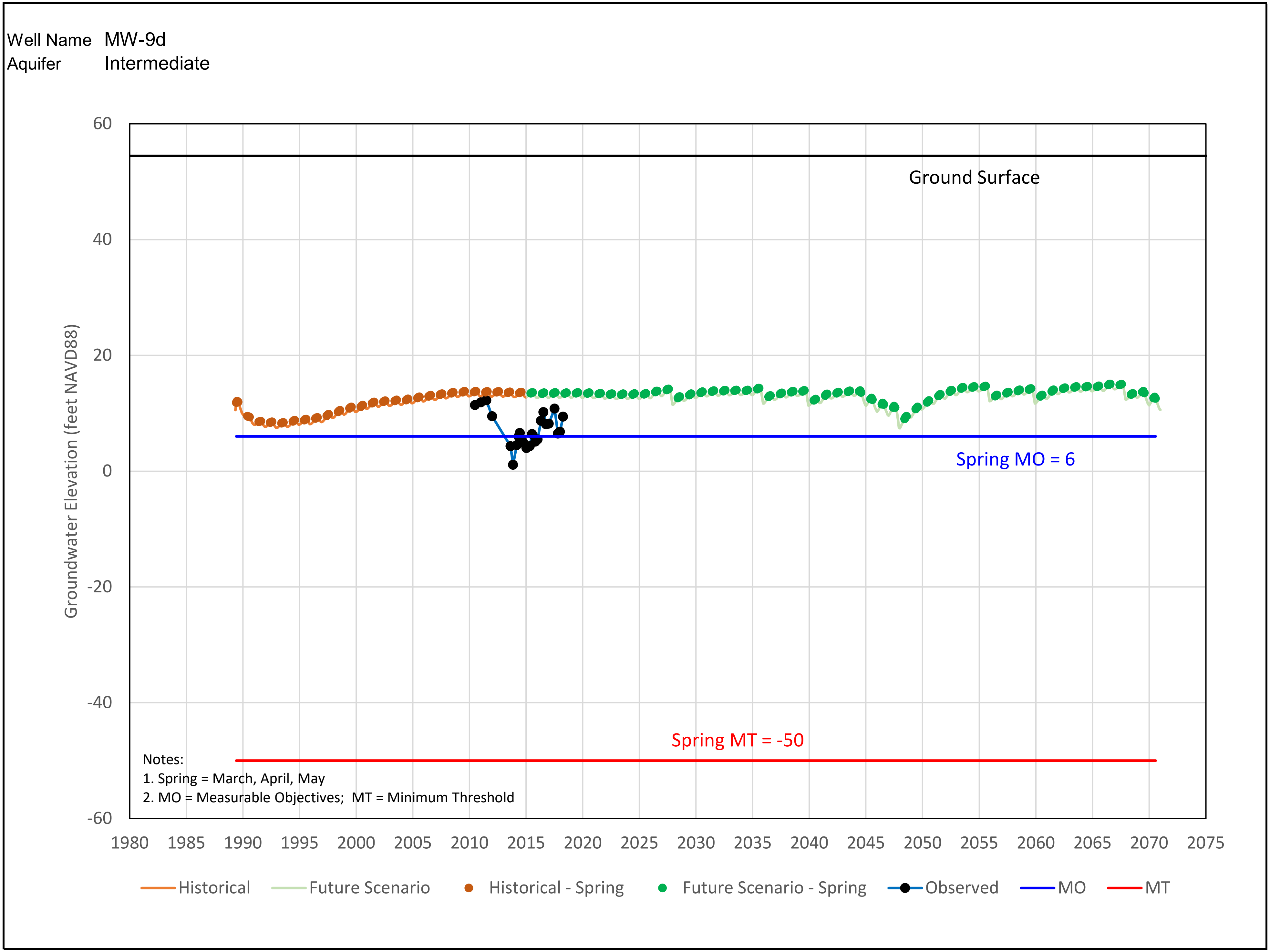
Well Name MW-8d
Aquifer Deep
Ground Surface
Spring MO = -8
Spring MT = -50
Groundwater Elevation (feet NAVD88)
20
10
0
-10
-20
-30
-40
-50
-60
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
Observed
MO
MT



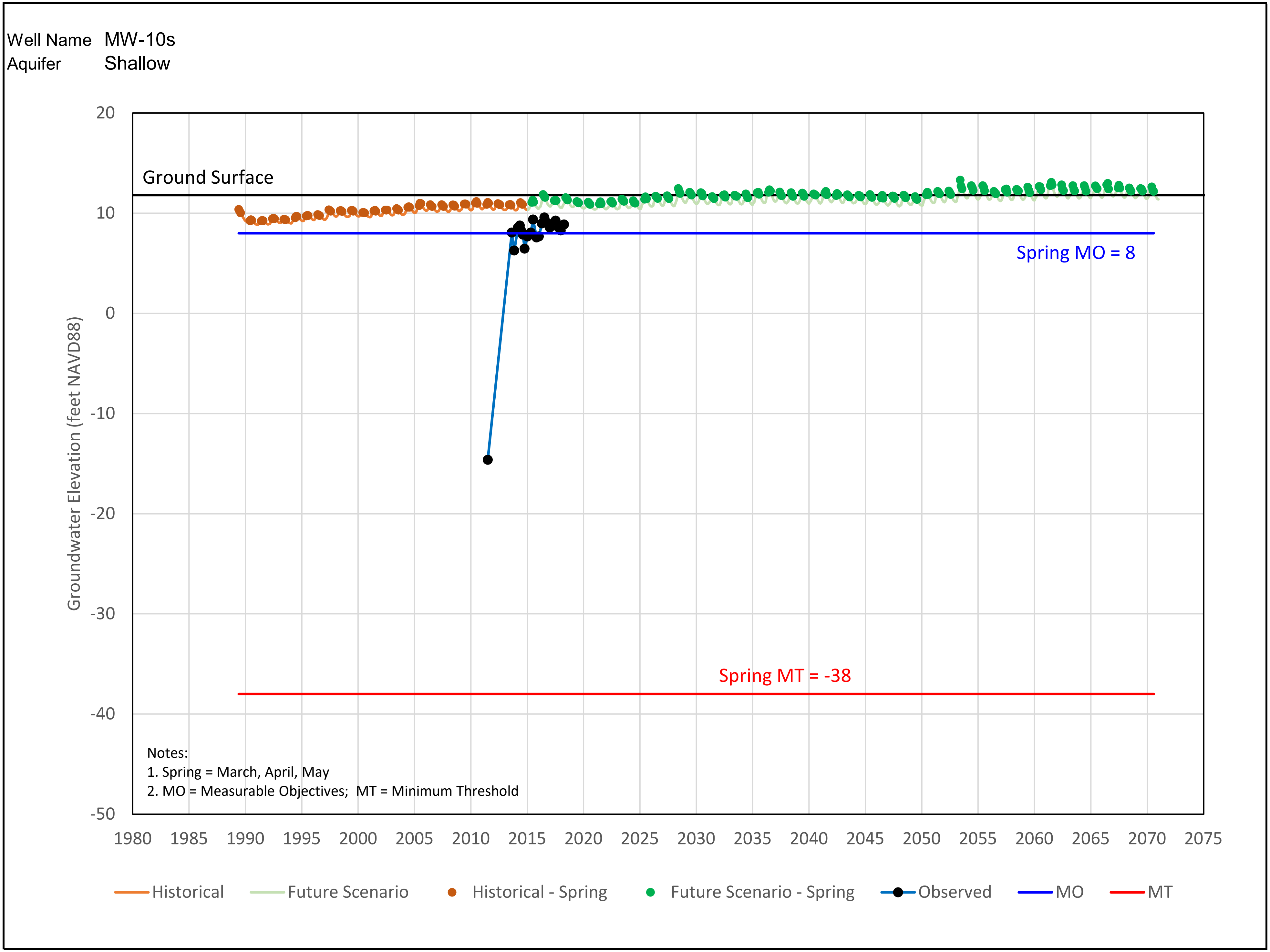
Well Name MW-9s
Aquifer Shallow
Ground Surface
Spring MO = 33
Spring MT = 4
Groundwater Elevation (feet NAVD88)
60
50
40
30
20
10
0
-10
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
Observed
MO
MT

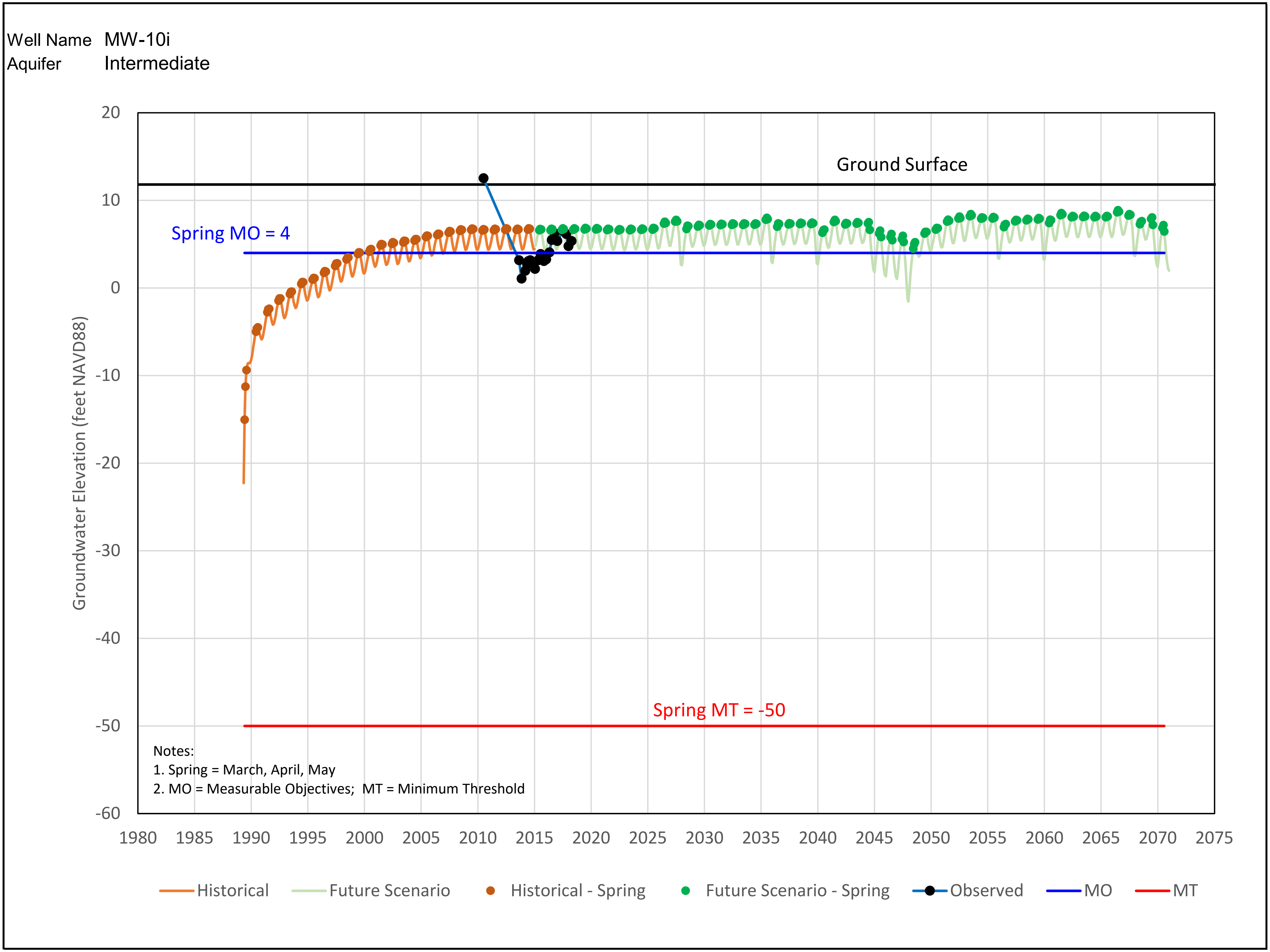
Well Name MW-9i
Aquifer Intermediate

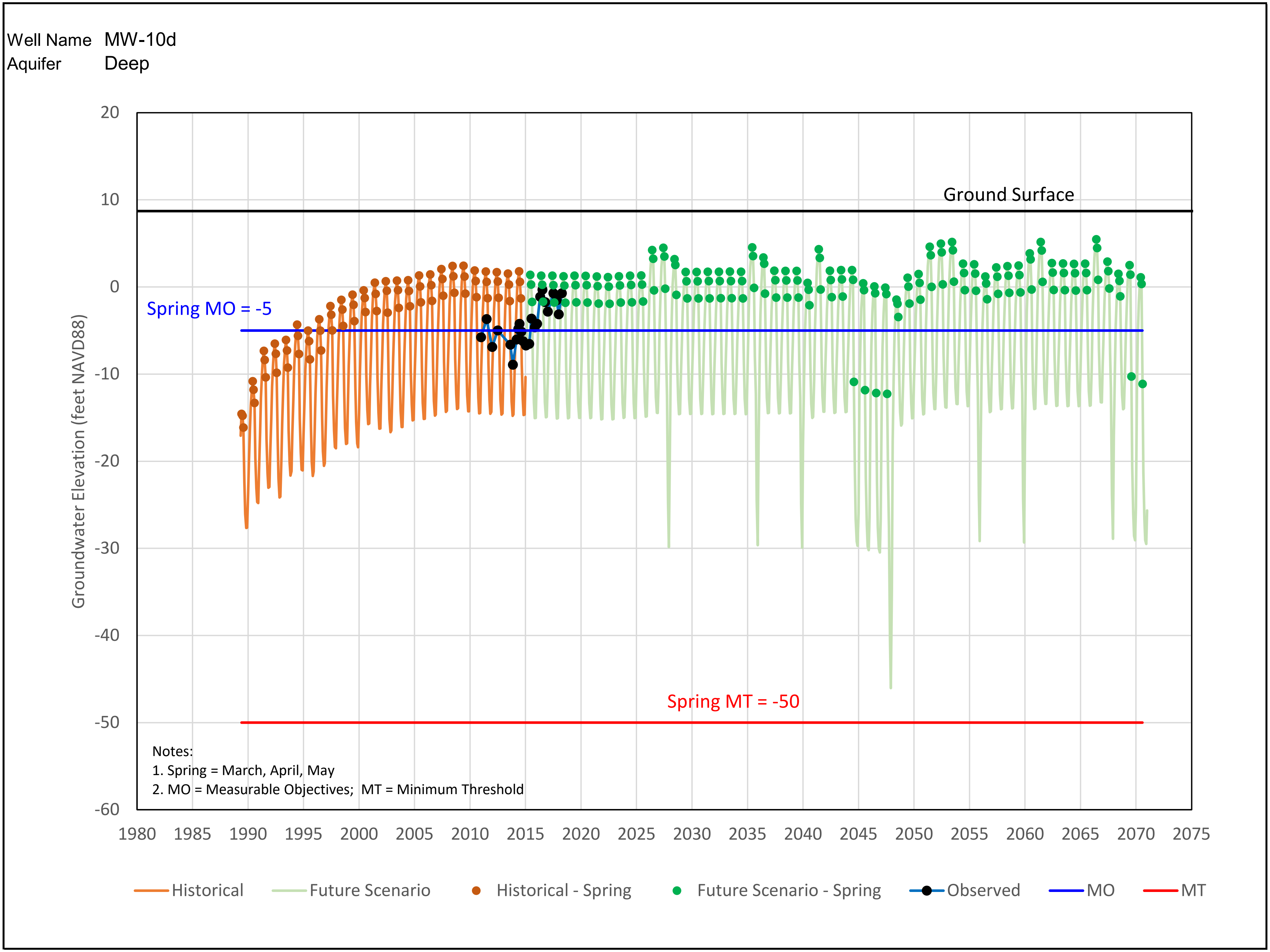




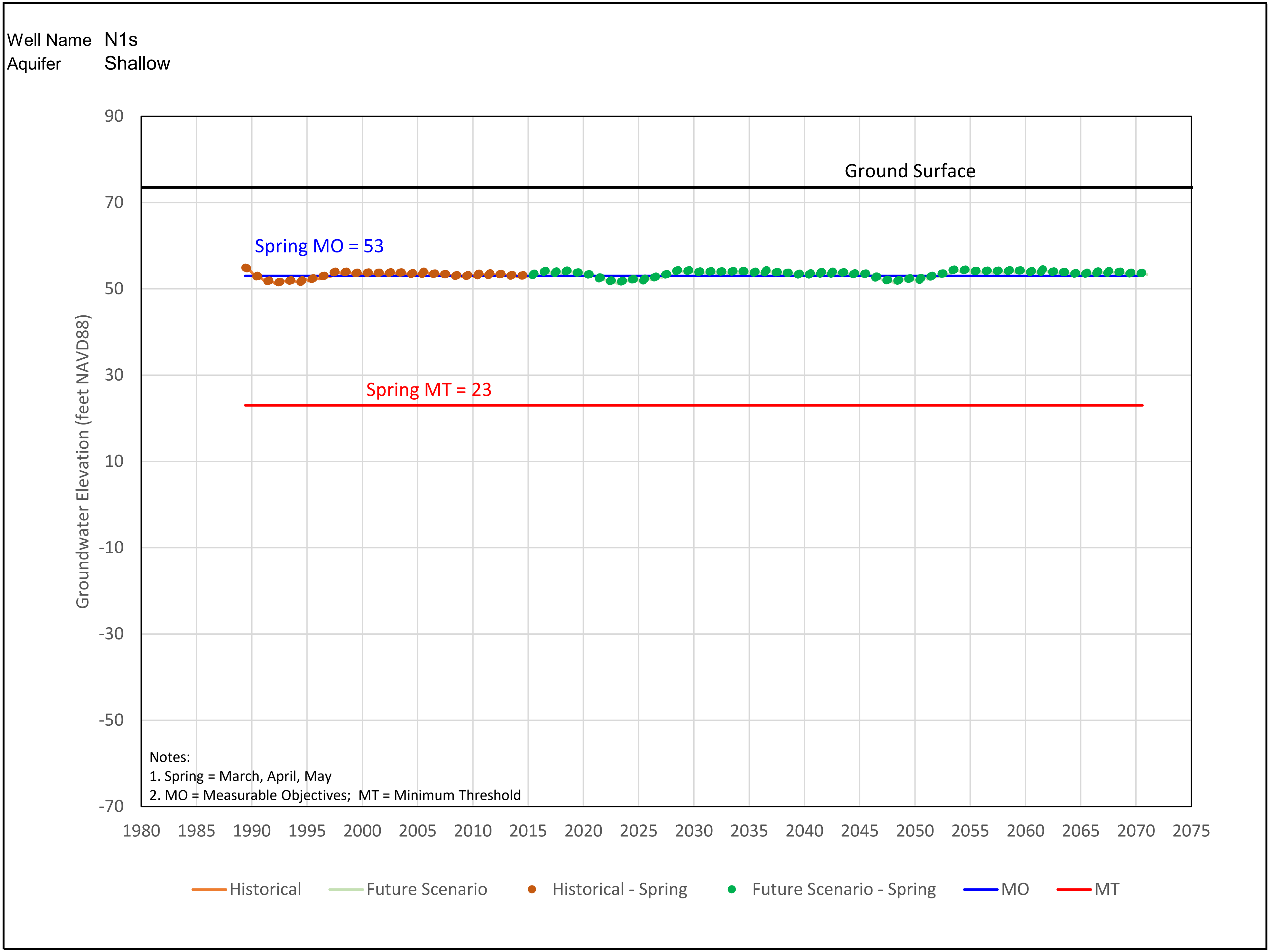
Well Name MW-9d
Aquifer Intermediate
Ground Surface
Spring MO = 6
Spring MT = -50
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Groundwater Elevation (feet NAVD88)
60
40
20
0
-20
-40
-60
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
Observed
MO
MT

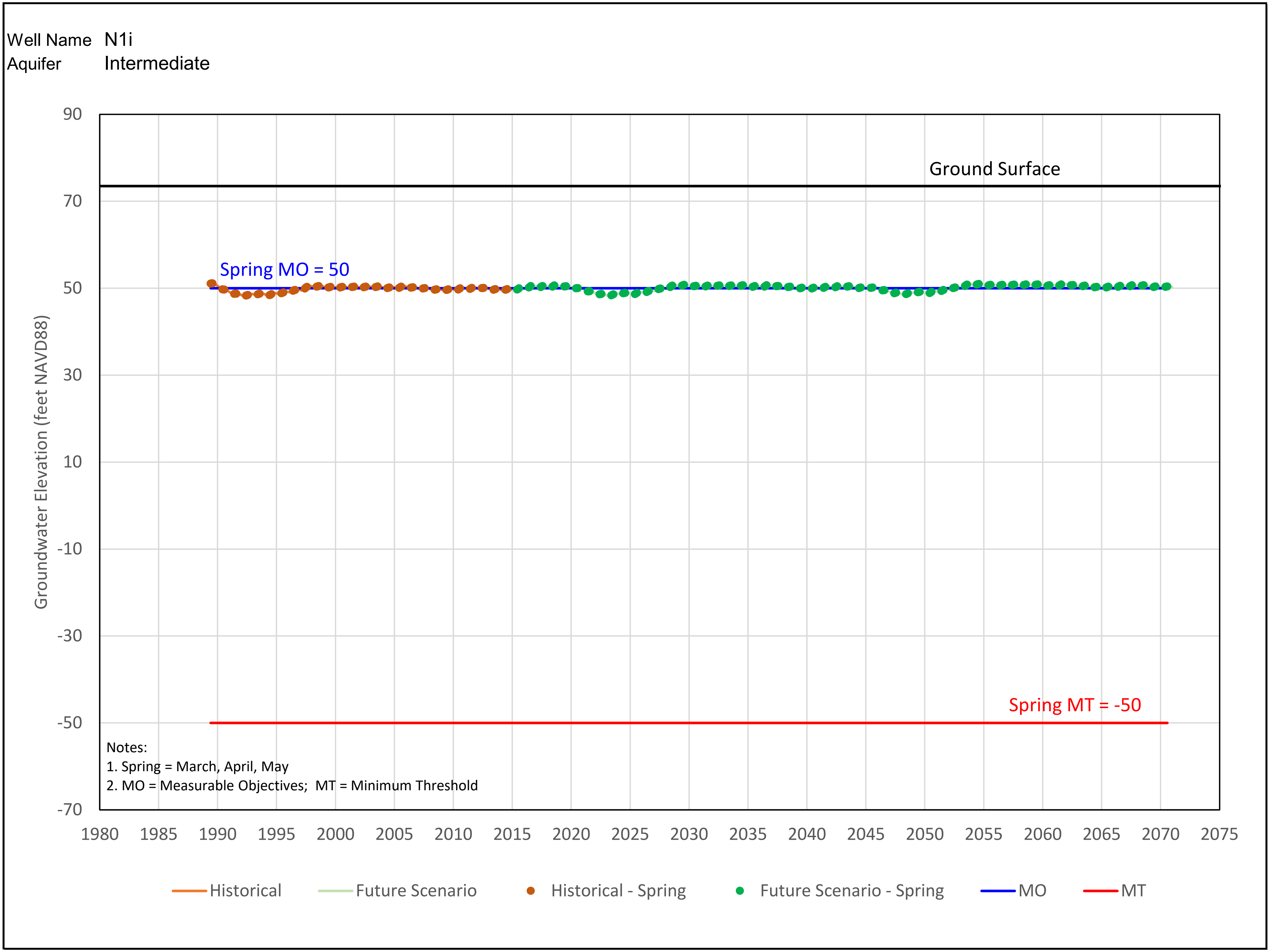

Well Name MW-10s
Aquifer Shallow
Ground Surface
Spring MO = 8
Spring MT = -38
Groundwater Elevation (feet NAVD88)
20
10
0
-10
-20
-30
-40
-50
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
Observed
MO
MT

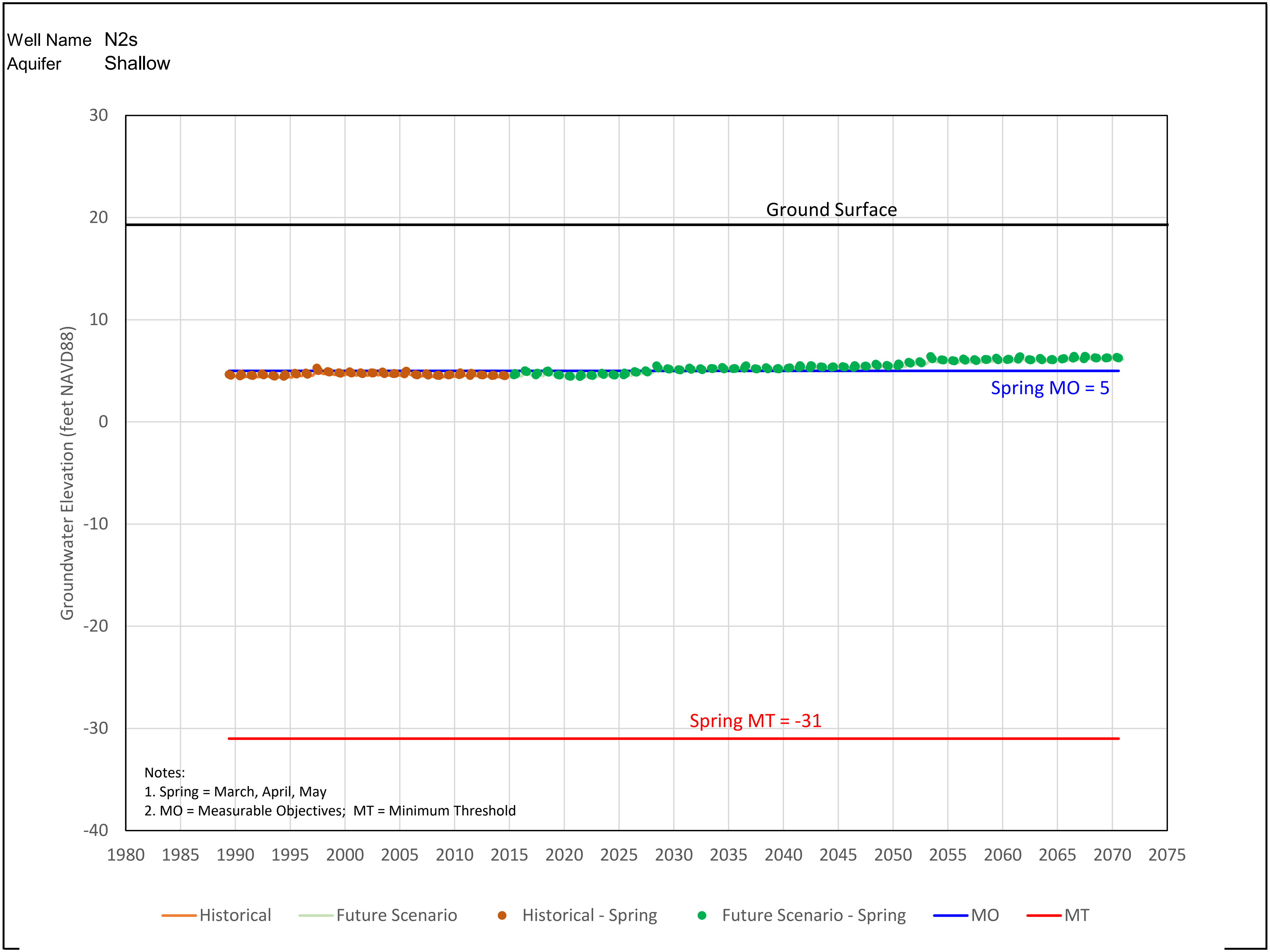

Well Name MW-10i
Aquifer Intermediate
Ground Surface
Spring MO = 4
Spring MT = -50
Groundwater Elevation (feet NAVD88)
20
10
0
-10
-20
-30
-40
-50
-60
1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
Observed
MO
MT



Well Name MW-10d
Aquifer Deep
Ground Surface
Spring MO = -5
Spring MT = -50
Groundwater Elevation (feet NAVD88)
20
10
0
-10
-20
-30
-40
-50
-60
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
Observed
MO
MT

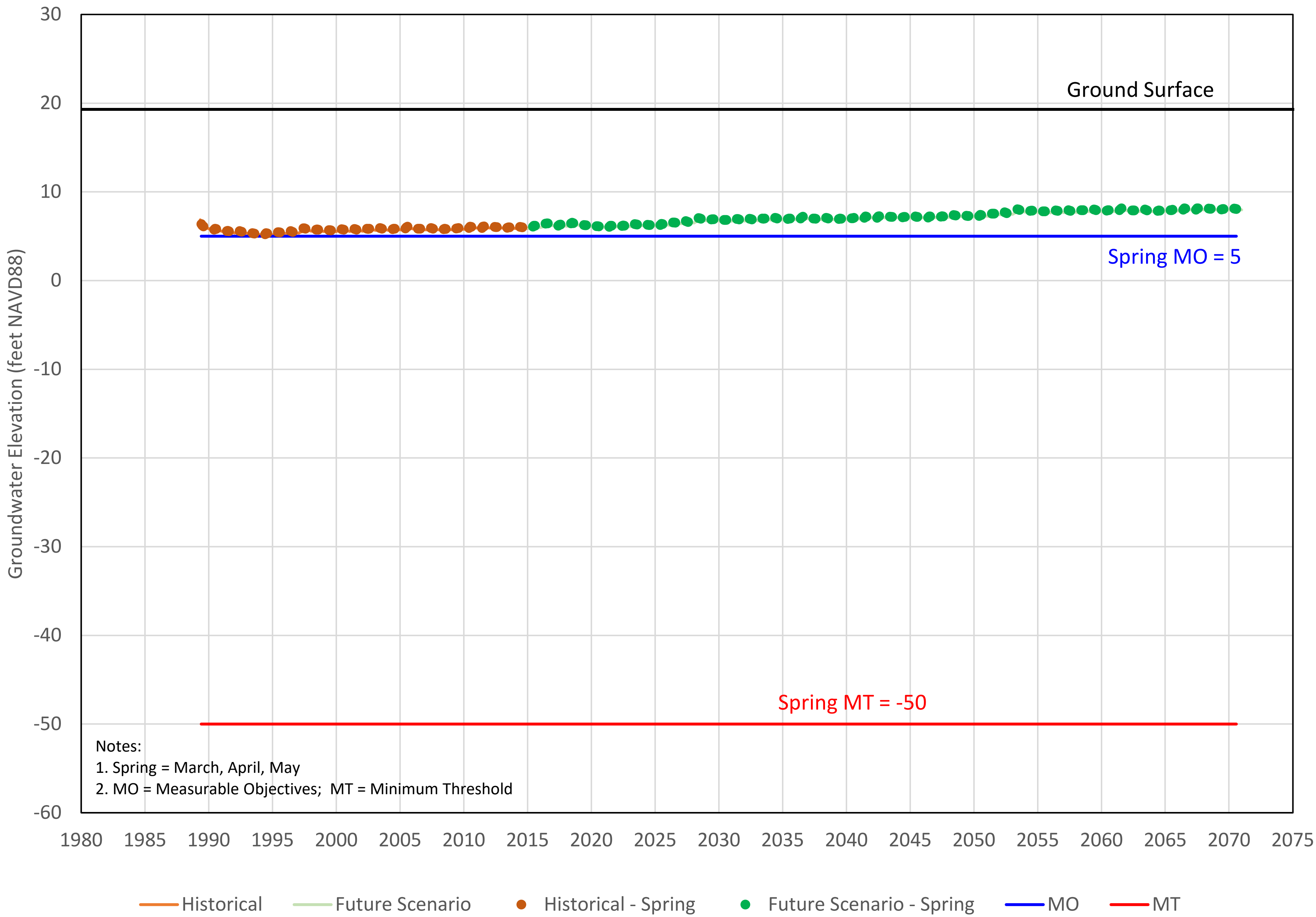

Well Name N1s
Aquifer Shallow
Ground Surface
Spring MO = 53
Spring MT = 23
Groundwater Elevation (feet NAVD88)
90
70
50
30
10
-10
-30
-50
-70
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
MO
MT


Well Name N1i
Aquifer Intermediate
Ground Surface
Spring MO = 50
Spring MT = -50
Groundwater Elevation (feet NAVD88)
90
70
50
30
10
-10
-30
-50
-70
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
MO
MT

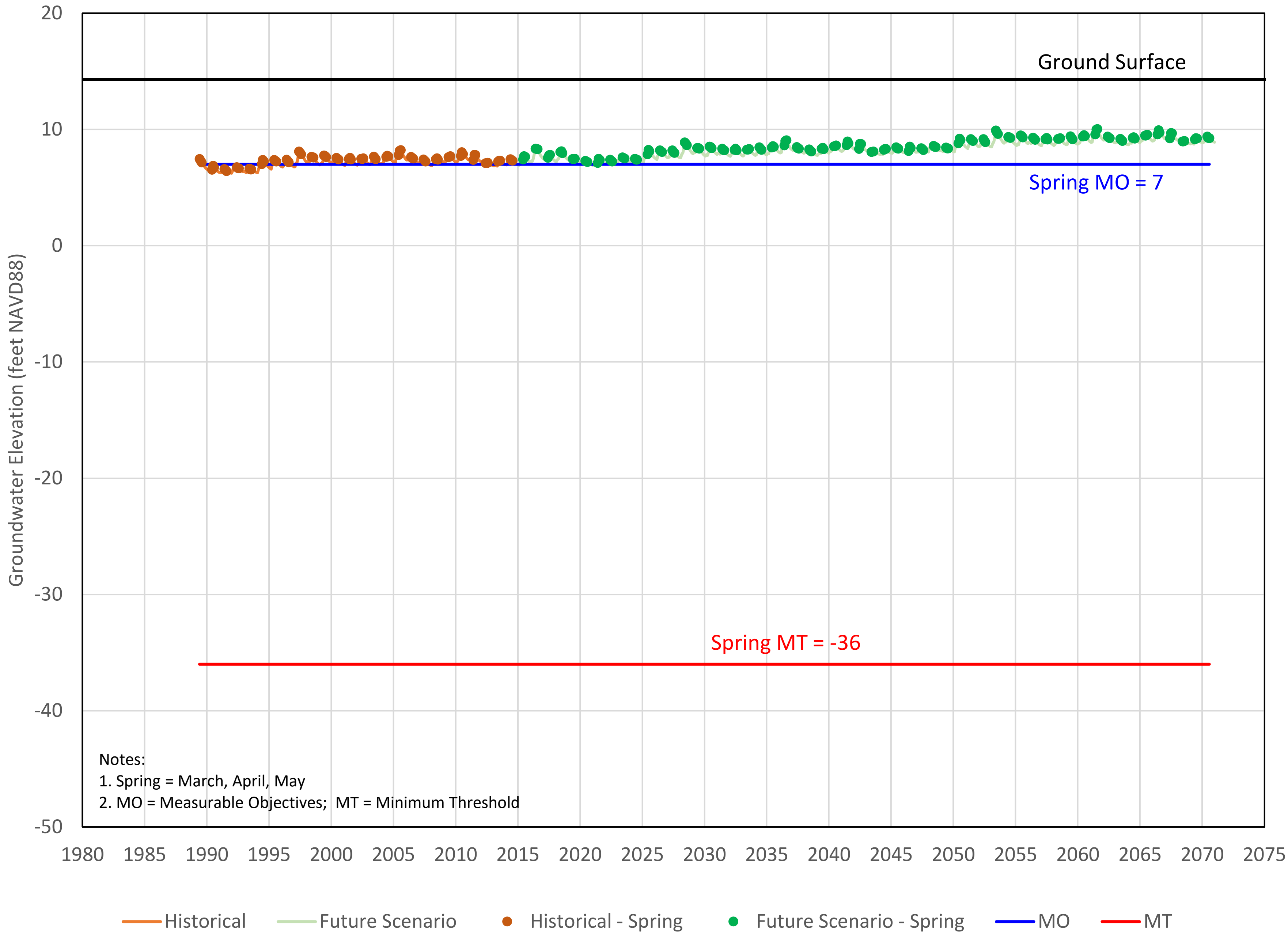


Well Name N2s
Aquifer Shallow
Ground Surface
Spring MO = 5
Spring MT = -31
Groundwater Elevation (feet NAVD88)
30
20
10
0
-10
-20
-30
-40
1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
MO
MT

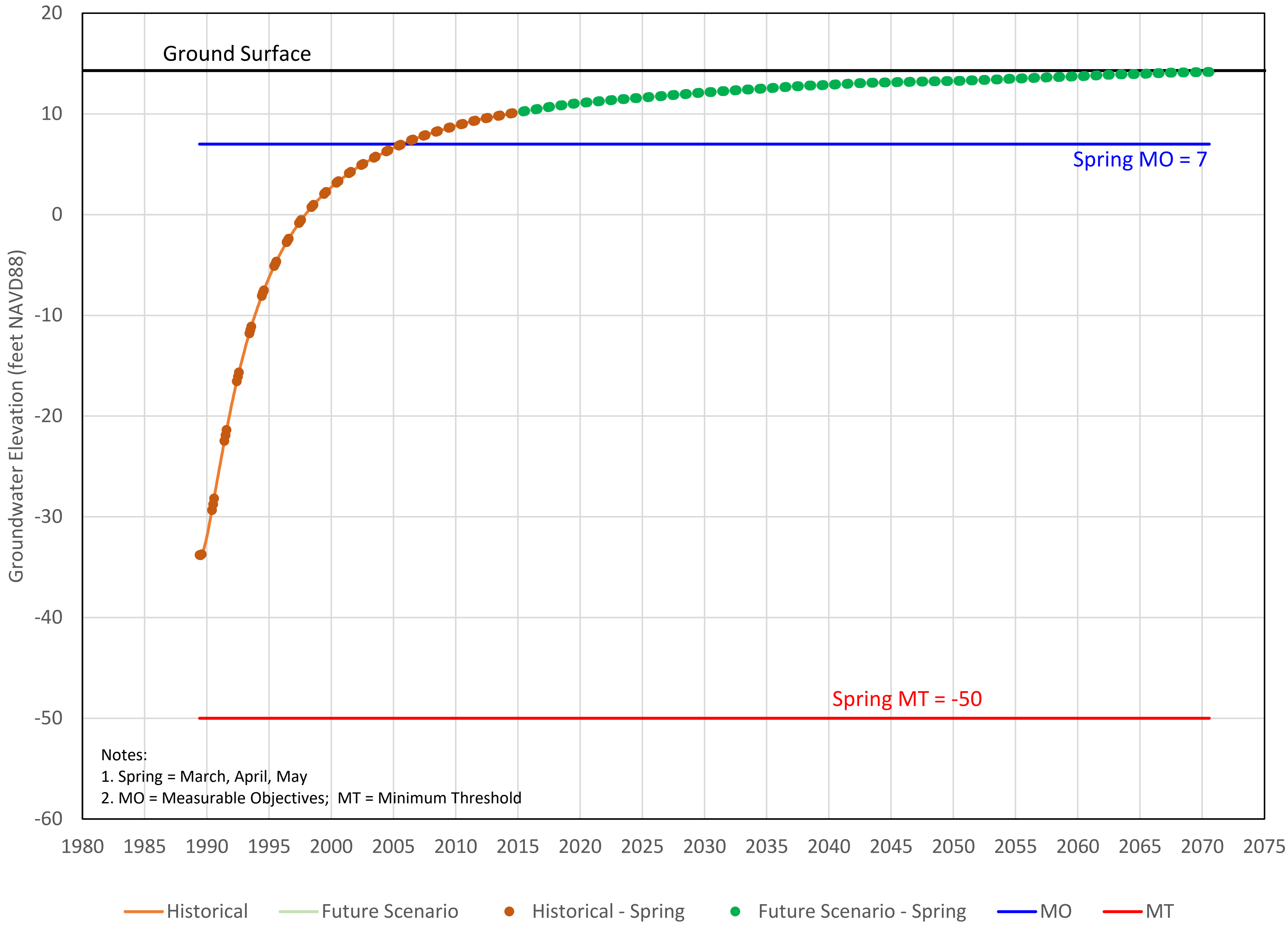
Well Name N2i
Aquifer Intermediate

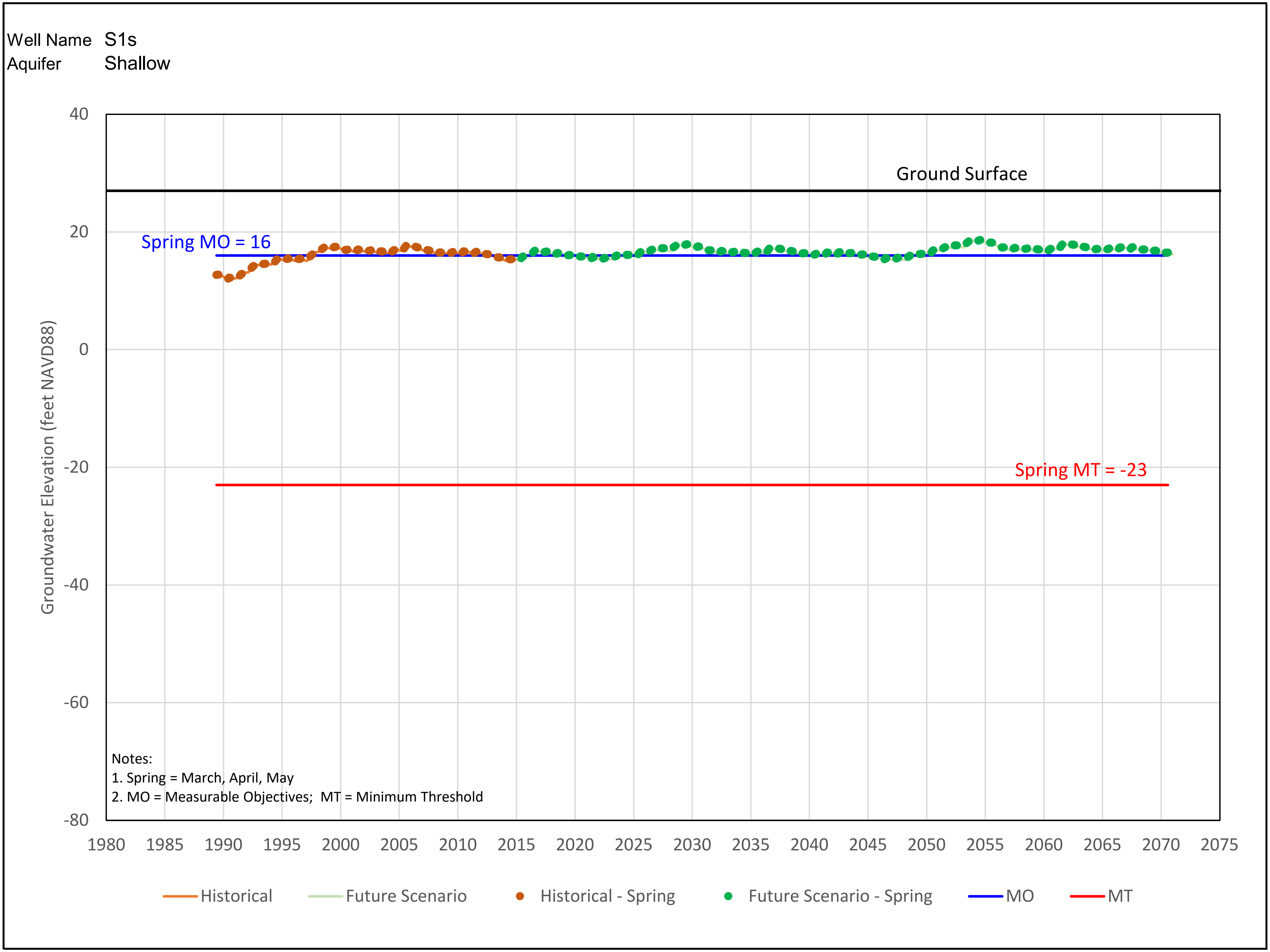


Well Name N3s
Aquifer Shallow

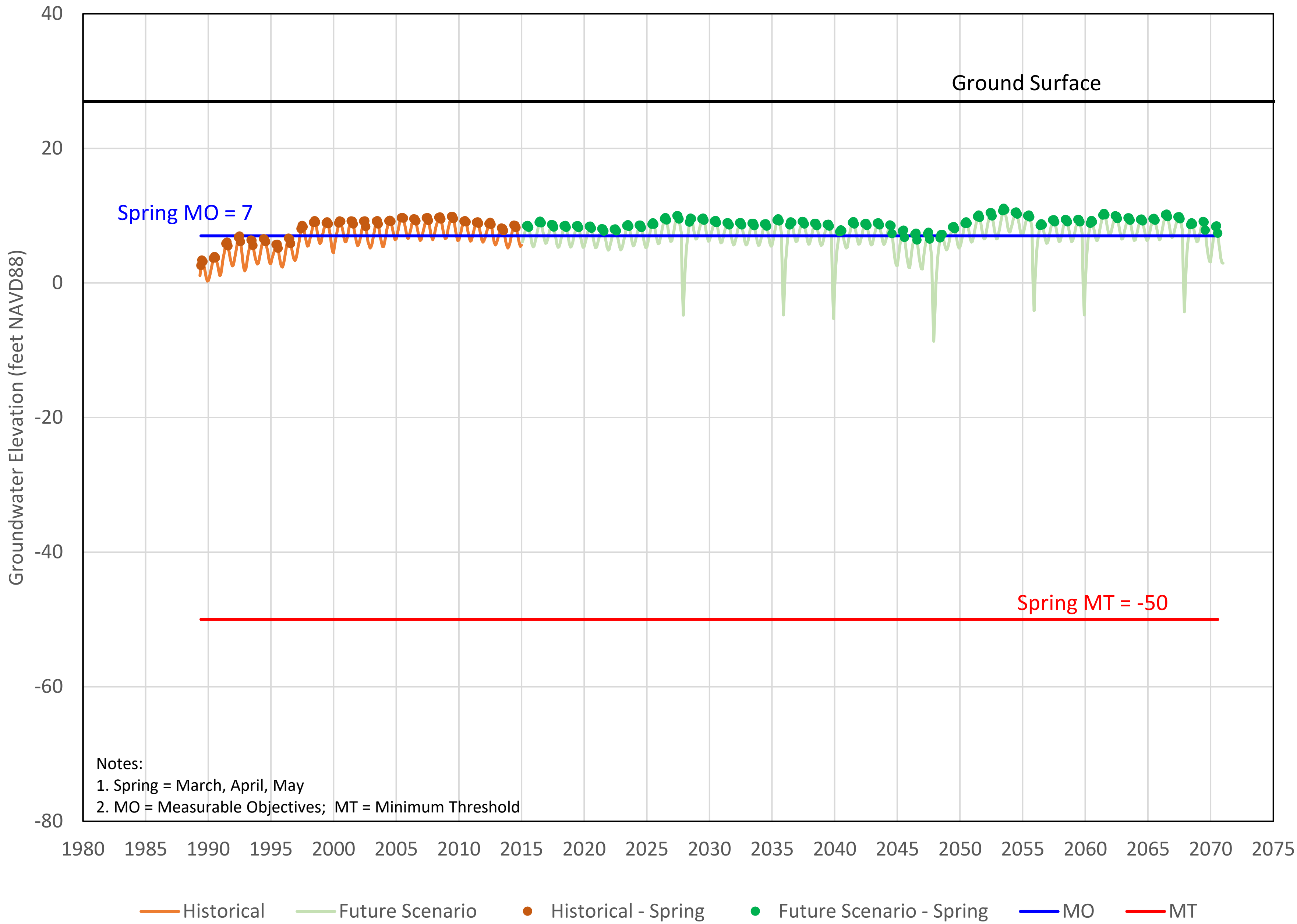


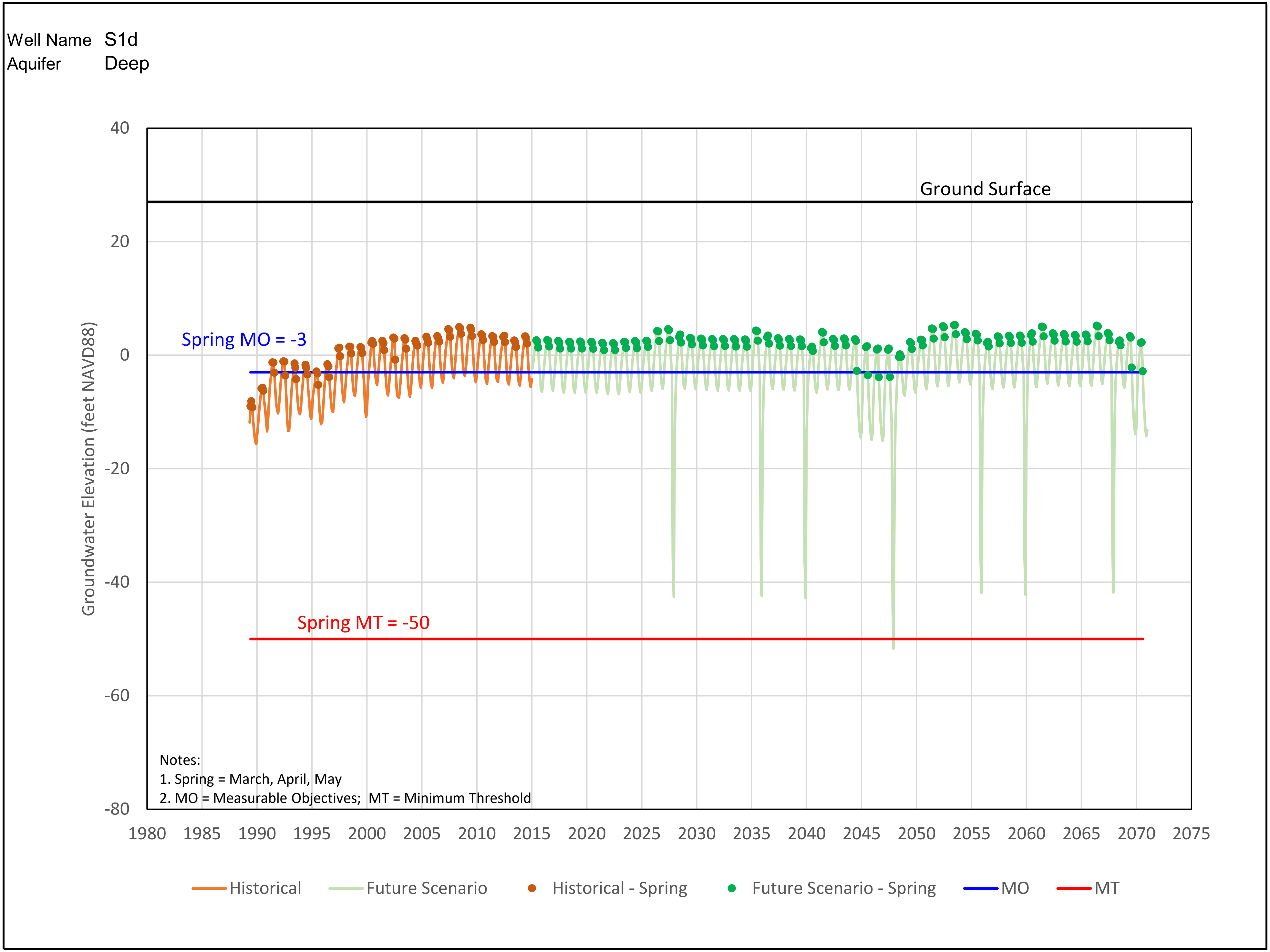
Well Name N3i
Aquifer Intermediate




Well Name S1s
Aquifer Shallow
Ground Surface
Spring MO = 16
Spring MT = -23
Groundwater Elevation (feet NAVD88)
40
20
0
-20
-40
-60
-80
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
MO
MT

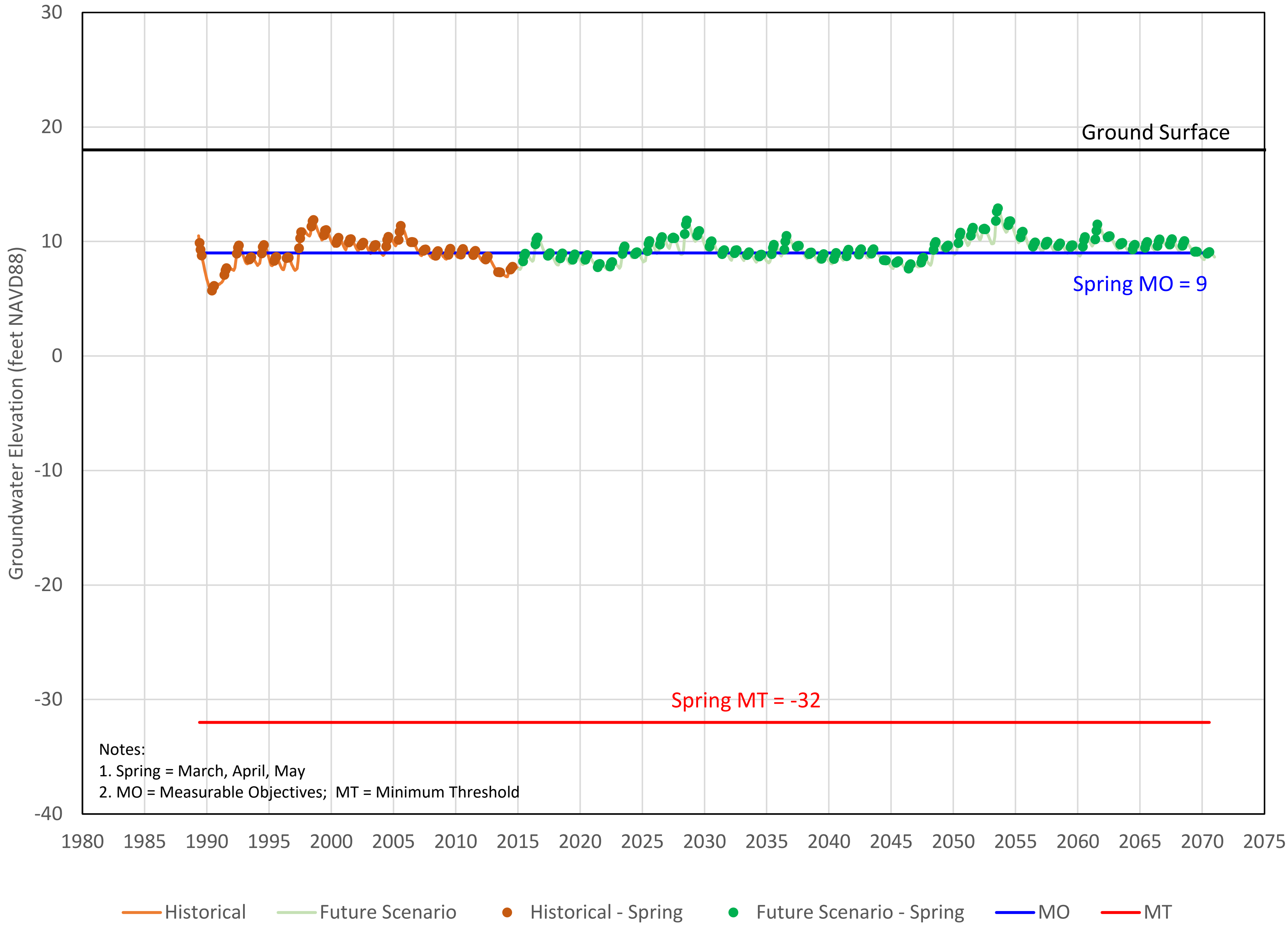
Well Name S1i
Aquifer Intermediate



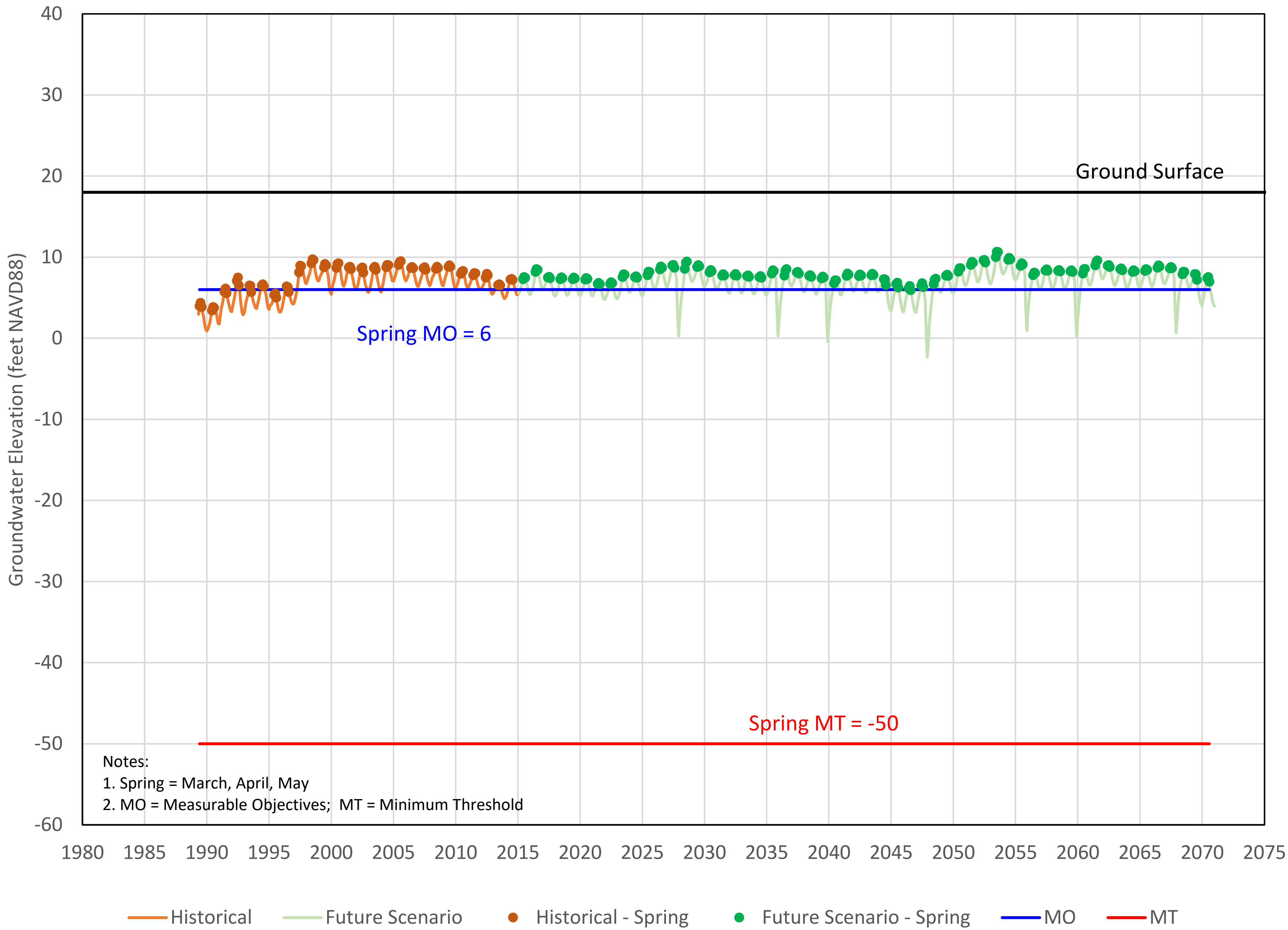


Well Name S1d
Aquifer Deep
Ground Surface
Spring MO = -3
Spring MT = -50
Groundwater Elevation (feet NAVD88)
40
20
0
-20
-40
-60
-80
1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
MO
MT

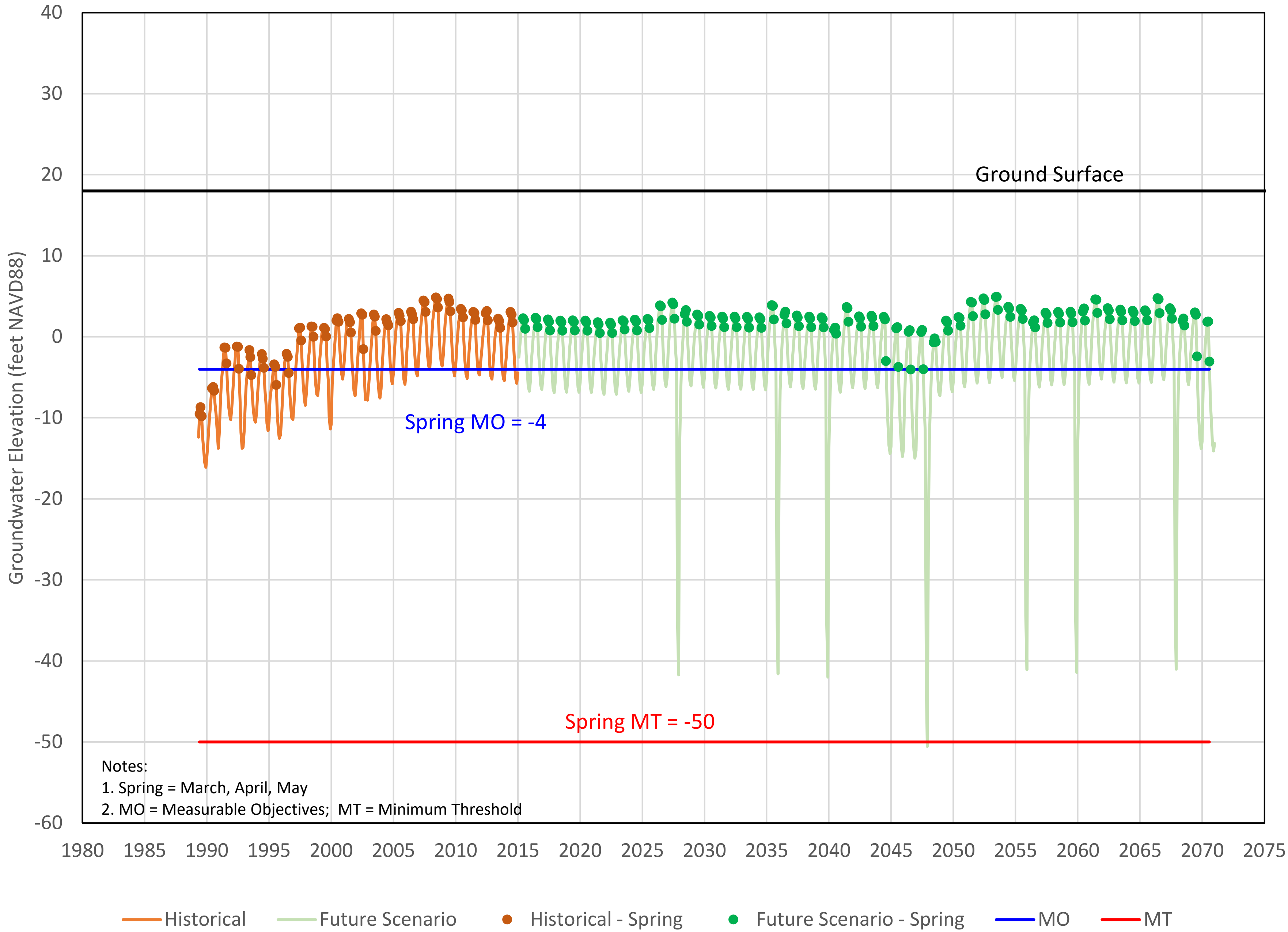
Well Name S2s
Aquifer Shallow

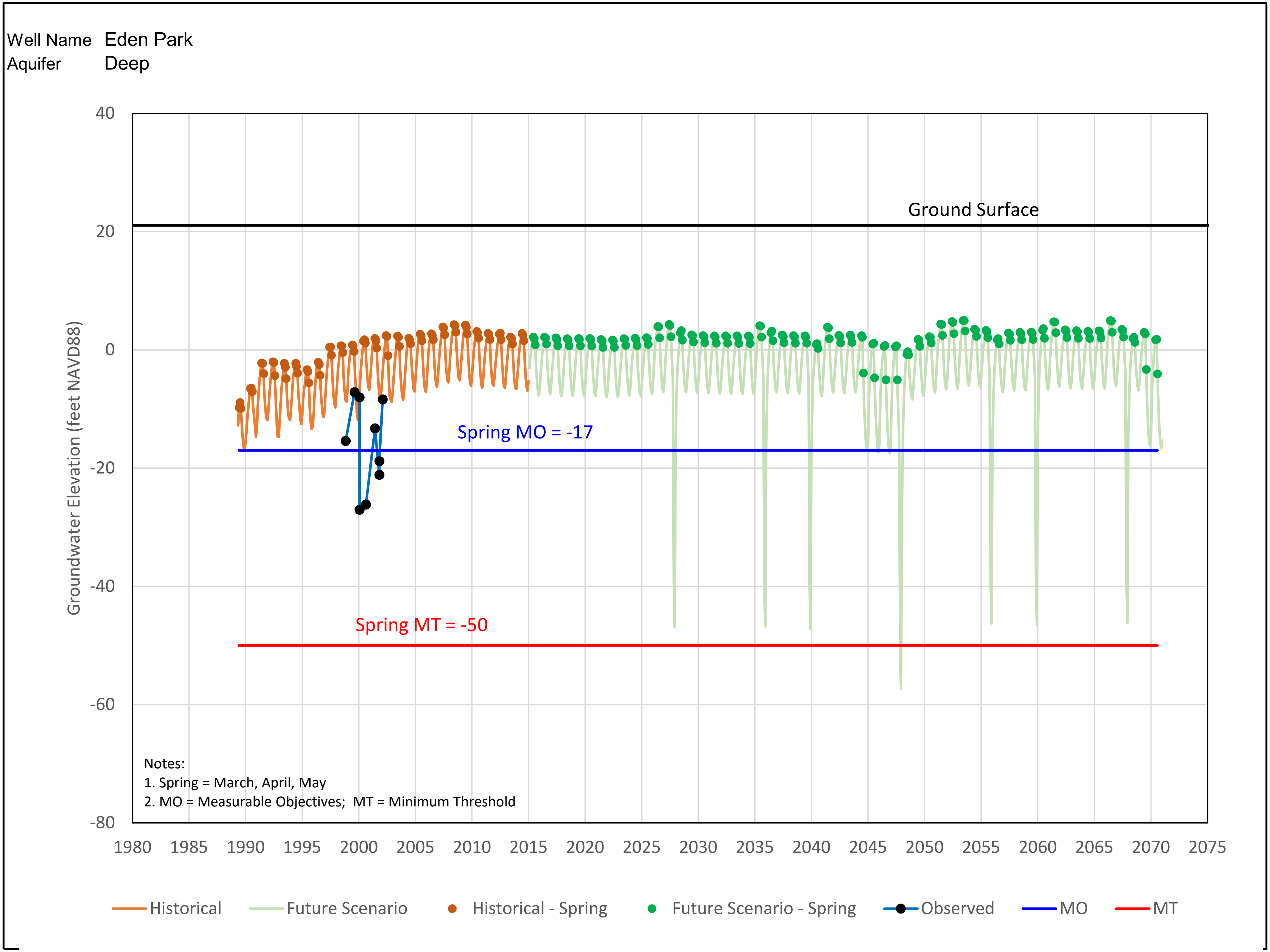


Well Name S2i
Aquifer Intermediate



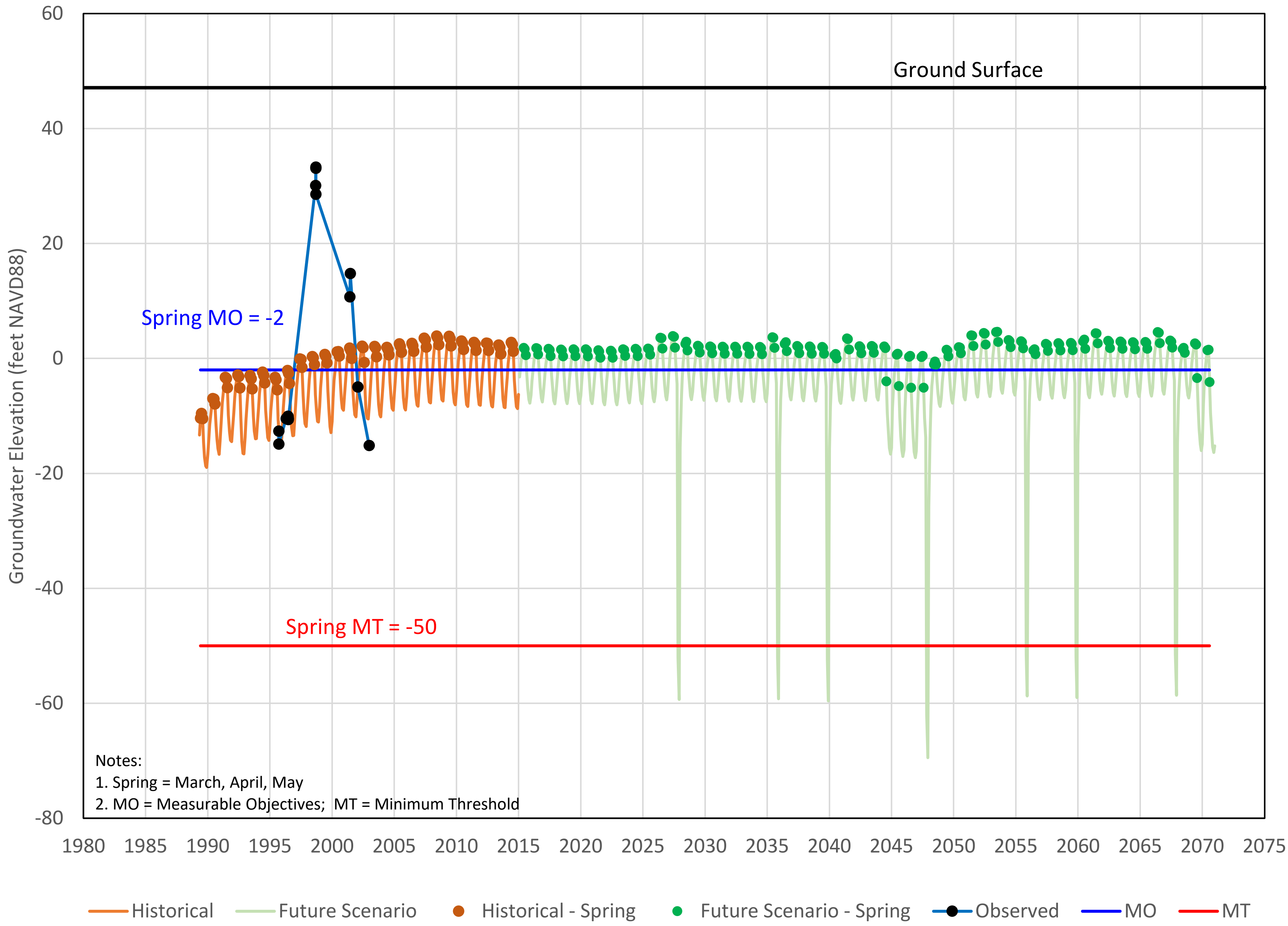
Well Name S2d
Aquifer Deep





Well Name Eden Park
Aquifer Deep
Ground Surface
Spring MO = -17
Spring MT = -50
Groundwater Elevation (feet NAVD88)
40
20
0
-20
-40
-60
-80
1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
Observed
MO
MT

Well Name Hayward Well D
Aquifer Deep



APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.B. Supporting Data for Groundwater Storage SMC

APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.B. Supporting Data for Groundwater Storage SMC

3.B.a Muir Reports With Groundwater Pumping Estimates

GROUNDWATER DISCHARGE

IN THE

EAST BAY PLAIN AREA

ALAMEDA COUNTY, CALIFORNIA

BY: KENNETH S. MUIR

PREPARED FOR THE

ALAMEDA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

HAYWARD, CA 94544

UNDER CONTRACT NUMBER C-95-320

JULY, 1996

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ABSTRACT

There were two forms of groundwater discharge occurring in the area of the East Bay Plain in 1995: natural discharge (evapotranspiration and subsurface discharge); and artifical discharge (pumpage).

The following table lists the values determined for the various discharge elements in the East Bay Plain area in 1995:

DISCHARGE ELEMENT		DISCHARGE (ACRE-FEET PER YEAR)
NATURAL DISCHARGE		
EVAPOTRANSPIRATION		25,800
SUBSURFACE		13,500
	SUBTOTAL	39,300
ARTIFICAL DISCHARGE		
AGRICULTURAL USE		910
DOMESTIC USE		620
INDUSTRIAL USE		1,820
	SUBTOTAL	3,350
	TOTAL	42,650

The values shown in the table illustrate that natural discharge was the predominant form of groundwater discharge from the East Bay Plain area in 1995.

Data indicates that over the past 30 years artifical groundwater discharge (pumping) has decreased and the subsurface discharge element of natural discharge has increased. Evapotranspiration has probably remained nearly constant.

INTRODUCTION

Purpose and Scope

The purpose of this study was to delineate and determine amounts of groundwater discharge in the East Bay Plain area of Alameda County, California (Figure 1).

The scope of this study included the following:

1. A description of the different elements of groundwater discharge that occur in the East Bay Plain area;

2. An estimate of the amount of the groundwater discharge for each of the individual elements; and

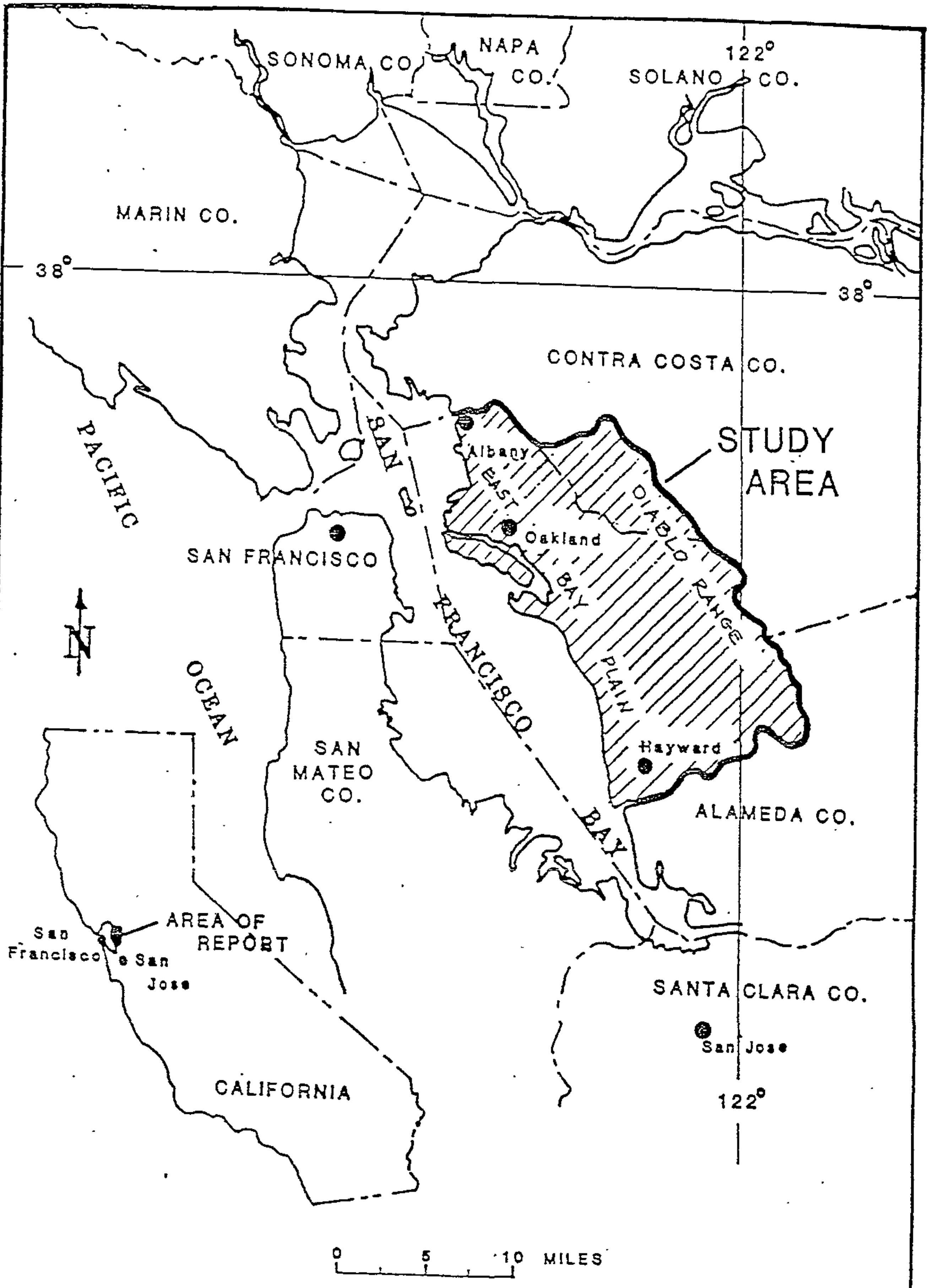


FIGURE 1. STUDY AREA

3. A discussion of how groundwater discharge has changed over the years.

This report deals with another phase of continuing studies that are designed to supply the elements needed for the understanding of the groundwater resources of the East Bay Plain area.

A previous report (Muir, 1995) discussed and evaluated the items of inflow (recharge) to the groundwater reservoir. This present report deals with the items of groundwater outflow (discharge).

The Alameda County Flood Control and Water Conservation District will utilize the information from the present study and associated studies to assist them in their groundwater management and planning decisions. The District has the responsibility, through the act that established it, to protect the groundwater and surface-water resources of the East Bay Plain area for beneficial use.

Location and General Features

The East Bay Plain area comprises about 222 square miles in Alameda and Contra Costa Counties. The area is made up of about 108 square miles of mountainous, uplands and about 114 square miles of flat, alluviated lowlands and bay and tidal marshes. The lowland area is known as the East Bay Plain (Figure 1). The present report focuses on these flat alluviated lowlands. The study area extends westward from the Hayward Fault to San Francisco Bay and from Albany on the north to Hayward on the south (Figure 1 and 2). Oakland is the largest city in the study area. The study area includes all of the groundwater subareas shown on Figure 2, except the Niles Cone and the Castro Valley Basin.

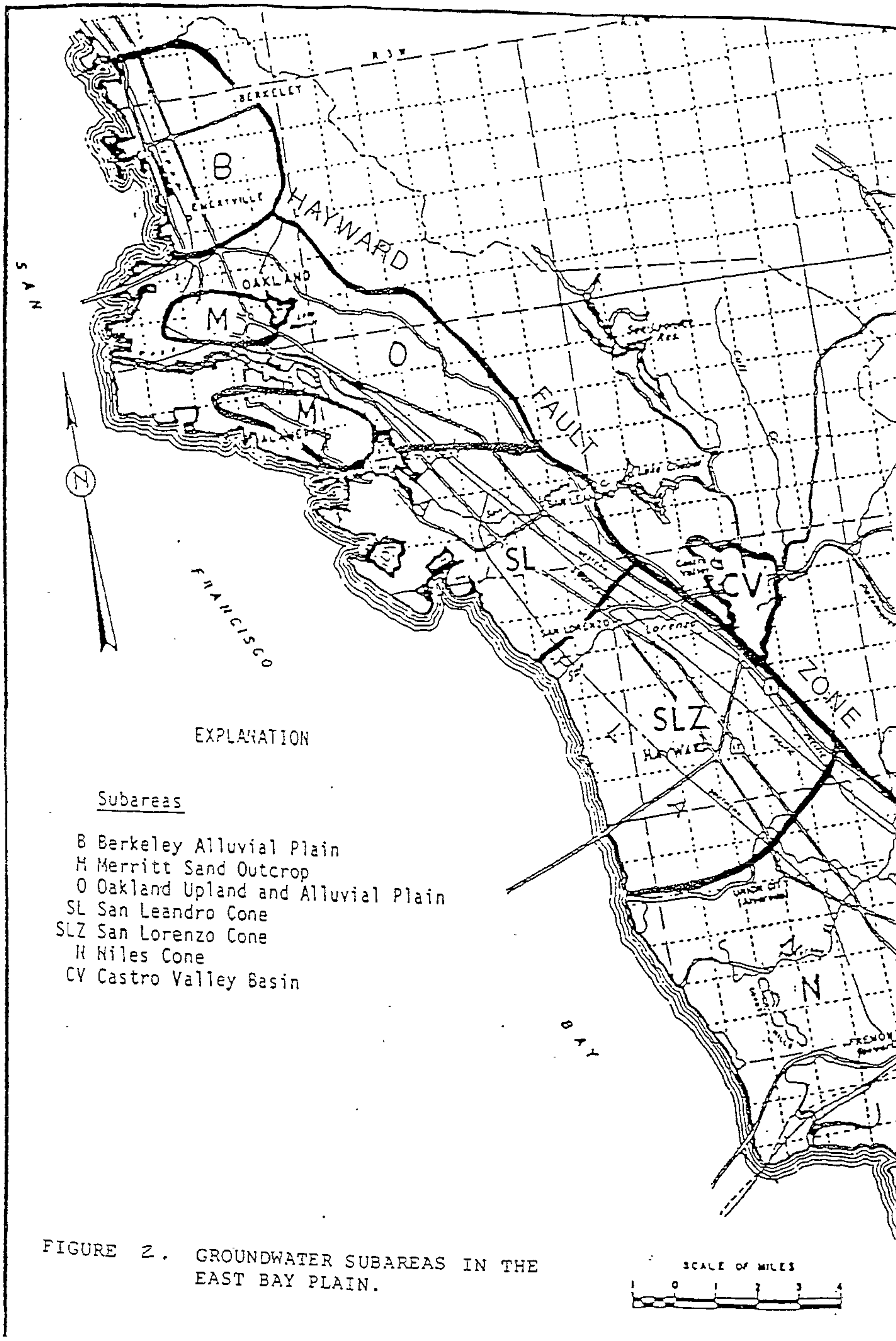
Principal land uses in the East Bay Plain area are residential, commercial, and industrial. There is also some agricultural use.

The study area has a mediterranean type climate. The summers are dry and warm and the winters wet. Most of the rain occurs during the months of November through March. Mean annual precipitation ranges from 16 inches in the lower elevations to over 26 inches in the higher elevations within the study area. The average annual precipitation over the entire area is approximately 23 inches.

San Leandro and San Lorenzo Creeks are the principal drainages. These creeks originate in the eastern highlands of the Diablo Range and drain westerly across the East Bay Plain into San Francisco Bay.

Two categories of geologic units are found in the East Bay Plain area: (1) consolidated rocks of Jurassic, Cretaceous, and Tertiary age, and (2) unconsolidated deposits of Pleistocene and Holocene age.

The consolidated rocks are mostly found in the hills east of the Hayward Fault and beneath the unconsolidated deposits. They form the bottom and



EXPLANATION

Subareas

B Berkeley Alluvial Plain
M Merritt Sand Outcrop
O Oakland Upland and Alluvial Plain
SL San Leandro Cone
SLZ San Lorenzo Cone
N Niles Cone
CV Castro Valley Basin

FIGURE 2. GROUNDWATER SUBAREAS IN THE EAST BAY PLAIN.

eastern boundaries of the East Bay Plain aquifer system. These units are probably about 10,000 feet thick.

The unconsolidated deposits lie beneath the East Bay Plain. Collectively, they make up the groundwater reservoir of the East Bay Plain area. They have a maximum thickness of about 1,100 feet.

The direction of groundwater flow beneath the East Bay Plain area is from the foothills of the Diablo Range westward toward San Francisco Bay.

Groundwater beneath the East Bay Plain is found mostly under confined conditions. Only some near surface deposits and the upper portions of the San Lorenzo and San Leandro Cones (Figure 2) contain groundwater under unconfined conditions.

GROUNDWATER DISCHARGE

There were two forms of groundwater discharge occurring in the area of the East Bay Plain in 1995: natural discharge (evapotranspiration and subsurface discharge); and artifical discharge (pumpage). In the past several other forms of natural groundwater discharge may have occurred: groundwater discharge to streams and spring discharge; neither of these forms of natural discharge were occurring in 1995.

Figure 3 graphically illustrates the elements that make up the groundwater inventory of the East Bay Plain area. Those elements lying on the left hand side of the diagram collectively represent recharge to the groundwater reservoir and those on the right discharge. This report evaluates the discharge elements. A previous report (Muir, 1995) evaluated the recharge elements. It should be noted that the element in the diagram labeled "surface runoff" represents discharge from the groundwater reservoir not runoff from rainfall. It is an inconsequental element in groundwater discharge at the present.

Natural Discharge

Natural discharge includes two elements: evapotranspiration and subsurface discharge.

Evapotranspiration

Evapotranspiration (ET) is the use of water by growing vegetation plus water evaporation from adjacent soils. It is considered a form of groundwater discharge (Figure 3) when evaluating groundwater-reservoir storage, and its recharge and discharge elements.

ET was determined by Muir (1995) for his groundwater-recharge report and is only summarized in this present report.

Muir (1995) developed an average effective yearly ET by using long-term climatic data from the East Bay Plain and correlating this data with ET

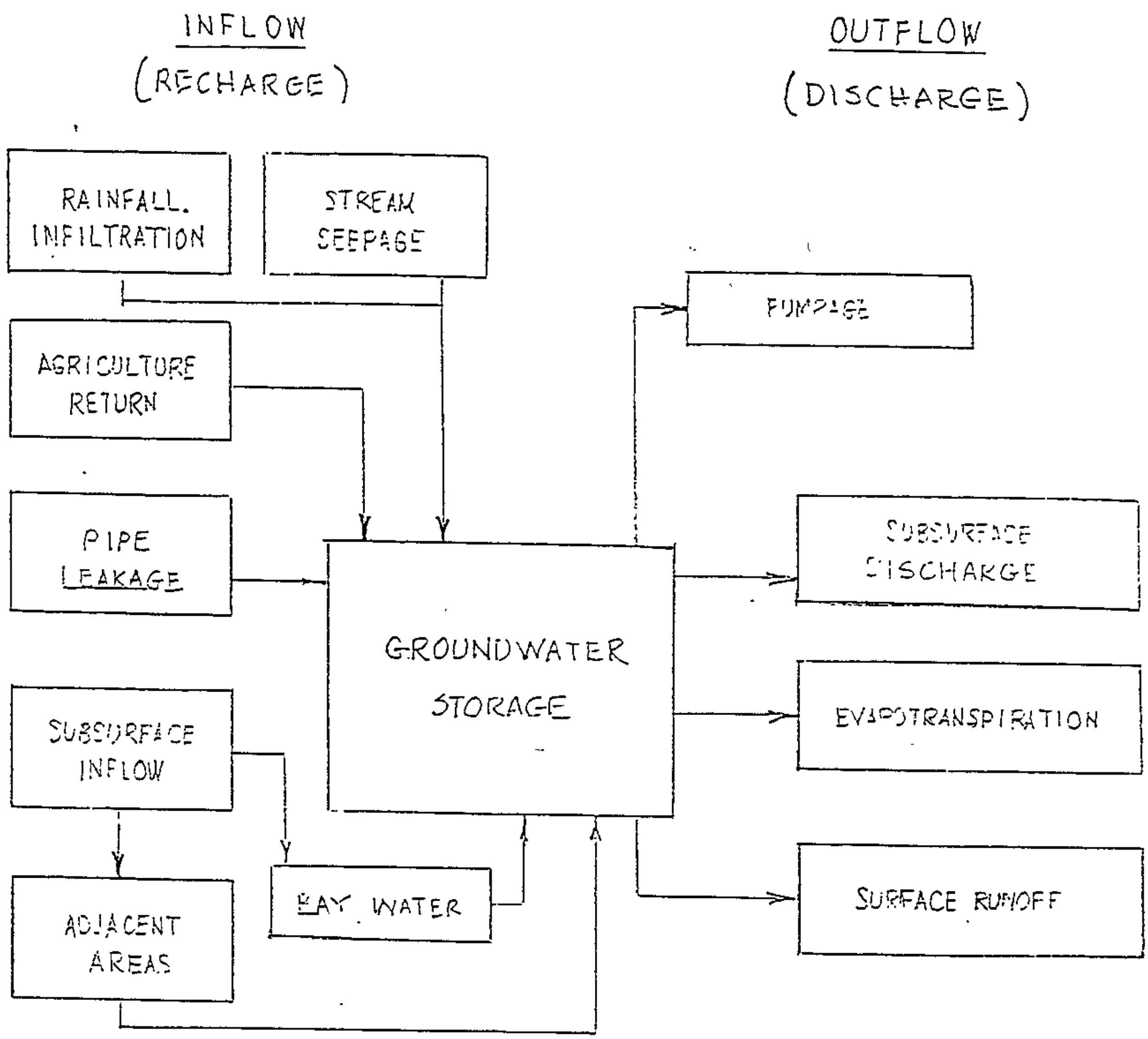


FIGURE 3. GROUNDWATER INVENTORY

studies made in comparable areas of California. He found that the average ET for the East Bay Plain was approximately 8 inches per year. This indicates that ET consumes about 38 percent of the water available from average rainfall. He then calculated the amount of water removed (discharged) from each groundwater subarea by ET. The following table lists the values that were obtained for the East Bay Plain.

TABLE 1

YEARLY AVERAGE EVAPOTRANSPIRATION FOR THE EAST BAY PLAIN

GROUNDWATER SUBAREAS (SEE FIGURE 2)		EVAPOTRANSPIRATION (ACRE-FEET)
BERKELEY ALLUVIAL PLAIN		3,260
OAKLAND UPLAND AND ALLUVIAL PLAIN		7,250
MERRITT SAN OUTCROP		2,920
SAN LORENZO CONE		6,520
SAN LEANDRO CONE		5,830
	TOTAL	25,780

Subsurface Discharge

Water level contours and gradients found beneath the East Bay Plain subareas (Figure 2) indicate that the direction of most groundwater flow is from east to west - from near the Hayward Fault towards San Francisco Bay.

There is some question as to what is occurring with groundwater flow in the south end of the study area, near Union City (Figure 2). The few water-level measurements available in this area make it impossible to make a definitive statement regarding direction of groundwater flow. However, the meager water-level data suggest that groundwater in the lower aquifer zones may be moving north while that in the upper zones may be moving south, probably resulting in a net subsurface flow of near zero.

The conclusion made by the author for the present report, based on water-level contours and gradients, is that the vast majority of subsurface groundwater discharge in 1995-96 was occurring at the bay margin, with flow toward the west and under San Francisco Bay.

Following are the steps, procedures, and criteria used in this report to determine the amount of subsurface groundwater discharge from the East Bay Plain:

1. The hydraulic conductivities used is this report are based on those developed by Woodward-Clyde (1992, 93) and Brown and Coldwell (1986) in the Hayward and San Leandro areas.

2. Determined average water levels and depth to water for each subarea at bay margin from drillers logs and monitor wells, taking into consideration the fact that the upper water-bearing zone is unconfined and the lower confined.

3. Determined groundwater gradient at bay margin for each subarea from water-level contour maps.

4. Determined average thickness of unconsolidated deposits at bay margin for each subarea.

5. Determined width of each subarea at bay margin.

6. Determined from water-level data how much of each subareas unconsolidated vertical section at its bay margin is saturated. This was a factor in the calculation of transmissivity.

7. For subsurface discharge calculations in the San Leandro and San Lorenzo Cones limited the depth of unconsolidated deposits to upper 600 feet. The few drillers and electric logs of wells that penetrate deeper than 600 feet indicate very little aquifer material in the zone from 600 feet to 1000 feet. The subsurface discharge calculations should be revised if, in the future, more deep wells are drilled and their lithologic data indicates that there are actually aquifer zones in the interval from 600 feet to 1000 feet.

8. Determined a transmissivity factor for each subarea for the depth zones of 5 feet to 200 feet and 200 feet to 600 feet. The transmissivities were calculated using the hydraulic conductivity data from Woodward-Clyde (1992, 93) and Brown and Caldwell (1986), and aquifer thickness based on aquifer-aquiclude percentages from Table 3 of Muir's geologic framework report (1992).

   It should be noted that hydraulic conductivity and width of the subareas will remain constant and the variable to subsurface discharge will be the saturated aquifer thickness and the groundwater gradient at, or near, the bay margin. Whatever influences the groundwater levels, be it aquifer recharge or discharge, will, in turn, govern the amount of subsurface discharge from the East Bay Plain.

   Table 2 and Table 3 lists the values developed to determine subsurface groundwater discharge from the East Bay Plain. The results shown in Table 3 indiciate that subsurface discharge in 1995 was 13,500 acre-feet.

TABLE 2

HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY OF AQUIFERS AT BAY MARGIN

GROUNDWATER SUBAREA (SEE FIGURE 2)	AVERAGE THICKNESS OF UNCONSOLIDATED DEPOSITS AT BAY MARGIN	AQUIFER PERCENTAGE	SATURATED AQUIFER THICKNESS (1) BY DEPTH ZONES (FEET)			HYDRAULIC CONDUCTIVITY (GPD/FT2) (2) BY DEPTH ZONES (FEET)			TRANSMISSIVITY (GPD/FT) (3) BY DEPTH ZONES (FEET)	
			5-30	30-200	200-600	5-30	30-200	200-600	5-200 (4)	200-600
BERKELEY ALLUVIAL PLAIN	350	31	8	53	47	161	700	320	32,400	15,040
OAKLAND ALLUVIAL PLAIN	550	25	6	43	88	161	700	320	26,500	28,200
SAN LEANDRO CONE	950	18	5	31	72	161	700	320	17,800	23,040
SAN LORENZO CONE	1,000	18	5	31	72	161	700	320	17,800	23,040

(1) ONLY UPPER 600 FEET OF DEPOSITS CONSIDERED. DEPOSITS BELOW 600 FEET CONSIDERED TO HAVE LITTLE AQUIFER MATERIAL, LOW TRANSMISSIVITY, AND SLIGHT GROUNDWATER GRADIENTS; SO LITTLE FLOW.

(2) HYDRAULIC CONDUCTIVITY, IN GALLONS PER DAY PER FOOT SQUARED (GPD/FT2).

(3) TRANSMISSIVITY, IN GALLONS PER DAY PER FOOT (GPD/FT).

(4) TRANSMISSIVITY FOR THE 5-200 FOOT ZONES ARE A WEIGHTED AVERAGE BASED ON THE HYDRAULIC CONDUCTIVITIES FOR THE 5-30 FOOT AND 30-200 FOOT ZONES AND THE SATURATED AQUIFER THICKNESS.

TABLE 3

SUBSURFACE - GROUNDWATER DISCHARGE AT BAY MARGIN, APRIL 1995

GROUNDWATER SUBAREA (SEE FIGURE 2)	TRANSMISSIVITY (GPD/FT) (1) BY DEPTH ZONES (FEET) 5-200	200-600	WIDTH AT BAY MARGIN (FEET)	GROUNDWATER GRADIENT (2) BY DEPTH ZONES (FEET) 5-200	200-600	OUTFLOW AT BAY MARGIN (ACRE-FEET) (ROUNDED) 5-200	200-600	TOTAL
BERKELEY ALLUVIAL PLAIN	32,400	15,040	23,760	$1.1X10^{-3}$	$4X10^{-3}$	900	1,600	2,500
OAKLAND ALLUVIAL PLAIN	26,500	28,200	31,680	$2.5X10^{-3}$	$2.9X10^{-3}$	2,300	2,900	5,200
SAN LEANDRO CONE	17,800	23,040	31,680	$1.6X10^{-3}$	$2.0X10^{-3}$	1,000	1,600	2,600
SAN LORENZO CONE	17,800	23,040	31,680	$2.9X10^{-3}$	$1.7X10^{-3}$	1,800	1,400	3,200
					TOTAL	6,000	7,500	13,500

(1) TRANSMISSIVITY, IN GALLONS PER DAY PER FOOT (GPD/FT).
(2) GRADIENTS ARE BASED ON APRIL 1995, WATER-LEVEL DATA

TABLE.3.1996

Artifical Discharge

Artifical discharge includes all forms of groundwater pumpage from wells, whether it be for agricultural, domestic, or industrial uses.

Pumpage

Agricultural Use - Five elements were considered in the determination of agricultural pumpage for the East Bay Plain: golf courses, cemeteries, schools and colleges, parks, and crops. Data from California Department of Water Resources Bulletins No. 113-3 (1975) and No. 113-4 (1986) and Sunset (1961) were used to make the estimates of agricultural pumpage.

Golf Courses - Only two golf courses located in the East Bay Plain use wells for irrigation purposes; all others use either reclaimed sewage water or water stored in lakes from captured rainfall runoff. It was estimated that the two golf courses pumped 390 arce-feet of groundwater in 1995.

Cemeteries - There are three cemeteries that use well water for irrigation purposes. These pumped a total of about 450 acre-feet in 1995.

Schools and Colleges - Several high schools and colleges use well water to irrigate athletic fields. Their total pumpage for 1995 was estimated to be only 20 acre-feet.

Parks - A number of parks in the East Bay Plain have wells for irrigation purposes. However, there is little use of these wells. Total park pumpage in 1995 was estimated to be 25 acre-feet.

Crops - In 1995 there were only 14 acres of row crops and several hot houses in the area of the East Bay Plain. Their estimated pumpage totaled 25 acre-feet.

Table 4 summaries the estimates that were determined for agricultural pumpage in the East Bay Plain for 1995. Total pumpage for all agricultural purposes was estimated to be 910 acre-feet.

TABLE 4

GROUNDWATER PUMPAGE FOR AGRICULTURAL USE IN THE EAST BAY PLAIN, 1995

	ACRE-FEET
PUMPAGE FOR GOLF COURCES	390
PUMPAGE FOR CEMETERIES	450
PUMPAGE FOR SCHOOLS AND COLLEGES	20
PUMPAGE FOR PARKS	25
PUMPAGE FOR CROPS	25
TOTAL	910

Domestic Use

Pumpage from individual domestic wells, wells operated by a mutual water association, and several private water system wells constitute the domestic use of groundwater in the East Bay Plain.

It was difficult to determine how much groundwater is being pumped by individual domestic wells. Most of the pumpage is from shallow wells in the depth range of 50 to 100 feet and is used for lawn and garden irrigation. Some of the groundwater pumped by individual domestic wells is consumed by household use. The pumpage estimates were based mostly on data supplied by Dave Williamson and Julio Abino of the East Bay Municipal Utility District (EBMUD) (oral and written communication, 1996) and Eileen Hughes of the California Environmental Protection Agency - Department of Toxic Substances Control (DTSC) (oral and written communication, 1993).

The EBMUD requires back-flow valves on any residential services that also have a well connected to the house plumbing. They supplied the author with a computer printout that listed registered residential services, by city, for those customers with back-flow valves. They said that they are certain that there are some residents with wells that are connected to their plumbing for which there are no back-flow valves, and consequently, no record with EBMUD of well use; also, that there are a number of individual domestic wells in their service area that are not connected into house plumbing. To develop pumpage values from the EBMUD data several assumptions were made: (1) 60 percent of the domestic wells pump in any one year period, (2) the number of home owners who haven't told EBMUD that they have wells connected to their house plumbing is probably about 5 percent of those registered, and (3) the number of domestic wells that are not connected to house plumbing probably is about 10 percent of those that are registered.

The factor used for domestic well use per year was based on data collected by DTSC. In 1987 they made a survey of domestic well use in a limited area of San Leandro. They obtained data on 31 wells. In 1987 these wells had a reported total yearly pumpage of 8.2 acre-feet or an average pumpage of 0.26 acre-feet per well per year. If it is assumed that these wells were used for the period spring thru fall, a period of 28 weeks, each well would have pumped about 3100 gallons of water per week. This translated into a pumping rate for each well of 6 gallons per minute if the pumps are in operation for 3 hours per day and 3 days per week. This pumping rate was considered reasonable by the author and was used to calculate pumpage by domestic wells.

Table 5 lists, by city, the amount of domestic wells and their pumpage in the areas serviced by the EBMUD in the East Bay Plain in 1995.

Table 6 lists groundwater pumpage determined for all domestic uses in the East Bay Plain in 1995.

TABLE 5

GROUNDWATER PUMPAGE BY DOMESTIC WELLS, IN 1995, IN THE AREA OF THE EAST BAY PLAIN SERVICED BY THE EAST BAY MUNICIPAL UTILITY DISTRICT

AREA	WELLS REGISTERED WITH EBMUD (1)	UNACCOUNTED WELLS (2)	TOTAL WELLS	PUMPAGE (ACRE-FEET) (3)
ALAMEDA	112	17	129	20
BERKELEY	12	2	14	2
EMERYVILLE	1	1	2	1
HAYWARD	46	7	53	8
OAKLAND	104	16	120	19
PIEDMONT	39	6	45	7
SAN LEANDRO	1,720	258	1,978	309
SAN LORENZO	504	76	580	90
TOTAL	2.538	383	2,921	456

(1) 1995, EBMUD = EAST BAY MUNICIPAL UTILITY DISTRICT

(2) ESTIMATED TO BE 15 PERCENT OF NUMBER OF REGISTERED WELLS: 5 PERCENT CONNECTED TO HOUSE PLUMBING AND 10 PERCENT NOT.

(3) BASED ON 60 PERCENT OF WELLS PUMPING AT 0.26 ACRE-FEET PER YEAR PER WELL.

TABLE.5.1996

TABLE 6

GROUNDWATER PUMPAGE FOR DOMESTIC USE IN THE EAST BAY PLAIN, 1995

	ACRE-FEET
*PUMPAGE BY DOMESTIC WELLS IN SERVICE AREA OF EAST BAY MUNICIPAL UTILITY DISTRICT	456
PUMPAGE BY MOHRLAND MUTUAL WATER ASSOCIATION, WEST HAYWARD AREA	69
*PUMPAGE BY DOMESTIC WELLS IN AREA OF CITY OF HAYWARD NOT SERVICES BY THE EAST BAY MUNICIPAL UTILITY DISTRICT	60
PUMPAGE BY PRIVATE DOMESTIC WATER SYSTEMS	32
TOTAL	617

*USED MOSTLY FOR LAWN AND GARDEN IRRIGATION

Industrial Use

Industrial use includes groundwater pumped by industrial concerns and by remediation projects.

A variety of sources were utilized to determine the amount of groundwater pumped for industrial purposes. The following individuals and agencies suppled data that were critical in the determination of industrial pumpage: Julio Albino of the EBMUD, Eileen Hughes of the DTSC, John Camp in the Environmental Compliance Department of the San Leandro Water Pollution Control District, and Joe Lucia the Water Source Administrator for the Hayward Sewage Treatment Plant. Using data supplied by the preceding and a list of industrial wells from county files individual industrial concerns were contacted to determine if they used groundwater.

It was found that only ten industrial concerns were using groundwater in the East Bay Plain. They pumped a total of 1015 acre-feet of groundwater in 1995.

The groundwater was used mainly in food processing and product manufacturing. The groundwater was pumped from wells deeper than 200 feet.

It was estimated that there are about 60 remediation projects in operation in the East Bay Plain in any one year period. These pump about 800 acre-feet of groundwater each year, all from wells less than 100 feet deep.

Total groundwater pumpage for industrial use in 1995 was 1815 acre-feet.

SUMMARY AND CONCLUSIONS

Table 7 lists the values determined for the various elements of groundwater discharge in the East Bay Plain area in 1995.

TABLE 7

GROUNDWATER DISCHARGE IN THE EAST BAY PLAIN AREA IN 1995

DISCHARGE ELEMENT		DISCHARGE (ACRE-FEET PER YEAR) (ROUNDED)
NATURAL DISCHARGE		
EVAPOTRANSPIRATION		25,800
SUBSURFACE		13,500
	SUBTOTAL	39,300
ARTIFICAL DISCHARGE		
AGRICULTURAL USE		910
DOMESTIC USE		620
INDUSTRIAL USE		1,820
	SUBTOTAL	3,350
	TOTAL	42,650

Table 7 illustriates that artifical discharge (pumpage) was a small increment of overall groundwater discharge.

For projection purposes the figures shown in Table 7 are probably valid for about the past 5 years and into the near future.

Thirty years ago artifical discharge was much greater than it is at the present time. At that time about 14,000 acres of crops were being irrigated with groundwater and over 50 industrial wells were in operation.

In contrast, with groundwater pumpage up and water levels down, subsurface discharge, which is directly related to the groundwater gradient at the bay margin, was less than at the present time.

During these same 30 years evapotranspiration has probably remained nearly constant.

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GROUNDWATER YIELD

OF THE

EAST BAY PLAIN

ALAMEDA COUNTY, CALIFORNIA

BY: KENNETH S. MUIR

PREPARED FOR THE

ALAMEDA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

HAYWARD, CA 94544

UNDER CONTRACT NUMBER C-95-320

NOVEMBER, 1996

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A B S T R A C T

The yield of the groundwater reservoir in the area of the East Bay Plain is the rate at which water can be pumped from wells year after year without decreasing groundwater in storage to the point where the intrusion of seawater from San Francisco Bay would occur.

It was estimated that at the present time the groundwater yield of the East Bay Plain is approximately 10,000 acre-feet per year.

I N T R O D U C T I O N

This report is the continuation of a series of reports prepared by the author (see bibliography) to define and evaluate the geologic features and hydrologic values of the groundwater reservoir that lies beneath the East Bay Plain (Figure 1). This report pertains to the groundwater yield of the reservoir.

Y I E L D

The term "groundwater yield" has many definitions, all of which are based on the long-term dependabilty of the water supply, as expressed by the balance of the items of the groundwater inventory (Figure 2). Rainfall infiltration, pipe leakage, and stream seepage are the more important sources of inflow to the study area (Muir, 1994). Evapotranspiration and subsurface discharge are the main items of outflow (Muir, 1996). The yield of the groundwater reservoir in the area of the East Bay Plain is the rate at which water can be pumped from wells year after year without decreasing groundwater in storage to the point where the pumping lift would become economically infeasible or where water of poor quality would begin to intrude into the reservoir. In this area because it lies adjacent to San Francisco Bay the intrusion of water of poor quality (seawater) probable, would occur first. In this case yield is tied in with groundwater storage. The groundwater storage can be depleted by pumping until water levels near the Bay are drawn down to near sea level. When this occurs, the average annual pumpage should not exceed a quantity equal to the long-term average inflow to the reservoir minus the quantity of subsurface discharge that must flow to the Bay annually to maintain a barrier against seawater intrusion. This would be the groundwater yield of the East Bay Plain Area.

This sounds simple enough - monitor the status of groundwater levels near the Bay and when they reach sea level evaluate inflow and outflow to obtain yield. Complicating this approach is the fact that in the East Bay Plain groundwater is stored in a reservoir system in which both unconfined and confined conditions occur - with most of the groundwater stored in the confined zone. This means that changes in storage reflect changes in

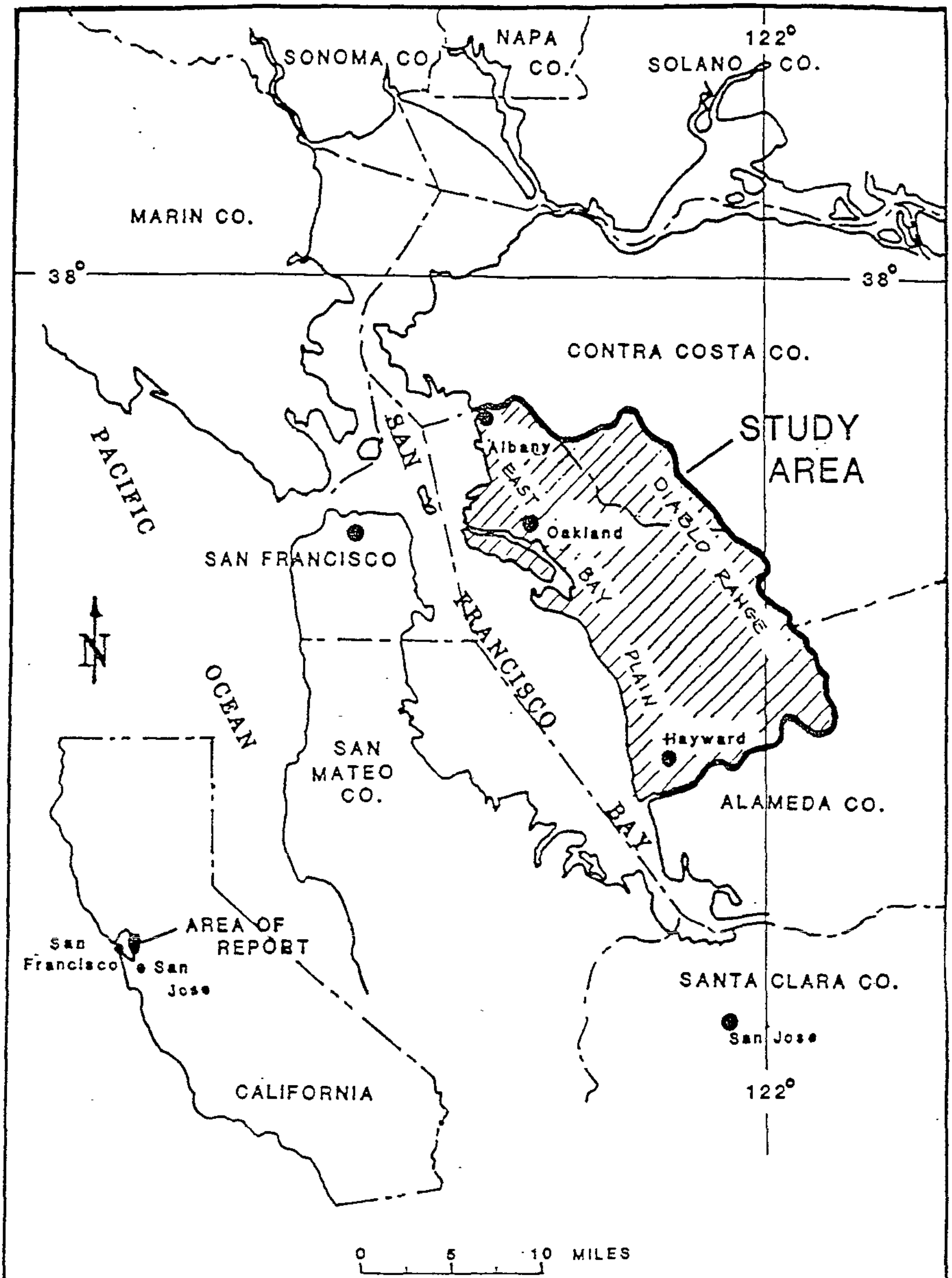


FIGURE 1. STUDY AREA

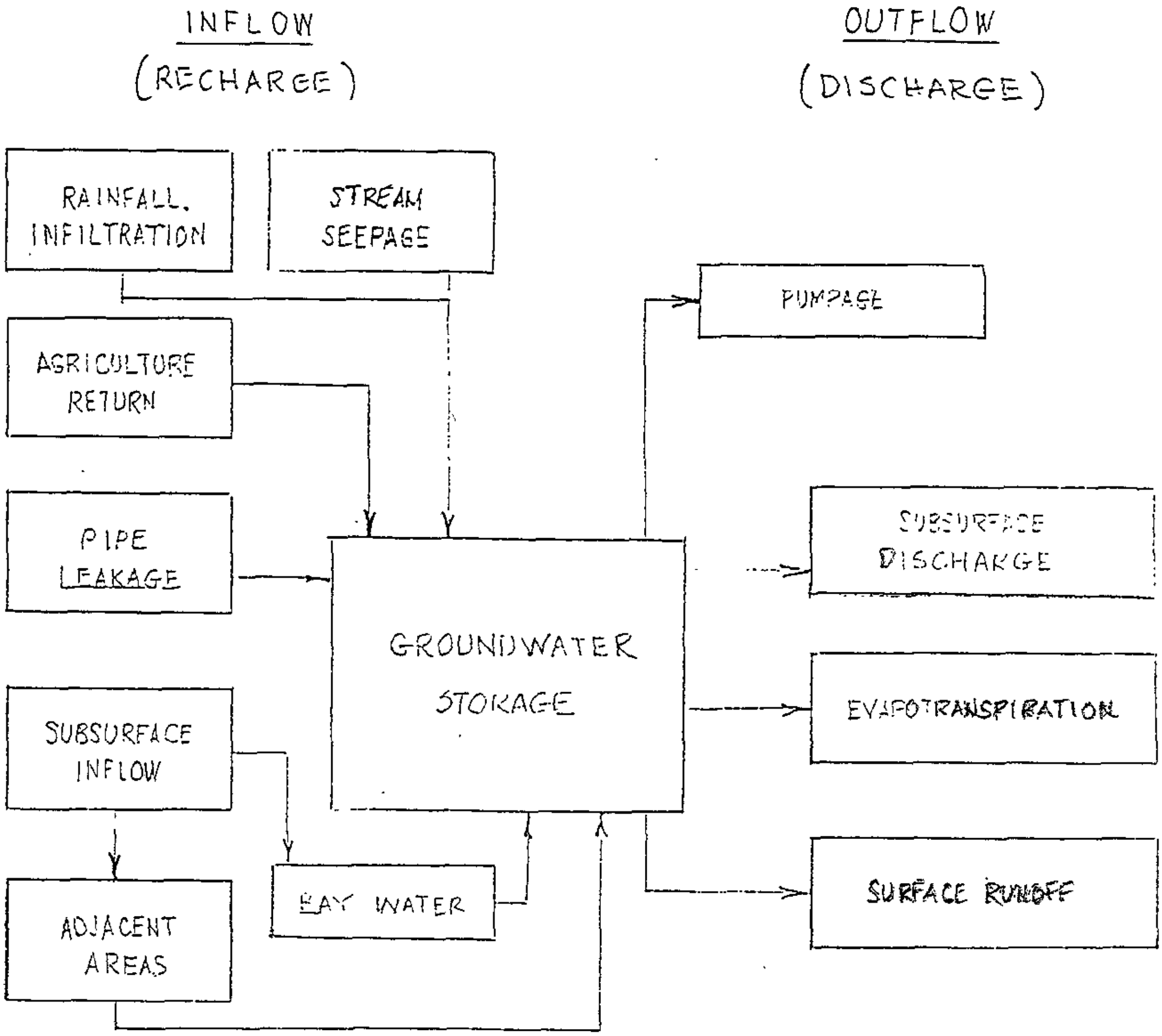


FIGURE 2. GROUNDWATER INVENTORY

pressure more than removal of water from the reservoir system. This is illustrated by a study done by the California Department of Water Resources (DWR, 1994) in which they estimated that about 2,500,000 acre-feet of groundwater is stored under the East Bay Plain - with about 80,000 acre-feet of this groundwater stored in the aquifers above sea level. They also state that groundwater levels (Figures 9 and 10) in some areas of the East Bay Plain indicate groundwater in storage below sea level has been and continues to be used, apparently with limited adverse impacts.

The main reason the determination of yield in the East Bay Plain cannot be estimated with a high degree of accuracy at the present time is because of the lack of complete data on inflow, outflow, aquifer transmissivity and because groundwater within the reservoir is not static, which means that the natural inflow - outflow relations of the reservoir system will probably continue to change.

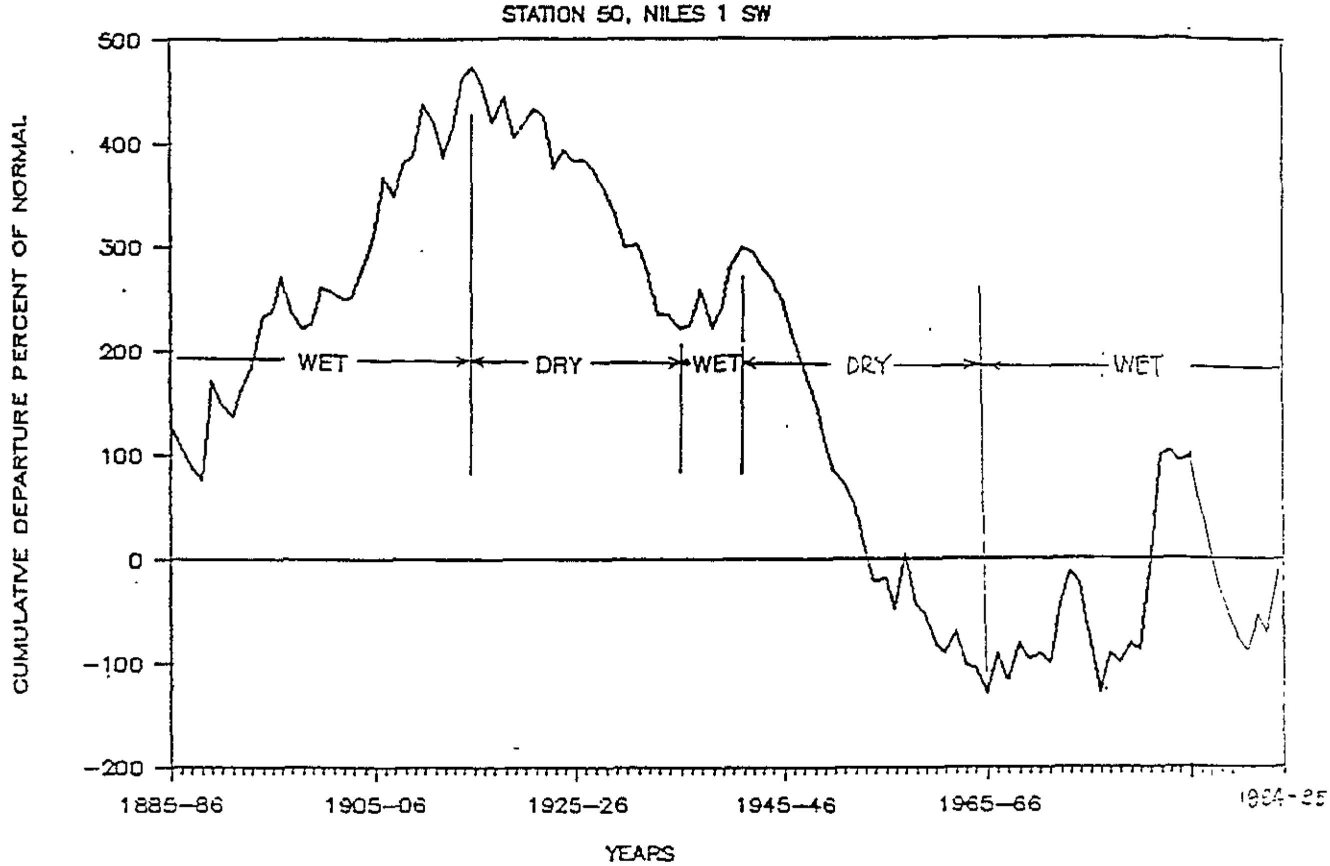
To make an approximation of the value of groundwater yield of the East Bay Plain inflow - outflow estimates from 1965 and 1995, rainfall data from Niles and Berkeley (Figure 3), hydrographs of selected wells (Figures 5-10), and the history of water use for the thirty-year period 1965 thru 1995 were utilized.

There were dramatic changes in land use in the East Bay Plain between the years 1965 and 1995. The area went from an industrial-agricultural land use to one of mostly urban growth. Along with urban growth came the decrease to almost nothing by 1995 in industrial-agricultural pumpage. The urbanized areas are supplied by water piped in from surface water sources from areas outside the East Bay Plain. Therefore, since about 1965 the draft on the groundwater reservoir both in the unconfined and confined zones has been reduced and water levels are rising and storage is increasing. For the period 1965 to 1995 water levels in the unconfined zone have shown fluctuations from no change to a rise of 10 feet and in the confined zone the increases range from an increase of 60 to 90 feet (see hydrographs of wells in Figures 5 thru 10 - see Figure 4 for their location). This was during a series of years where rainfall averaged slightly higher than the long-term normal and the area was experiencing a relatively minor wet cycle (Figure 3). Based on data from the DWR Report (DWR, 1994) it is estimated that groundwater storage in the zone from 0 to 200 feet increased about 25,000 acre-feet between 1965 and 1995. This indicates inflow was greater than outflow and that groundwater yield was not being exceeded.

It is estimated that groundwater outflow from the East Bay Plain in 1965 was about 81,000 acre-feet and inflow was about 30,000 acre-feet. In 1995 inflow was about 46,000 acre-feet while outflow was about 43,000 acre-feet. This points out why water levels and consequently, groundwater storage have been on the increase since 1965. How inflow and outflow have varied and progressed over the past 30 years is unknown.

Using information found in the preceding paragraphs and data presented by Muir in 1994 and 1995 (Muir, 1994 and Muir, 1996) it was estimated that subsurface discharge to maintain the seawater - freshwater interface at the

CUMULATIVE DEPARTURE



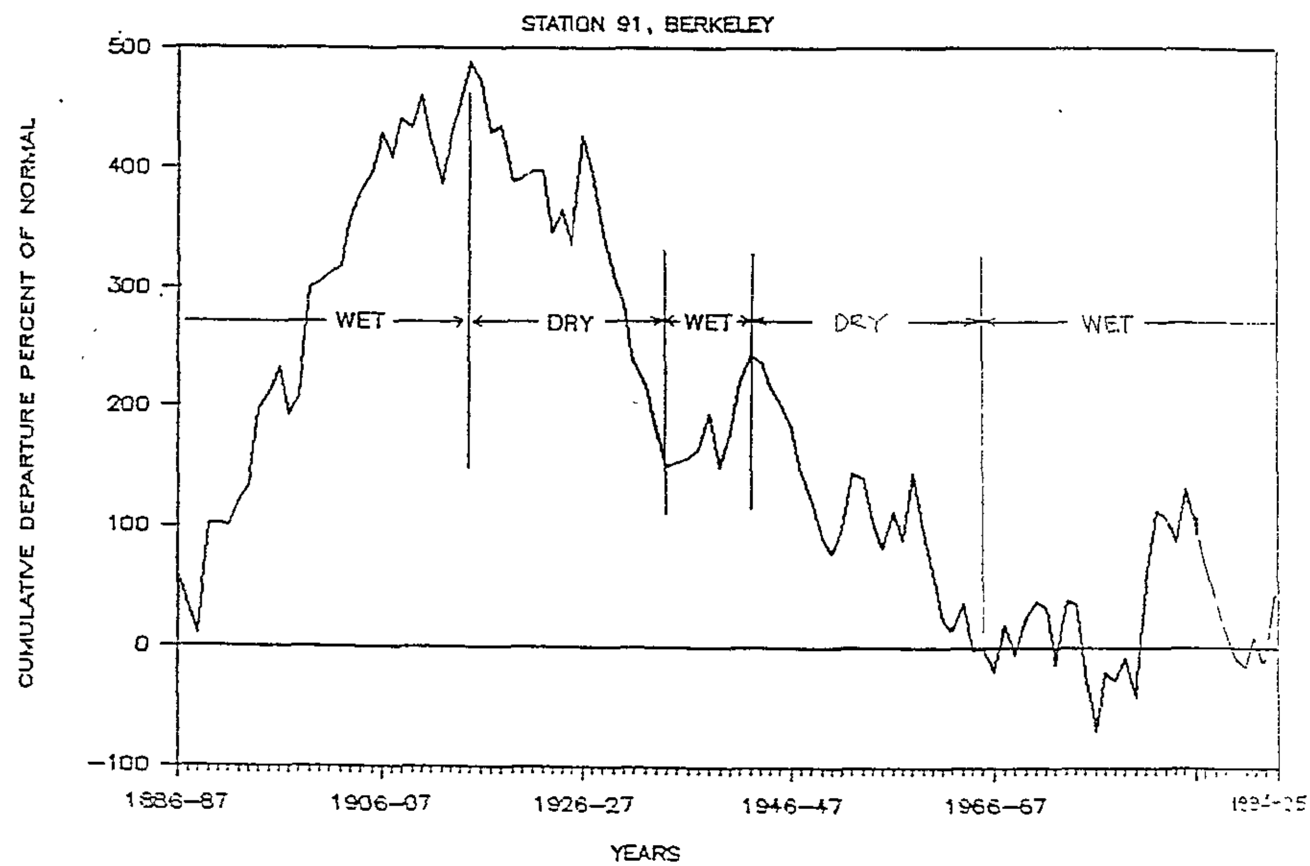
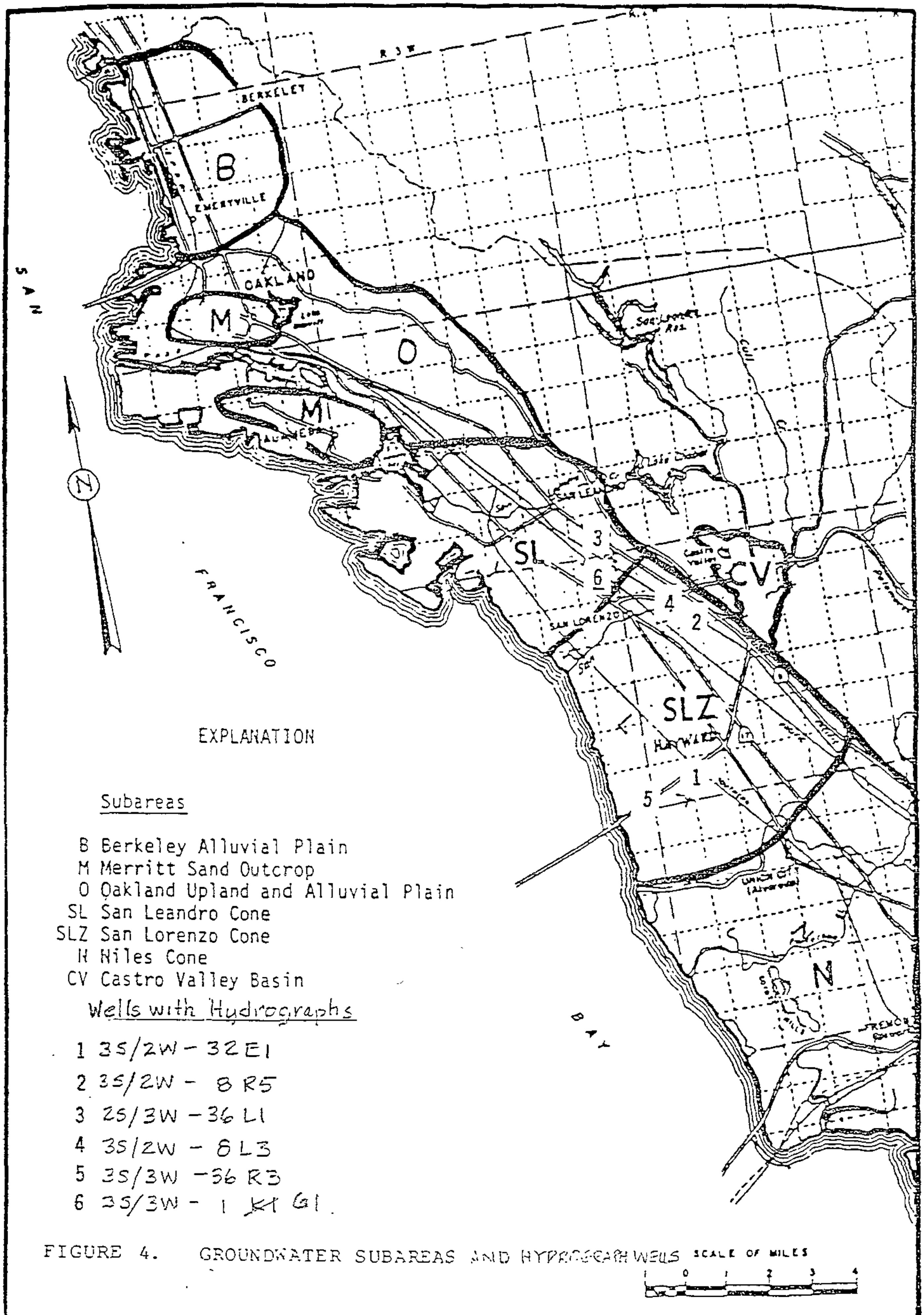


FIGURE 3. Cumulative Departure of Rainfall.



EXPLANATION

Subareas

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CV Castro Valley Basin

Wells with Hydrographs

1 3S/2W - 32E1
2 3S/2W - 8R5
3 2S/3W - 36L1
4 3S/2W - 8L3
5 3S/3W - 36R3
6 3S/3W - 1 ~~K1~~ G1

FIGURE 4. GROUNDWATER SUBAREAS AND HYDROGRAPH WELLS

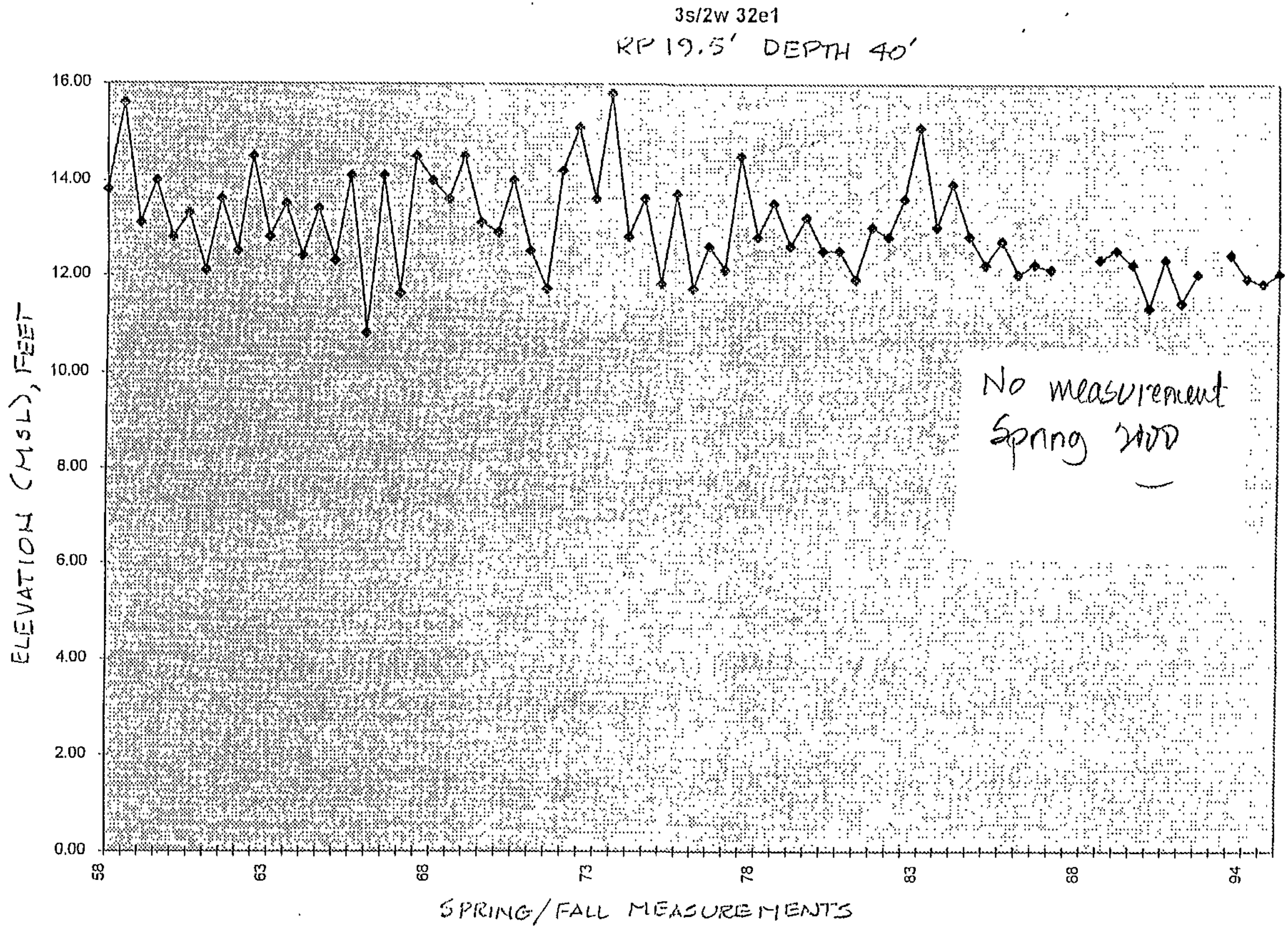

FIGURE 5. FLUCTUATIONS OF WATER LEVELS IN SHALLOW ZONE

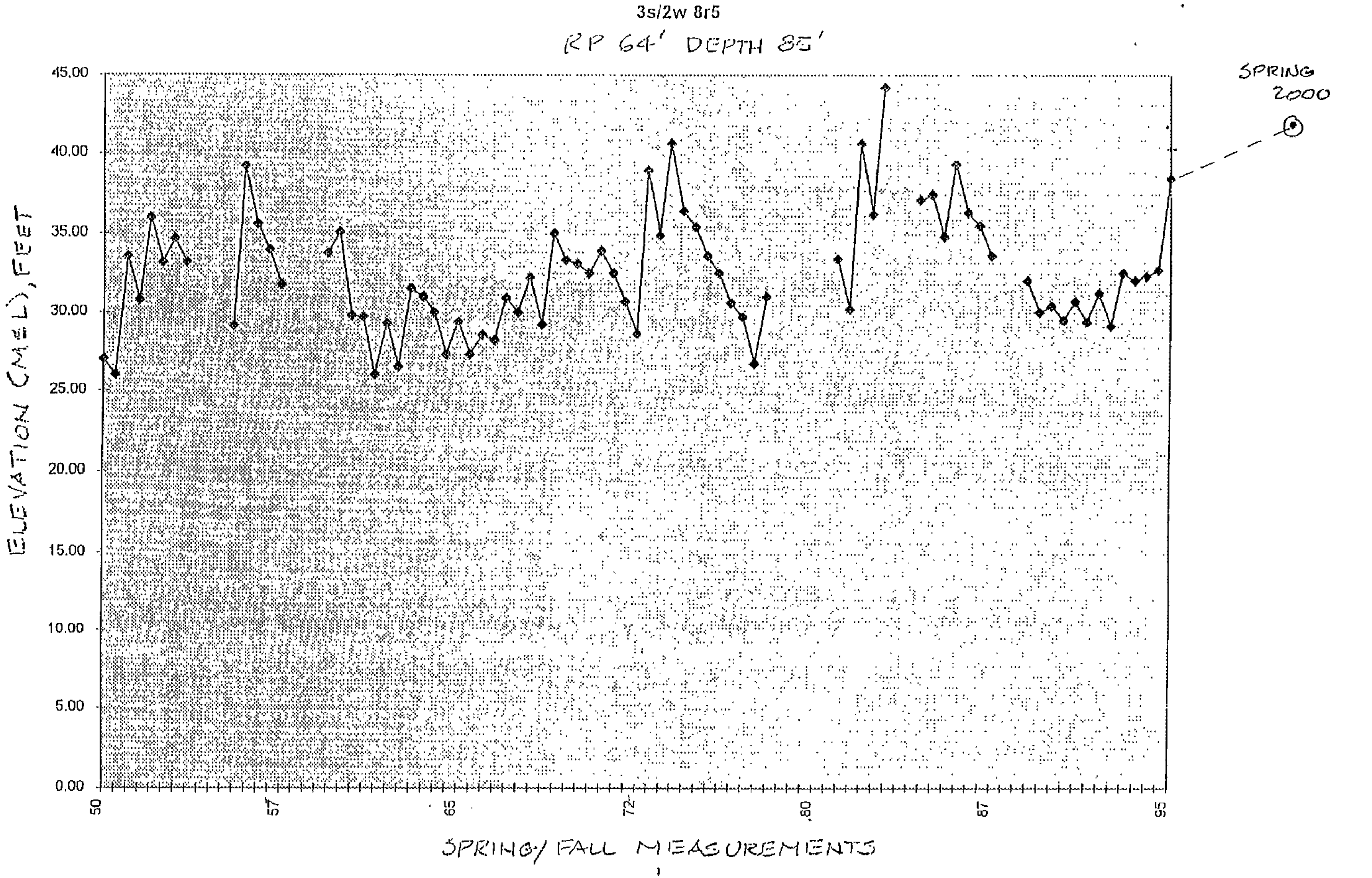

FIGURE 6. FLUCTUATIONS OF WATER LEVELS IN SHALLOW ZONE

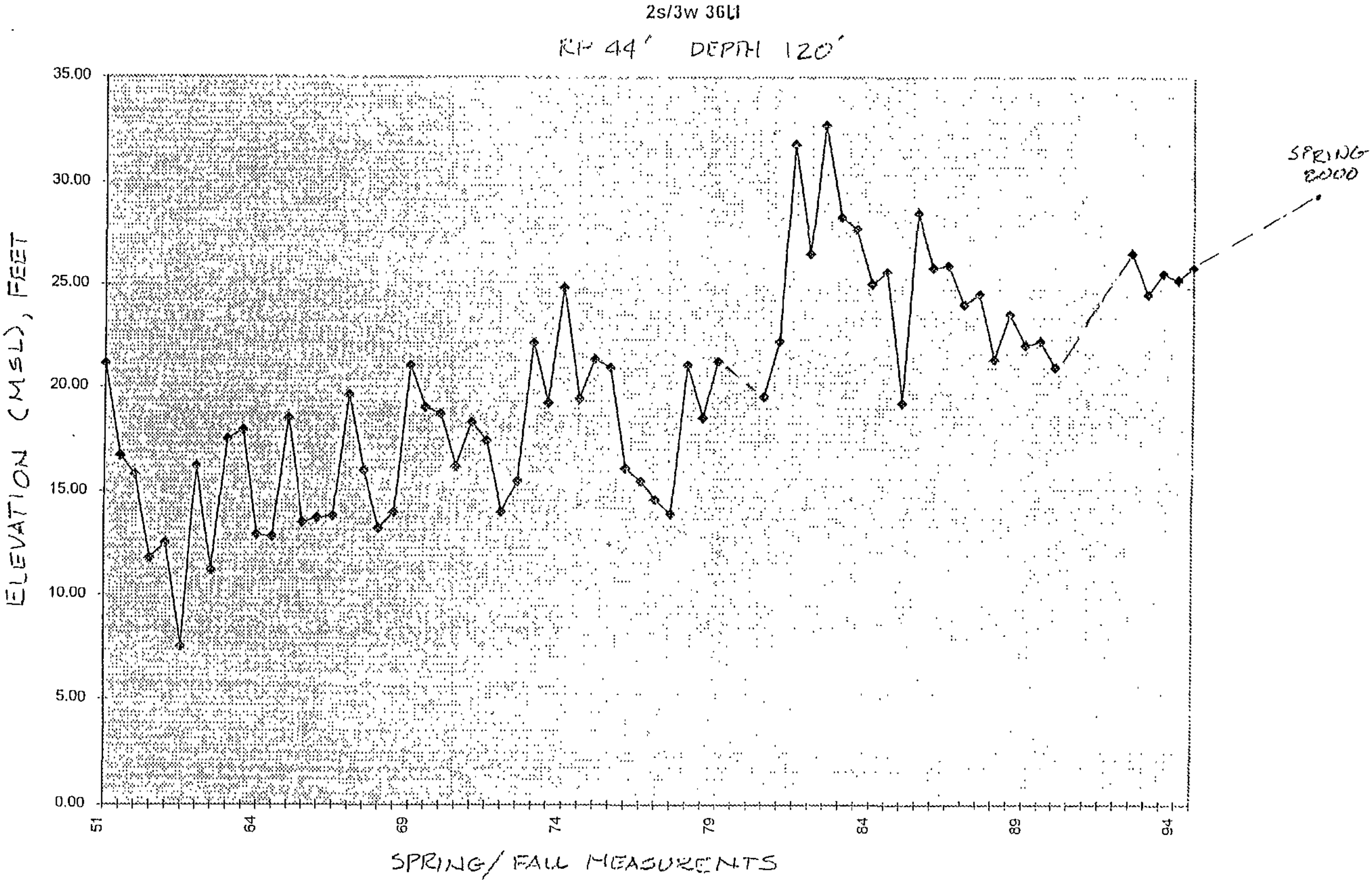

FIGURE 7. FLUCTUATIONS OF WATER LEVELS IN SHALLOW ZONE

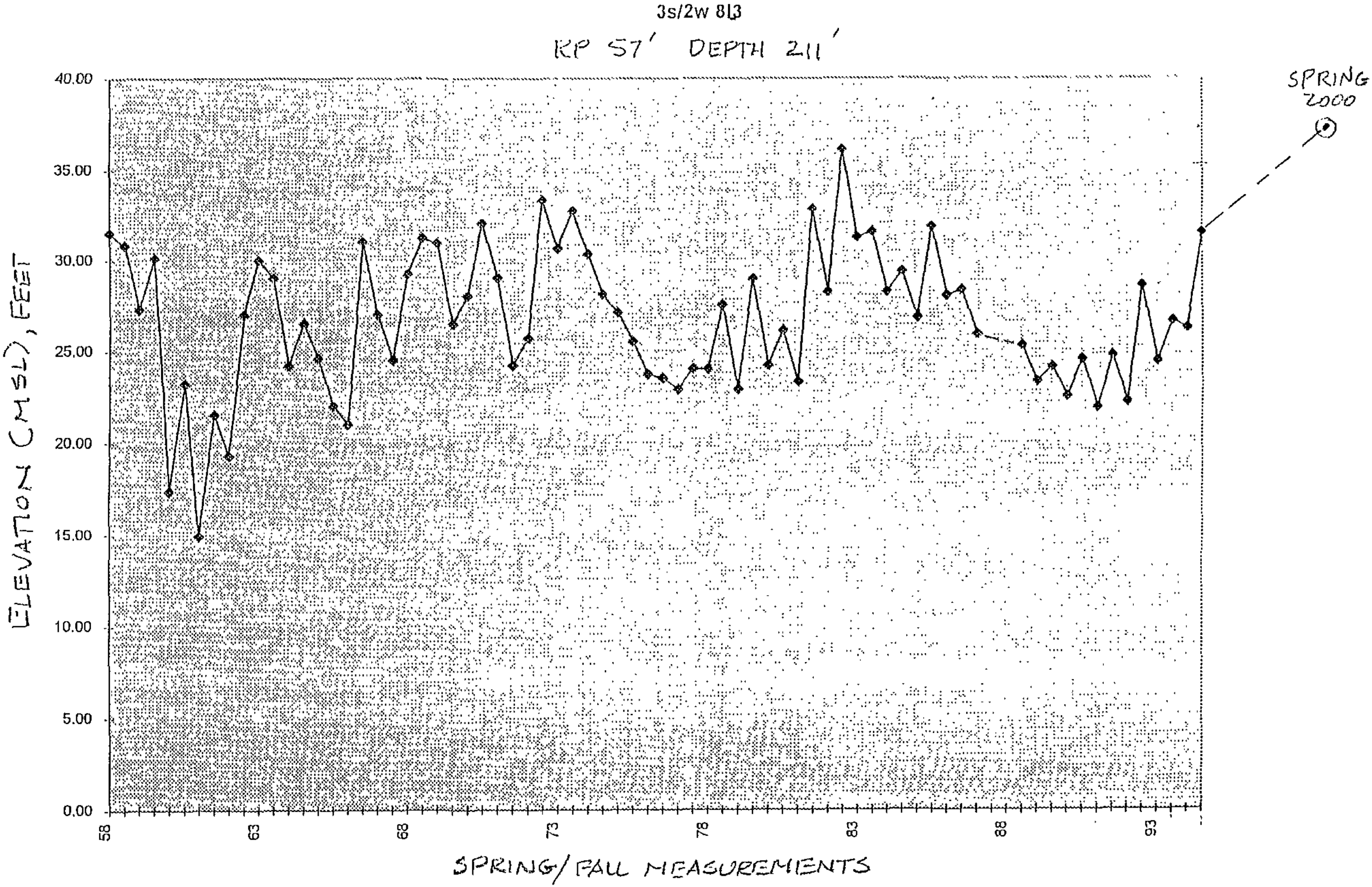

FIGURE 8. FLUCTUATIONS OF WATER LEVELS IN SHALLOW ZONE

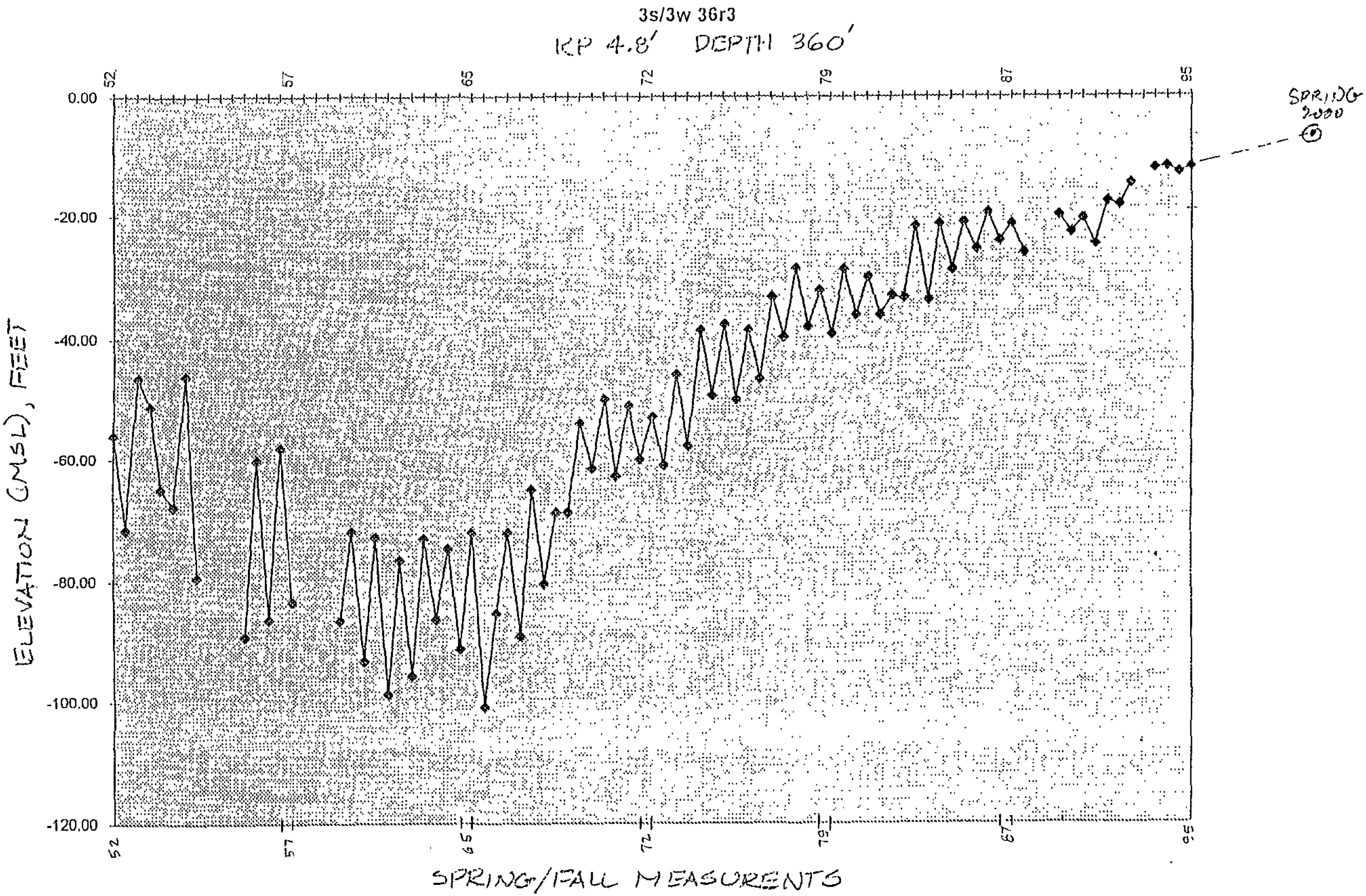

FIGURE 9. FLUCTUATIONS OF WATER LEVELS IN DEEP ZONE

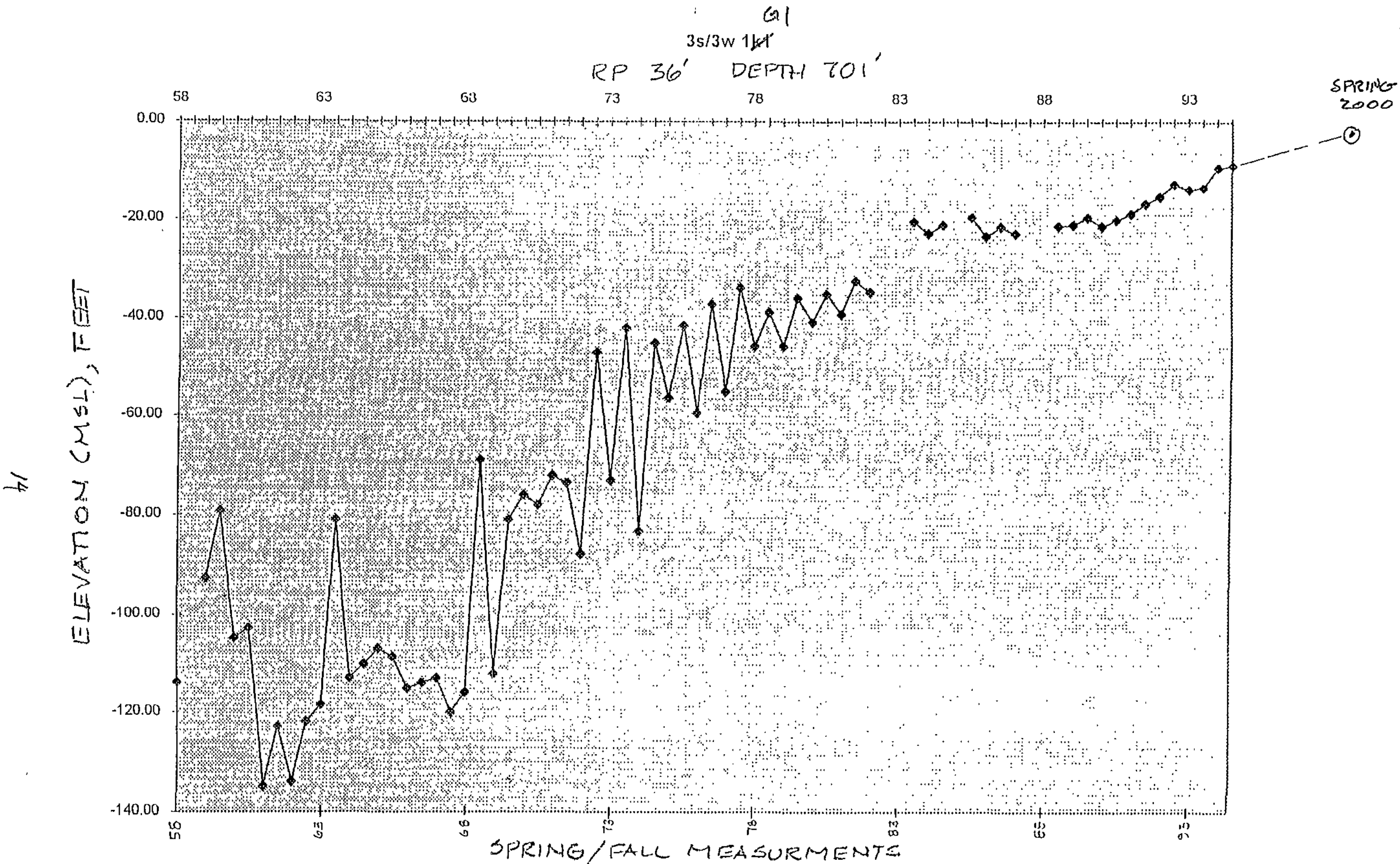

FIGURE 10. FLUCTUATIONS OF WATER LEVELS IN DEEP ZONE

Bay Margin was about 10,200 acre-feet per year. Based on the figure of 10,200 acre-feet per year for subsurface discharge and 25,800 acre-feet per year for evapotranspiration groundwater yield of the East Bay Plain is estimated to be about 10,000 acre-feet per year.

As previously stated the determination of groundwater yield for the East Bay Plain was made difficult because of the lack of the hydrologic parameters needed for a viable evaluation. However, the author felt that a yield figure based on even scantly data would be better than none at all. It establishes a starting point and the yield value can be revised when more hydrologic data becomes available.

REFERENCES

Department of Water Resources, 1994. Ground Water Storage Capacity of a Portion of the East Bay Plain, Alameda County, California: 35 p.

APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.B. Supporting Data for Groundwater Storage SMC

3.B.b NEBIGSM Groundwater Pumping Estimates

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DRAFT MEMORANDUM

To:	Mike Tognolini, EBMUD Eric Cartwright, ACWD	**CC:**	Dan Wendell
From:	Chris Smith, and Yiguo Liang	**Date:**	November 18, 2002
Reviewed by:	Ali Taghavi		
Subject:	**Estimates of GW Pumping in the SEBP-NCGB IGSM**		

The purpose of this memorandum is to document the methodology of estimating the groundwater pumping for input into the IGSM for the Southeast Bay Plain and Niles Cone Groundwater Basin Integrated Ground and Surface water Model (IGSM).

There are currently total of 328 records in the pumping data set. The groundwater pumping input data is developed in two separate sets of records, in the NCGB area and in the SEBP area, as follows:

- Records 1-280 are groundwater pumping in the NCGB area by specific wells
- Records 281-315 (except 285, and 299) are groundwater pumping in the SEBP area by specific wells
- Records 285 and 299 are groundwater pumping records for Holy Sepulchre Cemetery and Mission Hill Golf Course, which are new records added to the NCGB area
- Records 316-317 are groundwater recharge records in the NCGB area
- Record 318 is estimated agricultural groundwater pumping in the NCGB area prior to 1974, and subsequent to 1974, data is represented in metered well pumping
- Record 319 is estimated urban pumping in the BHF area prior to 1974, and subsequent to 1974, data is represented in metered well pumping
- Record 320 is estimated recharge in the Dry Creek
- Record 321 is not used
- Record 322 is the total recharge above and below Hayward fault in the NCGB area
- Record 323 is total domestic pumping in the SEBP area
- Records 324-328 are the estimated agricultural pumping for sub-regions 5-9, respectively.

Following are detailed description of the sources of data, analysis and/or interpretation methods used for each data in the above records.

The NCGB records are from the original NCGB IGSM input data sets except records 285 and 299, which were not included in the NCGB IGSM model input data. The historical monthly values for October 1964 to September 1985 are from the original calibrated NCGB model input database, and monthly values for October 1985 to September 2000 are from the NCGB model database that is updated to December 2001. Because this portion of data is directly incorporated into the current model, this

this memo will not describe those records. The SEBP records and the two additional NCGB records (285 and 299) are described below.

Pumping data for records 281 to 315 are complied based on three databases:

1. **Database 1 (DB 1):** Summary Table.xls. This database is compiled by EBMUD and contains the annual (1964 to 2000) pumping estimation for 19 groups of pumping records, primarily the industrial pumping in SEBP area. However, there are records of groundwater pumping for irrigation wells as well as domestic pumping for the SEBP area.
2. **Database 2 (DB 2):** BSPNORES.shp. This database is compiled by EBMUD and contains annual surface water delivery records to 83 SEBP industrial customers that potentially use groundwater as part of their water supply. These customers are identified to be potential groundwater users because they have backflow devices installed. These customers are in the cities of San Leandro, San Lorenzo, Oakland, Alameda, and Hayward, for the years 1986-2000. In addition, the deliveries for February and August are provided in this database.
3. **Database 3 (DB 3):** Hunts (082202).xls. This database is compiled by ACWD and contains annual pumping estimation and monthly distribution pattern for the Hunts cannery plants.

Because the model input database is in monthly time step, the annual database is distributed into monthly based on specific patterns for use categories of industrial, non-agricultural, irrigation, domestic, and agricultural/irrigation, as described below.

Two other sources of pumping are not included in the NCGB pumping. These include shallow groundwater pumping at gas stations and other spill sites; although the deeper extractions that may be from the Newark aquifer are included. In addition, domestic pumping from wells whose discharge opening are less than 2 inches, and irrigating sites less than one acre are not metered, and therefore, are not included in the groundwater pumping database.

Industrial Wells:

The annual industrial pumping records are distributed to monthly data based on monthly patterns for municipal/industrial water use in the study area. The primary monthly water use pattern is developed from charts available in the Department of Water Resources (DWR) publication "Municipal and Industrial Water Use: San Francisco Bay District, October 1965". The general patterns recorded in this publication showed peak water use in the summer months and less water use during the winter. The primary monthly pattern was adjusted for the industries or users that a February and August surface water use rate was provided in DB 2 data source. In some cases, the February and August water use rates could not fit the patterns from the DWR publication. These unusual patterns may be attributed to inaccurate data records or to unknown factors particular to each industry. In these cases, the primary monthly pattern from the DWR publication was used.

There are five industries in DB2 that have relatively large surface water use but no groundwater pumping estimates were provided in DB1. These five industries are: Alameda Gateway, George Burehler Jr., Monarch Ventures, P. F. Holdings LLC, R & A Trcuking. In order to estimate the groundwater pumping for these five industries, an analysis was conducted for nine other industries for

Table 1. Comparison of Groundwater

Estimated Groundwater Pumping *(AF/Yr)										
Year/Name	AB&I	Fleischman's/ Standard Brand	GP Gypsum	Hudson Lumber	Kelloggs / HB Chapman	Rattos	Red Star Yeast	Sconza Candy	Tharco	TOTAL
1986	673	390	384	14	59	32	246	0	0	1797
1987	673	411	384	14	59	32	246	0	0	1818
1988	673	547	384	19	34	32	246	0	31	1966
1989	673	521	384	25	23	32	246	0	31	1934
1990	307	530	384	16	23	32	267	37	31	1627
1991	307	399	384	16	12	32	261	37	31	1479
1992	307	455	384	8	0	32	252	37	31	1506
1993	307	439	384	0	0	32	264	37	31	1494
1994	307	165	353	0	0	32	258	37	31	1183
1995	40	478	322	0	0	32	252	37	31	1193
1996	40	329	322	0	0	32	252	37	31	1043
1997	40	394	322	0	0	32	246	37	31	1102
1998	40	243	322	0	0	32	252	37	0	926
1999	40	226	322	0	0	32	243	37	0	900
2000	40	201	322	0	0	32	240	37	0	873
Average	298	382	357	7	14	32	251	27	20	1389
Surface Water Delivery (AF/Yr)										
Year/Name	AB&I	Fleischman's/ Standard Brand	GP Gypsum	Hudson Lumber	Kelloggs / HB Chapman	Rattos	Red Star Yeast	Sconza Candy	Tharco	TOTAL
1986	94	541	138	30	0	6	78	2	18	907
1987	176	520	77	27	0	7	208	2	22	1039
1988	31	636	53	21	0	20	335	3	17	1114
1989	56	488	119	16	0	4	332	2	18	1034
1990	11	394	148	18	0	4	254	3	21	853
1991	14	429	53	17	96	5	258	2	19	892
1992	17	451	142	26	175	6	239	2	15	1074
1993	19	713	116	36	191	5	268	7	20	1376
1994	18	912	53	29	129	0	254	2	24	1421
1995	27	950	12	21	174	6	255	3	18	1466
1996	27	1011	68	23	7	2	219	2	17	1376
1997	37	869	110	21	3	0	258	1	20	1321
1998	44	677	93	17	2	0	273	1	16	1122
1999	29	496	89	4	3	0	267	1	18	906
2000	40	444	31	1	3	0	247	1	16	780
Average	43	635	87	20	52	4	250	2	19	1112

*Source: EBMUD

There are five industries in DB2 that have relatively large surface water use but no groundwater pumping estimates were provided in DB1. These five industries are: Alameda Gateway, George Burehler Jr., Monarch Ventures, P. F. Holdings LLC, R & A Trcuking. In order to estimate the groundwater pumping for these five industries, an analysis was conducted for nine other industries for which both surface water delivery and groundwater pumping data is available. These nine industries are listed in Table 1. This table compares the surface water delivery (from DB2) and estimated groundwater pumping provided by EBMUD. Note that the amount of surface water delivery is approximately the same as that for groundwater pumping for these nine industries as a whole, and for most of them individually. Therefore, an assumption was made that most of these industries receive approximately same amount of surface water and groundwater for their operation. This assumption was extended to estimate the groundwater pumping for the five industries listed above for the period of 1986-2000.

Since there is no surface water delivery data in DB2 for the period 1964-1985, the groundwater pumping for this period is estimated based on correlation to DB1 dataset. The 1964-85 annual groundwater pumping for the five industries listed above, and four municipal users (City of Alameda, City of San Leandro, San Leandro School District, and the San Lorenzo School District) was estimated based on average ratio of groundwater pumping between total annual pumping for all industries in DB1 and these users, for the period 1986-2000. The ratio was applied to a linearly extrapolated groundwater pumping based on industries in DB1 database back to 1965, to develop groundwater pumping for the above municipal users and industries. The annual estimated groundwater pumping data was then distributed to monthly based on the monthly pattern of surface water use.

Annual pumping records for the cannery industry was distributed to monthly data based on the monthly patterns available from Hunts Pumping data. This pattern was used for both Del Monte and Hunts canneries. Fleischman Yeast has monthly pumping records from 1986 to 2000. The monthly pattern for this period was used to estimate monthly pumping for the period 1964 and 1985. Similarly, Red Star Yeast is assumed to have the same monthly pattern of groundwater pumping as the Fleischmann due to the similarity of water use. Records of annual groundwater pumping for Kellogs and Granny Goose are evenly distributed to monthly due to lack of more detailed information on them, and assuming that these industries pumped evenly for washing and cleaning throughout the year. These records are shown on Table 2.

Table 2
Method of Monthly Distribution of Pumping for Each Industry

Pumping Record No.	Industry Name	Data Source	Distribution Method
281	American Brass & Iron	EBMUD (Summary Table.xls)	Adjusted DWR Monthly Pattern
282	Alameda Gateway	EBMUD (BPSNORES.SHP)	Adjusted DWR Monthly Pattern
289	Del Monte Well1	EBMUD (Summary Table.xls)	Hunts (canning) pumping pattern
290	Del Monte Well2	EBMUD (Summary Table.xls)	Hunts (canning) pumping pattern
291	Fleischmann	EBMUD (Summary Table.xls)	Pattern from measured 1986-2000 data
292	George Burehler Jr.	EBMUD (BPSNORES.SHP)	Adjusted DWR Monthly Pattern
293	GP Gypsum	EBMUD (Summary Table.xls)	Adjusted DWR Monthly Pattern
294	Granny Goose	EBMUD (Summary Table.xls)	Evenly distributed to each month
295	Not Used	N/A	N/A
296	Hudson Lumber	EBMUD (Summary Table.xls)	Adjusted DWR Monthly Pattern
297	Kellogs	EBMUD (Summary Table.xls)	Evenly distributed to each month
301	Monarch Ventures	EBMUD (BPSNORES.SHP)	Adjusted DWR Monthly Pattern
302	P.F. Holdings	EBMUD (BPSNORES.SHP)	Adjusted DWR Monthly Pattern
303	Hunt PlantA Well	ACWD (Hunts_082202.xls)	From ACWD (Hunts_082202.xls)
304	Hunt PlantB Well1	ACWD (Hunts_082202.xls)	From ACWD (Hunts_082202.xls)
305	Hunt PlantB Well2	ACWD (Hunts_082202.xls)	From ACWD (Hunts_082202.xls)
306	Hunt PlantB Well3	ACWD (Hunts_082202.xls)	From ACWD (Hunts_082202.xls)
307	R & A Trucking	EBMUD (BPSNORES.SHP)	Adjusted DWR Monthly Pattern

308	Rattos	EBMUD (Summary Table.xls)	Adjusted DWR Monthly Pattern
309	Red Star Yeast	EBMUD (Summary Table.xls)	Same pattern as the Fleischmann
310	Sconza Candy	EBMUD (Summary Table.xls)	Adjusted DWR Monthly Pattern
314	Tharco	EBMUD (Summary Table.xls)	Adjusted DWR Monthly Pattern
315	Trailer Haven	EBMUD (Summary Table.xls)	Adjusted DWR Monthly Pattern

Irrigation Wells

Wells in golf courses, cemeteries, and school districts are assumed to pump water for irrigation purpose. Therefore, the monthly distribution of groundwater pumping is assumed to be the same pattern as the monthly ET pattern for turf grass. Annual pumping for San Leandro and San Lorenzo school districts for the period of 1964-1985 is estimated as described in Industrial Wells. The cemetery pumping quantity provided in DB1 includes pumping for three cemeteries, two of which are outside the model area. Therefore, the pumping for Holy Sepulchre Cemetery is estimated proportional to the relative acreage to the total acreage of all three cemeteries. The records for the other two cemeteries that are outside model area are assumed zero. Table 3 lists the records used for irrigation water use.

Table 3
Records of Groundwater Pumping for Irrigation Use

Pumping Record No.	Pumper Name
283	Alameda Golf Course
284	Cemetery-Cypress (Not in Model Area)
285	Cemetery-Holy Sepulchre
286	Cemetery-Mt View (Not in Model Area)
298	Marina Golf Course
299	Mission Hill Golf Course
311	San Leandro School District
312	San Lorenzo School District
313	San Lorenzo Park

Municipal Wells

Wells in City of Alameda, City of San Leandro, and Mohrland Mutural Water Co are assumed to pump water in the same monthly pattern as the city water use, as obtained from the Department of Water Resources (DWR) publication "Municipal and Industrial Water Use: San Francisco Bay District, October 1965". Annual pumping estimations for users of City of Alameda and City of San Leandro for the period of 1964-1985 are described in Industrial Wells. The municipal wells are listed in Table 4.

Table 4 Records of Groundwater Pumping for Municipal Use	
Pumping Record No.	**Pumper Name**
287	City of Alameda
288	City of San Leandro
300	Mohrland Mutural Water Co.

Domestic Pumping

The domestic pumping is estimated to be 439 AF/Yr, based on Kenneth Muir's estimates (EBMUD DB 1). The domestic pumping is typically used for domestic irrigation, and therefore is distributed to monthly data based on turf grass ET monthly pattern. The spatial distribution of the domestic pumping is based on location of available backflow devices as mapped by EBMUD. The domestic pumping is therefore distributed to each model element based on the density of backflow device estimated to be in each finite element. Record number 323 in model input data file is assigned to domestic pumping in SEBP area.

Agricultural Pumping

Agricultural pumping in the SEBP area is estimated based on the unit water use methodology. Since the Alameda and Marina/Tony Lema Golf Courses have groundwater pumping data and irrigated acreage data, the unit water use for turf irrigation in SEBP area is estimated based on long-term average value for these two golf courses. Table 5 shows the average unit water use for these two golf courses to be 2.4 AF/AC. This unit water use is applied to other turf irrigation acreages based on irrigation area from DWR land use data.

Table 5. Average Unit Water Use for Turf Irrigation in SEBP Area*

	Acreage**	Pumping*** (AF/Yr)	Unit Water Use (AF/AC)
Marina/Tony Lema Golf Course	155	399	2.6
Alameda Golf Course	188	430	2.3
Average	**172**	**415**	**2.4**

* Data for Marina/Tony Lema Golf Couse is for 1982-2000 and for Alameda Golf Course is for 1965-1986.

** Based on USGS quad sheet.

*** Reported by EBMUD

Table 6. NCGB-SEBP IGSM South East Bay Plain Acreage and Water Supply Summary

	ACREAGE			Irrigated Turf Water Supply				Urban Water Supply				Unit Water Use (Unit: AF/AC)		
	Irrigation	Urban	Total Developed	Irrigation By Well [1]	Estimated Ag. Pumping [2]	Reclaimed Water [3]	Total	M&D Pumping [1]	Industrial Pumping [1]	Imported Surface Water [1]	Total	Turf Irrigation [4]	D&I [5]	Overall [6]
1965	1102	34510	35612	595	1743	0	2338	733	4846	70379	75958	2.12	2.20	2.20
1966	1102	34510	35612	591	1743	0	2334	727	4804	71508	77039	2.12	2.23	2.23
1967	1102	34510	35612	588	1743	0	2331	722	4750	71496	76967	2.12	2.23	2.23
1968	1102	34510	35612	584	1743	0	2327	716	4693	72913	78322	2.11	2.27	2.26
1969	1102	34510	35612	579	1743	0	2322	711	4639	73167	78516	2.11	2.28	2.27
1970	1102	34510	35612	576	1743	0	2319	705	4584	74465	79754	2.10	2.31	2.30
1971	1099	34497	35596	572	1743	0	2315	700	4529	69596	74825	2.11	2.17	2.17
1972	1097	34485	35582	568	1740	0	2308	695	4475	73257	78427	2.10	2.27	2.27
1973	1093	34474	35567	565	1731	0	2296	689	4419	68390	73498	2.10	2.13	2.13
1974	1092	34461	35553	560	1724	0	2284	684	4365	66879	71928	2.09	2.09	2.09
1975	1088	34450	35538	557	1718	0	2275	678	4310	68368	73355	2.09	2.13	2.13
1976	1086	34437	35523	553	1710	0	2263	672	4255	71151	76078	2.08	2.21	2.21
1977	1083	34425	35508	549	1703	0	2252	667	4303	46594	51564	2.08	1.50	1.52
1978	1080	34414	35494	546	1695	0	2241	662	3868	47586	52115	2.07	1.51	1.53
1979	1076	34402	35478	541	1688	0	2229	656	4014	55669	60339	2.07	1.75	1.76
1980	1075	34392	35467	537	1684	0	2221	650	3759	55037	59446	2.07	1.73	1.74
1981	1071	34379	35450	534	1673	0	2207	645	3525	59874	64045	2.06	1.86	1.87
1982	1068	34368	35436	885	1669	0	2554	640	3373	59431	63443	2.39 [7]	1.85	1.86
1983	1065	34355	35420	926	1661	0	2587	634	3319	61078	65030	2.43	1.89	1.91
1984	1063	34344	35407	921	1655	0	2576	628	3263	66357	70249	2.42	2.05	2.06
1985	1059	34332	35391	917	1648	0	2565	624	3208	68648	72480	2.42	2.11	2.12
1986	1057	34319	35376	903	1639	0	2542	703	3020	69654	73377	2.40	2.14	2.15
1987	1063	34316	35379	515	1632	430 [8]	2577	724	2872	68503	72099	2.42	2.10	2.11
1988	1070	34314	35384	453	1652	430	2535	732	2976	60525	64233	2.37	1.87	1.89
1989	1077	34312	35389	447	1668	430	2545	591	3026	57230	60847	2.36	1.77	1.79
1990	1084	34310	35394	448	1683	430	2561	545	1907	57677	60129	2.36	1.75	1.77
1991	1091	34307	35398	446	1701	430	2577	544	1780	52630	54954	2.36	1.60	1.63
1992	1098	34305	35403	440	1721	430	2590	552	1731	53167	55450	2.36	1.62	1.64
1993	1106	34301	35407	449	1738	430	2617	567	1748	55310	57625	2.37	1.68	1.70
1994	1113	34299	35412	451	1751	430	2632	549	1562	57745	59856	2.36	1.75	1.76
1995	1120	34296	35416	447	1768	430	2644	536	1361	57931	59828	2.36	1.74	1.76
1996	1120	34296	35416	463	1785	430	2677	537	1353	61620	63510	2.39	1.85	1.87
1997	1120	34296	35416	473	1785	430	2687	545	1307	62785	64636	2.40	1.88	1.90
1998	1120	34296	35416	472	1785	430	2687	538	1232	59623	61393	2.40	1.79	1.81
1999	1120	34296	35416	480	1785	430	2695	535	1164	62056	63755	2.41	1.86	1.88
2000	1120	34305	35425	457	1785	430	2672	536	1141	64478	66156	2.39	1.93	1.94
Avg	**1091**	**34385**	**35476**	**572**	**1716**	**430**	**2455**	**638**	**3208**	**63133**	**66978**	**2.25**	**1.95**	**1.96**

Note:

1 Base on data received from EBMUD. See text for estimation method
2 Data estimated based on unit water use from Alameda Golf Course and Marina/Tony Lema Golf Course
3 Reclaimed water used by Alameda Golf Course. Estimated based on 1987 reported reclamation wate use
4 Total turf irrigation water divided by irrigation acreage
5 Total domestic and industrial water supply divided by urban acreage
6 The sum of total irrigation water supply and total urban water supply divided by total developed acreage
7 Tony Lema Golf Course went into operation
8 Alameda Golf Course stopped to use G.W and started to use reclaimed water

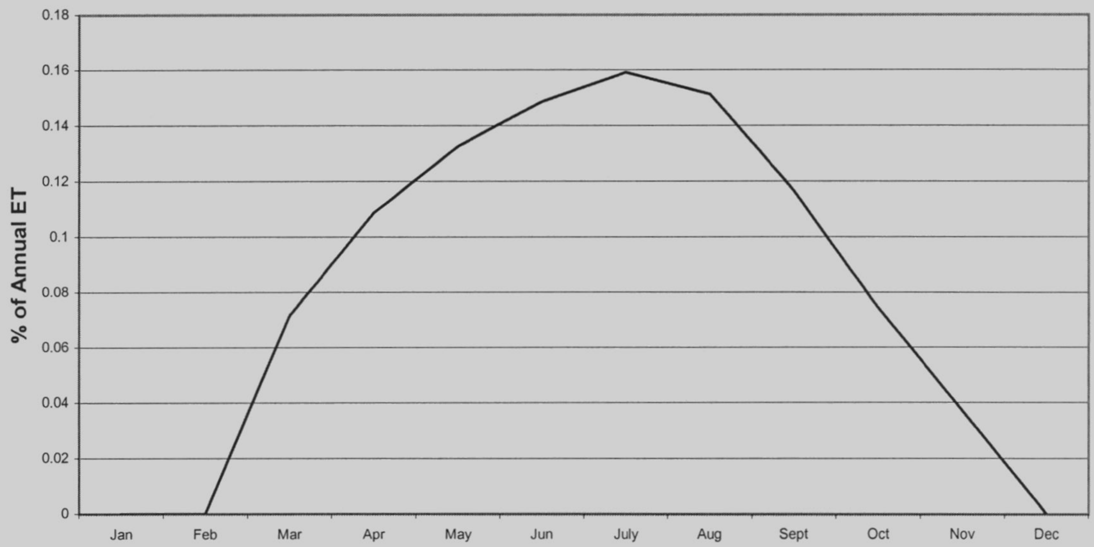
Table 7. NCGB-SEBP IGSM NCGB Acreage and Water Supply Summary

	Acreage			Agricultural Water Supply [1]				Municipal Water Supply [1]					Unit Water Use (Unit: AF/AC)		
	Agricultural	Urban	Total Developed	Agricultural	City Parks	Non-Municipal Recreation	Total Ag Water Supply	ACWD GW Production	CUCC GW Production [7]	Industrial	Surface Water	Total Muni. Water Supply	Ag [2]	M&I [3]	Overall [4]
1965	10733	15318	26051	19367 [5]	145	0	19512	10605	0	28	10885	21518	1.82	1.40	1.58
1966	9782	15715	25497	18438	145	0	18583	11286	0	28	12704	24017	1.90	1.53	1.67
1967	8828	16108	24936	14213	145	0	14358	12135	0	26	13726	25887	1.63	1.61	1.61
1968	7875	16500	24375	13109	145	0	13254	12936	0	25	12630	25591	1.68	1.55	1.59
1969	6922	16892	23814	12110	145	0	12255	13842	0	24	12419	26286	1.77	1.56	1.62
1970	7122	17284	24406	12776	145	0	12921	13577	0	23	12955	26555	1.81	1.54	1.62
1971	4917	17676	22593	8728	145	0	8873	13336	0	22	14058	27416	1.80	1.55	1.61
1972	4716	18589	23305	8668	145	0	8813	13660	0	24	15221	28904	1.87	1.55	1.62
1973	4617	19501	24118	8379	145	0	8524	12750	0	22	16521	29294	1.85	1.50	1.57
1974	4917	20414	25331	4339 [6]	431	4	4774	11838	185	20	18152	30195	0.97	1.48	1.38
1975	5019	21326	26345	6114	911	541	7566	16100	2079	4727	17205	40111	1.51	1.88	1.81
1976	5019	22239	27258	7986	1029	764	9779	14373	2135	4326	19293	40128	1.95	1.80	1.83
1977	4694	23151	27845	5517	685	847	7049	9133	621	2648	22691	35094	1.50	1.52	1.51
1978	4716	23622	28338	4726	756	438	5920	11336	254	2101	17788	31479	1.26	1.33	1.32
1979	4414	24092	28506	4838	546	478	5862	11994	1169	1751	23170	38084	1.33	1.58	1.54
1980	4315	24563	28878	4511	1056	653	6220	14939	270	1711	20815	37735	1.44	1.54	1.52
1981	4517	25032	29549	4657	1372	627	6656	15963	678	1520	18800	36960	1.47	1.48	1.48
1982	3814	25505	29319	3211	1301	436	4947	14804	0	1346	12532	28683	1.30	1.12	1.15
1983	3814	25975	29789	3293	1351	432	5076	14443	0	1273	20193	35910	1.33	1.38	1.38
1984	3012	26447	29459	3239	919	363	4521	16729	276	1368	17396	35769	1.50	1.35	1.37
1985	2710	26917	29627	3192	1021	366	4579	17731	356	1507	27148	46741	1.69	1.74	1.73
1986	3012	27388	30400	2443	1181	382	4006	19457	372	1428	25890	47147	1.33	1.72	1.68
1987	2912	27387	30299	2664	1389	604	4657	22987	680	1816	27936	53419	1.60	1.95	1.92
1988	2776	27861	30637	2345	1399	437	4181	22914	708	1685	28524	53830	1.51	1.93	1.89
1989	2640	28338	30978	1634	1387	343	3364	22696	810	1868	29302	54676	1.27	1.93	1.87
1990	2503	28818	31321	1382	1489	463	3334	24029	392	2121	25143	51686	1.33	1.79	1.76
1991	2368	29295	31663	1516	1049	392	2957	23260	769	2004	22317	48350	1.25	1.65	1.62
1992	2230	29759	31989	1220	1158	416	2793	25258	819	2109	24863	53049	1.25	1.78	1.75
1993	2094	30203	32297	1329	1124	299	2752	22349	274	1970	23499	48091	1.31	1.59	1.57
1994	1960	30735	32695	1352	1319	223	2894	16030	0	1777	36320	54127	1.48	1.76	1.74
1995	2394	31283	33677	1199	1173	202	2574	15306	0	1793	29765	46863	1.08	1.50	1.47
1996	2394	31283	33677	1095	1471	210	2776	15618	0	1682	31035	48334	1.16	1.55	1.52
1997	2394	31283	33677	733	1743	240	2716	20642	0	1637	38252	60530	1.13	1.93	1.88
1998	2394	31283	33677	424	1259	46	1729	16938	0	1570	37793	56301	0.72	1.80	1.72
1999	2394	31283	33677	246	1117	57	1420	19554	0	1462	35162	56178	0.59	1.80	1.71
2000	2394	31283	33677	326	1335	129	1789	20570	0	1876	39212	61658	0.75	1.97	1.88
Avg	**4259**	**24732**	**28991**	**5314**	**897**	**289**	**6500**	**16420**	**357**	**1426**	**22537**	**40739**	**1.53**	**1.63**	**1.66**

Note:

1. Data from ACWD
2. Total agricultural water supply divided by agricultural acreage
3. Total municipal water supply divided by urban acreage
4. The sum of total agricultural water supply and total municipal water supply divided by total developed acreage
5. From 1965 to 1973, agricultural demand was restimated using CUAW method.
6. Since 1974, agricultural demand is metered.
7. ACWD acquired CUCC service area in 1994.

Figure 1. ET monthly pattern for pasture in the SEBP_NCGB area



Water Use Consistency

In order to ensure that the water uses in the two basins are consistent, an annual analysis of water use by type and land use acreage was performed. Tables 6 and 7 show the results. According to these tables, overall water use in each area is 1.96 AF/AC and 1.66 AF/AC in SEBP and NCGB, respectively.

Summary

Based on the available data for the Southeast Bay Plain and Niles Cone groundwater basin, the long-term average annual groundwater pumping for all model area is estimated to be approximately 39,797 AF/Yr. Tables 8 and 9 summarize the average annual groundwater pumping by each basin and for each category. Figures 2 and 3 show the categorized annual groundwater pumping for the SEBP and NCGB areas, respectively.

Table 8. Average Annual Pumping (AF) in the SEBP Areas (1965-2000)

	Pumping Category	Amount
Sub Total M&I		**3,842**
	Domestic Use	439
	Municipal Wells	199
	Industrial Wells	3,208
Sub Total Agricultural		**2,288**
	Crop Irrigation	N/A
	Turf Irrigation by Well	572
	Turf Irrigation by Estimation	1716
Total Groundwater Pumping		**6,130**

Table 9. Average Annual Pumping (AF) in the NCGB Area (1965-2000)		
	Pumping Category	**Amount**
Sub-total Irrigation		**6,211**
	Agricultural Crop Irrigation	5,314
	Turf Irrigation	897
Sub-total M&I		**21,787**
	Industrial	1,426
	Non-municipal recreation	289
	Citizen's Utility Co.(inherited by ACWD)	357
	ACWD production	16,420
	Estimated Urban	3,295
Sub-total Others		**5,669**
	Aquifer Reclamation	4,676
	Salinity Barrier	65
	L.U.F.T. cases	25
	Misc.	917
Total NCGB		**33,666**

Figure 2. Annual Groundwater Pumping in the SEBP Area

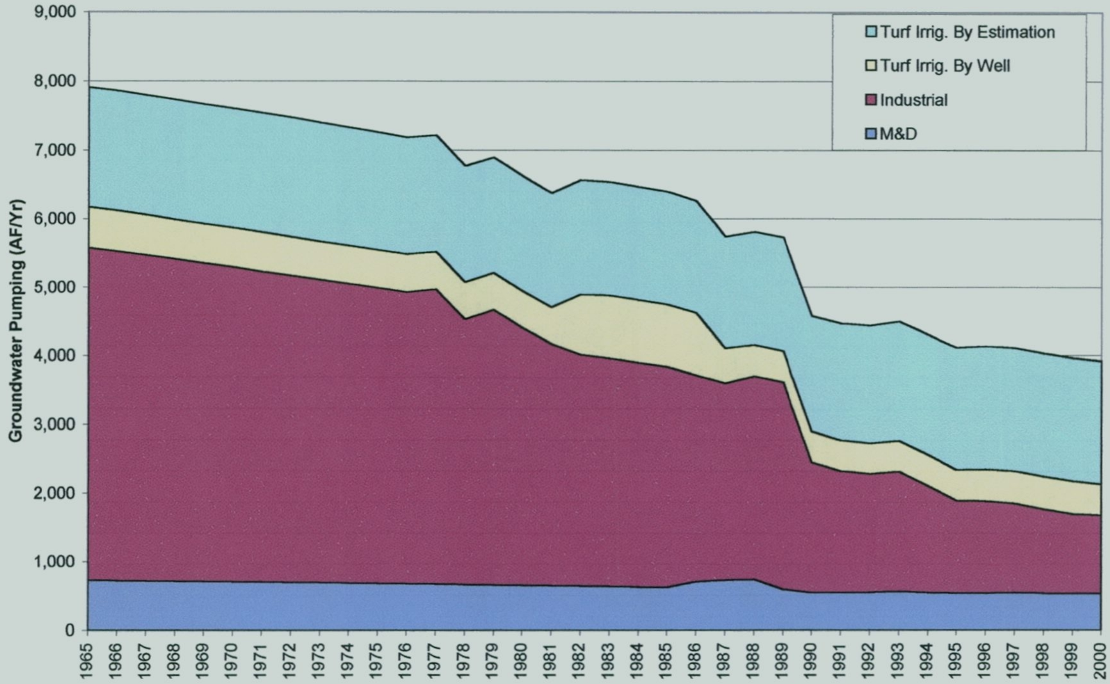


Figure 3. Annual Groundwater Pumping in the NCGB Area

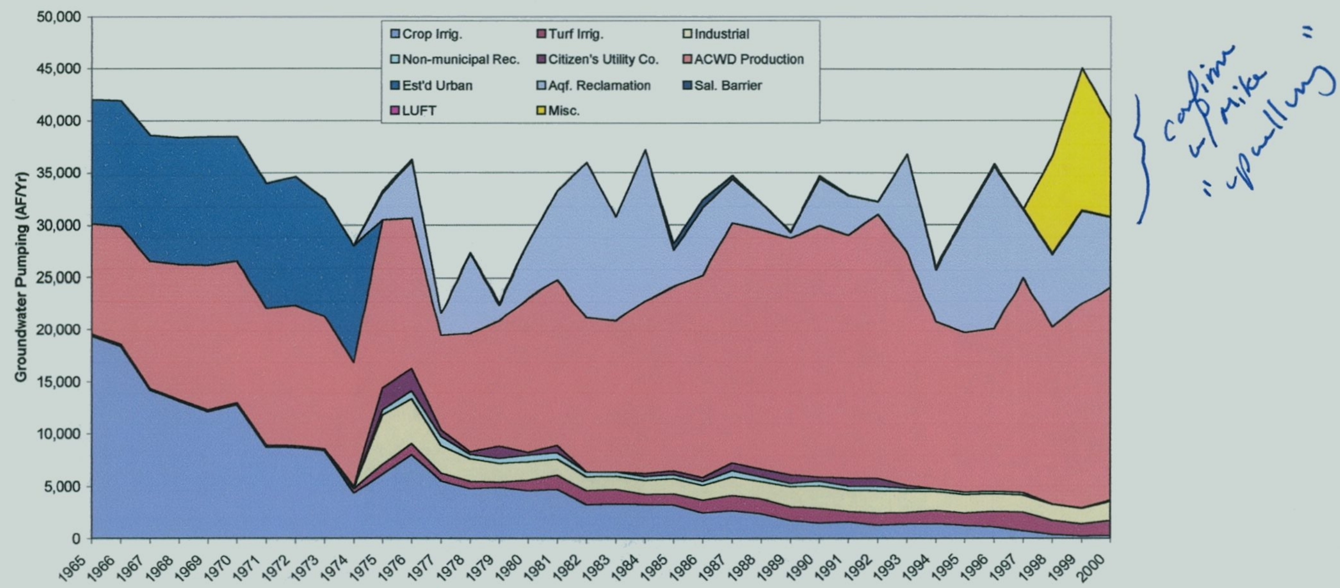
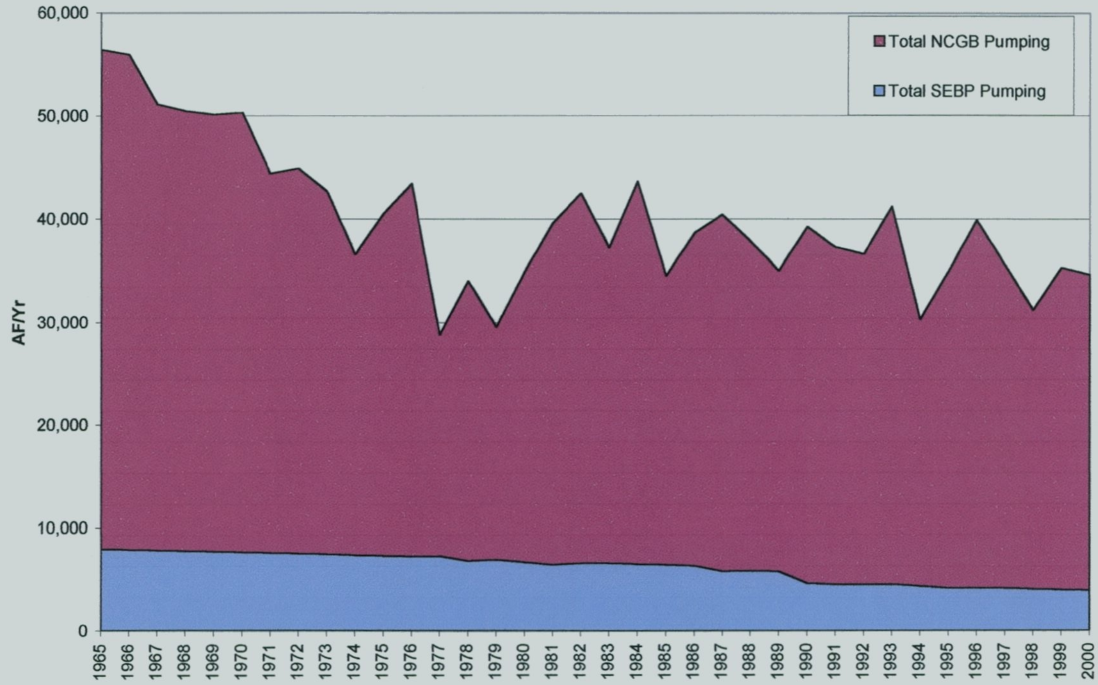


Figure 4 shows the annual groundwater pumping for NCGB and SEBP areas for the 1965 to 2000 water years.

Figure 4. Annual Groundwater Pumping for NCGB and SEBP Areas



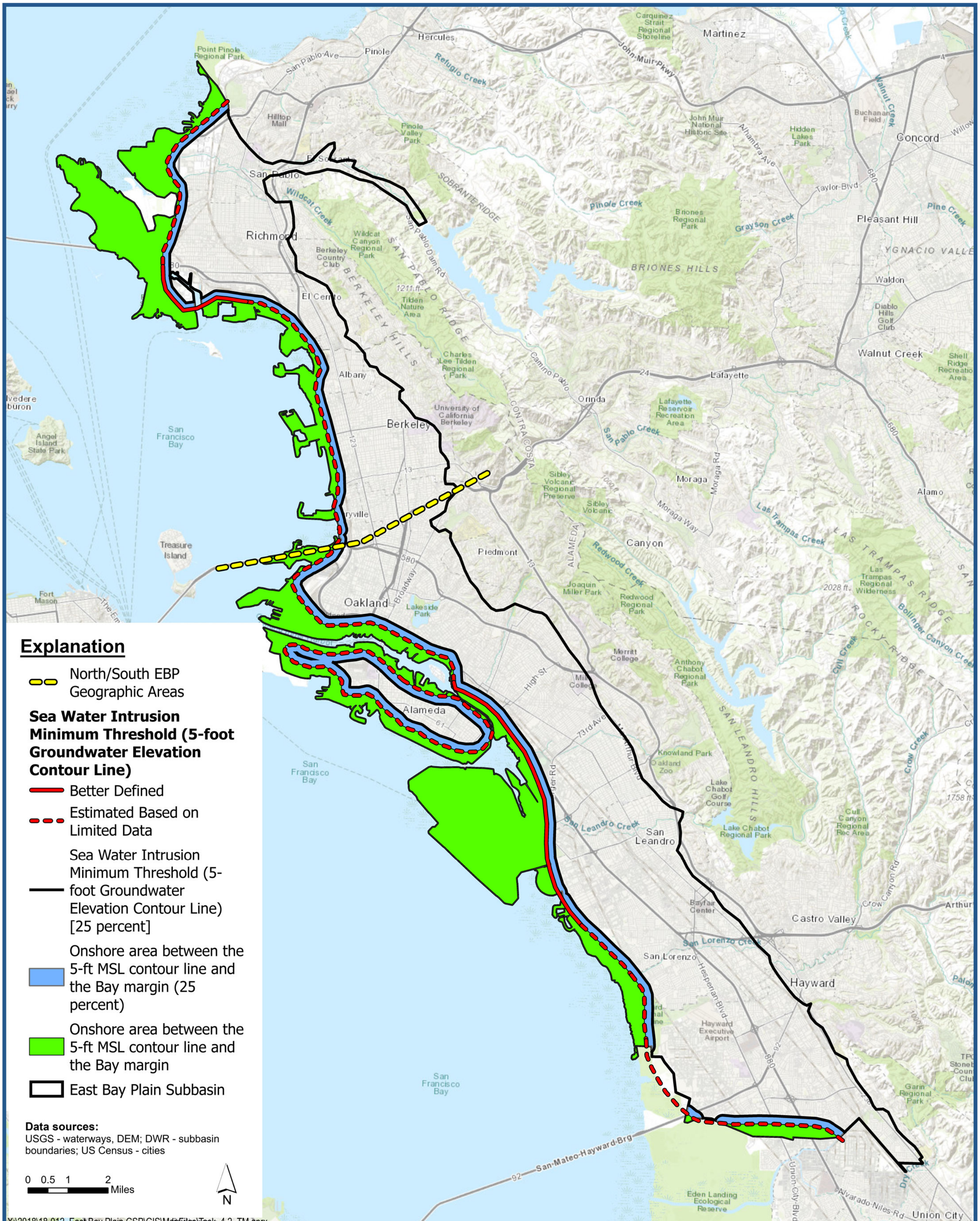
APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.C. Supporting Data for Seawater Intrusion SMC

APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.C. Supporting Data for Seawater Intrusion SMC

3.C.a Inland Migration Map



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Seawater Intrusion Minimum Threshold (25 percent)

East Bay Plain Subbasin
Groundwater Sustainability Plan

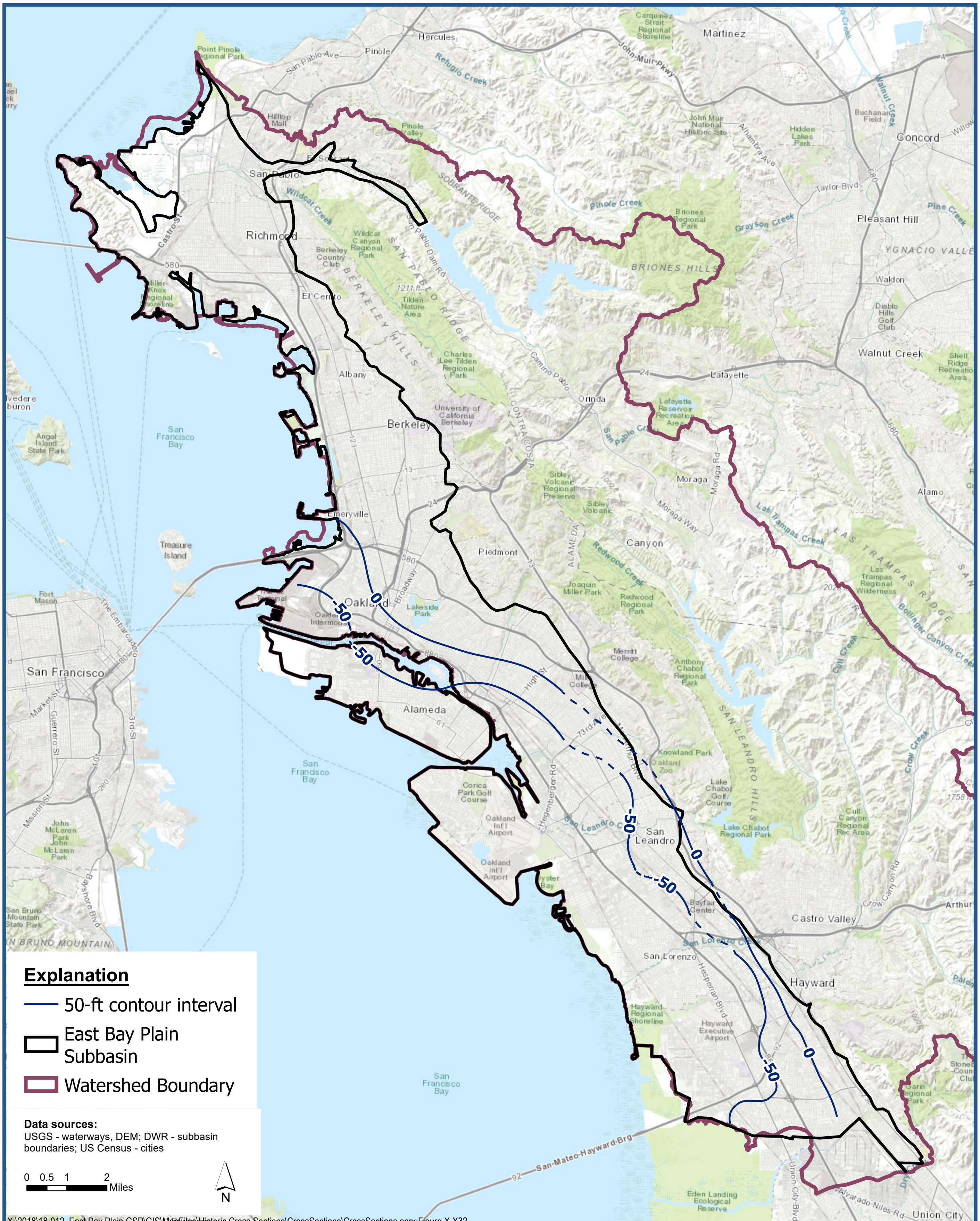
Figure 1-1

APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.D. Supporting Information for Subsidence SMC

3.D. Supporting Information for Subsidence SMC

3.D.a Historical Groundwater Elevation Contour Maps



Luhdorff & Scalmanini Consulting Engineers

Undifferentiated Deeper Aquifers Groundwater Elevation Contour Map - Spring 1958

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 3D-1

Luhdorff & Scalmanini Consulting Engineers

Undifferentiated Upper Aquifers Groundwater Elevation Contour Map - Fall 1958

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 3D-2

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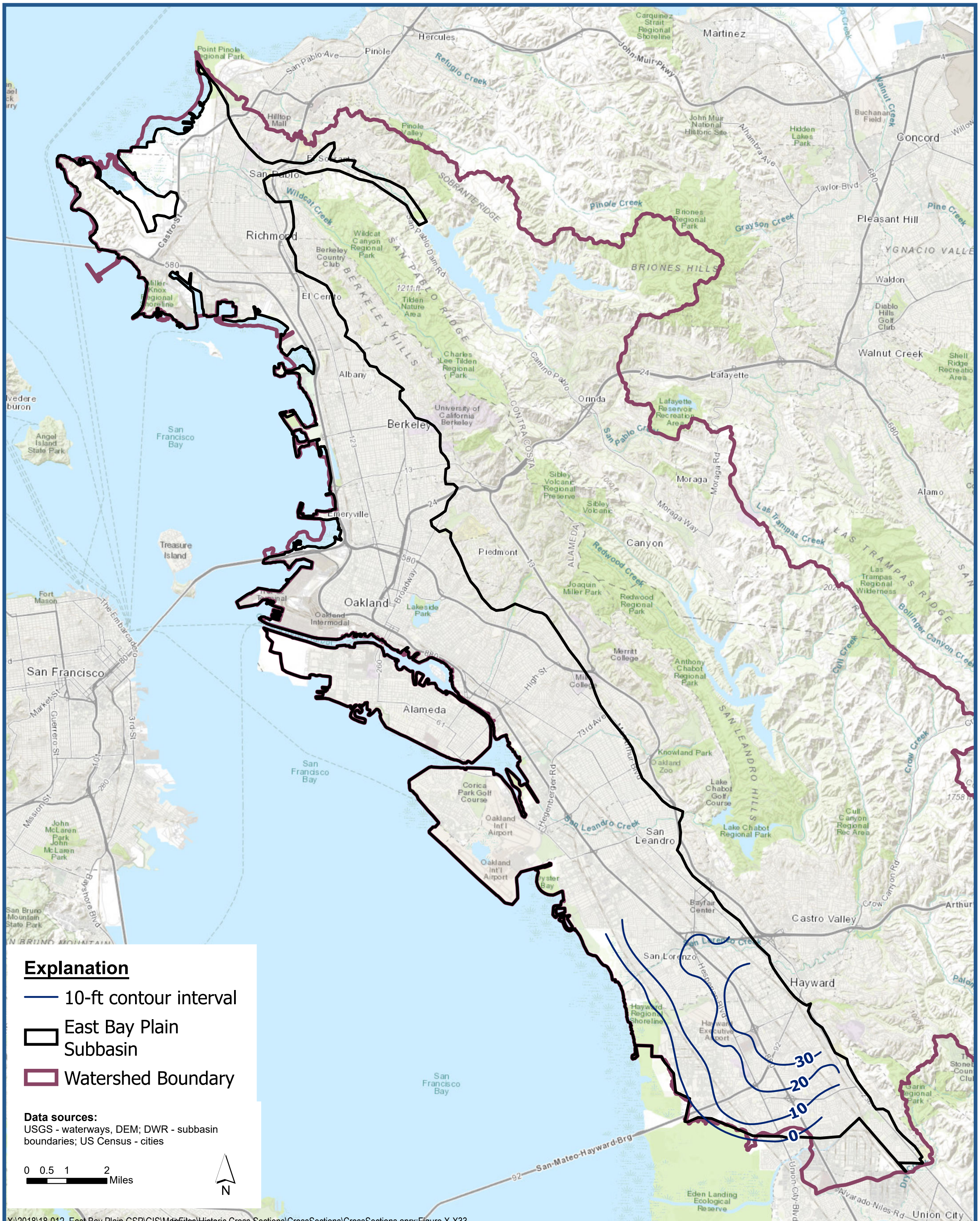
Undifferentiated Deeper Aquifers Groundwater Elevation Contour Map - Spring 1961

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure 3D-3



Luhdorff & Scalmanini
Consulting Engineers

Undifferentiated Shallow Aquifers Groundwater Elevation Contour Map - Spring 1961

Figure 3D-4

East Bay Plain Subbasin
Groundwater Sustainability Plan

APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.D. Supporting Information for Subsidence SMC

3.D.b Groundwater Elevation Hydrographs

Section E-3

Intermediate Aquifer Zone Groundwater Hydrographs

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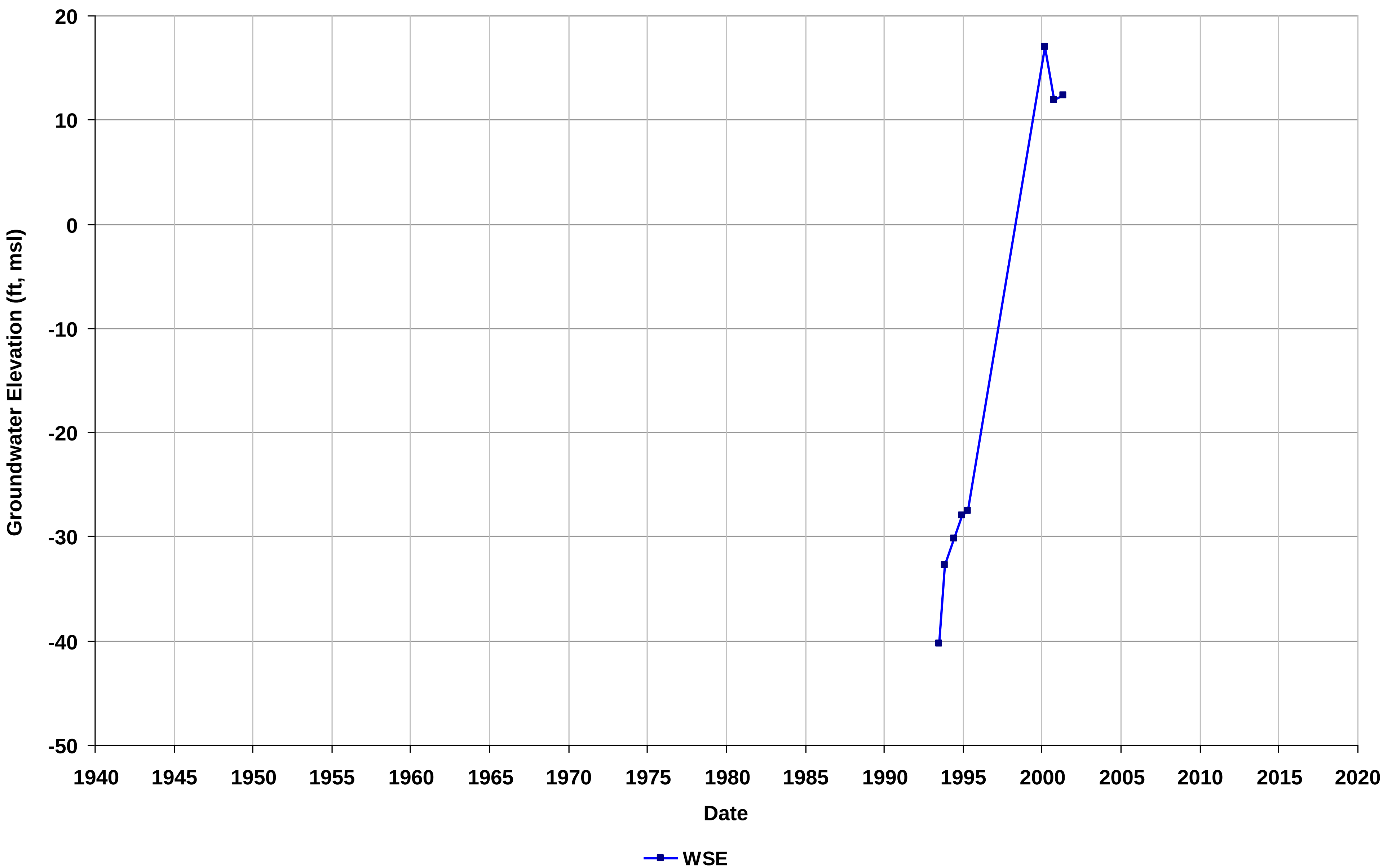
Wells with Hydrographs - Intermediate Aquifer (Historical Lows)

Figure E-3

East Bay Plain Subbasin
Groundwater Sustainability Plan

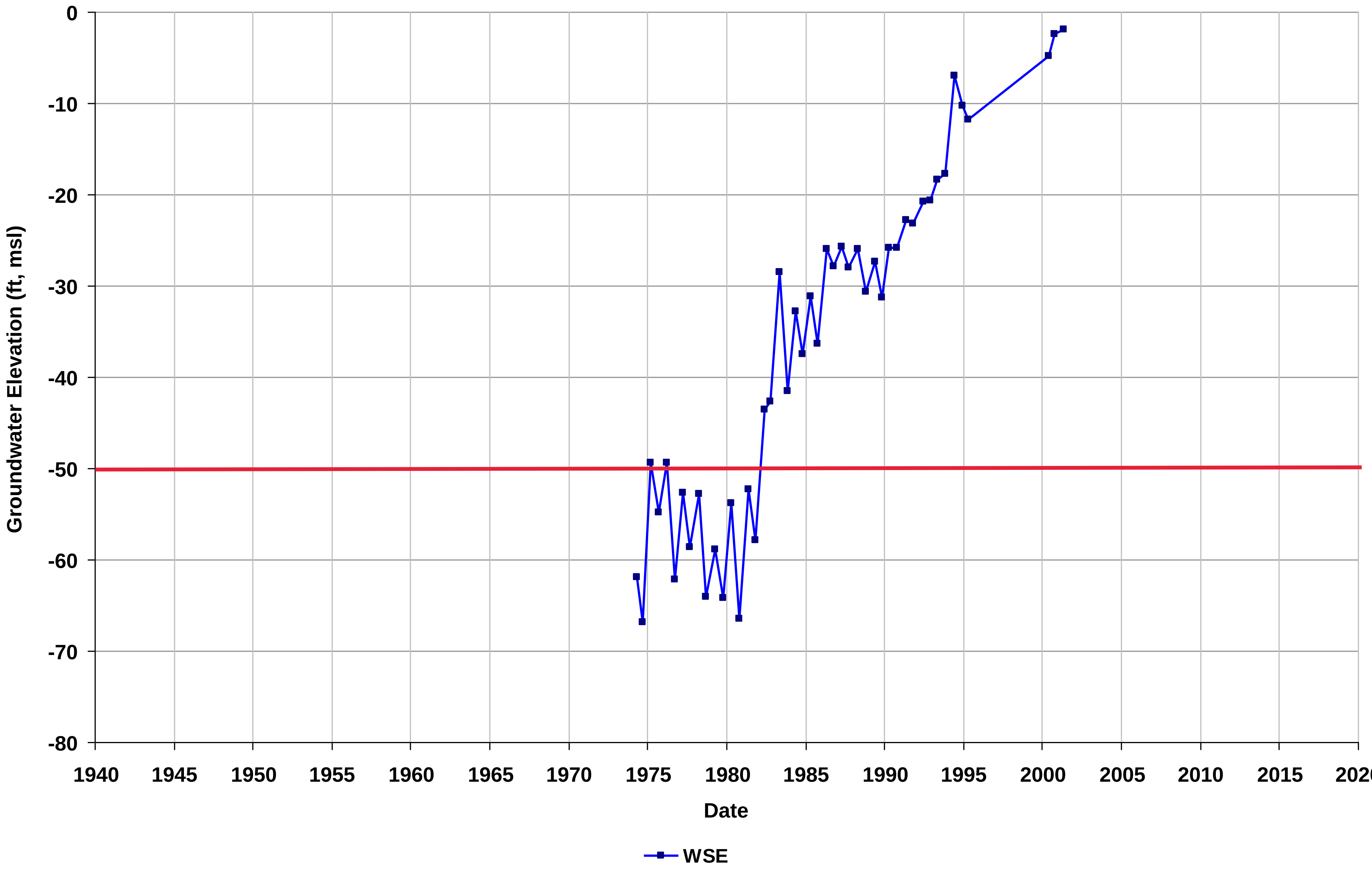
Well Name: 01S/04W-04R01
Depth Zone: Intermediate
Subbasin: East Bay Plain
GSE (ft, msl):

Total Depth (ft bgs): 320
Perf. Interval (ft bgs): 220-320
T/R/S: 01S/04W/04
Well Use: Industrial



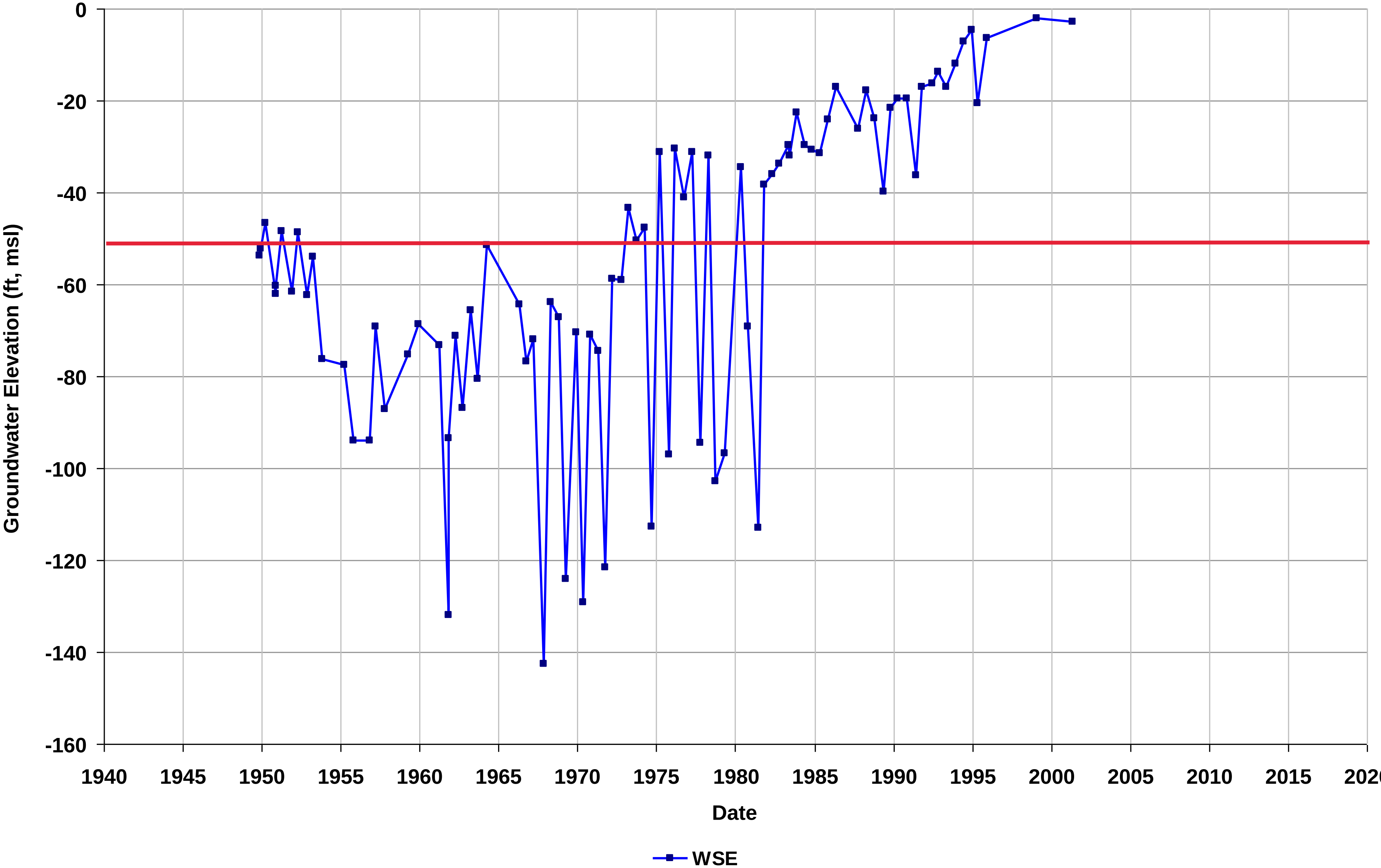
Well Name: 02S/03W-22P03
Depth Zone: Intermediate
Subbasin: East Bay Plain
GSE (ft, msl): 24

Total Depth (ft bgs): 300
Perf. Interval (ft bgs):
T/R/S: 02S/03W/22
Well Use: Industrial



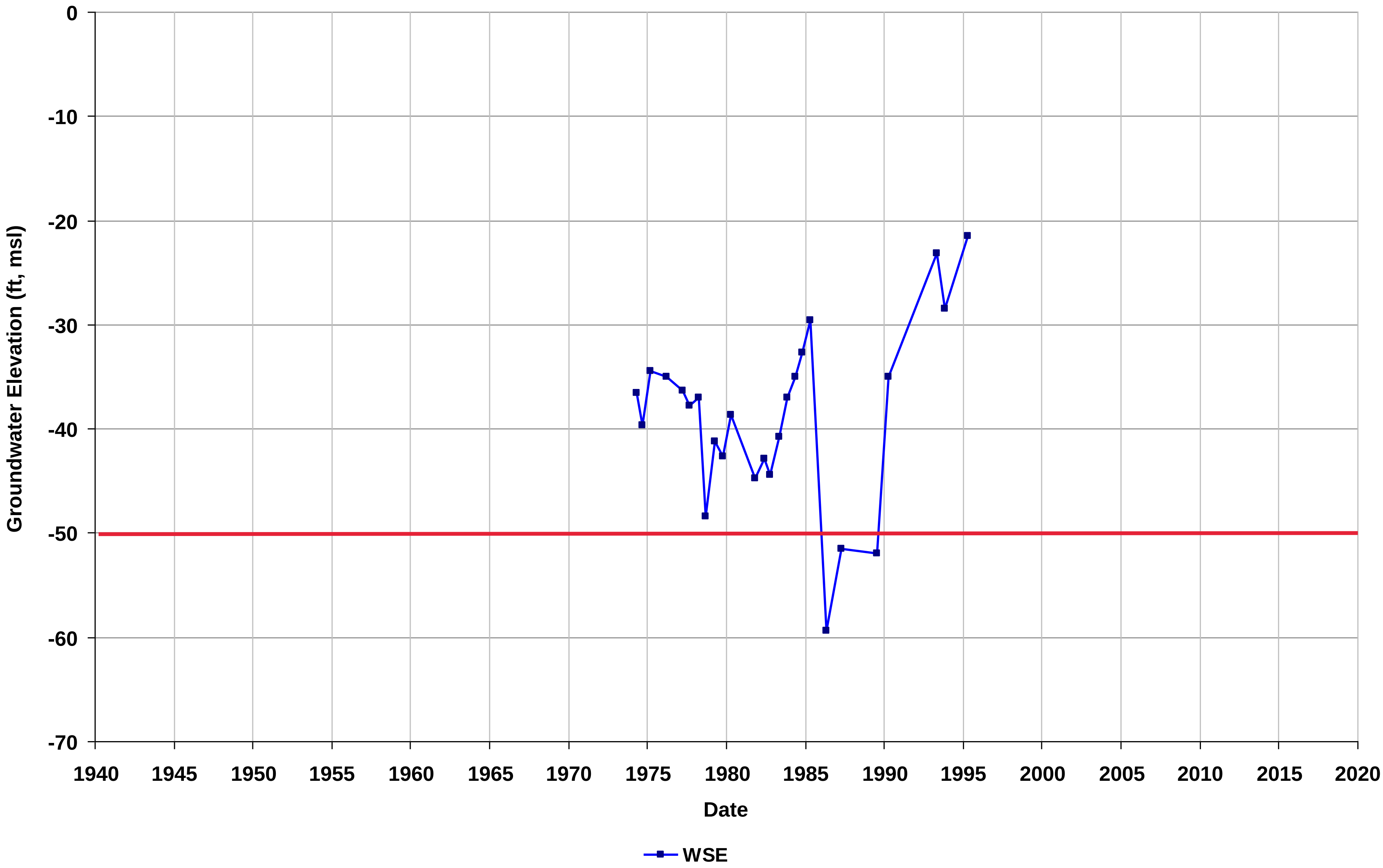
Well Name: 02S/03W-28G01
Depth Zone: Intermediate
Subbasin: East Bay Plain
GSE (ft, msl):

Total Depth (ft bgs): 250
Perf. Interval (ft bgs):
T/R/S: 02S/03W/28
Well Use: Irrigation



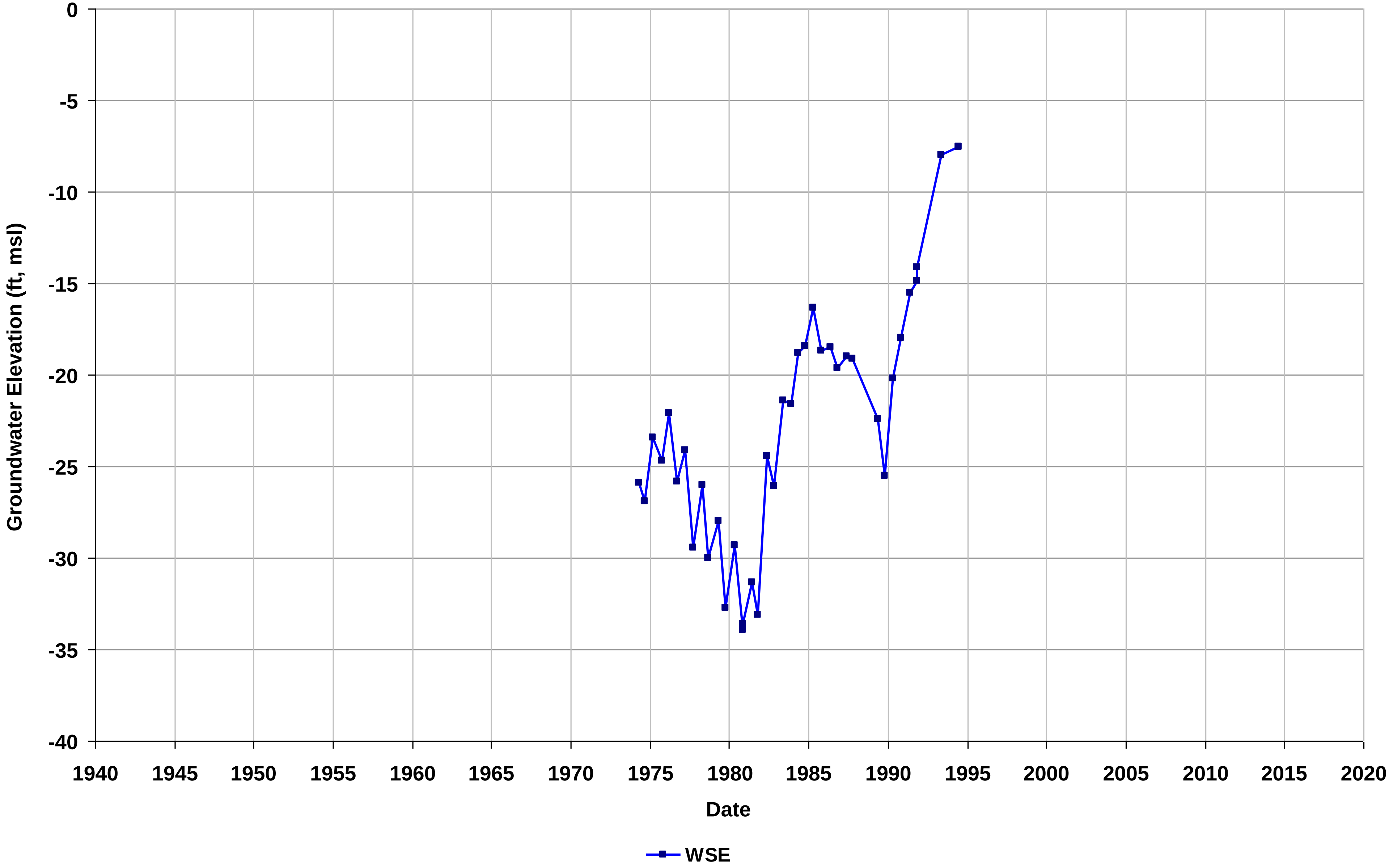
Well Name: 02S/04W-03E01
Depth Zone: Intermediate
Subbasin: East Bay Plain
GSE (ft, msl):

Total Depth (ft bgs): 353
Perf. Interval (ft bgs): 269-345
T/R/S: 02S/04W/04
Well Use: Irrigation



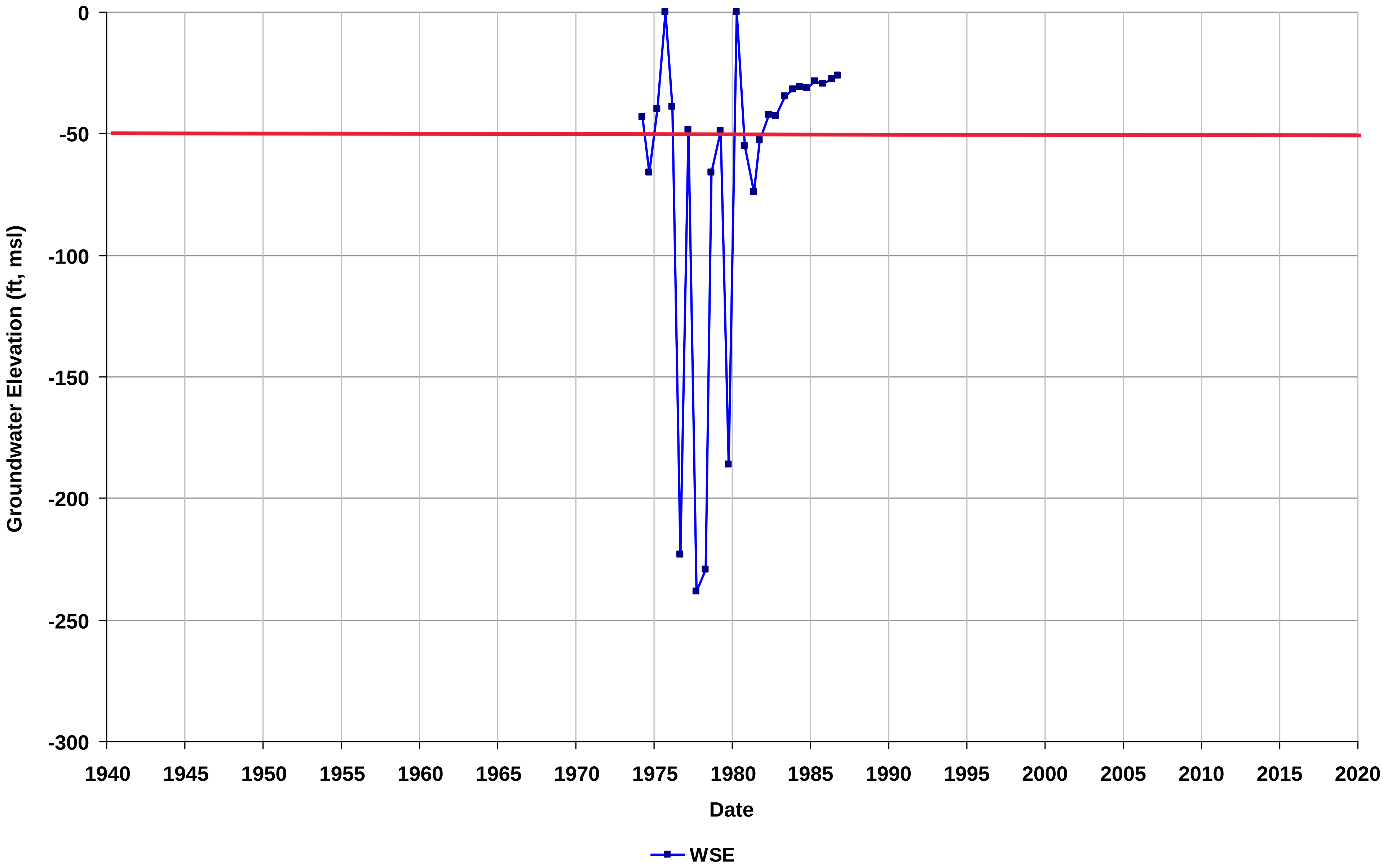
Well Name: 02S/04W-12R01
Depth Zone: Intermediate
Subbasin: East Bay Plain
GSE (ft, msl):

Total Depth (ft bgs): 325
Perf. Interval (ft bgs):
T/R/S: 02S/04W/13
Well Use: Residential



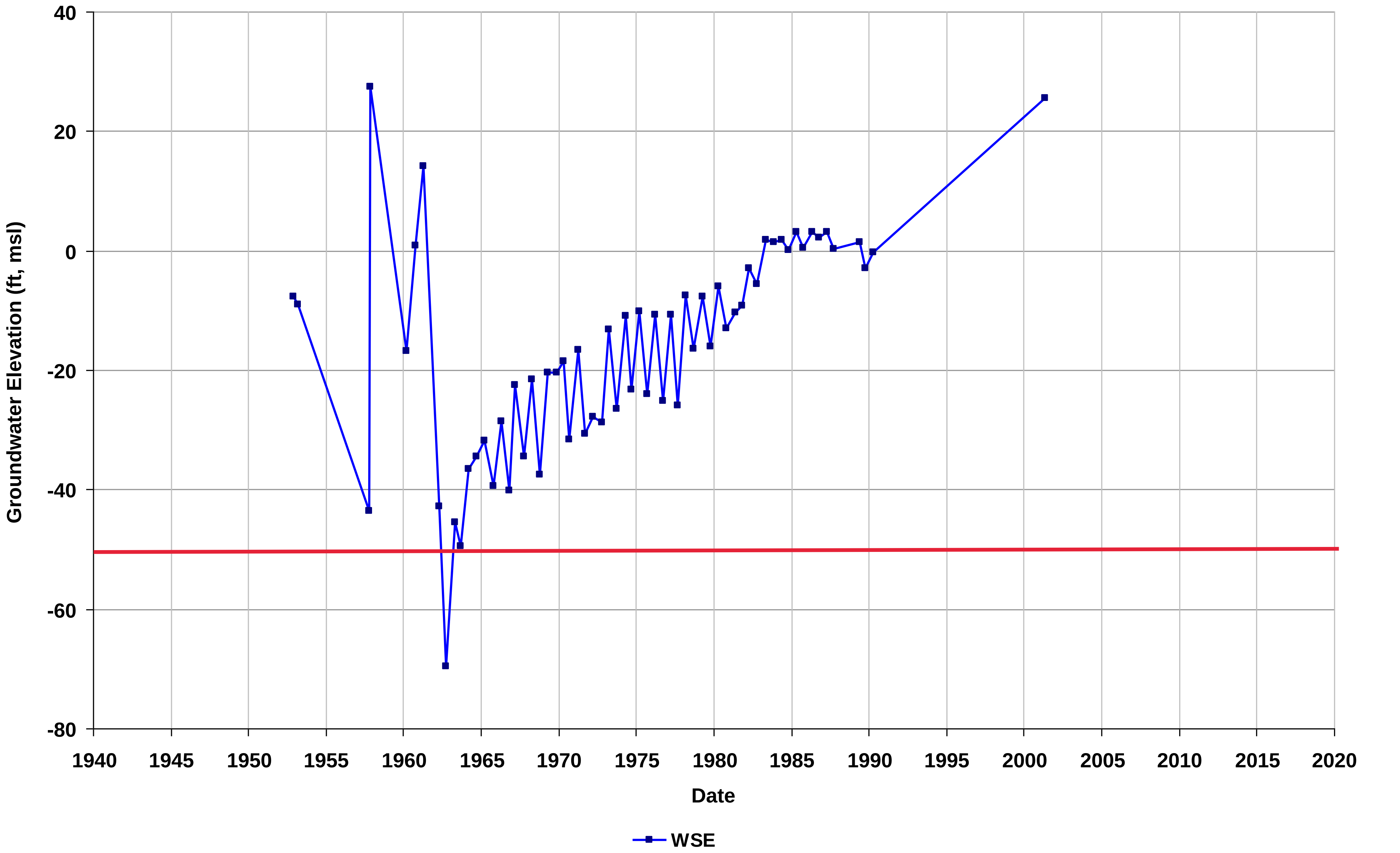
Well Name: 02S/04W-25A01
Depth Zone: Intermediate
Subbasin: East Bay Plain
GSE (ft, msl):

Total Depth (ft bgs): 325
Perf. Interval (ft bgs):
T/R/S: 02S/04W/25
Well Use: Irrigation



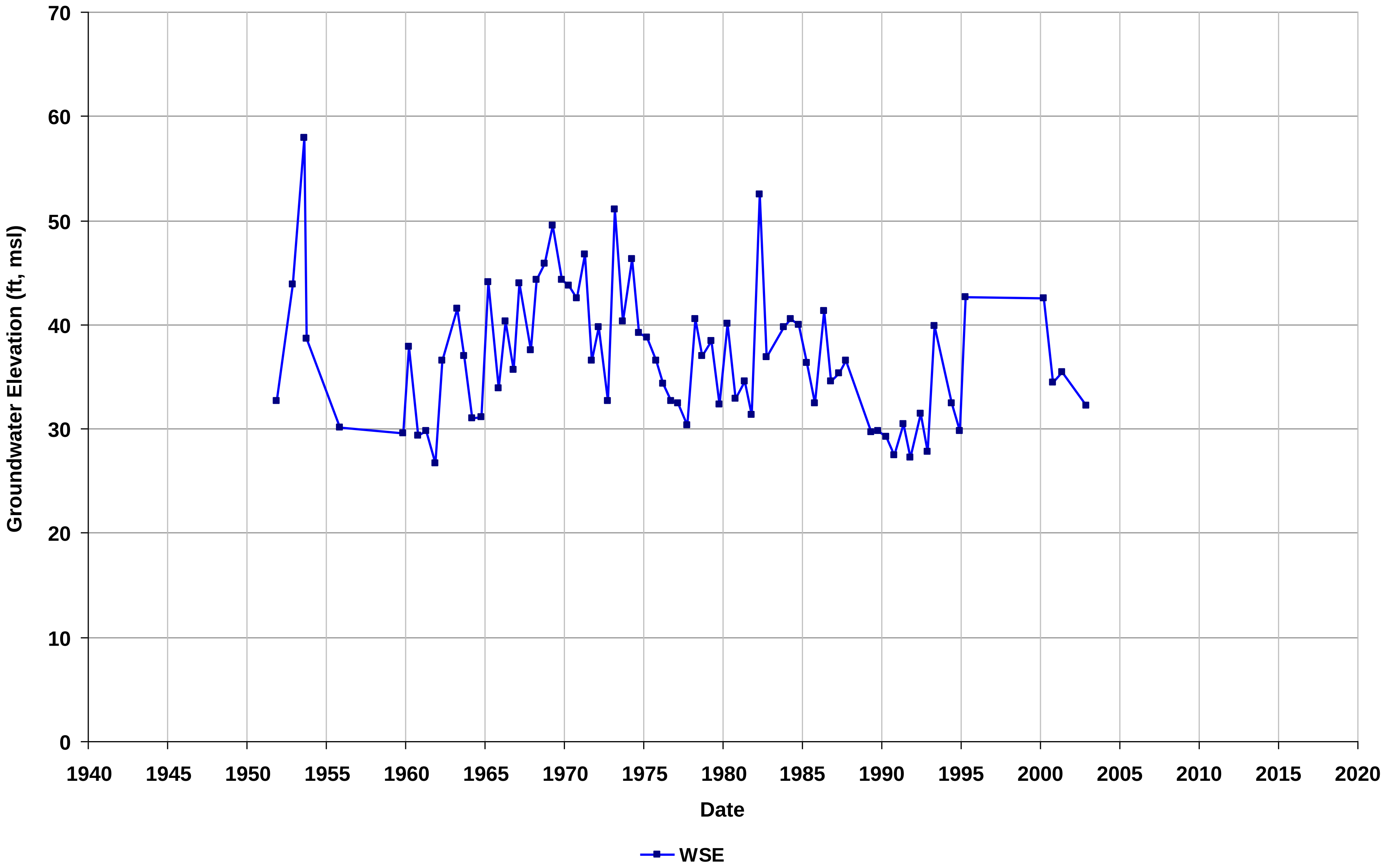
Well Name: 03S/02W-06R02
Depth Zone: Intermediate
Subbasin: East Bay Plain
GSE (ft, msl):

Total Depth (ft bgs): 440
Perf. Interval (ft bgs): 200-410
T/R/S: 03S/02W/06
Well Use: Irrigation



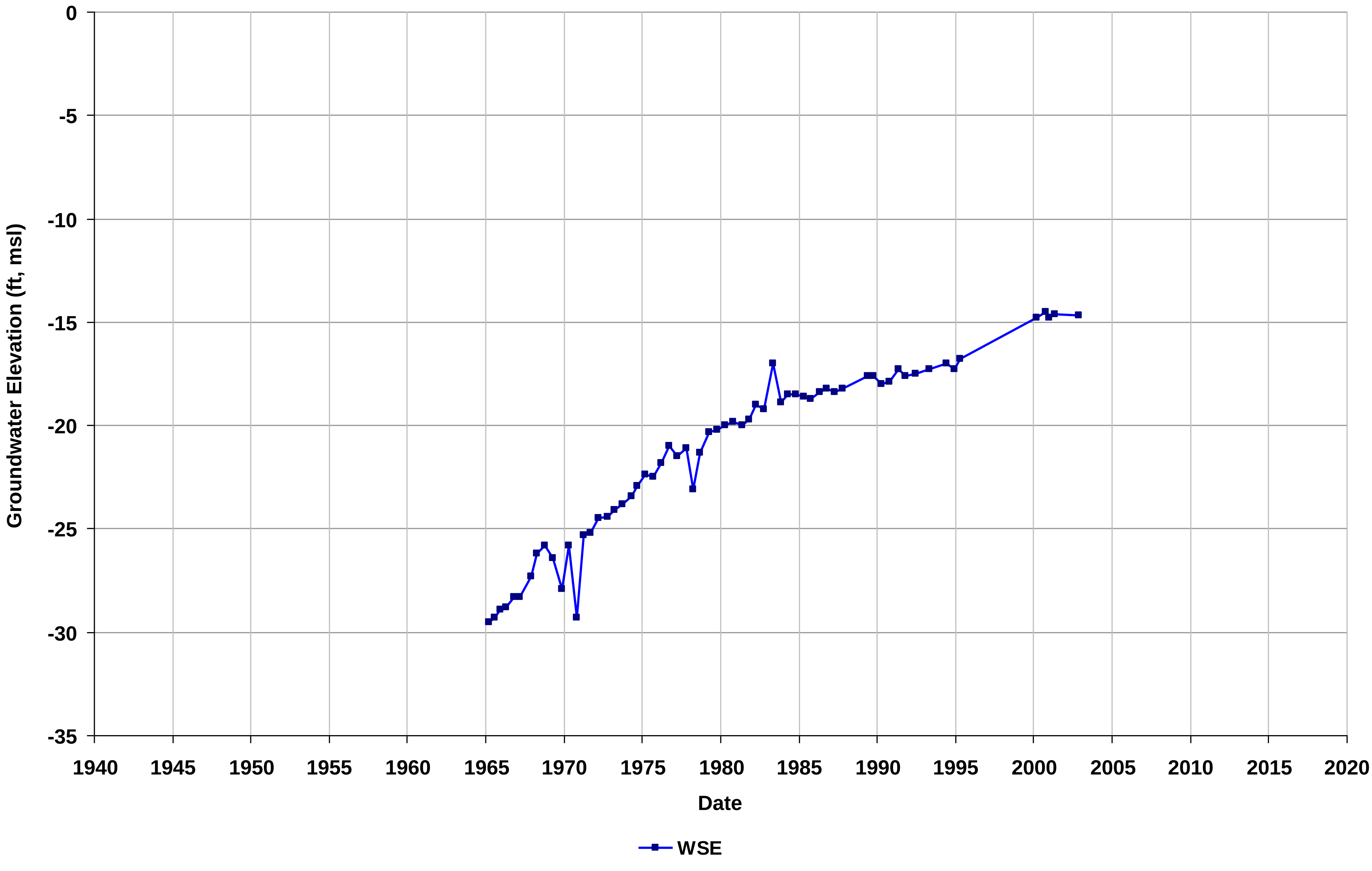
Well Name: 03S/02W-27A01
Depth Zone: Intermediate
Subbasin: East Bay Plain
GSE (ft, msl): 87

Total Depth (ft bgs): 300
Perf. Interval (ft bgs):
T/R/S: 03S/02W/26
Well Use: Irrigation



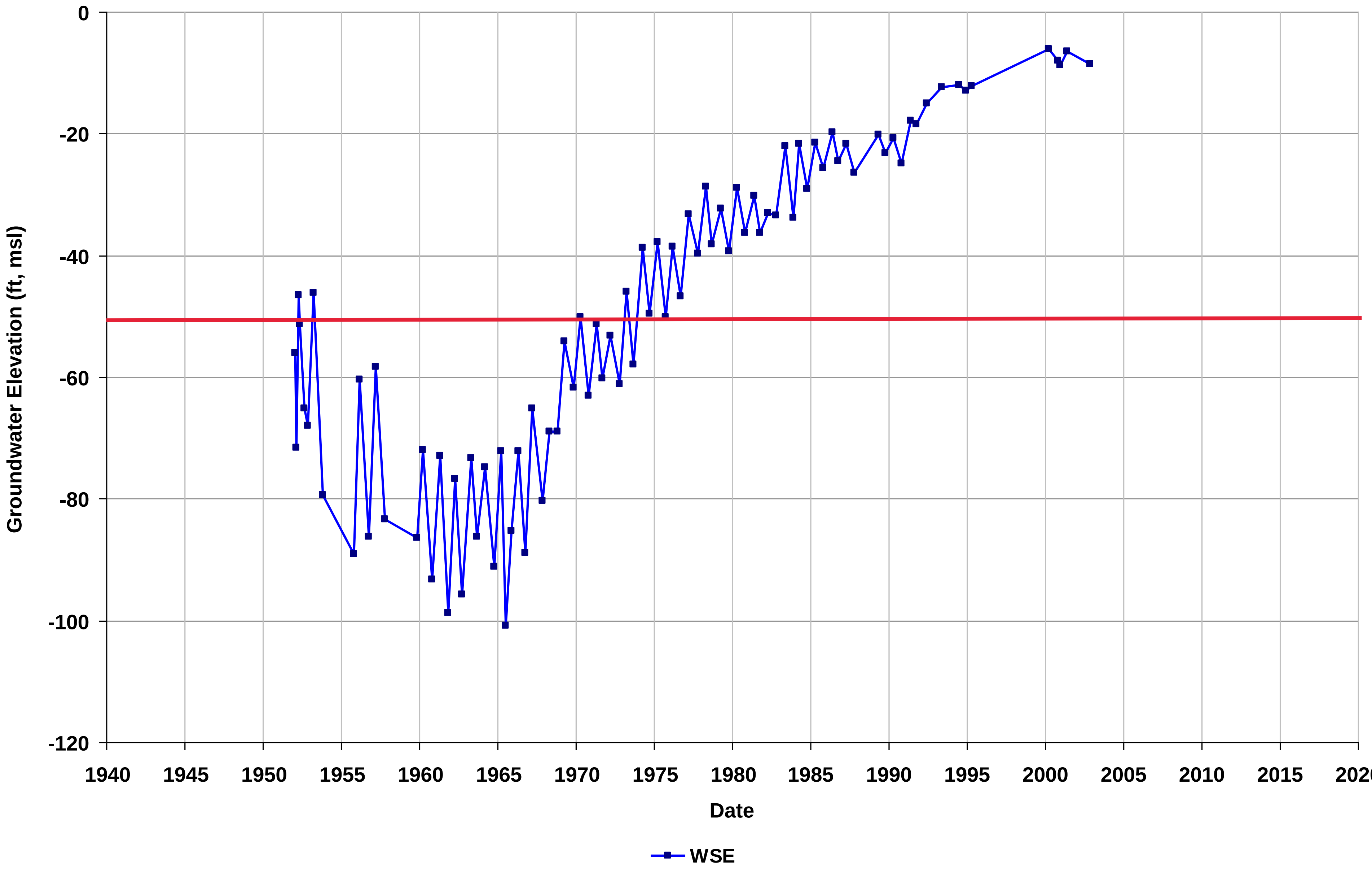
Well Name: 03S/03W-36R02
Depth Zone: Intermediate
Subbasin: East Bay Plain
GSE (ft, msl): 4

Total Depth (ft bgs): 265
Perf. Interval (ft bgs):
T/R/S: 03S/02W/31
Well Use: Industrial



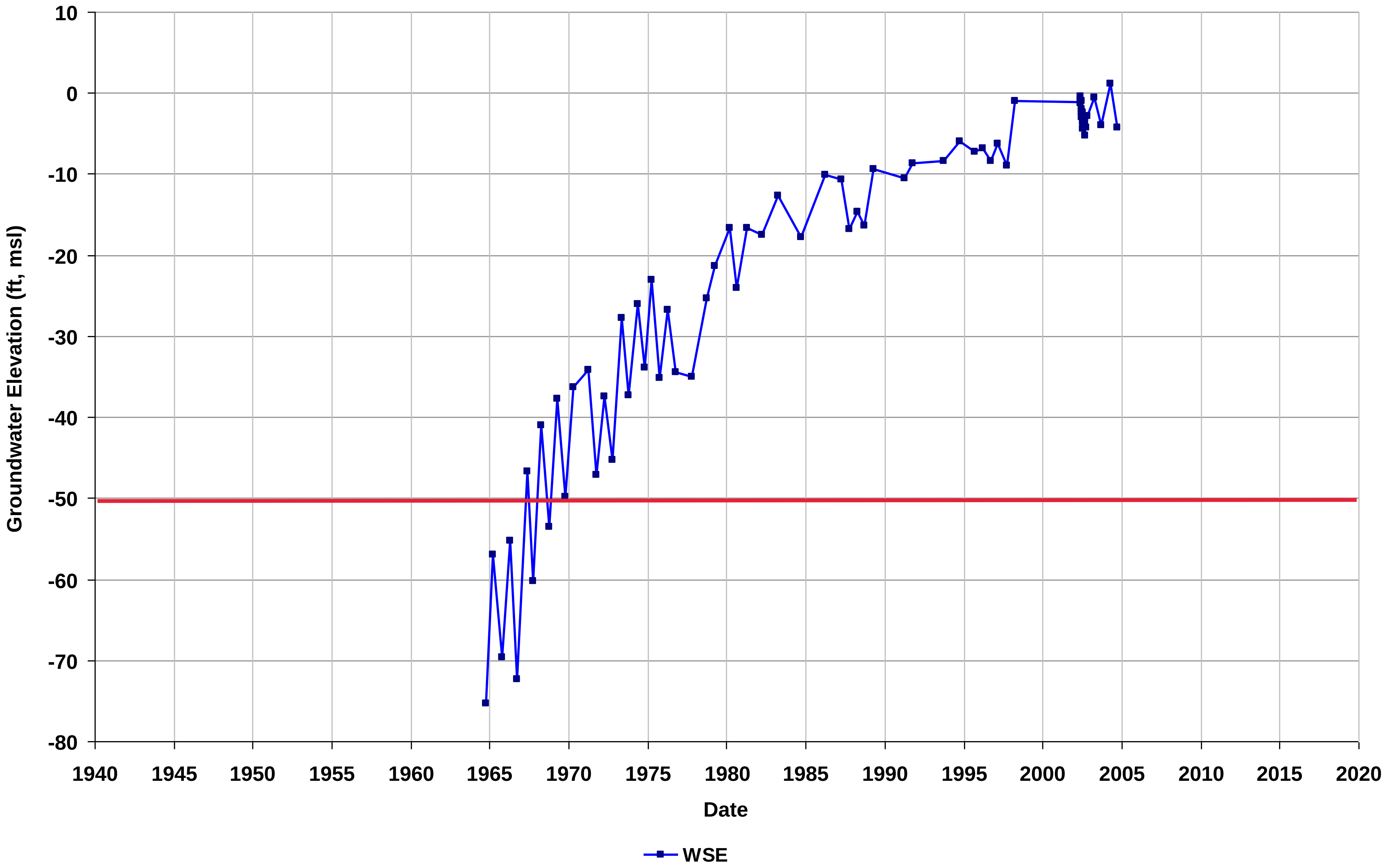
Well Name: 03S/03W-36R03
Depth Zone: Intermediate
Subbasin: East Bay Plain
GSE (ft, msl): 6

Total Depth (ft bgs): 350
Perf. Interval (ft bgs): 303-327
T/R/S: 03S/02W/31
Well Use: Industrial



Well Name: 04S/03W-13B01
Depth Zone: Intermediate
Subbasin: Niles Cone
GSE (ft, msl):

Total Depth (ft bgs): 441
Perf. Interval (ft bgs): 310-357
T/R/S: 04S/03W/13
Well Use: Observation



Section E-4

Deep Aquifer Zone Groundwater Hydrographs

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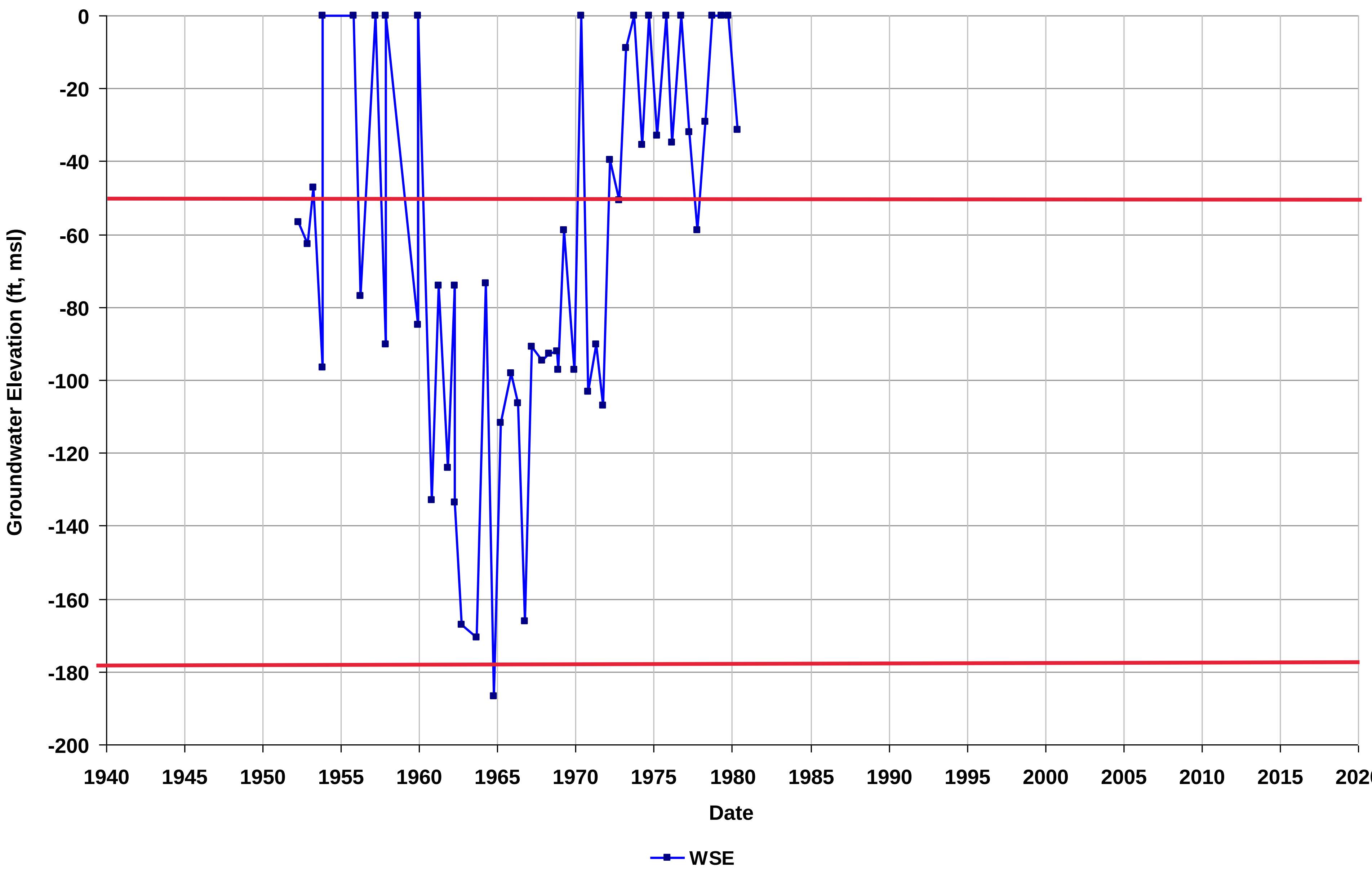
Wells with Hydrographs - Deep Aquifer

Figure E-4

East Bay Plain Subbasin
Groundwater Sustainability Plan

Well Name: 03S/02W-17Q02
Depth Zone: Deep
Subbasin: East Bay Plain
GSE (ft, msl):

Total Depth (ft bgs): 505
Perf. Interval (ft bgs):
T/R/S: 03S/2W/17
Well Use: Unknown



Section E-5

Multiple Aquifer and Unknown Aquifer Zone Groundwater Hydrographs

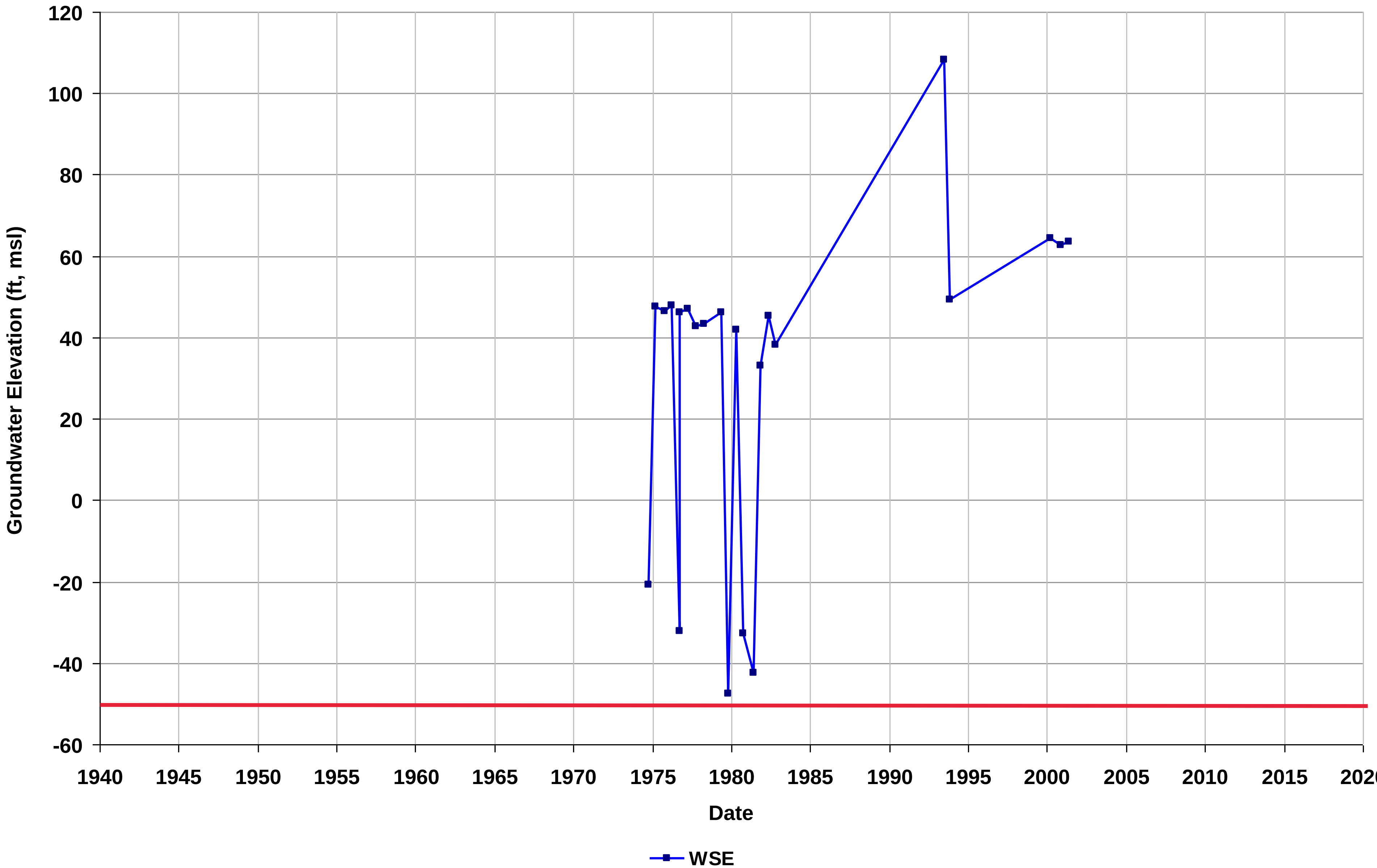
Wells with Hydrographs - Multiple Aquifers

Figure E-5

East Bay Plain Subbasin
Groundwater Sustainability Plan

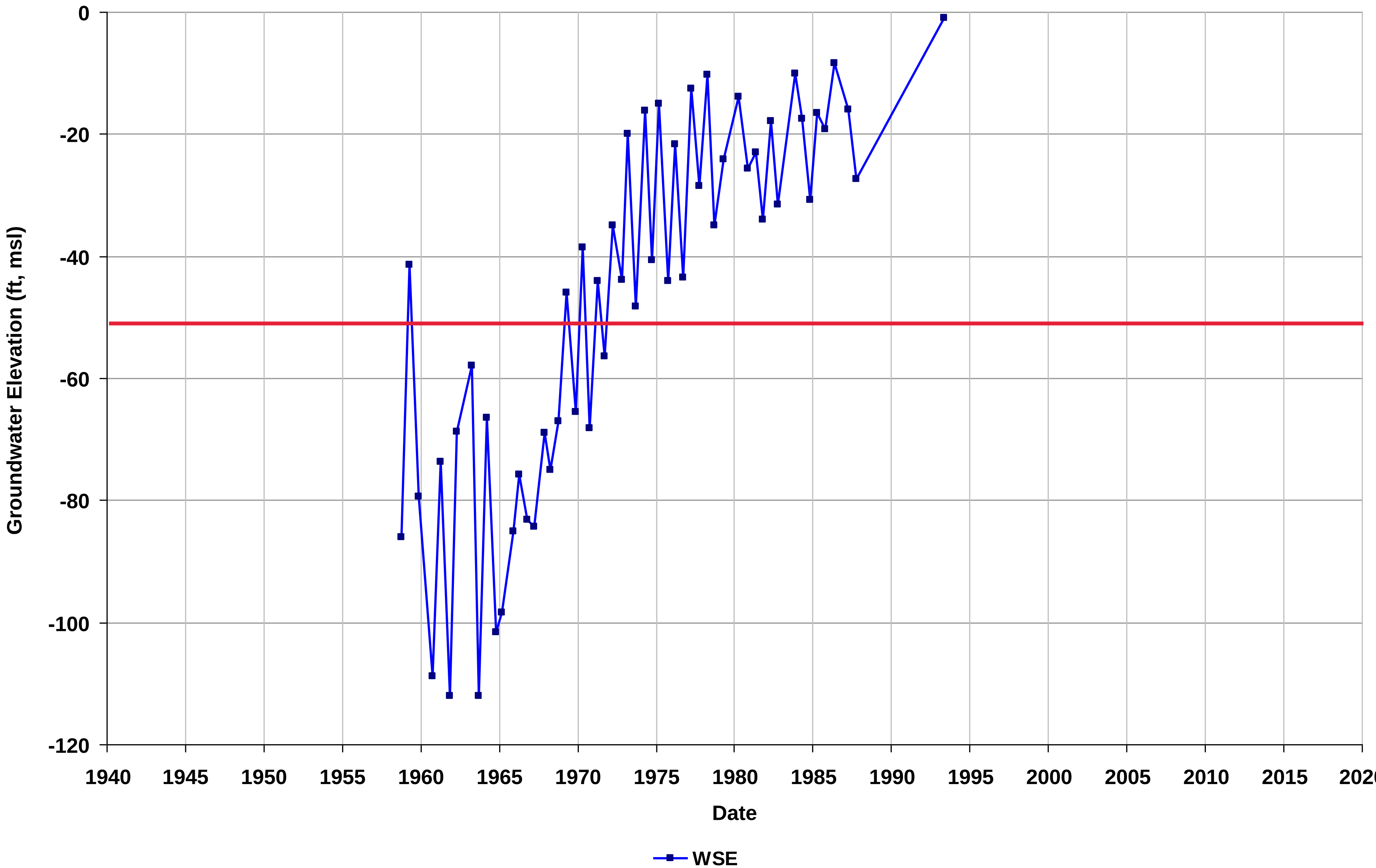
Well Name: 02S/03W-10G01
Depth Zone: Shallow-Intermediate-Deep
Subbasin: East Bay Plain
GSE (ft, msl):

Total Depth (ft bgs): 440
Perf. Interval (ft bgs): 127-437
T/R/S: 02S/03W/10
Well Use: Irrigation



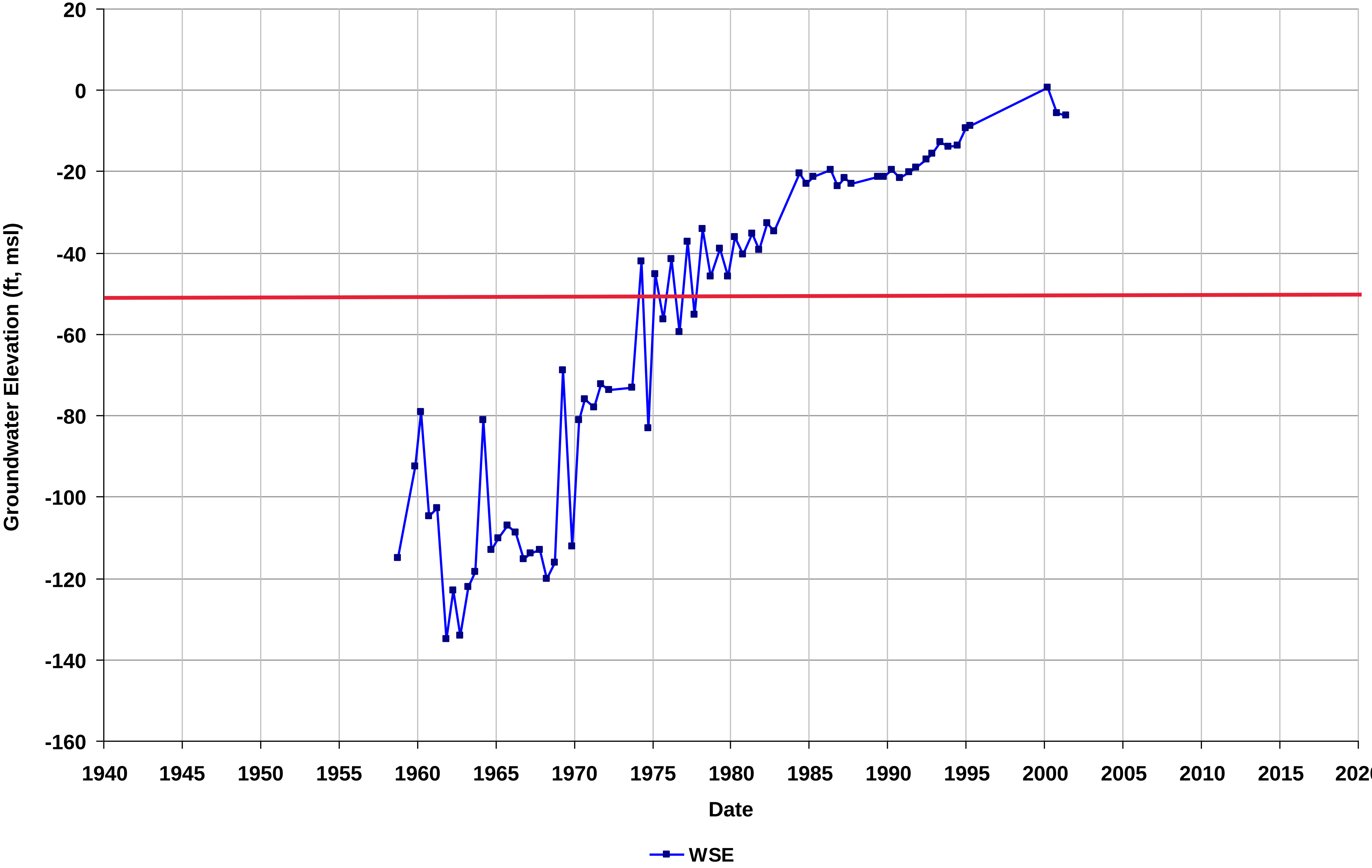
Well Name: 03S/02W-35R01
Depth Zone: Shallow-Intermediate-Deep
Subbasin: East Bay Plain
GSE (ft, msl):

Total Depth (ft bgs): 570
Perf. Interval (ft bgs): 114-565
T/R/S: 03S/02W/35
Well Use: Irrigation



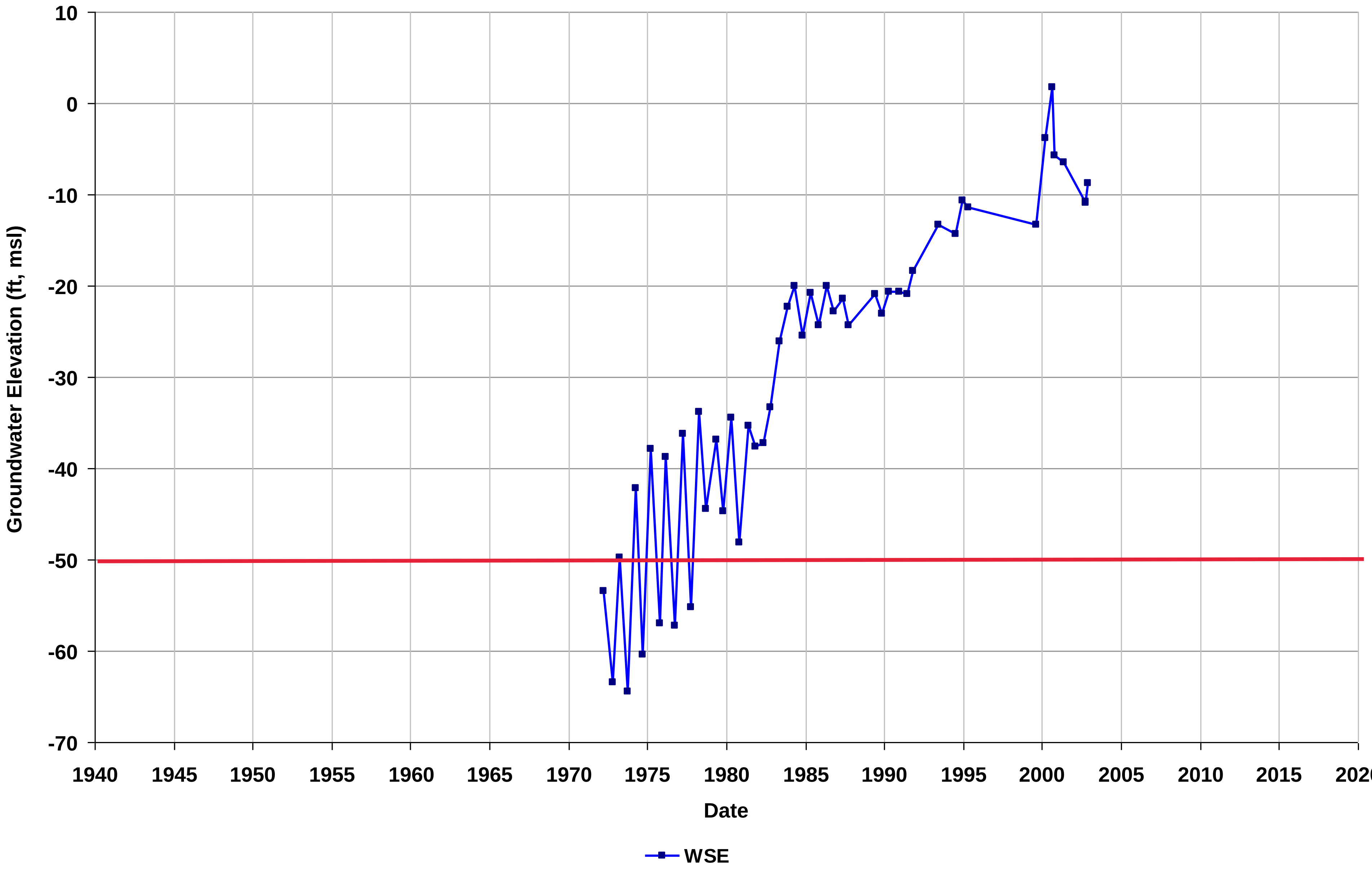
Well Name: 03S/03W-01G01
Depth Zone: Intermediate-Deep
Subbasin: East Bay Plain
GSE (ft, msl):

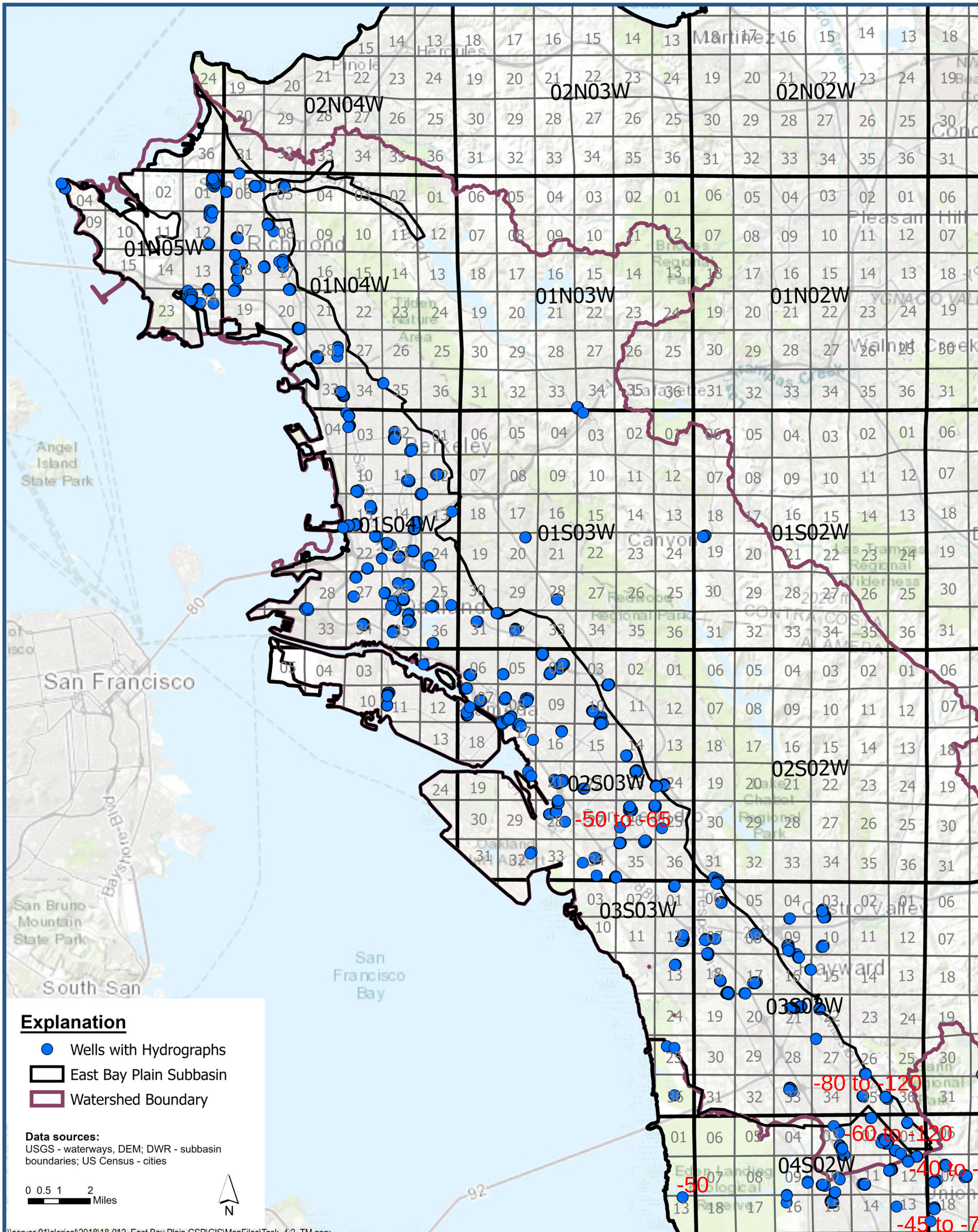
Total Depth (ft bgs): 701
Perf. Interval (ft bgs): 351-685
T/R/S: 03S/03W/01
Well Use: Irrigation



Well Name: 03S/03W-14K02
Depth Zone: Shallow-Intermediate-Deep
Subbasin: East Bay Plain
GSE (ft, msl): 6

Total Depth (ft bgs): 993
Perf. Interval (ft bgs): 162-990
T/R/S: 03S/03W/14
Well Use: Industrial





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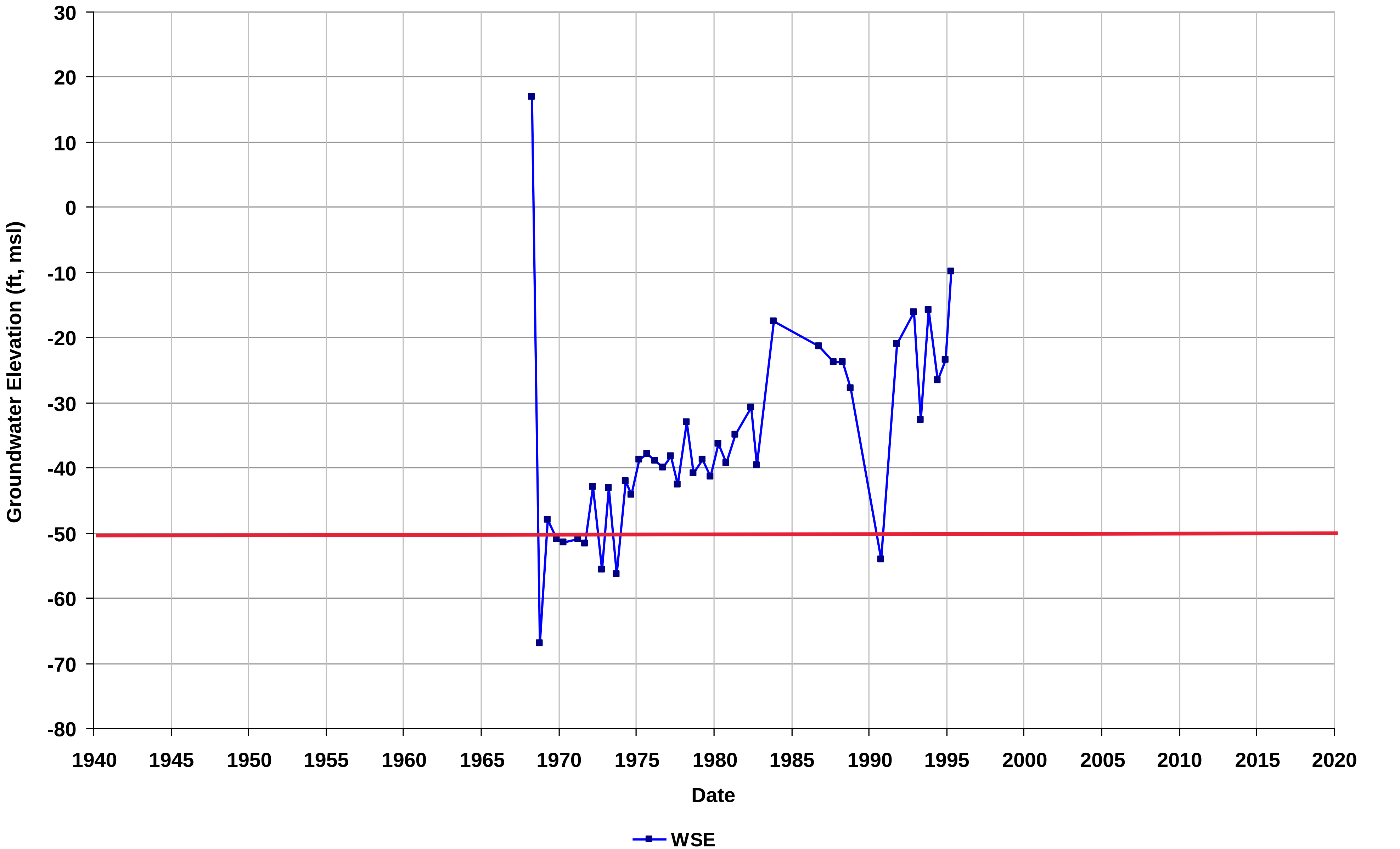
Wells with Hydrographs - Unknown Aquifer

East Bay Plain Subbasin
Groundwater Sustainability Plan

Figure E-6

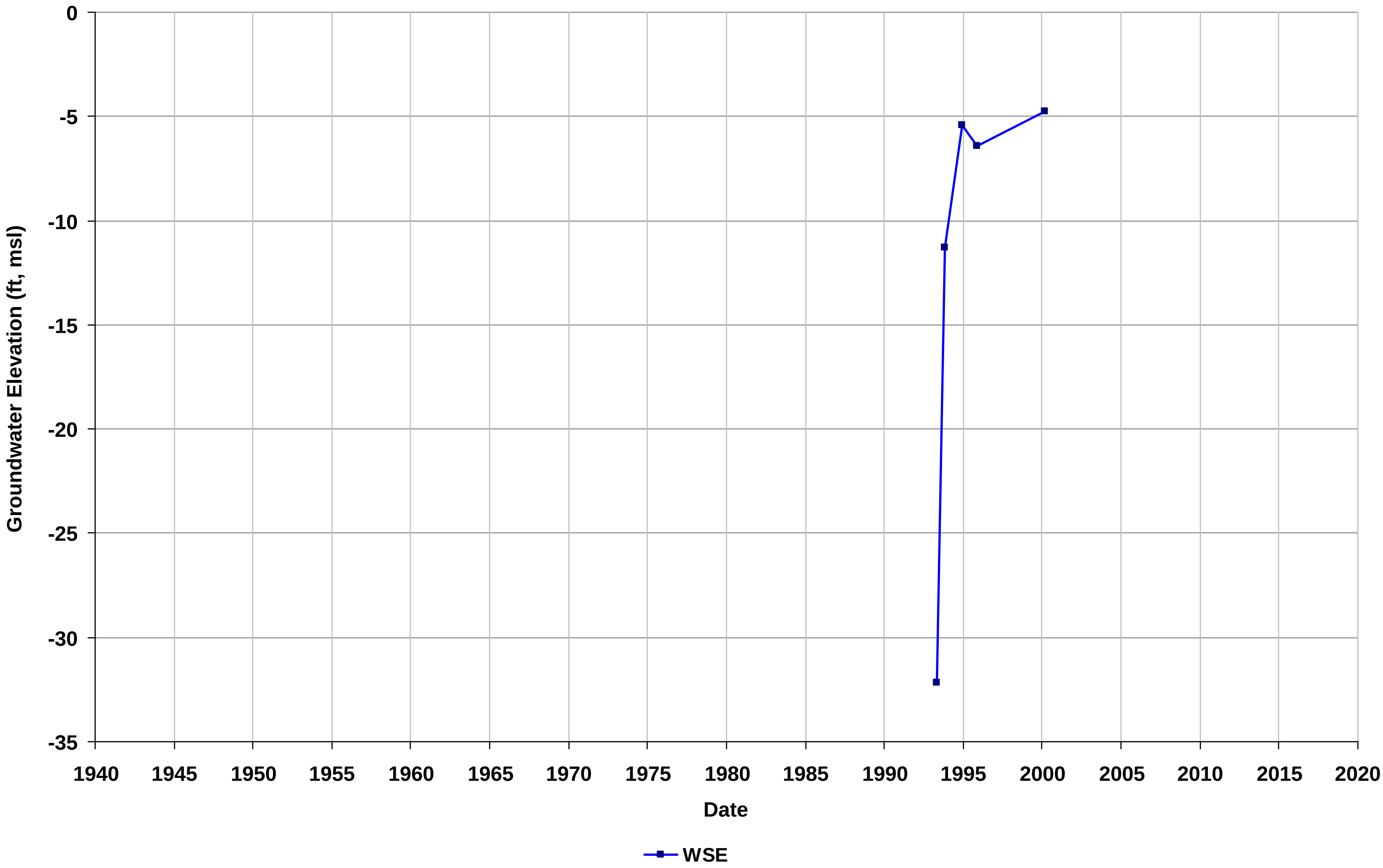
Well Name: 02S/03W-27H08
Depth Zone: Unknown
Subbasin: East Bay Plain
GSE (ft, msl):

Total Depth (ft bgs):
Perf. Interval (ft bgs):
T/R/S: 02S/03W/26
Well Use: Irrigation



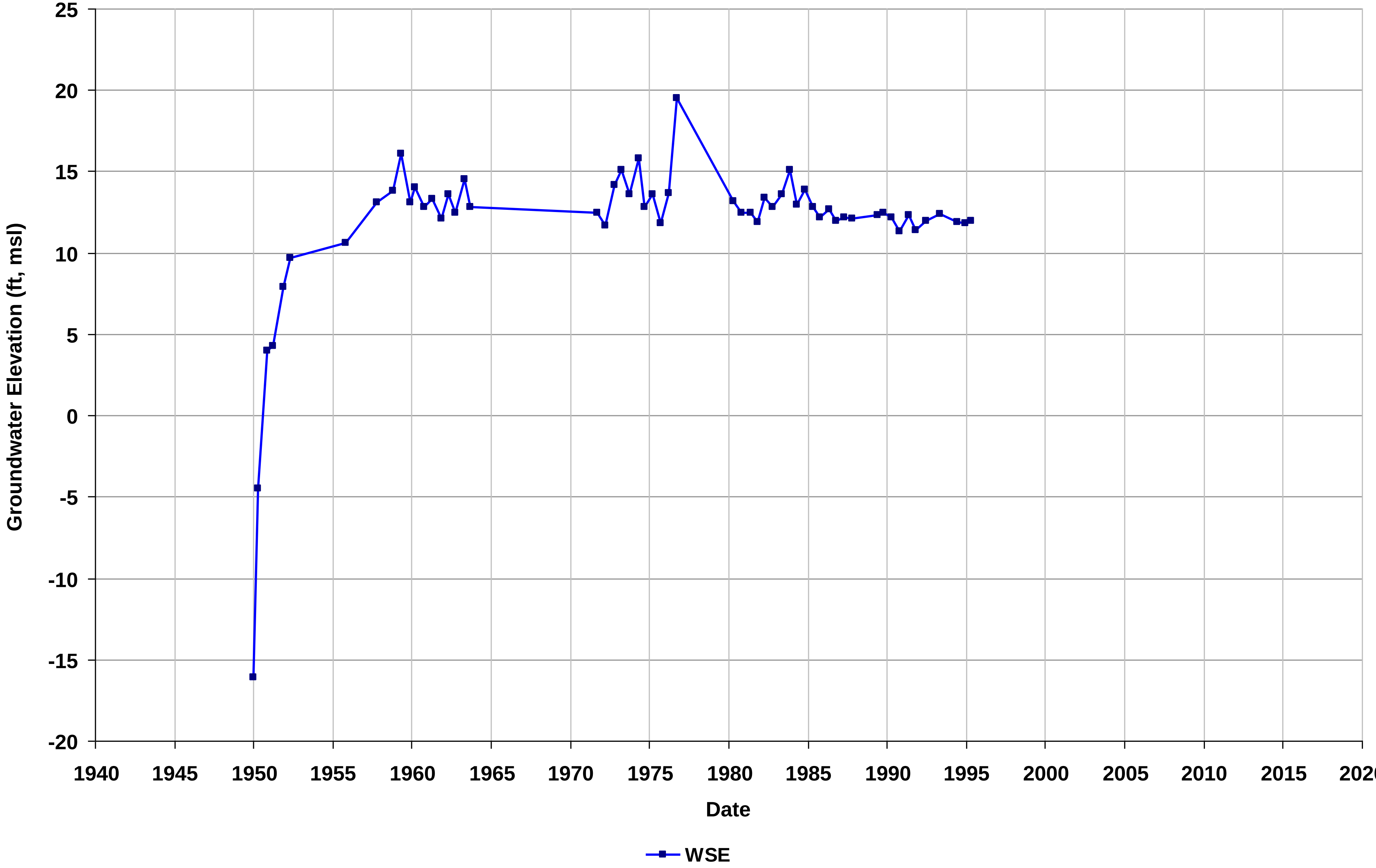
Well Name: 02S/03W-28G02
Depth Zone: Unknown
Subbasin: East Bay Plain
GSE (ft, msl):

Total Depth (ft bgs):
Perf. Interval (ft bgs):
T/R/S: 02S/03W/28
Well Use: Unknown



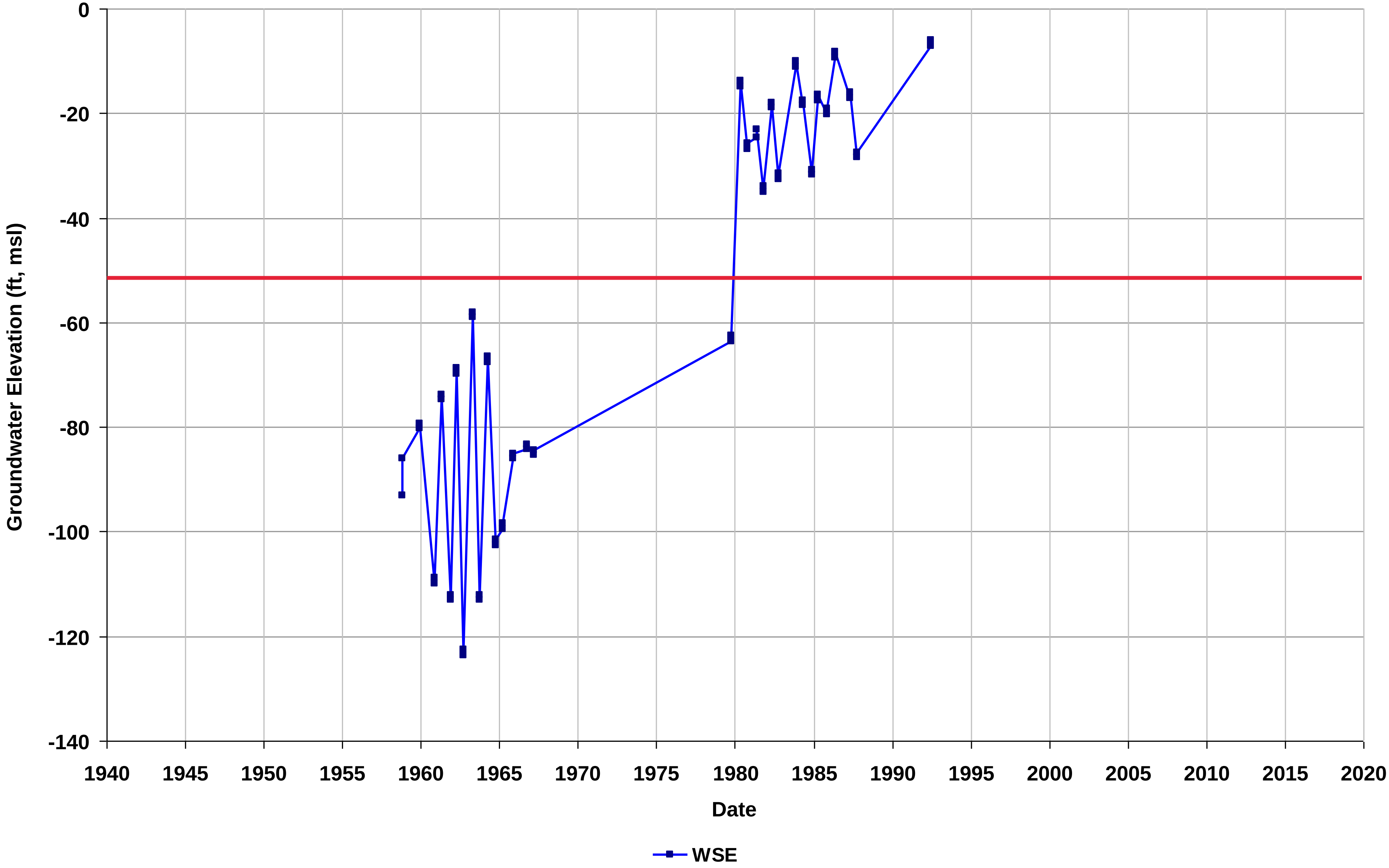
Well Name: 03S/02E-32E01
Depth Zone: Unknown
Subbasin: Niles Cone
GSE (ft, msl):

Total Depth (ft bgs):
Perf. Interval (ft bgs):
T/R/S: 03S/2W/32
Well Use: Unknown



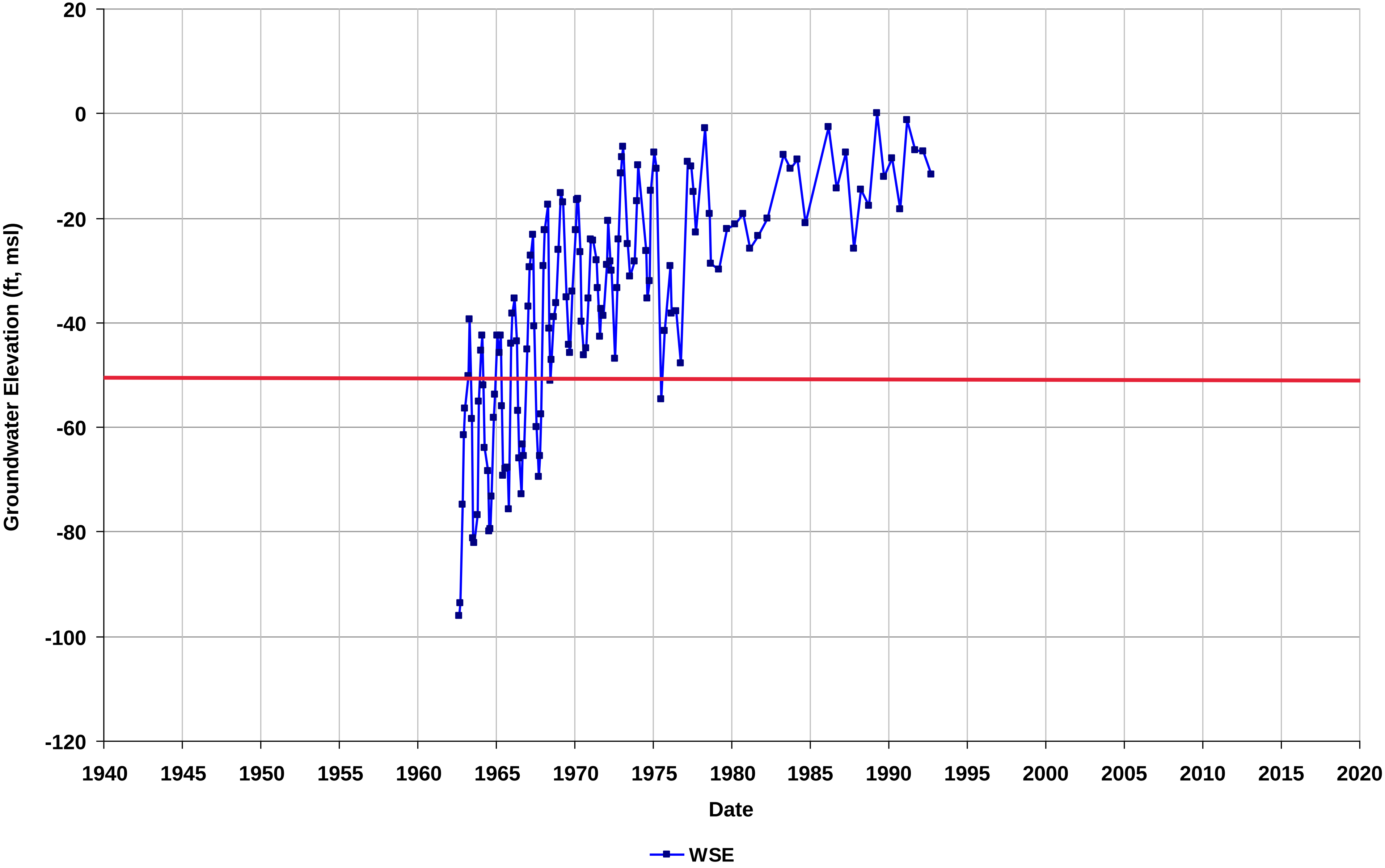
Well Name: 03S/02E-35R01
Depth Zone: Unknown
Subbasin: Niles Cone
GSE (ft, msl):

Total Depth (ft bgs):
Perf. Interval (ft bgs):
T/R/S: 03S/2W/35
Well Use: Unknown



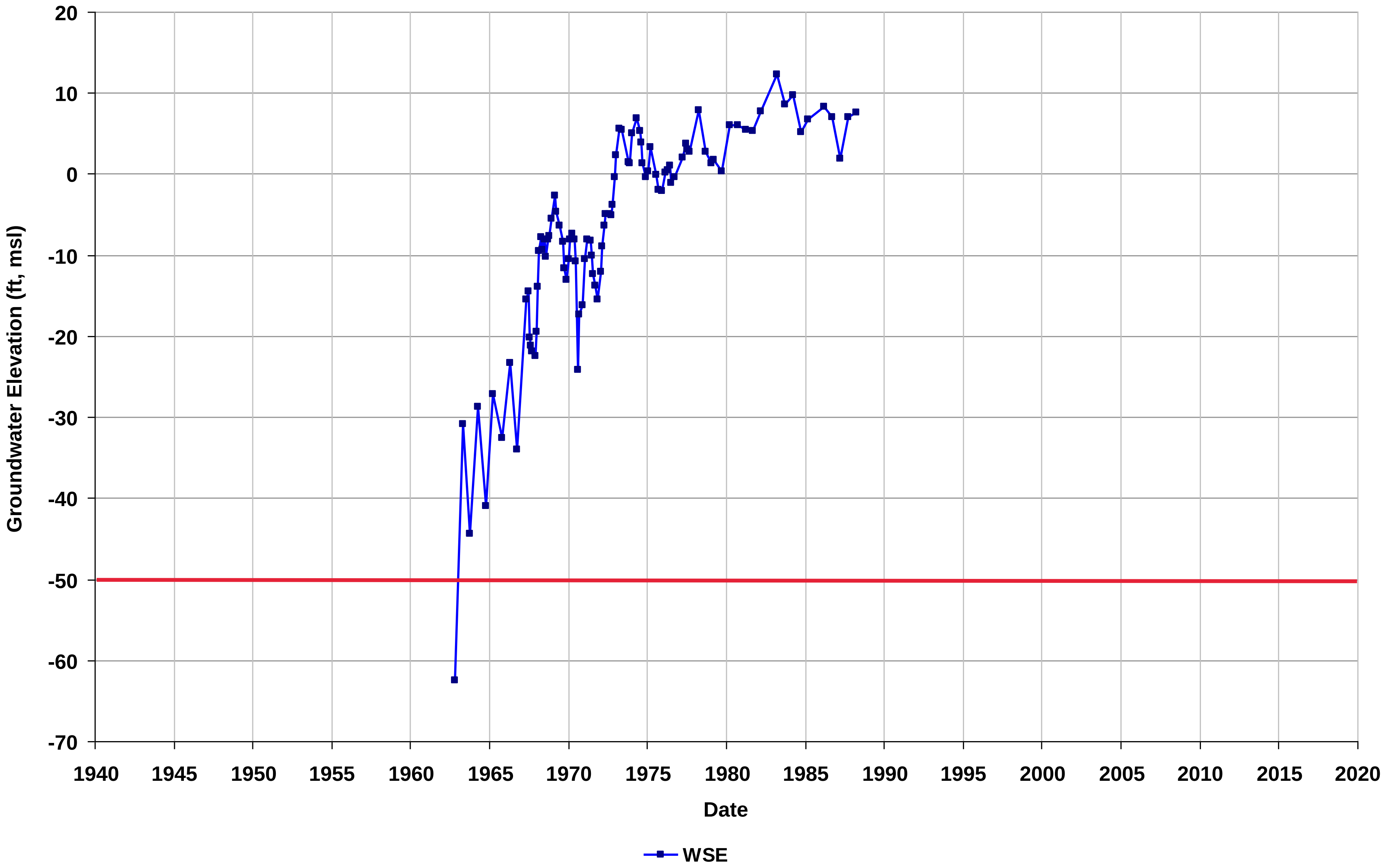
Well Name: 04S/01W-07G03
Depth Zone: Unknown
Subbasin: Niles Cone
GSE (ft, msl):

Total Depth (ft bgs):
Perf. Interval (ft bgs):
T/R/S: 04S/01W/07
Well Use:



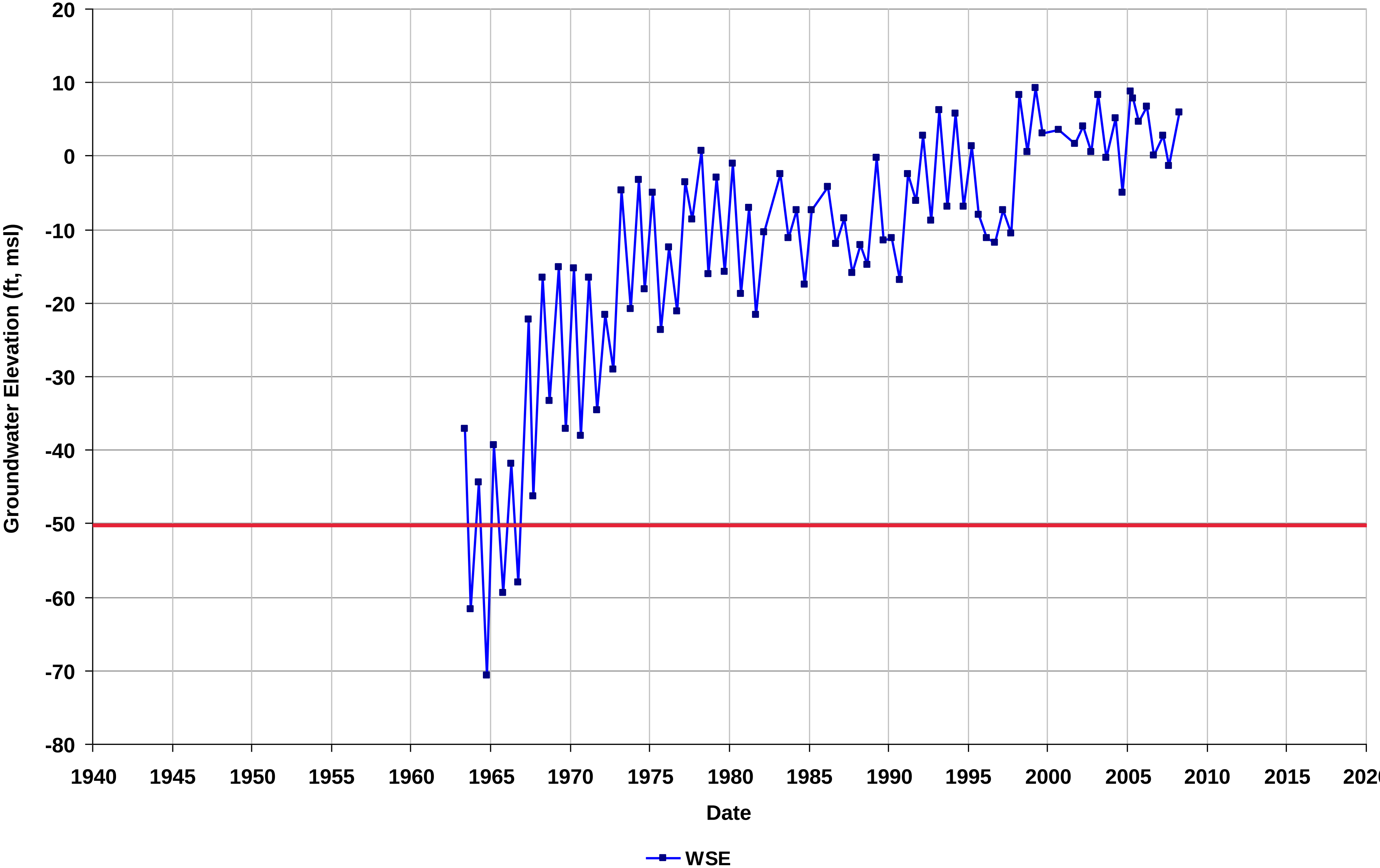
Well Name: 04S/01W-18H03
Depth Zone: Unknown
Subbasin: Niles Cone
GSE (ft, msl):

Total Depth (ft bgs):
Perf. Interval (ft bgs):
T/R/S: 04S/01W/19
Well Use:



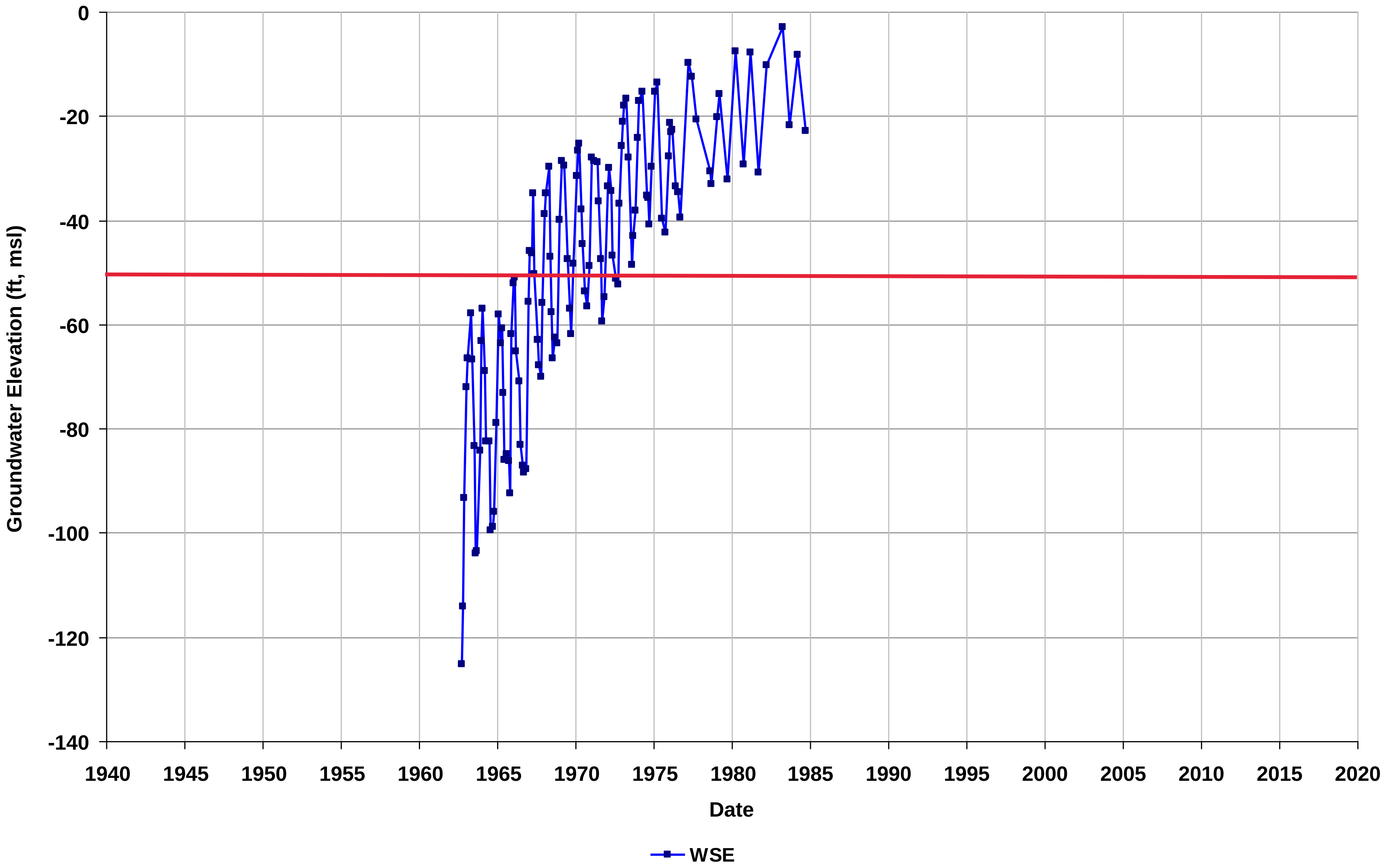
Well Name: 04S/01W-18M09
Depth Zone: Unknown
Subbasin: Niles Cone
GSE (ft, msl):

Total Depth (ft bgs):
Perf. Interval (ft bgs):
T/R/S: 04S/01W/18
Well Use:



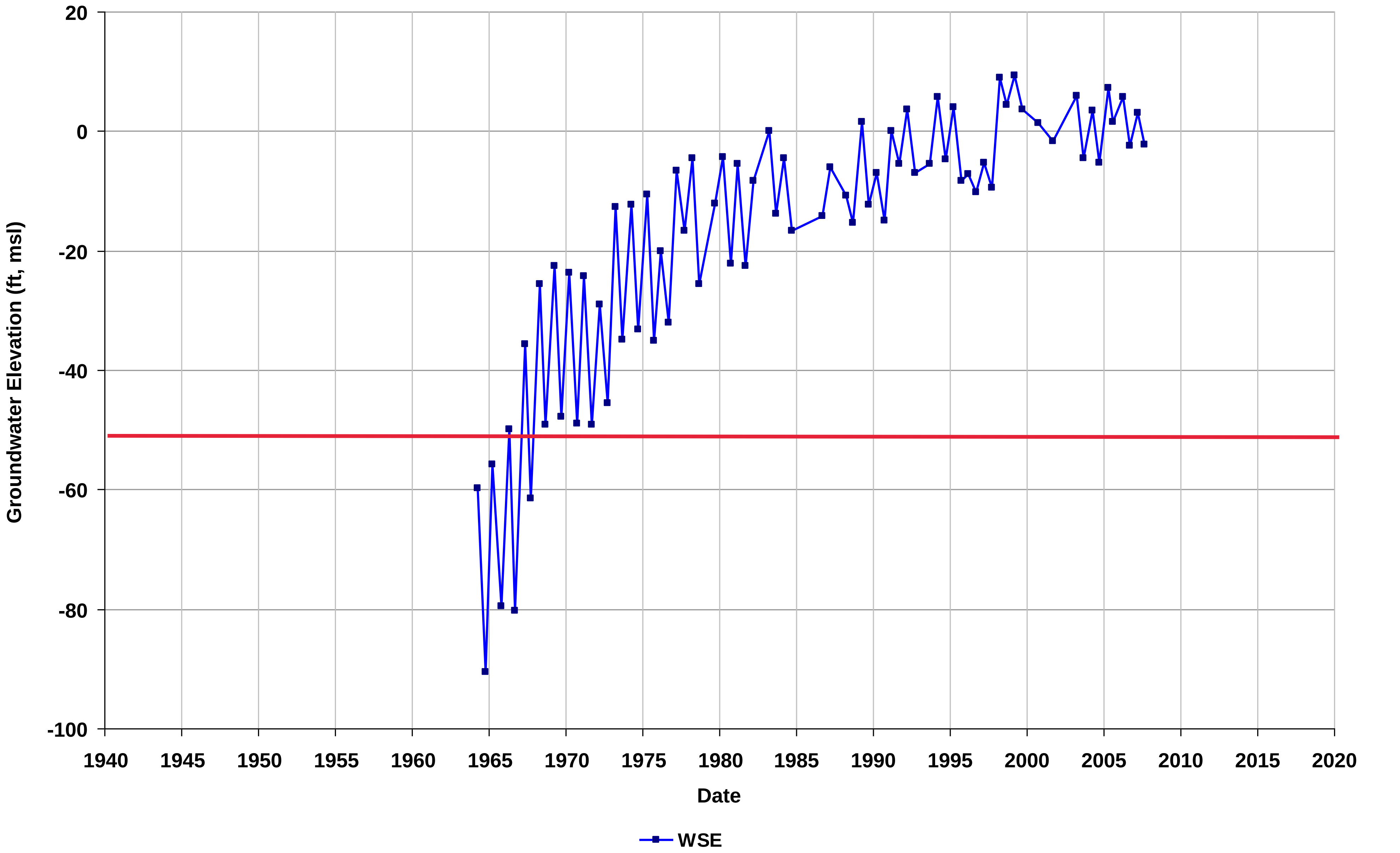
Well Name: 04S/02W-03G02
Depth Zone: Unknown
Subbasin: Niles Cone
GSE (ft, msl):

Total Depth (ft bgs):
Perf. Interval (ft bgs):
T/R/S: 04S/02W/03
Well Use:



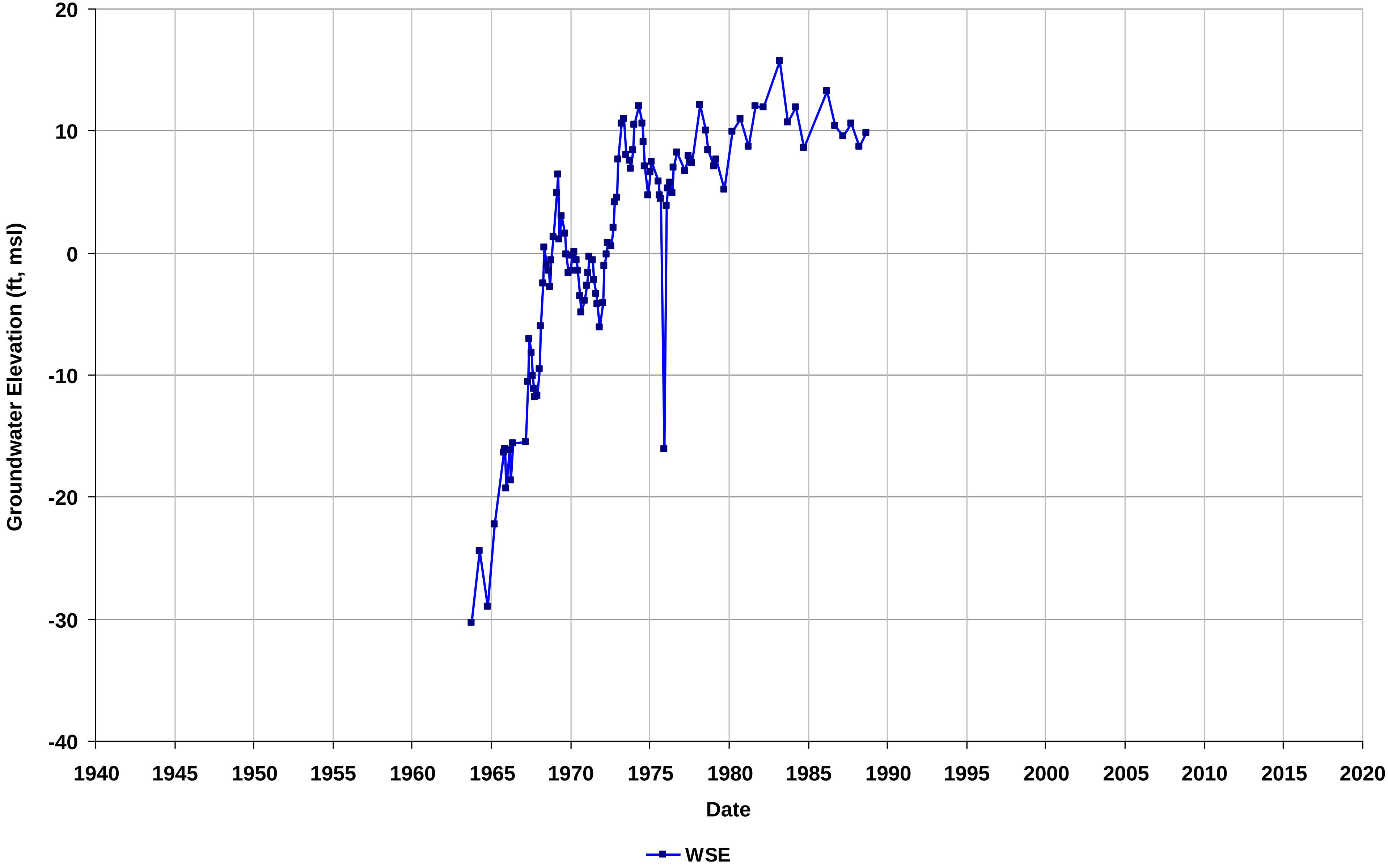
Well Name: 04S/02W-03K01
Depth Zone: Unknown
Subbasin: Niles Cone
GSE (ft, msl):

Total Depth (ft bgs):
Perf. Interval (ft bgs):
T/R/S: 04S/02W/03
Well Use:



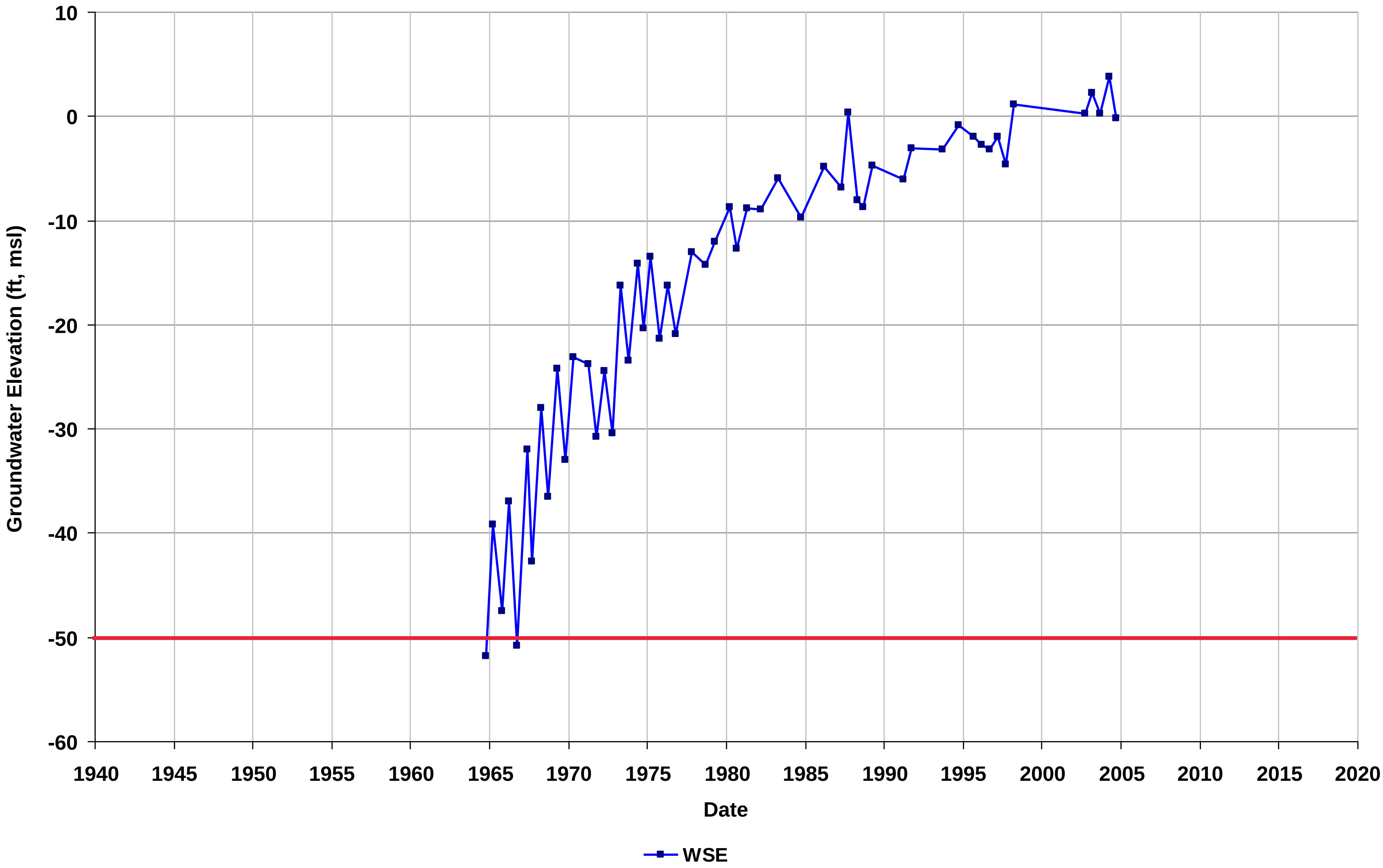
Well Name: 04S/02W-13E02
Depth Zone: Unknown
Subbasin: Niles Cone
GSE (ft, msl):

Total Depth (ft bgs):
Perf. Interval (ft bgs):
T/R/S: 04S/02W/13
Well Use:



Well Name: 04S/03W-13B02
Depth Zone: Unknown
Subbasin: Niles Cone
GSE (ft, msl):

Total Depth (ft bgs):
Perf. Interval (ft bgs):
T/R/S: 04S/03W/13
Well Use:



Well Name: 04S/03W-13B03
Depth Zone: Unknown
Subbasin: Niles Cone
GSE (ft, msl):

Total Depth (ft bgs):
Perf. Interval (ft bgs):
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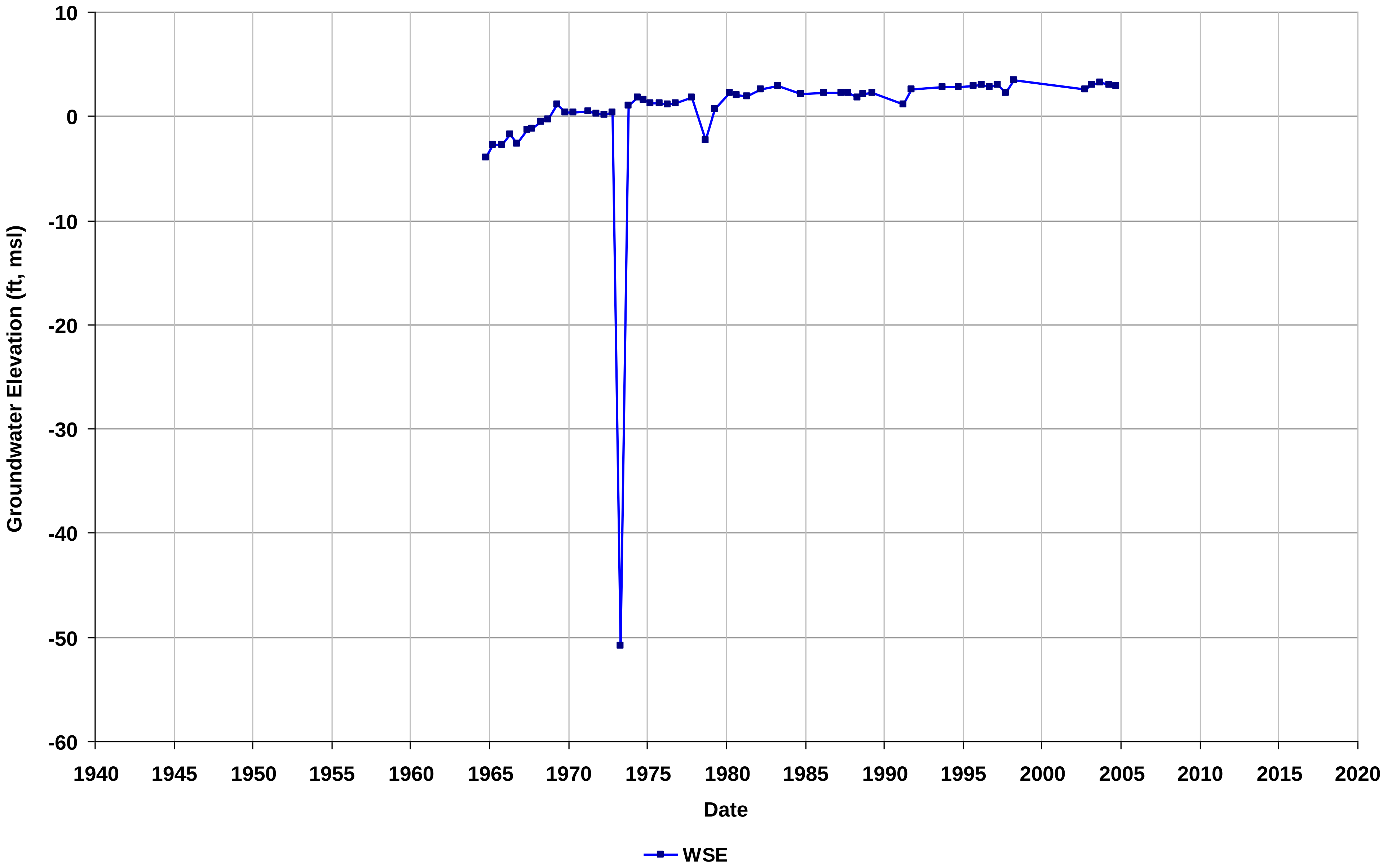
Well Use:



APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.D. Supporting Information for Subsidence SMC

3.D.c Narrative Description of Historical Groundwater Levels deep, were drilled for the old airport. Several of the wells are still being used by the golf course and the original Oakland Airport. Since then, much of Bay Farm Island has been reclaimed.

Castro Valley Water District

From the mid-1800's, groundwater was the sole water source for the Castro Valley Area. The Hayward fault was recognized as a water bearing zone: "*there is a streak of water-bearing formation extending through the town [Hayward] in a northwest and southeast direction extending nearly parallel to the foothills. Along this streak, which does not exceed 20 feet in width, there are many springs and abundant supply of water can be obtained from dug wells at a depth of about 10 feet. At the time of an earthquake, 1868, a crack opened along this streak, and from it a small stream of sand and water flowed for several hours*".

In 1930, the area was a bedroom community of 2000 (there were 1200 residents in 1926). The primary local industry was poultry raising and fruit orchards. From the late 1910's, groundwater levels had steadily dropped, and in several locations, wells had gone dry. In response to this, the Castro Valley Water District was formed by a vote of the residents (656 to 110) in late 1930, and bonds were issued in order to construct a water distribution system. It was known that the local water supplies were insufficient, and the residents planned on acquiring water from either the Niles Cone area, from the San Francisco Hetch Hetchy Aqueduct, or from EBMUD (Mokelumne River water). In May, 1931, the Castro Valley Water District was acquired by EBMUD.

Richmond

In the 1830's, the Franciscan outcrop on the west side of Richmond (Potrero Hill) was an island, and it was reported that deep water ships could navigate the slough east of the hill. Filling of the slough began in the 1850's and was completed in the 1920's. Even though it had an excellent port, it was not developed until 1900 because of clouded land titles and threats of lawsuits.

Richmond, as we know it, developed as a direct result of the railroads and the 1906 San Francisco earthquake. In 1899, the Santa Fe Railroad selected the area to be the deep-water port in the East Bay and a major railway repair station. Prior to this, the area was grazing/farm land with small towns, San Pablo, Rust (the name was changed to El Cerrito circa 1911), and Stege Junction (soon shortened to Stege) near the eastern hills. There were approximately 1805 people in the entire area in 1899. In 1901, ferry traffic was first initiated; in 1902, the Standard Oil Company refineries were established. In the beginning, there were two settlements: Point Richmond (the western hills) and the City of Richmond (the plains east of the hills). The two sections incorporated as the City of Richmond in 1905. A few years later, the town of Pullman developed east of Richmond, adjacent to the railroad tracks. As with Oakland, the 1906 earthquake cause a massive population increase after 1906 (the earthquake also created Albany, which was incorporated in 1908.) By 1913 there were 15,585 people in the Richmond area.

The first water company, the Richmond Water Company, was created by landowners as an inducement to home buyers at Point Richmond. Between 1900 and 1906, water was obtained from a series of wells in the vicinity of Castro Street, just north of I-580, and piped to a reservoir on top of Point Richmond. The field contained ten 12-inch wells, 118 to 250 feet deep. In 1906, there were 398 customers. The Richmond Water Company was purchased by the Syndicate Water Company in February, 1906, which in turn was purchased by the Peoples Water Company in 1907. During its one year existence, the Syndicate Water Company drilled the Richmond Well Field and developed the San Pablo Well Field 1. By 1910, The Peoples Water Company provided approximately 90 percent of the water to the area with the remainder by the smaller firms. All of the smaller firms were eventually purchased by the Peoples Water Company or disbanded.

Even as early as 1910, it was recognized that the pumping rate (3 to 4 million gallons per day) of the San Pablo alluvial fan was significantly more than the annual replenishment of the aquifers (the safe yield was estimated to be in the range of 2 million gallons per day). On May 11, 1911, the Richmond Municipal Water District was created for the express purpose of developing additional water supplies. It was approved by a vote of the residents (797 to 511) on December 3, 1912. Over the next several years, various water sources were studied and evaluated. These included development of surface water supplies in the hills east of the City (dams), or pumping water from the Sacramento River from either Martinez or Toland's Landing (at the mouth of the delta). Circa 1916, the issue was submitted to the voters (ie: the authority to issue bonds). The bond issue failed, and the District disbanded.

Water to the area was pumped from five major well fields. Four of these were located adjacent to the San Pablo and Wildcat Creeks, while the fifth was located in downtown Richmond. In 1913, there were approximately 350 wells in the District. Of that number, 240 were privately owned with the remainder being owned by private and public water companies. These wells supplied a total of 3 to 4 million gallons per day. In 1913, the average daily use was 71 gallons per day per person.

The groundwater in the Pullman District and in the vicinity of Cerrito Hill was near the ground surface (Cerrito Hill is a low hill in the central part of the southern Richmond plain). Wells in this area were generally 100 feet deep, and many gently overflowed. In the area northeast of Cerrito Hill, in the area east of Wall Street, and from Cutting Boulevard north to Grand View Terrace, the wells were drilled 100 to 140 feet deep and water stood 16 to 20 feet below the ground surface. The wells between Wildcat and San Pablo Creeks were drilled 170 to 500 feet deep. Over-pumping caused the water level in the San Pablo Well Fields to drop 30 feet between 1907 and 1911.

The groundwater in this area normally had a higher mineral content than other parts of the East Bay Area, and had to be treated by industrial users. Overpumping exacerbated the situation by causing sea water intrusion. In November, 1913, the Richmond wells had chlorine levels as high as 660 ppm. At that time, 100 ppm was thought to be the upper limit for human consumption. Test results from several groundwater samples are listed below (Tables 7 and 8). (Chlorine was listed in the tests, not chloride.)

Table 7: Analysis of Richmond Well Water (November 1, 1913), values in parts per million

Impurity	Union Water Richmond	Peoples Water Richmond	Peoples Water San Pablo	Sacramento River
$SiO_2+Al_2O_3+Fe_2O_3$	21.8	21.4	19.4	19.2
Ca	45.6	150.2	84.0	16.0
Mg	19.0	52.8	33.4	7.8
Na	48.0	98.7	46.6	14.0
Cl	34.1	399.0	129.2	12.8
CO_3 (equiv to HCO_3)	139.9	129.0	127.2	46.6
SO_4	17.1	31.1	50.4	6.4
Total dissolved matter	322.5	882.2	490.2	122.8
HCO_3	278.4	262.3	258.7	94.7
$CaCO_3$ (temp. hardness)	228.2	215.0	212.0	77.6
$CaCO_3$ from calcium	114.0	376.0	210.0	40.0
$CaCO_3$ from magnesium	78.0	217.0	137.0	32.0
Total	192.0	593.0	347.0	72.0

Table 8: Chlorine Content of Various Richmond Wells, September to October, 1913

Well Location	Chlorine Content (ppm)
Richmond Wells	660.0
San Pablo No. 1, Composite	61.2
San Pablo No. 1, well B	39.6
San Pablo No. 2, well 5	41.6
Single well	55.4
San Pablo No. 2, wells 6, 8, 10	47.2
Standard Oil Company, No. 2 (230 feet)	36.8
Standard Oil Company, No. 12 (290 feet)	44.2
Standard Oil Company, No. 16 (397 feet)	38.6
Southern Pacific Well (300 feet)	33.2
Santa Fe Company	45.0
Hercules Powder Company	34.2
Santa Fe Wells	399.0
Sacramento River (Toland's landing)	12.8
Curry Bottling Works	82.0

Richmond Wells - This was a group of seven to nine 12 inch wells drilled north of the Santa Fe Railway, between Ohio, Chanslor, Second, and Seventeenth Streets. The wells were 115 to 203 feet deep. The estimated capacity was 500,000 gallons per day, but the 5 year average yield (1907-1911) was 306,000 gallons per day (Table 9). This was the first well field in the area and was drilled in the early 1900's. The field was abandoned in the mid-1910's.

Table 9: Water Levels in the Central Richmond Well Field.

Well No.	Depth (feet)	Water Level, well idle	Water Level, well operating*
1	132	15	20
2	138	15	21
3	115	15	22
6	118	16	20
7	118	17	-
8	153	12	-
9	203	12	-

* Field was pumping 16,000 gallons per hour. When pumping 25,000 gallons per hour, the water level dropped to 38 feet from the ground surface

San Pablo Well Field No. 1 - This field was located in the town of Old San Pablo, between Wildcat and San Pablo Creeks (Alvarado Street and Church Lane). The tract of land on which the wells were drilled (lot 137) was approximately 1 mile long, with the creeks being approximately 1/4 mile apart at the west end, and 3/4 mile apart at the east end. (Reports of the day indicate that the 1/4 mile wide part of the land was at the east end of the lot. We switched the compass descriptions because we was unable to reconcile the original directions with the actual lot location/orientation.)

There were ten, 10 inch wells that were 134 to 359 feet deep. Nine of them were active. Half were drilled in 1906 and the remainder in 1910-1911. An additional well was drilled in the late 1910's. Their estimated capacity was 550,000 gallons per day, but the 5 year average yield (1907-

1911) was 348,000 gallons per day (Table 10). There are some reports that indicate that wells were drilled in this area as early as May, 1899. The field was abandoned in September, 1920.

Table 10: Water Levels in the San Pablo Well Field No. 1

well no.	depth (feet)	water level, well idle	water level, well operating
1	180	38	58
2	183	26	89
3	179	28	63
4	170	28	61

San Pablo Well Field No. 2 - This field was located at the northwest corner of the intersection of the Southern Pacific railroad tracks and Parr Boulevard (now the site of the old Crown Cork facility, Figure 21). There are eleven 10 inch wells varying in depth from 265 feet to 510 feet. Nine wells were drilled in 1907, and 2 more in 1910. In 1907, these wells yielded almost 2 million gallons per day. Because of overpumping, the yield decreased to 600,000 gallons per day in 1912 (a reduction of almost 70 percent), and to 300,000 gallons per day in 1918. In 1913, some of the wells were producing saline water, suggesting that there had been sea water intrusion. The field was abandoned in January, 1919. Hickey (1907) contains photographs of wells being drilled in this field.

San Pablo Creek Wells - As a result of the significant decline of the San Pablo Well Fields 1 and 2, 25 wells were drilled along the axis of the narrow valley in which San Pablo Creek flowed. Twenty-three of the wells were 50 to 100 feet deep, three were over 100 feet deep, and one was more than 200 feet deep. There was a 10 inch well, six 12 inch wells, and eighteen 14 inch wells, which produced approximately 300,000 gallons of water per day and were brought on-line in August, 1912. Provisions were made to allow pumping of water from San Pablo Creek into the well supply line. This was rarely done because there was only sufficient water during high water flows and the water was generally too muddy to be put into the system.

Wildcat Wells - These wells were located near the head of Wildcat Creek, where the old County road from Berkeley to Orinda crossed the creek (at Wegner Road). While these wells were technically within the Richmond District, the water generated by this system was used in Berkeley. None was used in Richmond. Within a small area 11 wells were drilled, 100 to 250 feet deep, and two 12 inch wells 275 and 293 feet deep. The water in the majority of the wells rose to near the ground surface. Four of the wells were drilled in 1911. There was also an 800 foot long tunnel. Water was only found in the first 200 feet. During the winter, water was also diverted from the creek. The wells, tunnel and creek diversion structures were connected to a small brick reservoir (15,000 gallons) at elevation 950 feet. The average yield of this system between 1902 and 1911 was 413,000 gallons per day. When the Claremont tunnel was driven in the late 1920's, the upper section of Wildcat Creek was diverted into the tunnel.

Other Richmond Area Water Companies

Other local water companies included the Union Water Company, the Fred Meyers Water Company, the McEwen Brothers Water Company, the Herbert Brown Water Company, the West San Pablo Water Company, and the Hercules Water Company. The larger industrial companies (such as the refineries) had private wells to supplement purchased water.

The *Union Water Company* supplied three areas in the Richmond area. One was Stege, one was west of the railroad tracks at Pullman, and the third was the subdivision at the Macdonald Avenue-Civic Center tract and the Grand View Terrace area. Water was pumped from a 12-inch diameter, 330 foot deep well at the west end of the San Pablo Well Field #1, and wells at each of Pullman

Stations #1, #2, #3, and #4. The Pullman Station #1 well was 120 feet deep on a 50 x 150 foot lot. The Pullman Station #2 well field was located on a triangular shaped, 21 acre lot on which 12 wells were drilled, with depths varying between 100 and 150 feet deep (Porter at Union Avenue). Pullman Stations #3 and #4 reportedly had single wells each, with depths less than 50 feet. Pullman Station #4 was southwest of 32nd Street, about 200 feet north of Portero Avenue.

There were tunnels at Bay View Park near Stege. The tunnels were located on a 50 x 175 foot lot and consisted of an 80 foot deep shaft from the bottom of which the tunnels were driven 100 feet north and south. The water was pumped to holding tanks at the top of Cerrito Hill. The tunnels produced up to 15,000 gallons per day.

The *Fred Meyers Water System* supplied water to two areas, a 400 acre area northeast of Pullman and the area south of Grand View Terrace. The supply to the area northeast of Pullman was provided by several (3?) wells that were approximately 100 feet deep. The other area was supplied by on-site wells.

Th*e McEwen Brothers Water System* supplied water to an area south of the Oakland Branch of the Santa Fe Railroad, between 1st and 16th Streets (the Santa Fe Tract). Water was pumped from 4 wells. The pumping plant and some of the wells were located on 5th street south of Ohio, and other wells were located north of 13th street at Ohio. The Company was purchased by the Peoples Water Company on February 15, 1907.

The *Herbert F. Brown Water System* supplied water to the 40 acres of the Brown-Andrade Tract. Water was pumped from one well. No other information was available.

The *West San Pablo Land and Water Company* supplied water exclusively to the Standard Oil Company. They had 12 wells ranging from 170 to 325 feet deep on lot 190 in San Pablo Rancho. They had 4 other wells closer to town. In 1911, they supplied about 450,000 gallons per day to the refinery.

The *Hercules Water Company* supplied water to the town of Pinole, primarily to the Hercules Powder Company. They had 3 wells on lots 179 and 183 in Rancho San Pablo (at the point where San Pablo Creek and Wildcat Creek are closest). The wells were 181 to 335 feet deep. Between 1908 and 1915, they pumped 46,000,000 gallons per year (130,000 gallons per day). Pumping continued until the early 1930's. They also had a small dam on Pinole Creek from which they drew water.

In 1912, the *Standard Oil Company* used 500,000 gallons per day from the West San Pablo Land and Water Company and 500,000 gallons per day from the Peoples Water Company. They also used about 25,000,000 gallons of salt water per day for condensing purposes. In 1907 they used 327,000 gallons of water per day.

The *Pullman Car Shops* purchased water from the Peoples Water Company. They also had several wells and two tunnels. The tunnels were 35 feet below the ground surface. One was 64 feet long; the other was 42 feet long.

The *Santa Fe Railroad* provided all their needs from wells drilled adjacent to the tracks at various locations. They had 6 wells in 1910, 11 wells in 1921, and 10 in 1923. Between 1910 and 1920, they pumped an average of 105,000,000 gallons per year.

Water Usage - Water usage in the Richmond area in 1912 is listed in Table 11:

Table 11: Production and Use of Water in Gallons per Day in Richmond, 1912.

Source	Production	Mfg.	Domestic	Sent outside of District
Private Wells (250)	533,500	---	533,500	---
Factory Wells	771,500	771,500	-----	---
Hercules Water Co.	130,000	----	----	130,000 to Pinole
Small Water CO's	39,000	----	39,000	-----
Main Well Fields	1,396,430	882,260	271,670	242,500 to Berkeley
Wild Cat Creek	312,600	---	----	312,600 to Berkeley
Sunset View Cemetery	55,000	55,000		
Union Water Co.	150,000	1,540	148,460	
Total	3,388,030	1,710,3000	992,630	685,100

Berkeley

In the early years, the Berkeley area contained two unincorporated towns, the college and the new town of Berkeley (founded in 1866) at the foot of the hills, and the town of Ocean View along the Bay. They were separated by several miles of open fields. The two towns merged on April 1, 1878.

The College of California (U.C. Berkeley) constructed the first water supply for the college and the surrounding town. The company, called the College Water Works (or the University Water Company), was incorporated on July 27, 1866, and water was first delivered in August, 1867. The water came from a dam on Strawberry Creek that was located at the foot of Panoramic Way, near Memorial Stadium. Two years later, the college decided it was not proper for them to operate a private company. In 1869, the college water works and water rights were sold to the Berkeley Water Works Company, owned by Mr. Berryman and Mr. Chappelle. Mr. Berryman bought out Mr. Chappelle in 1877. This firm constructed a series of tunnels and small dams on Strawberry Creek and Wildcat Creek (fall, 1877), and the Berryman reservoir, holding 8,000,000 gallons in North Berkeley. The California Institution for the Education of the Deaf, Dumb, and Blind (now the Kerr Center) was supplied by water from 2 private water tunnels (1000 feet long), a well, and a large spring in the hills behind the school.

This was not the end of the attempts by the University to produce its own water. Between 1883 and 1886, the University bored a 1400 foot long tunnel that produced about 3000 gallons per day. In 1890, they drilled 73 wells in the hills north of the University. The wells were 10 to 73 feet deep. Only one produced water. A short tunnel was bored at that site. It produced water for a few days, but quickly dried up. In 1892, a 120 foot deep, 6 inch diameter well was drilled in the bed of Strawberry Creek within 40 feet of the eastern boundary line of the university property. A second well, 500 feet deep, was drilled about 30 feet further up the canyon. Between 1900 and 1910, there was a series of student reports analyzing the building of dams across Strawberry and Claremont Creeks. Foundation evaluation test pits were dug in Claremont Canyon in the late 1890's.

Little is known about the water supply of Ocean View. All of the houses had private wells, but it appears that a small private water company, the Land and Town Improvement Association existed. In 1877, it laid 2,600 feet of pipe and offered to sell water from its well. One of the early wells is still in use. It was drilled prior to 1868, and is used by the Safeway located at Shattuck Avenue and Rose Street.

In 1882, Mr. Berryman sold out to Mr. Hopkins, though the company continued under the same name. In June, 1883, Berkeley experienced a water shortage, the first of many over the next 20 years. Garden watering was limited to one day a week. Soon after, the citizens suggested that water be brought in from Lake Temescal or that artesian wells be drilled. In 1884, the Berryman reservoir was enlarged to 23,000,000 gallons, and the Hopkins reservoir was constructed south of the California Institution for the Education of the Deaf, Dumb, and Blind (2,500,000 gallons). The Berkeley Water Works was transferred to the Alameda Water Company (also owned by Mr. Hopkins) in 1885.

Mr. Hopkins died at the age of 70, leaving the business to his wife who became an absentee owner living in San Francisco. She neglected the business, refusing to expand or improve the water supply. As a result, Berkeley suffered through a series of water shortages throughout the 1890's. The Contra Costa Water Company, which serviced Oakland, indicated that it would relieve the Berkeley situation if the Alameda Water Company would give up its franchise or buy available water. The Alameda Water Company would do neither. In 1896, the company admitted that it could not continue to adequately service West Berkeley. It gave up its franchise to service that area to the Contra Costa Water Company.

There was such a water shortage in Berkeley during 1898, that on July 15, the town trustees made watering a lawn or a garden a misdemeanor. This created such a stir that it was repealed at the next board meeting. This shortage prompted the citizens to seriously consider municipal ownership. In December, 1899, a Citizens' Syndicate was ready to submit to the town trustees a proposal to fund bonds for the purchase of the Alameda Water Company and for the development of additional water supplies. The proposal was reviewed, and on January 27, 1900, the committee in charge of reviewing the proposal reported against it. The engineers' evaluation of the proposed water supplies (a dam across Pinole Creek and the drilling of wells in the San Pablo Creek area) suggested that these would only provide sufficient water for a few years (very prophetic, see the San Pablo wells discussion) and that it would be unwise for Berkeley to commit itself to any project relying solely upon these wells. Berkeley drilled a test well in San Pablo that tested 4800 gallons per hour. A few months later (June, 1900), the town trustees approved the sale of the Alameda Water Company to the Contra Costa Water Company. The holdings included pipelines, 800 acres of land in Alameda and Contra Costa Counties, and three reservoirs: the Summit (40,000,000 gallons), the Berryman (30,000,000 gallons), and the Garber (10,000,000 gallons) It also included 174 acres of land at the head of Claremont Canyon. In 1961, those lands were transferred to the University of California as open space.

In 1911, water supplied to Berkeley was produced from the following (Figure 22):

Berryman Tunnel

Five hundred feet long, north of the head of Cordonices Creek (on Queens Road about 150 feet south of Quail Lane). It was 3 x 5 feet and heavily timbered. In 1938, the outlet pipes had rotted, and flow from the tunnel had been significantly reduced. The tunnel was opened up, and it was observed that the original timbering had rotted and the tunnel had filled with caved material. Approximately 210 feet of the tunnel were cleaned out. At that point, a concrete plug was installed and a 4 inch cement lined cast iron pipe was laid to direct the flow of water to the sewer in Quail Lane.

Average yield	1902-1911	91,200 gallons per day
Maximum yield	1906	123,200 gallons per day
Minimum yield	1908	63,800 gallons per day

Summit Tunnel

Three thousand feet long, 500 feet north of the Tunnel Road (Fish Ranch Road) at 1000 foot elevation. The tunnel was 6 feet high and 4 feet wide.

Average yield	1902-1911	726,000 gallons per day

Pfeiffer Springs and Tunnels

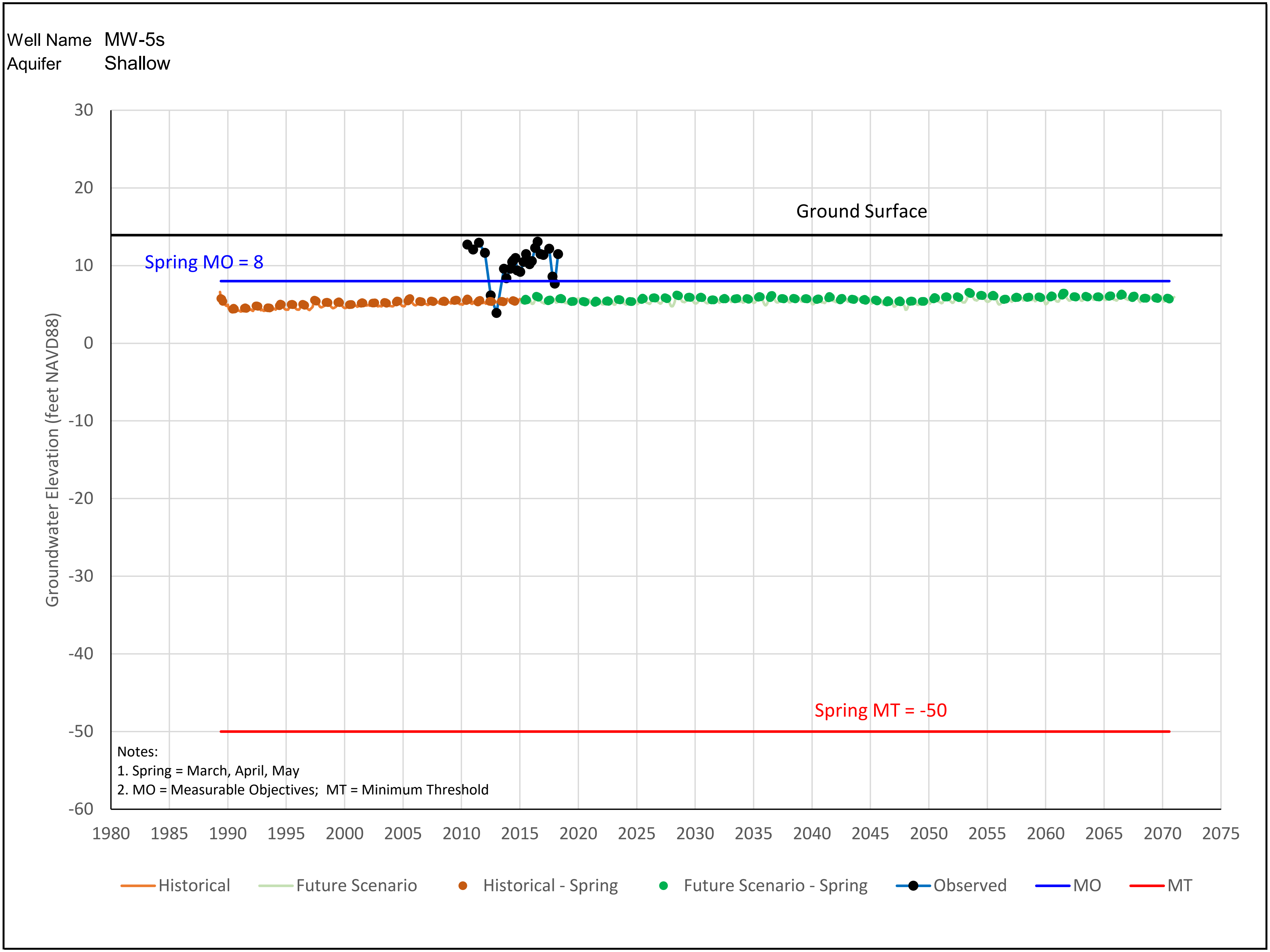
Six springs and 3 tunnels near the head of Strawberry Creek, 1/4 mile south of the county line at a 700 foot elevation. The tunnels were 3 feet wide, 6 feet high, and 40, 75, and 150 feet long. The springs were developed by the excavation of wells. The wells were about 4 feet in diameter and 20 feet deep with stone walls.

Average yield	1902-1911	45,900 gallons per day

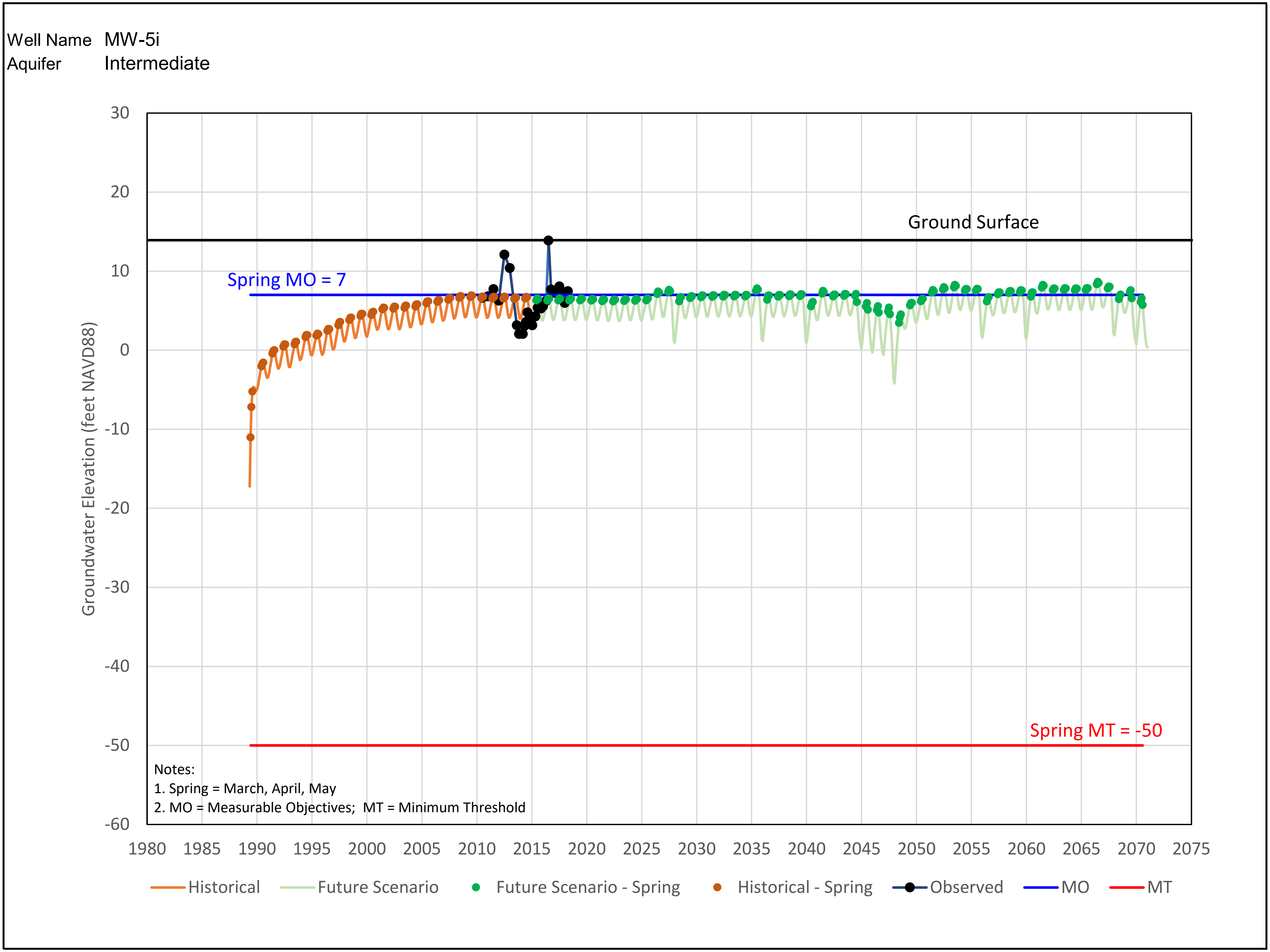
APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.D. Supporting Information for Subsidence SMC

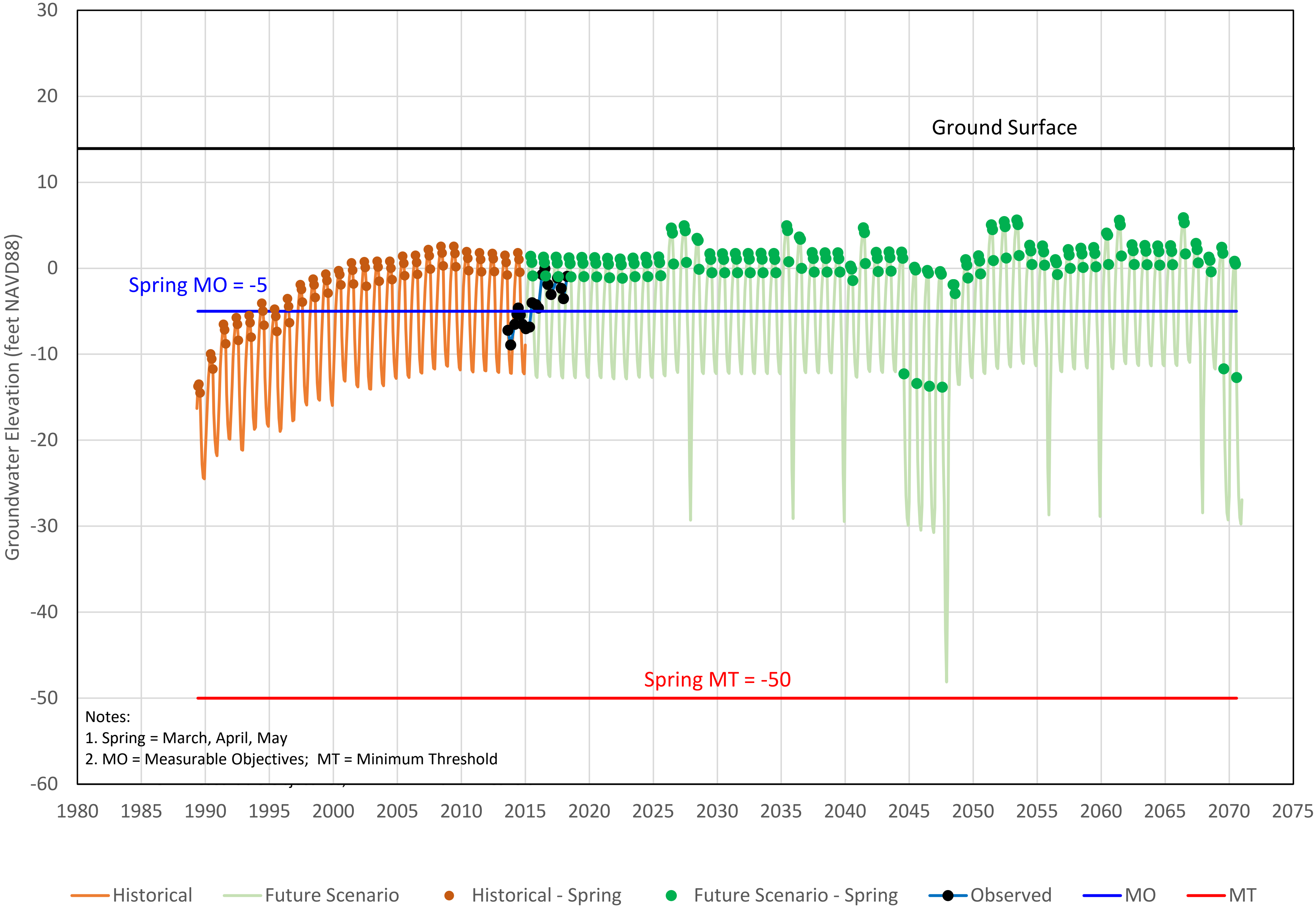
3.D.d Subsidence Groundwater Level Hydrographs With MT/MO



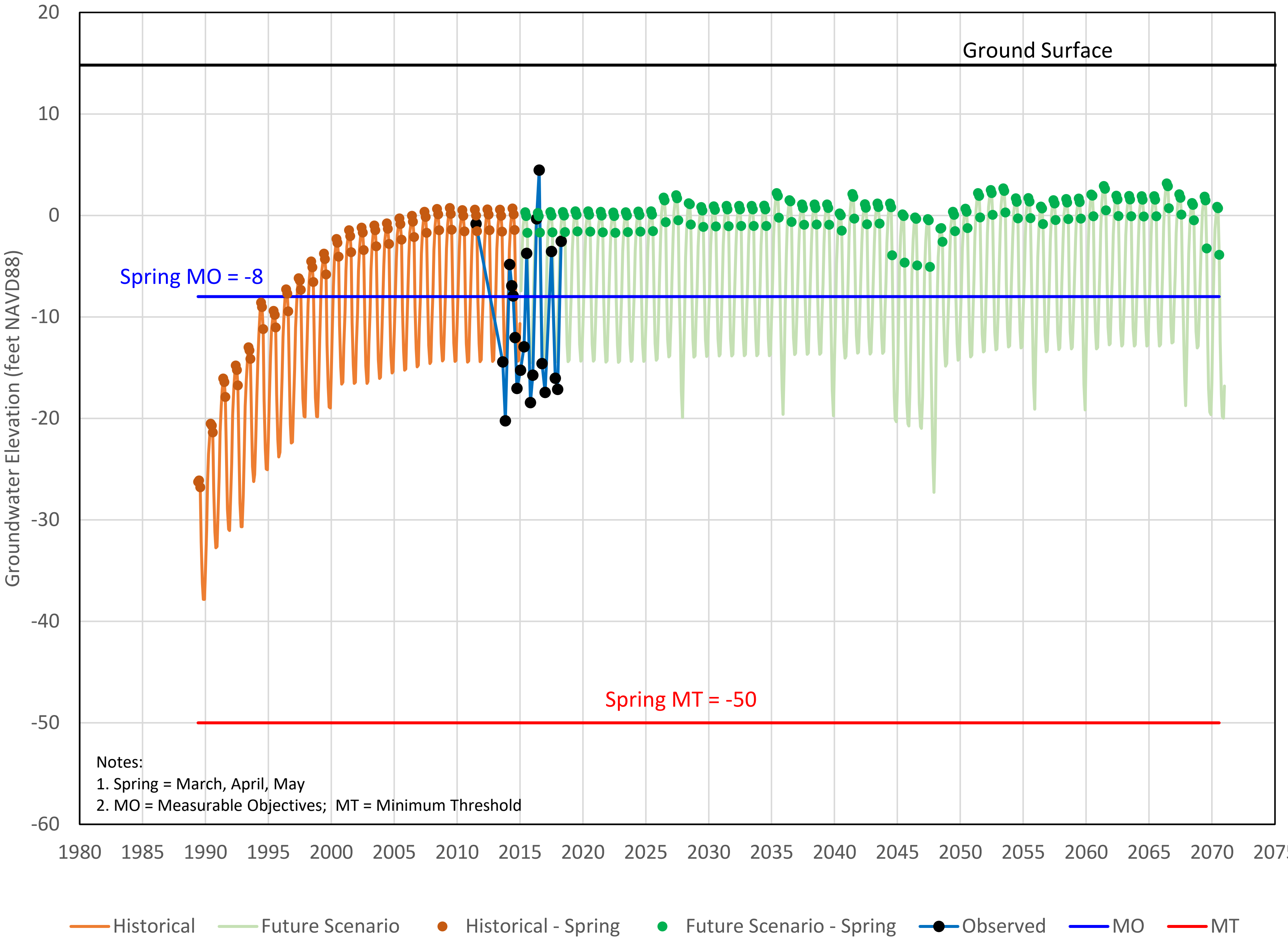
Well Name MW-5s
Aquifer Shallow
Ground Surface
Spring MO = 8
Spring MT = -50
Groundwater Elevation (feet NAVD88)
30
20
10
0
-10
-20
-30
-40
-50
-60
1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
Observed
MO
MT


Well Name MW-5i
Aquifer Intermediate
Ground Surface
Spring MO = 7
Spring MT = -50
Groundwater Elevation (feet NAVD88)
30
20
10
0
-10
-20
-30
-40
-50
-60
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Future Scenario - Spring
Historical - Spring
Observed
MO
MT

Well Name MW-5d
Aquifer Deep

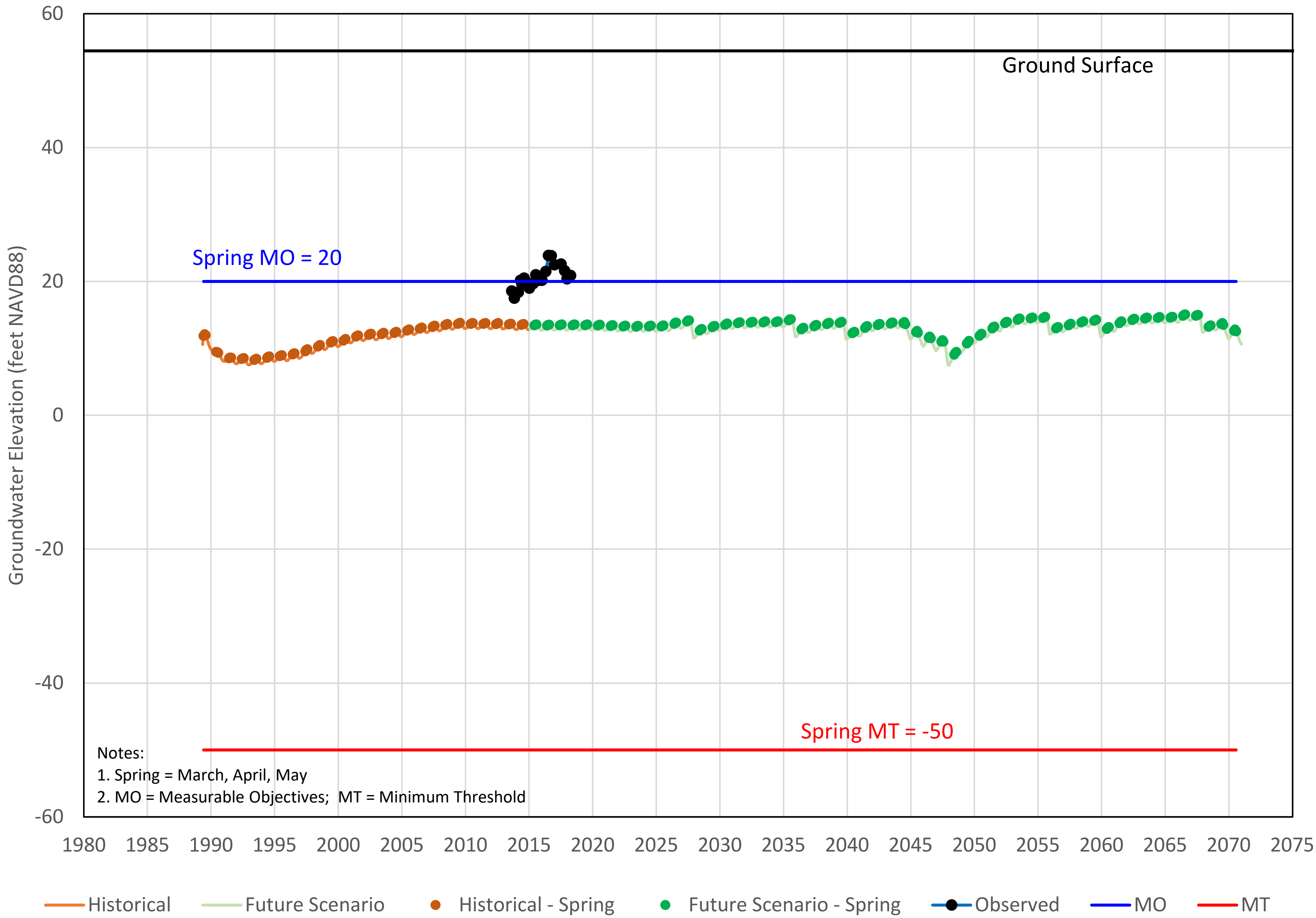


Well Name MW-8d
Aquifer Deep

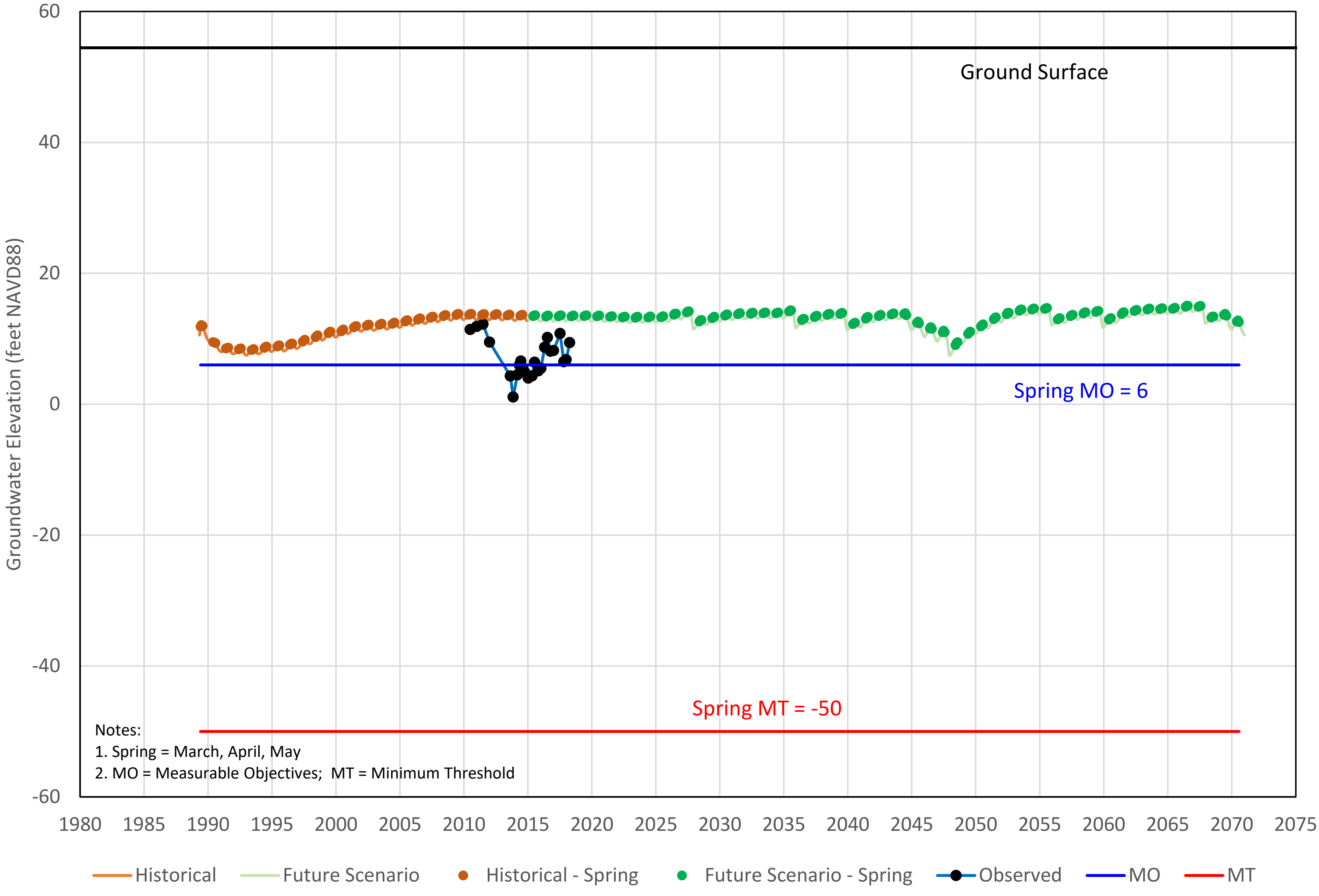


Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold

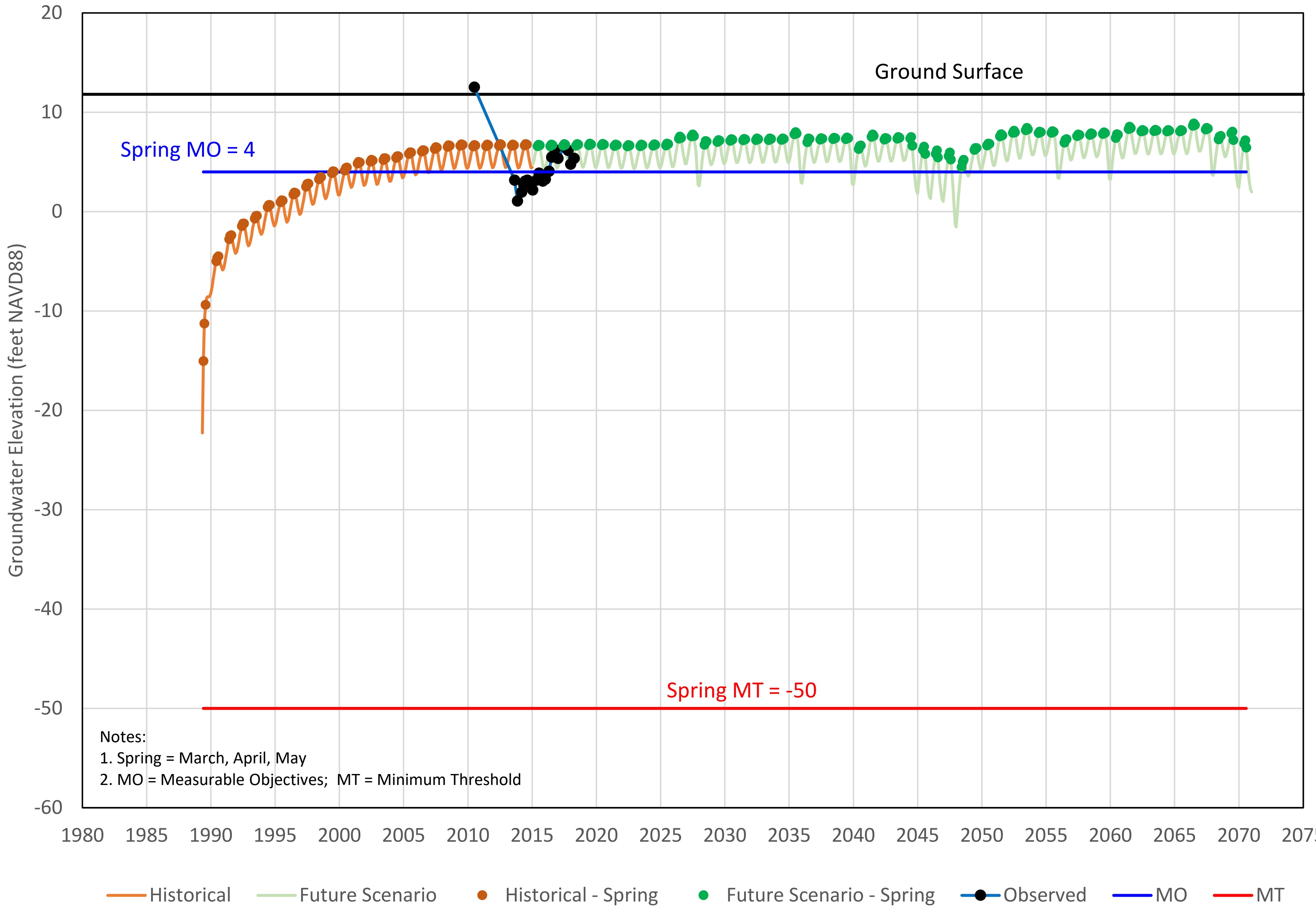
Well Name MW-9i
Aquifer Intermediate

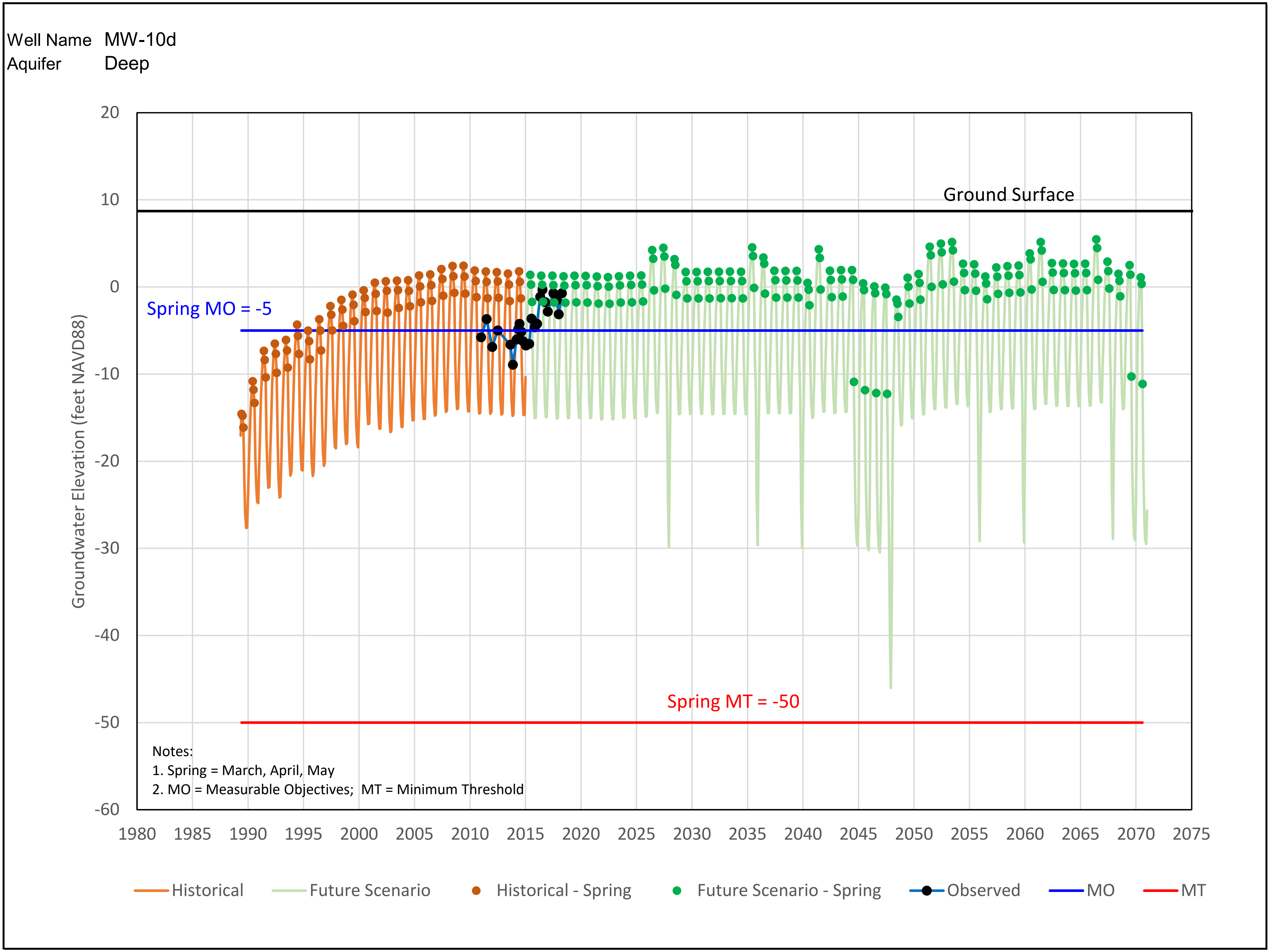


Well Name MW-9d
Aquifer Intermediate

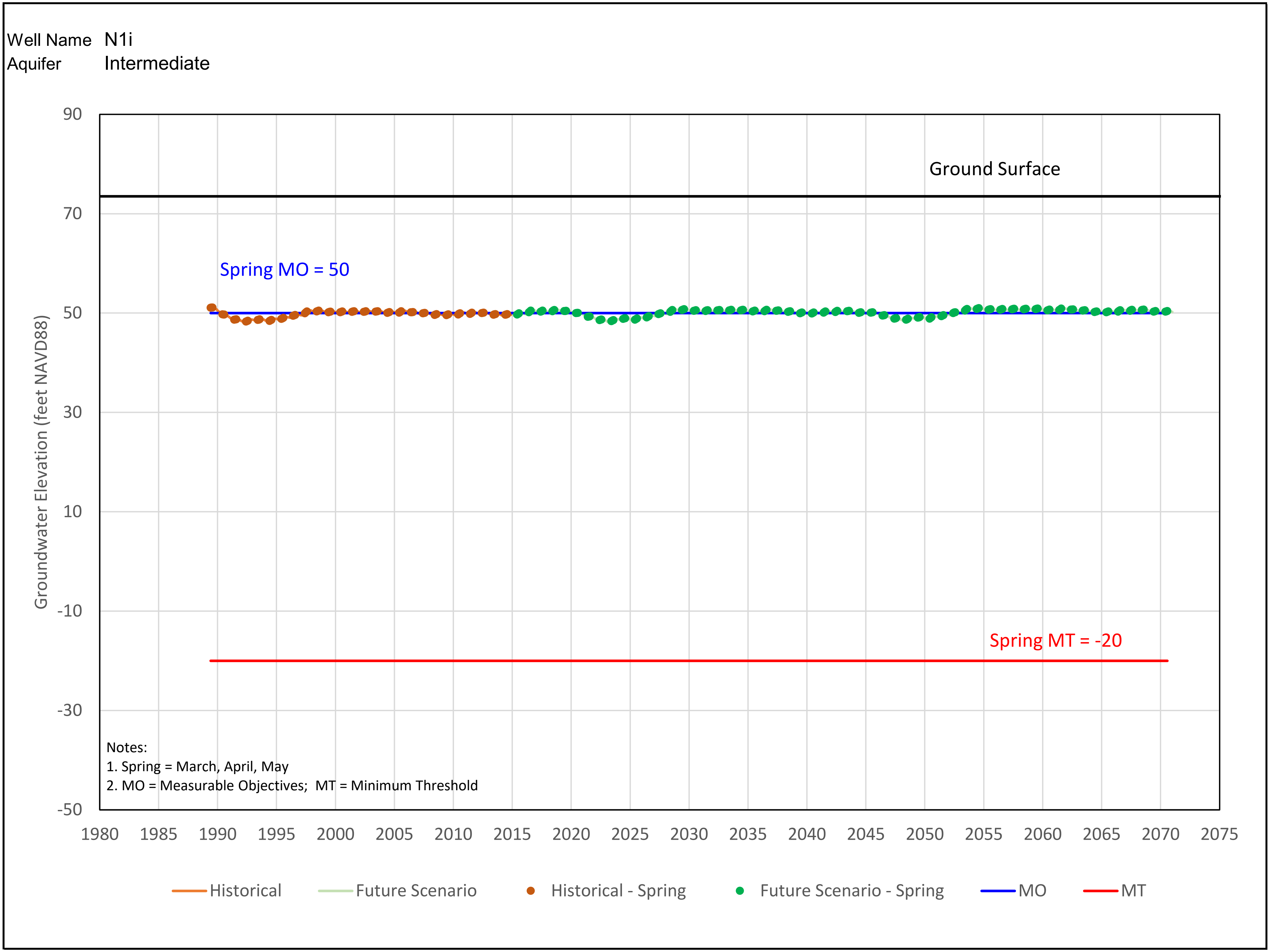


Well Name MW-10i
Aquifer Intermediate

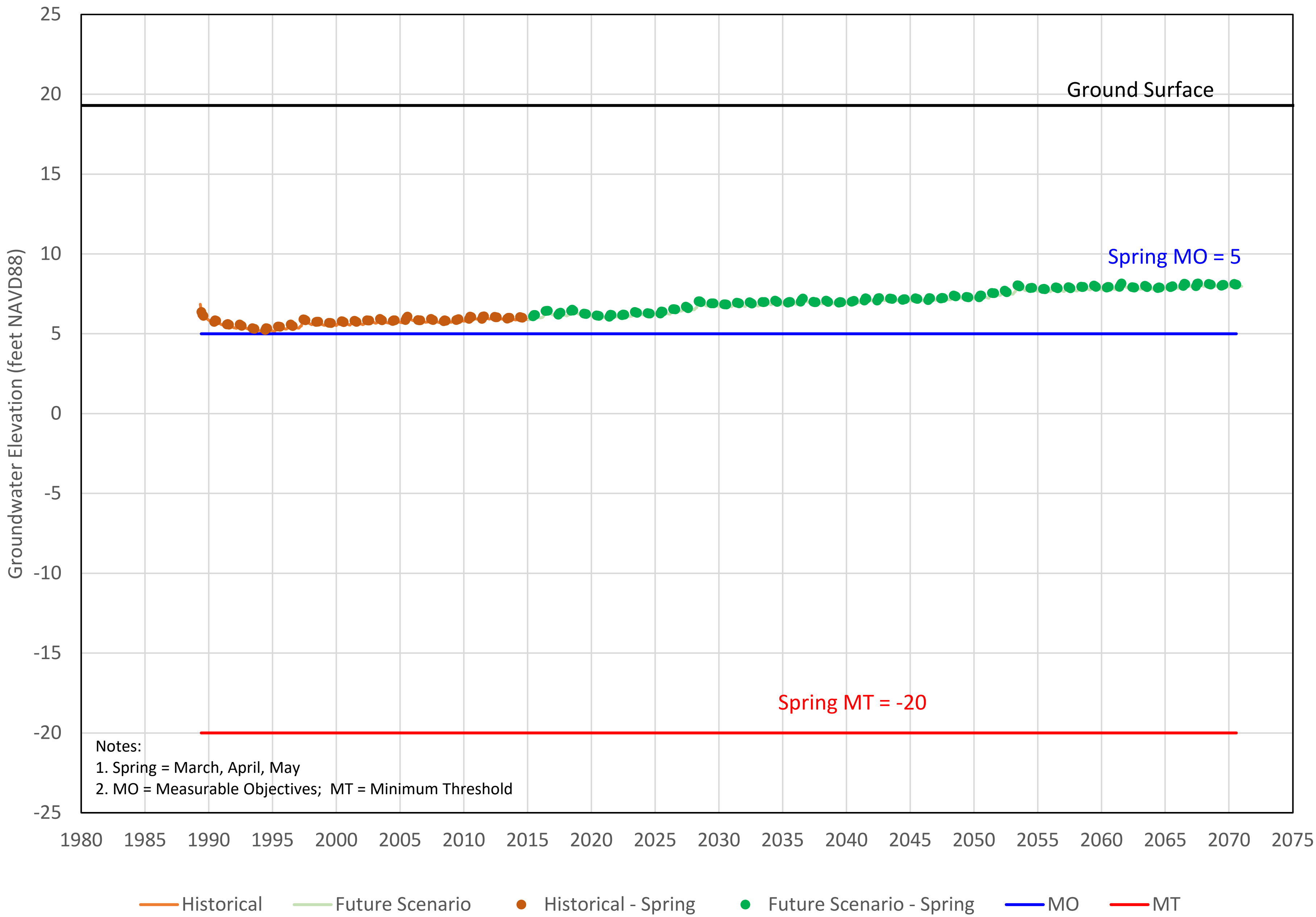




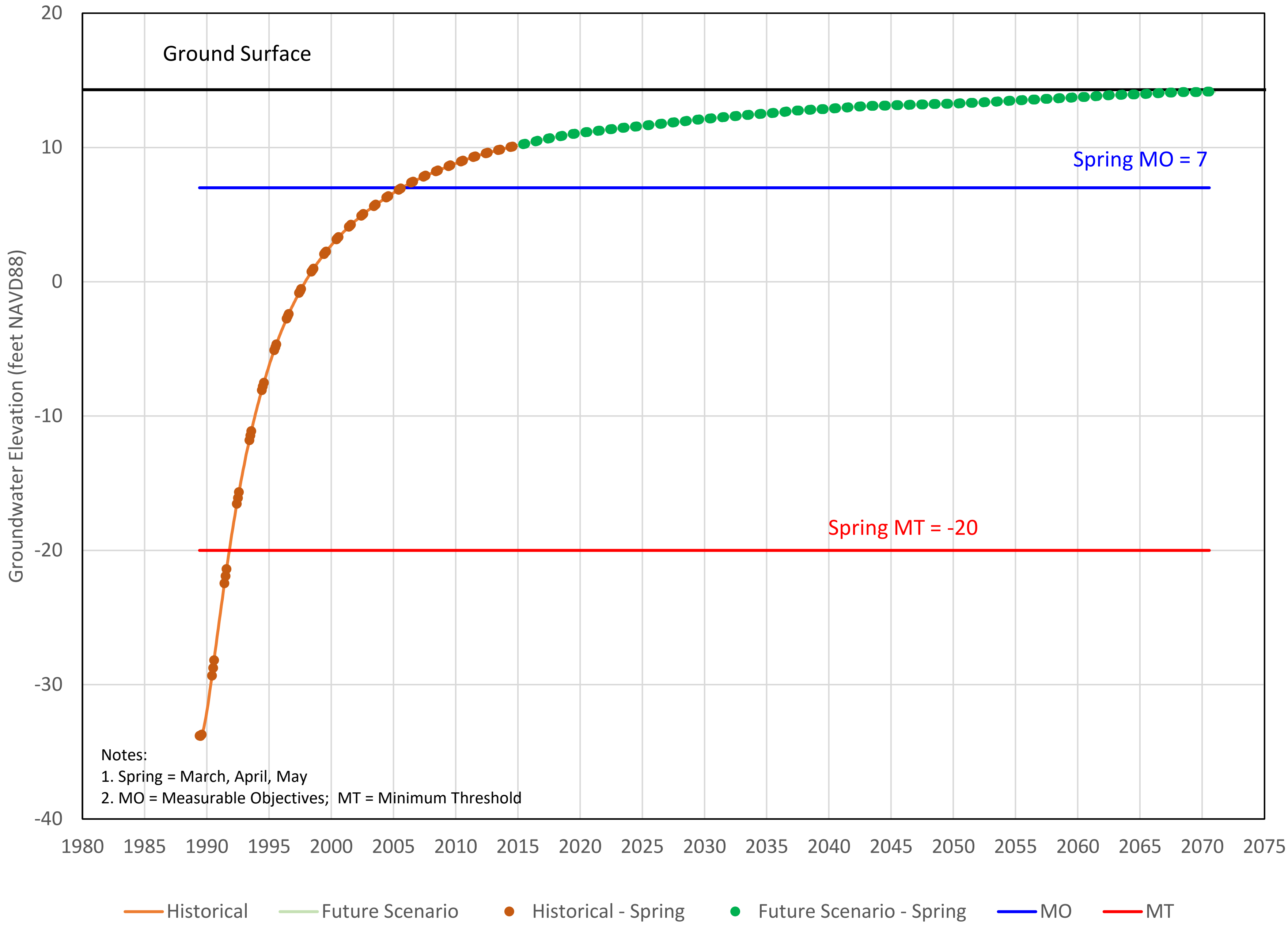
Well Name MW-10d
Aquifer Deep
Ground Surface
Spring MO = -5
Spring MT = -50
Groundwater Elevation (feet NAVD88)
20
10
0
-10
-20
-30
-40
-50
-60
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
Observed
MO
MT

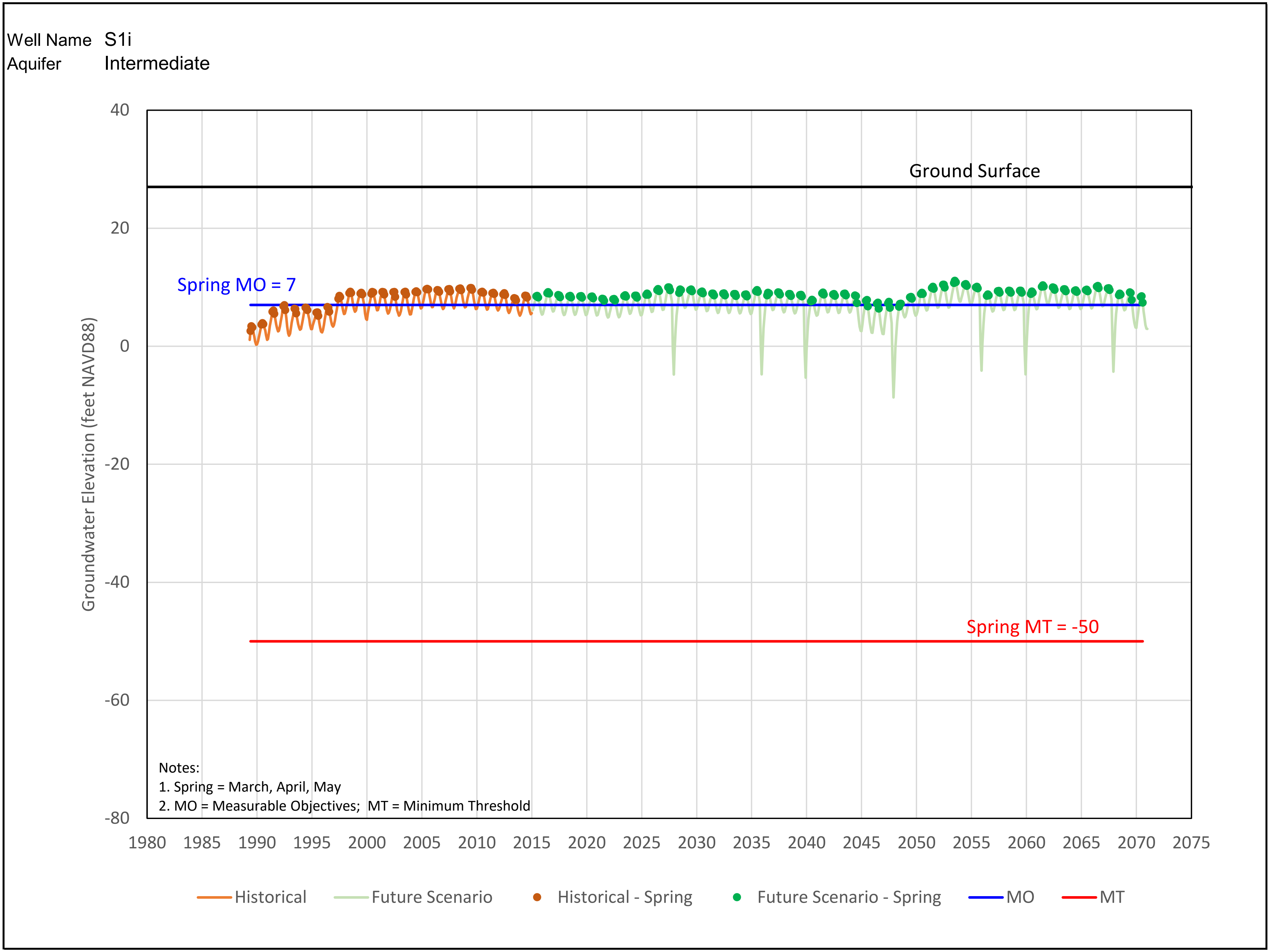

Well Name N1i
Aquifer Intermediate
Ground Surface
Spring MO = 50
Spring MT = -20
Groundwater Elevation (feet NAVD88)
90
70
50
30
10
-10
-30
-50
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
MO
MT

Well Name N2i
Aquifer Intermediate

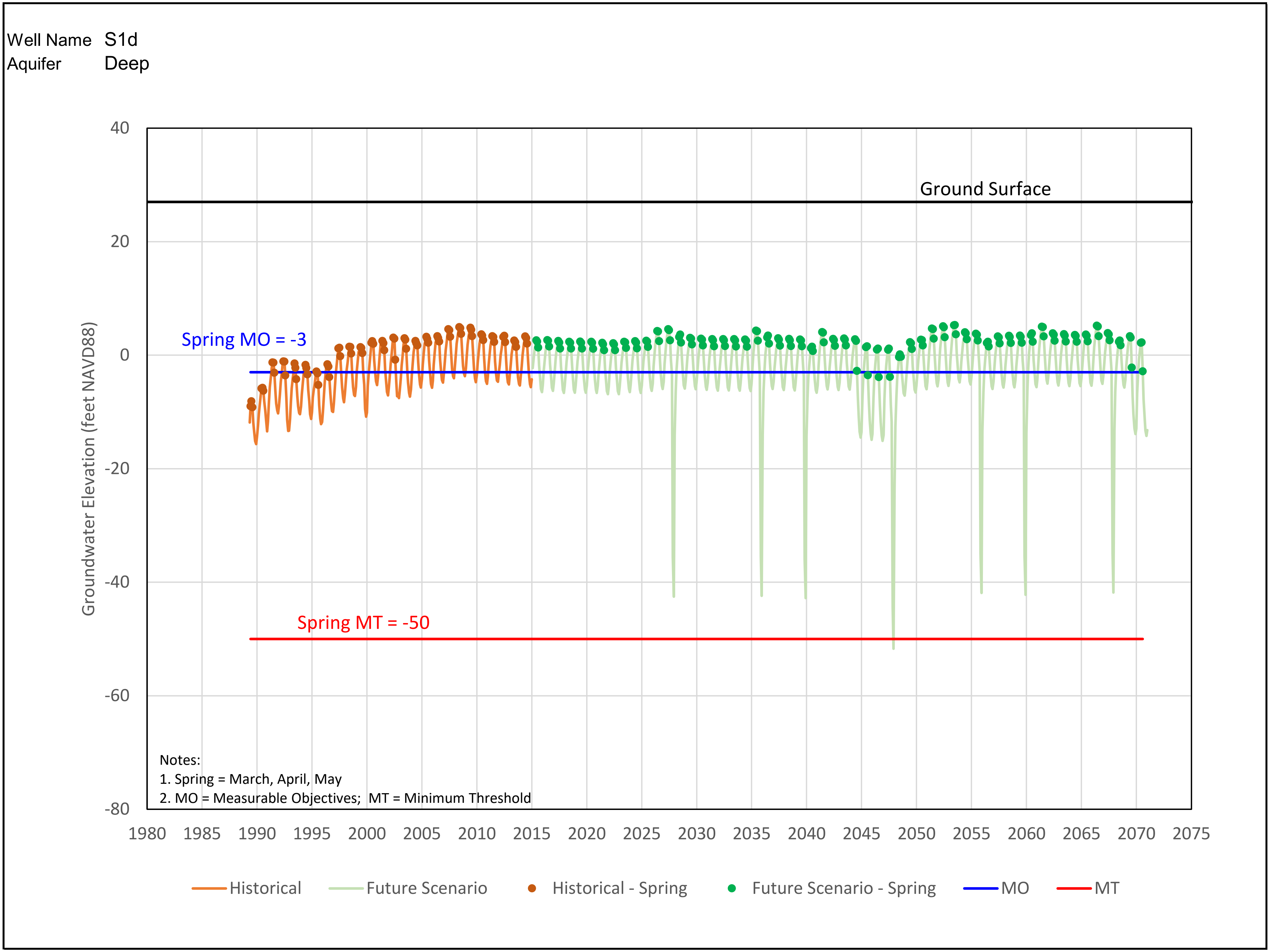


Well Name N3i
Aquifer Intermediate

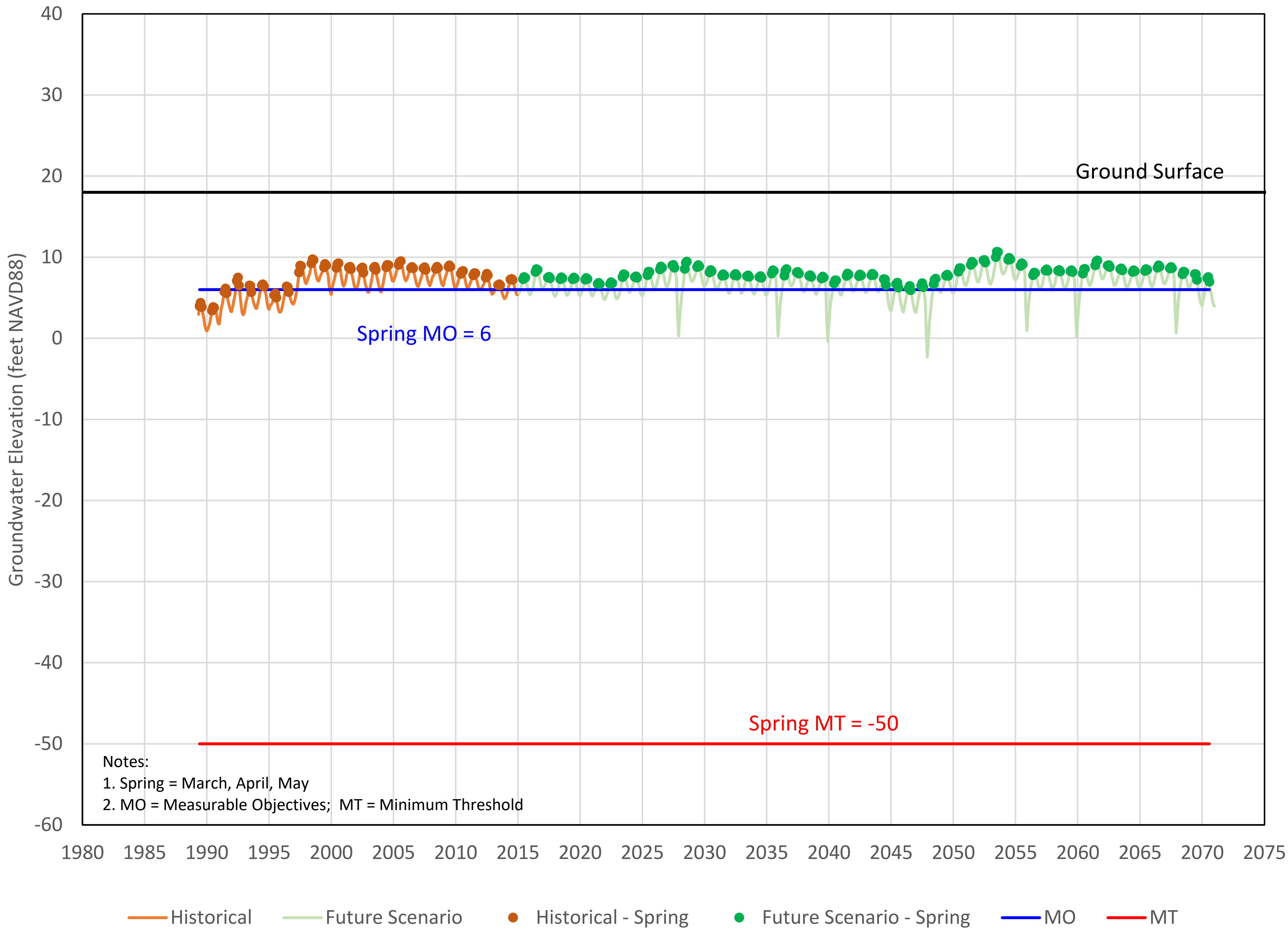




Well Name S1i
Aquifer Intermediate
Ground Surface
Spring MO = 7
Spring MT = -50
Groundwater Elevation (feet NAVD88)
40
20
0
-20
-40
-60
-80
1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
MO
MT

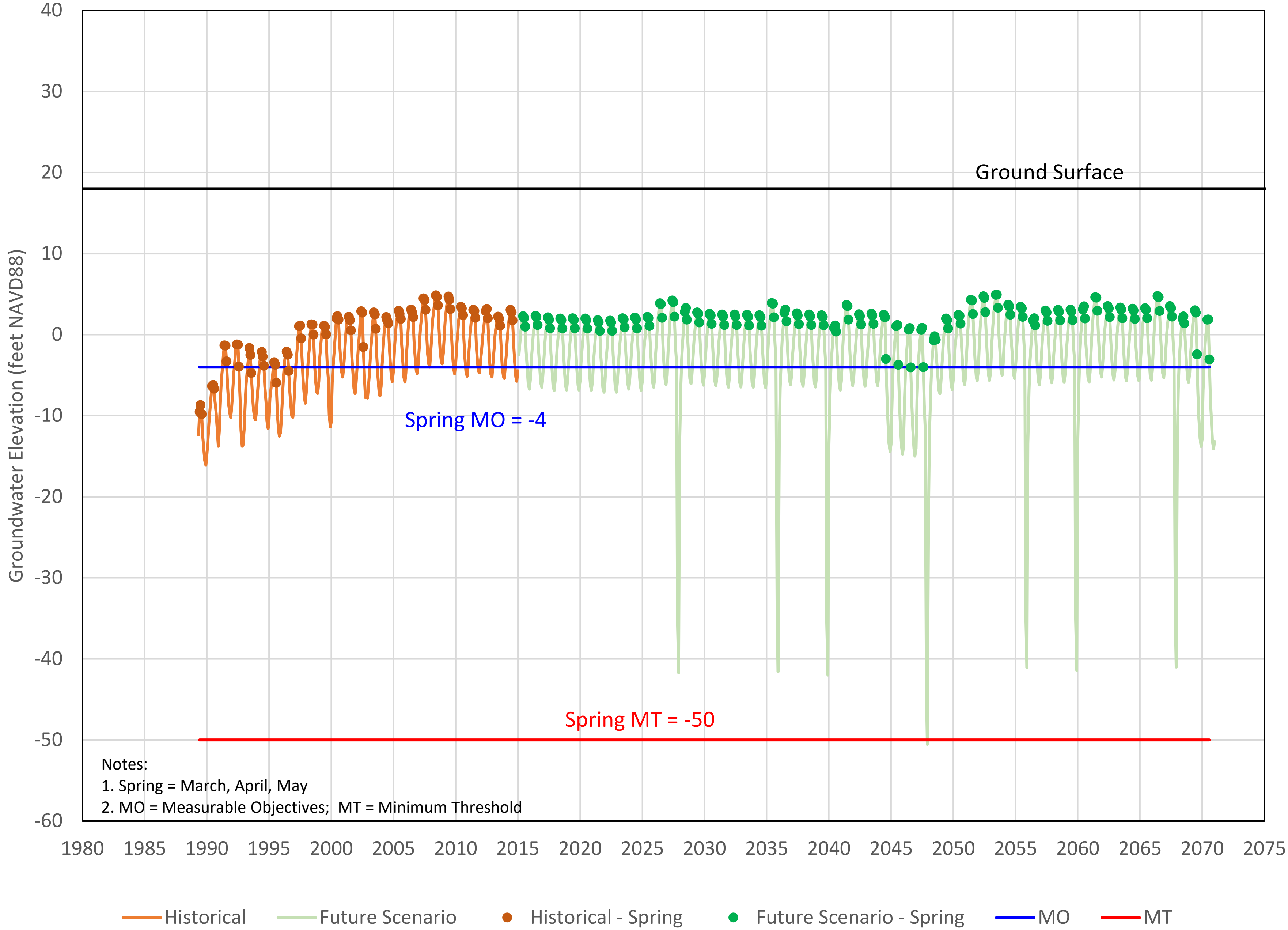

Well Name S1d
Aquifer Deep
Ground Surface
Spring MO = -3
Spring MT = -50
Groundwater Elevation (feet NAVD88)
40
20
0
-20
-40
-60
-80
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
2055
2060
2065
2070
2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
MO
MT

Well Name S2i
Aquifer Intermediate

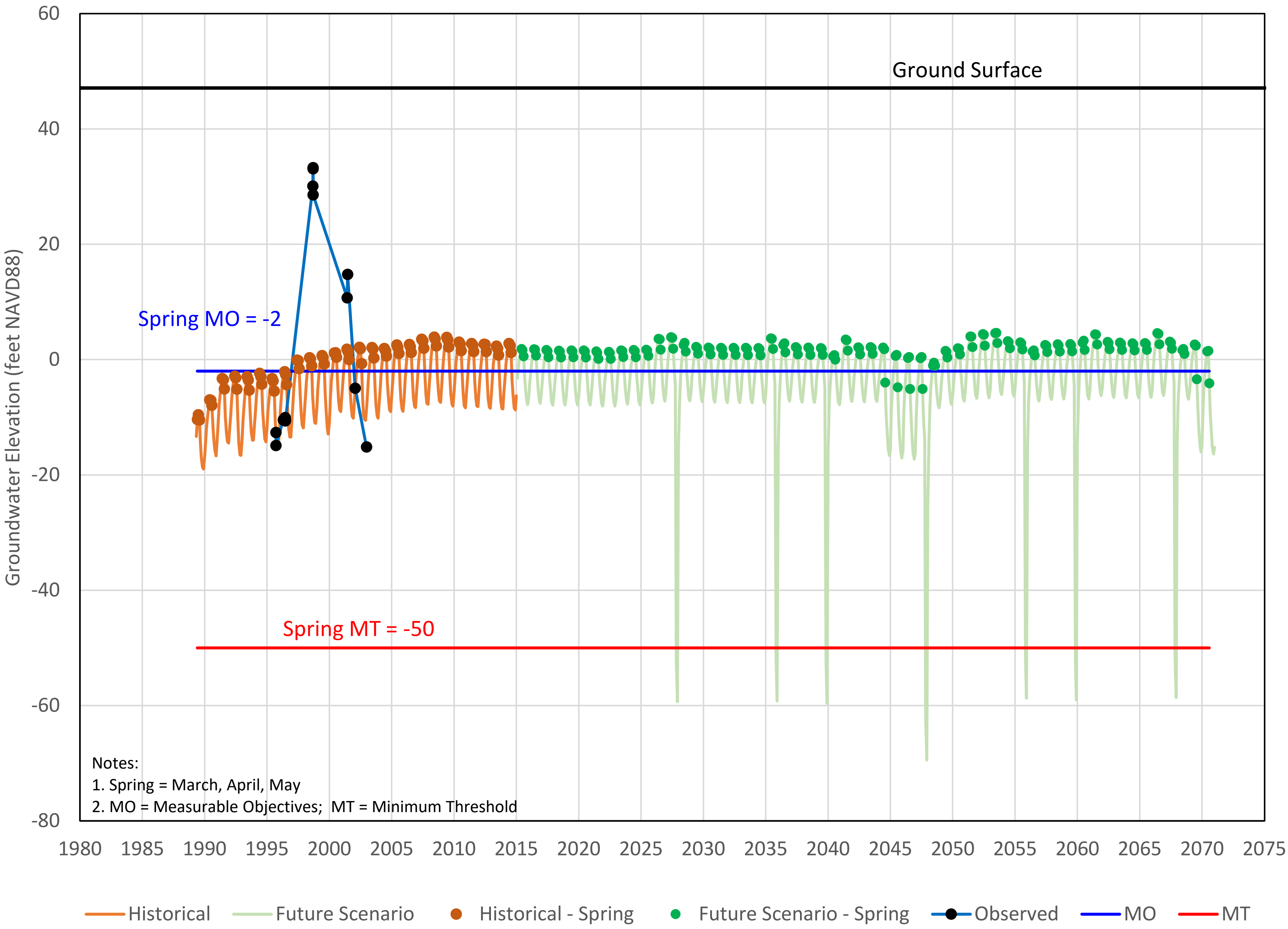


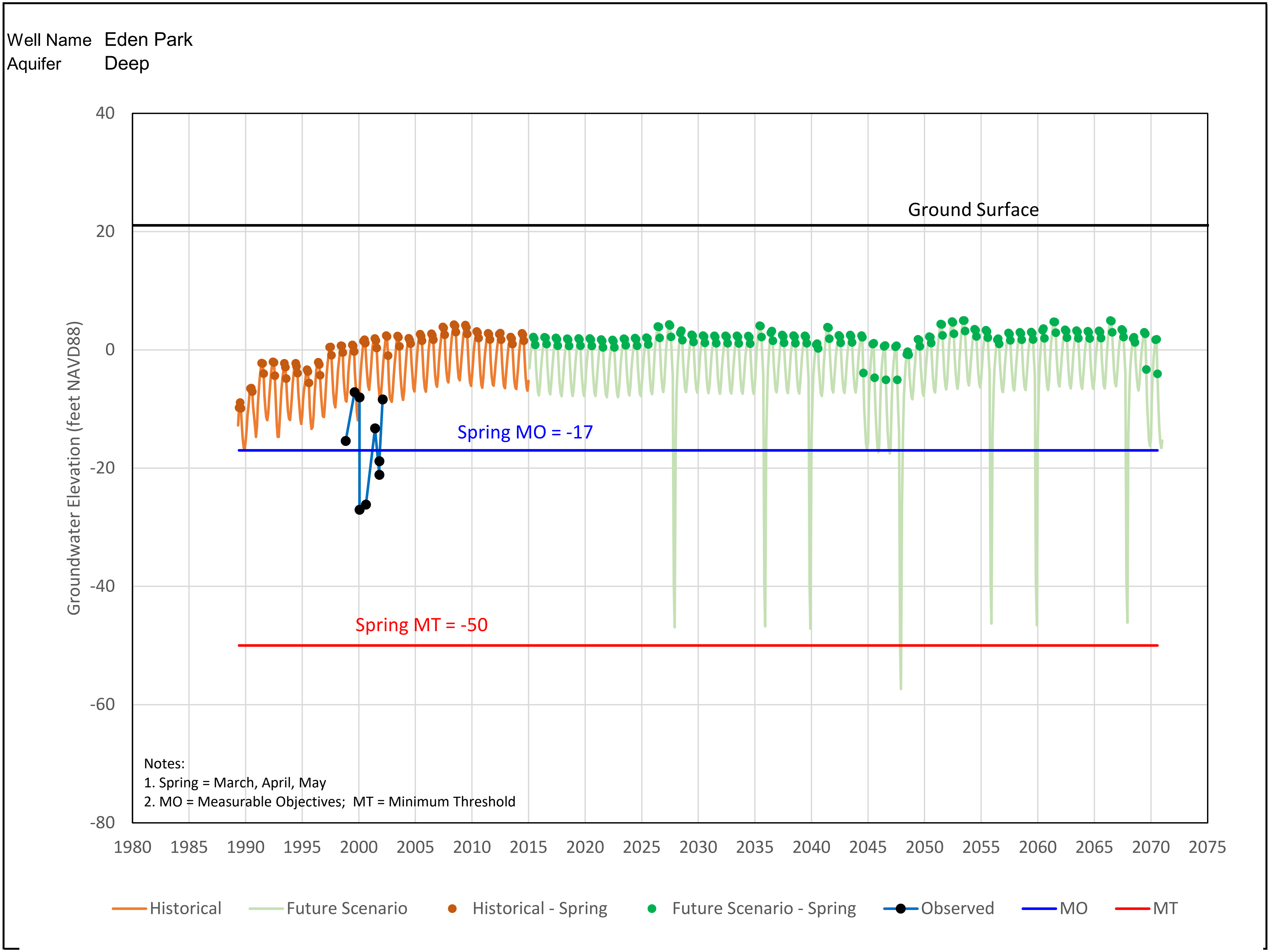
X:\2018\18-012 East Bay Plain GSP\Task_5.3\MO_MT Graphs\[Subsidence_v2.xlsx]

Well Name S2d
Aquifer Deep



Well Name Hayward Well D
Aquifer Deep




Well Name Eden Park
Aquifer Deep
Ground Surface
Spring MO = -17
Spring MT = -50
Groundwater Elevation (feet NAVD88)
40
20
0
-20
-40
-60
-80
1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075
Notes:
1. Spring = March, April, May
2. MO = Measurable Objectives; MT = Minimum Threshold
Historical
Future Scenario
Historical - Spring
Future Scenario - Spring
Observed
MO
MT

APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.E. Supporting Data for Groundwater Quality SMC

APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.E. Supporting Data for Groundwater Quality SMC

3.E.a Historical Groundwater Quality Data for RMS Wells

Table E-1. Summary of Groundwater Quality Data for Representative Monitoring Sites

Well ID	Date	Screen Top-Bottom	Aquifer Designation	Arsenic Concentration (µg/L)	Nitrate (as NO3) Concentration (mg/L)	Chloride Concentration (mg/L)	TDS Concentration (mg/L)	GSA Location
MW-5S	12/15/08	200-210	Shallow/Int	3.4	NA	56.4	459	EBMUD
MW-5I	12/15/08	315-325	Intermediate	18.7	NA	63.4	454	EBMUD
MW-5D	7/12/07	500-630	Deep	0.45	<0.085	93	460	EBMUD
MW-5D	12/16/14	500-630	Deep	NA	<0.009	96	490	EBMUD
MW-5D	11/18/15	500-630	Deep	NA	<0.009	82	450	EBMUD
MW-5D	12/21/16	500-630	Deep	NA	<0.013	84	470	EBMUD
MW-5D	12/19/17	500-630	Deep	NA	<0.091	57	410	EBMUD
MW-5D	12/10/18	500-630	Deep	NA	0.19	79	460	EBMUD
MW-5D	10/10/19	500-630	Deep	NA	<0.070	81	460	EBMUD
MW-5D	8/10/20	500-630	Deep	NA	<0.035	84	460	EBMUD
MW-5D	Range	500-630	Deep	0.45	<0.009 to 0.19	57 to 96	410 to 490	EBMUD
MW-5D	Average	500-630	Deep	0.45	0.06	82	458	EBMUD
MW-8D	3/9/00	420-480	Deep	<14.6	<0.006	50	NA	EBMUD
MW-9S	12/17/08	110-120	Shallow	1.5	NA	51.9	614	EBMUD
MW-9I	12/17/08	200-210	Intermediate	2.2	NA	47.2	428	EBMUD
MW-9D	12/17/08	325-335	Intermediate	3.2	NA	52.6	474	EBMUD
MW-10S	12/16/08	100-120	Shallow	6.0	NA	42.9	390	EBMUD
MW-10I	12/16/08	340-360	Intermediate	6.0	NA	53.4	465	EBMUD
MW-10D	12/16/08	590-610	Deep	1.9	NA	123	528	EBMUD
S2-MWS1	1/20/99	50-80	Shallow	NA	NA	15,000	27,000	EBMUD
S2-MWS2	1/20/99	140-180	Shallow	NA	NA	3,500	6,100	EBMUD
S2-MWD1	NS	480-500	Deep	NA	NA	NA	NA	EBMUD
MW-N1S	NS	TBD	Shallow	NA	NA	NA	NA	EBMUD
MW-N1I	NS	TBD	TBD	NA	NA	NA	NA	EBMUD
MW-N2S	NS	TBD	Shallow	NA	NA	NA	NA	EBMUD
MW-N2I	NS	TBD	TBD	NA	NA	NA	NA	EBMUD
MW-N3S	NS	TBD	Shallow	NA	NA	NA	NA	EBMUD
MW-N3I	NS	TBD	Intermediate	NA	NA	NA	NA	EBMUD
MW-S1S	NS	TBD	Shallow	NA	NA	NA	NA	Hayward
MW-S1I	NS	TBD	Intermediate	NA	NA	NA	NA	Hayward
MW-S1D	NS	TBD	Deep	NA	NA	NA	NA	Hayward
MW-S2S	NS	TBD	Shallow	NA	NA	NA	NA	Hayward
MW-S2I	NS	TBD	Intermediate	NA	NA	NA	NA	Hayward
MW-S2D	NS	TBD	Deep	NA	NA	NA	NA	Hayward
Well D	10/29/02	500-585	Deep	1.2	NA	46	366	Hayward
Well D	April 2006	500-585	Deep	NA	NA	58	440	Hayward
Well D	6/17/06	500-585	Deep	NA	NA	52	430	Hayward
Well D	Range	500-585	Deep	1.2	NA	46 to 58	366 to 440	Hayward
Well D	Average	500-585	Deep	1.2	NA	52	412	Hayward

Well ID	Date	Screen Top-Bottom	Aquifer Designation	Arsenic Concentration (µg/L)	Nitrate (as NO3) Concentration (mg/L)	Chloride Concentration (mg/L)	TDS Concentration (mg/L)	GSA Location
Eden Park		460-530	Deep	NA	NA	NA	NA	Hayward

TBD = To De Determined; RMS not installed yet but planned for installation in 2022; NS = Not Sampled; NA = Not Available

APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.F. Supporting Data for Surface Water Depletion SMC

APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.F. Supporting Data for Surface Water Depletion SMC

3.F.a Surface Water – Groundwater Interaction Model Data Summary

Table F-1. Percentage of Stream Reaches Connected to Groundwater Under Steady-State Conditions

Scenario	Average Annual Pumping (AFY)	Average Annual Injection (AFY)	San Pablo	Wildcat	Sausual	Peralta	San Leandro	San Lorenzo
Baseline w/ SLR 2022 to 2071	3,600	0	98%	75%	14%	38%	100%	61%
Sustainable Yield w/ SLR 2022 to 2017	12,500	0	98%	68%	14%	25%	100%	61%
Sustainable Yield Change from Baseline	**8,900**	**0**	**0%**	**-7%**	**0%**	**-13%**	**0%**	**0%**
Baseline w/o SLR; 2000 to 2015	3,600	0	98%	75%	14%	38%	100%	61%
1960s Pumping w/o SLR; 1960s	23,000	0	98%	71%	7%	25%	71%	24%
1960s Change from Baseline	**19,400**	**0**	**0%**	**-4%**	**-7%**	**-13%**	**-29%**	**-37%**

Note: Change in connectivity on Peralta Creek is due to change in only one grid square out of 8 total grid square comprising creek (i.e., creek reach is limited distance so one grid square = 13%);
Changes in connectivity on San Lorenzo Creek are unlikely to impact streamflow very much because majority of creek reach within EBP Subbasin is lined.

Table F-2. Average Streamflow (cfs) Under Steady-State Conditions

Scenario	Average Annual Pumping (AFY)	Average Annual Injection (AFY)	San Pablo	Wildcat	Sausual	Peralta	San Leandro	San Lorenzo
Baseline w/ SLR 2022 to 2071	3,600	0	6.5	4.4	NA	NA	8.8	15.7
Sustainable Yield w/ SLR 2022 to 2017	12,500	0	5.9	4.1	NA	NA	8.4	15.7
Sustainable Yield Change from Baseline	**8,900**	**0**	**-0.6**	**-0.3**			**-0.4**	**0.0**
Baseline w/o SLR; 2000 to 2015	3,600	0	5.8	4.2	NA	NA	8.4	15.2
1960s Pumping w/o SLR; 1960s	23,000	0	5.5	4.1	NA	NA	6.9	14.6
1960s Change from Baseline	**19,400**	**0**	**-0.3**	**-0.1**			**-1.5**	**-0.6**

Note: These changes in streamflow among different scenarios do not quantify how such changes may impact summer baseflows (assuming baseflows occur), because of insufficient field data.

Table F-3. Net Groundwater Inflow (cfs) to Streams Under Steady-State Conditions

Scenario	Average Annual Pumping (AFY)	Average Annual Injection (AFY)	San Pablo	Wildcat	Sausual	Peralta	San Leandro	San Lorenzo
Baseline w/ SLR 2022 to 2071	3,600	0	0.1	-0.7	NA	NA	0.1	1.1
Sustainable Yield w/ SLR 2022 to 2017	12,500	0	-0.6	-1.0	NA	NA	-0.3	1.1
Sustainable Yield Change from Baseline	**8,900**	**0**	**-0.7**	**-0.3**	**NA**	**NA**	**-0.4**	**0.0**
Baseline w/o SLR; 2000 to 2015	3,600	0	-0.4	-0.8	NA	NA	0.0	1.0
1960s Pumping w/o SLR; 1960s	23,000	0	-0.8	-0.8	NA	NA	-1.5	0.3
1960s Change from Baseline	**19,400**	**0**	**-0.4**	**0.0**	**NA**	**NA**	**-1.5**	**-0.7**

Table F-4. Average Shallow Zone Groundwater Levels Near Streams

Scenario	Average Annual Pumping (AFY)	Average Annual Injection (AFY)	SPC-2 San Pablo	SPC-3 San Pablo	SPC-1 San Pablo	SLC-2 San Leandro	SLC-1 San Leandro
Baseline w/ SLR 2022 to 2071	3,600	0	59.3	50.7	29.0	45.6	6.2
Sustainable Yield w/ SLR 2022 to 2017	12,500	0	59.3	50.2	27.6	44.8	4.4
Sustainable Yield Change from Baseline	**8,900**	**0**	**0.0**	**-0.5**	**-1.4**	**-0.8**	**-1.8**
Baseline w/o SLR; 2000 to 2015	3,600	0	59.3	50.7	28.9	45.5	5.9
1960s Pumping w/o SLR; 1960s	23,000	0	59.2	50.6	28.8	42.5	-0.1
1960s Change from Baseline	**19,400**	**0**	**-0.1**	**-0.1**	**-0.1**	**-3.0**	**-6.0**

Table F-5. Comparison of Changes in Connectivity, Streamflow, Net Groundwater Inflow, and Shallow GW Levels along Major Creeks

	San Pablo	Wildcat	San Leandro
Sustainable Yield Change in Connectivity	0%	-7%	0%
Sustainable Yield Change in Streamflow	-0.6	-0.3	-0.4
Sustainable Yield Change in Net GW to Stream (cfs)	-0.7	-0.3	-0.4
Sustainable Yield Change in Shallow GWLs	0.0 to -1.4	0.0 to -1.4	-0.8 to -1.8
1960s Change in Connectivity (%)	0%	-4%	-29%
1960s Change in Streamflow (cfs)	-0.3	-0.1	-1.5
1960s Change in Net GW to Stream (cfs)	-0.4	0.0	-1.5
1960s Change in Shallow GWLs (ft)	-0.1	-0.1	-3.0 to -6.0

Notes: Change in groundwater levels for Wildcat Creek assumed to be same as change in groundwater levels at San Pablo Creek

APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.G. Supplemental Monitoring Network

APPENDIX 3. SUSTAINABLE MANAGEMENT CRITERIA

3.G. Supplemental Monitoring Network

3.G.a Non-RMS Candidate Wells

Table 3G-1. Summary of Candidate Wells for Possible Inclusion in EBP Subbasin GSP Non-RMS Well Monitoring Network.

Well I.D.	Reference Point Elevation (ft MSL)	Well Depth (ft bgs)	Screen Top-Bottom (ft bgs)	Aquifer Designation	Last Known Measurement Date	Well Owner	GSA Location
OW-1	148[a]	300	140-220; 240-300	Shallow and Intermediate	1/22/21	Richmond Country Club	EBMUD
OW-2	52[a]	400	135-195; 235-315; 335-395	Shallow and Intermediate	1/22/21	Contra Costa CCD	EBMUD
OW-3	72[a]	240	120-130; 150-200; 210-230	Shallow and Intermediate	1/22/21	Salesian High School	EBMUD
OW-4	98[a]	125	28-38; 65-120	Shallow	1/22/21	Children's Hospital	EBMUD
MW-1B	10.70[b]	55	40-50	Shallow	12/10/97	Port of Oakland	EBMUD
MW-1C	10.63[b]	157	142-152	Shallow	12/10/97	Port of Oakland	EBMUD
MW-2B	12.93[b]	55	40-50	Shallow	12/10/97	Port of Oakland	EBMUD
MW-2C	13.00[b]	163	138-158	Shallow	12/10/97	Port of Oakland	EBMUD
MW-3B	13.91[b]	85	60-80	Shallow	12/10/97	Port of Oakland	EBMUD
MW-3C	14.20[b]	210	185-205	Shallow	12/10/97	Port of Oakland	EBMUD
MW-4B	11.62[b]	85	60-80	Shallow	12/10/97	Port of Oakland	EBMUD
MW-4C	11.72[b]	185	160-180	Shallow	12/10/97	Port of Oakland	EBMUD
MW-5B	12.80[b]	85	60-80	Shallow	12/10/97	Port of Oakland	EBMUD
MW-5C	12.94[b]	185	160-180	Shallow	12/10/97	Port of Oakland	EBMUD
MW-6B	10.83[b]	85	70-80	Shallow	12/10/97	Port of Oakland	EBMUD
MW-6C	11.16[b]	183	168-178	Shallow	12/10/97	Port of Oakland	EBMUD
MW-7B	10.69[b]	85	70-80	Shallow	12/10/97	Port of Oakland	EBMUD
MW-7C	10.54[b]	224	199-219	Intermediate	12/10/97	Port of Oakland	EBMUD
MW-1	8.68[c]	650	540-560; 570-590;650-650	Deep	Ongoing[d]	EBMUD	EBMUD
MW-2S	9.77[c]	60	40-60	Shallow	Ongoing[d]	EBMUD	EBMUD
MW-2I	9.82[c]	200	160-190	Shallow	Ongoing[d]	EBMUD	EBMUD
MW-3	9.45[c]	660	520-650	Deep	Ongoing[d]	EBMUD	EBMUD
MW-4	8.61[c]	650	520-650	Deep	Ongoing[d]	EBMUD	EBMUD
MW-6	9.20[c]	655	480-650	Deep	Ongoing[d]	EBMUD	EBMUD
MW-7	7.38[c]	640	510-630	Deep	Ongoing[d]	EBMUD	EBMUD
Farmhouse	52[e]	540	500-530	Deep	8/3/2007	EBMUD	EBMUD
EBAY-2	7.0[f]	860	830-860	Deep	Ongoing[g]	EBMUD	EBMUD
EBAY-3	7.0[f]	550	530-550	Deep	Ongoing[g]	EBMUD	EBMUD
EBAY-4	7.0[f]	318	298-318	Intermediate	Ongoing[g]	EBMUD	EBMUD
EBAY-5	7.0[f]	138	128-138	Shallow	Ongoing[g]	EBMUD	EBMUD
EBAY-6	7.0[f]	45	35-45	Shallow	Ongoing[g]	EBMUD	EBMUD
Well A	NA[h]	550	245-265; 440-450; 475-530	Int/Deep	5/17/96	Hayward	Hayward

Well I.D.	Reference Point Elevation (ft MSL)	Well Depth (ft bgs)	Screen Top-Bottom (ft bgs)	Aquifer Designation	Last Known Measurement Date	Well Owner	GSA Location
Well B MW-S	NA[h]	232	172-182; 212-222	Shallow and Intermediate	12/2/10	Hayward	Hayward
Well B MW-I	NA[h]	382	302-312; 362-372	Intermediate	12/2/10	Hayward	Hayward
Well B MW-D	12.5	535	440-450; 505-525	Deep	12/2/10	Hayward	Hayward
Well C	12.5	466	370-410; 422-456	Intermediate and Deep	10/29/02	Hayward	Hayward
Well E	NA[h]	535	470-490; 500-525	Deep	12/2/10	Hayward	Hayward

[a]Reported Reference Point in CASGEM online system; estimated value that is not surveyed.

[b]Reported Reference Point is relative to a Port of Oakland datum known as Mean Lower Low Water (MLLW).

[c]Reported Reference Point from May 2009 survey relative to NGVD 29.

[d]Ongoing groundwater level readings are collected with transducers installed and maintained by EBMUD.

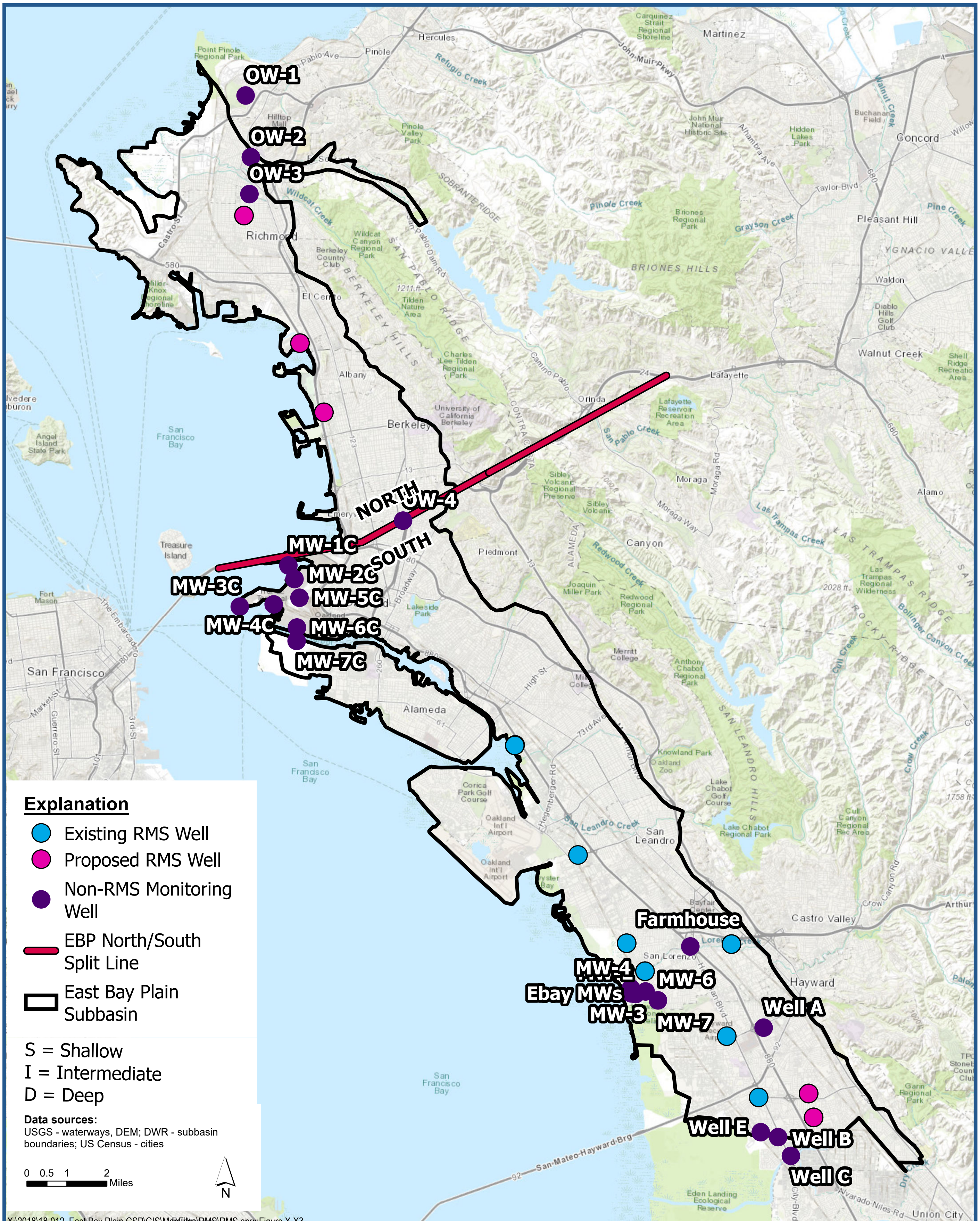
[e]Estimated land surface elevation from Google Earth.

[f]Estimated Land Surface Elevation relative to National Geodetic Vertical Datum (NGVD) 1929 from USGS (2015).

[g]Ongoing measurements collected by USGS as part of extensometer monitoring program.

[h]Not Available

[i]Reported Reference Point elevation relative to NAVD 88 (USGS, 2018)



LSCE TEAM

Potential Groundwater Level Non-RMS Wells

Figure 3G-1

East Bay Plain Subbasin
Groundwater Sustainability Plan