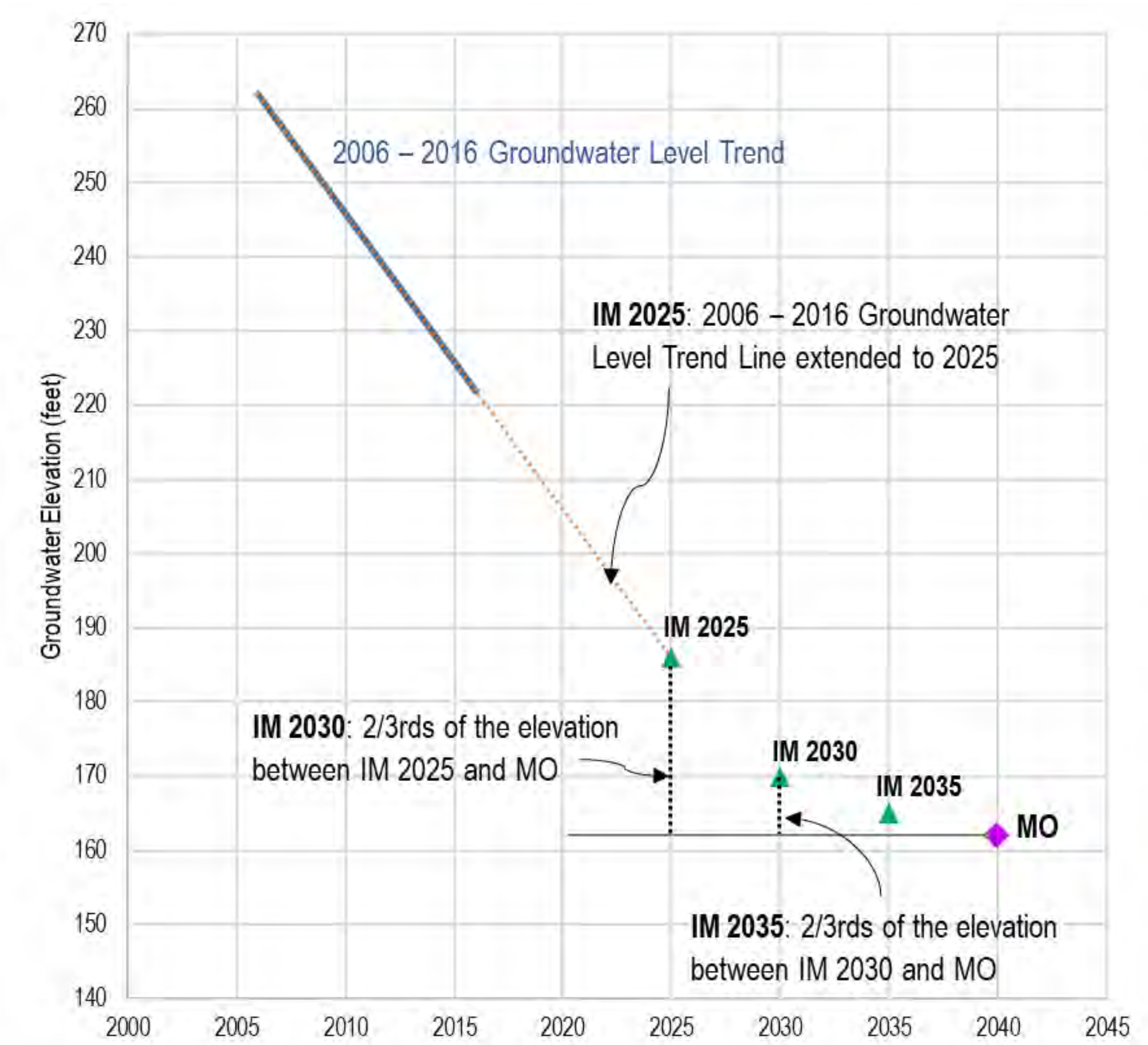

Figure 20. Example of Interim Milestone Method for GKGSA and MKGSA Represenative Monitoring Sites

4 REFERENCES

Kang, S., Knight, R., & Goebel, M. (2022). Improved imaging of the large-scale structure of a groundwater system with airborne electromagnetic data. *Water Resources Research*, 58, e2021WR031439. https://doi.org/10.1029/2021WR031439

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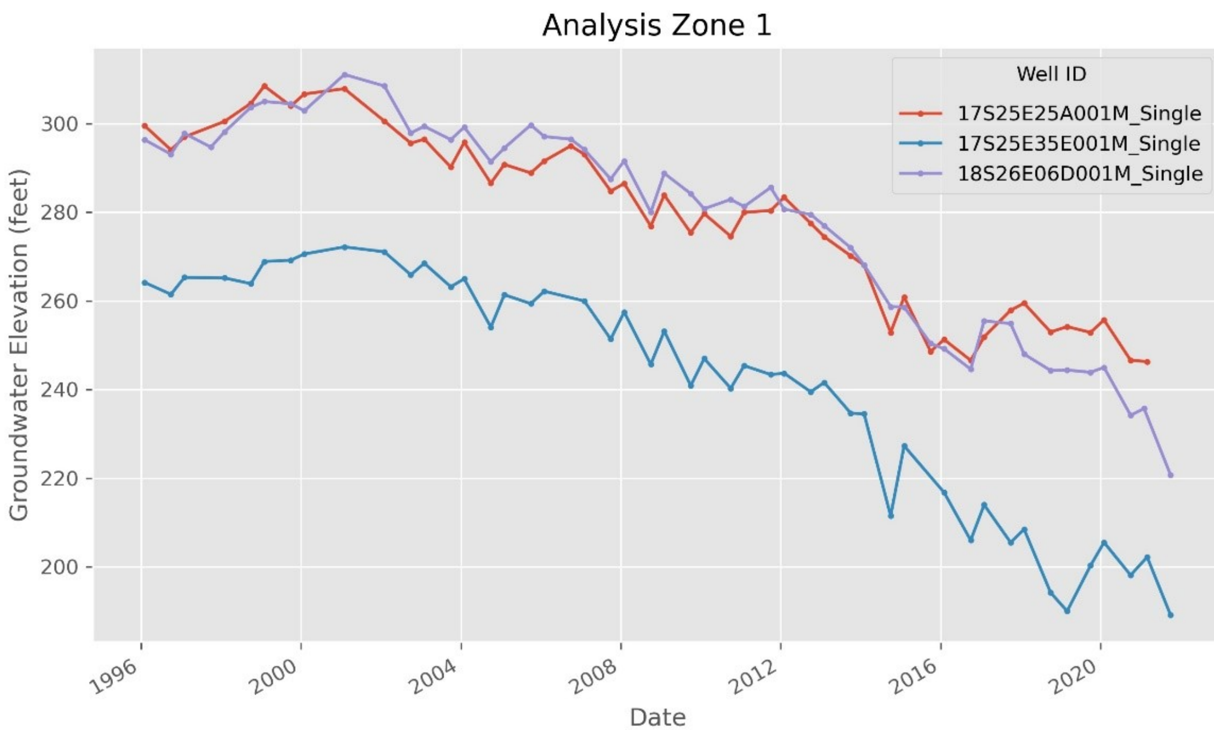
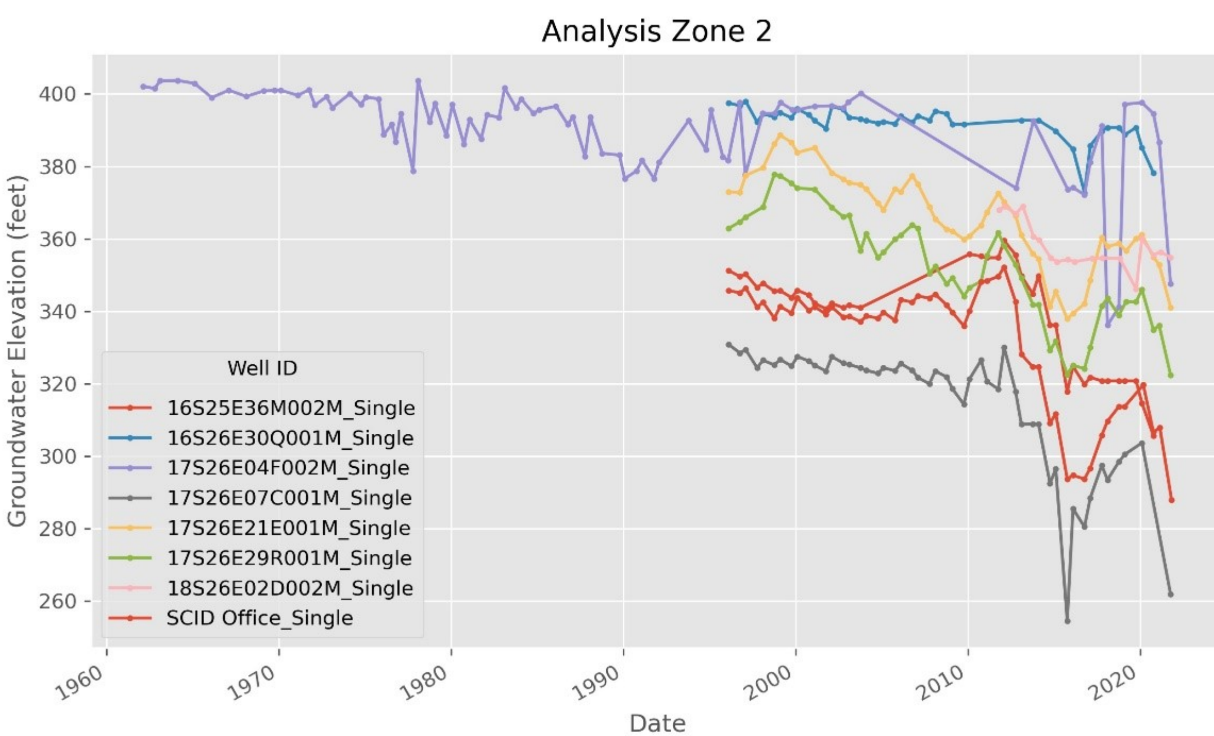
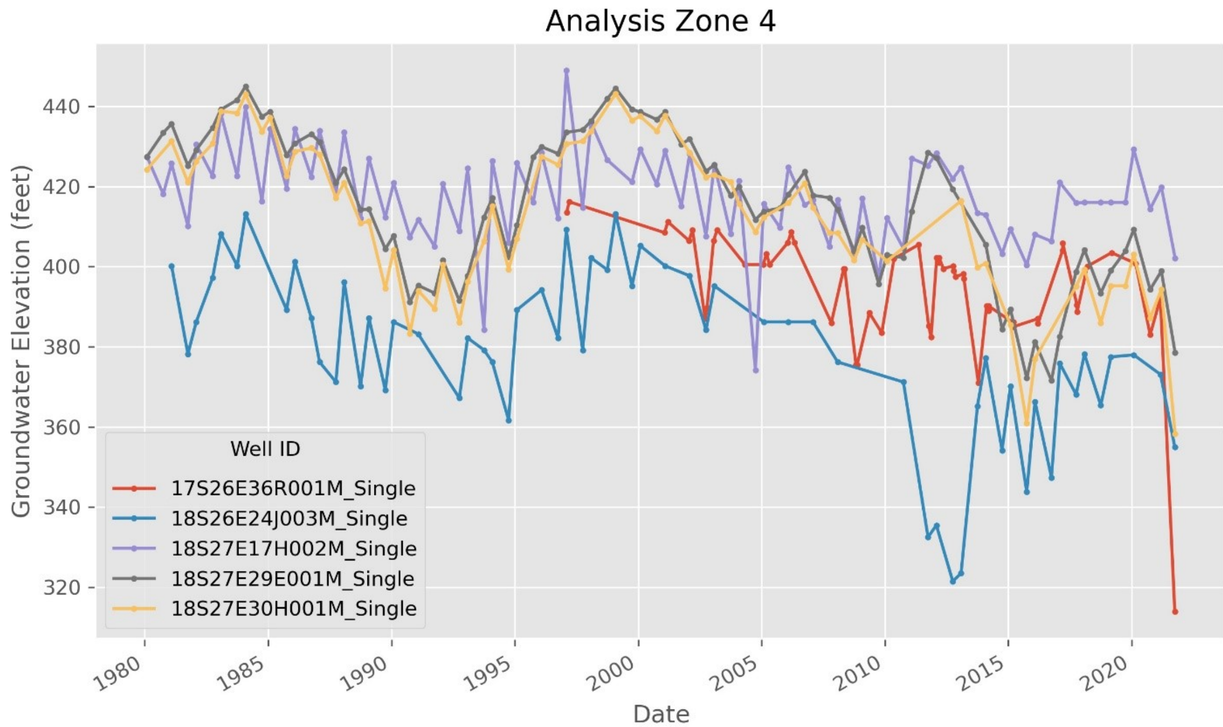
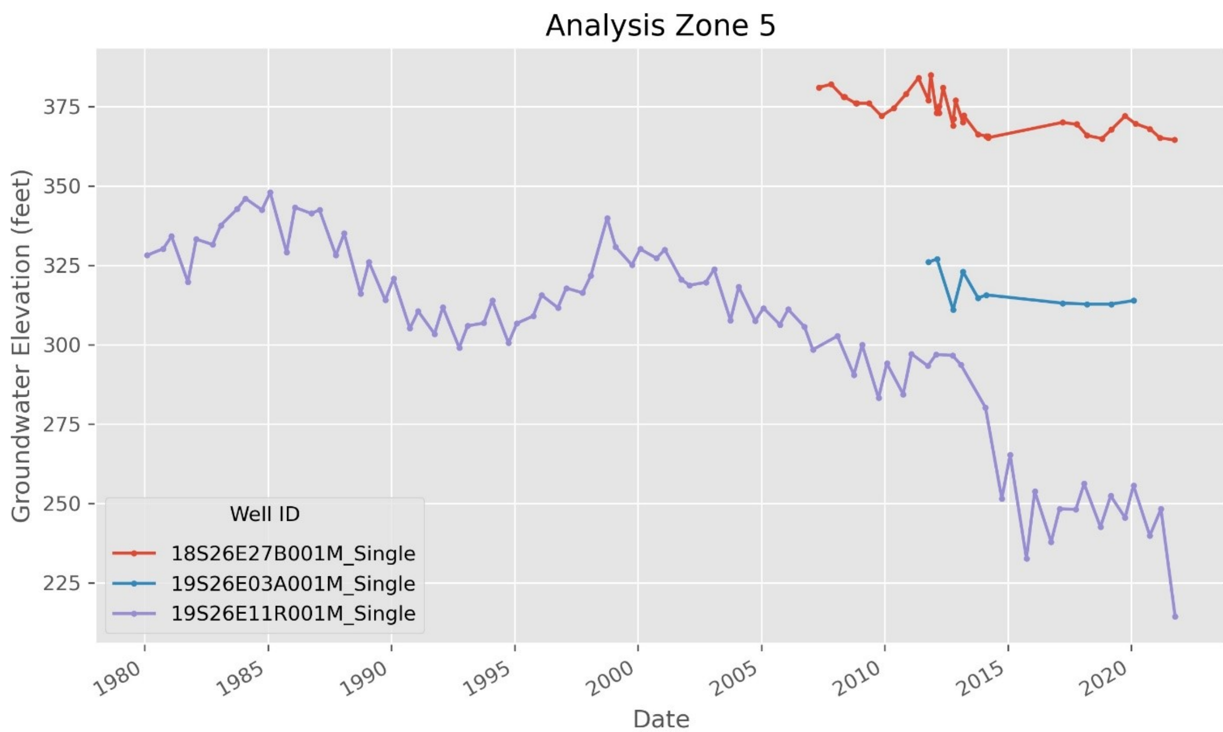
Appendix A

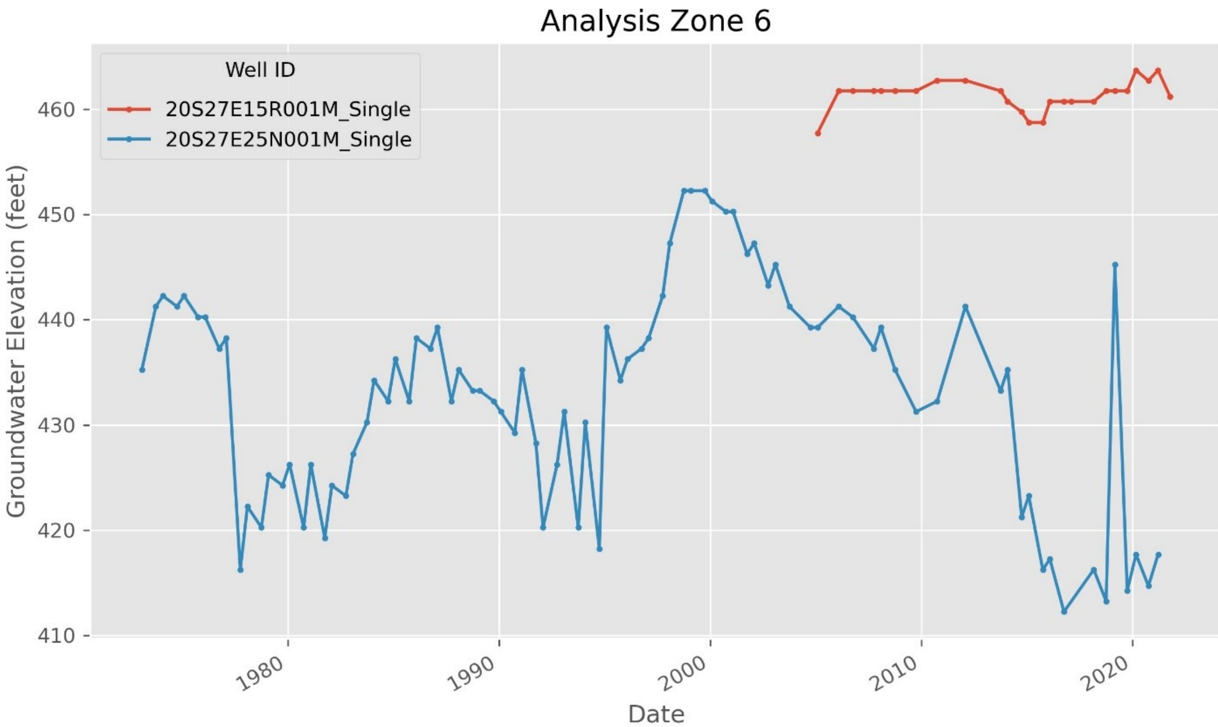
Representative Monitoring Site Hydrographs by Aquifer and Analysis Zone

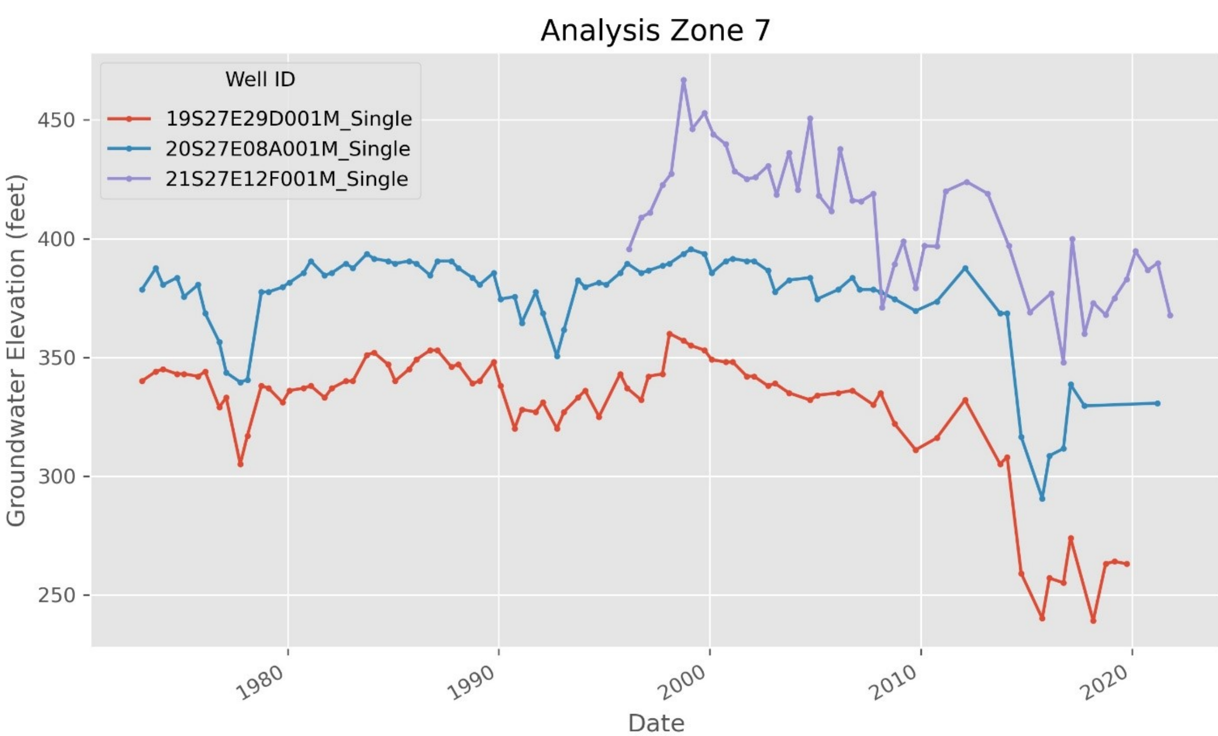

Analysis Zone 1
Well ID
17S25E25A001M_Single
17S25E35E001M_Single
18S26E06D001M_Single
Groundwater Elevation (feet)
300
280
260
240
220
200
1996
2000
2004
2008
2012
2016
2020
Date

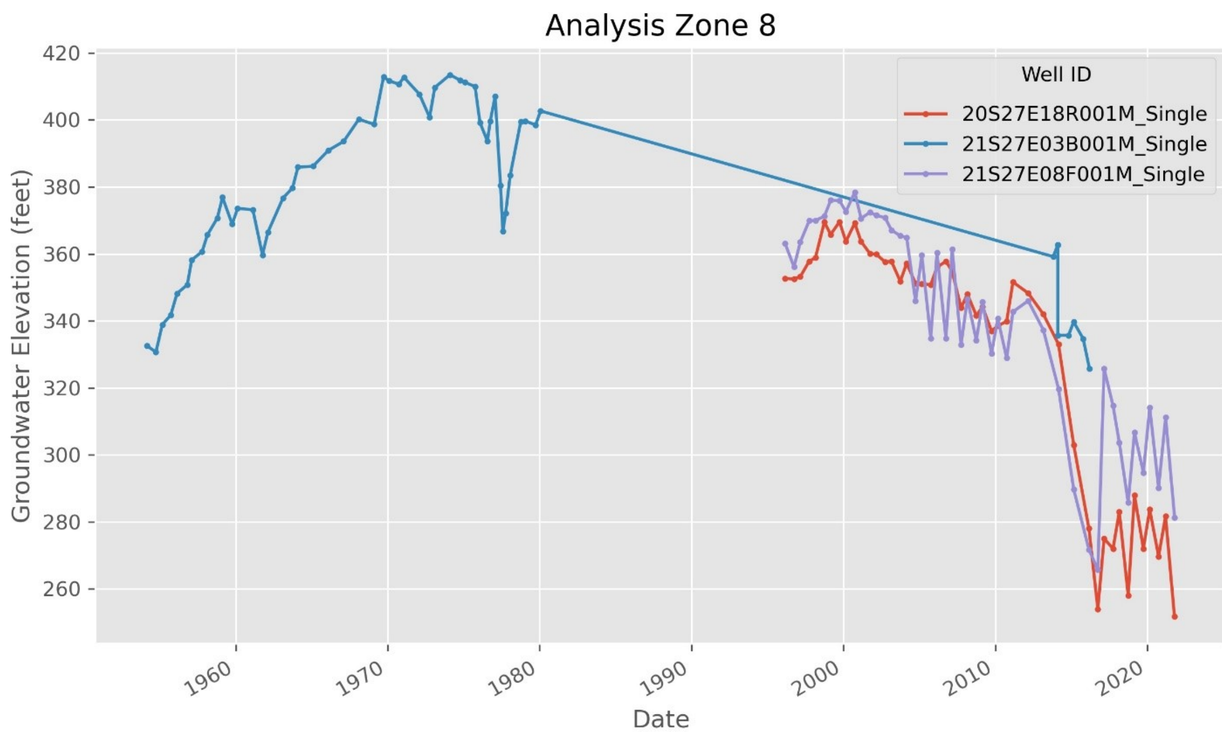

Analysis Zone 2
Well ID
16S25E36M002M_Single
16S26E30Q001M_Single
17S26E04F002M_Single
17S26E07C001M_Single
17S26E21E001M_Single
17S26E29R001M_Single
18S26E02D002M_Single
SCID Office_Single
Groundwater Elevation (feet)
400
380
360
340
320
300
280
260
1960
1970
1980
1990
2000
2010
2020
Date

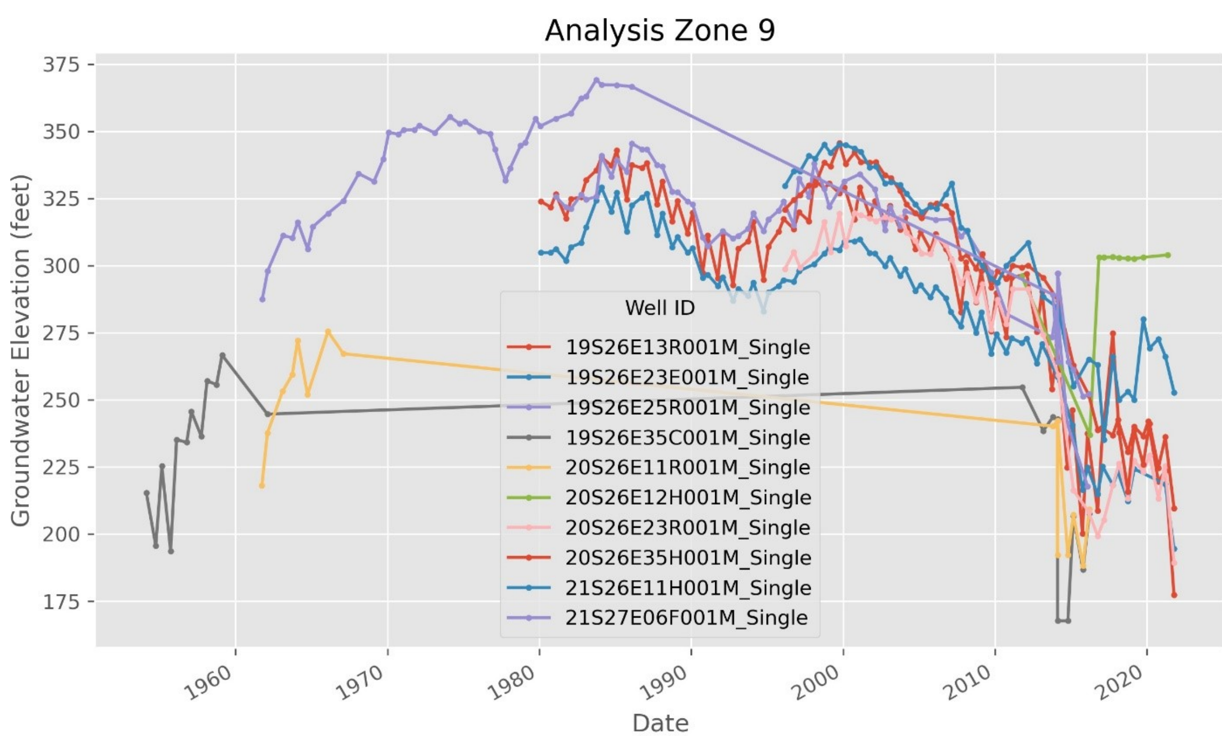

Analysis Zone 4
Groundwater Elevation (feet)
440
420
400
380
360
340
320
Well ID
17S26E36R001M_Single
18S26E24J003M_Single
18S27E17H002M_Single
18S27E29E001M_Single
18S27E30H001M_Single
1980
1985
1990
1995
2000
2005
2010
2015
2020
Date

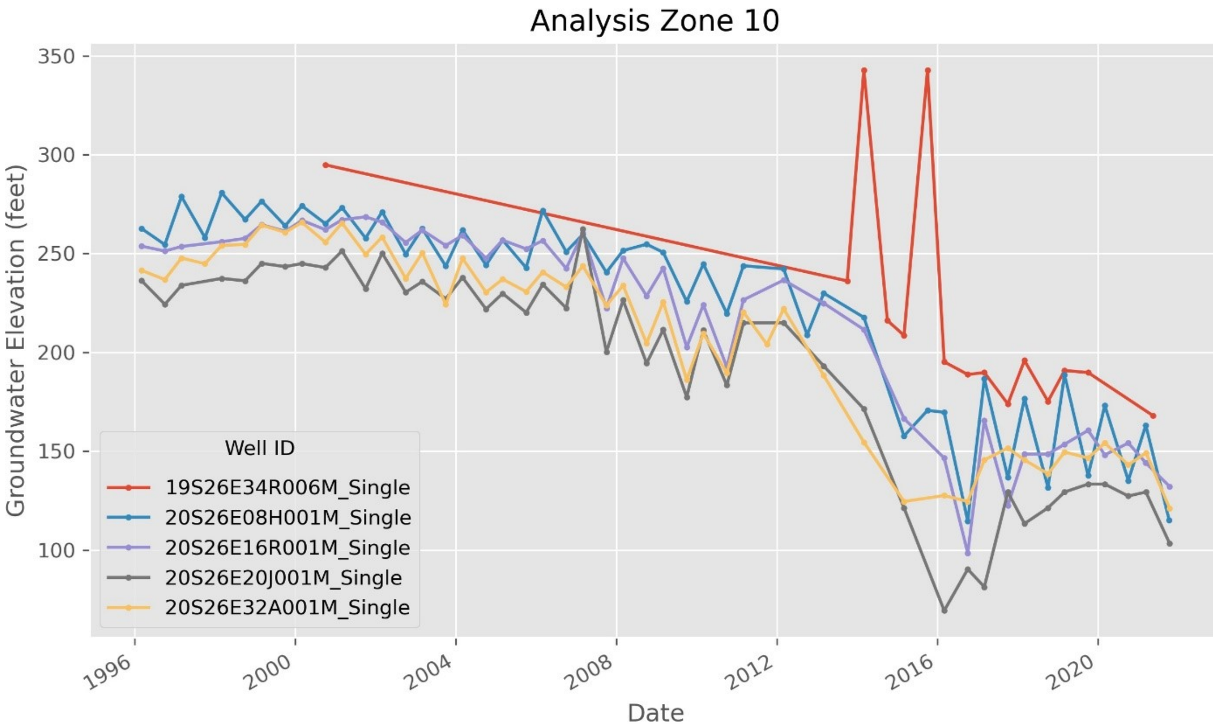

Analysis Zone 5
Groundwater Elevation (feet)
375
350
325
300
275
250
225
Well ID
18S26E27B001M_Single
19S26E03A001M_Single
19S26E11R001M_Single
1980
1985
1990
1995
2000
2005
2010
2015
2020
Date

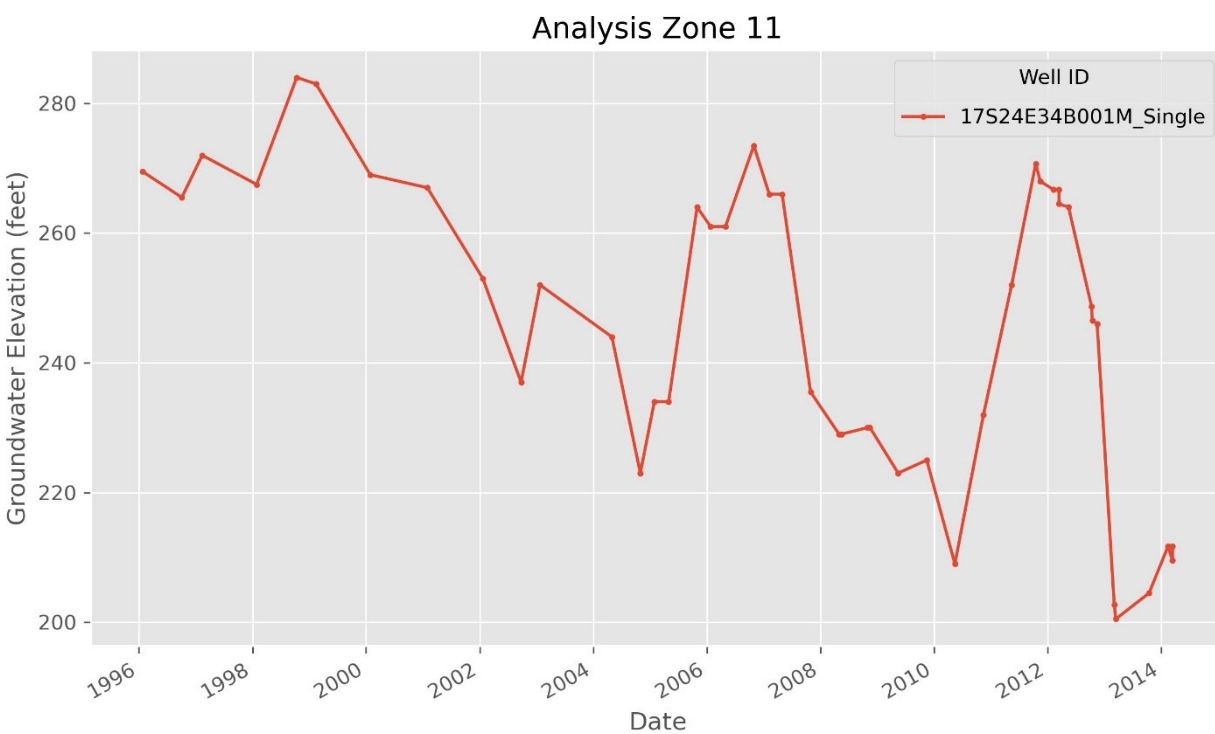

Analysis Zone 6
Well ID
20S27E15R001M_Single
20S27E25N001M_Single
Groundwater Elevation (feet)
410
420
430
440
450
460
1980
1990
2000
2010
2020
Date

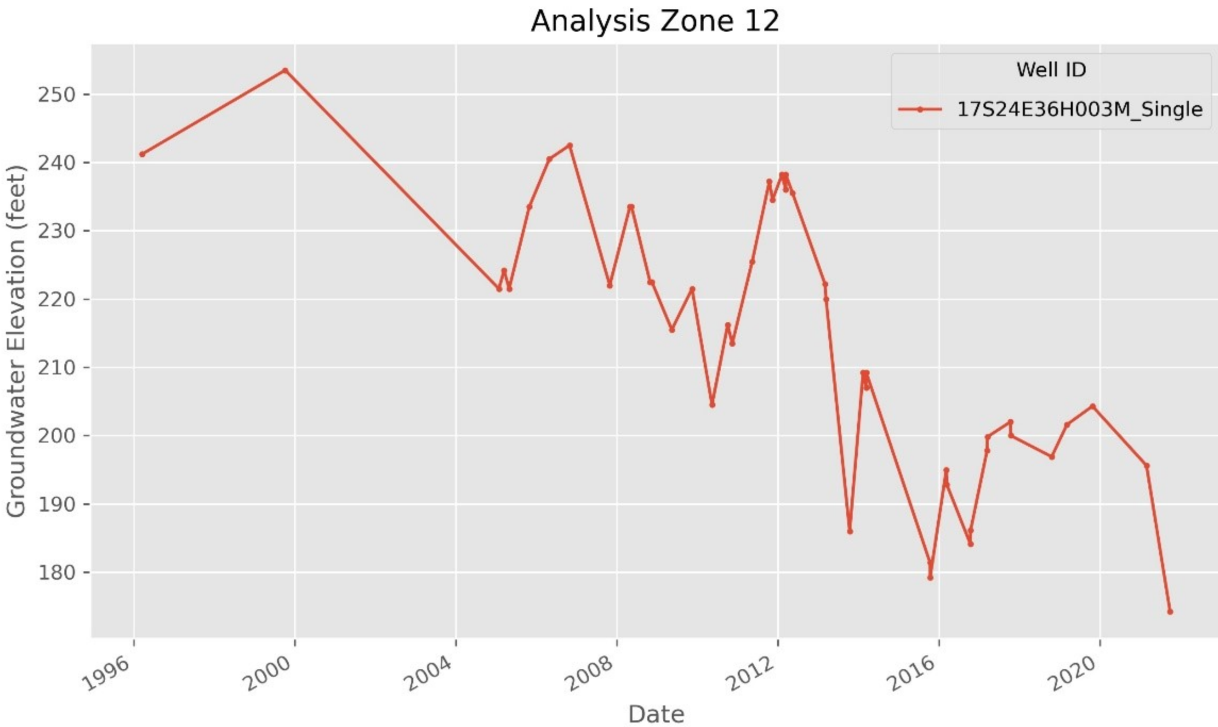

Analysis Zone 7
Well ID
19S27E29D001M_Single
20S27E08A001M_Single
21S27E12F001M_Single
Groundwater Elevation (feet)
250
300
350
400
450
1980
1990
2000
2010
2020
Date

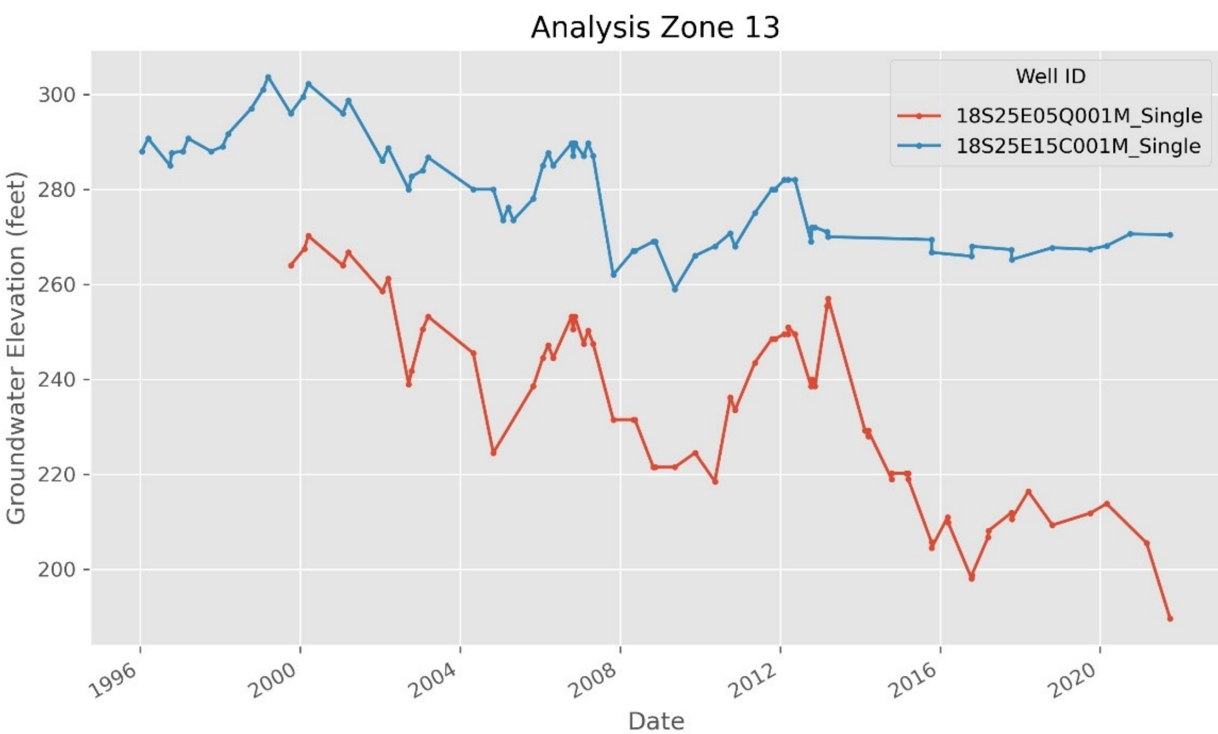

Analysis Zone 8
Groundwater Elevation (feet)
Date
Well ID
20S27E18R001M_Single
21S27E03B001M_Single
21S27E08F001M_Single
420
400
380
360
340
320
300
280
260
1960
1970
1980
1990
2000
2010
2020

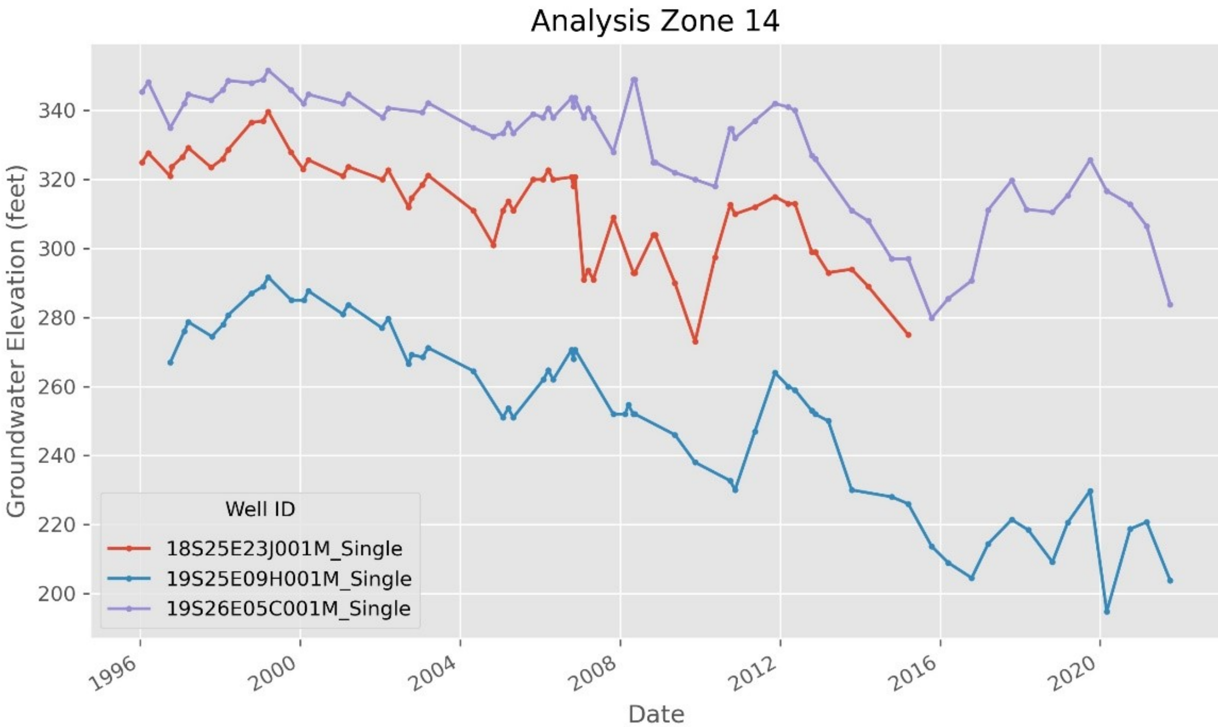

Analysis Zone 9
Groundwater Elevation (feet)
Date
Well ID
19S26E13R001M_Single
19S26E23E001M_Single
19S26E25R001M_Single
19S26E35C001M_Single
20S26E11R001M_Single
20S26E12H001M_Single
20S26E23R001M_Single
20S26E35H001M_Single
21S26E11H001M_Single
21S27E06F001M_Single
375
350
325
300
275
250
225
200
175
1960
1970
1980
1990
2000
2010
2020

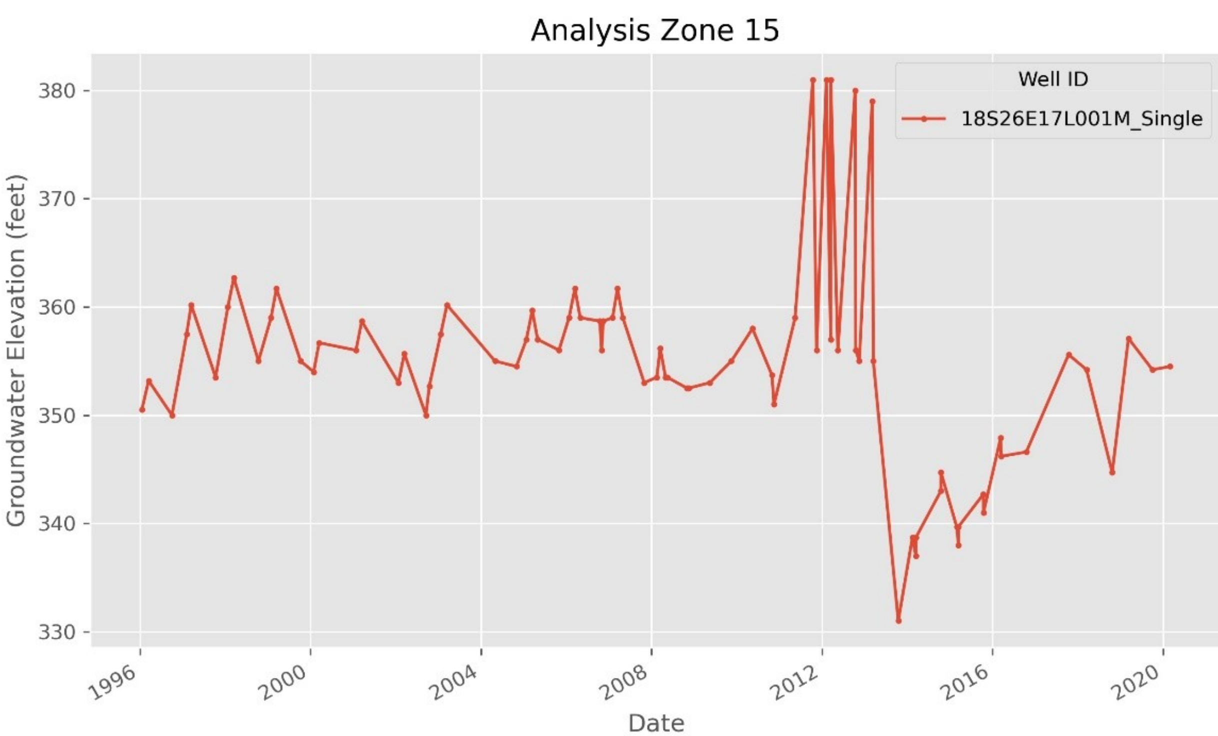

Analysis Zone 10
Groundwater Elevation (feet)
350
300
250
200
150
100
Well ID
19S26E34R006M_Single
20S26E08H001M_Single
20S26E16R001M_Single
20S26E20J001M_Single
20S26E32A001M_Single
1996
2000
2004
2008
2012
2016
2020
Date

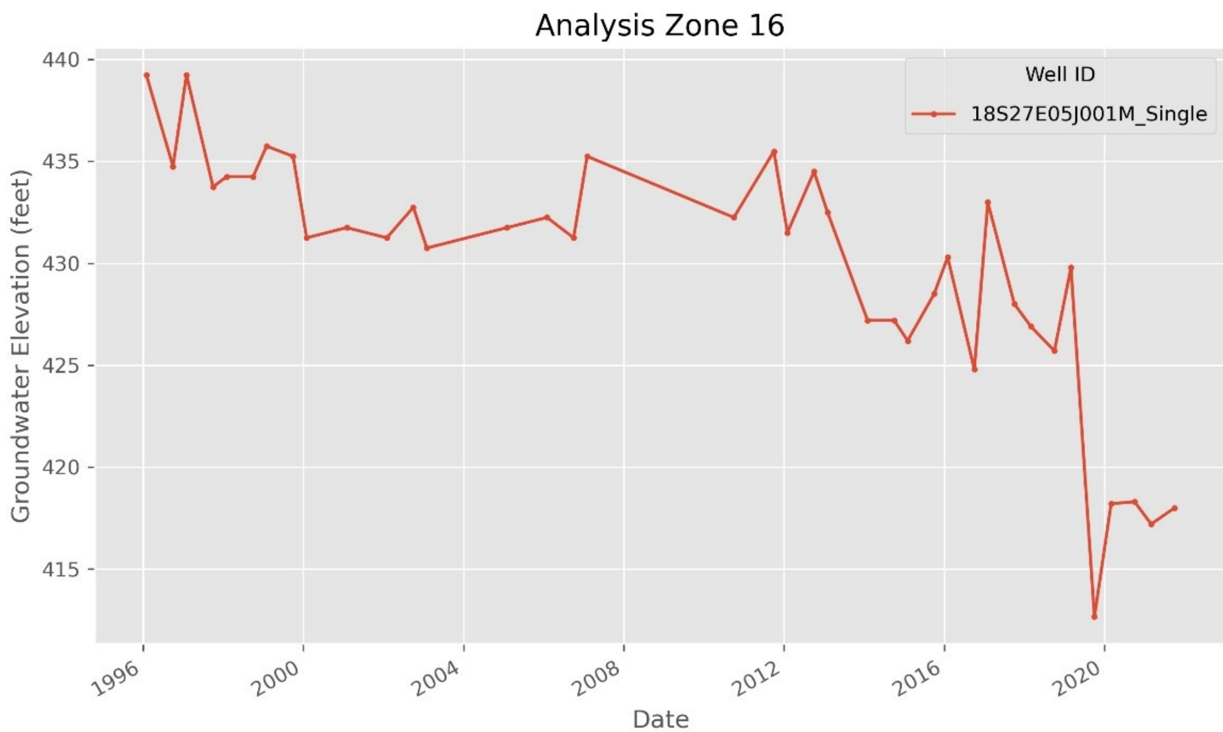

Analysis Zone 11
Groundwater Elevation (feet)
280
260
240
220
200
Well ID
17S24E34B001M_Single
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Date

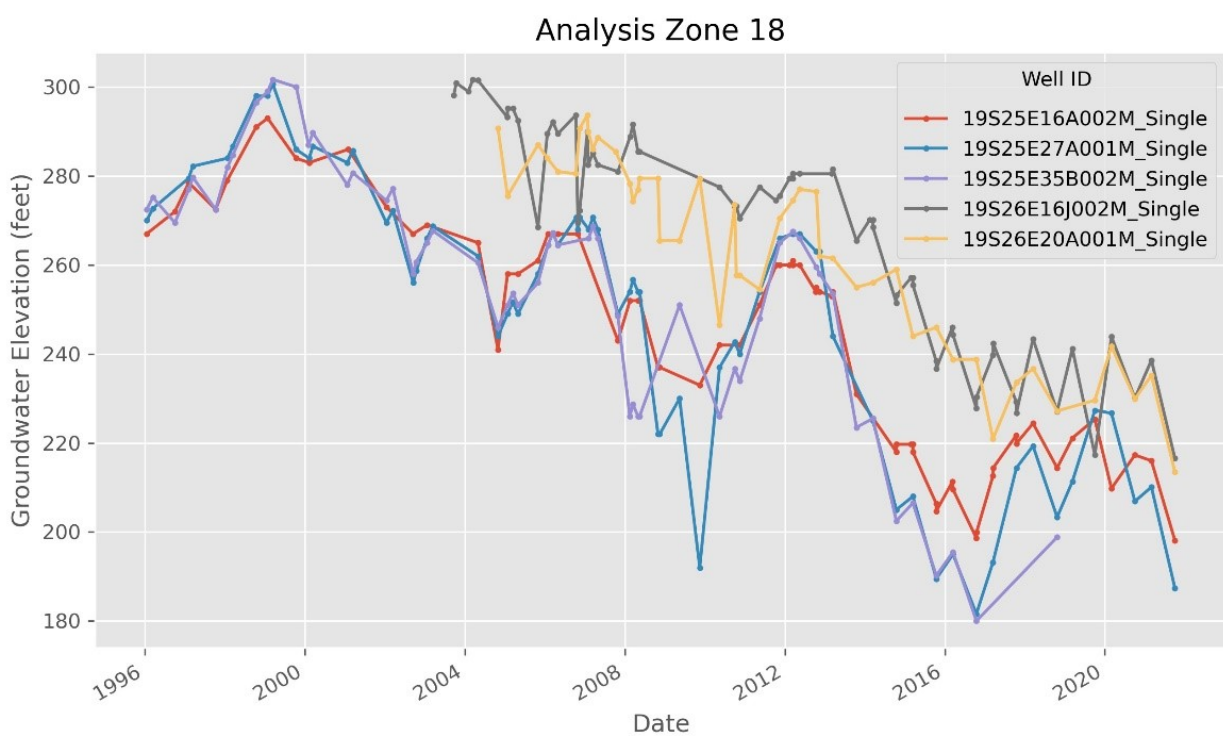

Analysis Zone 12
Well ID
17S24E36H003M_Single
Groundwater Elevation (feet)
250
240
230
220
210
200
190
180
1996
2000
2004
2008
2012
2016
2020
Date

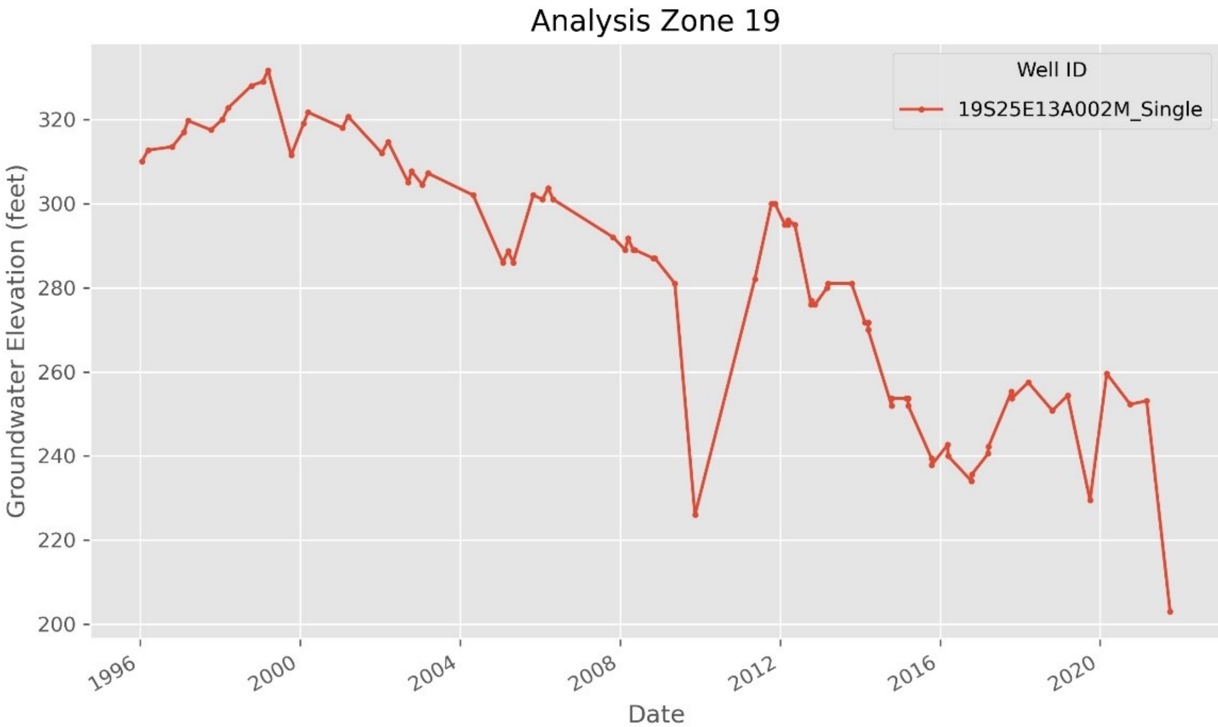

Analysis Zone 13
Well ID
18S25E05Q001M_Single
18S25E15C001M_Single
Groundwater Elevation (feet)
300
280
260
240
220
200
1996
2000
2004
2008
2012
2016
2020
Date

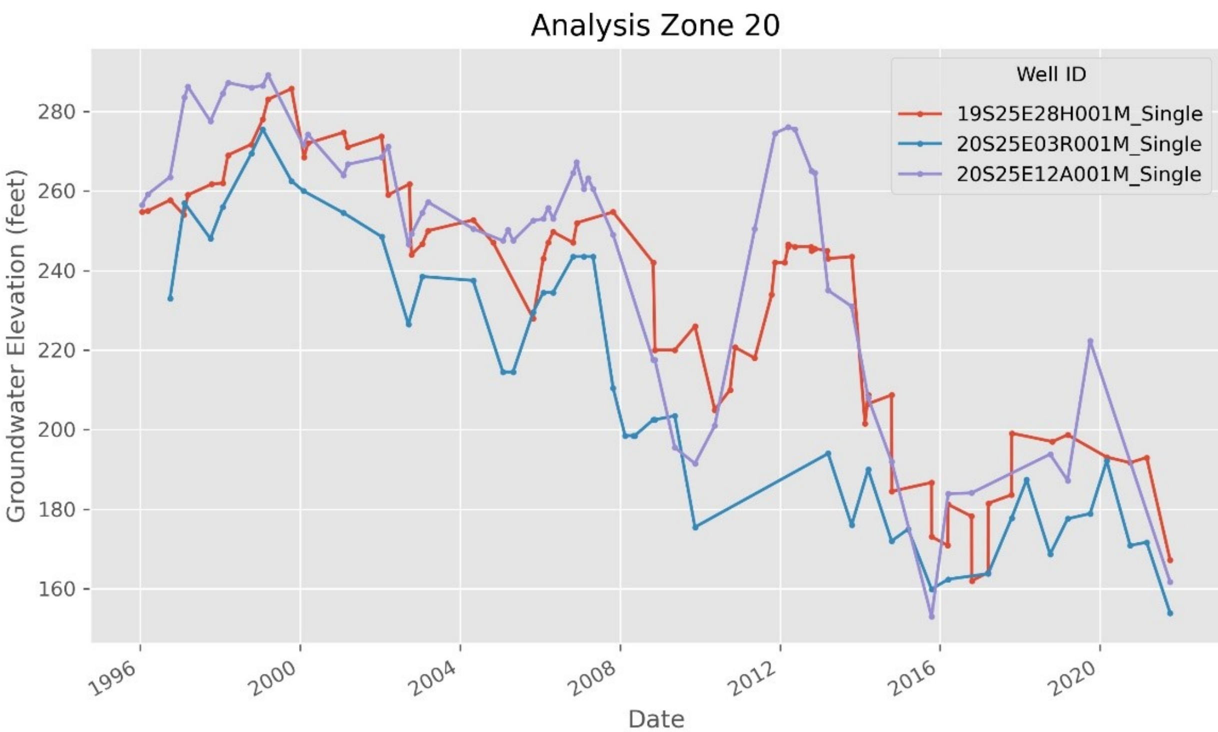

Analysis Zone 14
Groundwater Elevation (feet)
340
320
300
280
260
240
220
200
Well ID
18S25E23J001M_Single
19S25E09H001M_Single
19S26E05C001M_Single
1996
2000
2004
2008
2012
2016
2020
Date

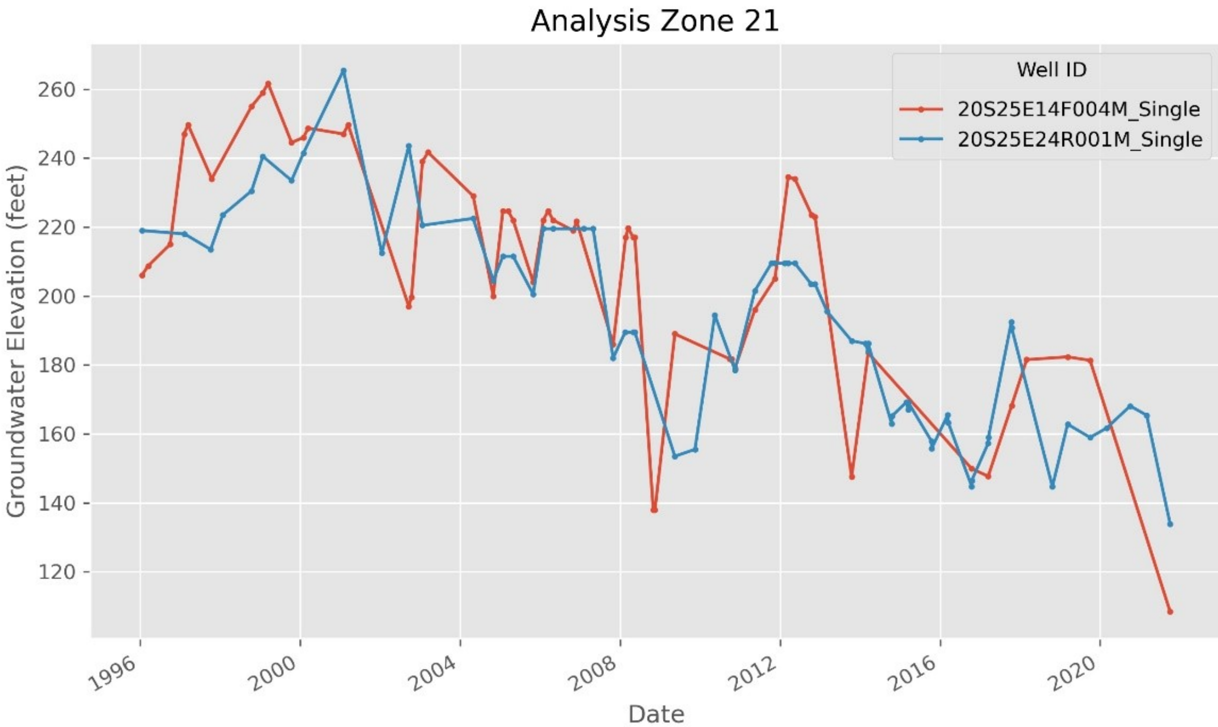

Analysis Zone 15
Groundwater Elevation (feet)
380
370
360
350
340
330
Well ID
18S26E17L001M_Single
1996
2000
2004
2008
2012
2016
2020
Date

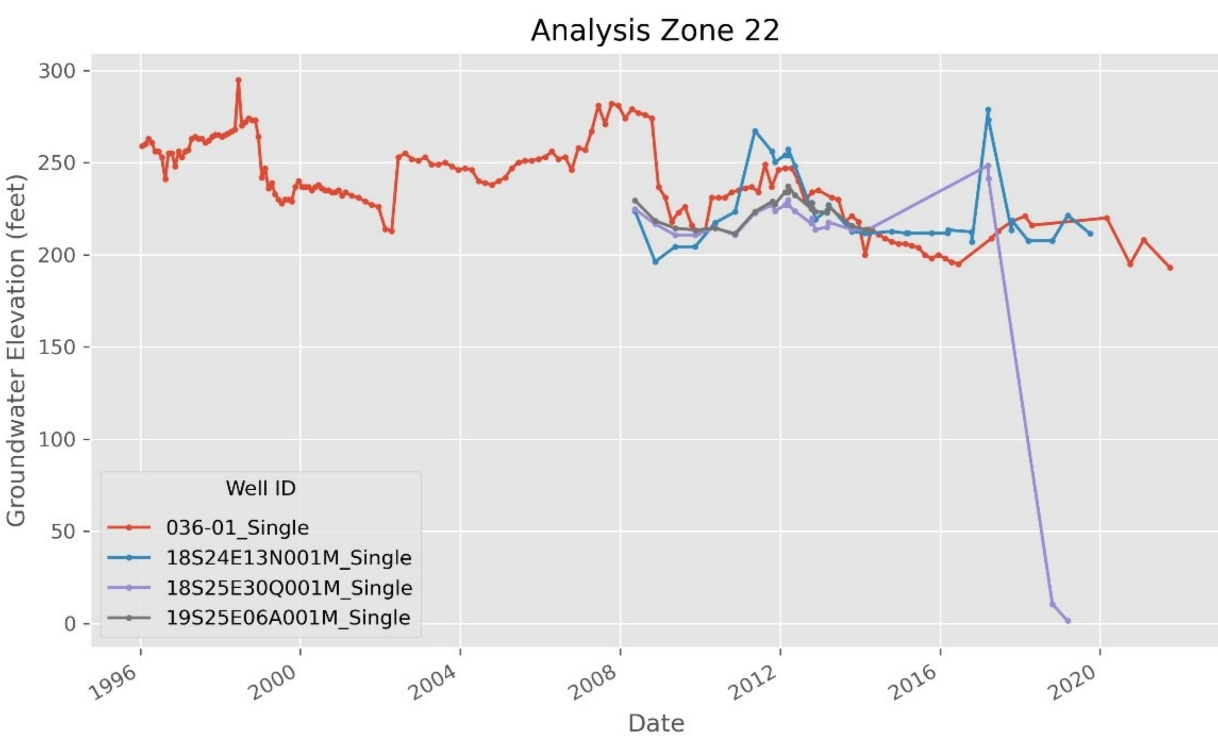

Analysis Zone 16
Well ID
18S27E05J001M_Single
Groundwater Elevation (feet)
440
435
430
425
420
415
1996
2000
2004
2008
2012
2016
2020
Date

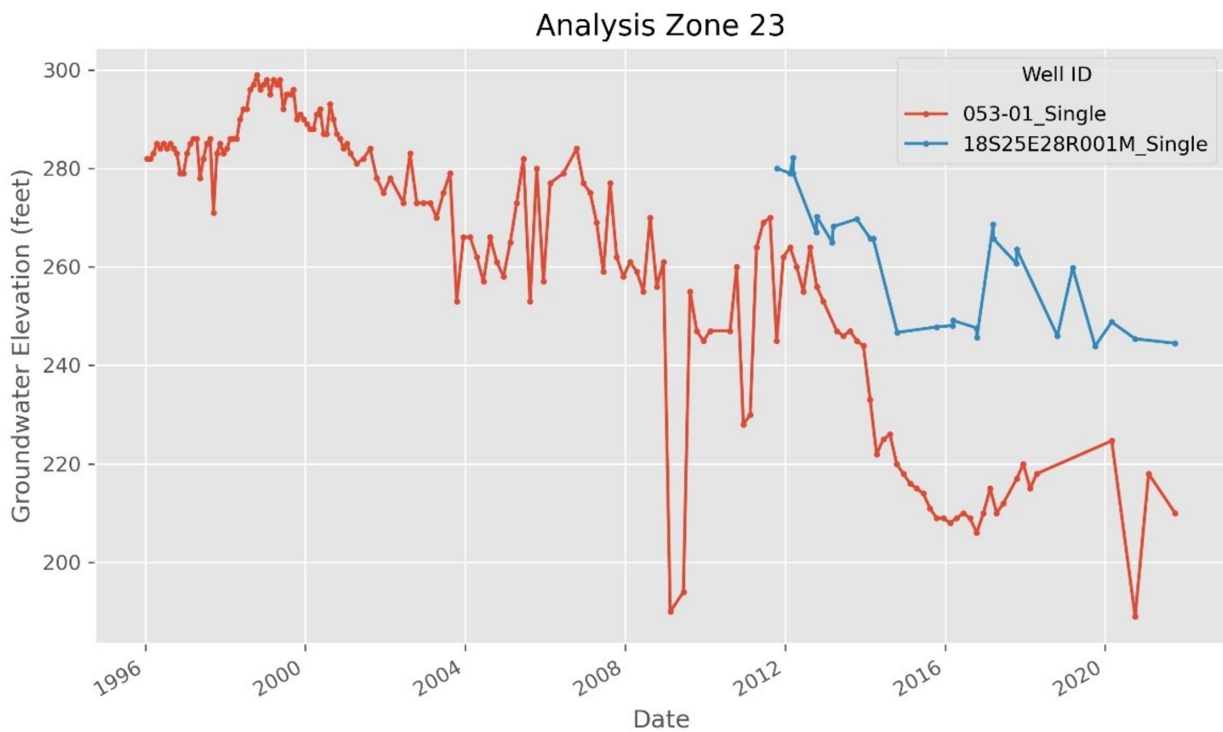

Analysis Zone 18
Well ID
19S25E16A002M_Single
19S25E27A001M_Single
19S25E35B002M_Single
19S26E16J002M_Single
19S26E20A001M_Single
Groundwater Elevation (feet)
300
280
260
240
220
200
180
1996
2000
2004
2008
2012
2016
2020
Date

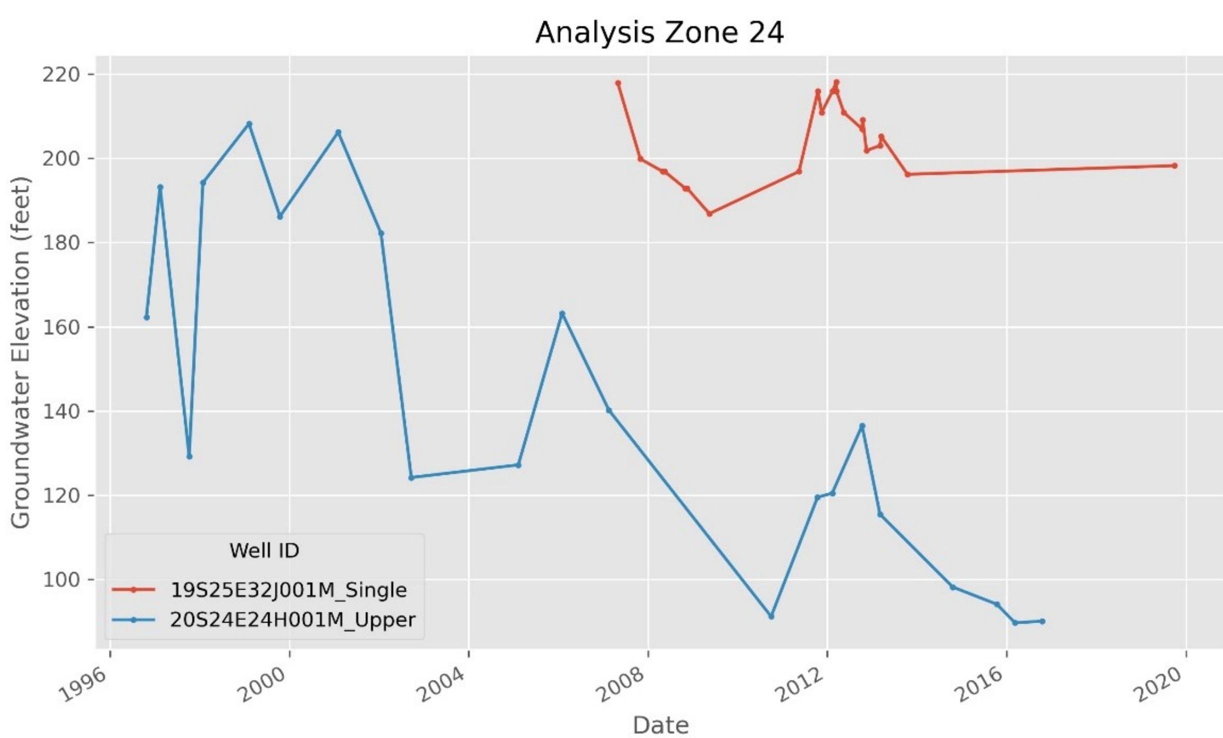

Analysis Zone 19
Well ID
19S25E13A002M_Single
Groundwater Elevation (feet)
320
300
280
260
240
220
200
1996
2000
2004
2008
2012
2016
2020
Date

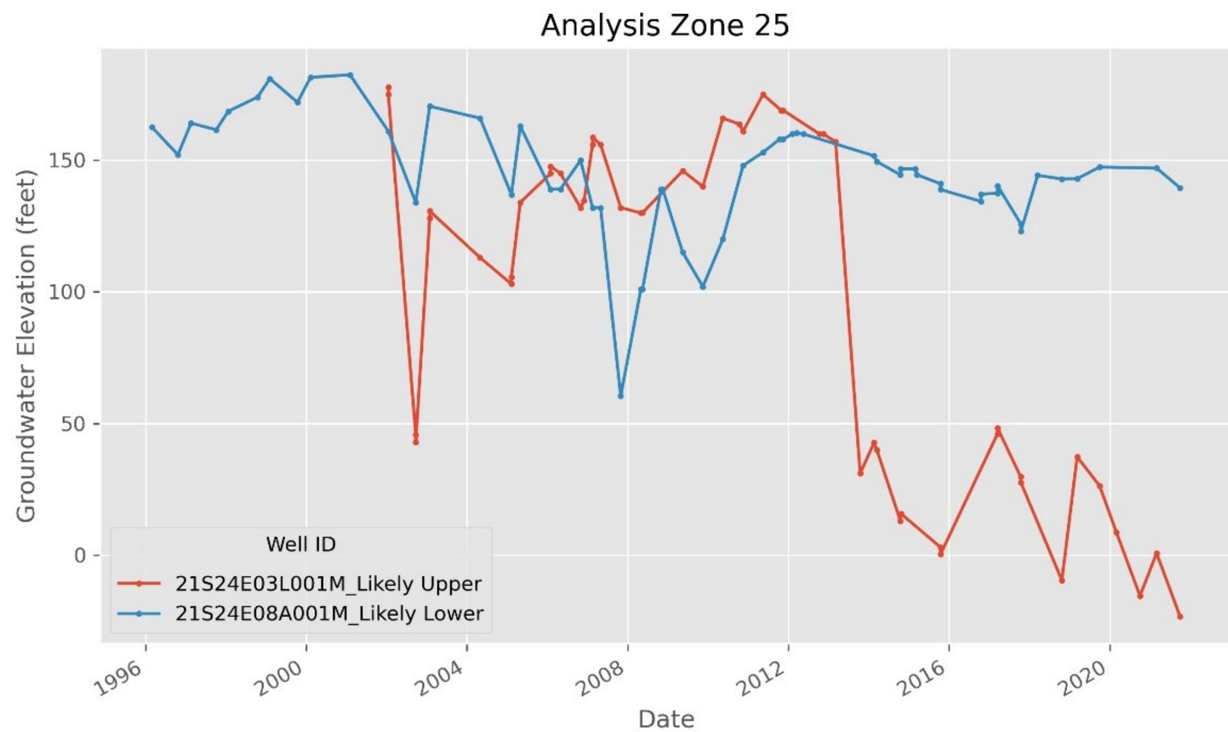

Analysis Zone 20
Well ID
19S25E28H001M_Single
20S25E03R001M_Single
20S25E12A001M_Single
Groundwater Elevation (feet)
280
260
240
220
200
180
160
1996
2000
2004
2008
2012
2016
2020
Date

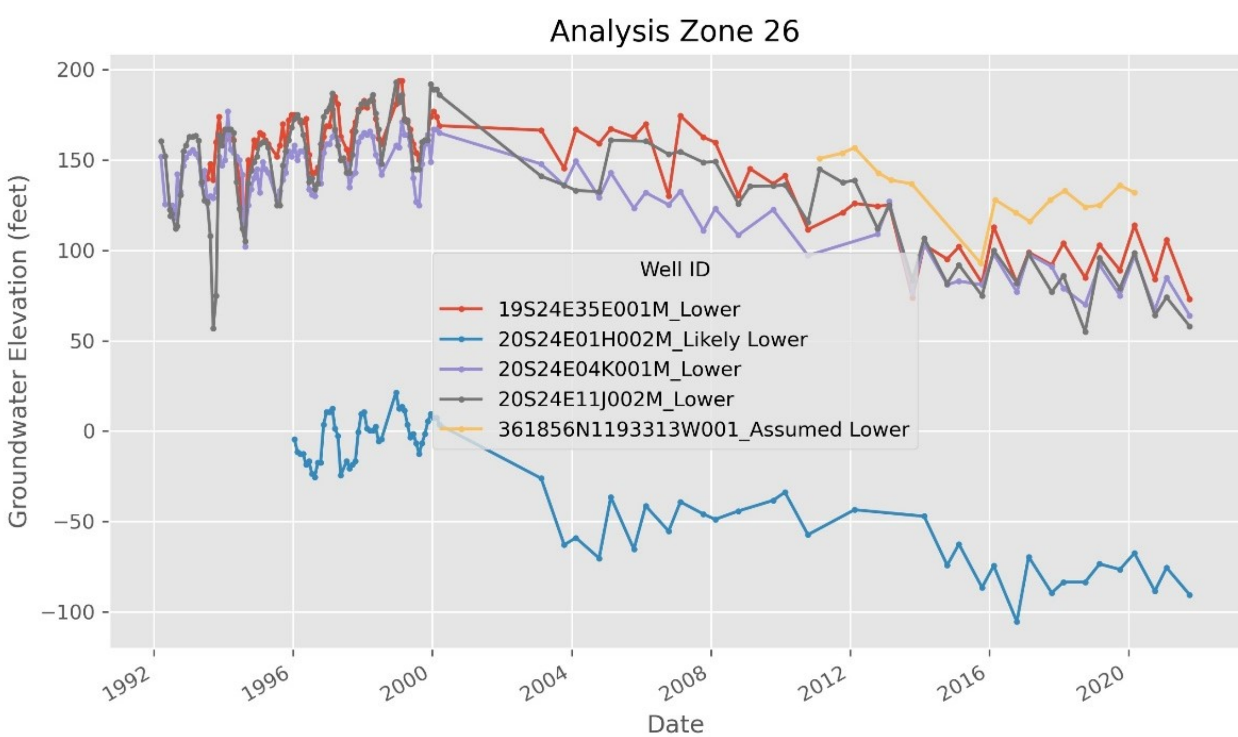

Analysis Zone 21
Well ID
20S25E14F004M_Single
20S25E24R001M_Single
Groundwater Elevation (feet)
260
240
220
200
180
160
140
120
1996
2000
2004
2008
2012
2016
2020
Date

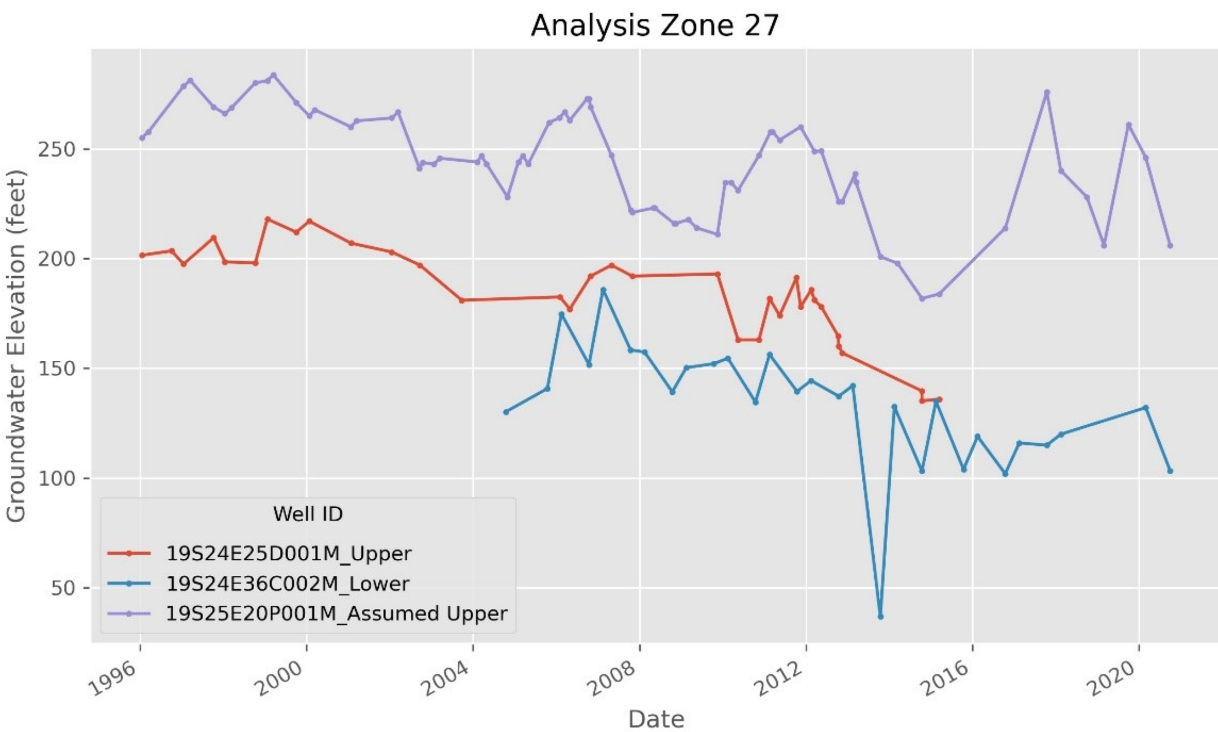

Analysis Zone 22
Well ID
036-01_Single
18S24E13N001M_Single
18S25E30Q001M_Single
19S25E06A001M_Single
Groundwater Elevation (feet)
300
250
200
150
100
50
0
1996
2000
2004
2008
2012
2016
2020
Date

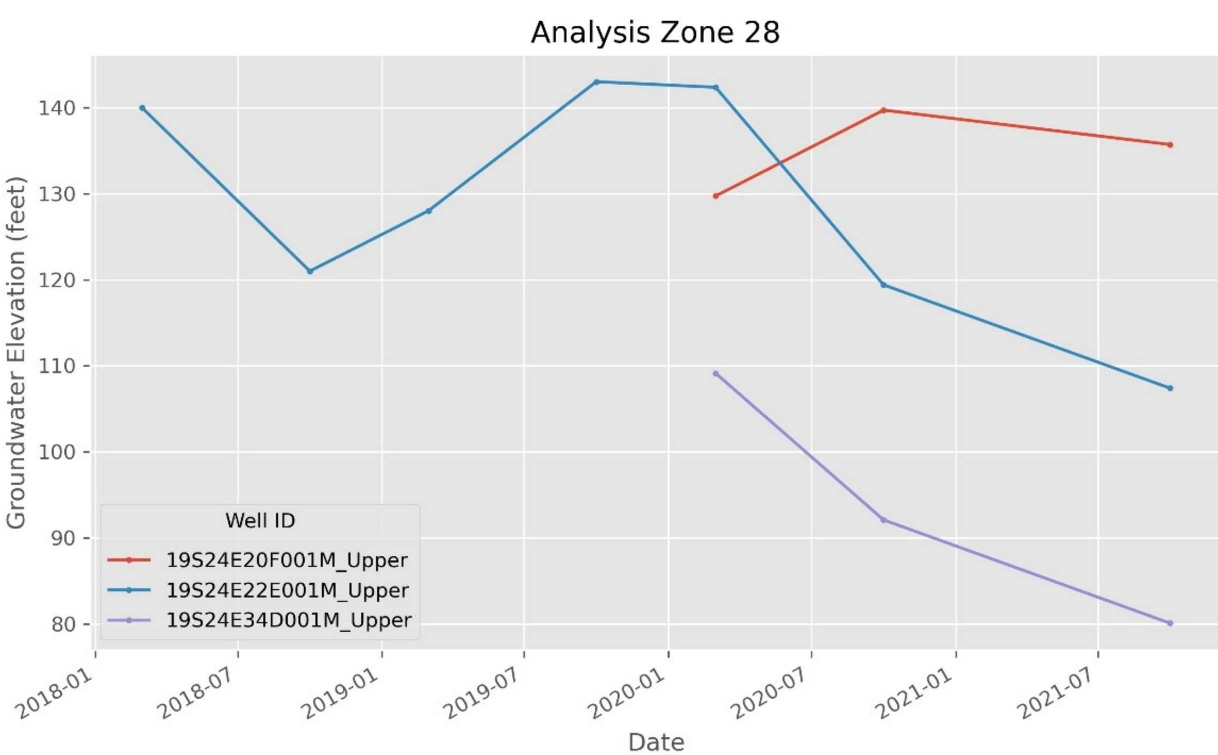

Analysis Zone 23
Well ID
053-01_Single
18S25E28R001M_Single
Groundwater Elevation (feet)
300
280
260
240
220
200
1996
2000
2004
2008
2012
2016
2020
Date

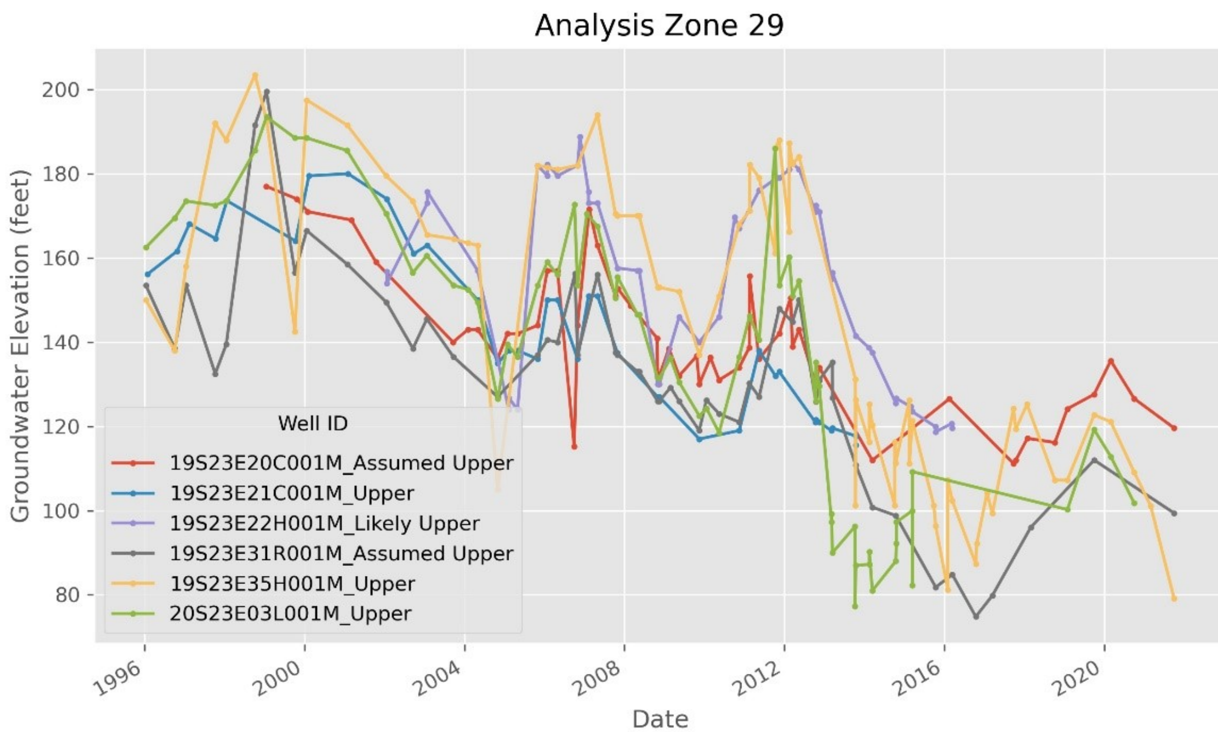

Analysis Zone 24
Well ID
19S25E32J001M_Single
20S24E24H001M_Upper
Groundwater Elevation (feet)
220
200
180
160
140
120
100
1996
2000
2004
2008
2012
2016
2020
Date

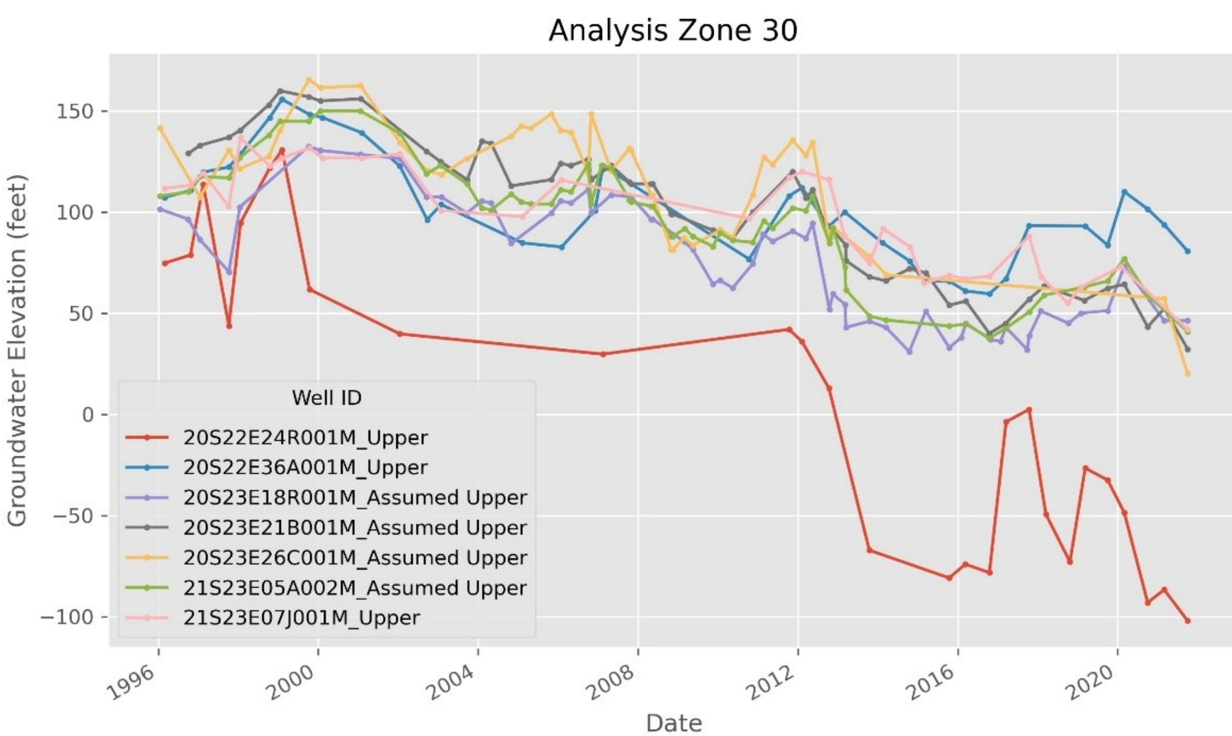

Analysis Zone 25
Groundwater Elevation (feet)
150
100
50
0
1996
2000
2004
2008
2012
2016
2020
Date
Well ID
21S24E03L001M_Likely Upper
21S24E08A001M_Likely Lower

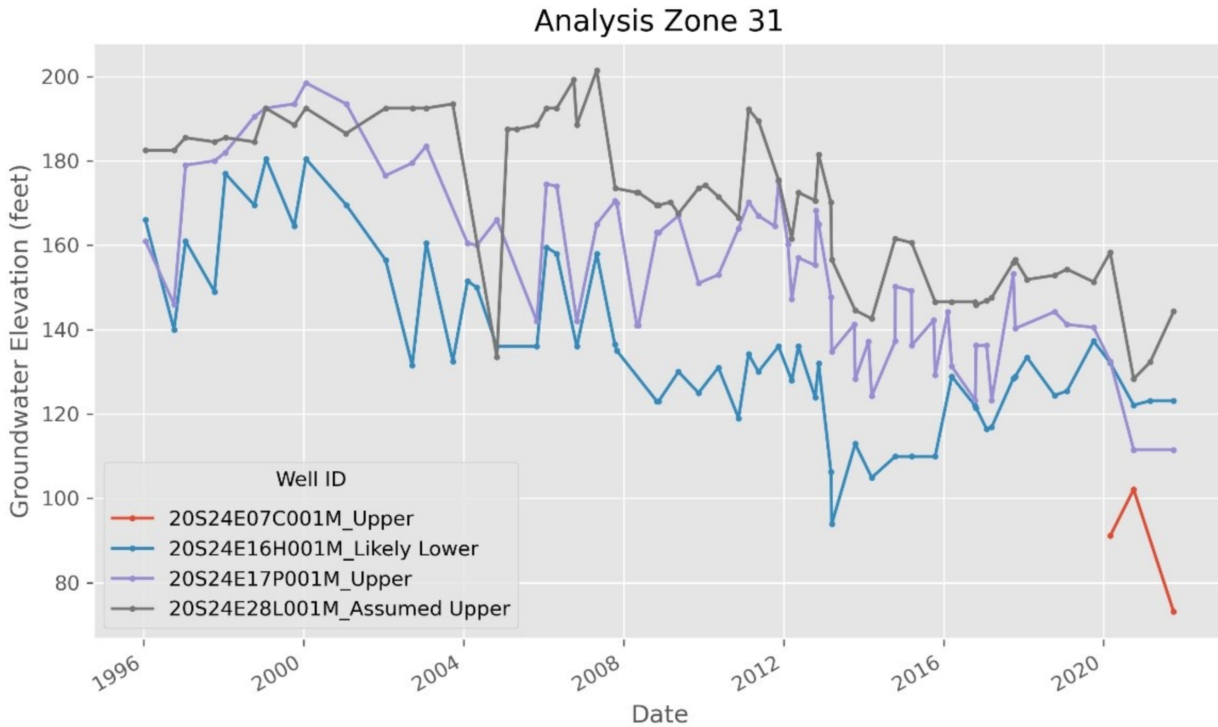

Analysis Zone 26
Groundwater Elevation (feet)
200
150
100
50
0
−50
−100
1992
1996
2000
2004
2008
2012
2016
2020
Date
Well ID
19S24E35E001M_Lower
20S24E01H002M_Likely Lower
20S24E04K001M_Lower
20S24E11J002M_Lower
361856N1193313W001_Assumed Lower

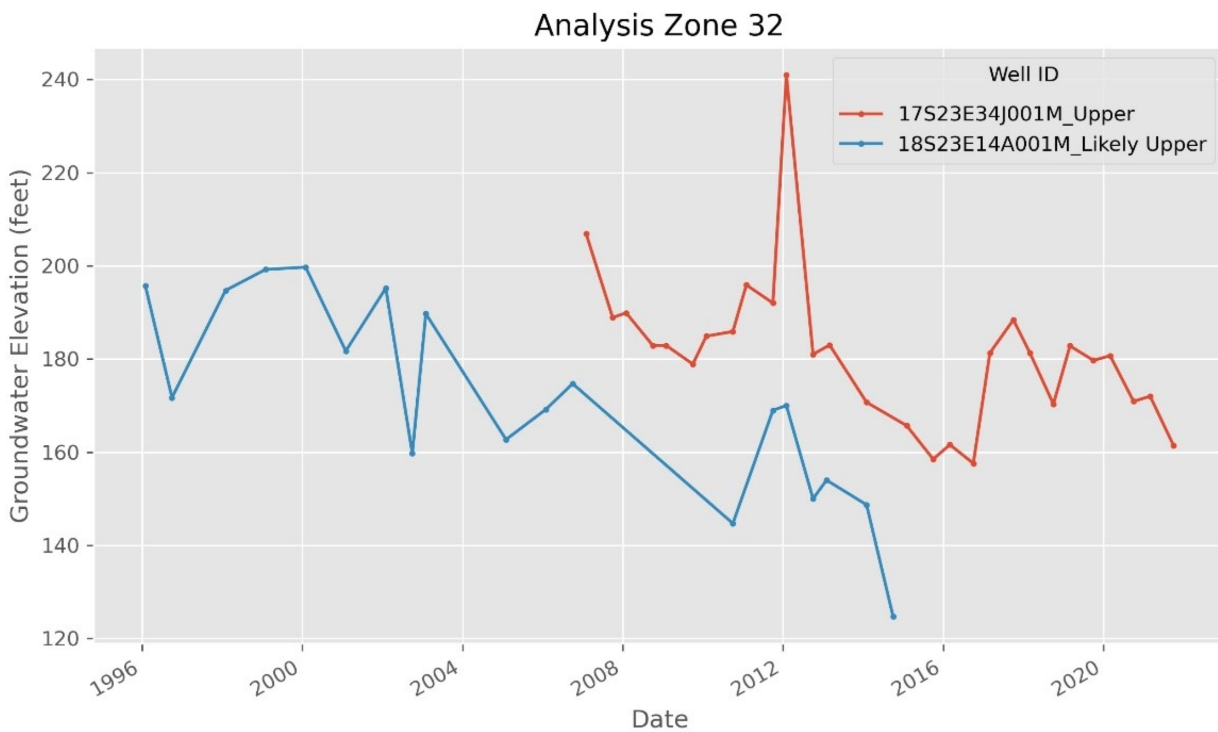

Analysis Zone 27
Groundwater Elevation (feet)
Date
250
200
150
100
50
1996
2000
2004
2008
2012
2016
2020
Well ID
19S24E25D001M_Upper
19S24E36C002M_Lower
19S25E20P001M_Assumed Upper

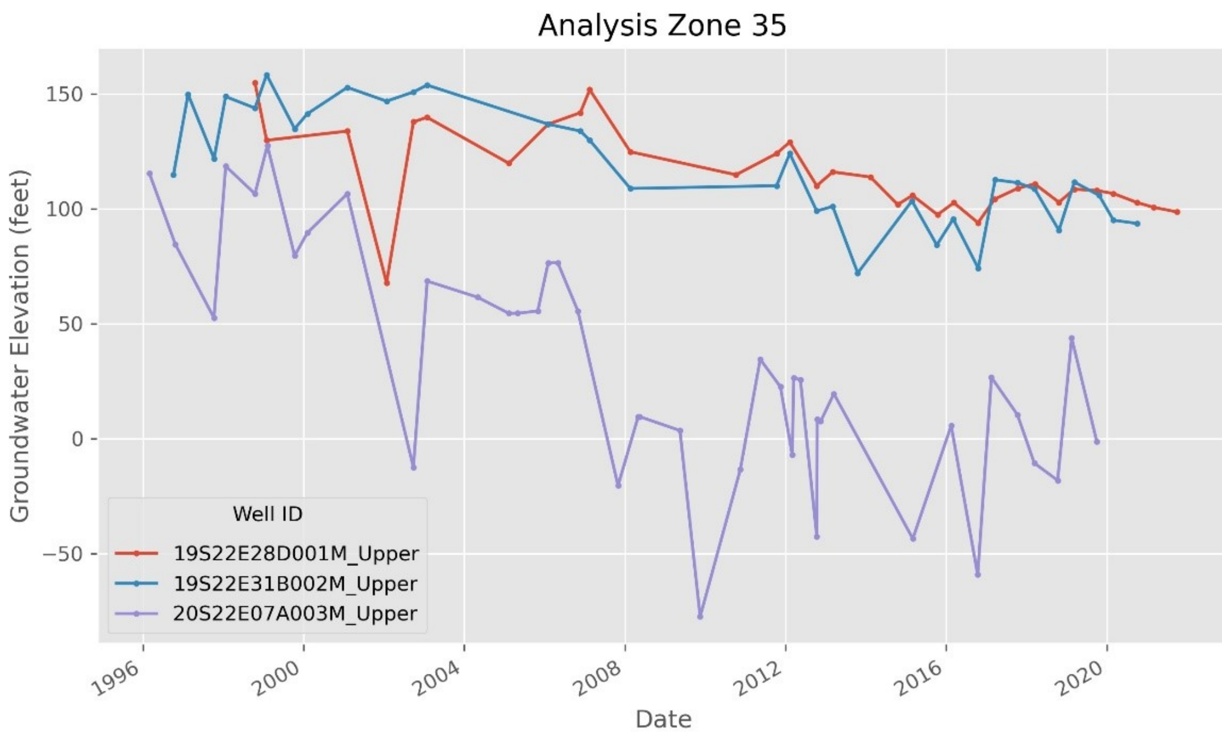

Analysis Zone 28
Groundwater Elevation (feet)
Date
140
130
120
110
100
90
80
2018-01
2018-07
2019-01
2019-07
2020-01
2020-07
2021-01
2021-07
Well ID
19S24E20F001M_Upper
19S24E22E001M_Upper
19S24E34D001M_Upper

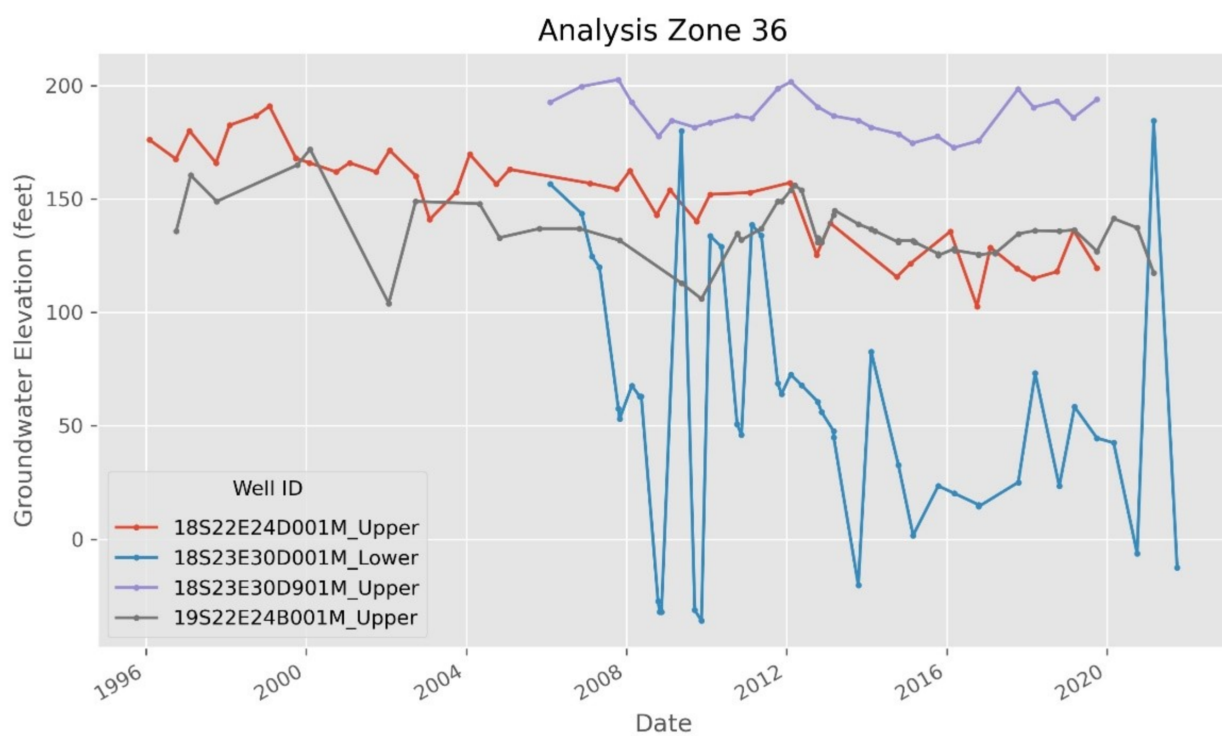

Analysis Zone 29
Groundwater Elevation (feet)
Date
Well ID
19S23E20C001M_Assumed Upper
19S23E21C001M_Upper
19S23E22H001M_Likely Upper
19S23E31R001M_Assumed Upper
19S23E35H001M_Upper
20S23E03L001M_Upper
80
100
120
140
160
180
200
1996
2000
2004
2008
2012
2016
2020

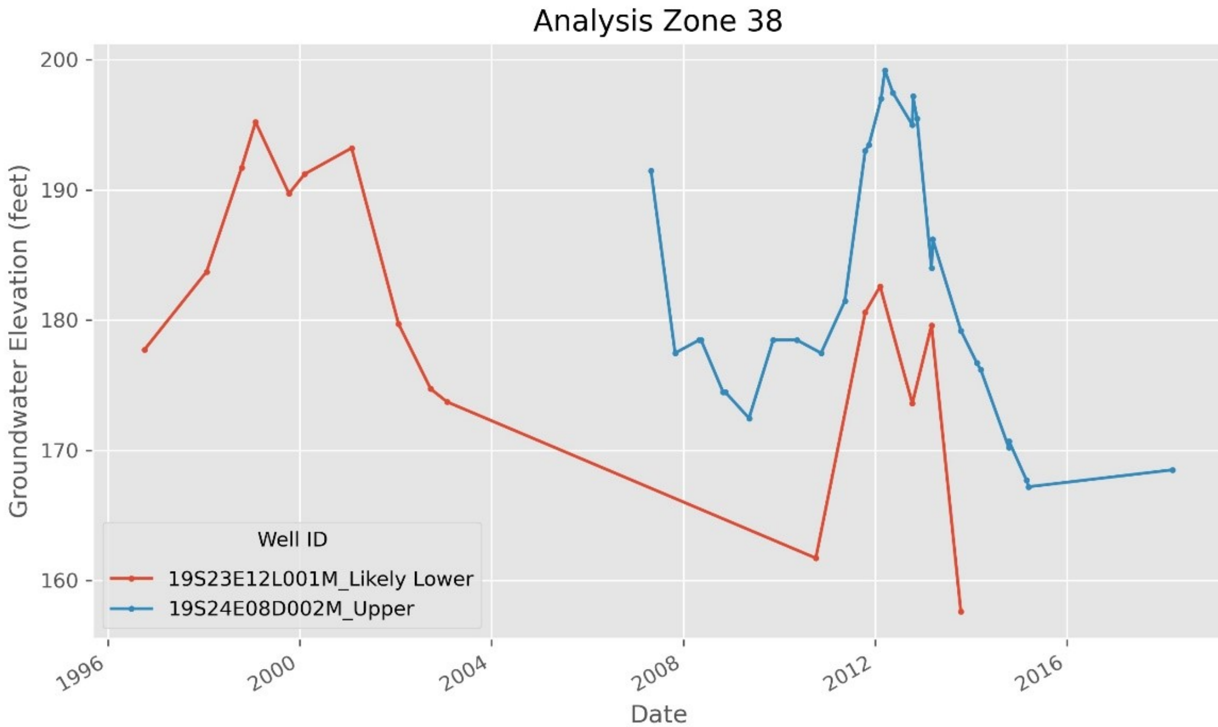

Analysis Zone 30
Groundwater Elevation (feet)
Date
Well ID
20S22E24R001M_Upper
20S22E36A001M_Upper
20S23E18R001M_Assumed Upper
20S23E21B001M_Assumed Upper
20S23E26C001M_Assumed Upper
21S23E05A002M_Assumed Upper
21S23E07J001M_Upper
−100
−50
0
50
100
150
1996
2000
2004
2008
2012
2016
2020

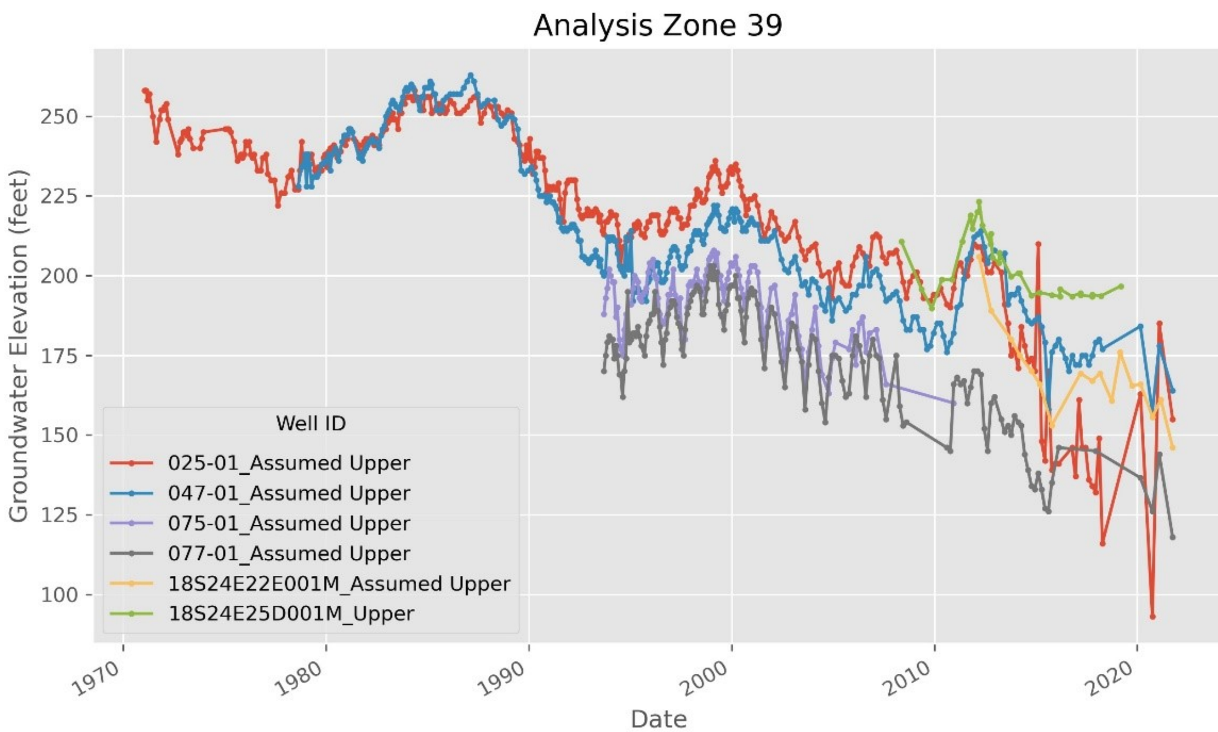

Analysis Zone 31
Groundwater Elevation (feet)
Date
Well ID
20S24E07C001M_Upper
20S24E16H001M_Likely Lower
20S24E17P001M_Upper
20S24E28L001M_Assumed Upper
200
180
160
140
120
100
80
1996
2000
2004
2008
2012
2016
2020


Analysis Zone 32
Groundwater Elevation (feet)
Date
Well ID
17S23E34J001M_Upper
18S23E14A001M_Likely Upper
240
220
200
180
160
140
120
1996
2000
2004
2008
2012
2016
2020


Analysis Zone 35
Groundwater Elevation (feet)
Date
Well ID
19S22E28D001M_Upper
19S22E31B002M_Upper
20S22E07A003M_Upper
150
100
50
0
−50
1996
2000
2004
2008
2012
2016
2020


Analysis Zone 36
Groundwater Elevation (feet)
Date
Well ID
18S22E24D001M_Upper
18S23E30D001M_Lower
18S23E30D901M_Upper
19S22E24B001M_Upper
200
150
100
50
0
1996
2000
2004
2008
2012
2016
2020


Analysis Zone 38
Groundwater Elevation (feet)
200
190
180
170
160
Well ID
19S23E12L001M_Likely Lower
19S24E08D002M_Upper
1996
2000
2004
2008
2012
2016
Date


Analysis Zone 39
Groundwater Elevation (feet)
250
225
200
175
150
125
100
Well ID
025-01_Assumed Upper
047-01_Assumed Upper
075-01_Assumed Upper
077-01_Assumed Upper
18S24E22E001M_Assumed Upper
18S24E25D001M_Upper
1970
1980
1990
2000
2010
2020
Date

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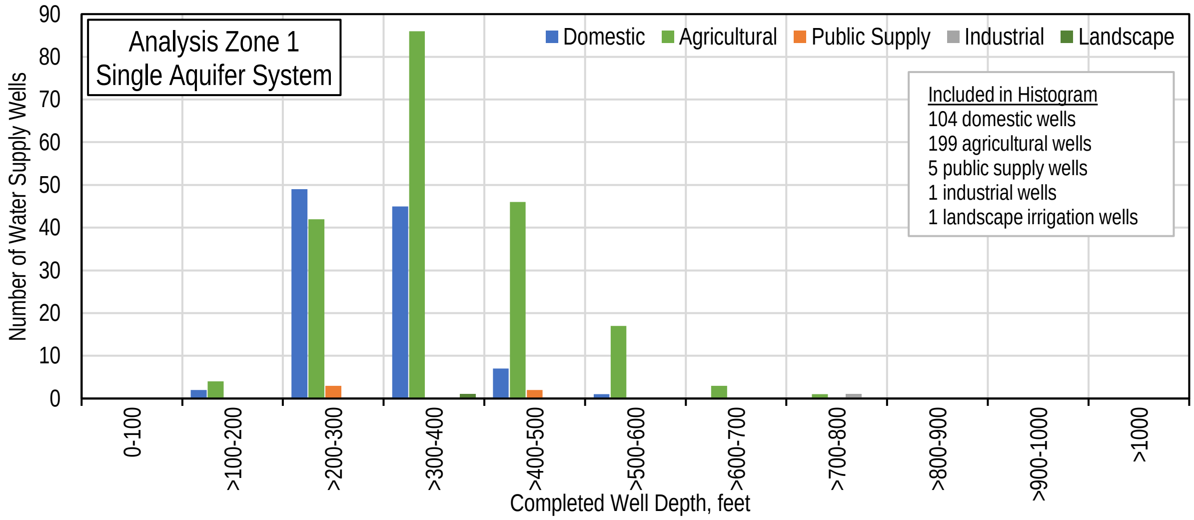
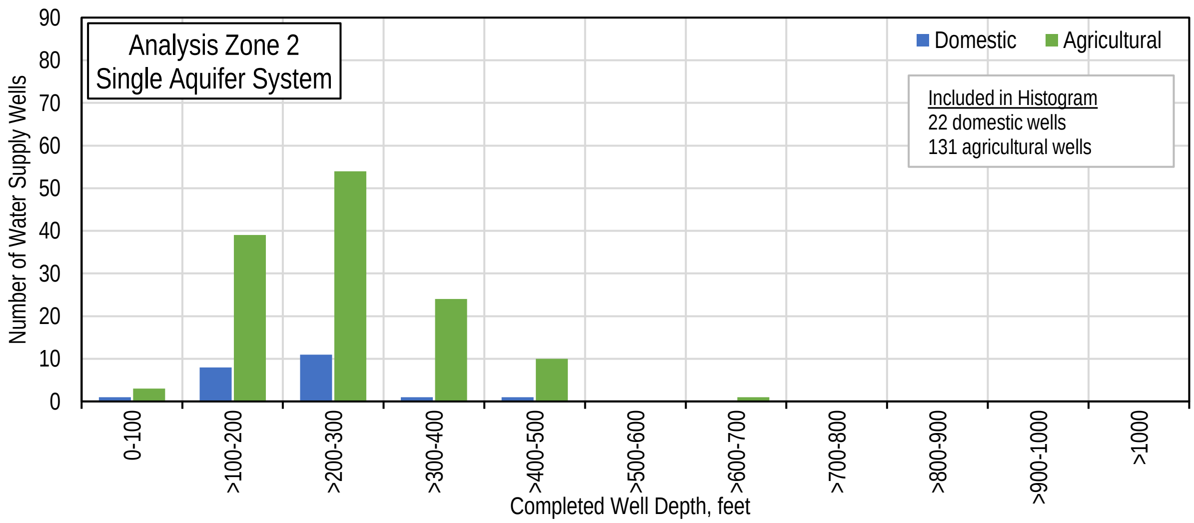
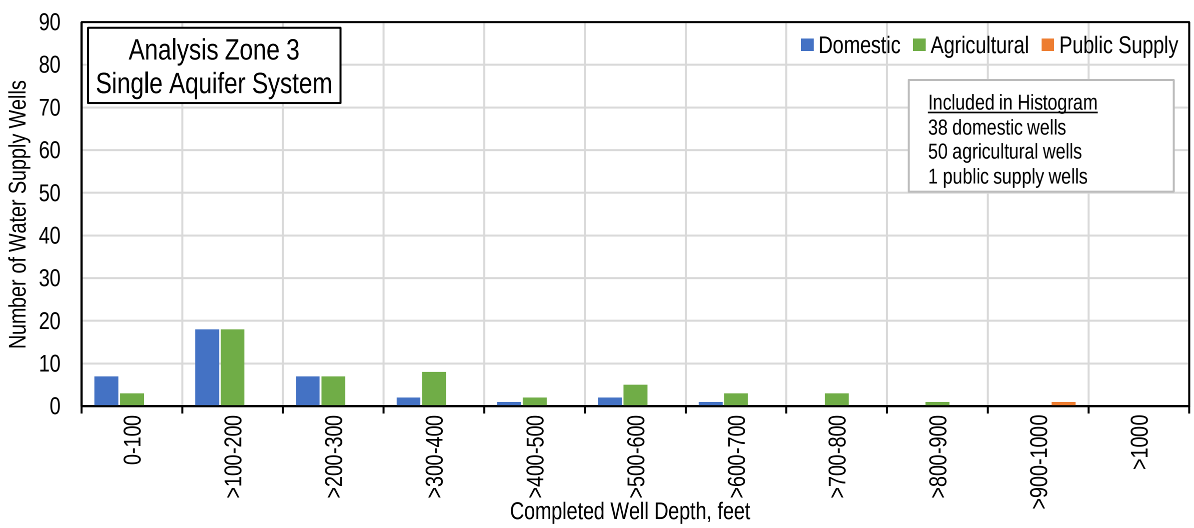
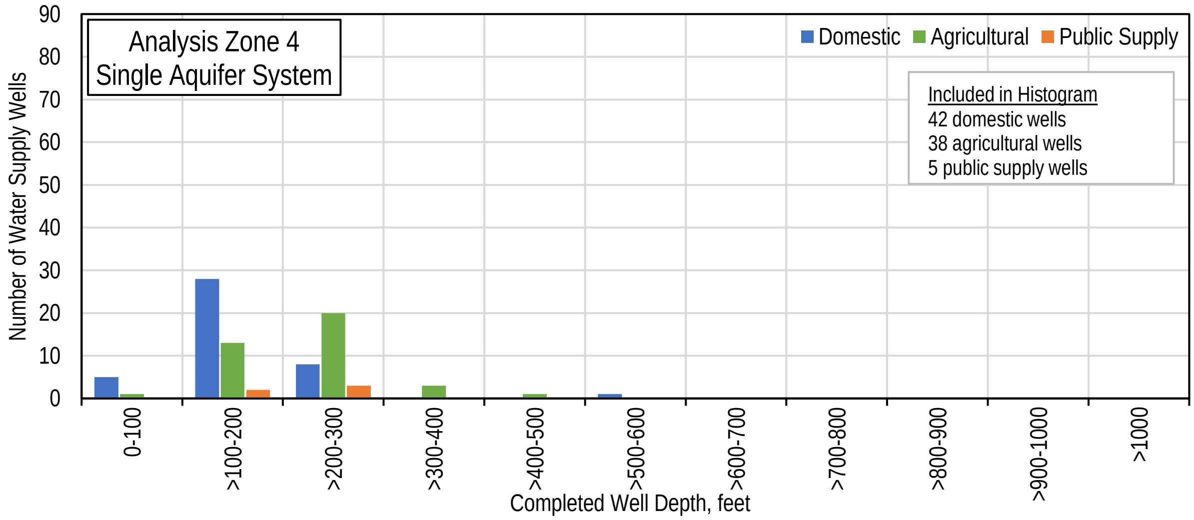
Appendix B

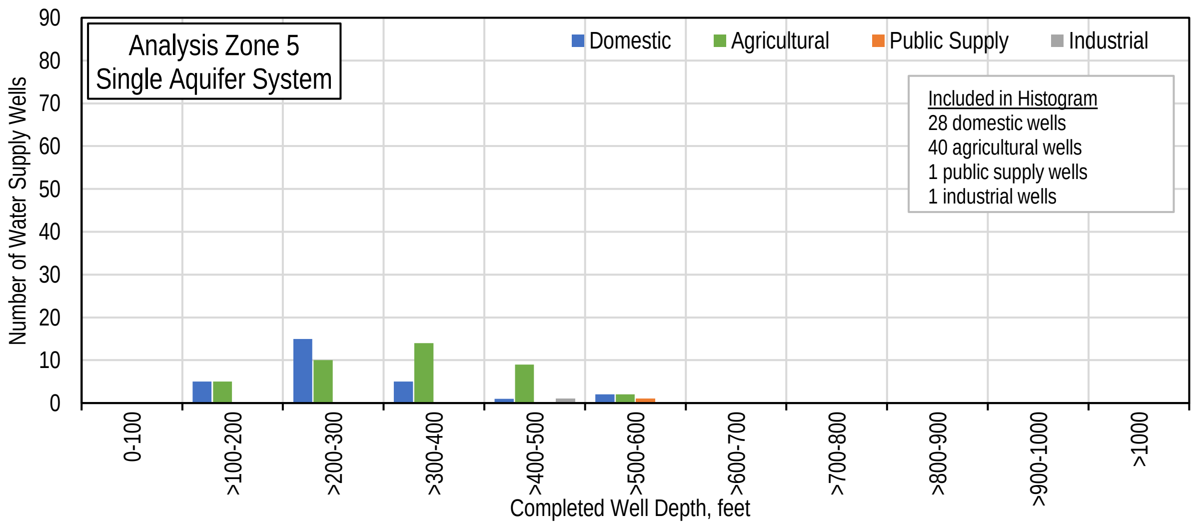
Completed Well Depth Histograms by Analysis Zone

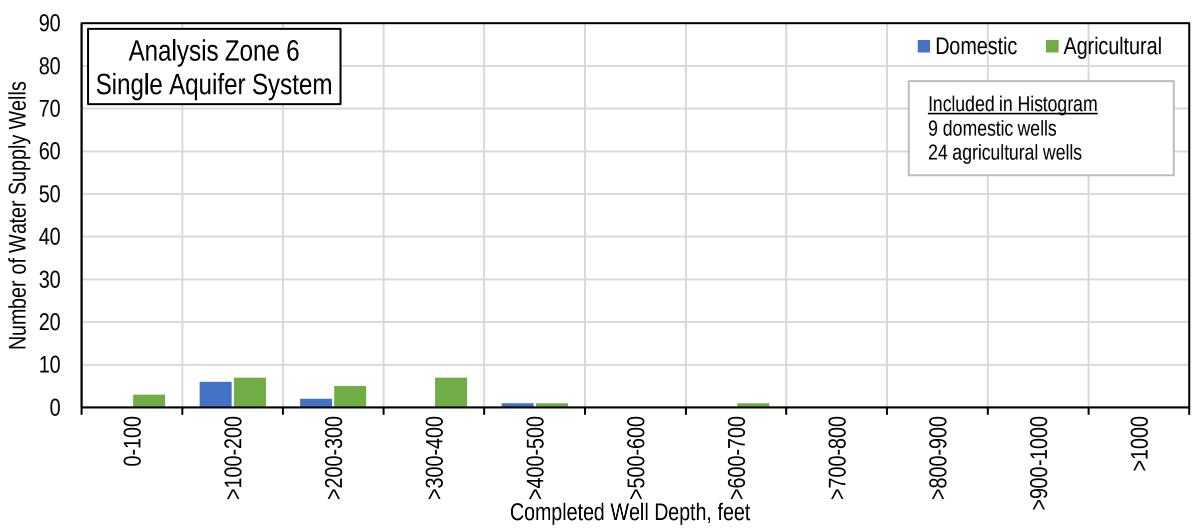

Analysis Zone 1
Single Aquifer System
Domestic
Agricultural
Public Supply
Industrial
Landscape
Included in Histogram
104 domestic wells
199 agricultural wells
5 public supply wells
1 industrial wells
1 landscape irrigation wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

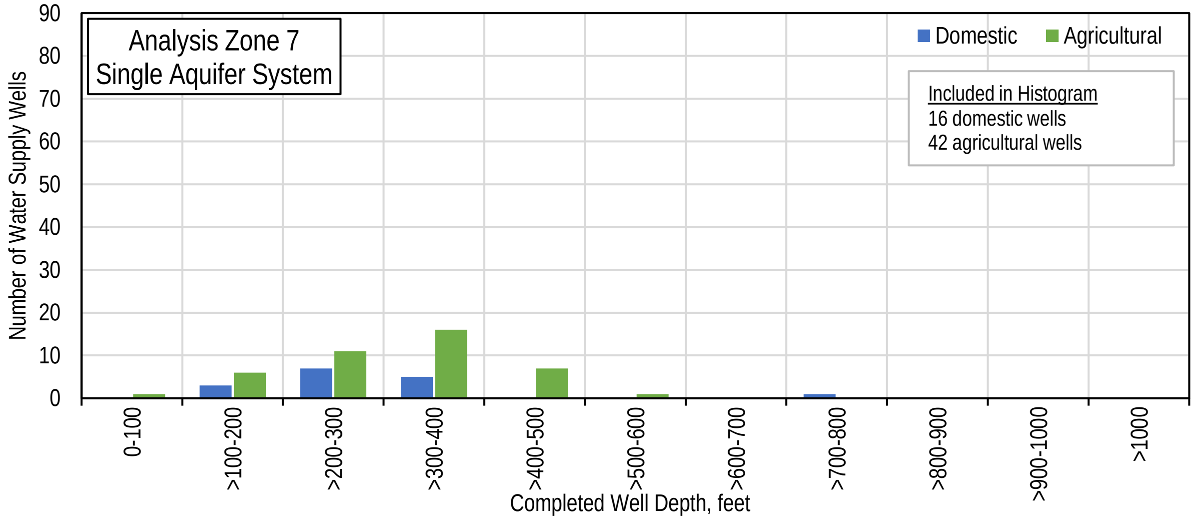

Analysis Zone 2
Single Aquifer System
Domestic
Agricultural
Included in Histogram
22 domestic wells
131 agricultural wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

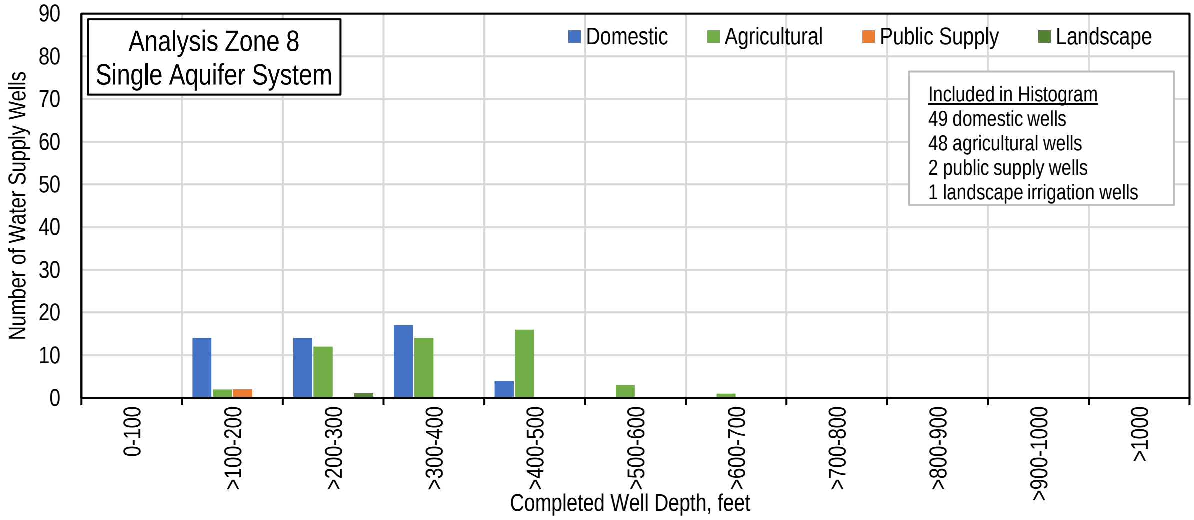

Analysis Zone 3
Single Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
38 domestic wells
50 agricultural wells
1 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

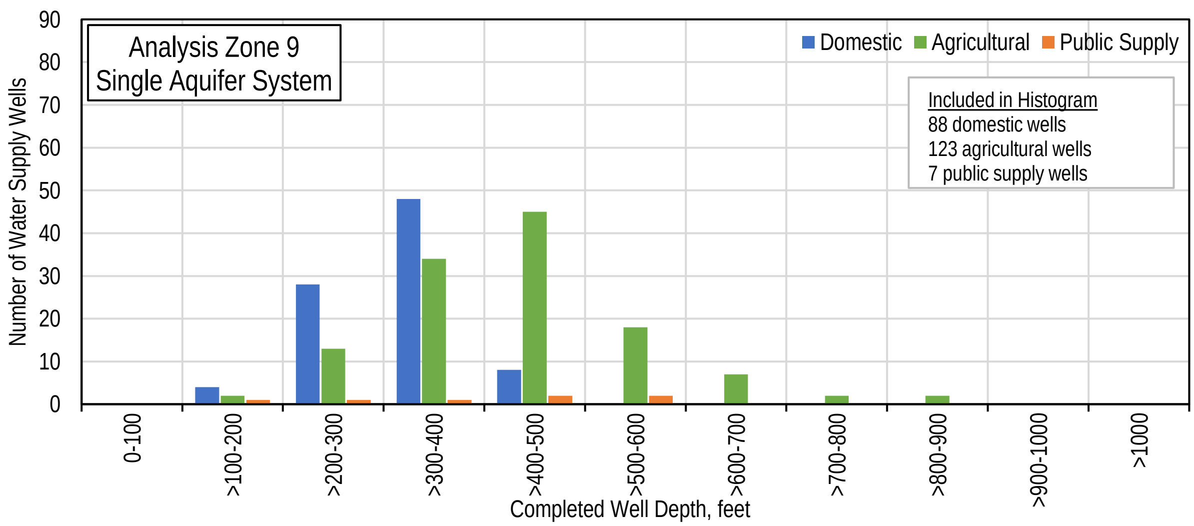

Analysis Zone 4
Single Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
42 domestic wells
38 agricultural wells
5 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

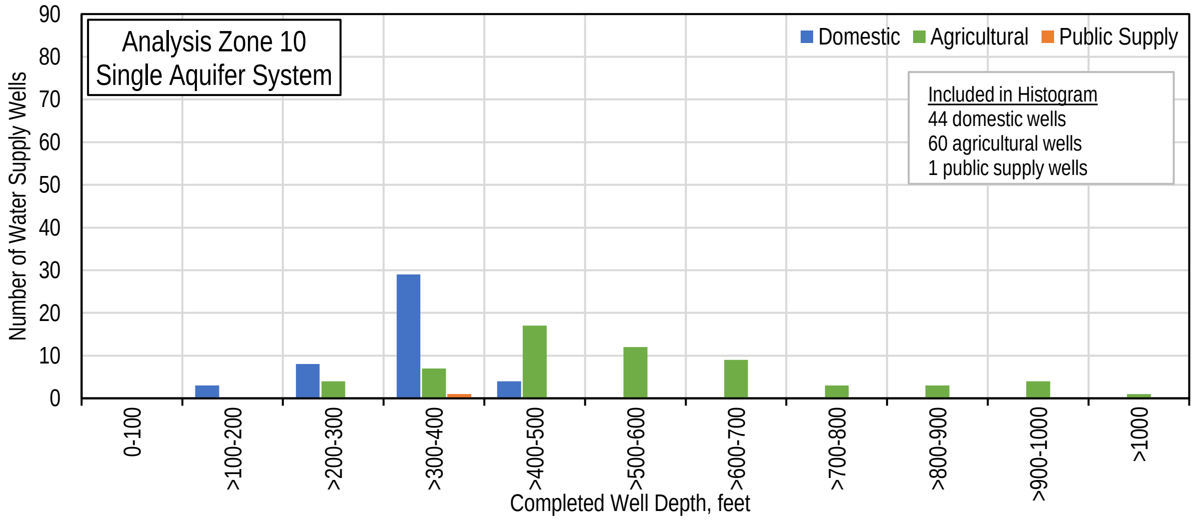

Analysis Zone 5
Single Aquifer System
Domestic
Agricultural
Public Supply
Industrial
Included in Histogram
28 domestic wells
40 agricultural wells
1 public supply wells
1 industrial wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

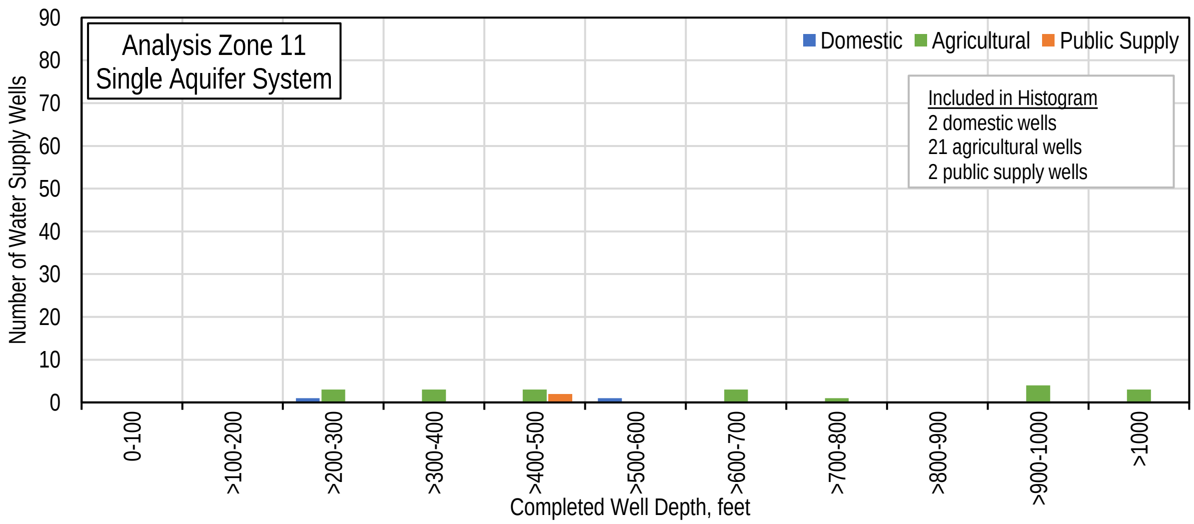

Analysis Zone 6
Single Aquifer System
Domestic
Agricultural
Included in Histogram
9 domestic wells
24 agricultural wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

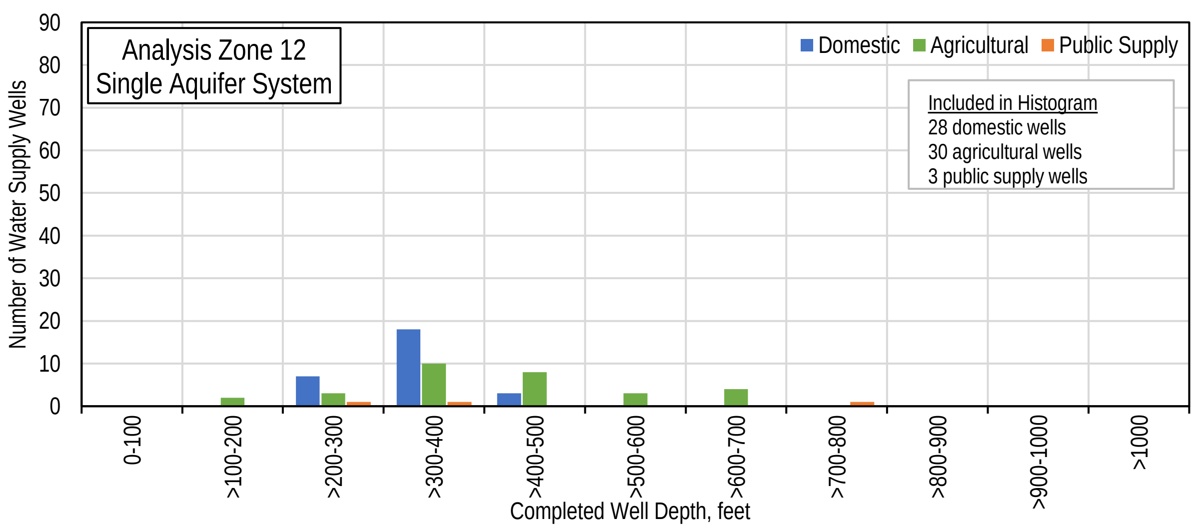

Analysis Zone 7
Single Aquifer System
Domestic
Agricultural
Included in Histogram
16 domestic wells
42 agricultural wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

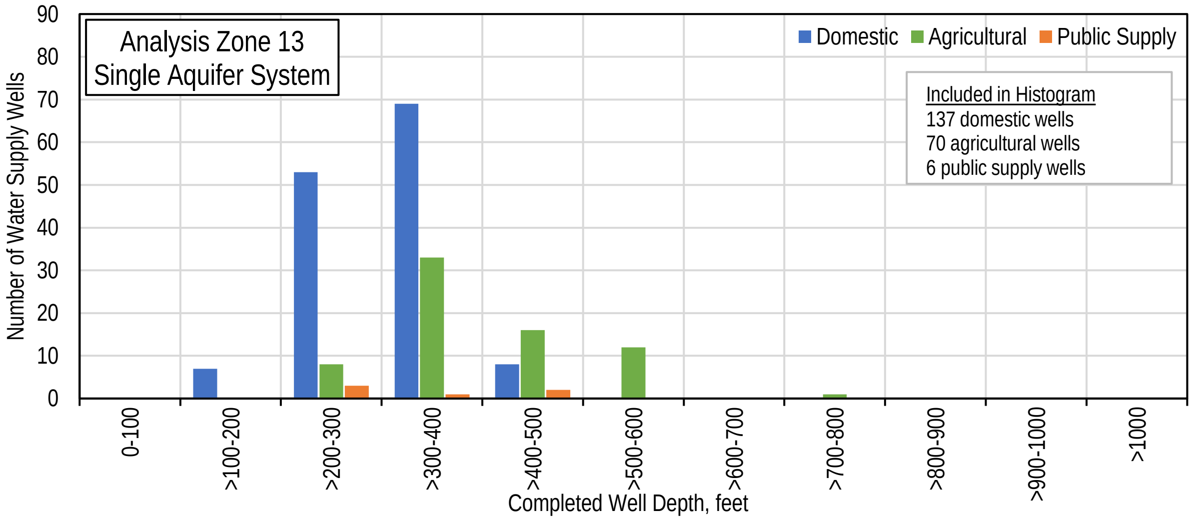

Analysis Zone 8
Single Aquifer System
Domestic
Agricultural
Public Supply
Landscape
Included in Histogram
49 domestic wells
48 agricultural wells
2 public supply wells
1 landscape irrigation wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

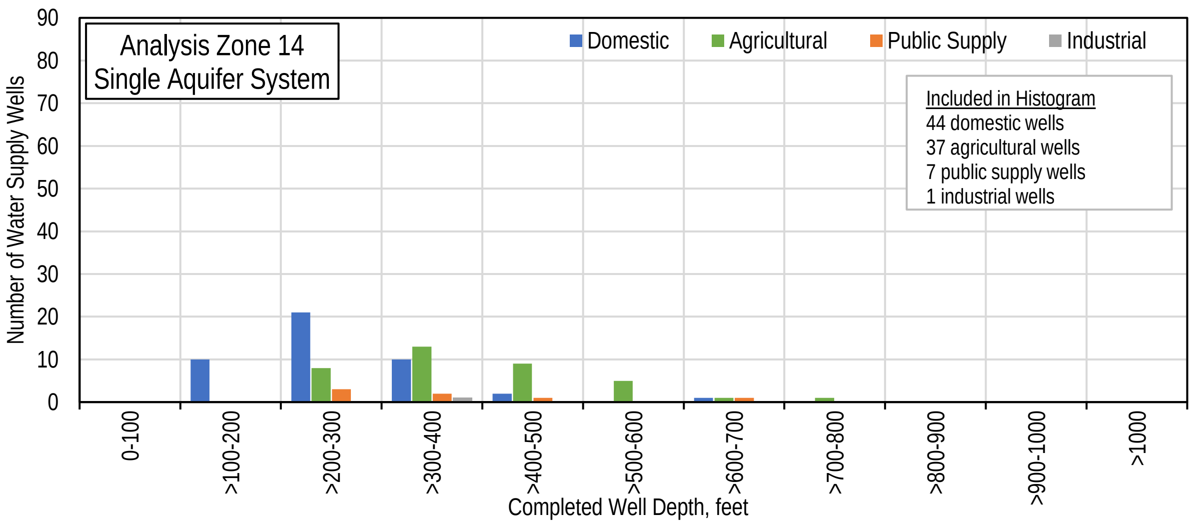

Analysis Zone 9
Single Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
88 domestic wells
123 agricultural wells
7 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

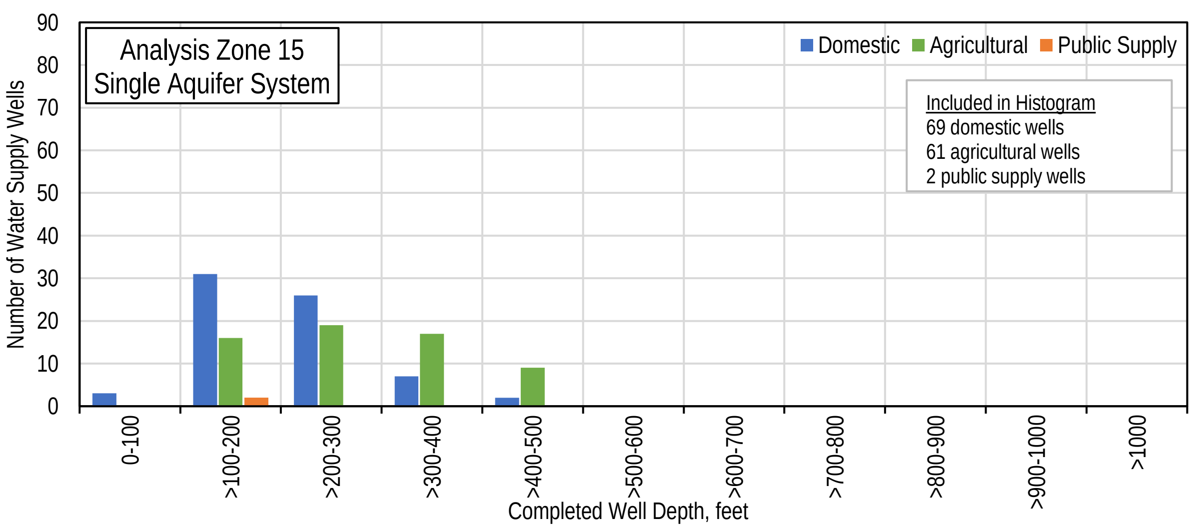

Analysis Zone 10
Single Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
44 domestic wells
60 agricultural wells
1 public supply wells
Number of Water Supply Wells
Completed Well Depth, feet
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000

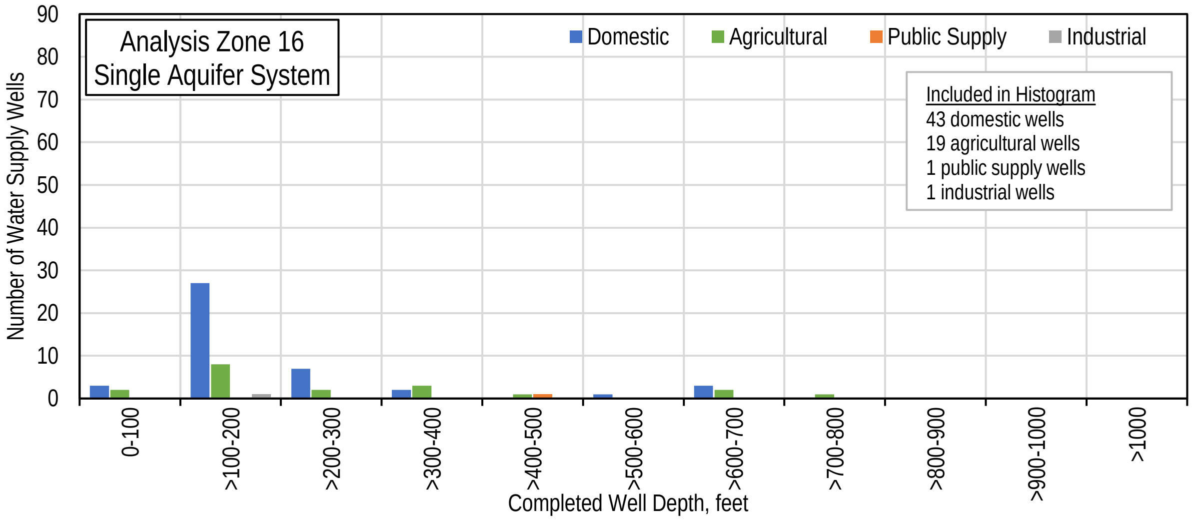

Analysis Zone 11
Single Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
2 domestic wells
21 agricultural wells
2 public supply wells
Number of Water Supply Wells
Completed Well Depth, feet
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000

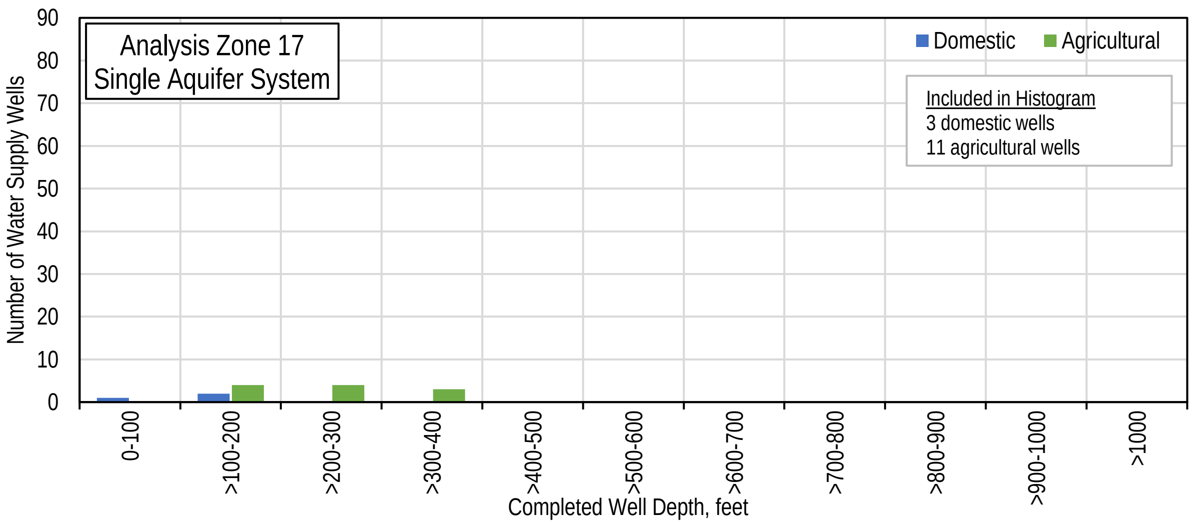

Analysis Zone 12
Single Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
28 domestic wells
30 agricultural wells
3 public supply wells
Number of Water Supply Wells
Completed Well Depth, feet
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000

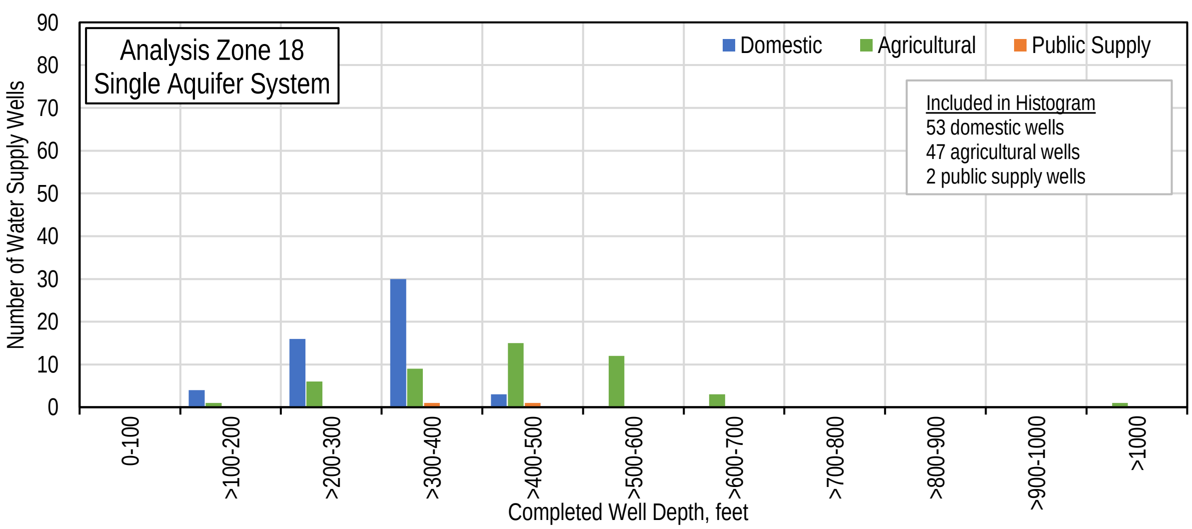

Analysis Zone 13
Single Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
137 domestic wells
70 agricultural wells
6 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

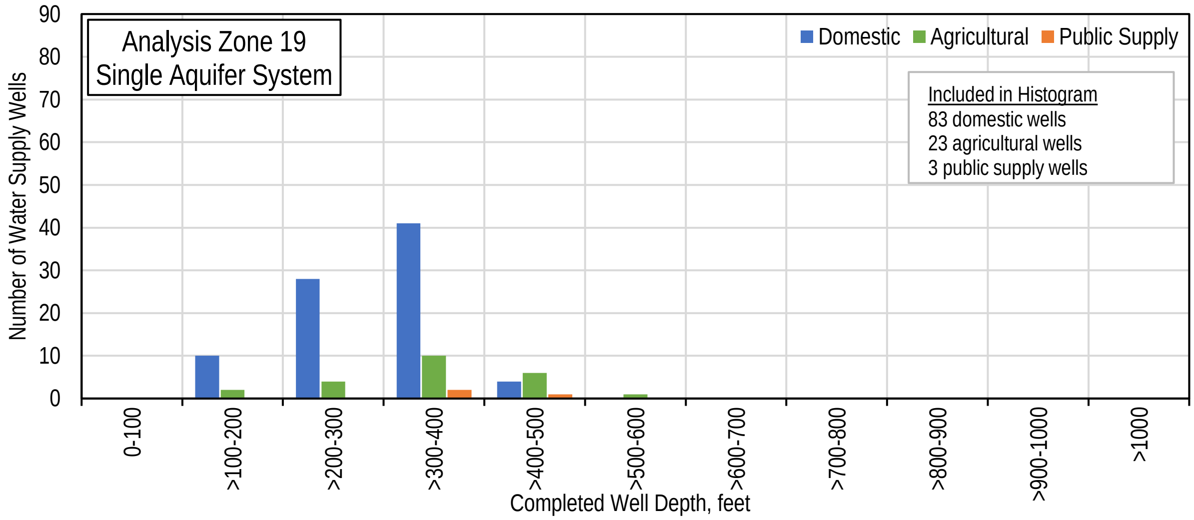

Analysis Zone 14
Single Aquifer System
Domestic
Agricultural
Public Supply
Industrial
Included in Histogram
44 domestic wells
37 agricultural wells
7 public supply wells
1 industrial wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

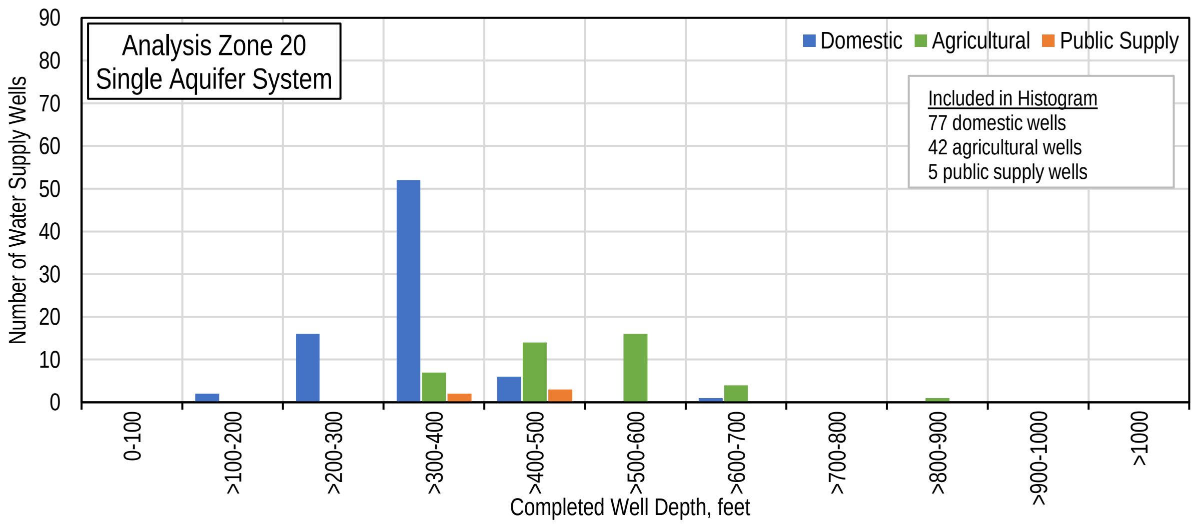

Analysis Zone 15
Single Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
69 domestic wells
61 agricultural wells
2 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

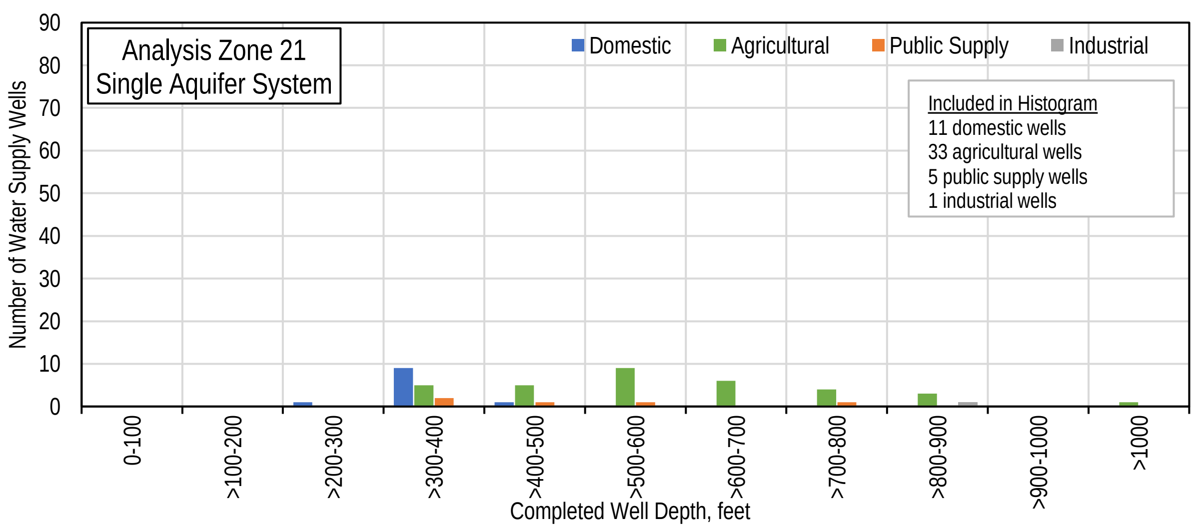

Analysis Zone 16
Single Aquifer System
Domestic
Agricultural
Public Supply
Industrial
Included in Histogram
43 domestic wells
19 agricultural wells
1 public supply wells
1 industrial wells
Number of Water Supply Wells
Completed Well Depth, feet
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000

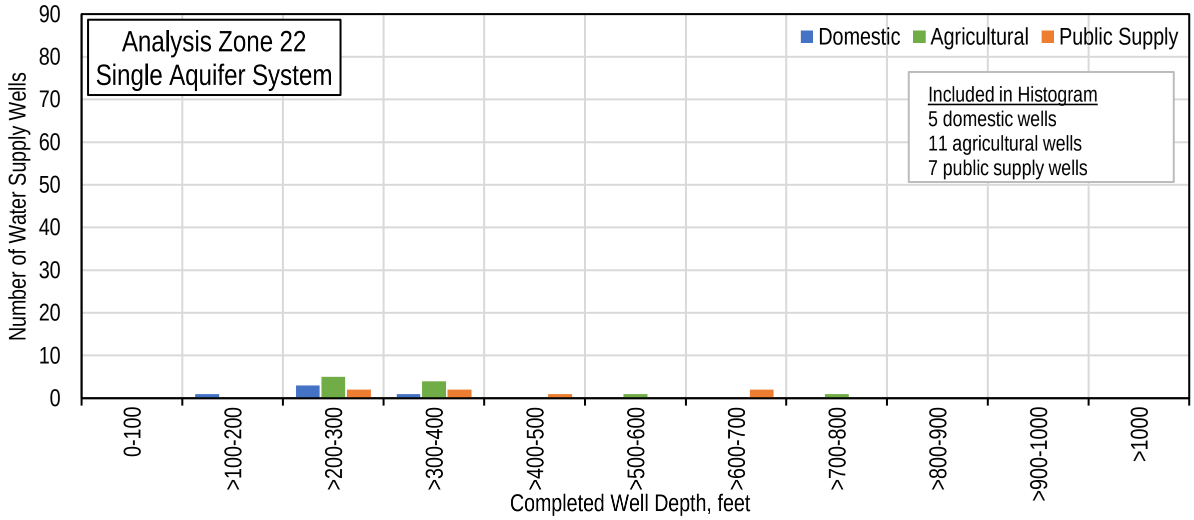

Analysis Zone 17
Single Aquifer System
Domestic
Agricultural
Included in Histogram
3 domestic wells
11 agricultural wells
Number of Water Supply Wells
Completed Well Depth, feet

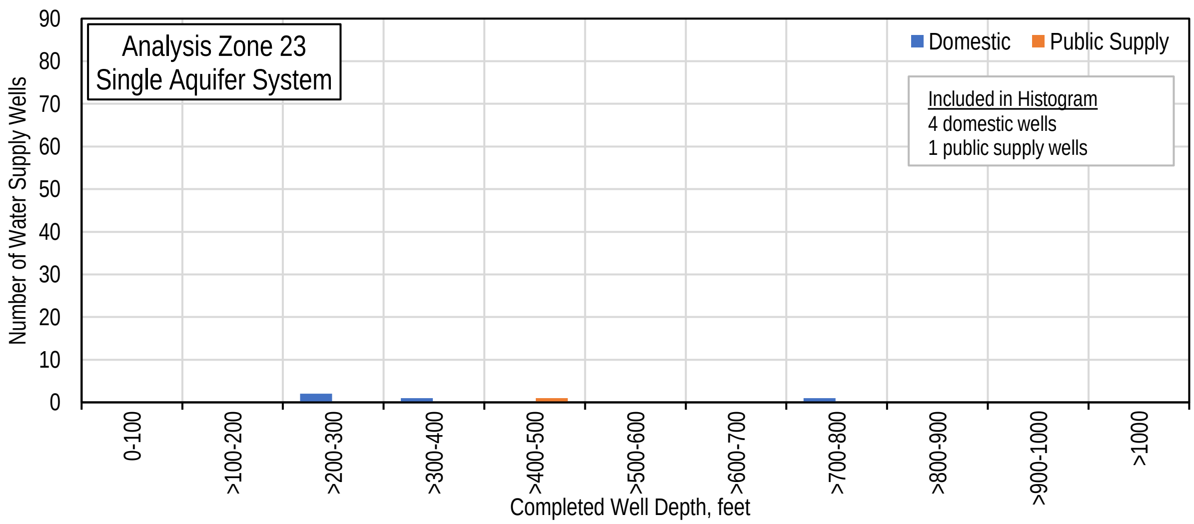

Analysis Zone 18
Single Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
53 domestic wells
47 agricultural wells
2 public supply wells
Number of Water Supply Wells
Completed Well Depth, feet

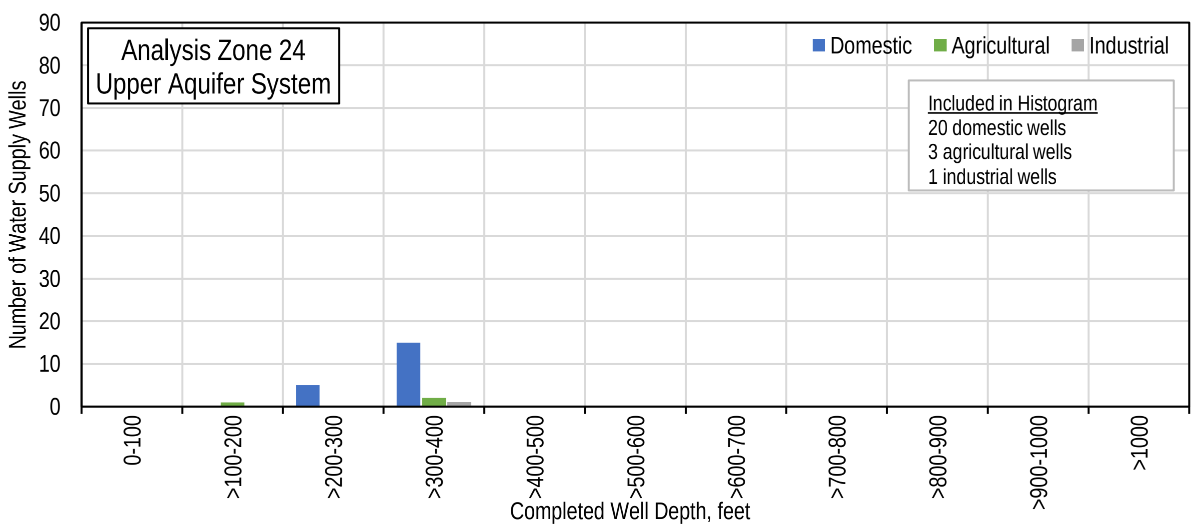

Analysis Zone 19
Single Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
83 domestic wells
23 agricultural wells
3 public supply wells
Number of Water Supply Wells
Completed Well Depth, feet
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000

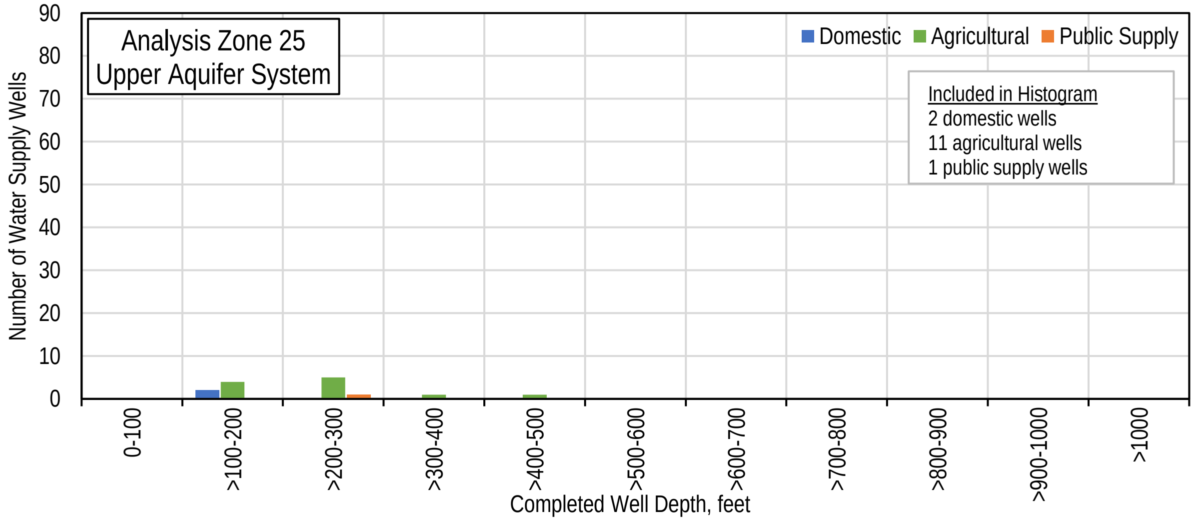

Analysis Zone 20
Single Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
77 domestic wells
42 agricultural wells
5 public supply wells
Number of Water Supply Wells
Completed Well Depth, feet
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000

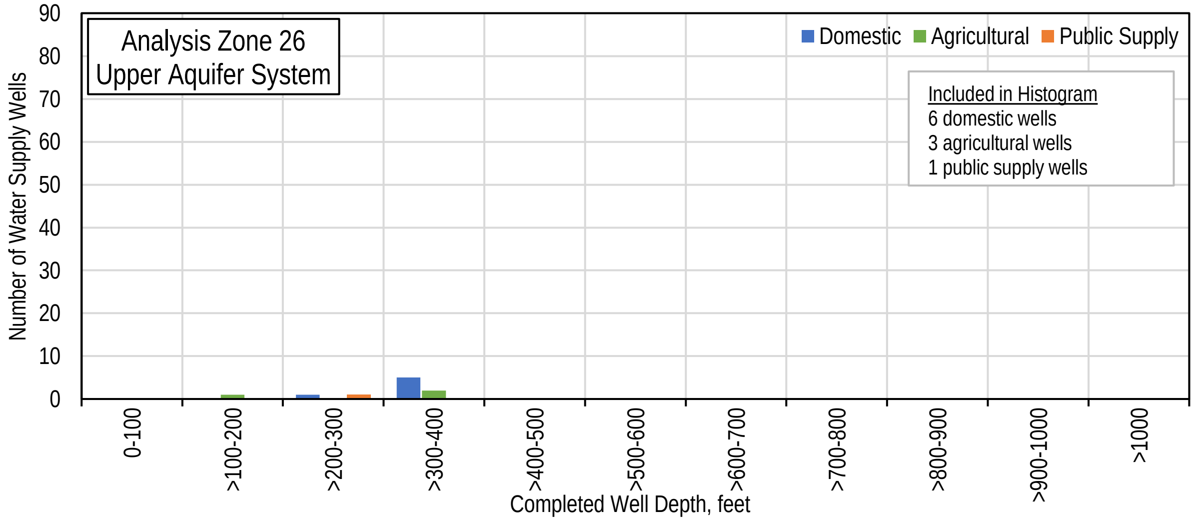

Analysis Zone 21
Single Aquifer System
Domestic
Agricultural
Public Supply
Industrial
Included in Histogram
11 domestic wells
33 agricultural wells
5 public supply wells
1 industrial wells
Number of Water Supply Wells
Completed Well Depth, feet
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000

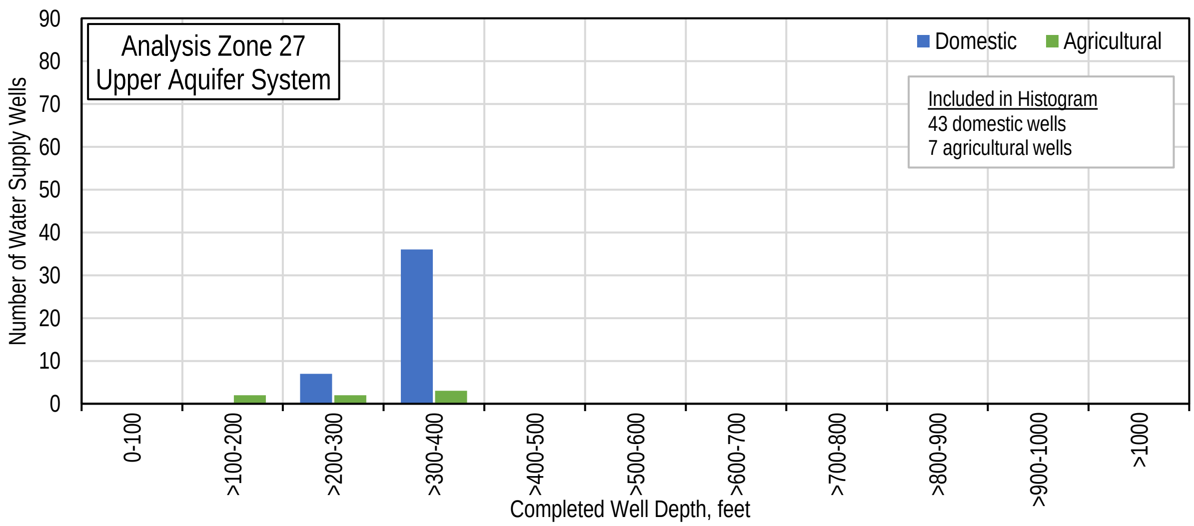

Analysis Zone 22
Single Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
5 domestic wells
11 agricultural wells
7 public supply wells
Number of Water Supply Wells
Completed Well Depth, feet
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000

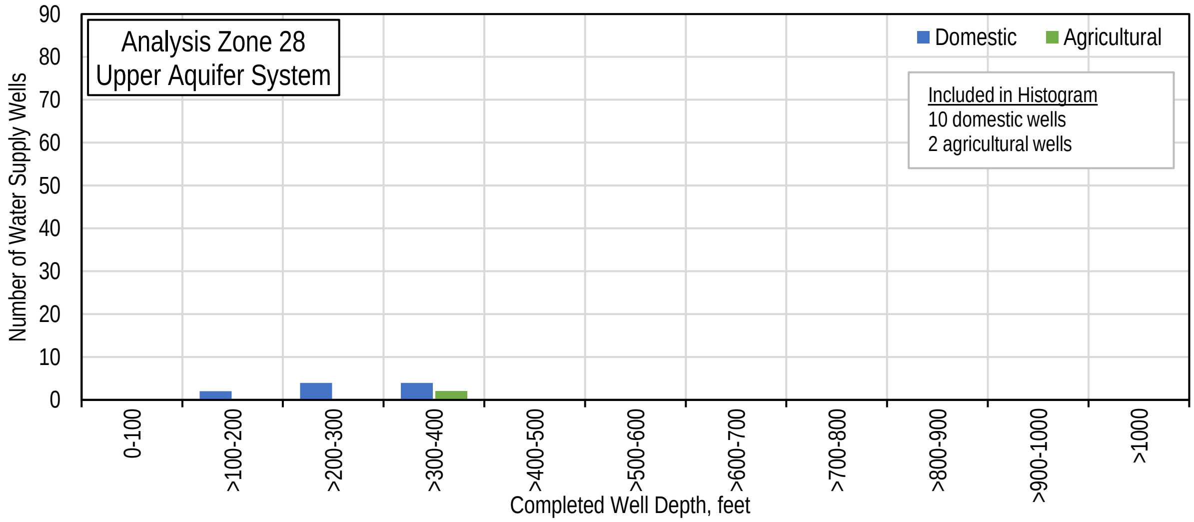

Analysis Zone 23
Single Aquifer System
Domestic
Public Supply
Included in Histogram
4 domestic wells
1 public supply wells
Number of Water Supply Wells
Completed Well Depth, feet

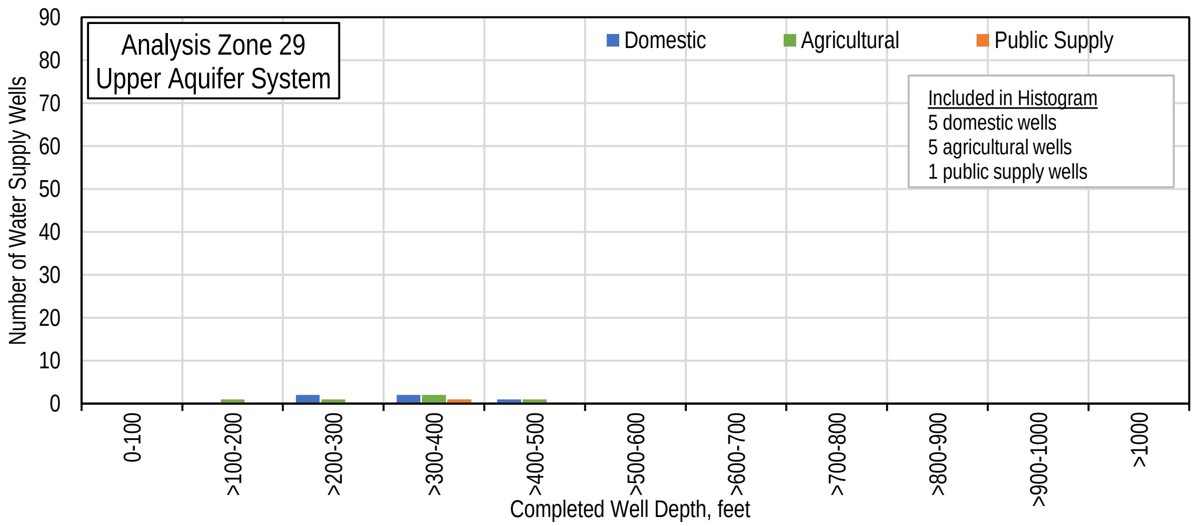

Analysis Zone 24
Upper Aquifer System
Domestic
Agricultural
Industrial
Included in Histogram
20 domestic wells
3 agricultural wells
1 industrial wells
Number of Water Supply Wells
Completed Well Depth, feet

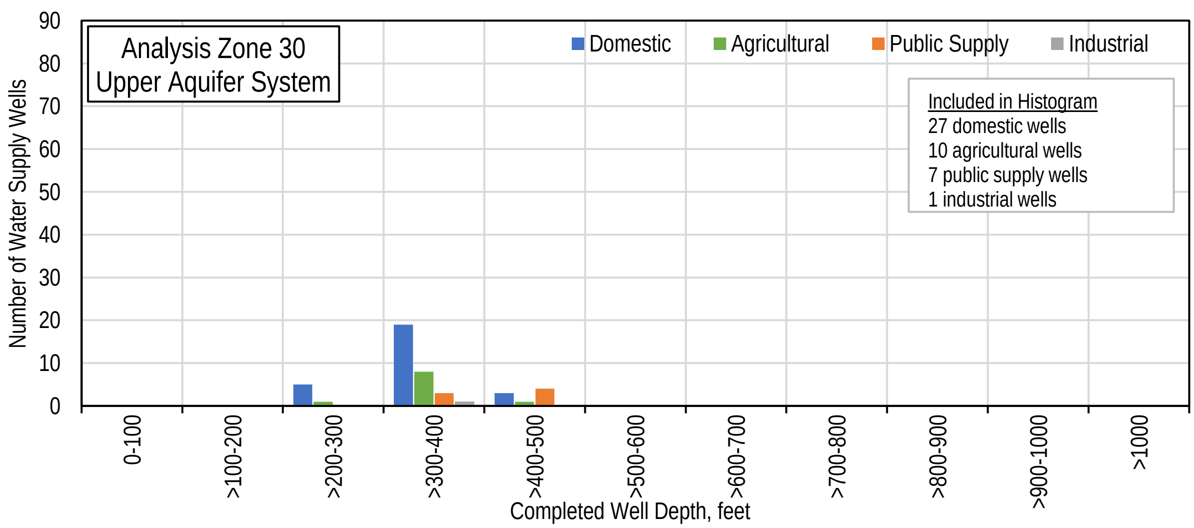

Analysis Zone 25
Upper Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
2 domestic wells
11 agricultural wells
1 public supply wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

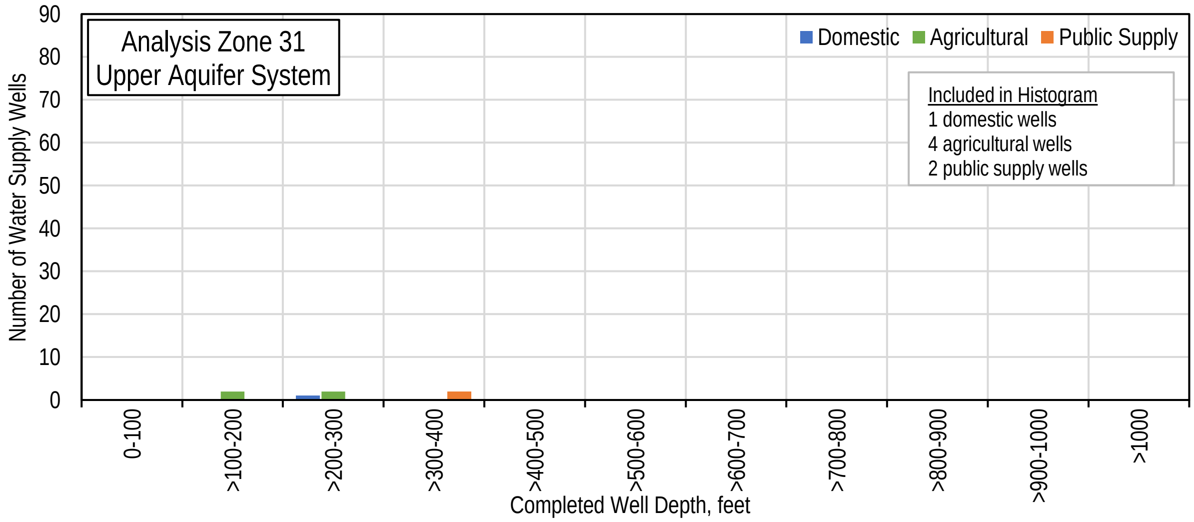

Analysis Zone 26
Upper Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
6 domestic wells
3 agricultural wells
1 public supply wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

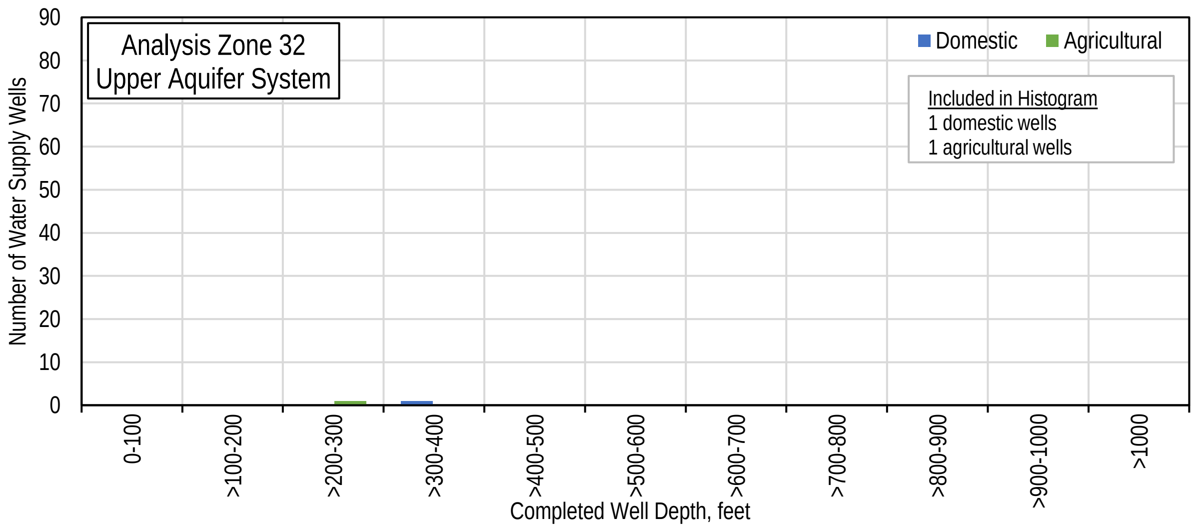

Analysis Zone 27
Upper Aquifer System
Domestic
Agricultural
Included in Histogram
43 domestic wells
7 agricultural wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

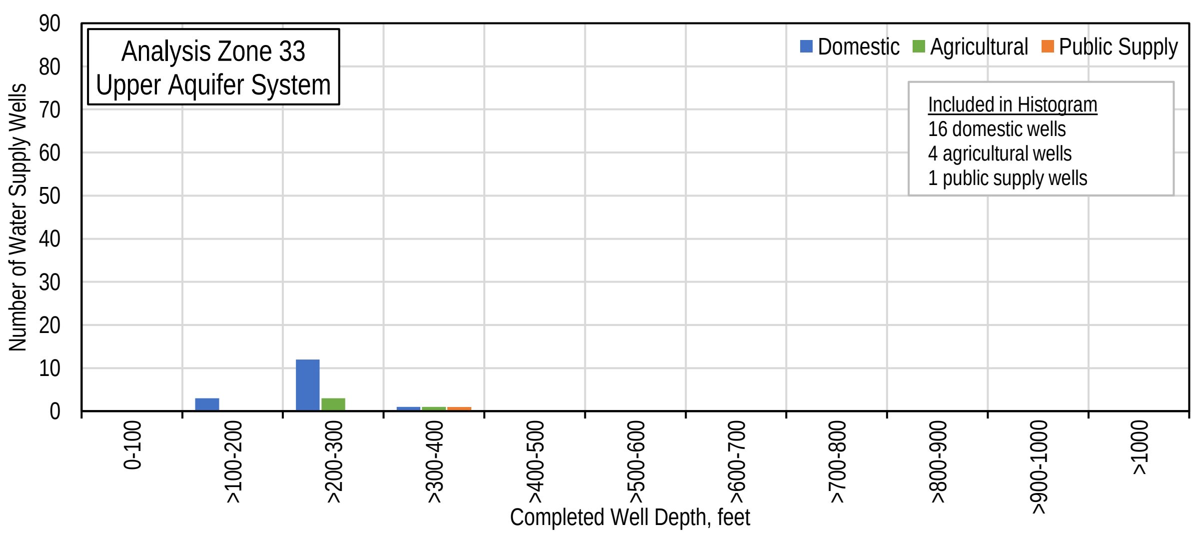

Analysis Zone 28
Upper Aquifer System
Domestic
Agricultural
Included in Histogram
10 domestic wells
2 agricultural wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

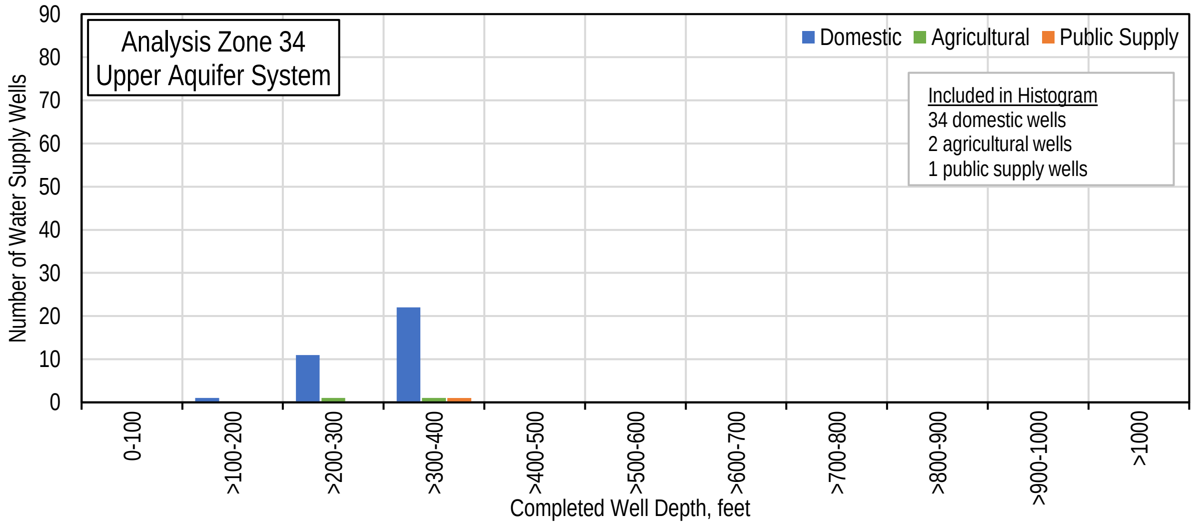

Analysis Zone 29
Upper Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
5 domestic wells
5 agricultural wells
1 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

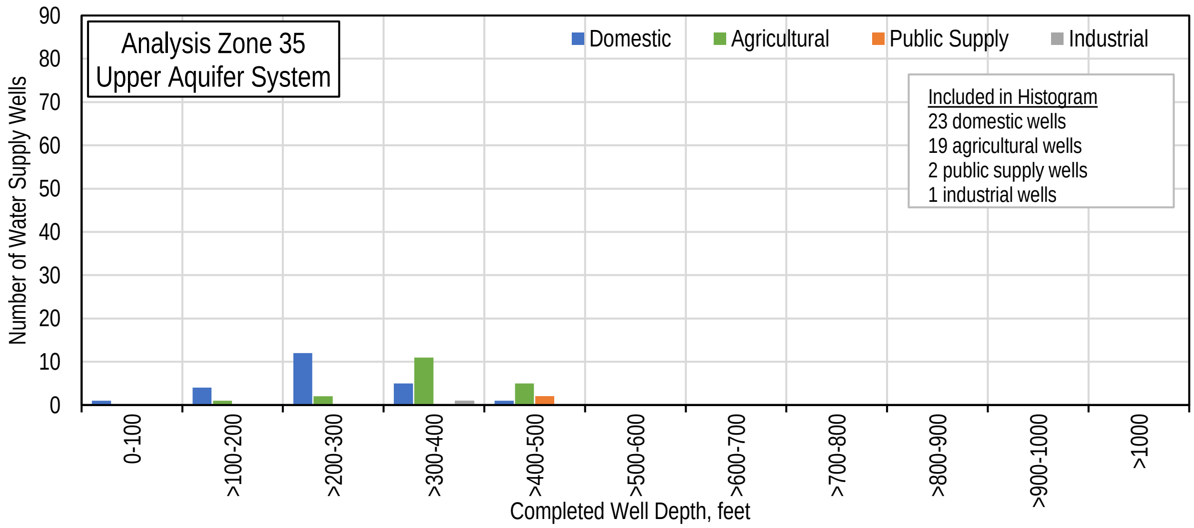

Analysis Zone 30
Upper Aquifer System
Domestic
Agricultural
Public Supply
Industrial
Included in Histogram
27 domestic wells
10 agricultural wells
7 public supply wells
1 industrial wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

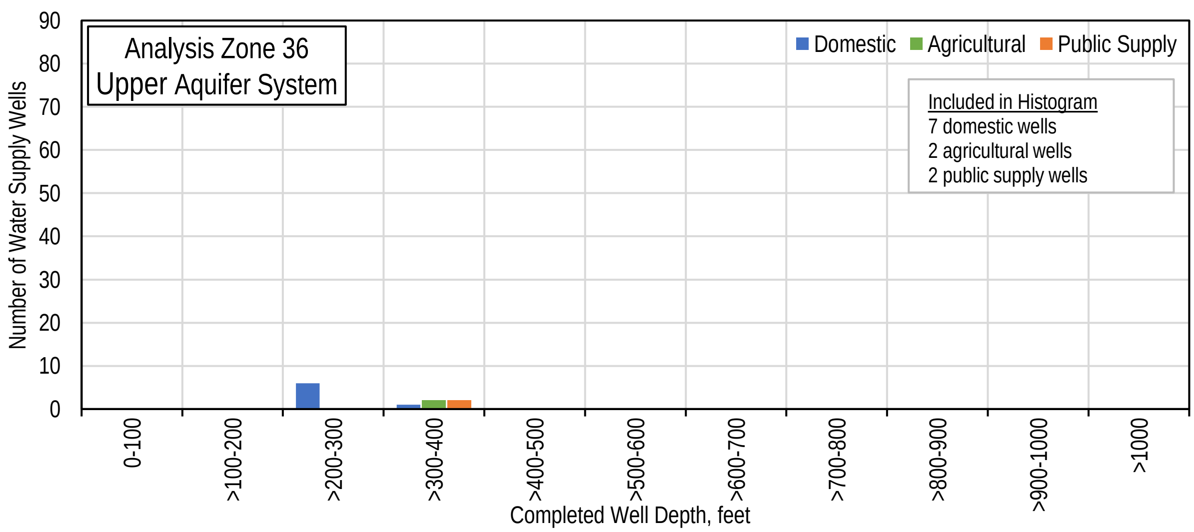

Analysis Zone 31
Upper Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
1 domestic wells
4 agricultural wells
2 public supply wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

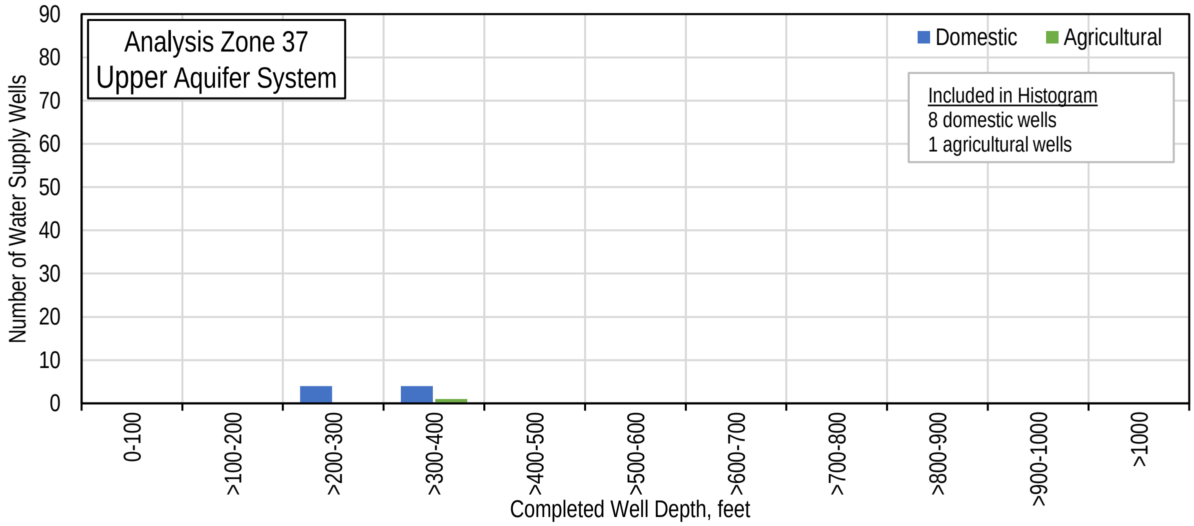

Analysis Zone 32
Upper Aquifer System
Domestic
Agricultural
Included in Histogram
1 domestic wells
1 agricultural wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

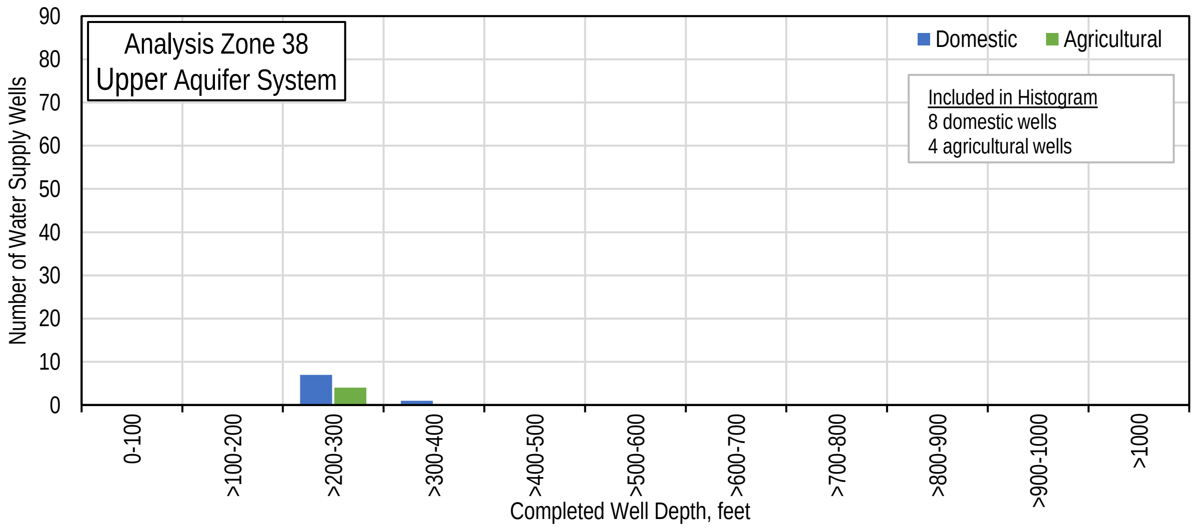

Analysis Zone 33
Upper Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
16 domestic wells
4 agricultural wells
1 public supply wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

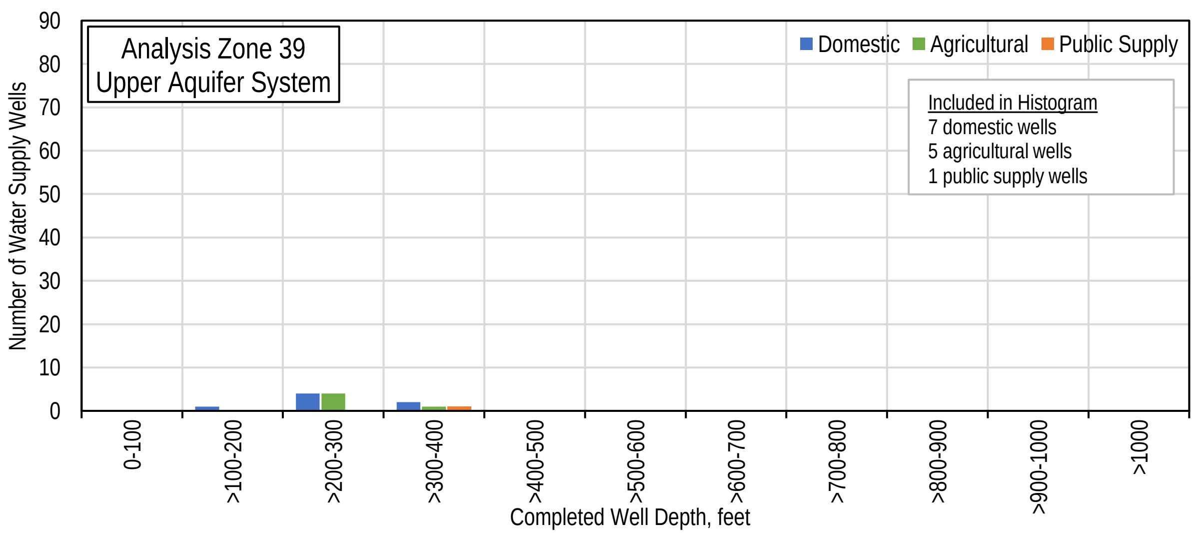

Analysis Zone 34
Upper Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
34 domestic wells
2 agricultural wells
1 public supply wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

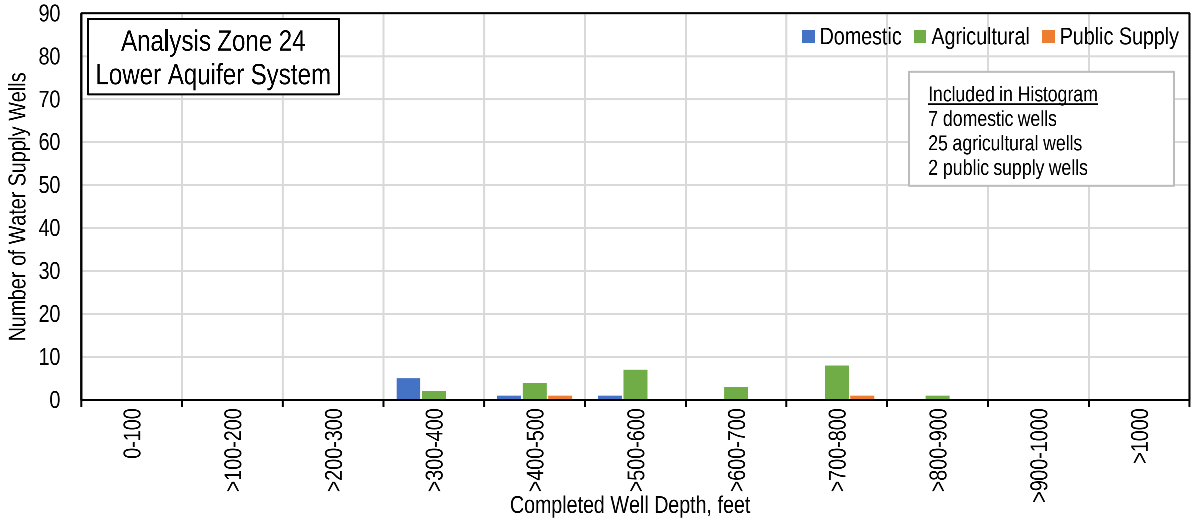

Analysis Zone 35
Upper Aquifer System
Domestic
Agricultural
Public Supply
Industrial
Included in Histogram
23 domestic wells
19 agricultural wells
2 public supply wells
1 industrial wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

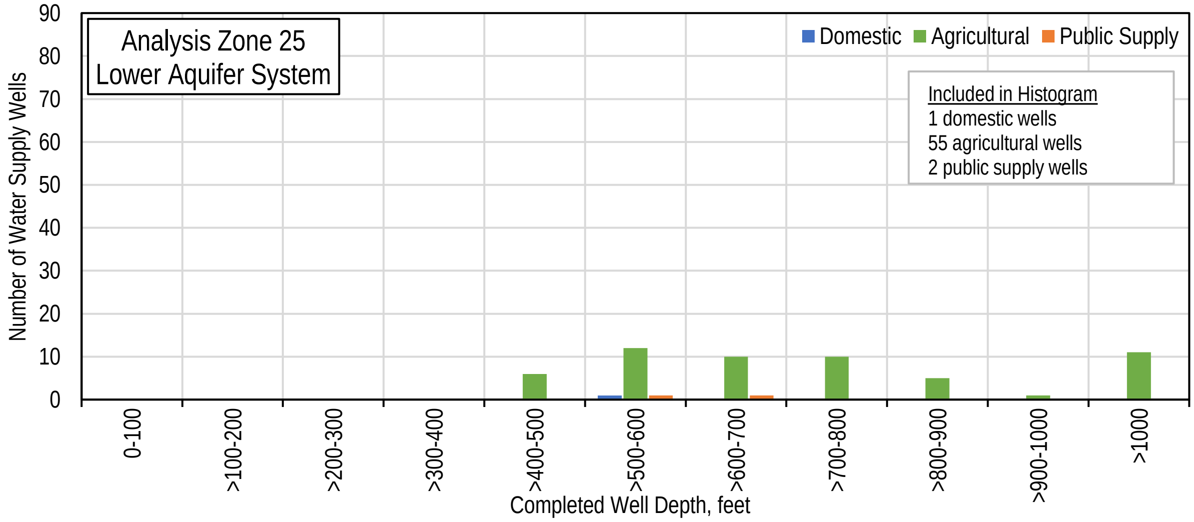

Analysis Zone 36
Upper Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
7 domestic wells
2 agricultural wells
2 public supply wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

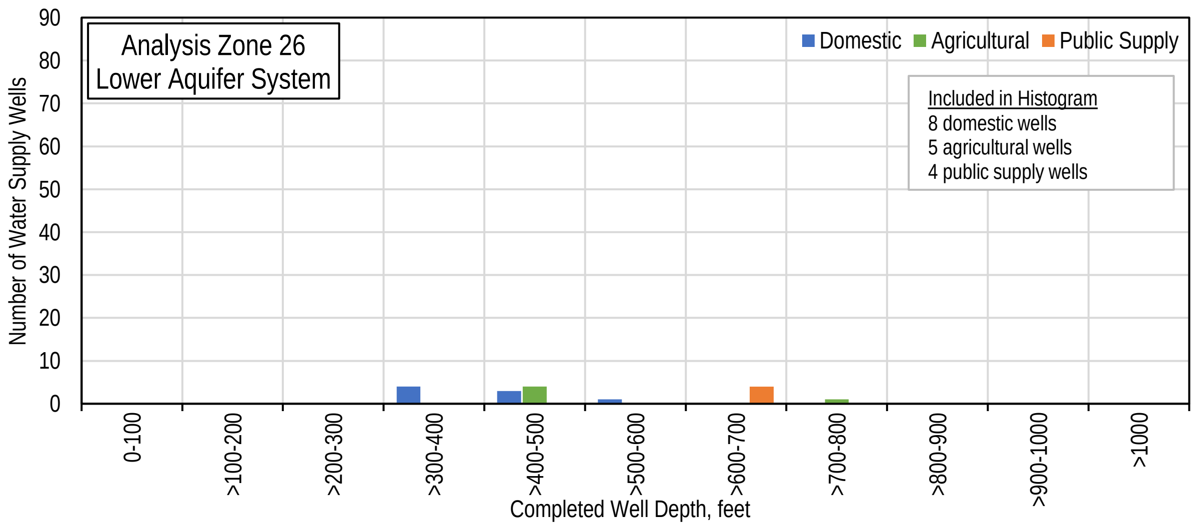

Analysis Zone 37
Upper Aquifer System
Domestic
Agricultural
Included in Histogram
8 domestic wells
1 agricultural wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

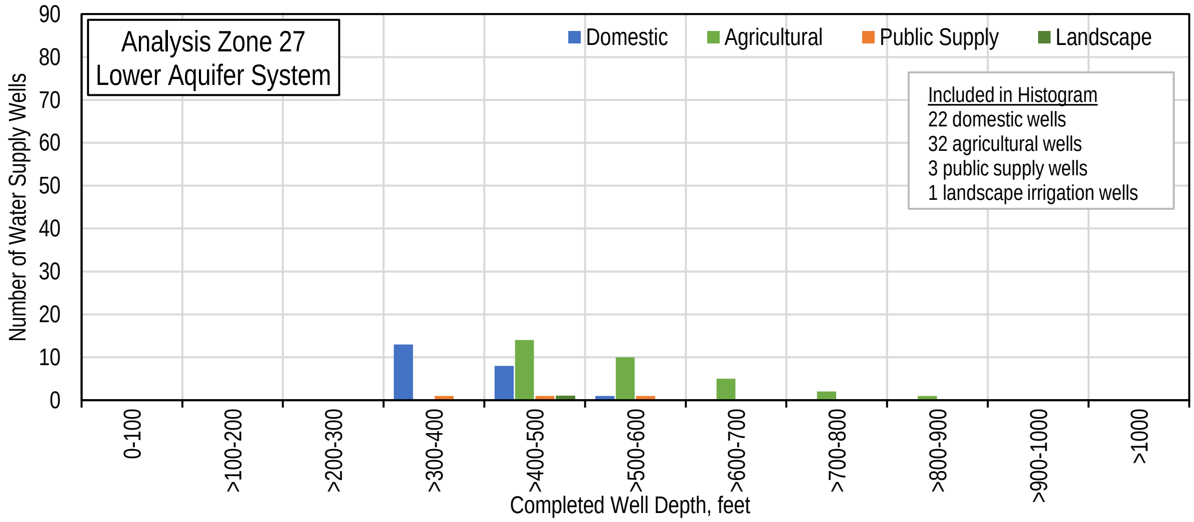

Analysis Zone 38
Upper Aquifer System
Domestic
Agricultural
Included in Histogram
8 domestic wells
4 agricultural wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

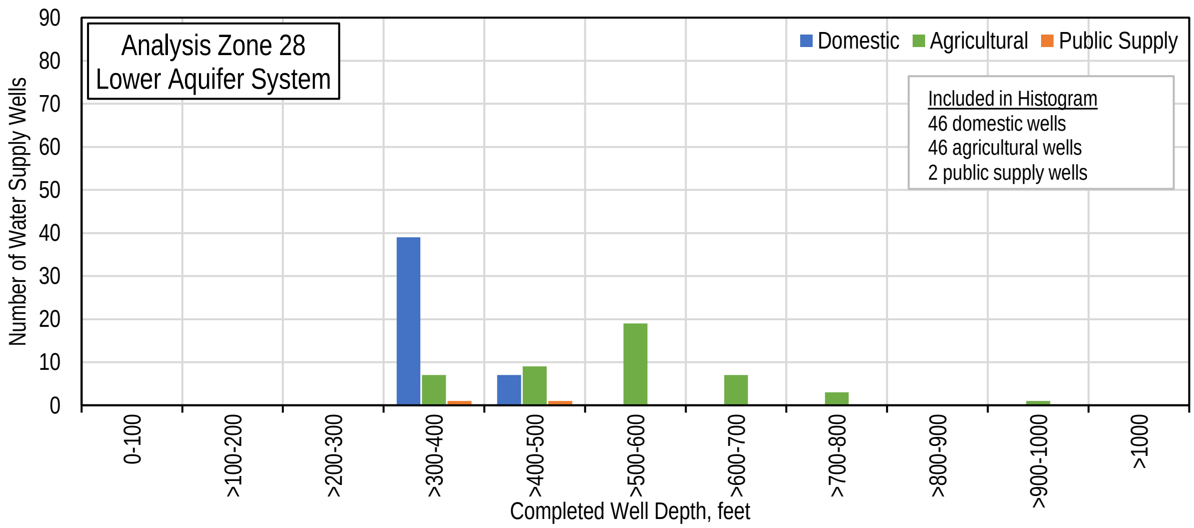

Analysis Zone 39
Upper Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
7 domestic wells
5 agricultural wells
1 public supply wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

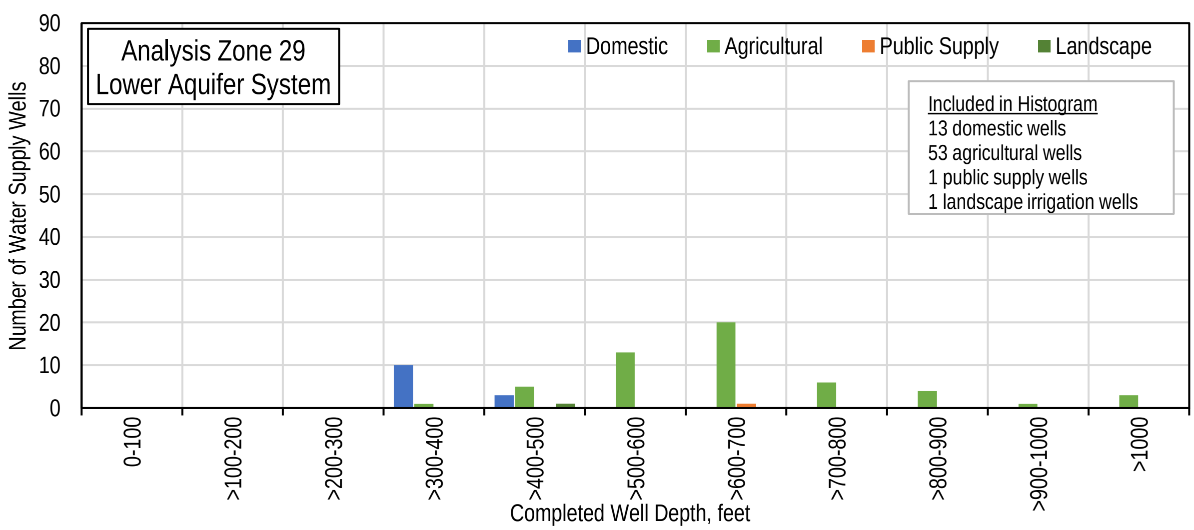

Analysis Zone 24
Lower Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
7 domestic wells
25 agricultural wells
2 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

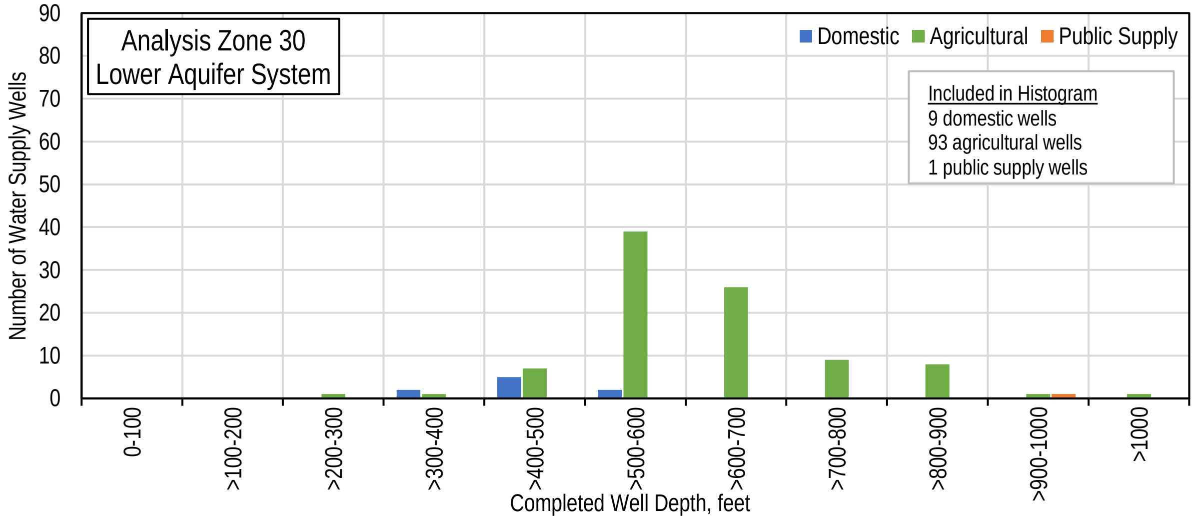

Analysis Zone 25
Lower Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
1 domestic wells
55 agricultural wells
2 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

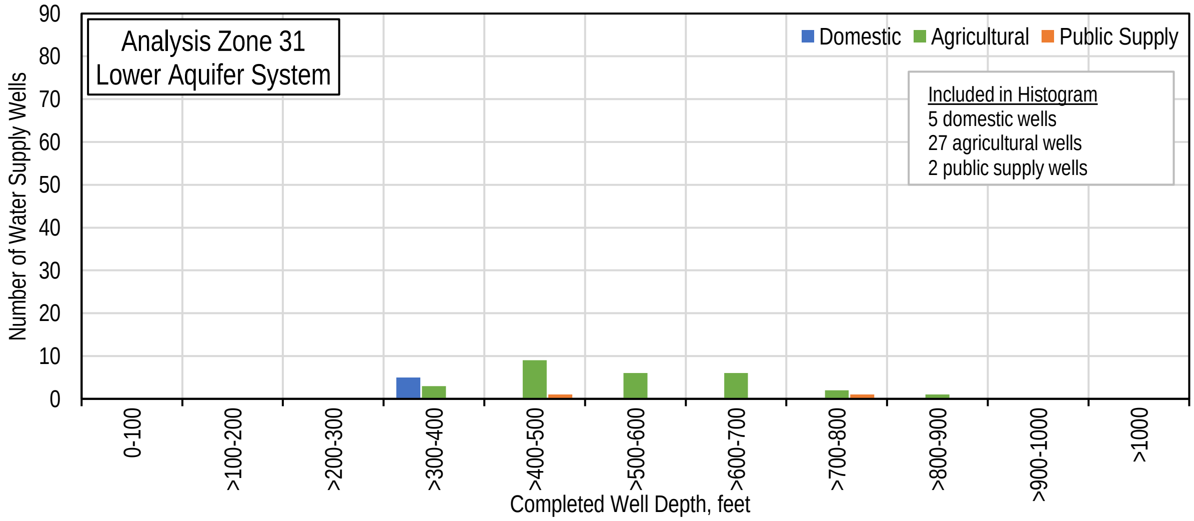

Analysis Zone 26
Lower Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
8 domestic wells
5 agricultural wells
4 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

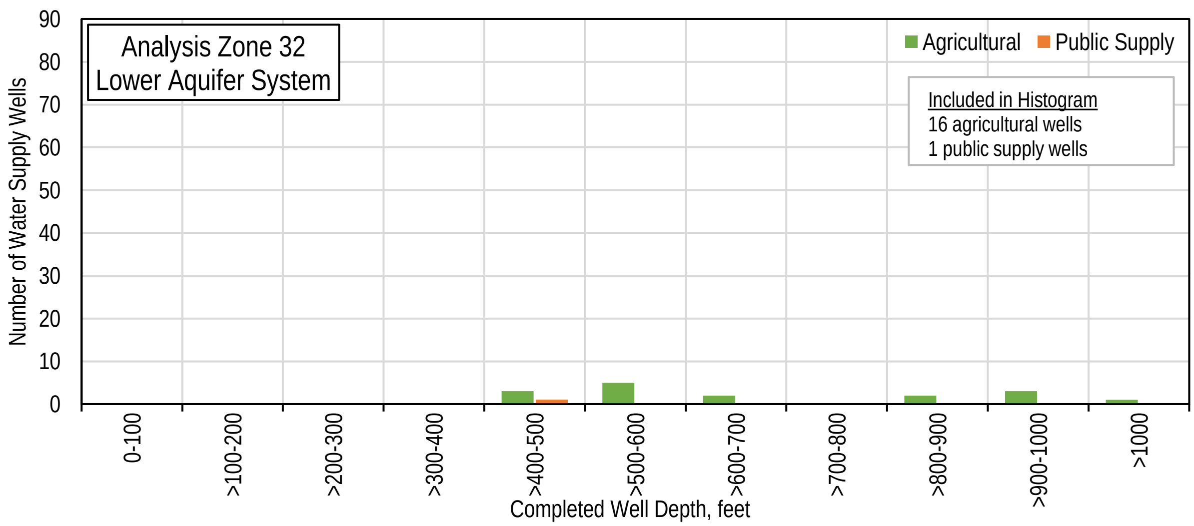

Analysis Zone 27
Lower Aquifer System
Domestic
Agricultural
Public Supply
Landscape
Included in Histogram
22 domestic wells
32 agricultural wells
3 public supply wells
1 landscape irrigation wells
Number of Water Supply Wells
Completed Well Depth, feet
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000

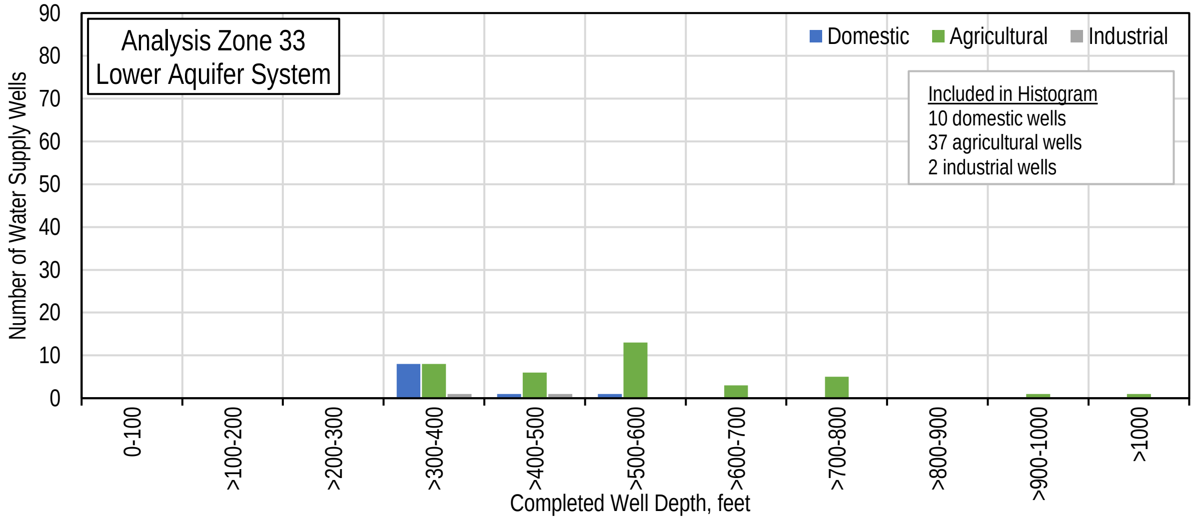

Analysis Zone 28
Lower Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
46 domestic wells
46 agricultural wells
2 public supply wells
Number of Water Supply Wells
Completed Well Depth, feet
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000

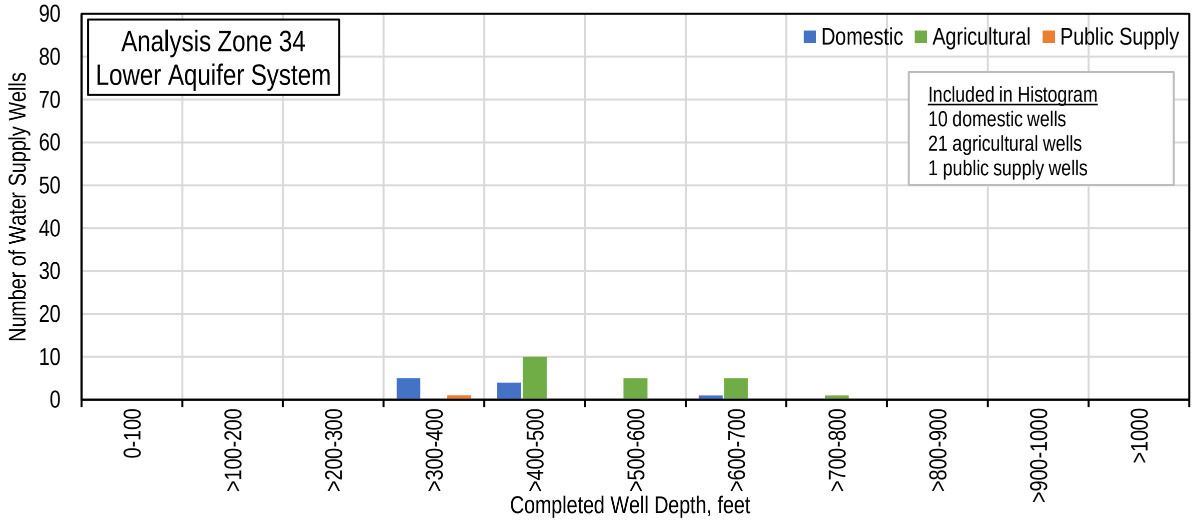

Analysis Zone 29
Lower Aquifer System
Domestic
Agricultural
Public Supply
Landscape
Included in Histogram
13 domestic wells
53 agricultural wells
1 public supply wells
1 landscape irrigation wells
Number of Water Supply Wells
Completed Well Depth, feet
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000

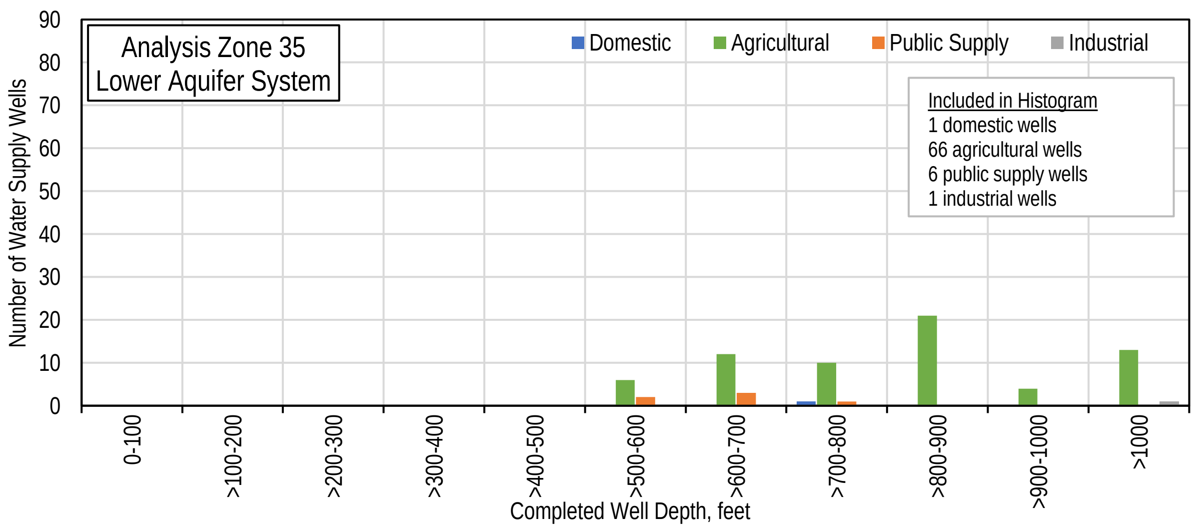

Analysis Zone 30
Lower Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
9 domestic wells
93 agricultural wells
1 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

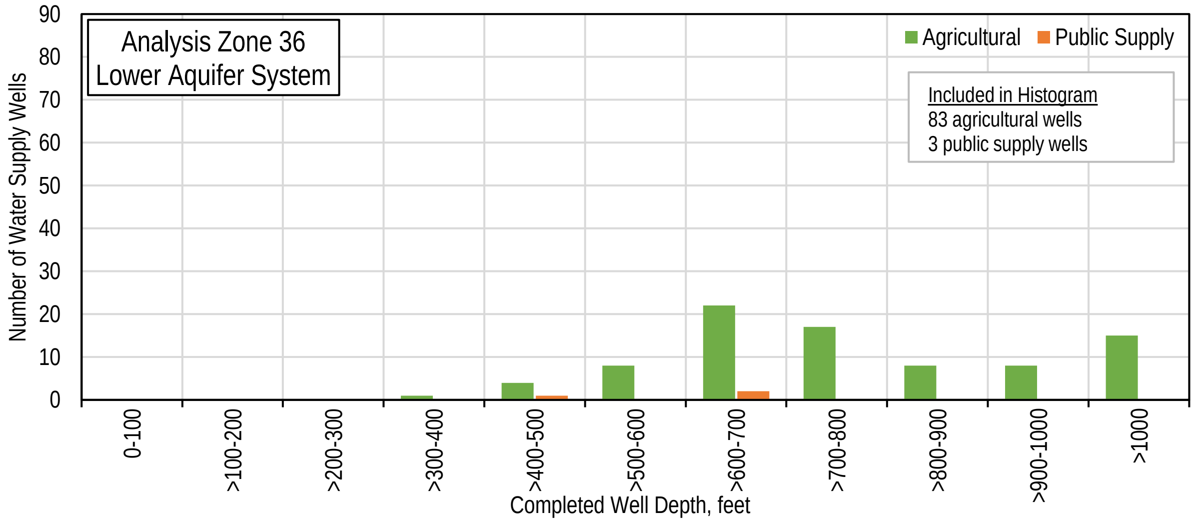

Analysis Zone 31
Lower Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
5 domestic wells
27 agricultural wells
2 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

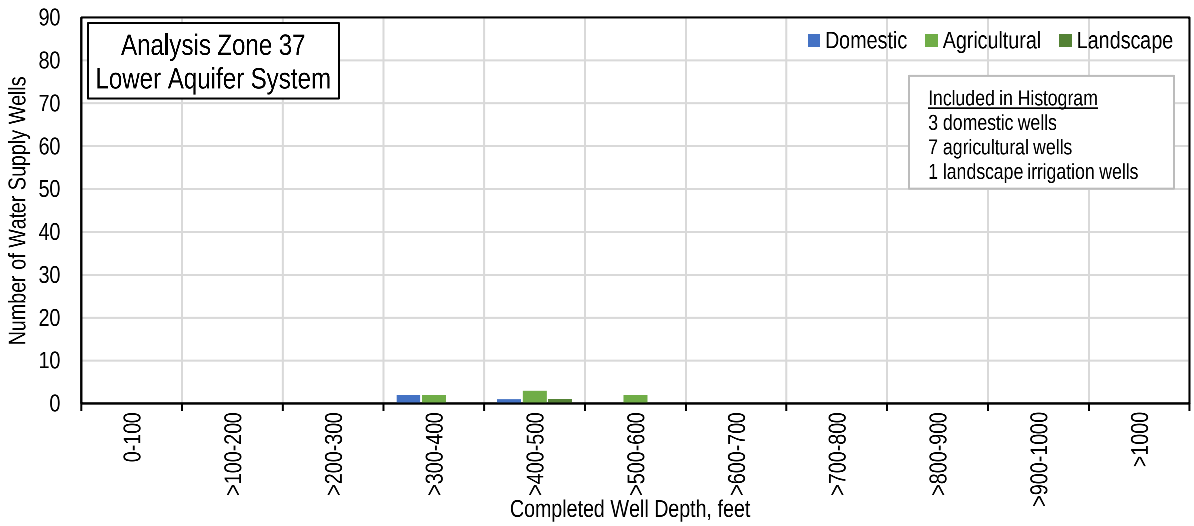

Analysis Zone 32
Lower Aquifer System
Agricultural
Public Supply
Included in Histogram
16 agricultural wells
1 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

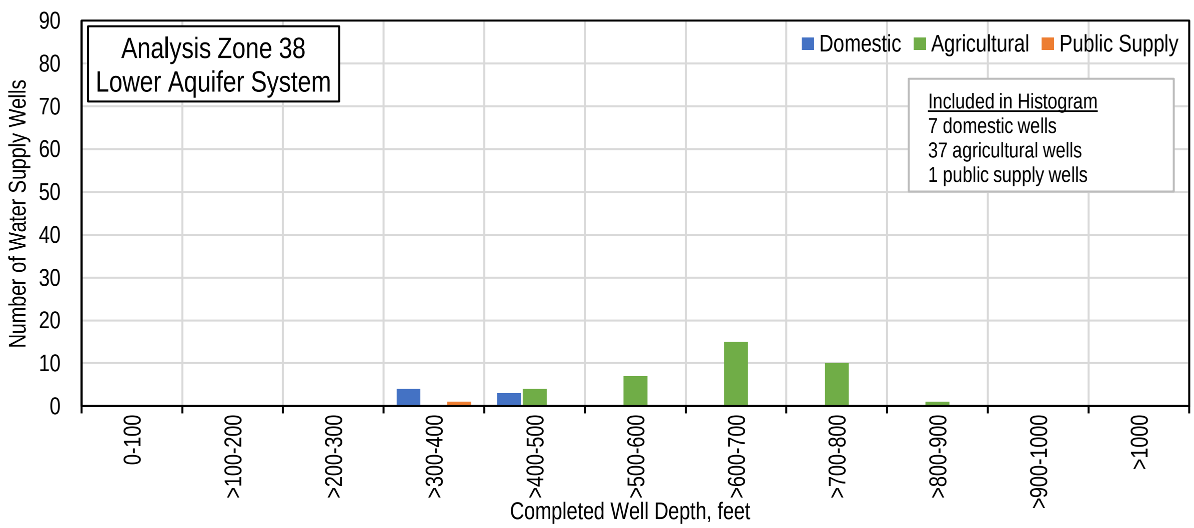

Analysis Zone 33
Lower Aquifer System
Domestic
Agricultural
Industrial
Included in Histogram
10 domestic wells
37 agricultural wells
2 industrial wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

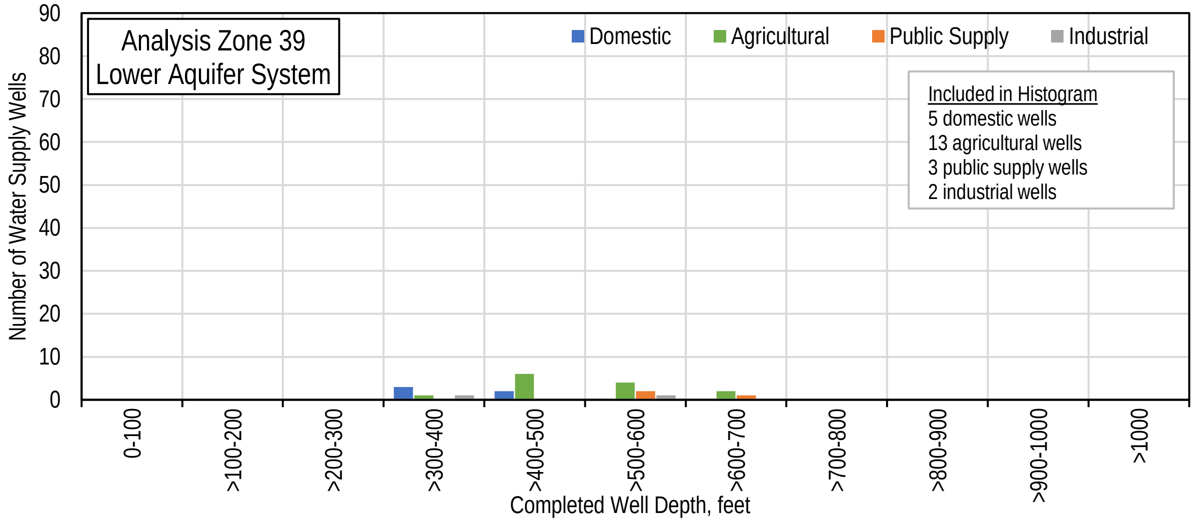

Analysis Zone 34
Lower Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
10 domestic wells
21 agricultural wells
1 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet


Analysis Zone 35
Lower Aquifer System
Domestic
Agricultural
Public Supply
Industrial
Included in Histogram
1 domestic wells
66 agricultural wells
6 public supply wells
1 industrial wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet


Analysis Zone 36
Lower Aquifer System
Agricultural
Public Supply
Included in Histogram
83 agricultural wells
3 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet


Analysis Zone 37
Lower Aquifer System
Domestic
Agricultural
Landscape
Included in Histogram
3 domestic wells
7 agricultural wells
1 landscape irrigation wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet


Analysis Zone 38
Lower Aquifer System
Domestic
Agricultural
Public Supply
Included in Histogram
7 domestic wells
37 agricultural wells
1 public supply wells
Number of Water Supply Wells
0
10
20
30
40
50
60
70
80
90
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet


Analysis Zone 39
Lower Aquifer System
Domestic
Agricultural
Public Supply
Industrial
Included in Histogram
5 domestic wells
13 agricultural wells
3 public supply wells
2 industrial wells
Number of Water Supply Wells
90
80
70
60
50
40
30
20
10
0
0-100
>100-200
>200-300
>300-400
>400-500
>500-600
>600-700
>700-800
>800-900
>900-1000
>1000
Completed Well Depth, feet

MONTGOMERY
& ASSOCIATES

Appendix C

90% Protective Elevations (Methodology 1), Groundwater Level Trend Elevations (Methodology 2), and Interpolated Minimum Threshold (Methodology 3) for Representative Monitoring Site Minimum Thresholds

90% Protective, Groundwater Level Trend, and Interpolated Minimum Threshold Elevations for Kaweah Subbasin Representative Monitoring Sites

Unique Well ID	Local Well ID	GSA	Aquifer System	Analysis Zone	Methodology 1 90% Protective Elevation (feet)	Methodology 2 Groundwater Level Trend Projection Elevation (feet)	Methodology 3 Interpolated Minimum Threshold (feet)
16S25E36M002M	16S25E36M002M	East Kaweah	Single	2	260	292	-
16S26E30Q001M	16S26E30Q001M	East Kaweah	Single	2	285	292	-
17S25E25A001M	17S25E25A001M	East Kaweah	Single	1	124	185	-
17S25E35E001M	KSB-2107	East Kaweah	Single	1	110	185	-
17S26E04F002M	KSB-2369	East Kaweah	Single	2	276	292	-
17S26E07C001M	17S26E07C001M	East Kaweah	Single	2	233	292	-
17S26E21E001M	KSB-2354	East Kaweah	Single	2	266	292	-
17S26E29R001M	17S26E29R001M	East Kaweah	Single	2	269	292	-
18S26E02D002M	18S26E02D002M	East Kaweah	Single	2	295	292	-
18S26E06D001M	18S26E06D001M	East Kaweah	Single	1	130	185	-
18S26E24J003M	18S26E24J003M	East Kaweah	Single	4	306	365	-
18S27E17H002M	18S27E17H002M	East Kaweah	Single	4	327	365	-
18S27E29E001M	18S27E29E001M	East Kaweah	Single	4	330	365	-
18S27E30H001M	18S27E30H001M	East Kaweah	Single	4	327	365	-
19S26E03A001M	19S26E03A001M	East Kaweah	Single	5	207	244	-
19S26E11R001M	19S26E11R001M	East Kaweah	Single	5	198	244	-
19S26E13R001M	19S26E13R001M	East Kaweah	Single	9	123	145	-
19S26E23E001M	Lindsay Well 15	East Kaweah	Single	9	103	145	-
19S26E25R001M	19S26E25R001M	East Kaweah	Single	9	98	145	-
19S26E34R006M	Lindsay Well 14	East Kaweah	Single	10	43	75	-
19S26E35C001M	19S26E35C001M	East Kaweah	Single	9	88	145	-
19S27E29D001M	19S27E29D001M	East Kaweah	Single	7	197	312	-
20S26E08H001M	KSB-2333	East Kaweah	Single	10	30	75	-
20S26E11R001M	20S26E11R001M	East Kaweah	Single	9	100	145	-
20S26E12H001M	Lindsay Well 11	East Kaweah	Single	9	112	145	-
20S26E16R001M	20S26E16R001M	East Kaweah	Single	10	39	75	-
20S26E20J001M	20S26E20J001M	East Kaweah	Single	10	32	75	-
20S26E23R001M	20S26E23R001M	East Kaweah	Single	9	98	145	-
20S26E32A001M	KSB-2344	East Kaweah	Single	10	35	75	-
20S26E35H001M	20S26E35H001M	East Kaweah	Single	9	104	145	-
20S27E08A001M	20S27E08A001M	East Kaweah	Single	7	211	312	-
20S27E15R001M	20S27E15R001M	East Kaweah	Single	6	354	429	-
20S27E18R001M	20S27E18R001M	East Kaweah	Single	8	194	235	-
20S27E25N001M	20S27E25N001M	East Kaweah	Single	6	363	429	-
21S26E11H001M	21S26E11H001M	East Kaweah	Single	9	110	145	-
21S27E03B001M	21S27E03B001M	East Kaweah	Single	8	237	235	-
21S27E06F001M	21S27E06F001M	East Kaweah	Single	9	119	145	-
21S27E08F001M	21S27E08F001M	East Kaweah	Single	8	199	235	-
21S27E12F001M	21S27E12F001M	East Kaweah	Single	7	287	312	-
SCID Office	SCID Office	East Kaweah	Single	2	243	292	-

Unique Well ID	Local Well ID	GSA	Aquifer System	Analysis Zone	Methodology 1 90% Protective Elevation (feet)	Methodology 2 Groundwater Level Trend Projection Elevation (feet)	Methodology 3 Interpolated Minimum Threshold (feet)
17S23E34J001M	KSB-1161	Greater Kaweah	Upper	32	-5	67	-
17S24E34B001M	KSB-1580	Greater Kaweah	Single	11	5	78	-
17S24E36H003M	KSB-1775	Greater Kaweah	Single	12	55	73	-
17S26E36R001M	KSB-2690	Greater Kaweah	Single	4	299	288	-
18S22E24D001M	KSB-0818	Greater Kaweah	Upper	37	-38	59	-
18S23E14A001M	KSB-1222	Greater Kaweah	Upper	32	5	73	-
18S23E30D001M	KSB-0905	Greater Kaweah	Lower	36	-311	-207	-
18S23E30D901M	KSB-0903	Greater Kaweah	Upper	36	-26	71	-
18S25E05Q001M	KSB-1936	Greater Kaweah	Single	13	93	81	-
18S25E15C001M	KSB-2058	Greater Kaweah	Single	13	109	110	-
18S25E23J001M	KSB-2147	Greater Kaweah	Single	14	164	169	-
18S26E17L001M	KSB-2297	Greater Kaweah	Single	15	250	313	-
18S26E27B001M	KSB-2466	Greater Kaweah	Single	5	199	349	-
18S27E05J001M	KSB-2822	Greater Kaweah	Single	16	328	415	-
19S22E24B001M	KSB-0856	Greater Kaweah	Upper	36	-36	25	-
19S22E28D001M	KSB-0616	Greater Kaweah	Upper	35	33	19	-
19S22E31B002M	KSB-0531	Greater Kaweah	Upper	35	27	57	-
19S23E12L001M	KSB-1259	Greater Kaweah	Lower	38	-129	56	-
19S23E21C001M	KSB-1055	Greater Kaweah	Upper	29	-9	51	-
19S25E09H001M	KSB-2017	Greater Kaweah	Single	14	142	92	-
19S25E13A002M	KSB-2200	Greater Kaweah	Single	19	151	114	-
19S25E16A002M	KSB-2015	Greater Kaweah	Single	18	75	91	-
19S25E27A001M	KSB-2089	Greater Kaweah	Single	18	72	57	-
19S25E28H001M	KSB-2021	Greater Kaweah	Single	20	23	56	-
19S25E32J001M	KSB-1937	Greater Kaweah	Upper	24	82	49	-
19S25E35B002M	KSB-2139	Greater Kaweah	Single	18	66	47	-
19S26E05C001M	KSB-2291	Greater Kaweah	Single	14	171	229	-
19S26E16J002M	KSB-2411	Greater Kaweah	Single	18	106	124	-
19S26E20A001M	KSB-2322	Greater Kaweah	Single	18	92	106	-
20S22E07A003M	KSB-0550	Greater Kaweah	Upper	35	20	-28	-
20S22E24R001M	KSB-0889	Greater Kaweah	Upper	30	-73	-17	-
20S22E36A001M	KSB-0890	Greater Kaweah	Upper	30	-79	-10	-
20S24E24H001M	KSB-1783	Greater Kaweah	Upper	24	51	56	-
20S25E03R001M	KSB-2095	Greater Kaweah	Single	20	8	17	55
20S25E12A001M	KSB-2197	Greater Kaweah	Single	20	17	18	65
20S25E14F004M	KSB-2114	Greater Kaweah	Single	21	-72	2	60
20S25E24R001M	KSB-2203	Greater Kaweah	Single	21	-63	-2	65
21S24E03L001M	KSB-1535	Greater Kaweah	Upper	25	89	-24	**
21S24E08A001M	KSB-1425	Greater Kaweah	Lower	25	-262	10	-

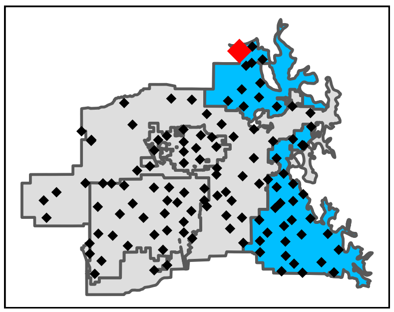
Unique Well ID	Local Well ID	GSA	Aquifer System	Analysis Zone	Methodology 1 90% Protective Elevation (feet)	Methodology 2 Groundwater Level Trend Projection Elevation (feet)	Methodology 3 Interpolated Minimum Threshold (feet)
025-01	KSB-1696	Mid-Kaweah	Upper	39	112	13	138
036-01	KSB-1884	Mid-Kaweah	Single	22	79	27	-
047-01	KSB-1699	Mid-Kaweah	Upper	39	107	157	-
053-01	KSB-1977	Mid-Kaweah	Single	23	52	56	-
075-01	KSB-1447	Mid-Kaweah	Upper	39	81	60	-
077-01	KSB-1427	Mid-Kaweah	Upper	39	81	33	-
18S24E13N001M	KSB-1689	Mid-Kaweah	Single	22	69	75	-
18S24E22E001M	KSB-1526	Mid-Kaweah	Upper	39	103	-139	85
18S24E25D001M	KSB-1690	Mid-Kaweah	Upper	39	114	161	-
18S25E28R001M	KSB-2014	Mid-Kaweah	Single	23	54	69	-
18S25E30Q001M	KSB-1819	Mid-Kaweah	Single	22	75	34	-
19S23E20C001M	KSB-0994	Mid-Kaweah	Lower	29	-12	71	-
19S23E22H001M	KSB-1168	Mid-Kaweah	Upper	29	3	30	-
19S23E31R001M	KSB-0946	Mid-Kaweah	Upper	29	-27	-72	-
19S23E35H001M	KSB-1226	Mid-Kaweah	Upper	29	3	-101	-
19S24E08D002M	KSB-1384	Mid-Kaweah	Upper	38	47	38	-
19S24E20F001M	KSB-1408	Mid-Kaweah	Upper	28	75	Drilled after 2016	-
19S24E22E001M	KSB-1545	Mid-Kaweah	Upper	28	86	Drilled after 2016	-
19S24E25D001M	KSB-1709	Mid-Kaweah	Upper	27	2	-6	88
19S24E34D001M	KSB-1536	Mid-Kaweah	Upper	28	77	Drilled after 2016	-
19S24E35E001M	KSB-1628	Mid-Kaweah	Lower	26	-109	-92	-
19S24E36C002M	KSB-1903	Mid-Kaweah	Lower	27	-98	-43	-
19S25E06A001M	KSB-1862	Mid-Kaweah	Single	22	76	35	-
19S25E20P001M	KSB-1905	Mid-Kaweah	Upper	27	24	90	-
20S23E03L001M	KSB-1129	Mid-Kaweah	Upper	29	-9	-81	-
20S23E18R001M	KSB-0948	Mid-Kaweah	Upper	30	-66	-173	-
20S23E21B001M	KSB-1071	Mid-Kaweah	Upper	30	-66	-126	-
20S23E26C001M	KSB-1206	Mid-Kaweah	Upper	30	-64	-20	-
20S24E01H002M	KSB-1770	Mid-Kaweah	Lower	26	-289	-150	-
20S24E04K001M	KSB-1506	Mid-Kaweah	Lower	26	-123	-39	-
20S24E07C001M	KSB-1320	Mid-Kaweah	Upper	31	58	Drilled after 2016	-
20S24E11J002M	KSB-1695	Mid-Kaweah	Lower	26	-119	-121	-
20S24E16H001M	KSB-1538	Mid-Kaweah	Lower	31	-115	62	-
20S24E17P001M	KSB-1431	Mid-Kaweah	Upper	31	58	88	-
20S24E28L001M	KSB-1477	Mid-Kaweah	Upper	31	58	60	-
21S23E05A002M	KSB-0976	Mid-Kaweah	Upper	30	-84	-141	-
21S23E07J001M	KSB-0922	Mid-Kaweah	Upper	30	-36	-22	-
361856N1193313W001	KSB-1706	Mid-Kaweah	Lower	26	-136	-287	-

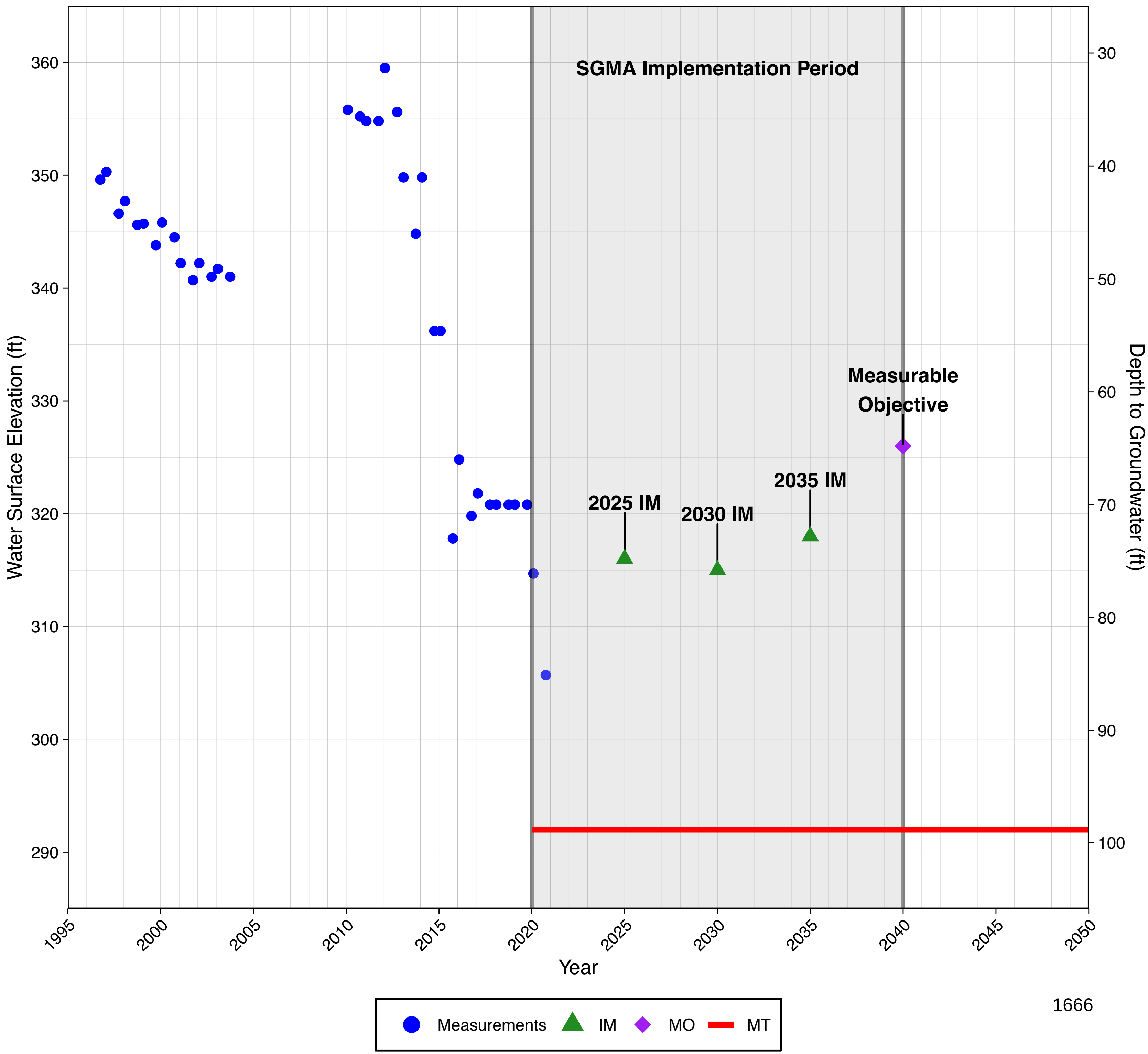
Note. bolded elevation indicates the minimum threshold assigned to the representative monitoring site

Appendix 3-B

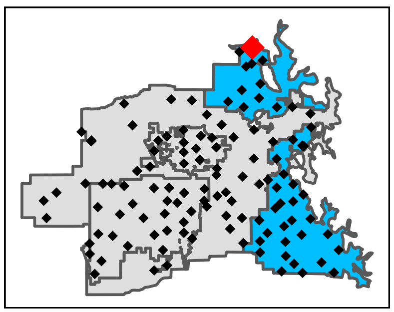
Representative Monitoring Well Hydrographs with Sustainable Management Criteria

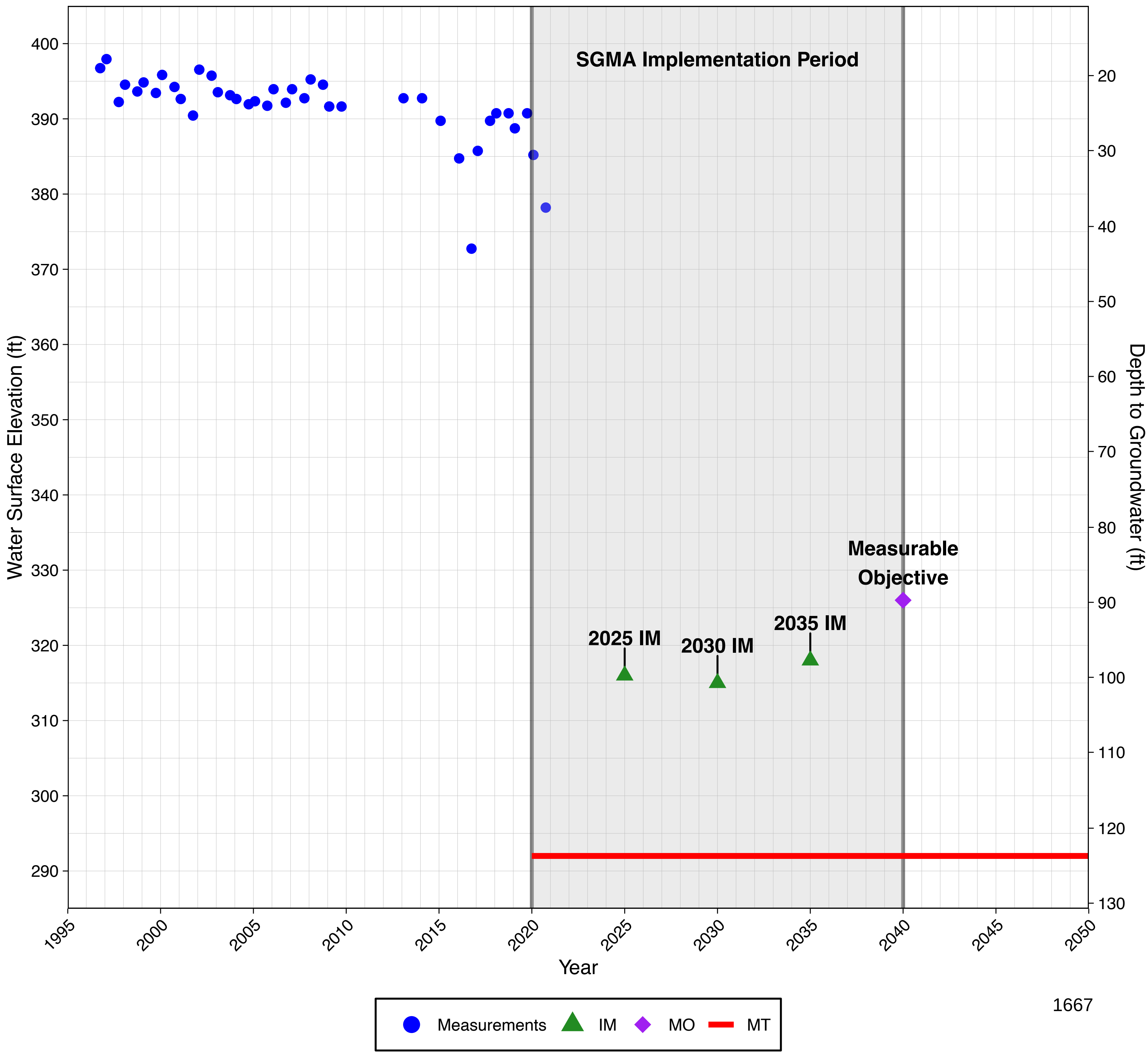
16S25E36M002M | East Kaweah
Single Aquifer System



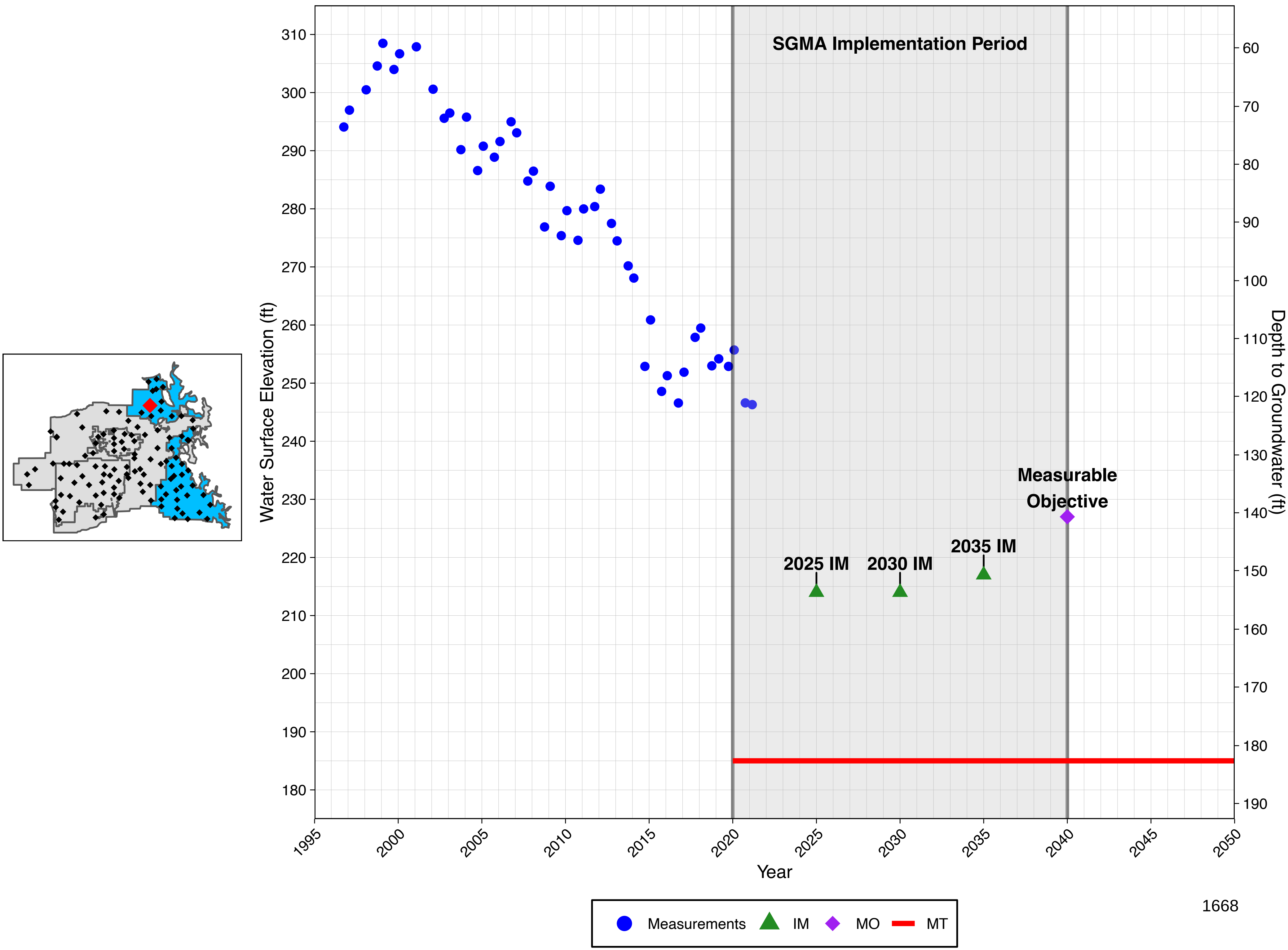


16S26E30Q001M | East Kaweah
Single Aquifer System

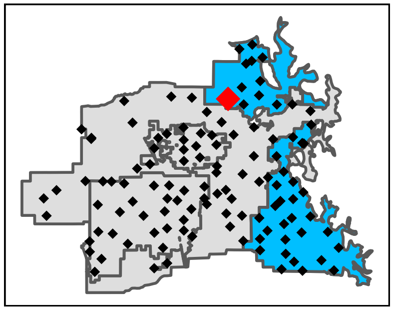


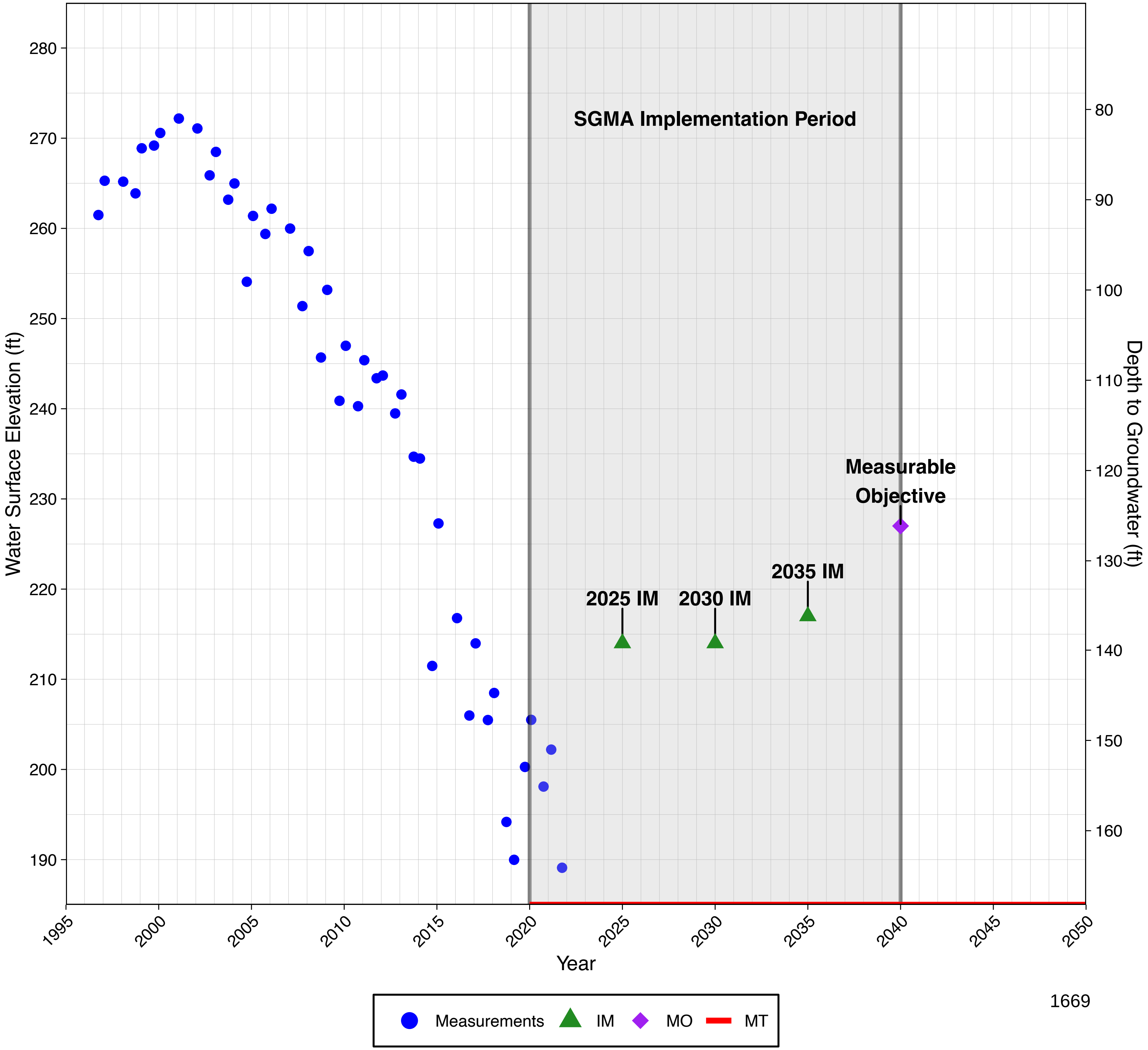


17S25E25A001M | East Kaweah
Single Aquifer System

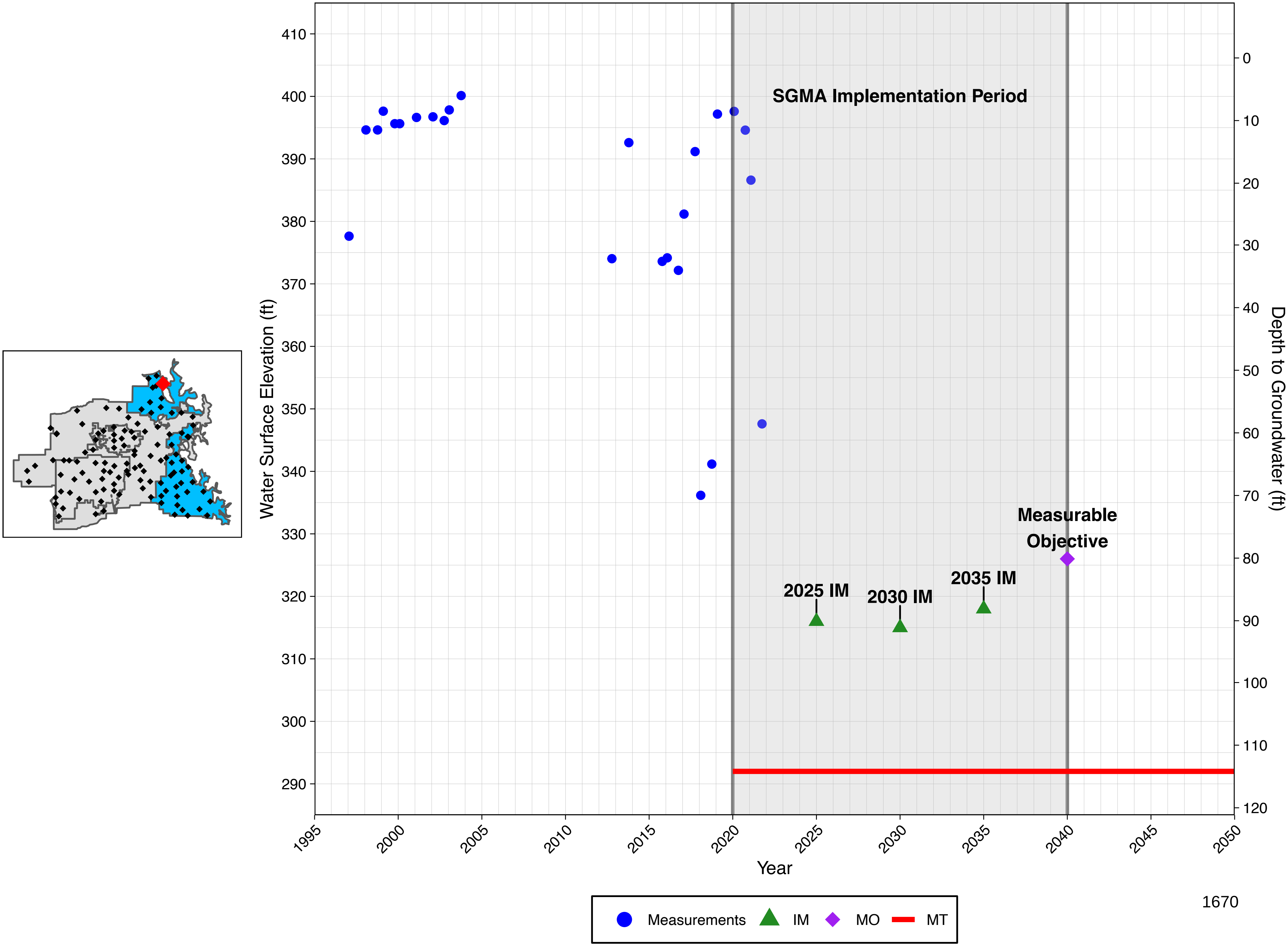


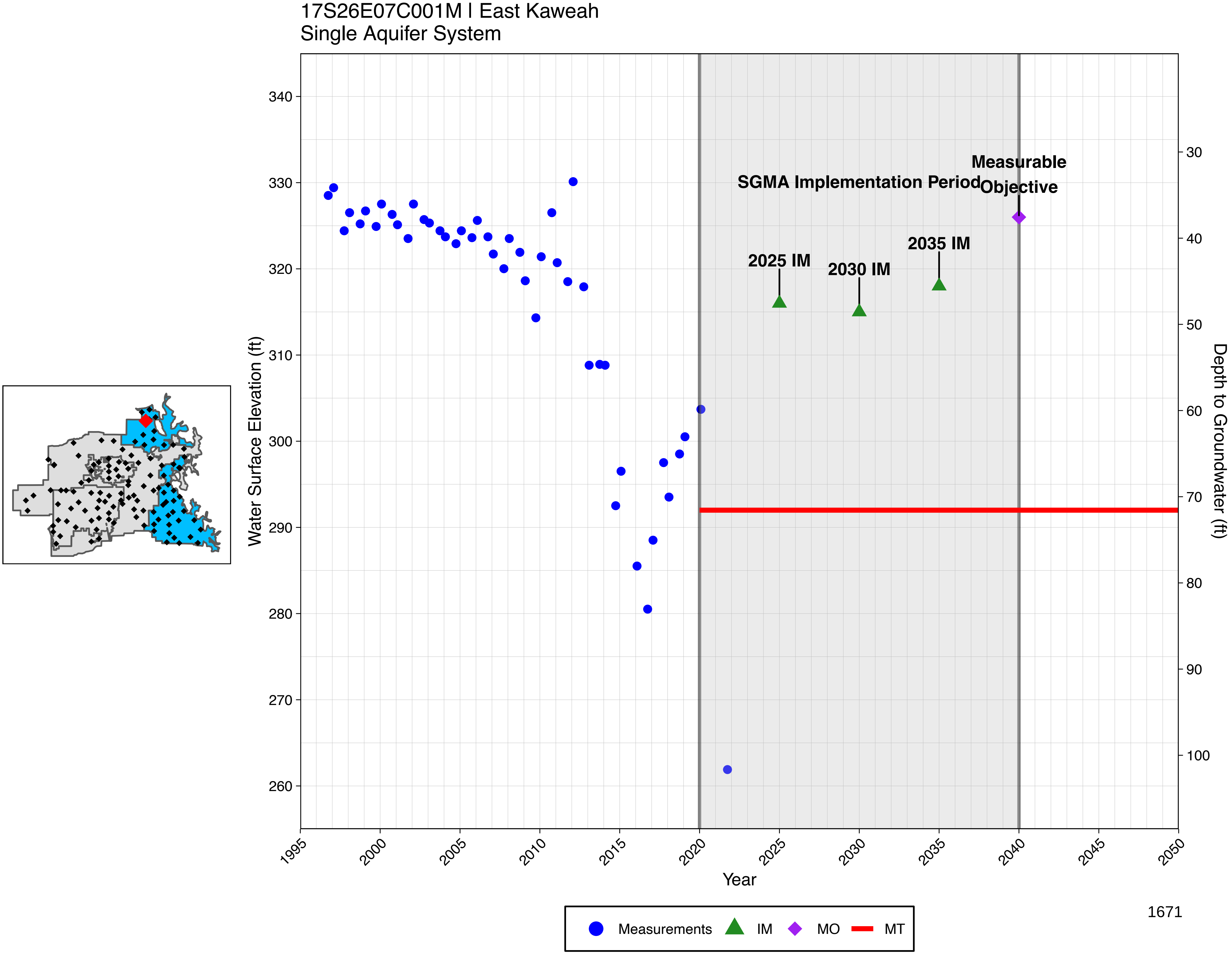
17S25E35E001M | East Kaweah
Single Aquifer System





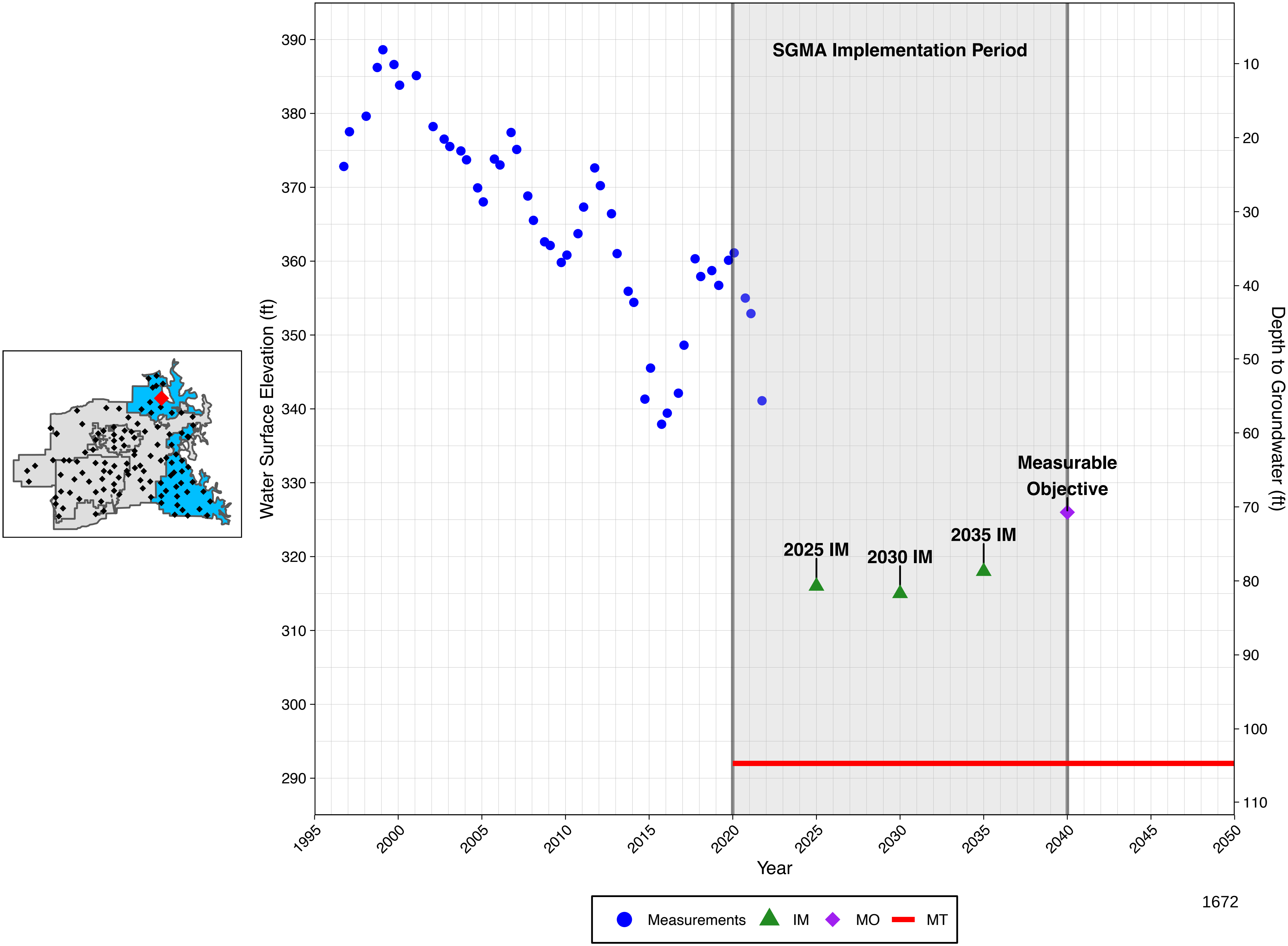
17S26E04F002M | East Kaweah
Single Aquifer System

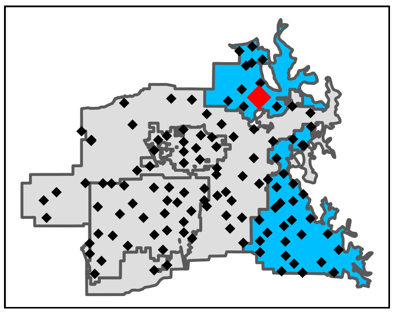


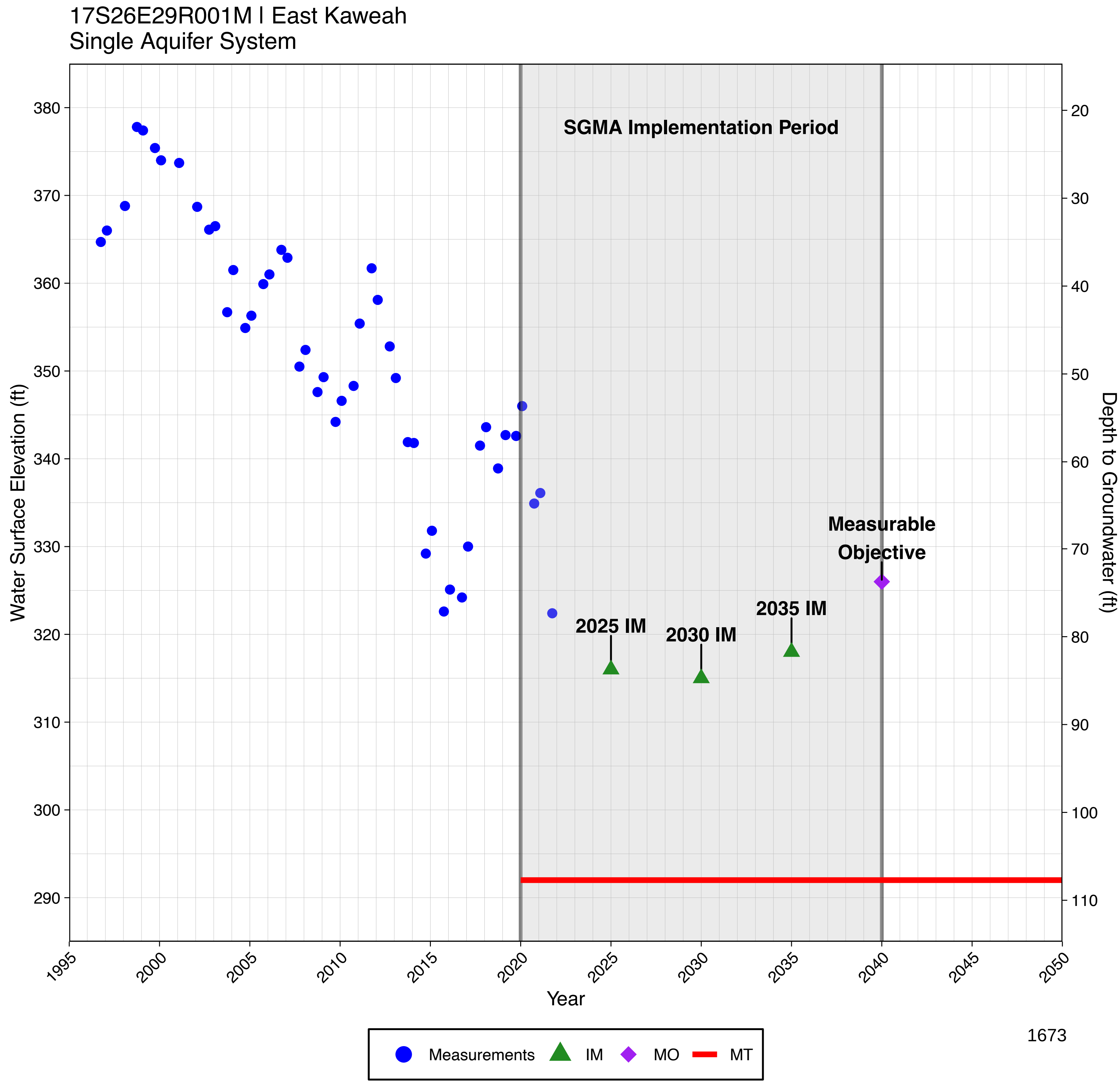


17S26E07C001M | East Kaweah
Single Aquifer System
SGMA Implementation Period
Measurable
Objective
2025 IM
2030 IM
2035 IM
Water Surface Elevation (ft)
Depth to Groundwater (ft)
Year
Measurements
IM
MO
MT

17S26E21E001M | East Kaweah
Single Aquifer System

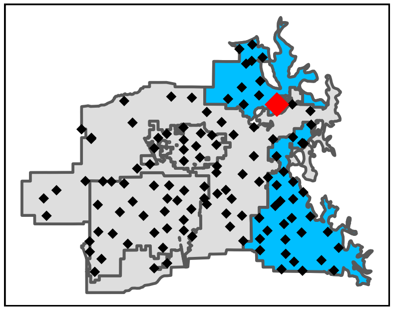


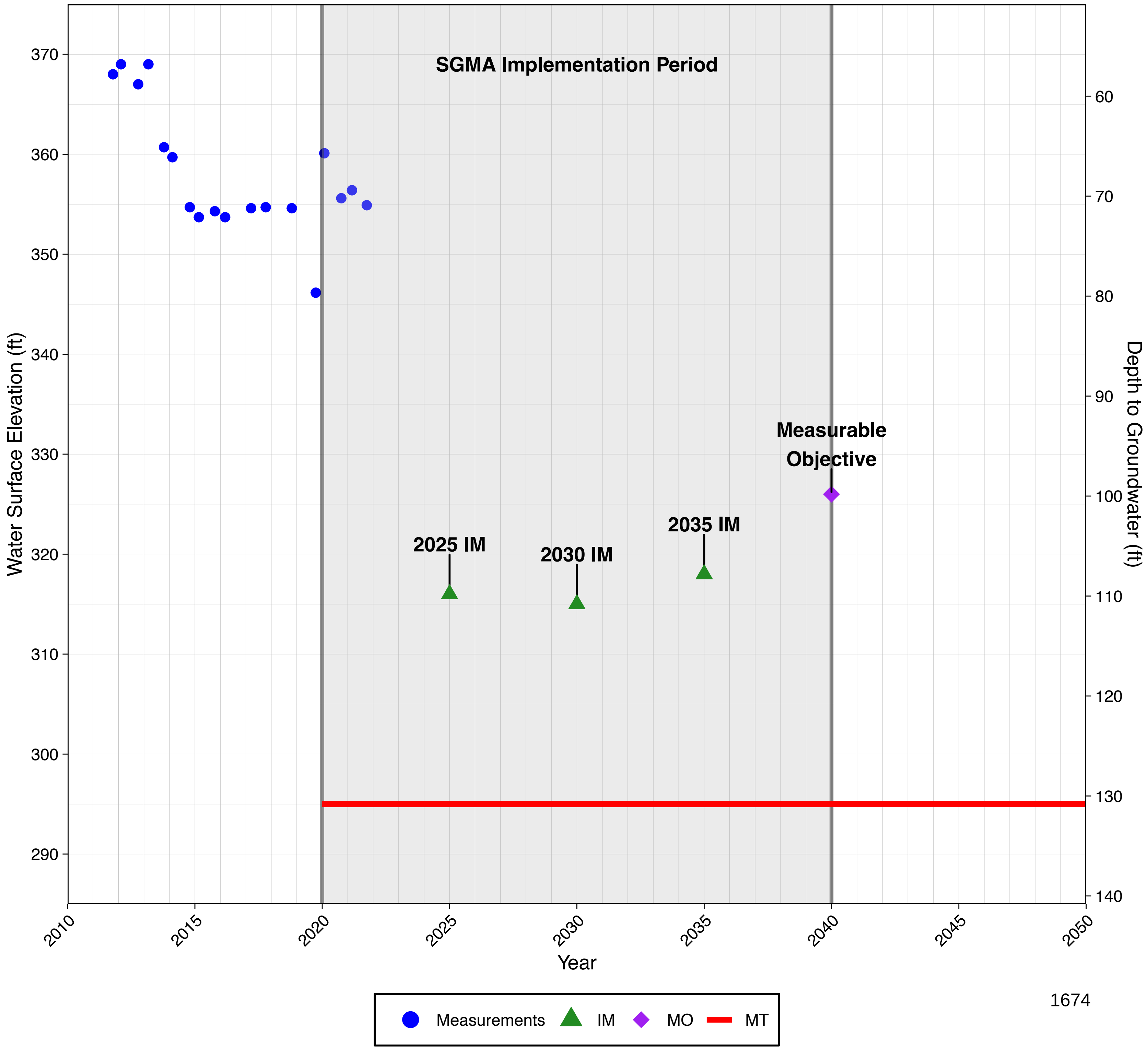




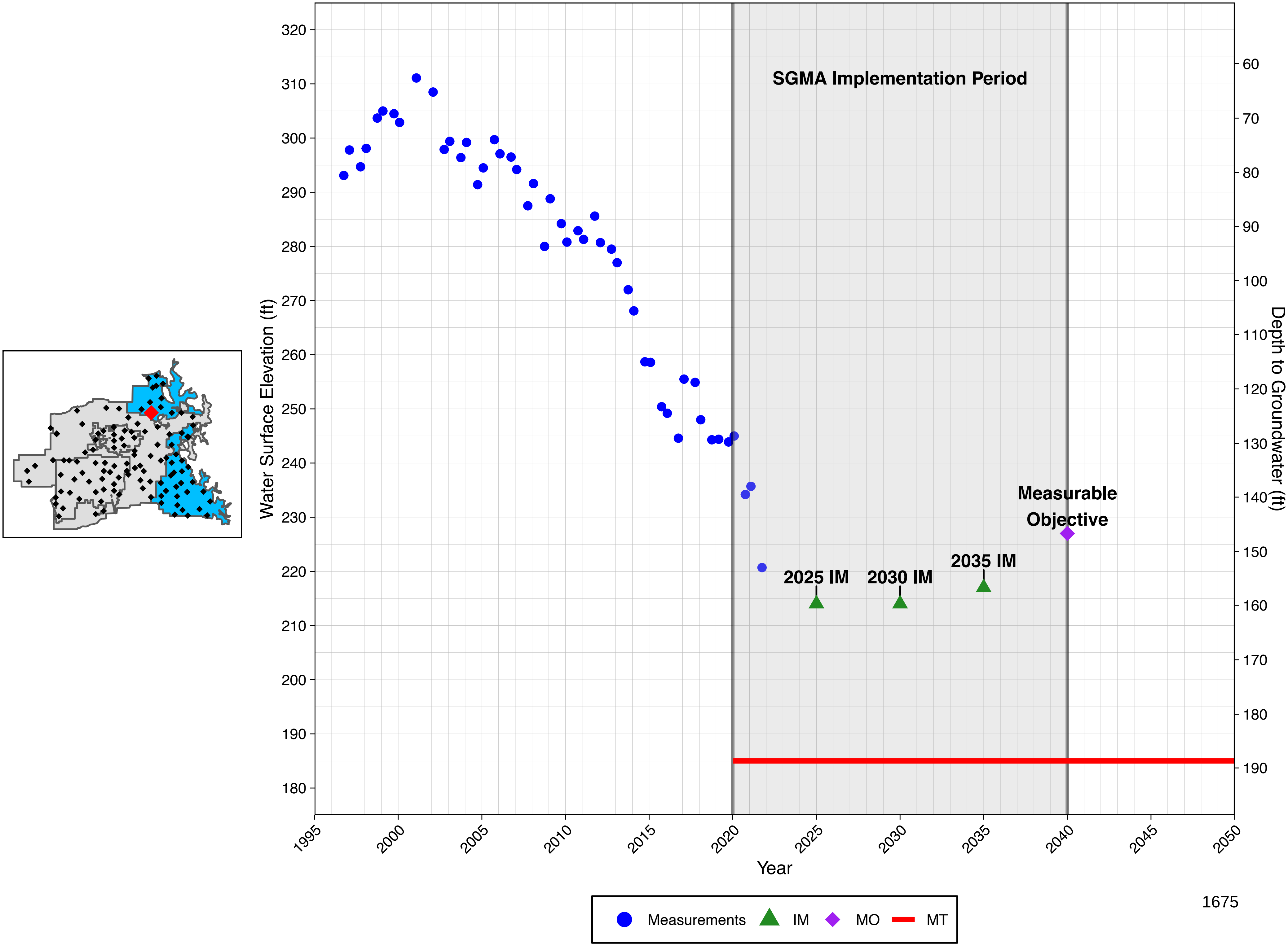
17S26E29R001M | East Kaweah
Single Aquifer System
SGMA Implementation Period
Measurable
Objective
2025 IM
2030 IM
2035 IM
Water Surface Elevation (ft)
Depth to Groundwater (ft)
Year
380
370
360
350
340
330
320
310
300
290
20
30
40
50
60
70
80
90
100
110
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Measurements
IM
MO
MT

18S26E02D002M | East Kaweah
Single Aquifer System

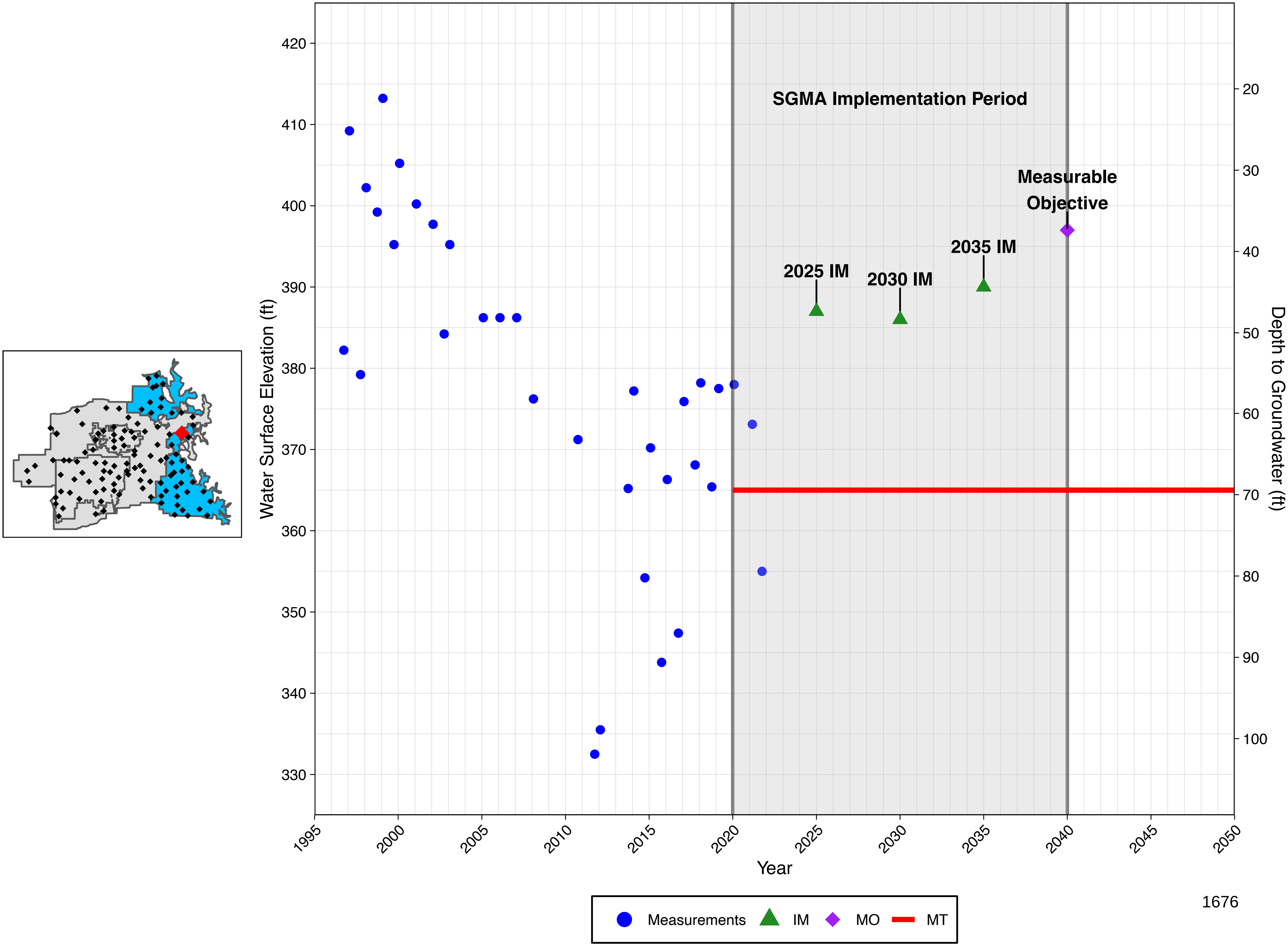




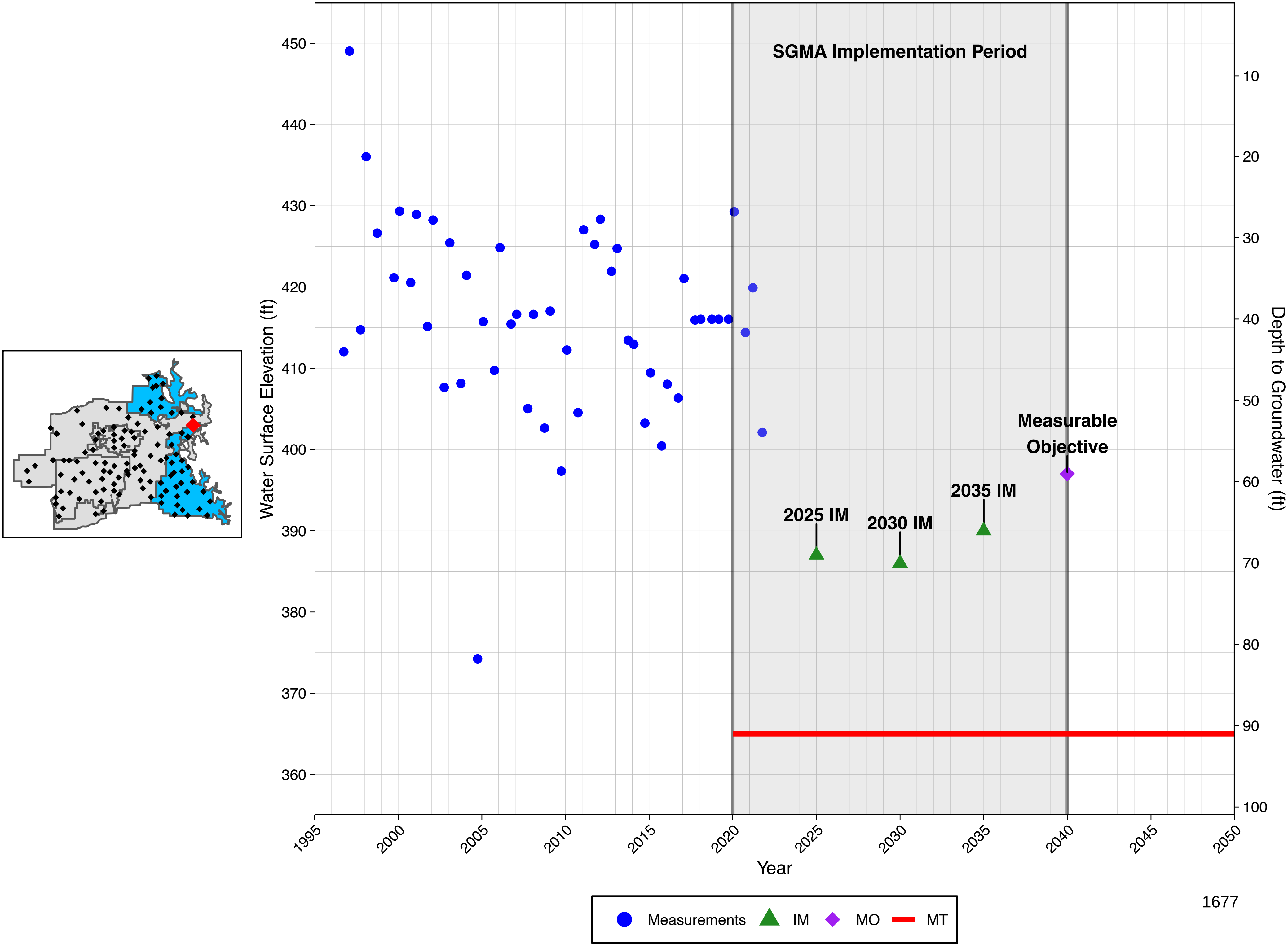
18S26E06D001M | East Kaweah
Single Aquifer System



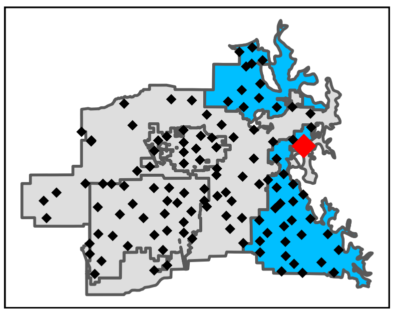
18S26E24J003M | East Kaweah
Single Aquifer System

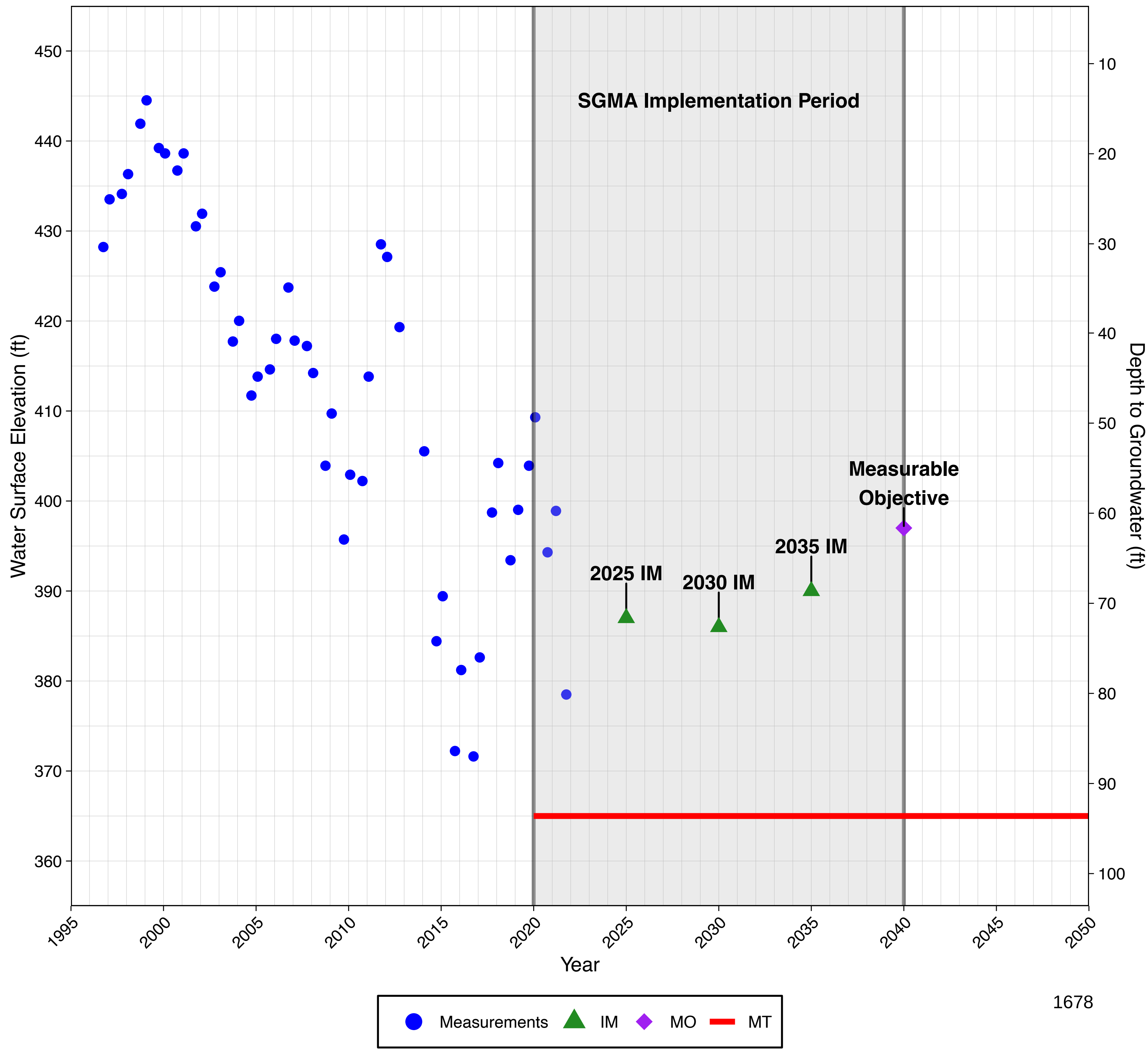


18S27E17H002M | East Kaweah
Single Aquifer System

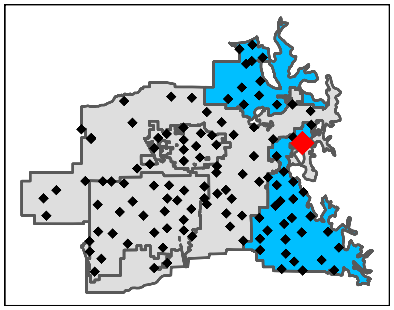


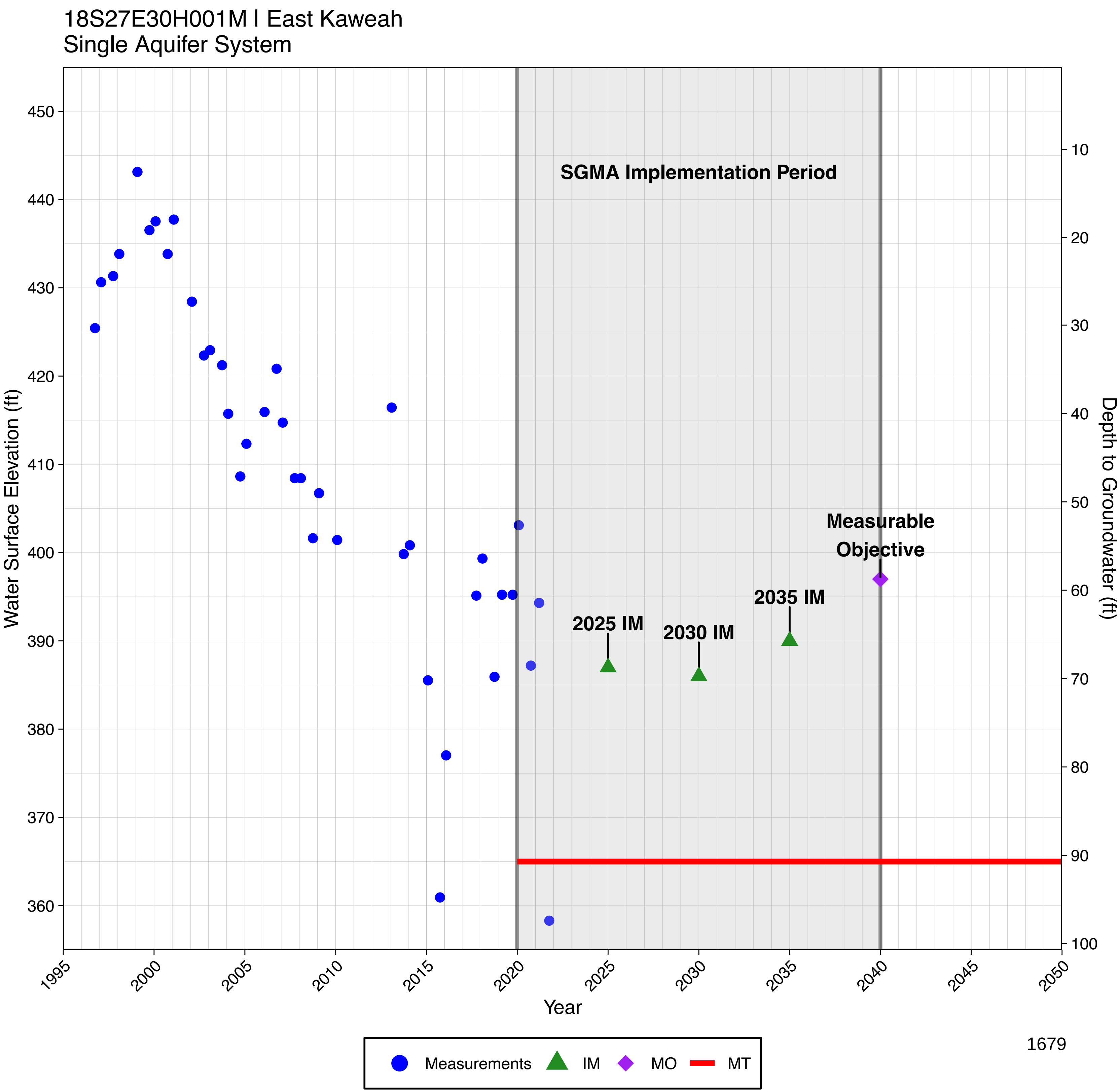
18S27E29E001M | East Kaweah
Single Aquifer System





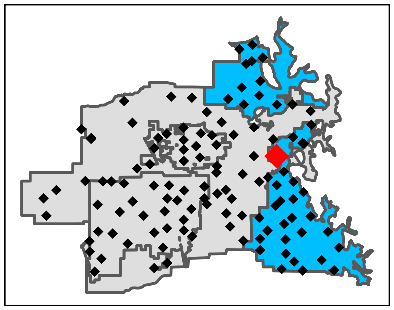
1678

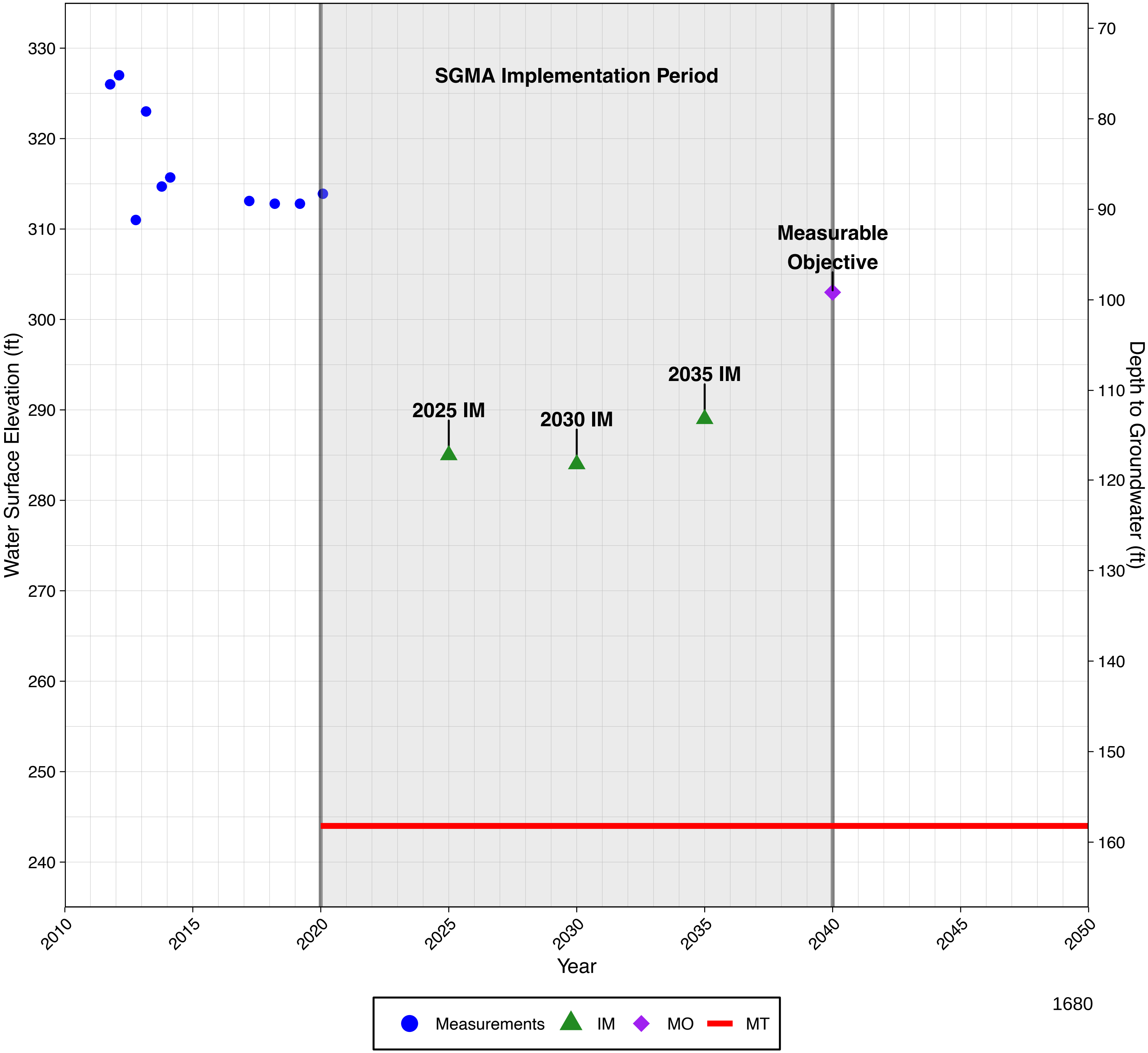




18S27E30H001M | East Kaweah
Single Aquifer System
SGMA Implementation Period
Measurable Objective
2025 IM
2030 IM
2035 IM
Water Surface Elevation (ft)
Depth to Groundwater (ft)
Year
Measurements
IM
MO
MT

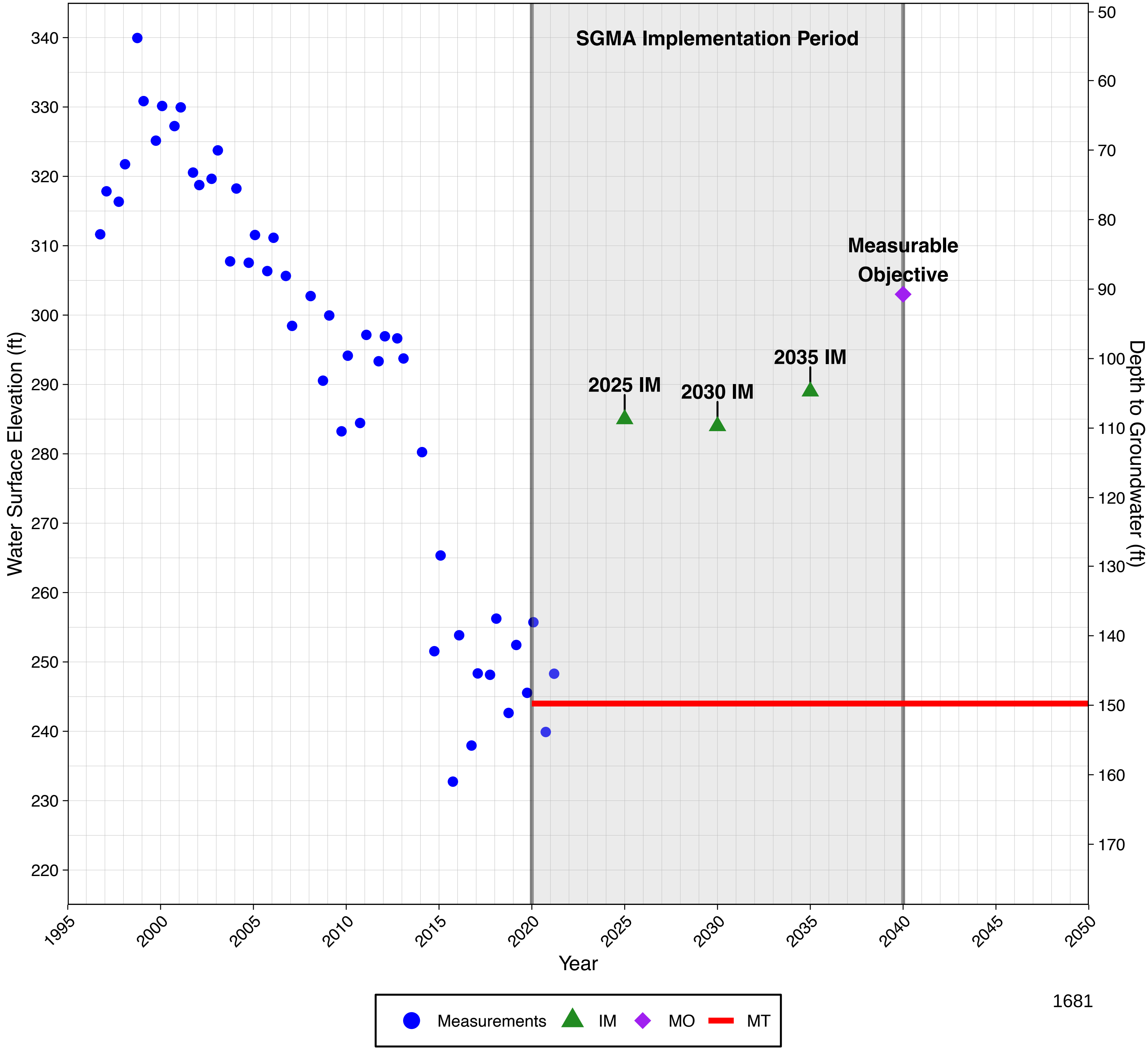
19S26E03A001M | East Kaweah
Single Aquifer System

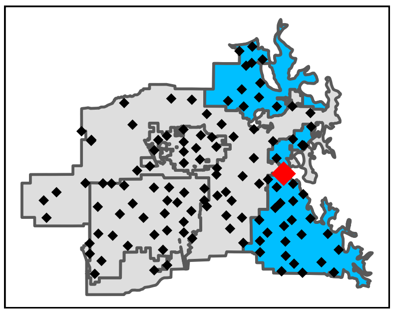




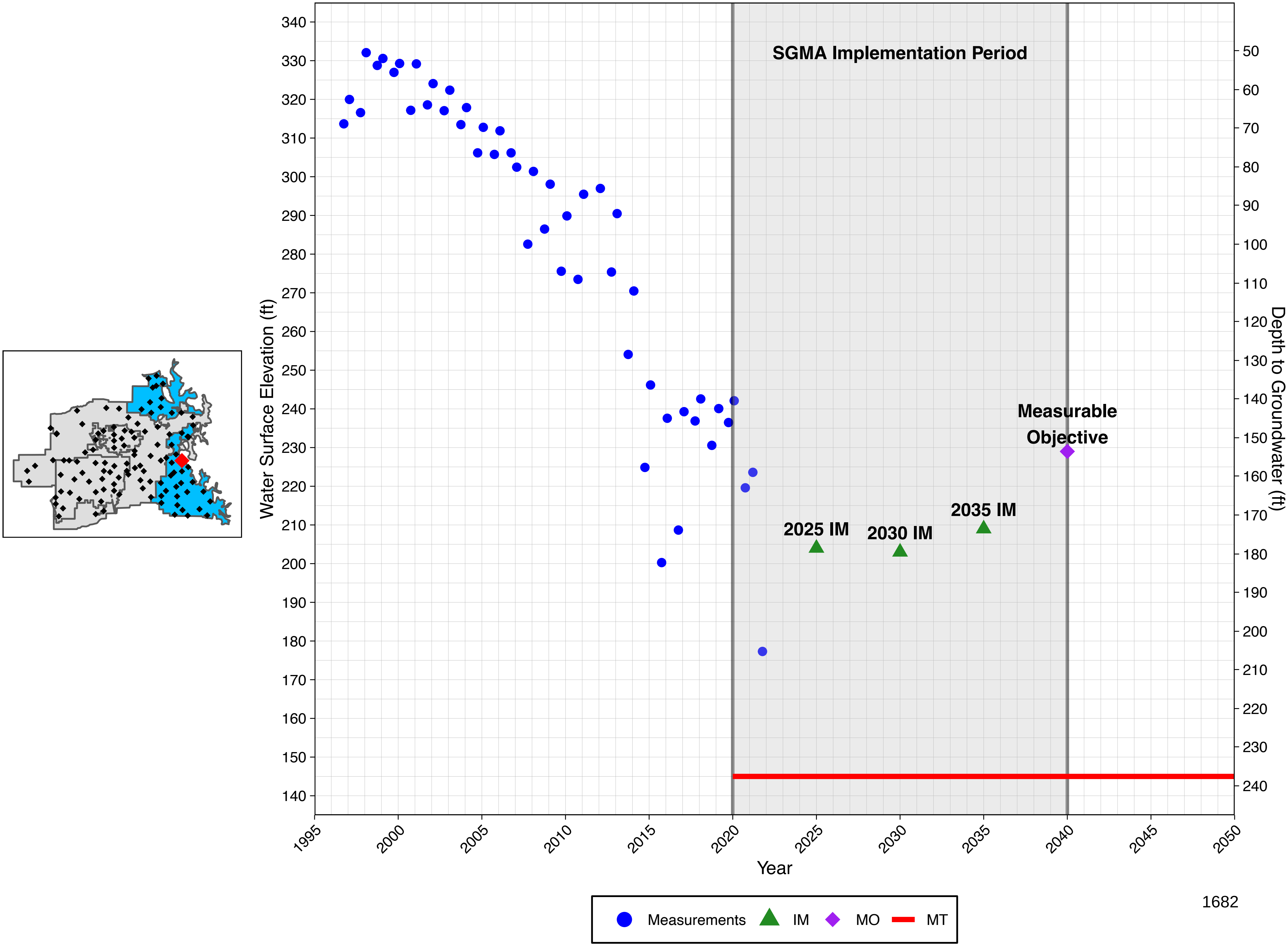
1680

19S26E11R001M | East Kaweah
Single Aquifer System

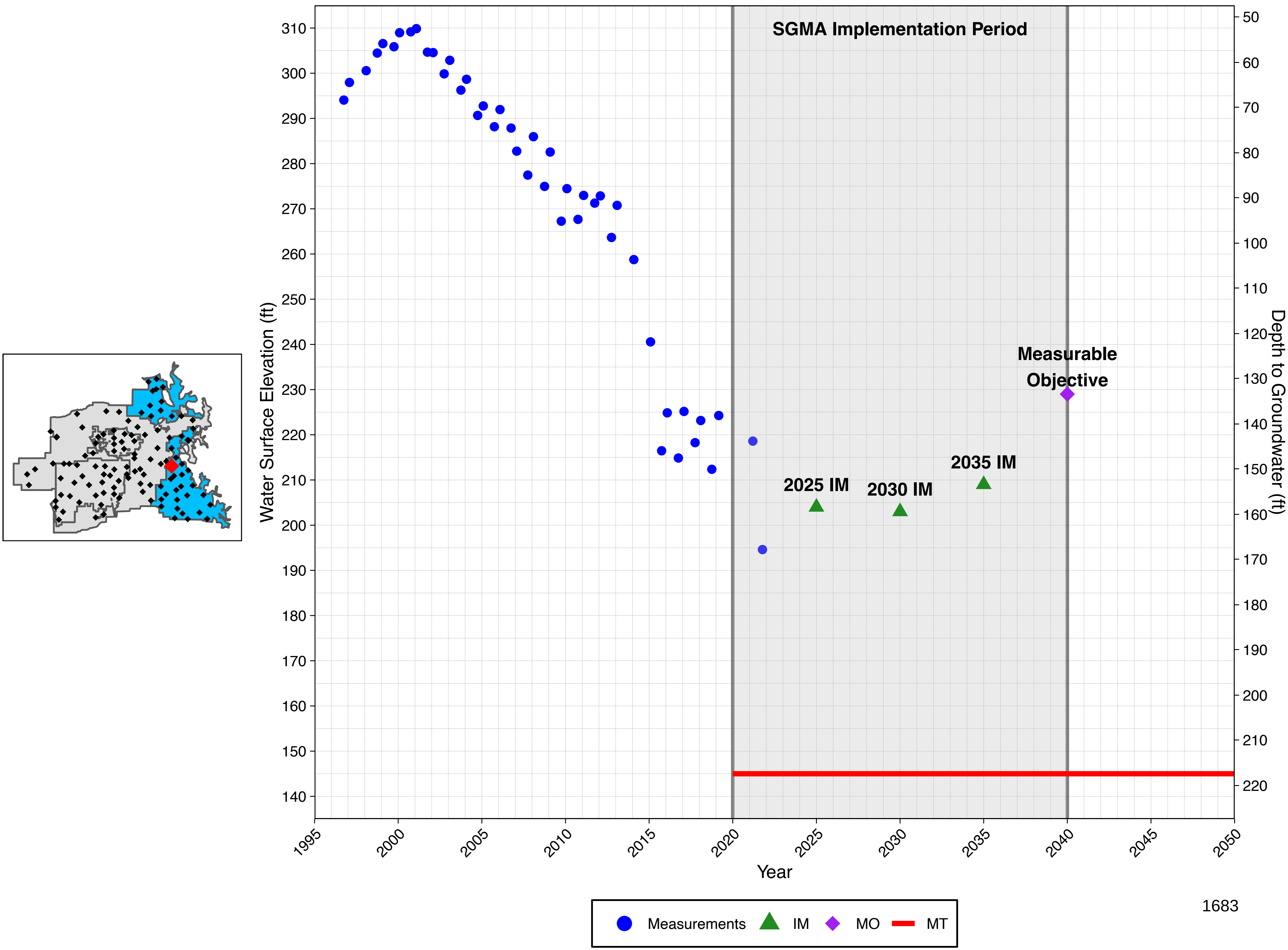




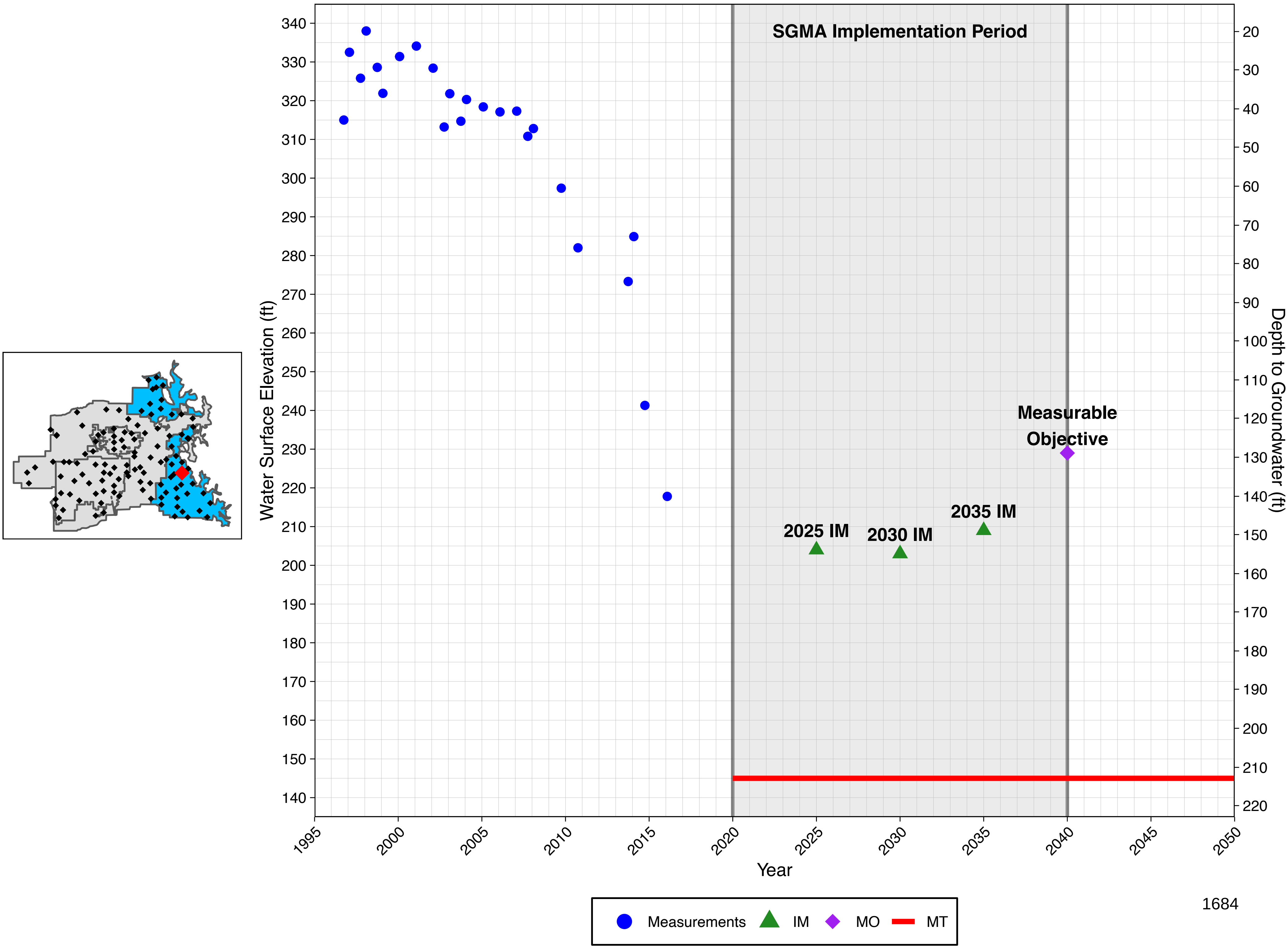
19S26E13R001M | East Kaweah
Single Aquifer System



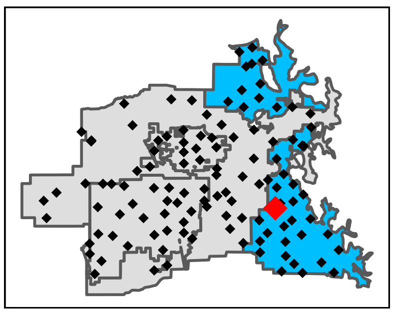
19S26E23E001M | East Kaweah
Single Aquifer System

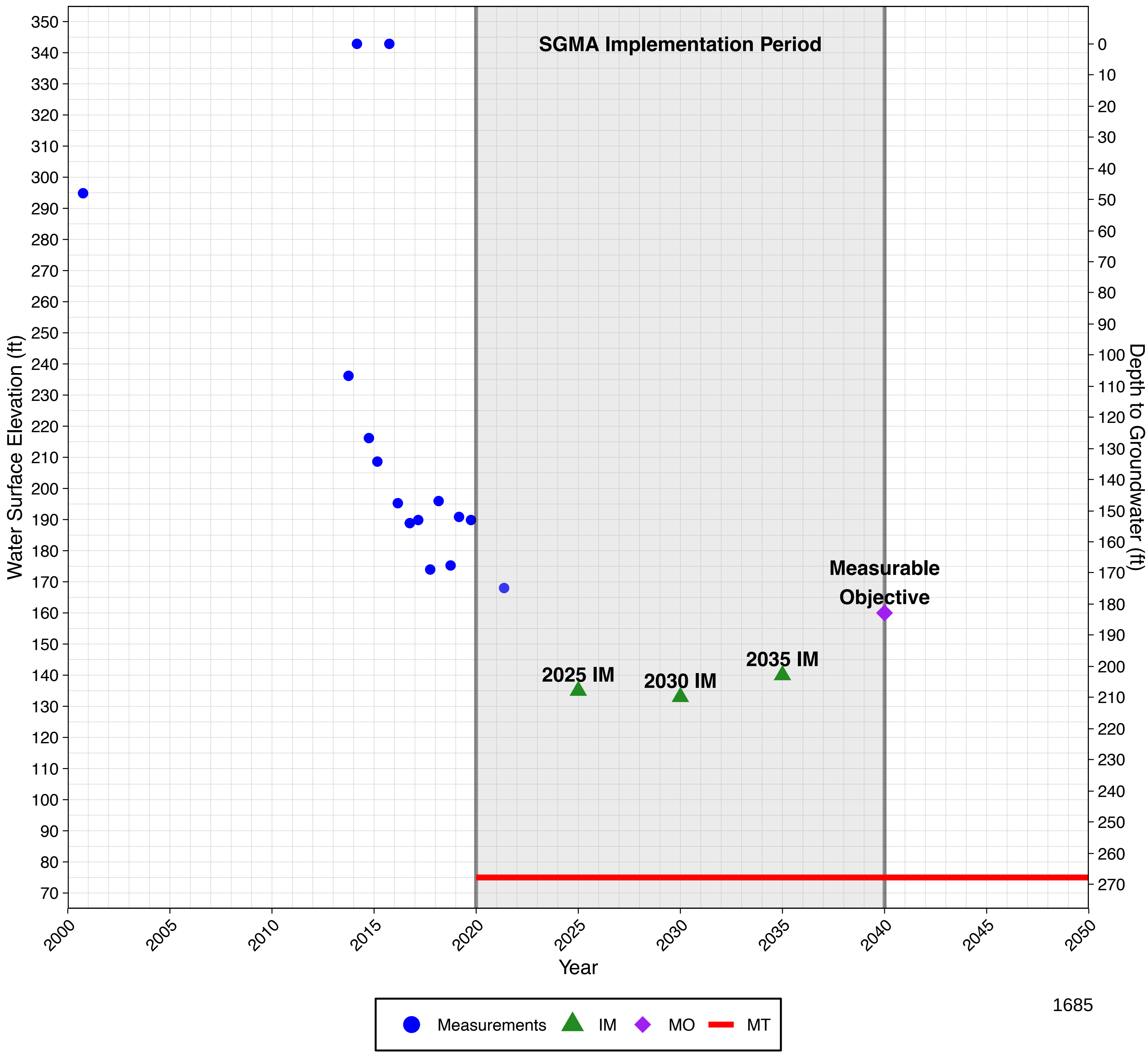


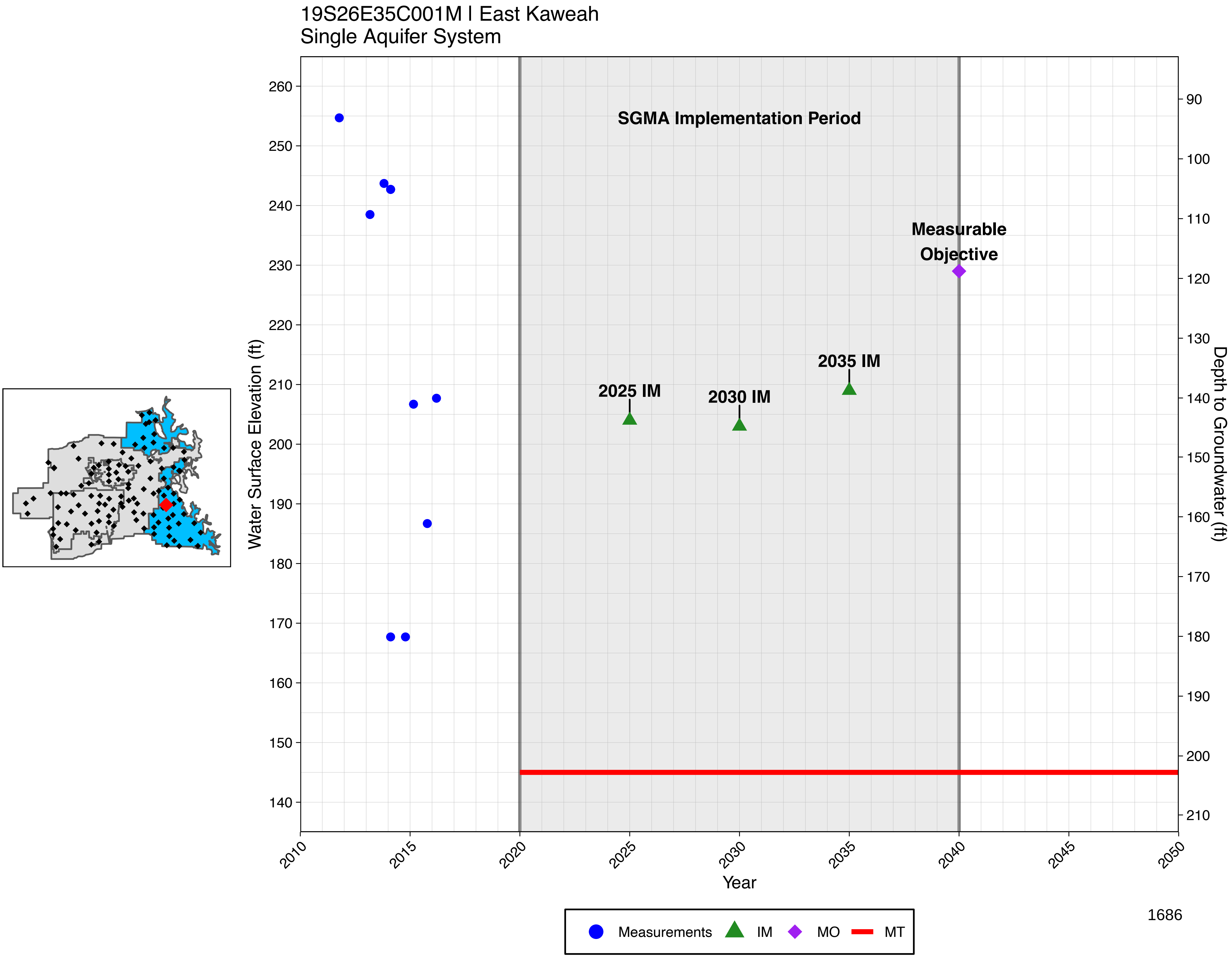
19S26E25R001M | East Kaweah
Single Aquifer System

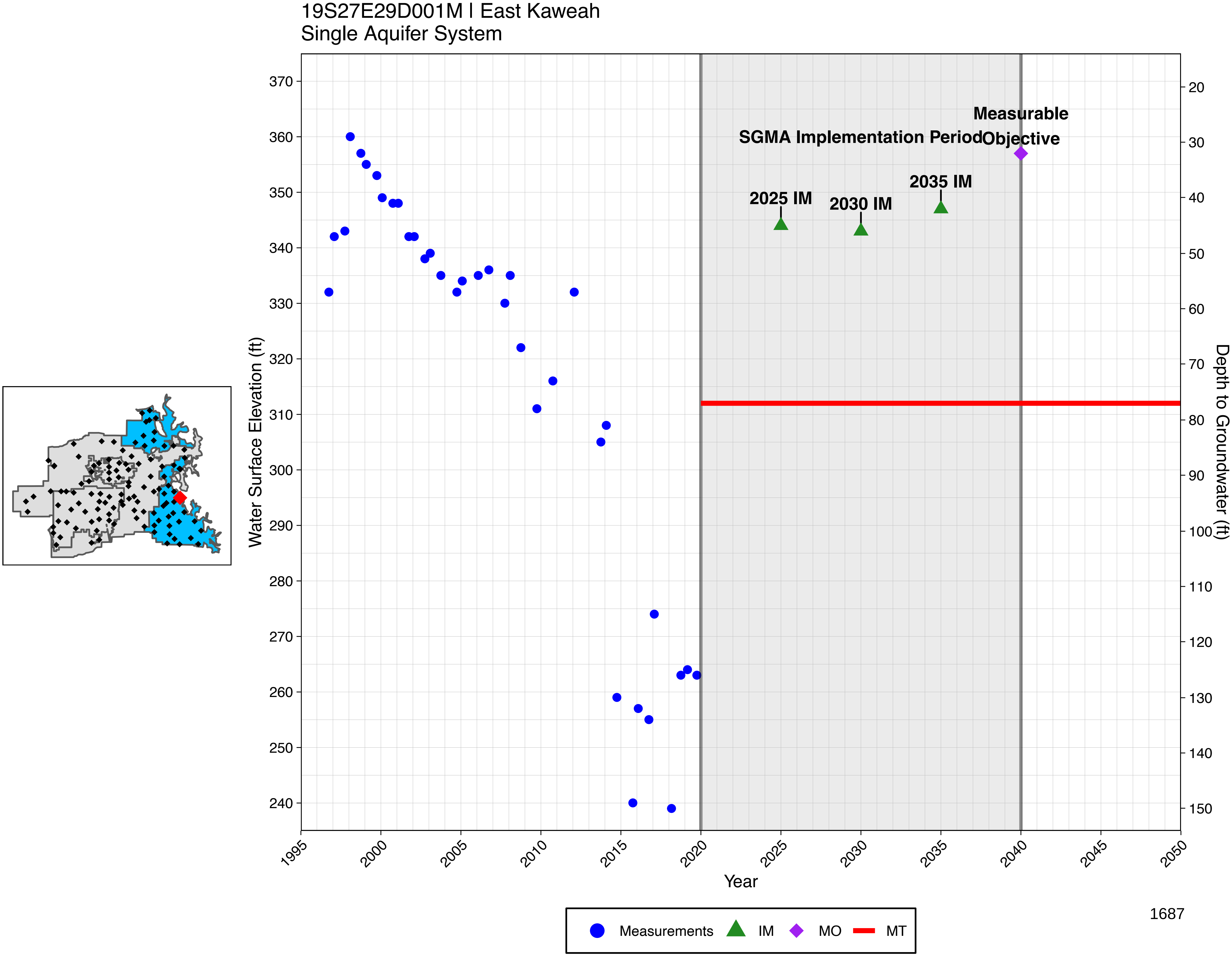


19S26E34R006M I East Kaweah
Single Aquifer System



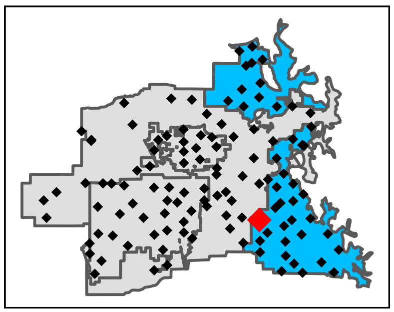


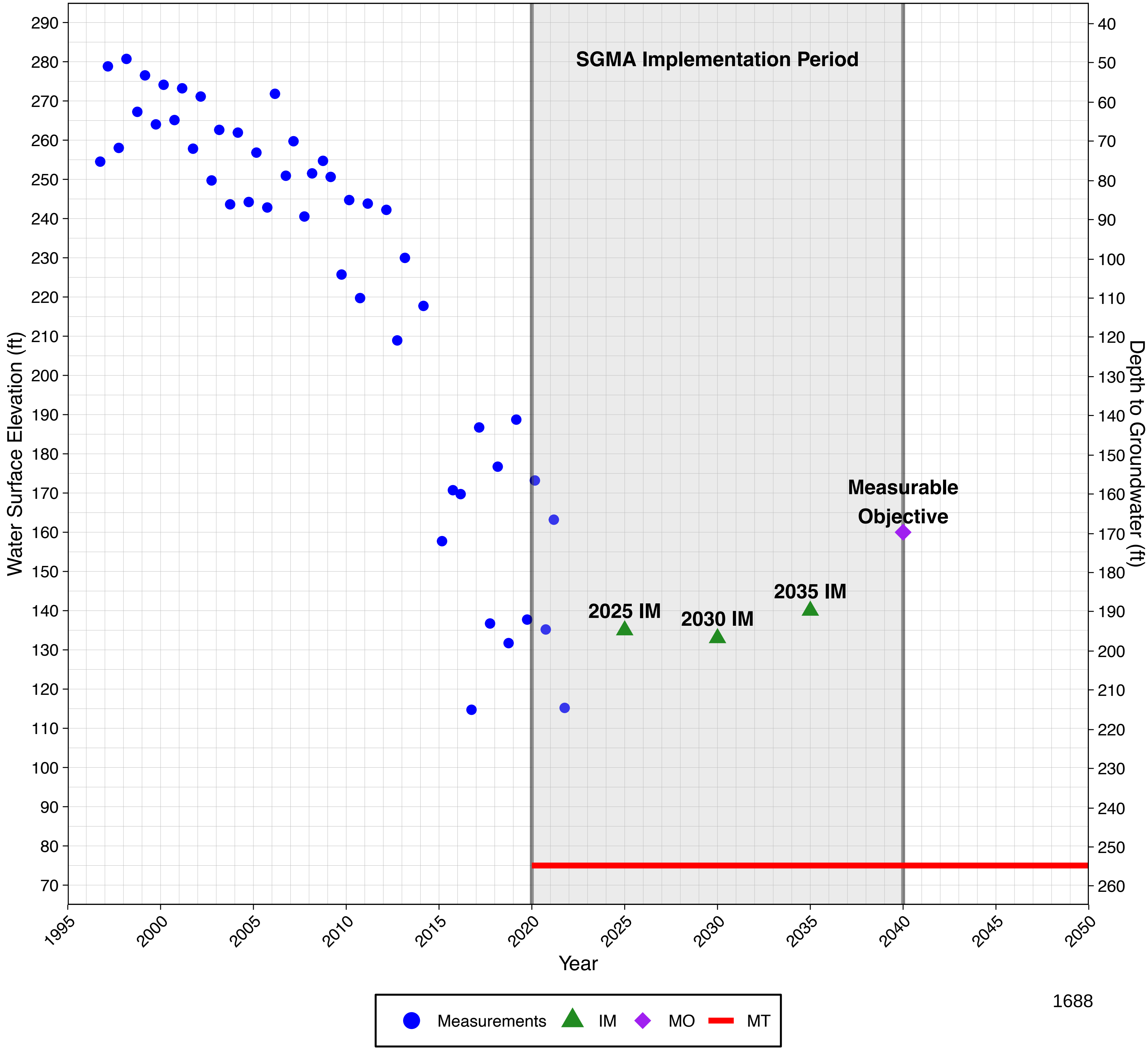

19S26E35C001M | East Kaweah
Single Aquifer System
SGMA Implementation Period
Measurable
Objective
2025 IM
2030 IM
2035 IM
Water Surface Elevation (ft)
Depth to Groundwater (ft)
Year
Measurements
IM
MO
MT



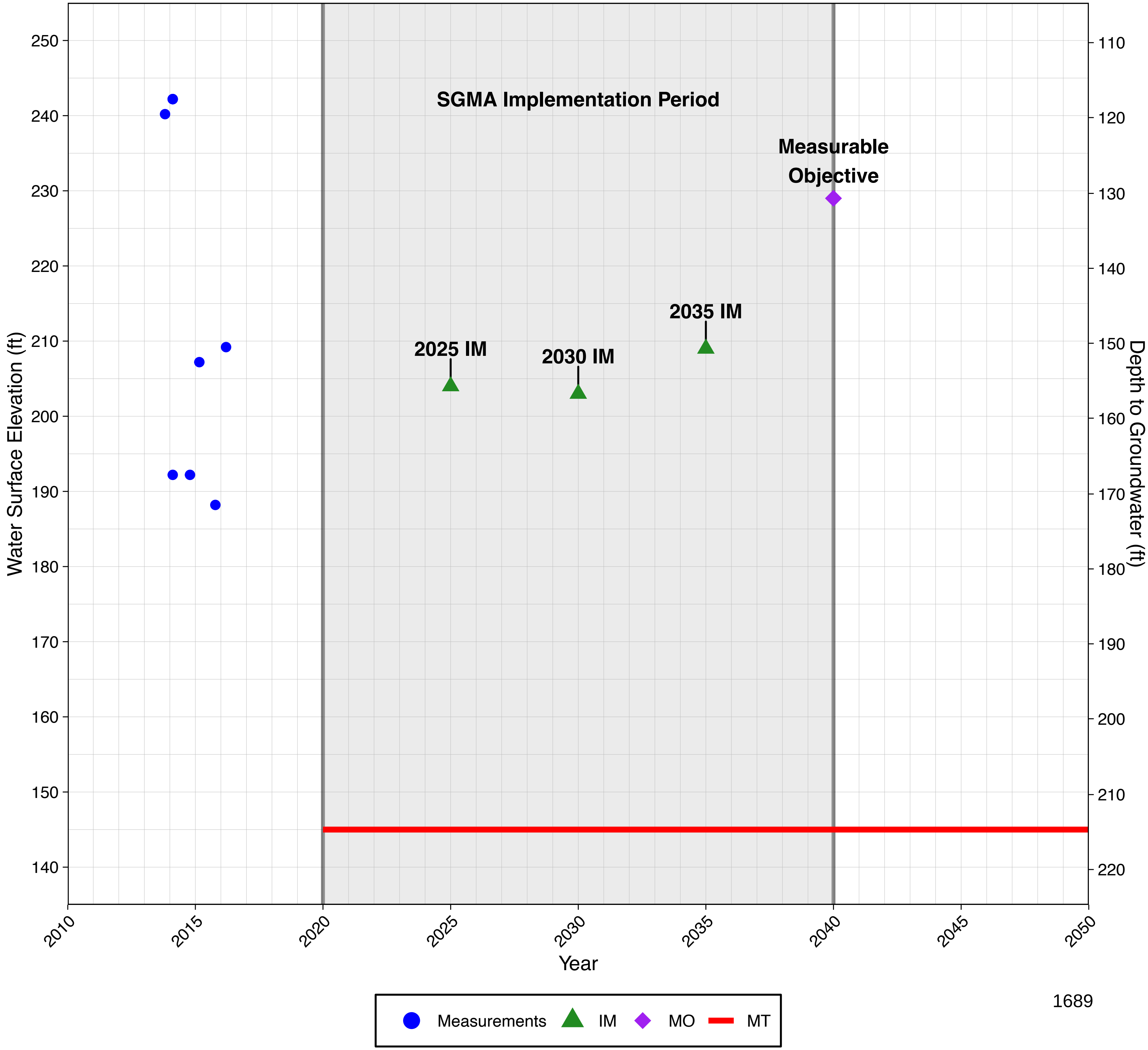
19S27E29D001M | East Kaweah
Single Aquifer System
Water Surface Elevation (ft)
Depth to Groundwater (ft)
Year
SGMA Implementation Period
Measurable Objective
2025 IM
2030 IM
2035 IM
Measurements
IM
MO
MT

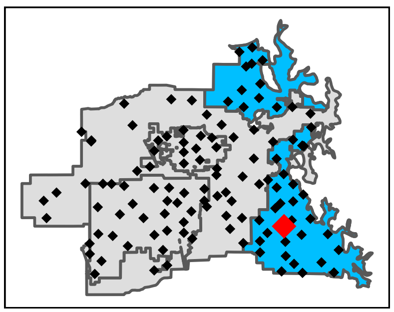
20S26E08H001M | East Kaweah
Single Aquifer System



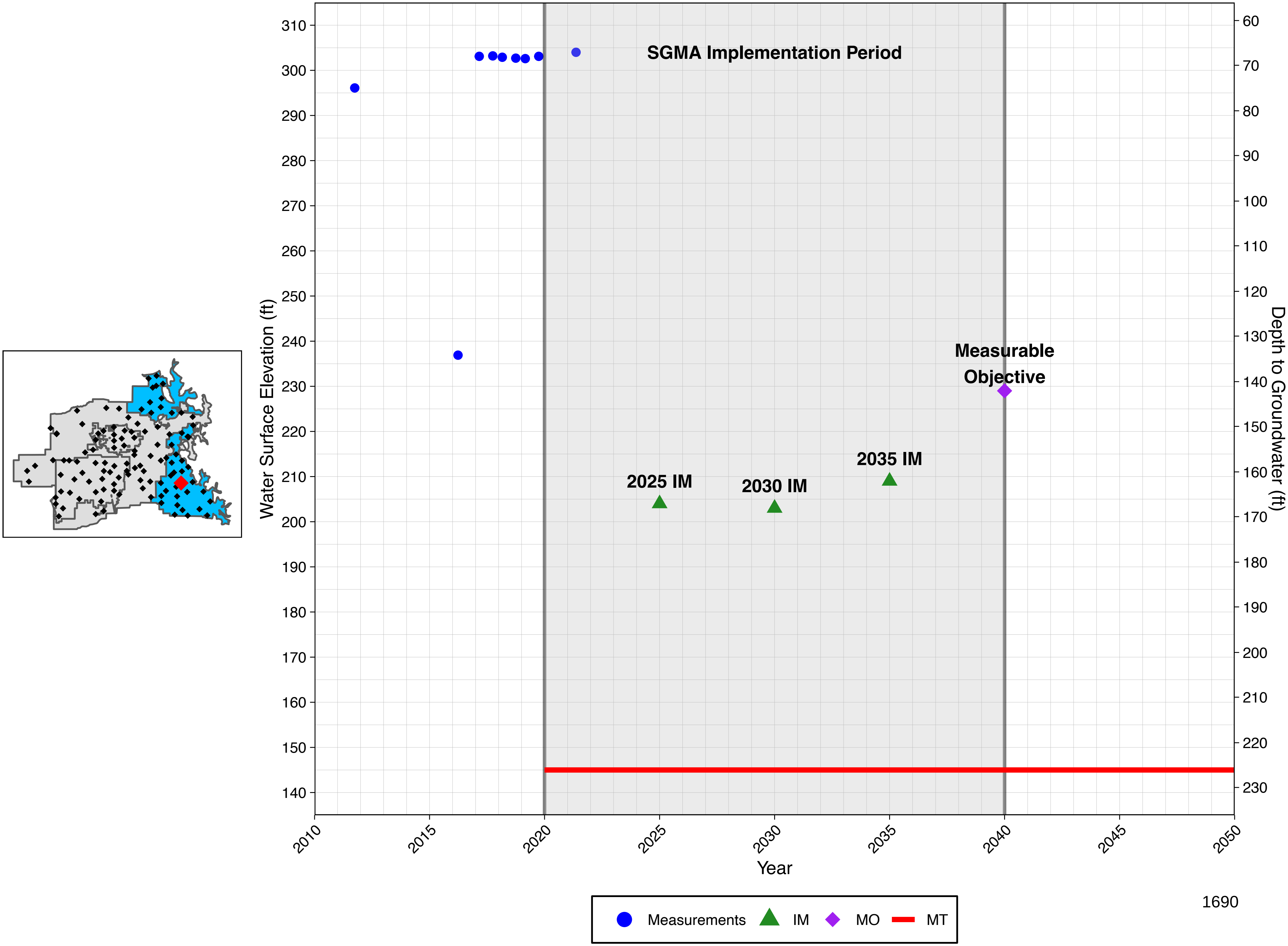


20S26E11R001M | East Kaweah
Single Aquifer System

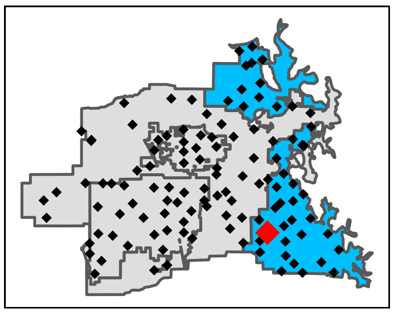


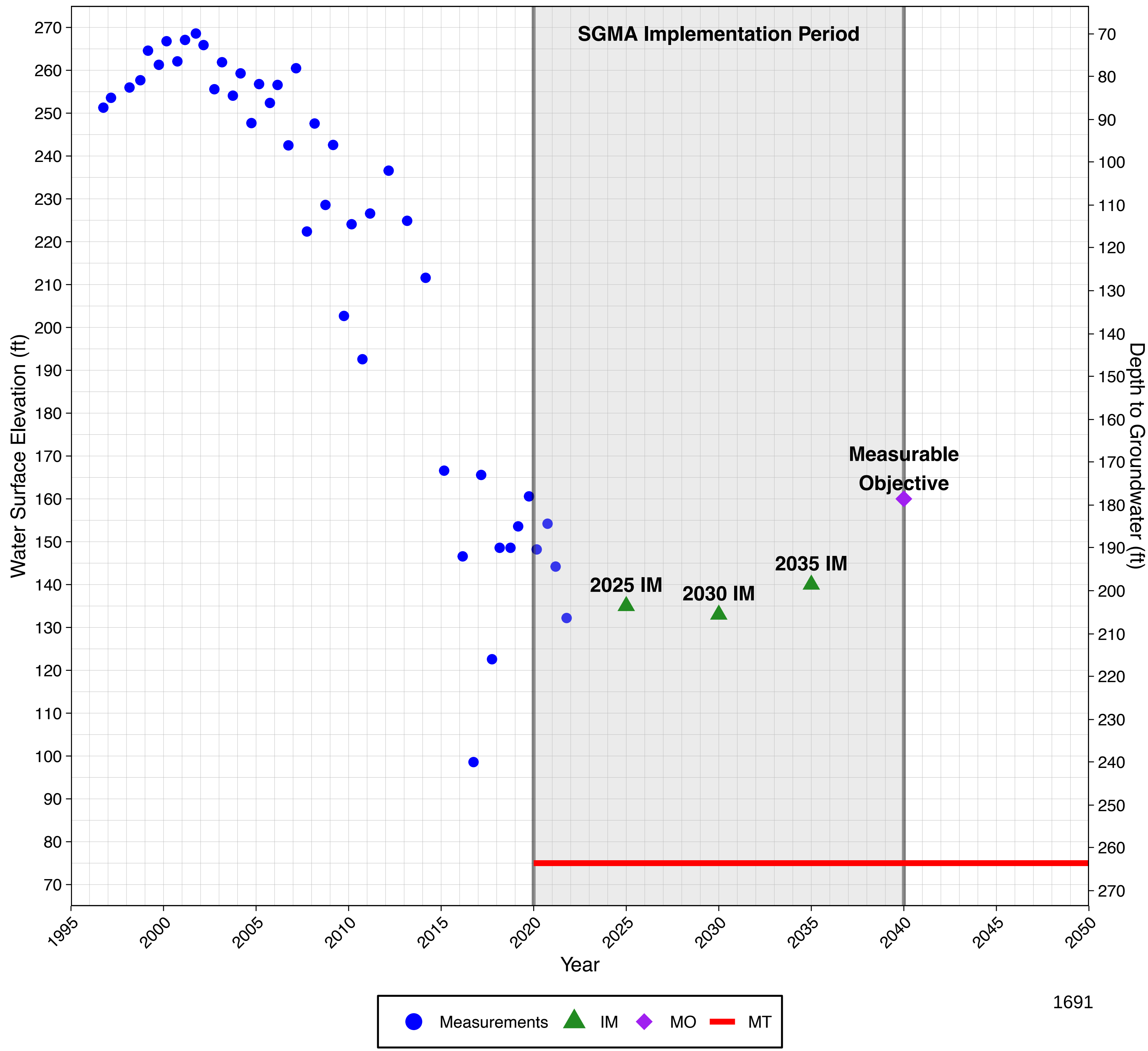


20S26E12H001M | East Kaweah
Single Aquifer System



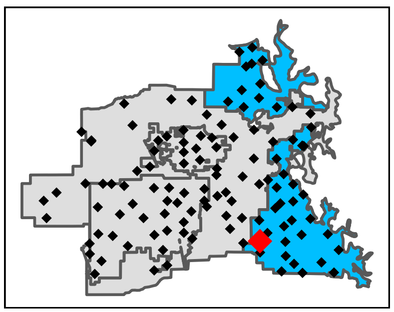
20S26E16R001M | East Kaweah
Single Aquifer System

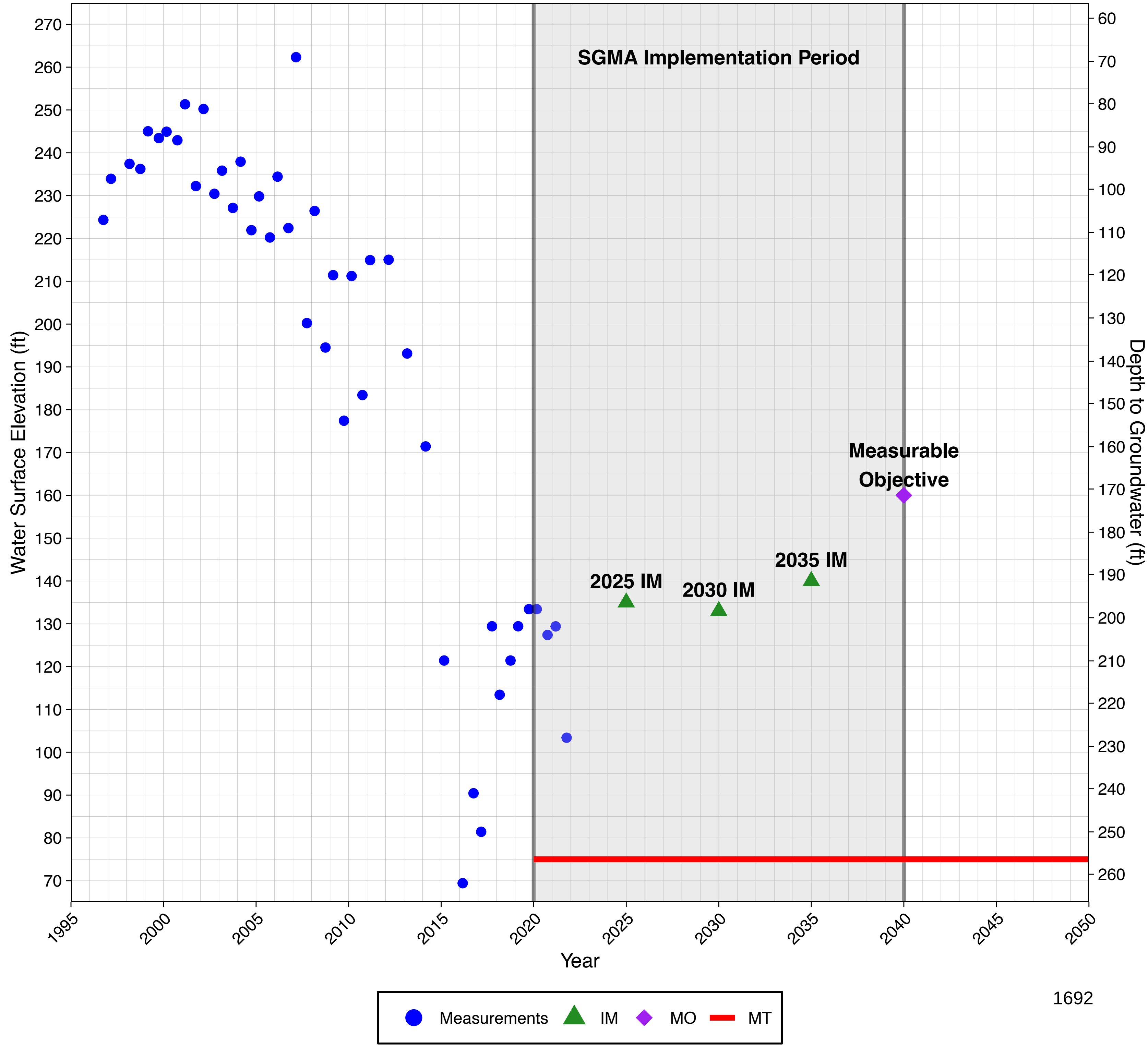




1691

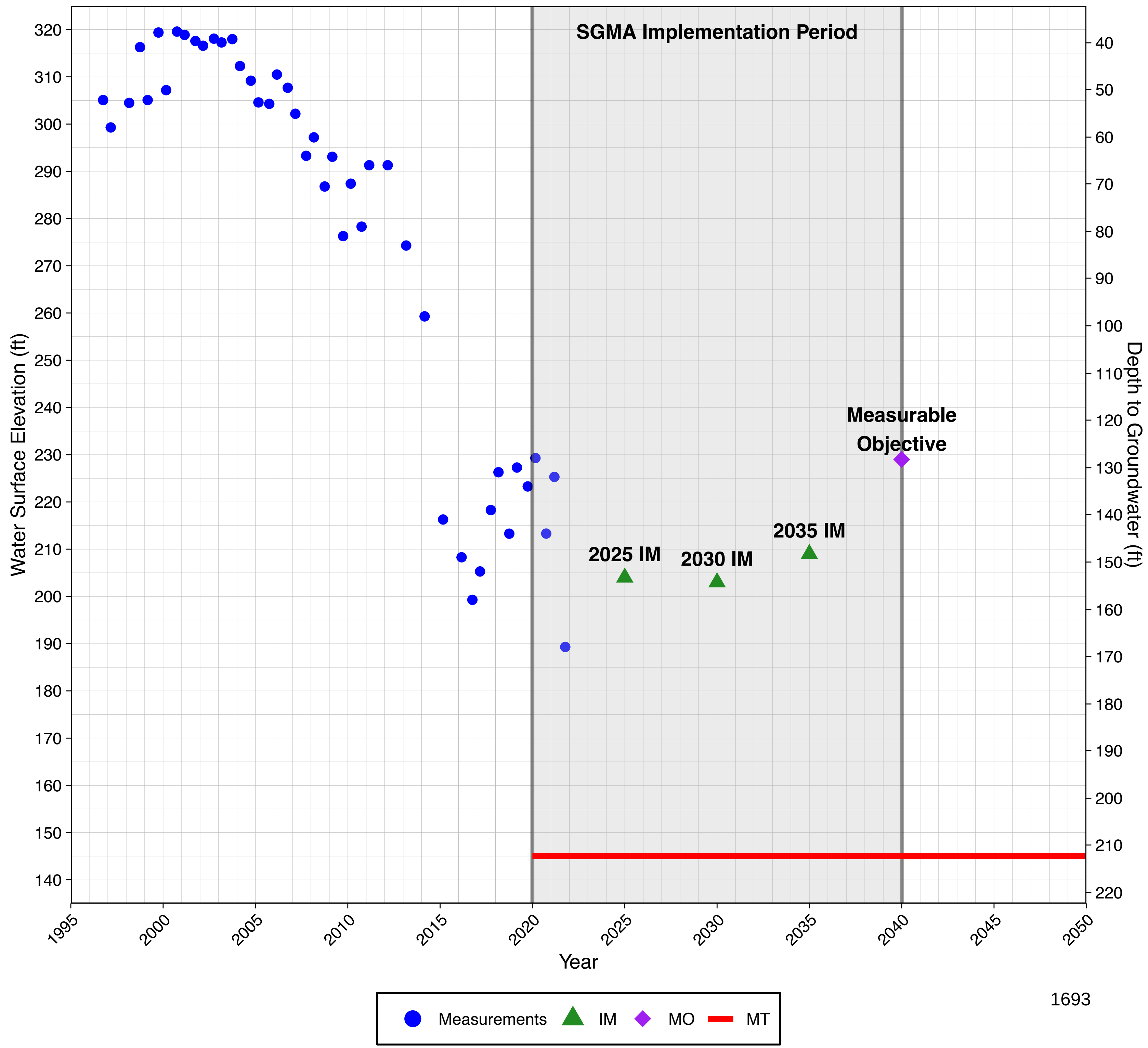
20S26E20J001M I East Kaweah
Single Aquifer System

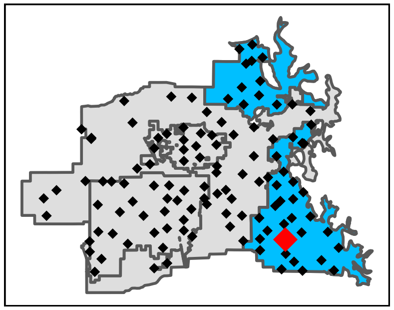


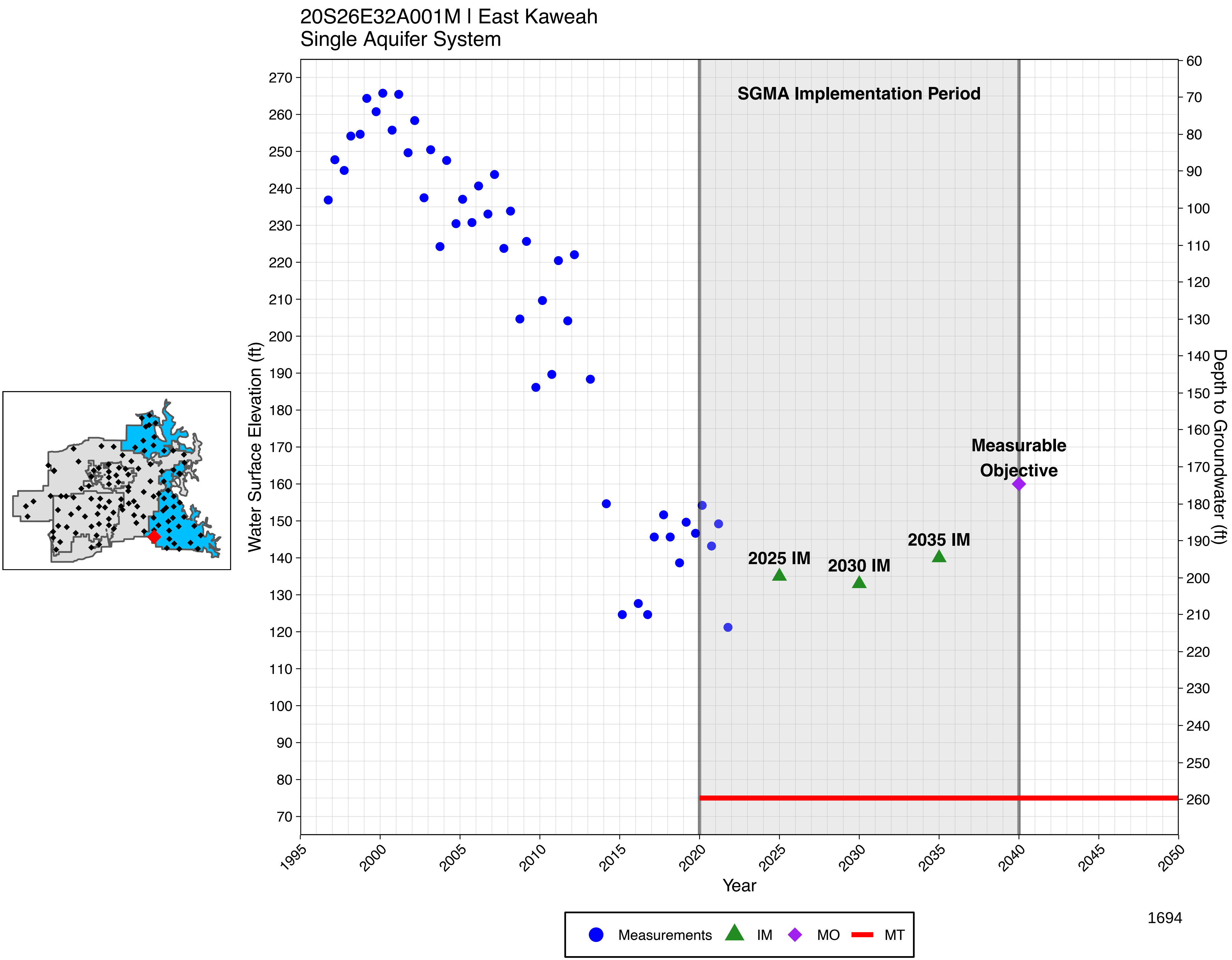


1692

20S26E23R001M | East Kaweah
Single Aquifer System

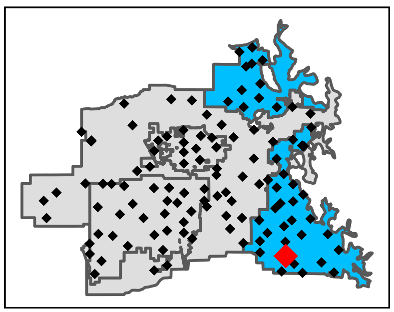


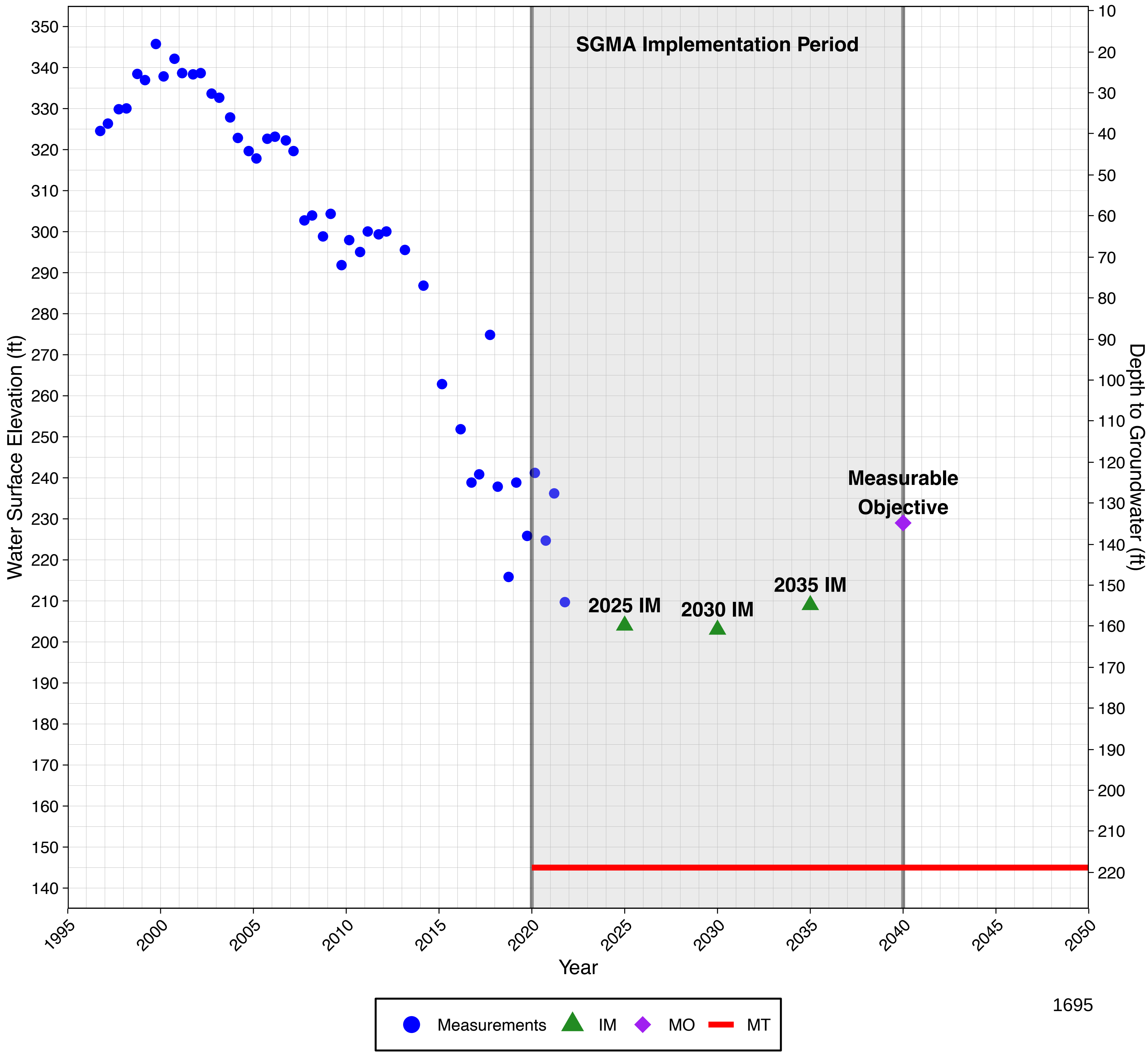




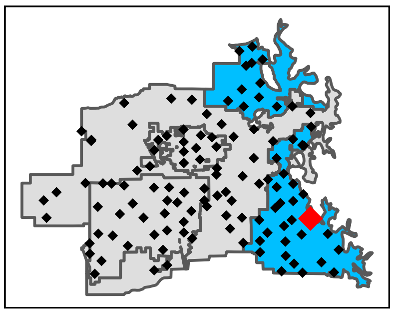
20S26E32A001M | East Kaweah
Single Aquifer System
SGMA Implementation Period
Measurable Objective
2025 IM
2030 IM
2035 IM
Water Surface Elevation (ft)
Depth to Groundwater (ft)
Year
Measurements
IM
MO
MT

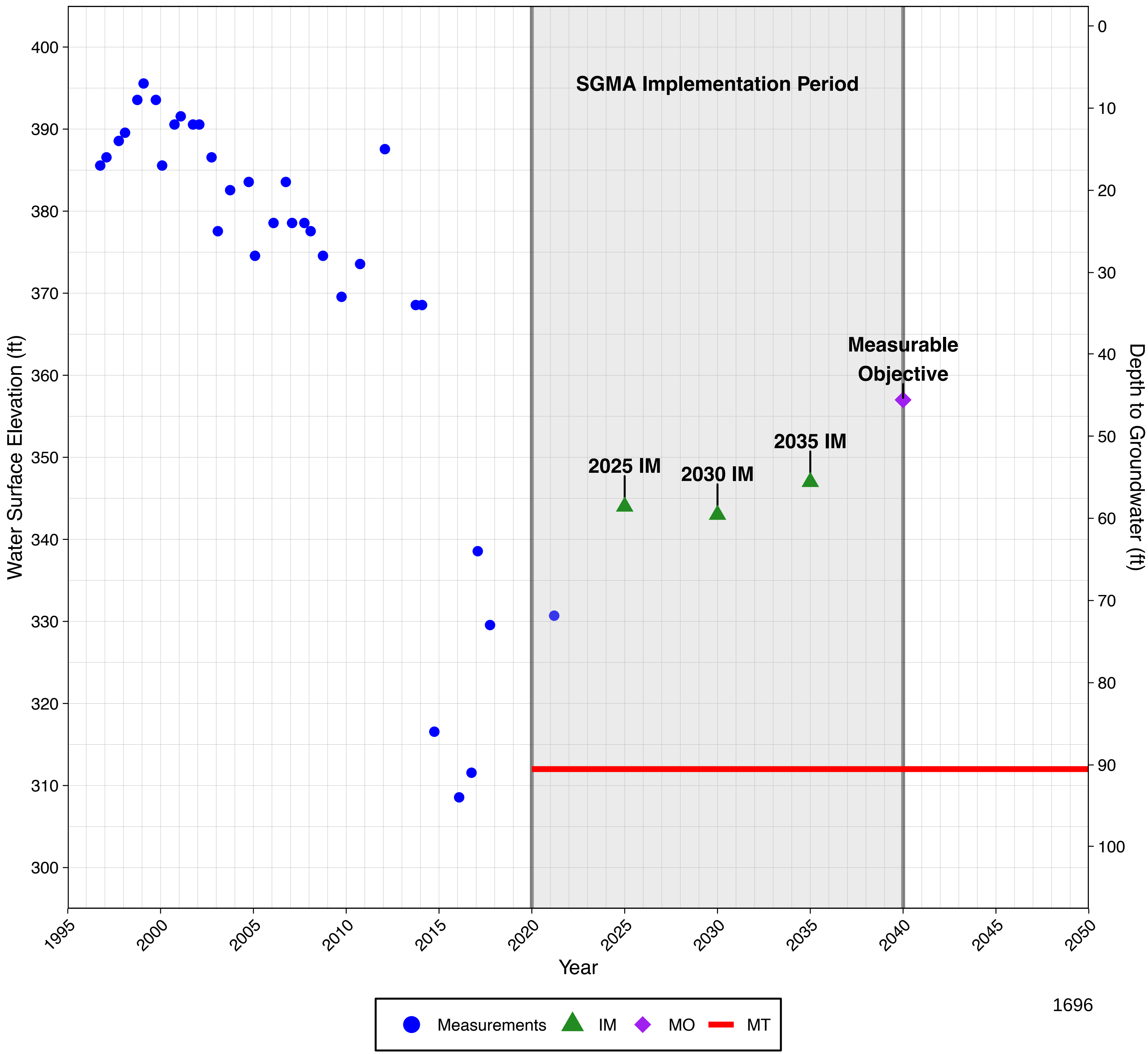
20S26E35H001M | East Kaweah
Single Aquifer System





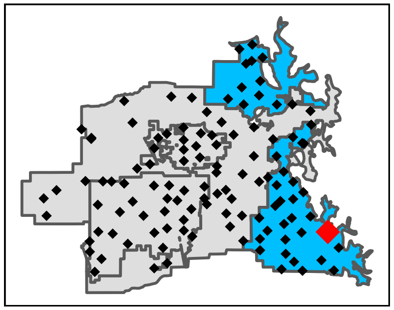
20S27E08A001M | East Kaweah
Single Aquifer System

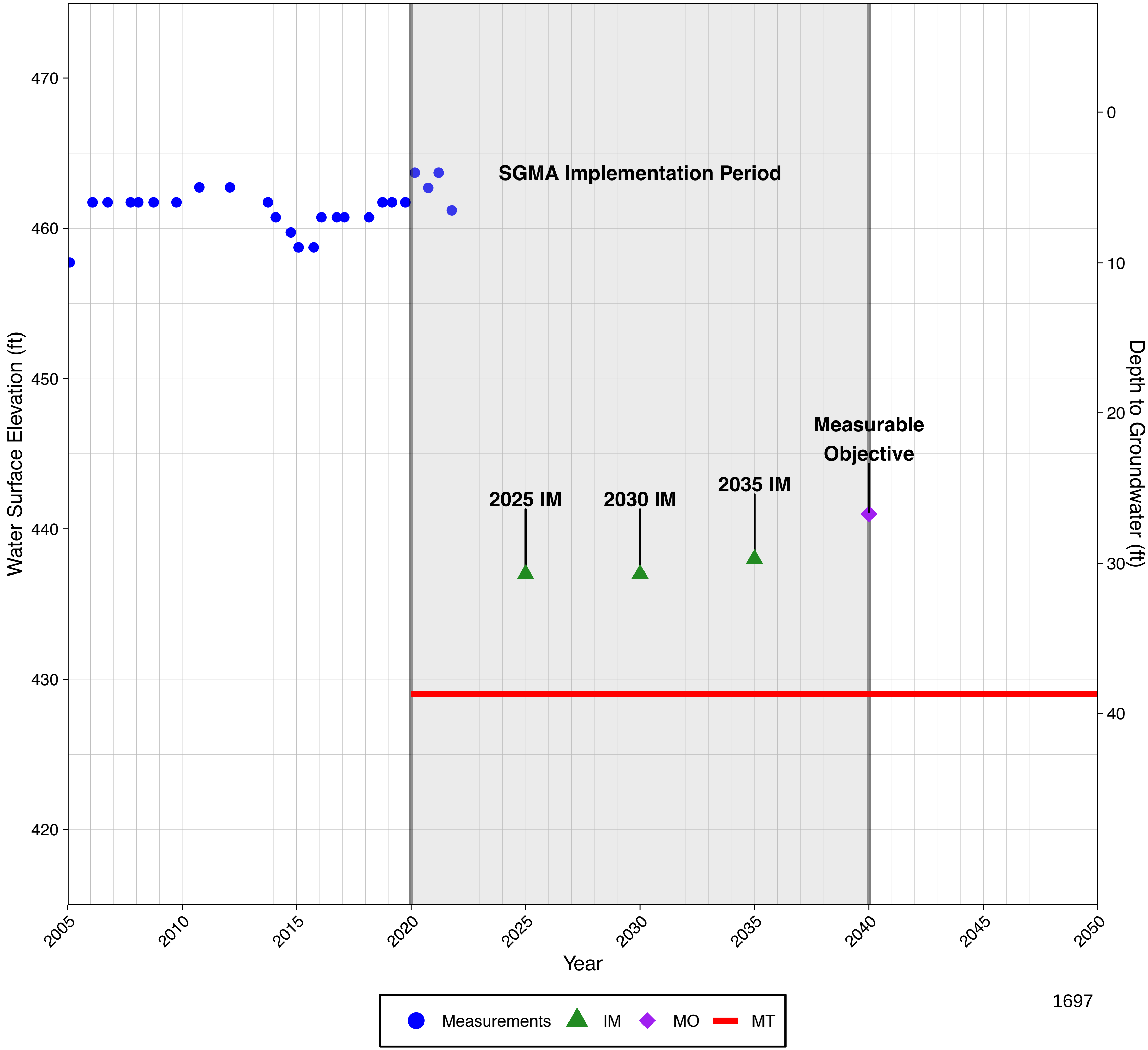




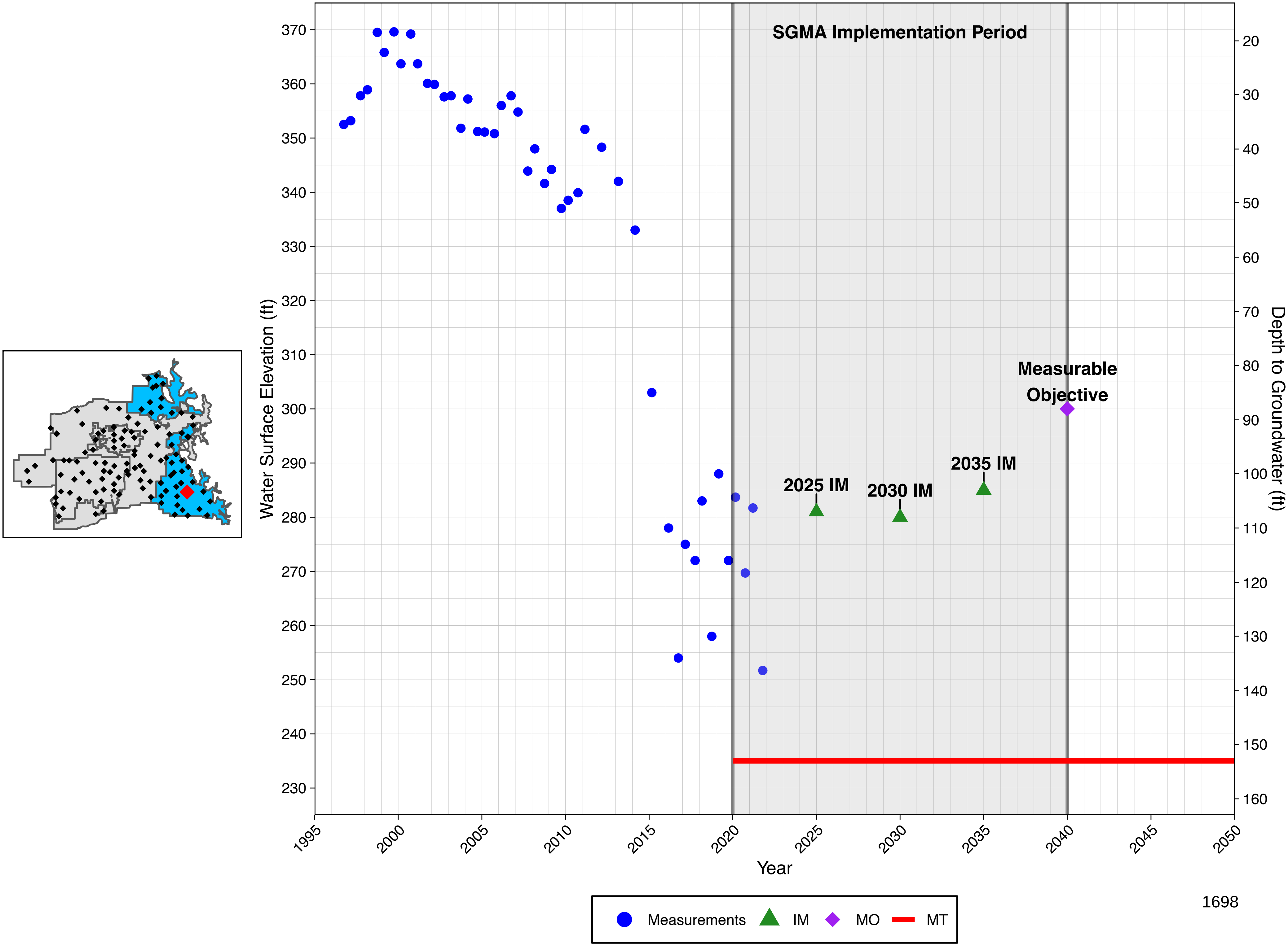
1696

20S27E15R001M | East Kaweah
Single Aquifer System

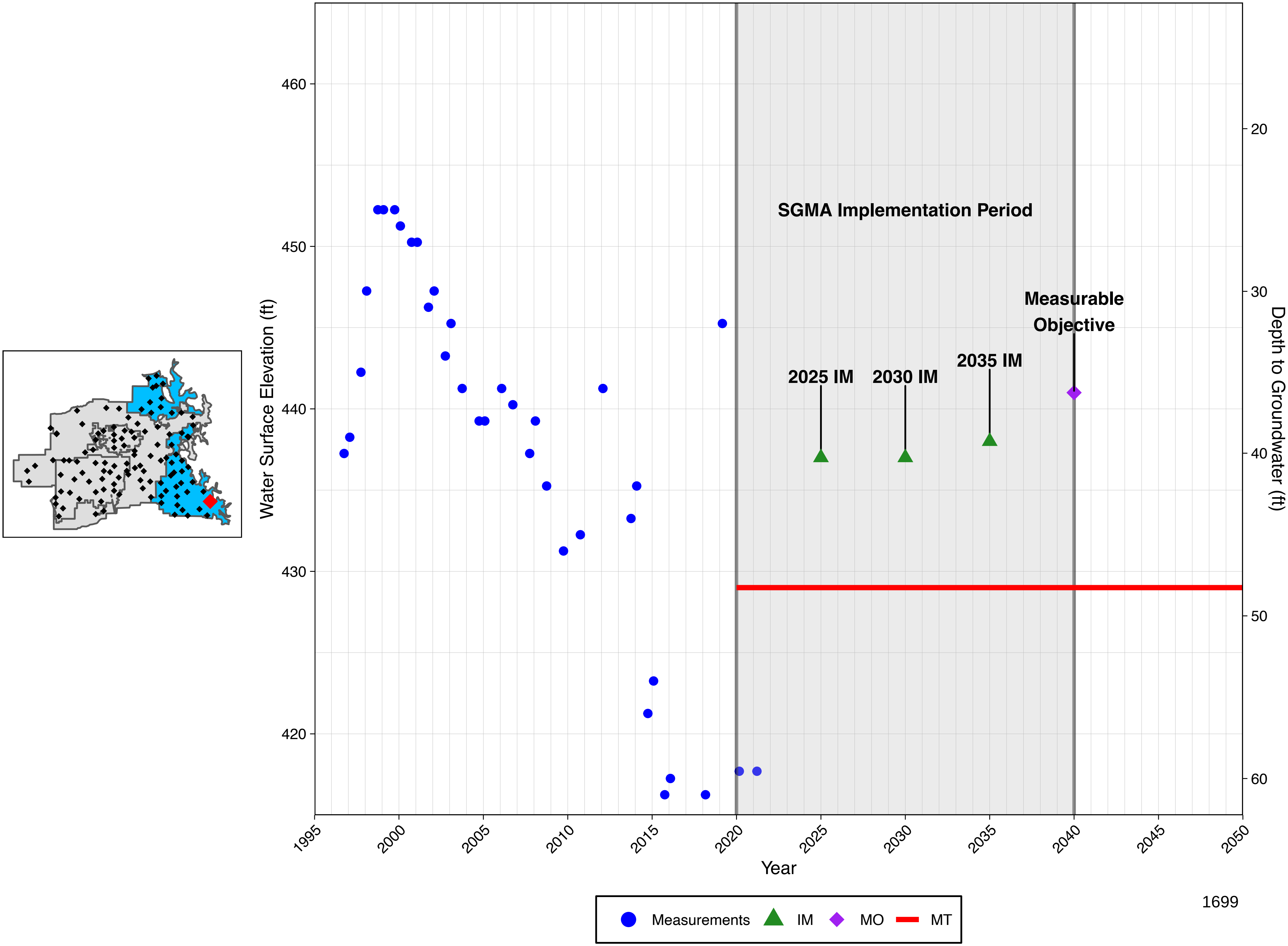




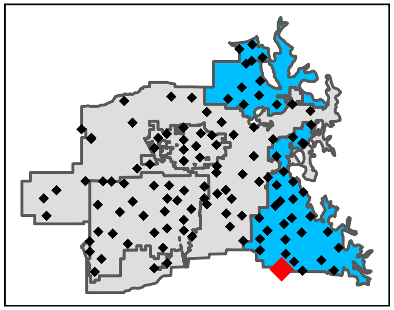
20S27E18R001M | East Kaweah
Single Aquifer System

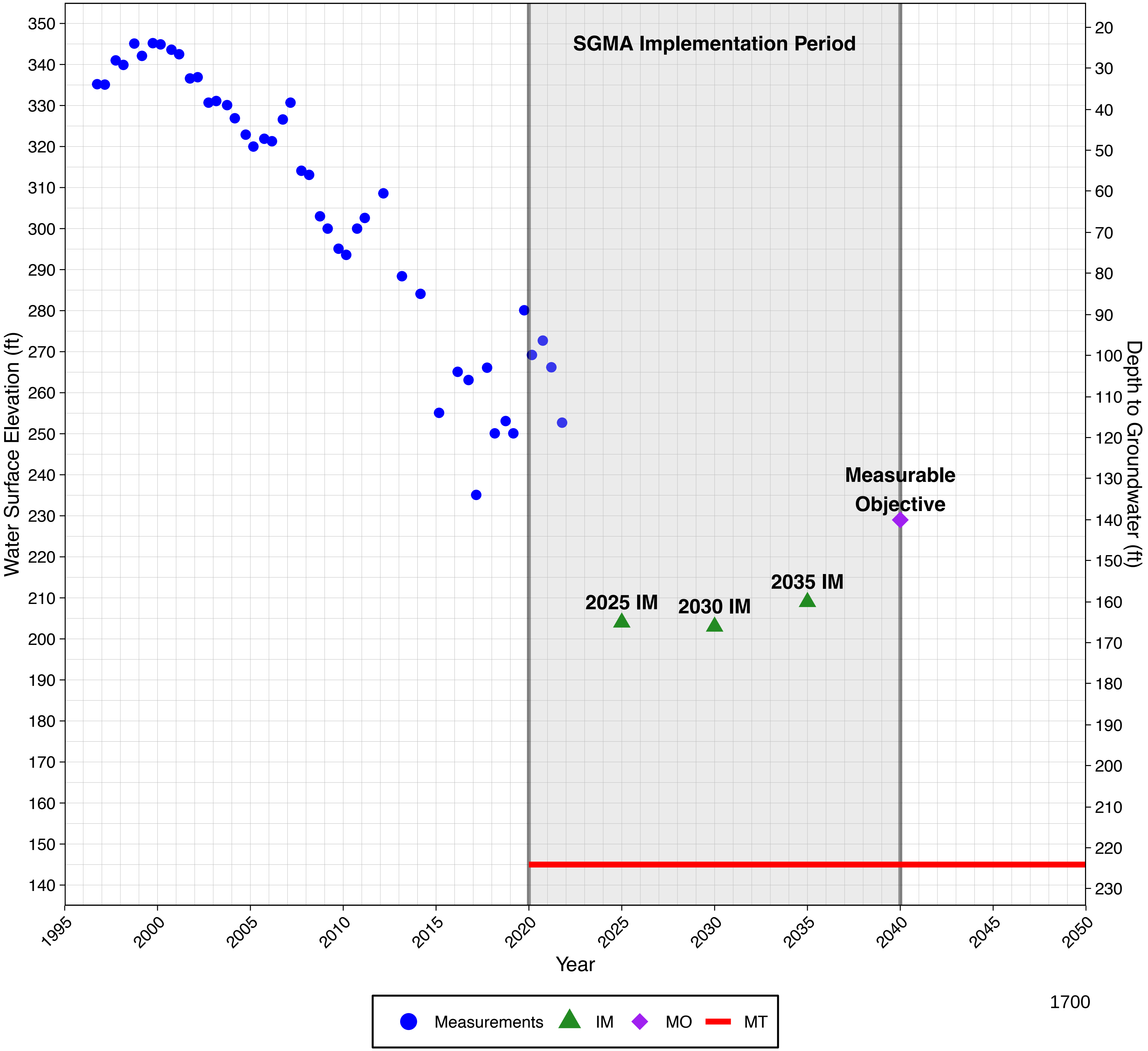


20S27E25N001M | East Kaweah
Single Aquifer System

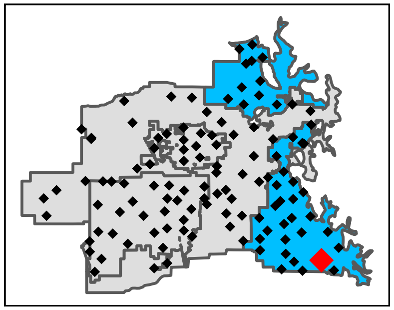


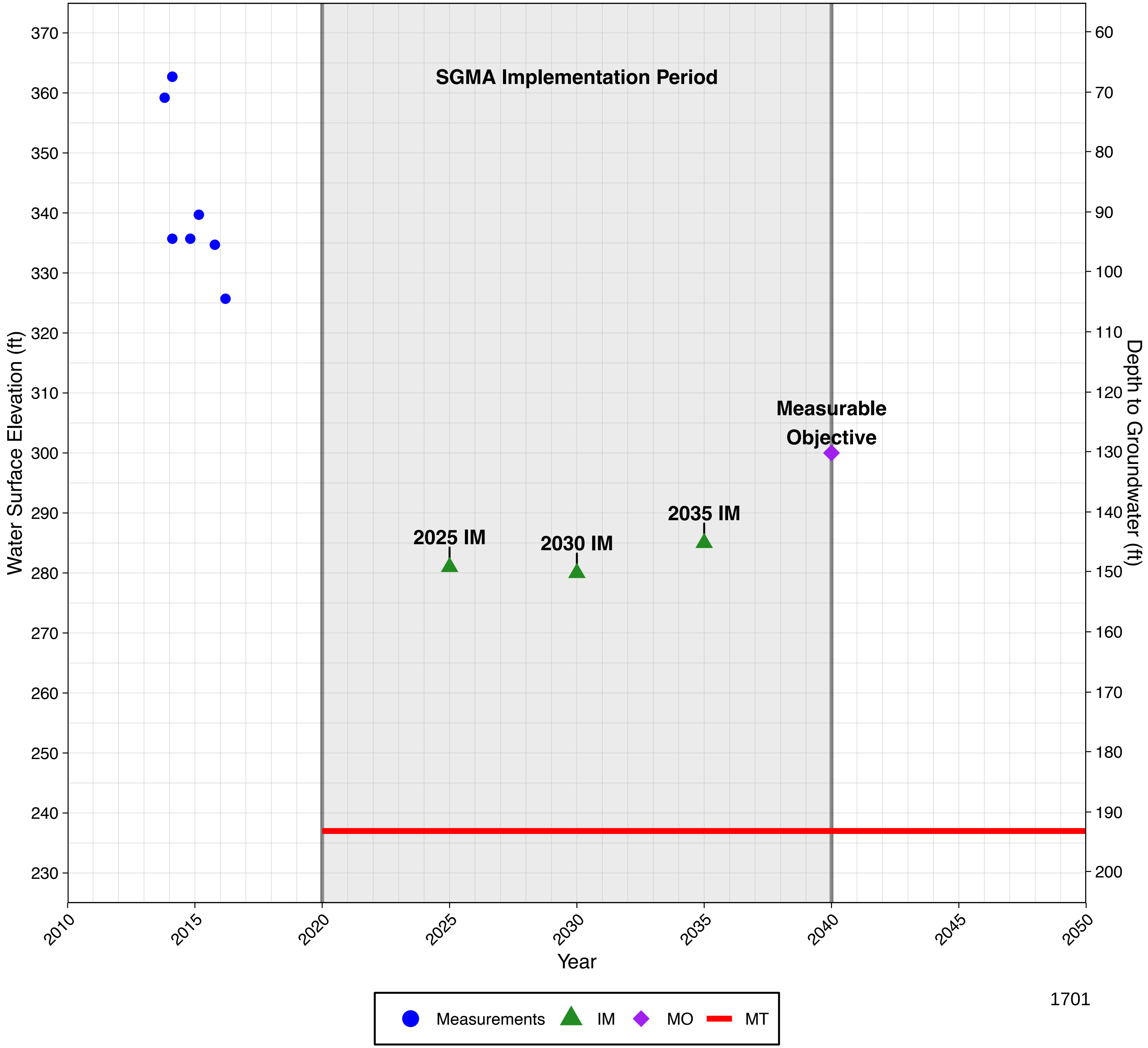
21S26E11H001M | East Kaweah
Single Aquifer System



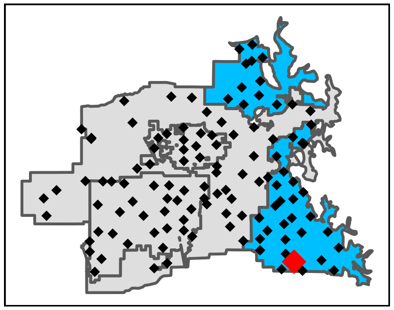


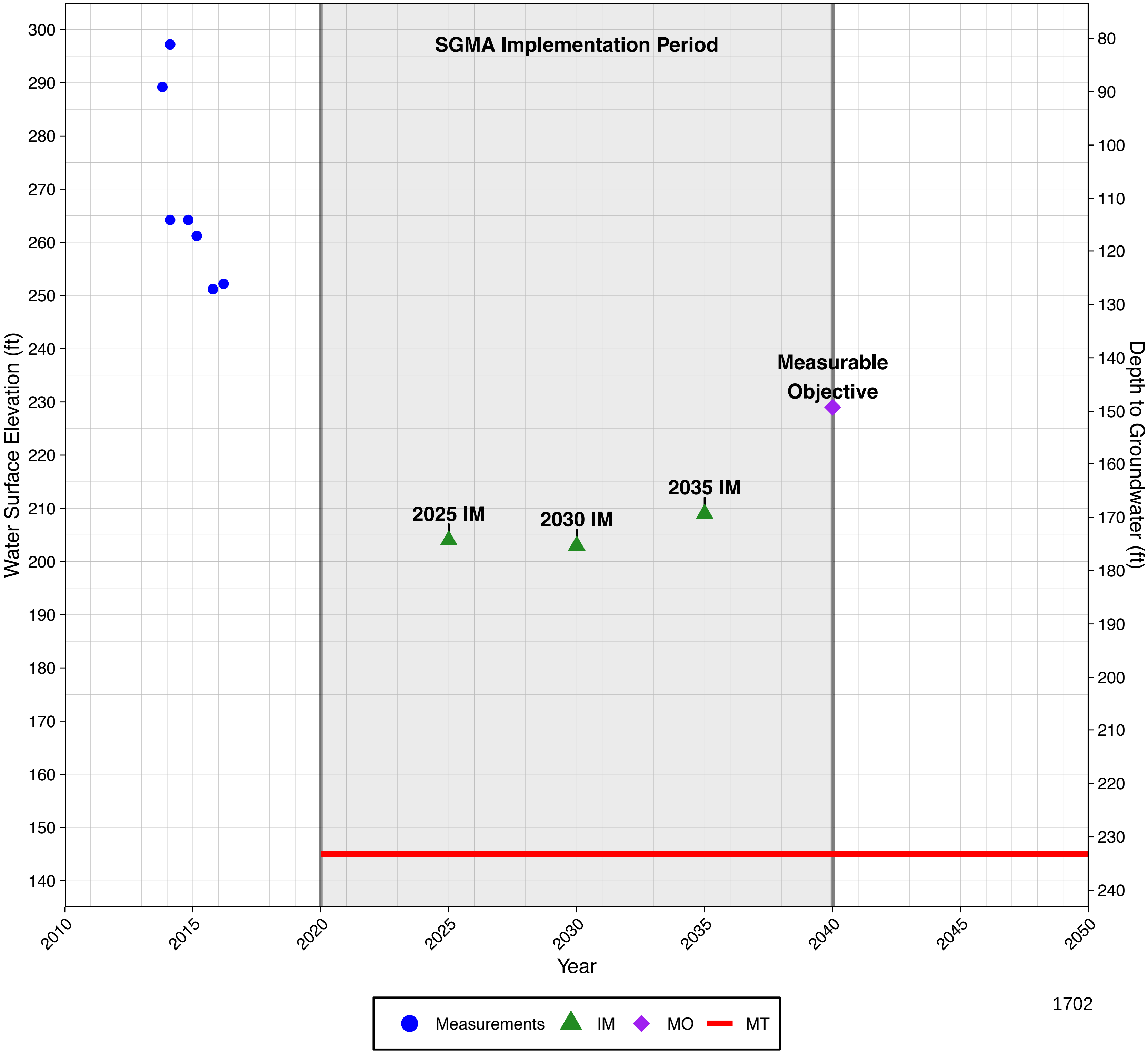
21S27E03B001M | East Kaweah
Single Aquifer System





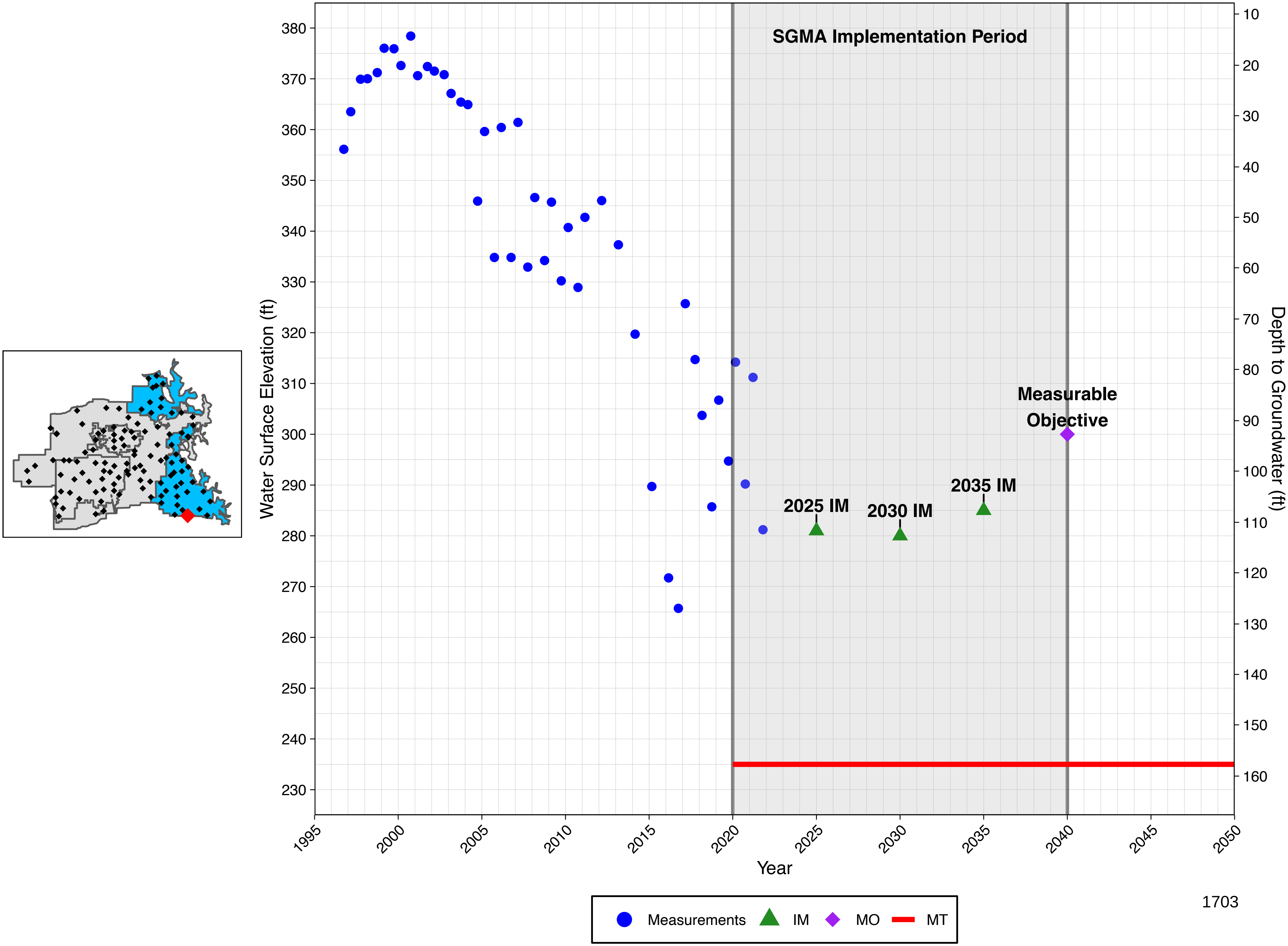
21S27E06F001M I East Kaweah
Single Aquifer System





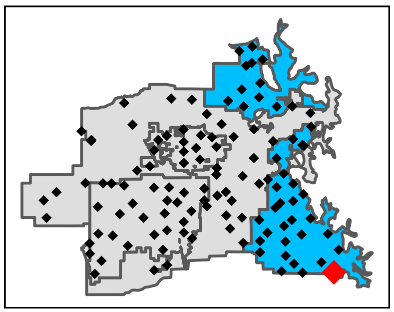
1702

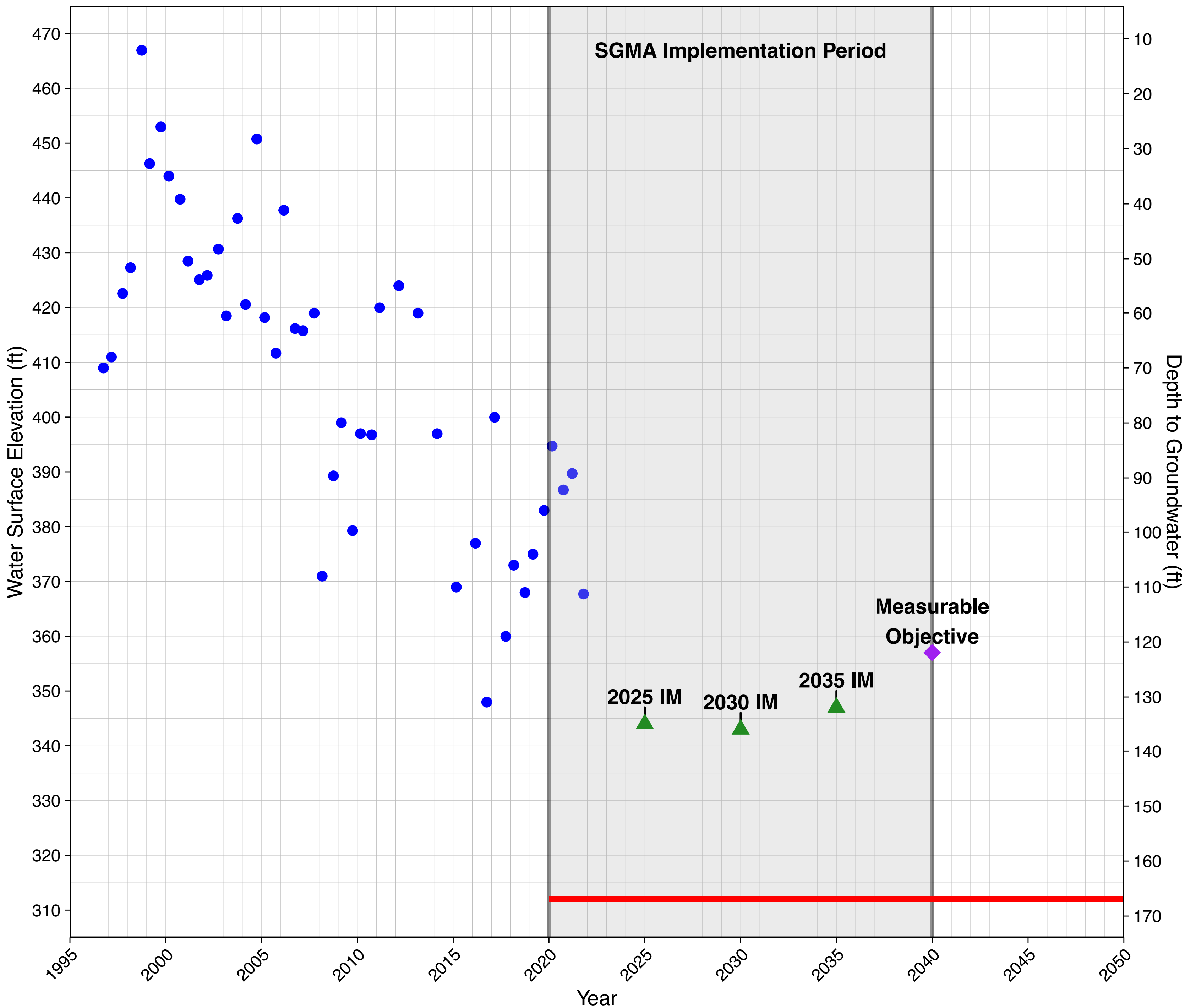
21S27E08F001M | East Kaweah
Single Aquifer System



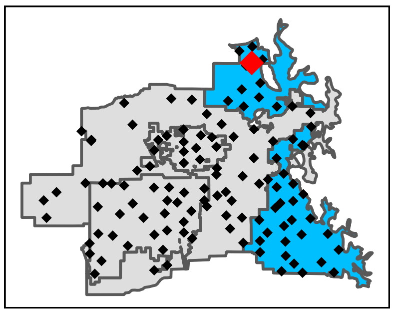
1703

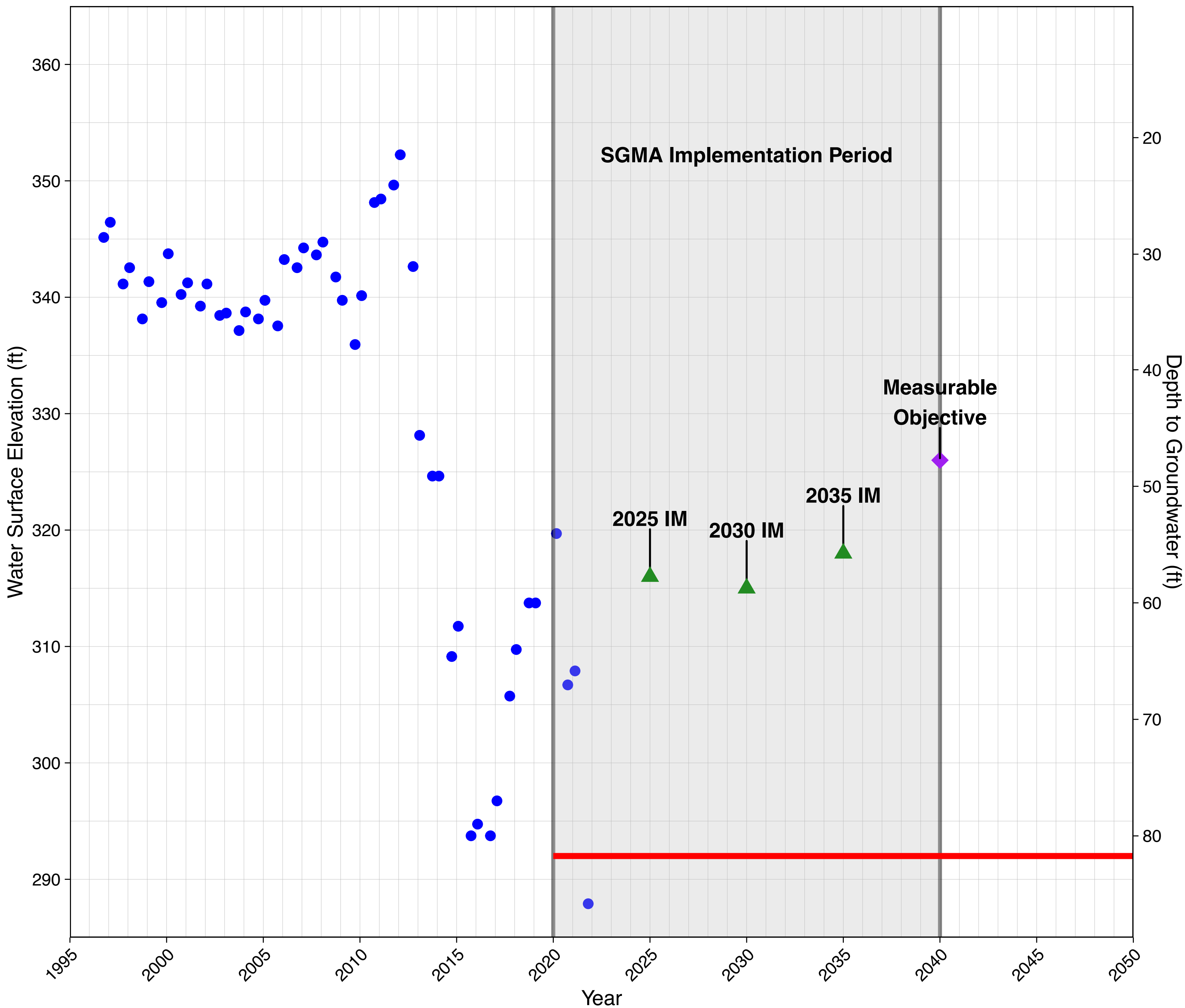
21S27E12F001M | East Kaweah
Single Aquifer System





SCID Office I East Kaweah
Single Aquifer System





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Appendix 3-C

Groundwater Levels and Water Quality Correlation Analysis

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130 N. Garden Street
Visalia, CA 93291-6362
Tel: (559) 636-1166
Fax: (559) 636-1177
www.ppeng.com

To:	East Kaweah GSA; File
From:	Morgan Campbell
Subject:	Groundwater Levels and Water Quality Correlation Analysis Results
Date:	September 2019

Purpose:

This memorandum serves as a summary of the statistical analysis, rationale, and exploration of the relationship between groundwater quality and groundwater levels. To simplify the sustainable management criteria process, the EKGSA originally aimed to utilize groundwater levels as a proxy measurement for water quality. However, under SGMA Section 354.28 and according to the BMP document (P. 17), in order to use a proxy measurement the GSP must demonstrate that there is a significant correlation between groundwater levels and other metrics. A linear regression between groundwater levels and contaminant concentrations was utilized to explore if a significant correlation existed between the Constituents of Concern (COCs) Arsenic, Chloride, DBCP, Nitrate, Sodium, and TCP and groundwater levels.

Recommendation & Conclusions:

Analysis was performed for each COC for data across the EKGSA as a whole and in the proposed Threshold Regions where groundwater properties are determined to act more similarly. The statistical tests on the whole, and at a more granular geographic level, show little to no evidence of any potential correlation between groundwater levels and groundwater quality within the EKGSA (*Tables 1-7 and Figures 1-12*). There are also challenges to the data coverage spatially and temporally through the EKGSA boundary. Therefore, the recommendation is that for COC evaluation within the EKGSA, groundwater levels are not an appropriate proxy for setting sustainable management criteria (i.e. minimum thresholds) due to a lack of statistical correlation between groundwater levels and COCs. To accurately account for changes in water quality, sustainable management criteria metrics should be based directly on measured constituent concentrations rather than by a proxy metric.

Assumptions:

Linear regression is an analysis that assesses whether one or more predictor variables explain the dependent (criterion) variable. To run a linear regression, the dataset must meet six key assumptions:

1. Linear relationship. Assumes that a linear model is the appropriate relationship between the dependent and independent variables.
2. Multivariate normality. Assumes that the data set is normally distributed.
3. No or little multicollinearity. Assumes that independent variables are not correlated with each other.
4. No auto-correlation. Auto-correlation occurs when there is a high degree of correlation between the values of the same variables across different observations in the data.

5. Homoscedasticity. Assumes that the random disturbance in the relationship between independent and dependent variables is the equal across all values of the independent variables.
6. Sample-size. The rule of thumb is that the regression analysis requires at least 10 cases per independent variable in the analysis.

The EKGSA water quality and depth to water dataset was assumed to meet Criterion 1-5. In instances where the sample-size of data was smaller than 10, but larger than 5, a linear regression was still run for informative purposes. These small sample sizes have been demarcated, as appropriate, in the text.

Methodology:

1. All available water quality data for the EKGSA boundary was downloaded out of GAMA GeoTracker for the base period of 1997-2017. All data was assumed to meet the aforementioned statistical assumptions required to run a linear regression.
2. Data was clipped in ArcGIS to associate well samples with their appropriate threshold region.
3. Groundwater elevations through time were used to provide groundwater level measurements for each quality sample taken. Only years where there are both water level data and water quality data were utilized in the analysis. It is necessary to have both water quality and groundwater levels taken in close temporal proximity to ensure a representative sample.
4. COC were selected based upon the information presented in the GSP Basin Setting document. For the purposes of this statistical analysis, Arsenic, Chloride, DBCP, Nitrate, Sodium, and TCP were explored. This was not intended to be an exhaustive list of all the COCs identified for the EKGSA, but rather an exploratory exercise.
5. Each COC sample result that had associated groundwater level reading was plotted on a scatterplot to compare the relationship between groundwater level (x-axis) and contaminant concentration (y-axis).
6. Each threshold region was plotted for each individual constituent as a separate data series to explore any statistical relationship between groundwater quality and groundwater levels.
7. For each dataset, a linear regression equation was drawn, and goodness of fit was assessed using the R-squared coefficient. A linear regression explores the relationship between a dependent variable (COC concentration) vs. an independent variable (depth to groundwater). R-squared is a statistical measure of how close the data are to the fitted regression line. The closer a R-squared value is to 1, the stronger the indication that there is a correlation between the data. The closer a R-squared value is to 0, the stronger the indication that there is not a correlation between the data.

Data & Results:

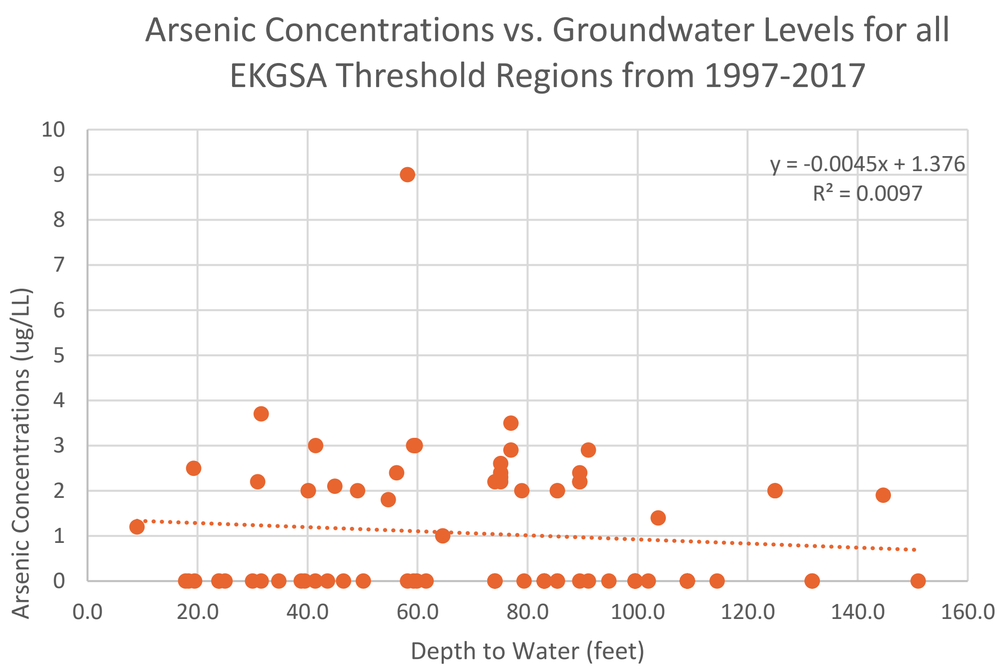

Figure 1. Arsenic concentrations versus groundwater levels for all EKGSA threshold regions from 1997 to 2017.

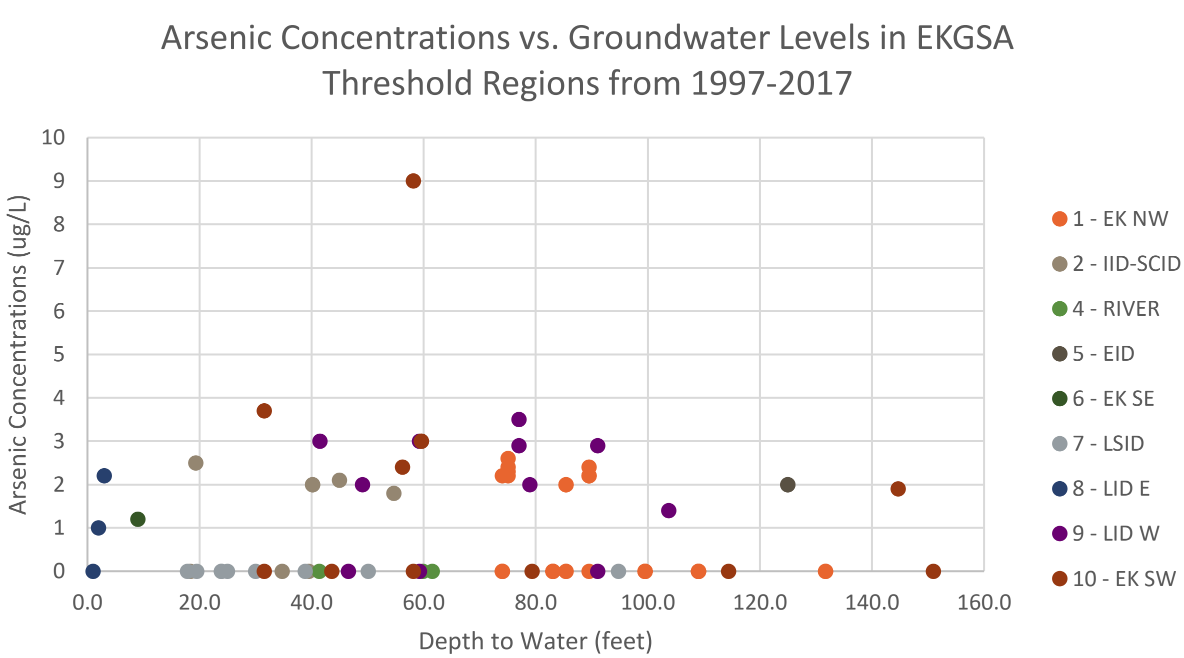

Figure 2. Arsenic concentrations versus groundwater levels split by EKGSA threshold regions from 1997 to 2017.

Table 1. Summary table of linear regression statistics for Arsenic concentrations versus groundwater levels for all EKGSA threshold regions from 1997 to 2017.

ARSENIC					
Threshold Region	**Sample Number**	**Linear Equation**	**R-squared Coefficient**	**Interpretation**	**Notes**
1 - EK NW	32	y = -0.0302x + 3.4738	0.2039	Weak negative correlation	
2 - IID-SCID	8*	y = 0.0209x + 0.5369	0.0556	Little or no correlation.	*Minimum recommended sample size for linear regressions is n=10.
3 - EK NE	0	--	--	Insufficient data to draw trendline.	
4 - RIVER	3*	y=0	n/a	No trend line can be drawn, all sample concentrations were measured at 0 mg/L.	*Minimum recommended sample size for linear regressions is n=10.
5 - EID	2	--	--	Insufficient data to draw trendline.	
6 - EK SE	1	--	--	Insufficient data to draw trendline.	
7 - LSID	9*	y=0	n/a	No trend line can be drawn, all sample concentrations were measured at 0 mg/L.	*Minimum recommended sample size for linear regressions is n=10.
8 - LID E	3*	--	--	Insufficient data to draw trendline.	
9 - LID W	10	y = 0.0007x + 1.8319	0.0001	Little or no correlation.	
10 - EK SW	12	y = -0.016x + 3.1039	0.0606	Little or no correlation.	
All Data	**80**	**y = -0.0045x + 1.376**	**0.0097**	**Little or no correlation.**	

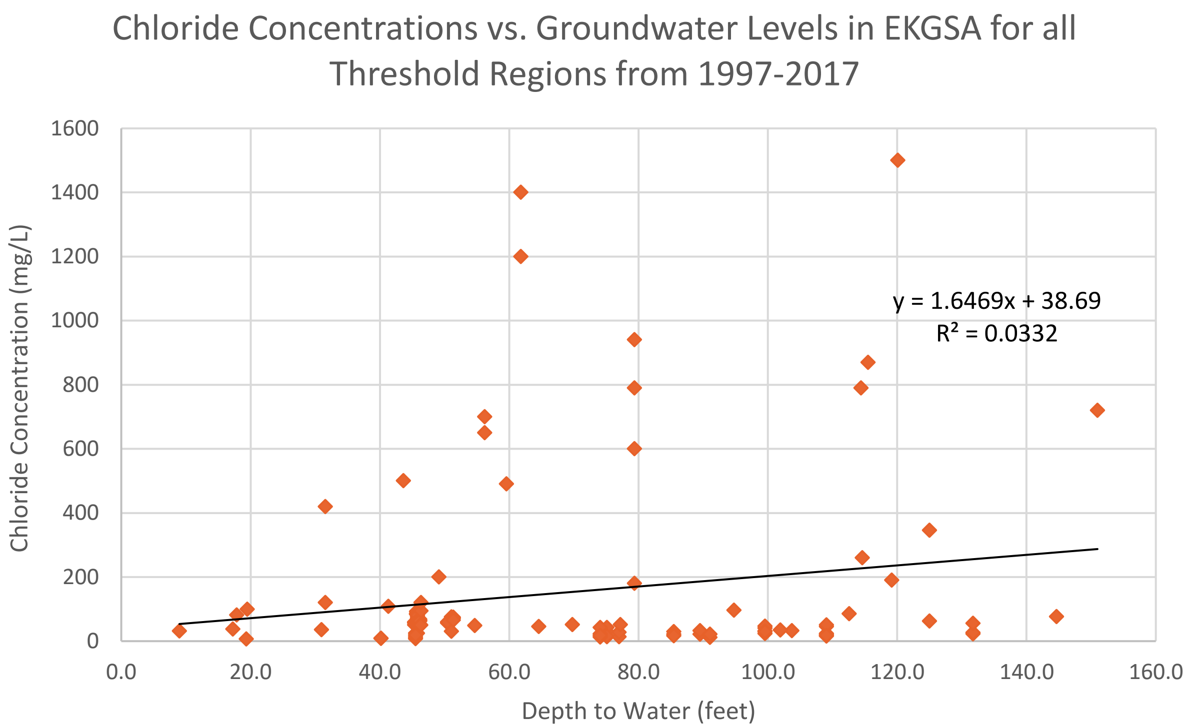

Figure 3. Chloride concentrations versus groundwater levels for all EKGSA threshold regions from 1997 to 2017.

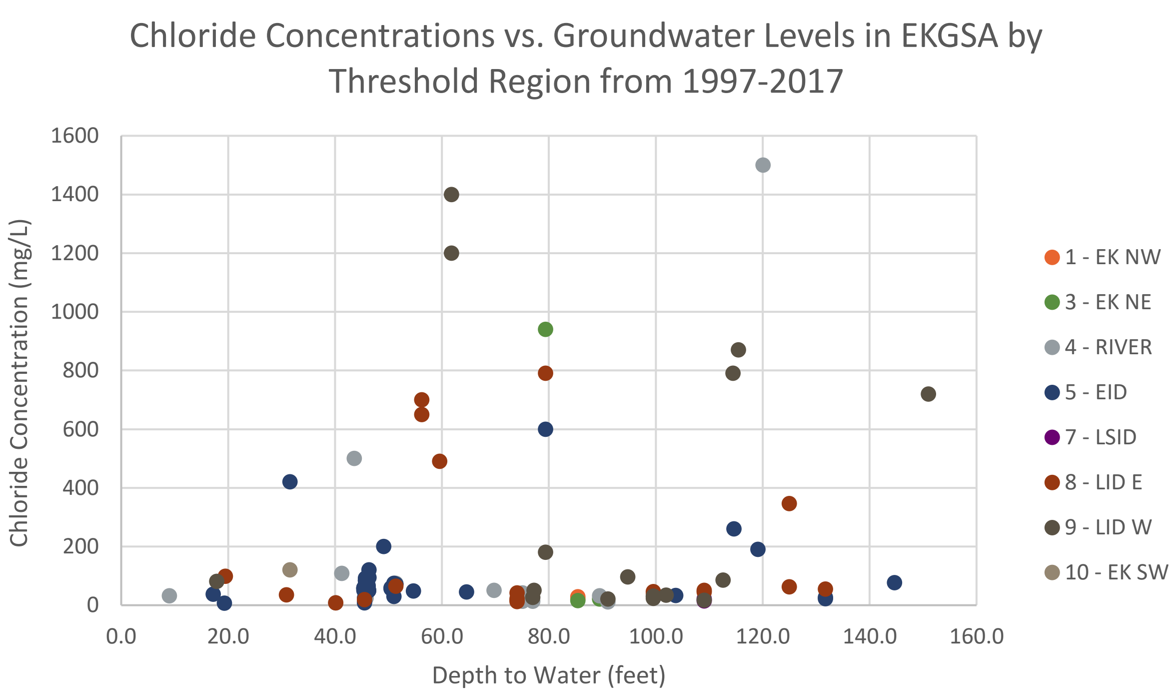

Figure 4. Chloride concentrations versus groundwater levels split by EKGSA threshold regions from 1997 to 2017.

Table 2. Summary table of linear regression statistics for Chloride concentrations versus groundwater levels for all EKGSA threshold regions from 1997 to 2017.

CHLORIDE					
Threshold Region	**Sample Number**	**Linear Equation**	**R-squared Coefficient**	**Interpretation**	**Notes**
1 - EK NW	3	--	--	Insufficient data to draw trendline.	
2 - IID-SCID	0	--	--	Insufficient data to draw trendline.	
3 - EK NE	3	--	--	Insufficient data to draw trendline.	
4 - RIVER	16	y = 5.1618x - 196.33	0.1493	Weak positive correlation.	
5 - EID	55	y = 0.5705x + 51.546	0.0244	Little or no correlation.	
6 - EK SE	0	--	--	Insufficient data to draw trendline.	
7 - LSID	2	--	--	Insufficient data to draw trendline.	
8 - LID E	19	y = -0.6502x + 236.07	0.0066	Little or no correlation.	
9 - LID W	17	y = -0.3044x + 360.65	0.0004	Little or no correlation.	
10 - EK SW	1	--	--	Insufficient data to draw trendline.	
All Data	**116**	**y = 1.6469x + 38.69**	**0.0332**	**Little or no correlation.**	

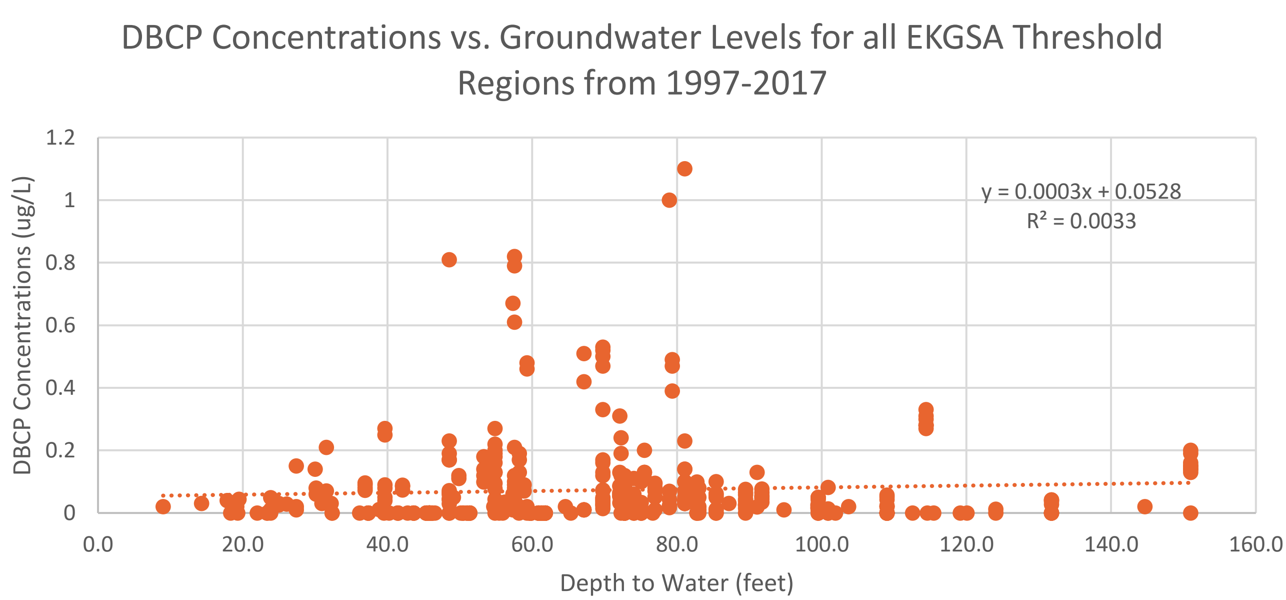

Figure 5. DBCP concentrations versus groundwater levels for all EKGSA threshold regions from 1997 to 2017.

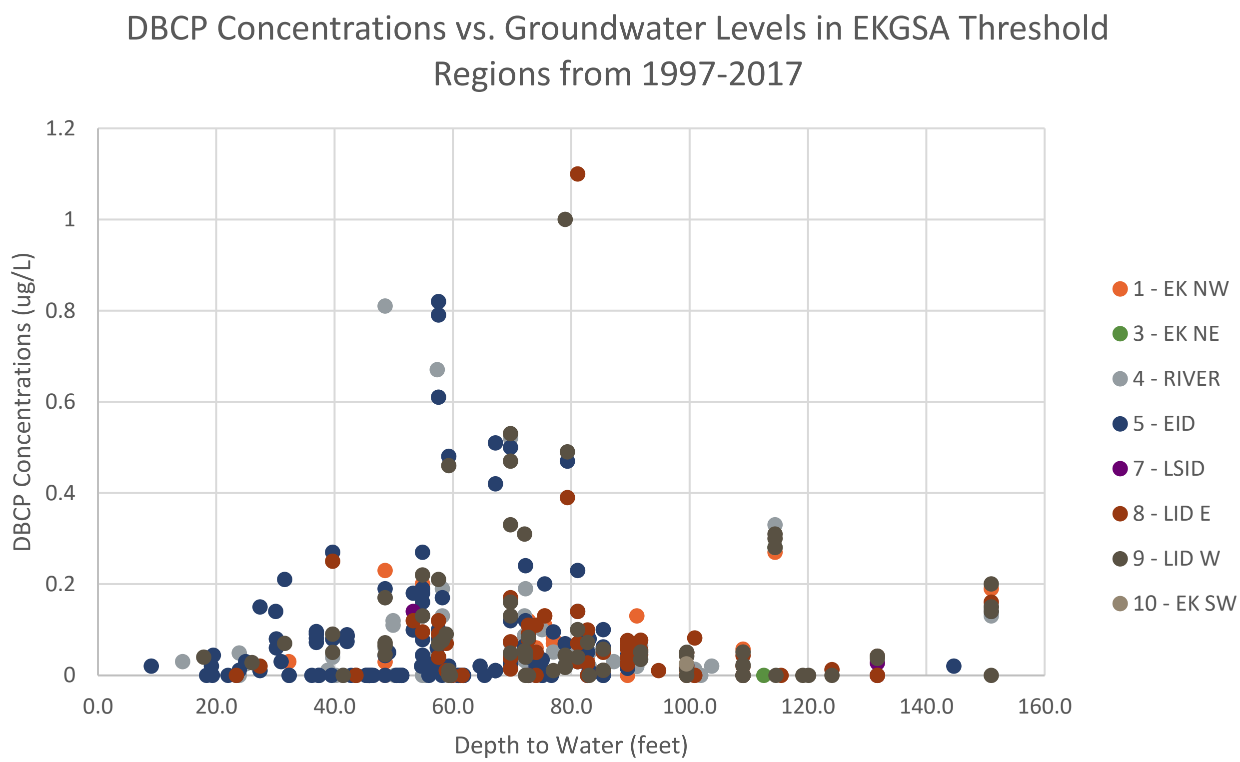

Figure 6. DBCP concentrations versus groundwater levels split by EKGSA threshold regions from 1997 to 2017.

Table 3. Summary table of linear regression statistics for DBCP concentrations versus groundwater levels for all EKGSA threshold regions from 1997 to 2017.

DBCP					
Threshold Region	**Sample Number**	**Linear Equation**	**R-squared Coefficient**	**Interpretation**	**Notes**
1 - EK NW	35	y = 0.0008x + 0.0013	0.0785	Little or no correlation.	
2 - IID-SCID	0	--	--	Insufficient data to draw trendline.	
3 - EK NE	2	--	--	Insufficient data to draw trendline.	
4 - RIVER	87	y = 0.0002x + 0.0493	0.0018	Little or no correlation.	
5 - EID	180	y = 0.0006x + 0.0299	0.0087	Little or no correlation.	
6 - EK SE	0	--	--	Insufficient data to draw trendline.	
7 - LSID	4	--	--	Insufficient data to draw trendline.	
8 - LID E	63	y = -0.0004x + 0.1093	0.0051	Little or no correlation.	
9 - LID W	72	y = -0.0003x + 0.1317	0.0025	Little or no correlation.	
10 - EK SW	1	--	--	Insufficient data to draw trendline.	
All Data	**444**	**y = 0.0003x + 0.0528**	**0.0033**	**Little or no correlation.**	

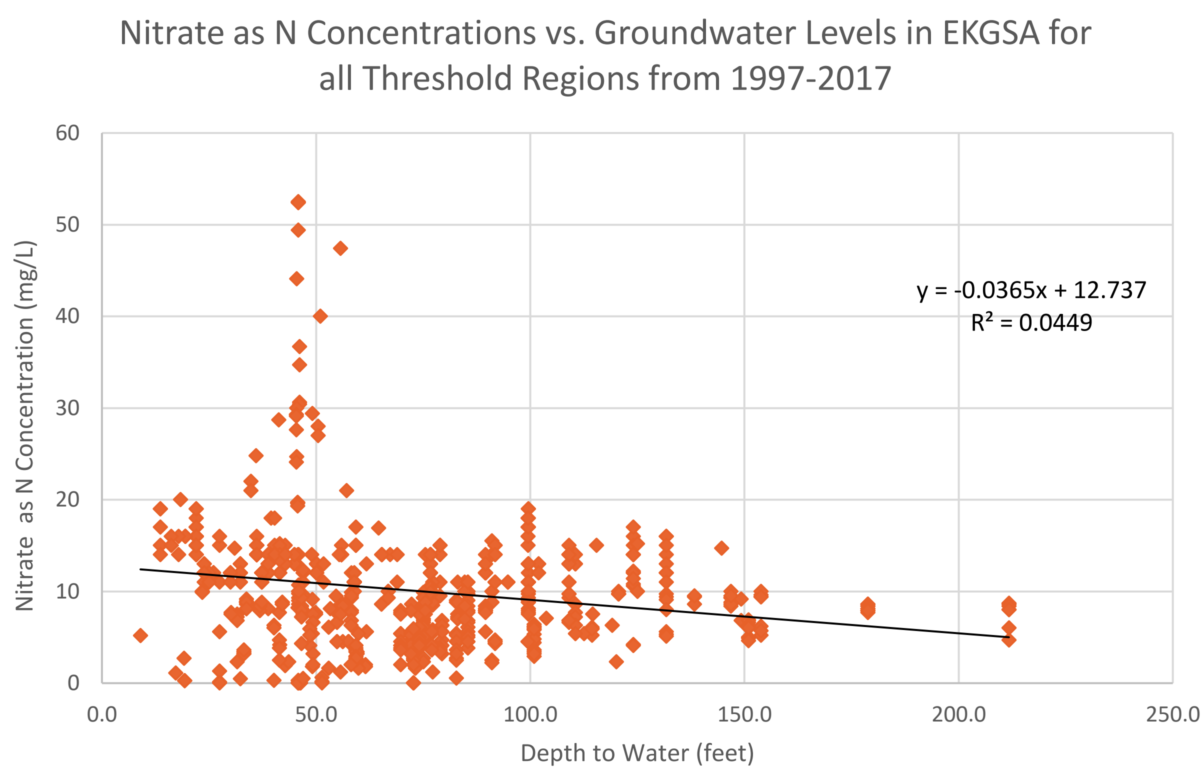

Figure 7. Nitrate concentrations (as N) versus groundwater levels for all EKGSA threshold regions from 1997 to 2017.

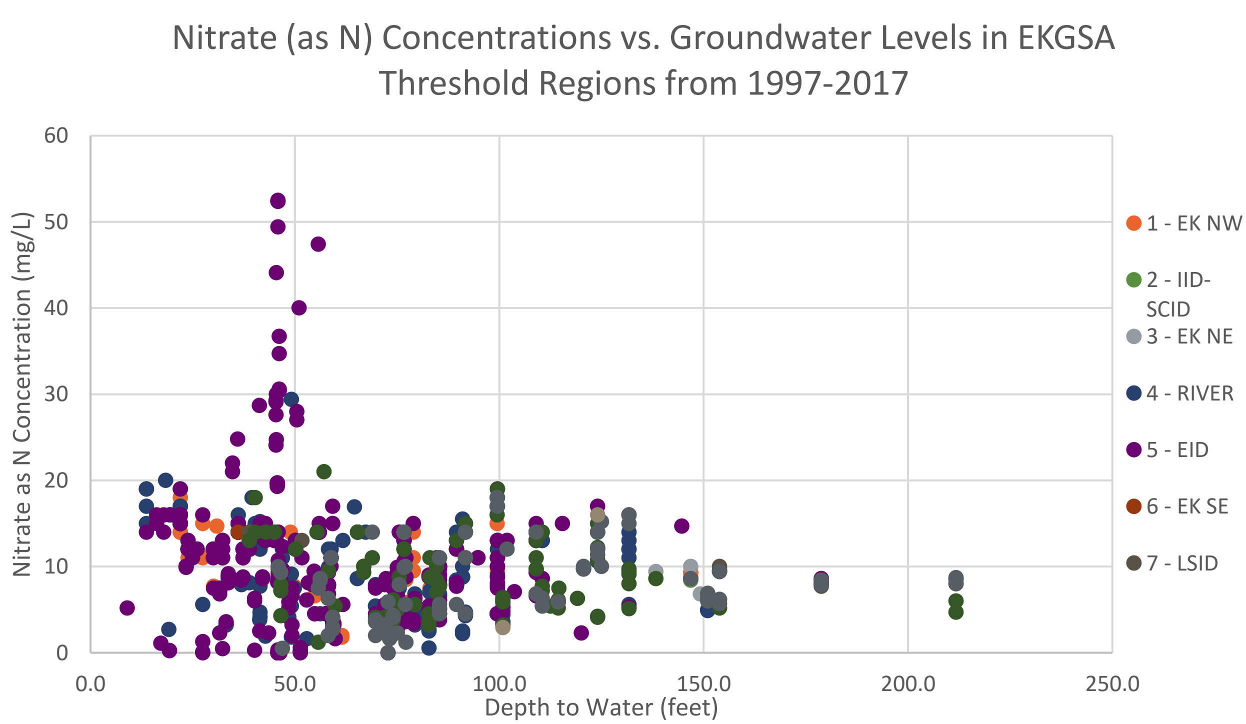

Figure 8. Nitrate concentrations (as N) versus groundwater levels split by EKGSA threshold regions from 1997 to 2017.

Table 4. Summary table of linear regression statistics for Nitrate as N concentrations versus groundwater levels for all EKGSA threshold regions from 1997 to 2017.

NITRATE					
Threshold Region	**Sample Number**	**Linear Equation**	**R-squared Coefficient**	**Interpretation**	**Notes**
1 - EK NW	89	y = -0.0503x + 14.07	0.2194	Weak negative correlation.	
2 - IID-SCID	1	--	--	Insufficient data to draw trendline.	
3 - EK NE	3	--	--	Insufficient data to draw trendline.	
4 - RIVER	207	y = -0.052x + 13.373	0.121	Weak negative correlation.	
5 - EID	337	y = -0.0482x + 13.719	0.0237	Little or no correlation.	
6 - EK SE	1	--	--	Insufficient data to draw trendline.	
7 - LSID	7	y = -0.031x + 12.729	0.2219	Weak negative correlation.	Minimum recommended sample size for linear regressions is n=10.
8 - LID E	91	y = -0.0216x + 11.278	0.0277	Little or no correlation.	
9 - LID W	83	y = 0.0197x + 5.7065	0.0469	Little or no correlation.	
10 - EK SW	2	--	--	Insufficient data to draw trendline.	
All Data	**821**	**y = -0.0365x + 12.737**	**0.0449**	Little or no correlation.	

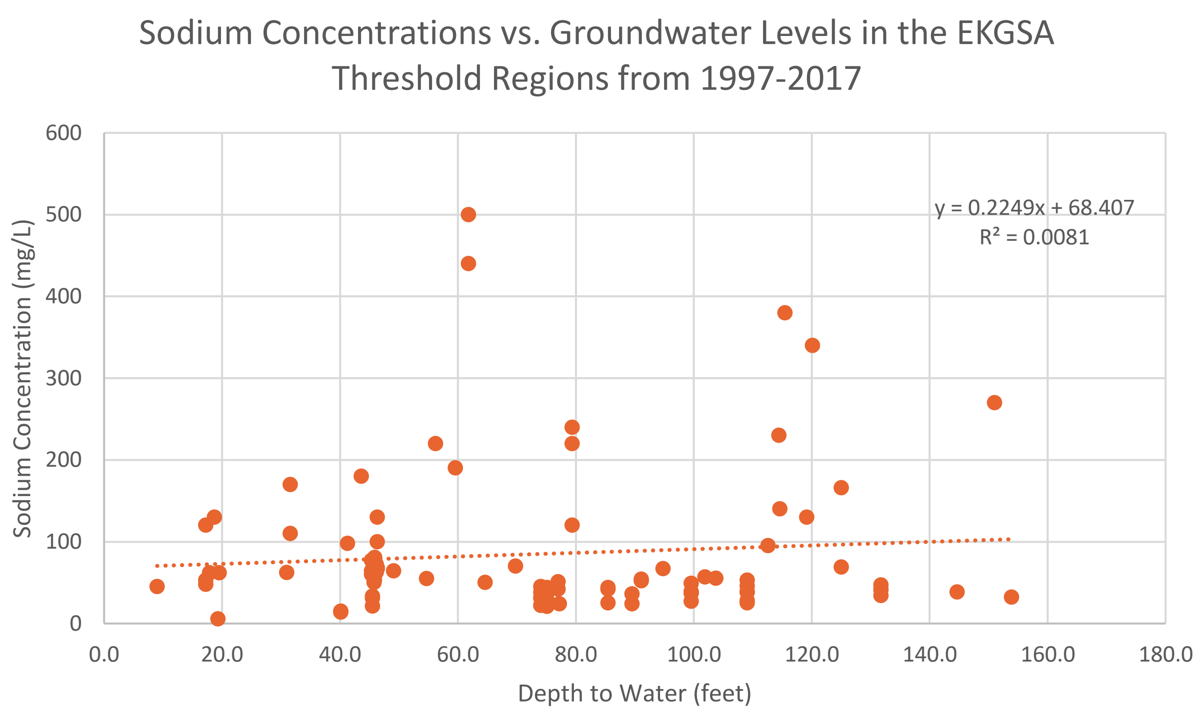

Figure 9. Sodium concentrations versus groundwater levels for all EKGSA threshold regions from 1997 to 2017.

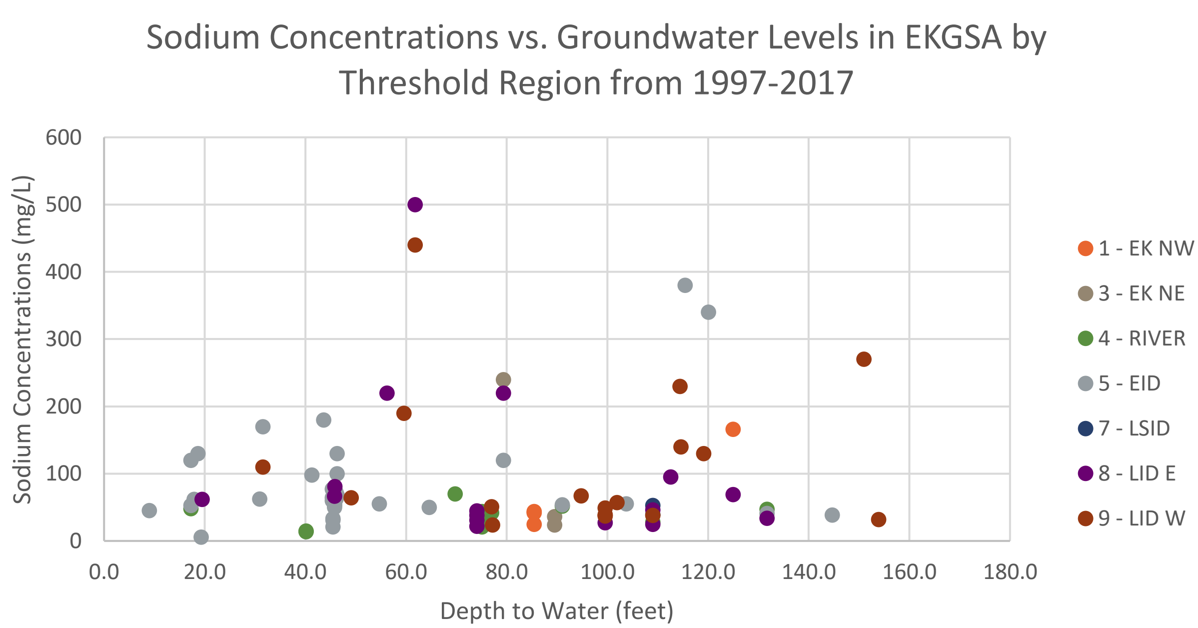

Figure 10. Sodium concentrations versus groundwater levels split by EKGSA threshold regions from 1997 to 2017.

Table 5. Summary table of linear regression statistics for Sodium concentrations versus groundwater levels for all EKGSA threshold regions from 1997 to 2017.

SODIUM					
Threshold Region	**Sample Number**	**Linear Equation**	**R-squared Coefficient**	**Interpretation**	**Notes**
1 - EK NW	5	y = 3.1325x - 238.23	0.8652	Strong, positive correlation	Minimum recommended sample size for linear regressions is n=10.
2 - IID-SCID	0	--	--	Insufficient data to draw trendline.	
3 - EK NE	3	--	--	Insufficient data to draw trendline.	
4 - RIVER	14	y = -0.0227x + 43.543	0.0012	Little or no correlation.	
5 - EID	45	y = 0.7968x + 41.767	0.1149	Weak, positive correlation.	
6 - EK SE	0	--	--	Insufficient data to draw trendline.	
7 - LSID	2	--	--	Insufficient data to draw trendline.	
8 - LID E	16	y = -0.9885x + 178.64	0.0635	Little or no correlation.	
9 - LID W	17	y = -0.2085x + 135.56	0.0038	Little or no correlation.	
10 - EK SW	0	--	--	Insufficient data to draw trendline.	
All Data	**102**	**y = 0.2249x + 68.407**	**0.0081**	**Little or no correlation.**	

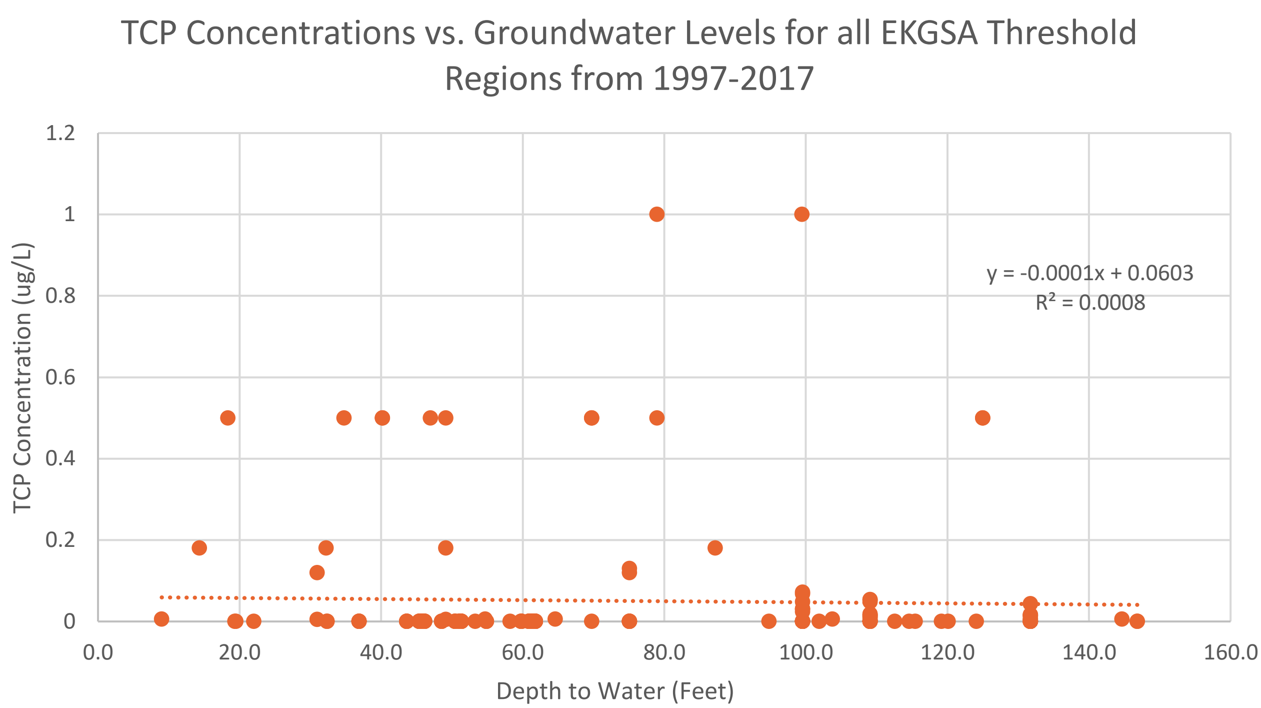

Figure 11. TCP concentrations versus groundwater levels for all EKGSA threshold regions from 1997 to 2017.

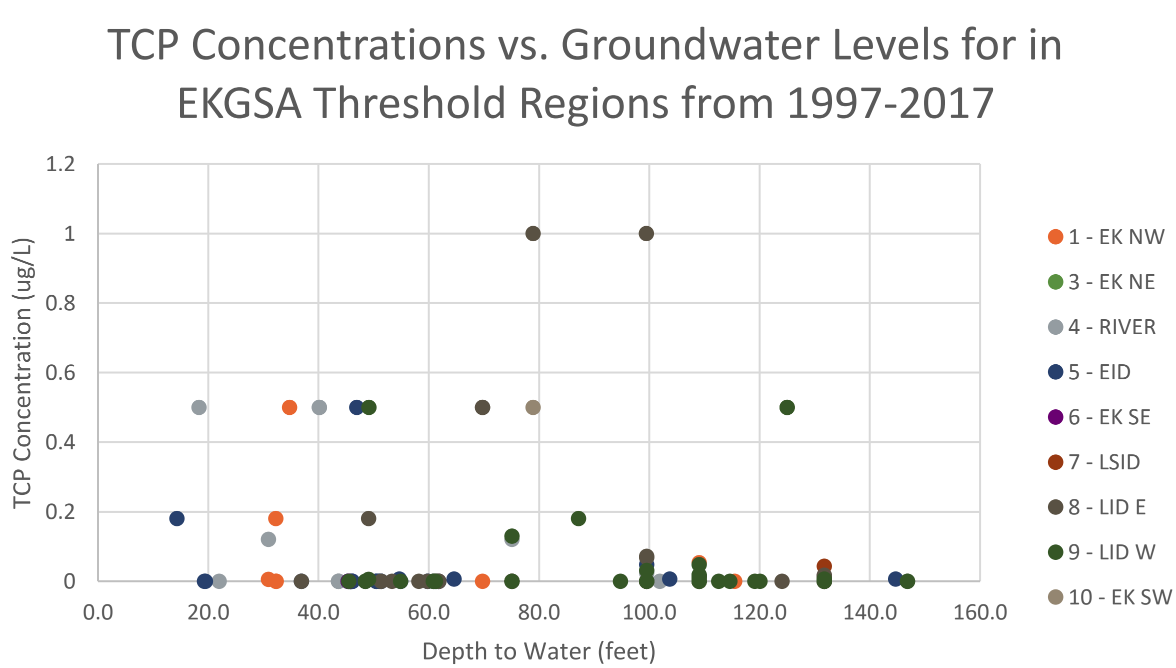

Figure 12. TCP concentrations versus groundwater levels split by EKGSA threshold regions from 1997 to 2017.

Table 6. Summary table of linear regression statistics for TCP concentrations versus groundwater levels for all EKGSA threshold regions from 1997 to 2017.

TCP					
Threshold Region	**Sample Number**	**Linear Equation**	**R-squared Coefficient**	**Interpretation**	**Notes**
1 - EK NW	12	y = -0.0015x + 0.1732	0.1642	Weak negative correlation	
2 - IID-SCID	0	--	--	Insufficient data to draw trendline.	
3 - EK NE	2	--	--	Insufficient data to draw trendline.	
4 - RIVER	30	y = -0.0016x + 0.1623	0.1112	Weak negative correlation.	
5 - EID	63	y = -0.0002x + 0.025	0.0065	Little or no correlation.	
6 - EK SE	3	--	--	Insufficient data to draw trendline.	
7 - LSID	2	--	--	Insufficient data to draw trendline.	
8 - LID E	33	y = -0.0006x + 0.1561	0.0047	Little or no correlation.	
9 - LID W	34	y = 0.00002x + 0.0555	0.00005	Little or no correlation.	
10 - EK SW	1	--	--	Insufficient data to draw trendline.	
All Data	**180**	**y = -0.0001x + 0.0603**	**0.0008**	**Little or no correlation.**	

Appendix 3-D

Potential Well Impact Summary

1 SUMMARY PURPOSE

This summary describes all water supply well completion data available for the San Joaquin Valley - Kaweah Subbasin (Subbasin) since January 1, 2002. The purpose of this summary is estimate for the number of wells that may be impacted by groundwater levels declining to elevations protective of 90% of wells in the Subbasin (described in Appendix 5A). These estimates can be used by the Groundwater Sustainability Agencies (GSAs) to develop well mitigation plans for their respective Groundwater Sustainability Plans (GSPs).

The majority of minimum thresholds described in Appendix 5A are at higher elevations than elevations protective of 90% of wells. The estimates of potentially impacted wells therefore overestimate the number of wells. However, since these estimates are to be used for determining the magnitude of wells to be addressed by mitigation plans, they can be considered worst-case estimates.

2 WELL RECORDS IN THE KAWEAH SUBBASIN

A majority of water supply wells installed in the Subbasin since 2002 have well construction information available from Department of Water Resources (DWR) Well Completion Reports submitted by well drillers. These well records are used to develop chronic lowering of groundwater level sustainable management criteria (SMC), as described in Appendix 5A. This summary supplements potential well impacts described in Appendix 5A by including wells without completed well depth information.

2.1 Data Sources and Quality Control

Well completion information compiled in this appendix is from the DWR Well Completion Report (WCR) dataset, downloaded on March 1, 2022. The WCR dataset does not contain a complete accurate dataset, however, it is the best public source of data available. For example, some wells in the dataset are likely dry or have been destroyed. To filter out wells that may have been abandoned or no longer represent typical modern well depths and current groundwater elevations, only well records drilled since 2002 are used for analysis. Furthermore, well completion reports are not always accurately located. Where coordinates of wells are unavailable, DWR locates the well in the middle of the Public Land Survey System section. The location given by DWR in the WCR dataset is used in this analysis.

2.2 Total Well Records

The majority of water supply well records used in the analysis have known well depths, and the well use type for wells without well depth data are generally proportional to those with depth information. The number of wells installed in the Subbasin both with and without known well depths are included in Table 1. Approximately 3,758 supply wells have been installed in the Subbasin since 2002. Of these, 3,353, or about 89%, have well completion data in the WCR dataset and are used in the SMC analysis described in Appendix A. The proportion of wells used for various purposes is nearly identical for the full WCR dataset compared to the subset of wells with known depths; almost all supply wells are either used for agricultural use (55%) or domestic use (41%). Comparatively small numbers of wells are used for public supply (3%), and industrial (1%) purposes. Since the subset of wells with known depths includes a majority of well records in the dataset and closely approximates well types installed in the Subbasin, it is an appropriate dataset to use to develop mitigation plans.

Table 1. Water Supply Well Records by Use Type

Well Use	All Water Supply Well Records from Jan 1, 2002		Well Records with Depth Information	
	Number of Wells	Percentage	Number of Wells	Percentage
Agricultural	2,061	55%	1,859	55%
Domestic	1,546	41%	1,364	41%
Public Supply	129	3%	117	3%
Industrial	22	1%	13	<1%
TOTAL	3,758	-	3,353	-

2.3 Well Records by GSA

Table 2 summarizes the number of well records by well use type for each GSA. There are approximately 1,276 well records in East Kaweah, 1,814 in Greater Kaweah, and 668 in Mid-Kaweah.

Table 2. Summary of Wells by GSA

Well Use Type	East Kaweah		Greater Kaweah		Mid-Kaweah		Total
	Number of Wells	Percentage	Number of Wells	Percentage	Number of Wells	Percentage	
Domestic	463	36%	814	45%	269	40%	1,546
Agricultural	793	62%	914	50%	354	53%	2,061
Public Supply	17	1%	71	4%	41	6%	129
Industrial	3	<1%	15	1%	4	1%	22
Total	1,276	-	1,814	-	668	-	3,758

2.4 Well Records by Analysis Zone

Well records from each analysis zone may be used by GSAs for well mitigation plans. The total number of well records in each aquifer zone is summarized in Table 3. Figure 1 shows the location of the analysis zones.

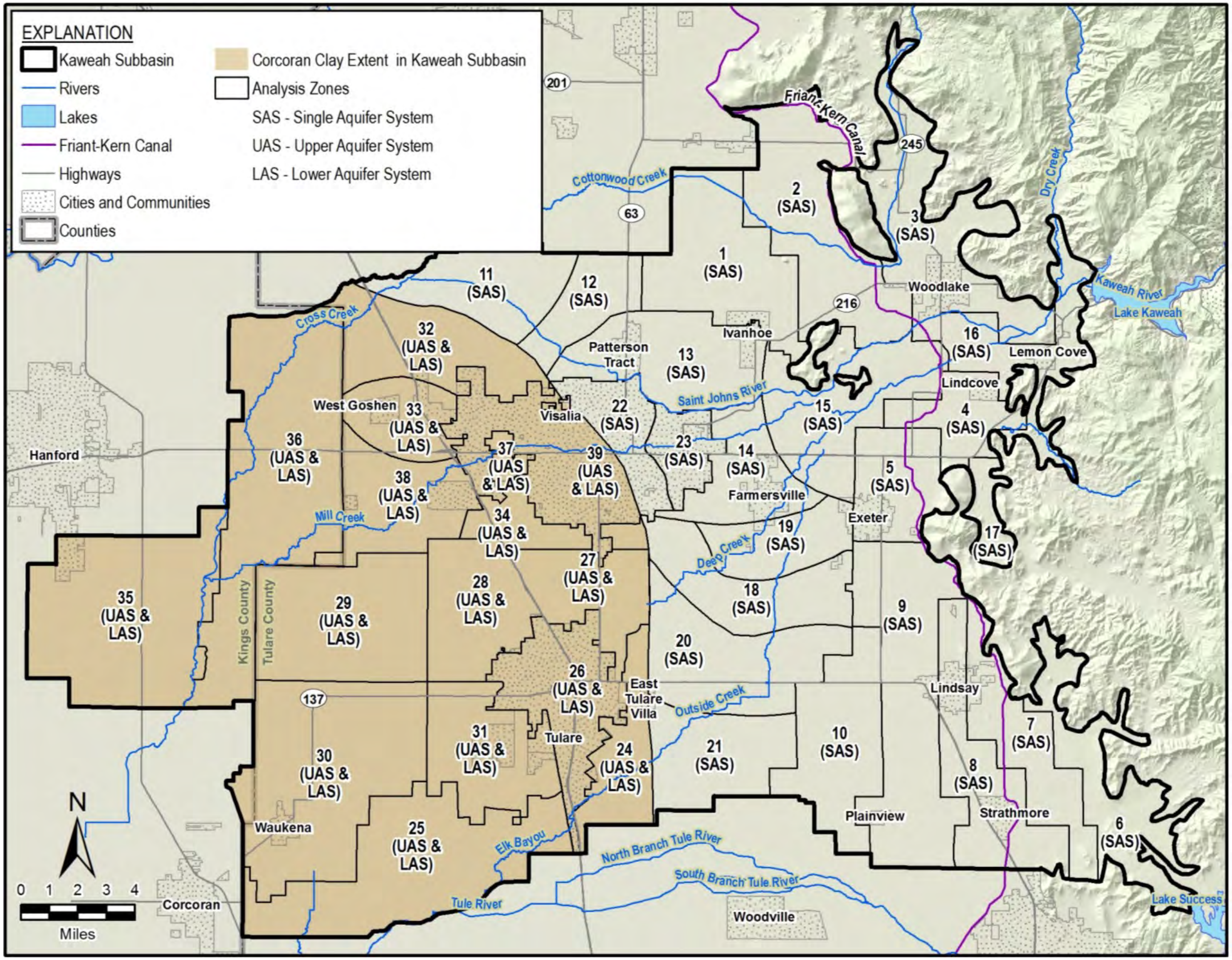

Figure 1. Kaweah Subbasin Analysis Zones

Table 3. Total Well Records by Analysis Zone

Analysis Zone	Agricultural Well Records	Domestic Well Records	Public Well Records	Industrial Well Records	Total Well Records
1	211	118	1	5	335
2	149	23	1	0	173
3	52	39	0	1	92
4	46	42	0	6	94
5	43	29	1	1	74
6	25	9	0	0	34
7	46	18	0	0	64
8	51	56	0	2	109
9	137	99	0	7	243
10	69	52	0	1	122
11	24	2	0	2	28
12	33	30	0	3	66
13	85	146	0	7	238
14	42	52	1	7	102
15	65	73	0	2	140
16	19	46	1	1	67
17	11	3	0	0	14
18	56	62	0	3	121
19	25	87	0	3	115
20	55	88	0	5	148
21	38	12	1	5	56
22	16	6	0	7	29
23	3	7	0	1	11
24	33	33	1	2	69
25	70	3	0	4	77
26	14	18	0	7	39
27	49	75	0	4	128
28	50	69	0	2	121
29	61	19	0	2	82
30	108	52	1	10	171
31	33	8	0	4	45
32	18	1	3	1	23
33	44	32	3	1	80
34	25	52	1	2	80
35	89	29	4	9	131
36	87	8	0	6	101
37	9	15	0	0	24
38	43	16	0	2	61
39	27	17	3	4	51
Total	2,061	1,546	22	129	3,758

3 POTENTIALLY IMPACTED WELLS

3.1 Well Records Shallower than Protective Well Depth by GSA

Wells shallower than protective well depths described in Appendix 5A may be impacted should groundwater elevations approach or exceed minimum thresholds during GSP implementation. The total number of well records shallower than protective well depths in each GSA is estimated using the percentage of wells shallower than the 90th percentile well depth by well use type. Selection of the 90th percentile well depth accounts for uncertainty in the data, especially regarding the likelihood the shallowest wells have been destroyed and replaced during ongoing dry conditions and declining groundwater levels. The analysis is completed using only wells with known well depths. The majority of minimum thresholds described in Appendix 5A are at higher elevations than elevations protective of 90% of wells. The tables that follow therefore overestimate the number of potentially impacted wells. However, since these estimates are to be used for determining the magnitude of wells to be addressed by mitigation plans, they can be considered worst-case estimates.

Table 4 through Table 6 show the approximate number of impacted wells in each GSA, including wells with unknown well depths.

- East Kaweah GSA – approximately 122 wells may be impacted, including 64 domestic wells, 55 agricultural wells, and 3 public supply wells (Table 4).
- Greater Kaweah GSA – approximately 167 wells may be impacted, including 105 domestic wells, 55 agricultural wells, and 7 public supply wells (Table 5).
- Mid-Kaweah GSA – approximately 43 wells may be impacted, including 22 domestic wells and 21 agricultural wells (Table 6).

Table 4. East Kaweah GSA Potentially Impacted Wells

Well Use Type	Well Records with Known Depth			All Well Records		
	Number of Wells	Number of Potentially Impacted Wells	Percentage Potentially Impacted Wells	Number of Wells	Number of Potentially Impacted Wells	Density of Impacted Wells (wells per square mile)
Domestic	418	58	14%	463	64	0.35
Agricultural	721	50	7%	793	55	0.30
Public Supply	16	3	19%	17	3	0.02
Industrial	2	0	0%	3	0	0
Total	1,157	111		1,276	122	0.67

Table 5. Greater Kaweah GSA Potentially Impacted Wells

Well Use Type	Well Records with Known Depth			All Well Records		
	Number of Wells	Number of Potentially Impacted Wells	Percentage Potentially Impacted Wells	Number of Wells	Number of Potentially Impacted Wells	Density of Impacted Wells (wells / square mile)
Domestic	732	96	13%	814	105	0.30
Agricultural	829	49	6%	914	55	0.16
Public Supply	64	6	10%	71	7	0.02
Industrial	8	0	0%	15	0	0
Total	1,633	151		1,814	167	0.48

Table 6. Mid-Kaweah GSA Potentially Impacted Wells

Well Use Type	Well Records with Known Depth			All Well Records		
	Number of Wells	Number of Potentially Impacted Wells	Percentage Potentially Impacted Wells	Number of Wells	Number of Potentially Impacted Wells	Density of Impacted Wells (wells / square mile)
Domestic	214	17	8%	269	22	0.13
Agricultural	309	18	6%	354	21	0.13
Public Supply	37	0	0%	41	0	0
Industrial	3	0	0%	4	0	0
Total	563	35		668	43	0.26

3.2 Well Records Shallower than Protective Well Depth by Analysis Zone

The total number of well records within each analysis zone may be used by the GSAs to estimate potential impacts to be addressed by Well Mitigation Programs. The approximate number of well records that are shallower than the protective well depth in each aquifer zone are summarized in Table 7. Figure 1 shows the location of the analysis zones.

Table 8. East Kaweah GSA Potentially Impacted Wells Summarized by Analysis ZoneTable 8 through Table 10 summarize estimated GSA-specific potential well impacts by well use type.

Table 7. Basinwide Potentially Impacted Wells Summarized by Analysis Zone

Analysis Zone	Agricultural Well Records	Domestic Well Records	Public Well Records	Industrial Well Records	Total Well Records
1	15	19	0	0	34
2	15	3	0	0	18
3	2	2	0	0	4
4	2	7	0	0	9
5	3	4	0	0	7
6	3	1	0	0	4
7	6	1	0	0	7
8	1	9	0	1	11
9	7	14	0	2	23
10	3	7	0	0	10
11	2	1	0	0	3
12	3	3	0	0	6
13	1	16	0	1	18
14	0	10	0	0	10
15	5	10	0	0	15
16	2	4	0	0	6
17	1	1	0	0	2
18	2	11	0	0	13
19	2	6	0	0	8
20	0	14	0	0	14
21	3	2	0	0	5
22	3	1	0	0	4
23	0	2	0	0	2
24	2	4	0	0	6
25	8	1	0	0	9
26	2	0	0	0	2
27	2	4	0	0	6
28	1	3	0	0	4
29	2	2	0	0	4
30	7	8	0	0	15
31	2	1	0	0	3
32	4	0	0	0	4
33	3	4	0	0	7
34	0	6	0	1	7
35	7	1	0	2	10
36	8	1	0	1	10
37	0	1	0	0	1
38	0	6	0	2	8
39	2	1	0	0	3
Total	131	191	0	10	332

Table 8. East Kaweah GSA Potentially Impacted Wells Summarized by Analysis Zone

Analysis Zone	Agricultural Well Records	Domestic Well Records	Public Well Records	Industrial Well Records	Total Well Records
1	15	19	0	0	34
2	15	3	0	0	18
3	2	2	0	0	4
4	1	5	0	0	6
5	2	3	0	0	5
6	3	1	0	0	4
7	6	1	0	0	7
8	1	9	0	1	11
9	7	14	0	2	23
10	3	7	0	0	10
Total	55	64	0	3	122

Table 9. Greater Kaweah GSA Potentially Impacted Wells Summarized by Analysis Zone

Analysis Zone	Agricultural Well Records	Domestic Well Records	Public Well Records	Industrial Well Records	Total Well Records
3	0	0	0	0	0
4	1	2	0	0	3
5	1	1	0	0	2
11	2	1	0	0	3
12	3	3	0	0	6
13	1	16	0	1	18
14	0	10	0	0	10
15	5	10	0	0	15
16	2	4	0	0	6
17	1	1	0	0	2
18	2	11	0	0	13
19	2	6	0	0	8
20	0	14	0	0	14
21	3	2	0	0	5
22	0	0	0	0	0
23	0	0	0	0	0
24	2	4	0	0	6
25	8	1	0	0	9
30	0	0	0	0	0
32	4	0	0	0	4
33	3	4	0	0	7
34	0	6	0	1	7
35	7	1	0	2	10
36	8	1	0	1	10
37	0	1	0	0	1
38	0	6	0	2	8
Total	55	105	0	7	167

Table 10. Mid-Kaweah GSA Potentially Impacted Wells Summarized by Analysis Zone

Analysis Zone	Agricultural Well Records	Domestic Well Records	Public Well Records	Industrial Well Records	Total Well Records
22	3	1	0	0	4
23	0	2	0	0	2
24	0	0	0	0	0
26	2	0	0	0	2
27	2	4	0	0	6
28	1	3	0	0	4
29	2	2	0	0	4
30	7	8	0	0	15
31	2	1	0	0	3
39	2	1	0	0	3
Total	21	22	0	0	43

Appendix 3-E

Technical Approach for Developing Subsidence Sustainable Management Criteria in the Kaweah Subbasin

MONTGOMERY
& ASSOCIATES
Water Resource Consultants

July 27, 2022

Technical Approach for Developing Subsidence Sustainable Management Criteria in the Kaweah Subbasin

Prepared for:

East Kaweah Groundwater Sustainability Agency
Greater Kaweah Groundwater Sustainability Agency
Mid-Kaweah Groundwater Sustainability Agency

Prepared by:

Montgomery & Associates
1023 Nipomo Street, Suite 200
San Luis Obispo, CA 93401

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ACRONYMS & ABBREVIATIONS

1-D Model .....1-Dimensional Compaction Numerical Model
DWR ....California Department of Water Resources
EKGSA ....East Kaweah Groundwater Sustainability Agency
GSA................Groundwater Sustainability Agency
GSP ....Groundwater Sustainability Plan
InSAR ....Interferometric Synthetic Aperture Radar
SGMA............Sustainable Groundwater Management Act
SMC ....Sustainable Management Criteria
Subbasin.........Kaweah Subbasin
TID.................Tulare Irrigation District
USGS ....United States Geological Survey

1 INTRODUCTION

This technical report describes the methodology for developing land subsidence sustainable management criteria (SMC) for the San Joaquin Valley - Kaweah Subbasin (Subbasin). The revisions are in response to the California Department of Water Resources' (DWR) incomplete determination of the 3 Groundwater Sustainability Plans (GSPs) submitted in January 2020 (DWR, 2022). The 3 GSPs are implemented by 3 Groundwater Sustainability Agencies (GSAs) covering the entirety of the Subbasin: East Kaweah GSA, Greater Kaweah GSA, and Mid-Kaweah GSA.

DWR provided a staff report with a statement of findings explaining the incomplete determination for the Subbasin GSPs. The staff report states, "the Plan does not define sustainable management criteria for subsidence in the manner required by Sustainable Groundwater Management Act (SGMA) and the GSP Regulations." DWR's findings specified the following:

- Because Mid-Kaweah and Greater Kaweah did not define subsidence criteria based on conditions that would substantially interfere with land surface uses and users in the Subbasin, Department staff have no basis for evaluating whether continued subsidence predicted by the Plans (potentially 15 feet in the next 20 years in the southwest portion of the Subbasin) would cause significant and unreasonable impacts to land surface uses.
- The East Kaweah GSP better comports with expectations based on the GSP Regulations to develop sustainable management criteria for subsidence. The East Kaweah GSP states that an undesirable result would occur if there were "significant loss of functionality of a structure or a facility to the point that, due to subsidence, the feature cannot be operated as designed requiring either retrofitting or replacement." The East Kaweah GSP identified the Friant-Kern Canal as critical infrastructure for users in the GSA area and determined that a loss of more than 10% of its capacity would be unacceptable. The East Kaweah GSP identified that subsidence over 9.5 inches cumulatively would result in the 10% loss in capacity and, therefore, used 9.5 inches of cumulative subsidence as the minimum threshold.
- The differences between Greater Kaweah and East Kaweah GSPs creates the potential for inconsistency in groundwater management between the Subbasins GSPs. A portion of the Greater Kaweah GSP area bisects the East Kaweah GSP area in the vicinity of the Friant Kern Canal. Greater Kaweah's subsidence minimum thresholds in this area allow for 1.0 to 1.2 inches per year of subsidence, or 20 to 24 inches cumulatively over the 20-year implementation period. Neither the East Kaweah nor the Greater Kaweah GSPs nor the Subbasin Coordination Agreement explain how up to 24 inches of subsidence in the

Greater Kaweah area can be accommodated without interfering with the 9.5-inch limit set by East Kaweah to protect the conveyance capacity of the Friant-Kern Canal. The GSPs will need to reconcile this apparent discrepancy.

DWR's recommended corrective actions include the following:

- Mid-Kaweah and Greater Kaweah must define sustainable management criteria for land subsidence in the manner required by SGMA and the GSP Regulations. The GSAs should develop criteria, including minimum thresholds, measurable objectives, interim milestones, and undesirable results based on the amount of subsidence that would substantially interfere with land surface uses. Developed criteria should be supported with information on the effects of subsidence on land surface beneficial uses and users and the amount of subsidence that would substantially interfere with those uses and users.
- Greater Kaweah also must explain how their minimum thresholds in the vicinity of identified critical infrastructure (i.e., the Friant Kern Canal) will not substantially interfere with the Canal's use (identified by East Kaweah GSA as an undesirable result). Address how the amount of potential cumulative subsidence allowed for by Greater Kaweah's subsidence rates, which currently exceeds the amount identified by East Kaweah that would cause an undesirable result, are compatible or provide revised rates for the eastern portion of the Subbasin that are compatible.

The GSAs were given up to 180 days from the receipt of DWR's staff report to address the deficiencies for land subsidence SMC. This document and the GSP revisions fulfill that purpose.

1.1 General Approach Used to Develop Sustainable Management Criteria

The general approach described herein focuses on estimating future total subsidence over various time horizons and addressing potential damage to water conveyance infrastructure and deep wells. No reliable direct correlation between total subsidence and well collapse has been found. Significant and unreasonable impacts to deep wells are based on commonly used well designs that accommodate subsidence. In the future, should more detailed and local information become available on damage to wells caused by subsidence, this information would be used to re-evaluate the impact of subsidence on well infrastructure.

1.2 Data Sources

In response to DWR comments, the GSAs reviewed the data sources and methods used to select subsidence SMCs. Information and tools used for establishing revised subsidence SMC include:

- Groundwater level monitoring in the Subbasin 1999-2021
- Historical Interferometric Synthetic Aperture Radar (InSAR) measured subsidence data
- Local subsidence benchmark monitoring data
- Possible future groundwater elevations based on revised minimum thresholds
- A 1-Dimensional Compaction Numerical Model (1-D Model) developed by Stanford University researchers
- A subsidence spreadsheet prediction tool developed for the GSAs to simplify and extrapolate subsidence predictions from 1-D Model to the rest of the Subbasin
- Water conveyance infrastructure locations

2 METHODOLOGY USED TO ESTIMATE FUTURE SUBSIDENCE

The methodology presented in this section estimates the total future subsidence that is the basis for setting minimum thresholds. Total subsidence is the annual sum of active subsidence caused by the most recent year's lowering of groundwater levels and any residual subsidence from previous years. The method uses historical groundwater elevations, historical subsidence measurements, the 1-D subsidence model, a subsidence spreadsheet prediction tool, and revised chronic lowering of groundwater levels minimum thresholds to establish estimated rates of total future maximum (worst-case) subsidence.

The 1-D model was built and calibrated using the following data and approach:

- An initial model was developed using Fall groundwater levels to simulate historical subsidence between 1999 and 2021.
- The model was calibrated against 2015 to 2021 subsidence data collected using InSAR available from DWR.
- The model was extended from 2021 through 2070 using minimum thresholds as the ultimate groundwater elevations.
  - Chronic lowering of groundwater levels minimum thresholds described in Appendix 5A are used to estimate a groundwater elevation trend between 2021 and 2040.
  - The minimum threshold "worst-case" groundwater elevations are held stable in the model between 2040 and 2070.

The 1-D model results are used to develop a simplified subsidence spreadsheet prediction tool to extrapolate the 1-D model predictions to other areas in the Subbasin. The subsidence predictions from the spreadsheet tool are used to evaluate the impact that subsidence might have on conveyance infrastructure if groundwater levels stabilize in 2040 at the chronic lowering of groundwater levels minimum thresholds.

2.1 1-Dimensional Compaction Numerical Model

A 1-D Model developed by Stanford University researchers (Lees *et al.*, 2022) estimates subsidence in two locations in and adjacent to the Subbasin. Stanford University researchers calibrated historical subsidence at the South Hanford and Tulare Irrigation District (TID) Sites, shown on Figure 1 (Lees *et al.*, 2022). Only the results from the South Hanford Site are published by Lees (2022). Stanford researchers used the calibrated 1-D Model to estimate the amount of future subsidence through 2070 at the two sites if groundwater elevation declines to the minimum thresholds.

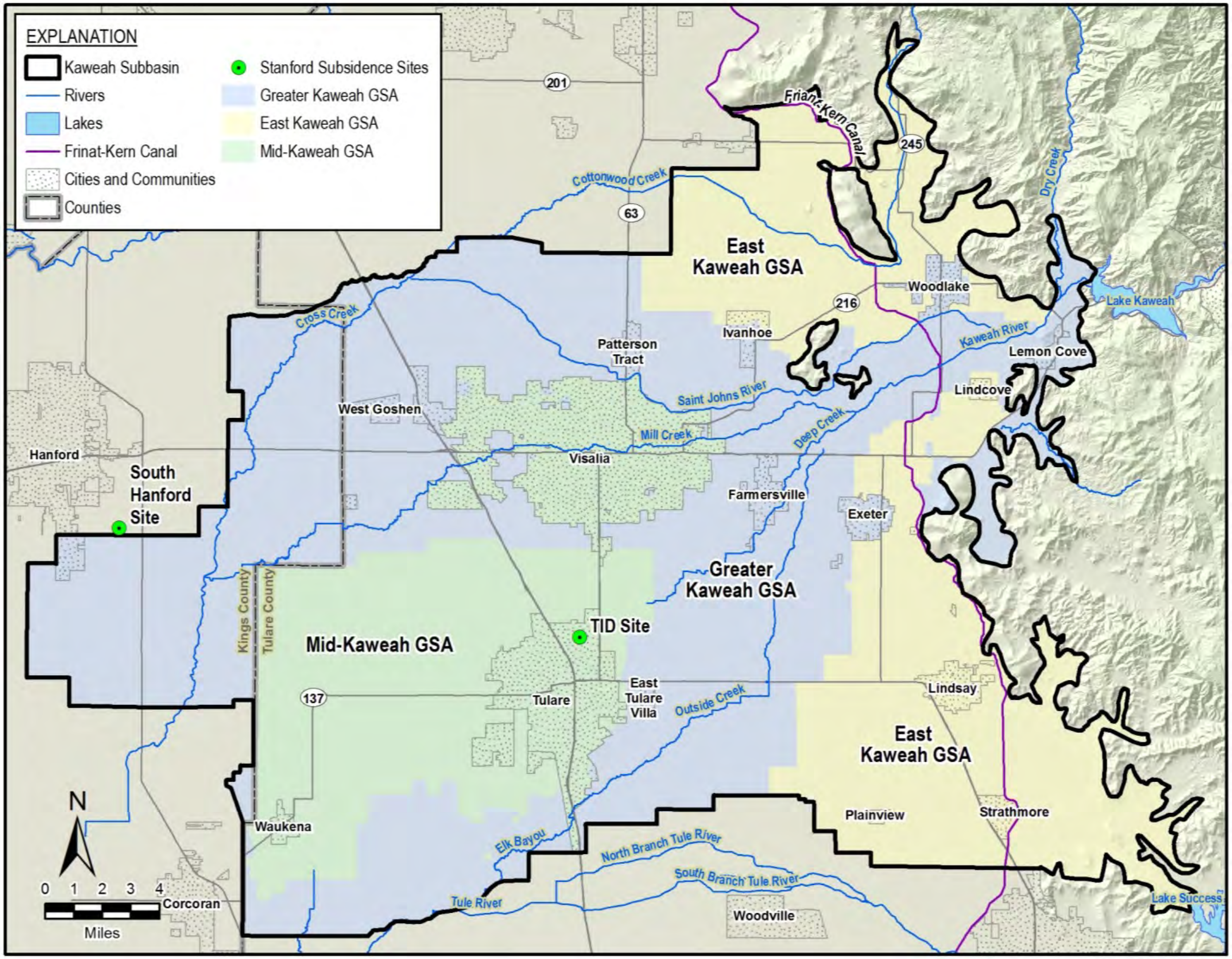

Figure 1. Subsidence Prediction Locations, derived from Lees *et al.*, 2022

2.1.1 Data Sources and Equations

The 1-D Model is built using governing equations for clay compaction with reduction in groundwater head. The equations were originally described in the late 1970s in a United States Geological Survey report (Helm, 1975). The Lees *et al.* (2022) model uses the number and thickness of various clay layers from geophysical logs, historical groundwater elevation data, and historical subsidence estimates from 1952 to 2017 to build and calibrate a model to match subsidence observations. Multiple physical parameters are adjusted to assess sensitivity and uncertainty and develop a range of potential solutions. The calibration results in reasonable values for vertical hydraulic conductivity, specific storage, initial stress, aquifer depth, and the residual timescale for subsidence (Lees *et al.*, 2022).

2.1.2 1-D Model Results

The 1-D model results show significant residual subsidence related to overdraft in the Subbasin is expected to occur for many decades following stabilization of groundwater elevations (Lees *et al.*, 2022). Most compaction, about 90 to 94% at the South Hanford site, occurs in the lower aquifer below the Corcoran Clay.

The model’s subsidence predictions for the worst case of groundwater elevations declining and stabilizing at the minimum thresholds are shown on Figure 2 for the South Hanford site and Figure 3 for the TID site. The blue lines on these figures show historical and predicted shallow aquifer groundwater elevations. The red lines on these figures show historical and predicted deep aquifer groundwater elevations. These lines demonstrate how groundwater elevations equilibrate at minimum thresholds beginning in 2040. The yellow line on these figures is the model-estimated subsidence, and the green dots are the measured subsidence from InSAR data.

Predicted subsidence at the South Hanford site is about 27 feet from 2020 to 2040 and about 18 feet from 2040 to 2070, for a total future subsidence of 45 feet. Predicted subsidence at the TID site is about 13 feet from 2020 to 2040 and about 8 feet from 2040 to 2070, for a total future subsidence of 21 feet. Models for both sites show residual subsidence continuing for decades after groundwater elevations stabilize in 2040. Figure 2 and Figure 3 do not show expected subsidence, but rather the maximum subsidence under worst-case conditions.

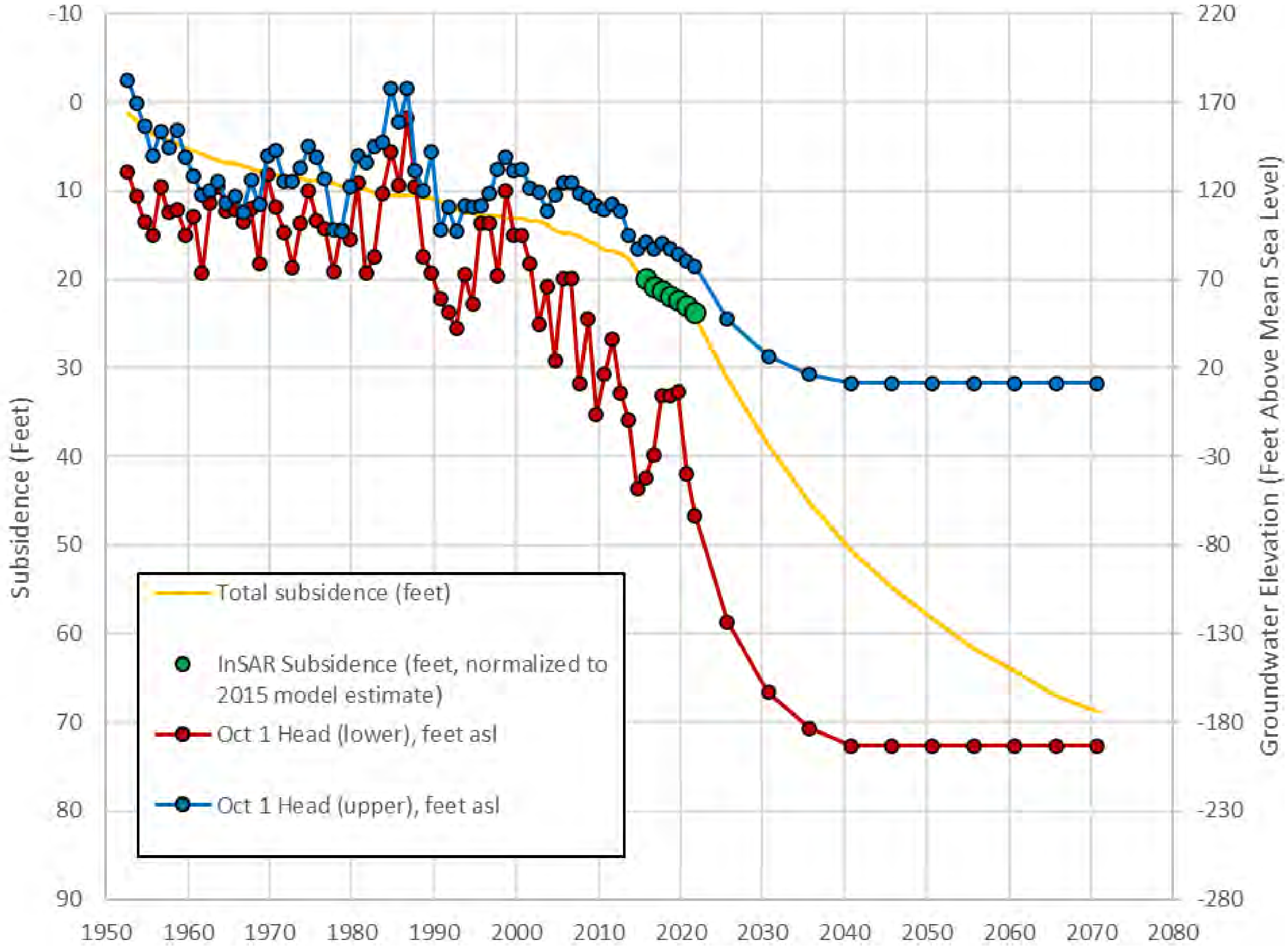

Figure 2. South Hanford Site Subsidence and Groundwater Elevation Time-Series, derived from Lees *et al*., 2022

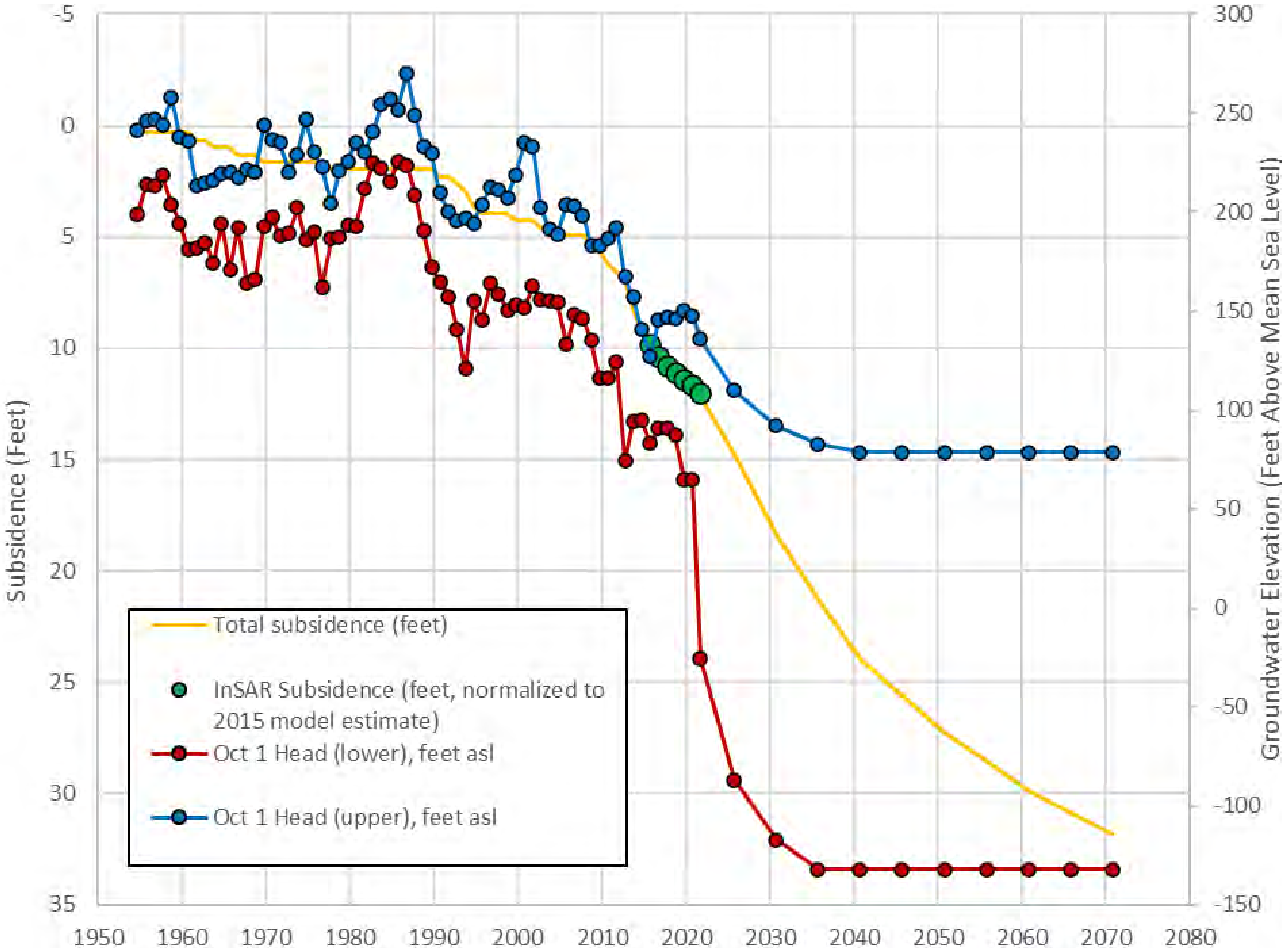

Figure 3. TID Site Subsidence and Groundwater Elevation Time-Series, derived from Lees *et al*., 2022

2.1.3 Subsidence Spreadsheet Prediction Tool

Results from the 1-D Model are used to develop a simple spreadsheet tool to predict subsidence spatially throughout the Subbasin. A grid of 77 points plotted at 2-mile intervals is used to extrapolate the 1-D Model subsidence predictions (Figure 4). This grid is chosen to align with the United States Geological Survey's (USGS) textural model of the San Joaquin Valley (Faunt, 2009). The spreadsheet tool is used to predict subsidence at each point from 2020 to 2040, and from 2040 to 2070 based on historical groundwater elevation trends and chronic lowering of groundwater levels minimum thresholds provided by the GSAs.

2.1.4 Spreadsheet Tool Data Sources

The parameters in the spreadsheet tool are historical groundwater elevation, groundwater elevation minimum threshold, and estimated clay thickness. Fall groundwater elevation from the GSP groundwater model for years 1999 through 2017 and recent manual measurements in 2021 are used to estimate annual groundwater elevations. Groundwater elevation time series are compiled for the Lower and Upper Aquifer Systems in areas where the Corcoran Clay is present and for the Single Aquifer System in areas where Corcoran Clay is absent. An initial estimate of fine sediment thickness is derived from the USGS' textural model of the San Joaquin Valley. The textural model lumps silts and clays and therefore overestimates total clay thickness.

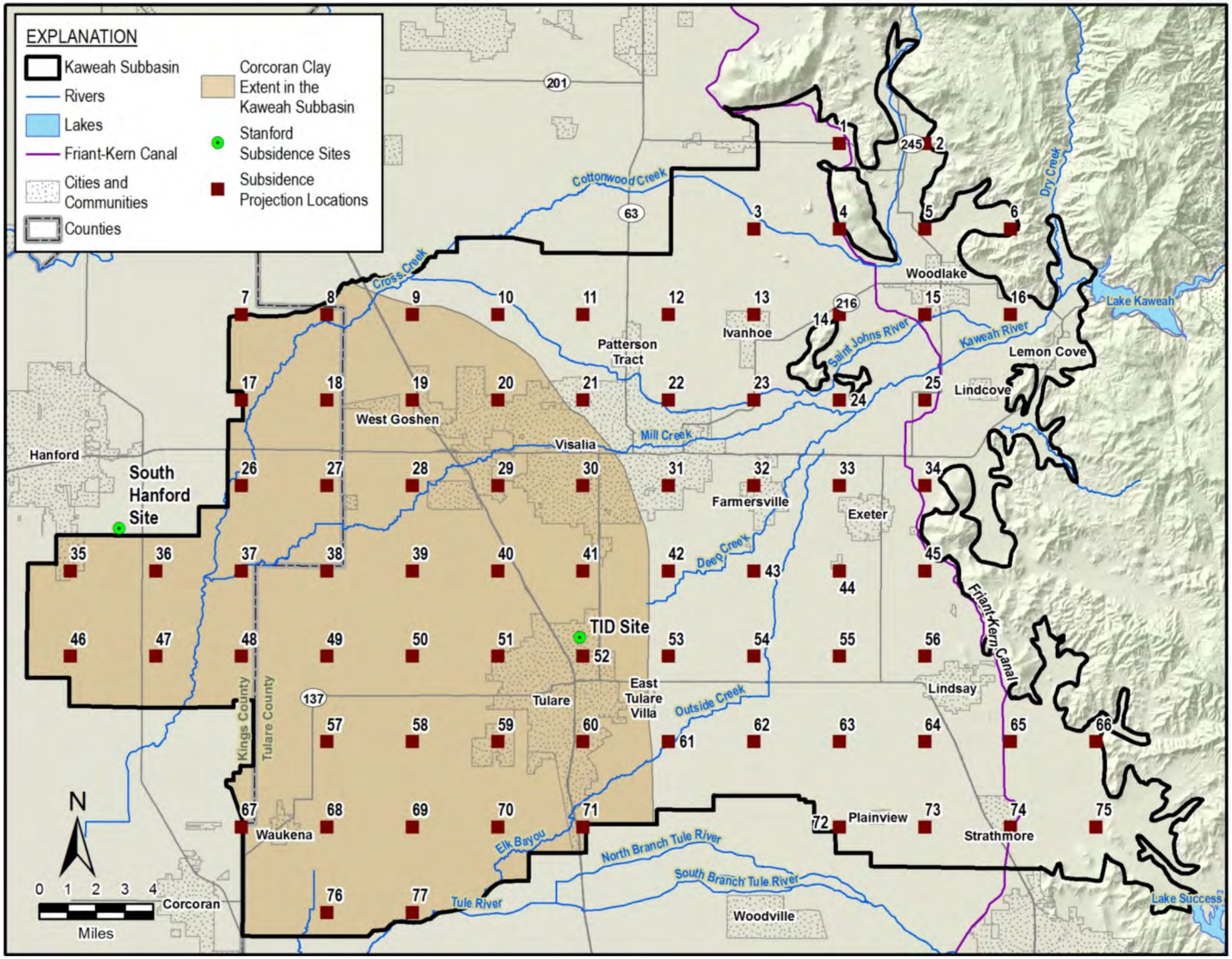

Figure 4. Subsidence Prediction Locations

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2.1.5 Equations to Extrapolate Subsidence Across the Subbasin

A simplified set of equations is developed to extrapolate subsidence predicted from the 1-D Models for the South Hanford and TID sites to other locations with less refined data. An identical set of equations and variables are matched in the spreadsheet tool to the 1-D Model results at both the South Hanford and TID sites, only changing clay thickness to reflect site specific clay thickness at each site from geophysical logs.

A simplified equation for cumulative subsidence (Equation 1) is developed using scaling factor (Equation 2) and residual subsidence (Equation 3). These equations are empirical approximations of the more complex, physically based set of compaction equations described in Lees *et al*., 2022 and Helm, 1975:

Equation 1

$$Cumulative\ Subsidence = (Overdraft \times scaling\ factor) + \sum_{0}^{n} residual\ subsidence_{(n)}$$

Equation 2

$$Scaling\ factor = total\ clay\ thickness^2 \times scaling\ coefficient$$

Equation 3

$$Residual\ subsidence_{(n)} = Active\ subsidence_{(n)} \times residual\ subsidence\ factor$$

Where n is the number of previous years of subsidence.

2.1.5.1 Equation 1: Cumulative Subsidence

$$Cumulative\ Subsidence = (Overdraft \times scaling\ factor) + \sum_{0}^{n} residual\ subsidence_{(n)}$$

The cumulative subsidence estimate is the sum of active subsidence from overdraft in the current year and residual subsidence from overdraft in all prior years. Active subsidence for the current year is calculated only if groundwater levels drop below the previously lowest measured groundwater levels.

Subsidence is influenced by groundwater levels in both the Upper and Lower Aquifer Systems. Lees *et al.* estimated that 93% of subsidence is related to overdraft in the Lower Aquifer System, and 7% of subsidence is related to overdraft in the Upper Aquifer System. Therefore, active subsidence is calculated for each aquifer and then weighted according to the percentages identified by Lees *et al*., 2022. In the Single Aquifer System area where the Corcoran Clay is not present, 7% of overdraft is assumed to contribute to subsidence because the Single Aquifer System is unconfined, like the Upper Aquifer System. Consequently, overdraft in the Single Aquifer System does not appear to cause as much subsidence as overdraft below the Corcoran Clay. This is supported by very little historical subsidence east of the Corcoran Clay observed in InSAR data from 2015 to 2022 (DWR InSAR data), or in DWR data from 1954 to 2006 (DWR TRE Altamira data), despite some observed historical overdraft.

2.1.5.2 Equation 2: Scaling Factor

$$Scaling\ factor = total\ clay\ thickness^2 \times scaling\ coefficient$$

A consistent scaling factor was applied to equation 1 by using a single scaling coefficient throughout the Subbasin and varying the total clay thickness. The clay thickness for South Hanford and TID sites was assigned using geophysical logs collected during well installations. Clay thickness was adjusted at other sites to calibrate the model as discussed in Section 2.1.7. The scaling coefficient is fit to the South Hanford and TID site data and held constant for the 77 prediction sites. This coefficient simplifies the governing differential equation described in Lees *et al*., 2022, that incorporates vertical hydraulic conductivity, storage coefficient, and the sum of squared individual clay layer thicknesses.

2.1.5.3 Equation 3: Residual Subsidence

$$Residual\ subsidence_{(n)} = Active\ subsidence_{(n)} \times residual\ subsidence\ factor$$

A simplified equation was developed to account for residual subsidence from previous years' active subsidence. The equation multiplies the active subsidence in any previous year by a residual subsidence factor that decreases over time. The equation is designed to add a lesser amount of residual subsidence over time as the effects of past overdraft diminish. The residual subsidence factor, shown on Figure 5, was fit to the 1-D Model data for South Hanford and TID sites and then applied throughout the Subbasin.

As an example, Figure 5 shows that after 50 years, only 20% of the active subsidence from the first year is added to the total subsidence calculation. Lees *et al*. (2022) and other research on subsidence has found that residual subsidence can occur for long periods, even after groundwater elevations stabilize. For example, at the South Hanford site, Lees *et al*. predicted that significant subsidence occurs for at least 64 years after overdraft stops and groundwater elevations are held constant. This long residual subsidence is due to much slower head equilibration and compaction in thick clay interbeds. Lees *et al.* acknowledges that this approach is conservative as they expect that the compressibility of clays will reduce over time as clays near ultimate compaction.

2.1.6 Spreadsheet Tool Development

Figure 6 shows how calculations from the spreadsheet tool fit the model used by Lees *et al*. for the South Hanford and TID sites. The results from Lees *et al*. are shown in yellow, and the results from the spreadsheet tool are shown in blue.

As shown on Figure 6, the spreadsheet tool is calibrated to groundwater elevation and subsidence from 1954 to 2017 to present. The 1954 to 1998 groundwater level and subsidence data are available at the South Hanford and TID sites, but not throughout the Subbasin. Subsidence predictions throughout the Subbasin were therefore based only on groundwater elevation data available from 1999 to 2021 and future estimated groundwater levels.

To demonstrate the effect of limiting the groundwater level data in the spreadsheet tool to data collected between 1999 and 2021, the fit between the spreadsheet tool using only data between 1999 and 2021 at the TID and South Hanford sites is shown with the Lees *et al*. results on Figure 7. The results on Figure 7 are not as accurate as the results using the more extensive groundwater elevation dataset from 1954 to 2017, shown on Figure 6. This is because residual subsidence from overdraft prior to 1999 is not accounted for in the Figure 7 results. However, Figure 7 shows that the error in the spreadsheet diminishes over time, suggesting the spreadsheet model remains valid for estimating long-term subsidence.

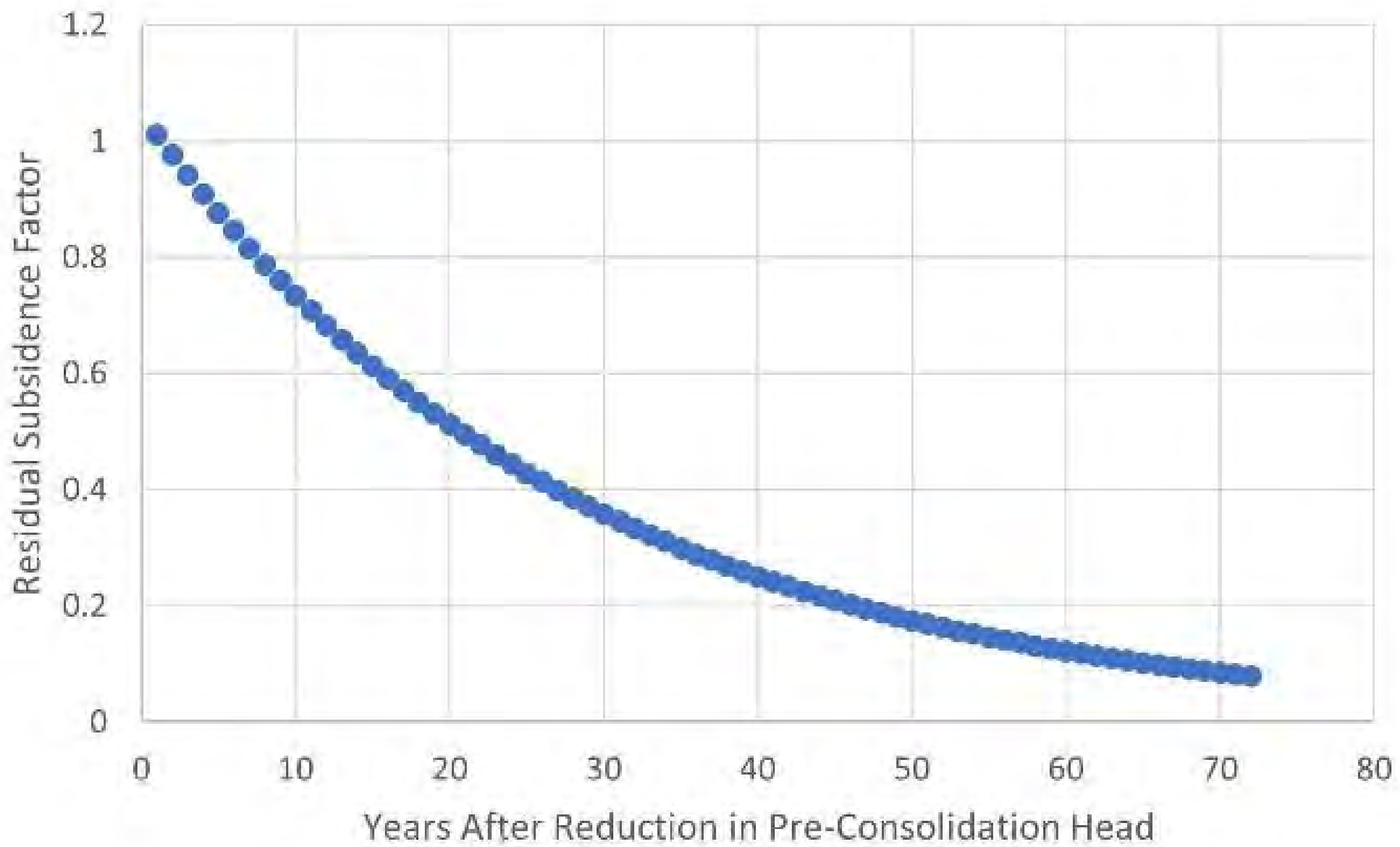
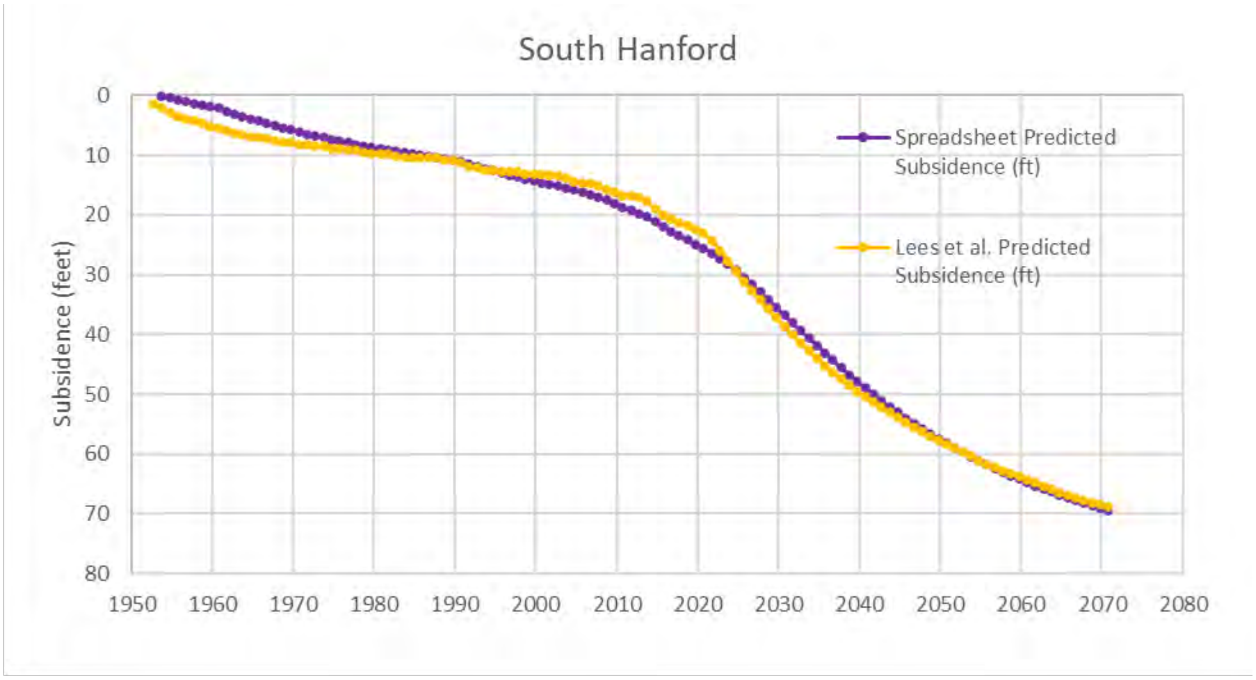


Figure 5. Residual Subsidence Factors for Years After Reduction in Pre-Consolidated Head



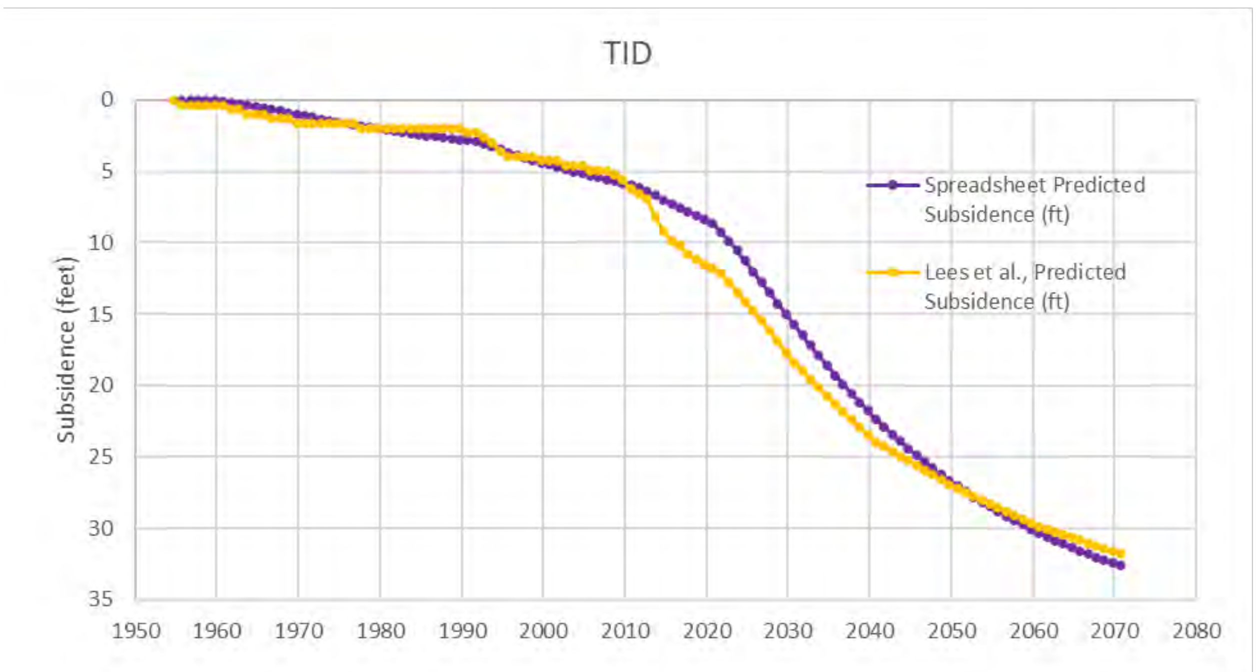
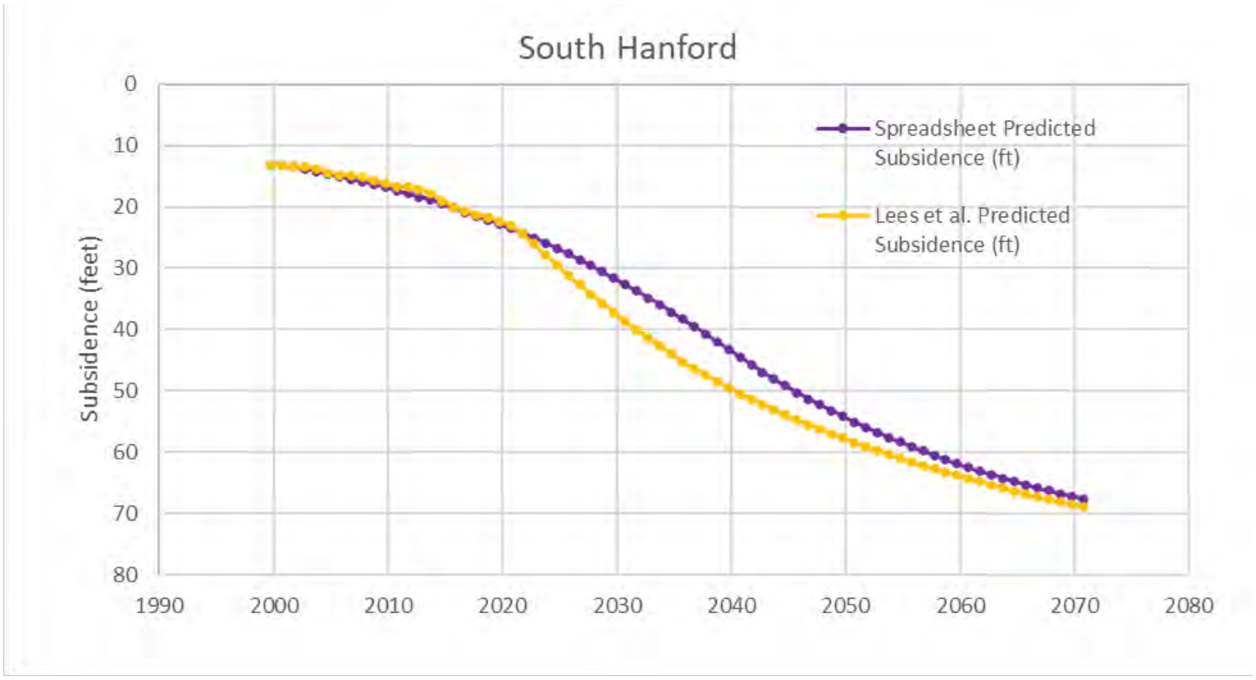


Figure 6. Spreadsheet and Model Predicted Subsidence at South Hanford and TID Sites, 1954-2070



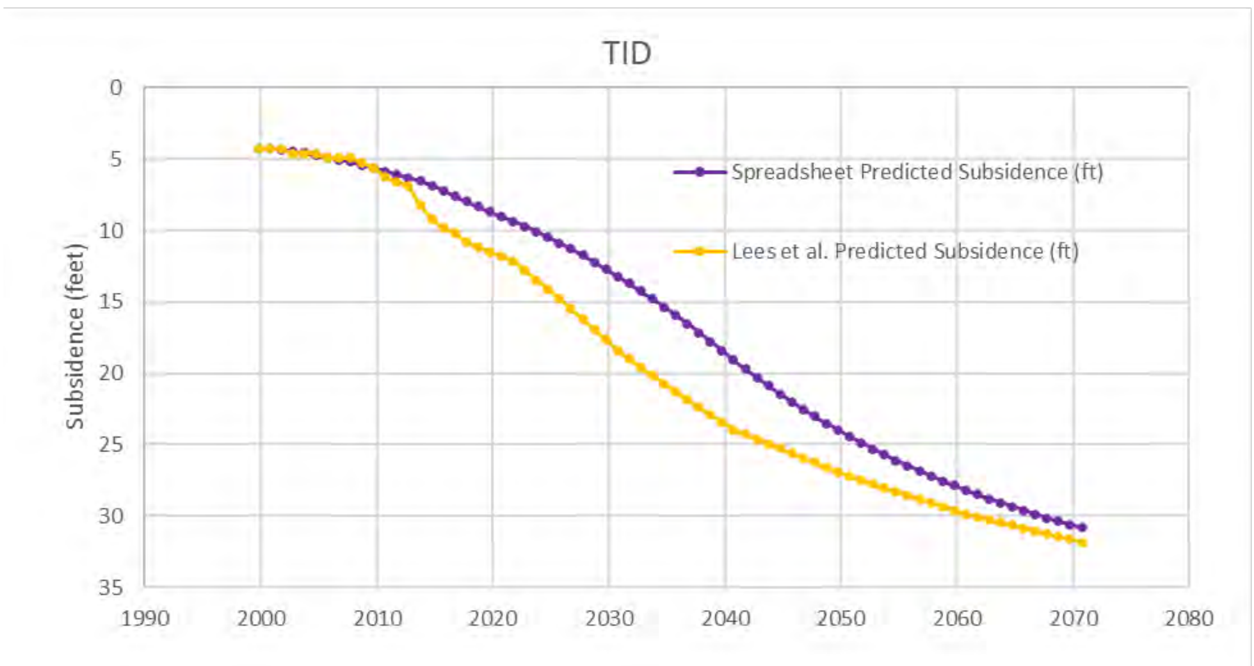


Figure 7. Spreadsheet and Model Predicted Subsidence at South Hanford and TID Sites, 1999-2070

2.1.7 Spreadsheet Tool Calibration

Total clay thickness is adjusted to calibrate the spreadsheet tool to match subsidence measured by InSAR between 2015 and 2021. The calibrated clay thickness is shown on Figure 8. This figure represents the total clay thickness, not the thickness of specific clay layers such as the Corcoran Clay. A comparison of the InSAR measured subsidence and calibrated model predicted subsidence is shown on Figure 9. Where subsidence was greatest in the western portion of the Subbasin, the model was calibrated to estimate slightly less subsidence than the InSAR data to account for underprediction shown on Figure 7. InSAR measured little to no subsidence in the eastern portion of the Subbasin where the Corcoran Clay is absent. The spreadsheet tool is not developed to estimate elastic subsidence or increase in land surface elevation when groundwater elevations increase, so subsidence in the eastern portion of the Subbasin may be slightly overestimated by this simplified approach.

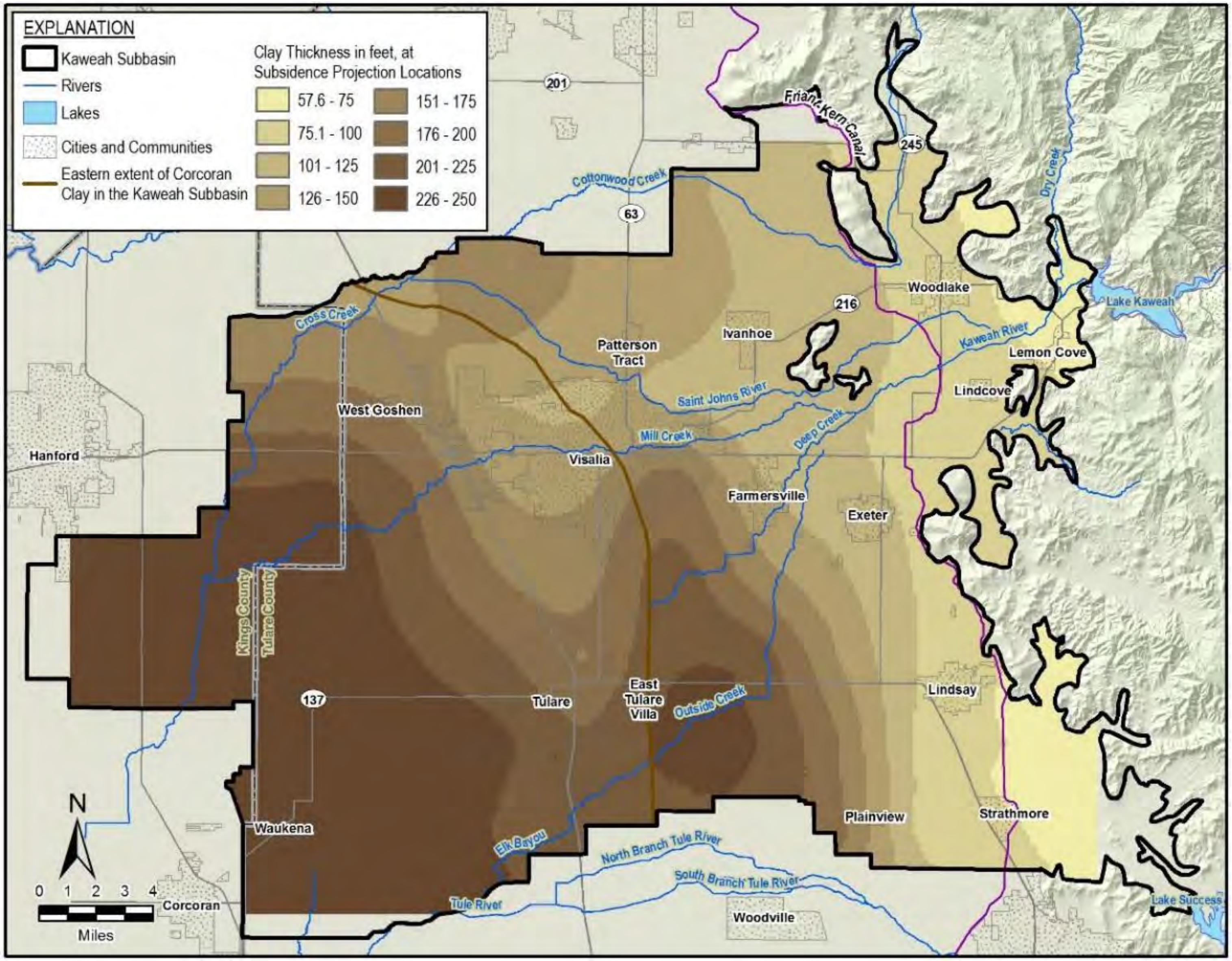


Figure 8. Clay Thickness from Spreadsheet Tool Calibration

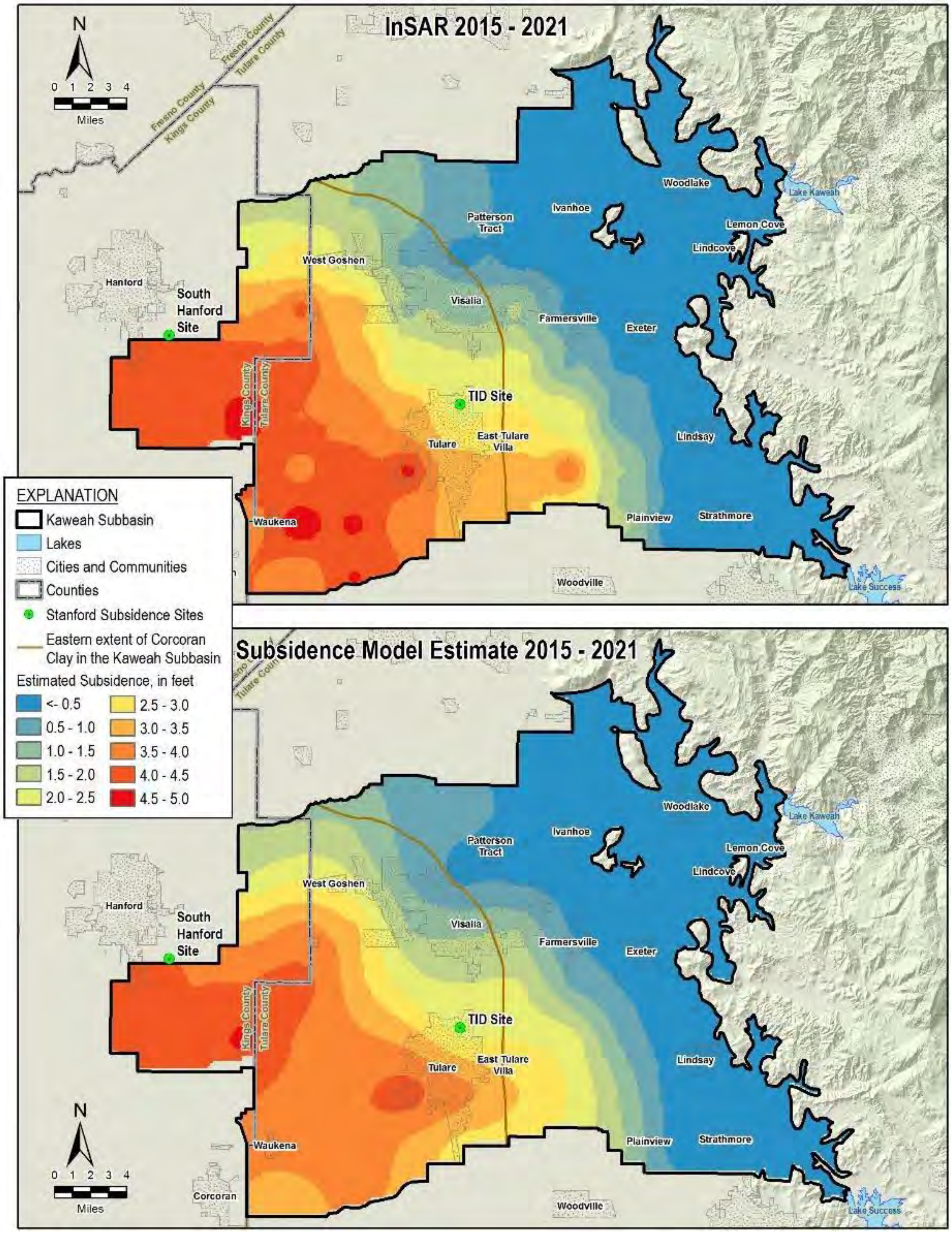


Figure 9. Subsidence from InSAR (top) Compared to Spreadsheet Model Estimate from 2015 to 2021 (bottom)

2.1.8 Spreadsheet Tool Results

Subsidence in the Subbasin is projected using the spreadsheet tool to continue over the SGMA planning and implementation horizon. This is substantiated by the results published by Lees *et al*., 2022, which estimates up to 10 feet of subsidence will occur at the South Hanford site even if groundwater level declines are halted immediately.

2.1.8.1 Subsidence at Groundwater Elevation Minimum Thresholds

If groundwater elevations decrease and stabilize at the minimum threshold, up to 20.2 feet of subsidence could occur between 2020 and 2040 (1 foot/year) as shown on Figure 10. Up to 22.9 feet of subsidence could occur between 2040 and 2070 (0.76 feet/year) as shown on Figure 11. These results are similar to the 1-D model results at the South Hanford site, which predicts approximately 27 feet of subsidence between 2020 and 2040, and 18 feet of subsidence from 2040 to 2070.

All subsidence between 2040 and 2070 is residual subsidence. The model assumes that the Subbasin achieves sustainability in 2040, and no new subsidence is activated over the ensuing 30 years. The subsidence shown on Figure 11 is the cumulative result of progressively less subsidence every year since 2040.

Figure 12 shows that Subbasin-wide subsidence could range between less than 1 foot and 43.1 feet over the full 50-year planning and implementation horizon. This equates to subsidence rates up to 10.4 inches per year. The greatest subsidence is located near the South Hanford site. Very little subsidence is predicted to occur along the eastern edge of the Subbasin.

Subsidence is measured in the Subbasin at a series of subsidence monitoring points, shown on Figure 13. The estimated subsidence when groundwater elevations stabilize at the minimum thresholds is shown for each subsidence measuring point in Table 1 as both a total subsidence and an equivalent subsidence rate.

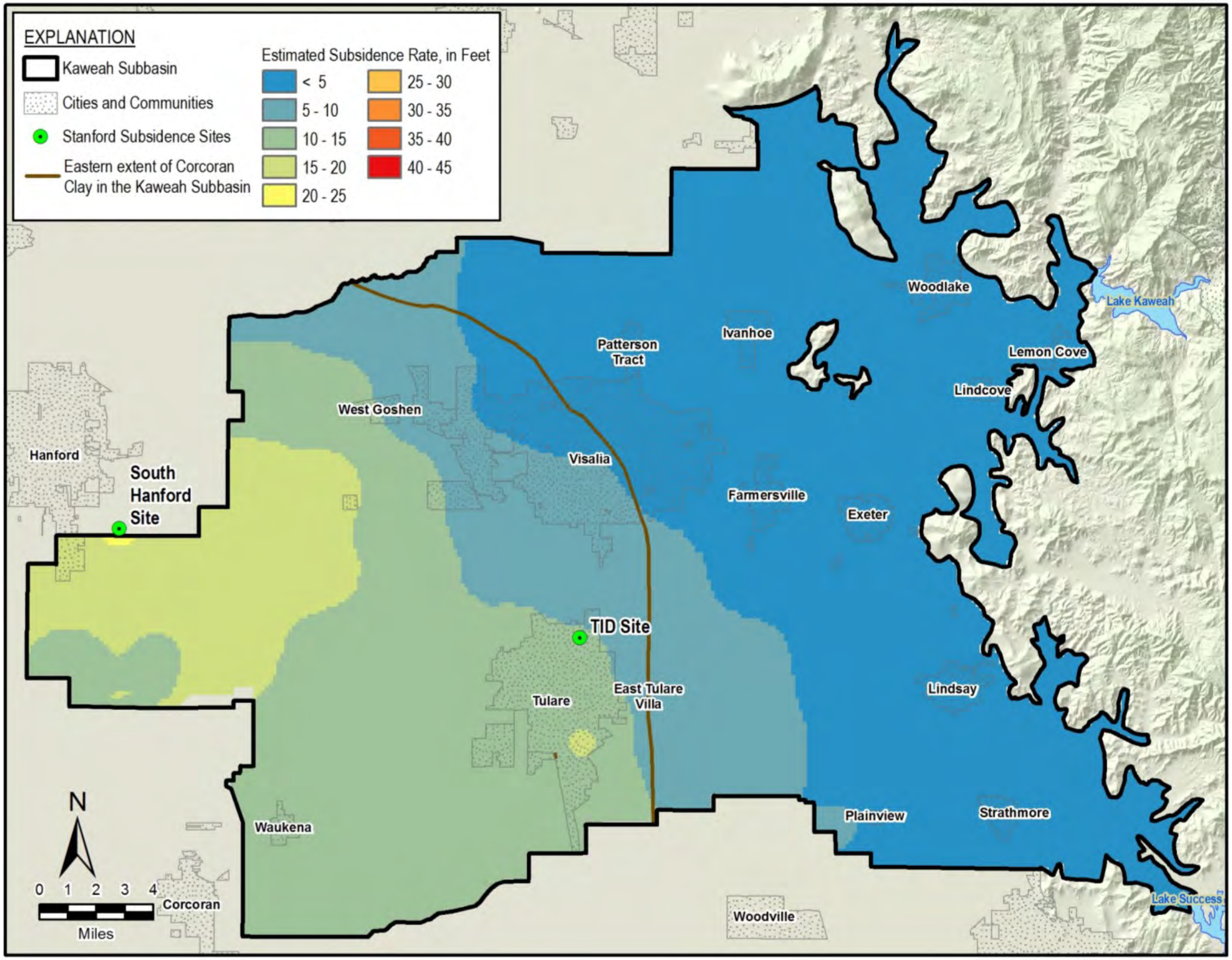


Figure 10. Spreadsheet Tool Estimated 2020 to 2040 Subsidence when Groundwater Levels Stabilize at Minimum Thresholds

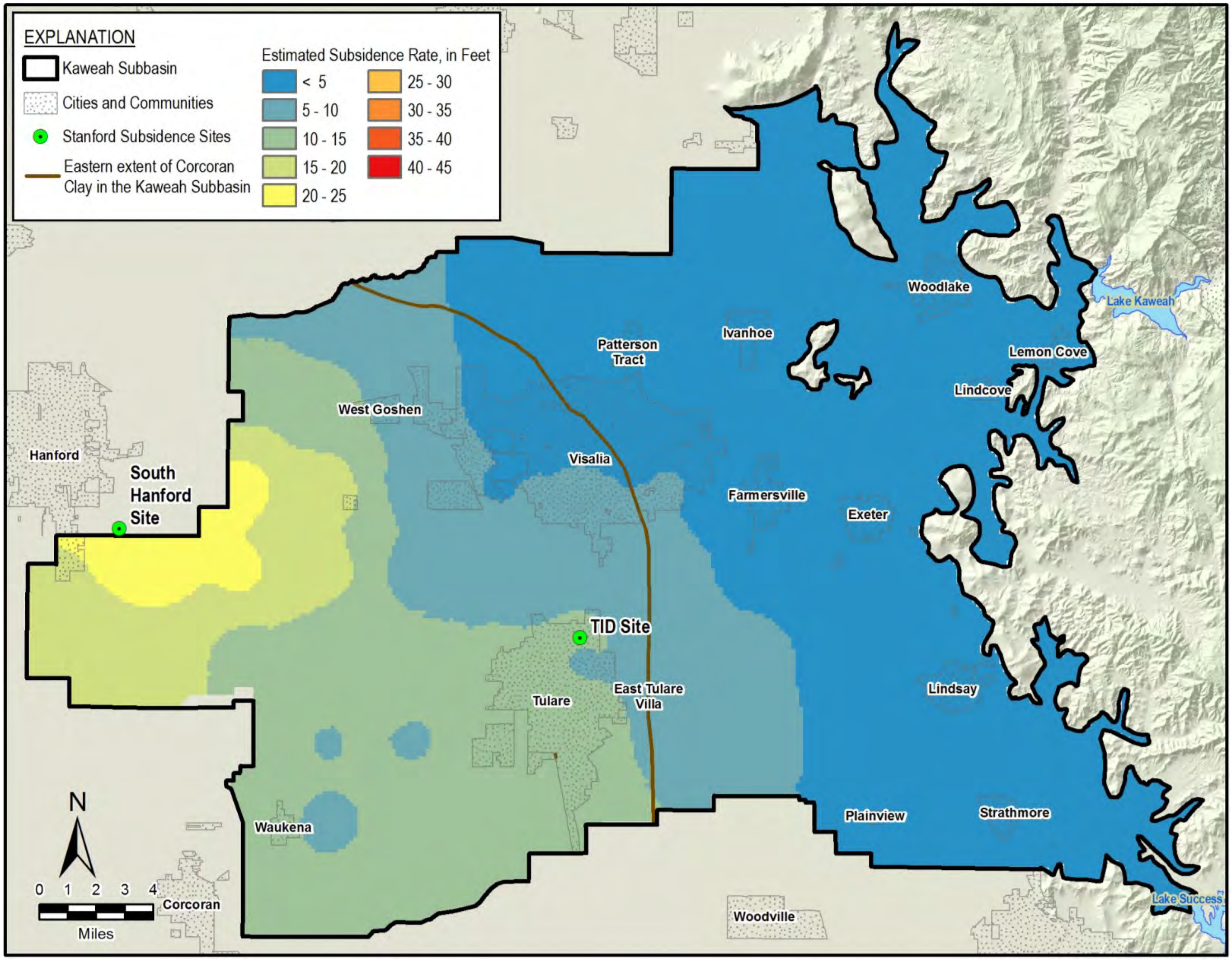


Figure 11. Spreadsheet Tool Estimated 2040 to 2070 Subsidence when Groundwater Levels Stabilize at Minimum Thresholds

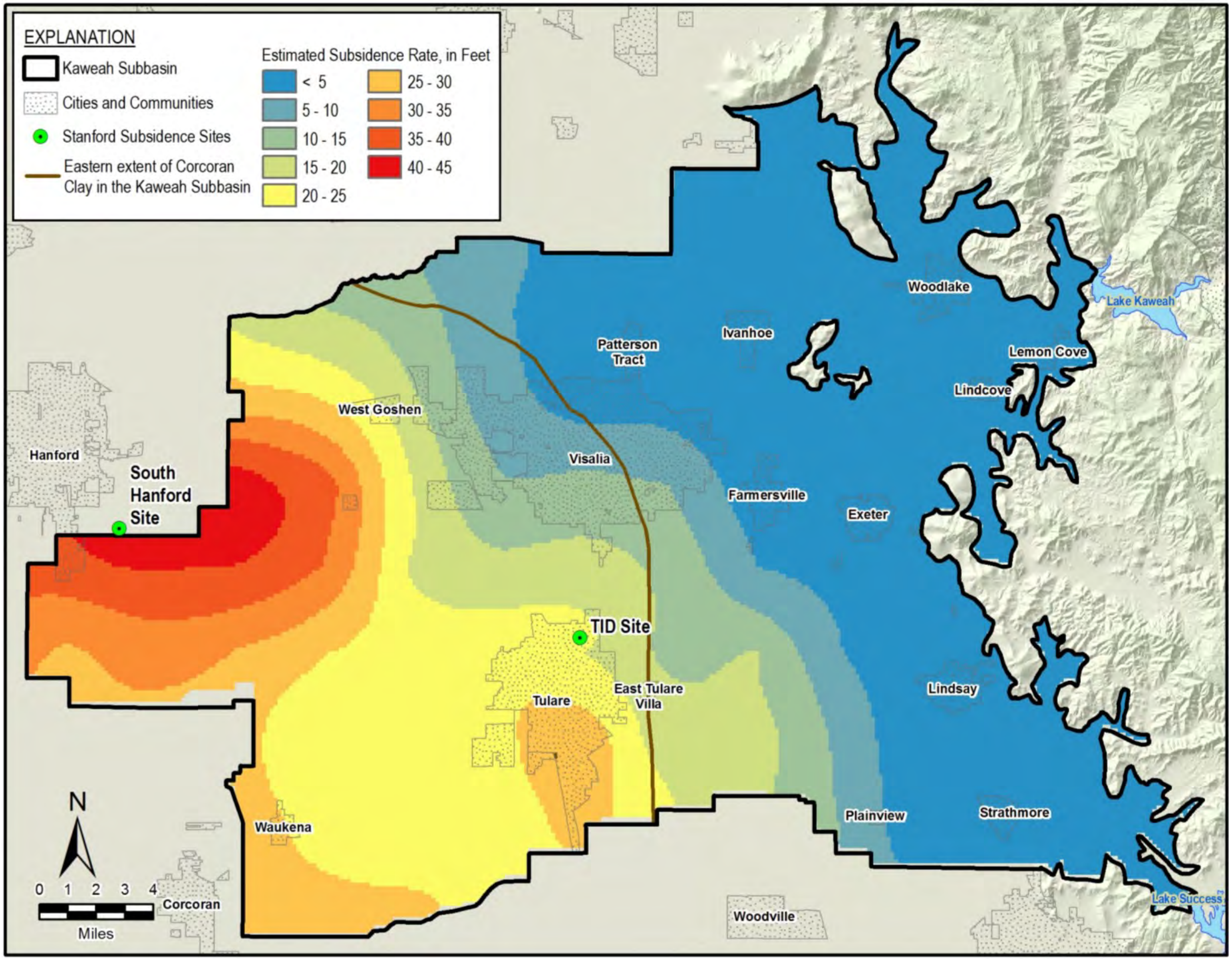


Figure 12. Spreadsheet Tool Estimated 2020 to 2070 Subsidence when Groundwater Levels Stabilize at Minimum Thresholds

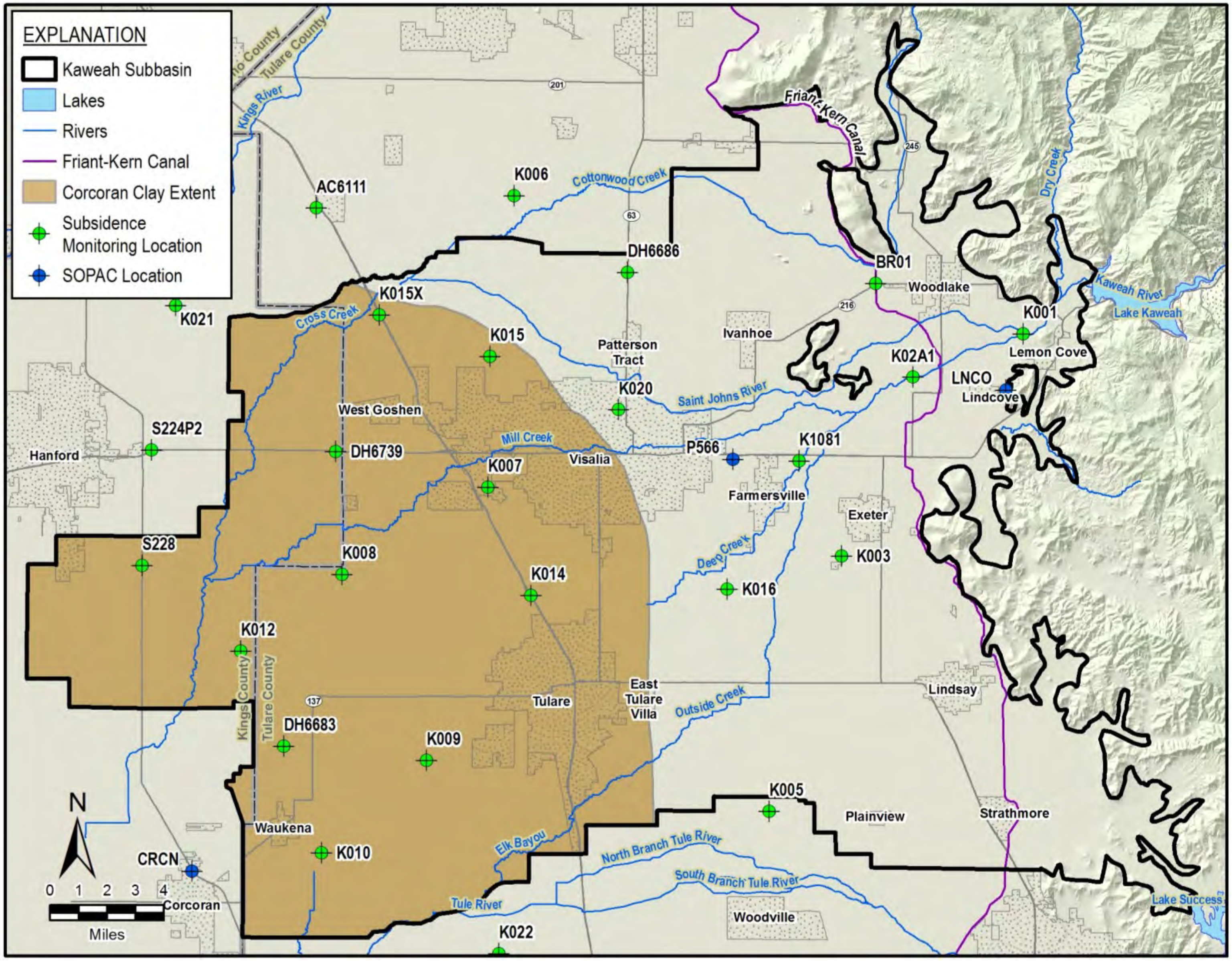


Figure 13. Subsidence Monitoring Points in and Around the Kaweah Subbasin

Table 1. Estimated Subsidence at Subbasin Monitoring Points when Groundwater Levels Stabilize at Minimum Thresholds

Subsidence Monitoring Point	2020 to 2040		2040 to 2070		2020 to 2070	
	Annual Subsidence (inch/year)	Total Subsidence (feet)	Annual Subsidence (inch/year)	Total Subsidence (feet)	Annual Subsidence (inch/year)	Total Subsidence (feet)
BR01	0.2	0.3	0.1	0.2	0.1	0.5
DH6683	7.6	12.7	4.4	10.9	5.7	23.6
DH6686	0.9	1.6	0.8	1.9	0.8	3.5
DH6739	9.5	15.9	6.1	15.2	7.5	31.1
K001	0.1	0.2	0.1	0.2	0.1	0.4
K003	0.7	1.2	0.6	1.4	0.6	2.6
K007	3.9	6.6	2.0	5.0	2.8	11.6
K008	9.8	16.3	6.2	15.5	7.6	31.8
K009	6.7	11.1	3.9	9.9	5.0	21.0
K010	7.9	13.2	4.3	10.9	5.8	24.0
K012	10.3	17.2	5.0	12.6	7.1	29.8
K014	5.9	9.9	3.7	9.2	4.6	19.1
K015	2.1	3.5	1.3	3.2	1.6	6.7
K015X	4.5	7.5	2.5	6.3	3.3	13.8
K016	2.6	4.4	2.1	5.2	2.3	9.5
K020	1.1	1.9	0.9	2.2	1.0	4.0
K02A1	0.1	0.2	0.1	0.2	0.1	0.4
K1081	0.3	0.5	0.1	0.4	0.2	0.9
P566	0.9	1.4	0.6	1.6	0.7	3.0
S228	10.8	18.0	9.0	22.5	9.7	40.5

2.1.8.2 Subsidence at Groundwater Elevation Measurable Objectives

If groundwater elevations decrease and stabilize at the measurable objectives in 2040, up to 18.9 feet of subsidence could occur between 2020 and 2040, as shown on Figure 14. Up to 16 feet of subsidence could occur between 2040 and 2070 as shown on Figure 15.

All subsidence between 2040 and 2070 is residual subsidence. The model assumes that the Subbasin achieves sustainability at the measurable objectives in 2040, and no new subsidence is activated over the ensuing 30 years. The subsidence shown on Figure 15 is the cumulative result of progressively less subsidence every year since 2040.

Figure 16 shows that subbasin-wide subsidence could range between less than 0.02 feet and 34.8 feet over the full 50-year planning and implementation horizon. This equates to subsidence rates of between 0.005 and 8.3 inches per year. The greatest subsidence is located near the South Hanford site and very little subsidence is predicted to occur along the eastern edge of the Subbasin.

The estimated subsidence when groundwater elevations stabilize at the measurable objective is shown for each of the subsidence measuring points in Table 2 as both a total subsidence and an equivalent subsidence rate.

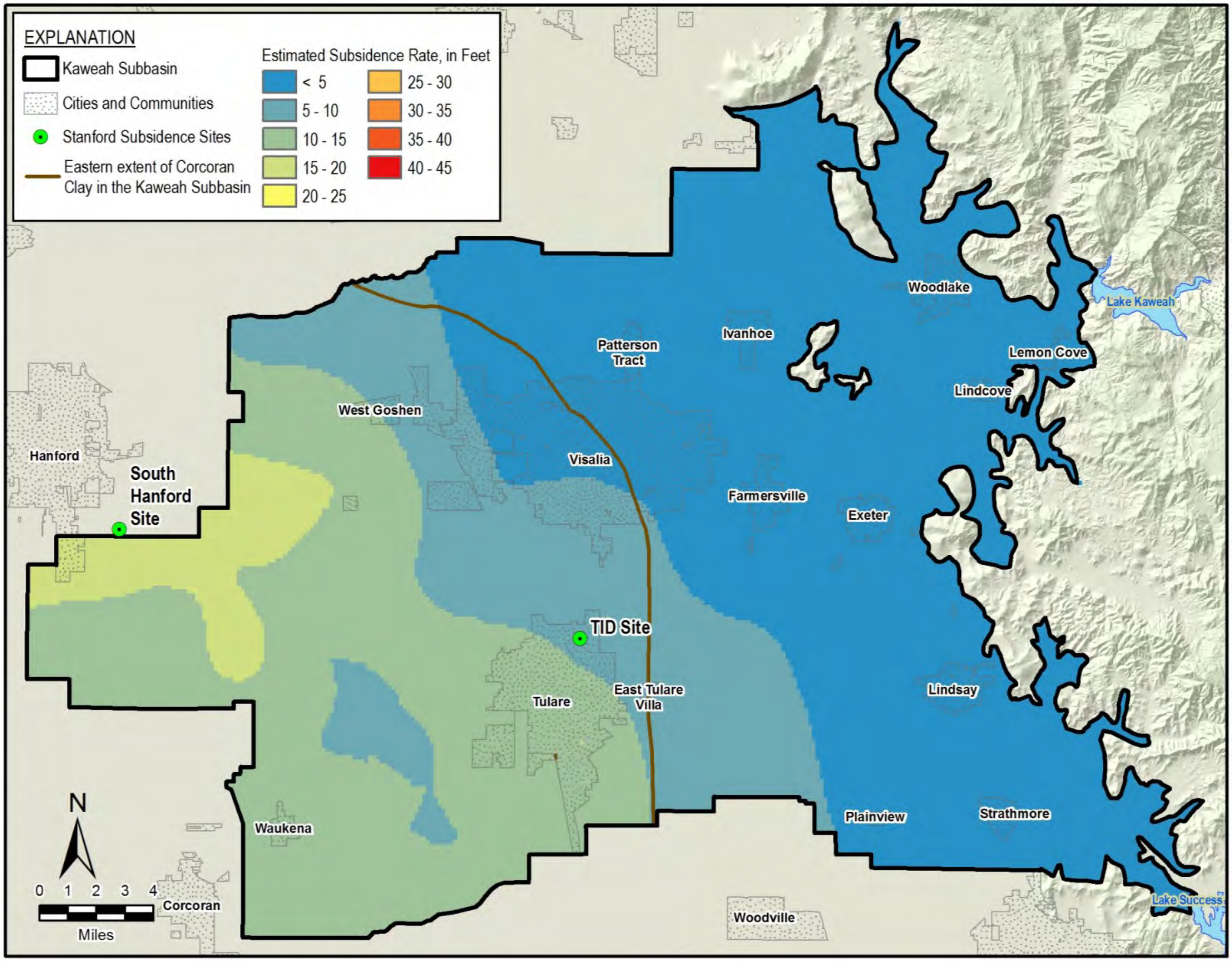


Figure 14. Spreadsheet Tool Estimated 2020 to 2040 Subsidence when Groundwater Levels Stabilize at Measaurable Objectives

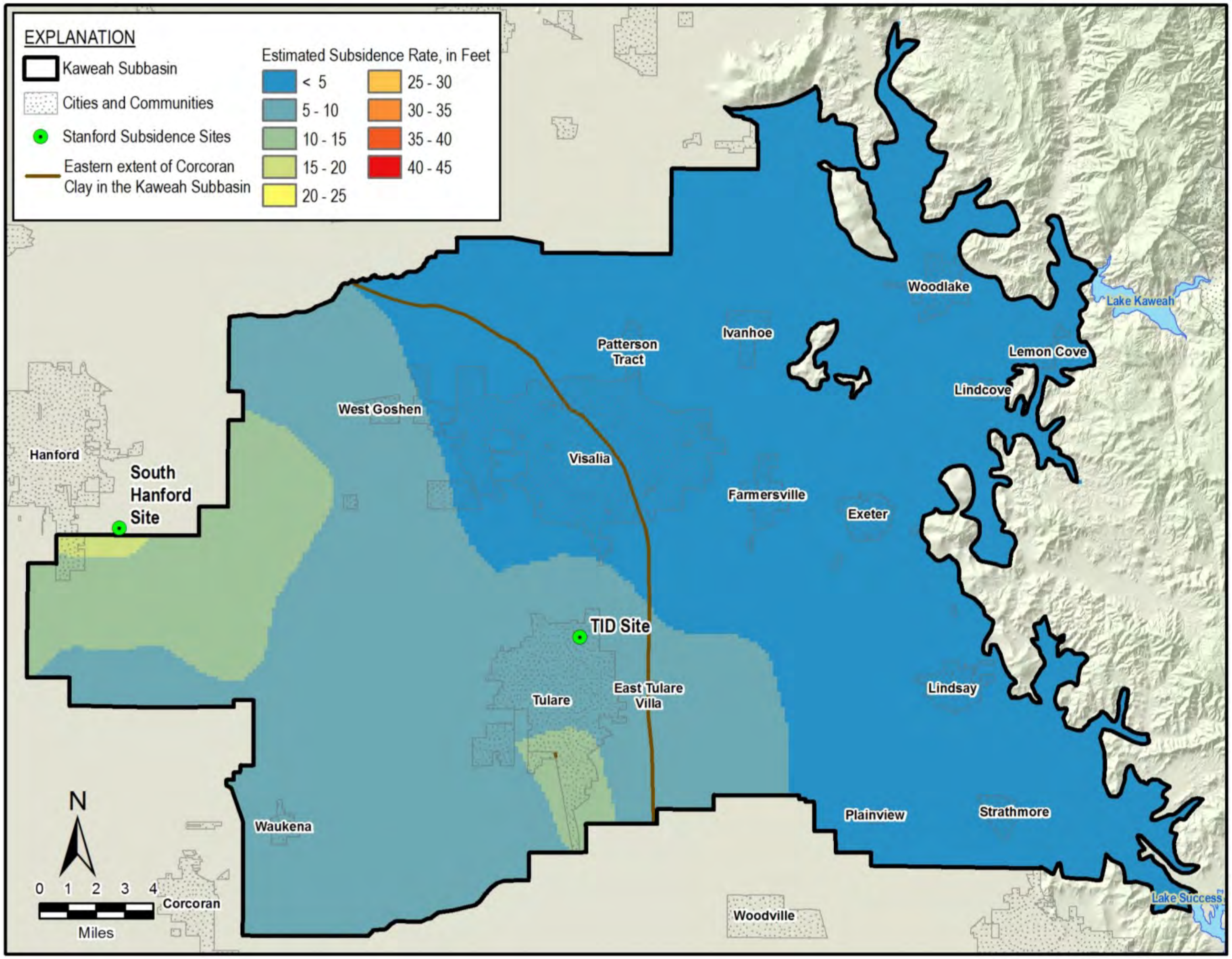


Figure 15. Spreadsheet Tool Estimated 2040 to 2070 Subsidence when Groundwater Levels Stabilize at Measaurable Objectives

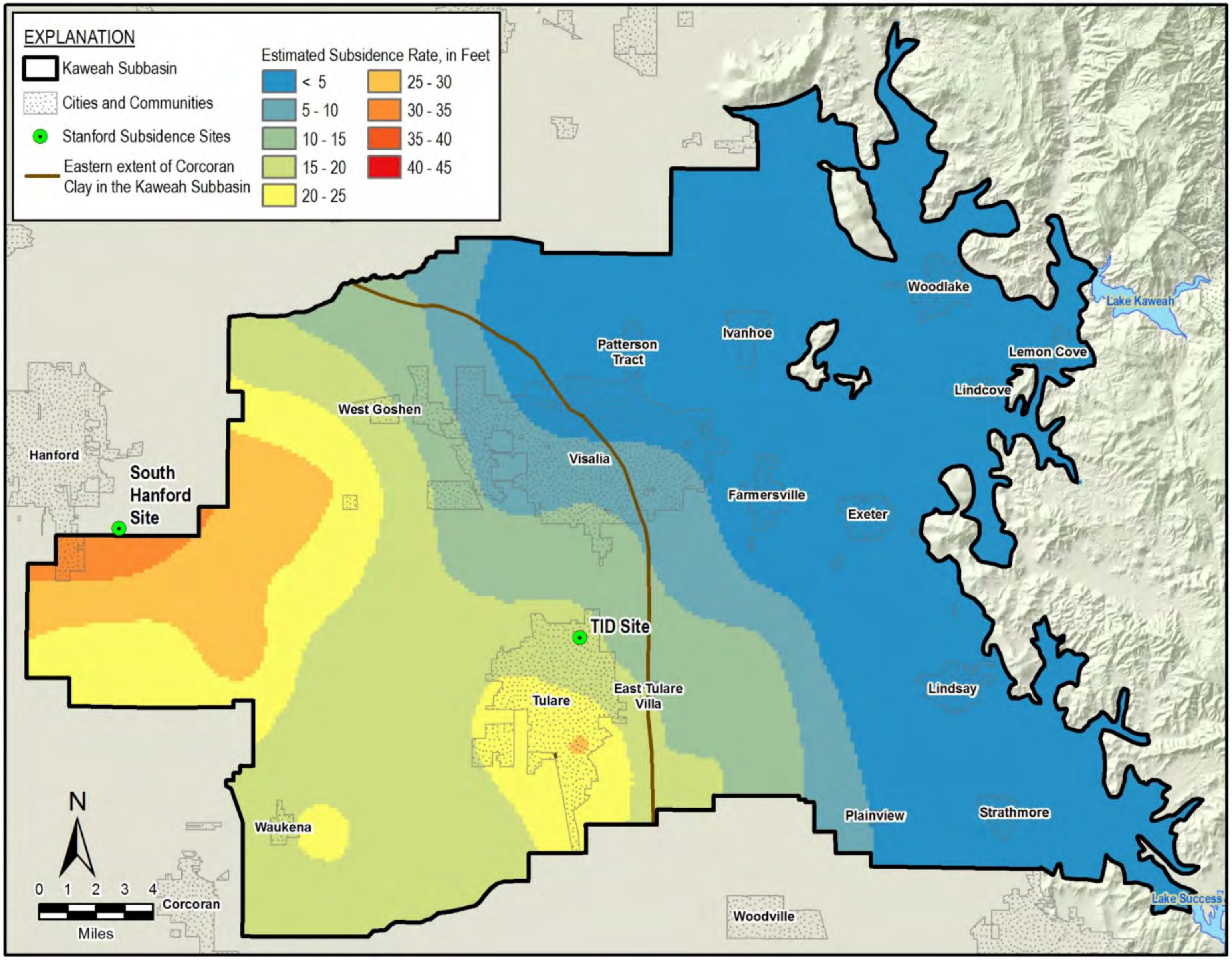


Figure 16. Spreadsheet Tool Estimated 2020 to 2070 Subsidence when Groundwater Levels Stabilize at Measaurable Objectives

Table 2. Estimated Subsidence at Subbasin Monitoring Points when Groundwater Levels Stabilize at Measurable Objectives

Subsidence Monitoring Point	2020 to 2040		2040 to 2070		2020 to 2070	
	Annual Subsidence (inch/year)	Total Subsidence (feet)	Annual Subsidence (inch/year)	Total Subsidence (feet)	Annual Subsidence (inch/year)	Total Subsidence (feet)
BR01	0.2	0.3	0.1	0.2	0.1	0.5
DH6683	6.8	11.4	3.0	7.5	4.5	18.9
DH6686	0.8	1.3	0.4	1.0	0.5	2.3
DH6739	8.1	13.4	3.7	9.2	5.4	22.6
K001	0.1	0.2	0.1	0.2	0.1	0.4
K003	0.6	1.0	0.3	0.7	0.4	1.7
K007	3.3	5.6	1.4	3.5	2.2	9.1
K008	7.8	12.9	3.4	8.5	5.1	21.4
K009	6.0	9.9	2.7	6.9	4.0	16.8
K010	7.3	12.1	3.3	8.1	4.9	20.3
K012	9.8	16.4	4.4	11.0	6.6	27.4
K014	5.2	8.7	2.4	6.0	3.5	14.7
K015	1.9	3.1	0.8	2.1	1.2	5.2
K015X	4.3	7.1	2.0	5.1	2.9	12.2
K016	2.3	3.8	1.2	3.0	1.6	6.8
K020	0.9	1.5	0.5	1.2	0.7	2.7
K02A1	0.1	0.2	0.1	0.1	0.1	0.4
K1081	0.3	0.6	0.1	0.3	0.2	0.9
P566	0.8	1.4	0.4	1.1	0.6	2.5
S228	9.8	16.4	5.8	14.4	7.4	30.8

2.2 Impact of Subsidence on Conveyance Infrastructure

Infrastructure in the Subbasin that may be affected by subsidence include roads, bridges, gas and water pipelines, power lines, canals, ditches, flood control waterways, railroad tracks, and wells. Although InSAR data show that up to 5 feet of subsidence has occurred in the Subbasin between 2015 and 2021, a survey of local infrastructure impacts indicated there has been no widespread damage caused by subsidence other than damage noted to water conveyance infrastructure and groundwater wells.

Subsidence predictions from the spreadsheet tool described in Section 2.1.8 are used to evaluate potential impacts to water conveyance infrastructure in the Subbasin, including subsidence along the Friant-Kern Canal and other important conveyance infrastructure described below. Water conveyance infrastructure including the Friant-Kern Canal and other important local conveyance is shown on Figure 17.

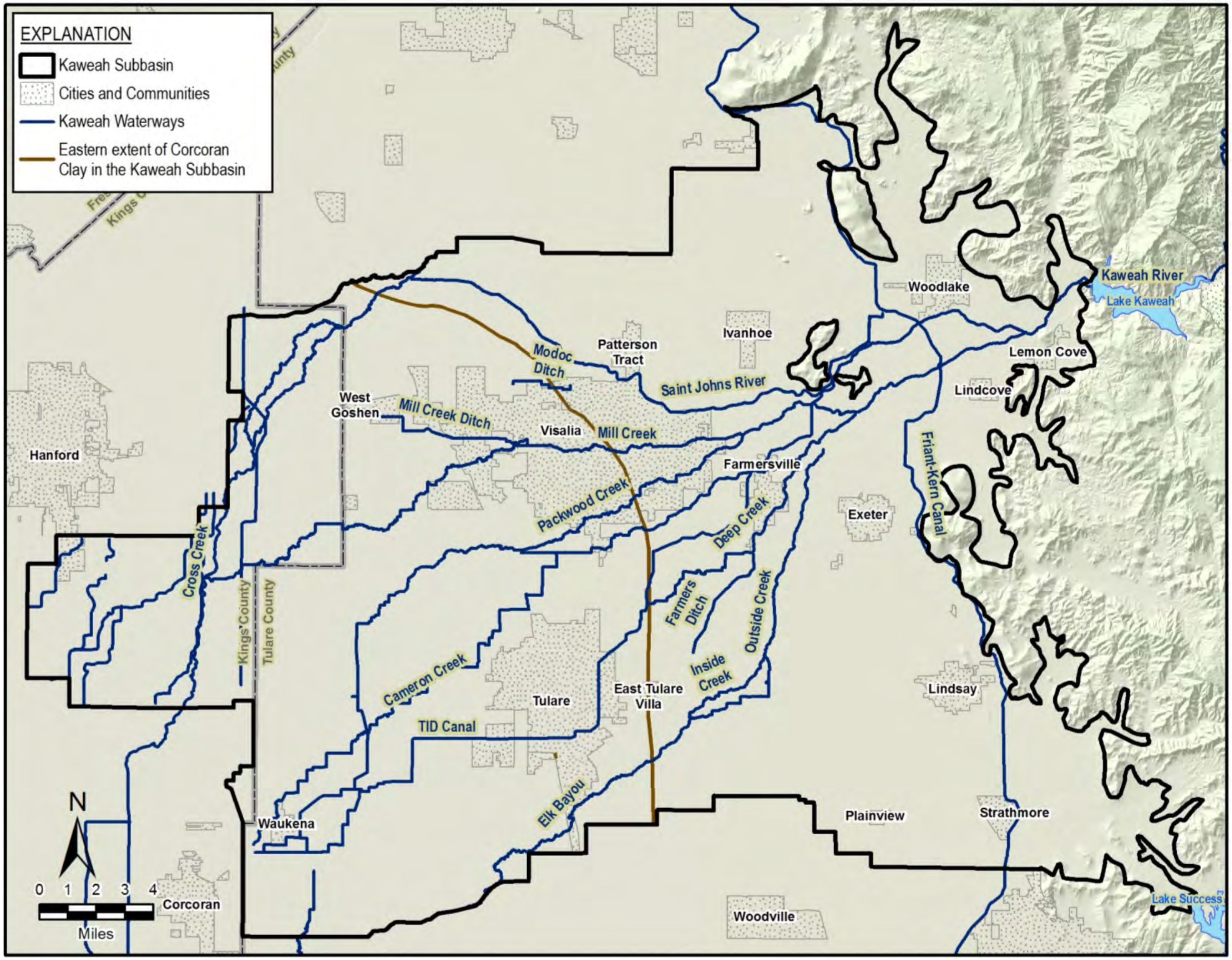


Figure 17. Conveyance Infrastructure Locations

2.2.1 Friant-Kern Canal

The East Kaweah Groundwater Sustainability Agency (EKSGA) identified the Friant-Kern Canal as the sole conveyance infrastructure in their portion of the Subbasin with potential to experience significant and unreasonable impacts due to subsidence. The EKGSA determined that a 10% loss of capacity would be significant and unreasonable. Using canal cross section and elevation data, EKGSA estimated that approximately 10 inches of total subsidence in the Subbasin would reduce the canal carrying capacity by 10%. This equates to a 50-year subsidence rate of 0.2 inches per year.

The subsidence spreadsheet tool was used to estimate the maximum subsidence along the Friant-Kern Canal. Figure 18 shows the maximum predicted subsidence along the Friant-Kern canal between 2020 and 2040 when groundwater levels are held at minimum thresholds. The maximum subsidence is 0.69 feet, or 0.41 inches per year. Figure 19 shows the maximum predicted subsidence between 2040 and 2070 when groundwater levels are held at minimum thresholds. The maximum subsidence is 0.69 feet, or 0.28 inches per year. Figure 20 shows the maximum predicted subsidence between 2020 and 2070 when groundwater levels are held at minimum thresholds. The maximum subsidence is 1.4 feet, or 0.34 inches per year.

Figure 21 shows the maximum predicted subsidence along the Friant-Kern Canal between 2020 and 2040 when groundwater levels are held at measurable objectives. The maximum subsidence is 0.55 feet, or 0.33 inches per year. Figure 22 shows the maximum predicted subsidence between 2040 and 2070 when groundwater levels are held at measurable objectives. The maximum subsidence is 0.39 feet, or 0.16 inches per year. Figure 23 shows the maximum predicted subsidence between 2020 and 2070 when groundwater levels are held at measurable objectives. The maximum subsidence is 0.94 feet, or 0.23 inches per year.

Estimated subsidence along the Friant-Kern Canal is greatest where it enters and leaves the Subbasin, which suggests there may be boundary errors in the analysis. These estimates at the boundaries are not considered reliable. Except for the boundaries, the greatest subsidence is estimated where the canal abuts the foothills in the middle of the Subbasin near the City of Exeter. The subsidence at this point is likely the maximum reliable subsidence from this analysis and is shown in Table 3. To date, very little subsidence has been noted in this area, as discussed in Section 2.1.7. Therefore, based on the model results, 10 inches (or 0.83 feet) of subsidence is possible, but not likely to occur and no significant impacts from subsidence to the Friant-Kern Canal are anticipated in the Subbasin.

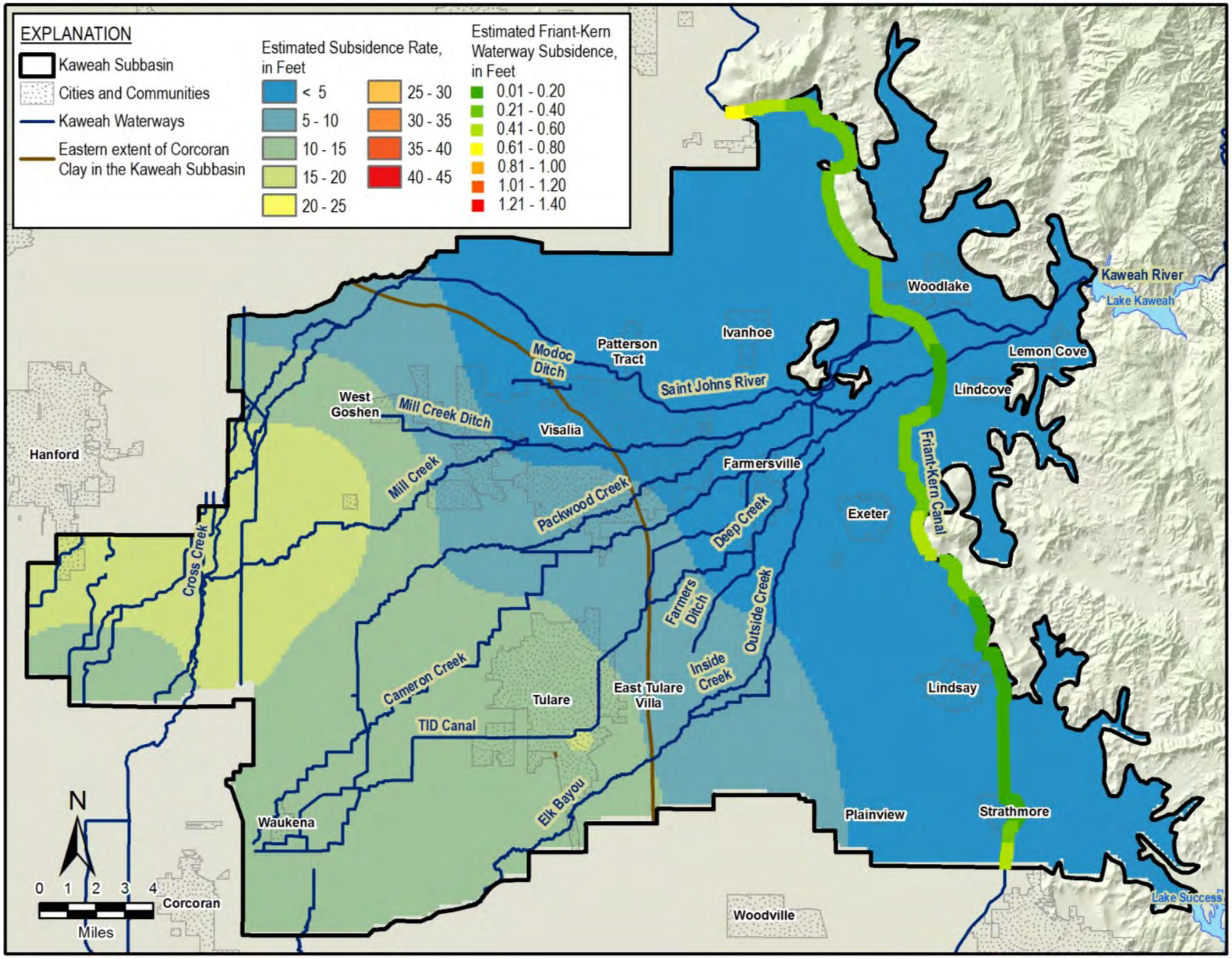


Figure 18. Estimated 2020 to 2040 Subsidence in Along Friant-Kern Canal when Groundwater Levels Stabilize at Minimum Thresholds

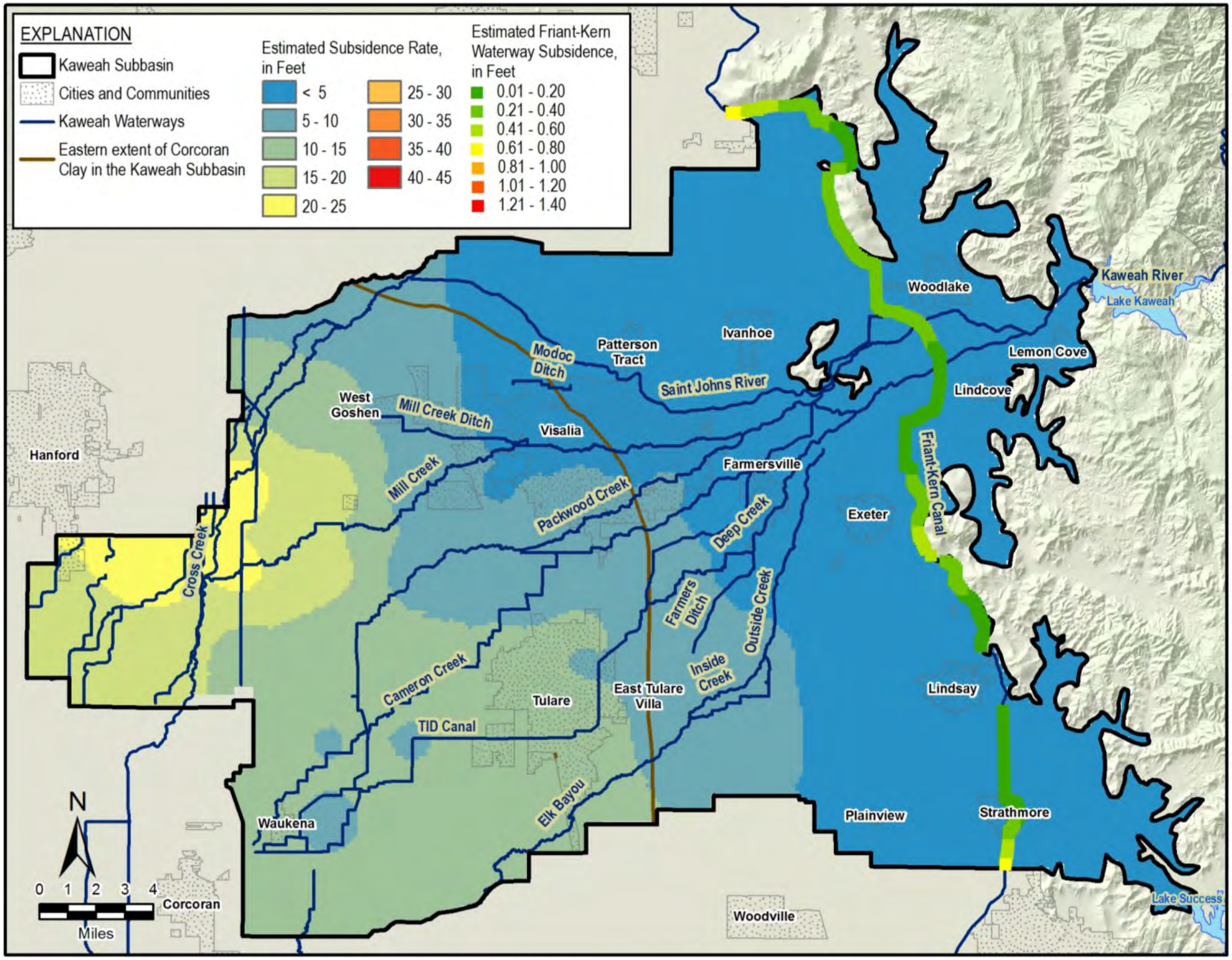


Figure 19. Estimated 2040 to 2070 Subsidence in Along Friant-Kern Canal when Groundwater Levels Stabilize at Minimum Thresholds

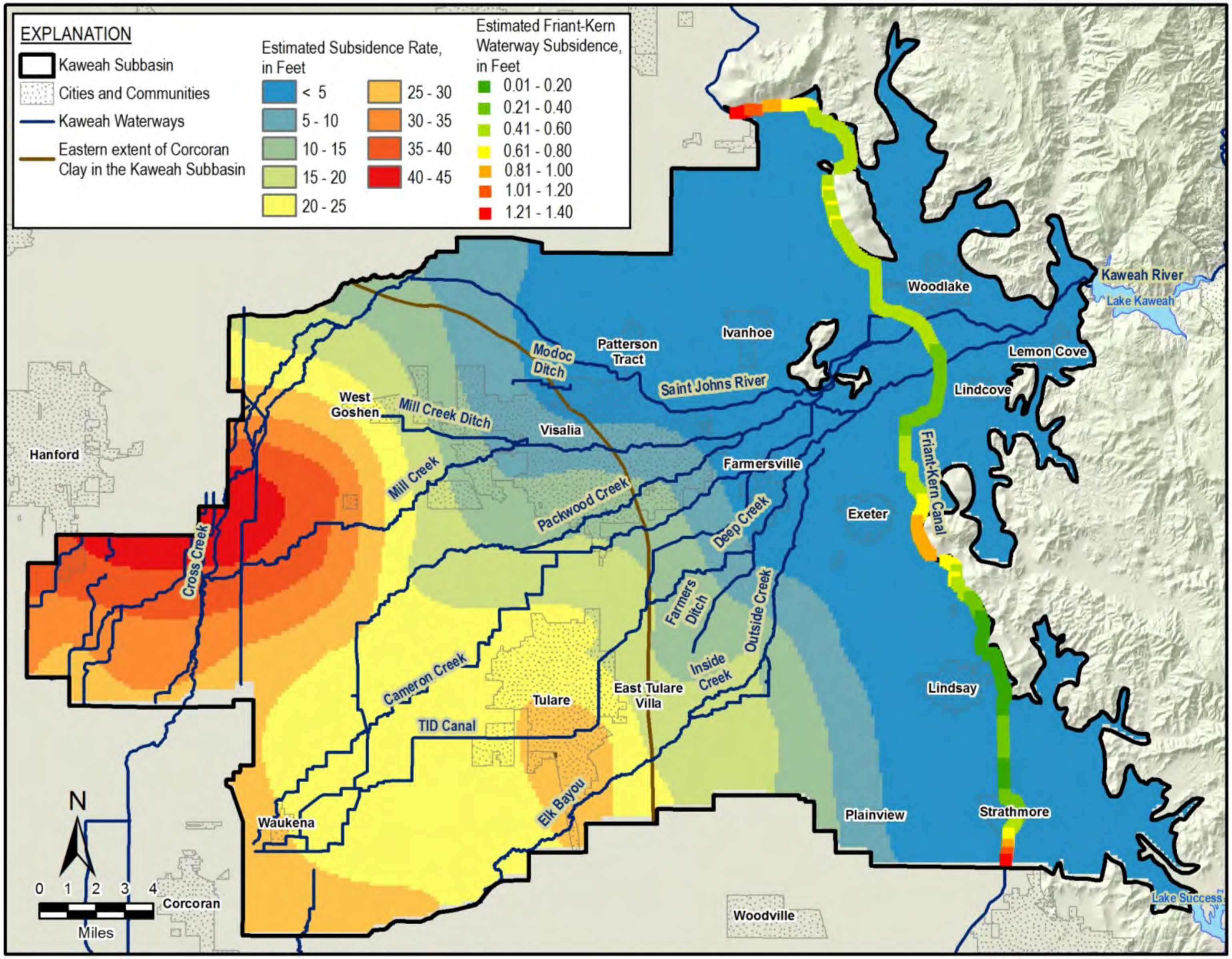


Figure 20. Estimated 2020 to 2070 Subsidence in Along Friant-Kern Canal when Groundwater Levels Stabilize at Minimum Thresholds

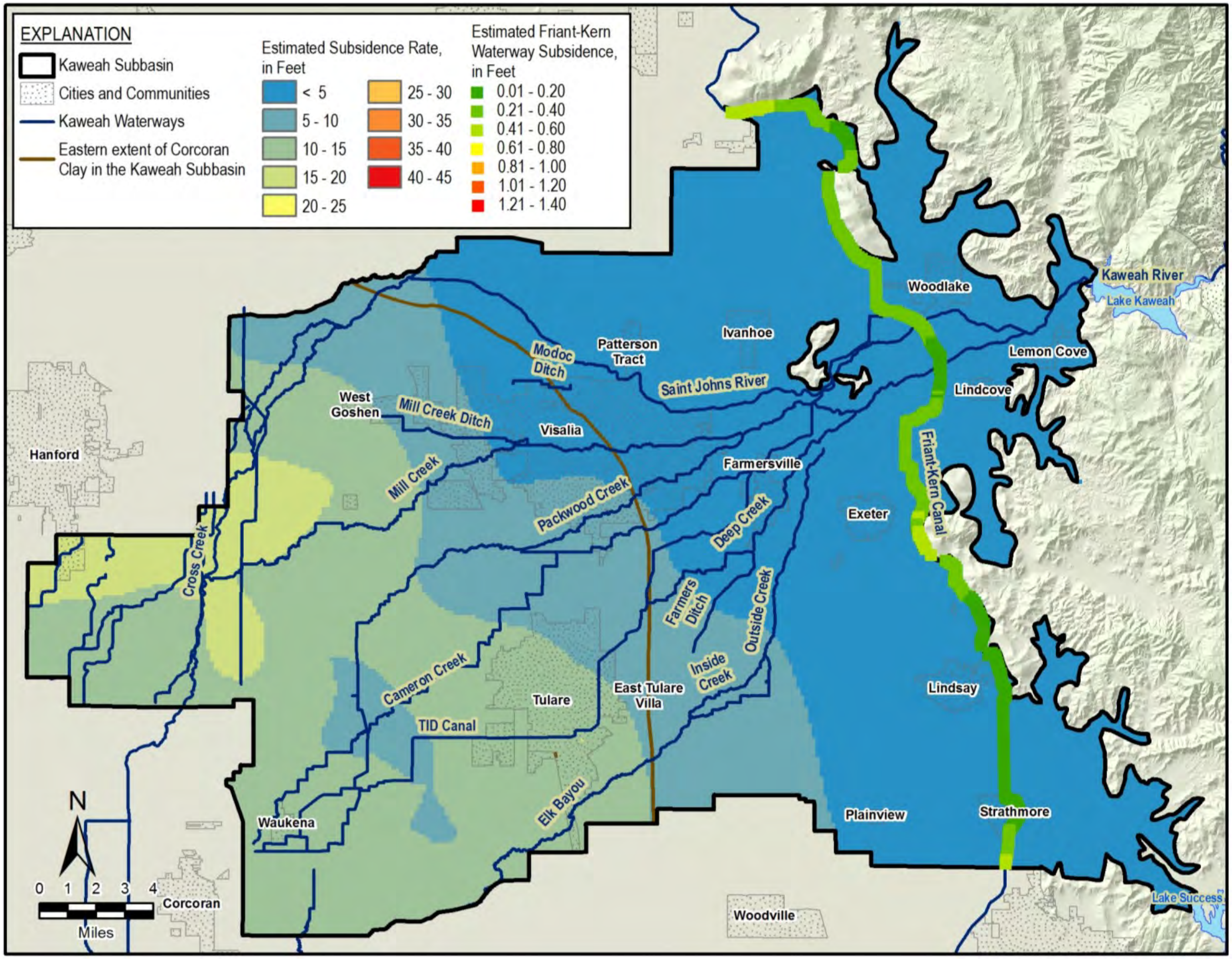


Figure 21. Estimated 2020 to 2040 Subsidence in Along Friant-Kern Canal when Groundwater Levels Stabilize at Measurable Objectives

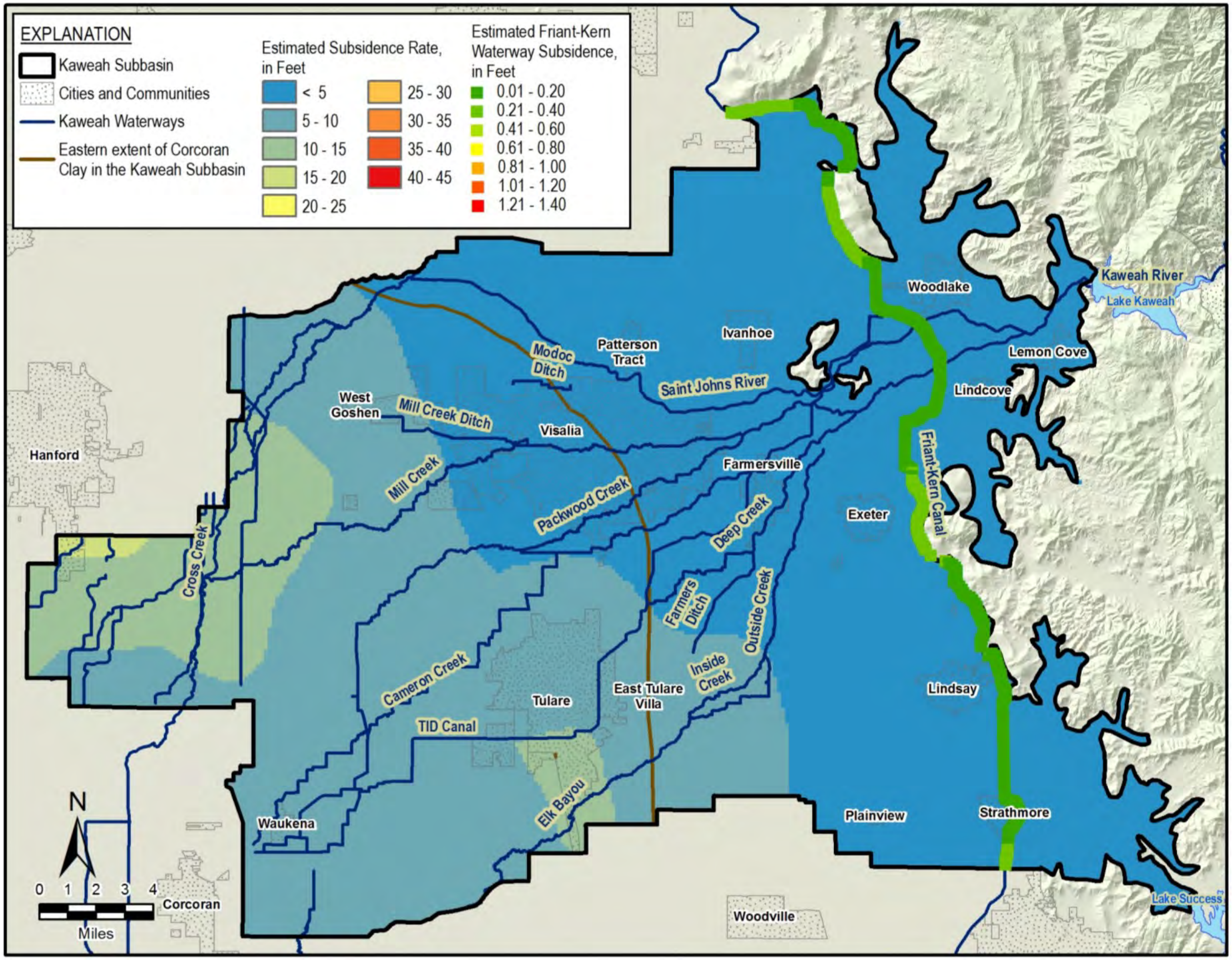


Figure 22. Estimated 2040 to 2070 Subsidence in Along Friant-Kern Canal when Groundwater Levels Stabilize at Measurable Objectives

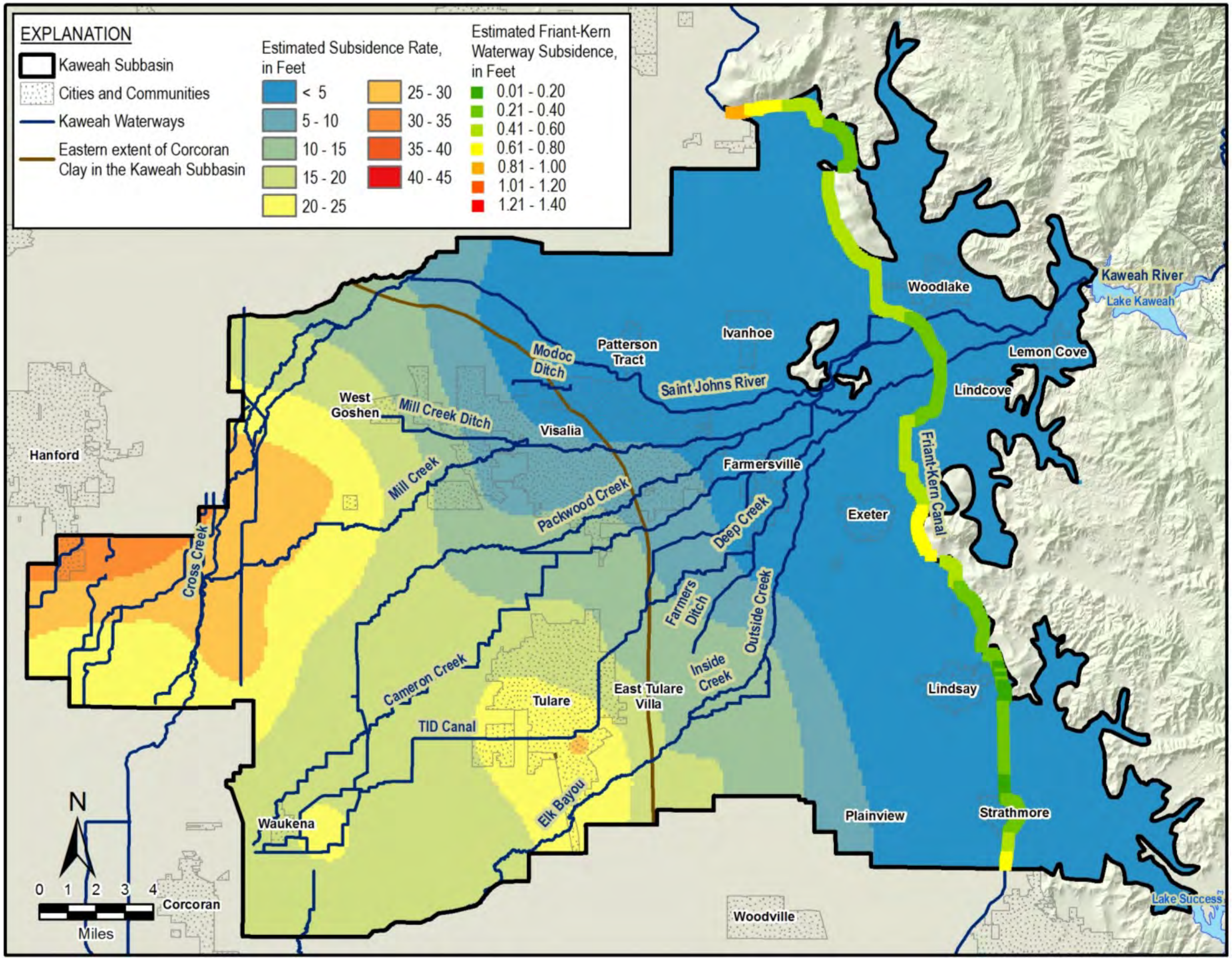


Figure 23. Estimated 2020 to 2070 Subsidence in Along Friant-Kern Canal when Groundwater Levels Stabilize at Measurable Objectives

Table 3. Maximum Estimated Subsidence Along the Friant-Kern Canal Near Exeter

Time Period	Total Subsidence (feet)	Equivalent Subsidence Rate (inch/yr)
Groundwater Levels Stabilize at Minimum Thresholds		
2020 to 2040	0.50	0.30
2040 to 2070	0.43	0.17
2020 to 2070	0.93	0.22
Groundwater Levels Stabilize at Measurable Objectives		
2020 to 2040	0.42	0.25
2040 to 2070	0.26	0.10
2020 to 2070	0.68	0.16

2.2.2 Conveyance Infrastructure

The capacity of water conveyance infrastructures other than the Friant-Kern canal is impacted only if they subside more upstream than downstream, because the subsidence flattens the conveyance gradient and causes a reduction in capacity. The GSAs determined that a 10% loss of capacity in any of these conveyances would be significant and unreasonable.

Based on experience with the TID main canal, the 10% loss of capacity is equated to differential subsidence where a waterway's upstream subsidence is 1 foot more than its downstream subsidence over 1.5 miles. Each major waterway is analyzed using the total subsidence maps shown in Section 2.1.8, and greater than 1 foot of differential subsidence over 1.5 miles is predicted on 11 conveyance reaches.

Figure 24 through Figure 26 show the locations of conveyance infrastructure that would potentially be significantly impacted for various levels of subsidence. Figure 24 through Figure 26 show which conveyance infrastructures may be significantly impacted if groundwater levels are held at minimum thresholds. Figure 27 through Figure 29 show which conveyance infrastructures may be significantly impacted if groundwater levels are held at measurable objectives. These figures show the number and extent of conveyance infrastructure that should be included in the GSA's mitigation plans.

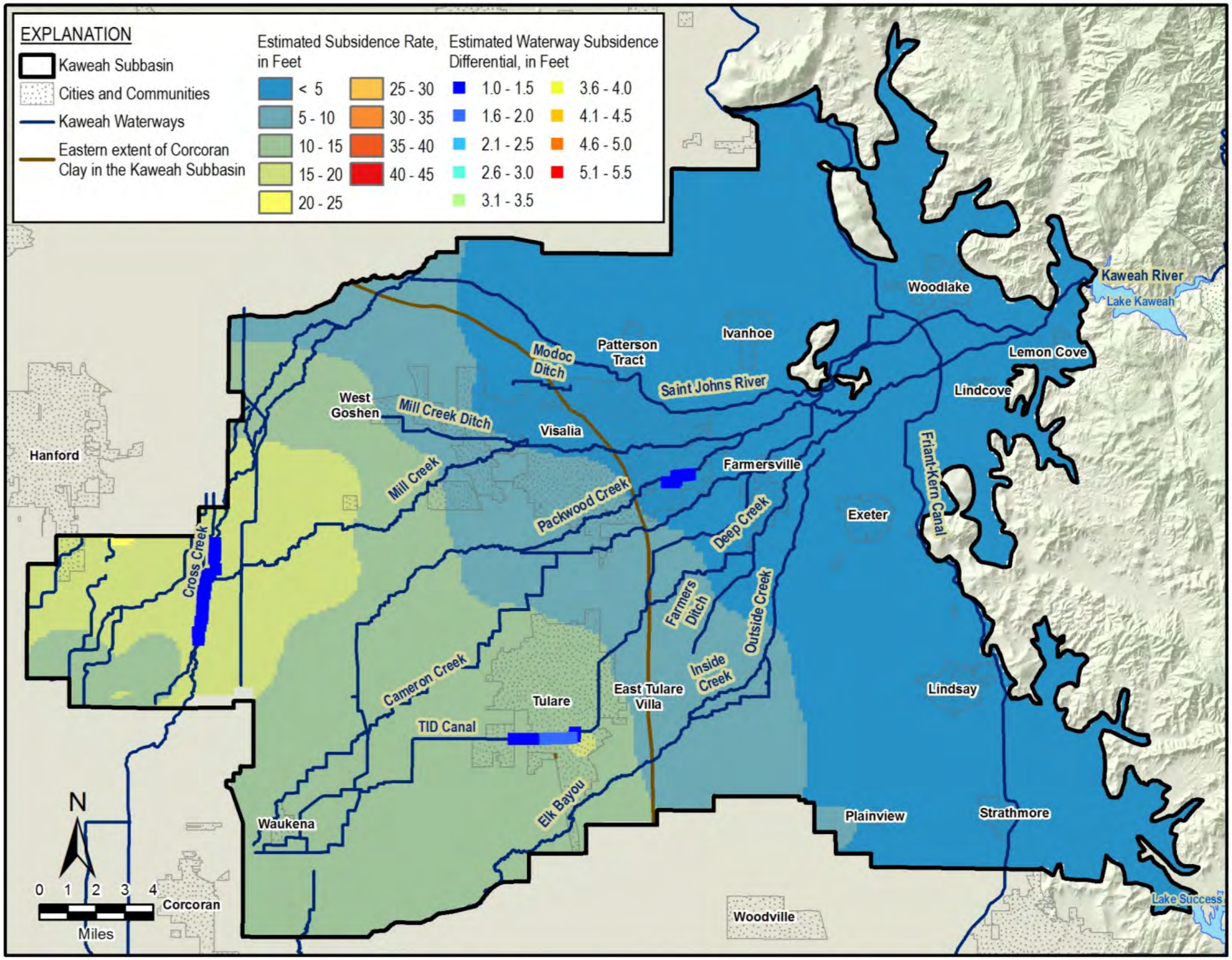


Figure 24. Estimated 2020 to 2040 Subsidence Impacts to Conveyance Infrastructure when Groundwater Levels Stabilize at Minimum Thresholds

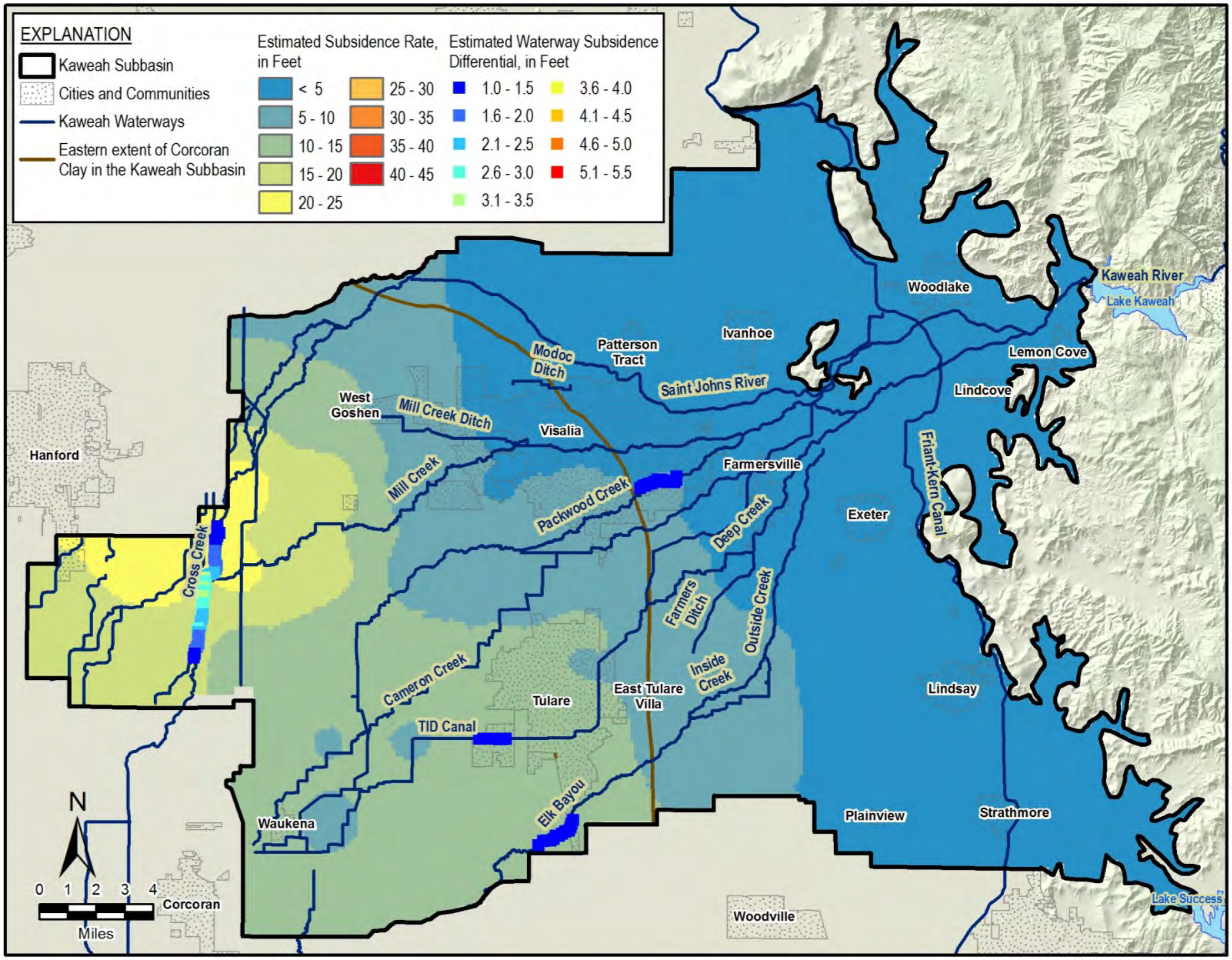


Figure 25. Estimated 2040 to 2070 Subsidence Impacts to Conveyance Infrastructure when Groundwater Levels Stabilize at Minimum Thresholds

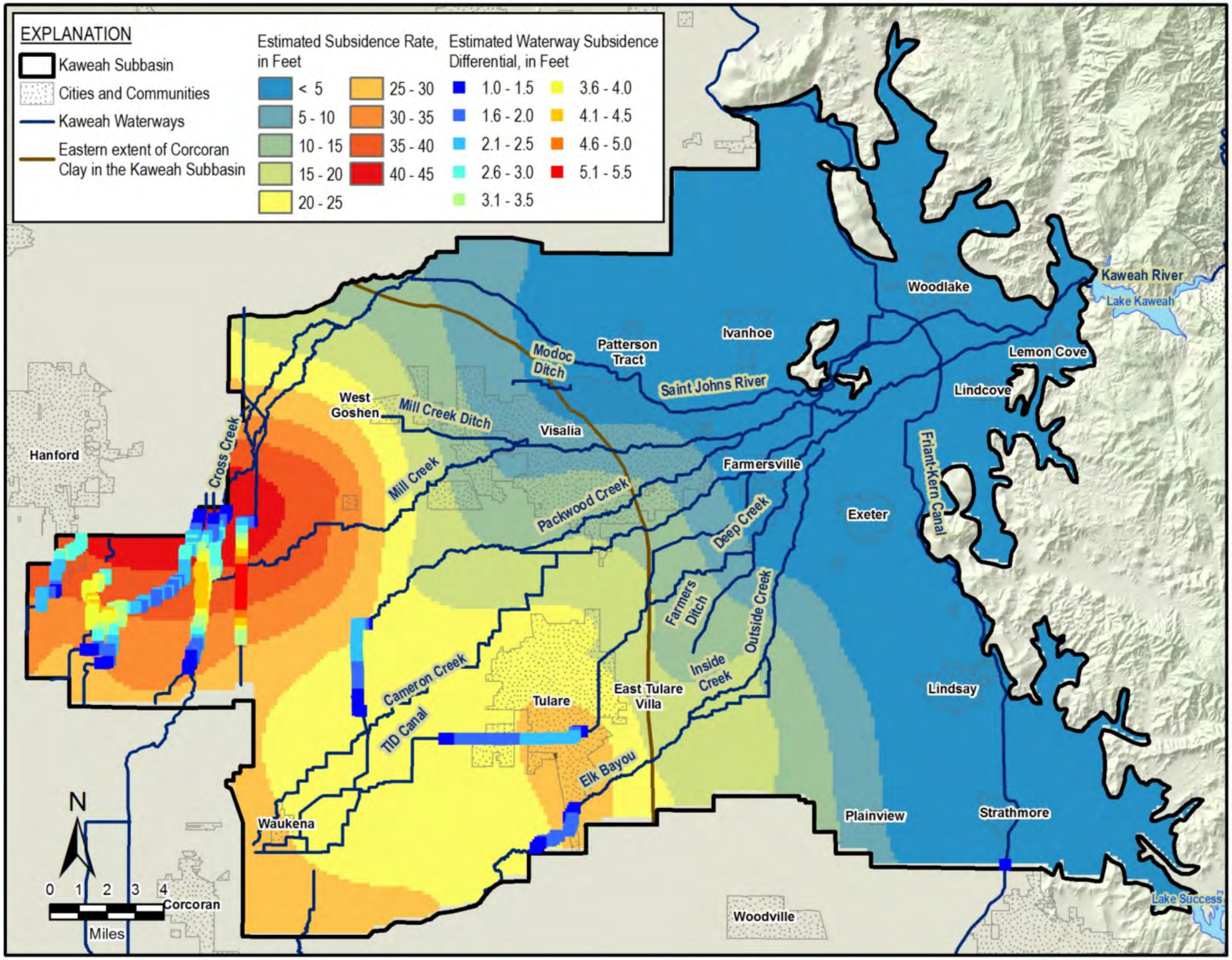


Figure 26. Estimated 2020 to 2070 Subsidence Impacts to Conveyance Infrastructure when Groundwater Levels Stabilize at Minimum Thresholds

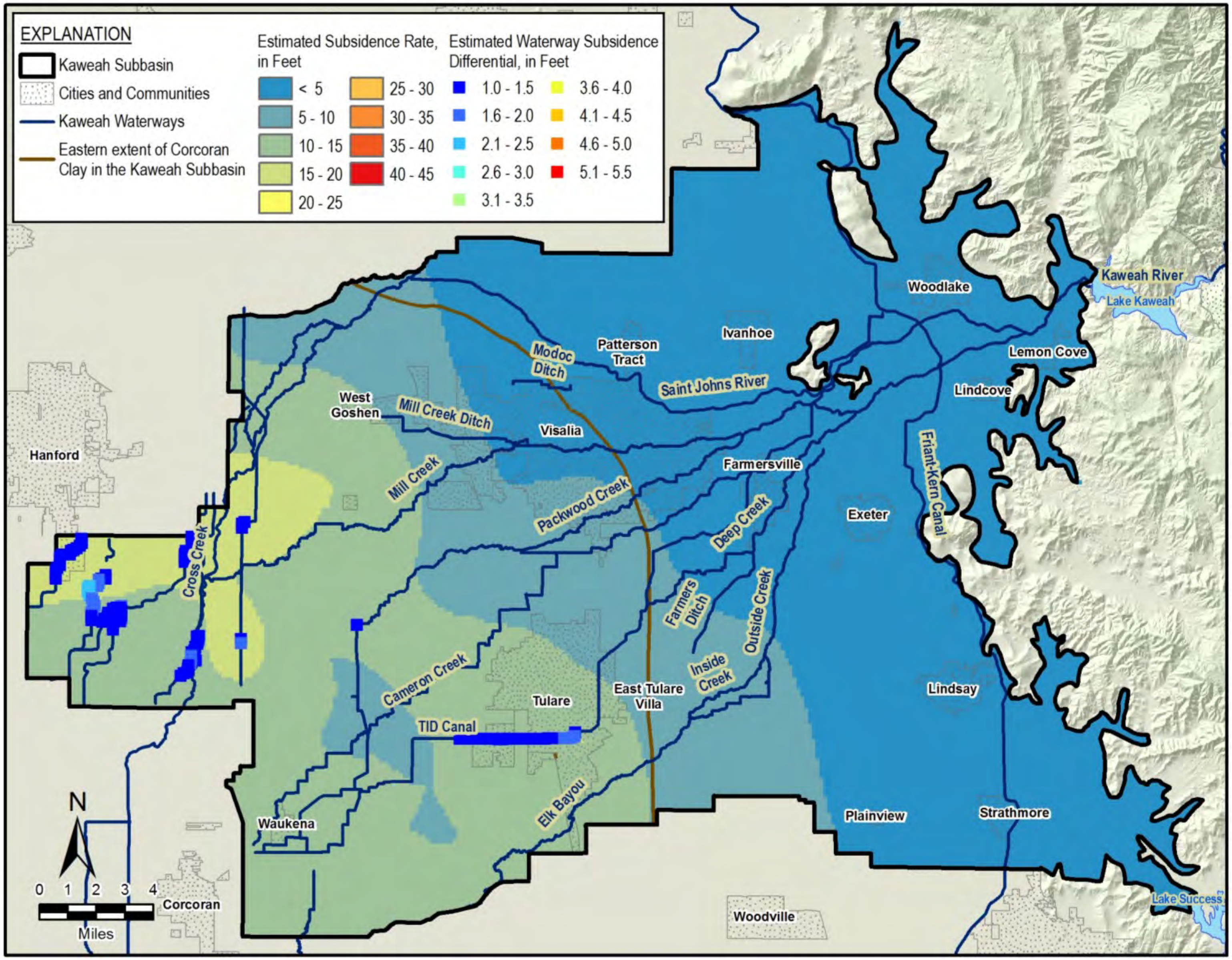


Figure 27. Estimated 2020 to 2040 Subsidence Impacts to Conveyance Infrastructure when Groundwater Levels Stabilize at Measurable Objectives

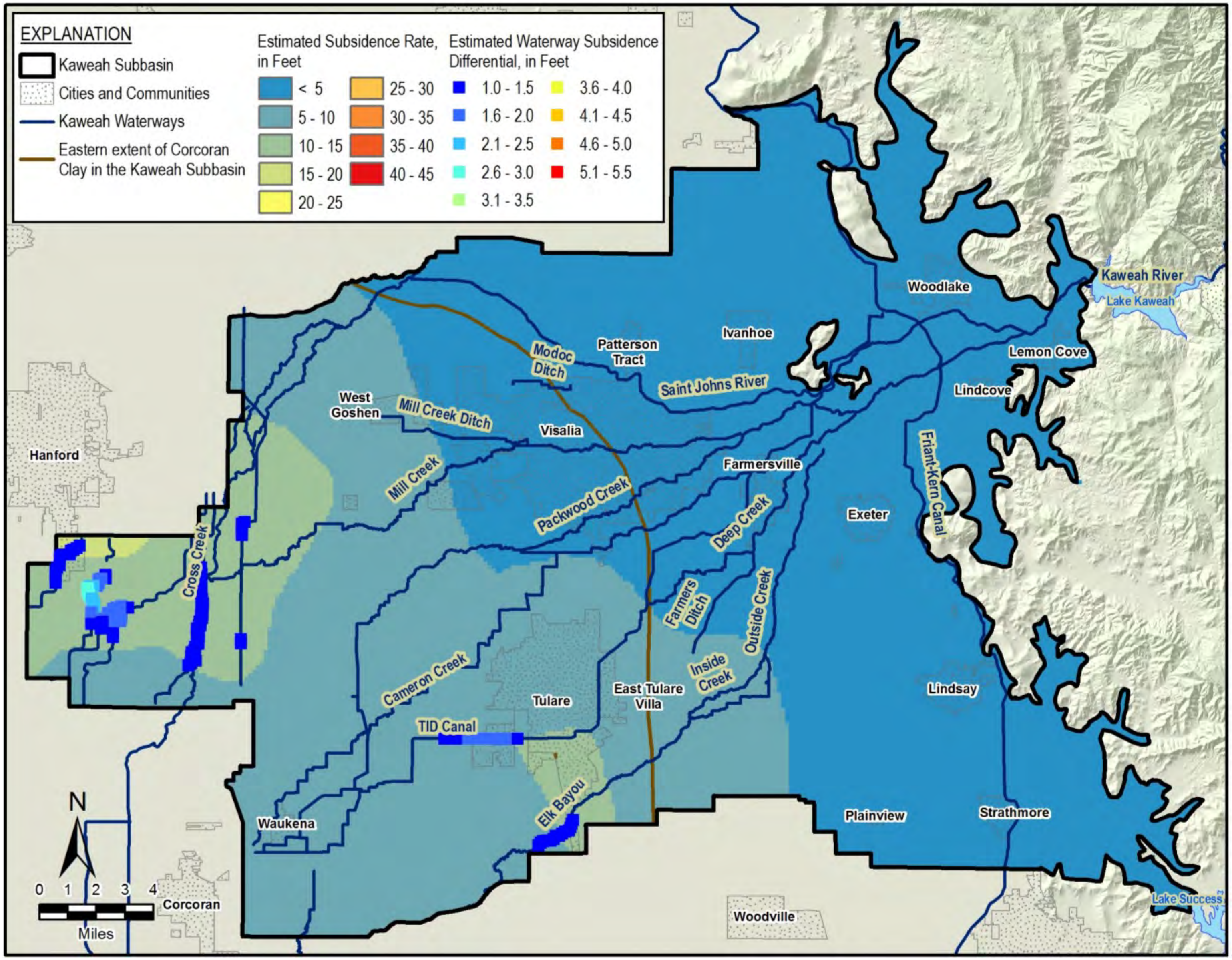


Figure 28. Estimated 2040 to 2070 Subsidence Impacts to Conveyance Infrastructure when Groundwater Levels Stabilize at Measurable Objectives

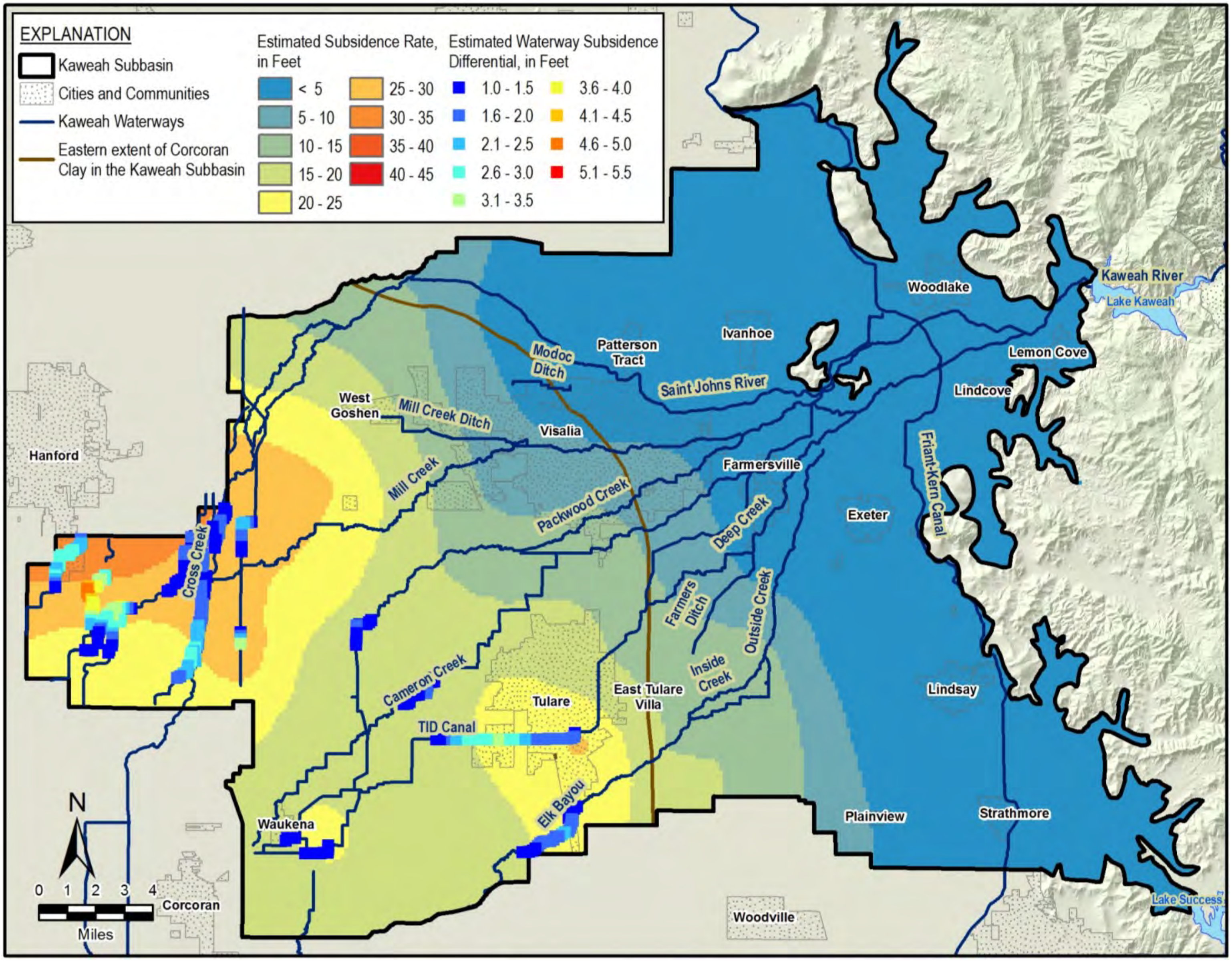


Figure 29. Estimated 2020 to 2070 Subsidence Impacts to Conveyance Infrastructure when Groundwater Levels Stabilize at Measurable Objectives

3 REFERENCES

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California Department of Water Resources GIS. https://gis.water.ca.gov/arcgis/rest/services/Elevation/Vertical_Displacement_SJV_DWR_1949_to_2005/MapServer/0

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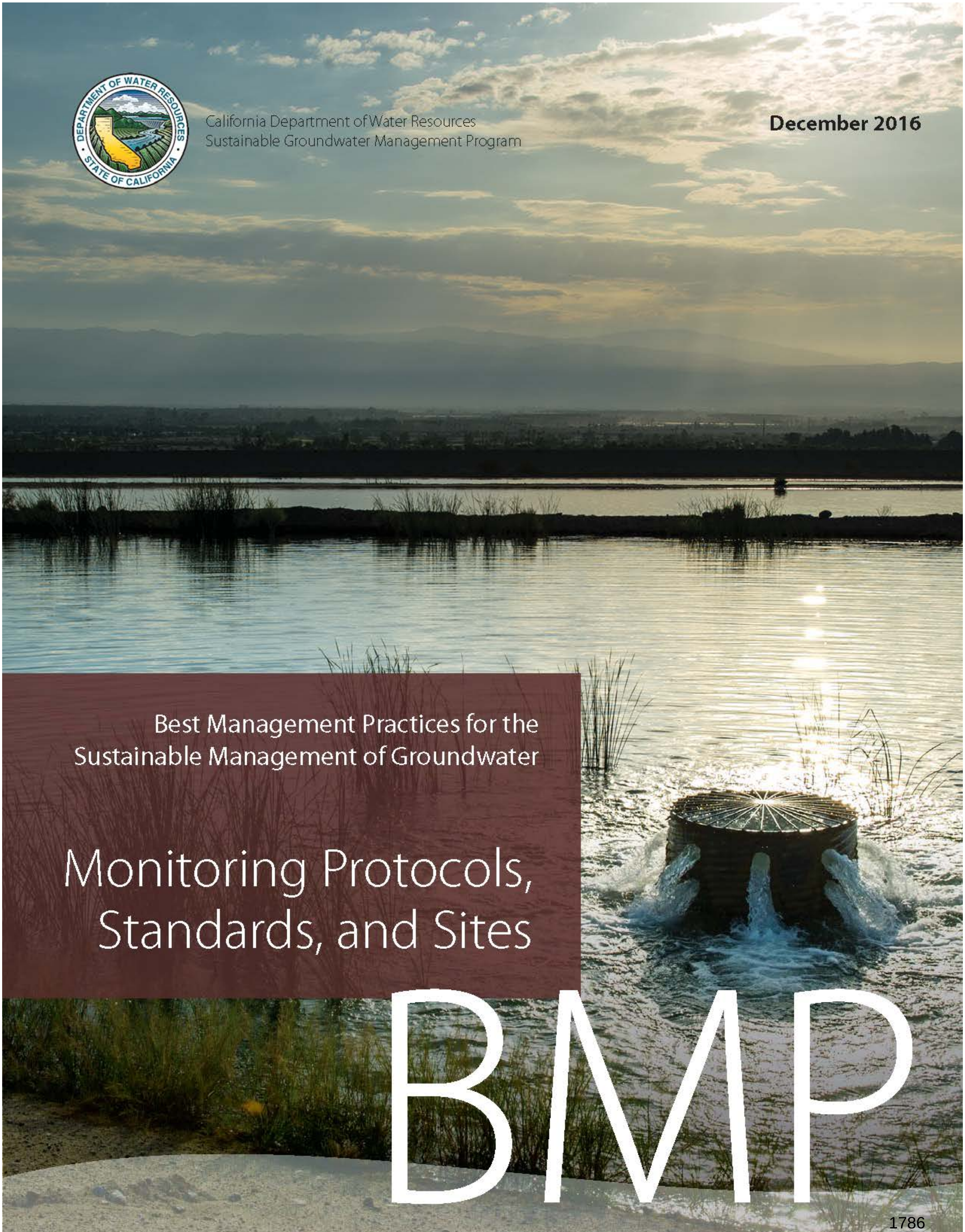
Appendix 4-A

DWR Monitoring Protocols, Standards, and Sites BMP



California Department of Water Resources
Sustainable Groundwater Management Program

December 2016

Best Management Practices for the
Sustainable Management of Groundwater

Monitoring Protocols, Standards, and Sites

BMP

1786

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California Natural Resources Agency
John Laird, Secretary for Natural Resources

Department of Water Resources
Mark W. Cowin, Director

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Division of Integrated Regional Water Management

Arthur Hinojosa Jr., Chief

Prepared under the direction of:

David Gutierrez, Sustainable Groundwater Management Program Manager
Rich Juricich, Sustainable Groundwater Management Branch

Prepared by:

Trevor Joseph, BMP Project Manager

Timothy Godwin
Dan McManus
Mark Nordberg
Heather Shannon
Steven Springhorn

With assistance from:

DWR Region Office Staff

Groundwater Monitoring Protocols, Standards, and Sites Best Management Practice

1. Objective

The objective of this *Best Management Practice* (BMP) is to assist in the development of Monitoring Protocols. The California Department of Water Resources (the Department or DWR) has developed this document as part of the obligation in the Technical Assistance chapter (Chapter 7) of the Sustainable Groundwater Management Act (SGMA) to support the long-term sustainability of California's groundwater *basins*. Information provided in this BMP provides technical assistance to Groundwater Sustainability Agencies (GSAs) and other stakeholders to aid in the establishment of consistent data collection processes and procedures. In addition, this BMP can be used by GSAs to adopt a set of sampling and measuring procedures that will yield similar data regardless of the monitoring personnel. Finally, this BMP identifies available resources to support the development of monitoring protocols.

This BMP includes the following sections:

1. Objective. A brief description of how and where monitoring protocols are required under SGMA and the overall objective of this BMP.
2. Use and Limitations. A brief description of the use and limitations of this BMP.
3. Monitoring Protocol Fundamentals. A description of the general approach and background of groundwater monitoring protocols.
4. Relationship of Monitoring Protocols to other BMPs. A description of how this BMP is connected with other BMPS.
5. Technical Assistance. Technical content providing guidance for regulatory sections.
6. Key Definitions. Descriptions of definitions identified in the GSP Regulations or SGMA.
7. Related Materials. References and other materials that provide supporting information related to the development of Groundwater Monitoring Protocols.

2. USE AND LIMITATIONS

BMPs developed by the Department provide technical guidance to GSAs and other stakeholders. Practices described in these BMPs do not replace the GSP Regulations, nor do they create new requirements or obligations for GSAs or other stakeholders. In addition, using this BMP to develop a GSP does not equate to an approval determination by the Department. All references to GSP Regulations relate to Title 23 of the California Code of Regulations (CCR), Division 2, Chapter 1.5, and Subchapter 2. All references to SGMA relate to California Water Code sections in Division 6, Part 2.74.

3. MONITORING PROTOCOL FUNDAMENTALS

Establishing data collection protocols that are based on best available scientific methods is essential. Protocols that can be applied consistently across all basins will likely yield comparable data. Consistency of data collection methods reduces uncertainty in the comparison of data and facilitates more accurate communication within basins as well as between basins.

Basic minimum technical standards of accuracy lead to quality data that will better support implementation of GSPs.

4. RELATIONSHIP OF MONITORING PROTOCOL TO OTHER BMPS

Groundwater monitoring is a fundamental component of SGMA, as each GSP must include a sufficient network of data that demonstrates measured progress toward the achievement of the sustainability goal for each basin. For this reason, a standard set of protocols need to be developed and utilized.

It is important that data is developed in a manner consistent with the basin setting, planning, and projects/management actions steps identified on **Figure 1** and the GSP Regulations. The inclusion of monitoring protocols in the GSP Regulations also emphasizes the importance of quality empirical data to support GSPs and provide comparable information from basin to basin.

Figure 1 provides a logical progression for the development of a GSP and illustrates how monitoring protocols are linked to other related BMPs. This figure also shows the context of the BMPs as they relate to various steps to sustainability as outlined in the GSP Regulations. The monitoring protocol BMP is part of the Monitoring step identified in **Figure 1**.

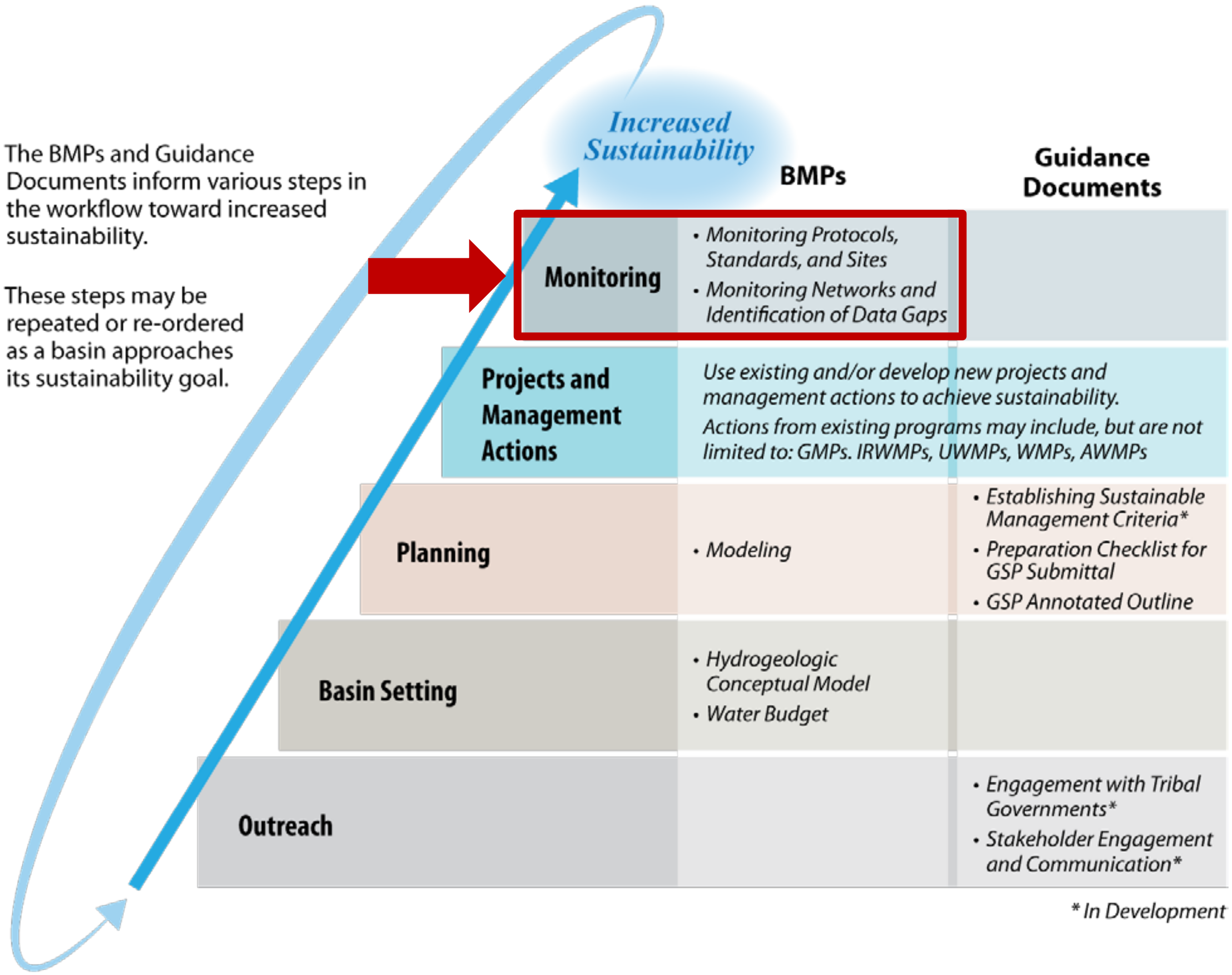

Figure 1 – Logical Progression of Basin Activities Needed to Increase Basin Sustainability

5. TECHNICAL ASSISTANCE

23 CCR §352.2. Monitoring Protocols. Each Plan shall include monitoring protocols adopted by the Agency for data collection and management, as follows:
(a) Monitoring protocols shall be developed according to best management practices.
(b) The Agency may rely on monitoring protocols included as part of the best management practices developed by the Department, or may adopt similar monitoring protocols that will yield comparable data.
(c) Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan, and modified as necessary.

The GSP Regulations specifically call out the need to utilize protocols identified in this BMP, or develop similar protocols. The following technical protocols provide guidance based upon existing professional standards and are commonly adopted in various groundwater-related programs. They provide clear techniques that yield quality data for use in the various components of the GSP. They can be further elaborated on by individual GSAs in the form of standard operating procedures which reflect specific local requirements and conditions. While many methodologies are suggested in this BMP, it should be understood that qualified professional judgment should be used to meet the specific monitoring needs.

The following BMPs may be incorporated into a GSP's monitoring protocols section for collecting groundwater elevation data. A GSP that adopts protocols that deviate from these BMPs must demonstrate that they will yield comparable data.

PROTOCOLS FOR ESTABLISHING A MONITORING PROGRAM

The protocol for establishment of a monitoring program should be evaluated in conjunction with the *Monitoring Network and Identification of Data Gaps* BMP and other BMPs. Monitoring protocols must take into consideration the *Hydrogeologic Conceptual Model, Water Budget, and Modeling* BMPs when considering the data needs to meet GSP objectives and the sustainability goal.

It is suggested that each GSP incorporate the Data Quality Objective (DQO) process following the U.S. EPA *Guidance on Systematic Planning Using the Data Quality Objectives Process* (EPA, 2006). Although strict adherence to this method is not required, it does provide a robust approach to consider and assures that data is collected with a specific purpose in mind, and efforts for monitoring are as efficient as possible to achieve the objectives of the GSP and compliance with the GSP Regulations.

The DQO process presents a method that can be applied directly to the sustainability criteria quantitative requirements through the following steps.

1. State the problem – Define sustainability indicators and planning considerations of the GSP and sustainability goal.
2. Identify the goal – Describe the quantitative measurable objectives and minimum thresholds for each of the sustainability indicators.
3. Identify the inputs – Describe the data necessary to evaluate the sustainability indicators and other GSP requirements (i.e. water budget).
4. Define the boundaries of the study – This is commonly the extent of the Bulletin 118 groundwater basin or subbasin, unless multiple GSPs are prepared for a given basin. In that case, evaluation of the coordination plan and specifically how the monitoring will be comparable and meet the sustainability goals for the entire basin.
5. Develop an analytical approach – Determine how the quantitative sustainability indicators will be evaluated (i.e. are special analytical methods required that have specific data needs).
6. Specify performance or acceptance criteria – Determine what quality the data must have to achieve the objective and provide some assurance that the analysis is accurate and reliable.
7. Develop a plan for obtaining data – Once the objectives are known determine how these data should be collected. Existing data sources should be used to the greatest extent possible.

These steps of the DQO process should be used to guide GSAs to develop the most efficient monitoring process to meet the measurable objectives of the GSP and the sustainability goal. The DQO process is an iterative process and should be evaluated regularly to improve monitoring efficiencies and meet changing planning and project needs. Following the DQO process, GSAs should also include a data quality control and quality assurance plan to guide the collection of data.

Many monitoring programs already exist as part of ongoing groundwater management or other programs. To the extent possible, the use of existing monitoring data and programs should be utilized to meet the needs for characterization, historical record documentation, and continued monitoring for the SGMA program. However, an evaluation of the existing monitoring data should be performed to assure the data being collected meets the DQOs, regulatory requirements, and data collection protocol described in this BMP. While this BMP provides guidance for collection of various regulatory based requirements, there is flexibility among the various methodologies available to meet the DQOs based upon professional judgment (local conditions or project needs).

At a minimum, for each monitoring site, the following information or procedure should be collected and documented:

- Long-term access agreements. Access agreements should include year-round site access to allow for increased monitoring frequency.
- A unique identifier that includes a general written description of the site location, date established, access instructions and point of contact (if necessary), type of information to be collected, latitude, longitude, and elevation. Each monitoring location should also track all modifications to the site in a modification log.

PROTOCOLS FOR MEASURING GROUNDWATER LEVELS

This section presents considerations for the methodology of collection of groundwater level data such that it meets the requirements of the GSP Regulations and the DQOs of the specific GSP. Groundwater levels are a fundamental measure of the status of groundwater conditions within a basin. In many cases, relationships of the sustainability indicators may be able to be correlated with groundwater levels. The quality of this data must consider the specific aquifer being monitored and the methodology for collecting these levels.

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

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

General Well Monitoring Information

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

- Groundwater elevation data will form the basis of basin-wide water-table and piezometric maps, and should approximate conditions at a discrete period in time. Therefore, all groundwater levels in a basin should be collected within as short a time as possible, preferably within a 1 to 2 week period.
- Depth to groundwater must be measured relative to an established Reference Point (RP) on the well casing. The RP is usually identified with a permanent marker, paint spot, or a notch in the lip of the well casing. By convention in open casing monitoring wells, the RP reference point is located on the north side of the well casing. If no mark is apparent, the person performing the measurement should measure the depth to groundwater from the north side of the top of the well casing.
- The elevation of the RP of each well must be surveyed to the North American Vertical Datum of 1988 (NAVD88), or a local datum that can be converted to NAVD88. The elevation of the RP must be accurate to within 0.5 foot. It is preferable for the RP elevation to be accurate to 0.1 foot or less. Survey grade global navigation satellite system (GNSS) global positioning system (GPS) equipment can achieve similar vertical accuracy when corrected. Guidance for use of GPS can be found at USGS http://water.usgs.gov/osw/gps/. Hand-held GPS units likely will not produce reliable vertical elevation measurement accurate enough for the casing elevation consistent with the DQOs and regulatory requirements.
- The sampler should remove the appropriate cap, lid, or plug that covers the monitoring access point listening for pressure release. If a release is observed, the measurement should follow a period of time to allow the water level to equilibrate.
- Depth to groundwater must be measured to an accuracy of 0.1 foot below the RP. It is preferable to measure depth to groundwater to an accuracy of 0.01 foot. Air lines and acoustic sounders may not provide the required accuracy of 0.1 foot.
- The water level meter should be decontaminated after measuring each well.

Where existing wells do not meet the base standard as described in the GSP Regulations or the considerations provided above, new monitoring wells may need to be constructed to meet the DQOs of the GSP. The design, installation, and documentation of new monitoring wells must consider the following:

- Construction consistent with California Well Standards as described in Bulletins 74-81 and 74-90, and local permitting agency standards of practice.
- Logging of borehole cuttings under the supervision of a California Professional Geologist and described consistent with the Unified Soil Classification System methods according to ASTM standard D2487-11.
- Written criteria for logging of borehole cuttings for comparison to known geologic formations, principal aquifers and aquitards/aquicludes, or specific marker beds to aid in consistent stratigraphic correlation within and across basins.
- Geophysical surveys of boreholes to aid in consistency of logging practices. Methodologies should include resistivity, spontaneous potential, spectral gamma, or other methods as appropriate for the conditions. Selection of geophysical methods should be based upon the opinion of a professional geologist or professional engineer, and address the DQOs for the specific borehole and characterization needs.
- Prepare and submit State well completion reports according to the requirements of §13752. Well completion report documentation should include geophysical logs, detailed geologic log, and formation identification as attachments. An example well completion as-built log is illustrated in **Figure 2.** DWR well completion reports can be filed directly at the Online System for Well Completion Reports (OSWCR) http://water.ca.gov/oswcr/index.cfm.

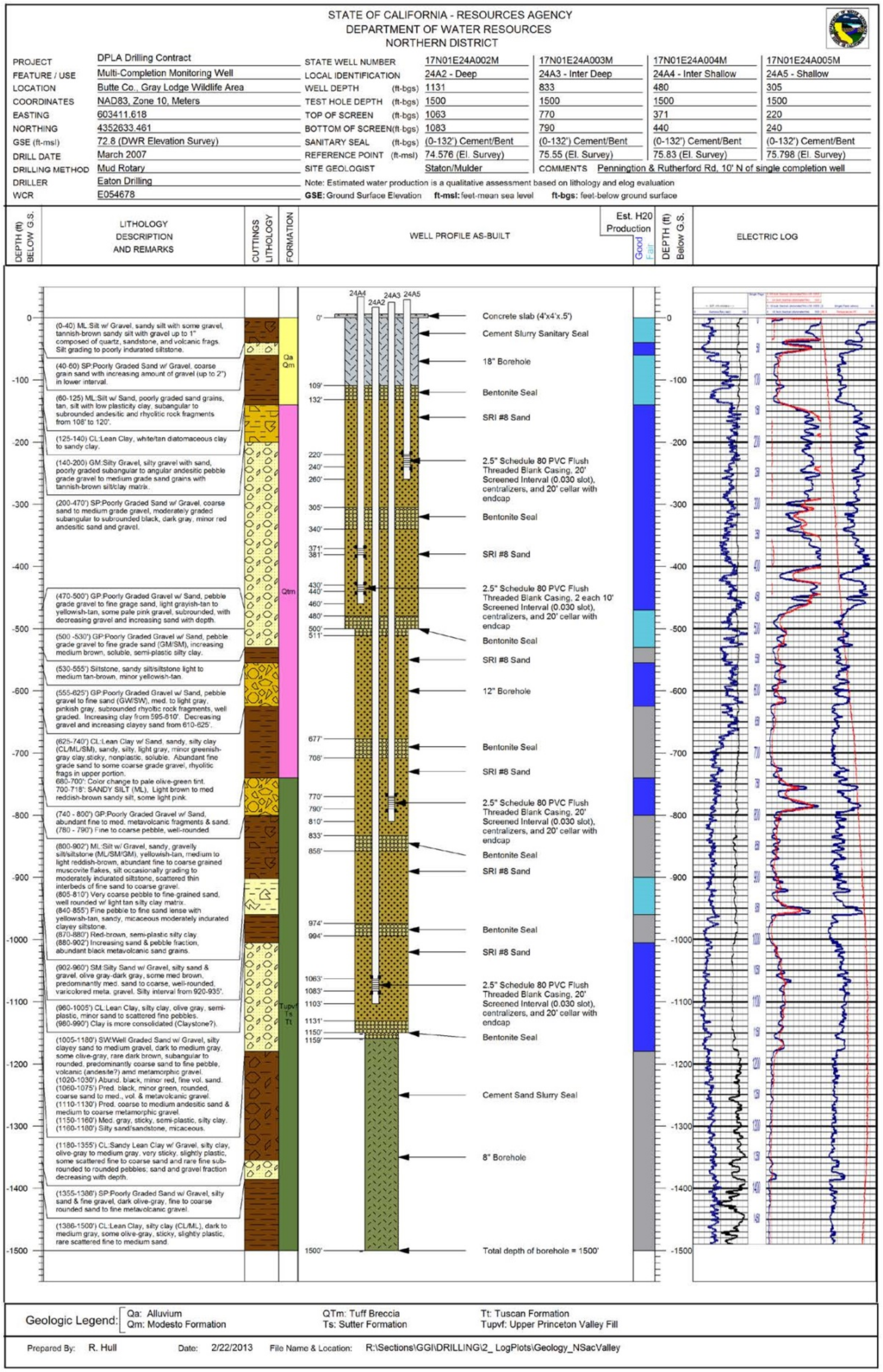

Figure 2 – Example As-Built Multi-Completion Monitoring Well Log

Measuring Groundwater Levels

Well construction, anticipated groundwater level, groundwater level measuring equipment, field conditions, and well operations should be considered prior collection of the groundwater level measurement. The USGS *Groundwater Technical Procedures* (Cunningham and Schalk, 2011) provide a thorough set of procedures which can be used to establish specific Standard Operating Procedures (SOPs) for a local agency. **Figure 3** illustrates a typical groundwater level measuring event and simultaneous pressure transducer download.

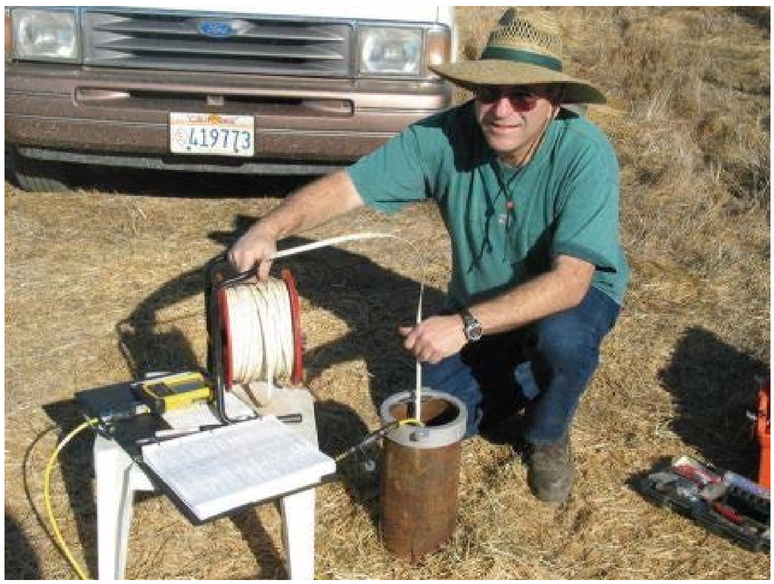

Figure 3 – Collection of Water Level Measurement and Pressure Transducer Download

The following points provide a general approach for collecting groundwater level measurements:

- Measure depth to water in the well using procedures appropriate for the measuring device. Equipment must be operated and maintained in accordance with manufacturer's instructions. Groundwater levels should be measured to the nearest 0.01 foot relative to the RP.
- For measuring wells that are under pressure, allow a period of time for the groundwater levels to stabilize. In these cases, multiple measurements should be collected to ensure the well has reached equilibrium such that no significant changes in water level are observed. Every effort should be made to ensure that a representative stable depth to groundwater is recorded. If a well does not stabilize, the quality of the value should be appropriately qualified as a

questionable measurement. In the event that a well is artesian, site specific procedures should be developed to collect accurate information and be protective of safety conditions associated with a pressurized well. In many cases, an extension pipe may be adequate to stabilize head in the well. Record the dimension of the extension and document measurements and configuration.

- The sampler should calculate the groundwater elevation as:

$$GWE = RPE - DTW$$

Where:

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

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

<u>Recording Groundwater Levels</u>

- The sampler should record the well identifier, date, time (24-hour format), RPE, height of RP above or below ground surface, DTW, GWE, and comments regarding any factors that may influence the depth to water readings such as weather, nearby irrigation, flooding, potential for tidal influence, or well condition. If there is a questionable measurement or the measurement cannot be obtained, it should be noted. An example of a field sheet with the required information is shown in **Figure 4**. It includes questionable measurement and no measurement codes that should be noted. This field sheet is provided as an example. Standardized field forms should be used for all data collection. The aforementioned USGS *Groundwater Technical Procedures* offers a number of example forms.
- The sampler should replace any well caps or plugs, and lock any well buildings or covers.
- All data should be entered into the GSA data management system (DMS) as soon as possible. Care should be taken to avoid data entry mistakes and the entries should be checked by a second person for compliance with the DQOs.

STATE OF CALIFORNA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WELL DATA

STATE WELL NUMBER	COUNTY	REFERENCE POINT ELEV.	MEASURING AGENCY
			DWR

NO MEASUREMENT	QUESTIONABLE MEASUREMENT
0. Measurement discontinued	0. Caved or deepened
1. Pumping	1. Pumping
2. Pump house locked	2. Nearby pump operating
3. Tape hung up	3. Casing leaky or wet
4. Can't get tape in casing	4. Pumped recently
5. Unable to locate well	5. Air or pressure gauge measurement
6. Well has been destroyed	6. Other
7. Special	7. Recharge operation at or nearby well
8. Casing leaky or wet	8. Oil in casing
9. Temporarily inaccessible	

DATE	N M	Q M	TAPE AT RP	TAPE AT WS	RP to WS	OBSR VR	COMMENTS

DWR 1213

Figure 4 – Example of Water Level Well Data Field Collection Form

Pressure Transducers

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

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

- The sampler must use an electronic sounder or chalked steel tape and follow the protocols listed above to measure the groundwater level and calculate the groundwater elevation in the monitoring well to properly program and reference the installation. It is recommended that transducers record measured groundwater level to conserve data capacity; groundwater elevations can be calculated at a later time after downloading.
- The sampler must note the well identifier, the associated transducer serial number, transducer range, transducer accuracy, and cable serial number.
- Transducers must be able to record groundwater levels with an accuracy of at least 0.1 foot. Professional judgment should be exercised to ensure that the data being collected is meeting the DQO and that the instrument is capable. Consideration of the battery life, data storage capacity, range of groundwater level fluctuations, and natural pressure drift of the transducers should be included in the evaluation.
- The sampler must note whether the pressure transducer uses a vented or non-vented cable for barometric compensation. Vented cables are preferred, but non-vented units provide accurate data if properly corrected for natural barometric pressure changes. This requires the consistent logging of barometric pressures to coincide with measurement intervals.
- Follow manufacturer specifications for installation, calibration, data logging intervals, battery life, correction procedure (if non-vented cables used), and anticipated life expectancy to assure that DQOs are being met for the GSP.
- Secure the cable to the well head with a well dock or another reliable method. Mark the cable at the elevation of the reference point with tape or an indelible marker. This will allow estimates of future cable slippage.
- The transducer data should periodically be checked against hand measured groundwater levels to monitor electronic drift or cable movement. This should happen during routine site visits, at least annually or as necessary to maintain data integrity.

- The data should be downloaded as necessary to ensure no data is lost and entered into the basin's DMS following the QA/QC program established for the GSP. Data collected with non-vented data logger cables should be corrected for atmospheric barometric pressure changes, as appropriate. After the sampler is confident that the transducer data have been safely downloaded and stored, the data should be deleted from the data logger to ensure that adequate data logger memory remains.

PROTOCOLS FOR SAMPLING GROUNDWATER QUALITY

The following protocols can be incorporated into a GSP's monitoring protocols for collecting groundwater quality data. More detailed sampling procedures and protocols are included in the standards and guidance documents listed at the end of this BMP. A GSP that adopts protocols that deviate from these BMPs must demonstrate that the adopted protocols will yield comparable data.

In general, the use of existing water quality data within the basin should be done to the greatest extent possible if it achieves the DQOs for the GSP. In some cases it may be necessary to collect additional water quality data to support monitoring programs or evaluate specific projects. The USGS *National Field Manual for the Collection of Water Quality Data* (Wilde, 2005) should be used to guide the collection of reliable data. **Figure 5** illustrates a typical groundwater quality sampling setup.

Figure 5 – Typical Groundwater Quality Sampling Event

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

Groundwater quality sampling protocols should ensure that:

- Groundwater quality data are taken from the correct location
- Groundwater quality data are accurate and reproducible
- Groundwater quality data represent conditions that inform appropriate basin management and are consistent with the DQOs
- All salient information is recorded to normalize, if necessary, and compare data
- Data are handled in a way that ensures data integrity

The following points are general guidance in addition to the techniques presented in the previously mentioned USGS *National Field Manual for the Collection of Water Quality Data.*

Standardized protocols include the following:

- Prior to sampling, the sampler must contact the laboratory to schedule laboratory time, obtain appropriate sample containers, and clarify any sample holding times or sample preservation requirements.
- Each well used for groundwater quality monitoring must have a unique identifier. This identifier must appear on the well housing or the well casing to avoid confusion.
- In the case of wells with dedicated pumps, samples should be collected at or near the wellhead. Samples should not be collected from storage tanks, at the end of long pipe runs, or after any water treatment.
- The sampler should clean the sampling port and/or sampling equipment and the sampling port and/or sampling equipment must be free of any contaminants. The sampler must decontaminate sampling equipment between sampling locations or wells to avoid cross-contamination between samples.
- The groundwater elevation in the well should be measured following appropriate protocols described above in the groundwater level measuring protocols.
- For any well not equipped with low-flow or passive sampling equipment, an adequate volume of water should be purged from the well to ensure that the groundwater sample is representative of ambient groundwater and not stagnant water in the well casing. Purging three well casing volumes is generally

considered adequate. Professional judgment should be used to determine the proper configuration of the sampling equipment with respect to well construction such that a representative ambient groundwater sample is collected. If pumping causes a well to be evacuated (go dry), document the condition and allow well to recover to within 90% of original level prior to sampling. Professional judgment should be exercised as to whether the sample will meet the DQOs and adjusted as necessary.

- Field parameters of pH, electrical conductivity, and temperature should be collected for each sample. Field parameters should be evaluated during the purging of the well and should stabilize prior to sampling. Measurements of pH should only be measured in the field, lab pH analysis are typically unachievable due to short hold times. Other parameters, such as oxidation-reduction potential (ORP), dissolved oxygen (DO) (in situ measurements preferable), or turbidity, may also be useful for meeting DQOs of GSP and assessing purge conditions. All field instruments should be calibrated daily and evaluated for drift throughout the day.
- Sample containers should be labeled prior to sample collection. The sample label must include: sample ID (often well ID), sample date and time, sample personnel, sample location, preservative used, and analytes and analytical method.
- Samples should be collected under laminar flow conditions. This may require reducing pumping rates prior to sample collection.
- Samples should be collected according to appropriate standards such as those listed in the *Standard Methods for the Examination of Water and Wastewater*, USGS *National Field Manual for the Collection of Water Quality Data,* or other appropriate guidance. The specific sample collection procedure should reflect the type of analysis to be performed and DQOs.
- All samples requiring preservation must be preserved as soon as practically possible, ideally at the time of sample collection. Ensure that samples are appropriately filtered as recommended for the specific analyte. Entrained solids can be dissolved by preservative leading to inconsistent results of dissolve analytes. Specifically, samples to be analyzed for metals should be field-filtered prior to preservation; do not collect an unfiltered sample in a preserved container.
- Samples should be chilled and maintained at 4 °C to prevent degradation of the sample. The laboratory's Quality Assurance Management Plan should detail appropriate chilling and shipping requirements.

- Samples must be shipped under chain of custody documentation to the appropriate laboratory promptly to avoid violating holding time restrictions.
- Instruct the laboratory to use reporting limits that are equal to or less than the applicable DQOs or regional water quality objectives/screening levels.

Special protocols for low-flow sampling equipment

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

Special protocols for passive sampling equipment

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

PROTOCOLS FOR MONITORING SEAWATER INTRUSION

Monitoring seawater intrusion requires analysis of the chloride concentrations within groundwater of each principal aquifer subject to seawater intrusion. While no significant standardized approach exists, the methodologies described above for degraded water quality can be applied for the collection of groundwater samples. In addition to the protocol described above, the following protocols should be followed:

- Water quality samples should be collected and analyzed at least semi-annually. Samples will be analyzed for dissolved chloride at a minimum. It may be beneficial to include analyses of iodide and bromide to aid in determination of salinity source. More frequent sampling may be necessary to meet DQOs of GSP. The development of surrogate measures of chloride concentration may facilitate cost-effective means to monitor more frequently to observe the range of conditions and variability of the flow dynamics controlling seawater intrusion.
- Groundwater levels will be collected at a frequency adequate to characterize changes in head in the vicinity of the leading edge of degraded water quality in each principal aquifer. Frequency may need to be increased in areas of known preferential pathways, groundwater pumping, or efficacy evaluation of mitigation projects.
- The use of geophysical surveys, electrical resistivity, or other methods may provide for identification of preferential pathways and optimize monitoring well placement and evaluation of the seawater intrusion front. Professional judgment

should be exercised to determine the appropriate methodology and whether the DQOs for the GSP would be met.

PROTOCOLS FOR MEASURING STREAMFLOW

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

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

To establish a new streamflow monitoring station special consideration must be made in the field to select an appropriate location for measuring discharge. Once a site is selected, development of a relationship of stream stage to discharge will be necessary to provide continuous estimates of streamflow. Several measurements of discharge at a variety of stream stages will be necessary to develop the ratings curve correlating stage to discharge. The use of Acoustic Doppler Current Profilers (ADCPs) can provide accurate estimates of discharge in the correct settings. Professional judgment must be exercised to determine the appropriate methodology. Following development of the ratings curve a simple stilling well and pressure transducer with data logger can be used to evaluate stage on a frequent basis. A simple stilling well and staff gage is illustrated in **Figure 6**.

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

Figure 6 – Simple Stilling Well and Staff Gage Setup

PROTOCOLS FOR MEASURING SUBSIDENCE

Evaluating and monitoring inelastic land subsidence can utilize multiple data sources to evaluate the specific conditions and associated causes. To the extent possible, the use of existing data should be utilized. Subsidence can be estimated from numerous techniques, they include: level surveying tied to known stable benchmarks or benchmarks located outside the area being studied for possible subsidence; installing and tracking changes in borehole extensometers; obtaining data from continuous GPS (CGPS) locations, static GPS surveys or Real-Time-Kinematic (RTK) surveys; or analyzing Interferometric Synthetic Aperture Radar (InSAR) data. No standard procedures exist for collecting data from the potential subsidence monitoring approaches. However, an approach may include:

- Identification of land subsidence conditions.
  - Evaluate existing regional long-term leveling surveys of regional infrastructure, i.e. roadways, railroads, canals, and levees.
  - Inspect existing county and State well records where collapse has been noted for well repairs or replacement.
  - Determine if significant fine-grained layers are present such that the potential for collapse of the units could occur should there be significant depressurization of the aquifer system.

  - Inspect geologic logs and the hydrogeologic conceptual model to aid in identification of specific units of concern.
  - Collect regional remote-sensing information such as InSAR, commonly provided by USGS and NASA. Data availability is currently limited, but future resources are being developed.
- Monitor regions of suspected subsidence where potential exists.
  - Establish CGPS network to evaluate changes in land surface elevation.
  - Establish leveling surveys transects to observe changes in land surface elevation.
  - Establish extensometer network to observe land subsidence. An example of a typical extensometer design is illustrated in **Figure 7**. There are a variety of extensometer designs and they should be selected based on the specific DQOs.

Various standards and guidance documents for collecting data include:

- Leveling surveys must follow surveying standards set out in the California Department of Transportation's Caltrans Surveys Manual.
- GPS surveys must follow surveying standards set out in the California Department of Transportation's Caltrans Surveys Manual.
- USGS has been performing subsidence surveys within several areas of California. These studies are sound examples for appropriate methods and should be utilized to the extent possible and where available:
  - http://ca.water.usgs.gov/land_subsidence/california-subsidence-measuring.html
- Instruments installed in borehole extensometers must follow the manufacturer's instructions for installation, care, and calibration.
- Availability of InSAR data is improving and will increase as programs are developed. This method requires expertise in analysis of the raw data and will likely be made available as an interpretative report for specific regions.

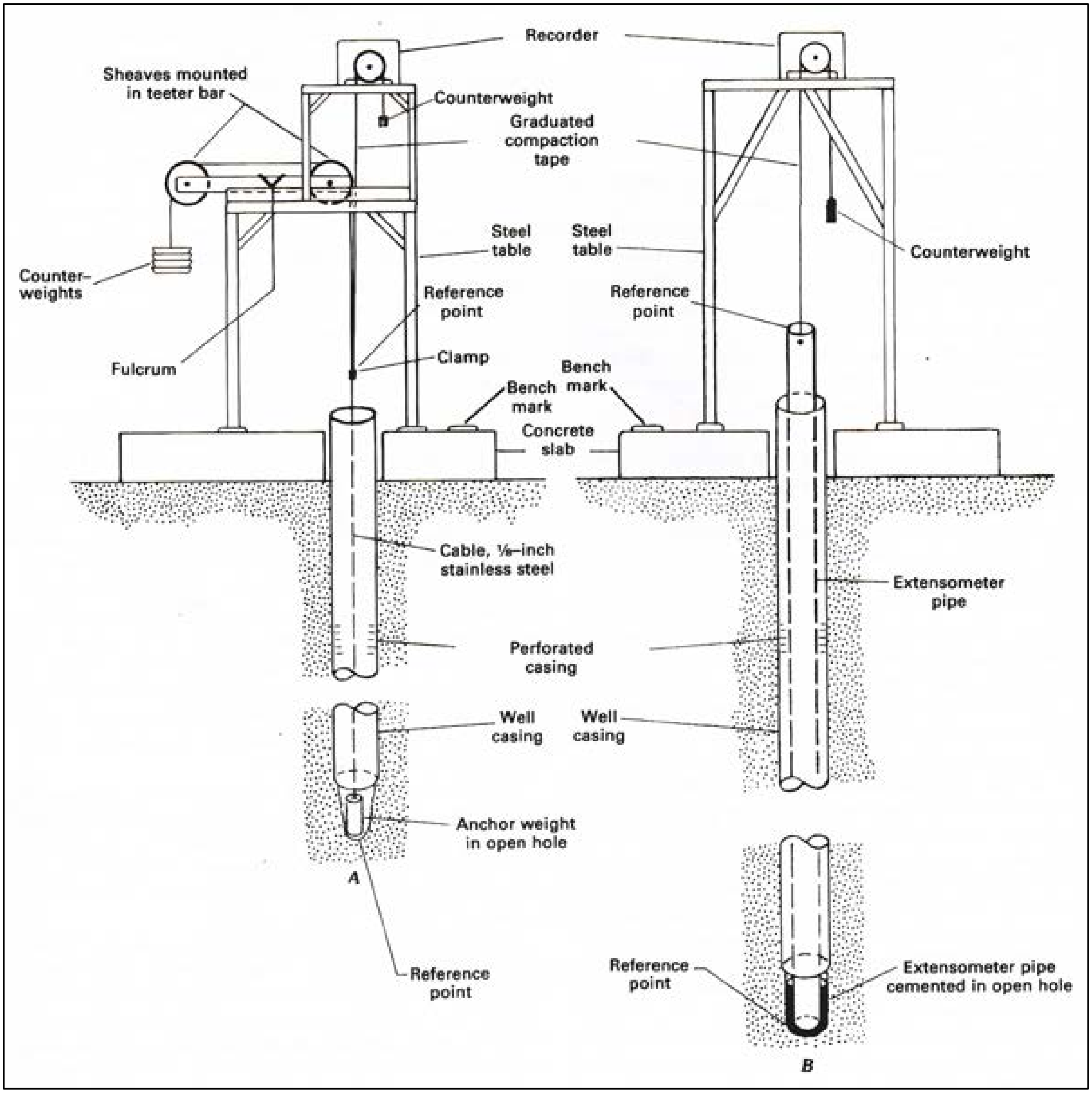

Figure 7 – Simplified Extensometer Diagram

6. KEY DEFINITIONS

The key definitions and sections related to Groundwater Monitoring Protocols, Standards, and Sites outlined in applicable SGMA code and regulations are provided below for reference.

Groundwater Sustainability Plan Regulations (California Code of Regulations §351)

- §351(h) "Best available science" refers to the use of sufficient and credible information and data, specific to the decision being made and the time frame available for making that decision, that is consistent with scientific and engineering professional standards of practice.
- §351(i) "Best management practice" refers to a practice, or combination of practices, that are designed to achieve sustainable groundwater management and have been determined to be technologically and economically effective, practicable, and based on best available science.

Monitoring Protocols Reference

§352.2. Monitoring Protocols

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

(a) Monitoring protocols shall be developed according to best management practices.

(b) The Agency may rely on monitoring protocols included as part of the best management practices developed by the Department, or may adopt similar monitoring protocols that will yield comparable data.

(c) Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan, and modified as necessary.

SGMA Reference

§10727.2. Required Plan Elements

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

7. Related Materials

CASE STUDIES

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Measuring Land Subsidence web page. U.S. Geological Survey. http://ca.water.usgs.gov/land_subsidence/california-subsidence-measuring.html

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Appendix 4-B

DMS Technical Memo

Appendix 4 -**DMS Summary**

Memo

To: Kaweah Subbasin GSAs
Mike Hagman, East Kaweah GSA
Eric Osterling, Greater Kaweah GSA
Paul Hendrix, Mid-Kaweah GSA

From: Chris Petersen and Maria Pascoal, GEI Consultants

Date: [Status]

Re: Draft Specifications for the Kaweah Subbasin Data Management System

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The Sustainable Groundwater Management Act (SGMA) regulations, established by the California Department of Water Resources (DWR), require that a Groundwater Sustainability Plan (GSP) must have a Data Management System (DMS) capable of securely storing and displaying information relevant to the development and implementation of the GSP. The Kaweah Subbasin will be managed by three Groundwater Sustainability Agencies (GSAs) under three GSPs. To effectively and cost-efficiently share data, the GSAs will use one DMS to store the Subbasin's SGMA data.

The DMS for the Kaweah Subbasin is currently being developed by GEI Consultants, Inc. (GEI) with data and analytical support from GSI Water Solutions (GSI). The purpose of this memorandum is to describe the specifications of the DMS. These specifications were developed based on the DMS development meeting held with the three GSAs in April 2018 and supported by Task Order KSB-05.2018 Amendment 2, Task 1 – Data Management System. This memorandum includes the following sections:

1. SGMA DMS Requirements
2. Data Structure
3. Data Contents
4. Web Interface
5. DMS Hosting
6. Summary

SGMA DMS Requirements

The Kaweah Subbasin DMS will be designed to meet the system and data requirements of SGMA.

1.1. System Requirements

The GSP Regulations (California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2) give broad requirements on data management, stating that a GSP must adhere to the following guidelines for a DMS:

> ***§ 352.6. Data Management System***
>
> *Each Agency shall develop and maintain a data management system that is capable of storing and reporting information relevant to the development or implementation of the [Groundwater Sustainability] Plan and monitoring of the basin.*
>
> *Note: Authority cited: Section 10733.2, Water Code.*
> *Reference: Sections 10727.2, 10728, 10728.2, and 10733.2, Water Code.*
>
> ***§ 352.4. Data and Reporting Standards***
>
> *(c) The following standards apply to wells:*
>
> *(3) Well information used to develop the basin setting shall be maintained in the Agency's data management system.*
>
> *Note: Authority cited: Section 10733.2, Water Code.*
> *Reference: Sections 10727.2, 10727.6, and 10733.2, Water Code.*
>
> ***§ 354.40. Reporting Monitoring Data to the Department***
>
> *Monitoring data shall be stored in the data management system developed pursuant to Section 352.6. A copy of the monitoring data shall be included in the Annual Report and submitted electronically on forms provided by the Department.*
>
> *Note: Authority cited: Section 10733.2, Water Code.*
> *Reference: Sections 10728, 10728.2, 10733.2, and 10733.8, Water Code.*

1.2. Data Requirements

SGMA defines sustainable groundwater management as "the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results."[1] Furthermore, SGMA outlines six undesirable results as follows:[2]

> *One or more of the following effects caused by groundwater conditions occurring throughout the basin:*
>
> *(1) Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic*

[1] §10721(v)
[2] §10721(x)

lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.

(2) Significant and unreasonable reduction of groundwater storage.

(3) Significant and unreasonable seawater intrusion.

(4) Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.

(5) Significant and unreasonable land subsidence that substantially interferes with surface land uses.

(6) Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

The presence or absence of the six undesirable results in a groundwater basin is determined by examining the sustainability indicator data for each. The Kaweah Subbasin DMS will store data relevant to each sustainability indicator as appropriate. There are multiple metrics by which the sustainability indicators may be observed. These metrics, as defined in the GSP Regulations and described by DWR in the Sustainable Management Criteria Best Management Practice (BMP) document,[3] are shown in **Figure 1**.

Figure 1. DWR's Sustainability Indicator Metrics

Sustainability Indicators	Lowering GW Levels	Reduction of Storage	Seawater Intrusion	Degraded Quality	Land Subsidence	Surface Water Depletion
Metric(s) Defined in GSP Regulations	• Groundwater Elevation	• Total Volume	• Chloride concentration isocontour	• Migration of Plumes • Number of supply wells • Volume • Location of isocontour	• Rate and Extent of Land Subsidence	• Volume or rate of surface water depletion

[3] https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/BMP_Sustainable_Management_Criteria_2017-11-06.pdf.

The Kaweah Subbasin DMS is designed to store data for each of the six sustainability indicators. Each sustainability indicator may track one or more types of data, as shown in **Table 1**.

Table 1. DMS Data Types to Monitor the SGMA Sustainability Indicators

Sustainability Indicator	Tracking Data							
					Water Quality			
	Water Level	Extensometer	GPS	InSAR	Chloride	±10 constituents	Stream stages	Well* and/or Site Data
Subsidence	✓	✓	✓	✓				✓
Water levels	✓							✓
Groundwater storage	✓							✓
Seawater intrusion	Not applicable (per GSP development)							
Surface water/ groundwater interaction	✓						✓	✓
Water quality	✓				✓	✓		✓

*May include aquifer, construction, lithology, and/or screen data

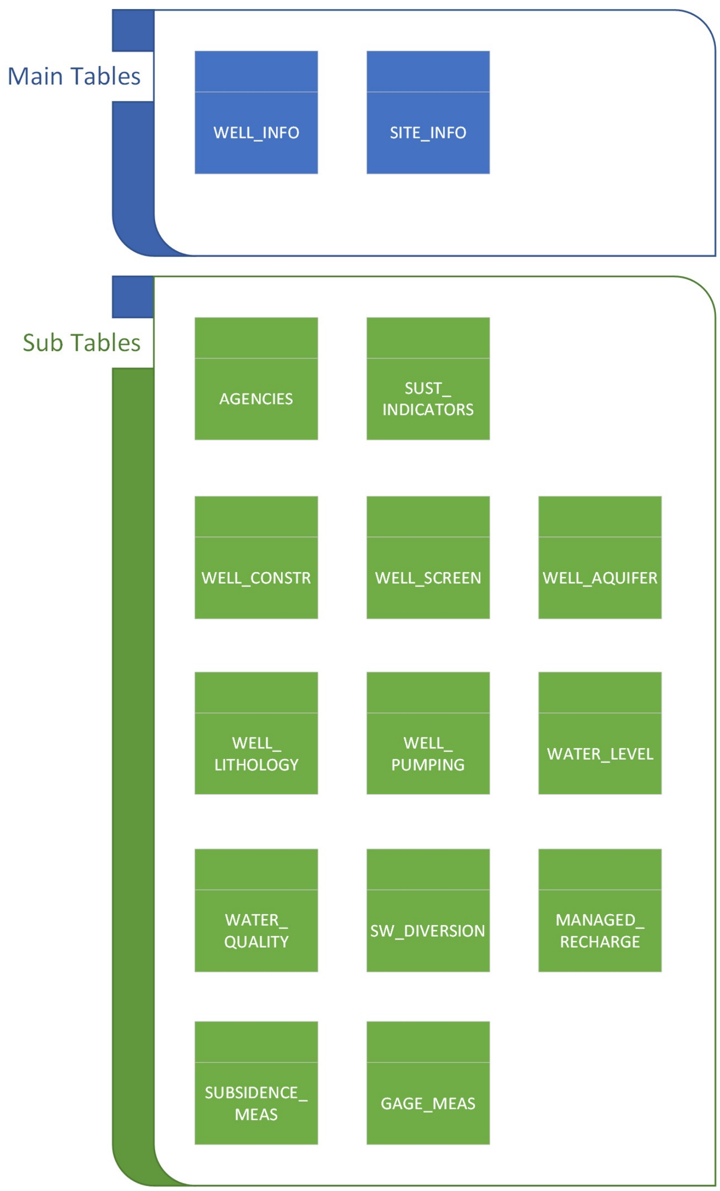
The Kaweah Subbasin DMS will accept the types of data shown in the columns of **Table 1**. However, the DMS will not necessarily be populated with historical data for each type. Data that was relied upon for 2020 GSP development is what will be uploaded in the DMS.

Data Structure

The DMS will consist of a database plus an online web viewer. Data stored in the DMS is separated by categories into tables. The tables contain columns and rows of data. Each field holds a specific type of data, such as a number, text, or date. The primary DMS data tables are shown as **Figure 2**. The figure is color-coordinated to show the relationship between tables:

- **Blue Tables** – Main tables that include point data with a unique identification and unique point location to be added to the database (e.g., Well_Info and Site_Info)
- **Green Tables** – Sub tables related to the main table that hold additional details about the well or site (e.g., correlation of a well point with water level or water quality)

Figure 2. Kaweah Subbasin DMS Tables – Main and Sub



A brief description of each main and sub table is provided in **Table 2**. There are lookup tables within each of the main and sub tables, but the lookup tables are very detailed and not outlined here. The lookup tables can be found in the upload templates described in the next section of this document.

Table 2. DMS Table Descriptions

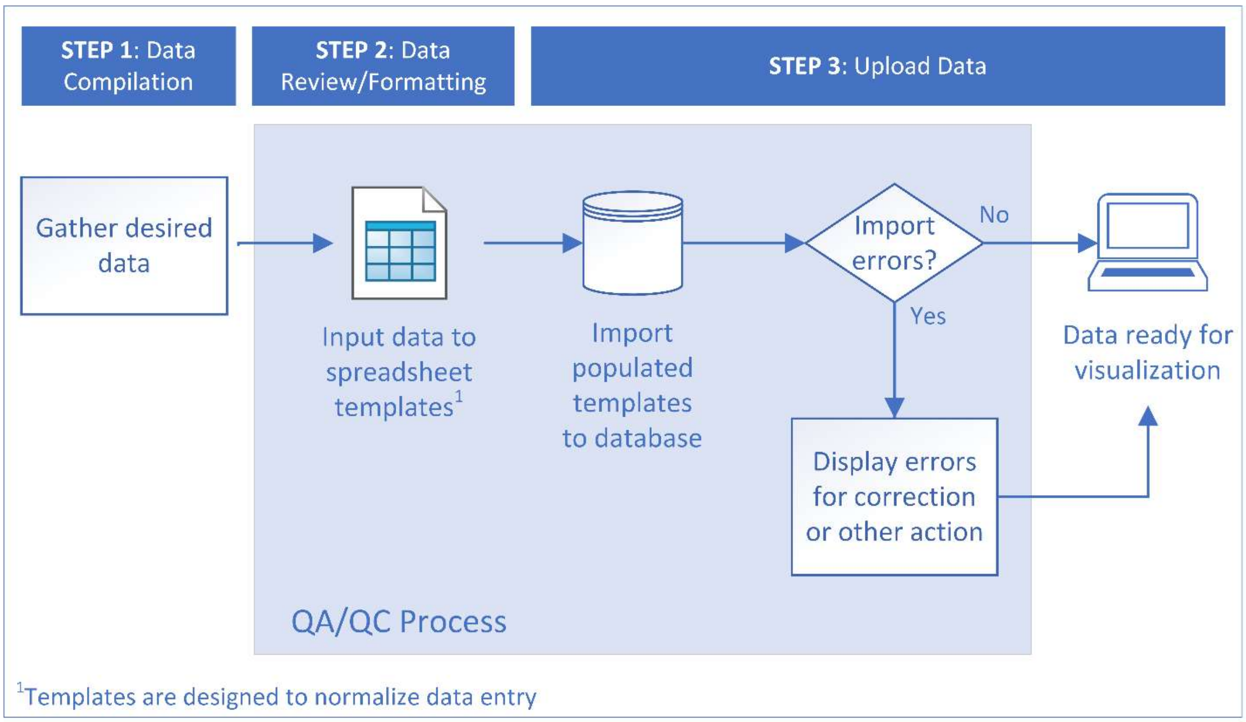
Table	Description
Main Tables	
Site Info	Information about type of station (well, recharge site, diversion, gage, extensometer, GSP) and geographic location
Well Info	General information about well, including identifiers used by various agencies
Sub Tables	
Agencies	Agency associated with the well and/or site or the collection of data at a well or site
Sustainability Indicators	Minimum Thresholds and Measurable Objectives set for monitoring network sites tracking Sustainable Management Criteria for SGMA compliance
Well Construction	Well construction information including depth, diameter, etc.
Well Construction Screen	Supplements ‘Well Construction’ with well screen information (one well can have many screens)
Well Geologic Aquifer	Information about the aquifer parameters of the well such as pumping test information, confinement, and transmissivity
Well Geologic Lithology	Lithologic information at a well site (each well may have many lithologies at different depths)
Water Level	Water level measurements for wells
Well Pumping	Pumping measurements for wells, annual or monthly
Managed Recharge	Recharge measurements for a recharge site, annual or monthly
SW Diversion	Diversion volume measurements for a diversion site, annual or monthly
Water Quality	Water quality data for wells or any other type of site
Subsidence Measurement	Elevation measurements from stations tracking land subsidence
Gage Measurement	Stage or discharge water level measurements from stream gages

Data Contents

Historical data will be populated into the DMS as needed to support the 2020 GSPs. State and Federal data available via online public databases will be brought directly from the data source to the DMS by the DMS development team.

Local Kaweah Subbasin data used to support GSP development will be collected by GEI and put into spreadsheet templates designed to normalize data entry. The templates will include a set of rules restricting formatting, alphanumeric properties, and other filters. This template process is shown as **Figure 3**.

Figure 3. Template Import Process for Local Data



The templates include validation parameters similar to CASGEM templates. CASGEM templates are shown in **Figure 4** as an example. The templates will have pop-up windows to describe what should be filled in for each column. If a specific filter must be applied, only values that meet the criteria will appear in a drop-down list. GEI will upload data to the DMS using these templates.

Figure 4. CASGEM Template Examples

CASGEM ID	Local or State Well Number	Date (MM/dd/yyyy)	24-hour Time, PST (hh:mm)	NM Code	QM Code
389011N1213514W001	Airport Well 4 MW	11/19/2018	6:49		
389011N12135	t Well 4 MW	12/14/2018	6:24		
389011N12135	t Well 4 MW	1/14/2019	7:23		
389011N12135	t Well 4 MW	2/14/2019	7:18		
389011N12135	t Well 4 MW	3/14/2019	7:44		
389011N12135	t Well 4 MW	4/16/2019	8:55		
388604N12135	-1	11/19/2018	9:15		

CASGEM ID
Please enter system generated CASGEM ID.

Example:
xxxxxxNxxxxxxxWxxx

CASGEM ID	Local or State Well Number	Date (MM/dd/yyyy)	24-hour Time, PST (hh:mm)	NM Code	QM Code	Reading at RP
389011N1213514W001	Airport Well 4 MW	11/19/2018	6:49			43.950
389011N1213514W001	Airport Well 4 MW	12/14/2018	6:24			
389011N1213514W001	Airport Well 4 MW	1/14/2019	7:23			
389011N1213514W001	Airport Well 4 MW	2/14/2019	7:18			
389011N1213514W001	Airport Well 4 MW	3/14/2019	7:44			
389011N1213514W001	Airport Well 4 MW	4/16/2019	8:55			[illegible]

No Measurement Code
Please select No Measurement Code.

All the Main and Sub Tables listed in **Table 2** will have a template. The compiled data will be reviewed by GEI before it is migrated into the database. The data review process will be focused and limited in scope. It will include the following checks:

- Identifying outliers that may have been introduced during the original data entry process
- Removing or flagging questionable data

Once the data has been compiled, input to the templates, and reviewed, it will be uploaded to the DMS and displayed on a visualization tool (GIS map) interface.

Moving forward, the templates will be used by the Kaweah Subbasin GSAs to prepare future data for DMS input.

Web Interface

The DMS begins with a database, stored locally or online, and is accompanied by a viewer that allows administrators to see the data in a user-friendly interface. The proposed Kaweah Subbasin DMS is a database built in Oracle plus a web application designed in JAVA.

The web application will display well and other instrument (e.g., extensometer) locations, identifying which wells or instruments are part of a representative monitoring network for the SGMA sustainability indicators.

- Clicking on a well site will display available historical water level or water quality data on a hydrograph
- Clicking on other monitoring points (e.g., extensometers) will display available historical data in tabular and chart format

The map displaying the DMS data will include additional geographic features such as GSA, local agency, and Bulletin 118 basin boundaries to provide context and facilitate interaction with the data.

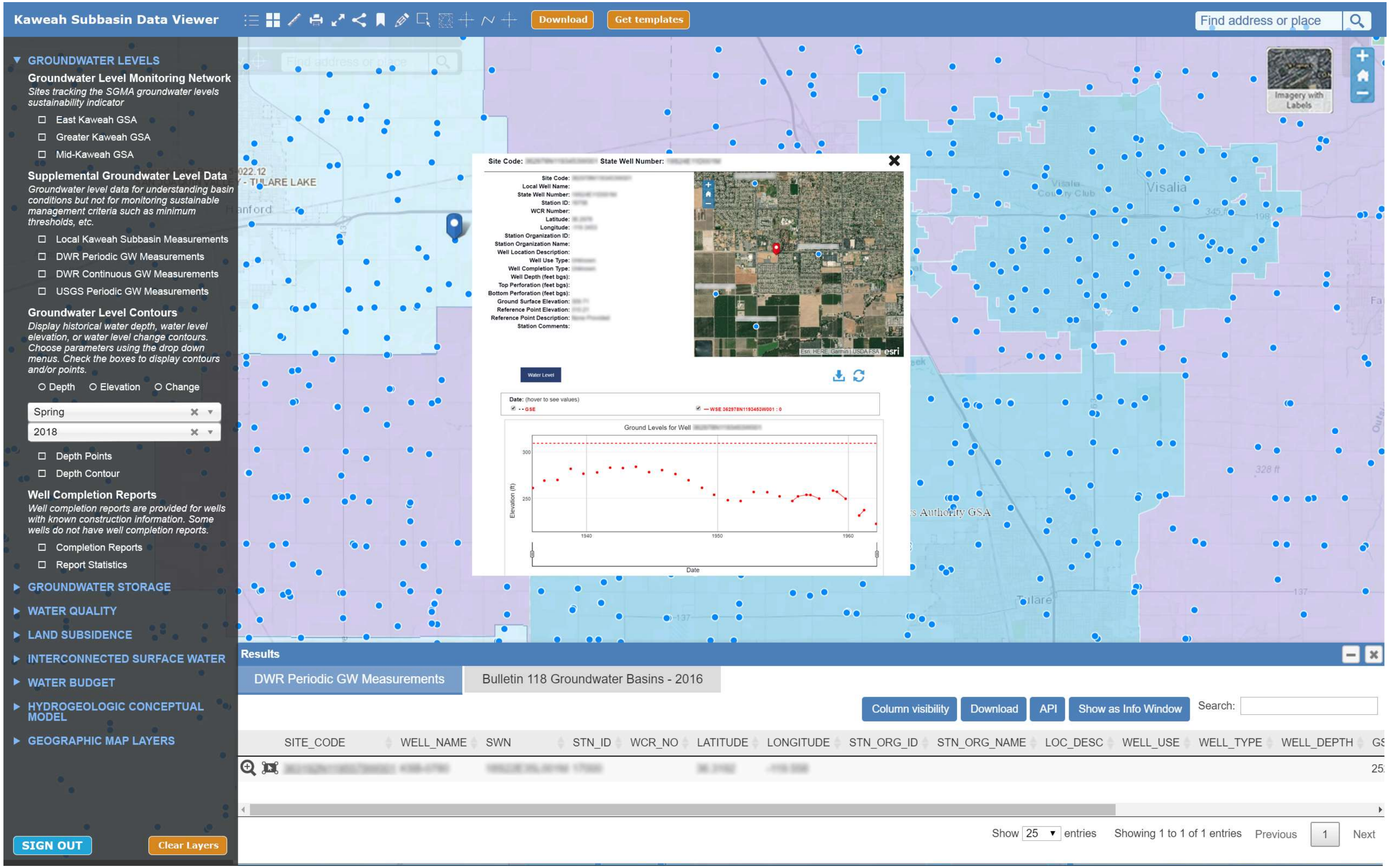
Representative monitoring network data will be made available for export to a spreadsheet format for analytical and reporting purposes. GSP Regulations Article 7 §356.2 outlines specific components to be reported annually (paraphrased):

- *General information including executive summary and location map (narrative)*
- Groundwater elevation contour maps (sourced by DWR) and hydrographs
- Groundwater extraction
- Surface water supply used or available for use, for groundwater recharge or in-lieu use
- *Total water use by water use sector and source (calculated)*
- Change in groundwater storage displayed in map and graph formats
- *Description of progress towards implementing the GSP (narrative)*

The items listed above are needed for each annual report to DWR. The Kaweah Subbasin DMS is designed to store all these items except for those shown in *italics*, which are either narratives or calculations that are done outside of the DMS.

See **Figure 5** for an example design for the Kaweah Subbasin data viewer.

Figure 5. Example Design for Kaweah Subbasin Data Viewer



DMS Hosting

GEI will host the DMS for the duration of the amended Task Order – through December 2019. After that time, hosting will be transferred to either a Kaweah Subbasin GSA or a participating agency. As of the April 2018 DMS Development Meeting, the GSAs decided to postpone choosing where the DMS would be hosted from the year 2020 forward. If needed, GEI may continue to host the DMS for a nominal fee.

Summary

The Kaweah Subbasin DMS will contain the information used to support GSP development. The data stored will be based on the requirements of SGMA and include relevant historical data collected during GSP development for each of the six sustainability indicators. The DMS will consist of an Oracle database with a web-based viewer designed using JAVA. Data will be available for export from the DMS using the web-based viewer. The DMS will be hosted on a GEI server through December 2019, after which time it will be hosted by a Kaweah Subbasin agency or stay with GEI for a fee.

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