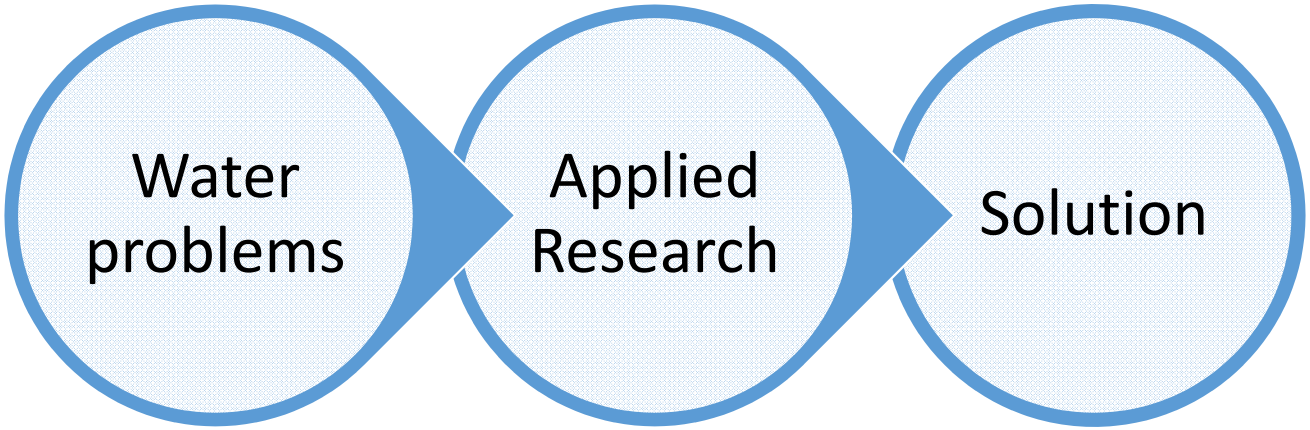
Conjunctive water management in an aquifer-floodplain recharge operation

Carlos Flores & Graham Fogg

Hydrologic Sciences Graduate Group

UC Davis

Approach for solving water issues



Water Problem: Tools for decision making & water scarcity

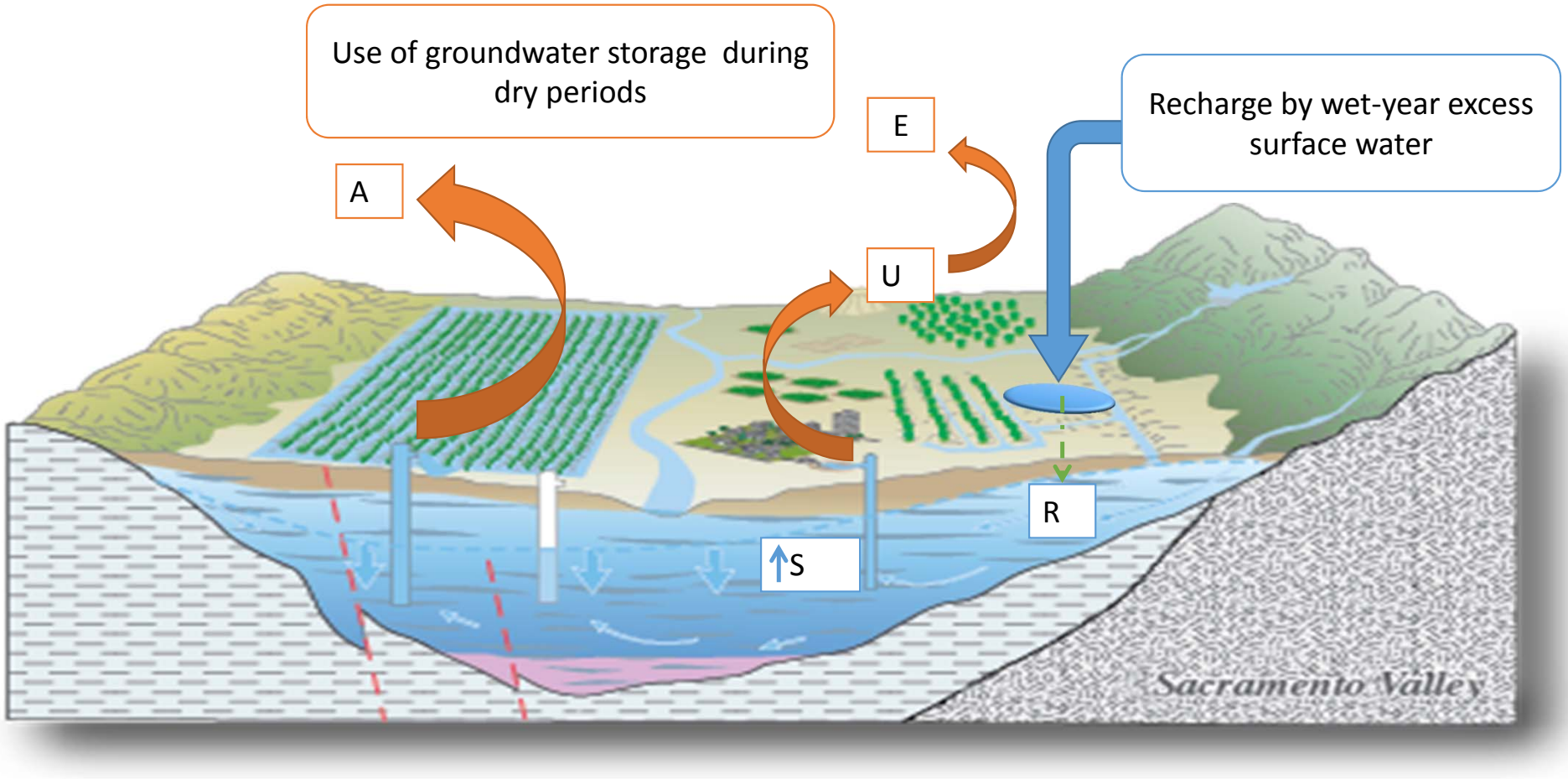
- Develop tools for adequate decision making
- Increase available water to meet demand in complex scenarios

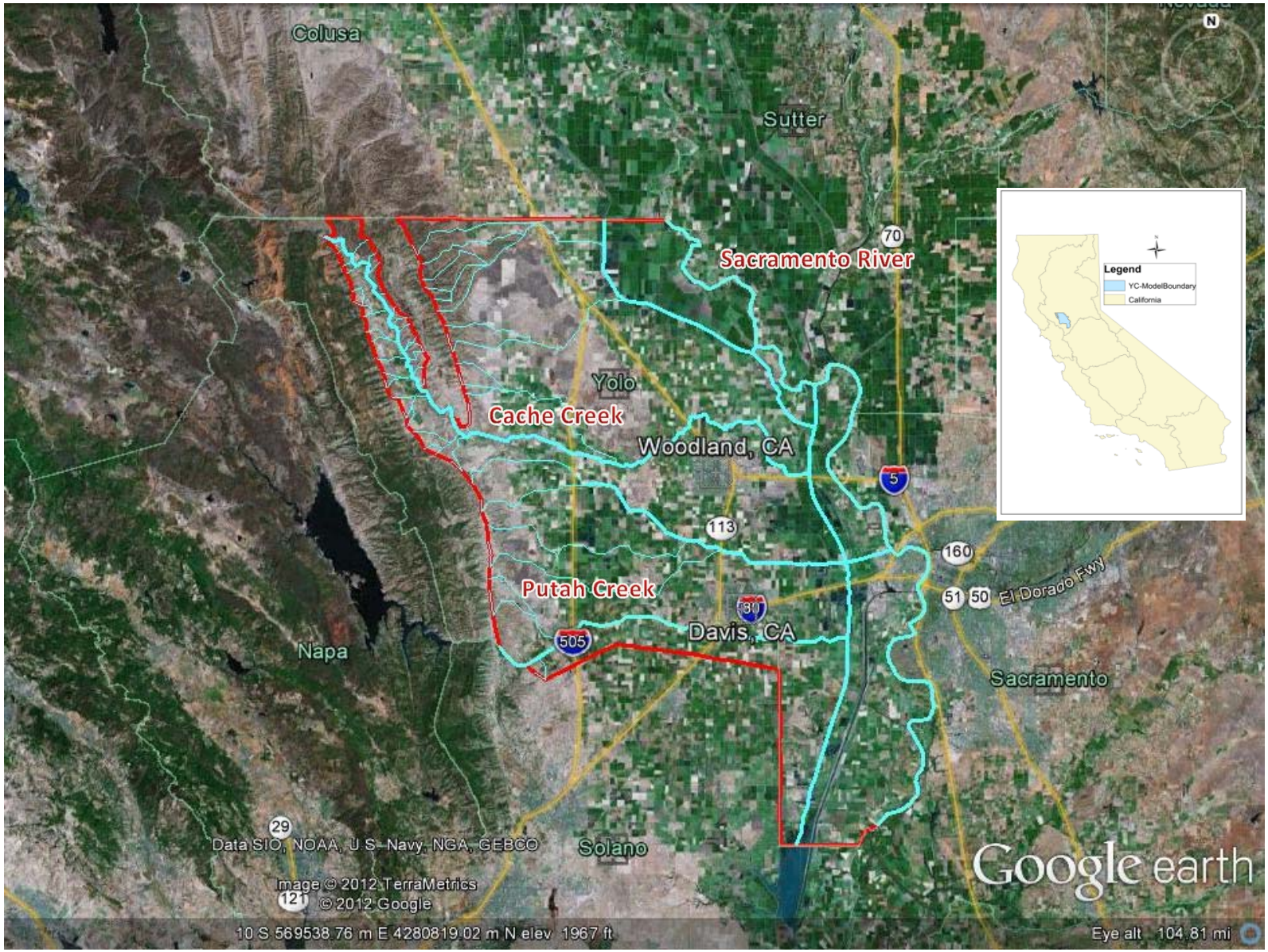
Applied Research

- For tools: Transfer function to estimate groundwater change in storage based on monitoring data.

- For scarcity: Conjunctive use

Conjunctive use base framework




Colusa
Sutter
Sacramento River
Yolo
Cache Creek
Woodland, CA
Putah Creek
Davis, CA
Napa
Sacramento
Solano
El Dorado Fwy
Legend
YC-ModelBoundary
California
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 TerraMetrics
© 2012 Google
Google earth
10 S 569538.76 m E 4280819.02 m N elev 1967 ft
Eye alt 104.81 mi

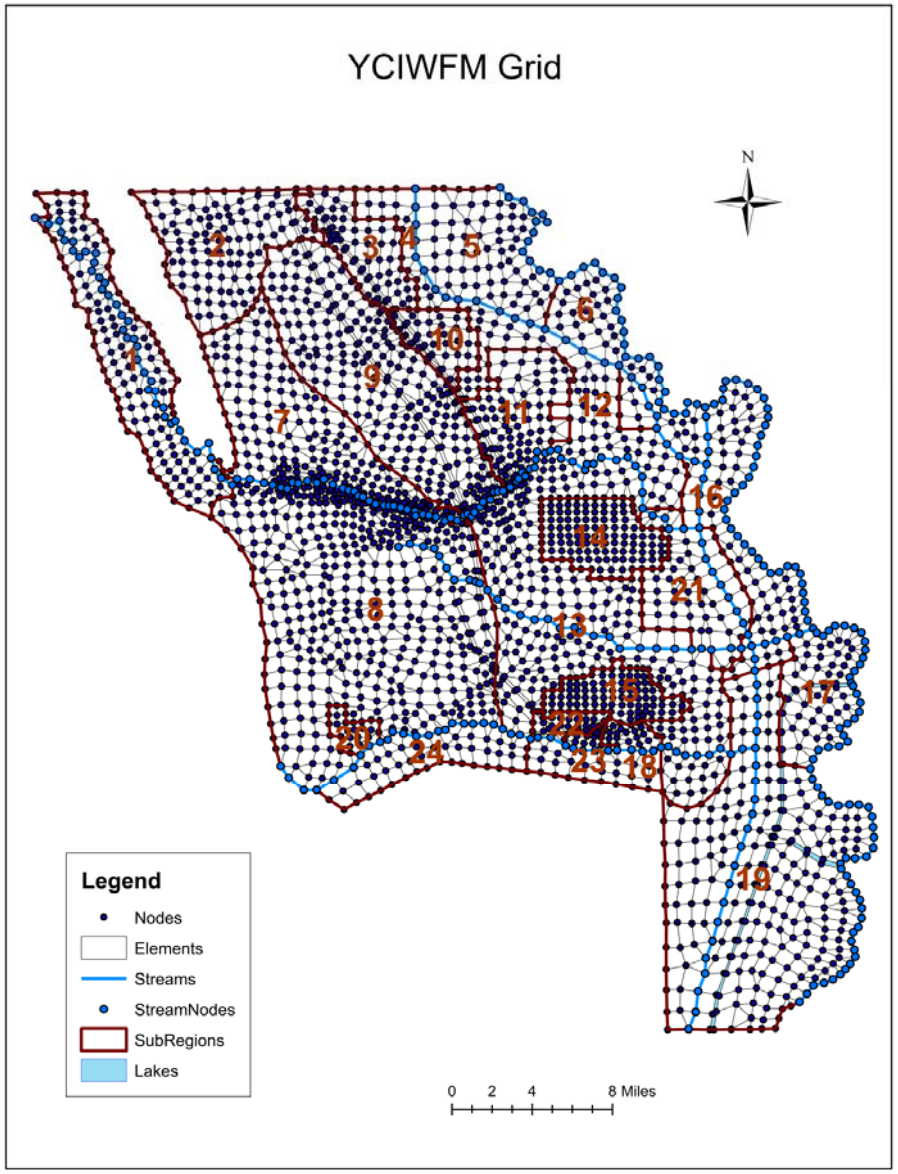
Applied Research

- Conjunctive use in aquifer-floodplain recharge operation

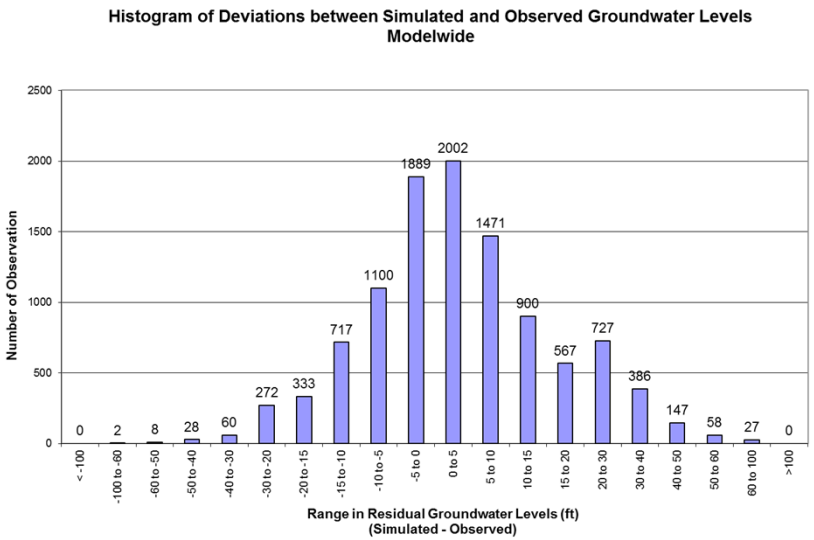
Applied Research

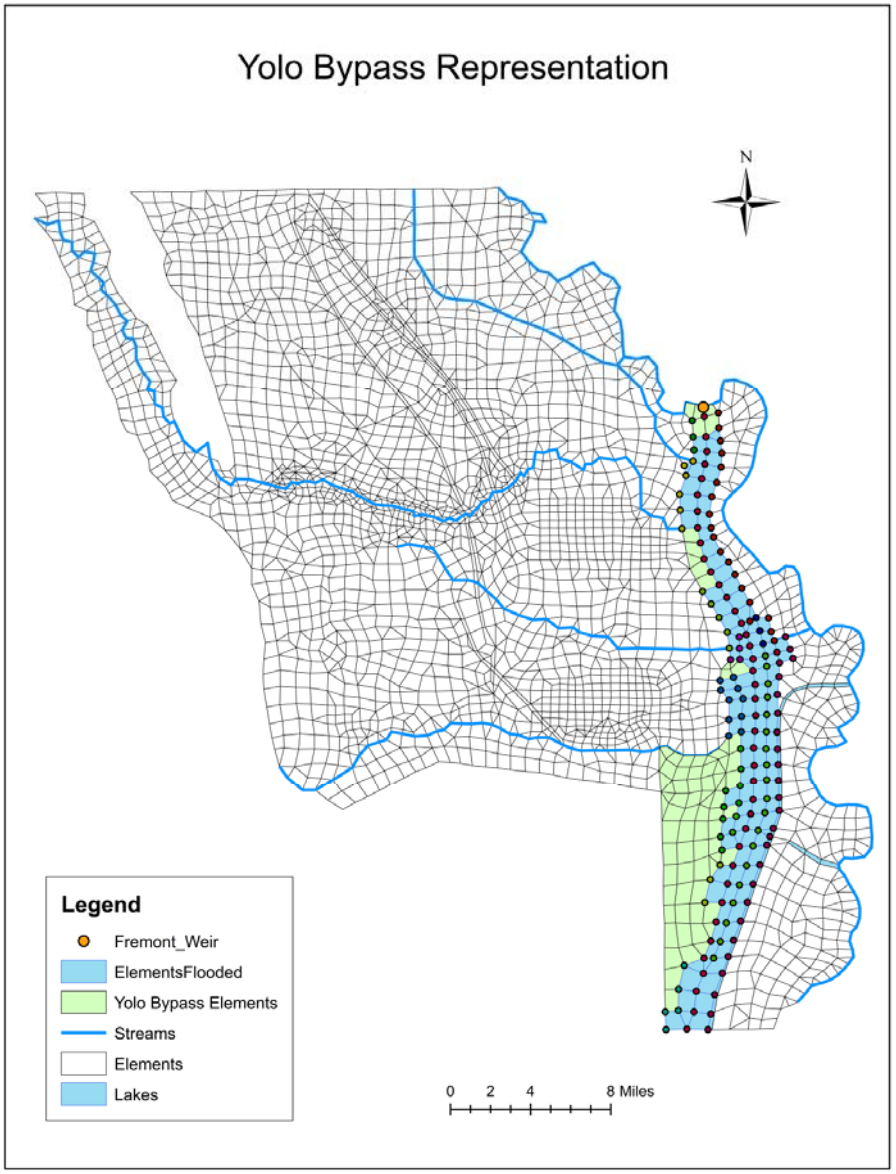
- ***Key questions:***
  - How can a downgradient semi-confined aquifer be recharged?
  - What would be the benefits of recharging at the discharge end of the system?
  - What would be a feasible hydrologic framework for conjunctive use in an aquifer-floodplain recharge operation?

- Approach: Integrated hydrologic modeling

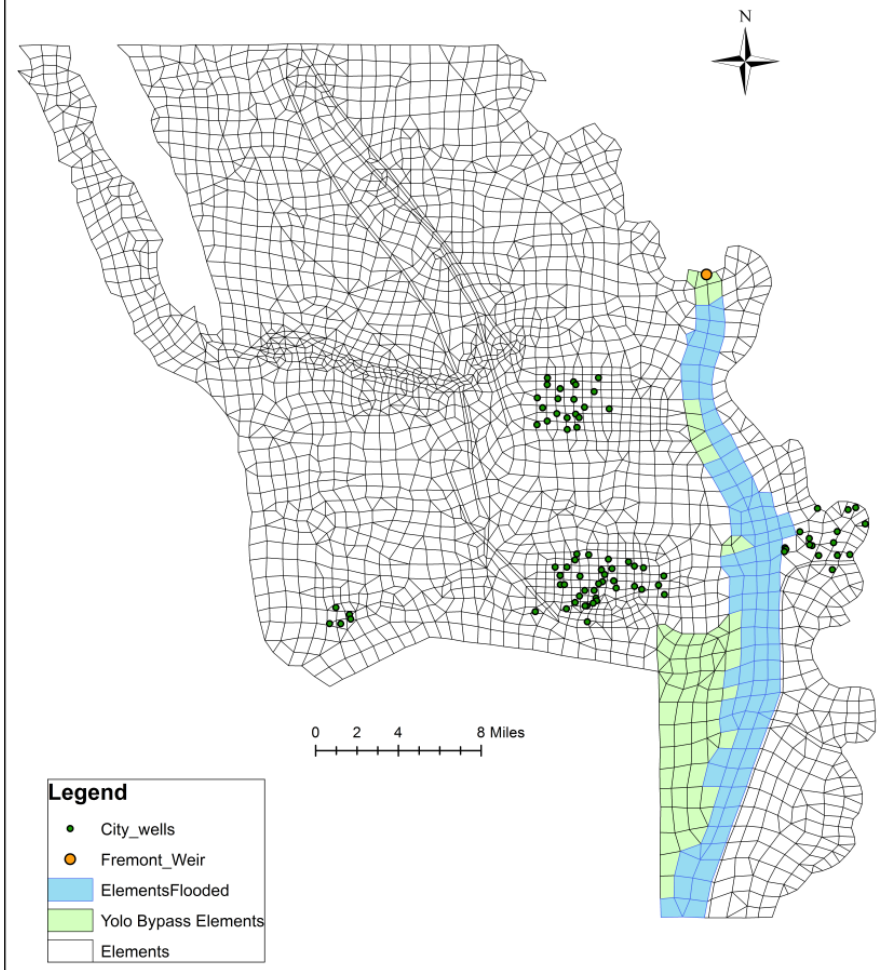


Layers: 3
Area: 884 sq.mi
Nodes: 2840
Elements: 3068
Average element size: 185 ac.
Min. element size:17 ac.
Max. element size: 659 ac.
Stream nodes: 424
Stream reaches: 44
Current data period: 1970-2000

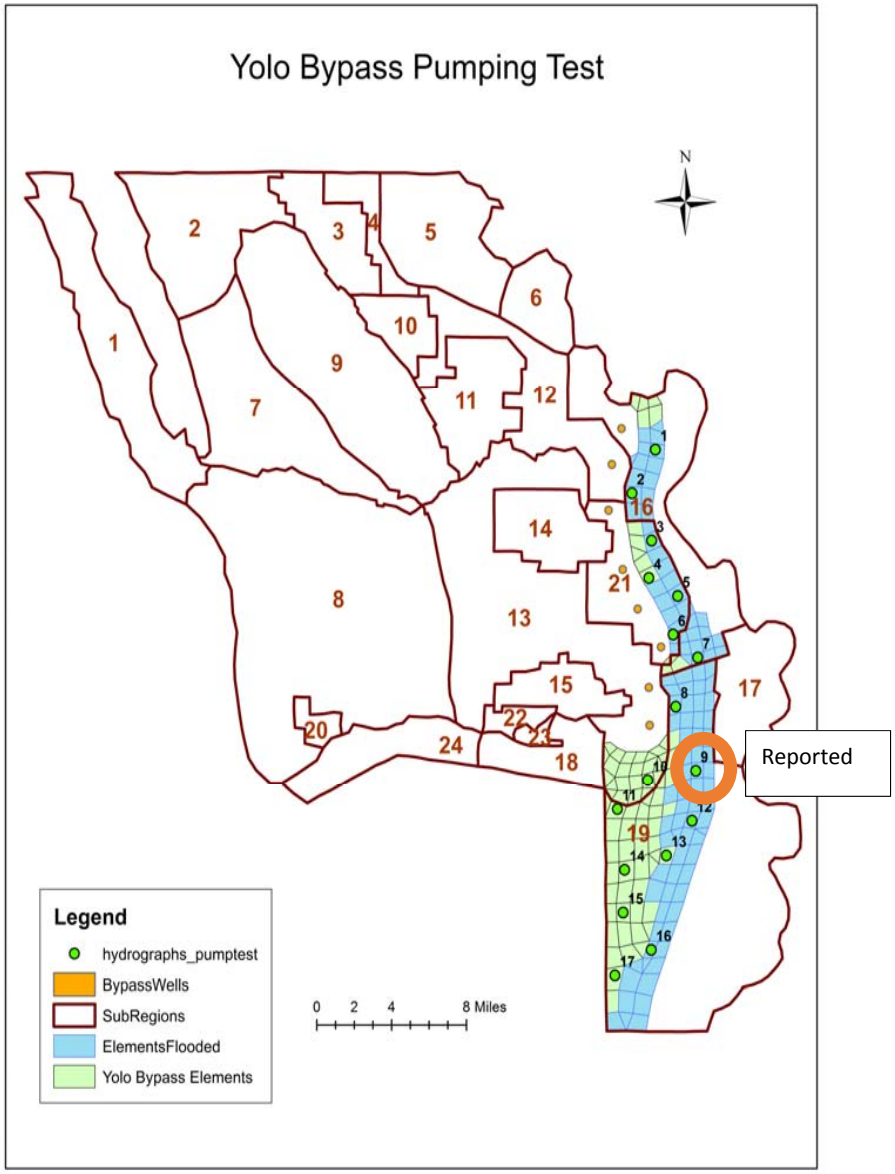


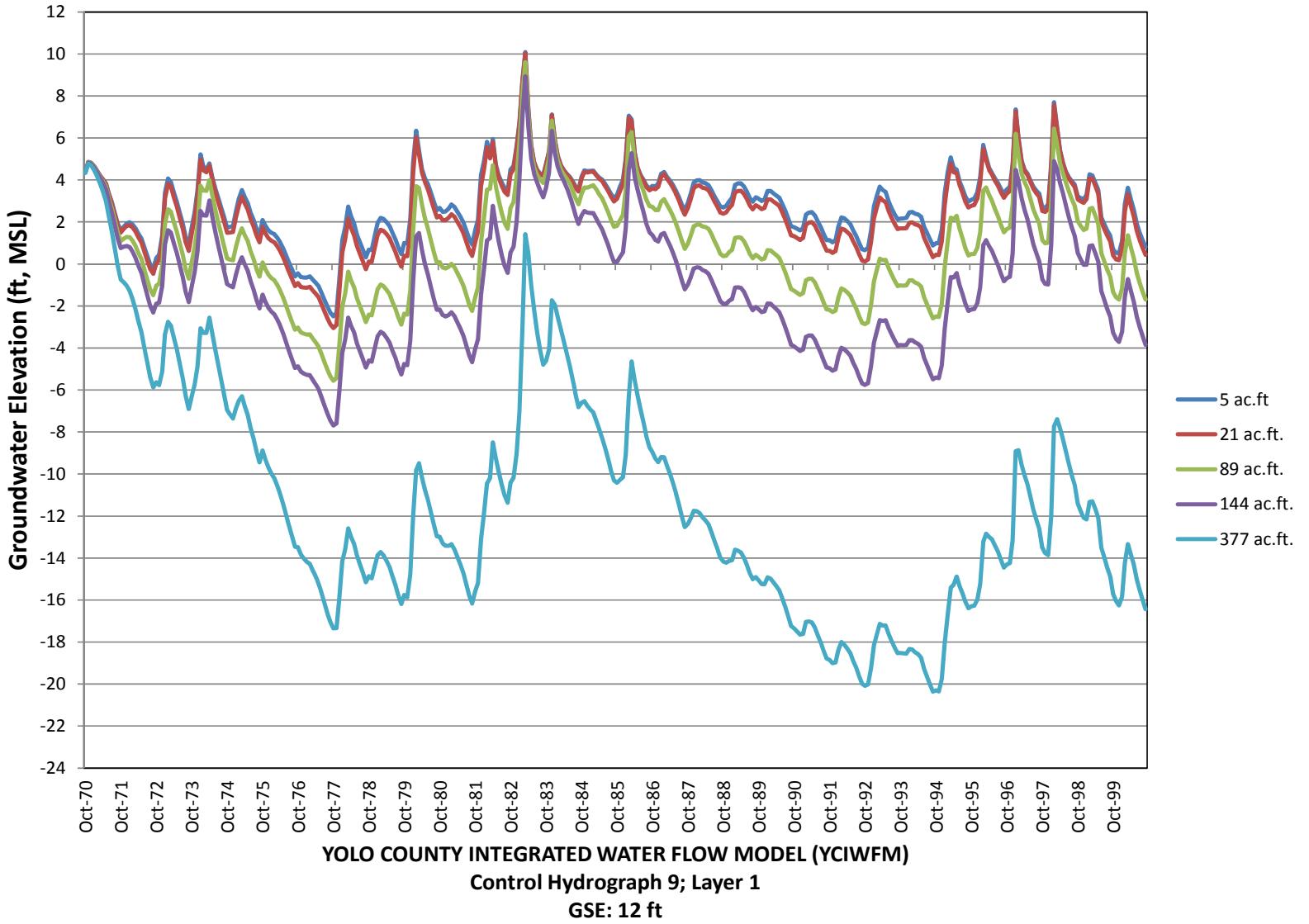

Yolo Bypass Representation
N
Legend
Fremont_Weir
ElementsFlooded
Yolo Bypass Elements
Streams
Elements
Lakes
0 2 4 8 Miles

Baseline Modeling Setup

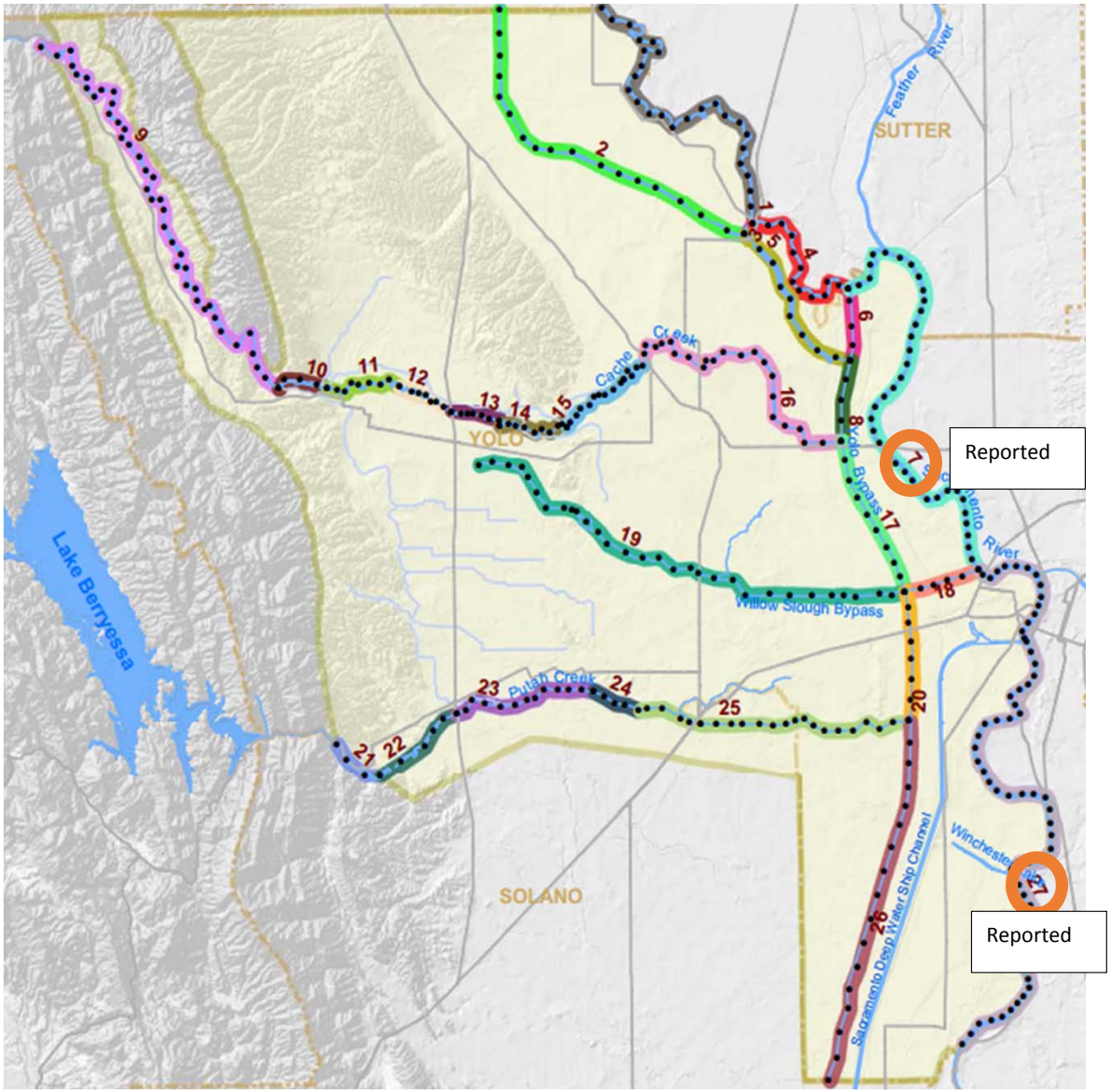


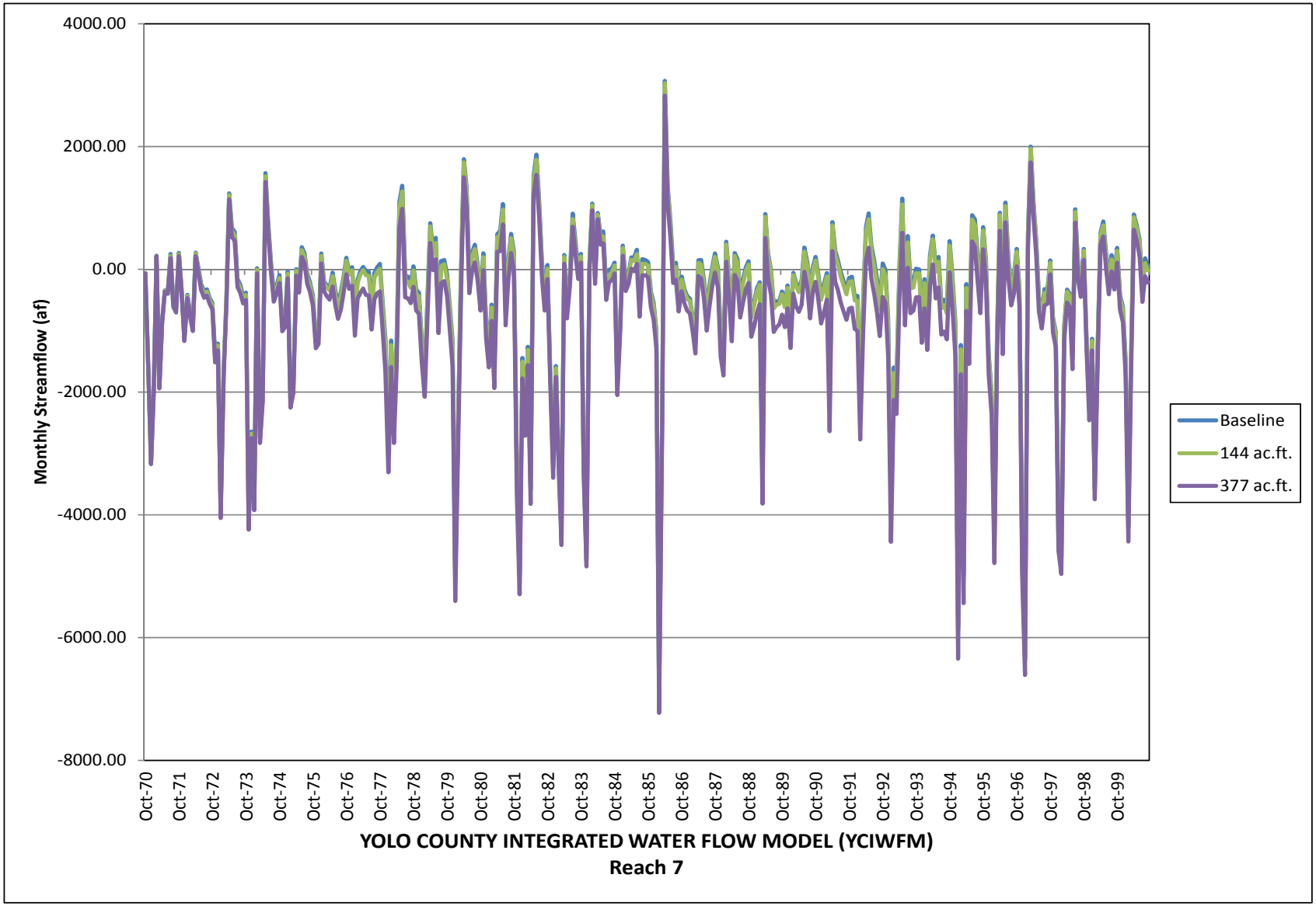
- Pump test:

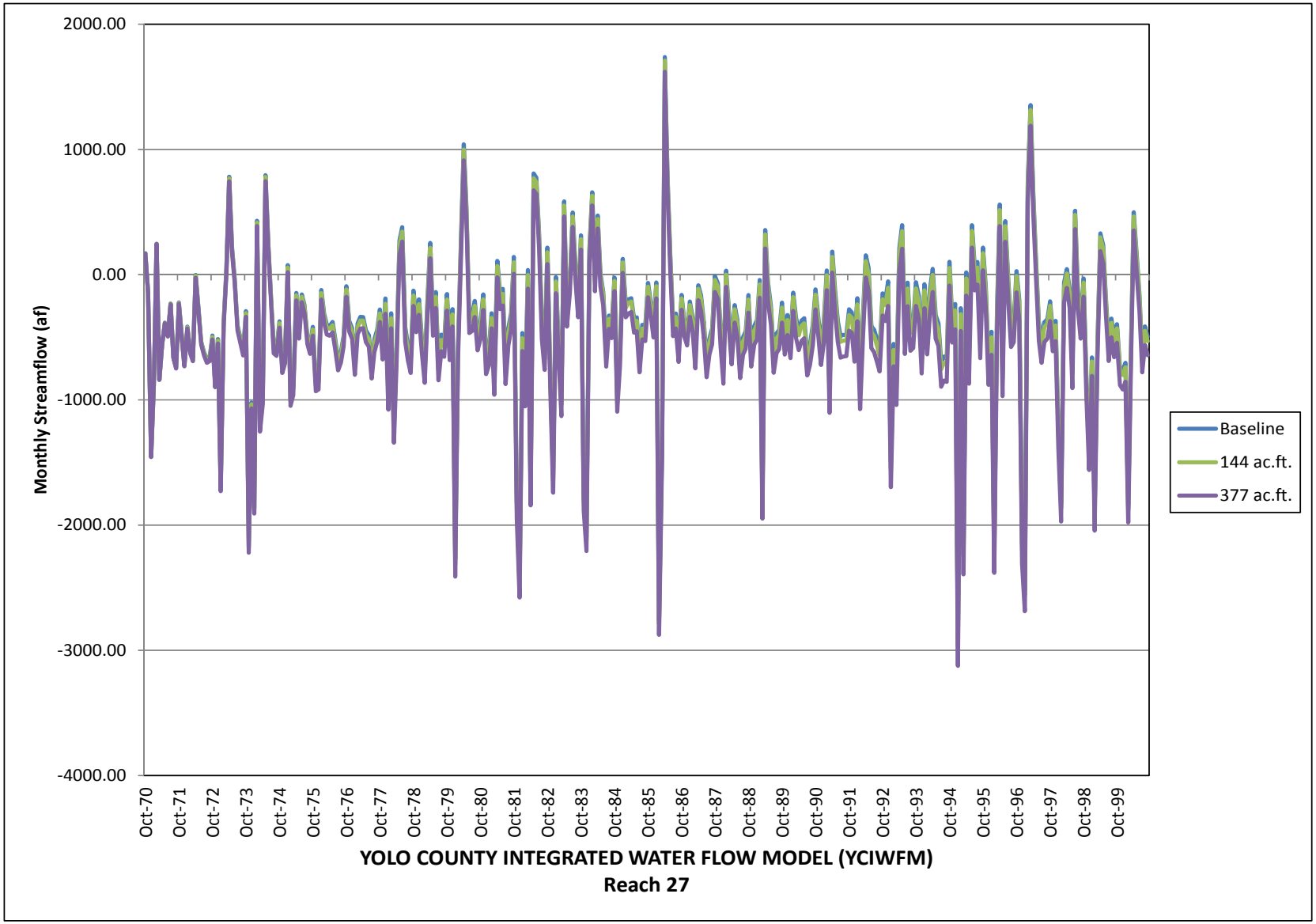

Yolo Bypass Pumping Test
N
Reported
Legend
hydrographs_pumptest
BypassWells
SubRegions
ElementsFlooded
Yolo Bypass Elements
0 2 4 8 Miles



YOLO COUNTY INTEGRATED WATER FLOW MODEL (YCIWFM)
Control Hydrograph 9; Layer 1
GSE: 12 ft

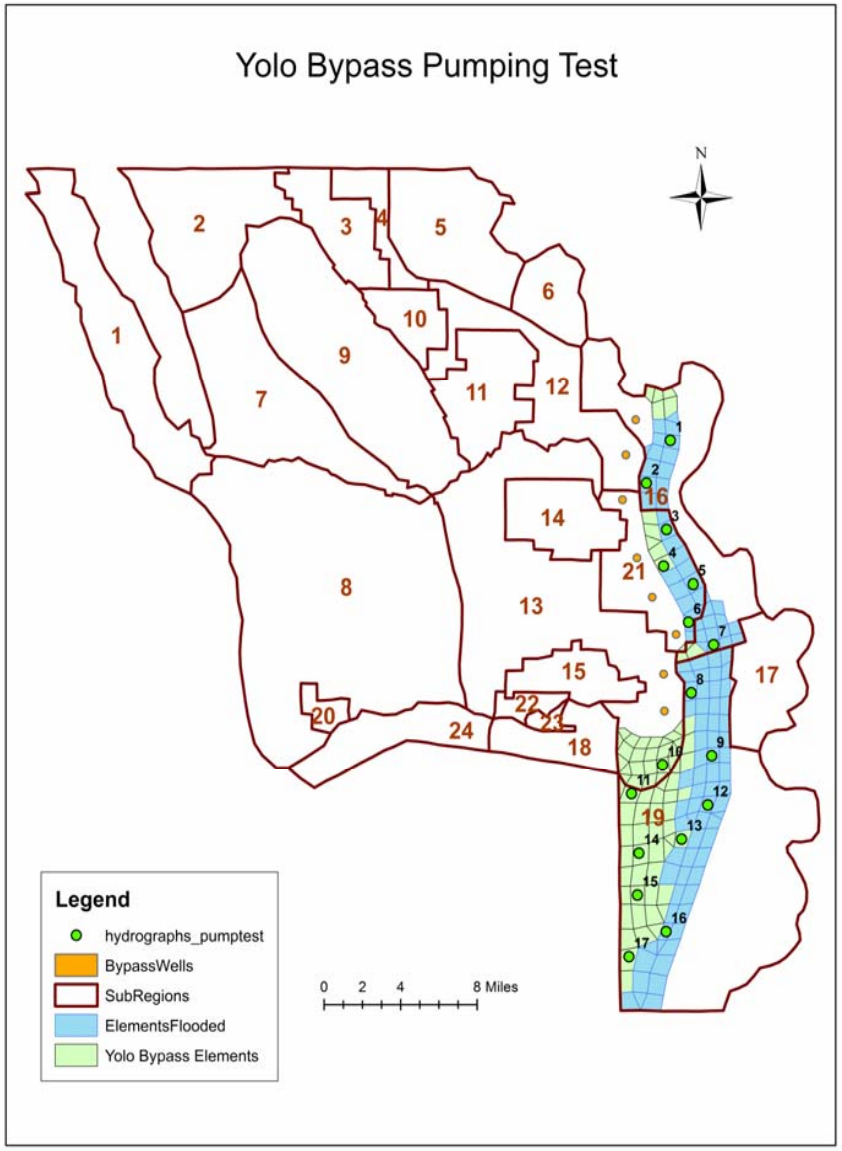

Reported
Reported
SUTTER
YOLO
SOLANO
Lake Berryessa
Feather River
Cache Creek
Putah Creek
Willow Slough Bypass
Yolo Bypass
Sacramento River
Sacramento Deep Water Ship Channel
Winchester
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27


4000.00
2000.00
0.00
-2000.00
-4000.00
-6000.00
-8000.00
Monthly Streamflow (af)
Oct-70
Oct-71
Oct-72
Oct-73
Oct-74
Oct-75
Oct-76
Oct-77
Oct-78
Oct-79
Oct-80
Oct-81
Oct-82
Oct-83
Oct-84
Oct-85
Oct-86
Oct-87
Oct-88
Oct-89
Oct-90
Oct-91
Oct-92
Oct-93
Oct-94
Oct-95
Oct-96
Oct-97
Oct-98
Oct-99
Baseline
144 ac.ft.
377 ac.ft.
YOLO COUNTY INTEGRATED WATER FLOW MODEL (YCIWFM)
Reach 7


2000.00
1000.00
0.00
-1000.00
-2000.00
-3000.00
-4000.00
Monthly Streamflow (af)
Oct-70
Oct-71
Oct-72
Oct-73
Oct-74
Oct-75
Oct-76
Oct-77
Oct-78
Oct-79
Oct-80
Oct-81
Oct-82
Oct-83
Oct-84
Oct-85
Oct-86
Oct-87
Oct-88
Oct-89
Oct-90
Oct-91
Oct-92
Oct-93
Oct-94
Oct-95
Oct-96
Oct-97
Oct-98
Oct-99
Baseline
144 ac.ft.
377 ac.ft.
YOLO COUNTY INTEGRATED WATER FLOW MODEL (YCIWFM)
Reach 27

Solution

- Downgradient semi-confined aquifer recharge:
  - Creating space for recharge and gradients by strategic excavations with pumping rates similar to municipal extractions that produce groundwater recharge.



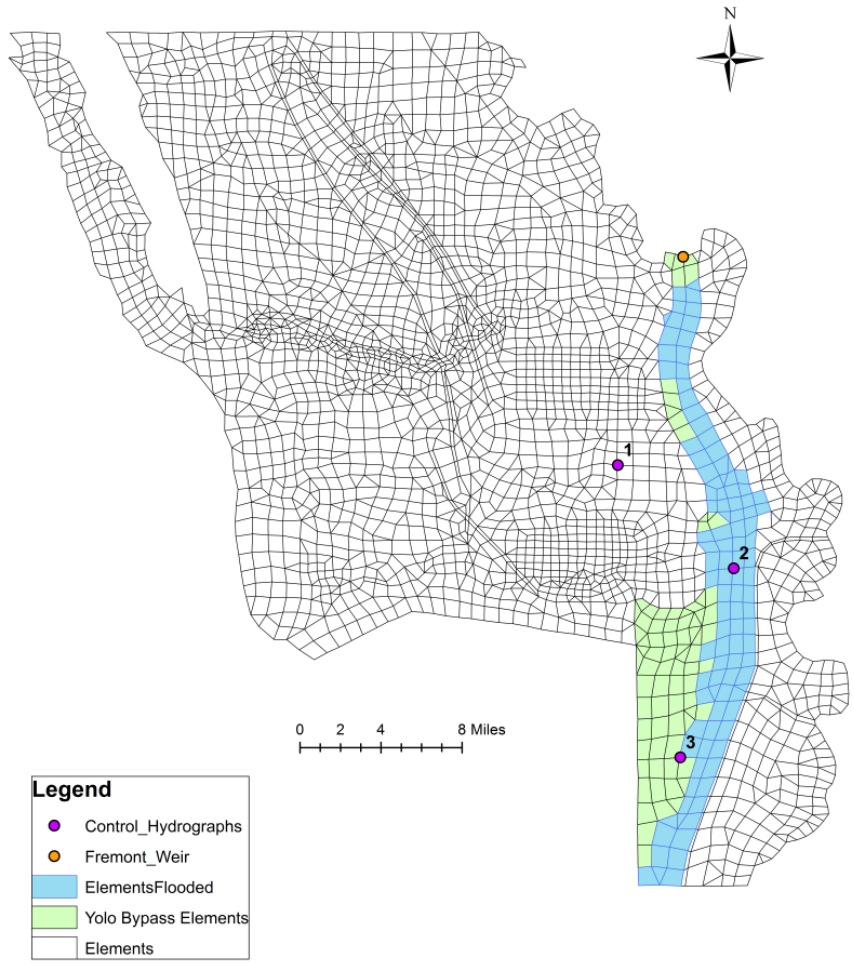
Upside down groundwater recharge

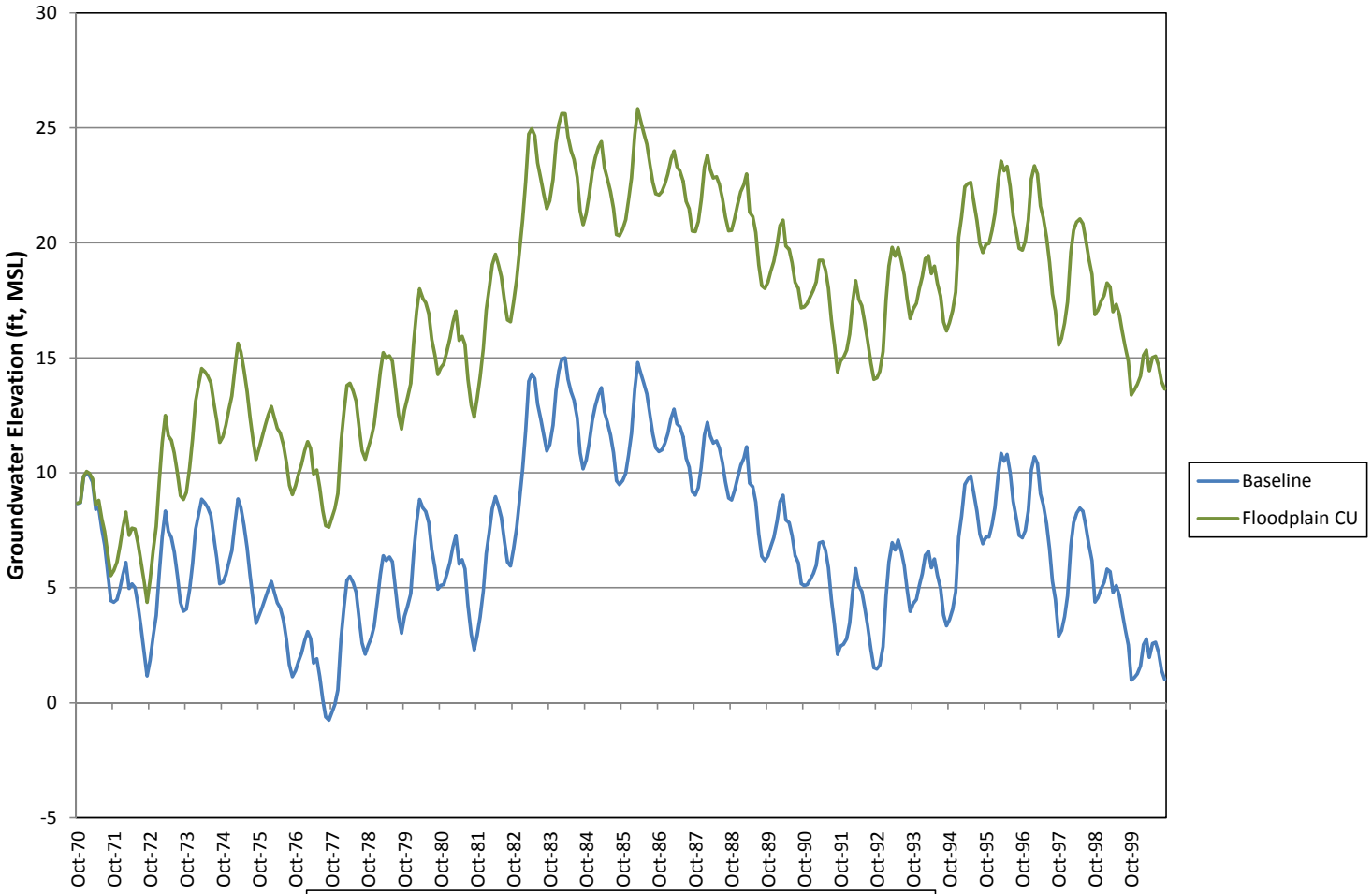
Pumping rate per well: 89 ac.ft./day

Extra inflow to Yolo Bypass: 6000 cfs (Jan – Apr)

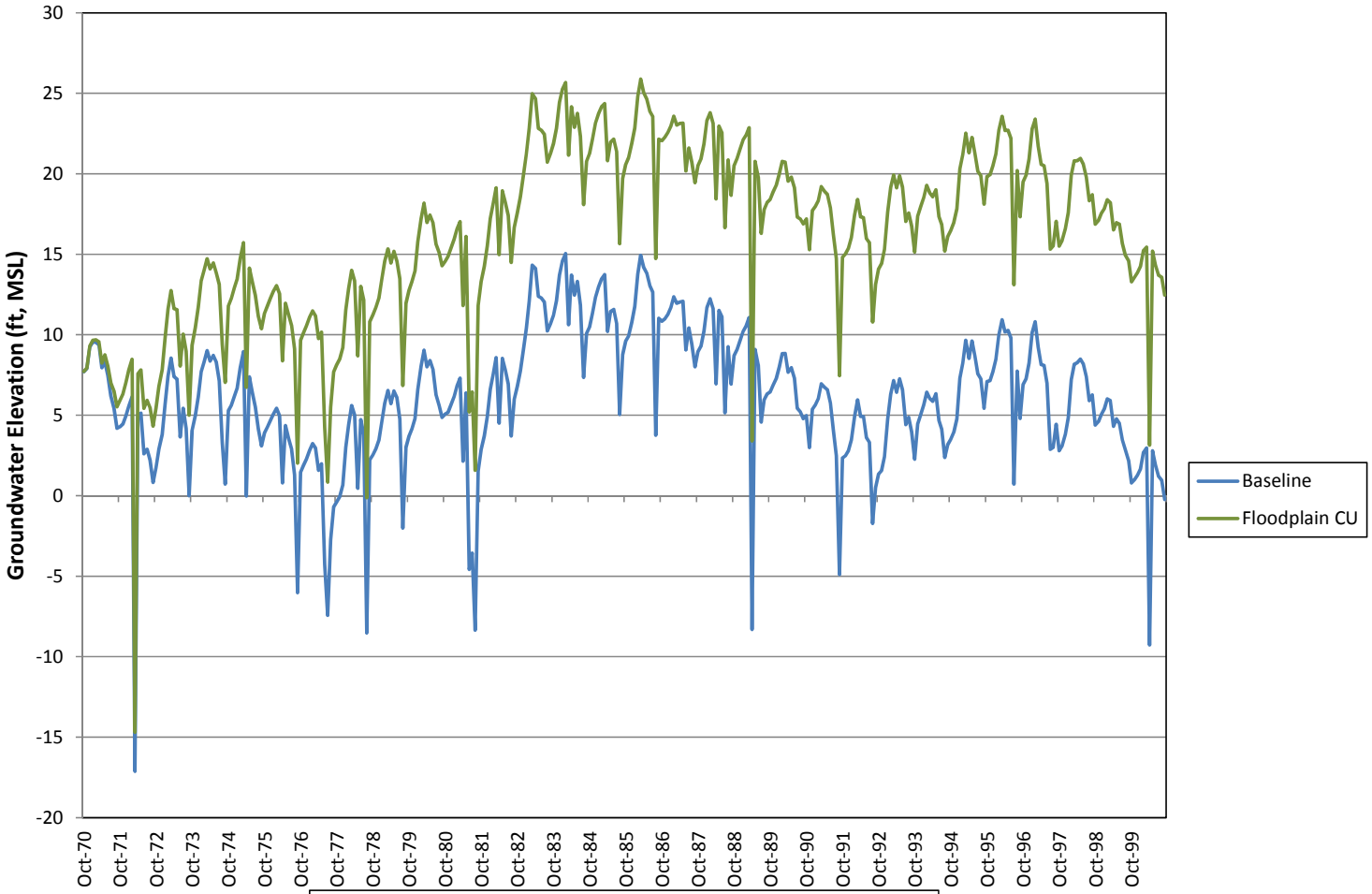
Benefits of recharging at the discharge end of the system

Control Hydrographs

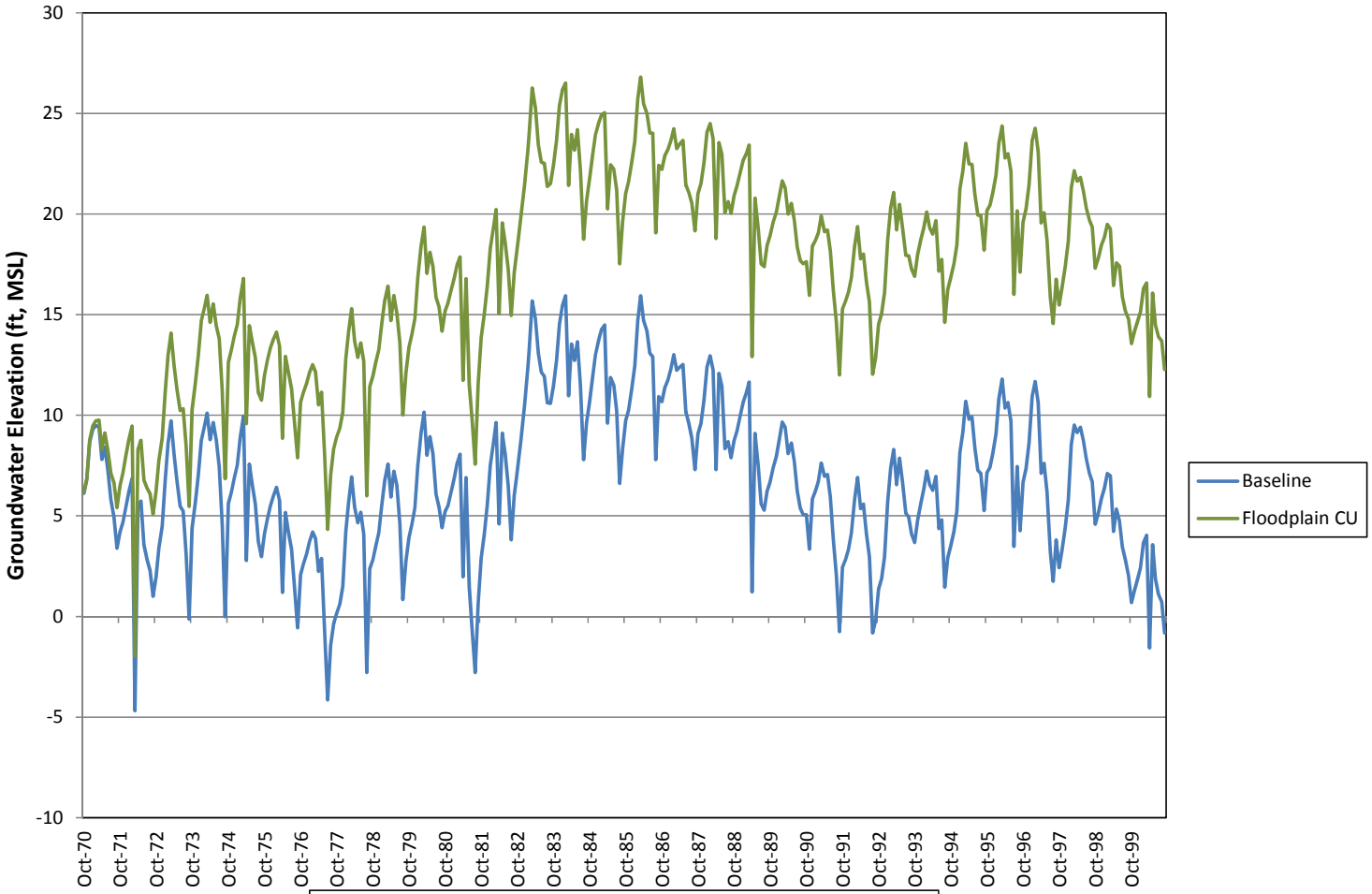




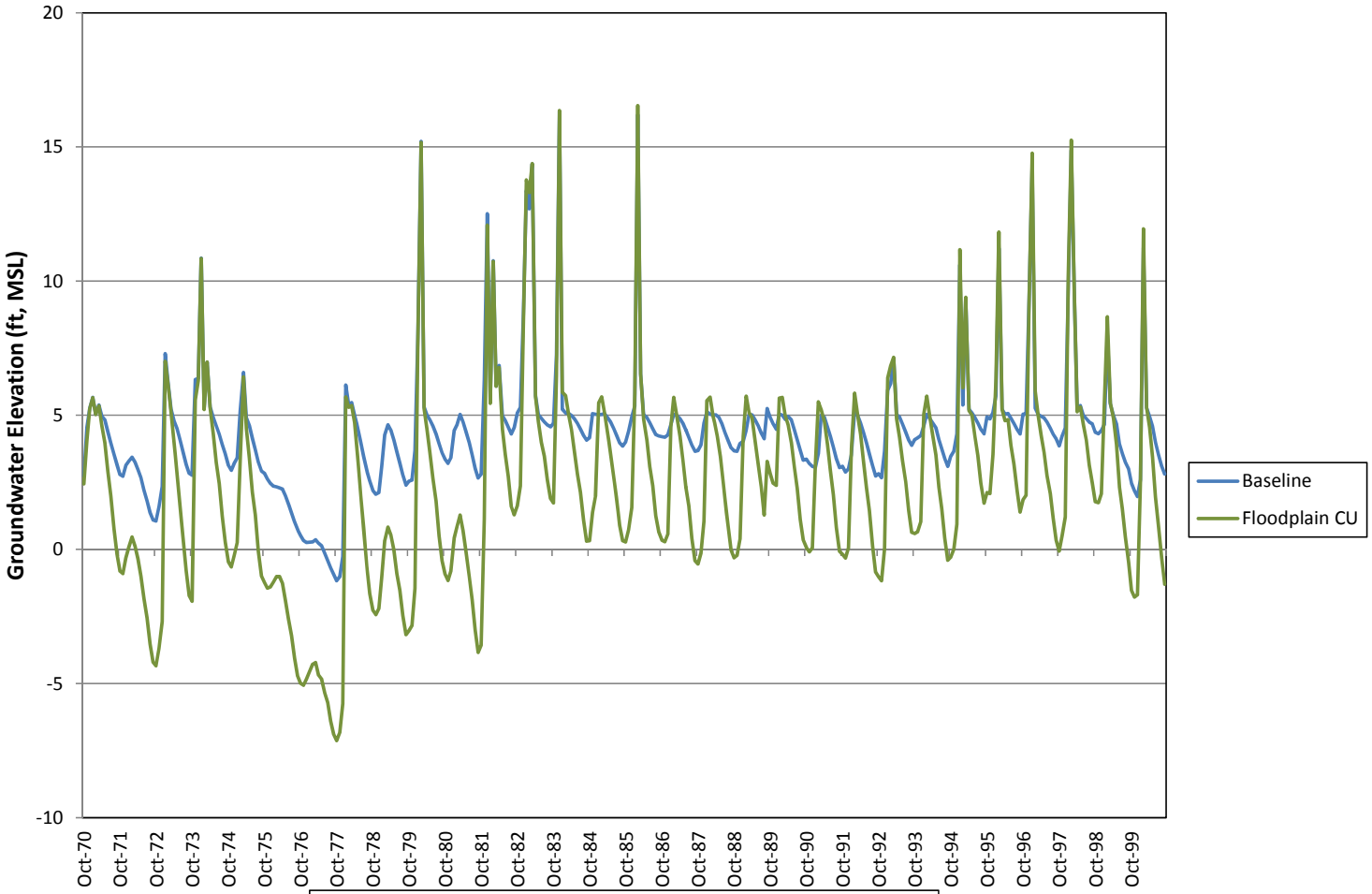
YOLO COUNTY INTEGRATED WATER FLOW MODEL (YCIWFM)
Control Hydrograph 1; Layer 1
GSE: 35 ft



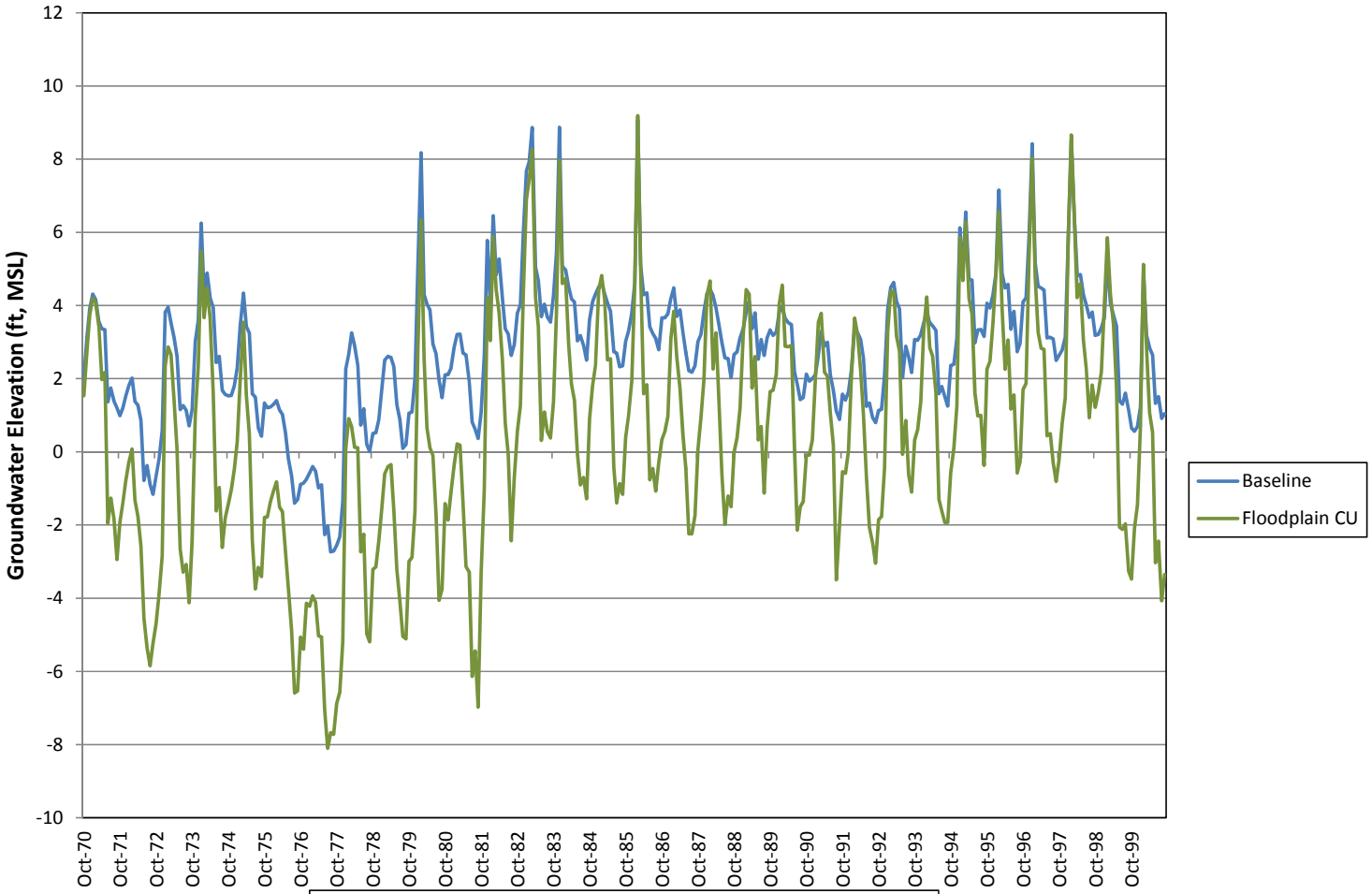
YOLO COUNTY INTEGRATED WATER FLOW MODEL (YCIWFM)
Control Hydrograph 1; Layer 2
GSE: 35 ft



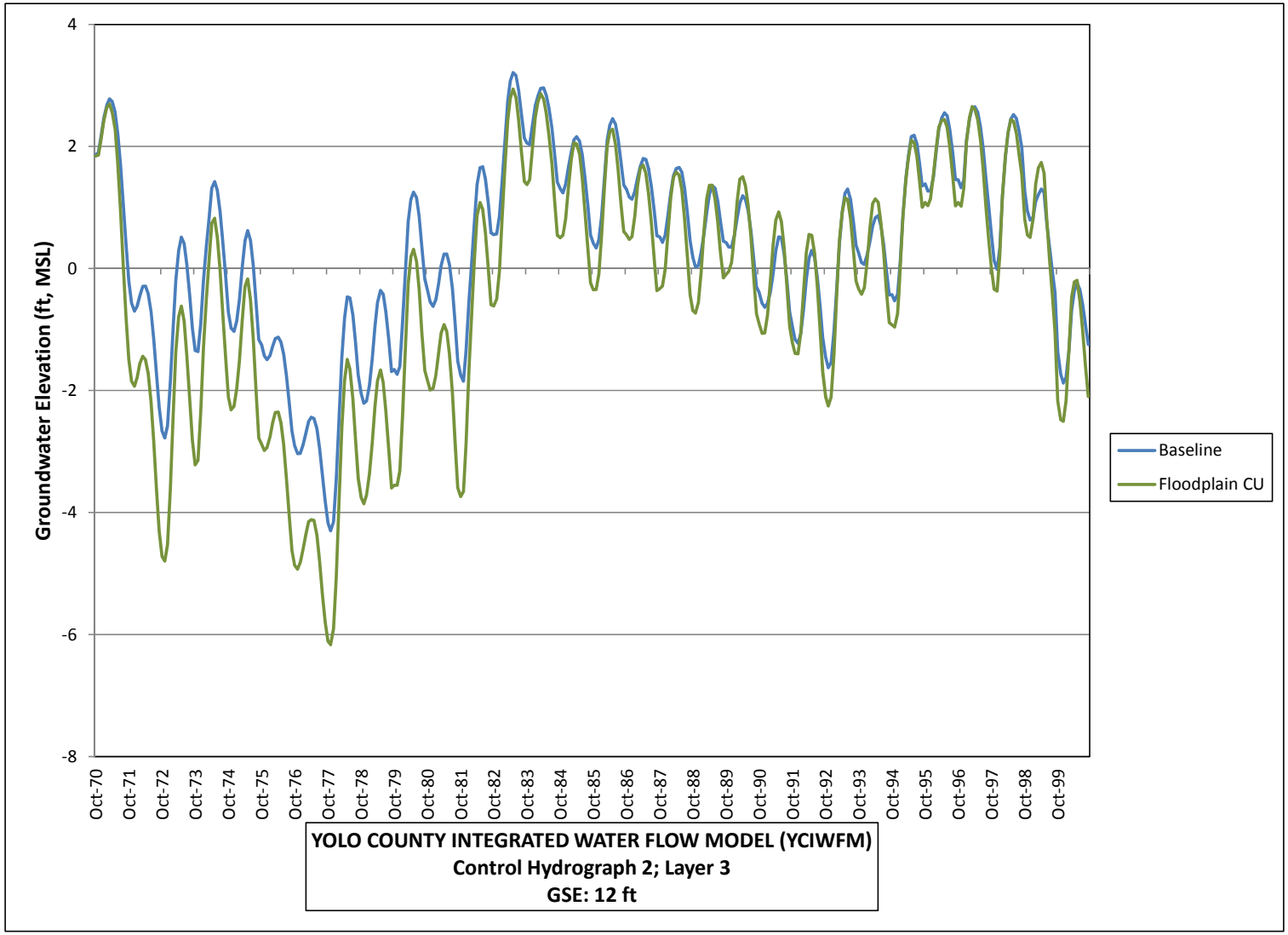
YOLO COUNTY INTEGRATED WATER FLOW MODEL (YCIWFM)
Control Hydrograph 1; Layer 3
GSE: 35 ft

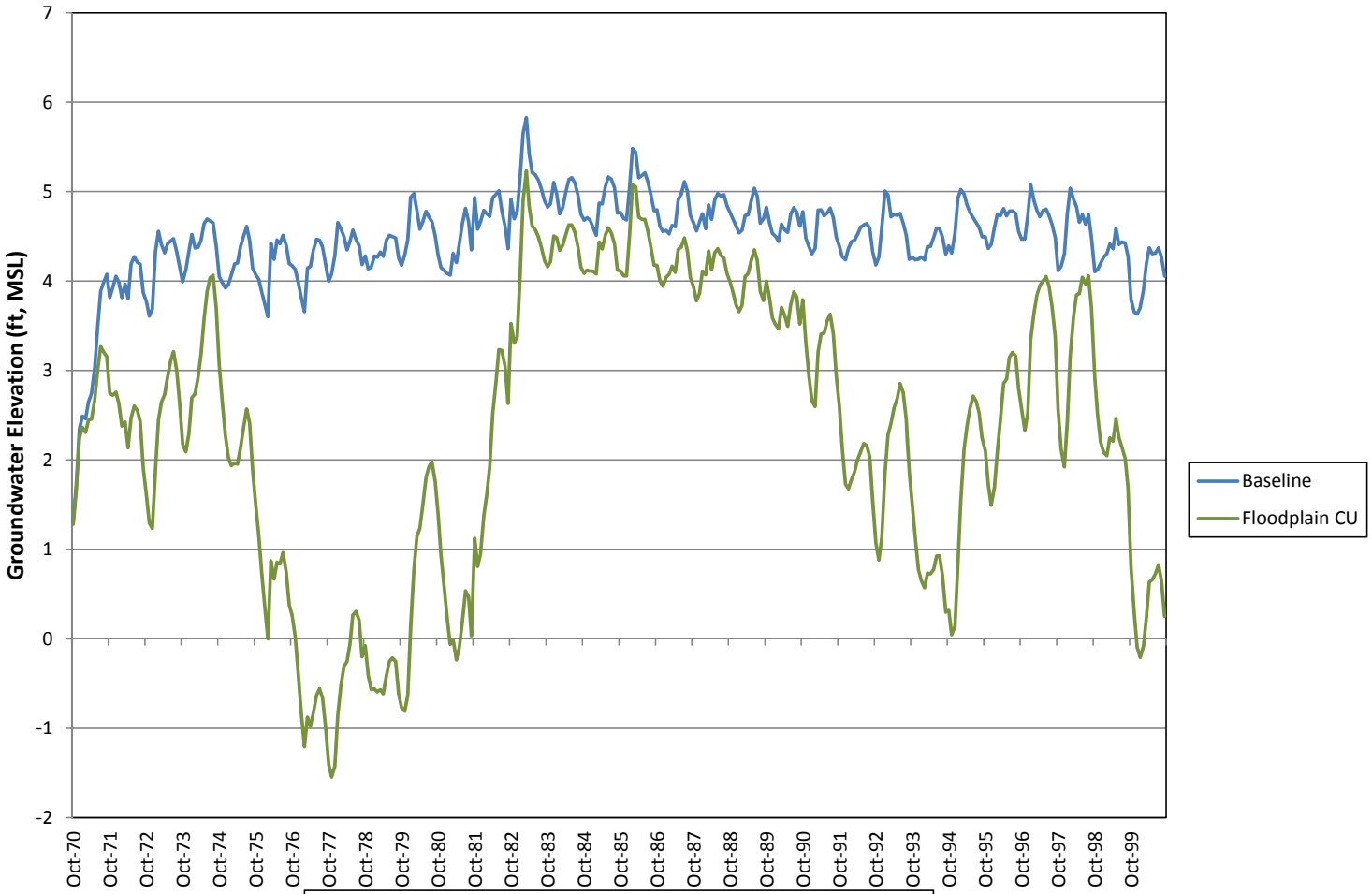


YOLO COUNTY INTEGRATED WATER FLOW MODEL (YCIWFM)
Control Hydrograph 2; Layer 1
GSE: 12 ft

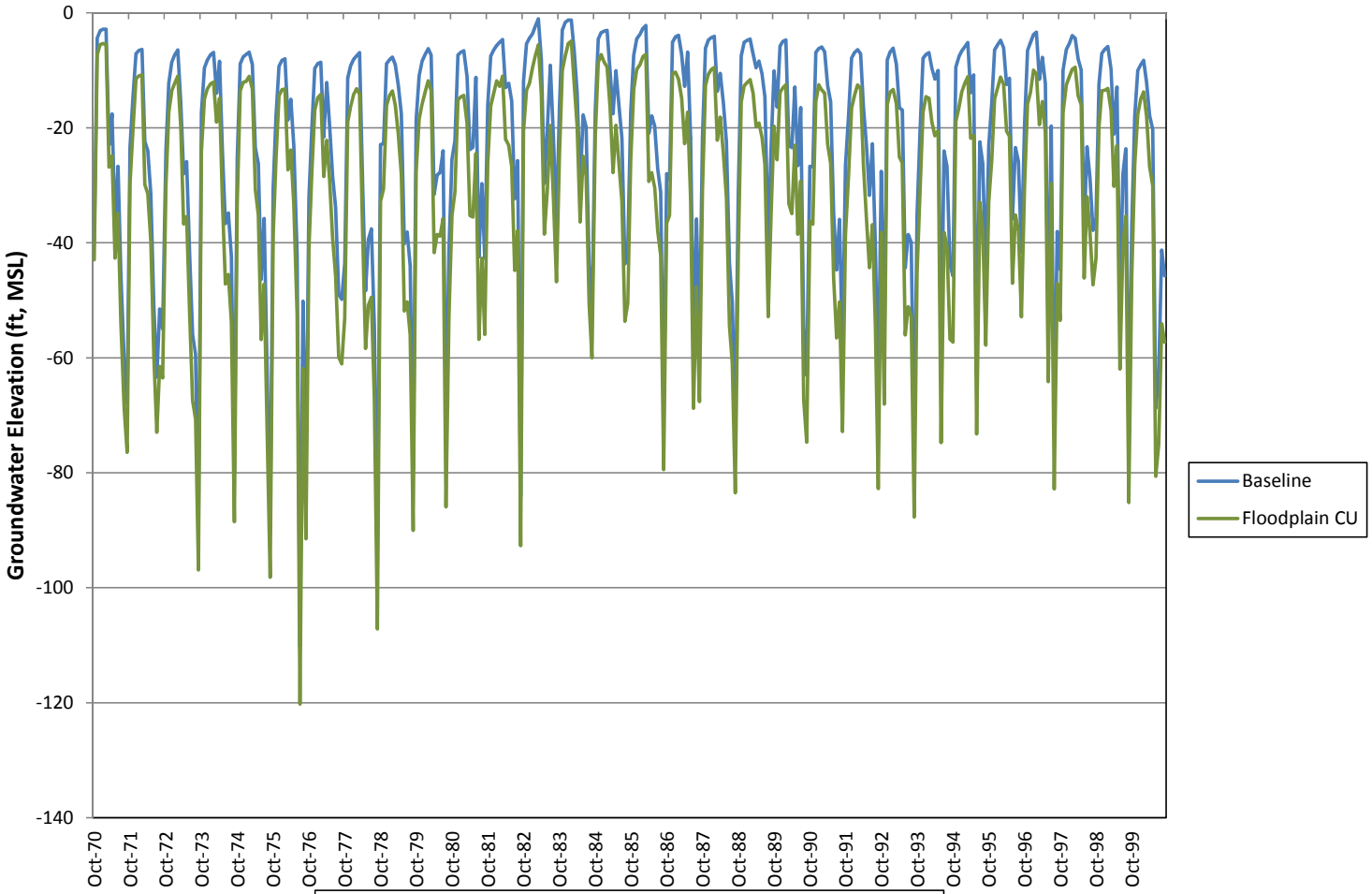


YOLO COUNTY INTEGRATED WATER FLOW MODEL (YCIWFM)
Control Hydrograph 2; Layer 2
GSE: 12 ft

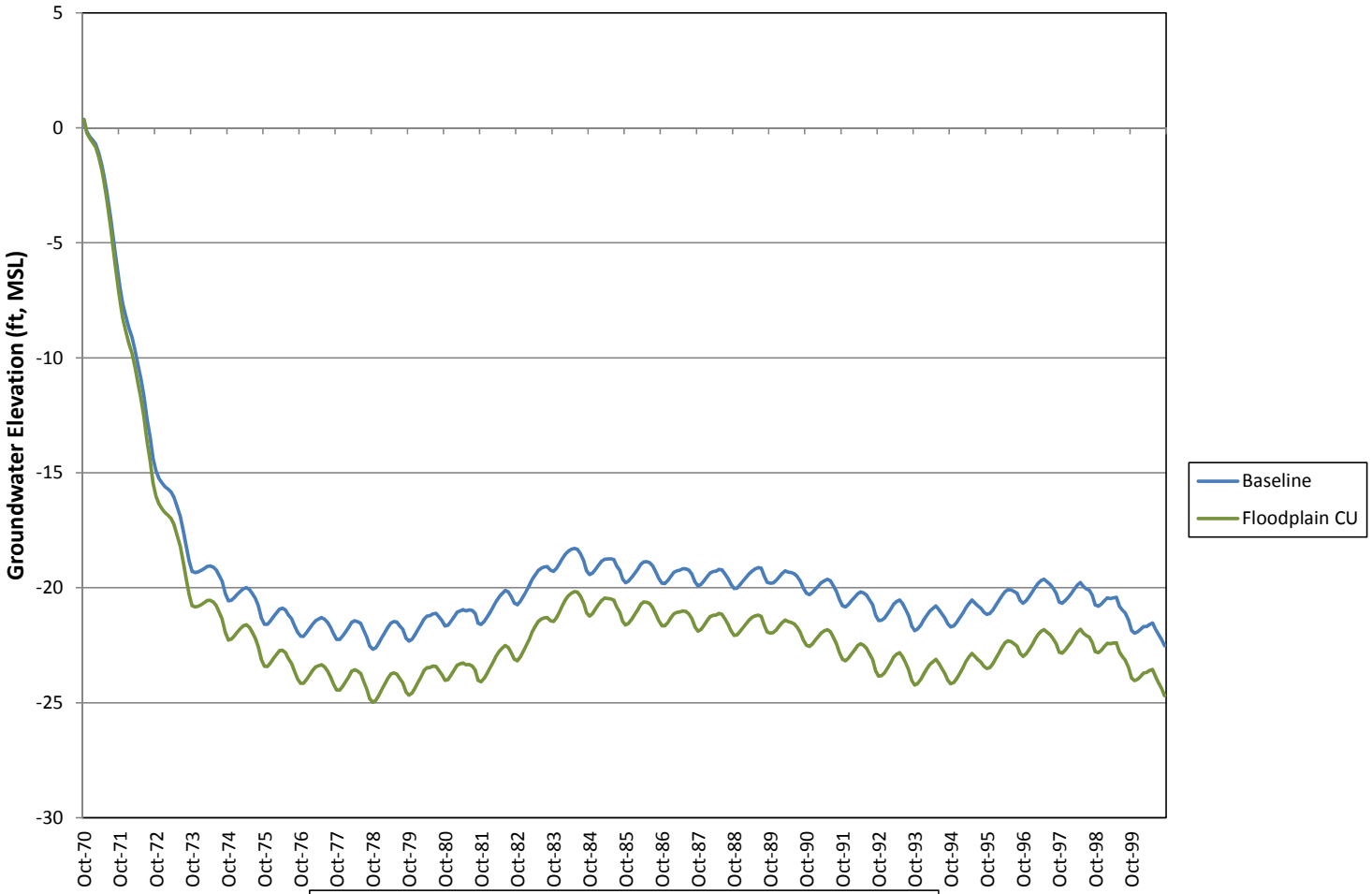

Groundwater Elevation (ft, MSL)
4
2
0
-2
-4
-6
-8
Oct-70
Oct-71
Oct-72
Oct-73
Oct-74
Oct-75
Oct-76
Oct-77
Oct-78
Oct-79
Oct-80
Oct-81
Oct-82
Oct-83
Oct-84
Oct-85
Oct-86
Oct-87
Oct-88
Oct-89
Oct-90
Oct-91
Oct-92
Oct-93
Oct-94
Oct-95
Oct-96
Oct-97
Oct-98
Oct-99
Baseline
Floodplain CU
YOLO COUNTY INTEGRATED WATER FLOW MODEL (YCIWFM)
Control Hydrograph 2; Layer 3
GSE: 12 ft



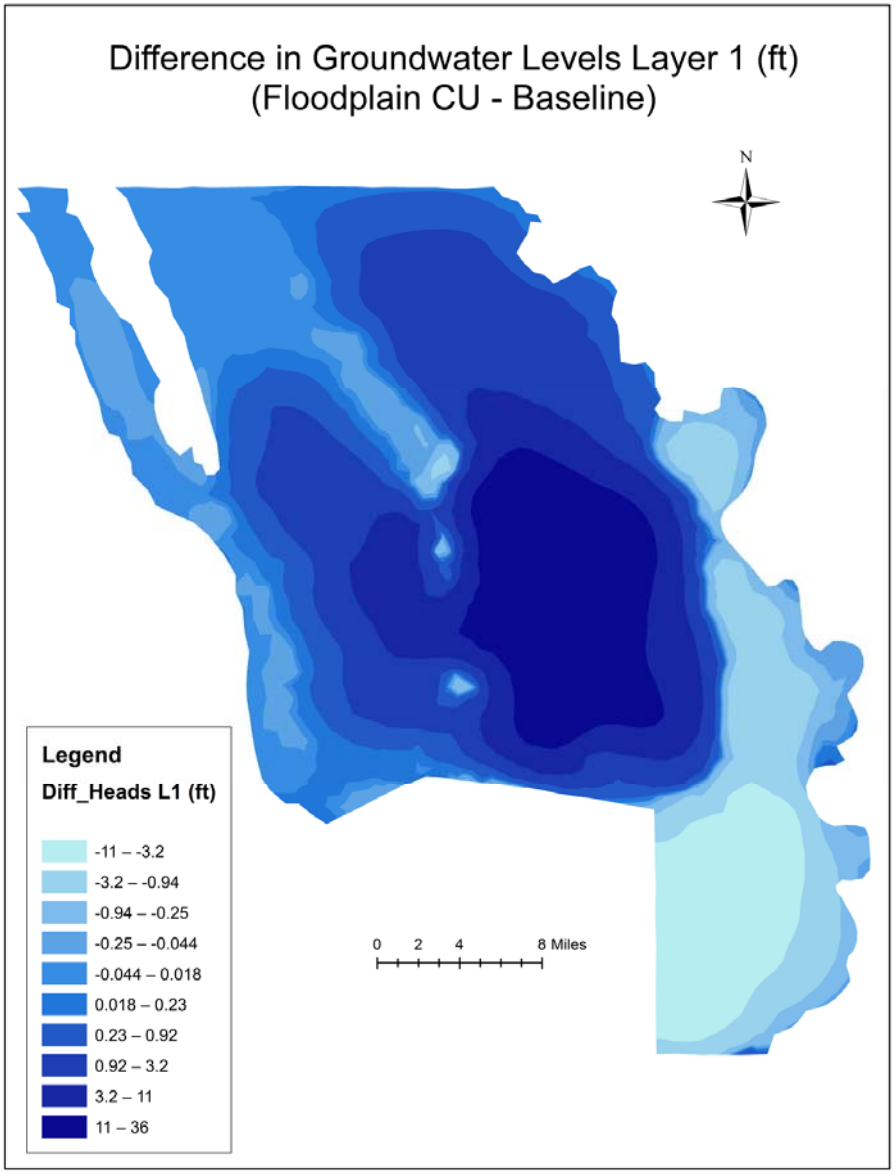
YOLO COUNTY INTEGRATED WATER FLOW MODEL (YCIWFM)
Control Hydrograph 3; Layer 1
GSE: 13 ft

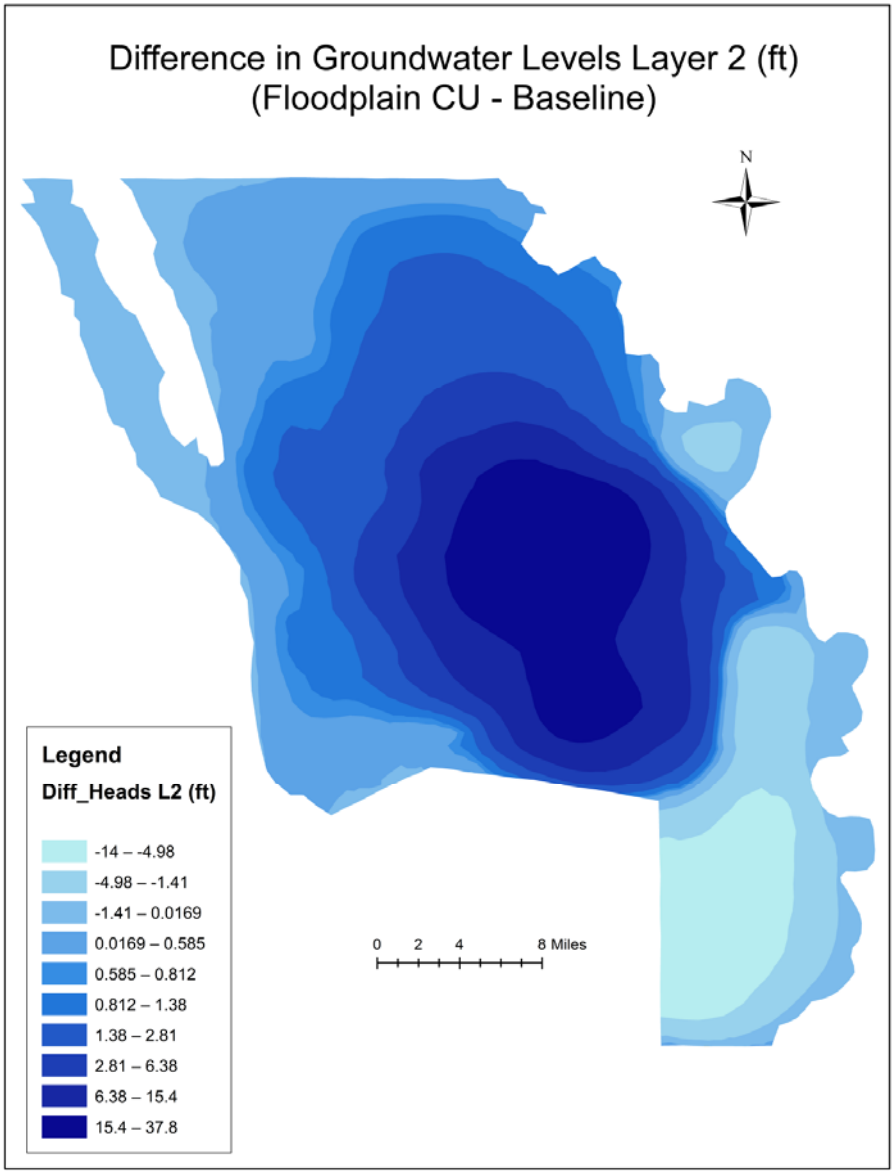


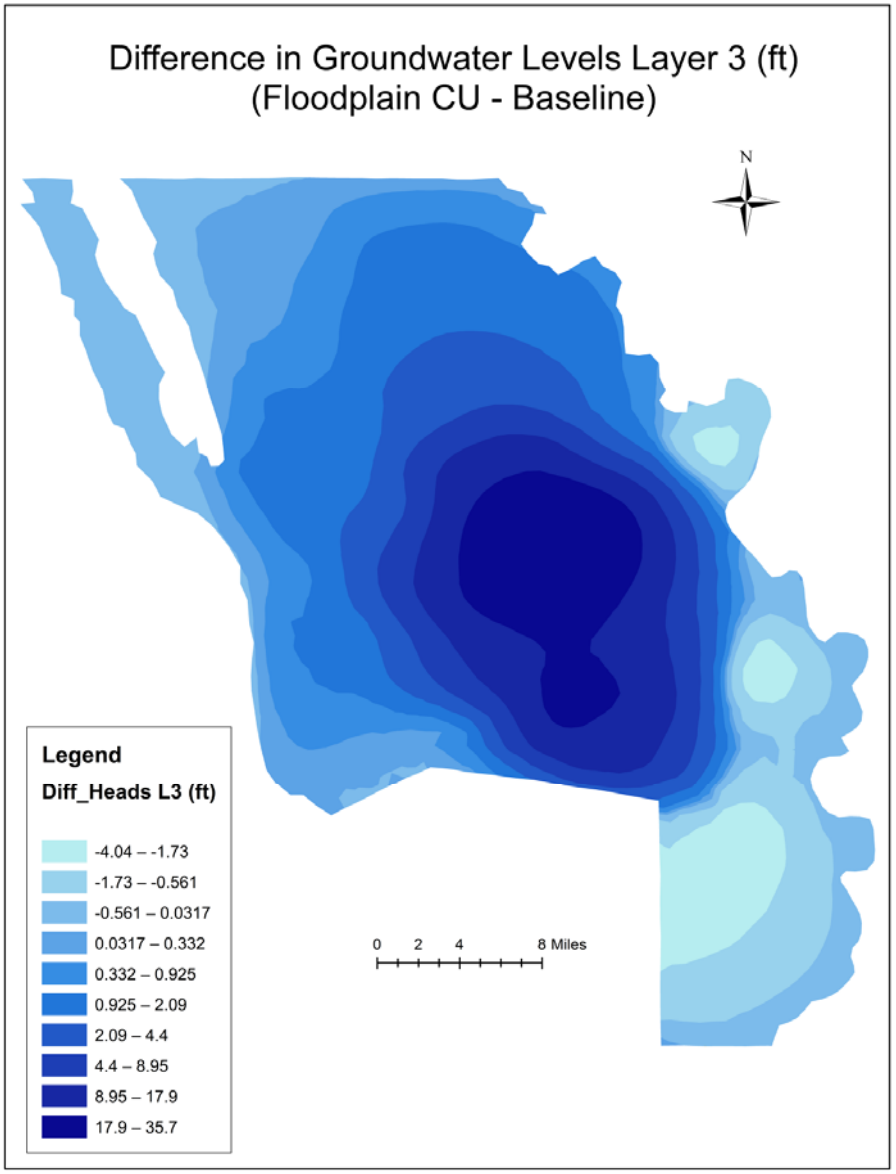
YOLO COUNTY INTEGRATED WATER FLOW MODEL (YCIWFM)
Control Hydrograph 3; Layer 2
GSE: 13 ft

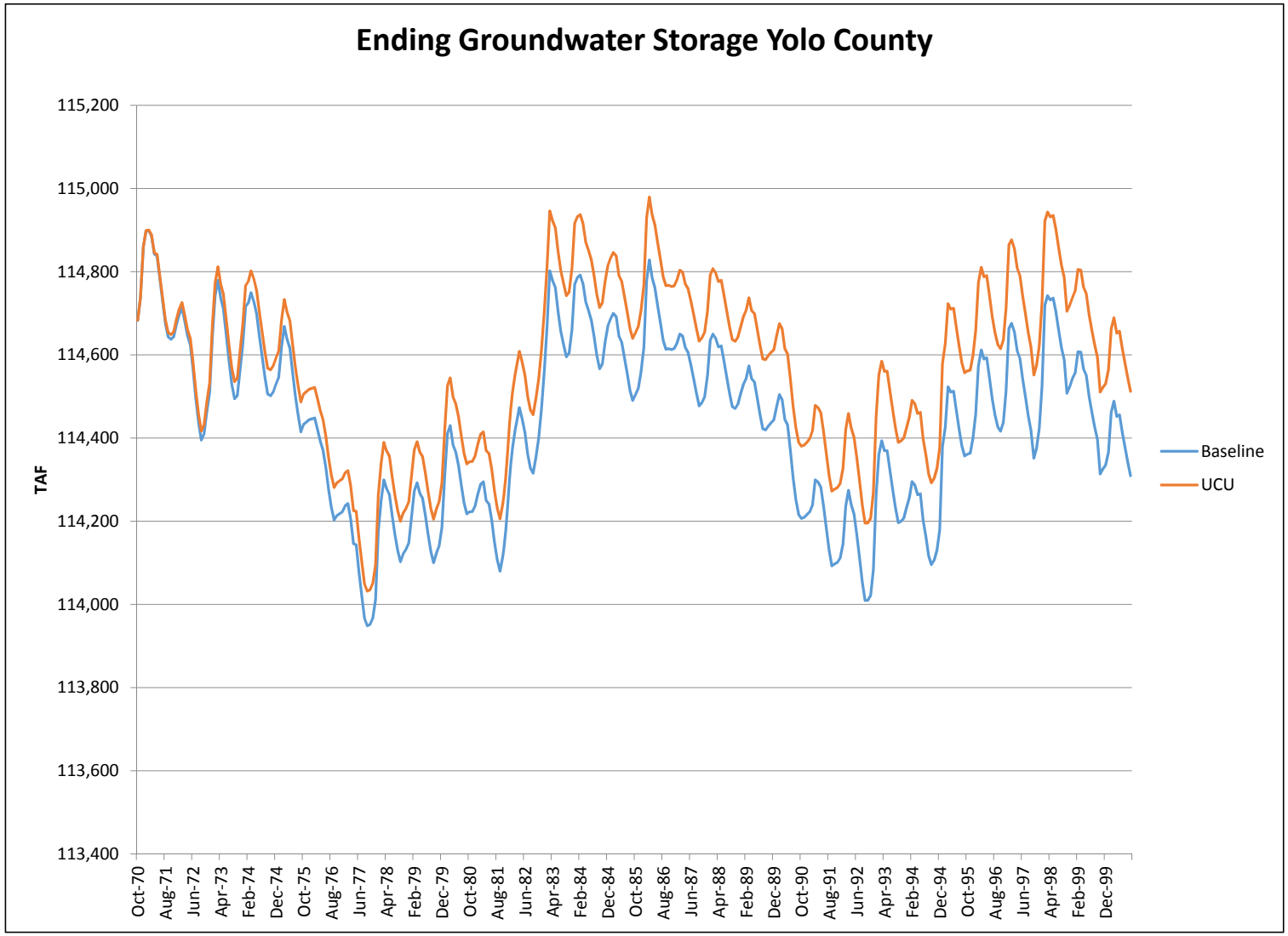


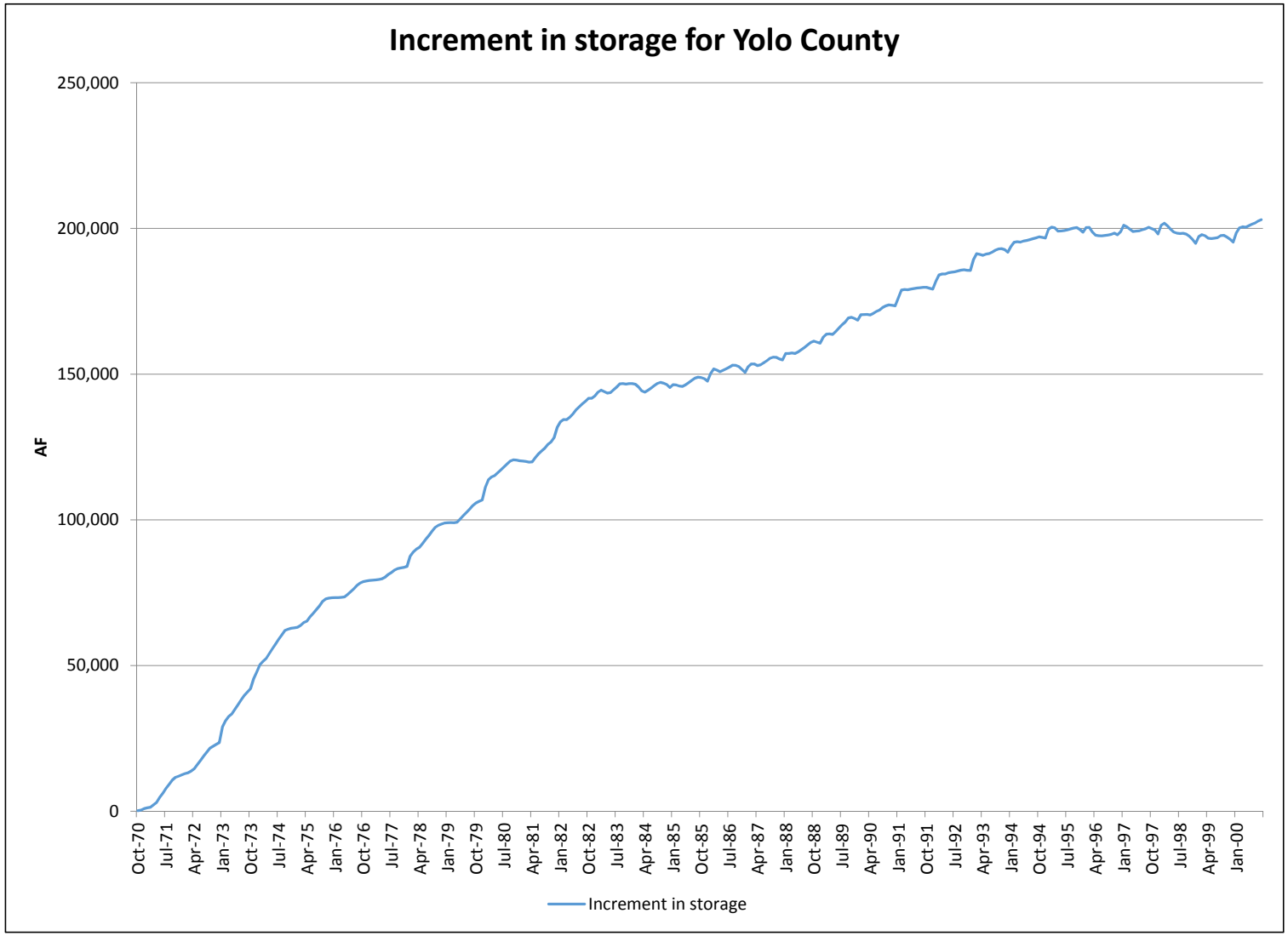
YOLO COUNTY INTEGRATED WATER FLOW MODEL (YCIWFM)
Control Hydrograph 3; Layer 3
GSE: 13 ft


Difference in Groundwater Levels Layer 1 (ft)
(Floodplain CU - Baseline)
N
Legend
Diff_Heads L1 (ft)
-11 – -3.2
-3.2 – -0.94
-0.94 – -0.25
-0.25 – -0.044
-0.044 – 0.018
0.018 – 0.23
0.23 – 0.92
0.92 – 3.2
3.2 – 11
11 – 36
0 2 4 8 Miles


Difference in Groundwater Levels Layer 2 (ft)
(Floodplain CU - Baseline)
N
Legend
Diff_Heads L2 (ft)
-14 – -4.98
-4.98 – -1.41
-1.41 – 0.0169
0.0169 – 0.585
0.585 – 0.812
0.812 – 1.38
1.38 – 2.81
2.81 – 6.38
6.38 – 15.4
15.4 – 37.8
0 2 4 8 Miles


Difference in Groundwater Levels Layer 3 (ft)
(Floodplain CU - Baseline)
N
Legend
Diff_Heads L3 (ft)
-4.04 – -1.73
-1.73 – -0.561
-0.561 – 0.0317
0.0317 – 0.332
0.332 – 0.925
0.925 – 2.09
2.09 – 4.4
4.4 – 8.95
8.95 – 17.9
17.9 – 35.7
0 2 4 8 Miles


Ending Groundwater Storage Yolo County
TAF
115,200
115,000
114,800
114,600
114,400
114,200
114,000
113,800
113,600
113,400
Oct-70
Aug-71
Jun-72
Apr-73
Feb-74
Dec-74
Oct-75
Aug-76
Jun-77
Apr-78
Feb-79
Dec-79
Oct-80
Aug-81
Jun-82
Apr-83
Feb-84
Dec-84
Oct-85
Aug-86
Jun-87
Apr-88
Feb-89
Dec-89
Oct-90
Aug-91
Jun-92
Apr-93
Feb-94
Dec-94
Oct-95
Aug-96
Jun-97
Apr-98
Feb-99
Dec-99
Baseline
UCU


Increment in storage for Yolo County
250,000
200,000
150,000
100,000
50,000
0
AF
Oct-70
Jul-71
Apr-72
Jan-73
Oct-73
Jul-74
Apr-75
Jan-76
Oct-76
Jul-77
Apr-78
Jan-79
Oct-79
Jul-80
Apr-81
Jan-82
Oct-82
Jul-83
Apr-84
Jan-85
Oct-85
Jul-86
Apr-87
Jan-88
Oct-88
Jul-89
Apr-90
Jan-91
Oct-91
Jul-92
Apr-93
Jan-94
Oct-94
Jul-95
Apr-96
Jan-97
Oct-97
Jul-98
Apr-99
Jan-00
Increment in storage

Feasible framework

Upside down groundwater recharge

Conjunctive water management in an aquifer-floodplain recharge operation

Thank you!

Carlos Flores & Graham Fogg

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UC Davis