Ground Water Modeling and Water Administration in Idaho

Presented by Gary Spackman

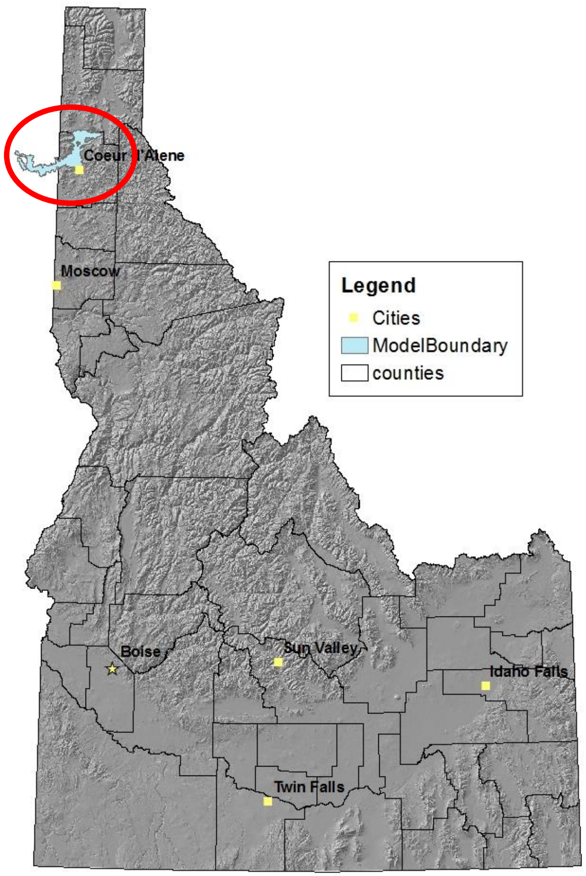
IDWR Groundwater Models

Several models in use by IDWR around the state:

- Rathdrum Prairie (Transient and Steady State),
- Treasure Valley (Transient version in development),
- Big Wood River Valley (Transient and Steady State) – release this spring,
- Eastern Snake Plain Aquifer (Transient and Steady State). This is our most robust model.

Transient Model – Simulate impacts over time.
Steady State Model – Simulate final impacts without time component.

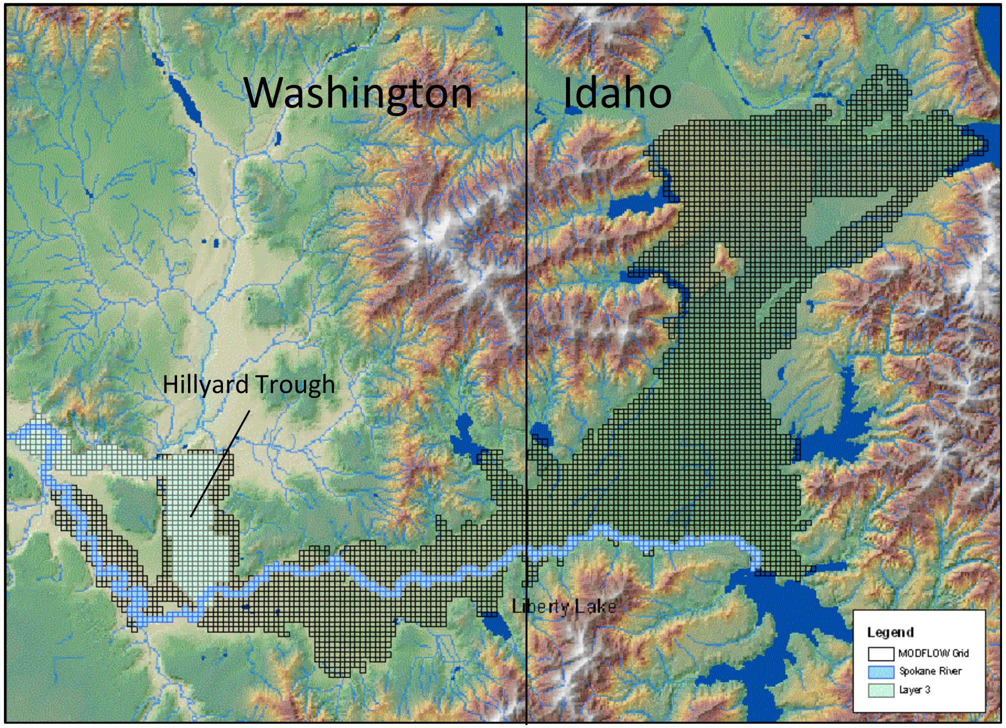
Spokane Valley-Rathdrum Prairie Aquifer Model (SVRP)



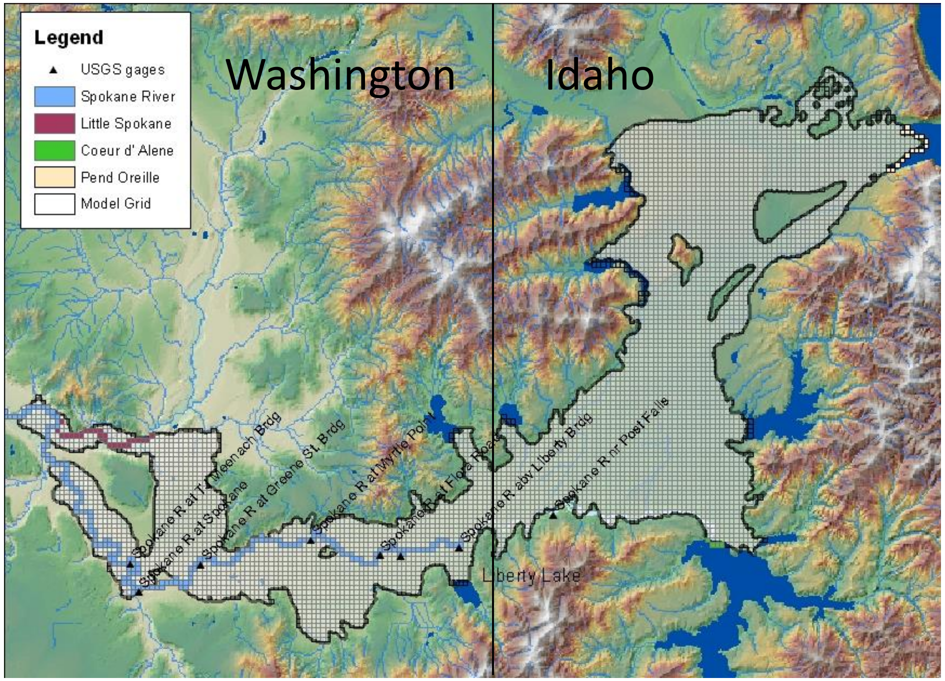
- Rathdrum Prairie Aquifer on the Idaho side, Spokane Valley Aquifer on the Washington side
- Composed of glacial outwash gravel
- The modeling team consisted of representatives from the IDWR, Washington Department of Ecology and the US Geological Survey

Model

- MODFLOW-2000
- 1320 ft x 1320 ft grid
- 1 layer unconfined
- 3 layers in Hillyard Trough
- Spokane River perched in Idaho



SVRP

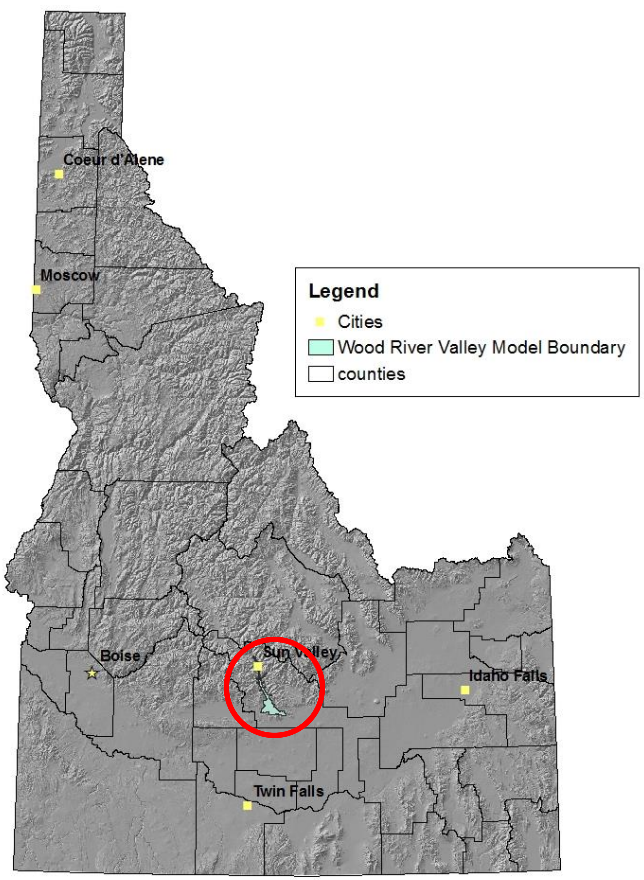


- Available 2007
- Simulates groundwater-surface water interaction with Little Spokane River, Lake PendOreille, Coeur d'Alene Lake, and Spokane River below Liberty Lake

Use of SVRP

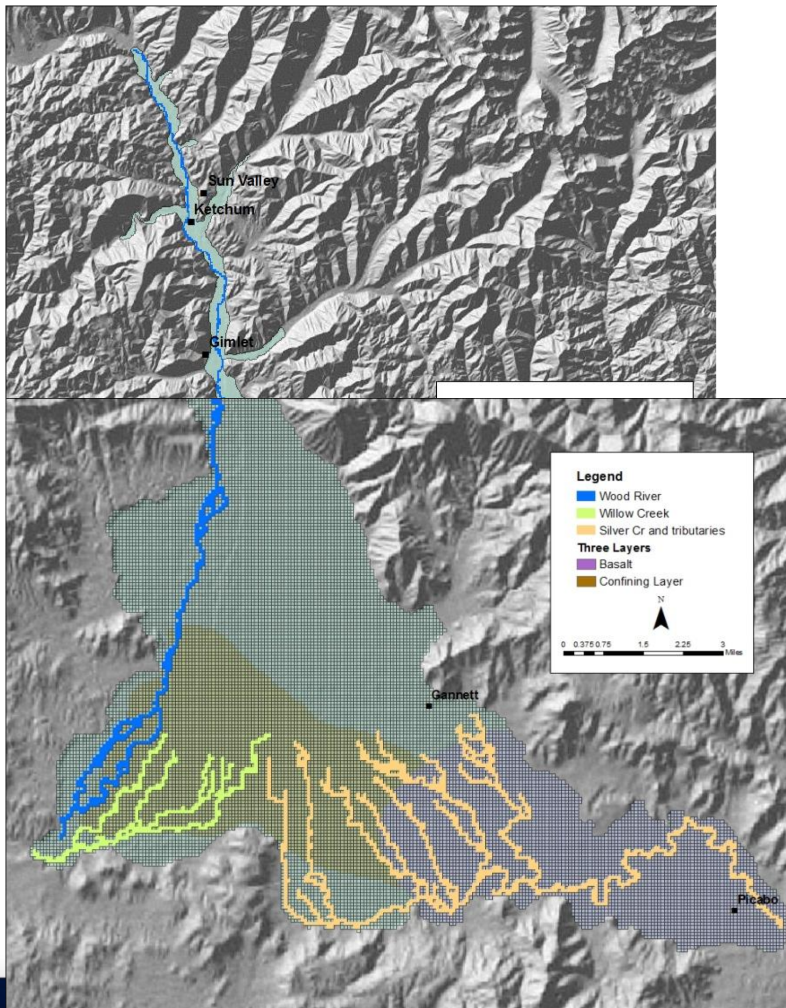
- Not used administratively
- Used to evaluate scenarios
  - Impact of anticipated growth
  - Best place to conduct recharge
  - Management of municipal well fields

Wood River Valley Aquifer Model (WRV)



- Wood River Valley Aquifer Model
  - Primarily sand and gravel deposited by ancestral Wood River with some basalt flows in the southeast and southwest
  - Model developed by the US Geological Survey and IDWR with input from representatives from local governments and agriculture

Wood River Valley Model (WRV)



- Available 2016
- MODFLOW-USG
  - 100 m x 100 m (328 ft x 328 ft) grid oriented north-south
  - Three layers in south
  - Simulates groundwater interaction with
    - Wood River
    - Willow Creek
    - Silver Creek and tributaries

Use of WRV

- WRV Model has not yet been used in an administrative setting
  - Useful for evaluating regional impacts on rivers and streams
    - Useful for evaluating the impact of ground water irrigation on the Wood River
    - Useful for evaluating the impact of ground water irrigation on Willow Creek
    - Useful for evaluating the impact of ground water irrigation on Silver Creek and its tributaries
  - Will be used to process transfers

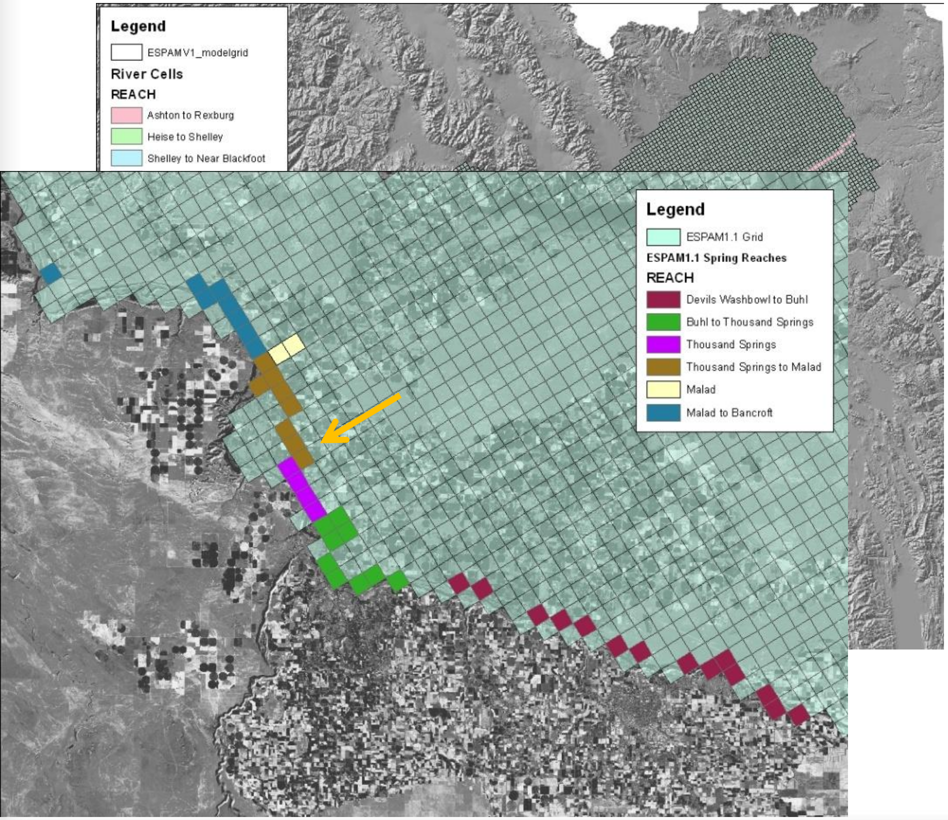
Eastern Snake Hydrologic Modeling Committee

- 1999 formed Eastern Snake Hydrologic Modeling Committee
- ESPAM Model development is a collaborative process involving the stake-holders (technical representation).
- Ensures all points of view are represented. Allows us to probe more questions than if developed in isolation.

<u>Members of the committee include</u>:

IDWR, US Fish and Wildlife, Eastern Idaho Water Users, Surface Water Coalition, Groundwater Users (IGWA), Idaho Power Co., IWRRI, US Bureau of Reclamation, US Geological Survey, University of Idaho, Boise State University, and several consultants representing individuals, businesses and cities.

Enhanced Snake Plain Aquifer Model Version 1.1 (ESPAM1.1)

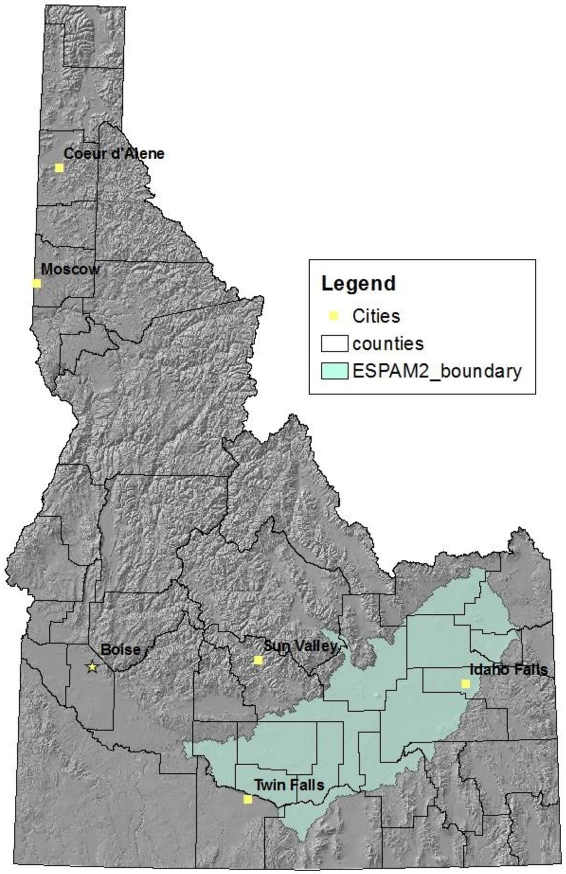


- Available 2004
- MODFLOW
  - Grid rotated 31.4˚ counter clockwise
    - 1 mi x 1 mi
  - River
    - 5 river reaches
      - Based on gauge locations
    - 6 spring reaches
      - Kjelstrom (1995) and Covington & Weaver (1990)

Time Discretization

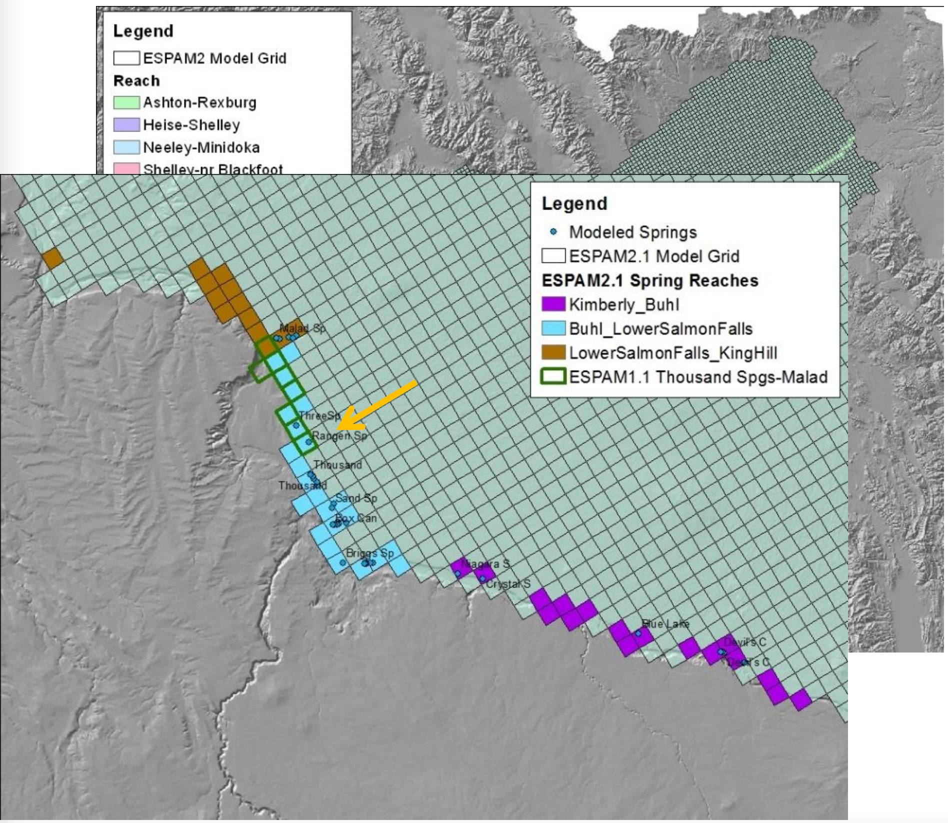
- 22 year time period
  - 6 month stress periods
    - Irrigation season
    - Non-irrigation season
- One land use distribution
  - Based on most recent survey

Eastern Snake Plain Aquifer Model Version 2.1 (ESPAM2.1)



- Eastern Snake Plain Aquifer
  - Layered basalt aquifer
  - Rubble in the interface between basalt flows transmits water readily
  - Model developed by the Eastern Snake Hydrologic Modeling Committee
    - Members include IDWR and representatives from Federal, and Local governments, industry, and irrigators

Eastern Snake Plain Aquifer Model Version 2.1 (ESPAM2.1)



- Available 2013
- MODFLOW-2000
  - Grid rotated 31.4˚ counter clockwise
    - Grid 1 mi x 1 mi
  - River
    - 5 river reaches
      - Based on gauge locations
    - 3 spring reaches
      - Based on river gages
      - 14 springs with transient calibration targets

ESPAM2.1 Model

- Calibration is the process of matching model output to measured observations. Want the difference to be as small as possible.
    - 28.5 years of observations,
    - One-month stress periods,
    - Over 43,000 water-level observations,
    - Over 2,000 river gains/losses,
    - Over 2,000 spring-discharge measurements.
- ESPAM2.1 is calibrated using automated software (PEST). This allows us to run many thousands of iterations to calibrate the model.
- Calibration gives us the aquifer properties that allow for the observed conditions.
- Model files are publicly available on our website (http://www.idwr.idaho.gov/Browse/WaterInfo/ESPAM/model_files/).

Using ESPAM2.1

- To run the model, we introduce stress (pumping, recharge, curtailment, etc.) and analyze the results.
- In response to the stress, the model will calculate:
    - Water-level changes,
    - Aquifer-storage changes,
    - Snake River gains/losses
    - Spring discharge.
- The model cannot think for itself; instead, human beings use the output from the model to make decisions.

Use of ESPAM2.1

- Used for planning
- Used for evaluating impact at the spring cells containing one of the 14 spring calibration targets
- Used for evaluating impact of ground water irrigated agriculture on Snake River reaches
- Used for processing transfers
- Scenarios
  - Impact of recharge at various locations
  - Impact of voluntary reductions at various locations

How is the gw model used?

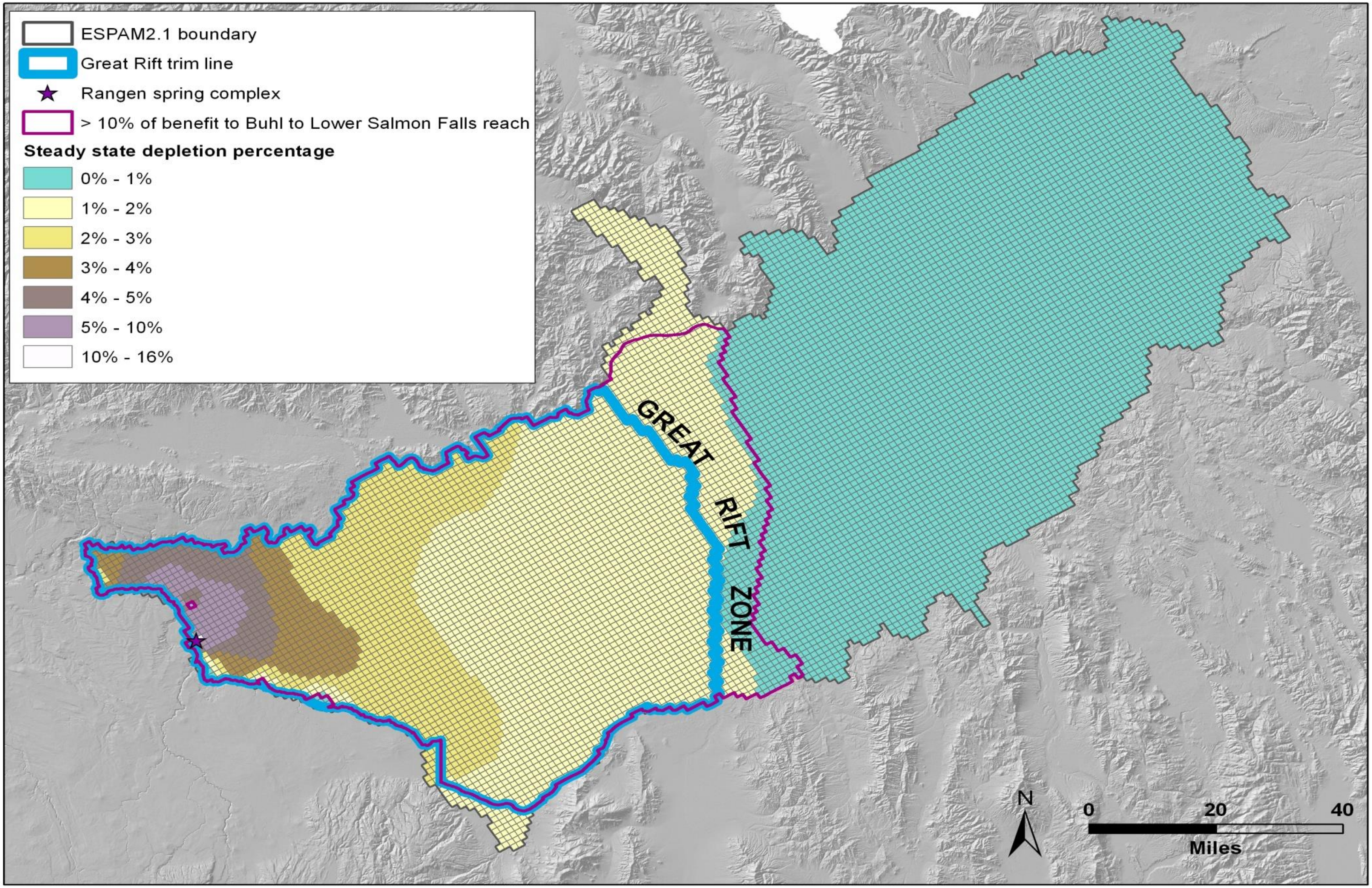
For Diversions Directly from Springs

Calculates depletions to spring flows caused by ground water pumping

Determines priority date for GW right curtailment to restore spring flow depletions

For Diversions from the Snake River

Determines priority date for GW right curtailment to restore spring flow depletions



ESPAM2.1 boundary
Great Rift trim line
Rangen spring complex
> 10% of benefit to Buhl to Lower Salmon Falls reach
Steady state depletion percentage
0% - 1%
1% - 2%
2% - 3%
3% - 4%
4% - 5%
5% - 10%
10% - 16%
GREAT RIFT ZONE
N
0
20
40
Miles

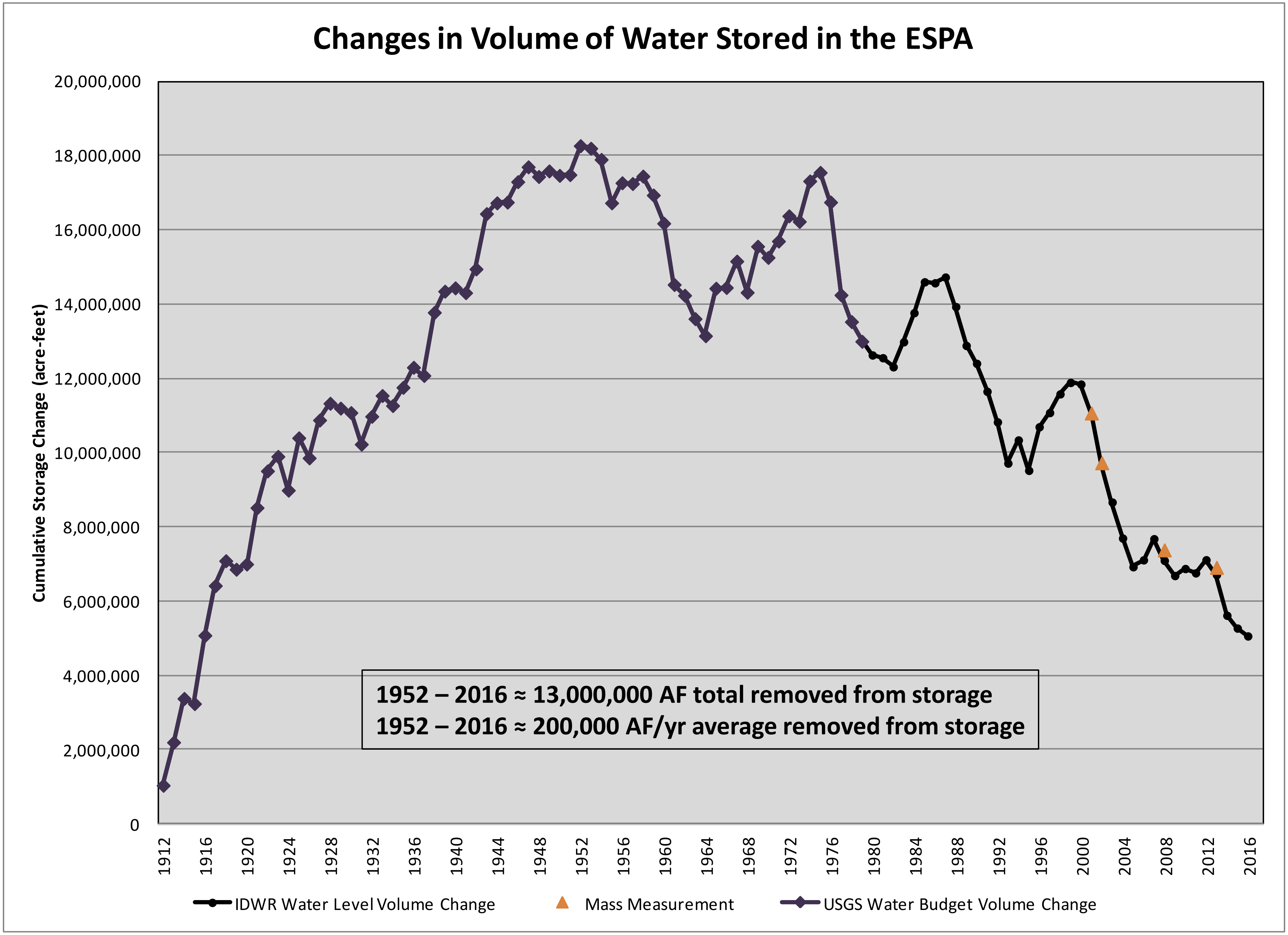
Aquifer Water Balance

Inflow – Outflow = ΔStorage

ESPA Inflows = Incidental recharge from SW irrigation, Canal Seepage, Perched River Seepage, Tributary Underflow, Precipitation.

ESPA Outflows = Non-Irrigated and Surface-Water Irrigated Evapotranspiration (ET), Spring Discharge, Well Pumping to support Groundwater Irrigated ET.

We can use estimates of aquifer storage to generate an aquifer "history."


Changes in Volume of Water Stored in the ESPA
Cumulative Storage Change (acre-feet)
20,000,000
18,000,000
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
1912
1916
1920
1924
1928
1932
1936
1940
1944
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
2004
2008
2012
2016
1952 – 2016 ≈ 13,000,000 AF total removed from storage
1952 – 2016 ≈ 200,000 AF/yr average removed from storage
IDWR Water Level Volume Change
Mass Measurement
USGS Water Budget Volume Change

How can we "balance the budget?"

A. Ground water to surface water conversions.
B. Managed aquifer recharge.
C. Demand reduction.
D. Pilot weather modification program.
E. Minimizing loss of incidental recharge.

-ESPA CAMP January 2009

The Surface Water Coalition Water Call

- The surface Water Coalition (SWC) is a group of surface-water users that has made a water call on junior priority groundwater users.
- Each year, shortfall projections are made (how much the SWC won't have) and the groundwater users must mitigate for or curtail their use of water.
- Uncertain for both junior and senior. Very expensive. Many people have surface and groundwater rights.
- Hasn't helped the underlying problem.
- Water users are now working together to solve the problem.

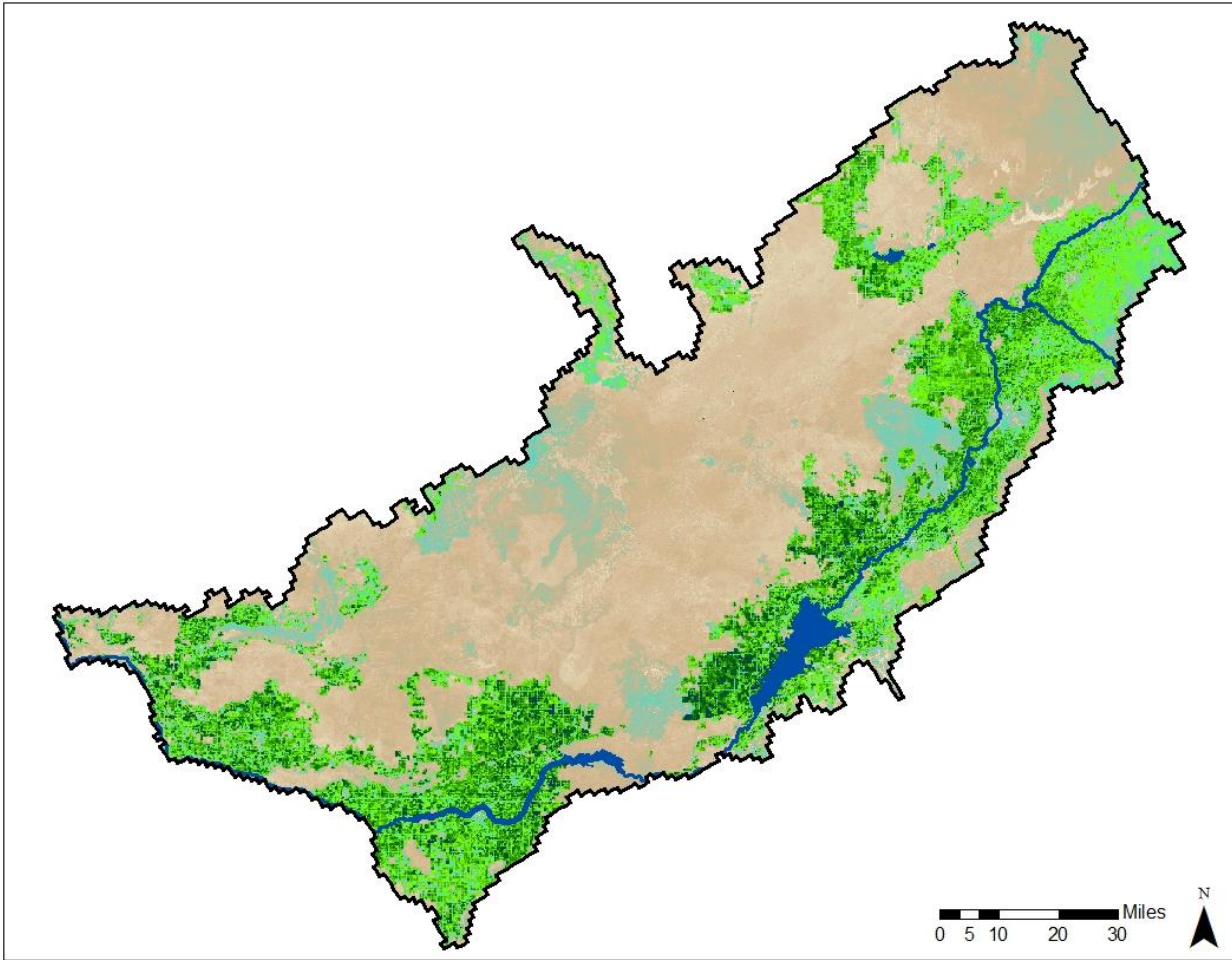
Final Settlement Agreement

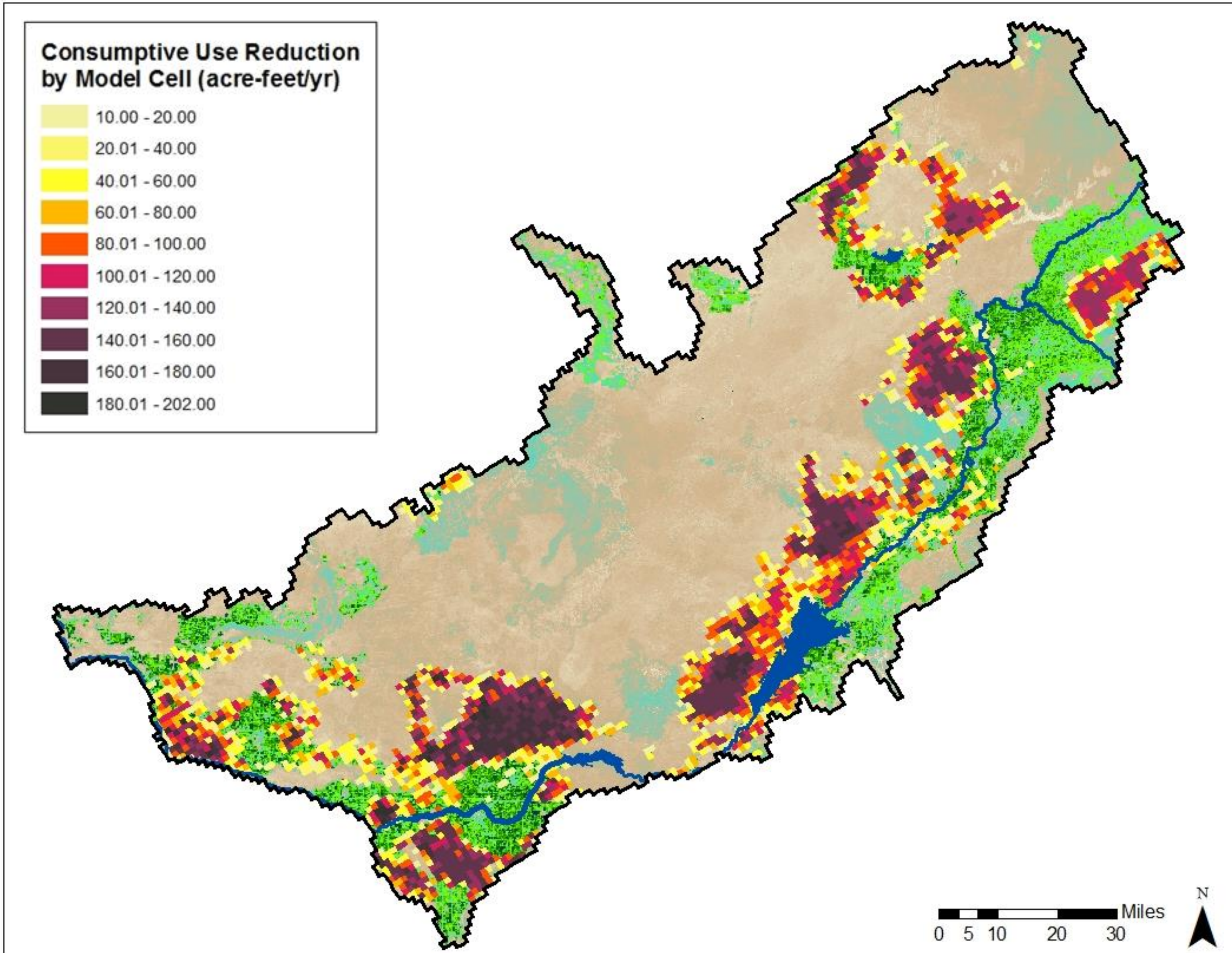
Long Term Practices (i.e. 2016 and beyond)

- Consumptive use reduction of ground water by 240,000 AF
- Annual storage water delivery of 50,000 AF
- Irrigation season reduction: April 1 – October 31
- Mandatory Measurement Devices by 2018
- Support state sponsored recharge program of 250 KAF annually
- Additional support for the following: NRCS conservation programs; new conversion projects; management of Trust Water Rights; and participation in review and possible recommendations of changes to IDWR administrative processes on the ESPA.

Modeling Consumptive Use Reduction

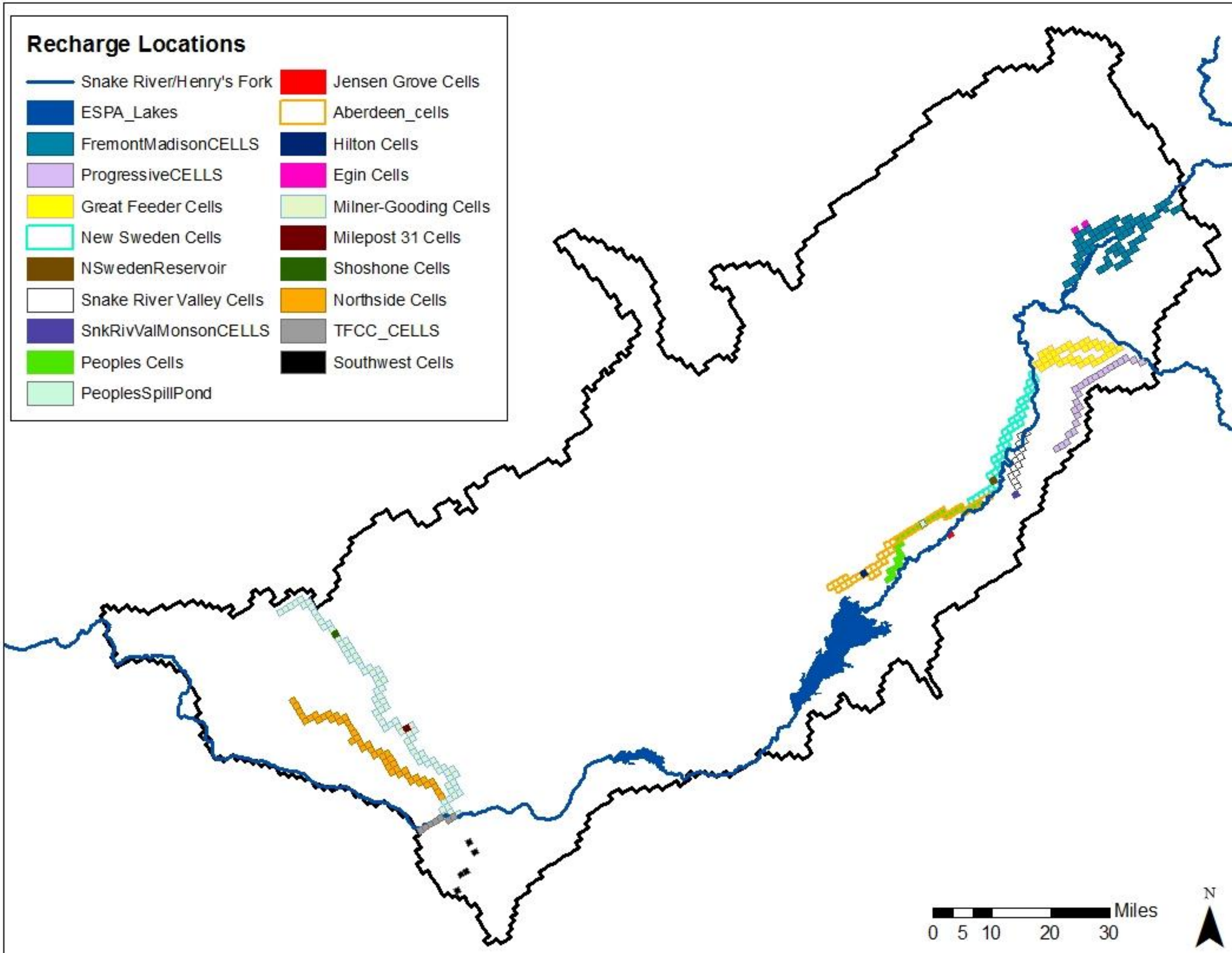
- Consumptive Use Reduction based on:
  - Reducing Consumptive use across the plain to obtain 240,000 acre-feet/year.
  - Distribute acreage reduction evenly across Groundwater Districts.

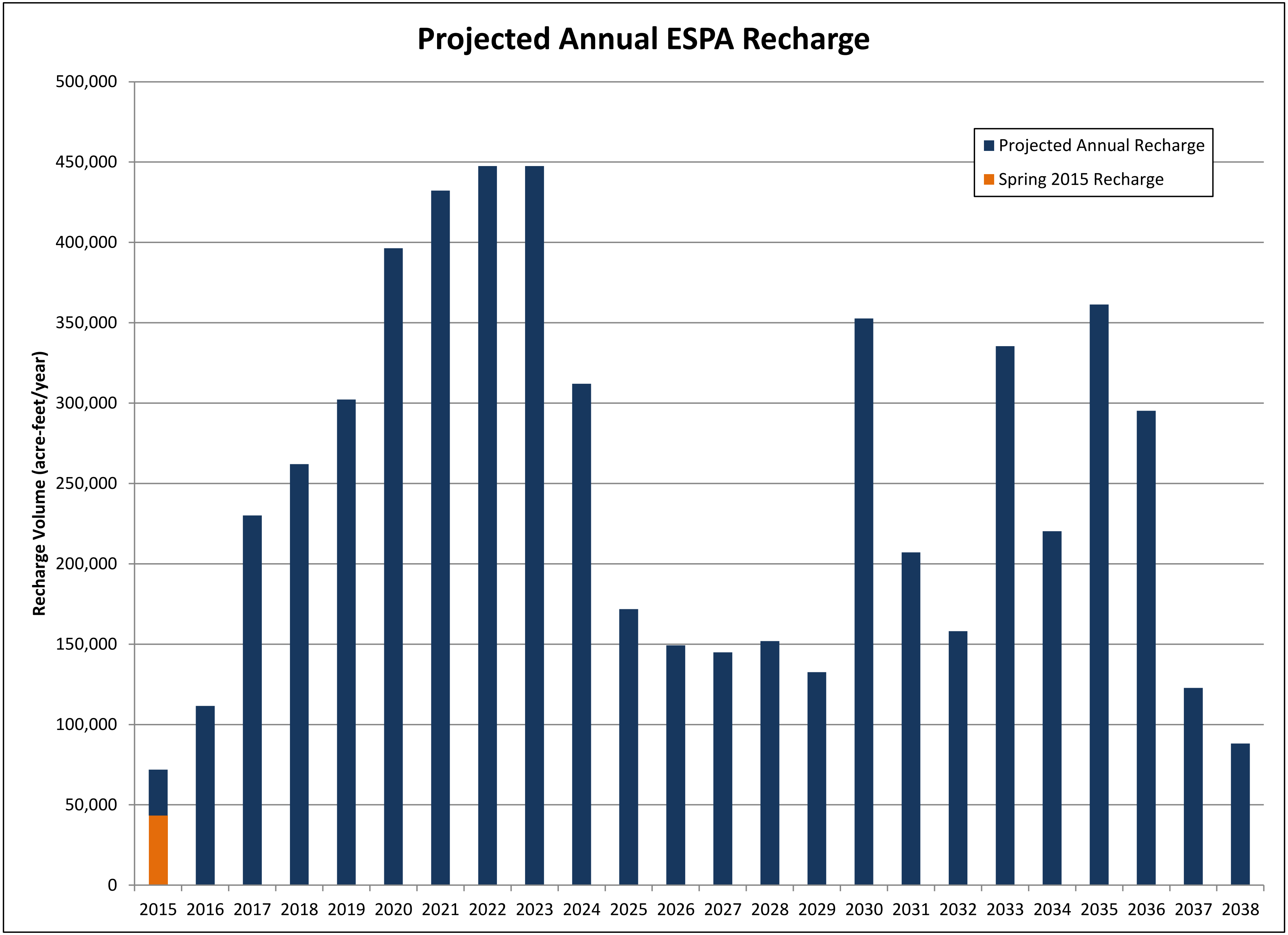

N
Miles
0 5 10 20 30

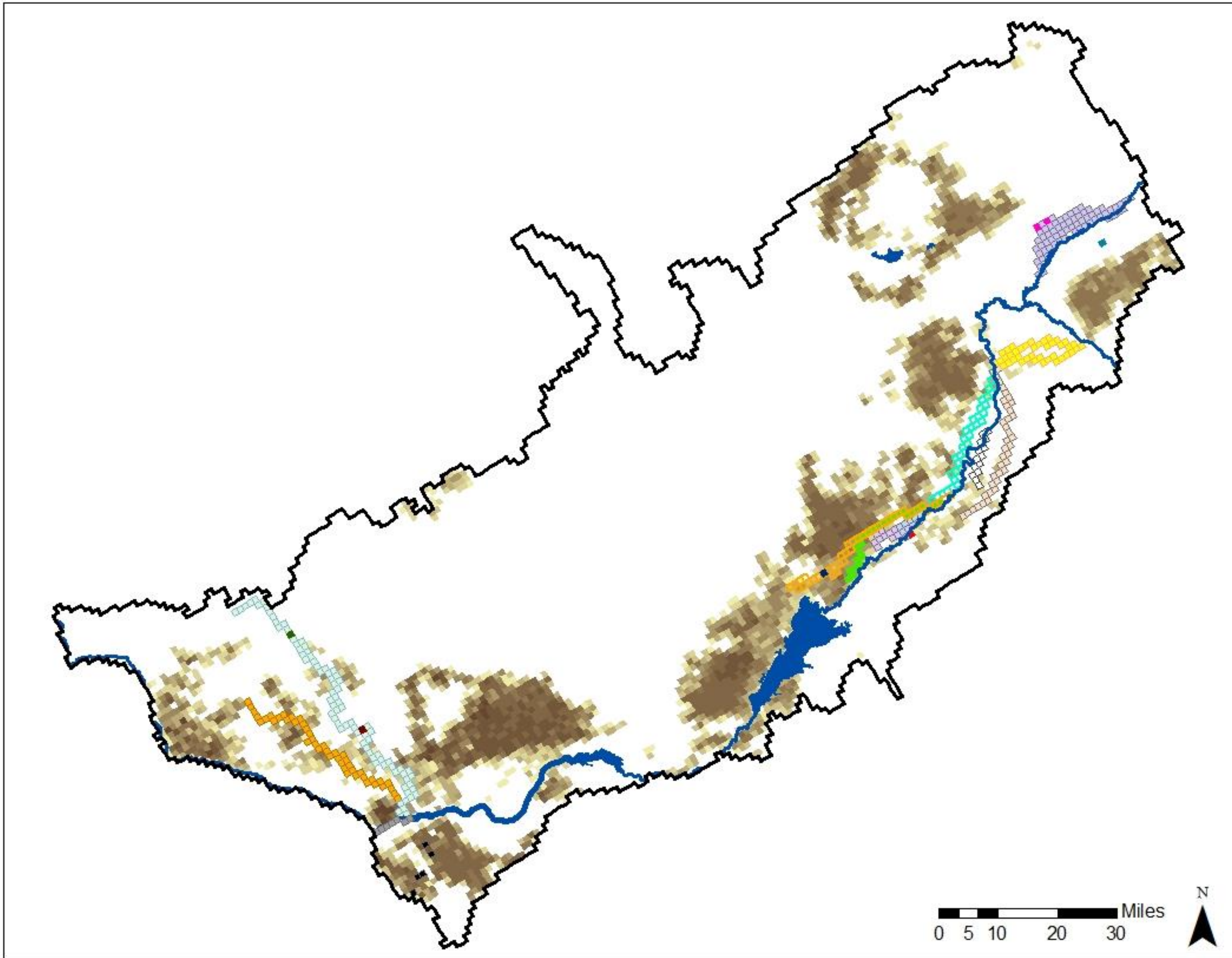

Consumptive Use Reduction by Model Cell (acre-feet/yr)
10.00 - 20.00
20.01 - 40.00
40.01 - 60.00
60.01 - 80.00
80.01 - 100.00
100.01 - 120.00
120.01 - 140.00
140.01 - 160.00
160.01 - 180.00
180.01 - 202.00
Miles
0 5 10 20 30
N

Modeling Recharge into the Future

- Recharge timing and volume based on:
  - Projected recharge capacities.
    - Based on current capacities and projected build-out of proposed recharge sites.
  - Water availability for recharge 1991-2014.
    - Mid to late 1990's were wet.
    - Therefore, projected recharge volumes in the 2020's are quite high.


Recharge Locations
Snake River/Henry's Fork
ESPA_Lakes
FremontMadisonCELLS
ProgressiveCELLS
Great Feeder Cells
New Sweden Cells
NSwedenReservoir
Snake River Valley Cells
SnkRivValMonsonCELLS
Peoples Cells
PeoplesSpillPond
Jensen Grove Cells
Aberdeen_cells
Hilton Cells
Egin Cells
Milner-Gooding Cells
Milepost 31 Cells
Shoshone Cells
Northside Cells
TFCC_CELLS
Southwest Cells
Miles
0 5 10 20 30
N

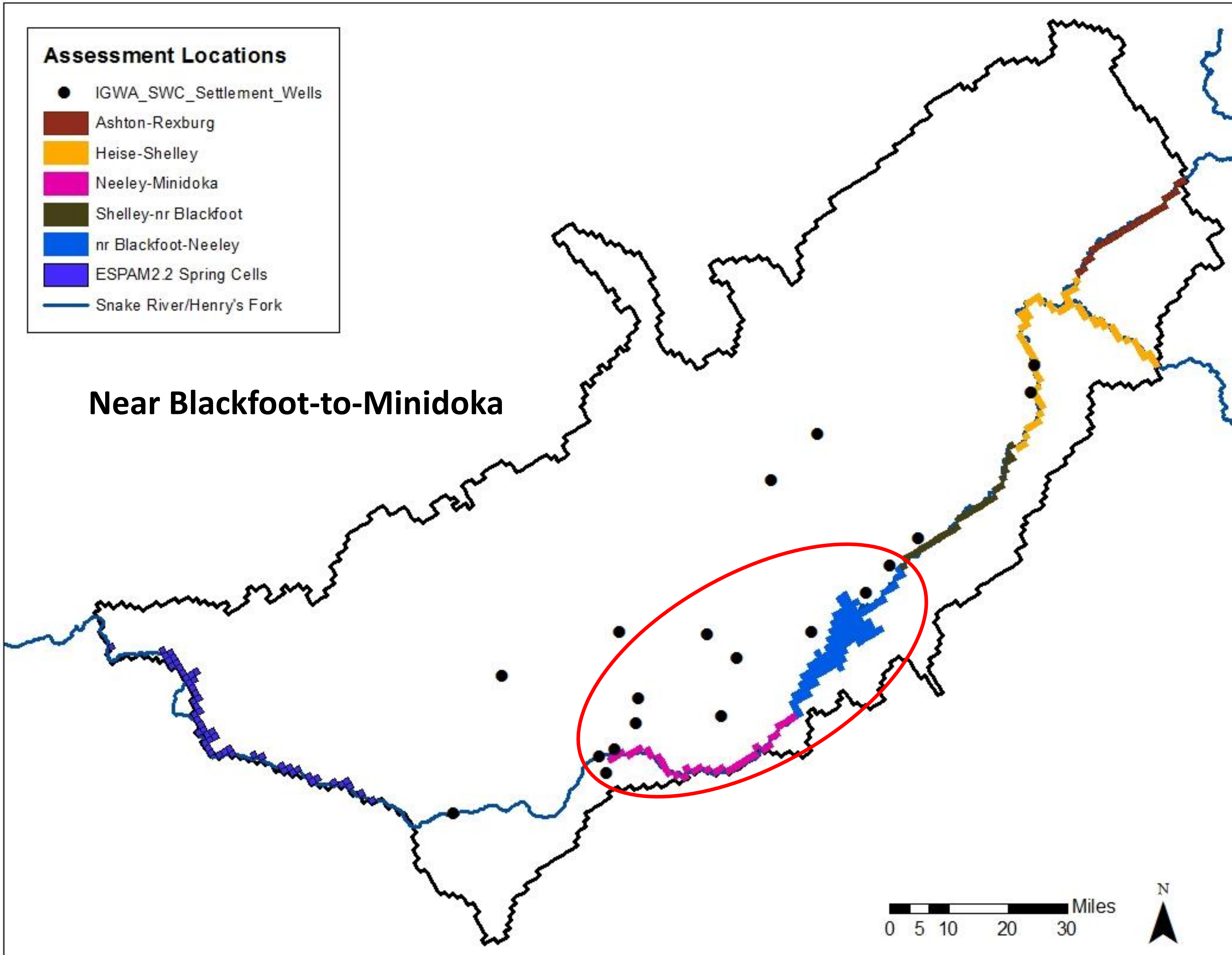

Projected Annual ESPA Recharge
Recharge Volume (acre-feet/year)
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Projected Annual Recharge
Spring 2015 Recharge
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038

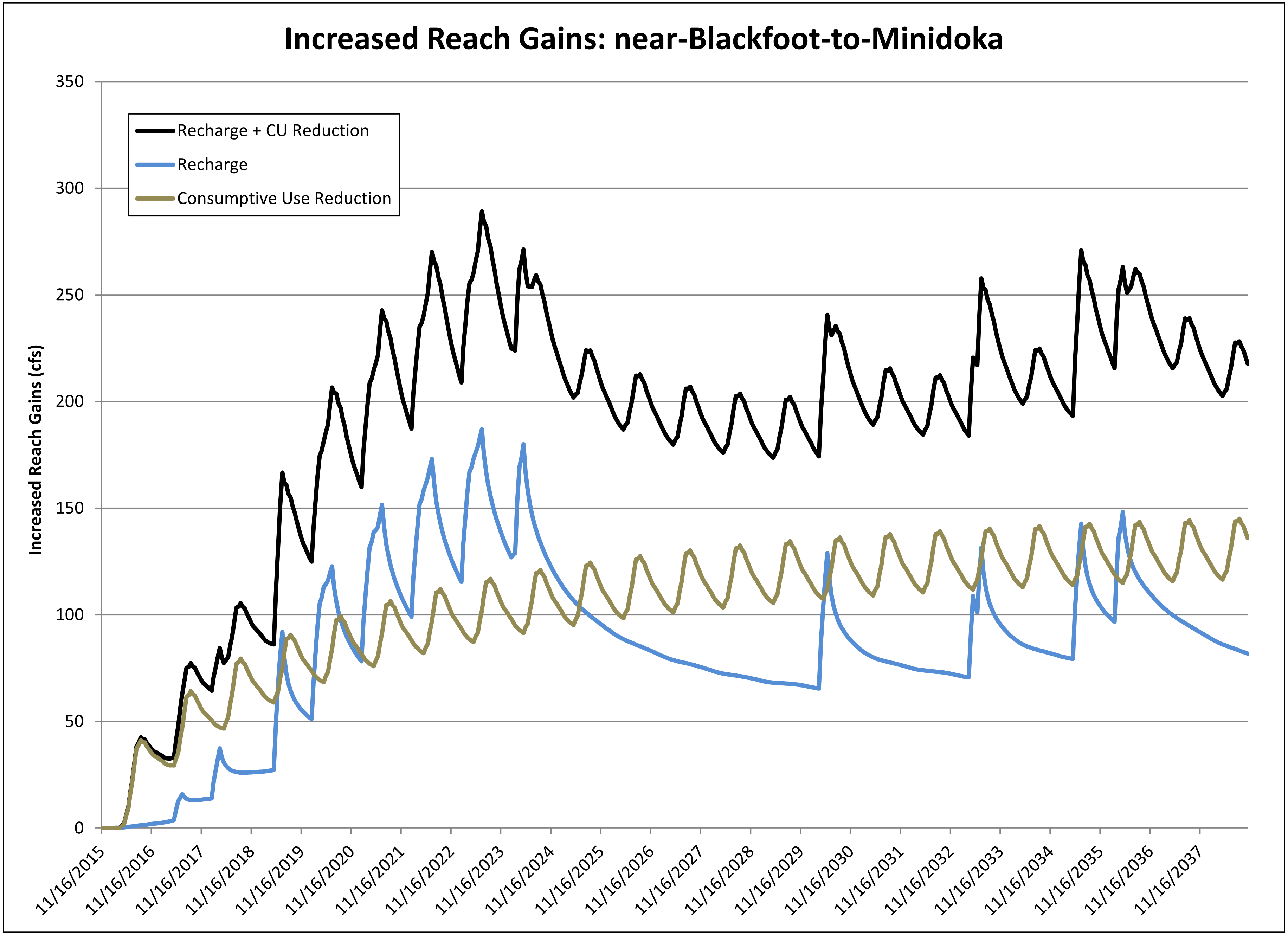

Miles
0 5 10 20 30
N

Benefits to Surface Water

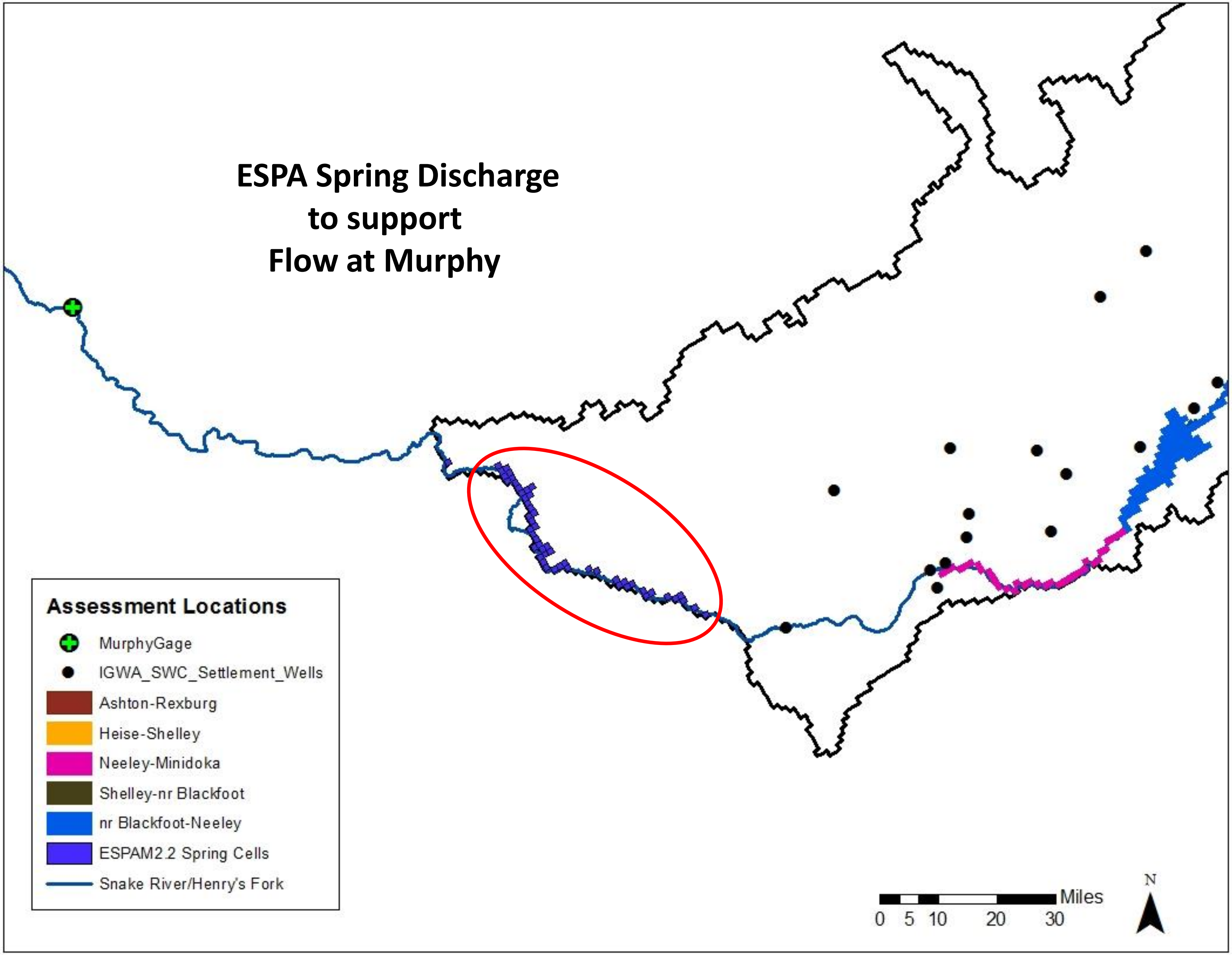
Benefits to Surface Water have been assessed relative to two objectives:

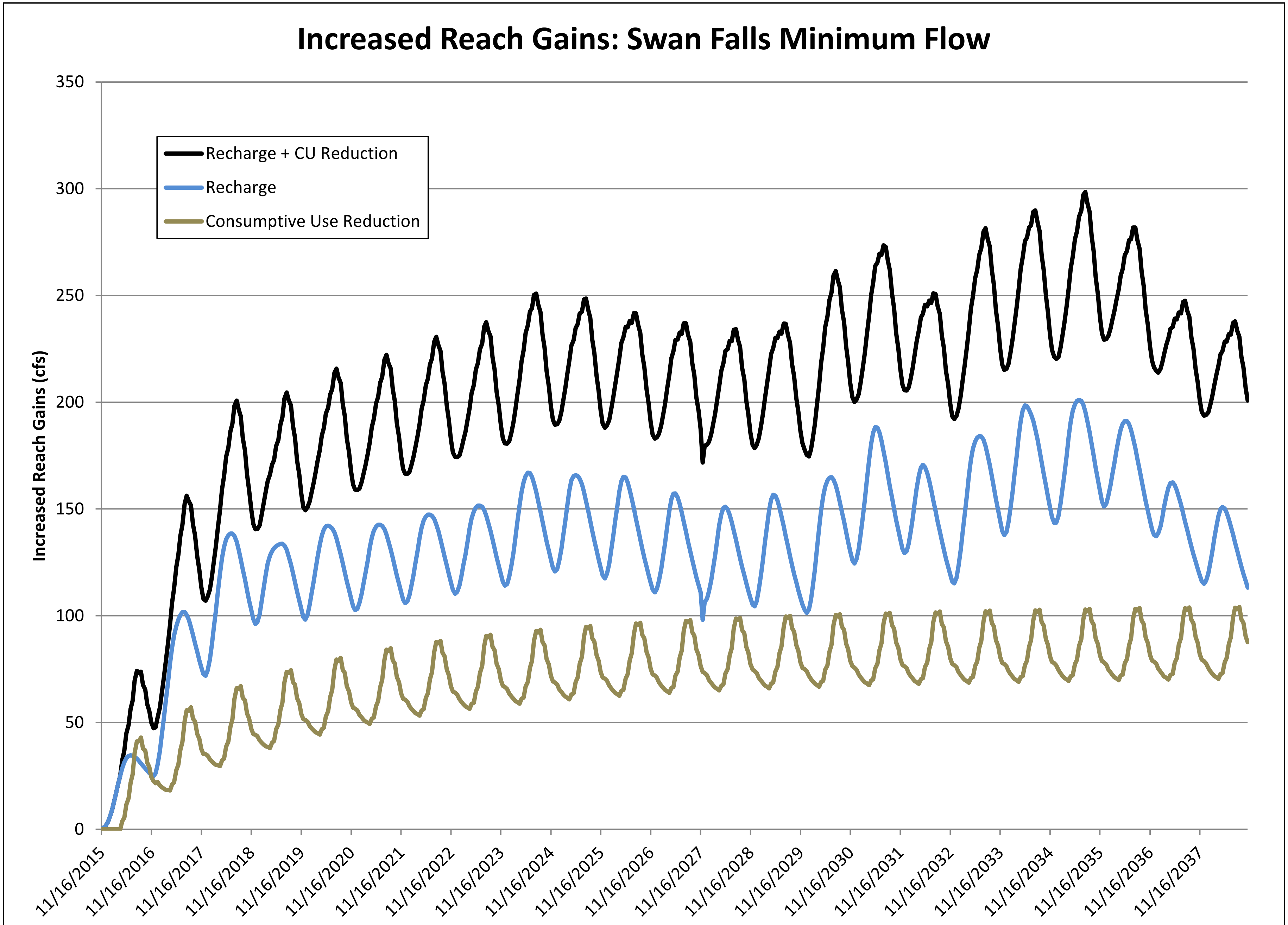
1. Increased reach gains in the nr Blackfoot-to-Minidoka reach.
2. Increased reach gains in relation flow at Murphy.


Assessment Locations
IGWA_SWC_Settlement_Wells
Ashton-Rexburg
Heise-Shelley
Neeley-Minidoka
Shelley-nr Blackfoot
nr Blackfoot-Neeley
ESPAM2.2 Spring Cells
Snake River/Henry's Fork
Near Blackfoot-to-Minidoka
Miles
0 5 10 20 30
N



Increased Reach Gains: near-Blackfoot-to-Minidoka
Recharge + CU Reduction
Recharge
Consumptive Use Reduction
Increased Reach Gains (cfs)
0
50
100
150
200
250
300
350
11/16/2015
11/16/2016
11/16/2017
11/16/2018
11/16/2019
11/16/2020
11/16/2021
11/16/2022
11/16/2023
11/16/2024
11/16/2025
11/16/2026
11/16/2027
11/16/2028
11/16/2029
11/16/2030
11/16/2031
11/16/2032
11/16/2033
11/16/2034
11/16/2035
11/16/2036
11/16/2037

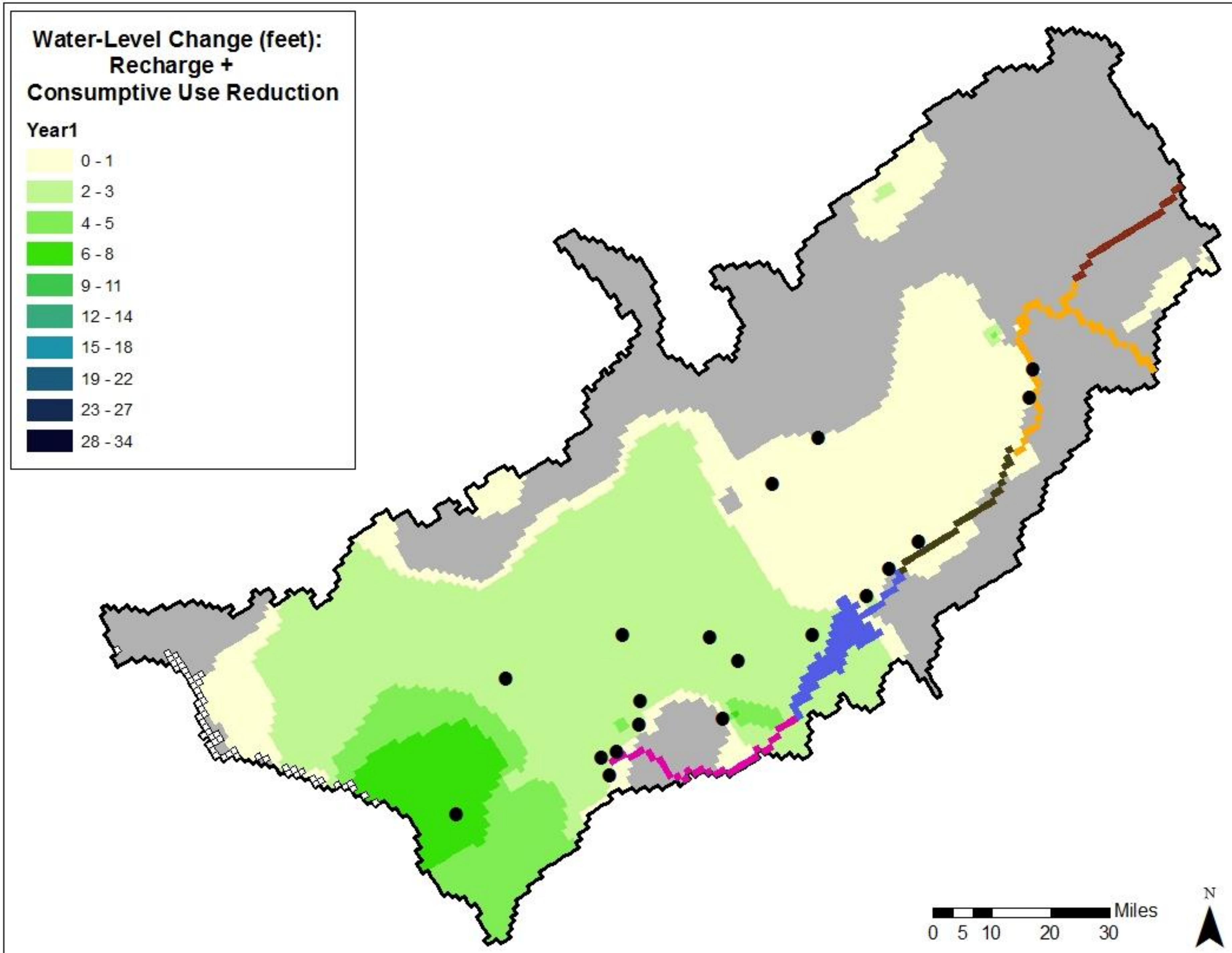

ESPA Spring Discharge
to support
Flow at Murphy
Assessment Locations
MurphyGage
IGWA_SWC_Settlement_Wells
Ashton-Rexburg
Heise-Shelley
Neeley-Minidoka
Shelley-nr Blackfoot
nr Blackfoot-Neeley
ESPAM2.2 Spring Cells
Snake River/Henry's Fork
Miles
0 5 10 20 30
N

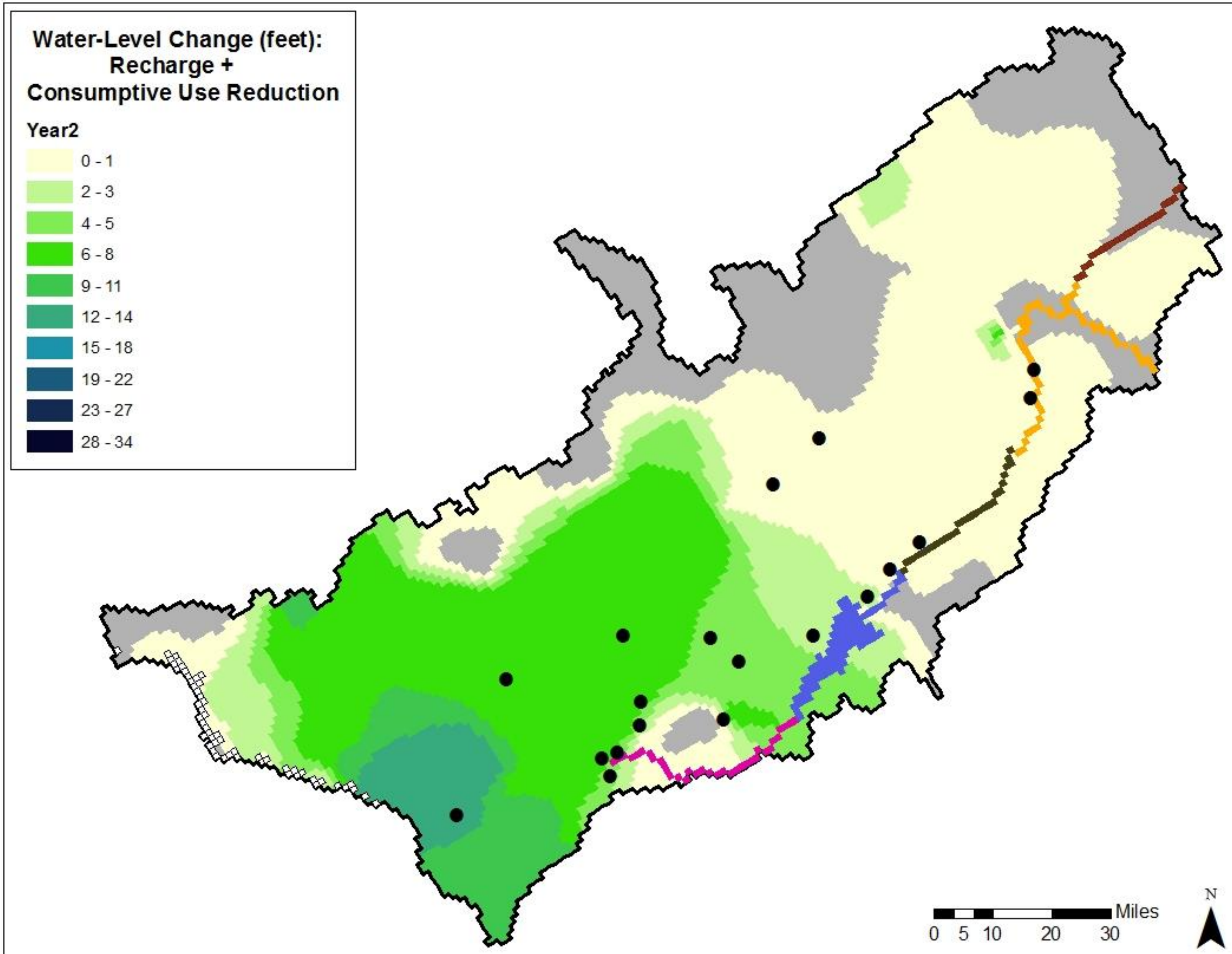

Increased Reach Gains: Swan Falls Minimum Flow
Recharge + CU Reduction
Recharge
Consumptive Use Reduction
Increased Reach Gains (cfs)
350
300
250
200
150
100
50
0
11/16/2015
11/16/2016
11/16/2017
11/16/2018
11/16/2019
11/16/2020
11/16/2021
11/16/2022
11/16/2023
11/16/2024
11/16/2025
11/16/2026
11/16/2027
11/16/2028
11/16/2029
11/16/2030
11/16/2031
11/16/2032
11/16/2033
11/16/2034
11/16/2035
11/16/2036
11/16/2037

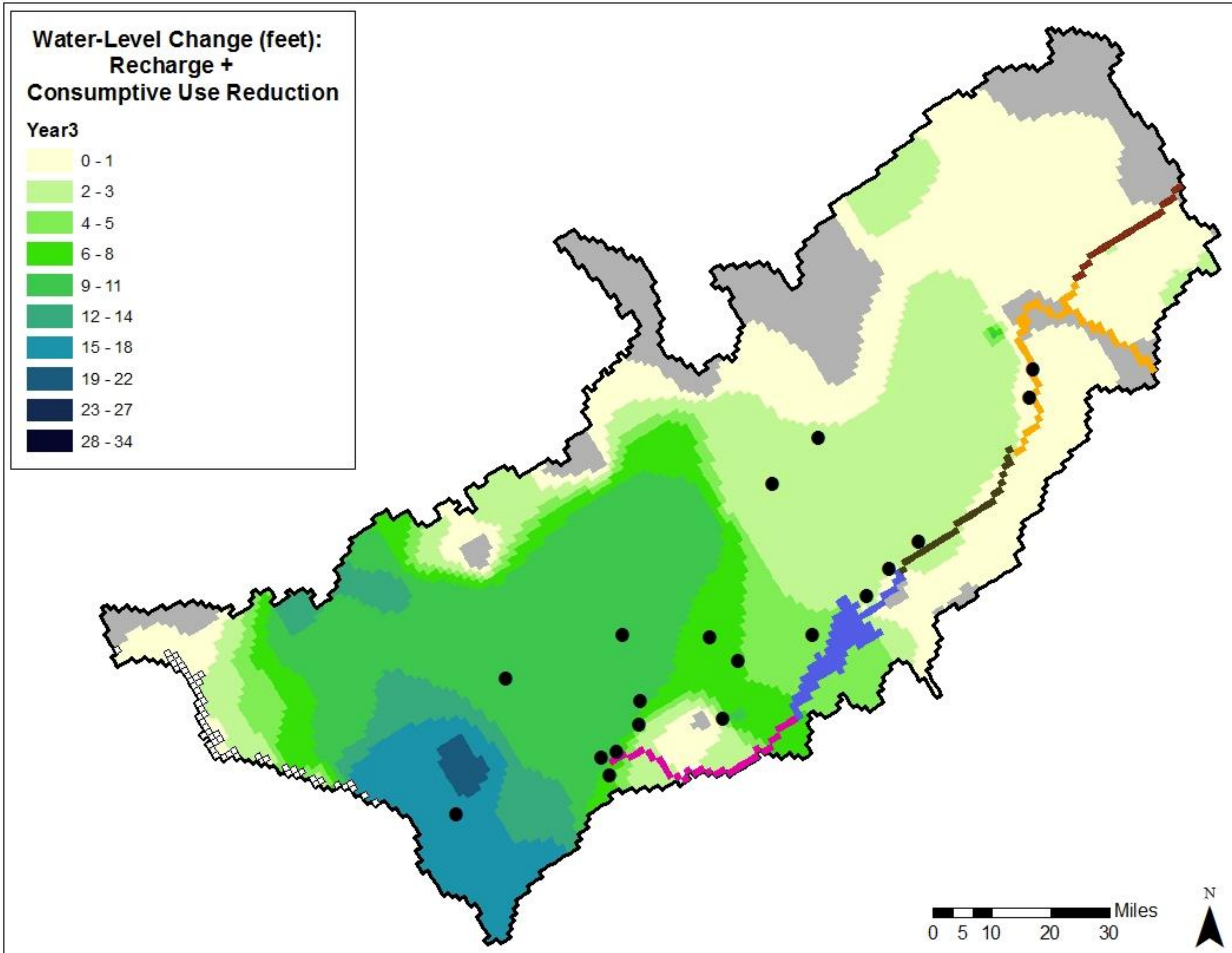
Benefits to Groundwater

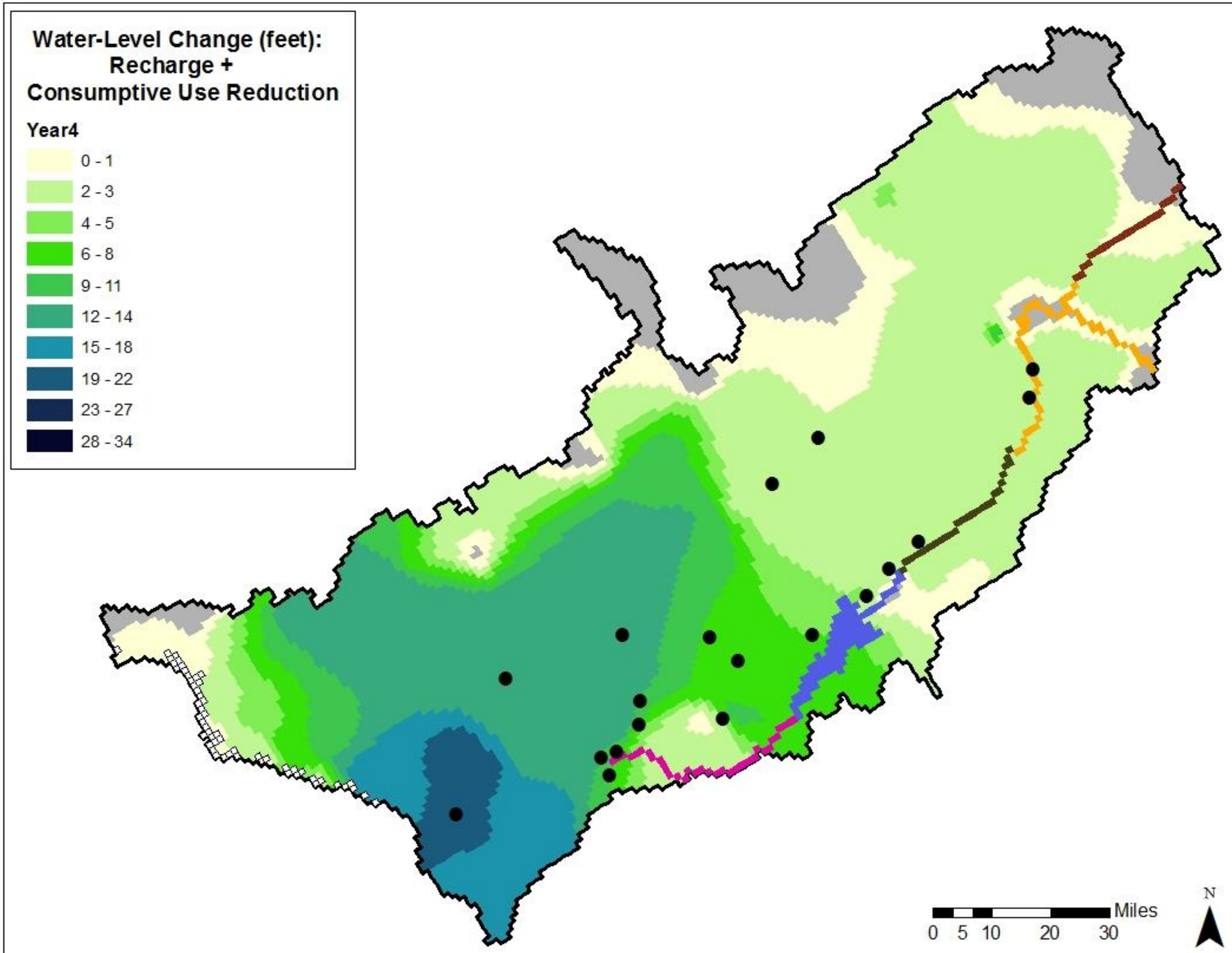
Benefits to Groundwater have been assessed in two ways:

1. Increased water levels across the ESPA.
2. Increased storage within the ESPA.

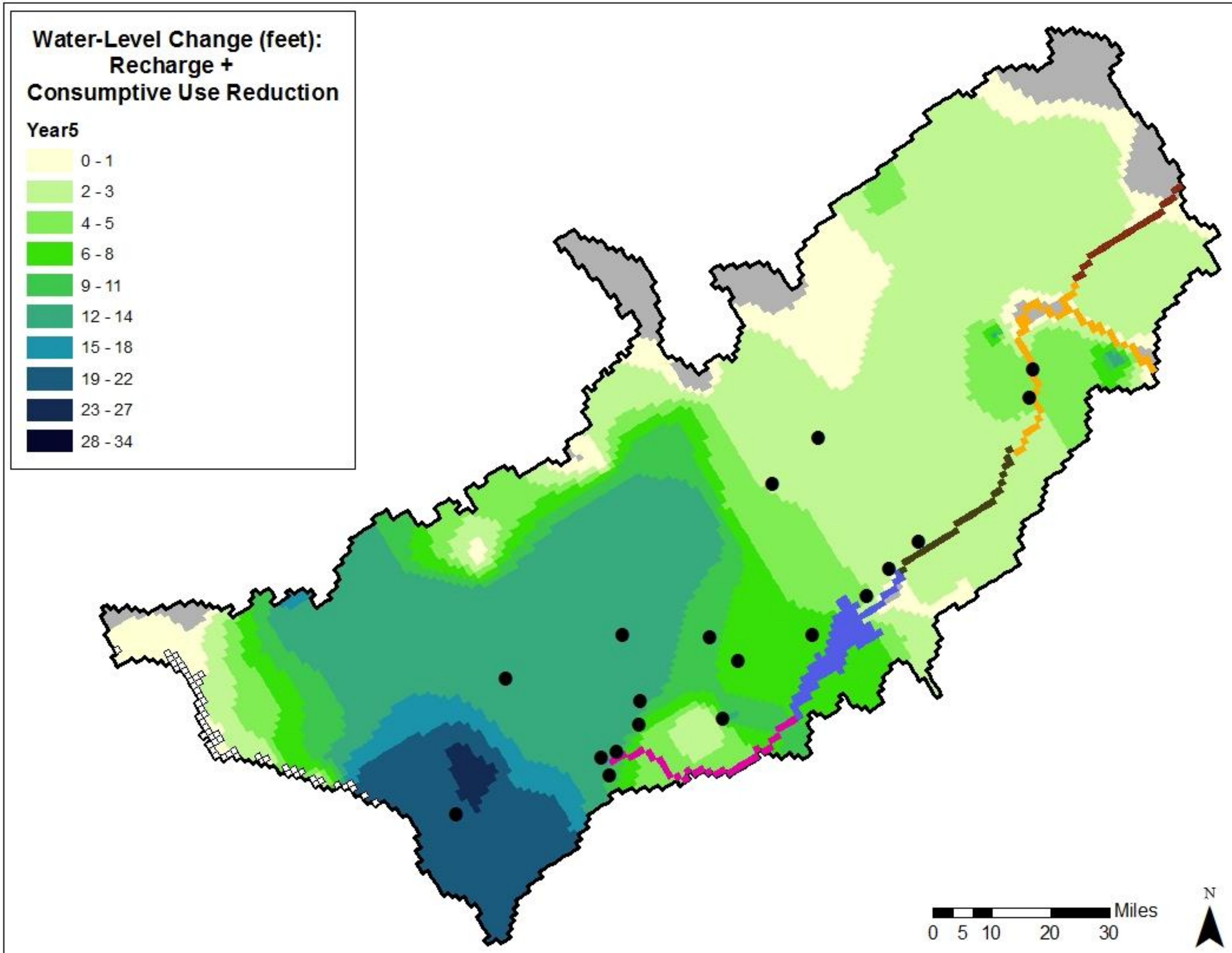

Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year1
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

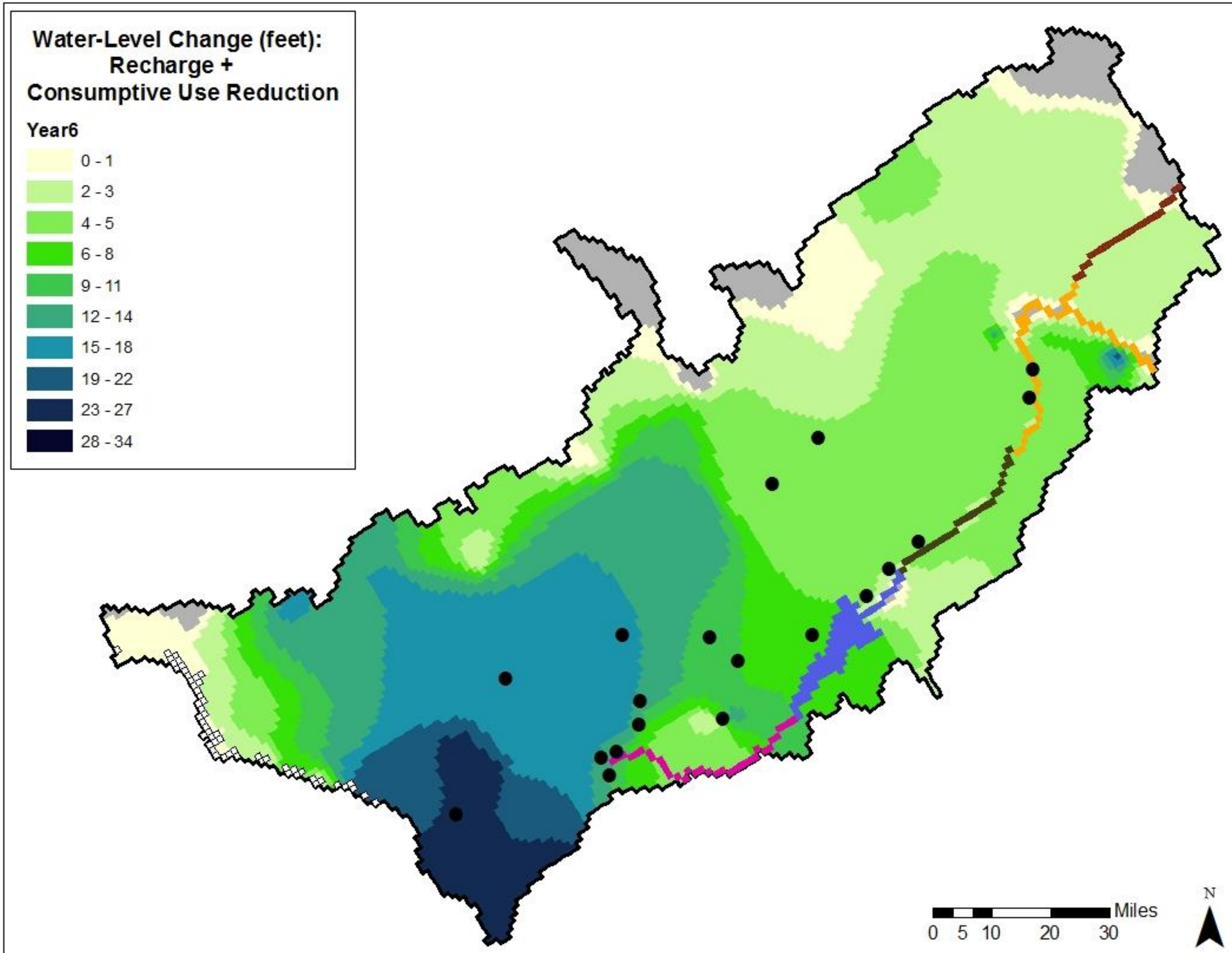

Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year2
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N


Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year3
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

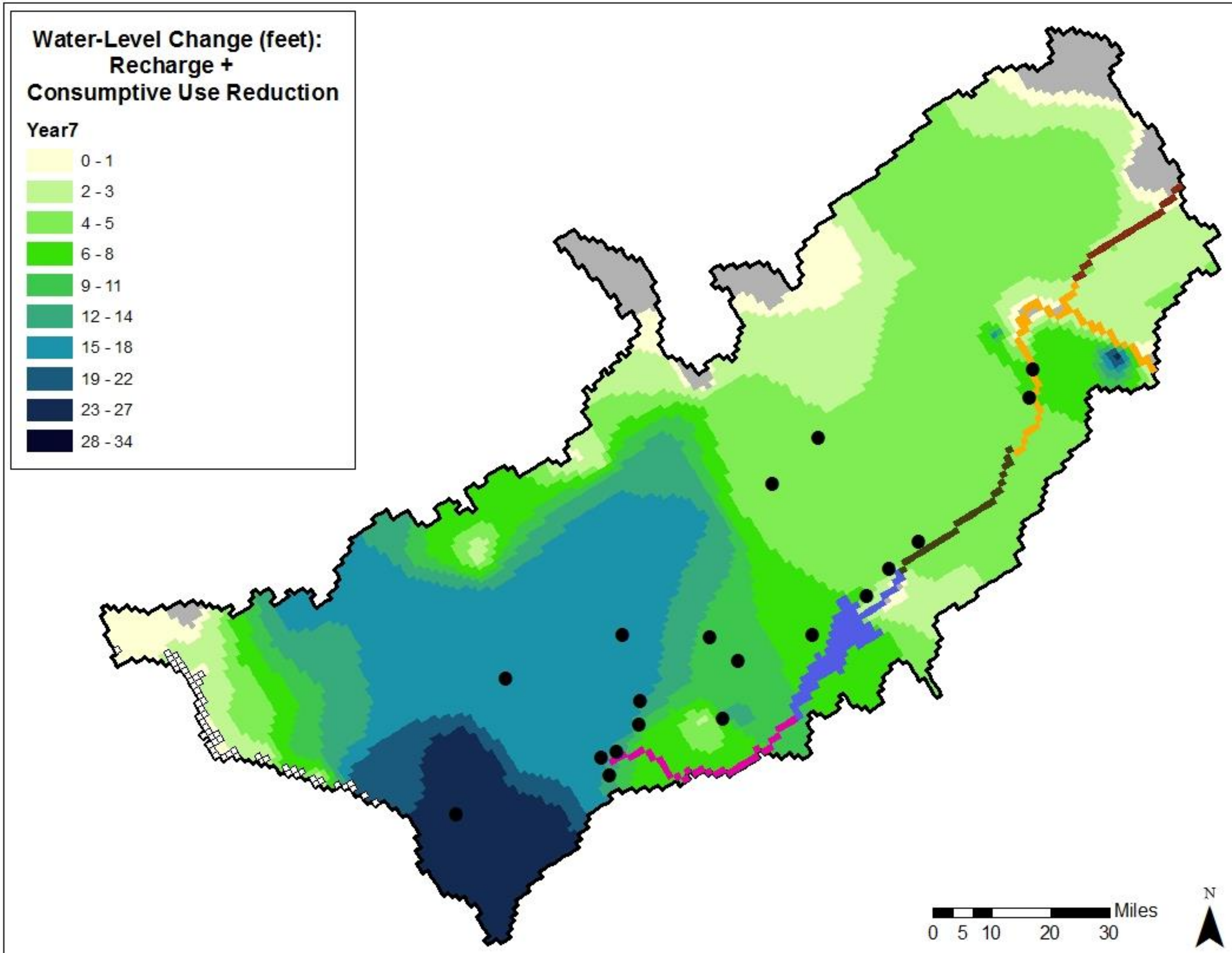


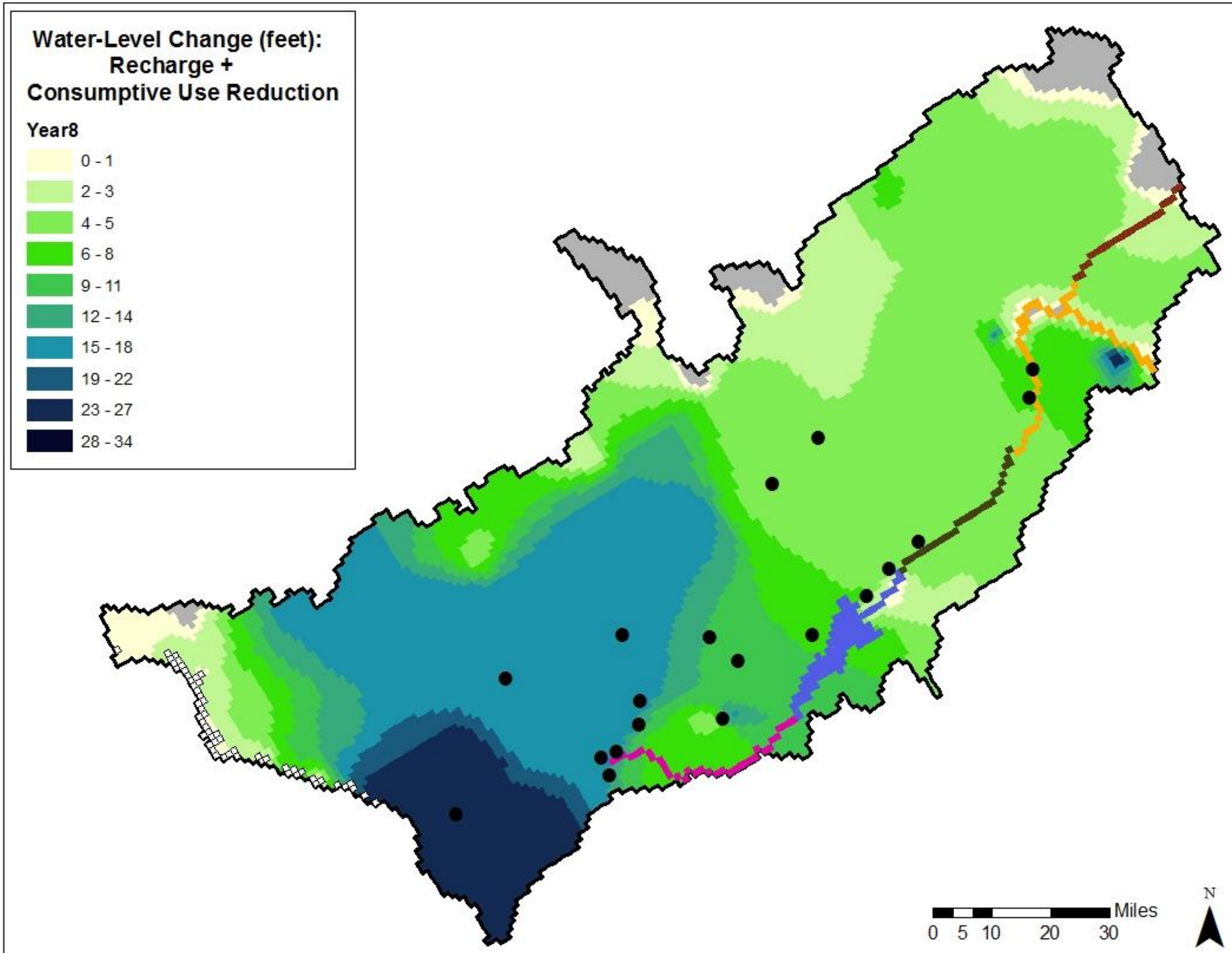
Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year4
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

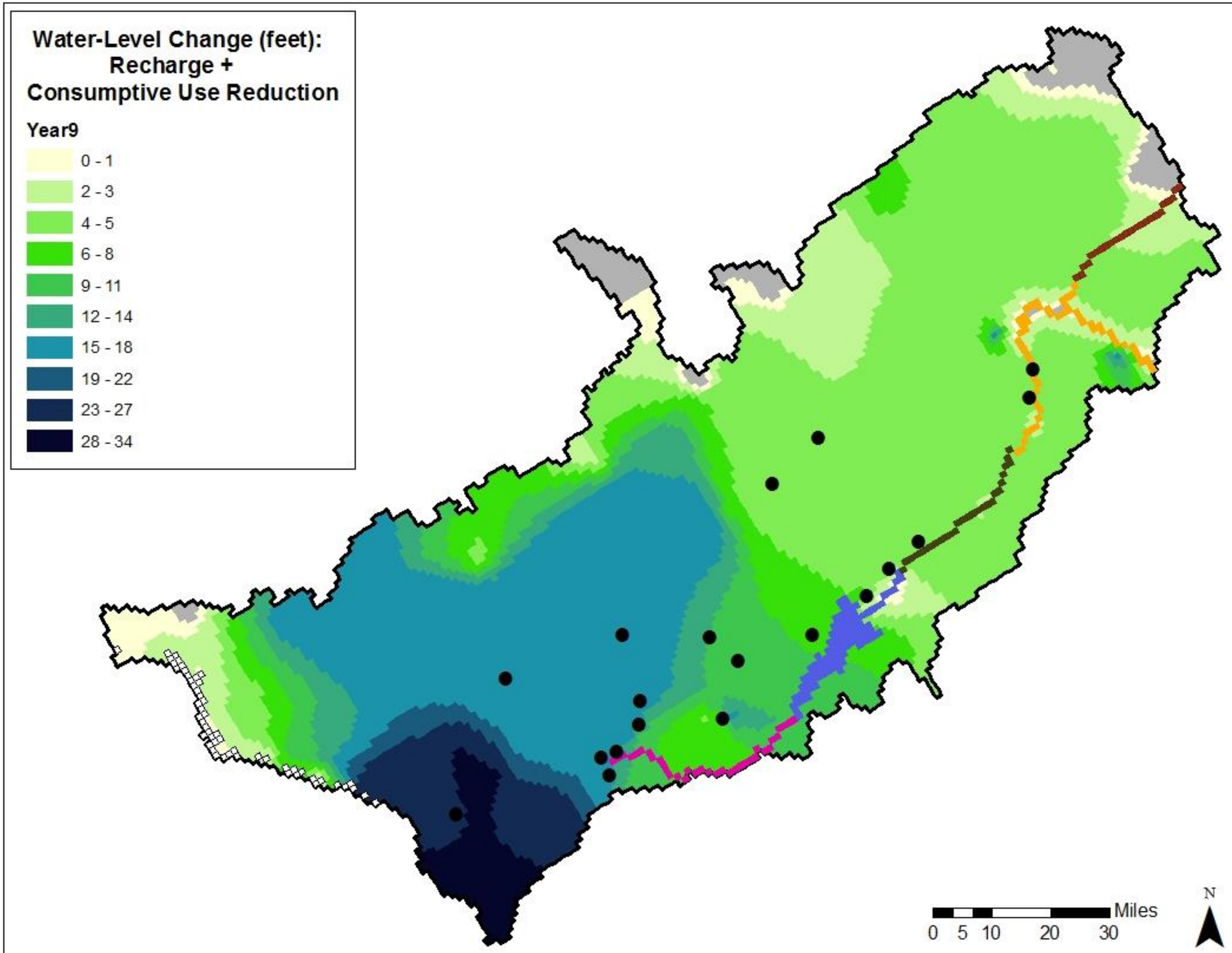

Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year5
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N



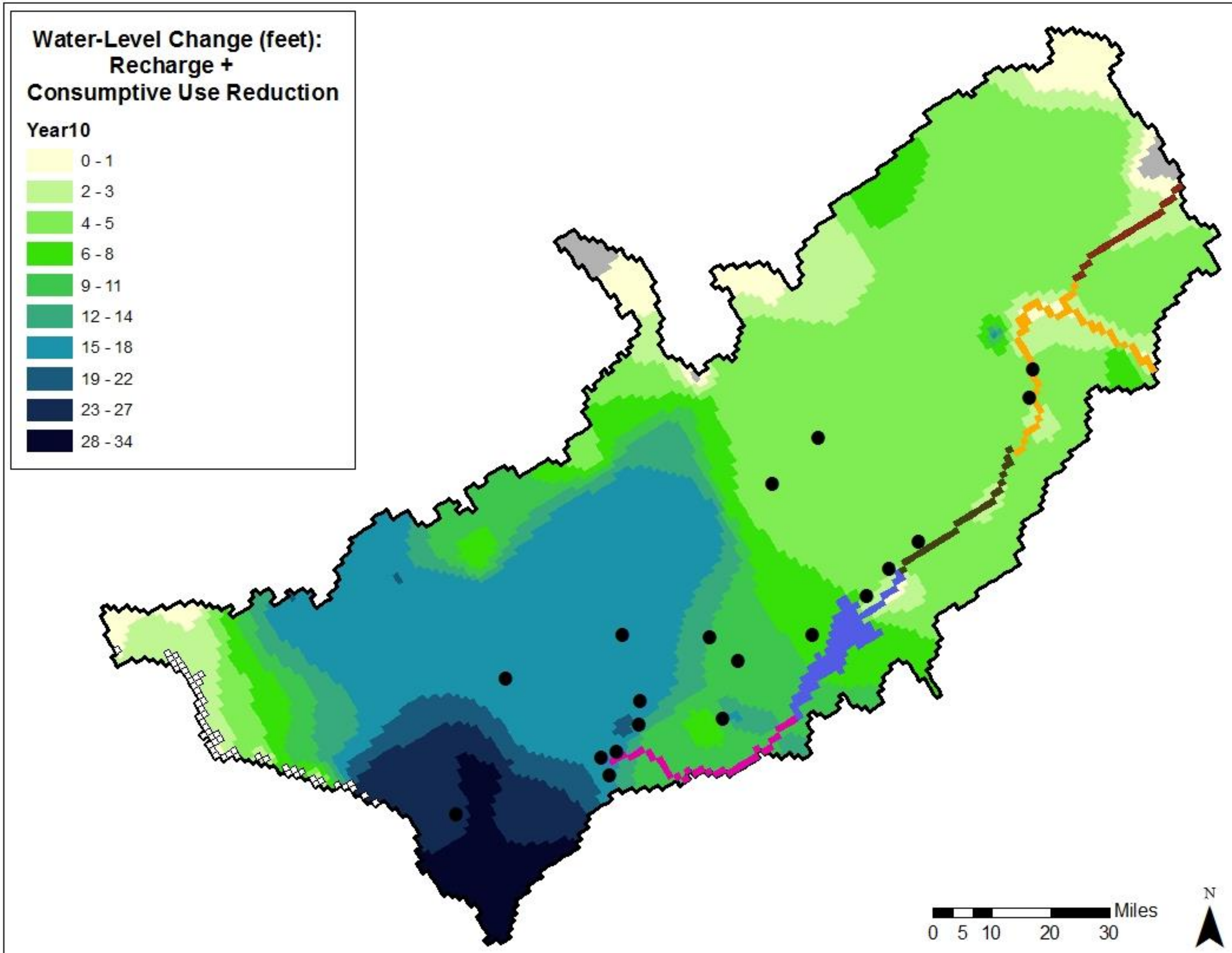
Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year6
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

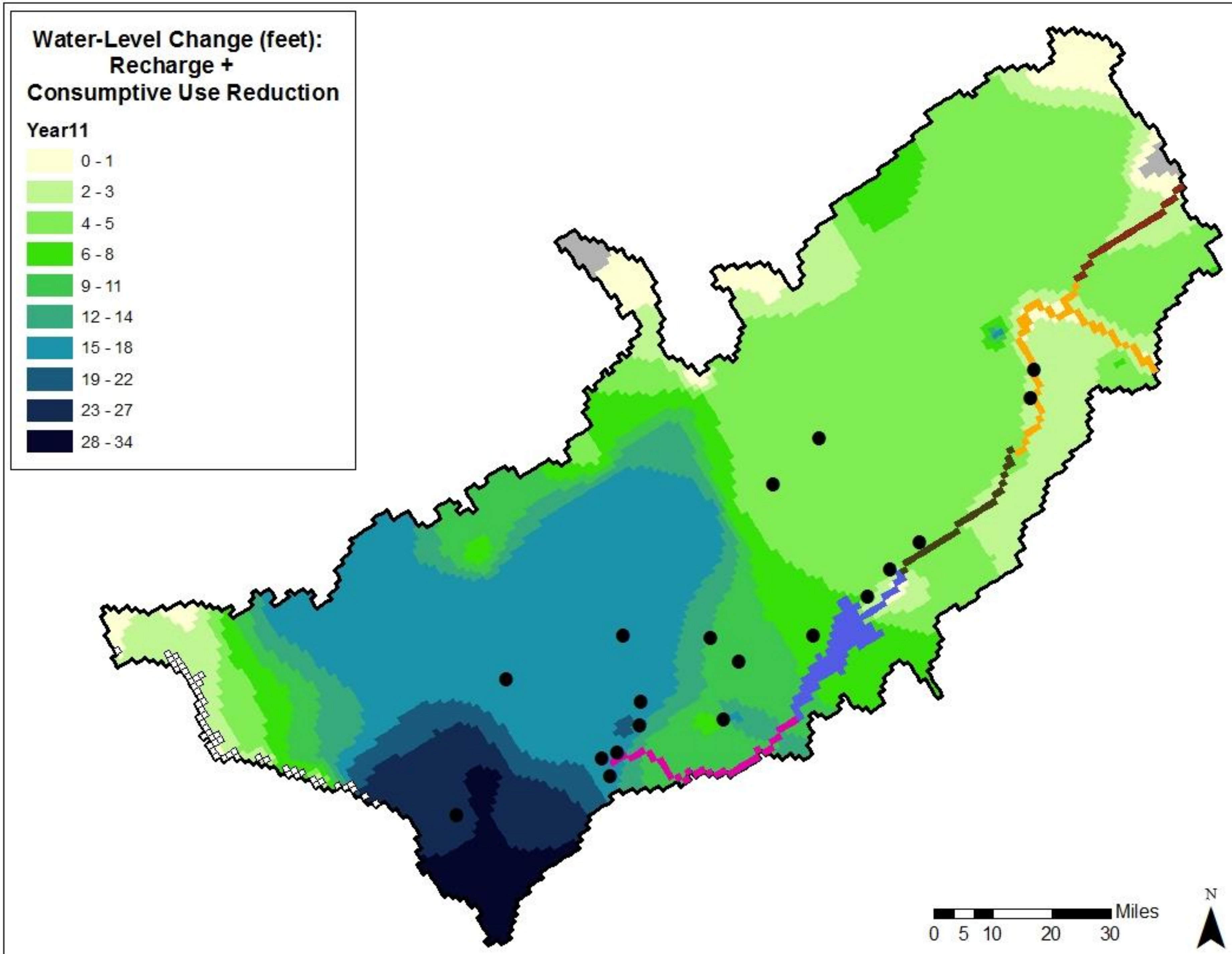

Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year7
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

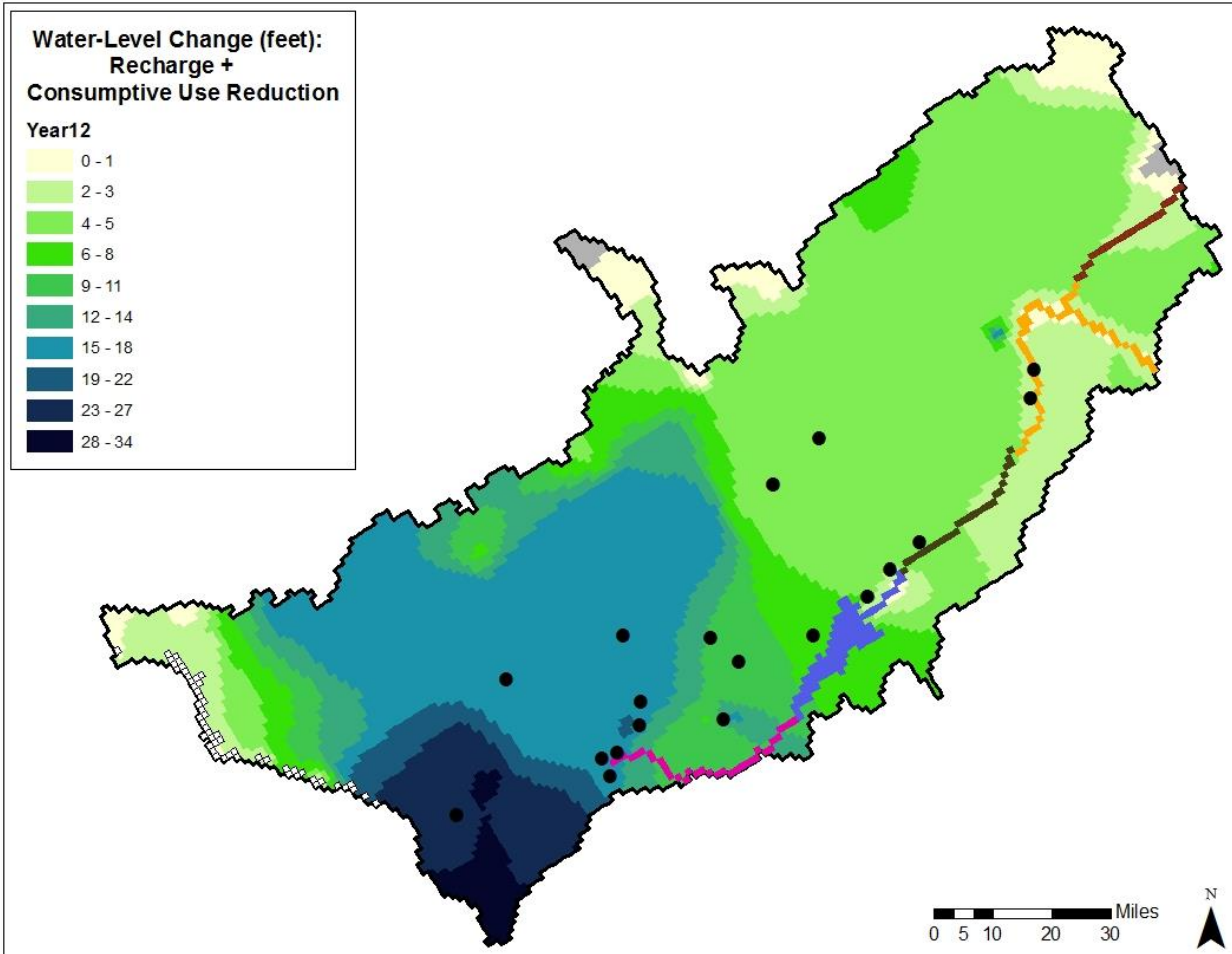

Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year8
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

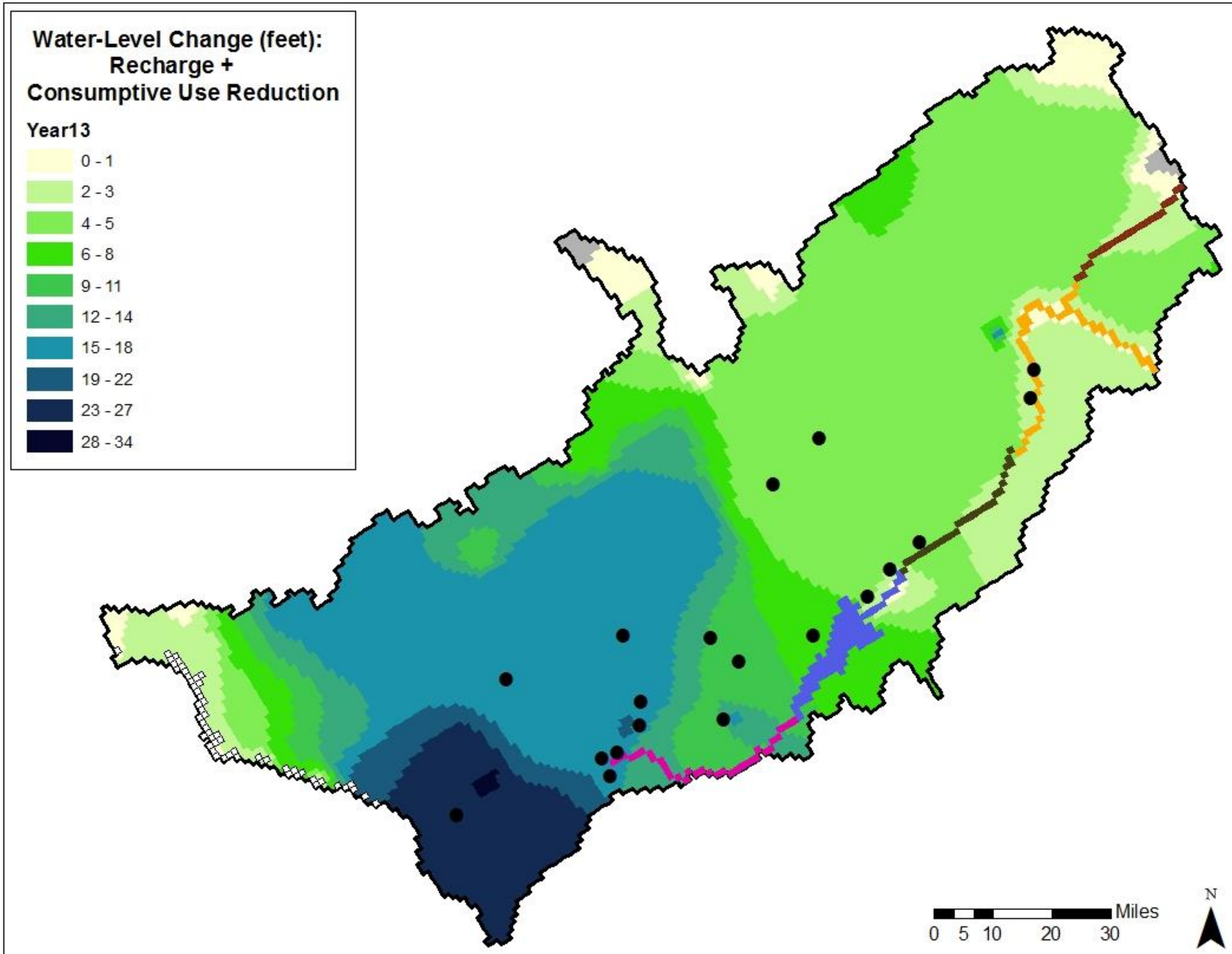


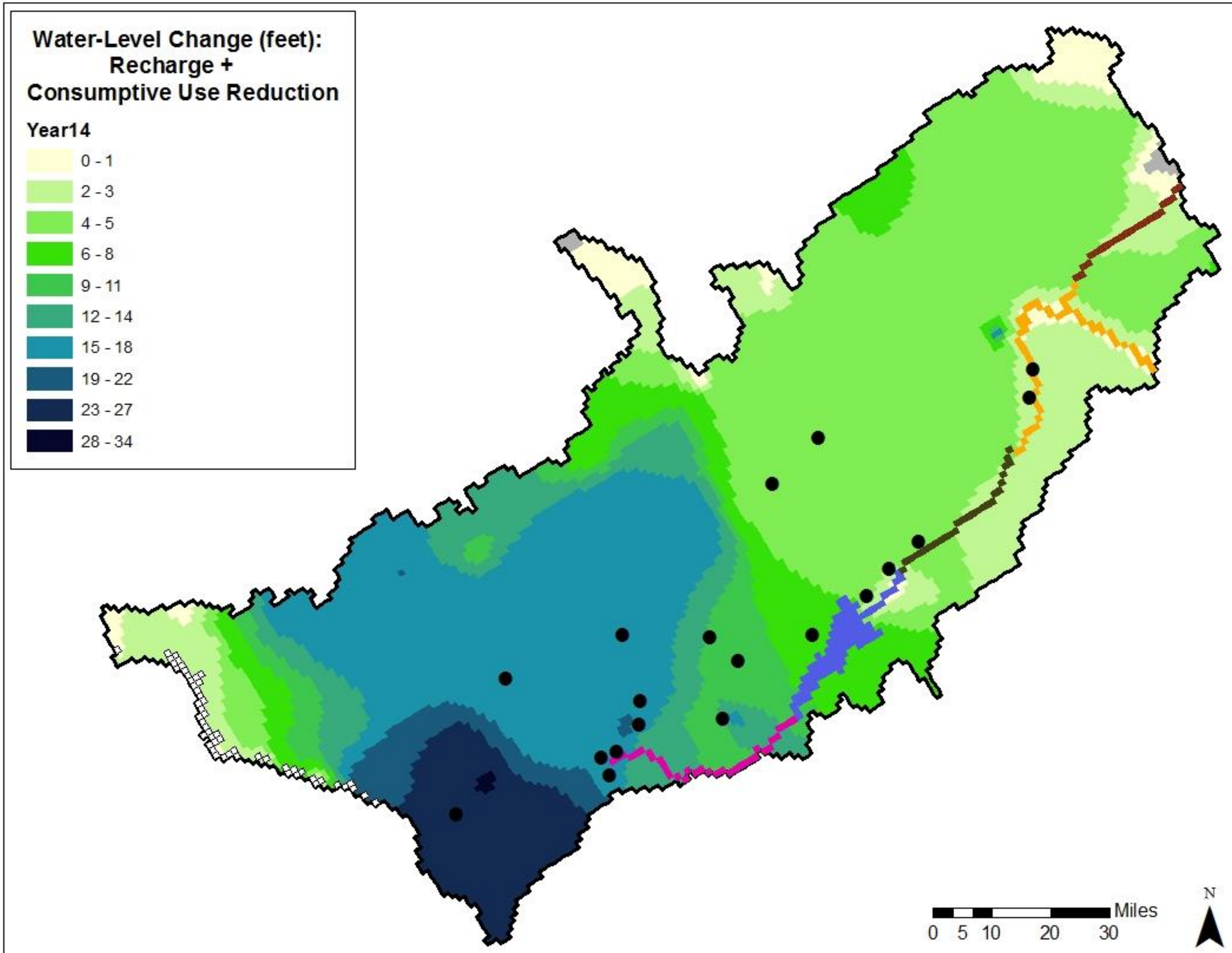
Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year9
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

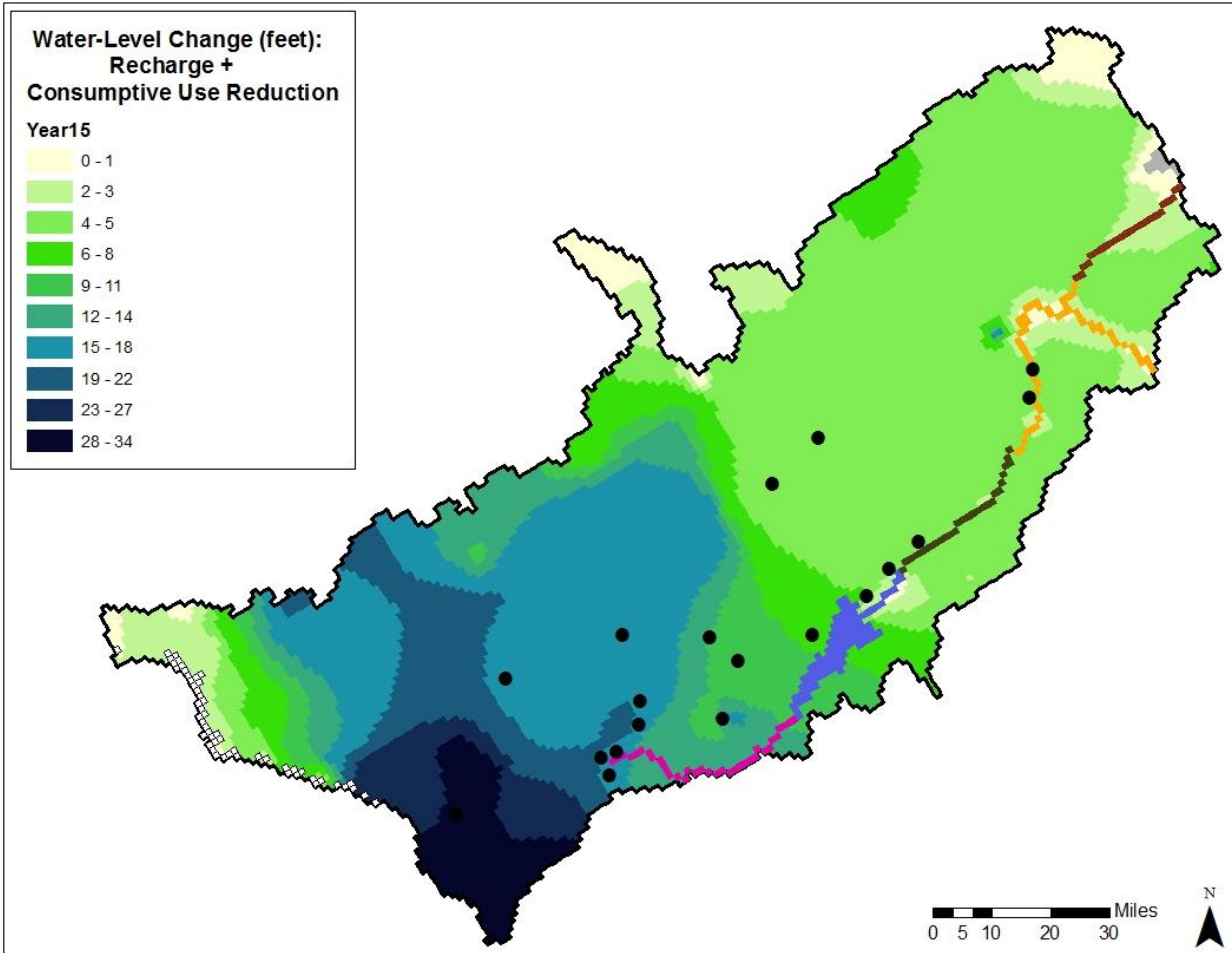

Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year10
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

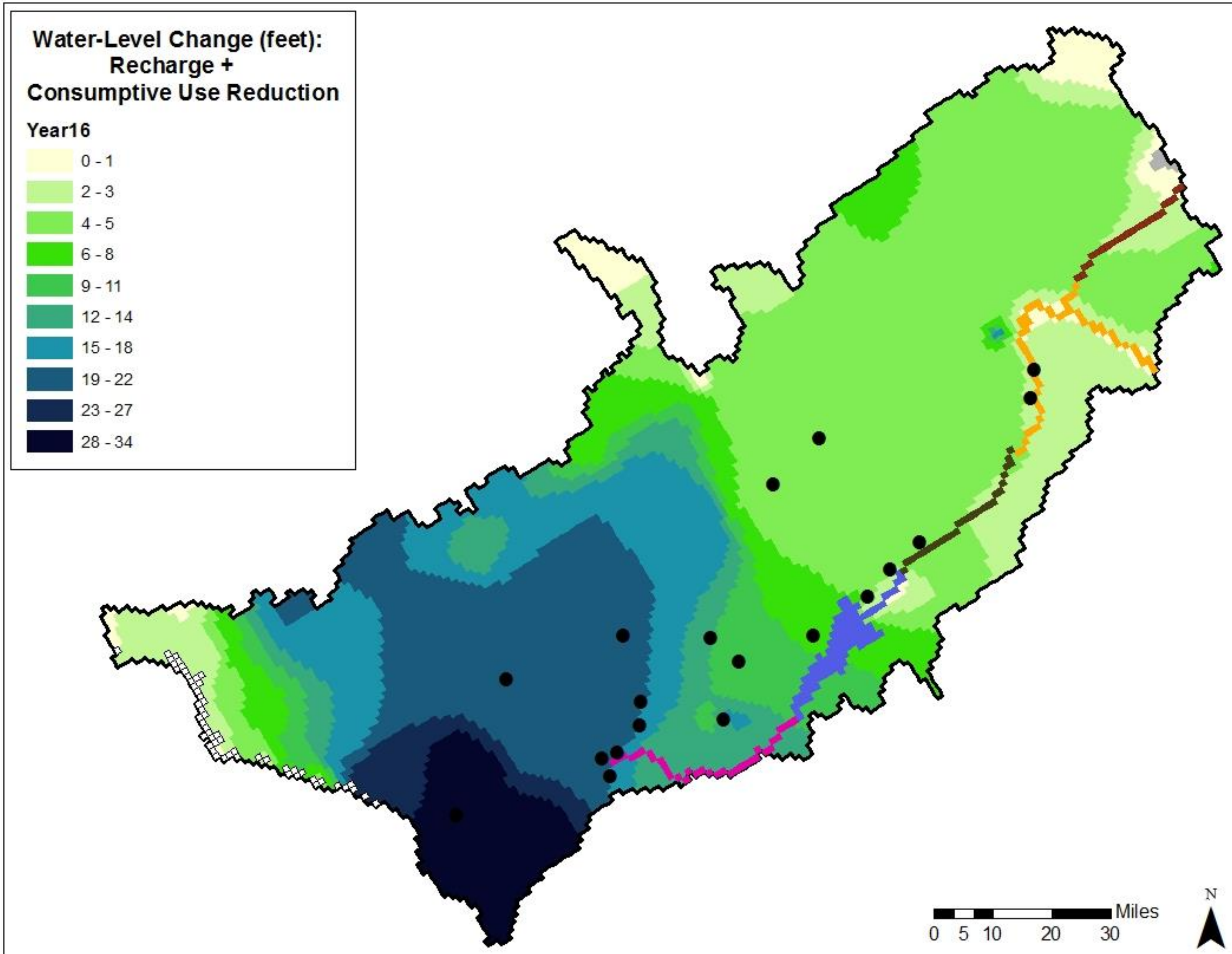

Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year11
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N


Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year12
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

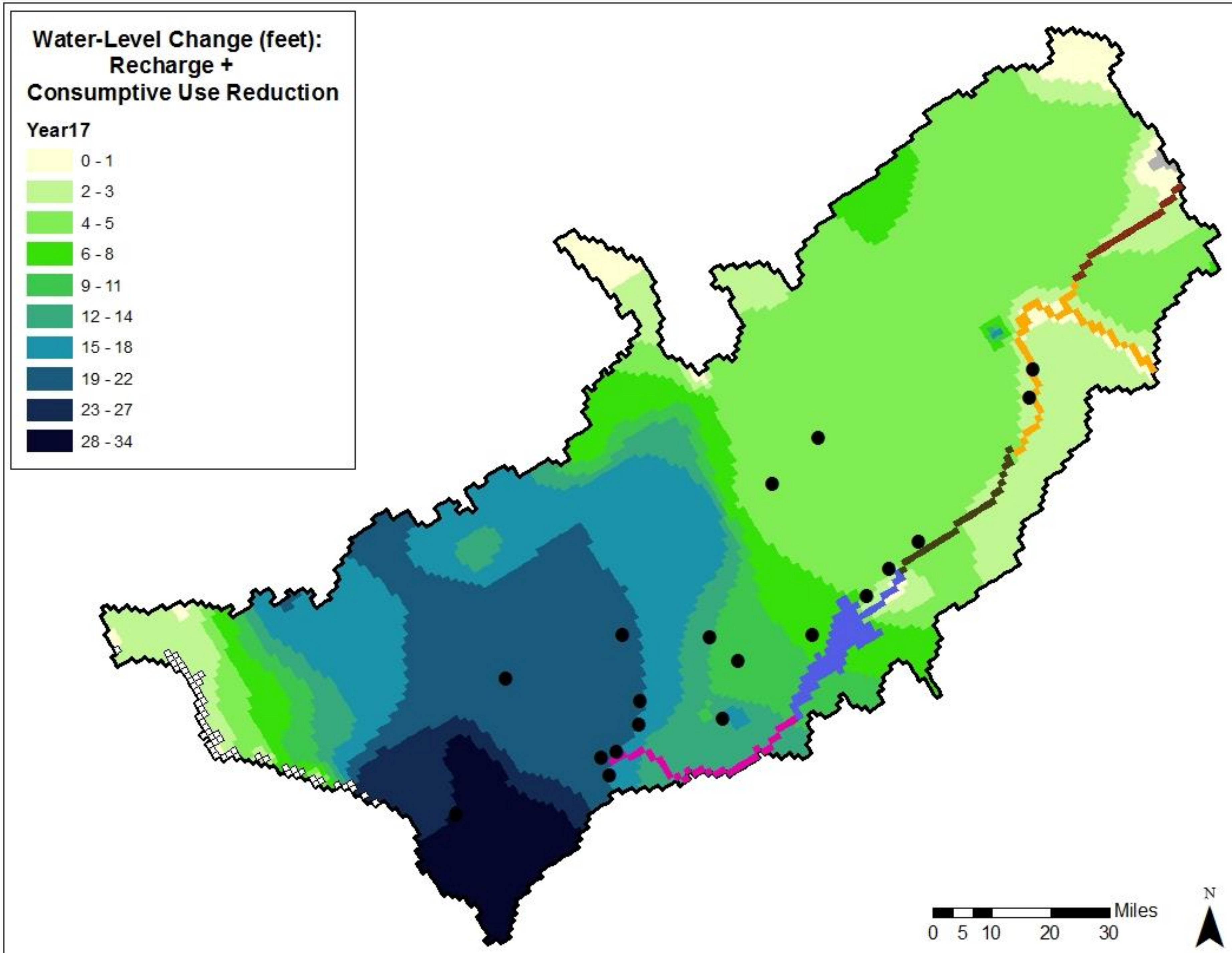

Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year13
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N


Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year14
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

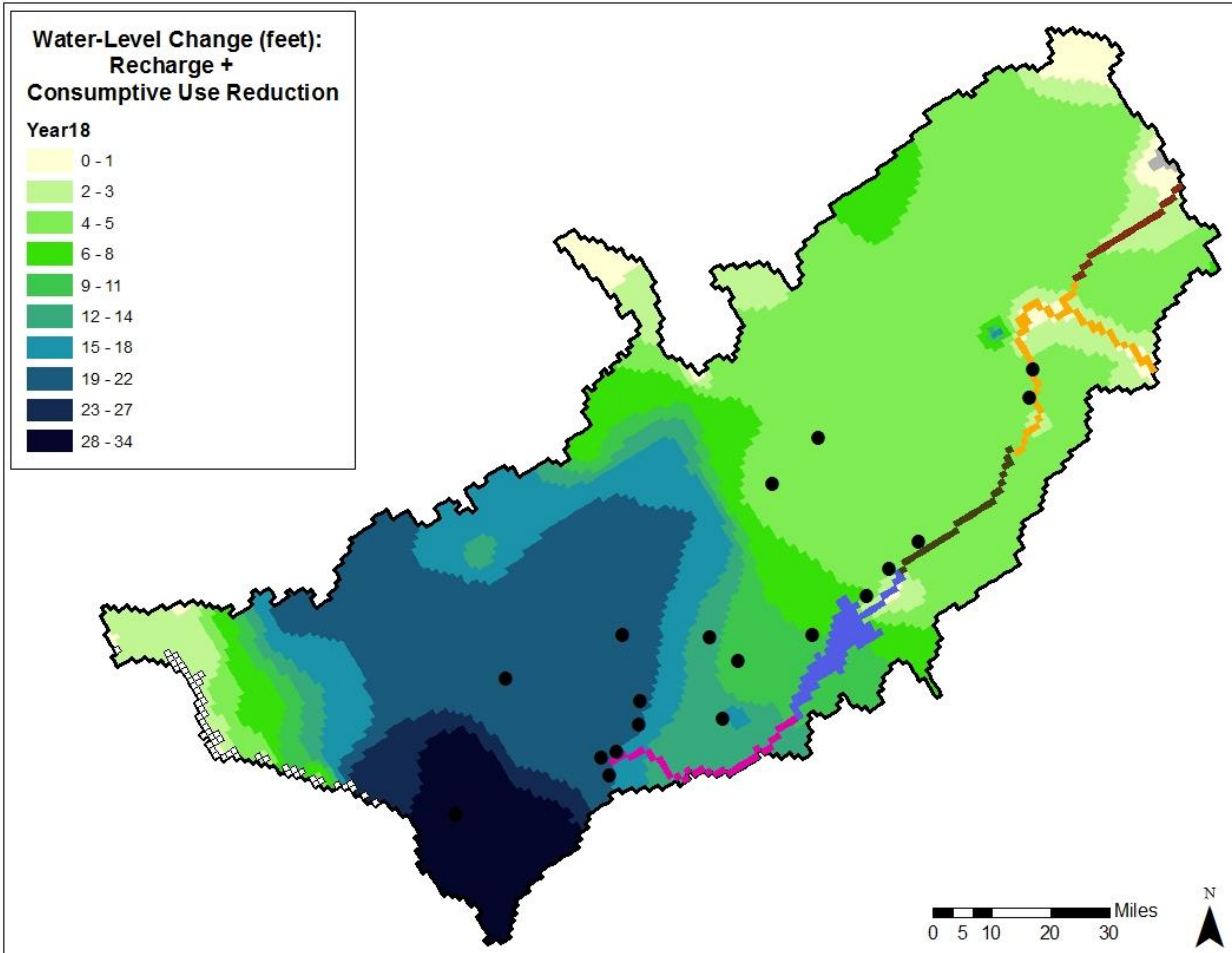

Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year15
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

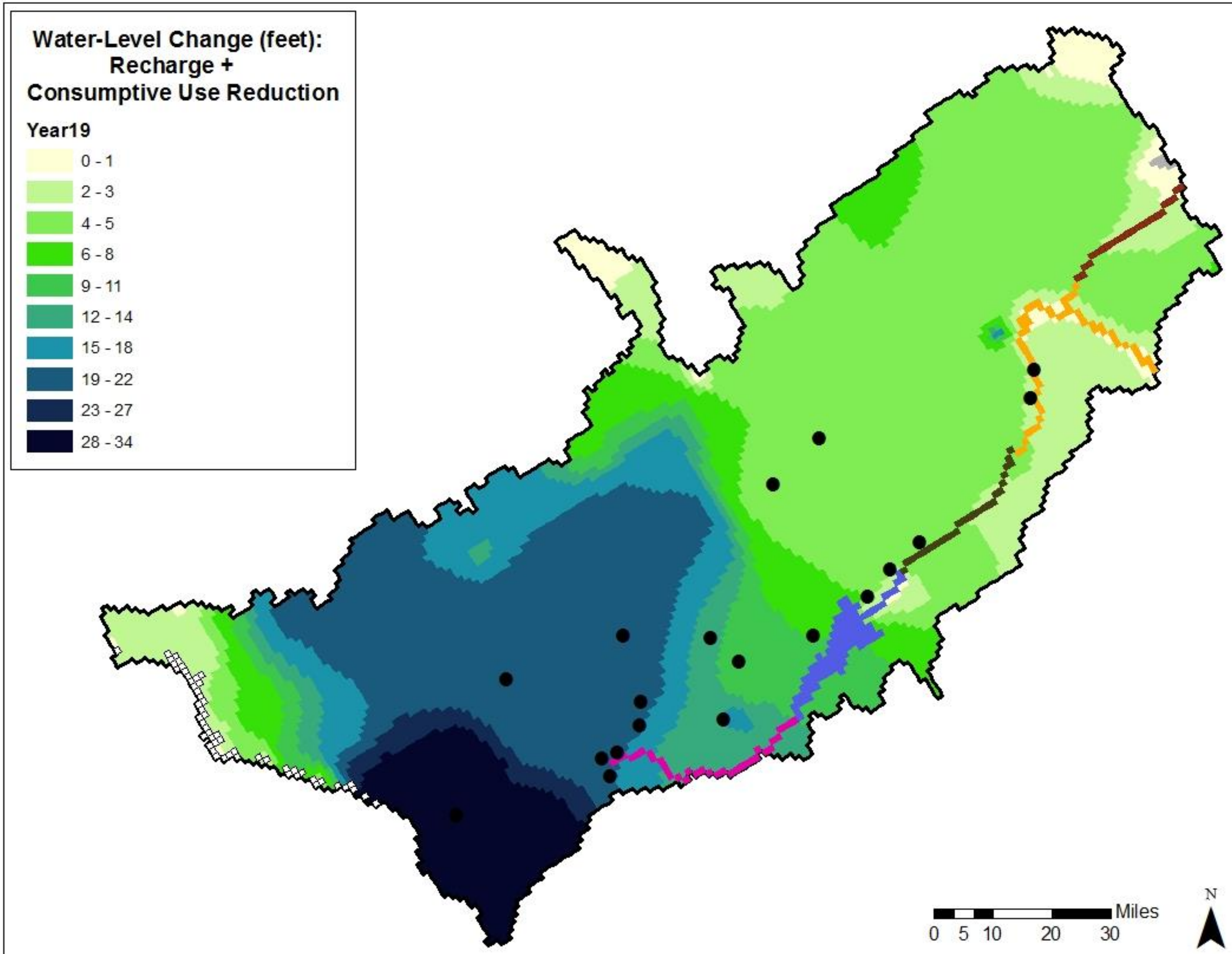


Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year16
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

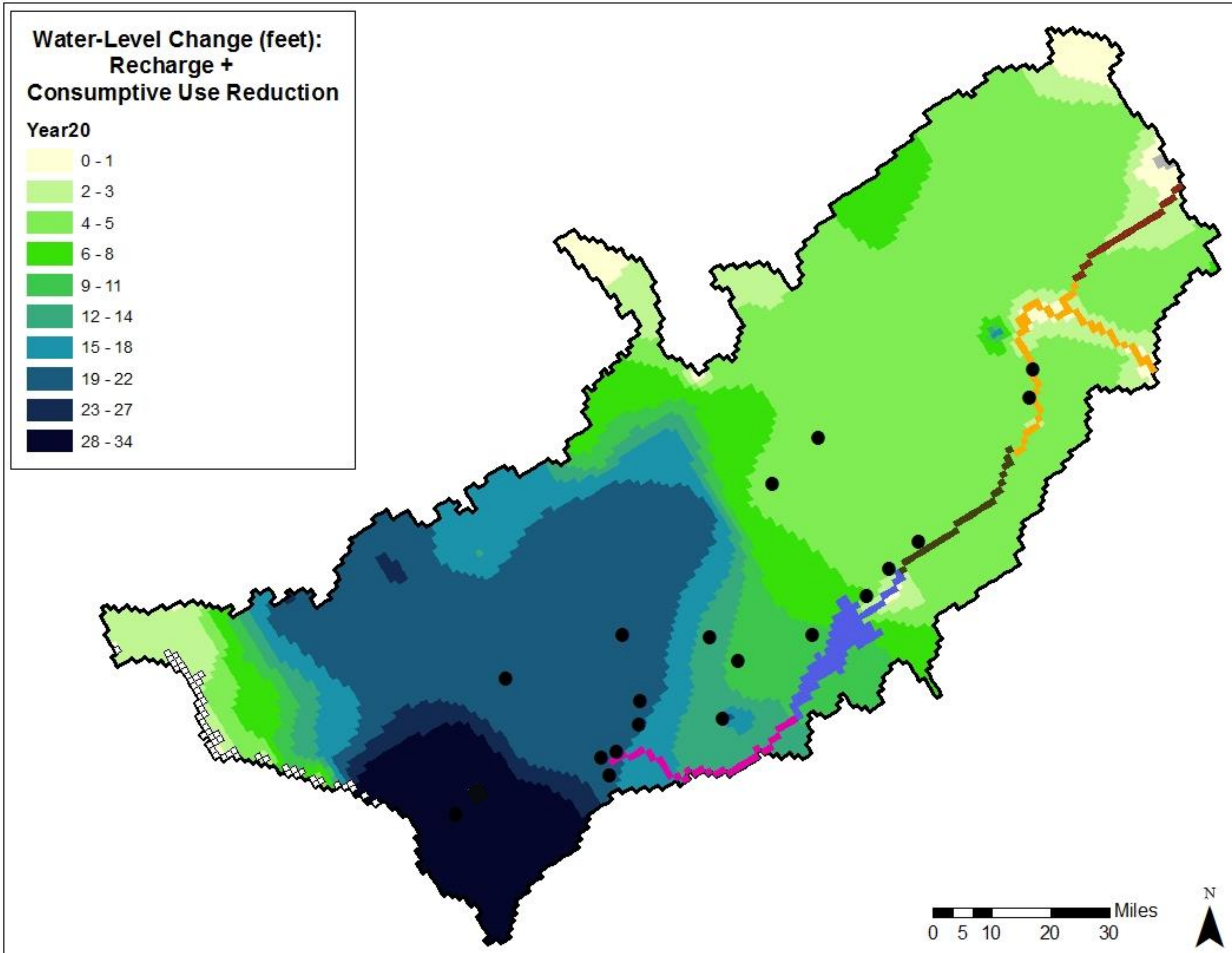


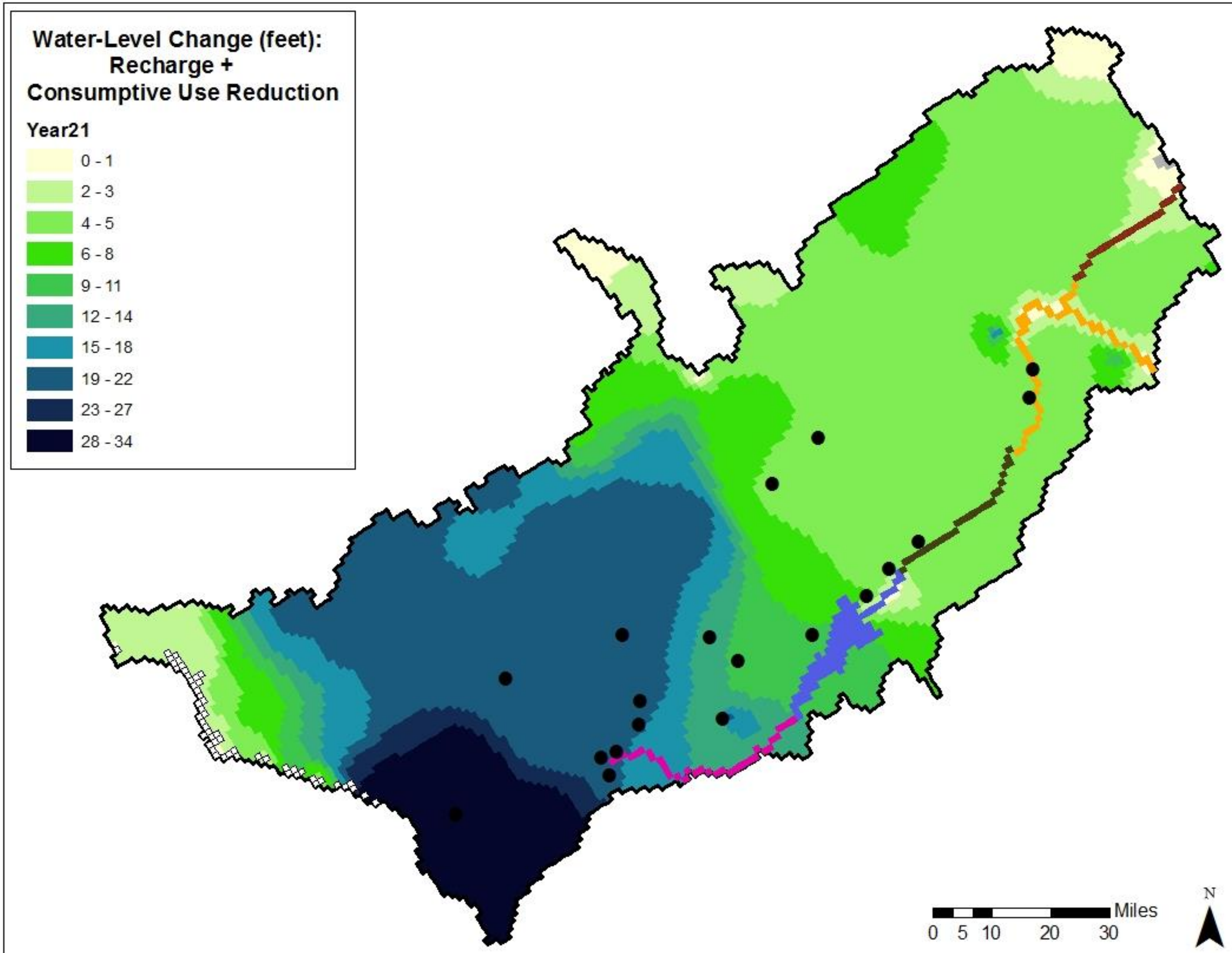
Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year17
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

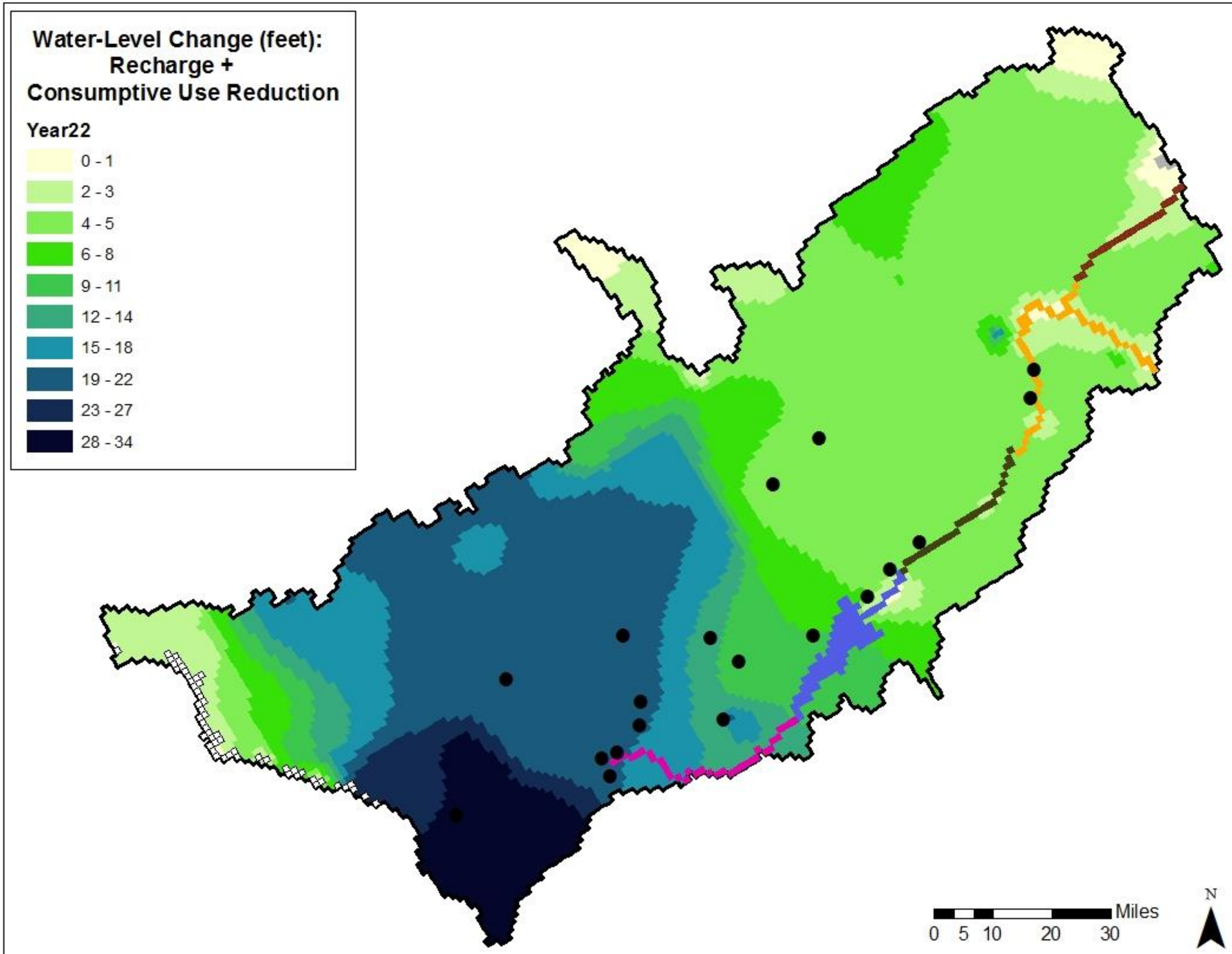

Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year18
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N

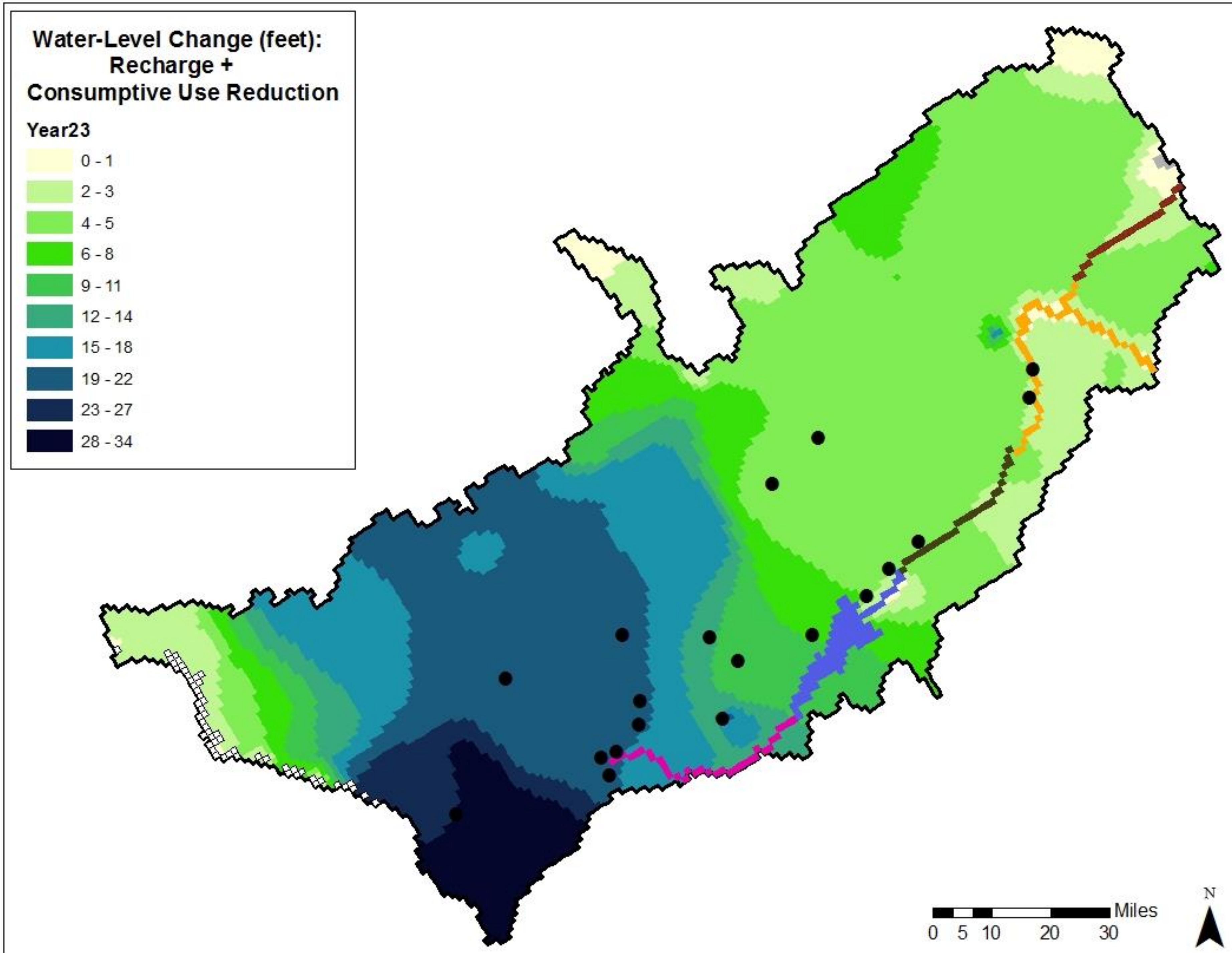


Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year19
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N


Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year20
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N


Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year21
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N


Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year22
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N


Water-Level Change (feet):
Recharge +
Consumptive Use Reduction
Year23
0 - 1
2 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 18
19 - 22
23 - 27
28 - 34
Miles
0 5 10 20 30
N


Questions

Input Into ESPAM2.1

Spatial data is converted to numerical input files.

This file gives the location, magnitude, and timing of stress (1.96 million lines long for the Consumptive Use Reduction scenario).

```
7087 0 NOPRINT
7085 STRESS PERIOD 1
1        81       45       65.50943024
1        78       41       235.6830392
1        78       41       488.0733079
1        80       45       474.0041377
1        80       45       4865.630058
1        78       42       165.4791347
1        81       47       246.9043785
1        79       44       397.493215
1        78       43       3121.749545
1        81       48       1464.754882
1        79       45       4.897959214
1        79       45       169.5736007
1        77       42       615.1887448
1        80       47       2966.630866
1        78       44       5824.228314
1        78       44       50.42778836
1        81       49       413.765371
1        77       43       5624.716446
1        80       48       238.7642092
1        80       48       269.9561345
1        80       48       4015.164509
1        78       45       2739.710824
1        78       45       875.3325868
1        78       45       1564.540791
1        79       47       1205.502095
1        77       44       5758.576238
1        80       49       3206.021883
1        80       49       316.504846
```

Settlement Agreement Term Usage

Language in the Term Sheet:

"Consumptive Use Volume Reduction" (3.a)

"Total ground water diversion shall be reduced…" (3.a.i)

"…total annual ground water reduction…" (3.a.ii)

"…ground water diversion reductions…" (3.e.iv)

"…consumptive use reductions…" (4.a)

=?

Diversion Based?

Consumptive Use Based?

Definitions

Diversion – The amount of water pumped by a water user for the irrigation of crops (groundwater users).

Evapotranspiration (ET) – The amount of water that is evaporated directly from soil and plant surfaces **+** the water that moves out of the soil profile by plant transpiration

Consumptive Use – The amount of water that is consumed by a crop. Analogous to ET.

Crop Irrigation Requirement (CIR) – The irrigation demand of a crop. Calculated as ET – Precipitation.

Will Reducing Diversions Solve the Problem?

“... believes LESA (Low Energy Sprinkler Application) is an ideal option for Idaho groundwater irrigators, who will be asked to reduce well water use by nearly 11 percent next season as part of a settlement for the Surface Water Coalition’s call. ‘This is why I’m excited about this technology. It should allow growers to meet that reduction without a decrease in yield or number of acres,’ [the expert] said.”

-Capital Press, October 2, 2015

The Issue with using Diversions

Reducing Diversions *without* reducing Consumptive Use can be accomplished with higher efficiency application. However, this <u>does not affect the water budget</u>.

There are two reasons why reducing pumping diversions will fail to solve (or even worsen) the water-balance problem:

1. Jevon's Paradox
    - Increased efficiency leads to increased demand.
2. Optimal water application
    - Leads to <u>**more**</u> Consumptive Use.

Studies Indicate More Water Use

"Our estimates indicate that for every 1% increase in the percent of acres irrigated with dropped nozzle irrigation systems, total water extraction increases by 1.8%, compared to what would have happened had the acres been irrigated by standard center pivot systems. Additionally, farmland that has the potential to be irrigated because it has an irrigation system installed, but was not irrigated, decreased by 0.24% for every 1% increase in dropped nozzles."

-Choices Magazine 2010
(Agricultural & Applied Economics Association)

How to Get Water Into the Ground?

- Use unlined canals that divert from river and cross the plain
- Most cost effective way to divert & recharge large volumes of water
- Contract with canal companies & irrigation districts to carry water to recharge
- Creates public/private partnership & outsources work to canal companies
- Supplement with spreading basins

Aquifer Recharge

- Have approximately $3.7 million in recharge capacity improvement projects underway
- Anticipate about $8 million under construction next winter and $10 million the following winter
- Even using existing canals, substantial improvements are needed to carry winter recharge water

Eastern Snake Plain Aquifer Modeling

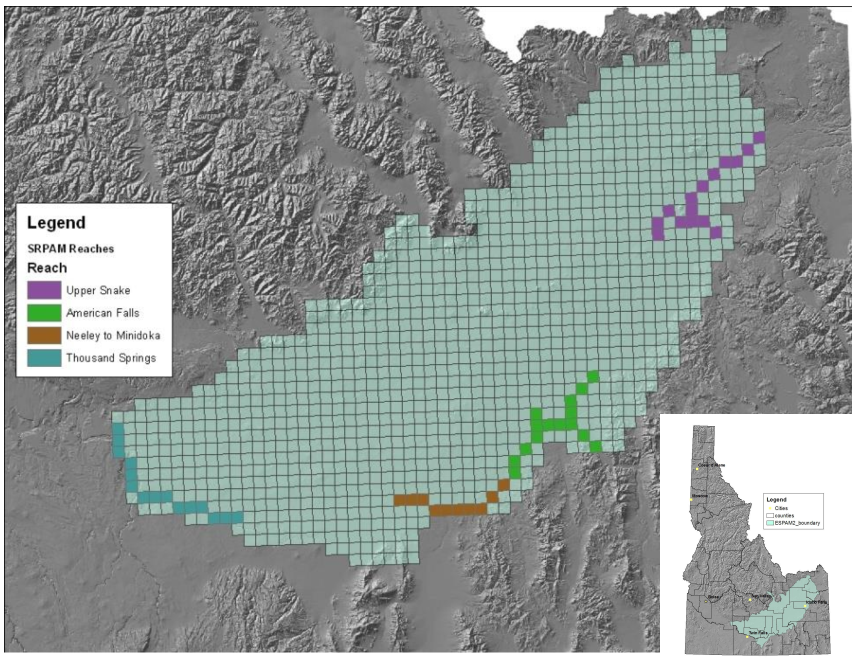
- Eastern Snake Plain Aquifer modeling began with University of Idaho modeling efforts in 1974.

- IDWR and University of Idaho continued development of the model (IDWR/UI Model). Converted the model to MODFLOW (SRPAM Model). MODFLOW is a widely used, opens source modeling code developed by the USGS

- Began collaborative model reformulation and development in 1999 (ESPAM Models).

IDAHO Department of Water Resources

Snake River Plain Aquifer Model



- Developed in 1972 at U of I
- Converted to MODFLOW by IDWR used 1993-2004
  - Grid north south
    - 3.1 mi x 3.1 mi
  - River
    - 3 river reaches
      - Based on gauge locations
    - 1 spring reach
      - Based on gauge locations
  - Time discretization
    - 1 year calibration period
      - Monthly stress periods
      - One land use distribution