characterization efforts and to support the cost analysis associated with the Needs Assessment.
Domestic depth groundwater quality estimates for six constituents are shown on the map: nitrate, arsenic, hexavalent chromium*, uranium, 1,2,3 trichloropropane (123 TCP), and perchlorate. For each constituent, groundwater quality estimates can be displayed for all Public Land Survey System (PLSS) sections statewide, or for only the PLSS sections that include at least one domestic well (domestic well counts and locations were obtained from the Department of Water Resources Online System of Well Completion Reports). Data fields for each section include the estimated average constituent concentration, the methodology used to calculate that average, the number of recent MCL/SMCL exceedances, and an overall water quality grade. The grade is a rated representation of the combined section detection and number of recent MCL/SMCL exceedances (see below). Section detections are represented by an MCL index, which is the constituent concentration divided by its regulatory threshold (MCL, SMCL, etc.). An MCL index of 1 reflects a value of the MCL/SMCL, while a 0.8 index represents a value of 80% the MCL/SMCL. The method indicates which of the three sources of data were used to estimate the section concentration: data from within the section, data from neighboring sections, or data from the groundwater unit. Other fields include area, the domestic well count, and the MTRS (the PLSS section number listed as meridian, township, range, and section).

Water Quality Grades:
6: Recent MCL exceedances > 0, average section detection > MCL
5: Recent MCL exceedances = 0, average section detection > MCL
4: Recent MCL exceedances > 0, average section detection < MCL
3: Recent MCL exceedances = 0, average section detection 80 – 100% of MCL
2: Recent MCL exceedances = 0, average section detection between 50 – 80% of MCL
1: Recent MCL exceedances = 0, average section detection < 50% of MCL
0: unknown water quality (no data available)

Ambient groundwater quality data from water supply well sources in the GAMA Groundwater Information System were processed through time and depth filters developed for this analysis in order to capture the depths accessed by domestic wells (by groundwater unit). This process allowed the analysis to include an increased amount of water quality data, and from sources typically

## Credits (Attribution)

For any questions or comments, please email Dori Bellan and/or Emily Houlihan, GAMA Program geologists.
dorian.bellan@waterbpo
emily.houlihan@waterbo

## URL

View

https://gispubl

not utilized for analyzing the domestic well water resource, creating a more robust analysis. Censored data (non-detect, below reporting, and zero-values) underwent a substitution process.

*For hexavalent chromium, a comparison value of 20 µg/L was used in place of an MCL.

## Layers

Needs_Assessment_Arsenic

## Terms of Use

All data in this map can be downloaded or connected to a GIS through the State Water Board REST endpoint, also accessed through the item details of each layer in this application.

GAMA Groundwater Information System — Water Boards

GAMA Home

Download GAMA Data

SWRCB Home

## CUSTOM GIS WELL PIE CHART REPORT

GIS LAYER: Groundwater Basins

GIS NAME: KLAMATH RIVER VALLEY - TULELAKE (1-002.01)

TIMEFRAME: All Years

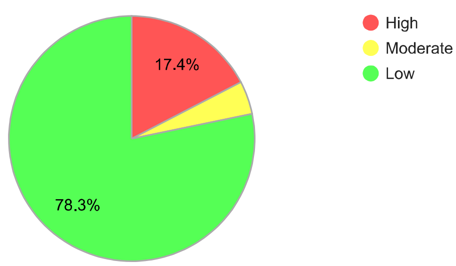
VIEW COUNTS BY: Distinct Wells

WELL CATEGORY: Domestic, Irrigation / Industrial, Monitoring, Municipal, Water Supply, Other

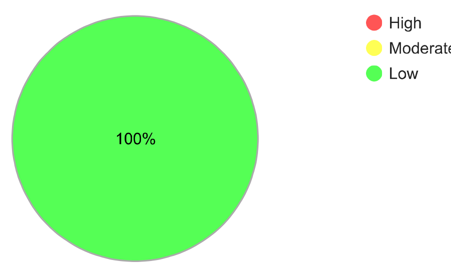
DATASETS: All Datasets

- **High -** Wells whose Maximum Sampling was Above the Comparison Concentration
- **Moderate -** Wells whose Maximum Sampling was Between 1/2 the Comparison Concentration and the Comparison Concentration
- **Low -** Wells whose Maximum Sampling was Below 1/2 the Comparison Concentration

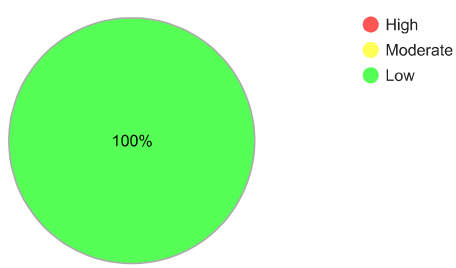
### Major Ions



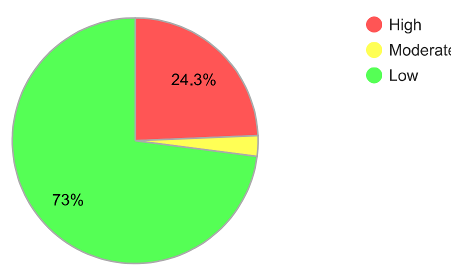

### Radionuclides



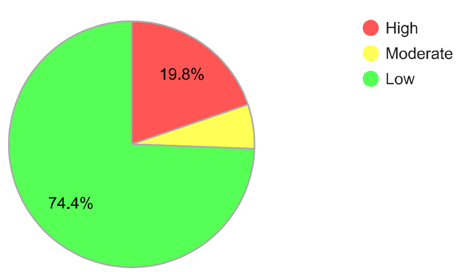

### Pesticides



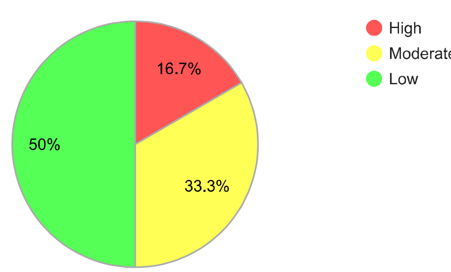

### Volatile Organic Compounds



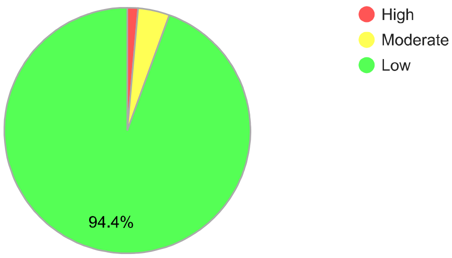

### Trace Elements




### Total Dissolved Solids



**Nutrients**



# Appendix H.
# Technical Memorandum – GDE Identification Data Processing Approach

MBK ENGINEERS
Water Resources ◆ Flood Control ◆ Water Rights

# TECHNICAL MEMORANDUM

**DATE:** September 10, 2021

**TO:** Tulelake GSAs

**PREPARED BY:** Jason Bone, MBK Engineers

**SUBJECT:** GDE Identification Data Processing Approach

# 1. BACKGROUND

Groundwater Dependent Ecosystems (GDE) are defined in the Sustainable Groundwater Management Act (SGMA) Regulations as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (23 CCR § 351[m]). The Natural Communities Commonly Associated with Groundwater (NCCAG) database was used to identify plants commonly associated with groundwater use. The NCCAG was developed by a working group comprised of the California Department of Water Resources (DWR), the California Department of Fish and Wildlife (CDFW), and The Nature Conservancy (TNC). Two habitat classes are included in the NCCAG dataset: 1) wetland features commonly associated with the surface expression of groundwater under natural and unmodified conditions; and 2) vegetation types commonly associated with the sub-surface presence of groundwater (phreatophytes).

An analysis was performed to evaluate each NCCAG against criteria to determine if it is a GDE. The criteria listed below identify characteristics which would make a NCCAG not a GDE.

1. Areas with a depth to groundwater greater than 30 feet.
2. Areas adjacent to agricultural surface water (i.e., canals and drains).
3. Areas adjacent to irrigated fields.
4. Areas adjacent to the Tule Lake Sumps.

# 2. NCCAG GIS DATA USED

The NCCAG database was available in 2 GIS shapefiles – i02_NCCAG_Vegetation_1_002_01.shp and i02_NCCAG_Wetlands_1_002_01.shp, which was downloaded in July 2020 from https://gis.water.ca.gov/app/NCDatasetViewer/.

### Summary of Vegetation and Wetlands NCCAG GIS Data

Tulelake Irrigation District contains the following NCCAGs Vegetation and Wetland Types:

| Vegetation Name | Count | Summary of Acres |
|---|---|---|
| Tule - Cattail | 1 | 56.82 |
| Greasewood | 2 | 10.01 |
| Wet Meadows | 39 | 715.62 |
| | | |
| **Wetland Name** | **Count** | **Summary of Acres** |
| Palustrine, Emergent, Persistent, Semi-permanently Flooded | 1 | 0.72 |
| Riverine, Lower Perennial, Unconsolidated Bottom, Permanently Flooded | 1 | 74.03 |
| Seep or Spring | 1 | 0.18 |
| Palustrine, Emergent, Persistent, Seasonally Flooded | 25 | 44.29 |
| Riverine, Unknown Perennial, Unconsolidated Bottom, Semi-permanently Flooded | 55 | 12.92 |
| | | |
| **Total Acres** | | **914.59** |

## 3. Data Used and Actions Taken to Evaluate Each of the Four Criteria

### Criteria 1 – Areas with a Depth to Groundwater Greater than 30 Feet

To determine areas where the depth to groundwater was greater than 30 feet, recent groundwater depth elevation data and ground elevation data were collected. Groundwater depths (Elevation in Feet above Mean Sea Level) were obtained from DWR's Water Data Library, and the land surface elevation data used was LiDAR IM Bare Earth DEM (Digital Elevation Model) data from https://gdg.sc.egov.usda.gov/. Groundwater depth elevation data from Spring 2019 were selected for this analysis, and ArcGIS Desktop software was used to find the difference between the ground surface elevation and Spring 2019 groundwater elevation depths. The analysis identified areas within the Tule Lake Subbasin where the depth to groundwater was greater than 30 feet, and ArcGIS Desktop software was used to intersect those areas with the NCCAGs GIS data. TNC has developed guidance documents to help GSAs identify GDEs. These guidance documents suggest that depth to groundwater greater than 30 feet would not support a GDE. NCCAGs in areas with depth to groundwater greater than 30 feet are assumed to not access groundwater and are represented as "Areas with a depth of groundwater greater than 30 feet" in Figure 2-37.

This analysis resulted in selecting parts of 31 NCCAGs polygons for a total of 99.76 acres of which 11 are Vegetation NCCAGs for 95.36 acres and the other 20 are Wetland NCCAGs for 4.4 acres.

### Criteria 2 – Areas Adjacent to Agricultural Surface Water

The majority of the Subbasin is agricultural land and intersected by a system of irrigation canals, ditches, and drains. The irrigation system brings in surface water which is available to the NCCAGs. To determine those areas adjacent to agricultural surface water, we analyzed the proximity of NCCAGs to those irrigation system features. Using GIS layers representing the irrigation system and ArcGIS Desktop software, we defined an area or buffer of 150 feet surrounding the irrigation system linear features. The irrigation system GIS layers were provided by Tulelake Irrigation District. NCCAGs within 150 feet of the irrigation conveyance facilities area are assumed to access the available surface water and are represented as “Area adjacent to agricultural surface water” in Figure 2-37.

This analysis resulted in selecting parts of 160 NCCAGs polygons for a total of 325.89 acres of which 60 are Vegetation NCCAGs for 262.06 acres and the other 100 are Wetland NCCAGs for 63.83 acres.

### Criteria 3 – Areas Adjacent to Irrigated Fields

Similar to areas adjacent to irrigation water conveyance facilities, areas near irrigated fields benefit from the irrigation water used to support crops. To determine those areas adjacent to irrigated fields, we analyzed the proximity of NCCAGs to the irrigated fields. Using a GIS layer representing the irrigated fields (provided by Tulelake Irrigation District) and ArcGIS Desktop software, we defined an area or buffer of 50 feet surrounding all the irrigated fields. ArcGIS Desktop software was used to identify which NCCAGs intersected with the irrigated fields and the 50-foot buffer. NCCAGs within 50 feet of the irrigated fields are assumed to access available surface water and are considered adjacent to irrigated fields, which are represented as “Areas adjacent to irrigated fields” in Figure 2-37.

This analysis resulted in selecting parts of 39 NCCAGs polygons for a total of 117.55 acres of which 22 are Vegetation NCCAGs for 104.29 acres and the other 17 are Wetland NCCAGs for 13.26 acres.

### Criteria 4 - Areas Adjacent to the Tule Lake Sumps

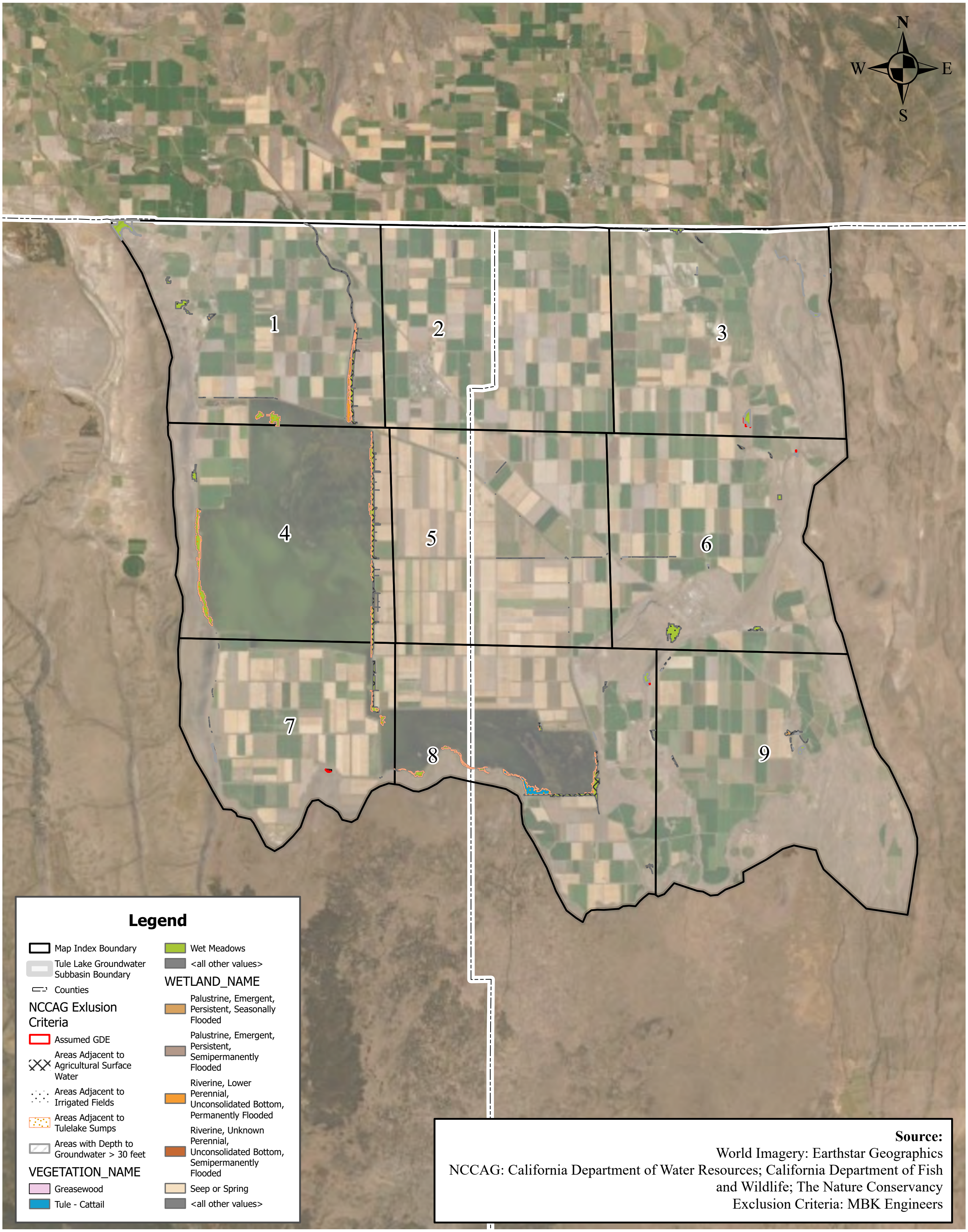
The Tule Lake Sumps provide water for adjacent ecosystems. To determine which NCCAGs are adjacent to the Tule Lake Sumps, we analyzed the proximity of NCCAGs to the Tule Lake Sumps, which typically have water year-round. Using a GIS layer representing the Tule Lake Sumps (provided by Tulelake Irrigation District) and ArcGIS Desktop software, we defined an area or buffer 150 feet surrounding all the Tule Lake Sumps. ArcGIS Desktop software was used to identify which NCCAGs intersected with the Tule Lake Sumps and the 150-foot buffer. NCCAGs within 150 feet of the Tule Lake Sumps are assumed to access available surface water and are considered adjacent to the Tule Lake Sumps, which are represented as “Areas adjacent to the sumps” in Figure 2-37.

This analysis resulted in selecting parts of 35 NCCAGs polygons for a total of 366.24 acres of which 33 are Vegetation NCCAGs for 359.49 acres and the other 2 are Wetland NCCAGs for 6.75 acres.

Jason Bone

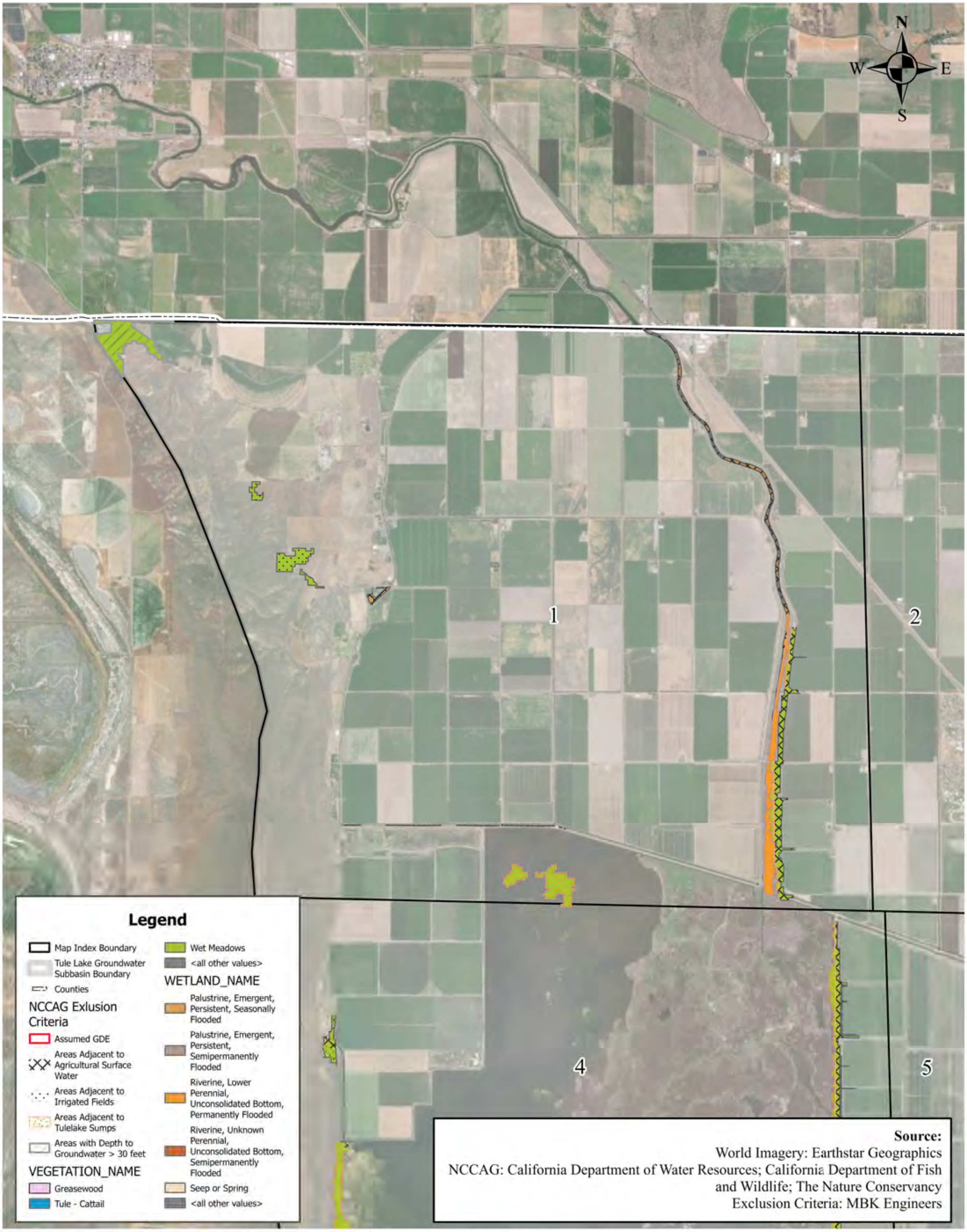
Jason Bone, MBK Engineers

JB/ab/oh
8888.10\GDE Identification Technical Memorandum 9-10-2021




MBK ENGINEERS

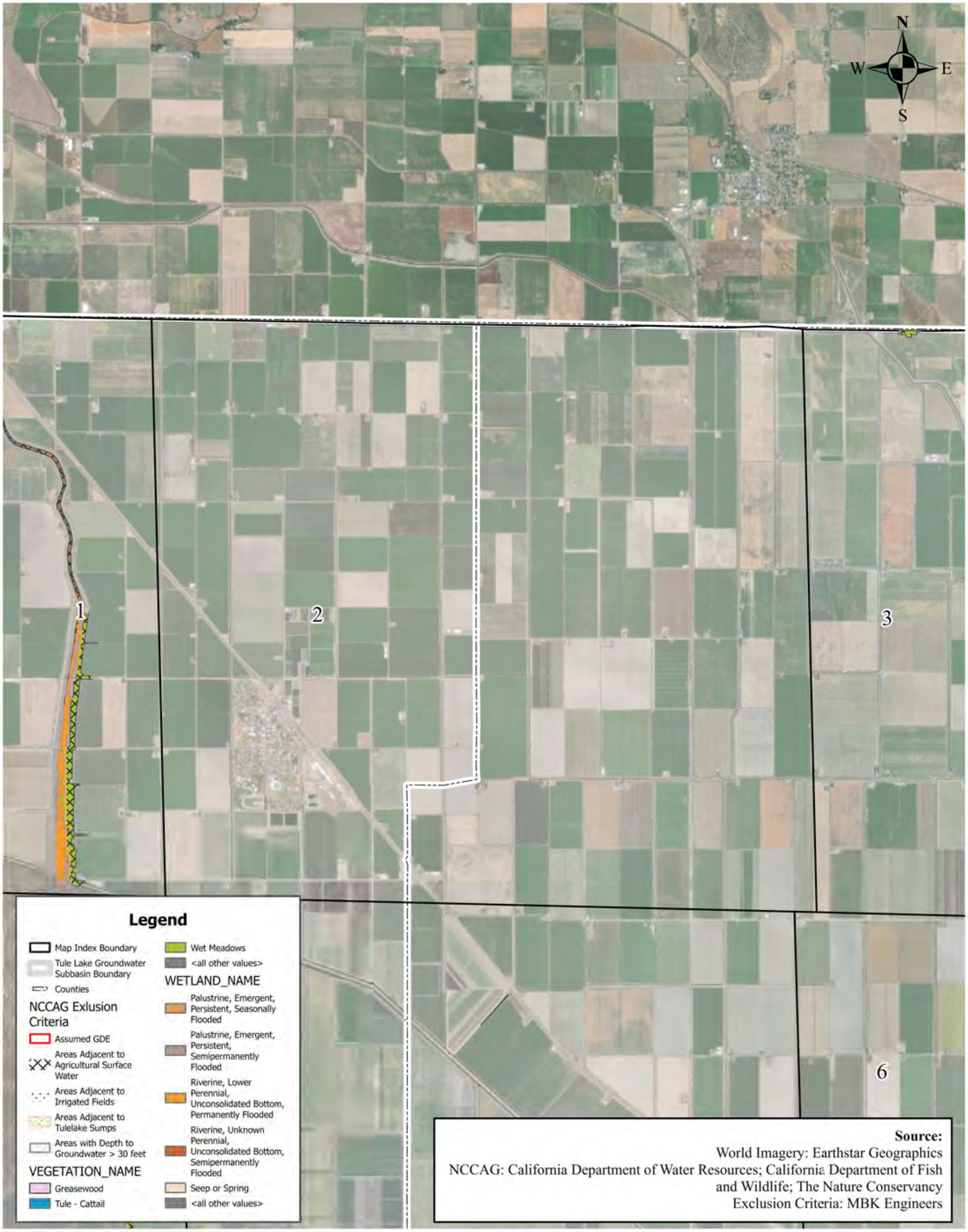
Natural Communities Commonly Associated Inside and Outside GDE Criteria




MBK ENGINEERS

Natural Communities Commonly Associated

Inside and Outside GDE Criteria

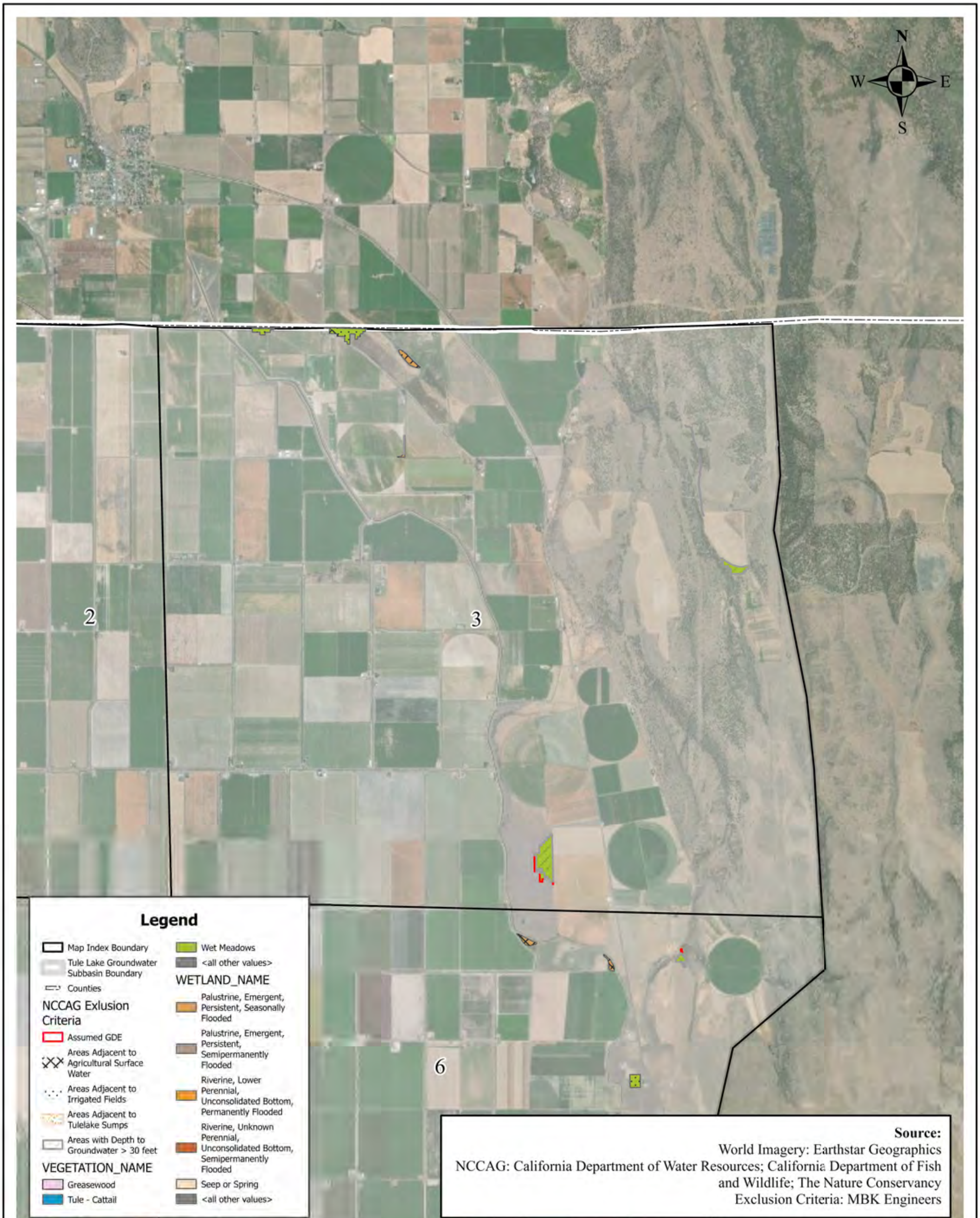



MBK ENGINEERS

Natural Communities Commonly Associated

Inside and Outside GDE Criteria

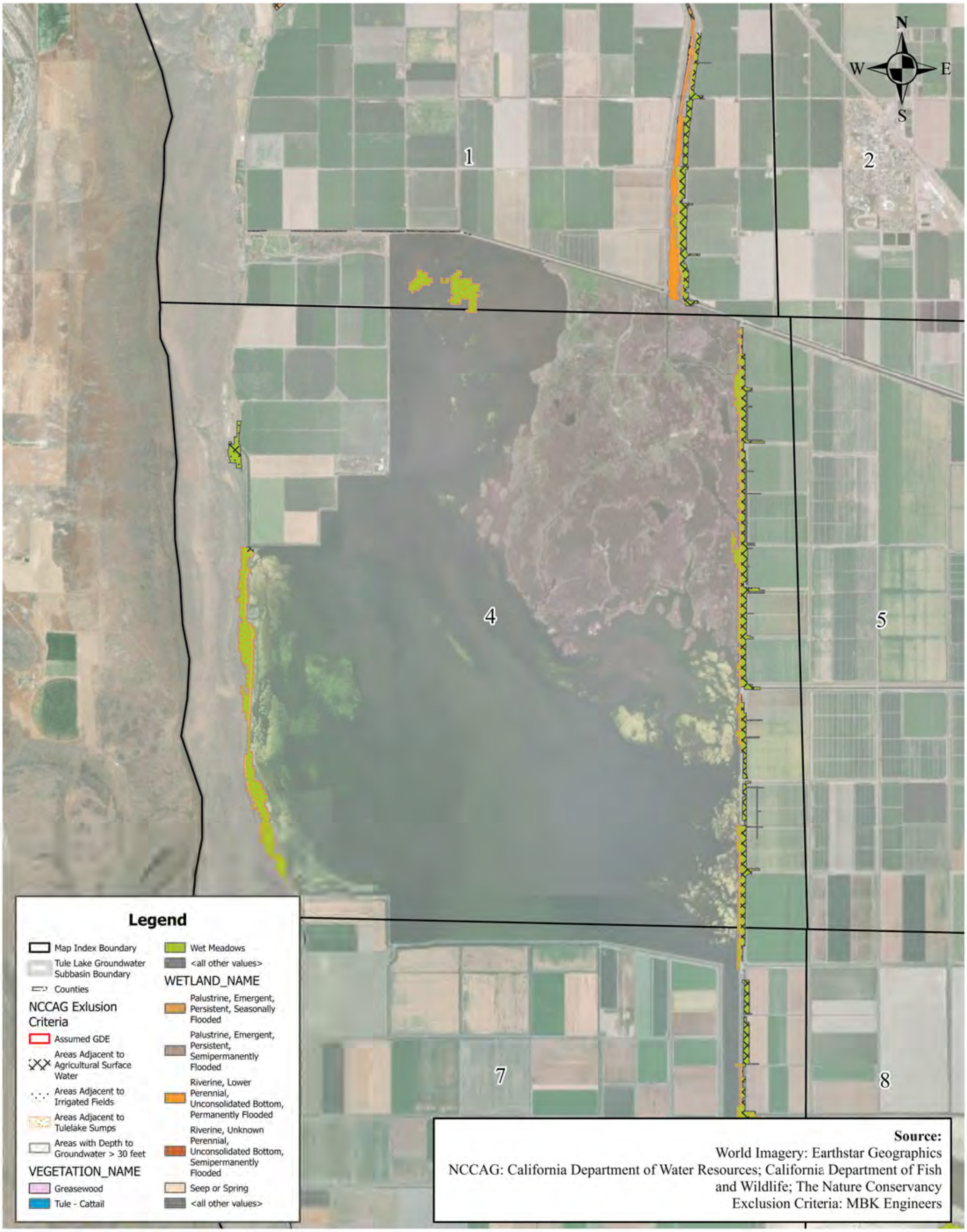
0 1 Miles




MBK ENGINEERS

Natural Communities Commonly Associated

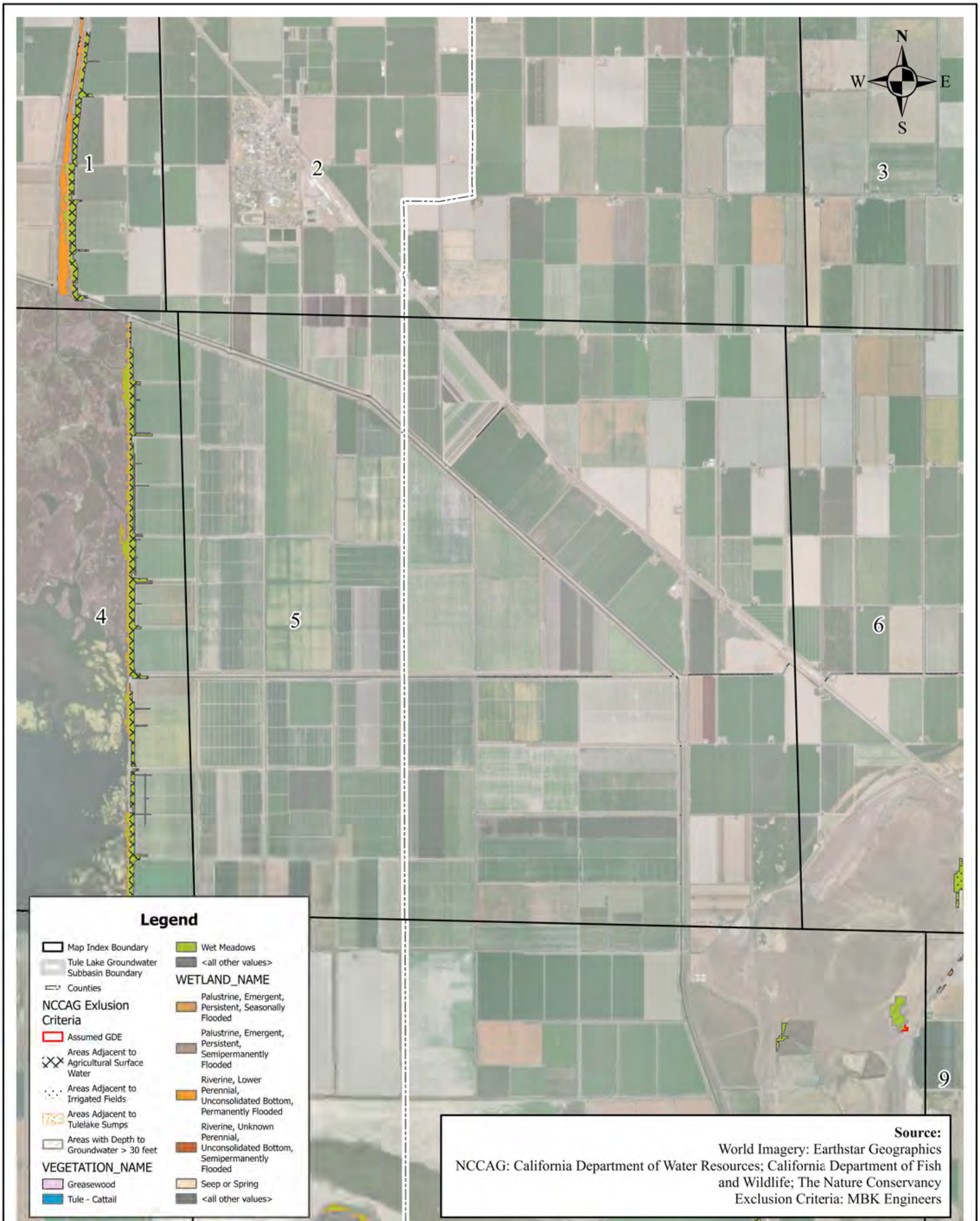
Inside and Outside GDE Criteria




MBK ENGINEERS

Natural Communities Commonly Associated
Inside and Outside GDE Criteria

0 1 Miles

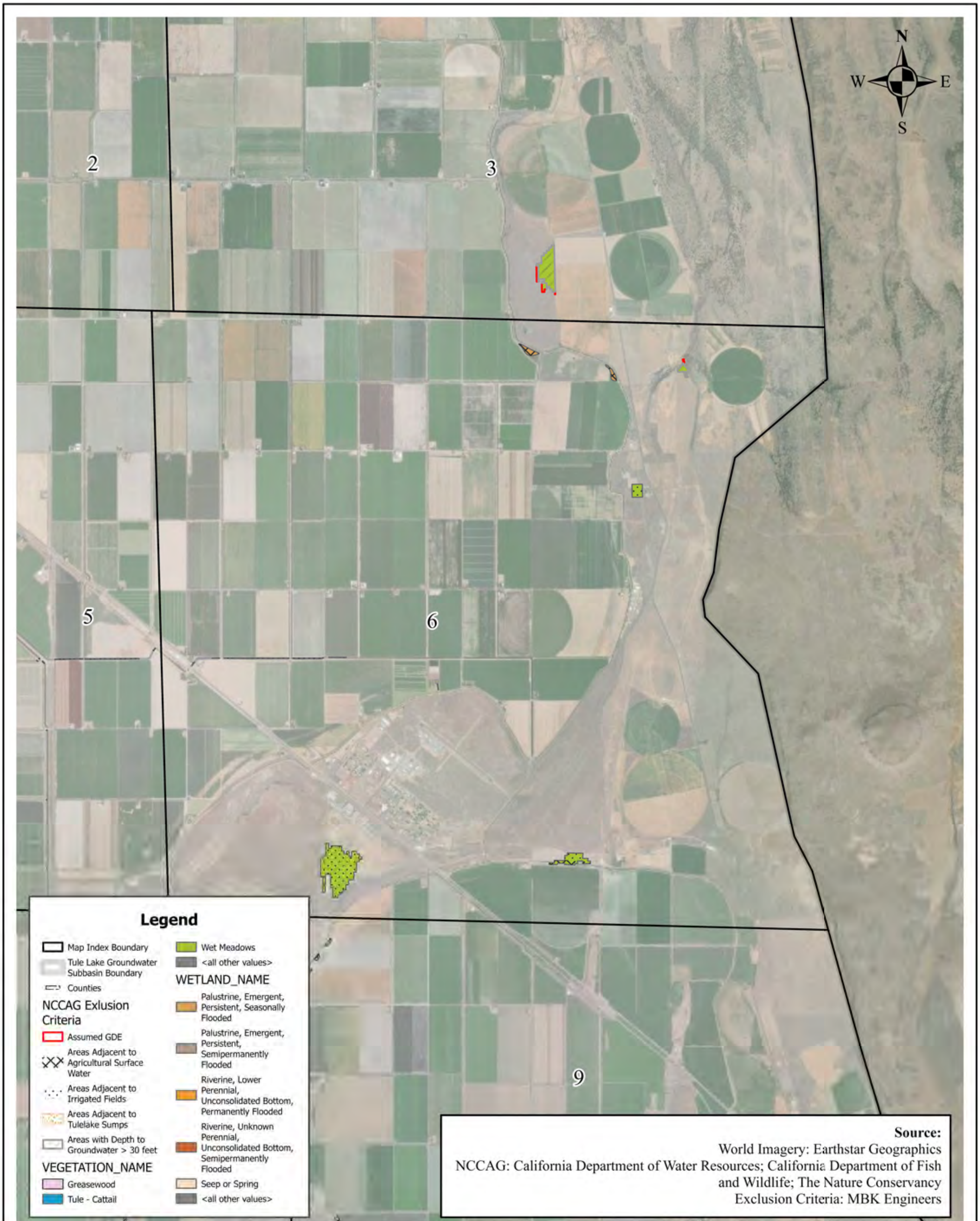



MBK ENGINEERS

Natural Communities Commonly Associated

Inside and Outside GDE Criteria

0 1 Miles

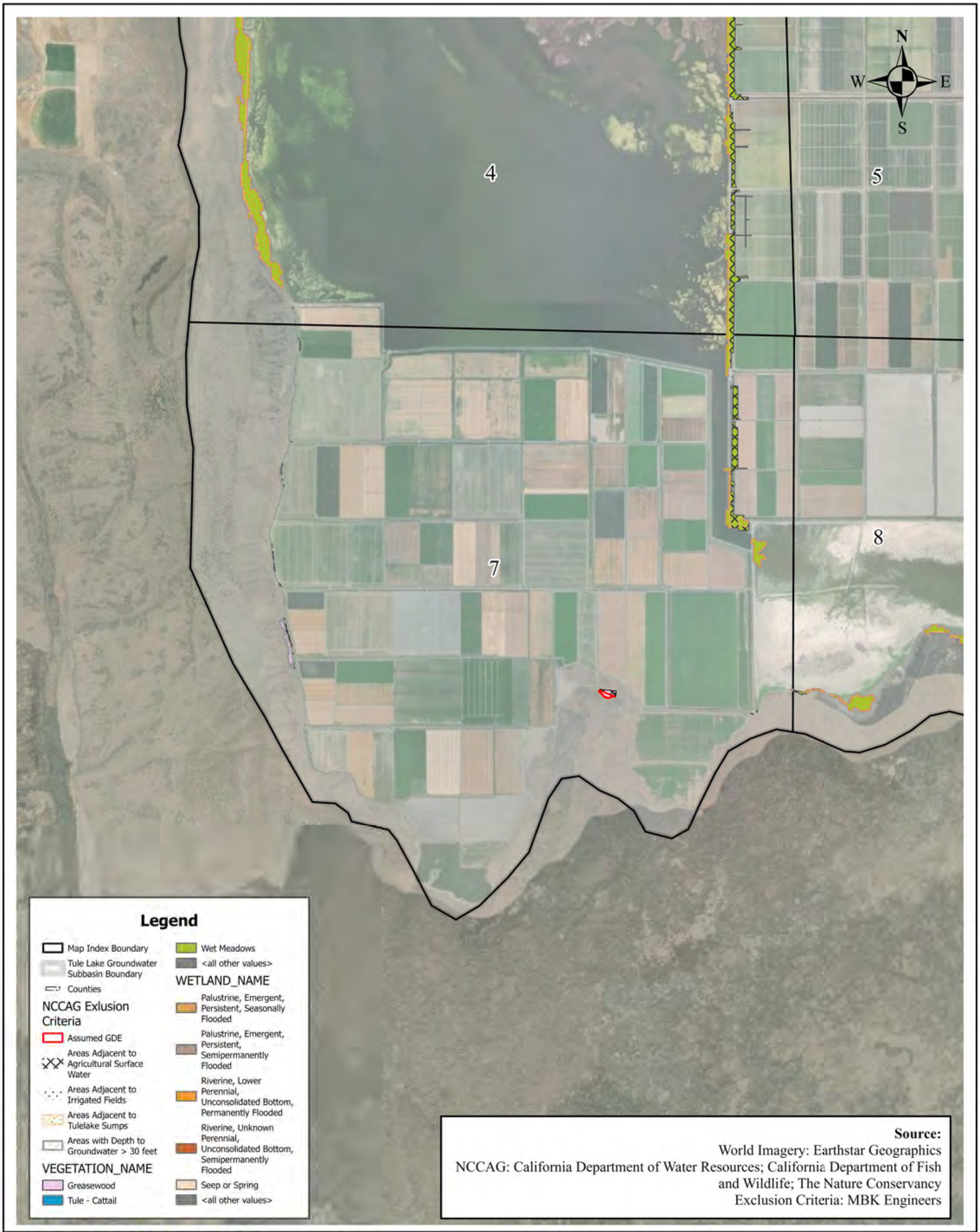



MBK ENGINEERS

Natural Communities Commonly Associated

Inside and Outside GDE Criteria

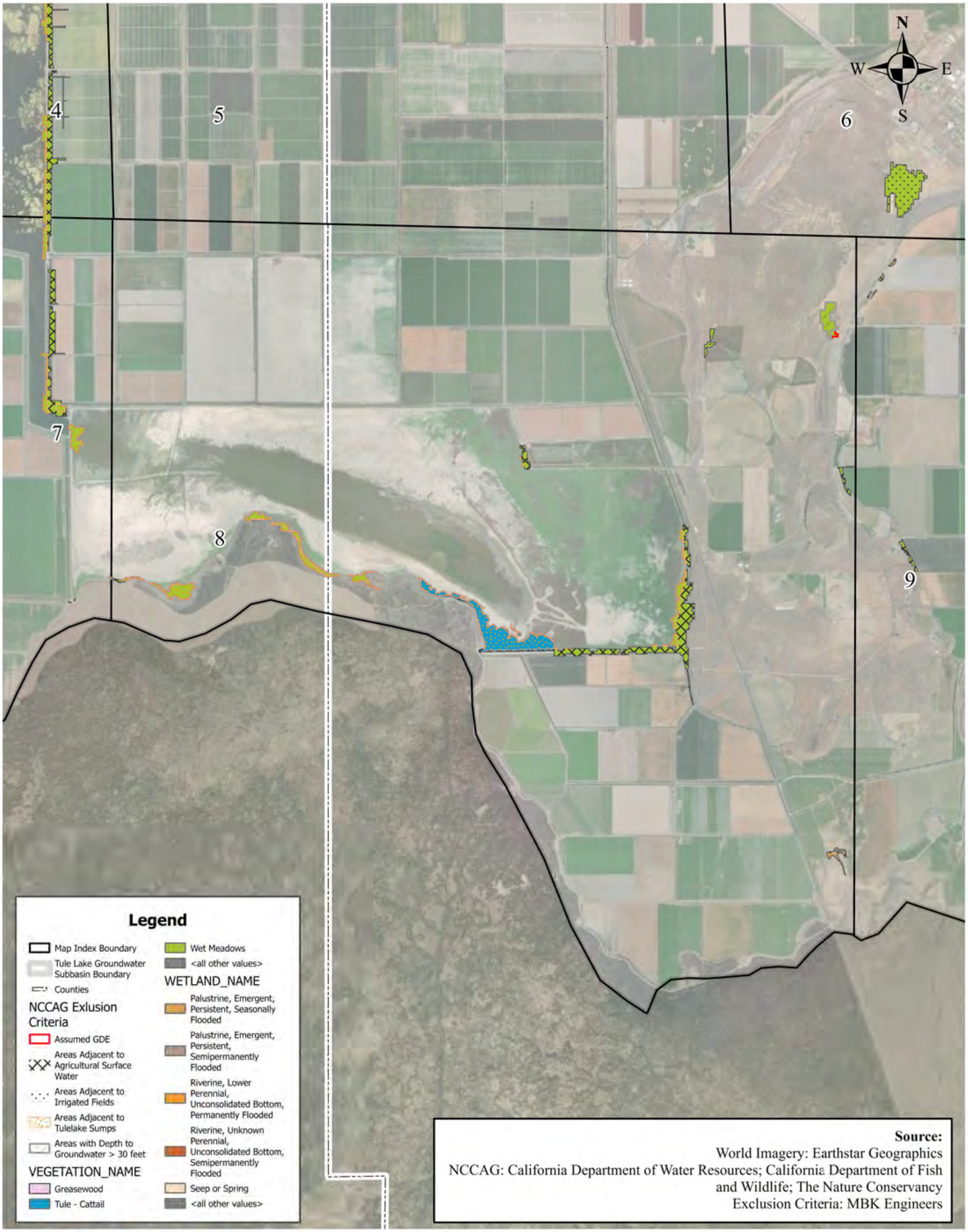
0 1 Miles




MBK ENGINEERS

Natural Communities Commonly Associated

Inside and Outside GDE Criteria

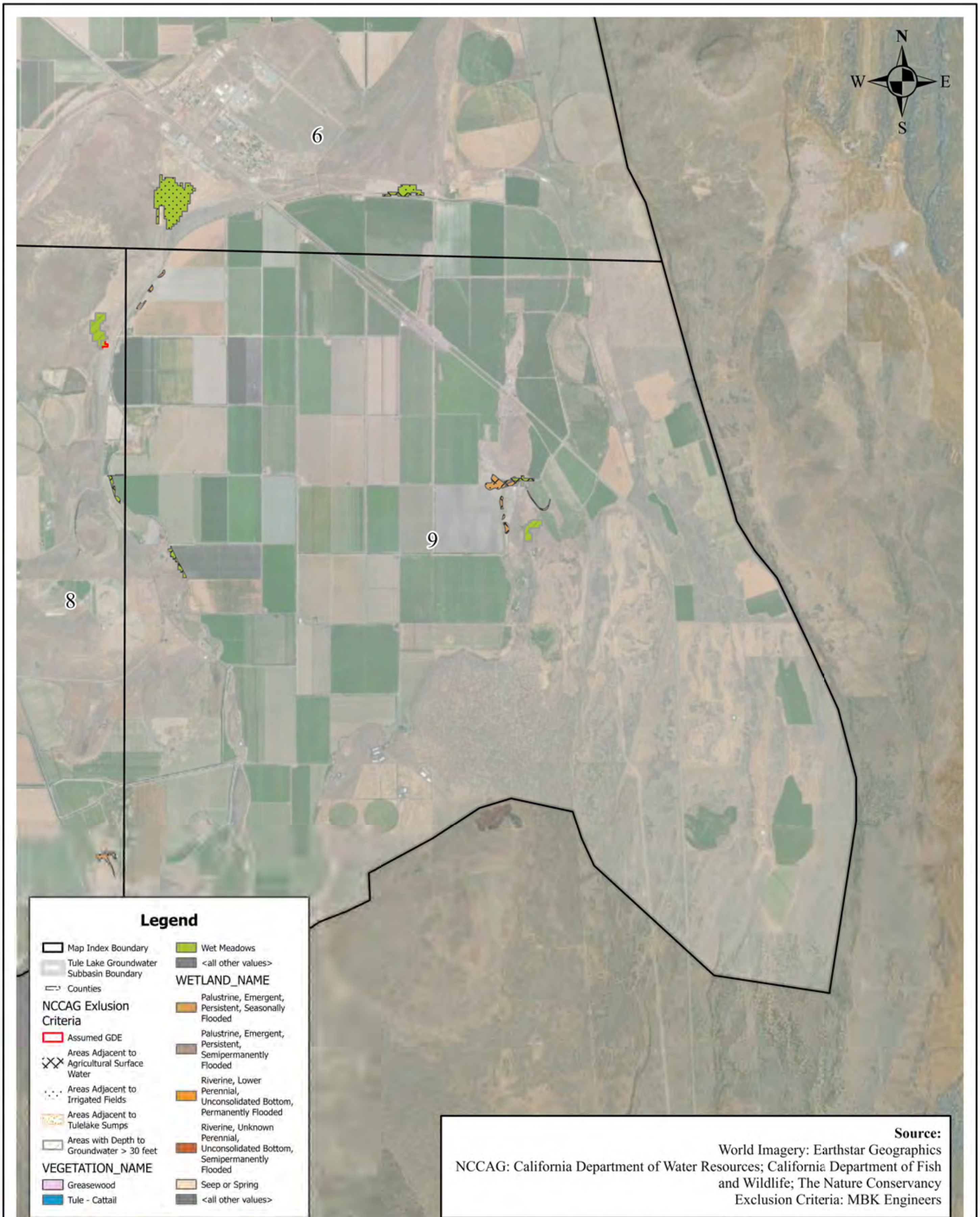



MBK ENGINEERS

Natural Communities Commonly Associated

Inside and Outside GDE Criteria

0 1 Miles




MBK ENGINEERS

Natural Communities Commonly Associated

Inside and Outside GDE Criteria

0 1 Miles

# Appendix I.
# Representative Monitoring Well – Well Completion Reports

**ORIGINAL**
**File with DWR**

STATE OF CALIFORNIA
# WELL COMPLETION REPORT
*Refer to Instruction Pamphlet*

No. 751030

DWR USE ONLY — DO NOT FILL IN
48N 4E-13
STATE WELL NO./STATION NO.
LATITUDE | LONGITUDE
APN/TRS/OTHER

Page ___ of ___
Owner's Well No. ___
Date Work Began 12/9/01, Ended 12/14/01
Local Permit Agency Siskiyou County Health
Permit No. 3697 Permit Date 6/27/01

## GEOLOGIC LOG

ORIENTATION (✓) x VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ___ FLUID ___

| DEPTH FROM SURFACE Ft. | to Ft. | DESCRIPTION (Describe material, grain size, color, etc.) |
|---|---|---|
| 0 | 1 | Gravel fill |
| 1 | 12 | Brn clay & sand |
| 12 | 40 | Yellow chalk |
| 40 | 50 | Gray clay |
| 50 | 55 | Brn & white pumice |
| 55 | 65 | Gray clay |

TOTAL DEPTH OF BORING 65 (Feet)
TOTAL DEPTH OF COMPLETED WELL 65 (Feet)



## WELL OWNER

## WELL LOCATION

Address 23234 Stateline Rd.
City Tulelake
County Siskiyou
APN Book 001 Page 140 Parcel 080
Township 48N Range 4E Section 13
Latitude ___ NORTH (DEG. MIN. SEC.) Longitude ___ WEST (DEG. MIN. SEC.)

## LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

*Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.*

## ACTIVITY (✓)

x NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (*Describe Procedures and Materials Under "GEOLOGIC LOG"*)

## PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) x livestock

## WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 7 (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 7'6" (Ft.) & DATE MEASURED 12/14/01
ESTIMATED YIELD * 20 (GPM) & TEST TYPE bailer
TEST LENGTH 1 (Hrs.) TOTAL DRAWDOWN 1 (Ft.)
* *May not be representative of a well's long-term yield.*

## CASING (S)

| DEPTH FROM SURFACE Ft. | to Ft. | BORE-HOLE DIA. (Inches) | BLANK | SCREEN | CON-DUCTOR | FILL PIPE | MATERIAL / GRADE | INTERNAL DIAMETER (Inches) | GAUGE OR WALL THICKNESS | SLOT SIZE IF ANY (Inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 23 | 10 | | | | | | | | |
| +1 | 23 | | x | | | | A53B | 6 | .250 | |
| 23 | 65 | 6 | | | | | | | | |

## ANNULAR MATERIAL

| DEPTH FROM SURFACE Ft. | to Ft. | CE-MENT (✓) | BEN-TONITE (✓) | FILL (✓) | FILTER PACK (TYPE/SIZE) |
|---|---|---|---|---|---|
| 0 | 23 | x | | | |

JAN 23 2002

## ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ___
*ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.*

## CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Larry G. DeSpain Well Drilling
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

3114 Boardman Ave., Klamath Falls, OR 97603
ADDRESS CITY STATE ZIP

Signed Larry G DeSpain 12/15/01 643450
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

46N-05E-01M

**ORIGINAL**
**File with DWR**

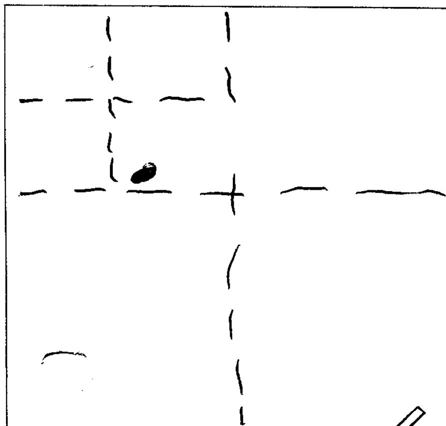
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
# WATER WELL DRILLERS REPORT

*Do not fill in*
No. 090610

Notice of Intent No. ______
Local Permit No. or Date ______

State Well No. ______
Other Well No. ______

(2) **LOCATION OF WELL** (See instructions):
County Modoc Owner's Well Number ______
Well address if different from above ______
Township 46N Range 5E Section 1
Distance from cities, roads, railroads, fences, etc.
S.E. ¼ of the S.W.¼



WELL LOCATION SKETCH

(3) **TYPE OF WORK:**
New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) **PROPOSED USE:**
Domestic ☒
Irrigation ☐
Industrial ☐
Test Well ☐
Stock ☐
Municipal ☐
Other ☐

(5) **EQUIPMENT:**
Rotary ☐ Reverse ☐
Cable ☒ Air ☐
Other ☐ Bucket ☐

(6) **GRAVEL PACK:**
Yes ☐ No ☒ Size ______
Diameter of bore ______
Packed from ______ to ______ ft.

(7) **CASING INSTALLED:**
Steel ☒ Plastic ☐ Concrete ☐

| From ft. | To ft. | Dia. in. | Gage or Wall |
|---|---|---|---|
| 0 | 78½ | 6 | .188 |

(8) **PERFORATIONS:** none
Type of perforation or size of screen

| From ft. | To ft. | Slot size |
|---|---|---|
| | | |

(9) **WELL SEAL:**
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 76 ft.
Were strata sealed against pollution? Yes ☒ No ☐ Interval 6 to 8 ft.
Method of sealing cement

(10) **WATER LEVELS:**
Depth of first water, if known 87 ft.
Standing level after well completion 20 ft.

(11) **WELL TESTS:**
Was well test made? Yes ☒ No ☐ If yes, by whom? self
Type of test Pump ☐ Bailer ☐ Air lift ☐
Depth to water at start of test 20 ft. At end of test 22 ft
Discharge 35 gal/min after 1 hours Water temperature 56
Chemical analysis made? Yes ☐ No ☒ If yes, by whom? ______
Was electric log made? Yes ☐ No ☒ If yes, attach copy to this report

(12) **WELL LOG:** Total depth 101 ft. Depth of completed well 101 ft.

| from ft. | to ft. | Formation (Describe by color, character, size or material) |
|---|---|---|
| 0 | 1 | fill |
| 1 | 5 | black soil |
| 5 | 12 | gray clay |
| 12 | 16 | brown clay |
| 16 | 45 | gray clay |
| 45 | 50 | pumic & clay layers |
| 50 | 57 | gray lava |
| 57 | 72 | sandstone & clay layers |
| 72 | 73 | pumic stone |
| 73 | 87 | gray clay |
| 87 | 101 | pumic & black sand |

Work started 8/16 1982 Completed 8/19 1982

**WELL DRILLER'S STATEMENT:**
*This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.*
SIGNED [signature] 534
(Well Driller)
NAME John A. Van Meter
(Person, firm, or corporation) (Typed or printed)
Address P.O. Box 204
City Malin, Ore Zip 97632
License No. 194473 Date of this report 8/19/82

CONFIDENTIAL
NOT FOR PUBLIC USE
WATER CODE SEC. 13752

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR
Page 1 of 2

AUG 02 2001

STATE OF CALIFORNIA
# WELL COMPLETION REPORT
*Refer to Instruction Pamphlet*

No. 751117

Owner's Well No. TID #14
Date Work Began 6/19/01, Ended 6/29/01
Local Permit Agency Modoc County
Permit No. 2001-14 Permit Date

DWR USE ONLY — DO NOT FILL IN
46N/05E-22
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

## GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID Air & Mud

| DEPTH FROM SURFACE Ft. to Ft. | | DESCRIPTION *Describe material, grain, size, color, etc.* |
|---|---|---|
| 0 | 5 | Topsoil |
| 5 | 15 | Gray sandy clay |
| 15 | 45 | Hard basalt |
| 45 | 65 | Clay |
| 65 | 80 | Sandy clay |
| 80 | 105 | Gray and black basalt |
| 105 | 215 | Cinders |
| 215 | 340 | Hard basalt |
| 340 | 380 | Cinders |
| 380 | 440 | Gray-black basalt |
| 440 | 480 | Fractured basalt |
| 480 | 500 | Hard basalt |
| 500 | 571 | Gray-black medium hard basalt |

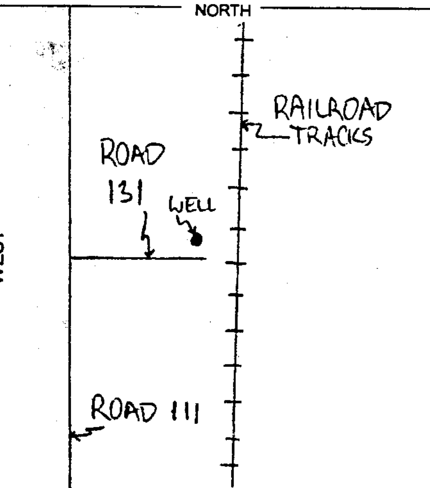
TOTAL DEPTH OF BORING 571 (Feet)
TOTAL DEPTH OF COMPLETED WELL 567 (Feet)

## WELL LOCATION

Address County Road 131
City Southwest of Newell CA 96134
County Modoc
APN Book 008 Page 080 Parcel 05
Township 46 N Range 5 E Section ~~16~~ 22
Latitude ___ DEG. MIN. SEC. Longitude ___ DEG. MIN. SEC.

## LOCATION SKETCH

NORTH




WEST / EAST

SOUTH

*Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary.* **PLEASE BE ACCURATE & COMPLETE.**

## ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

## PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
✓ Irrigation — Industrial
MONITORING —
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

## WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 18 (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 18.5 (Ft.) & DATE MEASURED
ESTIMATED YIELD ~~500~~ 9500 (GPM) & TEST TYPE Airlift
TEST LENGTH 0.5 (Hrs.) TOTAL DRAWDOWN ~~0.2~~ 23.0 (Ft.)
*May not be representative of a well's long-term yield.*

## CASING (S)

| DEPTH FROM SURFACE Ft. to | Ft. | BORE-HOLE DIA. (Inches) | BLANK | SCREEN | CON-DUCTOR | FILL PIPE | MATERIAL / GRADE | INTERNAL DIAMETER (Inches) | GAUGE OR WALL THICKNESS | SLOT SIZE IF ANY (Inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 20 | 38 | | | ✓ | | A53B | 33.25 | 0.375 | |
| +2 | 114 | 31 | ✓ | | | | A53B | 23.25 | 0.375 | |
| 114 | 234 | 31 | | ✓ | | | A53B | 23.25 | 0.375 | 0.125 |
| 234 | 254 | 31 | ✓ | | | | A53B | 23.25 | 0.375 | |
| 254 | 314 | 31 | | ✓ | | | A53B | 23.25 | 0.375 | 0.125 |
| 314 | 334 | 31 | ✓ | | | | A53B | 23.25 | 0.375 | |

## ANNULAR MATERIAL

| DEPTH FROM SURFACE Ft. to | Ft. | CE-MENT (✓) | BEN-TONITE (✓) | FILL (✓) | FILTER PACK (TYPE/SIZE) |
|---|---|---|---|---|---|
| 0 | 98 | ✓ | | | |
| 98 | 234 | | | | 1/2 x 3/4 SRI |
| 234 | 244 | | ✓ | | |
| 244 | 314 | | | | 1/2 x 3/4 SRI |
| 314 | 324 | | ✓ | | |
| 324 | 558 | | | | 1/2 x3/4 SRI |

## ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

## CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Lang Exploratory Drilling
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

P.O. Box 5279 Elko NV 89801-5279
ADDRESS CITY STATE ZIP

Signed [signature] 07/11/01 694686
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

DEC 10 2001

ORIGINAL
File with DWR



STATE OF CALIFORNIA

# WELL COMPLETION REPORT

*Refer to Instruction Pamphlet*

No. 751117

DWR USE ONLY — DO NOT FILL IN 46N/05E-22

STATE WELL NO./STATION NO.

LATITUDE | LONGITUDE

APN/TRS/OTHER

Owner's Well No. TID #14

Date Work Began 6/19/01, Ended 6/29/01

Local Permit Agency Modoc County

Permit No. 2001-14 Permit Date

## GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD REVERSE FLUID Air & Mud

| DEPTH FROM SURFACE Ft. | to Ft. | DESCRIPTION Describe material, grain, size, color, etc. |
|---|---|---|
| 0 | 5 | Topsoil |
| 5 | 15 | Gray sandy clay |
| 15 | 45 | Hard basalt |
| 45 | 65 | Clay |
| 65 | 80 | Sandy clay |
| 80 | 105 | Gray and black basalt |
| 105 | 215 | Cinders |
| 215 | 340 | Hard basalt |
| 340 | 380 | Cinders |
| 380 | 440 | Gray-black basalt |
| 440 | 480 | Fractured basalt |
| 480 | 500 | Hard basalt |
| 500 | 571 | Gray-black medium hard basalt |

TOTAL DEPTH OF BORING 571 (Feet)

TOTAL DEPTH OF COMPLETED WELL 567 (Feet)

## WELL LOCATION

Address County Road 131

City Southwest of Newell CA 96134

County Modoc

APN Book 008 Page 080 Parcel 05

Township 46 N Range 5 E Section ~~16~~ 22

Latitude ___ DEG. MIN. SEC. Longitude ___ DEG. MIN. SEC.

## LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

*Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary.* PLEASE BE ACCURATE & COMPLETE.

## ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
- ___ Deepen
- ___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

## PLANNED USES (✓)

WATER SUPPLY
- ___ Domestic ___ Public
- ✓ Irrigation ___ Industrial

MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

## WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 18 (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL 18.5 (Ft.) & DATE MEASURED

ESTIMATED YIELD * 500 (GPM) & TEST TYPE Airlift

TEST LENGTH 0.5 (Hrs.) TOTAL DRAWDOWN 0.2 (Ft.)

*May not be representative of a well's long-term yield.*

## CASING (S)

| DEPTH FROM SURFACE Ft. | to Ft. | BORE-HOLE DIA. (Inches) | BLANK | SCREEN | CON-DUCTOR | FILL PIPE | MATERIAL / GRADE | INTERNAL DIAMETER (Inches) | GAUGE OR WALL THICKNESS | SLOT SIZE IF ANY (Inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| 334 | 554 | 31 | | ✓ | | | A53B | 23.25 | 0.375 | 0.125 |
| 554 | 567 | 31 | ✓ | | | | A53B | 23.25 | 0.375 | |
| 0 | 420 | 31 | ✓ | | | | A53B | 2.067 | 0.1574 | Sounder |

## ANNULAR MATERIAL

| DEPTH FROM SURFACE Ft. | to Ft. | CE-MENT (✓) | BEN-TONITE (✓) | FILL (✓) | FILTER PACK (TYPE/SIZE) |
|---|---|---|---|---|---|
| 558 | 571 | ✓ | | | |

## ATTACHMENTS (✓)

- ___ Geologic Log
- ___ Well Construction Diagram
- ___ Geophysical Log(s)
- ___ Soil/Water Chemical Analysis
- ___ Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

## CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Lang Exploratory Drilling
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

P.O. Box 5279 Elko NV 89801-5279
ADDRESS CITY STATE ZIP

JUL 10 2001

Signed ___ WELL DRILLER/AUTHORIZED REPRESENTATIVE 07/11/01 DATE SIGNED 694686 C-57 LICENSE NUMBER



IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

47N05E01M

**ORIGINAL**
**File with DWR**

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
# WATER WELL DRILLERS REPORT

*Do not fill in*
No. 098953

Notice of Intent No.
Local Permit No. or Date

State Well No.
Other Well No.

**(12) WELL LOG:** Total depth 65 ft. Depth of completed well 65 ft.

| from ft. | to ft. | Formation (Describe by color, character, size or material) |
|---|---|---|
| 0 | 1 | BROWN SAND |
| 1 | 3 | BROWN CLAY |
| 3 | 17 | LIGHT YELLOW CLAY |
| 17 | 19 | DARK BROWN SAND |
| 19 | 23 | GRAY SHALE |
| 23 | 46 | BLACK SAND & SMALL GRAVEL |
| 46 | 61 | DARK GRAY SANDSTONE |
| 61 | 63 | GRAY LAVA ROCK |
| 63 | 65 | DARK GRAY SANDSTONE |

NOV 7 1983

CONFIDENTIAL WELL LOG
Water Code Section 13752.
These data are restricted to
public agencies for use
in making studies.

CONFIDENTIAL — NOT FOR PUBLIC USE — WATER CODE SEC. 13752

**(2) LOCATION OF WELL** (See instructions):
County Modoc Owner's Well Number
Well address if different from above
Township 47N Range 5E Section 1
Distance from cities, roads, railroads, fences, etc.
E. END OF COUNTY RD 102

WELL LOCATION SKETCH: X

**(3) TYPE OF WORK:**
New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

**(4) PROPOSED USE:**
Domestic ☒
Irrigation ☐
Industrial ☐
Test Well ☐
Stock ☐
Municipal ☐
Other ☐

**(5) EQUIPMENT:**
Rotary ☒ Reverse ☐
Cable ☐ Air ☒
Other ☐ Bucket ☐

**(6) GRAVEL PACK:**
Yes ☐ No ☒ Size
Diameter of bore 6"
Packed from ___ to ___ ft.

**(7) CASING INSTALLED:**
Steel ☒ Plastic ☐ Concrete ☐

| From ft. | To ft. | Dia. in. | Gage or Wall |
|---|---|---|---|
| +1½ | 48½ | 6 | 250 |

**(8) PERFORATIONS:**
Type of perforation or size of screen

| From ft. | To ft. | Slot size |
|---|---|---|
| | | |

**(9) WELL SEAL:**
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 20 ft.
Were strata sealed against pollution? Yes ☐ No ☒ Interval ___ ft.
Method of sealing

**(10) WATER LEVELS:**
Depth of first water, if known 23 ft.
Standing level after well completion 11 ft.

**(11) WELL TESTS:**
Was well test made? Yes ☒ No ☐ If yes, by whom? EES
Type of test Pump ☐ Bailer ☐ Air lift ☒
Depth to water at start of test 11 ft. At end of test 11 ft
Discharge 100+ gal/min after 1 hours Water temperature 54°
Chemical analysis made? Yes ☐ No ☒ If yes, by whom?
Was electric log made? Yes ☐ No ☒ If yes, attach copy to this report

Work started 9/13/82 Completed 9/15/82

**WELL DRILLER'S STATEMENT:**
*This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.*
SIGNED E E Storey 00525
(Well Driller)
NAME E E STOREY WELL DRILLING
(Person, firm, or corporation) (Typed or printed)
Address 3847 Hope
City KLAMATH FALLS ORE Zip 97601
License No. 192492 Date of this report 12/1/82

DWR 188 (REV. 7-76) **IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM**

47N/5E-~~8~~ 4

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

# WATER WELL DRILLERS REPORT

**ORIGINAL**
**File with DWR**

*Do Not Fill In*

№ 62637

State Well No.
Other Well No. CONFIDENTIAL LOG Water Code Sec. 13752

(2) LOCATION OF WELL:
County Modoc Owner's number, if any
Township, Range, and Section T 47N R5E Sec.5
Distance from cities, roads, railroads, etc. S.E. corner of the S.W.¼ of the S.E.¼ M.D.M.

(3) TYPE OF WORK (check):
New Well [X] Deepening [ ] Reconditioning [ ] Destroying [ ]
*If destruction, describe material and procedure in Item 11.*

(4) PROPOSED USE (check):
Domestic [X] Industrial [ ] Municipal [ ]
Irrigation [ ] Test Well [ ] Other [ ]

(5) EQUIPMENT:
Rotary [ ]
Cable [X]
Other [ ]

(6) CASING INSTALLED:
STEEL: OTHER:
SINGLE [X] DOUBLE [ ]

If gravel packed

| From ft. | To ft. | Diam. | Gage or Wall | Diameter of Bore | From ft. | To ft. |
|---|---|---|---|---|---|---|
| 0 | 56 | 6" | ¼ | | | |

Size of shoe or well ring: none
Size of gravel:
Describe joint welded

(7) PERFORATIONS OR SCREEN:
Type of perforation or name of screen none

| From ft. | To ft. | Perf. per row | Rows per ft. | Size in. x in. |
|---|---|---|---|---|
| | | | | |

(8) CONSTRUCTION:
Was a surface sanitary seal provided? Yes [X] No [ ] To what depth 56 ft.
Were any strata sealed against pollution? Yes [X] No [ ] If yes, note depth of strata
From 10 ft. to 12 ft.
From ft. to ft.
Method of sealing cased

(9) WATER LEVELS:
Depth at which water was first found, if known 10 ft.
Standing level before perforating, if known ft.
Standing level after perforating and developing 8 ft.

(10) WELL TESTS: bailer test
Was pump test made? Yes [ ] No [X] If yes, by whom? self
Yield: 35 gal./min. with none ft. drawdown after 1 hrs.
Temperature of water 54 Was a chemical analysis made? Yes [ ] No [X]
Was electric log made of well? Yes [ ] No [X] If yes, attach copy

(11) WELL LOG:
Total depth 75 ft. Depth of completed well 71 ft.
Formation: *Describe by color, character, size of material, and structure*
ft. to ft.

0----4----top soil
4---23---yelllow clay
23---68---gray clay
68---72--- pumice gravel and sand
72--75--gray clay

Work started 2/12 1973 Completed 2/13 1973

WELL DRILLER'S STATEMENT:
*This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.*

NAME John A. Van Meter
(Person, firm, or corporation) (*Typed or printed*)

Address P.O. Box 204 Malin, Oregon 97632

[SIGNED] John A. Van Meter
(Well Driller)

License No. 194473 Dated 2/13, 1973

SKETCH LOCATION OF WELL ON REVERSE SIDE

DWR 188 (REV. 9-68)

25179-950 9-68 50M TRIP ΔD OSP

ORIGINAL
File with DWR



STATE OF CALIFORNIA

# WELL COMPLETION REPORT

*Refer to Instruction Pamphlet*

No. 751112

DWR USE ONLY — DO NOT FILL IN: 48N/04E-13
STATE WELL NO./STATION NO.
LATITUDE | LONGITUDE
APN/TRS/OTHER

Owner's Well No. TID #5
Date Work Began 7/14/01, Ended 7/26/01
Local Permit Agency Siskiyou County
Permit No. 3713 Permit Date

## GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID Air & Mud

| DEPTH FROM SURFACE Ft. | to Ft. | DESCRIPTION *Describe material, grain, size, color, etc.* |
|---|---|---|
| 0 | 917 | Dark olive gray lake sediments |
| 917 | | Dark olive gray to black, weak to moderately |
| | 940 | vesicular basalt |
| 970 | 970 | Gray flow breccia |
| 970 | | Gray, fragemented, locally vesicular basalt |
| | 1020 | with some clay |
| 1020 | | Gray, finely vesicular basalt, vesicles range from |
| | 1130 | open to mineral filled |
| 1130 | 1150 | Dark gray to gray green sand with clay |
| 1150 | 1160 | Olive green clay |
| 1170 | | Interbedded blue gray to olive green clay and |
| | 1200 | gray to dark gray basalt |
| 1200 | 1220 | Dark gray to gray vesicular basalt |
| 1220 | | Dark gray to gray vesicular basalt with fracture |
| | 1230 | fill material |
| 1230 | 1240 | Varicolored clay |
| 1240 | | Gray to gray green, locally vesicular basalt, |
| | 1270 | locally fractured |
| 1270 | | Gray to red brown, vesicular to scoriaceous |
| | 1380 | basalt |
| 1380 | 1388 | Gray, massive, weakly vesicular basalt |
| 1388 | 1398 | Gray, massive strongly vesicular basalt |
| 1398 | | Dark gray to black basalt, interbedded soft |
| | 1560 | vesicular and massive |
| 1560 | 1570 | Basalt, becomes more massive |

TOTAL DEPTH OF BORING 1570 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1567 (Feet)

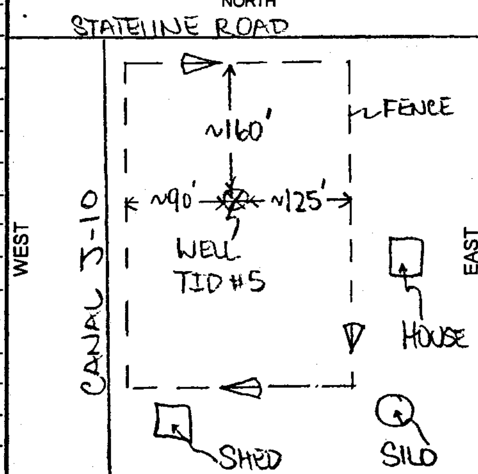
## WELL OWNER

## WELL LOCATION

Address Stateline Road at J-10 Canal
City Tulelake CA 96134
County Siskiyou
APN Book 001 Page 014 Parcel 07
Township 48 N Range 4 E Section 13
Latitude ___ DEG. MIN. SEC. Longitude ___ DEG. MIN. SEC.

### LOCATION SKETCH

NORTH




*Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary.* **PLEASE BE ACCURATE & COMPLETE.**

### ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

### PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
✓ Irrigation — Industrial
MONITORING —
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

### WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 29.12 (Ft.) & DATE MEASURED 8/14/01
ESTIMATED YIELD 10,500 (GPM) & TEST TYPE Pump
TEST LENGTH 73.98 (Hrs.) TOTAL DRAWDOWN 96.39 (Ft.)
*May not be representative of a well's long-term yield.*

### CASING (S)

| DEPTH FROM SURFACE Ft. | to Ft. | BORE-HOLE DIA. (Inches) | BLANK | SCREEN | CON-DUCTOR | FILL PIPE | MATERIAL / GRADE | INTERNAL DIAMETER (Inches) | GAUGE OR WALL THICKNESS | SLOT SIZE IF ANY (Inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 17 | 38 | | | ✓ | | A53B | 33.25 | 0.375 | |
| +1 | 402 | 31 | ✓ | | | | A53B | 23.25 | 0.375 | |
| 378.8 | 935.2 | 19 | ✓ | | | | A53B | 13.376 | 0.312 | |
| 935.2 | 955.2 | 19 | | ✓ | | | A53B | 13.376 | 0.312 | 0.125 |
| 955.2 | 1015 | 19 | ✓ | | | | A53B | 13.376 | 0.312 | |
| 1015 | 1036 | 19 | | ✓ | | | A53B | 13.376 | 0.312 | 0.125 |

### ANNULAR MATERIAL

| DEPTH FROM SURFACE Ft. | to Ft. | CE-MENT (✓) | BEN-TONITE (✓) | FILL (✓) | FILTER PACK (TYPE/SIZE) |
|---|---|---|---|---|---|
| 0 | 462.0 | ✓ | | | |
| 462.0 | 487.6 | | | ✓ | Sand |
| 487.6 | 871.0 | | | ✓ | Crushed gravel |
| 871.0 | 883.0 | ✓ | | | |
| 883.0 | 910.0 | | | | Sand |
| 910 | 1565 | | | | 1/2 x 3/4 SRI |

### ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other

*ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.*

### CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

DEC 10 2001

NAME Lang Exploratory Drilling
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

P.O. Box 5279 | Elko | NV | 89801-5279
ADDRESS | CITY | STATE | ZIP

Signed [signature] WELL DRILLER/AUTHORIZED REPRESENTATIVE
08/28/01 DATE SIGNED
694686 C-57 LICENSE NUMBER



IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File With DWR



STATE OF CALIFORNIA

# WELL COMPLETION REPORT

*Refer to Instruction Pamphlet*

No. 751112

DWR USE ONLY — DO NOT FILL IN: 48N/04E-13

STATE WELL NO./STATION NO. — LATITUDE — LONGITUDE — APN/TRS/OTHER

Owner's Well No. TID #5

Date Work Began 7/14/01, Ended 7/26/01

Local Permit Agency Siskiyou County

Permit No. 3713 Permit Date

## GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD REVERSE FLUID Air & Mud

| DEPTH FROM SURFACE Ft. | to Ft. | DESCRIPTION Describe material, grain, size, color, etc. |
|---|---|---|
| 0 | 917 | Dark olive gray lake sediments |
| 917 | | Dark olive gray to black, weak to moderately |
| | 940 | vesicular basalt |
| 970 | 970 | Gray flow breccia |
| 970 | | Gray, fragemented, locally vesicular basalt |
| | 1020 | with some clay |
| 1020 | | Gray, finely vesicular basalt, vesicles range from |
| | 1130 | open to mineral filled |
| 1130 | 1150 | Dark gray to gray green sand with clay |
| 1150 | 1160 | Olive green clay |
| 1170 | | Interbedded blue gray to olive green clay and |
| | 1200 | gray to dark gray basalt |
| 1200 | 1220 | Dark gray to gray vesicular basalt |
| 1220 | | Dark gray to gray vesicular basalt with fracture |
| | 1230 | fill material |
| 1230 | 1240 | Varicolored clay |
| 1240 | | Gray to gray green, locally vesicular basalt, |
| | 1270 | locally fractured |
| 1270 | | Gray to red brown, vesicular to scoriaceous |
| | 1380 | basalt |
| 1380 | 1388 | Gray, massive, weakly vesicular basalt |
| 1388 | 1398 | Gray, massive strongly vesicular basalt |
| 1398 | | Dark gray to black basalt, interbedded soft |
| | 1560 | vesicular and massive |
| 1560 | 1570 | Basalt, becomes more massive |

TOTAL DEPTH OF BORING 1570 (Feet)

TOTAL DEPTH OF COMPLETED WELL 1567 (Feet)

## WELL LOCATION

Address Stateline Road at J-10 Canal

City Tulelake CA 96134

County Siskiyou

APN Book 001 Page 014 Parcel 07

Township 48 N Range 4 E Section 13

Latitude ___ DEG. MIN. SEC. Longitude ___ DEG. MIN. SEC.

## LOCATION SKETCH

NORTH / SOUTH / WEST / EAST

*Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary.* PLEASE BE ACCURATE & COMPLETE.

## ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

## PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
✓ Irrigation ___ Industrial

MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

## WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL 29.12 (Ft.) & DATE MEASURED 8/14/01

ESTIMATED YIELD 10,500 (GPM) & TEST TYPE Pump

TEST LENGTH 73.98 (Hrs.) TOTAL DRAWDOWN 96.39 (Ft.)

*May not be representative of a well's long-term yield.*

## CASING (S)

| DEPTH FROM SURFACE Ft. | to Ft. | BORE-HOLE DIA. (Inches) | BLANK | SCREEN | CONDUCTOR | FILL PIPE | MATERIAL / GRADE | INTERNAL DIAMETER (Inches) | GAUGE OR WALL THICKNESS | SLOT SIZE IF ANY (Inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1036 | 1076 | 19 | ✓ | | | | A53B | 13.376 | 0.312 | |
| 1076 | 1096 | 19 | | ✓ | | | A53B | 13.376 | 0.312 | 0.125 |
| 1096 | 1136 | 19 | ✓ | | | | A53B | 13.376 | 0.312 | |
| 1136 | 1557 | 19 | | ✓ | | | A53B | 13.376 | 0.312 | 0.125 |
| 1557 | 1567 | 19 | ✓ | | | | A53B | 13.376 | 0.312 | |
| +1 | 370 | 31 | ✓ | | | | A53B | 2.067 | 0.154 | Sounder |

## ANNULAR MATERIAL

| DEPTH FROM SURFACE Ft. | to Ft. | CEMENT (✓) | BENTONITE (✓) | FILL (✓) | FILTER PACK (TYPE/SIZE) |
|---|---|---|---|---|---|
| 0 | 462.0 | ✓ | | | |
| 462.0 | 487.6 | | | ✓ | Sand |
| 487.6 | 871.0 | | | ✓ | Crushed gravel |
| 871.0 | 883.0 | ✓ | | | |
| 883.0 | 910.0 | | | | Sand |
| 910 | 1565 | | | | 1/2 x 3/4 SRI |

DEC 10 2001

## ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___

*ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.*

## CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Lang Exploratory Drilling
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

P.O. Box 5279 — ADDRESS; Elko — CITY; NV — STATE; 89801-5279 — ZIP

Signed ___ WELL DRILLER/AUTHORIZED REPRESENTATIVE; 08/28/01 — DATE SIGNED; 694686 — C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

48N/04E-18M1

**ORIGINAL**

**File with DWR**

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

# WATER WELL DRILLERS REPORT

*Do not fill in*

No. 078748

N[illegible] [illegible]ntent No. ____

Local Permit No. or Date ____ APN 001-110-100

State Well No. ____

Other Well No. ____

(1 [illegible]

Add[illegible]

City [illegible]

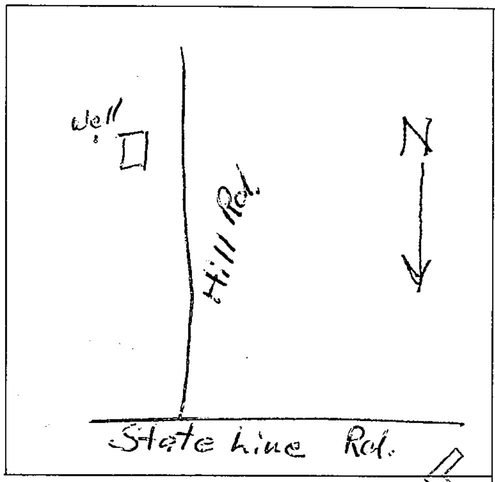
**(2) LOCATION OF WELL** (See instructions):

County Siskiyou Owner's Well Number ____

Well address if different from above ____

Township 48N Range 4E Section 18

Distance from cities, roads, railroads, fences, etc. ____




WELL LOCATION SKETCH

**(3) TYPE OF WORK:**

New Well ☒ Deepening ☐

Reconstruction ☐

Reconditioning ☐

Horizontal Well ☐

Destruction ☐ (Describe destruction materials and procedures in Item 12)

**(4) PROPOSED USE:**

Domestic ☒

Irrigation ☒

Industrial ☐

Test Well ☐

Stock ☒

Municipal ☐

Other ☐

**(5) EQUIPMENT:**

Rotary ☒ Reverse ☐

Cable ☐ Air ☐

Other ☐ Bucket ☐

**(6) GRAVEL PACK:**

Yes ☒ No ☐ Size 3/8

Diameter of bore ____

Packed from 20 to 38 ft.

**(7) CASING INSTALLED:**

Steel ☒ Plastic ☐ Concrete ☐

**(8) PERFORATIONS:**

Type of perforation or size of screen ____

| From ft. | To ft. | Dia. in. | Gage or Wall | From ft. | To ft. | Slot size |
|---|---|---|---|---|---|---|
| +2 | -38 | 6" | .250 | -22 | -38 | ¼ X 5 |

**(9) WELL SEAL:**

Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 20 ft.

Were strata sealed against pollution? Yes ☐ No ☒ Interval ____ ft.

Method of sealing Casing & Cement.

**(10) WATER LEVELS:**

Depth of first water, if known 10 ft.

Standing level after well completion 6 ft.

**(11) WELL TESTS:**

Was well test made? Yes ☒ No ☐ If yes, by whom? Mike Wright

Type of test Pump ☐ Bailer ☐ Air lift ☒

Depth to water at start of test 6 ft. At end of test 20 ft

D[illegible] 20 gal/min after 1 hours Water temperature 66

Che[illegible] analysis made? Yes ☐ No ☒ If yes, by whom? ____

Was electric log made? Yes ☐ No ☒ If yes, attach copy to this report

**(12) WELL LOG:** Total depth 38 ft. Depth of completed well 33 ft.

| from ft. | to | ft. | Formation (Describe by color, character, size or material) |
|---|---|---|---|
| 0 | - | 10 | Brown Sand |
| 10 | - | 20 | (SWL 6') Brown Sand |
| 20 | - | 38 | " Gravel & Black Sand |

DEC [illegible] 1991

Work started 11/8 19 91 Completed 11/12 19 91

WELL DRILLER'S STATEMENT: 1379

*This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.*

SIGNED [signature]
(Well Driller)

NAME Roger Chancellor Drilling
(Person, firm, or corporation) (Typed or printed)

Address 12150 Hill Rd.

City Klamath Falls, OR. Zip 97603

License No. ____ Date of this report ____



DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

**ORIGINAL**

**File with DWR**

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

# WATER WELL DRILLERS REPORT

48N/12E-16 *Do not fill in*

No. 11064

Notice of Intent No.

Local Permit No. or Date

State Well No.

Other Well No.

(2) **LOCATION OF WELL** (See instructions):

County Siskiyou Owner's Well Number

Well address if different from above

Township 48 N Range 12 E Section 16

Distance from cities, roads, railroads, fences, etc.

S.W. ¼ of the S.W. ¼

WELL LOCATION SKETCH

(3) **TYPE OF WORK:**

New Well ☒ Deepening ☐

Reconstruction ☐

Reconditioning ☐

Horizontal Well ☐

Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) **PROPOSED USE:**

Domestic ☒

Irrigation ☐

Industrial ☐

Test Well ☐

Stock ☒

Municipal ☐

Other ☐

(5) **EQUIPMENT:**

Rotary ☐ Reverse ☐

Cable ☒ Air ☐

Other ☐ Bucket ☐

(6) **GRAVEL PACK:**

Yes ☐ No ☒ Size

Diameter of bore

Packed from to ft.

(7) **CASING INSTALLED:**

Steel ☒ Plastic ☐ Concrete ☐

(8) **PERFORATIONS:**

Type of perforation or size of screen

| From ft. | To ft. | Dia. in. | Gage or Wall | From ft. | To ft. | Slot size |
|---|---|---|---|---|---|---|
| 0 | 31 | 6 | .188 | | | |
| | | | | | | |
| | | | | | | |

(9) **WELL SEAL:**

Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 30 ft.

Were strata sealed against pollution? Yes ☒ No ☐ Interval 30 ft.

Method of sealing XXXXX cement

(10) **WATER LEVELS:**

Depth of first water, if known 7 ft.

Standing level after well completion 7 ft.

(11) **WELL TESTS:**

Was well test made? Yes ☒ No ☐ If yes, by whom? self

Type of test Pump ☐ Bailer ☒ Air lift ☐

Depth to water at start of test 7 ft. At end of test 8 ft

Discharge 30 gal/min after 1 hours Water temperature 55

Chemical analysis made? Yes ☐ No ☒ If yes, by whom?

Was electric log made? Yes ☐ No ☒ If yes, attach copy to this report

(12) **WELL LOG:** Total depth 135 ft. Depth of completed well 135 ft.

| from ft. to ft. | Formation (Describe by color, character, size or material) |
|---|---|
| 0--5 | top soil |
| 5--27 | gray clay and sand |
| 27--120 | gray clay |
| 120--130 | sand and pumice gravel |
| 130--135 | gray clay |

Work started 9/20 1977 Completed 9/22 1977

WELL DRILLER'S STATEMENT:

*This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.*

SIGNED John A. Van Meter (Well Driller) 534

NAME John A. Van Meter
(Person, firm, or corporation) (Typed or printed)

Address P.O. BOX 204

City Malin, Oregon Zip 97632

License No. 194473 Date of this report 9/30/77

CONFIDENTIAL — NOT FOR PUBLIC USE — WATER CODE SEC. 13752

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM 43816-950 7-76 50M QUAD OSP

ORIGINAL
File with DWR

Page 1 of 1

AUG 02 2001

STATE OF CALIFORNIA
# WELL COMPLETION REPORT
*Refer to Instruction Pamphlet*
No. 751108

DWR USE ONLY — DO NOT FILL IN
48N/04E-30
STATE WELL NO./STATION NO.
LATITUDE | LONGITUDE
APN/TRS/OTHER

Owner's Well No. TID #1
Date Work Began 5/26/01, Ended 6/8/01
Local Permit Agency Siskiyou County Health Dept.
Permit No. 3666 Permit Date

## GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID Air & Mud

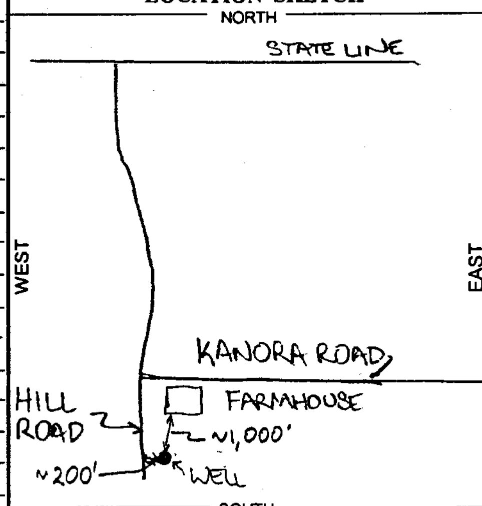
| DEPTH FROM SURFACE Ft. | to Ft. | DESCRIPTION (Describe material, grain, size, color, etc.) |
|---|---|---|
| 0 | 160 | Sand, gravel and clay |
| 160 | 200 | Dark brown basalt |
| 200 | 210 | Hard basalt |
| 210 | 220 | Fractured basalt |
| 220 | 350 | Hard basalt |
| 350 | 710 | Fractured basalt |
| 710 | 730 | Basalt with light gray clay |
| 730 | 740 | Light brown basalt with minor black basalt |

TOTAL DEPTH OF BORING 740 (Feet)
TOTAL DEPTH OF COMPLETED WELL 734 (Feet)

## WELL LOCATION

Address Hill Road
City Tulelake CA 93614
County Siskiyou
APN Book 001 Page 017 Parcel 10
Township 48 N Range 4 E Section 30
Latitude ___ DEG. MIN. SEC. Longitude ___ DEG. MIN. SEC.

### LOCATION SKETCH




*Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.*

### ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

### PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
✓ Irrigation — Industrial
MONITORING —
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

## WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER 200 (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 22.6 (Ft.) & DATE MEASURED 6/8/01
ESTIMATED YIELD * 600 (GPM) & TEST TYPE Airlift
TEST LENGTH 1 (Hrs.) TOTAL DRAWDOWN 0.2 (Ft.)
*May not be representative of a well's long-term yield.*

## CASING (S)

| DEPTH FROM SURFACE Ft. | to Ft. | BORE-HOLE DIA. (Inches) | BLANK | SCREEN | CON-DUCTOR | FILL PIPE | MATERIAL / GRADE | INTERNAL DIAMETER (Inches) | GAUGE OR WALL THICKNESS | SLOT SIZE IF ANY (Inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 20 | 38 | | | ✓ | | A53B | 33.25 | 0.375 | |
| +2 | 260 | 31 | ✓ | | | | A53B | 23.25 | 0.375 | |
| 260 | 700 | 31 | | ✓ | | | A53B | 23.25 | 0.375 | 0.125 |
| 700 | 734 | 31 | ✓ | | | | A53B | 23.25 | 0.375 | |
| +1 | 380 | 31 | ✓ | | | | A53B | 2.067 | 0.1574 | Sounder |

## ANNULAR MATERIAL

| DEPTH FROM SURFACE Ft. | to Ft. | CE-MENT (✓) | BEN-TONITE (✓) | FILL (✓) | FILTER PACK (TYPE/SIZE) |
|---|---|---|---|---|---|
| 0 | 220 | ✓ | | | |
| 220 | 230 | | | | 8 X 12 Sand |
| 230 | 290 | | | | 1/8 X 3/8 SRI |
| 290 | 734 | | | | 1/2 X 3/4 SRI |
| 734 | 740 | ✓ | | | |

### ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

### CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME Lang Exploratory Drilling
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
P.O. Box 5279 Elko NV 89801-5279
ADDRESS CITY STATE ZIP
Signed [signature]
WELL DRILLER/AUTHORIZED REPRESENTATIVE
07/11/01 DATE SIGNED
694686 C-57 LICENSE NUMBER

DEC 10 2001

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

**ORIGINAL**

**File with DWR**

Notice of Intent No.

Local Permit No. or Date

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

# WATER WELL DRILLERS REPORT

*Do not fill in*

No. 099000

State Well No. 48N/4E-31

Other Well No.



(
A
C Zip

**(2) LOCATION OF WELL** (See instructions):

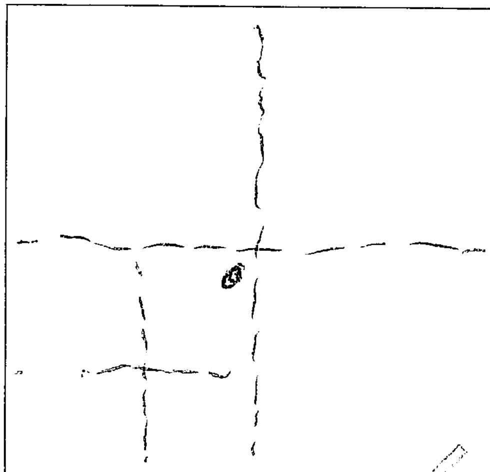
County Siskiyou Owner's Well Number

Well address if different from above

Township 48N Range 4E Section 31

Distance from cities, roads, railroads, fences, etc.

N.E. ¼ of the S.W. ¼



WELL LOCATION SKETCH

**(3) TYPE OF WORK:**

New Well [X] Deepening [ ]
Reconstruction [ ]
Reconditioning [ ]
Horizontal Well [ ]
Destruction [ ] (Describe destruction materials and procedures in Item 12)

**(4) PROPOSED USE:**

Domestic [X]
Irrigation [ ]
Industrial [ ]
Test Well [ ]
Stock [ ]
Municipal [ ]
Other [ ]

**(5) EQUIPMENT:**

Rotary [ ] Reverse [ ]
Cable [ ] Air [X]
Other [ ] Bucket [ ]

**(6) GRAVEL PACK:**

Yes [ ] No [X] Size
Diameter of bore
Packed from to ft.

**(7) CASING INSTALLED:**

Steel [X] Plastic [ ] Concrete [ ]

| From ft. | To ft. | Dia. in. | Gage or Wall |
|---|---|---|---|
| 0 | 20 | 6 | .250 |

**(8) PERFORATIONS:** none

Type of perforation or size of screen

| From ft. | To ft. | Slot size |
|---|---|---|
| | | |

**(9) WELL SEAL:**

Was surface sanitary seal provided? Yes [X] No [ ] If yes, to depth 19 ft.

Were strata sealed against pollution? Yes [ ] No [X] Interval ft.

Method of sealing cement & casing

**(10) WATER LEVELS:**

Depth of first water, if known 28 ft.

Standing level after well completion 7 ft.

**(11) WELL TESTS:**

Was well test made? Yes [X] No [ ] If yes, by whom?

Type of test Pump [ ] Bailer [ ] Air lift [X]

Depth to water at start of test ft. At end of test ft

Discharge 20 gal/min after 1 hours Water temperature 56

Chemical analysis made? Yes [ ] No [X] If yes, by whom?

Was electric log made? Yes [ ] No [X] If yes, attach copy to this report

**(12) WELL LOG:** Total depth 40 ft. Depth of completed well 29 ft.

| from ft. | to ft. | Formation (Describe by color, character, size or material) |
|---|---|---|
| 0 | 6 | top soil |
| 6 | 25 | blue clay |
| 25 | 29 | sand & gravel |
| 29 | 40 | gravel |

Work started 9/16 1981 Completed 9/16 1981

**WELL DRILLER'S STATEMENT:**

*This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.*

SIGNED [signature] (Well Driller)

574

NAME John A. Van Meter
(Person, firm, or corporation) (Typed or printed)

Address P.O. Box 204

City Malin, Ore. Zip 97632

License No. 194473 Date of this report 10/2/81

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR
Page 1 of 2

STATE OF CALIFORNIA
# WELL COMPLETION REPORT
*Refer to Instruction Pamphlet*
No. 751115

DWR USE ONLY — DO NOT FILL IN
48N/05E-26
STATE WELL NO./STATION NO.
LATITUDE | LONGITUDE
APN/TRS/OTHER

Owner's Well No. TID #8
Date Work Began 8/16/01, Ended 9/7/01
Local Permit Agency Modoc County
Permit No. 2001-8 Permit Date

## GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID Air & Mud

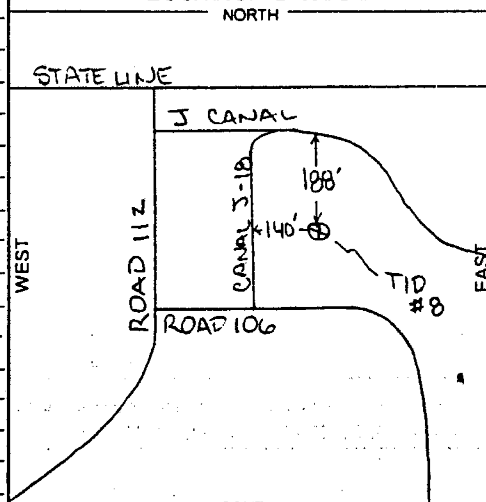
| DEPTH FROM SURFACE Ft. | to Ft. | DESCRIPTION *Describe material, grain, size, color, etc.* |
|---|---|---|
| 0 | 1240 | Gray clay, lake bottom sediments |
| 1240 | 1305 | Basalt, vesicular to amygdaloidal, fractured |
| 1305 | 1320 | Sandstone and siltstone |
| 1320 | 1336 | Massive basalt |
| 1336 | 1474 | Basalt, vesicular to amygdaloidal, fractured |
| 1474 | 1530 | Basalt, massive, vesicular, and amygdaloidal |
| 1530 | 1578 | Basalt, vesicular to amygdaloidal |
| 1578 | 1610 | Ash rich clay and silt |
| 1610 | 1640 | Basalt, massive, vesicular and amygdaloidal |
| 1640 | 1670 | Claystone to siltstone |
| 1670 | 1720 | Basalt, massive |
| 1720 | 1745 | Claystone to siltstone |
| 1745 | 1750 | Medium to coarse grained volcanic sand |
| 1750 | 1770 | Claystone to siltstone |
| 1770 | 1810 | Basalt, massive, locally fractured |

TOTAL DEPTH OF BORING 1810 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1807 (Feet)

## WELL LOCATION

Address J Canal & Canal J-18
City South of Malin, Or. in CA
County Modoc
APN Book 005 Page 040 Parcel 14
Township 48 N Range 5 E Section 26
Latitude ___ DEG. MIN. SEC. Longitude ___ DEG. MIN. SEC.

## LOCATION SKETCH




*Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.*

## ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

## PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
✓ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

## WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 33 (Ft.) & DATE MEASURED 9/3/01
ESTIMATED YIELD * 3935 (GPM) & TEST TYPE Pump
TEST LENGTH 27.25 (Hrs.) TOTAL DRAWDOWN 267 (Ft.)
*May not be representative of a well's long-term yield.*

## CASING (S)

| DEPTH FROM SURFACE Ft. | to Ft. | BORE-HOLE DIA. (Inches) | BLANK | SCREEN | CON-DUCTOR | FILL PIPE | MATERIAL / GRADE | INTERNAL DIAMETER (Inches) | GAUGE OR WALL THICKNESS | SLOT SIZE IF ANY (Inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 15 | 38 | | | ✓ | | A53B | 33.25 | 0.375 | |
| +1 | 400 | 31 | ✓ | | | | A53B | 23.25 | 0.375 | |
| 379.9 | 1250 | 19 | ✓ | | | | A53B | 13.25 | 0.375 | |
| 1250 | 1635 | 19 | | ✓ | | | A53B | 13.25 | 0.375 | 0.125 |
| 1635 | 1650 | 19 | ✓ | | | | A53B | 13.25 | 0.375 | |
| 1650 | 1802 | 19 | | ✓ | | | A53B | 13.25 | 0.375 | 0.125 |

## ANNULAR MATERIAL

| DEPTH FROM SURFACE Ft. | to Ft. | CE-MENT (✓) | BEN-TONITE (✓) | FILL (✓) | FILTER PACK (TYPE/SIZE) |
|---|---|---|---|---|---|
| 0 | 456 | ✓ | | | |
| 456 | 466 | | | | 1/8 X 3/8 SRI |
| 466 | 1175 | | | ✓ | Crushed Gravel |
| 1175 | 1200 | ✓ | | | |
| 1200 | 1210 | | | | 1/8 x 3/8 SRI |
| 1210 | 1787 | | | | 1/2 x 3/4 SRI |

## ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other
*ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.*

## CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME Lang Exploratory Drilling
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
P.O. Box 5279 — ADDRESS; Elko — CITY; NV — STATE; 89801-5279 — ZIP
Signed [signature] WELL DRILLER/AUTHORIZED REPRESENTATIVE
09/18/01 DATE SIGNED
694686 C-57 LICENSE NUMBER

DEC 10 2001

DWR 188 REV. 11-97
IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR



STATE OF CALIFORNIA

# WELL COMPLETION REPORT

*Refer to Instruction Pamphlet*

No. 751115

DWR USE ONLY — DO NOT FILL IN
48N/05E-26
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. TID #8
Date Work Began 8/16/01, Ended 9/7/01
Local Permit Agency Modoc County
Permit No. 2001-8 Permit Date

## GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID Air & Mud

| DEPTH FROM SURFACE Ft. to Ft. | DESCRIPTION *Describe material, grain, size, color, etc.* |
|---|---|
| 0 - 1240 | Gray clay, lake bottom sediments |
| 1240 - 1305 | Basalt, vesicular to amygdaloidal, fractured |
| 1305 - 1320 | Sandstone and siltstone |
| 1320 - 1336 | Massive basalt |
| 1336 - 1474 | Basalt, vesicular to amygdaloidal, fractured |
| 1474 - 1530 | Basalt, massive, vesicular, and amygdaloidal |
| 1530 - 1578 | Basalt, vesicular to amygdaloidal |
| 1578 - 1610 | Ash rich clay and silt |
| 1610 - 1640 | Basalt, massive, vesicular and amygdaloidal |
| 1640 - 1670 | Claystone to siltstone |
| 1670 - 1720 | Basalt, massive |
| 1720 - 1745 | Claystone to siltstone |
| 1745 - 1750 | Medium to coarse grained volcanic sand |
| 1750 - 1770 | Claystone to siltstone |
| 1770 - 1810 | Basalt, massive, locally fractured |

TOTAL DEPTH OF BORING 1810 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1807 (Feet)

## WELL LOCATION

Address J Canal & Canal J-18
City South of Malin, Or. in CA
County Modoc
APN Book 005 Page 040 Parcel 14
Township 48 N Range 5 E Section 26
Latitude ___ DEG. MIN. SEC. Longitude ___ DEG. MIN. SEC.

## LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

*Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.*

## ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

## PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
✓ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

## WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 33 (Ft.) & DATE MEASURED 9/3/01
ESTIMATED YIELD 3935 (GPM) & TEST TYPE Pump
TEST LENGTH 27.25 (Hrs.) TOTAL DRAWDOWN 267 (Ft.)
*May not be representative of a well's long-term yield.*

## CASING (S)

| DEPTH FROM SURFACE Ft. to Ft. | BORE-HOLE DIA. (Inches) | BLANK | SCREEN | CON-DUCTOR | FILL PIPE | MATERIAL / GRADE | INTERNAL DIAMETER (Inches) | GAUGE OR WALL THICKNESS | SLOT SIZE IF ANY (Inches) |
|---|---|---|---|---|---|---|---|---|---|
| 1802 - 1807 | 19 | ✓ | | | | A53B | 13.25 | 0.375 | Cement |
| | | | | | | | | | Bullnose |
| +1 - 370 | 31 | ✓ | | | | A53B | 2.067 | 0.154 | Sounder |

## ANNULAR MATERIAL

| DEPTH FROM SURFACE Ft. to Ft. | CE-MENT (✓) | BEN-TONITE (✓) | FILL (✓) | FILTER PACK (TYPE/SIZE) |
|---|---|---|---|---|
| 1787 - 1810 | ✓ | | | |

## ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

## CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

DEC 10 2001

NAME Lang Exploratory Drilling
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
P.O. Box 5279 Elko NV 89801-5279
ADDRESS CITY STATE ZIP
Signed ___ WELL DRILLER/AUTHORIZED REPRESENTATIVE 09/18/01 DATE SIGNED 694686 C-57 LICENSE NUMBER

DWR 188 REV. 11-97 IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

48N 5E-35F1 48N/5E-35

**ORIGINAL**
**File with DWR**

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
# WATER WELL DRILLERS REPORT

*Do Not Fill In*

№ 128124

State Well No.
Other Well No.
CONFIDENTIAL LOG
Water Code Sec. 13752

**(1) OWNER:**

**(2) LOCATION OF WELL:**
County Modoc Owner's number, if any
Township, Range, and Section T 48N R 5E Sec. 35
Distance from cities, roads, railroads, etc. S.E.¼ of the N.W.¼ M.D.M.

**(3) TYPE OF WORK (check):**
New Well [X] Deepening [ ] Reconditioning [ ] Destroying [ ]
*If destruction, describe material and procedure in Item 11.*

**(4) PROPOSED USE (check):**
Domestic [X] Industrial [ ] Municipal [ ]
Irrigation [ ] Test Well [ ] Other [ ]

**(5) EQUIPMENT:**
Rotary [ ]
Cable [X]
Other [ ]

**(6) CASING INSTALLED:**
STEEL: OTHER:
SINGLE [X] DOUBLE [ ]

| From ft. | To ft. | Diam. | Gage or Wall | If gravel packed: Diameter of Bore | From ft. | To ft. |
|---|---|---|---|---|---|---|
| 0 | 20 | 6" | .280 | | | |
| | | | | | | |

Size of shoe or well ring: none Size of gravel:
Describe joint XXXXX weld

**(7) PERFORATIONS OR SCREEN:**
Type of perforation or name of screen none

| From ft. | To ft. | Perf. per row | Rows per ft. | Size in. x in. |
|---|---|---|---|---|
| | | | | |

**(8) CONSTRUCTION:**
Was a surface sanitary seal provided? Yes [X] No [ ] To what depth 20 ft.
Were any strata sealed against pollution? Yes [X] No [ ] If yes, note depth of strata
From 8 ft. to 12 ft.
From ft. to ft.
Method of sealing cased

**(9) WATER LEVELS:**
Depth at which water was first found, if known 25 ft.
Standing level before perforating, if known 6 ft.
Standing level after perforating and developing 6 ft.

**(10) WELL TESTS:**
Was pump test made? Yes [ ] No [X] If yes, by whom? bailer
Yield: 40 gal./min. with ½ ft. drawdown after 1 hrs.
Temperature of water 55 Was a chemical analysis made? Yes [ ] No [X]
Was electric log made of well? Yes [ ] No [X] If yes, attach copy

**(11) WELL LOG:**
Total depth 33 ft. Depth of completed well 32 ft.
Formation: *Describe by color, character, size of material, and structure*
ft. to ft.

0---1--top soil
1---3---brown sand
3---12---brown clay and sand
12--14---brown clay
14---22--layers of brown and blue clay
22--25---gray clay
25---30--pumice gravel and black sand
30--33---pumice gravel and brown sand

CONFIDENTIAL LOG
Water Code Sec. 13752

Work started 6/17 1975, Completed 6/18 1975

WELL DRILLER'S STATEMENT:
*This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.*

NAME John A. Van Meter
(Person, firm, or corporation) (*Typed or printed*)

Address P.O. Box 204 Malin, Oregon 97632

[SIGNED] John A. Van Meter
(Well Driller)

License No. 194473 Dated 6/19, 1975

SKETCH LOCATION OF WELL ON REVERSE SIDE

DWR 188 (REV. 9-68)

67139-760 8-72 30M TRIP OSP

# Appendix J.
# Groundwater Monitoring Plan

# TULELAKE IRRIGATION DISTRICT

## GROUNDWATER MONITORING PLAN

TID

# TABLE OF CONTENTS

# INTRODUCTION

The purpose of this groundwater monitoring plan is to provide a reference and procedural basis for groundwater monitoring in the Tule Lake Subbasin (1-2.01). Using the policies and procedures set forth in this plan the Tulelake Irrigation District, hereafter referred to as TID, will regularly and systematically monitor groundwater elevations at designated monitoring sites. With the data collected under this plan, along with the existing data that TID has compiled since 2001, TID will be able to demonstrate seasonal and long-term trends of groundwater elevations in the Tule Lake Subbasin. The information gathered will be reported to the California Department of Water Resources (DWR) under the California Statewide Groundwater Elevation Monitoring (CASGEM) program.

# MONITORING PLAN RATIONALE

## TULE LAKE SUBBASIN (1-2.01)

TID lies within the Tule Lake Subbasin of the Upper Klamath River Groundwater Basin. TID's boundary encompasses most of, if not the entire, California portion of the Tule Lake Subbasin. The Tule Lake Subbasin is located within the California portion of the Klamath Basin, approximately 30 miles southeast of the City of Klamath Falls, OR, and is split by the boundary of Siskiyou County and Modoc County. The subbasin is bounded to the west by the Gillems Bluff Fault that forms the steep eastern slope of Sheepy Ridge, which separates the Tule Lake and Lower Klamath subbasins. The subbasin is bounded to the east by the Big Crack Fault that forms the western edge of the block faulted mountains between Tule Lake and Clear Lake Reservoir. The subbasin is bounded to the south by the low-lying volcanic fields on the north slope of the Medicine Lake Highlands. As stated in Bulletin 118, the subbasin is bounded to the north by the state boundary of Oregon and California.

The principal water-bearing formations in the Tule Lake Subbasin include Tertiary to Quaternary lake deposits and volcanics.

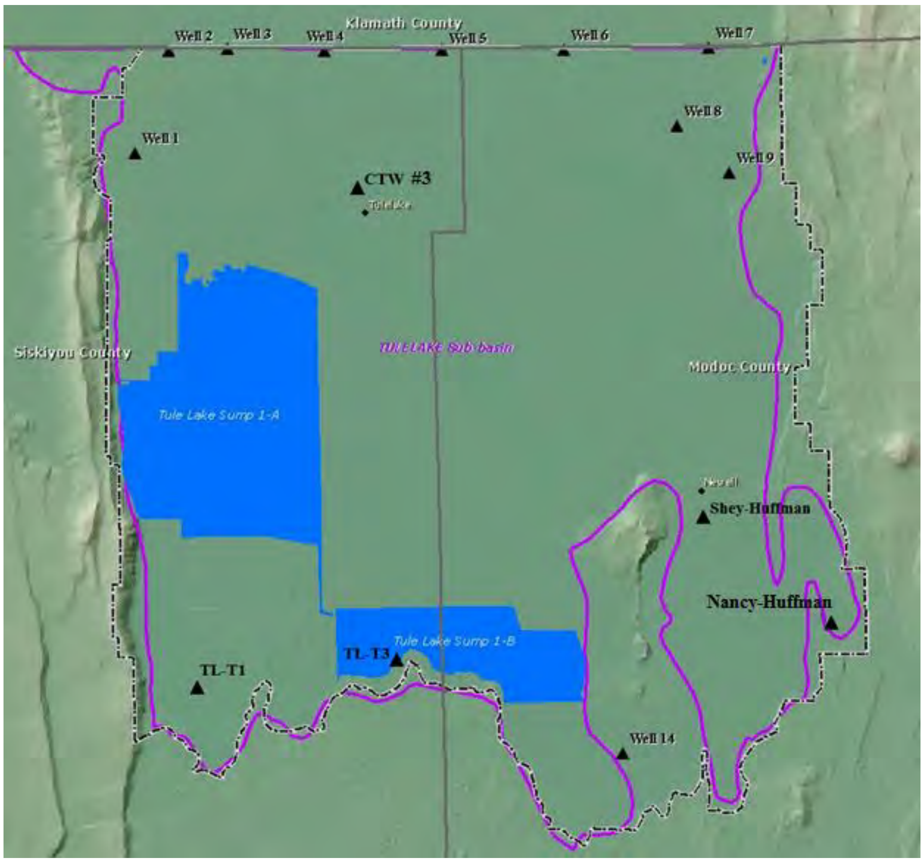
There are two principal sources of recharge in the subbasin: underflow from the rapidly replenished and permeable unconfined system of adjacent volcanic rocks, and infiltration of surface water through marginally permeable sedimentary deposits. The area surrounding the subbasin consists of mainly Holocene and Miocene volcanic rocks that capture most of the incipient precipitation and intermittent stream flow by infiltration through fractures. This source of recharge is believed to be the most significant for the subbasin due to the very slow infiltration rates in the sedimentary deposits.

## HISTORY OF GROUNDWATER MONITORING IN THE TULE LAKE SUBBASIN (1-2.01)

TID has been monitoring groundwater levels within the Tule Lake Subbasin since 2001. The 2001 to present data has been collected from the ten wells that TID owns within the district, and more recently, TID has collected data from five additional privately owned sites. DWR also measures about fifty wells in the Tule Lake Subbasin including the ten TID wells. The DWR monitored wells throughout the subbasin are a mixture of domestic, irrigation, industrial, monitoring, municipal, and stock wells of varying depths. All of the wells are measured by DWR during spring, summer, and fall of every year. A map of the DWR monitoring sites can be found in Appendix A.

## WELL NETWORK

The well network that TID monitors consists of 15 wells which are spread throughout the Tule Lake Subbasin within the District's boundary. The sites that were selected by TID were done so in order to provide the best overall coverage available of the Tule Lake Subbasin. A map of the well network is shown in Figure 1 below.




▲ Monitoring Sites — · — TID Boundary ——— Tule Lake Subbasin

**Figure 1. TID Groundwater Monitoring Network**

Of the 15 monitoring sites, 10 of them are owned and operated by TID. They are most commonly known as TID 1 through 9 and TID 14. Most of these wells are positioned in the northern most part of the California portion of the Tule Lake Subbasin, with the exception of TID 14 which is located in the southern section in an area known as the Panhandle. The additional five wells that TID monitors under the CASGEM program are privately owned sites. The site shown on the map as CTW #3 is the newest well drilled by the City of Tulelake located at the northern tip of the city limits. The sites depicted as TL-T1 and TL-T3 are well test sites drilled by the U.S. Fish and Wildlife Service within the confines of the Tule Lake National Wildlife Refuge. The remaining two wells are situated in the southeast portion of the Tule Lake Subbasin in an area known as Copic Bay, and both are owned by a local farming entity identified as the Huffman Brothers. All 10 of TID's wells, as well as the two wells owned by the U.S. Fish and Wildlife Service, are designated as CASGEM wells. The wells known as CTW #3, Shey-Huffman, and

Nancy-Huffman are designated as Voluntary due to a confidentiality agreement between TID and the owners. All pertinent well information for each of the TID monitoring sites can be found in Appendix B.

# MONITORING SCHEDULE

TID's monitoring of the groundwater elevation of each of the monitoring sites is done on a monthly basis. Collection and documentation of groundwater elevation data of all monitoring sites is conducted within a single day within the first full week of each month of the year. This gives a sufficient month by month picture of the groundwater fluctuation. In the case of temporary inaccessibility to any of the sites due to weather conditions, or any other conditions, collection of the data for those sites is done as soon as possible when the conditions improve.

# FIELD METHODS

## REFERENCE POINT

All reference point (RP) information for each of TID's monitoring sites can be found in the table in Appendix B. A photograph and written description of the reference point for each monitoring site can be found in Appendix C.

## RECORDING DEPTH TO WATER MEASUREMENTS

TID's method for recording depth to water measurements is the Electric Sounding Tape Method. All measurements for a single recording period are recorded on a single TID Groundwater Field Data Sheet, of which an example can be found in Appendix D.

## DEPTH TO WATER MEASUREMENT INSTRUCTIONS

### BEFORE MAKING A MEASUREMENT:

- Inspect the electric sounding tape and electrode probe before using it in the field. Check the tape for wear, kinks, frayed electrical connections and possible stretch; the cable jacket tends to be subject to wear and tear. Test that the battery and replacement batteries are fully charged.

- Check the distance from the electrode probe's sensor to the nearest foot marker on the tape, to ensure that this distance puts the sensor at the zero foot point for the tape. If it does not, a correction must be applied to all depth-to-water measurements. Record this correction on the TID Groundwater Field Data Sheet.

- Check the circuitry of the electric sounding tape before lowering the electrode probe into the well. To determine proper functioning of the tape mechanism, dip the electrode probe into tap water and observe whether the indicator light and beeper indicate a closed circuit.

- Wipe down the electrode probe and 5 to 10 feet of the tape with a disinfectant wipe, rinse with de-ionized or tap water, and dry.

## MAKING A MEASUREMENT:

- Identify the appropriate site on the TID Groundwater Field Data Sheet and record whether or not the well is running, the pumping rate, and the accumulated acre-feet meter reading in the designated columns for the site.

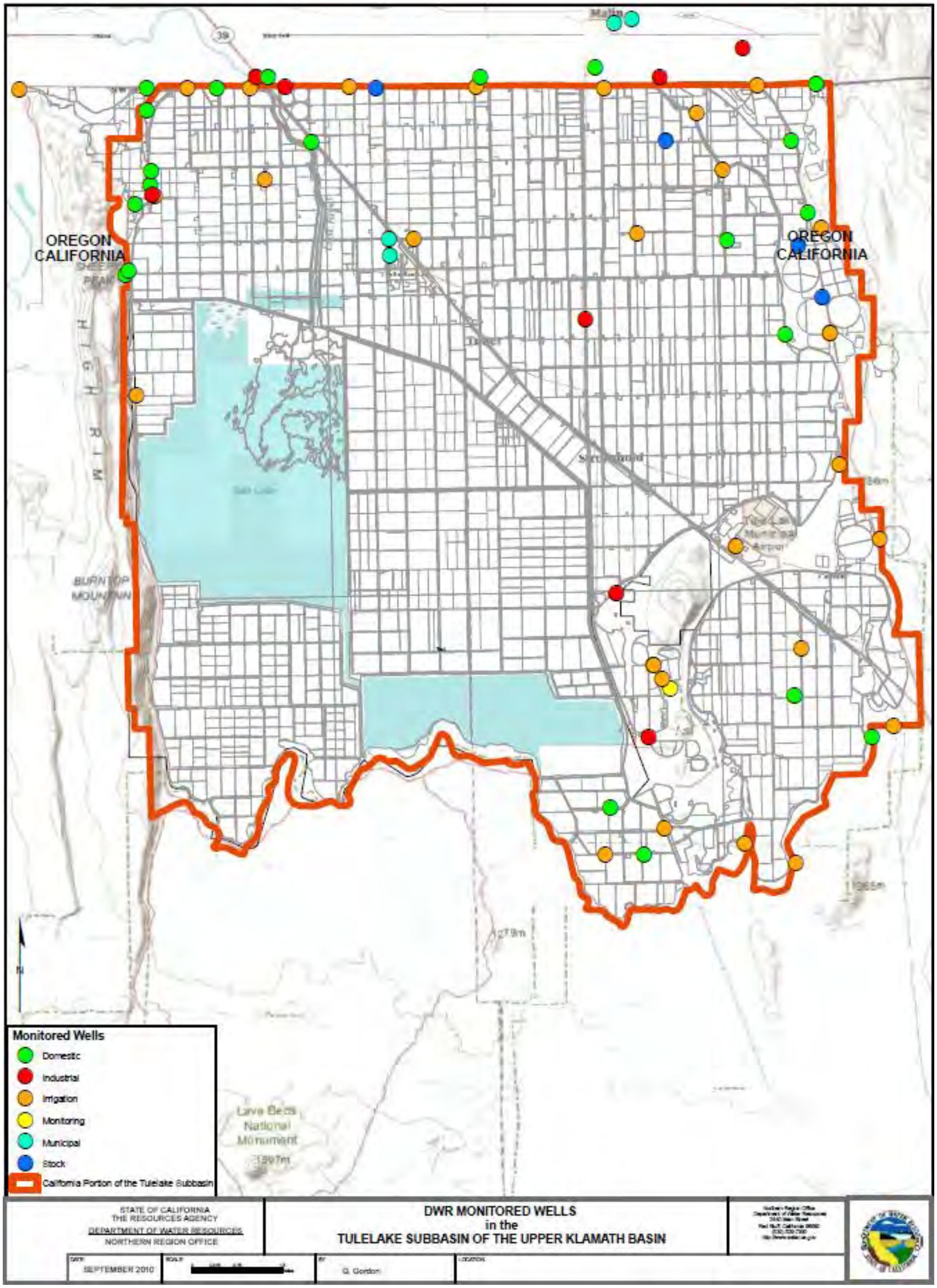
- Lower the electrode probe slowly into the well until the indicator shows that the circuit is closed and contact with the water surface is made. Avoid letting the tape rub across the top of the well casing. Place the tip or nail of the index finger on the insulated wire at the RP and read the depth to water to the nearest 0.1 foot. Record this value in the "DEPTH to WATER" column of the TID Groundwater Field Data Sheet for the appropriate site.

- Record any notable comments, problems, or inaccuracies in the "COMMENT" section for the appropriate site.

## AFTER MAKING A MEASUREMENT:

- Wipe down the electrode probe and the section of the tape that was submerged in the well water, using a disinfectant wipe and rinse thoroughly with de-ionized or tap water. Dry the tape and probe and rewind the tape onto the tape reel. Do not rewind or otherwise store a dirty or wet tape.

## APPENDIX A: DWR TULE LAKE SUBBASIN MONITORING MAP



# APPENDIX B: TID MONITORING WELL INFORMATION

| Local Well ID | TID #1 | TID #2 | TID #3 | TID #4 |
|---|---|---|---|---|
| State Well Number | 48N04E30F002M | 48N04E18J001M | 48N04E16M001M | 48N04E15K001M |
| Reference Point ELEV | 4047.75 | 4057.99 | 4056.23 | 4051.35 |
| Ground Surface ELEV | 4047.05 | 4056.02 | 4055.73 | 4049.60 |
| Well Use | Irrigation | Irrigation | Irrigation | Irrigation |
| Well Status | Active | Active | Active | Active |
| Well Coordinates | E 121.5567 N 41.9721 | E 121.5455 N 41.9980 | E 121.5251 N 41.9979 | E 121.4931 N 41.9978 |
| Well Completion Type | Single | Single | Single | Single |
| Total Well Depth / Drilled Depth | 740 / 740 | 1545 / 1550 | 1680.57 / 1710 | 1432.8 / 1440 |
| Screen Interval #1 | 260-700 | 1260-1540 | 1153.1-1292.32 | 1211.65-1432.8 |
| Screen Interval #2 | -- | -- | 1334.44-1354.46 | -- |
| Screen Interval #3 | -- | -- | 1375.49-1455.58 | -- |
| Screen Interval #4 | -- | -- | 1476.62-1536.82 | -- |
| Screen Interval #5 | -- | -- | 1599.89-1680.57 | -- |
| Screen Interval #6 | -- | -- | -- | -- |
| Well Completion Report Number | 751108 | 751109 | 751110 | 751111 |
| Groundwater Basin of Well | Tule Lake Subbasin 1-2.01 | Tule Lake Subbasin 1-2.01 | Tule Lake Subbasin 1-2.01 | Tule Lake Subbasin 1-2.01 |

| Local Well ID | TID #5 | TID #6 | TID #7 | TID #8 |
|---|---|---|---|---|
| State Well Number | 48N04E13K001M | 48N05E16P001M | 48N05E14R001M | 48N05E26D001M |
| Reference Point ELEV | 4051.44 | 4054.28 | 4068.45 | 4050.29 |
| Ground Surface ELEV | 4050.50 | 4052.38 | 4068.29 | 4049.10 |
| Well Use | Irrigation | Irrigation | Irrigation | Irrigation |
| Well Status | Active | Active | Active | Active |
| Well Coordinates | E 121.4519 N 41.9971 | E 121.4106 N 41.9962 | E 121.3609 N 41.9963 | E 121.3727 N 41.9762 |
| Well Completion Type | Single | Single | Single | Single |
| Total Well Depth / Drilled Depth | 1566.83 / 1570 | 2380 / 2600 | 2020 / 2030 | 1807.35 / 1810 |
| Screen Interval #1 | 935.18-955.18 | 822.61-1084.77 | 814.26-1155.03 | 1247.45-1647.47 |
| Screen Interval #2 | 1015.44-1035.51 | 1375.28-1719.34 | 1255.65-1336.09 | 1662.23-1802.35 |
| Screen Interval #3 | 1075.71-1095.63 | 1805.29-2108.14 | 1396.6-1436.85 | -- |
| Screen Interval #4 | 1135.79-1556.81 | 2257.02-2358.1 | 1497.24-1537.37 | -- |
| Screen Interval #5 | -- | -- | 1577.66-1617.78 | -- |
| Screen Interval #6 | -- | -- | 1678.47-2020 | -- |
| Well Completion Report Number | 751112 | 751113 | 751114 | 751115 |
| Groundwater Basin of Well | Tule Lake Subbasin 1-2.01 | Tule Lake Subbasin 1-2.01 | Tule Lake Subbasin 1-2.01 | Tule Lake Subbasin 1-2.01 |

| Local Well ID | TID #9 | TID #14 | TL-T1 Q3B | TL-T3 GP |
|---|---|---|---|---|
| State Well Number | 48N05E36D001M | 46N05E22D001M | -- | -- |
| Reference Point ELEV | 4049.25 | 4037.78 | 4034.1 | 4047.1 |
| Ground Surface ELEV | 4047.91 | 4037.47 | 4032.7 | 4045.6 |
| Well Use | Irrigation | Irrigation | Observation | Observation |
| Well Status | Active | Active | Inactive | Inactive |
| Well Coordinates | E 121.3555 N 41.9647 | E 121.3955 N 41.8174 | E 121.5420 N 41.8341 | E 121.4697 N 41.8391 |
| Well Completion Type | Single | Single | -- | -- |
| Total Well Depth / Drilled Depth | 2043.04 / 2060 | 567 / 571 | 500/500 | 500/500 |
| Screen Interval #1 | 1060.46-1941.59 | 114.11-234.16 | Open Hole 20-500 | Open Hole 20-500 |
| Screen Interval #2 | 1982.49-2022.54 | 254.14-314.16 | -- | -- |
| Screen Interval #3 | -- | 334.14-554.25 | -- | -- |
| Screen Interval #4 | -- | -- | -- | -- |
| Screen Interval #5 | -- | -- | -- | -- |
| Screen Interval #6 | -- | -- | -- | -- |
| Well Completion Report Number | 751116 | 751117 | -- | -- |
| Groundwater Basin of Well | Tule Lake Subbasin 1-2.01 | Tule Lake Subbasin 1-2.01 | Tule Lake Subbasin 1-2.01 | Tule Lake Subbasin 1-2.01 |

| Local Well ID | Shey-Huffman | Nancy-Huffman | CTW #3 |
|---|---|---|---|
| State Well Number | -- | -- | -- |
| Reference Point ELEV | 4045.2 | 4048.8 | 4038.2 |
| Ground Surface ELEV | 4044.9 | 4047.7 | 4037.6 |
| Well Use | Irrigation | Irrigation | Municipal |
| Well Status | Active | Active | Active |
| Well Coordinates | E 121.3650 N 41.8774 | E 121.3255 N 41.8492 | E 121.4815 N 41.9605 |
| Well Completion Type | Single | Single | Single |
| Total Well Depth / Drilled Depth | 520/520 | 212/212 | 2761 / 2790 |
| Screen Interval #1 | 80-245 | Open Hole 20-212 | 2560.5-2761 |
| Screen Interval #2 | Open Hole 245-520 | -- | -- |
| Screen Interval #3 | -- | -- | -- |
| Screen Interval #4 | -- | -- | -- |
| Screen Interval #5 | -- | -- | -- |
| Screen Interval #6 | -- | -- | -- |
| Well Completion Report Number | 962868 | 782127 | 797943 |
| Groundwater Basin of Well | Tule Lake Subbasin 1-2.01 | Tule Lake Subbasin 1-2.01 | Tule Lake Subbasin 1-2.01 |

# APPENDIX C: TID MONITORING WELL REFERENCE POINT INFORMATION

**Reference points for all monitoring sites are marked with fluorescent orange paint.**

**TID #1:** The reference point is the lip of the sounding tube located on the west side of the well casing

**TID #2:** The reference point is the lip of the sounding tube located on the south side of the well casing

**TID #3:** The reference point is the lip of the sounding tube located on the west side of the well casing

**TID #4:** The reference point is the lip of the sounding tube located on the south side of the well casing

**TID #5:** The reference point is the lip of the sounding tube located on the west side of the well casing


**TID #6:** The reference point is the lip of the sounding tube located on the north side of the well casing

**TID #7:** The reference point is the lip of the sounding tube located on the south side of the well casing

**TID #8:** The reference point is the lip of the sounding tube located on the west side of the well casing

**TID #9:** The reference point is the lip of a hole in the casing located on the north side of the well casing

**TID #14:** The reference point is the lip of the sounding tube located on the west side of the well casing

**Shey-Huffman:** The reference point is the lip of the sounding tube located on the west side of the well casing

**Nancy-Huffman:** The reference point is the lip of a hole in the casing located on the south side of the well casing

**TL-T1:** The reference point is the lip of a hole in the top of the well casing

**TL-T3:** The reference point is the lip of a hole in the top of the well casing

**CTW #3:** The reference point is the lip of a hole in the casing located on the north side of the well casing

## APPENDIX D: TID GROUNDWATER FIELD DATA SHEET

**DATE:** __________ **TID GROUNDWATER FIELD DATA SHEET** **YEAR:** __________

| WELL SITE | CA STATE WELL # | TIME | R/NR | GPM | ACRE FEET | DEPTH to WATER | COMMENTS |
|---|---|---|---|---|---|---|---|
| TID #1 | 48N04E30F002M | | | | | | |
| TID #2 | 48N04E18J001M | | | | | | |
| TID #3 | 48N04E16M001M | | | | | | |
| TID #4 | 48N04E15K001M | | | | | | |
| TID #5 | 48N04E13K001M | | | | | | |
| TID #6 | 48N05E16P001M | | | | | | |
| TID #7 | 48N05E14R001M | | | | | | |
| TID #8 | 48N05E26D001M | | | | | | |
| TID #9 | 48N05E36D001M | | | | | | |
| TID #14 | 46N05E22D001M | | | | | | |
| Q-3-B | | | | | | | |
| Gazebo Point | | | | | | | |
| Shey-Huffman | | | | | | | |
| Nancy-Huffman | | | | | | | |
| City of Tulelake | | | | | | | |

# Appendix K.
# Numerical Flow Model Documentation

# Numerical Flow Model Documentation

Appendix K

September 2021

Tulelake Subbasin Groundwater Sustainability Agencies

## Contents

# 1. Introduction

On behalf of the Tulelake Subbasin Groundwater Sustainability Agencies (GSAs), CH2M HILL Engineers, Inc. (CH2M and now Jacobs Engineering Group, Inc. [Jacobs]) has developed an integrated groundwater/surface-water flow model of an area encompassing the Tulelake groundwater Subbasin (Subbasin) in portions of Siskiyou and Modoc Counties, California and extends to the north of the Subbasin within Klamath County, Oregon. This report, prepared by Jacobs, documents the development, calibration, and application of this numerical model to support the four GSAs in preparation of a Groundwater Sustainability Plan (GSP). This model is hereafter referred to as the GSA Model to differentiate it from other numerical models developed in recent years for this area and to emphasize its intended use to support the GSAs in the development of the GSP.

The GSA Model integrates the three-dimensional (3D) groundwater and surface-water systems, land surface processes, and water management operations. Development of this model included the assimilation of information on land use, water infrastructure, hydrogeologic conditions, and agricultural water demands and supplies. The GSA Model was built upon two existing numerical groundwater flow models for the region developed by the United States Geological Survey (USGS) (Gannett et al., 2012, and Pischel et al., 2015). The GSA Model is based upon the best available data and information as of January 2020. It is expected that this model will be updated as additional monitoring data are collected and analyzed and as knowledge of the hydrogeologic conceptual model evolves during implementation of the GSP.

The center of the Subbasin is located at latitude 41.94°N and longitude 121.42°W, approximately 300 miles north of downtown Sacramento. **Figure 1-1** (figures are located at the end of their respective sections) shows the location of the Subbasin. The study area boundary (shown in yellow in **Figure 1-1**) was selected to coincide with natural hydrologic features, such as catchment and Subbasin (1-002.01) boundaries, to help establish a hydrologic framework for the GSA Model.

## 1.1 Background

In 2014, in response to the continued overdraft of many of California's groundwater basins, the State of California enacted the Sustainable Groundwater Management Act (SGMA) to provide local and regional agencies the authority to sustainably manage groundwater. The Tulelake Subbasin is subject to SGMA because it is one of 127 basins and subbasins identified in 2014 by the California Department of Water Resources (DWR) as being medium- or high-priority, based on population, groundwater use, and other factors. Under SGMA, high- and medium-priority basins not identified as critically overdrafted must be managed according to a GSP by January 31, 2022. DWR has identified the Tulelake Subbasin (1-002.01) as a medium-priority subbasin. SGMA requires medium-priority groundwater subbasins being managed by a groundwater sustainability agency to reach or maintain sustainability within 20 years of implementing its GSP. Within the framework of the SGMA, sustainable groundwater management is defined as the management and use of groundwater in a manner that can be maintained during the planning and implementation period without causing undesirable results. The GSA Model has been developed to help prepare water budgets and guide planning efforts associated with the GSP.

## 1.2 Modeling Objectives

The modeling objectives include the following:

- Support development of land, surface water, and groundwater budgets for historical, current, and future conditions within the Tulelake Subbasin to support preparation of the GSP.
- Help guide the development of sustainable management criteria (SMC) as part of the GSP process.
- Support refinement of monitoring networks during implementation of the GSP, if needed.

- Provide insights into how implementation of projects and management actions, if needed, could potentially affect groundwater conditions during implementation of the GSP.

The GSA Model is only one line of analysis being used to help the GSAs develop and implement its GSP. This model will not ultimately "decide" whether the Subbasin is being managed sustainably. Collection, reporting, and analysis of field data during GSP implementation will be used in conjunction with SMC to demonstrate to DWR whether the Subbasin is being managed sustainably. One of the main purposes of the model is to provide plausible water budgets associated with potential future conditions, so the GSAs can develop a plan for the continued responsible management of the Subbasin.

## 1.3 Model Function

To achieve the modeling objectives, the GSA Model was developed and calibrated using available data and professional judgment. This 3D model was constructed and calibrated to simulate monthly groundwater and surface-water flow conditions within a 610 square mile ($mi^2$) area encompassing the Subbasin. The USGS codes MODFLOW-OWHM: One Water Hydrologic Flow Model version 2 (Boyce et al., 2020) and the Basin Characterization Model version 8 (Flint et al., 2013; Flint and Flint, 2014) were used in conjunction with the graphical-user-interface Groundwater Vistas version 8 (Environmental Simulations Inc., [ESI], 2020) and other custom utilities to develop and use the GSA Model to achieve the modeling objectives. Subsequent sections of this report provide additional details regarding the development and application of the GSA Model.

## 1.4 Model Assumptions and Limitations

The development of the GSA Model included the following assumptions and limitations:

- Subsurface geologic materials, including granular unconsolidated material (e.g., gravel, sand, silt, and clay), and volcanic material (weathered and competent) are all modeled as equivalent porous media.
- Groundwater and surface water are modeled as a single-density fluid.
- Monthly stress periods have been incorporated into the simulations. As such, variations in flow processes that occur within a given month are not explicitly simulated; instead, monthly average flow rates are implemented.
- In the absence of detailed well logs, assumptions had to be made regarding well construction and locations for some of the pumping wells represented in the model.
- Mathematical models like the GSA Model described herein can only approximate surface and subsurface flow processes, despite their high degree of precision. A major cause of uncertainty in these types of models is the discrepancy between the coverage of measurements needed to understand site conditions and the coverage of measurements generally made under the constraints of limited time and budget (Rojstaczer, 1994).
- Because the GSA Model is a flow model, it cannot perform solute transport calculations. Therefore, it cannot directly provide estimates or forecasts of constituent concentrations in the modeled environment. Therefore, other approaches are being implemented to support the GSA in addressing water quality aspects of its GSPs.

Given these assumptions and limitations, numerical flow models like the GSA Model should be considered tools to provide insight and qualitative projections of future conditions. Therefore, important planning decisions that use output from the GSA Model must be made with an understanding of the uncertainty in and sensitivity to model input parameters. These planning decisions should also consider other site data, local and regional drivers, professional judgment, and the inclusion of safety factors.

# 2. Conceptual Model Overview

The Subbasin is a portion of Upper Klamath River Groundwater Basin located in California and Oregon. The subbasin is bounded to the west by the Gillems Bluff Fault which extends beneath and is a major structural feature of the Medicine Lake volcanic highlands (Lavine 1994). The fault forms the steep eastern escarpment of Sheepy Ridge, which separates the Tule Lake and Lower Klamath subbasins (DWR 2003b). The basin boundary extends to the fault-controlled drainage divide between the Tule Lake and Lower Klamath Lake subbasins (the crest of Sheepy Ridge). Volcanic deposits extend eastward from the crest beneath the Quaternary sediment and are penetrated by wells, which are producing from the volcanic deposits on the west margin of the basin (Gannett 2016). The subbasin is bounded to the east by the Saddle Blanket Fault Zone, a north-trending normal fault which forms the western edge of the block faulted mountains between Tule Lake and Clear Lake Reservoir. The subbasin extends to a portion of the Quaternary volcanic deposits which includes irrigation wells (Gannett et al. 2007). Clear Lake Reservoir is the headwaters of Lost River. Lost River flows north into Oregon, and meanders through the Poe and Langell valleys before it flows south into California and ends at the Tule Lake sump (DWR 2003b). The subbasin is bounded to the south by the low-lying volcanic fields on the north slope of the Medicine Lake Highlands. Medicine Lake occupies the crater at the peak of this large, relatively young shield volcano. The subbasin includes the Peninsula and extends to the east to the Saddle Blanket Fault Zone. Wells in these areas where the volcanics are exposed, mostly produce from the surficial volcanic deposits, but some wells penetrate through the surficial deposits and underlying basin-filling sediments to the underlying volcanic strata (Gannett 2016). To the north, the basin extends into Oregon and is bounded by northwest trending normal faults on the south side of the mountain block dividing Poe Valley from the Tule Lake Subbasin. Approximately two thirds of the subbasin are in California. For the purposes of this Groundwater Sustainability Plan and SGMA, the subbasin is bounded to the north by the state boundary of Oregon and California.

Local precipitation and infiltration of surface water from the channels, lakes and sumps of the Lower Klamath and Tule Lake subbasins provide recharge for the alluvial aquifer system. Water levels in the alluvial aquifer fluctuate seasonally in response to canal and irrigation operations (DWR 2003a). Surface water supplies available to the Tulelake Irrigation District provide an unknown amount of groundwater recharge. These surface water supplies include natural flow from the Klamath River, stored water from Upper Klamath lake and Lake Ewauna, return flows from upstream irrigation, and flow from the Lost River.

Aquifer discharge occurs when groundwater is extracted by wells, discharges to streams, is evapotranspired by phreatophytes, or flows out of the groundwater basin in the subsurface (DWR 2003a). Most groundwater production in the Tule Lake Subbasin is from the underlying volcanic strata, volcanic deposits on the periphery of the basin, and volcanic deposits that partly overlie basin-filling sediment in the Peninsula area. However, wells in any of these areas may produce from surficial volcanic deposits, basinfilling sediments, or underlying volcanic strata (Pischel and Gannett 2015). In general, interbasin groundwater flow from the Tule Lake Subbasin is southward (Gannett, et al. 2007).

# 3. Numerical Model Construction

## 3.1 Code Selection

The USGS code MODFLOW-OWHM: One Water Hydrologic Flow Model (OneWater) version 2 (Boyce et al., 2020) was selected for this modeling effort, in conjunction with the graphical-user-interface Groundwater Vistas version 8 (ESI, 2020) and other custom utilities to develop the GSA Model. OneWater is an updated formulation, built upon the MODFLOW-2005 (Harbaugh, 2005) framework. OneWater accommodates the development of a 3D, physically based, spatially distributed, integrated groundwater/surface-water flow model. The OneWater code was selected for the following reasons:

- OneWater is based on MODFLOW-2005, which has been used extensively in groundwater evaluations worldwide for many years and is well-documented. OneWater contains an improved solution scheme that can handle a variety of complex, variably saturated flow conditions, which are relevant to groundwater conditions in the Subbasin.
- OneWater has been benchmarked and verified, so the numerical solutions generated by the code have been compared with analytical solutions, subjected to scientific review, and used on other modeling projects. Verification of the code confirms that OneWater can accurately solve the governing equations that constitute the mathematical model.
- OneWater accommodates a comprehensive suite of groundwater and surface-water boundary conditions.

### 3.1.1 Numerical Assumptions

OneWater is conceptualized mathematically into two hydrologic flow regimes: surface flow and subsurface flow. The surface-flow regime, as configured for the GSA Model described herein, includes runoff, and channel flow interaction with the subsurface. The subsurface-flow regime underlies the surface-flow regime and includes variably saturated zones representing porous media through which groundwater flows and can interact with the surface-flow regime.

### 3.1.2 Scientific Basis

The theory and numerical techniques that are incorporated into OneWater have been scientifically tested. The governing equations of variably saturated subsurface flow have been solved by several modeling codes over the past few decades, on a wide range of field problems. Therefore, the scientific basis of the theory and the numerical techniques for solving these equations have been well-established. The OneWater user's manual (Boyce et al., 2020) detail the governing equations and other information on the codes.

### 3.1.3 Data Formats

Several American Standard Code for Information Interchange (ASCII) data files were used to parameterize the GSA Model. **Table 3-1** shows the grouping of various data items in the GSA Model input files.

Table 3-1. OneWater Input File Description

| File Extension | Version | Purpose [a] | Parameters [a,b] |
|---|---|---|---|
| BAS | 6 | • Basic Package establishes active and inactive cells and initial heads | • IBOUND array by layer (active domain)<br>• Initial heads by layer |
| DIS | NA | • Discretization Package establishes information on how time and space are subdivided<br>• Establishes whether the numerical solution is steady state or transient | • Grid cell dimensions<br>• Layer interface elevations<br>• Stress period durations<br>• Number of time steps per stress period<br>• Time step multiplier<br>• Stress period type (steady state or transient) |
| UPW | 1 | • Upstream Weighting Package contains aquifer hydraulic parameters, which constrain flow between model cells | • Horizontal and vertical hydraulic conductivity<br>• Groundwater storage parameters |
| FMP | 4 | • Farm Process contains soil, vegetation, water source, and water use information<br>• Controls supply and demand to facilitate computation of runoff, groundwater recharge from precipitation and applied water, and agricultural pumping | • Consumptive use terms<br>• Soil type<br>• Rooting depths<br>• Irrigation efficiency<br>• Groundwater root flag and root pressures<br>• Capillary fringe<br>• Vadose zone options<br>• ET factors<br>• Water source and delivery information<br>• Irrigation fractions |
| GHB | OWHM | • General-Head Boundary Package controls groundwater inflow and outflow from the Tulelake Sumps and through lateral subsurface boundaries | • Boundary head and conductance by stress period<br>• Model layer designations |
| RIV | OWHM | • River package controls surface water and groundwater exchanges associated with the Lost River and primary conveyance canals within the Subbasin | • Boundary head and conductance by stress period<br>• Model layer designations |
| DRT | 7 | • Drain Return Package directs rejected recharge to streams | • Drain head and conductance<br>• Recipient SFR nodes for drained groundwater |
| MNW | 2 | • Multi-Node Well Package simulates agricultural groundwater pumping | • Well dimension and construction information<br>• Groundwater pumping rate by stress period<br>• Model layer(s) designations |
| NWT | 1.2.0 | • Newton Solver solves the governing flow equations | • Solver iteration and closure terms<br>• Backtracking and other solver options |
| NAM | NA | • Name File specifies names of input and output files | • No parameters are included |
| OC | NA | • Output Control File specifies the type of runtime information to write to output files | • User-defined print and save statements |

[a] As implemented in the GSA Model. Alternative uses of the package are also possible.

[b] Not intended to be an exhaustive list of input parameters. Please see the model code documentation and online resources for additional information.

NA = not applicable, because it is built into the main OneWater code

Output from the GSA Model also follows the USGS MODFLOW output file formats and includes ASCII as well as binary files. Although a variety of optional output files can be generated with the OneWater code, **Table 3-2** summarizes the main output files used for this modeling effort.

Table 3-2. Selected OneWater Output File Description

| File Name or Extension | Content |
|---|---|
| LST | • ASCII listing file containing runtime information included in the simulation |
| FB-Details | • ASCII file containing Farm Process inflows and outflows by water balance subregions for all output times |
| FDS | • ASCII file containing supply and demand information for all output times |
| HDS | • Binary file containing cell-by-cell modeled groundwater elevations for all output times |
| CBB | • Binary file containing cell-by-cell subsurface flows for all output times |

## 3.2 Model Domain

A numerical model must use discrete space to represent the hydrologic system. The simplest way to discretize space is to subdivide the study area into many subregions (i.e., grid blocks) of the same size. This grid-building strategy was implemented for this modeling effort and is described in the following subsections. The model domain of the GSA Model was developed to fully encompass the Tulelake Subbasin as defined by the final Basin Boundary Modifications distributed in 2018 by the California Department of Water Resources (DWR). In general, the model boundary was extended beyond the Tulelake Subbasin to the watershed margins to fully capture the extent of the greater basin from which water may contribute to the Tulelake Subbasin. In some instances, there are boundaries for which the contributing area intersects lower elevations within valleys from which the GSP Model extent was delineated. At these locations, groundwater elevations will be prescribed based on available groundwater elevation data to account for potential flow across these boundaries as discussed in Section 3.7.2.1.

### 3.2.1 Areal Characteristics of Model Grid

The GSA Model grid mathematically represents a 610-square-mile area that includes the Subbasin and a portion of the surrounding contributing area. The model grid is aligned north-south and east-west and georeferenced to the 1983 North American Datum (NAD83) of the Universal Transverse Mercator (UTM) Zone 10 North coordinate system, in units of U.S. feet. The GSA Model boundary follows hydrologic boundaries surrounding the Subbasin to encompass areas that are potentially hydraulically connected to the Subbasin. Figure 3-1 shows the GSA Model domain, which is partitioned into grid blocks (i.e., cells) horizontally spaced on 250-foot centers, which results in 272,064 active cells per model layer. The 250-foot cell spacing allows for sufficient spatial resolution to support development of water budgets for the GSP.

### 3.2.2 Vertical Characteristics of Model Grid

The GSA Model was subdivided into six vertically stacked layers to provide a 3D representation of the principal aquifers. Table 3-3 lists the model layer designations and thicknesses. These layers were developed to provide sufficient vertical resolution to facilitate the following:

- Evaluation of the effects of groundwater pumping on shallow and regional water resources
- Assignment of pumping stresses to appropriate depths within the aquifer that reflect the major producing zones within the aquifer system

Table 3-3. Summary of Model Layers

| Model Layer | Description | Model Layer Thickness (feet) | Depth of Layer Bottom (feet bgs) |
|---|---|---|---|
| 1 | • Comprised primarily of quaternary sedimentary deposits within Subbasin surrounded by quaternary volcanic rocks, and tertiary volcanic rocks | 0.4 to 3,743 | 0.4 to 3.743 |
| 2 | • Comprised primarily of tertiary sedimentary rocks within the Subbasin surrounded by tertiary volcanic rocks | 183 to 900 | 202 to 3,943 |
| 3 | • Comprised primarily of tertiary sedimentary rocks within the Subbasin surrounded by tertiary volcanic rocks | 183 to 900 | 402 to 4,143 |
| 4 | • Comprised primarily of tertiary mixed sedimentary and volcanic deposits within the Subbasin surrounded by tertiary volcanic rocks | 300 to 800 | 935 to 4,818 |
| 5 | • Comprised primarily of tertiary mixed sedimentary and volcanic deposits within the Subbasin surrounded by tertiary volcanic rocks | 300 to 800 | 1420 to 5,493 |
| 6 | • Comprised primarily of tertiary mixed sedimentary and volcanic deposits within the Subbasin surrounded by tertiary volcanic rocks | 200 to 1,100 | 1,931 to 6,593 |

bgs = below ground surface

Model Layers 1 and 2 are set as unconfined, convertible layers to allow transmissivity to vary temporally and spatially according to the layer's saturated thickness and horizontal hydraulic conductivity. Model Layers 3, 4, 5, and 6 are set as confined, so transmissivity only varies spatially according to the cell thickness and horizontal hydraulic conductivity therein.

Model Layers 1 and 2 are set as unconfined, convertible layers to allow transmissivity to vary temporally and spatially according to the layer's saturated thickness and horizontal hydraulic conductivity. Model Layers 3, 4, 5, and 6 are set as confined, so transmissivity only varies spatially according to the cell thickness and horizontal hydraulic conductivity therein.

Layer thicknesses were devised based on the USGS regional model and DWR derived top of volcanic contours and cross-sections developed as part of the Upper Klamath Basin Hydrogeologic Investigation (DWR, 2003). Model Layer 1 thicknesses of the GSP Model were established to be the same thickness of the USGS regional model. Total thickness of Model Layers 2 and 3 of the GSP Model were initially established based on the Layer 2 thicknesses of the USGS model. Model Layer 3, however, was modified to better reflect the bottom of basin fill sediments based on DWR top of volcanic structure contours and cross-sections. Model Layers 4 and 5 were split into an even thickness to capture screening intervals from pumping wells that extend through these depths. Finally, Model Layer 6 was extended beyond the deepest pumping wells in the region to provide an adequate buffer between the deepest pumping wells and the bottom most layer of the GSP Model.

## 3.3 Surface Parameters

The surface parameters required by the GSA Model are the land surface elevations, surface water feature characteristics, soils distribution, land use, and water balance subarea distribution.

### 3.3.1 Topography

A 10-meter digital elevation model (DEM) raster dataset along with 1-meter LiDAR data forms the basis for land surface elevations covering the modeling domain. These land surface elevations were assigned to the top of Model Layer 1. Elevation data were processed using ArcGIS Version 10 software. **Figure 3-2** illustrates the land surface elevations incorporated into the top of the model grid.

### 3.3.2 Soils Data

Soils data were obtained from the Natural Resource Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) for the extent of the GSA Model. SSURGO data were processed to obtain a distribution of texture classification across the model domain. Texture classification was then translated into a simulated soil category to serve as input to FMP (**Table 3-4**). Dominant soil type was then assigned to each model grid cell based on the spatial distribution of each simulated soil category (**Figure 3-3**). Default soil categories

Table 3-1 - Translation of NRCS Texture Class to Simulated Soil Category

| Simulated Soil Category | Texture Classification |
|---|---|
| Sand | Sand |
| | Cinders |
| | Fragmental Material |
| Sandy Loam | Clay Loam |
| | Silty Clay Loam |
| | Silty Clay |
| | Clay |
| Silty Clay | Loamy Sand |
| | Sandy Loam |
| | Loam |
| | Slightly Decomposed Plant Material |
| | Silt Loam |
| | Cobbly Loam |
| | Stony Loam |
| | Gravelly Loam |
| | Gravelly Sand |
| | Unweathered bedrock |

### 3.3.3 Surface Water Features

Within the Subbasin a complex series of conveyance systems exist that are used to convey water throughout the Tulelake Irrigation District (TID). The following sections provide a description of these surface water conveyance features and their characterization for implementation in the GSA Model.

#### 3.3.3.1 Lost River and Tulelake Irrigation District Conveyance System

TID is comprised of a system of main canals and canal laterals that receive water from the Lost River and other conveyance systems in the Oregon extent of the GSA Model. **Figure 3-4** presents the extent of TID's main canals, canal laterals, and Lost River as simulated in the GSA Model. Flow through the Lost River is diverted into TID's conveyance system from which water is distributed throughout the Subbasin to provide water for irrigation use.

Assumptions associated with the simulation of these surface water features is discussed further under Section 3.7.2.2.

Adjacent to TID's main canals and laterals are a series of open-ditch drains that are used to drain agricultural fields and convey water throughout the irrigation district. Figure 3-5 presents the extent of TID's drain system through the Subbasin as simulated in the GSA Model. Assumptions associated with the simulation of TID's drain system is discussed further under Section 3.7.2.3.

#### 3.3.3.2 Tulelake Sumps

Within the Subbasin exist two surface water features, referred to as the Tulelake Sumps, that serve as important habitat for wildlife refuge, collection and containment of drainage water and flood flows, and to supply irrigation water throughout the Subbasin (WMP, 2017). Figure 3-6 presents the extent of the Tulelake Sumps as simulated in the GSA Model. The Tulelake Sumps are operated in accordance with the United States Fish and Wildlife Service Biological Opinion dated July 13th, 1998 and the 1999 Regulation for Tule Lake Sump Modified Rules. The Biological Opinion prescribes water level requirements throughout the year in order to maintain appropriate conditions to prevent flooding and to provide suitable habitat for wildlife. To control water-levels in the Tulelake Sumps, TID recirculates water from the sumps into the irrigation system and utilizes the D-Plant pumping station to remove water from the Tulelake Sumps. The location of the D-Plant pumping station is shown in Figure 3-6. Water removed through D-Plant is pumped through Sheepy Ridge to the west providing water to refuges and conveyance systems to the west of the Subbasin. Assumptions associated with the simulation of the Tulelake Sumps is discussed further under Section 3.7.2.4.

### 3.3.4 Land Use

#### 3.3.4.1 Tulelake Subbasin

Available land use datasets were compiled from Modoc and Siskiyou Counties and TID to establish a set of land use conditions throughout the Tulelake Subbasin. Within the Tulelake Subbasin, land use is primarily comprised of agricultural crop categories along with some riparian and native vegetation and urban areas. Riparian and native vegetation areas were assumed to persist throughout the analysis period of the GSA Model as established through the county datasets. However, two sets of agricultural conditions were identified, as discussed in the following paragraphs, to establish two sets of land use conditions within TID representing 2008 (Figure 3-7) and 2010 (Figure 3-8) conditions.

TID annual crop acreage data for years 2000 through 2018 were analyzed to develop crop categories and land use conditions that could be simulated in the GSA Model. Crop categories provided in the TID reports were lumped into six different crop categories for inclusion in the GSA Model based on similar annual crop consumptive use requirements of each crop type. Crops with similar demands were combined to create a single category for simulation in the GSA Model (Table 3-1). In general, the predominant crop types within TID are alfalfa, grains, mint, potatoes, and pasture. Mint, potatoes and a number of other crops were combined based on similar consumptive use requirements into an 'All Other Crops' category.

Table 3-1 presents crop acreage for the 2008 and 2010 periods based on the GSA Model crop category and the associated TID crop report category. Generally, the crops grown within TID have been relatively stable over the analysis period, however, there are years where significant idling of fields can occur due to availability of water and various water management programs instituted to support farmers in fallowing fields within a given year. Most notably are the years 2001 and 2010 when significant idling occurred throughout TID. Based on the crop acreage trends, two years were selected to represent two separate land use conditions throughout TID. First, the year 2008 was selected to represent average conditions within TID, where the acreages reflected the crop distribution in a normal or average year (Figure 3-7). The year 2010 was selected to represent years in which significant idling occurred as the idle acreage in this year was deemed to represent average idle conditions in TID

(**Figure 3-8**). The 2010 land use acreage was used to represent land use in the GSA Model for the years of 2001, 2010, and 2014-2015 when crop idling occurred. All other years during the simulation period have been assigned 2008 land use conditions.

Table 3-2 Simulated Crop Category and Average TID Crop Acreage for Historical Period

| Model Category | TID Crop Report Category | 2008 Acreage | 2010 Acreage |
|---|---|---|---|
| Alfalfa | Alfalfa | 19,921 | 16,120 |
| | Other Hay | 2,541 | 3,564 |
| All Other Crops | Onions | 2,449 | 1,874 |
| | Mint | 2,584 | 3,035 |
| | Beets | 0 | 0 |
| | Peas | 153 | 0 |
| | Horseradish | 436 | 358 |
| | Strawberries | 0 | 81 |
| | Potatoes/Spuds | 8,033 | 5,770 |
| Grains | Barley | 3,582 | 8,030 |
| | Wheat | 17,471 | 9,850 |
| | Oats | 114 | 360 |
| | Rye | 40 | 55 |
| Idle | Idle | 1,863 | 11,695 |
| | House/Farmstead | 658 | 671 |
| Pasture | Pasture | 1,283 | 1,314 |
| Urban | Res. Comm. Ind. | 289 | 338 |

#### 3.3.4.2 Oregon Klamath Project Water Users and Private Groundwater Pumping

While the primary focus of the GSA Model is to simulate groundwater conditions in the Tulelake Subbasin, significant irrigation occurs just beyond the California-Oregon border, to the north of the Subbasin. Similar to Tulelake Irrigation District, most of the area within the Oregon portion of the GSA Model domain are comprised of water users that receive surface water supply from the Bureau of Reclamation's Klamath Project. Limited spatially distributed land use data for these water users was available during the development of the GSA Model. Thus, estimates of irrigable acreage and crop consumptive use for the year 2008 were used from the On-Project Plan (OPP) to help inform potential consumptive use quantities of water for areas within the Oregon portion of the GSA Model domain. **Table 3-3** presents estimates of irrigable acreage, consumptive use, water requirements, and on-farm efficiencies for districts within the Oregon portion of the GSA Model domain

Based on the estimated on-field water requirement for these irrigation districts, the regions within GSA Model for each irrigation district was assigned a crop coefficient based on the Alfalfa crop which has an approximate water requirement of 33 acre-inch per acre which aligns closely to the on-field water requirements presented in **Table 3-3**.

Table 3-3 Estimates of Crop Consumptive Use for Oregon Based Irrigation Districts

| District Name | Total District Irrigable Acreage[1] | Consumptive Use (AFY) | On-Field Water Requirement (AFY) | On-Field Water Requirement (Acre-Inch/acre) | On-Farm Efficiency Estimate |
|---|---|---|---|---|---|
| Klamath Irrigation District | 49,980 | 116,570 | 140,060 | 33.6 | 0.83 |
| Malin Irrigation District | 3,480 | 8,080 | 9,700 | 33.4 | 0.83 |
| Shasta View Irrigation District) | 4,900 | 11,140 | 13,360 | 32.7 | 0.83 |
| Van Brimmer Ditch Company | 4,790 | 11,560 | 14,220 | 35.6 | 0.81 |
| [1]Total District acreages presented represent the total acres within the Klamath Project and does not necessarily reflect District acreages contained in the GSA Model. | | | | | |

#### 3.3.4.3 Private Lands

Most of the irrigated agricultural lands within the GSA Model are within the Klamath Project and receive a surface water supply. However, there are some areas where agriculture is dependent solely on groundwater pumping. Limited information is known regarding irrigation demands, on-farm efficiency, and well locations for these areas. Areas were identified through discussions with local stakeholders and through consultation of aerial imagery to identify areas outside of known water purveyor service areas that appear to contain irrigated agriculture. Consumptive use estimates for these areas were assumed to be consistent with an alfalfa crop.

### 3.3.5 Water Balance Subarea Delineation

As part of FMP development, water balance subareas (WBS) are designated to help control supply and demand specifications and input and output data. WBS specification for the GSA Model were delineated based primarily on TID distribution systems, Klamath Project water users within the GSA Model domain, and areas that are deemed irrigated but do not receive water as part of an irrigation district. **Figure 3-9** presents the distribution of WBS throughout the GSA Model domain.

## 3.4 Subsurface Flow Parameters

The subsurface hydraulic parameters required by the GSA Model are the horizontal hydraulic conductivity (Kh), vertical hydraulic conductivity (Kv), specific yield (Sy), and specific storage (Ss).

### 3.4.1 Hydraulic Conductivity

Initial hydraulic conductivity distributions and parameterizations were adopted from Upper Klamath Basin groundwater flow model developed by the USGS (Gannett et al., 2012). **Figure 3-10** presents hydraulic property zonation for layers 1 through 3 from the upper Klamath Basin model as presented in Gannett et al., 2012. In layer 1, the Tulelake region is comprised of primarily quaternary sediments throughout the Subbasin with quaternary volcanic deposits to the south of the Tule Lake Sumps. In layer 2, the majority of the Subbasin is comprised of tertiary sediments of younger basins and tertiary volcanic rocks to the south. Finally, in Layer 3, the Subbasin is comprised of primarily tertiary mixed sedimentary and volcanic deposits with tertiary volcanic rocks to the south. **Table 3-4** presents the hydraulic conductivity and vertical anisotropy ratio for each the primary units in layers 1 through 3 from the Upper Klamath Basin Model (Gannett et al., 2012). Parameterization and zonation of subsurface hydraulic properties were adapted from the Upper Klamath Basin model for the GSA

Model. Additional layer and parameter refinements were made during the calibration process of the GSA model as discussed in Sectio 4.

Table 3-4 – Upper Klamath Basin Model Hydraulic Conductivity

| Layer | Lithology | Hydraulic Conductivity (feet/day) | Vertical Anisotropy [Kh:Kv] |
|---|---|---|---|
| 1 | Quaternary sediment | 501 | 18 |
| | Quaternary volcanic deposits | 1 | 100 |
| 2 | Tertiary sediments – Younger basins | 25 | 250 |
| | Tertiary volcanic rocks | 10 | 1000 |
| 3 | Tertiary mixed sedimentary volcanic deposits | 1 | 10 |
| | Tertiary volcanic rocks | 50 | 22 |
| Vertical anisotropy represents the ratio of horizontal hydraulic conductivity to vertical hydraulic conductivity. | | | |

### 3.4.2 Groundwater Storage

Groundwater storage (i.e., storativity) is handled through the assignment of two parameters, including the Specific Yield (Sy) and Specific Storage (Ss). Model Layers 1 and 2 are set as unconfined, convertible layers to allow transmissivity to vary temporally and spatially according to the layer's saturated thickness and Kh. These model layers require the user to input both Sy and Ss values, which can vary on a cell-by-cell basis. If a model cell during a given stress period in Model layers 1 or 2 is fully saturated, then the model computes a storativity as the product of the Ss and cell thickness. If a model cell during a given stress period in Model layers 1 or 2 is partially saturated, then the model uses the Sy. Model layers 3, 4, 5, and 6 are set as confined, so the model computes for each stress period a storativity value as the product of the Ss and cell thickness for these model layers. Thus, groundwater storage properties do not vary temporally in Model layers 3, 4, 5, and 6. The GSA Model was initially assigned uniform Sy and Ss values of 10 percent and 1×10-6 per foot ($ft^{-1}$), respectively, based on literature values and professional judgement. Section 4 describes the modification of these values during the calibration process.

## 3.5 Time Discretization

The calibration version of the GSA Model simulates historical hydrologic conditions from October 1997 through September 2018, whereas the projection version of the GSA Model simulates future hydrologic conditions from October 2018 through September 2071. All versions of the GSA Model include monthly stress periods to adequately simulate seasonal hydrologic processes.

## 3.6 Initial Flow Conditions

The establishment of a transient GSA Model necessitates establishment of initial flow conditions in the hydrologic system. Initial conditions refer to the initial distribution of heads (i.e., groundwater elevations) throughout the model domain. Initial conditions for the calibration simulations were established in a "spin-up" manner. This step involved assigning initial heads intended to approximate September 1997 conditions and then allowing the monthly stress periods to "work through" the monthly conditions through September 1999 (i.e., the end of the spin-up period). Additionally, most data used in development of GSA Model boundary conditions started in the year 2000. Therefore, model output data from the spin-up period are not included in the assessment of calibration or water budgets. Thus, presentation of calibration results and water budgets described in Sections 4 and 5 are representative of October 1, 1999 through September 30, 2018 (i.e., WYs2000 through 2018).

## 3.7 Boundary Conditions

### 3.7.1 Specified-flux Boundaries

The following section describes boundary conditions in the GSA Model where either a volumetric or linear flux is used to simulate various flow processes.

#### 3.7.1.1 Precipitation and Reference Evapotranspiration

FMP requires input of precipitation and reference evapotranspiration to establish climatic conditions in the land surface system water budget. Precipitation and reference evapotranspiration were processed from the US. Geological Survey (USGS) Basin Characterization Model (BCM) (Flint et al., 2013). BCM utilized a down-scaling approach to process PRISM based climate data from 800-meter down to 270-meter resolution to provide more spatial variability. Precipitation and reference evapotranspiration data were then sample to each model grid cell of the GSP Model to provide monthly precipitation and reference evapotranspiration rates throughout the model domain for the entire model simulation period.

**Figure 3-11** presents annual precipitation totals based on the gridded BCM data mapped across the extent of GSA Model. On average, the region experiences approximately 13.6 inches per year with a low of 7.9 inches per year in water year 2001 and a maximum of 21.6 inches per year in water year 1998.

An analysis was conducted to compare the BCM based gridded reference evapotranspiration to an average of two local AgriMET stations in the Klamath Region (Klamath Falls and Worden stations). **Figure 3-12** presents annual estimates of reference evapotranspiration based on an average of all grid cells in the model domain versus the average of the two AgriMET stations. In general, the AgriMET stations measured a larger amount of annual reference evapotranspiration as compared to the gridded BCM data. In part, this is due to the reference crop from the AgriMET stations being based on alfalfa rather than a short or long grass reference crop. Based on this comparison, and the difference in reference crops, a correction factor was applied to the BCM gridded data to better reflect local measurements of reference evapotranspiration and the alfalfa reference crop.

**Figure 3-13** presents monthly average BCM potential evapotranspiration before and after adjusting to local AgriMET station data. In general, the applied correction factor increases reference evapotranspiration from May through September during the irrigation season of the region.

#### 3.7.1.2 Consumptive Use

To estimate crop consumptive use, FMP utilizes reference evapotranspiration and crop coefficients to determine a crop specific consumptive use estimate. Monthly crop coefficients were developed based on AgriMET station data for crop specific actual evapotranspiration in conjunction with the reference evapotranspiration. **Figure 3-14** presents monthly crop coefficients (Kc) for each of the GSA Model crop categories. Consumptive use is related to the Kc and $ET_0$ based on **Equation 3-1**, as follows:

$$\text{Consumptive Use} = Kc \times ET_0 \qquad (3\text{-}1)$$

Kc values were associated with crop category and land use polygon throughout the model domain (**Figures 3-7 and 3-8**). These data, along with areal fractions of land use per cell, serve as input to the GSA Model to define the consumptive use of water for each WBS.

#### 3.7.1.3 Tulelake Irrigation District Water Deliveries

Within FMP, shallow groundwater and precipitation serve as the first sources of water utilized to meet consumptive use demands within a WBS. In areas of irrigated agriculture within TID, an additional source of water is provided through Non-Routed Deliveries (NRDs) specified as part of FMP. NRDs represent the delivery of combined surface water and groundwater from TID as specified monthly volumes of water available for consumptive use demands. Water delivery estimates were provided by TID based on the deliveries of water from each canal system. Delivery estimates were then distributed to each WBS representative of TID. Figure 3-15 presents the annual TID water deliveries for each of the TID WBS as presented in Figure 3-9. The majority of TID's water deliveries occur within the California portion of the J System at approximately 48 TAFY on average during the historical simulation period. The remaining water deliveries average approximately 39 TAFY for a total of approximately 86 TAFY for the historical simulation period.

#### 3.7.1.4 Tulelake Irrigation District and Known Private Groundwater Pumping

Throughout the Subbasin groundwater is pumped from TID wells and private users augment surface water supplies for irrigation. Figure 3-16 presents the locations of simulated pumping wells in the GSA Model. TID maintains ten pumping wells throughout the Subbasin that are used to augment supplies in the TID conveyance system. Annual production rates for the TID pumping wells were available throughout the historical simulation period of the GSA Model. Annual rates were distributed into monthly pumping rates for incorporation in the MNW package of the GSA Model.

Figure 3-17 presents the annual pumping distribution for all simulated wells within the Subbasin. Due to limited private pumping records throughout the historical simulation period, WY 2014 was assumed to represent typical groundwater pumping volumes for the private groundwater pumping wells in the Subbasin. WY 2014 monthly pumping rates were specified for each of the private pumping wells for each year of the simulation assuming that the demand on these wells is constant from year-to-year. Pumping values for WY 2014 at the private pumping wells ranged from a high of approximately 5 TAFY to a minimum of 0 TAFY with an average pumping rate of approximately 1.2 TAFY per well.

#### 3.7.1.5 Calculated Private Groundwater Pumping

Private groundwater pumping in the GSA Model that are outside of the TID service area are estimated and simulated through the FMP. Model cells associated with irrigated land uses can pump groundwater from a 'virtual well' to supplement sources of water. In the case where a water source is not provided, the irrigated area is assumed to utilize local groundwater as the sole supply. Irrigation requirements, and ultimately private groundwater pumping, are based on the consumptive use of the model cell's land use minus the availability of precipitation and shallow groundwater to satisfy consumptive use demands. The remaining consumptive use demand is pumping from layer 4 of the GSA Model.

#### 3.7.1.6 Canal Lateral Leakage

Leakage to groundwater associated with the TID canal laterals were specified directly in the GSA Model as a linear flux. Monthly estimates of canal leakage were obtained from TID's H20Sys water budget accounting dataset. Canal system specific rates were distributed evenly across model grid cells that intersect with the canal laterals (Figure 3-4). Figure 3-18 presents the estimated annual canal lateral leakage by canal system. The J System makes up the bulk of the conveyance system, and therefore, canal lateral leakage ranging from a low of approximately 12 TAFY in WY 2001 to a maximum of 83 TAFY in WY 2002. The amount of canal lateral leakage is dependent on the surface water availability from the Klamath Project for that year, where 2001 was a low surface water supply year resulting in minimal leakage from canals. The North N, Q and R, and M and South N Systems all portray a similar low in canal lateral leakage in 2001. Total canal lateral leakage for the entire TID conveyance system is approximately 96 TAFY on average.

### 3.7.2 Head-dependent Flux Boundaries

The following section describes boundary conditions in the GSA Model where the flux used to simulate various hydrologic processes are dependent on groundwater elevations (i.e., heads) in the aquifer.

#### 3.7.2.1 Subsurface Lateral Flow

Head-dependent subsurface lateral flow boundary conditions were implemented in three separate locations to account for potential subsurface inflow and outflow along the GSA Model boundaries. Figure 3-19 presents the locations of the Northern, Northwestern, and Southern subsurface lateral boundary conditions. Head and conductance values were specified for each stress period of the GSA Model to represent head conditions along each of these boundary locations to allow for subsurface flow across the model boundary. Measured water-levels at wells near to the boundary were utilized to assign head values through time (Figure 3-19). Figure 3-20 and 3-21 present measured water level data and the resulting simulated groundwater elevation simulated in the GSA Model for the Northern and Southern lateral subsurface flow boundaries. Limited measured data was available in proximity to the Northwestern subsurface lateral boundary, thus, a static average value of 4047.7 feet above NAVD88 was specified for this boundary.

#### 3.7.2.2 Lost River and Tulelake Irrigation District Main Canals

Minimum elevations were extracted from the topographic surface used to define the top elevation of layer 1 of the GSA Model at each of the model grid cells that comprise the Lost River and TID main canals (Figure 3-4). A scheme was developed to represent the timing of flows through the Lost River and TID's main canals where the elevation assigned to respective cells of the RIV package are either assigned a stage elevation (system is flowing) or a channel bottom elevation (system is not flowing) depending on the timing of flows through the system. The stage elevation was assumed to be 5 feet greater than the channel bottom elevation to reflect conditions of the channel feature passing flow through the system. Leakage from the Lost River and TID Main Canals is computed through the RIV package based on assigned conductance values for each grid cell. Conductance values and timing of flows will be adjusted during the calibration process as described under Section 4.

#### 3.7.2.3 Tulelake Irrigation District Drains

Groundwater discharge to drains is simulated through the DRT package. Minimum elevations were extracted and assigned for each grid cell intersected by TID drains (Figure 3-5). To reduce any potential numerical feedback conductance values of DRT cells that overlap with the RIV package was set to zero, effectively turning off the DRT package in this cell. Flow to drains is then calculated based on the gradient between the underlying water table and the elevation assigned at the drain cell, scaled by the conductance term of the drain cell.

#### 3.7.2.4 Tulelake Sumps

Surface water and groundwater exchange from the Tulelake Sumps is simulated through the GHB package. GSA Model grid cells covering the extent of the Tulelake Sumps serve as the spatial extent of the GHB (Figure 3-6). Conductance values and head elevation values are specified for each cell of the GHB package. Figure 3-22 presents monthly average measured Tulelake Sump water surface elevations specified for each cell of the Tulelake Sump GHB as provided by TID. An average value of 4,034.74 was assigned for the first two years of the historical simulation period due to limited availability of measured data during this time.

#### 3.7.2.5 Groundwater Recharge from Precipitation

Groundwater recharge from precipitation is computed by the FMP package, whereby the water that is not consumed through consumptive use is available for either recharge or overland runoff.

#### 3.7.2.6 Groundwater Recharge from Applied Water

Groundwater recharge from applied water is derived through the FMP package, based on the on-farm efficiency term. The inefficient losses, like precipitation, can either recharge the aquifer or become overland runoff. This boundary condition only applies to irrigated crops.

#### 3.7.2.7 Shallow Groundwater Evapotranspiration

Shallow groundwater uptake is simulated through the FMP package, whereby crops can utilize shallow groundwater as a source of supply to meet consumptive use water demands. Access to shallow groundwater is determined based on the crop rooting depths, capillary fringe height, and the elevation of the water table during a given month in the simulation. This boundary condition is applied areally across the top of the entire model domain.

### 3.7.3 No-Flow Boundaries

The lateral model boundary cells depicted in Figure 3-1 that are not assigned other boundary conditions and the bottom of the deepest model layer (i.e., Model layer 6) are assigned the no-flow boundary condition. Inherent with the assignment of no-flow boundaries is the assumption that these boundaries coincide with locations of groundwater divides.

# 4. Model Calibration

Model calibration is a process of tuning numerical model parameters to adequately replicate measured field conditions of interest. The numerical models described herein were calibrated in accordance with the Standard Guide for Calibrating a Ground-Water Flow Model Application (American Society for Testing and Materials, 1996) and the Modeling BMP (DWR, 2016a). As described in Section 3.5, WYs 1998 through 2018 were selected as the historical simulation period, however, the historical calibration period has been selected as WY 2000 through WY 2018 due to the availability of data associated with surface water conditions, land use, groundwater pumping, and Tulelake Sump water surface elevation. This section discusses the calibration targets, process, and results, including the historical and current water budgets.

## 4.1 Calibration Targets

Quantitative and qualitative calibration targets were selected to evaluate progress during calibration of the GSA Model. Time-varying heads at well locations throughout the Subbasin served as quantitative calibration targets. Calibration involved adjusting Kh, Kv, storativity, RIV and DRT package conductance, and other boundary condition parameters within reasonable ranges until there was adequate consistency between modeled and calibration target values. Calibration summary statistics were computed for head targets to provide a quantitative measure of the GSA Model's ability to replicate head target values. Head calibration was evaluated using the following summary statistics:

- Residual, computed as the modeled head value minus the target (i.e., measured) head value
- Mean residual (MR), computed as the sum of all residuals divided by the number of observations
- Root mean squared residual (RMSR), computed as the square root of the mean of all squared residuals
- RMSR divided by the range of target head values (RMSR/Range)
- Coefficient of determination ($R^2$), computed as the square of the correlation coefficient

During the quantitative calibration effort, Jacobs executed work with the following general goals:

- Minimize global bias in heads (e.g., all heads being too high or too low as compared with the target heads)
- Minimize the spatial bias of residuals in key subareas of the model domain
- Minimize residuals, MR, RMSR, and RMSR/Range values
- Strive for $R^2$ values as close to 1.00 as possible

In addition to calibrating to transient heads, qualitative targets were also used to aid in the calibration process. Calibration summary statistics were not computed for qualitative calibration targets. The qualitative targets used for the modeling effort are as follows:

- General groundwater flow patterns throughout the model domain
- Estimates of leakage from TID's Main Canals
- Tulelake Sump water balance closure calculated based on estimated and simulated Tulelake Sump inflows and outflows

Targets classified as “qualitative” should not be interpreted as being unimportant. The main distinction is that summary statistics are not computed for qualitative targets, because doing so is not a requirement or is even typical for groundwater flow model documentation. **Figure 4-1** shows the head calibration target locations.

## 4.2 Calibration Process

The calibration process focused on defining FMP parameter values, surface and subsurface parameter distributions, and boundary-condition values until there was a reasonably close match to both quantitative and qualitative targets. The main parameters adjusted during the calibration process were the Kh and Kv values within and outside of the Basin, TID Main Canals conductance, and FMP parameter values. Parameter values were adjusted throughout the calibration process to provide goodness of fit for the calibration targets as previously discussed.

The product resulting from this calibration process was an integrated groundwater/surface-water flow model that incorporates important aspects of the hydrogeologic conceptual model and the professional judgment of engineers and scientists familiar with the study area. The following section describes the results of the calibration effort.

## 4.3 Calibration Results

The following subsections describe the calibration results for time-varying groundwater levels, general groundwater flow patterns, TID Main Canals Leakage, and the Tulelake Sump Water Balance. Calibrated values for key parameters and boundary conditions are also presented.

### 4.3.1 Groundwater Levels

**Figure 4-2** presents the modeled versus target (i.e., measured) groundwater levels to evaluate potential global biases and the overall ability of the GSA Model’s to replicate historical groundwater elevations. In general, points trend along the one-to-one correlation line with some points falling above and below the line. This highlights that the GSP Model does not contain a global bias where all modeled groundwater levels are either always above or always below this line. Global calibration statistics for the data presented in **Figure 4-2** are listed in **Table 4-1** and are within industry standards for adequate model calibration (e.g., small MR with an RMSR/Range < 10 percent with an $R^2$ close to 1).

Table 4-1 – Calibration Summary Statistics for Groundwater Elevations

| Global Calibration Statistics | Value | Unit |
|---|---|---|
| Mean Residual (MR) | -0.3 | feet |
| Root Mean Squared Residual (RMSR) | 17.5 | feet |
| Range of Measured Values (Range) | 177 | feet |
| RMSR/Range | 9.88 | percent |
| Coefficient of Determination ($R^2$) | 0.23 | unitless |
| Number of Values | 7,281 | unitless |
| Residual is computed by subtracting the target (i.e. measured) groundwater level from the modeled groundwater level. | | |

Although there is no indication of global bias in modeled groundwater elevations, there is an indication of some degree of spatial bias. For example, there is also a cluster of points in the x-axis range of 4,100 to 4,150 feet above the North American Vertical Datum of 1988 (NAVD88) in **Figure 4-2** where the model tends to underestimate groundwater levels. Figure 4-3 is provided to further evaluate spatial biases in modeled groundwater elevations by displaying a spatial distribution of MR values for each calibration target well. According to this figure, there is some spatial bias in the eastern portion of the Subbasin and in Oregon to the Northeast where modeled heads tend to underestimate the target heads. In this portion of the model domain there is a series of canals and drains that enter the Subbasin connecting with TID conveyance systems. No information was readily available at the time of developing the GSA Model to quantify the potential for groundwater recharge from canal and drain flows in this region. Thus, the GSA Model tends to underestimate groundwater recharge and resulting groundwater elevations. Additionally, there are wells in the northeast where the model is able to simulate water levels in good agreement with measured data. As you move south, along the eastern end of the Subbasin, there is a mixture of over and underestimates when comparing simulated to measured groundwater levels.

Figure 4-4 includes hydrograph comparisons of transient modeled and target groundwater levels. The horizontal and vertical axes on the hydrographs presented in Figure 4-4 have been standardized to facilitate making comparisons among the hydrographs. In general, simulated groundwater levels follow similar trends to the target groundwater-level data. However, in some instances, the GSA Model either overestimates or underestimates groundwater levels. Additionally, depending on the layer from which the target well was screened in the GSA Model, the groundwater hydrograph may portray larger or smaller groundwater level fluctuations as compared to groundwater-level target data.

Figure 4-5 illustrates the modeled water table during May 2016, which contained above average annual precipitation (Figure 3-11). It is provided to illustrate general patterns of groundwater flow. Groundwater generally moves from North to South through the Subbasin flattening out in the central portion of the Subbasin where agricultural groundwater pumping and the TID drains and sumps tend to flatten out the groundwater elevation gradients. Beyond the Subbasin to the South, flow generally continues towards the Southern lateral subsurface boundary. The overall groundwater flow pattern being illustrated in Figure 4-5 is reasonable based on the understanding of groundwater use in the Basin and local hydrogeologic characteristics.

### 4.3.2 Main Canals Leakage

Main canal conductance served as one of the primary calibration parameters for fine-tuning of the GSA Model by comparing simulated leakage from main canals with estimated values. Figure 4-6 presents a comparison of estimated and simulated total annual main canal seepage. Estimated canal seepage is based on H20Sys water budget estimates provided by TID. On average, total main canal leakage is estimated to be approximately 59 TAFY as compared to the 54 TAFY simulated by the GSA Model. The modeled main canal leakage generally follows similar trends as the estimated main canal leakage with higher leakage in the earlier period of the historical simulation period (WY 2002 through WY 2008) and a reduction in leakage from WY 2009 through WY 2018. Due to the simplistic implementation of canal wetting and drying in the GSA Model, the model is not quite able to capture the year-to-year variability that is likely driven by the amount of flow through the system in any given year. The GSA Model likely overestimates the main canal stage in some years and underestimates stage in others causing the resulting leakage estimates to over or underestimate as compared to the estimated main canal leakage. Due to the nature of the canal leakage being estimates, the performance of the GSA Model in simulating canal leakage is deemed adequate. Further study of TID conveyance systems could better characterize the amount of leakage that occurs from these canals to improve estimates of main canal leakage throughout the Subbasin.

### 4.3.3 Sump Water Balance

Considering the complexities of the TID conveyance system operations including the operations of the Tulelake Sumps to meet regulatory requirements and for use as storage for recirculation of irrigation water, an external Tulelake Sump water balance was developed as a means to calibrate the volume of water discharging to drains in the GSA Model. **Figure 4-7** presents the components of the Tulelake Sump water balance considered as part of this effort. Ultimately, water leaving the subsurface through drains is either recirculated directly from the drains for irrigation or flows into the Tulelake Sumps. Depending on water surface elevation conditions, water is pulled from the Tulelake Sump from a series of pumps (D-Plant, R, 11, and 12) or flows by gravity into the Q and R canal systems to the South (**Figure 4-7**). Pumps R, 11, and 12 recirculate water from the Tulelake Sumps back into canals for irrigation purposes. However, water removed through D-Plant pumping facility to pump water through Sheepy Ridge to the west of the Subbasin to supplement refuge and irrigation supplies in areas to the west. Estimates of water recirculated through Pumps R, 11, and 12 were incorporated in the Tulelake Sump water balance based on H20Sys Water Balance estimates provided by TID. Pumping through D-Plant was continually monitored throughout the historical past providing monthly estimates of the volume of water removed from the system to support the Tulelake Sump water balance. The records for D-Plant pumping provide a key piece of observed data for the surface water budget that helps provide confidence in the GSA Model's representation of the system. D-Plant pumping represents the summation of flows out of the basin that is typically only estimated in most basin water budgets.

Considering the Tulelake Sumps are open water bodies, precipitation and evaporation from these water bodies were also considered as part of the Tulelake Sump water balance. An open water evaporation estimate for the Klamath Region was used based on study by Risley and Gannett, 2006 to provide a monthly estimate of evaporation from the Tulelake Sumps. Based on these estimates, the open water evaporation was estimated to be approximately 49 inches per year. Given that the Tulelake sumps cover approximately 13,000 acres, this evaporation rate equates to a total annual evaporation of approximately 53 TAFY. This annual estimate of open water evaporation serves as an outflow from the Tulelake Sumps water balance. For precipitation, annual GSA model average precipitation was used in conjunction with the Tulelake Sump area to provide an estimate of annual precipitation falling directly on the Tulelake Sumps equal to approximately 10 TAFY on average.

**Figure 4-8** presents the time-series annual sump water balance. The data driving this water balance is a combination of GSA Model simulated values, external calculations, and water balance estimates from the H20Sys Spreadsheets provided by TID. The primary driver of inflows to the Tulelake Sumps is the drain inflow. To maintain water levels in the Sumps, the drain inflow is balanced through recirculation of water through pumps and canal headworks, and loss to groundwater. The largest outflow from the Tulelake Sumps was D-Plant pumping between WY 2000 through WY 2009 which average approximately 57 TAFY during this period. From WY 2010 through WY 2018, D-Plant pumping was utilized to a lesser extent, averaging approximately 18 TAFY of water removed through D-Plant pumping. Based on this configuration of the Sump Water Balance, there is some imbalance to the water budget, however the overall error is a relatively small percentage of the total exchange of water through this system. Such an imbalance may result from TID operations not adequately captured at the monthly scale of the estimates and GSA Model simulated values as shown. The primary goal was to reduce the imbalance as much as possible while maintaining adequate calibration results and metrics as previously discussed.

### 4.3.4 Surface Parameters

The primary surface parameters modified during the calibration process was the conductance values associated with the TID Main Canals as simulated through the RIV package. Calibrated conductance values in the RIV package ranged from 500 to 10,000 square feet per day. Conductance values were modified across the district to better match estimates of TID Main Canal leakage.

### 4.3.5 Subsurface Parameters

Initial distributions of hydraulic conductivity were adapted from the Upper Klamath Basin model as discussed under Section 3.4.1. Through the calibration process of the GSA Model, hydraulic conductivity distribution and parameter values were modified to meet the previously discussed calibration targets. **Figures 4-9** through **4-14** presents the hydraulic conductivity distribution for each of the six layers incorporated in the GSA Model.**Table 4-2** presents the calibrated subsurface parameter values for each model layer and corresponding lithologic unit within the layer.

Table 4-2 – Calibrated Subsurface Parameters

| Model Layer | Unit | Hydraulic Conductivity (ft/day) | Vertical Anisotropy [Kh:Kv] | Specific Storage |
|---|---|---|---|---|
| 1 | Qs | 100 | 100 | 2.40E-03 |
| | Qv | 5 | 100 | 2.40E-03 |
| | Tve | 1 | 1,000 | 2.40E-03 |
| | Tvw | 1 | 1,000 | 2.40E-03 |
| | Tsy | 25 | 10 | 2.40E-03 |
| | Tso | 25 | 10 | 2.40E-03 |
| 2 | Tso | 25 | 10 | 4.36E-05 |
| | Tsv | 25 | 10 | 4.36E-05 |
| | Tsy | 25 | 10 | 4.36E-05 |
| | Tve | 1 | 100 | 4.36E-05 |
| | Tvw | 1 | 100 | 4.36E-05 |
| 3 | Tso | 25 | 10 | 4.36E-05 |
| | Tsv | 25 | 10 | 4.36E-05 |
| | Tsy | 25 | 10 | 4.36E-05 |
| | Tve | 1 | 1,000 | 4.36E-05 |
| | Tvw | 1 | 1,000 | 4.36E-05 |
| 4 | Tsv | 3 | 10 | 1.68E-05 |
| | Tve | 1 | 1,000 | 1.68E-05 |
| | Tvw | 1 | 1,000 | 1.68E-05 |
| 5 | Tsv | 3 | 10 | 1.68E-05 |
| | Tve | 1 | 1,000 | 1.68E-05 |
| | Tvw | 1 | 1,000 | 1.68E-05 |
| 6 | Tsv | 3 | 10 | 1.05E-05 |
| | Tve | 1 | 1,000 | 1.05E-05 |
| | Tvw | 1 | 1,000 | 1.05E-05 |

Notes:
Qs = Quaternary sedimentary deposits
Qv = Quaternary volcanic rocks
Tve = Tertiary volcanic rocks (east)
Tvw = Tertiary volcanic rocks (west)
Tsy = Tertiary sedimentary rocks (younger basins)
Tso = Tertiary sedimentary rocks (older basins)
Tsv = Tertiary mixed sedimentary and volcanic deposits
Vertical anisotropy represents the ratio of horizontal hydraulic conductivity to vertical hydraulic conductivity.
Specific yield is specified as 10% for Layers 1 and 2; Layers 3 through 4 do not have a specific yield as these layers are simulated as confined.

### 4.3.6 Numerical Mass Balance

It is important to review the numerical mass balance of model simulations to ensure that good mathematical closure is achieved. The percent discrepancy in the mass balance for each stress period ranged from -0.001 to 0.0002 percent in the calibration simulation. The cumulative percent discrepancy in the numerical mass balance was -0.06 percent in the calibration simulation. Thus, the transient historical model achieved excellent numerical mass balances associated with the water budgets described in the following sections.

## 4.4 Historical and Current Water Budgets

GSP Regulations Section 354.18 requires the GSA to develop historical, current, and projected water budgets for the Subbasin. The historical water budget evaluates the availability and reliability of past surface water supplies and agricultural demands. The 20-year hydrologic period of WYs 1999 through 2018 was selected for developing the historical water budget to include a period of representative hydrology, while capturing recent Subbasin operations. The current water budget evaluates the availability and reliability of more recent surface water supplies and agricultural demands. WY 2018 was selected for developing the current water budget representing recent hydrology and Subbasin operations.

The water budgets described herein have been developed in accordance with the general guidelines provided in DWR's Water Budget BMP (DWR, 2016b) to help quantify the volumetric rate of water entering and leaving the Basin. Water enters and leaves the Basin naturally, such as through precipitation and streamflow, and through human activities, such as pumping and groundwater recharge from irrigation. Separate historical, current, and projected water budgets have been developed for two different "systems", including the land system and groundwater system. **Table 4-3** lists the water budget components for each of these systems.

Table 4-3 – Land and Groundwater Systems Water Budget Components

| Land System Inflow Components | Land System Outflow Components |
|---|---|
| Precipitation | Evapotranspiration of Precipitation |
| Water into the Rootzone | Evapotranspiration of Applied Water |
| Surface Water Deliveries | Runoff from Farm |
| Groundwater Deliveries | Groundwater Recharge from Precipitation and Applied Water |
| | Shallow Groundwater Evapotranspiration |
| **Groundwater System Inflow Components** | **Groundwater System Outflow Components** |
| Groundwater Recharge from Precipitation and Applied Water | Irrigation and M&I Groundwater Pumping |
| Canal Laterals Leakage | Private Groundwater Pumping |
| Tulelake Sumps Leakage | Groundwater Discharge to Drains |
| Main Canals and Lost River Leakage | Shallow Groundwater Evapotranspiration |
| Subsurface Flow into Subbasin | Groundwater Discharge to Tulelake Sumps |
| | Groundwater Discharge to Main Canals and Lost River |
| | Subsurface Flow Out of Subbasin |

### 4.4.1 Land System

**Table 4-4** presents averages of the individual Subbasin components of the historical and current land system water budgets. **Figure 4-15** presents the annual time series of each Subbasin component of the historical and current land system water budgets. Tabulated water budget values presented herein are reported to the nearest whole number, in TAF, from the GSA Model. This has been done out of convenience. It is not the intention of the authors to imply that the values are accurate to the nearest TAF.

Table 4-4 – Historical and Current Average Annual Land System Budget

| Groundwater Budget Term | Historical Average Annual Flow (TAFY) WYs 2000-2018 | Current Annual Flow (TAFY) WY 2018 |
|---|---|---|
| **Inflows** | | |
| Precipitation | 89 | 116 |
| Water into the Rootzone | 5 | 4 |
| Surface Water Deliveries | 100 | 89 |
| Groundwater Deliveries | 6 | 5 |
| **Total Inflow** | 200 | 214 |
| **Outflows** | | |
| Evapotranspiration of Precipitation | 36 | 59 |
| Evapotranspiration of Applied Water | 90 | 80 |
| Runoff from Farm | 11 | 10 |
| Groundwater Recharge from Precipitation & Applied Water | 58 | 61 |
| Shallow Groundwater Evapotranspiration | 5 | 4 |
| **Total Outflow** | 200 | 214 |

According to the GSA Model, the Subbasin experienced an average of approximately 200 TAFY of land inflows and outflows during the 20-year historical period. Primary inflows to the Subbasin land system water budget are surface water deliveries for irrigation and precipitation, whereas, the primary outflows from the Subbasin land system water budget are evapotranspiration of applied water and groundwater recharge from precipitation and applied water. The hierarchy of inflow and outflows under current conditions is the same as that under the historical period, however, the total inflows and outflows under current conditions are approximately three TAFY greater than historical condition average.

### 4.4.2 Groundwater System

**Table 4-5** presents averages of the individual Subbasin components of the historical and current groundwater system water budgets. **Figure 4-16** presents the annual time series of each Subbasin component of the historical and current groundwater system water budgets.

According to the GSA Model, the Subbasin experienced an average of approximately 236 TAFY of groundwater inflows during the 20-year historical period. Primary inflows to the Subbasin groundwater system water budget are canal laterals leakage, main canal and lost river leakage, and groundwater recharge from precipitation and applied water. Groundwater outflows from the Subbasin averaged approximately 240 TAFY with the largest outflow components being groundwater discharge to drains and irrigation and M&I groundwater pumping. The hierarchy of inflow and outflows under current conditions is the same as that under the historical period.

Over the 20-year historical period, the change in groundwater storage declined by approximately 4 TAFY which is approximately 1.7% of the average total inflows and outflows. Under current conditions, the change in stored groundwater was less 1 TAFY with the groundwater system being very close to in balance for WY 2018. The small decline in groundwater stored under the historical period is likely within the uncertainty of the estimates of the water budget. Thus, the estimated change in groundwater storage is within the potential error of groundwater budget estimates, meaning small changes to individual water budget estimates could potentially result in no change in groundwater storage over time.

Table 4-5 – Historical and Current Average Annual Groundwater System Budget

| Groundwater Budget Term | Historical Average Annual Flow (TAFY) WYs 2000-2018 | Current Annual Flow (TAFY) WY 2018 |
|---|---|---|
| **Inflows** | | |
| Groundwater Recharge from Precipitation & Applied Water | 59 | 80 |
| Canal Laterals Leakage | 92 | 93 |
| Tulelake Sumps Leakage | 5 | 7 |
| Main Canals and Lost River Leakage | 63 | 72 |
| Subsurface Flow into Subbasin | 17 | 17 |
| **Total Inflow** | 236 | 269 |
| **Outflows** | | |
| Irrigation & M&I Groundwater Pumping | 42 | 27 |
| Private Groundwater Pumping | 6 | 5 |
| Total Subbasin Groundwater Pumping | 48 | 32 |
| Groundwater Discharge to Drains | 171 | 192 |
| Shallow Groundwater Evapotranspiration | 5 | 5 |
| Groundwater Discharge to Tulelake Sumps | 0 | 0 |
| Groundwater Discharge to Main Canals and Lost Rivers | 2 | 2 |
| Subsurface Flow Out of Subbasin | 14 | 21 |
| **Total Outflow** | 240 | 251 |
| **Change in Stored Groundwater** | -4 | 17 |

# 5. Model Projections

## 5.1 Assumed Future Conditions

GSP Regulations Section 354.18 requires the GSA to develop historical, current, and projected water budgets for the Basin. Section 4.4 discusses the historical and current water budgets. To develop the projected water budget, certain boundary conditions needed to be modified from the calibration version of the model, which was used to evaluate historical conditions, to convert it into a projection tool configured to simulate assumed future climatic conditions.

As part of the GSP development effort, two projected simulation runs were developed using the GSA Model representing future baseline conditions and future baseline conditions with assumptions of projected climate change. The following sections describe the process of converting the historical model into a projection model for the future baseline and future baseline with climate change conditions.

### 5.1.1 Climate Change

One requirement of the projected water budget is to account for climate change. Projected climate conditions were adapted from the DWR provided data and tools representing future climate change scenarios. As described in the *Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development* (DWR, 2018), a time-period analysis was incorporated in the GSA Model to translate historical variability to conditions representative of the climate change trends established in the 2070 climate change scenario.

From the DWR climate change scenario, historical reference evapotranspiration and precipitation values were adjusted to reflect projected changes in temperature and precipitation under the DWR 2070 climate change scenario. Figure 5-1 presents annual precipitation under historical and 2070 climate change adjusted conditions. Under projected conditions, historical annual precipitation is projected to increase from an average of 13.6 inches to an average of 14.4 inches. Figure 5-2 presents annual $ET_0$ under historical and 2070 climate change adjusted conditions. Under 2070 climate conditions, reference evapotranspiration is projected to increase as compared to historical conditions by approximately 3.2 inches per year. To develop the 52-year future period covering WY 2019 through WY 2071, historical precipitation and $ET_0$ adjusted for 2070 climate conditions were repeated to cover the project simulation period.

### 5.1.2 Surface Water Availability

As discussed in previous sections, surface water for irrigation plays a large role in the operations of the TID system. Historical Klamath Project operations were used to develop a set of surface water conditions that reflect historical hydrologic conditions which were then compared to predictions of surface water supply based on the Klamath Project Interim Operations model. The Klamath Project Interim Operations model was developed by the U.S. Bureau of Reclamation and is the accepted model for preforming planning-level analyses of the Klamath Project.

Based on the Klamath Project Interim Operations model, projected annual surface water availability at Anderson-Rose Dam was estimated representing the total surface water availability for conveyance into the TID system. Total surface water availability was combined with TID groundwater pumping volumes to represent total supply for TID. Figure 5-3 presents historical versus projected total supply for TID for the historical simulation period. In general, supplies are projected to be close to historical conditions with some increases and decreases in certain years as compared to historical conditions. For the historical simulation period, historical supply averaged approximately 122 TAFY as compared to 121 TAFY under projected conditions.

Total TID supply was then split into estimates of surface water deliveries by TID canal system and canal lateral leakage as scaled by the change in projected supply as compared to historical conditions. Monthly fractions of the total surface water deliveries that served as deliveries or canal lateral leakage were developed based on historical estimates. Assuming current operations of the TID system will continue, these monthly fractions were applied to the projected total surface water availability. **Figure 5-4** presents the historical versus projected annual TID water deliveries. Projected water deliveries are generally within the range of historical values with an average volume of water delivered of approximately 100 to 110 TAFY under projected conditions as compared to the 100 TAFY historical average. Estimated surface water deliveries were incorporated for the projected simulation period as NRDs as described under Section 3.7.12. **Figure 5-5** presents the historical and projected total canal lateral leakage. Projected canal lateral leakage is generally within the range of historical values with an average canal lateral leakage of approximately 98 TAFY under projected conditions as compared to the 96 TAFY historical average. Projected canal lateral leakage was distributed evenly across each canal system and prescribed as a volumetric flux for the projected period as described under Section 3.7.16.

Additional sources of supply into TID canals and drains come from operational spills from upgradient irrigation districts and through recirculation of Tulelake Sump and drain water within TID. Limited information is available regarding the quantity of water entering TID's canals and drains. For the purposes of the projected simulations, spills into TID were assumed to be fixed under historical conditions. As such, any changes in surface water conditions are based solely on the projected volume of water available as part of TID's Klamath Project supply.

### 5.1.3 Groundwater Pumping

Considering the availability of surface water in the Subbasin is projected to be similar to historical conditions, historical groundwater pumping rates per well were repeated based on repetition of pumping rates from WY 1998 through WY 2018 to cover the full projected period. Groundwater pumping well locations and construction information are assumed to be consistent with historical conditions.

### 5.1.4 Sump Water Levels

Operations of the Tulelake Sumps are assumed to be consistent with historical conditions. Thus, monthly historical Tulelake Sump water surface elevations were repeated to cover the future simulation period.

### 5.1.5 Lateral Subsurface Boundaries

Lateral subsurface boundaries in the GSA Model represent transient groundwater elevation conditions requiring a full time-series of conditions under future conditions. Considering the uncertainty in groundwater elevations into the future, the historical timeseries associated with the boundary condition locations presented in **Figure 3-18** are repeated to cover the entire projected simulation period.

## 5.2 Model Setup for Projection Scenarios

For the future baseline simulation, the GSA Model was configured to run the historical and projected simulation periods as one continuous simulation. Simulating the historic and projected periods as a continuous simulation ensures that there are no discontinuities in Subbasin conditions between the end of the historical period and the start of the projection period. **Table 5-1** presents a comparison of the assumptions associated with the historical and projection simulations.

Table 5-1: Overview of Assumptions for the Historical and Projection Periods

| Simulation Item | Assumption/Basis for Historical Simulation Periods | Assumption/Basis for Projection Simulation Periods |
|---|---|---|
| Hydrologic Period | • Historical: WYs 1999 through 2018<br>• Monthly time intervals | • WYs 2019 through 2071 as represented by a repeating pattern of historical conditions (WY 1997 through 2018)<br>• Monthly time intervals |
| Precipitation | • Downscaled PRISM (PRISM Climate Group, 2020) precipitation dataset, as processed using the BCM (Flint et al., 2013) | • Repeating pattern of historical precipitation for projection baseline<br>• Climate change adjustment factors applied to projection baseline based on the DWR 2070 climate scenario (DWR, ) |
| Reference Evapotranspiration | • $ET_0$ is computed using the BCM (Flint et al., 2013) based on air temperature projections<br>• Klamath Region AgriMET Stations: Klamath Falls and Worden used to correct of BCM $ET_0$ | • Repeating pattern of historical $ET_0$ for future baseline conditions<br>• Repeating pattern of historical $ET_0$ adjusted to reflect DWR 2070 climate change scenario |
| Crop Coefficients | • Monthly crop coefficients developed based on AgriMET station data | • Same as historical |
| Land Use/Cropping | • 2008 and 2010 TID reported crop acreages with 2008 representative of average conditions and 2010 representative of years when crop idling occurred | • Repeating pattern of 2008 and 2010 land use conditions based on historical designation |
| Surface Water Availability | • Based on water balance estimates from TID's H20Sys for WY 2000 through WY 2018; WY 1998 and WY 1999 filled in with average conditions | • Historical conditions with modified conditions representing future conditions<br>• Repeating pattern of projected historical conditions |
| Well Infrastructure | • Input from TID, WUMP program, and OWRD | • Same as historical |
| Sump Water Elevation | • Historical measured daily water surface elevation averaged on a monthly interval | • Repeating pattern of historical monthly average water surface elevation |
| Subsurface Lateral Flow | • Based on historical measured water levels in the vicinity of each subsurface lateral boundary location | • Repeating pattern of historical monthly groundwater elevations |

## 5.3 Projected Groundwater Levels

**Figure 5-6** includes hydrograph comparisons of transient modeled and target groundwater levels for the future baseline and future baseline with 2070 climate scenario conditions. Simulated groundwater levels are presented from the start of the historical simulation period (WY 1998) through the end of the projected period (WY 2071). The horizontal and vertical axes on the hydrographs presented in **Figure 5-6** have been standardized to facilitate making comparisons among the hydrographs. In general, simulated groundwater levels tend to decline through the historical simulation period and level-off through the end of the project simulation period. Overall, there are minor changes in the future baseline as compared to the future baseline with climate change scenario except for a number of wells that portray lower groundwater levels under the future baseline with 2070 climate as compared to future baseline conditions.

## 5.4 Projected Water Budgets

The following sections provide comparisons of the projected water budgets to the historical water budget for the land and groundwater system water budgets. Water budget estimates are subject to change in future GSP updates as the understanding of Subbasin conditions evolves during implementation of the GSP.

### 5.4.1 Land System

**Table 5-2** presents averages of the individual Subbasin components of the historical, future baseline, and future baseline with 2070 climate conditions land system water budgets. **Figure 5-7** presents the annual time series of each Subbasin component of the historical and future baseline land system water budgets. In general, the hierarchy of inflows and outflows from the land system are consistent under historical and future conditions. This is expected due to the projected boundary conditions reflecting a repeating pattern of historical conditions. However, minor changes are observed under the future baseline with climate change scenario for precipitation and evapotranspiration of precipitation and applied water. These changes are result of the projected changes in climate as defined by the 2070 climate change scenario. Overall, the changes in climate tend to drive more throughput from the system with more total inflow and outflow as compared to historical and future baseline conditions.

Table 5-2 – Average Annual Historical and Projected Land System Water Budgets

| Groundwater Budget Term | Historical Average Annual Flow (TAFY) WYs 2000-2018 | Future Baseline Average Annual Flow (TAFY) WYs 2019-2071 | Future Baseline with 2070 Climate Conditions Average Annual Flow (TAFY) WYs 2019-2071 |
|---|---|---|---|
| **Inflows** | | | |
| Precipitation | 89 | 93 | 96 |
| Water into the Rootzone | 5 | 5 | 5 |
| Surface Water Deliveries | 100 | 100 | 110 |
| Groundwater Deliveries | 6 | 6 | 6 |
| **Total Inflow** | 200 | 203 | 218 |
| **Outflows** | | | |
| Evapotranspiration of Precipitation | 36 | 36 | 38 |
| Evapotranspiration of Applied Water | 90 | 90 | 99 |
| Runoff from Farm | 11 | 12 | 12 |
| Groundwater Recharge from Precipitation & Applied Water | 58 | 60 | 63 |
| Shallow Groundwater Evapotranspiration | 5 | 5 | 5 |
| **Total Outflow** | 200 | 203 | 218 |

### 5.4.2 Groundwater System

**Table 5-3** presents averages of the individual Subbasin components of the historical, future baseline, and future baseline with 2070 climate conditions groundwater system water budgets. **Figure 5-8** presents the annual time series of each Subbasin component of the historical and future baseline groundwater system water budgets. In general, the hierarchy of inflows and outflows from the land system are consistent under historical and future conditions. This is expected due to the projected boundary conditions reflecting a repeating pattern of historical conditions. However, minor changes are observed under the future baseline with climate change scenario for groundwater recharge from precipitation and applied water and Main Canals and Lost River leakage. These changes are a result of the projected changes in climate as defined by the 2070 climate change scenario. Overall, the changes in climate tend to drive more throughput from the system with more total inflow and outflow as compared to historical and future baseline conditions.

Similar to current conditions, the two future projections result in no change in stored groundwater averaged over the projected simulation period. According to the change in stored groundwater and trends observedin the simulated projected groundwater-level hydrographs indicate that the Subbasin is generally stablereflecting sustainable conditions.

Table 5-3 – Average AnnualHistorical and Projected Groundwater Water Budgets

| Groundwater Budget Term | Historical Average Annual Flow (TAFY) WYs 2000-2018 | Future Baseline Average Annual Flow (TAFY) WYs 2019-2071 | Future Baseline with 2070 Climate Conditions Average Annual Flow (TAFY) WYs 2019-2071 |
|---|---|---|---|
| **Inflows** | | | |
| Groundwater Recharge from Precipitation & Applied Water | 59 | 59 | 63 |
| Canal Laterals Leakage | 92 | 93 | 93 |
| Tulelake Sumps Leakage | 5 | 6 | 6 |
| Main Canals and Lost River Leakage | 63 | 66 | 66 |
| Subsurface Flow into Subbasin | 17 | 15 | 15 |
| **Total Inflow** | 236 | 238 | 242 |
| **Outflows** | | | |
| Irrigation & M&I Groundwater Pumping | 42 | 42 | 42 |
| Private Groundwater Pumping | 6 | 6 | 6 |
| Total Subbasin Groundwater Pumping | 48 | 47 | 48 |
| Groundwater Discharge to Drains | 171 | 165 | 165 |
| Shallow Groundwater Evapotranspiration | 5 | 5 | 5 |
| Groundwater Discharge to Tulelake Sumps | 0 | 0 | 0 |
| Groundwater Discharge to Main Canals and Lost Rivers | 2 | 1 | 1 |
| Subsurface Flow Out of Subbasin | 14 | 20 | 22 |
| **Total Outflow** | 240 | 239 | 242 |
| **Change in Stored Groundwater** | -4 | 0 | 0 |

# 6. Conclusions and Recommendations

Jacobs has developed an integrated groundwater/surface-water flow model called the GSA Model of an area encompassing the Tulelake Subbasin in Modoc and Siskiyou Counties, California. This report was prepared by Jacobs to support the GSAs in the preparation of the GSP. This model integrates the 3D groundwater and surface-water systems, land surface processes, and operations. The model was constructed and calibrated to simulate groundwater and surface-water flow conditions within a 610 $mi^2$ area encompassing the Basin using the USGS OneWater code (Boyce et al., 2020) and the USGS BCM (Flint et al., 2013; Flint and Flint, 2014). The calibration version of the GSA Model simulates historical hydrologic conditions from October 1997 through September 2018, whereas the projection version of the GSA Model simulates future hydrologic conditions from October 2018 through September 2071. The climate change projections are based on DWR's 2070 climate change scenario (DWR, 2018). All versions of the model include monthly stress periods to adequately simulate seasonal hydrologic processes.

The historical and projected groundwater systems all indicate that the Subbasin is relatively in balance where the annual average change in storage ranges from a decrease of 4 TAFY under historical conditions to zero TAFY of change under projected conditions. Projected hydrographs indicate that the Subbasin is likely converging on a new equilibrium where water levels are generally stable over the SGMA implementation period.

Now that the GSA Model has been developed to support the GSAs in the preparation of the GSP, it could also be used during the implementation of the GSP to aid in the following:

- Help prioritize and refine the monitoring well network used to demonstrate whether the Subbasin is being managed sustainably
- Forecast potential outcomes to potential conditions or actions not evaluated herein
- Test hypotheses about interrelationships among different hydrologic processes of interest
- Support the GSA with decisions related to managing their water supply portfolios resulting in capital investments for projects and management actions, if necessary
- Provide technical graphics to support public outreach efforts
- Aid in the development of annual SGMA-related reports to DWR, as needed
- Support constructive dispute resolution on the basis of objective scientific analyses, if necessary

# 7. Works Cited

American Society for Testing and Materials. 1996. Standard Guide for Calibrating a Ground-Water Flow Model Application. D5981-96. Reapproved 2002.

Boyce, S.E., Hanson, R.T., Ferguson, I., Schmid, W., Henson, W., Reimann, T., Mehl, S.M., and Earll, M.M., 2020, One-Water Hydrologic Flow Model: A MODFLOW based conjunctive-use simulation software: U.S. Geological Survey Techniques and Methods 6–A60, 435 p., https://doi.org/10.3133/tm6A60.

California Department of Water Resources (DWR), 2018. Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development. Guidance Document for the Sustainable Management of Groundwater. July.

California Department of Water Resources (DWR), 2016a. Best Management Practices for the Sustainable Management of Groundwater. Modeling BMP. December.

California Department of Water Resources (DWR), 2016b. Best Management Practices for the Sustainable Management of Groundwater. Water Budget BMP. December.

California Department of Water Resources (DWR), 2003. Tulelake Subbasin – Hydrogeologic Investigation. California Department of Water Resources Draft Report.

Environmental Simulations Inc. [ESI]. 2020. Guide to Using Groundwater Vistas Version 8. Fifth Edition. July.

Flint, L.E. and Flint, A.L., 2014, California Basin Characterization Model: A Dataset of Historical and Future Hydrologic Response to Climate Change, (ver. 1.1, May 2017): U.S. Geological Survey Data Release, https://doi.org/10.5066/F76T0JPB.

Flint, L.E., Flint, A.L., Thorne, J.H., and R. Boynton, 2013. Fine-scale hydrologic modeling for regional landscape applications: the California Basin Characterization Model development and performance. Ecol Process 2, 25 (2013). https://doi.org/10.1186/2192-1709-2-25.Gannett, M.W., Wagner, B.J., and Lite, K.E., Jr., 2012, Groundwater simulation and management models for the upper Klamath Basin, Oregon and California: U.S. Geological Survey Scientific Investigations Report 2012–5062, 92 p.

Gannett, M.W., Wagner, B.J., and Lite, K.E., Jr., 2012, Groundwater simulation and management models for the upper Klamath Basin, Oregon and California: U.S. Geological Survey Scientific Investigations Report 2012–5062, 92 p.

Harbaugh, A.W. 2005. MODFLOW-2005, the U.S. Geological Survey Modular Ground-water Model -- the Ground-Water Flow Process. U.S. Geological Survey Techniques and Methods 6 A16.

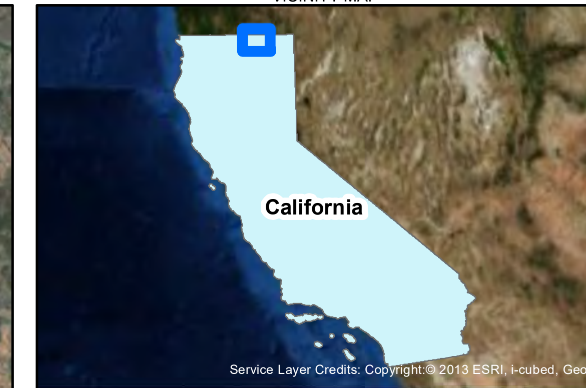
Pischel, E.M., and Gannett, M.W., 2015, Effects of groundwater pumping on agricultural drains in the Tule Lake subbasin, Oregon and California: U.S. Geological Survey Scientific Investigations Report 2015–5087, 44 p., http://dx.doi.org/10.3133/sir20155087.

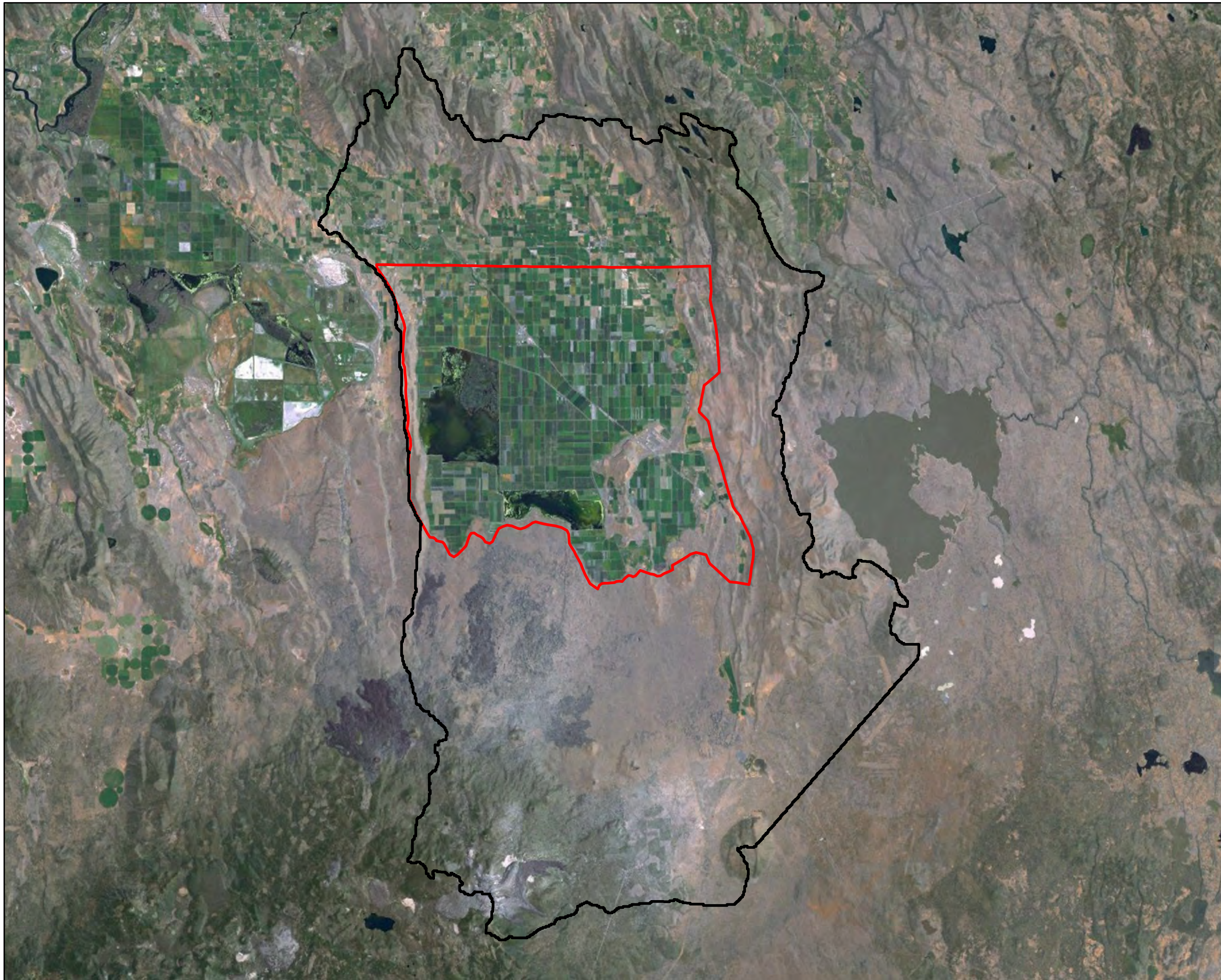
Risley, J.C., and Gannett, M.W., 2006, An evaluation and review of water-use estimates and flow data for the Lower Klamath and Tule Lake National Wildlife Refuges, Oregon and California: U.S. Geological Survey Scientific Investigations Report 2006-5036, 18.

Rojstaczer, S.A. 1994. The Limitations of Groundwater Models. Journal of Geological Education. v.42, pp. 362-368.

Tulelake Irrigation District. Water Management Plan 2017 Criteria. September 2017

VICINITY MAP



LEGEND
- Groundwater Model Active Domain
- Tulelake Subbasin

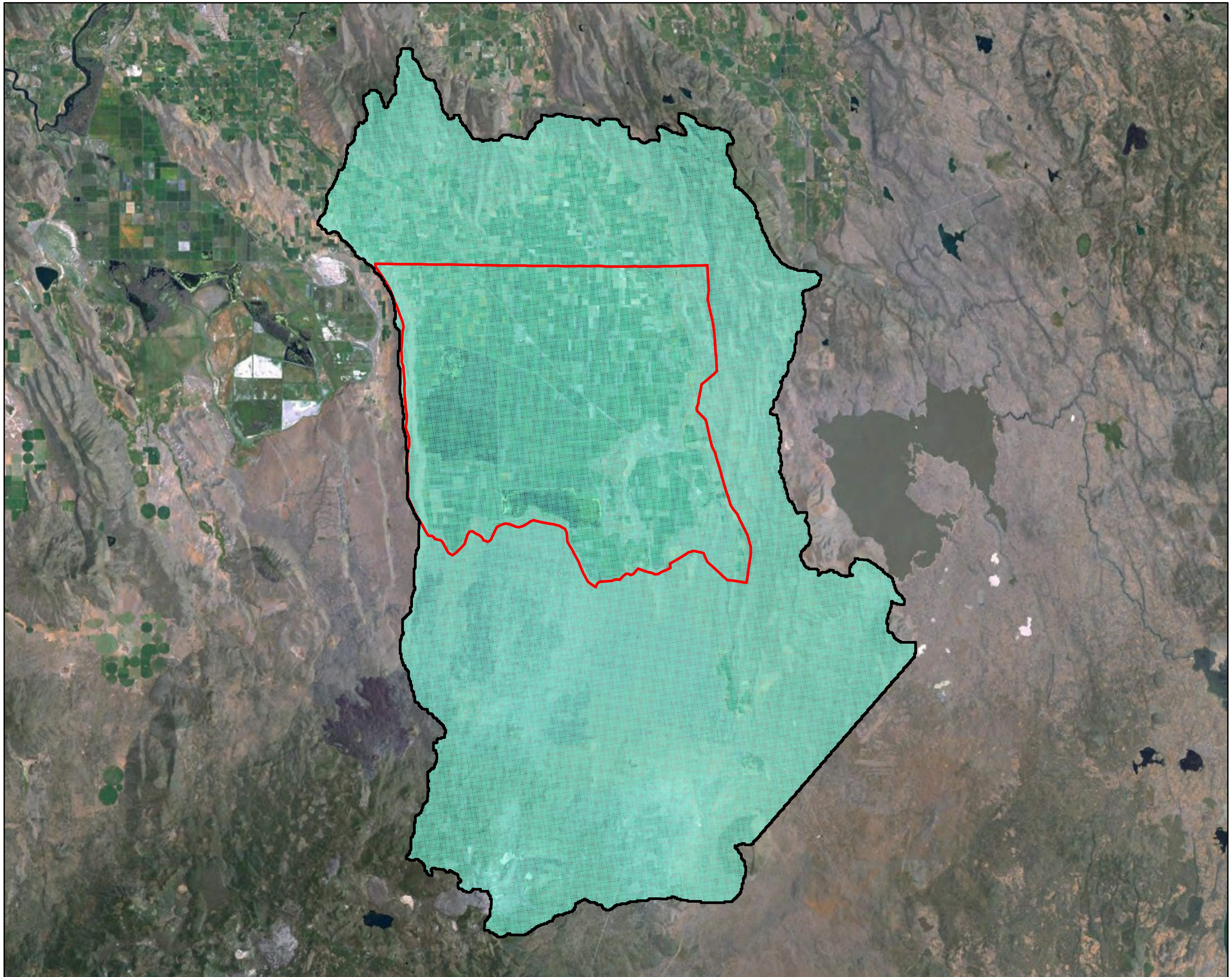
Notes:

CA = California

OR = Oregon

N

**FIGURE 1-1**
**Study Area Map**
*Tulelake Subbasin Groundwater Model*
*Tulelake, California*



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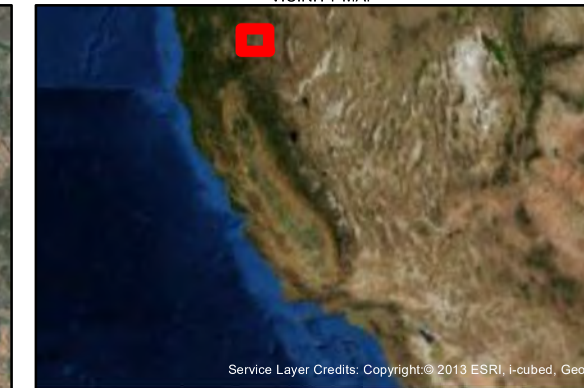


LEGEND

- Model Domain Boundary
- Tulelake Groundwater Subbasin
- Active Model Cell Boundary

Notes:

N

**FIGURE 3-1**
**Model Domain: Plan View**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*



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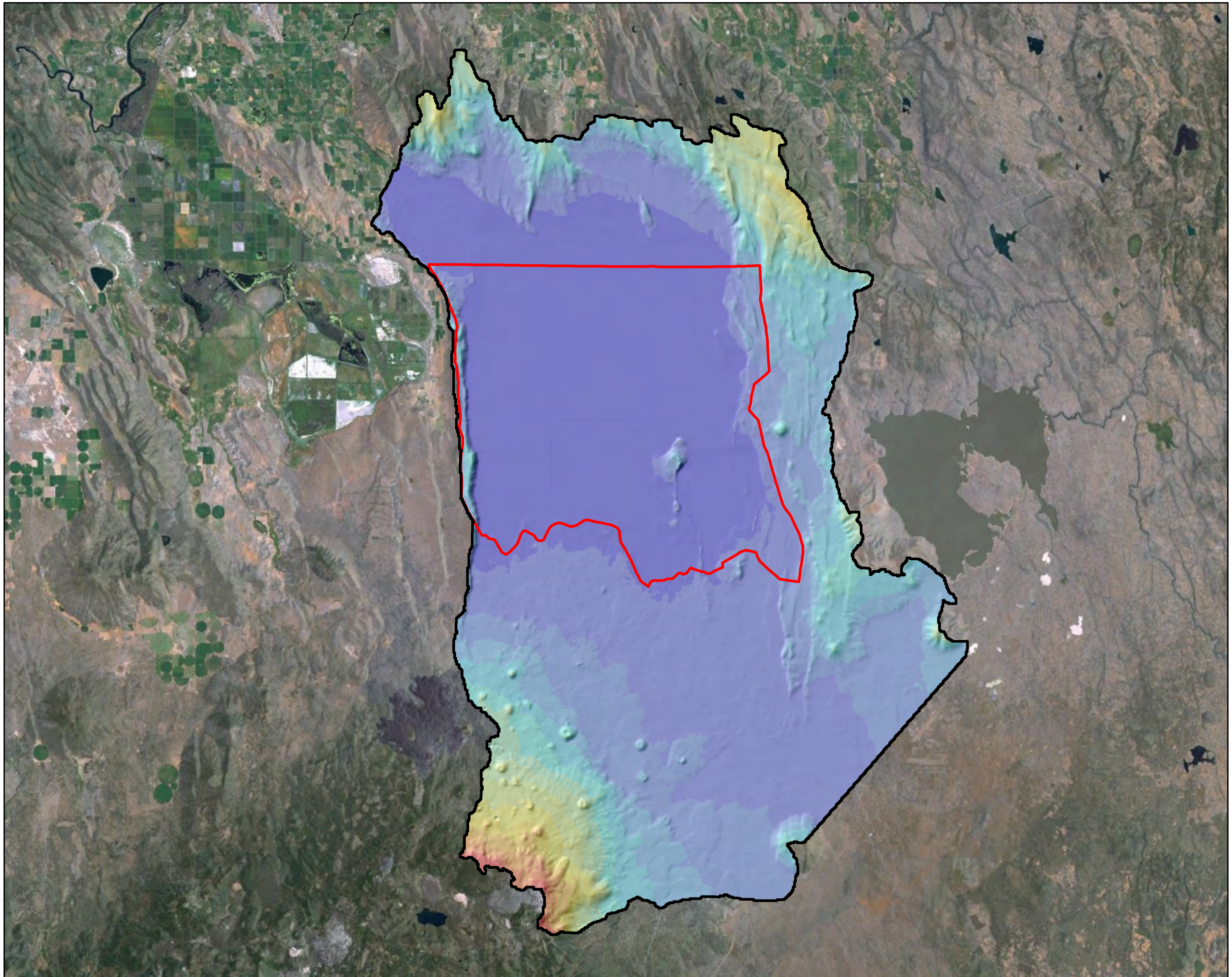

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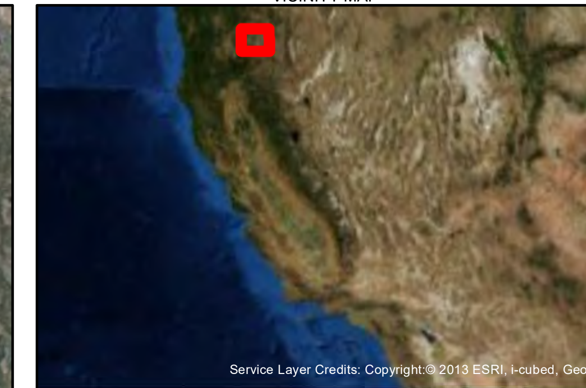


LEGEND

- Model Domain Boundary
- Tulelake Groundwater Subbasin

**Modeled Land Surface Elevation (feet NAVD88)**

- 7,302 - 7,893
- 6,999 - 7,301
- 6,726 - 6,998
- 6,438 - 6,725
- 6,164 - 6,437
- 5,907 - 6,163
- 5,649 - 5,906
- 5,376 - 5,648
- 5,118 - 5,375
- 4,890 - 5,117
- 4,678 - 4,889
- 4,465 - 4,677
- 4,268 - 4,464
- 4,101 - 4,267
- 4,024 - 4,100

Notes:

CA = California
OR = Oregon
NAVD88 = North American Vertical Datum of 1988

N

**FIGURE 3-2**
**Modeled Land Surface Elevations**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*



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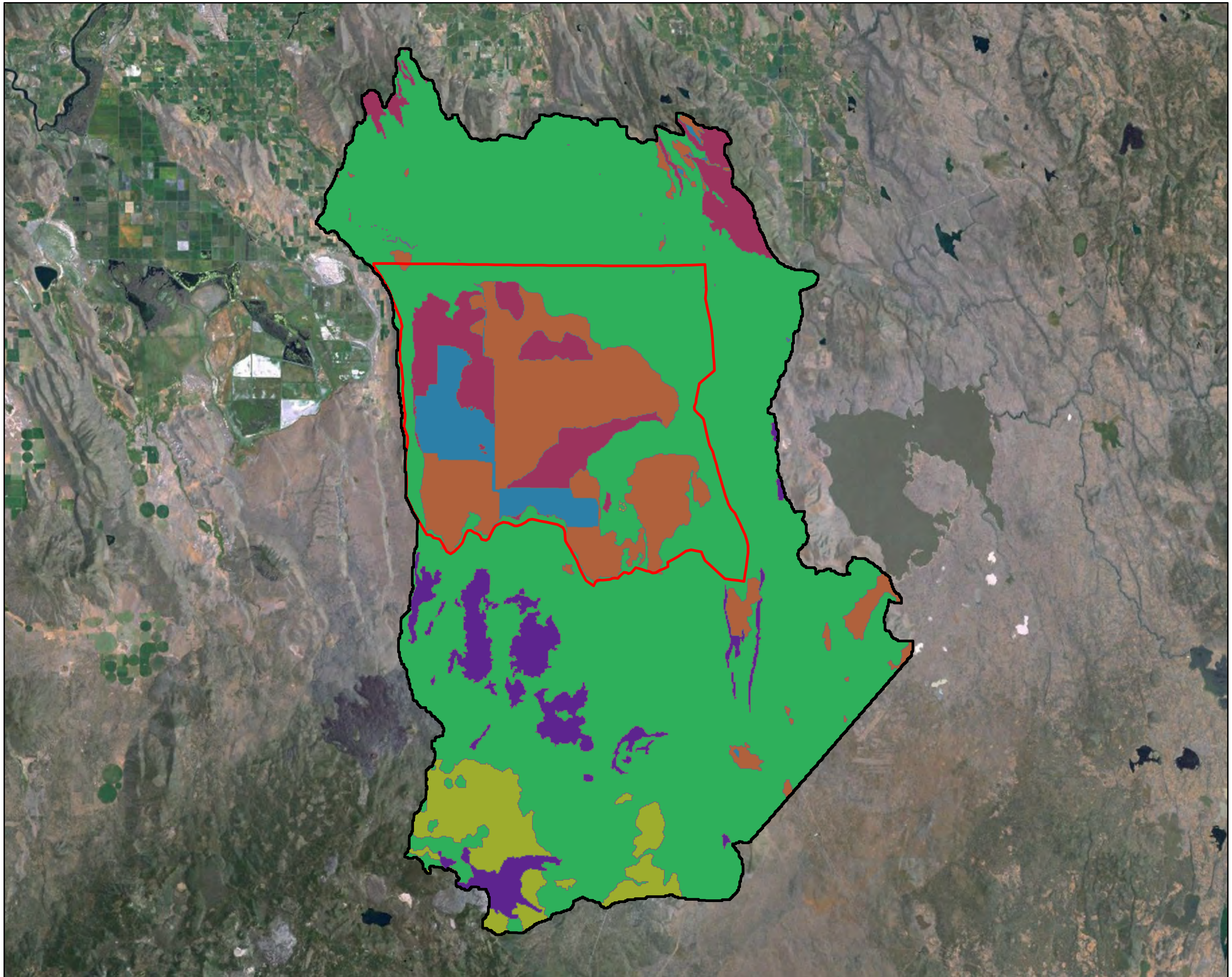

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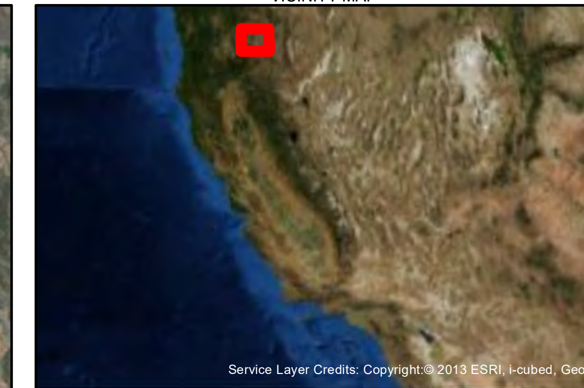


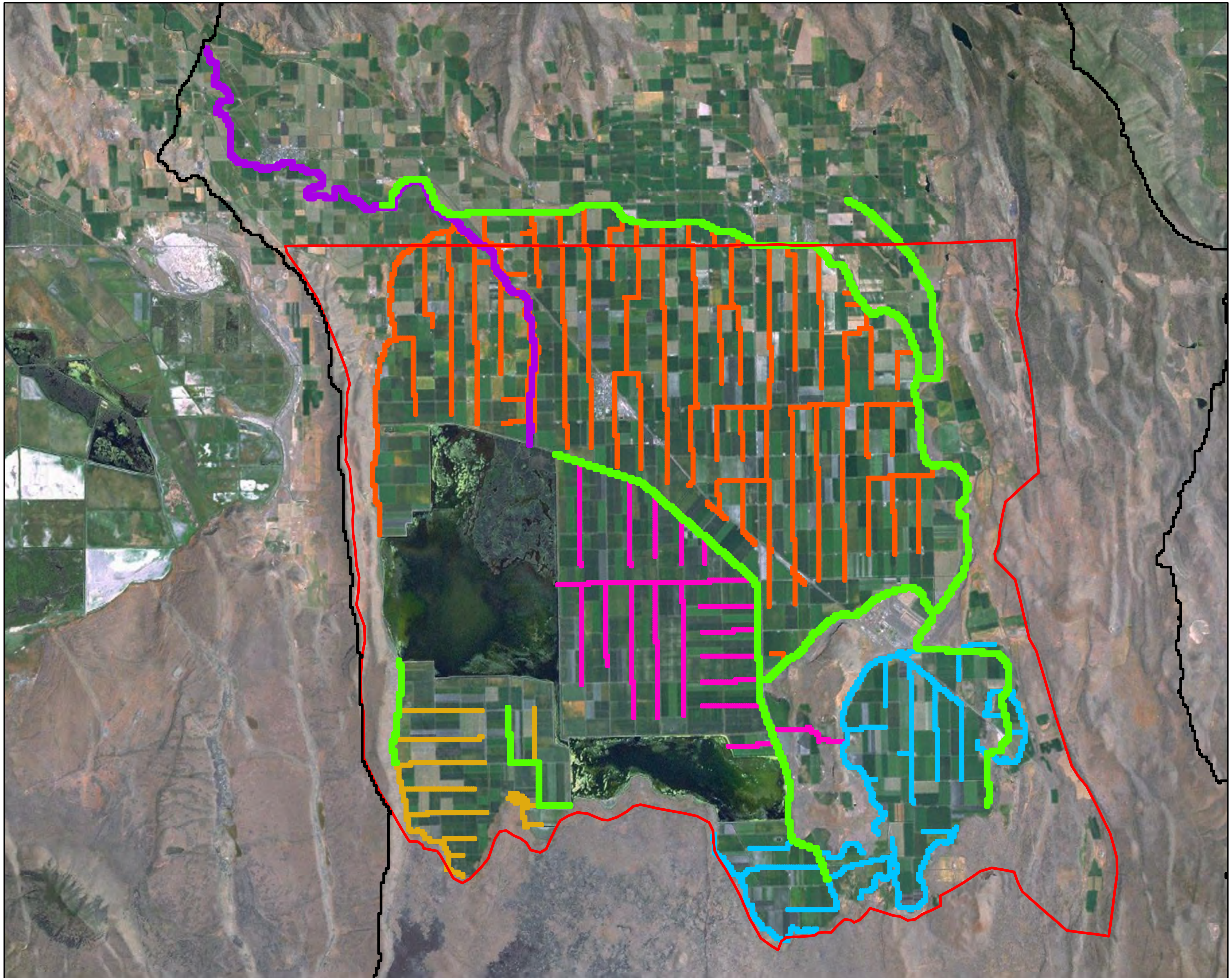

LEGEND

- Model Domain Boundary
- Tulelake Groundwater Subbasin
- Sand
- Sandy Loam
- Silt
- Silty Clay
- Unweathered Bedrock
- Water

Notes:

N

**FIGURE 3-3**
**Modeled Distribution of Soil Types**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*





Notes:

TID = Tulelake Irrigation District

N

**FIGURE 3-4**
**Simulated Lost River and Tulelake Irrigation District Conveyance Systems**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*



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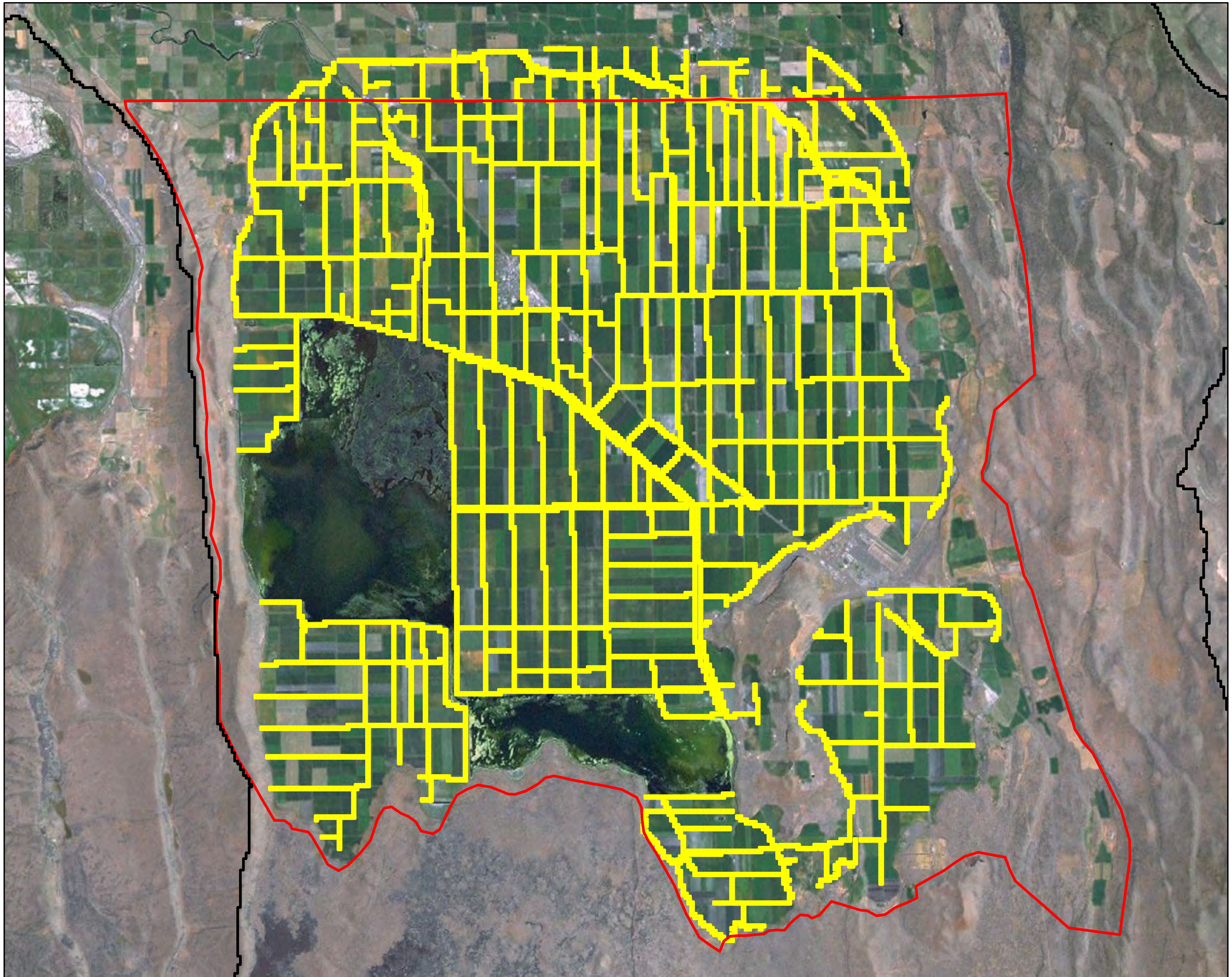

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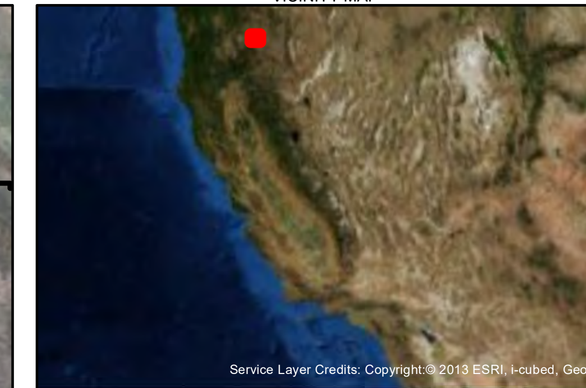


LEGEND

- Model Domain Boundary
- Tulelake Groundwater Subbasin
- Simulated TID Drains

Notes:

TID = Tulelake Irrigation District

N

**FIGURE 3-5**
**Simulated Tulelake Irrigation District Drains**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*



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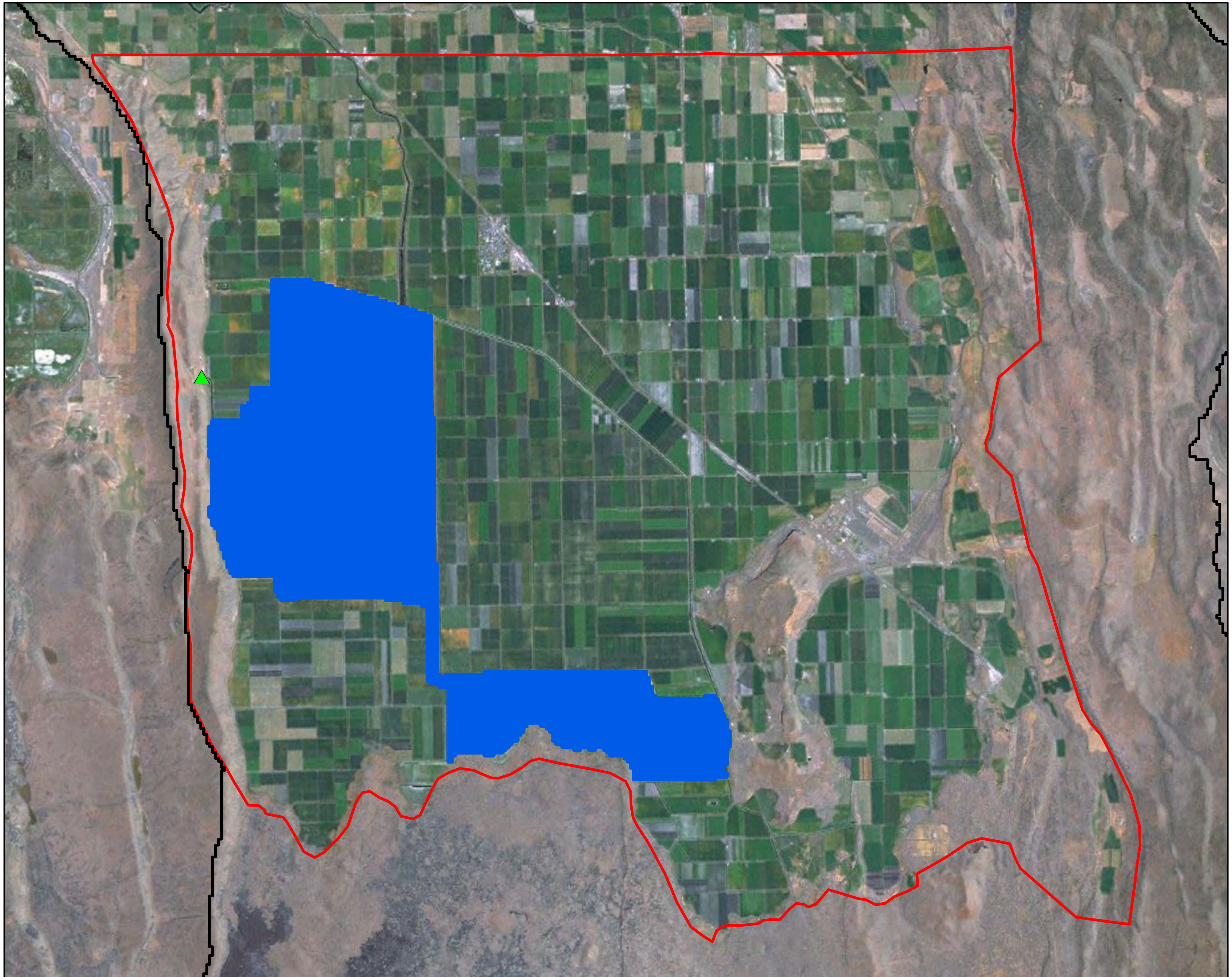

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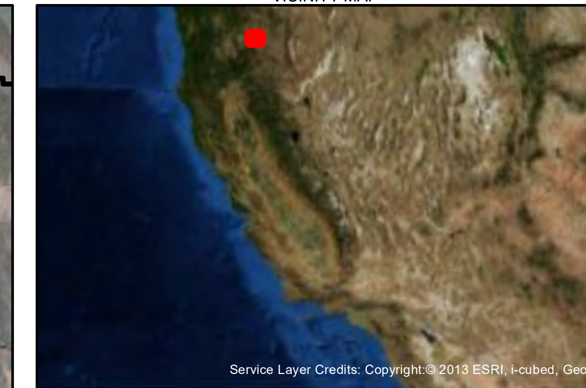



LEGEND

- D-Plant Pumping Location
- Simulated Tulelake Sumps
- Model Domain Boundary
- Tulelake Groundwater Subbasin

Notes:

N

**FIGURE 3-6**
**Simulated Tulelake Sumps**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*



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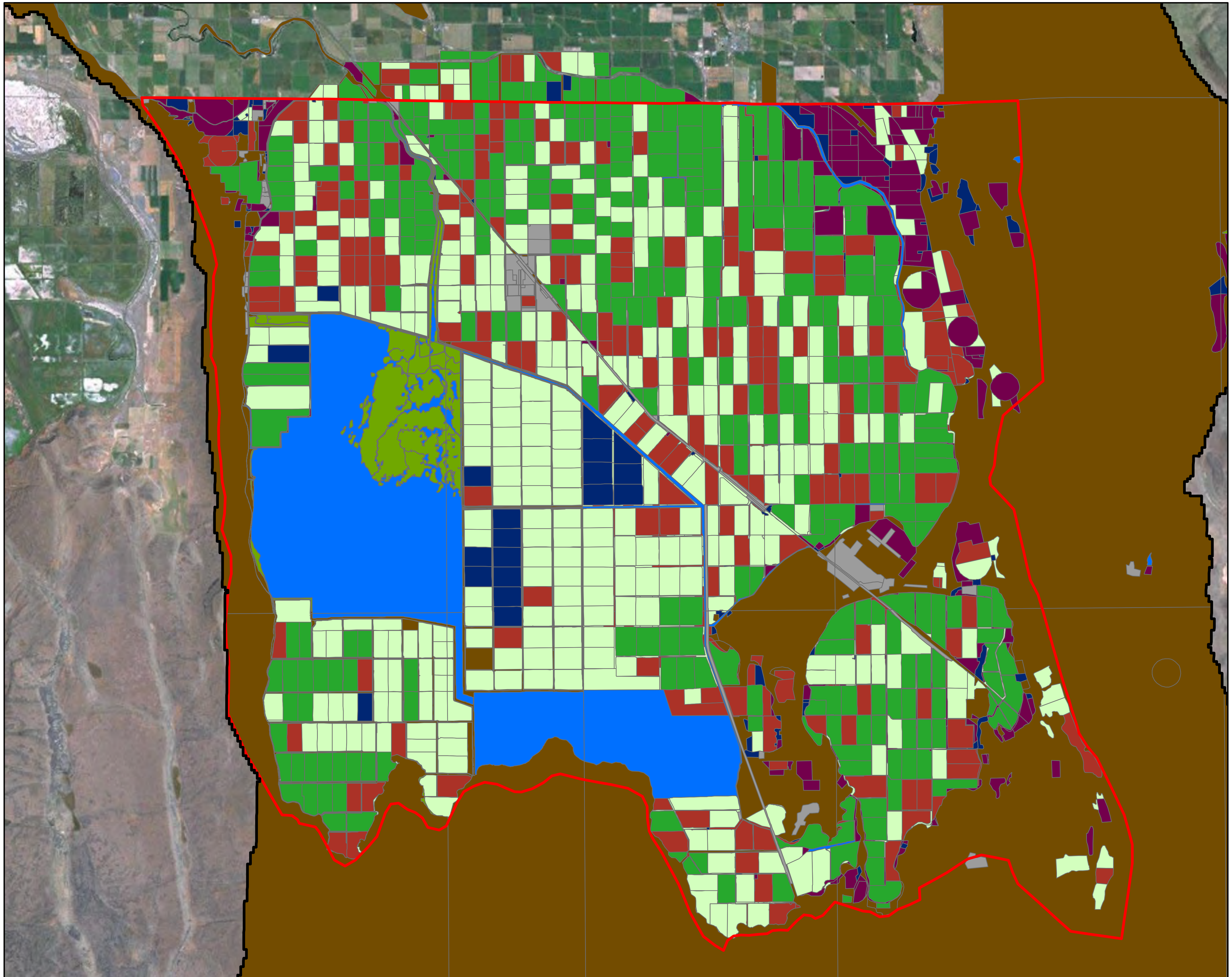
VICINITY MAP

LEGEND

- Model Domain Boundary
- Tulelake Groundwater Subbasin

**Simulated Land Use Categories**

- Alfalfa
- All Other Crops
- Grains
- Idle
- Native Vegetation
- Pasture
- Riparian Vegetation
- Urban
- Water

Notes:

N

**FIGURE 3-7**
**2008 Simulated Land Use**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*



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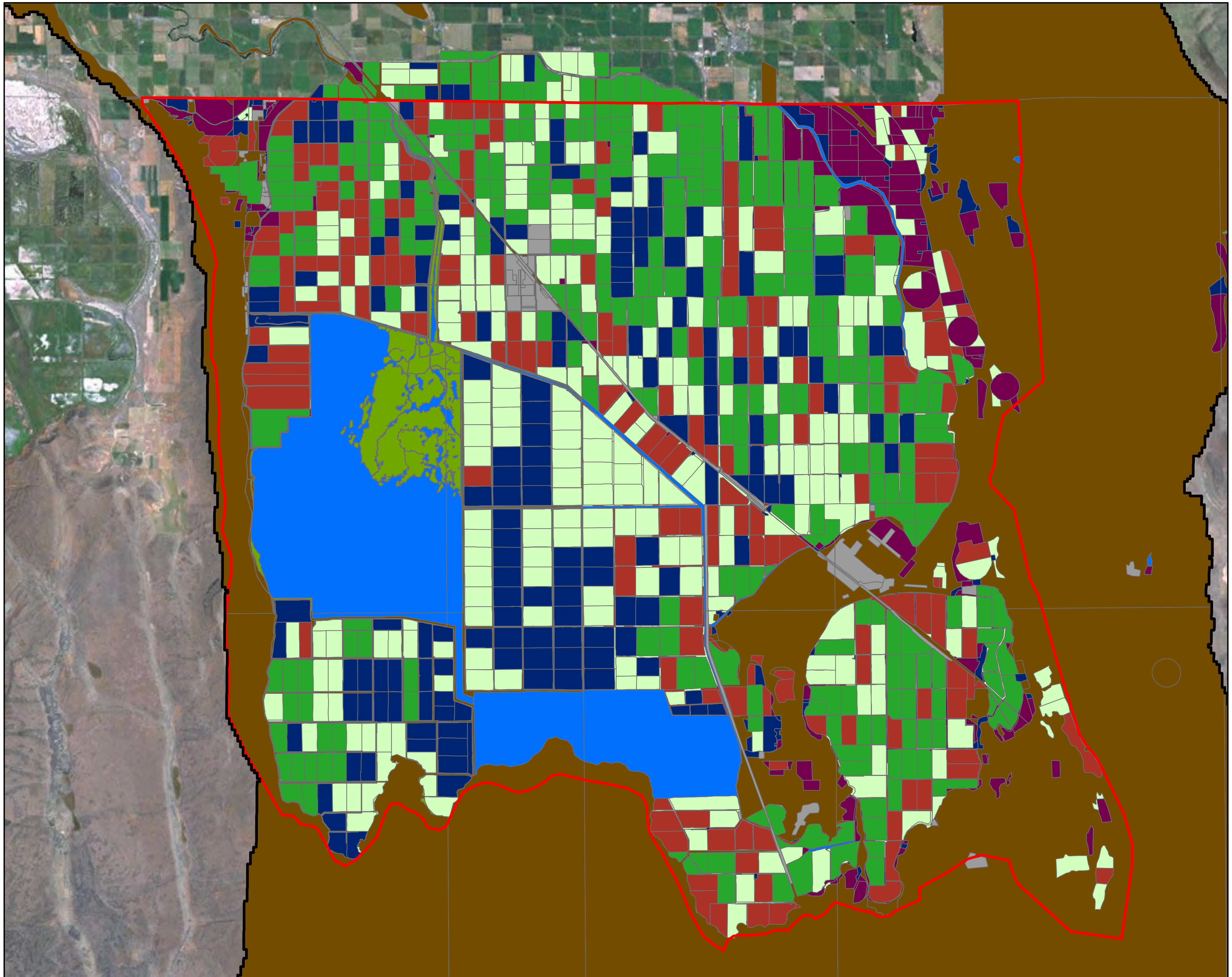

VICINITY MAP


LEGEND

- Model Domain Boundary
- Tulelake Groundwater Subbasin

**Simulated Land Use Categories**

- Alfalfa
- All Other Crops
- Grains
- Idle
- Native Vegetation
- Pasture
- Riparian Vegetation
- Urban
- Water

Notes:

N

**FIGURE 3-8**
**2010 Simulated Land Use**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*

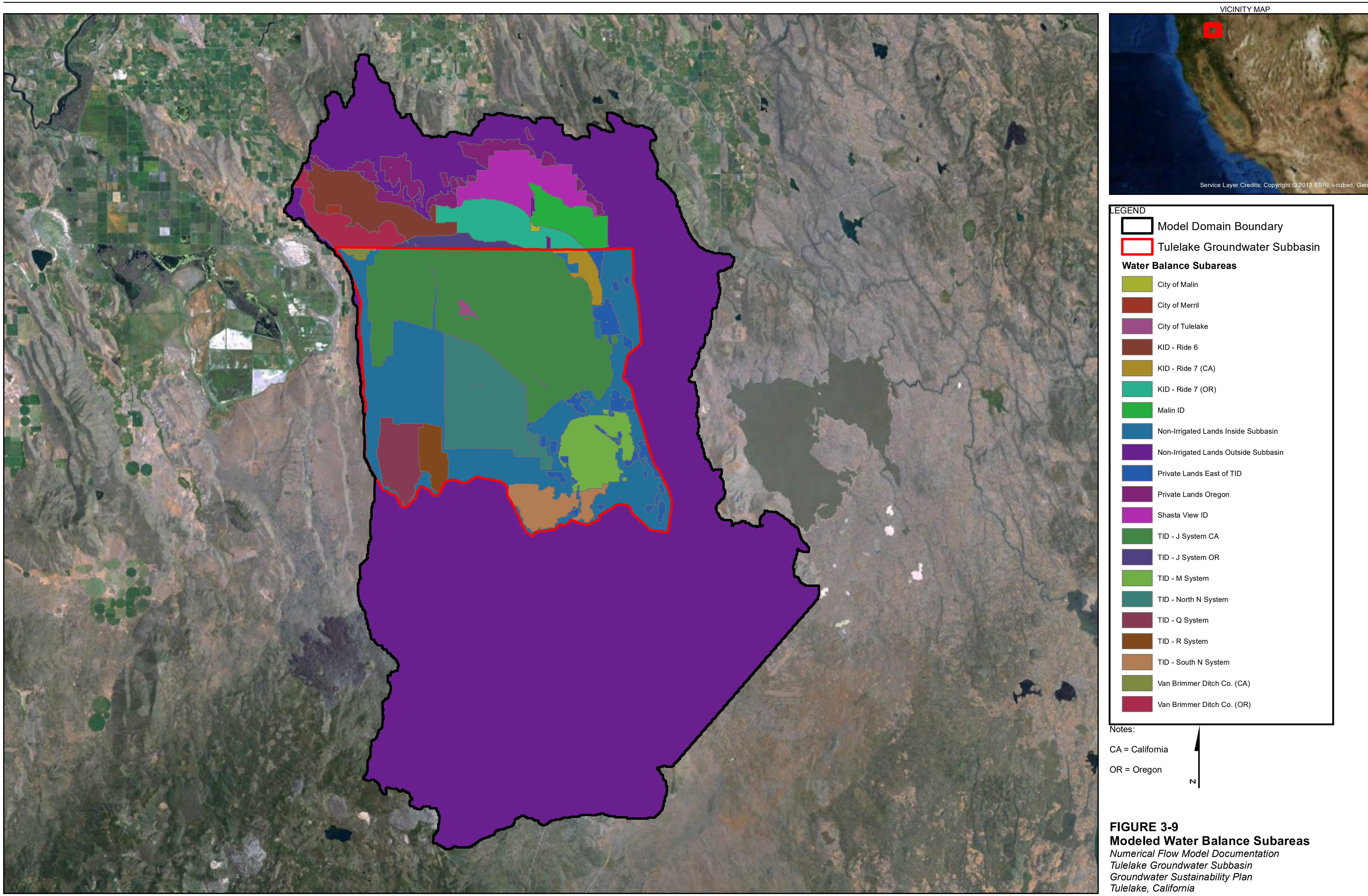


**FIGURE 3-9**
**Modeled Water Balance Subareas**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*

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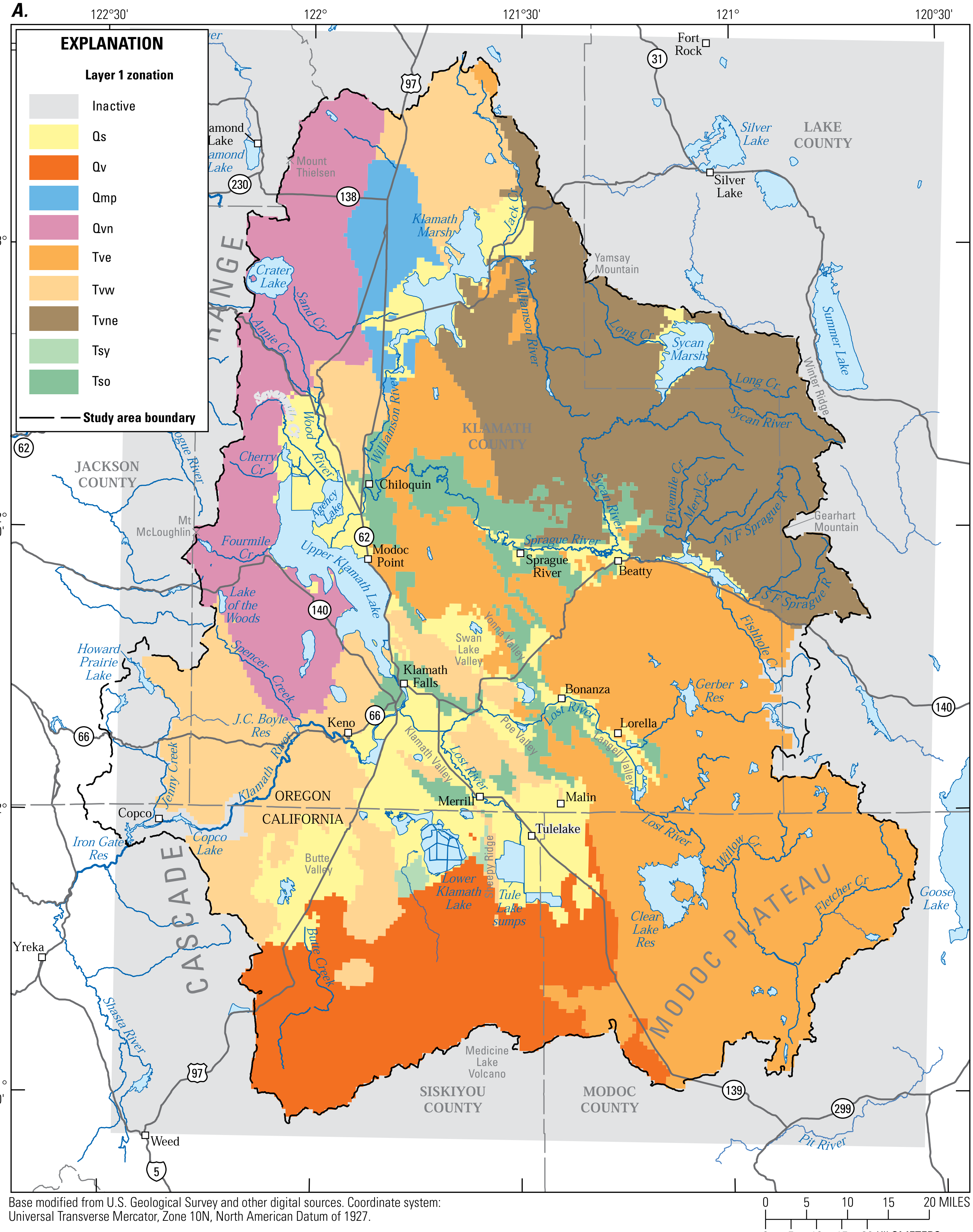
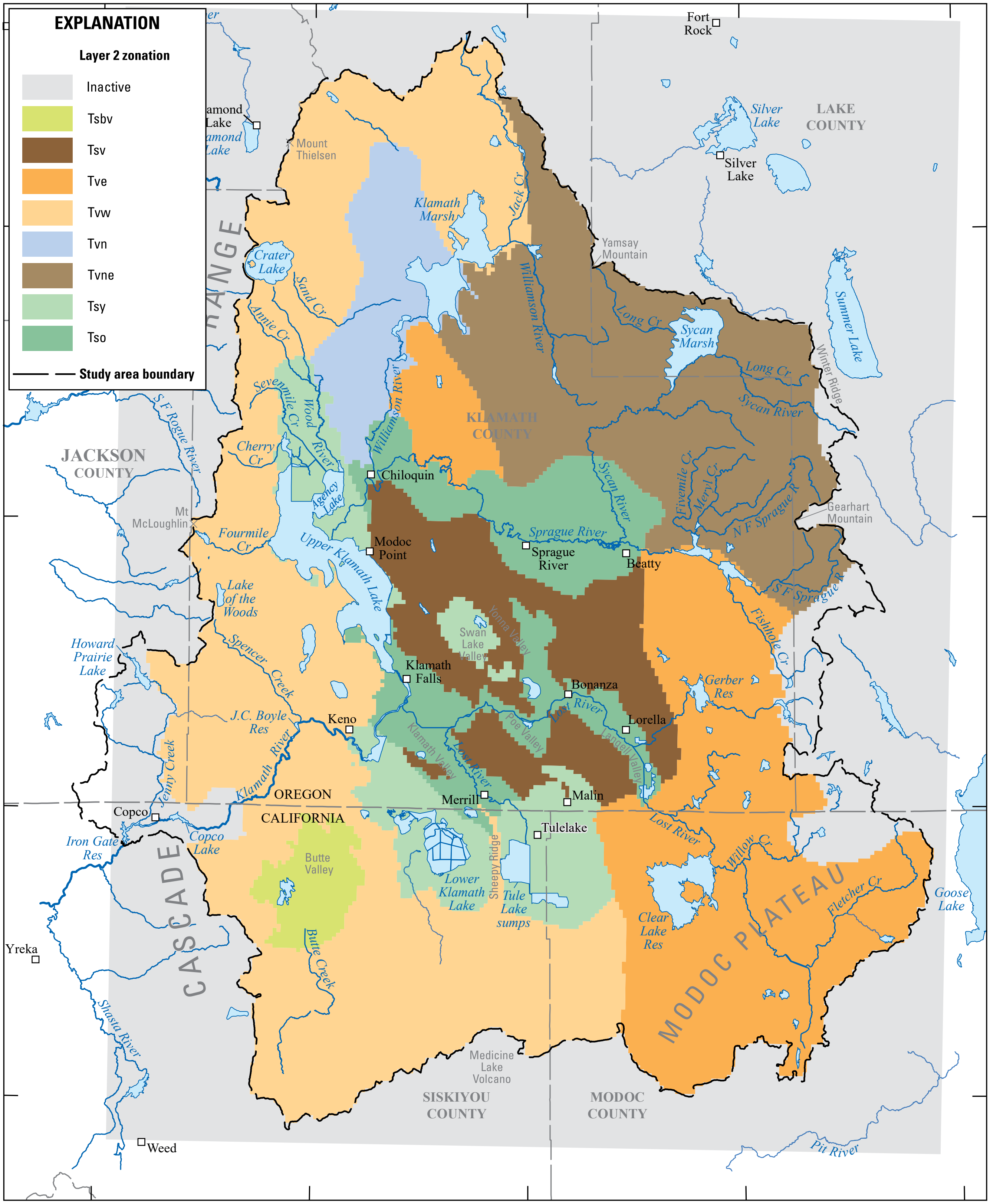



**Figure 6.** Upper Klamath Basin, Oregon and California, regional groundwater flow model hydraulic-conductivity zonation. (*A*) Layer 1 zonation; (*B*) Layer 2 zonation; and (*C*) Layer 3 zonation. Hydrogeologic unit definitions: Qs, Quaternary sediment; Qv, Quaternary volcanic deposits; Qvn, Quaternary volcanic deposits north; Qmp, Quaternary Mazama pumice; Tvn, Tertiary volcanic deposits north; Tsbv, Tertiary sediments, Butte Valley; Tsy, Tertiary sediments younger basins; Tso, Tertiary sediments older basins; Tsv, Tertiary mixed sedimentary and volcanic deposits; Tvw, Tertiary volcanic rocks west; Tve, Tertiary volcanic rocks east; Tvne, Tertiary volcanic rocks northeast.

***B.***




0 5 10 15 20 MILES
0 5 10 15 20 KILOMETERS

Base modified from U.S. Geological Survey and other digital sources. Coordinate system: Universal Transverse Mercator, Zone 10N, North American Datum of 1927.

**Figure 6.**—Continued

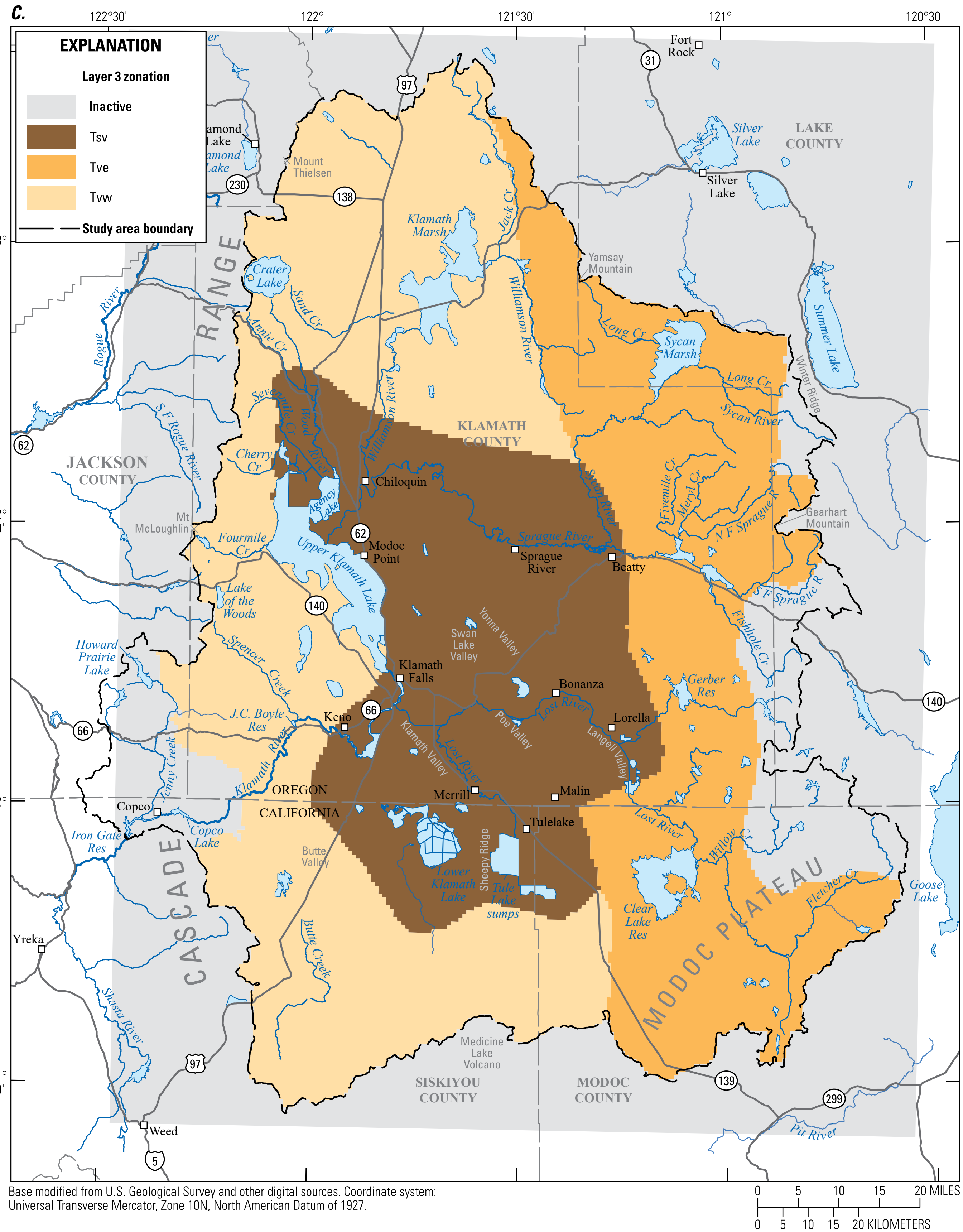



**Figure 6.**—Continued

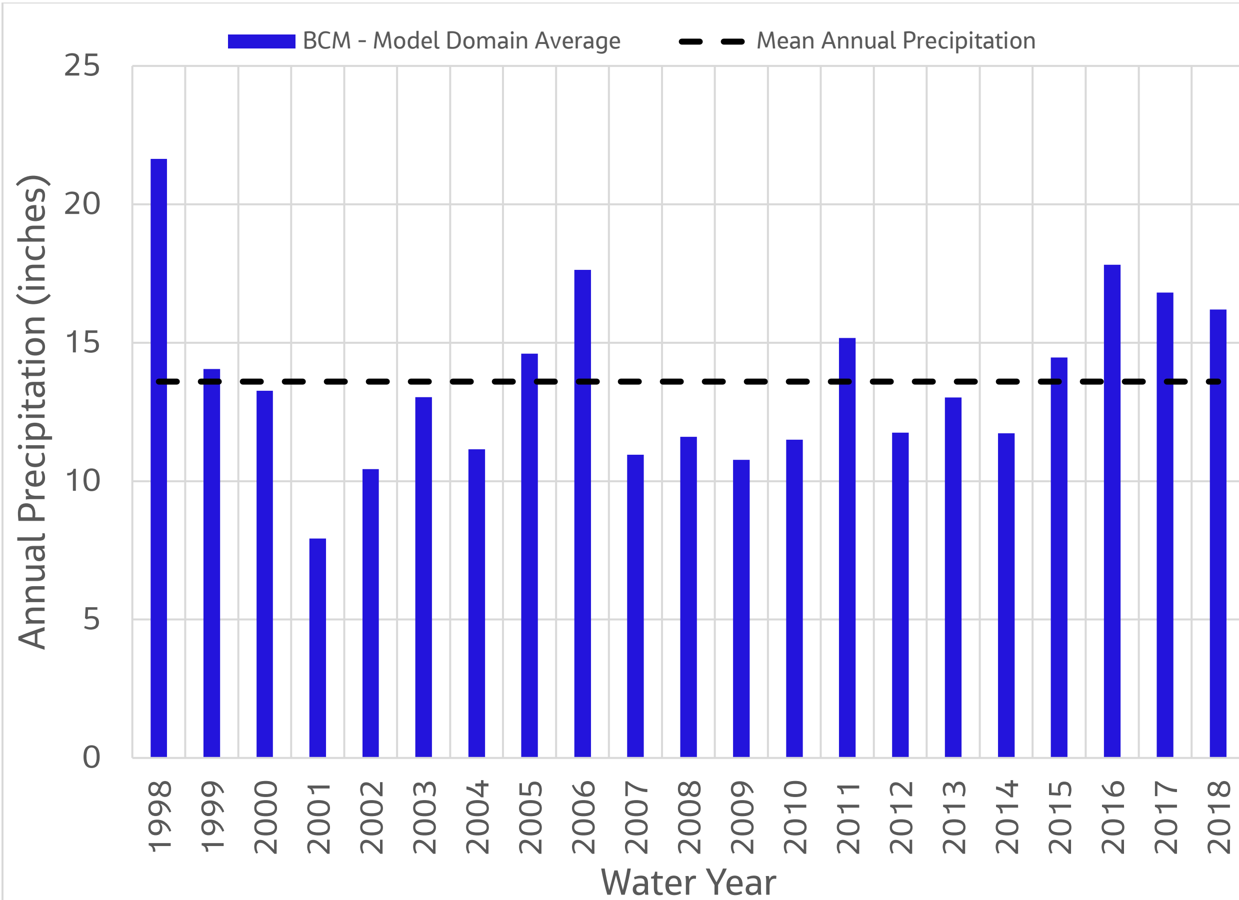



Figure 3-11 – Modeled Annual Precipitation

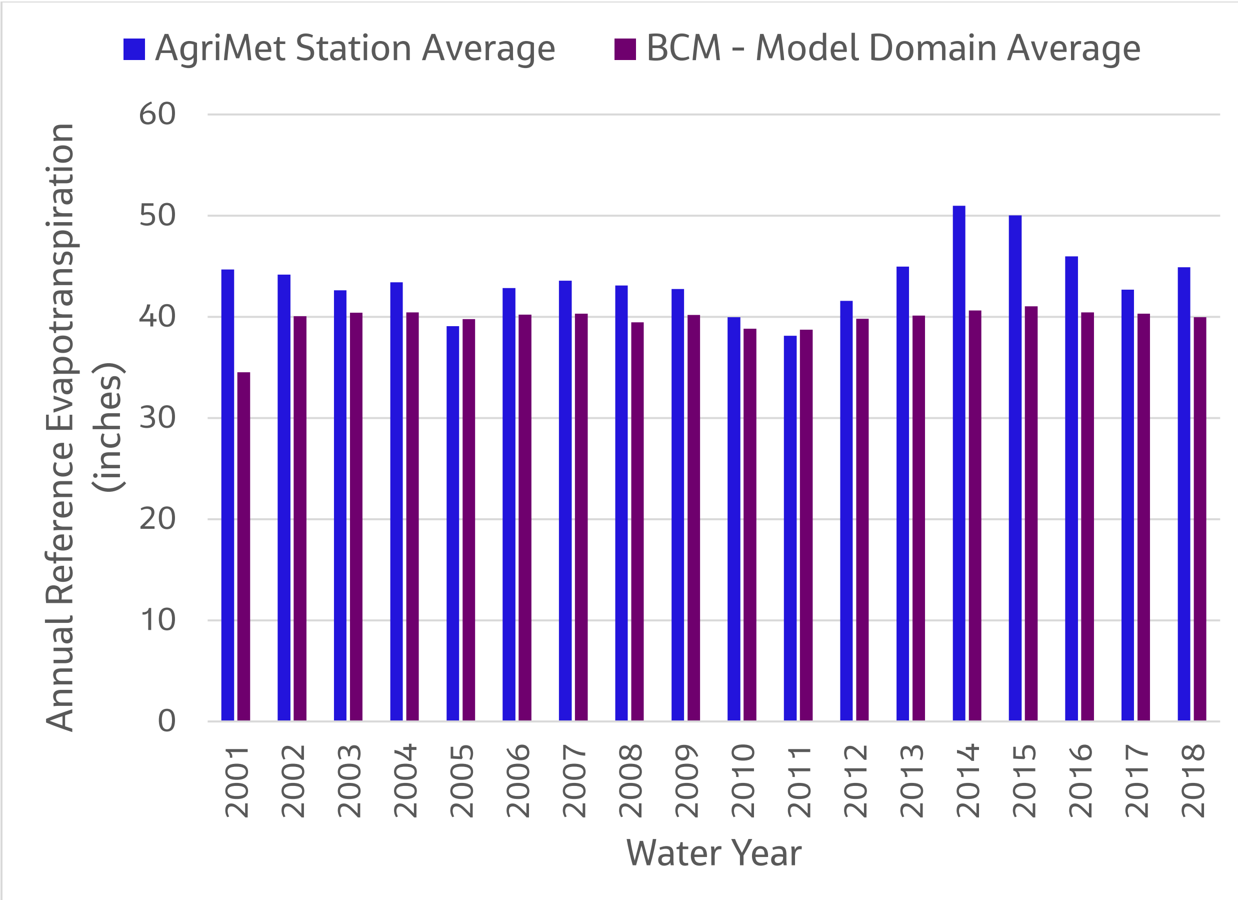



Figure 3-12 – Annual Reference Evapotranspiration

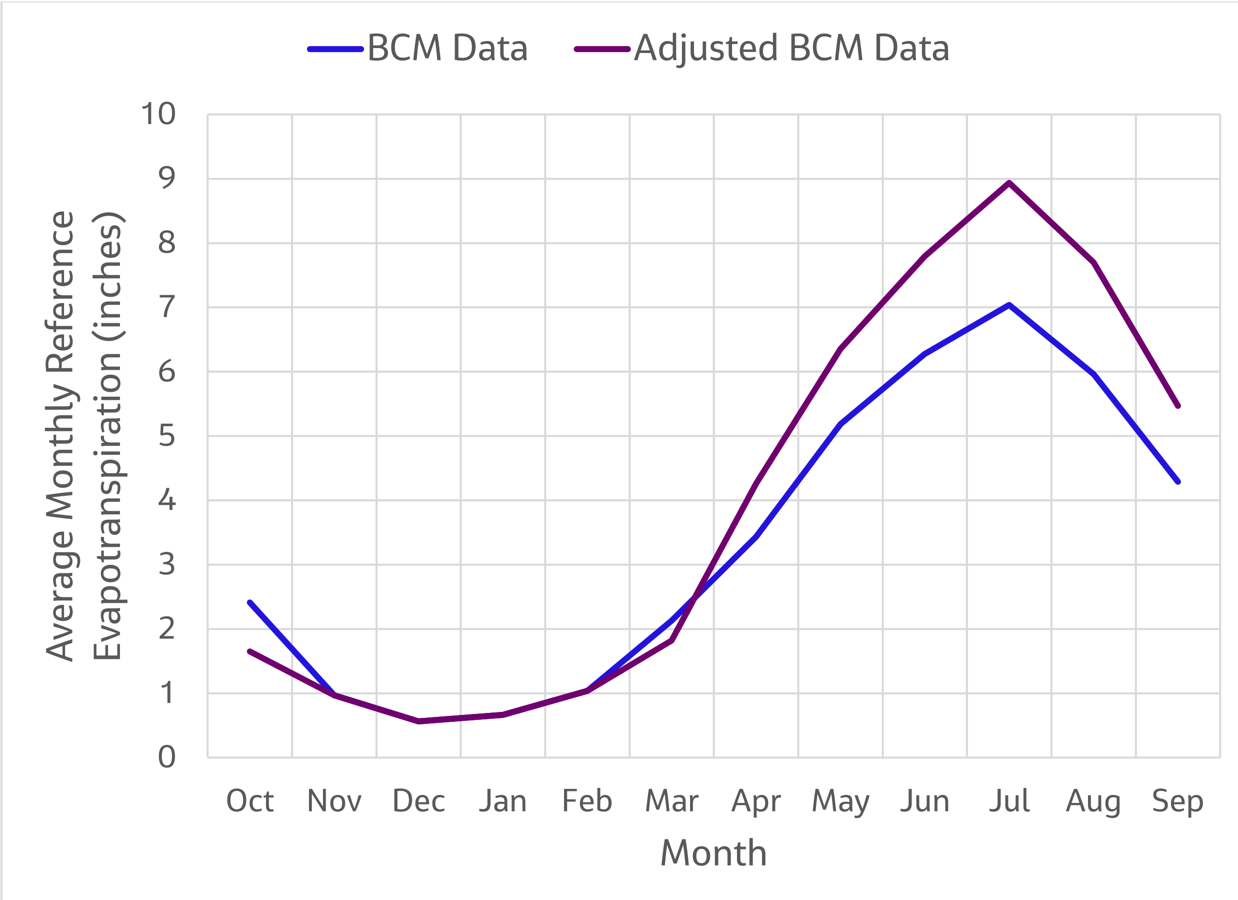



Figure 3-13 – Monthly Average Reference Evapotranspiration

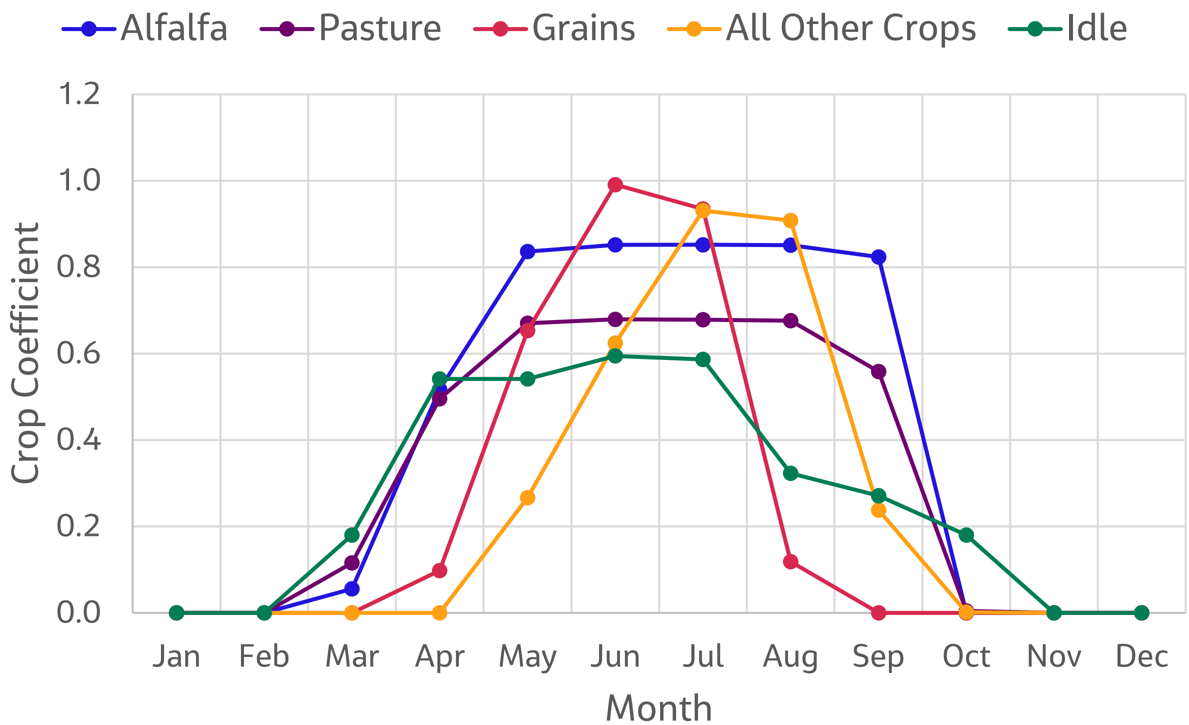



Figure 3-14 - Monthly Crop Coefficients

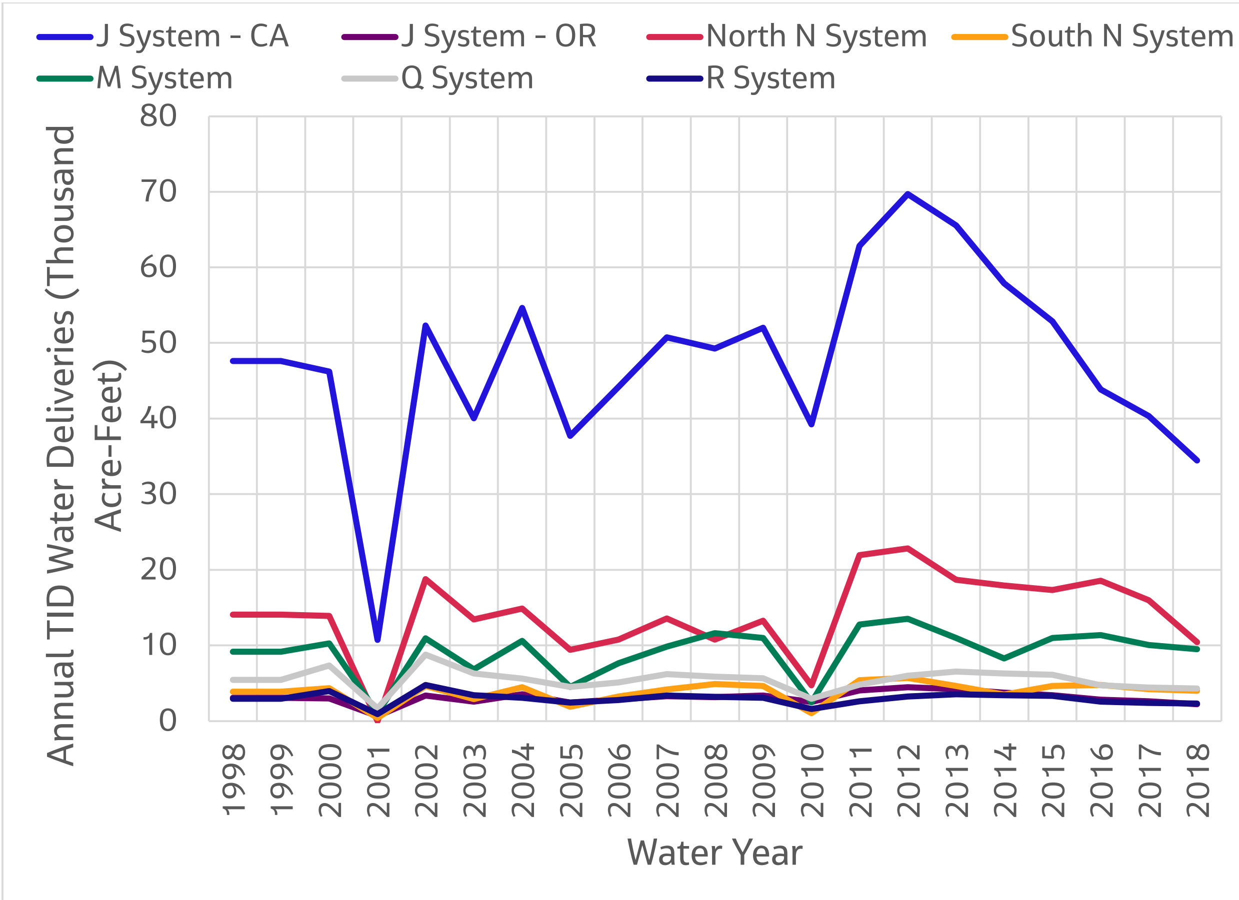
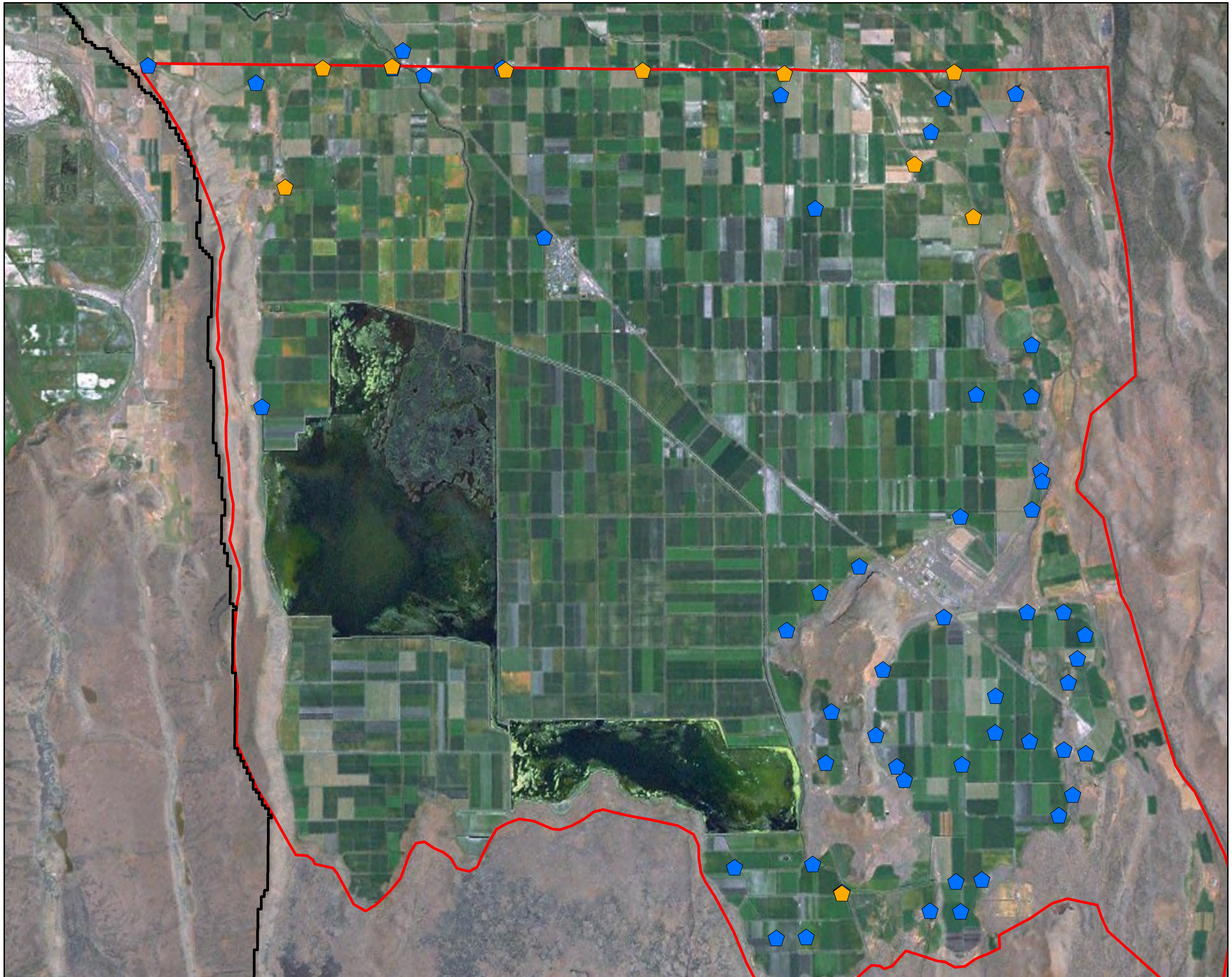
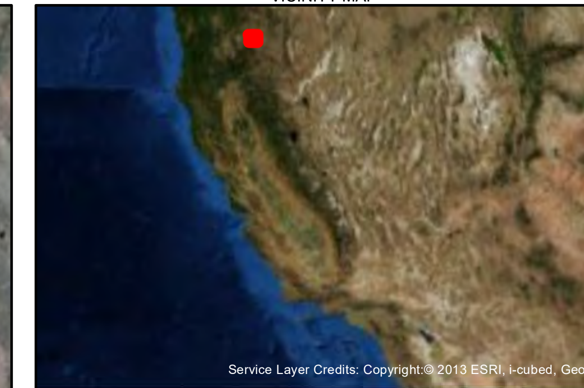



Figure 3-15 – Annual TID Water Deliveries



VICINITY MAP




LEGEND

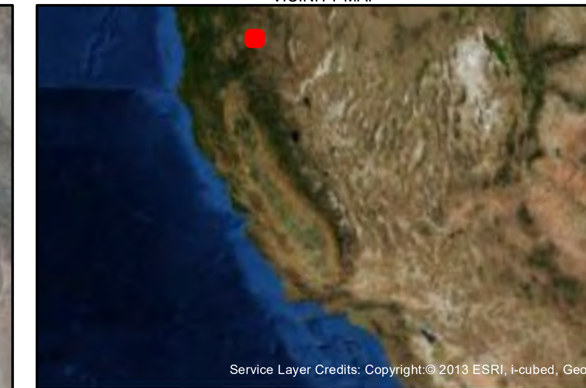
**Simulated Pumping Well**

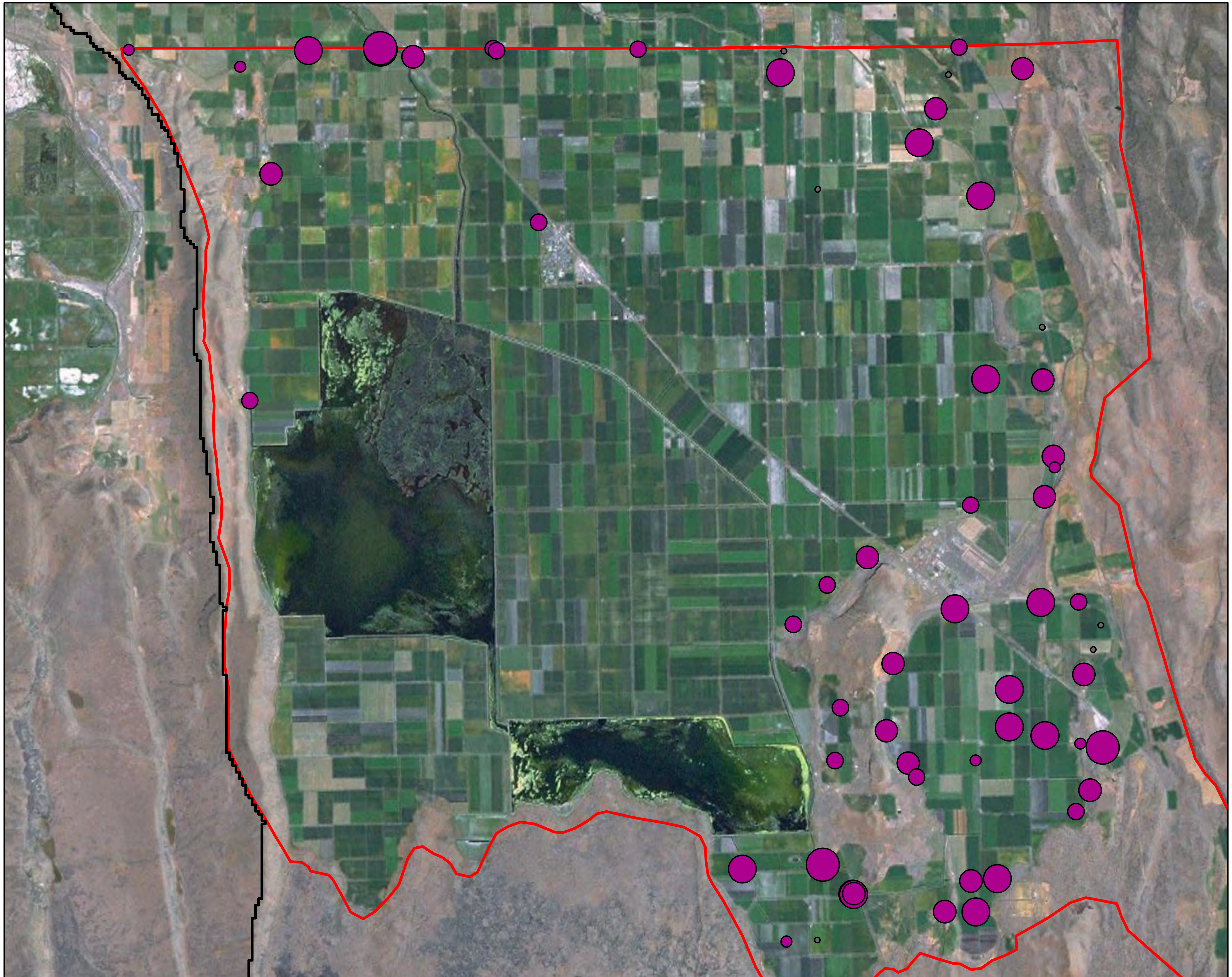
- Private Well
- TID Well
- Model Domain Boundary
- Tulelake Groundwater Subbasin

Notes:

N

**FIGURE 3-16**
**Simulated Pumping Well Locations**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*




Notes:

WY = Water Year

**FIGURE 3-17**
**WY 2014 Annual Pumping Volume at Simulated Pumping Wells**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*

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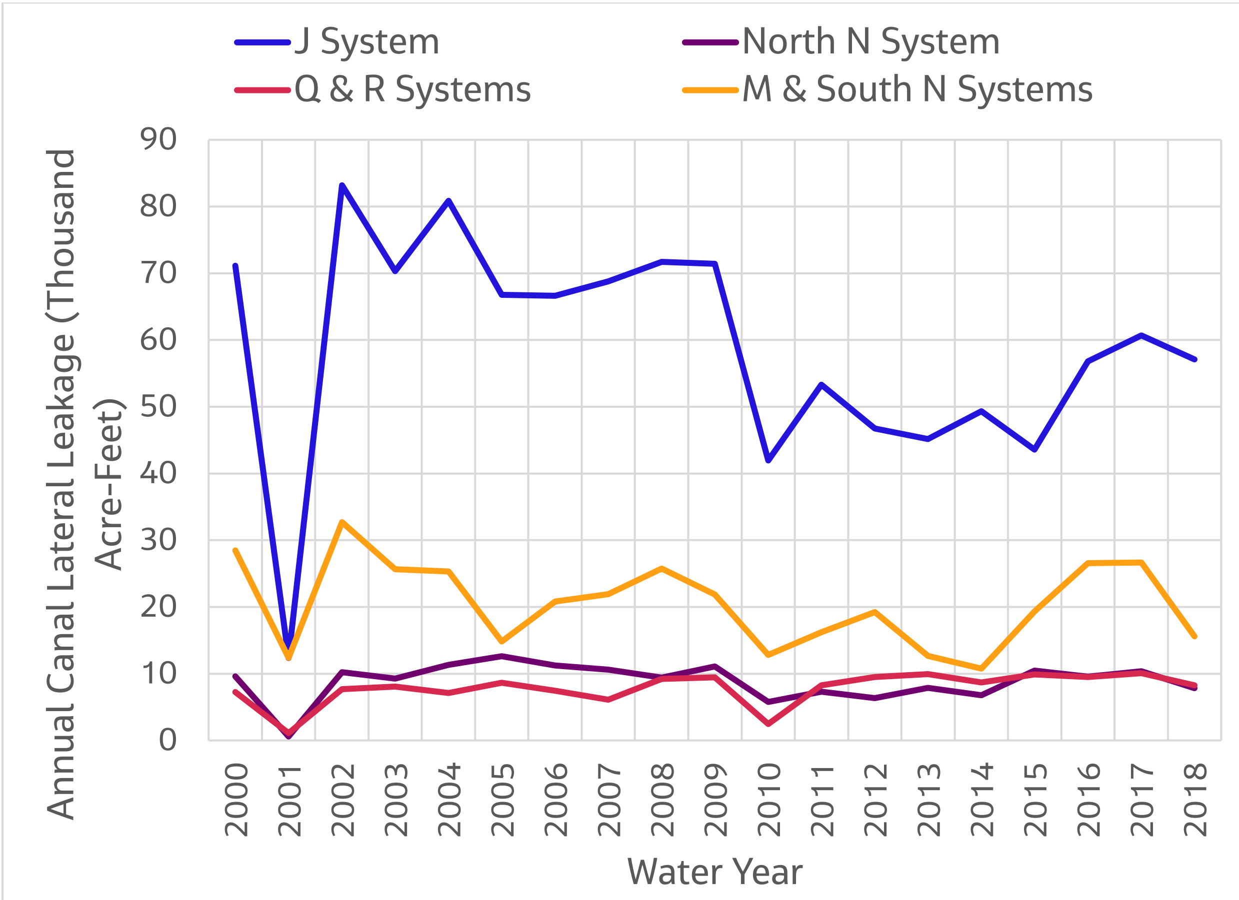
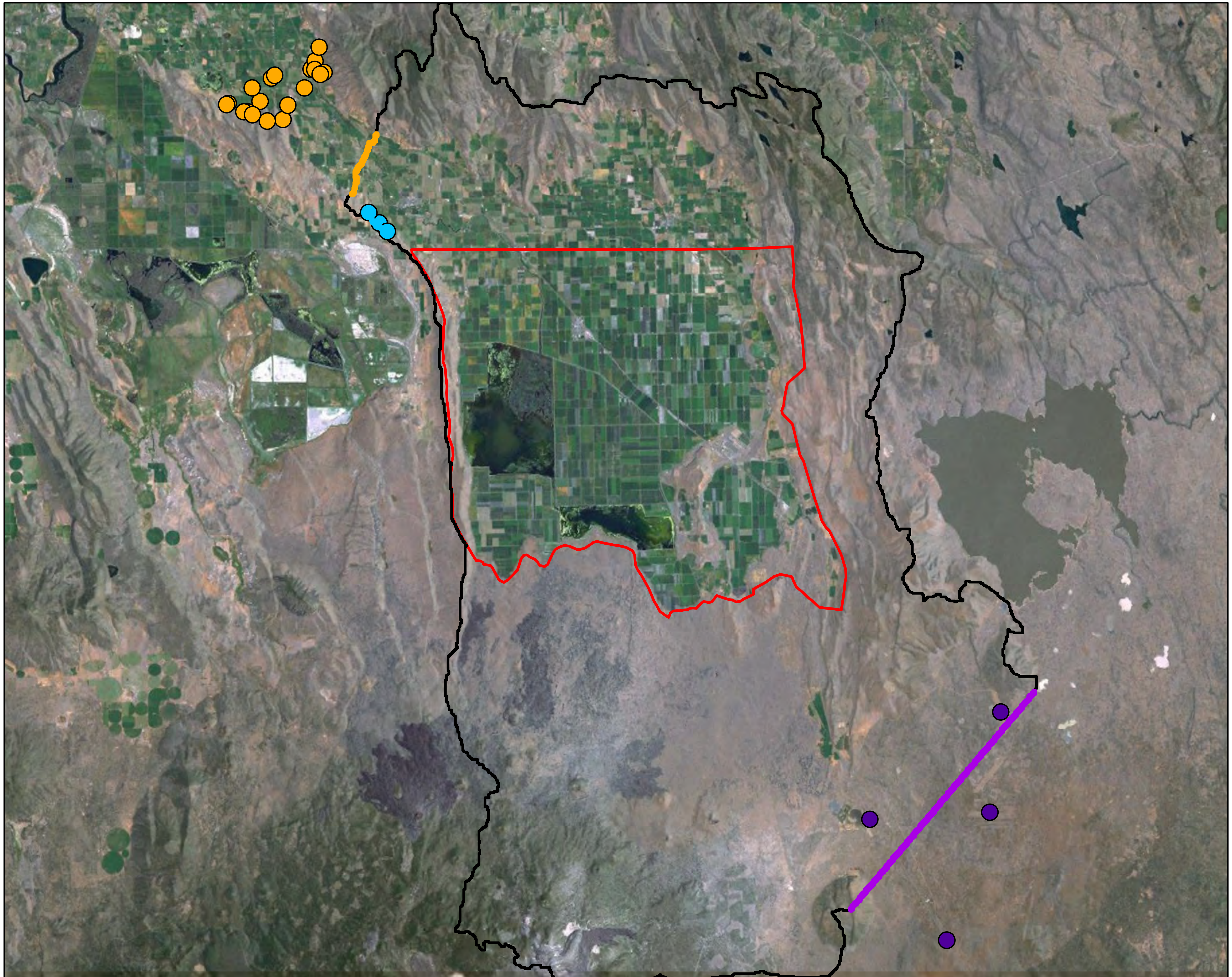
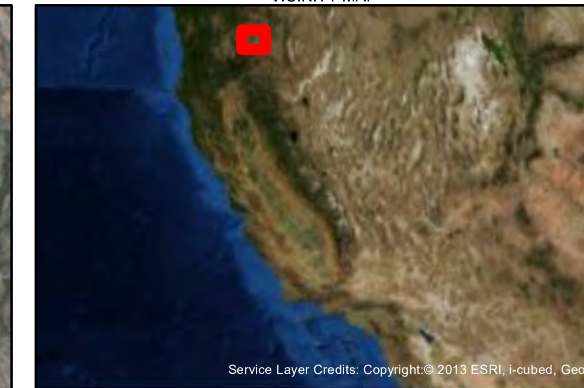



Figure 3-18 – Annual Estimated Canal Lateral Leakage



VICINITY MAP




LEGEND
- Northern General Head Boundary
- Northwestern General Head Boundary
- Southern General Head Boundary
- Northern Boundary Wells
- North Western Boundary Wells
- Southern Boundary Wells
- Groundwater Model Active Domain
- Tulelake Subbasin

Notes:

N

**FIGURE 3-19**
**Lateral Subsurface Boundary Locations**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*

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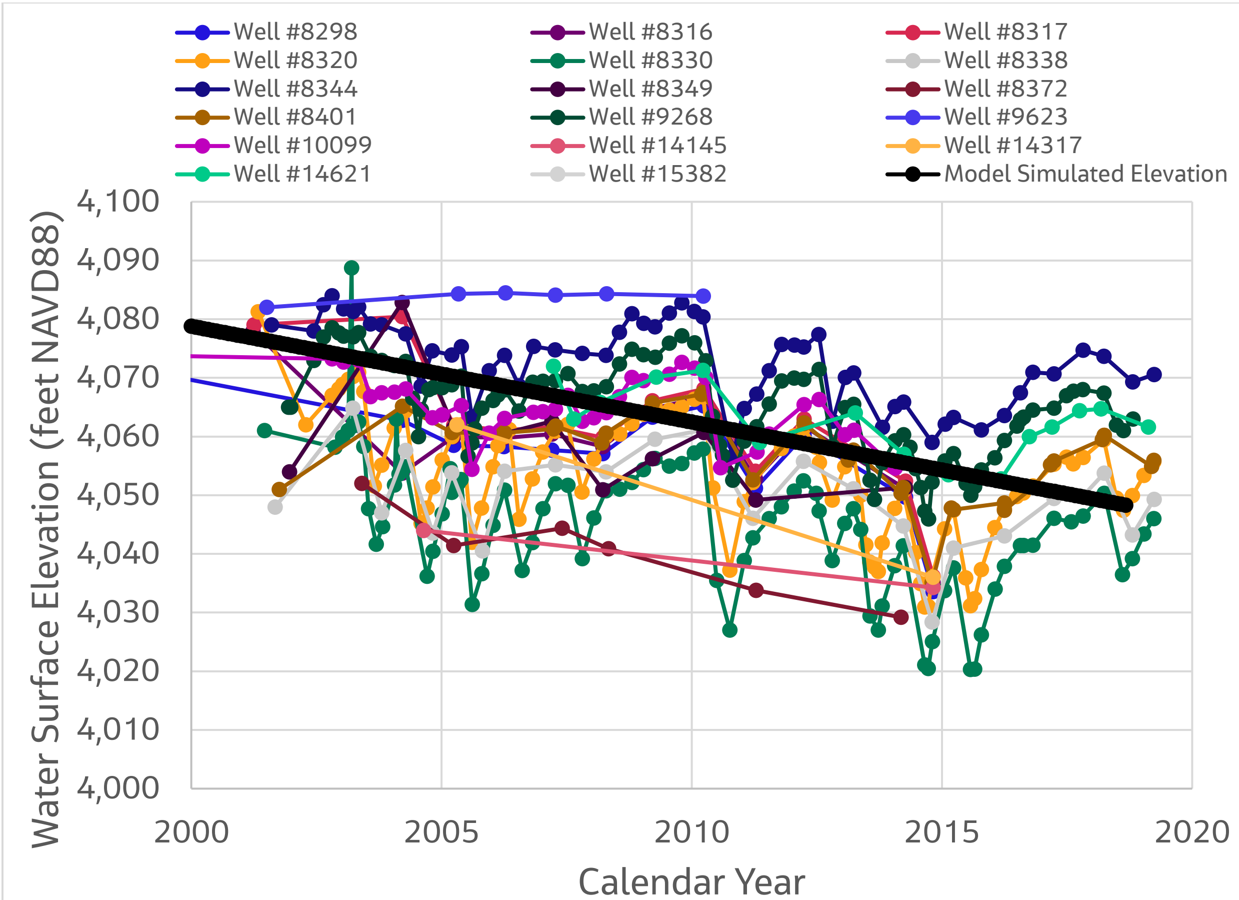



Figure 3-20 – Northern General Head Boundary Water Level Data

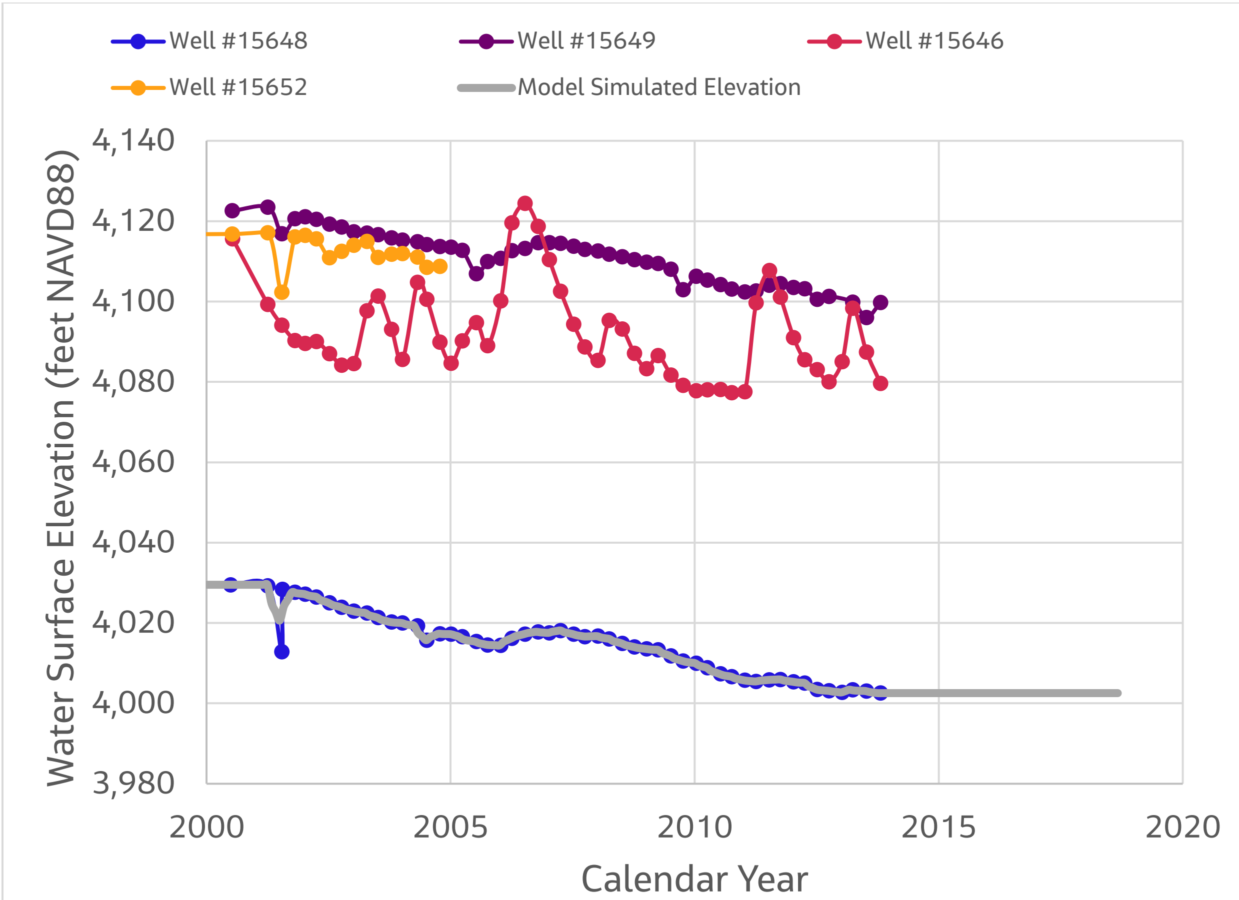



Figure 3-21 – Southern Boundary Water Level Data

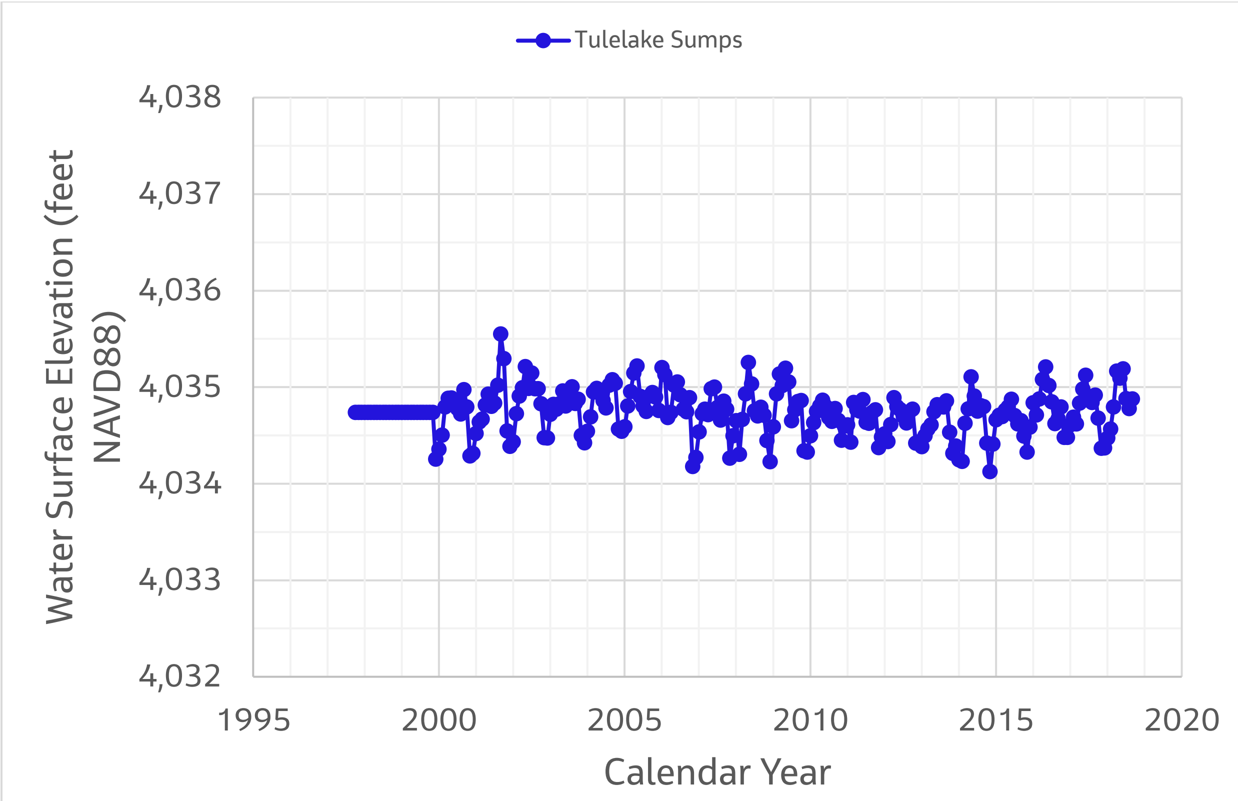
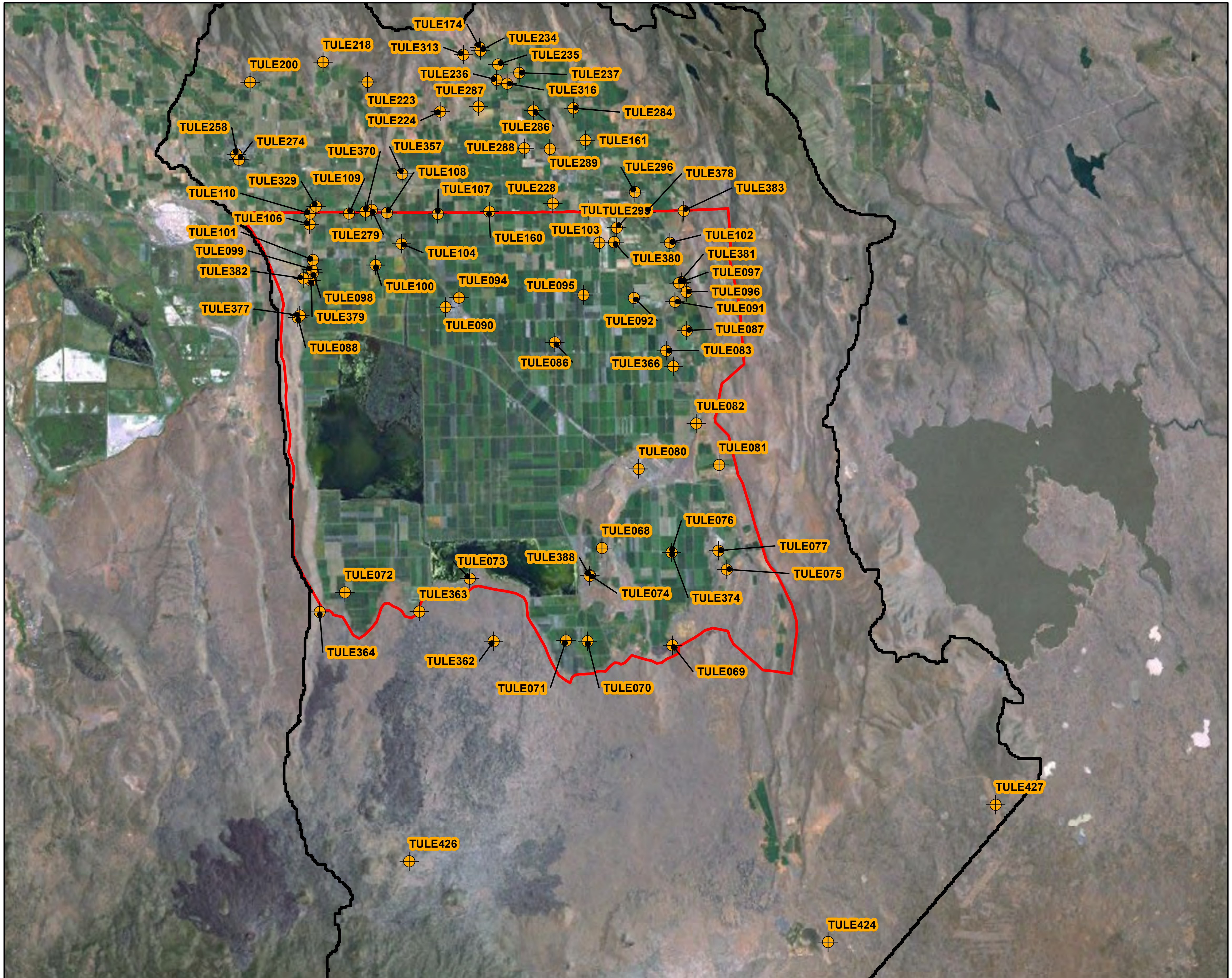
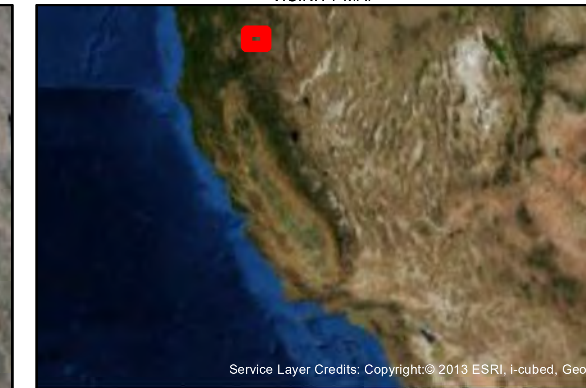



Figure 3-22 – Tulelake Sumps Historical Water Surface Elevation




VICINITY MAP




LEGEND

- Target Well Locations
- Model Domain Boundary
- Tulelake Groundwater Subbasin

Notes:

N

**FIGURE 4-1**
**Calibration Target Locations**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*

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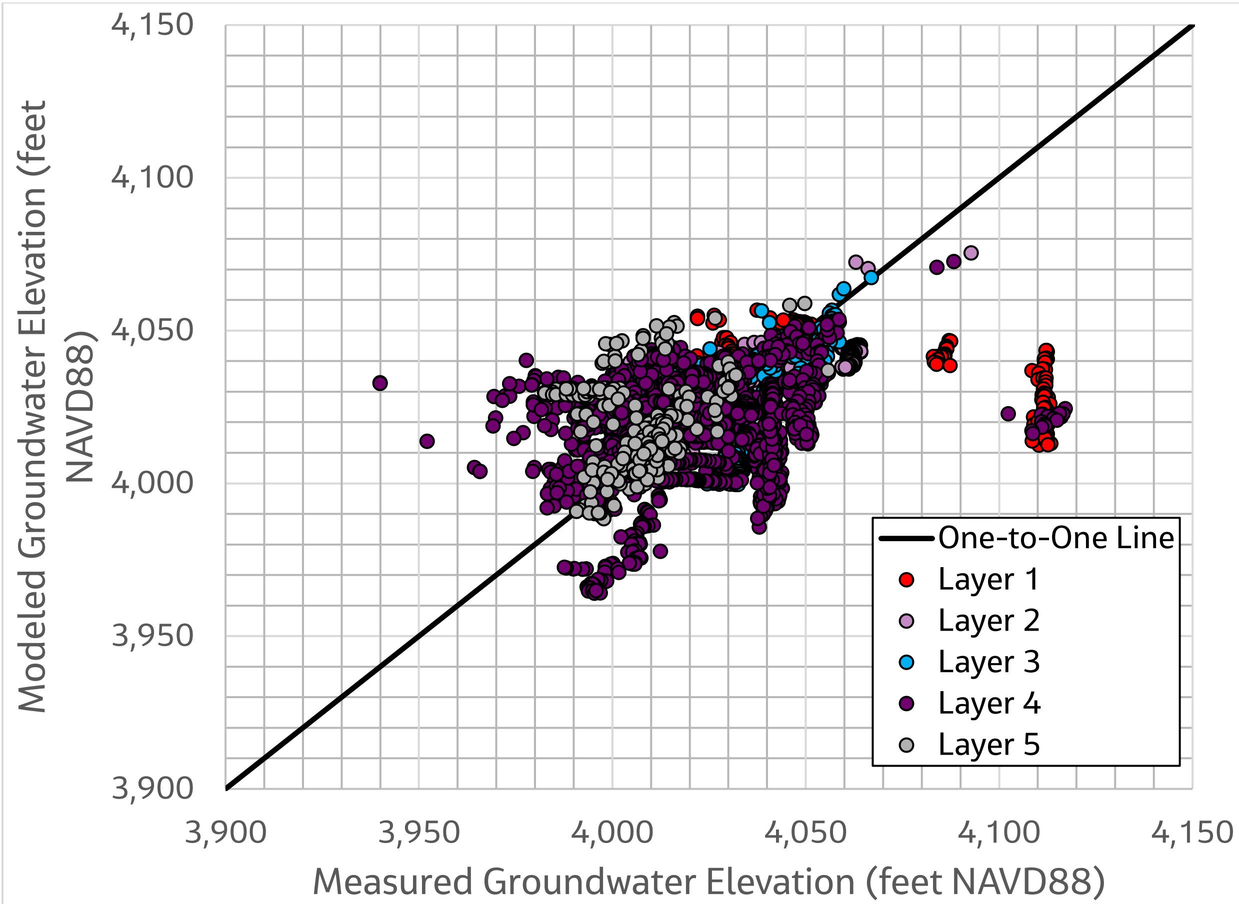
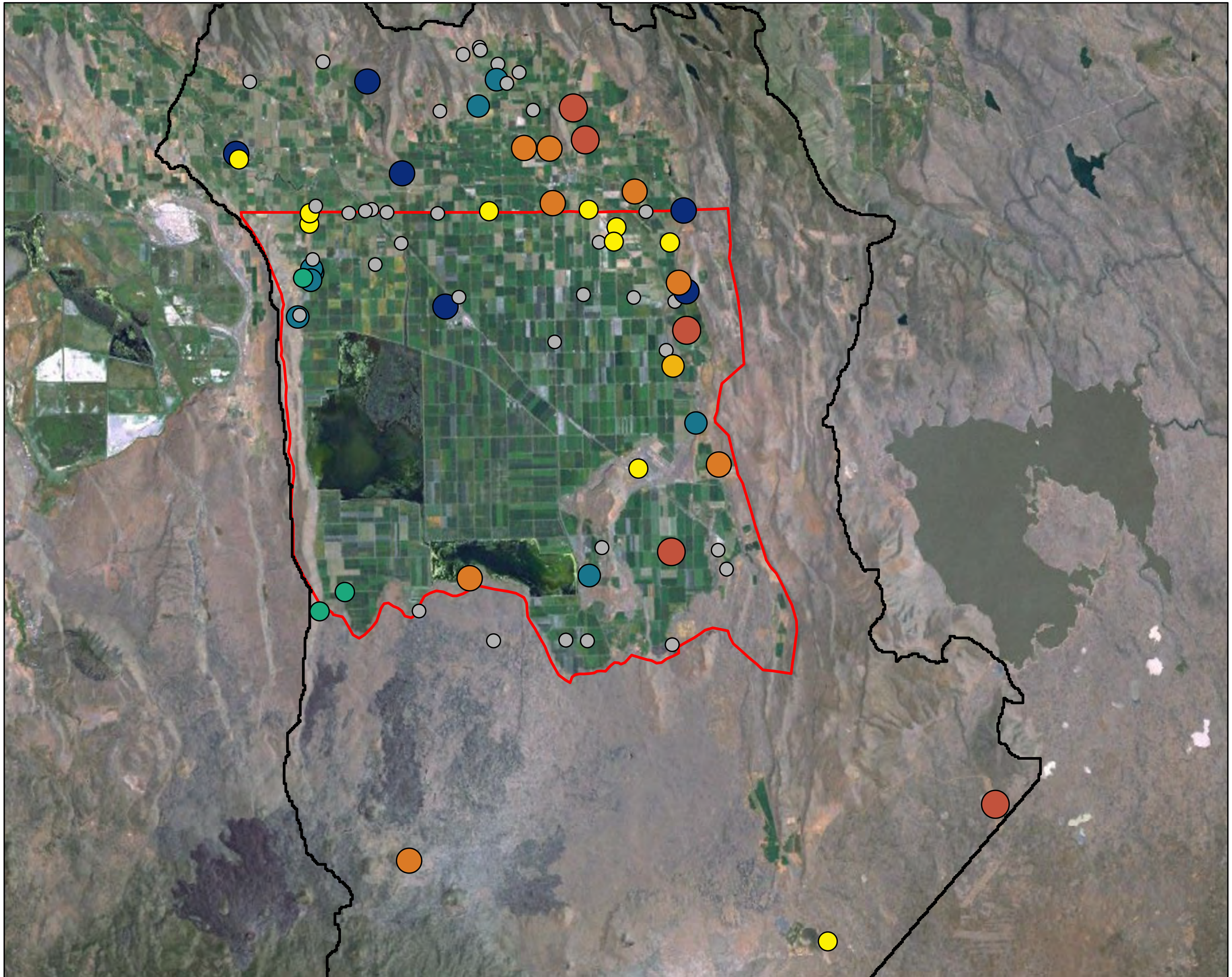
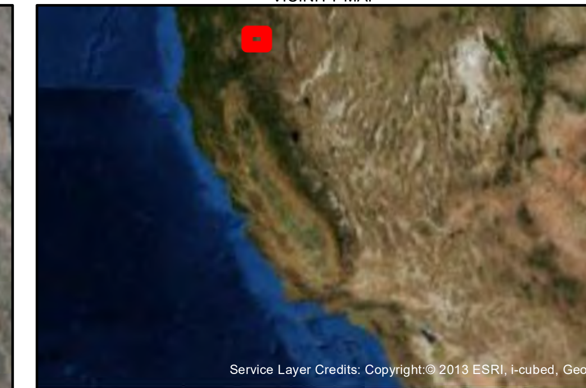



Figure 4-2 – Modeled Versus Target Groundwater Elevations



VICINITY MAP




LEGEND

**Mean Residual (feet)**

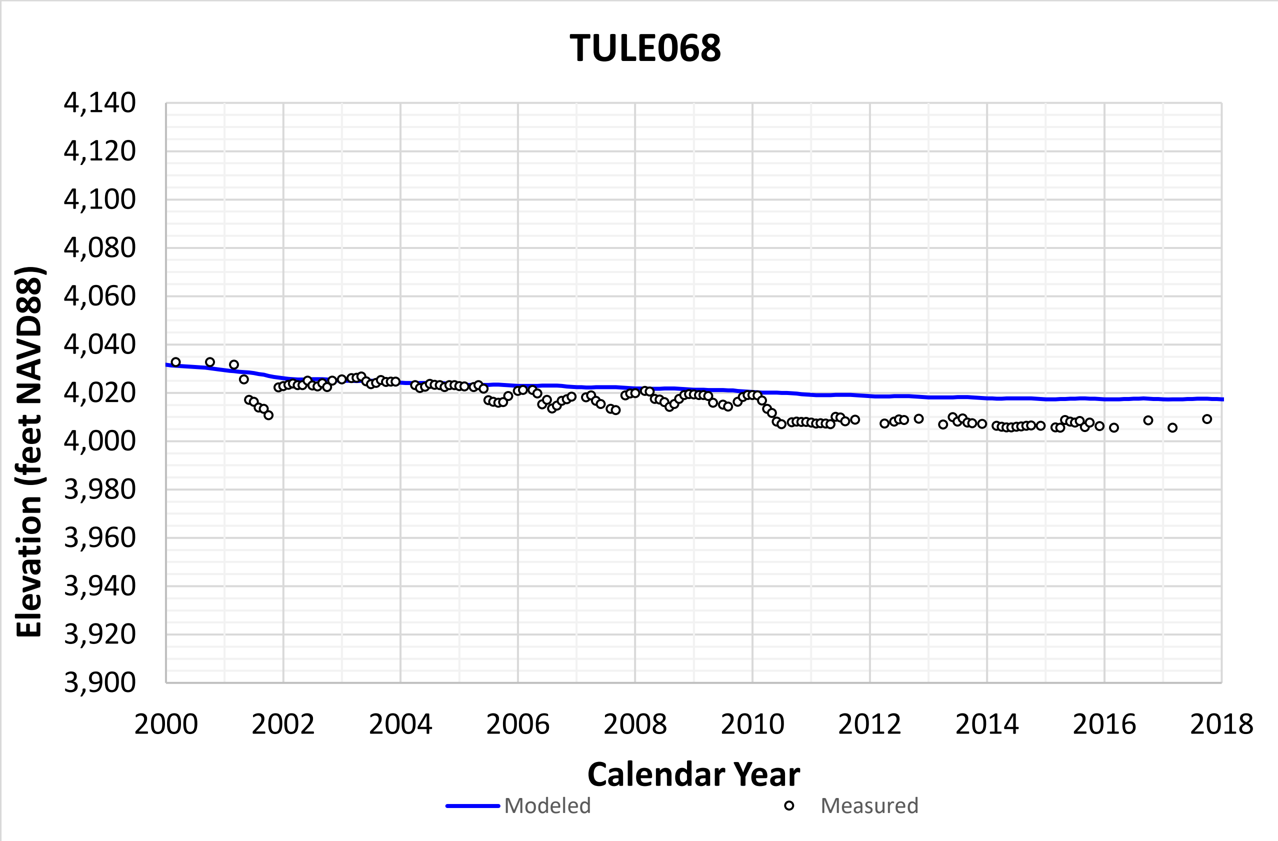
- -92 - -25
- -24 - -15
- -14 - -10
- -9 - -5
- -4 - 5
- 6 - 10
- 11 - 15
- 16 - 25
- 26 - 40
- Model Domain Boundary
- Tulelake Groundwater Subbasin

Notes:

The residual is computed by subtracting the target (measured) groundwater elevation from the modeled groundwater elevation. The meanresidual values represent the average of the residuals from all measurement times at a given target well during the calibration period.

N

**FIGURE 4-3**
**Map of Mean Residuals**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*



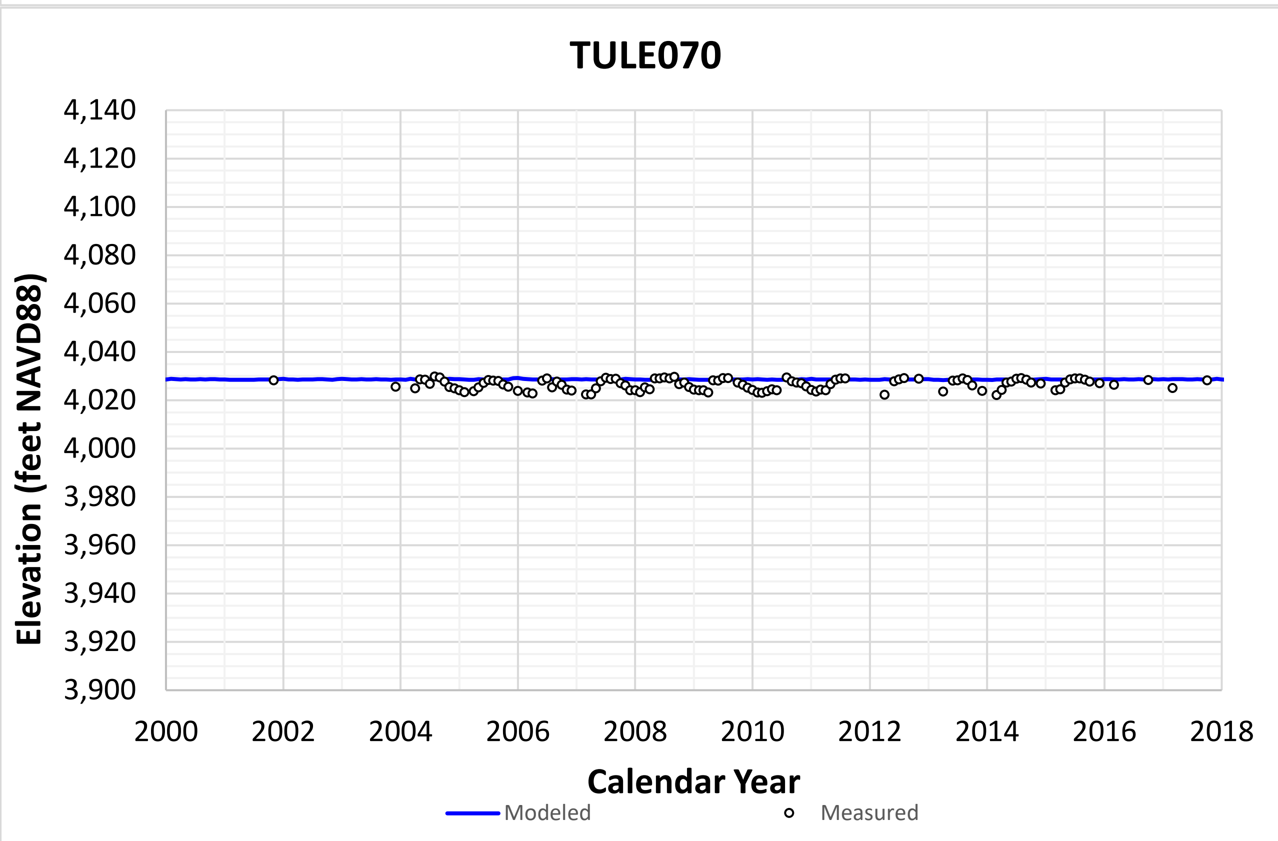
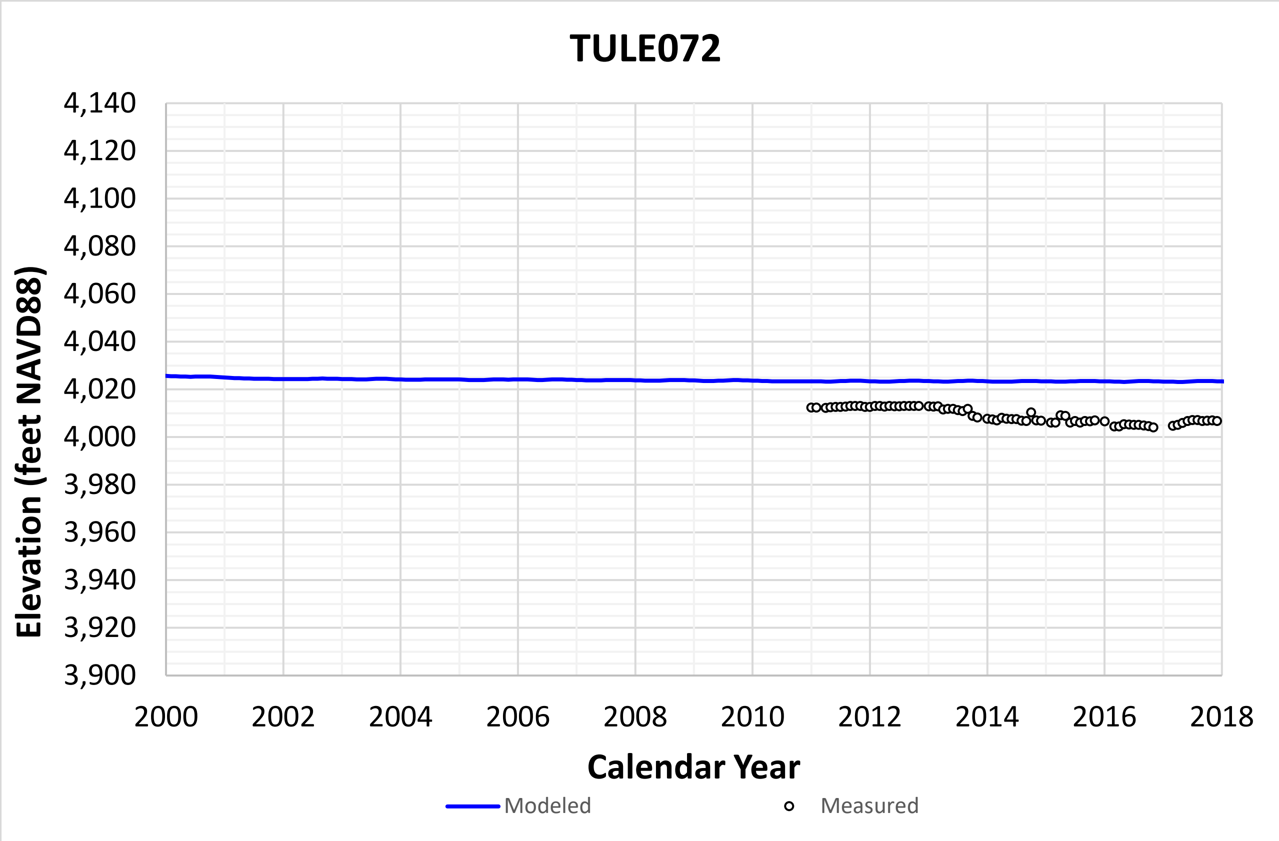




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



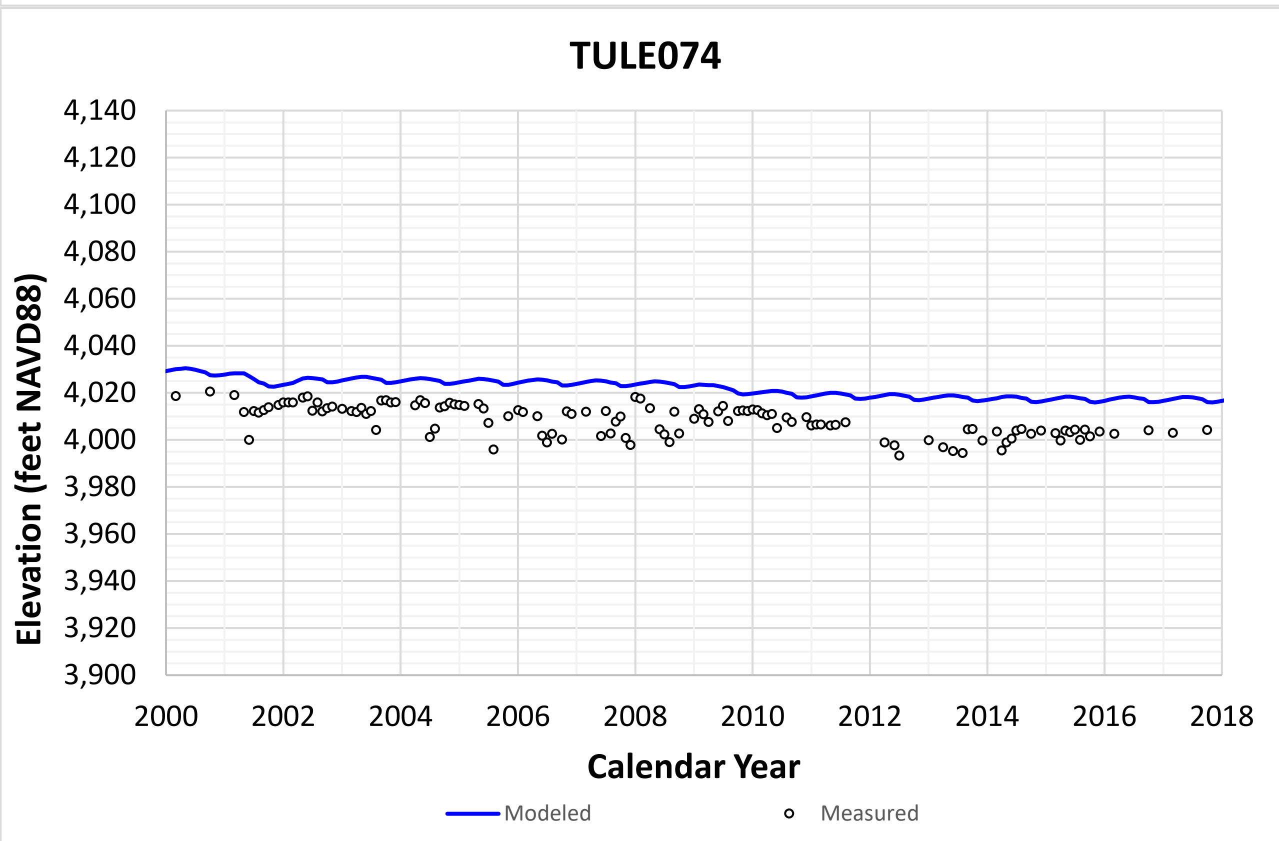
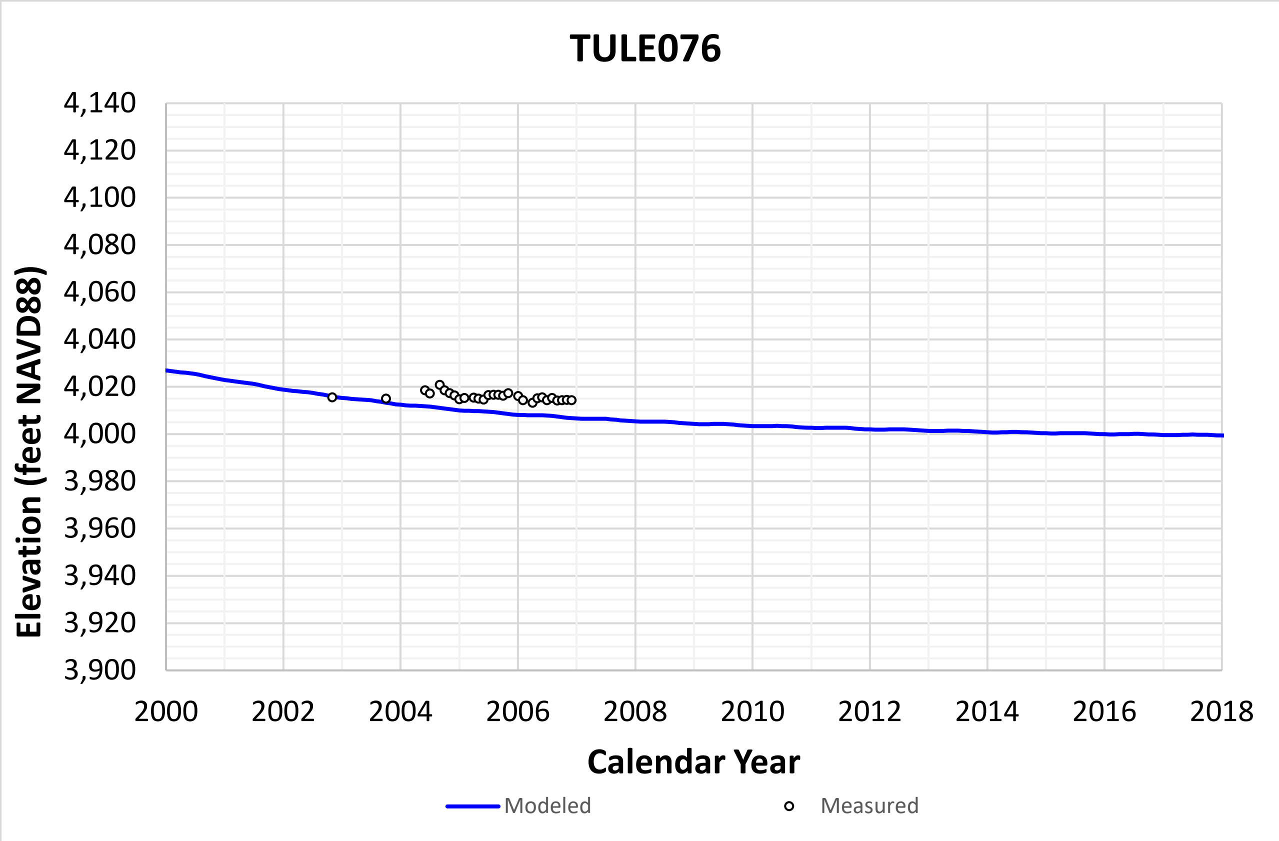




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



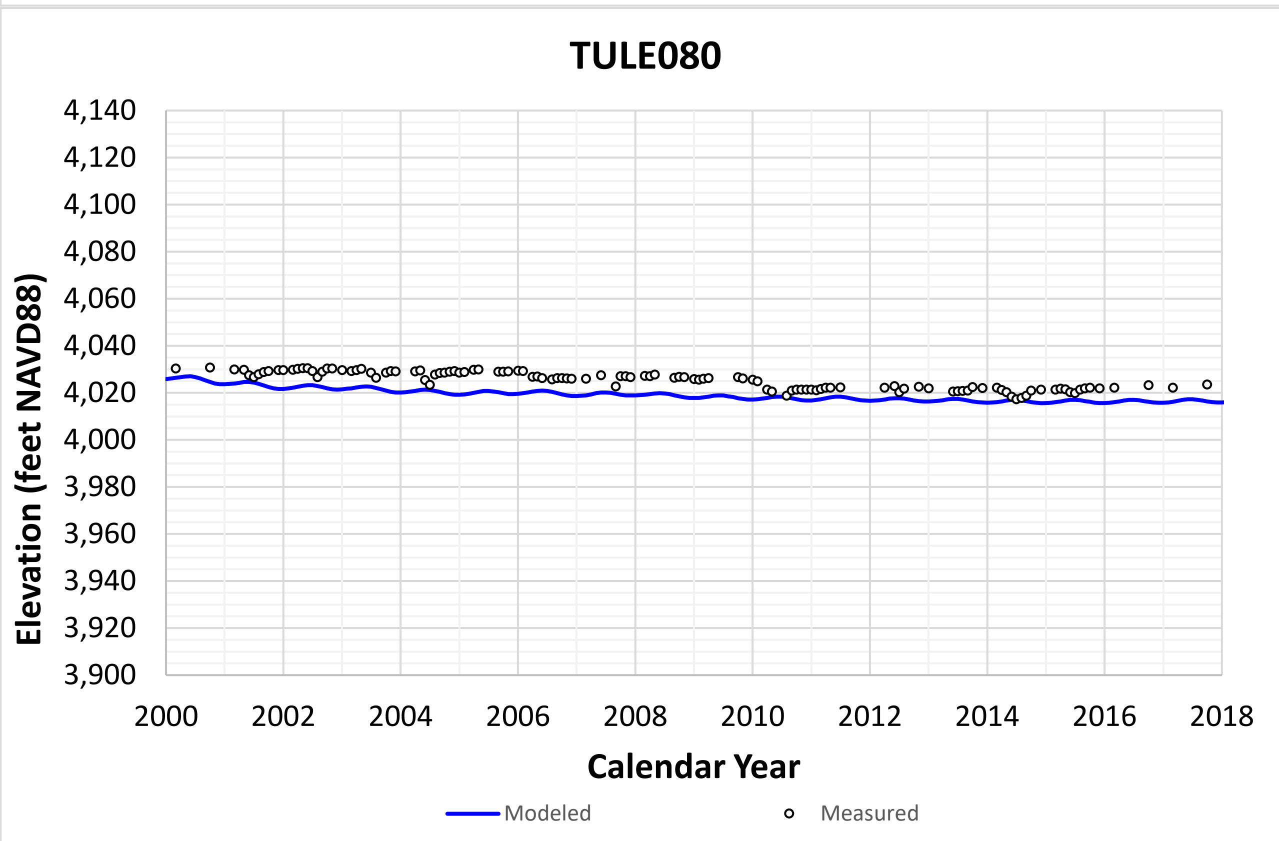
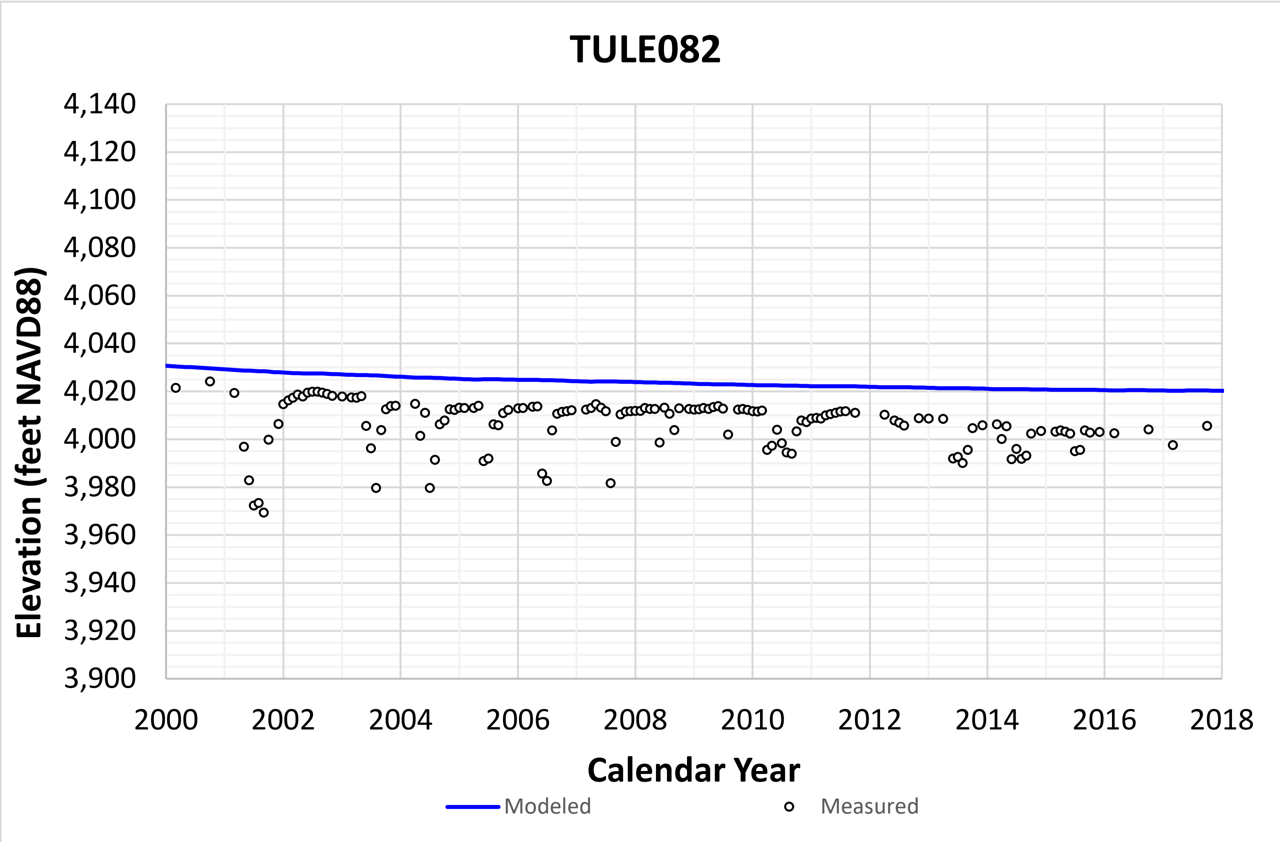




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



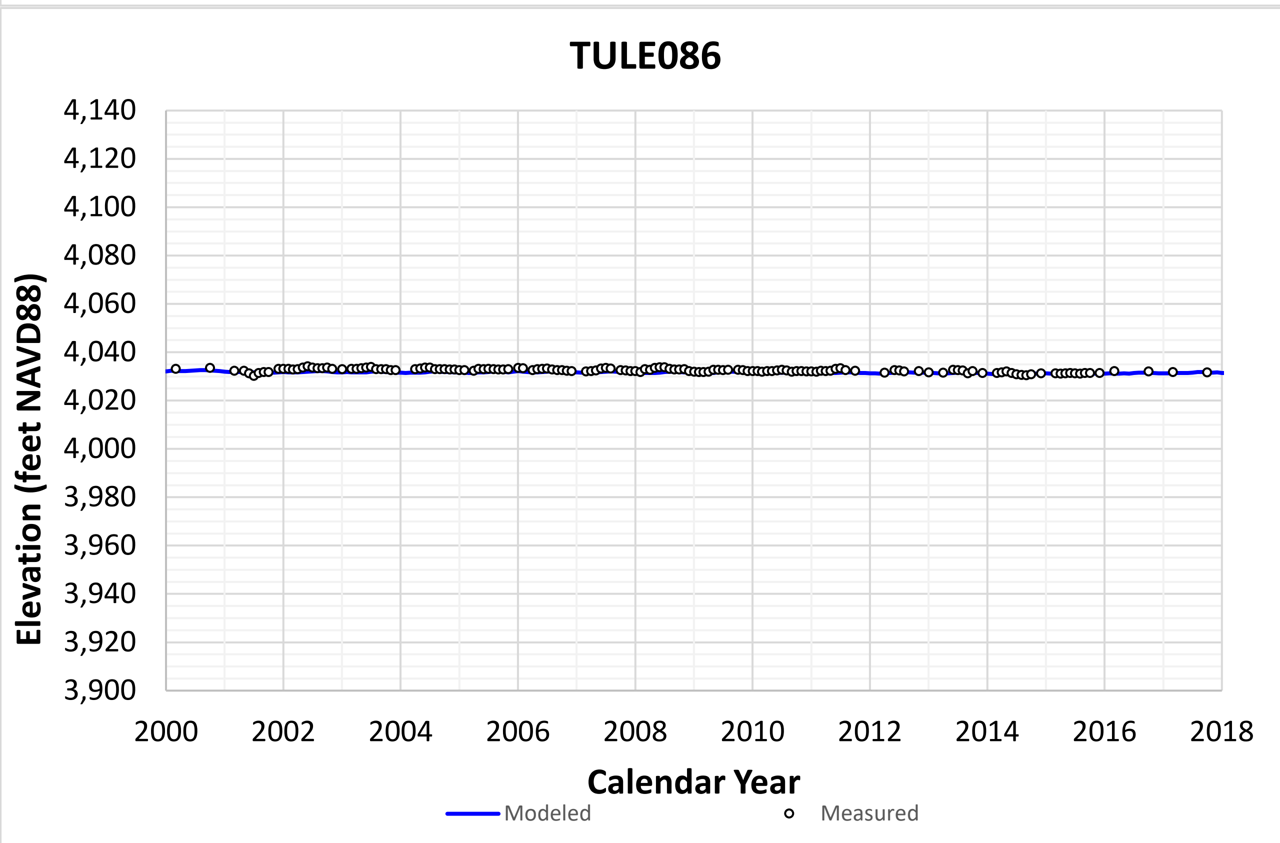
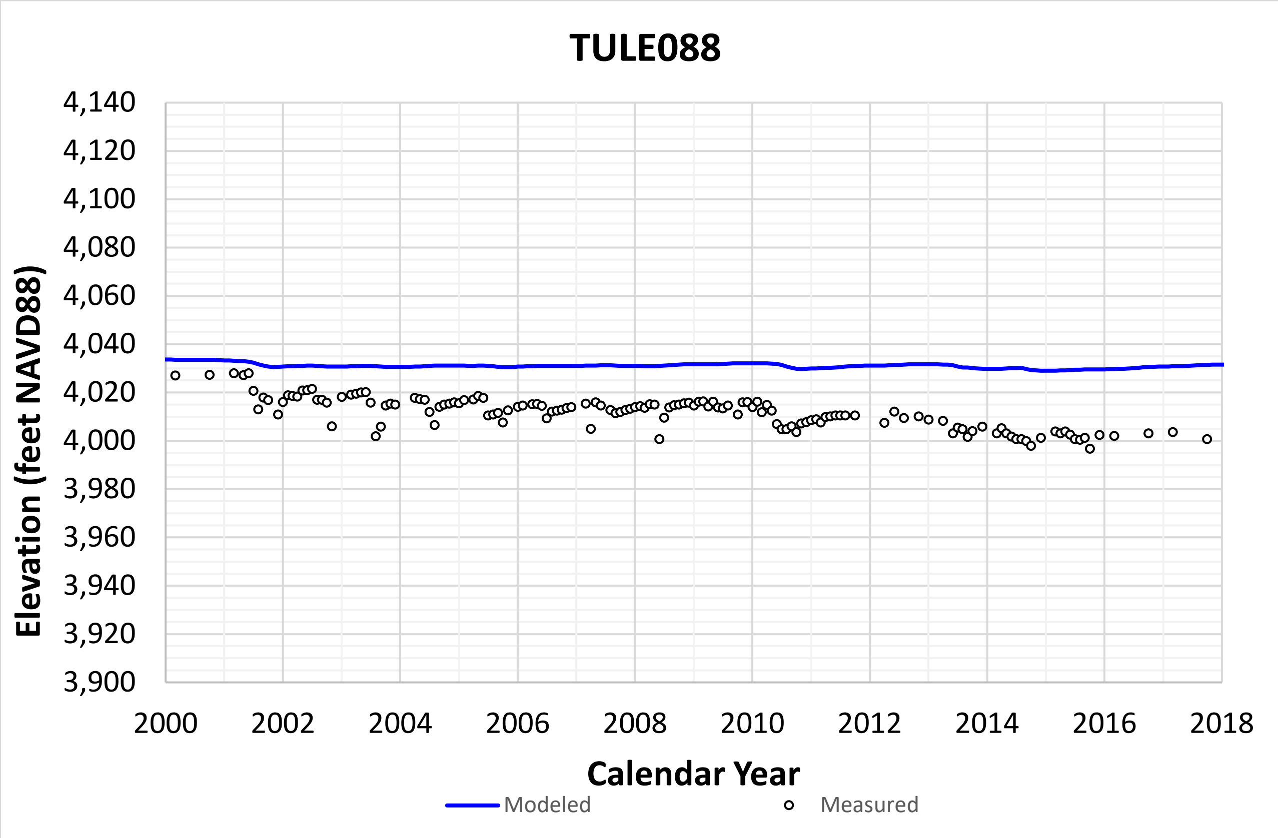




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



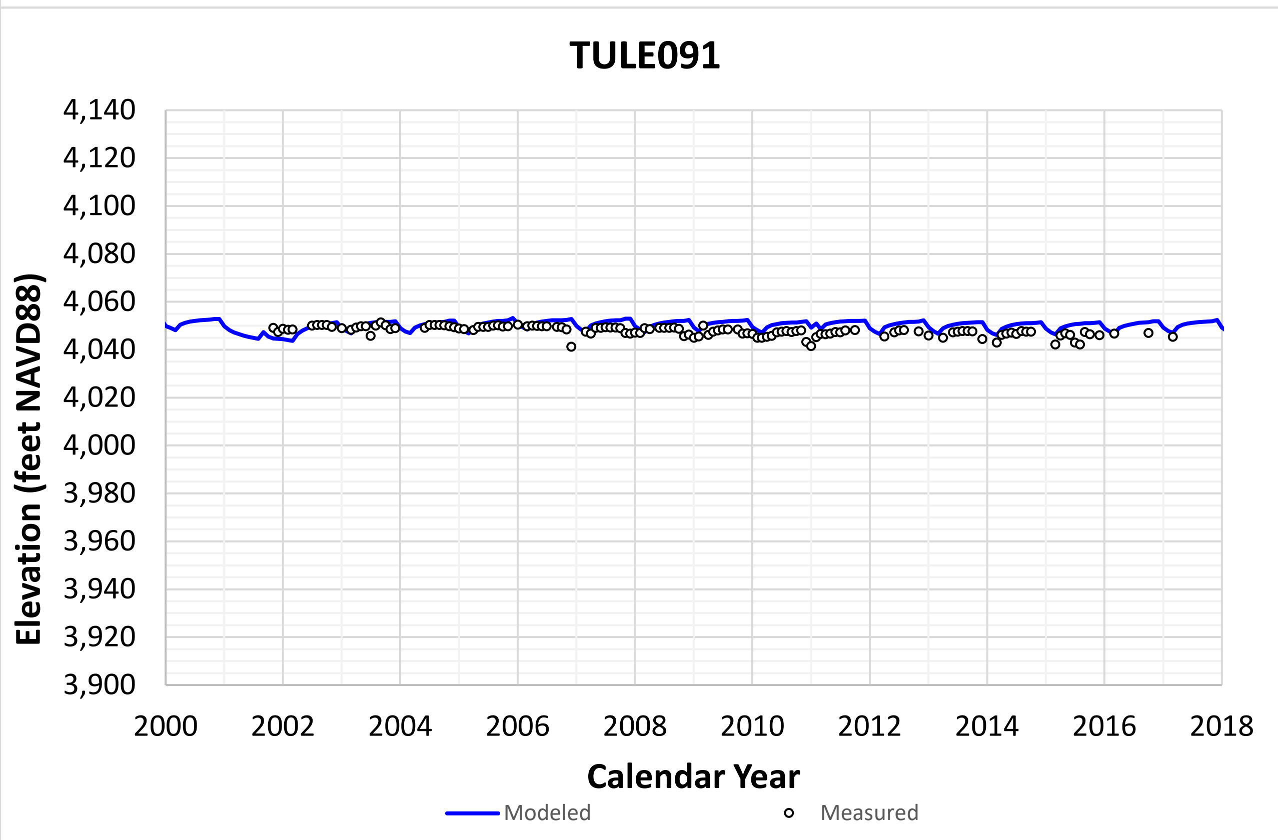
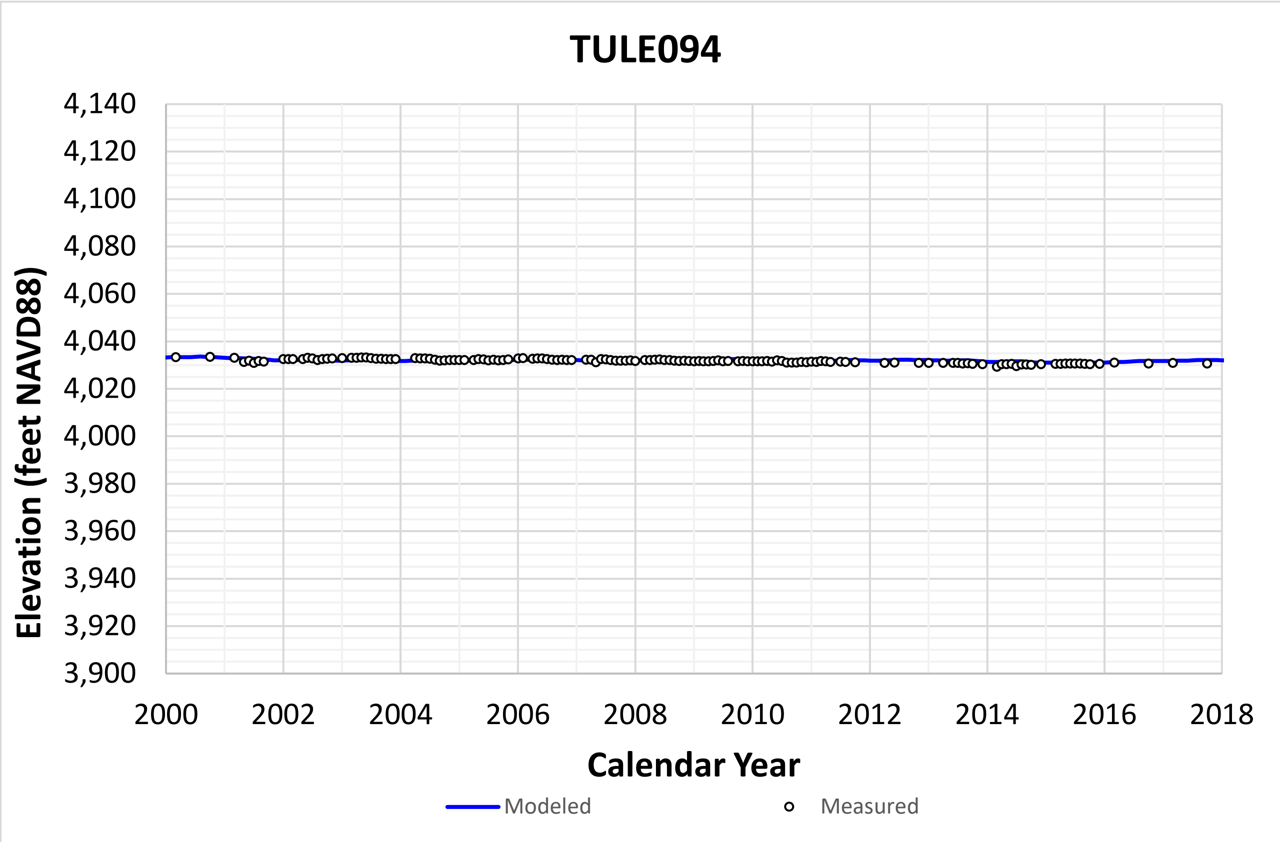




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



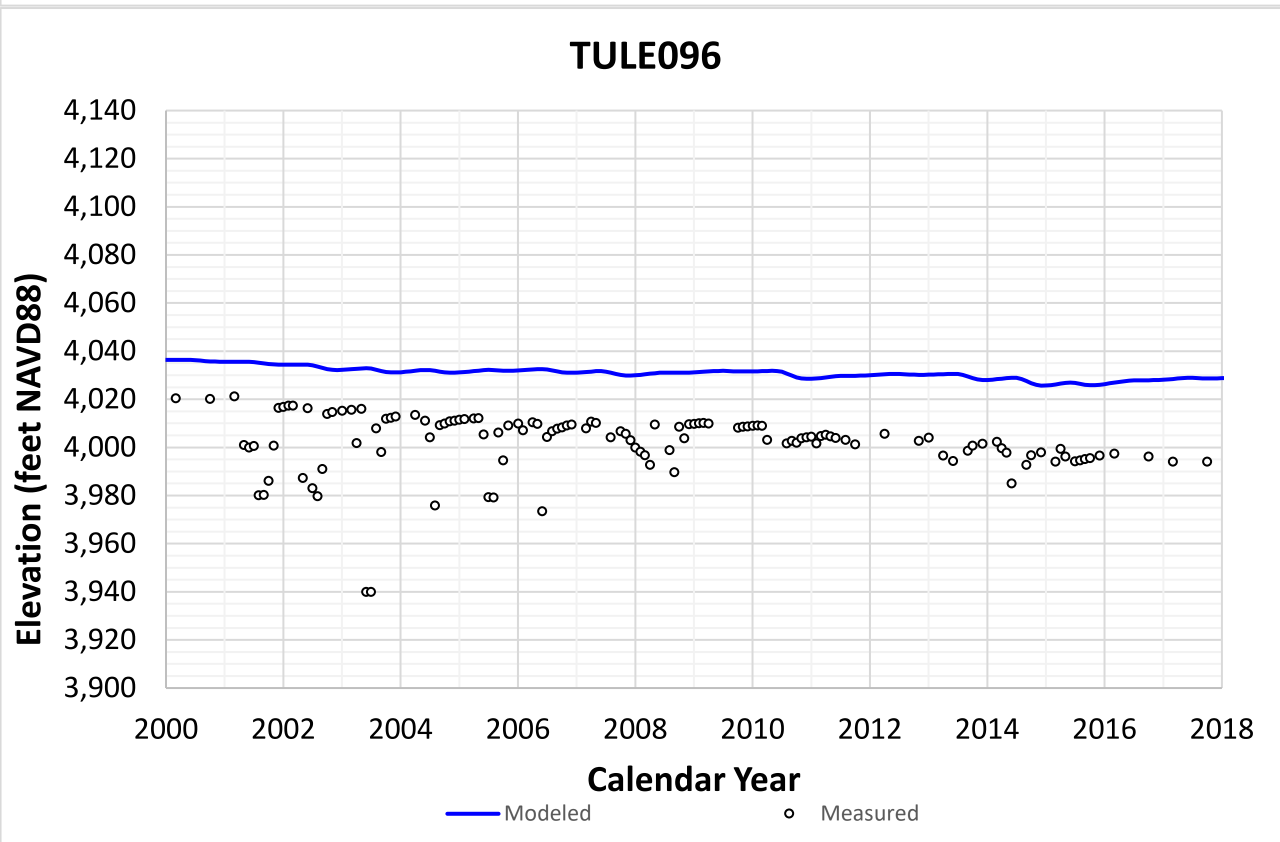
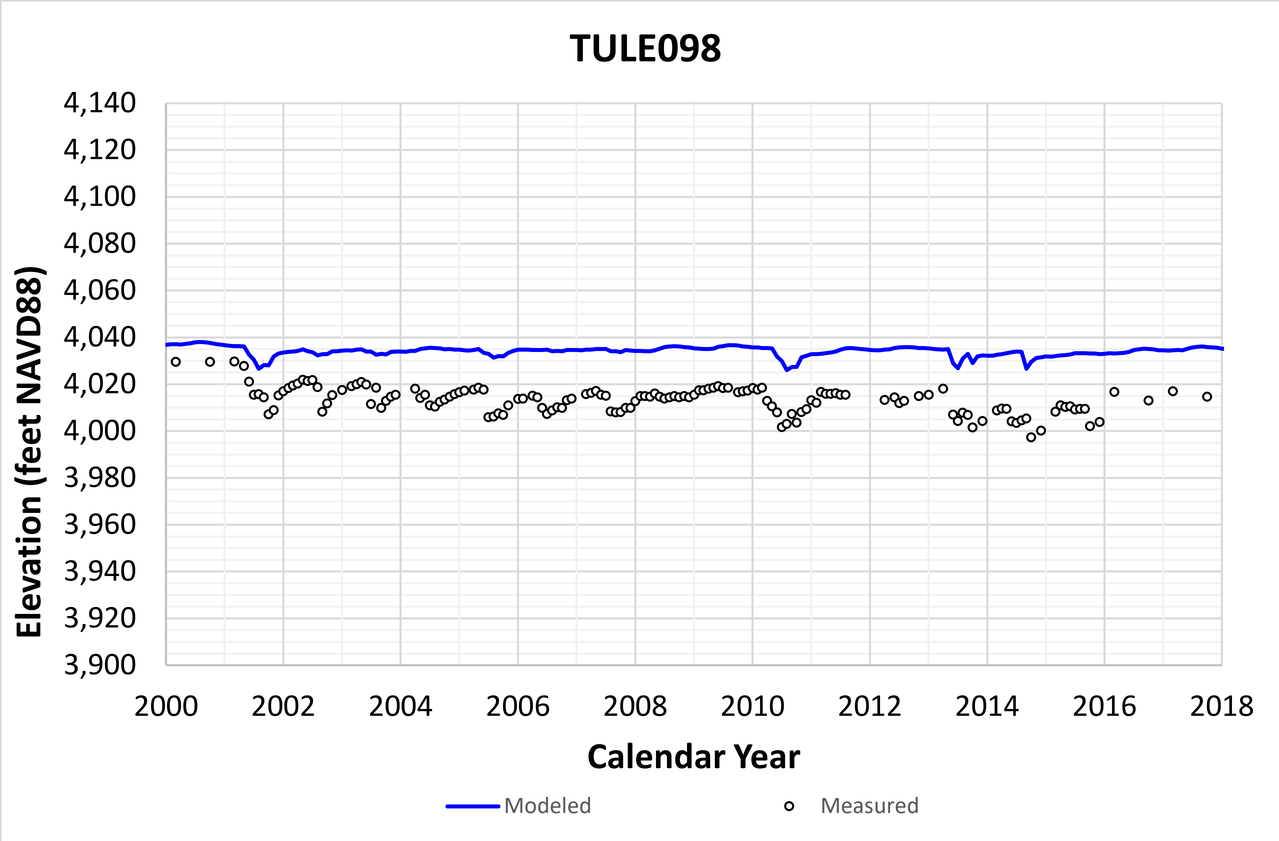




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



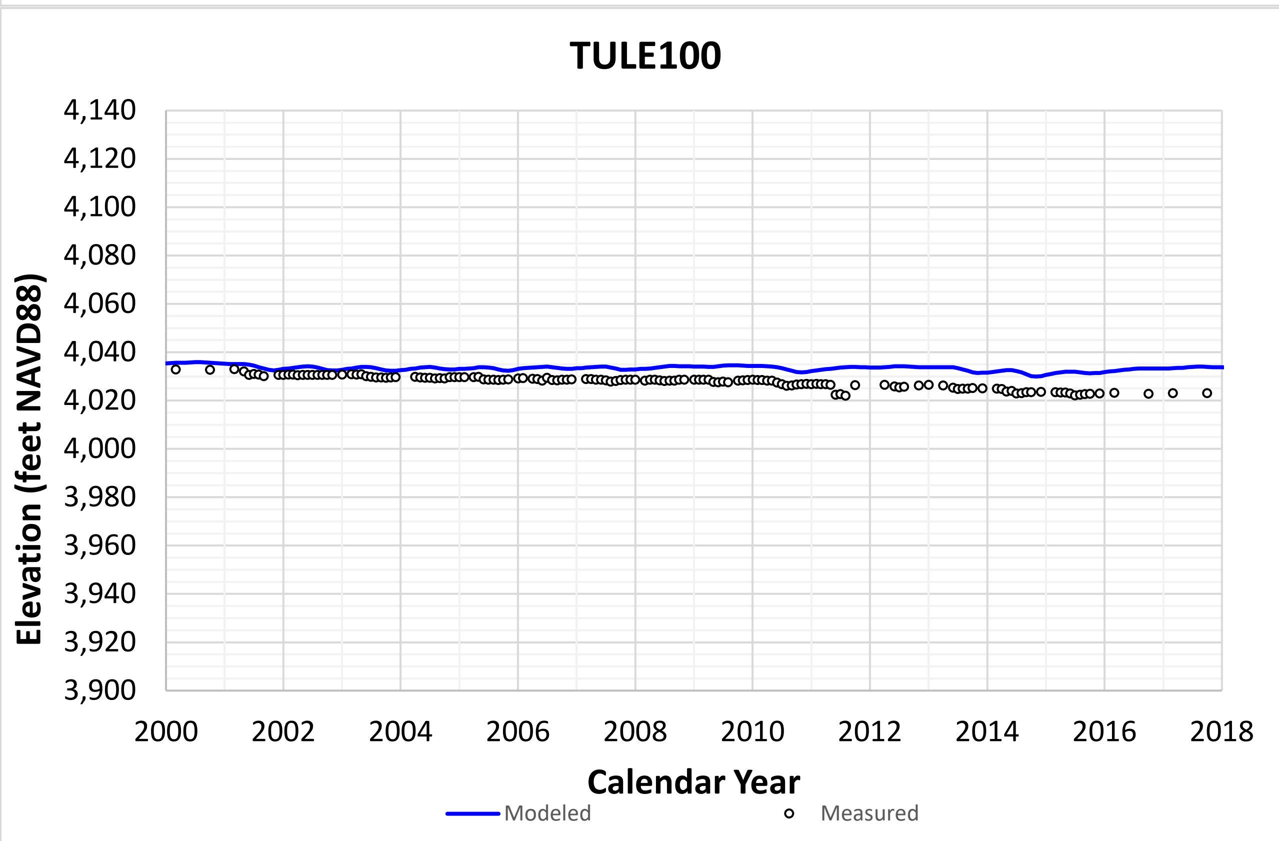
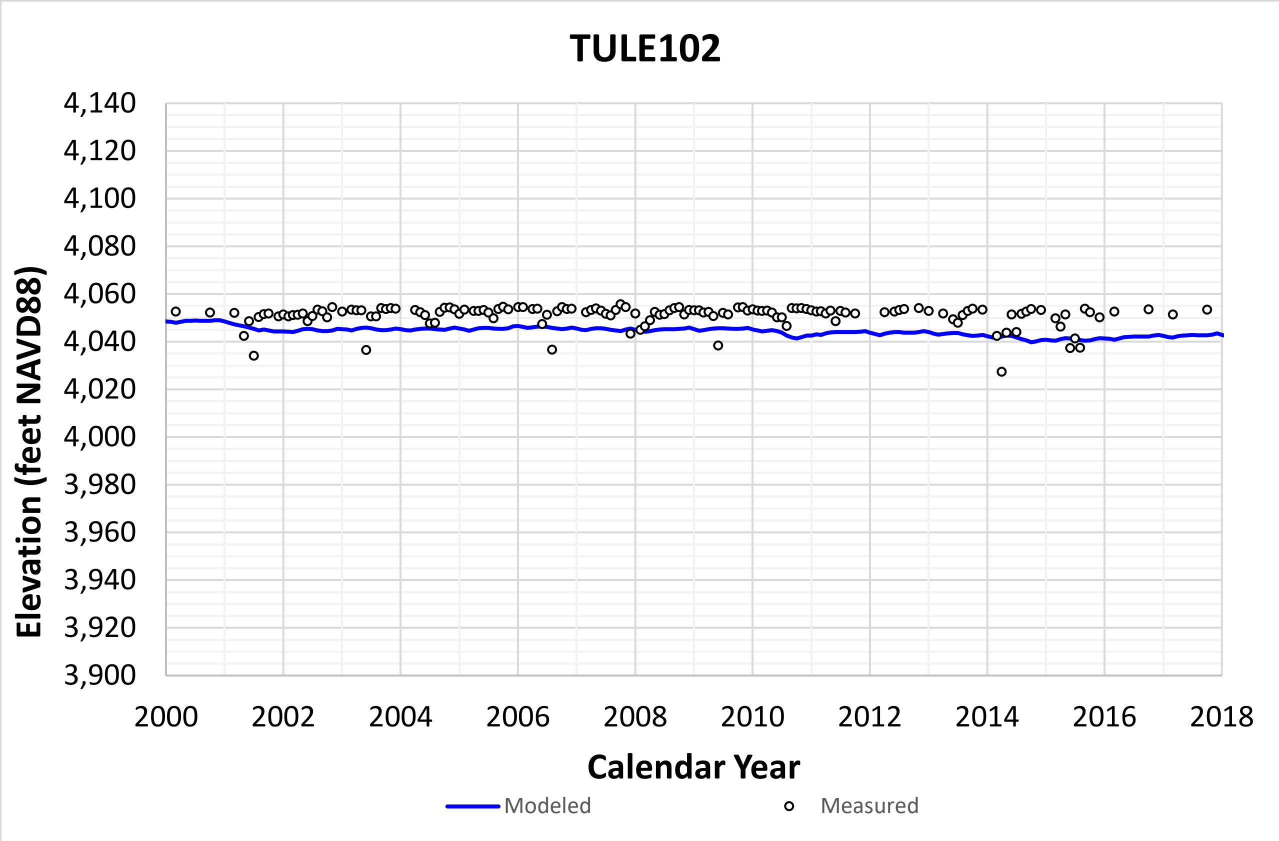




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



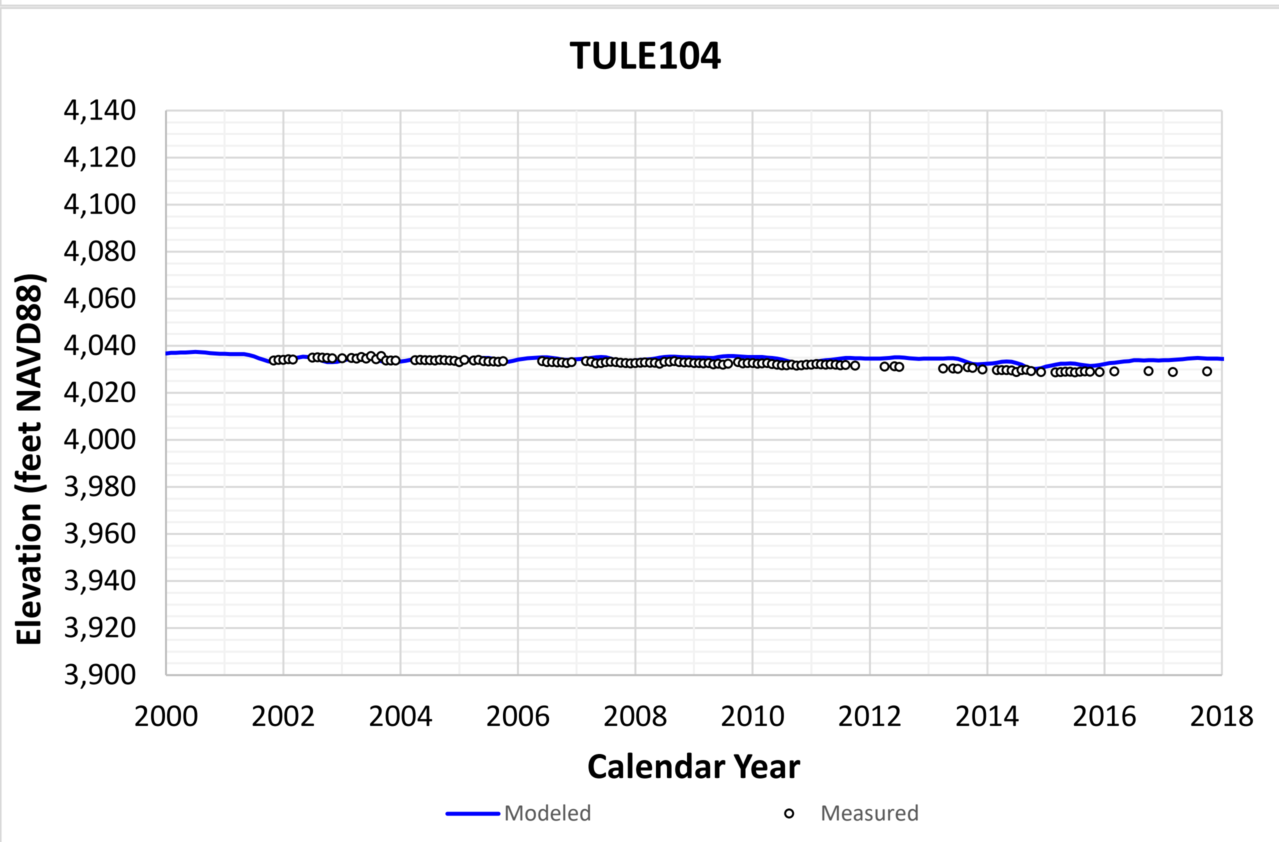
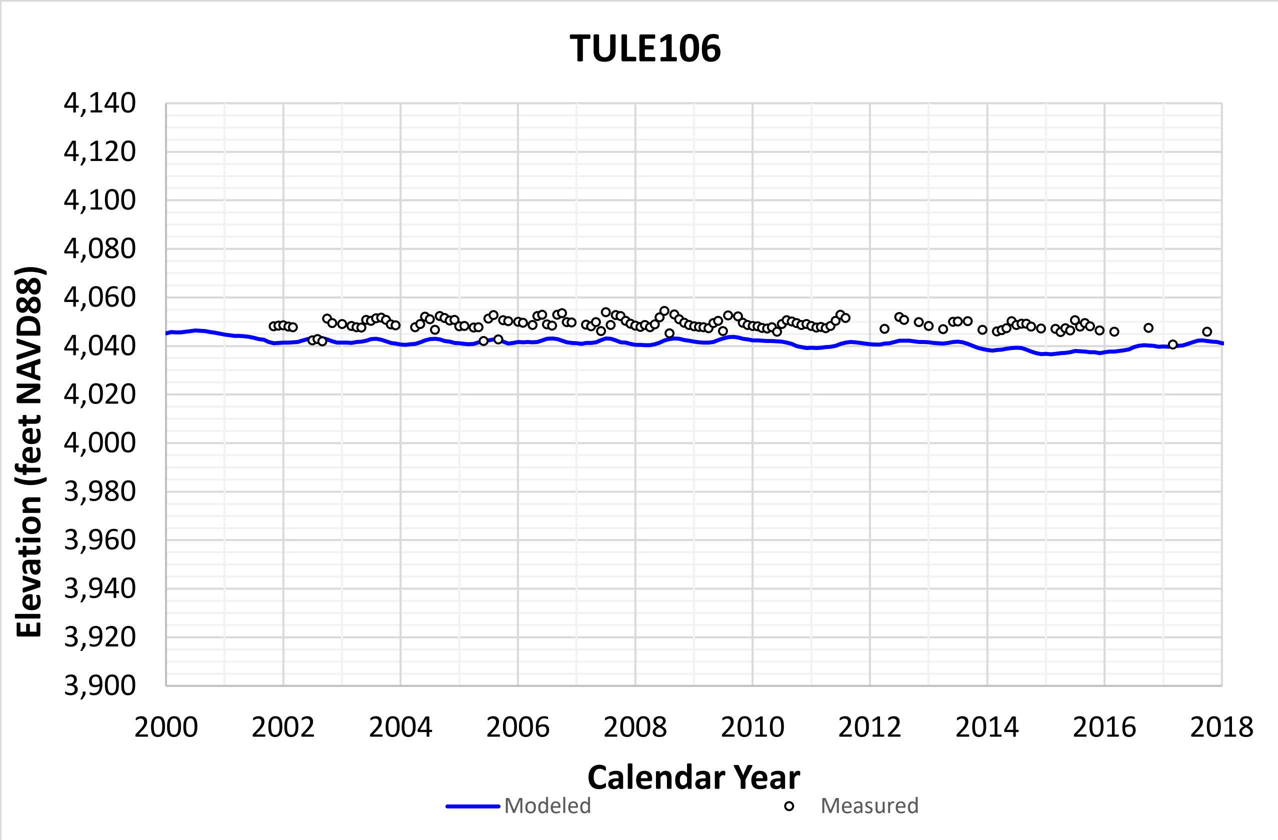




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



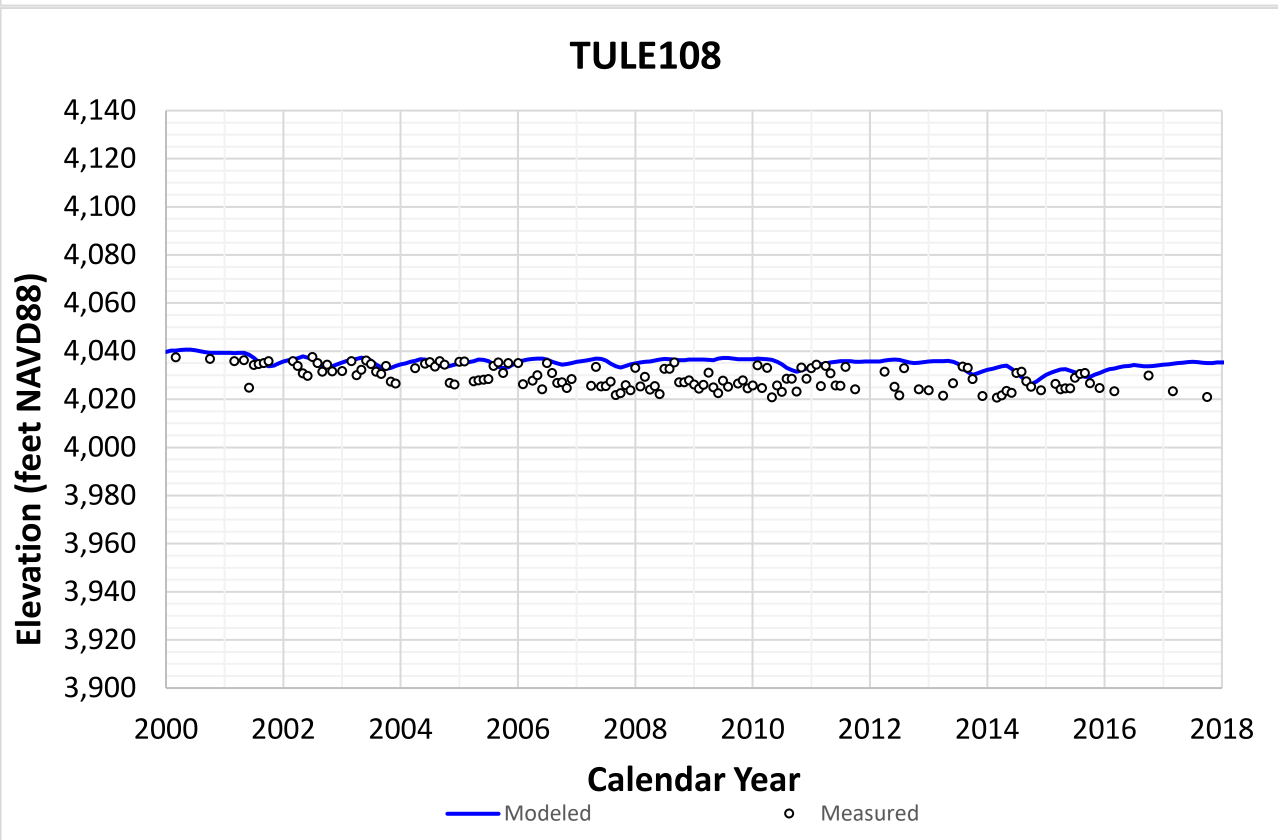
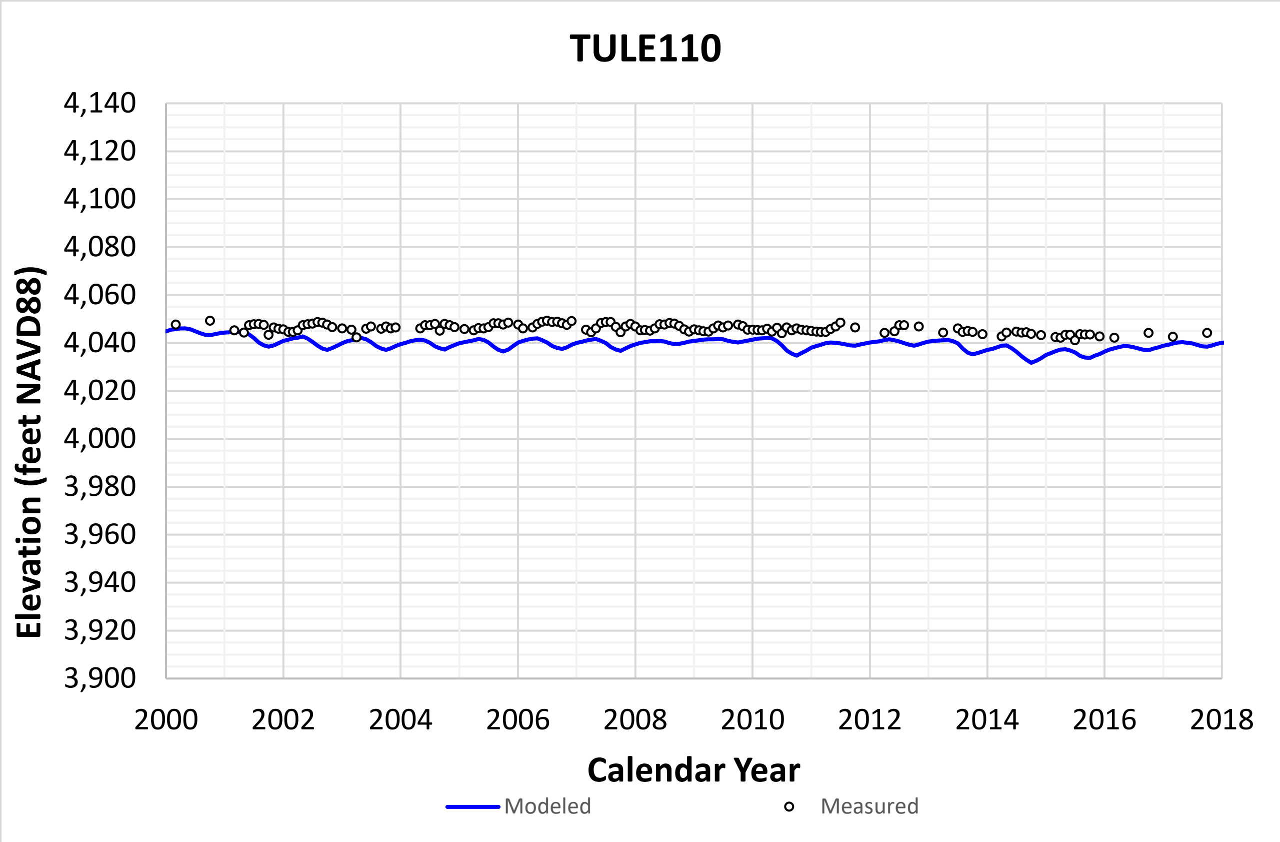




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs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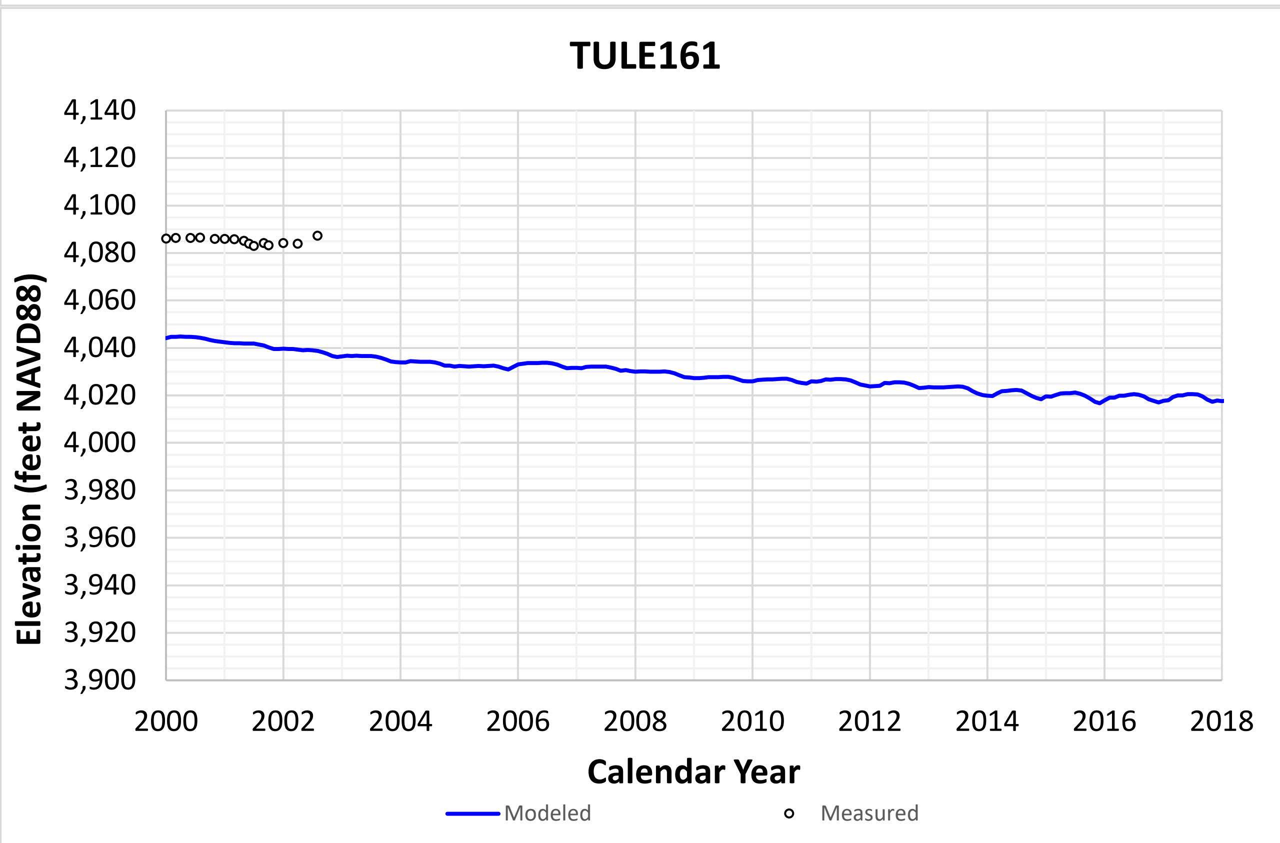
4,120
4,100
4,080
4,060
4,040
4,020
4,000
3,980
3,960
3,940
3,920
3,900
Elevation (feet NAVD88)
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Calendar Year
Modeled
Measured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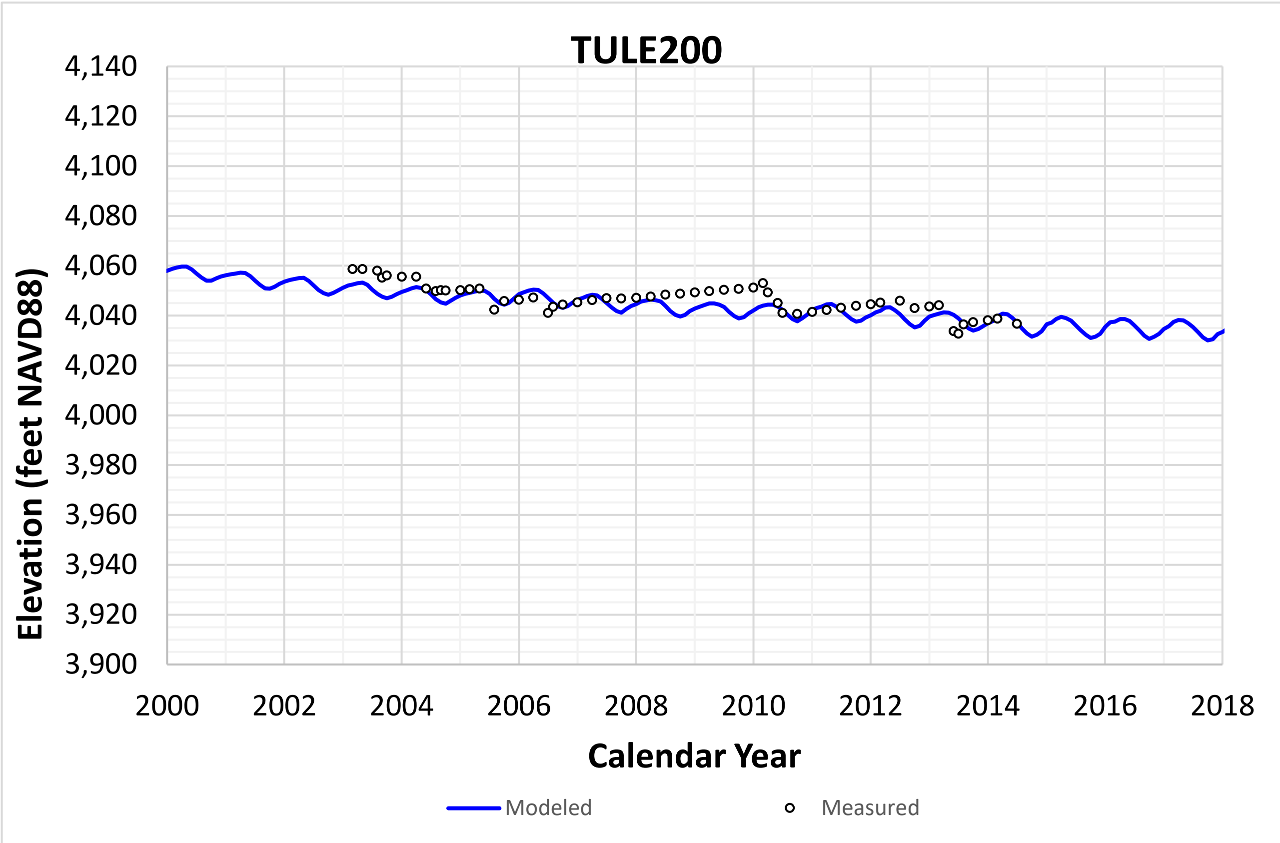
4,040
4,020
4,000
3,980
3,960
3,940
3,920
3,900
Elevation (feet NAVD88)
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Calendar Year
Modeled
Measured



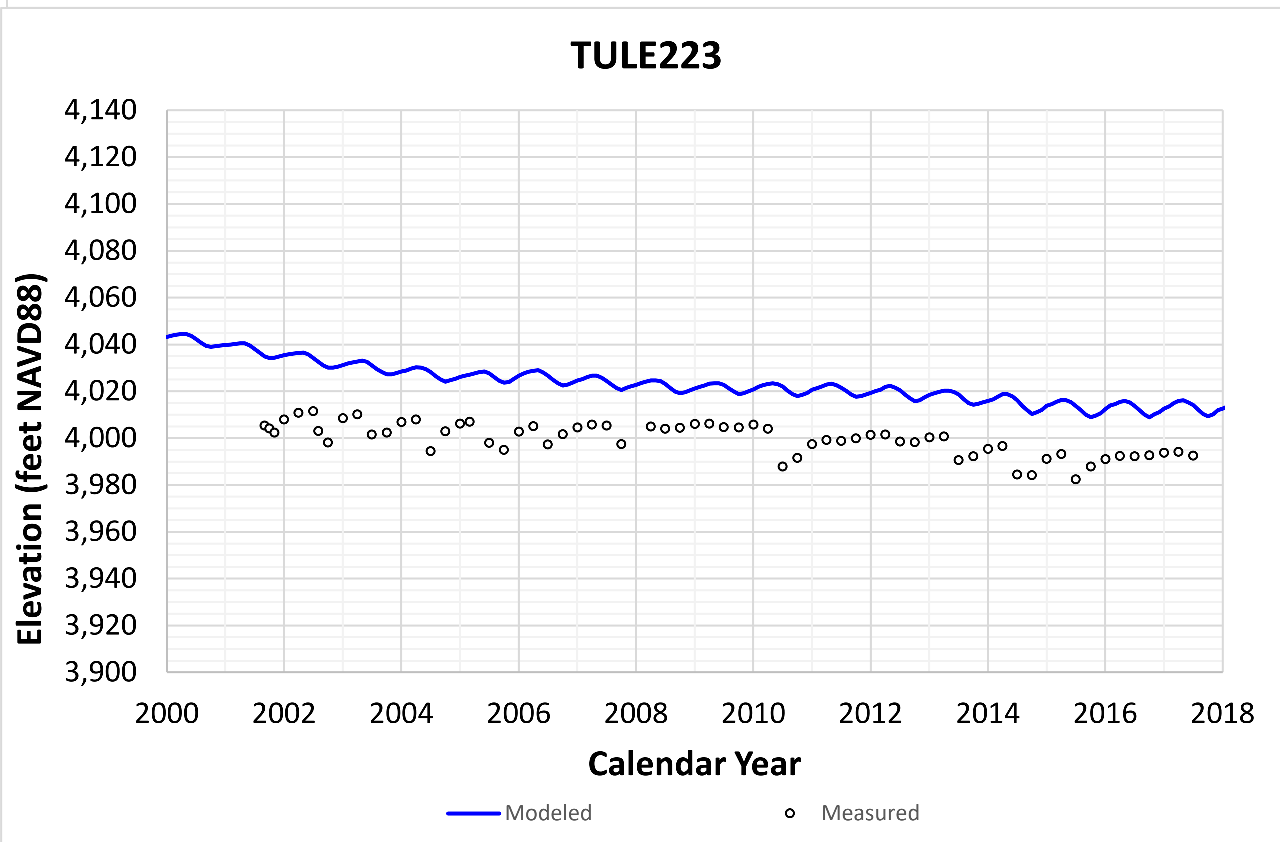
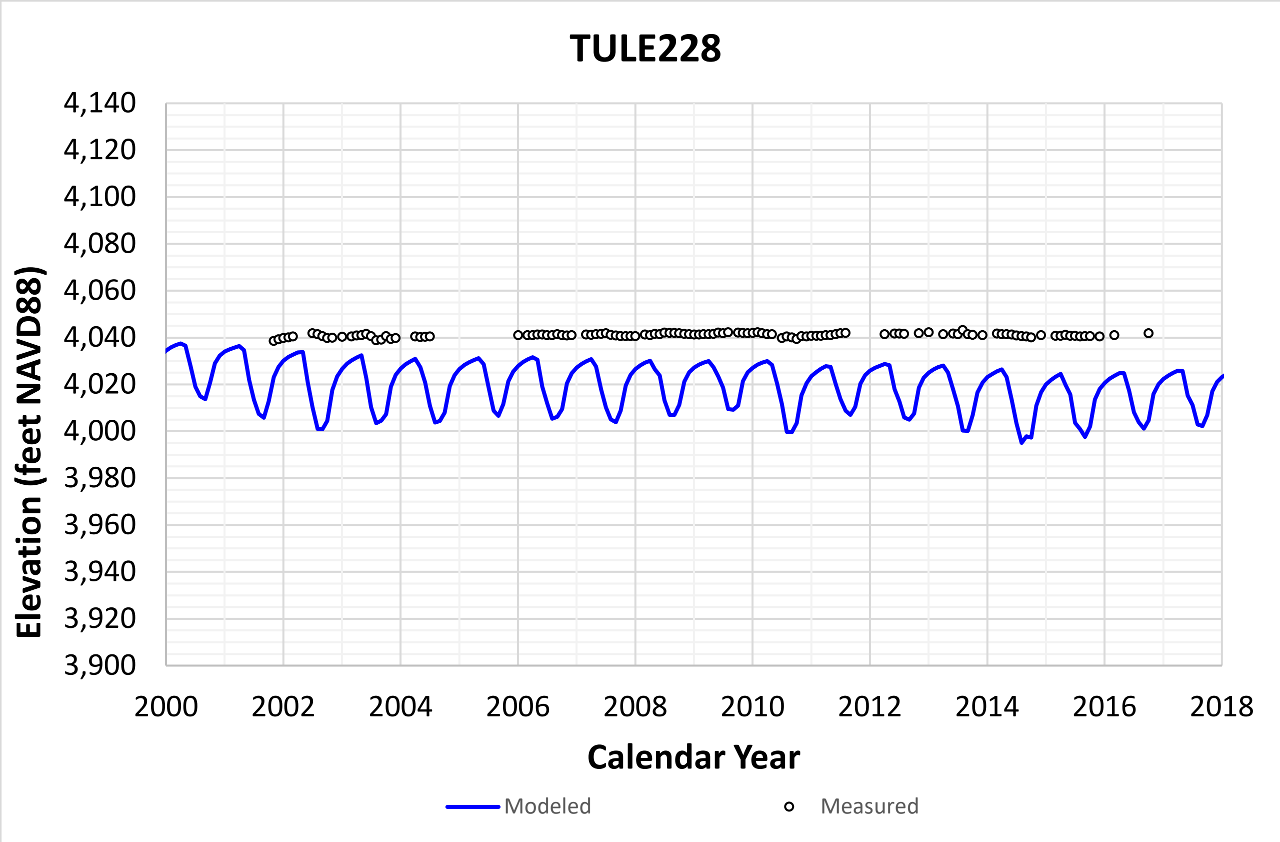




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



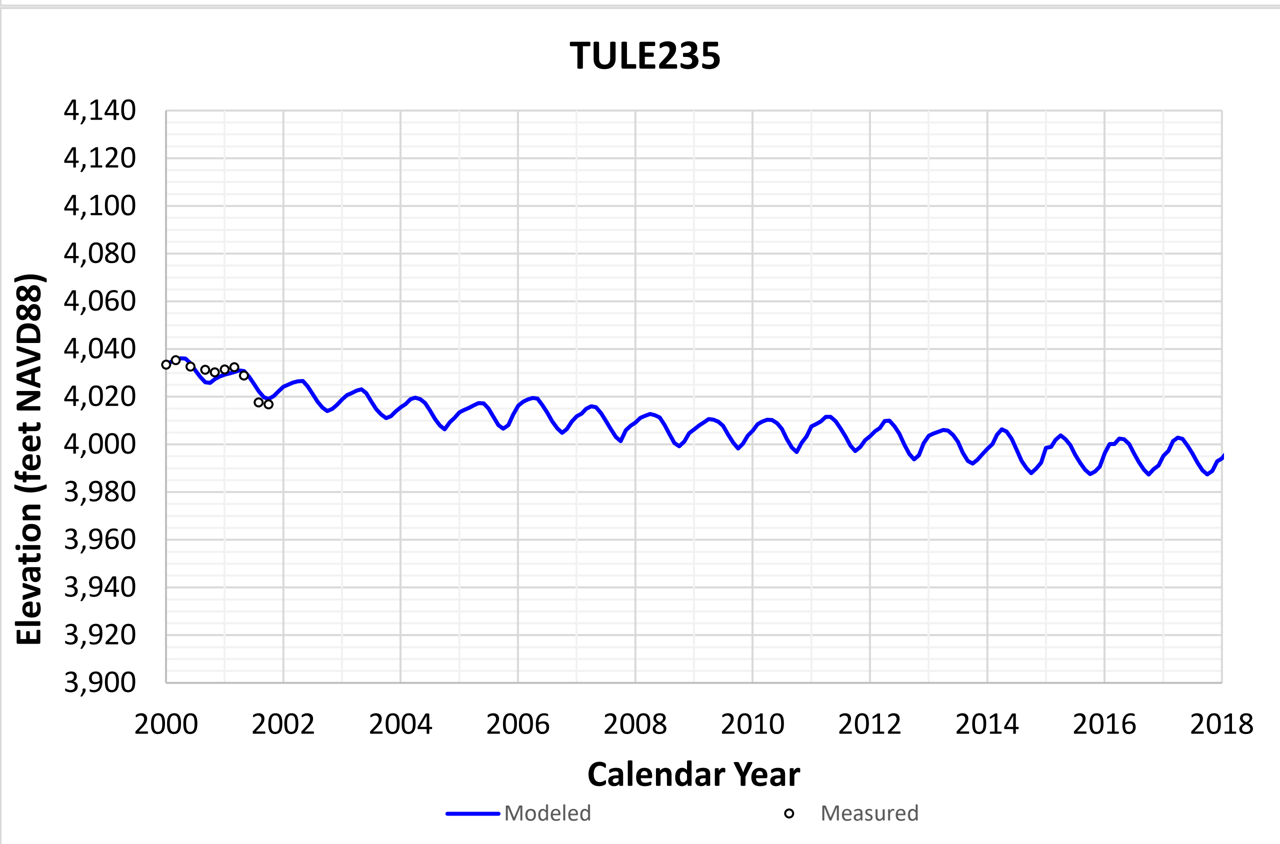
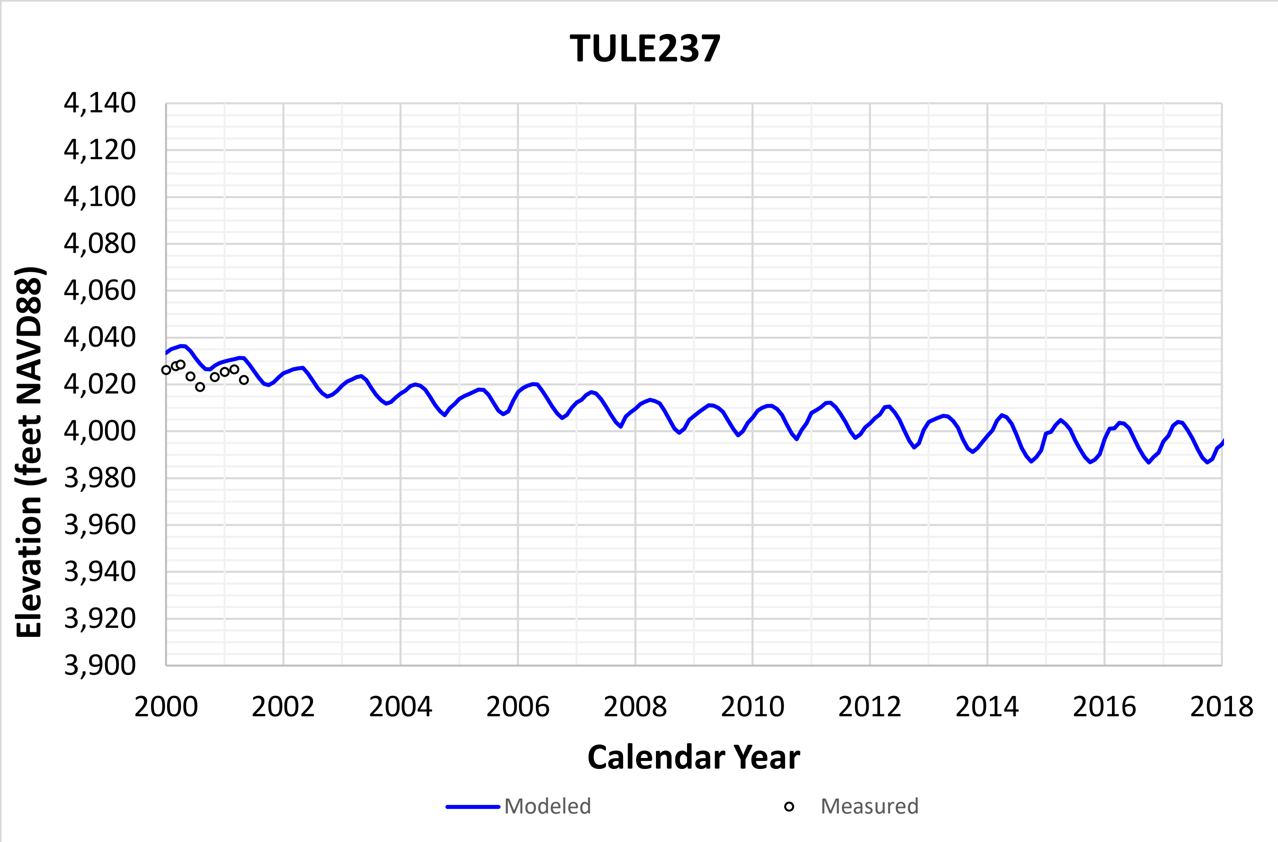




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



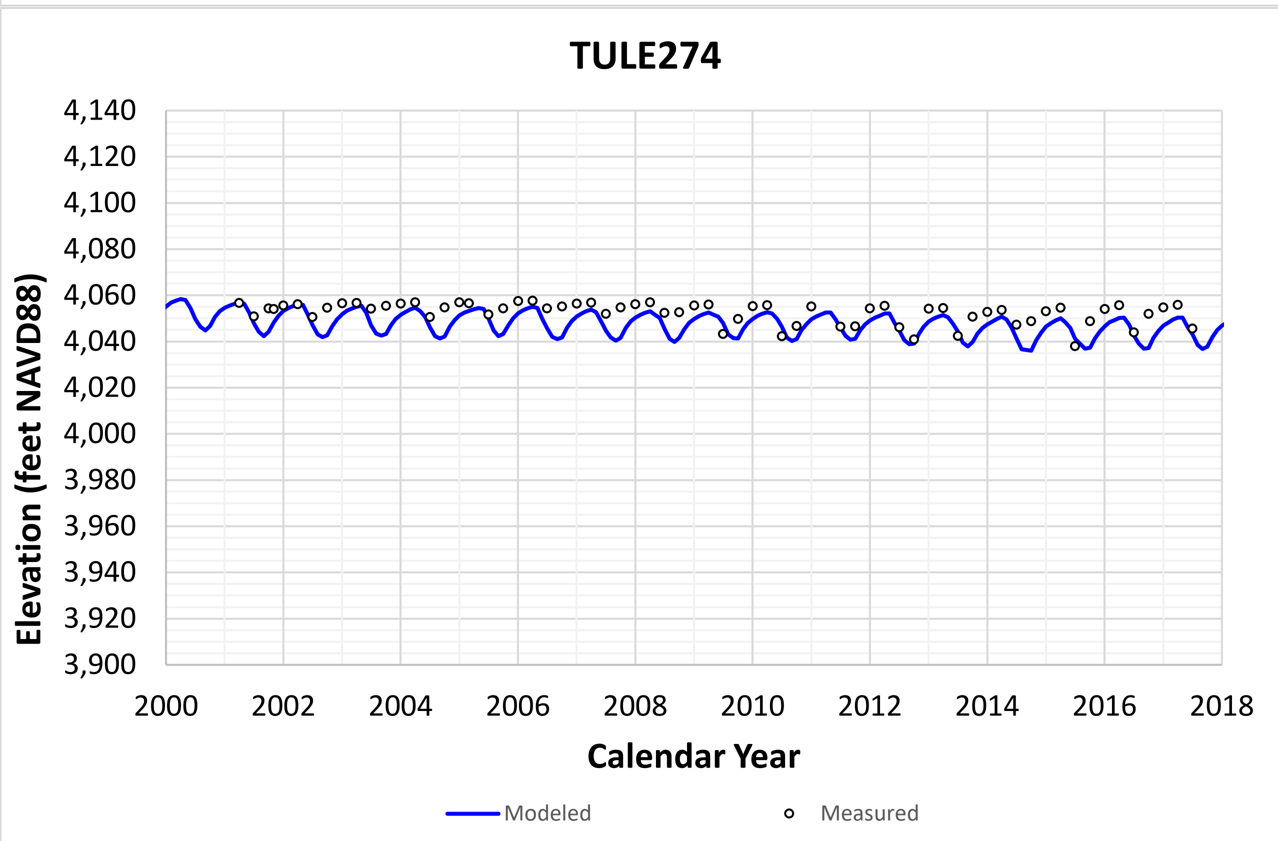
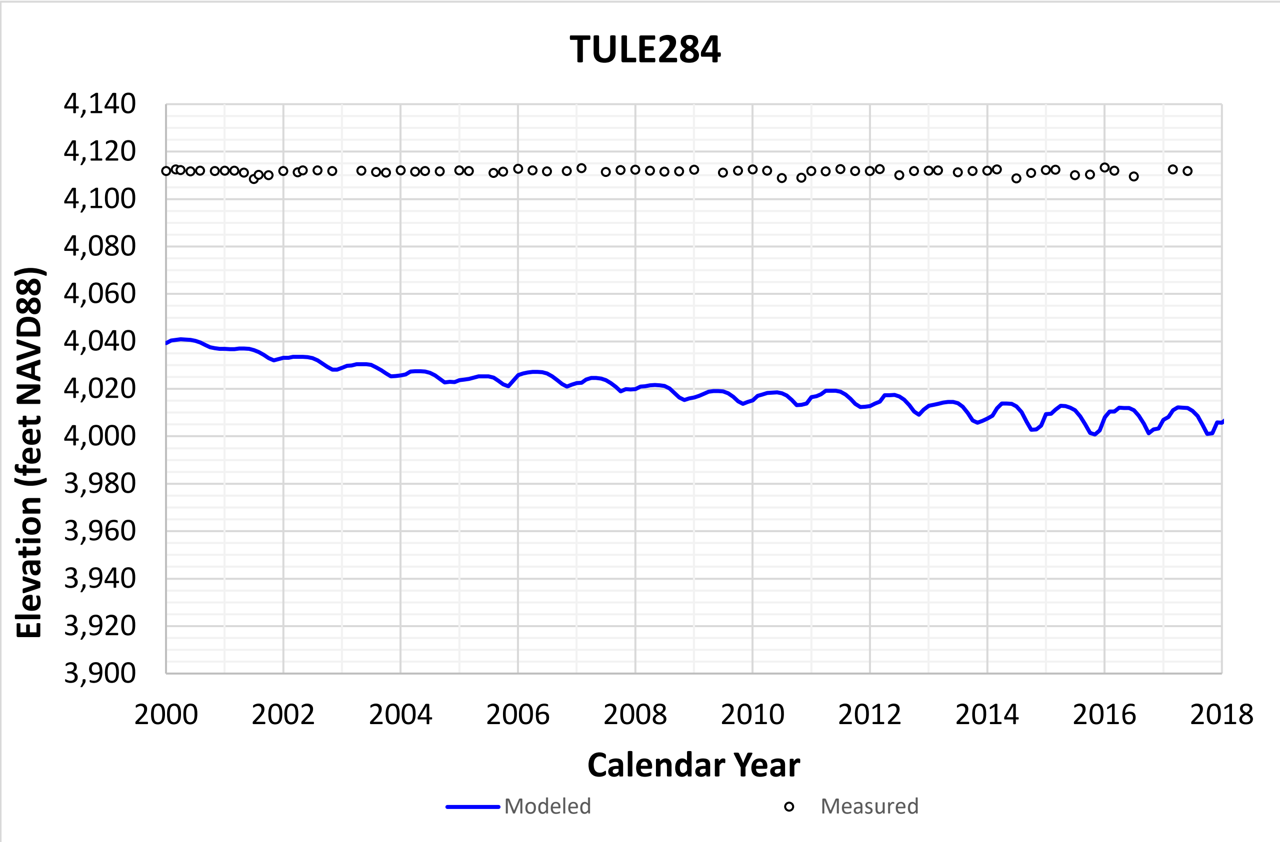




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



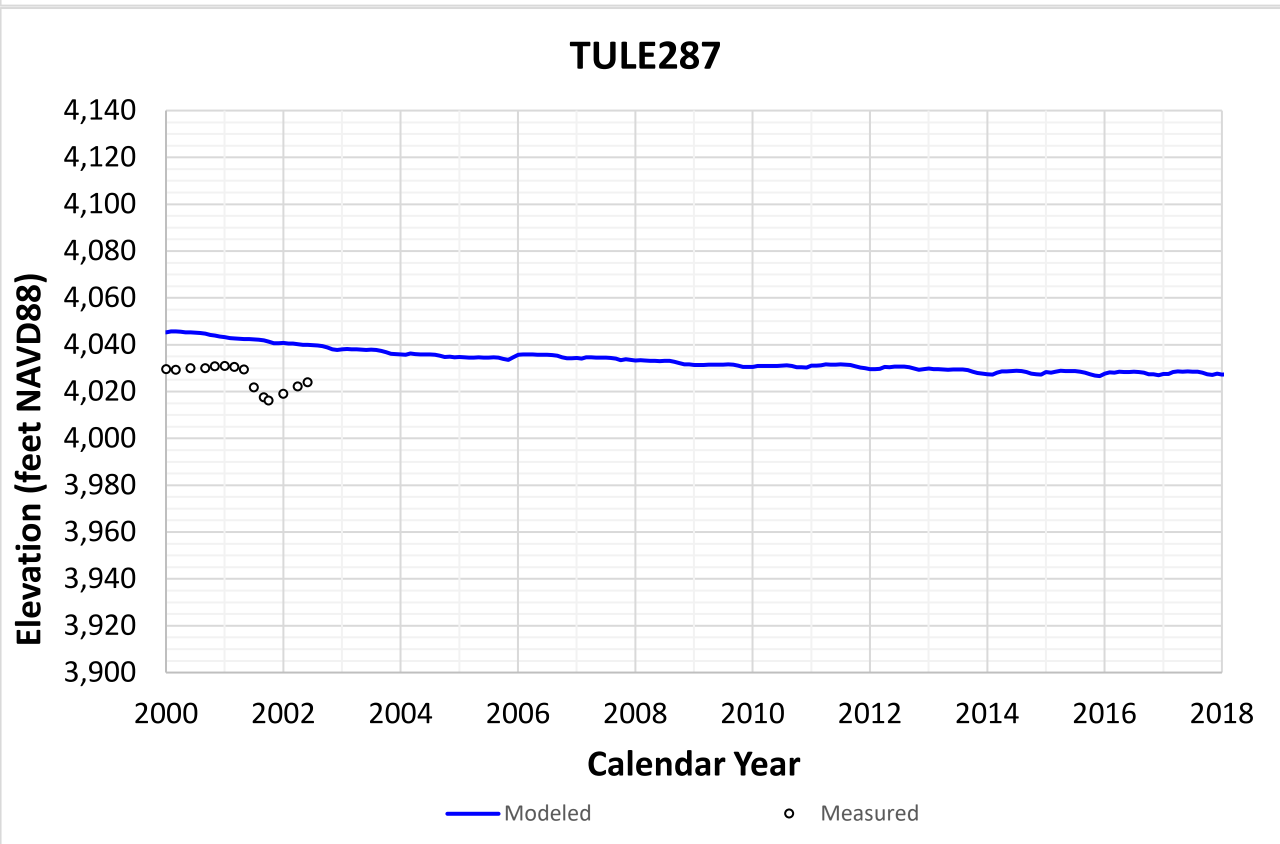
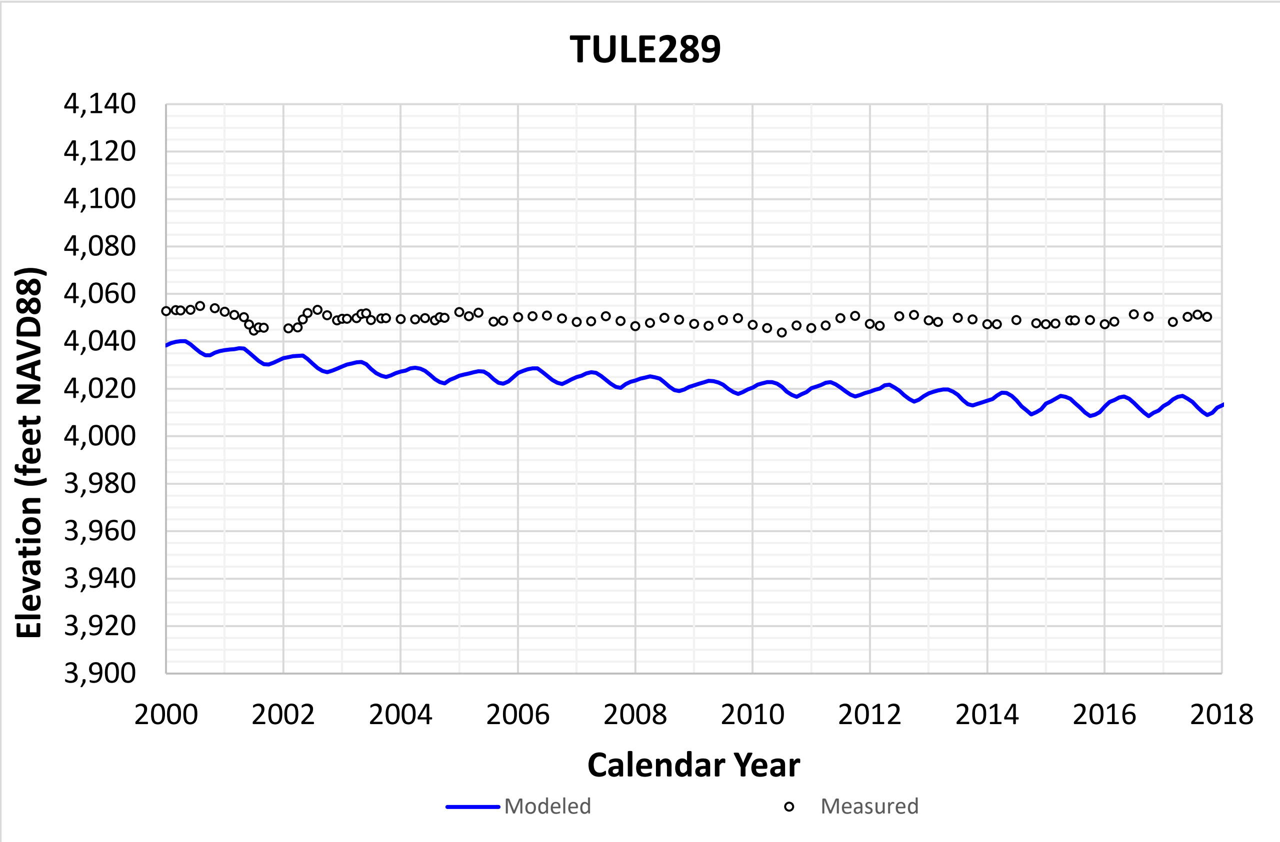




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs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4,060
4,040
4,020
4,000
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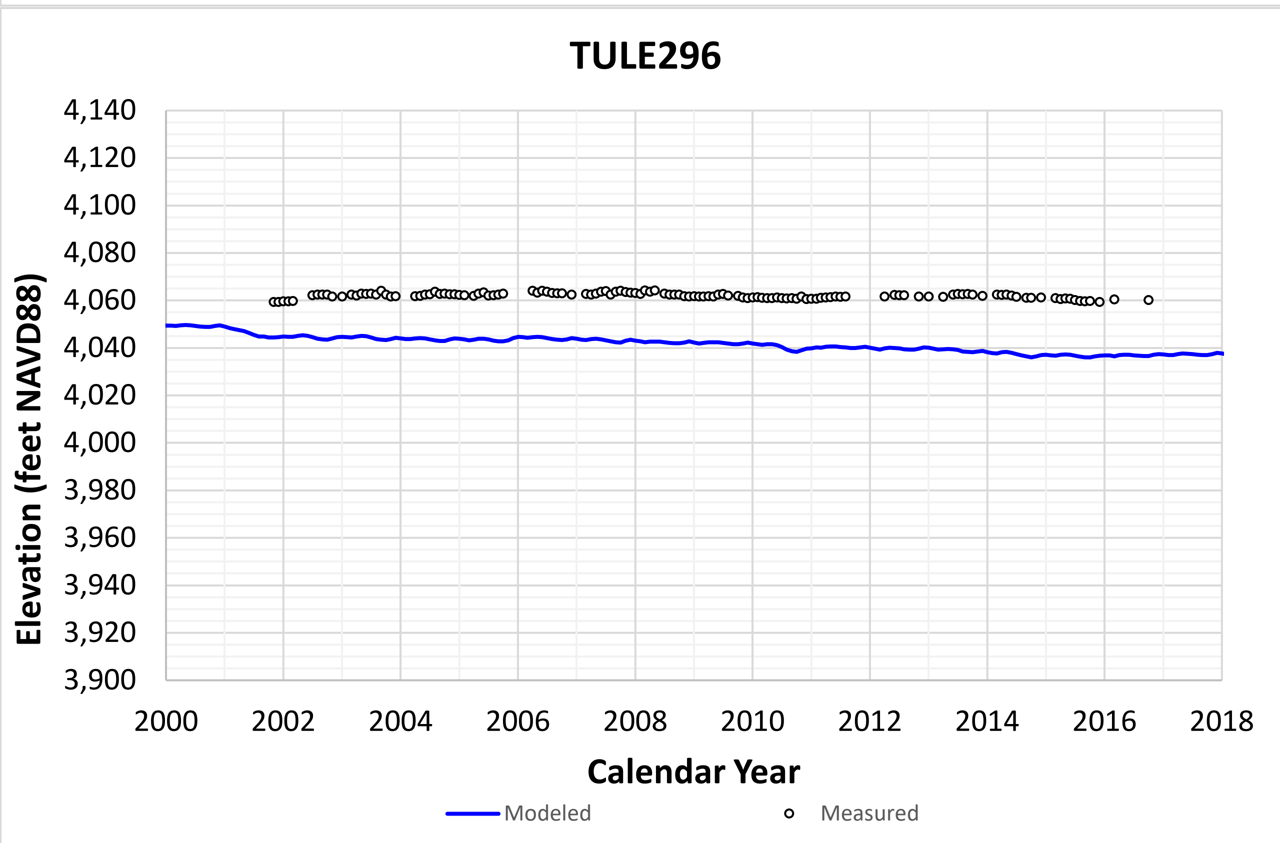
3,960
3,940
3,920
3,900
Elevation (feet NAVD88)
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Calendar Year
Modeled
Measured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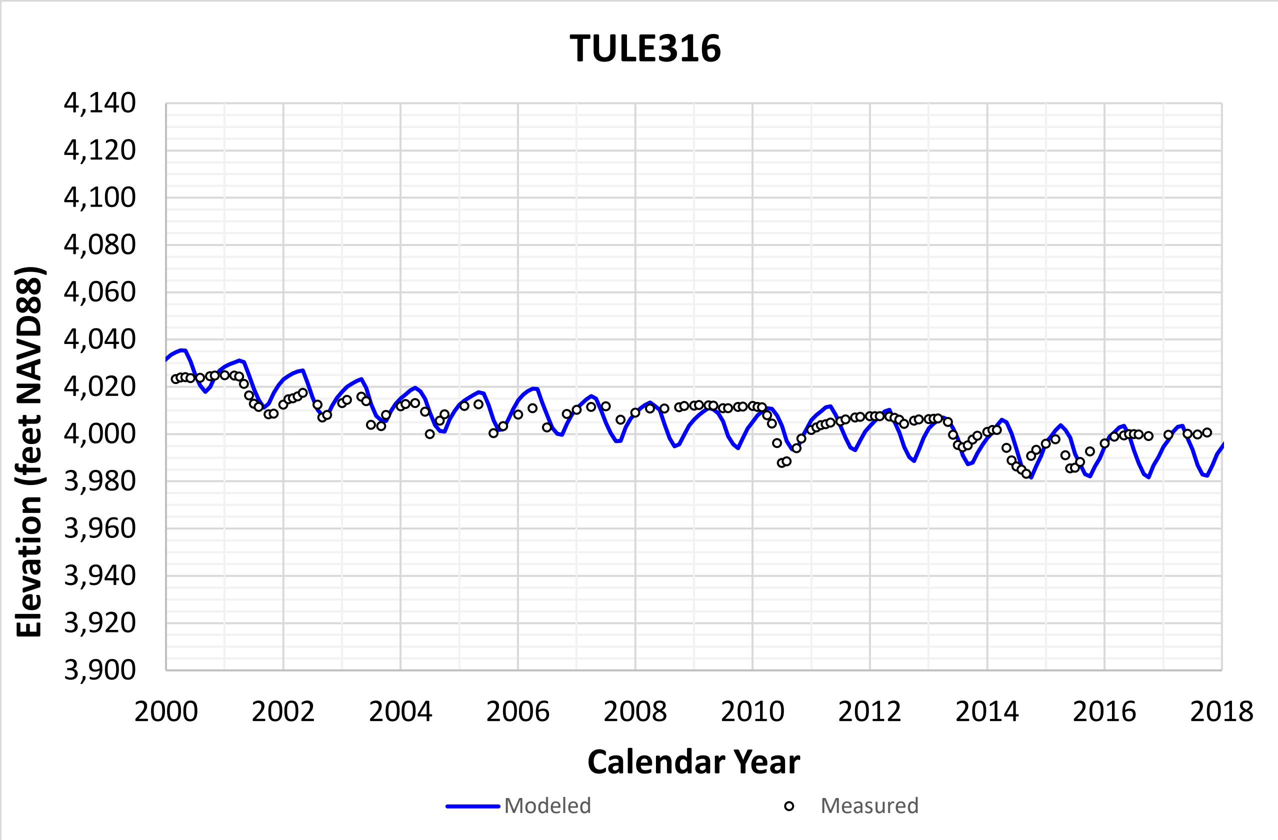
3,900
Elevation (feet NAVD88)
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Calendar Year
Modeled
Measured



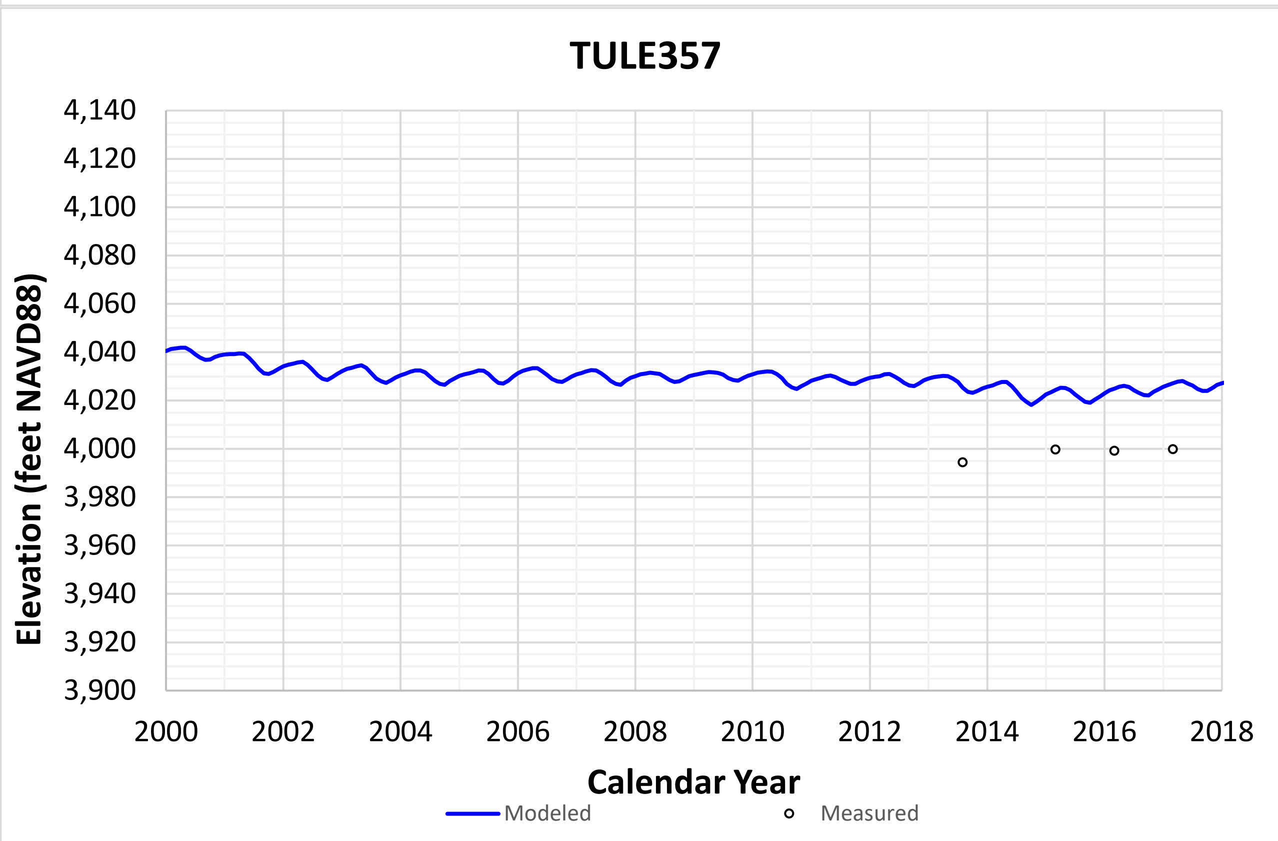
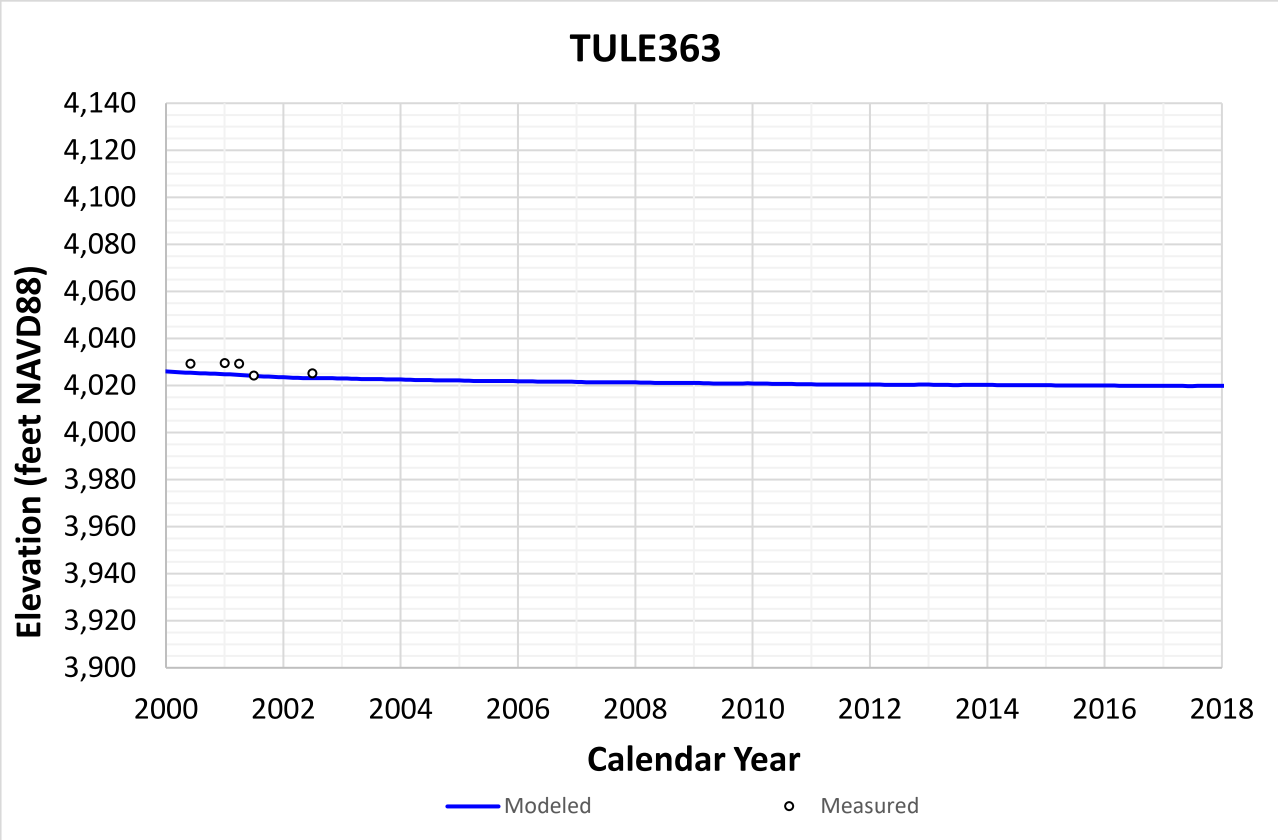




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



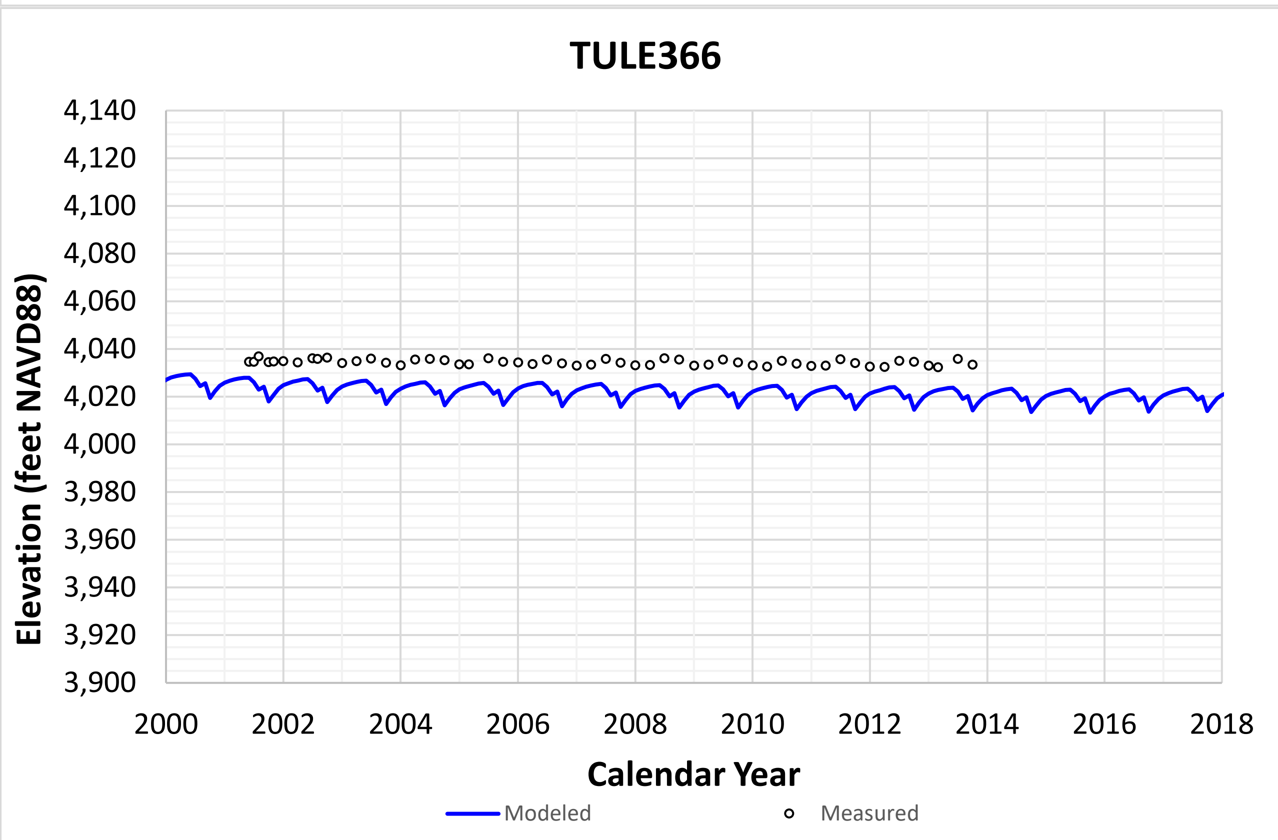
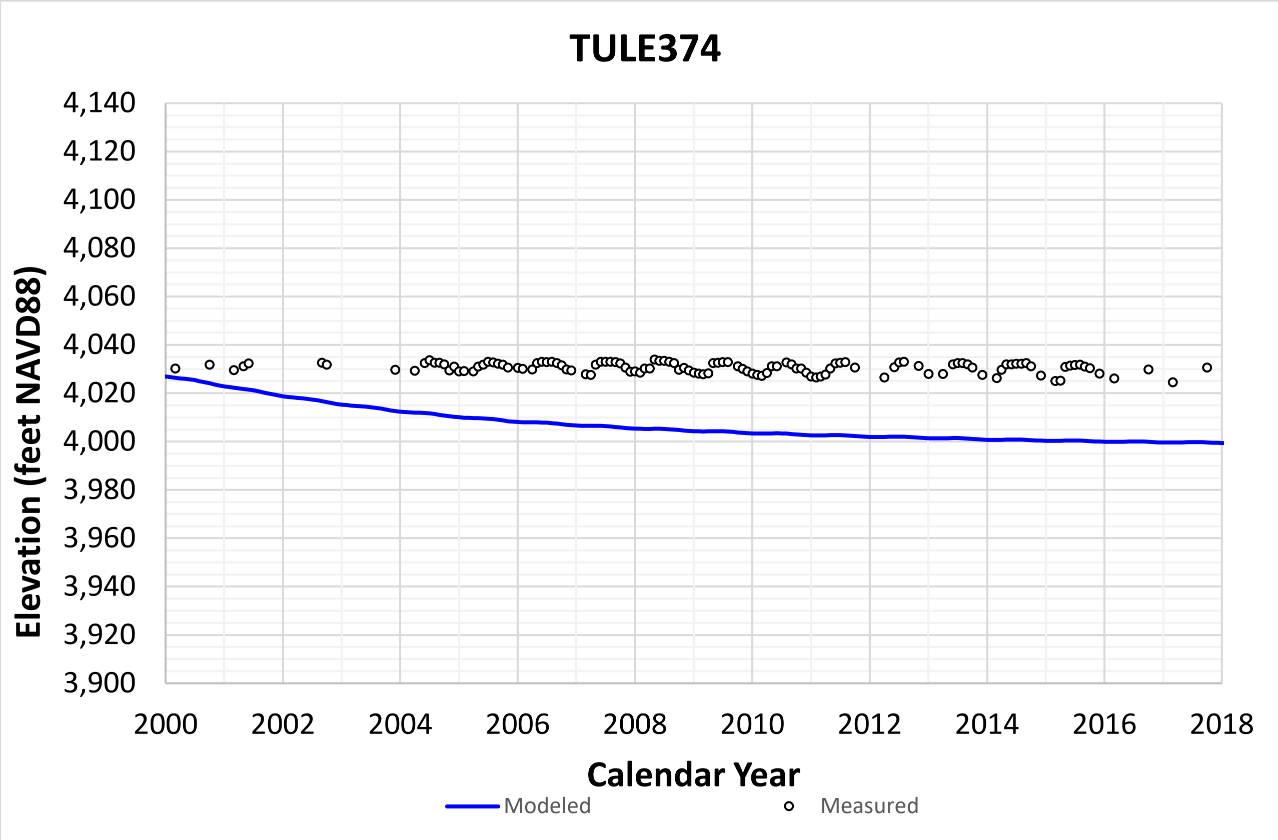




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



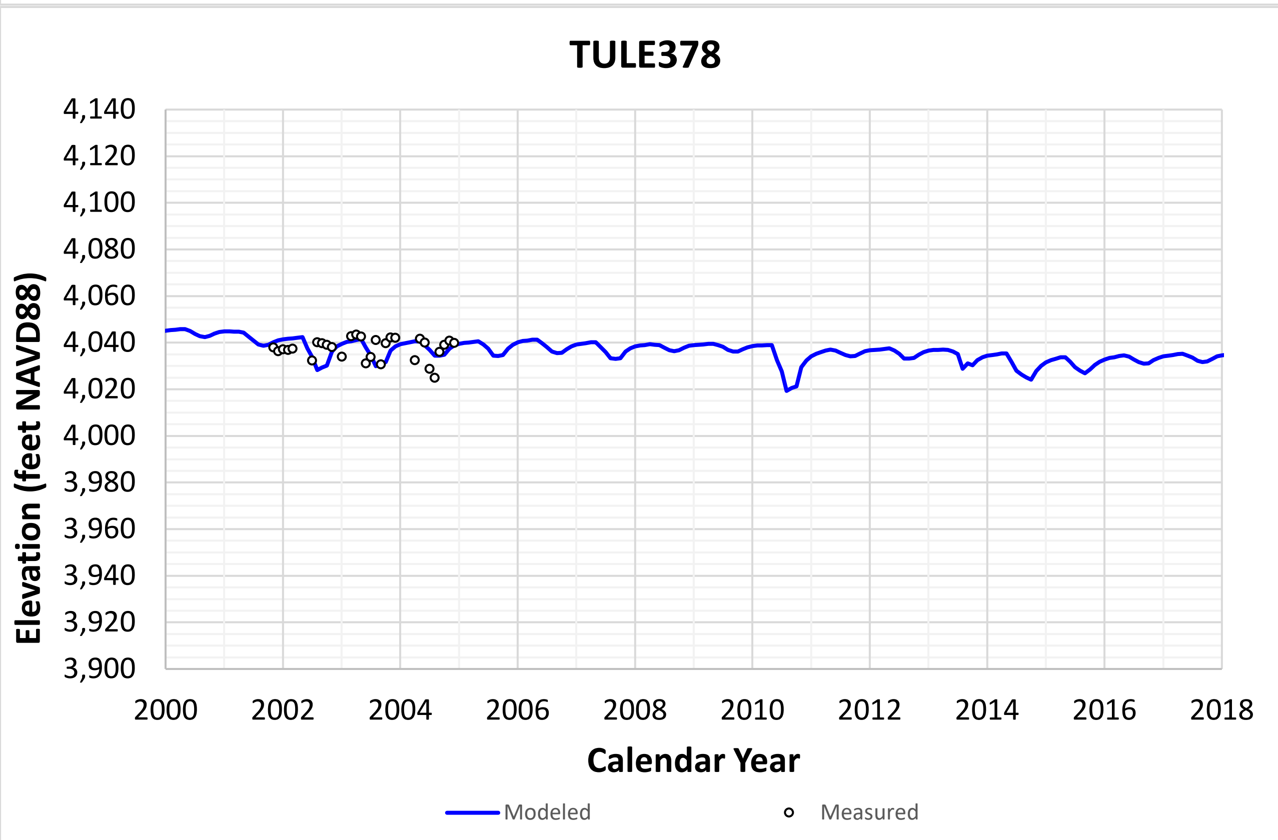
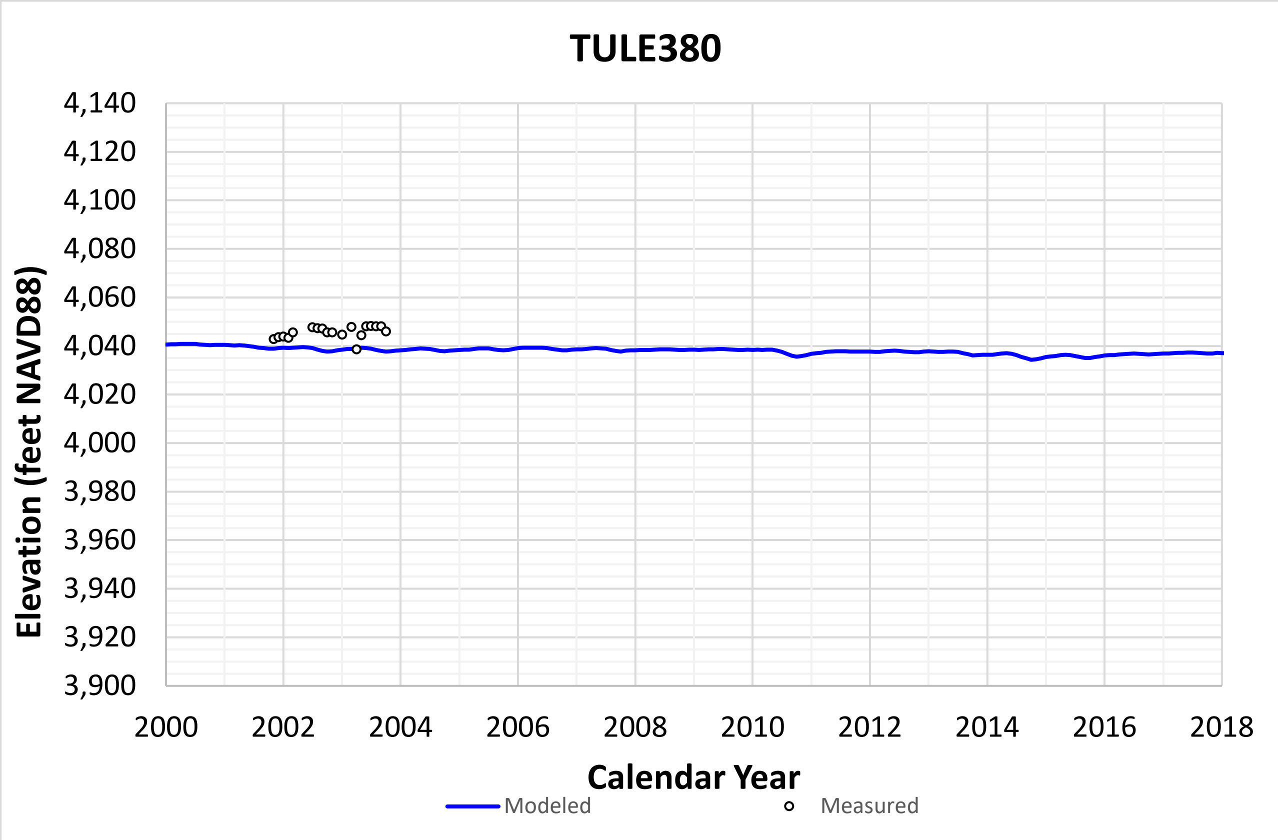




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



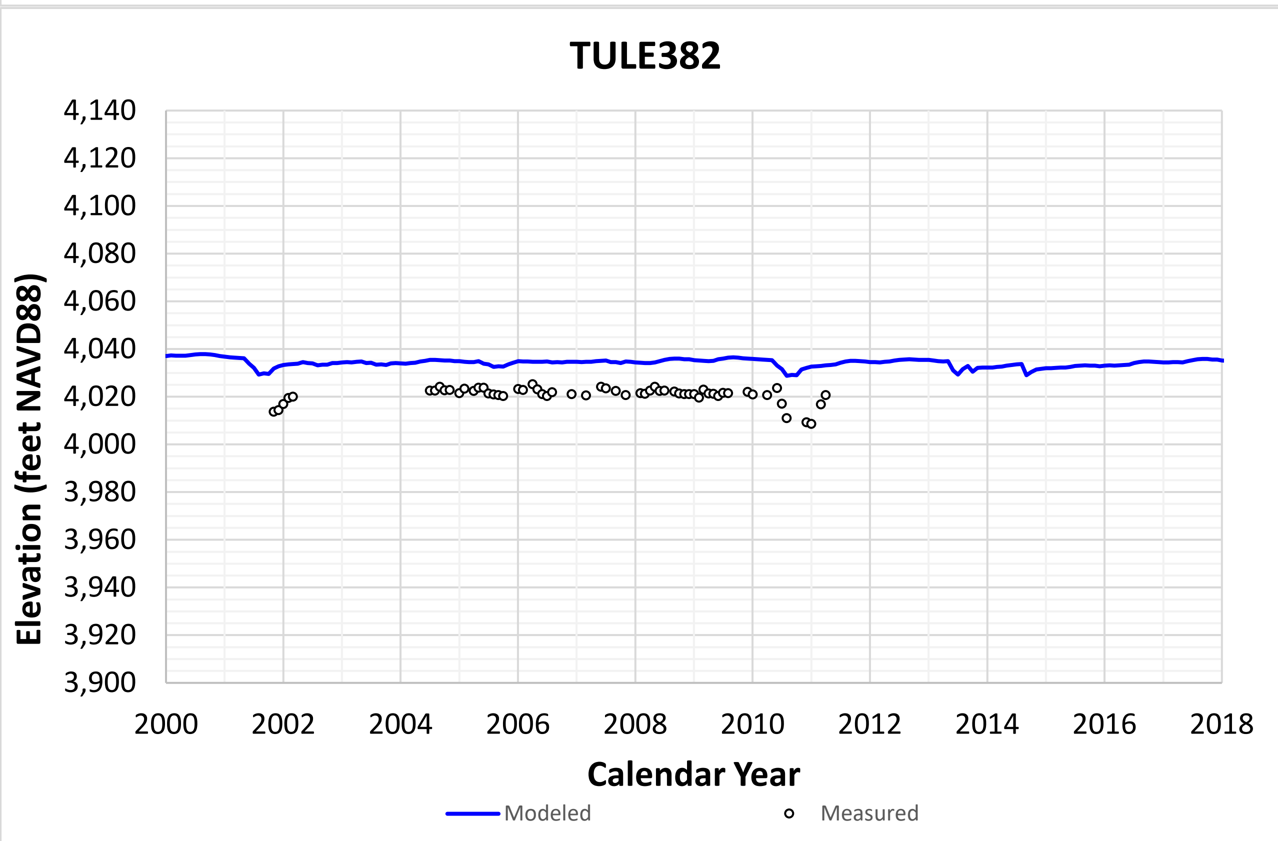
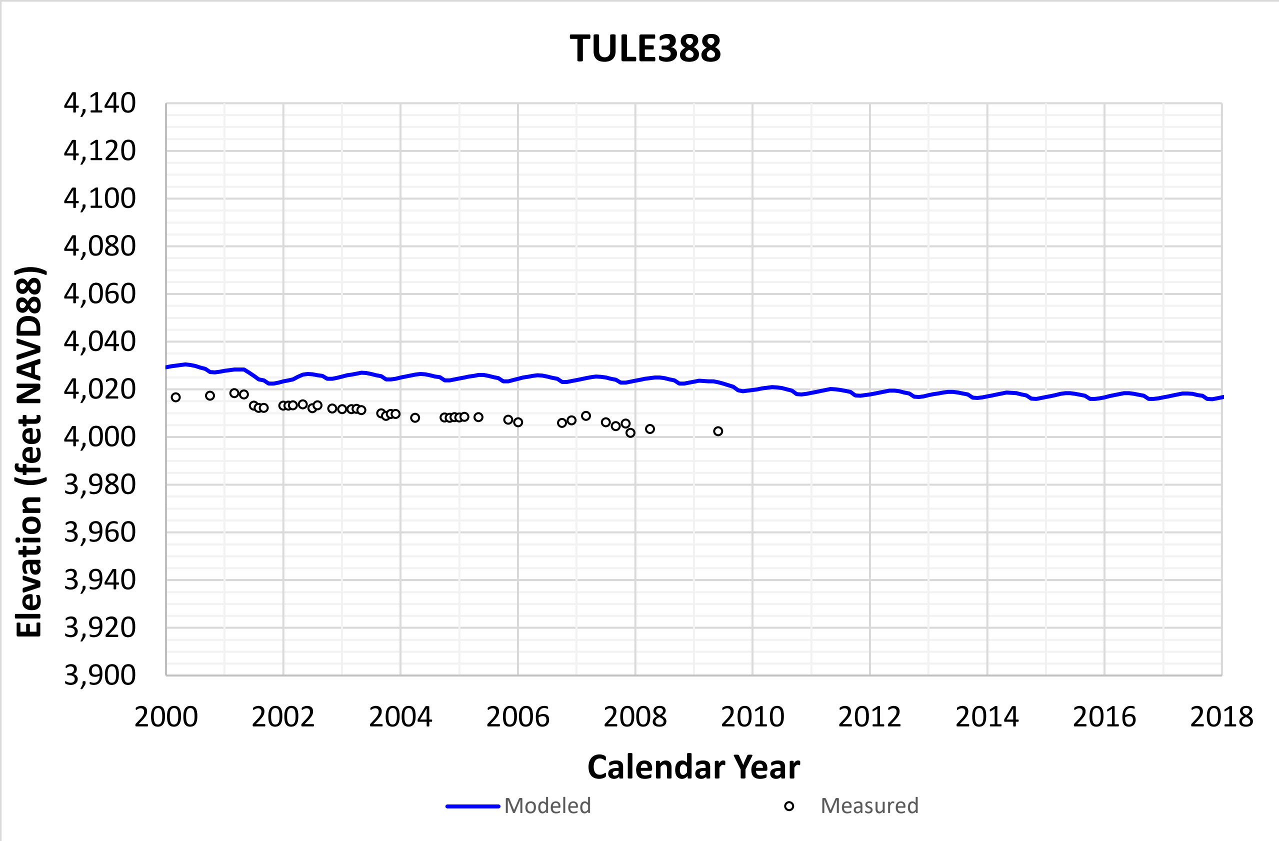




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs



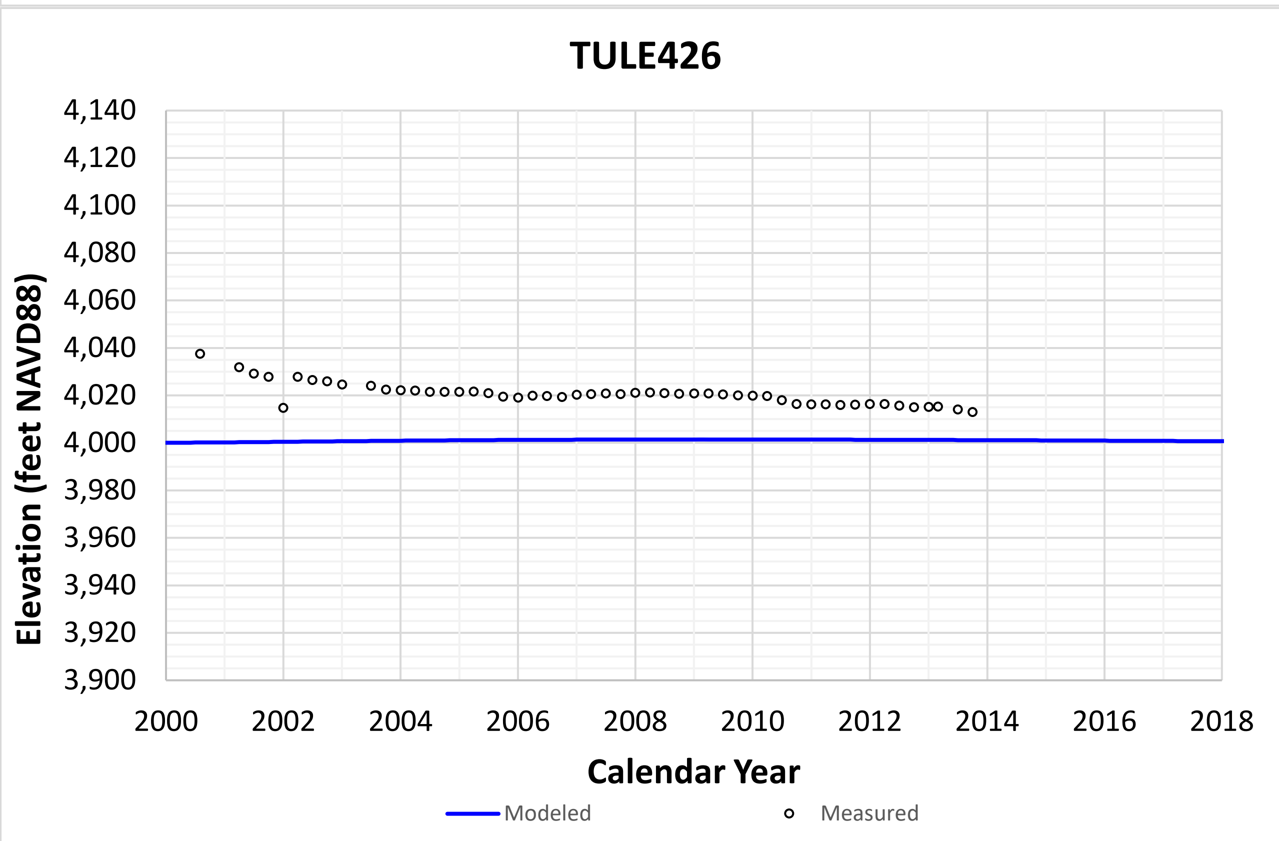
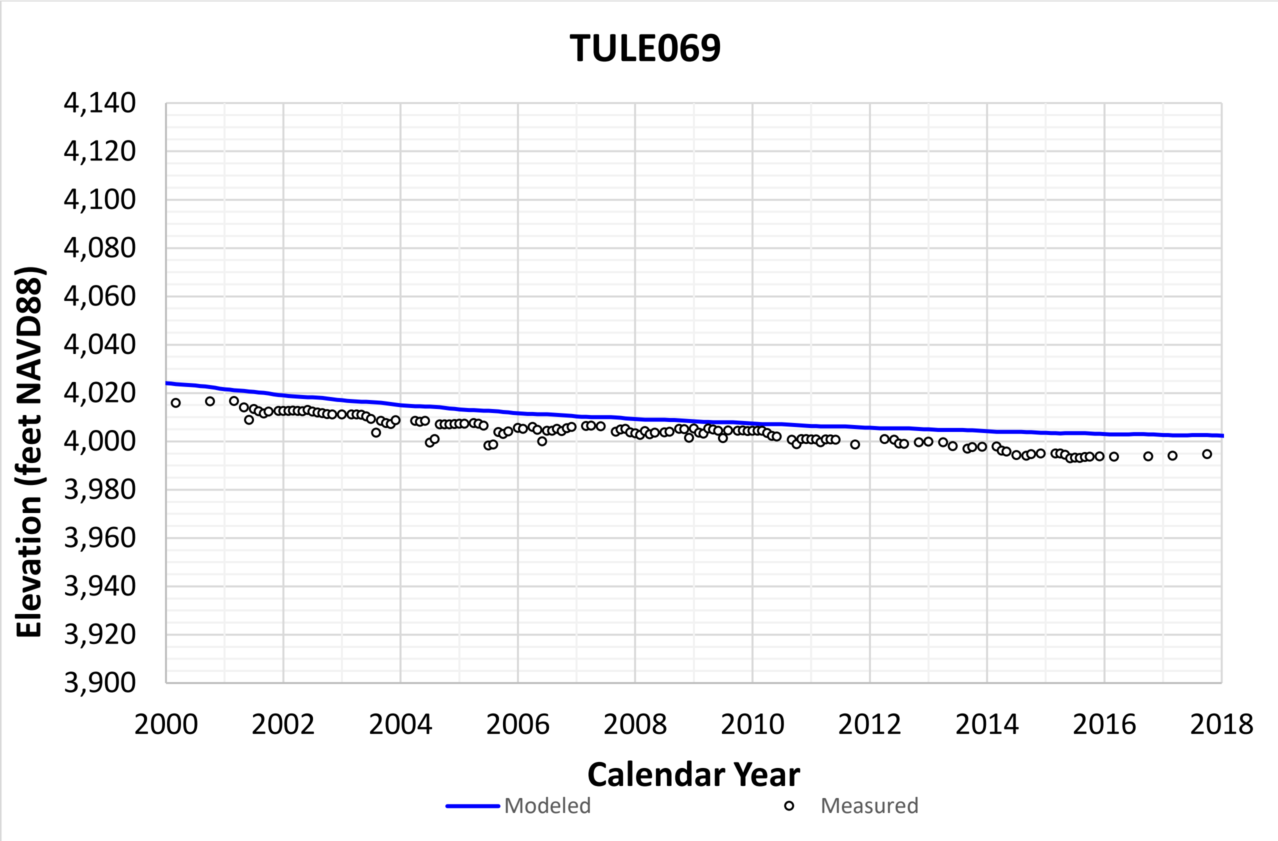




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs


TULE069
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Elevation (feet NAVD88)
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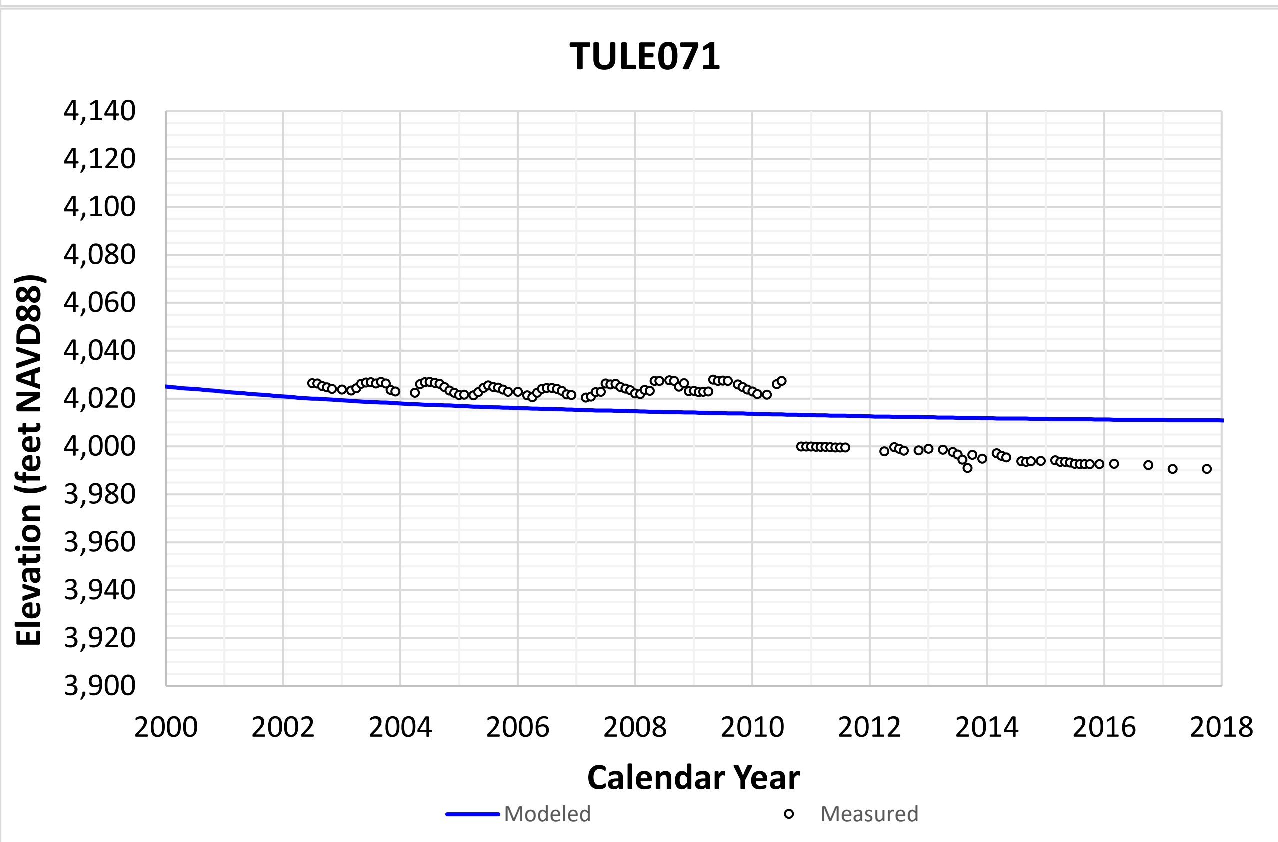
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Elevation (feet NAVD88)
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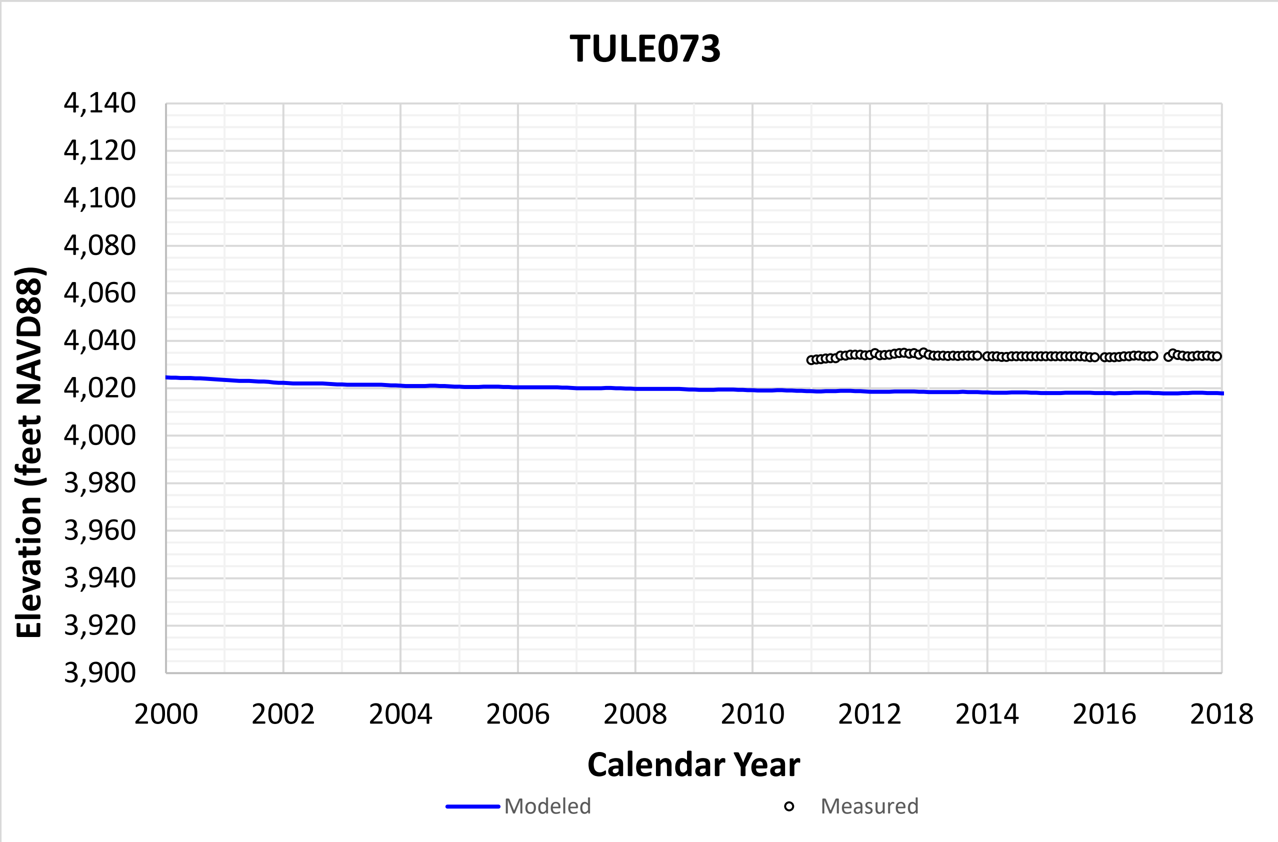
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Elevation (feet NAVD88)
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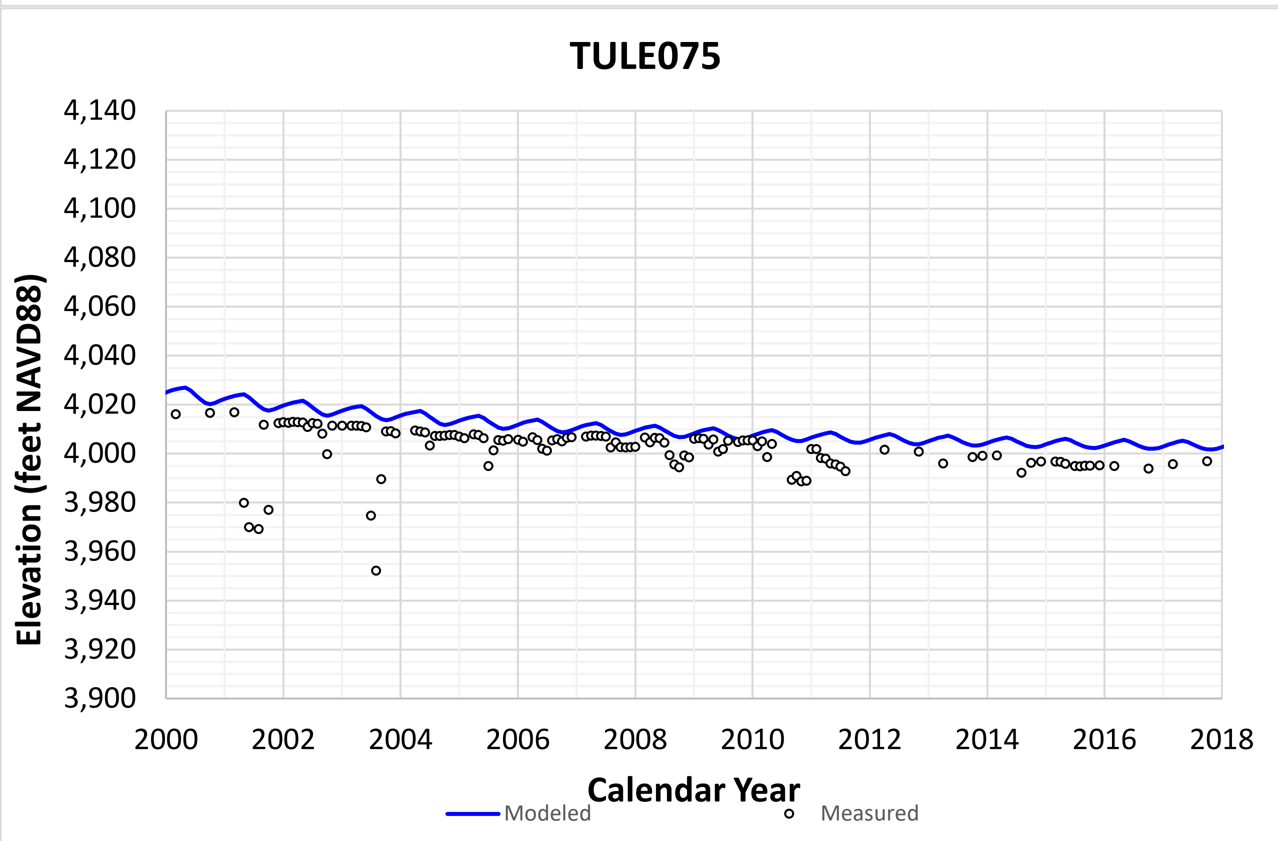
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Elevation (feet NAVD88)
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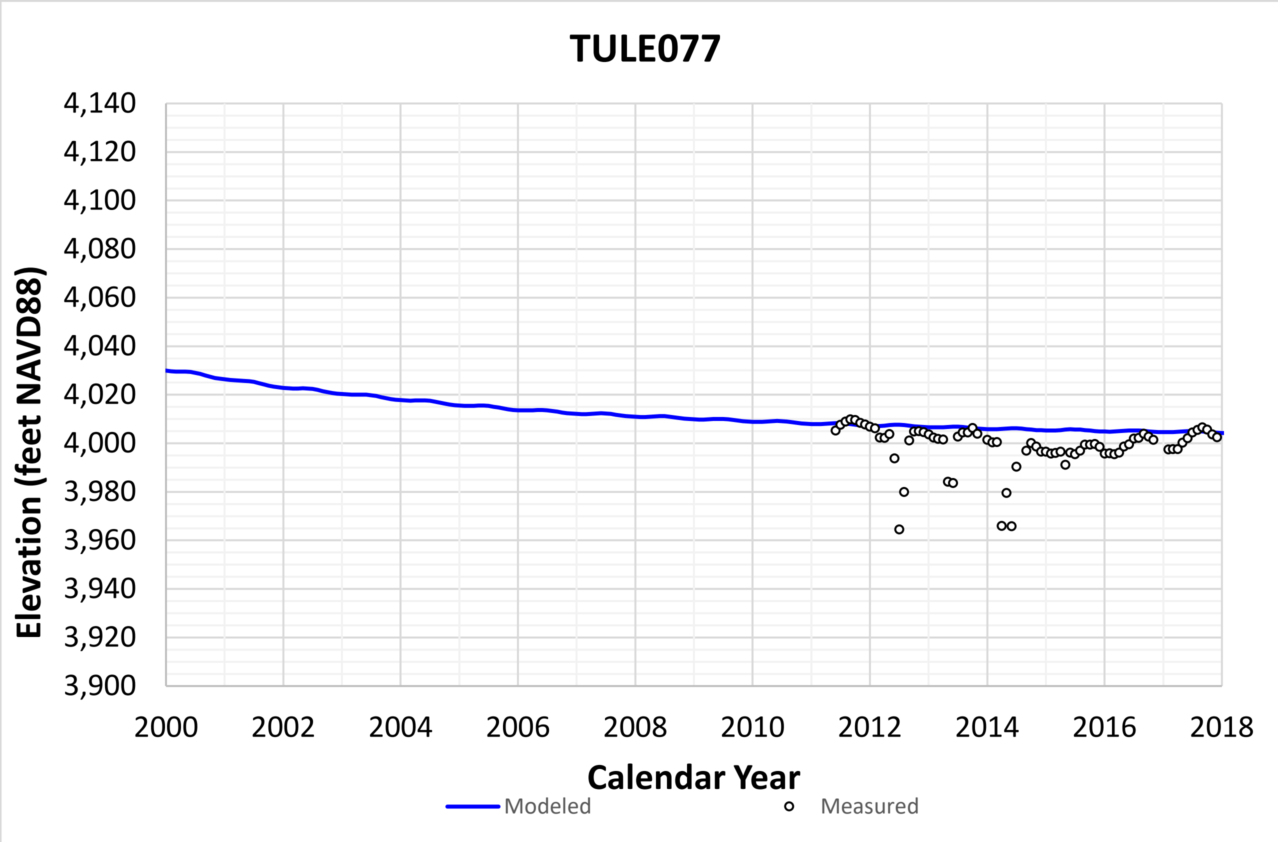
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Elevation (feet NAVD88)
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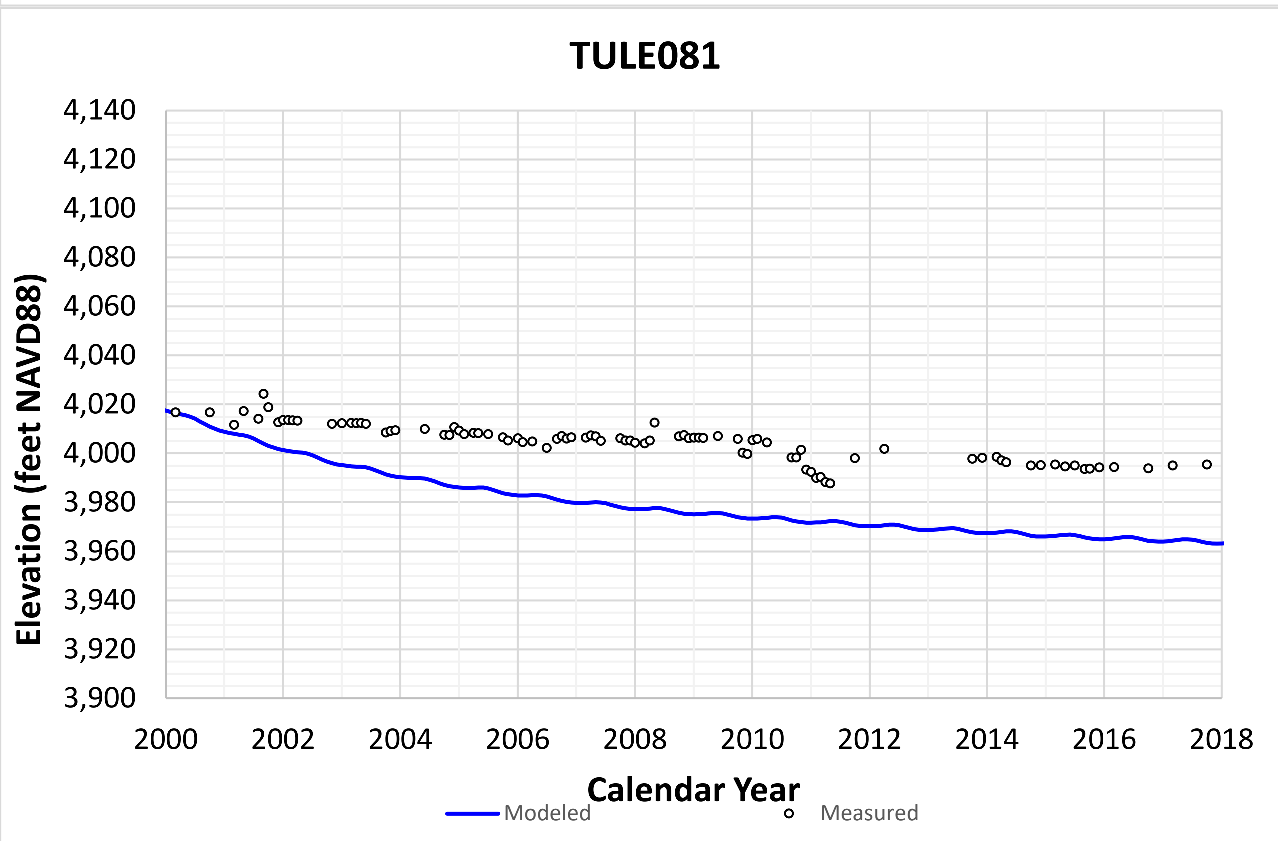
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Elevation (feet NAVD88)
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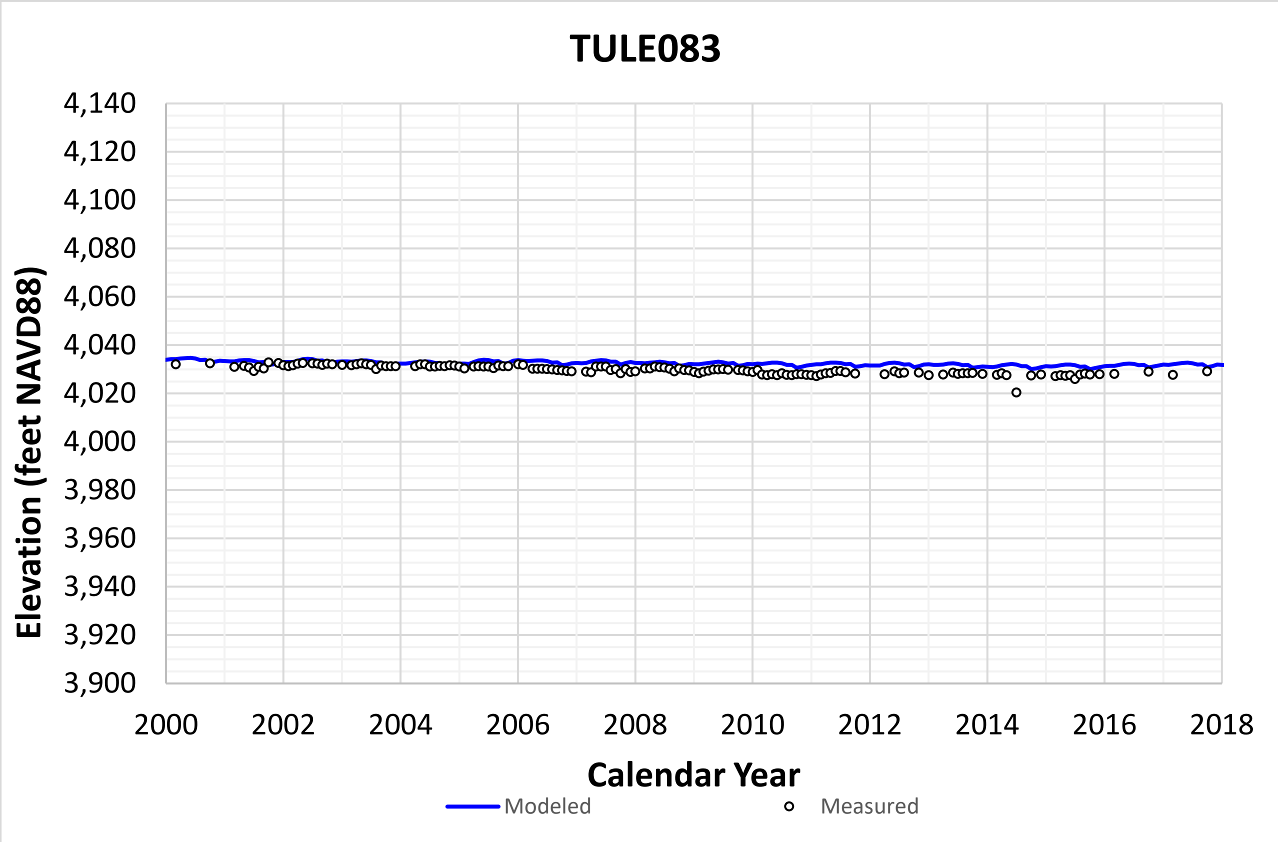
Calendar Year
Modeled
Measured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4,120
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3,980
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Elevation (feet NAVD88)
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Calendar Year
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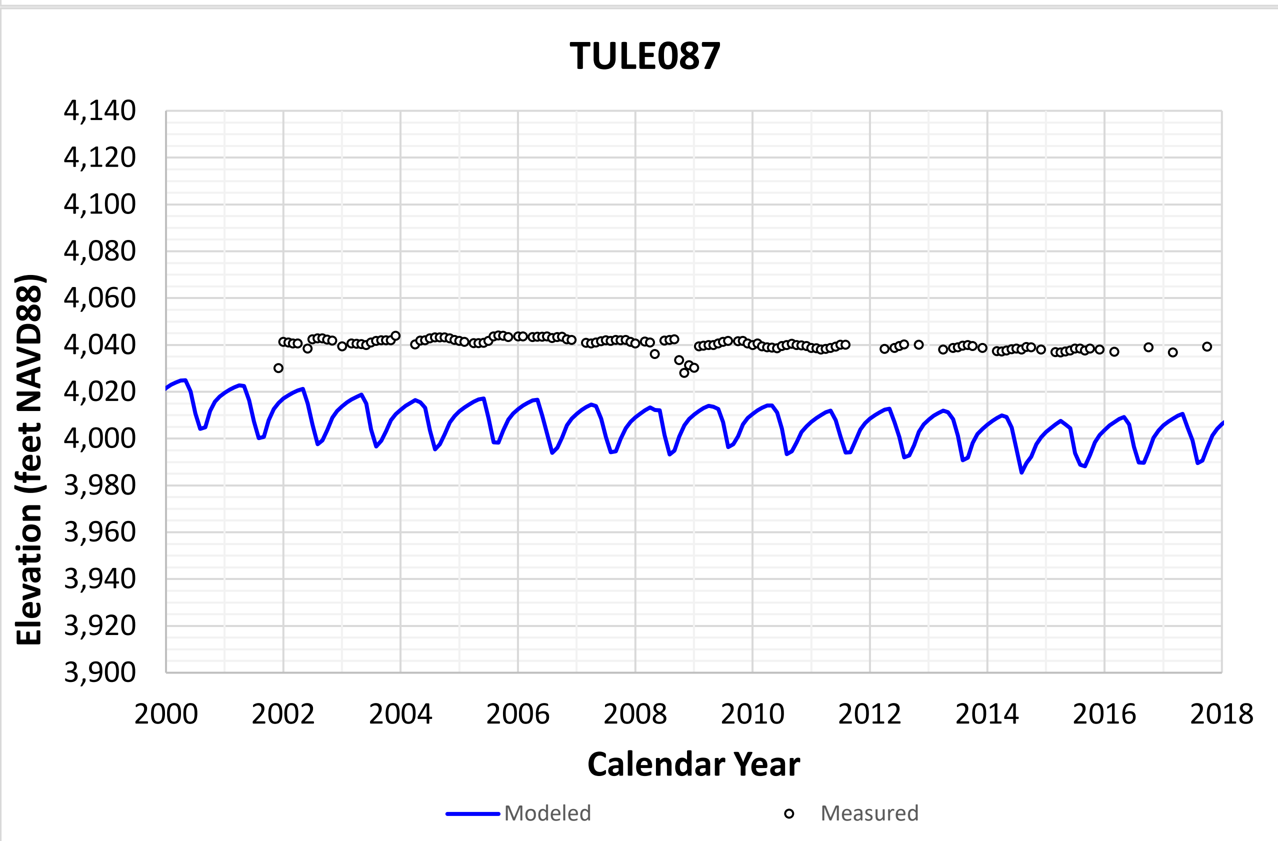
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Elevation (feet NAVD88)
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Calendar Year
Modeled
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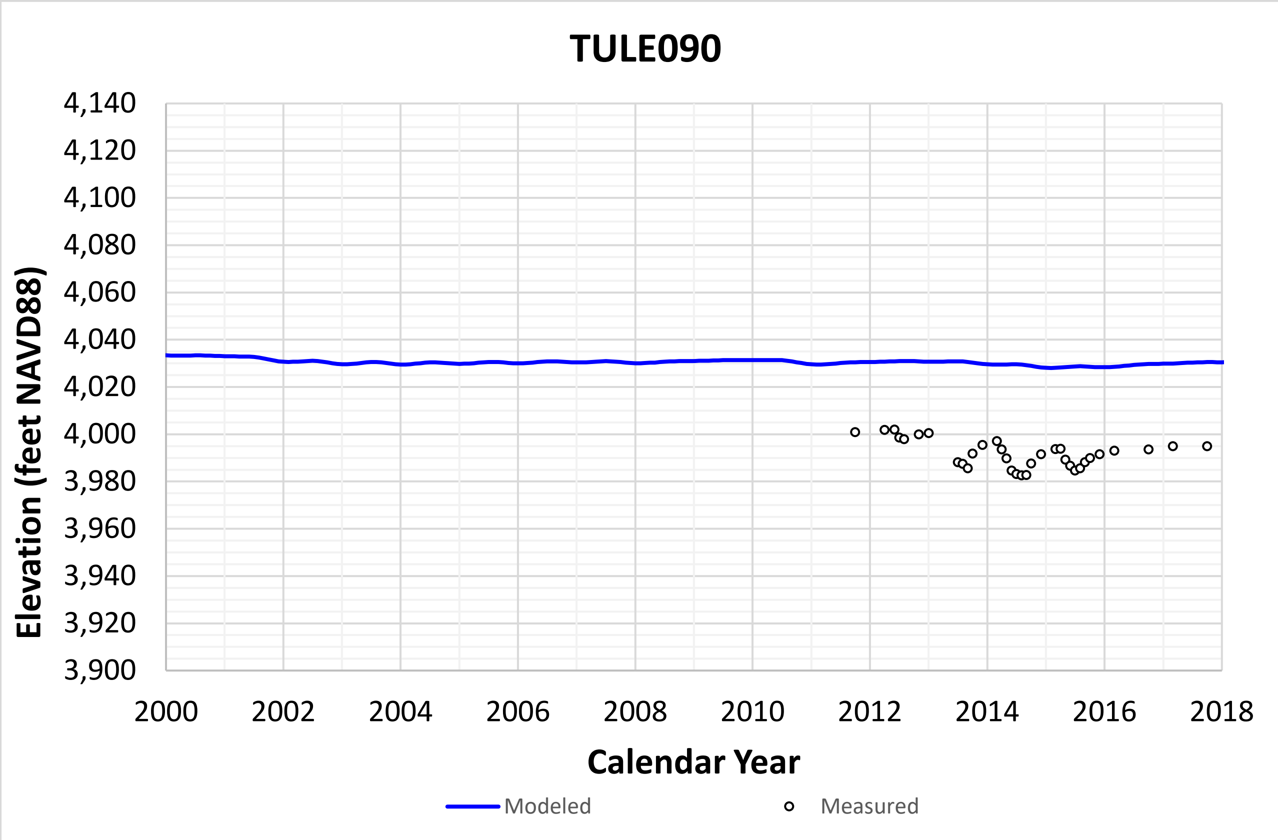

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Elevation (feet NAVD88)
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Calendar Year
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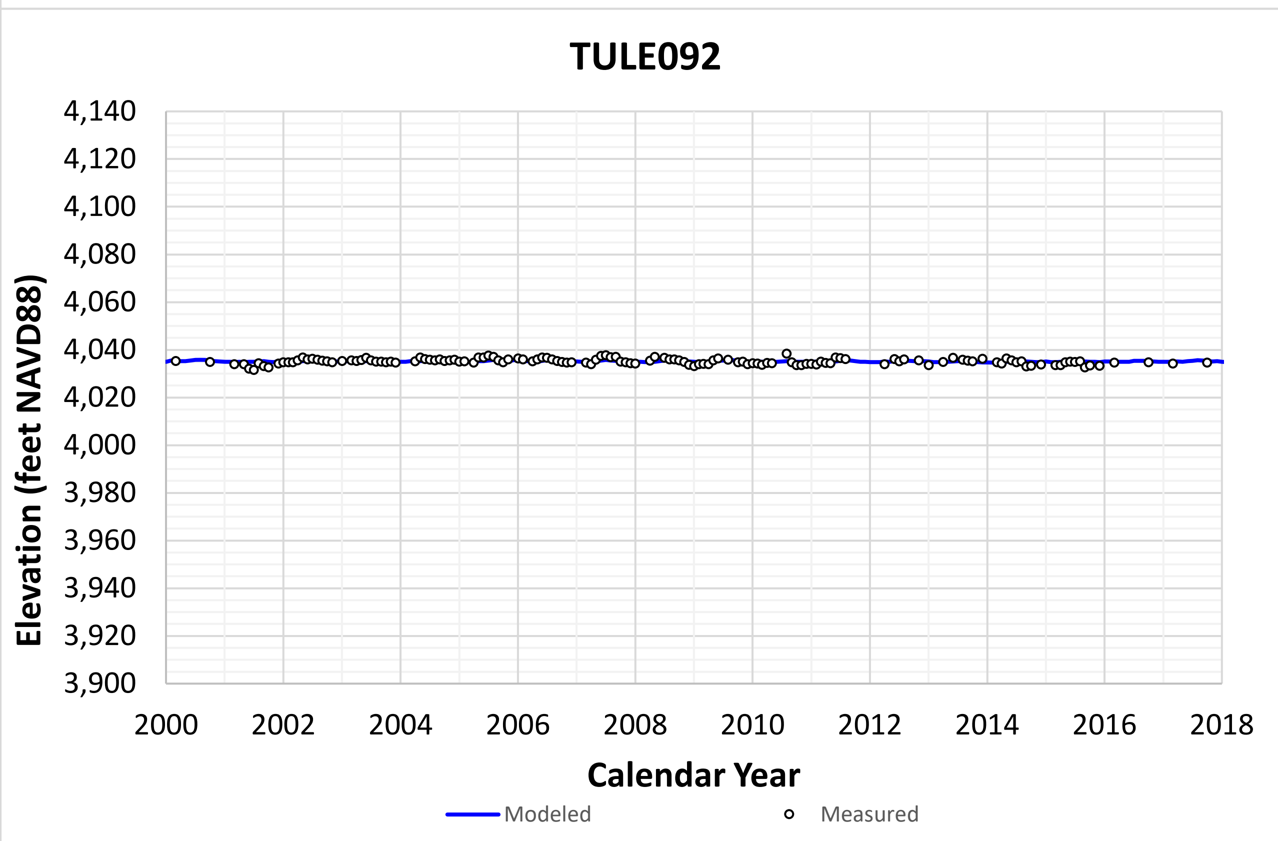

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Elevation (feet NAVD88)
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Calendar Year
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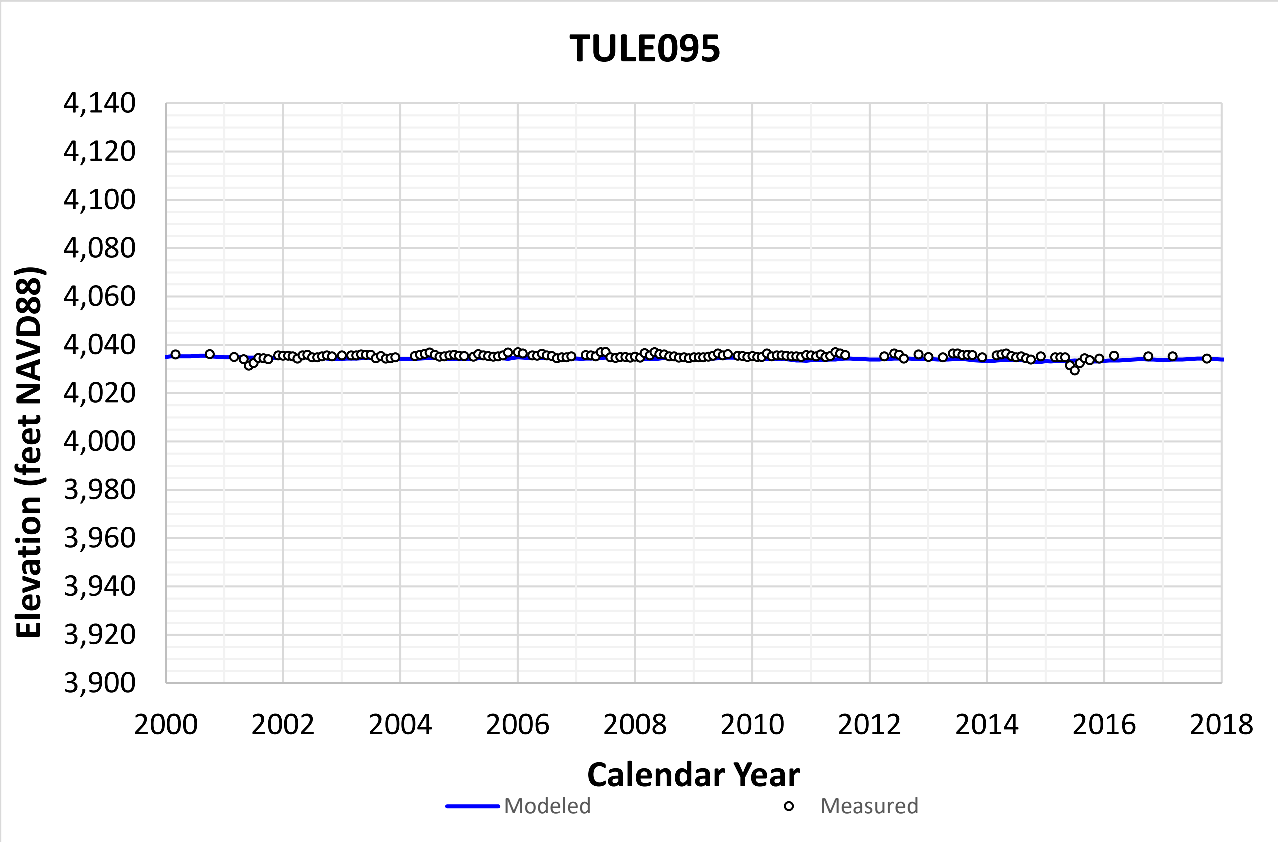
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Elevation (feet NAVD88)
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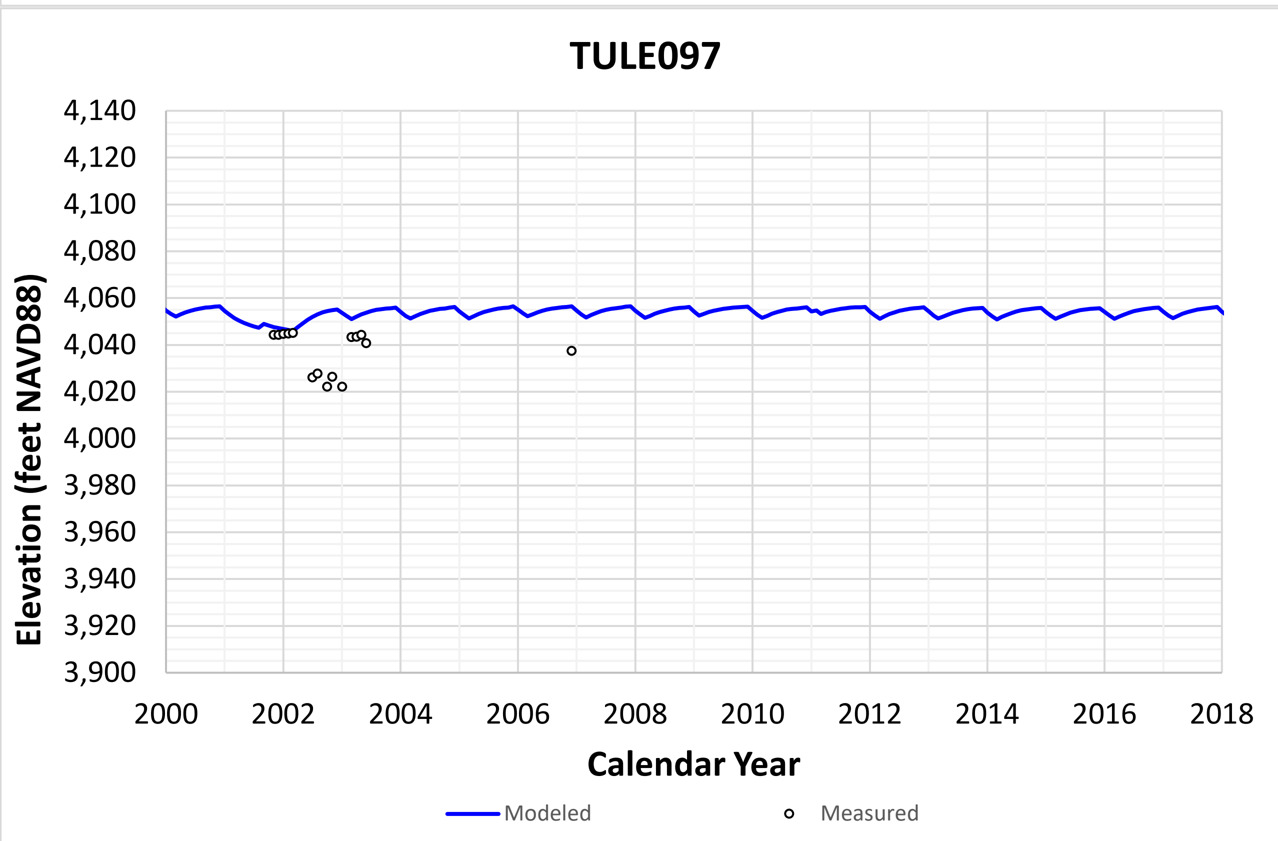
Calendar Year
Modeled
Measured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4,040
4,020
4,000
3,980
3,960
3,940
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Elevation (feet NAVD88)
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Calendar Year
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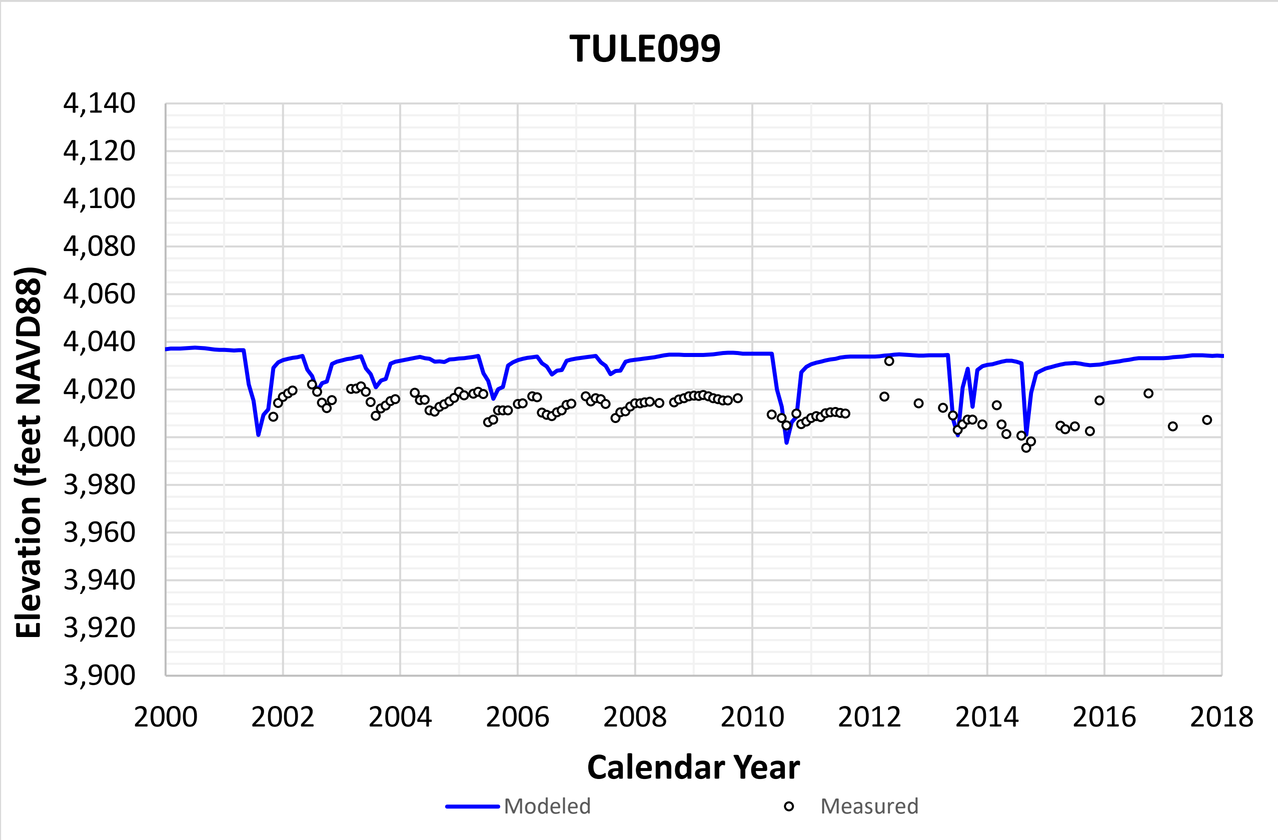
TULE099
Elevation (feet NAVD88)
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4,120
4,100
4,080
4,060
4,040
4,020
4,000
3,980
3,960
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Calendar Year
Modeled
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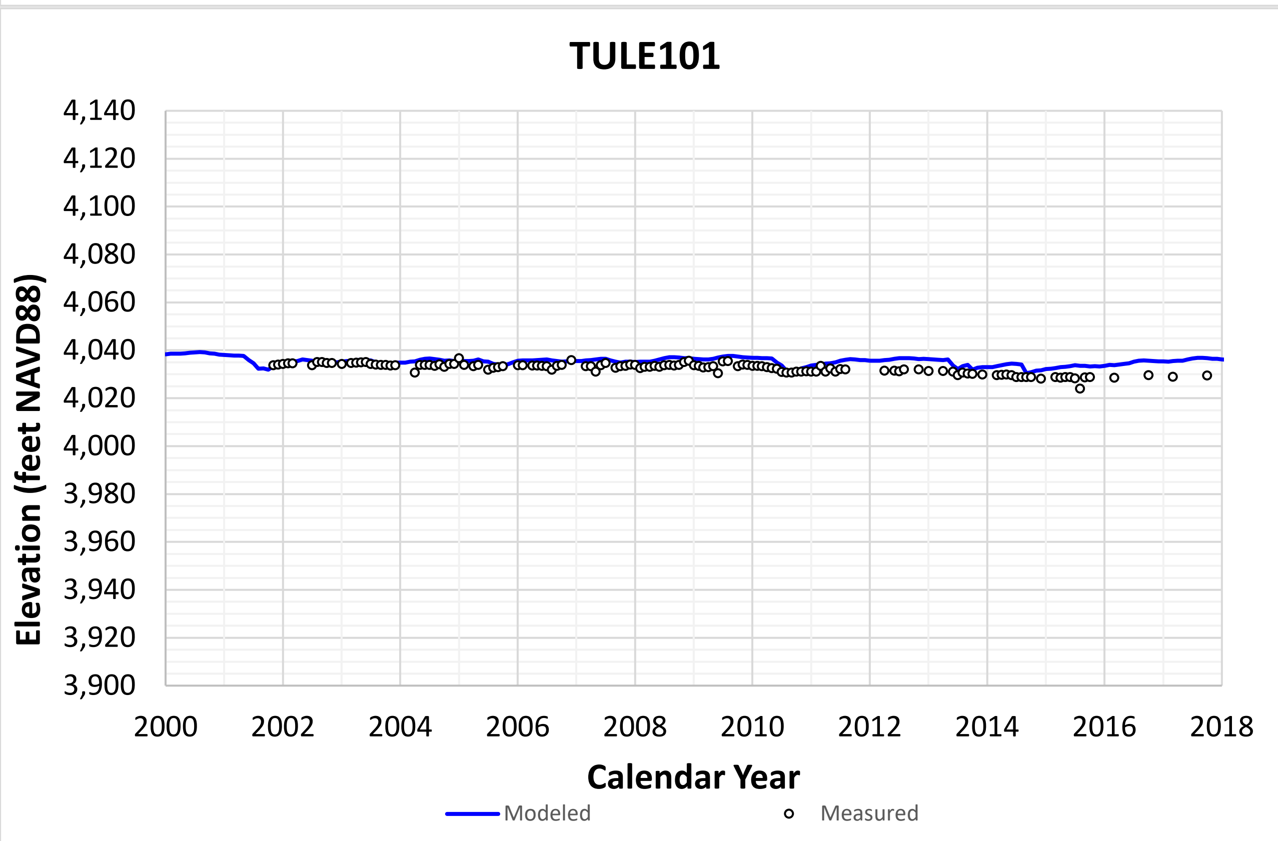
TULE101
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4,100
4,080
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4,020
4,000
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3,960
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3,920
3,900
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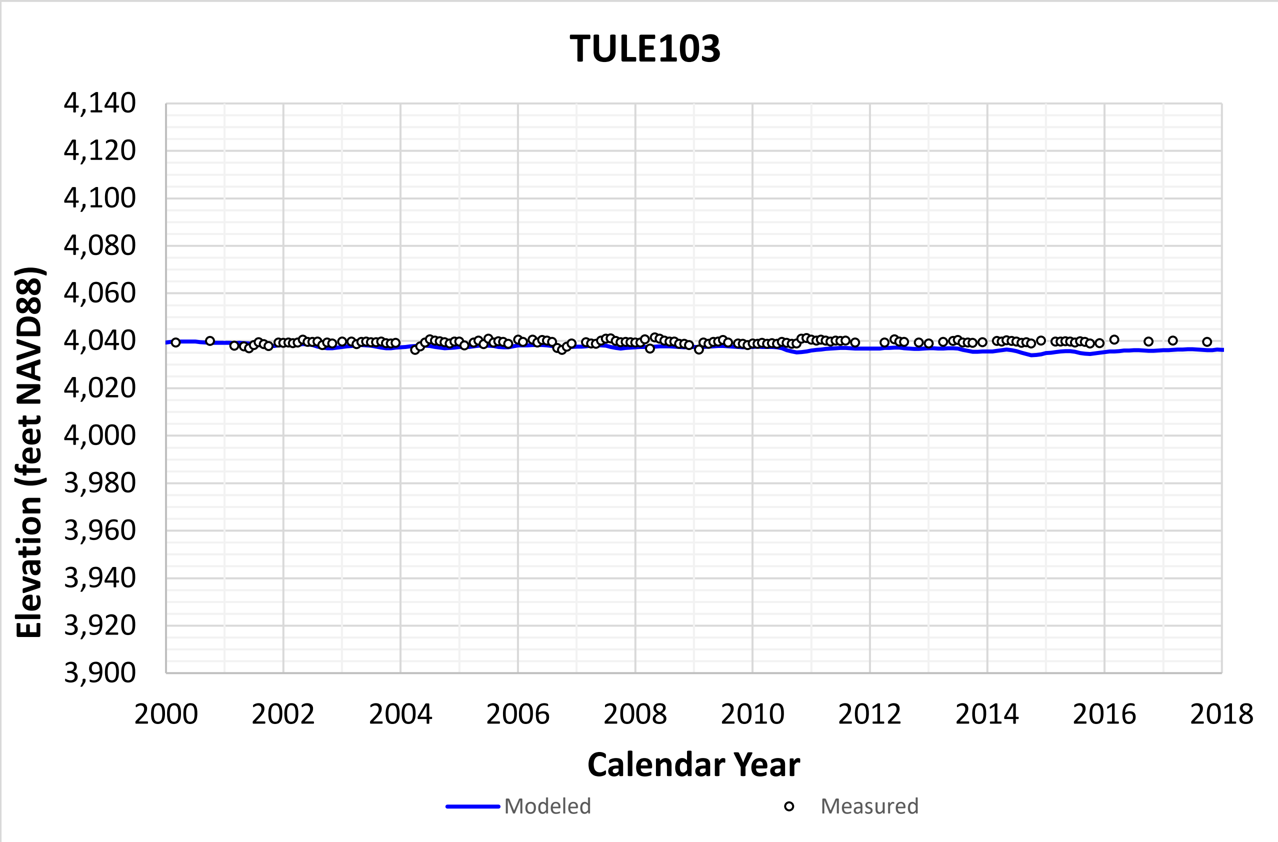
Calendar Year
Modeled
Measured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3,940
3,920
3,900
Elevation (feet NAVD88)
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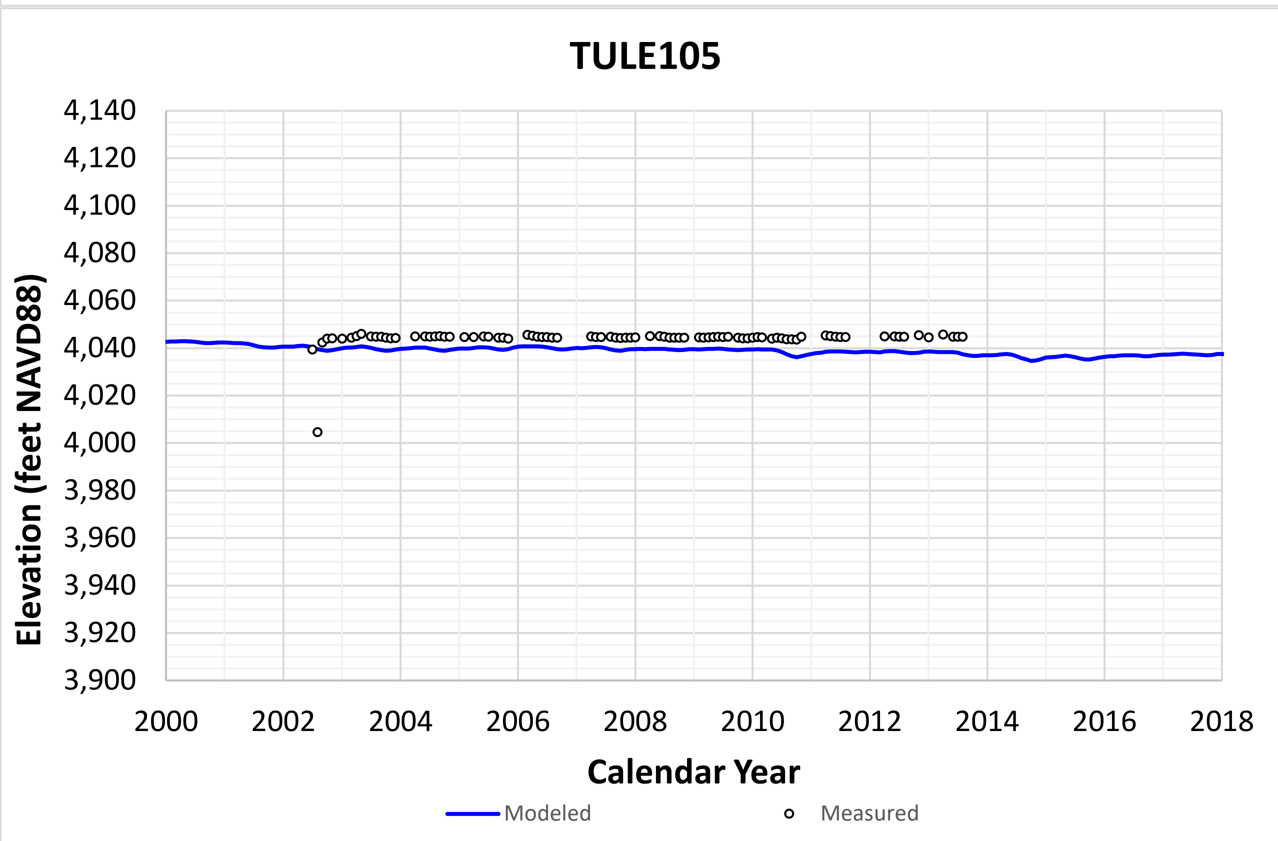
Calendar Year
Modeled
Measured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Elevation (feet NAVD88)
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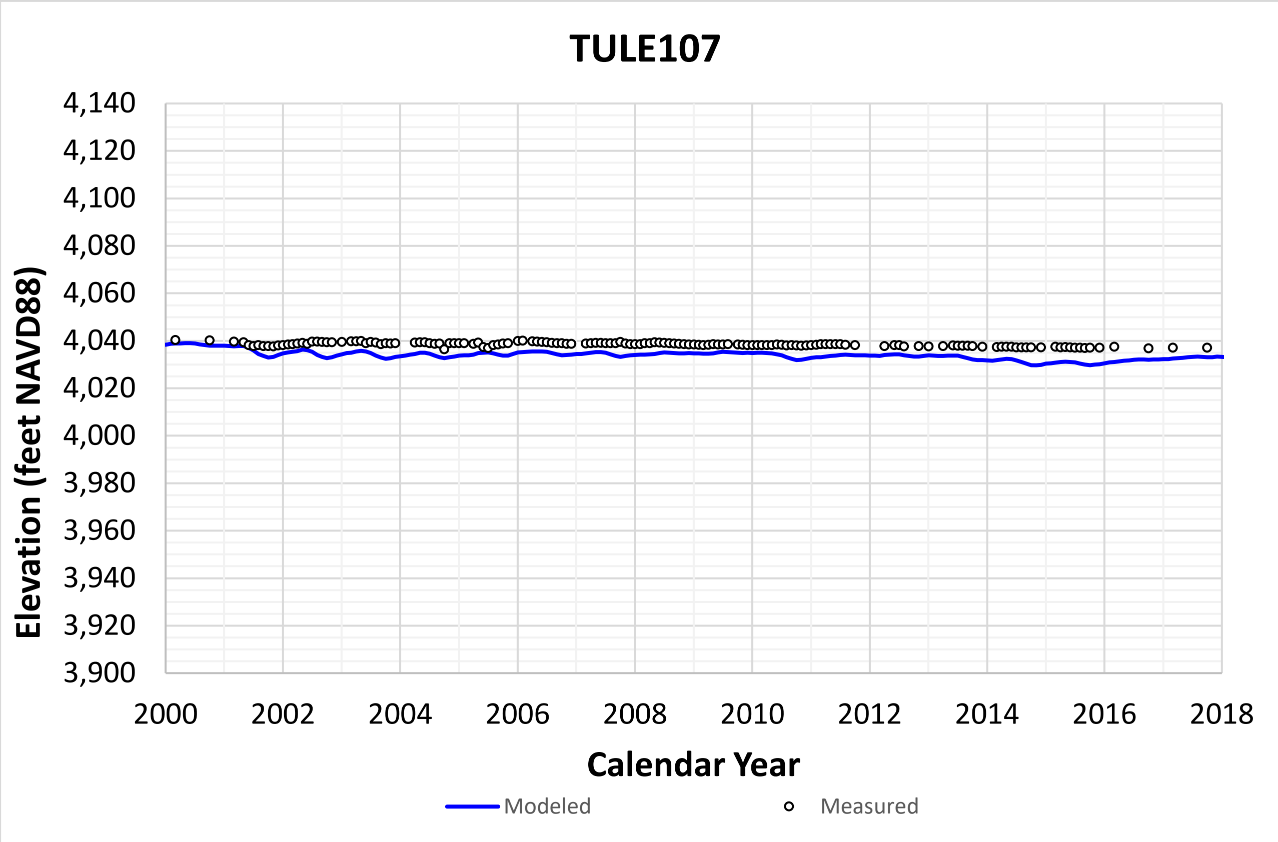
Calendar Year
Modeled
Measured


TULE107
Elevation (feet NAVD88)
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4,040
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3,980
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3,920
3,900
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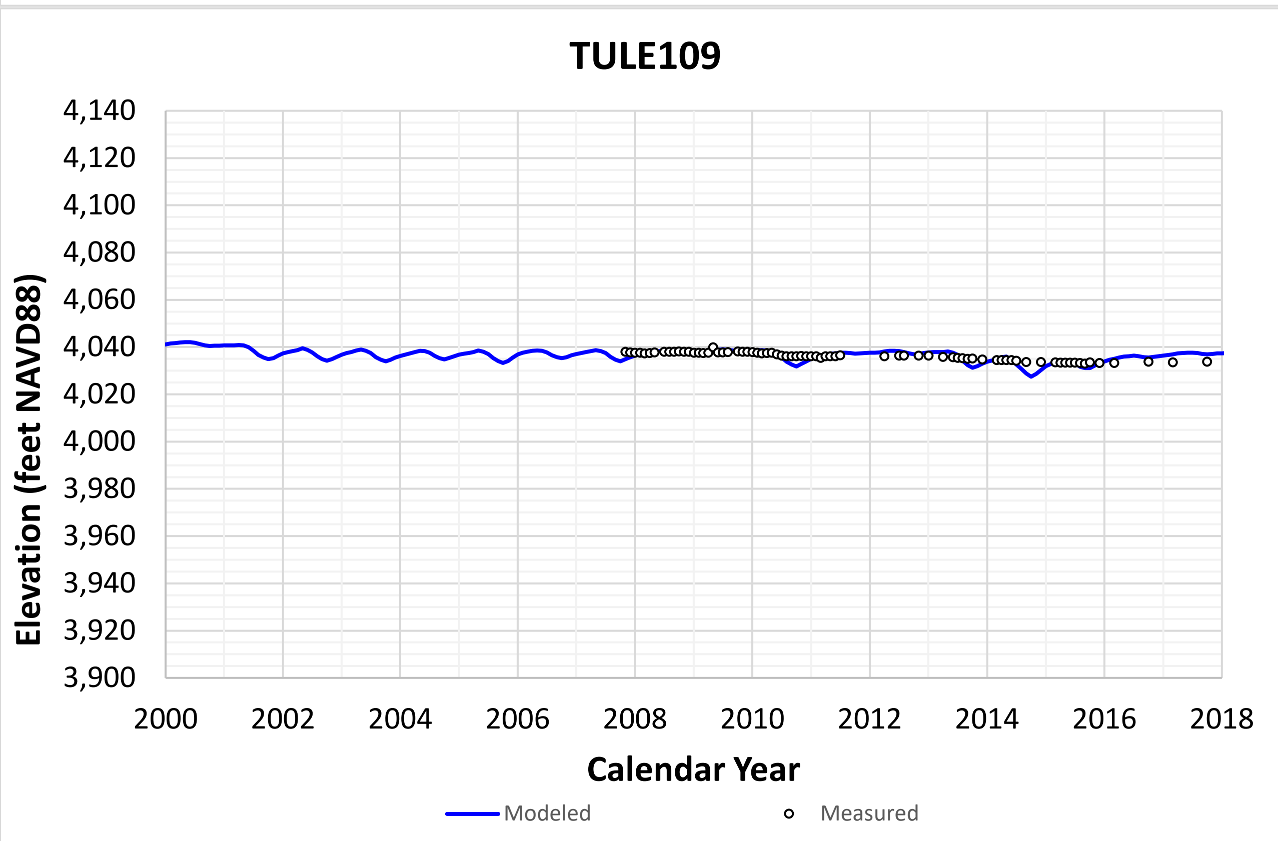
Calendar Year
Modeled
Measured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Elevation (feet NAVD88)
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3,980
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3,940
3,920
3,900
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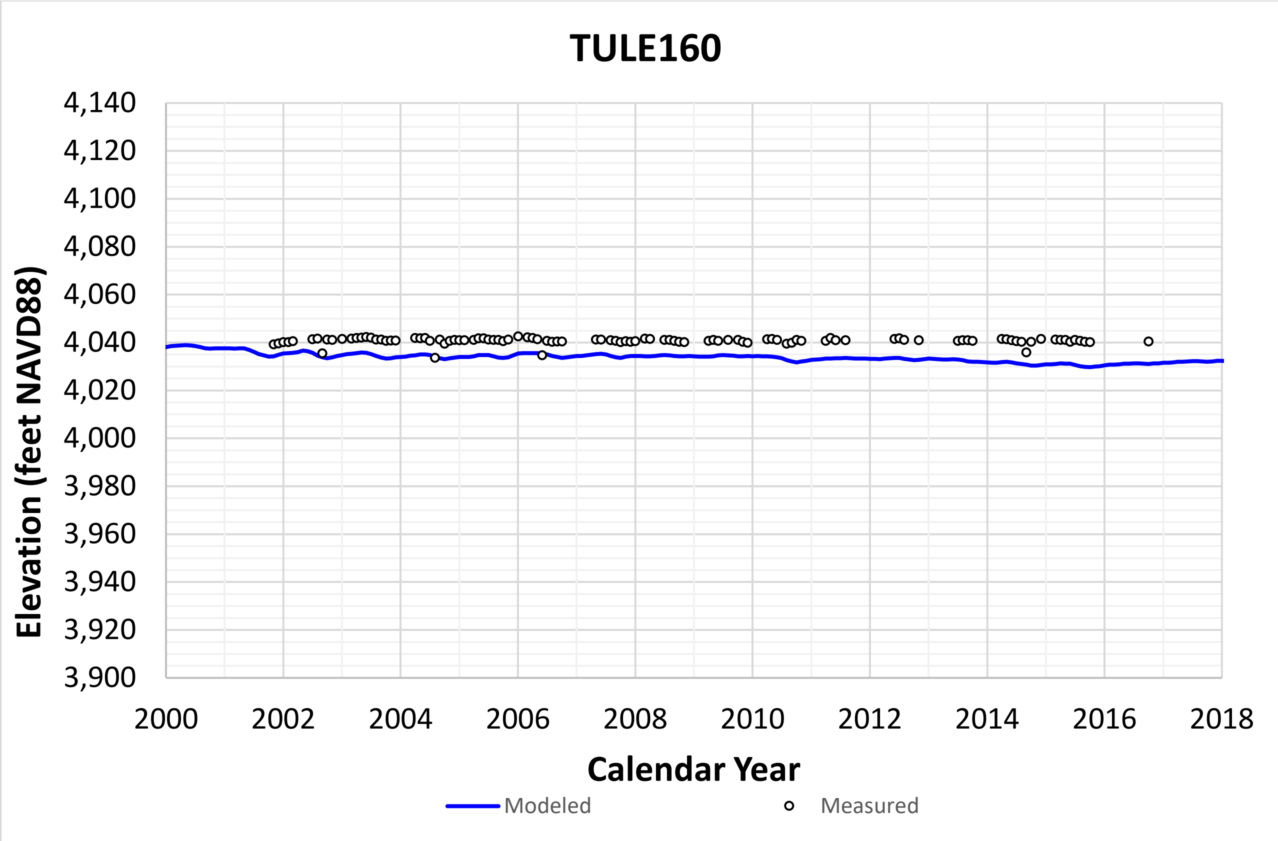
Calendar Year
Modeled
Measured


TULE160
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3,900
Elevation (feet NAVD88)
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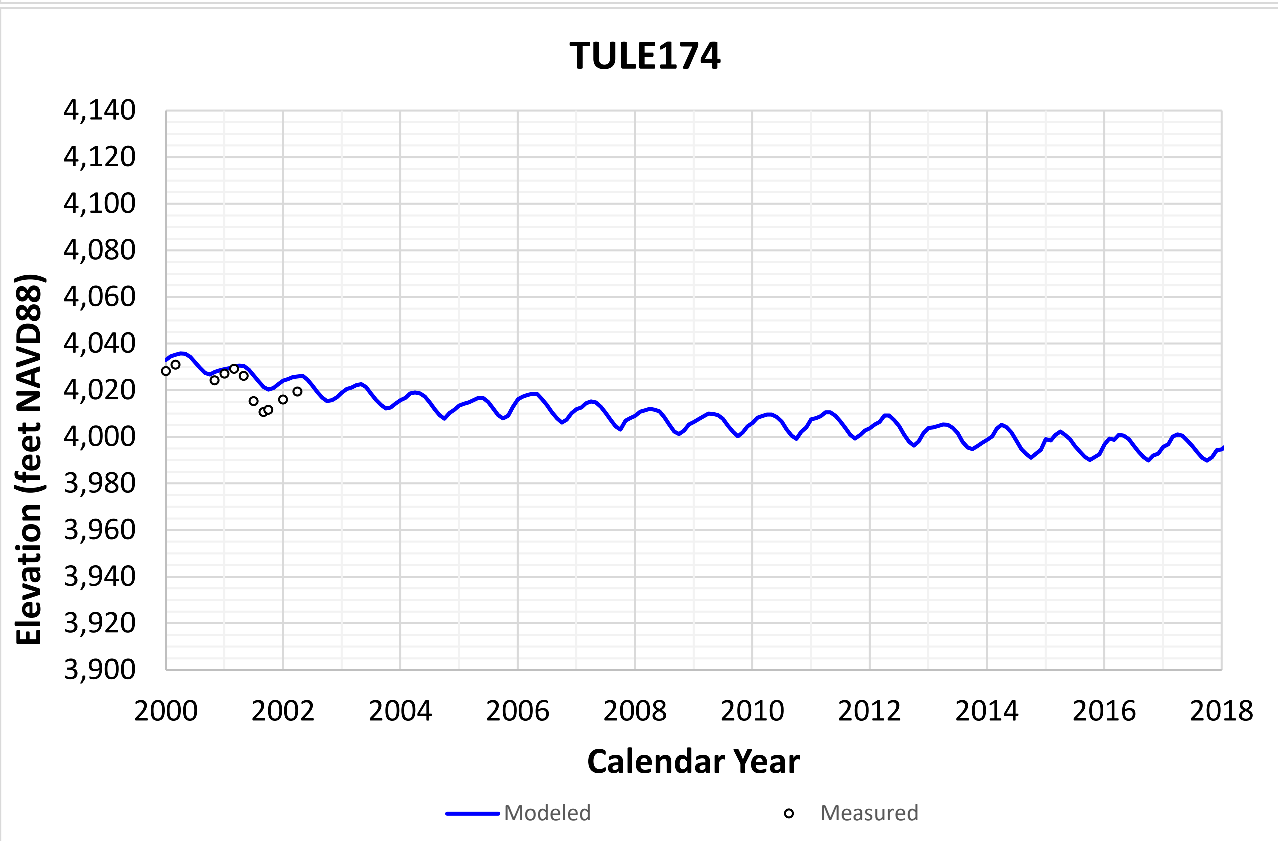
Calendar Year
Modeled
Measured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Elevation (feet NAVD88)
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Calendar Year
Modeled
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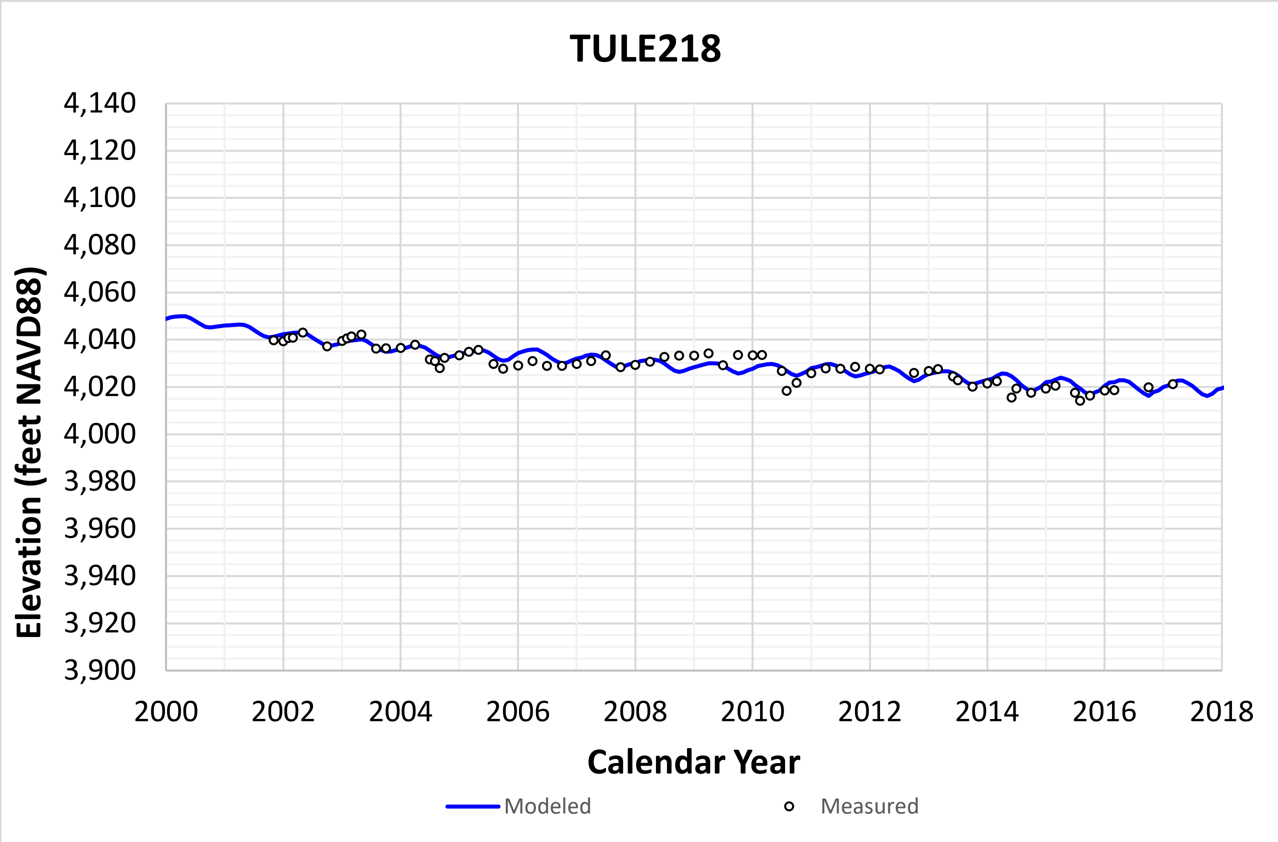
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Elevation (feet NAVD88)
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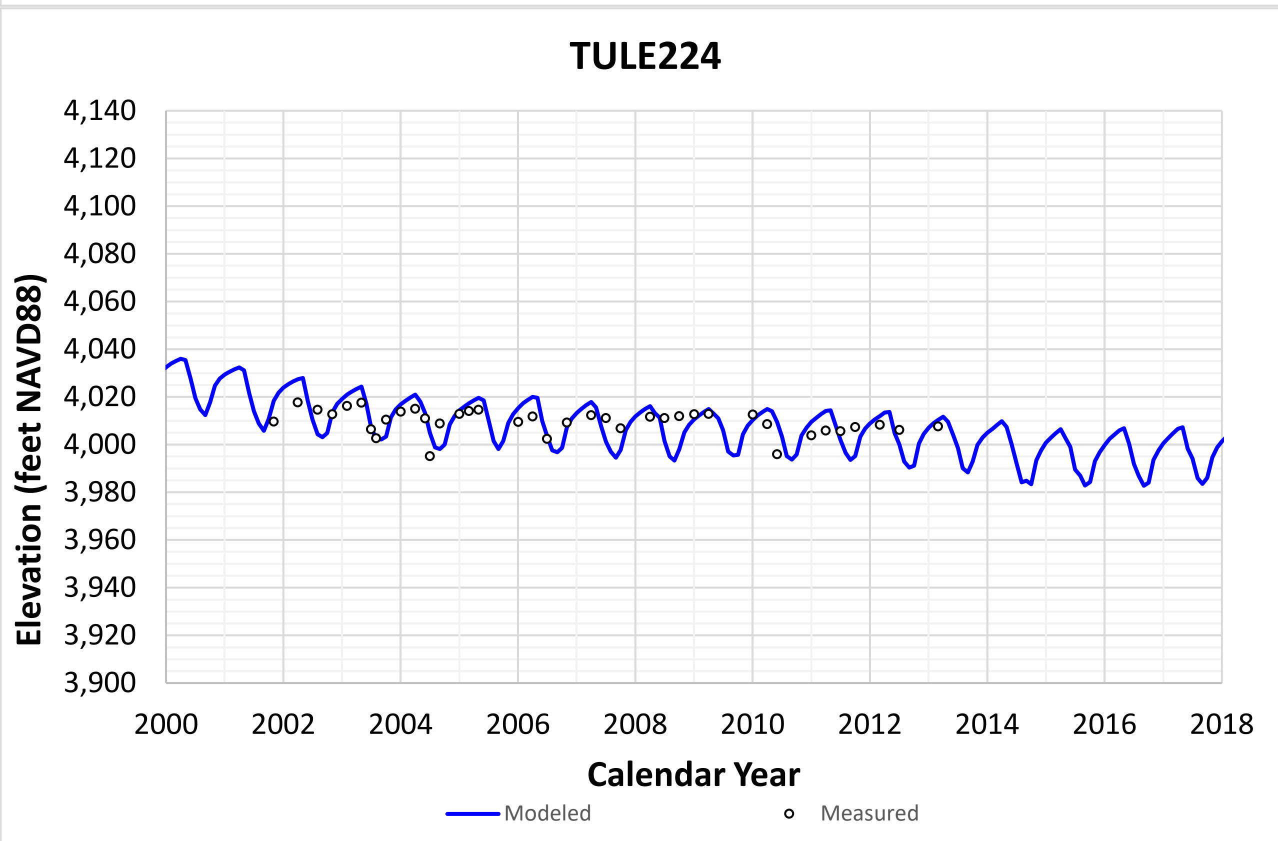
Calendar Year
Modeled
Measured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Elevation (feet NAVD88)
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Calendar Year
Modeled
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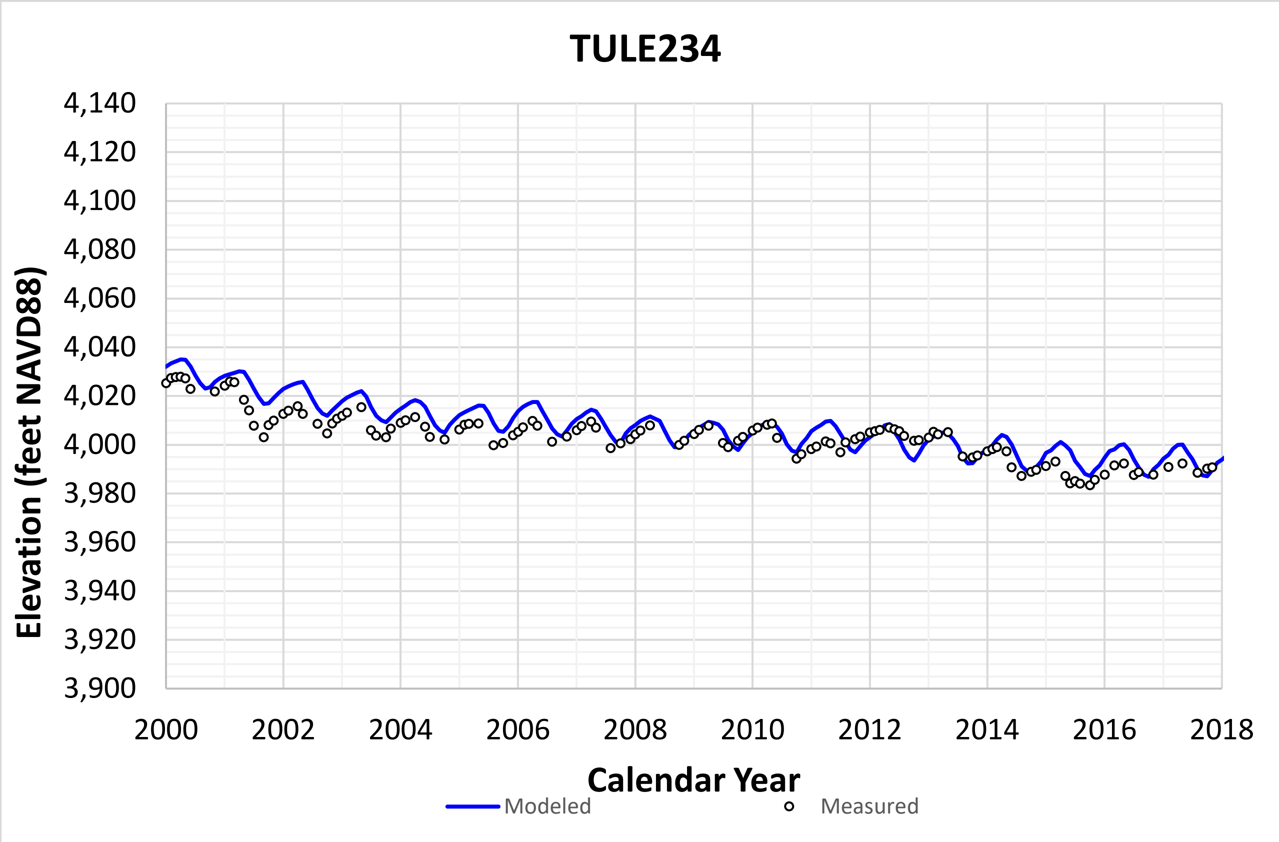
TULE234
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Elevation (feet NAVD88)
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Calendar Year
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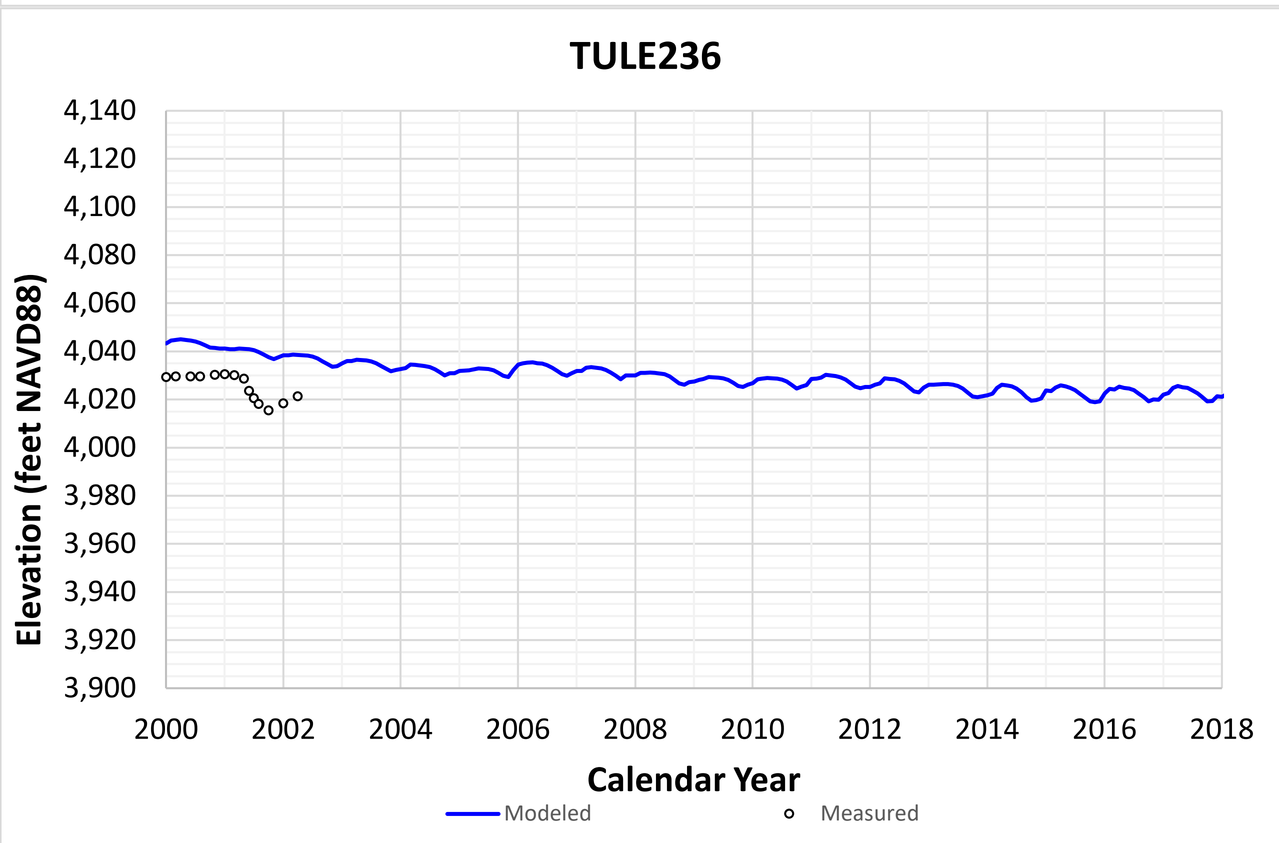
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3,940
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3,900
Elevation (feet NAVD88)
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Calendar Year
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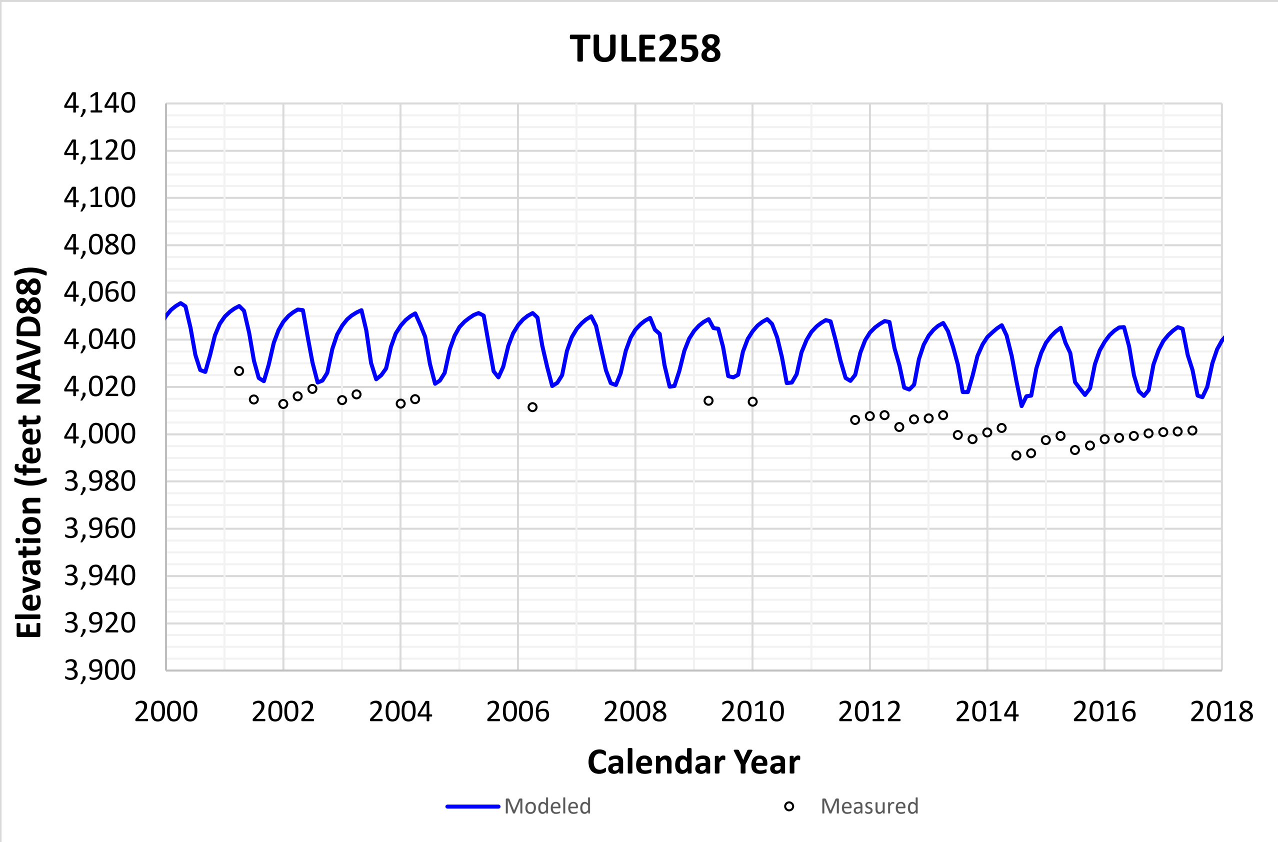
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Elevation (feet NAVD88)
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Calendar Year
Modeled
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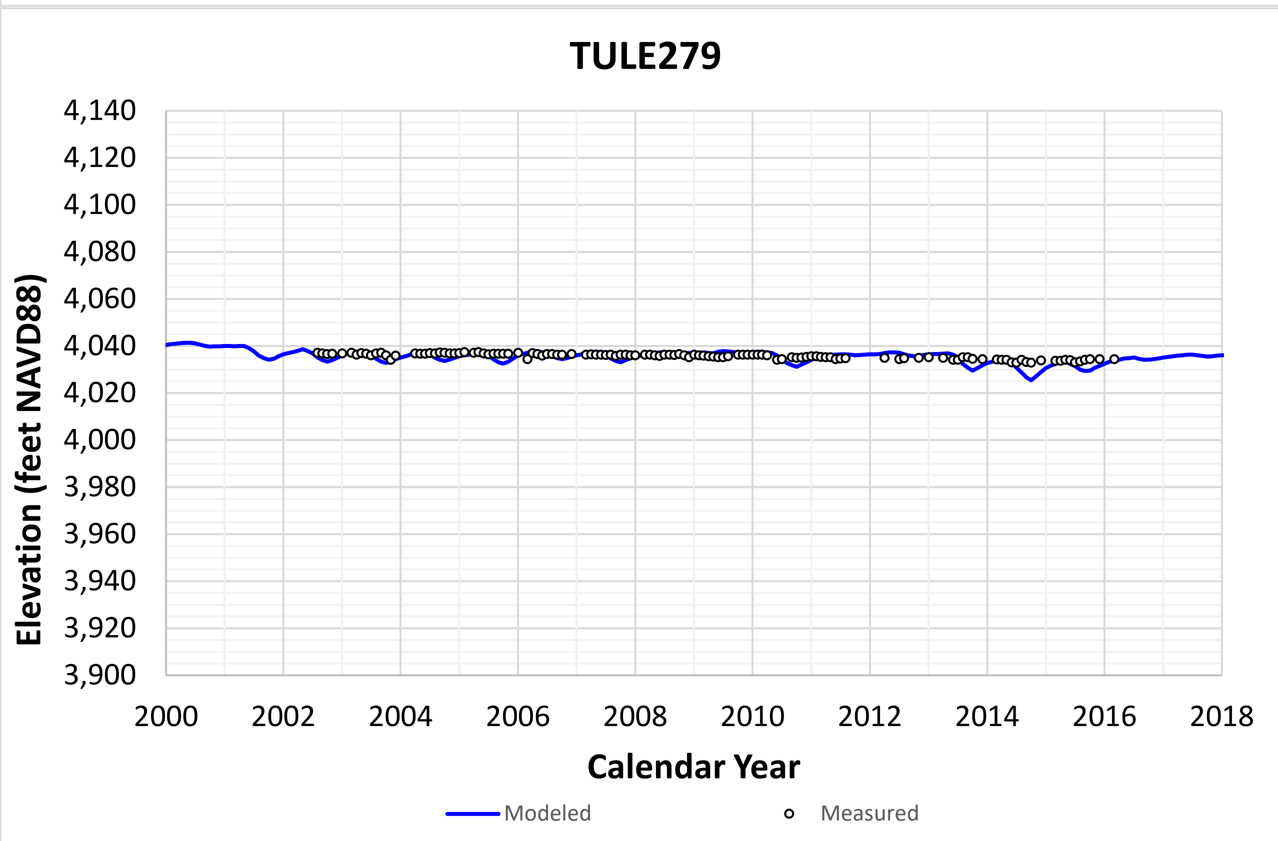
TULE279
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3,900
Elevation (feet NAVD88)
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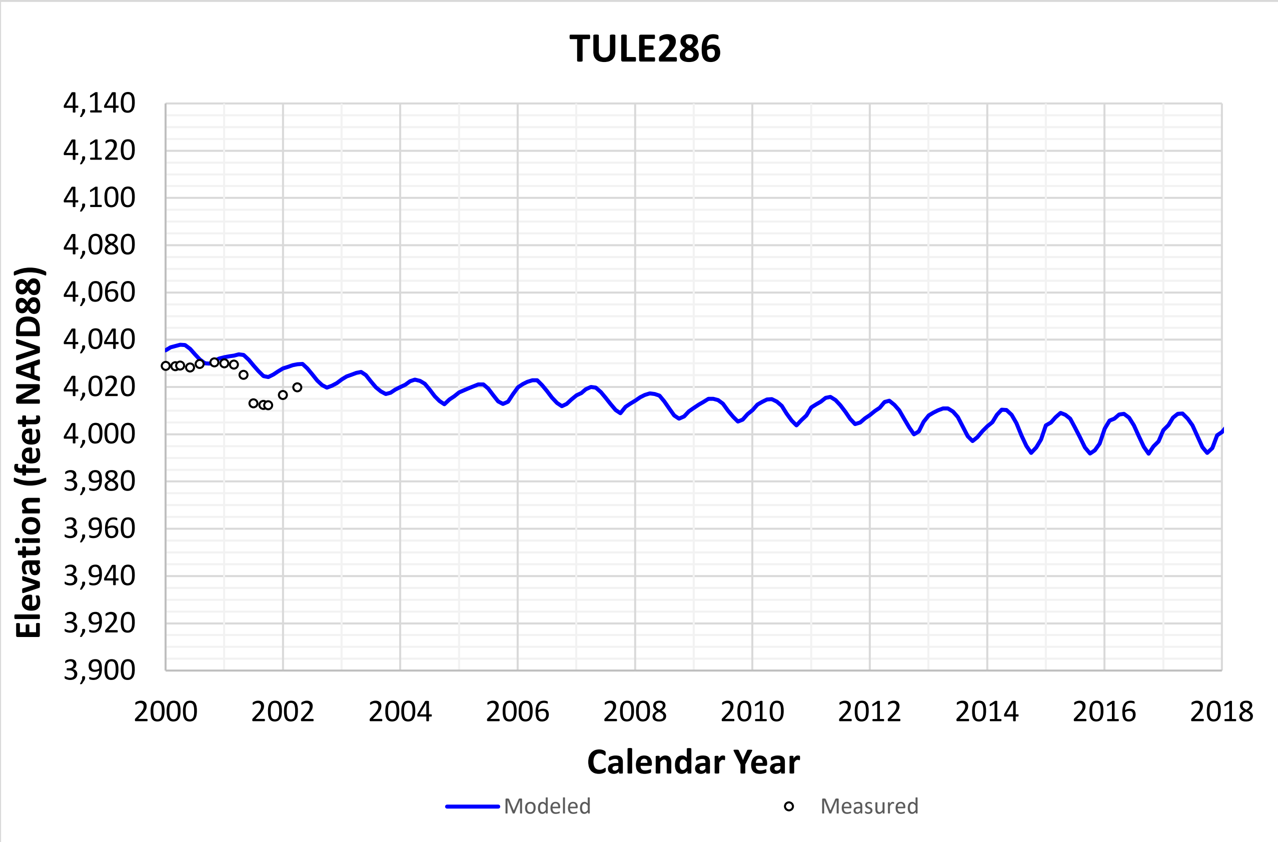
Calendar Year
Modeled
Measured



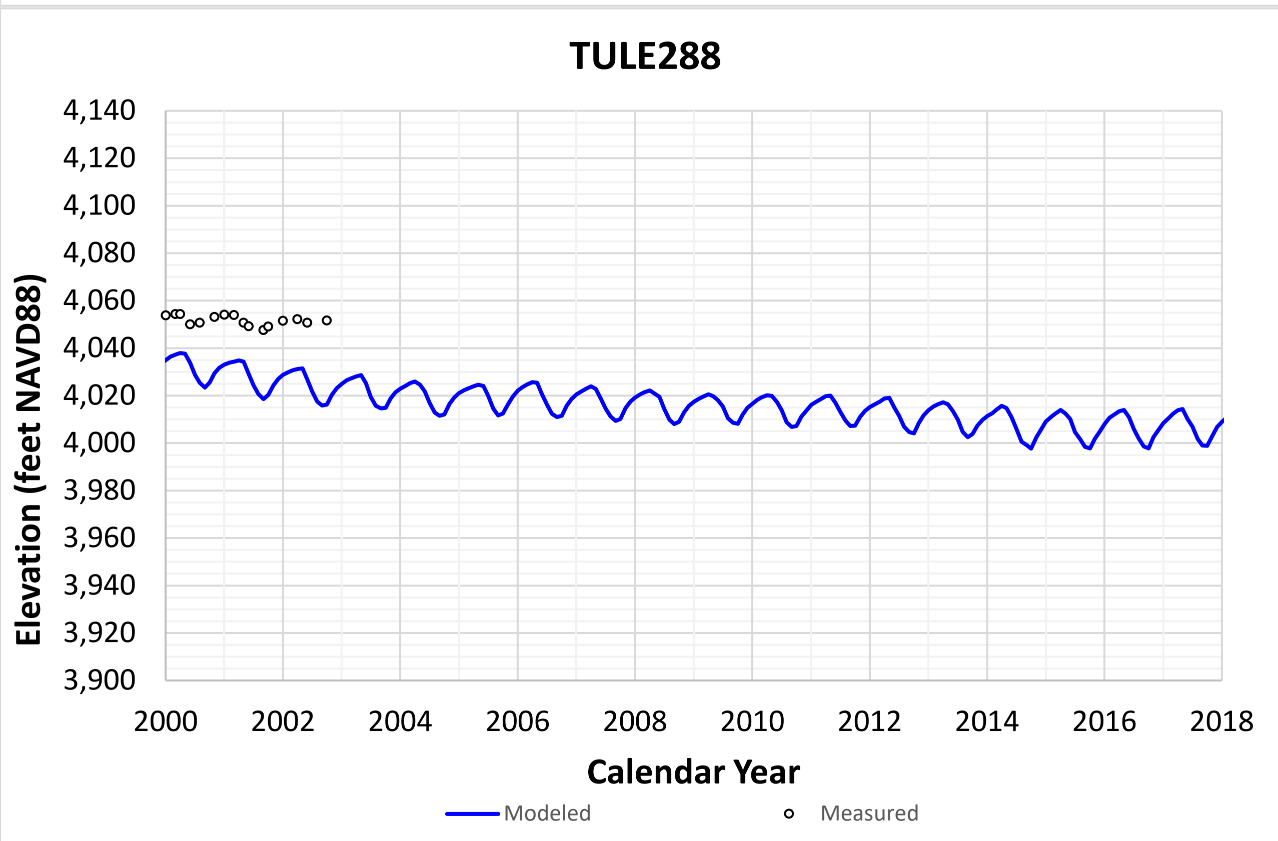
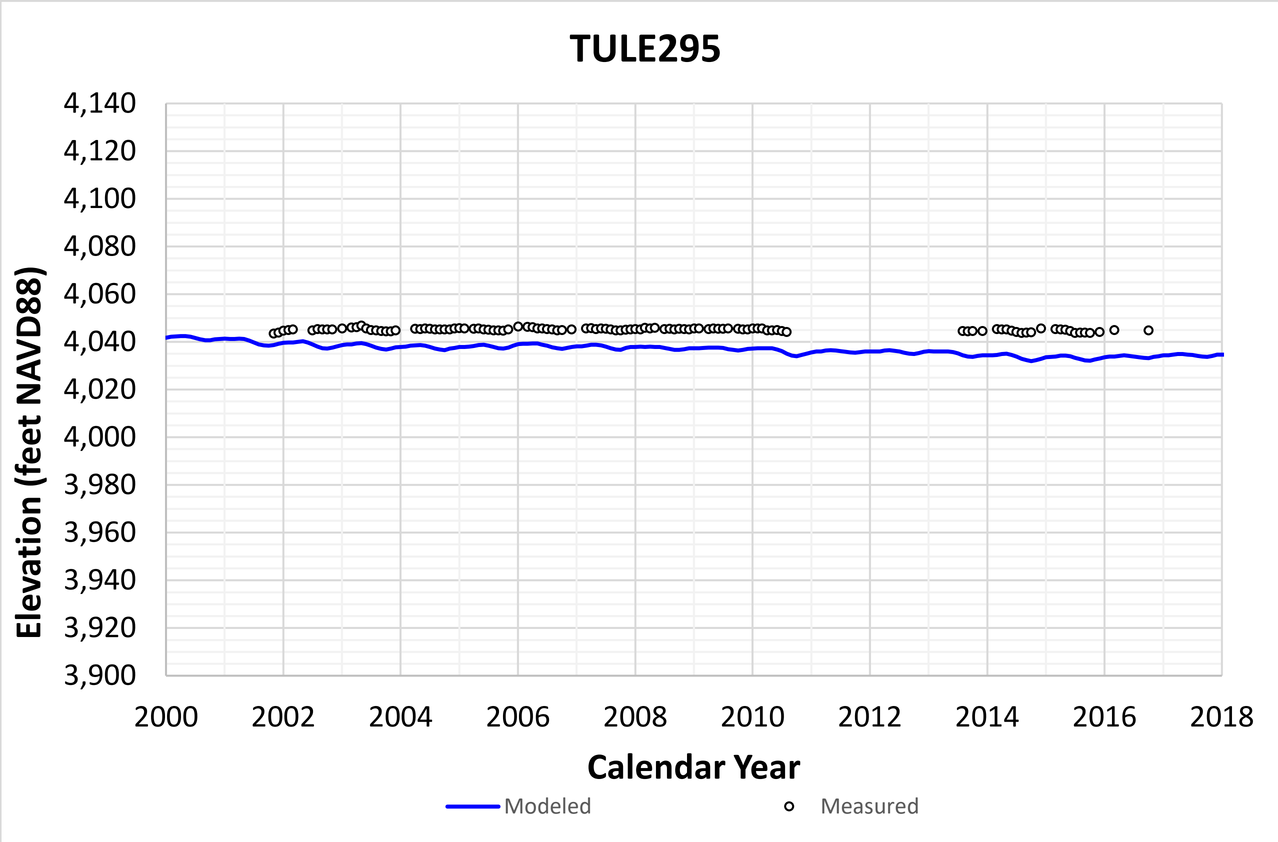




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs


TULE295
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3,960
3,940
3,920
3,900
Elevation (feet NAVD88)
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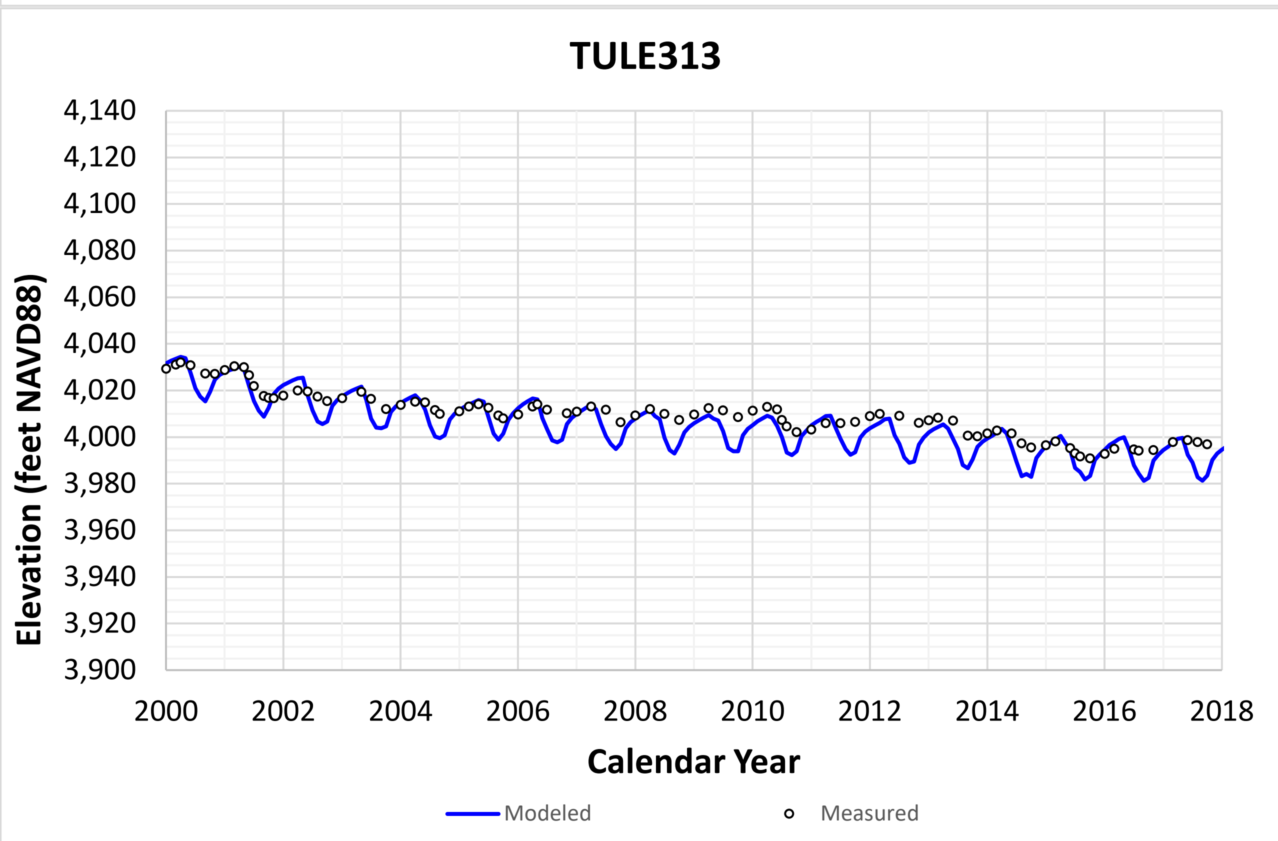
2016
2018
Calendar Year
Modeled
Measured


TULE313
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3,980
3,960
3,940
3,920
3,900
Elevation (feet NAVD88)
2000
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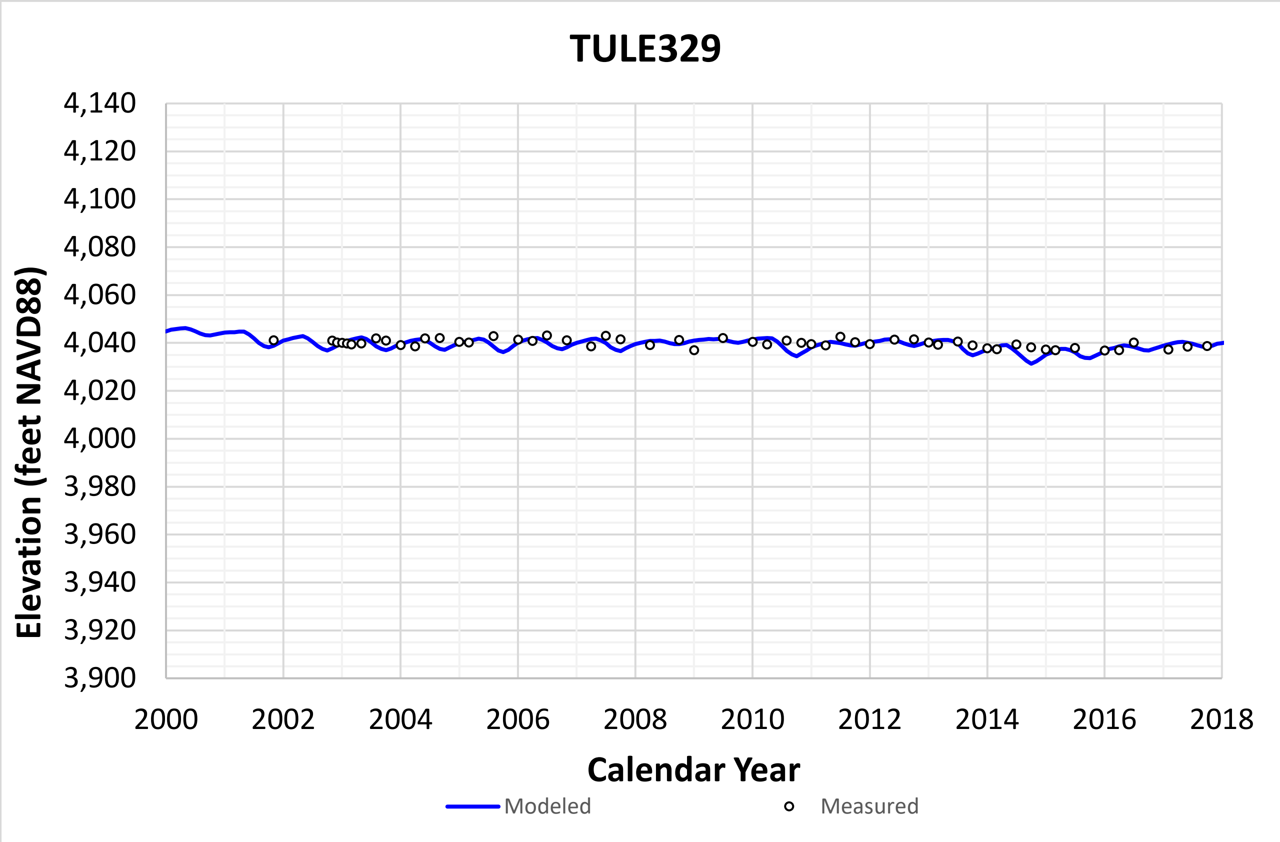
2018
Calendar Year
Modeled
Measured


TULE329
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3,980
3,960
3,940
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3,900
Elevation (feet NAVD88)
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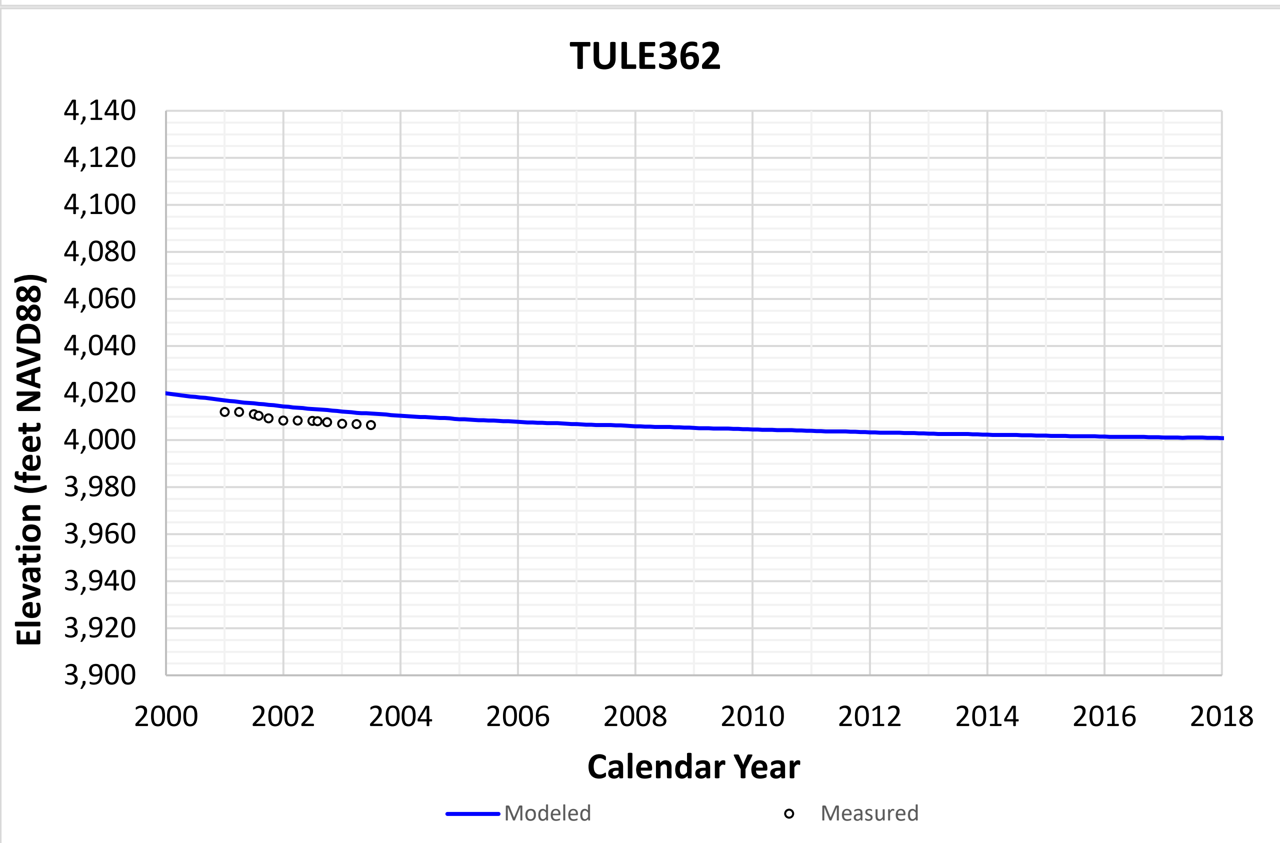
Calendar Year
Modeled
Measured


TULE362
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4,000
3,980
3,960
3,940
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3,900
Elevation (feet NAVD88)
2000
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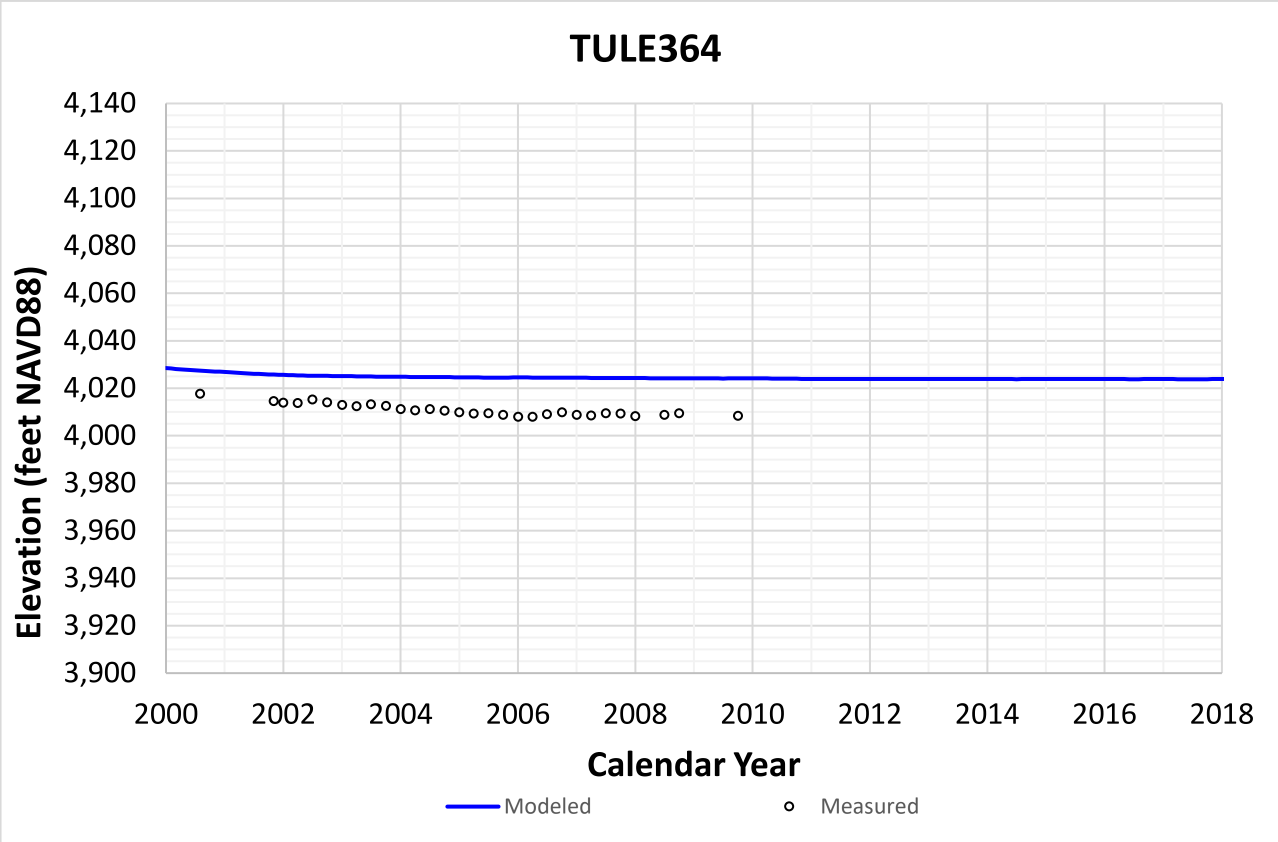
Calendar Year
Modeled
Measured


TULE364
Elevation (feet NAVD88)
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4,120
4,100
4,080
4,060
4,040
4,020
4,000
3,980
3,960
3,940
3,920
3,900
2000
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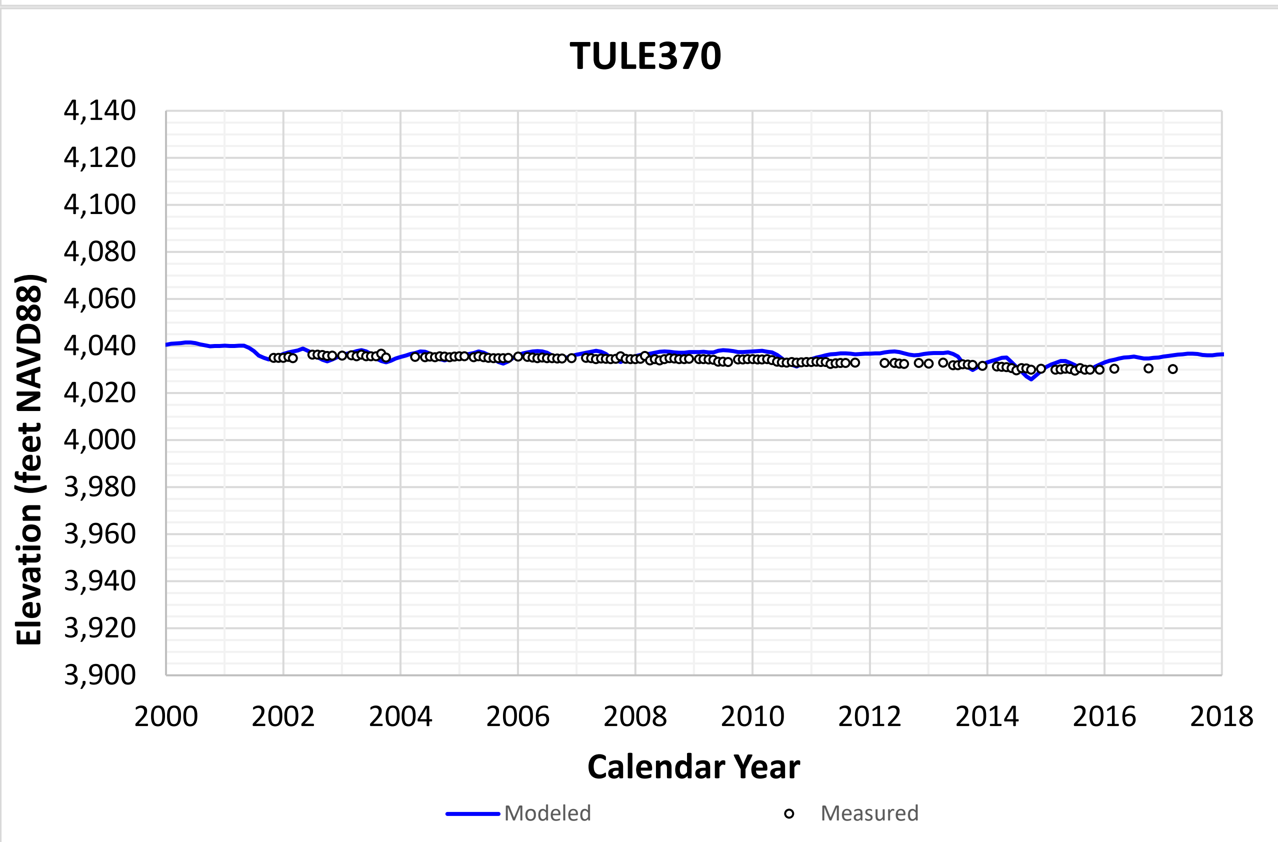
2014
2016
2018
Calendar Year
Modeled
Measured


TULE370
Elevation (feet NAVD88)
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4,120
4,100
4,080
4,060
4,040
4,020
4,000
3,980
3,960
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3,900
2000
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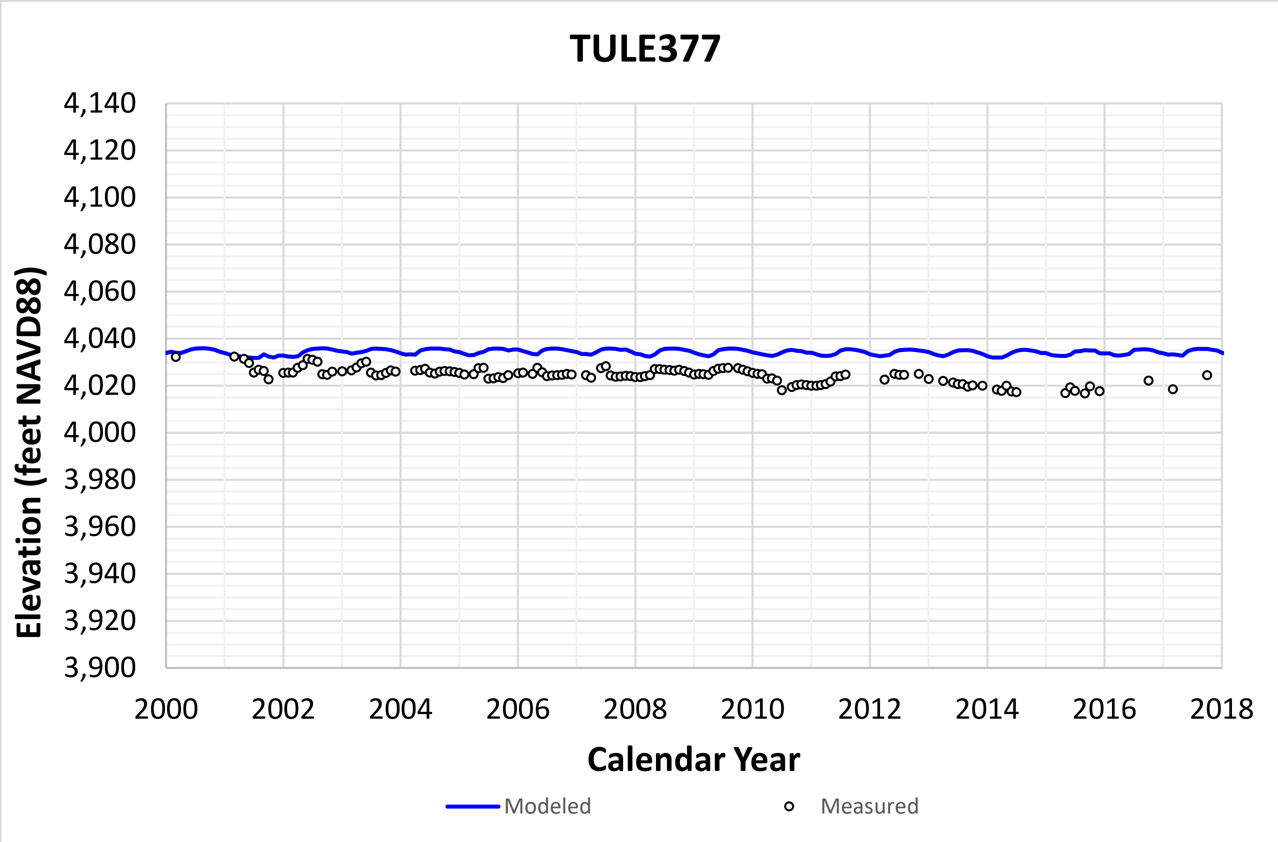
2018
Calendar Year
Modeled
Measured



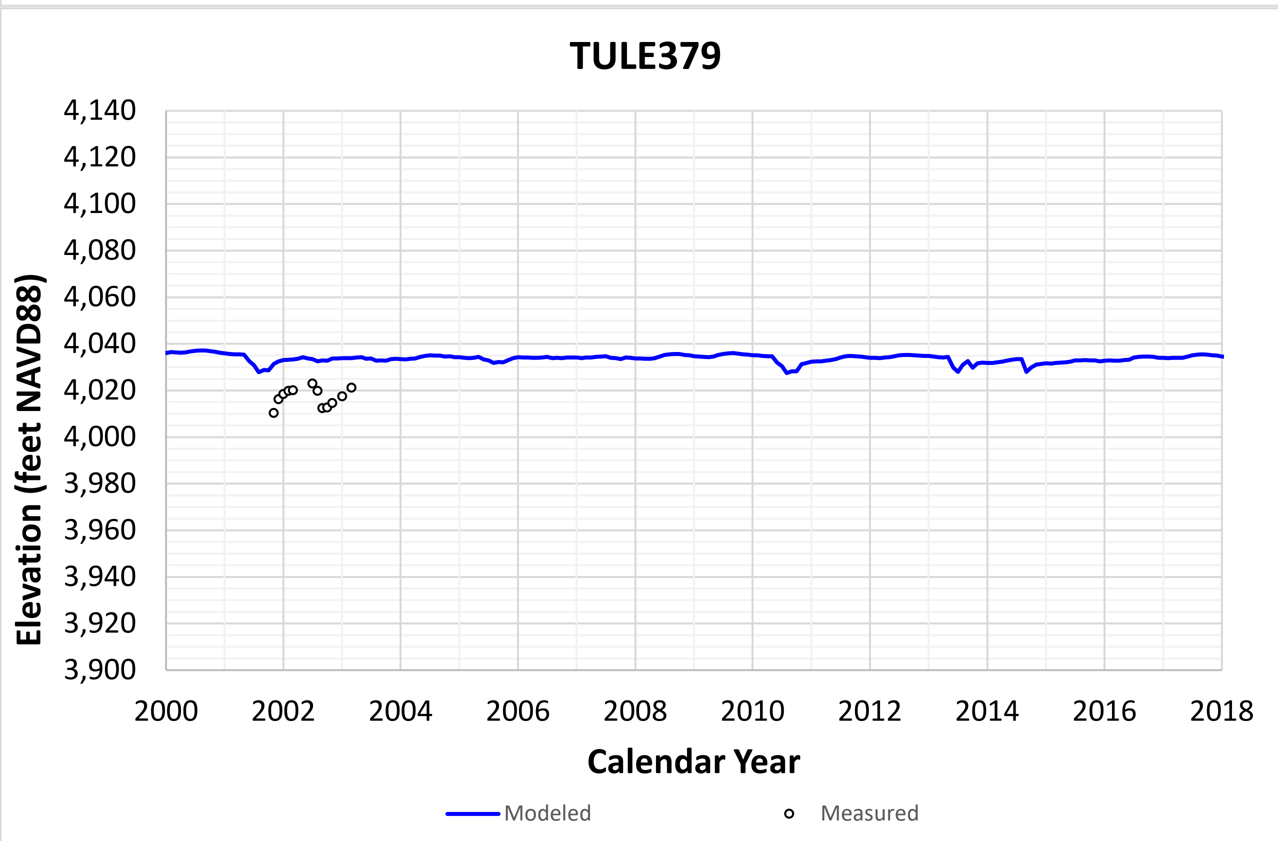
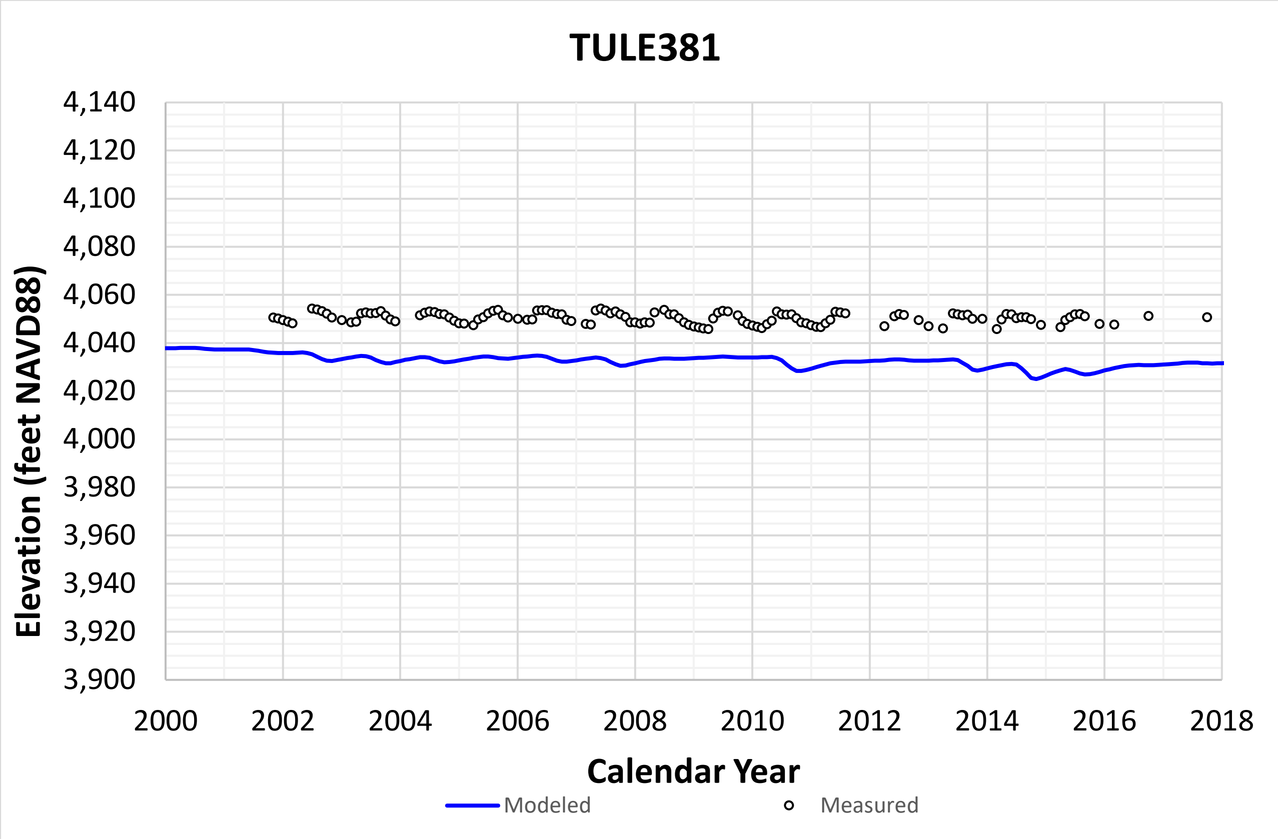




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs


TULE381
Elevation (feet NAVD88)
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4,120
4,100
4,080
4,060
4,040
4,020
4,000
3,980
3,960
3,940
3,920
3,900
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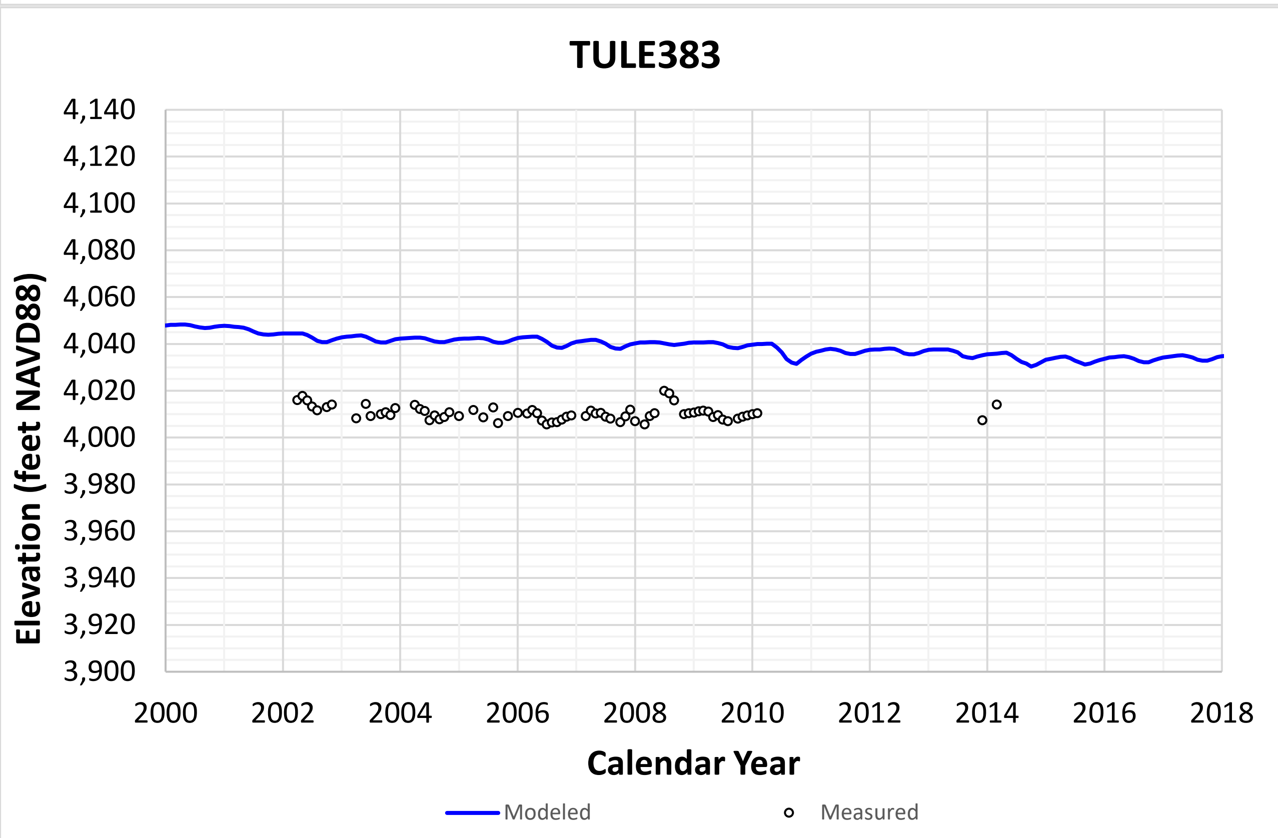
Calendar Year
Modeled
Measured


TULE383
Elevation (feet NAVD88)
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4,120
4,100
4,080
4,060
4,040
4,020
4,000
3,980
3,960
3,940
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3,900
2000
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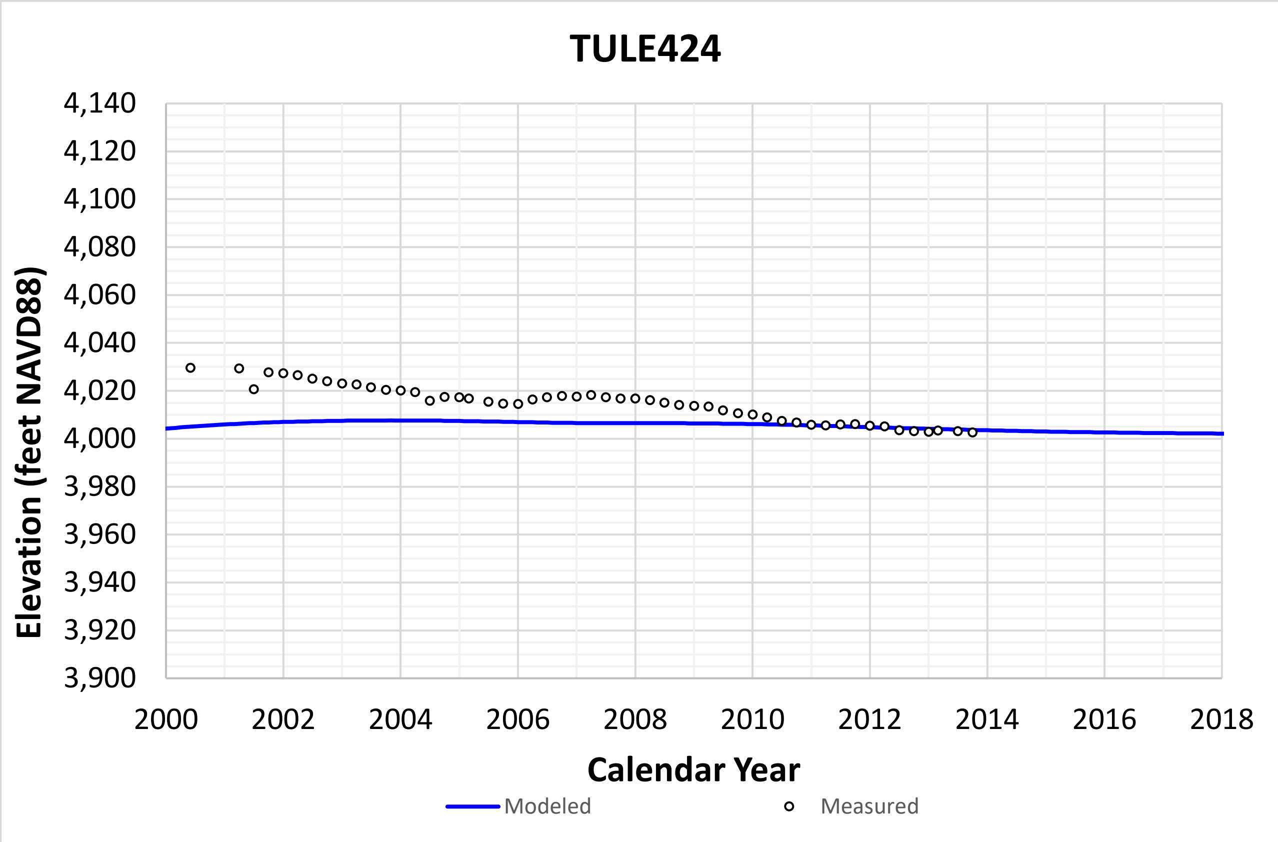
2018
Calendar Year
Modeled
Measured



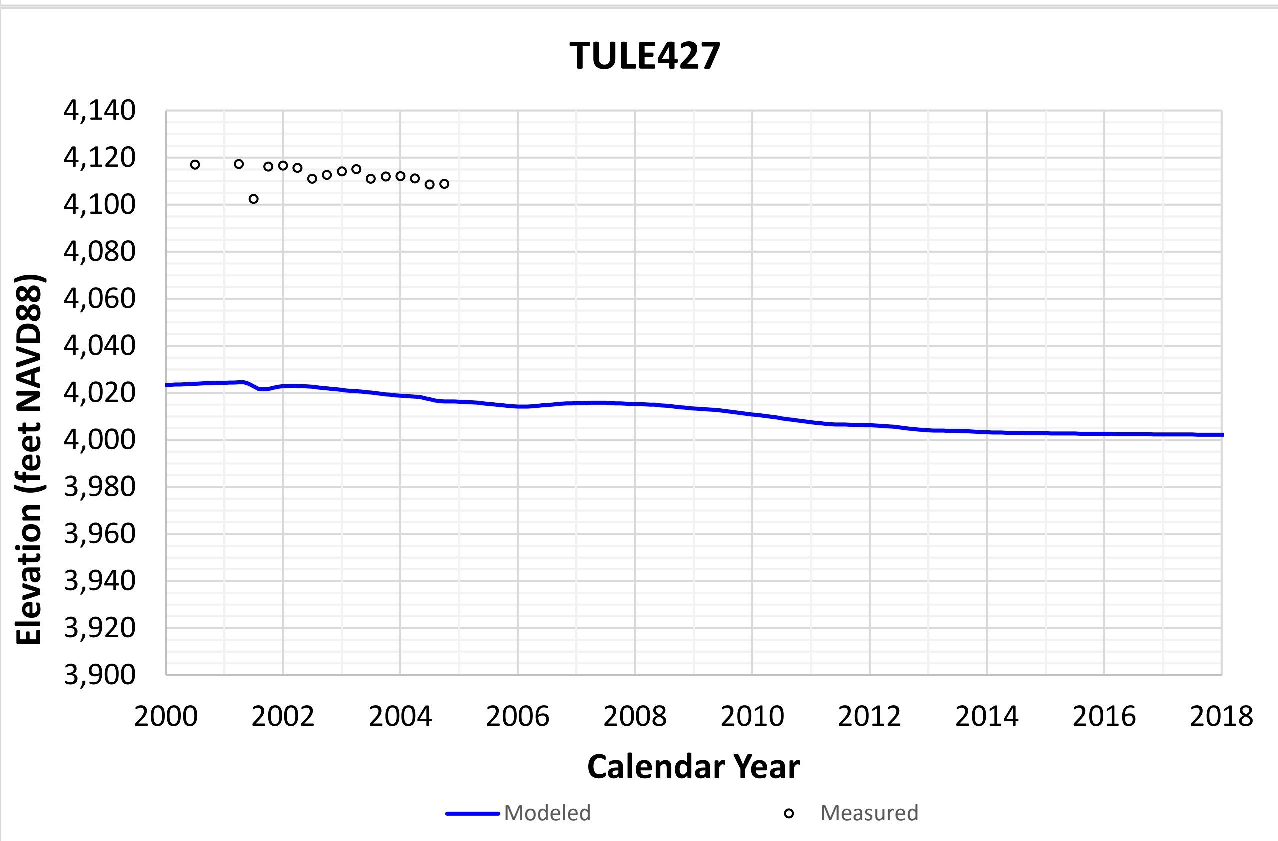
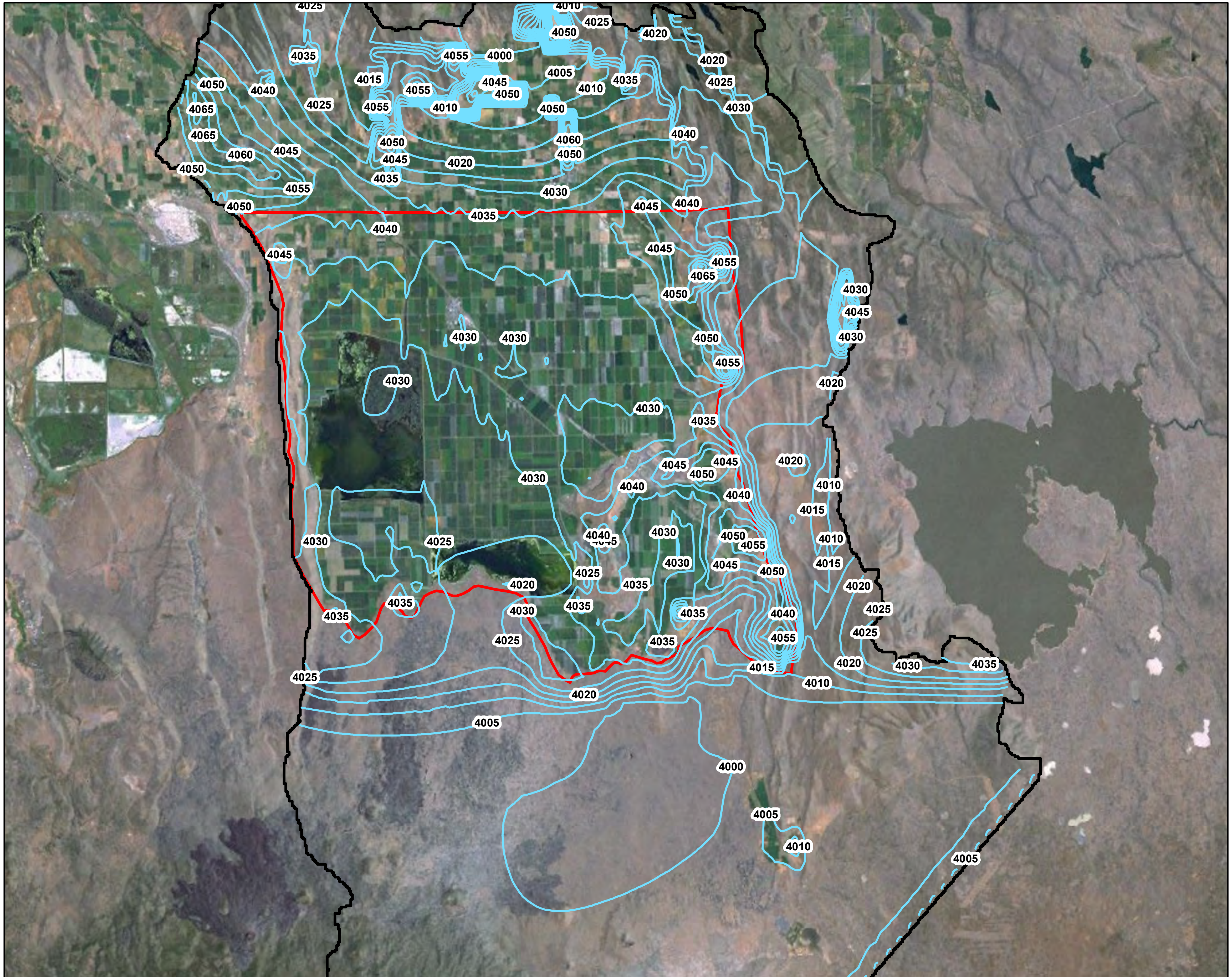




Figure 4-4
Modeled versus Measured Groundwater Elevation Hydrographs

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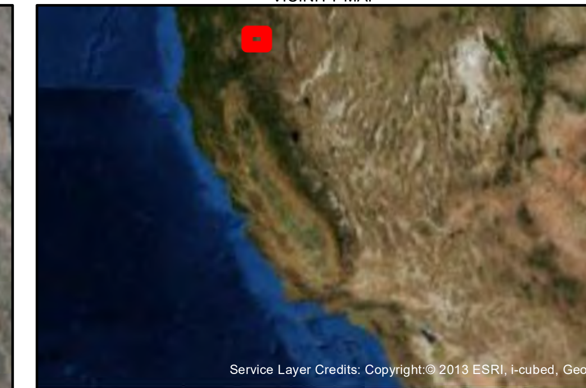


LEGEND

**Water Table Elevation Contour (feet NAVD88)**

Contour Interval = 5 feet

Model Domain Boundary

Tulelake Groundwater Subbasin

Notes:

NAVD88 = North American Vertical Datum of 1988

N

**FIGURE 4-5**
**Modeled Water Table During a Normal Year**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*

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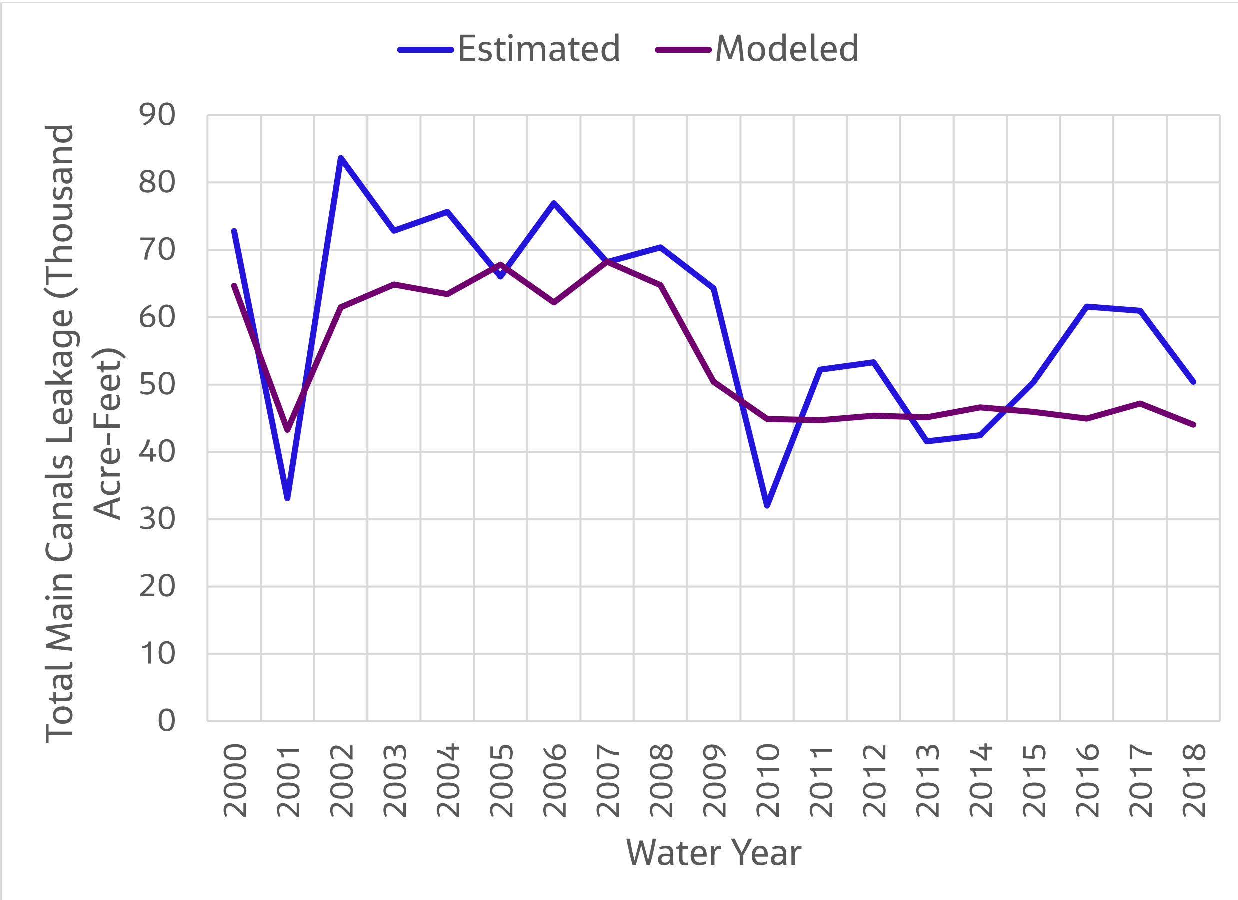
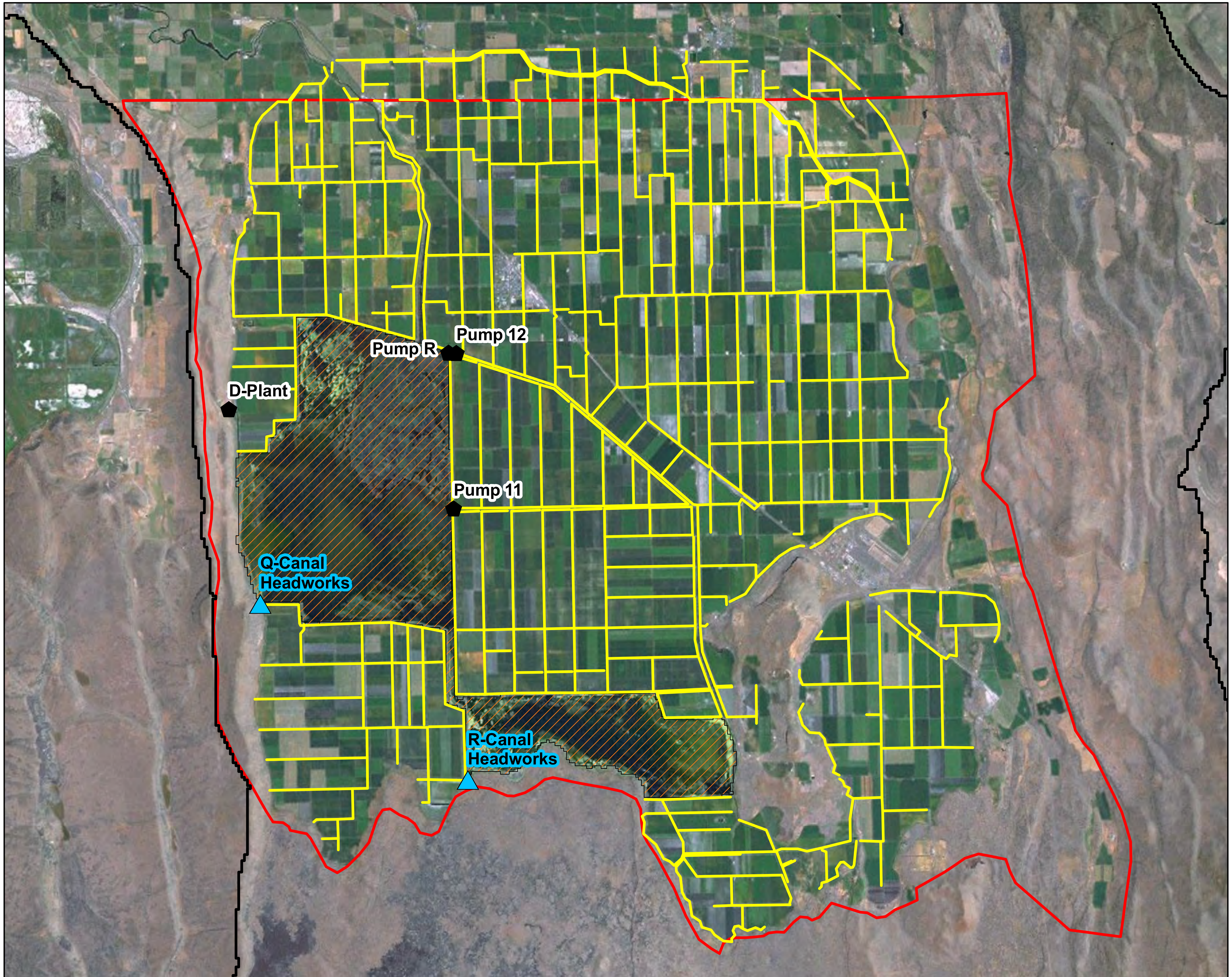



Figure 4-6 – Simulated Versus Estimated Main Canal Leakage

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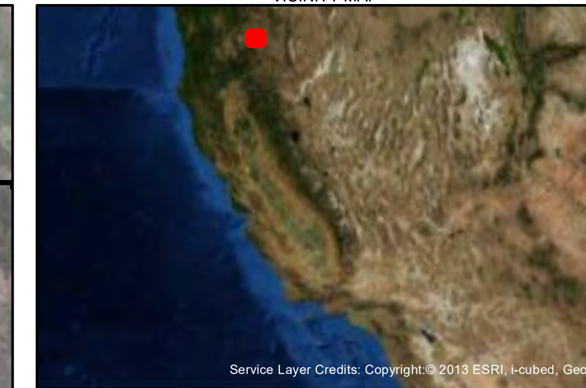



LEGEND

- Canal Headworks
- TID Pumps
- Drains
- Areal Extent of Gain/Loss from Groundwater, Precipitation, & Open Water Evaporation
- Model Domain Boundary
- Tulelake Groundwater Subbasin

Notes:

TID = Tulelake Irrigation District

N

**FIGURE 4-7**
**Tulelake Sump Water Balance Components**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*

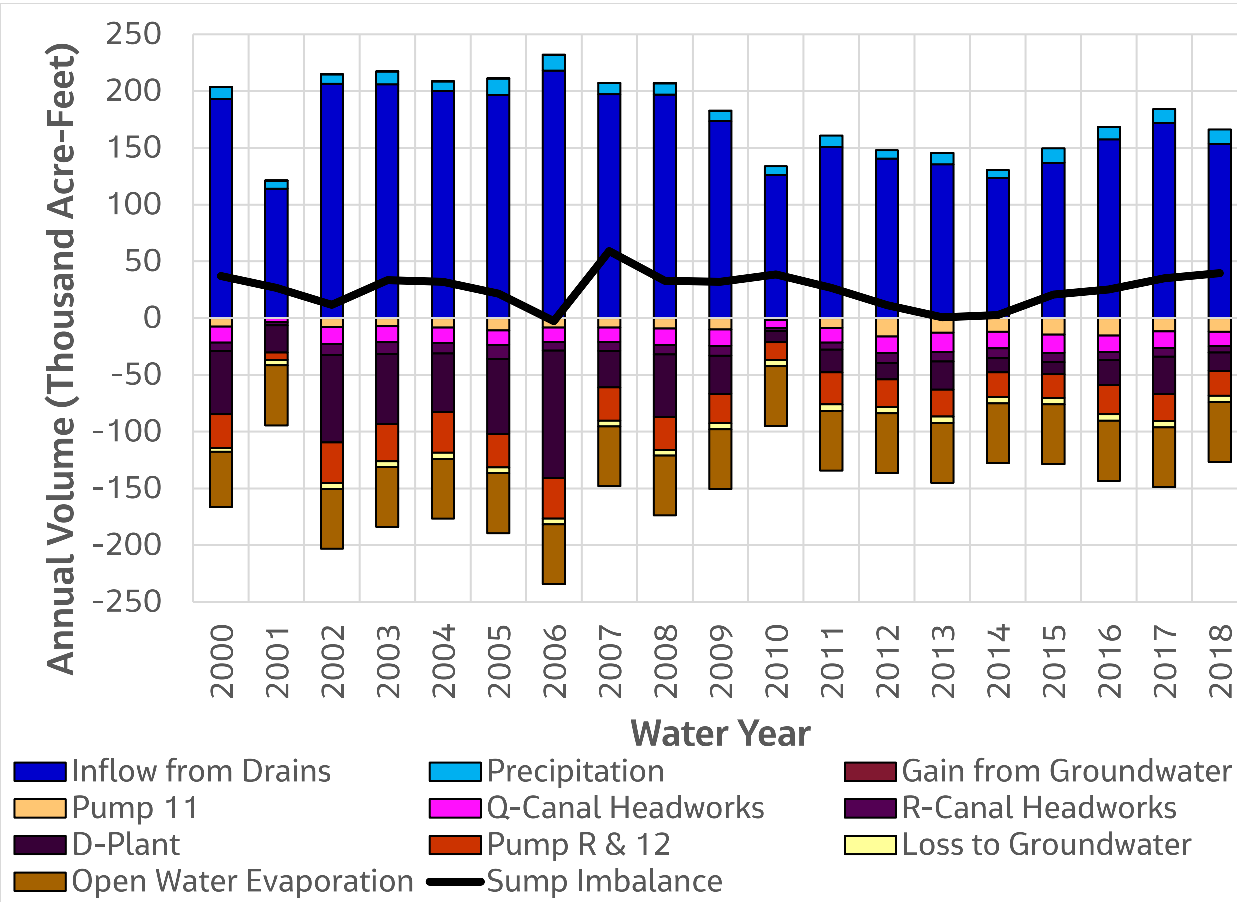
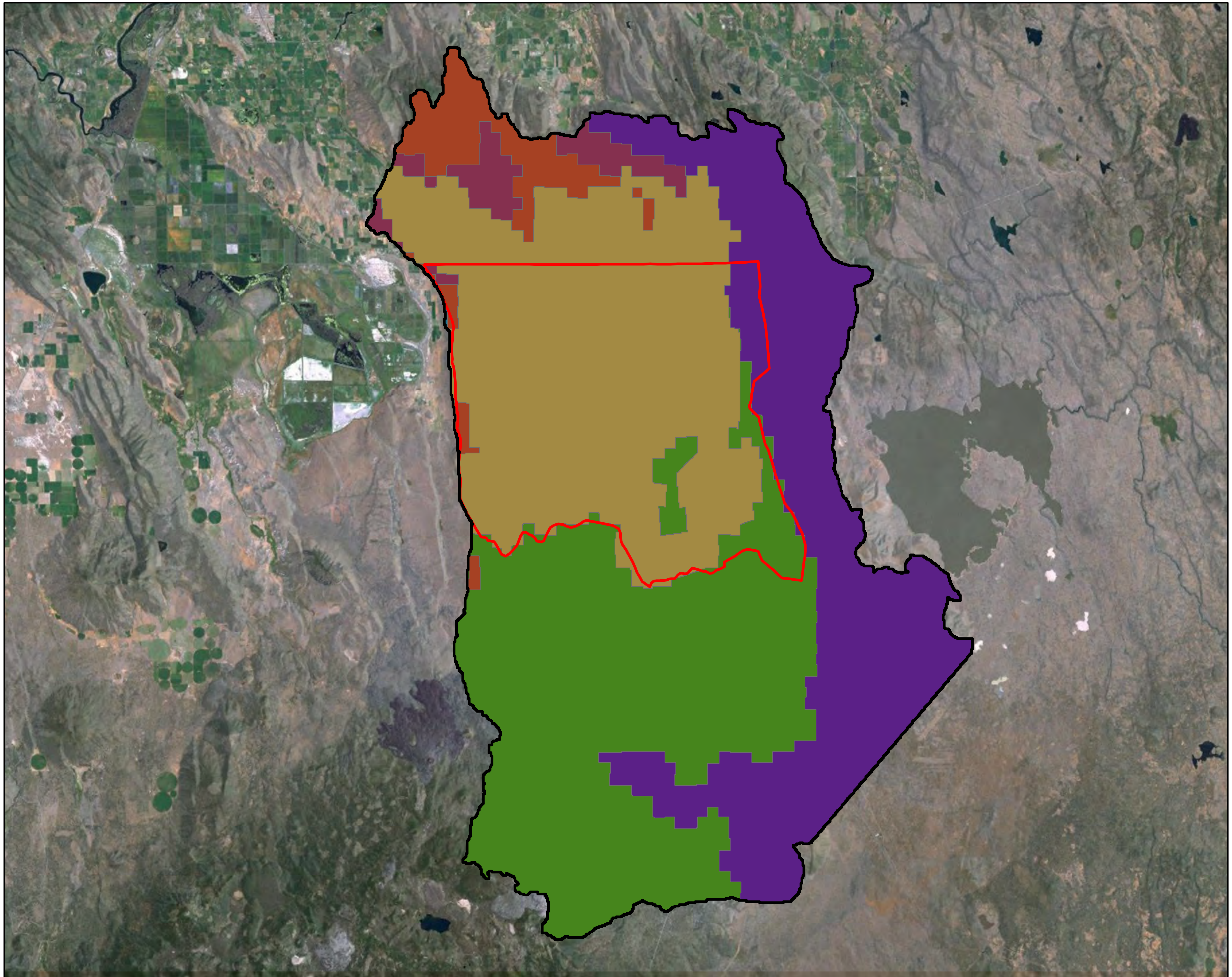



Figure 4-8 – Annual Sump Water Balance



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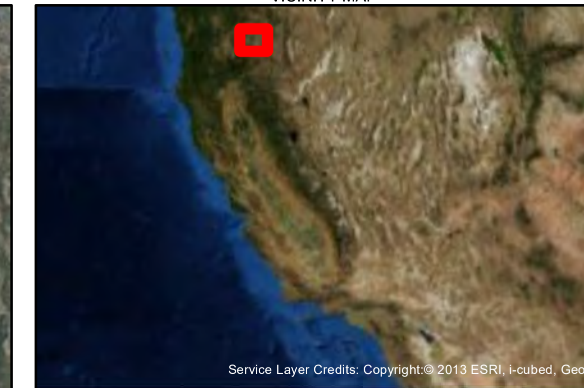


LEGEND

- Model Domain Boundary
- Tulelake Groundwater Subbasin

**Hydrostratigraphic Unit**

- Qs
- Qv
- Tso
- Tsy
- Tve
- Tvw

Notes:

Qs = Quaternary sedimentary deposits
Qv = Quaternary volcanic rocks
Tve = Tertiary volcanic rocks (East)
Tvw = Tertiary volcanic rocks (West)
Tsy = Tertiary sedimentary rocks (younger basins)
Tso = Tertiary sedimentary rocks (older basins)
Tsv = Tertiary mixed sedimentary and volcanic deposits

N

**FIGURE 4-9**
**Model Layer 1 Hydrostratigraphic Units**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*



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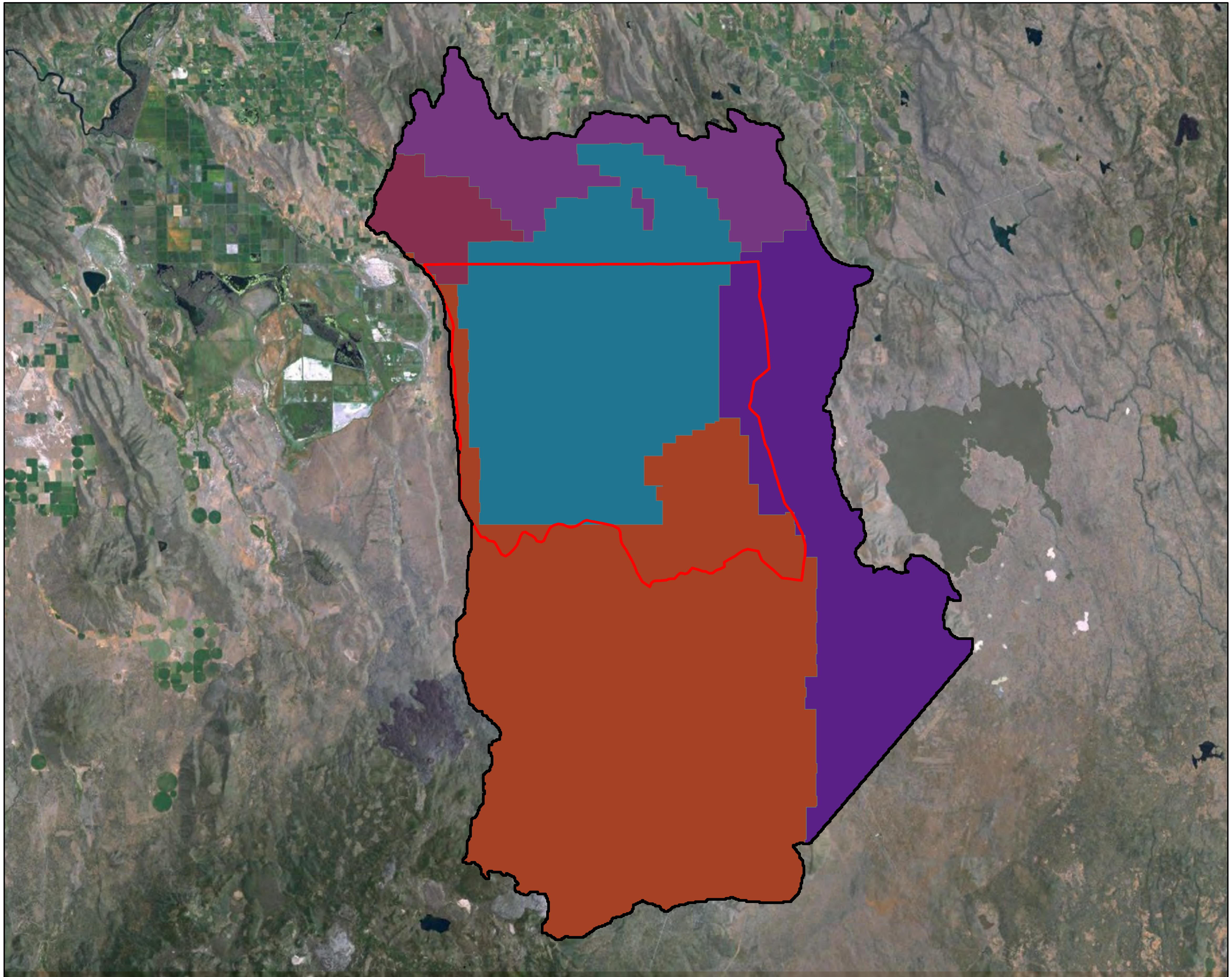

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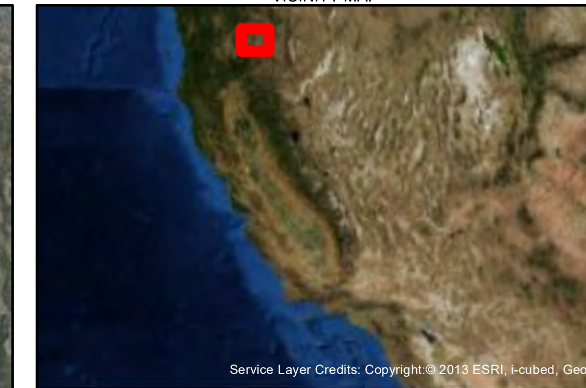


LEGEND

- Model Domain Boundary
- Tulelake Groundwater Subbasin

**Hydrostratigraphic Unit**

- Qs
- Qv
- Tso
- Tsv
- Tsy
- Tve
- Tvw

Notes:

Qs = Quaternary sedimentary deposits
Qv = Quaternary volcanic rocks
Tve = Tertiary volcanic rocks (East)
Tvw = Tertiary volcanic rocks (West)
Tsy = Tertiary sedimentary rocks (younger basins)
Tso = Tertiary sedimentary rocks (older basins)
Tsv = Tertiary mixed sedimentary and volcanic deposits

N

**FIGURE 4-10**
**Model Layer 2 Hydrostratigraphic Units**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*

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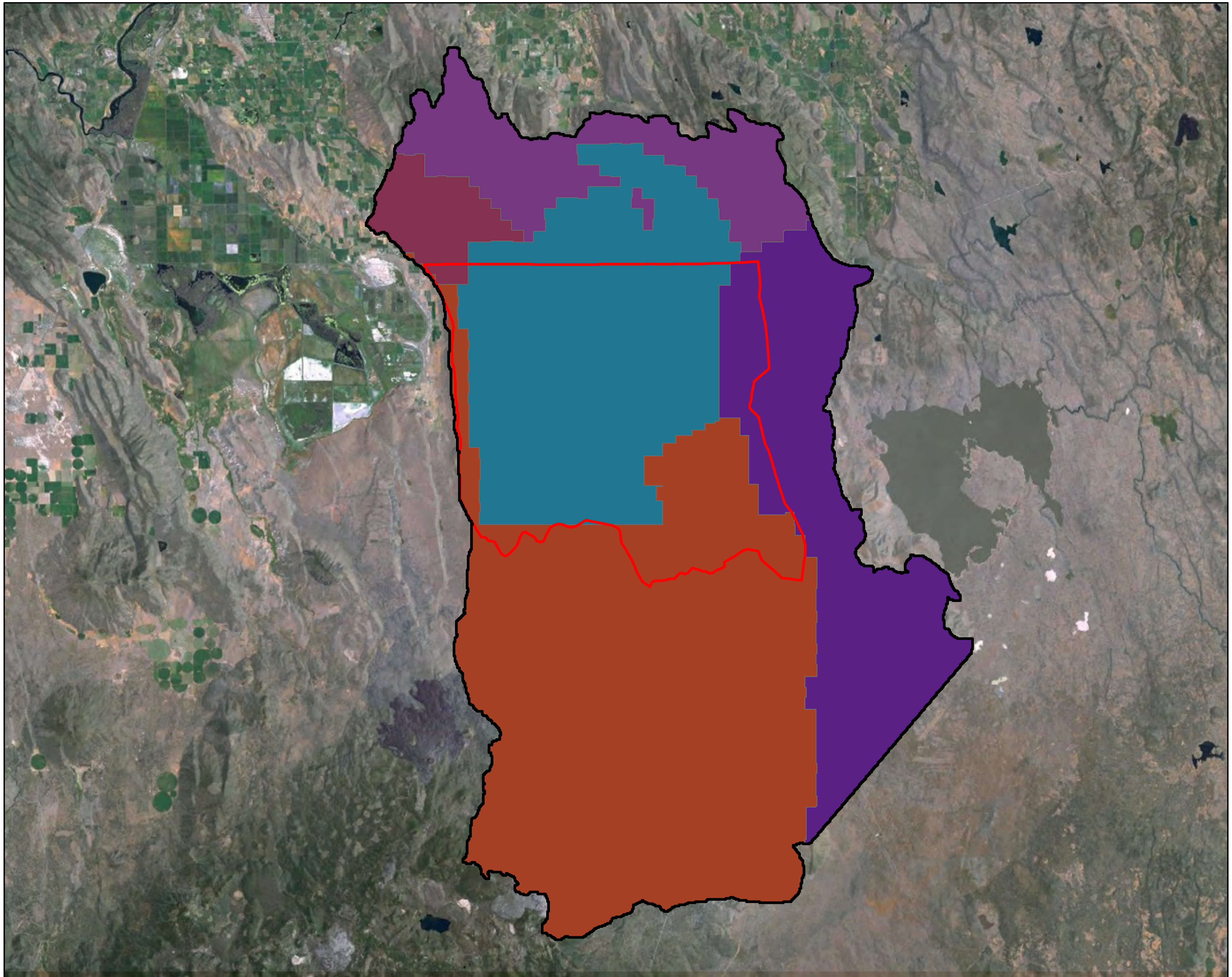

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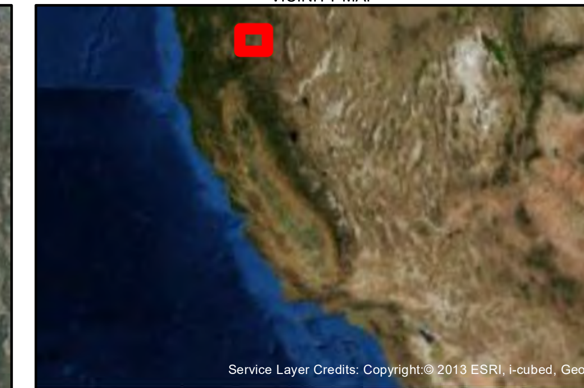


LEGEND

Model Domain Boundary
Tulelake Groundwater Subbasin

**Hydrostratigraphic Unit**

Qs
Qv
Tso
Tsv
Tsy
Tve
Tvw

N

Notes:

Qs = Quaternary sedimentary deposits
Qv = Quaternary volcanic rocks
Tve = Tertiary volcanic rocks (East)
Tvw = Tertiary volcanic rocks (West)
Tsy = Tertiary sedimentary rocks (younger basins)
Tso = Tertiary sedimentary rocks (older basins)
Tsv = Tertiary mixed sedimentary and volcanic deposits

**FIGURE 4-11**
**Model Layer 3 Hydrostratigraphic Units**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*



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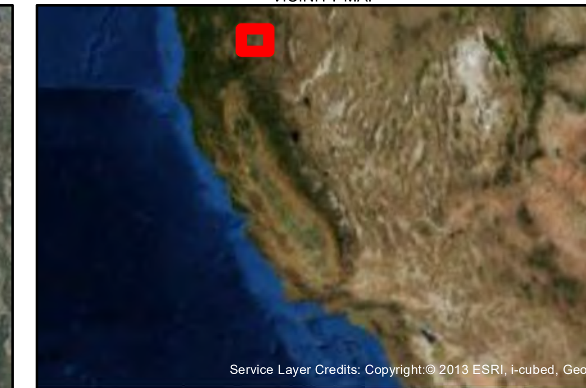
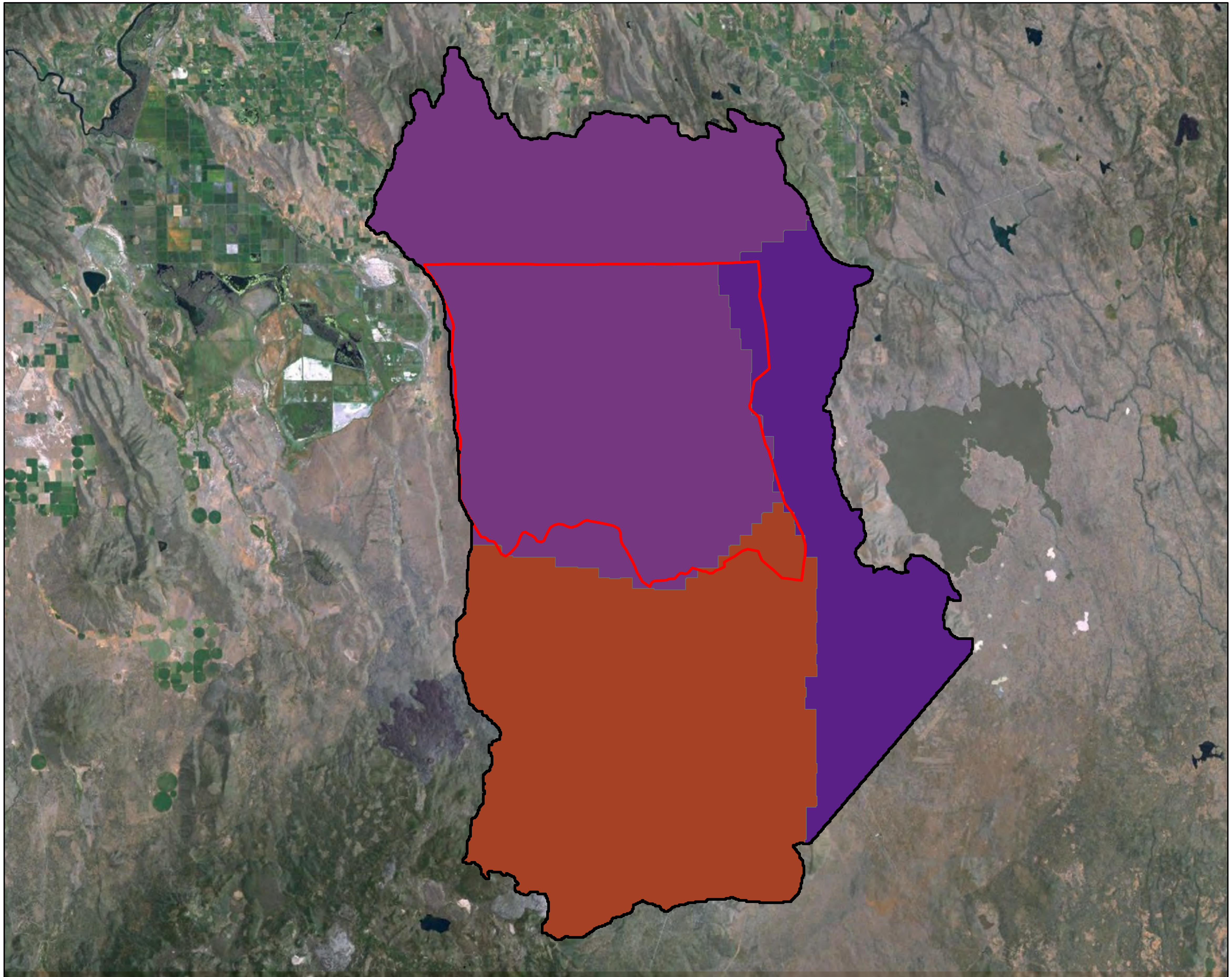
VICINITY MAP




Notes:

Qs = Quaternary sedimentary deposits
Qv = Quaternary volcanic rocks
Tve = Tertiary volcanic rocks (East)
Tvw = Tertiary volcanic rocks (West)
Tsy = Tertiary sedimentary rocks (younger basins)
Tso = Tertiary sedimentary rocks (older basins)
Tsv = Tertiary mixed sedimentary and volcanic deposits

**FIGURE 4-12**
**Model Layer 4 Hydrostratigraphic Units**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*

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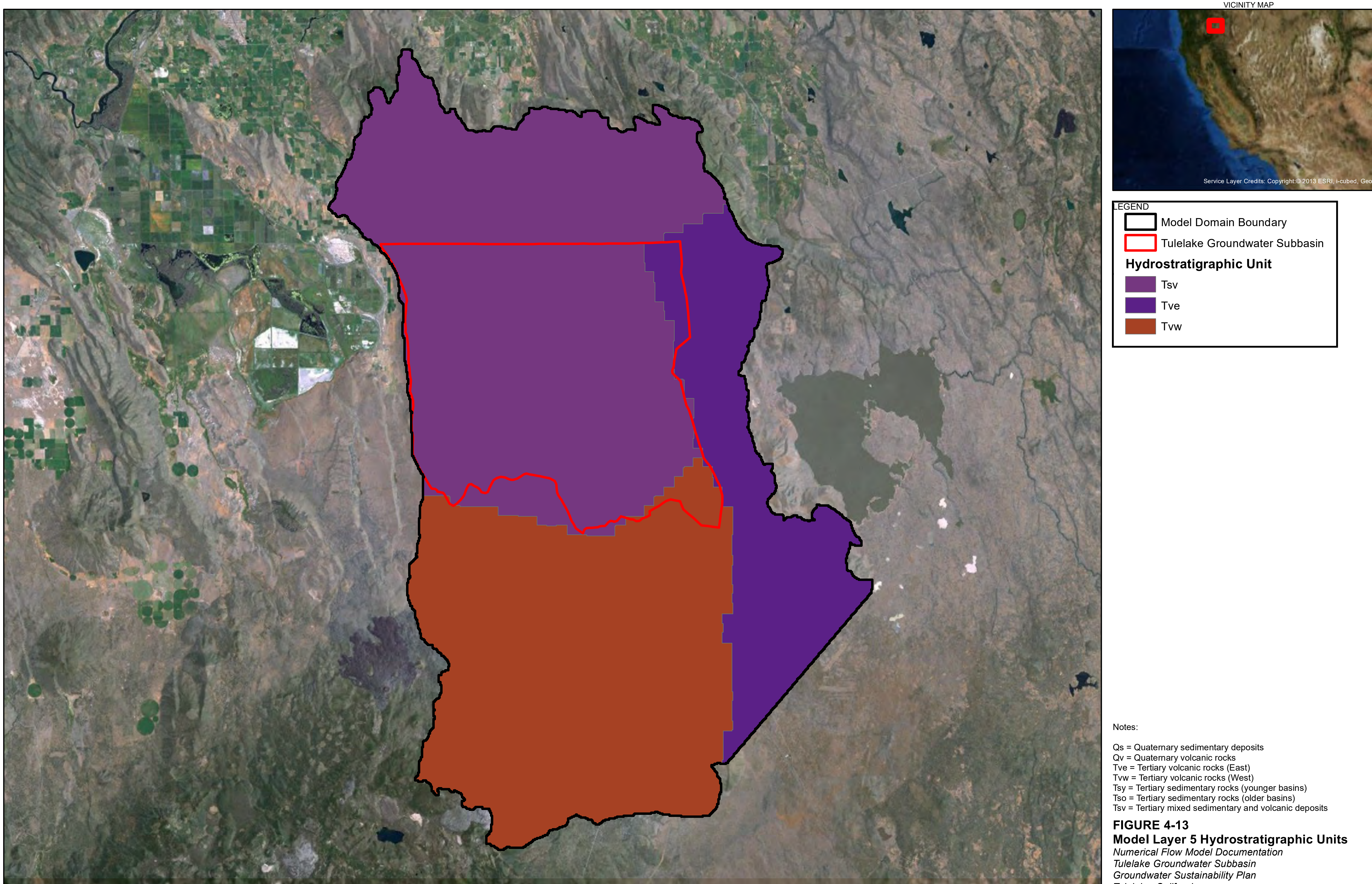


Notes:

Qs = Quaternary sedimentary deposits
Qv = Quaternary volcanic rocks
Tve = Tertiary volcanic rocks (East)
Tvw = Tertiary volcanic rocks (West)
Tsy = Tertiary sedimentary rocks (younger basins)
Tso = Tertiary sedimentary rocks (older basins)
Tsv = Tertiary mixed sedimentary and volcanic deposits

**FIGURE 4-13**
**Model Layer 5 Hydrostratigraphic Units**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*

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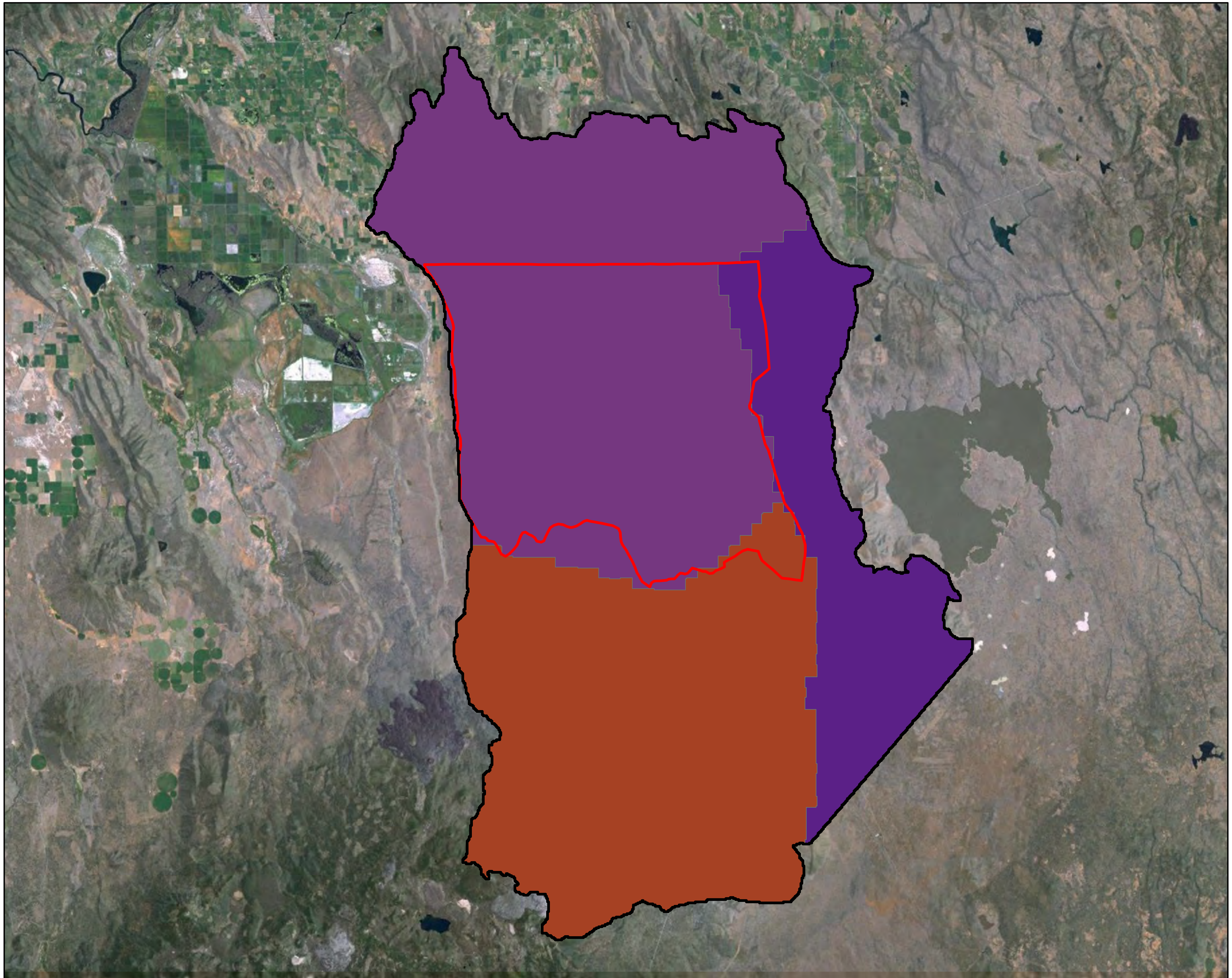

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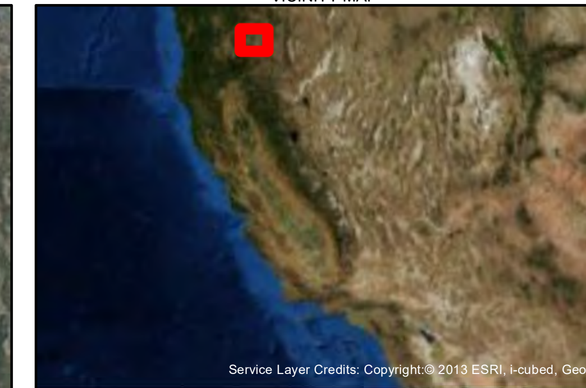


LEGEND

- Model Domain Boundary
- Tulelake Groundwater Subbasin

**Hydrostratigraphic Unit**

- Tsv
- Tve
- Tvw

Notes:

Qs = Quaternary sedimentary deposits
Qv = Quaternary volcanic rocks
Tve = Tertiary volcanic rocks (East)
Tvw = Tertiary volcanic rocks (West)
Tsy = Tertiary sedimentary rocks (younger basins)
Tso = Tertiary sedimentary rocks (older basins)
Tsv = Tertiary mixed sedimentary and volcanic deposits

**FIGURE 4-14**
**Model Layer 6 Hydrostratigraphic Units**
*Numerical Flow Model Documentation*
*Tulelake Groundwater Subbasin*
*Groundwater Sustainability Plan*
*Tulelake, California*

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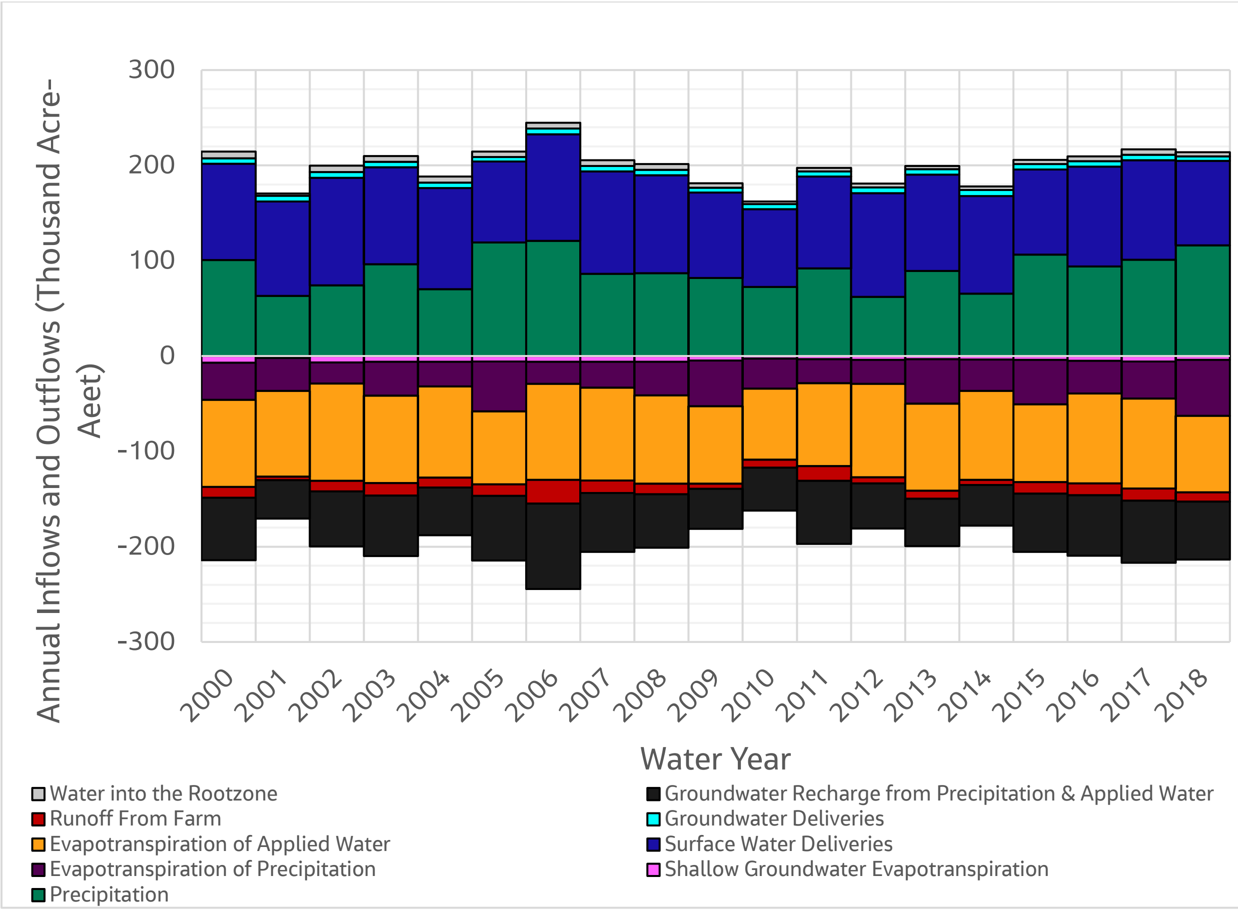



Figure 4-15 – Historical Annual Land Surface Budget

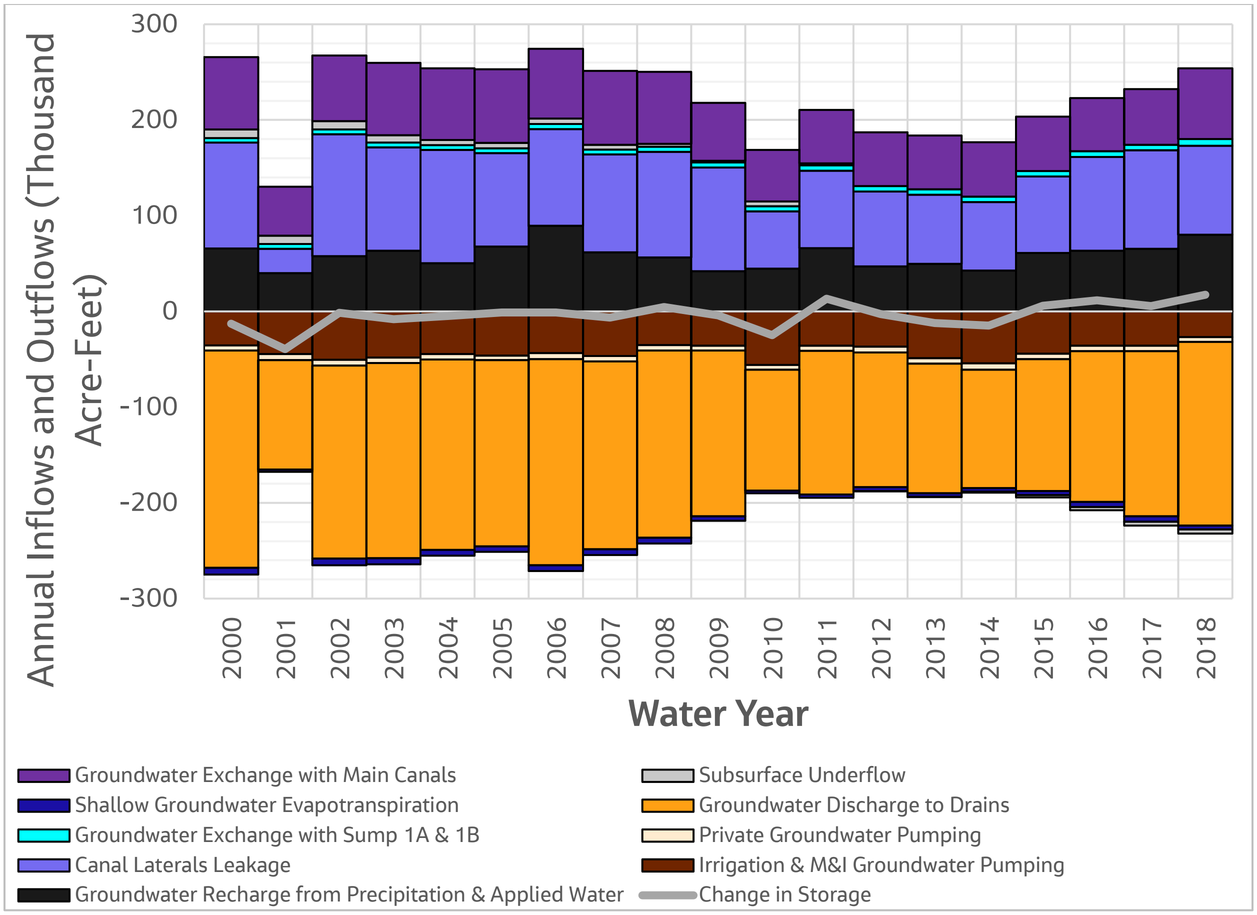



Figure 4-16 – Historical Annual Groundwater System Water Balance

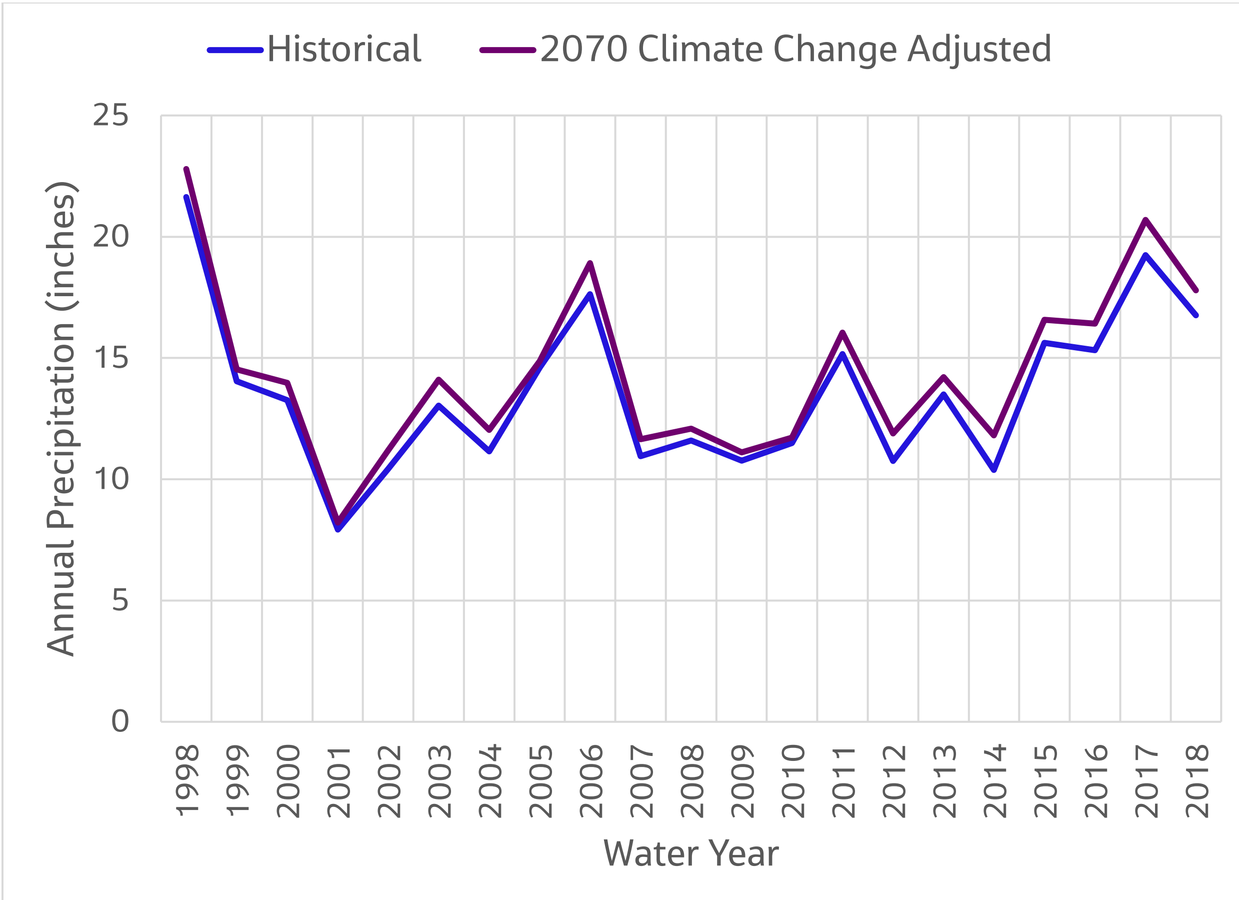



Figure 5-1 – Historical Versus 2070 Climate Change Adjusted Precipitation

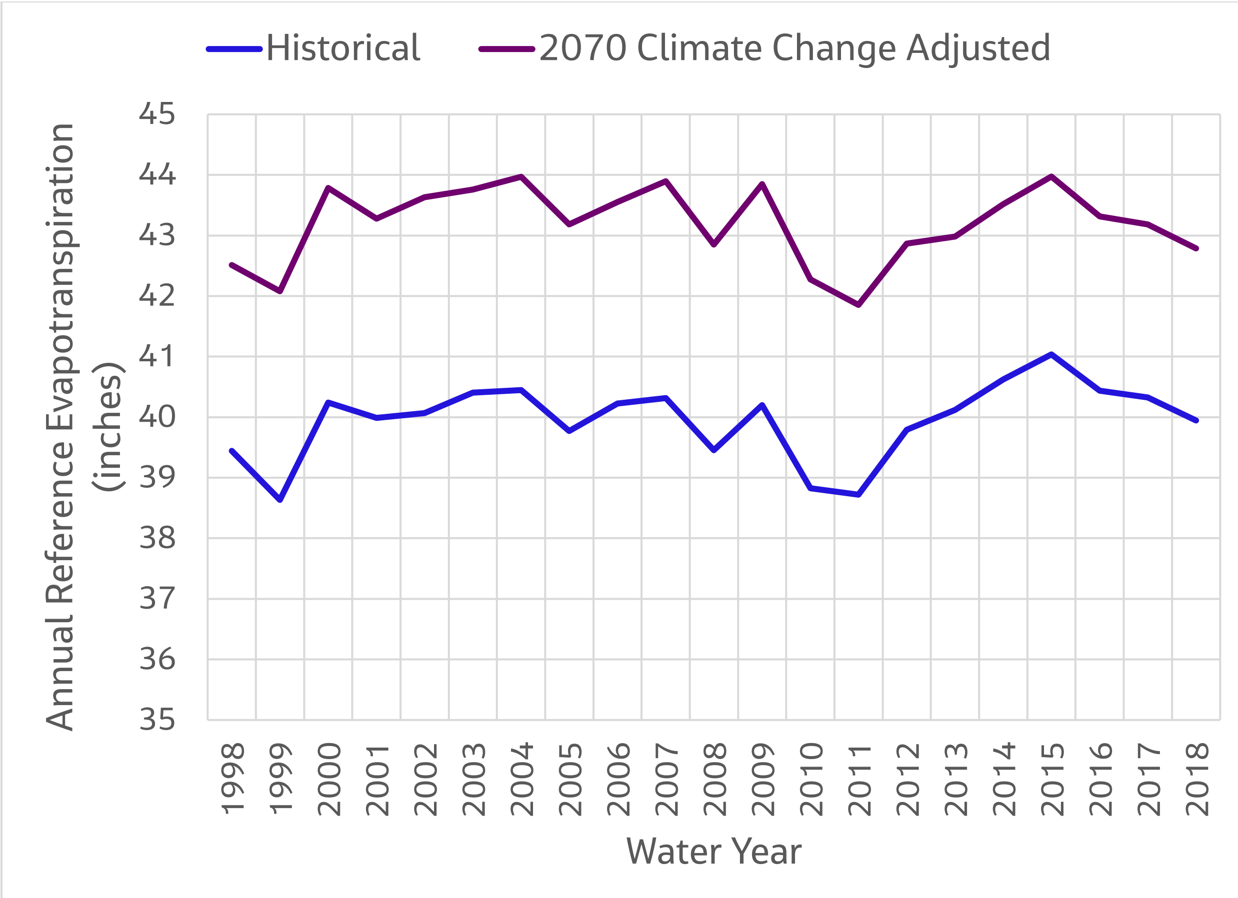



Figure 5-2 – Historical Versus 2070 Climate Change Adjusted Reference Evapotranspiration

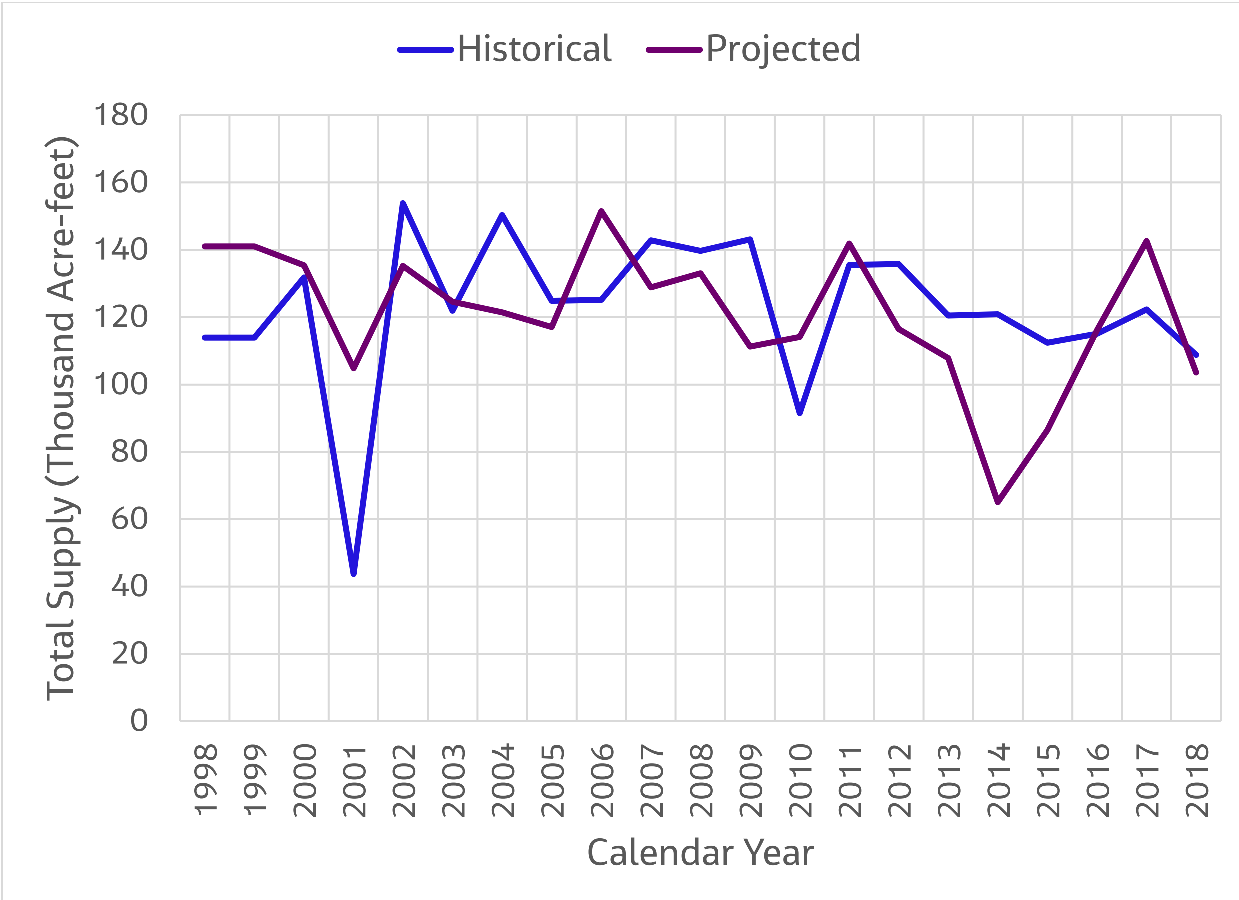



Figure 5-3 – Historical Versus Projected TID Total Supply

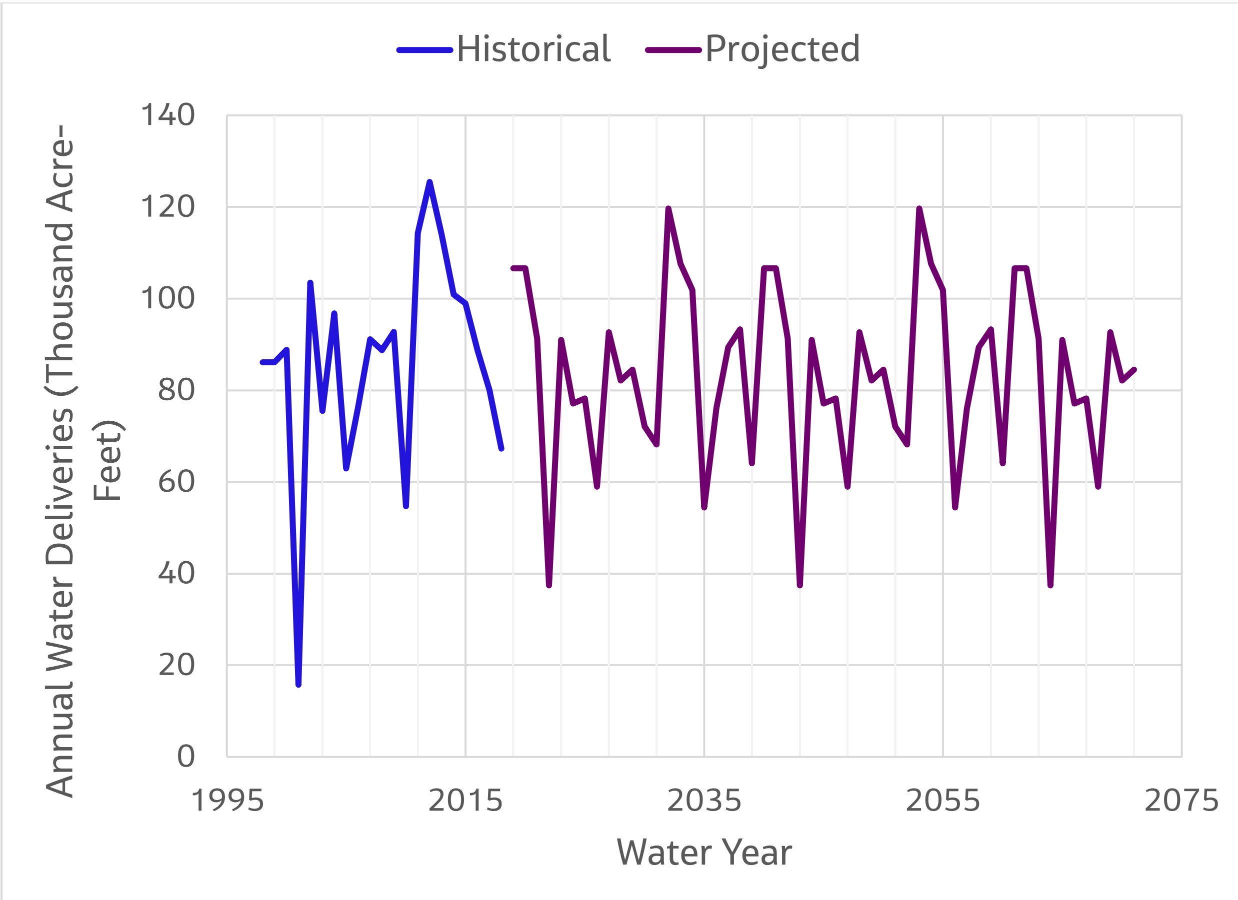



Figure 5-4 – Historical and Projected TID Water Deliveries

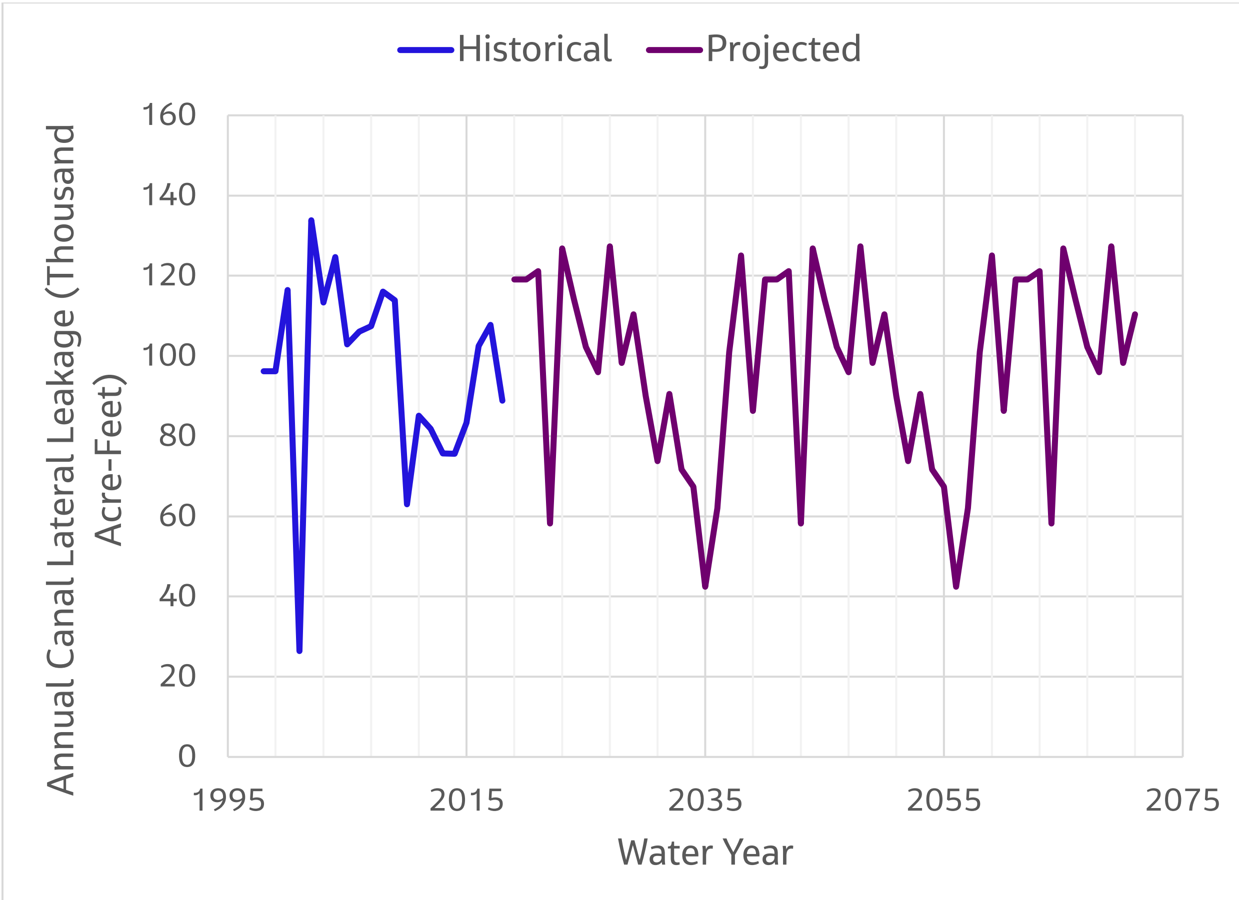
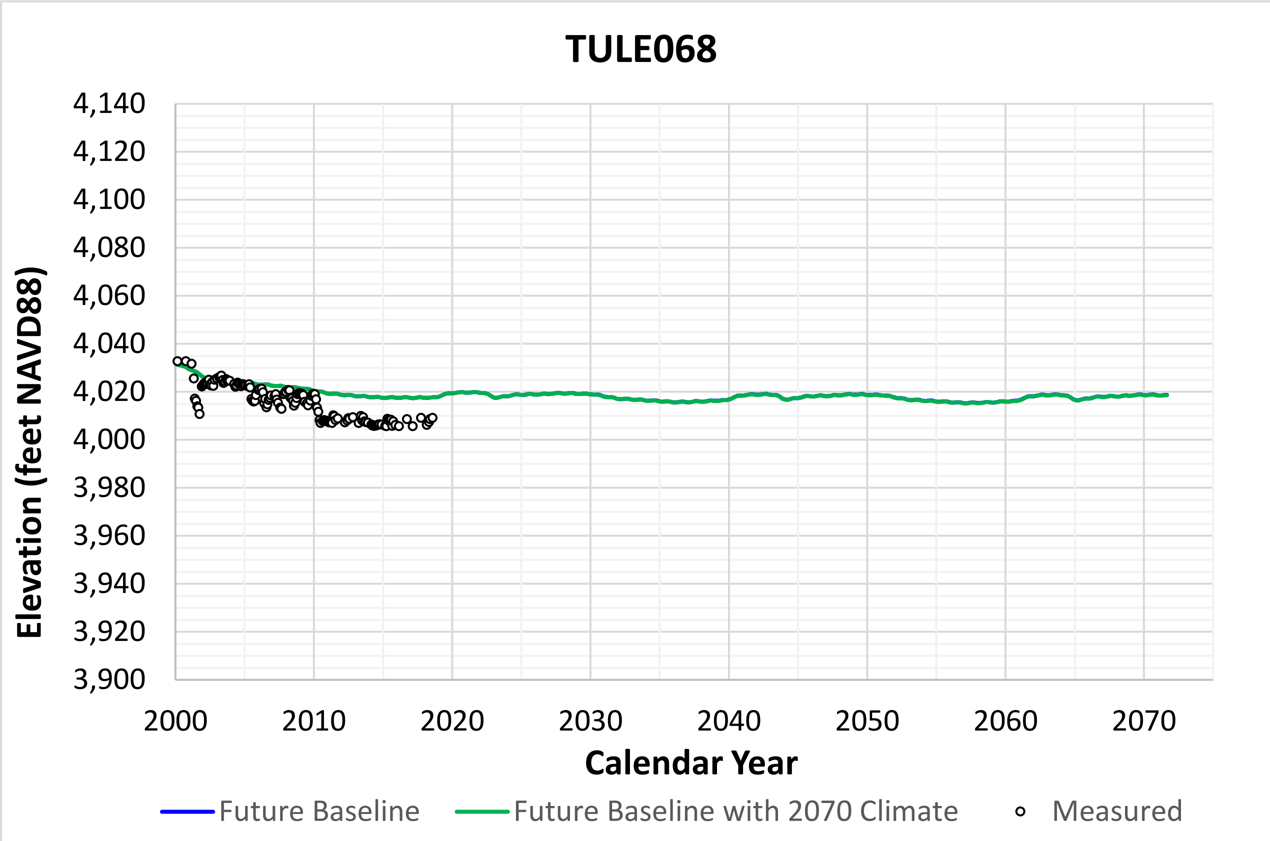



Figure 5-5 – Historical and Projected Canal Lateral Leakage



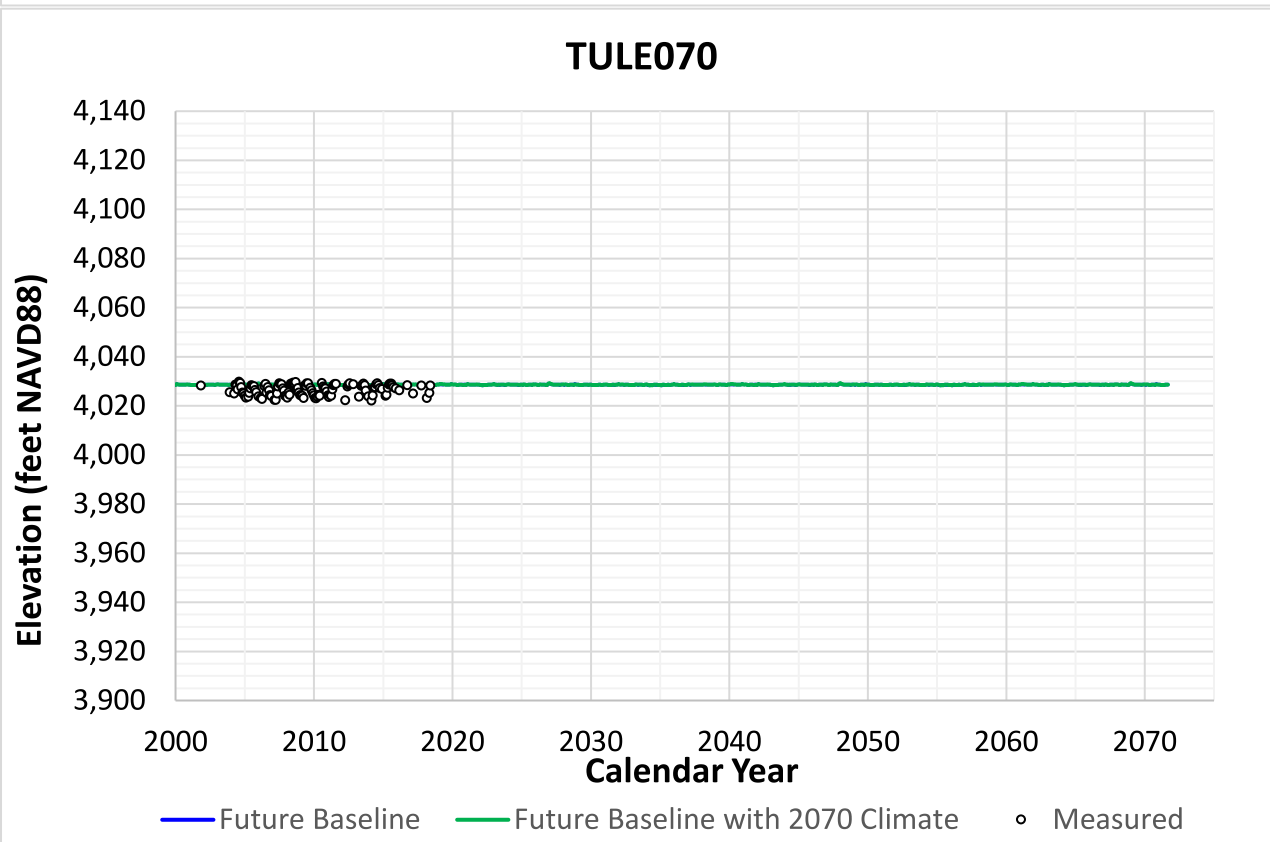
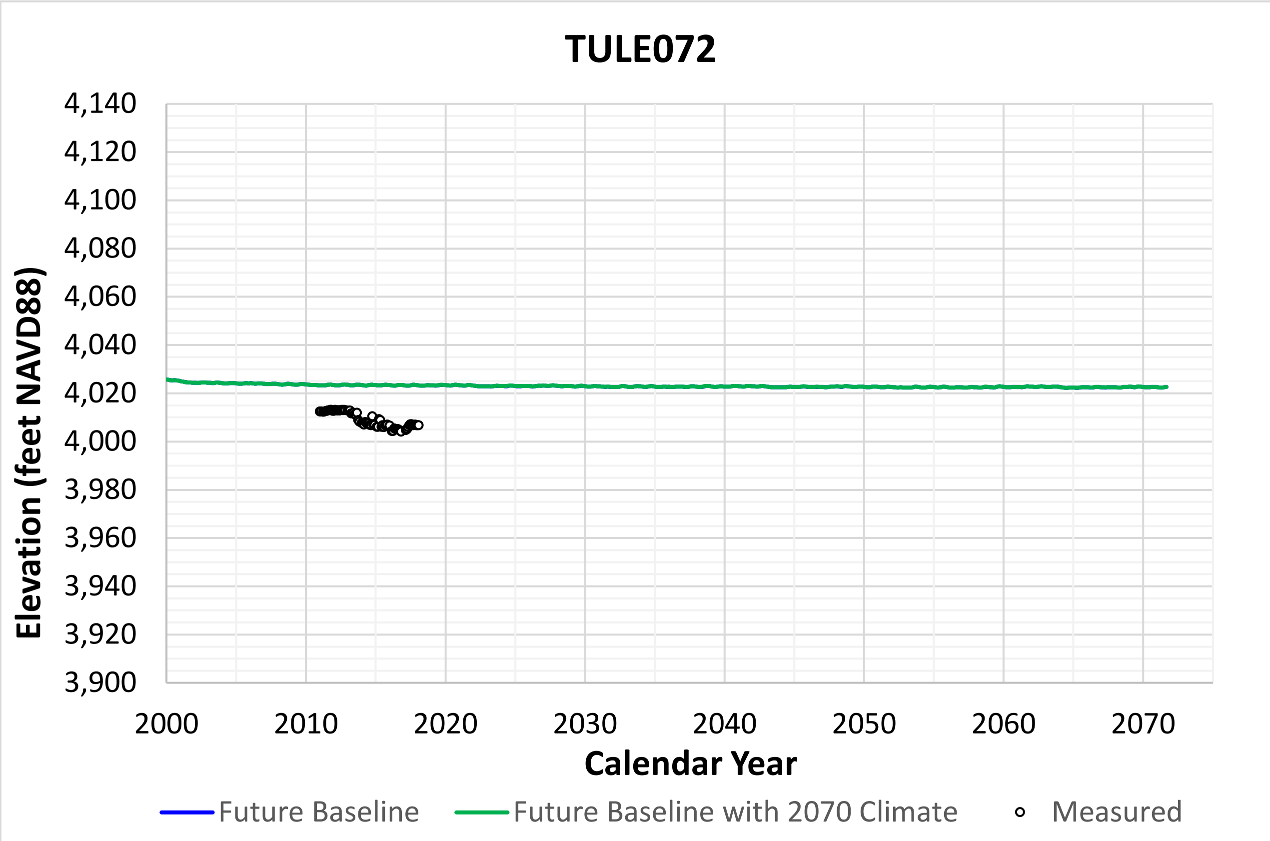




**Figure 5-6**
Comparison of Projected Groundwater Levels



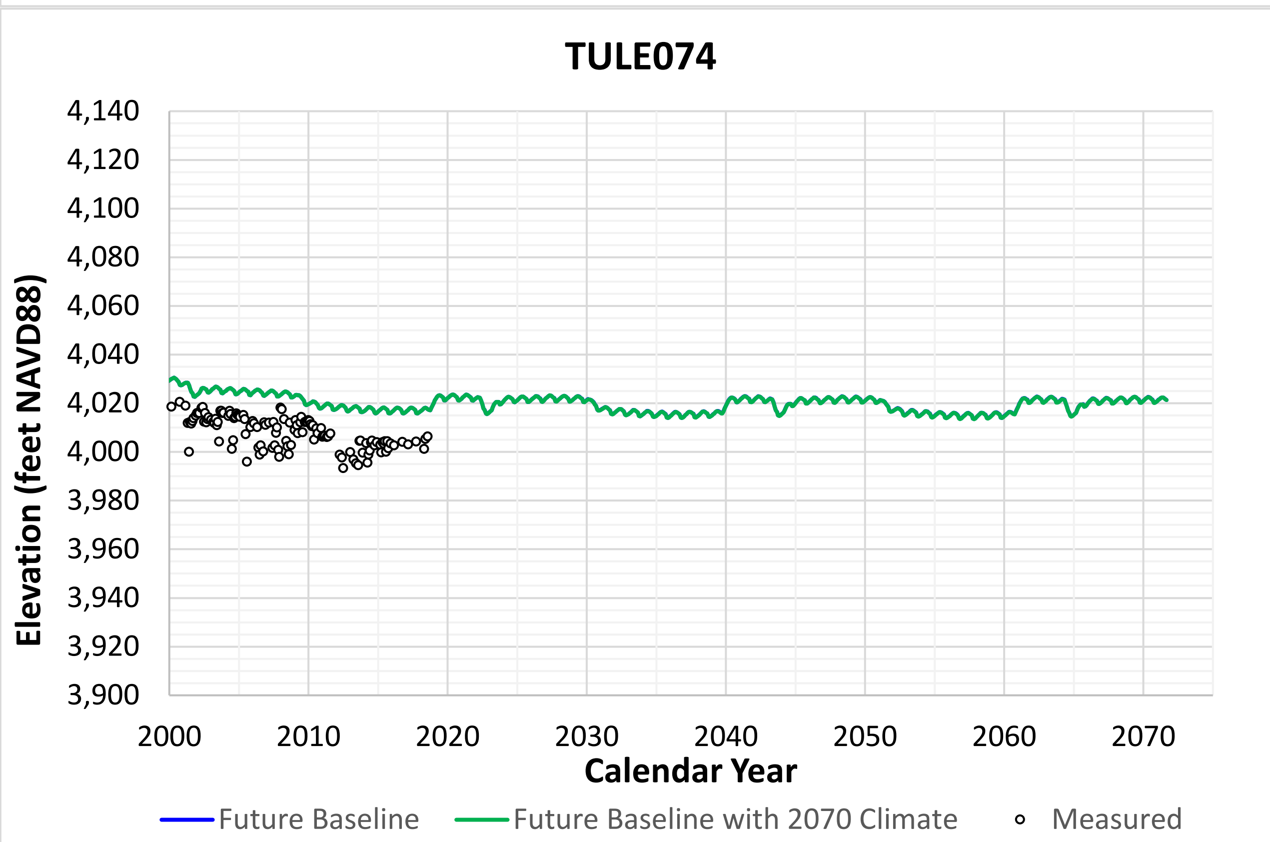
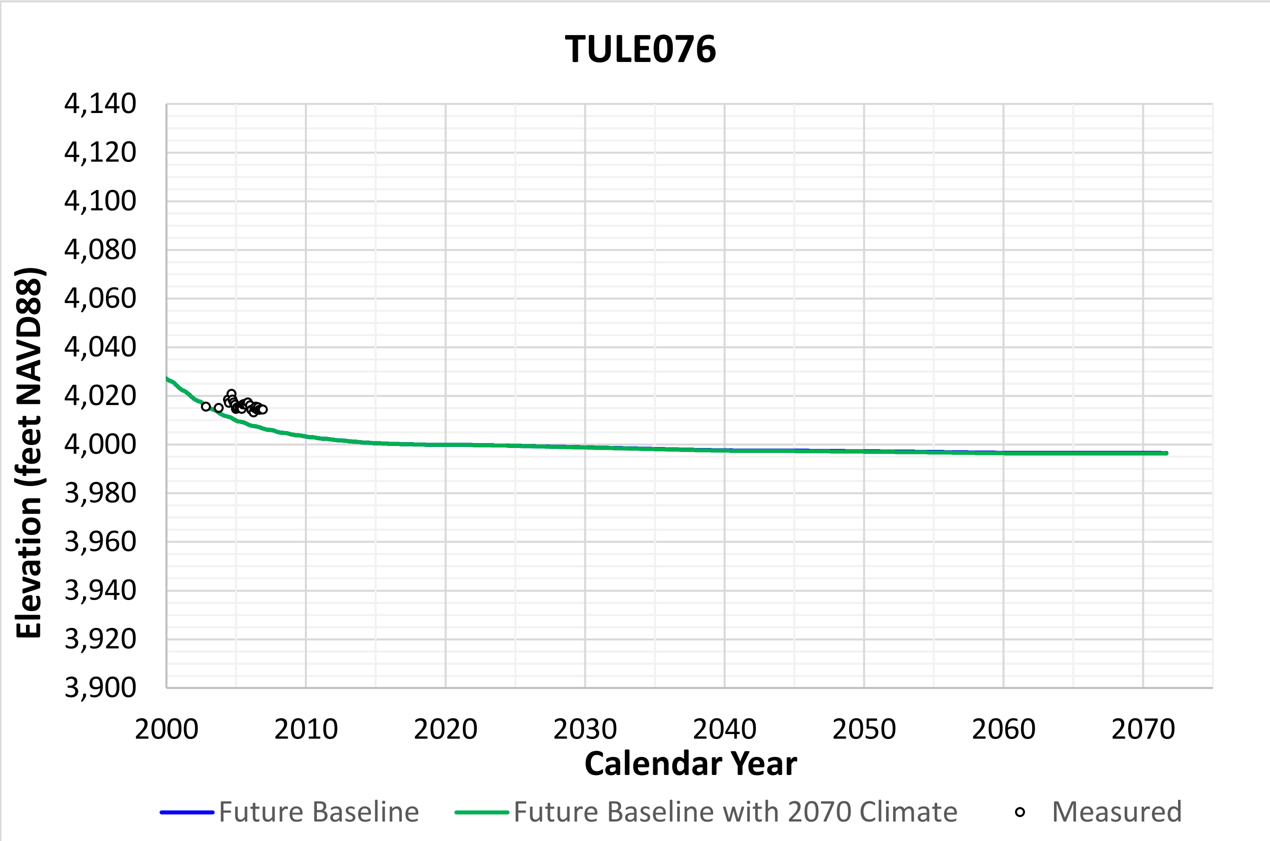




**Figure 5-6**
Comparison of Projected Groundwater Levels



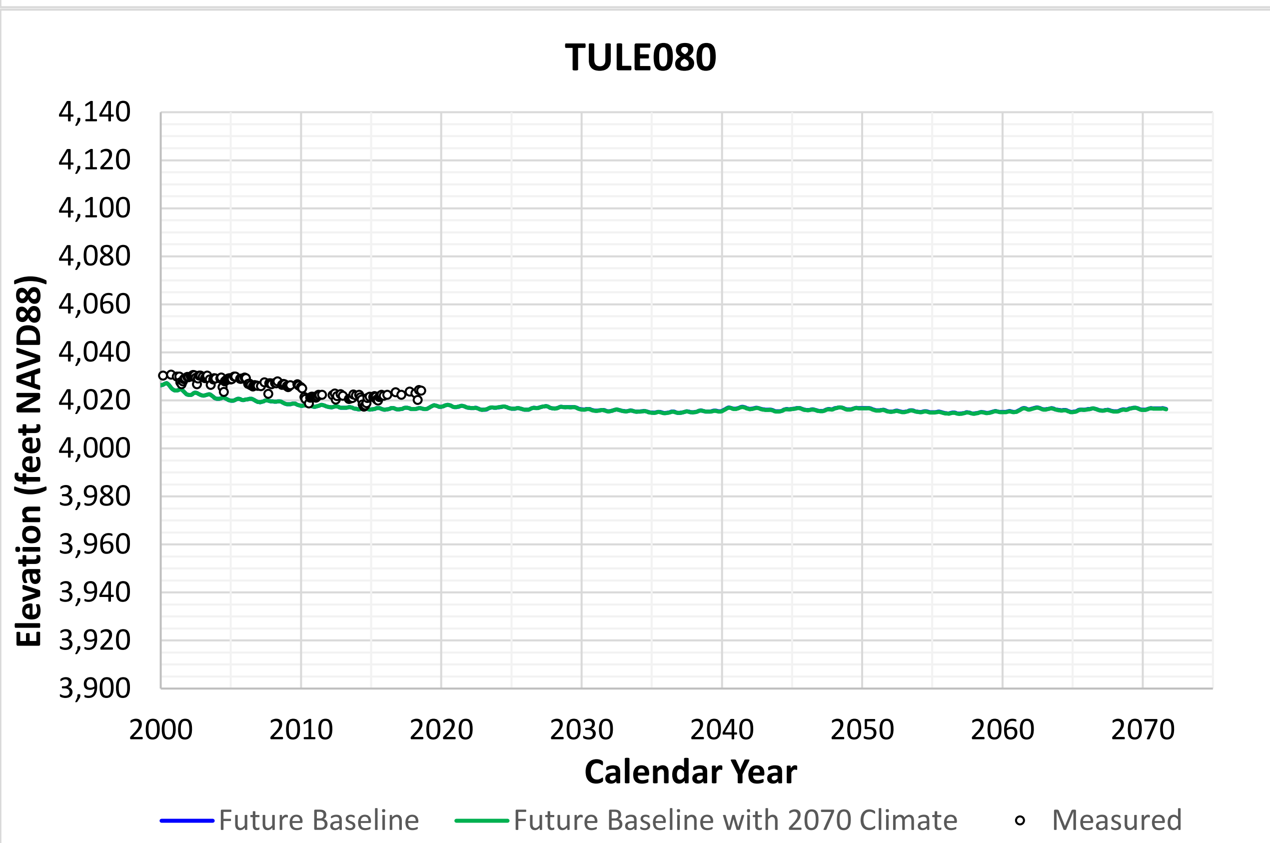
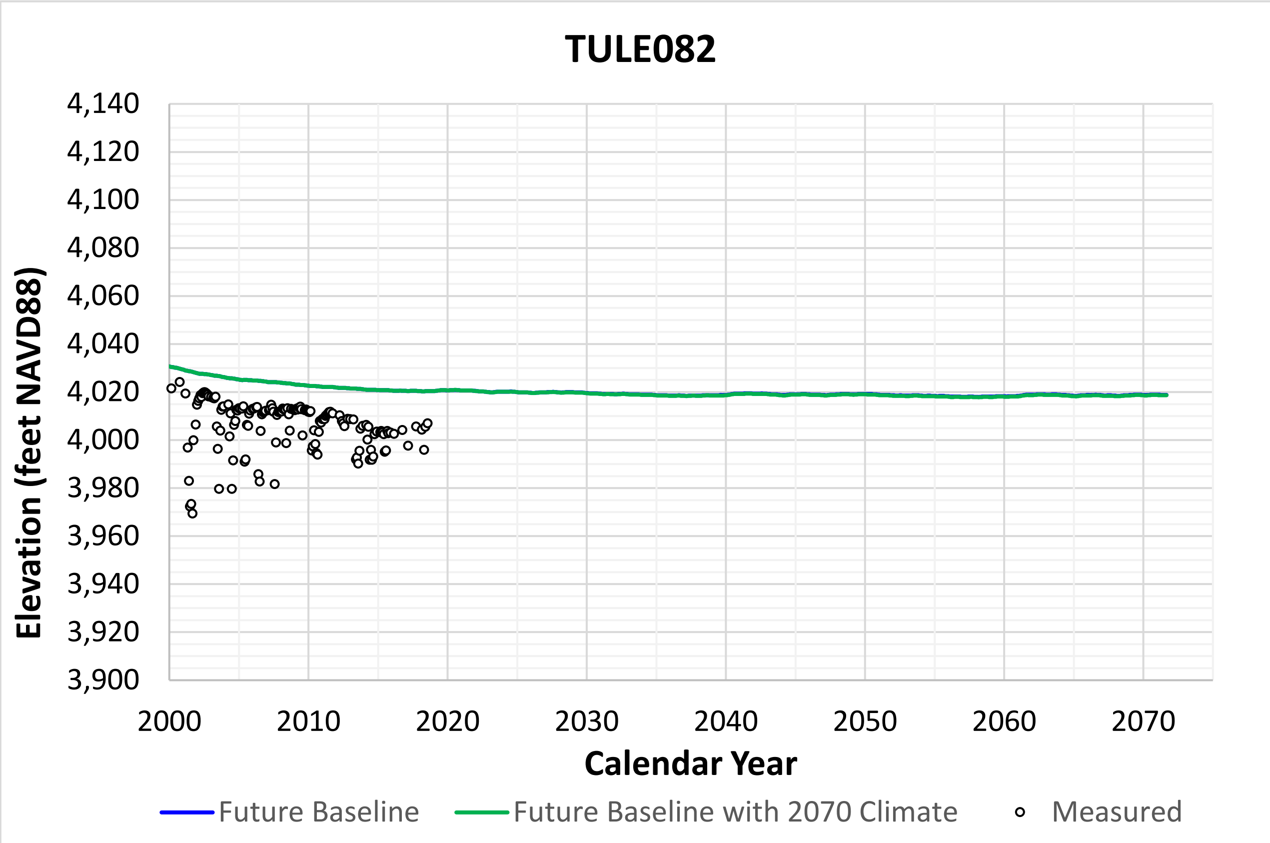




**Figure 5-6**
Comparison of Projected Groundwater Levels



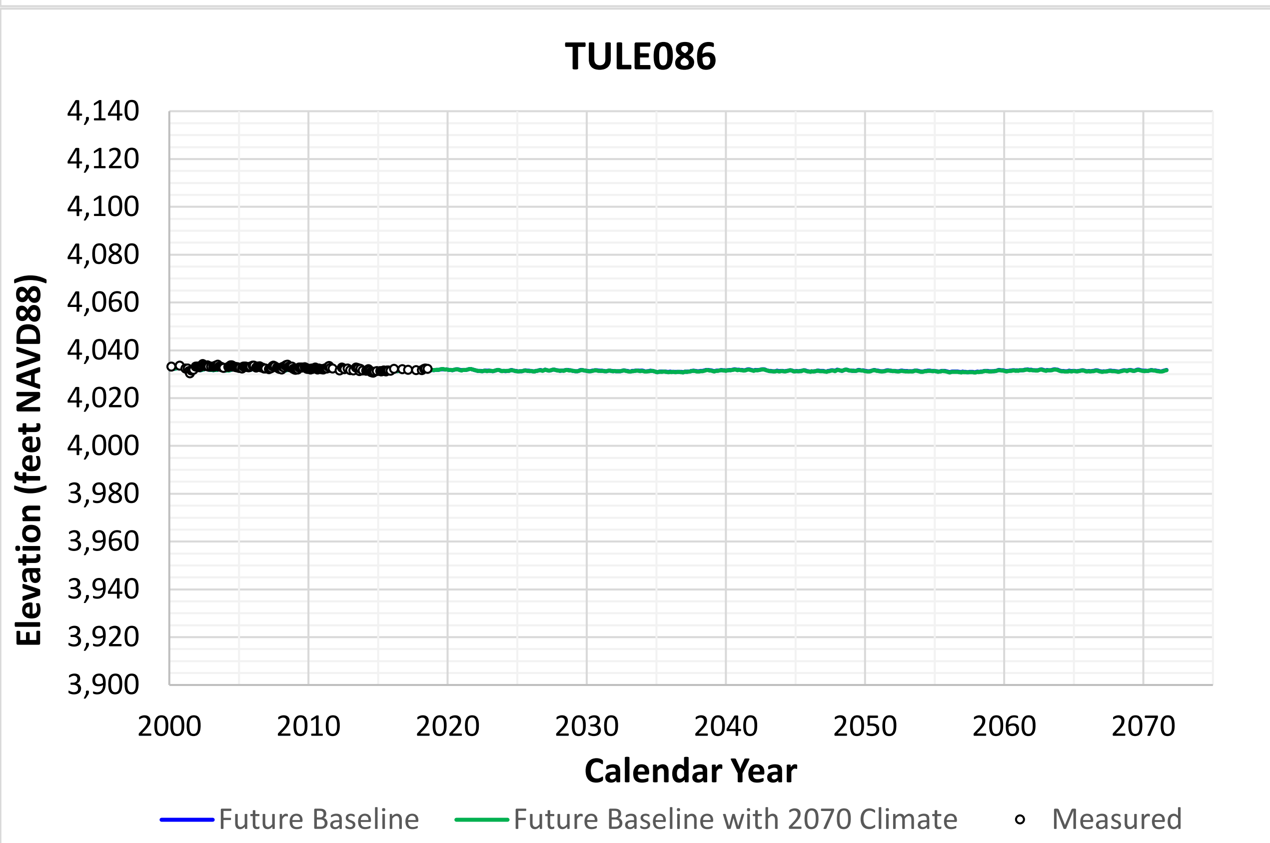
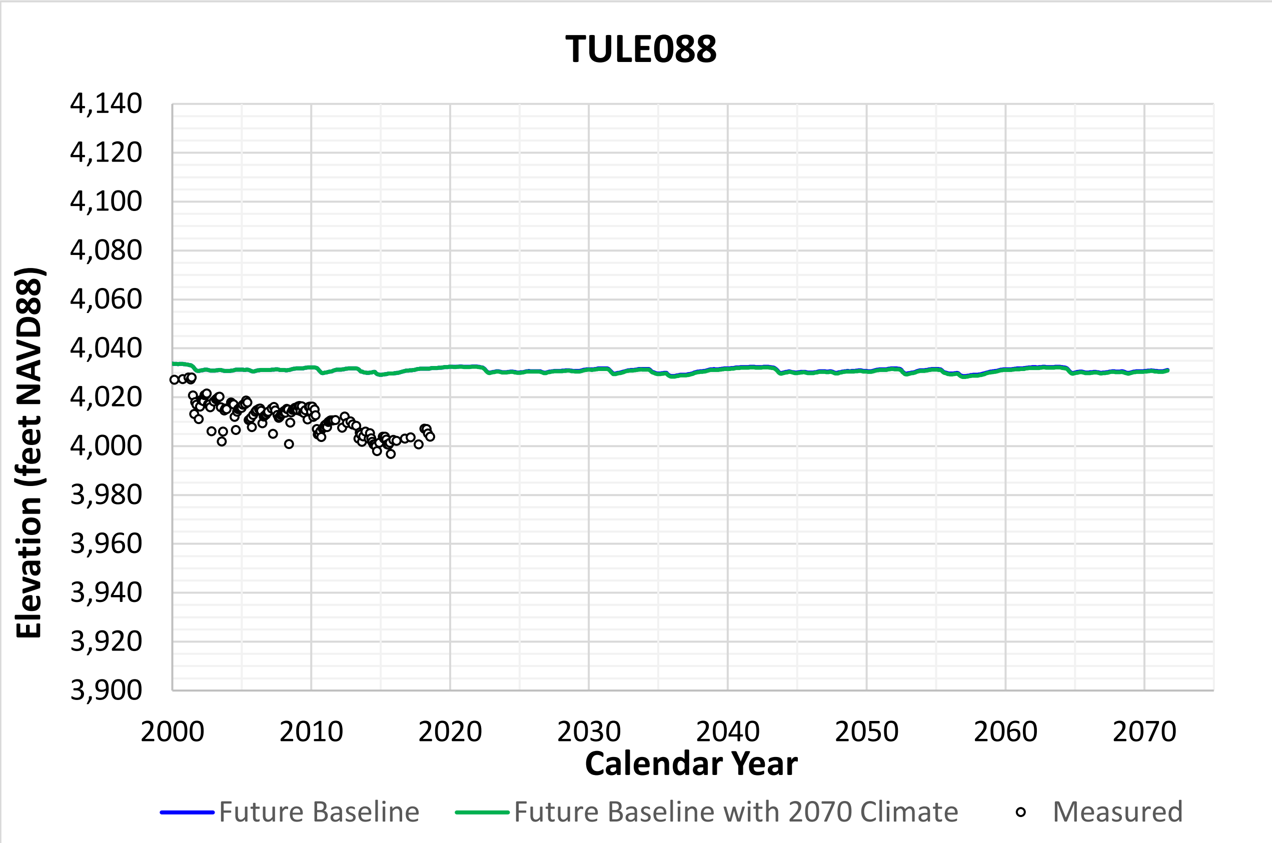




**Figure 5-6**
Comparison of Projected Groundwater Levels



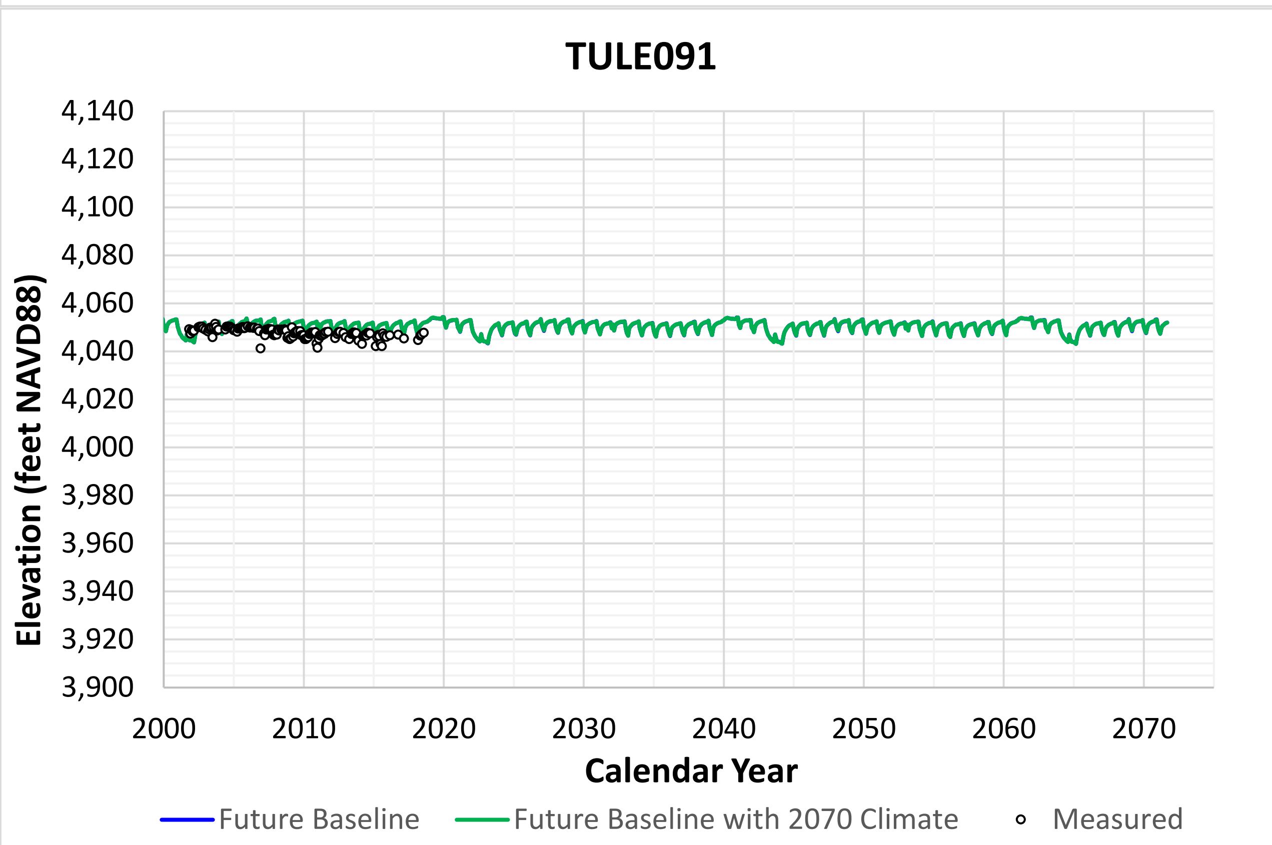
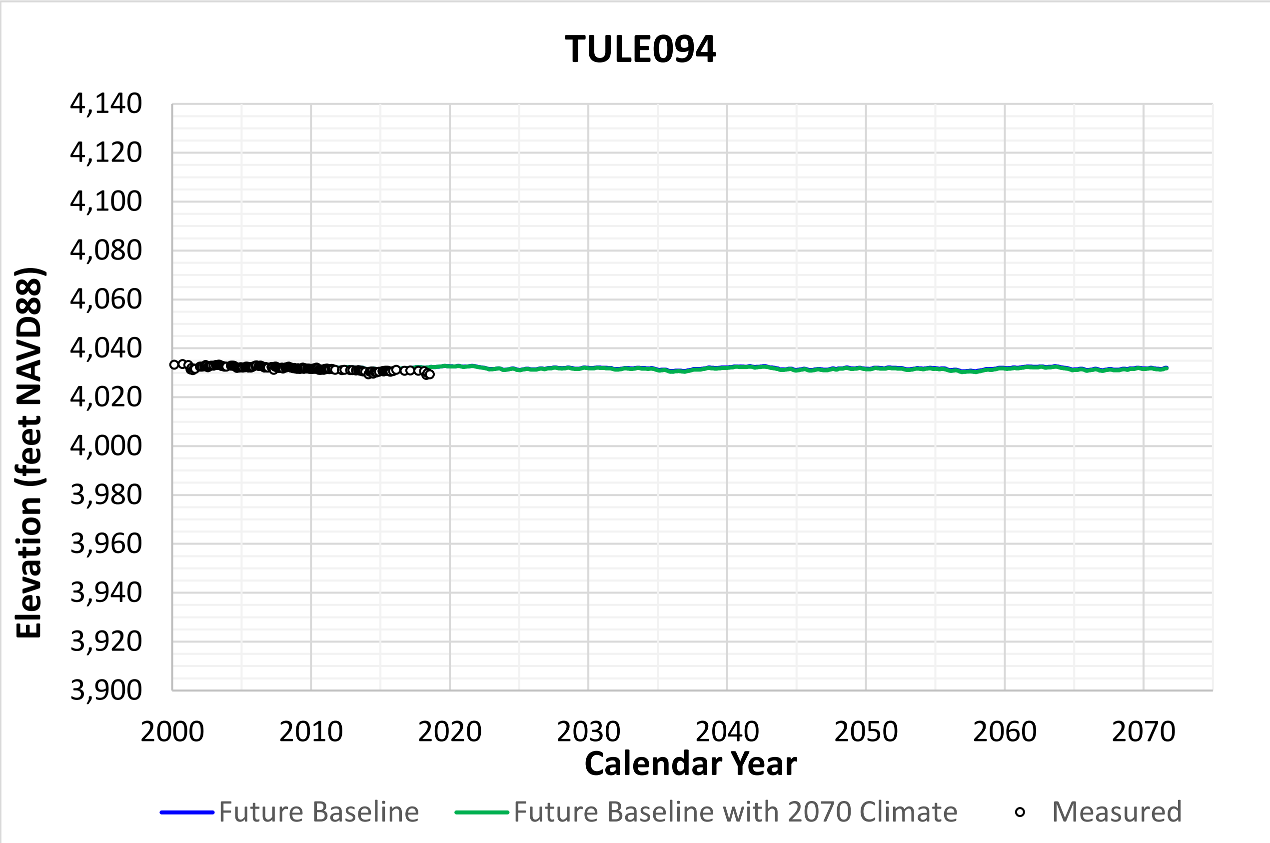




**Figure 5-6**
Comparison of Projected Groundwater Levels



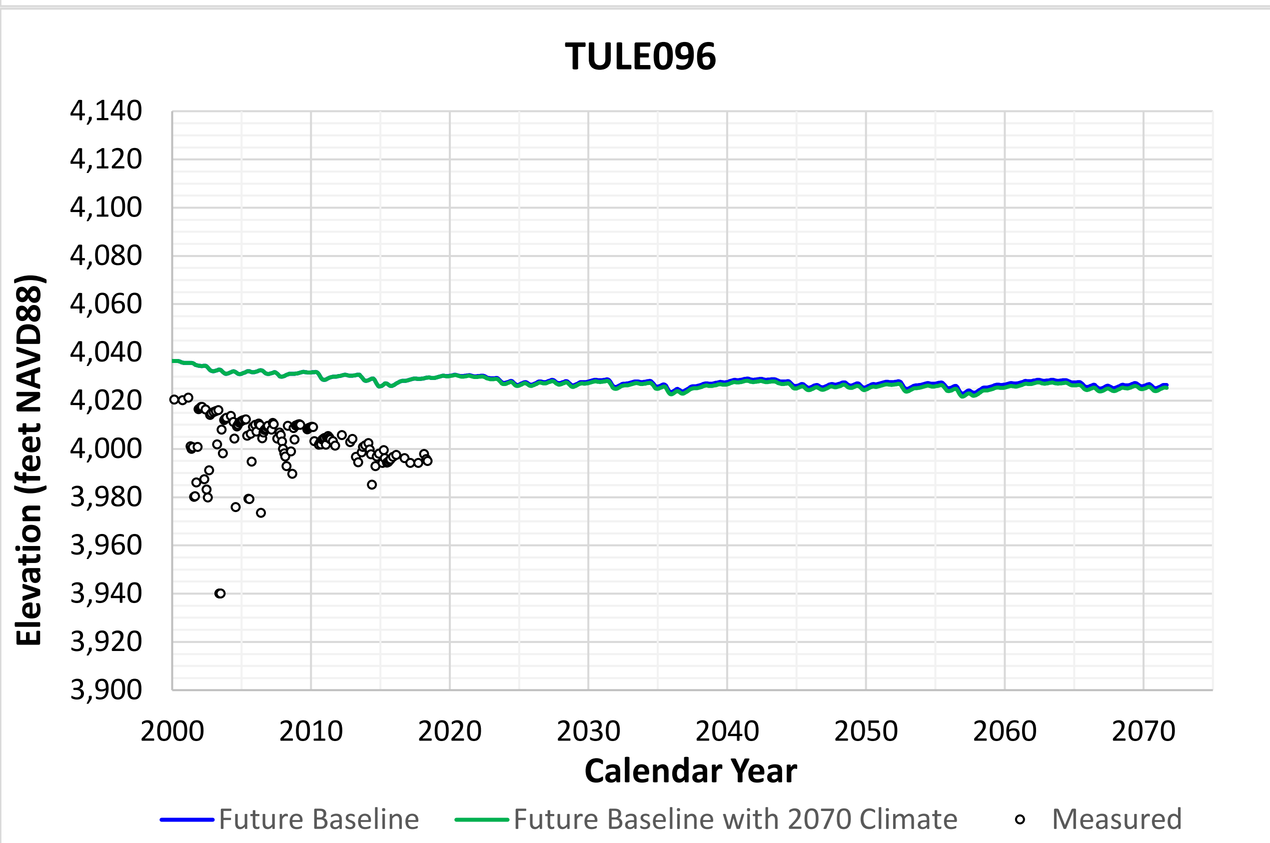
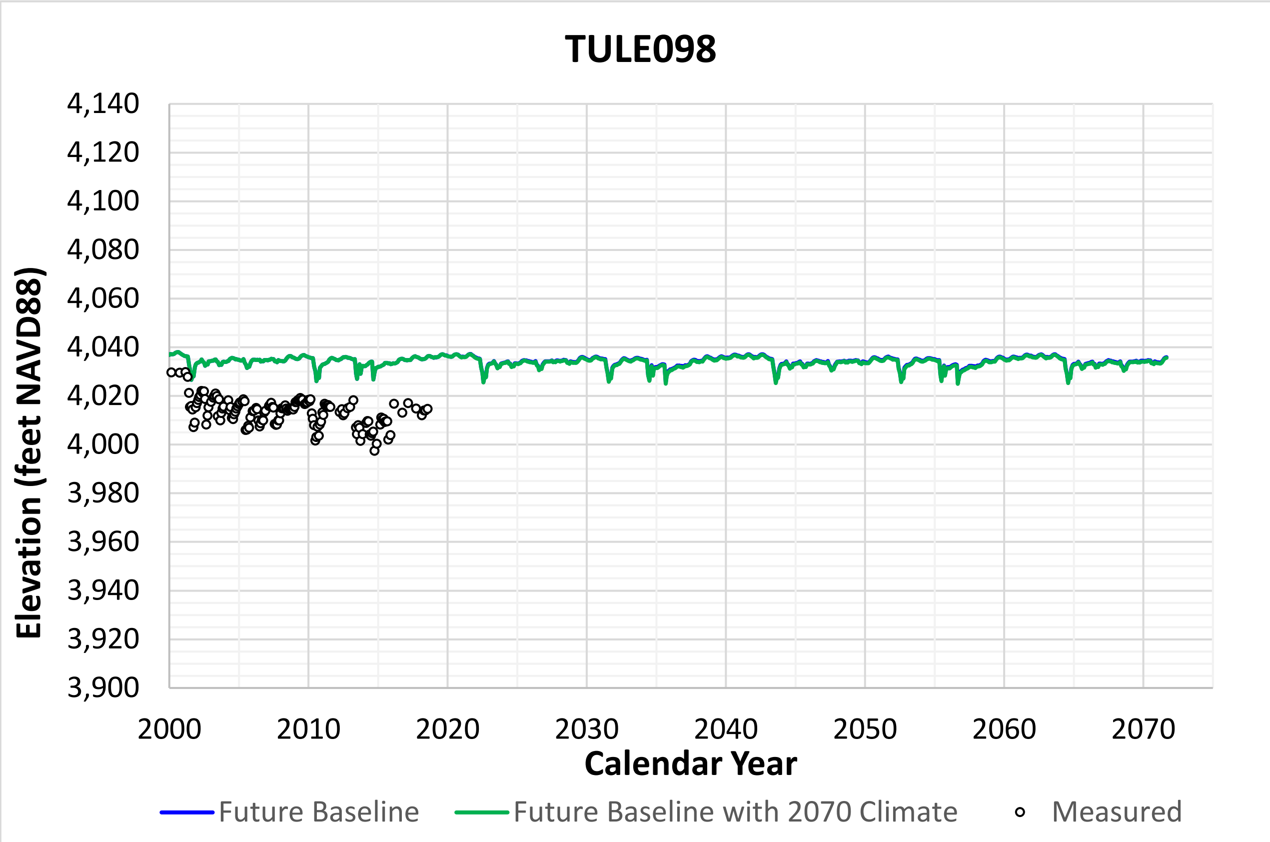




**Figure 5-6**
Comparison of Projected Groundwater Levels



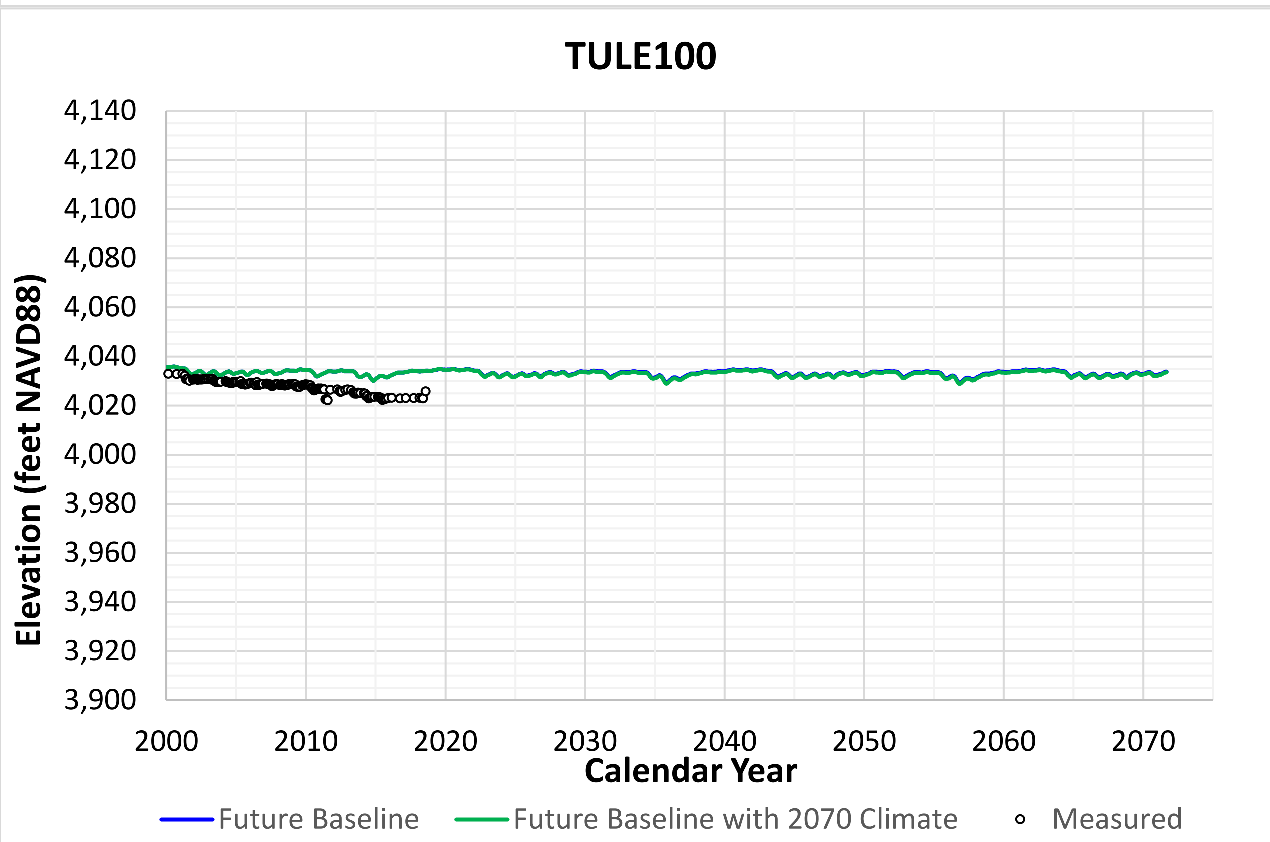
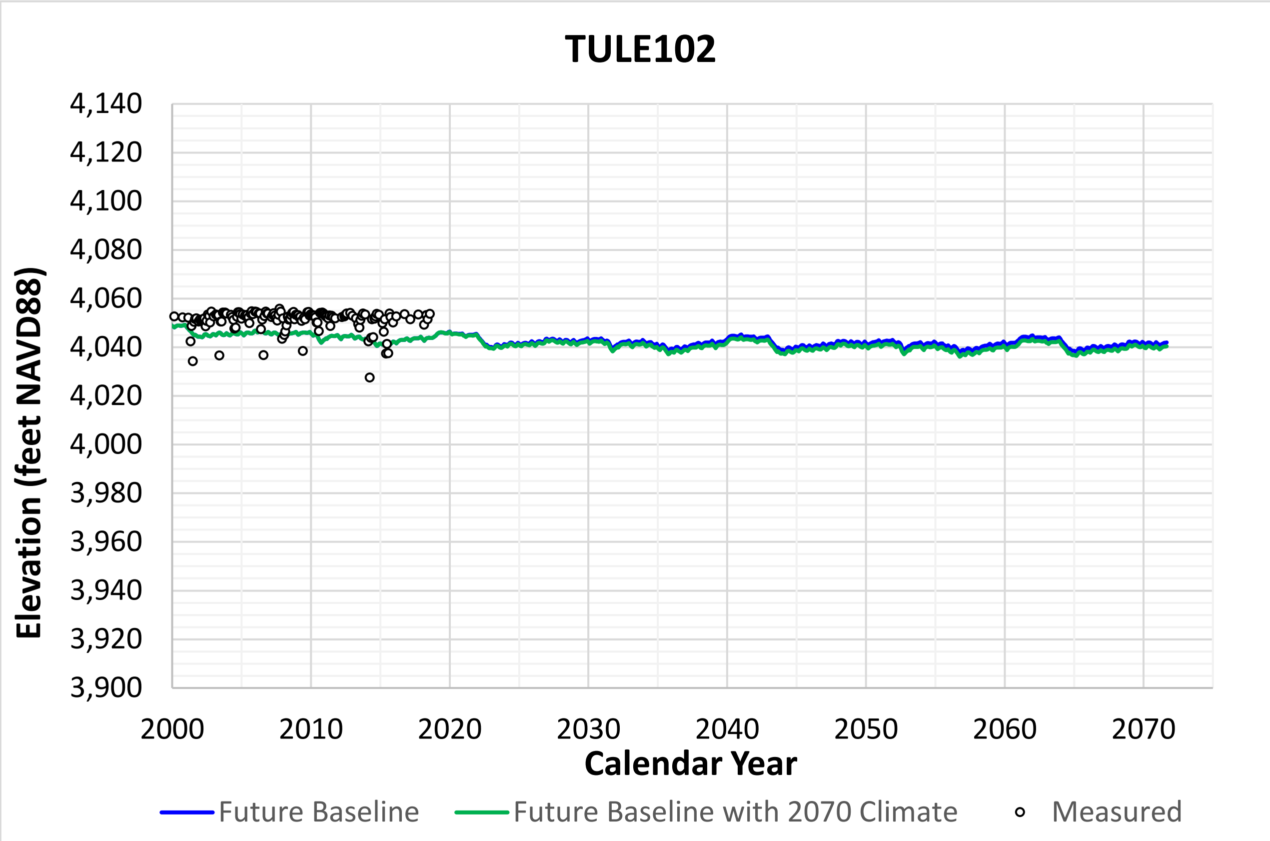




**Figure 5-6**
Comparison of Projected Groundwater Levels



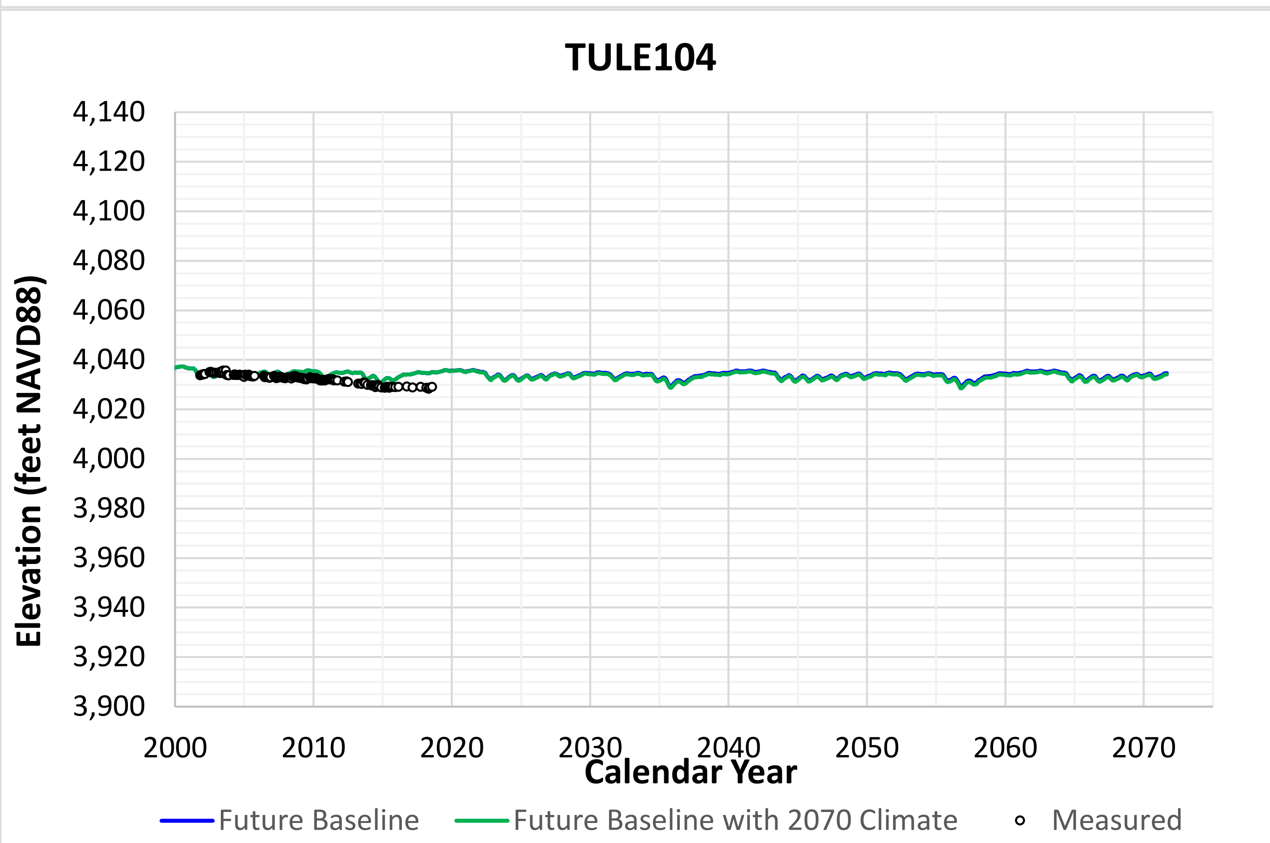
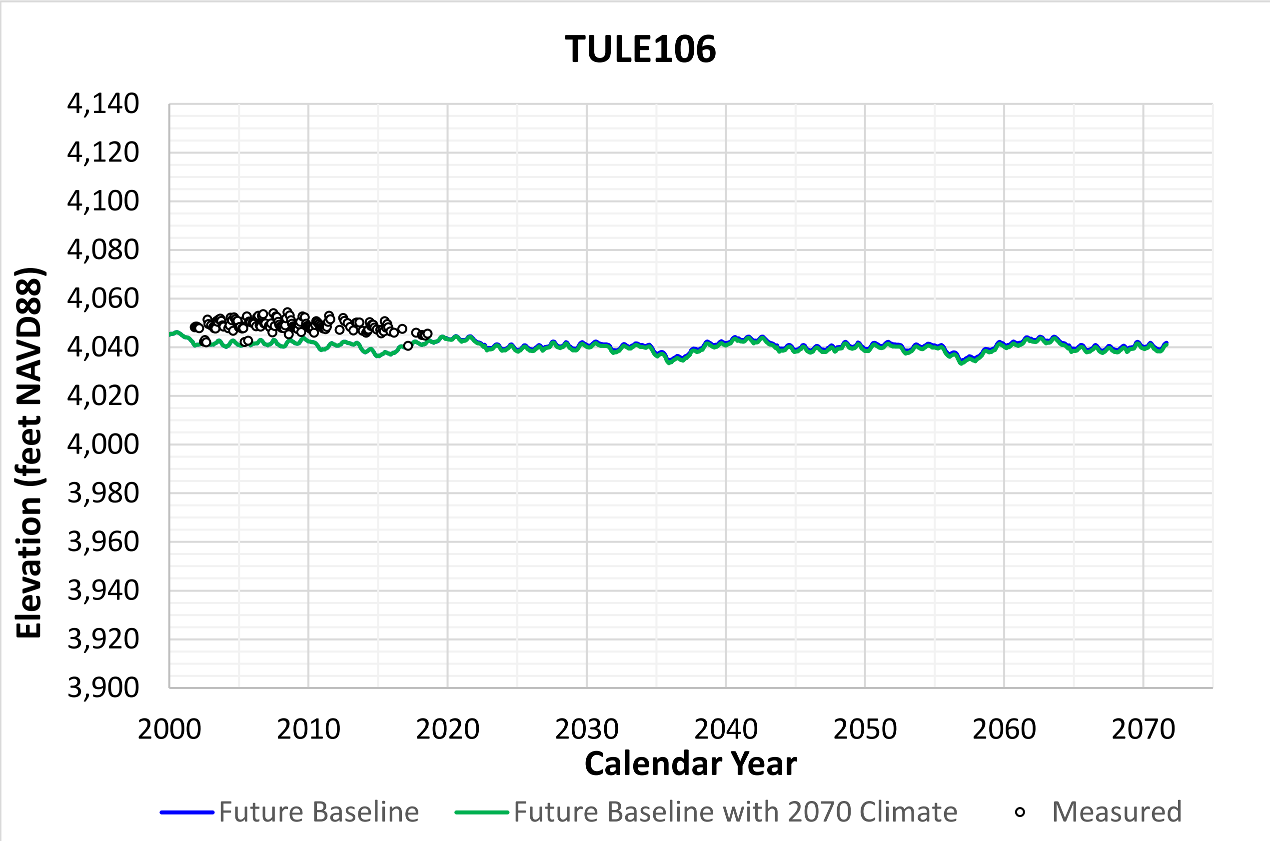




**Figure 5-6**
Comparison of Projected Groundwater Levels



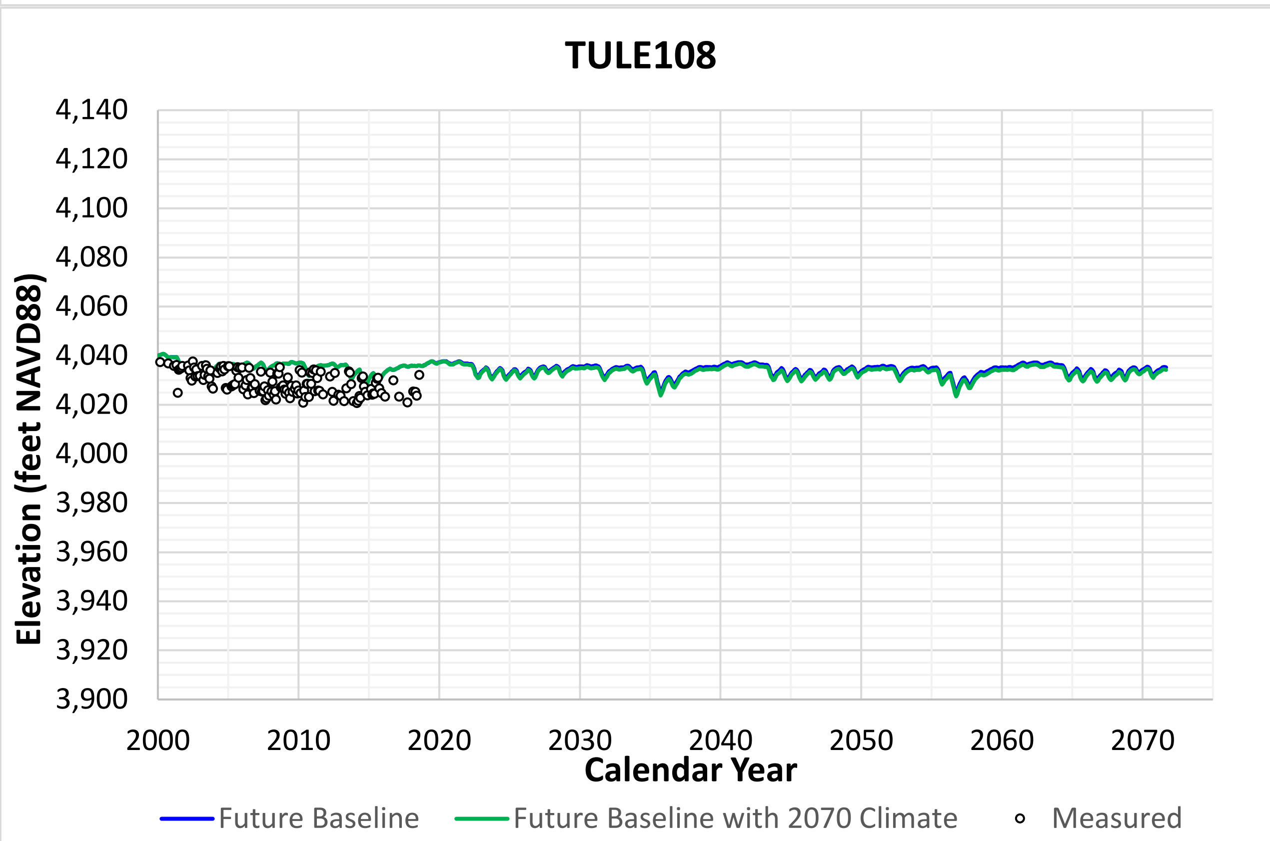
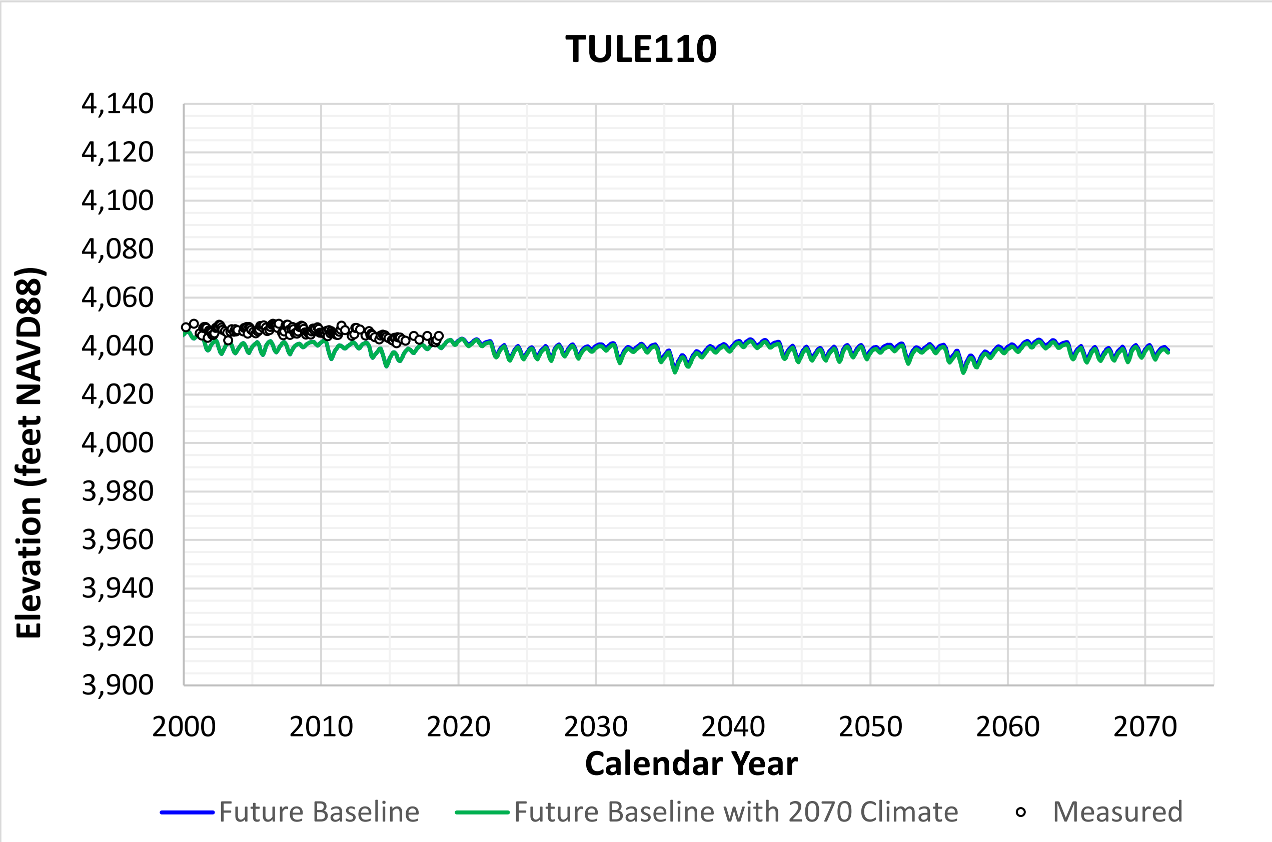




**Figure 5-6**
Comparison of Projected Groundwater Levels



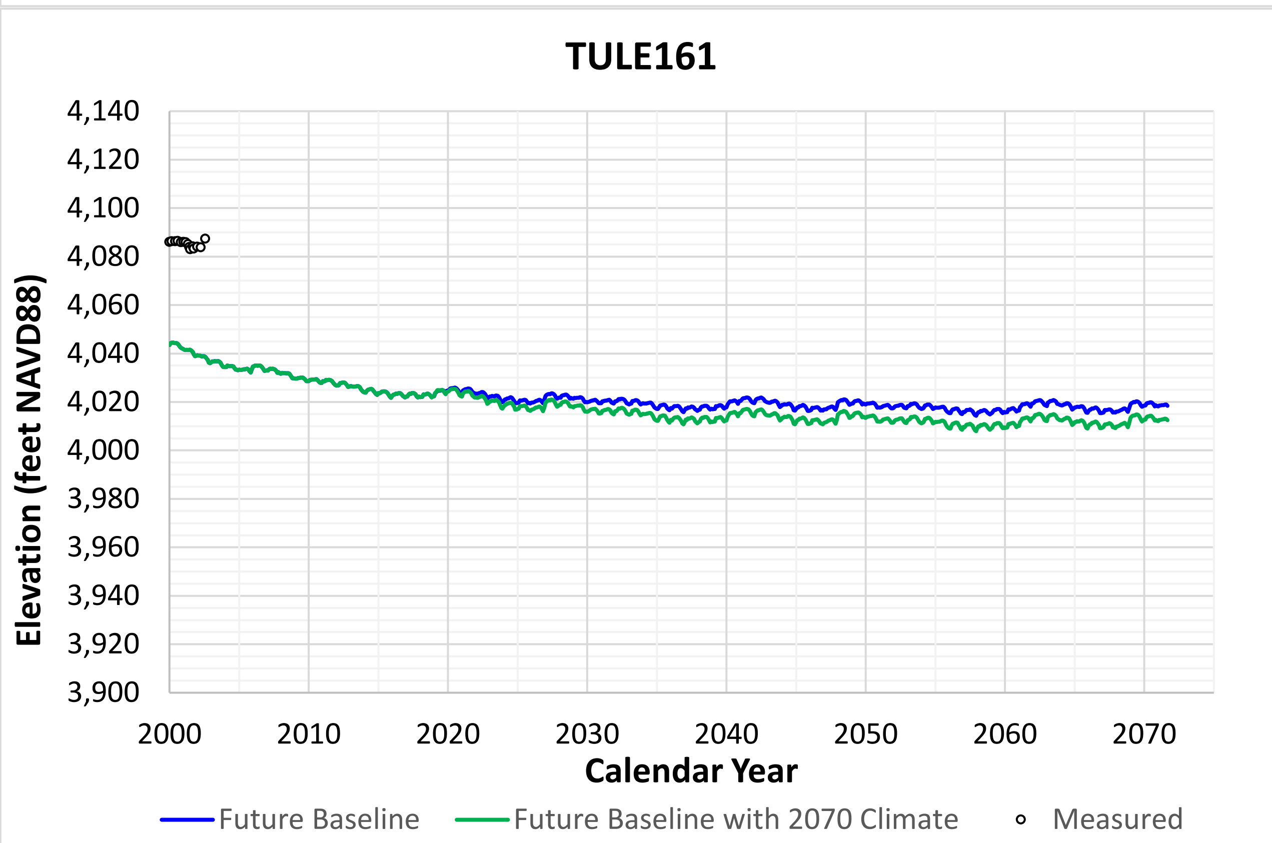
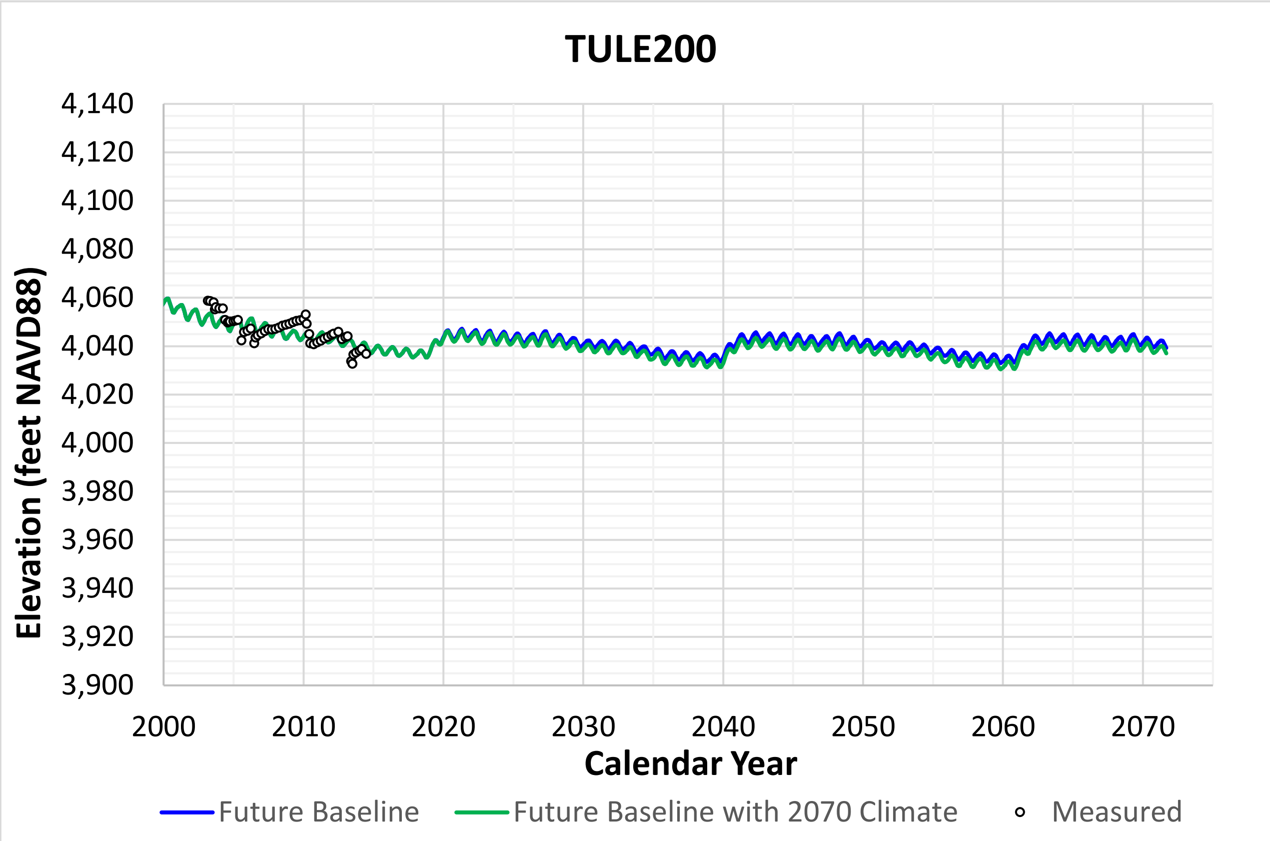




**Figure 5-6**
Comparison of Projected Groundwater Levels



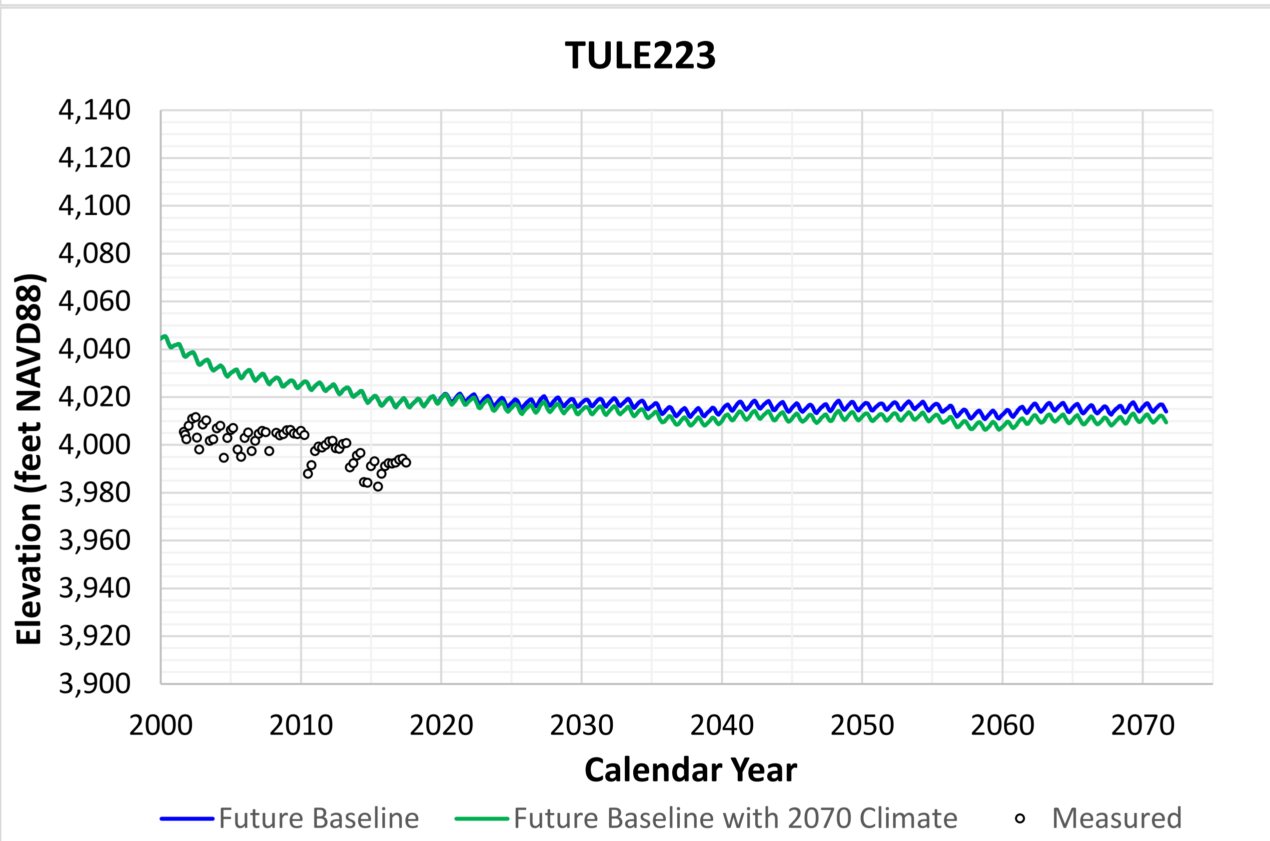
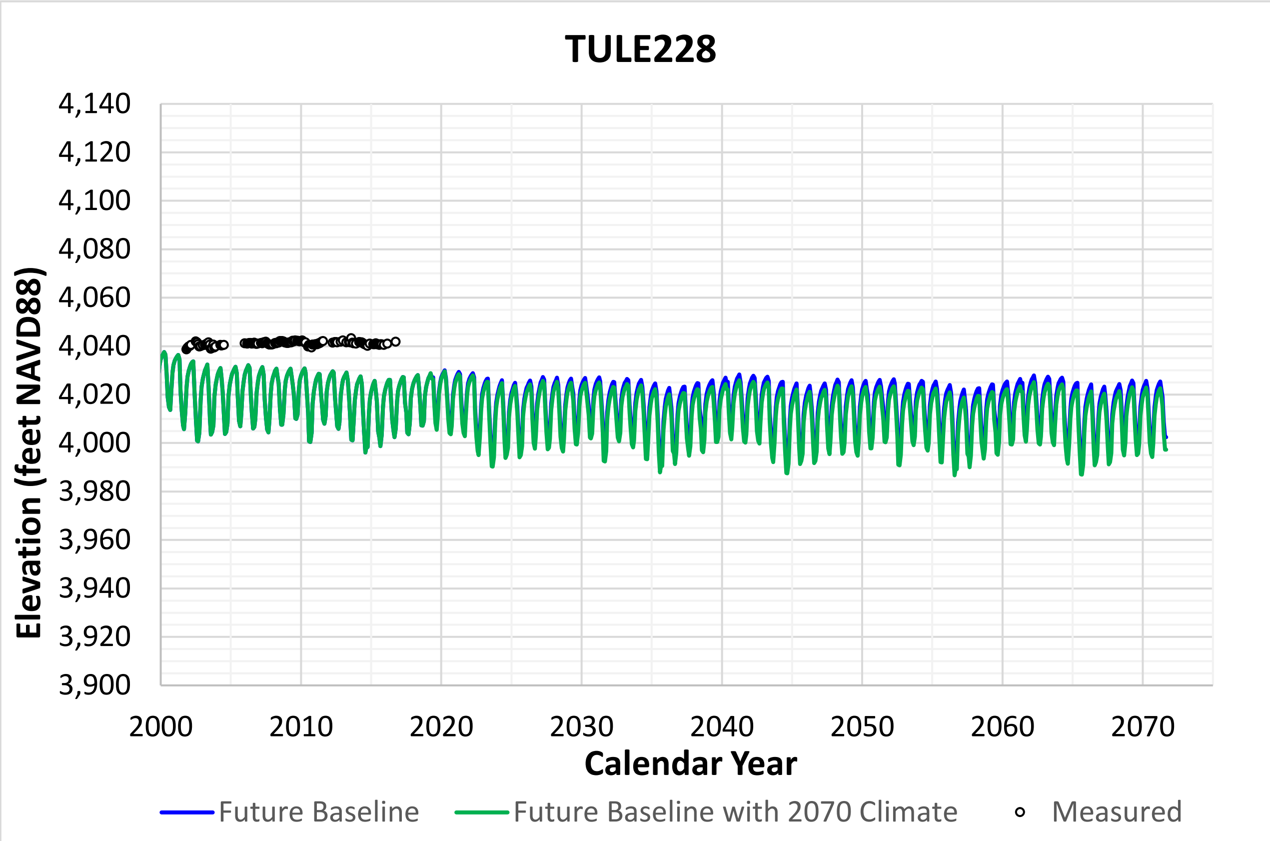




**Figure 5-6**
Comparison of Projected Groundwater Levels



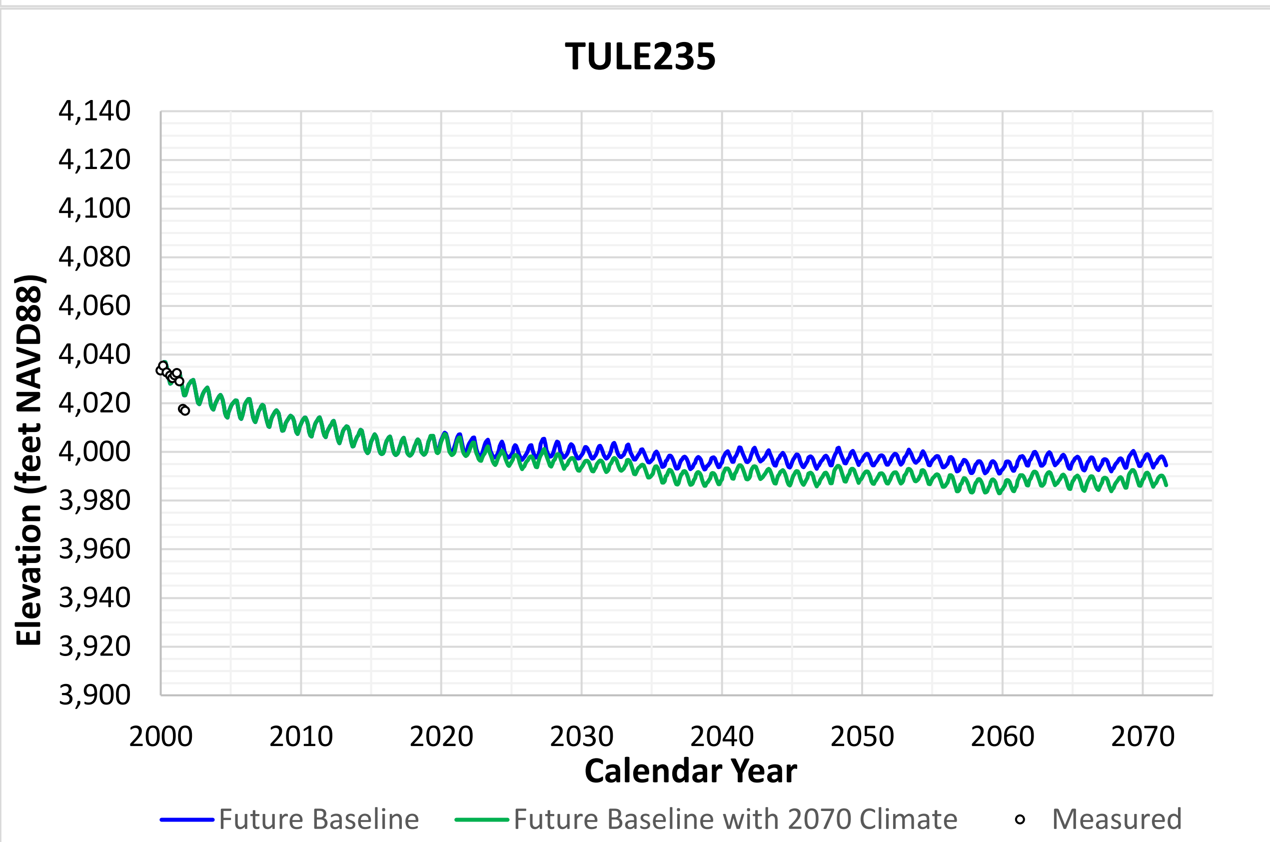
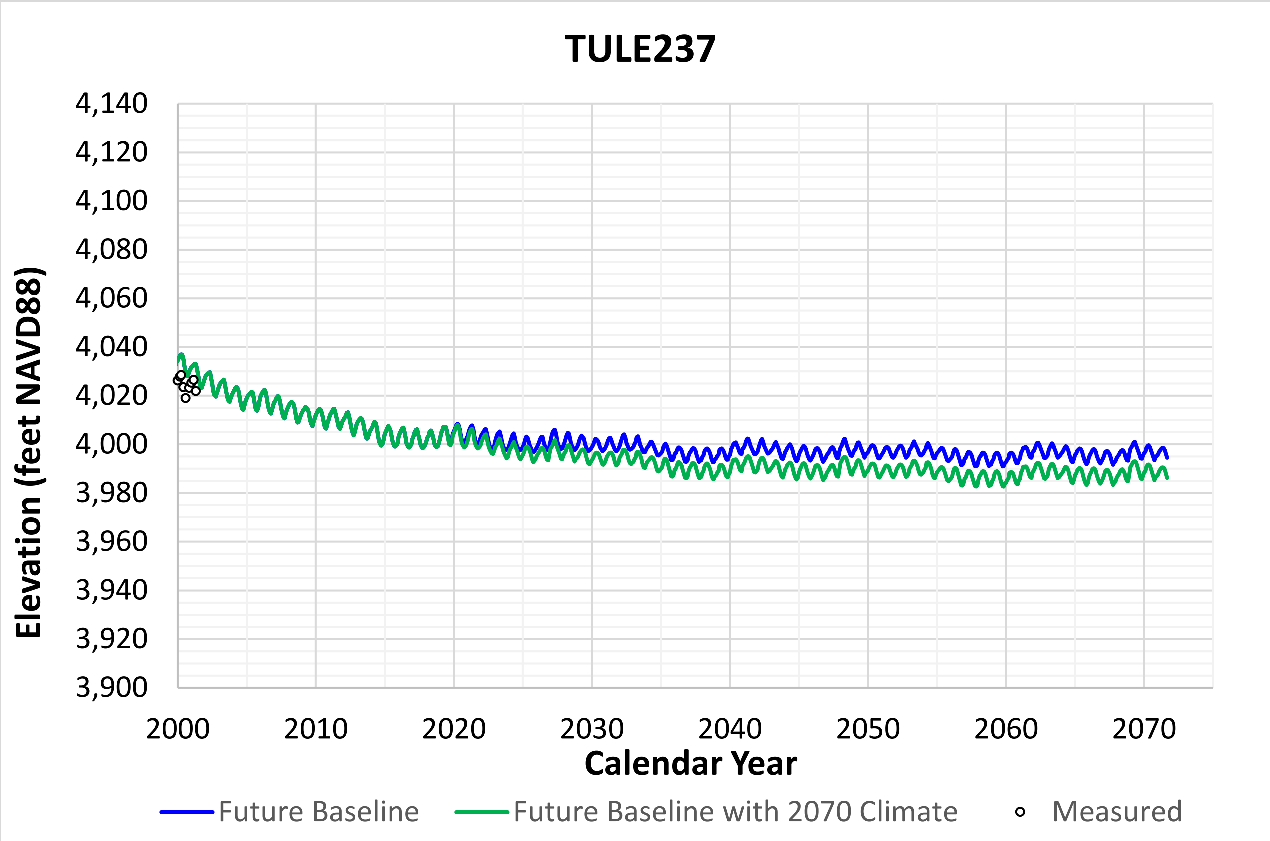




**Figure 5-6**
Comparison of Projected Groundwater Levels



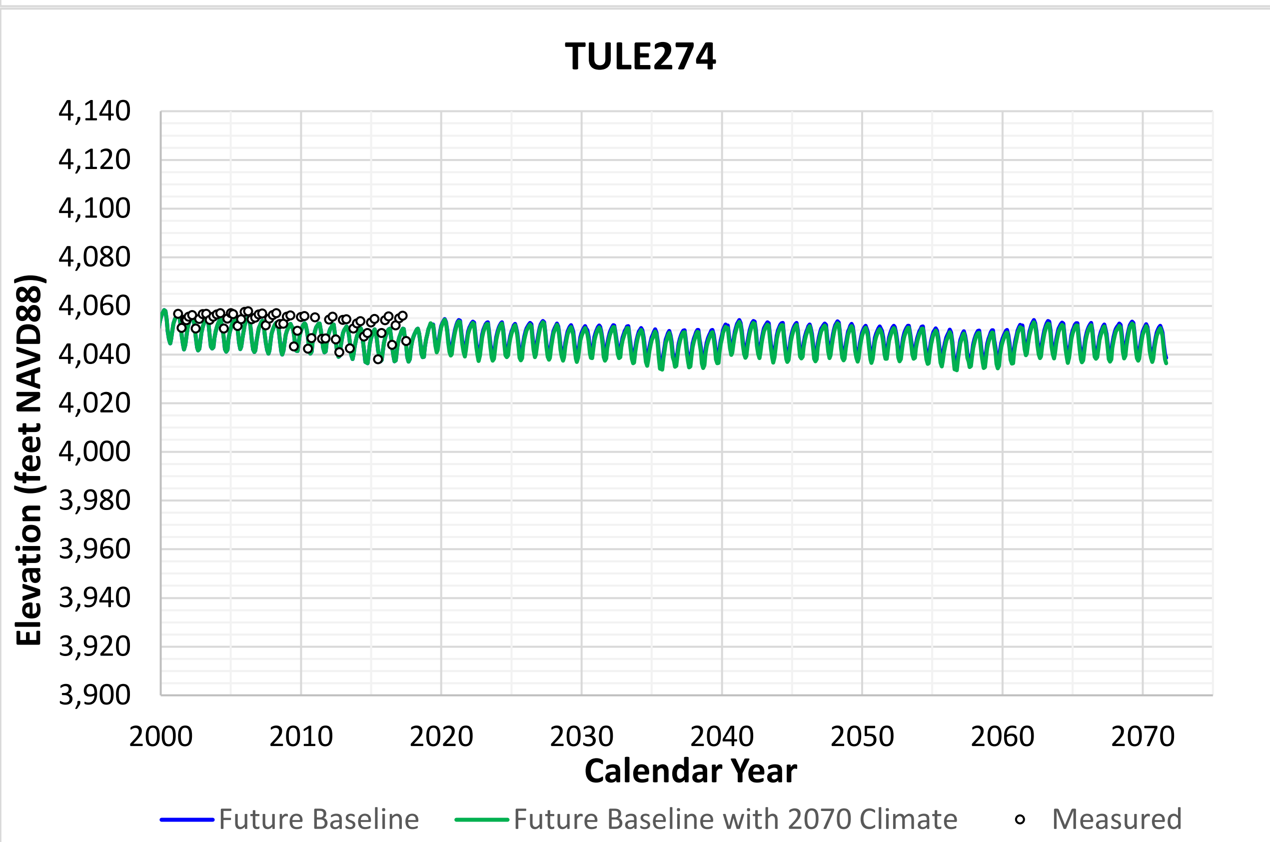
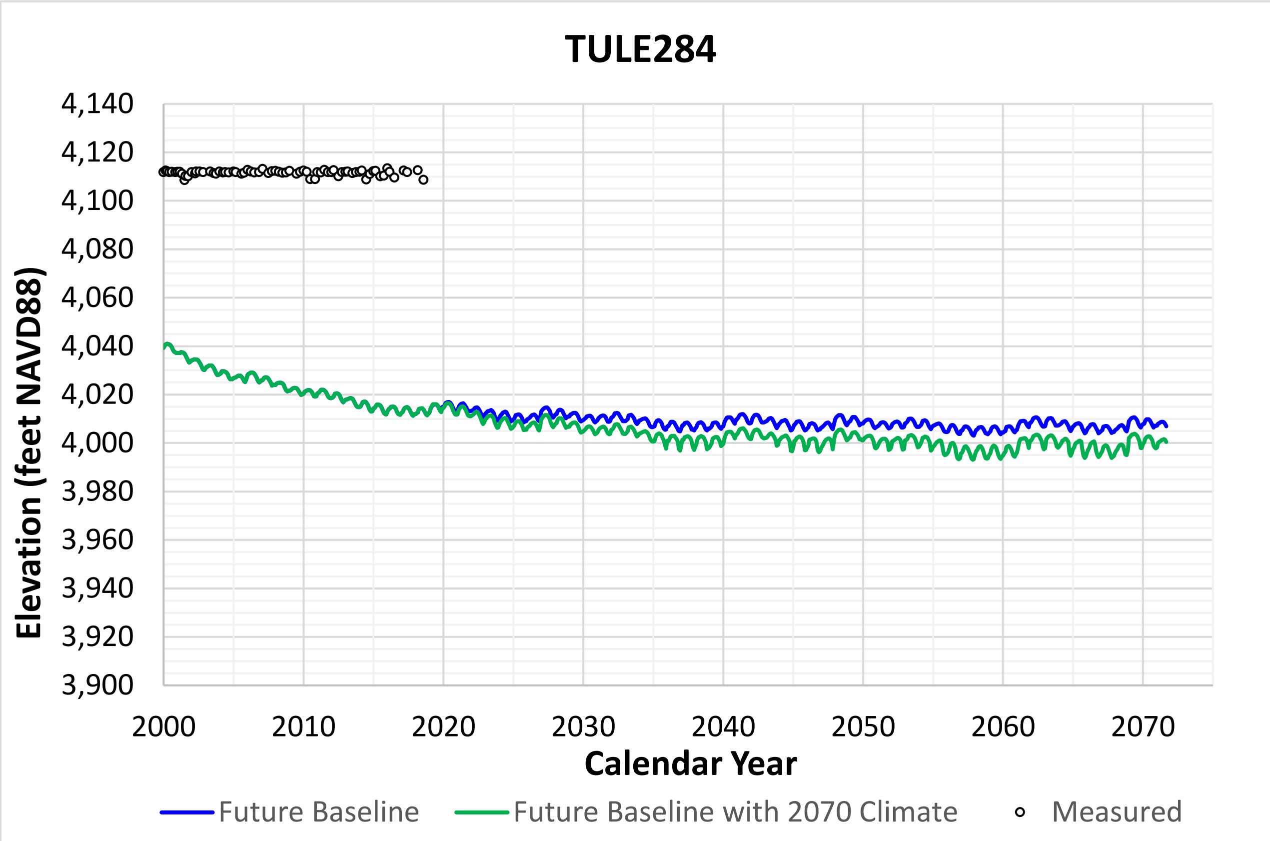




**Figure 5-6**
Comparison of Projected Groundwater Levels



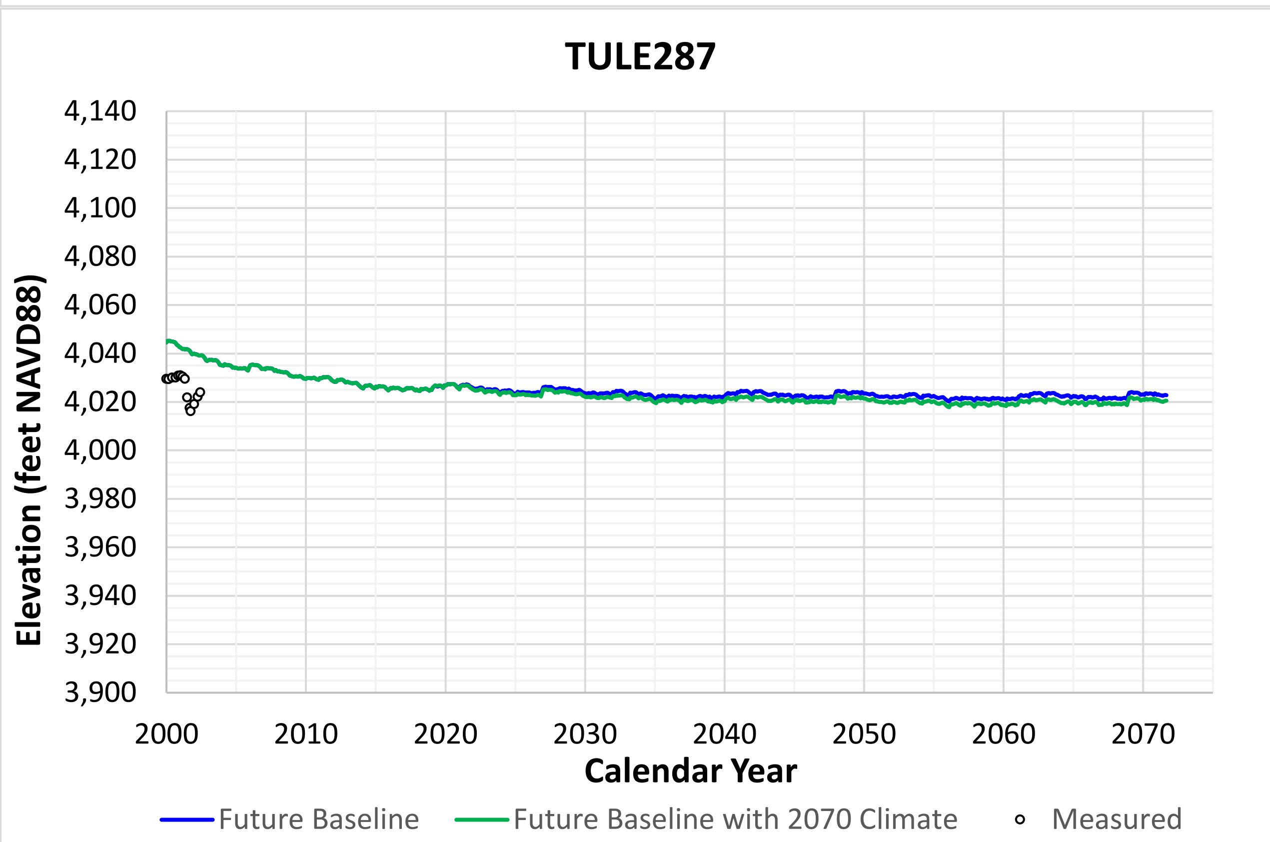
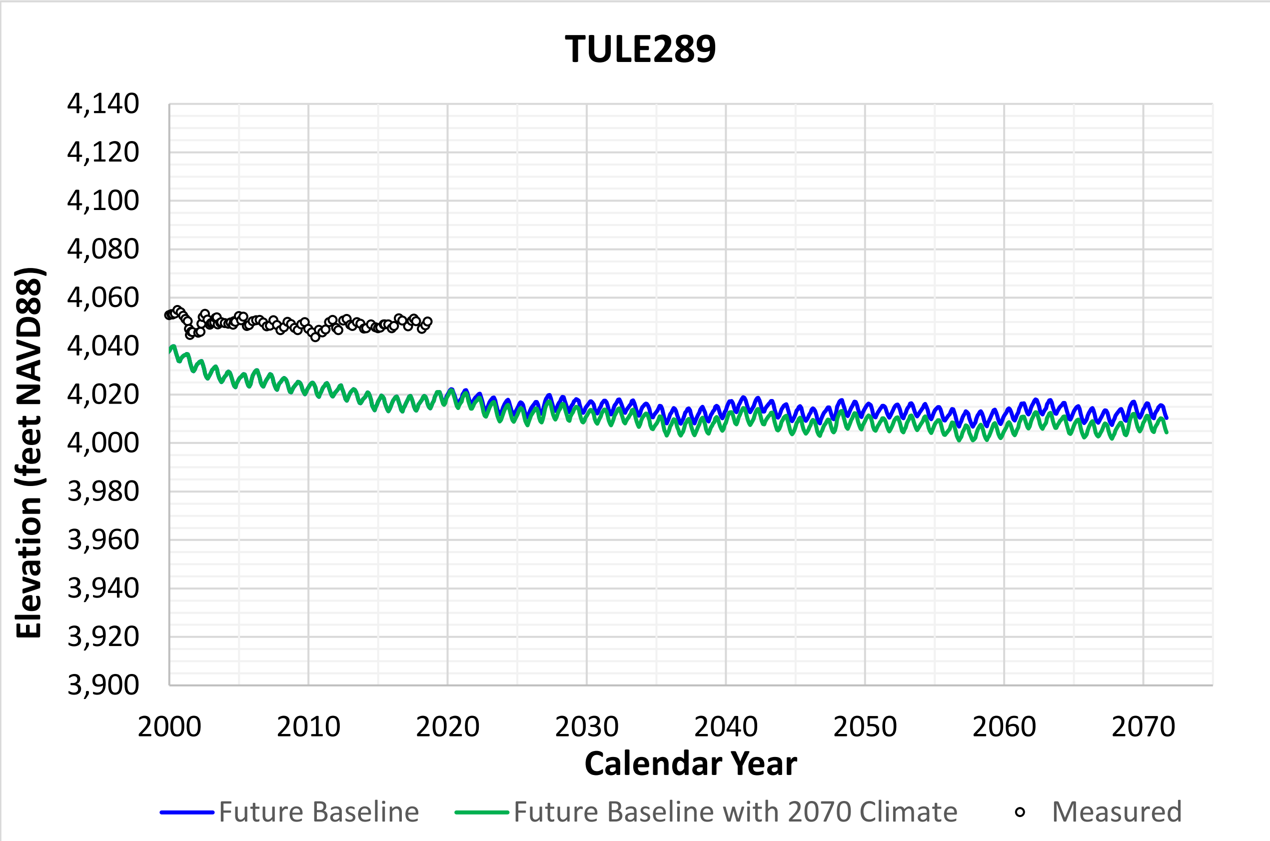




**Figure 5-6**
Comparison of Projected Groundwater Levels



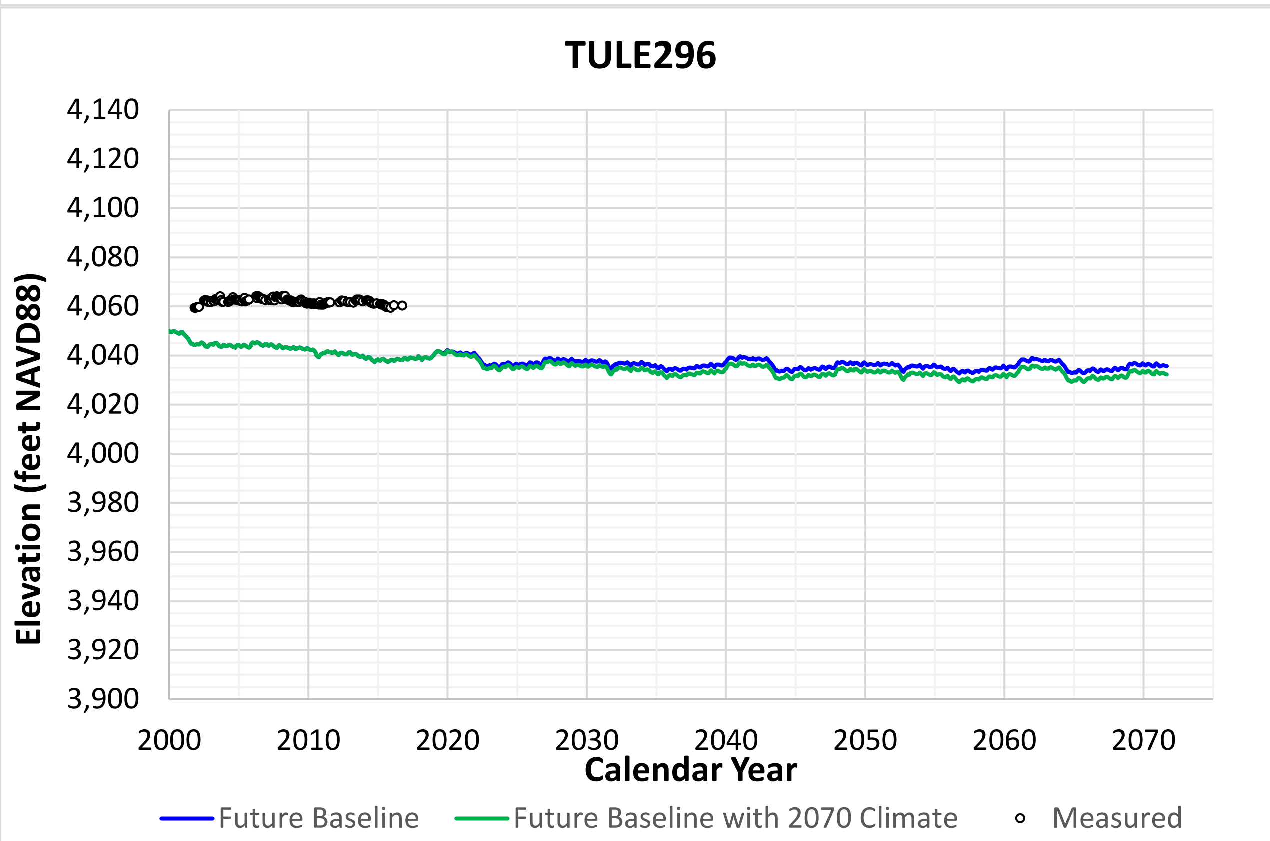
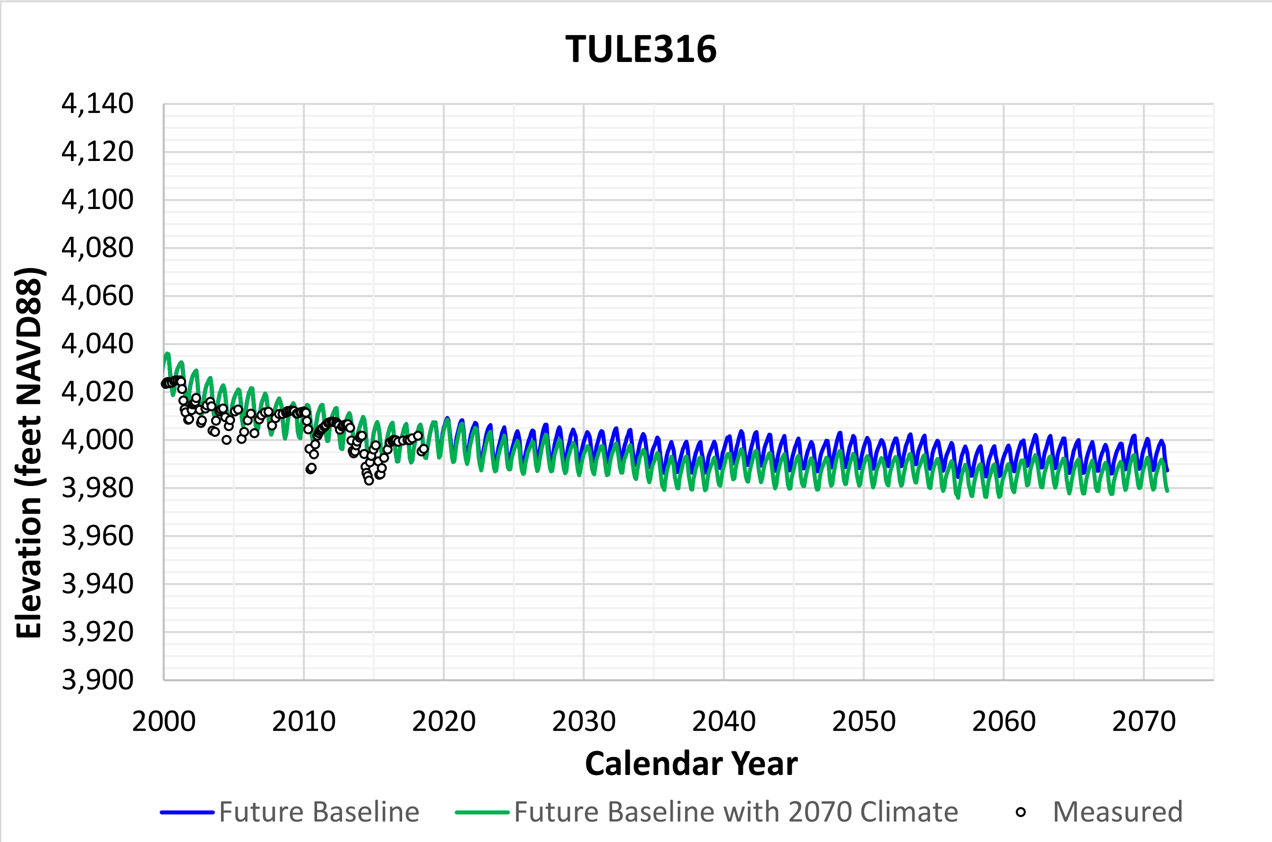




**Figure 5-6**
Comparison of Projected Groundwater Levels



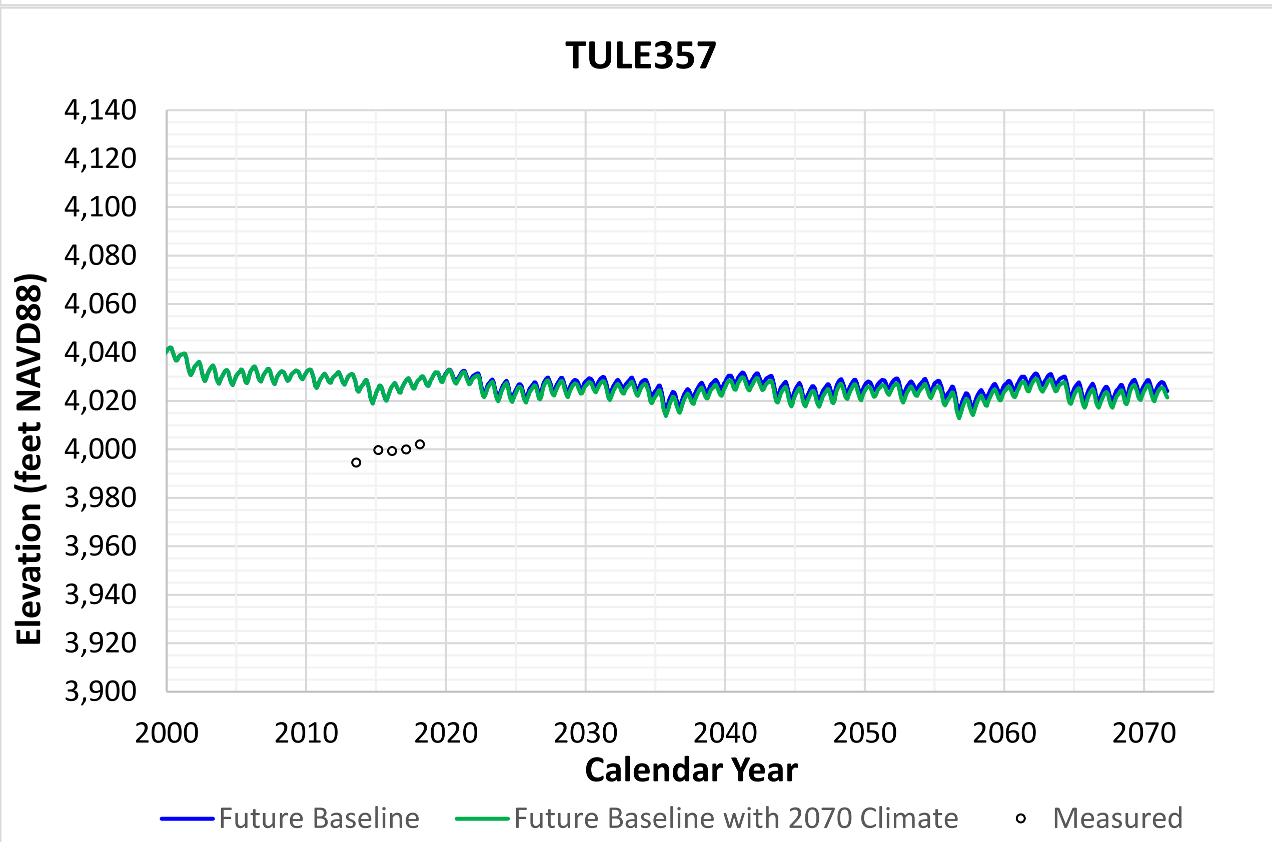
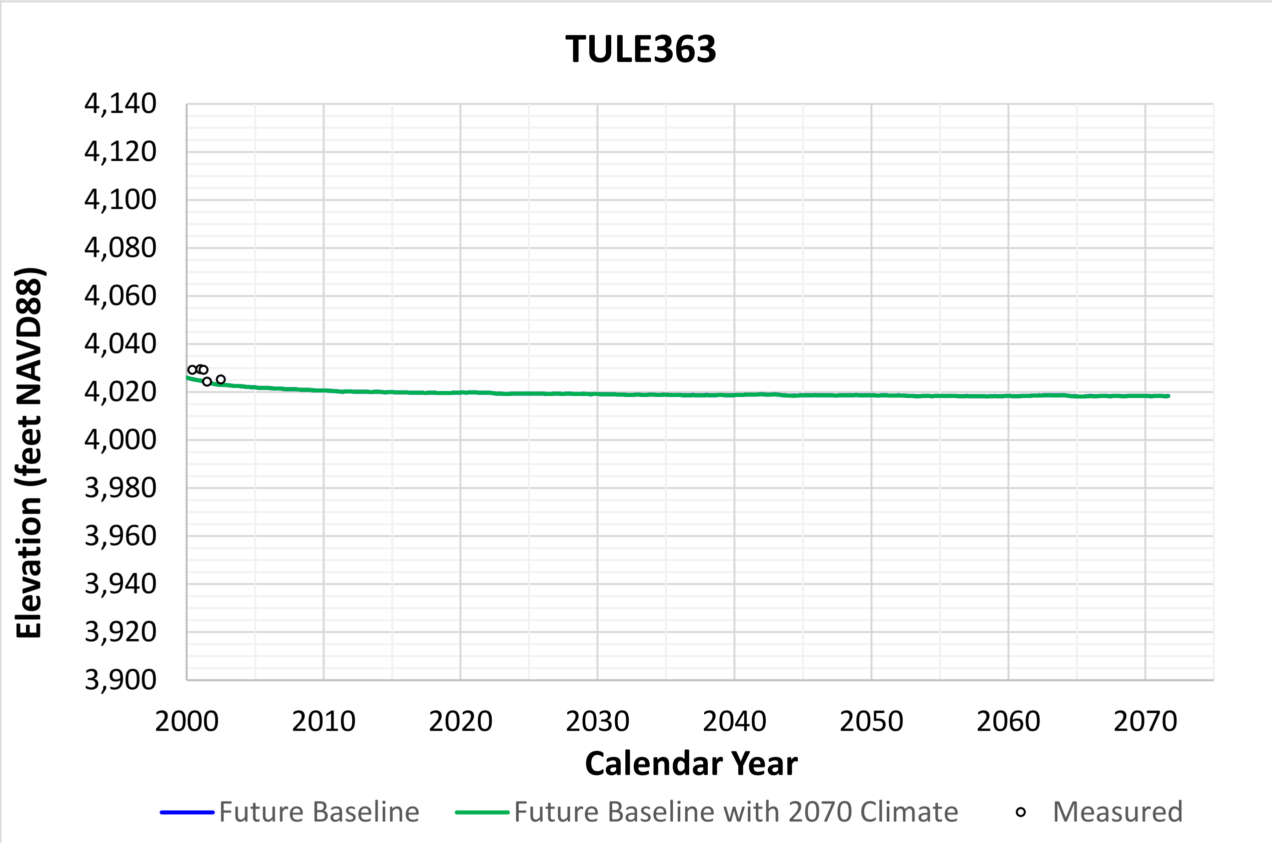
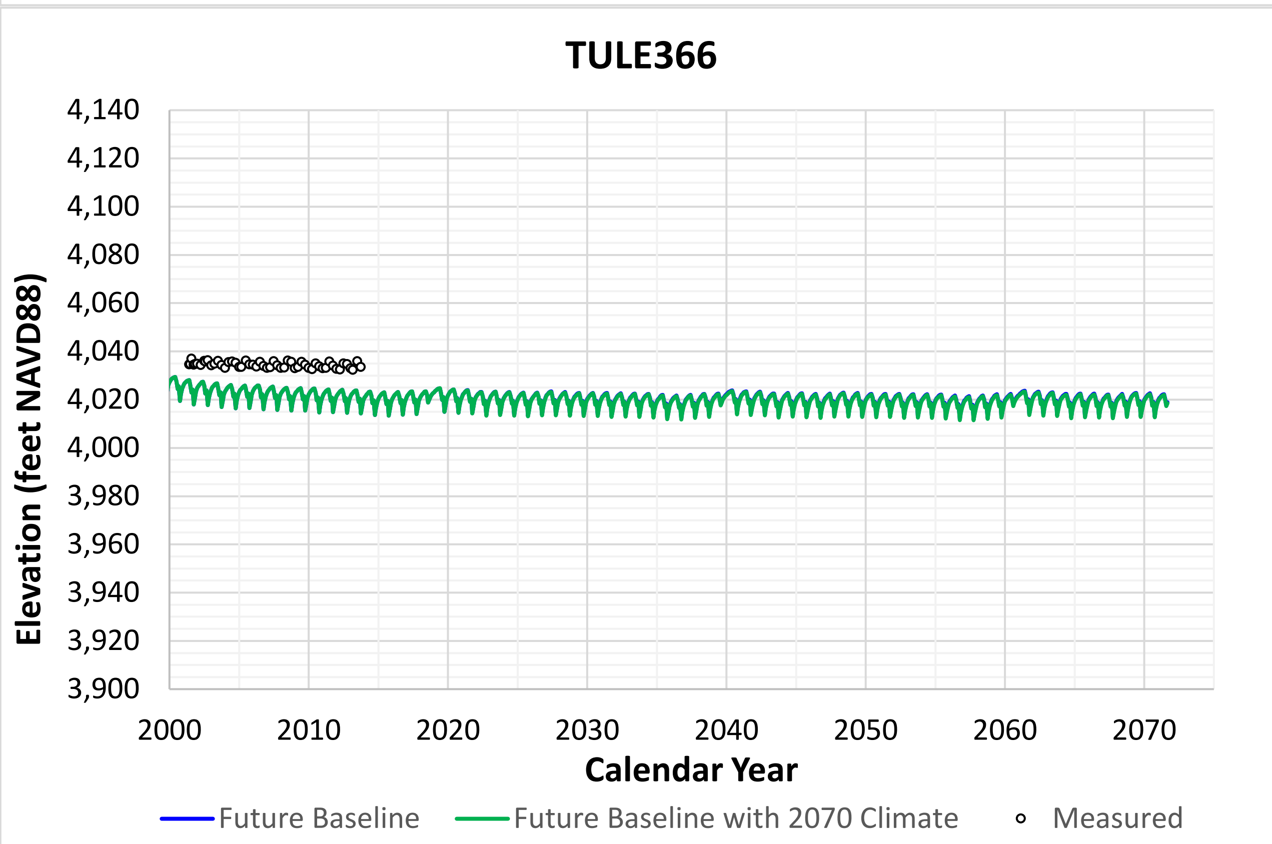




**Figure 5-6**
Comparison of Projected Groundwater Levels

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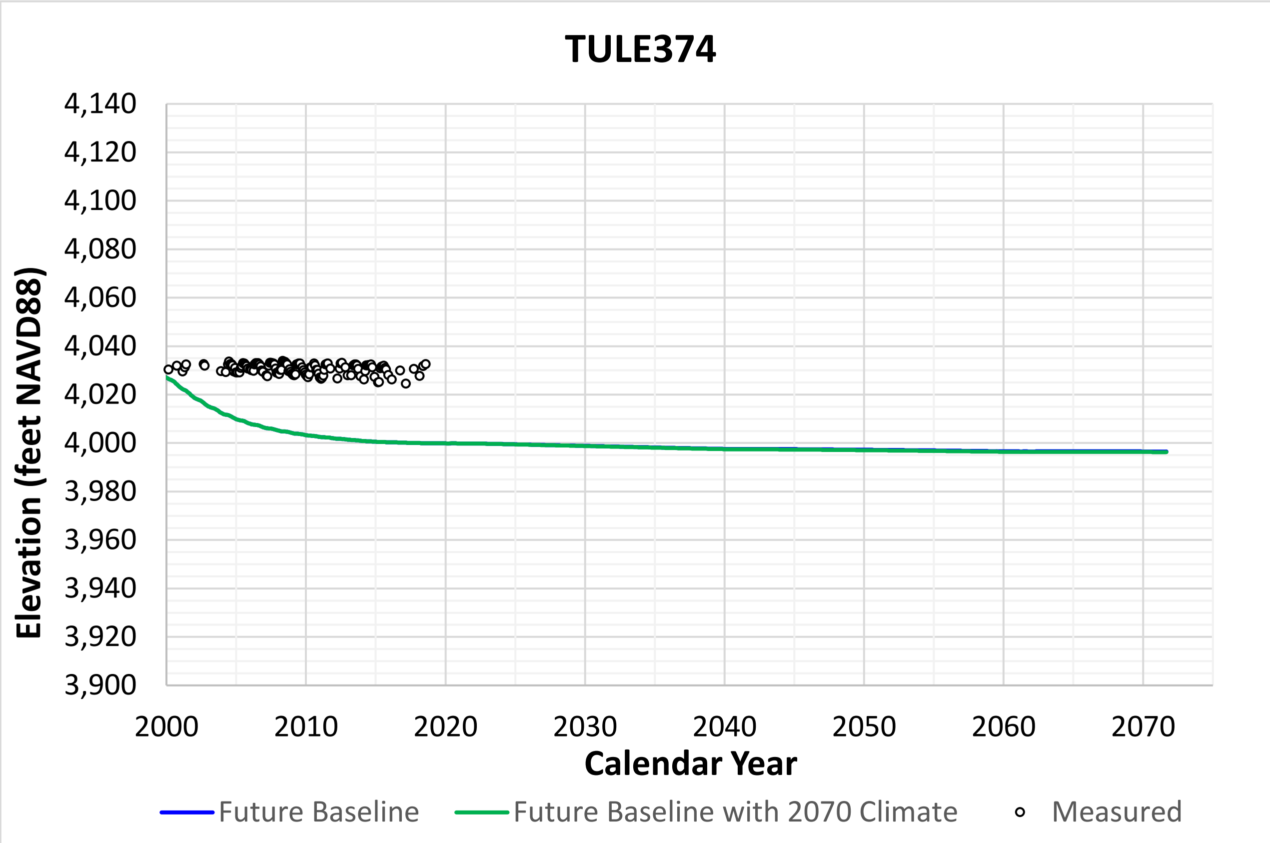


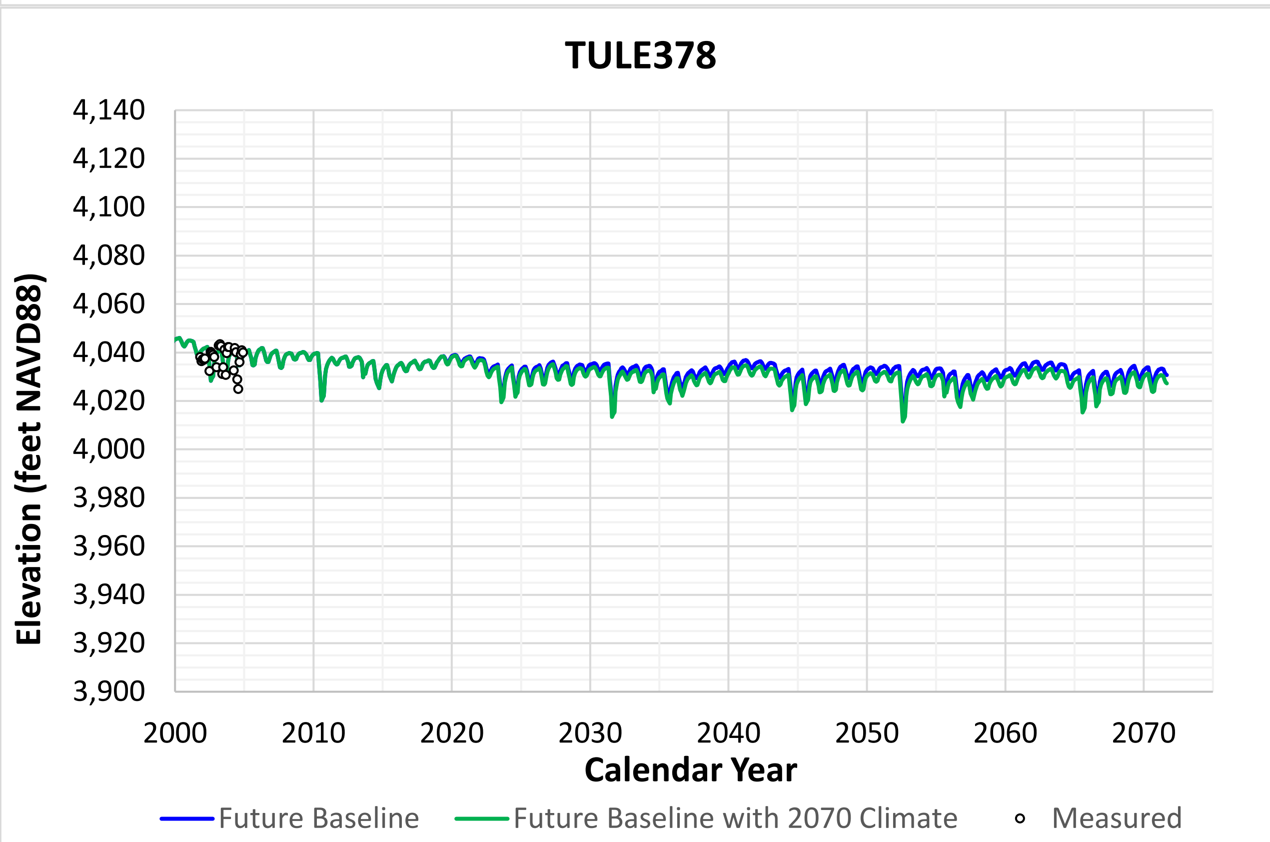


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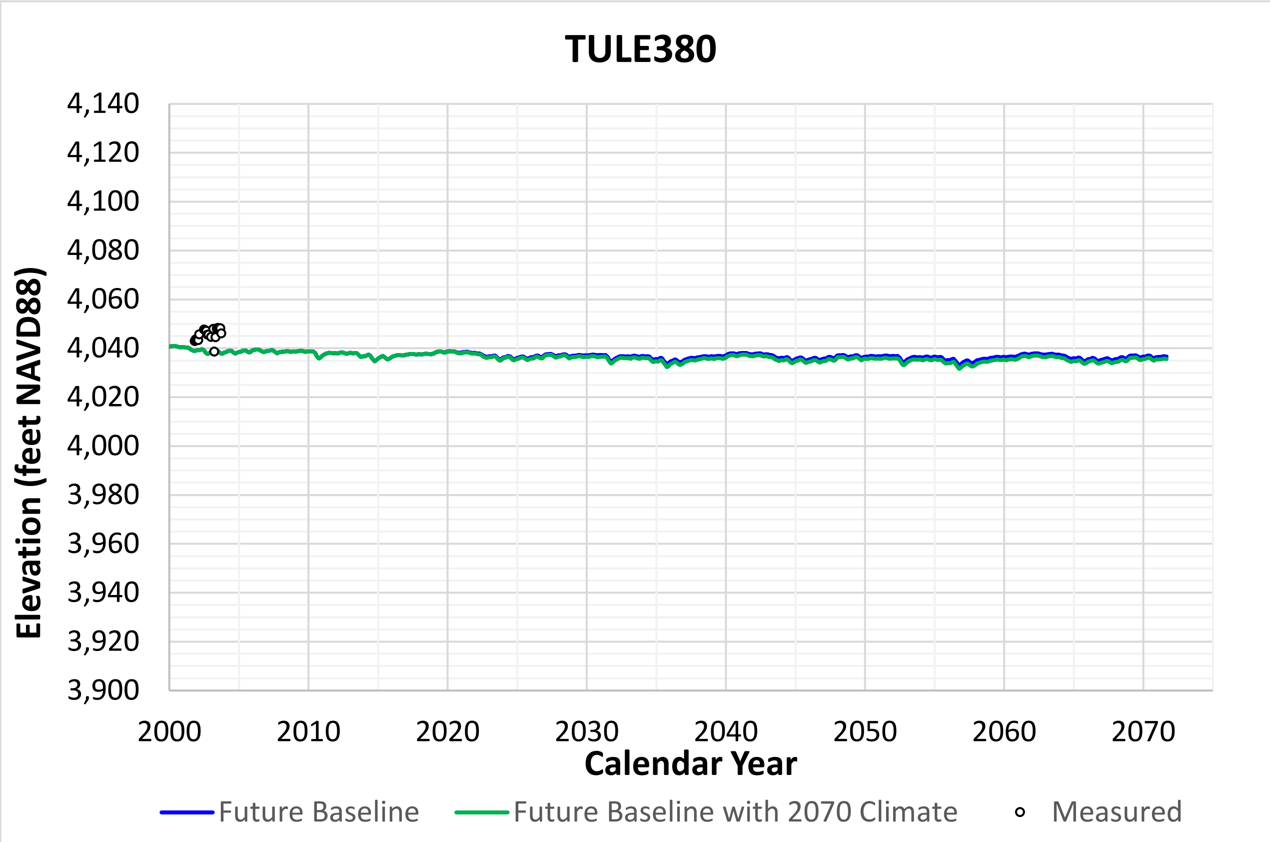


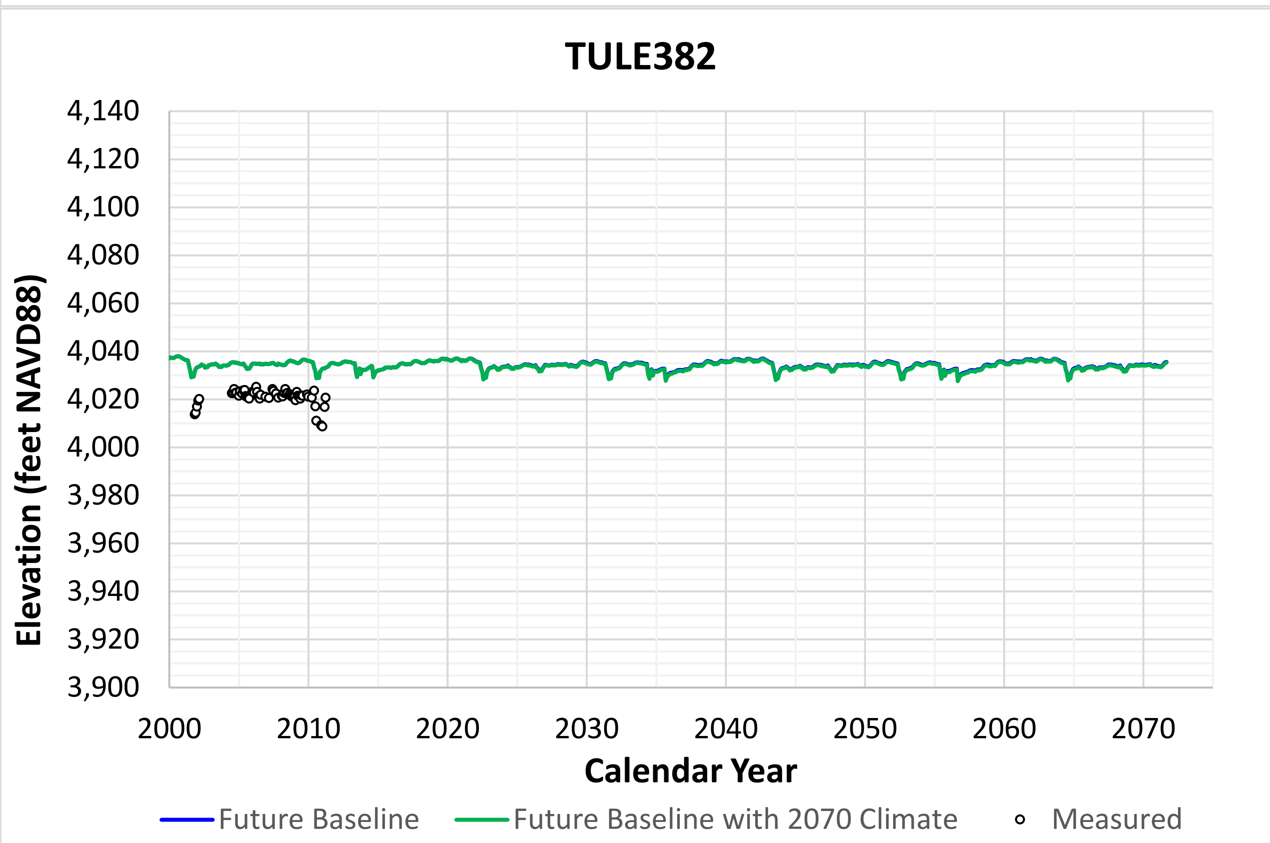


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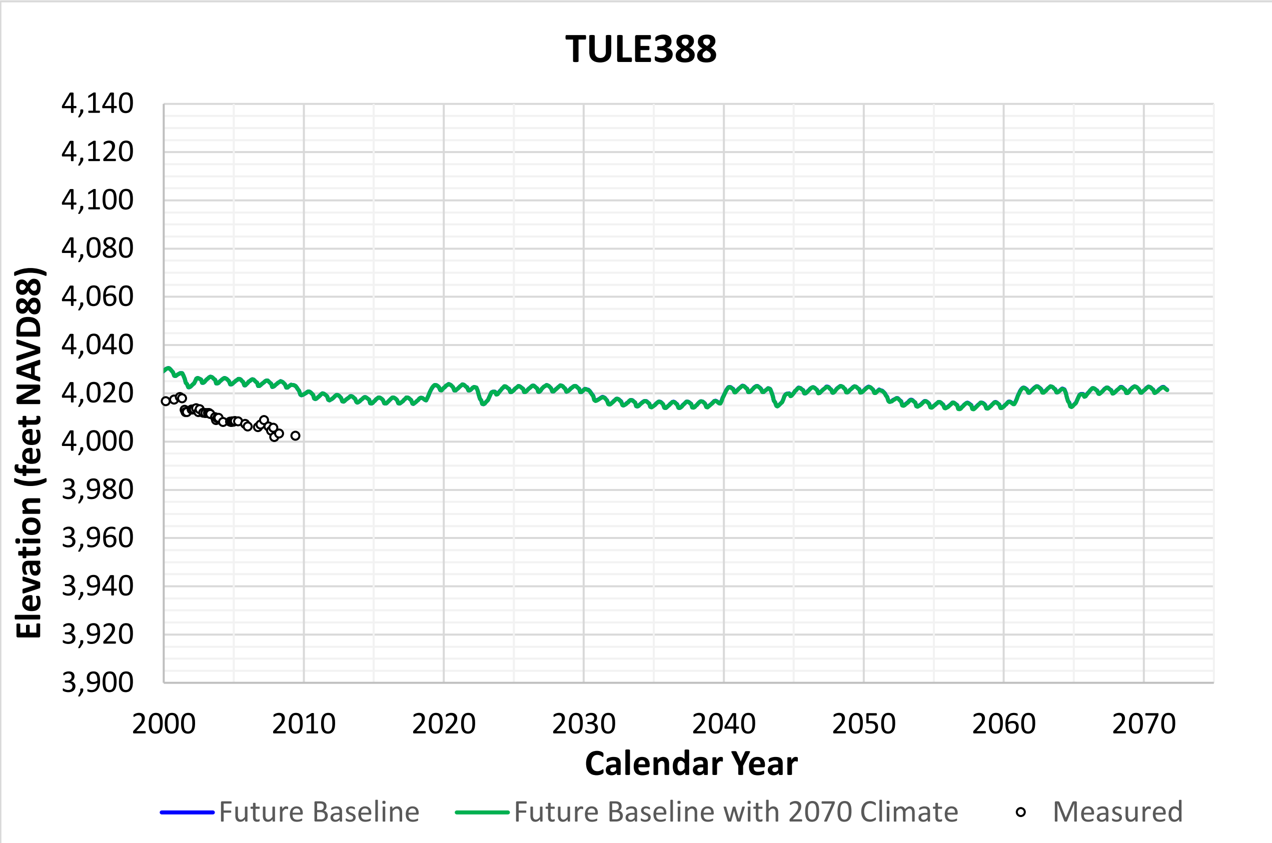


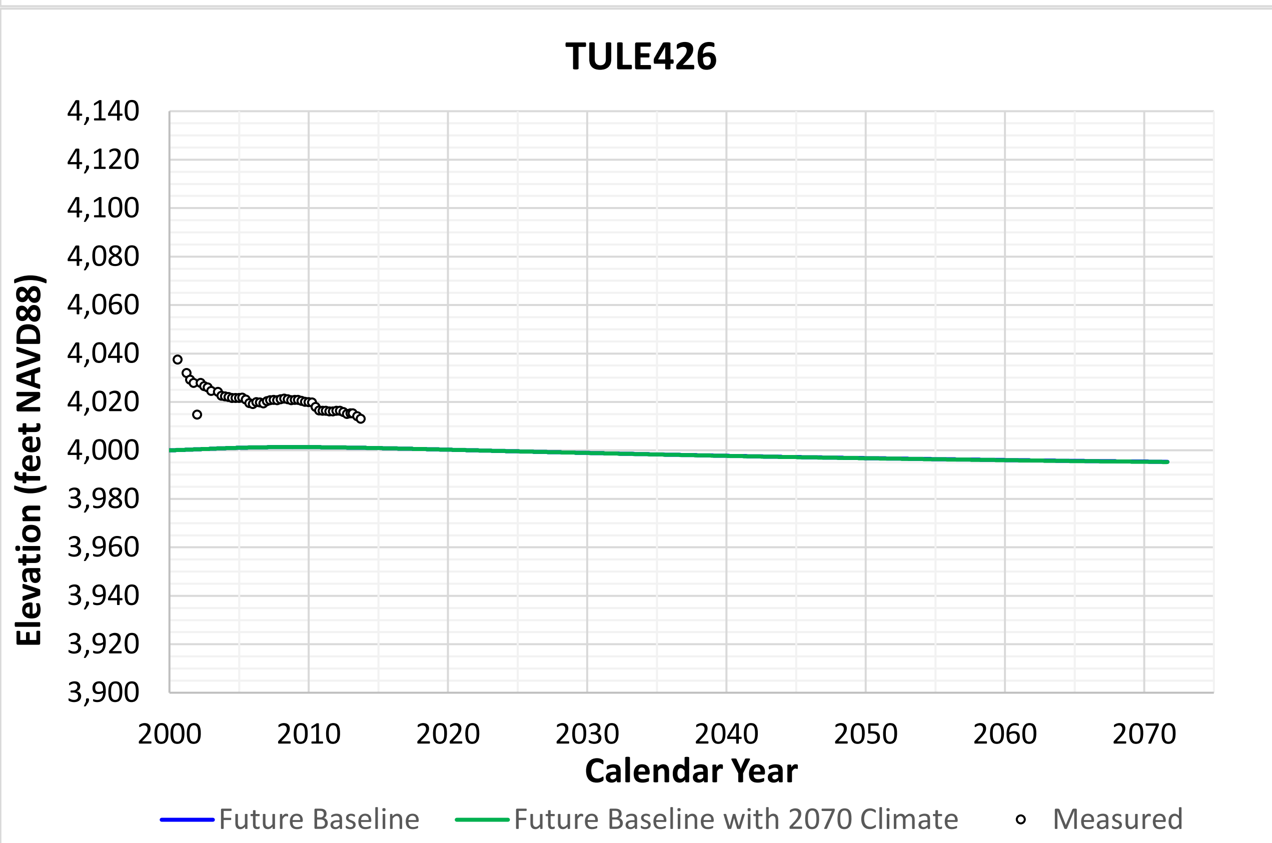


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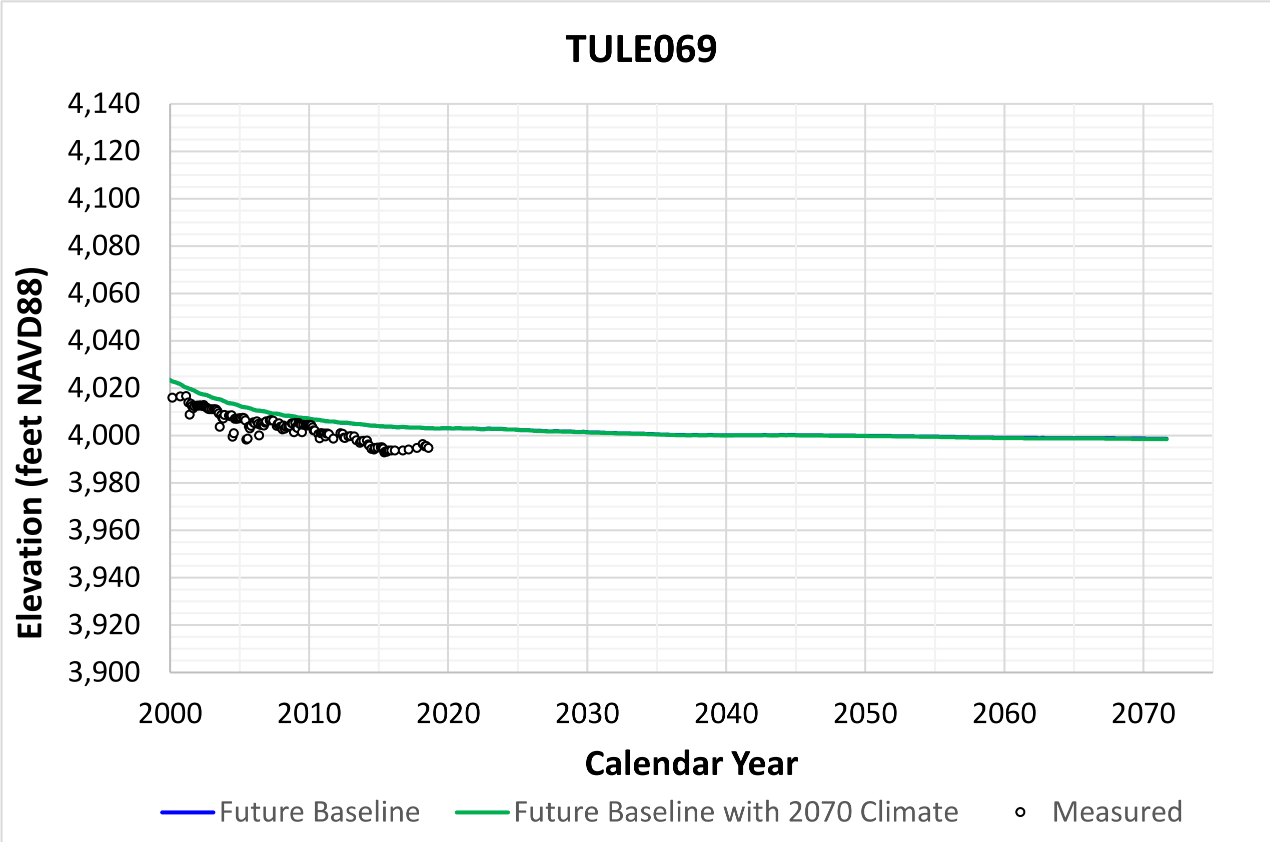


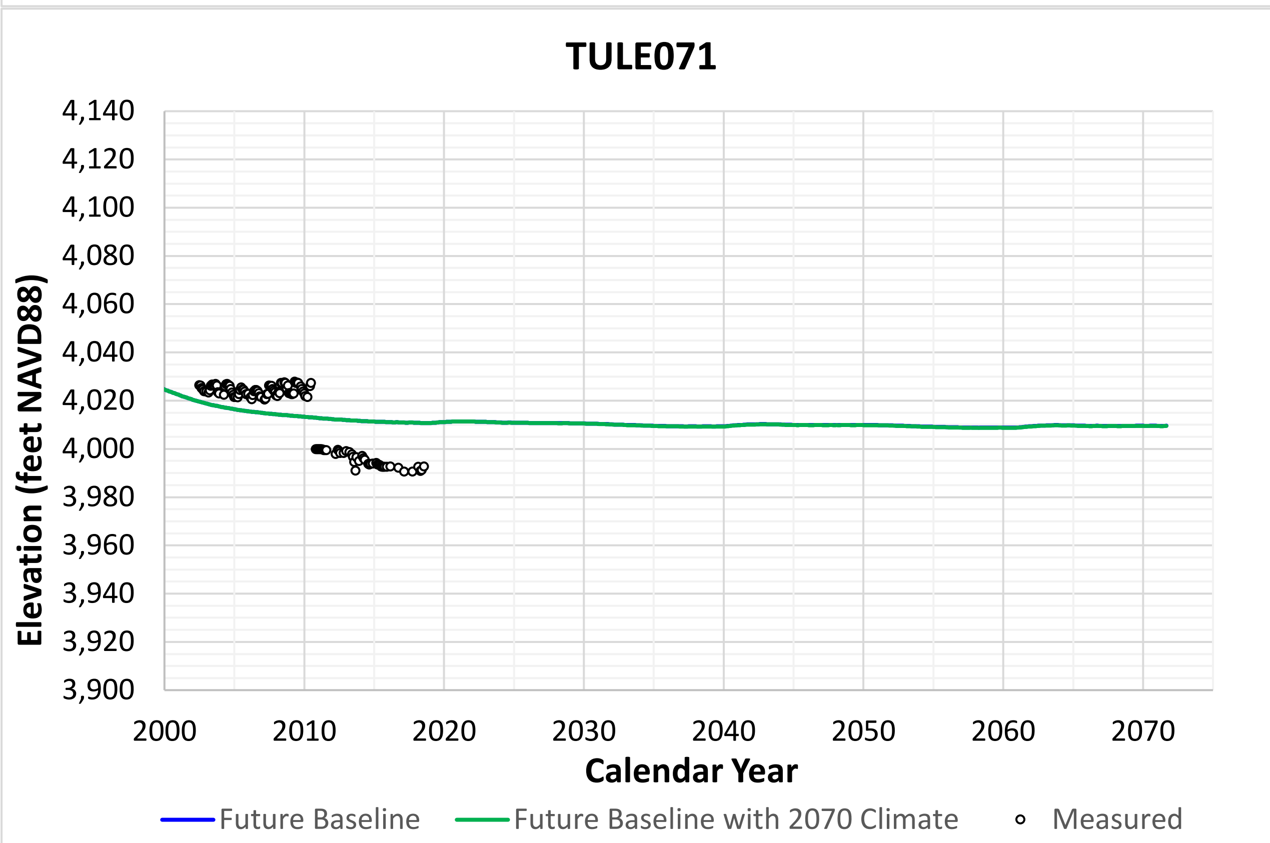


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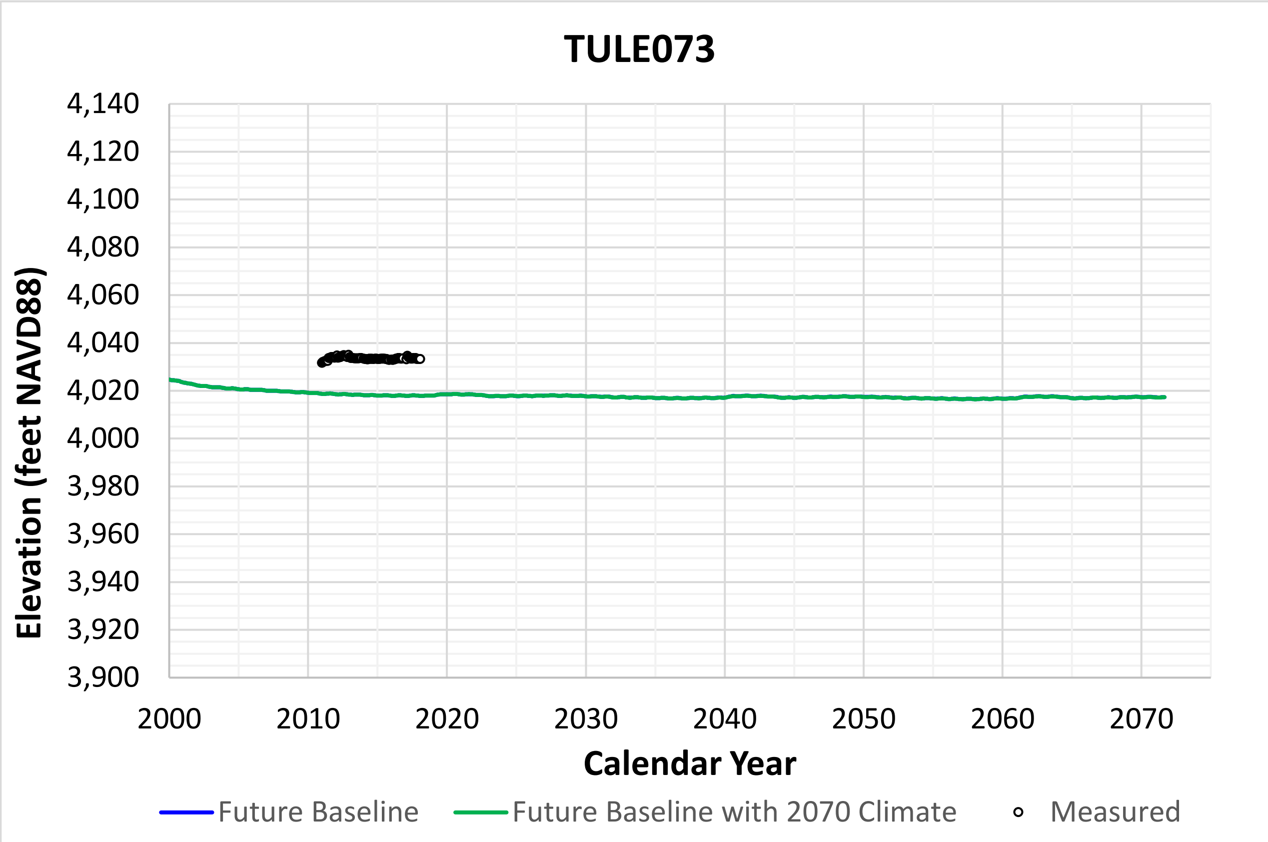


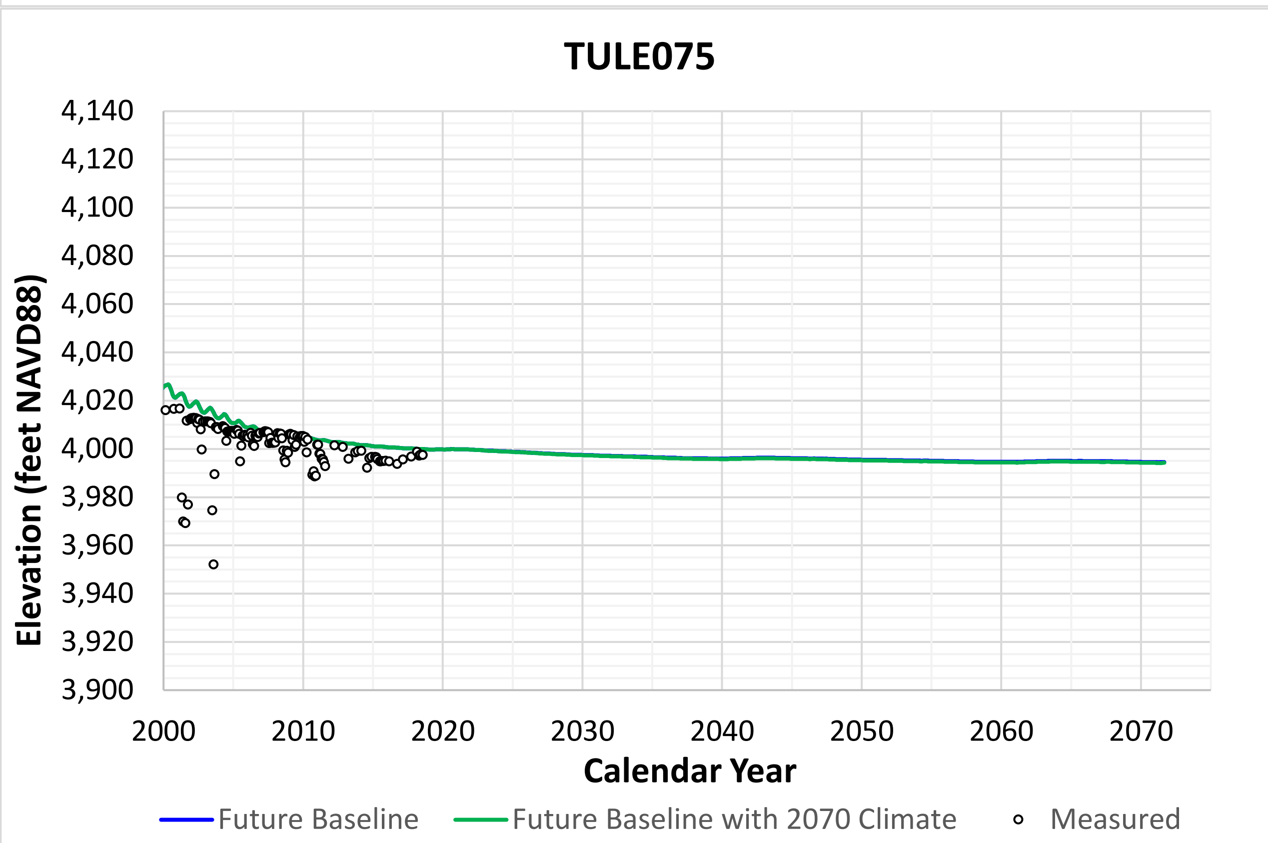


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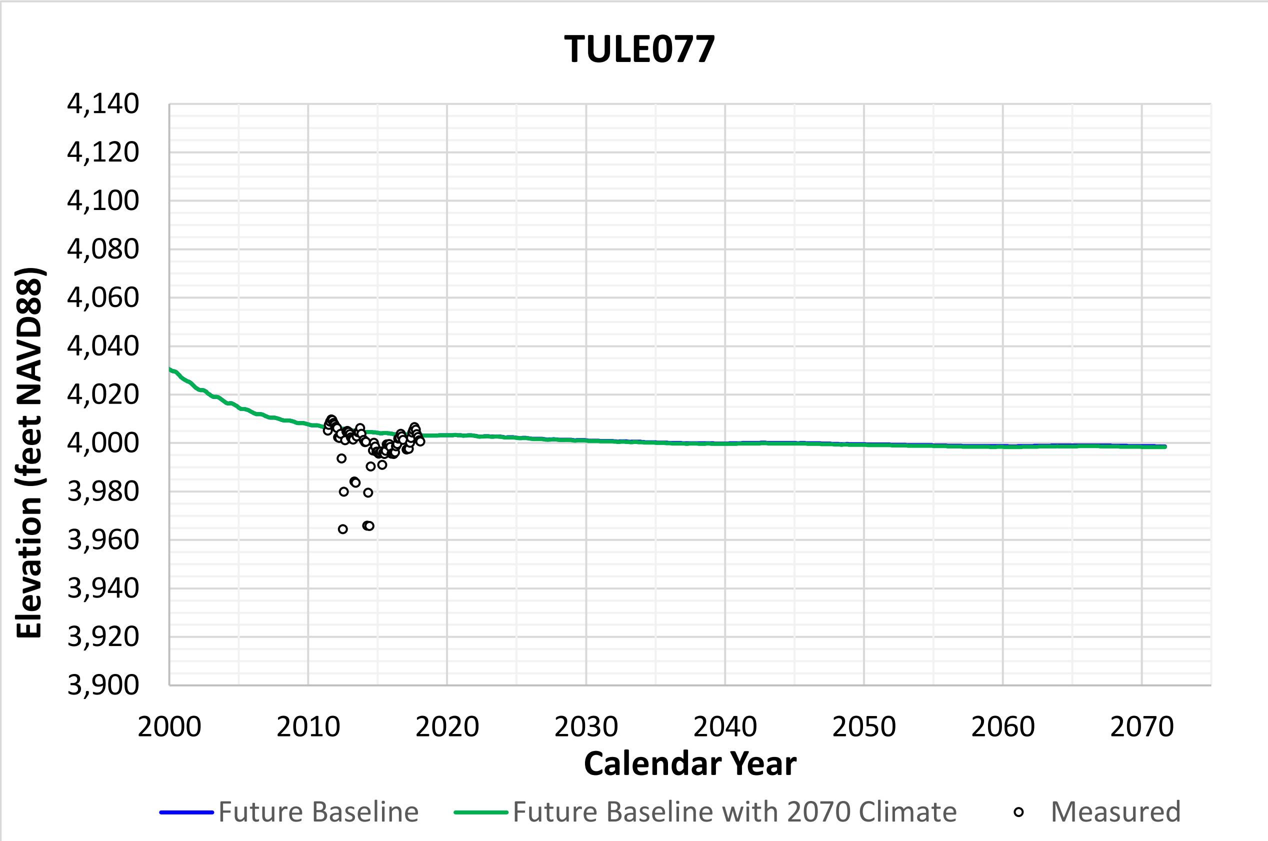


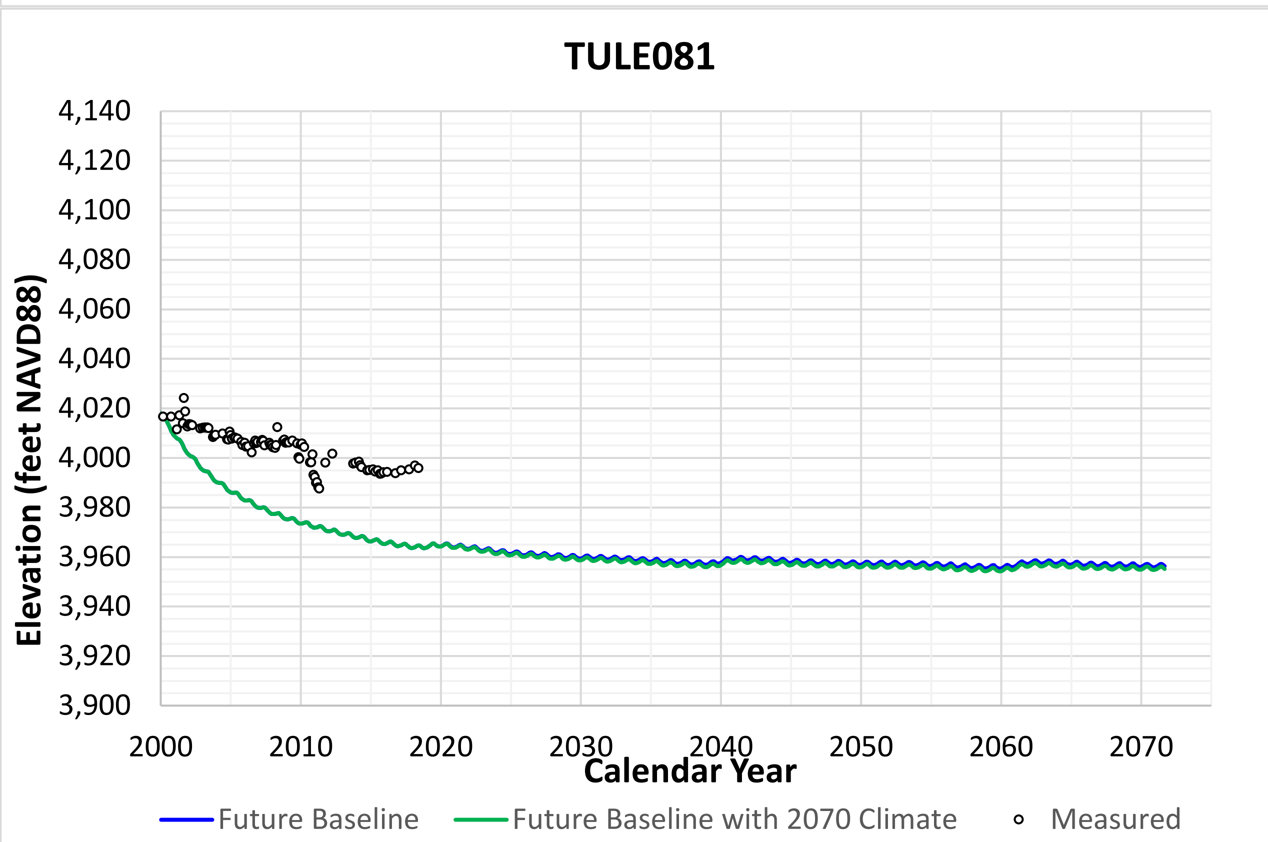


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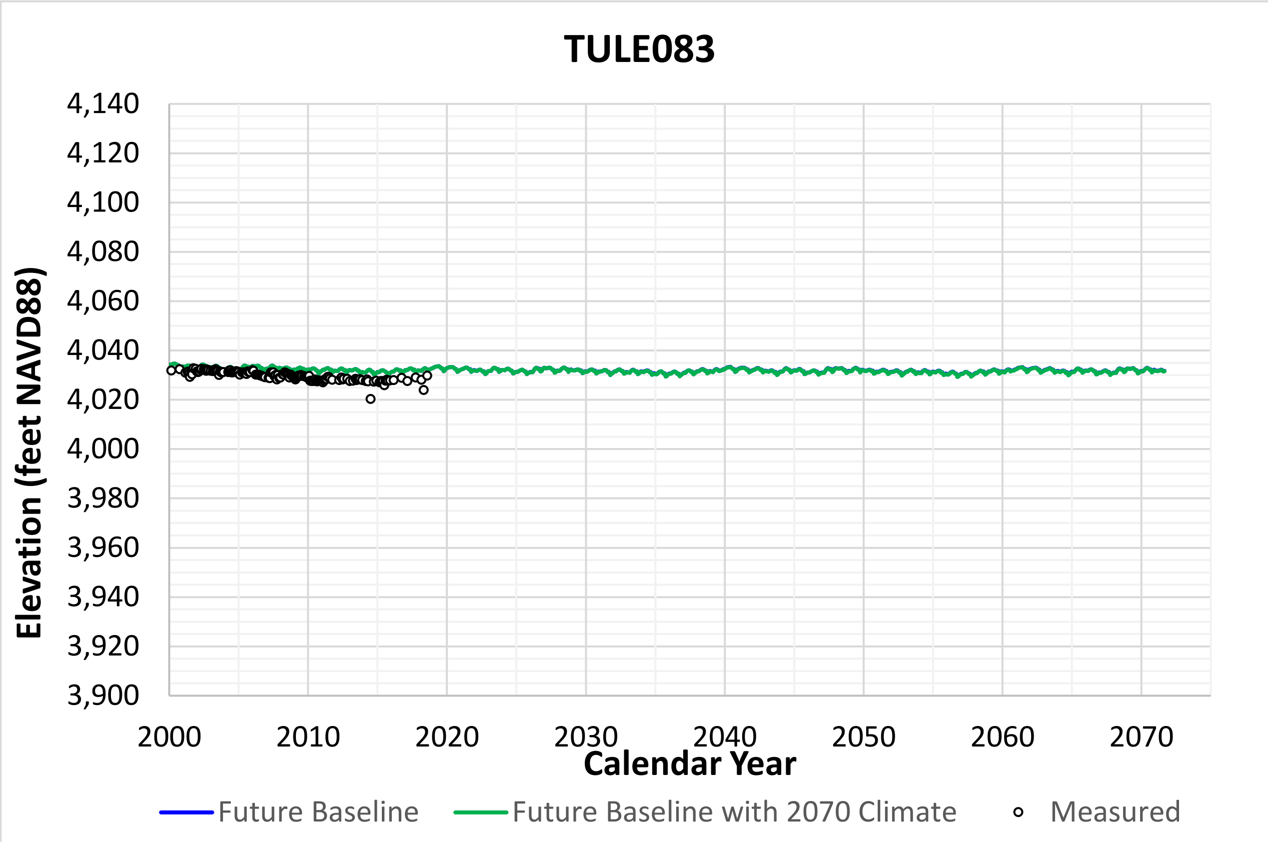


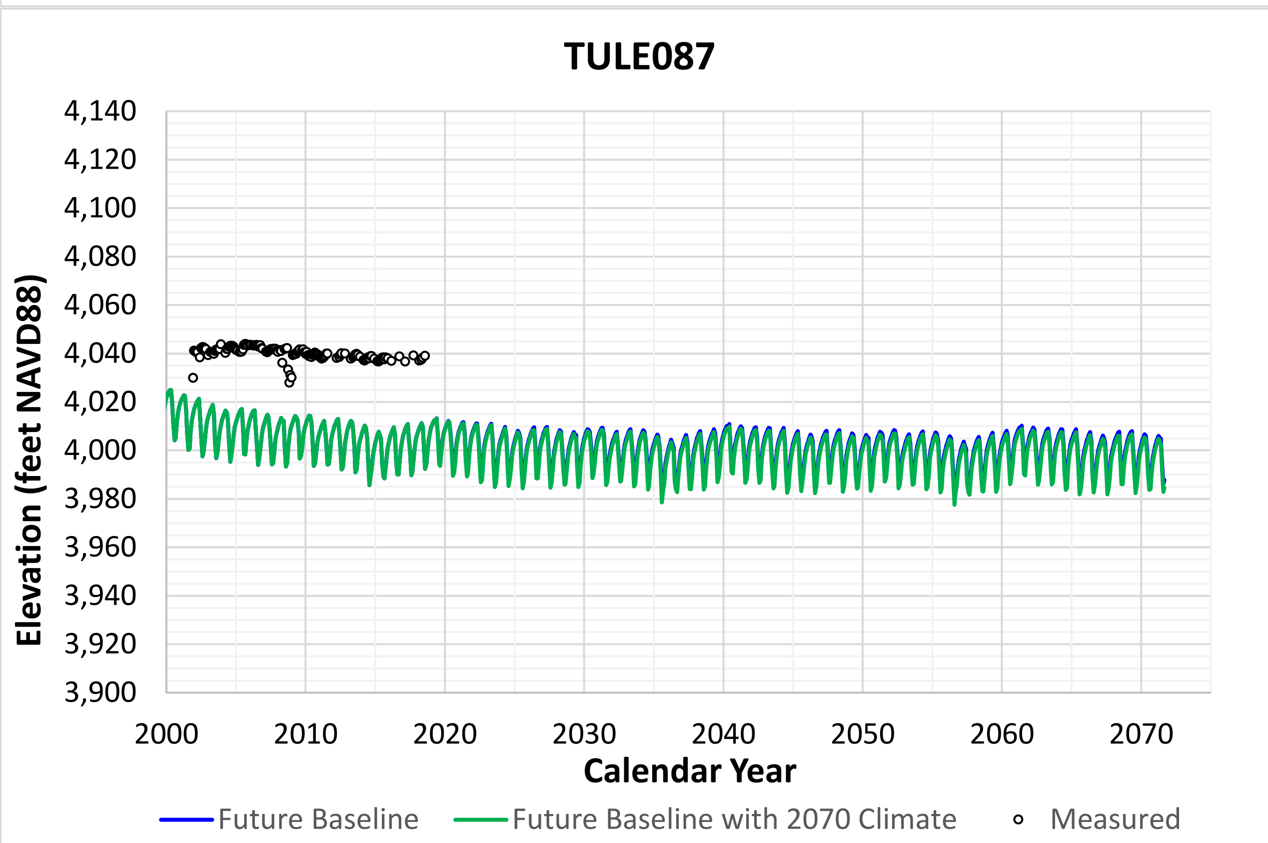


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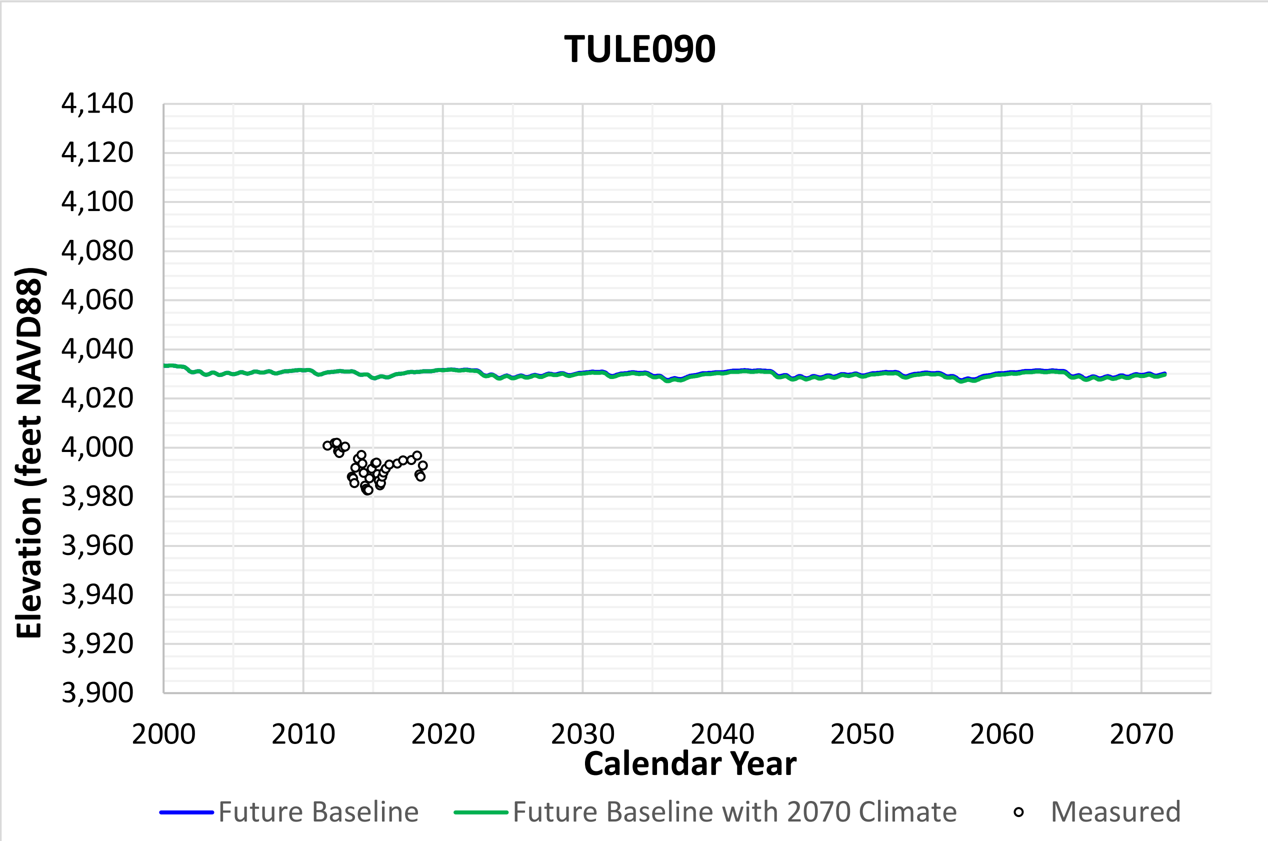


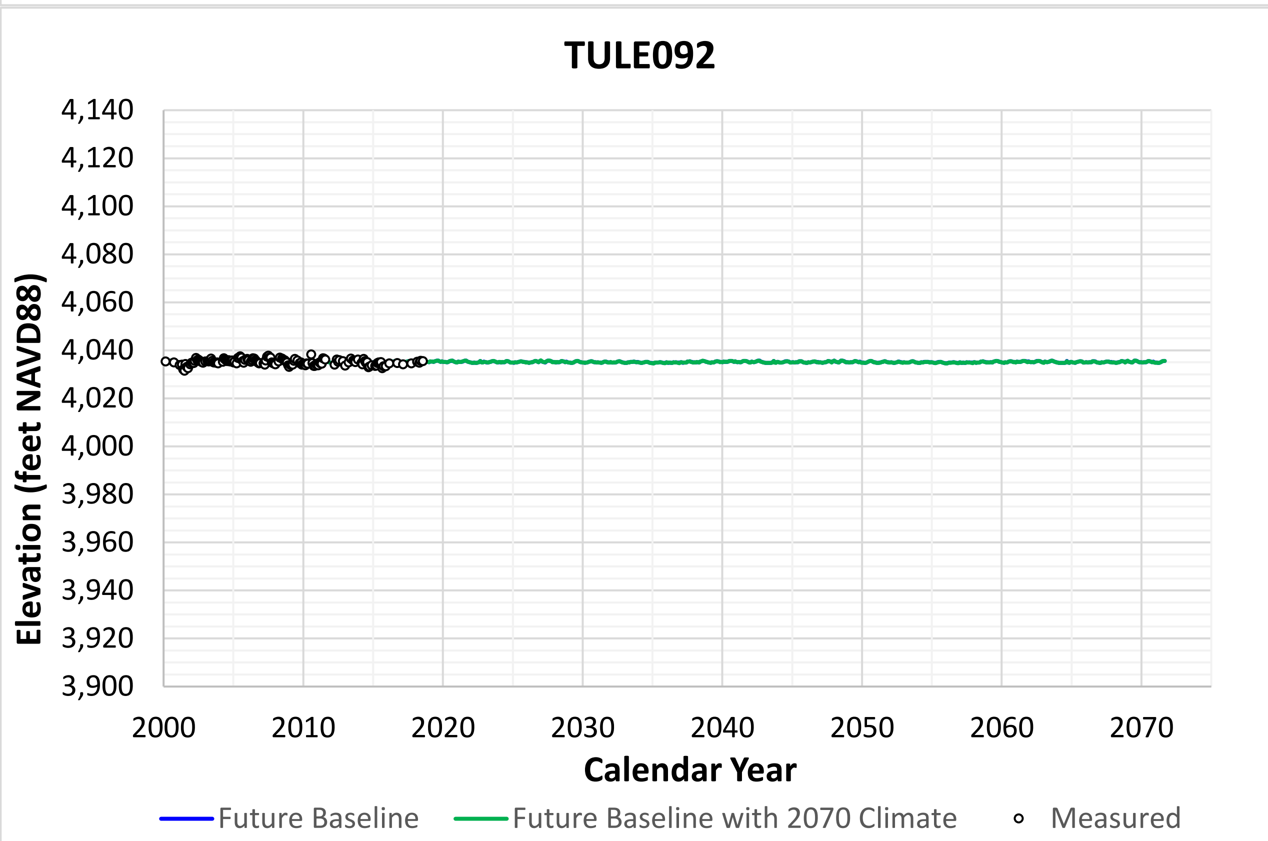


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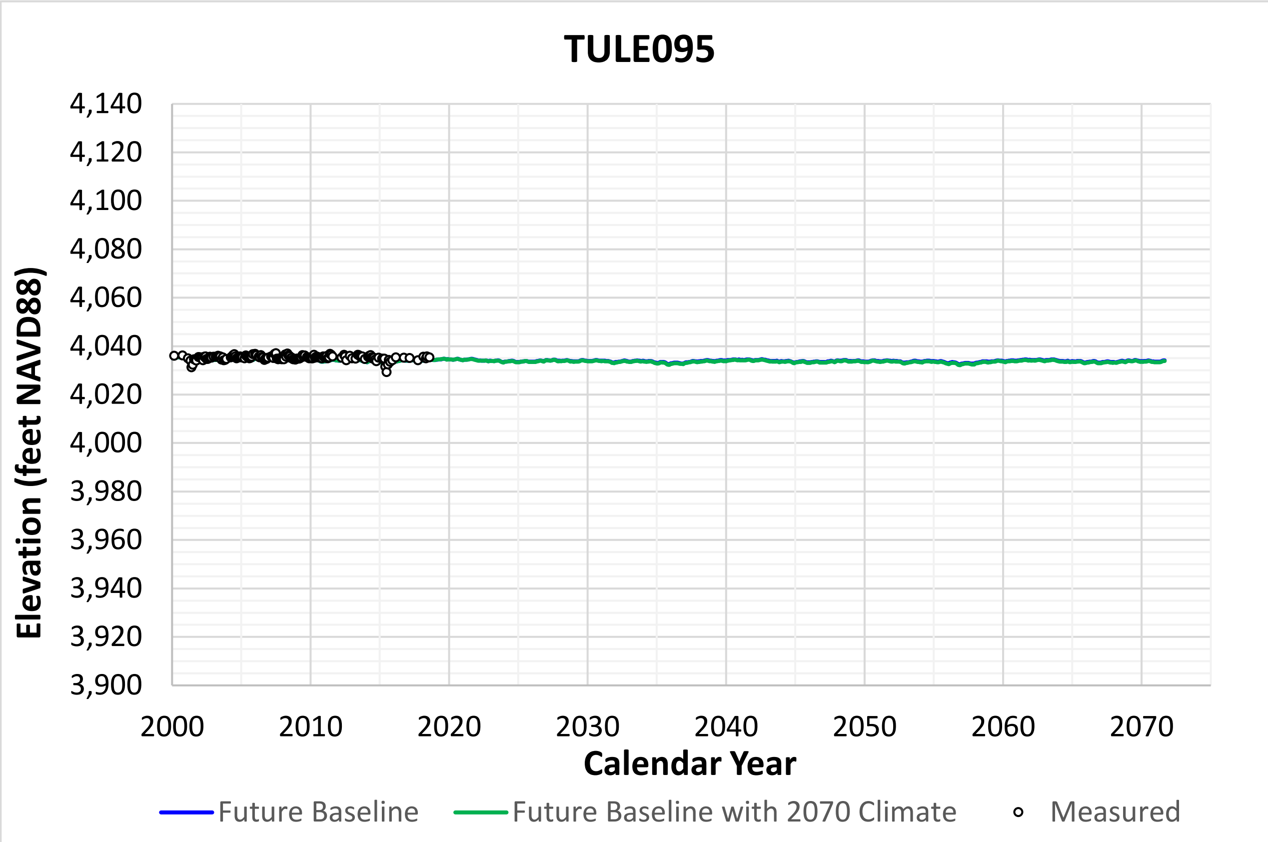


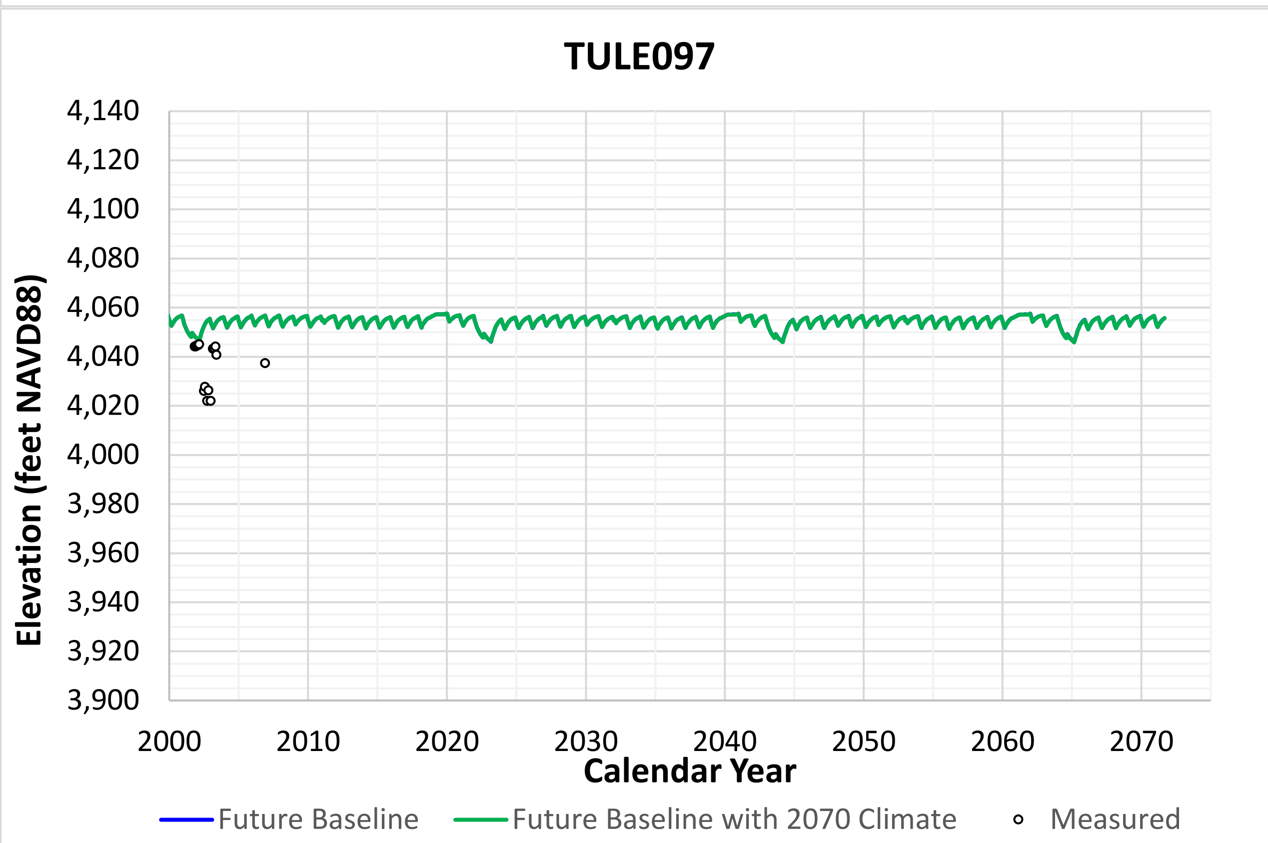


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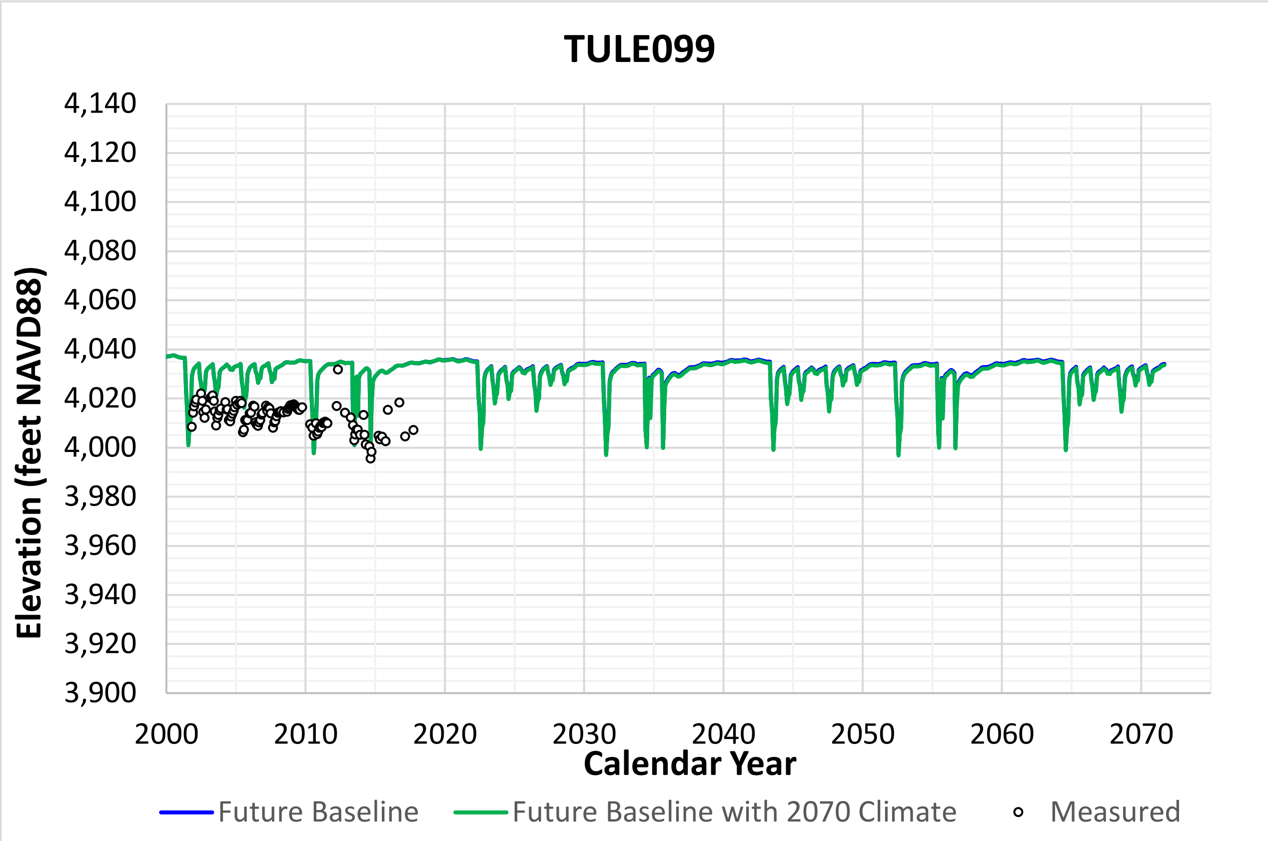
Comparison of Projected Groundwater Levels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4,080
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4,000
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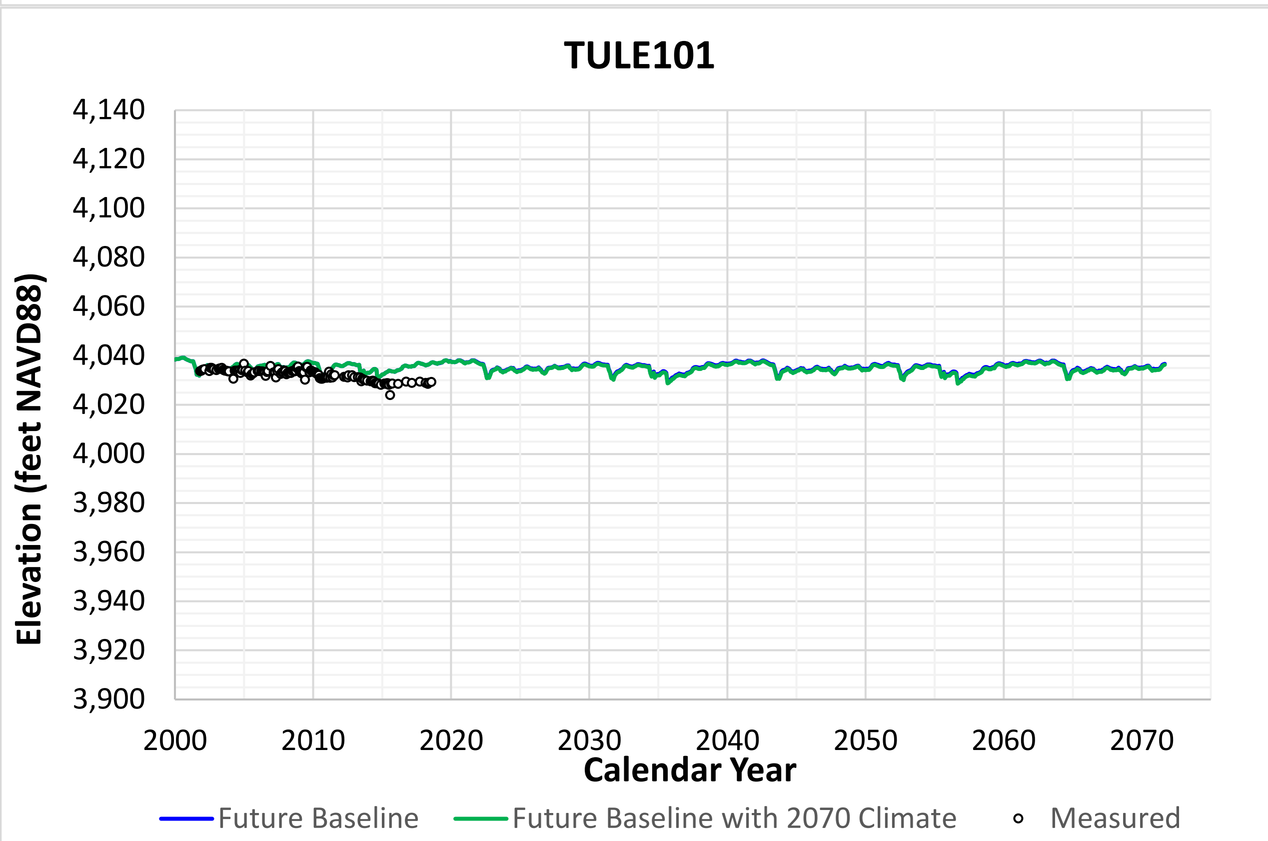
3,940
3,920
3,900
Elevation (feet NAVD88)
2000
2010
2020
2030
2040
2050
2060
2070
Calendar Year
Future Baseline
Future Baseline with 2070 Climate
Measured


TULE101
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Elevation (feet NAVD88)
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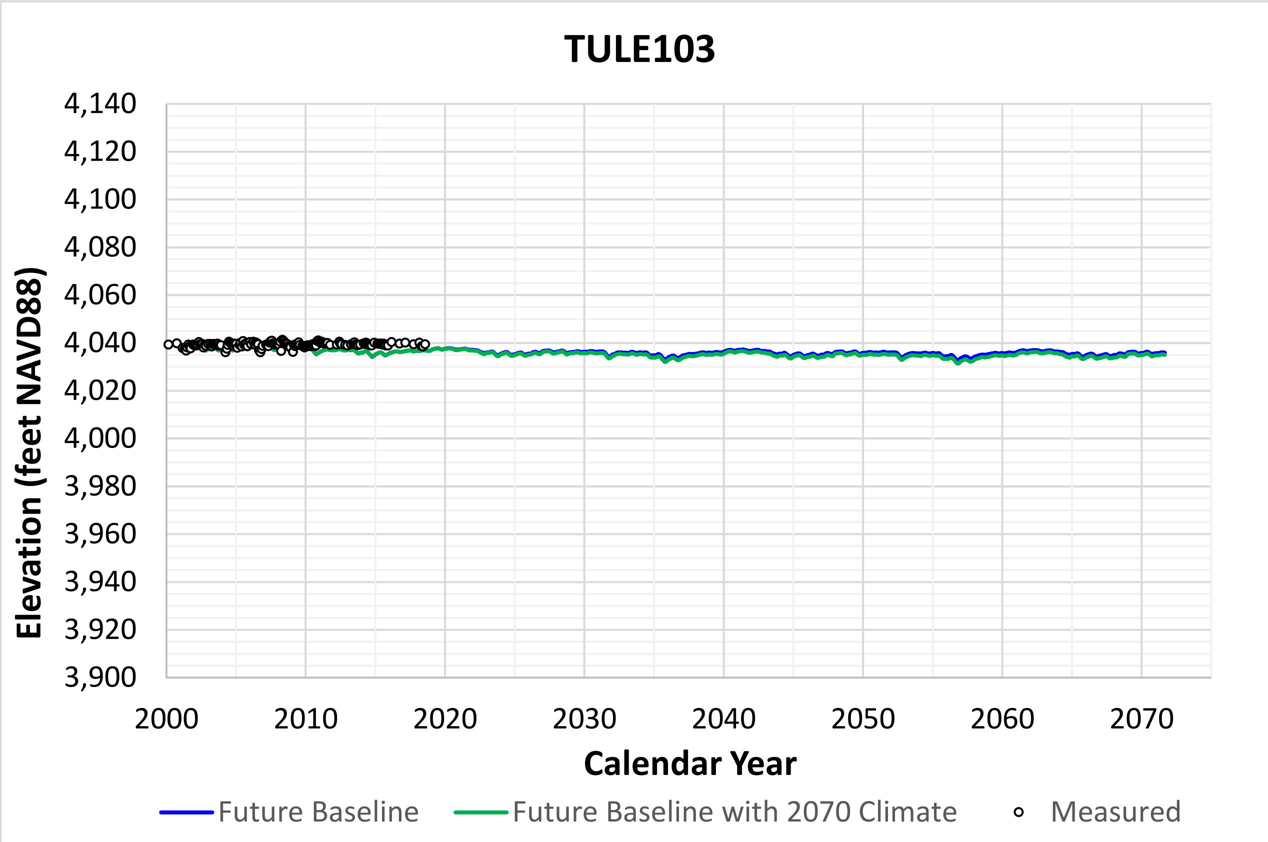
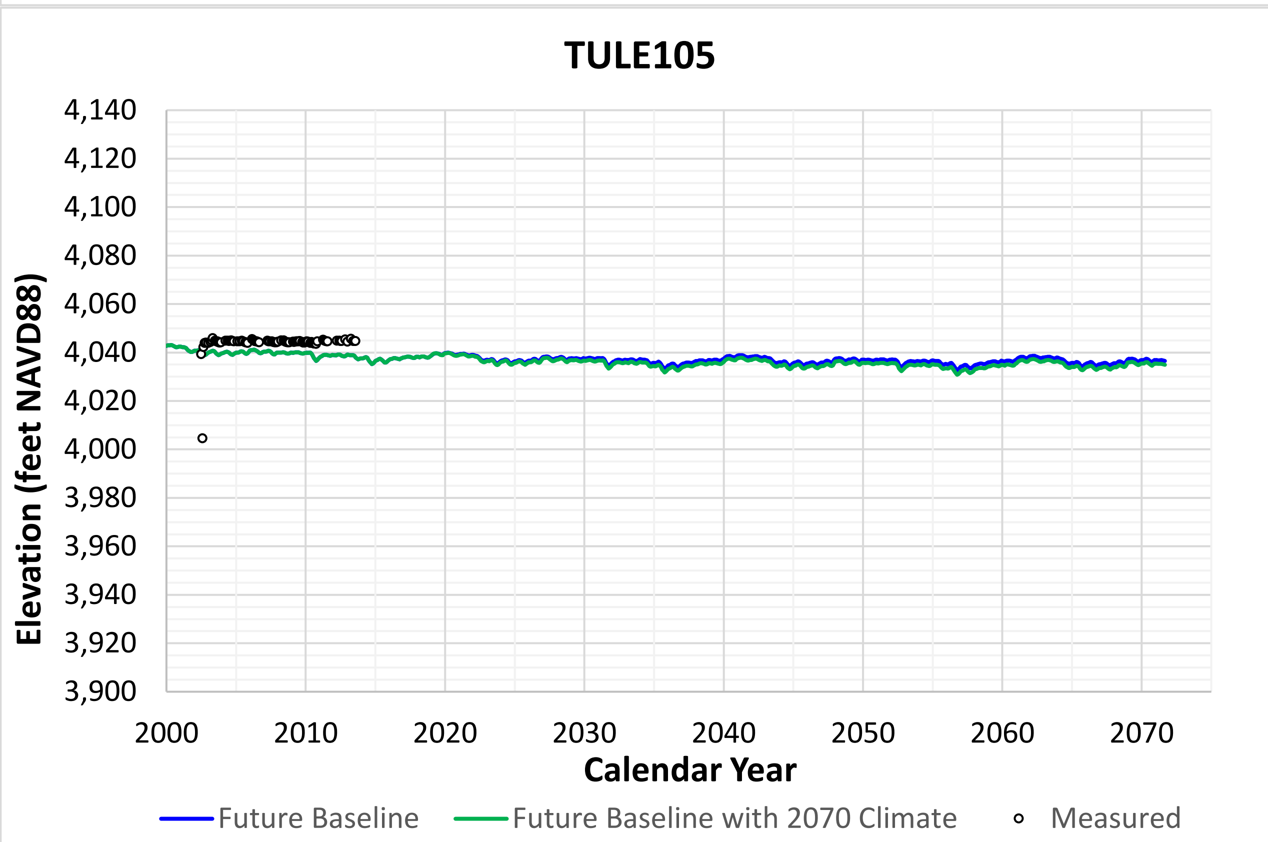
Calendar Year
Future Baseline
Future Baseline with 2070 Climate
Measured

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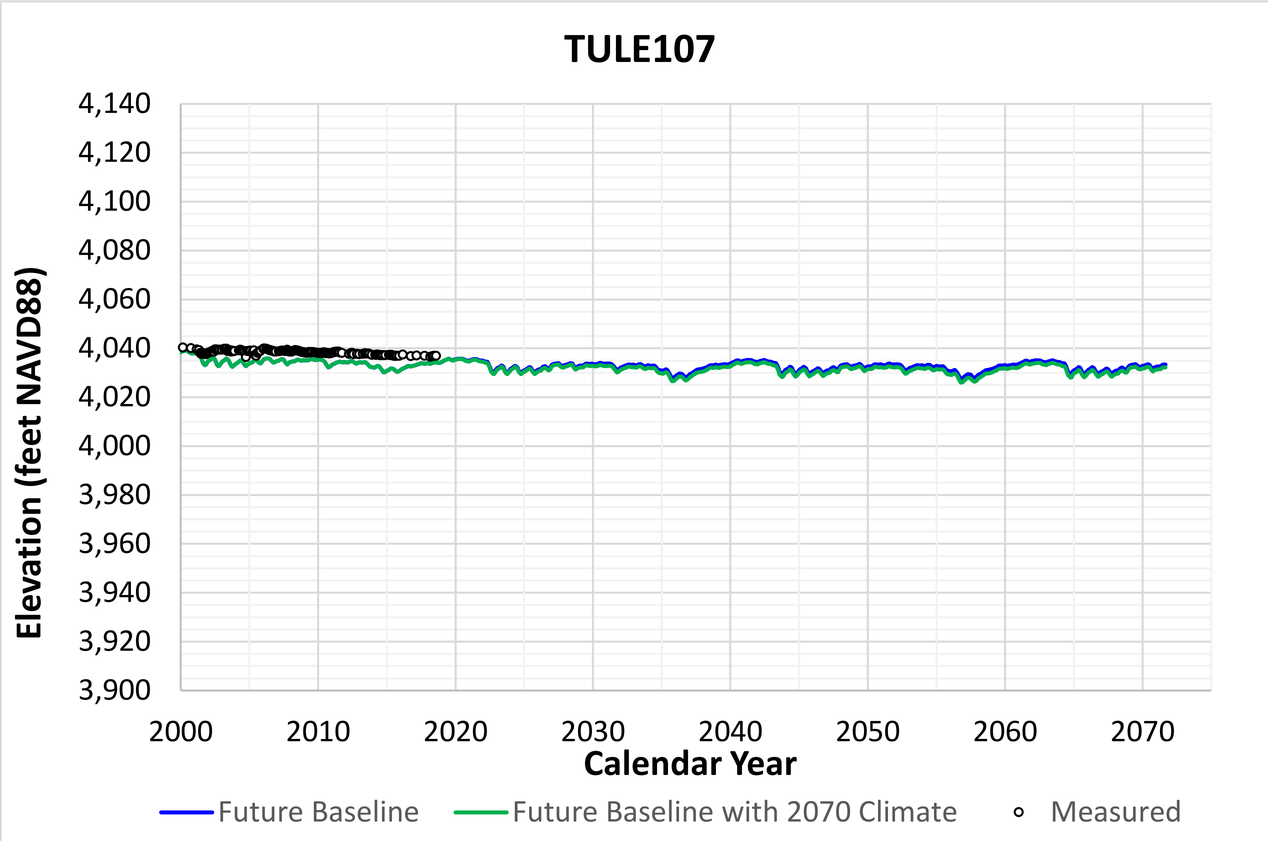
Comparison of Projected Groundwater Levels



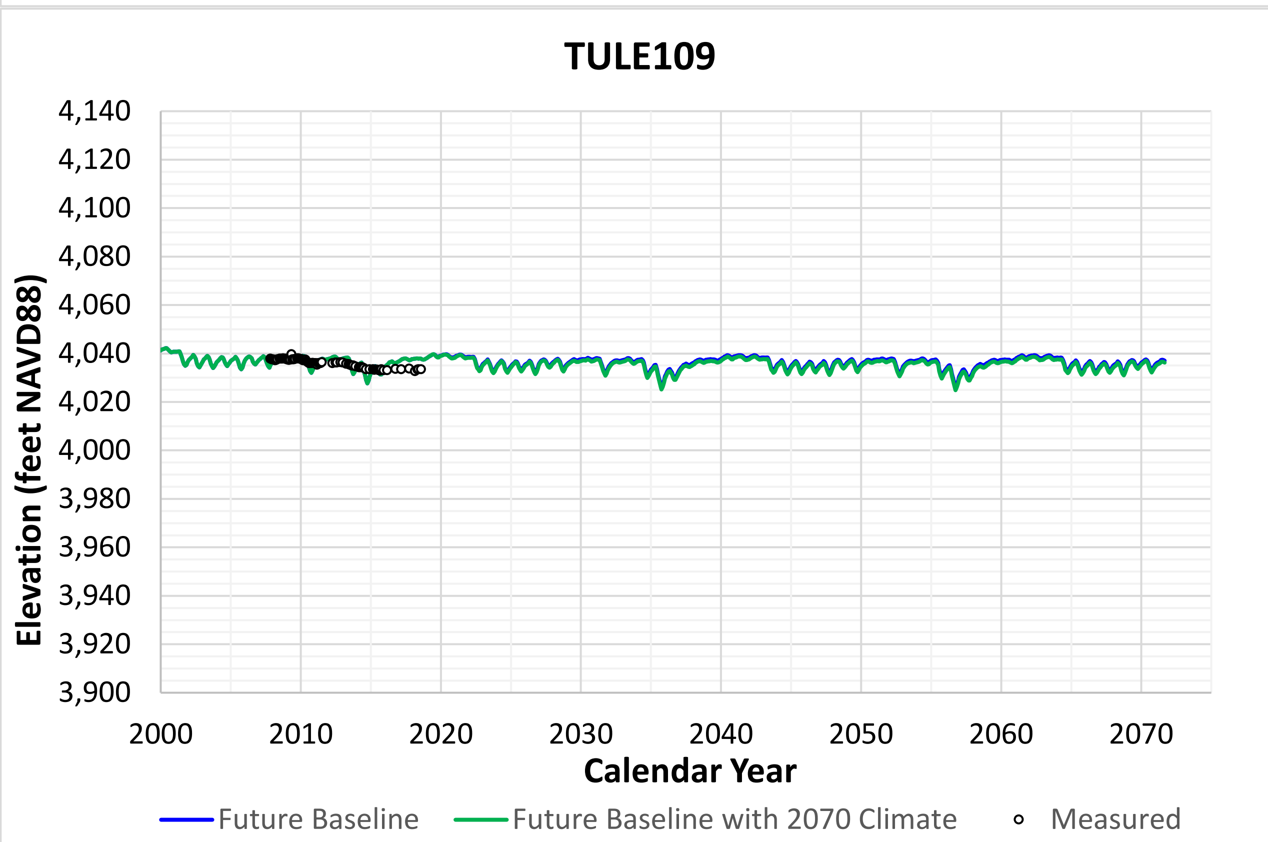
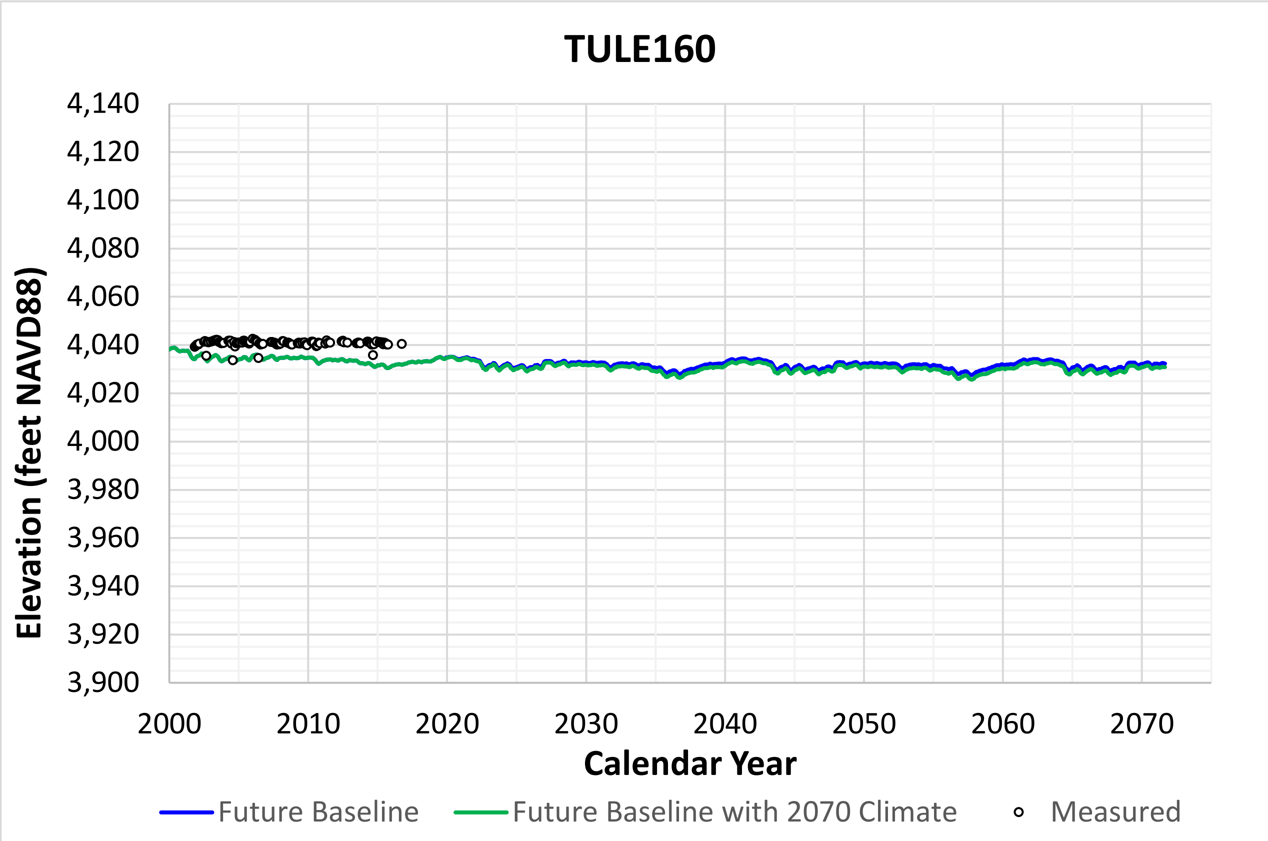
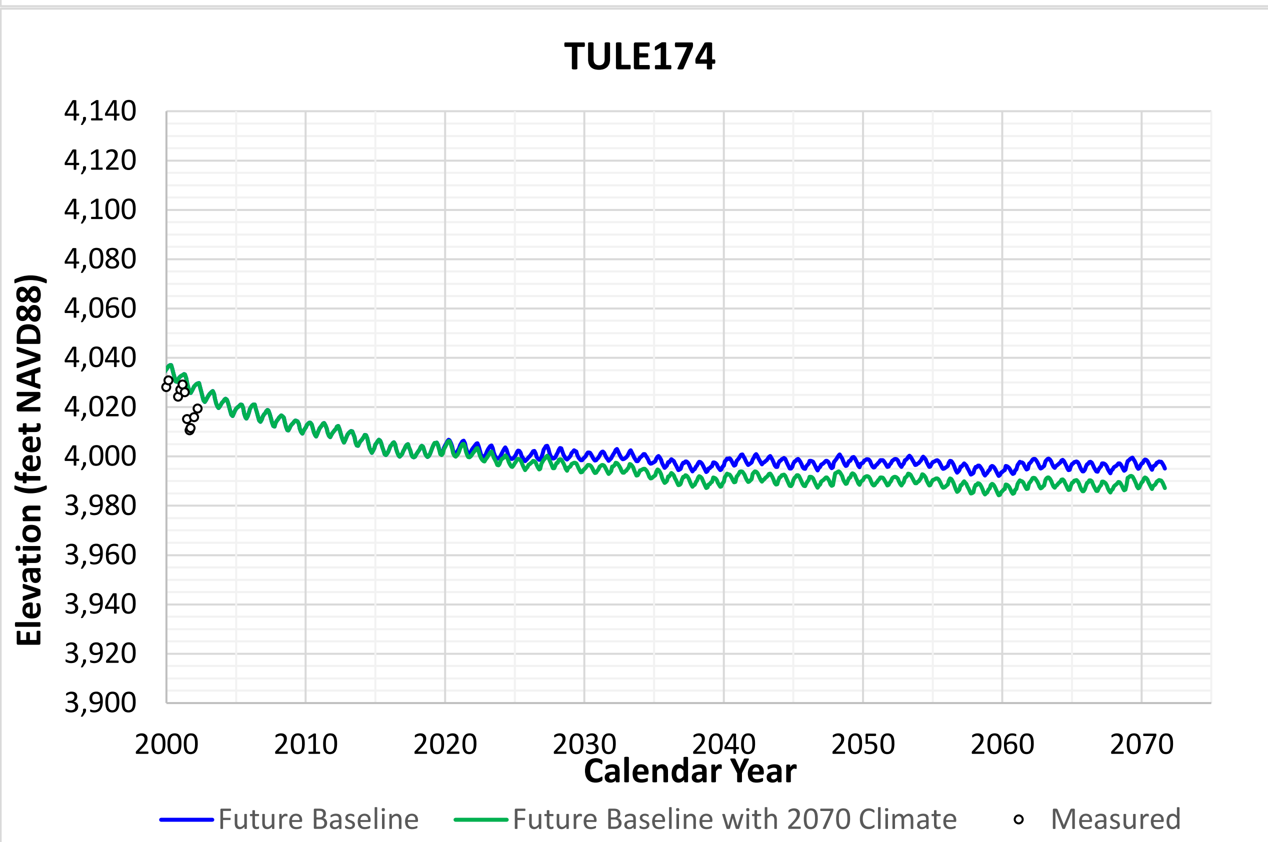




**Figure 5-6**
Comparison of Projected Groundwater Levels

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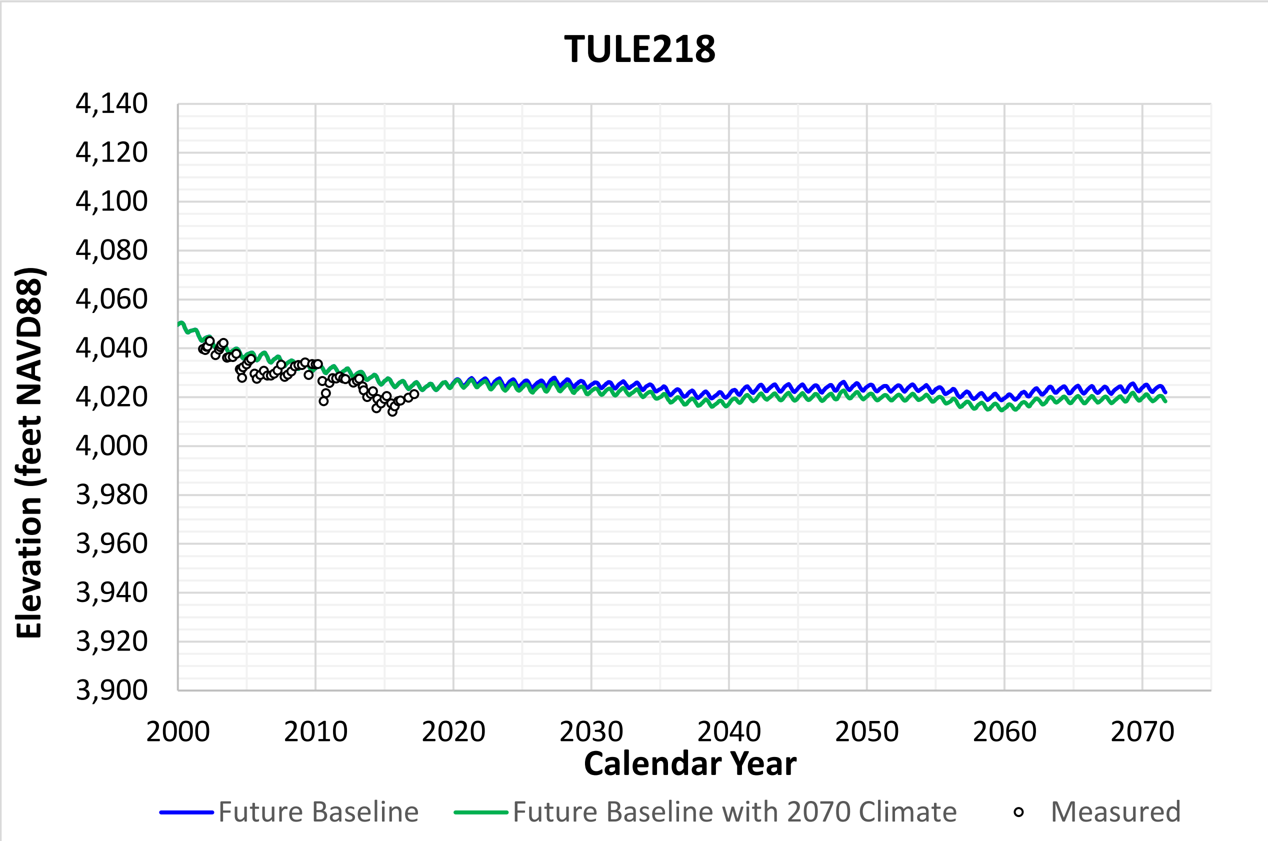
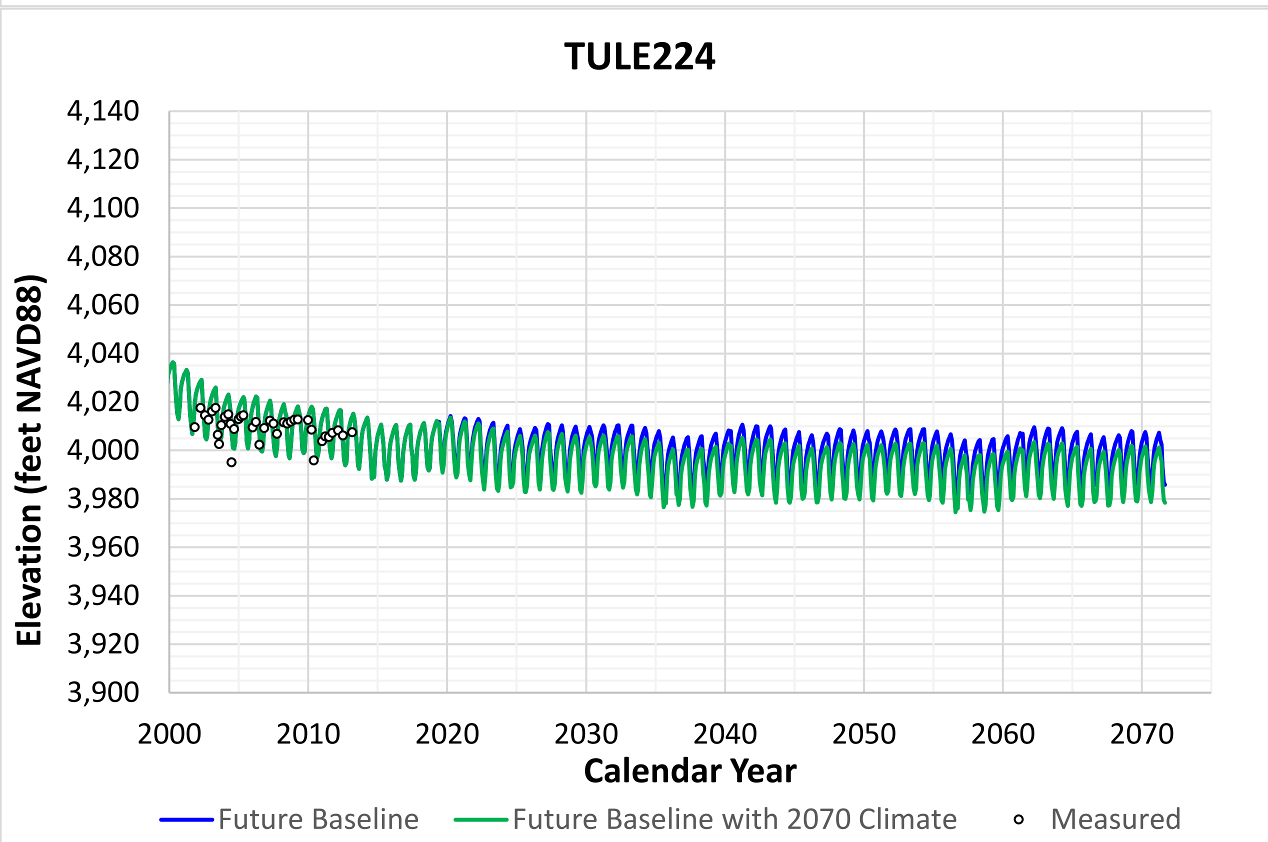
Comparison of Projected Groundwater Levels

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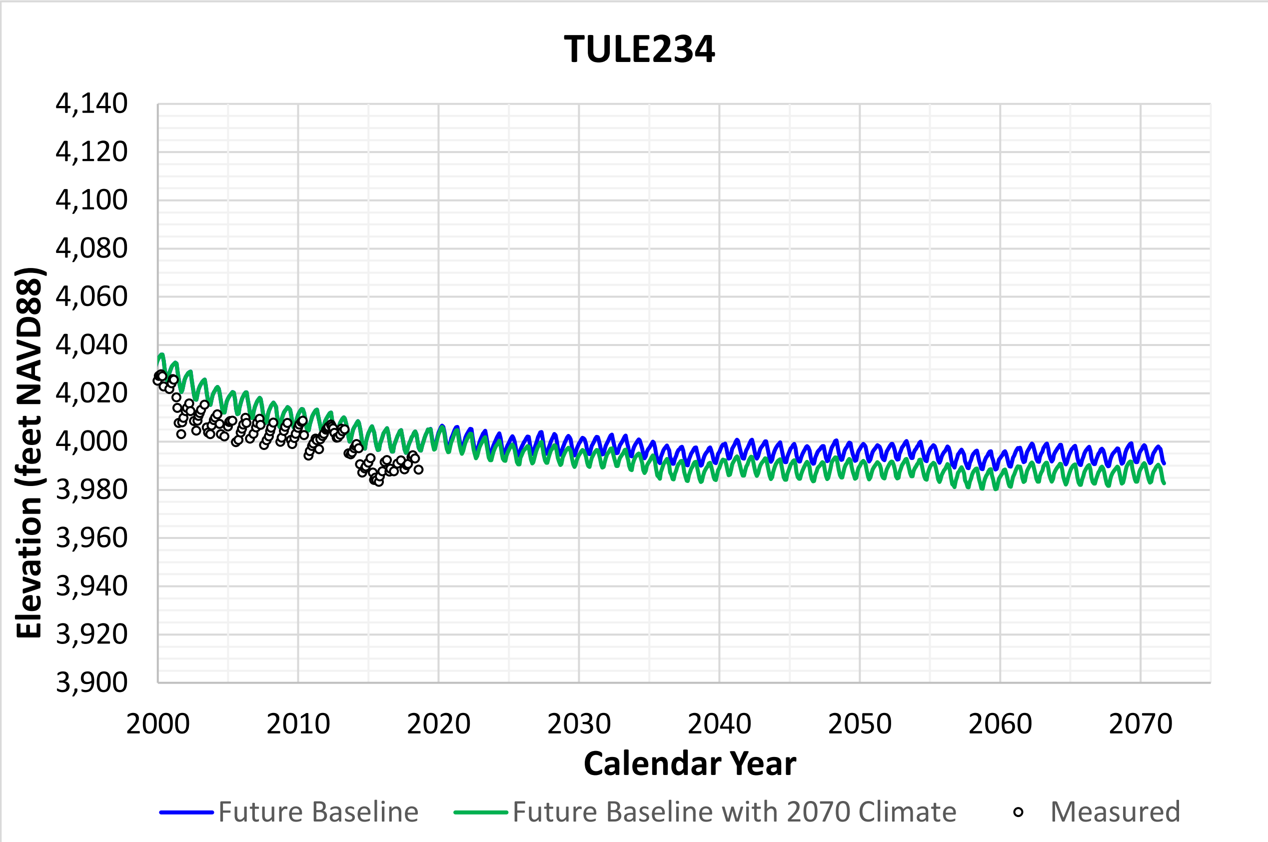
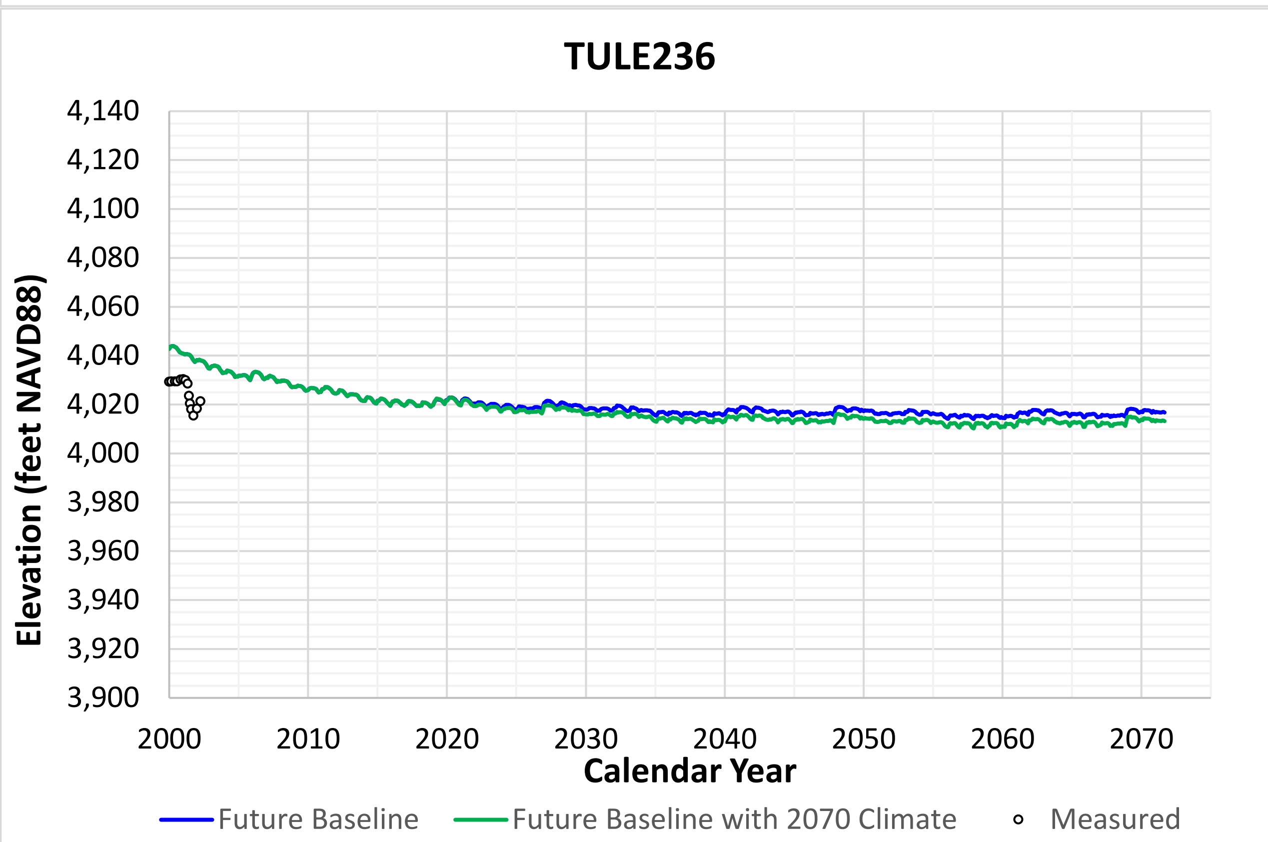
Comparison of Projected Groundwater Levels

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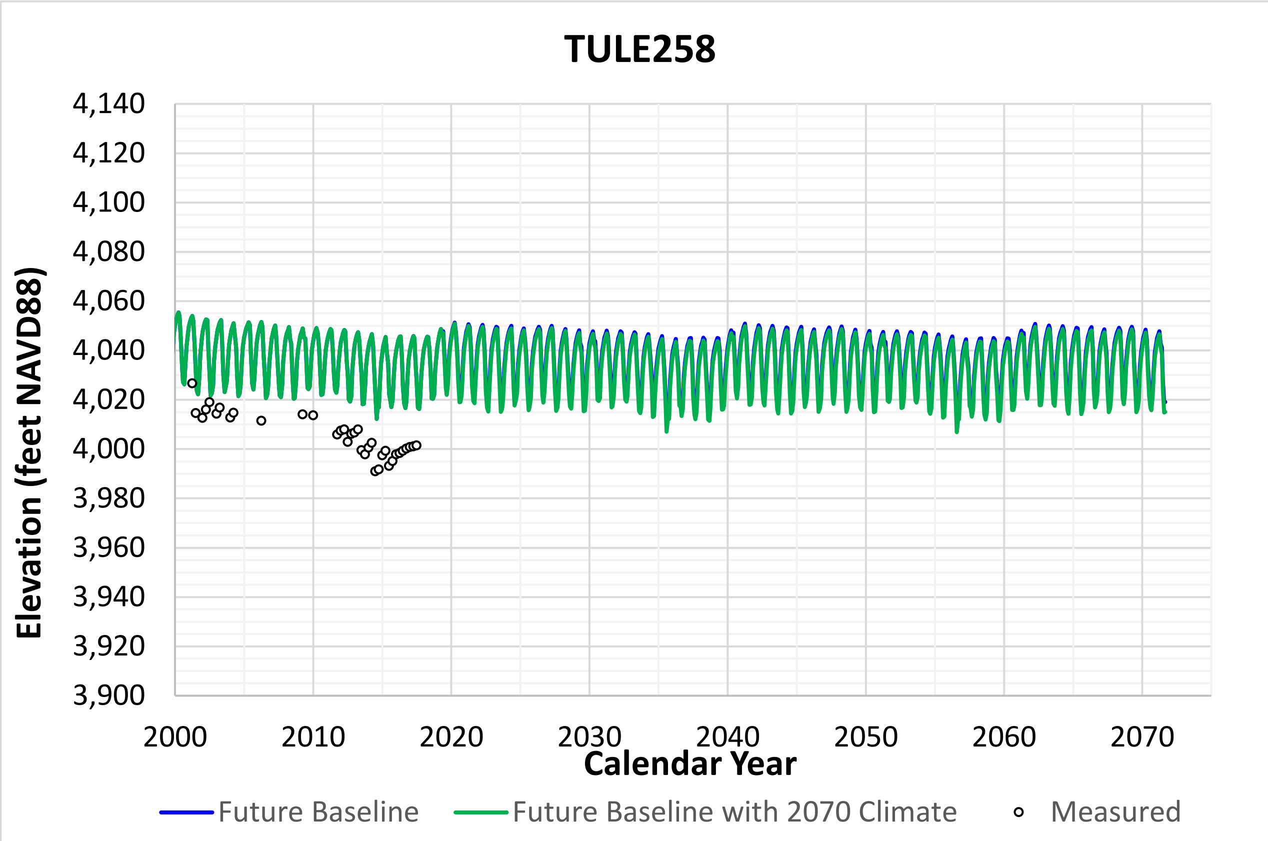
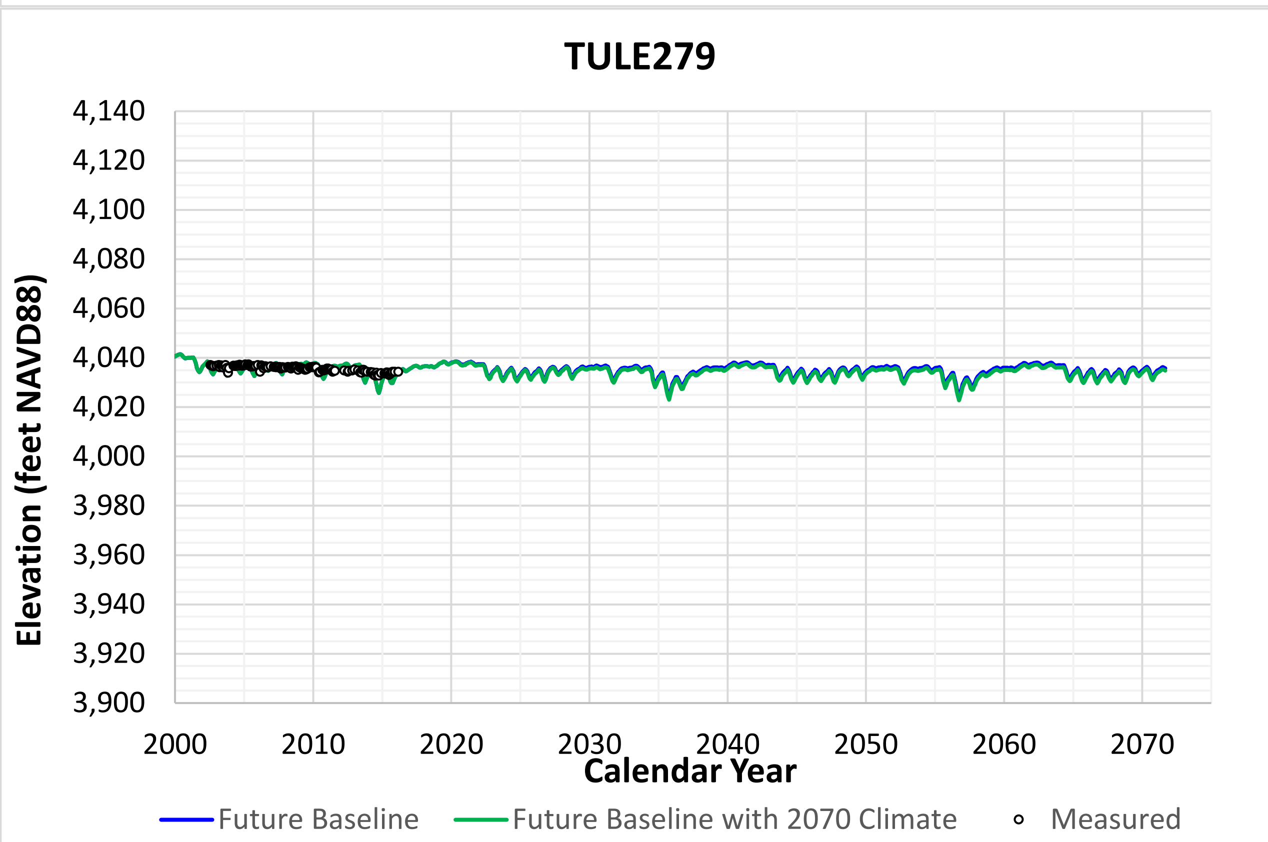
Comparison of Projected Groundwater Levels

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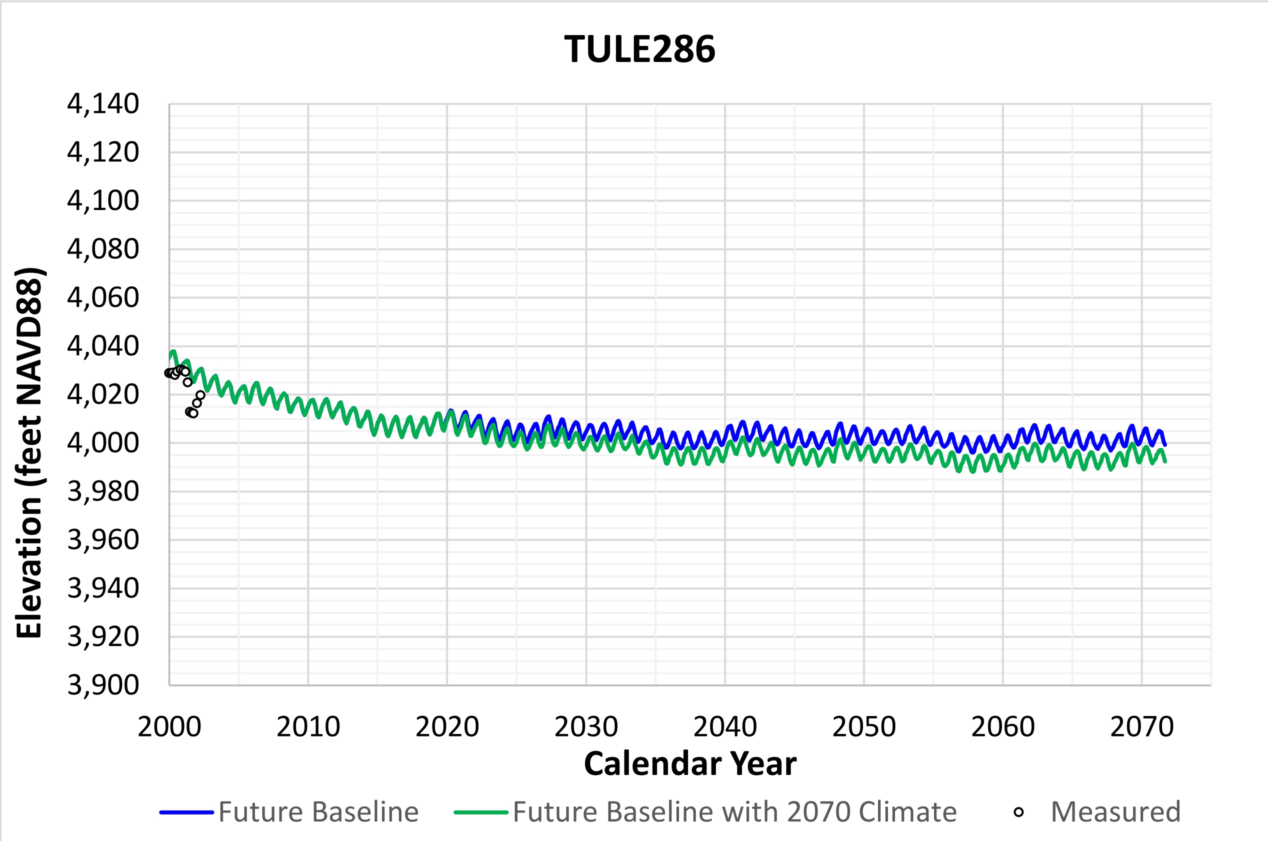
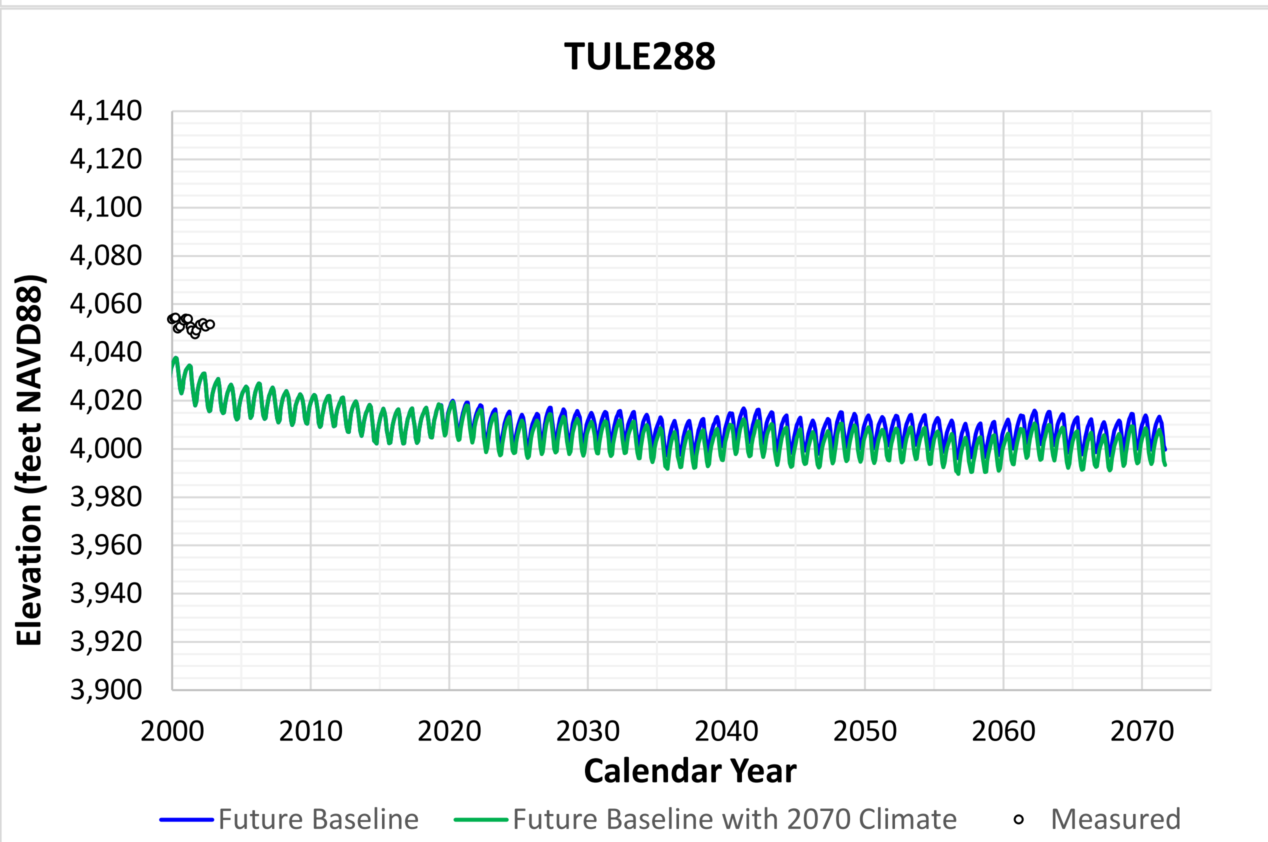
Comparison of Projected Groundwater Levels

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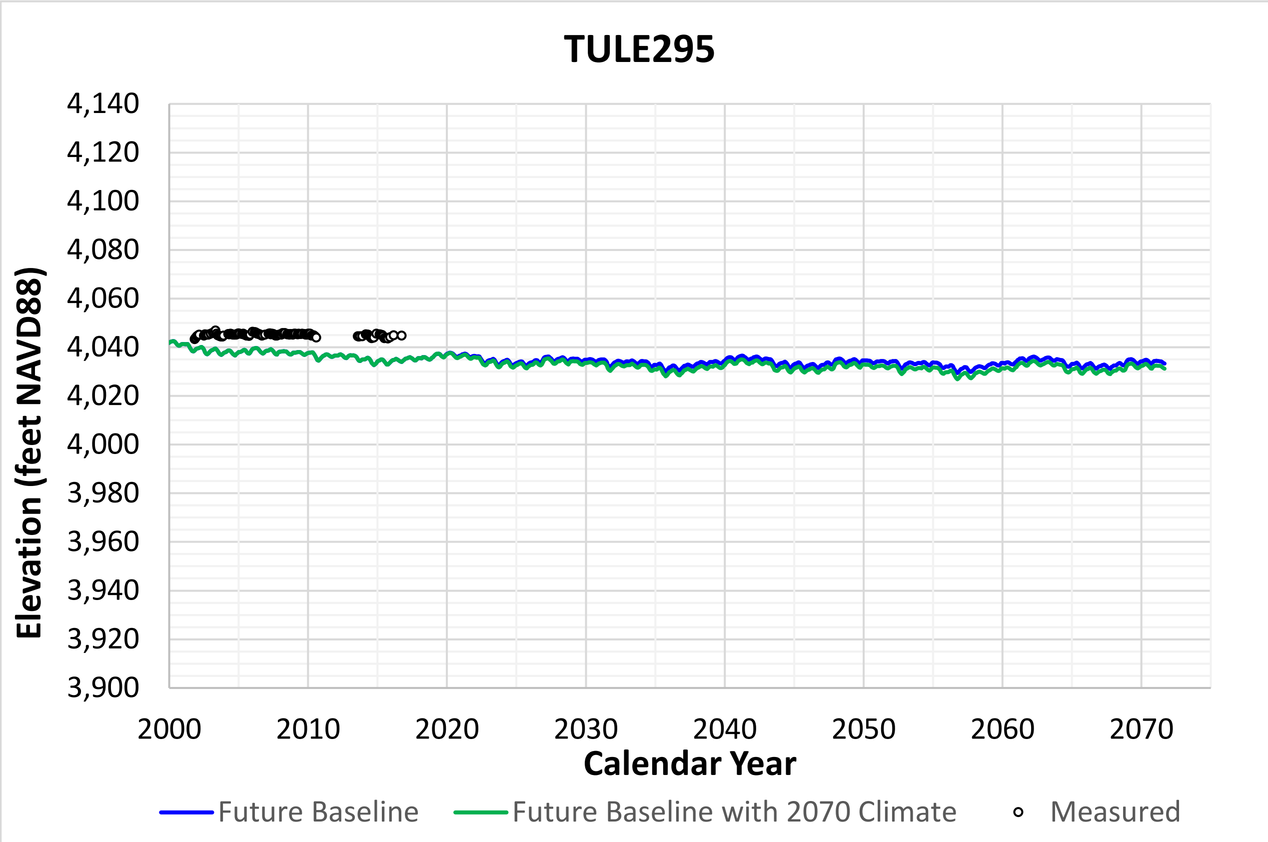
Comparison of Projected Groundwater Levels



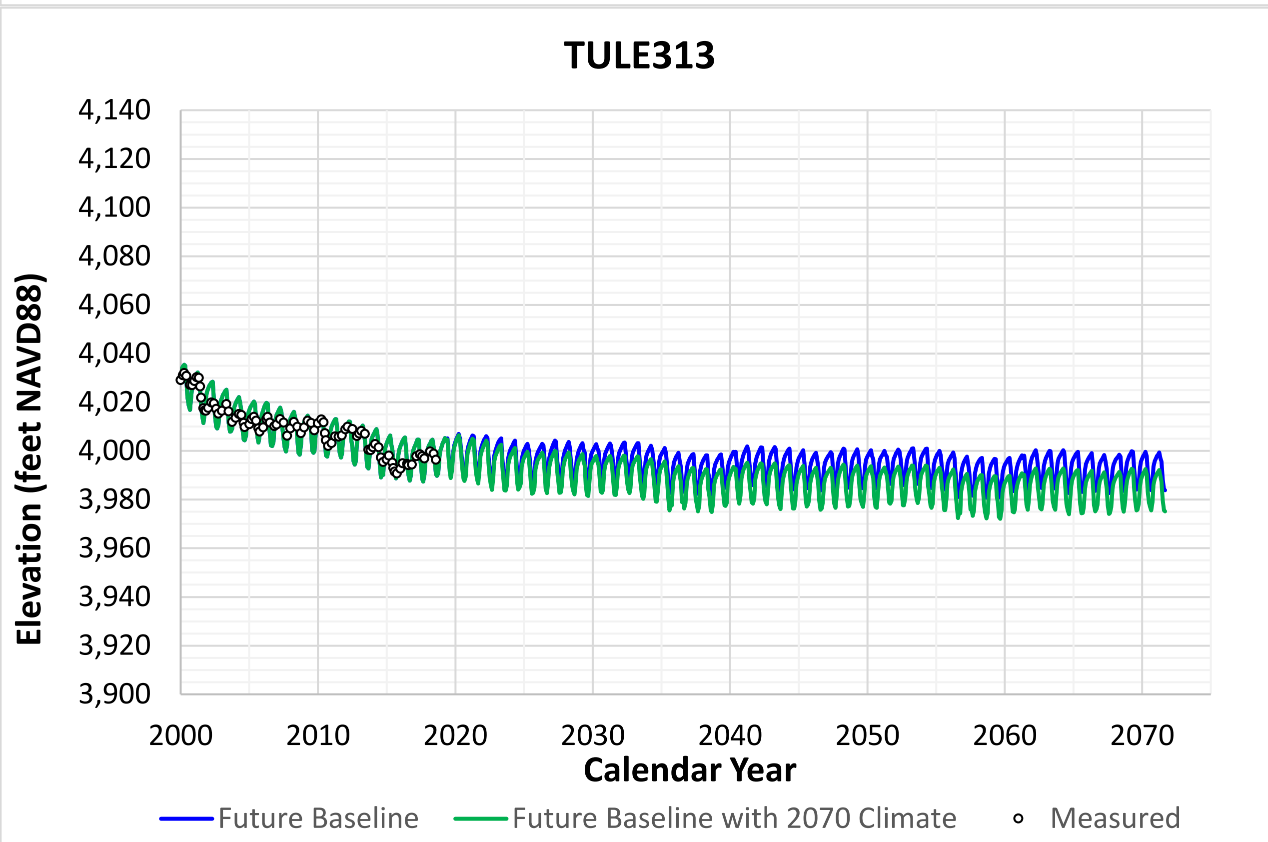
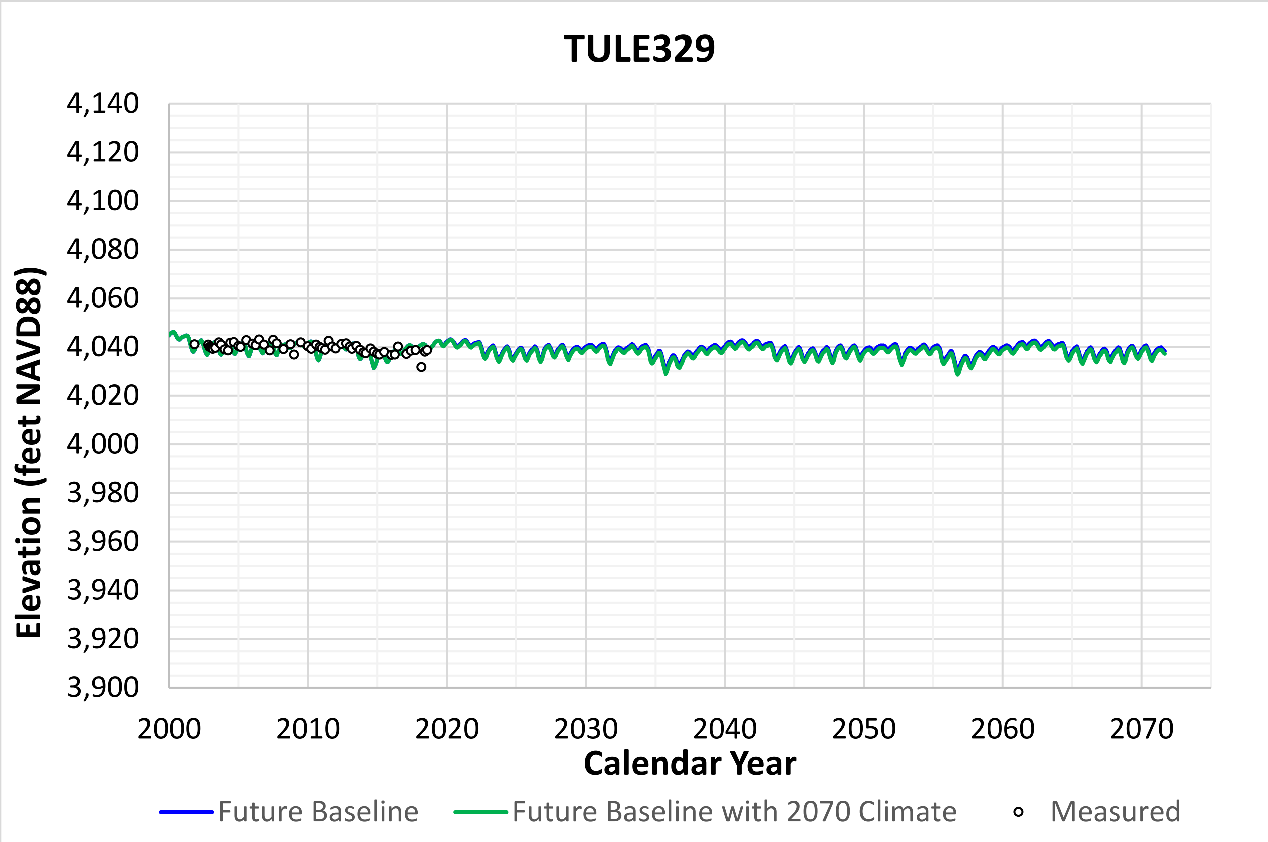




**Figure 5-6**
Comparison of Projected Groundwater Levels



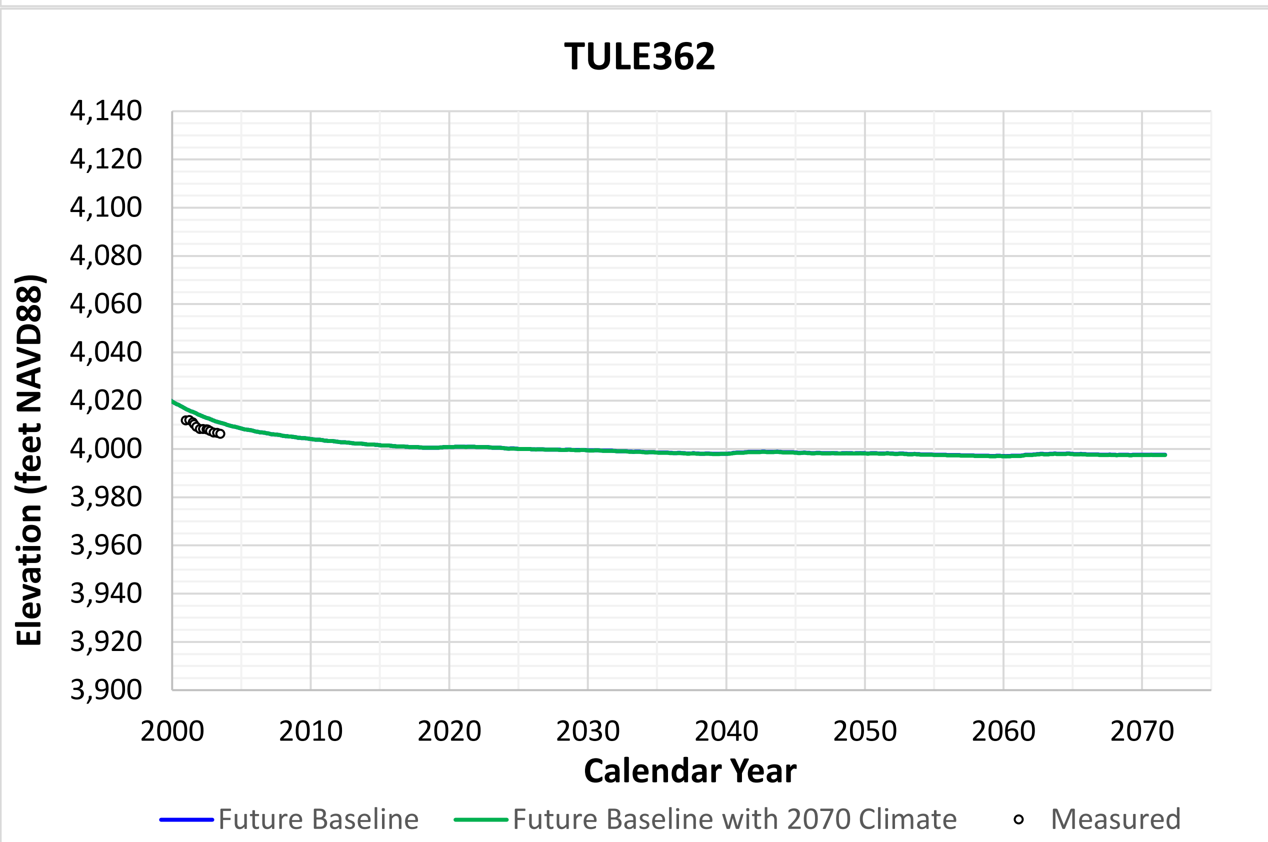
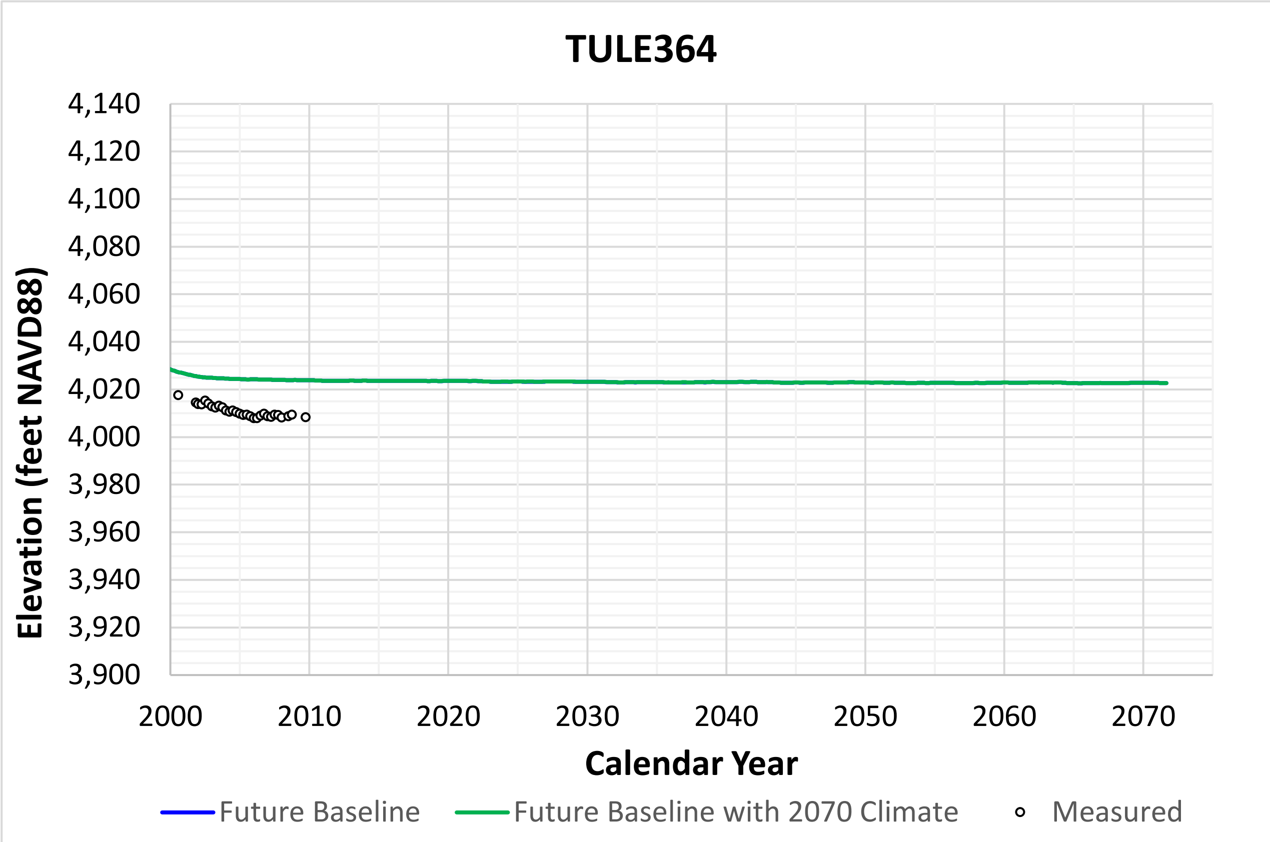




**Figure 5-6**
Comparison of Projected Groundwater Levels



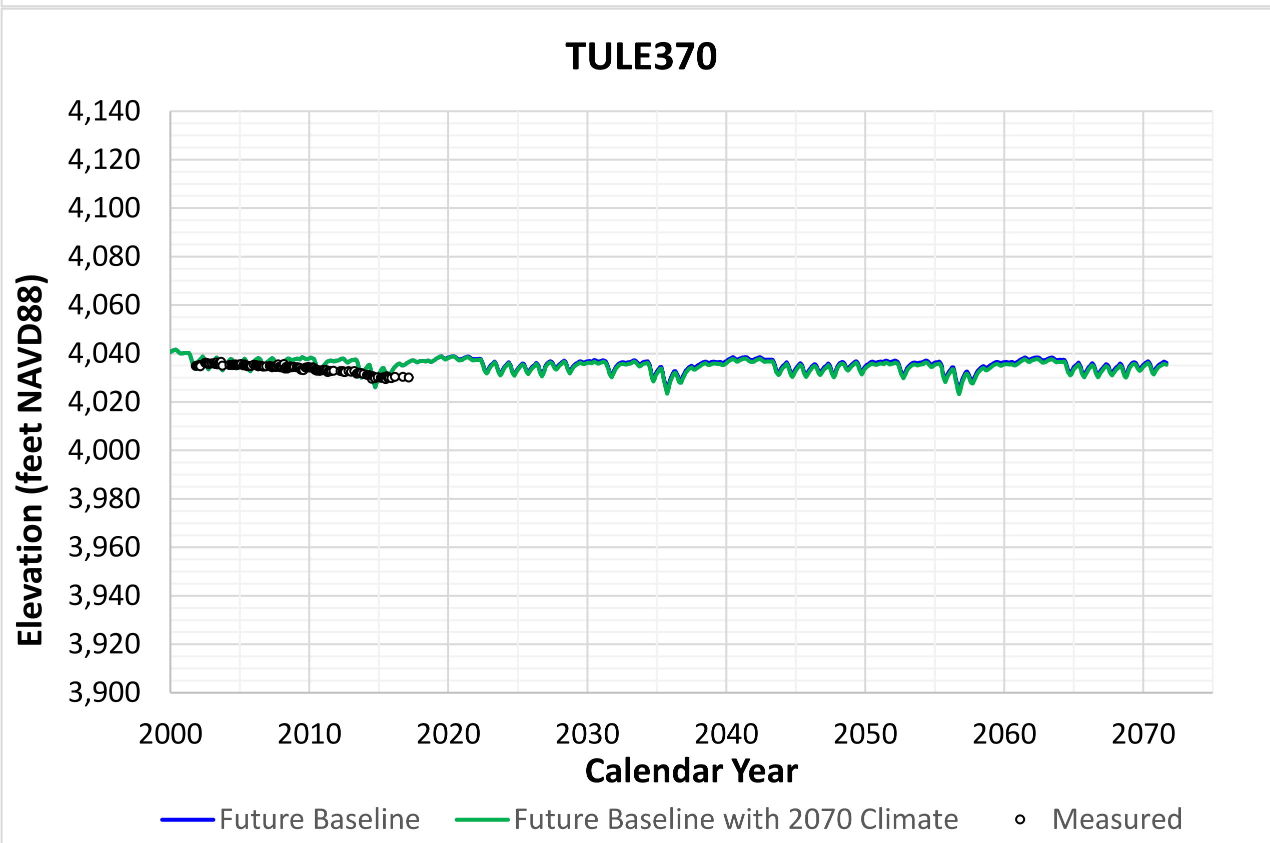
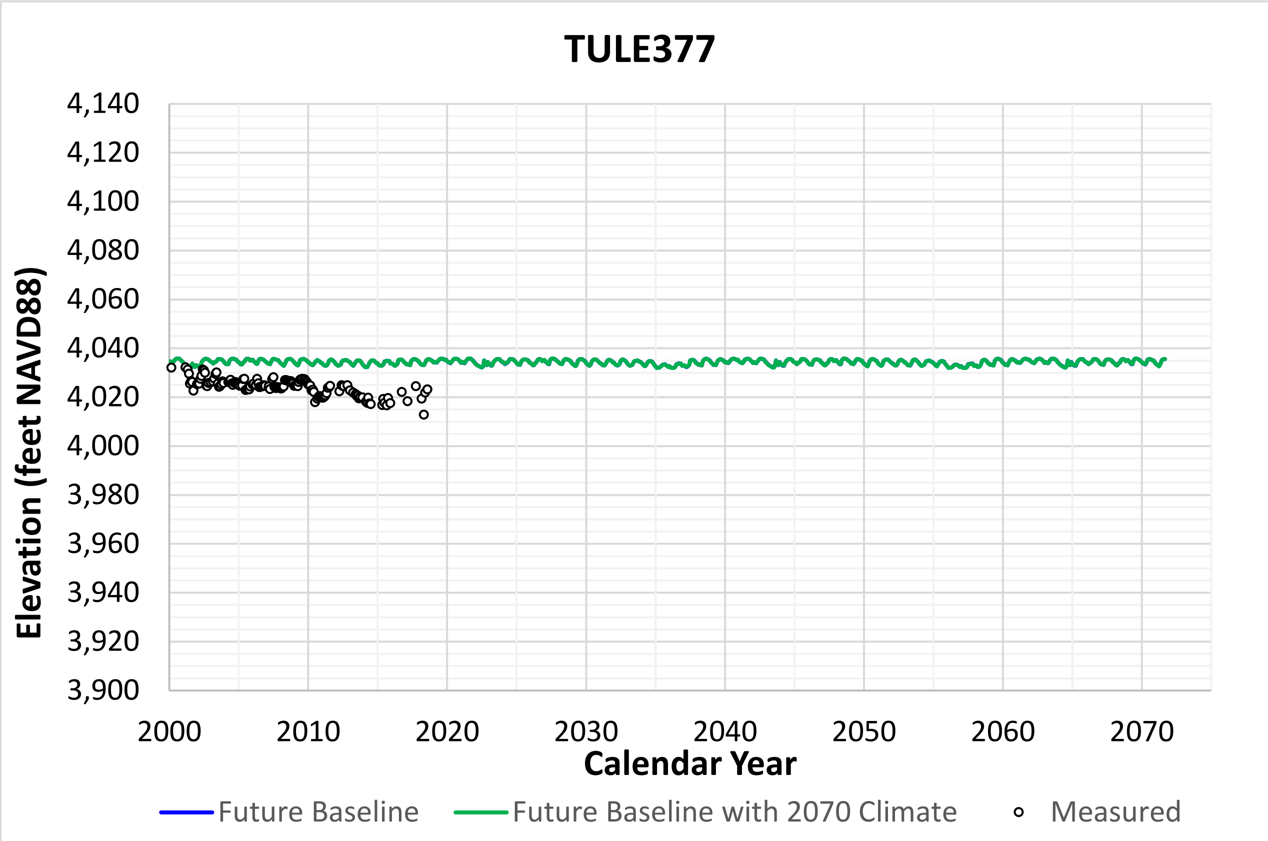




**Figure 5-6**
Comparison of Projected Groundwater Levels



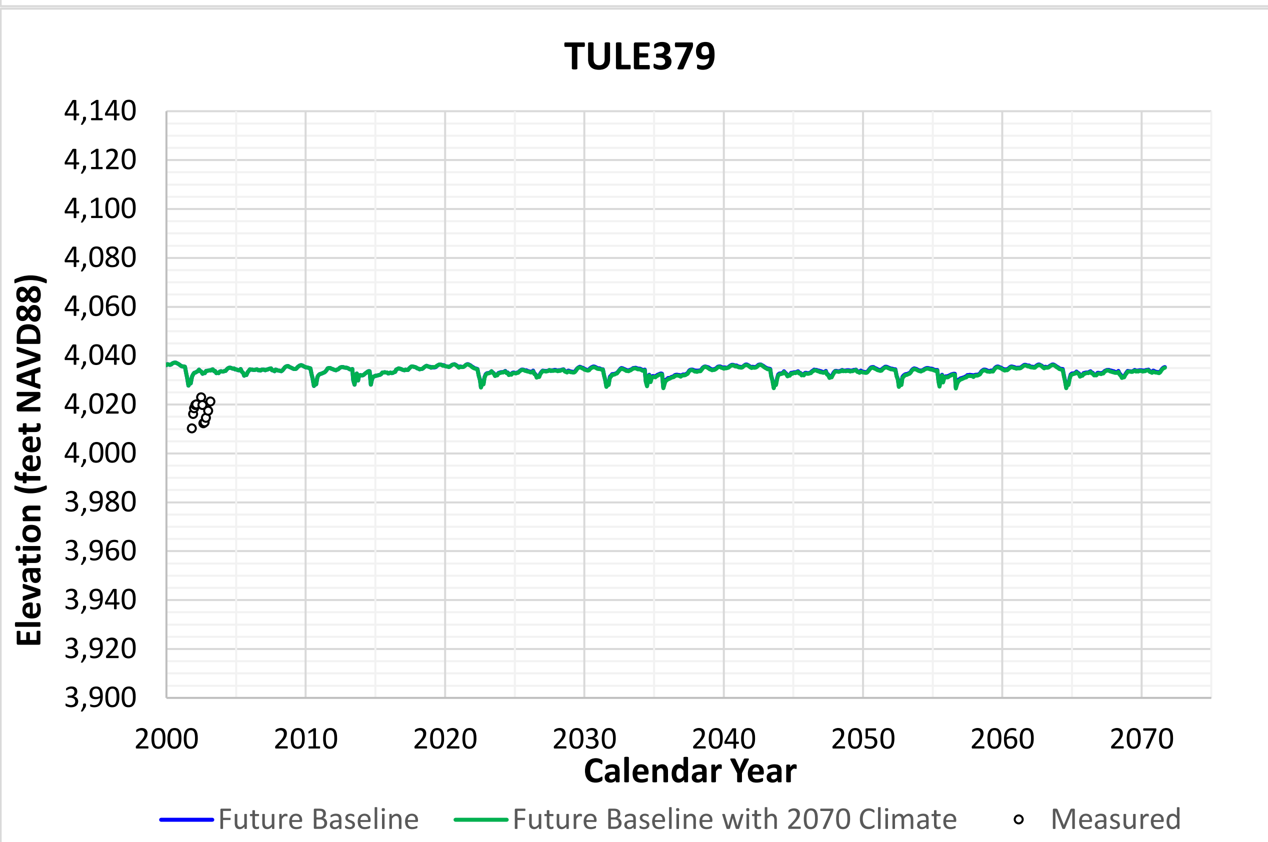
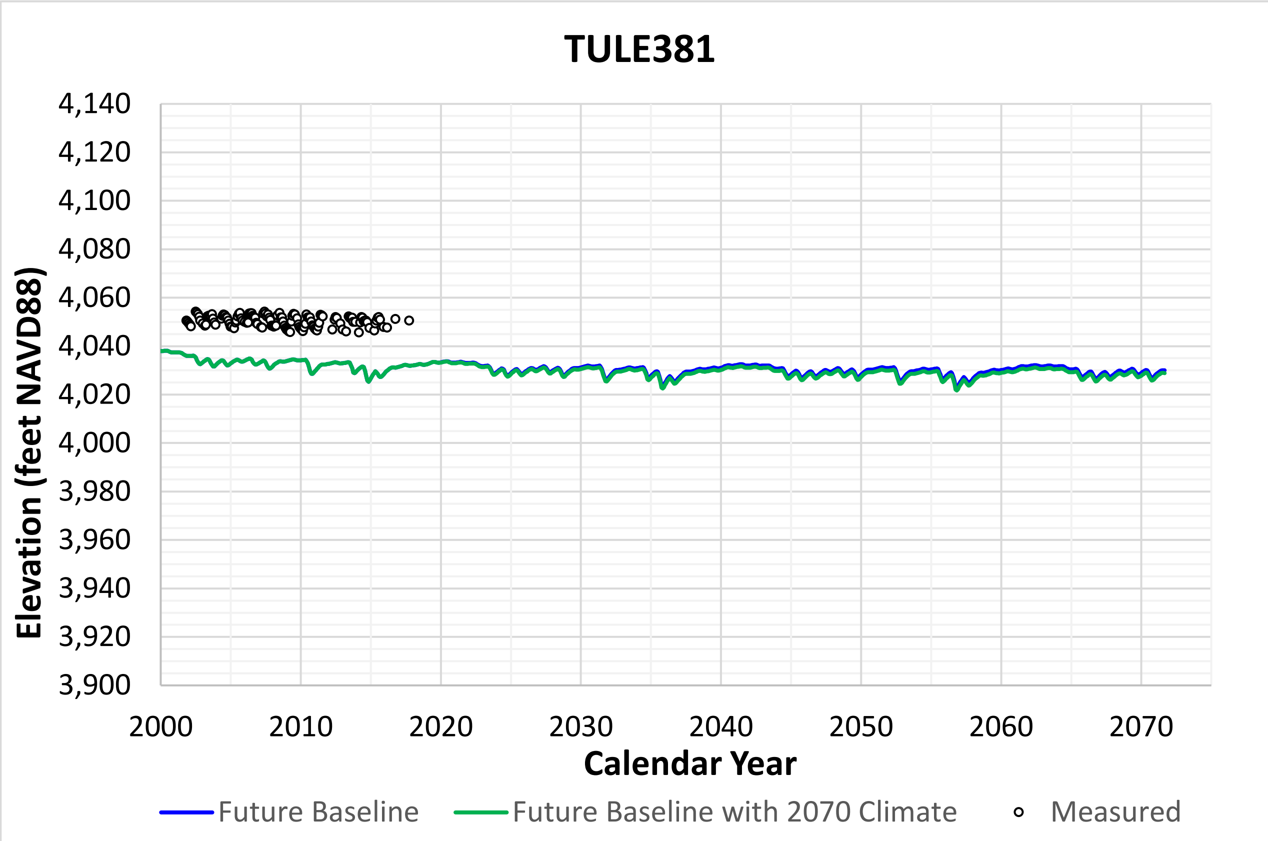
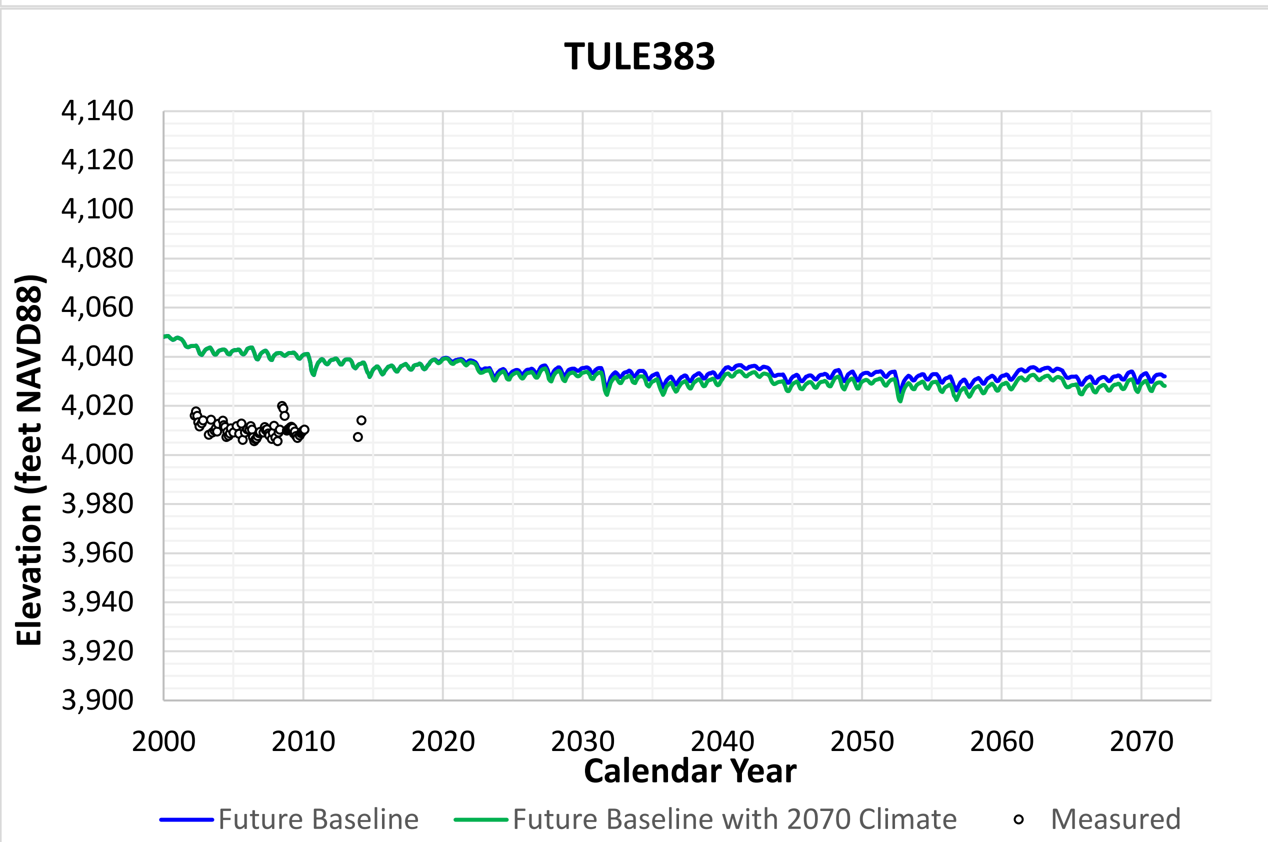




**Figure 5-6**
Comparison of Projected Groundwater Levels

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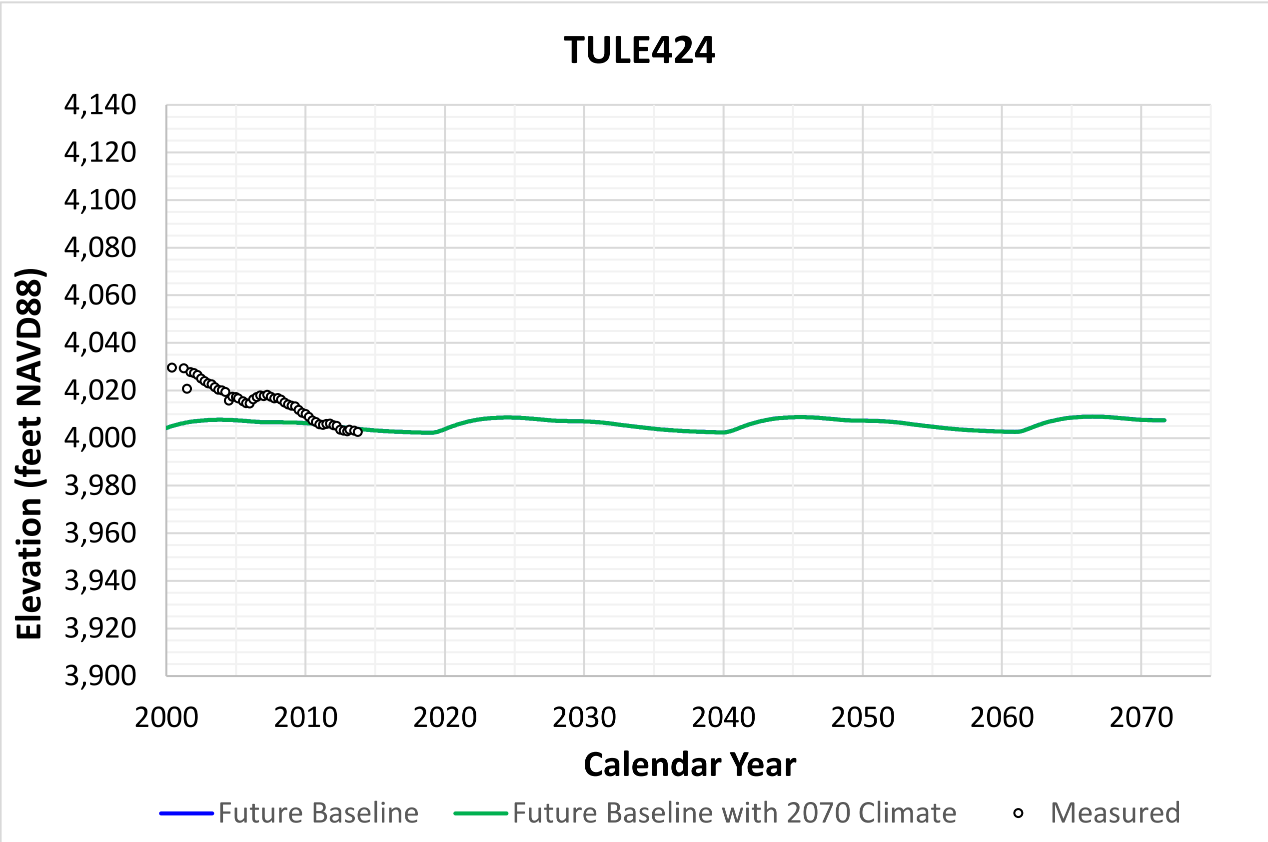
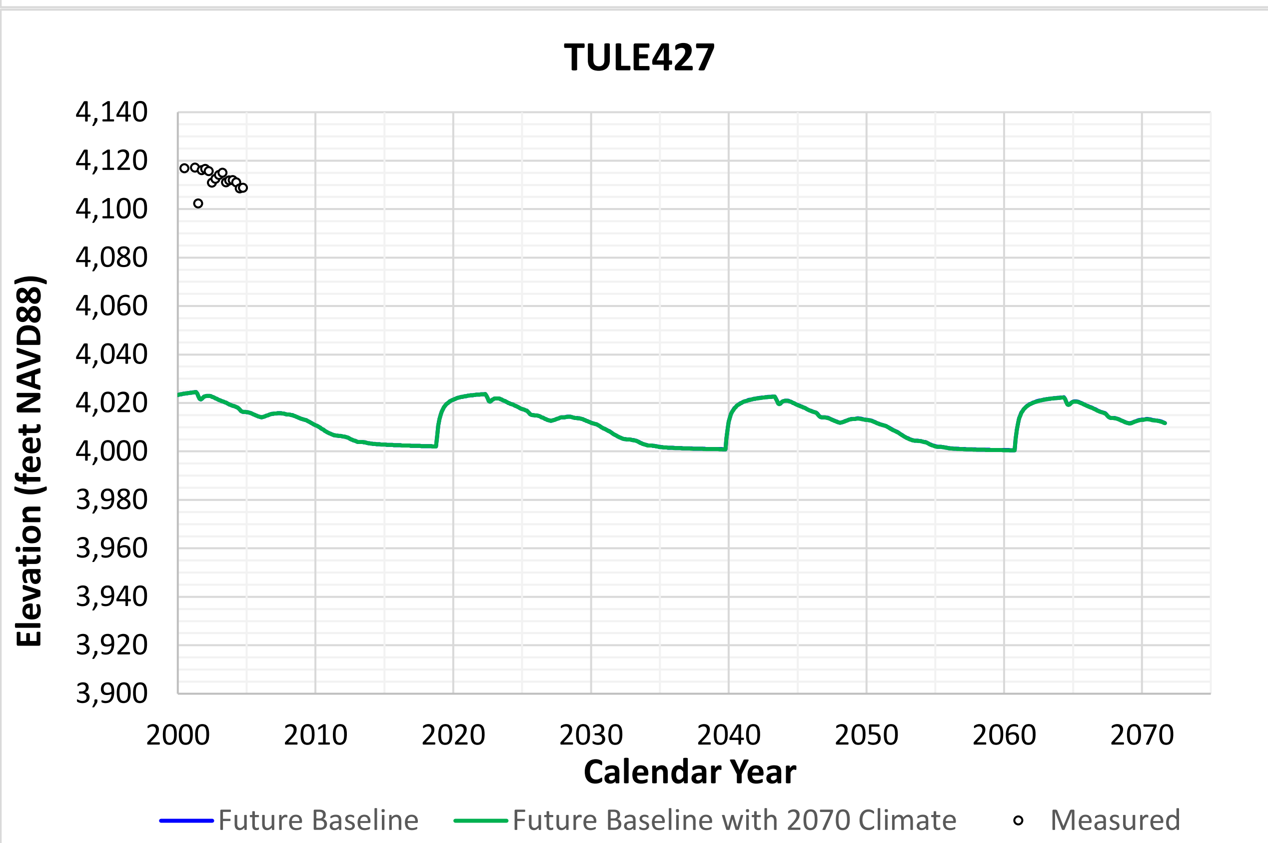
Comparison of Projected Groundwater Levels

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Comparison of Projected Groundwater Levels

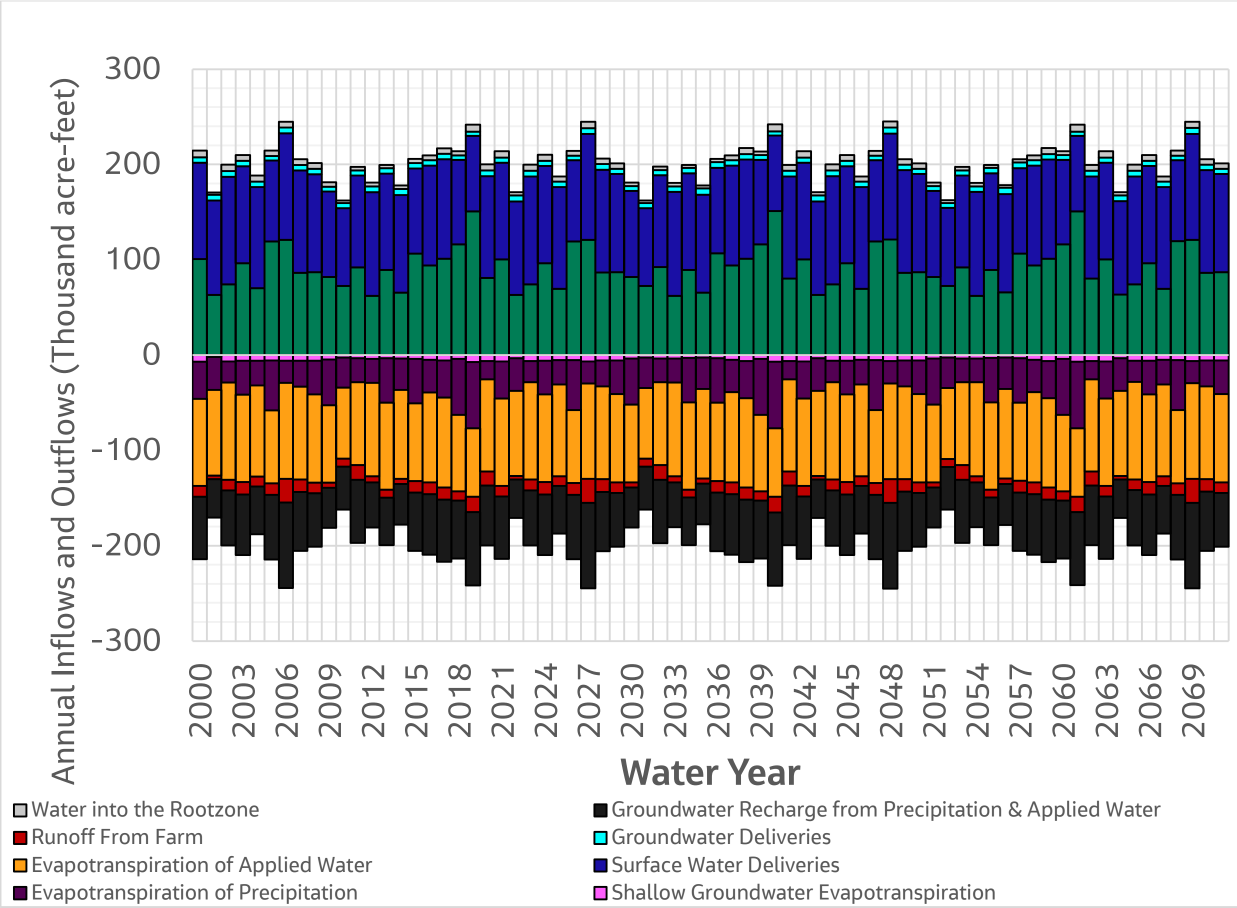


Figure 5-7 – Historical and Projected Annual Land System Water Balance

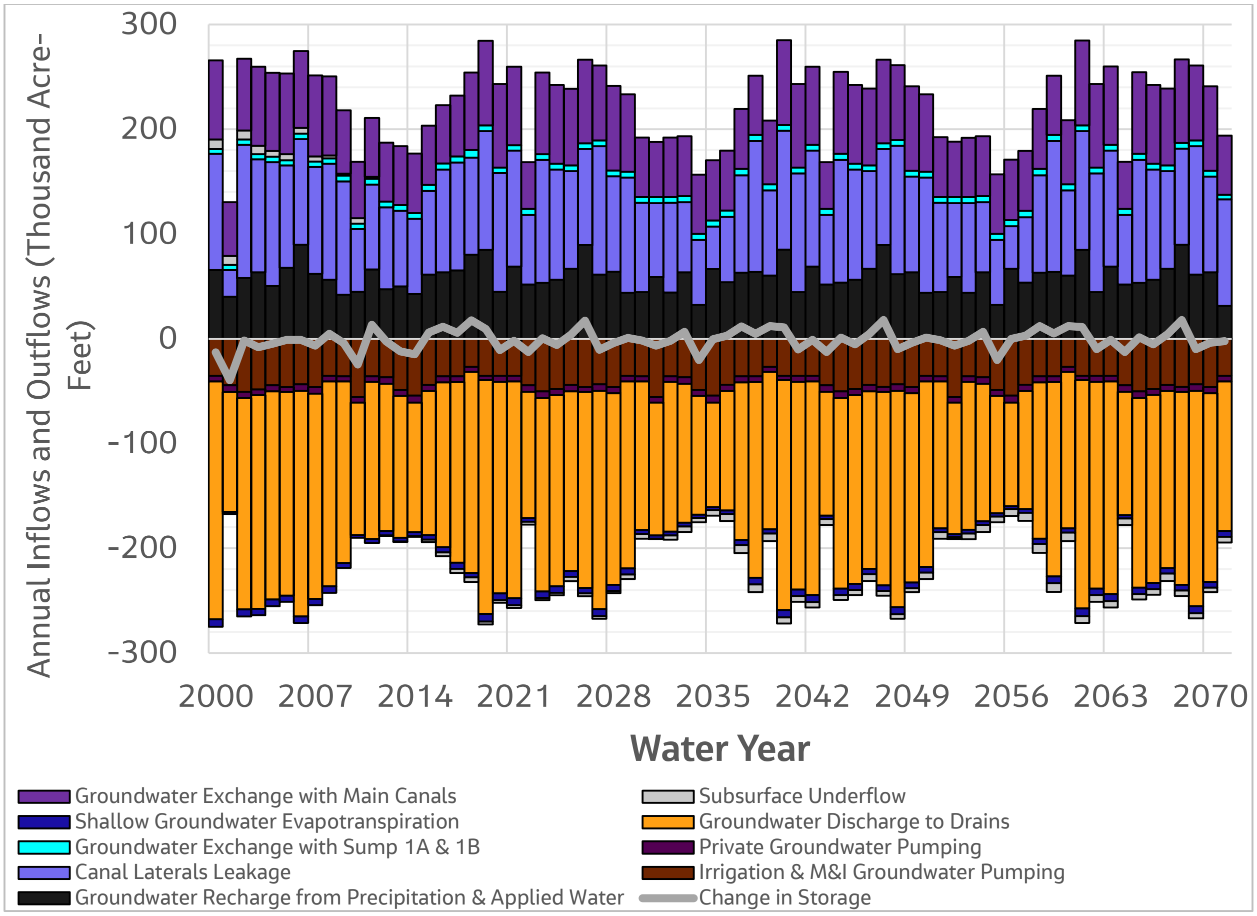


Figure 5-8 - Historical and Projected Annual Groundwater System Water Balance

# Appendix L.
# Ad Hoc Committee Meeting Summary, June 1, 2021

*Water Resources ◆ Flood Control ◆ Water Rights*

# MEETING SUMMARY

**DATE:** June 4, 2021

**TO:** File: Tulelake Subbasin GSP

**FROM:** Kyle Knutson

**SUBJECT:** June 1, 2021 Ad Hoc Committee Meeting Summary

On June 1, 2021, Angela Bezzone and Kyle Knutson participated in a Tule Lake Core Team Ad Hoc Committee meeting to discuss undesirable result definitions and minimum thresholds (MT) for the Tulelake Subbasin Groundwater Sustainability Plan (GSP). Also in attendance were Gary Wright and Kraig Beasly of the Tulelake Irrigation District (TID) Groundwater Sustainability Agency (GSA), and Matt Huffman, David King, Ken Masten, and Mike Byrne of the Tulelake Subbasin Advisory Committee. Below is a summary of the group's recommendation for undesirable result definitions and agreed upon approach for MTs.

Table 1. Undesirable Results Definitions

| Undesirable Result | Proposed GSP Definition |
|---|---|
| Chronic Lowering of Groundwater Levels | Groundwater elevations dropping below the Minimum Threshold criteria at four representative monitoring locations over three consecutive spring measurements. |
| Change-In-Storage | Monitoring of groundwater levels will be used as a proxy for this undesirable result. |
| Land Subsidence | Monitoring of groundwater levels will be used as a proxy for this undesirable result. |
| Depletion of Interconnected Surface Water | As stated above, the only surface water within the Subbasin is a small portion of the Lost River which terminates in the Tule Lake Sumps. This system is highly regulated as part of the US Bureau of Reclamation's Klamath Project. Due to the nature of the Lost River and Sumps, a separate monitoring network for groundwater-surface water interaction has not been developed. However, DWR Monitoring Well No. 48N04E22M001M is located adjacent to the Lost River and is included in the Groundwater Level Monitoring Network. Groundwater elevations dropping below the Minimum Threshold criteria at this representative monitoring locations over three consecutive spring measurements. |
| Degraded Water Quality | Changes in groundwater quality due to SGMA-related groundwater management activities (such as groundwater extraction and groundwater recharge) and groundwater quality that causes significant and unreasonable reductions in long-term viability of domestic, agricultural, municipal, and environmental uses over the planning and implementation horizon of this GSP as indicated by water quality data measured in at least 50% of representative monitoring wells exceeding the minimum thresholds for a groundwater quality constituent for two consecutive measurements at each location during non-drought years. |
| Seawater Intrusion | Not applicable for Tulelake Subbasin |

In regard to minimum thresholds for the Tulelake Subbasin GSP representative monitoring wells, the group agreed to use a combination of domestic wells depths within a 3-mile radius of representative monitoring wells or the historical low groundwater level measurement at the representative monitoring well plus a 10% buffer. For representative monitoring wells relying upon the historical low groundwater level as the MT, the Committee recommends an evaluation of groundwater levels at the end of the current irrigation season to consider the impact of the current drought conditions on groundwater levels.

Kyle Knutson

Kyle Knutson

KK/ab

# Appendix M. Representative Groundwater Monitoring Well Hydrographs

MBK ENGINEERS
Water Resources ◆ Flood Control ◆ Water Rights

# TECHNICAL MEMORANDUM

**DATE:** June 14, 2024

**PREPARED BY:** Chris Connor

**REVIEWED BY:** Angela Bezzone, P.E. and Kyle Knutson, P.E.

**SUBJECT:** Updated Methodology for Determination of Minimum Thresholds

## Purpose

As documented in Appendix L of the Tule Lake Subbasin Groundwater Sustainability Plan (GSP), the Groundwater Sustainability Agencies (GSAs) provided direction on the methodology used to establish minimum thresholds (MTs) for groundwater levels at each representative monitoring well. On January 18, 2024, the Department of Water Resources (DWR) transmitted a letter to the GSAs (Attachment A). The letter stated that the GSP was found to be “incomplete” and identified two corrective actions relative to the MTs, which are generally described below. Based upon the comments received in the DWR letter, the purpose of this technical memorandum is to provide an overview of the updated methodology to establish MTs for the GSP and describe how the corrective actions have been addressed.

## Well Completion Report Review

During development of the GSP, well completion reports (WCR) for the Tule Lake Subbasin were downloaded from DWR’s Well Completion Report Map Application (Application)[1] and reviewed using ESRI’s ArcGIS mapping software. Due to the length of time between development of the GSP and this effort to revise the GSP, the WCRs were downloaded again to ensure that any new WCRs and any changes to WCRs were included. On March 28, 2024, 428 WCRs[2] were downloaded and stored in a file geodatabase. Unless a WCR has coordinates, the Application assigns the WCR to the centroid of the associated Public Land Survey System section. There were eight instances where the centroid of a section was adjacent to, but outside of the Tule Lake Subbasin boundary. Due to the proximity of the centroid in these instances, it was assumed that the accompanying WCRs were likely related to wells within the Tule Lake Subbasin and therefore included in the analysis. The wells were organized into the following six categories.

1. Domestic (156 of 428)
2. Irrigation (135 of 428)
3. Public Supply (4 of 428)

[1] https://gis.water.ca.gov/app/wcr/

[2] Records within the database did not always contain well completion reports. These records were not removed from the overall analysis, nor were they removed from the counts that follow in this memorandum.

4. Industrial, Other, or Unknown (43 of 428)
5. Monitoring (62 of 428)
6. Destroyed (28 of 428)

Next, 98 wells were removed from the analysis (eight wells identified as Other that were additionally categorized as Test Well or Vapor Extraction, 62 wells identified as Monitoring, and 28 wells identified as Destroyed), leaving a total of 330 WCRs to be evaluated to establish MTs.

Upon further review of the remaining 330 WCRs, 23 additional wells were removed from the analysis for the reasons below.

- Well was drilled for sparging (14 wells identified as Industrial, Other or Unknown)
- Issues arose during drilling, which resulted in not completing construction of the well (1 well identified as Irrigation and 1 well identified as Other)
- Note on WCR confirmed well has been destroyed (1 well identified as Irrigation, 1 well identified as Domestic, and 3 wells identified as Unknown)
- Well is a duplicate (1 Irrigation well)
- Well is no longer in use, and household associated with well is abandoned (1 well identified as Other, see Attachment E which includes the WCR with an additional note about well status)

In addition, during review of the remaining 330 WCRs, 2 wells were reassigned to a different category for the reason below.

- Well has since been deepened (2 Other reassigned to Domestic)

In total, 307 (428 less 98 less 23) wells were used to update the MTs for the representative monitoring wells.

The 307 wells were organized into the following six categories.

1. Domestic (155 of 307)
2. Irrigation (132 of 307)
3. Public Supply (4 of 307)
4. Industrial, Other, or Unknown (17 of 307)
5. Monitoring (0 of 307)
6. Destroyed (0 of 307)

# Corrective Action A: Minimum Threshold Determination

As described in the GSP, the primary water supply for agricultural operations within the Tule Lake Subbasin is surface water from the Klamath Project. If the surface water supply is not sufficient to meet demand within the Tulelake Irrigation District (District) then the District will operate its groundwater wells to provide additional water supply. Lastly, private irrigation well owners within the District will operate their wells if the surface water supply and District well supply is not sufficient to meet their demand. Based on these operations, there were two methodologies established to determine the MT at each representative monitoring well, which are described below.

- Representative monitoring wells that are used for irrigation have MTs set to the well's lowest static groundwater level measurement recorded plus a 10 percent buffer.
- The "Near" function in ArcGIS Pro software was used to associate each of the 307 WCRs with the closest representative monitoring well. All representative monitoring wells that are not an irrigation well have MTs set to either the shallowest or second shallowest well within its Near grouping. However, if there are not any wells within a representative monitoring well's Near grouping, then the MT is equal to the well's lowest static groundwater level measurement recorded plus a 10 percent buffer.

Table 1 below shows the lowest static groundwater level measurement recorded at each of the representative monitoring wells identified as irrigation wells and the corresponding MT.

**Table 1 MTs for Representative Monitoring Wells Identified as Irrigation Wells**

| Representative Monitoring Well | Lowest Static Well Measurement (ft bgs) | Date | Updated Minimum Threshold (ft bgs) |
|---|---|---|---|
| 48N04E30F002M (TID Well 1) | 71.70 ft | 10/1/2022 | 79 |
| 48N04E13K001M (TID Well 5) | 81.66 ft | 10/1/2022 | 90 |
| 46N05E22D001M (TID Well 14) | 48.39 ft | 12/1/2022 | 54 |
| 48N05E26D001M (TID Well 8) | 66.81 ft | 8/1/2022 | 74 |

Table 2 below shows the updated minimum thresholds for each representative monitoring well that is not identified as an irrigation well.

**Table 2 MTs for Non-Irrigation Representative Monitoring Wells**

| Representative Monitoring Well | Original MT (ft bgs) | Updated MT (ft bgs) | Notes |
|---|---|---|---|
| 46N05E01P001M | 24 | 24 | The two shallowest wells in WCR database have since been deepened. MT is set to shallowest remaining well, which is a domestic well with a depth of 24'. |
| 48N04E22M001M | 50 | 120 | The shallowest well was an irrigation well with a depth of 31'; however, since private irrigation wells are not a main source of supply* the MT was based on the shallowest non-irrigation well, which is a domestic well with a depth of 120'. |
| 48N04E19C001M | 29 | 33 | The shallowest well was an irrigation well with a depth of 28'; however, since private irrigation wells are not a main source of supply* the MT was based on the shallowest non-irrigation well, which is a domestic well with a depth of 33'. |
| 47N05E04M001M | 15 | 33 | MT is set to the shallowest domestic well (33'). WCR database has a double entry for a 31' deep irrigation well; however, since private irrigation wells are not a main source of supply* the MT was based on the shallowest non-irrigation well. |
| 47N05E01N001M | 49 | 42 | There is a 15' domestic well drilled in 1996; however, based upon a review of a historical hydrograph for 47N05E01N001M this well likely went dry in 2011, which is prior to SGMA. Therefore, the MT is set to the next shallowest well which is a domestic well with a depth of 42'. |
| 48N04E31M001M | 48 | 29 | MT is set to shallowest well which is a domestic well with a depth of 29'. |
| 41S12E19Q001W | 50 | 39 | The shallowest well is a 14' deep domestic well; however, based on a conversation with the well owner the well is no longer in use, and the household associated with well is abandoned (see Attachment E). MT is set to the next deepest domestic well which has a depth of 39'. There is a 33' deep irrigation well; however, since private irrigation wells are not a main source of supply* the MT was based on the shallowest non-irrigation well. |
| 46N05E21J001M | 32 | 32 | MT is set to 32', which is the depth of 46N05E21J001M as it is the shallowest well in its group. |
| 48N05E35F001M | 32 | 29 | MT is set to 29' to cover a domestic well that was initially grouped with TID Well 8; however, it was moved to the 48N05E35F001M group to ensure it was covered. |
| TL-T1 Q3B | 35 | 35 | There are no wells near TL-T1 Q3B, as noted above the MT is set to lowest measurement recorded plus a 10% buffer. |
| TL-T3 GP | 16 | 16 | There are no wells near TL-T3 GP, as noted above the MT is set to lowest measurement recorded plus a 10% buffer. |

*As identified above, the primary water supply for agricultural operations within the Tule Lake Subbasin is surface water from the Klamath Project. If the surface water supply is not sufficient to meet demand within the Tulelake Irrigation District (District) then the District will operate its groundwater wells to provide additional water supply. Lastly, private irrigation well owners within the District will operate their wells if the surface water supply and District well supply is not sufficient to meet their demand.

Table 3 below summarizes the original MTs identified in the GSP and the updated MTs based on the analysis described above. Hydrographs for each representative monitoring well, including the updated MTs, are provided in Attachment B.

**Table 3 Original and Updated MTs for all Representative Monitoring Wells**

| Representative Monitoring Well | Original MT (ft bgs) | Change (ft) | Updated MT (ft bgs) |
|---|---|---|---|
| 46N05E01P001M | 24 | +0 | 24 |
| 48N04E22M001M | 50 | -70 | 120 |
| 48N04E19C001M | 29 | +1 | 28 |
| 48N04E30F002M (TID Well 1) | 80 | +1 | 79 |
| 47N05E04M001M | 15 | -18 | 33 |
| 47N05E01N001M | 49 | +7 | 42 |
| 48N04E31M001M | 48 | +19 | 29 |
| 41S12E19Q001W | 50 | +0 | 50 |
| 48N04E13K001M (TID Well 5) | 212 | +122 | 90 |
| 46N05E21J001M | 32 | +0 | 32 |
| 46N05E22D001M (TID Well 14) | 99 | +45 | 54 |
| 48N05E35F001M | 32 | +3 | 29 |
| 48N05E26D001M (TID Well 8) | 304 | +230 | 74 |
| TL-T1 Q3B | 35 | +0 | 35 |
| TL-T3 GP | 16 | +0 | 16 |

# Corrective Action B: Potential Dewatered Wells

Corrective Action B within DWR's letter requested the GSAs to determine the number of wells potentially dewatered if an undesirable result were to occur. For this analysis, it was assumed that the water levels dropped uniformly across all wells within its Near grouping. Four thresholds were examined for each representative monitoring well.

1. Total number of potential dewatered wells if MT is reached
2. Total number of potential dewatered wells if MT is exceeded by up to one (1) foot
3. Total number of potential dewatered wells if MT is exceeded by up to five (5) feet
4. Total number of potential dewatered wells if MT is exceeded by up to ten (10) feet

Table 4 provides the results of the exercise described above. Maps showing each representative monitoring well and the associated potentially dewatered wells are provided in Attachment C.

### Table 4 Number of Potential Dewatered Wells if an MT is Reached or Exceeded

| Representative Monitoring Well | MT (ft bgs) | MT is Reached | Exceed by 1' | Exceed by 5' | Exceed by 10' |
|---|---|---|---|---|---|
| 46N05E01P001M | 24 | 1 | 1 | 1 | 1 |
| 48N04E22M001M | 120 | 3* | 3 | 6 | 6 |
| 48N04E19C001M | 28 | 1 | 1 | 2 | 2 |
| 48N04E30F002M (TID Well 1) | 79 | 0 | 0 | 0 | 0 |
| 47N05E04M001M | 33 | 2* | 2 | 3 | 5 |
| 47N05E01N001M | 42 | 2* | 2 | 4 | 7 |
| 48N04E31M001M | 29 | 1 | 1 | 1 | 1 |
| 41S12E19Q001W | 39 | 3* | 3 | 3 | 3 |
| 48N04E13K001M (TID Well 5) | 90 | 0 | 0 | 0 | 0 |
| 46N05E21J001M | 32 | 1 | 1 | 1 | 1 |
| 46N05E22D001M (TID Well 14) | 54 | 0 | 0 | 0 | 0 |
| 48N05E35F001M | 29 | 1 | 1 | 2 | 2 |
| 48N05E26D001M (TID Well 8) | 74 | 0 | 0 | 0 | 0 |
| TL-T1 Q3B | 35 | 0 | 0 | 0 | 0 |
| TL-T3 GP | 16 | 0 | 0 | 0 | 0 |

**Refer to notes in Table 2 regarding wells used to determine MTs*

If undesirable results were to occur, they would likely be experienced by domestic wells users first as they tend to be shallower than irrigation wells, public water supply wells, industrial wells, and other/unknown wells. If groundwater levels were to decline below MTs then these domestic wells would potentially be dewatered, resulting in the need for deepening or replacement. As shown in the analysis above, the MTs are protective of domestic and water supply groundwater wells within the Tule Lake Subbasin. As described in Table 2, there are 4 irrigation wells and 2 domestic wells that are not protected by the MTs, as reflected in Table 4. However, the wells are no longer in use, not a primary water supply source, and/or may have gone dry during drought periods prior to SGMA, which led to those wells being excluded from the analysis.

In many cases if an MT is reached at any given representative monitoring well, then a single well could potentially be dewatered. As identified in Section 5.2.1.3 of the GSP the GSAs developed an undesirable result definition that includes both a number of measurements and a period of time. In regard to the number of measurements, as an exceedance at a single representative monitoring well could be a localized issue, the GSAs developed an undesirable result definition that MTs at four representative monitoring wells (i.e., 4 out of 15 or approximately 26% ) to exceed their MTs. As noted in Section 5.2.1.3 and Section 6.1.7 of the GSP, the GSAs plan to conduct additional monitoring at these wells, and in the event of an MT exceedance at a single representative monitoring well, the GSAs will meet to discuss if additional monitoring or action is necessary to hopefully prevent an issue from spreading. In an effort to prevent undesirable results from occurring, the GSAs developed the combination of the undesirable result definition and the plan for additional monitoring. In regard to the period of time to be considered, the undesirable result definition states that MTs need to be exceeded for three consecutive spring measurements to account for one to two year extreme hydrologic conditions that could result in outlier measurements.

# Corrective Action B: Level of Impacts to Potential GDEs

Corrective Action B of DWR's letter also requested the GSAs to identify the level of impacts to potential Groundwater Dependent Ecosystems (GDEs) if undesirable results were to occur. As identified in Appendix H of the GSP, a total of 5.1 acres of potential GDEs have been identified within the Tule Lake Subbasin which covers a total area of 110,521 acres. This 5.1 acres is generally in five locations described below and shown on the maps in Attachment C.

1. Two potential areas of Greasewood totaling 1.5 acres located in the southwestern area of the Subbasin.
2. Two potential areas of Wet Meadows totaling 2.4 acres located in the eastern area of the Subbasin.
3. One potential area of Wet Meadows totaling 1.2 acres located in the southeastern area of the Subbasin.

As noted in Section 6.1.4 of the GSP, the GSAs have identified the potential GDEs as a data gap and plan to conduct a field inspection of these areas to better understand the vegetation present and confirm potential rooting depths. In addition, as noted in Section 6.1.3 of the GSP, the GSAs have identified the lack of monitoring wells as a data gap as additional monitoring could provide the GSAs a better understanding of water levels near the potential GDEs and confirm if the vegetation is able to access groundwater. Therefore, the GSAs through GSP implementation will attempt to gain a better understanding of these areas via field inspections and additional monitoring.

As noted in the GSP, the Tule Lake Subbasin is currently being sustainably managed. Projects and management actions like those noted above will promote better understanding of the Subbasin and allow for continued sustainability. If undesirable results were to occur, then up to 5.1 acres of potential GDEs may be impacted.

# Attachments

Attachment A: January 18, 2024 letter from Department of Water Resources

Attachment B: Representation monitoring well hydrographs

Attachment C: Maps showing potentially dewatered wells

Attachment D: Maps showing potential GDE locations

Attachment E: Updated Well Completion Report

January 18, 2024

Brad Kirby
Tulelake Irrigation District GSA
P.O. Box 699
Tulelake, CA 96134
tid@cot.net

RE: Klamath River Valley – Tulelake Subbasin - 2022 Groundwater Sustainability Plan

Dear Brad Kirby,

The Department of Water Resources (Department) has evaluated the groundwater sustainability plan (GSP or Plan) submitted for the Klamath River Valley – Tulelake Subbasin. The Department has determined that the Plan is "incomplete" pursuant to Section 355.2(e)(2) of the GSP Regulations.

The Department based its incomplete determination on recommendations from the Staff Report, included as an enclosure to the attached Statement of Findings, which describes that the Subbasin's Plan does not satisfy the objectives of the Sustainable Groundwater Management Act (SGMA) nor substantially comply with the GSP Regulations. The Staff Report also provides corrective actions which the Department recommends the Subbasin's groundwater sustainability agencies (GSAs) review while determining how to address the deficiencies.

The Subbasin's GSAs have 180 days, the maximum allowed by the GSP Regulations, to address the identified deficiencies. Where addressing the deficiencies requires modification of the Plan, the GSAs must adopt those modifications into the GSP and all applicable coordination agreement materials, or otherwise demonstrate that those modifications are part of the Plan before resubmitting it to the Department for evaluation no later than July 16, 2024. The Department understands that much work has occurred to advance sustainable groundwater management since the GSAs submitted the GSP in January 2022. To the extent to which those efforts are related or responsive to the Department's identified deficiencies, we encourage you to document that as part of your Plan resubmittal. The Department prepared a Frequently Asked Questions document to provide general information and guidance on the process of addressing deficiencies in an "incomplete" determination.

Department staff will work expeditiously to review the revised components of your Plan resubmittal. If the revisions sufficiently address the identified deficiencies, the Department will determine that the Plan is "approved". In that scenario, Department staff will identify additional recommended corrective actions that the GSAs should address early in implementing the GSP (i.e., no later than the first required periodic evaluation). Among other items, those corrective actions will recommend the GSAs provide more detail on their plans and schedules to address data gaps. Those recommendations will call for significantly expanded documentation of the plans and schedules to implement specific projects and management actions. Regardless of those recommended corrective actions, the Department expects the first periodic evaluations, required no later than January 2027 – one-quarter of the way through the 20-year implementation period – to document significant progress toward achieving sustainable groundwater management.

If the Subbasin's GSAs cannot address the deficiencies identified in this letter by July 16, 2024, then the Department, after consultation with the State Water Resources Control Board, will determine the GSP to be "inadequate". In that scenario, the State Water Resources Control Board may identify additional deficiencies that the GSAs would need to address in the state intervention processes outlined in SGMA.

Please contact Sustainable Groundwater Management staff by emailing sgmps@water.ca.gov if you have any questions related to the Department's assessment or implementation of your GSP.

Thank You,

Paul Gosselin

Paul Gosselin
Deputy Director
Sustainable Groundwater Management

Attachment:

1. Statement of Findings Regarding the Determination of Incomplete Status of the Klamath River Valley – Tulelake Subbasin Groundwater Sustainability Plan

# STATE OF CALIFORNIA
# DEPARTMENT OF WATER RESOURCES

## STATEMENT OF FINDINGS REGARDING THE DETERMINATION OF INCOMPLETE STATUS OF THE KLAMATH RIVER VALLEY – TULELAKE SUBBASIN GROUNDWATER SUSTAINABILITY PLAN

The Department of Water Resources (Department) is required to evaluate whether a submitted groundwater sustainability plan (GSP or Plan) conforms to specific requirements of the Sustainable Groundwater Management Act (SGMA or Act), is likely to achieve the sustainability goal for the Tulelake Subbasin, and whether the GSP adversely affects the ability of an adjacent basin or subbasin to implement its GSP or impedes achievement of sustainability goals in an adjacent basin or subbasin. (Water Code § 10733.) The Department is directed to issue an assessment of the GSP within two years of its submission. (Water Code § 10733.4.) This Statement of Findings explains the Department's decision regarding the submitted Plan by the Tulelake Irrigation District Groundwater Sustainability Agency, Modoc County Groundwater Sustainability Agency, Siskiyou County Groundwater Sustainability Agency, and City of Tulelake Groundwater Sustainability Agency (collectively, the GSAs or Agencies) for the Klamath River Valley – Tulelake Subbasin (Basin No. 1-002.01).

Department management has reviewed the enclosed Staff Report, which recommends that the identified deficiencies should preclude approval of the GSP at this time. Based on its review of the Staff Report, Department management is satisfied that staff have conducted a thorough evaluation and assessment of the Plan and concurs with, and hereby adopts, staff's recommendation and all the corrective actions provided. The Department thus determines the Plan Incomplete based on the staff assessment and recommendations. In particular, the Department finds:

The GSAs must provide a more detailed explanation and justification regarding the development of the sustainable management criteria for groundwater levels, particularly the undesirable results and minimum thresholds, and quantitatively describe the effects of those criteria on the interests of beneficial uses and users of groundwater. Department staff recommend the GSAs consider and address the following:

a. The GSAs must re-evaluate minimum thresholds for wells that previously were established based on pumping (dynamic) depths, and set minimum thresholds based on a depletion of supply at static depths (i.e., Tulelake Irrigation District wells #5, #8, and #14 or any other deep groundwater wells, or those with well depths greater than 500 feet, the GSAs decide to set SGMA criteria for).

b. The GSAs should analyze the number of wells that may be dewatered and the level of impacts to groundwater dependent ecosystems that may occur without rising to significant and unreasonable levels constituting undesirable results. Identify the number and location of wells that may be negatively affected when minimum thresholds are reached. The GSAs should explain how well mitigation will be considered by the GSAs during their management of the Subbasin in a project or management action as part of the GSP. Department staff also encourage the GSAs to review the Department's April 2023 guidance document titled *Considerations for Identifying and Addressing Drinking Water Well Impacts*.[1]

[1] https://water.ca.gov/Programs/Groundwater-Management/Drinking-Water-Well.

Based on the above, the GSP submitted by the Agencies for the Klamath River Valley – Tulelake Subbasin is determined to be incomplete because the GSP does not satisfy the requirements of SGMA, nor does it substantially comply with the GSP Regulations. The corrective actions provided in the Staff Report are intended to address the deficiencies that, at this time, preclude approval. The Agencies have up to 180 days to address the deficiencies outlined above and detailed in the Staff Report. Once the Agencies resubmit their Plan, the Department will review the revised GSP to evaluate whether the deficiencies were adequately addressed. Should the Agencies fail to take sufficient actions to correct the deficiencies identified by the Department in this assessment, the Department shall disapprove the Plan if, after consultation with the State Water Resources Control Board, the Department determines the Plan inadequate pursuant to 23 CCR § 355.2(e)(3)(C).

Signed:

Karla Nemeth

Karla Nemeth, Director
Date: January 18, 2024

Enclosure: Groundwater Sustainability Plan Assessment Staff Report – Klamath River Valley – Tulelake Subbasin

# State of California
# Department of Water Resources
# Sustainable Groundwater Management Program
# Groundwater Sustainability Plan Assessment
# Staff Report

| | |
|---|---|
| Groundwater Basin Name: | Klamath River Valley – Tulelake Subbasin (No. 1-002.01) |
| Submitting Agency: | Tulelake Irrigation District Groundwater Sustainability Agency, Modoc County Groundwater Sustainability Agency, Siskiyou County Groundwater Sustainability Agency, and City of Tulelake Groundwater Sustainability Agency |
| Submittal Type: | Initial GSP Submission |
| Submittal Date: | January 31, 2022 |
| Recommendation: | Incomplete |
| Date: | January 18, 2024 |

The Sustainable Groundwater Management Act (SGMA)[1] allows for any of the three following planning scenarios: a single groundwater sustainability plan (GSP) developed and implemented by a single groundwater sustainability agency (GSA); a single GSP developed and implemented by multiple GSAs; and multiple GSPs implemented by multiple GSAs and coordinated pursuant to a single coordination agreement.[2] Here, as presented in this staff report, a single GSP covering the entire basin was adopted and submitted to the Department of Water Resources (Department, DWR) for review.[3]

The Tulelake Irrigation District, Modoc County, Siskiyou County, and City of Tulelake GSAs (collectively, the GSAs) jointly submitted the Tule Lake Groundwater Sustainability Plan (GSP or Plan) to the Department for evaluation and assessment as required by SGMA and the GSP Regulations.[4] The GSP covers the entire Klamath River Valley – Tulelake Subbasin (Subbasin) for the implementation of SGMA.

Evaluation and assessment by the Department is based on whether an adopted and submitted GSP, either individually or in coordination with other adopted and submitted GSPs, complies with SGMA and substantially complies with the GSP Regulations. Department staff base their assessment on information submitted as part of an adopted GSP, public comments submitted to the Department, and other materials, data, and reports that are relevant to conducting a thorough assessment. Department staff have

[1] Water Code § 10720 *et seq*.
[2] Water Code § 10727.
[3] Water Code §§ 10727(b)(1), 10733.4; 23 CCR § 355.2.
[4] 23 CCR § 350 *et seq*.

evaluated the GSP and have identified deficiencies that staff recommend should preclude its approval.[5] In addition, consistent with the GSP Regulations, Department staff have provided corrective actions[6] that the GSAs should review while determining how and whether to address the deficiencies. The deficiencies and corrective actions are explained in greater detail in Section 3 of this staff report and are generally related to the need to define sustainable management criteria in the manner required by SGMA and the GSP Regulations.

This assessment includes four sections:

- **Section 1 – Evaluation Criteria:** Describes the legislative requirements and the Department's evaluation criteria.
- **Section 2 – Required Conditions:** Describes the submission requirements, GSP completeness, and basin coverage required for a GSP to be evaluated by the Department.
- **Section 3 – Plan Evaluation:** Provides a detailed assessment of identified deficiencies in the GSP. Consistent with the GSP Regulations, Department staff have provided corrective actions for the GSAs to address the deficiencies.
- **Section 4 – Staff Recommendation:** Provides staff's recommendation regarding the Department's determination.

[5] 23 CCR §355.2(e)(2).
[6] 23 CCR §355.2(e)(2)(B).

# 1 EVALUATION CRITERIA

The Department evaluates whether a Plan conforms to the statutory requirements of SGMA[7] and is likely to achieve the basin's sustainability goal.[8] To achieve the sustainability goal, the Plan must demonstrate that implementation will lead to sustainable groundwater management, which means the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results.[9] Undesirable results are required to be defined quantitatively by the GSAs overlying a basin and occur when significant and unreasonable effects for any of the applicable sustainability indicators are caused by groundwater conditions occurring throughout the basin.[10] The Department is also required to evaluate whether the Plan will adversely affect the ability of an adjacent basin to implement its groundwater sustainability program or achieve its sustainability goal.[11]

For a Plan to be evaluated by the Department, it must first be determined that it was submitted by the statutory deadline[12] and that it is complete and covers the entire basin.[13] Additionally, for those GSAs choosing to develop multiple GSPs, the Plan submission must include a coordination agreement.[14] The coordination agreement must explain how the multiple GSPs in the basin have been developed and implemented utilizing the same data and methodologies and that the elements of the multiple GSPs are based upon consistent interpretations of the basin's setting. If these required conditions are satisfied, the Department evaluates the Plan to determine whether it complies with SGMA and substantially complies with the GSP Regulations.[15] As stated in the GSP Regulations, "[s]ubstantial compliance means that the supporting information is sufficiently detailed and the analyses sufficiently thorough and reasonable, in the judgment of the Department, to evaluate the Plan, and the Department determines that any discrepancy would not materially affect the ability of the Agency to achieve the sustainability goal for the basin, or the ability of the Department to evaluate the likelihood of the Plan to attain that goal."[16]

When evaluating whether the Plan is likely to achieve the sustainability goal for the basin, Department staff review the information provided for sufficiency, credibility, and consistency with scientific and engineering professional standards of practice.[17] The Department's review considers whether there is a reasonable relationship between the

[7] Water Code §§ 10727.2, 10727.4, 10727.6.
[8] Water Code § 10733(a).
[9] Water Code § 10721(v).
[10] 23 CCR § 354.26.
[11] Water Code § 10733(c).
[12] 23 CCR § 355.4(a)(1).
[13] 23 CCR §§ 355.4(a)(2), 355.4(a)(3).
[14] 23 CCR § 357.4.
[15] 23 CCR § 350 *et seq*.
[16] 23 CCR § 355.4(b).
[17] 23 CCR § 351(h).

information provided by the GSAs and the assumptions and conclusions presented in the Plan, including: whether the interests of the beneficial uses and users of groundwater in the basin have been considered; whether sustainable management criteria and projects and management actions described in the Plan are commensurate with the level of understanding of the basin setting; and whether those projects and management actions are feasible and likely to prevent undesirable results.[18] The Department also considers whether the GSAs have the legal authority and financial resources necessary to implement the Plan.[19]

To the extent overdraft is present in a basin, the Department evaluates whether the Plan provides a reasonable assessment of the overdraft and includes reasonable means to mitigate overdraft if present.[20] When applicable, the Department will assess whether coordination agreements have been adopted by all relevant parties and satisfy the requirements of SGMA and the GSP Regulations.[21] The Department also considers whether the Plan provides reasonable measures and schedules to eliminate identified data gaps.[22] Lastly, the Department's review considers the comments submitted on the Plan and evaluates whether the GSAs have adequately responded to the comments that raise credible technical or policy issues with the Plan.[23]

The Department is required to evaluate the Plan within two years of its submittal date and issue a written assessment.[24] The assessment is required to include a determination of the Plan's status.[25] The GSP Regulations provide three options for determining the status of a Plan: approved,[26] incomplete,[27] or inadequate.[28]

Even when the Department determines a Plan is approved, indicating that it satisfies the requirements of SGMA and is in substantial compliance with the GSP Regulations, the Department may still recommend corrective actions.[29] Recommended corrective actions are intended to facilitate progress in achieving the sustainability goal within the basin and the Department's future evaluations, and to allow the Department to better evaluate whether implementation of the Plan adversely affects adjacent basins. While the issues addressed by the recommended corrective actions in an approved Plan do not, at the time the determination was made, preclude its approval, the Department recommends that the issues be addressed to ensure the Plan's implementation continues to be consistent with SGMA and the Department is able to assess progress in achieving the

[18] 23 CCR §§ 355.4(b)(1), (3), (4) and (5).
[19] 23 CCR § 355.4(b)(9).
[20] 23 CCR § 355.4(b)(6).
[21] 23 CCR § 355.4(b)(8).
[22] 23 CCR § 355.4(b)(2).
[23] 23 CCR § 355.4(b)(10).
[24] Water Code § 10733.4(d); 23 CCR § 355.2(e).
[25] Water Code § 10733.4(d); 23 CCR § 355.2(e).
[26] 23 CCR § 355.2(e)(1).
[27] 23 CCR § 355.2(e)(2).
[28] 23 CCR § 355.2(e)(3).
[29] Water Code § 10733.4(d).

basin's sustainability goal.[30] Unless otherwise noted, the Department proposes that recommended corrective actions be addressed by the submission date for the first periodic assessment.[31]

After review of the Plan, Department staff may conclude that the information provided is not sufficiently detailed, or the analyses not sufficiently thorough and reasonable, to evaluate whether it is likely to achieve the sustainability goal for the basin. If the Department determines the deficiencies precluding approval may be capable of being corrected by the GSAs in a timely manner,[32] the Department will determine the status of the Plan to be incomplete. A Plan deemed incomplete may be revised and resubmitted to the Department for reevaluation of whether all deficiencies have been addressed and incorporated into the Plan within 180 days after the Department makes its incomplete determination. The Department will review the revised Plan to evaluate whether the identified deficiencies were sufficiently addressed. Depending on the outcome of that evaluation, the Department may determine the resubmitted Plan is approved. Alternatively, the Department may find a formerly deemed incomplete GSP is inadequate if, after consultation with the State Water Resources Control Board, it determines that the GSAs have not taken sufficient actions to correct any identified deficiencies.[33]

The staff assessment of the Plan involves the review of information presented by the GSAs, including models and assumptions, and an evaluation of that information based on scientific reasonableness. In conducting its assessment, the Department does not recalculate or reevaluate technical information provided in the Plan or perform its own geologic or engineering analysis of that information. The recommendation to approve a Plan does not signify that Department staff, were they to exercise the professional judgment required to develop a Plan for the basin, would make the same assumptions and interpretations as those contained in the Plan, but simply that Department staff have determined that the assumptions and interpretations relied upon by the submitting GSAs are supported by adequate, credible evidence, and are scientifically reasonable.

Lastly, the Department's review and assessment of an approved Plan is a continual process. Both SGMA and the GSP Regulations provide the Department with the ongoing authority and duty to review the implementation of the Plan.[34] Also, GSAs have an ongoing duty to reassess their GSPs, provide annual reports to the Department, and, when necessary, update or amend their GSPs.[35] The passage of time or new information may make what is reasonable and feasible at the time of this review to not be so in the future. The emphasis of the Department's periodic reviews will be to assess the GSA's progress toward achieving the basin's sustainability goal and whether implementation of

[30] Water Code § 10733.8.
[31] 23 CCR § 356.4.
[32] 23 CCR § 355.2(e)(2)(B)(i).
[33] 23 CCR § 355.2(e)(3)(C).
[34] Water Code § 10733.8; 23 CCR § 355.6.
[35] Water Code §§ 10728, 10728.2.

the Plan adversely affects the ability of GSAs in adjacent basins to achieve their sustainability goals.

# 2 REQUIRED CONDITIONS

A GSP, to be evaluated by the Department, must be submitted within the applicable statutory deadline.[36] The GSP must also be complete and must, either on its own or in coordination with other GSPs, cover the entire basin. If a GSP is determined to be incomplete, Department staff may recommend corrective actions that address minor or potentially significant deficiencies identified in the GSP. The GSAs in a basin, whether developing a single GSP covering the basin or multiple GSPs, must sufficiently address those required corrective actions within the time provided, not to exceed 180 days, for the GSP to be reevaluated by the Department and potentially approved.

## 2.1 SUBMISSION DEADLINE

SGMA required basins categorized as high- or medium-priority as of January 1, 2017 and to submit a GSP no later than January 31, 2022.[37]

The GSAs submitted the Tule Lake Groundwater Sustainability Plan GSP to the Department on January 31, 2022, in compliance with the statutory deadline.

## 2.2 COMPLETENESS

GSP Regulations specify that the Department shall evaluate a GSP if that GSP is complete and includes the information required by SGMA and the GSP Regulations.[38]

The GSAs submitted an adopted GSP for the entire Subbasin. Department staff determined that the Tule Lake Groundwater Sustainability Plan GSP was complete and include the required information, sufficient to warrant an evaluation by the Department. Therefore, the Department posted the GSP to its website on February 14, 2022.

## 2.3 BASIN COVERAGE

A GSP, either on its own or in coordination with other GSPs, must cover the entire basin.[39] A GSP that intends to cover the entire basin may be presumed to do so if the basin is fully contained within the jurisdictional boundaries of the submitting GSAs.

The GSP intends to manage the entire Tulelake Subbasin and the jurisdictional boundaries of the submitting GSAs appear to cover the entire Subbasin.

[36] Water Code § 10720.7.
[37] Water Code § 10720.7(a)(2).
[38] 23 CCR § 355.4(a)(2).
[39] Water Code § 10727(b); 23 CCR § 355.4(a)(3).

# 3 PLAN EVALUATION

As stated in Section 355.4 of the GSP Regulations, a basin "shall be sustainably managed within 20 years of the applicable statutory deadline consistent with the objectives of the Act." The Department's assessment is based on a number of related factors including whether the elements of a GSP were developed in the manner required by the GSP Regulations, whether the GSP was developed using appropriate data and methodologies and whether its conclusions are scientifically reasonable, and whether the GSP, through the implementation of clearly defined and technically feasible projects and management actions, is likely to achieve a tenable sustainability goal for the basin.

Department staff have identified deficiencies in the GSP, the most serious of which preclude staff from recommending approval of the GSP at this time. Department staff believe the GSAs may be able to correct the identified deficiencies within 180 days. Consistent with the GSP Regulations, Department staff are providing corrective actions related to the deficiencies, detailed below, including the general regulatory background, the specific deficiency identified in the GSP, and the specific actions to address the deficiency.

Additionally, Department staff note some of the information presented in the water budget, including the assumption that surface water supplies will be delivered at historical levels and the projection of no future overdraft, is not supported by, but rather is at variance with information contained in the Plan. The Plan acknowledges that surface water availability has been limited in the Subbasin beginning in 2001[40] and that groundwater use has generally increased. The GSAs concludes that "if surface water supply were to decrease, groundwater extractions would likely increase potentially leading to the chronic lowering of groundwater levels."[41] The Plan acknowledges a reduction in surface water deliveries since 2001, but also predicts that water deliveries will remain at current levels or higher for the foreseeable future;[42] however, the Plan includes a study by the U.S. Bureau of Reclamation that predicts that future surface water deliveries may be limited.[43] In light of this information, Department staff believe it is prudent for the GSA's to evaluate scenarios in which surface water deliveries are reduced, and develop projects and management actions that could be implemented, as needed, to respond in the event such reductions occur.

[40] Tulelake GSP, Section 2.2.2.1, pp. 63-64.
[41] Tulelake GSP, Section 5.2.1.2, p. 104.
[42] Tulelake GSP, Appendix K, Table 5-2, p. 375.
[43] U.S. Bureau of Reclamation, *Final Report. Klamath River Basin Study. Technical Memorandum 86-68210-2016-06*, p. 272. March 1, 2016.

## 3.1 Deficiency 1. The GSP does not develop sustainable management criteria for the chronic lowering of groundwater levels in a manner substantially compliant with the GSP Regulations.

### 3.1.1 Background

It is up to the GSA to define undesirable results and GSAs must describe the effect of undesirable results on the beneficial uses and users of groundwater.[44] From this definition, the GSA establishes minimum thresholds, which are quantitative values that represent groundwater conditions at representative monitoring sites that, when exceeded individually or in combination with minimum thresholds at other monitoring sites, may cause the basin to experience undesirable results.[45] Put another way, the minimum thresholds represent conditions that, if not exceeded, should prevent the basin from experiencing the undesirable results identified by the GSA. Minimum thresholds for chronic lowering of groundwater levels are the groundwater elevation indicating a depletion of supply at a given location that may lead to undesirable results.[46] Quantitative values for minimum thresholds should be supported by information and criteria relied upon to establish and justify the minimum threshold,[47] and a quantitative description of how conditions at minimum thresholds may affect the interests of beneficial uses and users of groundwater.[48]

### 3.1.2 Deficiency

Department staff conclude that the GSAs did not define undesirable results and minimum thresholds for the chronic lowering of groundwater levels in the manner required by SGMA and the GSP Regulations. As explained below, the GSP does not identify minimum thresholds with sufficient supporting information to allow Department staff to evaluate whether the criteria are reasonable or whether operating the Subbasin to avoid those thresholds is consistent with avoiding undesirable results. Furthermore, some of the proposed thresholds appear to have been developed improperly by relying on groundwater levels determined while active pumping is occurring, which may measure depletion of supply for an individual well but does not provide the static groundwater measurements necessary to assess the depletion of supply for the Subbasin.

It is the responsibility of the Department to evaluate whether a GSA has considered the interests of beneficial uses and users of groundwater, including groundwater dependent ecosystems and any domestic users who may be impacted by lowering groundwater levels, as part of the planned management of the basin.[49] The GSAs have set thresholds based on the shallowest domestic well, however based on public information described

[44] 23 CCR § 354.26 (b)(3), § 354.28 (b)(4).
[45] 23 CCR § 354.28, DWR Best Management Practices for the Sustainable Management of Groundwater: Sustainable Management Criteria (DRAFT), November 2017.
[46] 23 CCR § 354.28 (c)(1).
[47] 23 CCR § 354.28 (b)(1).
[48] 23 CCR § 354.28 (b)(4).
[49] 23 CCR § 355.4 (b)(4).

below, impacts to beneficial users may be occurring in the Subbasin that are not anticipated or included in the Plan. Department staff conclude additional information is needed about how the GSAs performed their analysis and evaluated the interests of beneficial uses and users when establishing sustainable management criteria for groundwater levels.

### 3.1.3 Deficiency Details

GSP Regulations require that GSAs describe the processes and criteria relied upon to define undesirable results caused by the chronic lowering of groundwater levels. Undesirable results occur when significant and unreasonable effects due to chronic lowering of groundwater levels are caused by conditions occurring throughout the basin.[50]

The GSAs developed sustainable management criteria for the chronic lowering of groundwater levels with the assumption that the Subbasin is currently being sustainably managed. The GSP states that an undesirable result is "a result that would cause significant and unreasonable impacts to beneficial uses and users of groundwater over the implementation period of this GSP" and would occur when groundwater elevations drop below the minimum threshold criteria at four of the 15 representative monitoring locations over three consecutive spring measurements.[51] The conditions that the GSAs state as potential causes of undesirable results include that the "[l]owering of groundwater levels would result in increased power costs to extract groundwater"[52] and "[i]n extreme cases, groundwater levels may decrease to an extent where the cost to pump water exceeds the value of the agriculture or effects a large number of domestic wells."[53] As discussed below, the description of undesirable results and establishment of minimum thresholds are not consistent with requirements of the GSP Regulations.

The GSP Regulations require GSAs to set minimum thresholds for chronic lowering of groundwater levels at "the groundwater elevation indicating a depletion of supply at a given location that may lead to undesirable results."[54] The GSP explains that minimum thresholds were determined by considering historical Subbasin conditions and are based on considerations for beneficial users and uses of groundwater.[55] The GSP establishes two different sets of groundwater level minimum thresholds for the representative monitoring wells, as follows:

1. If the monitoring well depth is less than 500 feet and within three miles of a domestic well(s), the minimum threshold is defined as the minimum domestic well depth at that monitoring well.

[50] 23 CCR § 354.26 (a).
[51] Tule Lake Subbasin GSP, Section 5.2.1.3, p. 104.
[52] Tule Lake Subbasin GSP, Section 5.2.1.3, p. 104.
[53] Tule Lake Subbasin GSP, Section 5.2.2.2, p. 105.
[54] 23 CCR § 354.28 (c)(1).
[55] Tule Lake Subbasin GSP, Section 5.3.1.2, p. 109.

2. If the monitoring well depth is greater than or equal to 500 feet, the minimum threshold is defined as the historical low groundwater measurement plus a 10 percent buffer, rounded up to the nearest whole number.

Department staff have identified two key problems with how the GSAs have set minimum thresholds. First, the GSP does not appear to use static groundwater level measurements as the basis for the sustainable management criteria for one or more of the representative monitoring site wells. The GSP Regulations require "static groundwater elevation measurements shall be collected at least two times per year, to represent seasonal low and seasonal high groundwater conditions."[56] There are discrepancies between the historical lows reported in Table 5.1 for two representative monitoring wells and the historical lows shown on hydrographs provided in the GSP; further, one representative monitoring well does not have a hydrograph (TID Well No. 8) in the GSP.[57] These discrepancies indicate that historical low groundwater levels may not be accurately depicted in these wells, which likely effect the sustainable management criteria set at these locations. The GSP states that representative monitoring wells are represented in hydrographs where static groundwater elevation data was measured,[58] but comparing well data in the GSP with hydrographs in the Department's SGMA Portal monitoring site, the minimum thresholds seem to be based on pumping or dynamic depths rather than static depths to groundwater. This is problematic because, as stated above, the GSP Regulations require that static measurements be made to represent basin conditions wholistically rather than individual well conditions. Department staff's evaluation is supported by a public comment from the State of Oregon Water Resources Department, stating, "these threshold values use the maximum pumping depth measurements as opposed to non-pumping levels. In some cases, this sets the minimum threshold hundreds of feet below the current water table elevations."[59]

Table 1, below, presents values reported in the GSP as historical low depths for three representative monitoring wells, and compares these values with the approximate "static" historical low estimated by Department staff (based on hydrographs presented in the GSP) and "dynamic" historical low values reported in the Department's SGMA Portal. All values are reported in feet below ground surface (ft bgs).

[56] 23 CCR §354.34(c)(1)(B).
[57] Tule Lake Subbasin GSP, Figure 2-24, p. 67, Figure 2-25, p. 68, and Figure 2-28, p. 69.
[58] Tule Lake Subbasin GSP, Section 2.2.2.1, p. 64.
[59] GSP Submittal Comments 1-002.01 TULELAKE, Department of Water Resources SGMA Portal, CDWR-Tule Lake Response Letter_20220812signedTB.pdf.

*Table 1. Comparison of Static Water Levels and Assumed Dynamic Water Levels.*

| Well No. | GSP Reported Historical Low (ft bgs) from Table 5.1 | Approximate "Static" Historical Low (ft bgs) from GSP Hydrograph | "Dynamic" Historical Low (ft bgs) from SGMA Portal |
|---|---|---|---|
| 48N04E13K001M (TID Well 5) | 192 | 58[60] | 192.3[61] |
| 48N05E26D001M (TID Well 8) | 276 | No Data Reported | 276.7[62] |
| 46N05E22D001M (TID Well 14) | 90 | 42[63] | 90.3[64] |

The data reported in the first column of Table 1, which is reported in the GSP as static low values, is far closer to "dynamic" pumping measurements from the same wells, shown in column 3, than "static" values extrapolated from the hydrograph provided in Appendix M of the GSP[65] (column 2 in Table 1). Staff conclude that the Plan misidentified the nature of well measurements reported in column 1 (and in Table 5.1 in the GSP) as static when they are apparently dynamic water level measurements. The difference is significant because the GSP defines minimum thresholds for chronic lowering of groundwater levels as a function of historical trends and the rate of groundwater elevation decline based on projected water use in the Subbasin, and dynamic measurements present significantly lower groundwater elevations than static measurements.[66] Furthermore, dynamic groundwater level measurements represent the efficiency of an individual well and do not represent static Subbasin conditions and therefore, do not represent the rate of groundwater elevation decline, meaning a reduction in pumping rates could still allow for large declines of non-pumping groundwater level before minimum thresholds are reached. As such, dynamic groundwater levels should not be used to establish sustainable management criteria. Best management practice and industry standard indicate that wells selected for inclusion in the GSAs' monitoring network, and by extension those with established sustainable management criteria, should be evaluated to ensure that groundwater level data obtained meet data quality objectives for that well.[67] "For example, some wells may be directly influenced by nearby pumping, or injection and observation of the aquifer response may be the purpose of the well. Otherwise, the network should contain an adequate number of wells to observe the overall static conditions and the specific project effects." The data quality objective process, which follows the U.S. EPA Guidance on Systematic Planning Using the Data Quality Objectives

[60] Data from June 2015.
[61] Department of Water Resources, SGMA Portal, Well Elevation Chart, 419971N1214519W001 (TID #5) [website], https://sgma.water.ca.gov/SgmaWell/well/wellelevationchart/24209#elevation, (Data from June 24, 2010, accessed 25 July 2023).
[62] Department of Water Resources, SGMA Portal, Well Elevation Chart, 419762N1213727W001 (TID #8) [website], https://sgma.water.ca.gov/SgmaWell/well/wellelevationchart/24257#elevation, (Data from September 26, 2002, accessed 25 July 2023).
[63] Data from July 2016.
[64] Department of Water Resources, SGMA Portal, Well Elevation Chart, 418174N1213955W001 (TID #14) [website], https://sgma.water.ca.gov/SgmaWell/well/wellelevationchart/24257#elevation, (Data from August 10, 2018, accessed 25 July 2023).
[65] Tule Lake Subbasin GSP, Appendix M, pp. 510-527.
[66] 23 CCR 354.28 (c)(1).
[67] 23 CCR §354.34(c)(1)(B), *DWR Best Management Practices for the Sustainable Management of Groundwater: Monitoring Networks and Identification of Data Gaps*, December 2016.

Process, presents a method that can be applied directly to the sustainability criteria quantitative requirements.[68] The GSAs should revise the minimum threshold for all wells to be based on a static groundwater level that represents a depletion of supply that would lead to undesirable results (see Corrective Action 1a).

The second problem Department staff identified with how the GSAs have set minimum thresholds is that the GSP does not demonstrate how the interests of beneficial uses and users were considered. The GSP Regulations require GSAs to consider how conditions at minimum thresholds may affect the interests of beneficial uses and users of groundwater.[69] Although the GSP refers to agricultural and domestic users, it does not provide a reasonably comprehensive description of the potential undesirable results that might be experienced by all beneficial uses and users during plan implementation. The GSP discusses the potential effects of the chronic lowering of groundwater levels related to agricultural use and the costs to pump groundwater, but does not mention potential effects on domestic users or other uses,[70] or define what the GSAs consider effects to "a large number of domestic wells"[71] to be, although the GSP acknowledges that in the Subbasin, at least "2,400 people are dependent on groundwater for domestic purposes."[72]

Declining groundwater levels have affected beneficial users in the Subbasin during implementation of the GSP, including impairments to drinking water access. In June 2023, the City of Tulelake was awarded grant funding to rehabilitate two wells including lowering a pump, provide bottled water, and install an emergency potable water filling station due to declines in regional groundwater levels.[73] Department staff are concerned that impacts to domestic and municipal water sources within the Subbasin may result from proposed groundwater management activities and that the GSP does not adequately identify those potential impacts nor plan to address them through projects and management actions. Information from the Department's California's Groundwater Live: Groundwater Levels 'Current Groundwater Level Conditions' dashboard[74] showed 7 monitoring wells at their 'All-Time Low', 23 monitoring wells 'Much Below Normal', 7 monitoring wells 'Below Normal', and 9 monitoring wells at 'Normal' or 'Above Normal' in the mid-summer of 2023. The GSA's Annual Report also reported a loss in storage of over 14,000 acre-feet during Water Year 2021-2022[75] and the hydrograph for representative monitoring well TL-T3 (located in the southern portion of the Subbasin near the Sump 1B area) shows

[68] DWR Best Management Practices for the Sustainable Management of Groundwater: Groundwater Monitoring Protocols, Standards, and Sites, December 2016.
[69] 23 CCR 354.28 (b)(4).
[70] Tule Lake Subbasin GSP, Section 5.2.1.2, p. 104.
[71] Tule Lake Subbasin GSP, Section 5.2.2.2, p. 105.
[72] Tule Lake Subbasin GSP, Executive Summary, p. 10.
[73] Department of Water Resources Small Community Drought Relief Program, City of Tulelake application: *Attachment I, Part III – Summary of Project Costs; Scope of Work and Project Description*, p. 6.
[74] Department of Water Resources, *California's Groundwater Live: Groundwater Levels 'Current Groundwater Level Conditions'* [website], https://storymaps.arcgis.com/stories/b3886b33b49c4fa8adf2ae8bdd8f16c3, (accessed 25 July 2023).
[75] Tule Lake Subbasin GSP Annual Report Water Year 2022, Table 2-3, p. 15.

groundwater levels within 1 foot of reaching the minimum threshold for that well[76]. If, after considering the deficiency described above, the GSAs retain minimum thresholds that allow for continued lowering of groundwater levels and those below historical lows, then it is reasonable to assume that additional wells may be impacted during implementation of the Plan. While SGMA does not require all impacts to groundwater uses and users to be mitigated, the GSAs should consider including a formal mitigation strategy, describing how drinking water impacts that may occur due to continued overdraft during the period between the start of Plan implementation and achievement of the Subbasin's sustainability goal will be addressed. If mitigation strategies are not included, the GSP should contain a thorough discussion, with supporting facts and rationale, explaining how and why the GSAs determined not to include specific actions or programs to monitor and mitigate drinking water impacts from continued groundwater lowering below 2015 levels.

Information is available to the GSAs to support their explanation and justification for the criteria established in their Plan. For example, the Department's well completion report dataset,[77] or other similar data, can be used to estimate the number and kinds of wells expected to be impacted at the proposed minimum thresholds. Additionally, public water system well locations and water quality data can currently be obtained using the State Water Board's Geotracker website.[78] Administrative contact information for public water systems, and well locations and contacts for state small water systems and domestic wells, can be obtained by contacting the State Water Board's Needs Analysis staff. The State Water Board is currently developing a database to allow for more streamlined access to this data in the future.

Department staff have determined that the GSAs have not considered possible worsening conditions, such as a reduction in expected surface water supplies, and therefore, the GSAs should evaluate and describe the potential effects on domestic wells and other beneficial users and uses of groundwater, such as environmental users. Although the GSP states that "[d]uring 2021 and some prior years, domestic wells within the Subbasin have experienced issues where the supply has gone dry",[79] Department staff do not believe that the GSAs have provided sufficient information to define if, and what, significant and unreasonable impacts could not occur in domestic wells or to other beneficial users (e.g., municipal drinking water sources, environmental, wetlands) before groundwater levels reach the minimum thresholds in monitoring wells less than 500 feet deep (defined as the minimum domestic well depth). Lastly, the use of what are suspected to be pumping groundwater level depths, reported as static groundwater level depths in the GSP as historical lows for these three representative wells, is also of concern to Department staff. Department staff have proposed recommended corrective actions,

[76] Tule Lake Subbasin GSP Annual Report Water Year 2022, Appendix B, p. 37.
[77] Department of Water Resources, *Well Completion Reports* [website], https://water.ca.gov/Programs/Groundwater-Management/Wells/Well-Completion-Reports, (accessed 3 April 2023).
[78] State Water Resources Control Board, *GeoTracker* [website], https://geotracker.waterboards.ca.gov/, (accessed 3 April 2023).
[79] Tule Lake Subbasin GSP, Section 6.1.6, p. 113.

described below, requiring the GSAs to identify undesirable results that it wishes to avoid and to establish minimum thresholds that will avoid undesirable results for groundwater users and uses in the Subbasin.

The GSAs do not disclose whether the proposed minimum thresholds may impact environmental uses and users such as the Subbasin's two main wetlands (including seasonal wetlands, permanent vegetation, and open water areas).[80] The GSP also does not account specifically for these uses and users in future groundwater system[81] or land system water budgets.[82] Several public comments made to the GSAs on the draft GSP and to the Department on the final GSP voice concerns that environmental users of groundwater were not considered in the water budget and sustainable management criteria. The GSAs responded to one such concern with the following statement: "the Tule Lake Sumps are operated pursuant to the Biological Opinion and impacted by Reclamation's operation of the Klamath Project. Therefore, operation of the Sumps and protection of beneficial users of the Sumps is outside the jurisdiction of this GSP."[83] Department staff do not agree with the GSAs that "protection of beneficial users of the Sumps is outside the jurisdiction of this GSP" because the Tule Lake Sumps water budget is a factor in Subbasin water budgets, management of the Subbasin's surface and groundwater could affect beneficial uses and users in the Sumps area, and because these groundwater uses and users are identified in the Plan.

While the GSP acknowledges the proposed thresholds could lead to impacts that include to beneficial uses and users if groundwater levels are depleted, the Plan does not provide a clear description of the circumstances under which such impacts would become significant and unreasonable to particular beneficial uses and users. Department staff are unable to determine whether the interests of beneficial uses and users or groundwater, as well as the land uses and property interests potentially affected by the use of groundwater in the Subbasin, have been considered.[84] The GSAs must identify the number, location, and percentage of wells that may be impacted at the proposed minimum thresholds, as well as those wells that may not be addressed through the proposed Domestic Well Assistance investigation[85] and explain how the interests of beneficial uses and users were considered. The GSA must also evaluate how the proposed management may impact environmental users such as groundwater dependent ecosystems (see Corrective Action 1b).

Additionally, the Tulelake Subbasin is one of only three medium-priority groundwater basins in California that are truncated by the state border but whose basin fill is in direct connection with basin-fill sediments in an adjacent state.[86] While the SGMA basin

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[80] Tule Lake Subbasin GSP, Section 2.1.1.3, p. 25.
[81] Tule Lake Subbasin GSP, Appendix K, Table 5-3, p. 376.
[82] Tule Lake Subbasin GSP, Appendix K, Table 5-2, p. 375.
[83] Tule Lake Subbasin GSP, Appendix C, "Responses to Public Comments" Table, Comment # 8.1, p. 236.
[84] 23 CCR § 355.4 (b)(4).
[85] Tule Lake Subbasin GSP, Section 6.1.6, pp. 113-114.
[86] Tule Lake Subbasin GSP, Section 2.2.1.1, pp. 46-47.

boundary ends at the state line, the U.S. Geological Survey identifies the area defined by the Department as the Klamath River Valley Basin as part of the Upper Klamath Groundwater Basin[87] located within both California and Oregon.[88] Though the GSP makes little mention of the hydrogeologic properties of the U.S. Geological Survey-designated northern portion of the basin, the GSP explains that an integrated groundwater and surface water flow model that included the north of the Subbasin within Klamath County, Oregon, was developed to prepare water budgets for the Subbasin.[89] However, The GSP explains that "[f]or the purposes of SGMA, the Subbasin is bounded to the north by the state boundary of Oregon and California."[90] Department staff agree that per SGMA,[91] the GSAs should consider whether their GSP impedes achievement of sustainability goals in adjacent subbasins within California. However, the law is silent about how GSAs should consider effects on adjacent subbasins outside of the state of California.

A public comment received from the Oregon Department of Water Resources (ODWR) states there have been historical impacts to beneficial uses and users in the Oregon portion of the overall hydrologic basin, which the comment claims have been caused by groundwater use in the California portion of the Klamath River Valley Basin (i.e., the Tulelake Subbasin). The letter details how the ODWR has implemented its own regulation of groundwater in the Klamath River Valley Basin as a result of historical impacts. The letter further states there are concerns about how the implementation of the Tulelake GSP may affect users in Oregon and impact the effectiveness of the regulations governing the Oregon portion of the Klamath River Valley Basin, including that the "plan does not address past groundwater budget imbalances dating back to at least 2001, significant groundwater level declines observed in 2020 and 2021, and large increases in domestic wells in Oregon going dry in 2021 and 2022".[92] While SGMA does not require a GSA to consider the interests of beneficial uses and users outside of California, under this unique circumstance, it may be prudent for the GSA to coordinate with the ODWR outside of the framework of SGMA.

### 3.1.4 Corrective Action 1

The GSAs must provide more detailed explanations and justifications regarding the sustainable management criteria for chronic lowering of groundwater levels, particularly the undesirable results and minimum thresholds and the effects of those criteria on the

[87] U.S. Geological Survey, *Upper Klamath Basin Groundwater Studies*, [website], https://www.usgs.gov/centers/oregon-water-science-center/science/upper-klamath-basin-groundwater-studies#overview, (accessed 22 September 2023).
[88] Tule Lake Subbasin GSP, Appendix K, p. 350.
[89] Tule Lake Subbasin GSP, Section 4, p. 93.
[90] Tule Lake Subbasin GSP, Section 2.2.1.1, p. 47.
[91] Water Code § 10733(c).
[92] GSP Submittal Comments 1-002.01 TULELAKE, Department of Water Resources SGMA Portal, CDWR-Tule Lake Response Letter_20220812signedTB.pdf.

interests of beneficial uses and users of groundwater. Specifically, the Plan must be amended as follows:

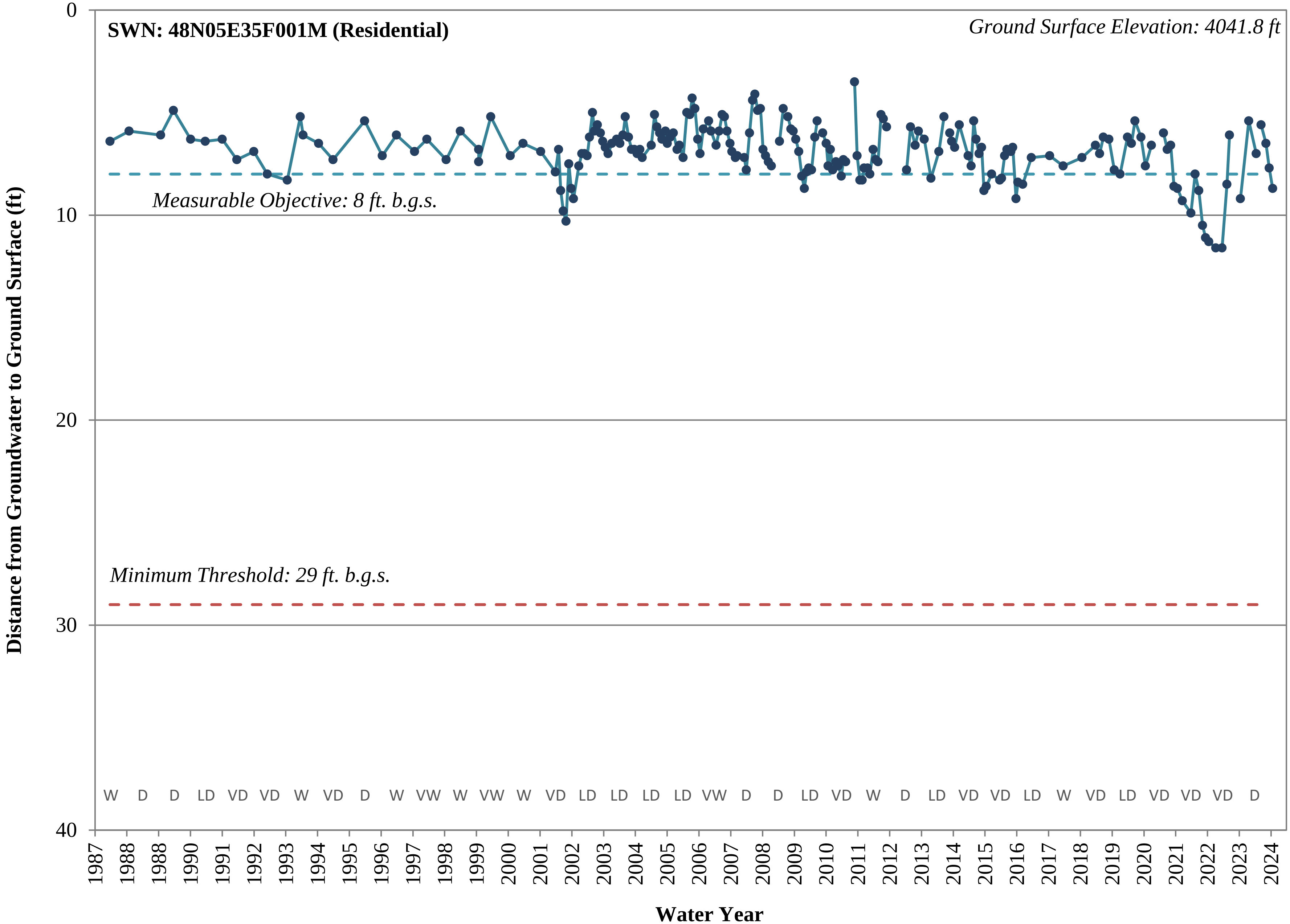
a. The GSAs must re-evaluate minimum thresholds for wells that previously were established based on pumping (dynamic) depths, and set minimum thresholds based on a depletion of supply at static depths (i.e., TID wells #5, #8, and #14 or any other deep groundwater wells, or those with well depths greater than 500 feet, the GSAs decide to set SGMA criteria for).

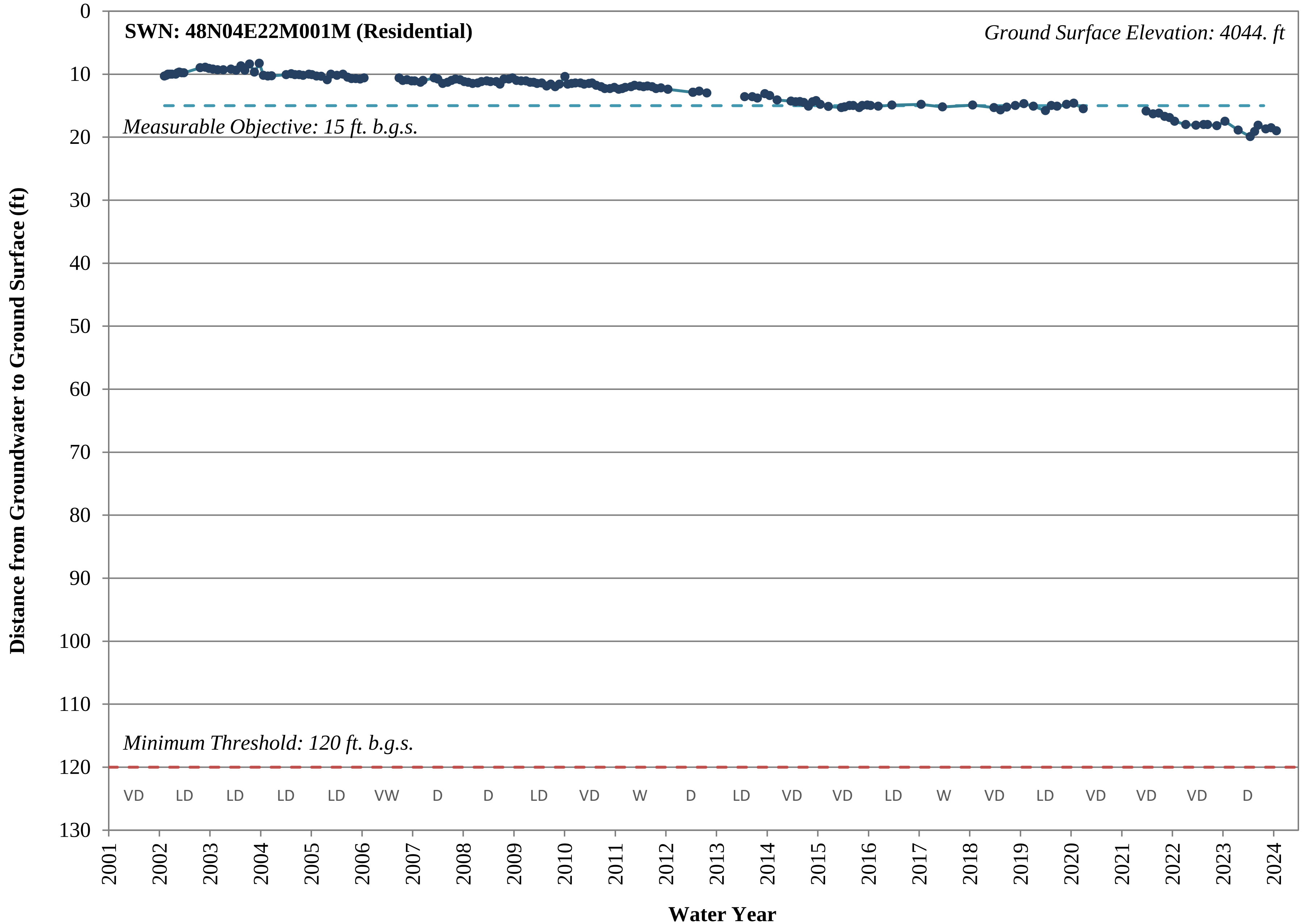
b. The GSAs should analyze the number of wells that may be dewatered and the level of impacts to groundwater dependent ecosystems that may occur without rising to significant and unreasonable levels constituting undesirable results. Identify the number and location of wells that may be negatively affected when minimum thresholds are reached. Compare well infrastructure for all well types in the Subbasin with minimum thresholds at nearby suitably representative monitoring sites. Document all assumptions and steps clearly so that it will be understood by readers of the GSP. Include maps of potentially affected well locations, identify the number of potentially affected wells by well type, and provide a supporting discussion of the effects. The GSAs should explain how well mitigation will be considered by the GSAs during their management of the Subbasin in a project or management action as part of the GSP. Department staff also encourage the GSAs to review the Department's April 2023 guidance document titled *Considerations for Identifying and Addressing Drinking Water Well Impacts*.[93]

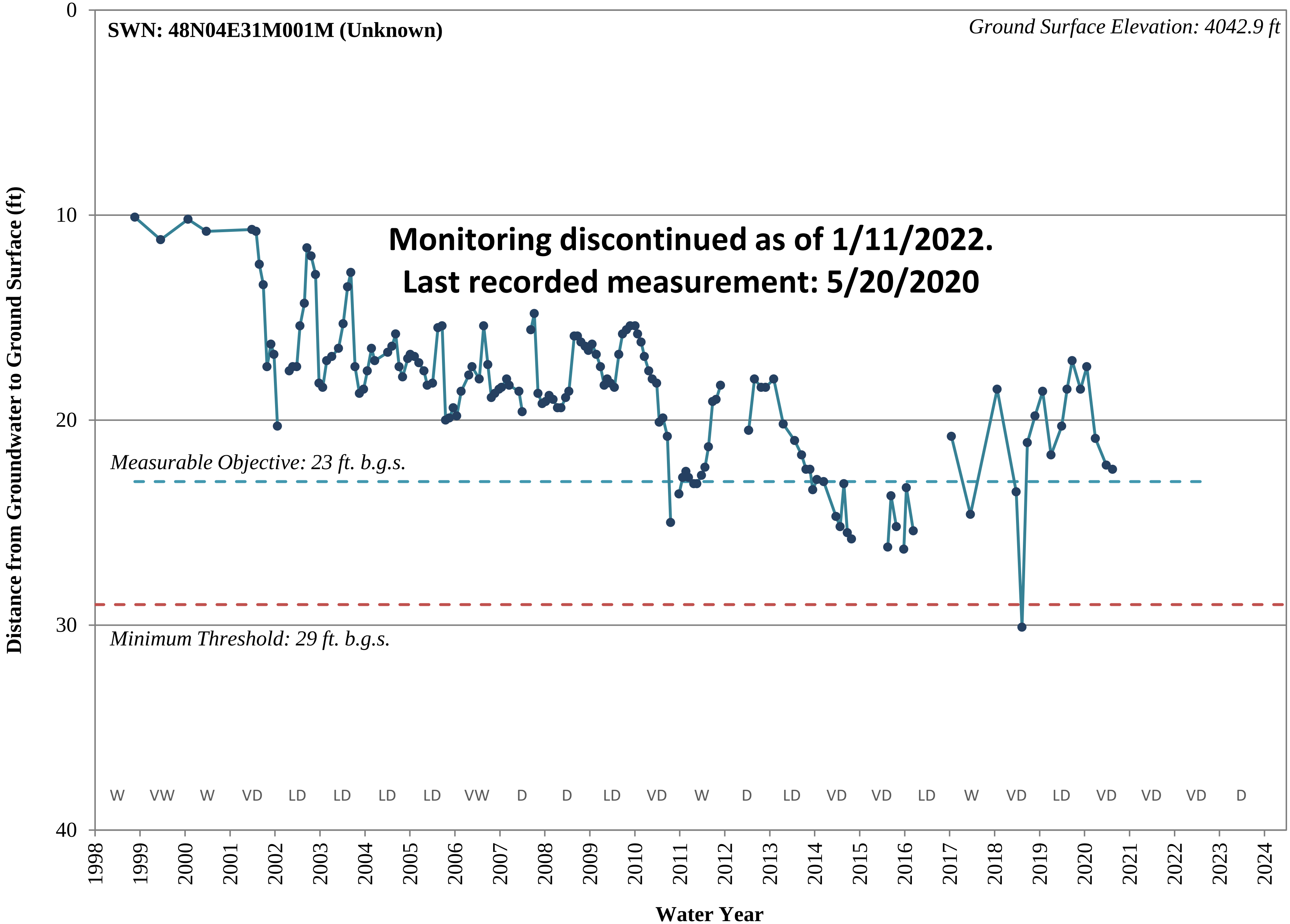
# 4 STAFF RECOMMENDATION

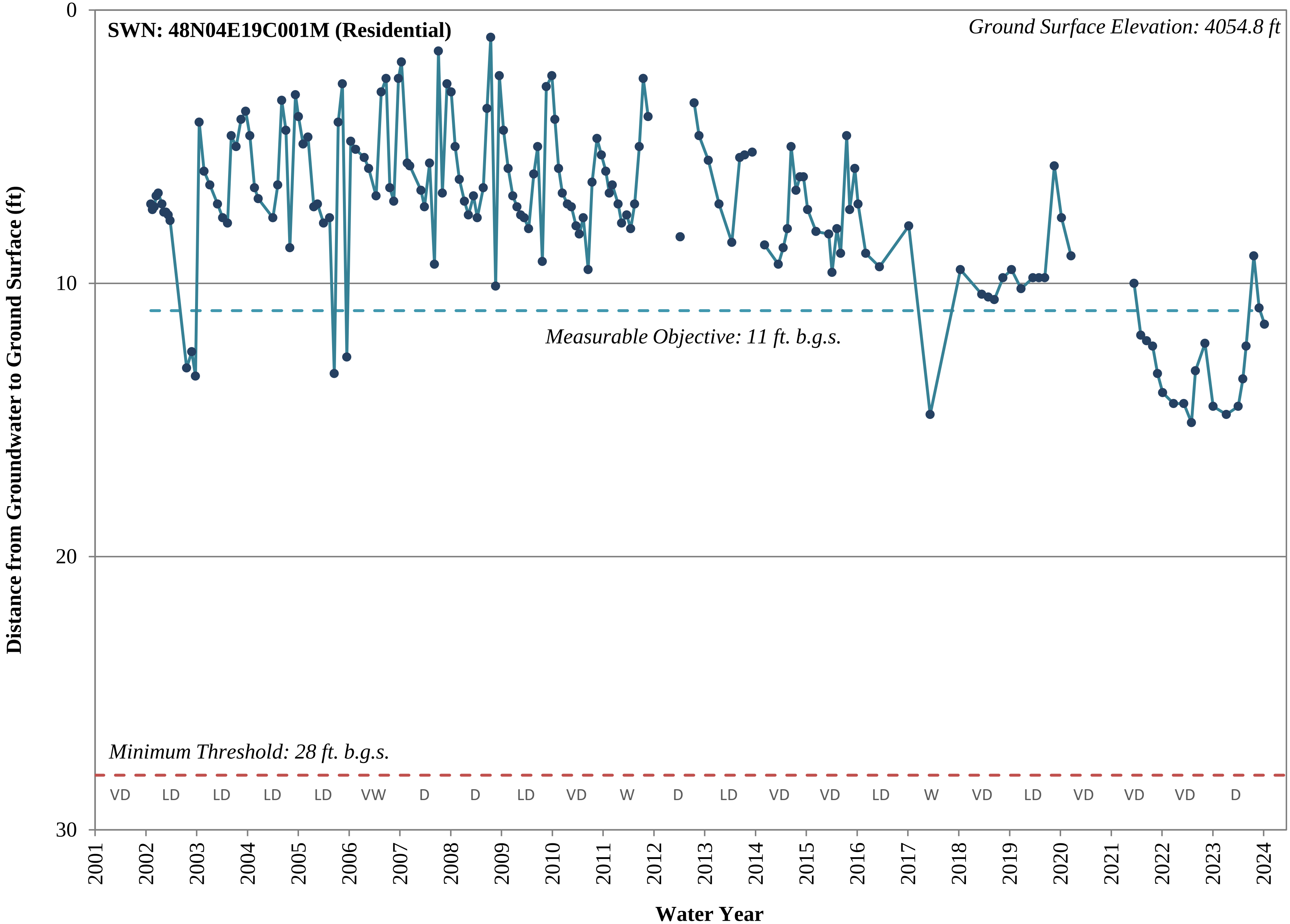
Department staff believe that the deficiencies identified in this assessment should preclude approval of the GSP for the Klamath River Valley – Tulelake Subbasin. Department staff recommend that the GSP be determined incomplete.

[93] https://water.ca.gov/Programs/Groundwater-Management/Drinking-Water-Well.

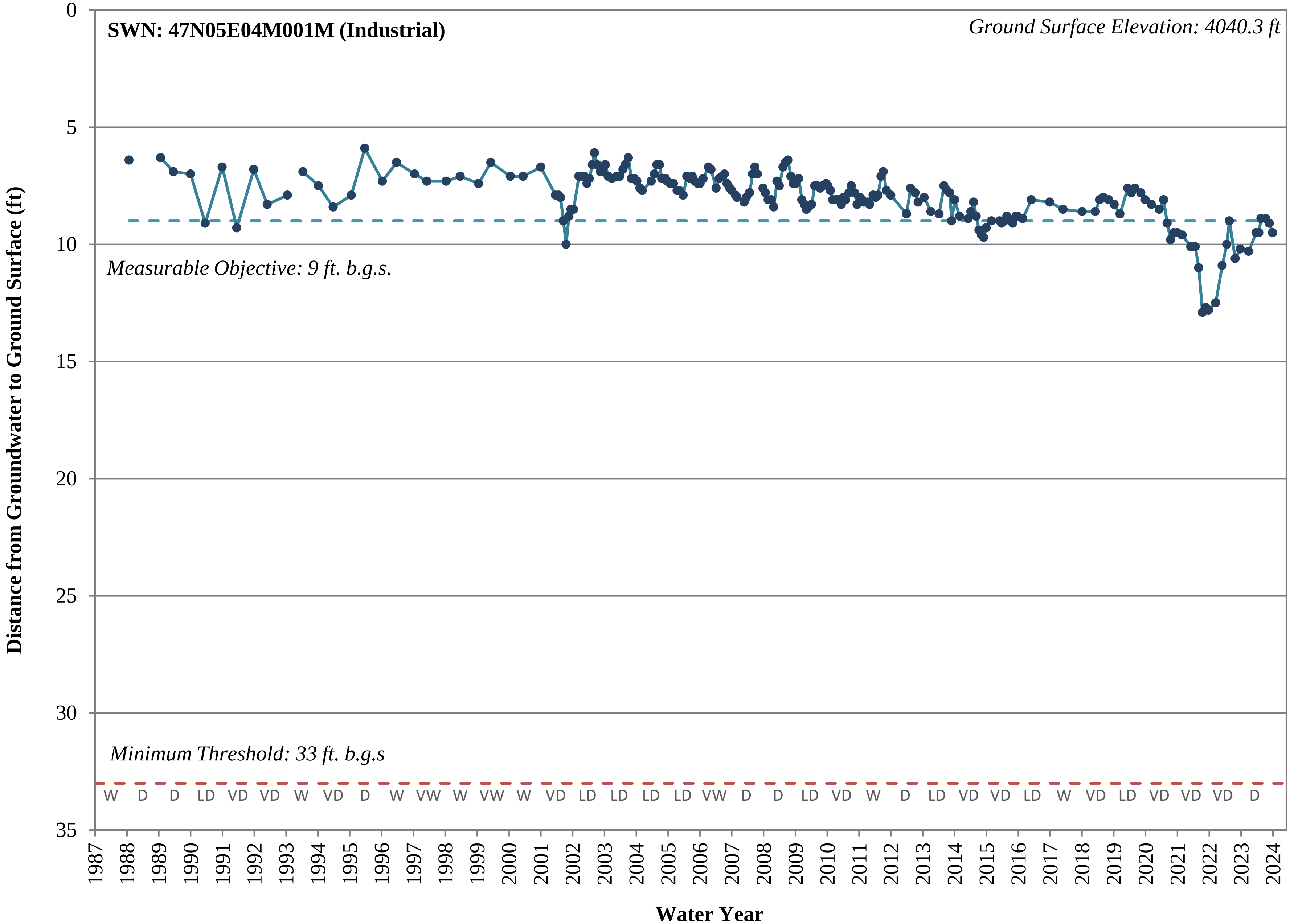

SWN: 48N05E35F001M (Residential)
Ground Surface Elevation: 4041.8 ft
Measurable Objective: 8 ft. b.g.s.
Minimum Threshold: 29 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
Water Year
0
10
20
30
40
W D D LD VD VD W VD D W VW W VW W VD LD LD LD LD VW D D LD VD W D LD VD VD LD W VD LD VD VD VD D
1987 1988 1988 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024


SWN: 48N04E22M001M (Residential)
Ground Surface Elevation: 4044. ft
Measurable Objective: 15 ft. b.g.s.
Minimum Threshold: 120 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
VD LD LD LD LD VW D D LD VD W D LD VD VD LD W VD LD VD VD VD D
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
Water Year

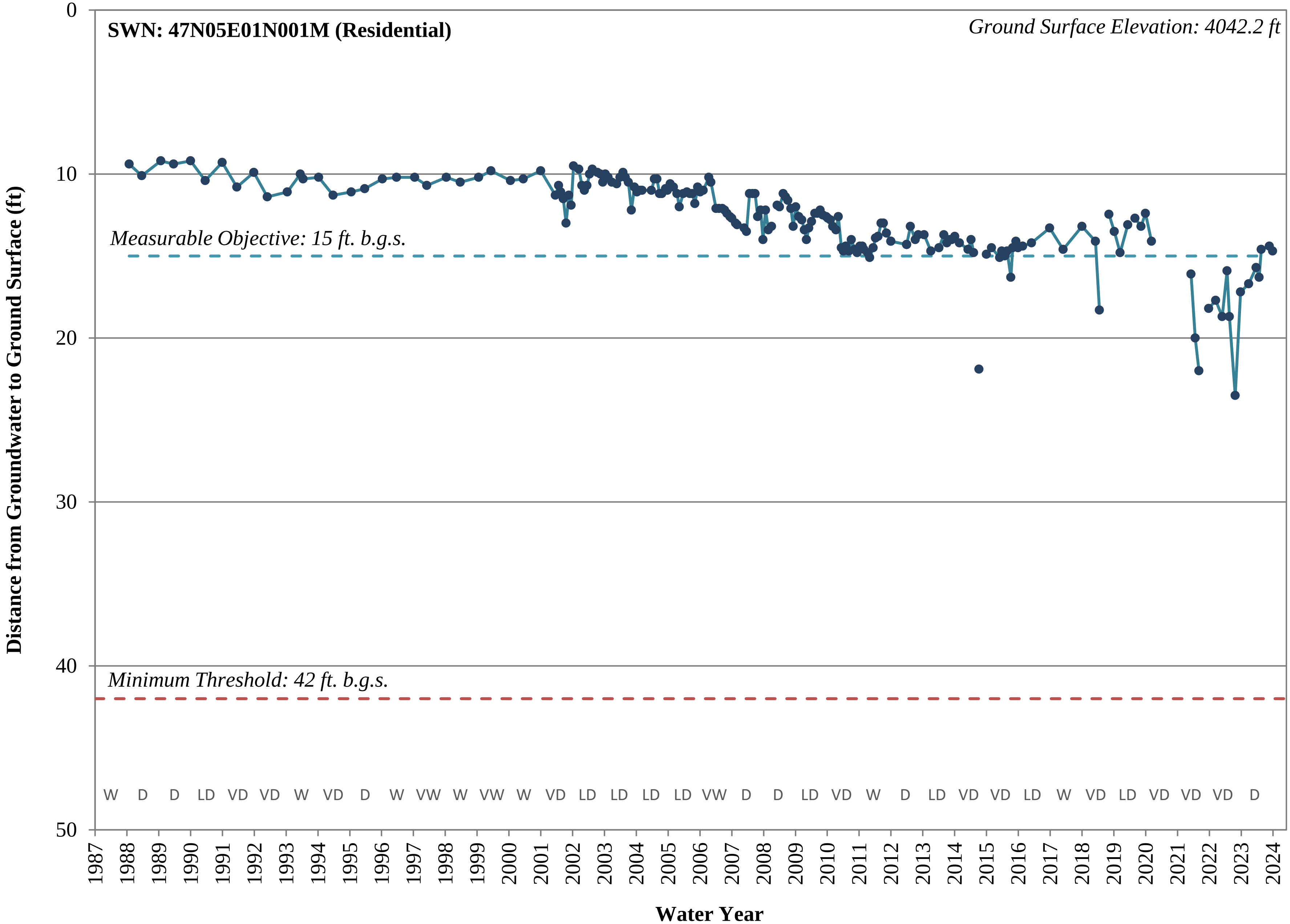

SWN: 48N04E31M001M (Unknown)
Ground Surface Elevation: 4042.9 ft
Monitoring discontinued as of 1/11/2022.
Last recorded measurement: 5/20/2020
Measurable Objective: 23 ft. b.g.s.
Minimum Threshold: 29 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
Water Year
W VW W VD LD LD LD LD VW D D LD VD W D LD VD VD LD W VD LD VD VD VD D



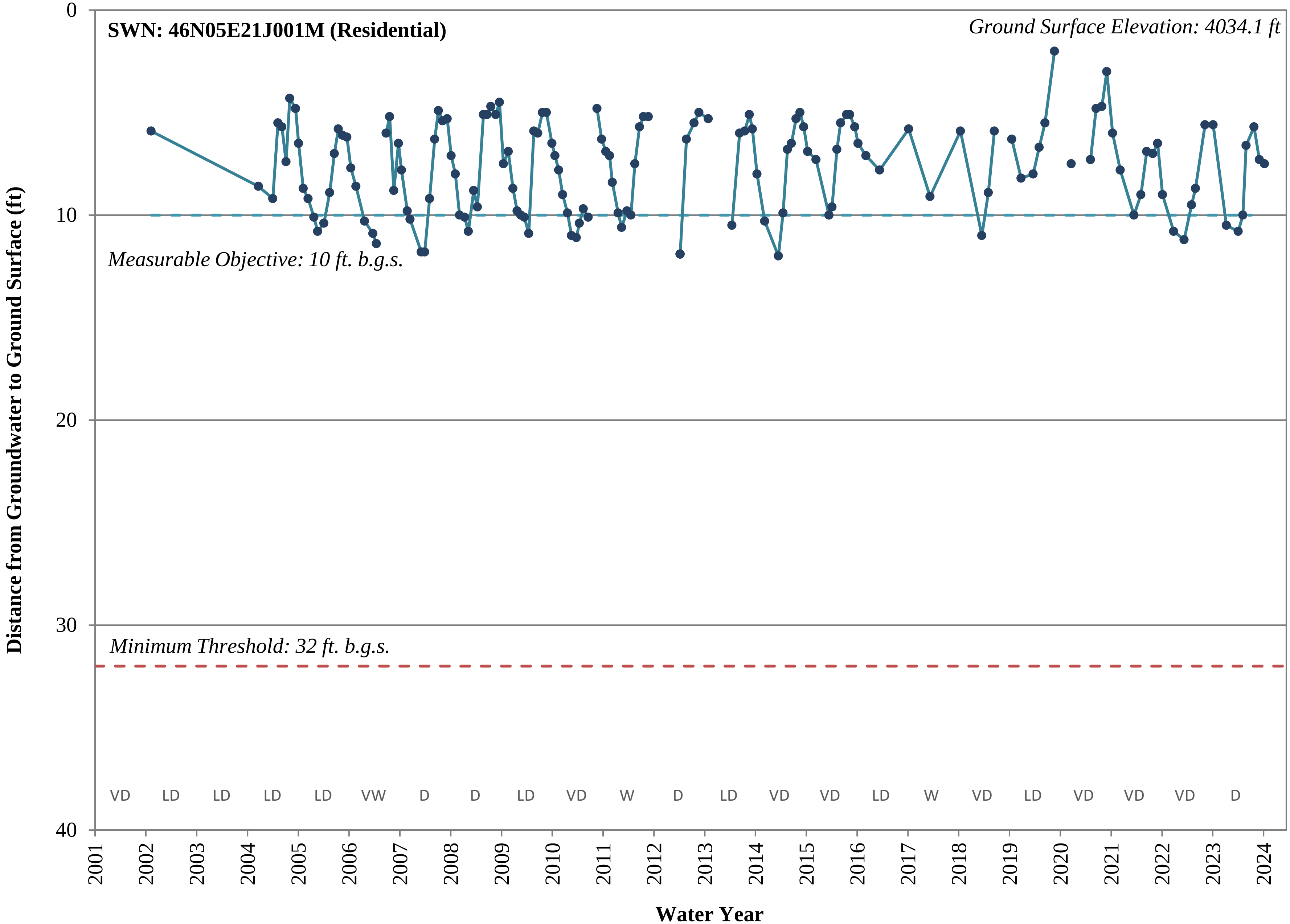
SWN: 48N04E19C001M (Residential)
Ground Surface Elevation: 4054.8 ft
Measurable Objective: 11 ft. b.g.s.
Minimum Threshold: 28 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
Water Year
0
10
20
30
VD LD LD LD LD VW D D LD VD W D LD VD VD LD W VD LD VD VD VD D
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024

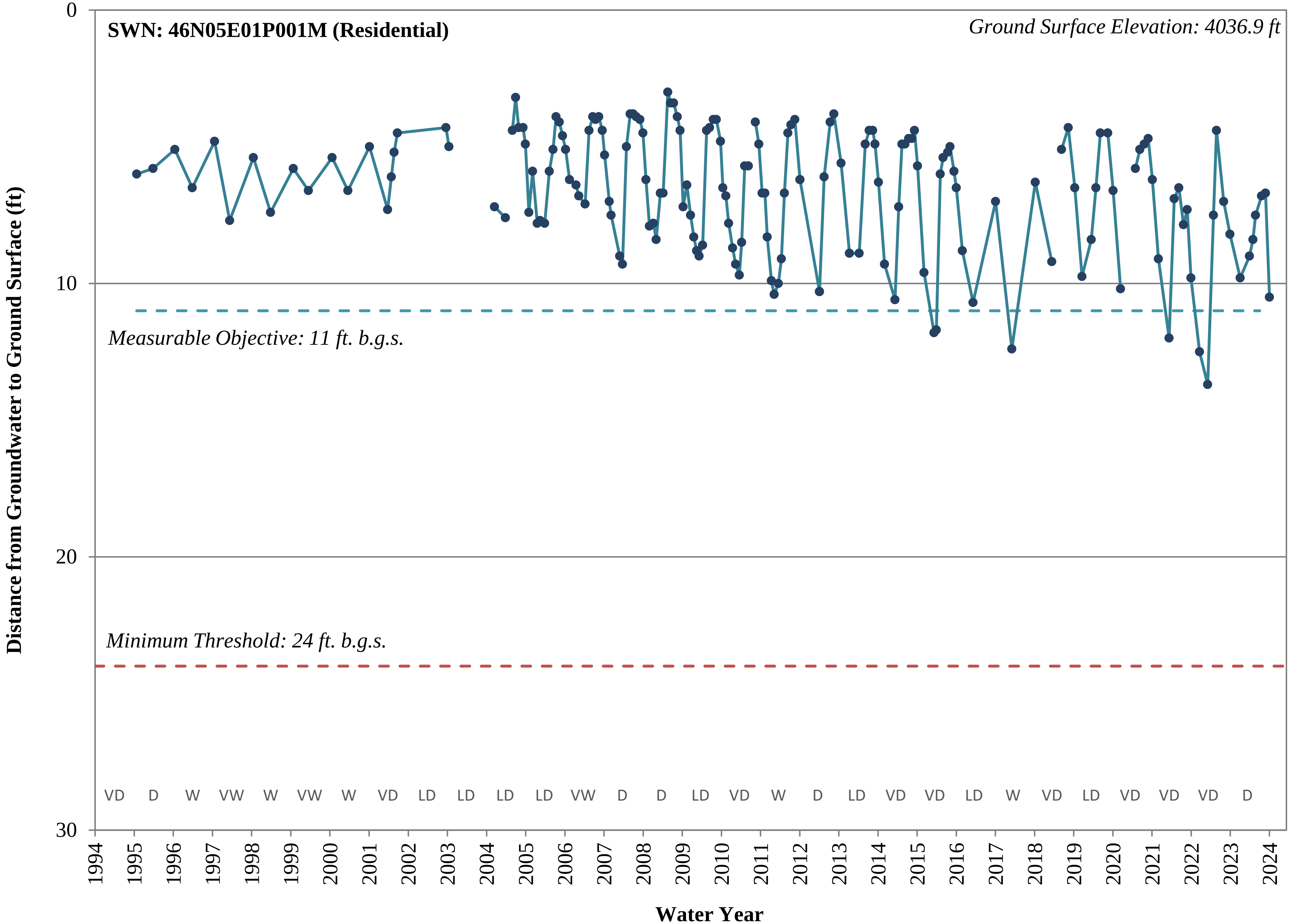


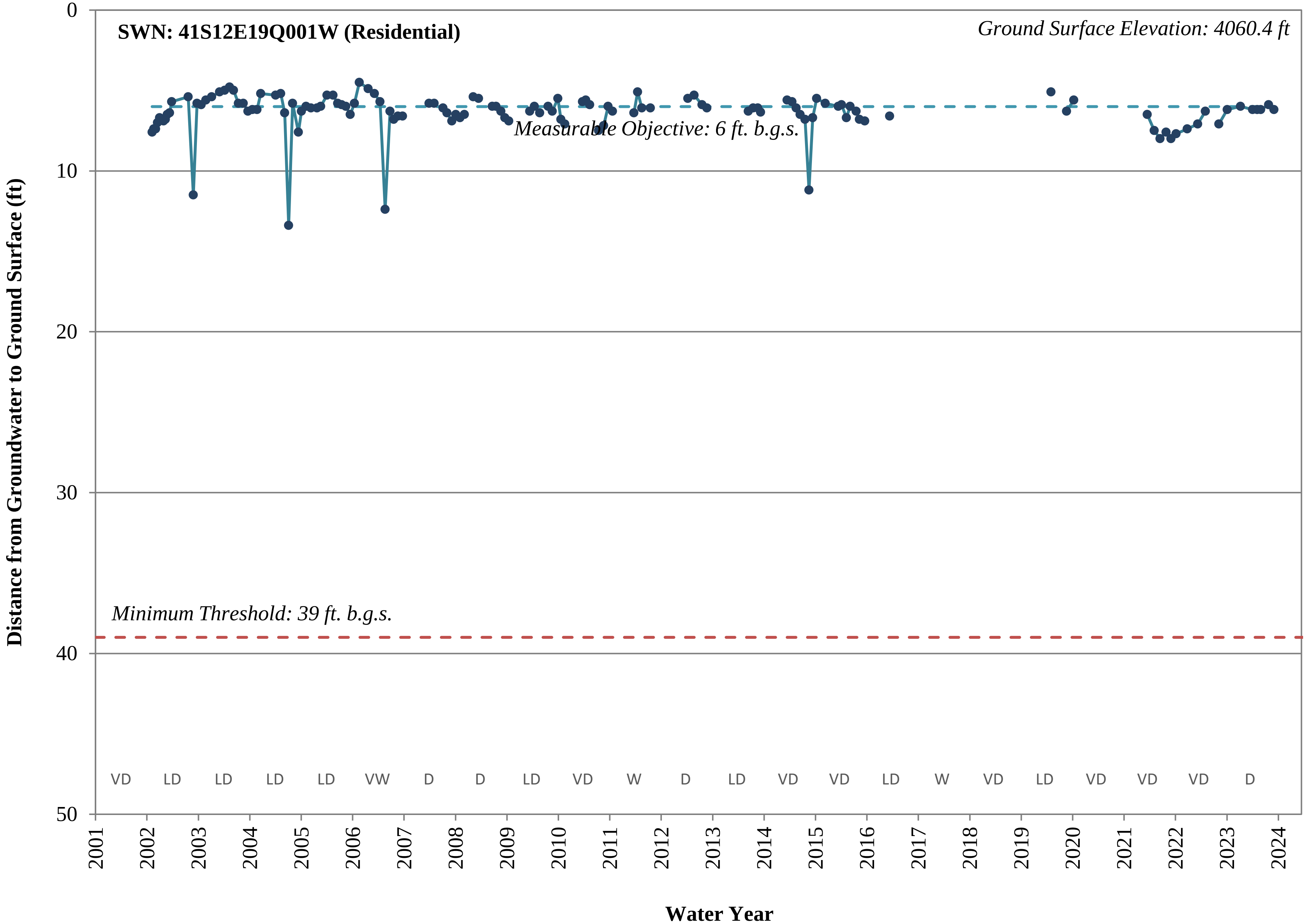
SWN: 47N05E04M001M (Industrial)
Ground Surface Elevation: 4040.3 ft
Measurable Objective: 9 ft. b.g.s.
Minimum Threshold: 33 ft. b.g.s
Distance from Groundwater to Ground Surface (ft)
Water Year
W D D LD VD VD W VD D W VW W VW W VD LD LD LD LD VW D D LD VD W D LD VD VD LD W VD LD VD VD VD D



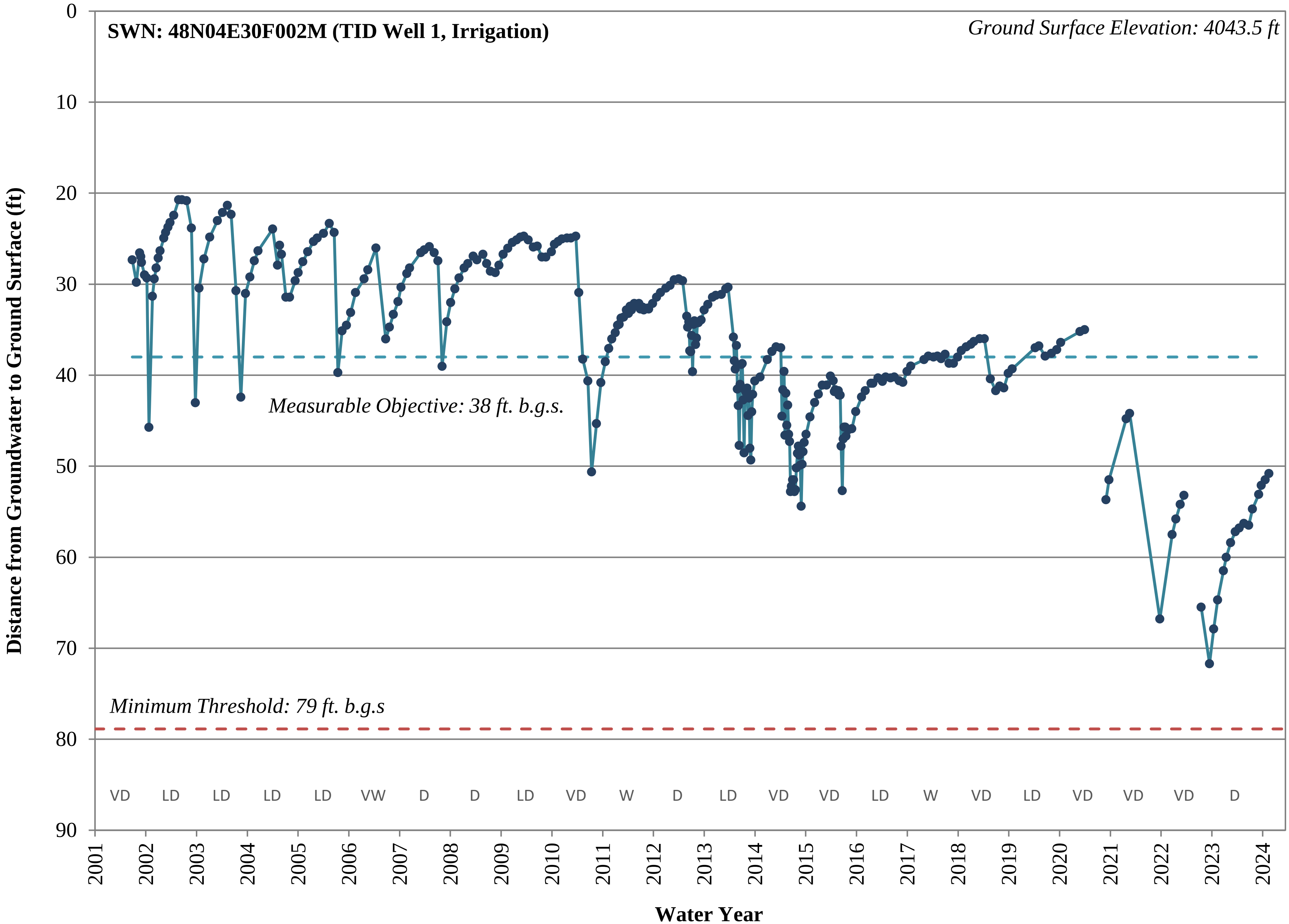
SWN: 47N05E01N001M (Residential)
Ground Surface Elevation: 4042.2 ft
Measurable Objective: 15 ft. b.g.s.
Minimum Threshold: 42 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
0
10
20
30
40
50
W D D LD VD VD W VD D W VW W VW W VD LD LD LD LD VW D D LD VD W D LD VD VD LD W VD LD VD VD VD D
1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
Water Year

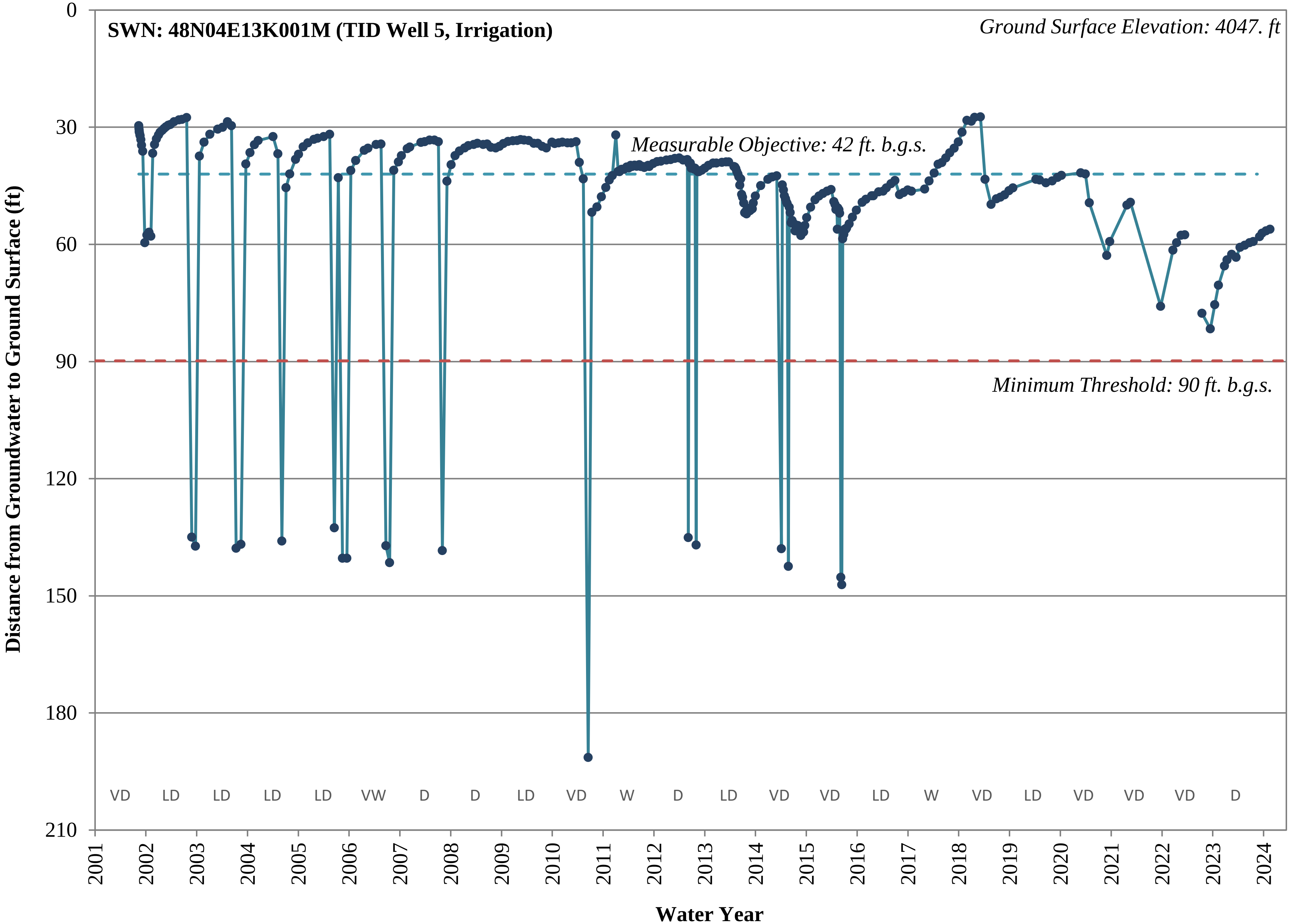

SWN: 46N05E21J001M (Residential)
Ground Surface Elevation: 4034.1 ft
Measurable Objective: 10 ft. b.g.s.
Minimum Threshold: 32 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
0
10
20
30
40
VD LD LD LD LD VW D D LD VD W D LD VD VD LD W VD LD VD VD VD D
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
Water Year


SWN: 46N05E01P001M (Residential)
Ground Surface Elevation: 4036.9 ft
Measurable Objective: 11 ft. b.g.s.
Minimum Threshold: 24 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
0
10
20
30
VD D W VW W VW W VD LD LD LD LD VW D D LD VD W D LD VD VD LD W VD LD VD VD VD D
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
Water Year



SWN: 41S12E19Q001W (Residential)
Ground Surface Elevation: 4060.4 ft
Measurable Objective: 6 ft. b.g.s.
Minimum Threshold: 39 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
0
10
20
30
40
50
VD LD LD LD LD VW D D LD VD W D LD VD VD LD W VD LD VD VD VD D
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
Water Year


SWN: 48N04E30F002M (TID Well 1, Irrigation)
Ground Surface Elevation: 4043.5 ft
Measurable Objective: 38 ft. b.g.s.
Minimum Threshold: 79 ft. b.g.s
Distance from Groundwater to Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
VD LD LD LD LD VW D D LD VD W D LD VD VD LD W VD LD VD VD VD D
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
Water Year



SWN: 48N04E13K001M (TID Well 5, Irrigation)
Ground Surface Elevation: 4047. ft
Measurable Objective: 42 ft. b.g.s.
Minimum Threshold: 90 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
0
30
60
90
120
150
180
210
VD
LD
LD
LD
LD
VW
D
D
LD
VD
W
D
LD
VD
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LD
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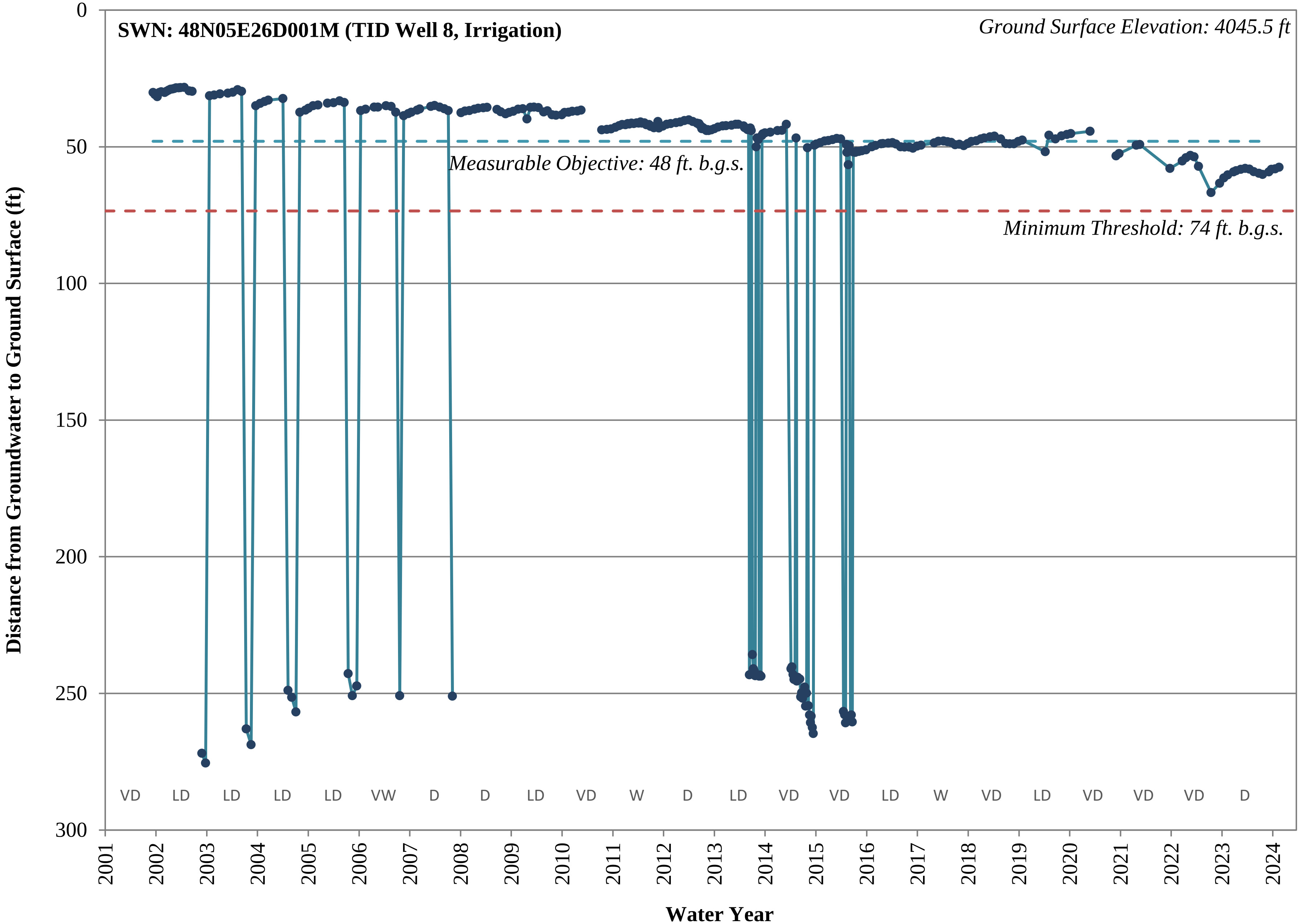
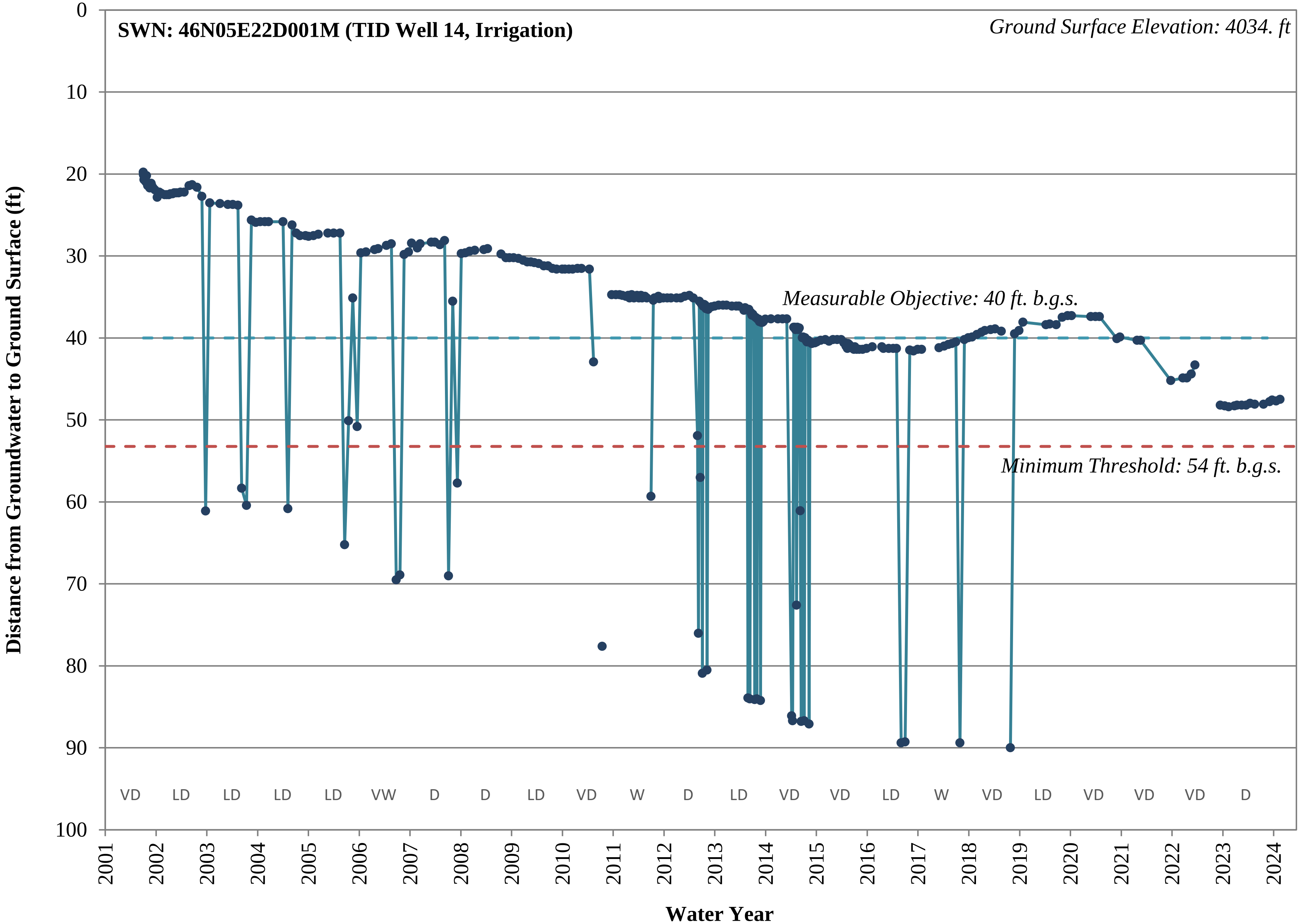
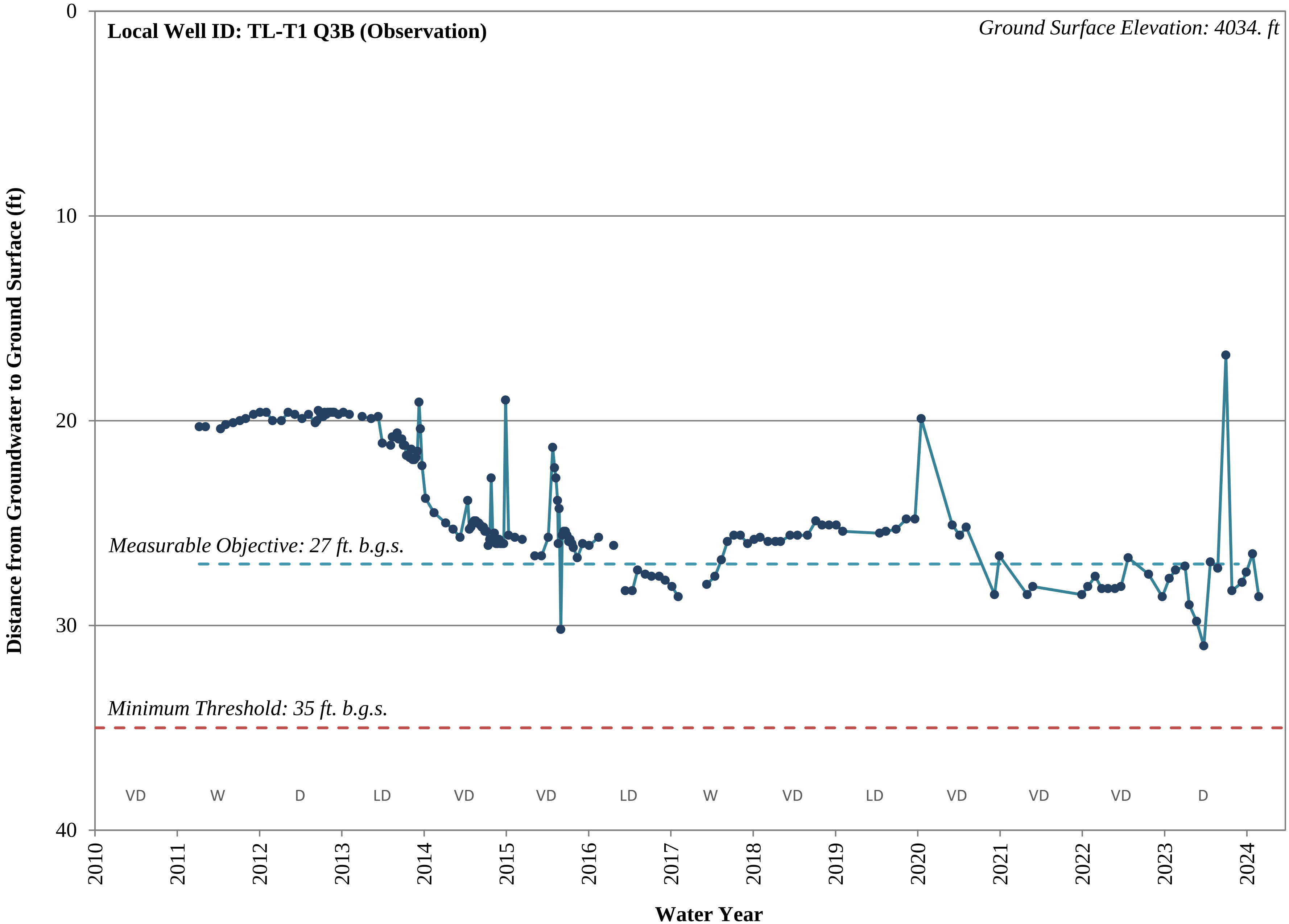
Water Year

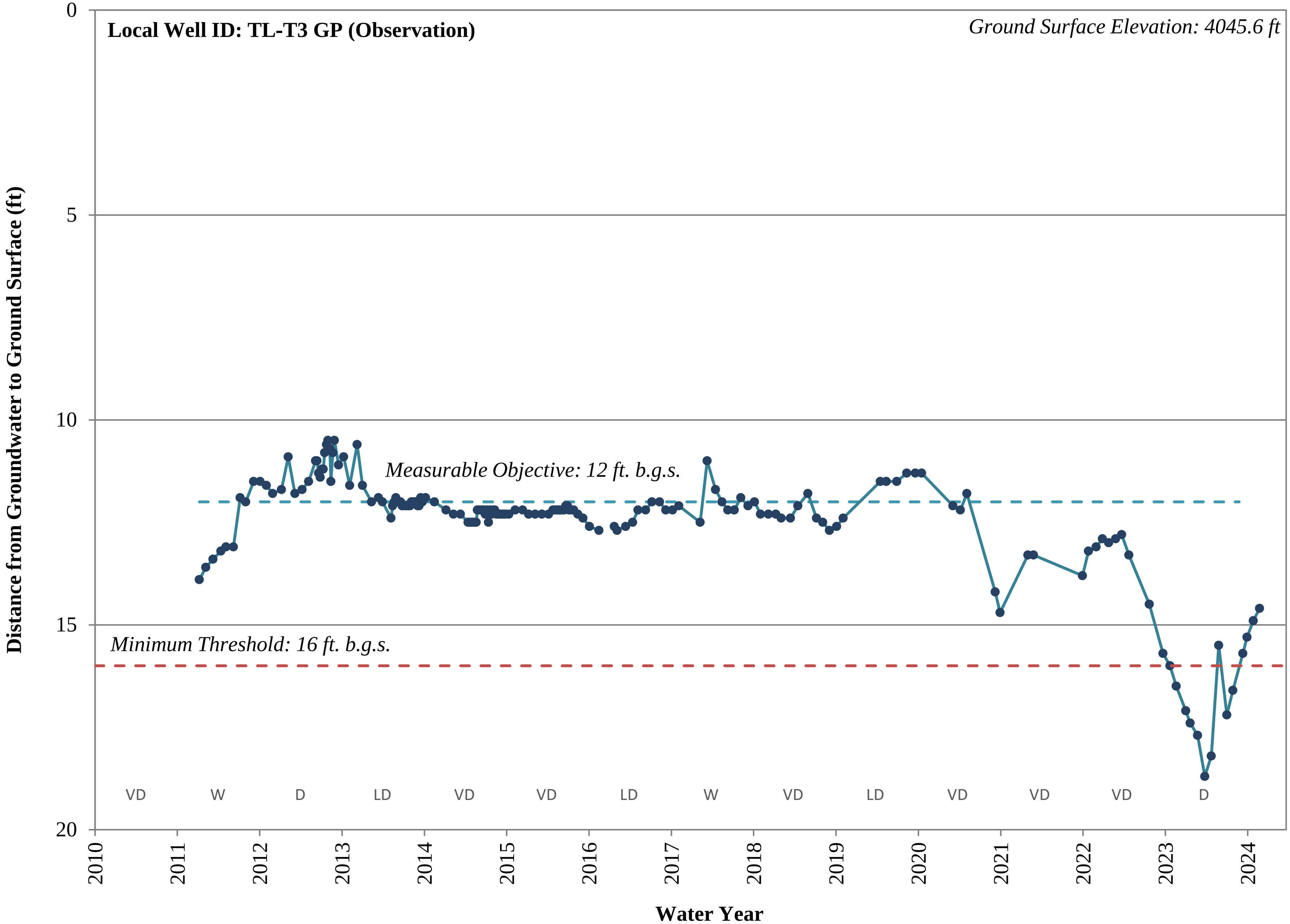


SWN: 48N05E26D001M (TID Well 8, Irrigation)
Ground Surface Elevation: 4045.5 ft
Measurable Objective: 48 ft. b.g.s.
Minimum Threshold: 74 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
0
50
100
150
200
250
300
VD LD LD LD LD VW D D LD VD W D LD VD VD LD W VD LD VD VD VD D
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
Water Year



SWN: 46N05E22D001M (TID Well 14, Irrigation)
Ground Surface Elevation: 4034. ft
Measurable Objective: 40 ft. b.g.s.
Minimum Threshold: 54 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
0
10
20
30
40
50
60
70
80
90
100
VD LD LD LD LD VW D D LD VD W D LD VD VD LD W VD LD VD VD VD D
2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
Water Year


Local Well ID: TL-T1 Q3B (Observation)
Ground Surface Elevation: 4034. ft
Measurable Objective: 27 ft. b.g.s.
Minimum Threshold: 35 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
0
10
20
30
40
VD W D LD VD VD LD W VD LD VD VD VD D
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
Water Year


Local Well ID: TL-T3 GP (Observation)
Ground Surface Elevation: 4045.6 ft
Measurable Objective: 12 ft. b.g.s.
Minimum Threshold: 16 ft. b.g.s.
Distance from Groundwater to Ground Surface (ft)
0
5
10
15
20
VD
W
D
LD
VD
VD
LD
W
VD
LD
VD
VD
VD
D
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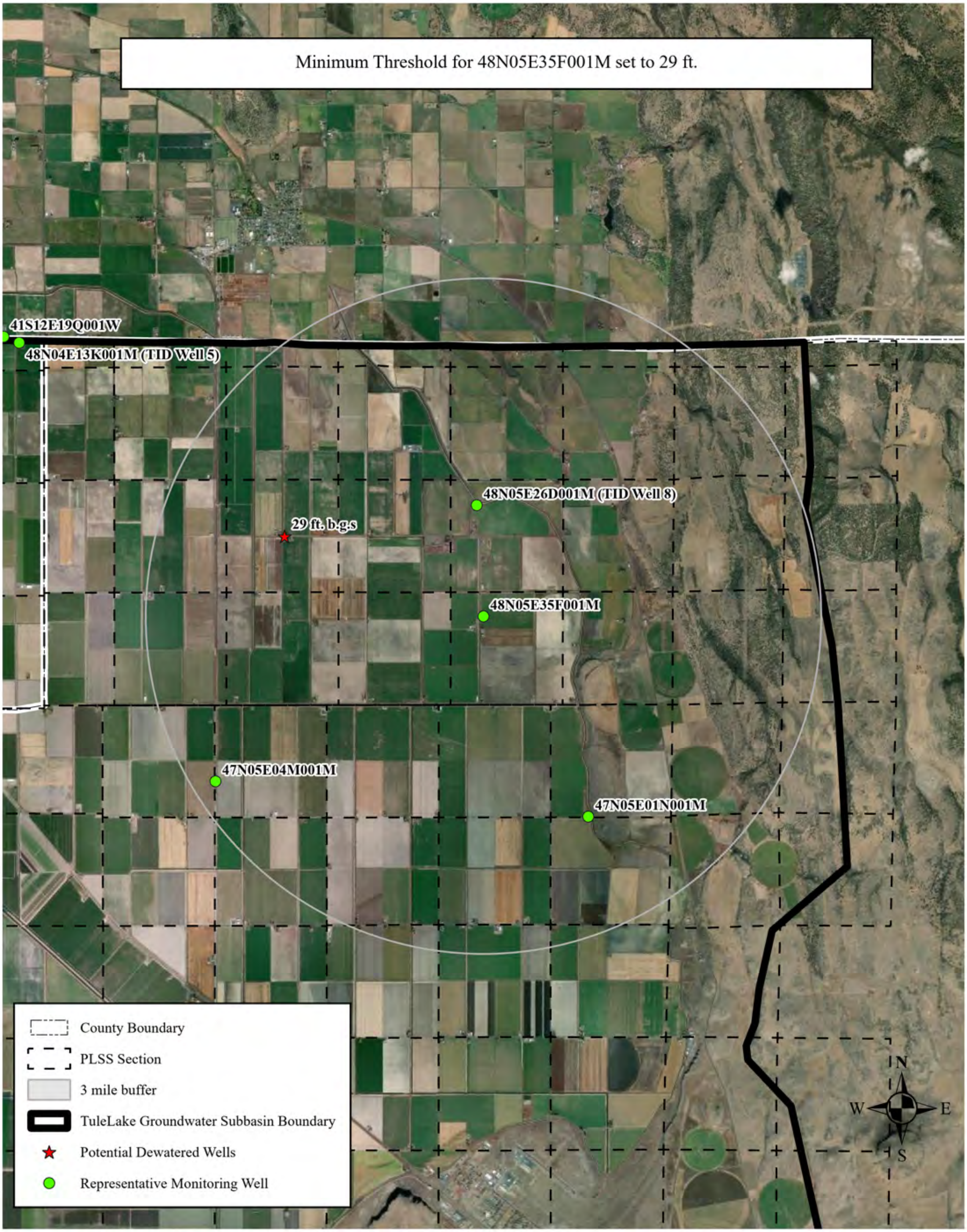
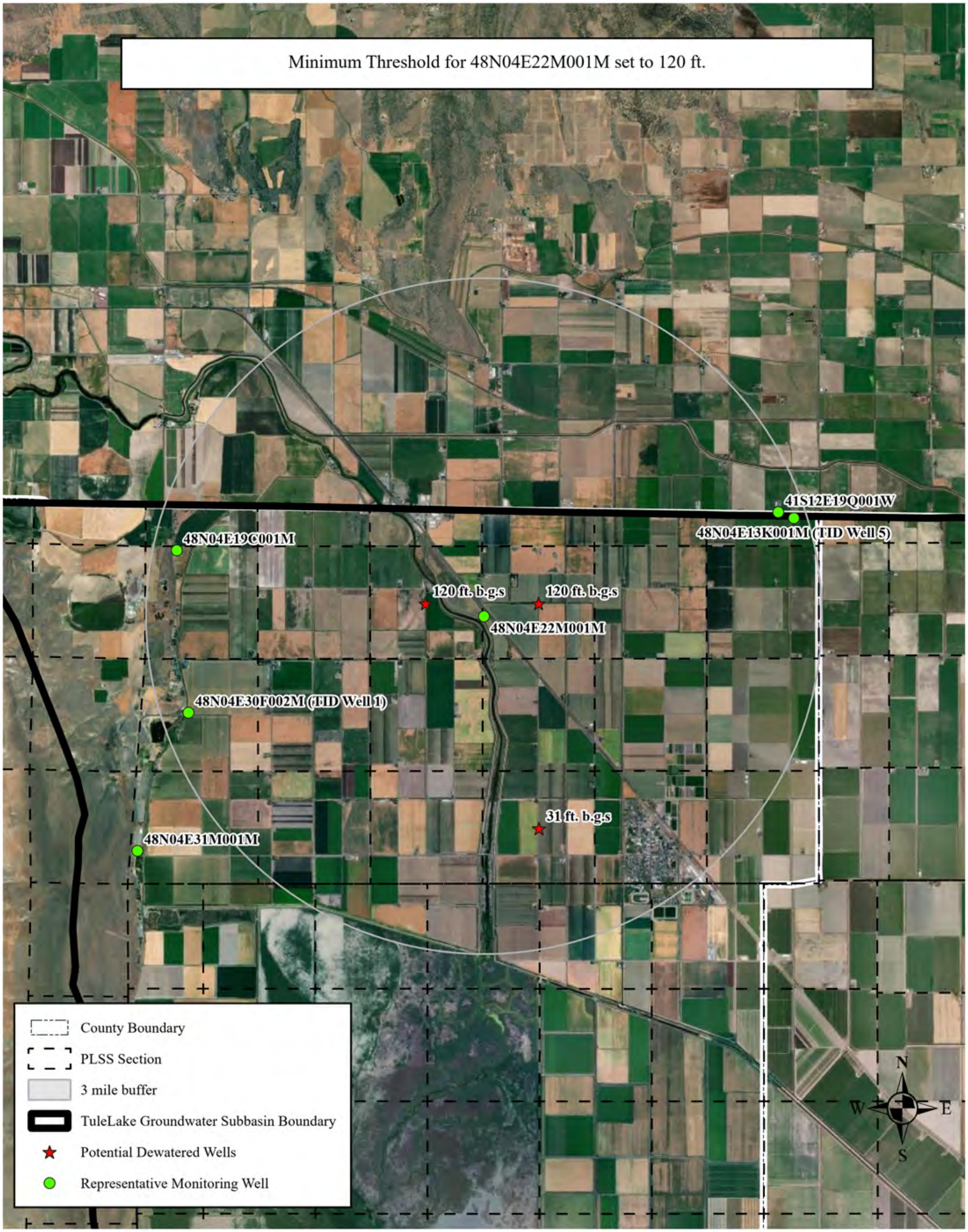
2023
2024
Water Year




MBK ENGINEERS

**Location of potential dewatered wells near representative monitoring well 48N05E35F001M**

0 ½ 1 Mi

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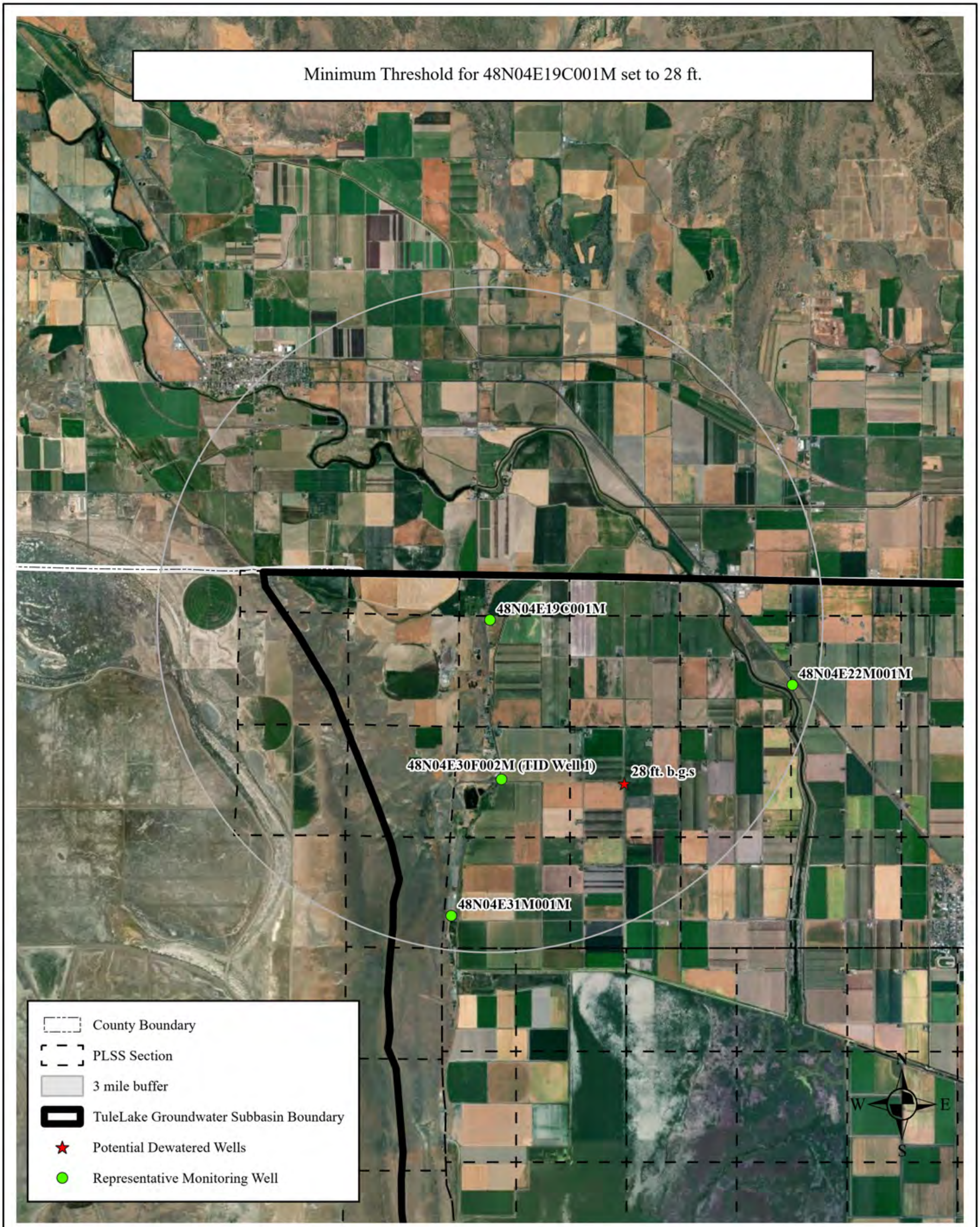
**Location of potential dewatered wells near representative monitoring well 48N04E22M001M**

0 ½ 1 Mi


MBK ENGINEERS

**Location of potential dewatered wells near representative monitoring well 48N04E31M001M**

0 ½ 1 Mi




MBK ENGINEERS

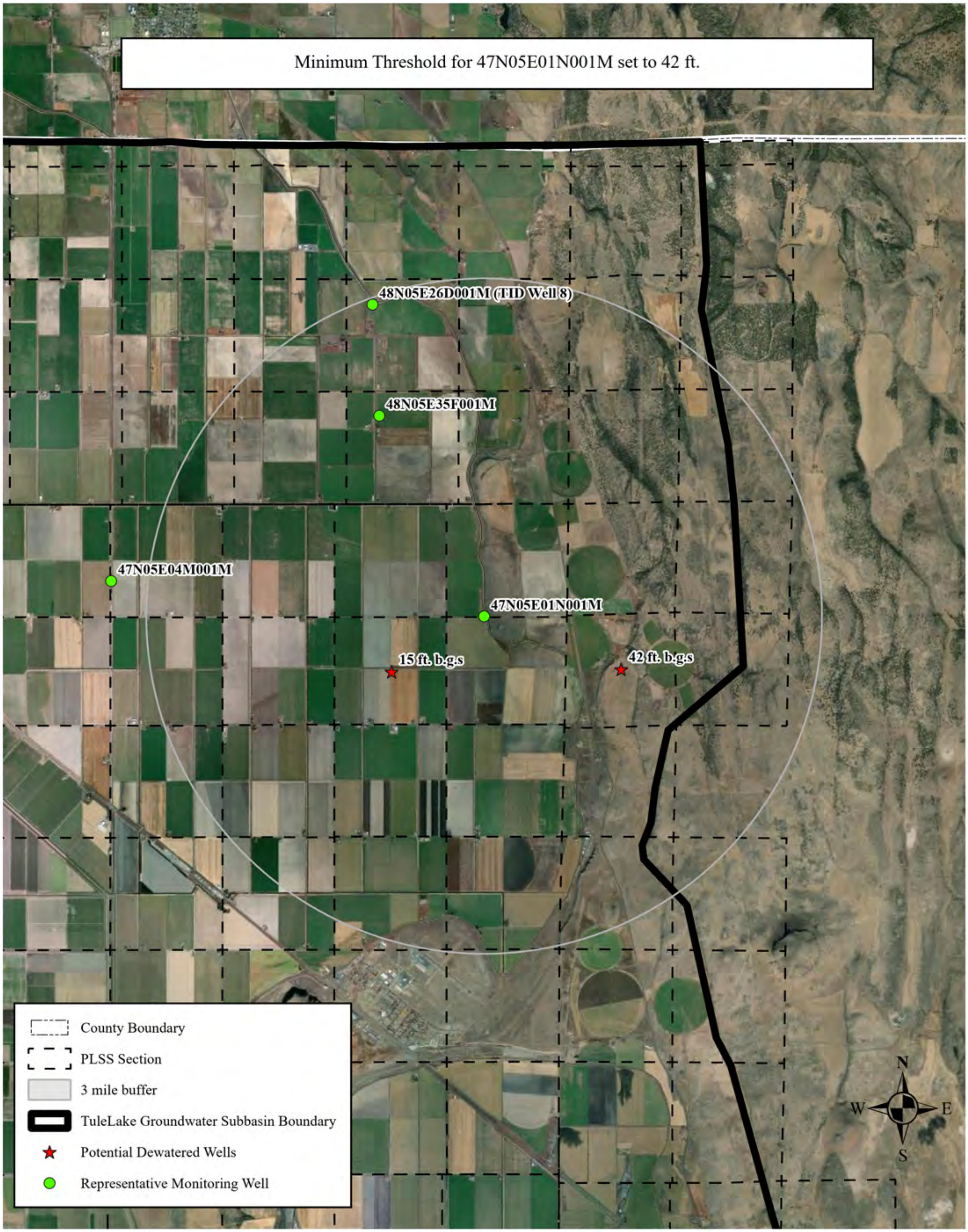
**Location of potential dewatered wells near representative monitoring well 48N04E19C001M**

0 ½ 1 Mi


MBK ENGINEERS

**Location of potential dewatered wells near representative monitoring well 47N05E04M001M**

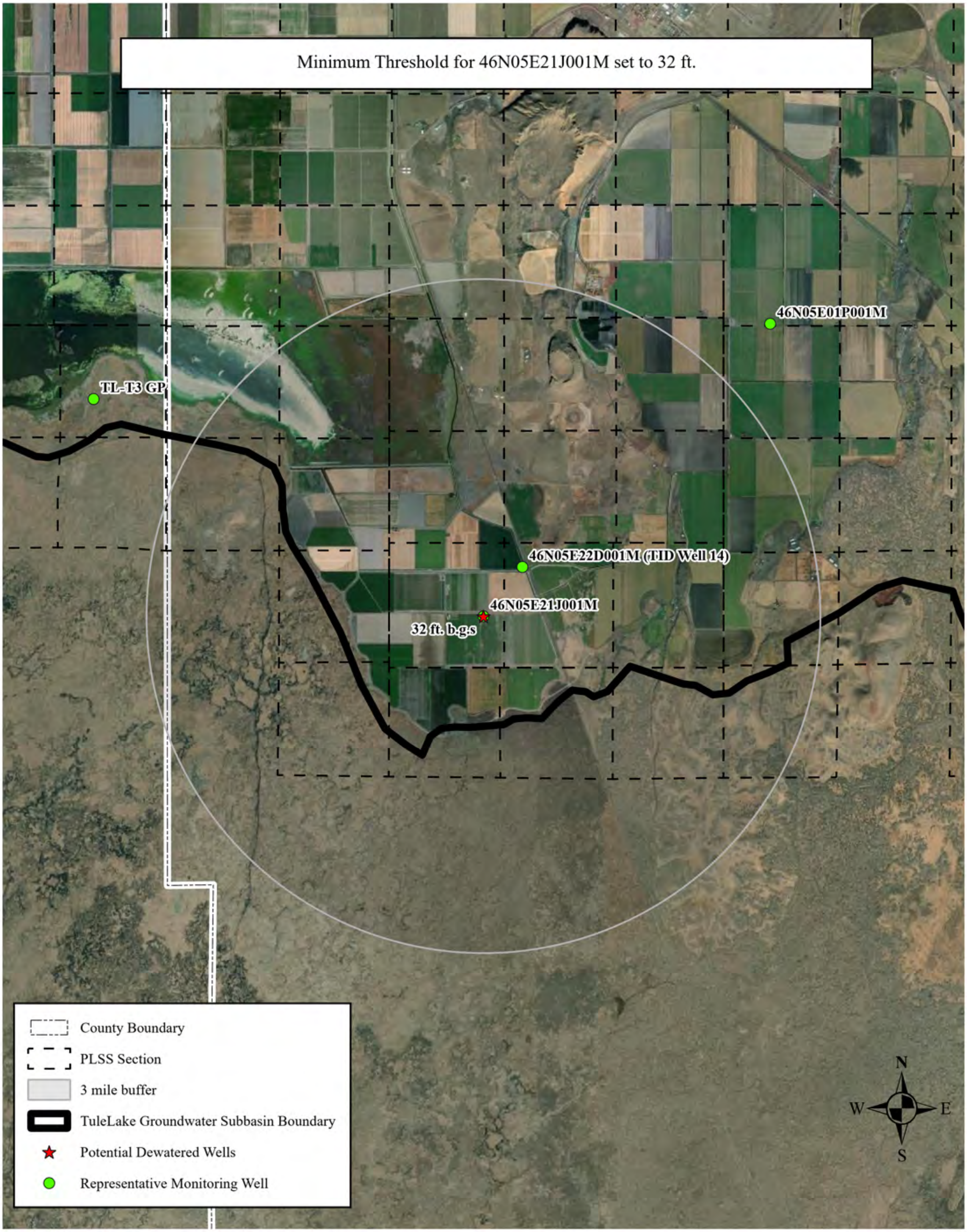
0 ½ 1 Mi




MBK ENGINEERS

**Location of potential dewatered wells near representative monitoring well 47N05E01N001M**

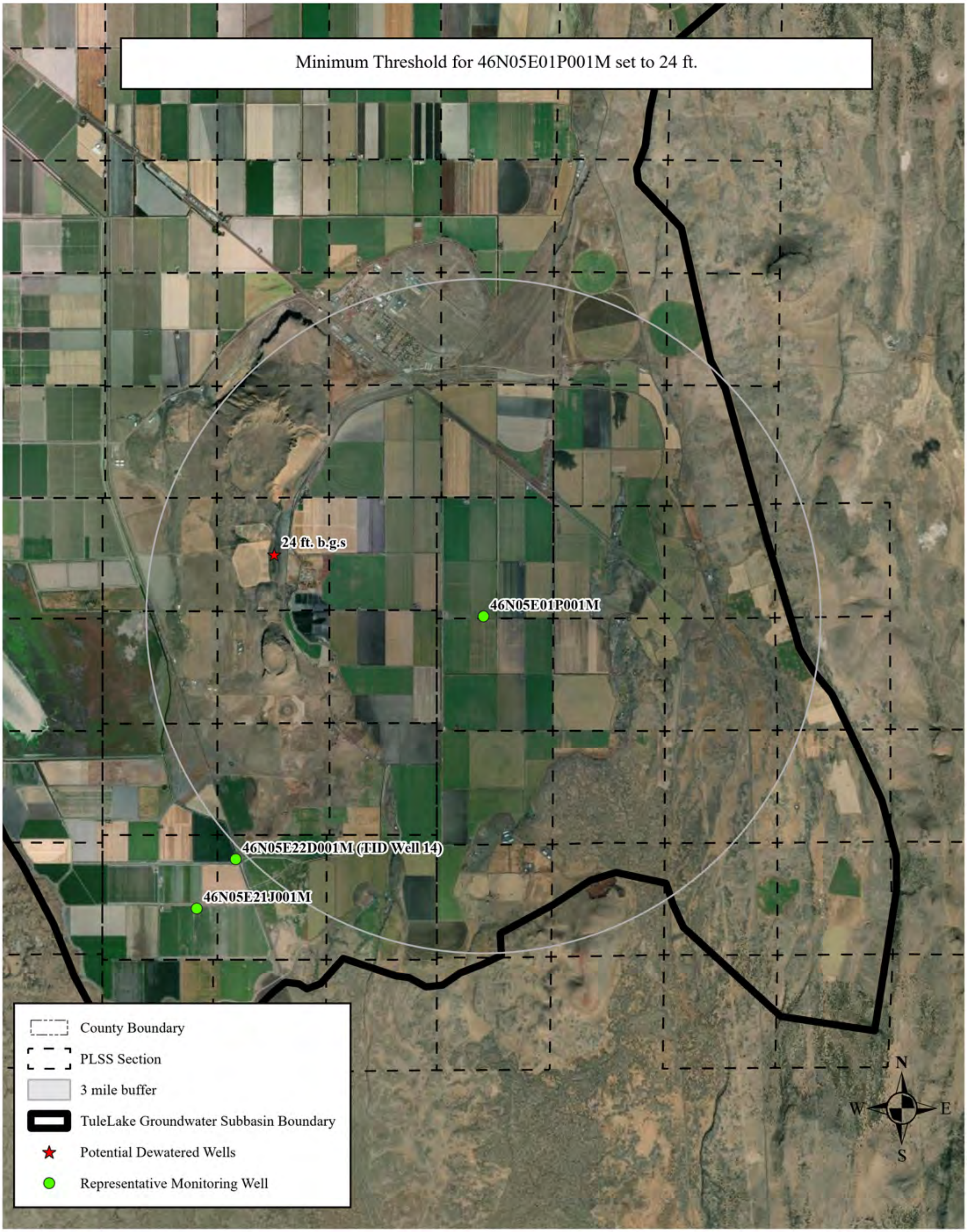
0 ½ 1 Mi




MBK ENGINEERS

**Location of potential dewatered wells near representative monitoring well 46N05E21J001M**

0 ½ 1 Mi

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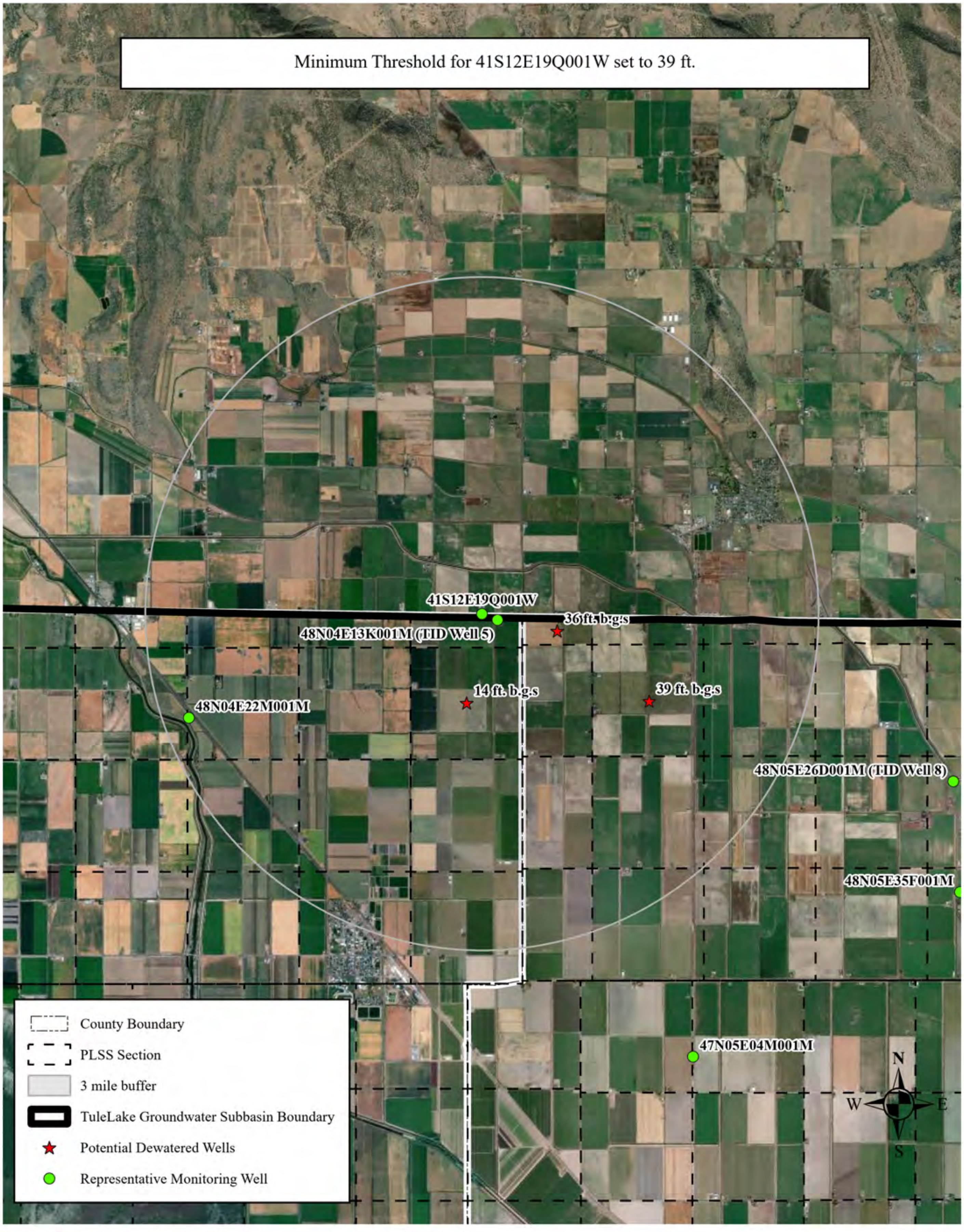
**Location of potential dewatered wells near representative monitoring well 46N05E01P001M**

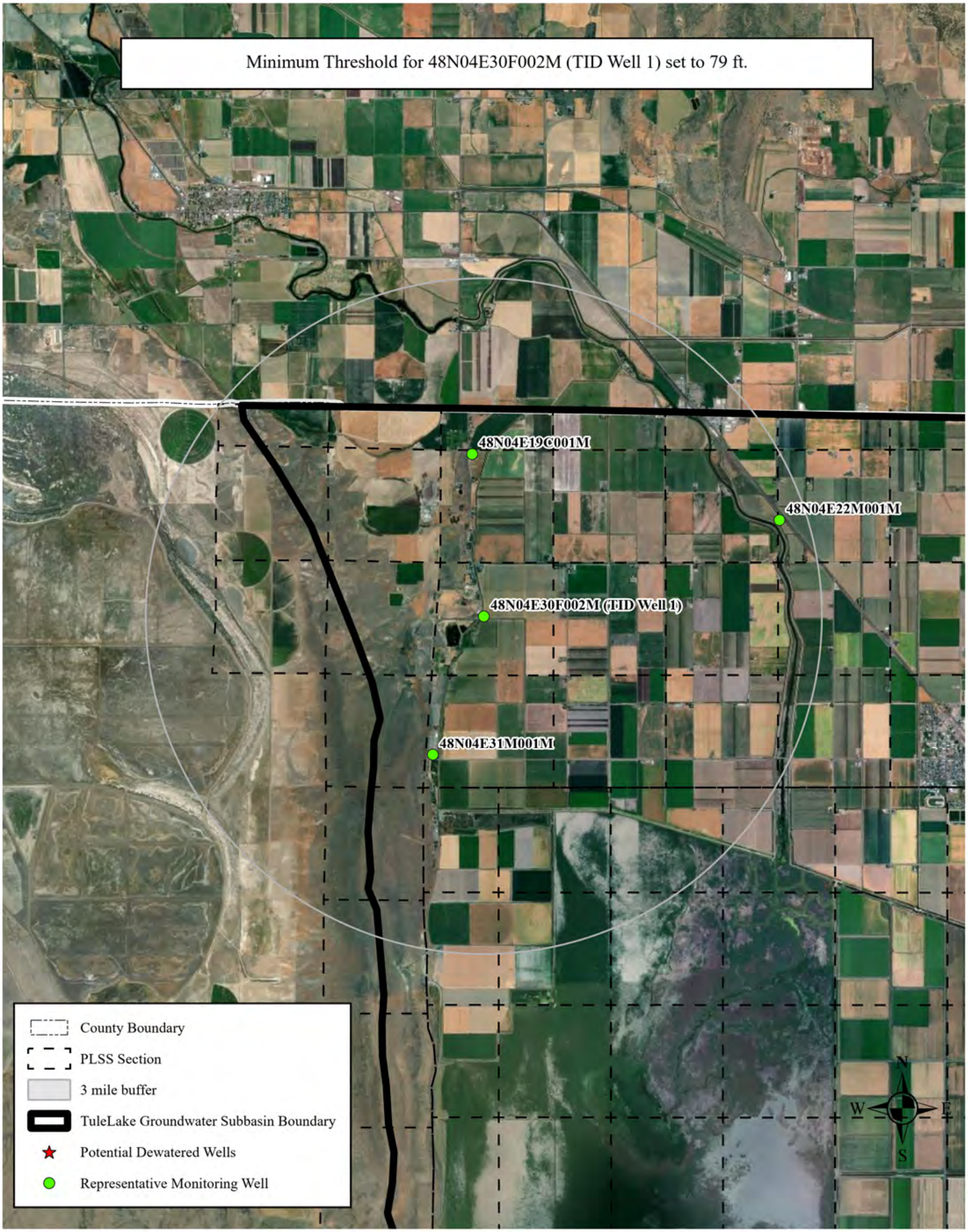
0 ½ 1 Mi




MBK ENGINEERS

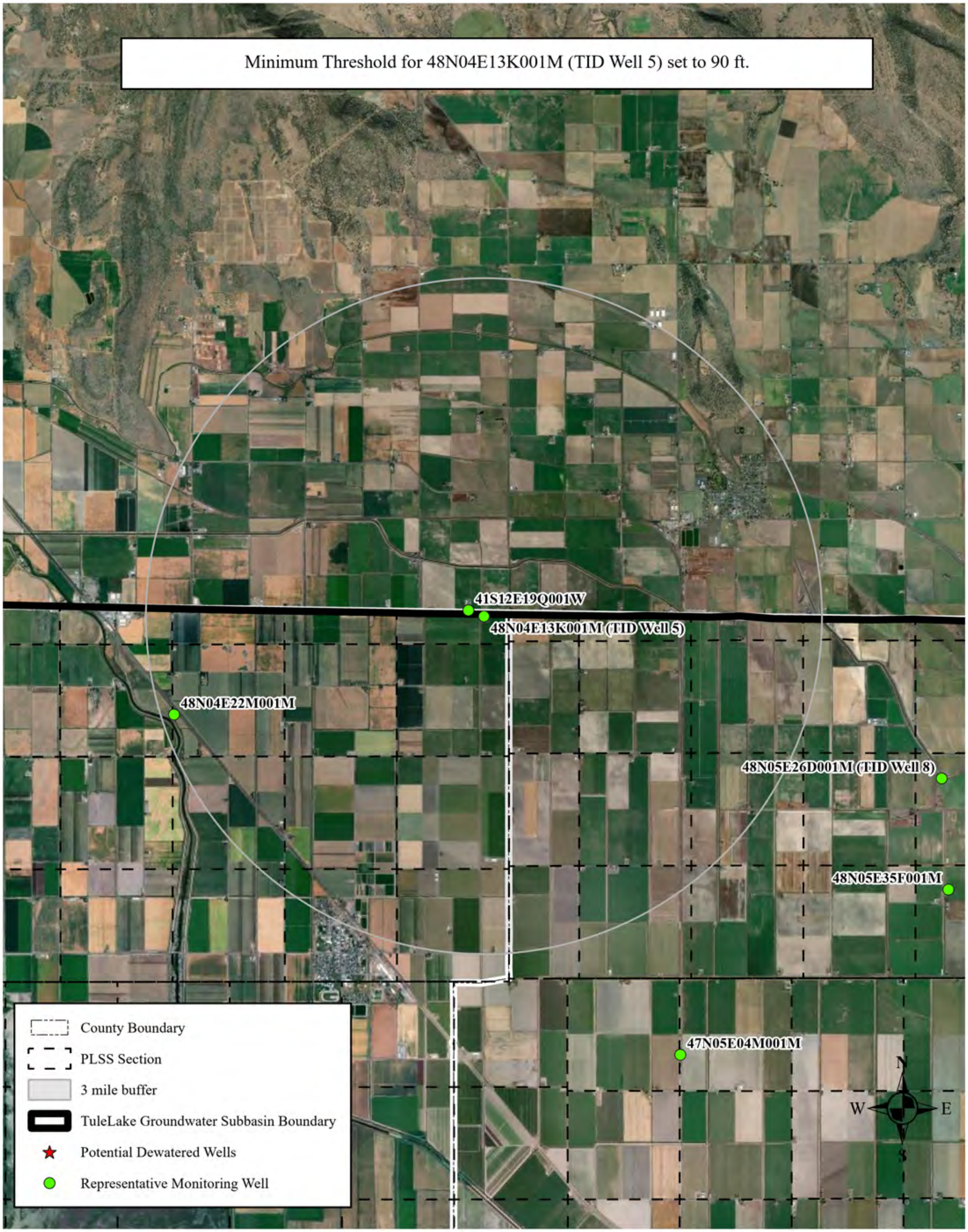
**Location of potential dewatered wells near representative monitoring well**
**41S12E19Q001W**

0 ½ 1 Mi




MBK ENGINEERS

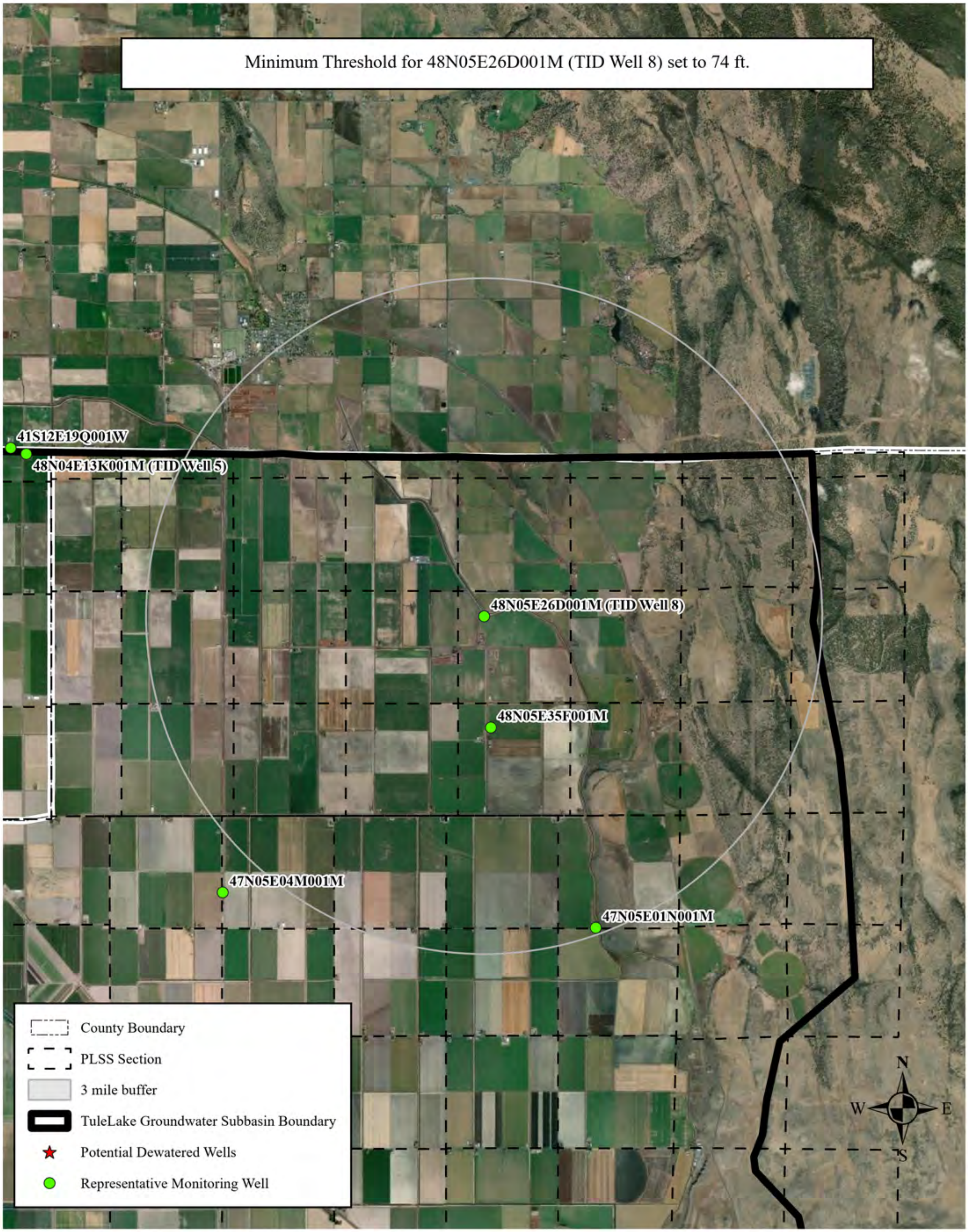
**Location of potential dewatered wells near representative monitoring well 48N04E30F002M (TID Well 1)**




MBK ENGINEERS

**Location of potential dewatered wells near representative monitoring well 48N04E13K001M (TID Well 5)**

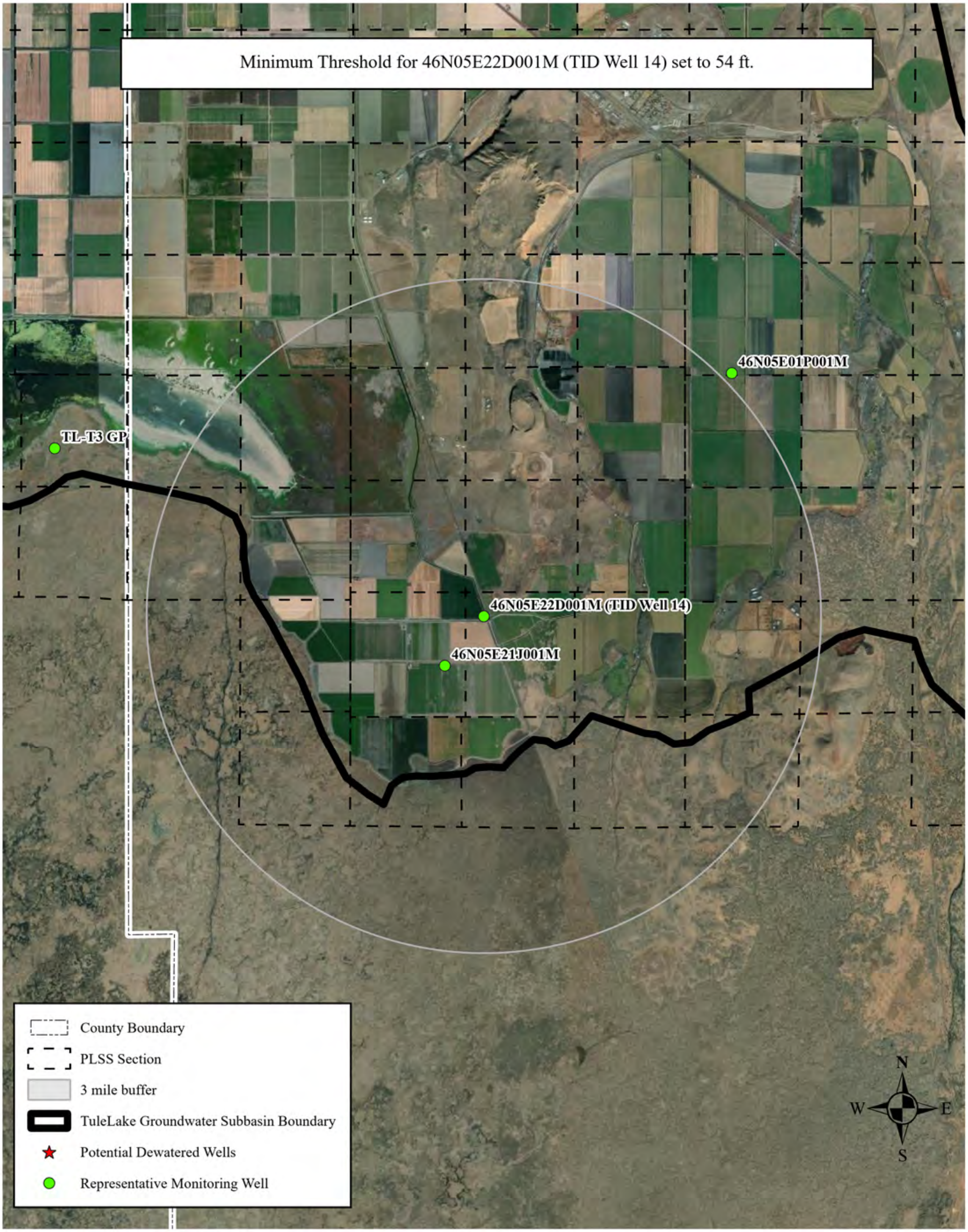
0 ½ 1 Mi




MBK ENGINEERS

**Location of potential dewatered wells near representative monitoring well 48N05E26D001M (TID Well 8)**

0 ½ 1 Mi

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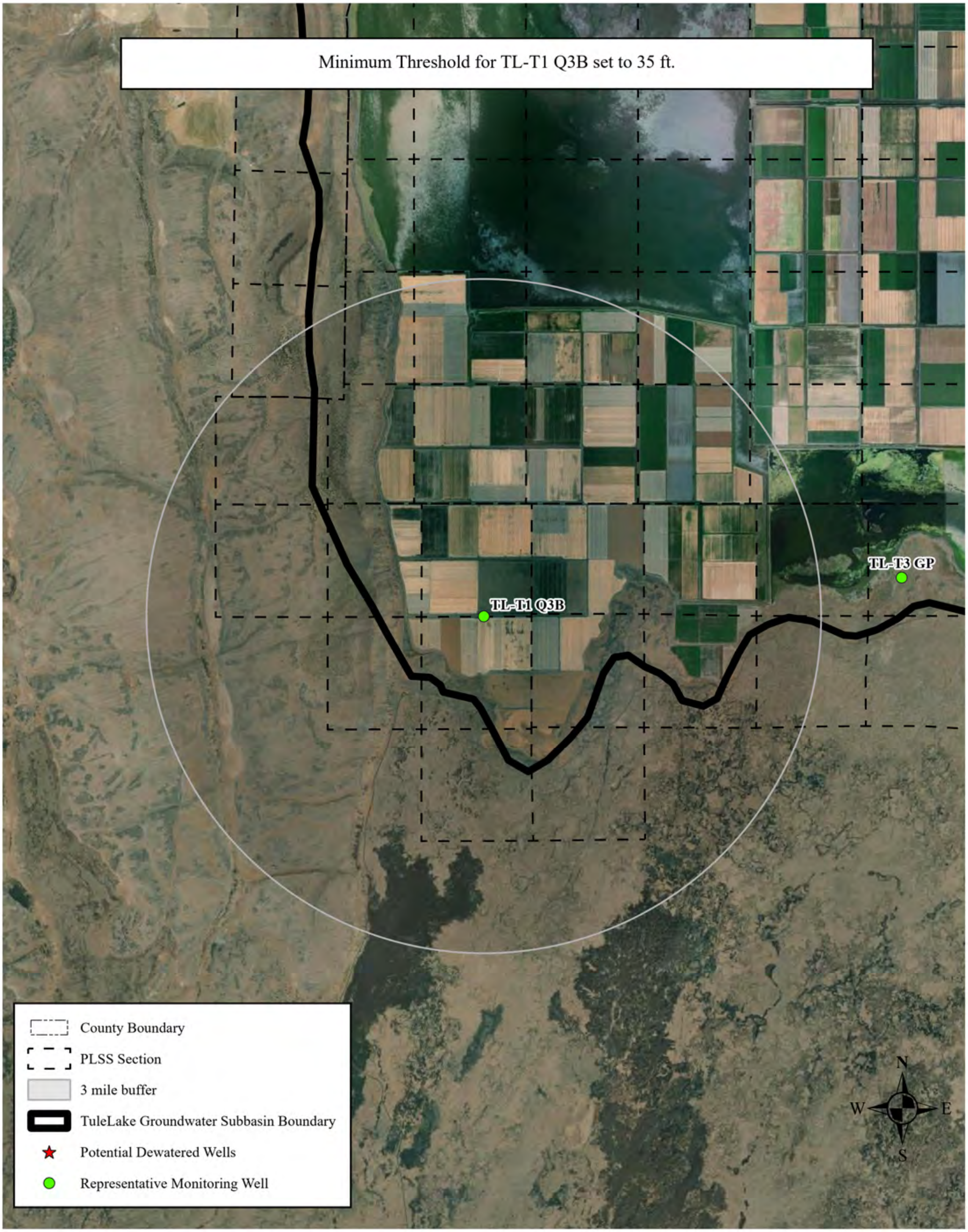
**Location of potential dewatered wells near representative monitoring well 46N05E22D001M (TID Well 14)**

0 ½ 1 Mi

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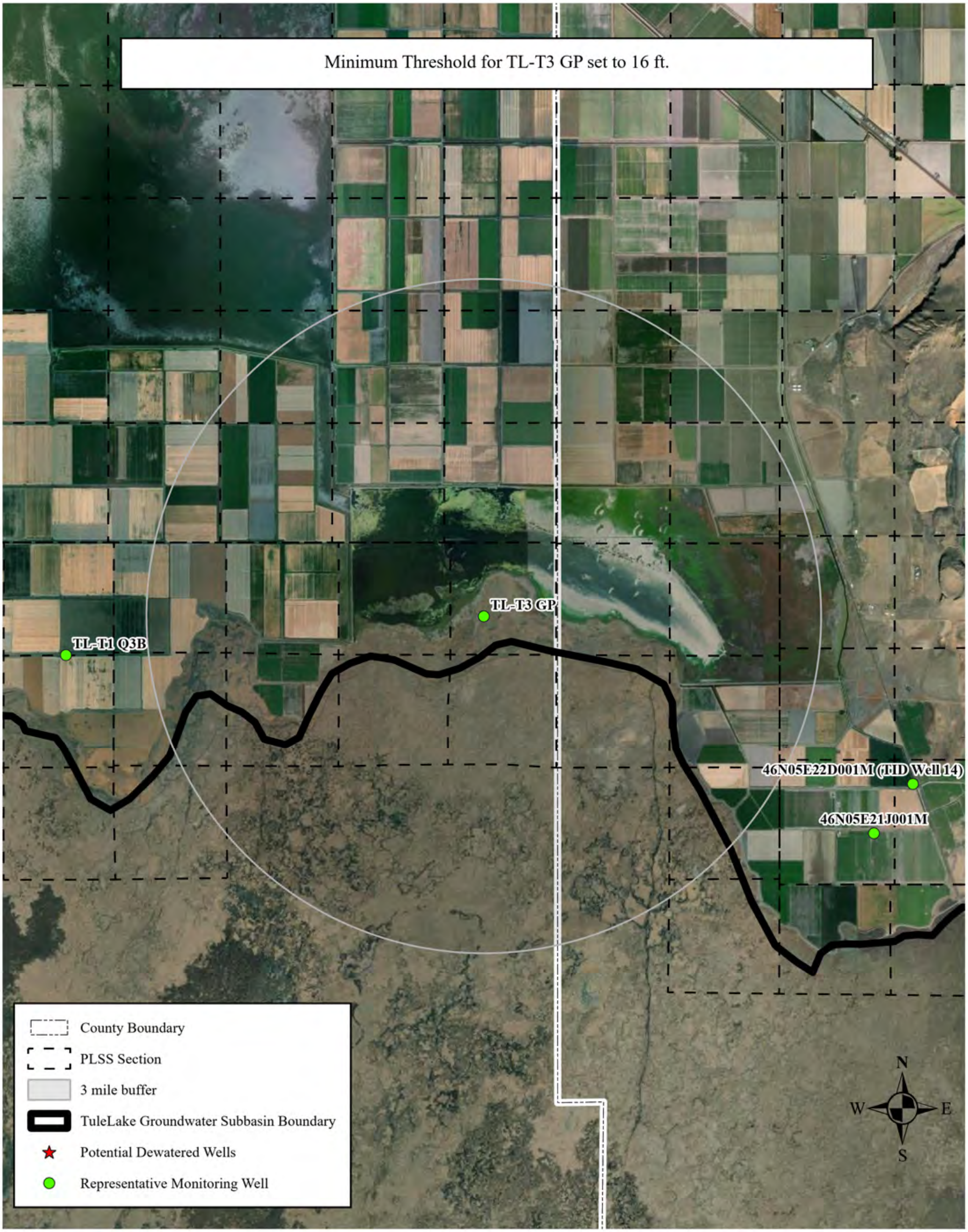
**Location of potential dewatered wells near representative monitoring well TL-T1 Q3B**

0 ½ 1 Mi

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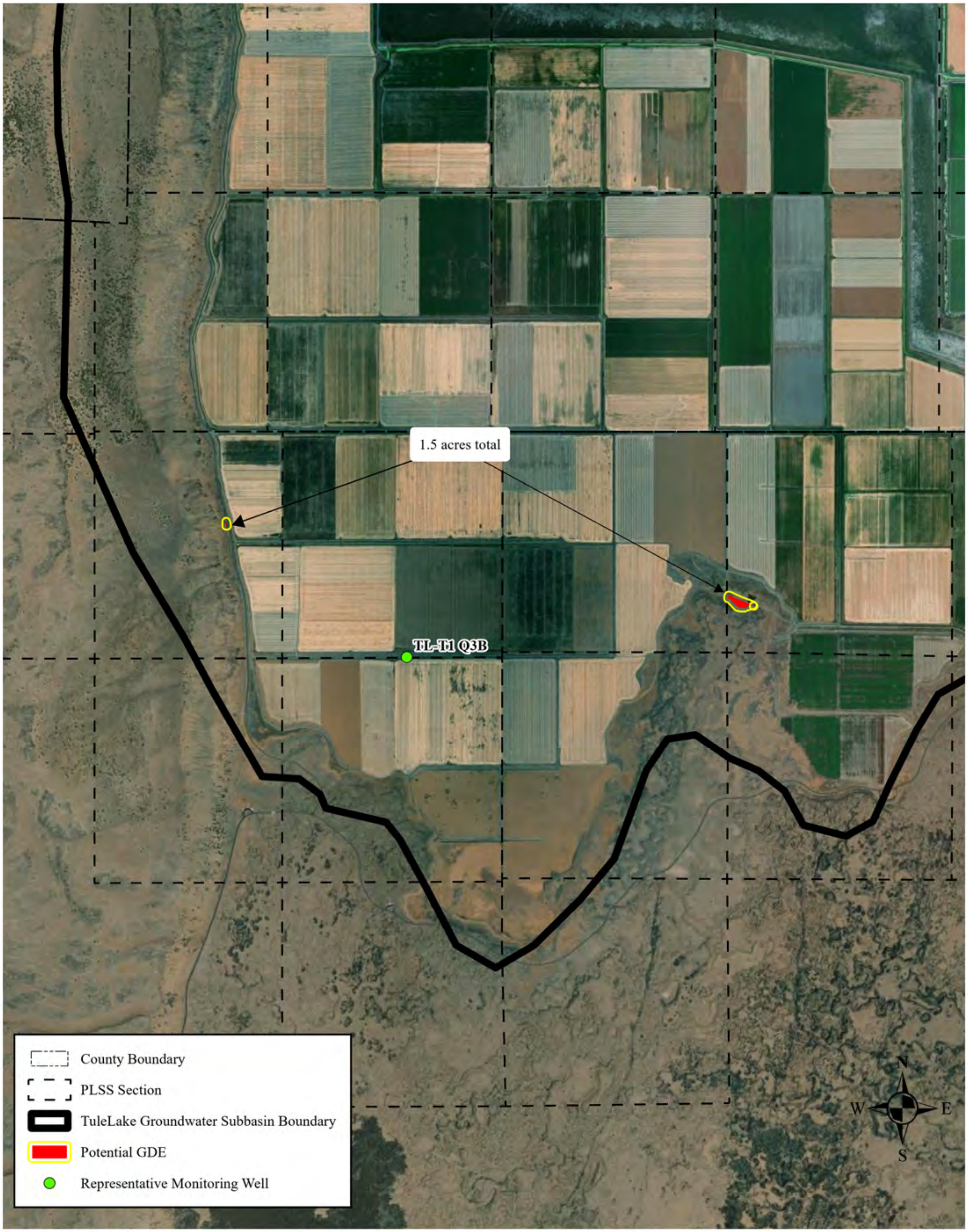
**Location of potential dewatered wells near representative monitoring well TL-T3 GP**

0 ½ 1 Mi

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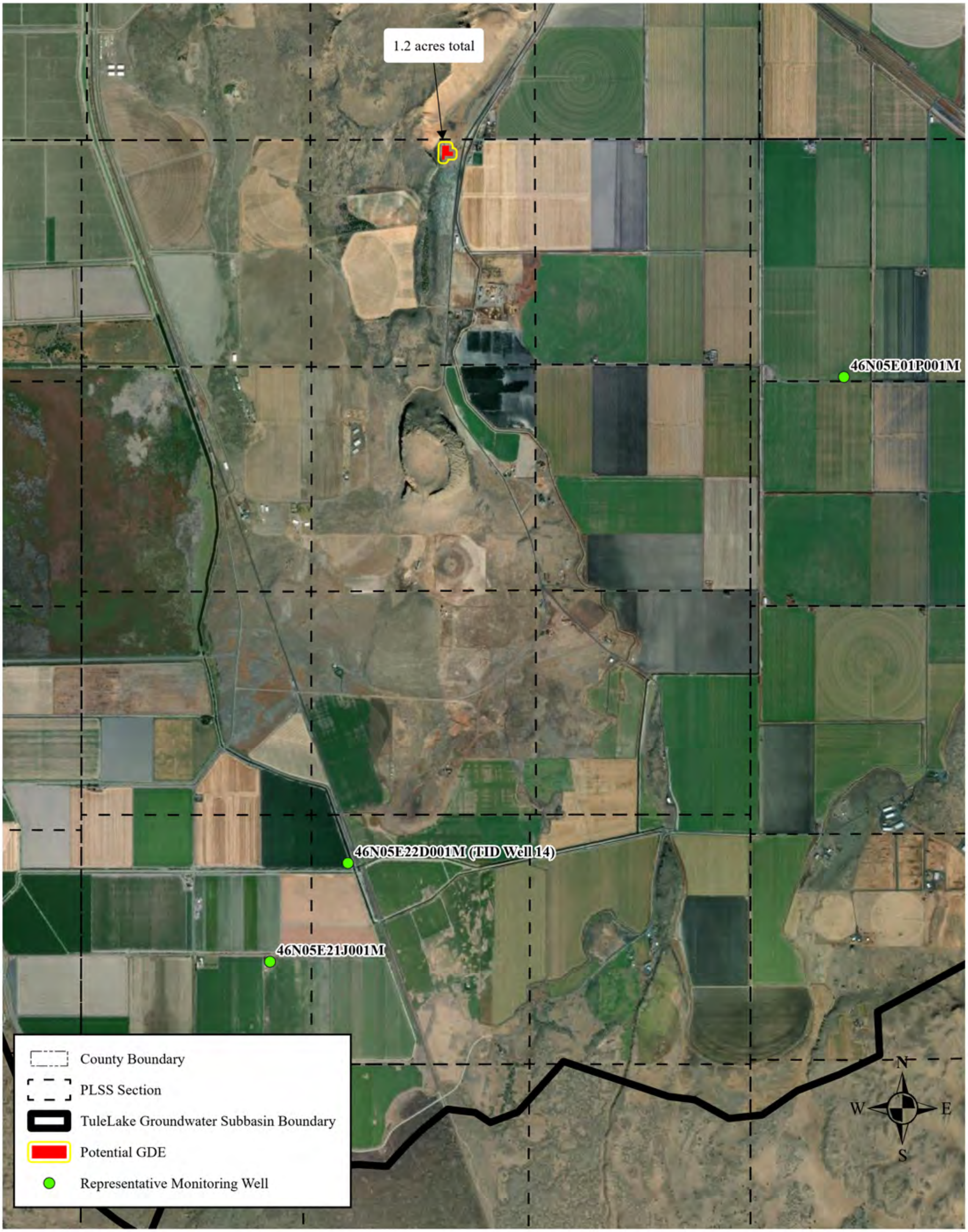
**Location of potential groundwater dependent ecosystems**

0 ¼ ½ Mi

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**Location of potential groundwater dependent ecosystems**

0 ¼ ½ Mi


MBK ENGINEERS

**Location of potential groundwater dependent ecosystems**

0 ¼ ½ Mi