STATE ENGINEER STATE OF NEVADA

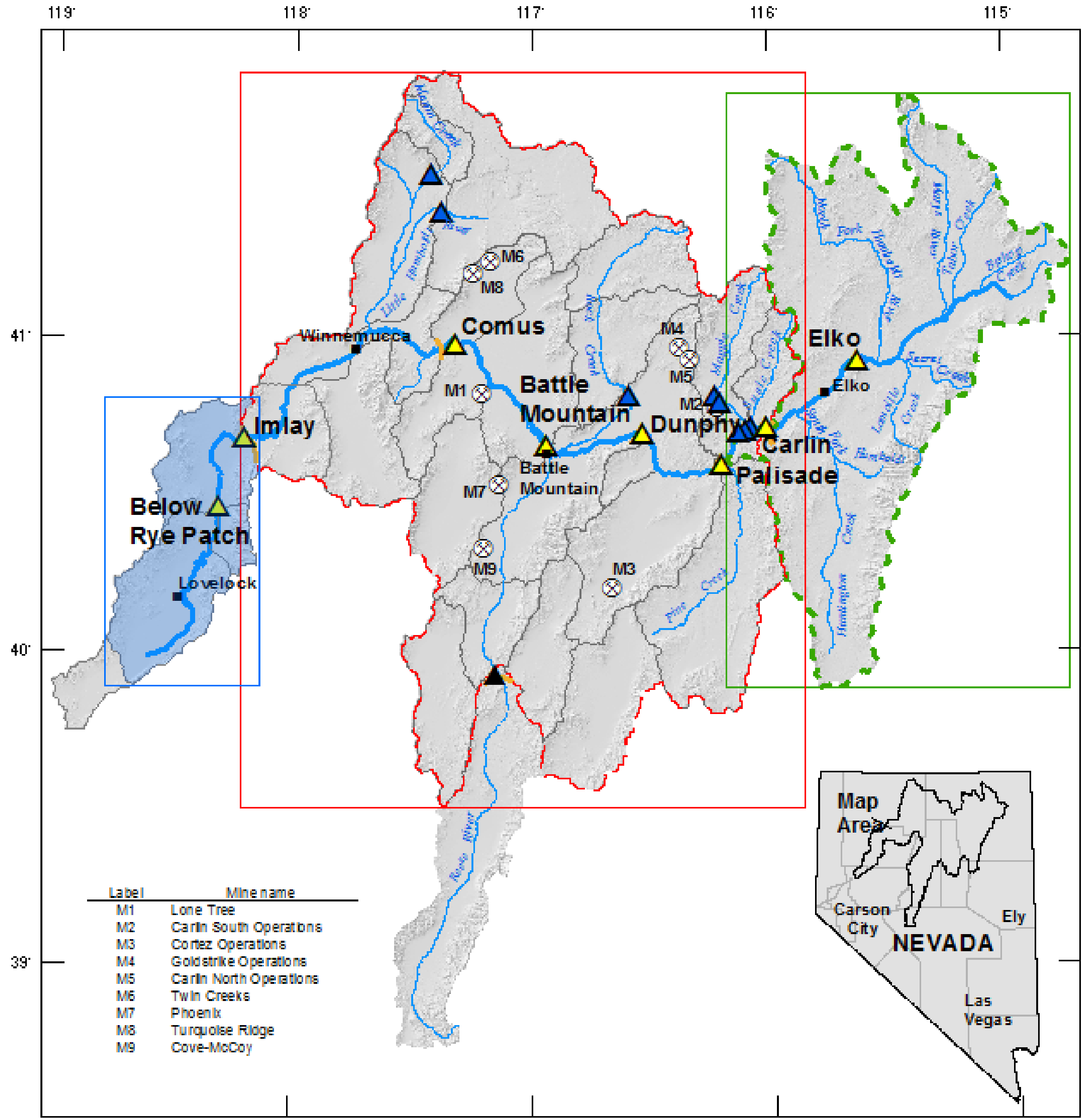
DRI Desert Research Institute

USGS

HUMBOLDT RIVER BASIN MODELING UPDATE

Lovelock & Winnemucca
January 9, 2018
Elko
January 10, 2018

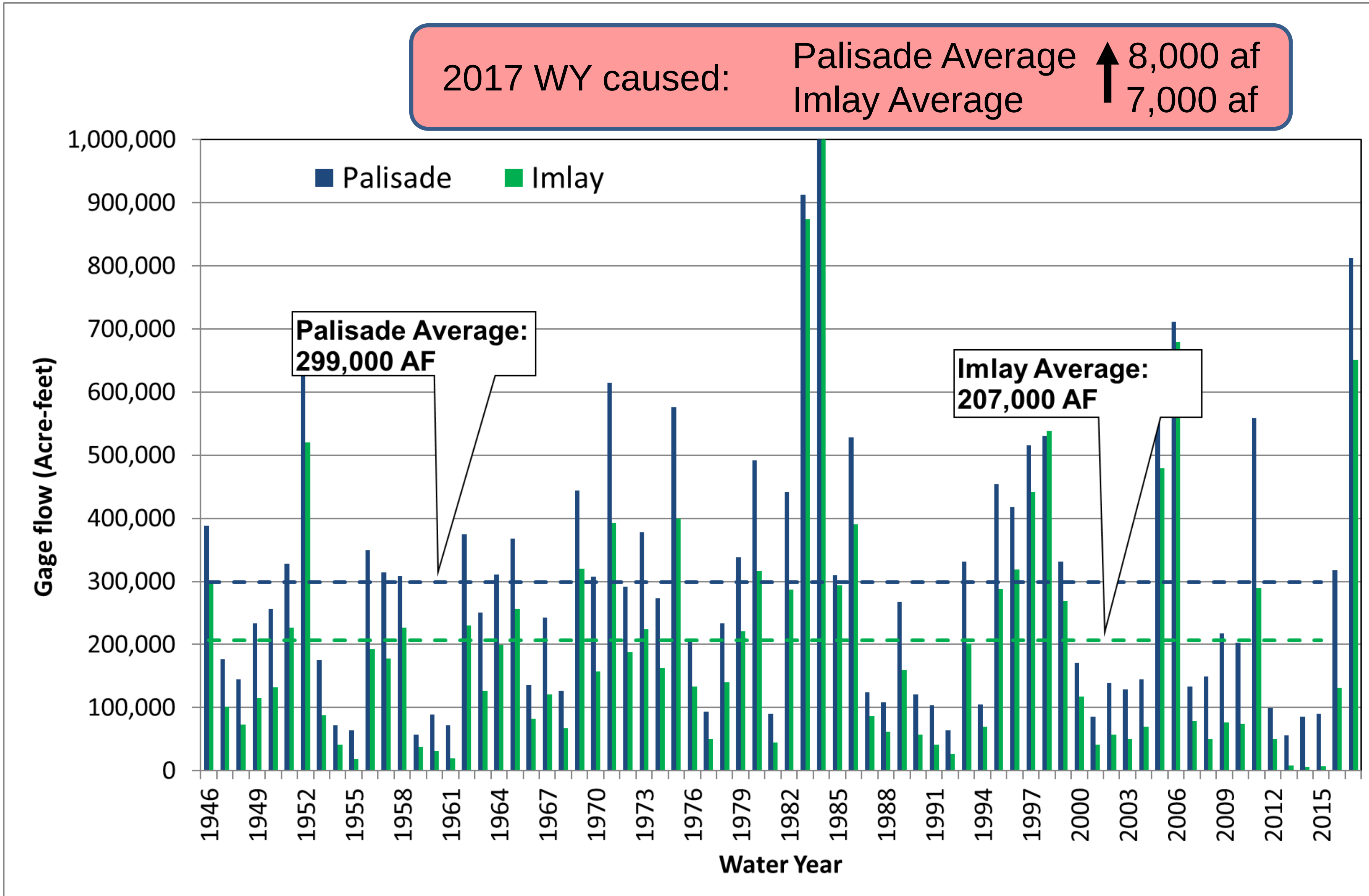
DEPARTMENT OF CONSERVATION & NATURAL RESOURCES



Humboldt River Basin Modeling Update - Outline

- Water supply forecast
- Water use and overview of modeling effort
- Ongoing modeling and hydrologic studies
  - Hydrology General Overview
  - ET Studies
  - Upper Basin Model
  - Middle Basin Model
  - Lower Basin Model
- Q & A

Humboldt River Flow, 1946-2017



Nevada/California SNOTEL Water Year (Oct 1) to Date Precipitation % of Normal

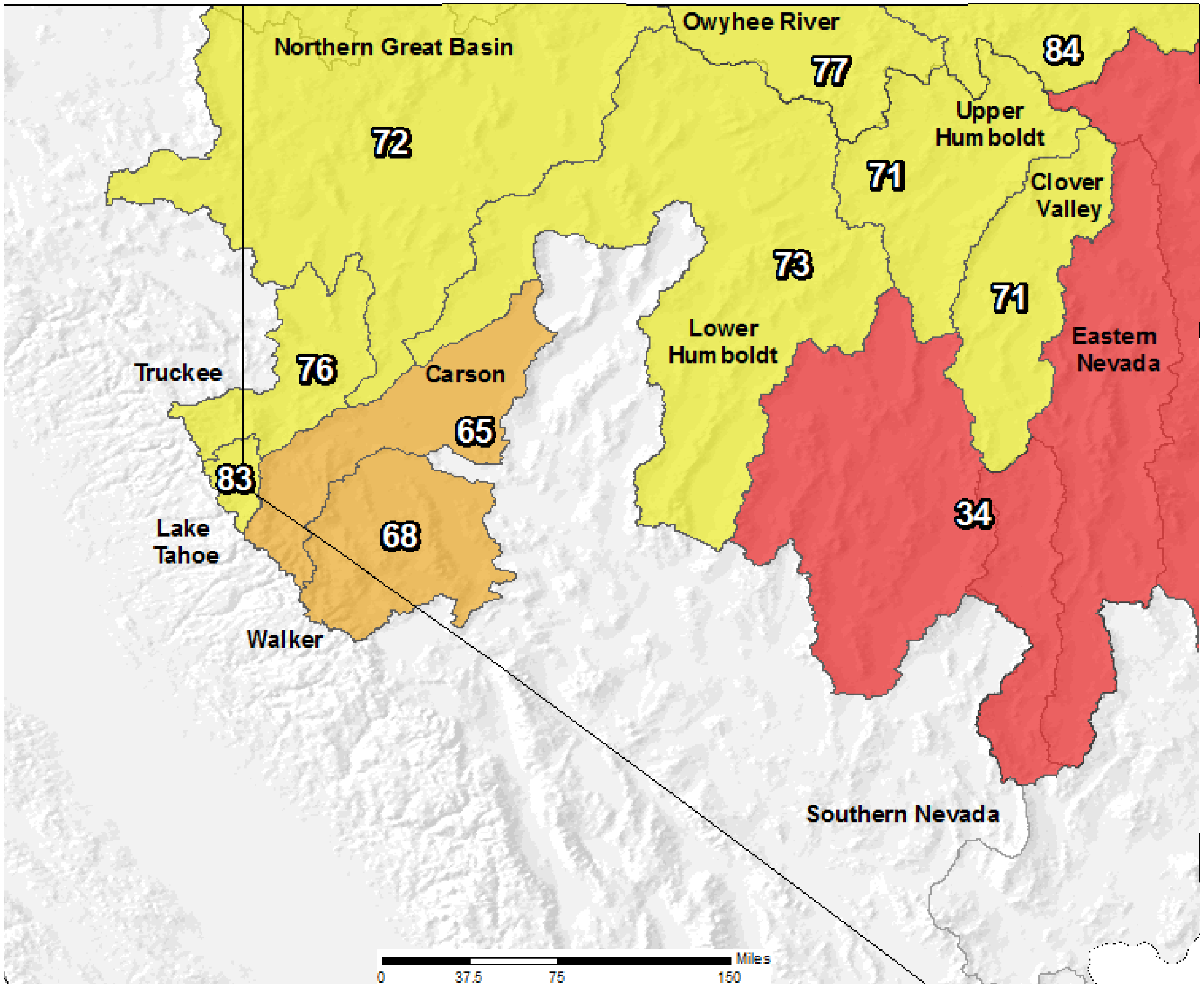
Jan 08, 2018

Water Year (Oct 1) to Date Precipitation Basin-wide Percent of 1981-2010 Average

- unavailable *
- <50%
- 50 - 69%
- 70 - 89%
- 90 - 109%
- 110 - 129%
- 130 - 149%
- >=150%

* Data unavailable at time of posting or measurement is not representative at this time of year

Provisional data subject to revision



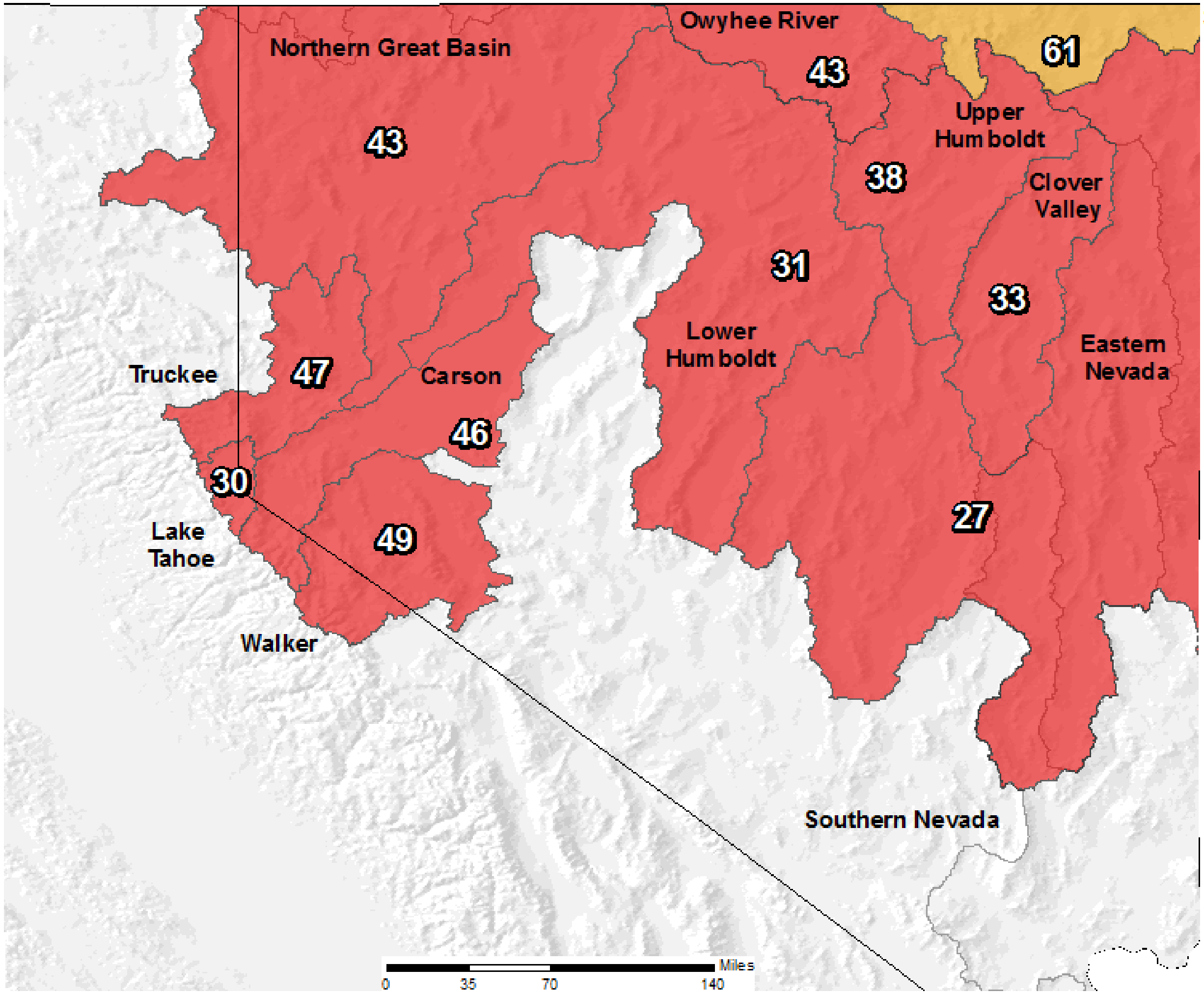
USDA NRCS

The water year to date precipitation percent of normal represents the accumulated precipitation found at selected SNOTEL sites in or near the basin compared to the average value for those sites on this day. Data based on the first reading of the day (typically 00:00).

Prepared by:
USDA/NRCS National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

Nevada/California SNOTEL Current Snow Water Equivalent (SWE) % of Normal

Jan 08, 2018



Current Snow Water Equivalent Basin-wide Percent of 1981-2010 Median

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Prepared by:
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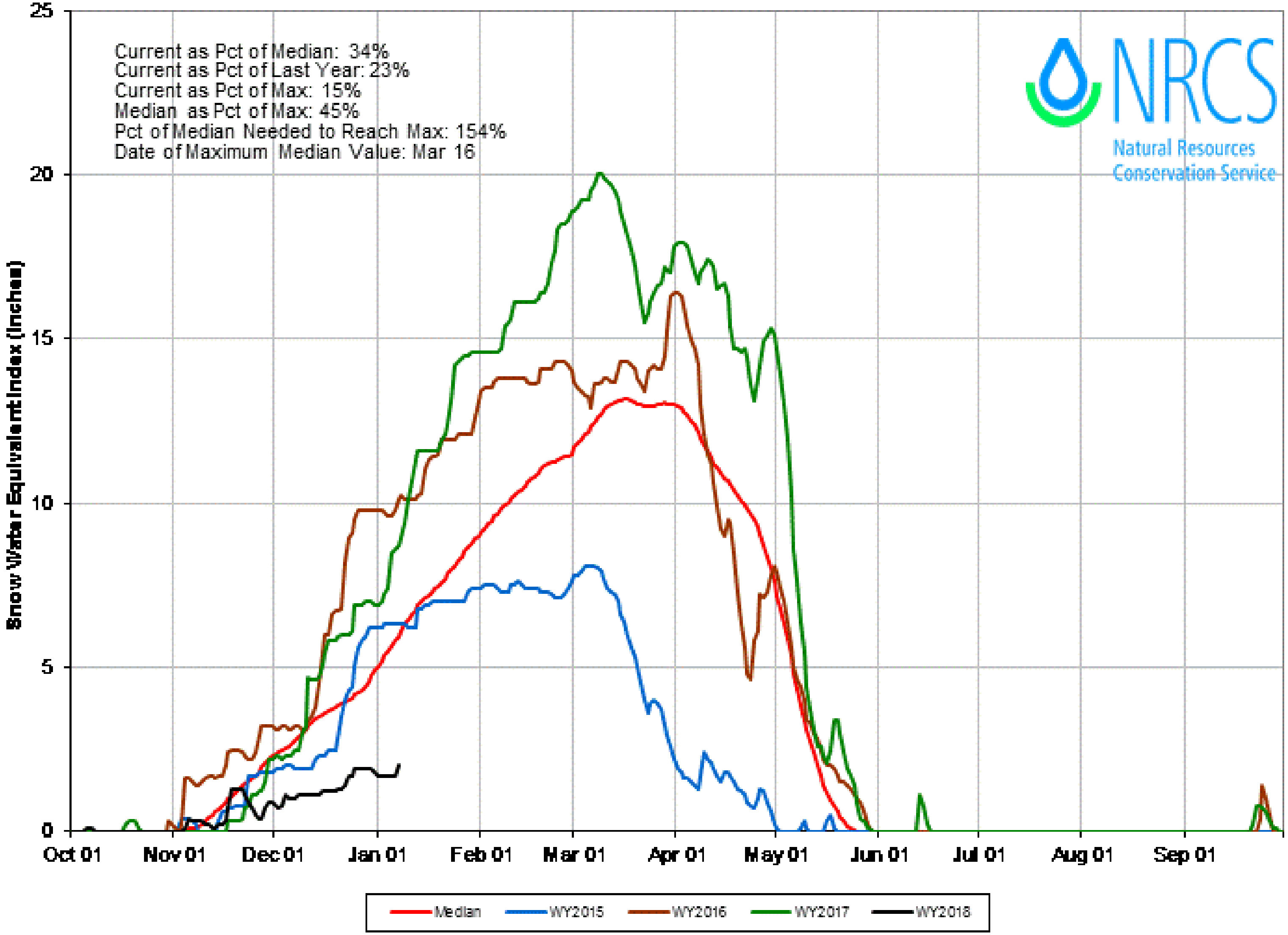
UPPER HUMBOLDT RIVER Time Series Snowpack Summary
Based on Provisional SNOTEL data as of Jan 07, 2018



Humboldt River Forecast

	Forecast Period	90% (KAF)	70% (KAF)	50% (KAF)	% Avg	30% (KAF)	10% (KAF)	30-yr Avg
Humboldt R at Palisade	MAR-JUL	45	105	146	54%	187	250	270
Humboldt R nr Imlay	MAR-JUL	6.3	27	63	30%	119	200	209

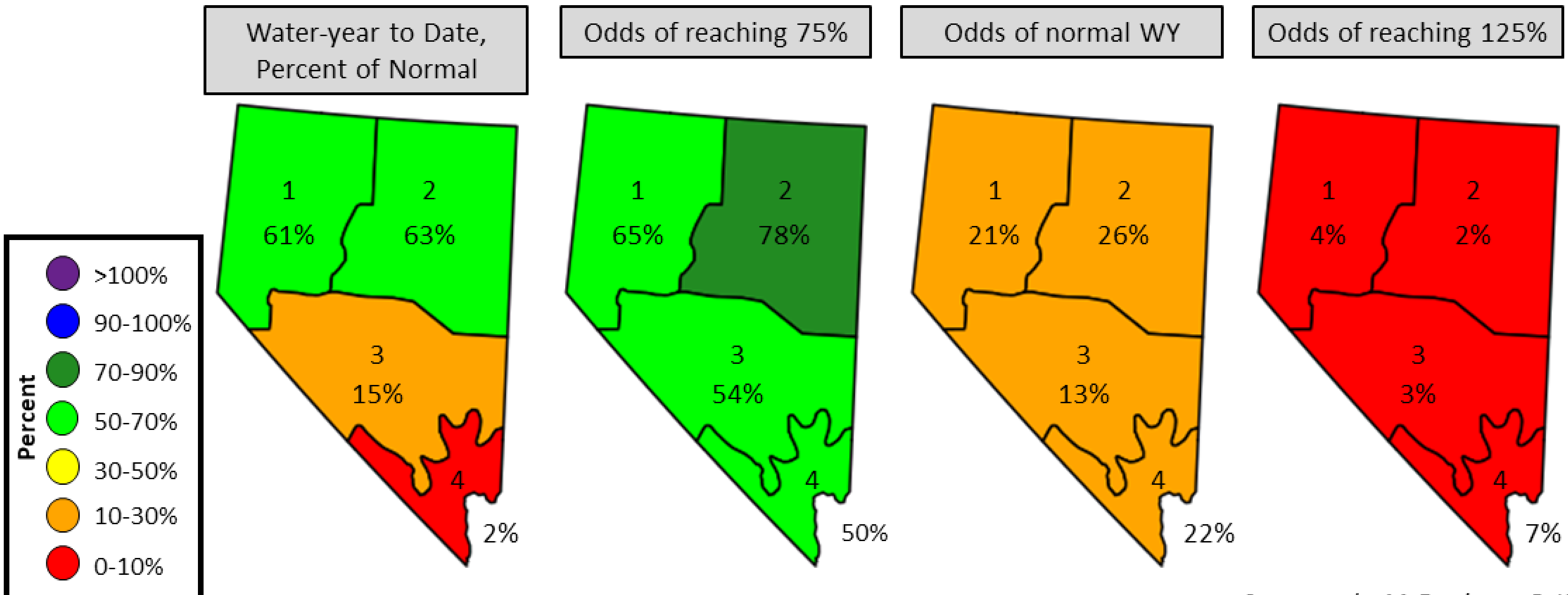
	Current (KAF)		Last Year	Average
	(KAF)	% of Capacity	(KAF)	(KAF)
Rye Patch Reservoir	157.3	81	14.8	69.2

Source: NRCS

Precipitation Odds for Water Year 2018

Historical odds of reaching 75%, 100%, 125%, or 150% of normal precipitation during Water Year 2018 (1 Oct 2017 – 30 Sept 2018) based on observed precipitation *through December 2017*

Nevada (based on precip through December 2017)						
Division	**WY to Date, % of Normal**	**Odds of 75% Normal WY**	**Odds of Normal WY**	**Odds of 125% Normal WY**	**Odds of 150% Normal WY**	**Odds of 175% Normal WY**
		All Yrs	**All Yrs**	**All Yrs**	**All Yrs**	**All Yrs**
1	61	65 (85)	21 (39)	4 (6)	1 (1)	0 (1)
2	63	78 (94)	26 (41)	2 (7)	0 (0)	0 (0)
3	15	54 (83)	13 (45)	3 (11)	1 (3)	0 (0)
4	2	50 (74)	22 (46)	7 (21)	3 (6)	0 (3)

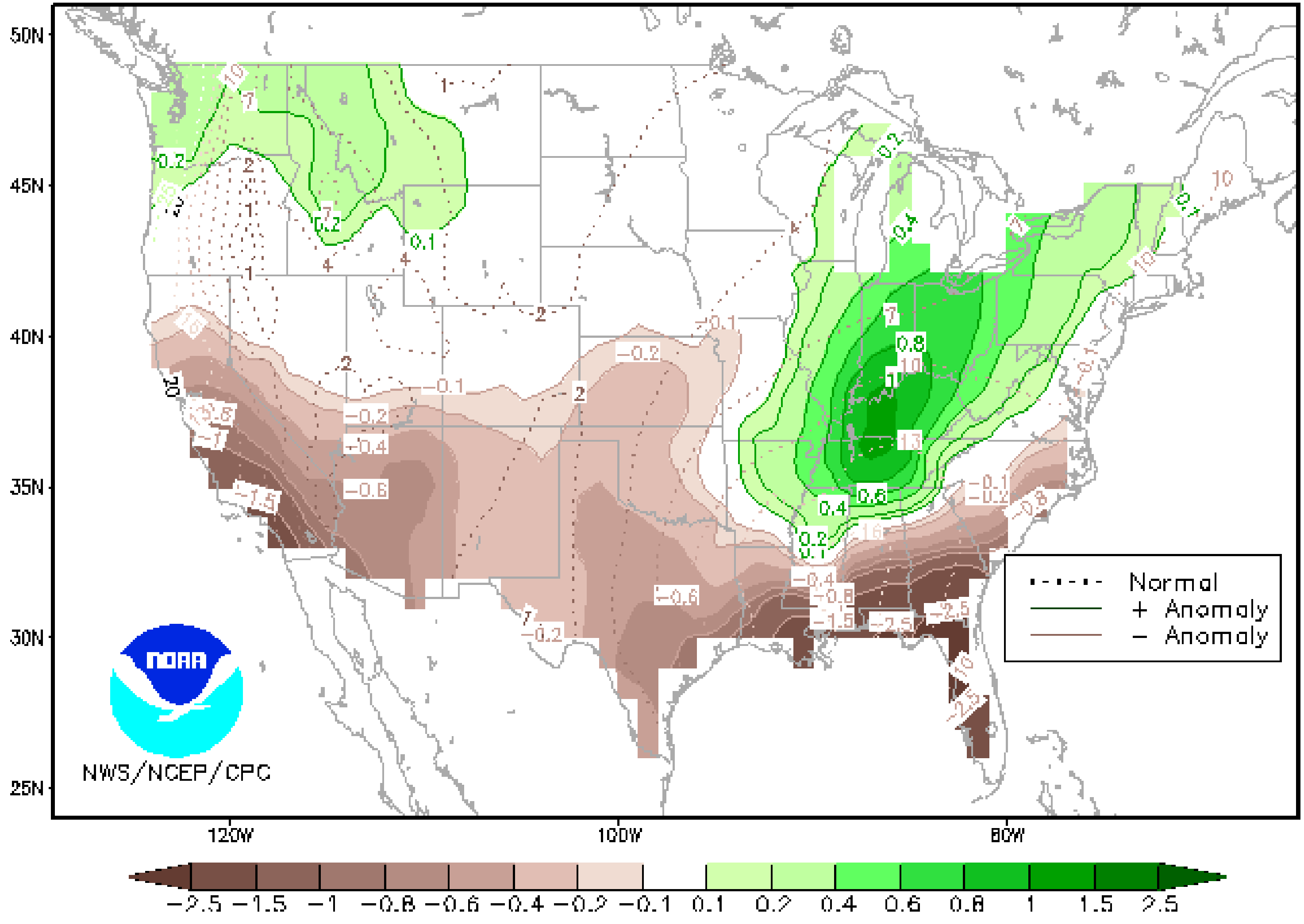


*Numbers in parenthesis represent odds if Oct-Dec precip was normal

As of 1 Jan 2018

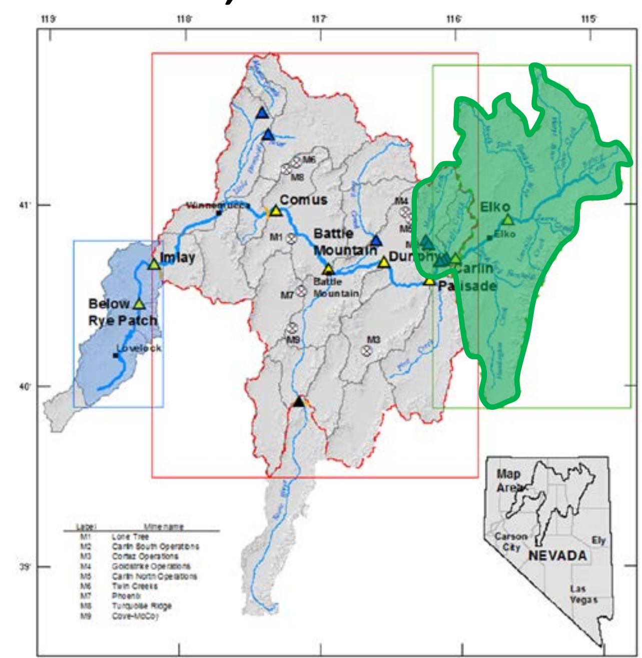
Summary by M. Dettinger, B. Kawzenuk, F.M Ralph

3 – Month Precipitation Outlook



Water Use

- Humboldt River adjudication finalized in 1930's
- 285,000 acres irrigated under the decree, rights total ~700,000 af
- Groundwater development began in 1950's
- Current groundwater appropriations = 716,000 af
- Perennial yield = 429,100 af
    - 133,000 af above Palisade
    - 296,100 af below Palisade
- Annual pumping ≈ 325,000 af
    - ~45,000 af above Palisade
    - ~280,000 af below Palisade



Order 1251: Required metering of all groundwater wells in HRB

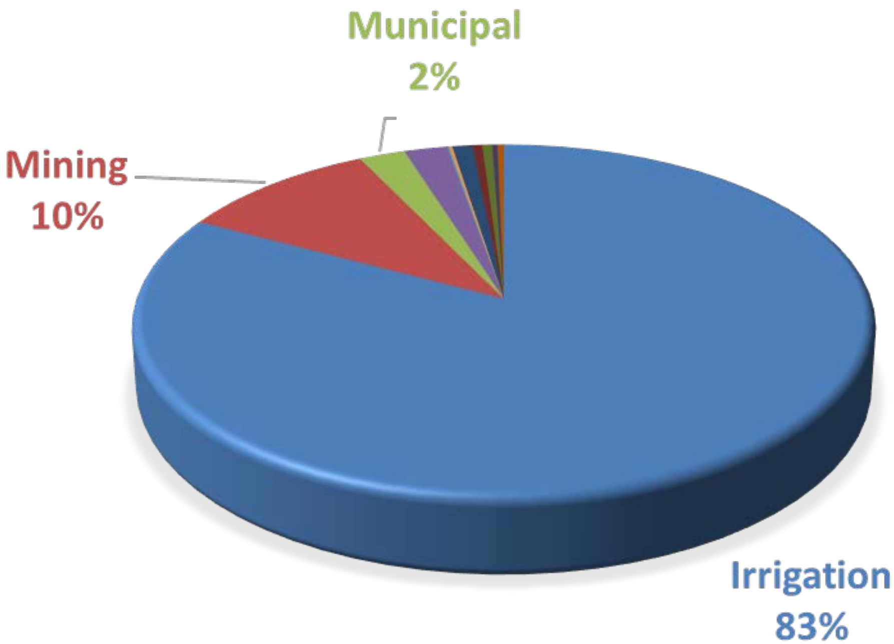
Compliance Statistics:

- 1,181 sites with meters
- 1,123 sites reported pumpage in 2017
- 95% compliance by sites
- 5% that did not report are very small users

Compliance measured in terms of pumped water is ~ 99%

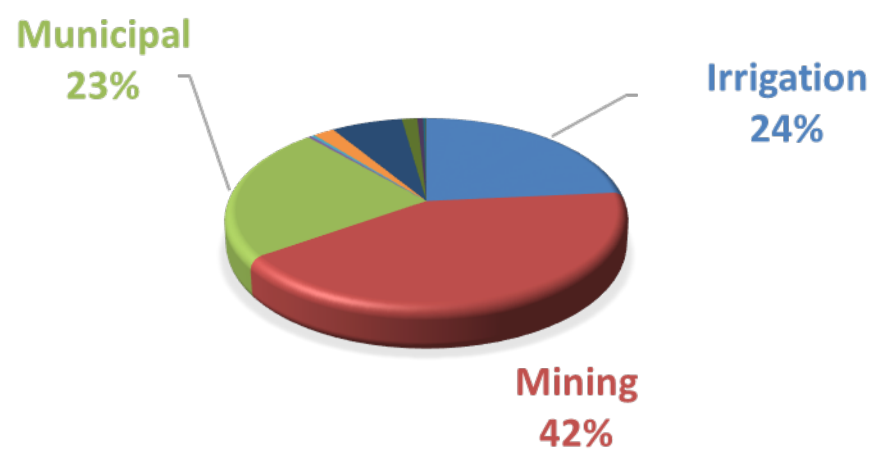
2016 Pumpage Inventory Results

MIDDLE & LOWER BASIN



~280,000 AF

UPPER BASIN: *ABOVE PALISADE*



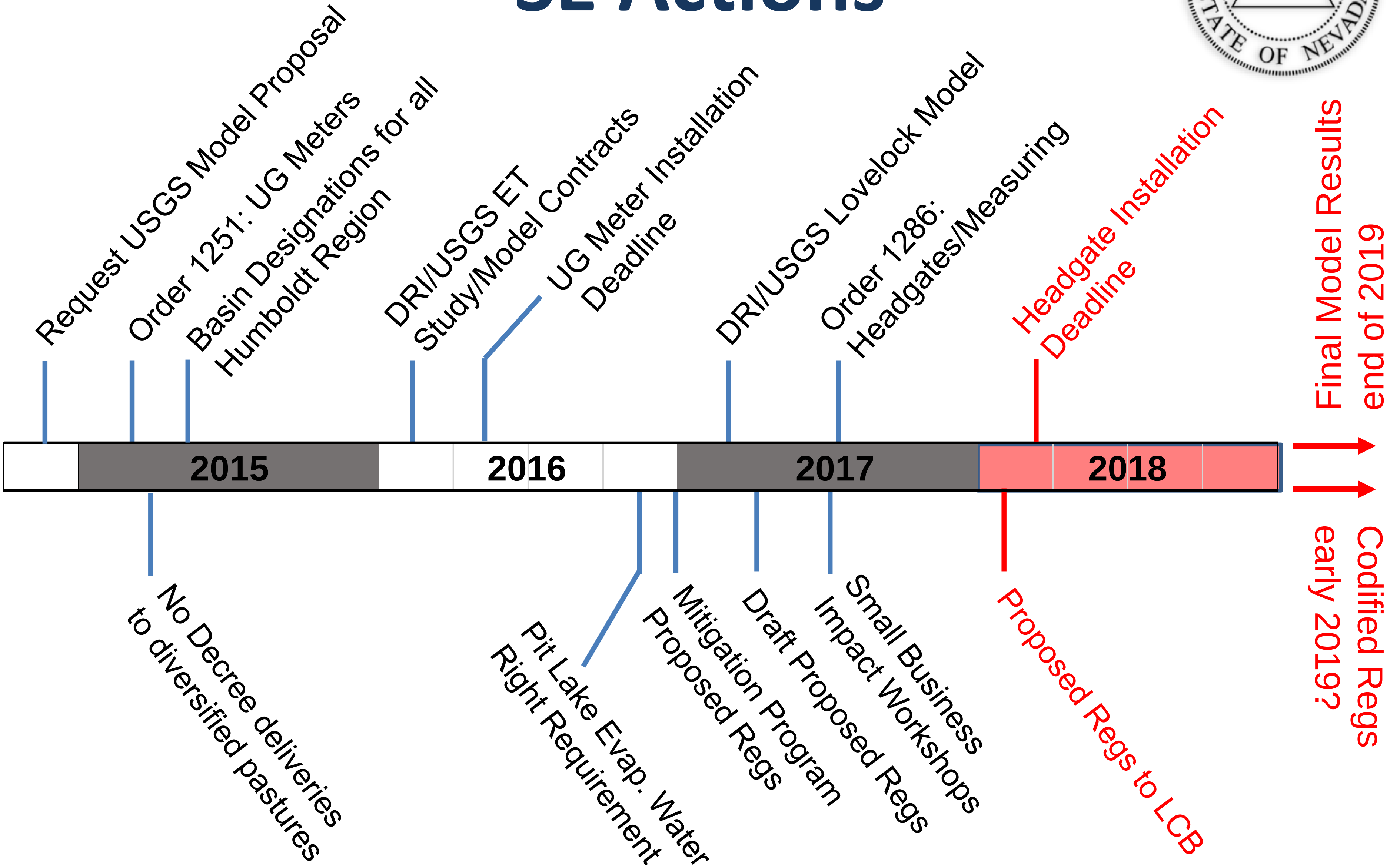
~43,000 AF

Problem

- Humboldt River is fully appropriated, surface water rights are senior to groundwater rights
- Downstream senior surface water right holders got very little water in 2013-2015 period and point to groundwater pumping as causing conflict
- Existing studies indicate that junior groundwater pumping can cause depletion of Humboldt River
- Extent of depletion caused by pumping and magnitude of conflict with senior surface water rights is not known

... NEED APPROPRIATE TOOLS AND SUPPORTING DATA TO MEASURE/MANAGE CONFLICT

SE Actions

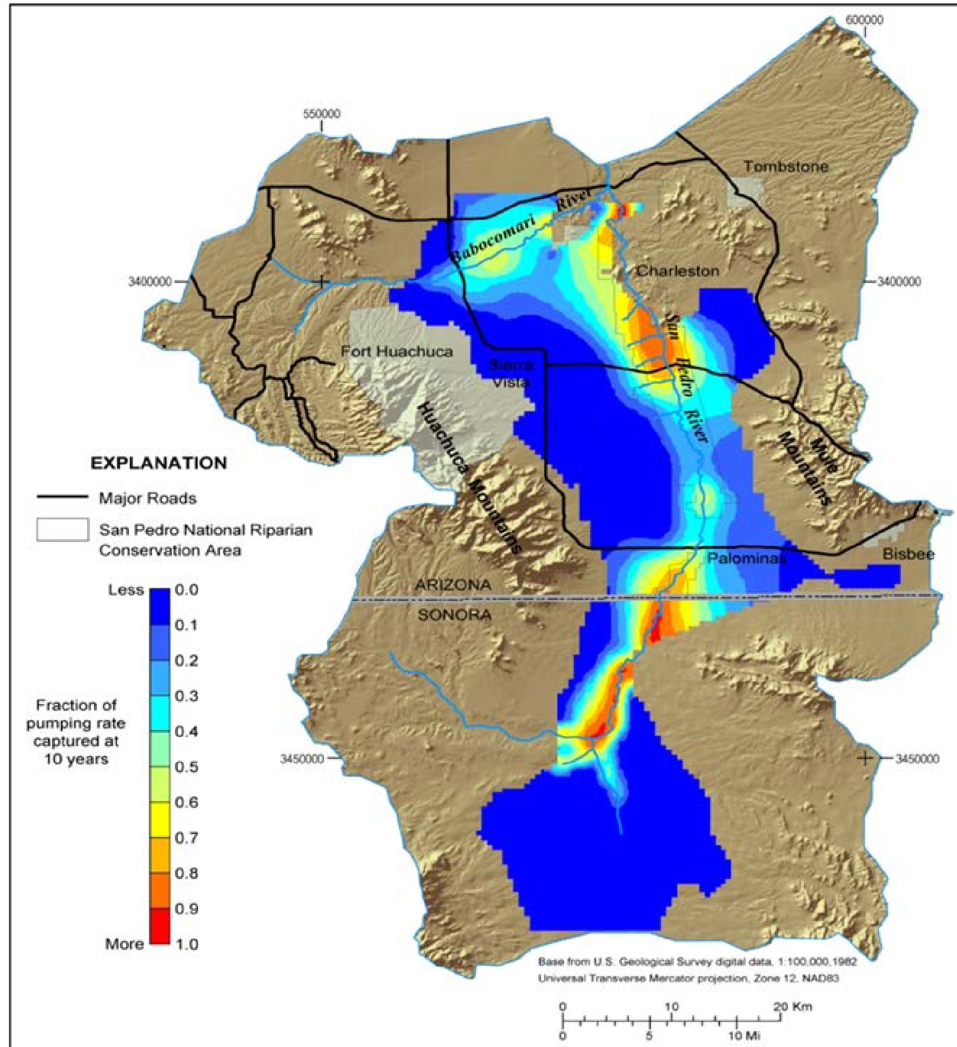

Request USGS Model Proposal
Order 1251: UG Meters
Basin Designations for all Humboldt Region
DRI/USGS ET Study/Model Contracts
UG Meter Installation Deadline
DRI/USGS Lovelock Model
Order 1286: Headgates/Measuring
Headgate Installation Deadline
Final Model Results end of 2019
2015
2016
2017
2018
No Decree deliveries to diversified pastures
Pit Lake Evap. Water Right Requirement
Proposed Regs
Mitigation Program
Draft Proposed Regs
Impact Workshops
Small Business
Proposed Regs to LCB
Codified Regs early 2019?

Ongoing Modeling

- In order for SE to manage the resource and enforce water law, must be able to determine amount and source of conflict
- SE contracted with USGS and DRI to develop groundwater models to quantify amount of river depletion caused by groundwater pumping
- $2.8M cost ($1.75M DWR/$1.1M USGS JFA)
- 4-year project, completion date = end of 2019

Hydrogeologic Model of the Humboldt River Basin

- Simulate the natural system
- Use existing models and geology data
- Calibrate to historic flow records, water levels, and pumpage
- Quantify how much surface water is actually captured by groundwater pumping
- Develop capture map showing distribution of capture % (potential capture) for model area
- Use models as tool to manage problem

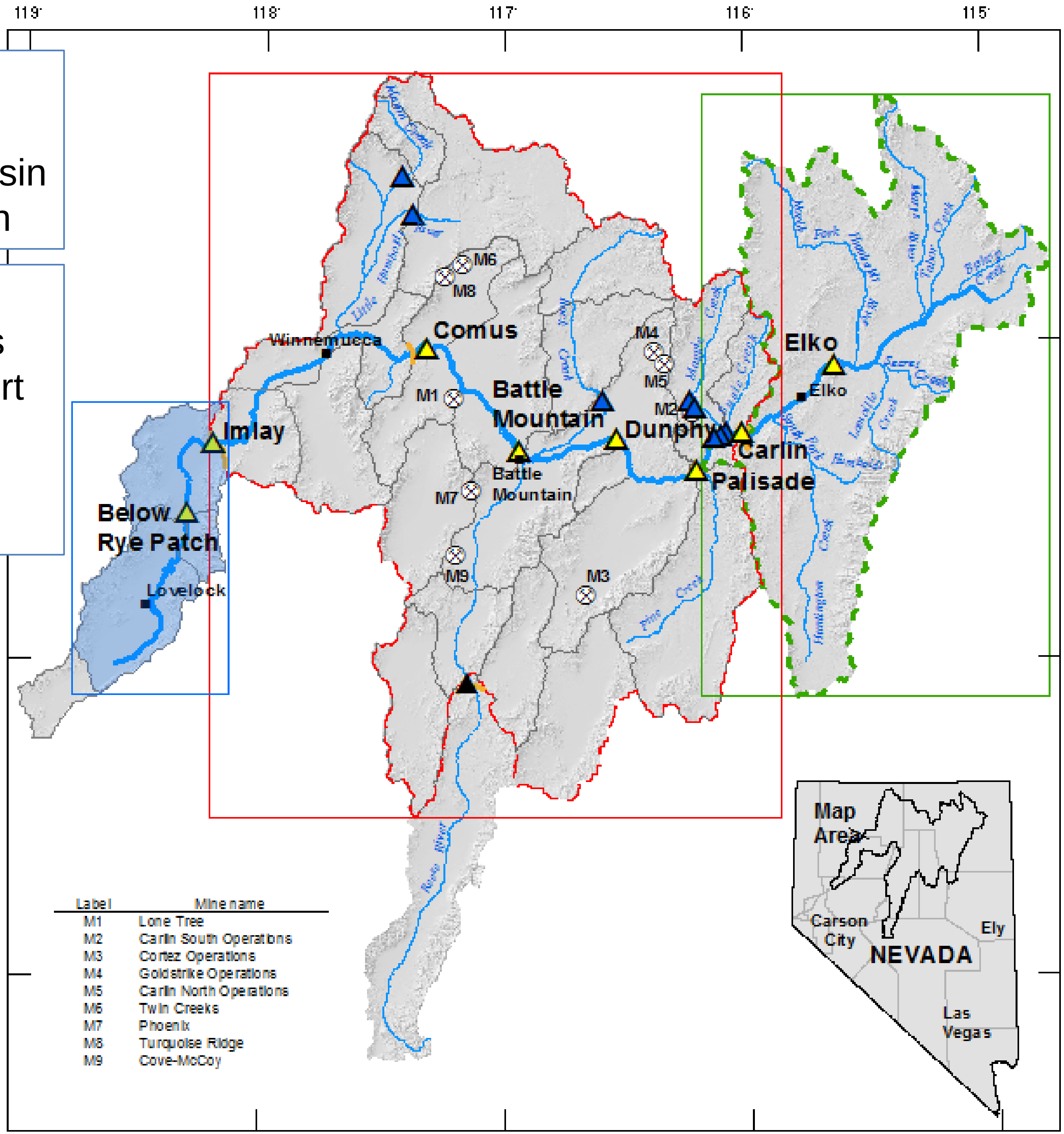


Model Areas

- DRI Upper Basin
- USGS Middle Basin
- Joint Lower Basin

DRI ET Study

- Covers all Basins
- Needed to support model water budgets and calibrate models



Groundwater 101

Kip Allander - USGS

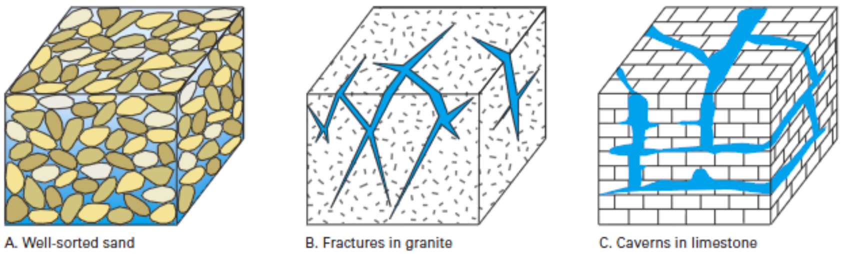
Groundwater Hydrology Principles

- What is groundwater?
- Groundwater and surface water, how are these connected or related?
- Where does water come from when pumping a well?
- What are groundwater models and why are they needed?

What is Groundwater?

- Liquid water in the subsurface.
- Water occupies spaces between sand, silt, and gravel in fill; or fractures and cavities in rocks.
- Water movement through and storage within the subsurface is governed by aquifer properties.

Permeability is ability of water to move through material.

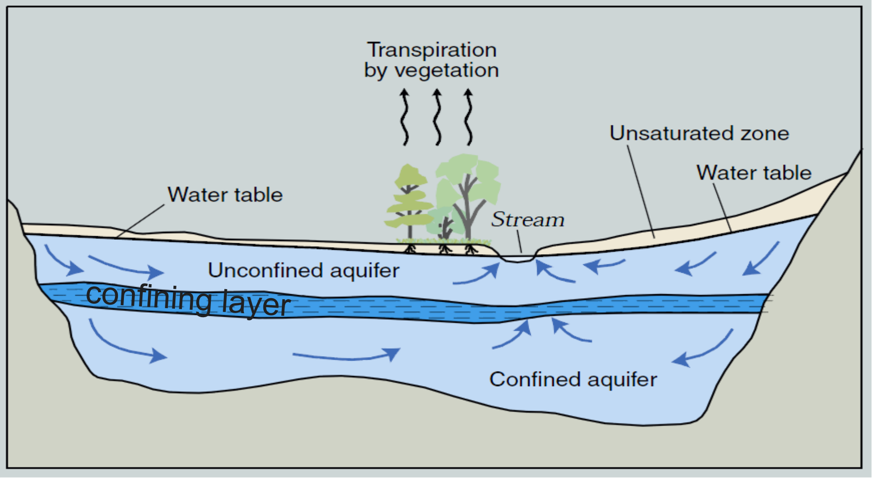


Storage is amount of water that can be extracted from a given volume of aquifer.

What is Groundwater?

Aquifers exist where groundwater can be developed to provide adequate supply to wells.

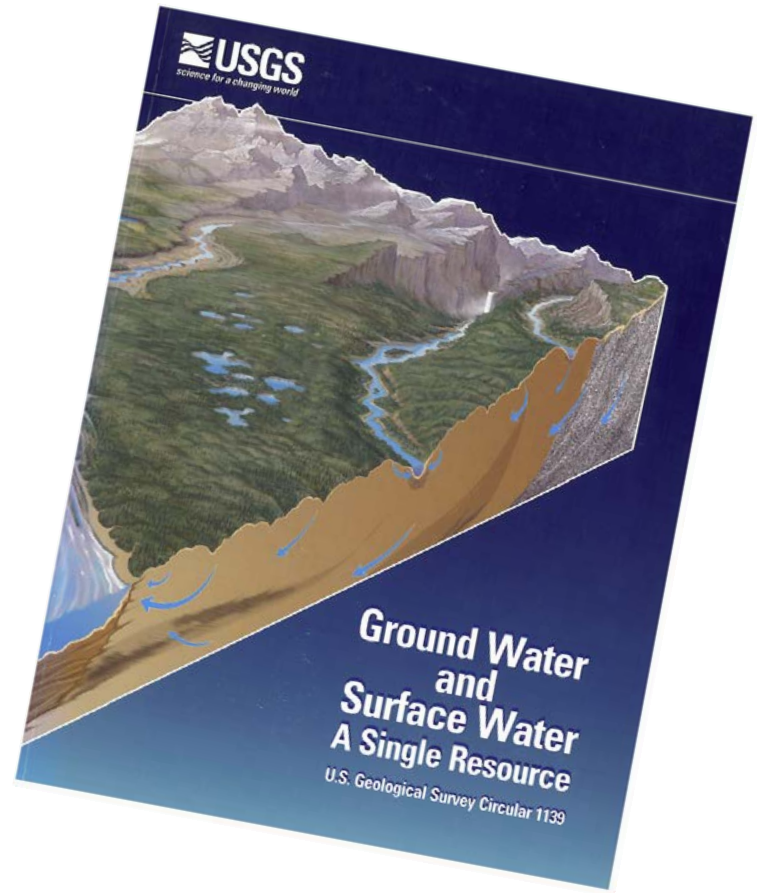
- Groundwater flows from areas of recharge to areas of discharge.



Groundwater and Surface Water, how are these connected or related?

Important concept for understanding how groundwater works.

Understanding is necessary for proper management of Nevada's water resources.



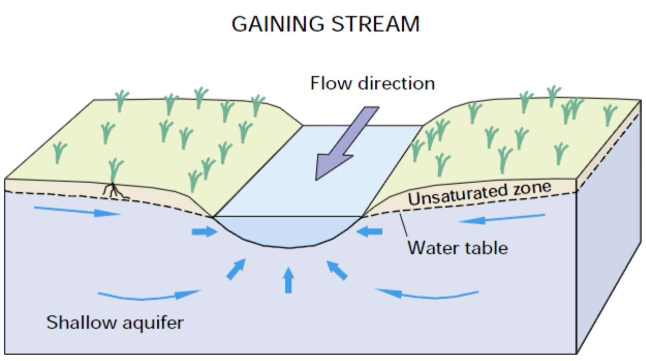
Winter, T.C., Harvey, J.W., Franke, O.L., and Alley, W.M., 1998, Ground water and surface water—A single resource: U.S. Geological Survey Circular 1139, 79 p. https://pubs.usgs.gov/circ/circ1139/

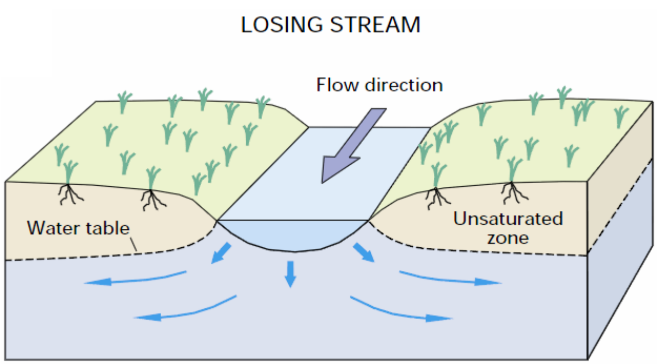
Groundwater and Surface Water are a single resource

- Streams flowing year-round are connected with groundwater.

- Groundwater can:
  - Discharge to a stream (gaining stream).
  - Receive water from a stream (losing stream).

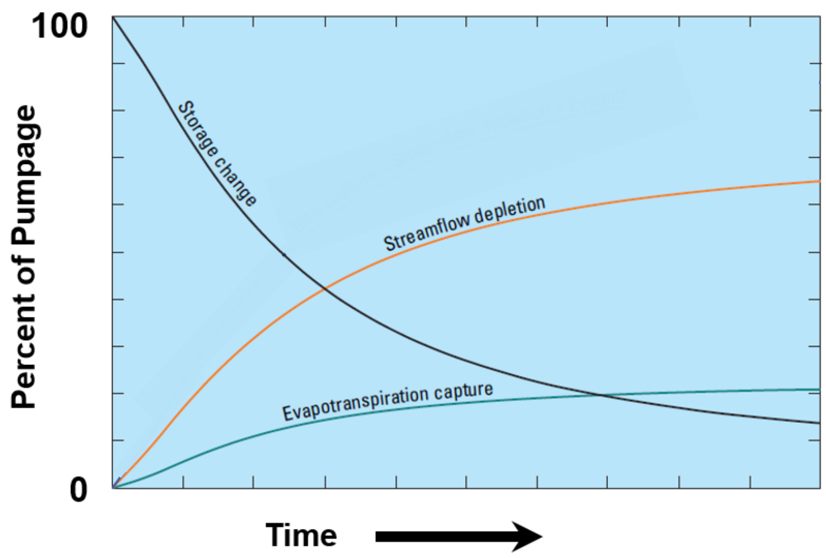
- Streams can:
  - Lose water to groundwater (losing).
  - Gain water from groundwater (gaining).

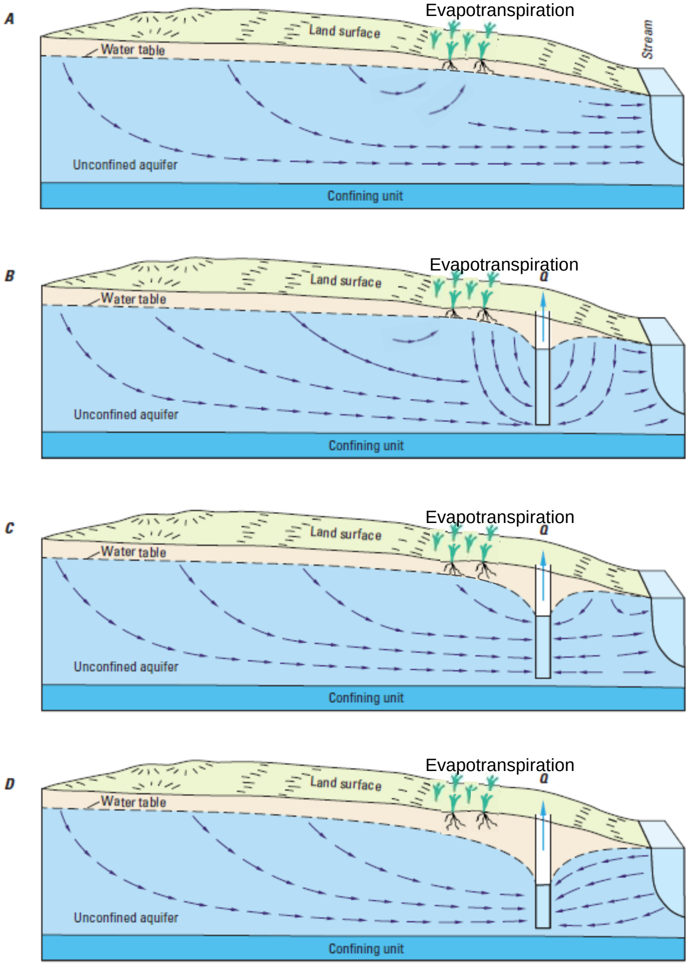




Where does water come from when pumping a well?

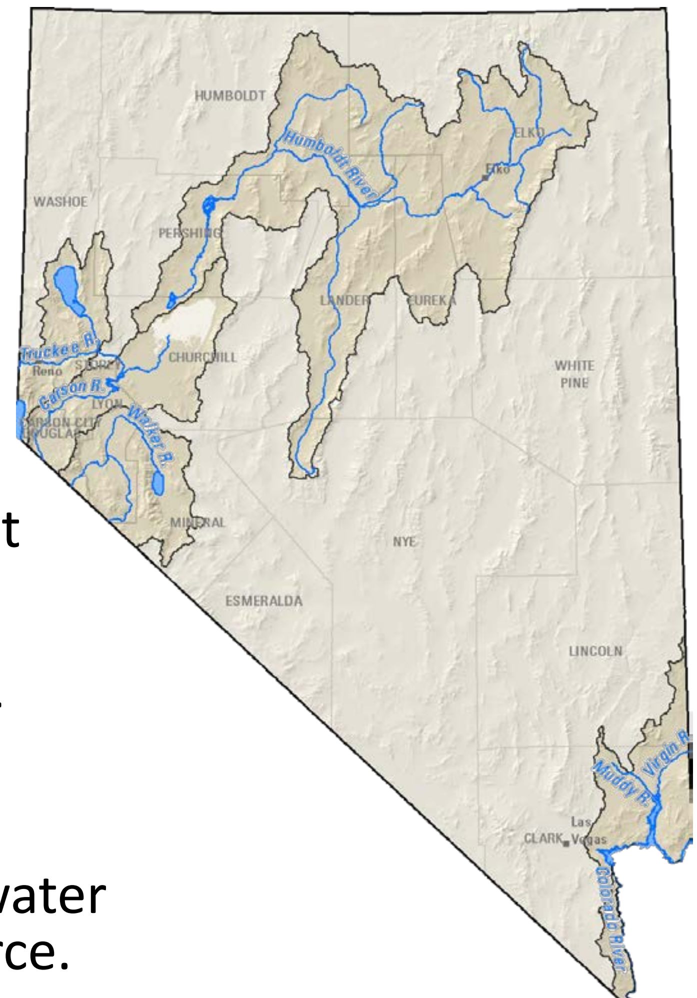
- Storage change – water from ground near well.
- Streamflow capture – diversion from stream.
- Evapotranspiration capture – water intercepted from plant use and evaporation.





Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion by wells—Understanding and managing the effects of groundwater pumping on streamflow: U.S. Geological Survey Circular 1376, 84 p. http://pubs.usgs.gov/circ/1376/

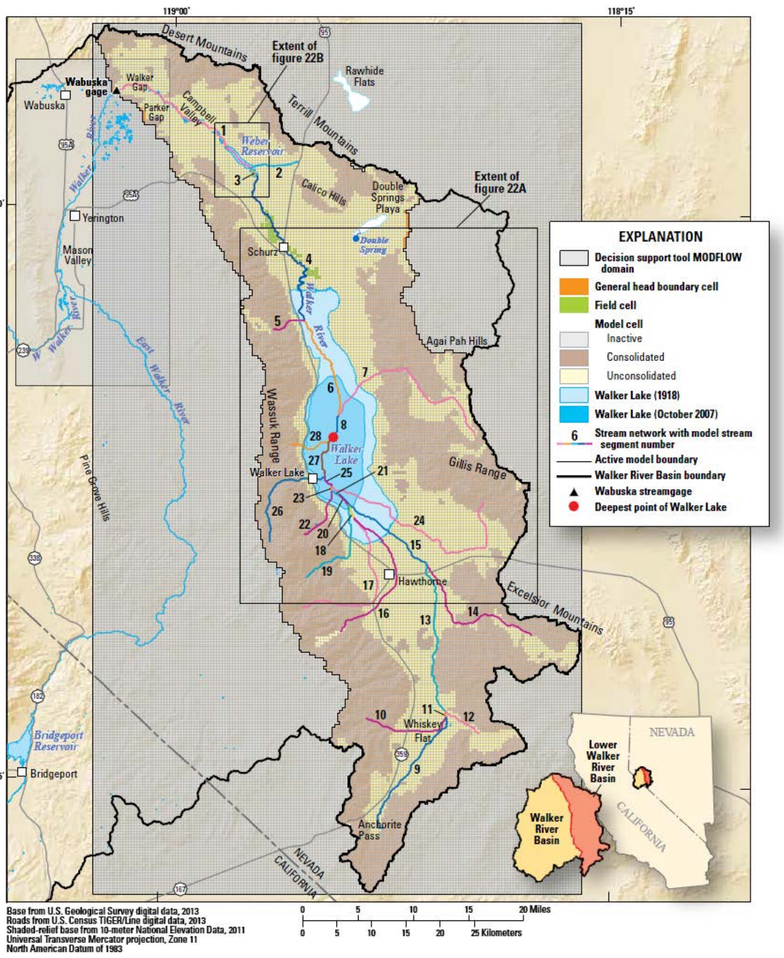
River Connected Groundwater Systems in Nevada



- River connected flow systems.
  - Much of the groundwater movement between Hydrographic areas is by streamflow.
  - 25 percent of Nevada's groundwater systems.
  - Substantial potential for conflict between groundwater and surface water users due to shared nature of resource.

What are Groundwater models?

- Mathematical representations of complex hydrologic systems.
- Simulate hydrologic systems based on principles, aquifer properties, and boundary conditions.



Groundwater flow equation:

$$\frac{\partial}{\partial x}\left[K_{xx}\frac{\partial h}{\partial x}\right]+\frac{\partial}{\partial y}\left[K_{yy}\frac{\partial h}{\partial y}\right]+\frac{\partial}{\partial z}\left[K_{zz}\frac{\partial h}{\partial z}\right]+W=S_S\frac{\partial h}{\partial t}$$

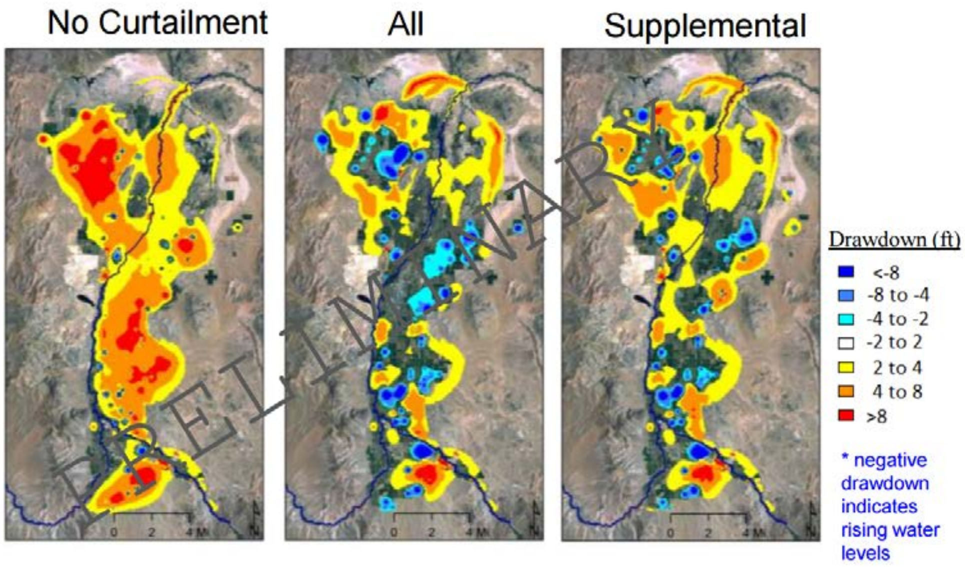
Why are Groundwater models needed?

- Use existing information and understanding to estimate properties that govern flow.
  - Referred to as calibration.

- Needed to understand complex system interactions and to inform results of management actions.

Aug. to Aug. Drawdown

Streamflow = 20%; Curtailment = 75%

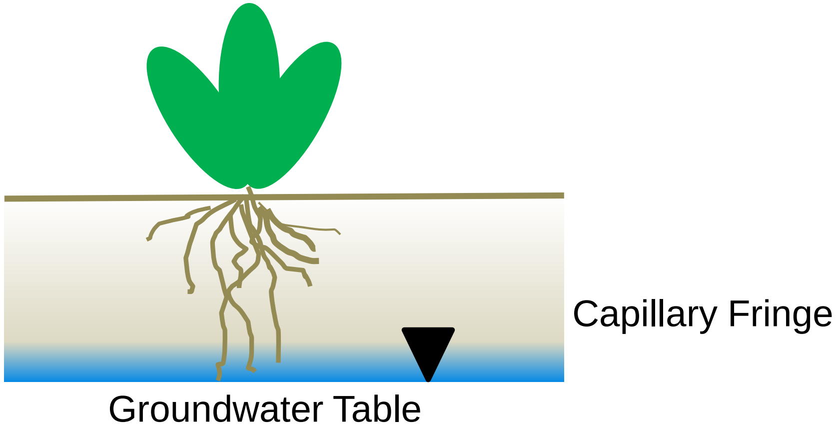


Evapotranspiration

Matt Bromley - DRI

Evapotranspiration

- Water recharged in the Humboldt River Basin is discharged through Evaporation and Transpiration
  - Playas
  - Open Water
  - Phreatophytes (plants that access and use groundwater)
- Evaporation + Transpiration = EvapoTranspiration (ET)
- ET Task: Estimate annual groundwater ET in each HA of the Humboldt River Basin

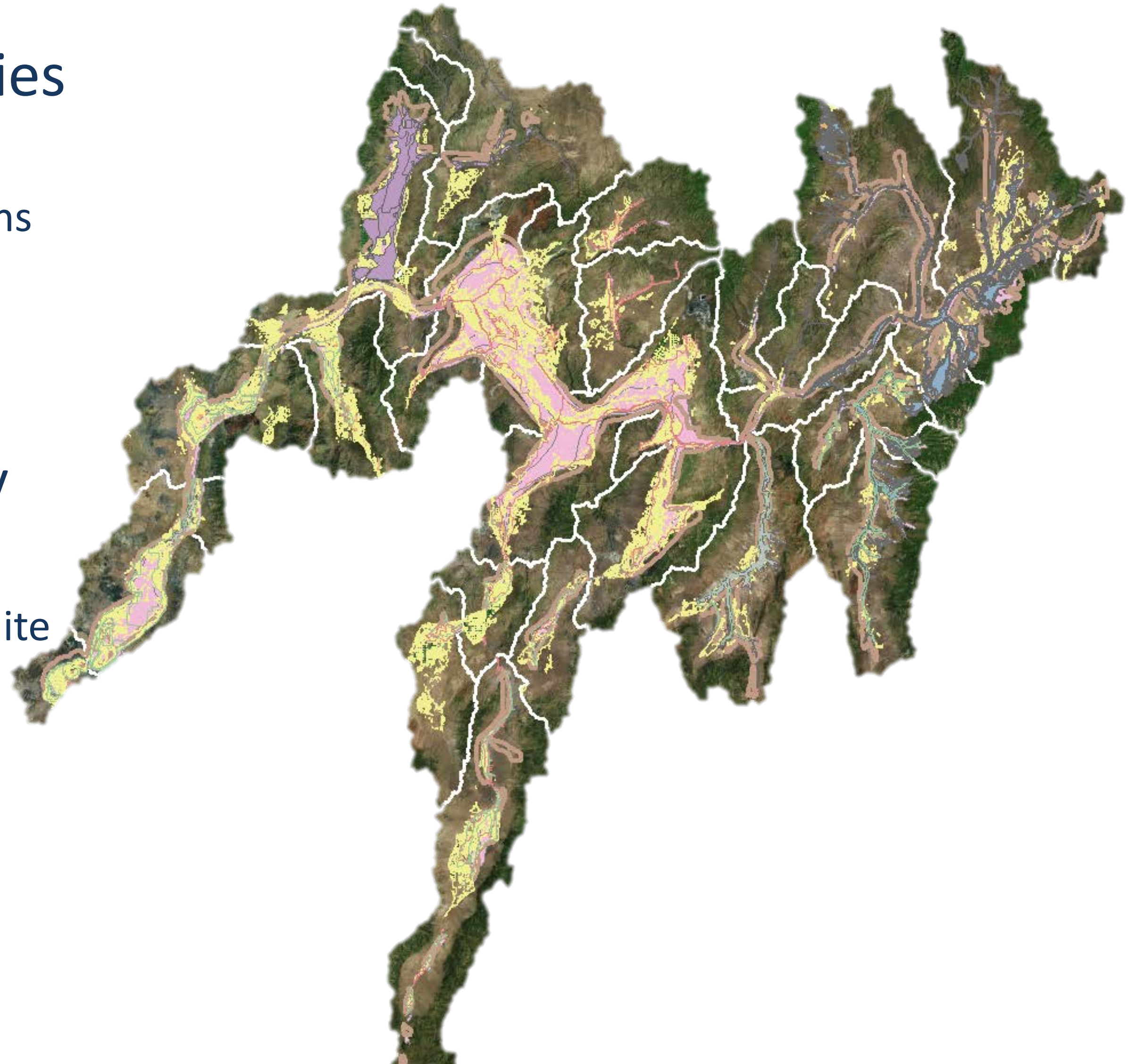


Tasks

- Review and compile previous groundwater ET estimates and develop a GIS database of
  - Phreatophyte boundaries
  - ET rates
  - ET volumes
- Modify discharge area boundaries based on satellite/aerial imagery and field investigations
- Apply new remote sensing and gridded weather data techniques to update ET rates and volumes
- Groundwater ET volumes used to support groundwater modeling efforts

Evaluating Discharge Boundaries

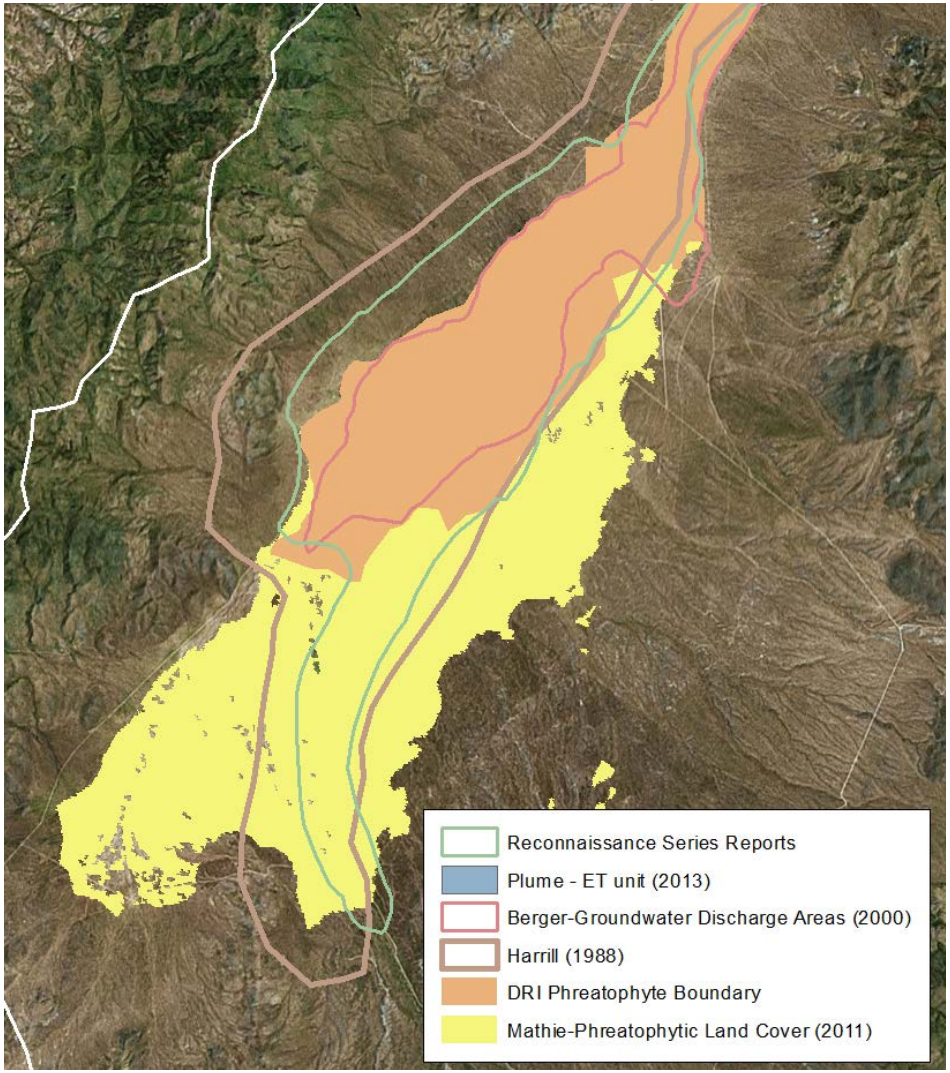
- Discharge Boundaries
  - Recon. Reports
  - Water Resource Bulletins
  - Water-Resource Investigation Reports
  - Other reports
- Assess their accuracy based on
  - Historical Landsat satellite imagery
  - High resolution aerial imagery
  - Digital elevation
  - Field investigations



Boundaries

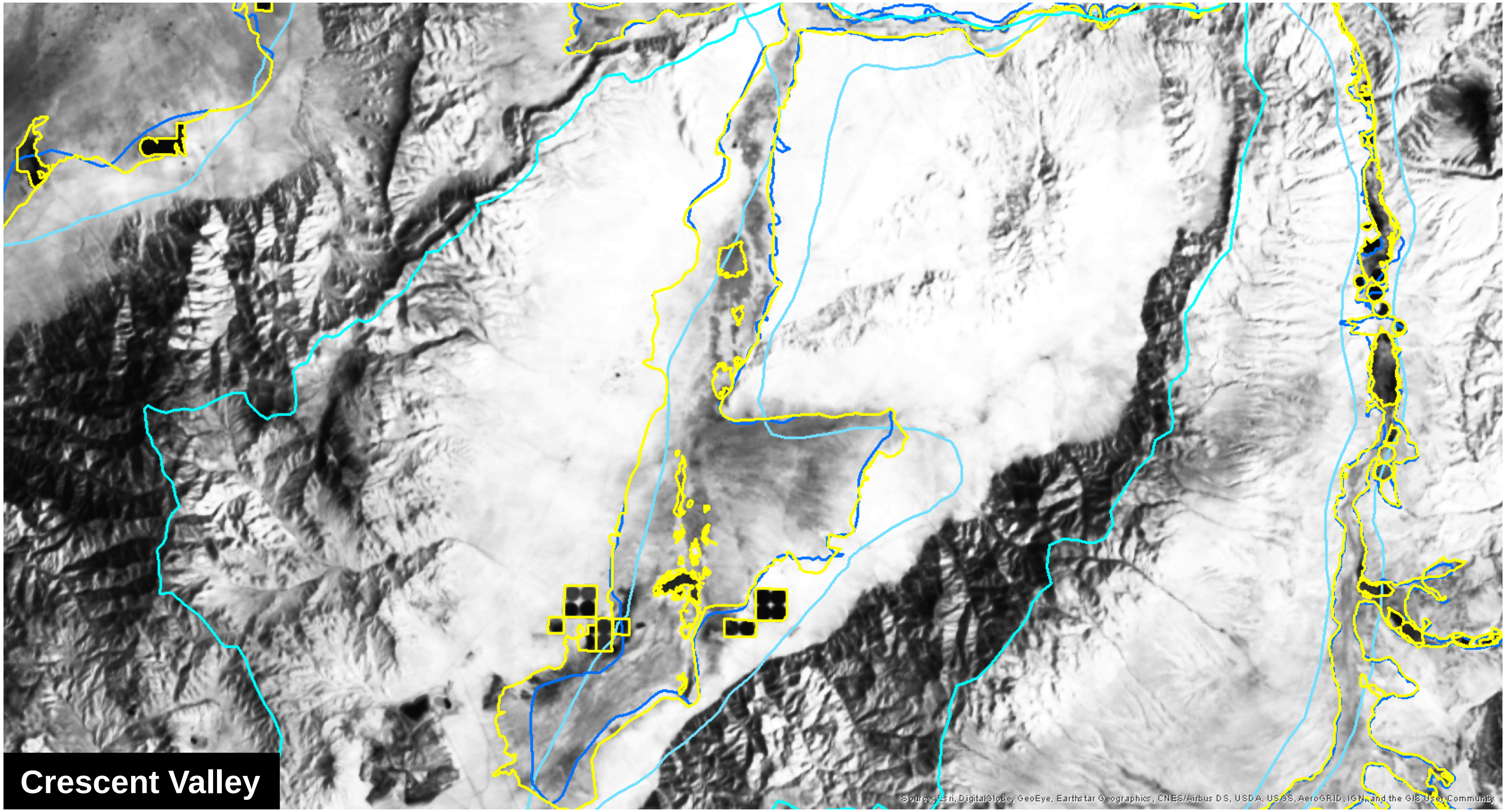
- Different reports have had very different discharge areas
  - Area is the squared term in volume, so correctly defining the discharge area in each basin is important
- DRI boundaries based on multiple datasets
  - Previous reports
  - Satellite and aerial imagery
  - Digital elevation data
  - Field investigations

Carico Lake Valley

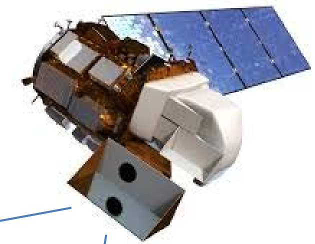


Boundaries

– Example: Landsat surface temperature helps to delineate groundwater discharge areas

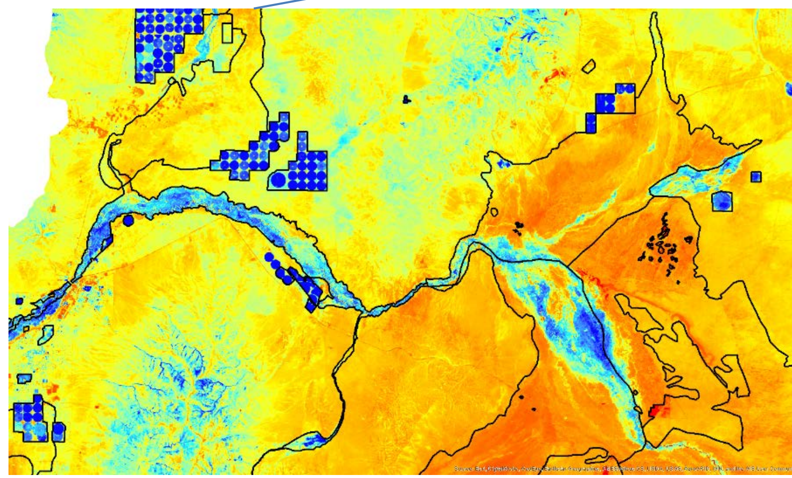


Methods

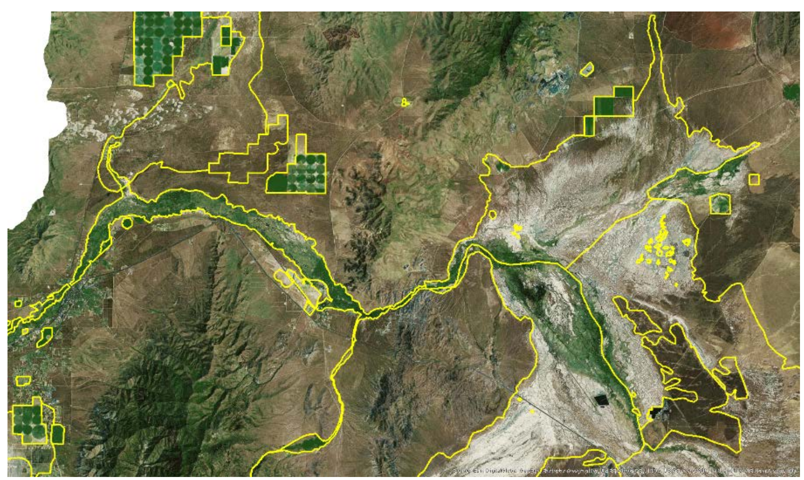


Groundwater ET rates based on:

- Published regression model using vegetation index and climate variables
  - Based on 40 site years of measured ET from phreatophytes in NV
- Landsat satellite images of vegetation vigor (greenness) from 1985-2016
- Gridded weather data from 1985-2016
  - Potential ET (PET)
  - Precipitation (PPT)



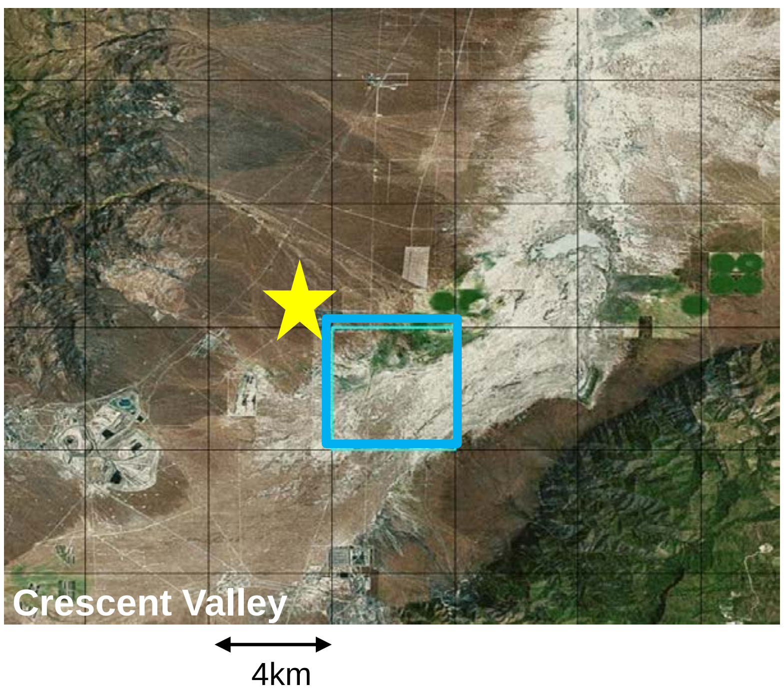
Vegetation Index (30m)

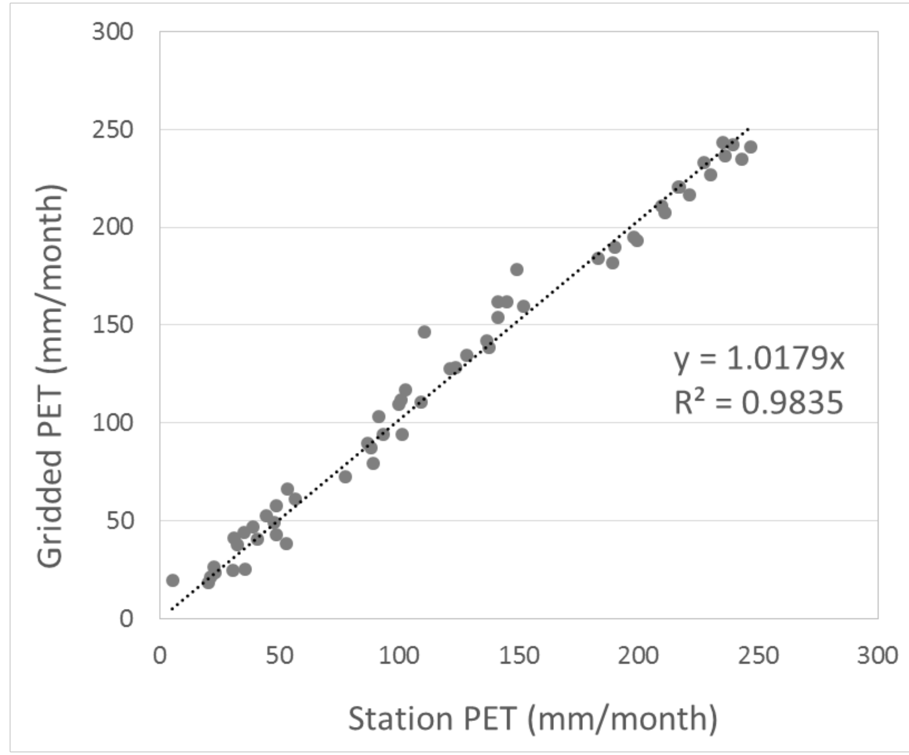


True Color

Validation of gridded meteorological data

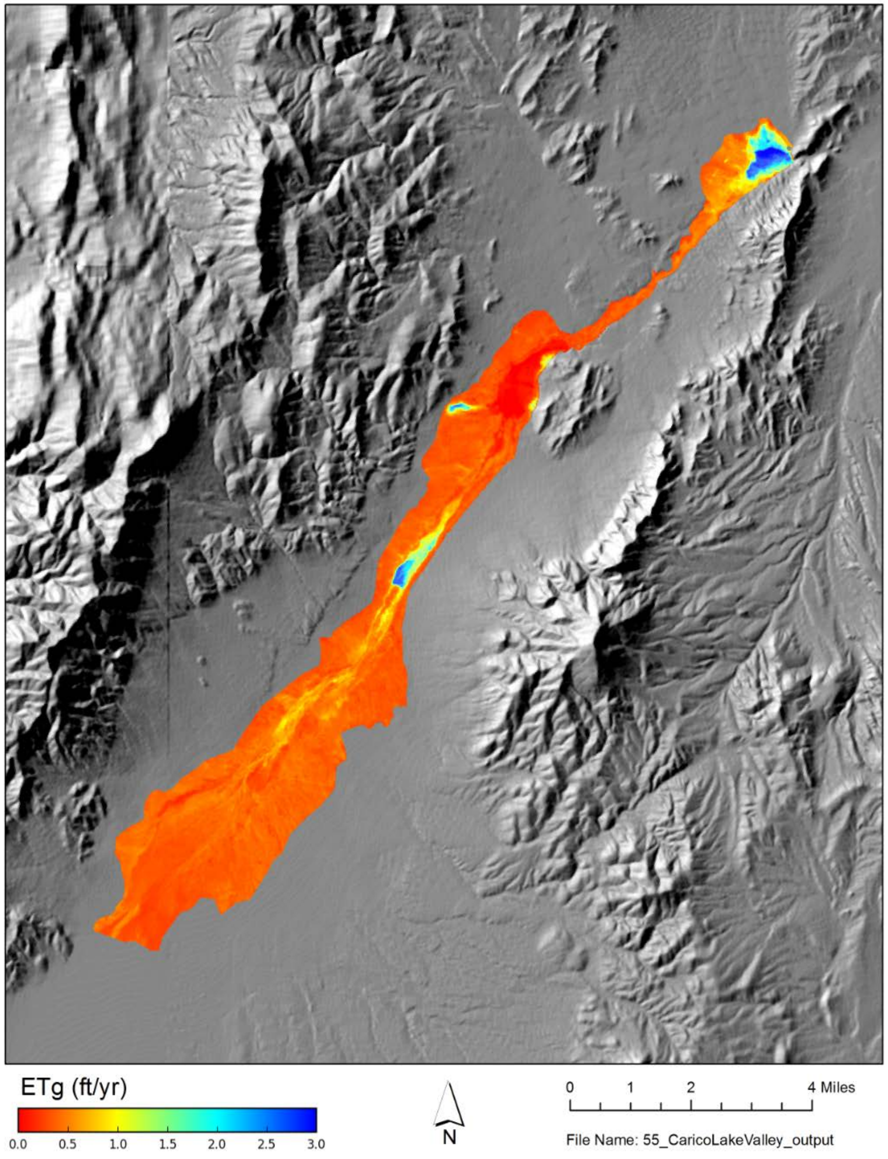
Analysis determined that gridded weather data and PET estimates compared favorably with data from weather stations





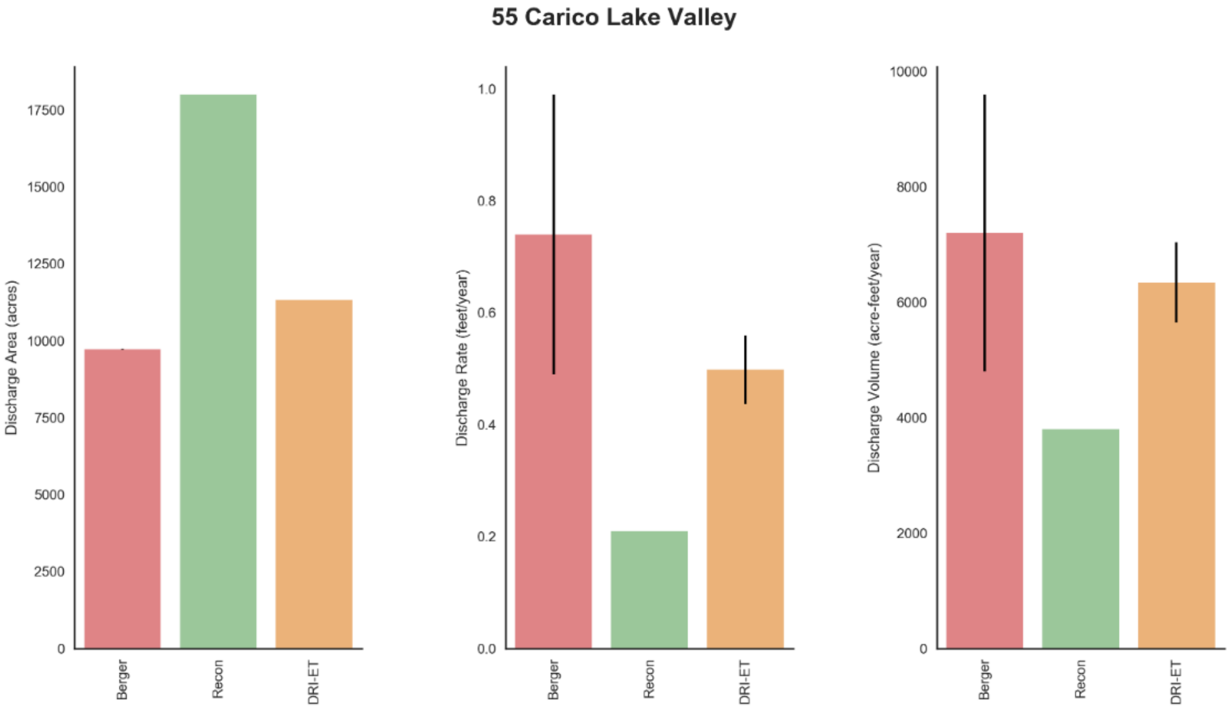
Processing

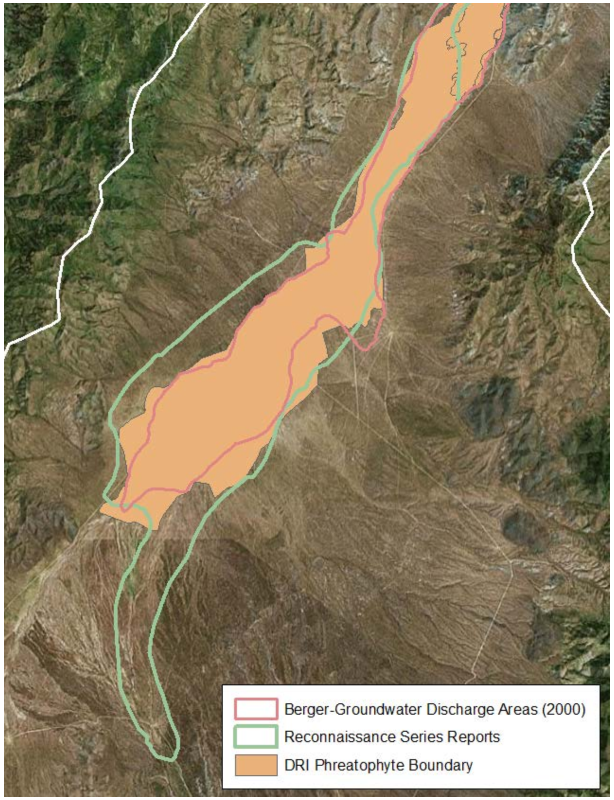
- Google Earth Engine was used to apply the model to the Landsat image archive
- Images of estimated groundwater ET were produced for the period of study (1985-2015)



Comparisons to Previous Reports

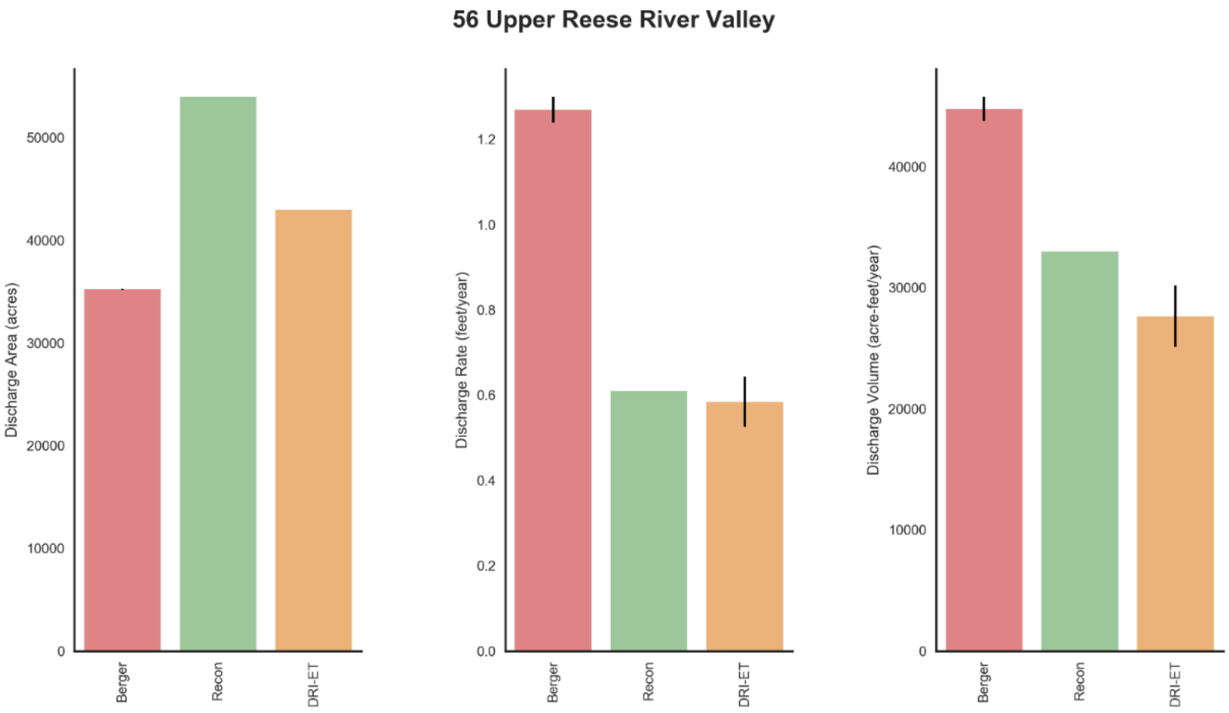
- DRI discharge area is slightly larger compared to Berger (2000), but smaller than Recon
- DRI rate and volume at lower end of Berger estimates





Comparisons to Previous Reports

- Additional areas of phreatophyte shrub were digitized in the DRI dataset. DRI area was larger than Berger (2000), but smaller than Recon Report
- Higher ETg rates from Berger (2000) resulted in a larger volume compared to Recon and DRI estimates



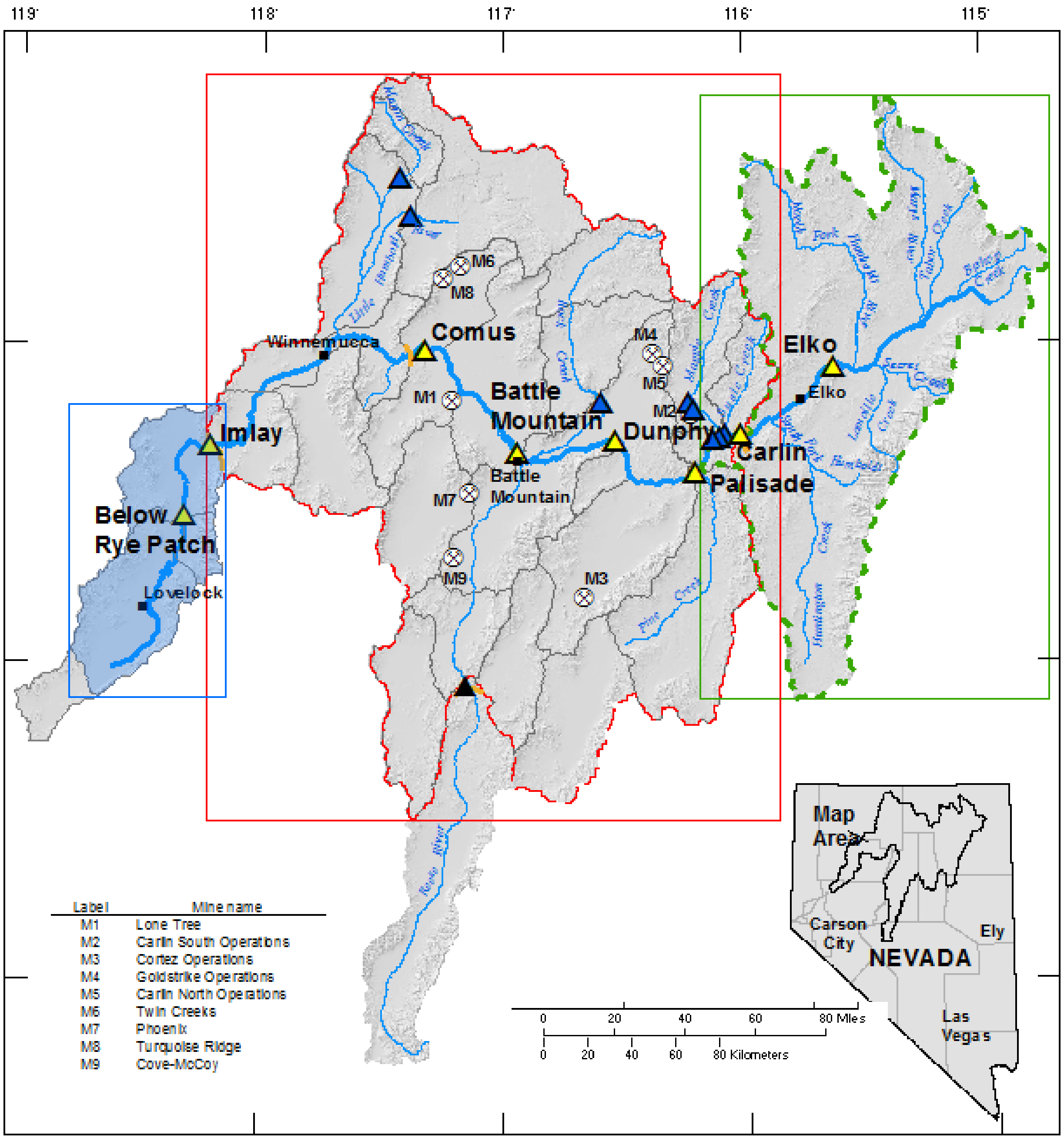
Upcoming ET Tasks

- Final QA/QC
- Draft Report
- Peer Review
- Assemble Geodatabase

Groundwater Models

Upper Basin Model

Greg Pohll - DRI



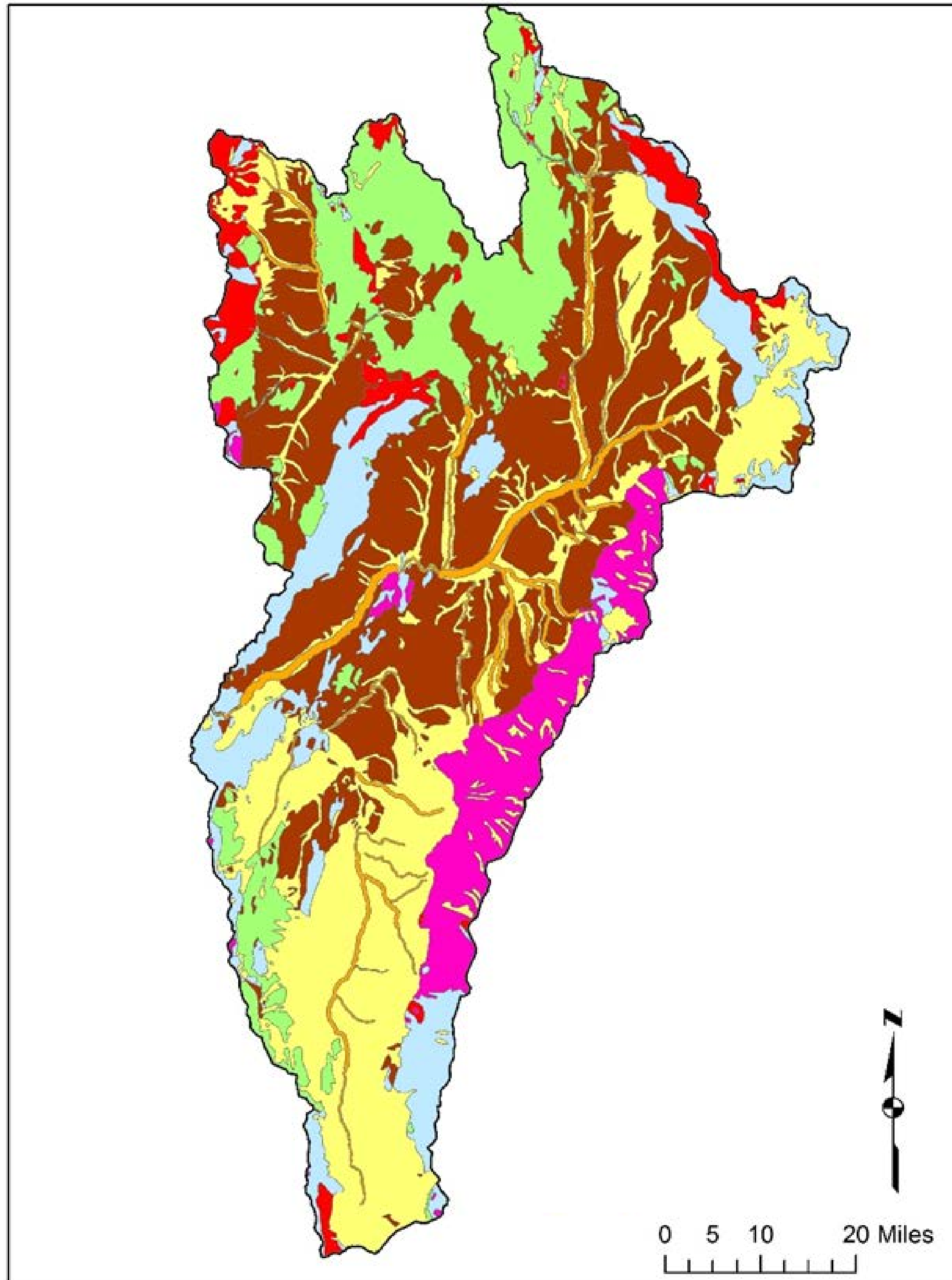
- Upper basin model - DRI
- Middle basin model - USGS
- Lower basin Model – USGS/DRI

Outline

- Geology
- Model grid
- Water Budget Components Considered
- Steady State Model Calibration Strategy
- Steady State Model Results

Geology Layer 1

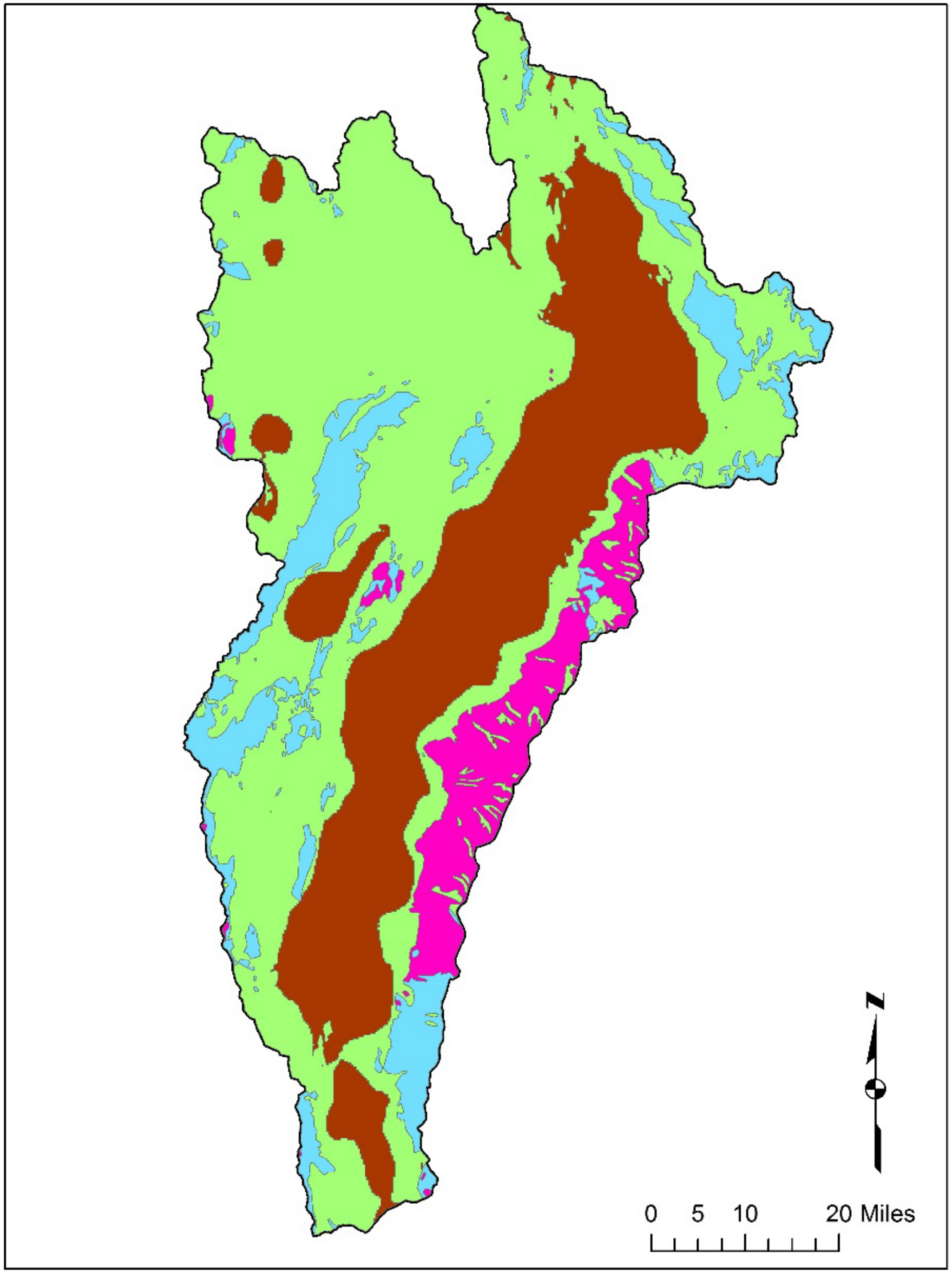
- Carbonates
- Intrusives/Metamorphic
- Alluvial slope
- Fluvial deposits
- Sedimentary
- Older basin fill
- Volcanics



300 ft thick

Geology Layer 2

Carbonates	
Intrusives/Metamorphic	
Alluvial slope	
Fluvial deposits	
Sedimentary	
Older basin fill	
Volcanics	

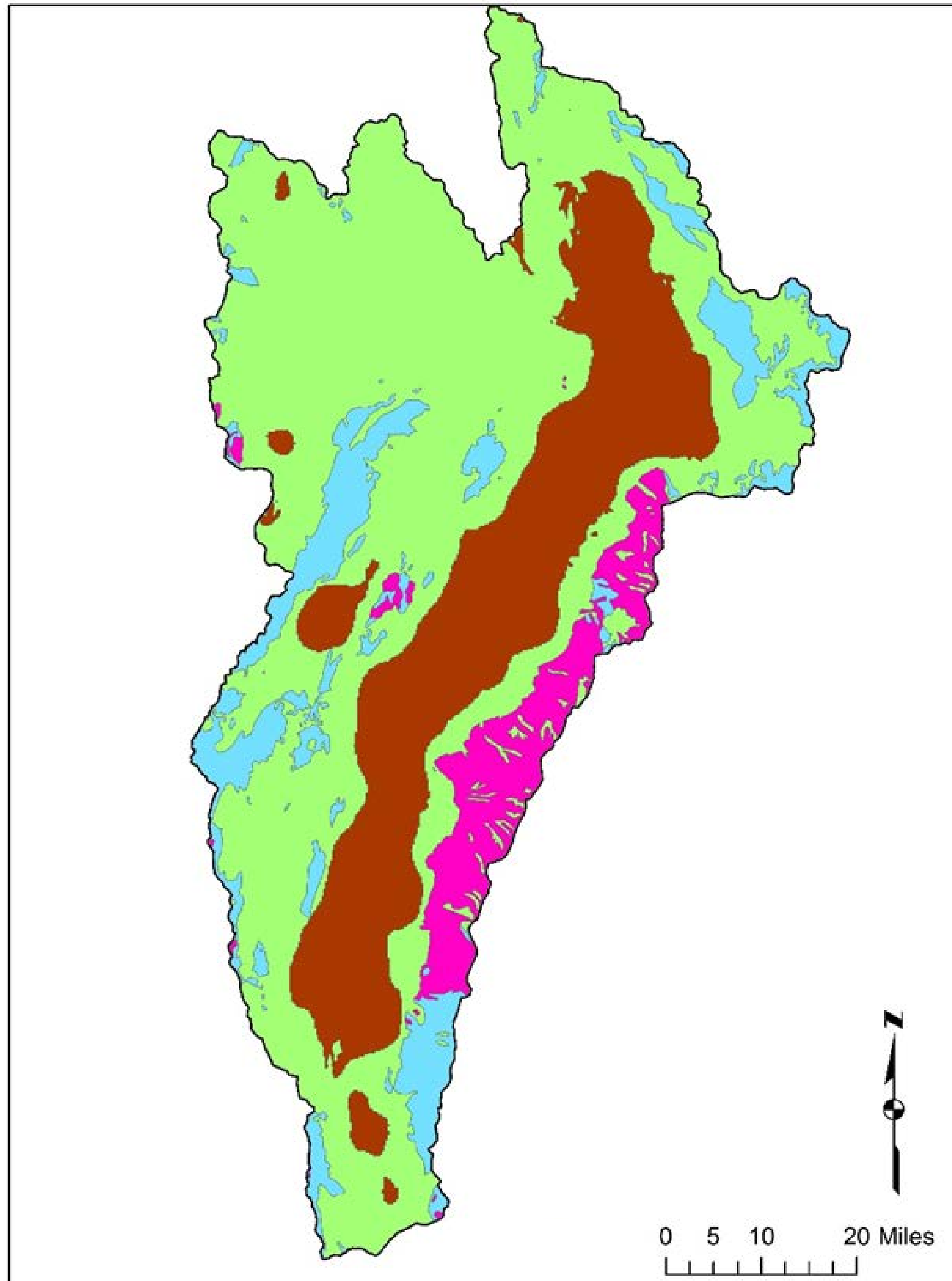


700 ft thick

Geology Layer 3

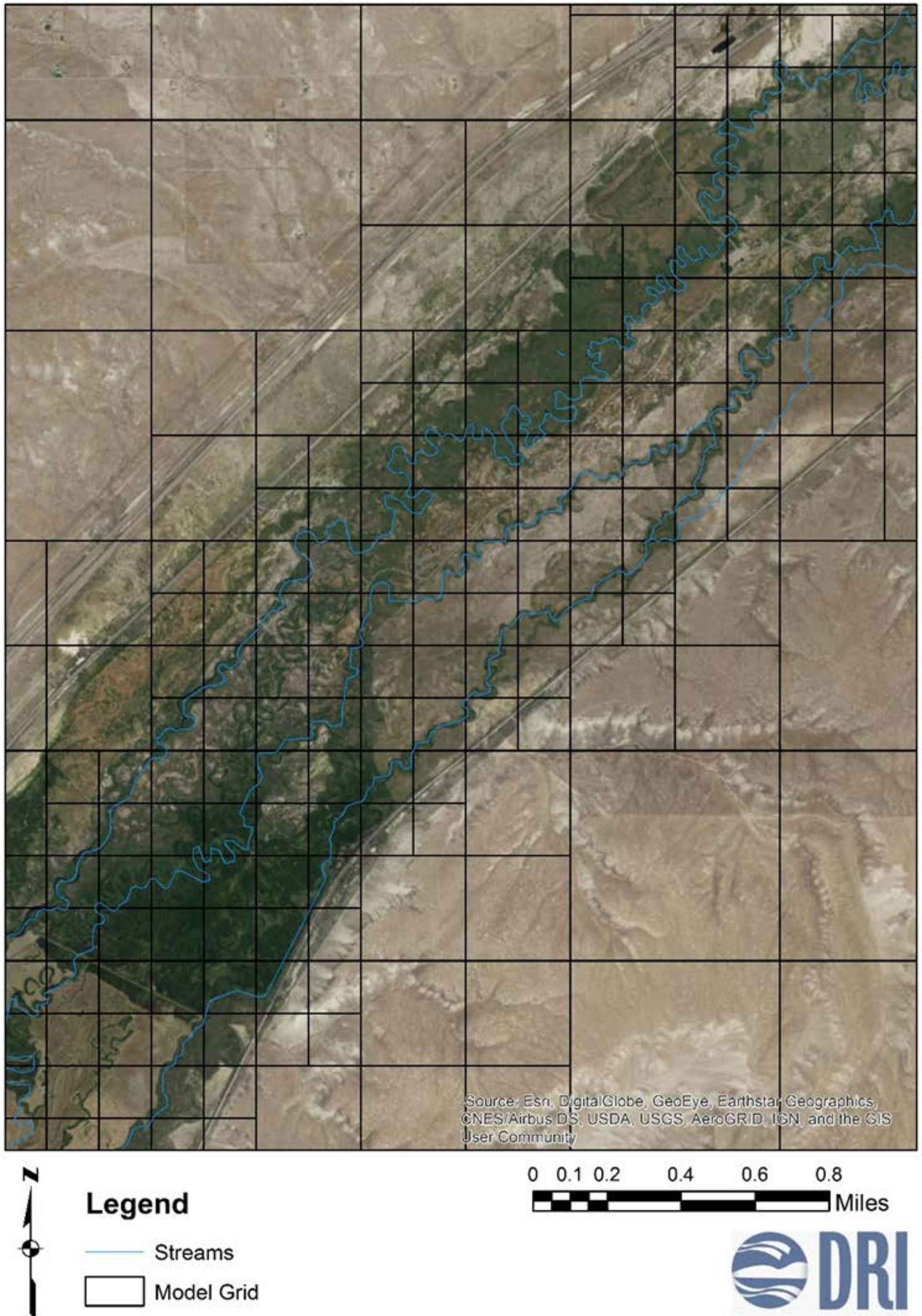
Carbonates	
Intrusives/Metamorphic	
Alluvial slope	
Fluvial deposits	
Sedimentary	
Older basin fill	
Volcanics	

Bottom elevation = 1,000 ft



Model Grid

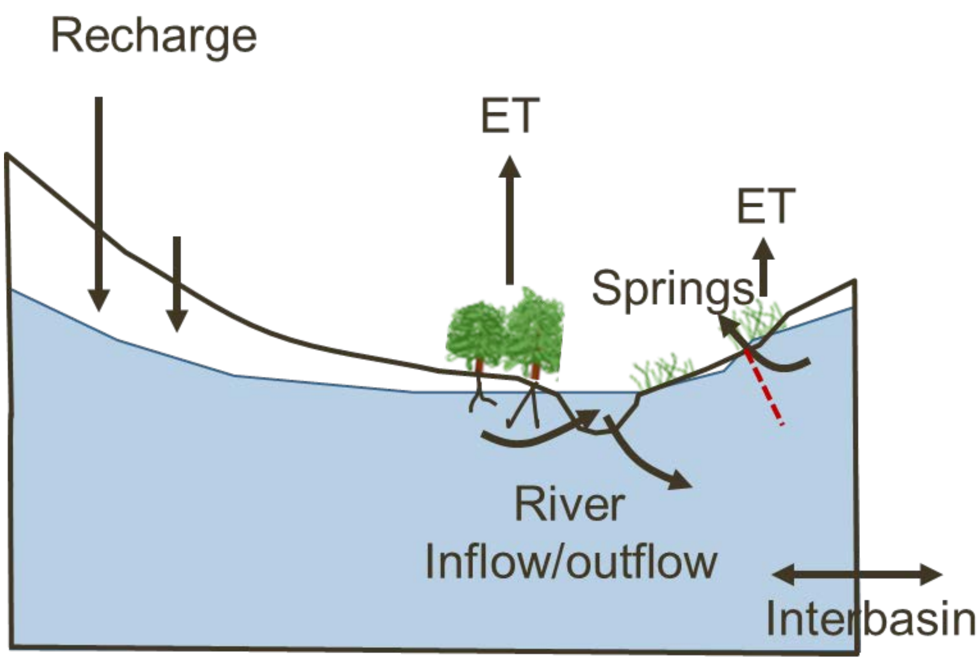
- Unstructured grid
- 750 ft at streams
- 3,000 ft elsewhere



DRI Desert Research Institute

Water Budget Components

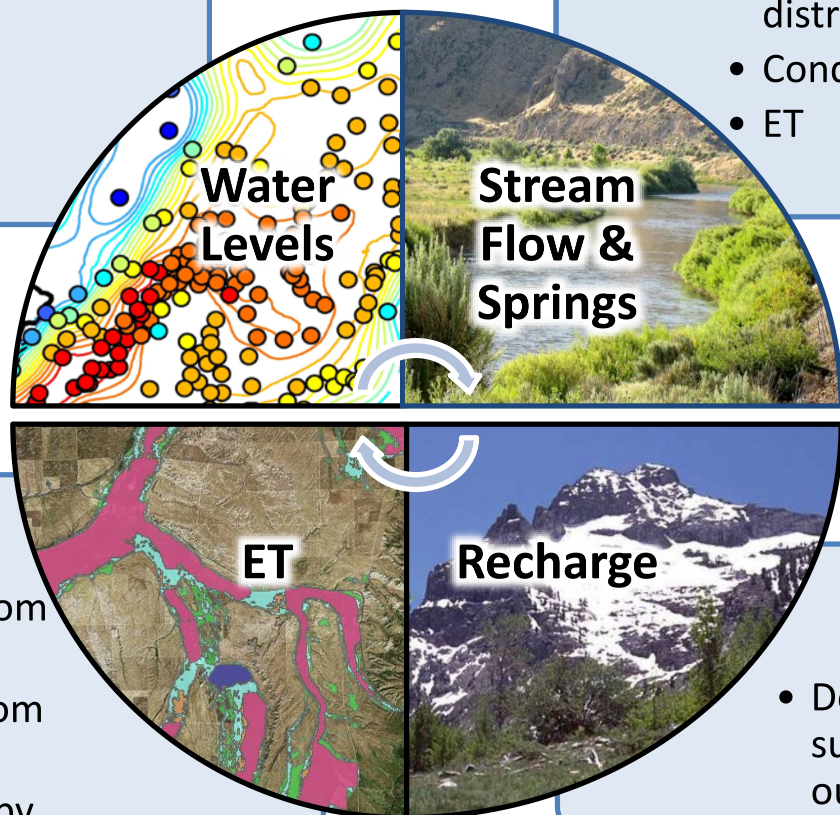
- <u>Recharge</u> is elevation dependent and drives all outflows from the system.
- <u>ET</u> is a function of water table depth, vegetation type and atmospheric water demand.
- <u>River</u> fluxes are dependent on gradient between river stage and water table and ET.
- <u>Springs</u> occur where groundwater daylights as a function of topography, geology or structure (faults).
- <u>Interbasin</u> flow can move water into/out of the basin



Calibration Strategy

- Horizontal K
- Recharge distribution

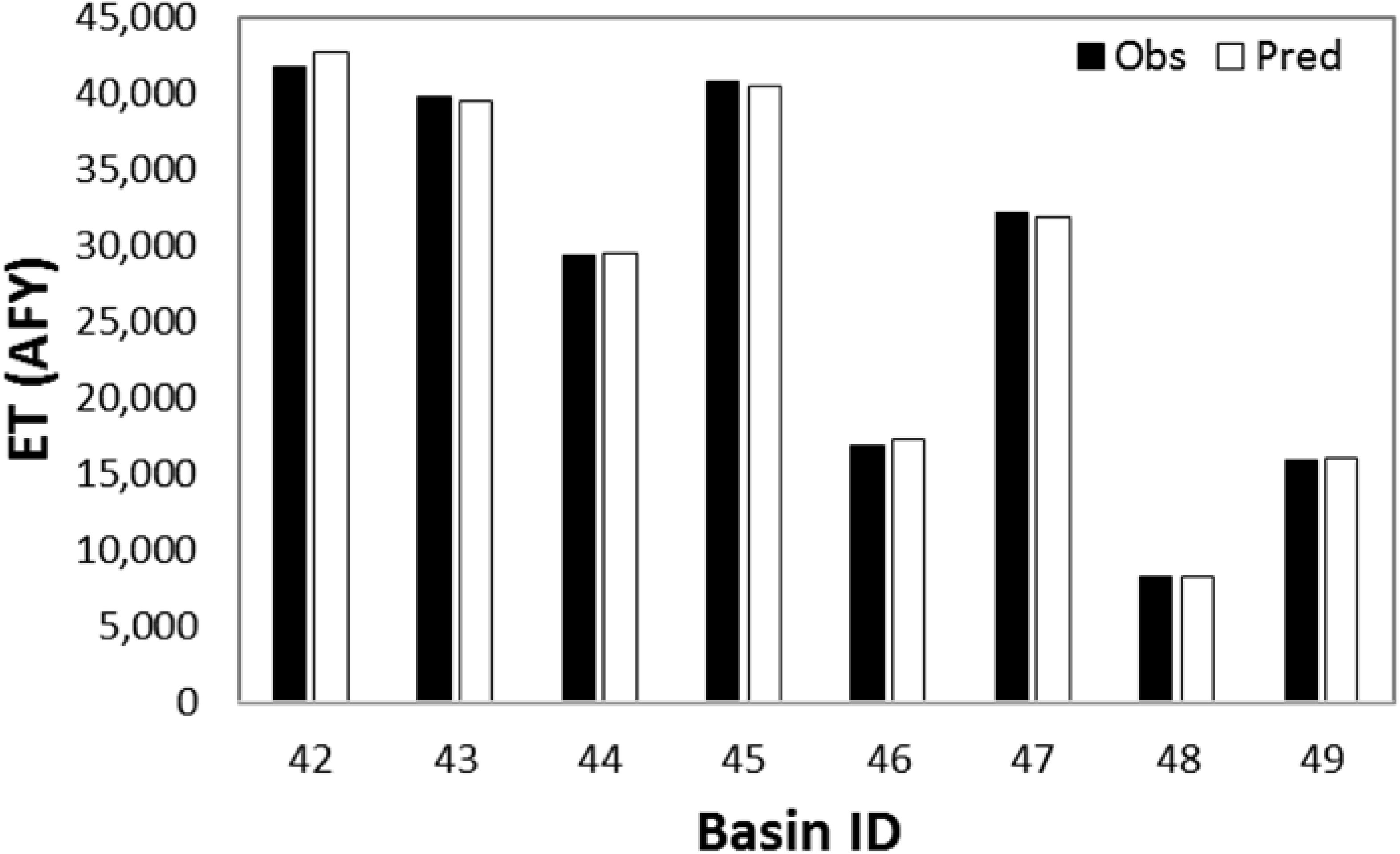
- Recharge distribution
- Conductance
- ET



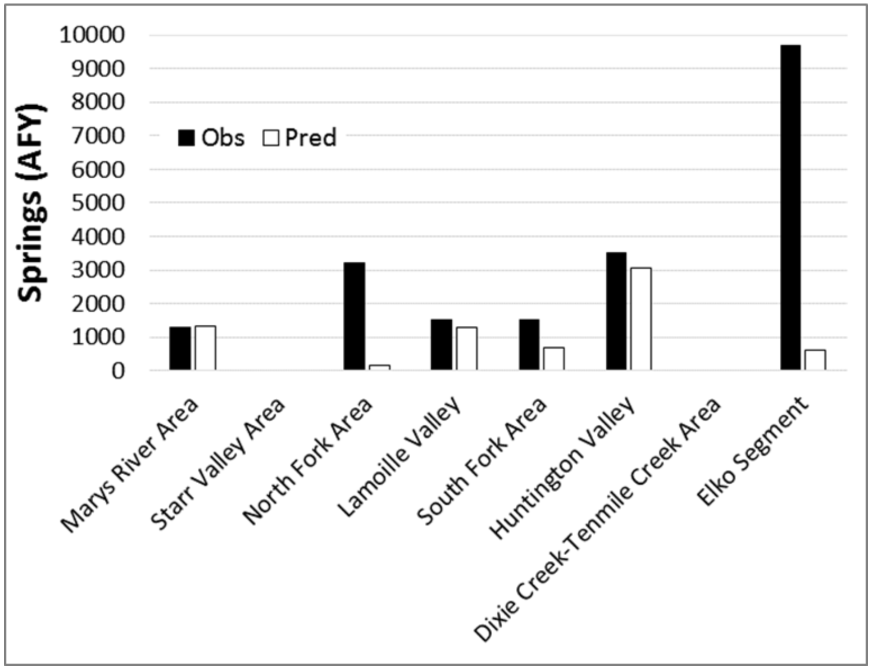
- Ext. depth from Walsh, 2007
- Adjust ET_0 from Justin et al.
- ET provided by Huntington et al.

- Define as sum of outflows

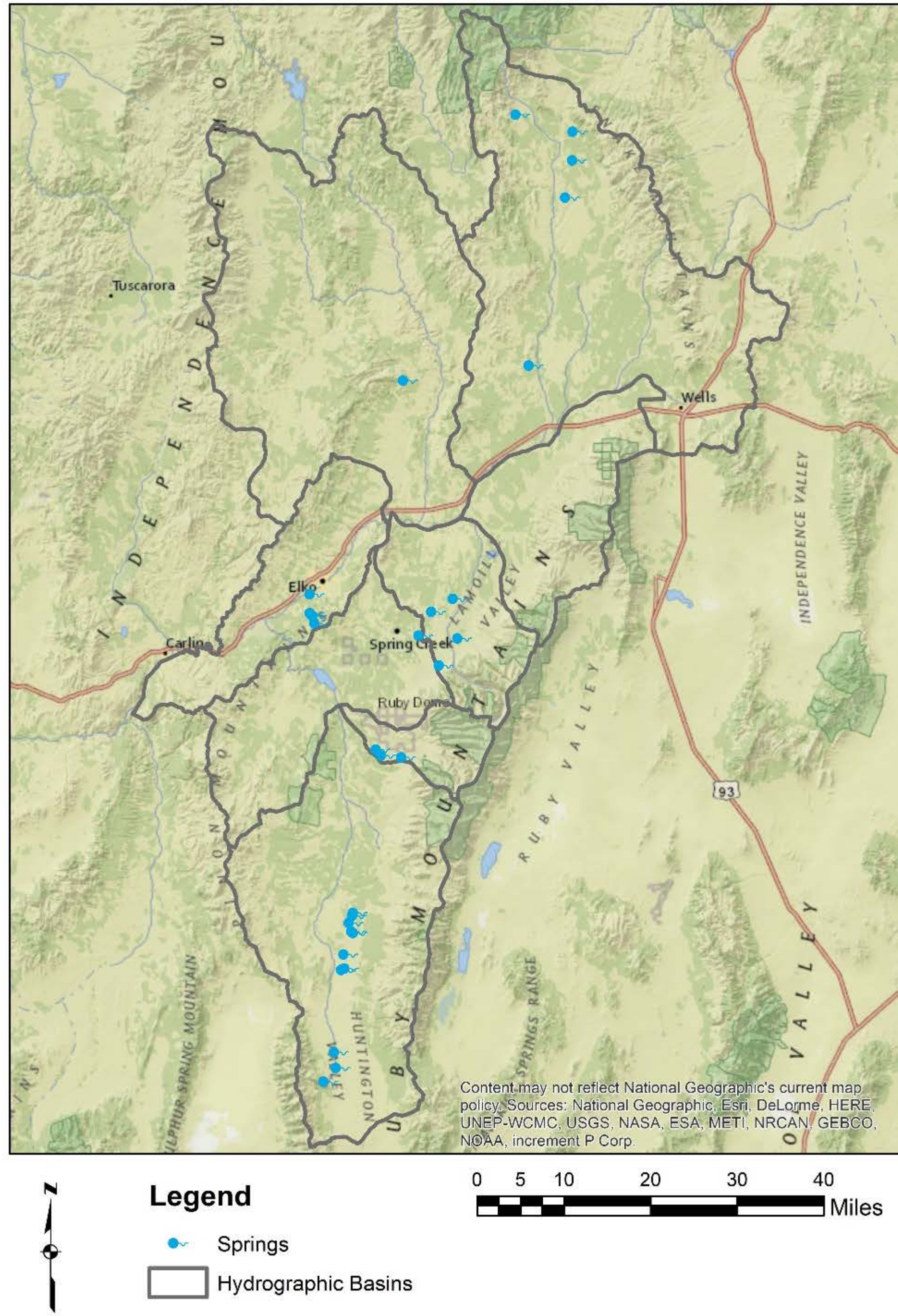
Evapotranspiration



Springs

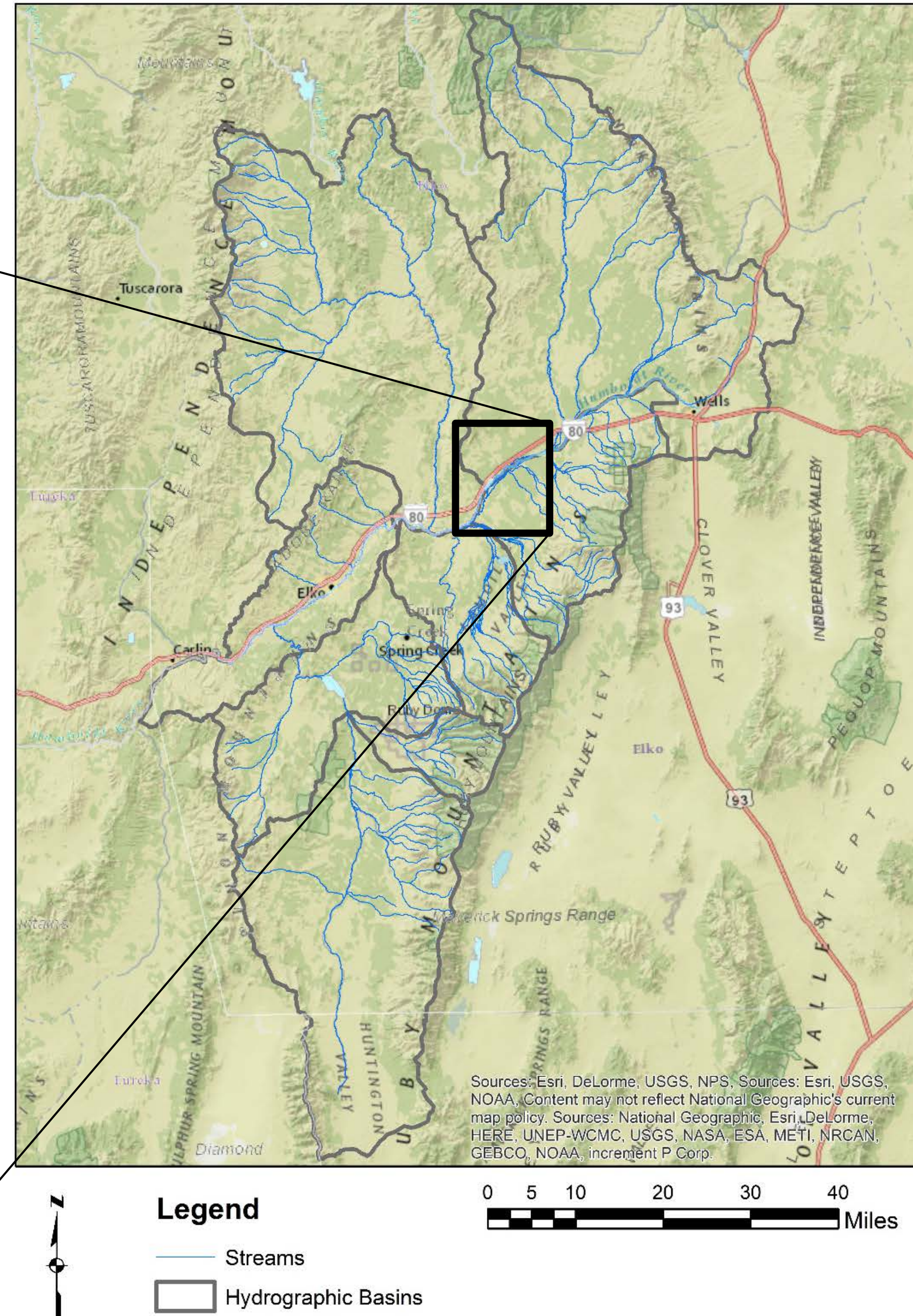


Springs (AFY)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Obs
Pred
Marys River Area
Starr Valley Area
North Fork Area
Lamoille Valley
South Fork Area
Huntington Valley
Dixie Creek-Tenmile Creek Area
Elko Segment

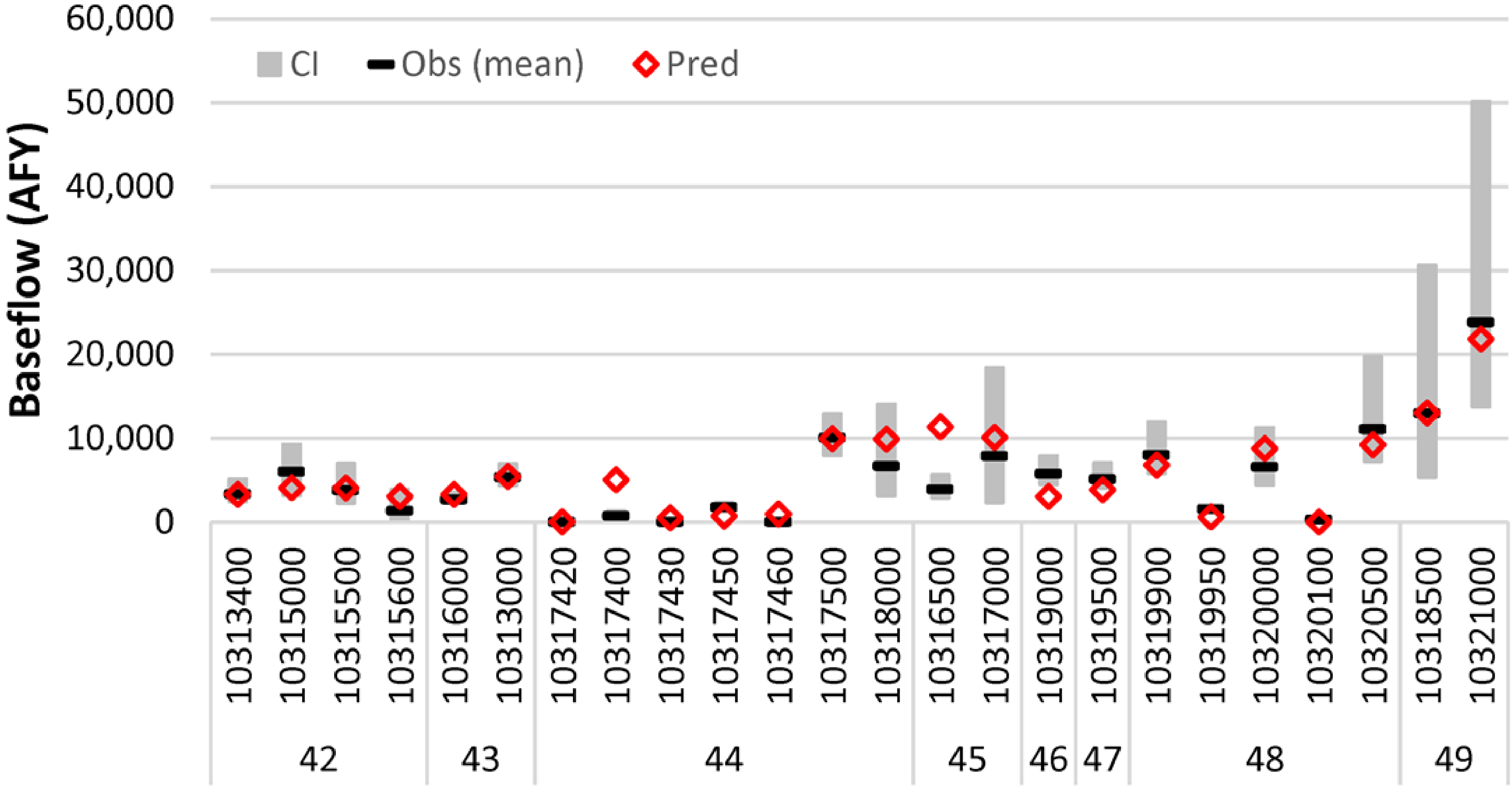


Tuscarora
Wells
Elko
Carlin
Spring Creek
Ruby Dome
INDEPENDENCE VALLEY
RUBY VALLEY
HUNTINGTON VALLEY
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.
N
Legend
Springs
Hydrographic Basins
0 5 10 20 30 40
Miles

Streams

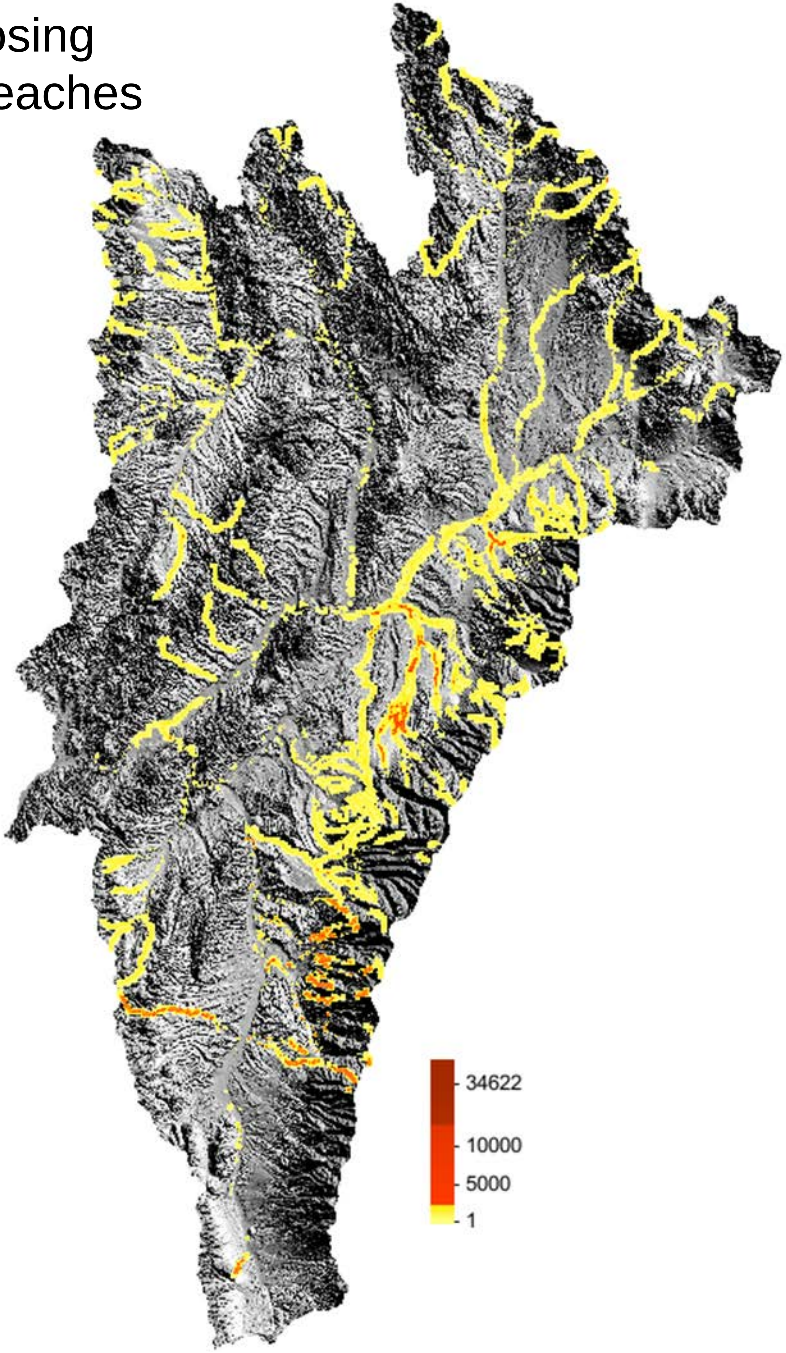

Tuscarora
Wells
Elko
Carlin
Spring Creek
80
93
CLOVER VALLEY
RUBY VALLEY
PEQUOP MOUNTAINS
Elko
HUNTINGTON
Diamond
Sources: Esri, DeLorme, USGS, NPS, Sources: Esri, USGS, NOAA, Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.
N
Legend
Streams
Hydrographic Basins
0 5 10 20 30 40
Miles

Streams

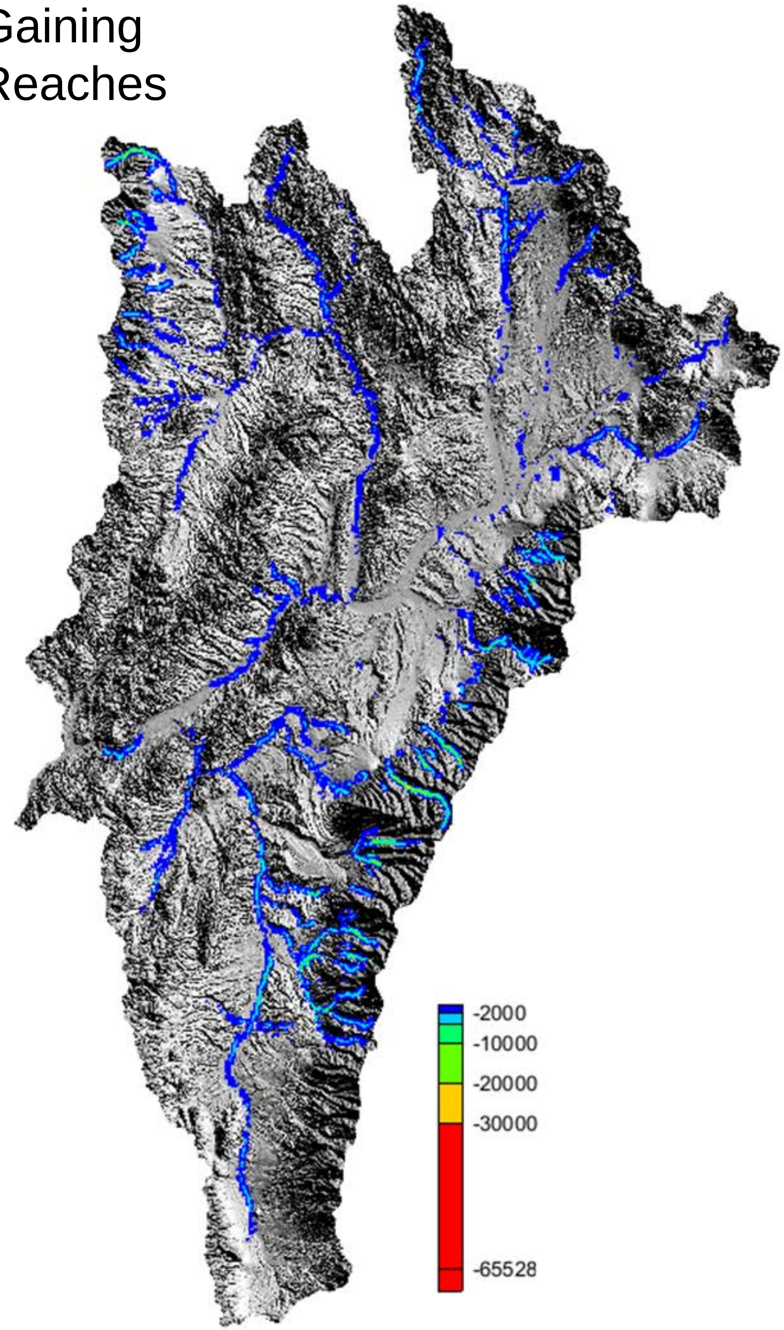


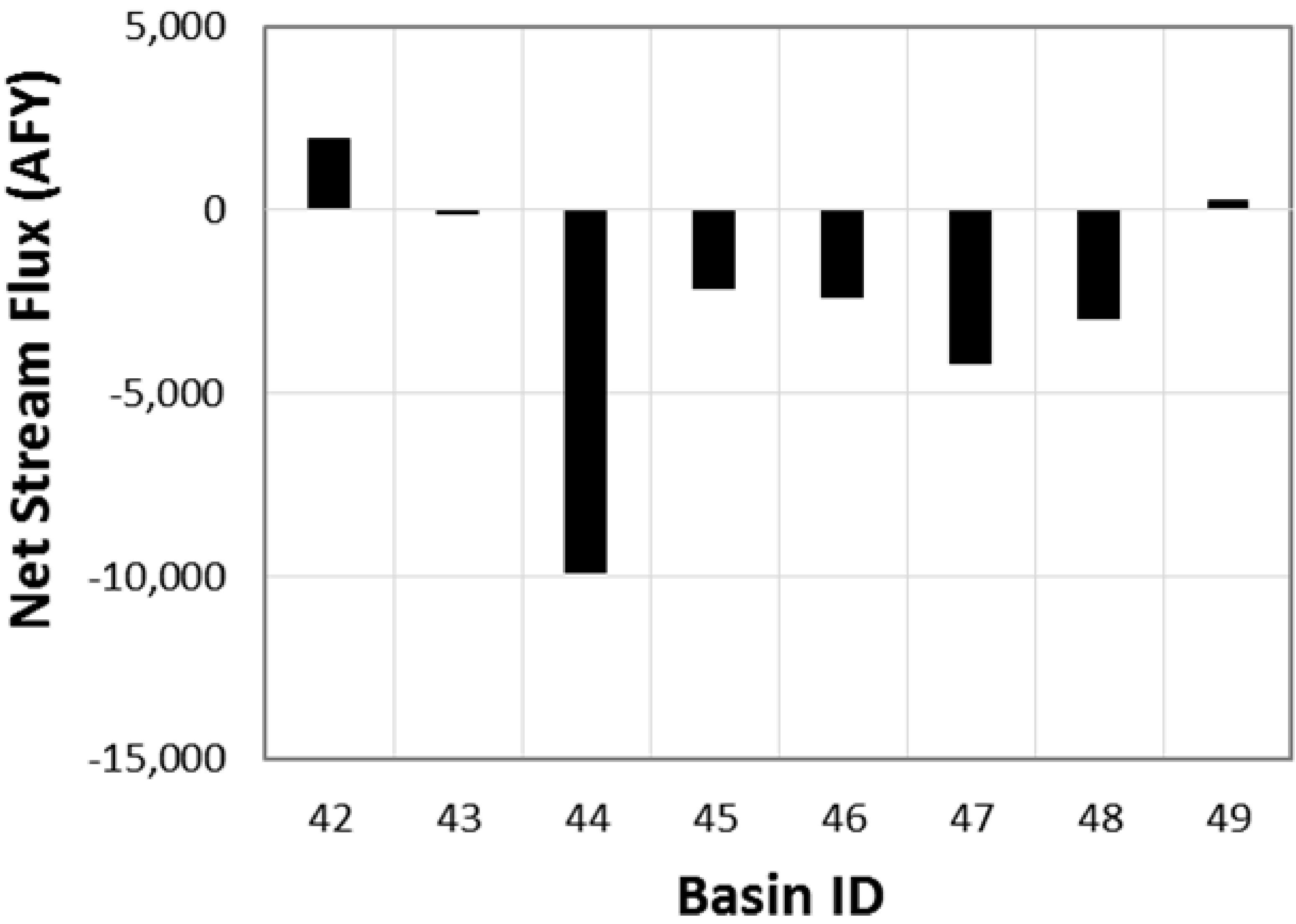
CI
Obs (mean)
Pred
Baseflow (AFY)
60,000
50,000
40,000
30,000
20,000
10,000
0
10313400
10315000
10315500
10315600
10316000
10313000
10317420
10317400
10317430
10317450
10317460
10317500
10318000
10316500
10317000
10319000
10319500
10319900
10319950
10320000
10320100
10320500
10318500
10321000
42
43
44
45
46
47
48
49

Losing Reaches



Gaining Reaches

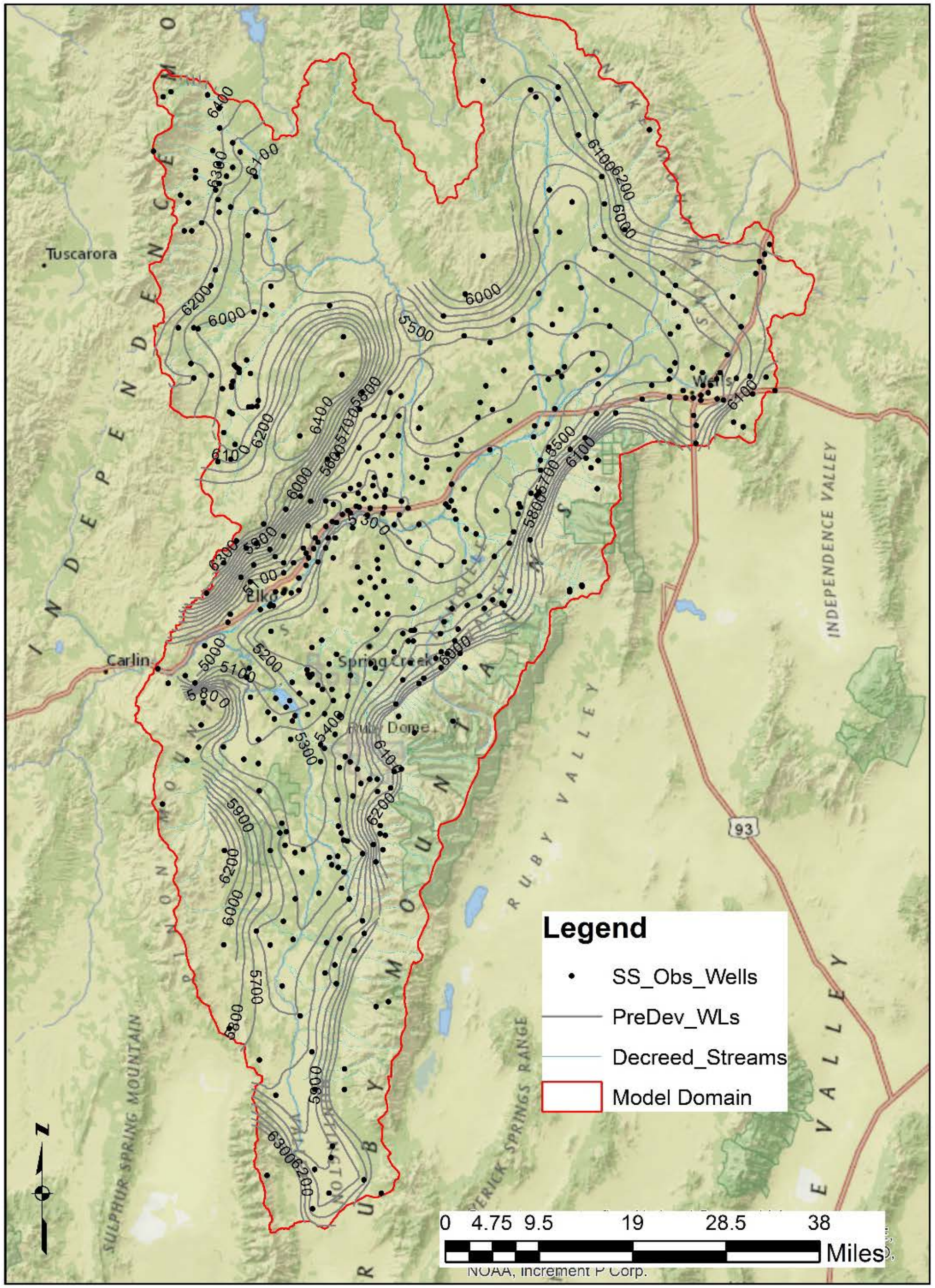




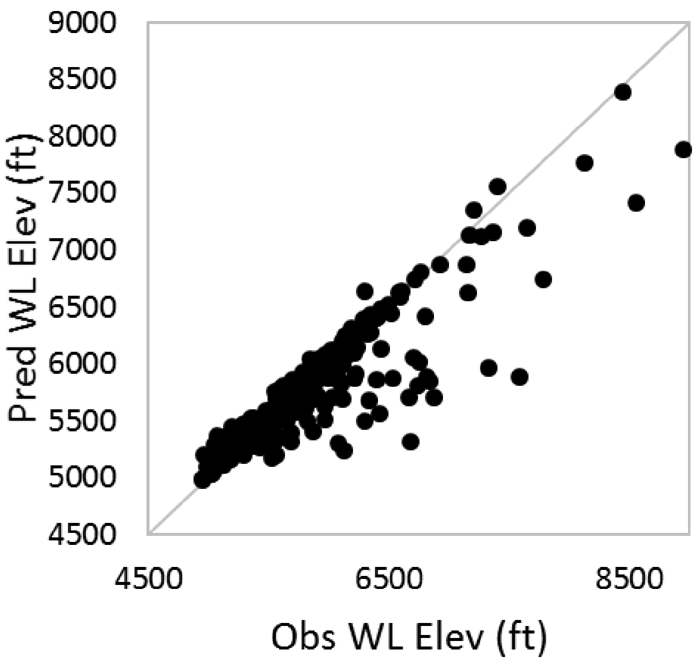
Primarily a gaining system

Water Levels

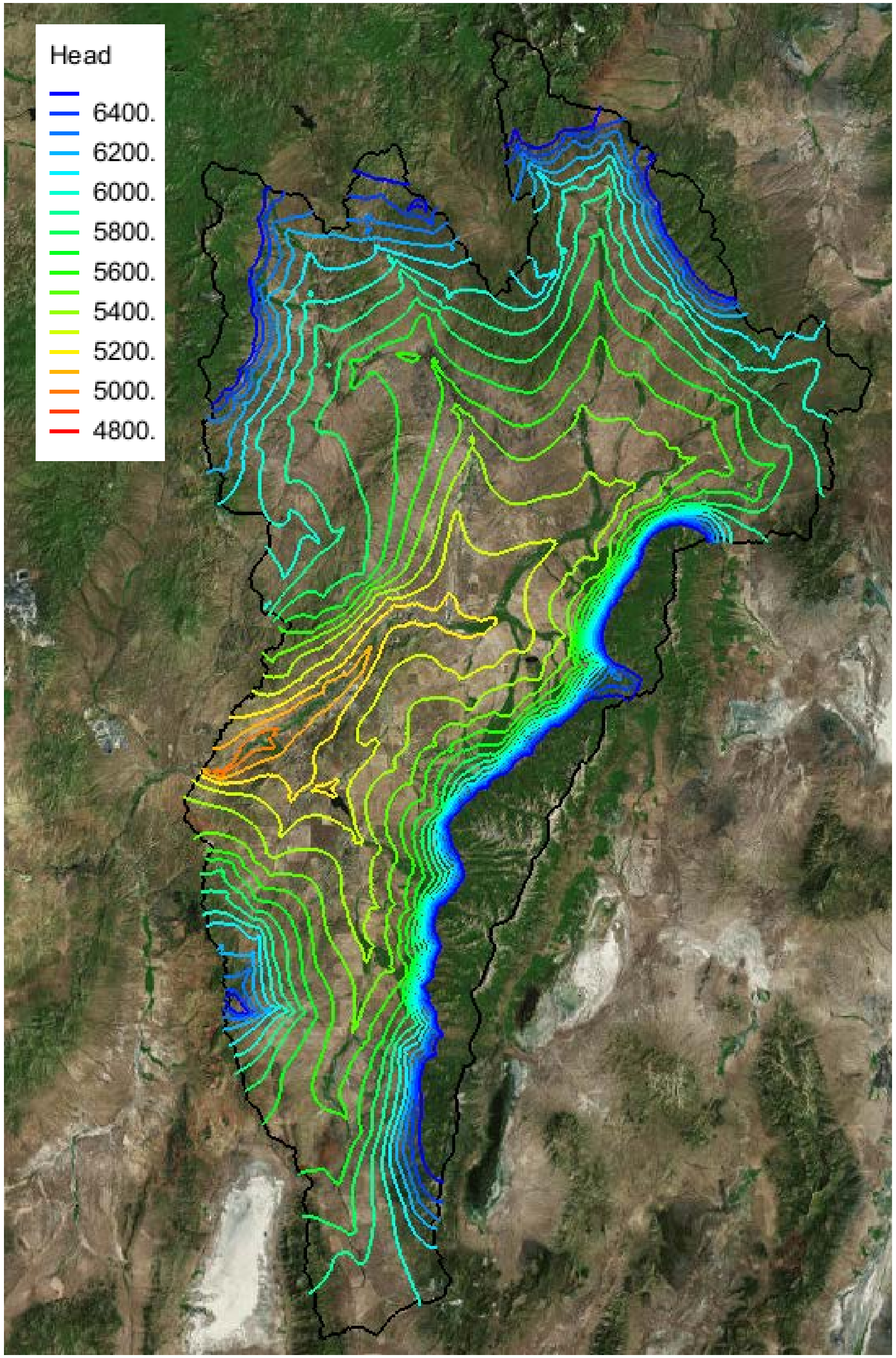
- Plume, 2009 dataset
- NDWR water level database
- NWIS database
- Well log database



Simulated Water Levels



Mean absolute error: 109 ft
Relative error = 6%



Water Budget

	Component	Model (AFY)
Inflow	Recharge	257,803
Outflow	ET	224,481
	Streamflow	18,208
	Springs*	7,092
	Interbasin Flow**	4,094
	GW Pumping	3,925

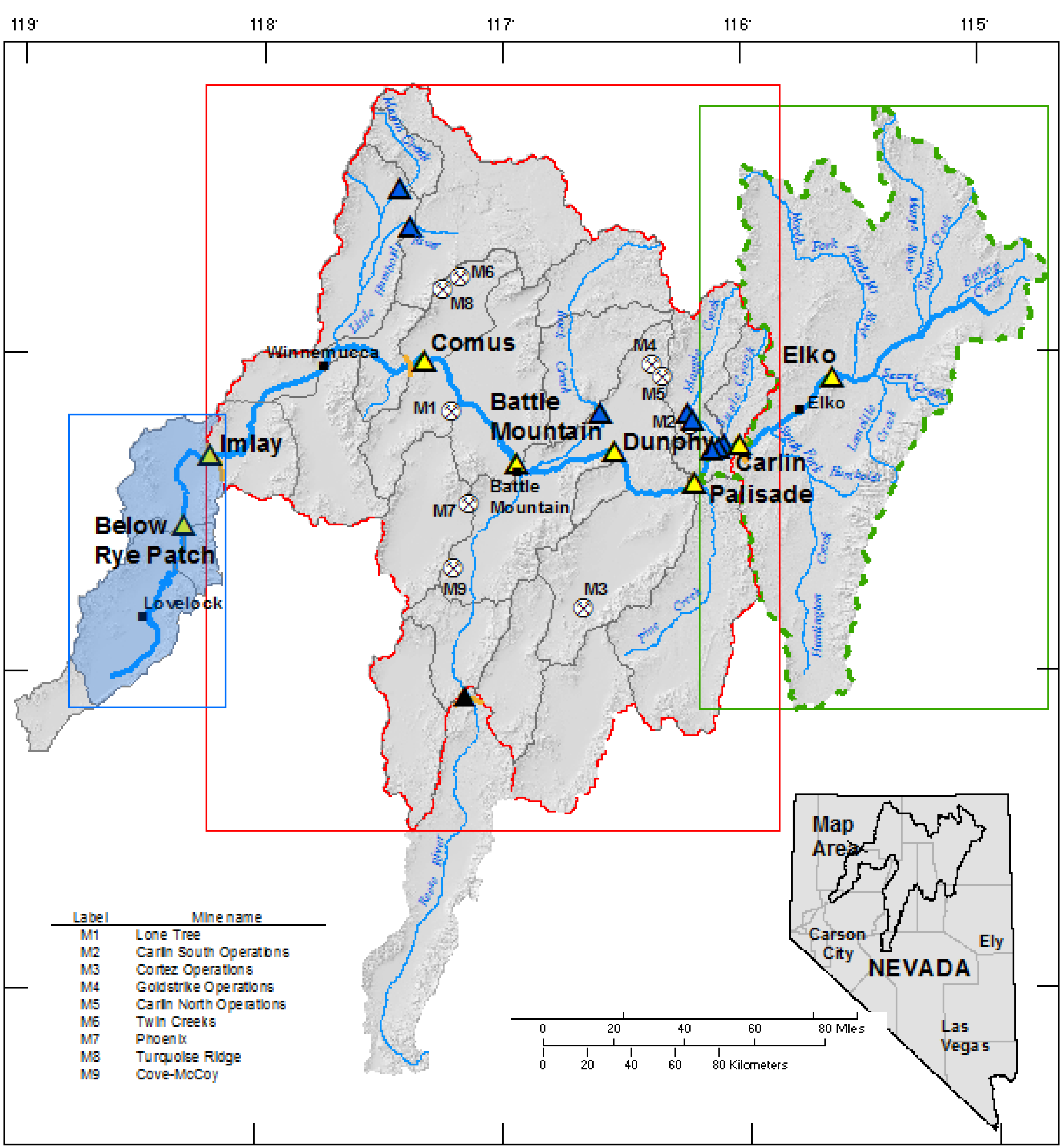
Next Steps

- Improve springflow calibration
- Improve higher elevation water level calibration
- Transient model
- Capture maps

Groundwater Models

Middle Basin Model

Kip Allander - USGS



- Upper basin model - DRI
- Middle basin model - USGS
- Lower basin Model – USGS/DRI

Evaluation of Streamflow Depletion Related to Groundwater Withdrawals in the Middle Humboldt River Basin

USGS

Stakeholder update

January 9 & 10, 2018

Lovelock, Winnemucca, and Elko NV

Review

- Groundwater flow model being developed to understand capture of Humboldt River by pumping.
- Major tasks:
  - Assemble datasets: Pumping, water-levels, mine-water management, hydrogeology, stream network, etc.
  - Develop method for understanding limitations of capture maps. (Capture Map Bias)
  - Estimate recharge distribution.
  - Develop and calibrate model.
  - Use model to estimate capture and impact of mine-dewatering.

Dataset progress in 2017

- Completed or mostly completed:
  - Depth to basement (basin fill)
  - Humboldt River cross-sections
  - N NV Rift
  - Groundwater levels – USGS and NDWR data; data from historic reports digitized.
  - Irrigation pumping
  - Humboldt gage datums surveyed. Now have accurate altitudes.
  - ET discharge areas.

Dataset progress in 2017

- USGS requires all data used in analysis be publicly available.
- Datasets published as they are completed.
- Following datasets released in 2017:

Smith, J.L., Warmath, Eric, and Medina, R.L., 2017, Groundwater discharge areas for the 14 hydrographic areas in the middle Humboldt River Basin, north-central Nevada: U.S. Geological Survey data release, https://doi.org/10.5066/F72805TT . (WRIR 2000-4168: Groundwater discharge areas.)

Smith, J.L., Welborn, T.L., and Medina, R.L., 2017, Evapotranspiration units and potential areas of groundwater discharge delineated July 20–24, 2009 in the upper Humboldt River Basin, northeastern Nevada: U.S. Geological Survey data release, https://doi.org/10.5066/F7668BN7 . (SIR 2013-5077).

Ponce, D.A., and Damar, N.A., 2017, Depth to pre-Cenozoic bedrock in northern Nevada: U.S. Geological Survey data release, https://doi.org/10.5066/F75B01DD . (Bulletin 2218 2-km pre-Cenozoic basement)

Welborn, T.L., and Medina, R.L., 2017, Depth-to-water area polygons, isopleths showing mean annual runoff, 1912-1963, and water-level altitude contours for the Humboldt River Basin, Nevada: U.S. Geological Survey data release, https://dx.doi.org/10.5066/F7XW4GXC . (Bulletin 32 datasets: water levels, water level altitude, isopleths of mean annual runoff.)

Mine-water management

Owner	Mine	Well Locations	Water Levels	Pumping	Pit Lakes	Water Management
Newmont	Carlin Trend	Yes	Yes	Yes	No	Yes
Newmont	Lone Tree	Yes	Yes	Yes	Yes	Yes
Newmont	Phoenix	Partial	Yes	Yes	Yes	Yes
Newmont	Twin Creeks	Yes	Yes	Yes	No	Yes
Barrick	Gold Strike	Yes	No	Yes	Yes	Yes
Barrick	Pipeline Cortez Hills	No	No	Yes	Yes	Yes
Barrick	Turquoise Ridge	Yes	Yes	Yes	Yes	Yes
Osgood	Pinson	Yes	Partial	Yes	Yes	Yes
Premier Gold	Cove-McCoy	Yes	Yes	Yes	No	Yes

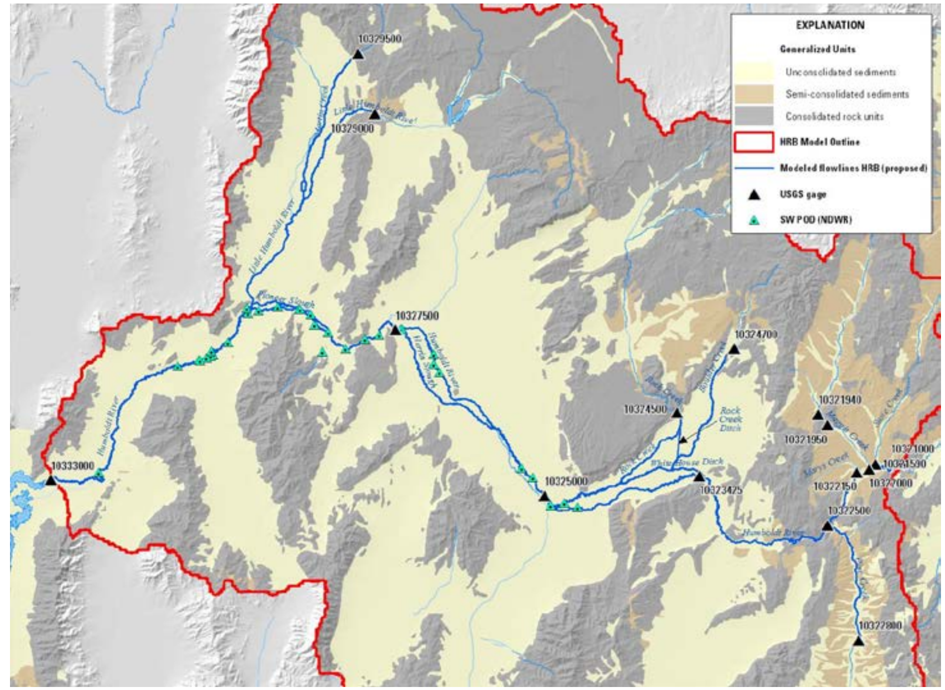
- Databases organized by mines
  - Well locations – framework created, nearly completed
  - Water levels –framework created, nearly completed
  - Pumping – framework created, nearly completed
  - Pit Lakes – data gathered, framework not yet completed
  - Water management – data gathered, framework not yet completed
- Next steps:
  - Contact mines for few remaining data gaps
  - Create pit lake and water management frameworks
  - Complete databases

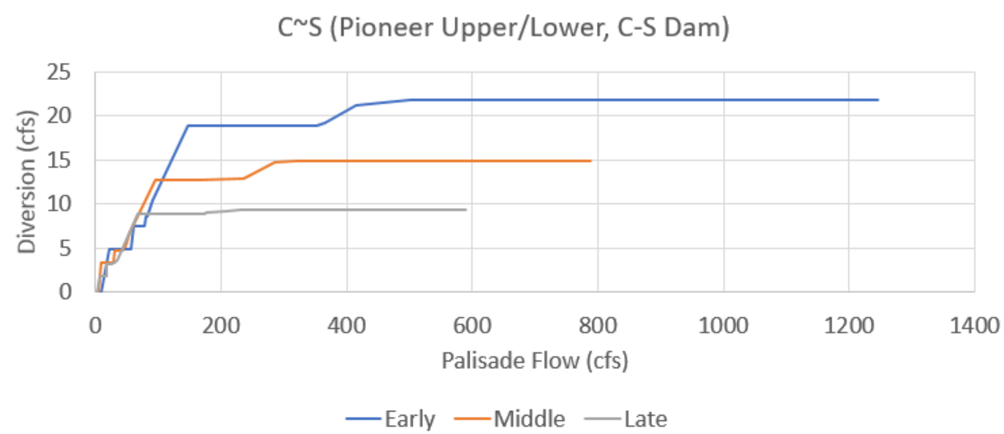
Non-Mine Pumping

- Irrigation pumping from crop inventories completed.
  - Some gaps and extrapolations.
- Public supply and power generation still being compiled.
- To be completed early 2018.

Stream Network and Diversions

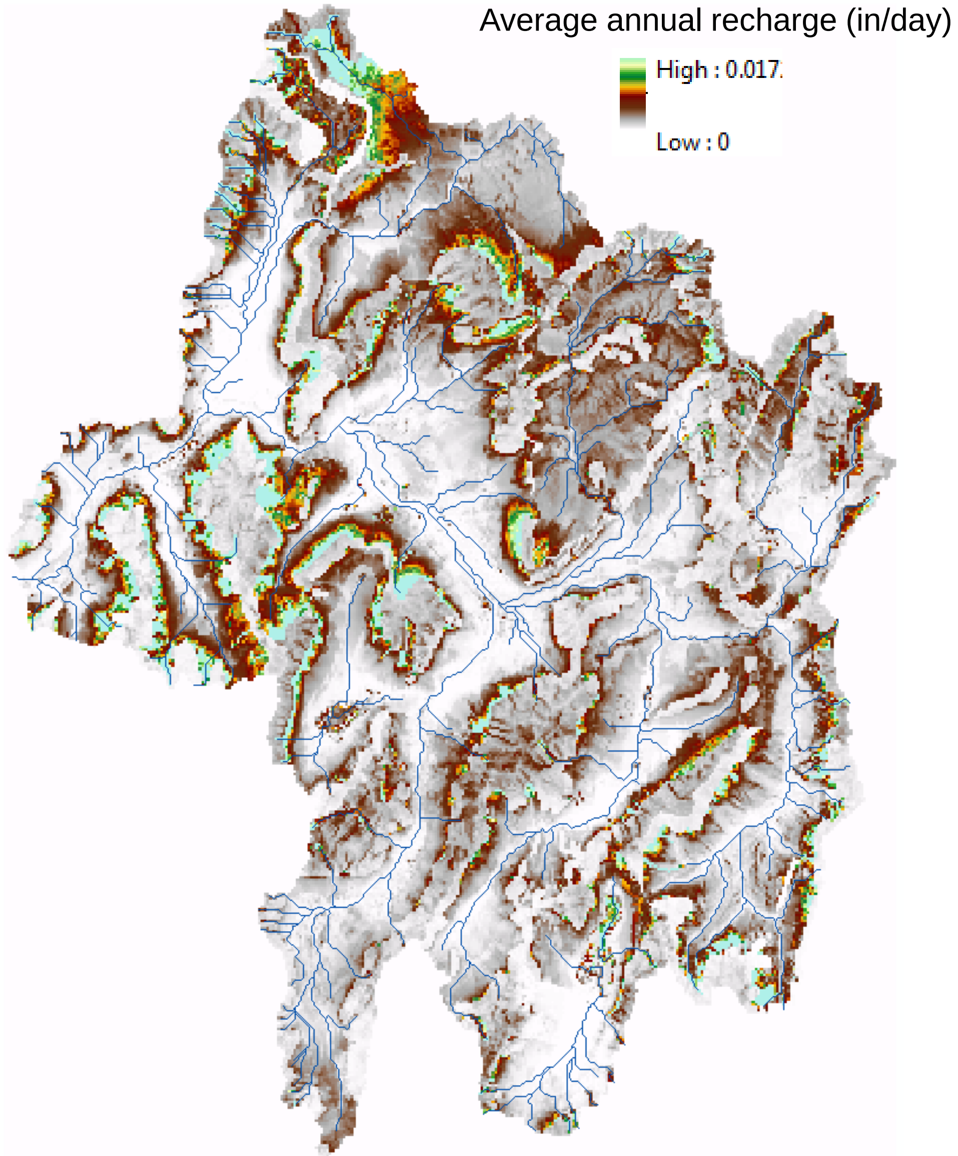
- Implemented.
- Flow simulated for main stem and major tributaries.
- Baseflow simulated for upstream perennial reaches.
- 23 points of diversion identified and implemented.
- Diversions are based on priority based on Palisade flow.





Recharge Distribution

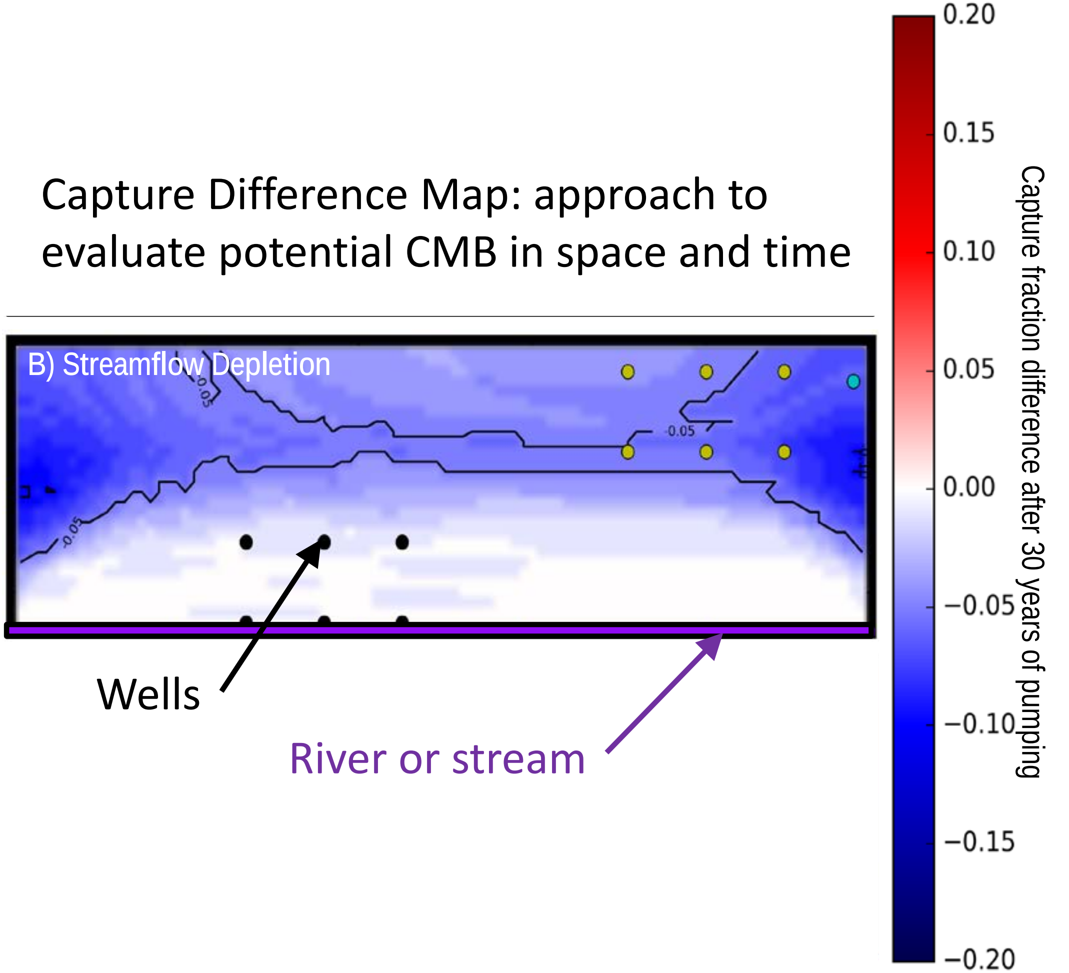
- Using watershed models (PRMS).
- Calibrated for 19 subbasins.
- In final stage of analysis.
- Preliminary distribution being used and shown here.



Capture Map Bias (CMB)

- CMB is over- or underestimation of capture using Capture Map methods.
- Can vary with location and time.
- Typically low near rivers.
- Generally accurate in areas of greatest concern.
- Journal article published in *Groundwater**

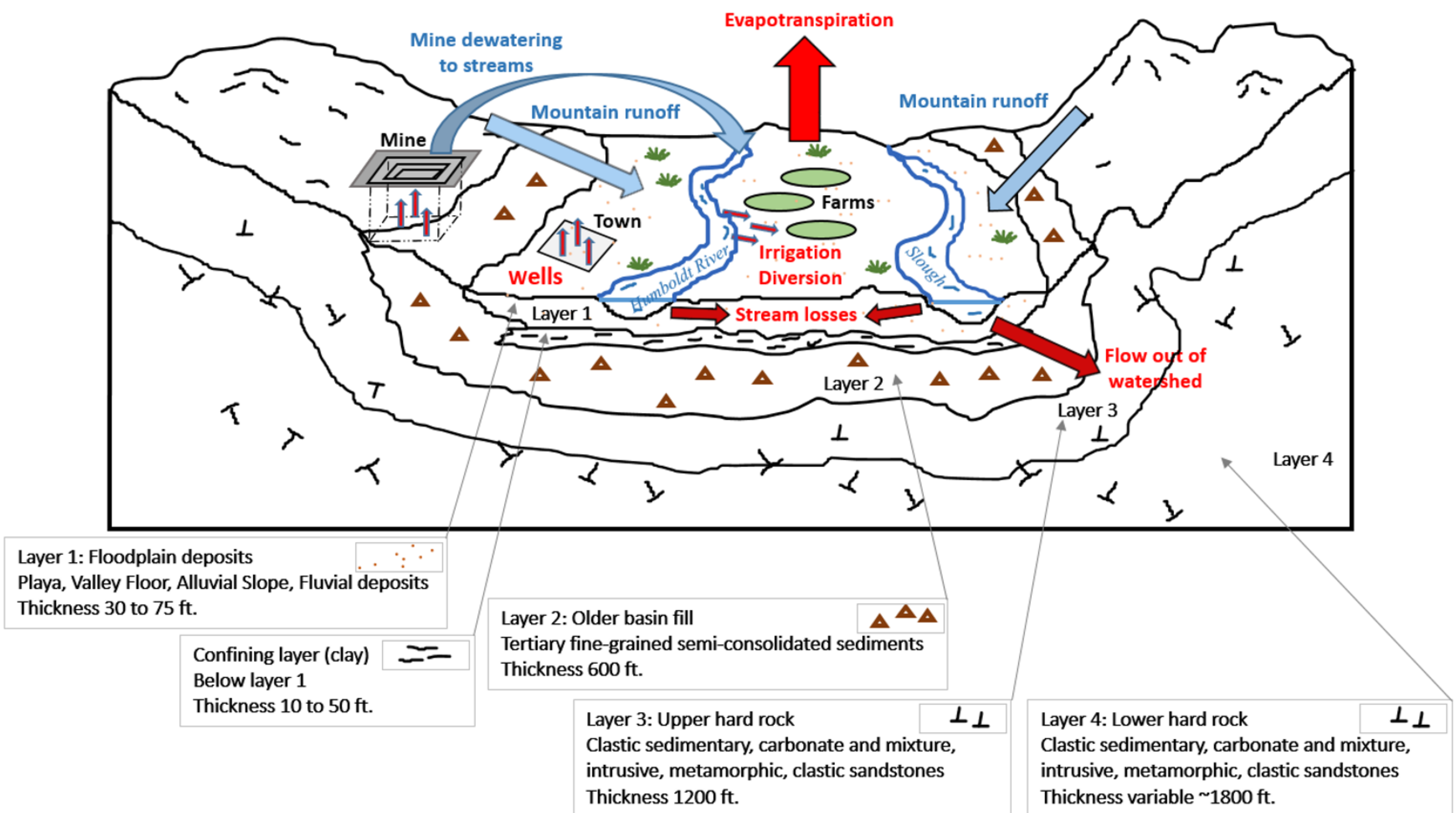
Capture Difference Map: approach to evaluate potential CMB in space and time



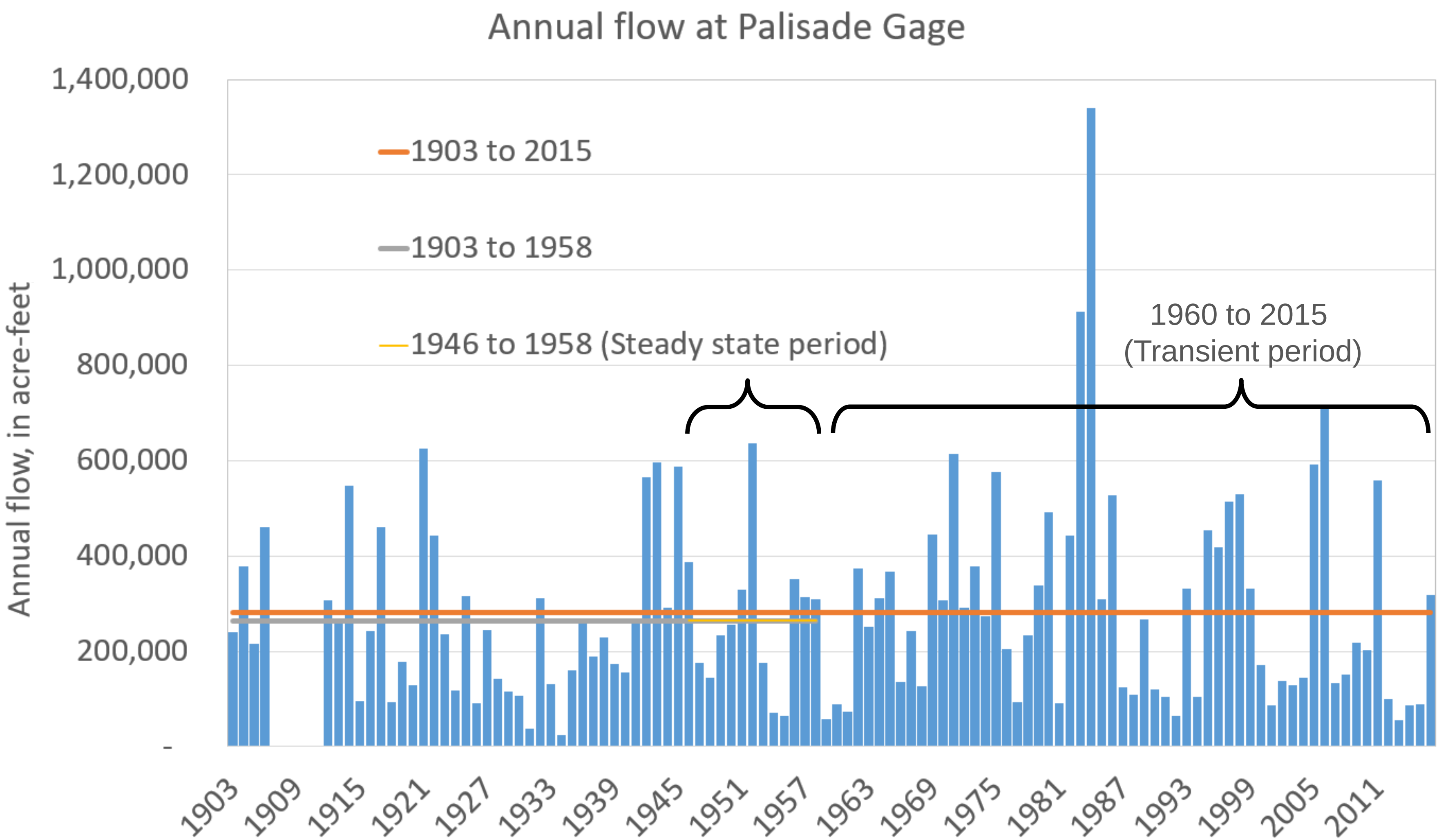
*Available at: https:/doi.org/10.1111/gwat.12597
Or contact cnadler@usgs.gov for free copy of the article.

Model Development and Calibration – Conceptual Model

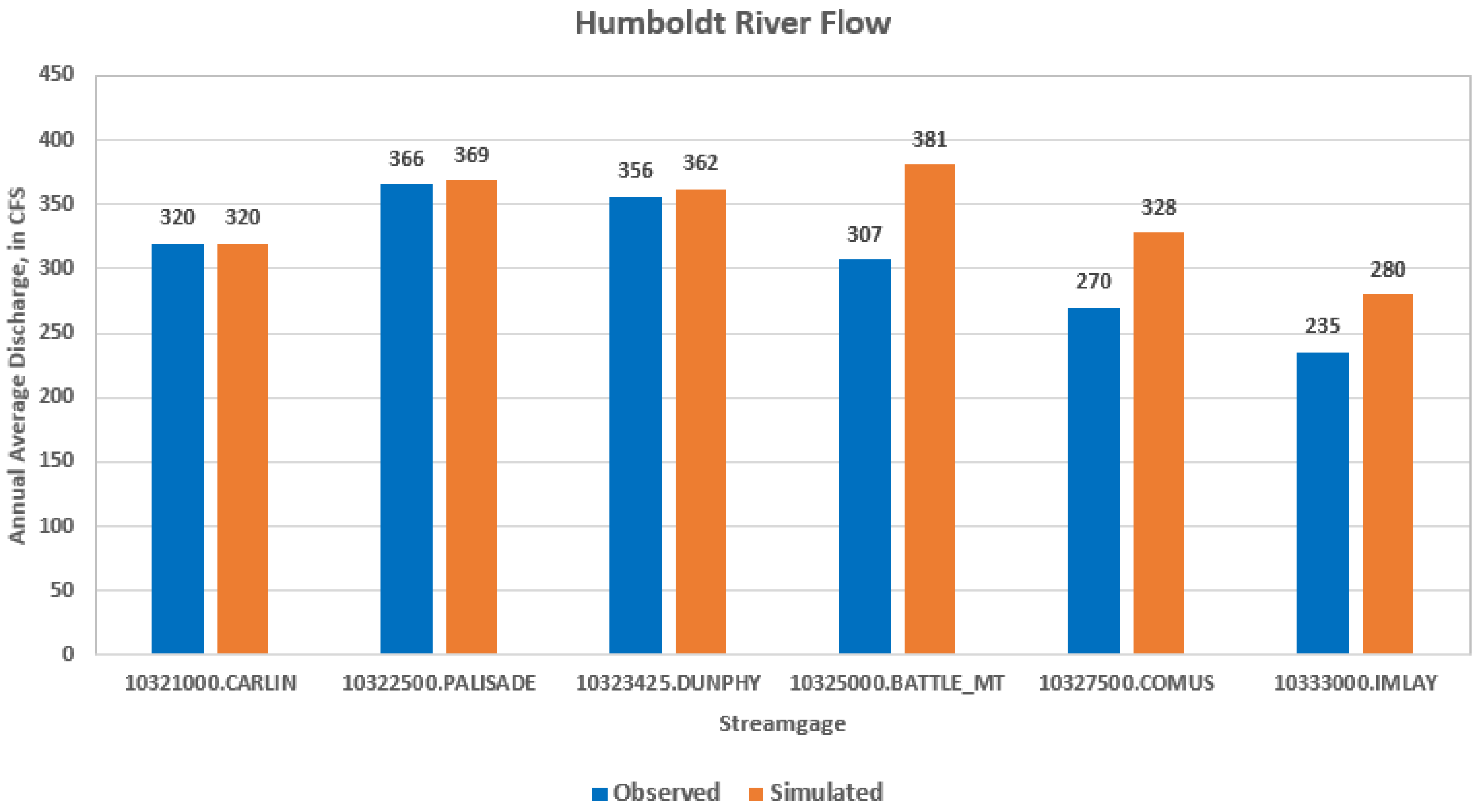
Humboldt River depletion conceptual model



Model Development and Calibration – Calibration Periods



Model Development and Calibration – Steady-State Flow Calibration



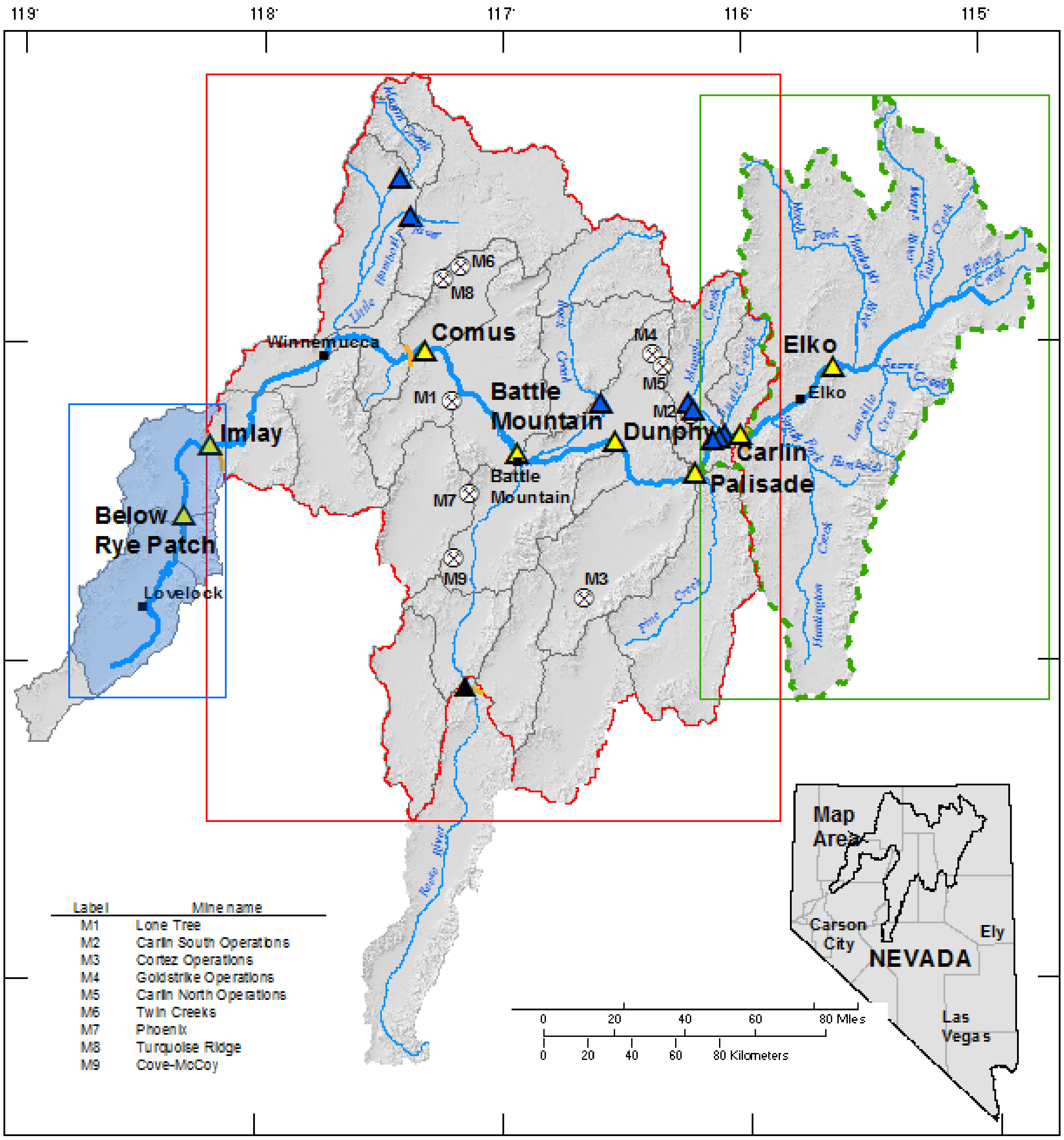
Model Development and Calibration – Plans for 2018

- Continue calibrating Steady State and Transient models.
- Finish coarse calibration of overall model.
- Refine calibrations by HA.
- Achieve satisfactory calibration.
- Produce preliminary capture analysis for developing conjunctive use regulation.

Groundwater Models

Lower Basin Model

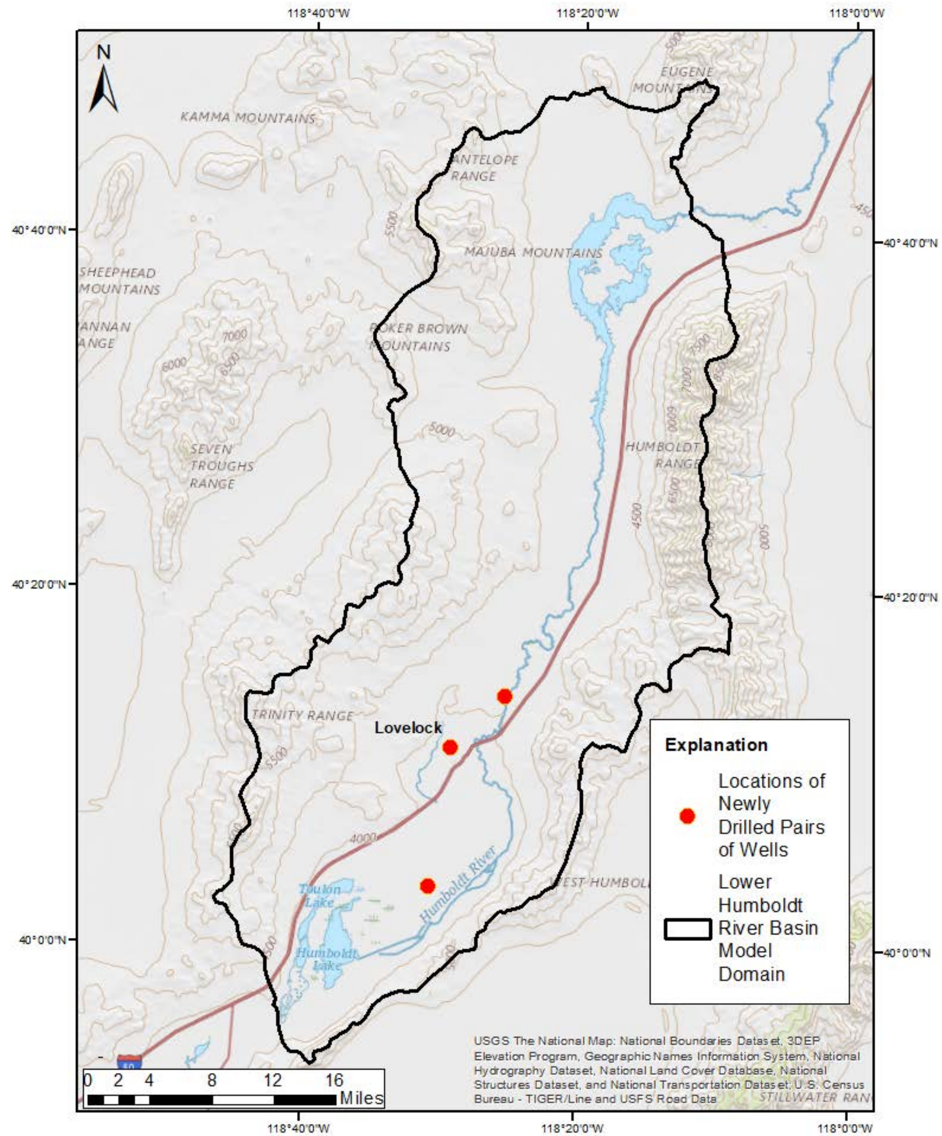
Greg Pohll - DRI



- Upper basin model - DRI
- Middle basin model - USGS
- Lower basin Model – USGS/DRI

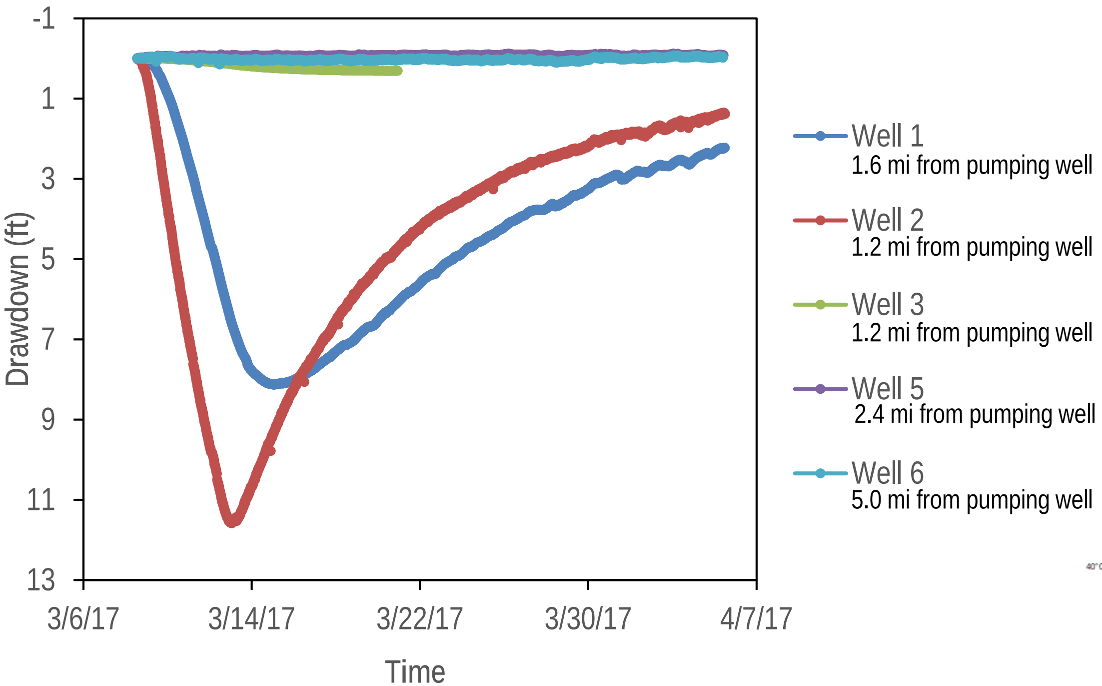
Progress

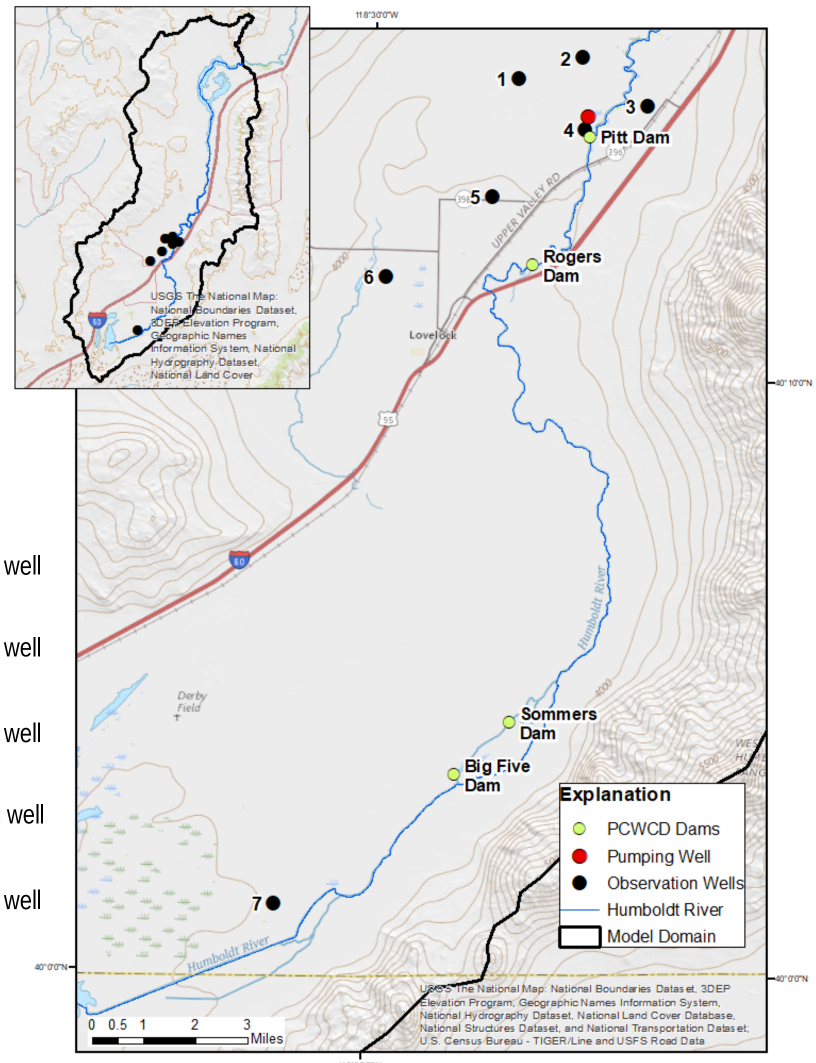
- Six (6) new monitoring wells drilled in 3 pairs
- Four (4) aquifer tests completed
  - Three (3) reports completed/in review
  - One (1) report in progress
- GW levels observed January 2017 - present
- Model construction under way
- Recharge analysis under way



Aquifer Test #1

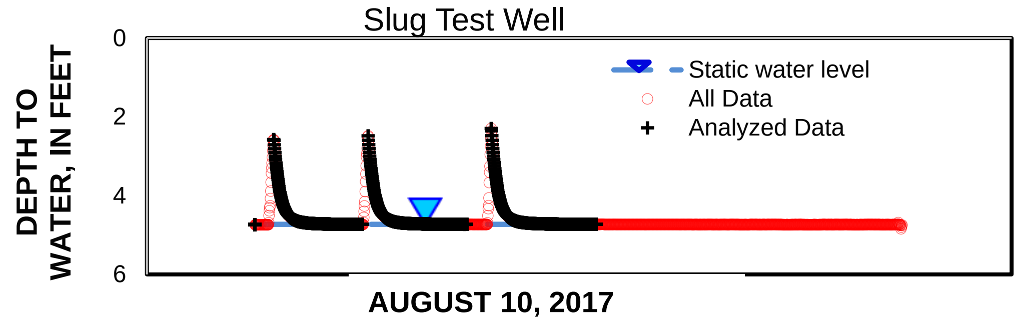
- Well pumped at 4400 GPM for 4 days and 40 minutes in March 2017
- MODFLOW model created & calibrated to estimate T and S values
- **T = 1,400 ft²/day, S = 0.0007, K = 2.8 ft/day**

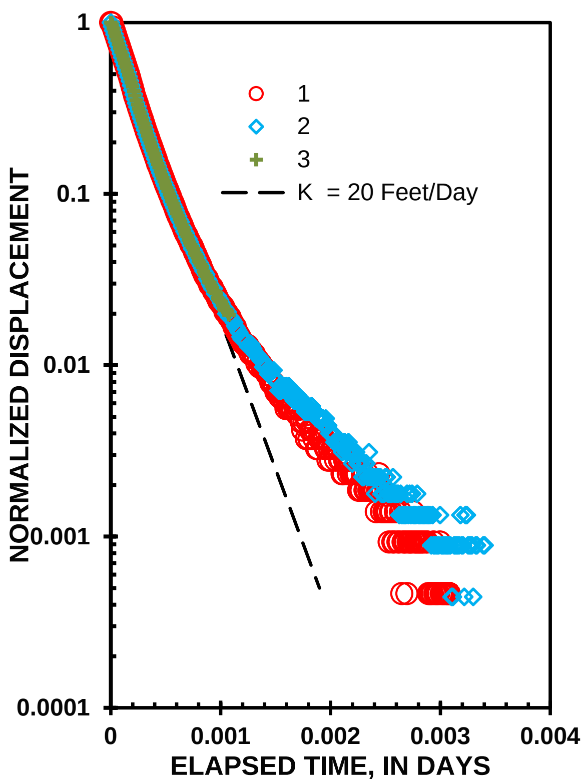


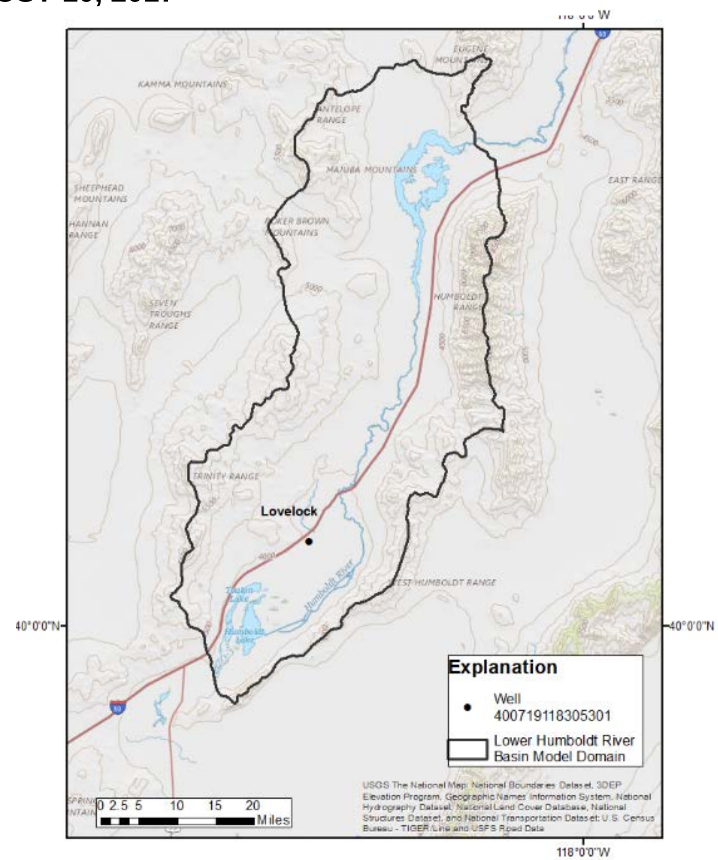


Aquifer Test #2

- 3 consecutive injection slug tests on 8/10/17
- 4.4 gallons of water rapidly poured into well each time
- 2.3 – 2.6 ft of water-level rise after each slug
- Bouwer and Rice (1976) analysis of water recovery data
- **T = 400 ft^2/day**

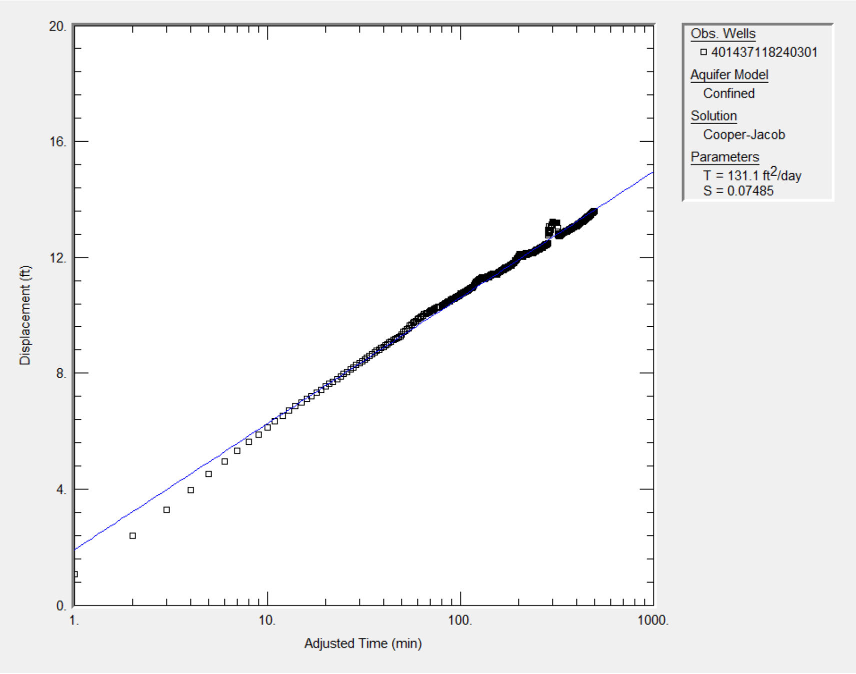




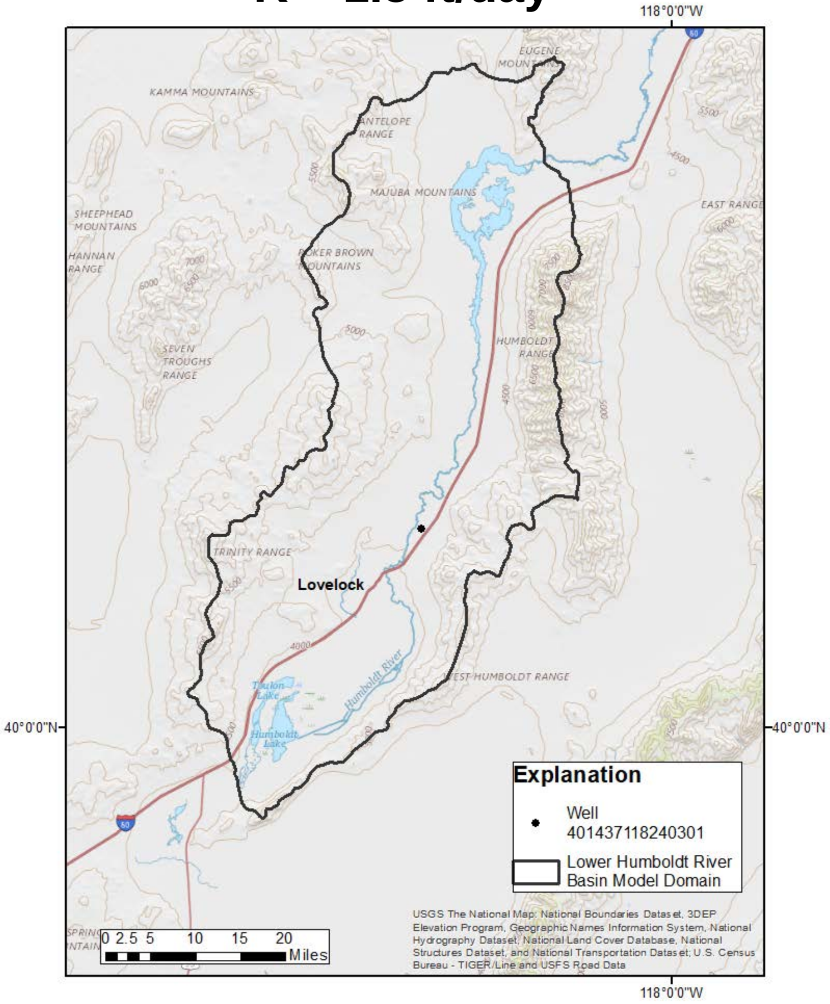


Aquifer Test #3

- Single-well pump test on 8/9/17
  - Pumped at 16.2 gpm for 8 hr &18 min
  - Recovery monitored for 21 hr & 21 min
- 13.6 ft drawdown
- Cooper-Jacob (1946) analysis of drawdown data

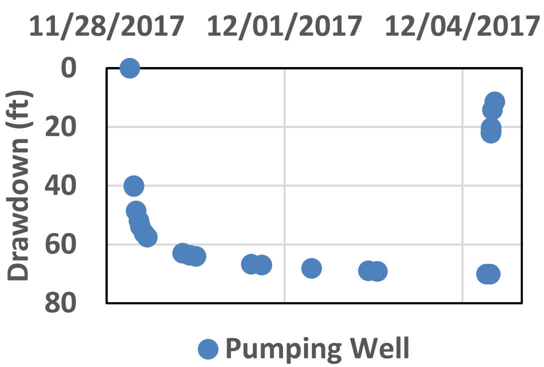


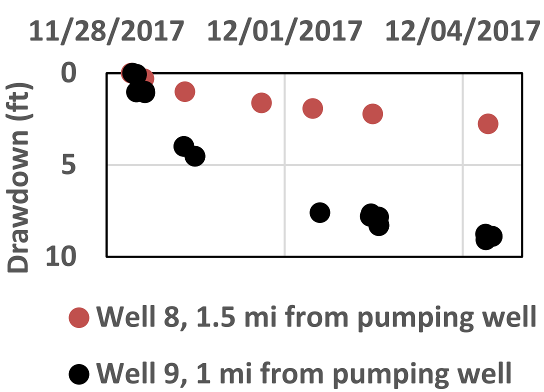
T = 130 ft²/day
K = 1.5 ft/day

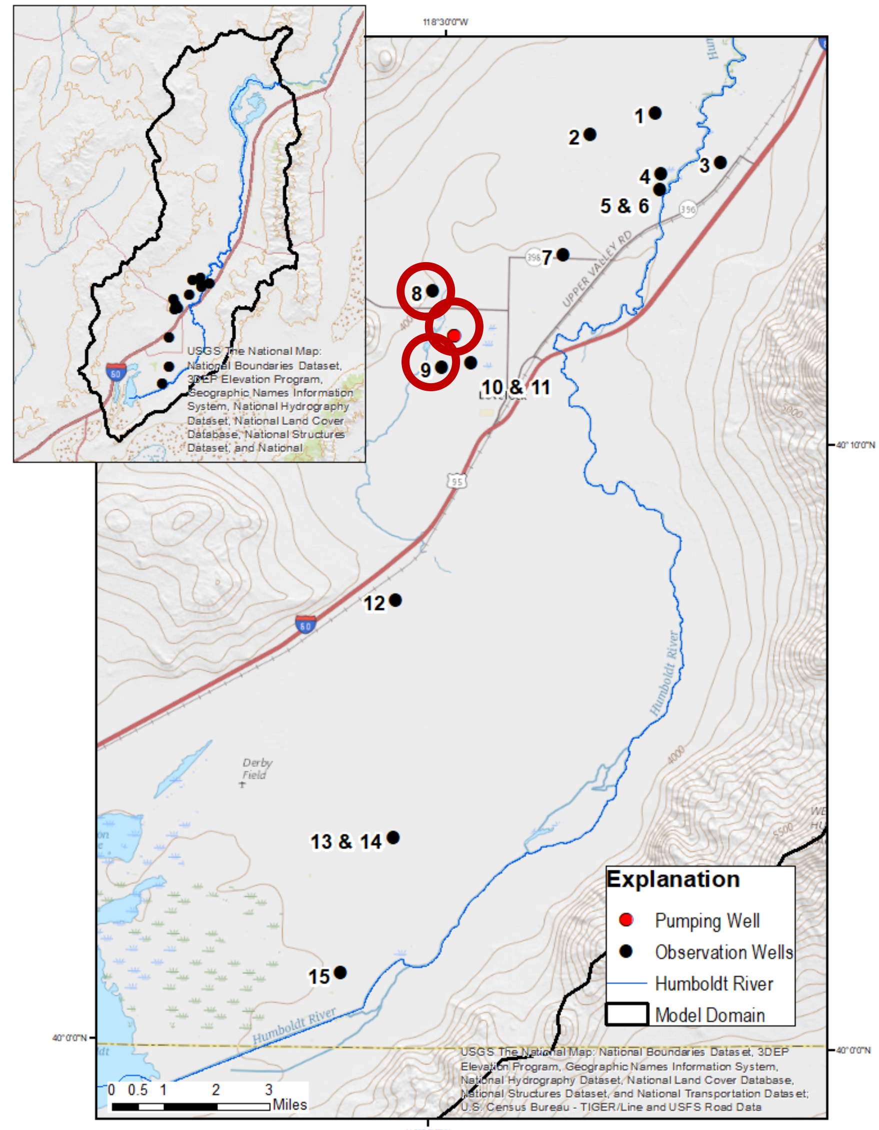


Aquifer Test #4

- Well pumped at 6000 – 6100 gpm for 6 days & 35 minutes
- 3 wells have experienced noticeable drawdown (red)
- Data collection completed early January
- Data will be evaluated collectively in MODFLOW model
- Previous test results will be incorporated

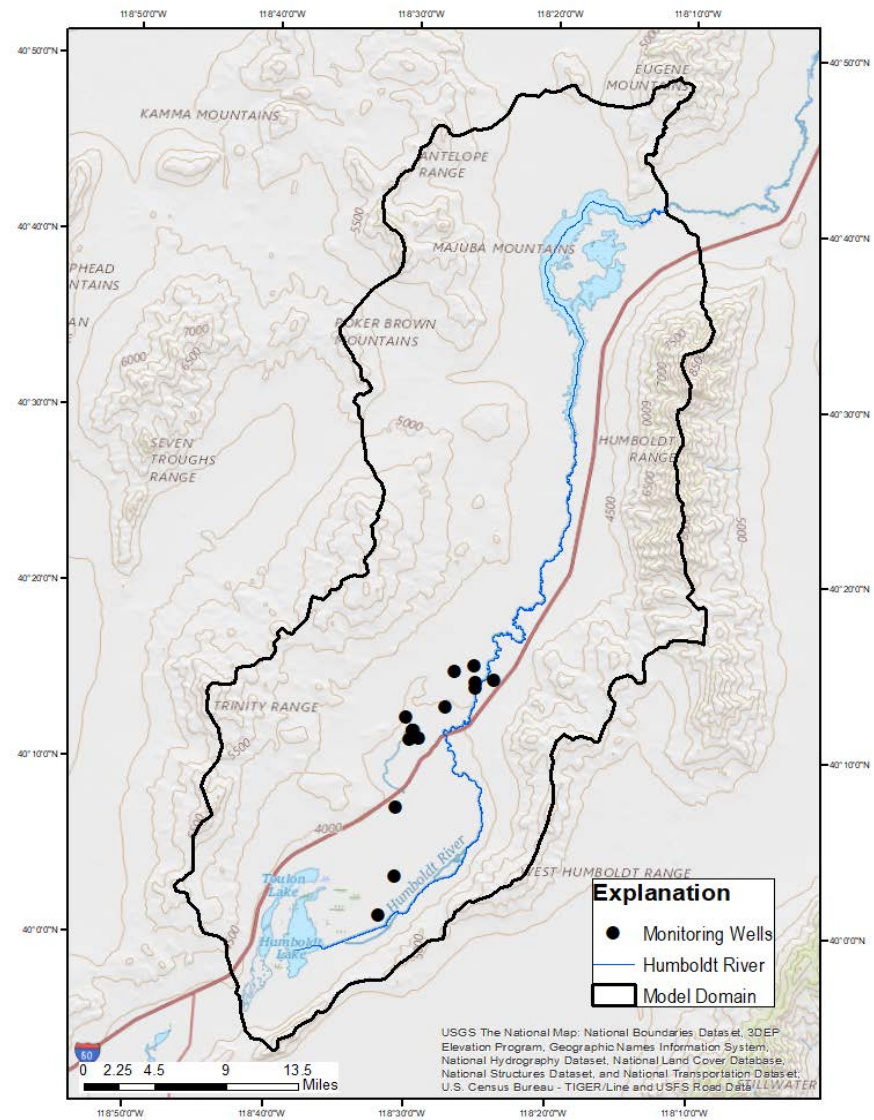




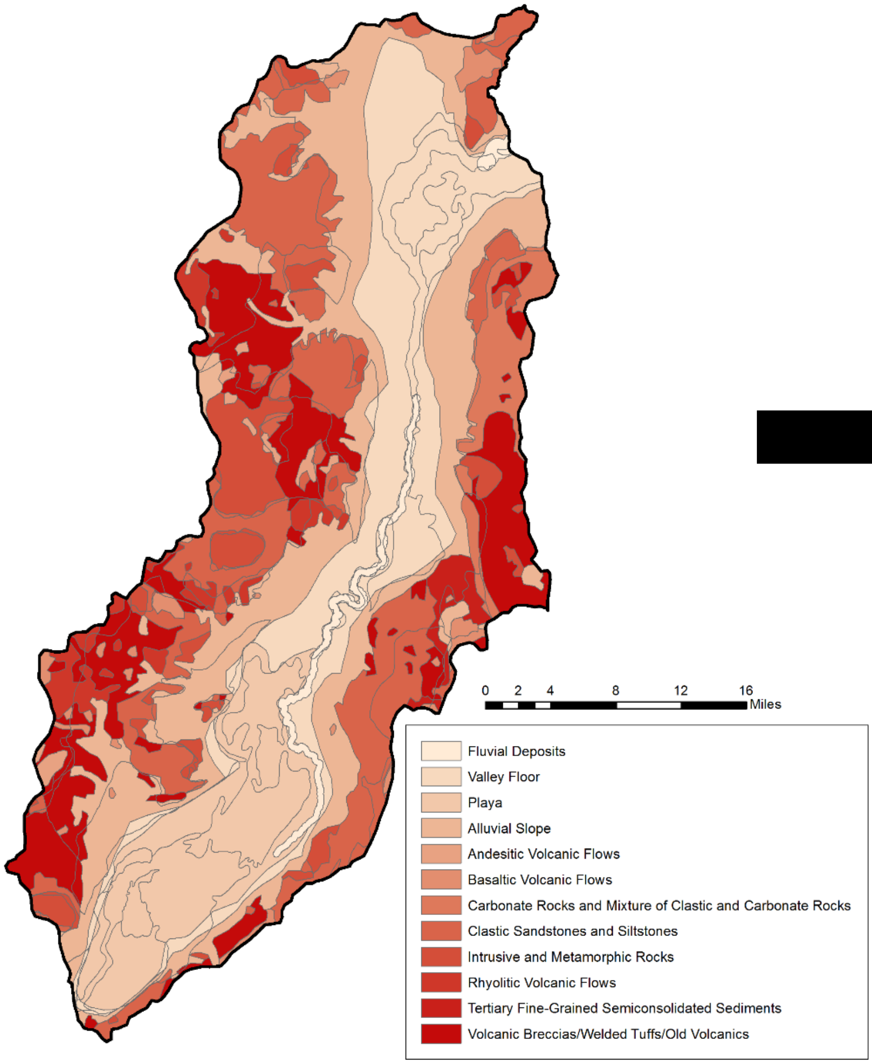


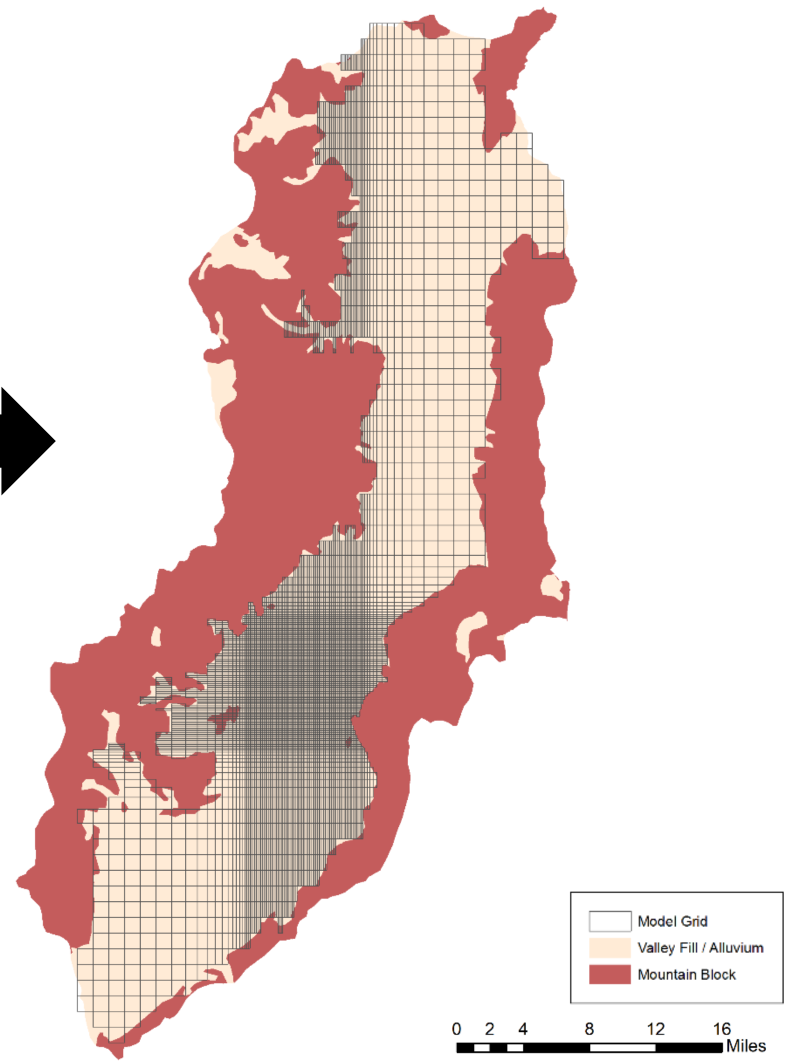
Groundwater Monitoring

- Groundwater levels monitored with pressure transducers and manual measurements January 2017 – present
- 15 wells monitored for various lengths of time
- Newly drilled shallow wells used to evaluate connection with canals/ditches



Model Domain



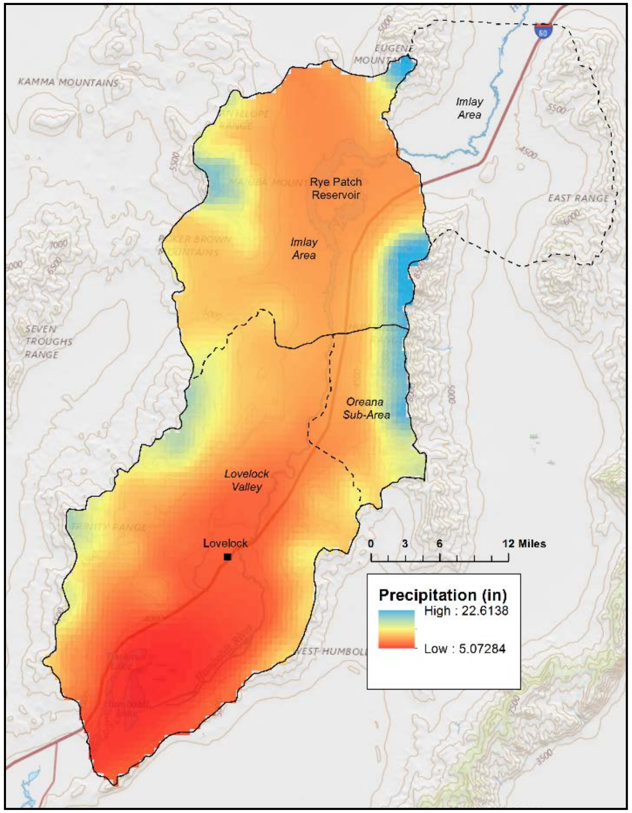


Hydrogeology modified from Maurer and others (2004)

Mountain Block Recharge

	Recharge (afy)				
Reference	**Lovelock**	**Oreana**	**Imlay**	**Model Domain**	**Methodology**
Everett and Rush, 1965	2,200	2,000	--	--	Maxey-Eakin
Eakin, 1962	--	--	4,000	--	Maxey-Eakin

- Additional estimates to be undertaken
- Final recharge rate will be calibrated within range of estimates
- Recharge to be applied proportionally according to precipitation zones

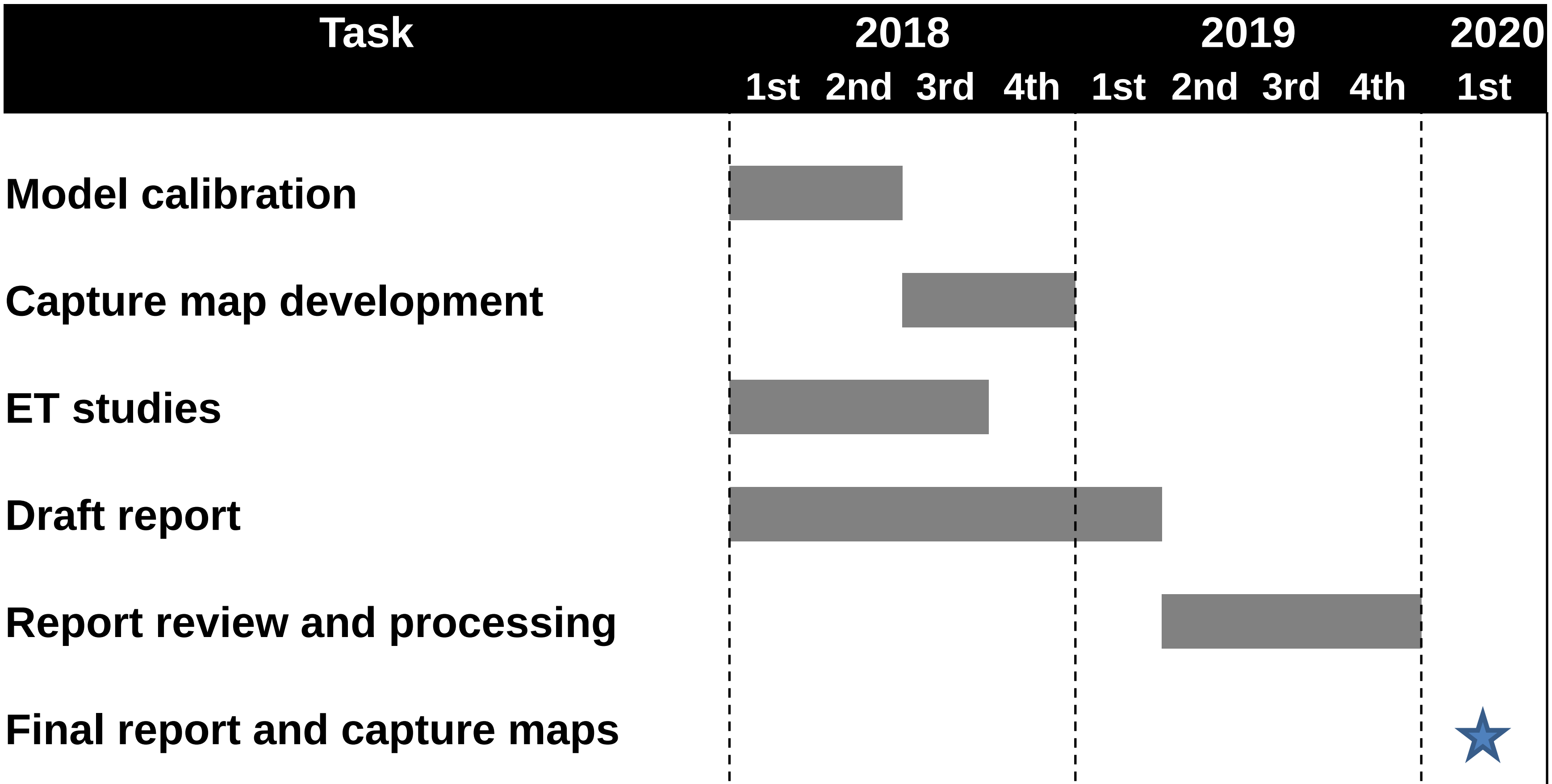


PRISM 30 year normal, 1981-2010

Next Steps

- Complete aquifer test #4 analysis
- Complete aquifer testing on newly drilled wells
- Complete recharge analysis
- Develop and calibrate steady-state model
- Develop capture maps
- Complete Scientific Investigations Report

Project Schedule




Questions