Climate Change Vulnerability Assessments: The Road to Resilience and Adaptation

March 13th, 2015

Coordinator: Michael J. Furniss, MJ Furniss & Associates

33rd Annual Salmonid Restoration Conference

RECLAMATION

Managing Water in the West

Multi-year Drought Effects on Winter-run Chinook Salmon in the Central Valley

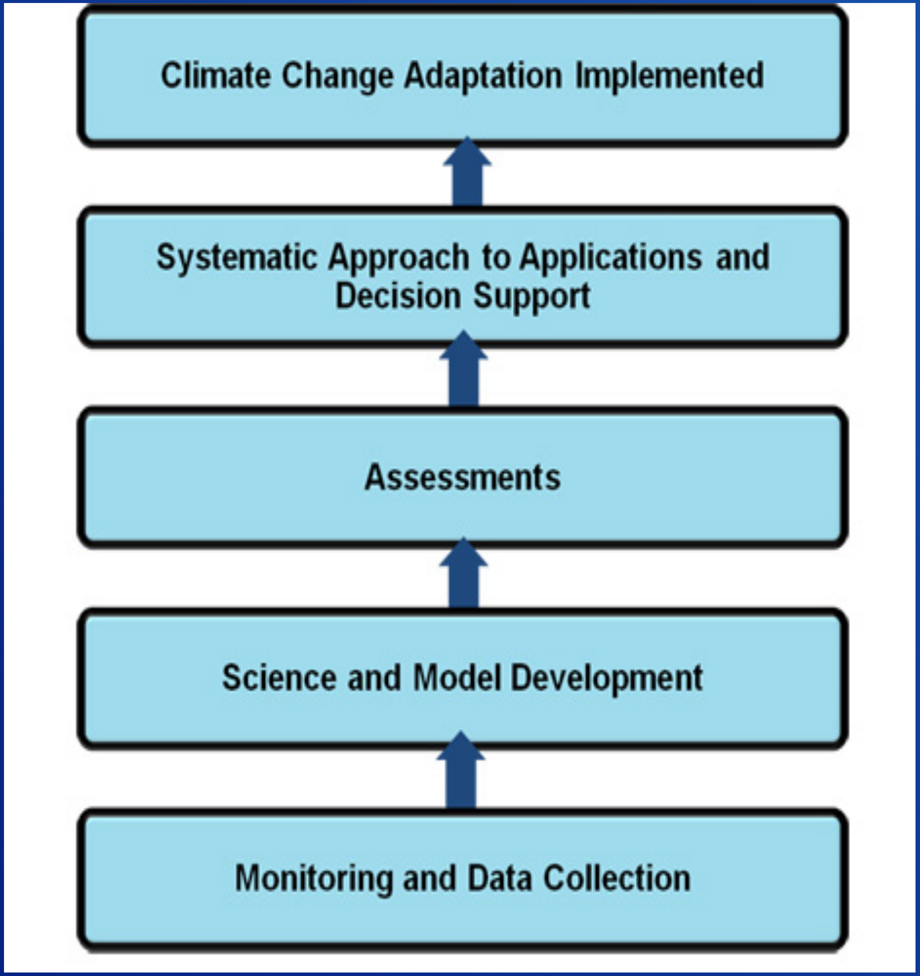
Josh Israel

U.S. Department of the Interior
Bureau of Reclamation

Outline

- Climate Impact Assessment
- WY 2014 Drought and Operations
- Brood Year 2013 Winter run Chinook Salmon Assessment
- Results….
- Life Cycle Model Integrates Impacts
- BY 14 Preliminary Assessment
- Monitoring Drought Effects

West-Wide Climate Risk Assessment



21st Cent.	Temp	Precip
Early	+1ºC	North: few percent increase
Middle	+2°C	
Later	+3ºC	South: up to 10% Decrease

RECLAMATION

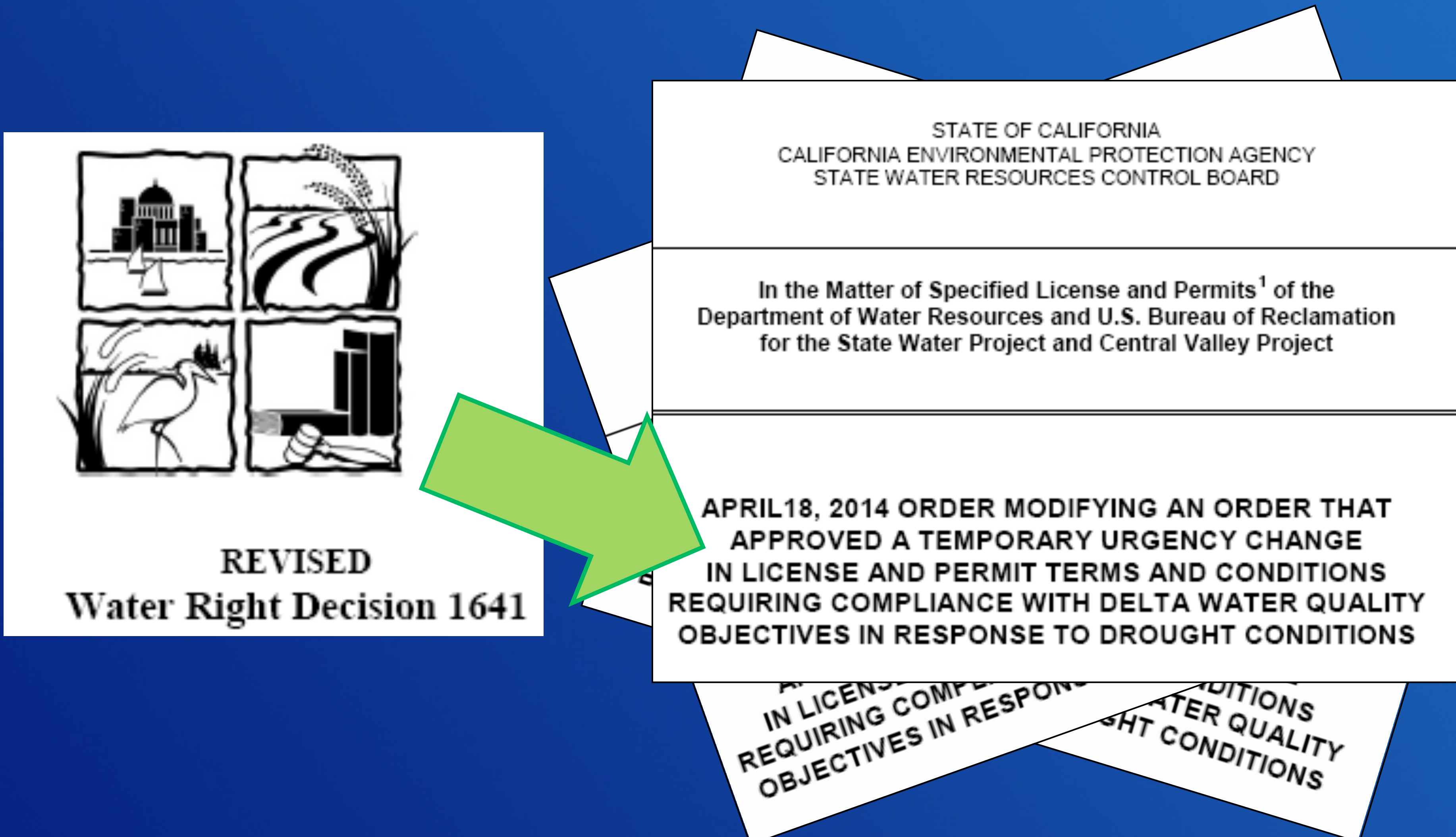
Reduced Coldwater & Floodplain Connectivity

Metric	Period	CT_NoCC	CT_Q5	CAT12	Percent Change from CT_NoCC	
					CT_Q5	CAT12
Shasta Coldwater Pool (percent of April months with Shasta storage less than 3,800 TAF)	2012-2040	41%	48%	14%	7%	-27%
	2041-2070	0%	7%	22%	7%	22%
	2071-2099	14%	14%	29%	0%	15%

Metric	Period	CT_NoCC	CT_Q5	CAT12	Percent Change from CT_NoCC	
					CT_Q5	CAT12
Sacramento River flows at Keswick Dam (percent of Feb–Jun months with <15,000 cfs)	2012-2040	96%	94%	90%	-2%	-6%
	2041-2070	97%	95%	92%	-2%	-5%
	2071-2099	94%	95%	94%	1%	0%

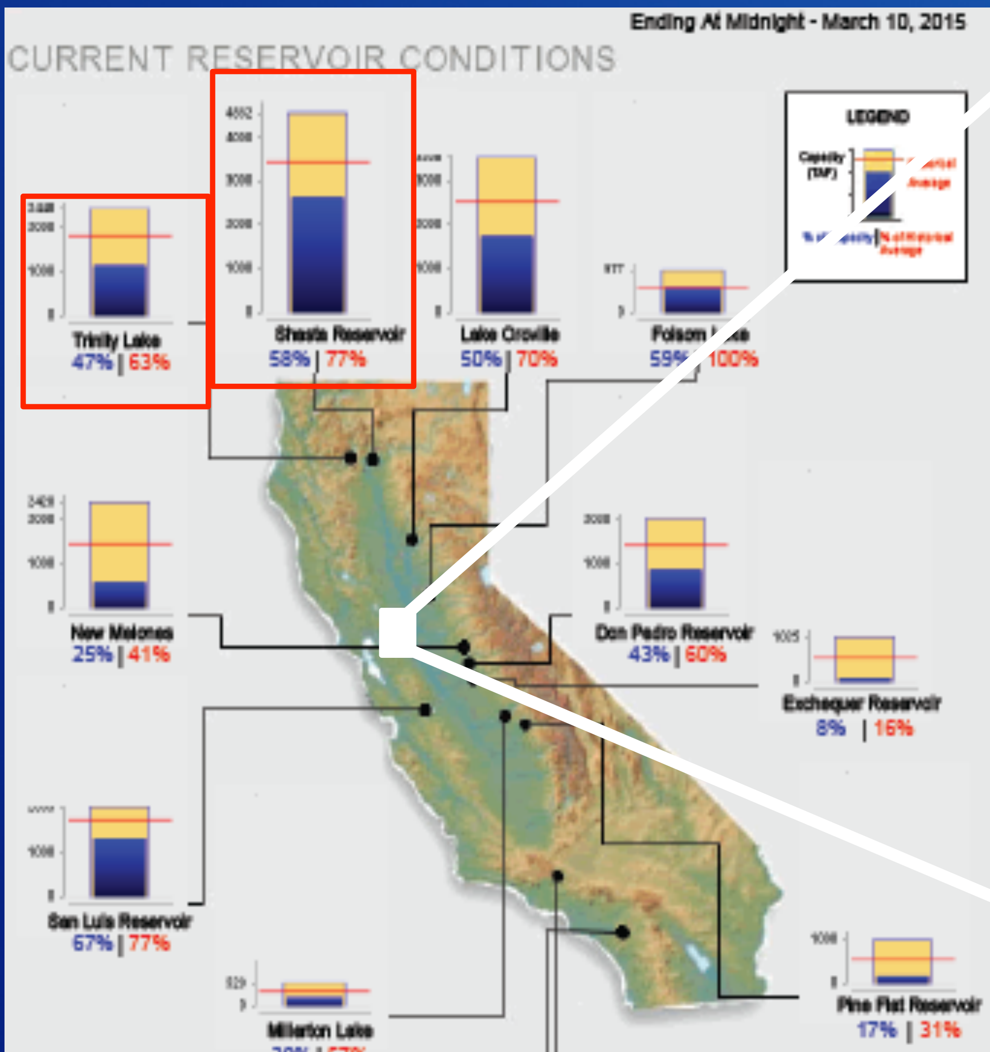
RECLAMATION

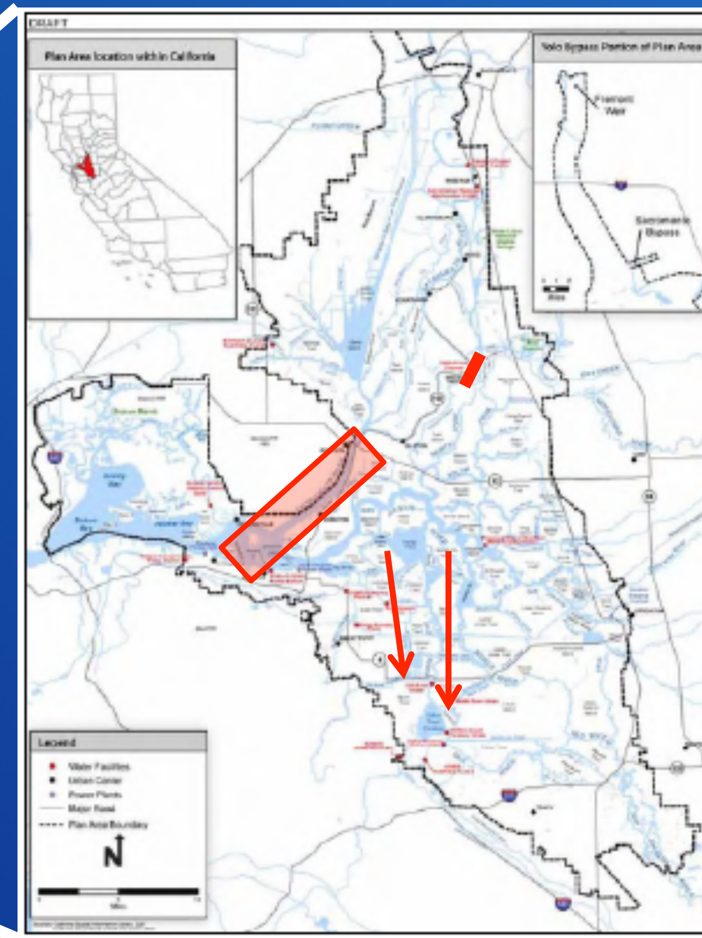
WY 2014 Drought Operations



WY 2014 Drought Modifications

Delta Cross Channel Gate,
Outflow, Old and Middle River





RECLAMATION

Collaborative Multiagency Technical Effort

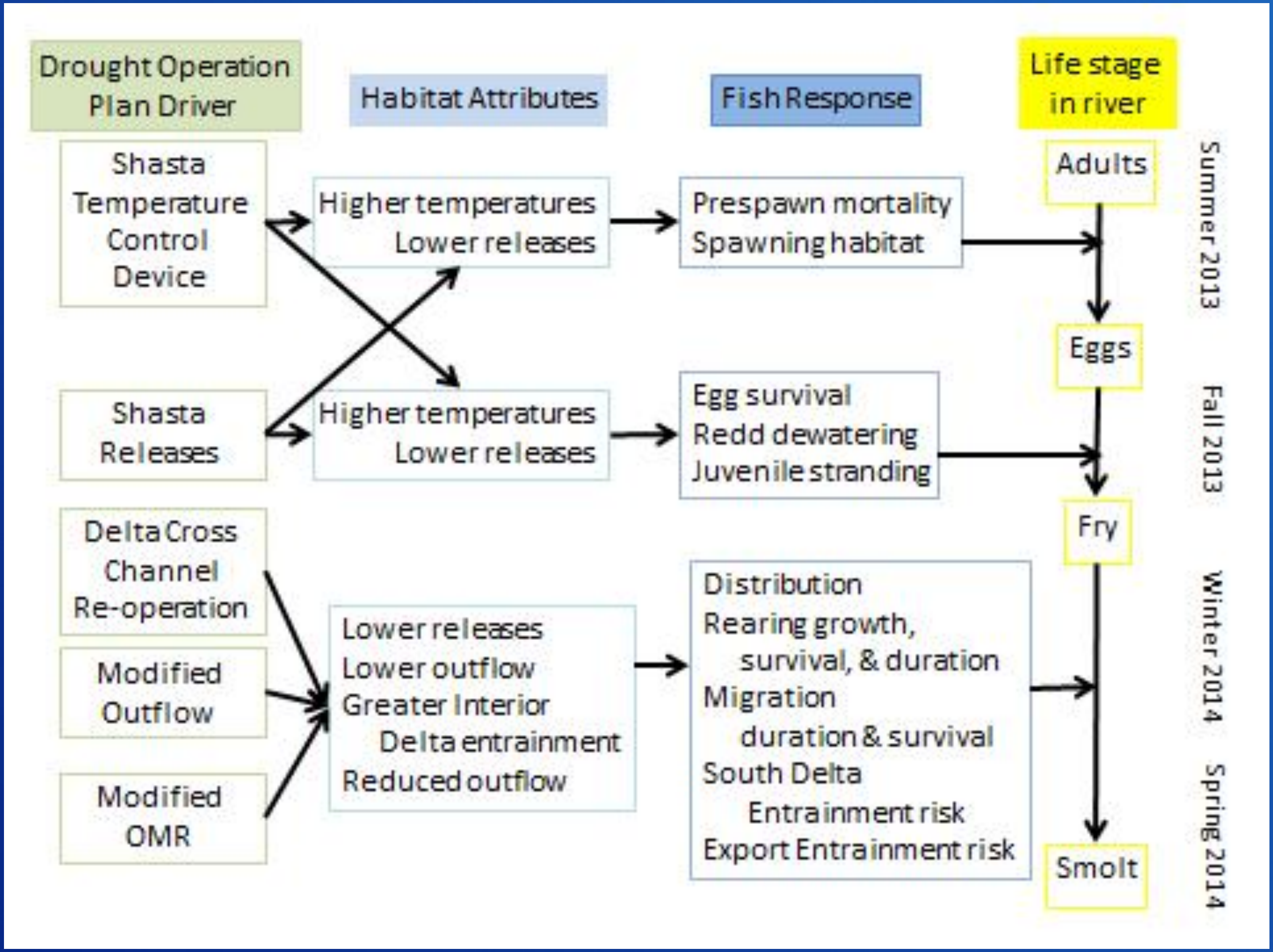

Brood Year 2013 Winter-run Chinook Salmon Drought Operations and Monitoring Assessment

March 2015

- Identified hypothsized drought effects
- Assemble monitoring data from Base Period (BY 2007-2012)
- Compare to BY2013
- Analyze and Synthesize these Impacts

RECLAMATION

Conceptual Model of Effects



RECLAMATION

Predictions of Effects from Drought

Conceptual Model Tier and Variable	Adults (Dec-May)	Eggs (June-Oct)	Fry (Aug-Dec)	Presmolts (Sep-Feb)	Smolts (Nov-May)
Biological Response					
Prespawn mortality	↑				
Egg survival		↓			
Juvenile stranding			↑	↑	↑
River rearing duration			↑	↑	
Rearing growth			↑	↑	
Rearing survival			↓	↓	↓
Lower river and Delta rearing duration			↓	↓	↓
Migration duration				↓	↓
Migration survival				↓	↓
Habitat Attributes					
Redd dewatering		↑			
Water temperature		↑	↑	↔	
Habitat capacity	↓	↔	↓	↓	↓
Outflow volume			↔	↔	↔
Interior Delta flow entrainment				↑	↑
Management Drivers					
Temperature control operations	No effect	No effect			
Shasta releases	↓	↓	↓	↓	↓
Delta Cross Channel gate opening			Did not alter RPA	↑	↑
Modified outflow				↓	↓
Modified OMR				↓	↓
Exports					↔

RECLAMATION

Did the drought conditions affect BY13 WRCS adults in the upper River

- River temperatures- Adult upstream migration- NO
- River flows- adults- NO
- Early/pre-spawn adult mortality- very low levels- NO
- ACID dam installed 1 month early- No observed affect- NO
- LSNFH- WRCS broodstock timing (Mar-Jul 13)- Normal- NO
- LSNFH- WRCS broodstock – No evidence of disease- NO

- No observed impacts to adults and their pre-spawn eggs

RECLAMATION

Did drought conditions impact Egg to Fry survival?

- Potentially

- Used Dynamic Simulation Model (Cramer Fish Science)
  - BY 2007-2012 modeled egg survival: Avg = 23%
  - 2013 modeled egg survival: 21%
  - No apparent difference

- Red Bluff Division Dam Passage Data
  - BY 2007-2012 egg to fry estimate = 31%
  - 2013 modeled egg to fry survival = 15.1%
  - Nearly 50% lower survival in BY 2013

RECLAMATION

Did the drought impact WRCS juvenile production?

- YES
- 2013 RBDD juvenile production index(JPI)= 2,485,787 fry
- NMFS juvenile production estimate (JPE)= 4,431,064 fry based on estimated number of females in carcass survey
- Some redd dewatering and stranding occurred, but not enough to account for lower RBDD passage of fry

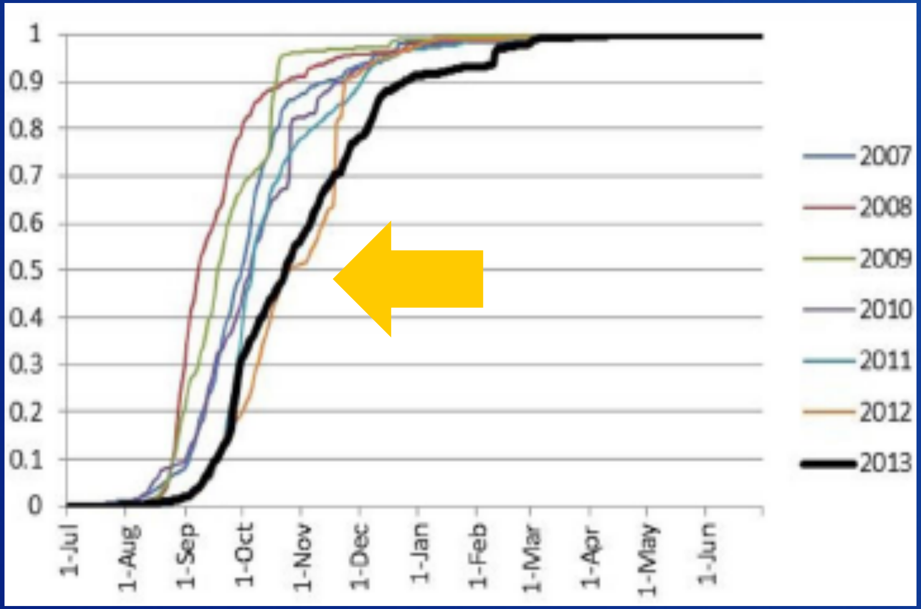
	Monthly Mean	Annual Mean	Daily Max Percentage	150% Daily Max Percentage
17-day Proportion	14%	23%	40%	50%
Winter Fry Eq. JPI	2,488,356	2,786,992	3,595,220	4,319,838
JPE Comparison (a)	-44%	-37%	-19%	-3%
Spring Juveniles estimated at RBDD	426,325	426,325	426,325	426,325
Winter + Spring	2,914,681	3,213,317	4,021,545	4,746,163
JPE Comparison(b): Winter + Spring	-34%	-27%	-9%	7%

RECLAMATION

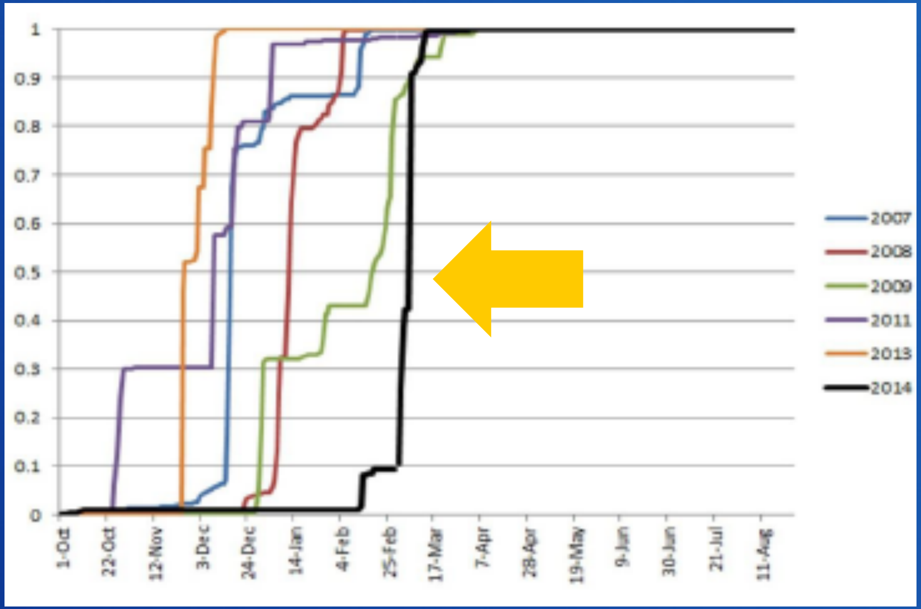
Did the drought impact WRCS river rearing and emigration patterns?

- YES, passage data from RBDD and Knights Landing screw traps demonstrate a prolonged period in the upper river.

RBDD RSTs



KL RSTs



RECLAMATION

Did the drought impact WRCS estuarine rearing and emigration patterns?

- **YES**
- Based on northern and western trawls in the Delta,
- WRCS entered the Delta later and exited sooner than previous 6 years

	BY 2007-2012				BY 2013
	LCL 95%	Mean	UCL 95%		
Northern Trawl					
Date of first WRCS	27-Oct	7-Dec	16-Jan		9-Feb
5%	20-Oct	7-Dec	17-Jan		12-Feb
25%	11-Nov	3-Jan	25-Feb		13-Feb
50%	23-Dec	1-Feb	13-Mar		15-Feb
75%	31-Dec	14-Feb	30-Mar		4-Mar
95%	10-Jan	28-Feb	17-Apr		14-Mar
100%	11-Jan	2-Mar	20-Apr		4-Apr
Western Trawl					
Date of first WRCS	26-Dec	17-Jan	8-Feb		14-Feb
5%	10-Jan	6-Feb	4-Mar		20-Feb
25%	11-Feb	4-Mar	25-Mar		5-Mar
50%	11-Mar	23-Mar	4-Apr		9-Mar
75%	25-Mar	3-Apr	12-Apr		14-Mar
95%	11-Apr	18-Apr	25-Apr		8-Apr
100%	16-Apr	28-Apr	10-May		11-Apr

RECLAMATION

Did the drought impact WRCS life history diversity?

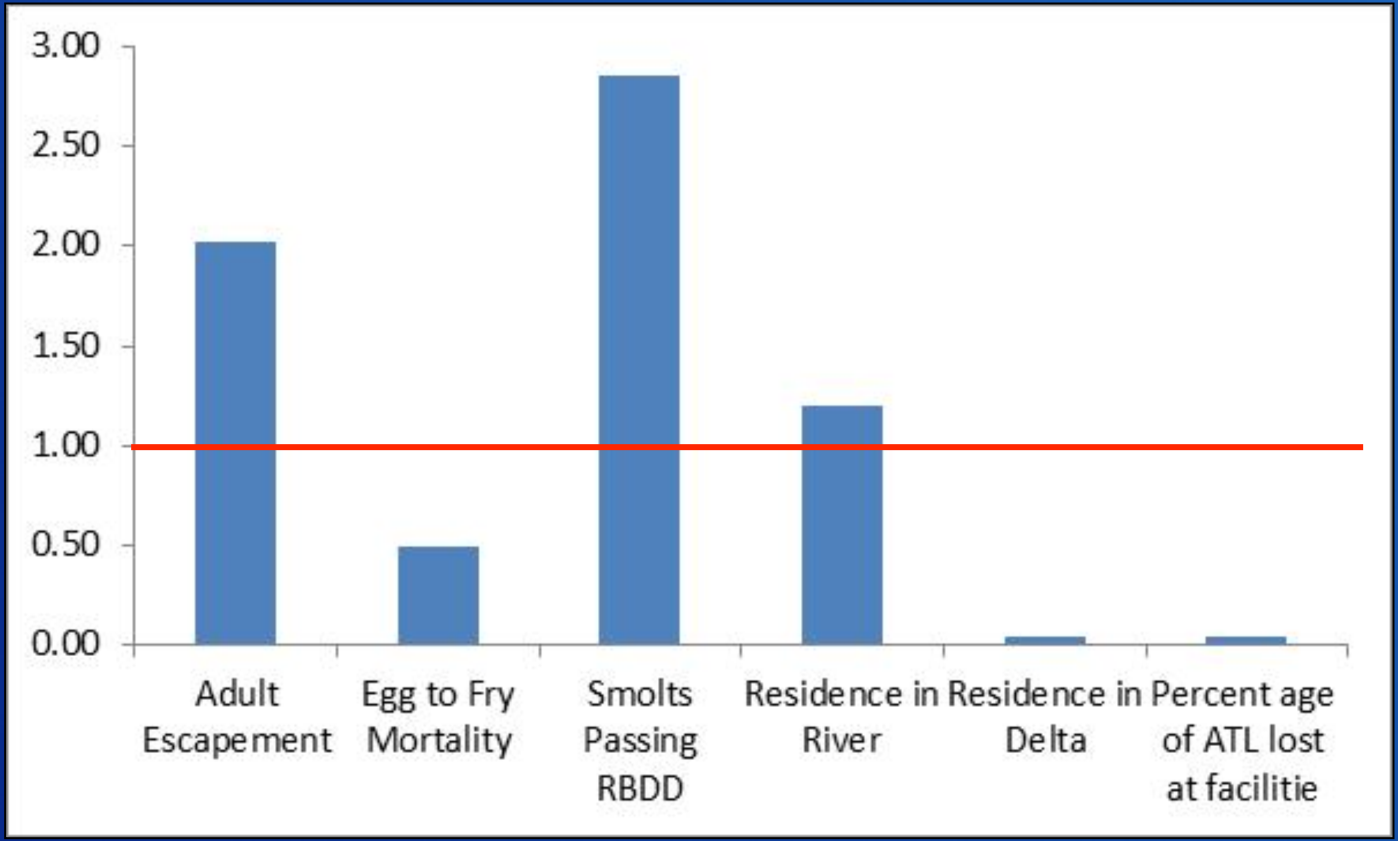
- YES.

- Based on RBDD RSTs
  - BY 2013: 57% of the WRCS were smolt sized
  - BY 2007-2012: 20% Average (range 10-47%)

- Team believed larger fish corresponded with longer residency in upper river in 2014.

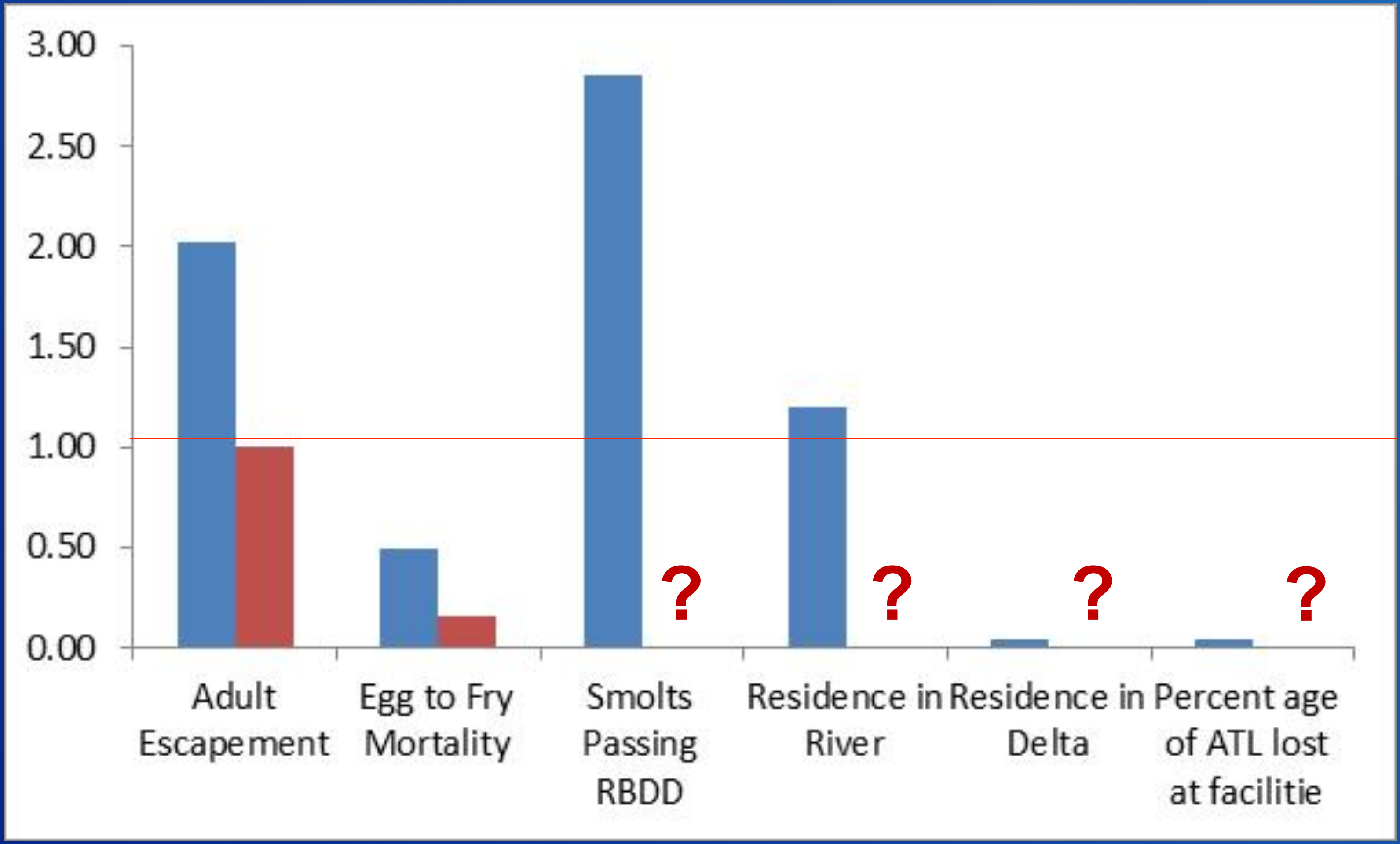
RECLAMATION

1.0 represents average value of the BY 2007-2012 comparative period



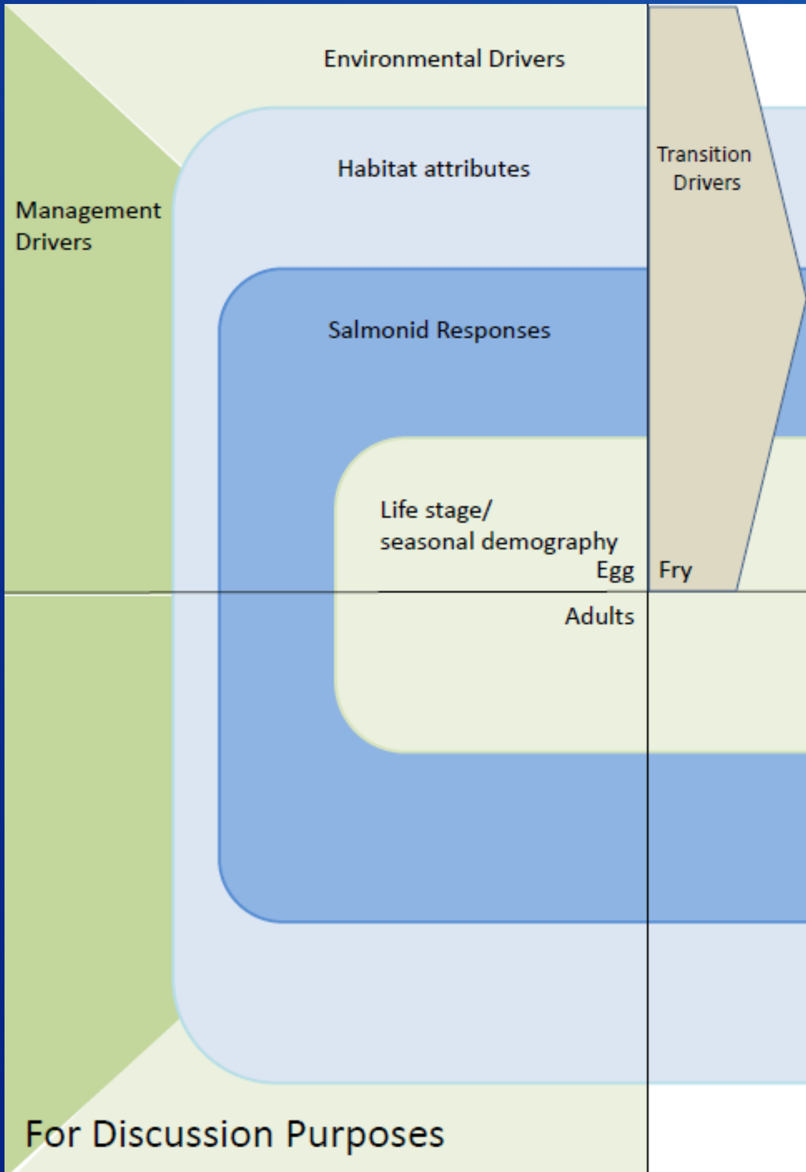
RECLAMATION

BY13 &14 WRCS Metrics



RECLAMATION

WRCS Management CM



<u>Tier 1: Landscape Attributes</u>

These could be the same as the Smelt MAST model. These include Erodible Sediment Supply, Geology, Vegetation, Proximity to Ocean, Proximity to Discharges, Proximity to Diversions

<u>Tier 2: Environmental Drivers</u>

Factors determined by landscape attributes

<u>Tier 2: Management Drivers</u>

Factors determined by landscape attributes and societal decisions

<u>Tier 3: Habitat Attributes</u>

Characteristics of the habitat possibly experienced

<u>Tier 4: Salmonid responses</u>

Ontogeny on salmonids during phase

<u>Tier 5: Life Stage/ Seasonal Demographics</u>

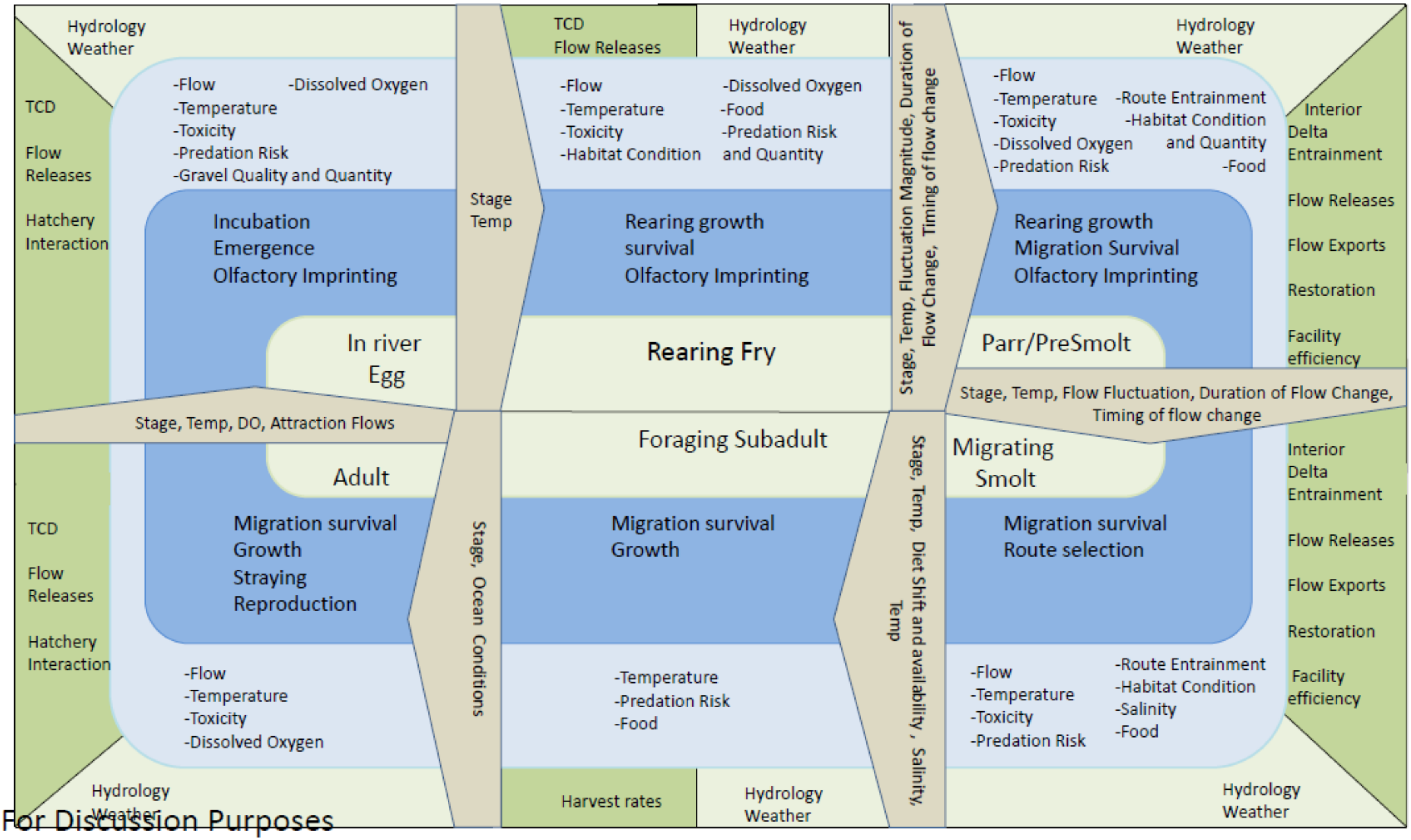
Parameters influences by habitat attributes and drivers

<u>Cross Tier: Transition Drivers</u>

rivers that link seasonal demographics of salmonids

WRCS Management CM

Landscape Attributes: Erodible Sediment Supply, Geology & Geomorphology, Vegetation, Proximity to Ocean, Proximity to Discharges, Proximity to Diversions

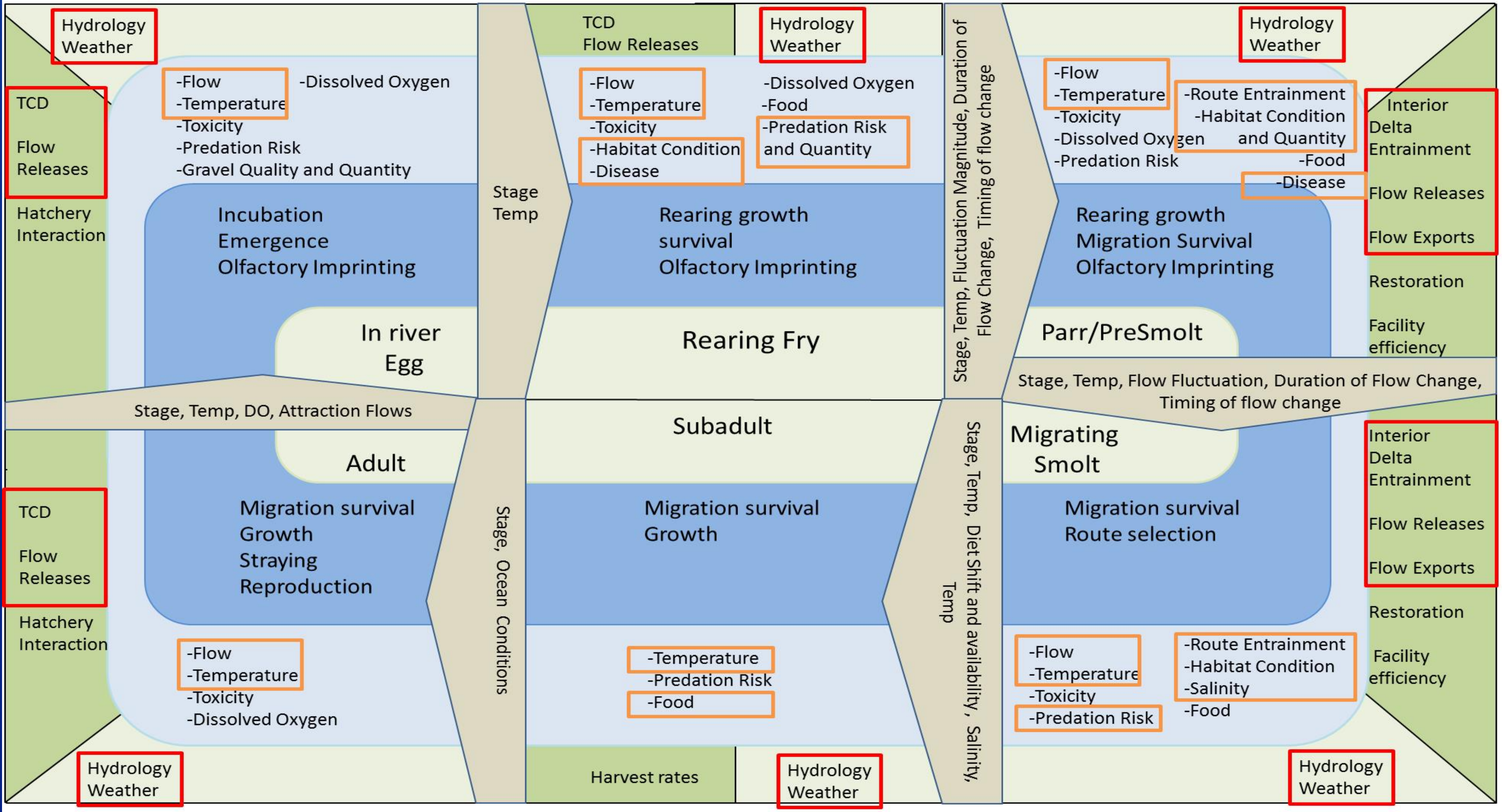


For Discussion Purposes

RECLAMATION

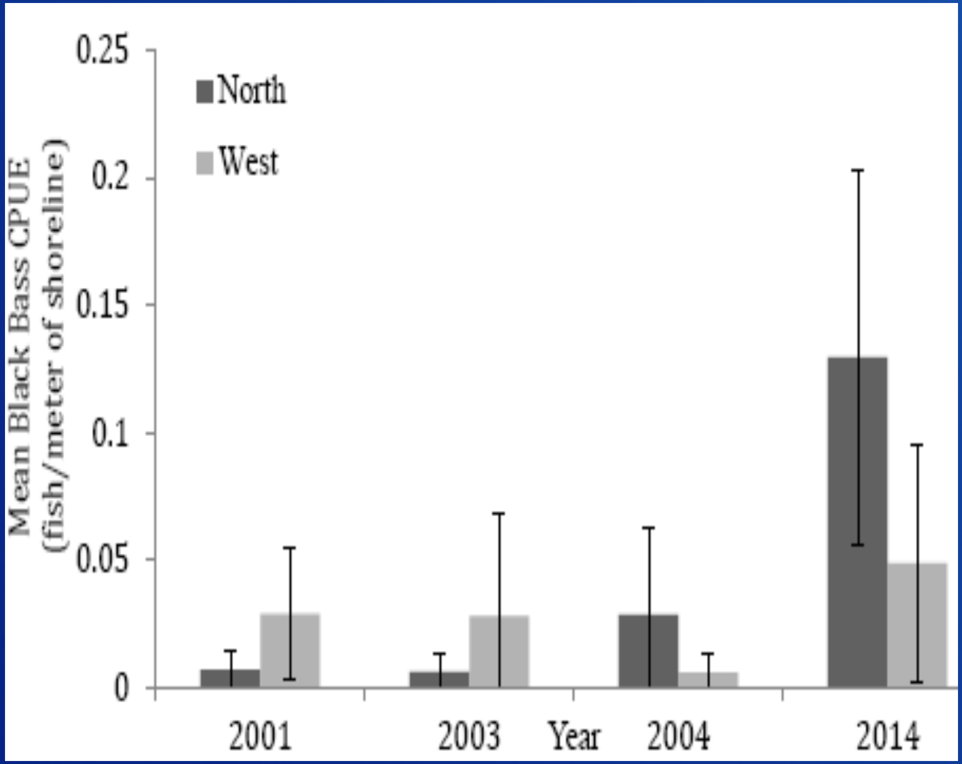
How may Climate Change Effect WRCS Habitat Attributes?

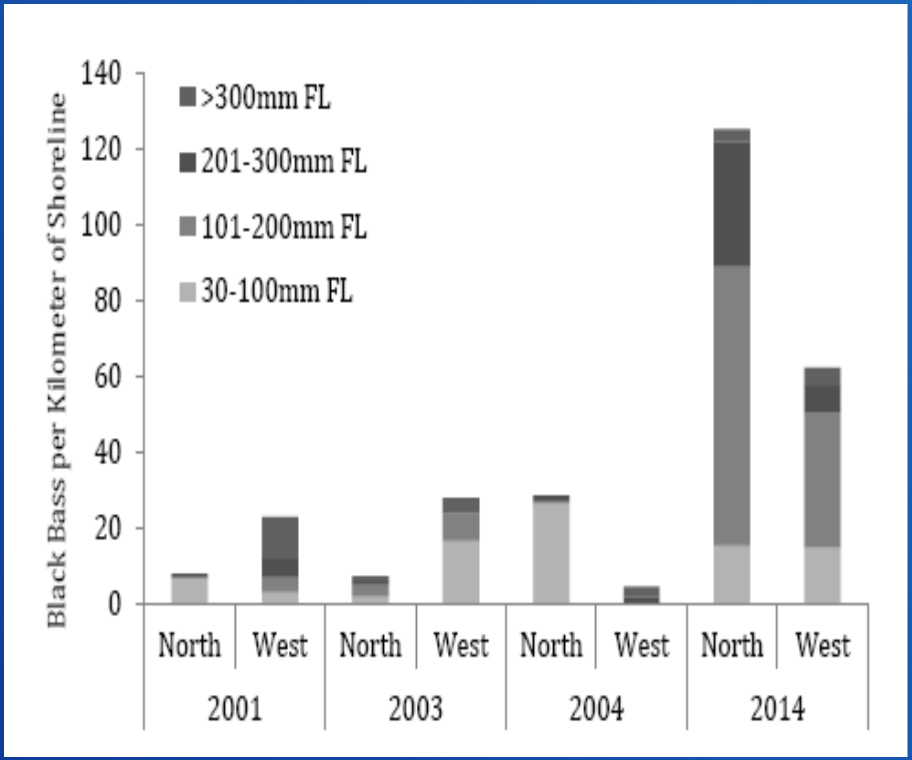
Landscape Attributes: Erodible Sediment Supply, Geology & Geomorphology, Vegetation, Proximity to Ocean, Proximity to Discharges, Proximity to Diversions



RECLAMATION

WY2014 experienced increase predators

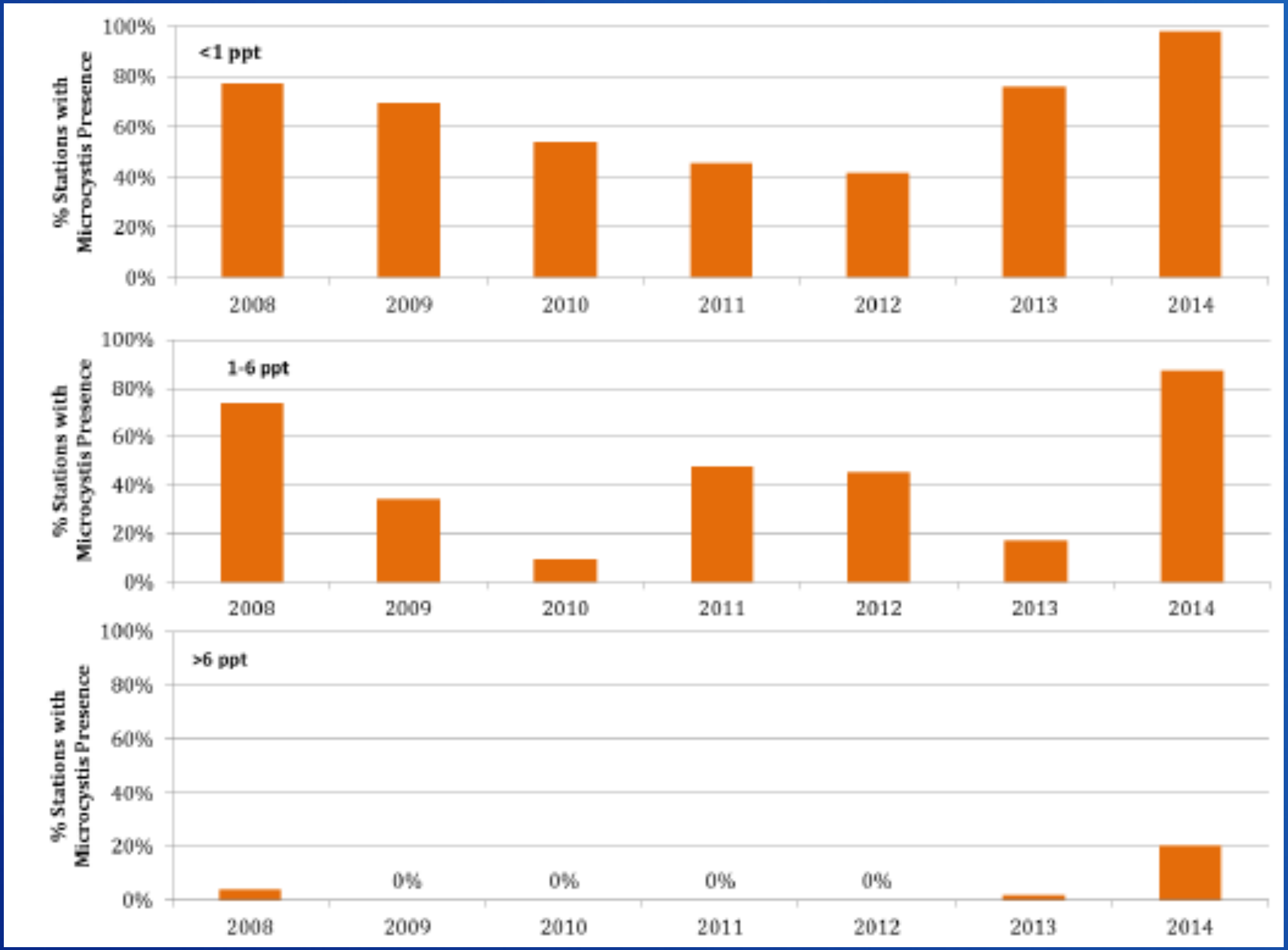




IEP 2014 MAST Report

RECLAMATION

WY2014 greatest detection of toxic algae since Fall observations noted



IEP 2014 MAST Report

RECLAMATION

Monitoring Climate Effect on WRCS

Abundance	Productivity	Spatial Distribution	Diversity
Adults			
❖ Expanded Ocean Fishery Monitoring		❖ Evaluate pre-spawn escapement using DIDSON to assess potential pre-spawn mortality	❖ Evaluation of growth and life history diversity in returning adult using otoliths
Eggs			
	❖ Recalibration of Sacramento Temperature Model using WY2014 temperature dataset		
Juveniles			
❖ Habitat utilization study to estimate carry capacity in mainstem rearing areas ❖ Remote sensing vegetation survey during migration period (spring)	❖ Complete juvenile condition and pathogen monitoring ❖ Increased count duration in salvage monitoring ❖ Complete taggins of any in-river releases hatchery fish to better evaluate spring season productivity, spatial distribution, and diversity	❖ Increased monitoring at Knights Landing until population is determined to emigrate past this location into Delta to evaluate exposure ❖ Modeling of daily proportion reverse flows at key Delta junctions to evaluate exposure into Delta ❖ Develop migration passage model for RBDD, Knights Landing, and Chipps Island	❖ Use of genetic stock identification in salvage and monitoring surveys to accurately categorize ESU
Subadults			
❖ Expanded Ocean Fishery Monitoring	❖ Continued Ocean Condition Monitoring		

RECLAMATION

Flow Availability Assessment for Salmonid Recovery Planning:

Green Valley and Dutch Bill Creeks, Russian River Watershed

Jeremy Kobor, MS, RG

Matt O'Connor, PhD, CEG

O'Connor Environmental, Inc.

Healdsburg, California

www.oe-i.com

O E I

Acknowledgements

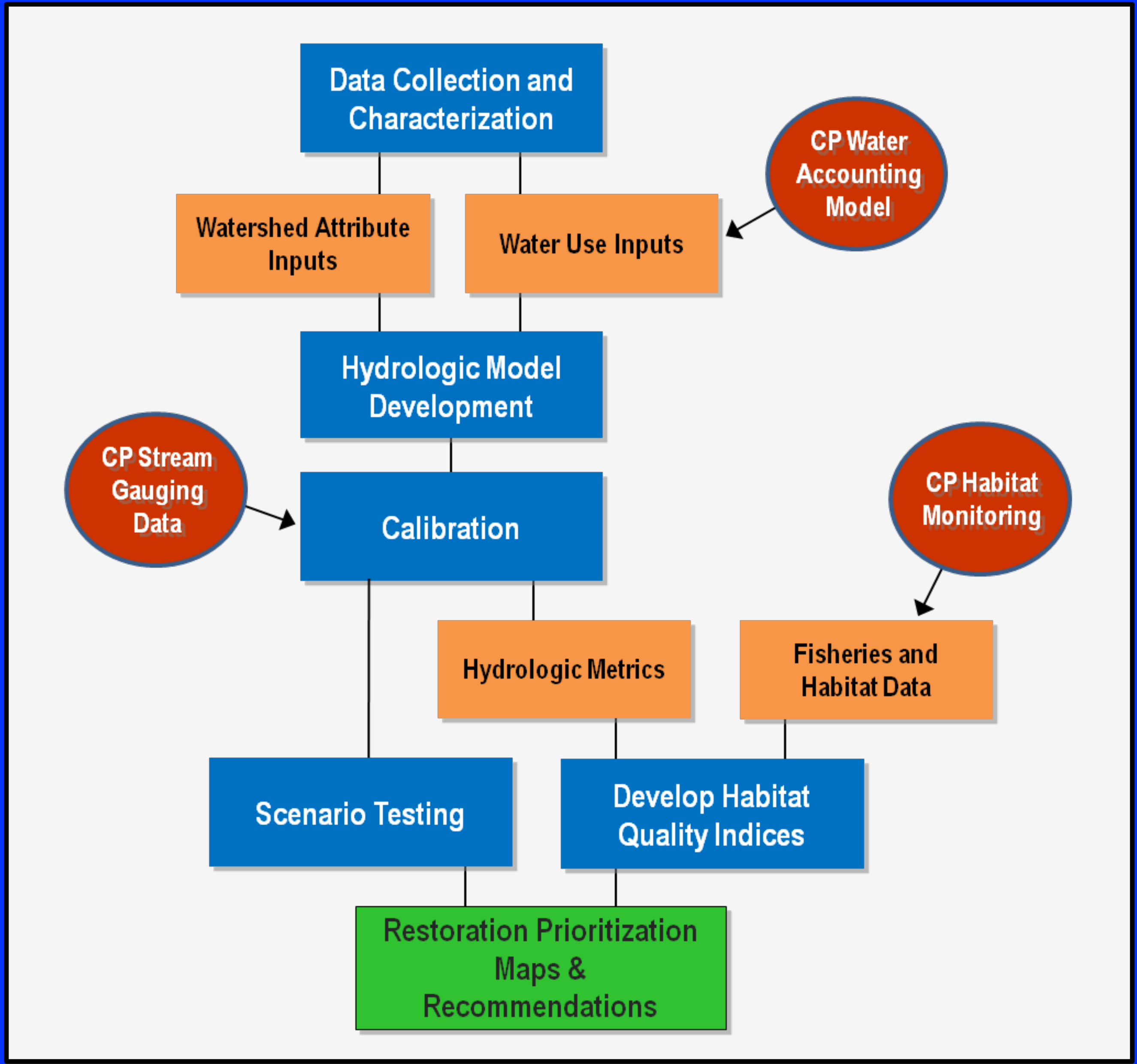
- Project Partner
  - Gold Ridge Resource Conservation District
- Project Funding
  - CDFW Fisheries Restoration Grant
  - OEI donated professional services for matching funds ($40k)
- Data Contributions
  - CDFW
  - NMFS
  - CEMAR
  - UCCE

Motivation

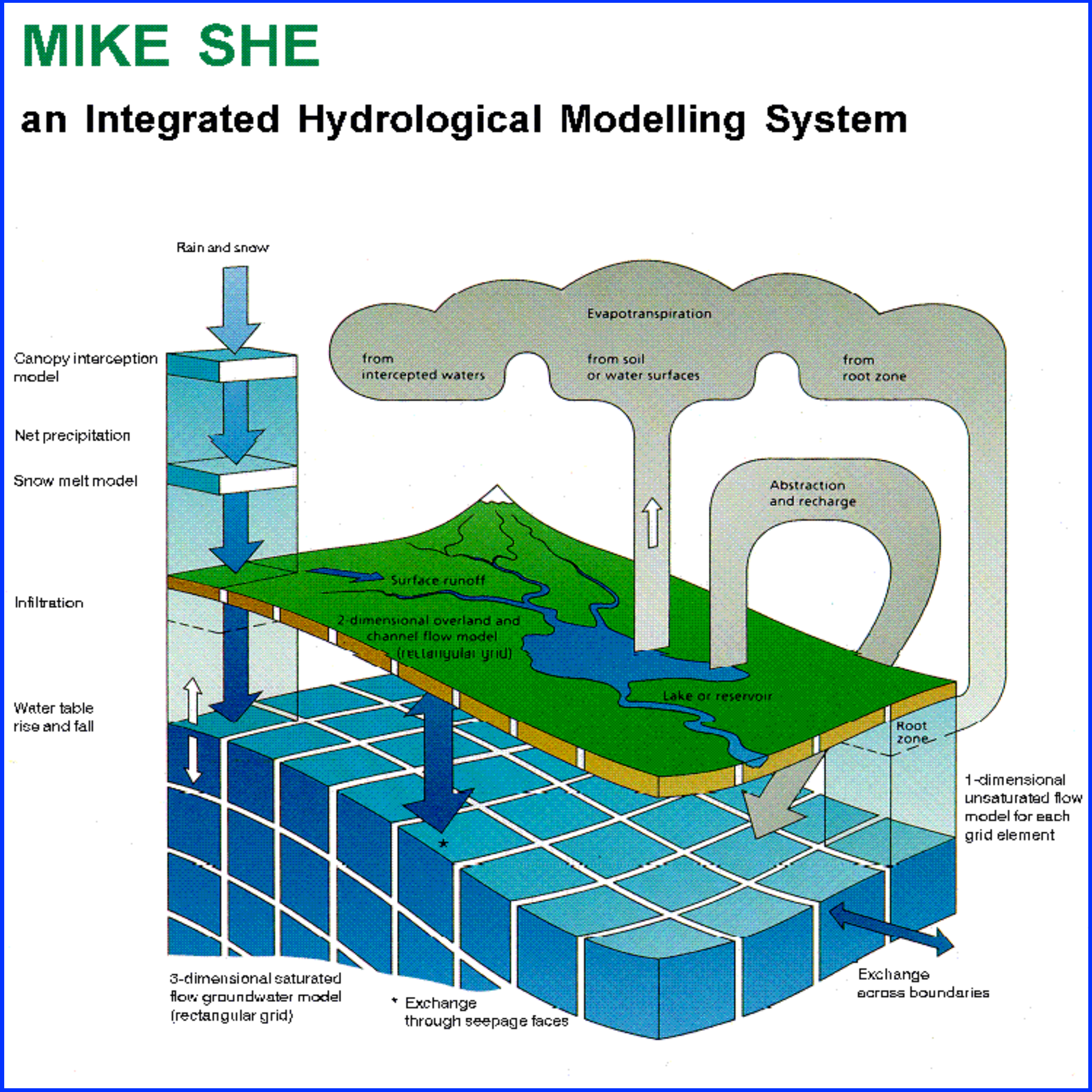
- Juvenile coho summer rearing habitat is limited by inadequate streamflows
- Spatial variation in flow conditions poorly understood
- Effective restoration planning requires a detailed understanding of flow conditions and consideration of watershed context
  - Targeting reaches with suitable habitat flows
  - Developing opportunities for flow augmentation
  - Planning for resilience to drought and climate change

O E I

Study Elements



Model Overview



Precipitation

Evapotranspiration

Overland Flow

Unsaturated Flow

Groundwater Flow

River and Lakes

Irrigation

Sediment Transport

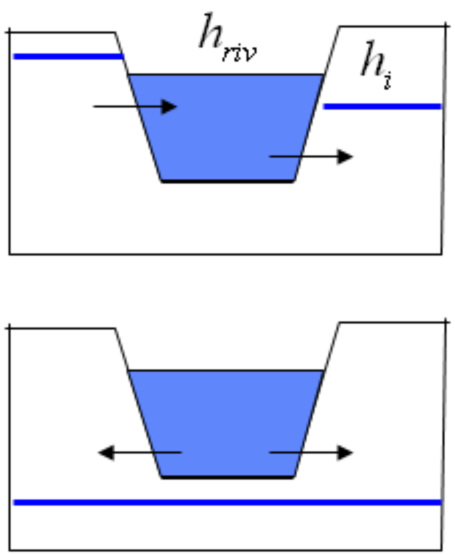
Water Quality

Model Overview

Water Level Gradient

Head difference between the river and the saturated zone is calculated as:

$$\Delta h = h_i - h_{riv}$$



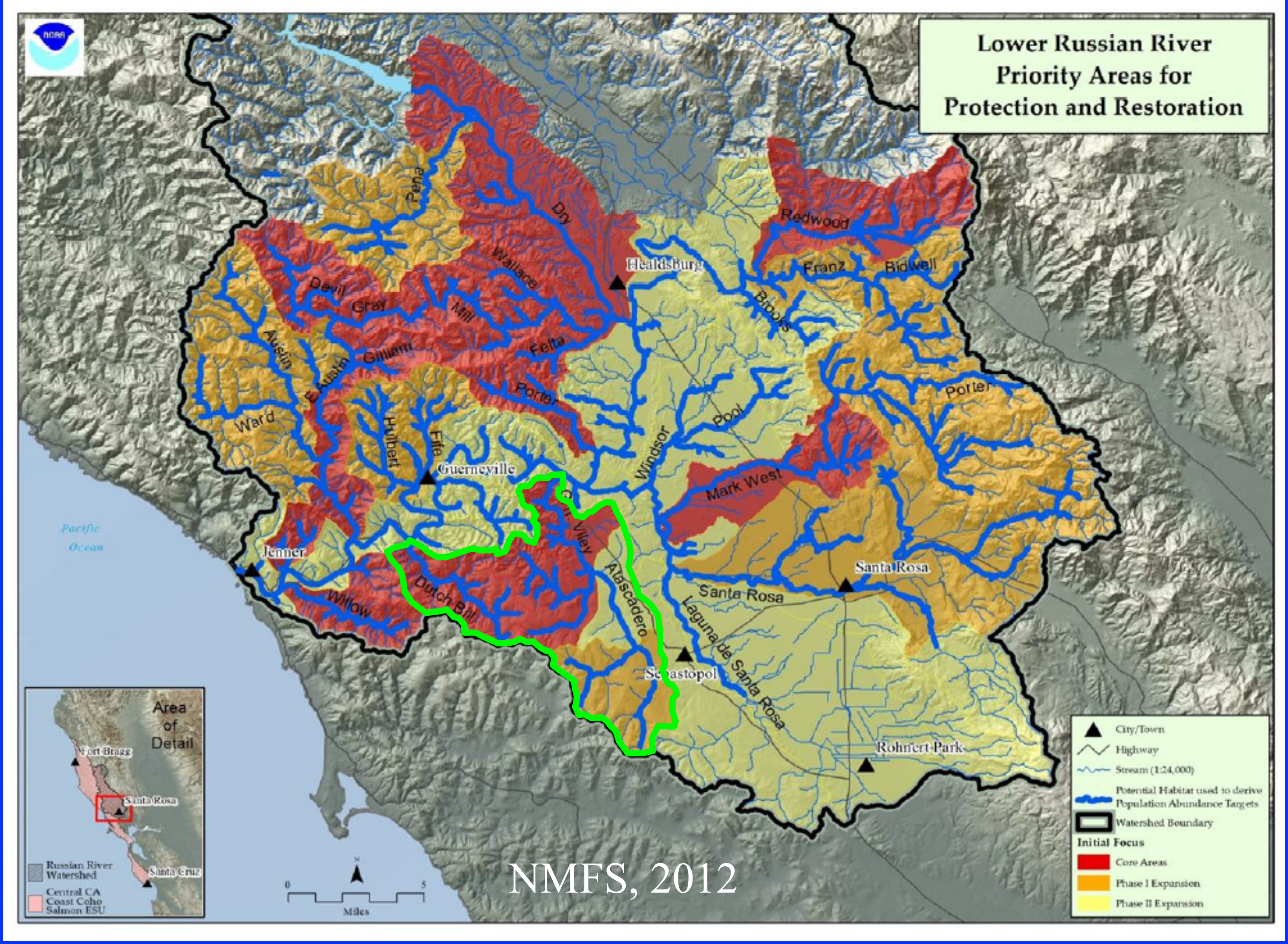
Conductance

Conductance calculated as the harmonic mean of the hydraulic conductivity of the aquifer and the river bed:

$$C_{i,sz-river} = \frac{1}{\dfrac{ds}{C_i \cdot da_i \cdot dx} + \dfrac{1}{C_{i,river} \cdot w_i \cdot dx}}$$

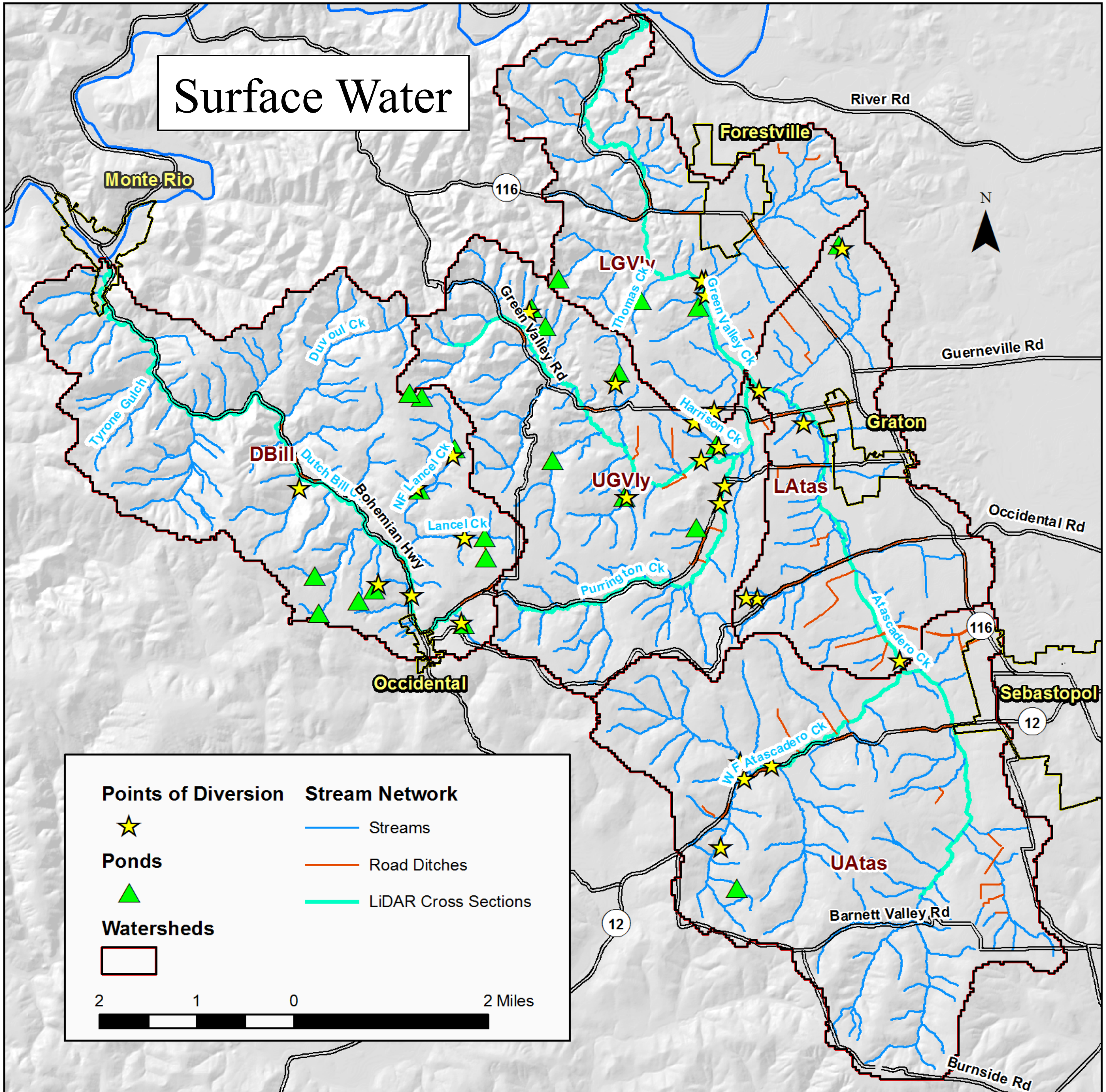
h_{riv}	river water level
h_i	head in grid cell i
C_i	hydraulic conductivity in saturated zone
$C_{i,river}$	leakage coefficient of river lining
da_i	saturated layer thickness
dx	SZ grid size
ds	Average flow length - distance
w_i	wetted perimeter in grid cell *i*

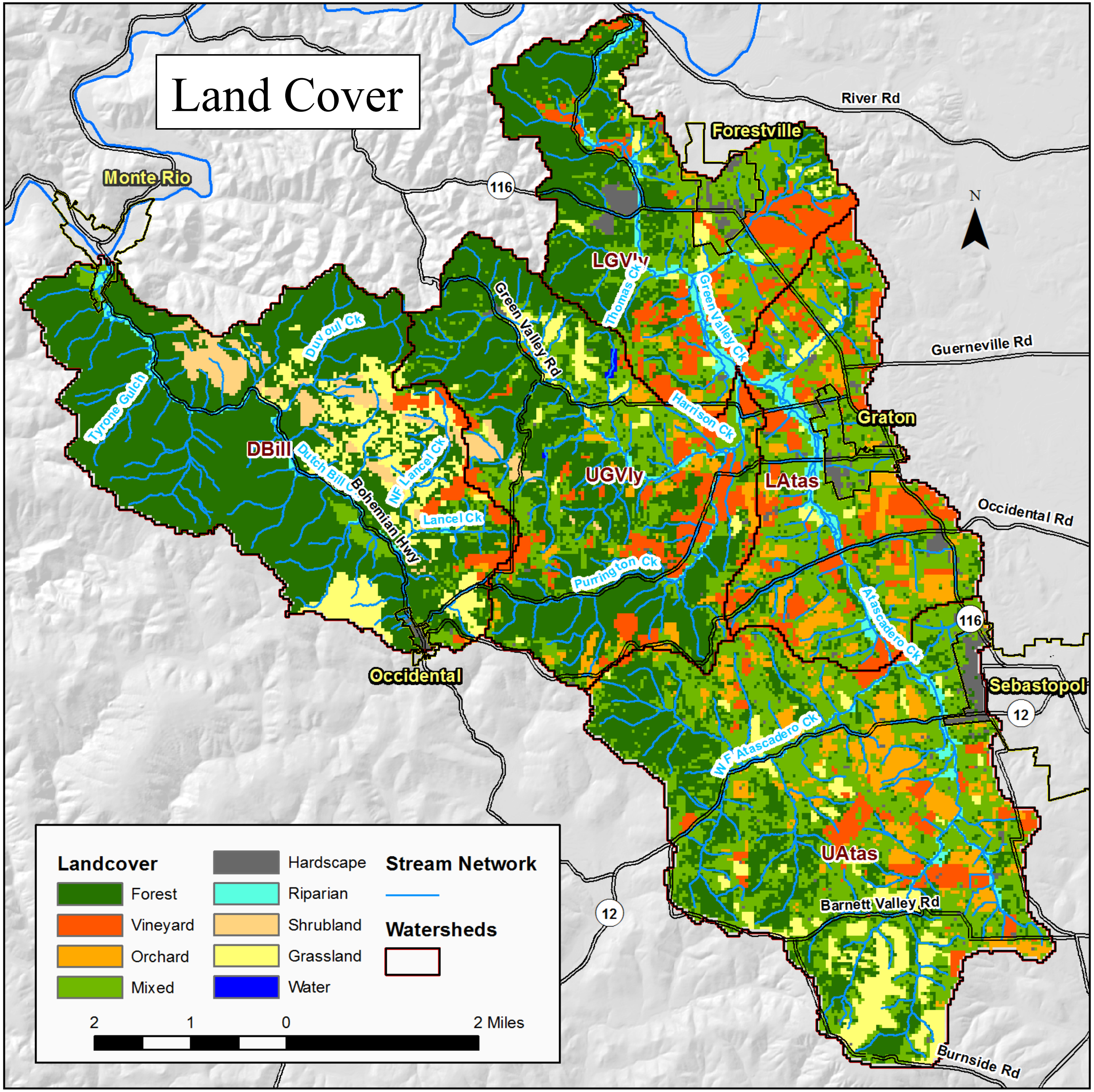
Study Area



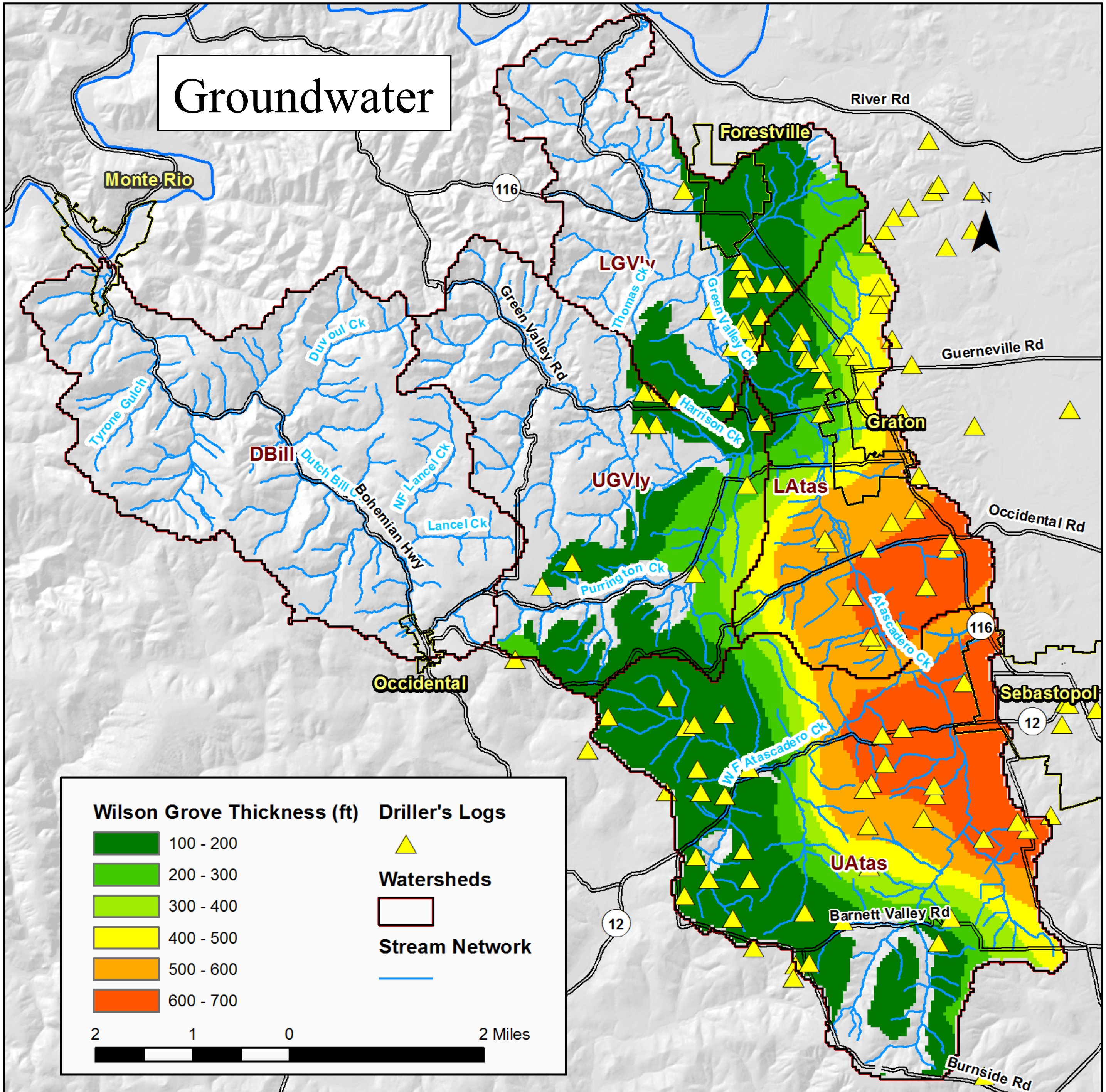
Lower Russian River
Priority Areas for
Protection and Restoration
Redwood
Franz
Bidwell
Healdsburg
Brooks
Dry
Pena
Wallace
Devil
Gray
Mill
Felta
Austin
E. Austin
Gilliam
Porter
Ward
Hulbert
Fife
Guerneville
Pool
Windsor
Mark West
Porter
Green Valley
Jenner
Willow
Dutch Bill
Atascadero
Santa Rosa
Santa Rosa
Laguna de Santa Rosa
Sebastopol
Rohnert Park
Pacific Ocean
Area of Detail
Fort Bragg
Santa Rosa
Santa Cruz
Russian River Watershed
Central CA Coast Coho Salmon ESU
Miles
City/Town
Highway
Stream (1:24,000)
Potential Habitat used to derive Population Abundance Targets
Watershed Boundary
Initial Focus
Core Areas
Phase I Expansion
Phase II Expansion
NMFS, 2012

Surface Water

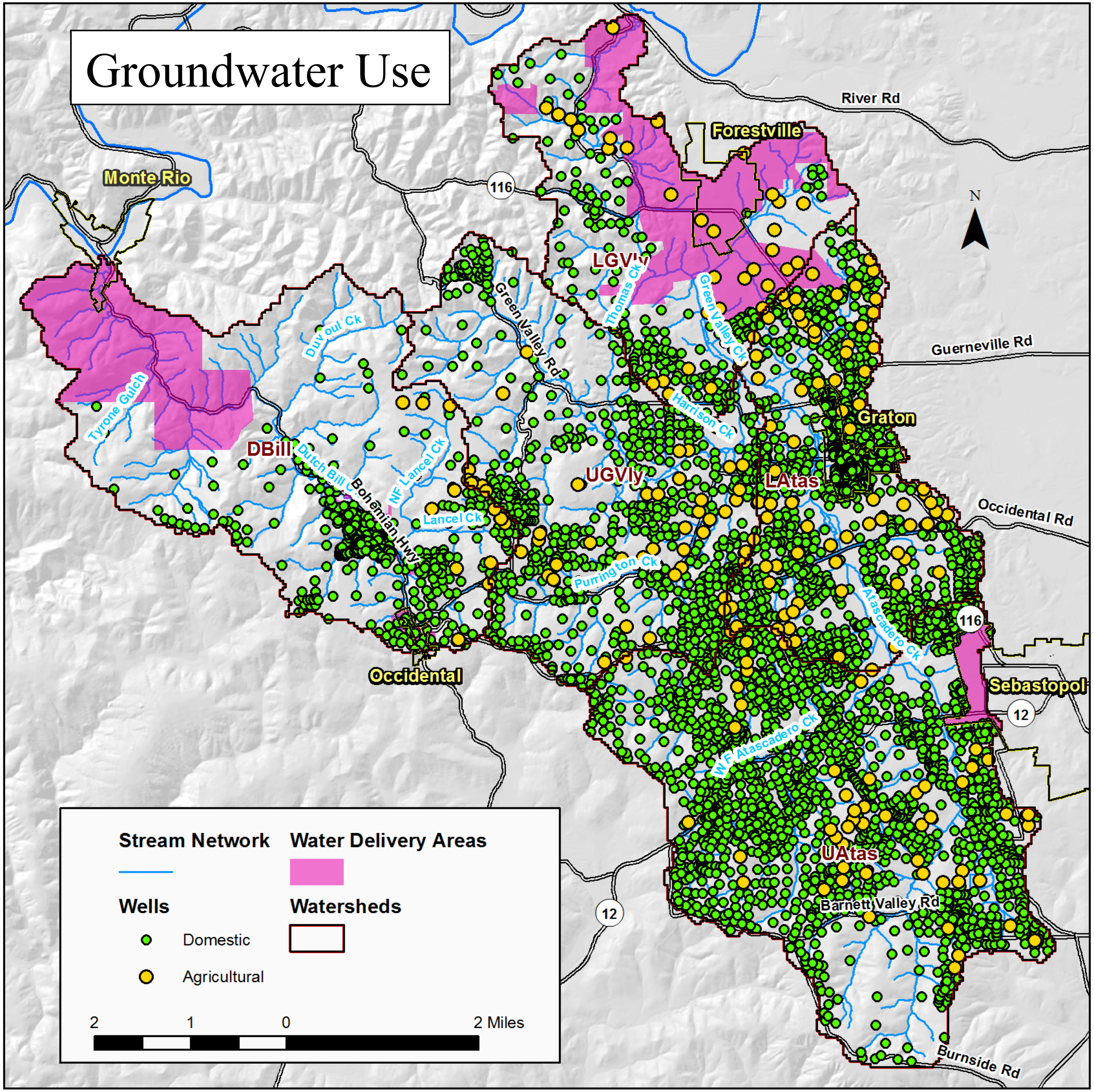




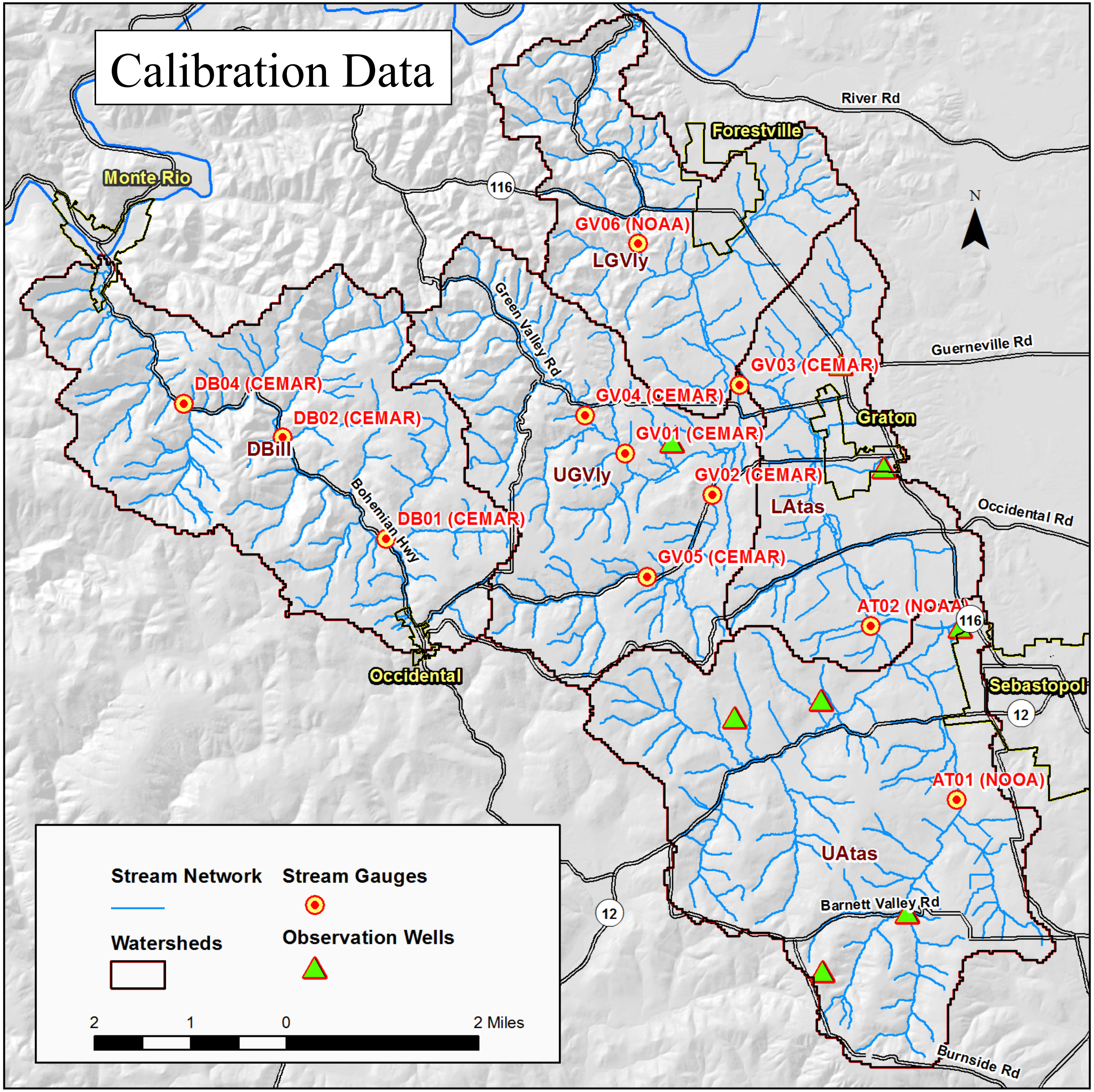
Land Cover
Monte Rio
Forestville
River Rd
116
Guerneville Rd
Graton
Occidental Rd
Occidental
Sebastopol
12
N
LGVly
UGVly
DBill
LAtas
UAtas
Tyrone Gulch
Duvoul Ck
Dutch Bill Ck
Bohemian Hwy
NF Lancel Ck
Lancel Ck
Green Valley Rd
Thomas Ck
Green Valley Ck
Harrison Ck
Purrington Ck
Atascadero Ck
W F Atascadero Ck
Barnett Valley Rd
Burnside Rd
Landcover
Forest
Vineyard
Orchard
Mixed
Hardscape
Riparian
Shrubland
Grassland
Water
Stream Network
Watersheds
2
1
0
2 Miles



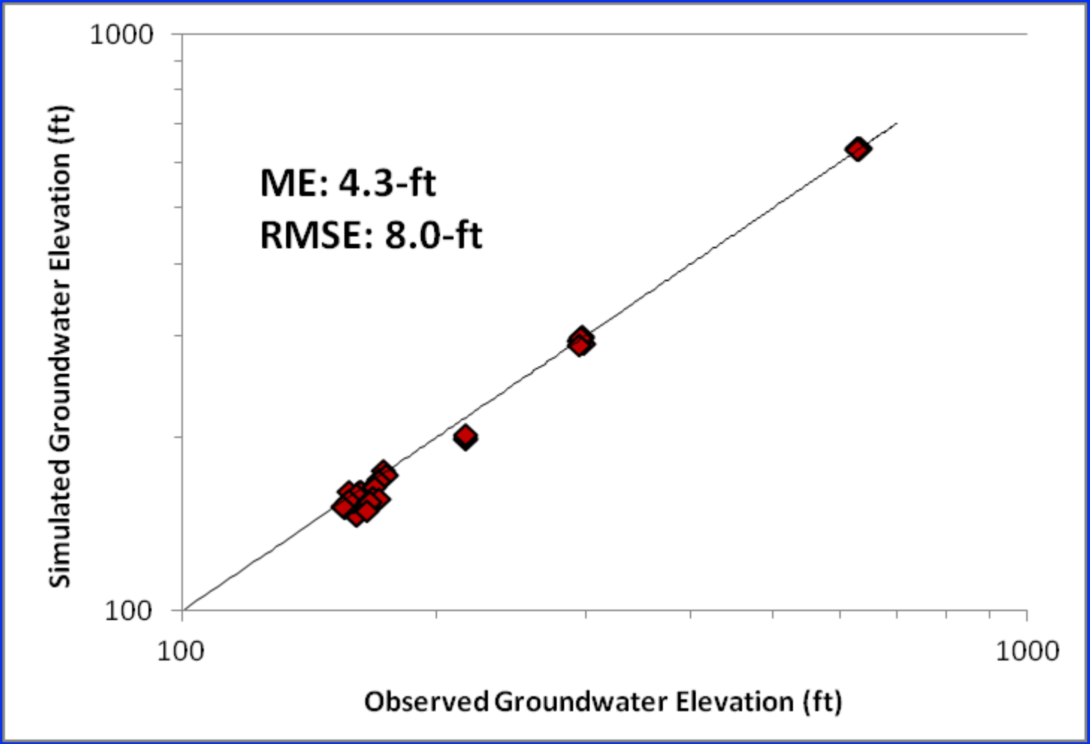
Groundwater
Monte Rio
Forestville
Graton
Occidental
Sebastopol
River Rd
Guerneville Rd
Occidental Rd
Barnett Valley Rd
Burnside Rd
Green Valley Rd
Bohemian Hwy
116
12
LGVly
UGVly
DBill
LAtas
UAtas
Thomas Ck
Green Valley Ck
Harrison Ck
Purrington Ck
Atascadero Ck
W.F. Atascadero Ck
Dutch Bill Ck
NF Lancel Ck
Lancel Ck
Duvoul Ck
Tyrone Gulch
N
Wilson Grove Thickness (ft)
100 - 200
200 - 300
300 - 400
400 - 500
500 - 600
600 - 700
Driller's Logs
Watersheds
Stream Network
2
1
0
2 Miles

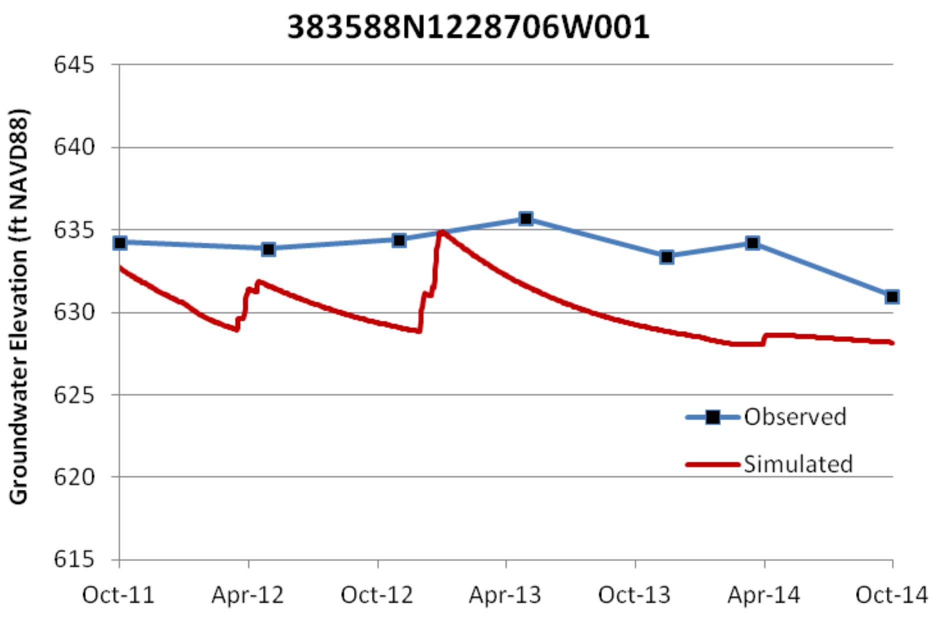

Groundwater Use
River Rd
Forestville
Monte Rio
116
LGVly
Thomas Ck
Green Valley Ck
Green Valley Rd
Duvoul Ck
Tyrone Gulch
Guerneville Rd
Harrison Ck
Graton
DBill
Dutch Bill Ck
Bohemian Hwy
NF Lancel Ck
Lancel Ck
UGVly
LAtas
Occidental Rd
Purrington Ck
Atascadero Ck
116
Occidental
Sebastopol
12
W F Atascadero Ck
UAtas
12
Barnett Valley Rd
Burnside Rd
N
Stream Network
Water Delivery Areas
Wells
Domestic
Agricultural
Watersheds
2
1
0
2 Miles

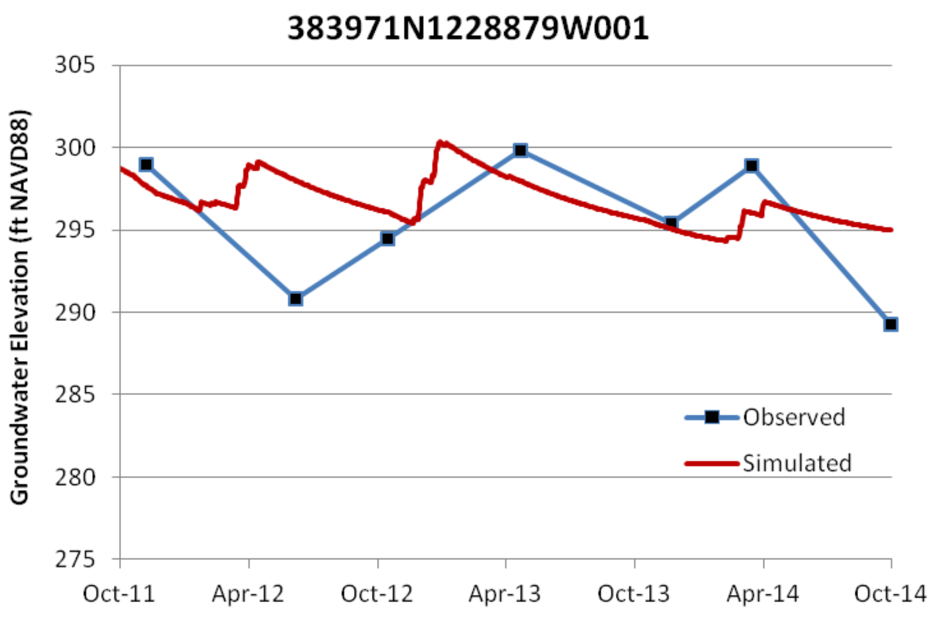
Calibration Data



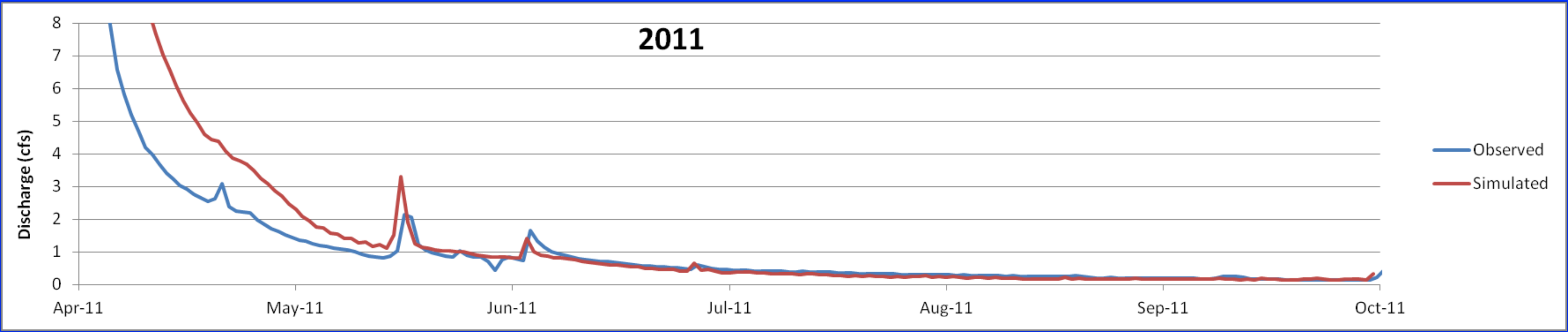
Groundwater Calibration

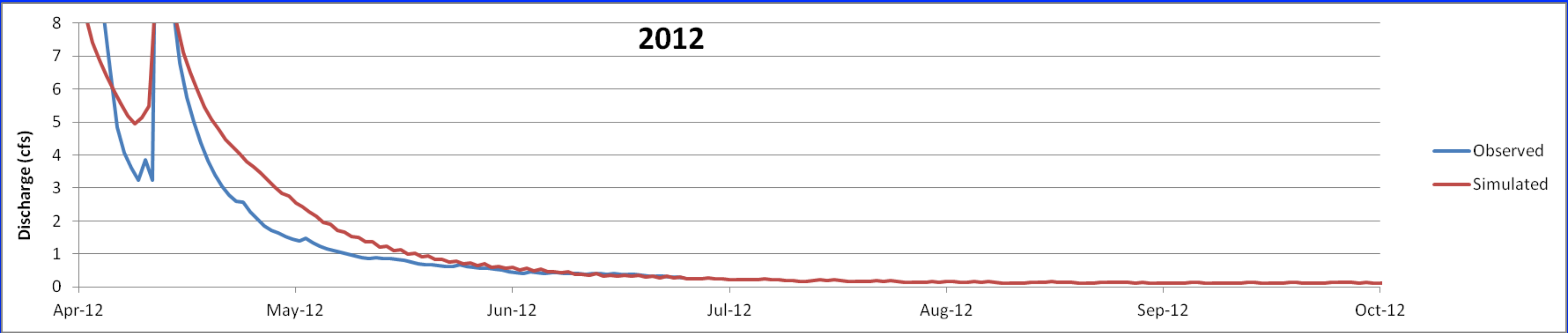


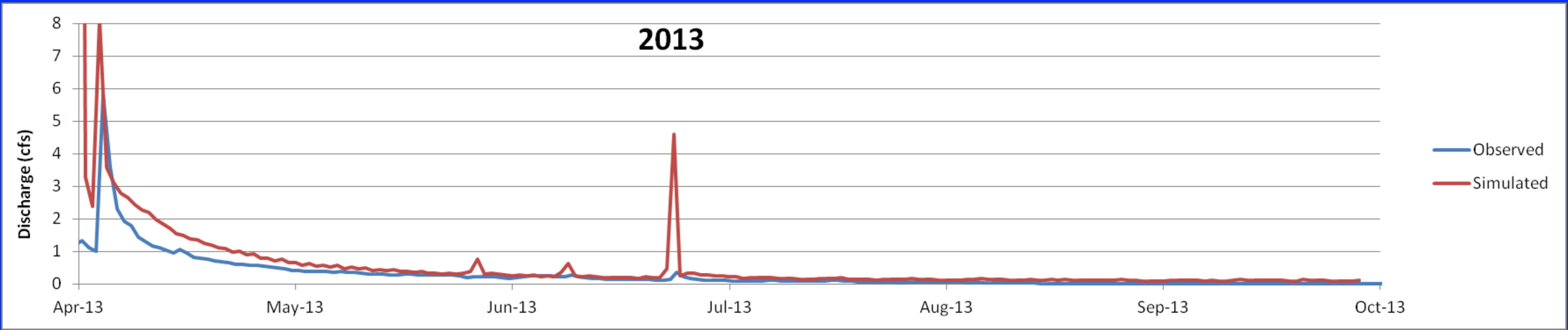




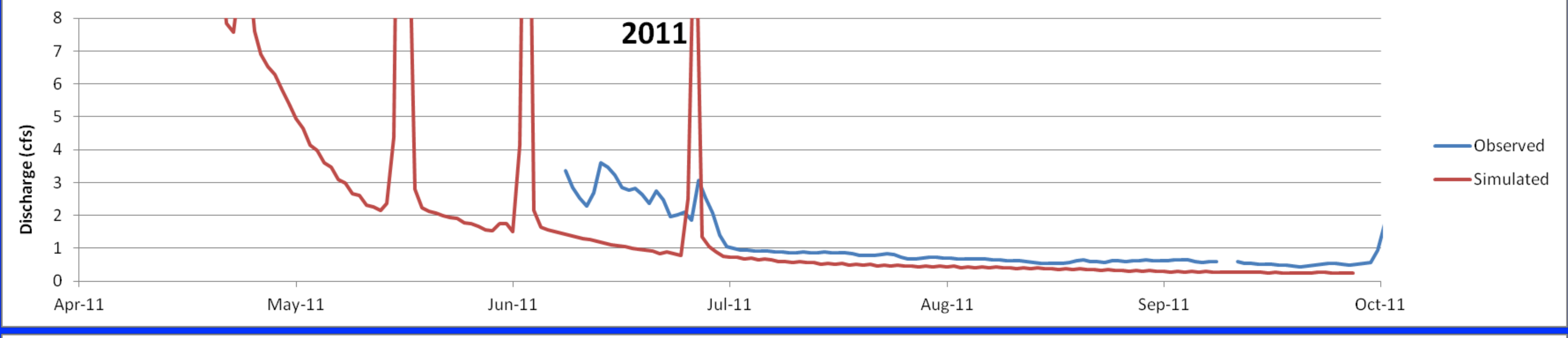
Calibration: Green Valley Creek

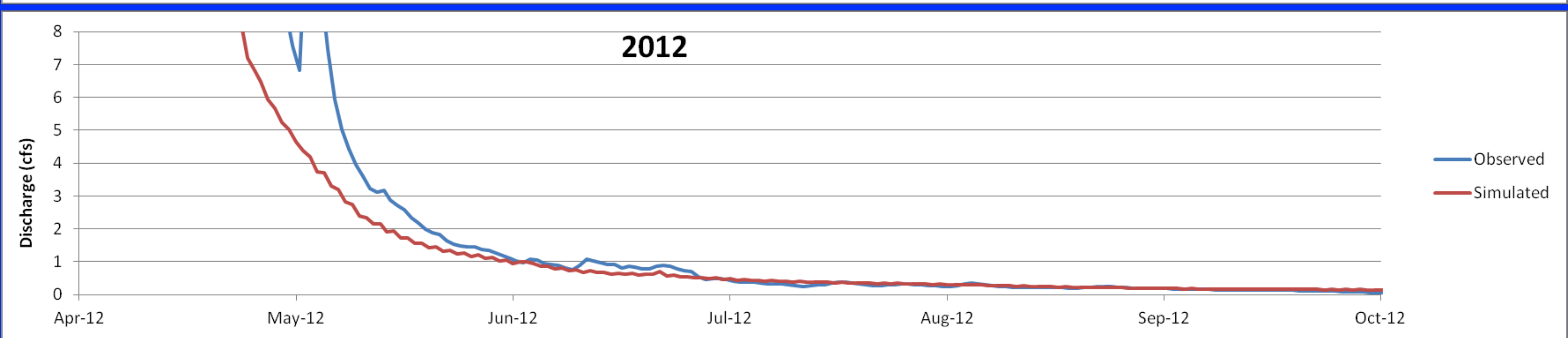


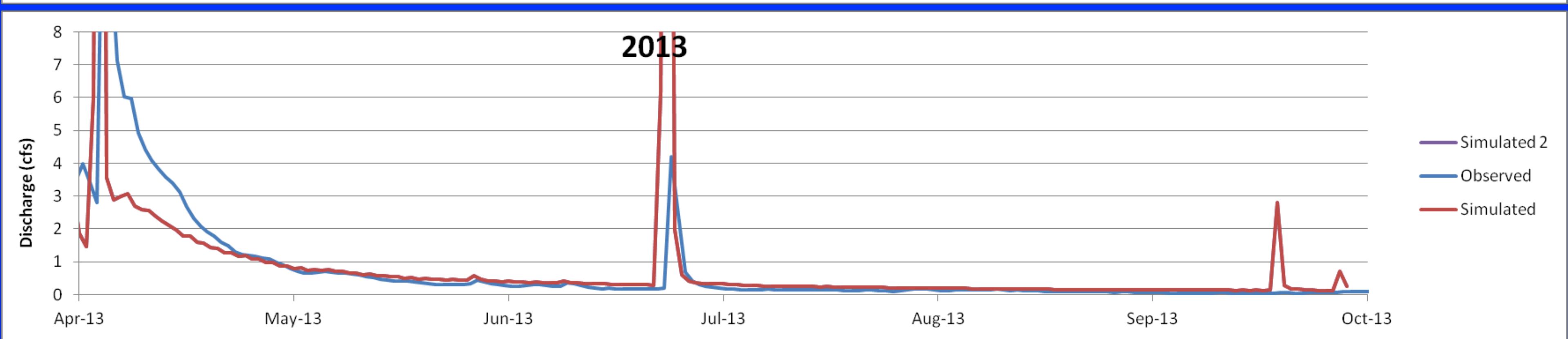




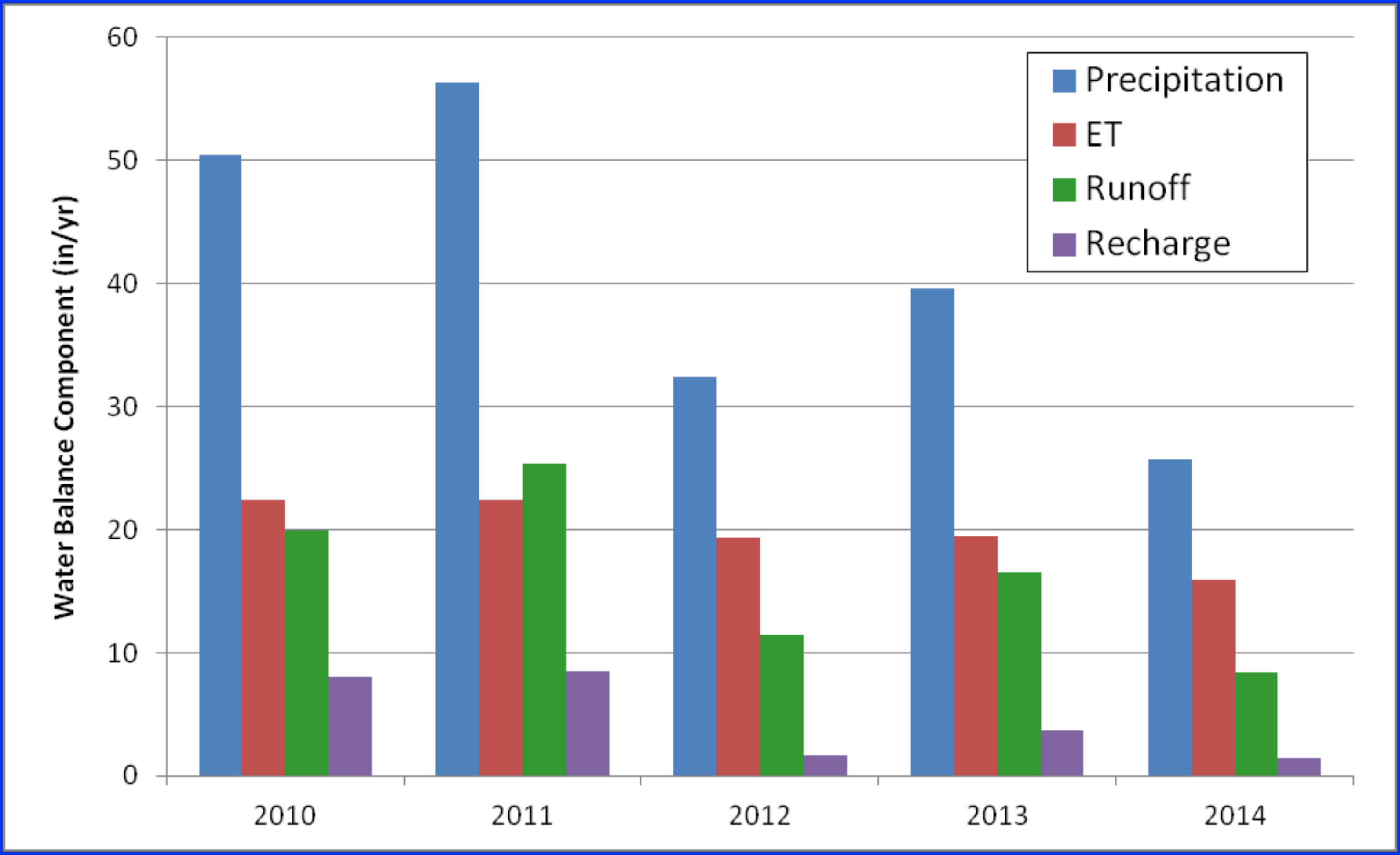
Calibration: Dutch Bill Creek

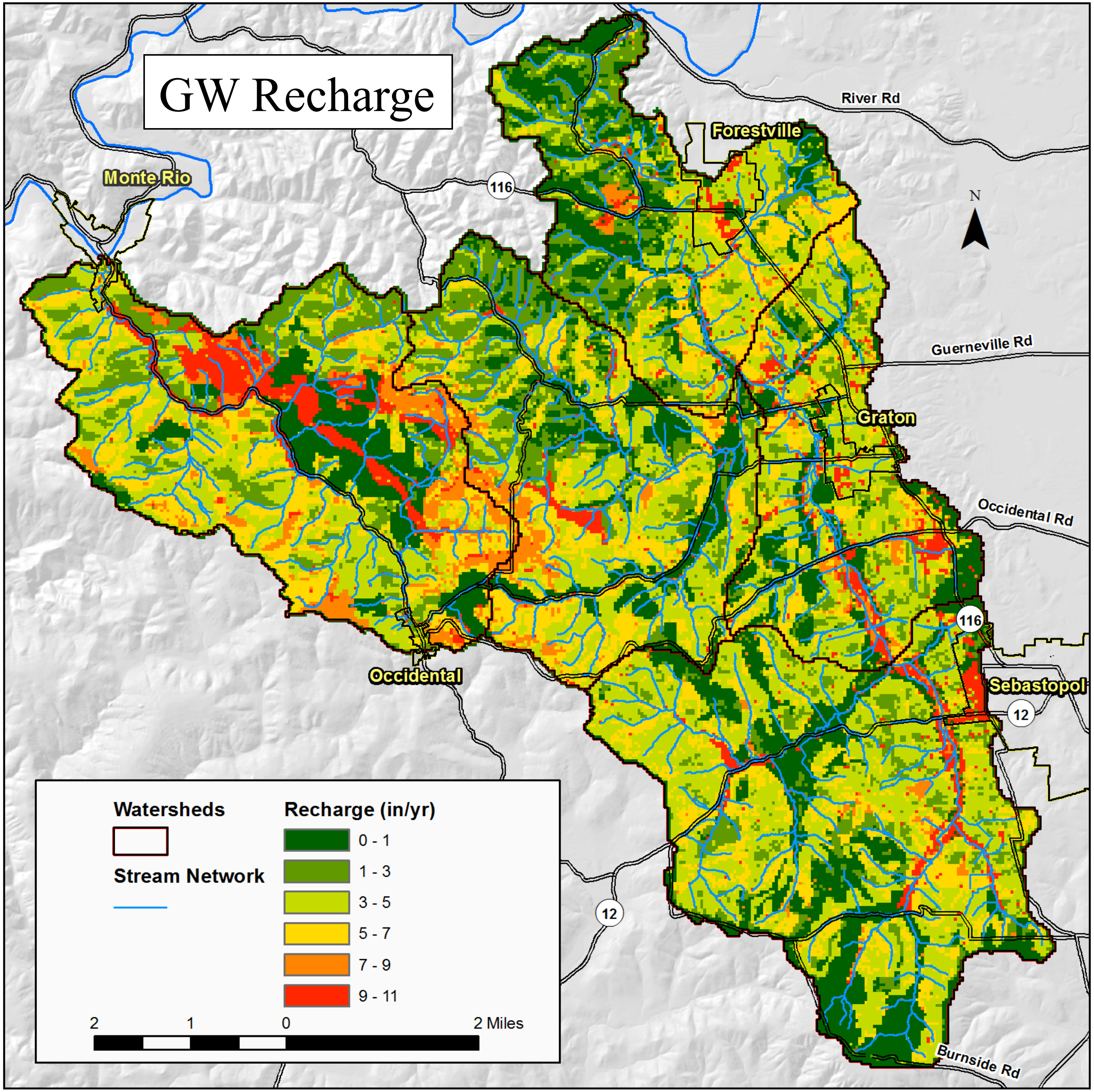






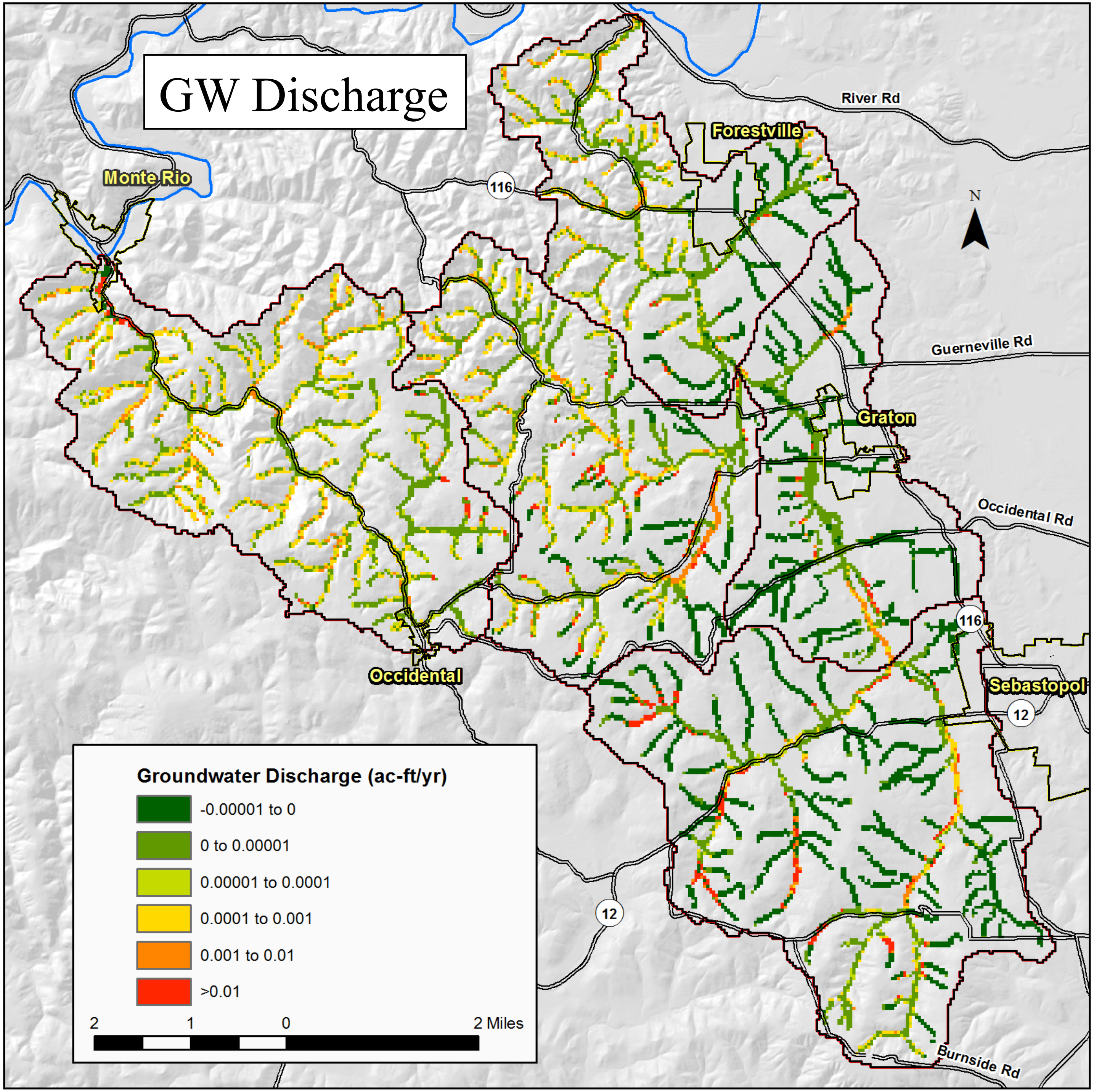
Results: Water Budget



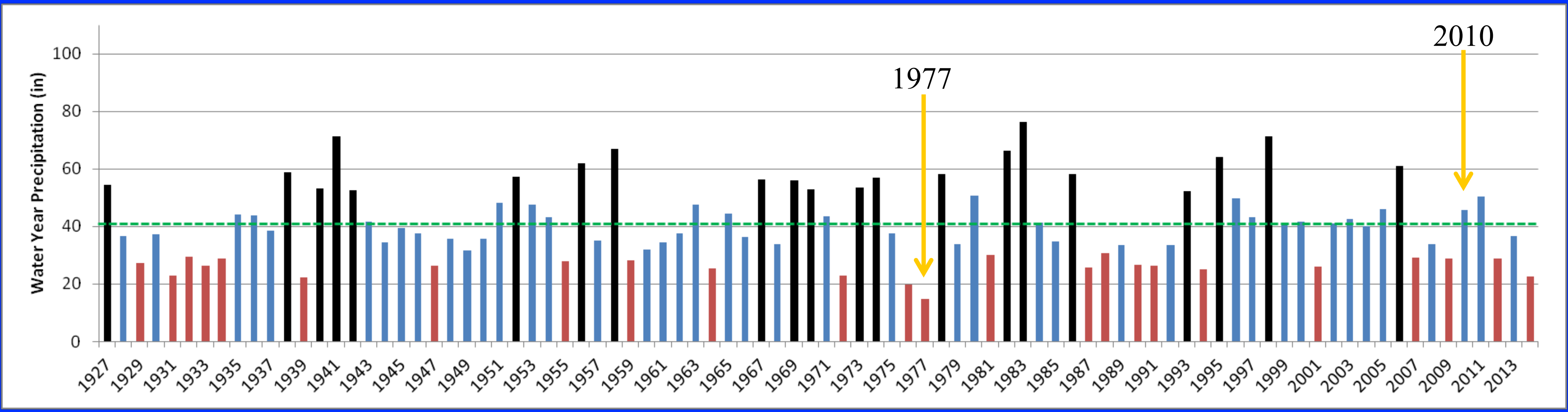


GW Recharge
River Rd
Forestville
Monte Rio
116
N
Guerneville Rd
Graton
Occidental Rd
116
Occidental
Sebastopol
12
12
Burnside Rd
Watersheds
Stream Network
Recharge (in/yr)
0 - 1
1 - 3
3 - 5
5 - 7
7 - 9
9 - 11
2
1
0
2 Miles

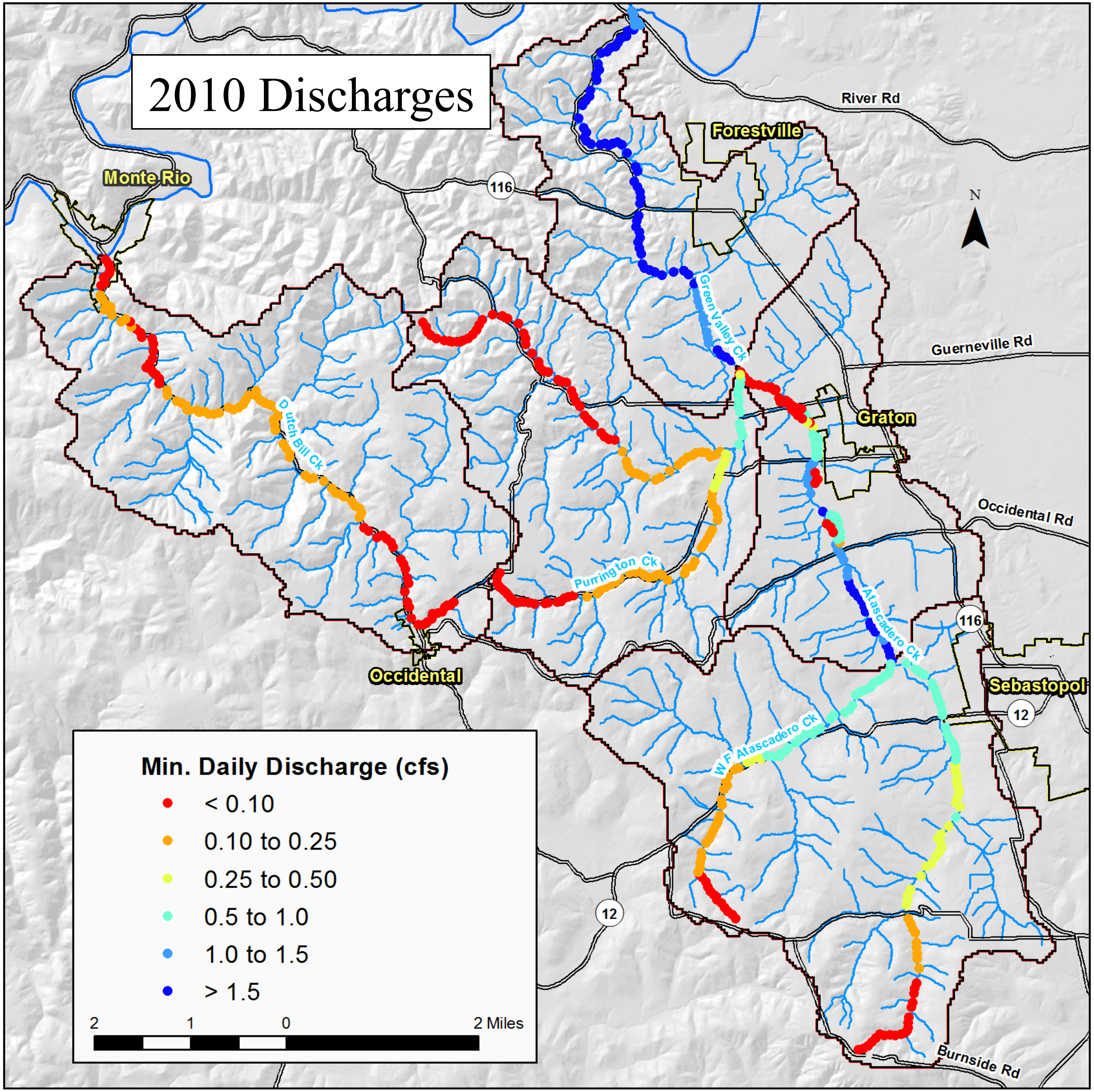
GW Discharge



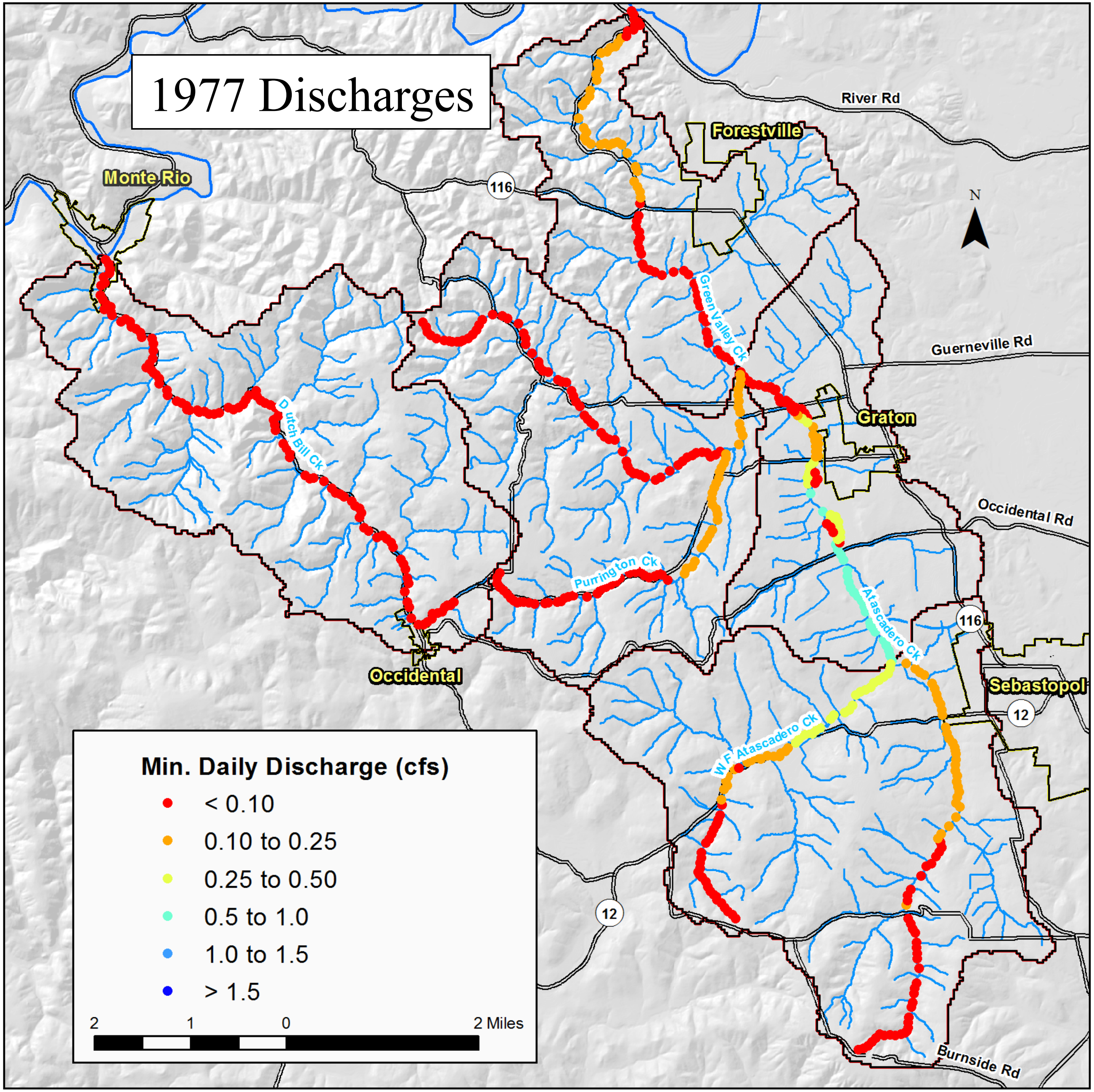
Hydrologic Conditions



- WY 2010 – Average Conditions (45.6 in)
- WY 1977 – Drought Conditions (14.6 in)

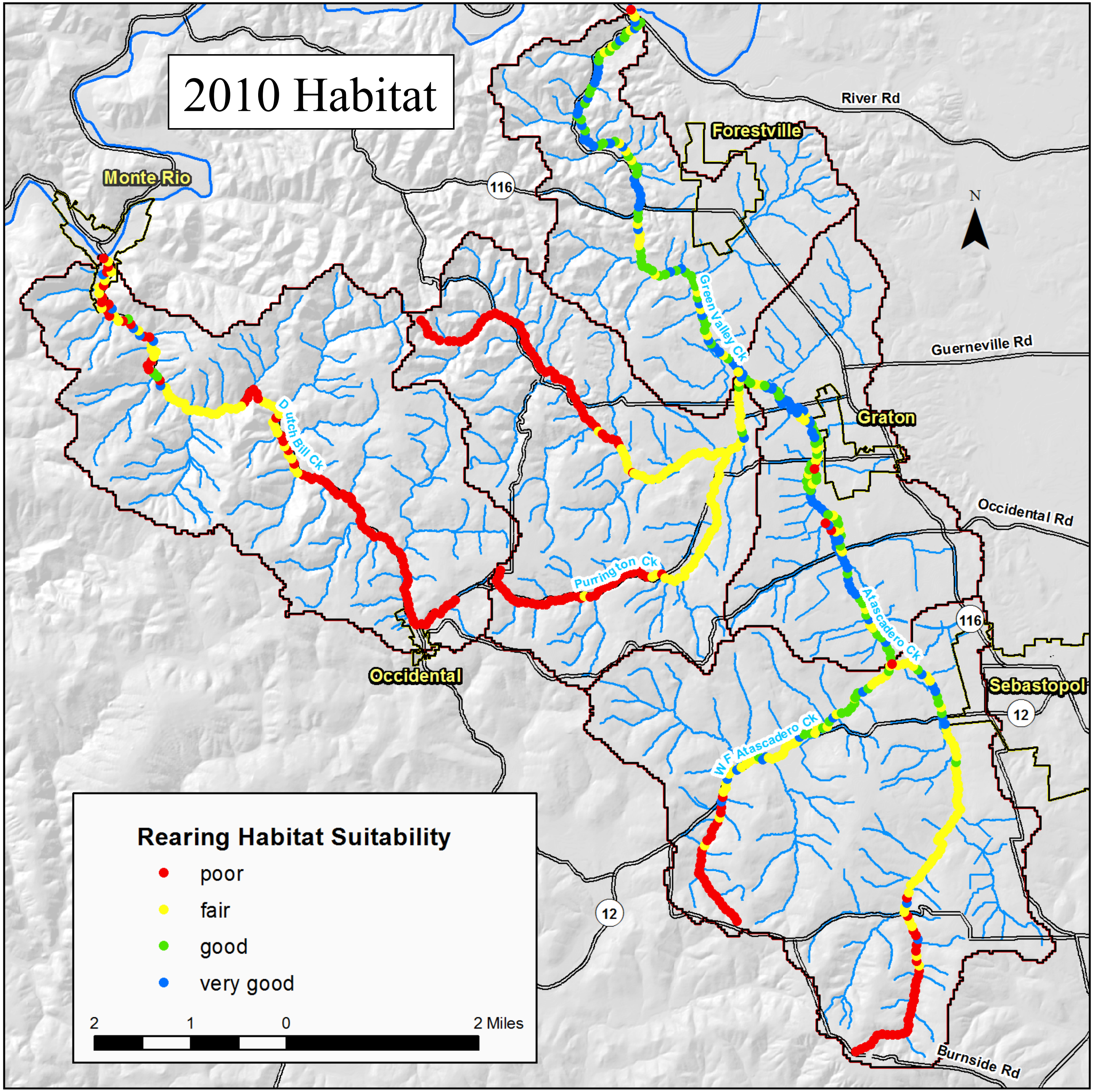

2010 Discharges
River Rd
Forestville
Monte Rio
116
Green Valley Ck
Guerneville Rd
Graton
Dutch Bill Ck
Occidental Rd
Purrington Ck
Atascadero Ck
116
Occidental
Sebastopol
12
W F Atascadero Ck
Min. Daily Discharge (cfs)
< 0.10
0.10 to 0.25
0.25 to 0.50
0.5 to 1.0
1.0 to 1.5
> 1.5
2
1
0
2 Miles
12
Burnside Rd
N

1977 Discharges



From Model Results to Habitat Suitability

- Critical riffle depth concept applied to simulated minimum daily flow depths
- Habitat Suitability Classes
  - Poor <0.1-ft
  - Fair 0.1 to 0.3-ft
  - Good 0.3 to 0.5-ft
  - Very Good >0.5-ft


2010 Habitat
Monte Rio
Forestville
River Rd
116
Guerneville Rd
Graton
Occidental Rd
Sebastopol
12
Occidental
Burnside Rd
Dutch Bill Ck
Green Valley Ck
Purrington Ck
Atascadero Ck
W.F. Atascadero Ck
N
Rearing Habitat Suitability
poor
fair
good
very good
2
1
0
2 Miles

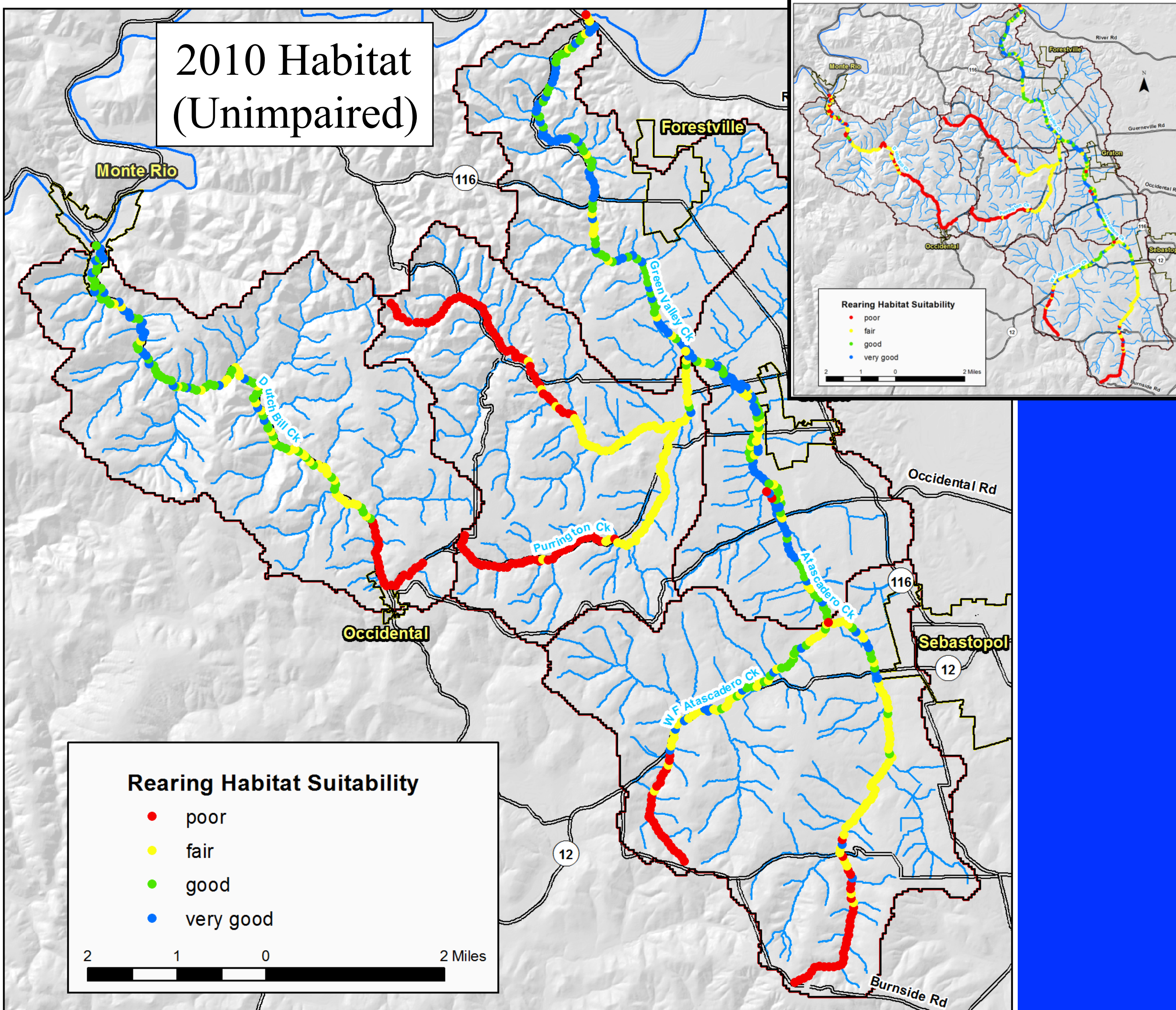
Existing Habitat

Hydrologic Condition	Habitat Quality	Available Habitat (miles)				
		Atascadero Creek	Upper Green Valley Creek	Lower Green Valley Creek	Dutch Bill Creek	All
Average	fair	5.9	4.2	0.8	2.9	13.7
	good	2.1	0.2	2.5	0.2	5.0
	very good	3.0	0.1	2.2	0.3	5.6
	Total	**11.0**	**4.4**	**5.5**	**3.4**	**24.3**
Drought	fair	6.6	3.2	3.6	1.6	15.0
	good	1.2	0.0	0.6	0.1	1.8
	very good	1.5	0.1	1.0	0.3	2.8
	Total	**9.3**	**3.3**	**5.1**	**2.0**	**19.7**

Model Scenarios

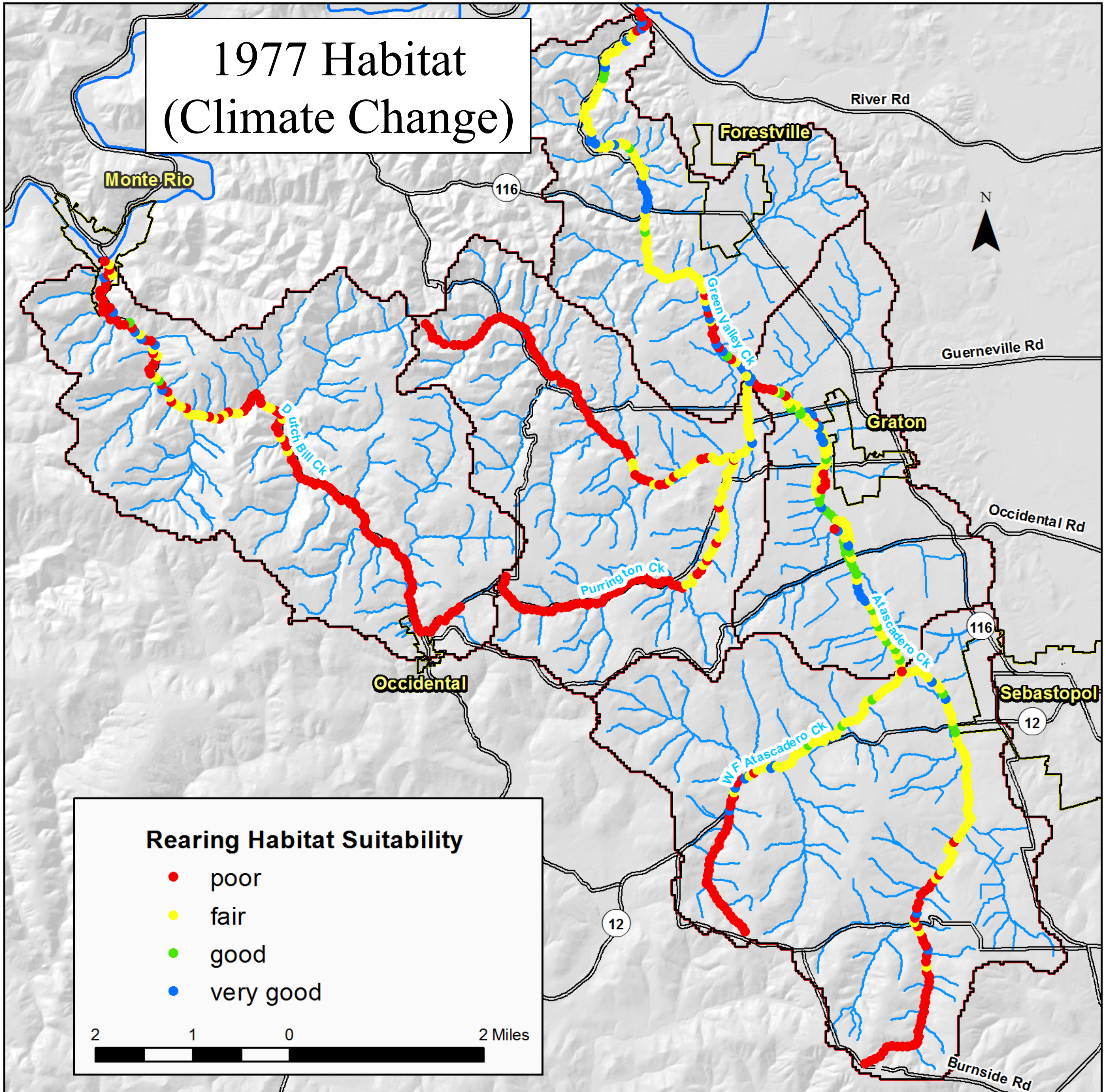
- Unimpaired
- Climate Change
  - Temperature increase of 3 to 4.3 degrees C
- Land Use Changes
  - Orchard to vineyard conversions
- Flow Augmentation
- Water Use Changes
  - Replacing direct diversions with groundwater
  - Reducing frost protection demands (microsprinklers)

2010 Habitat (Unimpaired)



Unimpaired Habitat

Hydrologic Condition	Additional Good/Very Good Habitat (feet)				
	Atascadero Creek	Upper Green Valley Creek	Lower Green Valley Creek	Dutch Bill Creek	All
Average	2,096	264	629	20,123	22,848
Drought	4,192	422	2,725	19,075	25,992



1977 Habitat
(Climate Change)
Rearing Habitat Suitability
poor
fair
good
very good
2
1
0
2 Miles
N
Monte Rio
Forestville
Graton
Occidental
Sebastopol
River Rd
Guerneville Rd
Occidental Rd
Burnside Rd
116
116
12
12
Dutch Bill Ck
Green Valley Ck
Purrington Ck
Atascadero Ck
W.F. Atascadero Ck

Climate Change Habitat

Hydrologic Condition	Loss of Good/Very Good Habitat (feet)				
	Atascadero Creek	Upper Green Valley Creek	Lower Green Valley Creek	Dutch Bill Creek	All
Average	-1,887	-218	-1,467	-21	-3,592
Drought	-2,112	-419	-3,354	-16	-5,901

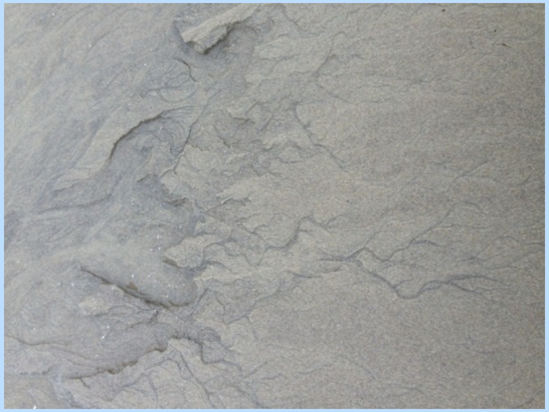
Summary

- Quantified spatial and temporal variability in flow and habitat conditions
- Marginal flow and habitat quality under existing conditions
- Significant increase in habitat extent and quality under unimpaired conditions
  - Changes are greatest under drought conditions
  - Significant opportunity for improvements in Dutch Bill
- Variable response to climate change
  - Smaller effects in Upper Green Valley and Dutch Bill
  - Larger effects in Lower Green Valley and Atascadero

Predicting Tidal Lagoon Response to Future Conditions Using a Simple Quantified Conceptual Model

Dane Behrens, PhD, PE ESA PWA

With Bob Battalio, PE, Matt Brennan, PhD, Christina Toms, Louis White, PE, Elena Vandebroek, PE, Philip Williams, PhD, PE



Overview

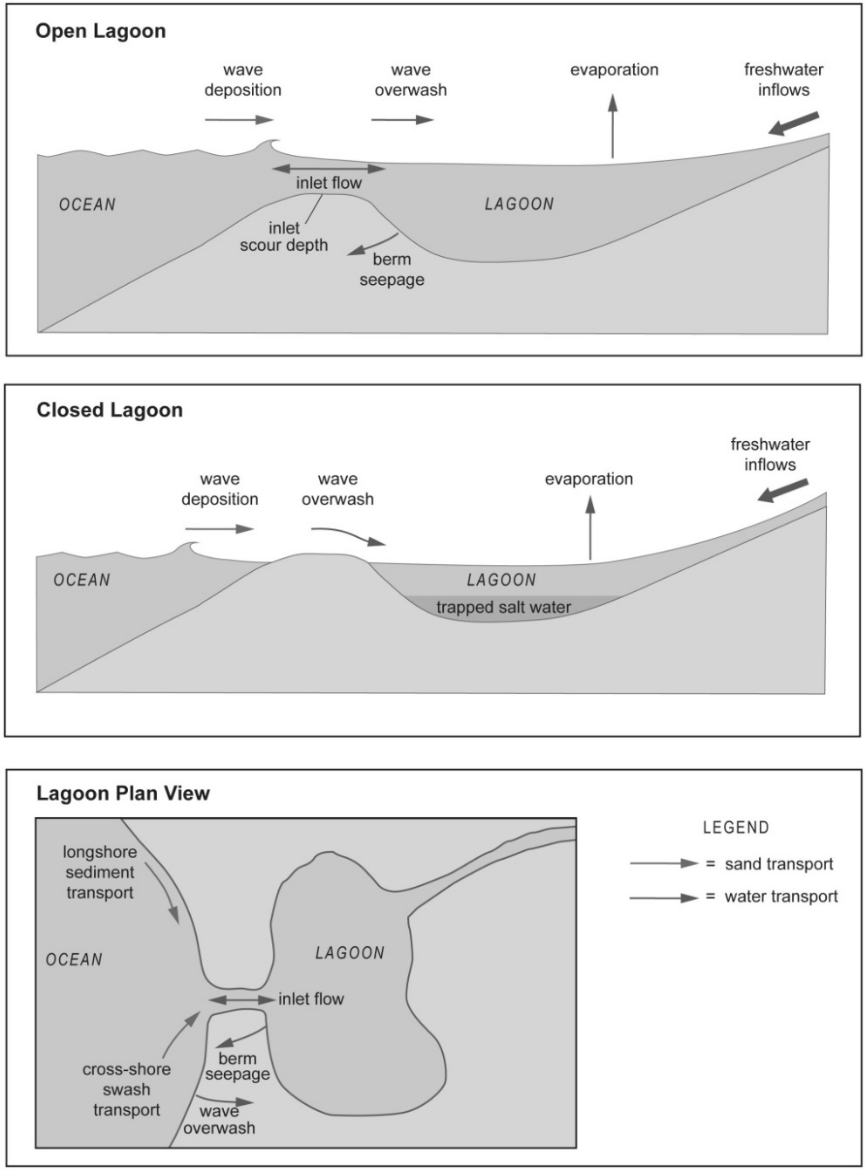
- California Coastal Lagoons
  - *Processes*
  - *Challenges*
  - *Information Needs*

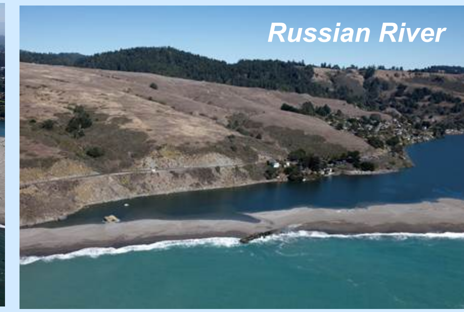
- Modeling Approach

- Example - Impacts of Climate Change
  - *Russian River Estuary*
  - *Smaller lagoons*

- Synthesis

CA Lagoons: *Key Processes*

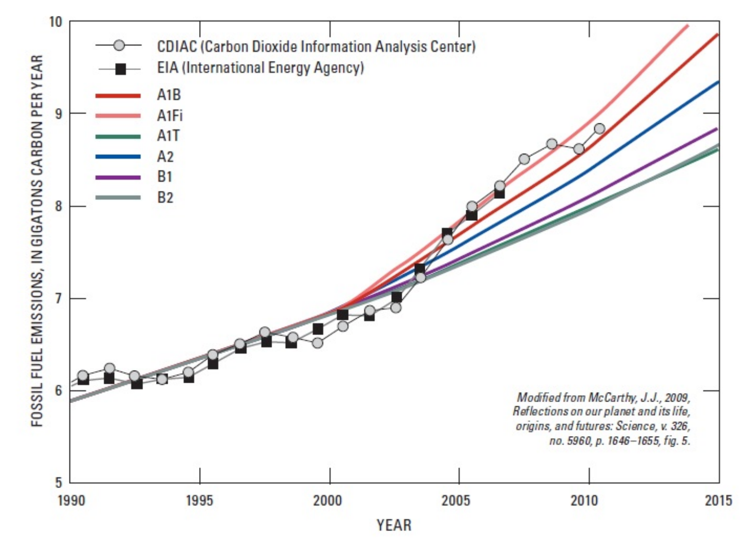




www.californiacoastline.org

CA Lagoons: *Challenges*

- **Sea level rise – upward adjustment of SLR curves**
- **Population growth - development**
- **Potential precip changes (Flint and Flint 2012)**
  - **Longer and drier summers regardless of precipitation trend**
  - **Greater variability in precipitation**
  - **Increased numbers of extended dry periods**
- **Nutrient loading**
- **Infrastructure, sedimentation influence habitat space**



McCarthy (2009)

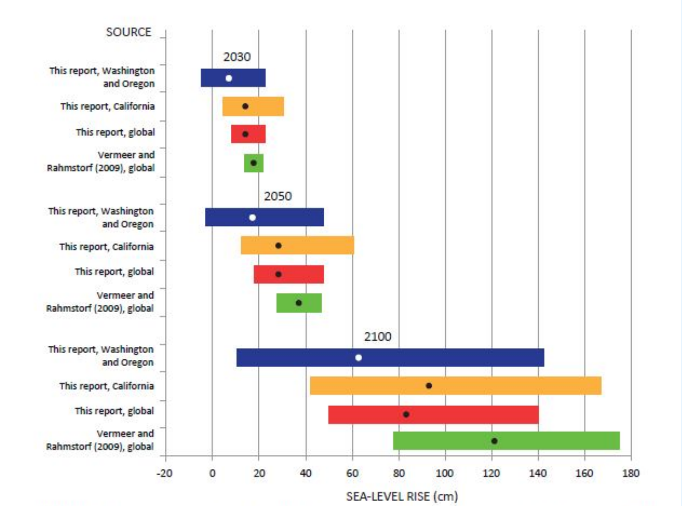


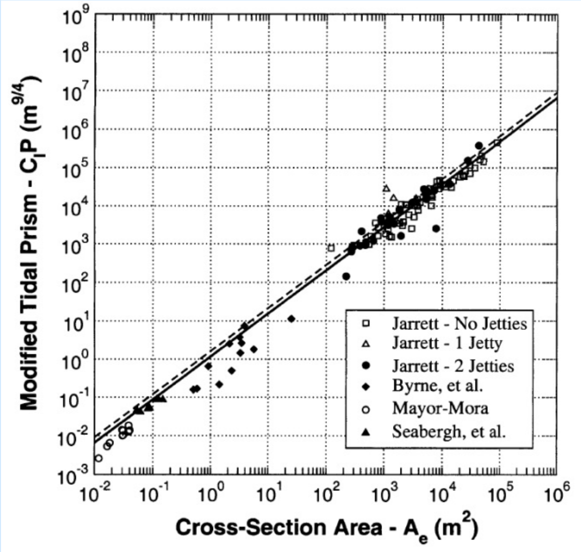
FIGURE 5.10 Committee's projected sea-level rise for California, Oregon, and Washington compared with global projections. The dots are the projected values and the colored bars are the ranges. Washington and Oregon = coastal areas north of Cape Mendocino; California = coastal areas south of Cape Mendocino.

NRC (2012)

ESA PWA

What Types of Tools Are Available?

Empirical Models for inlet geometry



- Useful, but need to be careful with interpreting broadly

Data-driven models of inlet closure

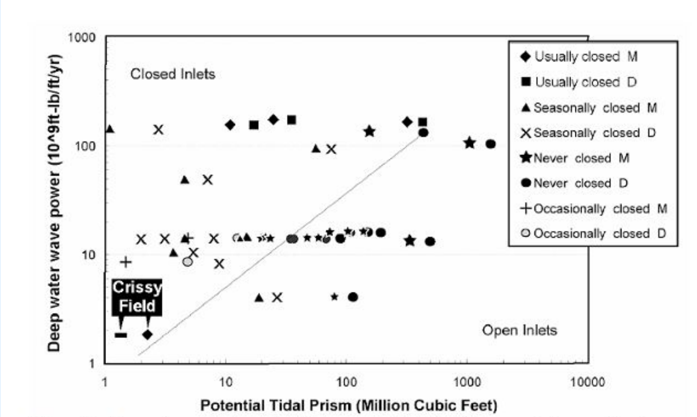
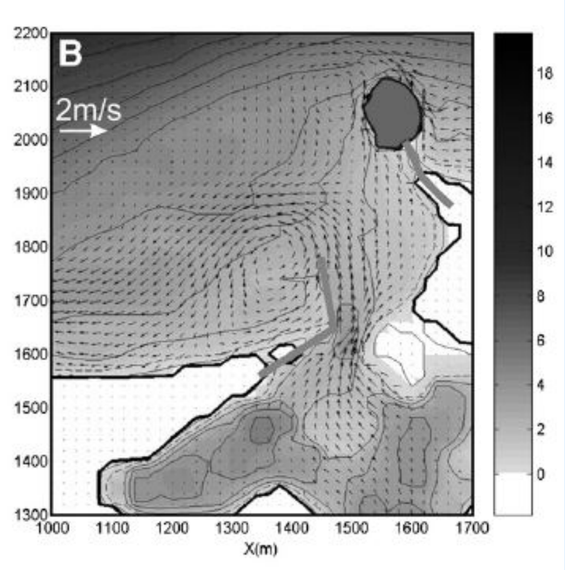


Figure 8. Power-based index of inlet closure potential with corrected annualized wave power. "M"=Mean tidal prism and "D"= diurnal tidal prism.

- Useful for big picture
- Neglects time-varying nature

2D/3D numerical models



- High accuracy, but expensive and difficult

Each of these tools answers different questions. Need some combination to answer the question of habitat

ESA PWA

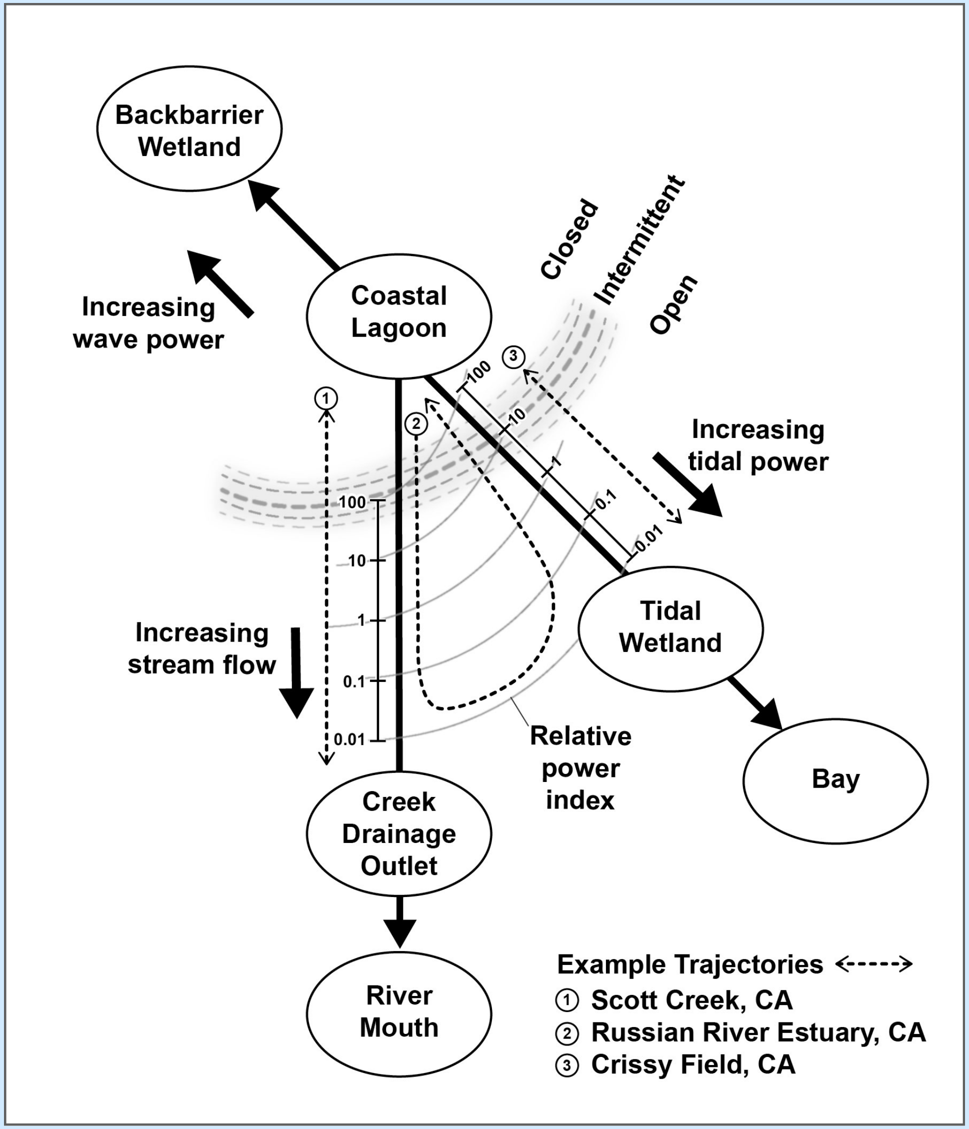
CA Lagoons: *Information Needs*

How do management actions, climate change, development, influence habitat?

- **Direct impacts**
- **Indirect impacts**

How does habitat vary throughout the season, from year to year?

- **Mouth "Always Open" or "Always Closed" is rare in CA.**
- **When open, how tidal is it?**
- **When closed, seepage, ET, wave overwash have strong impacts on hydrology**



Behrens et al. (in review)

How do we address these needs?

Goal:

- **Create a way of quantifying habitat changes**
  - **Quantify proven conceptual models**
  - **Leverage ongoing research**
  - **Leverage aspects of older models that worked well**

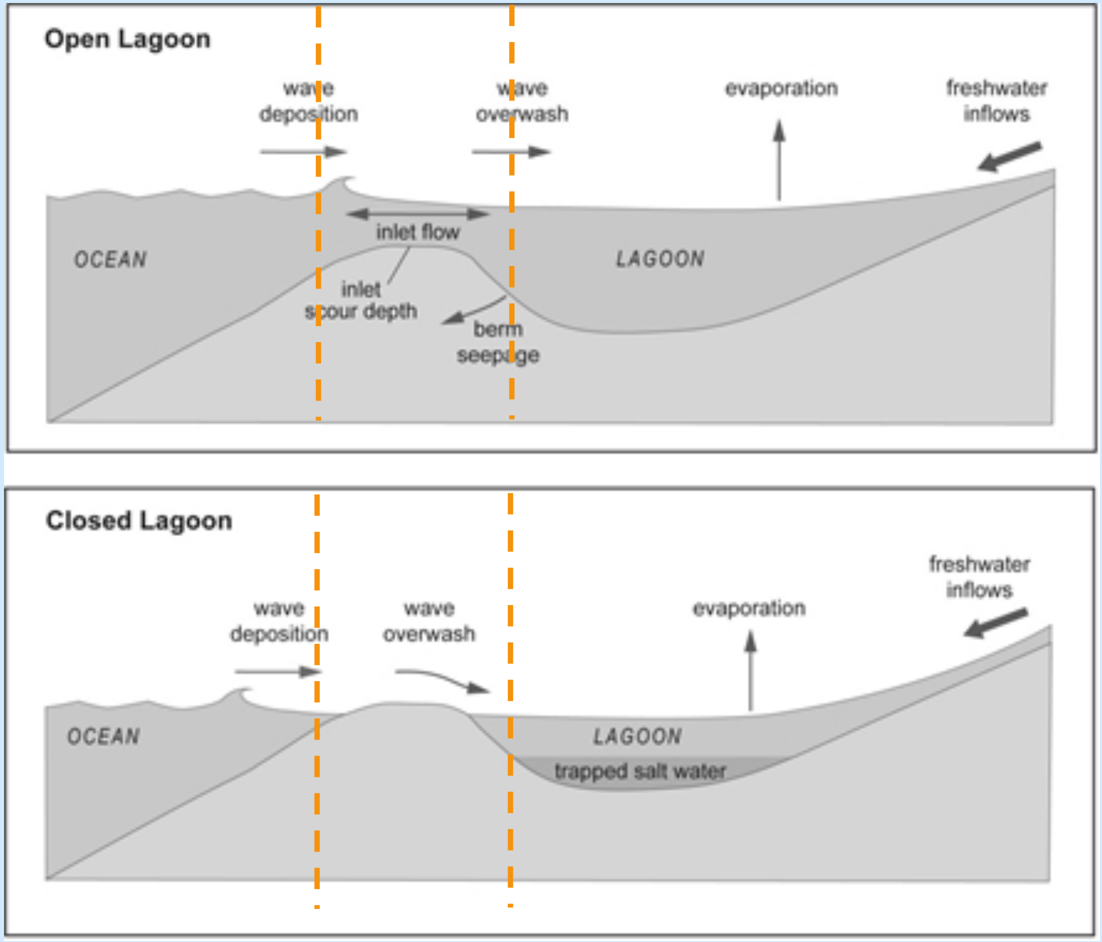
Modeling Approach: *Quantified Conceptual Model*

Site-Specific Characteristics
- Lagoon hypsometry
- Beach shape, sediment size
- Boundary conditions

Coastal Forcing
- Tides – affect inlet hydraulics
- Waves – affect beach/inlet

Lagoon Hydrology
- Apply water balance

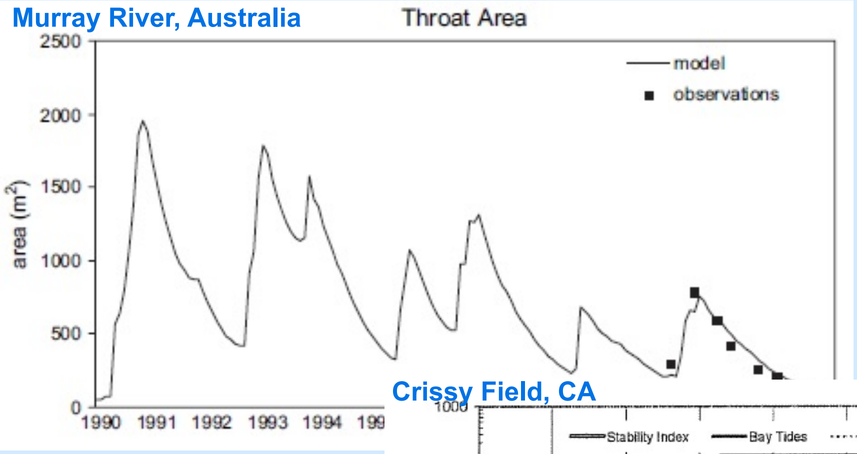
Inlet/Beach Morphodynamics
- Movable channel bed
- Inlet flows from 1D momentum or empirical
- Inlet geometry from empirical relations
- Sedimentation from wave action
- Erosion from channel hydraulics

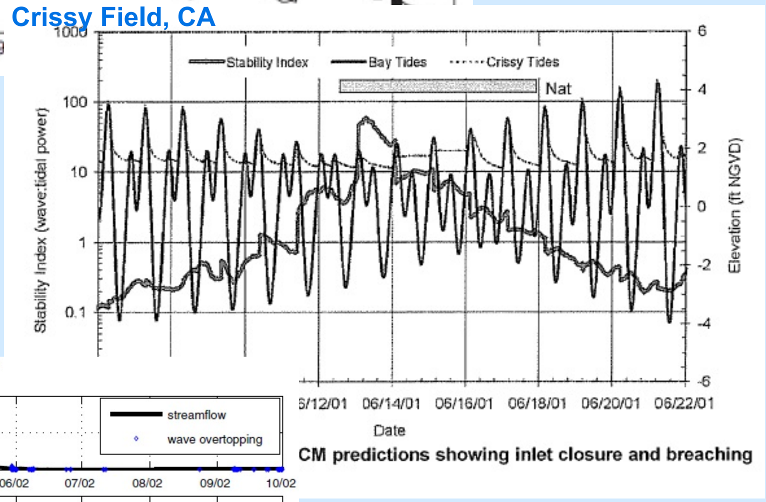


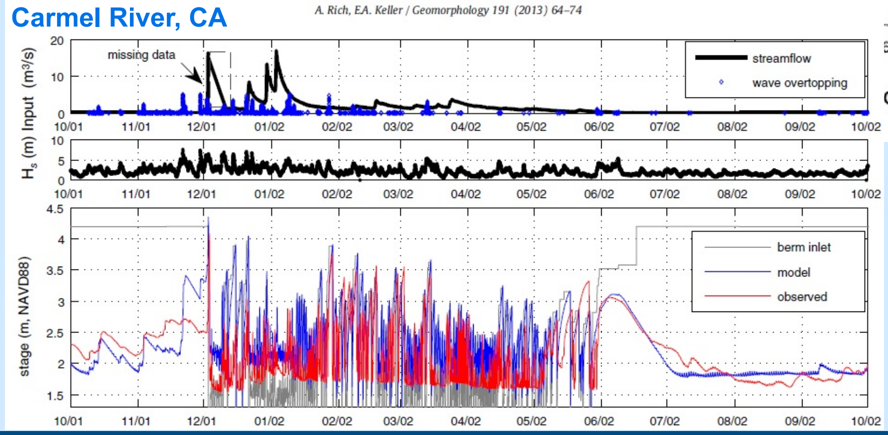
Quantified Conceptual Model

Development

- Williams and Cuffe (1993)
- Goodwin (1996)
- Shuttleworth et al (2005)
- Battalio et al (2006)
  - Crissy Field
- Rich and Keller (2012, 2013)
  - Carmel River
  - Devereux Slough
- ESA PWA (2010-2015)
  - Scott Creek
  - Mission Creek
  - Devereux Slough
  - Goleta Slough
  - Russian River



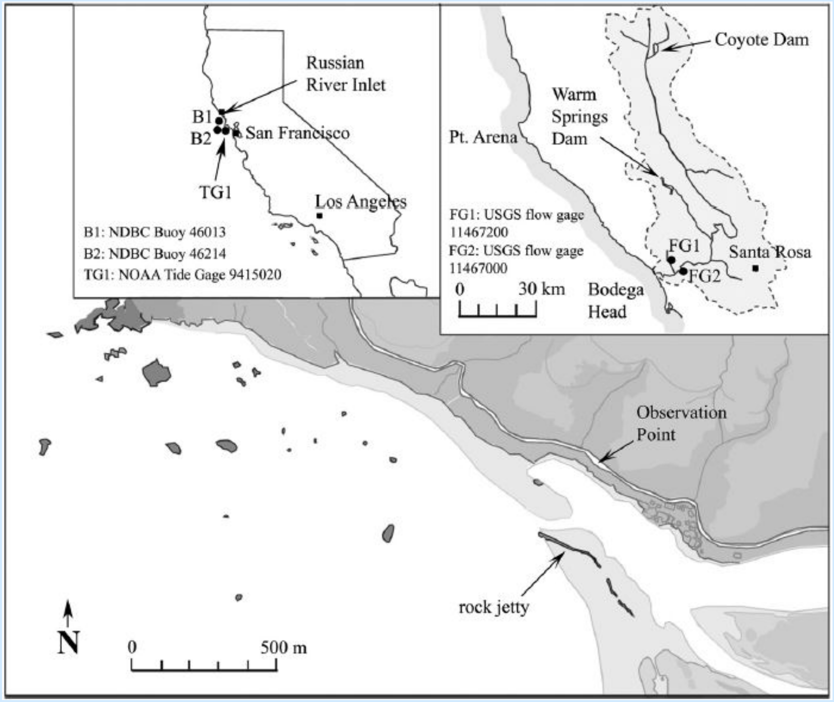




ESA PWA

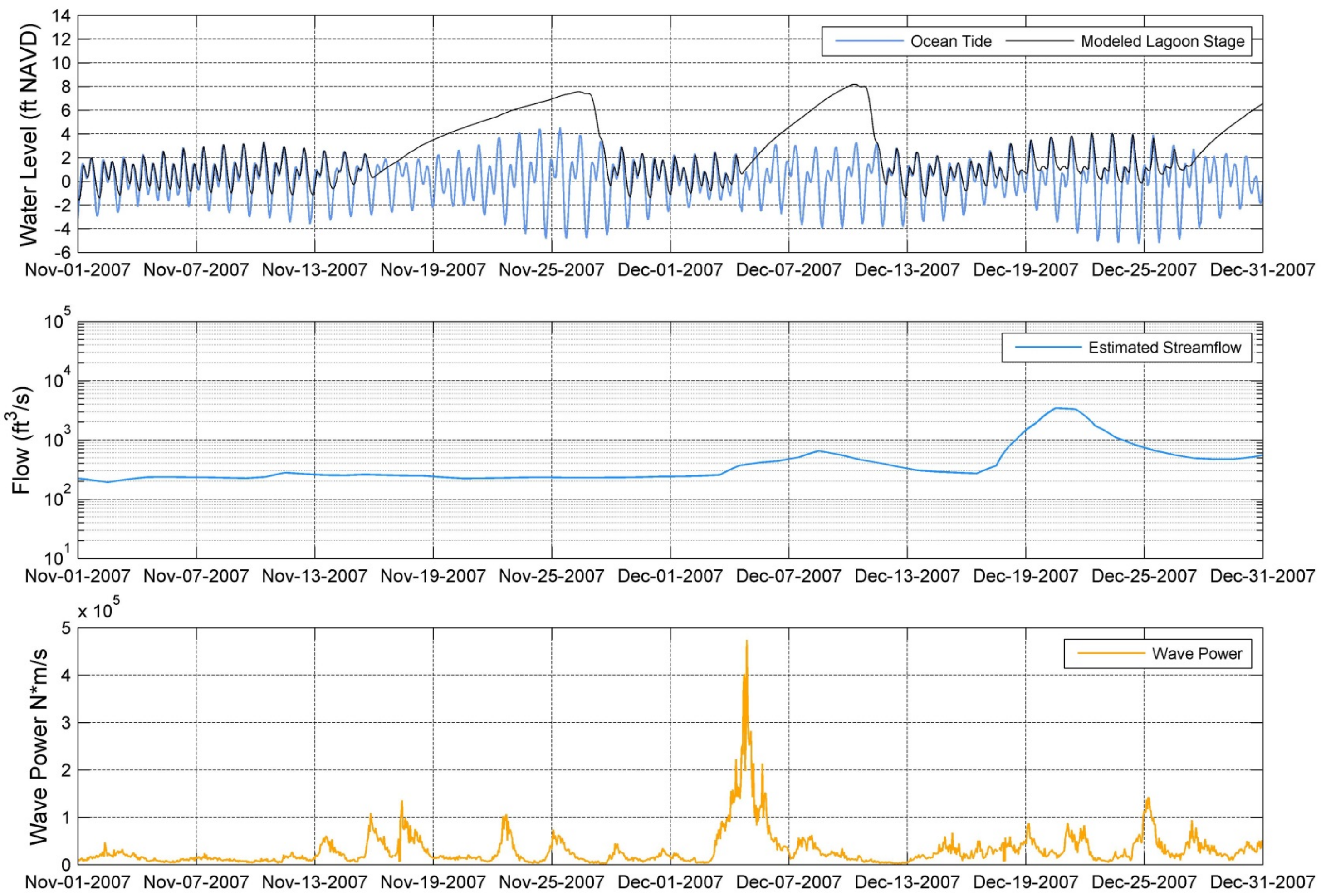
Case Example: *Russian River (Sonoma County)*

- Large tidal prism (1600 Ac-ft)
- Annual floods: 10,000-100,000 cfs
- Closes 0-20 times per year
- Heavily managed (base flow maintained)
- Model run from 2001-2010



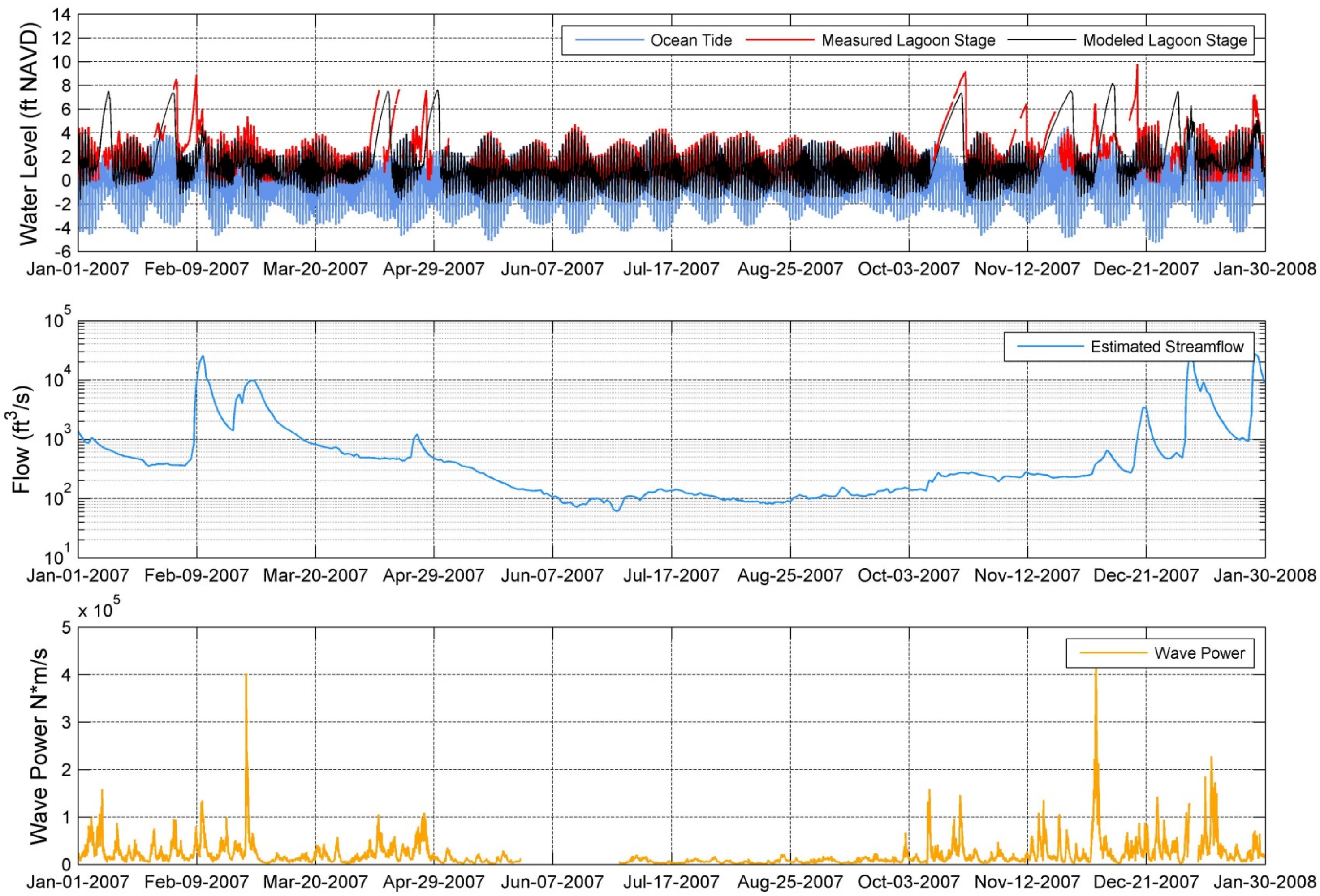
www.californiacoastline.org

Case Example: *Russian River*

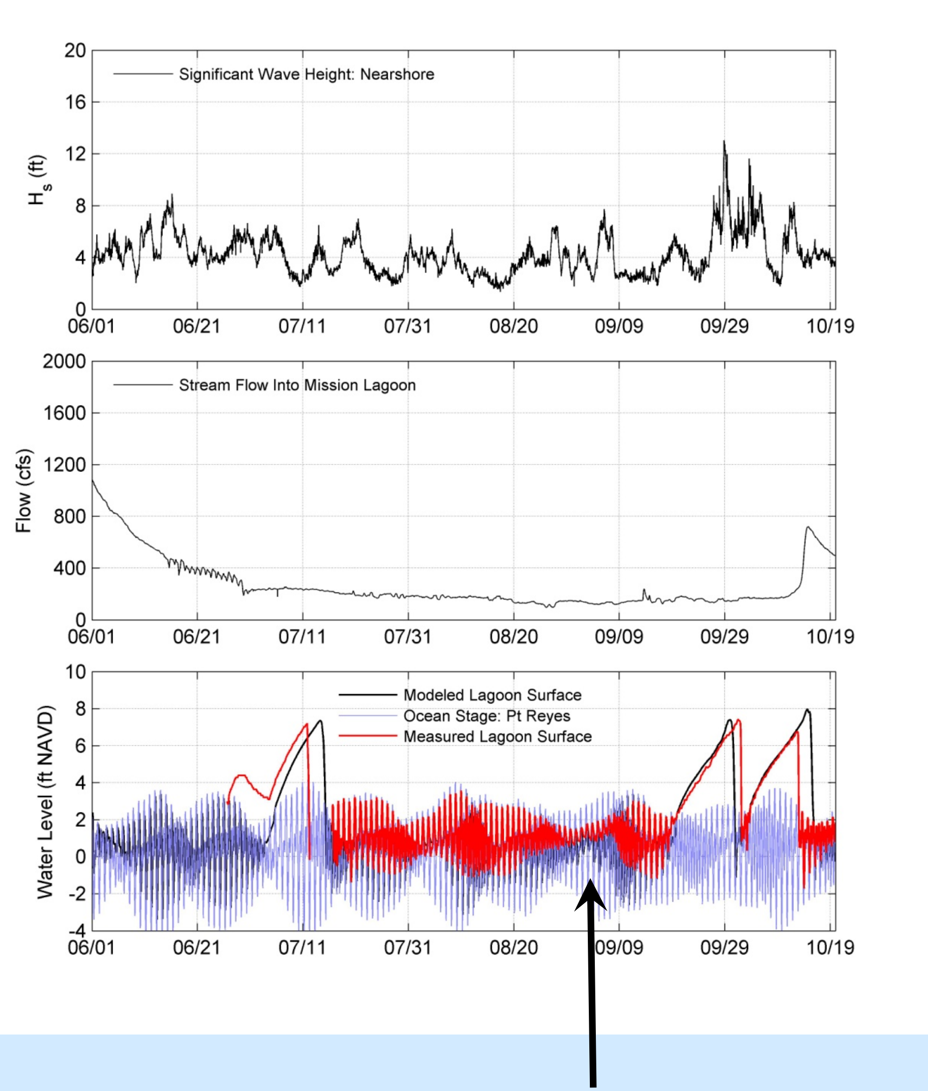


ESA PWA

Case Example: *Russian River*



Case Example: *Russian River*



ESA PWA

Potential Climate Change Impacts: Precipitation/Runoff

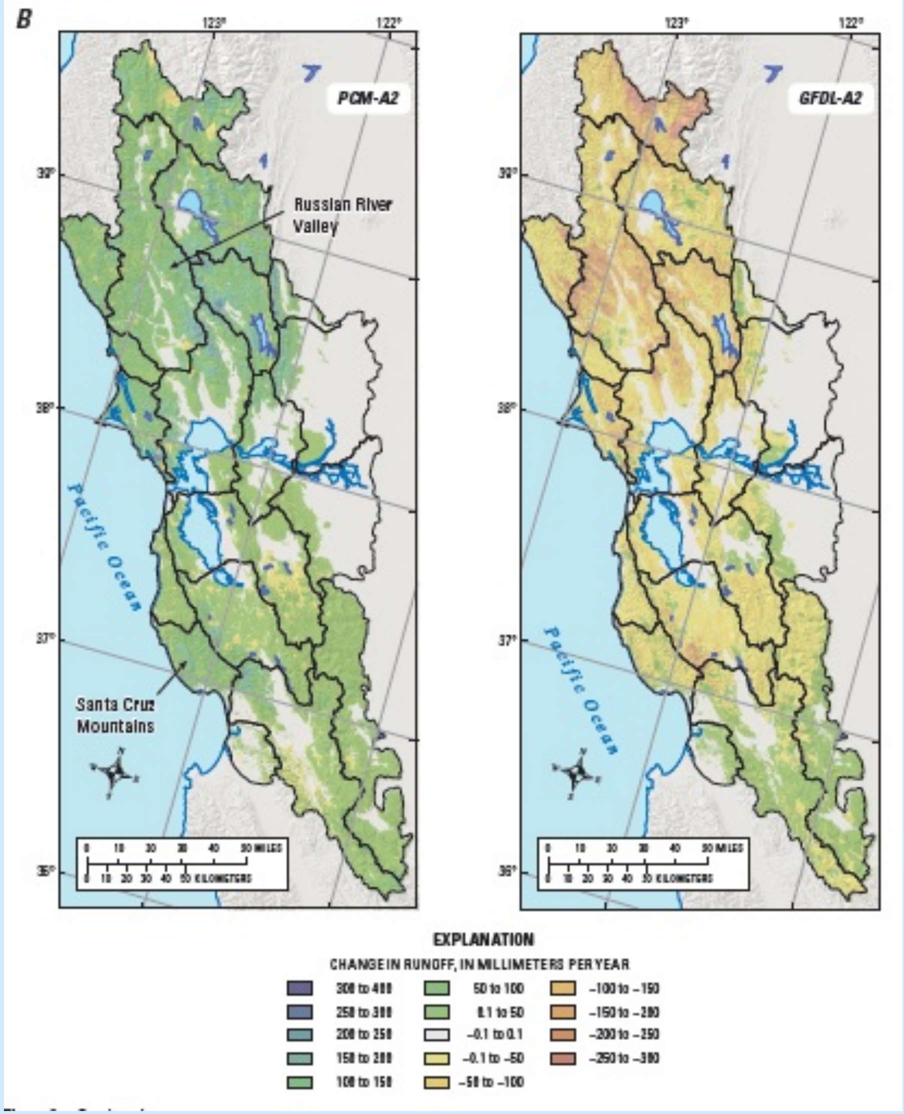
GCM downscaling

- Temperature and precipitation trends downscaled using statistical techniques
- Two emission scenarios
  - A2: “medium-high” emissions
  - B1: “low” emissions
- Calibrated to 17 stream gage locations

Potential Trends

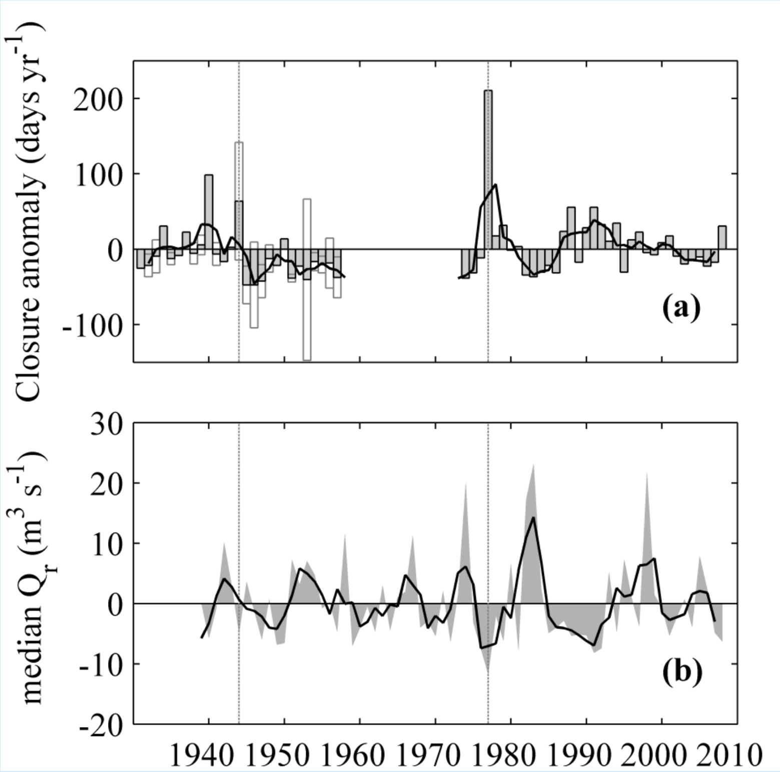
- Models differ in results
- Shift in peak Jan to Feb
- Less fall (Oct-Nov) and spring (Apr-May) precipitation
- ET increases

Parallel Climate Model | **NOAA CM2.1 Model**



ESA PWA

Why Runoff is Important to Habitat: *Observations*

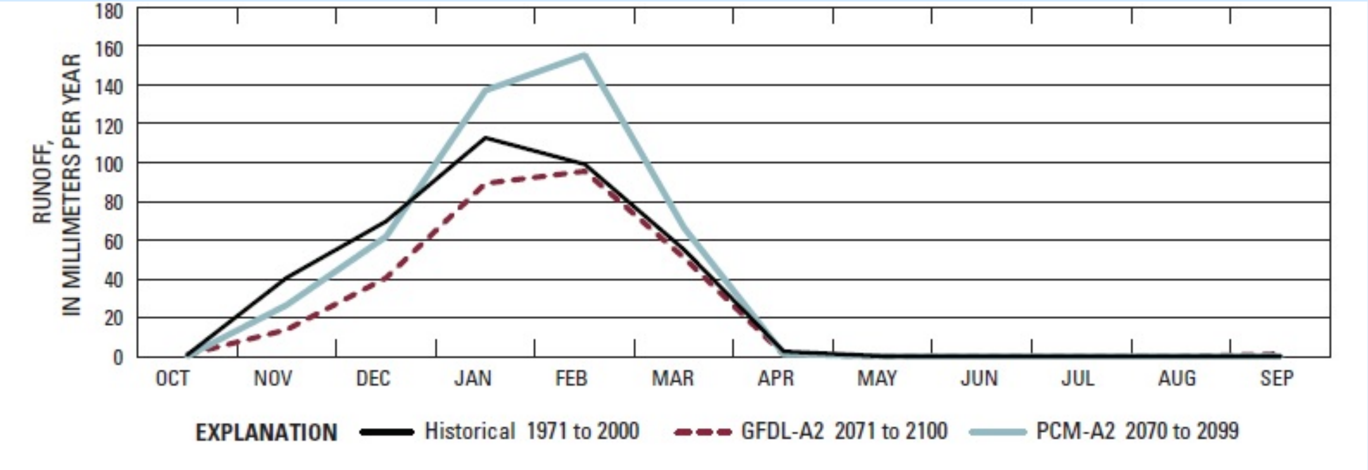


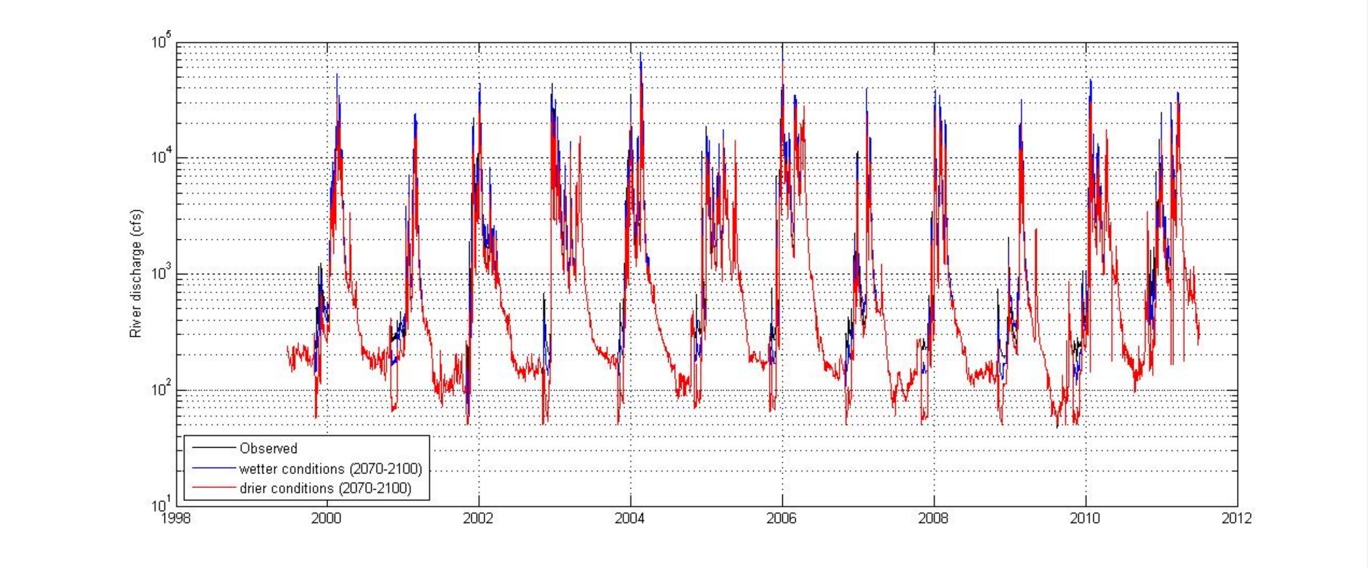
Behrens et al. 2013

Influence on length of closure

- Higher flows shorten the length of closures

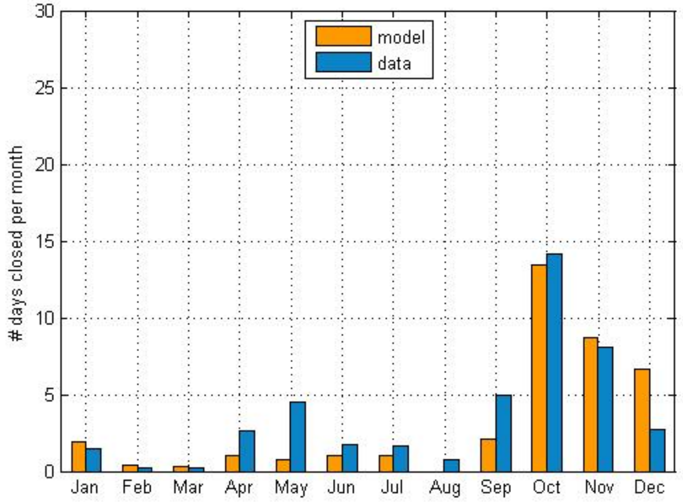
Potential Change in Runoff



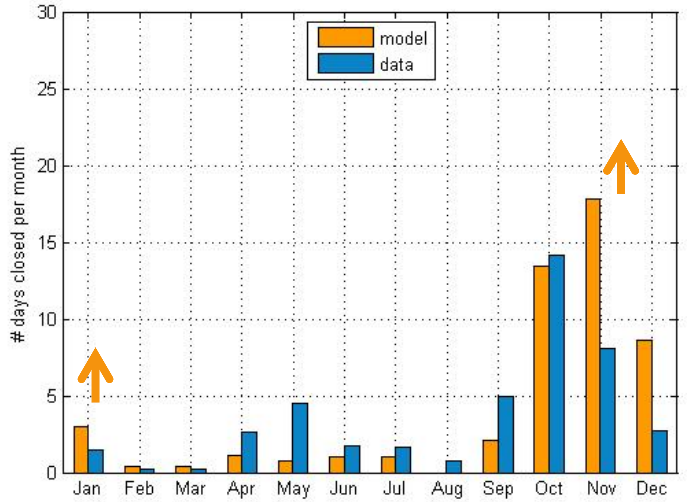


Model: *Response to Change*

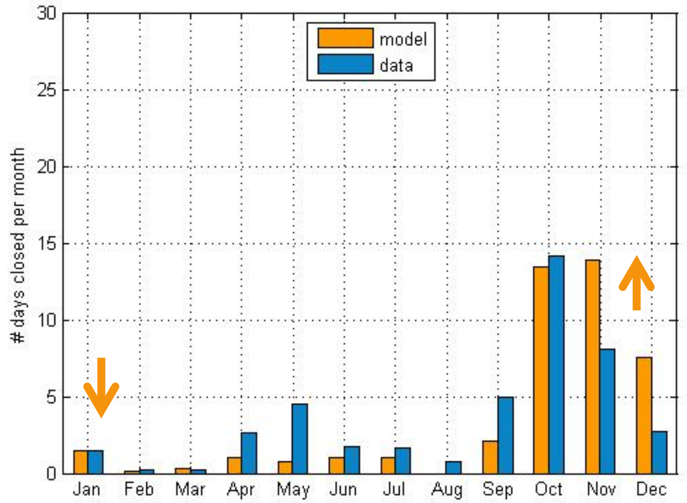
Observed Inflows



Drier conditions (2070-2100)



Wetter conditions (2070-2100)



Either route could lead to more inlet closure

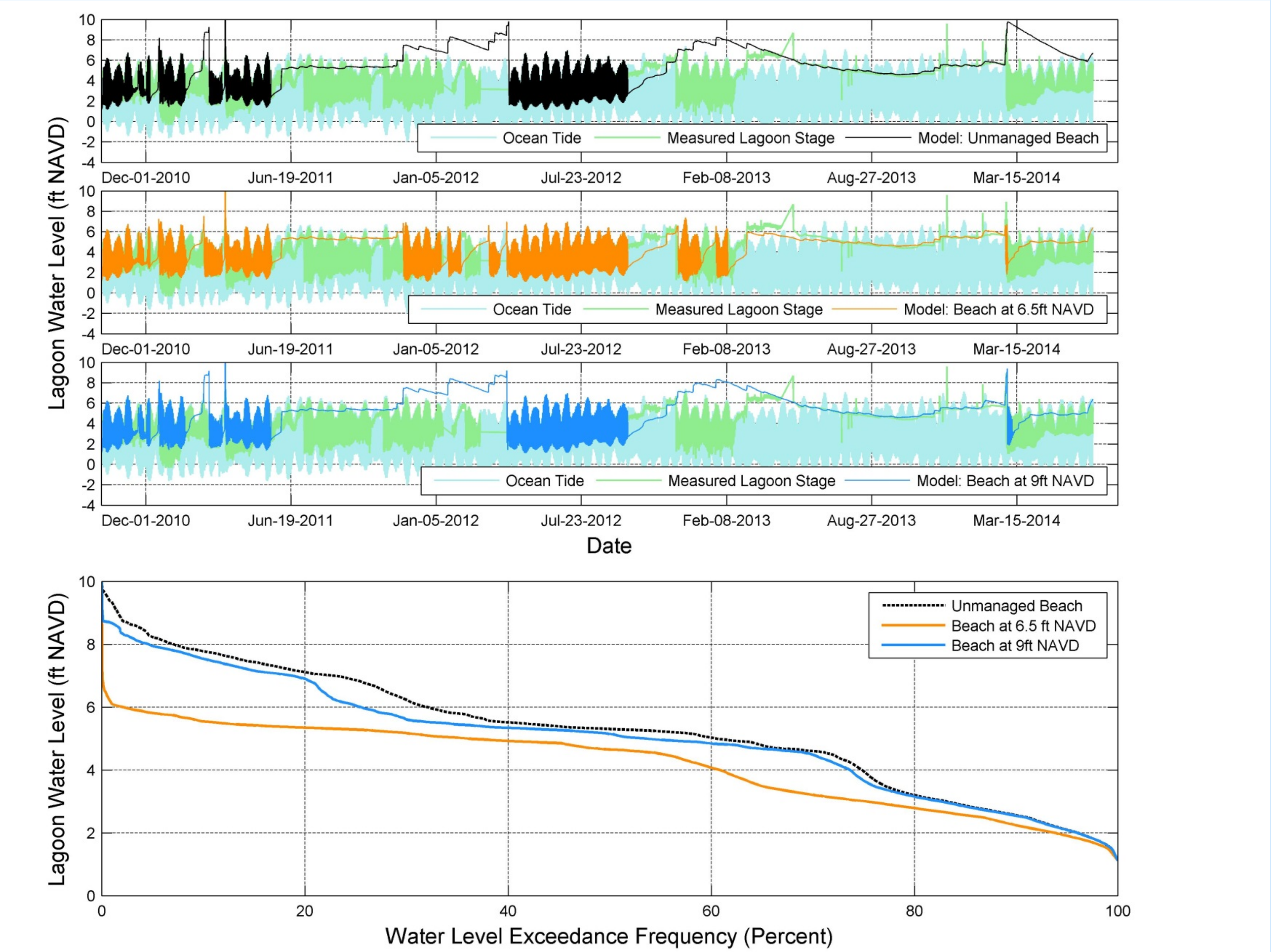
Case Example: *Representative smaller lagoon*

- **Small tidal prism (150 Ac-ft)**
- **Peak floods: <10,000 cfs**
- **Closes seasonally**
- **Lagoon extremely sensitive to changes in freshwater flow**

Potential Case Examples:

- **Combine SLR and Immobility of infrastructure**
- **Reduction in habitat space from landward beach retreat**
- **Changes in runoff**
- **Changes in ET**

Case Example: *Representative smaller lagoon*



ESA PWA

Summary

Linkages between stressors (management actions, climate change, development) and salmonid habitat still need understanding

Time series "QCM" approach has potential for relating these things

- **Still a work in progress, but low cost and provides meaningful results**
- **Allows comparison of a range of different scenarios**

Ongoing projects will help with development across a broader range of lagoons

- **Russian River**
- **San Lorenzo River**
- **Mission Creek**
- **Goleta Slough**

Acknowledgements

ESA PWA:

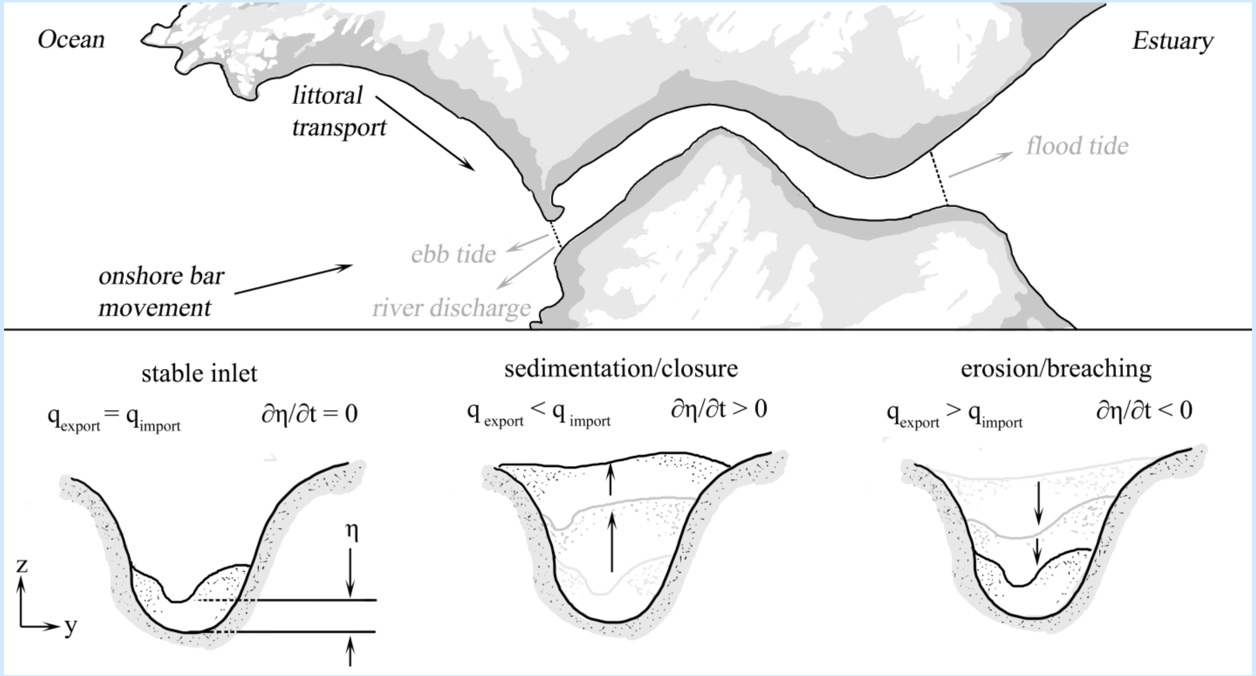
Matt Brennan, Bob Battalio, Christina Toms, Louis White, Elena Vandebroek, Eddie Divita, To Dang

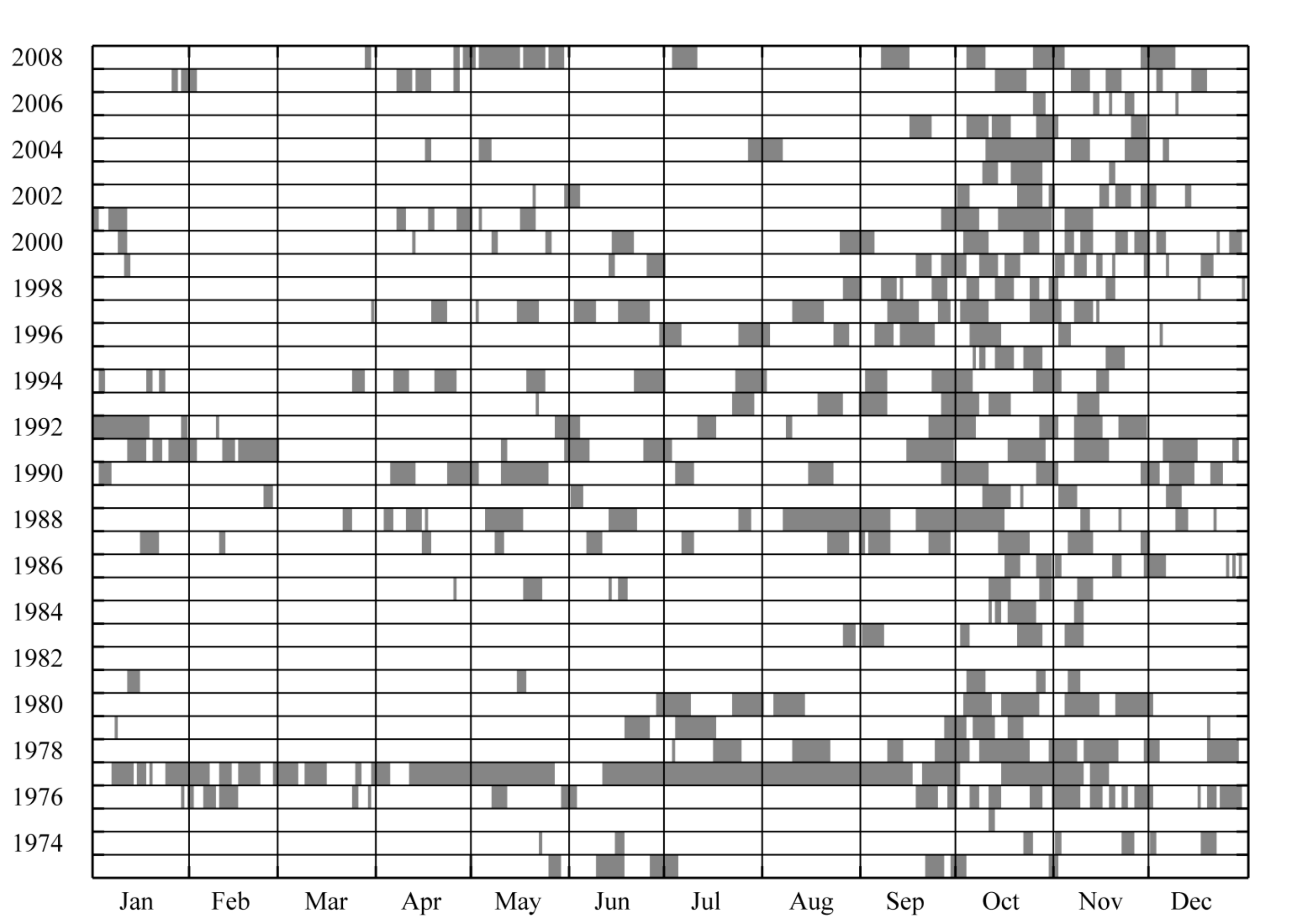
SCWA:

Chris Delaney, Jessica Martini-Lamb;

Discussions and Insight:

Andy Rich, Megan Williams, John Largier, Fabian Bombardelli, Dave Revell, Peter Goodwin, Phil Williams, Dave Hubbard


Ocean
Estuary
littoral transport
flood tide
ebb tide
onshore bar movement
river discharge
stable inlet
$q_{export} = q_{import}$
$\partial\eta/\partial t = 0$
sedimentation/closure
$q_{export} < q_{import}$
$\partial\eta/\partial t > 0$
erosion/breaching
$q_{export} > q_{import}$
$\partial\eta/\partial t < 0$
η
z
y


2008
2006
2004
2002
2000
1998
1996
1994
1992
1990
1988
1986
1984
1982
1980
1978
1976
1974
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec