Yuba County IRWMP | 2015 UPDATE

APPENDIX 11-2

Robust Decision Support

Authors: Vishal K. Mehta, Laura Forni, Nicholas Depsky and David Purkey (SEI);
Elizabeth Betancourt (Forsgren Inc)
Date: February 2014

ROBUST DECISION SUPPORT FOR THE YUBA IRWMP

Robust decision support (RDS) applies a participatory framework[1] to integrate the natural, social, and political aspects of water resource management in a quantitative model for Integrated Water Resource Management (IWRM). Water demand across sectors—agriculture, industry, energy, urban, environment—is affected by climate variability and further complicated by social and contractual issues amongst many users of the Yuba. These factors are difficult to integrate because social, political, and economic boundaries often overlap watershed boundaries and other physical delineations critical to water resources systems.

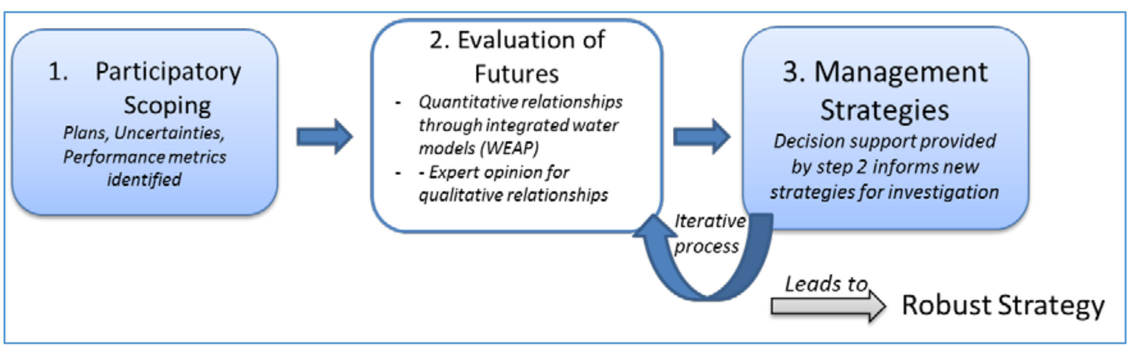
A. Methodology

In brief, the RDS process allows:

- Consideration of many possible futures (an ensemble) rather than a single best estimate;
- Prioritization of strategies that perform well across many possible futures rather than for one particular future; and
- Adaptive strategies for changing conditions.

RDS employs water resources computer models (in this case, using WEAP) and rich visualization of possible futures (in this case, using Tableau). The 3 three steps of RDS are shown in Figure 1 and described in detail below

Figure 1: The Robust Decision Support (RDS) Process



1. Participatory scoping: involves collecting stakeholders' issues of concerns, objectives and management strategies using a formal problem formulation framework called XLRM (Table 1). The XLRM Framework is comprised of:

[1] This approach has been shaped by the academic literature on decision making under deep uncertainty, most significantly by the Robust Decision Making approach described in "Shaping the Next One Hundred Years" by Lempert, Popper and Bankes. 2003. Santa Monica, CA. 187 pp.). RDM is a process rather than a fixed set of practices, and SEI uses the term Robust Decision Support for its rendition of RDM, to emphasize both its own rendition of RDM, as well as the fact that our goal is to support decision-making, not to make decisions for stakeholders.

- X: exogenous factors or uncertainties that are outside the control of water managers;
- L: management responses or levers that can be implemented by water managers;
- R: models that describe the relationships between uncertainties and levers; producing
- M: metrics of performance that can be used to evaluate various management options.

Table 2 shows how well the XLRM framework maps to the IRWMP language.

Table 1: The XLRM Problem formulation table

Exogenous Factors /Uncertainties (X)	Management Levers/Strategies (L)
Uncertain factors that are outside of the control of water managers but which have the potential to impact the decisions being made. *e.g. population change; climate change; new regulation …*	The options under consideration by water managers to improve the performance of a water system under consideration. *e.g. new canals; recycled water, re-operating reservoirs …*
Relationships/Models (R)	**Performance Metrics (M)**
Models that are constructed to capture the relationship between uncertain factors, management strategies, and system performance. *e.g. WEAP Modeling; expert opinion …*	The measures that will be used to evaluate the potential performance of the selected strategies in the face of identified uncertainties. *e.g. flows at specific points; compliance with regulations*

Table 2: Mapping of XLRM to DWR's IRWMP guidelines

Exogenous Factors/Uncertainties (X)	Management Levers/Strategies (L)
Uncertain factors that are outside of the control of water managers but which have the potential to impact the decisions being made. **ISSUES OF CONCERN**	The options under consideration by water managers to improve the performance of a water system under consideration. **RESOURCE MANAGEMENT STRATEGIES/PROJECTS**
Relationships/Models (R)	**Performance Metrics (M)**
Models that are constructed to capture the relationship between uncertain factors, management strategies, and system performance. WEAP MODEL/**REGION DESCRIPTION**	The measures that will be used to evaluate the potential performance of the selected strategies in the face of identified uncertainties. **GOALS AND OBJECTIVES**

Core Working Group

In June 2013, a core working group (CWG) was formed, made up of individuals from the main interest groups involved in the Regional Water Management Group (RWMG). The RDS process, especially the XLRM formulation, is being implemented with the CWG (Table 3). As of February 2014, three XLRM workshops have been conducted:

September 18, 2013: The first RDS workshop covered the overview of RDS and a complete run of each of the XLRM components. Dominant categories of uncertainties (X's) that emerged were climate, regulatory and land use change uncertainties. A limited set of L's (management strategies) and M's (metrics) were also distilled for further deliberation.

November 2013: The second RDS workshop dwelled deeper into climate and regulatory uncertainties. The CWG was asked to identify specific trajectories of these uncertainties that they would like to see integrated within the model.

January 16, 2013: The third RDS workshop covered land and water use.

Table 3: Members of the Core Working Group

Organization:	Contact:	Phone:	Email:	Address:
YCWA	Scott Matyac	530-741-6278 x 117	smatyac@ycwa.com	1220 F Street, Marysville CA, 95901
Browns Valley Irrigation District	Walter Cotter	743-5703	walter@bvid.org	Post Office Box 6, Browns Valley, CA 95918
North Yuba Water District	Jenny Cavalier	692-2564	jcavalier@nywd.org	8691 La Porte Road, Brownsville, CA 95919
City of Wheatland	Dane Schilling	888-9929	dschilling@wheatland.ca.gov	111 C Street, Wheatland, CA 95692
Hallwood Irrigation Company	Mike Filice	701-2087	mfilice@northtreefire.com	Post Office Box 1349, Marysville, CA 95901
Yuba County Community Dev. & Srvcs Agency	Mike Lee	749-5430	mlee@co.yuba.ca.us	915 8th Street, Suite 123 Marysville, CA 95901
South Yuba River Citizens League	Caleb Dardick	530-265-5961 x 207	caleb@syrcl.org	216 Main Street Nevada City, CA 95959

2. Evaluation of vulnerabilities

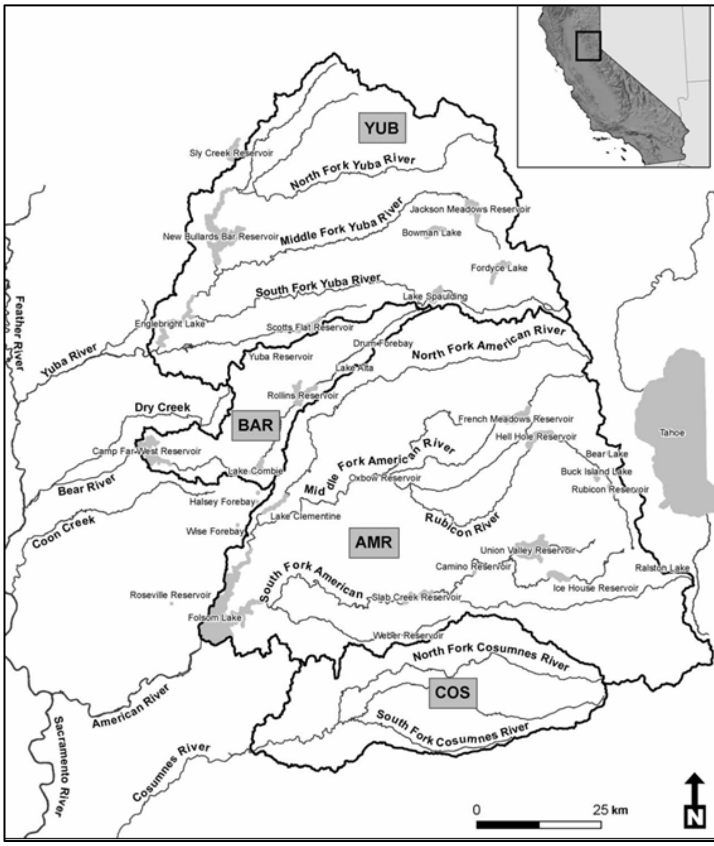
The vulnerabilities of the Yuba region under current management and under the variety of uncertainties distilled in step 1 are then explored by running an integrated water resources model of the Yuba under an ensemble of scenarios. System vulnerability is then assessed using specific metrics under each of many categories of objectives that are identified in step 1.

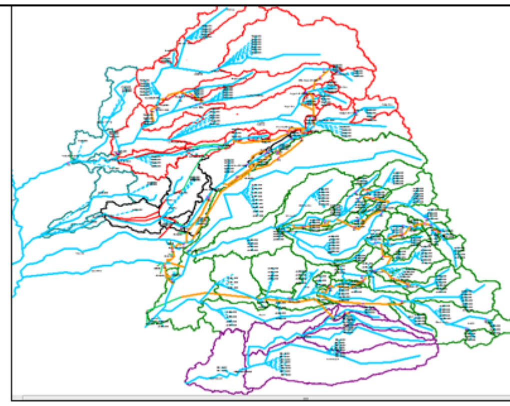
The Yuba model

The integrated model that we are building for this purpose tiers off from a published model of the CABY region (see Figure 2 below) built by SEI (Mehta et al. 2011) using the WEAP water resources planning platform (www.weap21.org).

Authors: Vishal K. Mehta, Laura Forni, Nicholas Depsky and David Purkey (SEI);
Elizabeth Betancourt (Forsgren Inc)
Date: February 2014

Figure 2: Summary of the CABY model, based on which the Yuba model is being built





The model includes 25 reservoirs, 36 hydropower plants, 39 diversions, 14 transmission links, 13 water delivery points and 68 IFR's

Project name	FERC No.	Owner	Powerplants (Total = 36)	Reservoirs (Total = 25)
Yuba River	2246	YCWA	2	1
Upper American River	2101	SMUD	8	6
Drum-Spaulding	2310	PGE	12	3
Narrows	1403	PGE	1	0
Middle Fork	2079	PCWA	5	3
Yuba-Bear	2266	NID	4	3
Ed Dorado ID	184	EID	1	2
Camp Far West	2997	SSWD[1]	1	1
Combie	2981	NID	1	1
Scotts Flat	5930	NID	1	1
Folsom	n/a	BOR[2]	0	1
Other reservoirs	n/a	misc.	0	3

[1] SSWD = South Sutter Water District; [2] BOR = Bureau of Reclamation.

Key elements of the Yuba model that are being built at the time of writing, and that will be deployed in the final analysis, are extension of the CABY model to the valley floor, representation of agricultural and municipal water demand, and extension of historical climate record to 2012.

3. Identifying robust management strategies

Based on the understanding of vulnerabilities from step 1, the stakeholders come up with possible management strategies they would like to explore that have the potential to overcome the same. These are the L's in the XLRM framework. This answers the question: **How do the projects perform under our chosen suite of uncertain futures? What trade-offs exist amongst different management strategies in the face of all identified uncertainties?** Robust strategies are those that perform consistently well under the most number of uncertainties, based on the measures of success identified in step 1.

B. An example

This section illustrates a limited RDS experiment that was conducted using the information from the first RDS workshop (in September 2013) and presented at the Oct 16th, 2013 RWMG meeting. The intention was to demonstrate what the entire workflow looked like, at a limited scale, and it was very well received.

1. XLRM Problem Formulation

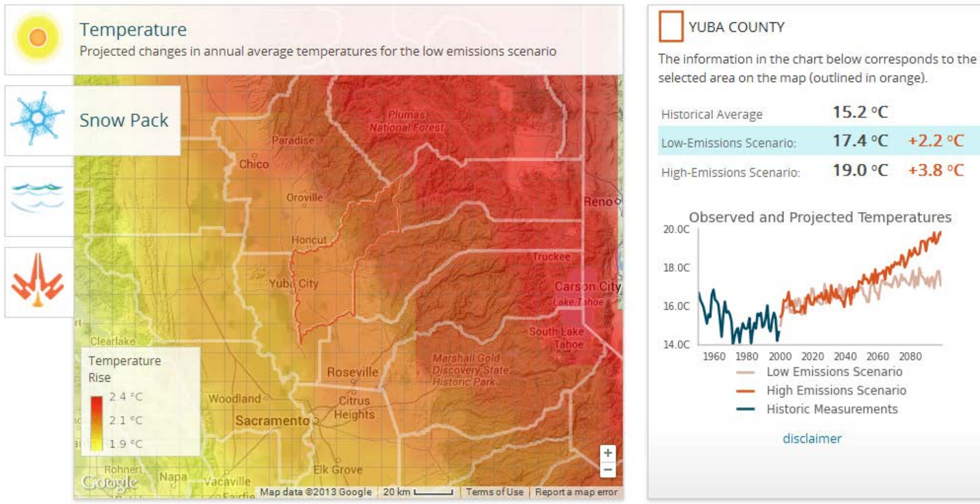
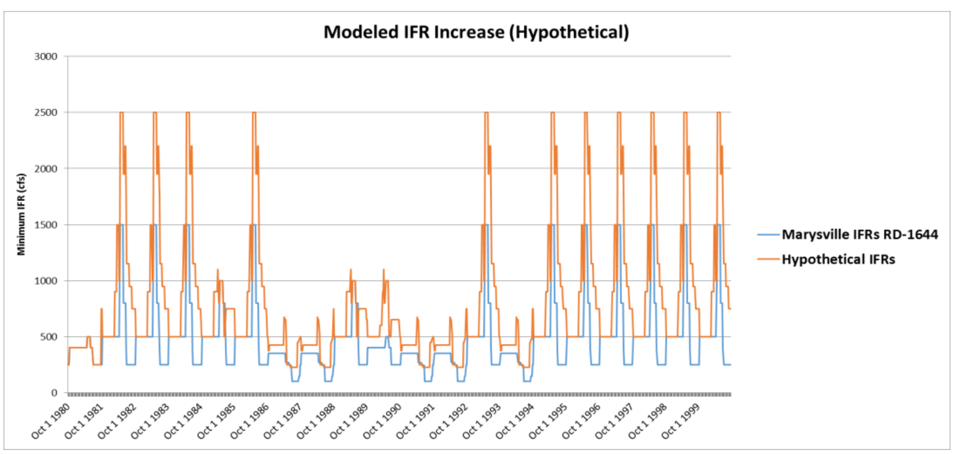
The CWG identified 4 main categories of uncertainties (issues of concern) – see Table 1. Of these climate and new regulations were included in the limited RDS experiment. Of the 3 new management strategies of interest, we included 1 (reservoir re-operation) and evaluated the system using specific metrics (Table 3) for 4 categories of objectives.

Table 3: XLRM Problem Formulation: *In bold are those topics that were included in the illustrative RDS experiment*

X=ISSUES OF CONCERN	L=MANAGEMENT STRATEGIES/PROJECTS
1. **CLIMATE** 2. LANDUSE 3. **NEW REGULATIONS** 4. ECONOMIC	1. ADDITIONAL STORAGE 2. WATER CONSERVATION **3. RESERVOIR RE-OPERATION**
REGIONAL DESCRIPTION/MODELS	**M=GOALS AND OBJECTIVES**
R=YUBA MODEL	1. **ECOLOGICAL** 2. **WATER SUPPLY** 3. **HYDROPOWER** 4. **FLOOD SAFETY**

Authors: Vishal K. Mehta, Laura Forni, Nicholas Depsky and David Purkey (SEI);
Elizabeth Betancourt (Forsgren Inc)
Date: February 2014

Table 4: Summary of the limited RDS experimental design:

Uncertainties	
Climate	(1) Historical climate, and (2) A 4deg C increase in temperature 
Regulatory	Instream Flow requierments (IFRs) at Smartville and Marysville under (1) RD-1644 (2) Hypothetical increase similar to increase from Lower Yuba Accord 
Management Strategy/Lever	
(1) Current operations of NBB	Given flood safety and annual storage concerns, a proposed project by YCWA is the installation of a new Mid-Level Outlet on New Bullards Bar Dam, and associated relaxation of flood pool reservation requirements by the US Army Corps of Engineers

(2) Reoperating New Bullards Bar

NBB Flood Pool Reservation (TAF)	Current	Potential Re-operated
Nov 1 – Mar 31	170	80
April 1 – April 30	100	50
May 1 – Oct 31	0	0

The above RDS design called for 8 Yuba model runs: evaluating 2 management strategies (Current, NBB –re-operations) against performance against 2 regulatory regimes (RD-1644 and an increased hypothetical IFR) under 2 climate regimes (historical and a warmer climate). The performance was evaluated against the objectives and associated metrics below:

The Yuba system was evaluated under above uncertainties against four objectives using the following metrics.

Water Supply Objective:

- End of May storage in New Bullards Bar Reservoir
- Groundwater use for meeting irrigation demands
- Out-of-Basin exports via the Drum-Spaulding canal

Hydropower Objective:

- Total power produced from Colgate PH & Narrows 1, 2 PH

Sustainability Objective:

- Number of weeks Lower Yuba River flows are no greater than the minimum in-stream flow requirement
- Inter-annual groundwater storage

Flood Safety Objective:

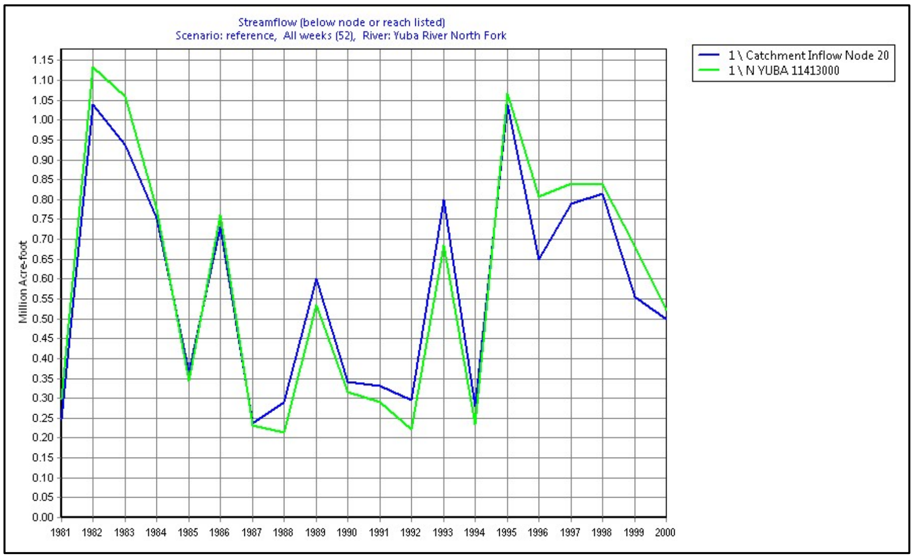
- Number of weeks in which storage at New Bullards Bar exceeds current flood pool operating limits

2. Yuba model development and runs

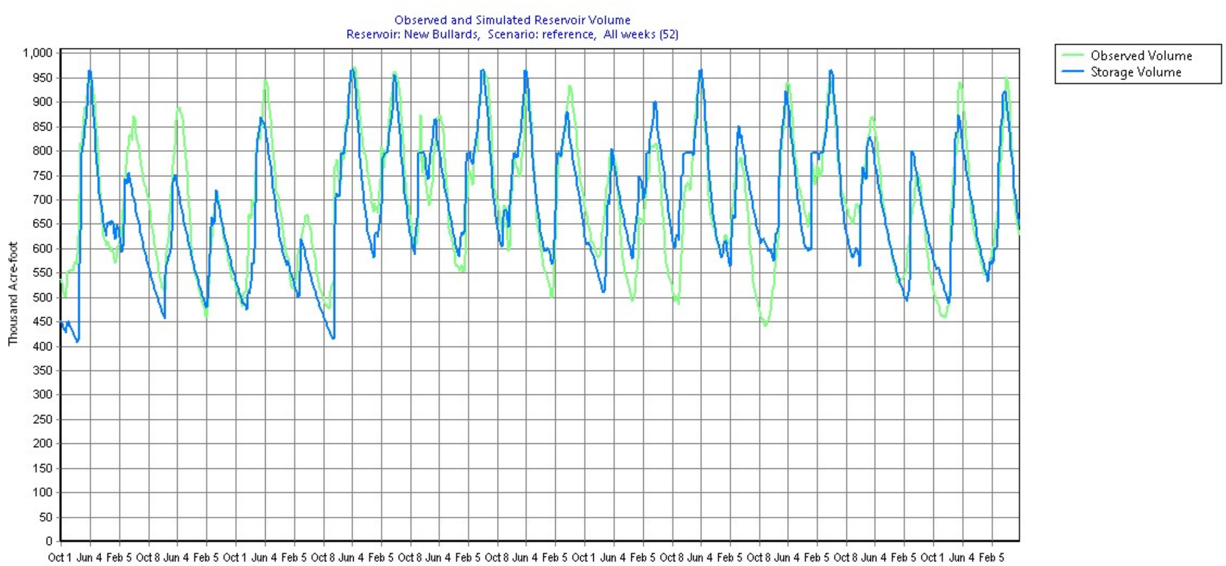
The Yuba model built in WEAP was extended to cover crop water demand and irrigation. Calibration was based on comparison with upstream river flows (Figure 3a), NBB reservoir levels (Figure 3b) and by comparing modeled applied irrigation against the DWR portfolio data on applied water for the DWR detailed analysis unit that covers the Yuba valley floor (Figure 3 c)

Figure 3: Selected Yuba model calibration results (

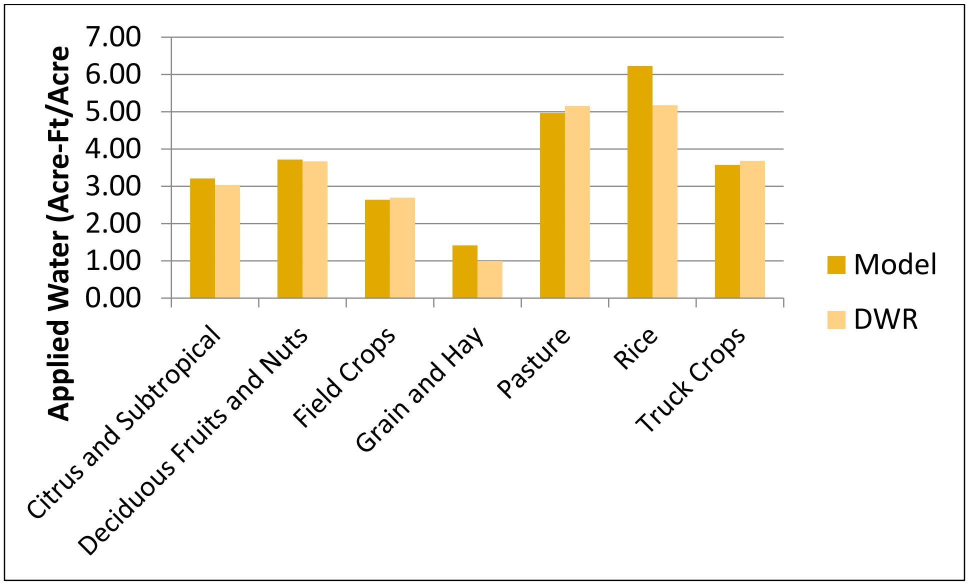
(a) 1981-200 annual flow in the North Yuba river at USGS 11413010 *(green:observed, blue :modeled)*



(b) Weekly New Bullards Bar Storage, 1989-2010 (green:observed, blue :modeled)



(c) Average annual irrigation water applied (1998-2001)



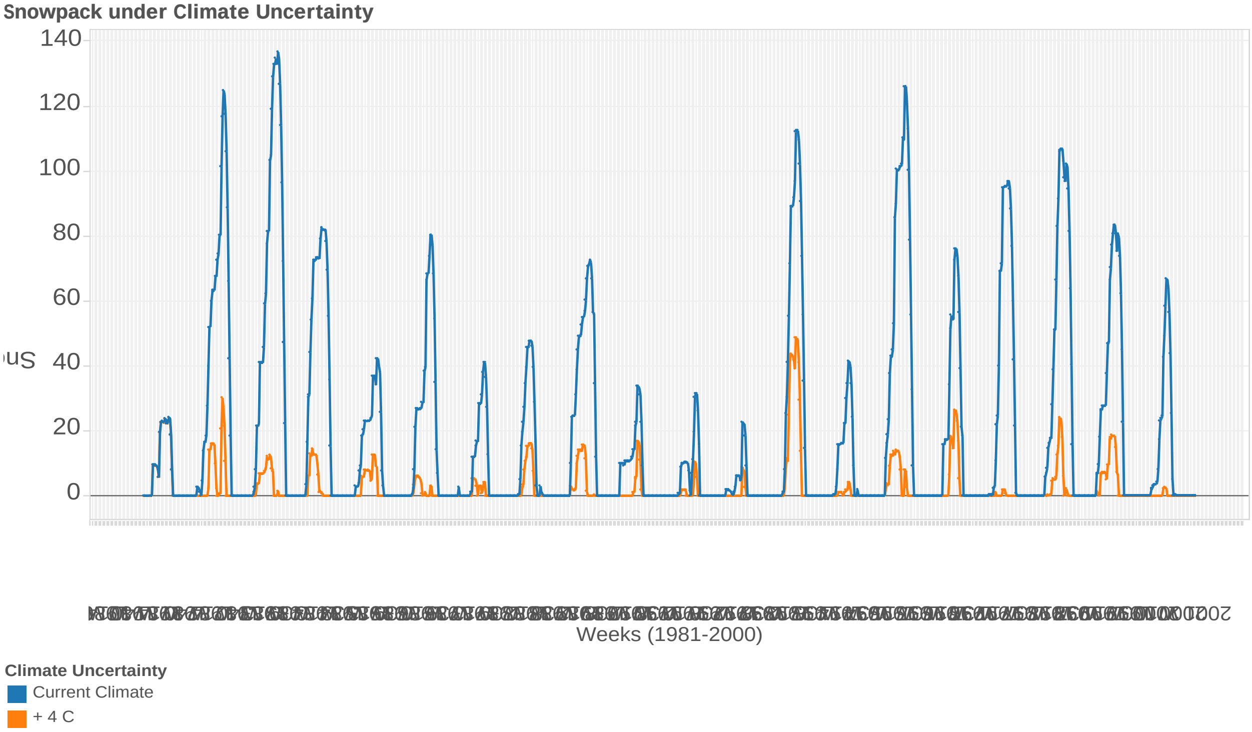
The Yuba model calibration-verification being completed, the RDS experiment was conducted by running it 8 times, each one corresponding to a specific combination of scenarios from the XLRM outputs explained earlier.

In the final experiment to be completed by August 2014, we expect many more runs corresponding to a larger number of uncertainties and management strategies, as well as larger list of objectives and metrics.

3. Results

The first vulnerability of the system to warming climate is the loss of snowpack that affects the Yuba region in all sectors.

Figure 4: Weekly snow depth under the 2 climate regimes



Below, we evaluate the system performance using each of the objectives and metrics developed in an earlier section, ending with a summary of lessons learned.

Objective: Water Supply

Metric: Average end of May Storage in NBB over 20 years (TAF)

Regulatory Uncertainty	Climate Uncertainty	Current	New Res. Operations
Current Reg	Current Climate	762	779
	+ 4 C	664	700
New IFR	Current Climate	755	770
	+ 4 C	662	692

- Impact of new regulations alone on end of May storage is minimal
- Climate warming substantially reduces end of May storage, due to earlier peak snowmelt running off during winter and spring months in which New Bullards Bar must maintain large flood pool storage under current operating rules
- Therefore, re-operating the flood pool significantly increases storage, even under warming

Metric: Avg annual groundwater use as percent of total irrigation over 20 years (%)

Regulatory Uncertainty	Climate Uncertainty	Current	New Res. Operations
Current Reg	Current Climate	30	27
	+ 4 C	57	52
New IFR	Current Climate	56	52
	+ 4 C	71	67

- Groundwater use increases under all uncertainty scenarios
- The greatest increase is under the combination of warming and new regulations
- Reservoir reoperation mitigates this increased use, but only slightly

Objective: Hydropower

Metric: Average Annual Hydropower production over 20 years (GWh)

Regulatory Uncertainty	Climate Uncertainty	Current	New Res. Operations
Current Reg	Current Climate	1,347	1,370
	+ 4 C	1,187	1,227
New IFR	Current Climate	1,325	1,340
	+ 4 C	1,183	1,216

- Warming climate has the potential to reduce hydropower generation (-160k MWh/yr) more than just increasing IFRs would (-22k MWh/yr)
- Reservoir re-operation mitigated loss in hydropower in the face of a warming climate and new regulations in all scenarios

Objective: Ecological sustainability

Metric: Number of weeks over 20 years during which Lower Yuba flows no greater than IFR

Smartville

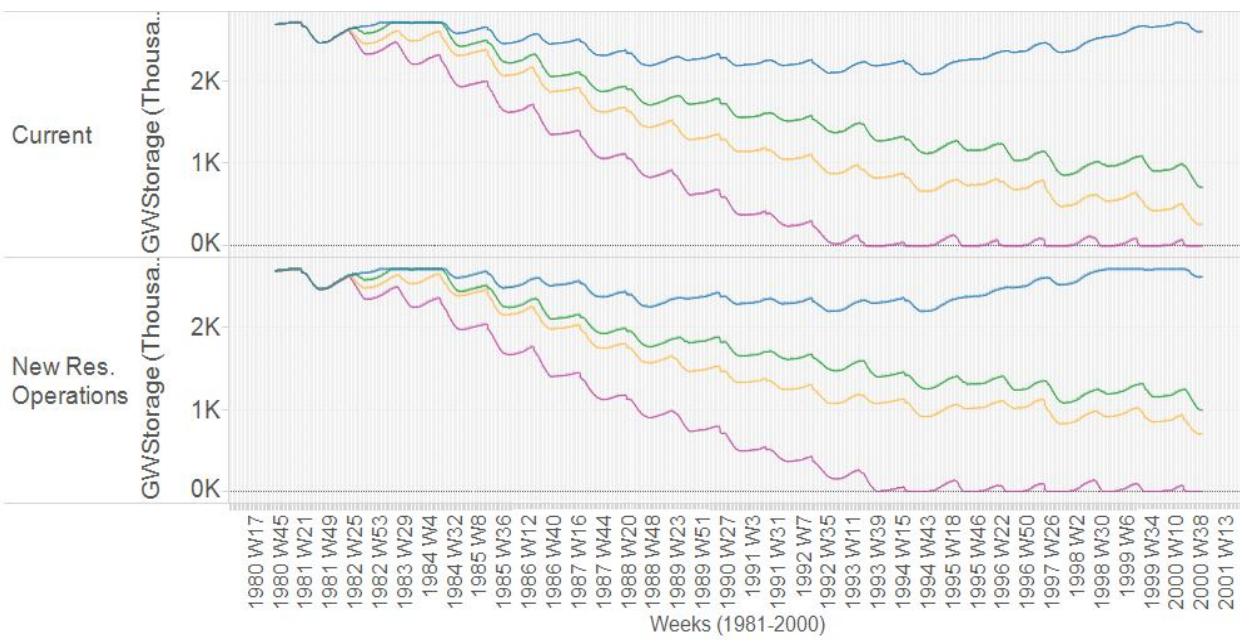
Regulatory Uncertainty	Climate Uncertainty	Current	New Res. Operations
Current Reg	Current Climate	22	21
	+4 C	38	34
New IFR	Current Climate	40	38
	+4 C	65	57

Marysville

Regulatory Uncertainty	Climate Uncertainty	Current	New Res. Operations
Current Reg	Current Climate	310	296
	+4 C	428	414
New IFR	Current Climate	423	421
	+4 C	517	500

- Flow at Smartville exceeds IFRs much more often than at Marysville
- In all cases, this week total increases, due to climate-altered hydrology and more stringent IFRs
- Re-operation is shown to slightly decrease the number of weeks in all cases in which flow is no greater than IFRs, implying that such re-operation may help supplement stream-flows in drier periods

Metric: Groundwater Storage, first 150 ft of aquifer



- Long-term aquifer drawdown is seen in all cases except for current regulations and current climate
- The first 150 ft of aquifer is drained in the combined new IFR + 4 C warming case
- Re-operation of New Bullards Bar has little impact on groundwater storage

Authors: Vishal K. Mehta, Laura Forni, Nicholas Depsky and David Purkey (SEI);
Elizabeth Betancourt (Forsgren Inc)
Date: February 2014

Objective: Flood safety

Metric: new Bullards Bar Flood pool encroachment during winters:-number of weeks in 20 years when storage exceeds 786 during Nov-Mar

Regulatory Uncertainty	Climate Uncertainty	Current	New Res. Operations
Current Reg	Current Climate	116	134
	+ 4 C	137	158
New IFR	Current Climate	115	133
	+ 4 C	137	157

- Flood pool encroachment increases under climate warming due to earlier snowmelt; new IFRs have little impact.
- As expected, reservoir re-operation increases flood pool encroachment under all cases, especially under climate warming

Results Summary

The limited RDS experiment above asked the question**: Is re-operating new Bullards Bar reservoir by decreasing winter flood pool storage an effective management strategy?**

The results imply that this strategy provides co-benefits across several objectives: water supply, hydropower production, and even one ecological objective i.e IFR's. It has no positive or negative impact on groundwater aquifer status. It does not however, meet flood safety objectives.