CDFW - Sites 60 day Evaluation Meeting No. 2 Meeting Agenda

Sites Reservoir Project

Date: *June 5, 2019* **Location:** *Jacobs Office: 2485 Natomas Park Drive, Suite 600*

Time: 11:30 am – 2:00

Purpose: Continue 60 day evaluation of Operational Scenarios.

Invitees:

Kristal Davis Fadtke- CDFW
Rob Thomson, Sites Authority
Kevin Spesert, Sites Authority
Ali Forsythe, Sites Authority
Duane Linander- CDFW
Ken Kundargi- CDFW
Lenny Grimaldo, ICF
Marin Greenwood, ICF
Jim Lecky, ICF
Mike Dietl, Reclamation
Filipe La Luz – CDFW
Chris Fitzer, ESA Associates
Rob Tull, Jacobs
John Spranza, HDR

Agenda:

Discussion Topic	**Topic Leader**	**Est Time**
1. Role Call	Kristal Davis Fadtke Rob Thomson	5 min
2. Review of Action Items from Previous Meeting	John Spranza	15 min
3. Henderson et al discussion	Marin Greenwood	60 min
4. Operations: Hydrology and Modeling a. Daily Model Discussion a. Assumptions b. Hydrology b. CalSim 5. Assumptions	Rob Tull	60 min
6. Next steps for 60 day schedule	Group discussion	10 min

Action items:

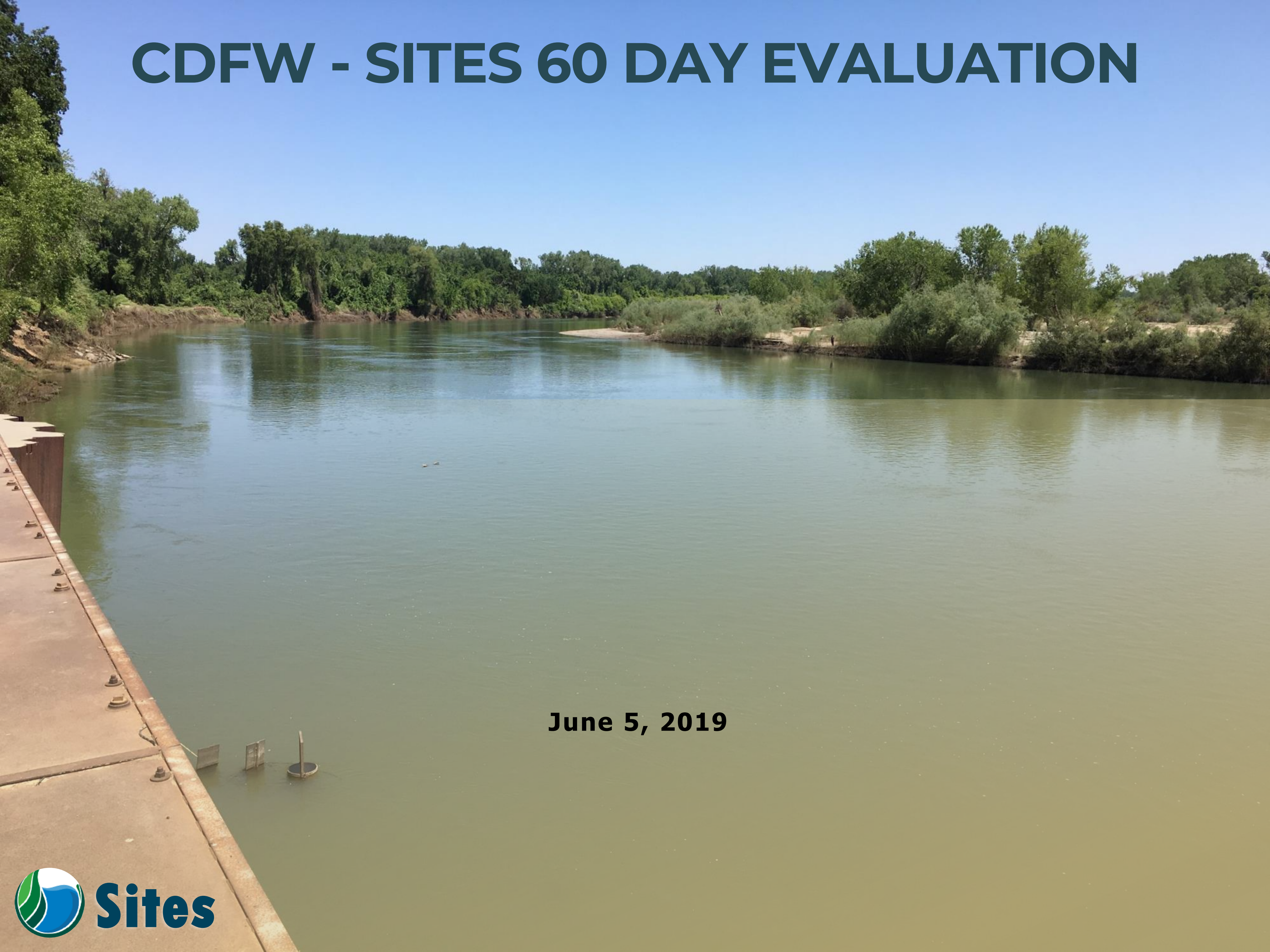
TABLE 1. ACTION ITEMS FROM PREVIOUS MEETING

Action Item		Owner	Deadline	Notes
1	Send 2018 Henderson Paper around	JJS	06/03/19	
2	Send hydrology presentation slides to CDFW and ESA	JJS	06/03/19	

Action Item		Owner	Deadline	Notes
3	CDFW to provide desired model years for next workshop	CDFW	06/04/19	
4	CDFW to provide contact for terrestrial discussions	CDFW	06/05/19	
5				
6				
7				

General Meeting Notes

CDFW - SITES 60 DAY EVALUATION



June 5, 2019

Sites

Agenda

- Introductions and Purpose
- Recap and Update
- OBAN and Flow-Mortality Approach
- USRDOM
- CalSim Details
- Next Steps

Purpose of the 60-day

Guide the Authority to increase the clarity of the Project Description and supporting analyses for an affordable project capable of providing meaningful water supply and dedicated ecosystem benefits looking toward

- Final EIR/EIS
- Permit applications

Action Items

- Distribution of Henderson
- Distribution of Presentation
- Definition of desired analysis years
- Coordination of other technical teams, contacts

Life-cycle and Flow Mortality Analyses

USRDOM and CalSim2 Details

Next Meeting Planning

This technical team

- Week of June 10
- Topics
- Action Items

Other technical teams?

Anticipated Issues

- Diversion rate and timing
- Trigger values
- Floodplain and Bypass habitat
- Coldwater pool development and release
- Flow stability supply development and release effects
- Flow-mortality analysis and scientific basis
- Sites Reservoir water quality and release effects
- Sediment management
- Delta Outflow management and effects


Next Steps?
Topics, Date

Daily Analysis of Divertible Flow Available for Sites Reservoir

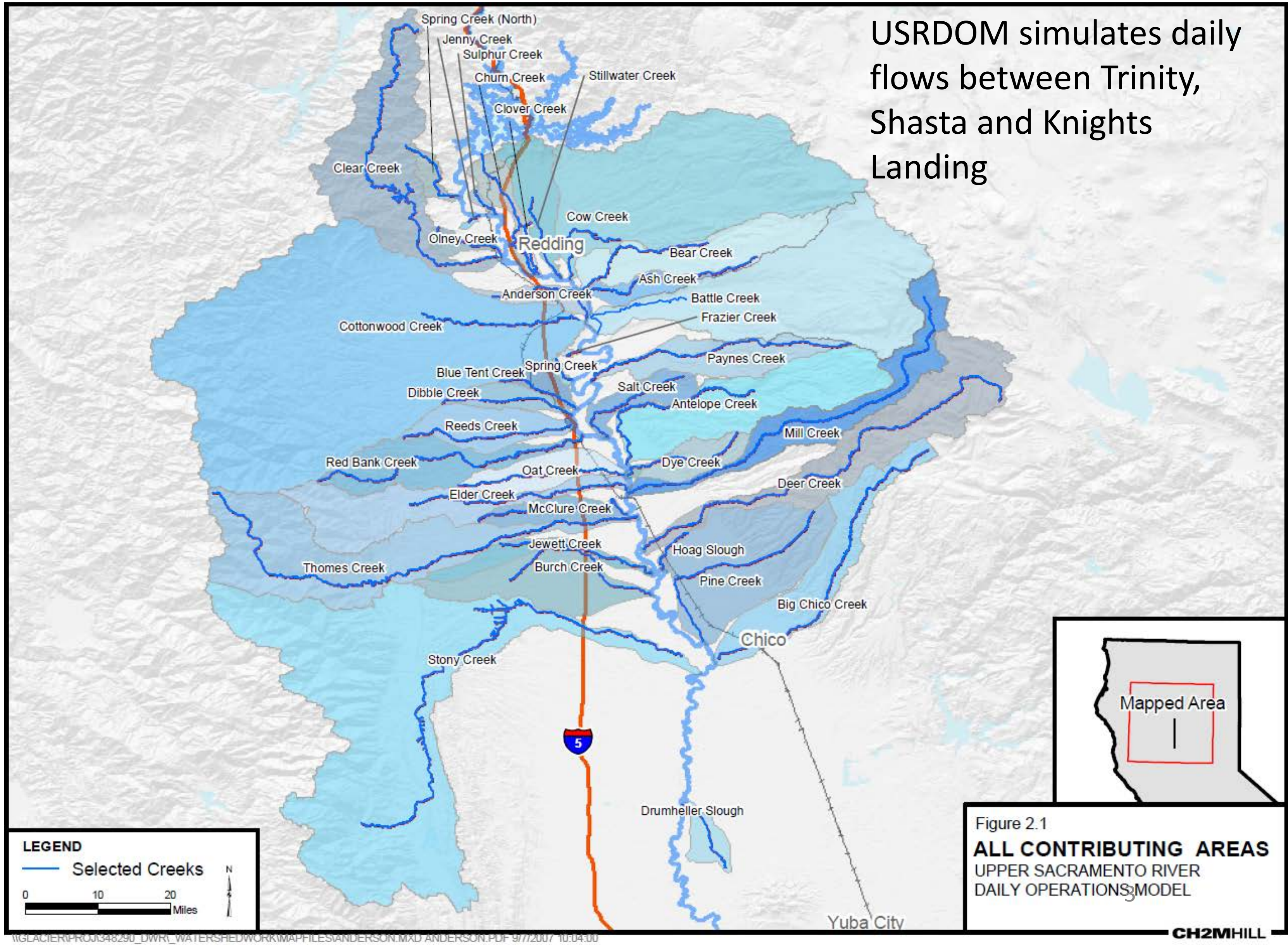
6-5-19

Daily Modeling for Sites Project

- A set of daily modeling tools has been developed to evaluate the quantity of flow available for potential diversions to the proposed Sites Reservoir under a range of hydrologic conditions and operations criteria
- These tools can be used to:
  - Support further understanding of the interactions of Sites Project with flow conditions in the Sacramento River
  - Evaluate the affect of various flow regulations, facility constraints, and operation criteria on flow availability for Sites Project

Daily Model - USRDOM

- Upper Sacramento River Daily Operations Model
- Simulates daily flow conditions in the Upper Sacramento River based on operations specified by CalSim II
- Can be used to evaluate Sites Reservoir benefits
- Original hydrology dataset included 82-year period from WY 1922 to WY 2003 using available historical gage records and operations data



USRDOM simulates daily flows between Trinity, Shasta and Knights Landing

Daily Modeling Application

USRDOM HindCast (2018)

- 1964 – 2018
- HEC5Q
- Calibrated with gage data (Sac R at Bend Bridge, Colusa, and Wilkins Slough)
- Simulates daily flows in the Upper Sacramento River based on CalSim outputs for WY 1964 - 2018

Flow Availability Tool

- 2009 – 2018
- Excel
- Inputs from USRDOM Hindcast (2018) model and gage data
- Determines daily flow availability for Sites diversions

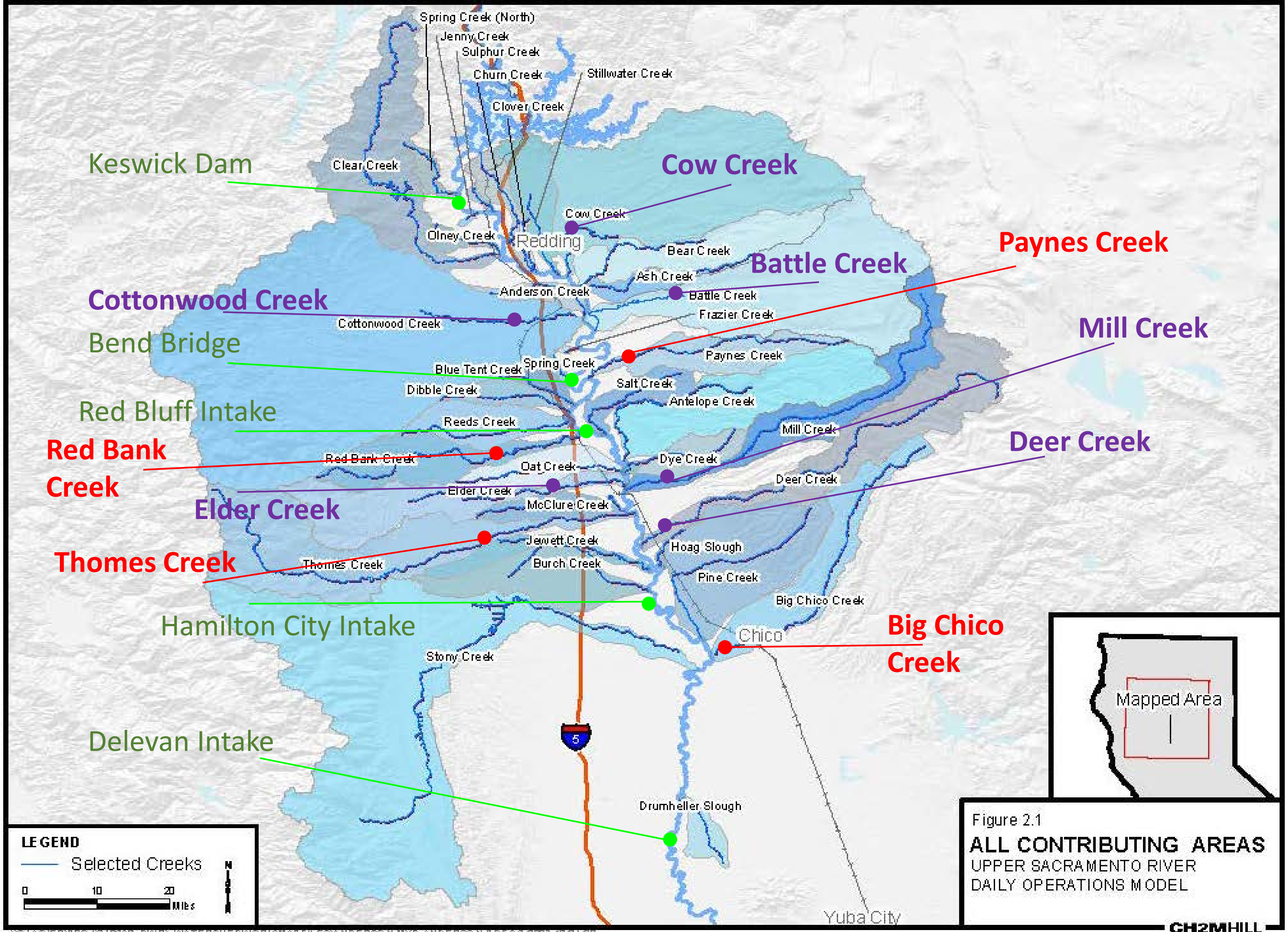
Divertible and Storable Flow Tool

- 2009 – 2018
- Excel & Power BI
- Inputs from USRDOM Hindcast (2018) model, Flow Availability Tool, and gage data
- Determines divertible and storable flow for Sites based on user specified conveyance constraints and diversion criteria
- Applications:
  - Education
  - Sensitivity Analysis
  - Diversion strategy based on system conditions

Upper Sacramento River Tributaries

- 11 tributaries along the Upper Sacramento River are used as inputs for USRDOM
- The first six historical datasets are used to estimate inflows for the remaining five datasets:

1. Deer Creek near Vina
2. Mill Creek near Los Molinos
3. Battle Creek near Cottonwood
4. Elder Creek near Paskenta
5. Cottonwood Creek near Cottonwood
6. Cow Creek near Millville
7. Big Chico Creek
8. Black Butte
9. Paynes Creek
10. Red Bank
11. Thomes Creek



Spring Creek (North)
Jenny Creek
Sulphur Creek
Churn Creek
Stillwater Creek
Clover Creek
Keswick Dam
Clear Creek
Cow Creek
Cow Creek
Olney Creek
Redding
Bear Creek
Paynes Creek
Battle Creek
Ash Creek
Anderson Creek
Battle Creek
Cottonwood Creek
Frazier Creek
Cottonwood Creek
Mill Creek
Bend Bridge
Paynes Creek
Spring Creek
Blue Tent Creek
Dibble Creek
Salt Creek
Antelope Creek
Red Bluff Intake
Reeds Creek
Mill Creek
Deer Creek
Red Bank
Creek
Red Bank Creek
Oat Creek
Dye Creek
Deer Creek
Elder Creek
Elder Creek
McClure Creek
Jewett Creek
Hoag Slough
Thomes Creek
Thomes Creek
Burch Creek
Pine Creek
Big Chico Creek
Hamilton City Intake
Chico
Big Chico
Creek
Stony Creek
Mapped Area
5
Delevan Intake
Drumheller Slough
LEGEND
Selected Creeks
0 10 20
Miles
N
Figure 2.1
ALL CONTRIBUTING AREAS
UPPER SACRAMENTO RIVER
DAILY OPERATIONS MODEL
Yuba City
CH2MHILL

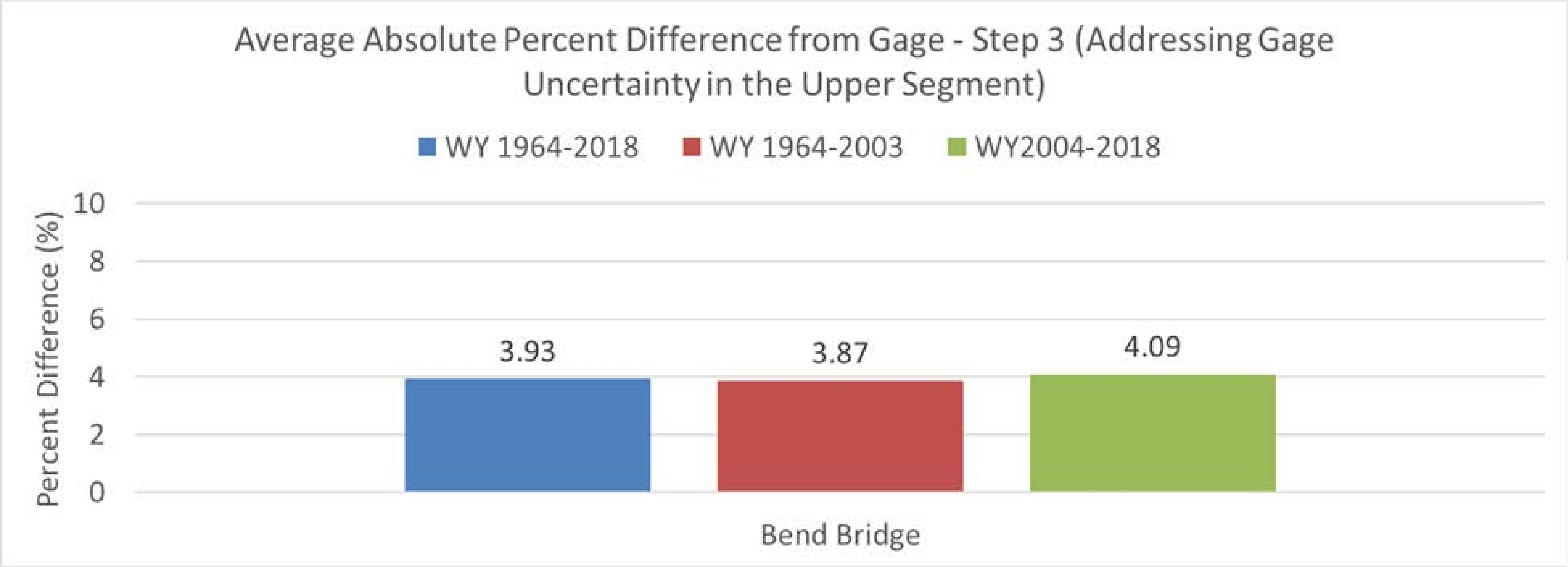
USRDOM HindCast Calibration

- “Closure Terms” (buffer flows) are used to account for ungaged tributaries and uncertainty between synthesized and observed flow data
- Two closure terms are used to account for all Sacramento River diversions, accretions, depletions, and inflows from tributaries that are not explicitly included in the model
  - Upper Segment Closure Term (UPPERSACRCLOSURE) – Accounts for region between Keswick and Bend Bridge
  - Middle Segment Closure Term (MIDDLESACRCLOSURE) – Accounts for region between Bend Bridge and Colusa Weir

USRDOM HindCast Calibration

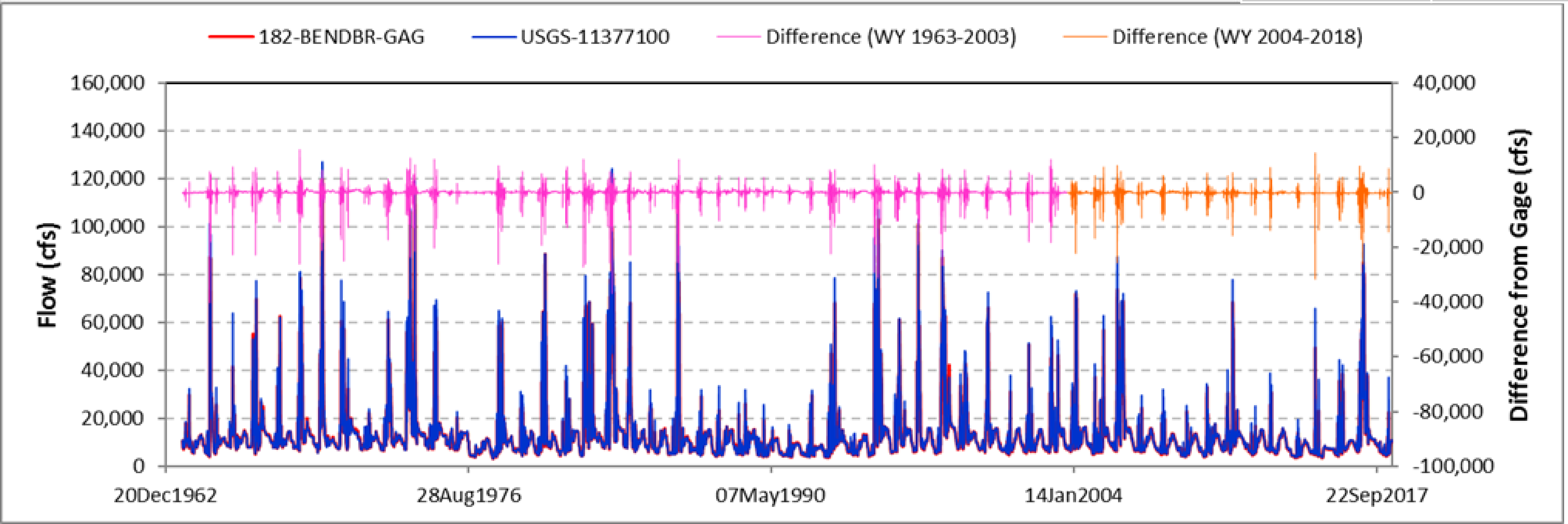
- The closure terms were refined over a 5 step process:
  - Step 1 - Upper Segment closure term is computed using a water balance estimate of all known inflows and diversions modeled upstream of Bend Bridge
  - Step 2 - Upper Segment closure term is iteratively refined to match gage readings for the Sacramento River at Bend Bridge
  - Step 3 – Upper Segment closure term is adjusted to account for potential gage error at Bend Bridge
  - Step 4 – Middle Segment closure term is developed to match gage readings for the Sacramento River at Colusa Weir
  - Step 5 – Middle Segment closure term is adjusted to account for potential gage error at Colusa Weir

Upper Segment Calibration

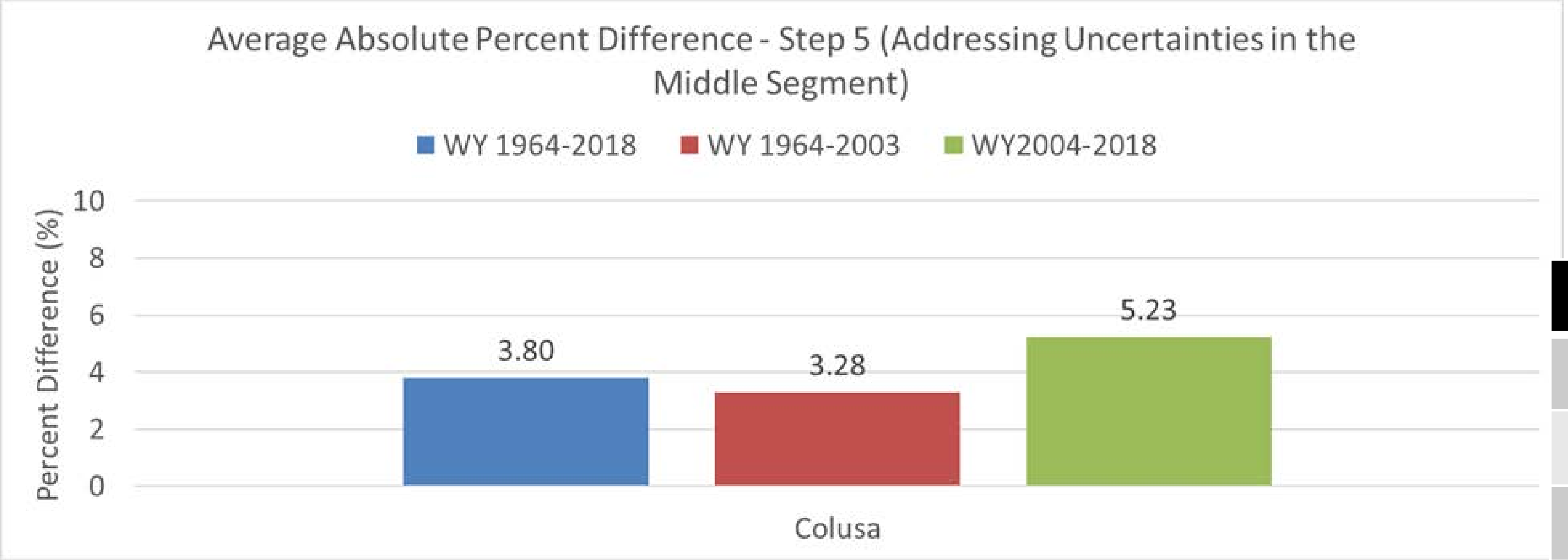


Sac R at Bend Bridge Flow (cfs) (WY 1964 -2018)

	Average	Min	Max
Observed	12,525.7	3,200.0	127,000.0
Modeled	12,424.1	3,134.4	119,688.6
Difference	-101.7	-40,395.5	14,788.6

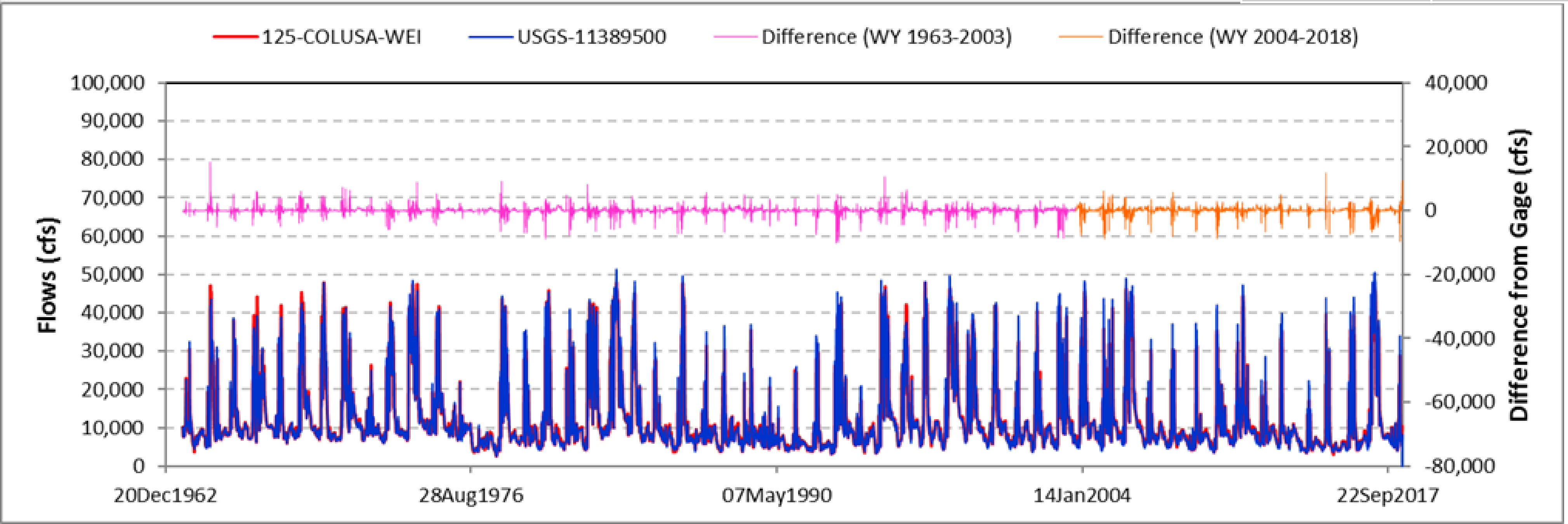


Middle Segment Calibration

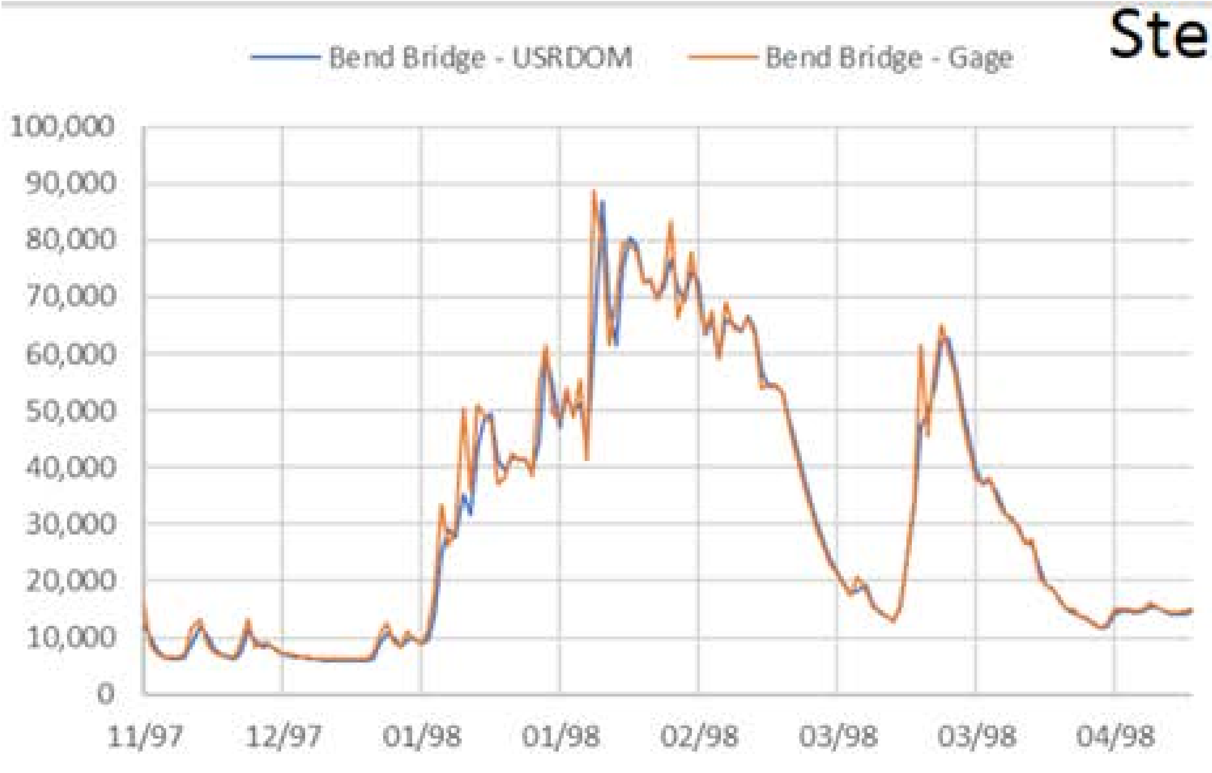


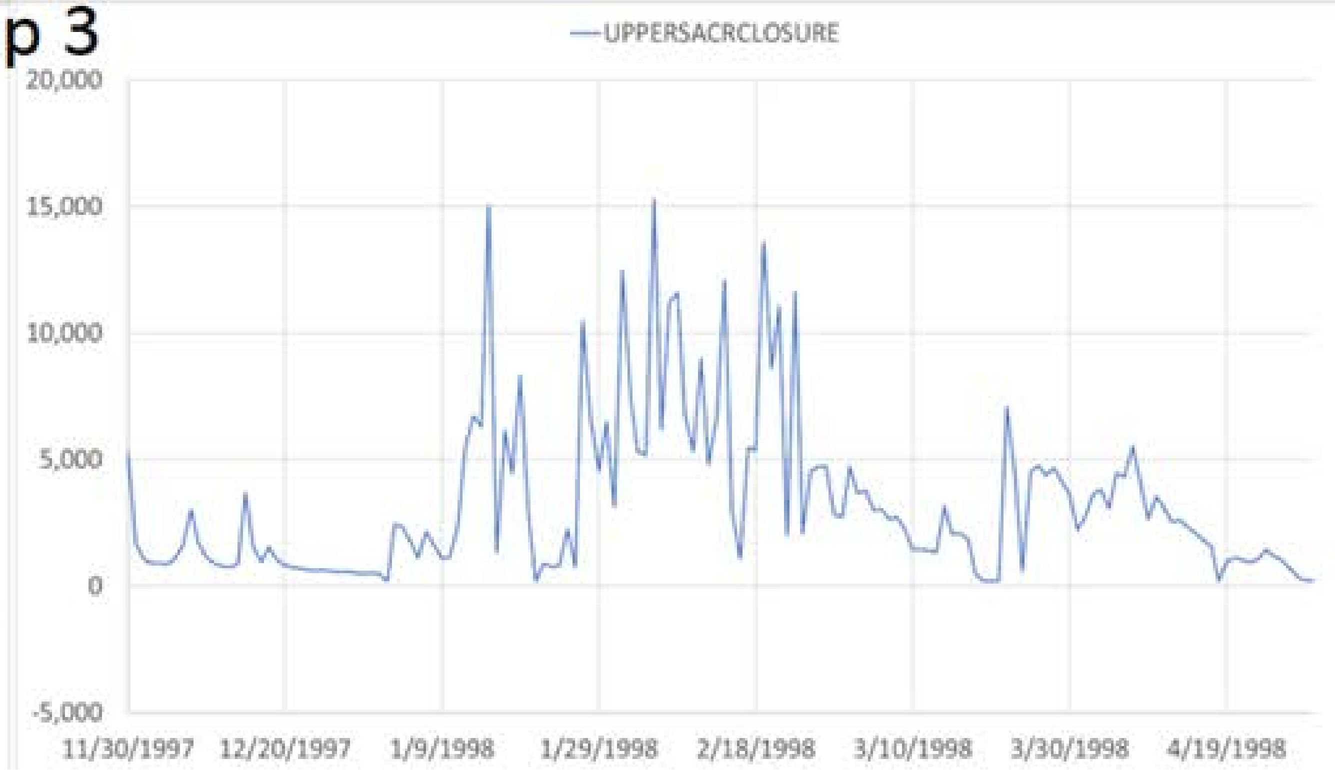
Sac R at Colusa Flow (cfs) (WY 1964 -2018)

	Average	Min	Max
Observed	11,708.5	0.0	51,300.0
Modeled	11,826.5	2,588.5	47,924.9
Difference	118.0	-10,130.4	15,287.7



Step 3

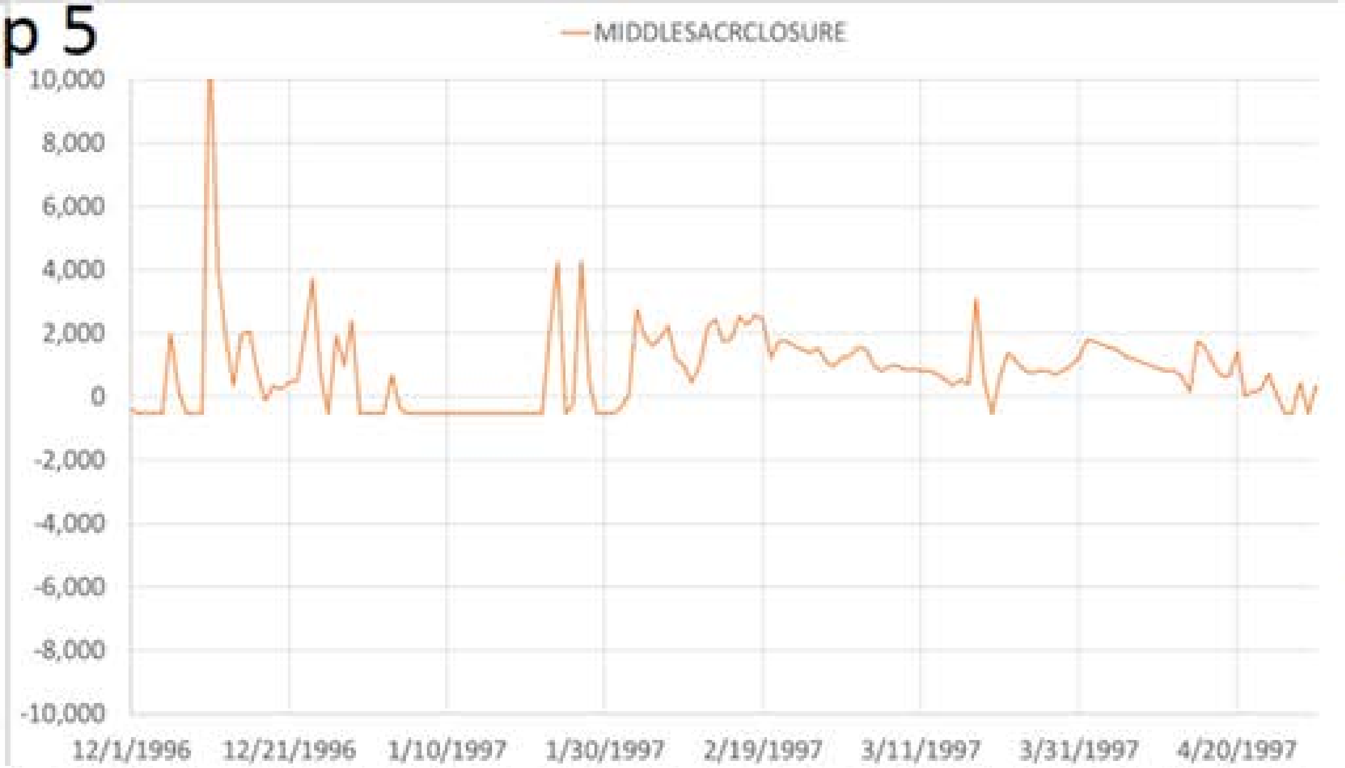




- USRDOM simulated flow (blue) vs USGS gage readings (orange) for the Sacramento River at Bend Bridge after calibrating USRDOM's Upper Segment

- Upper Segment Closure Term

Step 5



- USRDOM simulated flow (grey) vs USGS gage readings (yellow) for the Sacramento River at Colusa Weir after calibrating USRDOM's Middle Segment
- Middle Segment Closure Term

Flow Availability Tool

- Determines daily flow available for diversion to Sites Reservoir, subject to hydrology and regulations outside the scope of Sites Project operations for October 1st, 2008 – May 31st, 2018
    - Period consistent with implementation of NMFS's RPA from the 2009 BiOp
- Flow availability is computed using historical records and accounting for current flow requirements
    - Delta balance conditions from COA reports
    - Term 91 conditions
    - Delta outflow requirements
    - Export/Inflow ratio constraint
    - San Joaquin River exports
    - Health and safety requirements
    - Fall X2
    - Spring X2
    - Jersey Point, Emmaton, Rio Vista water quality standards

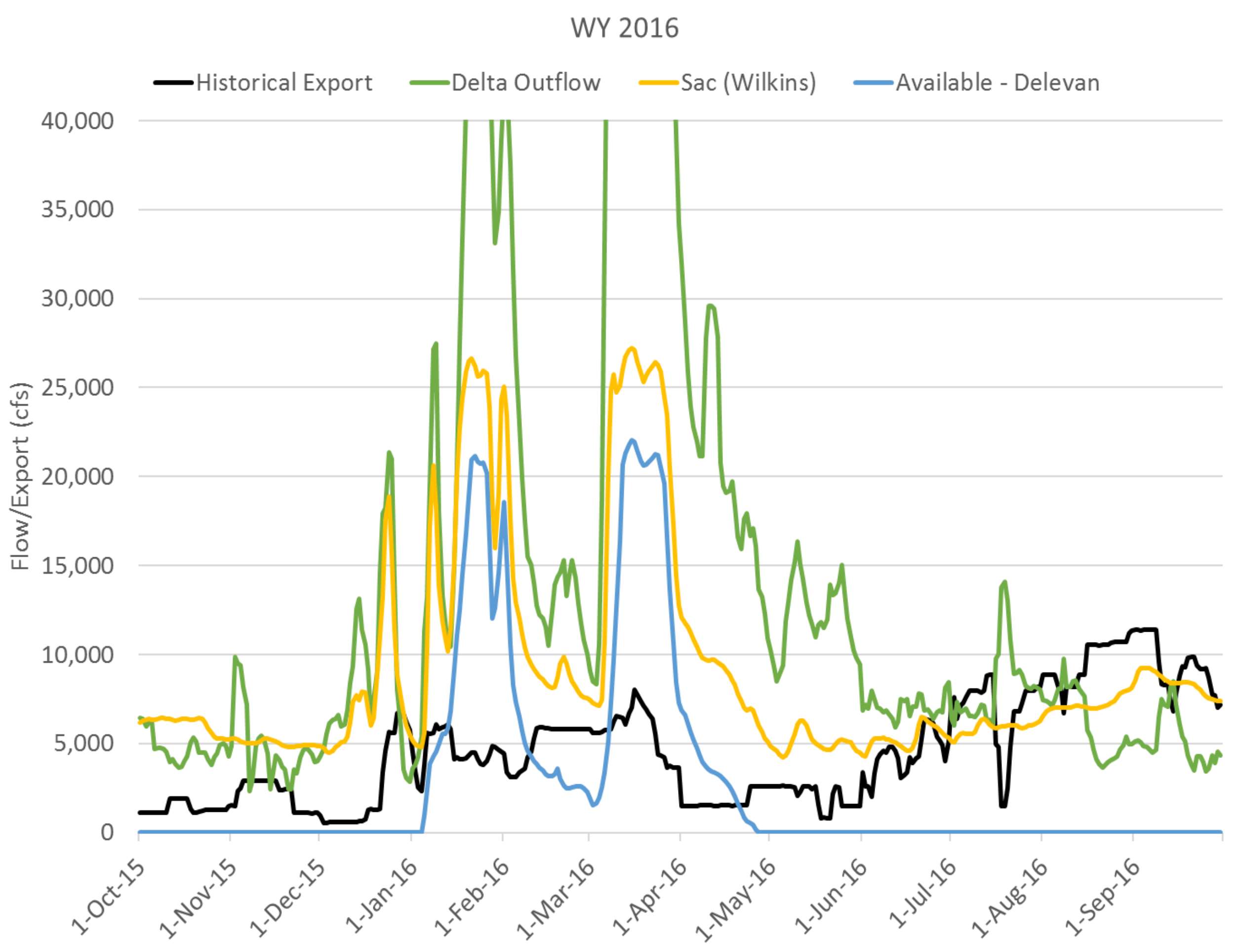
Historical Data Compilation for the Flow Availability Tool

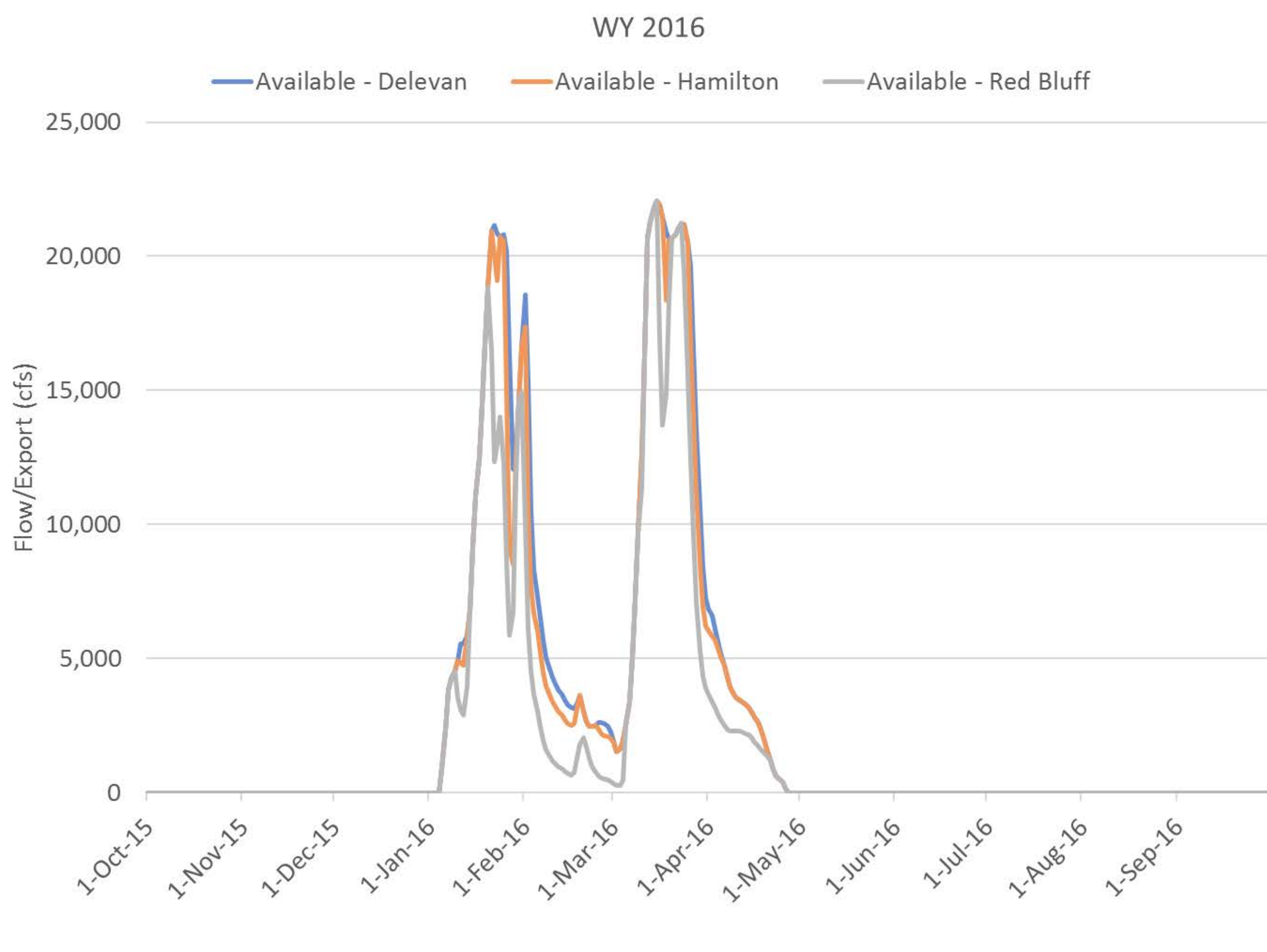
- USGS Daily Flow
  - American River at Fair Oaks
  - Sacramento tributary flow (inputs for USRDOM)
- CDEC Daily Data
  - San Luis storage from WY 2007 through May 2018
  - Feather River flow
- Reclamation Data (inputs for USRDOM)
- Outputs from the USRDOM HindCast Model
- CVO COA Reports from WY 2008 through November 2017
- Dayflow from WY 2008 through WY 2017

Historical Data Compilation for the Flow Availability Tool

- Delta Operations for Salmonids and Sturgeon (DOSS) meeting summaries from January 2009 through June 15th 2018
- Smelt Working Group (SWG) meeting summaries from January 2009 through June 15th 2018
- Delta Assessment Team (DAT) Summaries from January 2009 through June 15th 2018
- Water Operations Management Team (WOMT) from January 2009 through June 15th 2018
- SWRCB Term 91 indicator data from January 2007 through May 2018

Flow Availability Tool – Example Figures





Divertible & Storable Flow Tool

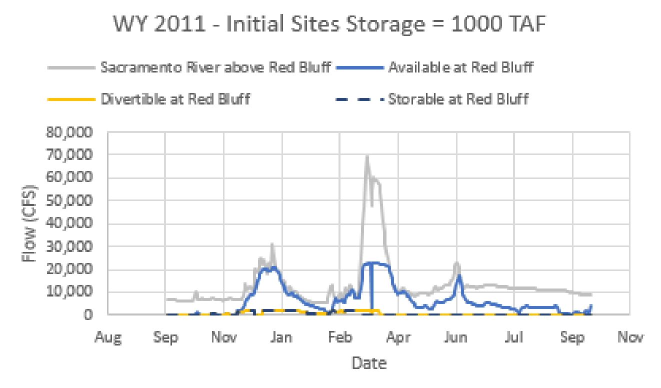
- Determines daily divertible and storable flow for Sites Project in October 1st, 2008 – May 31st, 2018 based on water availability and user specified conveyance constraints and diversion criteria
- The tool includes a dashboard with options to toggle between various combinations of hydrographs, diversion criteria, and initial storage conditions
- Results can be viewed in Excel and Power BI
- Divertible Flow = "Available Flow" subject to flow requirements and conveyance constraints associated with Sites Project
- Storable Flow = "Divertible Flow" subject to storable capacity

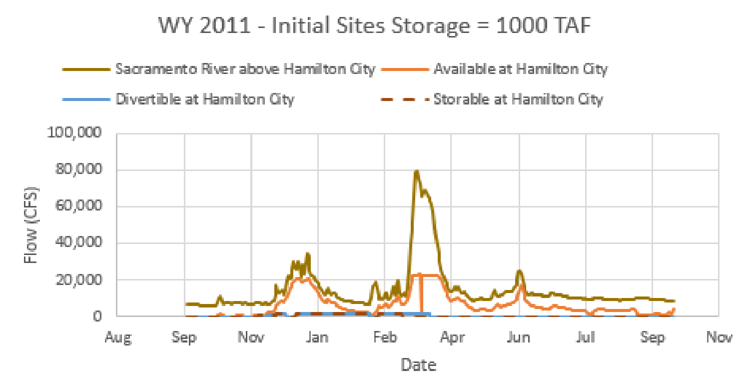
Divertible & Storable Flow Tool Excel Dashboard

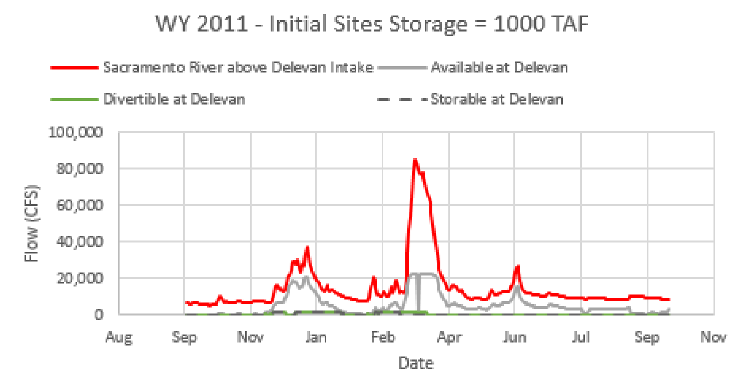
User Specifications	Run Current Setup
Year:	2011
Initial Sites Storage (TAF):	1,000
Diversion Criteria:	
Sites Storage Capacity (TAF)	1,810
Intake Conveyance Capacities	
TCC	2,100
GCC	1,800
Delevan	2,000
Bypass Requirements (cfs)	
Sac R Below Red Bluff	3,250
Sac R Below Hamilton City	4,000
Sac R Below Delevan Intake	5,000
Wilkins Slough	5,000
Freeport (July-Nov)	11,000
Freeport (Dec, Feb-Jun)	13,000
Freeport (Jan)	15,000
Delta Outflow	0
Pulse Definition Controls	
Beginning month (CY)	10
Ending month (CY)	5
Initiation Threshold (cfs)	15,000
Maintenance Threshold (cfs)	15,000
Removal of Restrictions (cfs)	25,000
Pulse Day Termination (days)	7
Diversion Season	
Starting Month (CY 7-12)	11
Ending Month (CY 1-6)	3
Min Pumping Levels (cfs)	
Red Bluff	125
Hamilton City	100
Delevan	500

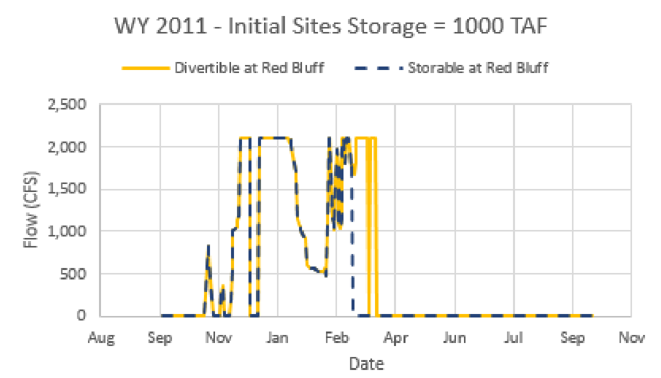
WY 2011 - Initial Sites Storage = 1000 TAF

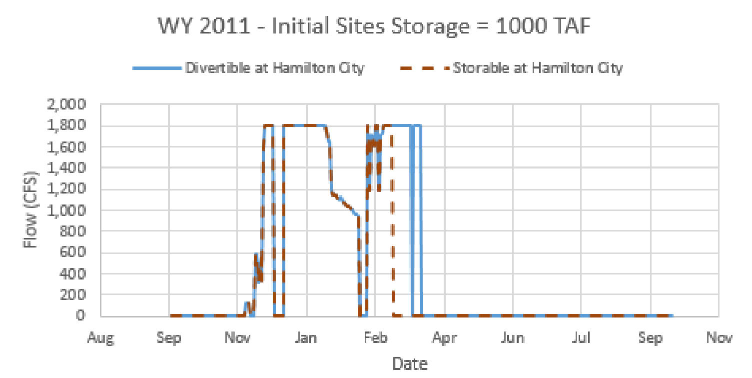
	Available Flow (TAF)			Divertible Flow (TAF)			Storable Flow (TAF)			Accumulative Storable Flow (TAF)			
Month	Red Bluff	Hamilton City	Delevan	Red Bluff	Hamilton City	Delevan	Red Bluff	Hamilton City	Delevan	Red Bluff	Hamilton City	Delevan	Total
10	6.13	6.13	6.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	13.84	13.84	13.84	11.46	0.70	1.23	11.46	0.70	1.23	11.46	0.70	1.23	13.40
12	777.43	767.18	712.63	89.91	69.55	79.52	89.91	69.55	79.52	101.38	70.25	80.76	252.39
1	626.22	533.40	417.34	108.76	100.78	98.33	108.76	100.78	98.33	210.14	171.03	179.08	560.25
2	202.34	168.63	81.03	51.66	54.84	29.78	51.66	54.84	29.78	261.80	225.87	208.86	696.53
3	872.93	855.47	783.45	116.75	105.58	116.91	39.64	34.18	39.65	301.44	260.05	248.51	810.00
4	823.63	801.42	651.46	0.00	0.00	0.00	0.00	0.00	0.00	301.44	260.05	248.51	810.00
5	281.95	280.89	277.75	0.00	0.00	0.00	0.00	0.00	0.00	301.44	260.05	248.51	810.00
6	453.06	436.01	424.89	0.00	0.00	0.00	0.00	0.00	0.00	301.44	260.05	248.51	810.00
7	226.33	226.33	226.33	0.00	0.00	0.00	0.00	0.00	0.00	301.44	260.05	248.51	810.00
8	209.55	209.55	209.55	0.00	0.00	0.00	0.00	0.00	0.00	301.44	260.05	248.51	810.00
9	59.11	58.92	58.92	0.00	0.00	0.00	0.00	0.00	0.00	301.44	260.05	248.51	810.00

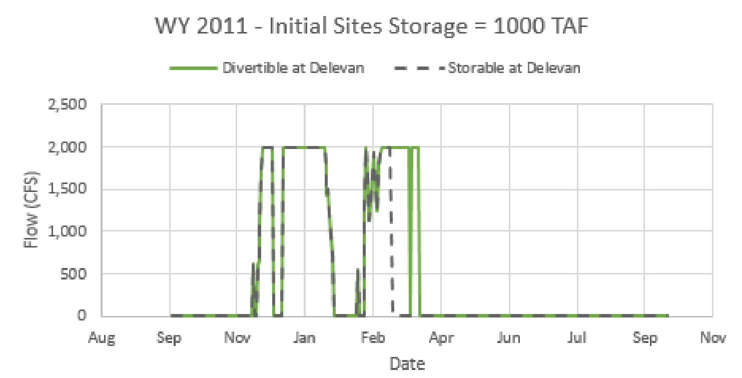








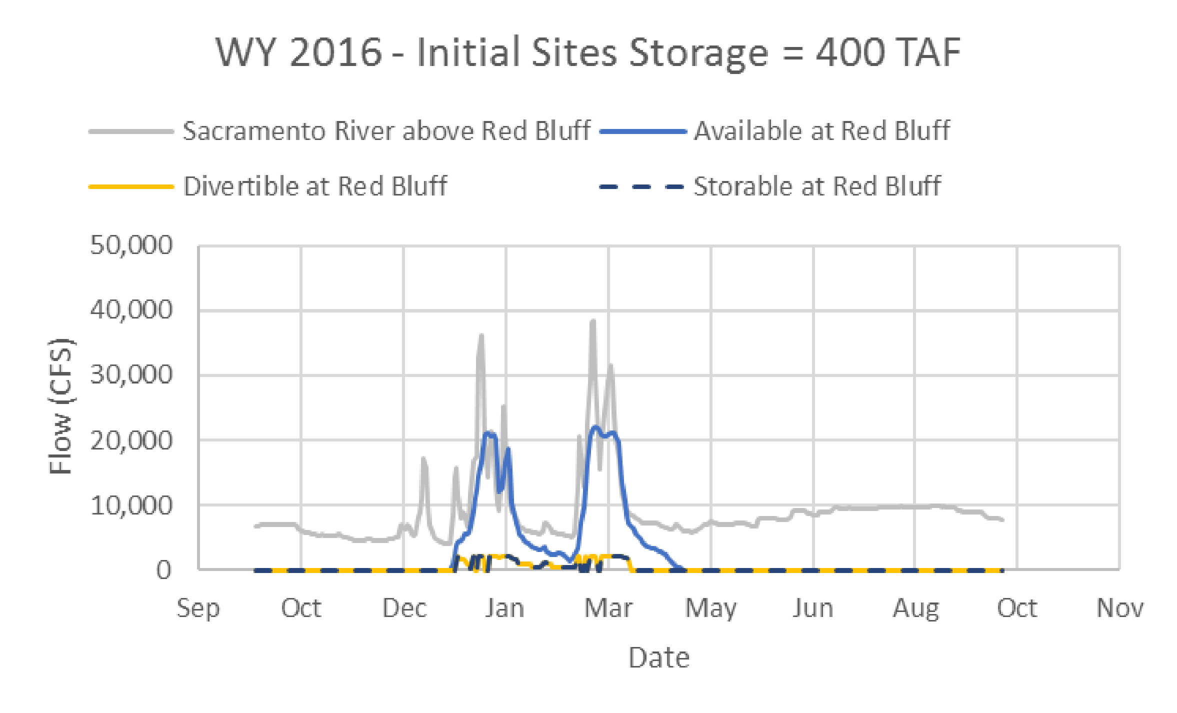




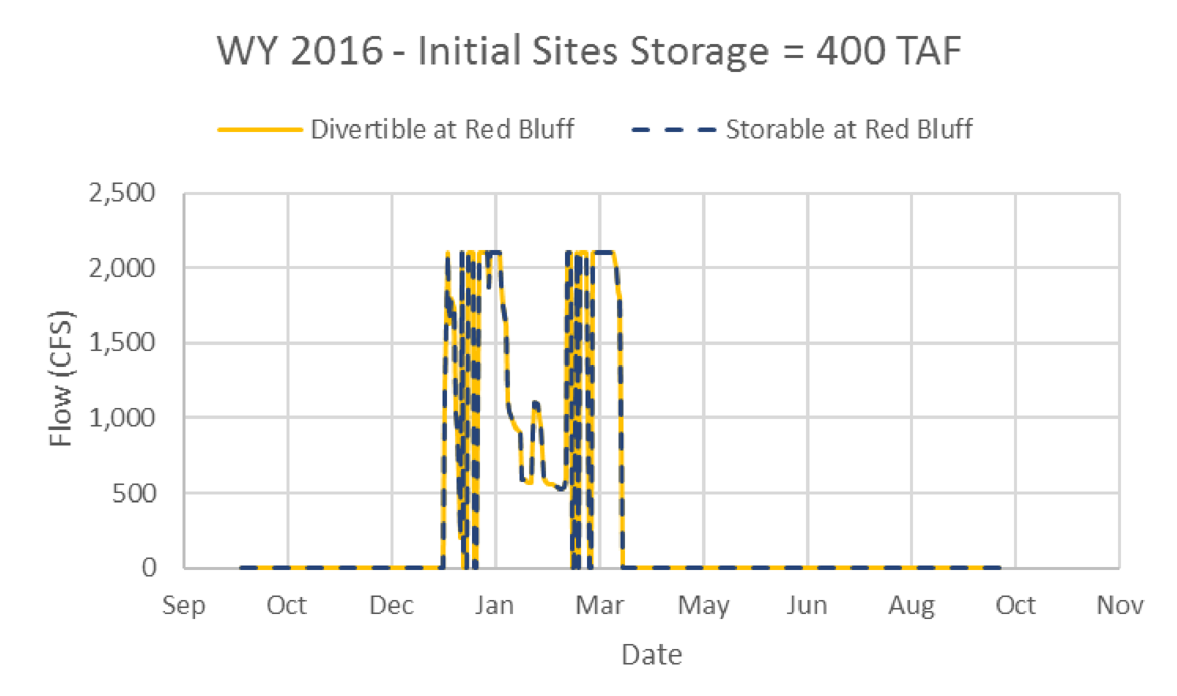
Example 1 (2016 hydrology with low initial Sites storage)

Year:	2016
Initial Sites Storage (TAF):	400
Diversion Criteria:	
Sites Storage Capacity (TAF)	1,810
Intake Conveyance Capacities	
TCC	2,100
GCC	1,800
Delevan	2,000
Bypass Requirements (cfs)	
Sac R Below Red Bluff	3,250
Sac R Below Hamilton City	4,000
Sac R Below Delevan Intake	5,000
Wilkins Slough	5,000
Freeport (July-Nov)	11,000
Freeport (Dec, Feb-Jun)	13,000
Freeport (Jan)	15,000
Diversion Season	
Starting Month (CY 7-12)	11
Ending Month (CY 1-6)	3
Min Pumping Levels (cfs)	
Red Bluff	125
Hamilton City	100
Delevan	500

Hydrology, availability, divertibility, and storability at Red Bluff intake:



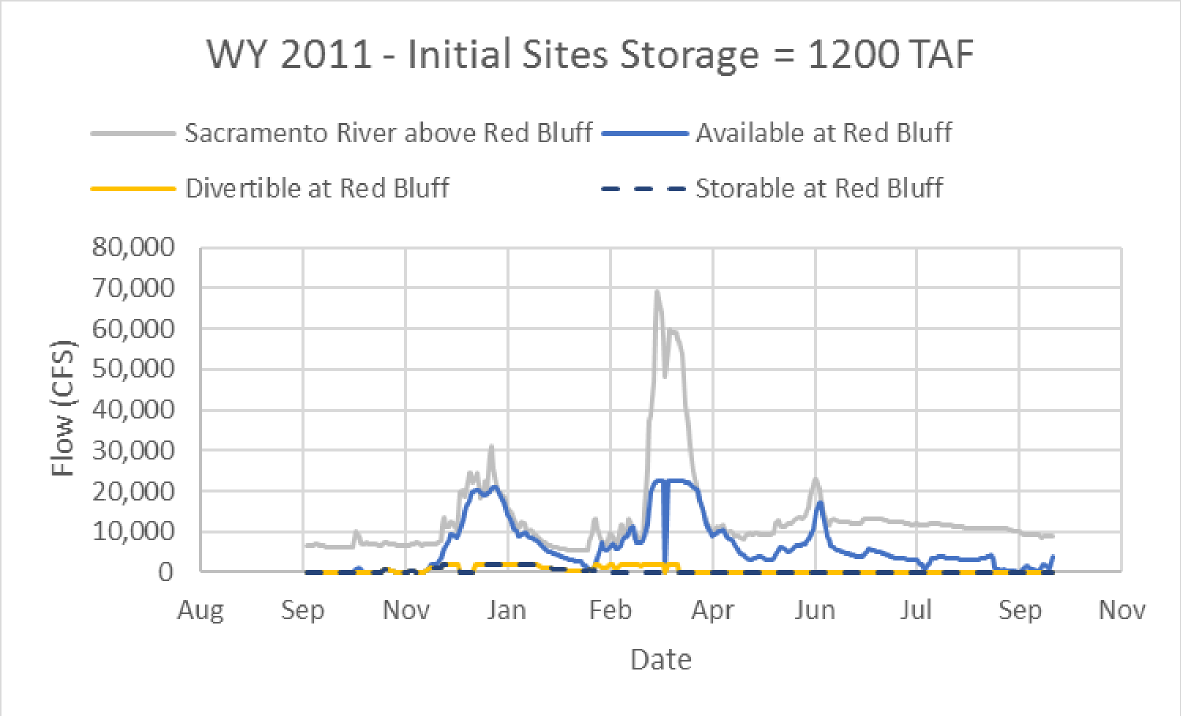
Zoomed in on Divertible and Storable Flow:



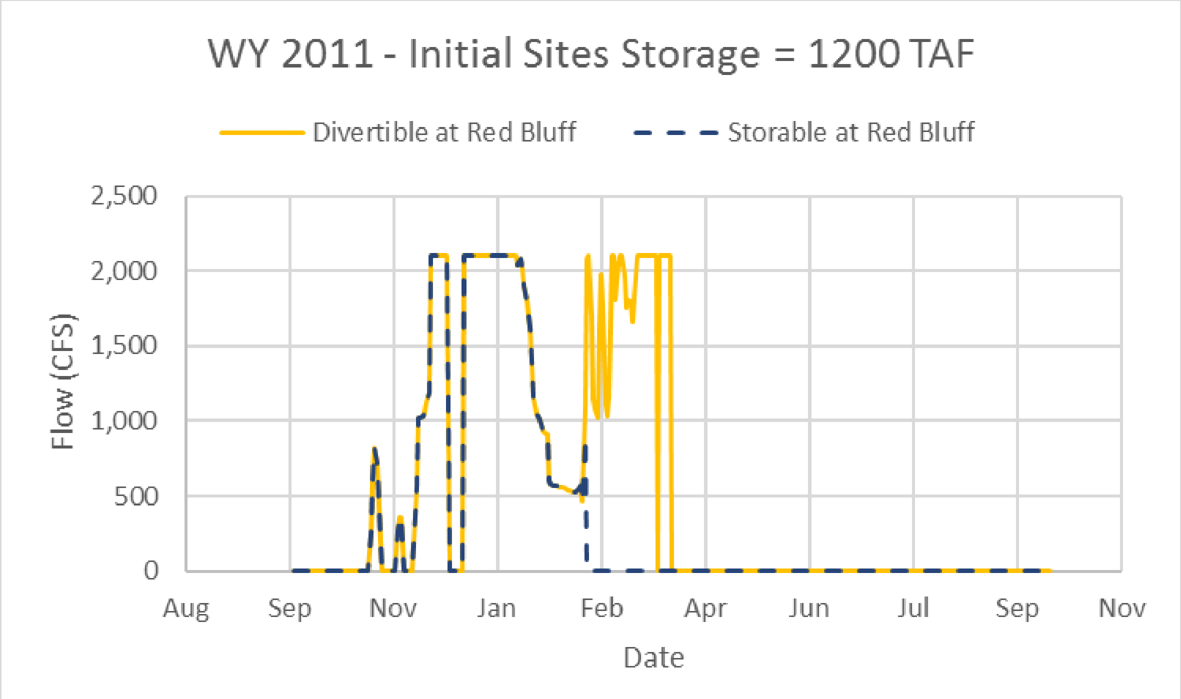
Example 2 (2011 hydrology with higher Sites storage)

Year:	2011
Initial Sites Storage (TAF):	1,200
Diversion Criteria:	
Sites Storage Capacity (TAF)	1,810
Intake Conveyance Capacities	
TCC	2,100
GCC	1,800
Delevan	2,000
Bypass Requirements (cfs)	
Sac R Below Red Bluff	3,250
Sac R Below Hamilton City	4,000
Sac R Below Delevan Intake	5,000
Wilkins Slough	5,000
Freeport (July-Nov)	11,000
Freeport (Dec, Feb-Jun)	13,000
Freeport (Jan)	15,000
Diversion Season	
Starting Month (CY 7-12)	11
Ending Month (CY 1-6)	3
Min Pumping Levels (cfs)	
Red Bluff	125
Hamilton City	100
Delevan	500

Hydrology, availability, divertibility, and storability at Red Bluff intake:



Zoomed in on Divertible and Storable Flow:



Ability to Evaluate Multiple Scenarios

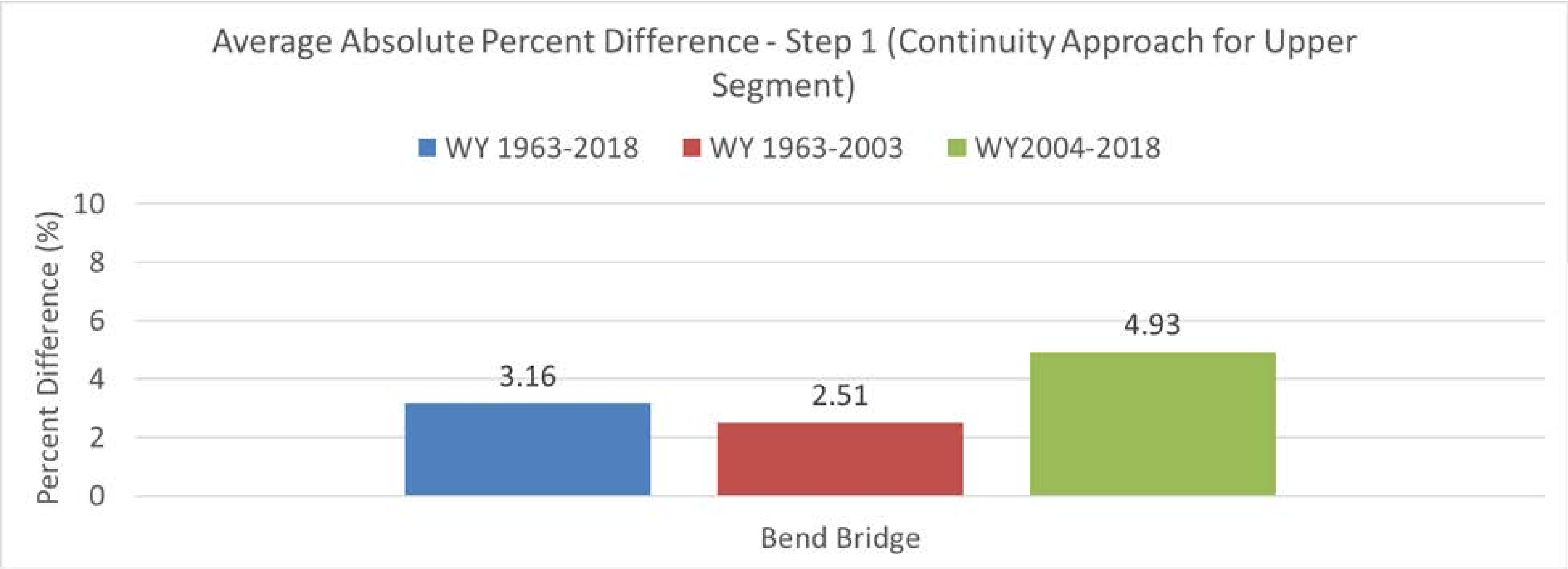
- A macro is built into the spreadsheet tool to iterate through multiple combinations of varying inputs and constraints
- The inputs and outputs from each scenario can be fed into Power BI to sift through the data and analyze relationships between the inputs (i.e., minimum pumping levels or bypass flow requirements) and outputs (i.e., Divertible and Storable flows)
  - Power BI is a business analytics service developed by Microsoft. It provides a platform for interactive visualizations of data

Supporting Slides

USRDOM HindCast Calibration – Step 1

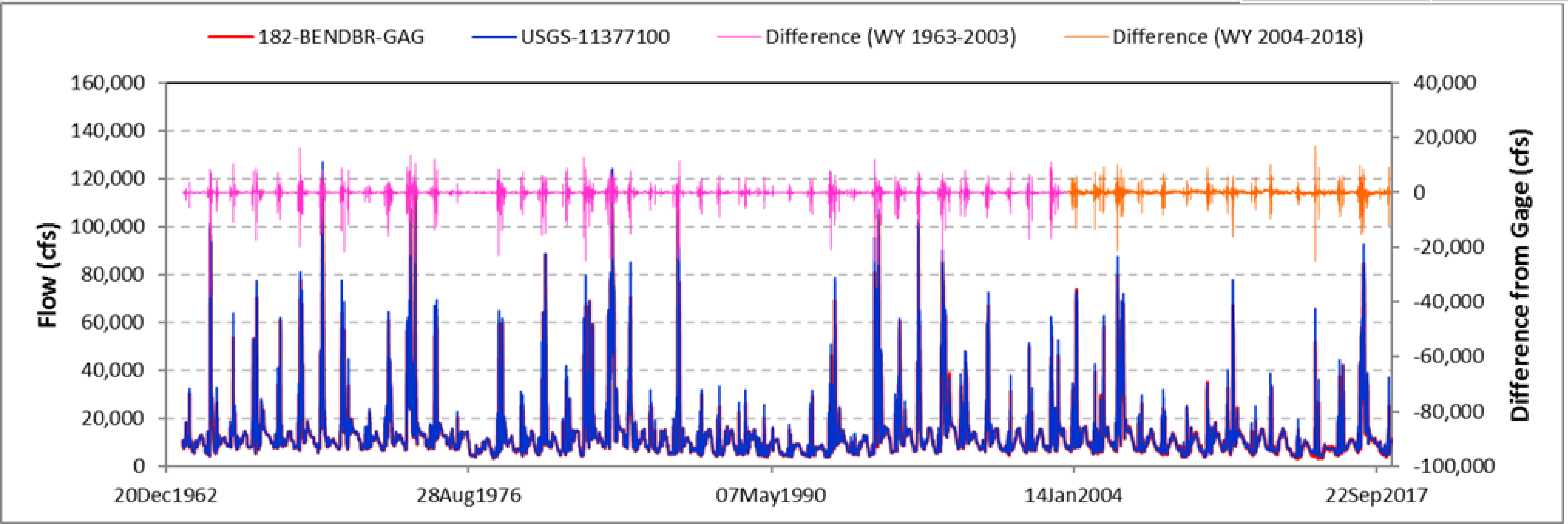
- The Upper Segment closure term is computed by estimating the differences between observed (gaged) flows at Bend Bridge and all known inflows and diversions modeled in USRDOM upstream of that location
- **UPPERSACRCLOSURE** = BB – [WR + SR + Cow + Cot + Bat – ACID]
  - Where:
    - BB = Sacramento River flow at Bend Bridge computed by USRDOM (182-BENDBR-GAG)
    - WR = Whiskeytown release (daily average from Reclamation's monthly data)
    - SR = Shasta release (difference between Keswick Dam and Whiskeytown release plus Clear Creek tunnel flow)
    - Cow = Cow Creek Inflow (USGS 11374000)
    - Cot = Cottonwood Creek Inflow (USGS 11376000)
    - Bat = Battle Creek Inflow (USGS 11376550)
    - ACID = ACID diversion (daily average from Reclamation's monthly data)

USRDOM HindCast Calibration – Step 1 Result



Bend Bridge Flow (cfs) (WY 1963 -2018)

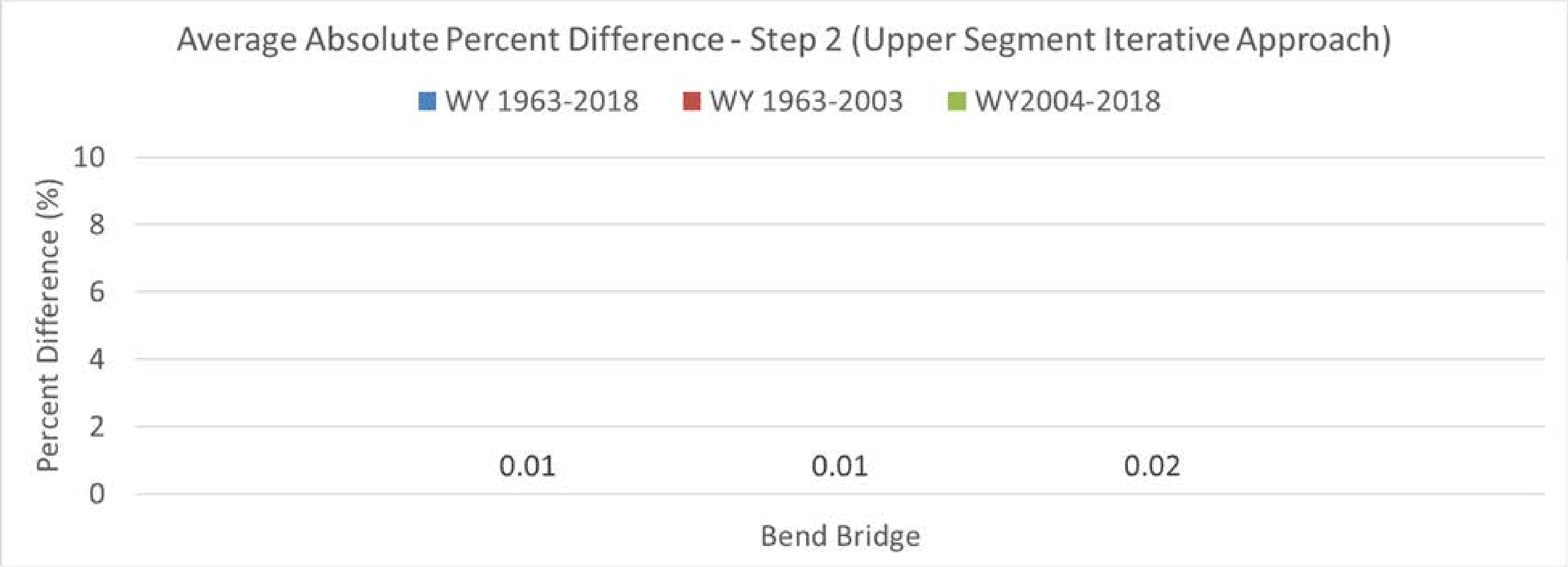
	Average	Min	Max
Observed	12,525.7	3,200.0	127,000.0
Modeled	12,482.3	3,143.8	119,440.4
Difference	-43.4	-38,236.1	16,200.8



USRDOM HindCast Calibration – Step 2

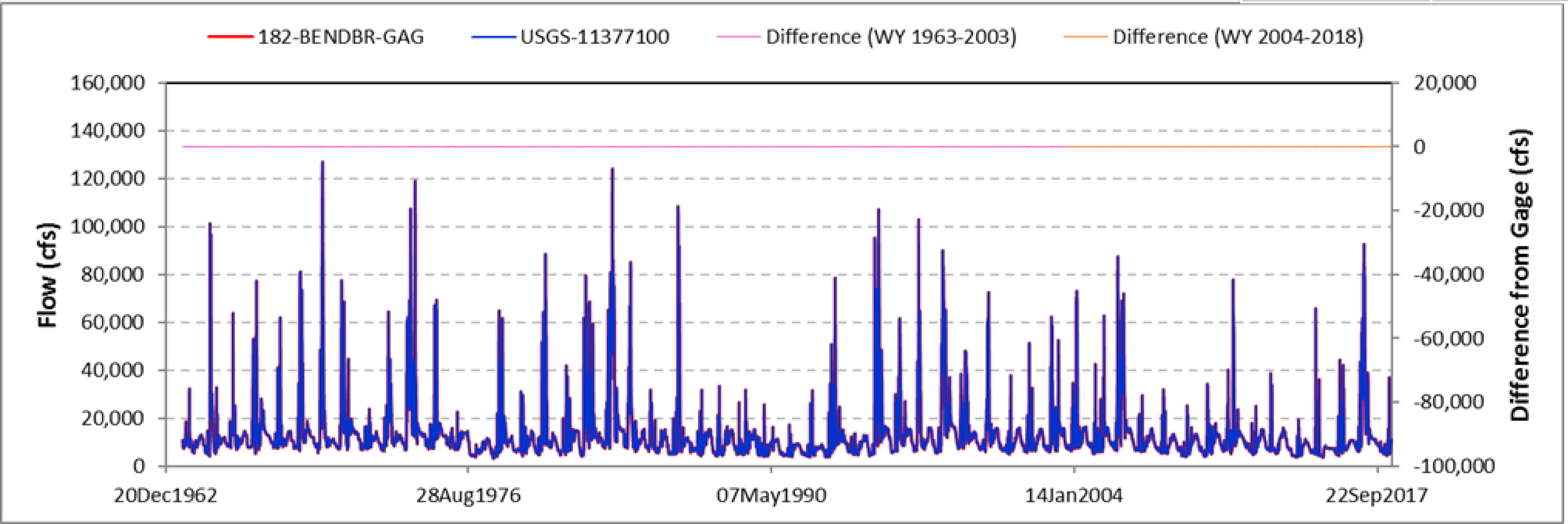
- The Upper Segment closure term is refined by setting it equal to itself plus the difference between gaged flow at Bend Bridge and USRDOM's synthesized flow at Bend Bridge
- The model is re-run, resulting in a smaller discrepancy between Bend Bridge gaged flow and Bend Bridge synthesized flow
- This process was repeated 3 more times (4 iterations in total)

USRDOM HindCast Calibration – Step 2 Result



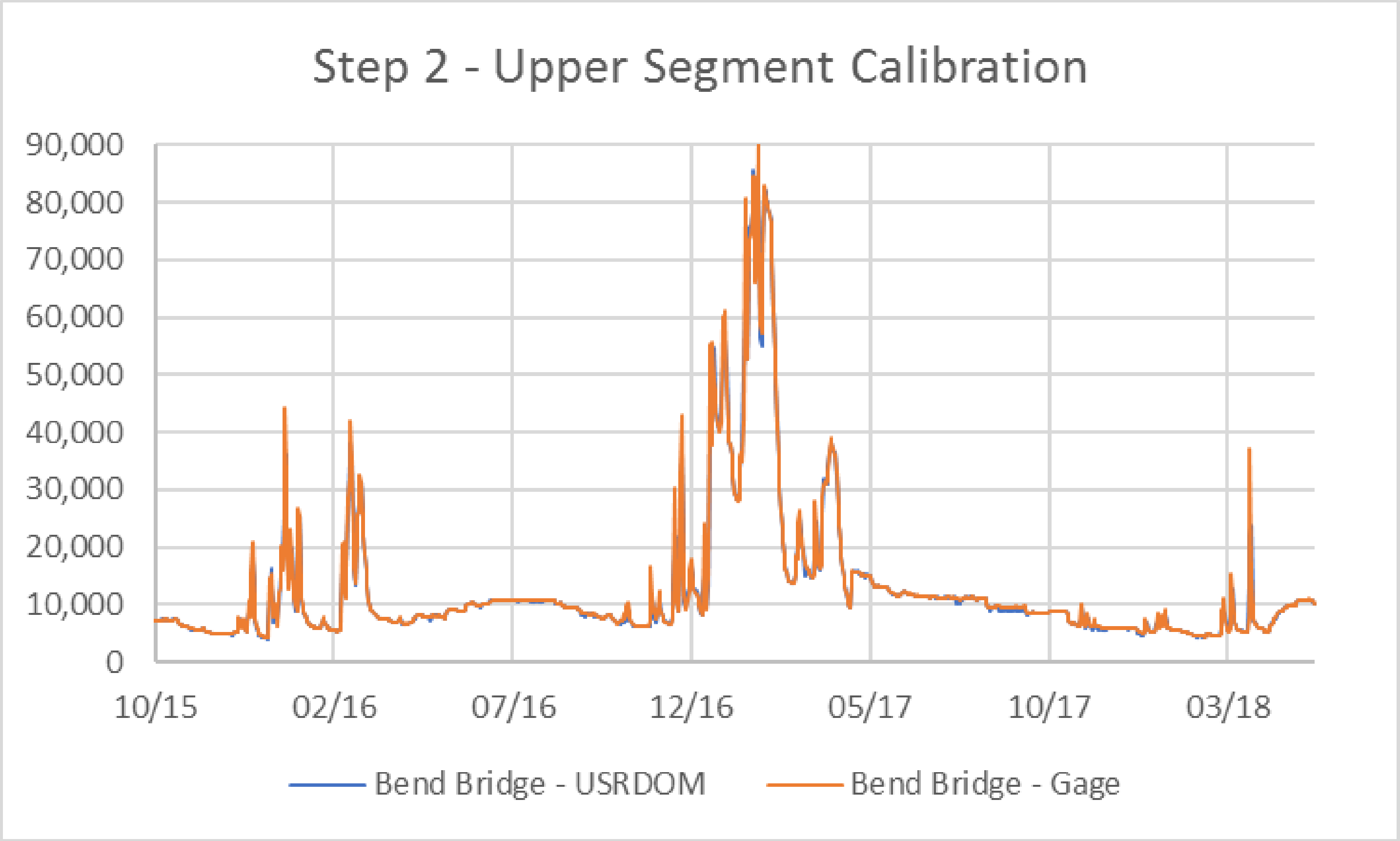
Bend Bridge Flow (cfs) (WY 1964 -2018)

	Average	Min	Max
Observed	12,525.7	3,200.0	127,000.0
Modeled	12,525.7	3,199.8	127,043.8
Difference	0.0	-264.4	114.9



USRDOM HindCast Calibration – Step 2

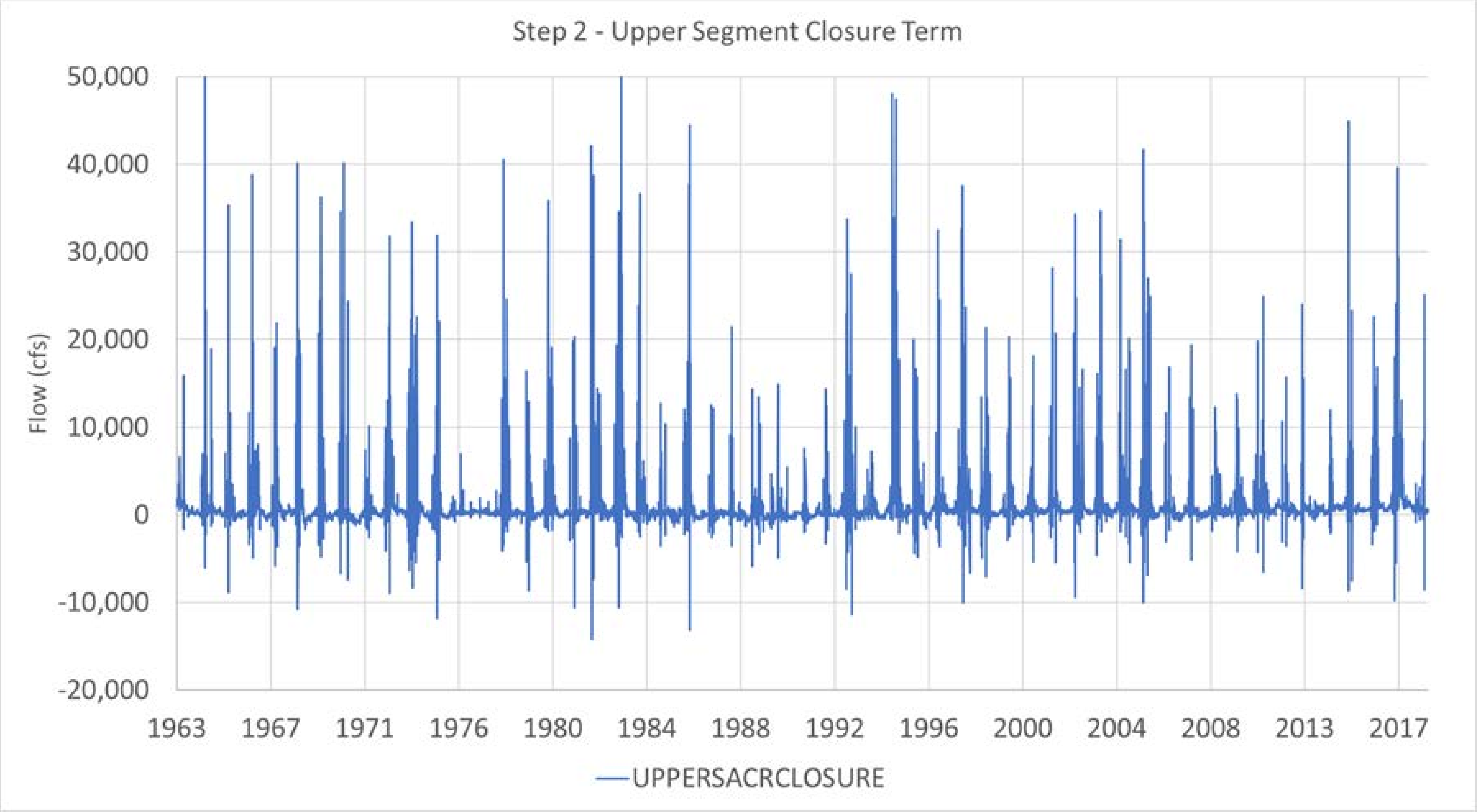
- The model near perfectly replicates gaged records at Bend Bridge



USRDOM HindCast Calibration – Step 2 Issues

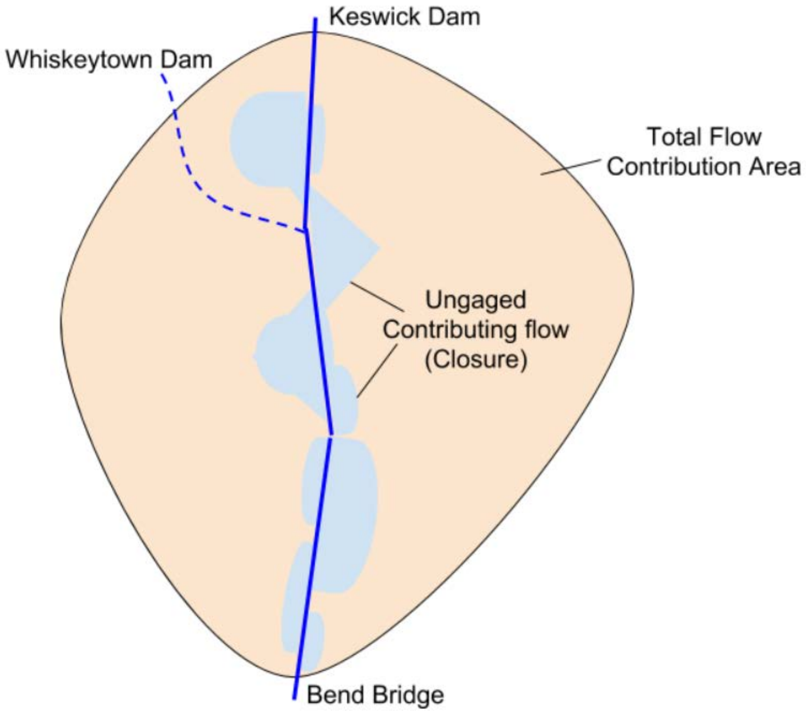
- The “Step 2” method assumes complete accuracy in gaged records and it does not account for gage error
- However, gage readings can become inaccurate for because of extreme weather conditions, damage to the gage, improper calibration, etc.

- The Upper Segment closure term often adds (positive values) and removes (negative values) a significant quantity of flow into and out of the river
  - In some of these instances, the magnitude of the closure term is too high to be attributed merely to unmodeled diversions, accretions, depletions, and tributary inflows
    - Gage error is assumed under these circumstances



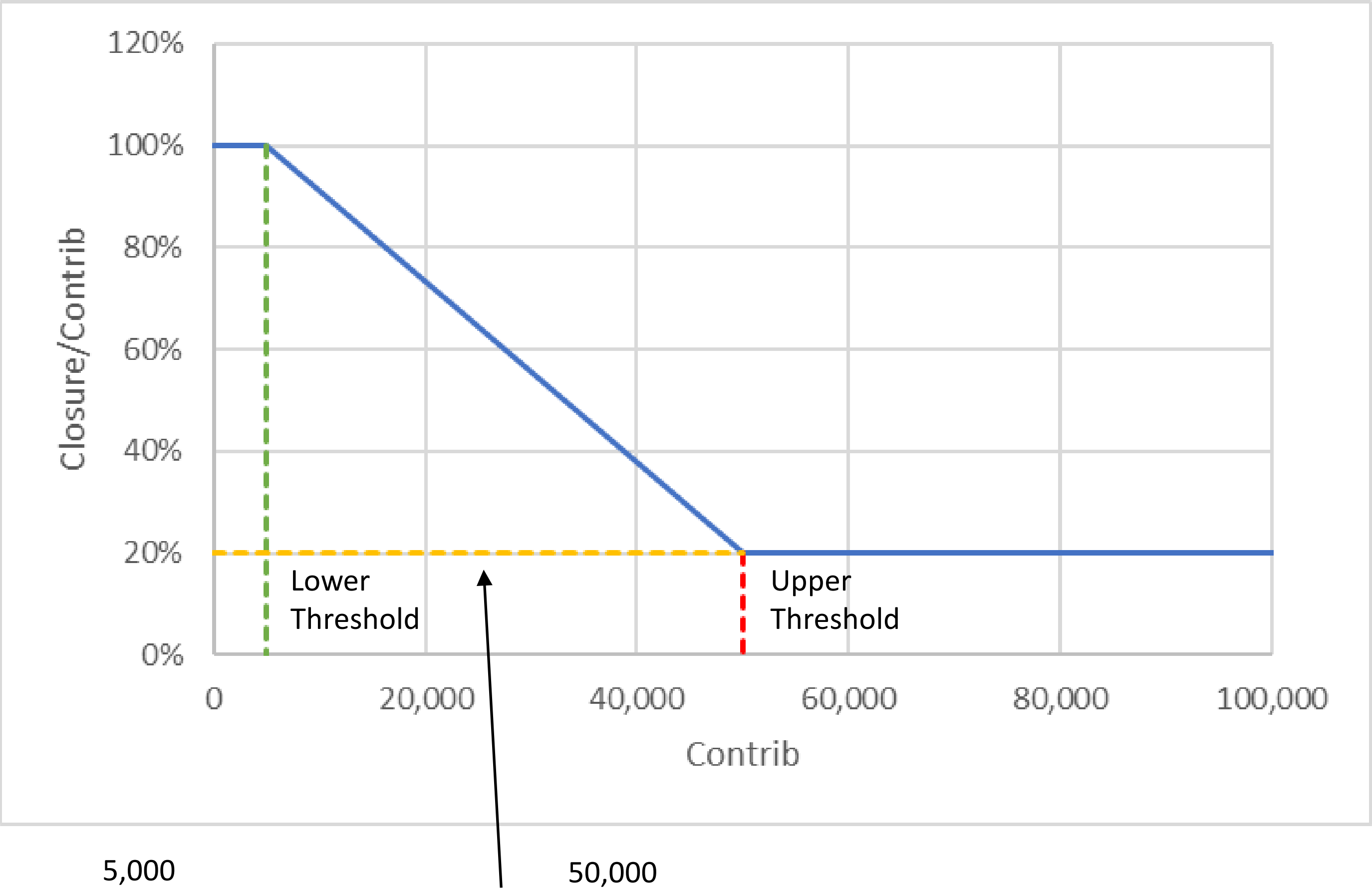
USRDOM HindCast Calibration – Step 3

- The purpose of Step 3 is to account for potential gage error at Bend Bridge.
- The Upper Segment closure term is adjusted to reduce unreasonably large magnitudes of flow from being brought into the river or taken out of it



Upper Segment Closure Term Rules:

1. Closure >= Background Closure
2. If Total Flow Contribution ≤ Background Closure:
   (Closure Term) / (Total Flow Contribution) = 100%
3. If Background Closure ≤ Total Flow Contribution ≤ Lower Threshold = 5,000 cfs
   (Closure Term) / (Total Flow Contribution) ≤ 100%
4. If Lower Threshold ≤ Total Flow Contribution ≤ Upper Threshold
   (Closure Term) / (Total Flow Contribution) ≤ [(Total Flow Contribution) * m_u + i_u] / 100
   Where:
   m_u = slope of Upper Segment curve = -0.00179
   i_u = y-intercept of Upper Segment curve = 109
5. If Total Flow Contribution ≥ Upper Threshold
   (Closure Term) / (Total Flow Contribution) ≤ $U_{r,u}$
   Where:
   $U_{r,u}$ = ungaged ratio of Upper Segment



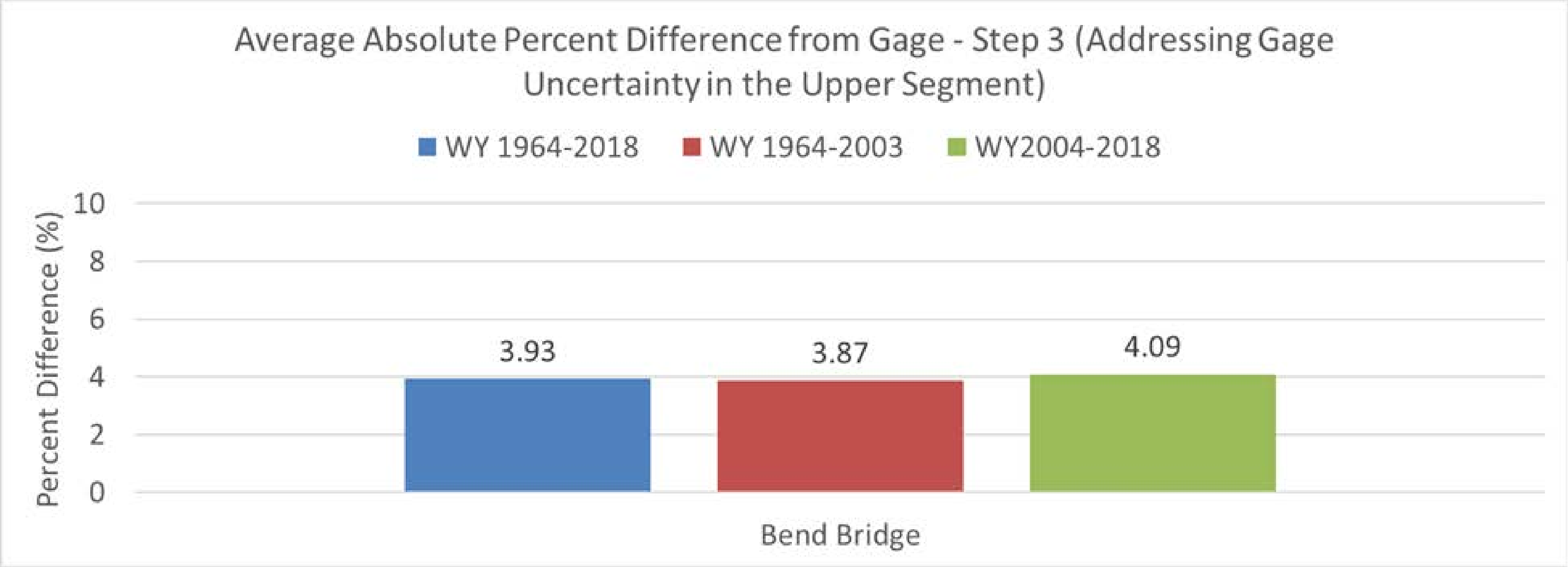
5,000

50,000

(Ungaged Area) / (Total Flow Contribution Area) = 19.8%

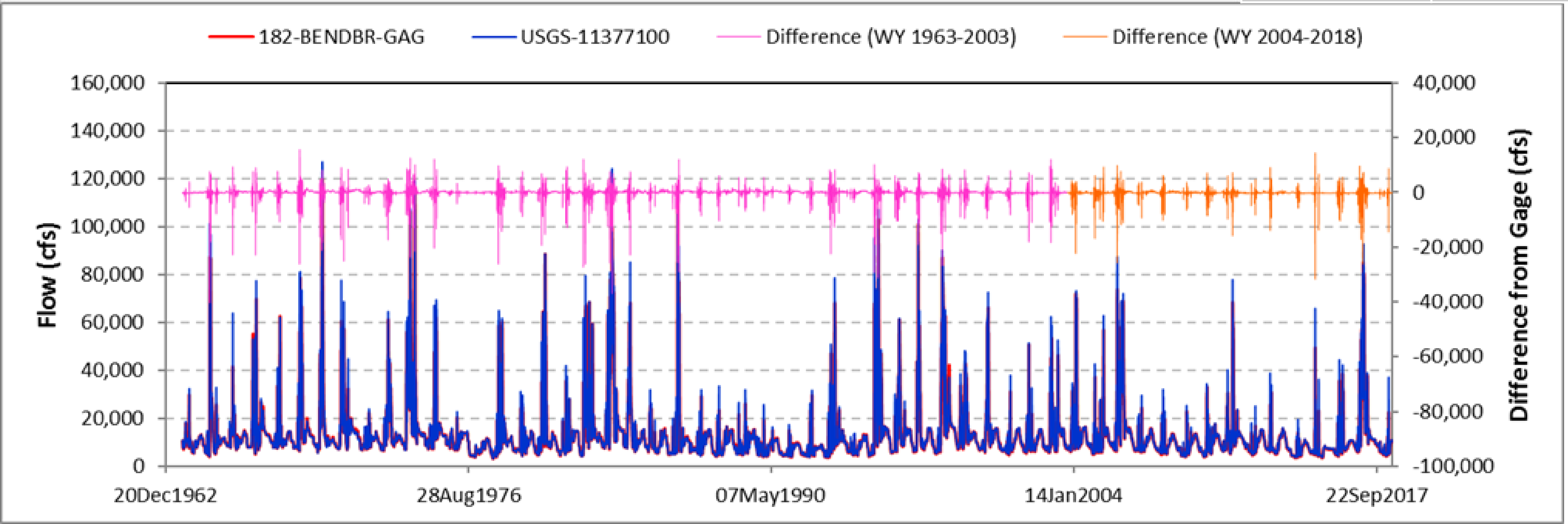
- **Closure** = Closure Term flow
- **Total Flow Contribution (Upper Segment)** = Bend Bridge flow – (Keswick Dam flow + Clear Creek Flow + Background Closure)
- **Background Closure** = Background closure term for the Upper Segment (average July-October closure term computed in Step 2) = 196 cfs
- **Lower Threshold** = Flow at which storm event covers roughly the total flow contribution area = 5,000 cfs
- **Upper Threshold** = Flow at which storm event significantly exceeds total flow contribution area = 50,000 cfs

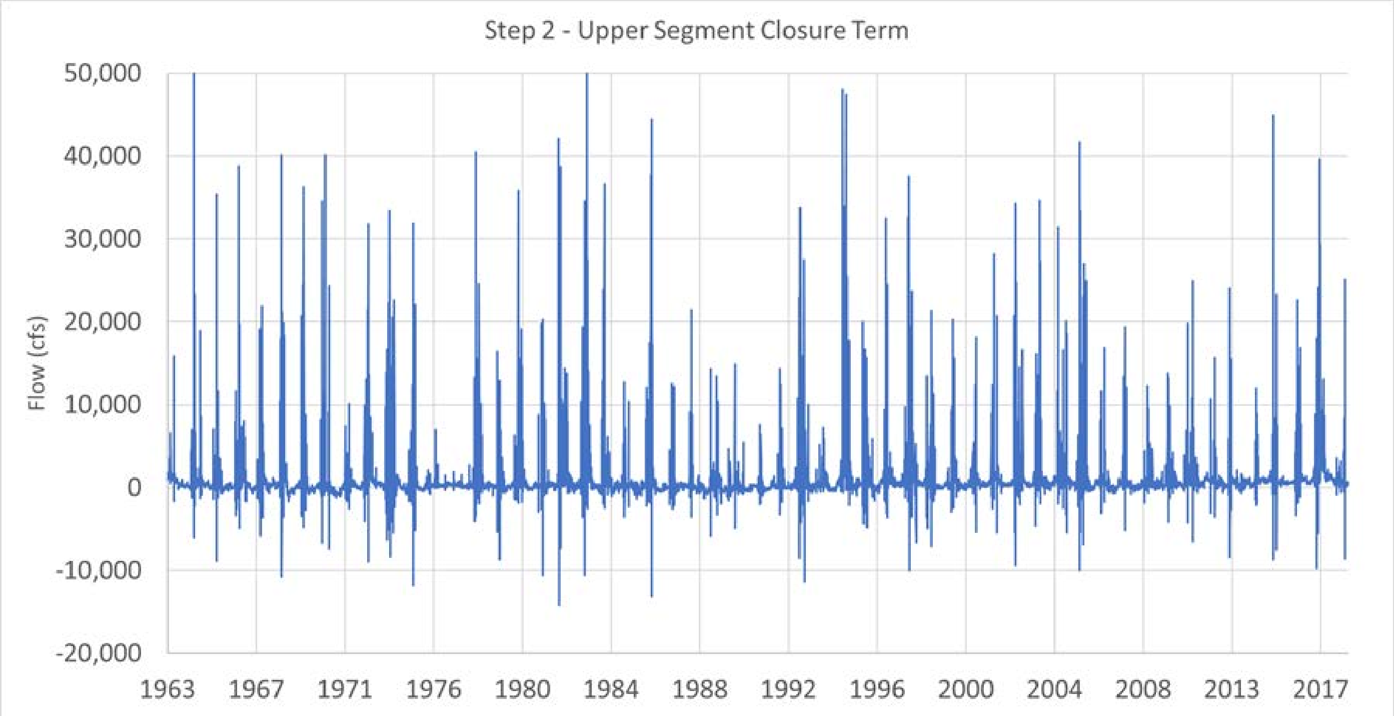
USRDOM HindCast Calibration – Step 3 Result

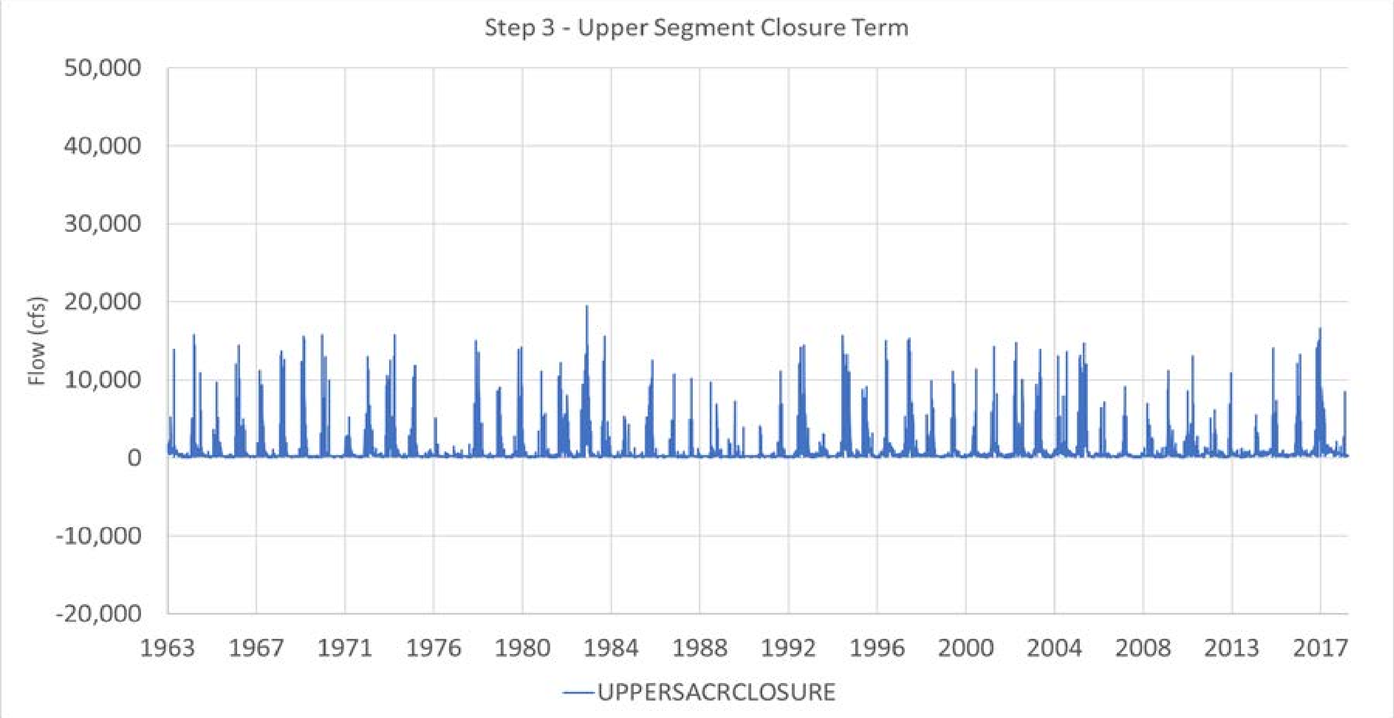


Bend Bridge Flow (cfs) (WY 1964 -2018)

	Average	Min	Max
Observed	12,525.7	3,200.0	127,000.0
Modeled	12,424.1	3,134.4	119,688.6
Difference	-101.7	-40,395.5	14,788.6

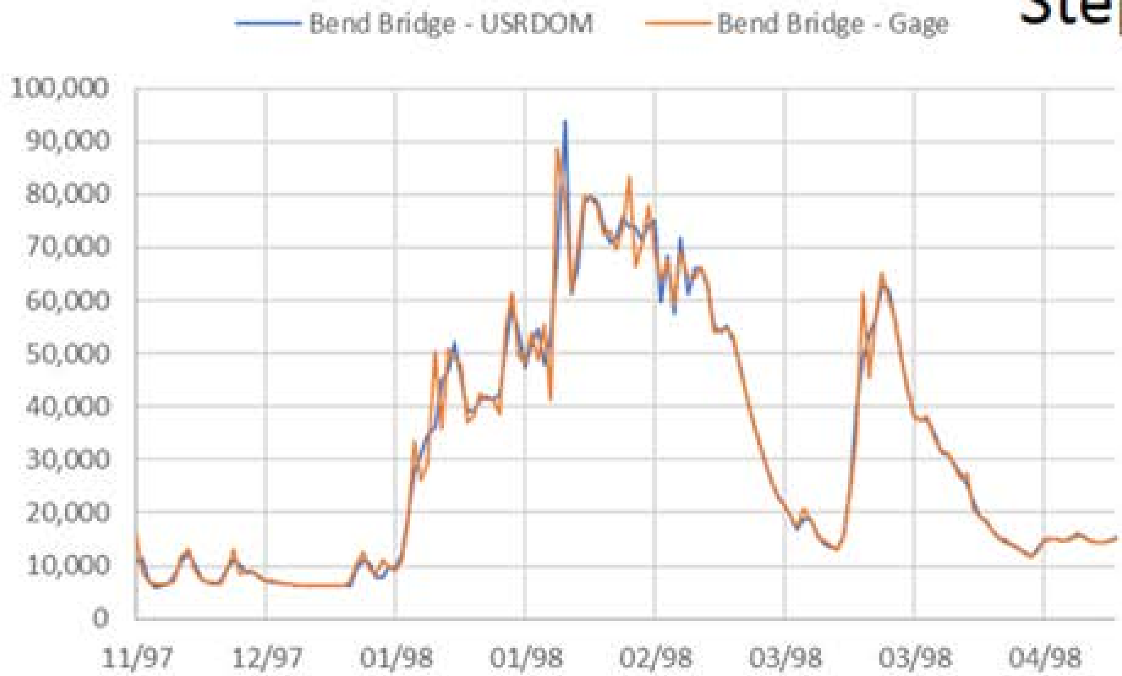


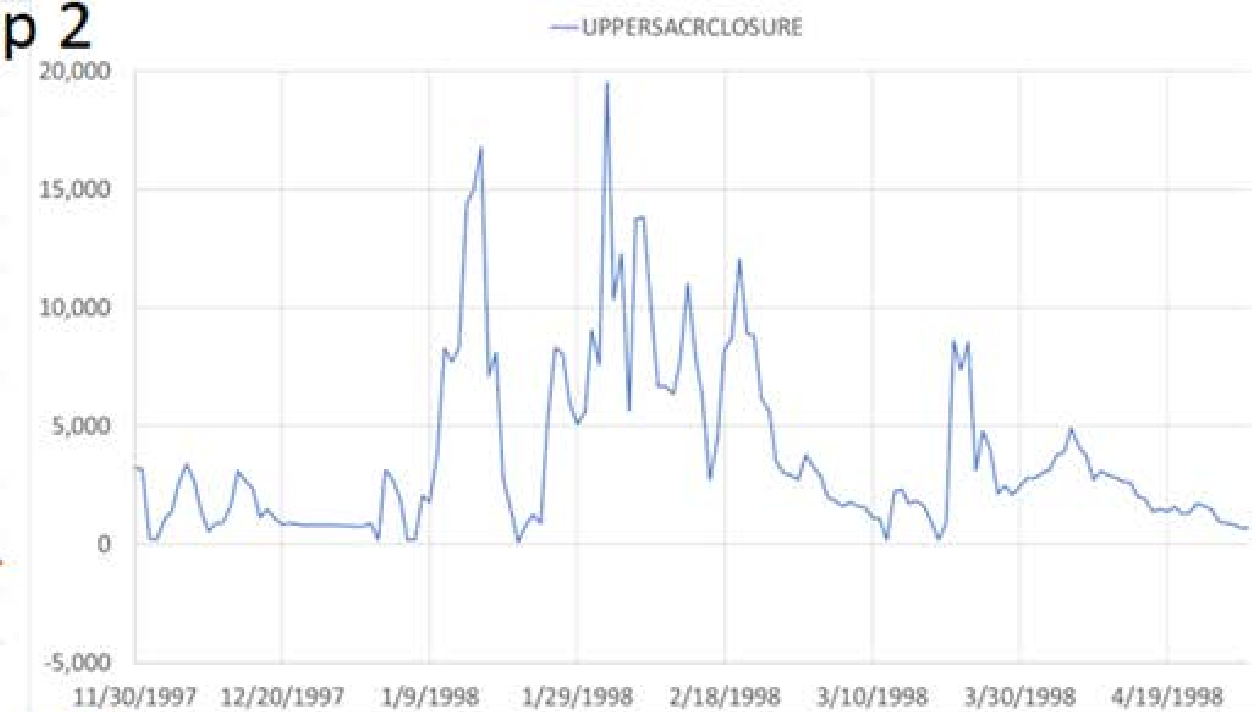




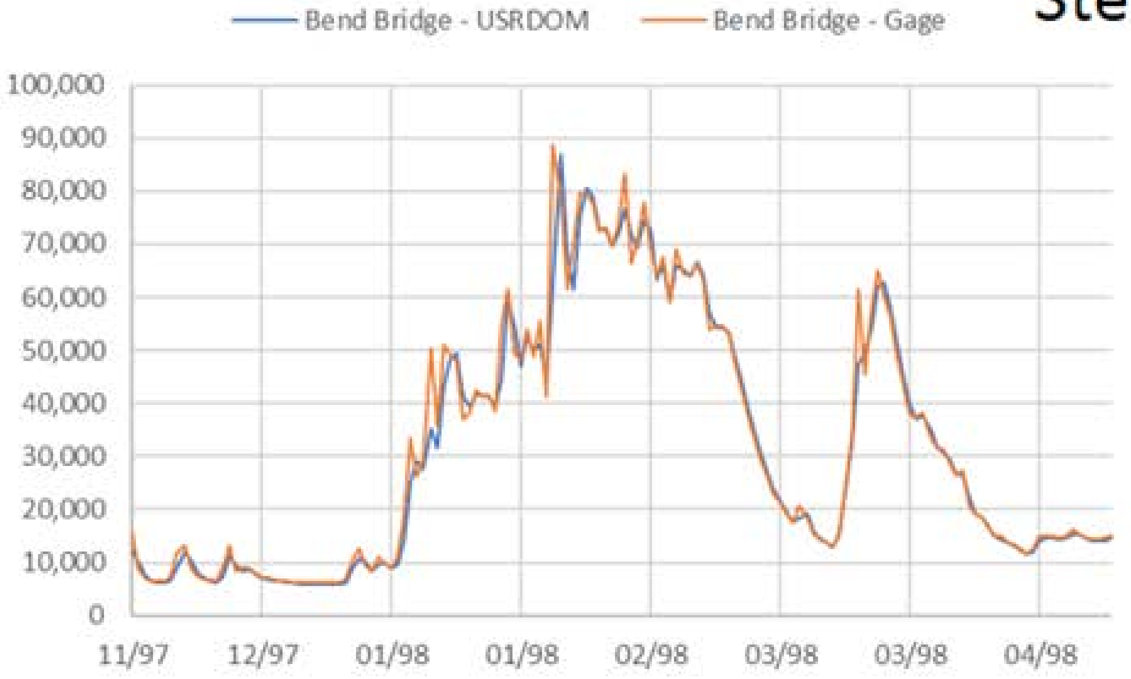
- The Upper Segment closure term no longer reaches magnitudes as high as it did in Step 2. In addition, the closure term never dips below zero since it is no longer permitted to remove flow from the system

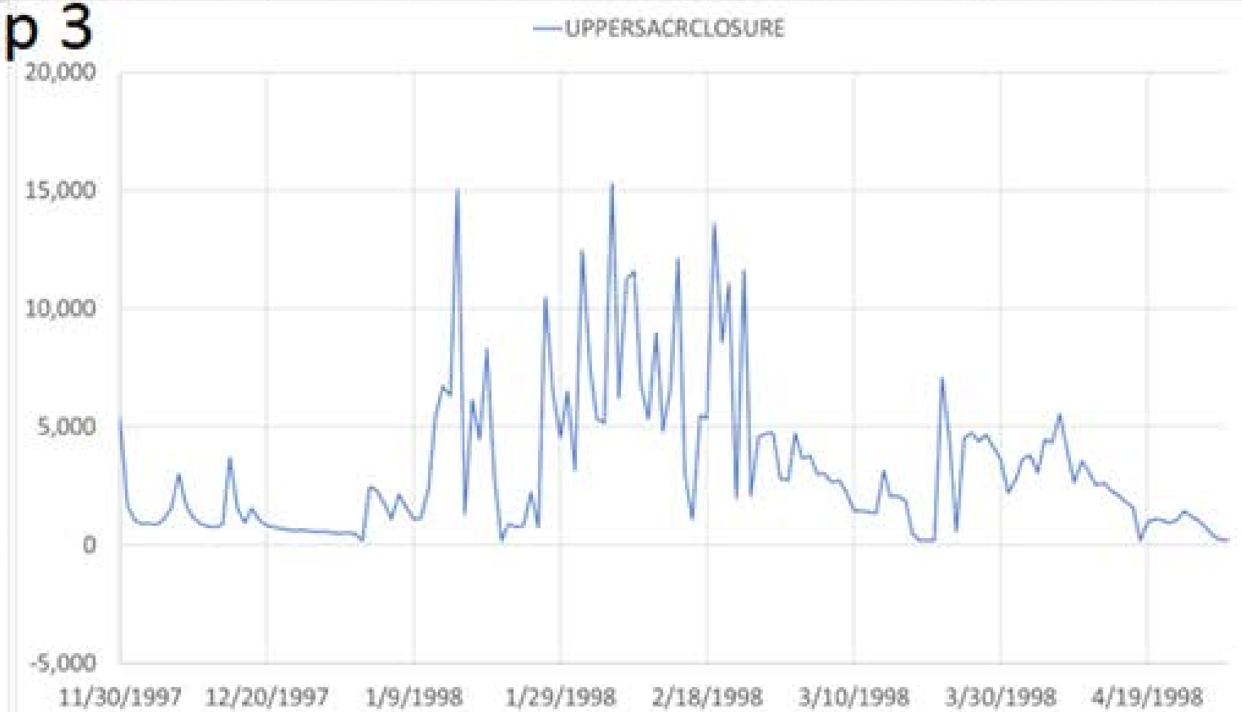
Step 2


Bend Bridge - USRDOM
Bend Bridge - Gage
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
11/97
12/97
01/98
01/98
02/98
03/98
03/98
04/98

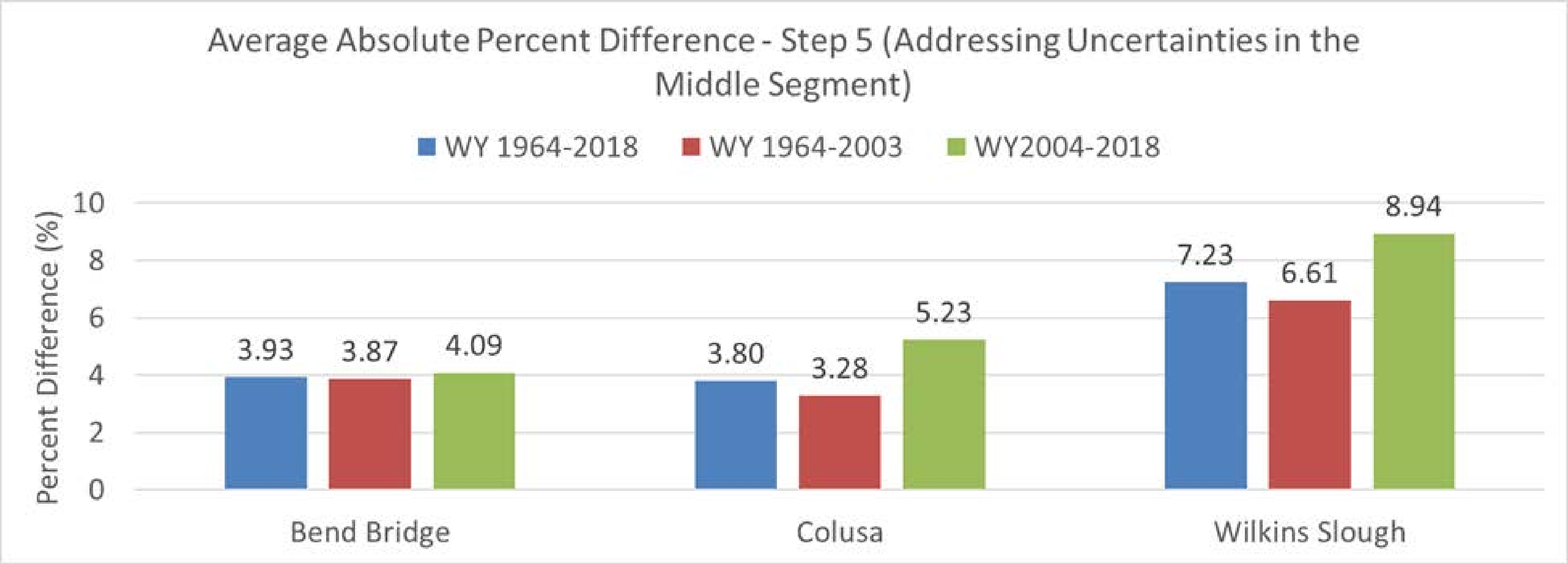

UPPERSACRCLOSURE
20,000
15,000
10,000
5,000
0
-5,000
11/30/1997
12/20/1997
1/9/1998
1/29/1998
2/18/1998
3/10/1998
3/30/1998
4/19/1998

Step 3


Bend Bridge - USRDOM
Bend Bridge - Gage
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
11/97
12/97
01/98
01/98
02/98
03/98
03/98
04/98


UPPERSACRCLOSURE
20,000
15,000
10,000
5,000
0
-5,000
11/30/1997
12/20/1997
1/9/1998
1/29/1998
2/18/1998
3/10/1998
3/30/1998
4/19/1998

Lower Segment Performance after Calibration



USGS Data

Location	Gage Number
ACID_Canal_at_Sharon	11370700
Antelope_Ck_nr_RedBluff	11379000
Battle_Ck_nr_Coleman	11376550
Battle_Ck_nr_Cottonwood	11376500
Bear_Ck_nr_Millville	11374100
BigChico_Ck_nr_Chico	11384000
Churn_Ck_blw_Newton_nr_Redding	11372060
Churn_Ck_nr_Redding	11372050
Clear_Ck_at_FrenchGulch	11371000
Clear_Ck_nr_Igo	11372000
ColusaWeir_Spill_to_Butte	11389470
Cottonwood_Ck_nr_Cottonwood	11376000
Cow_Ck_nr_Millville	11374000
Deer_Ck_nr_Vina	11383500
Elder_Ck_nr_Paskenta	11379500

Location	Gage Number
Mcloud_R_at_Baird	10151
Mill_Ck_nr_LosMolinos	11381500
MoultonWeir_Spill_to_Butte	11389350
Paynes_Ck_nr_RedBluff	11377500
Pit_R_nr_Ydalpom	11366500
RedBank_Ck_nr_Rawson	11378860
RedBank_Ck_nr_RedBluff	11378800
Sac_R_abv_BendBridge	11377100
Sac_R_at_Antler	10052
Sac_R_at_BendBridge	11377200
Sac_R_at_Butte	11389000
Sac_R_at_Colusa	11389500
Sac_R_at_Kennett	11369500
Sac_R_at_Keswick	11370500
Sac_R_at_KnightsLanding	11391000

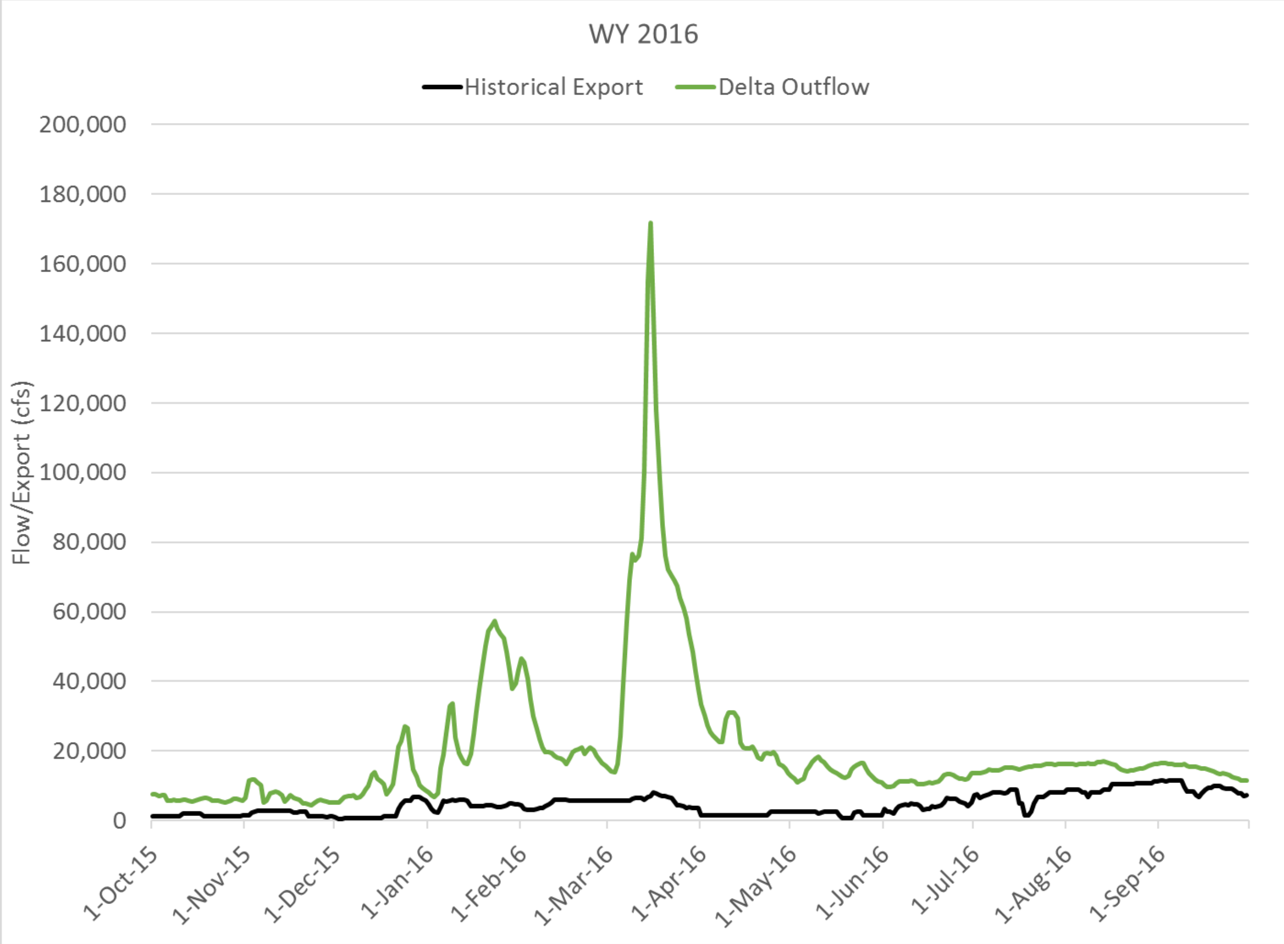
Location	Gage Number
JudgeFrancisCarr_nr_FrenchGul	11525430
Sac_R_bl_WilkinsSlough_nr_Grime	11390500
Sac_R_opp_MoultonWeir	11389390
Spring_Ck_a_Keswick	11371600
Stony_Ck_nr_HamCity	11388500
Thomas_Ck_at_Rawson	11382090
Thomes_Ck_at_Paskenta	11382000
TisdaleWeir_nr_Grimes	11390480
Trinity_R_abv_Coffee	11523200
Trinity_R_at_Lewiston	11525500
Sac_R_opp_MoultonWeir	11389390

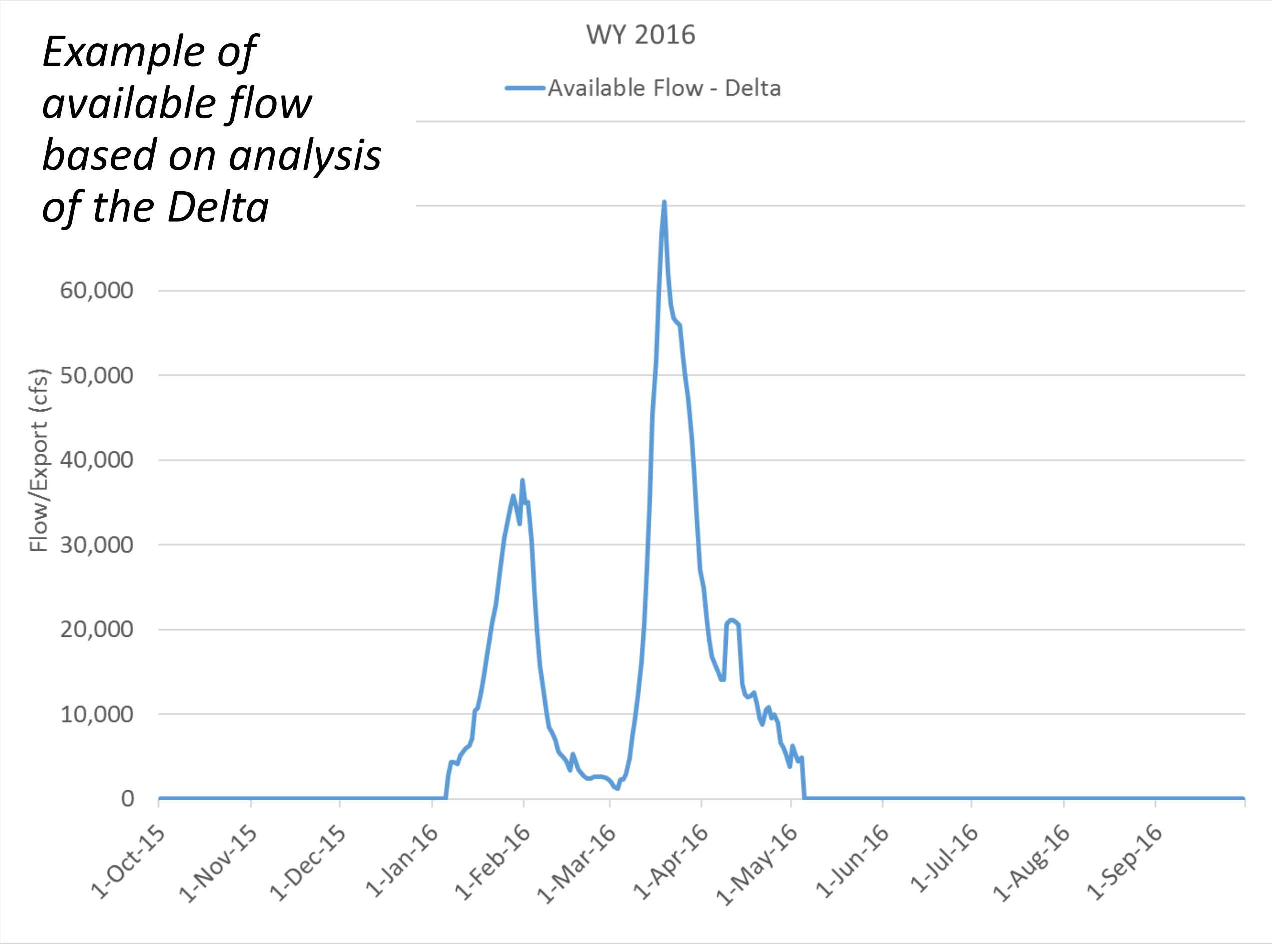
Data from Reclamation

Location	Data (October 1, 2001 – May 31, 2018)
Carr Powerplant (JCR)	Generation Release
Keswick	Evaporation, Reservoir Storage, Computed Inflow, Total Release
Lewiston	Evaporation, Reservoir Storage, Computed Inflow, Total Release
Shasta	Evaporation, Reservoir Storage, Computed Inflow, Total Release
Trinity	Evaporation, Reservoir Storage, Computed Inflow, Total Release
Whiskeytown	Evaporation, Reservoir Storage, Computed Inflow, Clear Creek Natural Flow, Total Release
ACID	Diversion
GC Canal	Diversion
TC Canal	Diversion

- ACID, TC Canal and GC Canal diversions are equal to the monthly average diversion

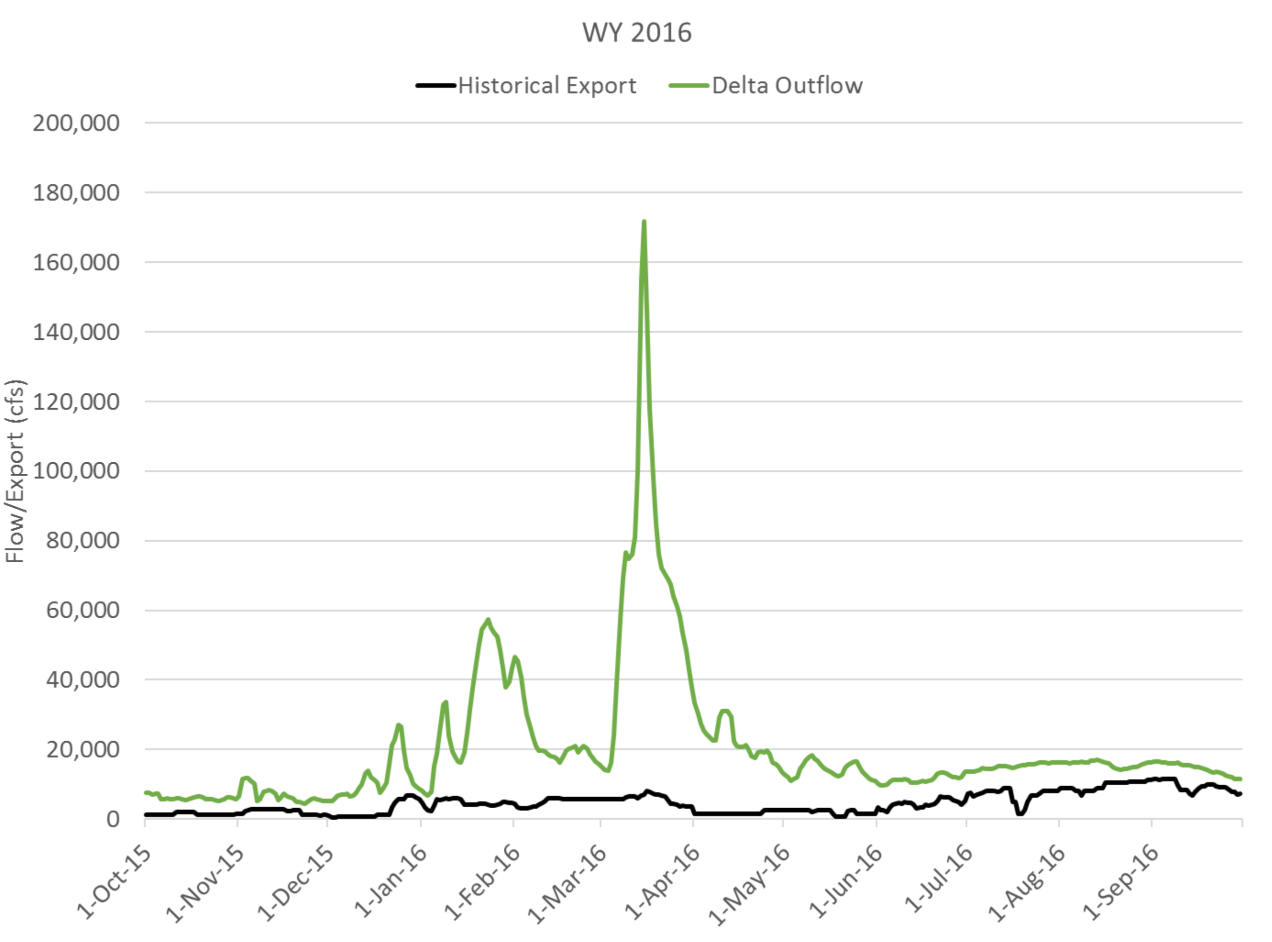
Flow Availability Tool – Preliminary Figures

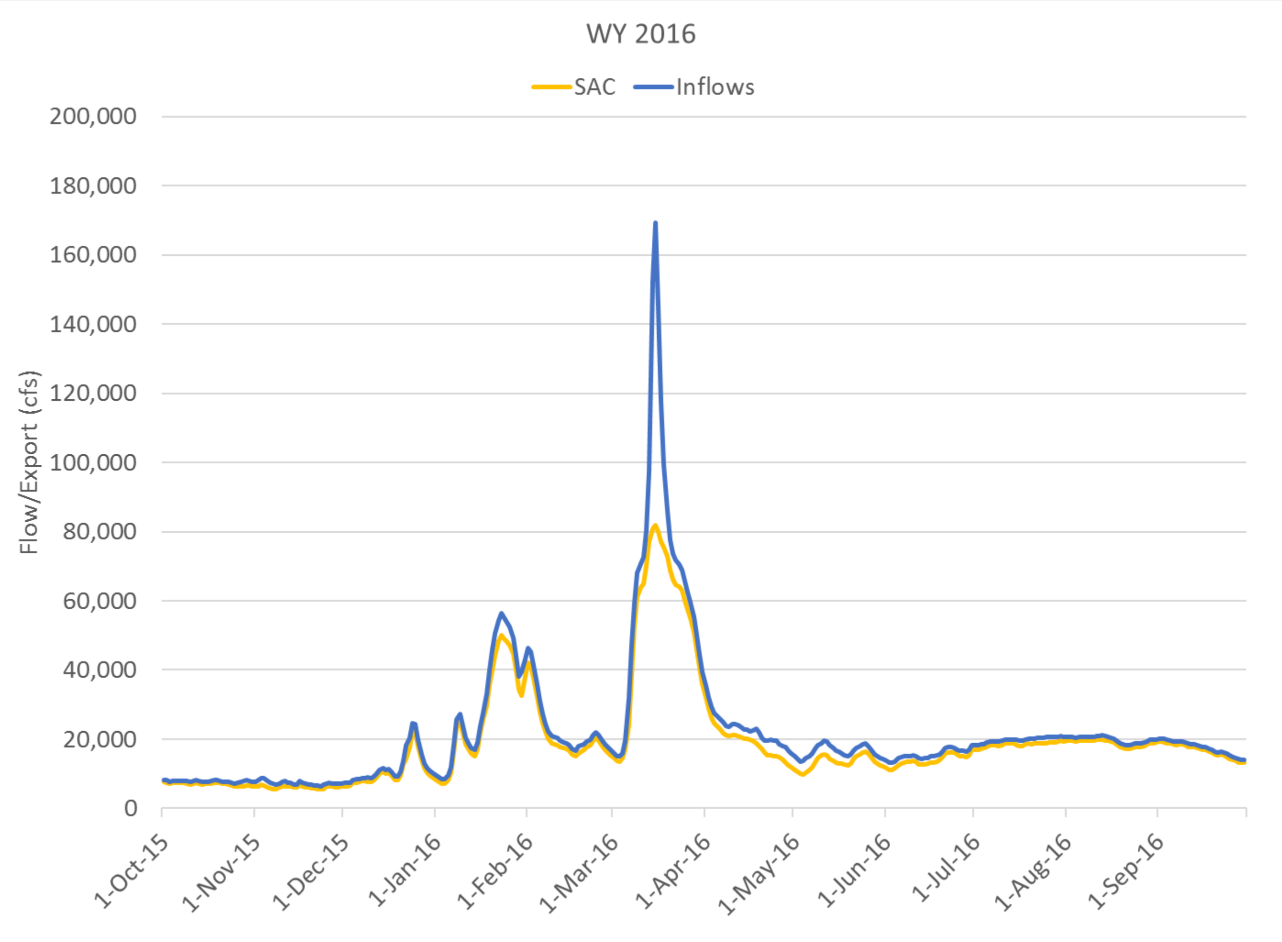




- Preliminary figures from the Flow Availability Tool help demonstrate how much water can be diverted to Sites on a daily time-step

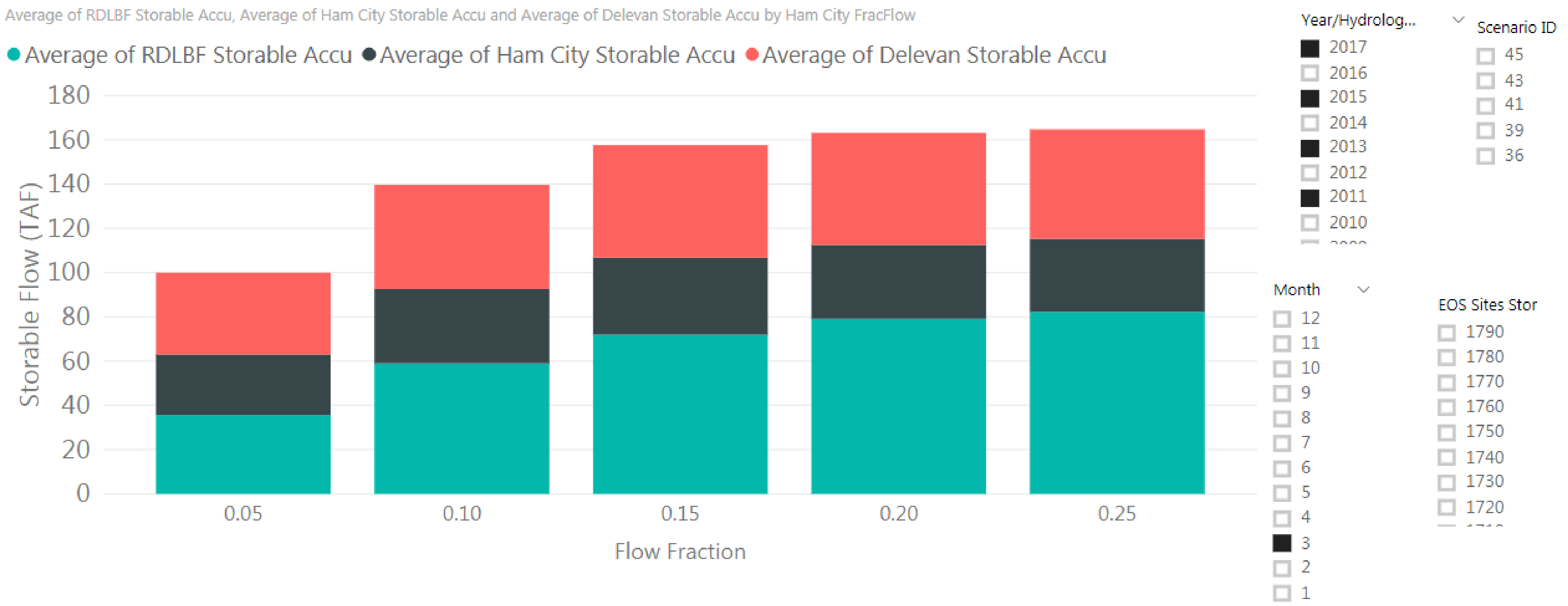
Flow Availability Tool – Preliminary Figures



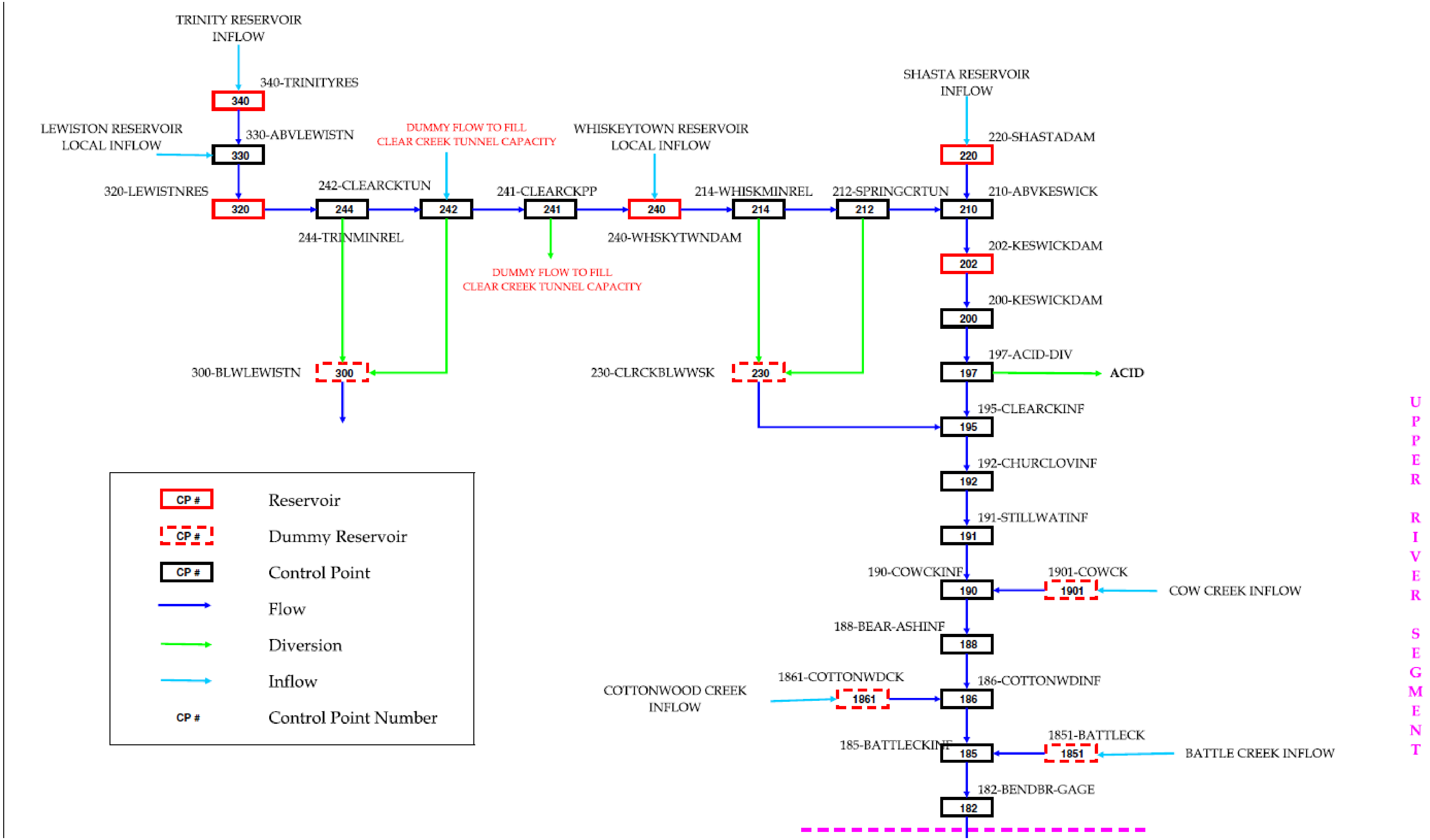


Power BI Dashboard

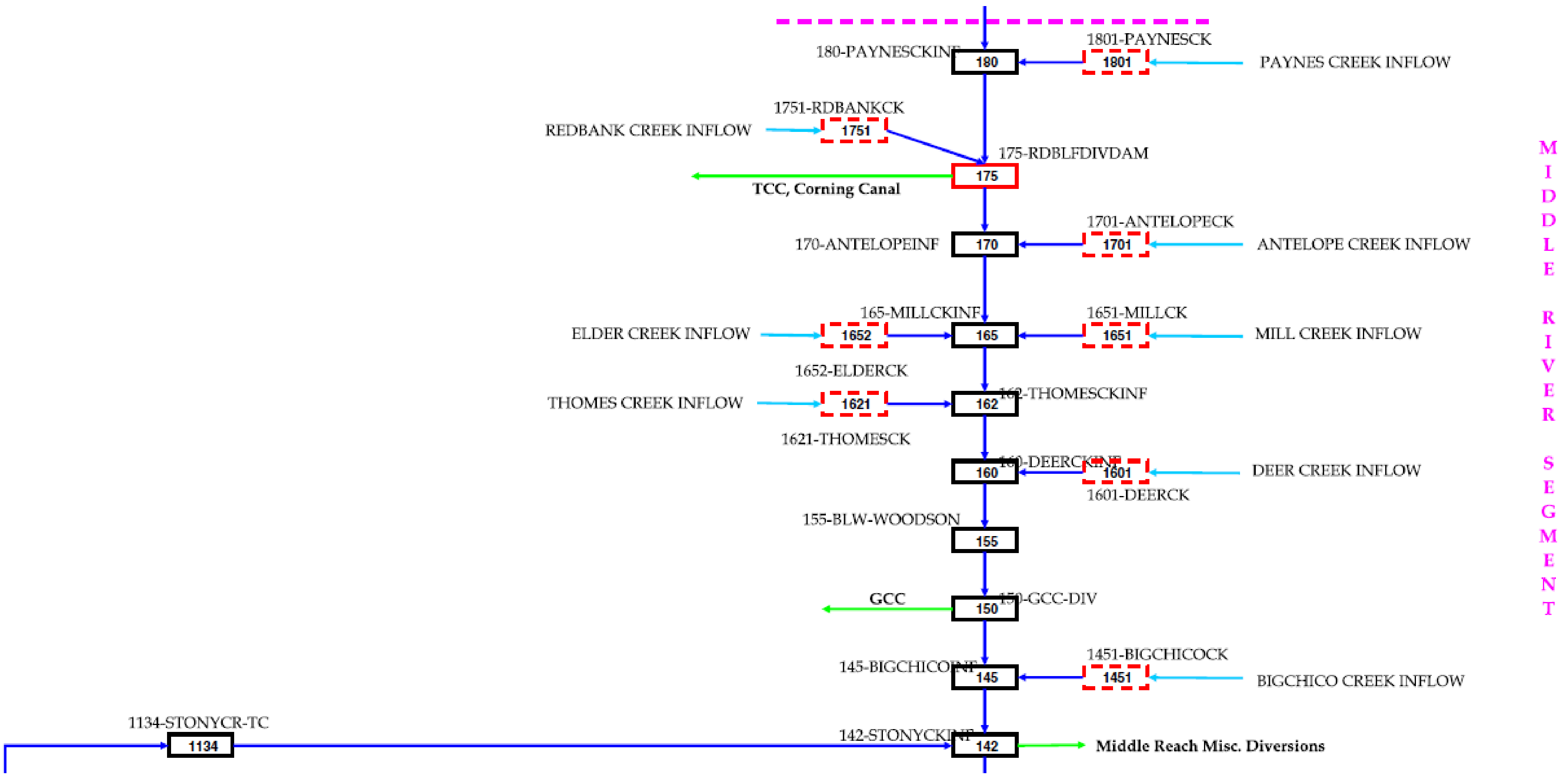
- For example, this stacked chart represents storable flow at each intake for WYs 2011, 2015, & 2017 under varying environmental “Flow Fraction” requirements



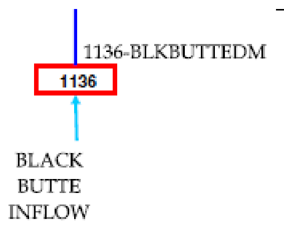
Delevan FracFlow	Average of RDLBF Storable Accu	Average of Ham City Storable Accu	Average of Delevan Storable Accu	Average of Total Storable Accu
0.05	35.64	27.35	37.00	99.99
0.10	58.94	33.58	47.20	139.71
0.15	71.96	34.72	50.93	157.61
0.20	79.10	33.35	50.67	163.12
0.25	82.17	33.05	49.50	164.72
Total	**65.56**	**32.41**	**47.06**	**145.03**



TRINITY RESERVOIR INFLOW
340-TRINITYRES
340
LEWISTON RESERVOIR LOCAL INFLOW
330-ABVLEWISTN
330
320-LEWISTNRES
320
242-CLEARCKTUN
244
242
244-TRINMINREL
DUMMY FLOW TO FILL CLEAR CREEK TUNNEL CAPACITY
241-CLEARCKPP
241
DUMMY FLOW TO FILL CLEAR CREEK TUNNEL CAPACITY
WHISKEYTOWN RESERVOIR LOCAL INFLOW
240
240-WHSKYTWNDAM
214-WHISKMINREL
214
212-SPRINGCRTUN
212
SHASTA RESERVOIR INFLOW
220-SHASTADAM
220
210-ABVKESWICK
210
202-KESWICKDAM
202
200-KESWICKDAM
200
197-ACID-DIV
197
ACID
300-BLWLEWISTN
300
230-CLRCKBLWWSK
230
195-CLEARCKINF
195
192-CHURCLOVINF
192
191-STILLWATINF
191
190-COWCKINF
190
1901-COWCK
1901
COW CREEK INFLOW
188-BEAR-ASHINF
188
1861-COTTONWDCK
1861
COTTONWOOD CREEK INFLOW
186-COTTONWDINF
186
185-BATTLECKINF
185
1851-BATTLECK
1851
BATTLE CREEK INFLOW
182-BENDBR-GAGE
182
CP # Reservoir
CP # Dummy Reservoir
CP # Control Point
Flow
Diversion
Inflow
CP # Control Point Number
UPPER RIVER SEGMENT



180-PAYNESCKINF
180
1801-PAYNESCK
1801
PAYNES CREEK INFLOW
1751-RDBANKCK
REDBANK CREEK INFLOW
1751
175-RDBLFDIVDAM
175
TCC, Corning Canal
170-ANTELOPEINF
170
1701-ANTELOPECK
1701
ANTELOPE CREEK INFLOW
165-MILLCKINF
ELDER CREEK INFLOW
1652
165
1651-MILLCK
1651
MILL CREEK INFLOW
1652-ELDERCK
THOMES CREEK INFLOW
1621
162
162-THOMESCKINF
1621-THOMESCK
160
160-DEERCKINF
1601
DEER CREEK INFLOW
1601-DEERCK
155-BLW-WOODSON
155
GCC
150
150-GCC-DIV
145-BIGCHICOINF
145
1451-BIGCHICOCK
1451
BIGCHICO CREEK INFLOW
1134-STONYCR-TC
1134
142-STONYCKINF
142
Middle Reach Misc. Diversions
MIDDLE RIVER SEGMENT



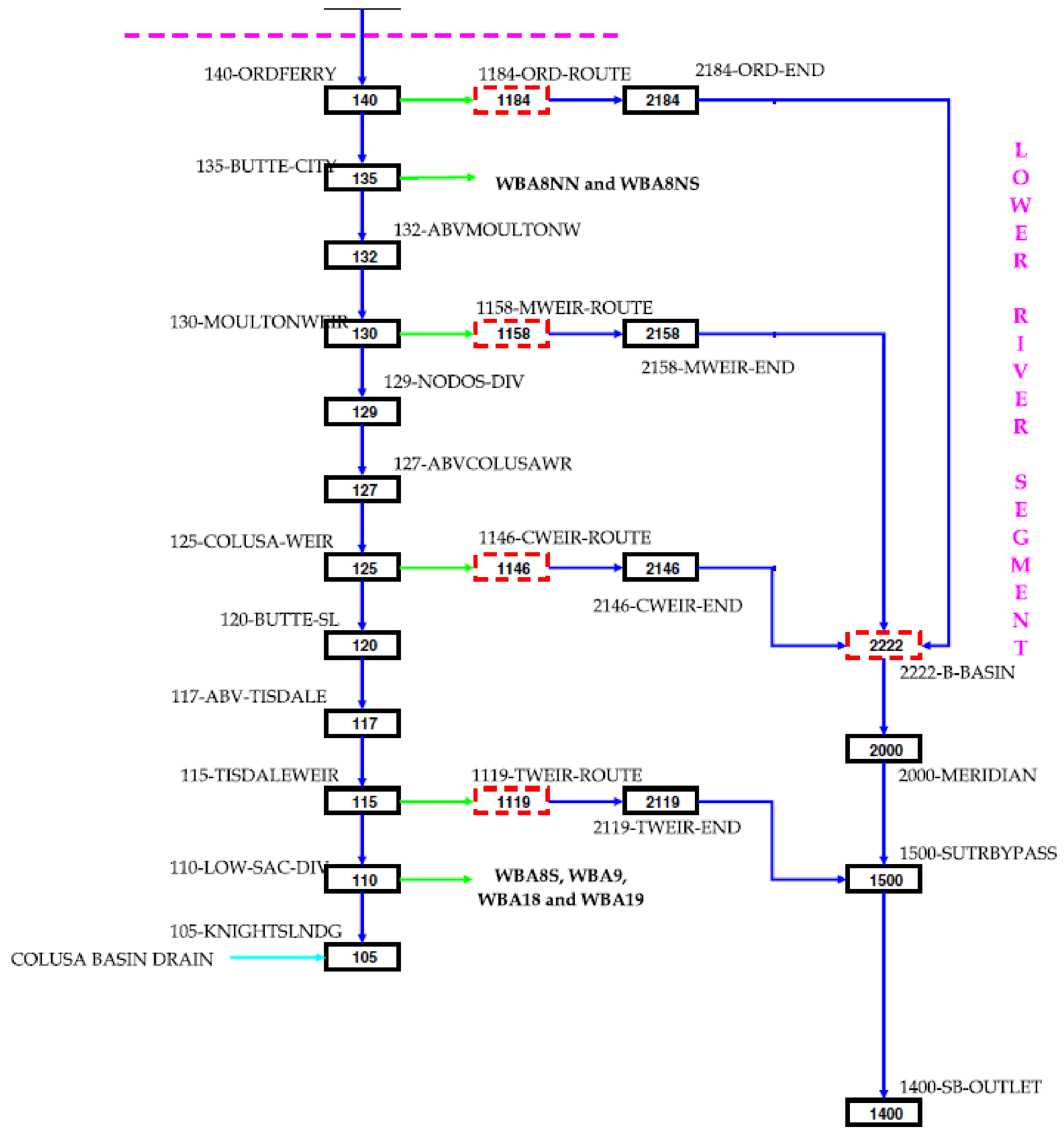
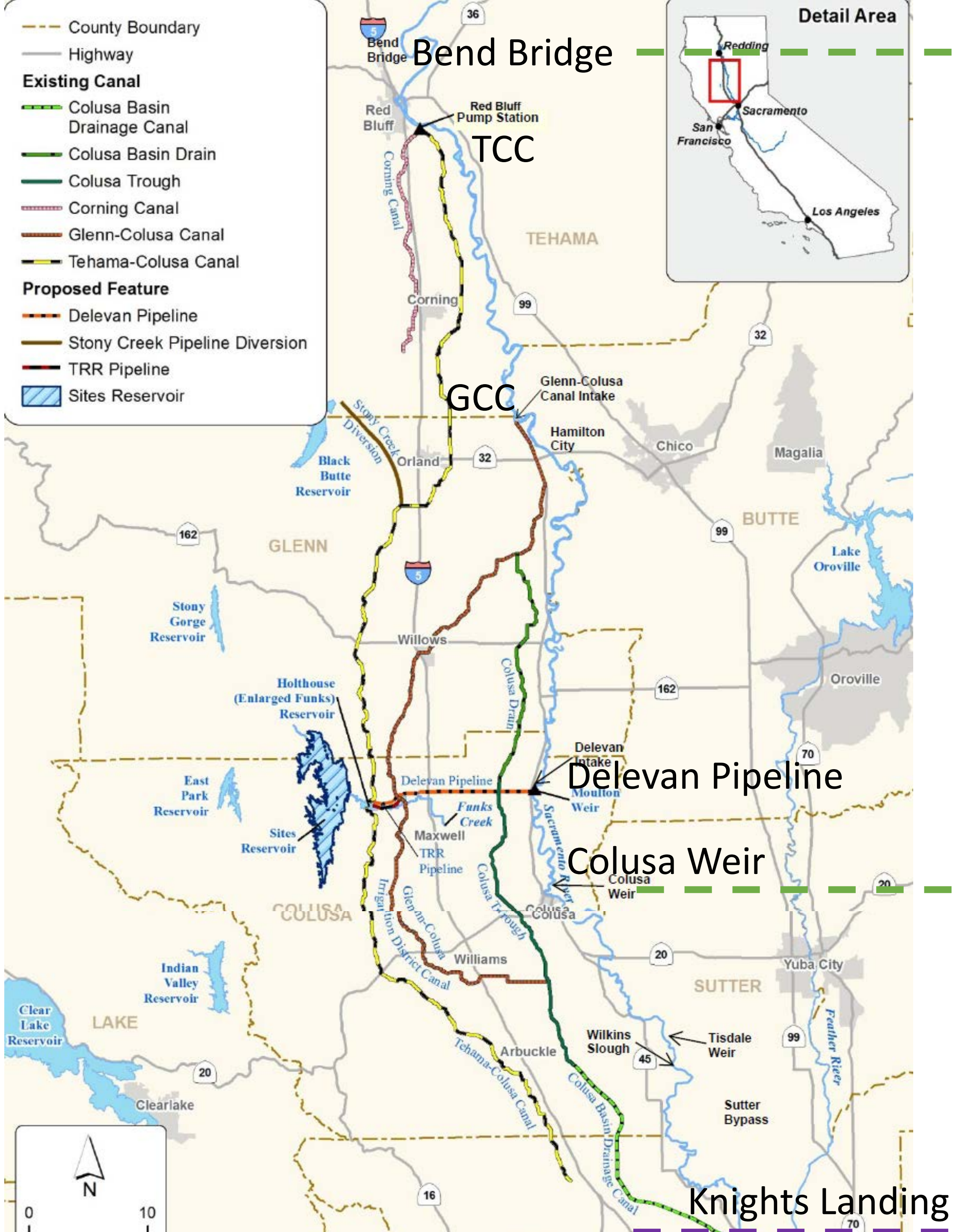


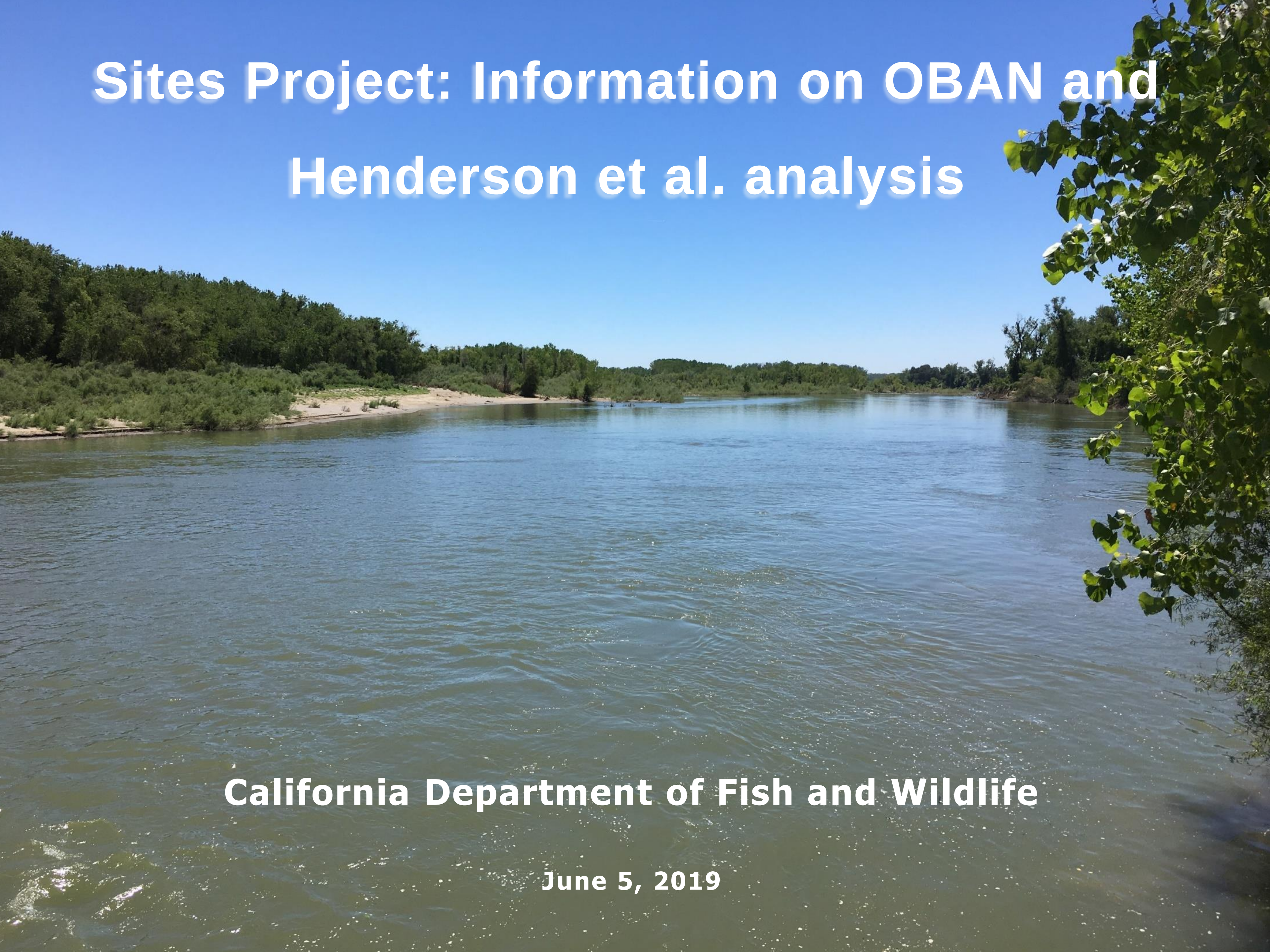
FIGURE 3.1
USRDOM CALIBRATION/VERIFICATION SCHEMATIC

Upper Segment ↑ (Whiskeytown & Shasta to Bend Bridge)



Middle Segment (Bend Bridge to Colusa Weir)

Lower Segment (Colusa Weir to Knights Landing)



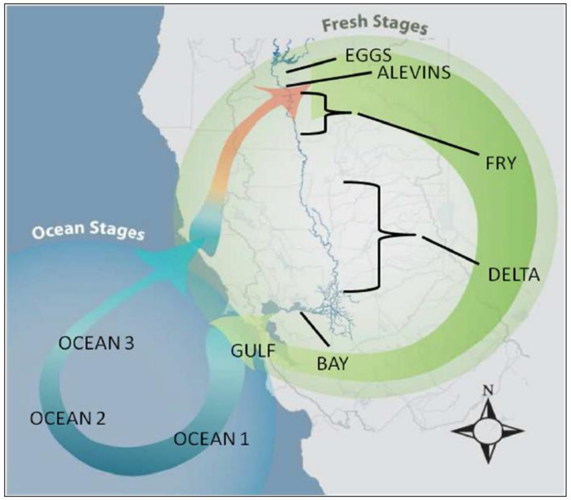
Sites Project: Information on OBAN and Henderson et al. analysis

California Department of Fish and Wildlife

June 5, 2019

Life Cycle Modeling: OBAN

General Details:



- Winter-Run Chinook Salmon
- Egg/alevin temperature effects
- Fry rearing flow effects
- Juvenile Yolo flow effects
- Juvenile south Delta export effects
- Juvenile DCC effects
- Ocean conditions not affected by project but included in model (productivity and harvest)
- More specifics in California WaterFix BA methods: Section 5.D.3.2.5 of Appendix 5D, https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/petitioners_exhibit/dwr/part2/dwr1142/App_5.D_Methods_update.pdf
- Use in WSIP: Section A.1.3 in https://cwc.ca.gov/-/media/CWC-Website/Files/Projects/Sites-Project/Appeal/AttachA.pdf

Life Cycle Modeling: OBAN

OBAN covariates:

- July-Sep temp. (eggs/alevins) - USRWQM
- Aug-Nov flow (fry) - USRDOM
- Dec-Mar Yolo flow (juveniles) - CalSim
- Dec-Jun exports (juveniles) - CalSim
- DCC (Dec-Mar) (juveniles) - CalSim
- Harvest; wind stress curl index – historical values
- Additional covariates considered but not included because of weak relationships: maximum monthly Bend Bridge flow (Aug-Nov); Delta bass catch per unit vessel; sea level height (Apr-Jun); Farallones upwelling (Apr-Jun); PDO (Oct-Mar); sea surface temp. (Jul-Feb)

Flow-Survival in OBAN

WISP - OBAN adjustment for flow-survival:

- WSIP: Survival downstream of RBDD adjusted for With Project
- Considered:
  - Michel (2016)
  - NMFS Winter-Run Life Cycle Model
  - Iglesias et al. (2017)
- Chose Iglesias et al. (2017):
  - Completed report (vs. preliminary analysis by Michel 2016)
  - Based on acoustic telemetry (vs. calibration to fitted data, i.e., WRLCM)

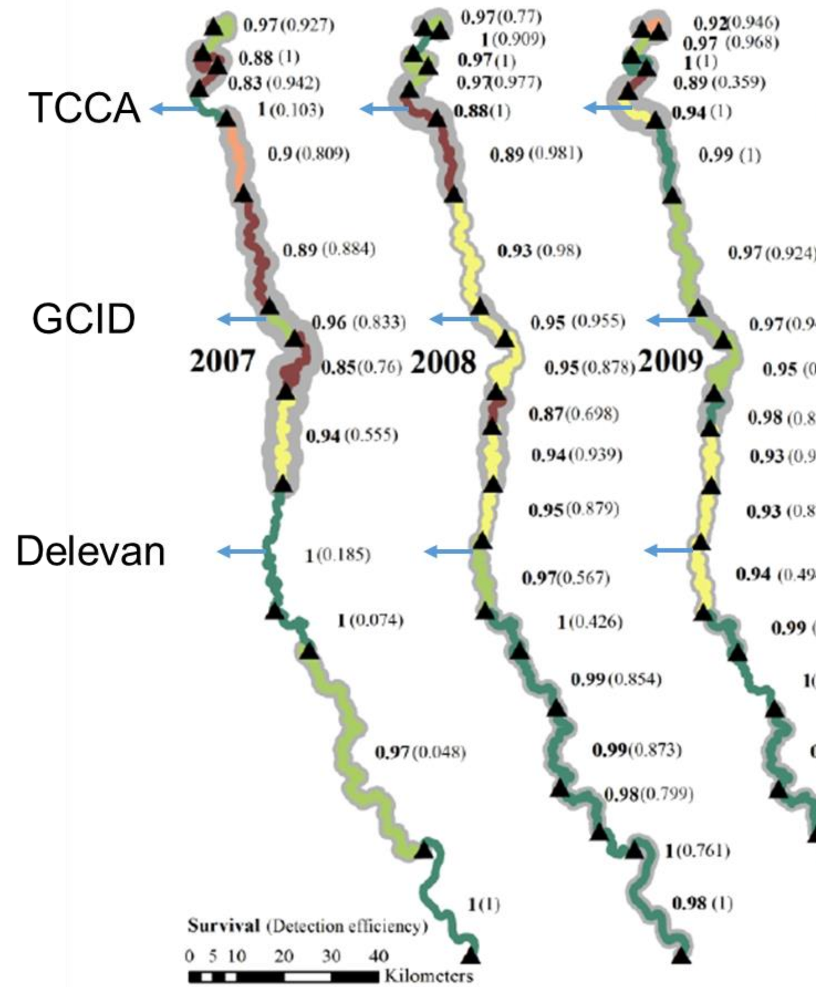
Flow-Survival in OBAN

BA - OBAN adjustment for flow-survival:

- For BA/ITP Application, use Henderson et al. (2018) model
- As with WSIP:
  - Adjust With Project scenario for relative change in survival compared to Without Project
  - Weighted annual survival difference
    - WRLCM monthly smolt timing: 0.269 (Jan.), 0.366 (Feb.), 0.348 (Mar.), 0.017 (Apr.)
    - Spatial variation in smolt starting location

Henderson et al. Flow-Survival Analysis

- Peer-reviewed (CJFAS)
- Multiple reaches from above Red Bluff down to Knights Landing
- Focus on Sites withdrawal period (winter/spring), daily timescale
- Incorporates flow and temperature effects
- Also includes other (non-operations) covariates



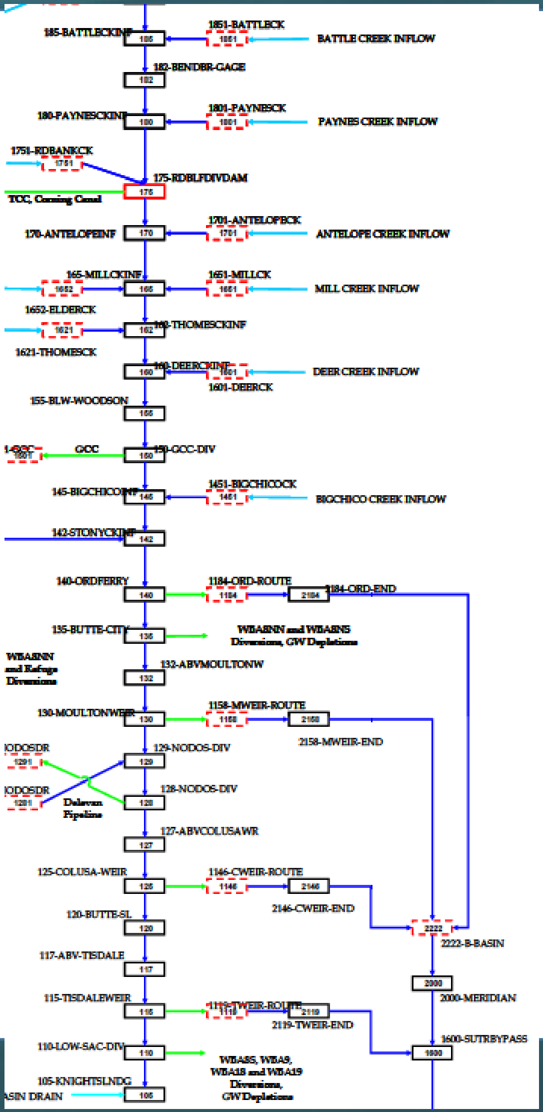
Henderson et al. Flow-Survival Analysis

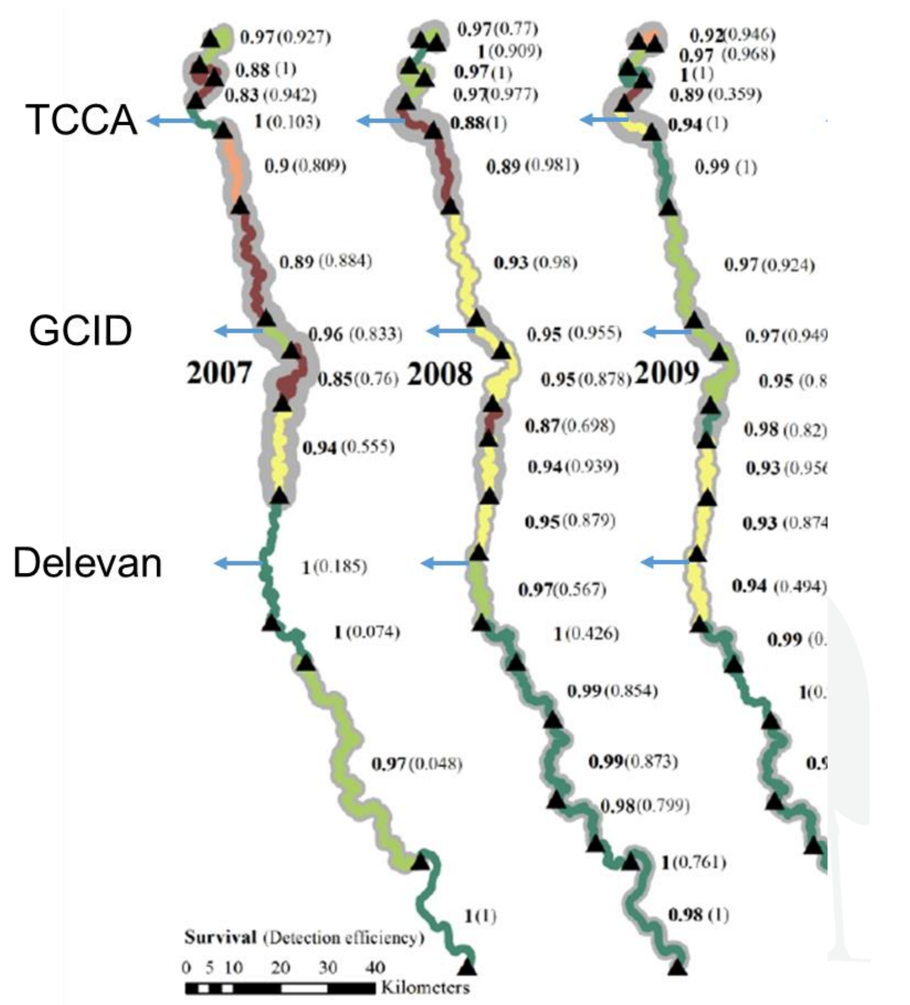
Table 1: A description of the covariates included in the mark recapture model.

Category	Covariate	Range	Definition	Hypothesized relationship with survival
Individual	Fish Length[1]	135 - 204 mm	Fork length	Larger fish may exceed gape width of predators
	Fish Condition[1]	0.59 - 1.32	Fulton's K	Increased condition improves predator escape capability
	Transit speed[2]	0.02 - 8.25 km h^{-1}	Reach specific transit speed	Faster moving fish have less exposure to predators
Release group	Batch release[2]	Binary	Tagged fish released concurrently with large hatchery releases.	Predator swamping
	Release reach[1]	Binary	Difference in survival between newly released fish and those released upstream.	Newly released hatchery fish are naïve and susceptible to predation
	Annual flow[3]	179 - 499 cms	Mean flow measured at Bend Bridge throughout outmigration (December-March).	Increased flows produce more habitat and predator refugia throughout the river
Reach specific	Sinuosity[4]	1.04 - 2.74	River distance divided by Euclidean distance.	More natural habitats have more predator refugia
	Diversion density[5]	0 - 1.05 num km^{-1}	Number of diversions per reach length.	Increased predator densities near diversions
	Adjacent cover density[6]	0.2 - 0.76 %	Percent of non-armored river bank with adjacent natural woody vegetation.	Increased cover produces more predator refugia
	Off-channel habitat density[6]	0 - 1.62 %	Off-channel habitat within 50 m of river expressed as percentage of river area	Increased off-channel habitat produces more predator refugia
Time varying	Temperature[7]	6.2 - 12.9 °C	Mean water temperature per reach	Increased temperatures results in increased predation due to higher metabolic demands of predators
	Inter-annual Reach flow[7]	215 – 447 cms	Mean water flow per reach	Higher flows within a reach will produce more habitat and predator refugia within that reach
	Intra-annual Reach flow[7]	129 – 902 cms	Mean water flow per reach and year	Higher intra-annual flows (e.g., precipitation or dam releases) decreases predation due to increased turbidity and increased predator refugia.

[1]Measured during tagging and release; [2]Observed travel times and mixed effects model estimates; [3]California Water Data Library; [4]National Hydrography Dataset; [5]Passage Assessment Database - verified by field survey; [6]Department of Water Resources; [7]River Assessment for Forecasting Temperature (RAFT) model

Implementing Henderson Flow-Survival





Implementing Henderson Flow-Survival

- Flow translation complete
- Next step is temperature translation
- +1 diversion in Delevan reach

Henderson reach (km)	USRDOM
518	185-BATTLECKINF
511	185-BATTLECKINF
504	182-BENDBRGAGE
492	180-PAYNESCKINF
480	180-PAYNESCKINF
475	175-RDBLFDIVDAM
456	165-MILLCKINF
421	150-GCC_DIV
412	150-GCC_DIV
389	142-STONYCKINF
380	140-ORDFERRY
363	135-BUTTE-CITY
349	132-ABV-MOULTONWEIR
325	125-COLUSA-WEIR
309	120-BUTTE-SL
287	117-ABV-TISDALE
259	110-LOW-SAC-DIV
239	105-KNIGHTSLNDG
227	Not in USRDOM

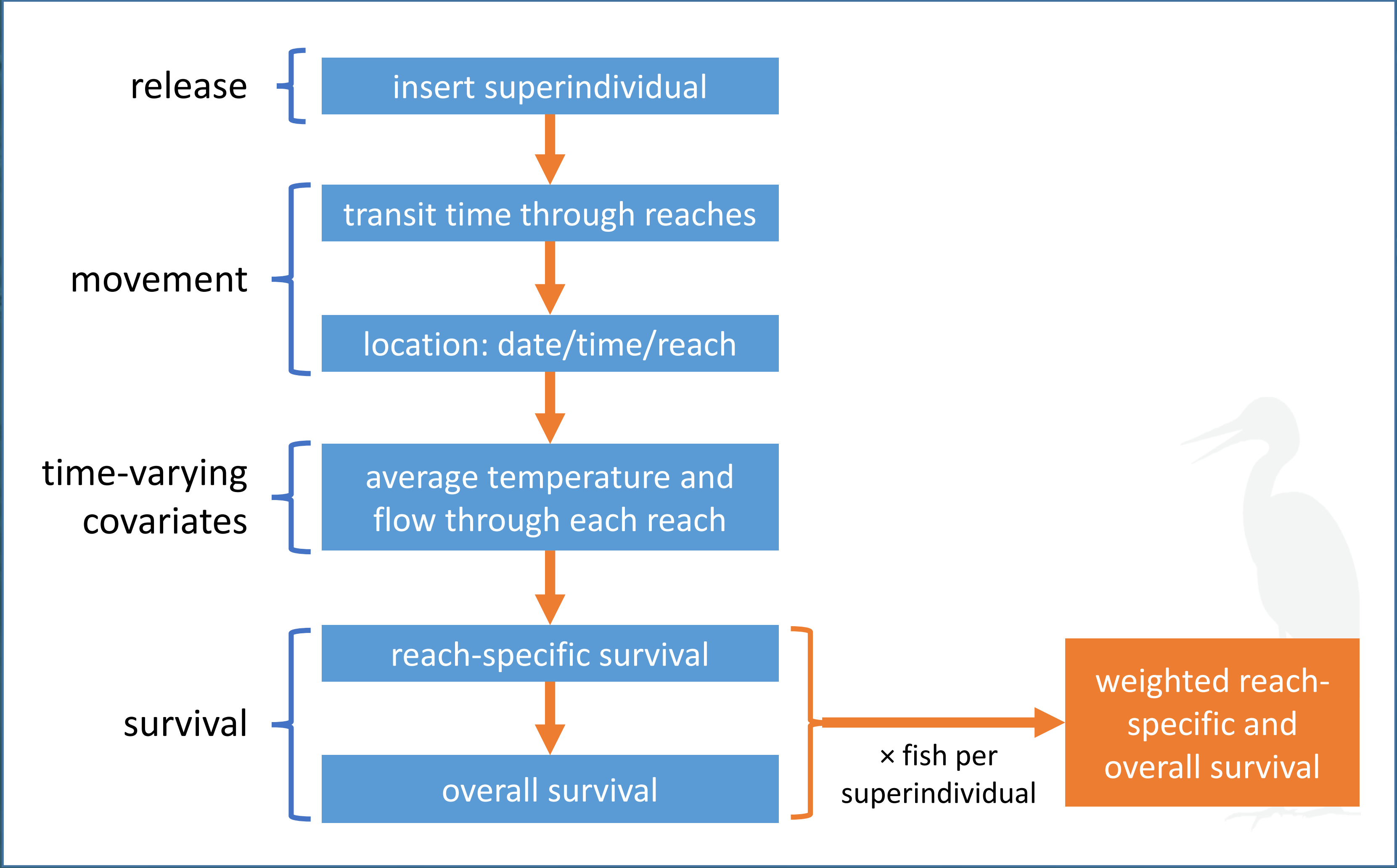
Implementing Henderson Flow-Survival

- Follows Henderson et al. approach: calculate time-varying covariates for individual fish based on temperatures and flows they experience
- Utilize flow and temperature effects on survival estimated from mark-recapture analysis by Henderson et al.
- Individual fish trajectories (which reach they’re in at a given time) calculated based on initial time/location, reach lengths, and reach-specific average transit speeds
- Hourly time step to accommodate sub-daily reach transit times
- Flow and temperature data upsampled to hourly resolution using cubic spline interpolation

Implementing Henderson Flow-Survival

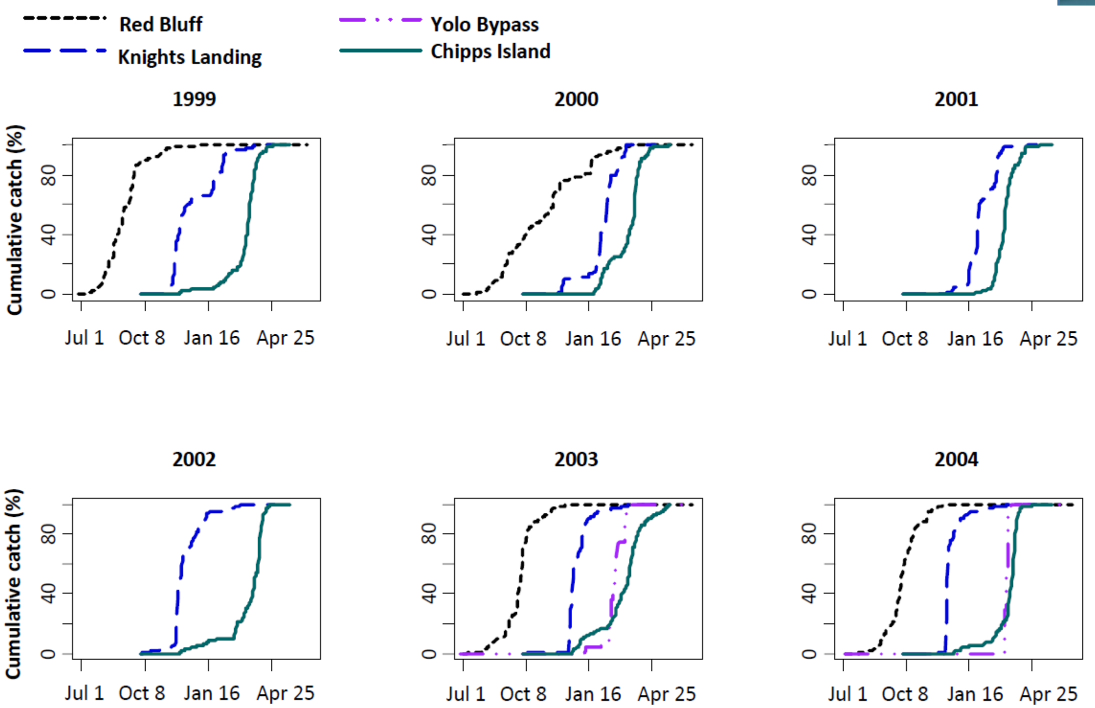
- "Superindividuals": each modeled individual represents multiple fish beginning migration at the same time
- Overall survival probability = average across all individuals weighted by the number of fish represented by each superindividual
- Annual survival rate integrates across all superindividuals
- Annual survival rates calculated for "With Project" and "Without Project"
- OBAN link:
  - Adjust With Project scenario for relative change in survival compared to Without Project
  - Run OBAN model over multiple cohorts representing multiple annual conditions

Implementing Henderson Flow-Survival



Initial Smolt Locations

- Many juveniles pass Red Bluff before Sites diversion period begins…
- Where do they go?



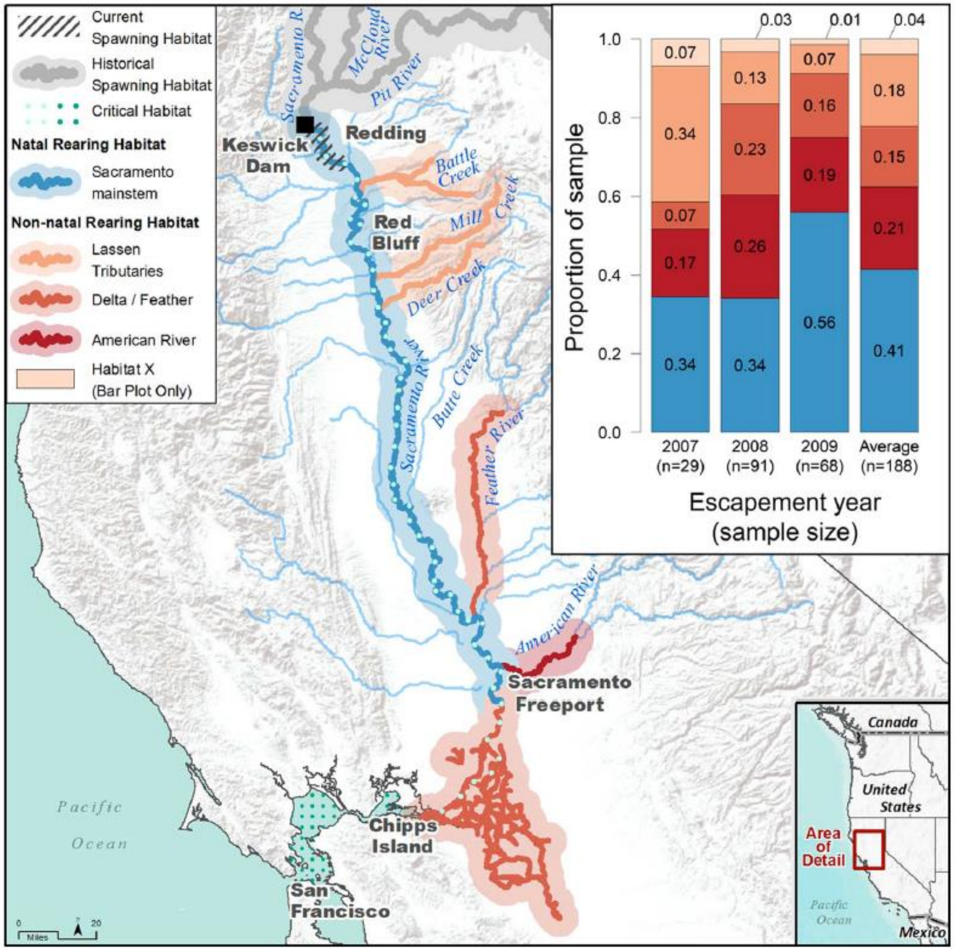
Migration Patterns of Juvenile Winter-run-sized Chinook Salmon (*Oncorhynchus tshawytscha*) through the Sacramento–San Joaquin Delta

Rosalie B. del Rosario[1], Yvette J. Redler[2], Ken Newman[3], Patricia L. Brandes[3], Ted Sommer[4], Kevin Reece[4], and Robert Vincik[5]

Initial Smolt Locations

Other considerations:

- Simplest case: all fish migrate from Jellys Ferry
- But…
  - Phillis et al. (2018) show diverse rearing habitat
  - Where are juveniles starting from, and when?
- Proposed approach: Analysis of beach seine data to estimate locations



Initial Smolt Locations

Other considerations:

- Johnson, R.R., D.C. Weigand, and F.W. Fisher. 1992. Use of Growth Data to Determine the Spatial and Temporal Distribution of Four Runs of Juvenile Chinook Salmon in the Sacramento River, California. November. 18 p.

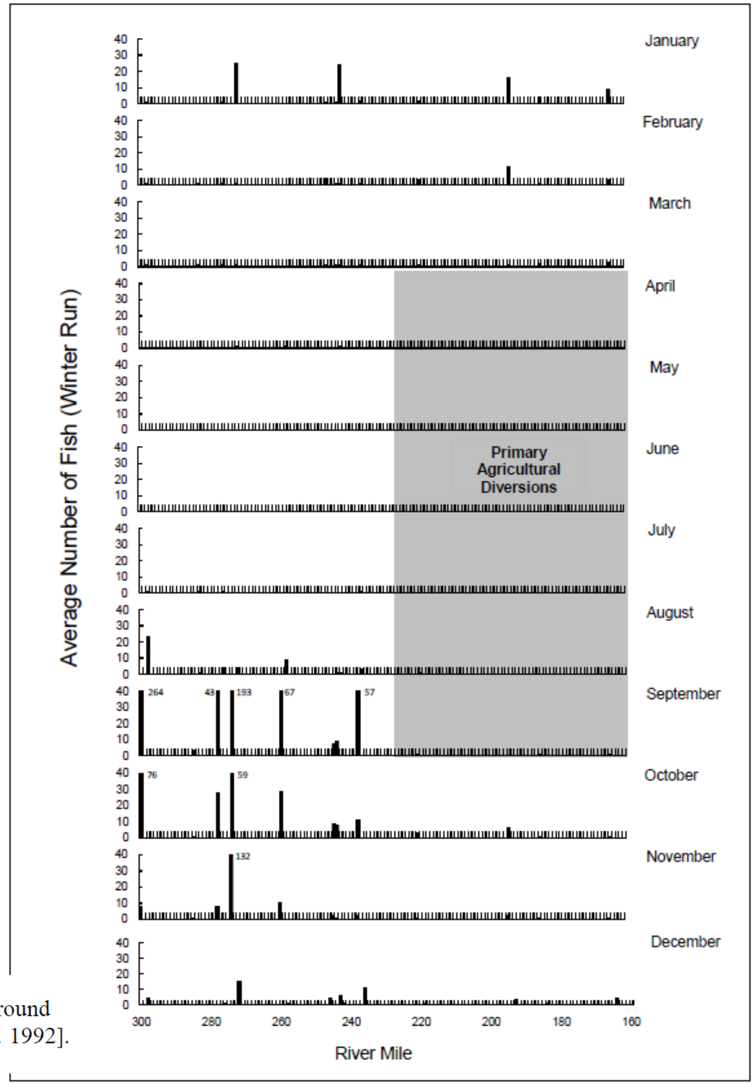


Figure 31. Spatial and temporal distribution of winter-run Chinook captured by the USFWS during year-round monthly beach seining at 13 sites in the Sacramento River, 1981 – 1991 [(N = 10,778) from Johnson *et al.* 1992].