Fish, Farm, and Fowl: Measuring the Benefits and Impacts of Floodplain Restoration on the Yolo Bypass

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American Rivers
-and-
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Katie Jagt, PE – Consulting Engineer
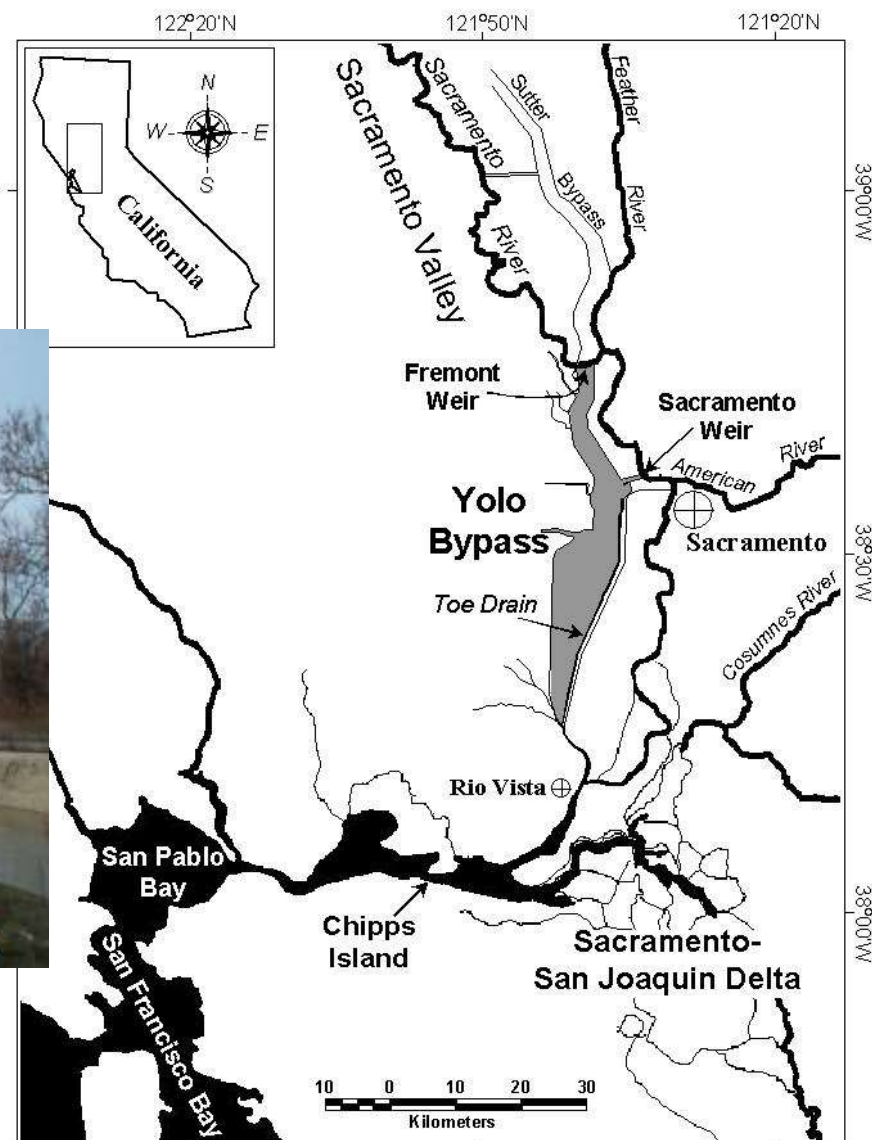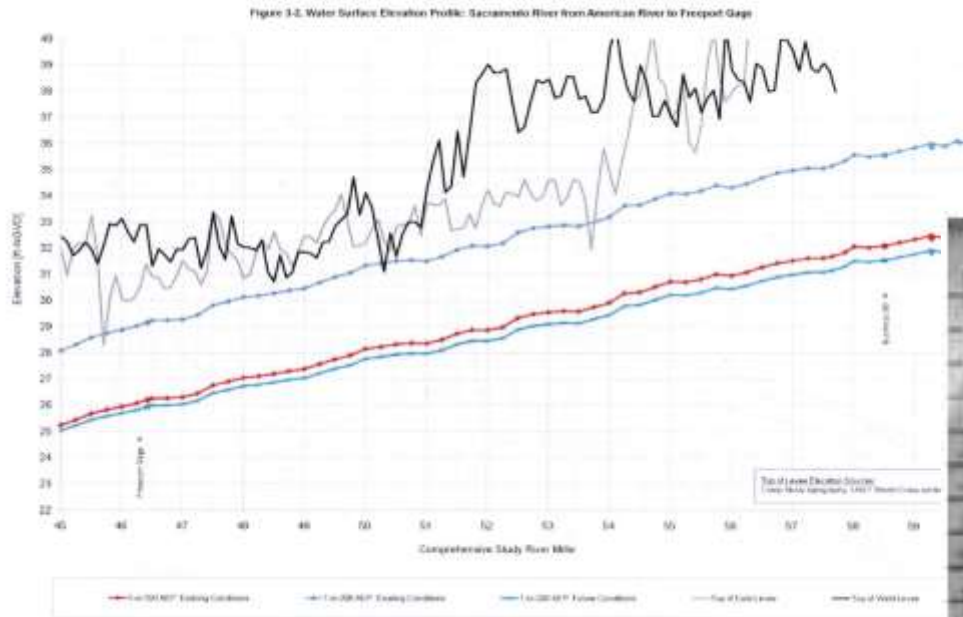
Yolo
Bypass and

Fremont Weir

Figure 1: Location of Yolo Bypass

Ecosystem and Flood Management Benefits

Figure 3-2. Water Surface Elevation Profile: Sacramento River from American River to Freeport Gage

WSE in the mainstem Sacramento drops 3-4 feet for 200 AEP. (SAFCA, 2008)

Below floodplain   Floodplain

Jeffres et al. 2008

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Thriving By Nature

Expected Annual Habitat Metric (EAH)

•Useful both as a screening and design tool.

•Adapted to measure habitat/benefit for a variety of species/objectives.

•Easily applied by any agency or consultant that uses standard tools and available data.

•Transparent and replicable i.e. not subject to distortion by hidden assumptions, qualitative indices, or weighting factors.

EAH – Matella and Jagt (2013)

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Ecosystem Variables

Physical
- Area
  - ✓ depth
  - ✓ velocity
  - ✓ cover
  - ✓ vegetation
  - ✓ connectivity

Hydrologic
- Duration
- Frequency
- Timing

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Ecosystem Relationships

Ecological Relevance	Season	Duration	Frequency
Splittail spawning and rearing	Feb – May	At least 21 days	At least 4 yr return period
Chinook salmon rearing	Dec – May	At least 14 days	At least 2 yr return period
Phytoplankton production	Dec – May	At least 2 days	1.3 yr return period
Zooplankton production	Dec – May	At least 14 days	1.3 yr return period
Benthic macroinvertebrate production	Dec – Sep	At least 1 day	2 yr return period

ADF Curves: Definition

Intensity-Duration-Frequency Curves in Hydrology
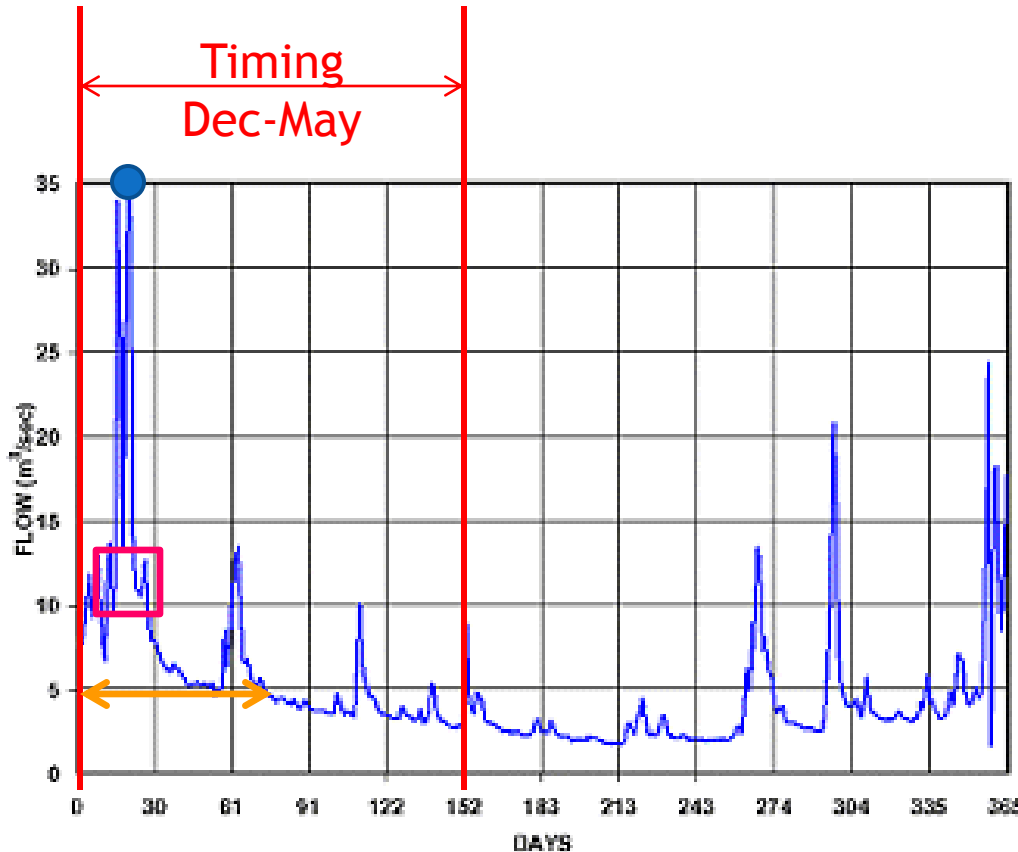
Defines the variable we are interested in for design (intensity) as a function of duration and frequency.

Area-Duration-Frequency Curves

Defines the variable we are interested in for design (quantity of functional habitat) as a function of duration and frequency.

HEC-EFM: Hydrologic Statistics

Durations

1-Day

3-Day

7-Day

14-Day

21-Day

28-Day

60-Day

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HEC-EFM: Hydrologic Statistics

Durations

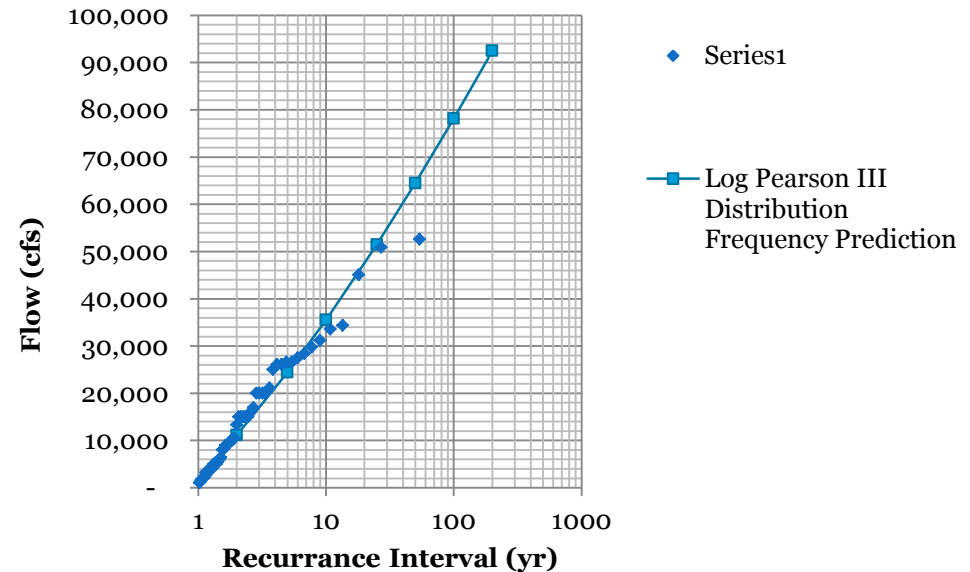**1-Day**

3-Day

7-Day

14-Day

21-Day

28-Day

60-Day

RANK	PEAK_FLOW_VALUE_Q(cfs)	LOGQ_cfs	(log Q – avg(logQ))^2	(log Q – avg(logQ))^3	Return Period (n+1)/m	Exceedence Probability (1/Tr)
1	52,600	4.721	0.4959	0.3492	54.00	0.019
2	50,900	4.707	0.4760	0.3284	27.00	0.037
3	45,100	4.654	0.4063	0.2589	18.00	0.056
4	34,400	4.537	0.2702	0.1404	13.50	0.074
5	33,598	4.526	0.2596	0.1323	10.80	0.093
6	31,201	4.494	0.2279	0.1088	9.00	0.111
7	29,800	4.474	0.2092	0.0957	7.71	0.130
8	28,400					
9	27,500					
10	26,599					
11	26,599					

Series1

Log Pearson III Distribution Frequency Prediction

Flow (cfs) vs Recurrance Interval (yr)

HEC-EFM: Hydrologic Statistics
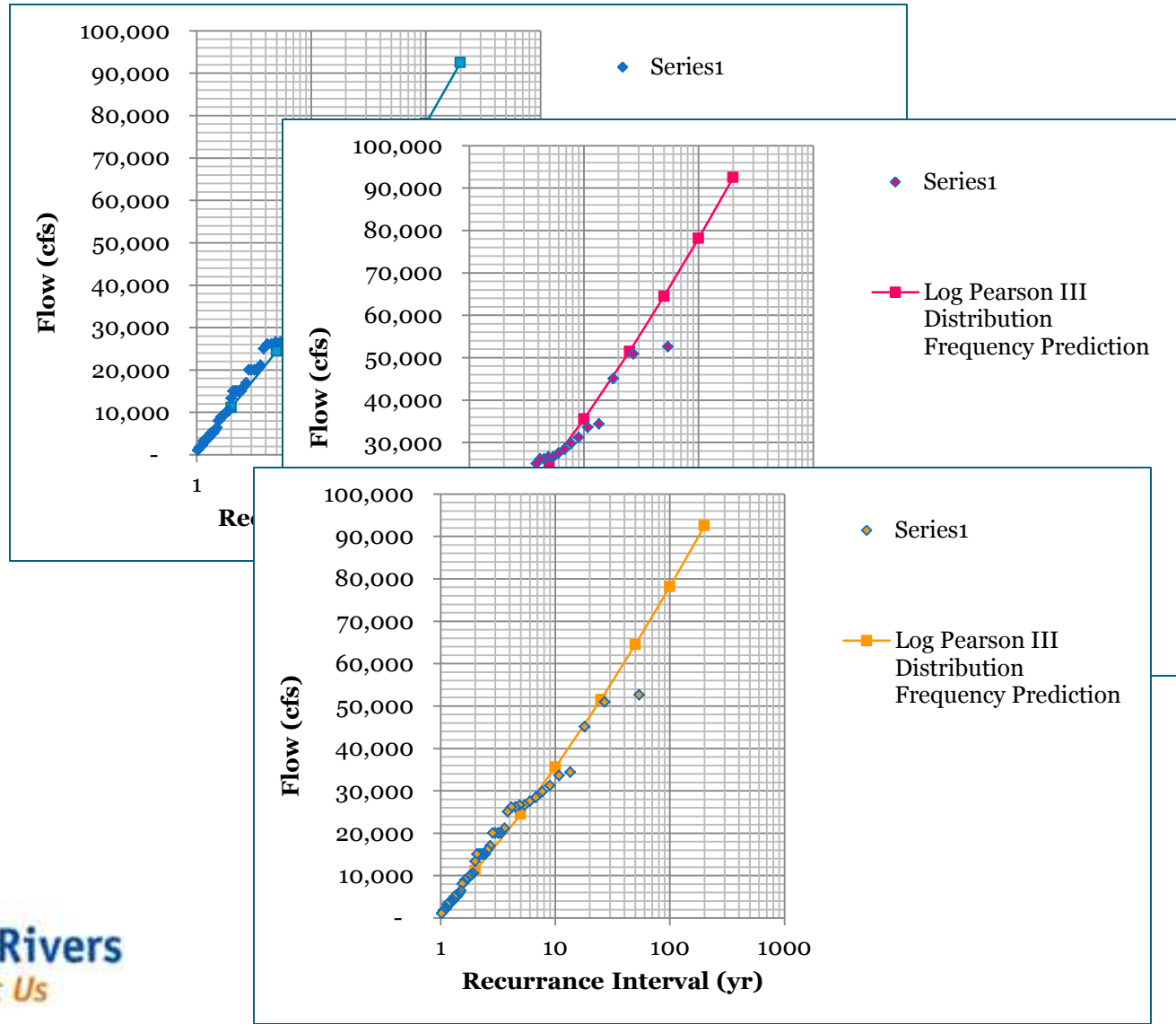
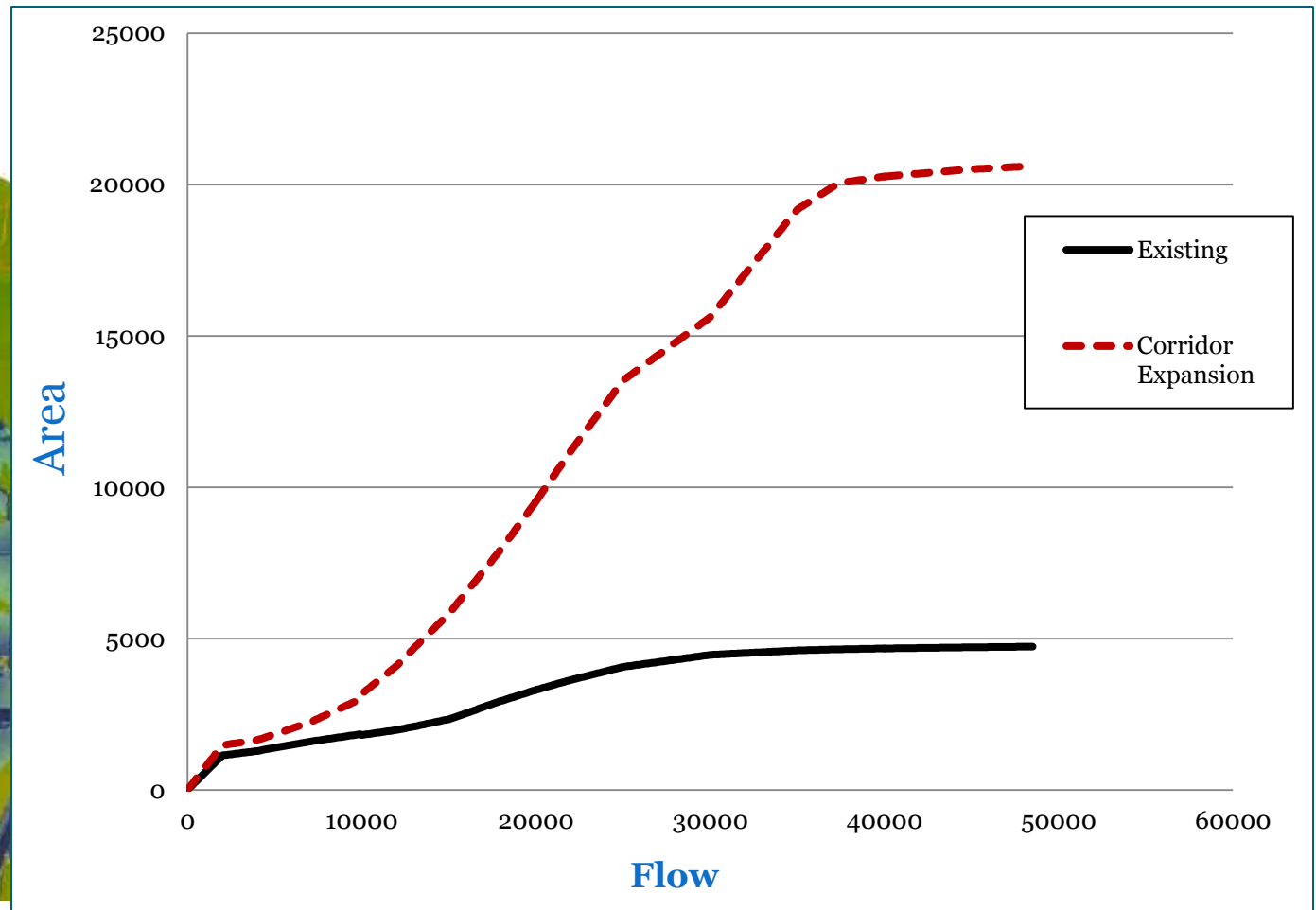**Durations**
1-Day

3-Day

7-Day

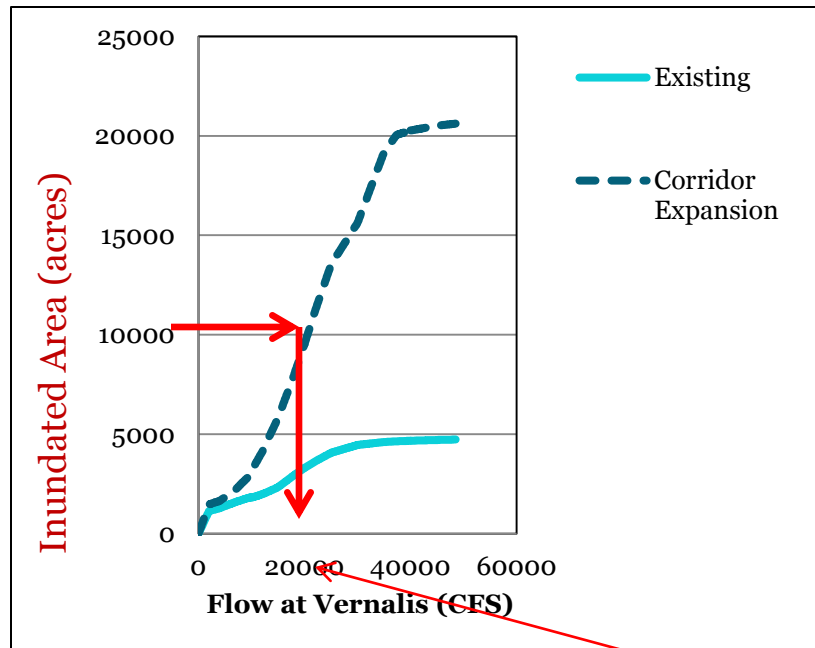**14-Day**

21-Day

28-Day

60-Day

Hydraulic models generate flow/inundated area curve

Combine Flow Frequency and and Inundated Area Curves to Develop ADF Curves
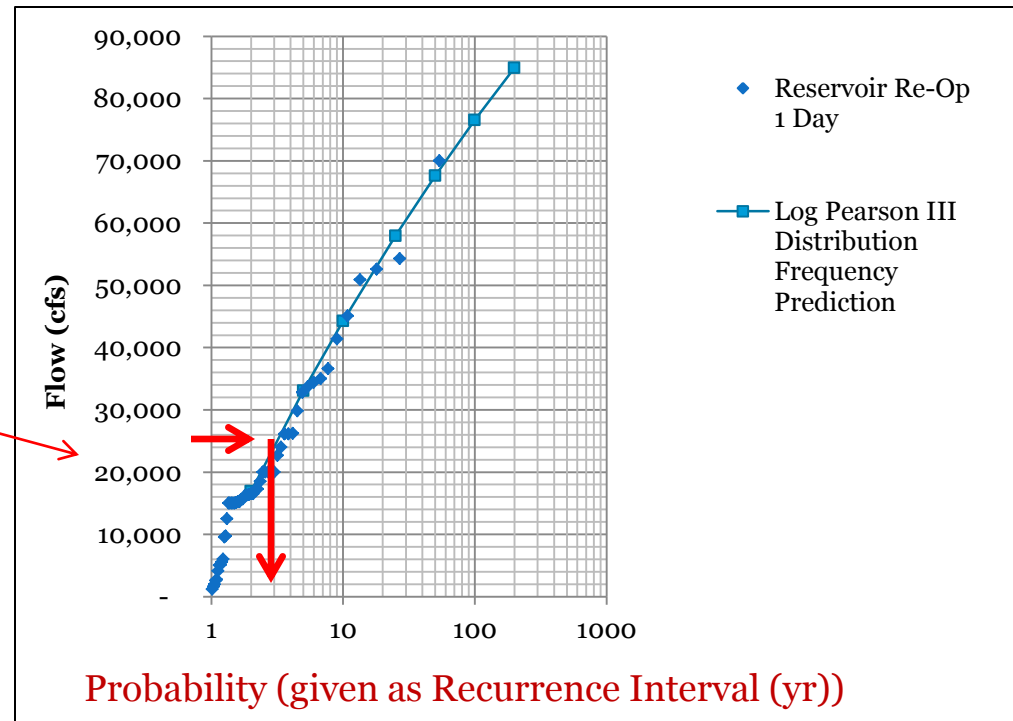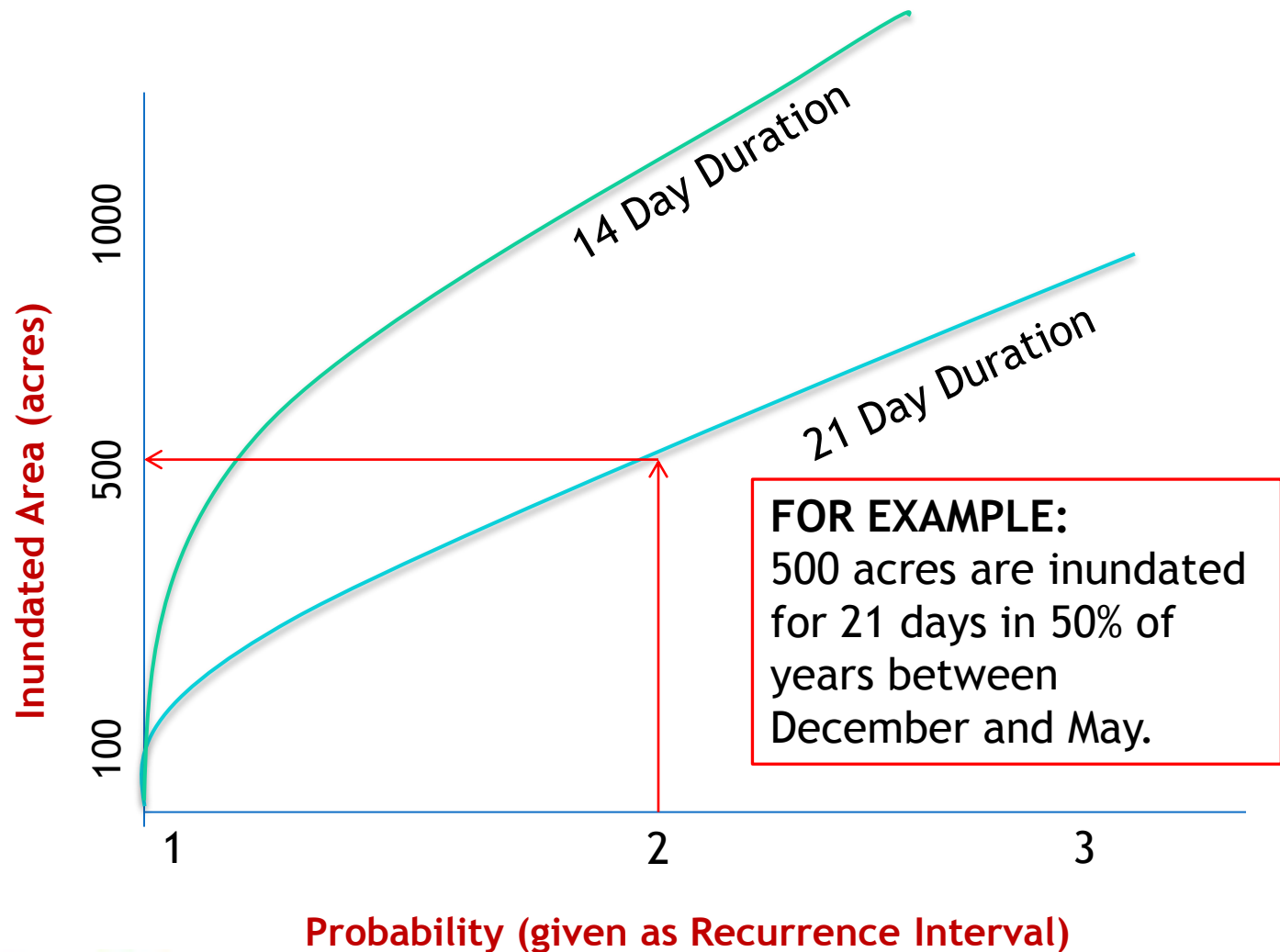
Q vs Area Curves

Recurrence Interval Curves for each duration—in total there are 28 of these curves.

Develop ADF Curves

Inundated Area (acres)

1000

500

100

14 Day Duration

21 Day Duration

FOR EXAMPLE:
500 acres are inundated for 21 days in 50% of years between December and May.

1   2   3

Probability (given as Recurrence Interval)

Develop ADF Curves

SACRAMENTO SPLITTAIL

Inundated Area (acres)

1000

500

100

21 Day D...

FOR EXAMPLE:
500 acres are inundated for 21 days in 50% of years between December and May.

1   2   3

Probability (given as Recurrence Interval)

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Automating the EAH Method

- Calculations automated using Python scripts
- Inputs
  - Scenarios
    - Hydrology (daily time step)
    - Geometry (flow : inundation area relationship)
  - Criteria (duration, timing)
- Pre-run multiple hydrologic criteria to generate look-up tables and enable instant queries.

Analysis Variables

Physical
- Area
  - ✓depth
  - ✓velocity
  - ✓cover
  - ✓vegetation
  - ✓connectivity

Spatial Variables

Temporal Variables

Hydrologic
- Duration
- Frequency
- Timing

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Powerful Scenario Analysis

Physical
- Area
  - ✓ depth
  - ✓ velocity
  - ✓ cover
  - ✓ vegetation
  - ✓ connectivity

Hydrologic
- Duration
- Frequency
- Timing

Physical Alterations
- Levee setbacks
- New bypasses
- Floodplain grading
- Weir and grade control structures
- Dredging
- Side channel reconnection

Hydrologic Alterations
- Weir Notching/lowering
- Reservoir Operations
- Climate Change

Related Analytical Efforts in Yolo Bypass

- Hydraulic models
- Fish habitat models / criteria
- Notch flow models / criteria
- Agriculture impact evaluation
- Benefits of the EAH method
  - Compatible
  - Complimentary
  - Very fast screening (not sufficient by itself for EIR\EIS)
  - Transparent, statistical approach not distorted by weighting factors or professional judgment
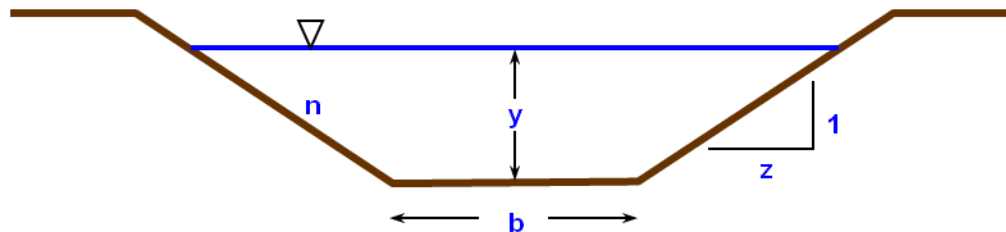
Yolo Scenarios Evaluated
"Bookends"

			SCENARIOS				
	Base	**1**	**2**	**3**	**4**	**5**	**6**
Fremont Weir Assumptions							
Notch Width (bottom)							
225 feet		✓	✓	✓	✓	✓	✓
20 feet							
No notch	✓						
Invert Elevation (notch)							
14 feet		✓	✓	✓	✓	✓	✓
17.5 feet							
Other							
Bypass geometry							
Longitudinal Berm(s)							
exclude wildlife area							
Toe Drain Barrier(s)							
Operational Rules							
Yolo County Proposal							
YC A - Feb 15		✓					
YC B- March 1				✓			
YC D - Feb 15 plus							
YC D- March 1 Plus							
CM 2 Operations							
CM 2 -May 15			✓				
CM 2 - no May							
Sensitivity Analyses							
March 15					✓		
March 31						✓	
15-Apr							✓

Notch Geometry
Notch Closure

Notch Hydraulics

- Bottom width is 225 feet
- Side slope is 2:1
- Bottom elevation is 14 feet
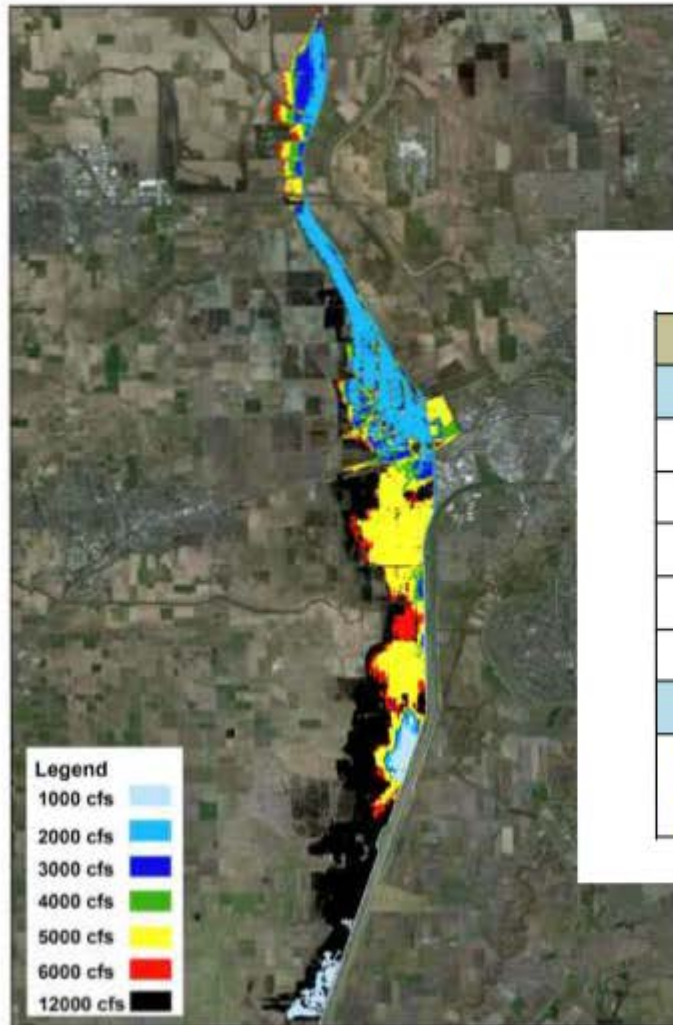- "Modeled" as trapezoidal channel flow split

Flow – Area Geometry

Legend
1000 cfs
2000 cfs
3000 cfs
4000 cfs
5000 cfs
6000 cfs
12000 cfs

Notes: Notch Only flow simulation

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Yolo Bypass Supplemental 2D Hydrodynamic Modeling
Model results – maximum inundation plots

Project No. 13-1014 | Created By: SB | Figure 1

Table 2. Modeled inundation area from MWD modeling

Flow (cfs)	Inundation Area (acres)
1,000[1]	1,500
2,000	4,700
3,000	6,500
4,000	7,700
5,000	13,300
6,000	14,900
12,000[1]	23,900

Notes:

[1] Supplemental scenario.

Inundation Timing and Duration Criteria

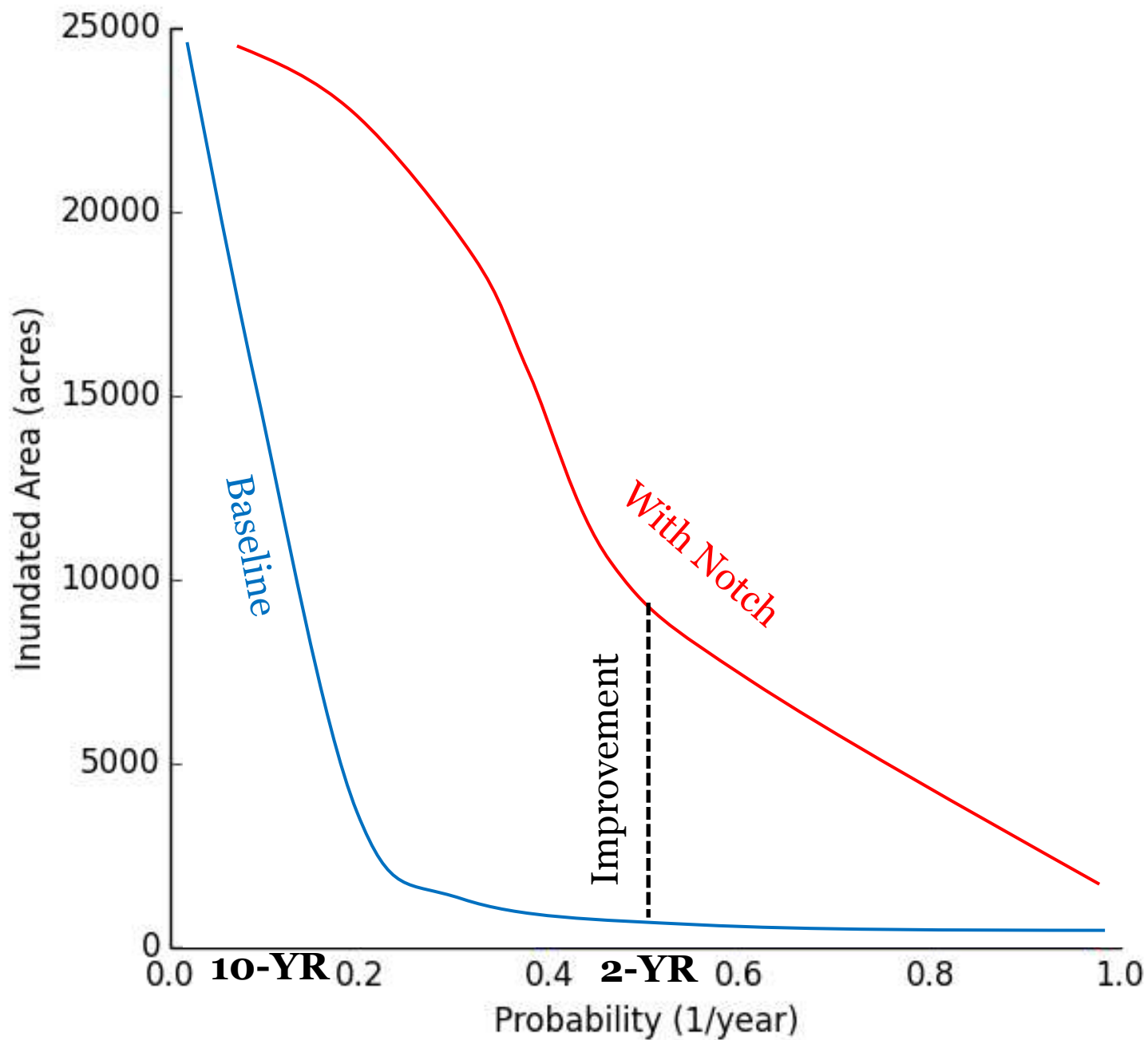| Fish	Timing	Duration (days)	Notes
Salmon*			
Winter Run	Nov. 15 - March 31	14, 21, 28, 45, 60	
Spring Run	Dec. 1 - April 30	14, 21, 28, 45, 60	YOY and yearlings
Fall Run	Dec. 1 - April 30	14, 21, 28, 45, 60	
28 days		28 days	
Splittail			
30 days	March 1 - May 15	21, 28, 45, 60	
Agriculture			
Unspecified crop	After Feb 15	1,3,7	
Unspecified crop	After March 11	1,3,7	
Unspecified crop	After March 15	1,3,7	
Unspecified crop	After April 1	1,3,7	
Unspecified crop	After April 15	1,3,7	
Unspecified crop	After May 1	1,3,7	
Unspecified crop	After May 15	1,3,7	
Waterfowl/Shorebirds	8/17 to 3/29	15	
Waterfowl	7/1 to 5/20	15	
Shorebirds	TBD		
Hunting Season on Refuge	TBD		
Swamp Timmothy			
Sensitivity 1	After 3/1/2014	7, 14	
Sensitivity 1	After 3/30/2014	7, 14	
Sensitivity 1	After 4/30/2014	7, 14	

*Salmon timing window (based on KL RST catch data 1997-2007, BDCP timing, and professional judgment)
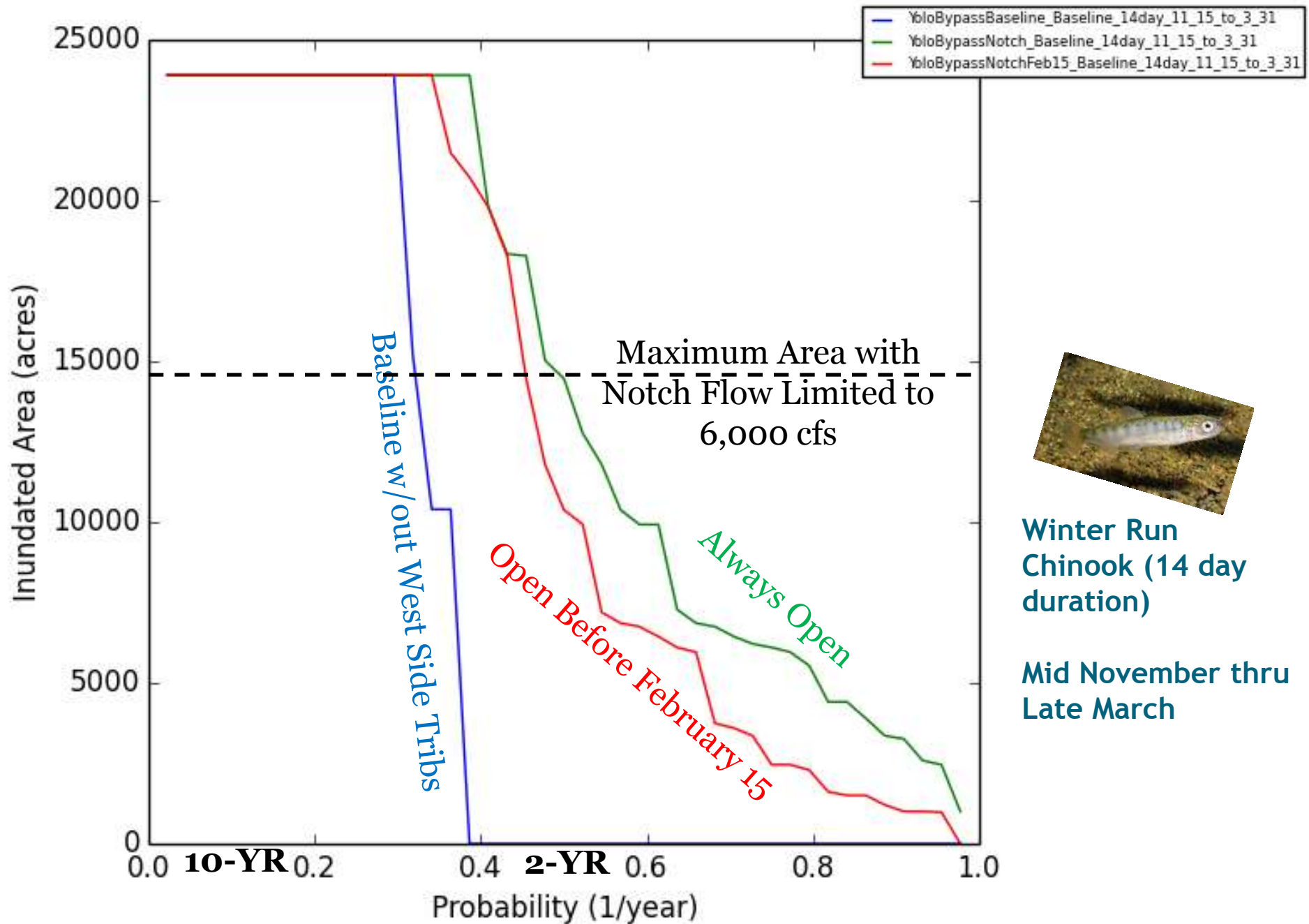
Representative Results for Yolo Bypass

- Species
  - Winter run Chinook salmon
  - Waterfowl
  - Swamp Timothy
  - Fall run Chinook salmon sensitivity to notch closure
- Area Duration Frequency Curves
  - Baseline *
  - Notch always open
  - Notch open before February 15
  - Notch open before March 15
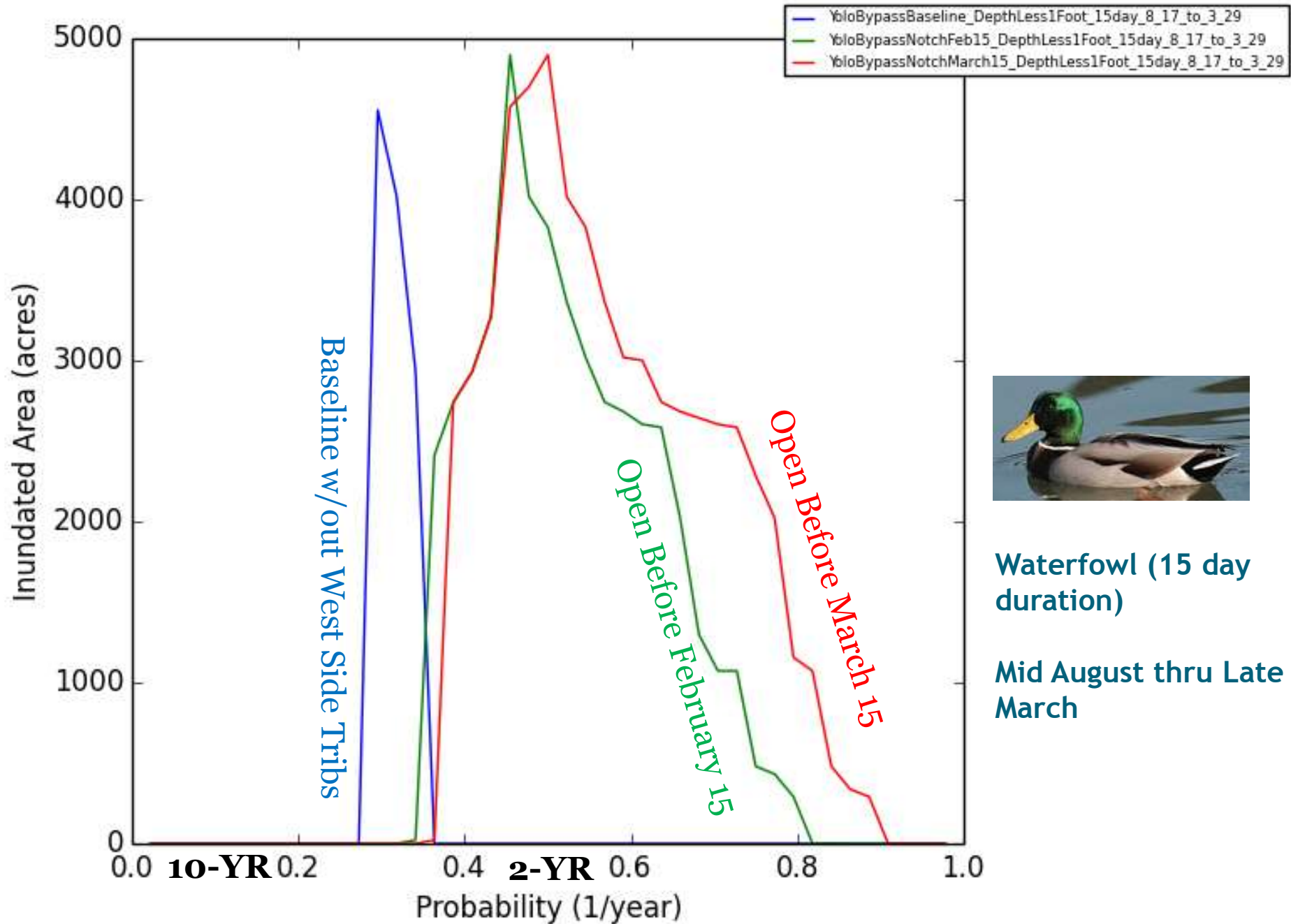
*Baseline scenarios do not include west side tributaries

ADF Plot

ADF Plot

Maximum Area with
Notch Flow Limited to
6,000 cfs

Baseline w/out West Side Tribs

Open Before February 15

Always Open

Winter Run
Chinook (14 day
duration)

Mid November thru
Late March

Inundated Area (acres)

Probability (1/year)

10-YR   2-YR

Legend:
YoloBypassBaseline_Baseline_14day_11_15_to_3_31
YoloBypassNotch_Baseline_14day_11_15_to_3_31
YoloBypassNotchFeb15_Baseline_14day_11_15_to_3_31

ADF Plot

Inundated Area (acres)

Probability (1/year)

YoloBypassBaseline_DepthLess1Foot_15day_8_17_to_3_29
YoloBypassNotchFeb15_DepthLess1Foot_15day_8_17_to_3_29
YoloBypassNotchMarch15_DepthLess1Foot_15day_8_17_to_3_29

Baseline w/out West Side Tribs

Open Before February 15

Open Before March 15

10-YR   2-YR

Waterfowl (15 day duration)

Mid August thru Late March

ADF Plot

Measure of Potential

Maximum Area with Notch Flow Limited to 6,000 cfs

Baseline w/out West Side Tribs

Open Before March 15

Open Before April 15

Swamp Timothy (No inundation >14 day duration after March 1)

Legend:
- YoloBypassBaseline_Baseline_14day_3_2_to_6_30
- YoloBypassNotchApril15_Baseline_14day_3_2_to_6_30
- YoloBypassNotchMarch15_Baseline_14day_3_2_to_6_30

Y-axis: Inundated Area (acres) — 0, 5000, 10000, 15000, 20000, 25000

X-axis: Probability (1/year) — 0.0, 0.2, 0.4, 0.6, 0.8, 1.0

10-YR   2-YR

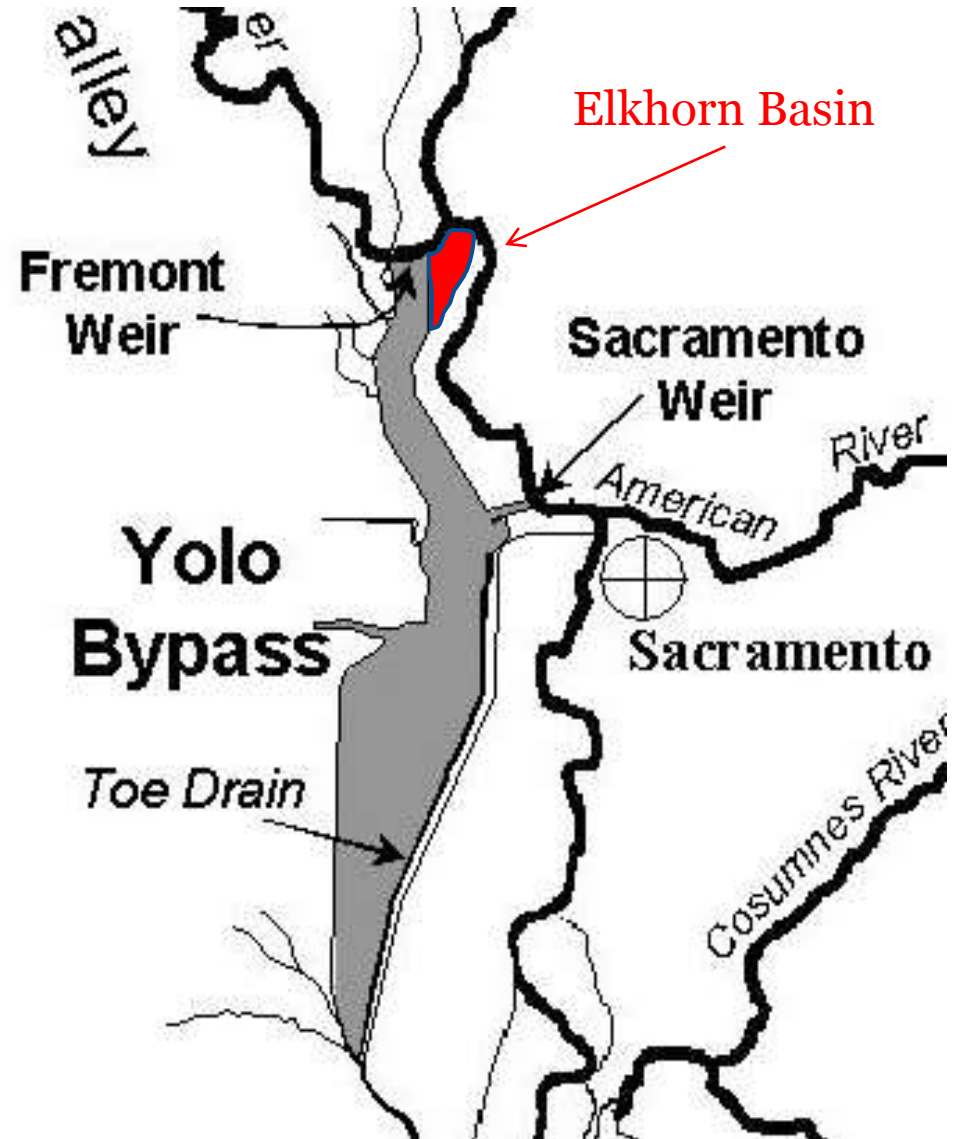ADF Plot

Agriculture March 2-Nov 15 (3 day)

Agriculture April 16-Nov 15 (3 day)
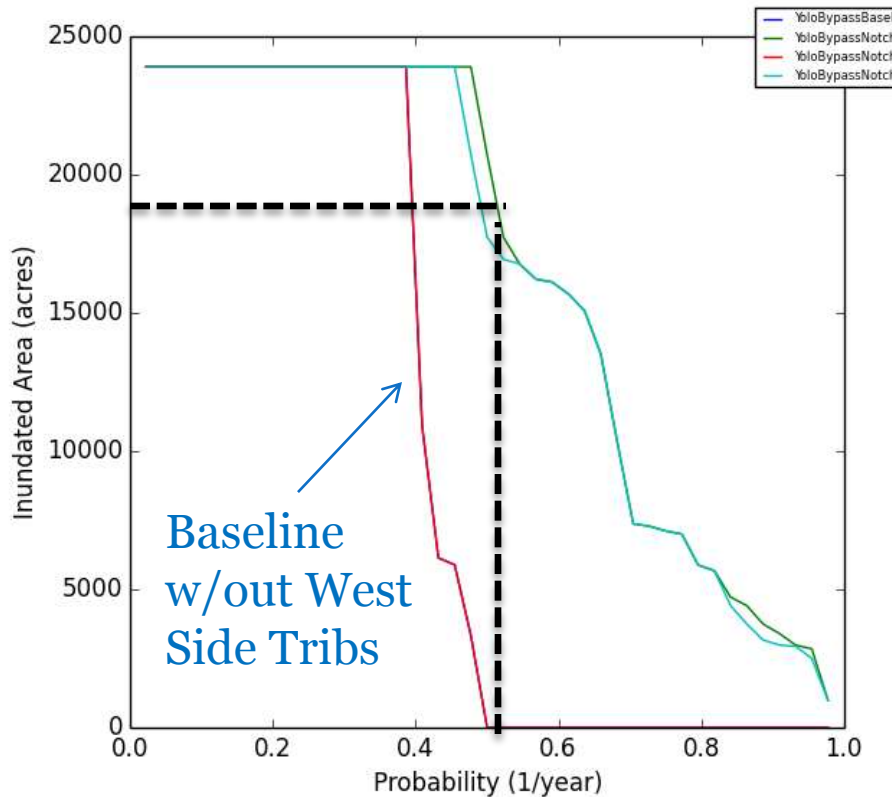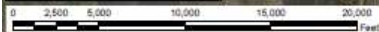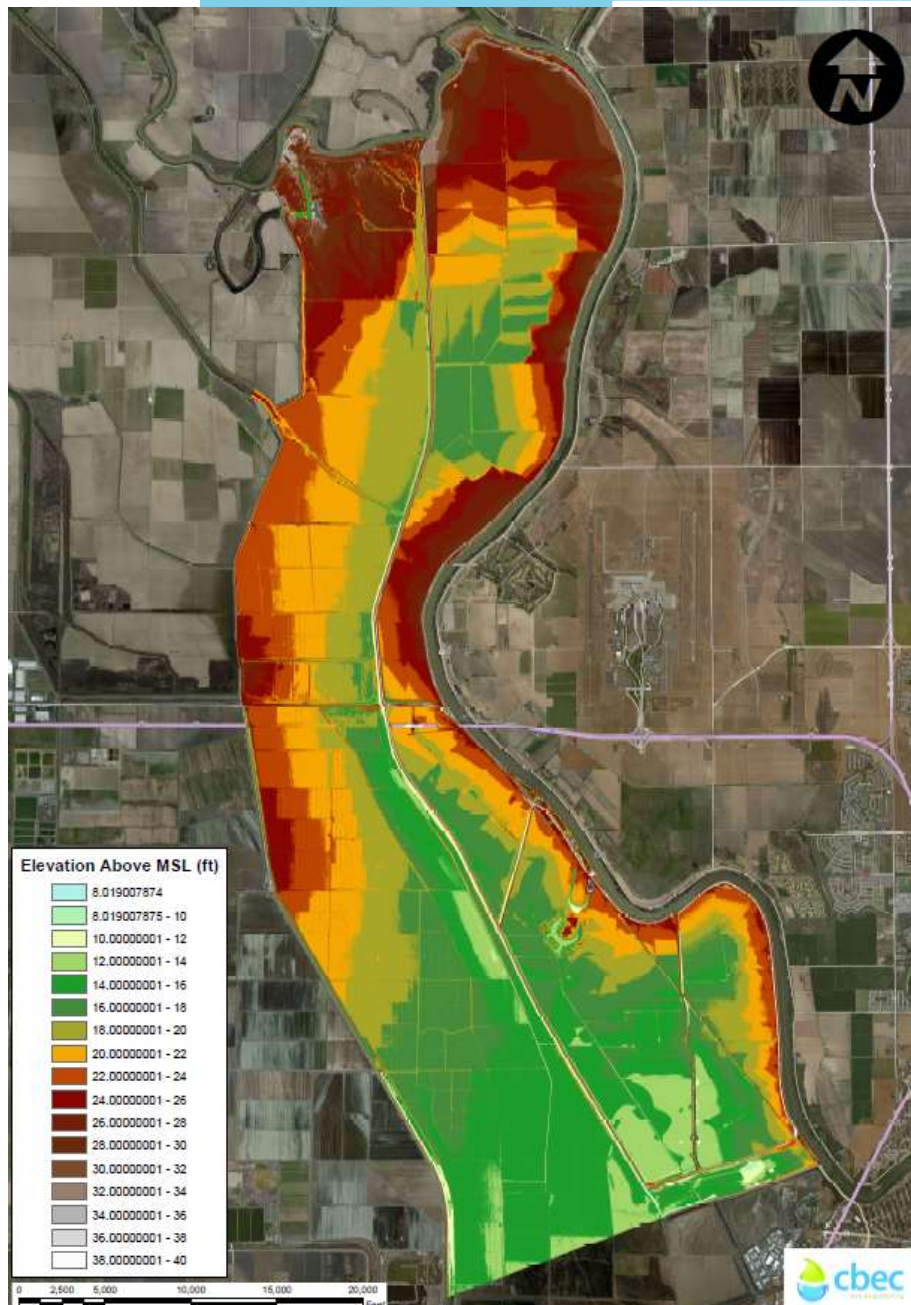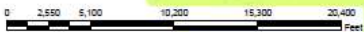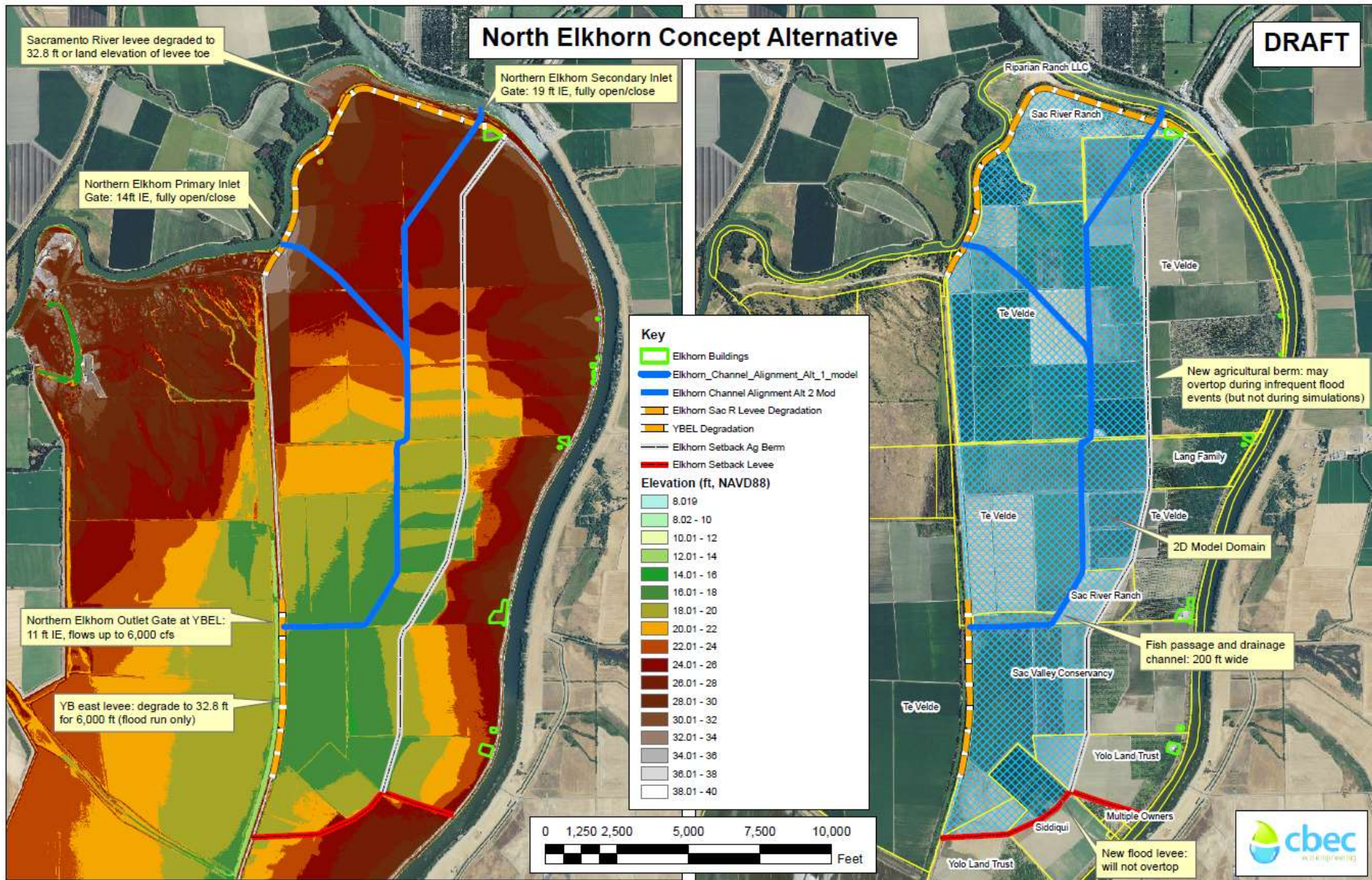
Lose 19k acres 50% of years
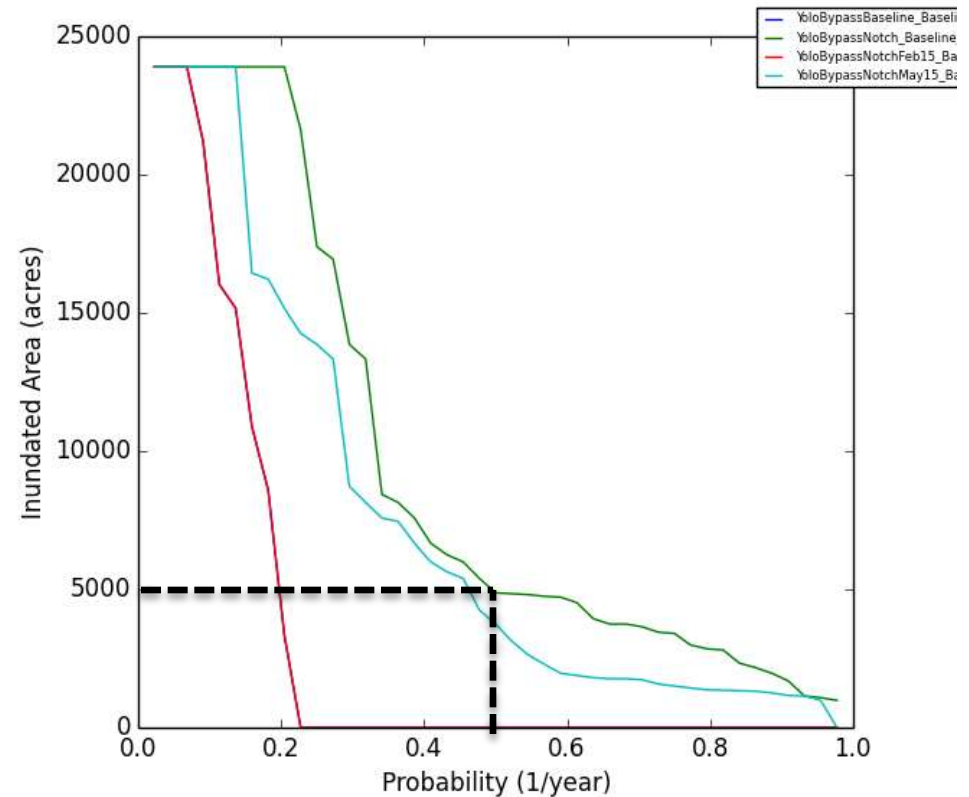
Lose 5k acres 50% of years

Elkhorn Basin Concept

Locally supported alternative to reduce flood risk and provide floodplain habitat for birds and fish
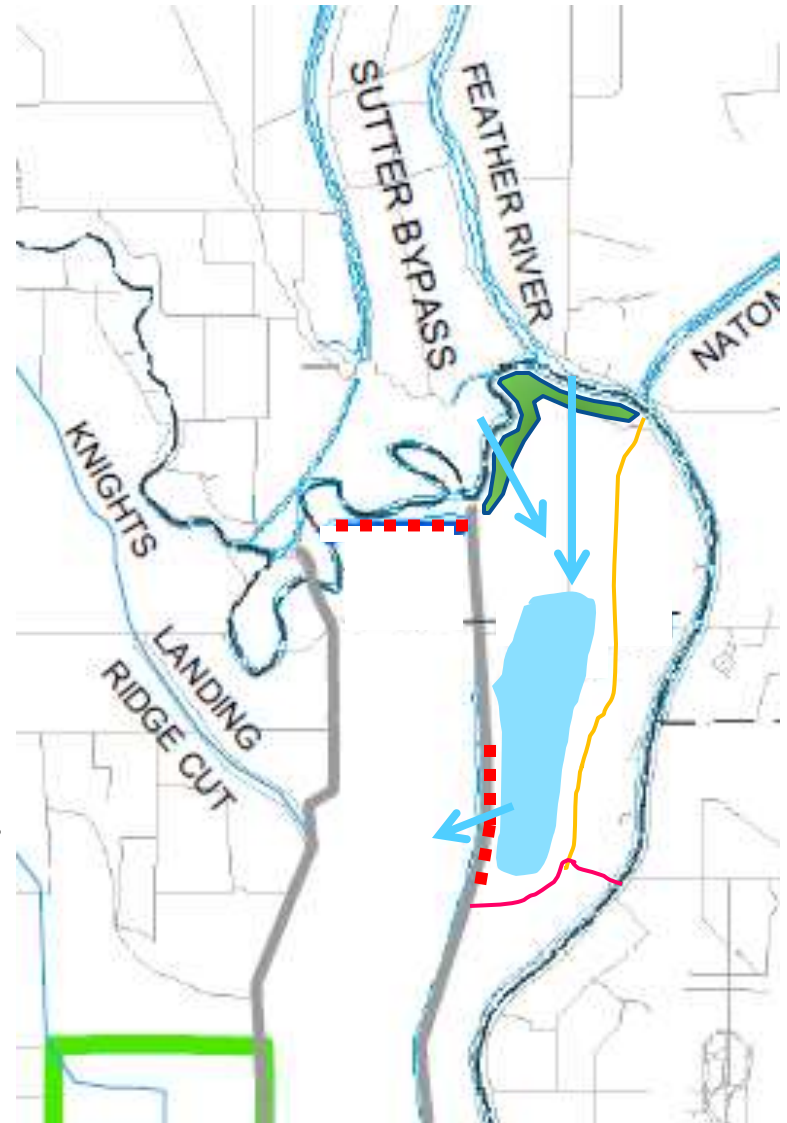
Elkhorn Basin

Fremont Weir

Sacramento Weir

Yolo Bypass

American River

Sacramento

Toe Drain

Cosumnes River

SFEI Historical Ecology

Habitat Types
— Elkhorn_Basin_Outline
historical_habitats_Delta
Habitat_Type
- open water
- fluvial open water
- intermittent pond/lake
- tidal freshwater emergent wetland
- non-tidal freshwater emergent wetland
- willow thicket
- willow riparian scrub/shrub
- valley foothill riparian
- wet meadow/seasonal wetland
- vernal pool complex
- alkali seasonal wetland complex
- stabilized interior dune vegetation
- grassland
- oak woodland/savanna

0 2,550 5,100 10,200 15,300 20,400 Feet

Elevation Above MSL (ft)
- 8.019007874
- 8.019007875 - 10
- 10.00000001 - 12
- 12.00000001 - 14
- 14.00000001 - 16
- 16.00000001 - 18
- 18.00000001 - 20
- 20.00000001 - 22
- 22.00000001 - 24
- 24.00000001 - 26
- 26.00000001 - 28
- 28.00000001 - 30
- 30.00000001 - 32
- 32.00000001 - 34
- 34.00000001 - 36
- 36.00000001 - 38
- 38.00000001 - 40

0 2,500 5,000 10,000 15,000 20,000 Feet

cbec

North Elkhorn Concept Alternative — DRAFT

Elkhorn Basin Concept

- Part of larger locally preferred alternative
- Allows downstream passage of Feather basin fish
- Provides for adult upstream passage
- Provides option to segregate or integrate with floodplain restoration on Yolo bypass
- Can be phased to provide biological benefits first and major flood benefits in second phase
- Multiple design and operation options

Inundation Mapping for EFM Analysis of Modeled Stage 2 of 3 Years from 12/1 to 5/15

Continuous Inundation Exceedance Every 2 of 3 Years from 12/1 to 5/15

Inundation Duration

- 4 Weeks
- 3 Weeks
- 2 Weeks
- 1 Week

Elkhorn "Bathtub" Mapping Based on Observed Sacramento River Stage

Next Steps

- Add west side tributary hydrology
- Evaluate additional scenarios
- Identify optimal scenarios
- Distribute screening tool for use in subsequent studies on Yolo bypass and elsewhere

Acknowledgements

- California Department of Fish and Wildlife
- CBEC
- Newfields
- Katie Jagt and Mary Matella