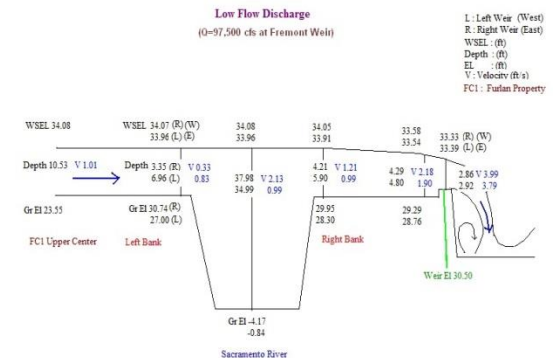


Flow Distribution of Confluence

(Sacramento River, Sutter & Yolo Bypass and Fremont Weir)

April, 2016

Sung Ho Lee,
Ph.D., PE
DWR/CVFPB
(Sungho.Lee@water.ca.gov)



Purpose

- ❑ Compare to 1997 & 2006 flood event using RMA2 hydraulic model
- ❑ Study discharge distribution & hydraulic parameters near the complex confluence area
- ❑ Project development and levee repair
- ❑ Flood management and channel capacity study
- ❑ Study alternatives of Fremont Weir
- ❑ Reduce flood risk at Sutter Bypass, Yolo Bypass and Sacramento River
- ❑ Datum – NGVD29 (USED: +3.0 ft, NVAD88: +2.28 ft)

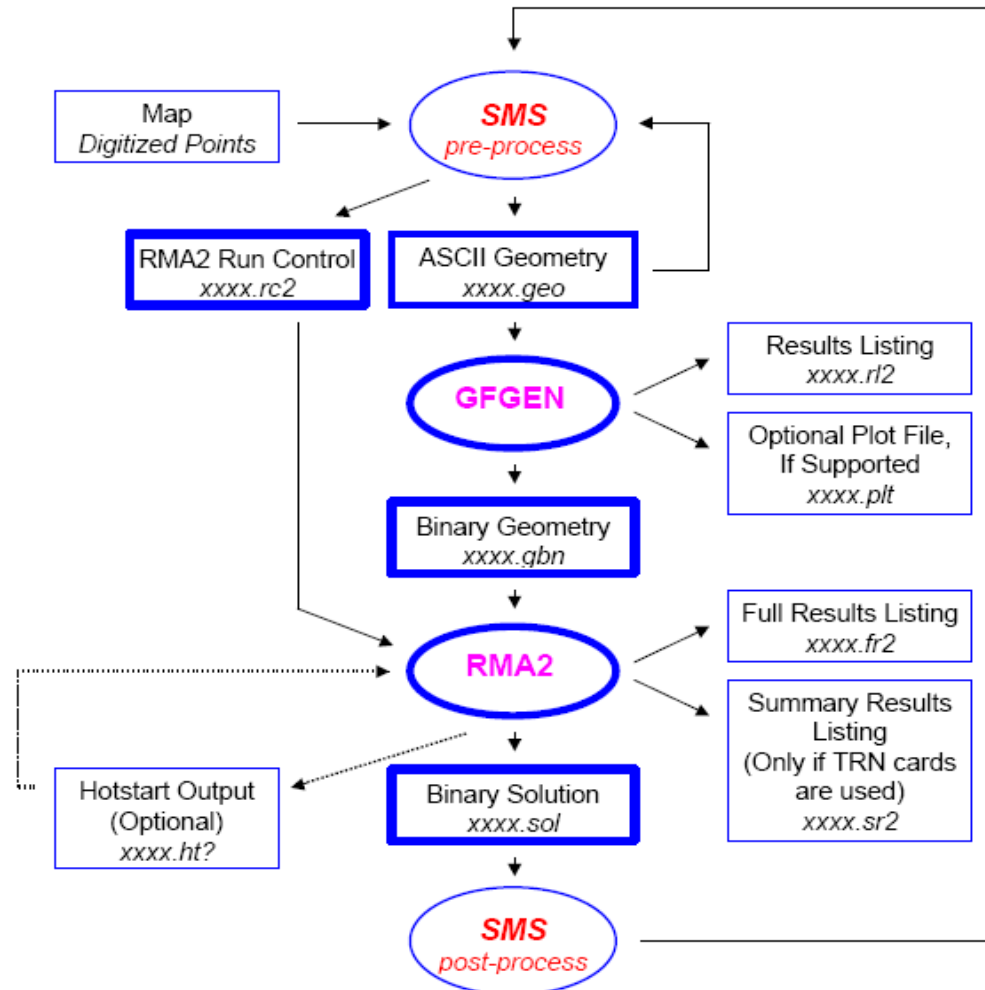
SMS and RMA2 Hydraulic Model

- Map Digitized Points
- SMS (pre-process)
- GFGEN (grid generation) – Create geometry and finite element mesh file
- RMA2 (Hydraulic Simulation)
- SMS (post-process)

Using RMA2

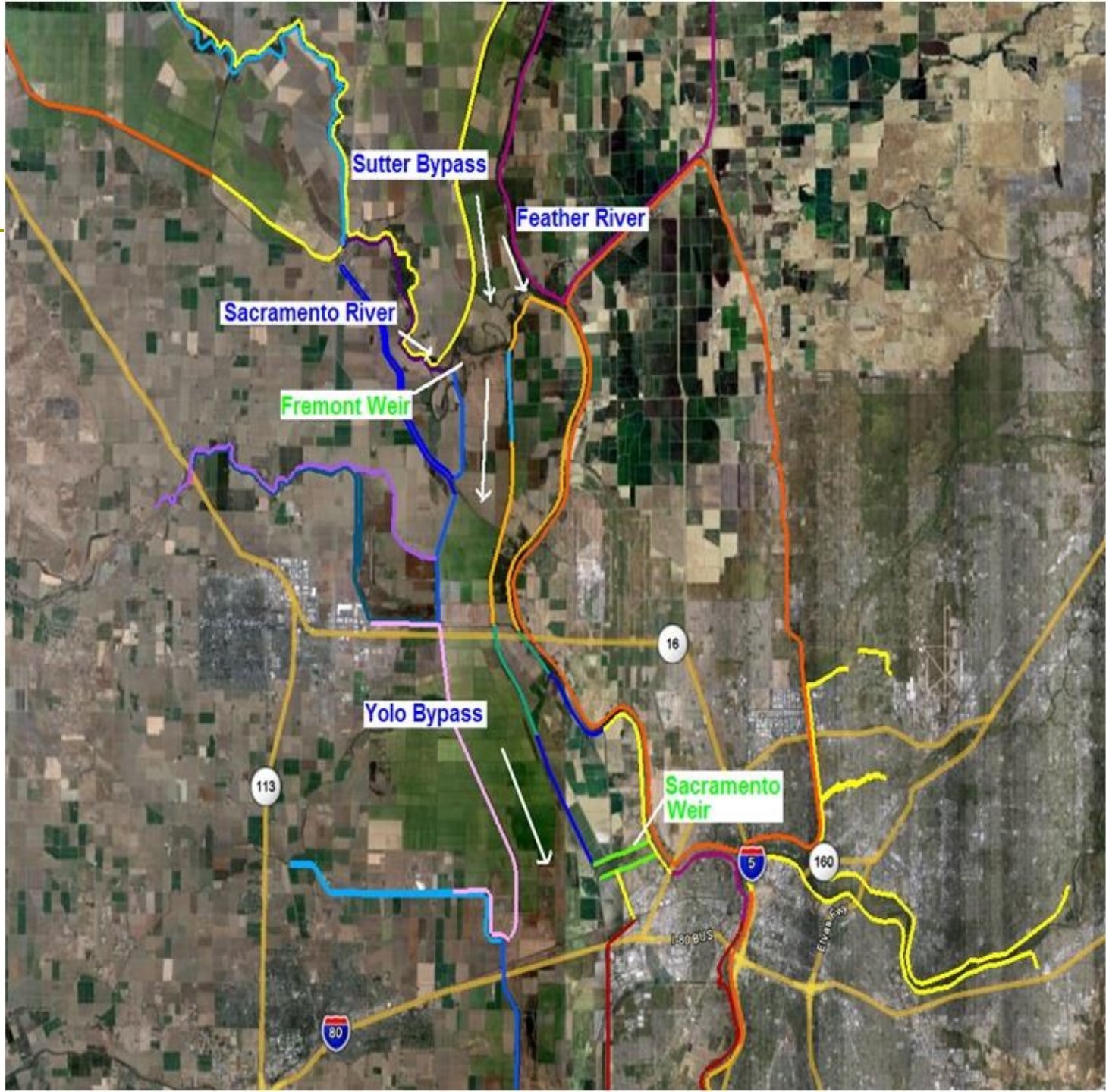
The RMA2 Modeling Process

The following flow chart illustrates the RMA2 modeling process. Items with bold borders are required, others are optional.

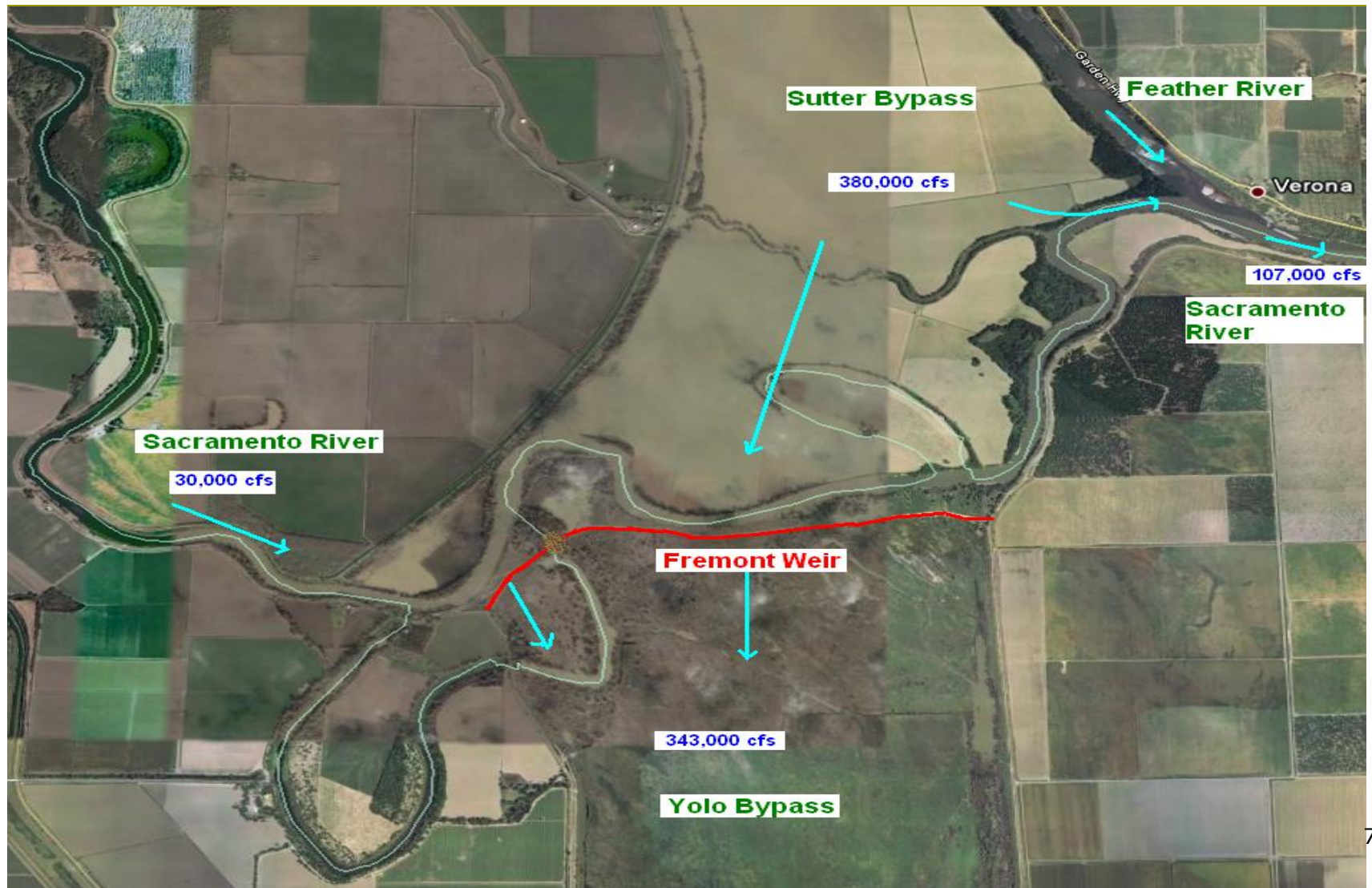


2-D Hydraulic Modeling

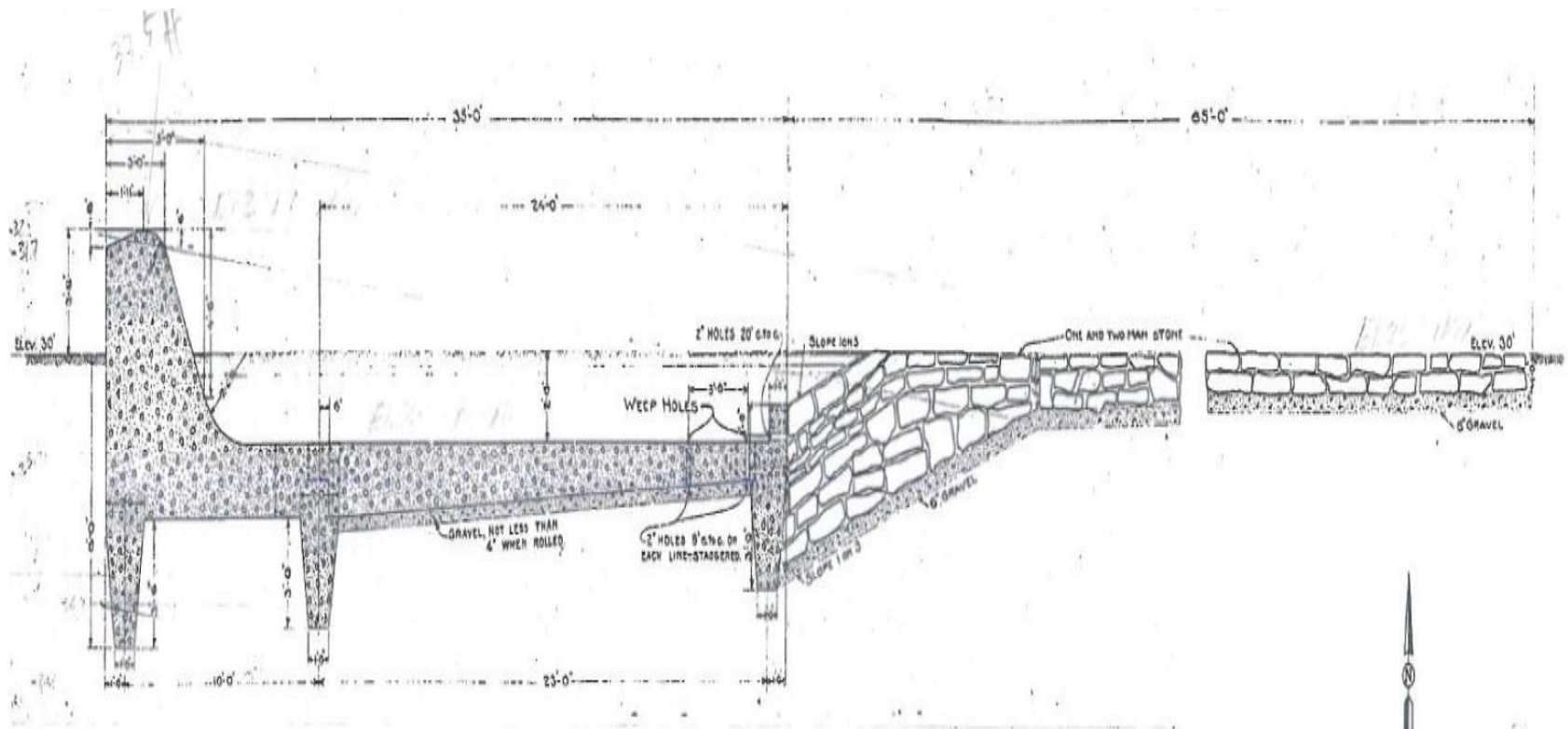
- ❑ RMA2 model
- ❑ Two-dimensional depth averaged finite element hydrodynamic model
- ❑ Compute WSEL & 2 D-horizontal velocity
- ❑ Reynolds form of Navier-Stokes equation
- ❑ Finite element method using Galerkin Method of weighted residuals
- ❑ Fully implicit and Newton-Raphson non linear iteration scheme



Design Flow of DWR



Fremont Weir Drawing (USED datum)



CROSS-SECTION FOR CREST HEIGHT OF 3'-6" TO
BE BUILT IN 40 FOOT SECTIONS



Fremont Weir (West & East End)



Flow (April, 2011)- look east from west bank



Fremont Weir West Bank



East (Left) Fremont Weir



Rattle Snake Island



© 2011 Google

©2010 Google

imagery Date: 6/13/2011 1993

38°45'47.32" N 121°39'41.07" W elev 36 ft

Eye alt 1550 ft

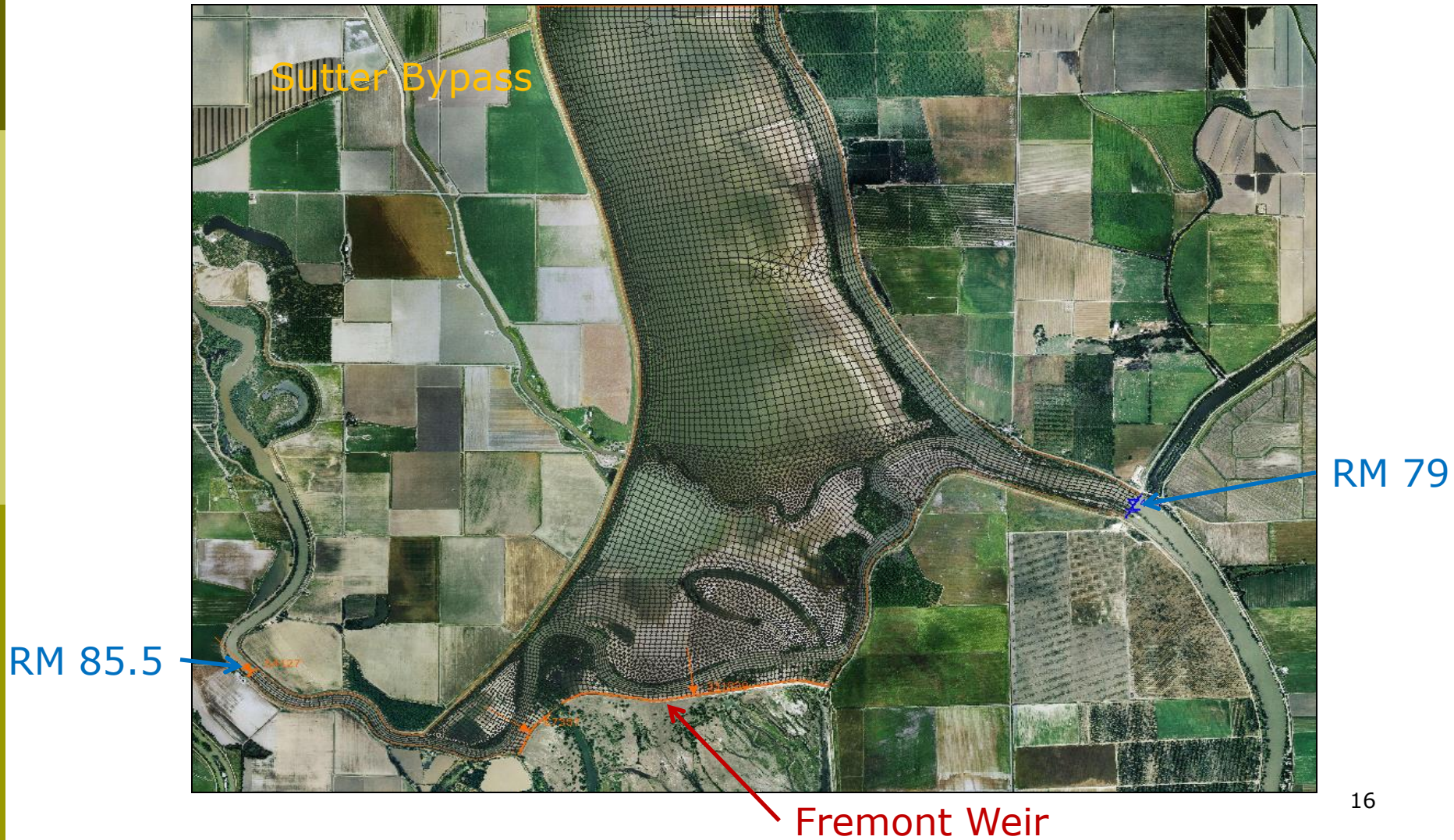
Rattle Snake Island (East, Middle & West Side)



West (Right) Fremont Weir



Model Boundaries



Three Cases Study (High, Medium and Low Flow)

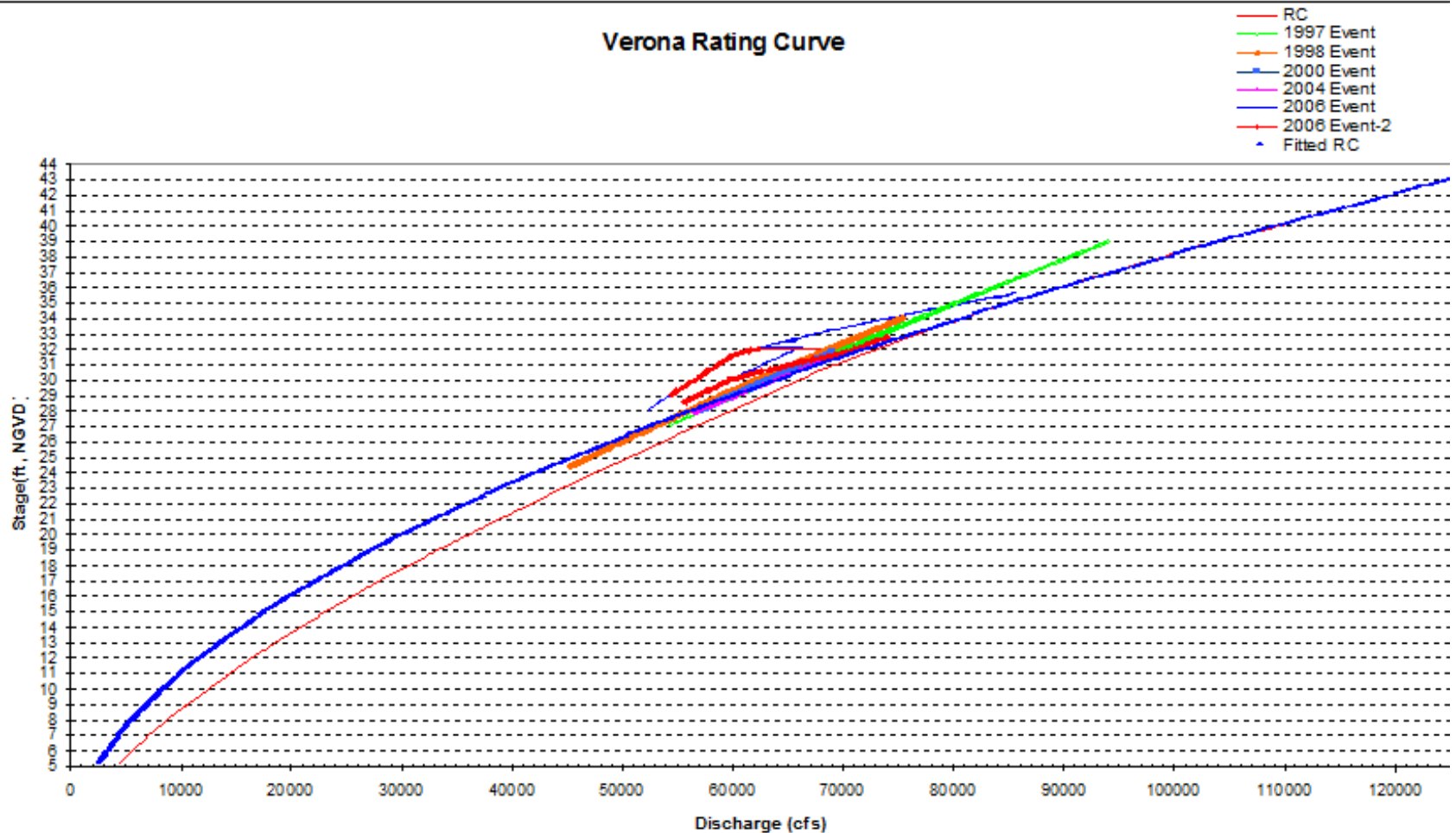
Event	Date	Fremont Weir (FRE)			Verona (VON)		
		RC		Measured	RC		Measured
		H	Q	H	H	Q	H
High Q	1/2/1997 23:00	39.47	397,000 (1997 RC)	39.47	39.09	104,000	39.09
Medium Q	1/2/2006 23:30	36.98	208,995 (2006 RC)	36.98	35.69	85,500	35.69
Low Q	4/6/2006 2:45	34.05	97,500 (2006 RC)	34.05	32.83	75,800	32.83

Q : Flow Discharge (cfs)

RC : Rating Curve

H : Elevation (ft)

Verona (VON) Rating Curve



Inflow Discharge

Event	Total Discharge (cfs)	Inflow			
		Sacramento R. (Fremont Weir) (cfs)	%	Sutter Bypass and Feather R. (cfs)	%
High Q	501,000	33,000	6.6	468,000	93.4
Medium Q	295,495	31,500	10.7	263,995	89.3
Low Q	173,300	27,000	15.6	146,300	84.4

Q : Flow Discharge (cfs)

Fr : Fremont Weir

WSEL : Water Surface Elevation

Roughness Coefficient Example

- Material Property Roughness (Manning' n)
 - Cultivated Field 0.03
 - Dense Trees 0.12
 - Grass 0.03
 - Main Channel 0.05
 - Main Channel 2 0.047
 - Mixed Channel Trees 0.048
 - Overbank 0.045
 - Scrub 0.09
 - Sparse Trees 0.08

2-D Model Simulation Result

Case	Date	Fremont Weir (FRE)				Verona (VON)			WSEL Difference
		Rating Curve		Simulation Result		Rating Curve		Measured Data	FRE-VON
		H	Q	H	Difference	H	Q	H	ft
High Flood	1/2/1997 23:00	39.47	397,000 (1997 RC)	39.48	+0.01	39.09	104,000	39.09	+0.38
Medium Flood	1/2/2006 23:30	36.98	208,995 (2006 RC)	36.73	-0.25	35.69	85,500	35.69	+1.29
Low Flood	4/6/2006 2:45	34.05	97,500 (2006 RC)	34.12	+0.07	32.83	75,800	32.83	+1.22

Q : Flow Discharge (cfs)

RC : Rating Curve

H : Elevation (ft)

2-D Model Result (Discharge)

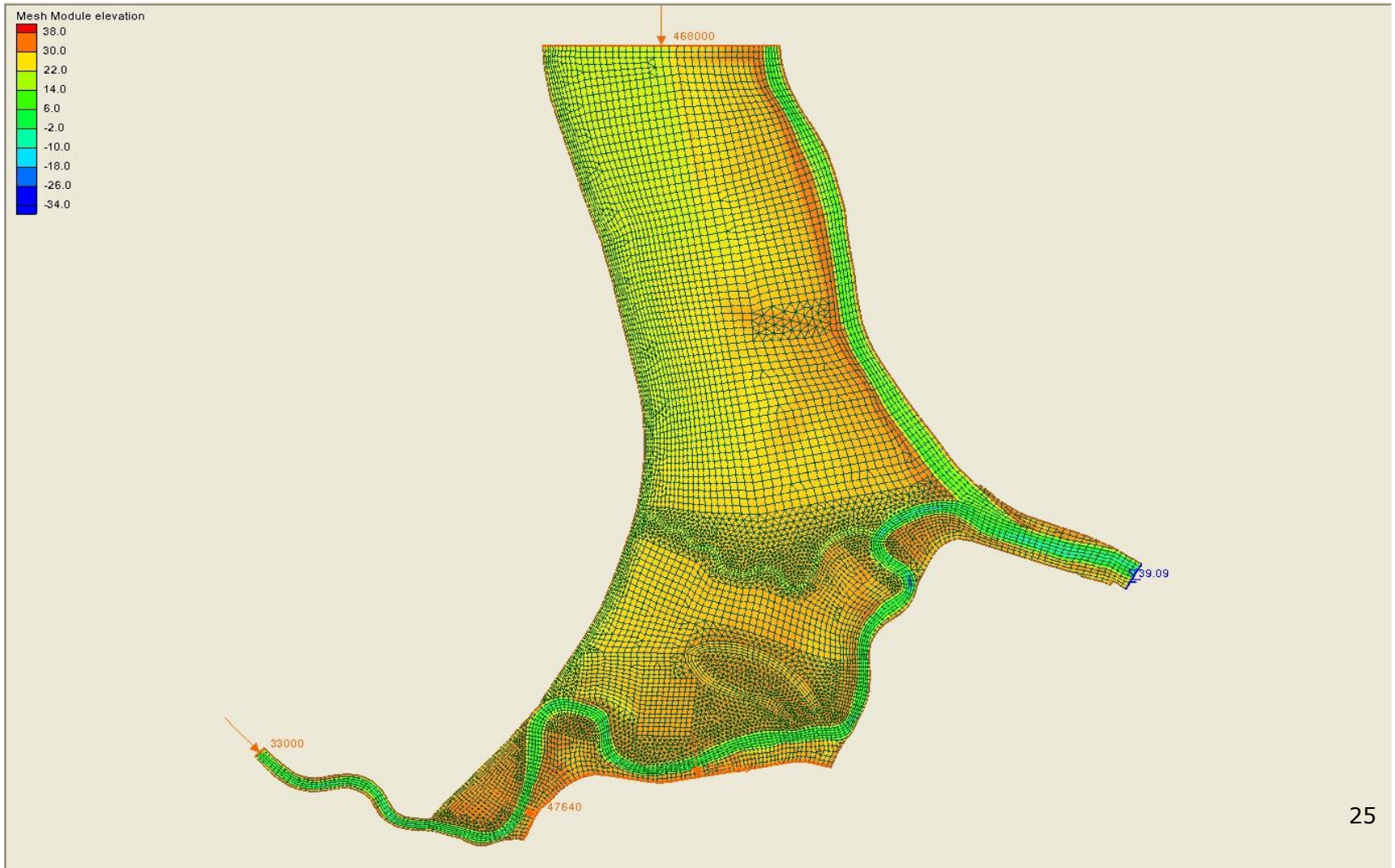
Event	Total Discharge (cfs)	Out Flow						
		Sutter Bypass (Fremont Weir)				Sacramento River (Verona)		
		WSEL (ft)	Q (cfs)	Detailed	Total	WSEL (ft)	Q (cfs)	Total
				%	%			%
High Q	501,000	39.47	397,000	100	79.2	39.09	104,000	20.8
Right Fr. Weir			47,640	12.0	9.5			
Left Fr. Weir			349,360	88.0	69.7			
Medium Q	294,495	36.98	208,995	100	71.0	35.69	85,500	29.0
Right Fr. Weir			25,080	12	8.5			
Left Fr. Weir			183,915	88	62.5			
Low Q	173,300	34.05	97,500	100	56.3	32.83	75,800	43.7
Right Fr. Weir			17,060	17.5	9.8			
Left Fr. Weir			80,440	82.5	46.4			

Hydraulic Results near Fremont Weir

	Location	Right (West) Fremont Weir				Left (East) Fremont Weir			
		Gr El	H	V	WSEL	Gr El	H	V	WSEL
High Q	Left Bank	30.74	8.68	1.05	39.46	27.00	12.32	2.78	39.27
	Sac River	-4.17	43.35	1.21	39.46	-0.84	40.27	1.70	39.35
	Right Bank	29.95	9.41	1.88	39.40	28.30	10.84	2.79	39.17
	Up of Weir	29.29	9.72	2.97	39.01	28.76	9.35	4.56	38.14
	Weir	30.50	8.35	3.78	38.84	30.50	7.32	6.51	37.80
Medium Q	Left Bank	30.74	5.95	0.66	36.70	26.97	9.56	1.65	36.51
	Sac River	-4.17	40.73	1.39	36.71	-0.84	37.47	1.10	36.53
	Right Bank	29.95	6.62	1.36	36.68	28.30	11.92	1.75	36.43
	Up of Weir	29.29	7.16	2.11	36.41	28.76	6.99	3.12	35.78
	Weir	30.50	5.81	2.87	36.29	30.50	5.07	4.96	35.55
Low Q	Left Bank	30.74	3.35	0.33	34.07	26.97	6.96	0.83	33.96
	Sac River	-4.17	37.98	2.13	34.08	-0.84	34.99	0.99	33.96
	Right Bank	29.95	4.21	1.21	34.05	28.30	5.90	0.99	33.91
	Up of Weir	29.29	4.29	2.18	33.58	28.76	4.80	1.90	33.54
	Weir	30.50	2.86	3.99	33.33	30.50	2.92	3.79	33.39

Q : Flow Discharge
 Gr El : Ground Elevation (ft)
 H : Depth (ft)
 V : Velocity (ft/s)
 WSEL : Water Surface Elevation (ft)

Mesh Elevation of Ground



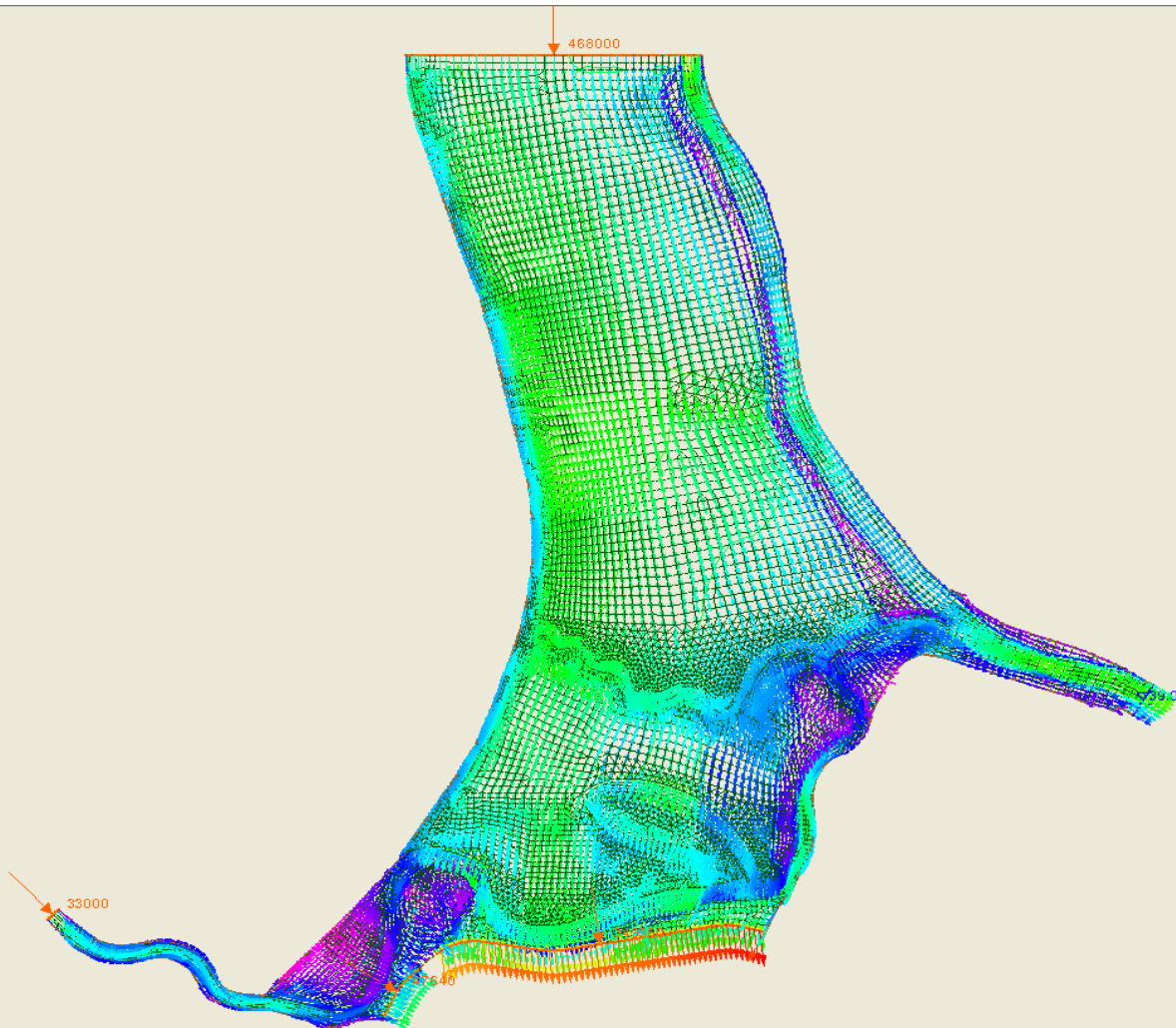
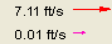
Velocity

High Flood (Q=397,000 cfs)

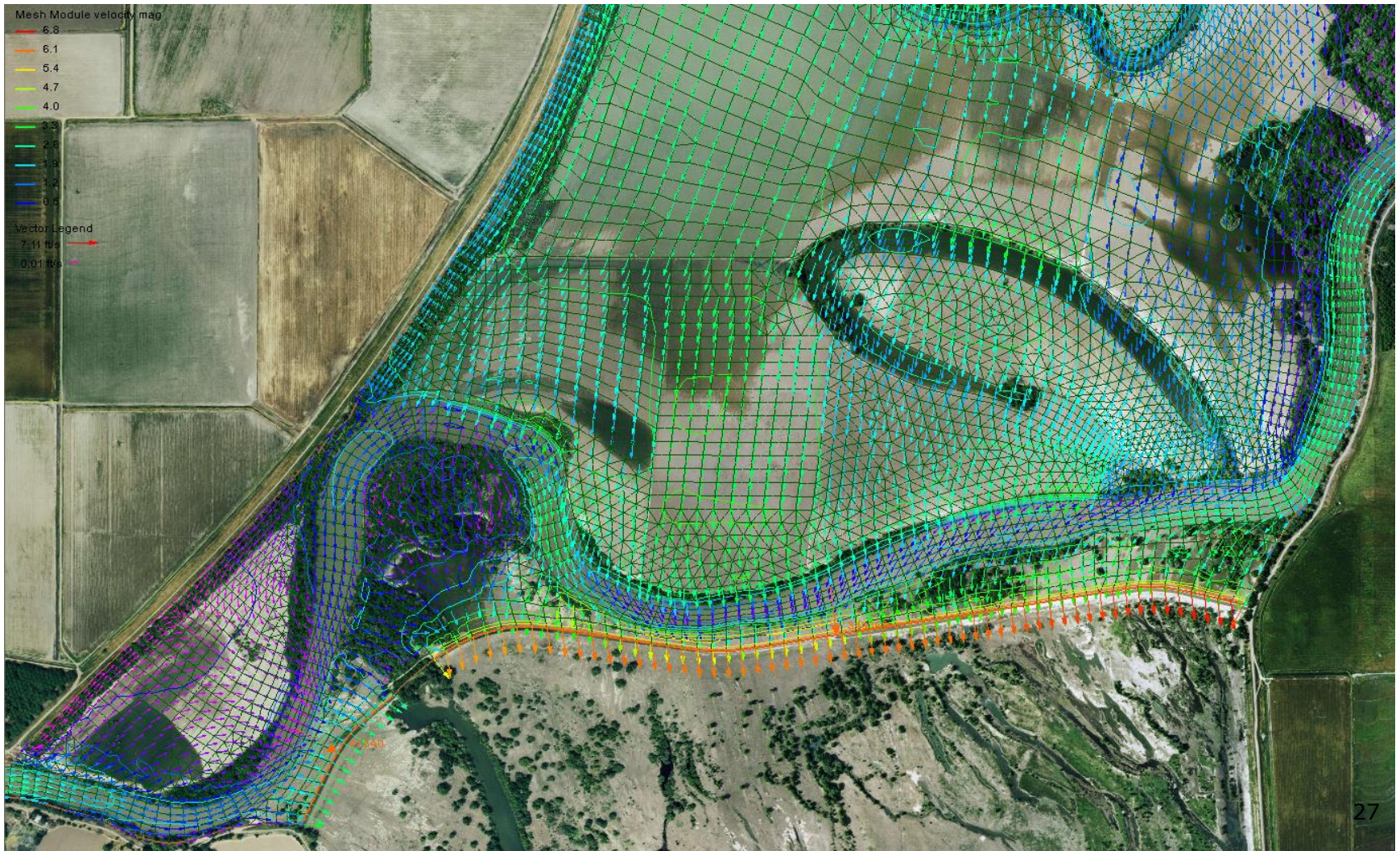
Mesh Module velocity mag



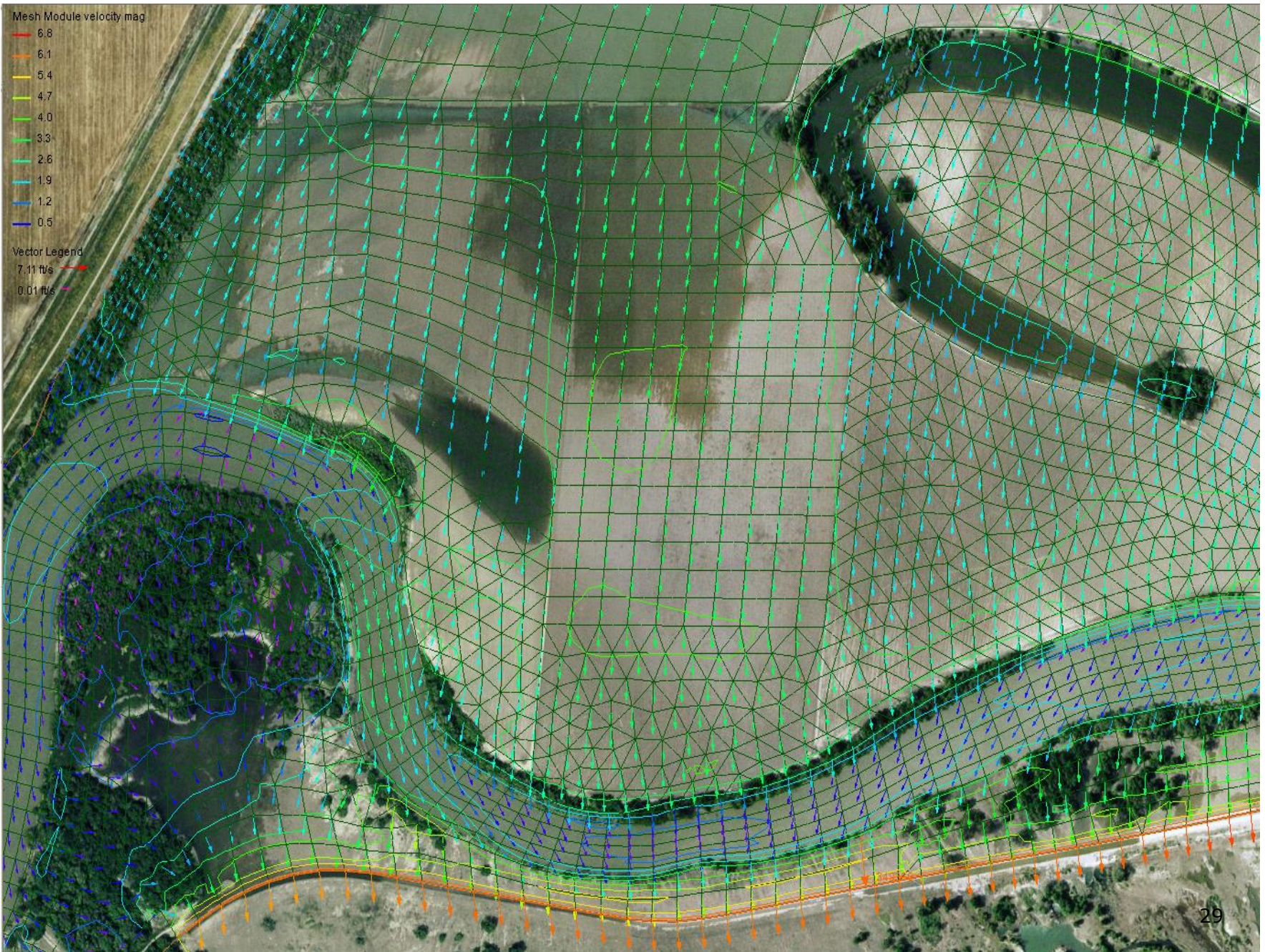
Vector Legend

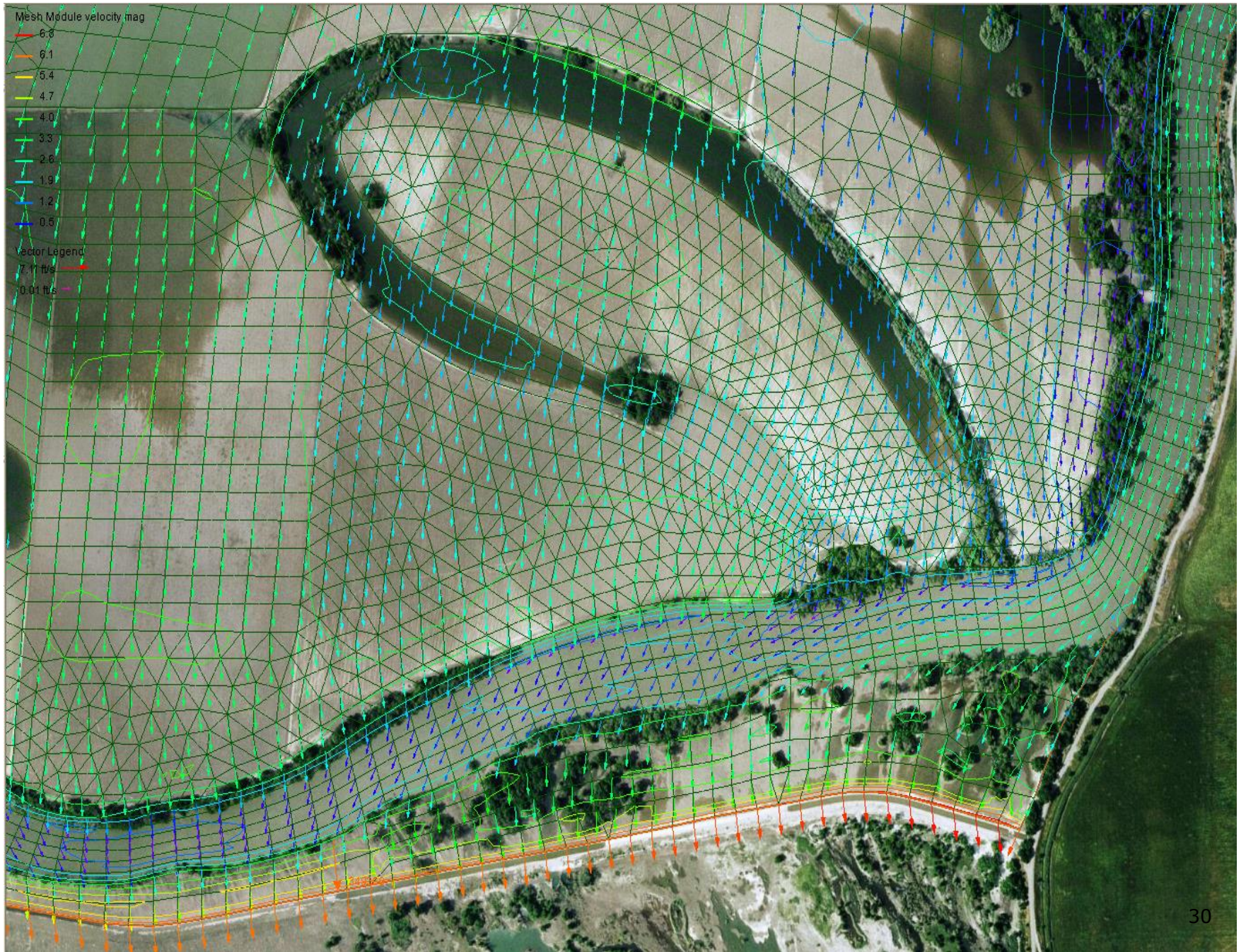


Velocity Vectors High Flood

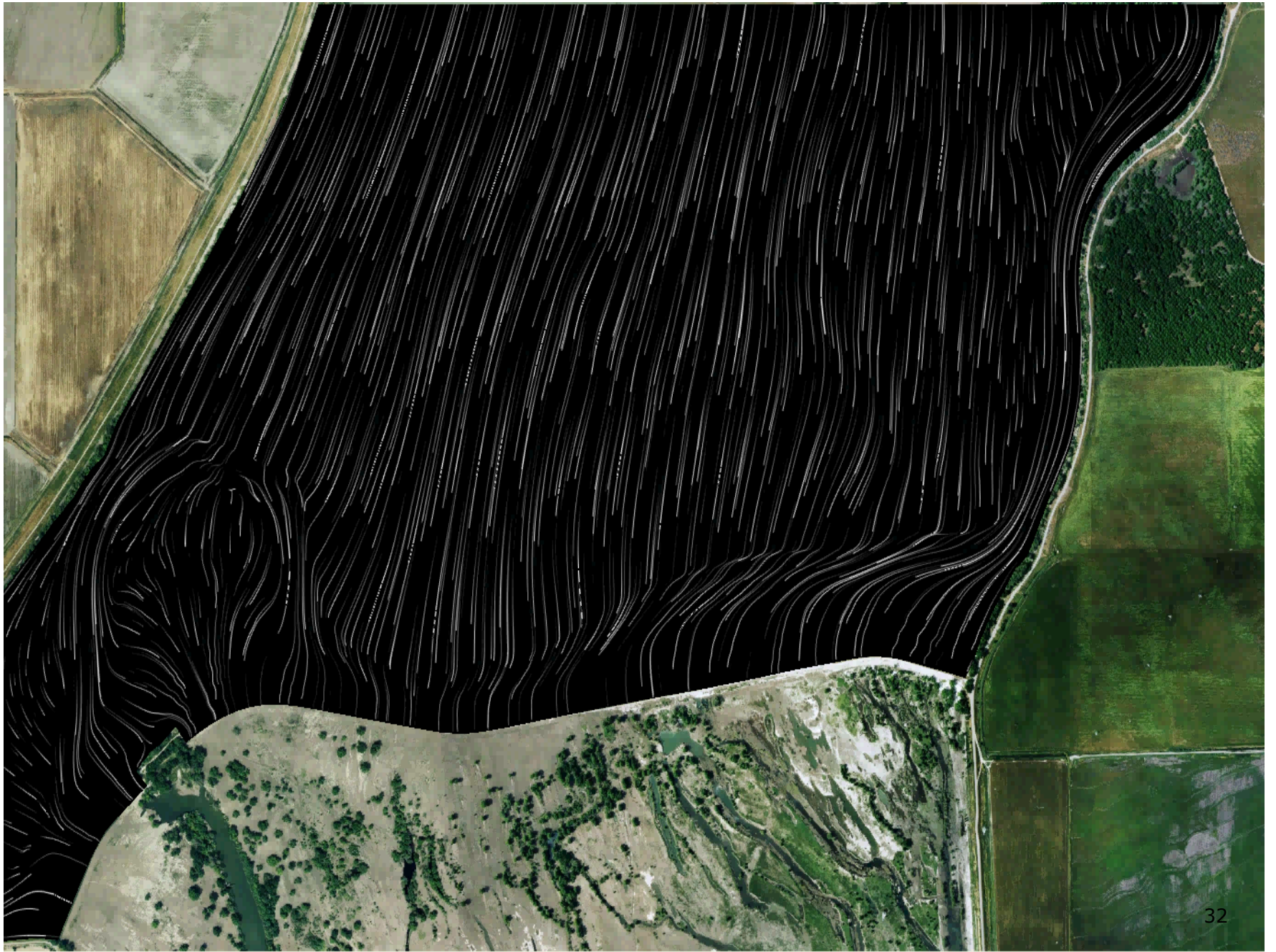








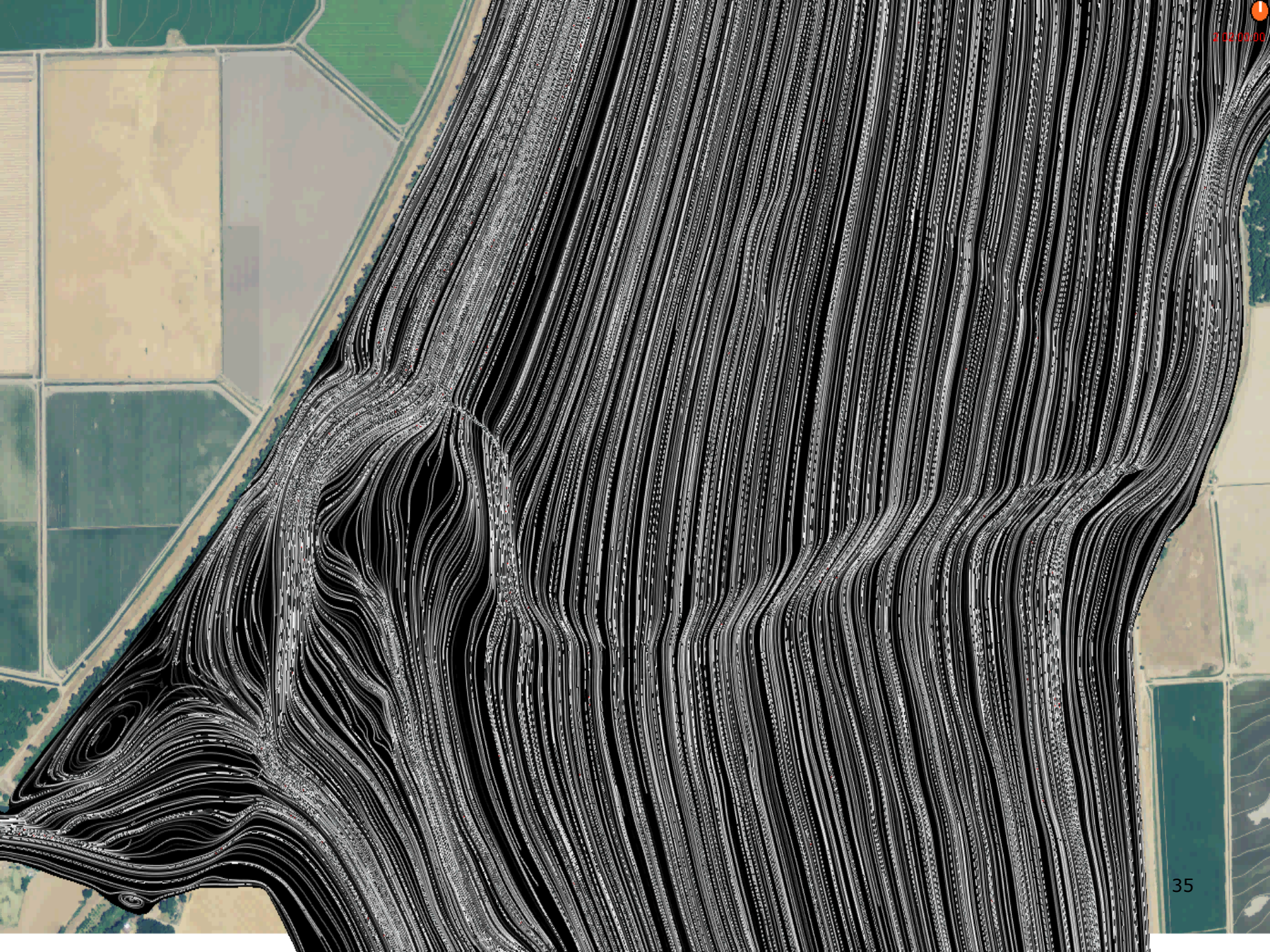




Sac River, Sutter Bypass and Fremont Weir





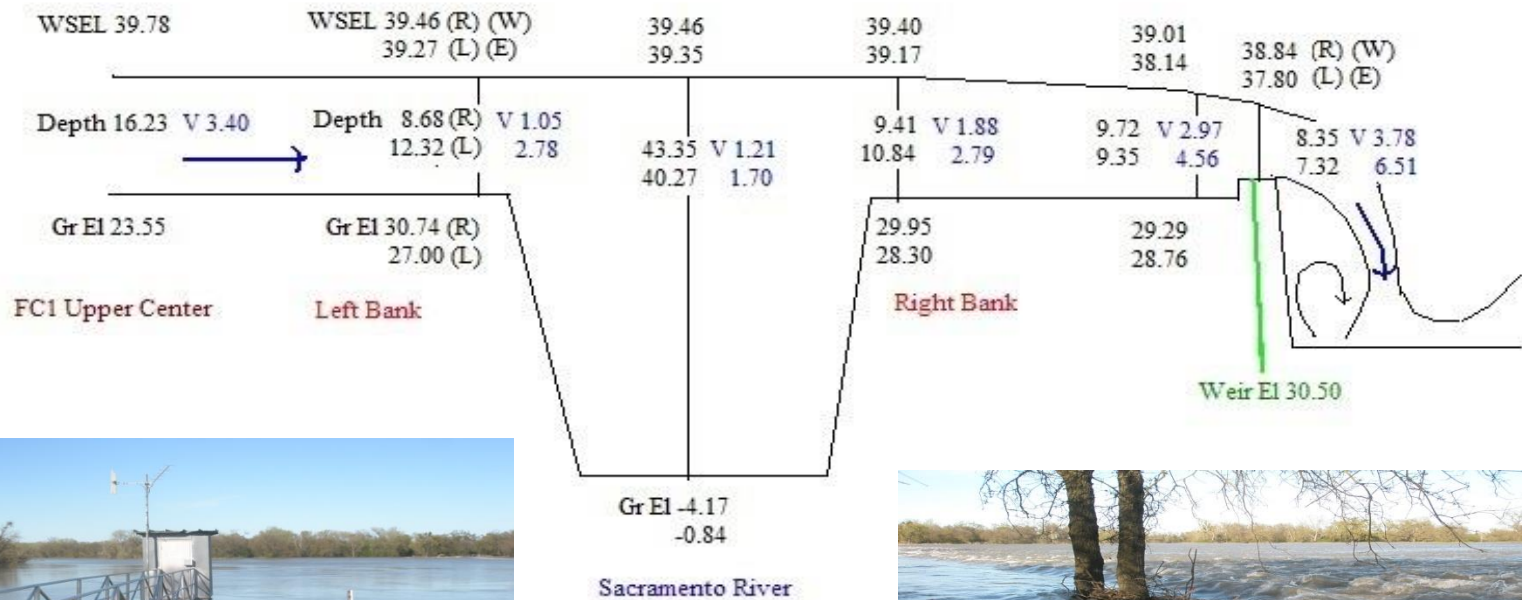


WSEL, Depth & Velocity

High Flood (Q=397,000 cfs-11,235 m³/s)

High Flow Discharge
(Q=397,000 cfs at Fremont Weir)

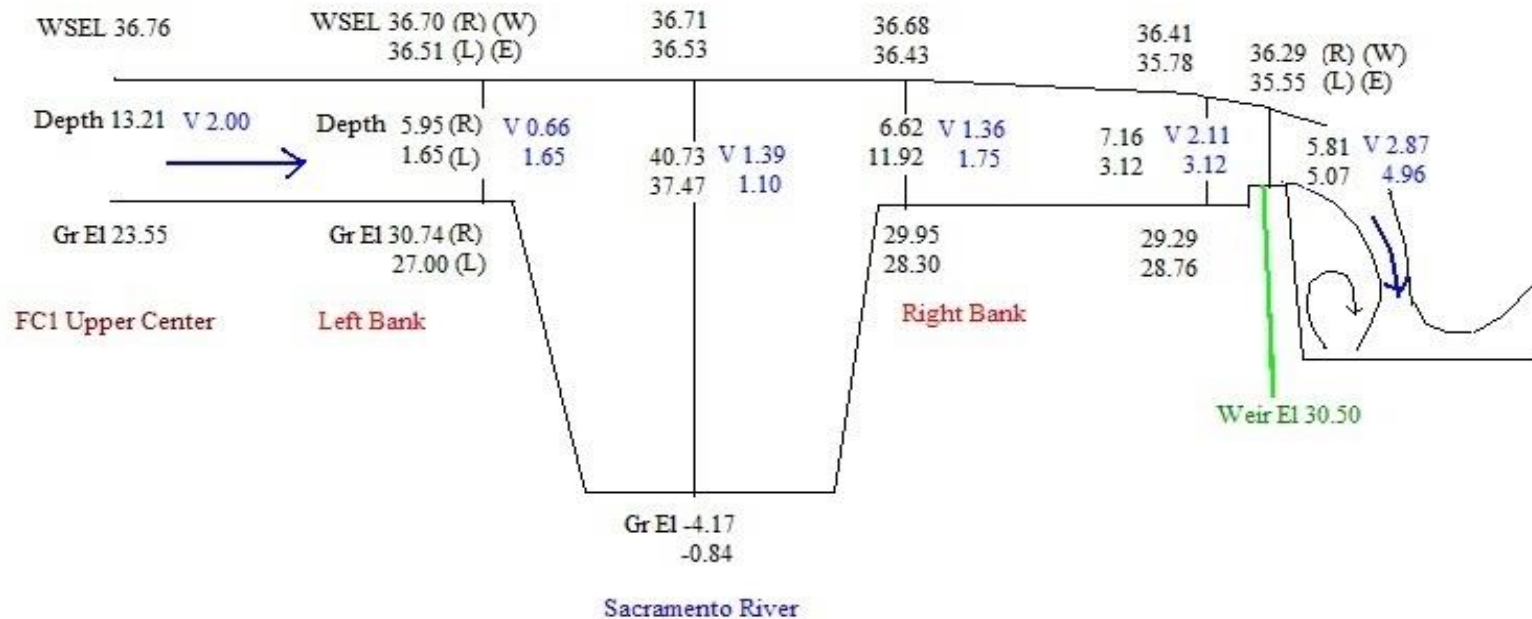
R : Right Weir (West)
L : Left Weir (East)
WSEL : (ft)
Depth : (ft)
EL : (ft)
V : Velocity (ft/s)
FC1 : Furlan Property



WSEL, Depth & Velocity Medium Flood (Q=208,995 cfs)

Medium Flow Discharge
(Q=208,995 cfs at Fremont Weir)

L : Left Weir (West)
R : Right Weir (East)
WSEL : (ft)
Depth : (ft)
EL : (ft)
V : Velocity (ft/s)
FC1 : Furlan Property

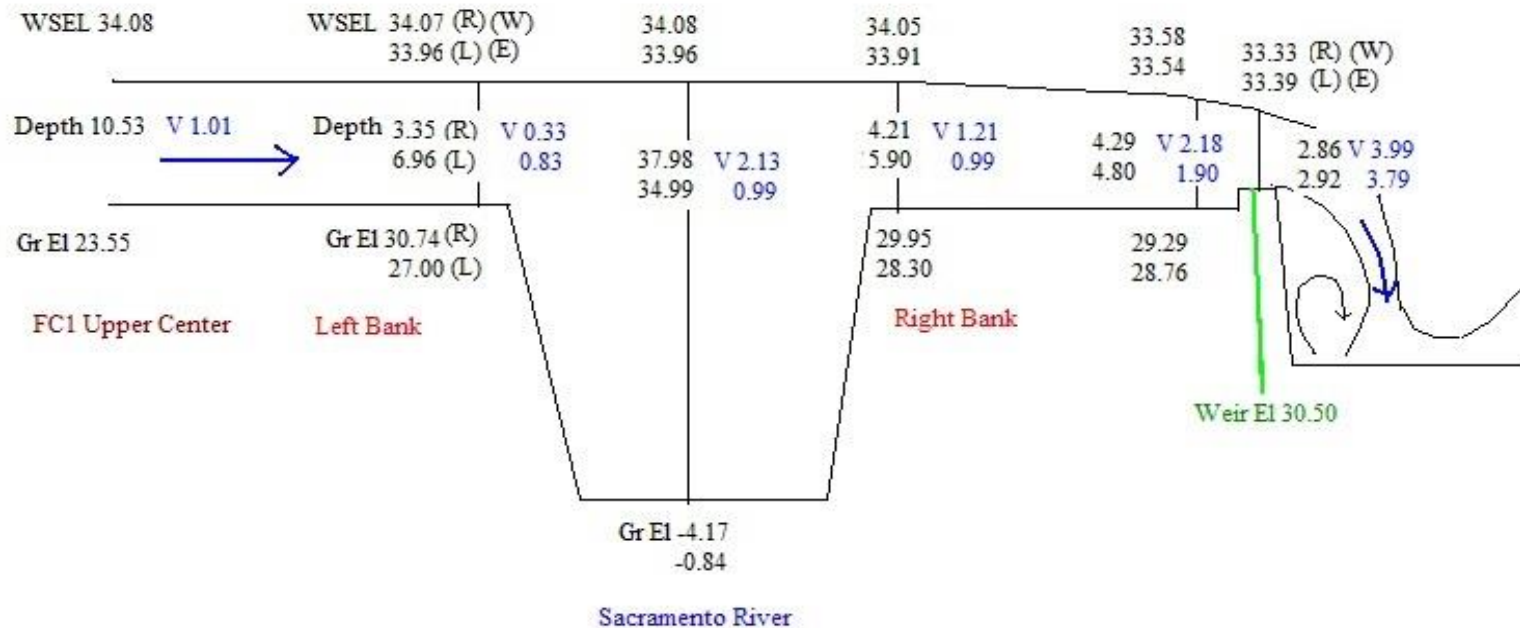


WSEL, Depth & Velocity

Low Flood (Q=97,500 cfs)

Low Flow Discharge
(Q=97,500 cfs at Fremont Weir)

L : Left Weir (West)
R : Right Weir (East)
WSEL : (ft)
Depth : (ft)
EL : (ft)
V : Velocity (ft/s)
FC1 : Furlan Property



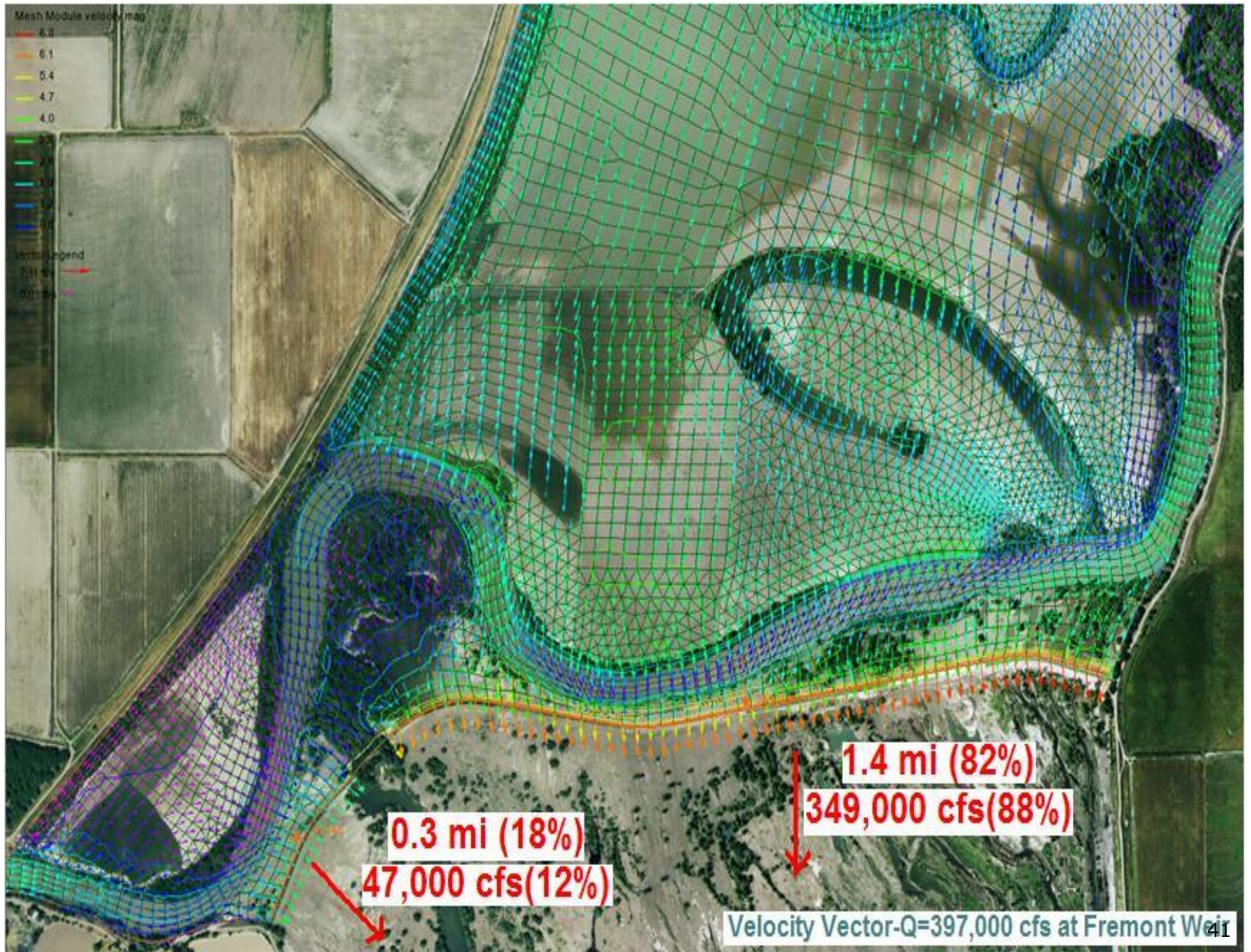
RMA2 Simulation Results

- Discharge Q= 397,000 cfs, 208,000 cfs & 97,500 cfs
- Weir: Right (West), Left (East)
- WSEL (Weir)
 - High - Right 38.84 ft, Left 37.80 ft (diff. -1.04 ft)
 - Medium - Right 36.29 ft, Left 35.55 ft (diff. -0.74 ft)
 - Low - Right 33.33 ft, Left 33.39 ft (diff. 0.06 ft)
- Depth (Weir)
 - High - Right 8.35 ft, Left 7.32 ft (diff. -1.03 ft)
 - Medium - Right 5.81 ft, Left 5.07 ft (diff. -0.74 ft)
 - Low - Right 2.86 ft, Left 2.92 ft (diff. 0.06 ft)
- Velocity (Weir)
 - High - Right 3.78 ft/s, Left 6.51 ft/s (diff. 2.73 ft/s)
 - Medium - Right 2.87 ft/s, Left 4.96 ft/s (diff. 2.09 ft/s)
 - Low - Right 3.99 ft/s, Left 3.79 ft/s (diff. -0.20 ft/s)

Flow Distribution

-Sutter Bypass & Sacramento River-

- Total Q: High- 501,000 cfs, Medium- 294,495 cfs
and 173,300 cfs
- High: 501,000 cfs
 - Sutter Bypass: 397,000 cfs (79.2 %)
 - Sacramento River (Verona): 104,000 cfs (20.8 %)
- Medium: 294,495 cfs
 - Sutter Bypass: 208,995 cfs (71.0 %)
 - Sacramento River (Verona): 85,500 cfs (29.0 %)
- Low: 173,300 cfs
 - Sutter Bypass : 97,500 cfs (56.3 %)
 - Sacramento River (Verona): 75,800 cfs (43.7 %)



Flow Split at Fremont Weir

- Weir length: Total 1.7 mi
 - Right (West) – 0.3 mi (18 %), Left (East) – 1.4 mi (82 %)
- Q= 397,000 cfs (High)
 - Left (East) Weir: 349,000 cfs (88 %)
 - Right (West) Weir: 48,000 cfs (12 %)
- Q= 209,000 cfs (Medium)
 - Left (East) Weir: 184,000 cfs (88 %)
 - Right (West) Weir: 25,000 cfs (12 %)
- Q= 97,500 cfs (Low)
 - Left (East) Weir: 80,500 cfs (82.5 %)
 - Right (West) Weir: 17,000 cfs (17.5 %)

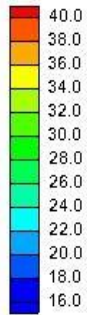
Conclusion

- ❑ 1-D model is not enough to represent hydraulic phenomenon for the complex confluence at Fremont Weir with medium and high flood conditions
- ❑ Need attention to flow separation at Fremont Weir for further flood management project, channel capacity study, levee or weir repair, and fish ladder/ fishway study

Further Discussion

- ❑ Sutter Bypass and Yolo Bypass issue
- ❑ More sediment deposit due to low velocity and high water depth at west bank of Yolo Bypass
- ❑ Need 2-D sediment transport model at he downstream of Fremont Weir (Yolo Bypass)
- ❑ Long term vegetation management issues & Roughness Coefficient in the channel
- ❑ Study Fish Ladder/ Passage (Fishway) facility at Fremont Weir
- ❑ Water Quality Management System (mercury)

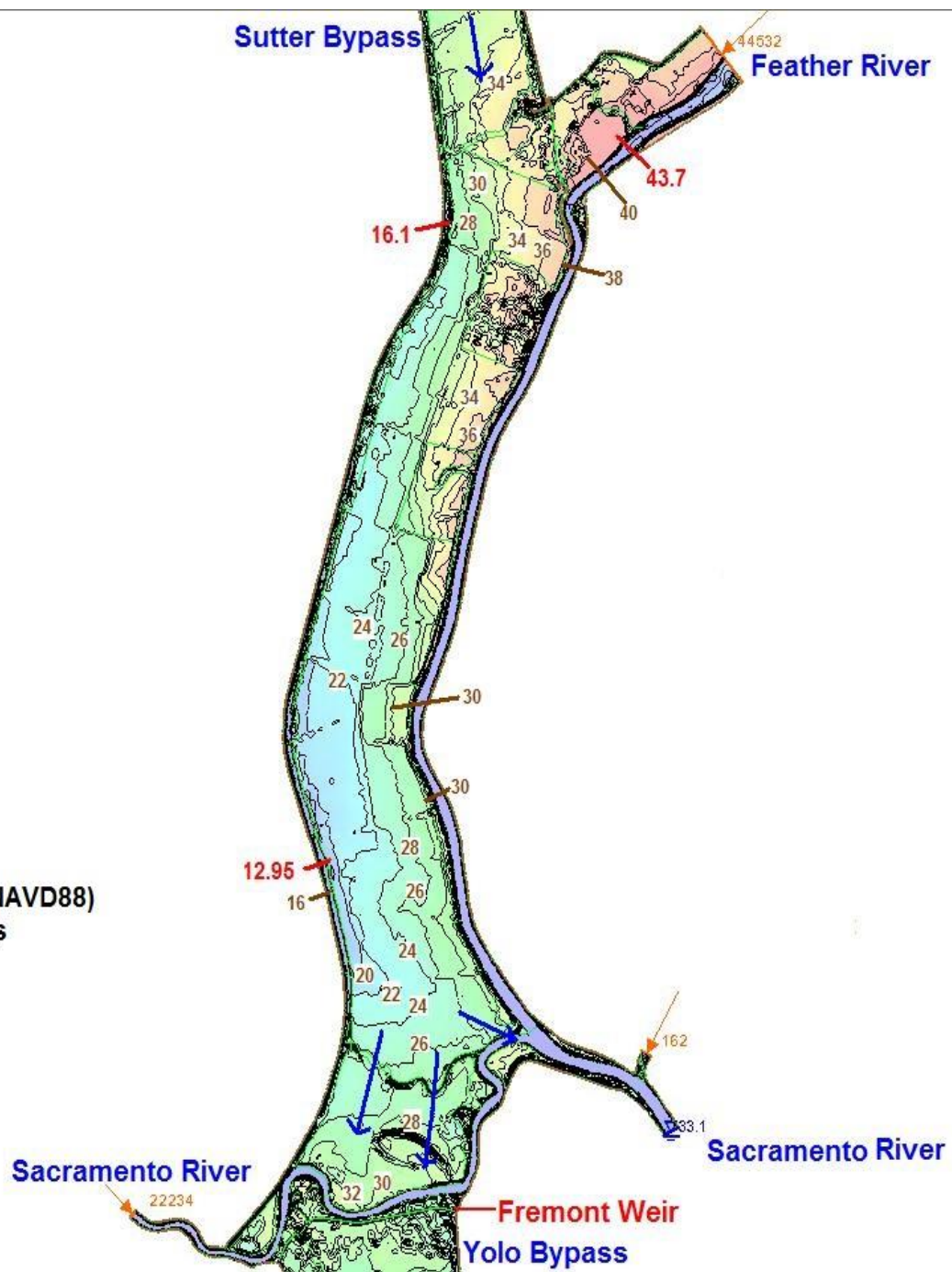
Mesh Module elevation

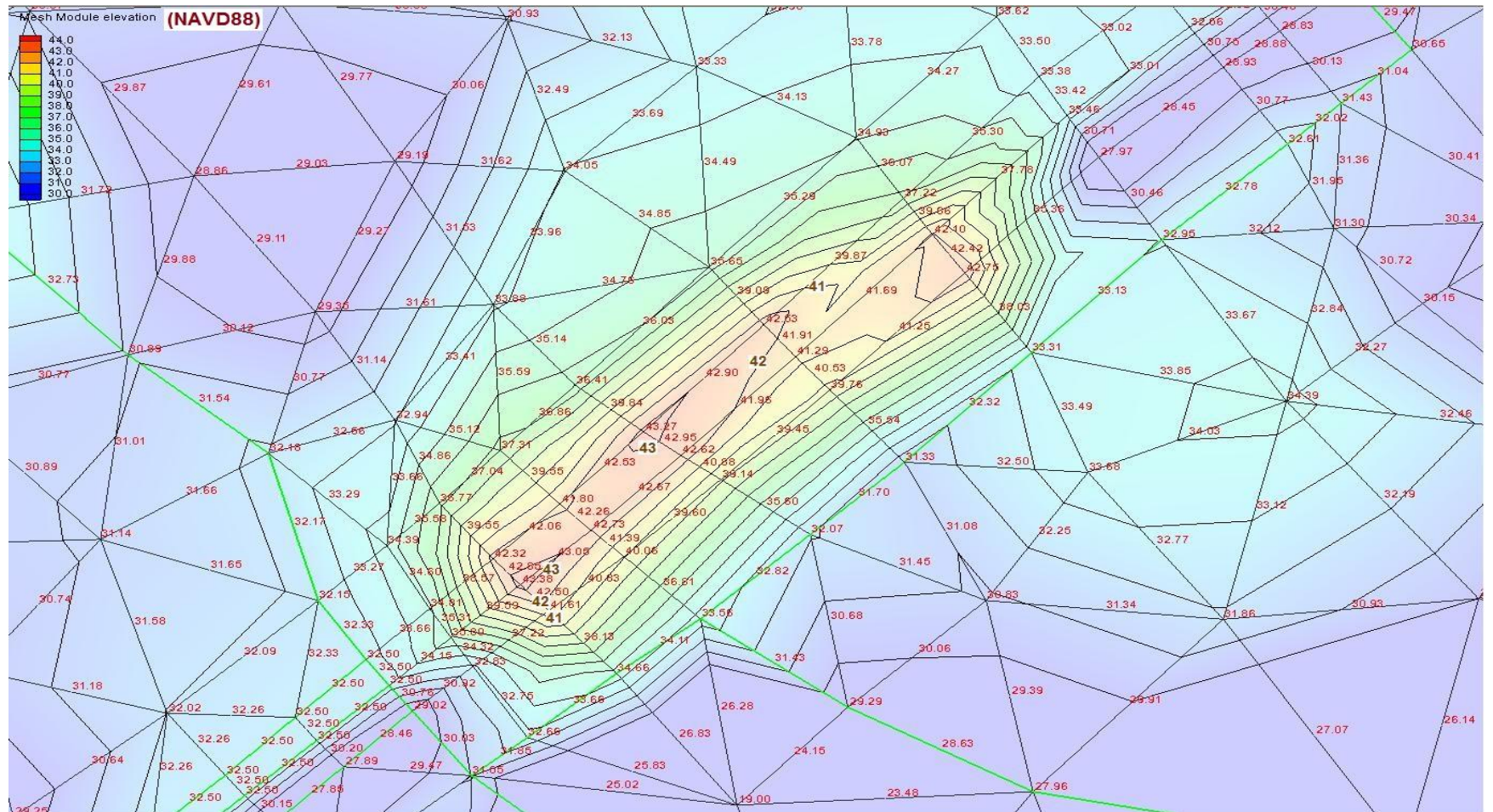
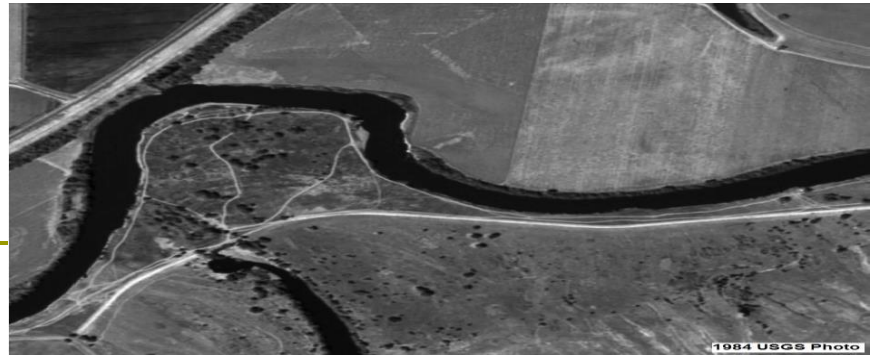


Sutter Bypass

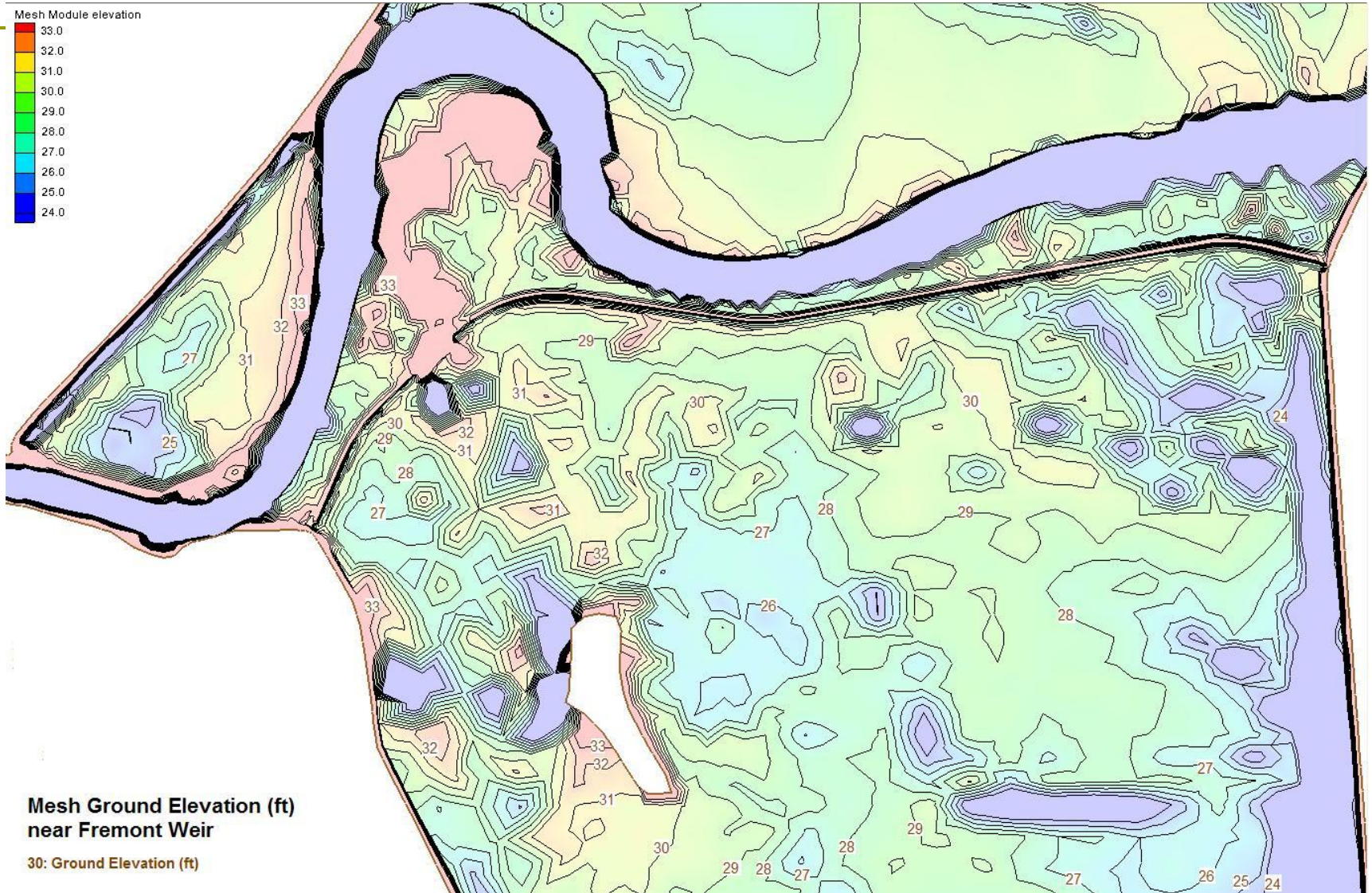
Feather River

Mesh Ground Elevation (ft) (NAVD88)
downstream of Sutter Bypass



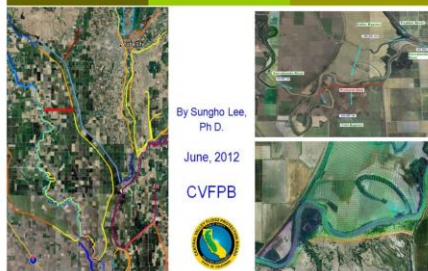


Fremont Weir & Yolo Bypass



Q & A: Sungho.Lee@water.ca.gov

Sutter Bypass 2-D H. Modeling



Sutter Bypass Two-Dimensional (2D) Hydraulic Model

Flood Modeling Session
(CWEMF 2015 Annual Meeting)

Presented by : Dr. Kyle Winslow (CH2M HILL)
& Dr. Sungho Lee (DWR/ CVFPB)

March 9, 2015

California Water and Environmental Modeling Forum SR SUPP 1

Flow Distribution of Confluence (Sacramento River, Sutter & Yolo Bypass and Fremont Weir)

April, 2016

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Sediment Transport Modeling

June, 2012

Sungho Lee, Ph.D.

Fully Coupled 1-D Mobile Bed River Sediment Transport Model (Unsteady Flow and Non-equilibrium Sediment Transport with Looped Network System)

April, 2016

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Vegetation Issues & Roughness Coefficient

December, 2009

CVFPB
Sungho Lee, Ph.D.

Fish Ladder/Passage (Fishway)

Dec., 2010

CVFPB
Sungho Lee, Ph.D.

Development of Integrated Water Quality Management System of Watershed -GIS and Water Quality Model-

Sept, 2009.

Sung Ho LEE, Ph.D

