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TECHNICAL MEMORANDUM

To: Wilton Fryer, Turlock Irrigation District

From: Jennifer Vick

Date: June 28, 2006

RE: SRP 10 Existing Conditions Habitat Modeling Results

INTRODUCTION

In response to habitat conditions observed at the SRP 9 project, the River 2D model was used to evaluate fish habitat for draft SRP 10 restoration project designs. The model was applied to three design iterations. Results from the first model iteration and recommended revisions to the project design were reported in a technical memorandum dated August 16, 2005. Based on model results, HDR, Inc. revised the project design to: (1) shift the north bank of the upstream meander to the north to reduce flow separation from the bank during high flows, and (2) lower the exit elevations of high flow scour channels to provide juvenile Chinook salmon rearing habitat during low winter baseflows (Figure 1). The model was applied to two alternative versions of this revised design – one that did not include pools constructed in the mainstem channel, and one that included pools ranging in depth from 4 ft to 6 ft at each meander apex. Model results for the revised design iterations (with and without pools) were provided in a technical memorandum dated February 10, 2006. To provide a basis for comparing post-restoration habitat conditions at SRP 10, the model was also applied to existing SRP 10 conditions. The existing condition model results are reported herein.

Domenichelli & Associates applied the River 2D model to assess habitat suitability for adult largemouth bass, adult smallmouth bass, Chinook salmon fry, and Chinook salmon juvenile habitat for seven flows ranging from 75 cfs to 5,000 cfs. Model application procedures and habitat suitability criteria were reported in the August 16, 2005 technical memorandum. Suitability criteria are also shown in Tables 1 and 2.

Table 1. Suitability criteria used for largemouth and smallmouth bass habitat modeling.

Criterion		Largemouth Bass	Smallmouth Bass
Velocity (ft/s)	(usable)	0-0.7	0-0.7
	(preferred)	0-0.2	0-0.3
Depth (ft)	(usable)	1.6-19.7	1.6-9.8
	(preferred)	3.3-19.7	3.3-9.8

Sources: Stuber et al. 1982, Edwards et al. 1983

Table 2. Suitability criteria used for fry and juvenile Chinook salmon habitat modeling.

	"Standard"		"Conservative[1]"	
Criterion	**Fry**	**Juvenile**	**Fry**	**Juvenile**
Velocity (ft/s)	0.0–1.2	0.1–2.2	0.0–0.6	0.0–1.0
Depth (ft)	0.2–2.0	0.5–6.5	0.2–2.0	0.5–6.5

Source: USFWS 1995
[1]The existing conditions model was applied using only the "conservative" criteria.

MODEL RESULTS

Largemouth Bass

Predicted habitat area for largemouth bass for existing conditions and the revised restoration design is shown in Table 3 and Figures 2 through 5. Habitat suitability maps are provided in Attachment A.

Table 3. Predicted total and weighted usable habitat area for largemouth bass for SRP 10 existing conditions and revised design iterations.

Flow (cfs)	Predicted Habitat Area (ft^2)					
	Existing Condition		Revised Design w/o Pools[1]		Revised Design with Pools[1]	
	Total	WUA	Total	WUA	Total	WUA
75	349,842	320,562	22	6	55,861	26,870
150	343,425	265,657	1,115	284	41,708	18,906
300	326,068	207,090	727	193	15,701	5,831
1,000	176,288	105,514	282	76	8,659	3,155
2,000	116,140	70,160	433	108	6,190	2,225
3,000	96,502	60,228	3,130	884	9,334	3,301
5,000	85,716	51,798	18,840	6,245	22,637	7,692

[1]Reported in February 10, 2006 Technical Memorandum

Model results for largemouth bass are as follows:

- For minimum spring flows required by the 1995 FERC Settlement Agreement (75–300 cfs), existing conditions at SRP 10 provide 326,000–350,000 ft^2 total area and 207,000–321,000 ft^2 weighted usable area of suitable largemouth bass habitat (Table 3, Figure 2). Suitable habitat occurs along the left side of the SRP 10 pit and throughout the channel from the downstream end of SRP 10 to the downstream project boundary (Attachment A). Small patches of suitable habitat also occur in the channel upstream of SRP 10 (but within the project boundary) (Attachment A).
- At higher flows (1,000–5,000 cfs), existing conditions at SRP 10 provide 86,000–176,000 ft^2 total area and 52,000–106,000 ft^2 weighted usable area of suitable largemouth bass habitat (Table 3, Figure 2). Suitable habitat area decreases with increasing flow, occurring in increasingly narrow bands along the channel banks within SRP 10 and in the downstream channel and on the inundated left-bank floodplain upstream of SRP 10 (Attachment A). By 5,000 cfs, most suitable habitat occurs on the left-bank floodplain upstream of SRP 10 (Attachment A).
- For minimum spring flows, the revised restoration design without pools reduces largemouth bass total suitable habitat area by >99% and weighted usable area of by 92% at 75 cfs, 77% at 150 cfs, and 63% at 300 cfs (Figure 2). During higher flows, when suitable bass habitat becomes available on the constructed floodplain, the restoration design reduced largemouth bass habitat by 78%– >99% for total area and 53%–60% for weighted usable area (Figure 2).

- For minimum spring flows, the revised restoration design with pools reduces largemouth bass total suitable habitat area by 84%–95% and weighted usable area of by 62%–84% (Figure 2). During higher flows that inundate the constructed floodplain, the design reduces largemouth bass habitat by 74%–95% for total area and 51%–58% for weighted usable area (Figure 2).
- Largemouth bass habitat density (ft^2 suitable habitat / ft channel length) at SRP 10 under existing conditions is 2–4 times greater than at the Riffle 64 control site and 4–9 times greater than at the Charles Road control site for the full range of flows modeled (Figure 3). Habitat density at SRP 10 for existing conditions also exceeds SRP 9 post-restoration for flows < 2,000 cfs (Figure 3). During higher flows sufficient to inundate the SRP 9 floodplain (i.e., ≥ 2,000 cfs), habitat density at SRP 9 post-restoration exceeds SRP 10 for existing conditions (Figure 3).

Smallmouth Bass

Predicted habitat area for smallmouth bass for existing conditions and the revised restoration design is shown in Table 4 and Figures 2 through 5. Habitat suitability maps are provided in Attachment A.

Table 4. Predicted total and weighted usable habitat area for smallmouth bass for SRP 10 existing conditions and revised design iterations.

Flow (cfs)	Predicted Habitat Area (ft^2)					
	Existing Condition		Revised Design w/o Pools[1]		Revised Design with Pools[1]	
	Total	WUA	Total	WUA	Total	WUA
75	195,827	170,915	22	6	55,860	34,334
150	187,821	160,167	1,113	305	41,708	20,782
300	168,528	125,913	727	208	15,702	6,852
1,000	99,515	69,270	283	87	3,414	1,404
2,000	81,119	56,539	433	108	6,169	2,551
3,000	72,187	51,371	3,130	943	9,249	3,891
5,000	58,190	40,372	18,837	6,658	22,142	8,207

[1]Reported in February 10, 2006 Technical Memorandum

Model results for smallmouth bass are as follows:

- For minimum spring flows (75–300 cfs), existing conditions at SRP 10 provide 169,000–199,000 ft^2 total area and 125,000–170,000 ft^2 weighted usable area of suitable smallmouth bass habitat (Table 4, Figure 4). Highly suitable habitat occurs throughout most of the channel from the downstream end of SRP 10 to the downstream project boundary and in a narrow band along the left bank within SRP 10 (Attachment A).
- At higher flows (1,000–5,000 cfs), existing conditions at SRP 10 provide 58,000–100,000 ft^2 total area and 40,000–69,000 ft^2 weighted usable area of suitable smallmouth bass habitat (Table 4, Figure 4). Suitable habitat area decreases with increasing flow, occurring in small patches along the left channel bank within SRP 10, along both banks in the downstream channel, and in small patches within the inundated left-bank floodplain upstream of SRP 10 (Attachment A). By 5,000 cfs, most suitable habitat occurs on the left-bank floodplain upstream of SRP 10 (Attachment A).
- For minimum spring flows, the revised restoration design without pools reduces smallmouth bass total suitable habitat area by ≥99% and weighted usable area of by 87% at 75 cfs, 85% at 150 cfs, and 75% at 300 cfs (Figure 4). During higher flows, when suitable smallmouth

bass habitat becomes available on the constructed floodplain, the restoration design reduces habitat by 68%– >99% for total area and 62%–97% for weighted usable area (Figure 4).

- For minimum spring flows, the revised restoration design with pools reduces smallmouth bass total suitable habitat area by 71%–91% and weighted usable area of by 70%–74% (Figure 4). During higher flows that inundate the constructed floodplain, the design reduces largemouth bass habitat by 62%–97% for total area and 55%–68% for weighted usable area (Figure 4).
- Smallmouth bass habitat density at SRP 10 for existing conditions is 1.4–3 times greater than at the Riffle 64 control site and 2–6 times greater than at the Charles Road control site for the full range of flows modeled (Figure 5). The difference in habitat density between SRP 10 and the control sites decreases with increasing flows. For flows ≤ 1,000 cfs, habitat density at SRP 10 is slightly greater than at SRP 9 post-restoration (Figure 5). For flows > 1,000 cfs, suitable habitat becomes available on the SRP 9 floodplain, and habitat density at SRP 9 greatly exceeds SRP 10 (Figure 5).

Chinook Salmon

Predicted habitat area for Chinook salmon fry and juveniles for the revised design and existing conditions is shown in Table 5 and Figures 6 and 7. Habitat suitability maps are provided in Attachment A.

Table 5. Predicted total habitat area of fry and juvenile Chinook salmon for SRP 10 design iterations.

Flow (cfs)	Predicted Habitat Area (ft2)					
	FRY			JUVENILE		
	Existing Condition	Revised Design w/o Pools	Revised Design with Pools	Existing Condition	Revised Design w/o Pools	Revised Design with Pools
75	61,267	26,433	29,305	163,905	101,682	87,030
150	57,162	20,072	27,753	151,604	30,411	78,428
300	50,006	16,620	26,081	139,224	20,158	52,399
1,000	47,154	17,176	26,958	115,887	19,041	37,066
2,000	36,380	52,349	52,226	95,371	46,095	51,288
3,000	29,939	225,677	289,382	77,943	371,475	389,356
5,000	24,115	447,764	456,782	64,329	254,393	264,264

Model results for Chinook salmon are as follows:

- For minimum spring flows (75–300 cfs), existing conditions at SRP 10 provide 50,000–61,000 ft^2 of suitable Chinook salmon fry rearing habitat (Table 5, Figure 6) and 139,000–164,000 ft^2 of suitable Chinook salmon juvenile rearing habitat (Table 5, Figure 7). Suitable fry habitat occurs in patches along the channel margins upstream and downstream of SRP 10 (but within the project boundaries); no fry habitat occurs within SRP 10 (Attachment A). Suitable juvenile habitat occurs along the left bank within SRP 10 and in large patches in the channel reaches upstream and downstream of SRP 10 (but within the project boundaries) (Attachment A).
- At higher flows (1,000–5,000 cfs), existing conditions at SRP 10 provide 24,000–47,000 ft^2 of suitable Chinook salmon fry rearing habitat (Table 5, Figure 6) and 64,000–116,000 ft^2 of suitable Chinook salmon juvenile rearing habitat (Table 5, Figure 7). Fry and juvenile habitat area decreases with increasing flow. Fry and juvenile habitat occurs in small patches on inundated floodplains upstream and downstream of SRP 10 (but within the project

boundaries) (Attachment A). During flows ≥ 1,000 cfs, all fry habitat and almost all juvenile habitat occurs in the channel reaches upstream of the SRP 10 pit.

- During flows that inundate high flow scour channels and floodplain surfaces, the restoration project substantially increases Chinook salmon fry and juvenile rearing habitat area. At flows of 2,000 cfs–5,000 cfs, the restoration design increases fry habitat area by 44% to 18 times (Table 5, Figure 6). At flows of 3,000 cfs–5,000 cfs, the proposed design increases juvenile habitat area by 3–4 times (Table 5, Figure 7).
- Compared to existing conditions, the proposed restoration design would reduce Chinook salmon fry rearing habitat area during flows < 1,500 cfs (Table 5, Figure 6) and juvenile habitat during flows < 2,000 (Table 4, Figure 6). This loss of habitat results from: (1) loss of habitat in channel reaches upstream and downstream of SRP 10 (but within the project boundary), (2) reduction in total channel length within the project reach, and (3) lower habitat density within the restored channel compared to existing conditions. The channel reaches upstream and downstream of SRP 10 were incorporated into the restoration design and the total channel length was shortened by 1,325 ft (40%) to achieve the channel gradient design criterion (for reducing bass habitat). The target channel gradient was defined as 0.0007 based on habitat surveys at the Charles Road and Riffle 64 reference sites (McBain & Trush 2004).

CONCLUSIONS

- Existing conditions at SRP 10 provide substantial habitat for largemouth and smallmouth bass, particularly during flows typical during the spring Chinook salmon rearing and outmigration season (i.e., flow < 2,000 cfs). The proposed project design would substantially reduce bass habitat area at the site for all flows modeled. Predicted habitat area and density for the SRP 10 restoration design (both with and without pools) is similar to (but somewhat less than) predicted habitat at the Charles Road and Riffle 64 reference sites and is substantially less than predicted habitat for the SRP 10 existing condition and SRP 9 post-restoration.

- The primary objective of the project is to reduce bass predation on outmigrant juvenile salmon. By reducing bass habitat during typical spring rearing and outmigration flows, the project theoretically should reduce interactions between bass and juvenile salmon, and thus reduce bass predation on salmon. The project, therefore, is expected to benefit salmon outmigration conditions relative to existing conditions, despite the reduced rearing habitat area. All attempts, however, should be made to provide suitable rearing and outmigration conditions in the project reach.

- Much of the reduction in bass habitat area was achieved by increasing channel gradient through the restoration reach, which also required reducing channel length. By incorporating relatively intact channel reaches upstream and downstream of the SRP 10 pit into the project, the design eliminates Chinook salmon fry and juvenile habitat currently available in these channel reaches, resulting in a net reduction in rearing habitat area during flows less than approximately 2,000 cfs. Rearing habitat provided by the project could be increased by incorporating relatively simple measures during project construction, such as adding large wood, scalloping banks, or other actions that provide cover and habitat complexity (see February 10, 2006 Technical Memorandum).

LITERATURE CITED

Edwards, E.A., G. Gebhart, and O.E., Maughan. 1983. Habitat Suitability Information: Smallmouth Bass. US Department of Interior, Fish and Wildlife Service. FW/OBS-82/10.36. 47pp.

McBain & Trush, Inc. 2005. Technical Memorandum, August 16, 2005 re: SRP 10 Design Recommendations. Prepared for Turlock Irrigation District, Turlock, California.

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Stuber, R.J., G. Gebhart, and O.E., Maughan. 1982. Habitat Suitability Information: Largemouth Bass. US Department of Interior, Fish and Wildlife Service. FW/OBS-82/10.16. 32pp.

USFWS (U.S. Fish and Wildlife Service). 1995. The relationship between instream flow and physical habitat availability for chinook salmon in the lower Tuolumne River, California. Prepared by US Fish and Wildlife Service Ecological Services Sacramento Field Office for Turlock Irrigation District and Modesto Irrigation District.

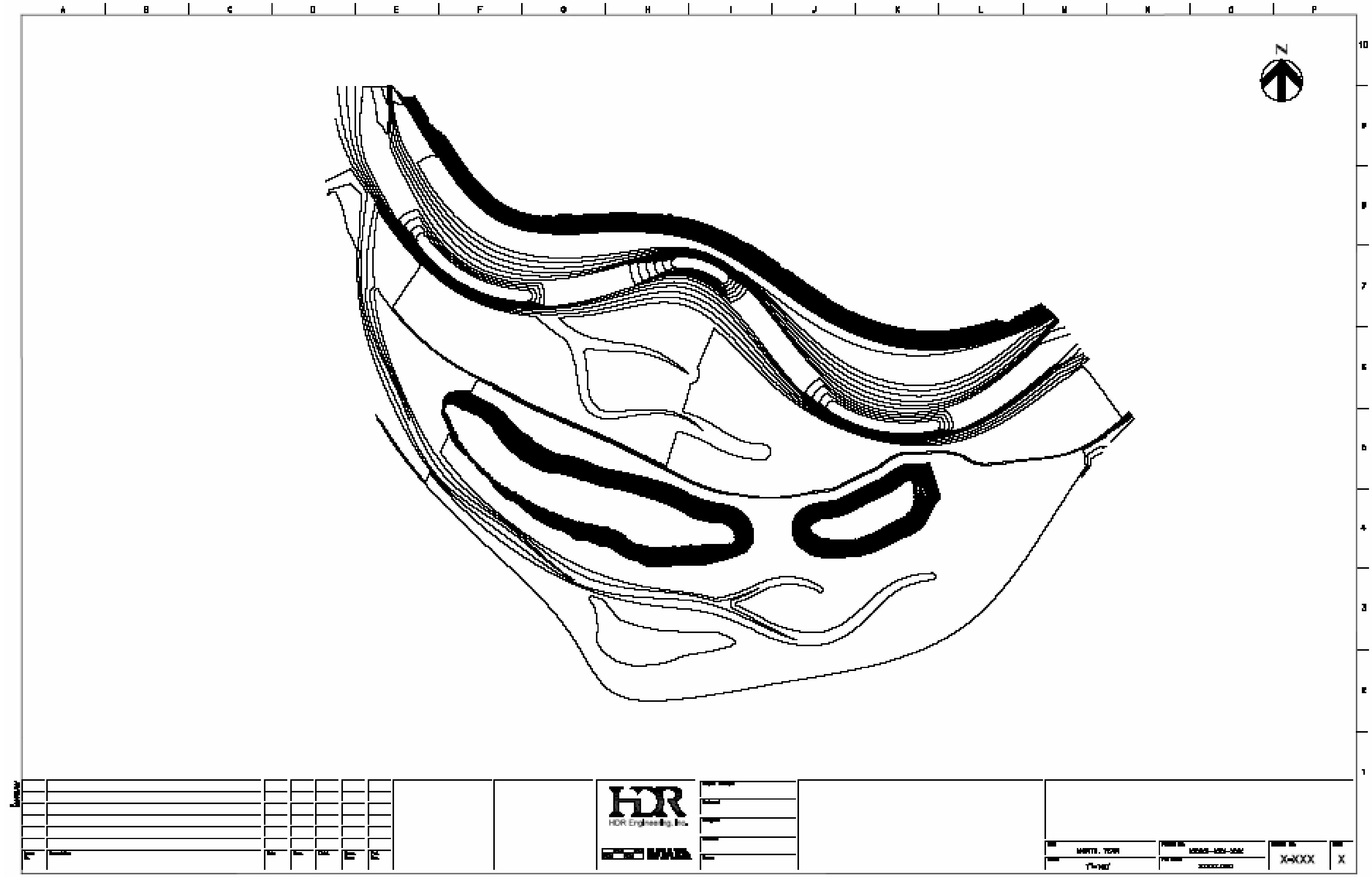
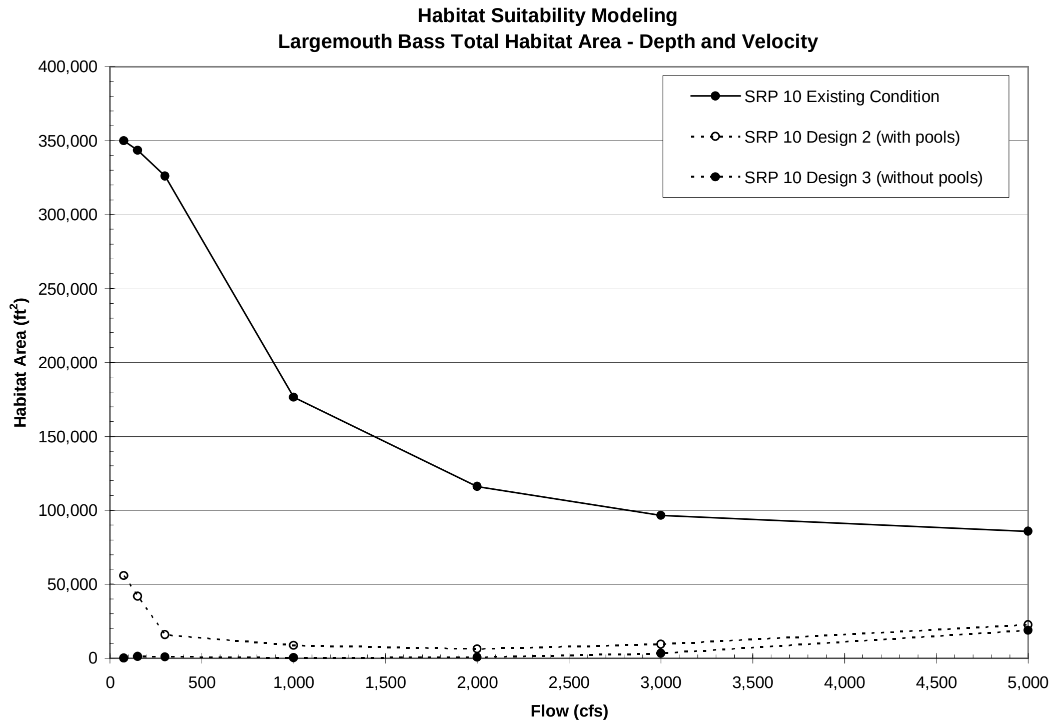


Figure 1. Revised SRP 10 design contours.



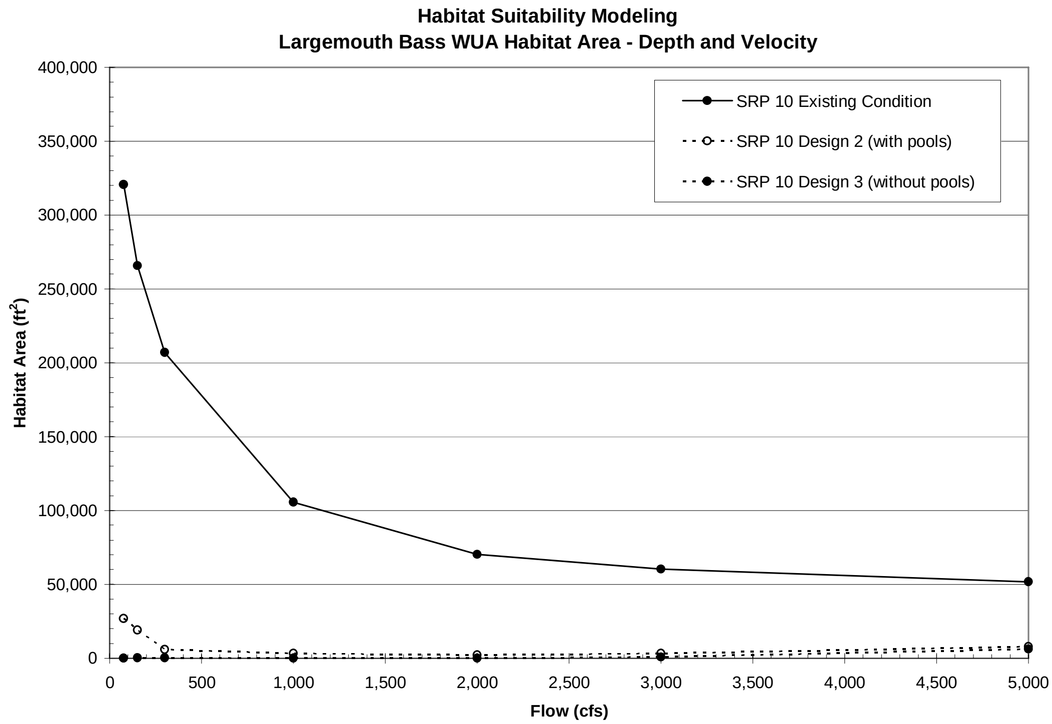
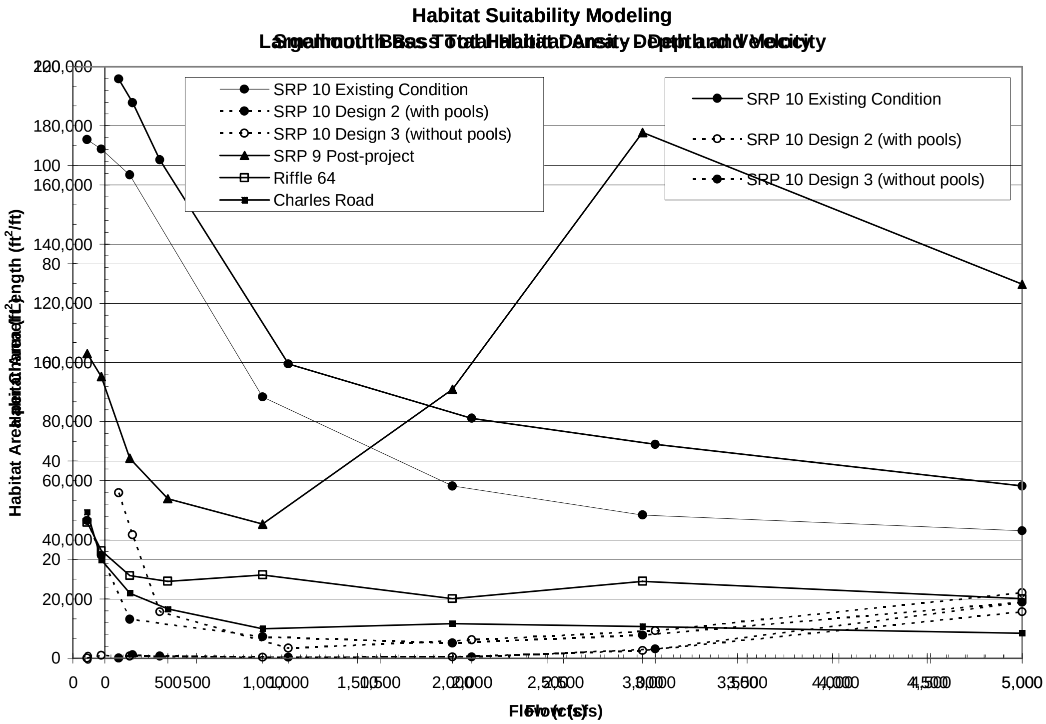


Figure 2. Predicted largemouth bass habitat area for SRP 10 design and existing conditions.



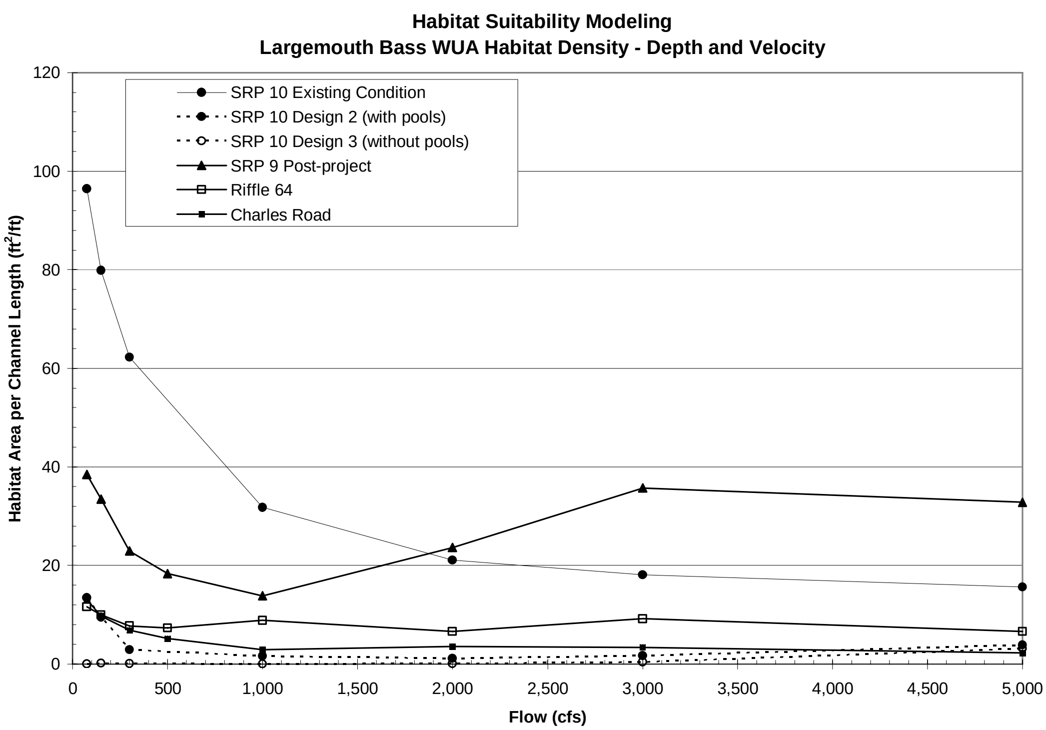


Figure 3. Predicted largemouth bass habitat area for revised SRP 10 design, SRP 10 existing condition, SRP 9 post-project, and channel reference sites.

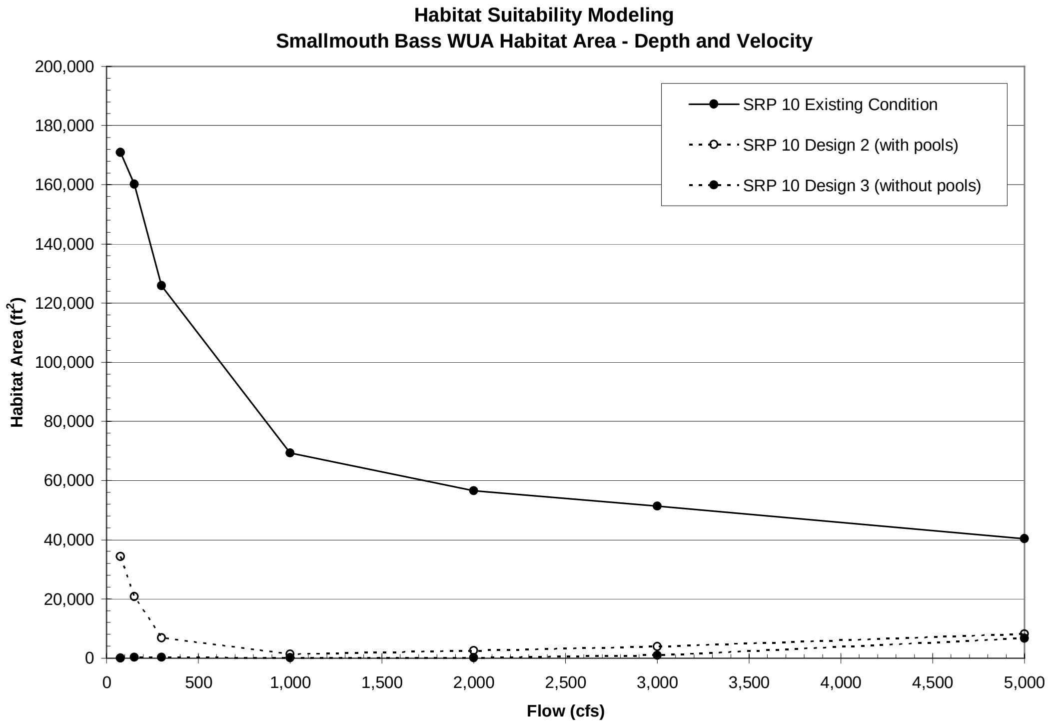
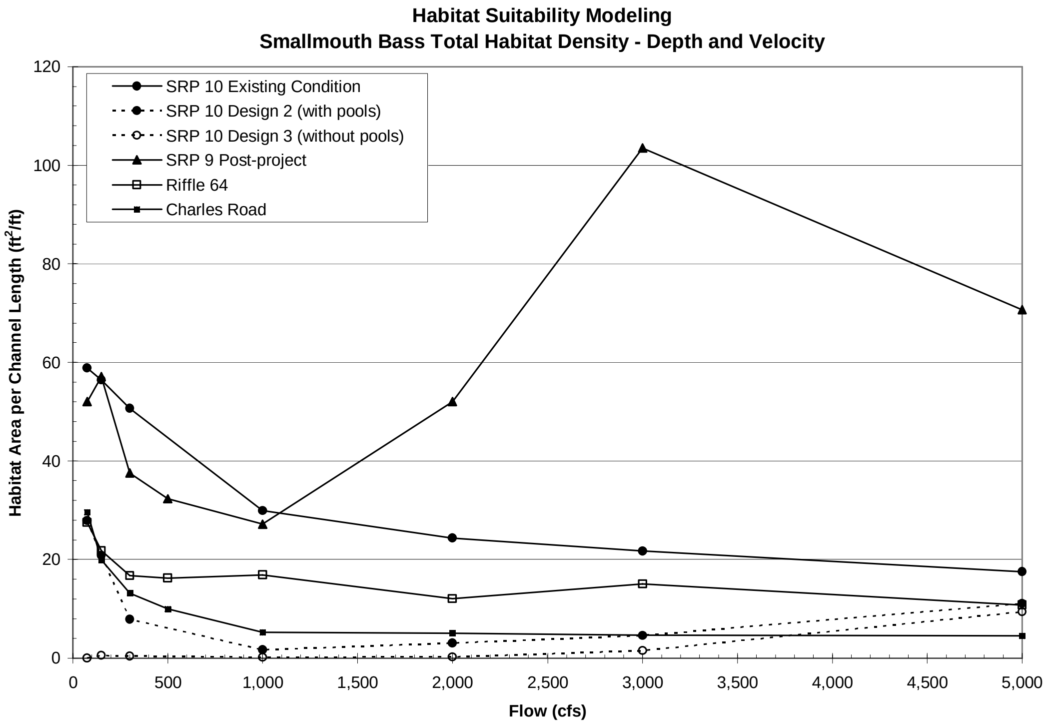


Figure 4. Predicted smallmouth bass habitat area for SRP 10 design and existing conditions.



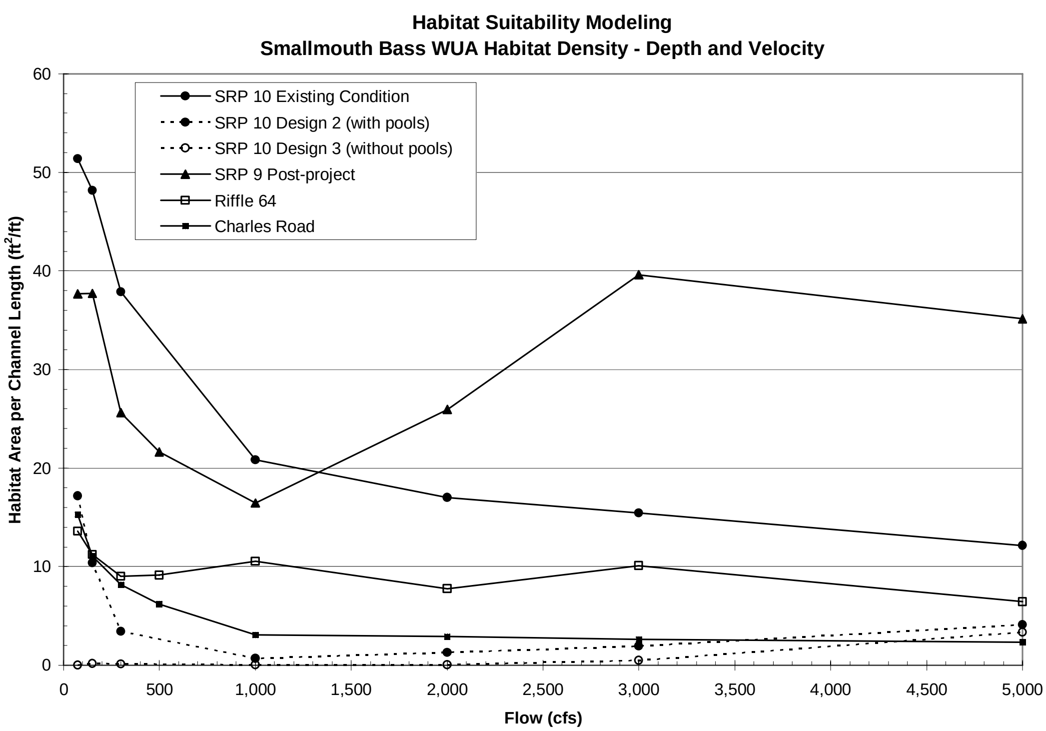
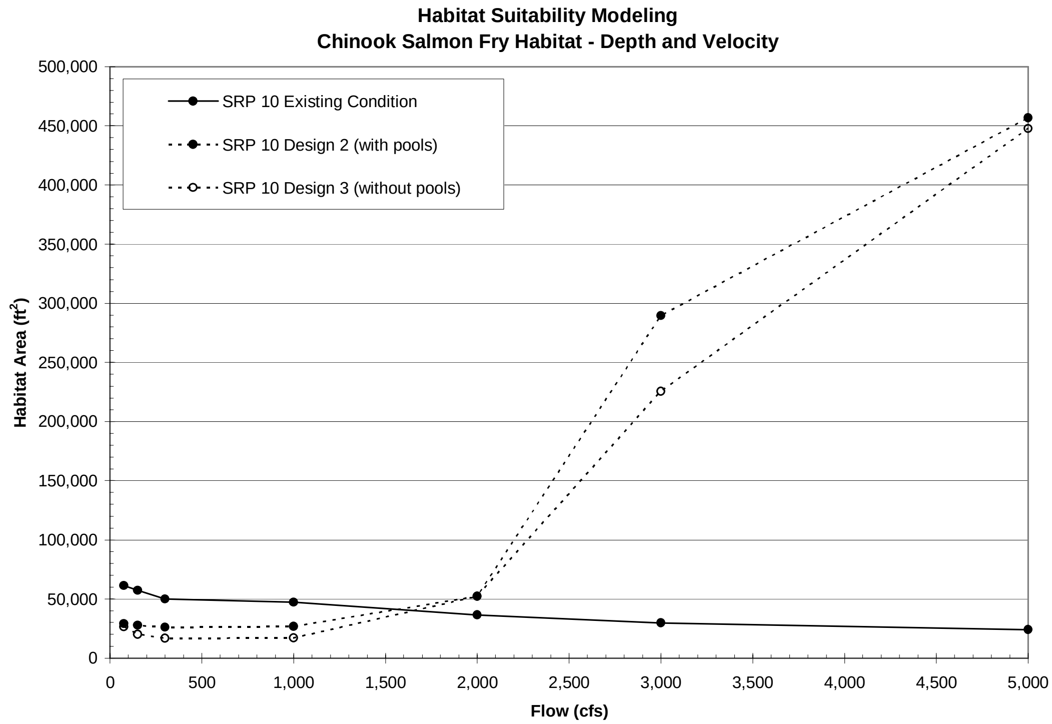


Figure 5. Predicted smallmouth bass habitat area for revised SRP 10 design, SRP 10 existing condition, SRP 9 post-project, and channel reference sites.



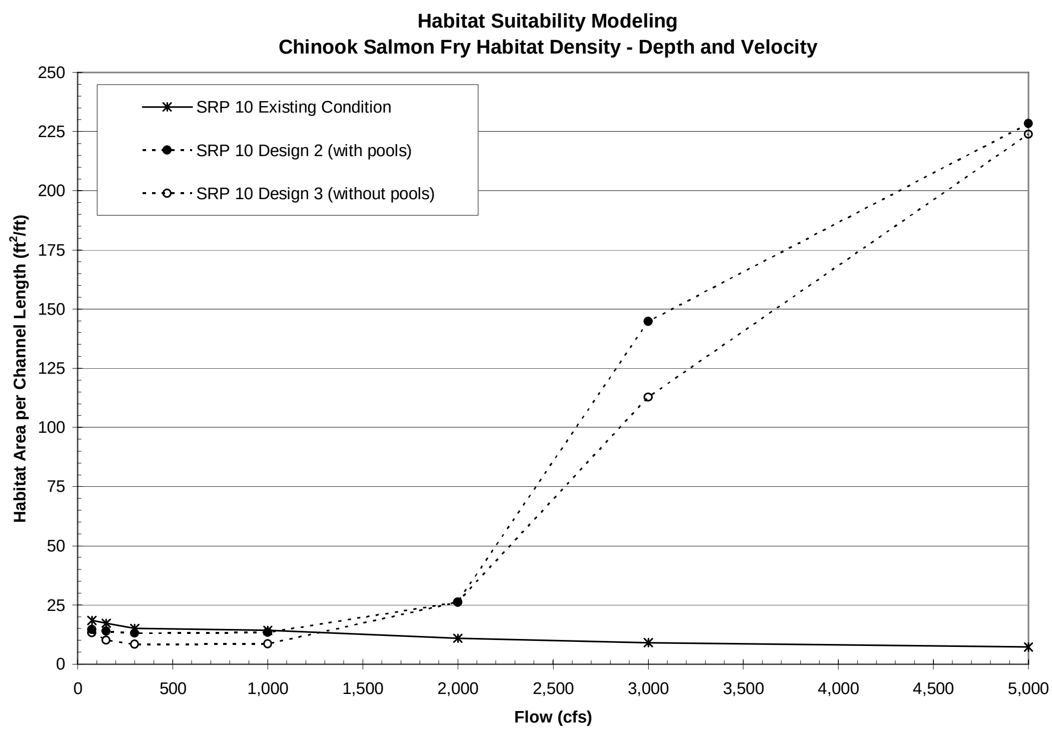
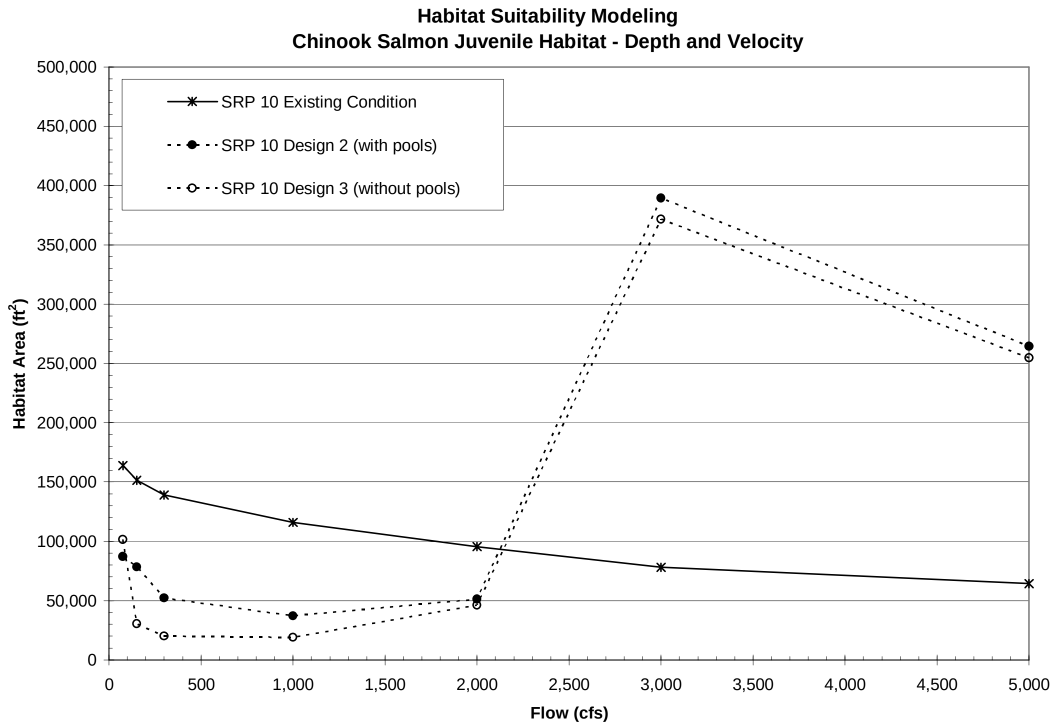


Figure 6. Predicted Chinook salmon fry habitat area for SRP 10 design and existing conditions.



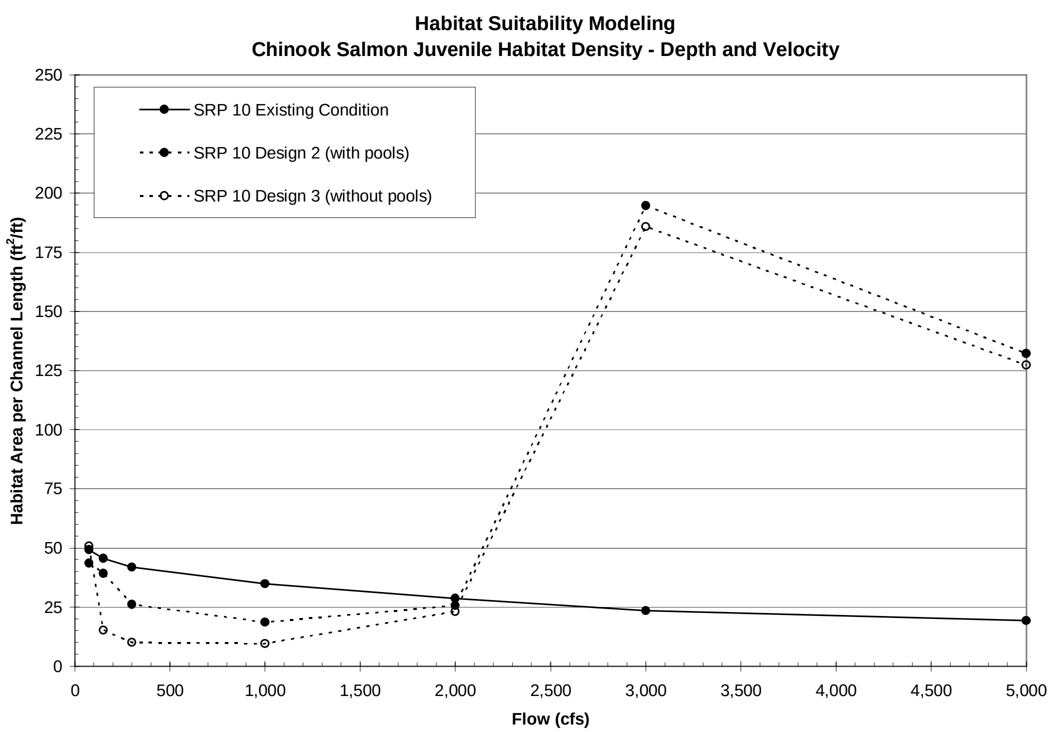


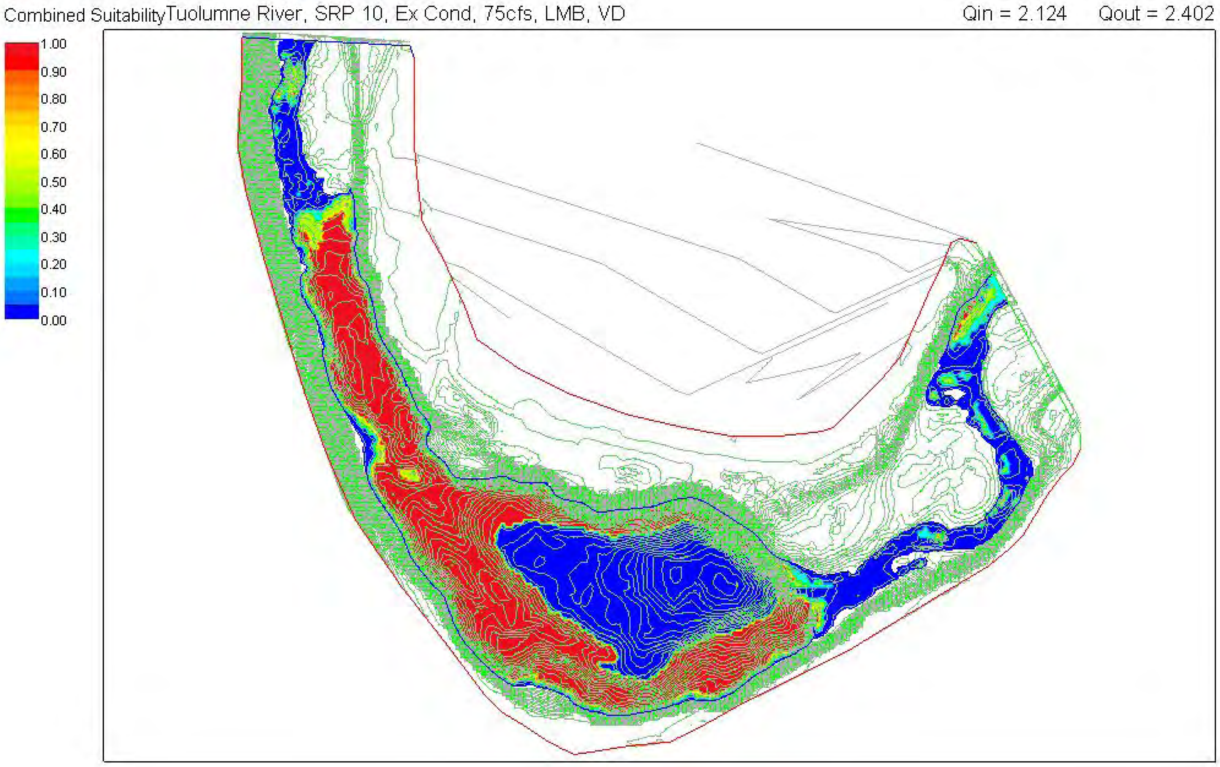
Figure 7. Predicted Chinook salmon juvenile habitat area for SRP 10 design and existing conditions.

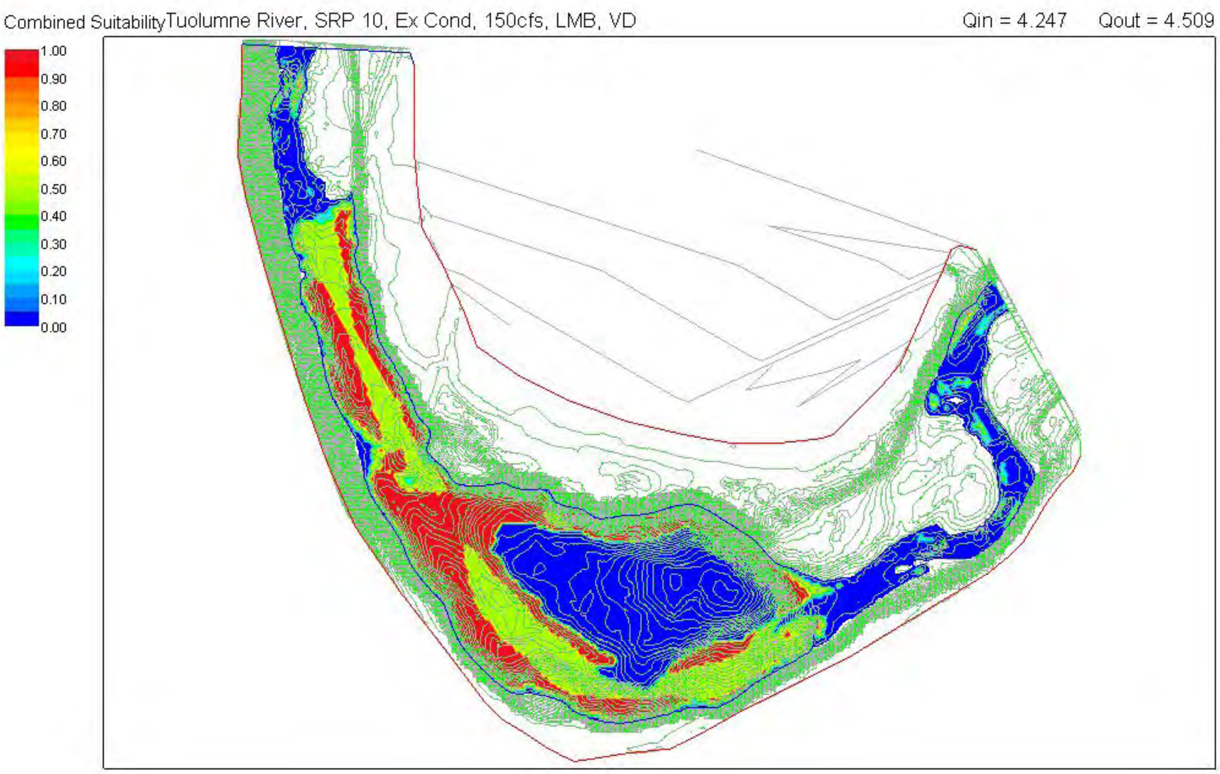
ATTACHMENT A.

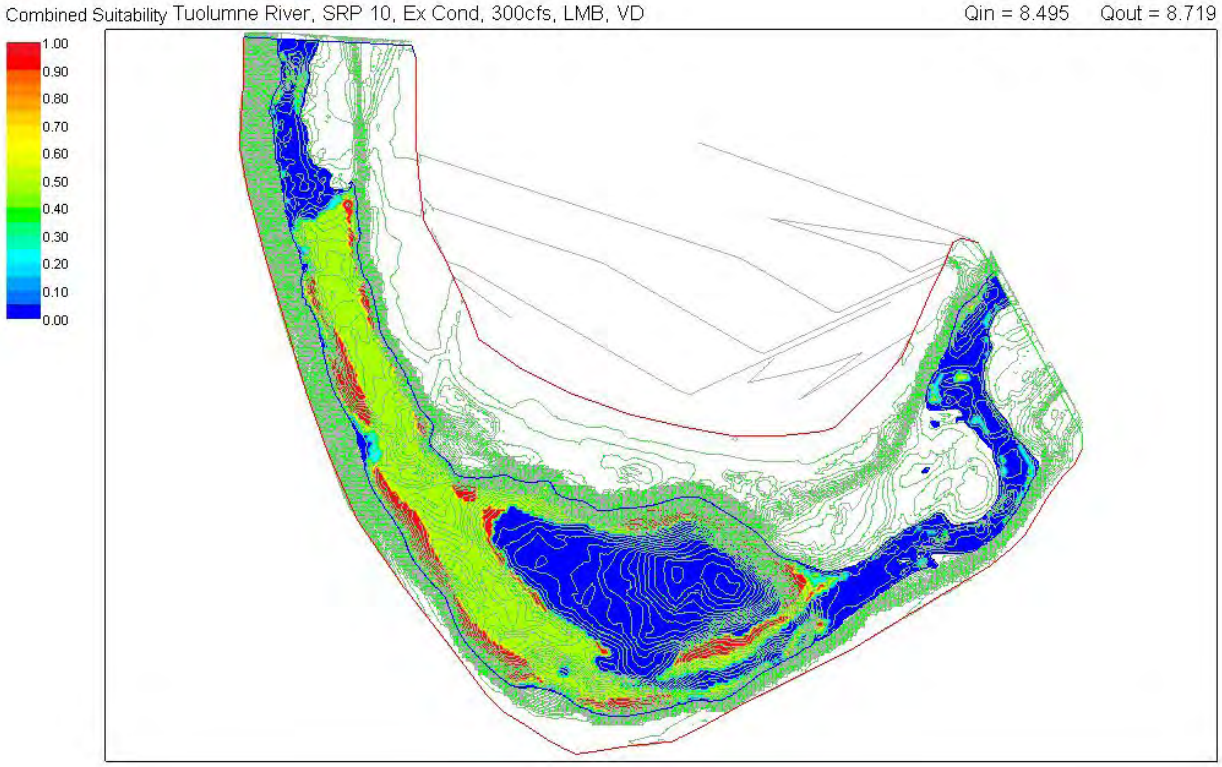
River 2D Model Results – "SRP 10 Existing Conditions"

[Note that velocity scale is meters/second.]

SPECIAL RUN POOL 10 - EXISTING CONDITIONS - LARGEMOUTH FIGURES



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0.50
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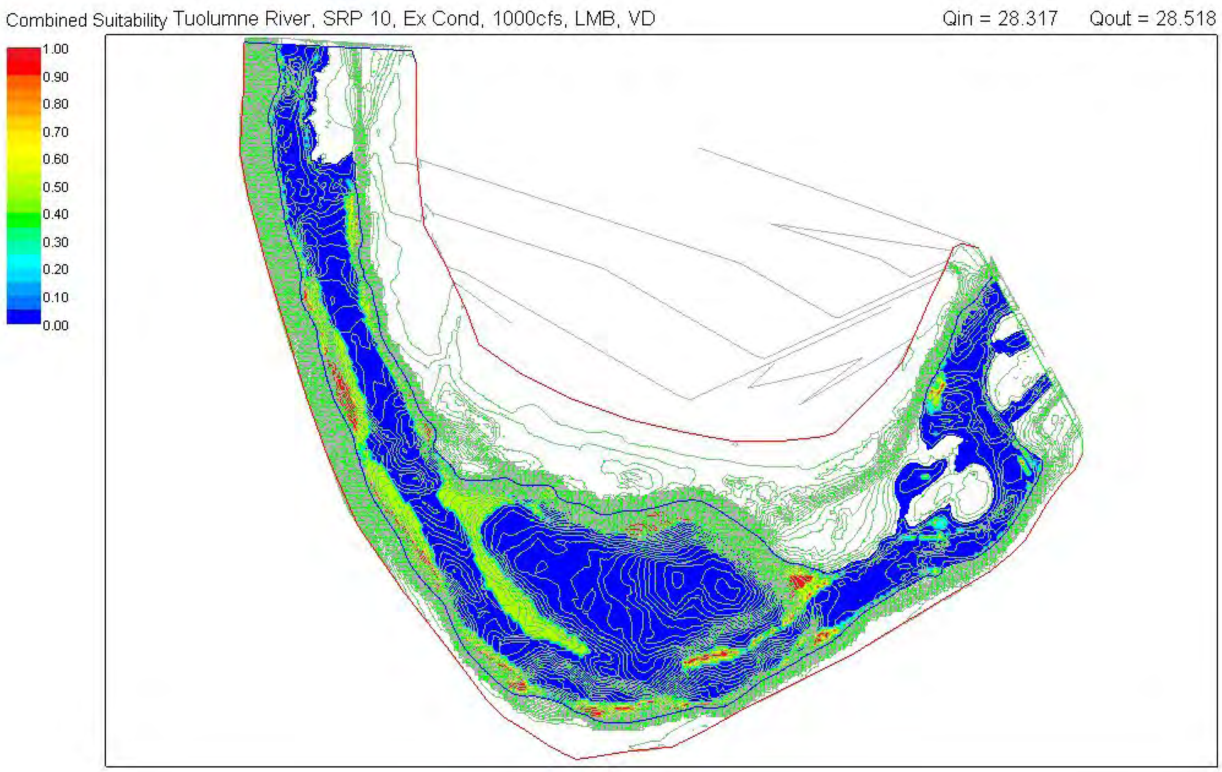
0.20
0.10
0.00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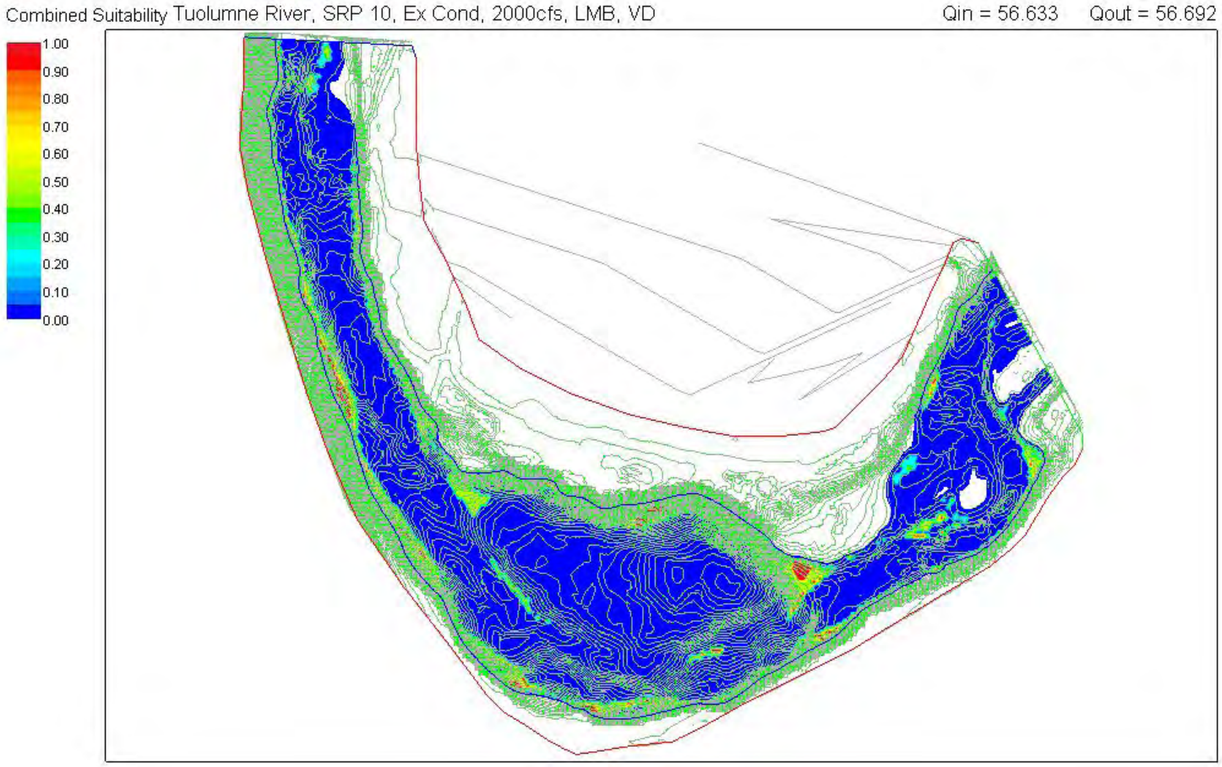
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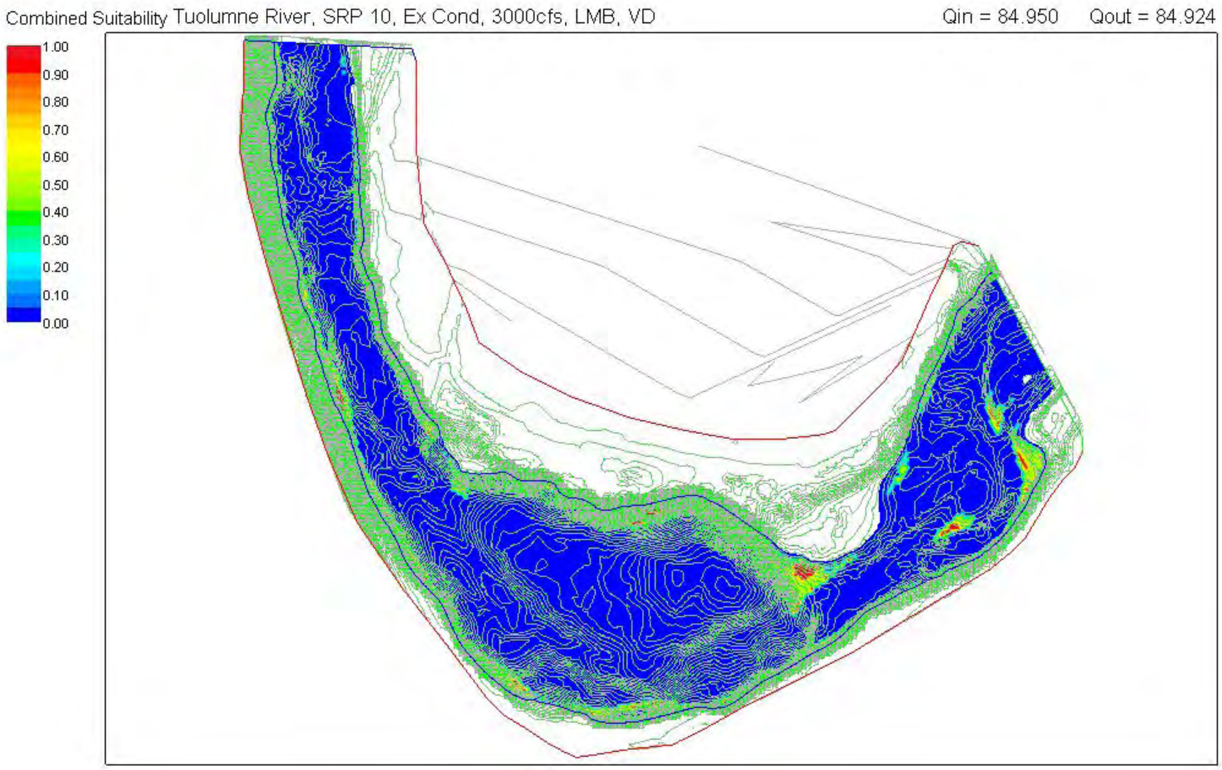
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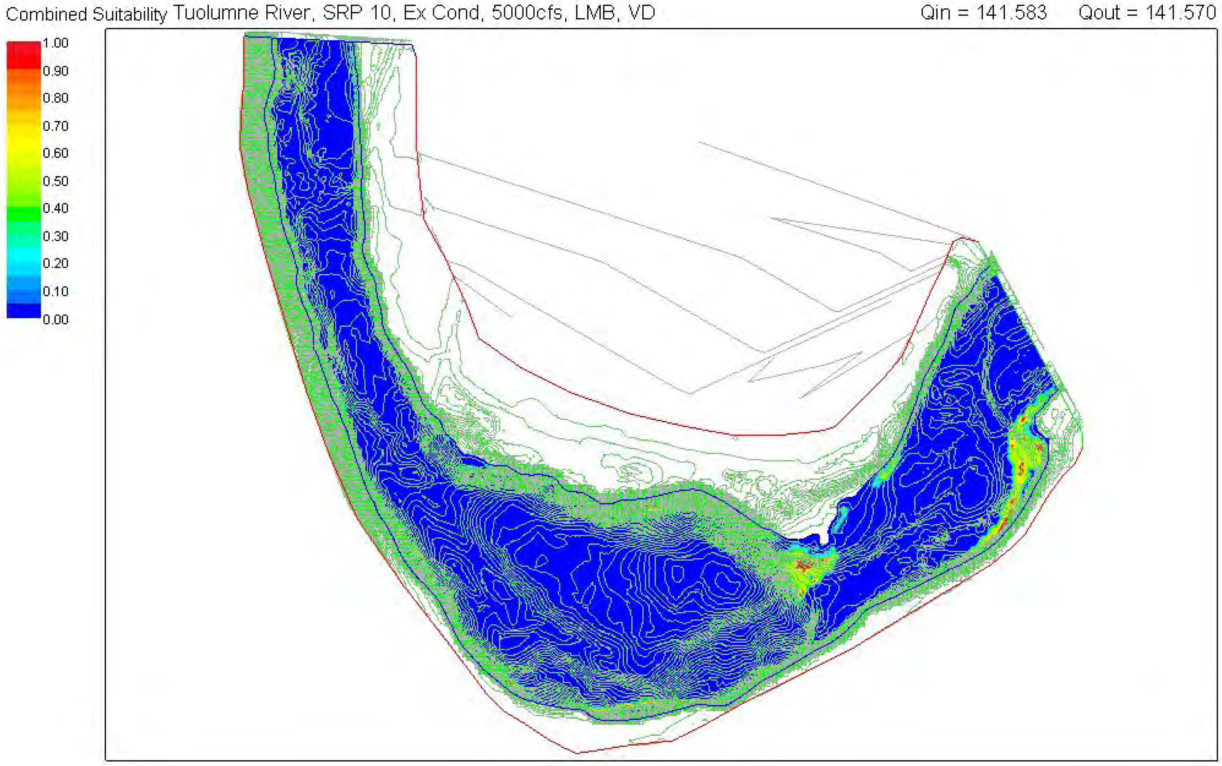
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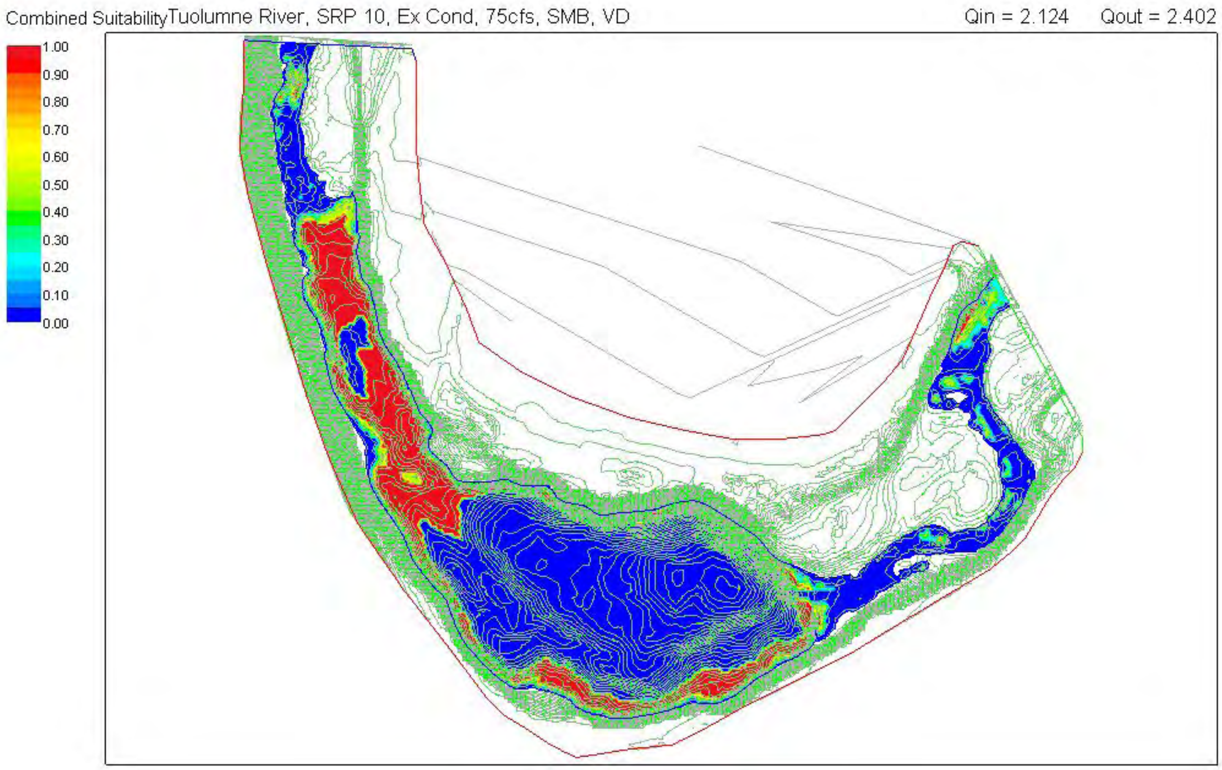
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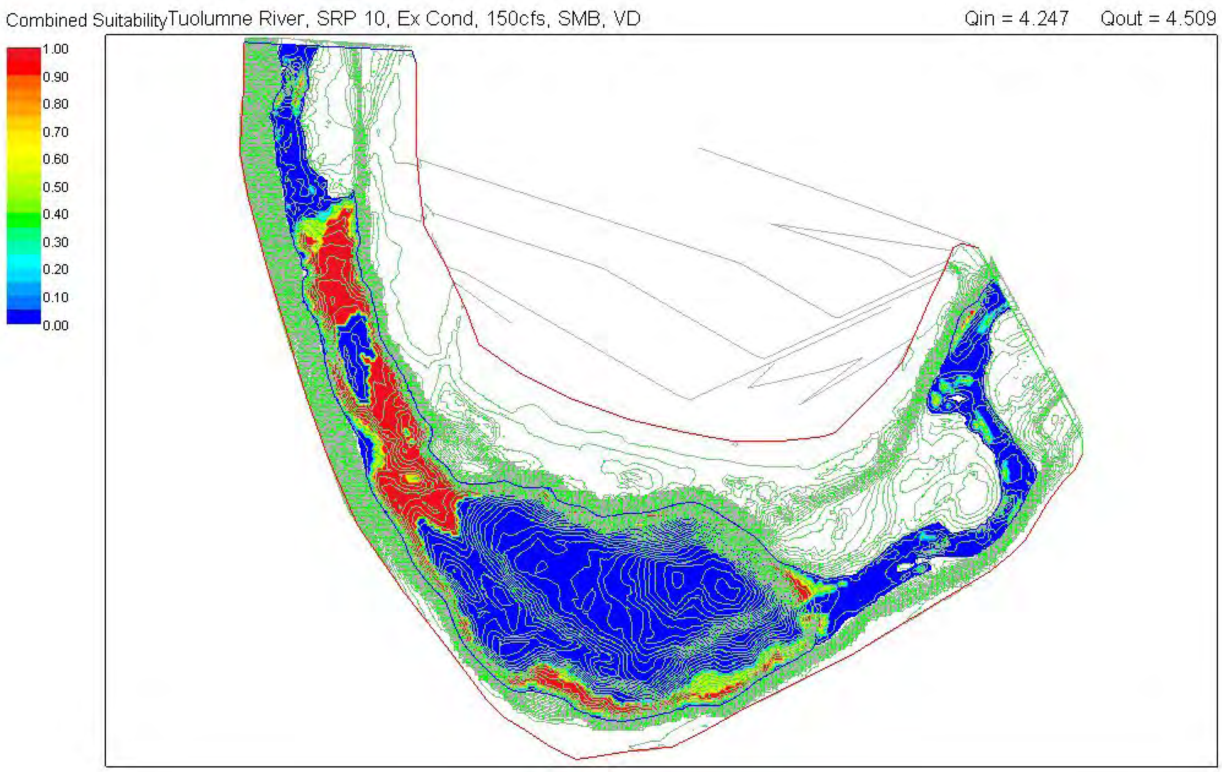
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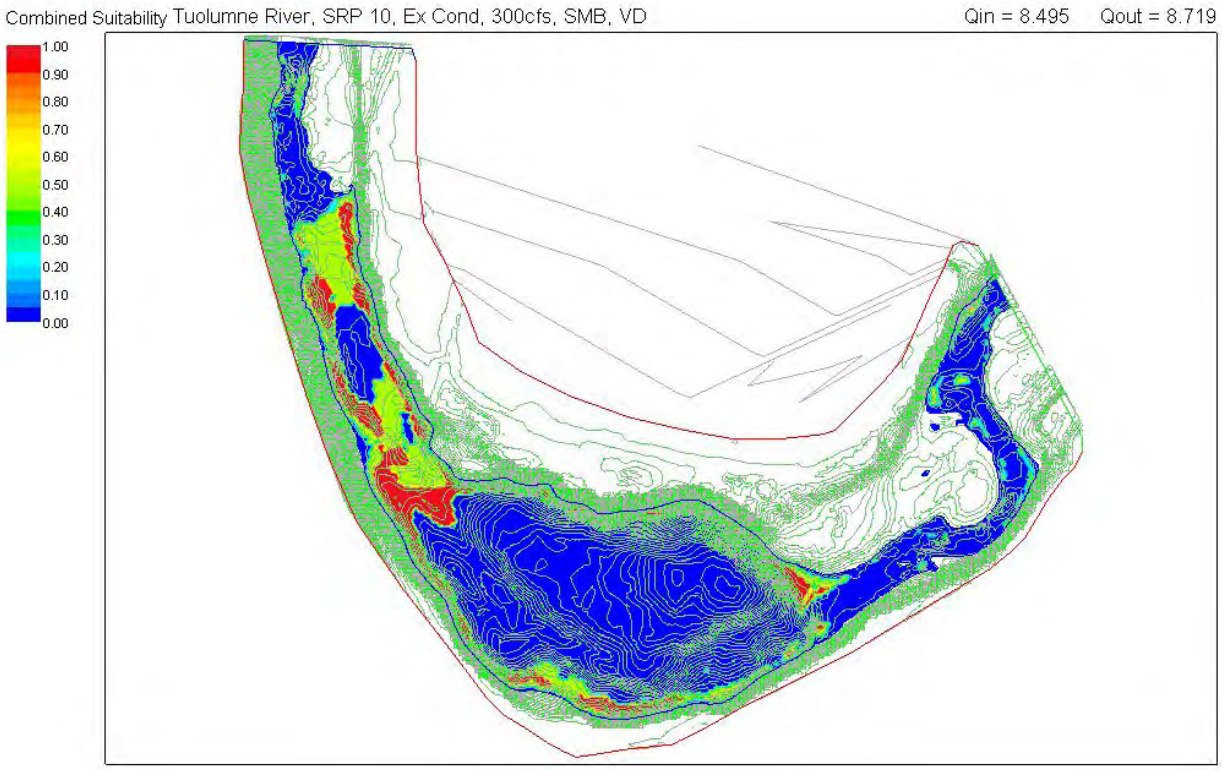
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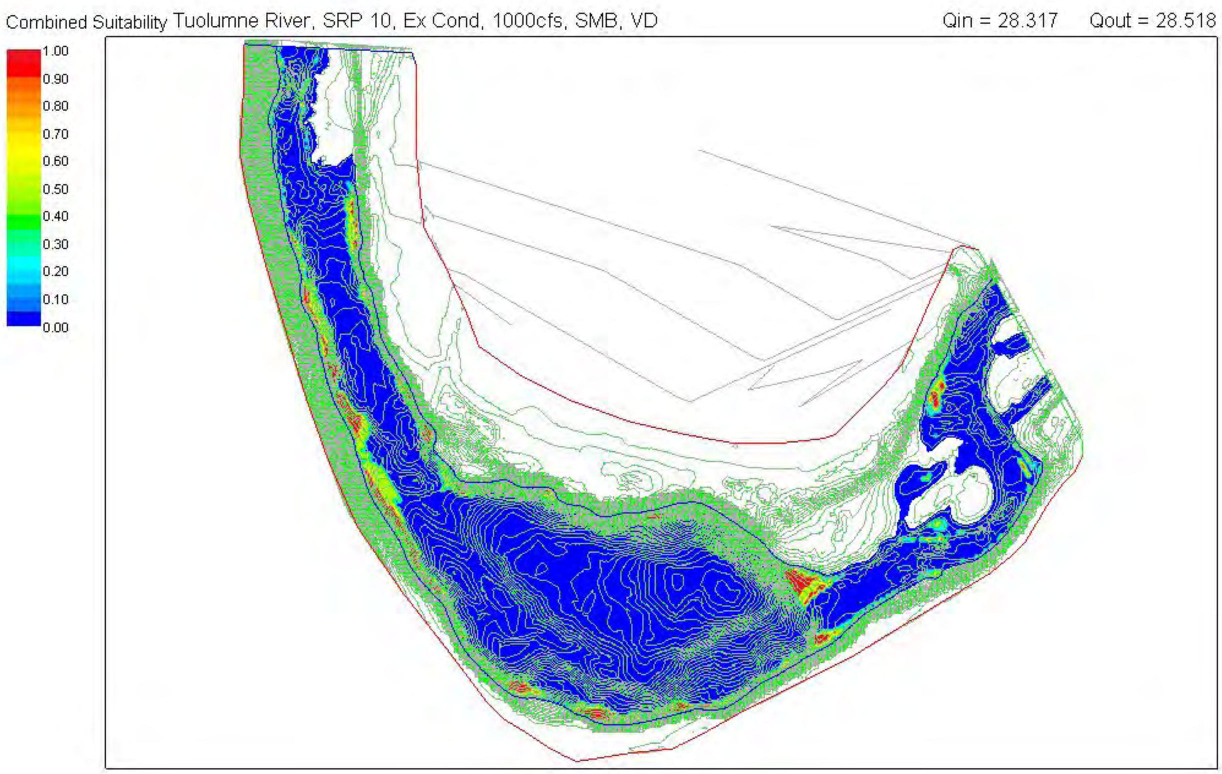
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Qin = 28.317
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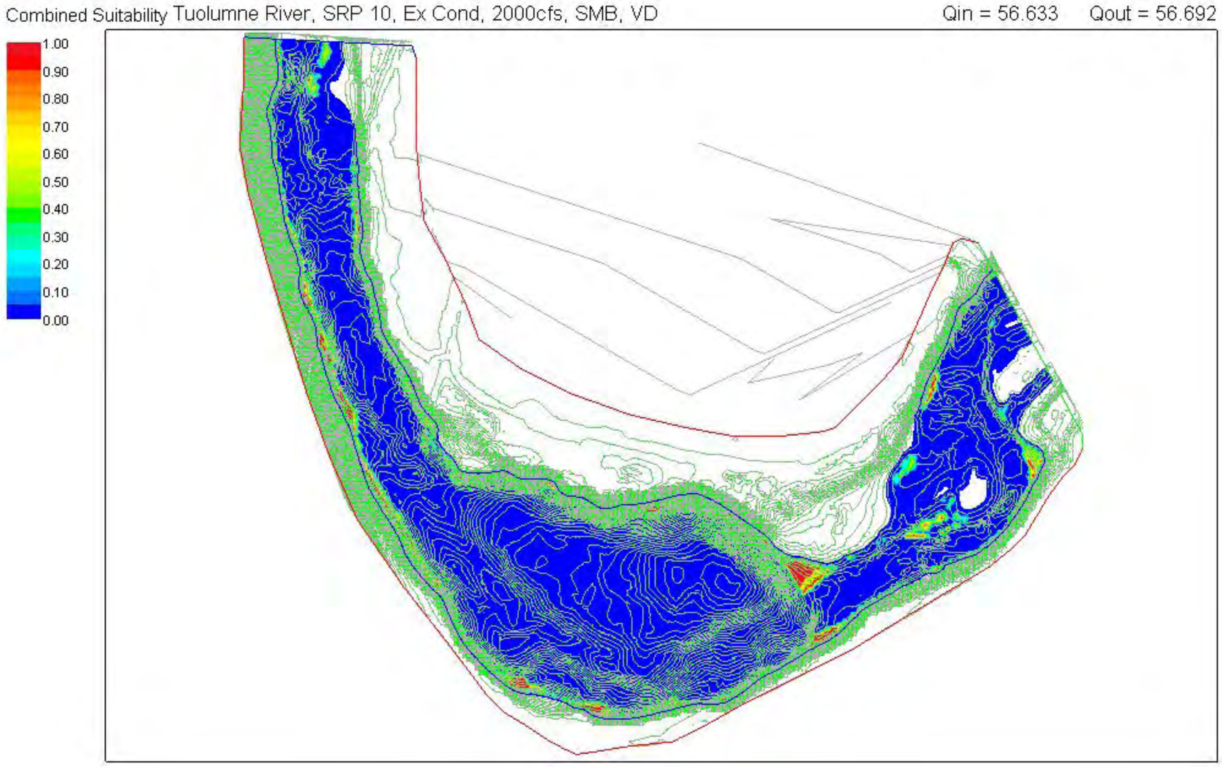
Combined Suitability Tuolumne River, SRP 10, Ex Cond, 2000cfs, SMB, VD
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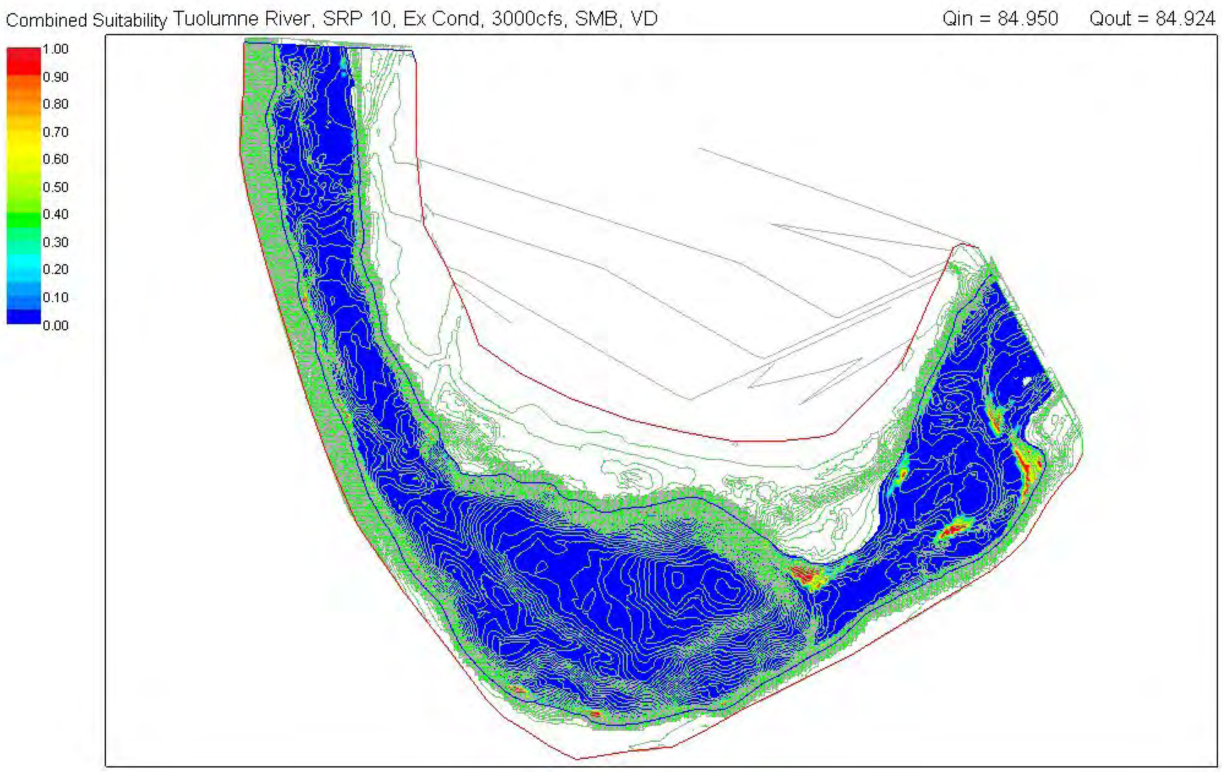
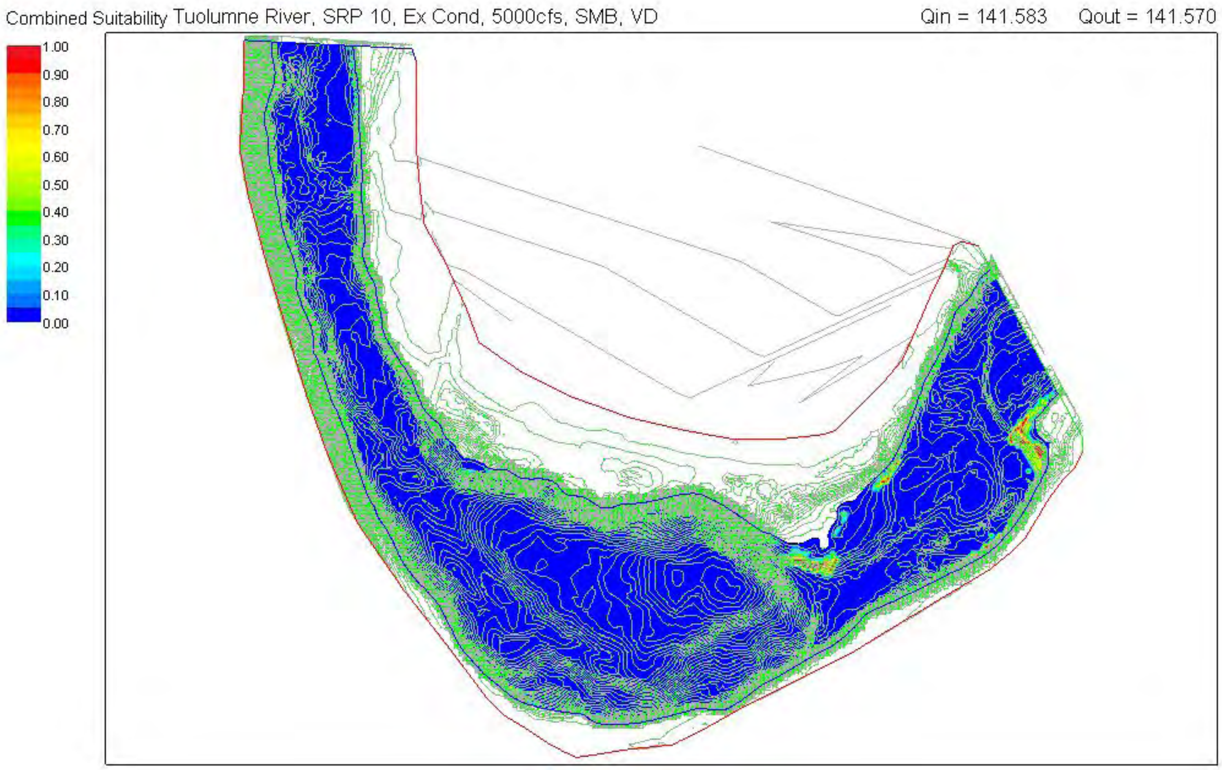
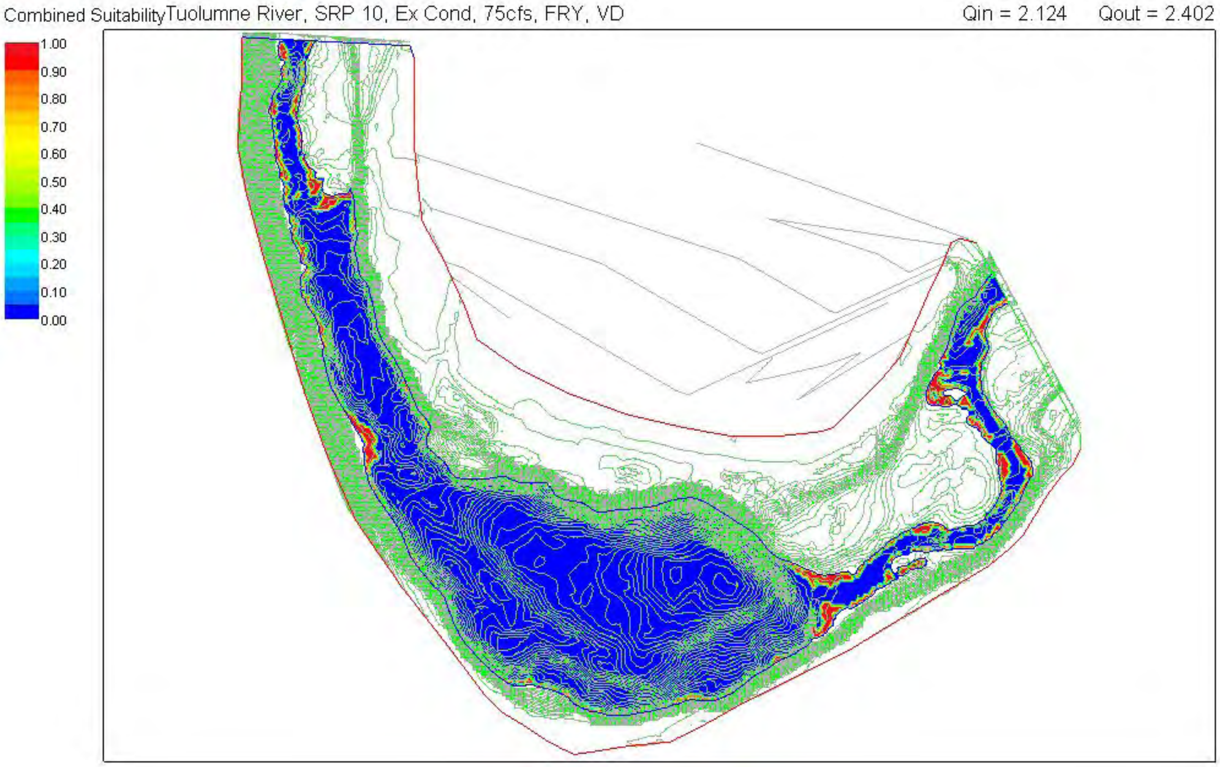
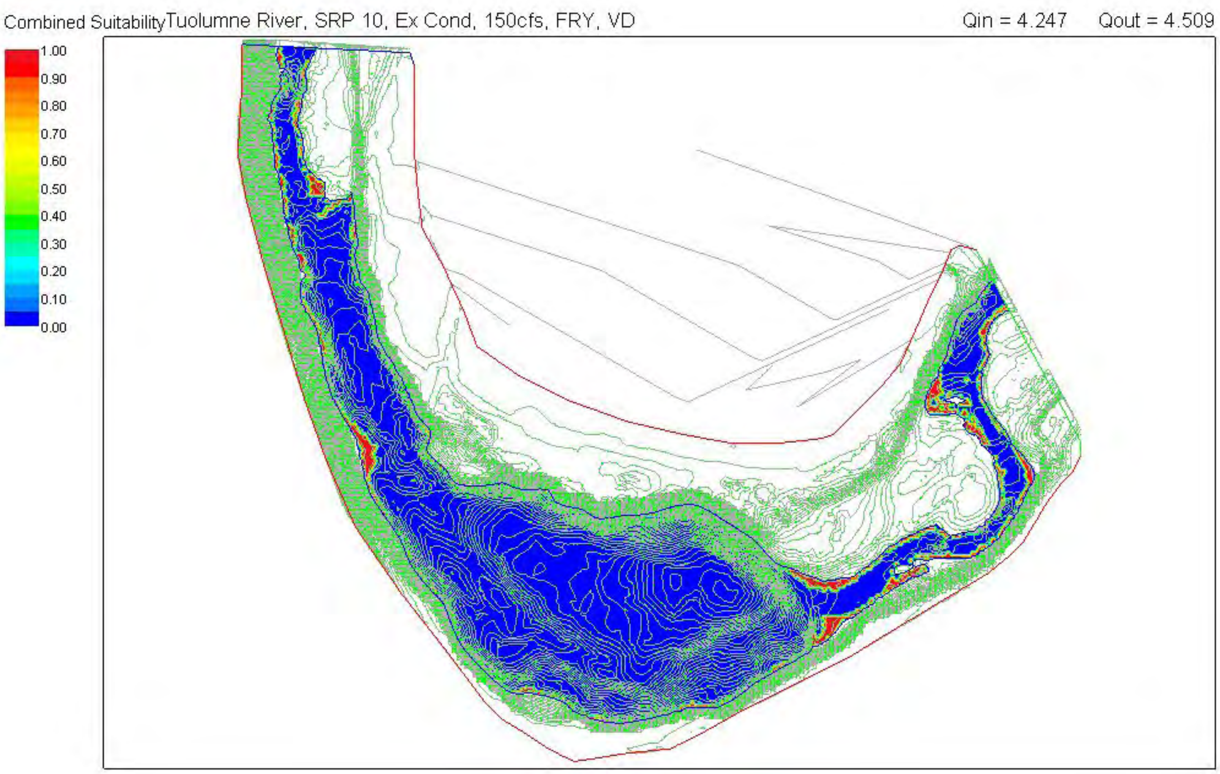
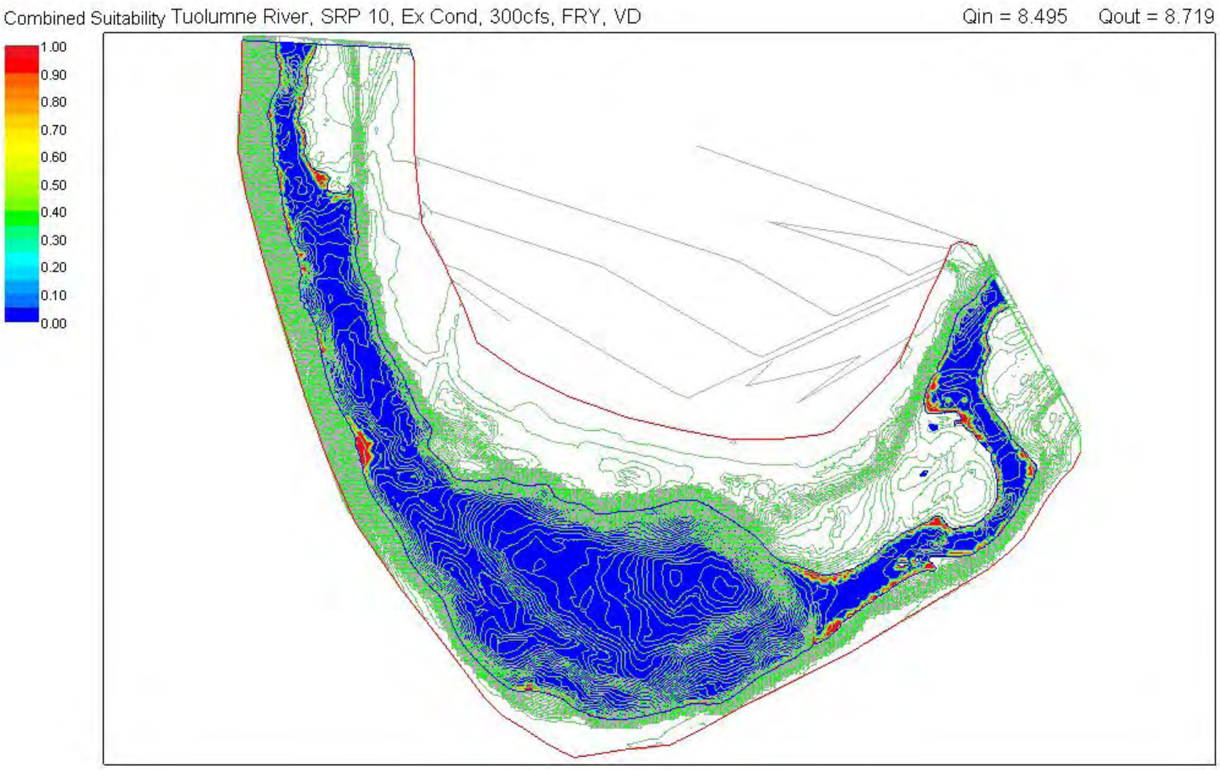
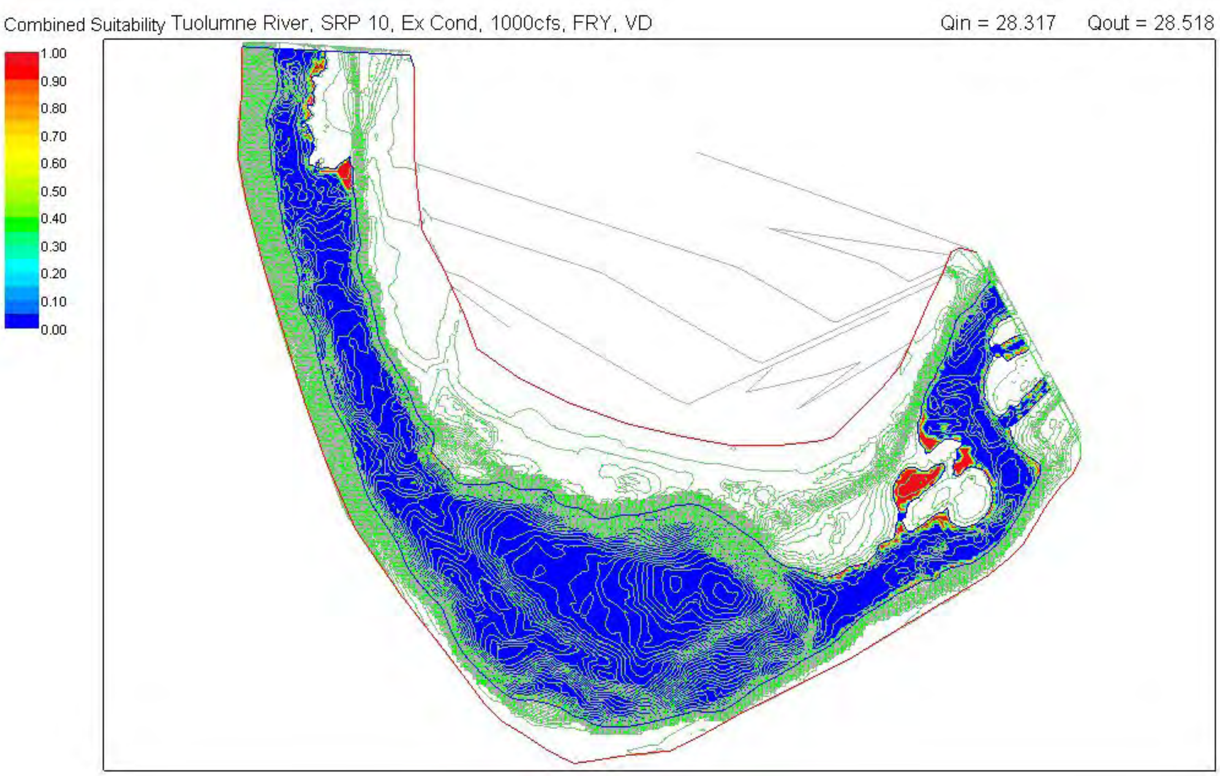

Combined Suitability Tuolumne River, SRP 10, Ex Cond, 3000cfs, SMB, VD
Qin = 84.950 Qout = 84.924
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

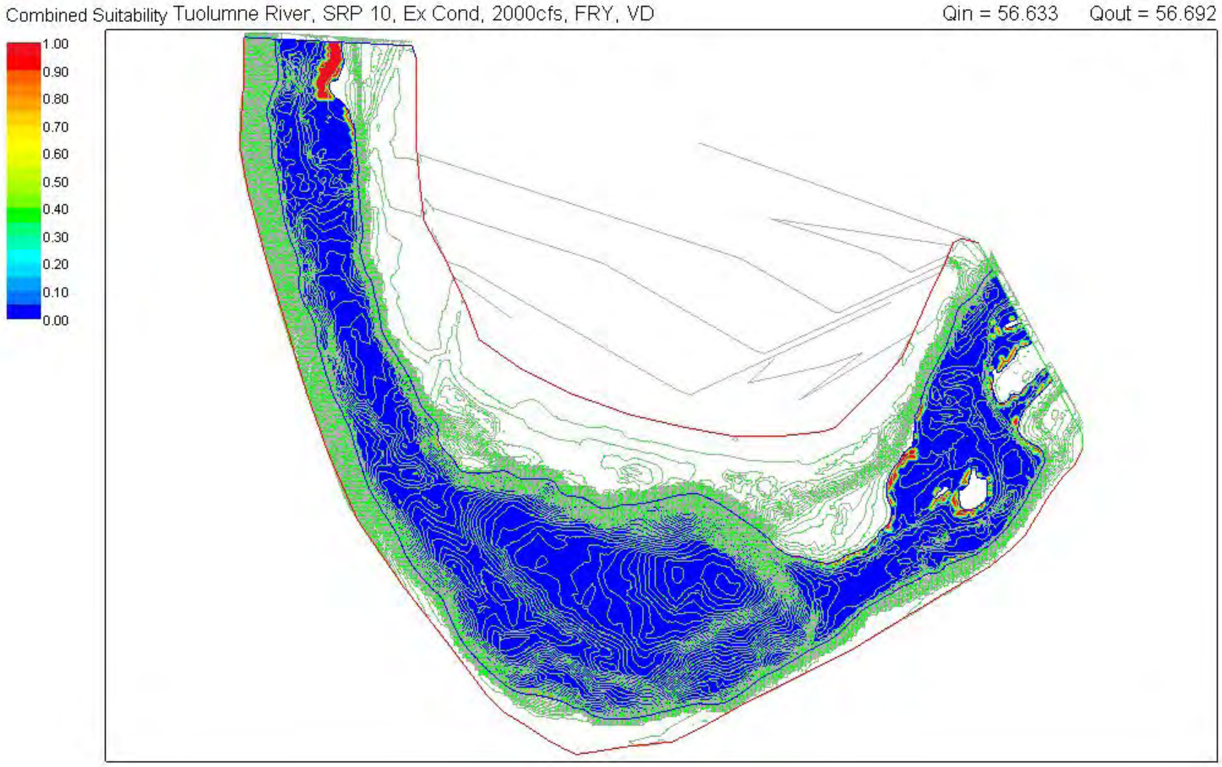

Combined Suitability Tuolumne River, SRP 10, Ex Cond, 5000cfs, SMB, VD
Qin = 141.583
Qout = 141.570
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

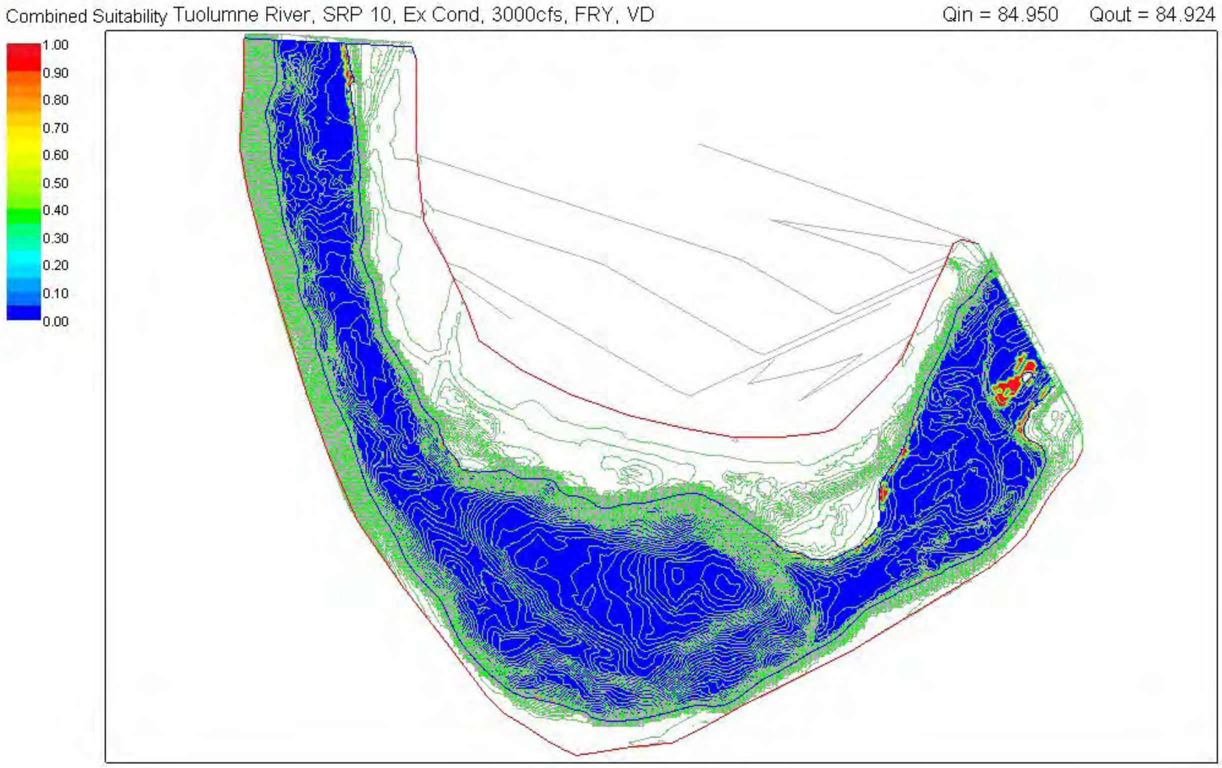

Combined Suitability
Tuolumne River, SRP 10, Ex Cond, 75cfs, FRY, VD
Qin = 2.124
Qout = 2.402
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

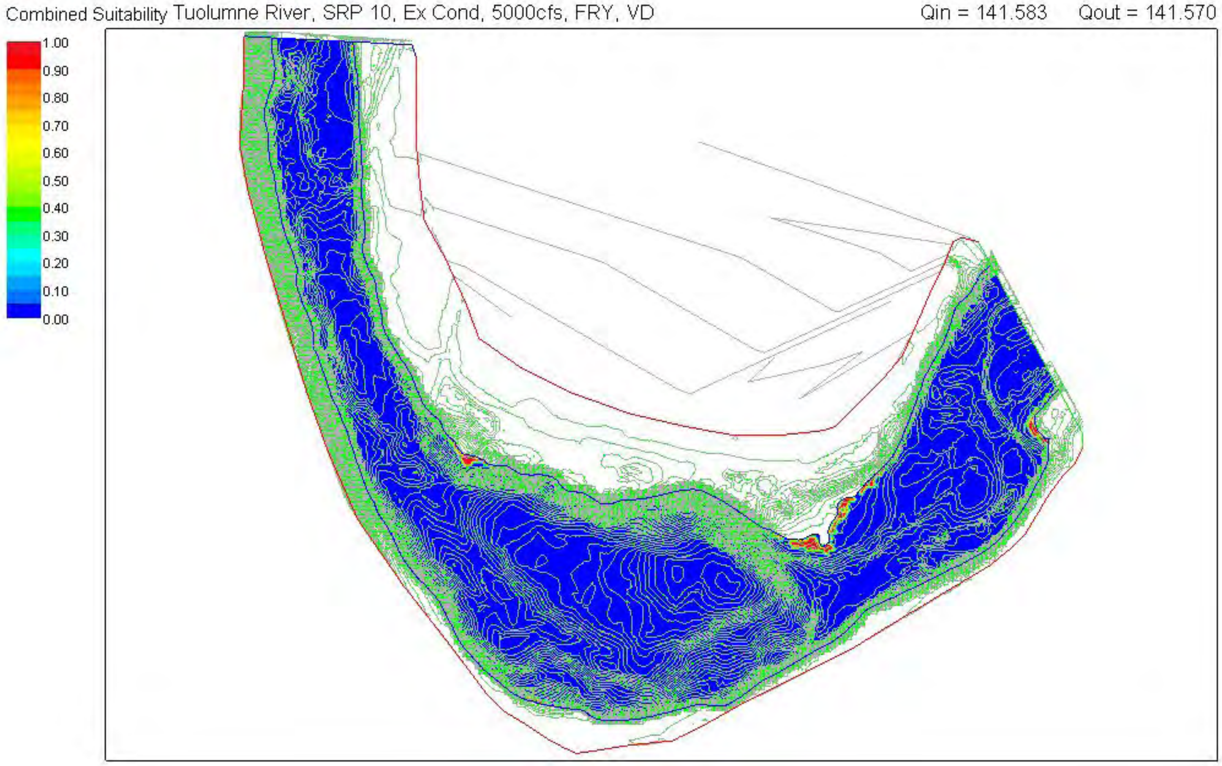

Combined Suitability
Tuolumne River, SRP 10, Ex Cond, 150cfs, FRY, VD
Qin = 4.247
Qout = 4.509
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

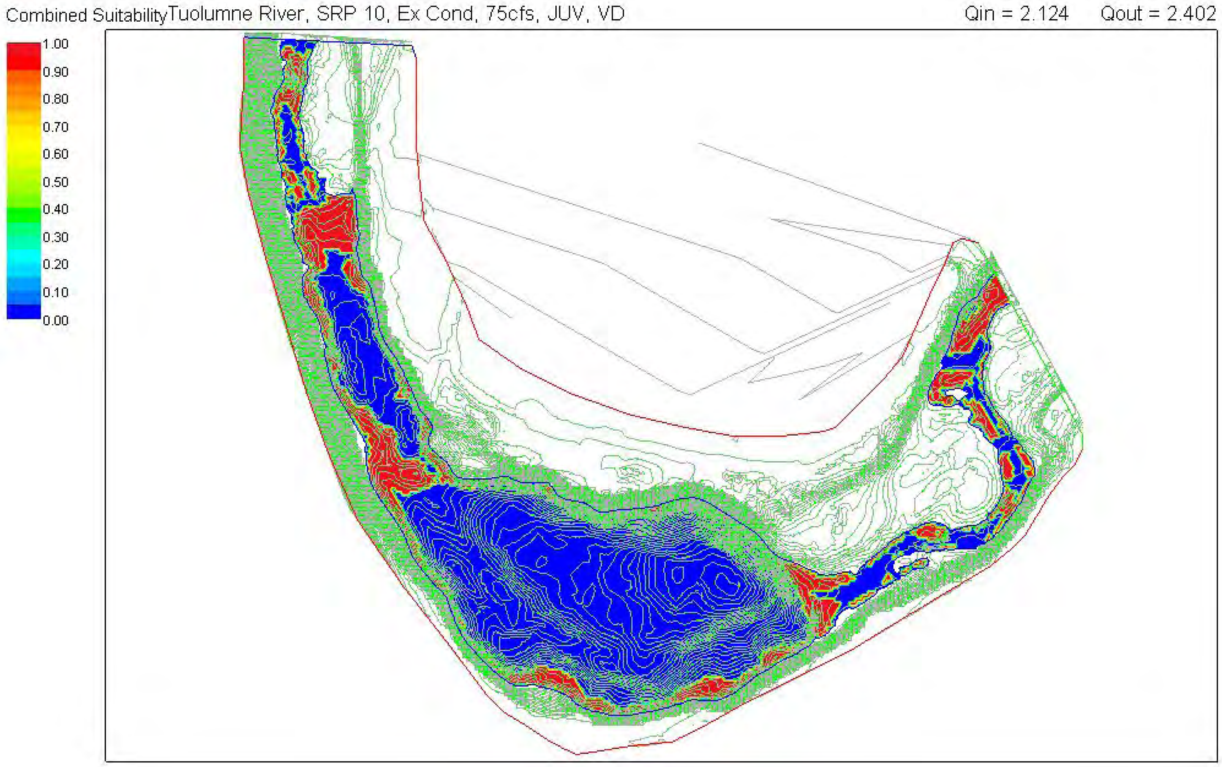

Combined Suitability Tuolumne River, SRP 10, Ex Cond, 300cfs, FRY, VD
Qin = 8.495
Qout = 8.719
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

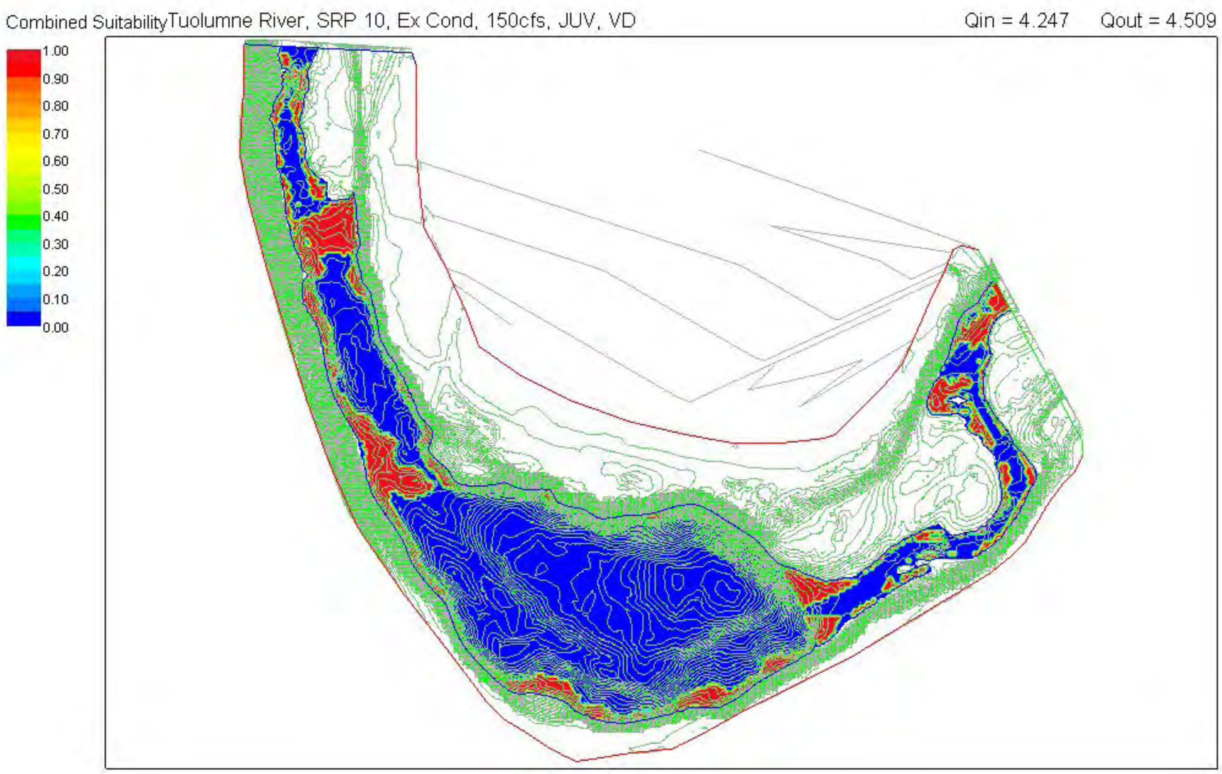

Combined Suitability Tuolumne River, SRP 10, Ex Cond, 1000cfs, FRY, VD
Qin = 28.317
Qout = 28.518
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

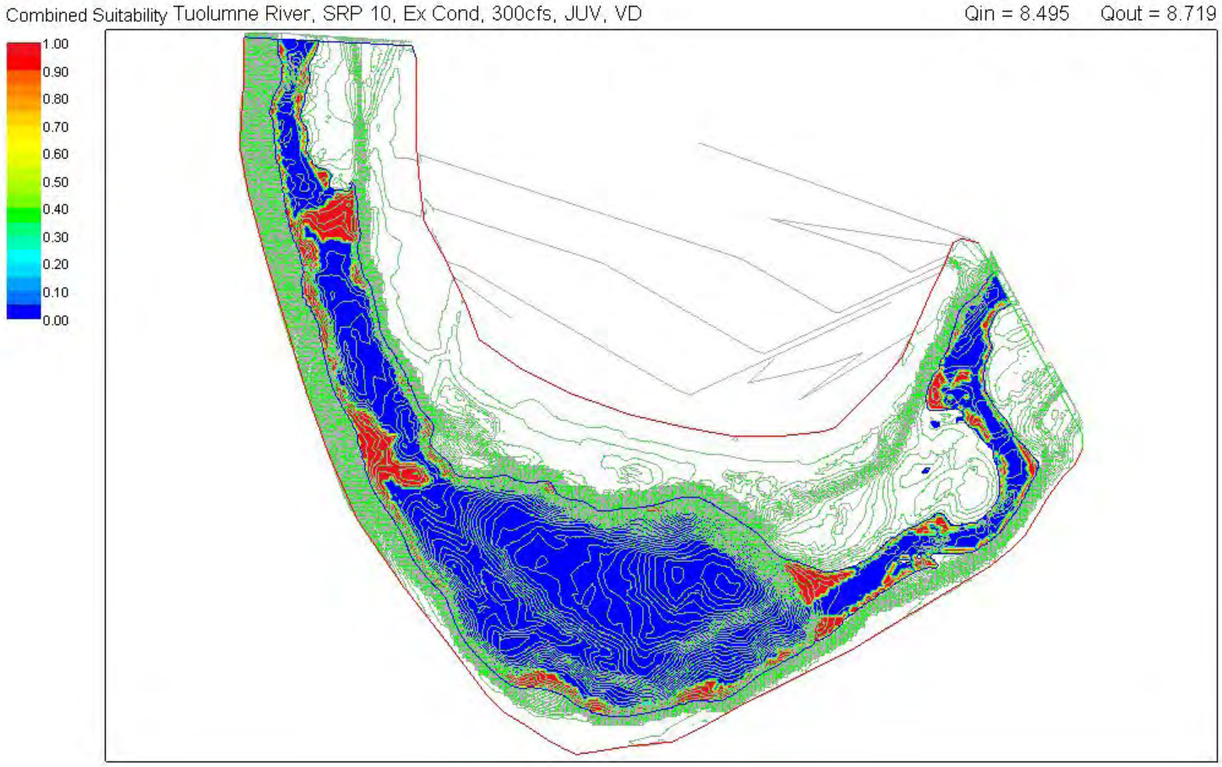

Combined Suitability Tuolumne River, SRP 10, Ex Cond, 2000cfs, FRY, VD
Qin = 56.633 Qout = 56.692
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

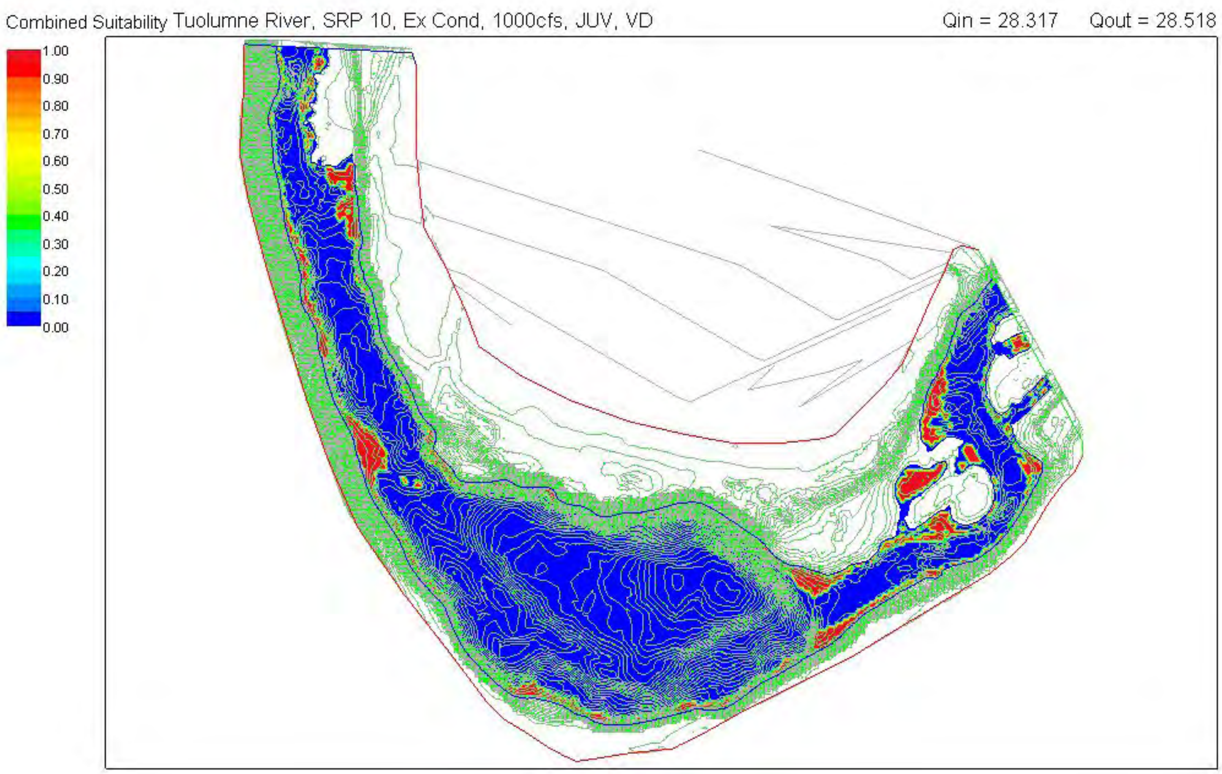

Combined Suitability Tuolumne River, SRP 10, Ex Cond, 3000cfs, FRY, VD
Qin = 84.950 Qout = 84.924
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

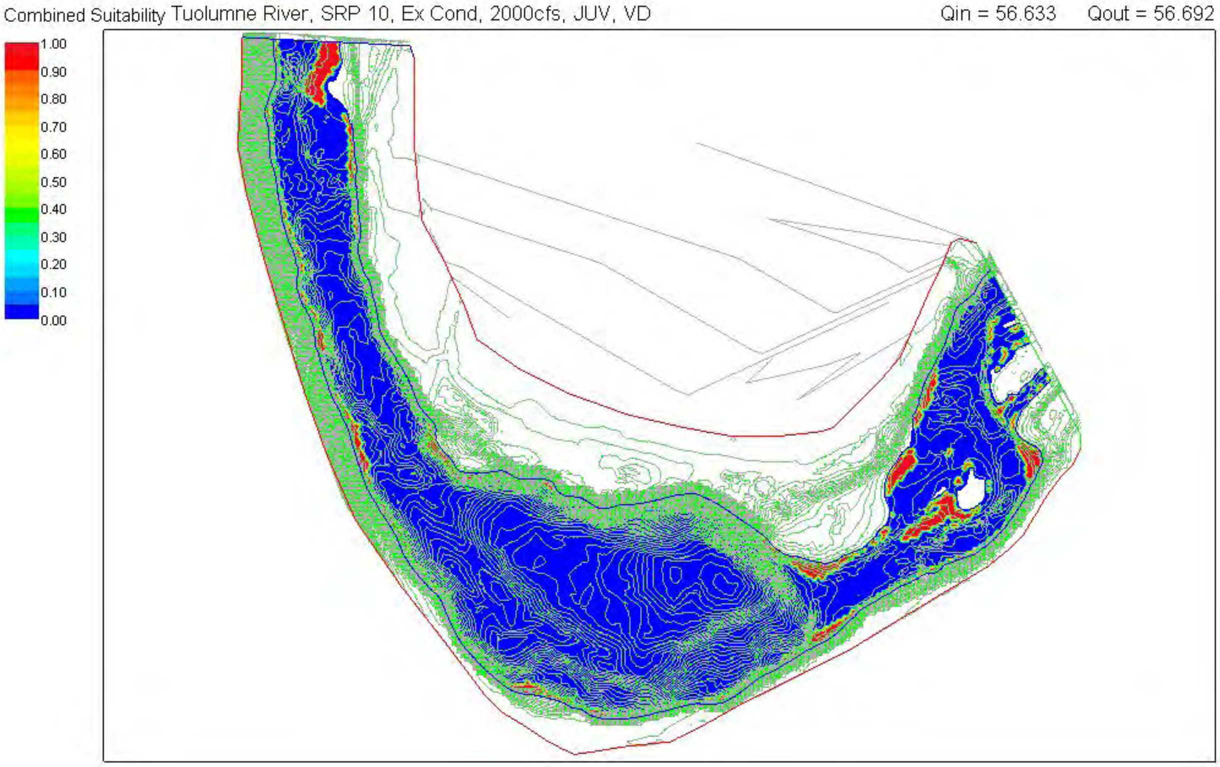

Combined Suitability Tuolumne River, SRP 10, Ex Cond, 5000cfs, FRY, VD
Qin = 141.583
Qout = 141.570
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

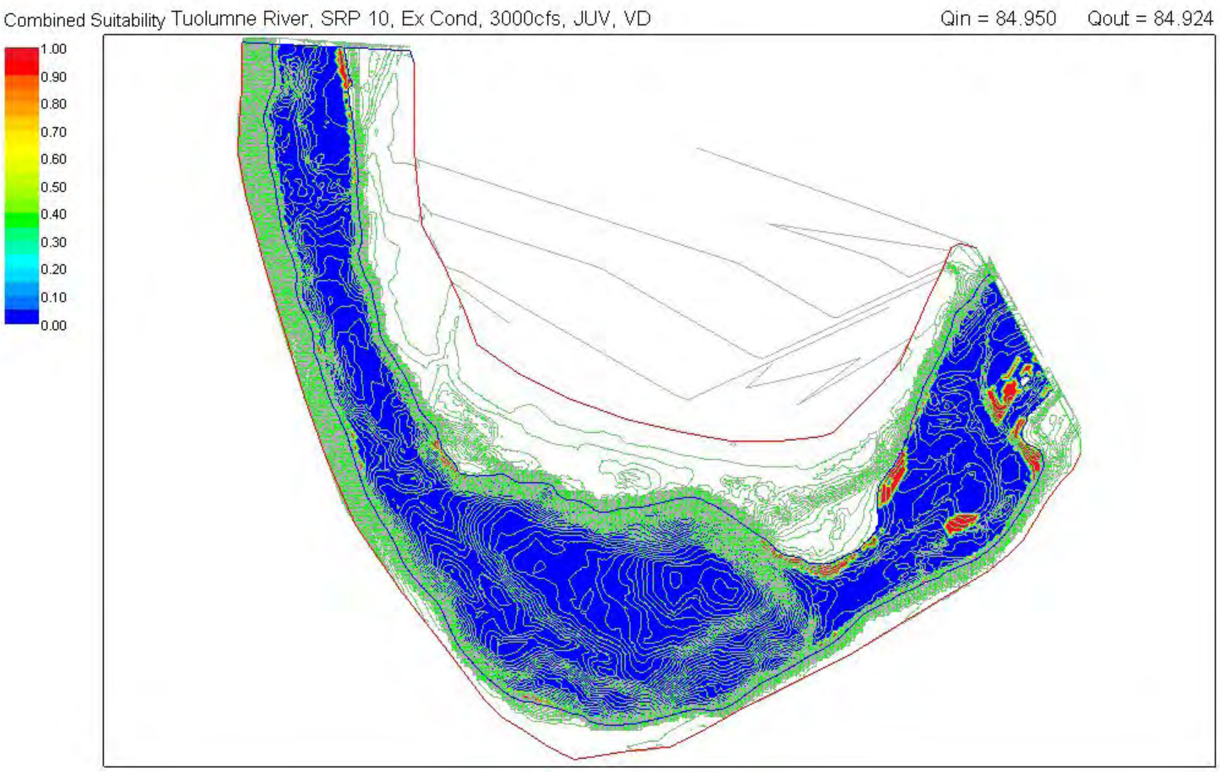

Combined Suitability
Tuolumne River, SRP 10, Ex Cond, 75cfs, JUV, VD
Qin = 2.124
Qout = 2.402
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

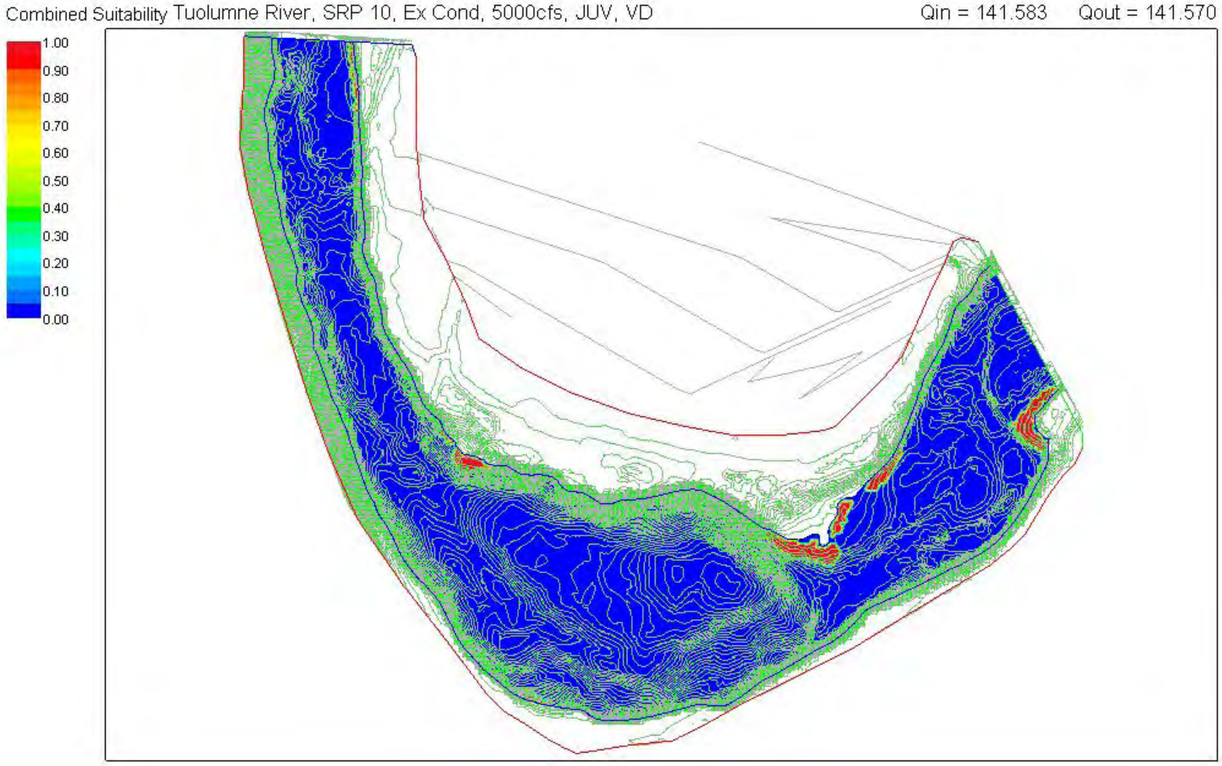

Combined Suitability
Tuolumne River, SRP 10, Ex Cond, 150cfs, JUV, VD
Qin = 4.247
Qout = 4.509
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability Tuolumne River, SRP 10, Ex Cond, 300cfs, JUV, VD
Qin = 8.495 Qout = 8.719
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

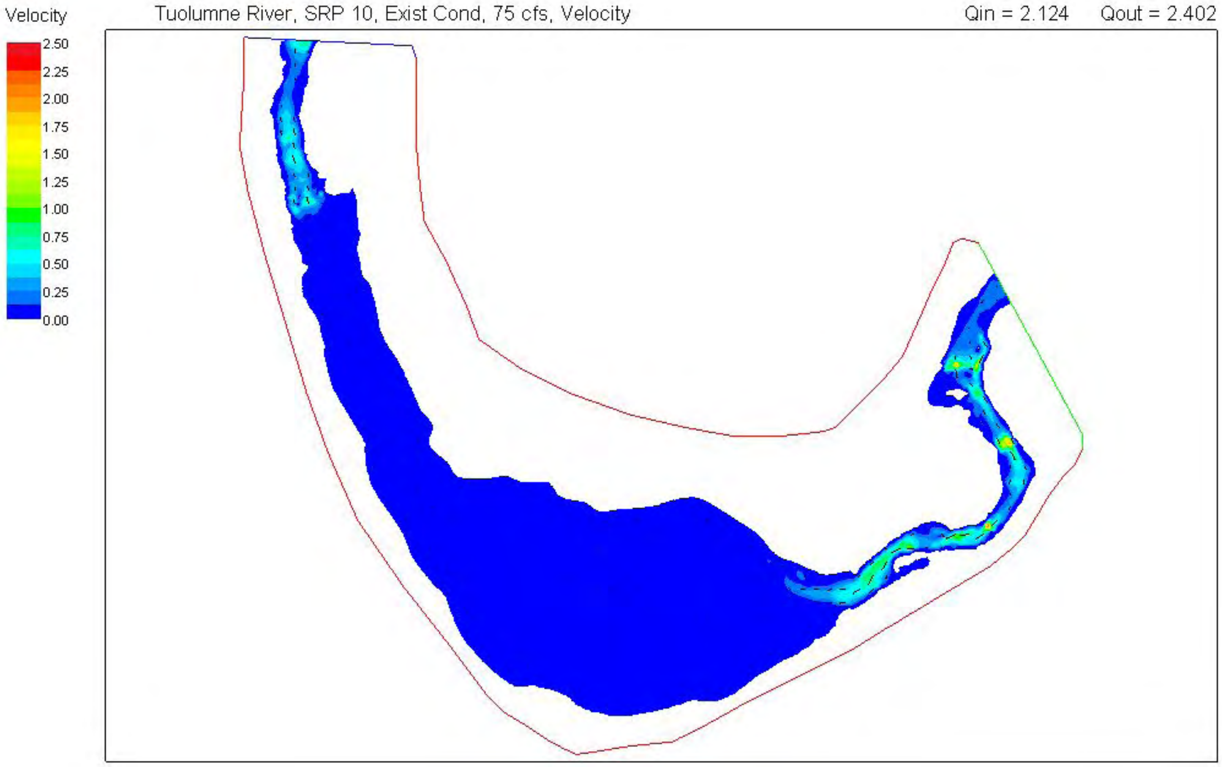

Combined Suitability Tuolumne River, SRP 10, Ex Cond, 1000cfs, JUV, VD
Qin = 28.317 Qout = 28.518
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

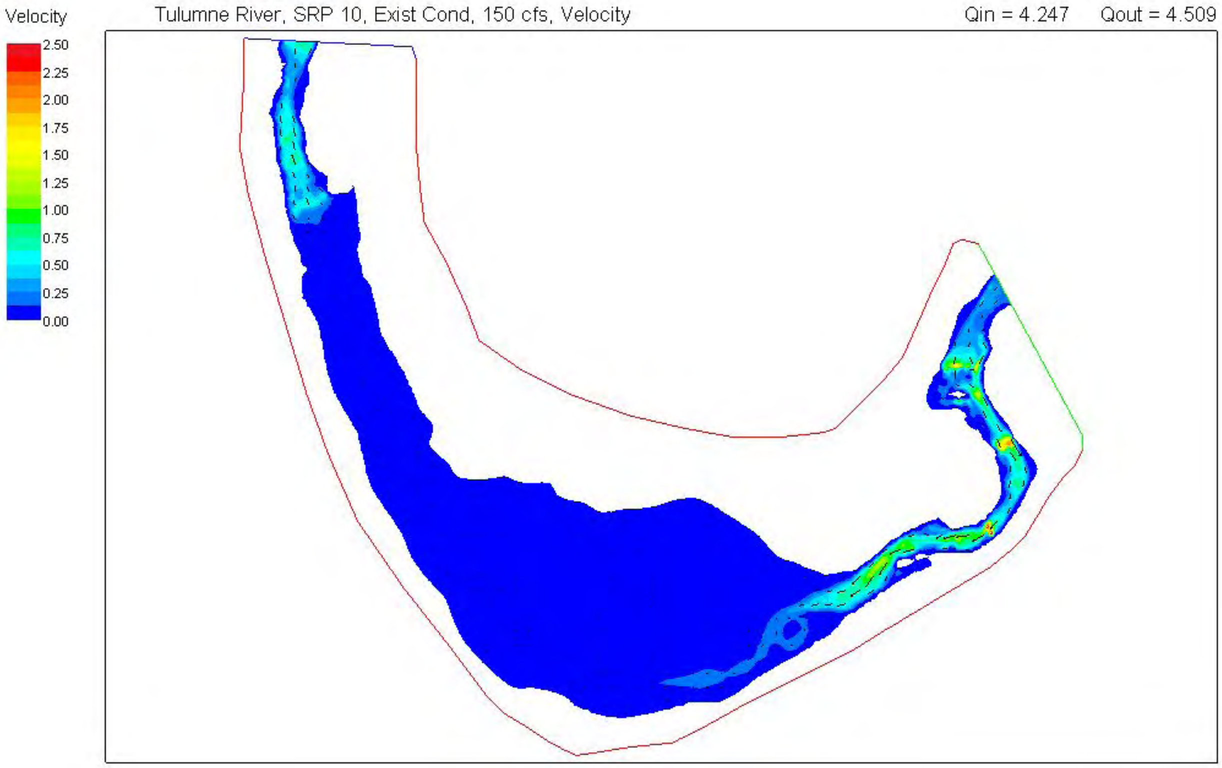

Combined Suitability Tuolumne River, SRP 10, Ex Cond, 2000cfs, JUV, VD
Qin = 56.633
Qout = 56.692
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00


Combined Suitability Tuolumne River, SRP 10, Ex Cond, 3000cfs, JUV, VD
Qin = 84.950
Qout = 84.924
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

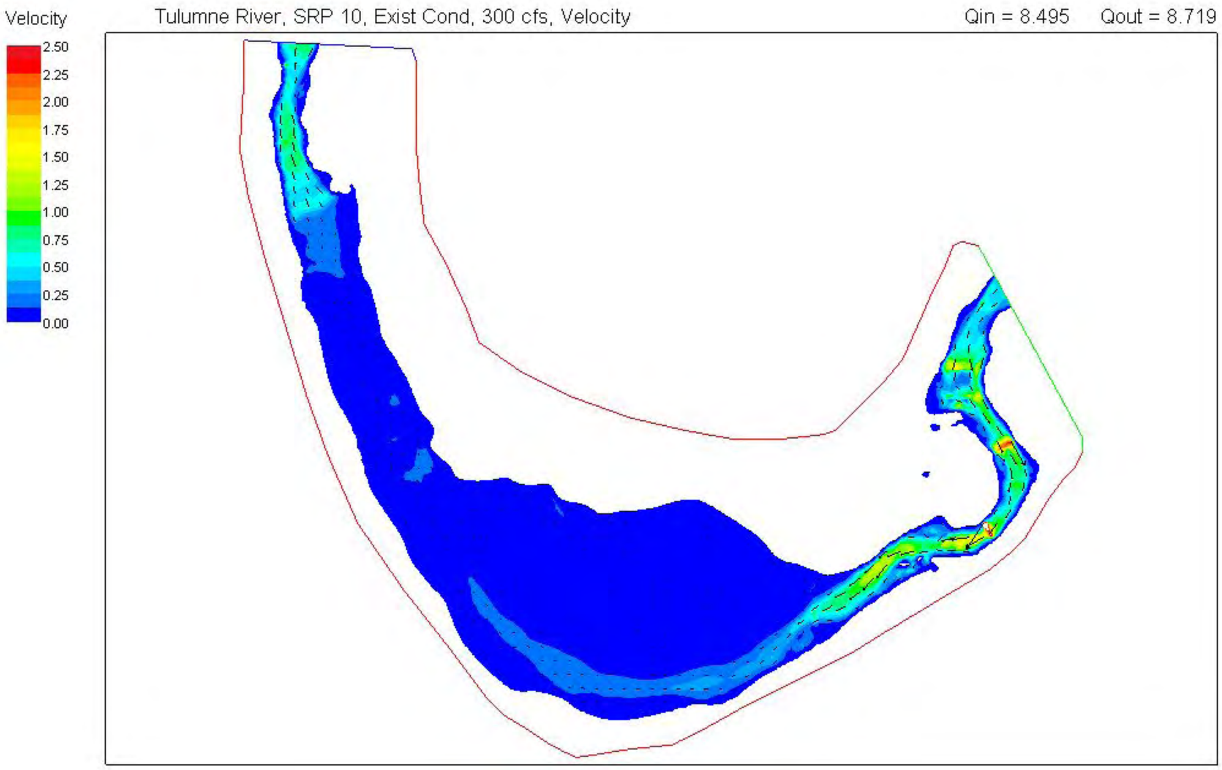

Combined Suitability Tuolumne River, SRP 10, Ex Cond, 5000cfs, JUV, VD
Qin = 141.583 Qout = 141.570
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00

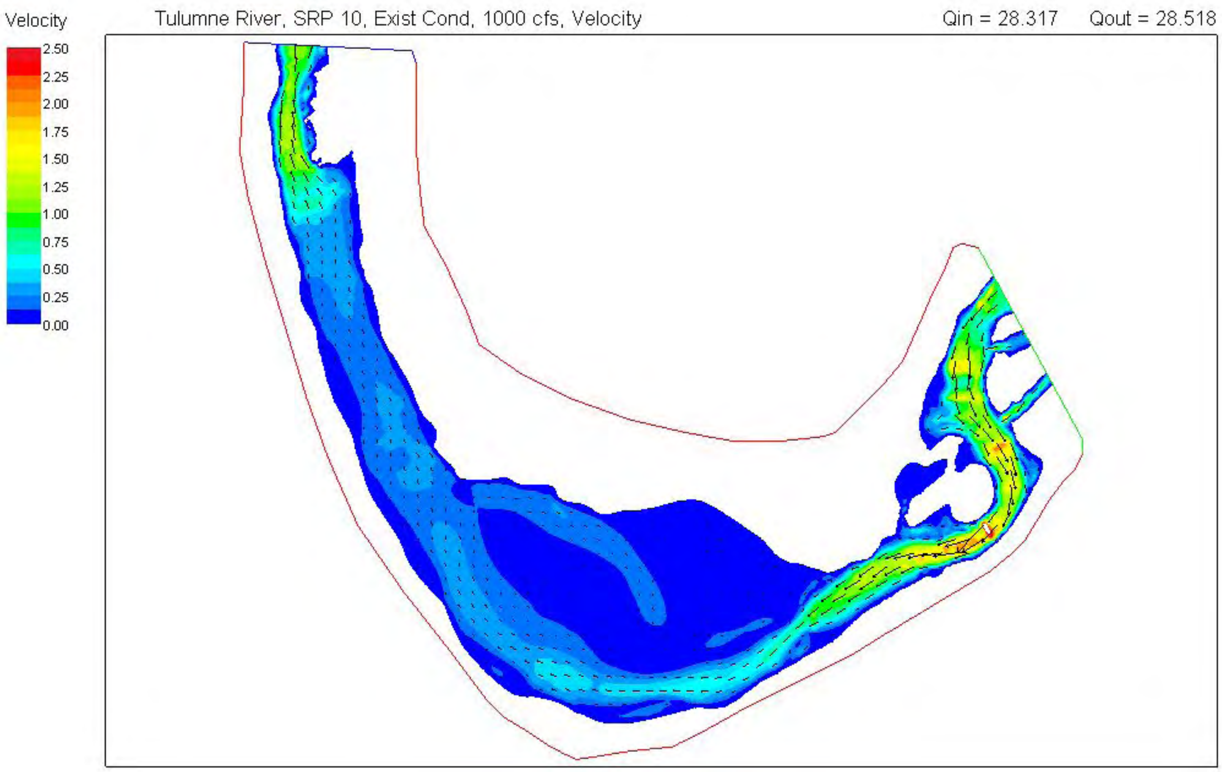
SPECIAL RUN POOL 10 - EXISTING CONDITIONS - VELOCITY FIGURES

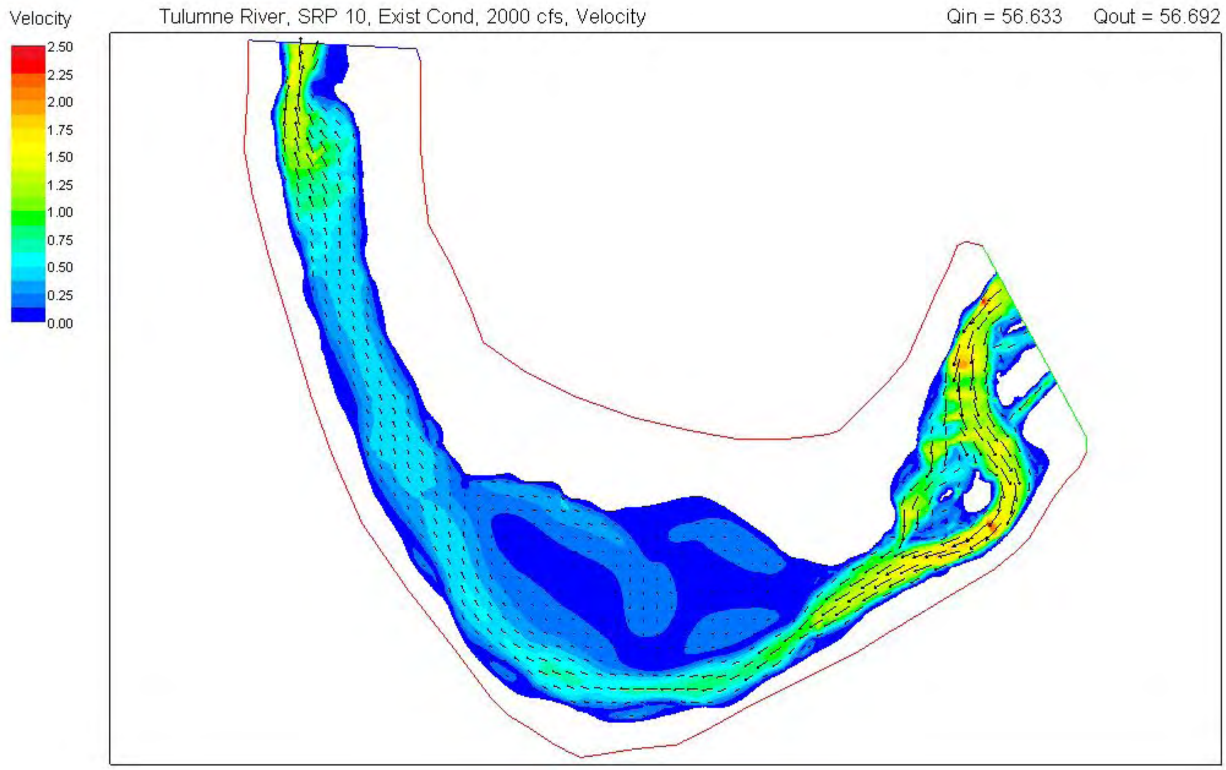


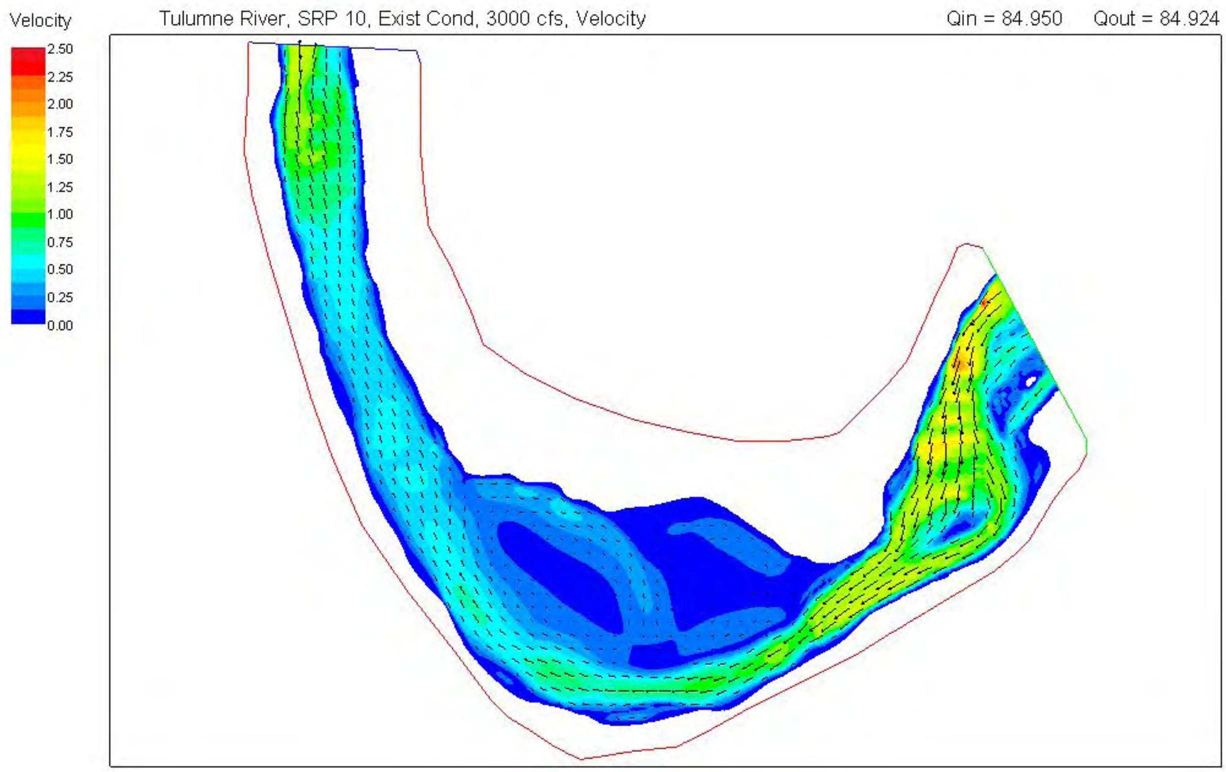


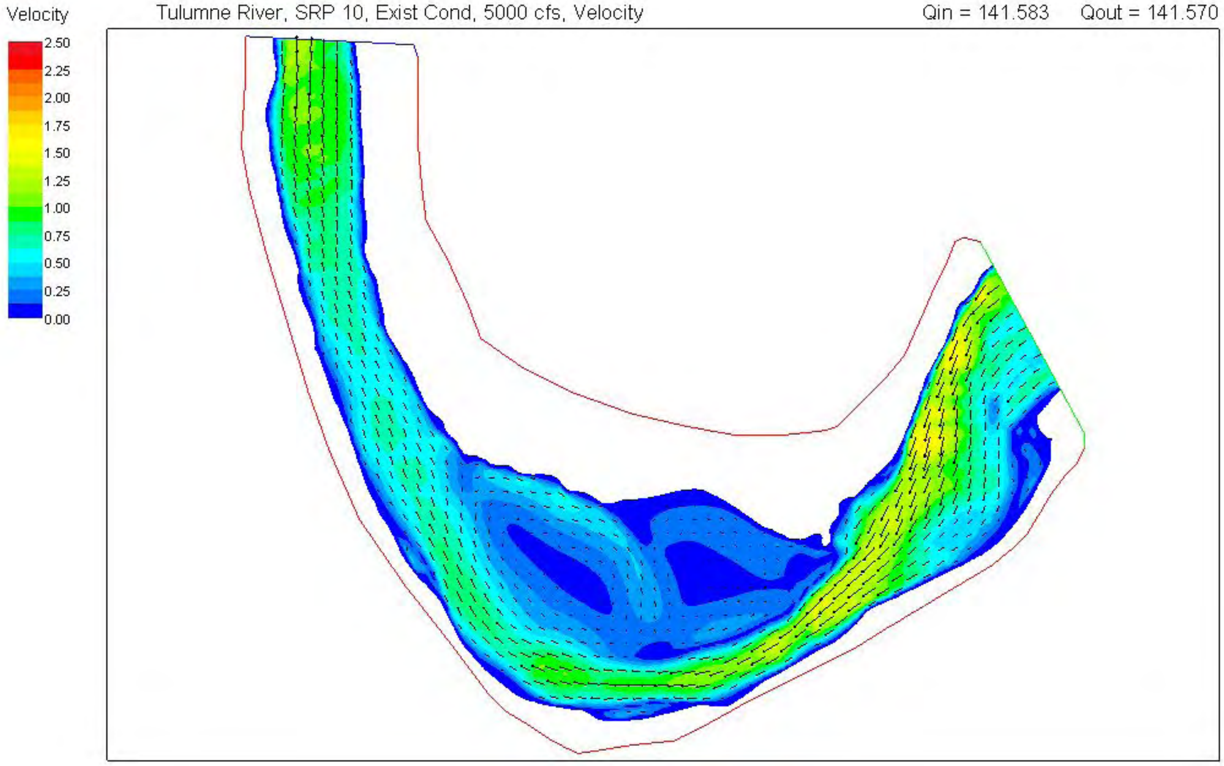
SPECIAL RUN POOL 10 - EXISTING CONDITIONS - VELOCITY FIGURES






Velocity
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Tulumne River, SRP 10, Exist Cond, 2000 cfs, Velocity
Qin = 56.633
Qout = 56.692


Velocity
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Tulumne River, SRP 10, Exist Cond, 3000 cfs, Velocity
Qin = 84.950
Qout = 84.924


Velocity
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Tulumne River, SRP 10, Exist Cond, 5000 cfs, Velocity
Qin = 141.583
Qout = 141.570