CHAPTER 4 | HEAD OF OLD RIVER BARRIER

BARRIER DESIGN, INSTALLATION AND OPERATION

In early April 2002, DWR installed and operated the temporary HORB. The spring HORB is a component of the south delta Temporary Barriers Project (TBP). The TBP mitigates for low water levels in the south delta and improves water circulation and quality for agricultural purposes. The HORB, as currently configured, is now fully permitted though 2005.

The spring HORB was first constructed in 1992. Since then, the barrier has been installed in 1994, 1996, 1997 (w/two culverts), 2000, 2001, and 2002. In 2000-2002 the barrier was installed with six culverts. The HORB was not installed in 1993, 1995 and 1998 due to high San Joaquin River flows. The HORB was not installed in 1999 due to landowner access problems. The HORB, a key component of VAMP, is intended to increase San Joaquin River Chinook salmon smolt survival by preventing them from entering Old River.

The HORB was originally designed to withstand a San Joaquin River flow of about 3,000 cfs. Through the years, the design and installation of the HORB has been revised on several occasions to accommodate different needs. Beginning in 2001, the barrier design included two versions. A "low-flow" barrier when San Joaquin River target flows are below 7,000 cfs would be built to a height of 10 feet mean sea level (MSL). A "high-flow" barrier for target flow of 7,000 cfs would be built to a height of 11 feet MSL and additional material would be placed to raise the abutments to 13 feet MSL. Both barrier versions are equipped with six 48-inch diameter operable culverts and an overflow weir back-filled with clay. In 2002, the low-flow version was installed.

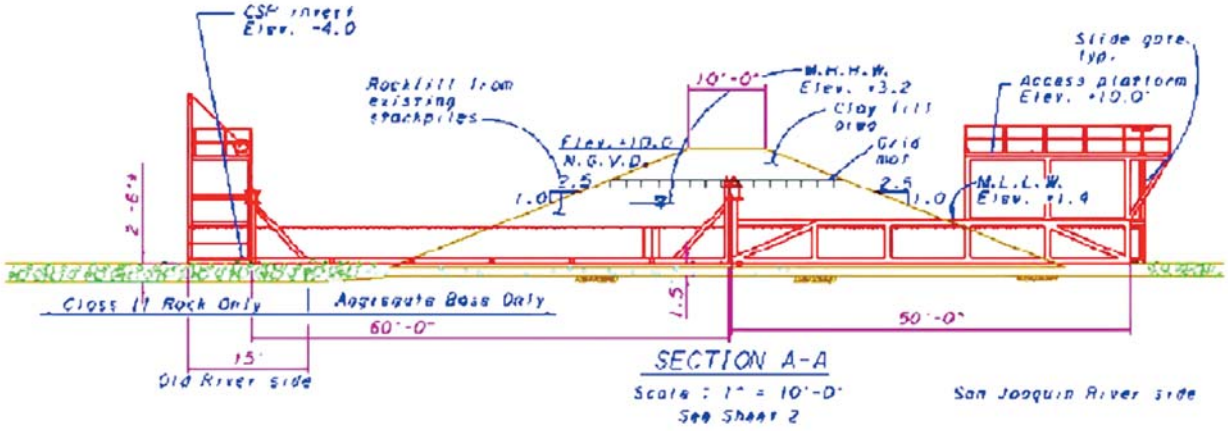
The dimensions of the 2002 HORB (Figure 4-1) were similar to the 2000 and 2001 HORB. The base width of the HORB in 2002 was 100 feet and the crest elevation was 10 feet MSL. The top of HORB was constructed with a 75-foot wide notch, protected with concrete grid mats and back-filled with clay. The HORB was designed to safely operate with flows corresponding to stages up to 8.5 feet MSL.

To help mitigate anticipated low water levels in the south delta (downstream of the HORB) caused by the operation of the HORB, two open culverts were installed in the barrier in 1997, and six operable culverts were installed beginning in 2000. Operation of the culverts is controlled by a slide gate control structure located on the upstream side of HORB. DWR relied on daily modeling and field data collection to monitor water levels at three locations within the south Delta to determine when and how long to operate the culverts. Generally, the model forecasts would tend to forecast low-low water levels lower than actual levels observed in the field. Consequently, DWR would make decisions regarding the culvert operations that would take this into consideration. It is expected that refinements to the model over time will provide modeling results that correspond more closely with field measurements.

The downstream outlet of each culvert was designed so fyke nets could be attached to evaluate fish passage. DFG staff conducted a fishery-monitoring program as part of the 2002 HORB operations.

FIGURE 4–1

Head of Old River Barrier (HORB)



Permitting and Construction

The various permit conditions that are placed on the Temporary Barriers Program, by the USFWS, National Marine Fisheries Service (NMFS), and DFG, require that the earliest in-water construction activities that can be conducted on the Head of Old River (HOR), Middle River (MR), and Old River at Tracy (ORT) barriers, during the Spring barrier installation period, are limited to no earlier than April 7. In addition, construction of the northern abutment and boat ramps of the Grant Line Canal (GLC) barrier and construction of out-of-water portions of the HOR, MR, and ORT barriers may not be started any earlier than April 1. Full closure of the GLC barrier is not required but construction of the north abutment and boat ramps must be completed to the extent that full barrier closure and operation can be readily achieved in a reasonable time frame, if and when directed by DWR. The permit conditions also require that all the above work be completed by April 15th, a total of 15 working days. Following is a brief summary of the various permit conditions:

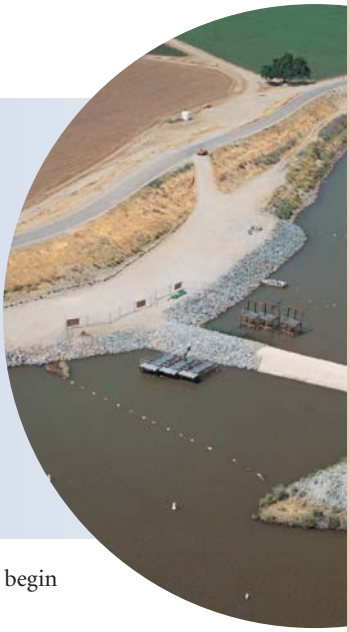
USFWS Biological Opinion

1) The spring HORB barrier installation may begin on April 1 but in-water work shall not occur until April 7, except for construction necessary to place the scour pad and the pad for the culverts (item No. 8, page 6);
2) DWR may begin construction of the Middle River barrier on April 1 but in-water work shall not occur until after April 7 (item No. 1, page 4);
3) DWR may begin construction of the Old River at Tracy barrier on April 1 but in-water work shall not commence before April 7 (item No. 2, page 4);
4) DWR may begin construction of the northern abutment and the boat ramp of the GLC barrier on April 1 provided that the HOR barrier is being constructed concurrently (item No. 3, page 5).

NMFS Biological Opinion

1) the spring HORB installation shall begin on April 1 (item 8, page 8);
2) the MR barrier construction may begin on April 7 (item 1, page6);
3) the ORT barrier construction may begin on April 1 (item2, page 6);
4) the northern abutment and boat ramp of the GLC barrier may begin construction on April 1 provided that the HORB is being constructed concurrently (item 3, page 7).

The downstream outlet of each culvert was designed so fyke nets could be attached to evaluate fish passage. DFG staff conducted a fishery-monitoring program as part of the 2002 HORB operations.



DFG 1601–HORB

HORB Spring Installation–All work in or near the stream zone will be confined to the period beginning no earlier than April.

DFG 1601–Agricultural Barriers

MR–All work in or near the stream zone will be confined to the period beginning no earlier than March 1.

ORT–All work in or near the stream zone will be confined to the period beginning no earlier than April 1.

GLC–All work in or near the stream zone will be confined to the period beginning no earlier than April 1.

TABLE 4–1

Flow in Old River Downstream of the Head of Old River Barrier–2002

DATE	MEAN DAILY FLOW (CFS)	DAILY MAX FLOW (CFS)	DAILY MIN FLOW (CFS)	DATE	MEAN DAILY FLOW (CFS)	DAILY MAX FLOW (CFS)	DAILY MIN FLOW (CFS)
April 1	870	1567	419	May 02	278	763	-113
April 2	898	1590	287	May 03	328	717	-164
April 3	889	1418	101	May 04	291	828	-169
April 4	858	1409	96	May 05	234	745	-76
April 5	758	1315	-26	May 06	364	750	-123
April 6	727	1111	-13	May 07	327	772	-33
April 7	616	1047	93	May 08	274	794	-197
April 8	596	1100	276	May 09	362	691	-11
April 9	543	1211	138	May 10	366	644	-83
April 10	471	1157	13	May 11	258	679	-73
April 11	577	1136	147	May 12	356	844	-36
April 12	519	1016	45	May 13	568	888	324
April 13	347	1015	-128	May 14	525	811	220
April 14	487	1372	-486	May 15	458	674	169
April 15	680	1821	77	May 16	417	661	0
April 16	538	832	49	May 17	371	648	115
April 17	541	822	225	May 18	388	575	142
April 18	412	838	-158	May 19	232	548	-161
April 19	259	687	-194	May 20	218	537	-33
April 20	229	577	-140	May 21	294	540	-11
April 21	232	851	-201	May 22	325	585	35
April 22	160	751	-233	May 23	331	607	-55
April 23	169	495	-226	May 24	409	1651	-239
April 24	205	559	-259	May 25	683	1612	-33
April 25	249	538	-148	May 26	923	1870	305
April 26	328	626	20	May 27	854	1752	-12
April 27	238	494	-66	May 28	713	1582	-129
April 28	180	595	-243	May 29	471	1334	23
April 29	241	638	-73	May 30	413	858	0
April 30	187	534	-225	May 31	492	889	68
May 01	200	766	-127				

In addition to the above conditions, water users of the South Delta Water Agency (SDWA) and the fisheries agencies impose separate mitigation requirements on DWR for installation and operation of the HORB by itself. As a result, DWR's contractor must sequentially close and start operation of the MR and ORT barriers, and complete as much construction of north abutment and boat ramps on the GLC barrier as possible, before they can close and operate the HORB.

From the contractors point of view there are really two milestones that must be completed in sequence. First and foremost is to obtain closure and operation of the barriers in accordance with the conditions imposed by the project permits/biological opinions and mitigation requirements. The second is to satisfy DWR's contract specifications. The first milestone can be achieved within the required 15 working days but it is unlikely that the contractor can complete the entire amount of work required to satisfy DWR's contract specifications within the same time period.

Therefore, the contractor's construction activities consist of placing enough materials to make sure they obtain closure and operation by April 15th, then following closure they continue placing barrier material above the water line until barrier construction is completed in accordance with DWR's contract specifications. The contractor then conducts site cleanup and demobilizes from the site. This is why work usually continues beyond the April 15 deadline.

Barrier Operations and Monitoring Plan

A barrier operations and monitoring plan was developed based on forecasting and monitoring of tidal conditions. DWR determined the number of culverts to be opened at the HORB so that water levels at Old River near Tracy Road Bridge, Middle River near

Howard Road and Grant Line Canal near Tracy Road Bridge would remain above 0.0 feet MSL. Based on modeling results and/or field monitoring of water levels in the south delta, all six culvert slide gates remained open from April 15 to May 24, 2002 when the HORB was breached.

The average daily flow through the culverts varied in response to tidal and San Joaquin River flow conditions. The characteristics of the flow through the culverts are complicated in that the flow rate is influenced by many variables, including the culvert inlet geometry, slope, size, culvert roughness, and approach and tail water conditions. An approximation of the combined net flow through the culverts, including any seepage through the barrier, was accomplished by measuring the flow in Old River just downstream of the HORB using Acoustic Doppler technology. A fixed Acoustic Doppler Current Meter was operated approximately 840 feet downstream of the HORB which recorded velocity measurements every 15 minutes during the period the HORB was operated (April 15 through May 24, 2002). The flow in Old River was then calculated using the known cross-sectional area of the channel as a function of the stage elevation at that location.

The mean daily flow measured in Old River during the operation of the HORB ranged from 160 to 568 cubic feet per second as shown in Table 4-1. These figures ignore the first and the last day of operation which is skewed by flows occurring before and after the HORB was closed or breached. On May 24, the barrier was breached, which accounts for the maximum flow of 1,651 cfs shown in Table 4-1. The negative flows listed indicate the channel below the HORB was filling on a flood tide; however, this does not mean that flows through the culverts were negative. As long at the river stages on the upstream side of the barrier remain higher than the downstream side, flows through the culverts will always be positive.

Barrier Emergency Response Plan

In addition to the operation and monitoring plan, DWR has also prepared an "Emergency Operations Plan for the Spring HORB". The plan provided that if the daily measured or forecasted flow at Vernalis exceeded a flow that would correspond to stage at the HORB of 10.0 feet MSL, and the stage was likely to exceed 11.0 feet MSL (the height of the barrier under the "high-flow" target), the barrier would be removed. Operation of the HORB was uneventful this year. Vernalis flows and stages at the barrier were not high enough in 2002 to warrant action under the emergency operations plan.

Seepage Monitoring

A seepage-monitoring program was initiated in April 2000 and continued this year, to evaluate the effects of HORB operations on seepage and groundwater on Upper Roberts Island.

Three seepage monitoring well sites were chosen in 2000 on Upper Roberts Island. Each site had two shallow wells, positioned 10 feet and 100 feet from the toe of the levee to monitor the seepage gradient to and from the San Joaquin River. In addition, a deeper well was drilled at Site 1 (near the Head of Old River) to determine vertical gradients.

In addition to the groundwater monitoring wells, a temporary gage was installed in April 2000 to record water surface elevations in the San Joaquin River, about 1,500 feet downstream of the HORB. Installation of a permanent tide gage was completed in early 2002. The water surface elevations in the San Joaquin River are compared to groundwater levels on Upper Roberts Island to determine how groundwater levels change relative to changing water level conditions in the river.

In November 2002, DWR completed a "Reclamation District 544 Seepage Monitoring Study". This is an ongoing study to document the seepage monitoring results from Upper Robert Island. (Copies of the report are available from DWR). Based on the 2000 and 2001 data, it is apparent that the San Joaquin River stage influences groundwater levels on Upper Roberts Island. When stage increases in the river, groundwater levels will rise toward the land surface, but not as rapidly as the river stage rises. However, over the monitoring period, river stage did not reach levels sufficient to raise groundwater levels to the point where seepage into crop root zones might occur.

Given the results of the seepage monitoring since April 2000, DWR expects that if a VAMP target flow of 7,000 was implemented, stages near the HORB would rise to about 7 1/2 to 8 feet MSL. This would translate to groundwater levels in the monitoring well closest to the levee of about 6 1/2 to 7 feet MSL. Because the ground surface elevation is 13 feet MSL near site 1, DWR concludes that seepage should not impact the root zone of crops that could be planted in this area.

The monitoring program will be continued in order to gather more data, particularly during high flow periods in the spring.

FISHERY MONITORING AT THE HEAD OF OLD RIVER BARRIER

During the VAMP 2002 test period, all six culverts in the HORB were operational. The six culverts are installed to maintain water quality and water levels in the south delta downstream of the HORB. Since the culverts are not screened, juvenile Chinook salmon and other fish species that pass near the culverts are vulnerable to entrainment. A fishery monitoring program was designed and implemented by the DFG to evaluate and quantify fish entrainment at the HORB. The specific objectives of the 2002 fishery investigations were:

- Determine the total number of juvenile Chinook salmon and other fish species entrained through the culverts at the HORB (Entrainment Monitoring).
- Determine the percentage of coded-wire tagged (CWT) salmon released at Mossdale and Durham Ferry entrained into Old River (Entrainment Monitoring).
- Determine tidal and diel effects on juvenile Chinook salmon entrainment (Entrainment Special Study).

Results of these fishery investigations are intended, in part, to provide information on the design and operation of a future permanent operable barrier at the head of Old River.

Materials and Methods

As part of the VAMP 2002 studies, a total of 148,502 CWT salmon smolts were released at Durham Ferry and Mossdale on April 18 and 19, respectively. Another 147,842 were released at the same locations on April 25 and 26. Salmon from the VAMP releases were used in the Entrainment Monitoring studies. For the Entrainment Special Study, eight uniquely color-marked groups of juvenile Chinook salmon (approximately 3,000 fish per group) were marked with photonic fluorescent microspheres at the Merced River Hatchery. The salmon were transported to the HORB and placed in live cages where they were held at least 10 hours before release. Each color-marked group was released approximately one mile upstream of the HORB, in the middle of the San Joaquin River. The color-marked releases coincided with the two VAMP salmon releases. On the night of April 19, one group was released on the ebb tide and one group on the flood tide. The following day, a group was released on the subsequent ebb and flood tides. The process was repeated on April 25.

Fish entrained into the culverts were caught with fyke nets. The nets have a 48 inch cylindrical mouth tapering down to a 1-foot square cod-end, are made of 1/4 inch braided mesh, and five of the nets are 60 feet long and one is 40 feet long. A live-box (15.5 x 19.5 x 36 inches), constructed of perforated aluminum sheet metal, was attached to the cod-end of each net. Each live-box has an aluminum baffle designed to reduce water velocities within the live-box and improve survival of captured fish. The fyke nets were attached to the culvert flanges on April 17. The nets were attached to the culverts by closing the culvert slide gates on the upstream side of the barrier, raising the flanges that slide over the culvert outfalls, and then strapping the nets over the flange. The 40 foot net was attached to culvert number 1 and the 60 foot nets were used on the remaining culverts. The culverts were numbered 1 through 6 with number 1 located next to the shoreline and number 6 located near mid-channel (Figure 4-2). On April 18, the flanges, with the attached fyke nets, were lowered down to the culvert outfalls and the live-boxes were attached to the cod-end of the nets to commence sampling.

The fyke nets were checked on every tide change until May 1. From May 1 through May 11, the nets were checked twice a day; in the morning and the evening. On May 12, the nets were removed. The nets were checked by closing the culvert slide gate, for a period of 30 to 45 minutes, which enabled the live-boxes to be pulled onto a boat so that the fish could be removed and placed into buckets. Once all the nets had been checked and reset, the collected fish were processed. The fish were speciated and counted. Fork lengths (mm) were recorded for up to 50 salmon per live-box. Salmon were checked for a clipped adipose fin and for the presence of a color mark on the dorsal, anal, or caudal fin. Salmon that had a clipped adipose fin were saved for CWT processing. The color and location of the dyed fin was noted for each color-marked salmon. During each net check, culvert

FIGURE 4–2

Culvert Numbers for HORB 2002

number, date, time, water temperature, tidal stage, and diel period was recorded. Except for the CWT smolts, all processed fish were released downstream of the fyke nets into Old River.

Entrainment Monitoring

Loss indices for the CWT salmon released as part of the VAMP survival studies at Durham Ferry and Mossdale were calculated based on data collected from April 18 to May 11. The loss index represents the percentage of CWT salmon entrained into the HORB culverts. As in previous years, the loss index is calculated using the equation:

$$I = (TC/TR)(TT/ST)$$

Where:

TC = Total number of CWT salmon collected in culvert fyke nets
TR = Total number of CWT released
TT = Total time (hours) during the test period
ST = Total time (hours) sampled at HORB during the test period

However, this year, for the nine occasions when a culvert was not monitored and/or the sample was lost, the total catch for the missing culvert was estimated by using the average of the other culverts for that sample period. Consequently, all sampling time is accounted for and TT/ST = 1, and the loss index is equal to TC/TR.

Catch-Per-Unit-Effort (CPUE) for salmon was calculated as the number of fish collected per hour. The percentage of color-marked salmon recovered in the fyke nets compared to the total number released was used as an index of entrainment vulnerability at the HORB.

RESULTS AND DISCUSSION

Results

The HORB was closed on April 15; however, construction on the barrier continued for another week. Due to the large gravel pad in front of the culverts and/or the ongoing construction and the water currents, gravel was swept through the culverts into the nets during the first three days of sampling. Nine samples were lost or not taken because it required considerable time and effort to retrieve the rock filled net from the bottom of the river. Several of the lost samples occurred during a critical time when the CWT and color-marked salmon were approaching the barrier.

The DFG monitored the HORB culverts for 25 days and collected 381 samples. The nets sampled 3,379 hours out of a possible 3,429 hours. Almost 18,000 fish were collected representing at least 28 species and 14 families of fish. No delta smelt, one juvenile steelhead, and 30 adult splittail were entrained. The most abundant species was Chinook salmon, followed by white catfish

TABLE 4–2

The raw abundance and composition of fishes entrained at the HORB in 2002. Chinook salmon catch is divided into CWT VAMP and nonVAMP released salmon, unmarked salmon, and color-marked salmon.

Cyprinidae	1
Red Shiner	1
Black Bullhead	1
Centrarchidae	1
Steelhead	**1**
American Shad	1
Prickly Sculpin	2
Sacramento Pikeminnow	2
Petromyzontidae	3
White Crappie	4
Tule Perch	4
Shimofuri Goby	5
Warmouth	9
Green Sunfish	10
Largemouth Bass	12
Golden Shiner	14
Sacramento Sucker	15
Black Crappie	19
Redear Sunfish	26
Brown Bullhead	26
Striped Bass	27
Bigscale Logperch	27
Splittail	**30**
Goldfish	37
Inland Silverside	88
Bluegill	118
Common Carp	199
Channel Catfish	560
Threadfin Shad	1,219
White Catfish	6,925
Total Chinook Salmon	**8,467**
CWT VAMP Salmon	4,145
CWT NonVAMP Salmon	1,213
Unmarked Salmon	2,748
Color-Marked Salmon	361
Total	**17,854**

FIGURE 4–3

The total daily catch of salmon smolts entrained at the HORB in 2002. The total catch is divided into nonVAMP, VAMP, and unmarked salmon.

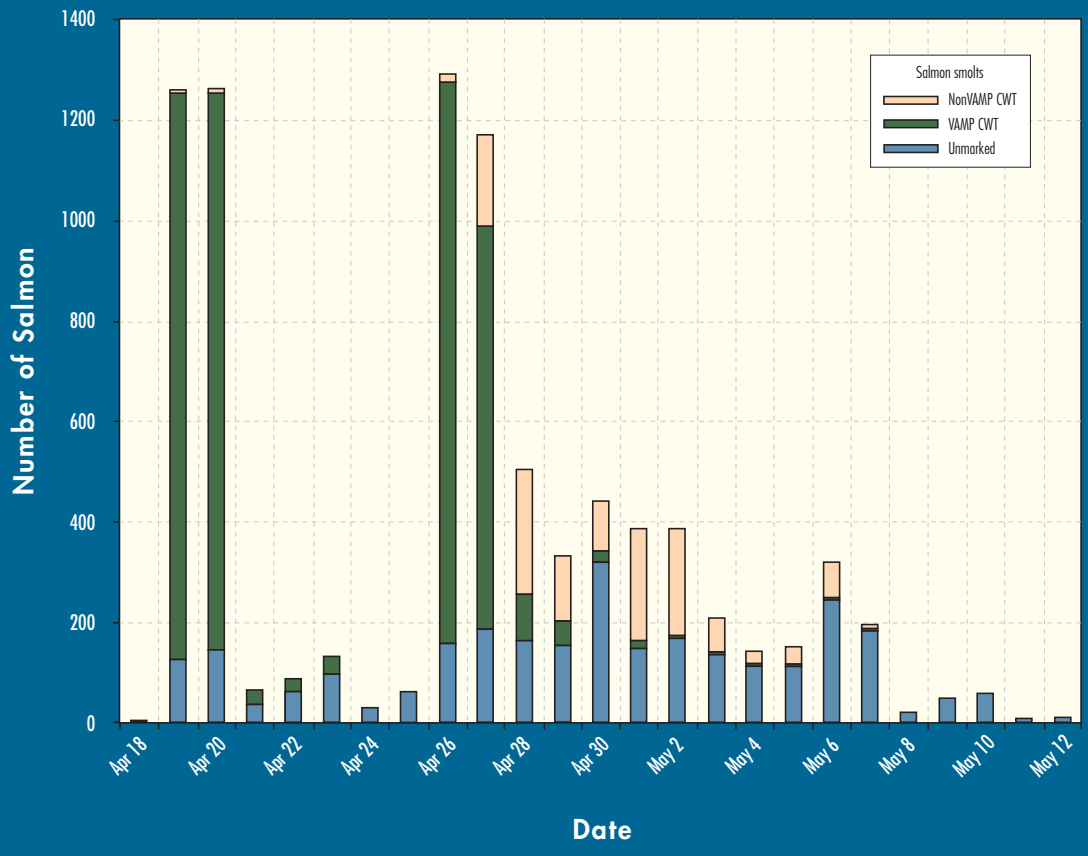


FIGURE 4–4

The number of CWT salmon caught by sampling period during the first VAMP releases in 2002. River stage for Old River is indicated by the line.

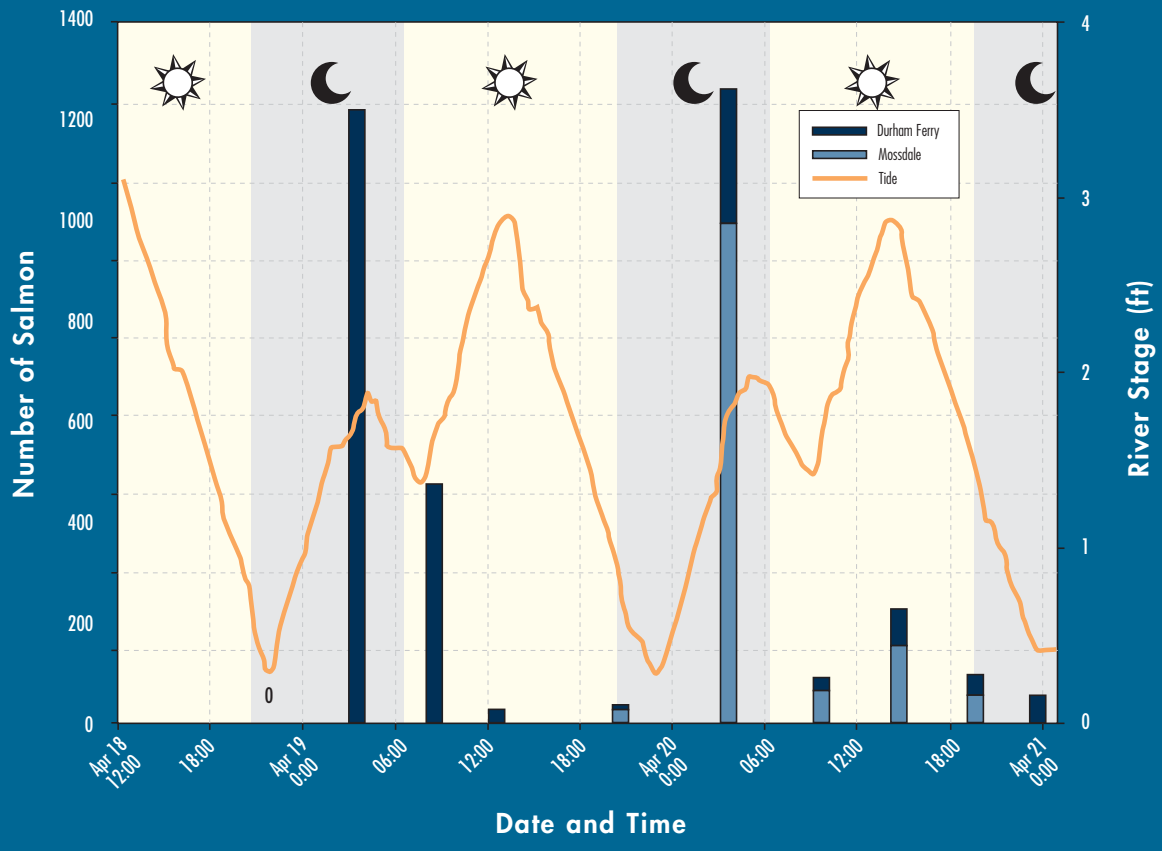


FIGURE 4–5

The number of CWT salmon caught by sampling period during the second VAMP releases in 2002. River stage for Old River is indicated by the line.

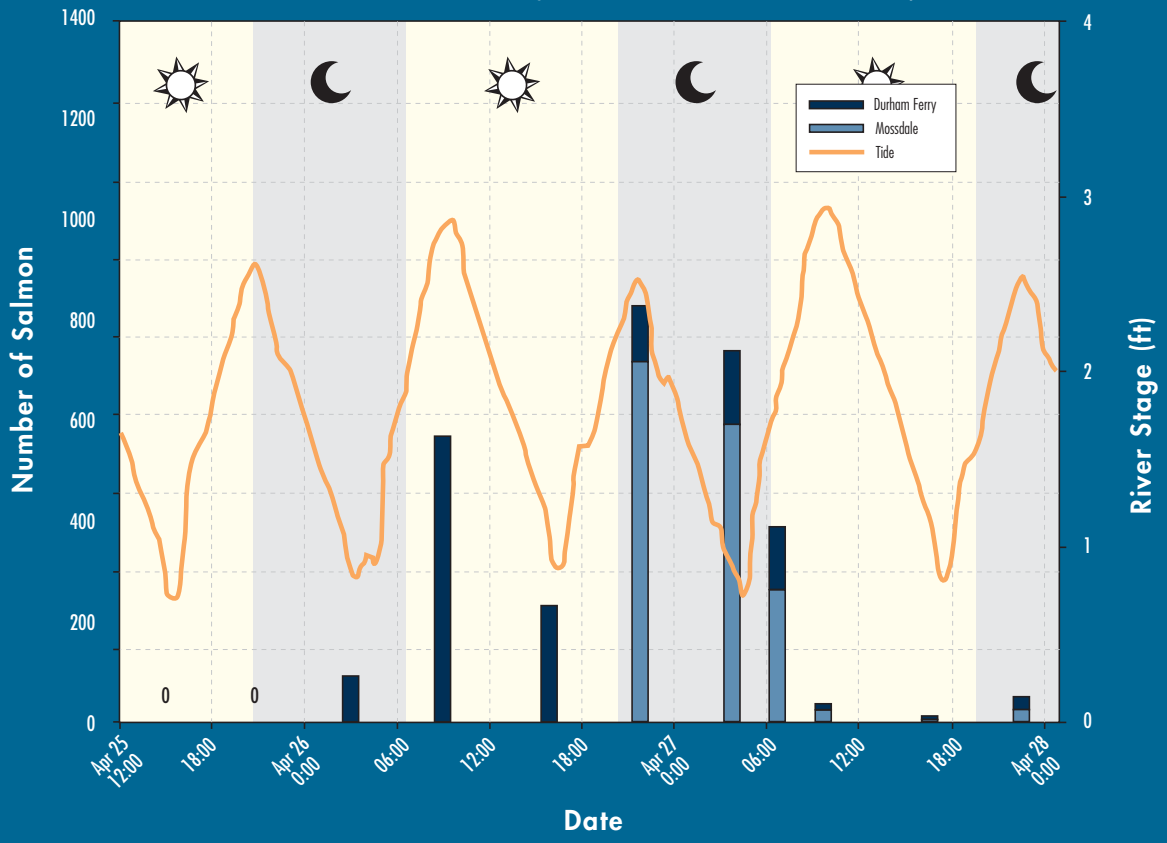
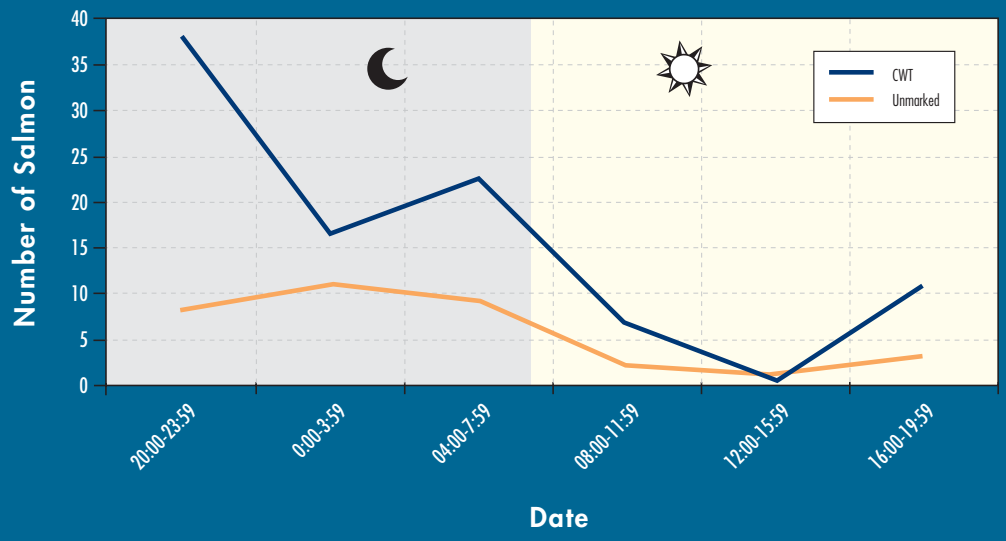


FIGURE 4–6

The average number of CWT and unmarked salmon caught over 24 hours, grouped into 4 hour time blocks.



(*Ictalurus catus*) (Table 4-2). CWT salmon dominated the catch in April and white catfish dominated the catch in May. Of the 8,493 salmon caught; 5,358 had a CWT; 2,748 were unmarked; and 361 had a color mark.

This year the number of CWT salmon increased 323 % over last year's CWT salmon entrainment (1,268 salmon). Salmon smolts were caught throughout the monitoring period although most of the VAMP released salmon were caught within a couple days of their release (Figure 4-3). During the first VAMP salmon release, it appears most of the Durham Ferry CWT salmon were entrained on the night of April 18 and the Mossdale released salmon were entrained on the night of April 19 (Figure 4-4). During the second VAMP release, the Durham Ferry salmon were entrained at a lower rate and few were caught on the night of April 25 (Figure 4-5). In contrast, the Mossdale salmon were entrained at a high rate on the night of April 26. The loss indices for the first Durham Ferry and Mossdale salmon releases were 1.6% and 1.7%, respectively. The loss indices for the second Durham Ferry and Mossdale releases were 1.0% and 2.3%, respectively. The overall loss index for the VAMP released salmon was 1.5%. This year's overall loss index is higher than the previous two years' indices of 0.5% and 0.8%.

TABLE 4–3

The percentage of color-marked salmon entrained for various diel and tidal stages. Due to some salmon escaping from their live-cages, the number of salmon released was estimated for the second releases.

NUMBER OF FISH RELEASED	DIEL	TIDE	FISH ENTRAINED	PERCENT RECOVERED
First Releases (19 & 20 April)				
3,032	Night	Flood	159	5.2%
3,009	Night	Ebb	46	1.5%
3,281	Day	Flood	15	0.5%
3,008	Day	Ebb	62	2.1%
Second Releases (25 & 26 April)				
2,990	Night	Flood	71	2.4%
3,000	Night	Ebb	10	0.3%
3,000	Day	Flood	39	1.3%
3,000	Day	Ebb	5	0.2%

Entrainment of the VAMP released salmon peaked during the late evening to midnight time block, and bottomed out in the afternoon at less than one fish per hour (Figure 4-6). The unmarked smolts had a steady rate of entrainment through the night and a relatively low rate during the day. For the entire monitoring duration, the average CPUE for the VAMP smolts per culvert was 1.6 ± 4.0. The highest CPUEs occurred soon after the VAMP releases, with a maximum CPUE of 32.5 on April 19. The average unmarked smolt CPUE (0.9 ± 1.3) was much lower than the VAMP CPUE. The highest unmarked CPUEs occurred in late April and early May, with a maximum CPUE of 7.5 on April 30.

To address tidal and diel effects, color-marked smolts were released on various tidal and diel period combinations. The first releases went well; however, some problems were encountered during the second release when an unknown number of smolts escaped from the holding pens before their intended release. The color-marked salmon were entrained within 5 hours at the HORB (Figure 4-7). Entrainment rates were higher for the first releases (2.3%) than the second releases (1.0%), but the overall entrainment rate (1.7%) was similar to the entrainment of the CWT smolts (Table 4-3). More smolts were caught at night than during the day, and more smolts were entrained during the flood than the ebb tide.

Salmon entrainment through the middle culvert was high this year (Figure 4-8). The remaining culverts entrained a similar amount of salmon, although the outside culverts (numbers 1 and 6) had a slightly lower overall entrainment rate. Culvert number 4 entrained 39% of the smolts during the day. On the day-ebb tides, culverts numbers 4 and 5 combined entrained almost 75% of the smolts (Table 4-4).

A current velocity meter (Swoffer Instruments, Inc., model 2100) was used on three occasions to estimate flows through each of the culverts. Velocity measurements were made near a low slack tide, a high slack tide, and on the ebb that was close to high slack. Due to the staff shortage and time constraints, only the ebb flow estimates occurred while we were monitoring the fyke nets. The other two readings took place after the fyke nets were removed at the end of the monitoring period. Results from the limited data gathered suggest culverts 2 through 6 had similar flows, and that culvert 1 averaged a little over 10 cfs less than the others (Table 4-4). Flows through the culverts were twice as high during low tide than high tide.

FIGURE 4–7

The total number of unmarked, color marked, and VAMP salmon caught by culvert. The total catch per culvert was adjusted for missing samples.

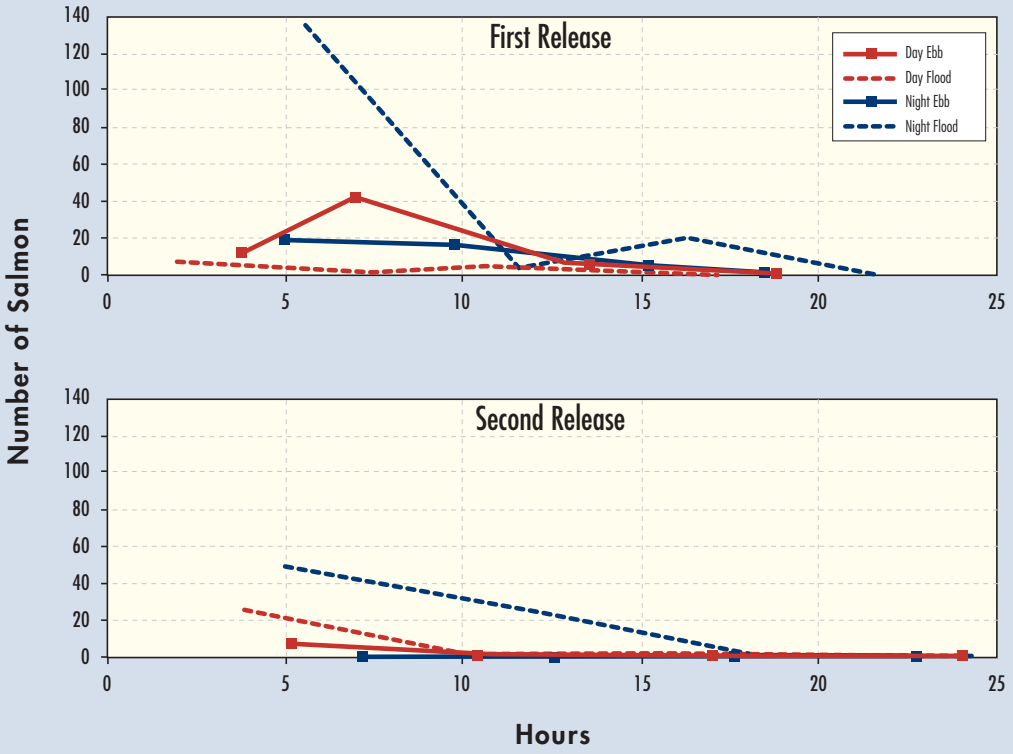


FIGURE 4–8

The total number of unmarked, color marked,and VAMP salmon caught by culvert. The total catch per culvert was adjusted for missing samples.

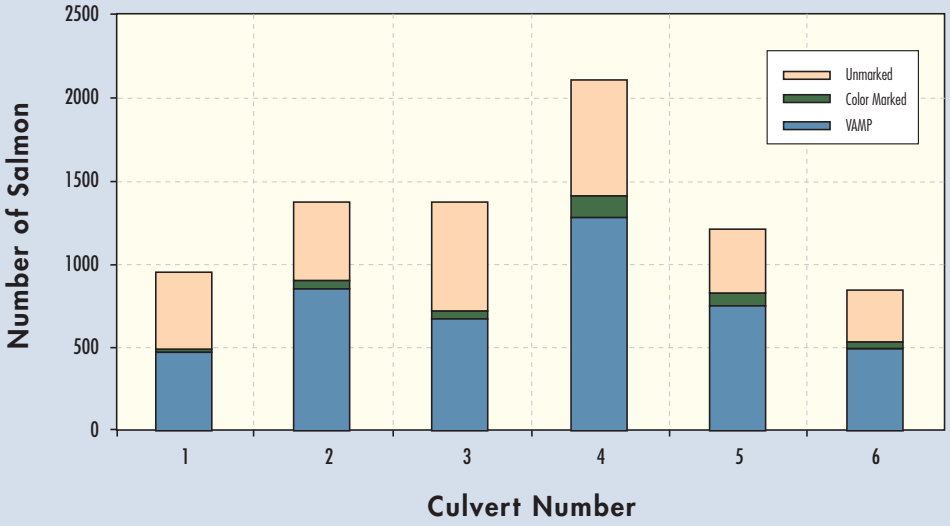


TABLE 4–4

The percentage of the VAMP salmon entrained, by culvert, for various diel and tidal stage combinations (top); and the average flow per culvert taken on three separate occasions (bottom).

ENTRAINMENT (PERCENT)								
DAY/ NIGHT	TIDE	*Culvert Number*						TOTAL
		1	2	3	4	5	6	
Day	Flood	8	18	13	38	11	12	100
Day	Ebb	7	3	6	46	28	9	100
Night	Flood	8	20	16	24	19	13	100
Night	Ebb	17	21	15	28	12	6	100
Wtd. Avg.		10	19	15	29	17	11	100
WATER FLOW (CFS)								
DATE	TIDE	*Culvert Number*						AVERAGE
		1	2	3	4	5	6	
May 16	High Slack	34	42	46	43	42	44	42
May 15	Ebb	48	55	57	53	63	58	56
May 07	Low Slack	70	92	88	92	91	90	87

Discussion

Despite a staff shortage and some sampling difficulties, the DFG successfully monitored fish entrainment at the HORB. Although the culvert monitoring duration increased 38% over 2001, the amount of fish entrained tripled. The increased catch was due primarily to Chinook salmon, white catfish and threadfin shad (*Dorosoma petensense*) which together comprised 93% of the total entrainment. The higher salmon entrainment this year could be due, in part, to less accumulation of debris in front of the culverts; the lower VAMP flows on the San Joaquin River which results in a higher proportion of the river flowing through the culverts; other environmental factors; and factors related to the barrier configuration and operation which may affect the hydraulics surrounding the barrier.

Similarly, the loss indices for the VAMP salmon were higher this year than in previous years. The loss indices within the two 2002 VAMP salmon releases varied. The loss indices for the first VAMP salmon release at Durham Ferry and Mossdale were similar. The loss indices for the second VAMP release were considerably different. The second Durham Ferry salmon release had a low loss index (1.0%) whereas the second Mossdale release, the following day, had a relatively high loss index (2.3%). The low loss index of the second Durham Ferry release was due to the low entrainment of salmon on the night of their release. In contrast, most of the entrained Mossdale salmon were caught the night of their release and they had a relatively high loss index. Typically, VAMP salmon entrainment is highest the night of their release.

The difference in the second VAMP loss indices could be due to slightly different salmon migration routes down the San Joaquin River, differential mortality, temporary debris obstruction of the culverts, and a combination of other environmental and behavioral factors. The majority of the Durham Ferry salmon could have migrated down the center or far side of the channel and avoided the HORB, and the Mossdale fish could have migrated closer to the HORB and were entrained. However, the Mossdale Kodiak Trawl (MKT) results indicate a similar catch trend between releases that was observed at the HORB. The MKT samples for fish in the middle of the San Joaquin River, just upstream of the HORB. The MKT only caught 250 VAMP salmon from the second Durham Ferry release compared to 573 salmon from the first release. The MKT caught more Mossdale VAMP salmon from the second release (41) compared to the first release (24). The MKT data suggests the lower loss indices at the HORB could be reflective of fewer salmon migrating pass the barrier. It is possible the second Durham Ferry released salmon experienced a high rate of mortality before reaching the HORB. The potential source of mortality affecting the second release group is unknown.

In contrast with the loss indices at the HORB, survival estimates from Chipps Island and Antioch (Chapter 5) suggest the second VAMP salmon release at Durham Ferry had a slightly higher survival than the release at Mossdale. The apparently higher numbers of Mossdale salmon at the HORB did not translate to higher survival through the Delta. In fact, few salmon from the second Durham Ferry and Mossdale releases were recovered at Chipps Island and Antioch indicating overall VAMP salmon survival was poor.

More CWT salmon were caught at night than during the day, and more were caught on the flood than the ebb tide. Both the VAMP salmon and unmarked salmon entrainment was relatively low in the afternoon. The larger catch of VAMP salmon at night could be confounded by their daytime release upstream of the barrier. Due to the timing of the VAMP release and the distance of the release sites from the HORB, most of these fish probably reached the barrier at night.

Tidal stage may effect entrainment. The river stage gage near the HORB on Old River indicated a relatively low tide near dusk during the first VAMP releases. The low tide creates a large head difference between water levels upstream and downstream of the barrier. The amount of water passing through the culverts depends on this head difference. Although the head difference at the HORB was shrinking on the ensuing flood tide after dusk, the CWT salmon approaching the barrier were still experiencing a large head difference. Over the next seven hours, on both nights (the ensuing high tide was still relatively low), entrainment of VAMP salmon was high. During the second VAMP release, the high tides occurred at dusk which resulted in less head difference as the smolts were approaching the barrier. This may have affected the number of smolts entrained at the barrier. Even with this smaller head difference, more smolts were still entrained at night than during the day.

Results from the Entrainment Special Study are similar to last year's Entrainment Special Study results. More color-marked salmon were entrained on a flood tide than on an ebb tide, and more were entrained at night than during the day. Marked salmon were entrained at the highest rate during a night-flood, although a large number of color-marked salmon were entrained on the day-ebb during the first release. As with the VAMP released salmon, more salmon were entrained during the first release than the second release. However, the lower entrainment index for the second release was confounded by some color-marked salmon escaping their live-cages.

Results from the 2002 Entrainment Monitoring Study and the Entrainment Special Study suggest salmon are more vulnerable to entrainment at night and on the flood tide. Even the unmarked salmon entrainment is higher at night than during the day. However, the VAMP salmon releases are not timed to address tidal-diel effects and their daytime releases may confound the diel results. The tidal effects on entrainment are still unclear. Water velocities through the culverts are greatest near a low slack tide which should result in the highest entrainment. This was not always the case. Some of the highest catches occurred during the flood. The changing hydraulics surrounding the barrier as the tide changes effects flows near the culverts which could affect entrainment. Also salmon smolt behavior and relative abundance near the barrier probably plays an important role in entrainment vulnerability.

Overall, the highest salmon entrainment occurred in culvert number 4 and the lowest in culvert numbers 1and 6. In contrast, in 2001, culvert number 6 entrained the most fish and entrainment in each culvert decreased as the culverts got closer to shore. This year, culvert number 4 entrained the most fish, and culvert numbers 1 and 6 entrained the fewest. However, since the remaining culverts had similar flows, the reason for the high entrainment in culvert number 4 and the low entrainment in culvert number 6 is still unclear. The reason for the difference in culvert entrainment this year from last year is also unclear. Lower flows on the San Joaquin River and slight differences in culvert angles could affect the flow through the culvert and thus, entrainment.

Unfortunately, the first VAMP release occurred while the HORB was under construction. A lot of time was wasted and several samples lost due to gravel accumulation in the nets. Future VAMP salmon studies should schedule their salmon releases after the completion of the barrier, typically 5 days after the HORB is "closed". To better address diel affects, VAMP should schedule one of the Mossdale releases for night. A night release, instead of the usual day release, could shed some light on entrainment at the HORB. A more systematic monitoring of flows through the culverts during future VAMP salmon releases would help us understand salmon entrainment as related to tide. Future studies should also assess juvenile Chinook salmon mortality associated with the barrier.