CHAPTER 4

Head of Old River Barrier

Installation of the spring temporary Head of Old River Barrier (HORB) was completed on April 9 with the initial operation commencing on April 15. Construction clean-up continued for a short period following the initial operation. 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 and operated, is now fully permitted though 2005.

BARRIER DESIGN, INSTALLATION AND OPERATION

The spring HORB was first constructed in 1992. Since then, the barrier has been installed in 1994, 1996, 1997 (w/two culverts), 2000, 2001, 2002, 2003 and 2004. In 2000–2004 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.

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 2004, the low-flow version was installed.

The dimensions of the 2004 HORB (Figure 4-1) were similar to the 2000, 2001, 2002 and 2003 HORB. The base width of the HORB in 2004 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 beginning in 1997, and six operable culverts were installed beginning in 2000. Operation of the culverts is controlled using slide gates 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 takes this into consideration when making decisions regarding the culvert operations.

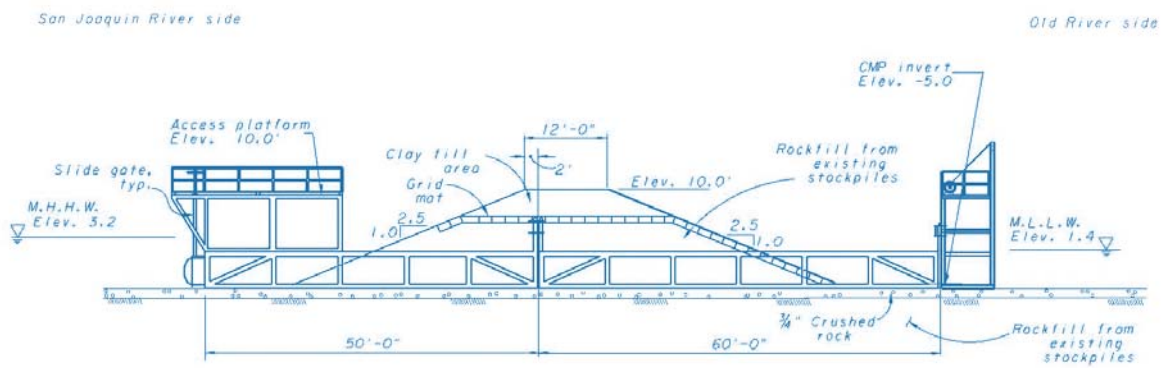
The downstream outlet of each culvert was designed so fyke nets could be attached to evaluate fish passage. DFG staff conducted a fishery-monitoring program as part of the 2004 HORB operations.

Permitting and Construction

The various permit conditions that are placed on the Temporary Barriers Program by the USFWS, National Marine Fisheries Service (NOAA), and DFG, require that the earliest in-water construction activities begin on the Head of Old River (HOR), Middle River (MR), and Old River at Tracy (ORT) barriers, during the Spring barrier installation period, 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

FIGURE 4-1

Spring Head of Old River Barrier Cross Section



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 (1-1-01-F-81)
(item and page of referenced report)

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).*

NOAA Biological Opinion (SWR-00-SA-289: MEA on the proposed ACOE permit (200000696))
(item and page of referenced report)

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, page 6);*
3) The ORT barrier construction may begin on April 1 *(item 2, 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).*

DFG 1601 – HORB (2081-2001-009-BD)

1) HORB Spring Installation – All work in or near the stream zone will be confined to the period beginning no earlier than April.
2) 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

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

TABLE 4-1
HORB Culvert Gate Status

Date	Culvert Number					
	1	2	3	4	5	6
4/14/04	x	x	x	O	O	O
4/15/04	x	x	x	O	O	O
4/16/04	x	x	x	O	O	O
4/17/04	x	x	x	O	O	O
4/18/04	x	x	x	O	O	O
4/19/04	x	x	x	O	O	O
4/20/04	x	x	x	O	O	O
4/21/04	x	x	x	O	O	O
4/22/04	x	x	x	O	O	O
4/23/04	x	x	x	O	O	P
4/24/04	x	x	x	O	O	P
4/25/04	x	x	x	O	O	P
4/26/04	x	x	x	O	O	P
4/27/04	x	x	x	O	O	P
4/28/04	O	x	O	O	P	P
4/29/04	O	x	O	O	O	O
4/30/04	O	x	O	O	O	O
5/01/04	O	x	O	O	O	O
5/02/04	O	x	O	O	O	O
5/03/04	O	x	O	O	O	O
5/04/04	O	x	O	O	O	O
5/05/04	O	x	O	O	O	O
5/06/04	O	x	O	P	O	O
5/07/04	O	x	O	P	O	O
5/08/04	O	x	O	P	O	O
5/09/04	O	x	O	P	O	O
5/10/04	O	x	O	P	O	O
5/11/04	O	x	O	P	O	O
5/12/04	O	x	O	P	O	O
5/13/04	O	x	O	P	O	O
5/14/04	P	x	O	P	O	O
5/15/04	P	x	O	P	O	O
5/16/04	P	x	O	P	O	O
5/17/04	P	x	O	P	O	O
5/18/04	P	x	O	P	O	O

O Open P Partially Open x Closed

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 continued work above the water beyond April 15 to cleanup the site and to demobilize.

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 and Grant Line above Doughty Cut would remain above 0.0 feet MSL and Middle River near Howard Road above 0.3 feet MSL. Based on modeling results and/or field monitoring of water levels in the south delta, three of the six culverts remained open from April 15 until May 19, 2004. Graphical results of the water level modeling are presented in Appendix B. On April 28, 2004 two additional culverts were opened and remained open until May 19, 2004. The sixth culvert slide gate (number 2 culvert) was stuck shut throughout the period the HORB was in place. A summary table of the culvert operation is provided in Table 4-1. Removal of the HORB commenced on May 19, 2004 and was completed by June 10, 2004.

Flow Measurements At and Around Barrier

DWR operates two Acoustic Doppler Current Meters (ADCM) in the vicinity of the HORB, one in the San Joaquin River 1,300 feet downstream of Old River and one in Old River 840 feet downstream of the HORB. The ADCMs record velocity measurements at a 15 minute interval from which flow values can be determined. Table 4-2 lists the daily mean, maximum and minimum flows for the April 1, 2004 through May 31, 2004 period for the two ADCMs. Both ADCMs suffered from technical difficulties that resulted in gaps in the available data for this period. The San Joaquin River below Old River ADCM had an internal battery failure that prevented data collection from April 6 at 18:15 through May 3 at 11:30. The Old River at Head ADCM

TABLE 4-2

Summary of Flows at DWR Acoustic Doppler Current Meters near HORB

Date	San Joaquin River below Old River				Old River below HORB (Old River at Head)			
	Number of Records	Mean Flow (cfs)	Maximum Flow (cfs)	Minimum Flow (cfs)	Number of Records	Mean Flow (cfs)	Maximum Flow (cfs)	Minimum Flow (cfs)
4/01/04	95	158	1,573	-1,547			(b)	
4/02/04	96	427	1,603	-1,262			(b)	
4/03/04	96	487	1,709	-1,281			(b)	
4/04/04	96	554	1,724	-1,171			(b)	
4/05/04	96	555	1,731	-1,262			(b)	
4/06/04	72		1,681	-1,221			(b)	
4/07/04			(a)				(b)	
4/08/04			(a)				(b)	
4/09/04			(a)				(b)	
4/10/04			(a)				(b)	
4/11/04			(a)				(b)	
4/12/04			(a)				(b)	
4/13/04			(a)				(b)	
4/14/04			(a)				(b)	
4/15/04			(a)				(b)	
4/16/04			(a)				(b)	
4/17/04			(a)				(b)	
4/18/04			(a)				(b)	
4/19/04			(a)				(b)	
4/20/04			(a)				(b)	
4/21/04			(a)				(b)	
4/22/04			(a)				(b)	
4/23/04			(a)				(b)	
4/24/04			(a)				(b)	
4/25/04			(a)				(b)	
4/26/04			(a)				(b)	
4/27/04			(a)				(b)	
4/28/04			(a)				(b)	
4/29/04			(a)				(b)	
4/30/04			(a)				(b)	
5/01/04			(a)				(b)	
5/02/04			(a)				(b)	
5/03/04	49		3,293	2,099	40		531	402
5/04/04	96	2,530	3,217	1,337	96	449	522	319
5/05/04	96	2,551	3,353	1,156	96	452	537	300
5/06/04	96	2,498	3,383	905	96	449	540	273
5/07/04	96	2,516	3,424	1,069	96	449	545	290
5/08/04	96	2,483	3,298	961	96	444	531	279
5/09/04	96	2,537	3,303	1,144	96	447	532	299
5/10/04	96	2,656	3,430	1,605	96	459	545	348
5/11/04	96	2,696	3,258	2,033	96	465	527	395
5/12/04	96	2,616	3,116	1,881	96	457	512	378
5/13/04	96	2,557	3,084	1,550	96	449	502	342
5/14/04	96	2,454	3,018	1,480	96	441	508	335
5/15/04	96	2,302	2,936	1,133	96	425	494	297
5/16/04	96	2,241	3,017	858	96	417	501	268
5/17/04	96	2,269	3,141	678	96	420	514	248
5/18/04	95	2,314	3,122	1,085	95	426	512	292
5/19/04	96	2,139	3,001	736	96	410	499	254
5/20/04	96	1,966	2,920	438	96	391	490	222
5/21/04	96	1,602	2,845	51	96	359	482	181
5/22/04	96	860	2,099	-970	9		334	185
5/23/04	96	826	2,107	-919			(c)	
5/24/04	96	686	1,898	-963			(c)	
5/25/04	96	508	1,760	-1,206			(c)	
5/26/04	96	421	1,632	-1,241			(c)	
5/27/04	96	438	1,489	-1,354			(c)	
5/28/04	96	400	1,530	-1,416			(c)	
5/29/04	96	368	1,501	-1,580			(c)	
5/30/04	96	301	1,467	-1,548			(c)	
5/31/04	96	274	1,589	-1,565			(c)	

[a] Internal battery failure.

[b] Meter inoperable while awaiting replacement equipment.

[c] Newly installed equipment unable to log data to data logger.

TABLE 4-3

Estimation of Total Flow Through HORB Culverts

Date	Culvert #4 Measured Flow (cfs)	Number of Fully Open Culverts [1]	Number of Partially Open Culverts [2]	Total Estimated Flow Through Culverts (cfs) [3]
4/14/04	51	3	0	204
4/15/04	65	3	0	204
4/16/04	73	3	0	204
4/17/04	73	3	0	204
4/18/04	77	3	0	204
4/19/04	81	3	0	204
4/20/04	73	3	0	204
4/21/04	72	3	0	204
4/22/04	68	3	0	204
4/23/04	75	2	1	156
4/24/04	73	2	1	156
4/25/04	76	2	1	156
4/26/04	77	2	1	156
4/27/04	72	2	1	156
4/28/04	66	3	2	244
4/29/04	67	5	0	340
4/30/04	62	5	0	340
5/01/04	64	5	0	340
5/02/04	63	5	0	340
5/03/04	62	5	0	340
5/04/04	61	5	0	340
5/05/04	59	5	0	340
5/06/04	62	5	0	340
5/07/04	30	4	1	292
5/08/04	21	4	1	292
5/09/04	21	4	1	292
5/10/04	21	4	1	292
5/11/04	22	4	1	292
5/12/04	22	4	1	292
5/13/04	22	4	1	292
5/14/04	21	3	2	244
5/15/04	20	3	2	244
5/16/04	19	3	2	244
5/17/04	19	3	2	244
5/18/04	18	3	2	244

[3] = [1] x A + [2] x B

A = Flow through fully open culvert. Assumed equal to average of measured flow through culvert #4 while fully open (4/14/04 through 5/06/04) = 68 cfs

B = Flow through partially open culvert. Assumed equal to average of measured flow through culvert #4 while partially open (5/08/04 through 5/18/04) = 20 cfs

TABLE 4-4

Estimate of Seepage Flow Through HORB

Date	Flow in Old River below HORB (Old River at Head ADCM) (cfs) [1]	Total Estimated Flow Through Culverts (cfs) [2]	Estimated Seepage Through HORB (cfs) [3] = [1] - [2]
5/04/04	449	340	109
5/05/04	452	340	112
5/06/04	449	340	109
5/07/04	449	292	157
5/08/04	444	292	152
5/09/04	447	292	155
5/10/04	459	292	167
5/11/04	465	292	173
5/12/04	457	292	165
5/13/04	449	292	157
5/14/04	441	244	197
5/15/04	425	244	181
5/16/04	417	244	173
5/17/04	420	244	176
5/18/04	426	244	182

was out of service April 1 through May 3 at 14:00 while awaiting replacement parts, and then again from May 22 at 02:15 through May 31 due to a technical problem that prevented it from logging data to the data logger.

Similar to 2003, DWR installed a Doppler "Argonaut" flow measuring device inside culvert #4. Data was recorded every 15 minutes during the period when the HORB was in operation. The flow through a completely submerged culvert is primarily dependent on the water levels at the two ends of the culvert, but is also dependent on culvert inlet geometry, slope, size and roughness. If it is assumed that all of these factors are similar for all six of the culverts, then the measured flow in culvert #4 would be a reasonable estimate of the flow in each of the other culverts. Table 4-3 summarizes the measured mean daily flows in culvert #4 and the estimation of the total flow through all of the culverts.

Since the HORB is a rock barrier there is also an unknown amount of seepage through it. The seepage through the HORB can be estimated as the difference between the measured flow at the Old River at Head ADCM and the estimated flow through the HORB culverts. For the period when both those flow records are available, May 4 through May 18, the estimated mean daily seepage averaged 152 cfs with a range of 103 cfs to 190 cfs (Table 4-4).

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. Vernalis flows and stages at the barrier were not high enough in 2004 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 has 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 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; this station is now rated and generating flow data. 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 Memorandum Report "Reclamation District 544 Seepage Monitoring Study 2001–2002". This is an ongoing study to document the seepage monitoring results from Upper Robert Island (Souverville, 2004). DWR also released the latest annual (2002–2003) report. Based on the 2000, 2001 and 2002–2003 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

All six culverts in the Head of Old River Barrier (HORB) were installed for the 2004 VAMP test period, although the number of culverts open varied throughout the period. 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 fish monitoring program was designed and implemented by the DFG to evaluate and quantify fish entrainment at the HORB. The specific objectives of the 2004 fishery investigations were to:

- Determine the total number of juvenile Chinook salmon and other fish species entrained through the culverts at the HORB (Entrainment Monitoring); and
- Determine the percentage of coded-wire tagged (CWT) salmon, released at Mossdale and Durham Ferry, entrained into Old River (Entrainment Monitoring).

Results from 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.

FIGURE 4-2

Culverts in the HORB

Culverts in the HORB were numbered from 1 to 6, with number 1 closest to shore. Culvert number 1 through 3 were closed initially but were opened 8 days later.

Material and Methods

As part of the 2004 VAMP studies, approximately 106,000 CWT salmon were released at Durham Ferry on April 22 and approximately 78,000 CWT salmon were released at Mossdale on April 23. Unlike in previous years, there was no replicate set of CWT releases the following week. Salmon from the VAMP releases were used in the Entrainment Monitoring studies. The secondary Entrainment Special Study was discontinued in 2004, therefore no color-marked salmon were released directly upstream of the HORB.

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, and are made of 1/4-inch braided mesh. Five of the six nets are 60 feet long and one net 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 culverts were numbered from 1 to 6 with number 1 located next to the shoreline (viewed from downstream) and number 6 located mid-channel (Figure 4-2). On April 20, the nets were attached to culvert numbers 4, 5 and 6 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 flanges. 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. Sampling began on the night of April 20. On the evening of April 28, fyke nets were attached to culvert numbers 1, 2 and 3 using the same technique. However, only culvert numbers 1 and 3 were opened that night. Culvert number 2 remained closed throughout the test period due to a malfunction in the slide gate.

The fyke nets were checked on every tide change until May 14, when the nets were removed from the culverts. The nets were checked by closing the culvert slides gate for about 30 minutes, which enabled personnel to pull the live-boxes onto a boat. Fish were removed from the live-boxes and placed into buckets. Once all the nets had been checked and reset, the collected fish were processed. All the fish were identified and counted. 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. A maximum of 50 CWT and unmarked salmon fork lengths (mm) were recorded per live-box. Culvert number, date, time, water temperature, tidal stage, and diel-period were recorded for each net check. Except for CWT smolts, all processed fish were released downstream of the fyke nets into Old River.

Loss indices for CWT salmon released as part of the VAMP survival studies at Durham Ferry and Mossdale were calculated using data collected from April 20 to May 14. The loss index rep-

resents the percentage of CWT salmon entrained into the HORB culverts. The loss index (I) is calculated using the equation:

$$I = (TC/TR)$$

where:

TC = Total number of CWT salmon collected in the fyke nets

TR = Total number of CWT released

Catch-Per-Unit-Effort (CPUE) for salmon was calculated as the number of fish collected per hour per culvert.

RESULTS

The HORB was closed on April 15; however, construction on the barrier continued into the following week. The DFG monitored the HORB culverts for 26 days, for approximately 2,450 hours, and collected 422 samples. Although the nets were attached to the open culverts for the entire test period, not all of the culverts were functioning properly. Mechanical breakdowns of the slide gates resulted in the partial opening of some of the gates throughout the monitoring period (Table 4-1). On April 20, the slide gates on culverts number 4, 5, and 6 were opened to maintain water levels downstream of the HORB. On April 23, prior to the Mossdale salmon release, the gear-box on slide gate number 6 became stripped and failed. The slide gate remained near the closed position until it was repaired the following week. All six culverts were scheduled to be opened on April 28 to maintain water levels downstream of the HORB. Failure of the operating mechanism on gate number 2 caused it to remain closed throughout the remainder of the test period. The slide gate gear box on culvert number 4 failed on May 6 and the gear-box on culvert number 1 failed on May 14.

Almost 8,000 fish were collected representing at least 29 species from 14 families of fish. No delta smelt *(Hypomesus transpacificus),* one juvenile steelhead *(Oncorhynchus mykiss),* and 22 adult splittail *(Pogonichthys macrolepidotus*) were collected. The most abundant species was white catfish *(Ictalurus catus),* followed by Chinook salmon and channel catfish *(Ictalurus punctatus)* (Table 4-5). Of the 1,805 salmon caught; 1,034 had a CWT; 756 were unmarked; and 15 had a color-mark (from fishery studies being conducted in the tributaries). Overall, the number of salmon entrained per hour (0.7) was lower than it was in the past three years (3.4 in 2003; 2.5 in 2002; 1.4 in 2001). Fork lengths were similar between the CWT (85 ± 5.8 mm) and unmarked (83 ± 8.6 mm) salmon.

Salmon smolts were caught throughout the monitoring period (Figure 4-3). Most of the VAMP-released salmon were caught within two days of their release. CWT salmon entrainment was the highest on the night of April 23, especially for Mossdale released salmon (Figure 4-4). The highest CPUEs for VAMP-released fish occurred on April 23: a CPUE of 29.2 fish/hour/culvert. The average unmarked salmon CPUE for the entire monitoring period was 0.3 ± 0.8 fish/hour/culvert. The highest unmarked salmon CPUE (7.0 fish/hour/culvert) occurred on May 9. The loss indices for Durham Ferry and Mossdale releases were each 0.4%. The overall loss index for VAMP CWT salmon was also 0.4%. This year, only one set of VAMP salmon releases occurred. As a result, comparisons will only be made between the one release this year and the first set of salmon releases in previous years. This year's overall loss index was lower than the last two years' loss indices (0.9% in 2003 and 1.4% in 2002) but similar to the 2001 loss index of 0.4%.

Initial entrainment of CWT salmon was similar to the 2002 results. Entrainment was highest in culvert number 4 and lowest in culvert number 6 (Figure 4-5). This is in contrast to 2003 when CWT salmon entrainment was highest in culvert number 6 and lowest in culvert number 4. The unmarked salmon had similar entrainment among the three culverts initially (Figure 4-5). However, once the other culverts were open on April 28, culvert number 6 entrained at least twice as many salmon as the other four culverts (Figure 4-6). More VAMP salmon were entrained at night (650) than during the day (127). Likewise, more unmarked salmon were entrained at night (600) than during the day (157).

TABLE 4-5

The raw abundance and composition of fishes entrained at the HORB in 2004. Chinook salmon catch is divided into CWT salmon, unmarked salmon and color-marked salmon.

Species	Catch
American Shad	1
Prickly Sculpin	1
Red Shiner	1
Sacramento Blackfish	1
Sacramento Pikeminnow	1
Steelhead	1
Golden Shiner	2
Goldfish	2
Tule Perch	2
Petromyzontidae Spp	3
Hitch	4
Shimofury Goby	5
Green Sunfish	7
Black Crappie	8
Largemouth Bass	8
Bigscale Logperch	8
Carp	17
Striped Bass	21
Splittail	22
Ameiurus Spp	30
Redear Sunfish	30
Inland Silverside	54
Sacramento Sucker	87
Bluegill	126
Threadfin Shad	222
Channel Catfish	258
White Catfish	5,235
Total Chinook Salmon	**1,805**
CWT VAMP Salmon	777
CWT NonVAMP Salmon	257
Unmarked Salmon	756
Color-Marked Salmon	15
Total	**7,962**

FIGURE 4-3

The daily average number of salmon entrained per culvert hour at the HORB in 2004. The catch is divided into coded wire tagged salmon (CWT) and unmarked salmon.

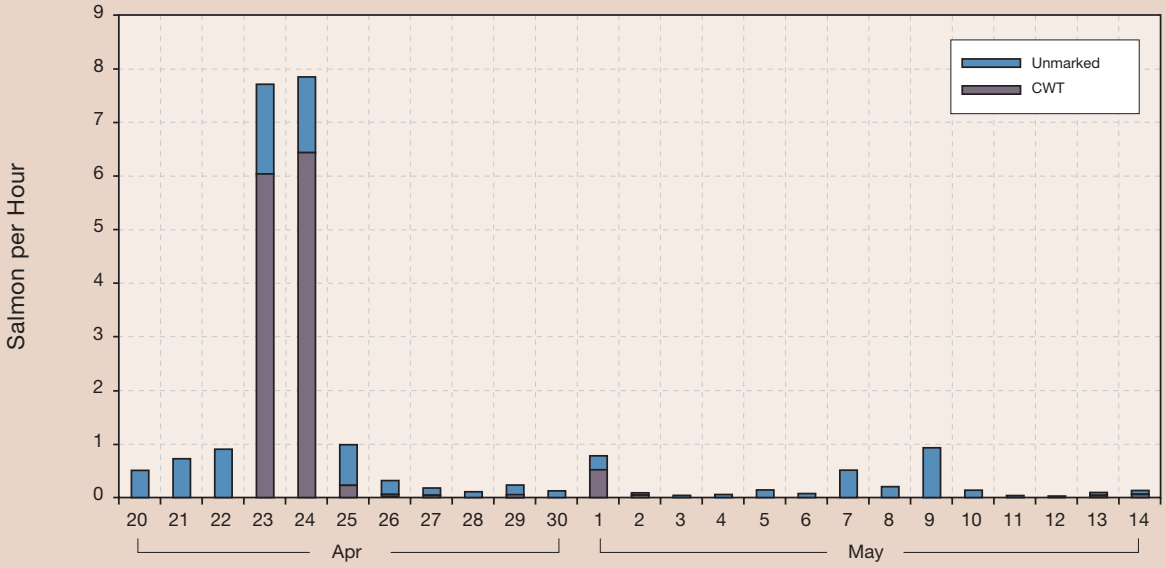


FIGURE 4-4

VAMP CWT salmon entrainment at the HORB. Salmon releases are indicated by the dashed lines. River stage at Old River is represented by the solid line.

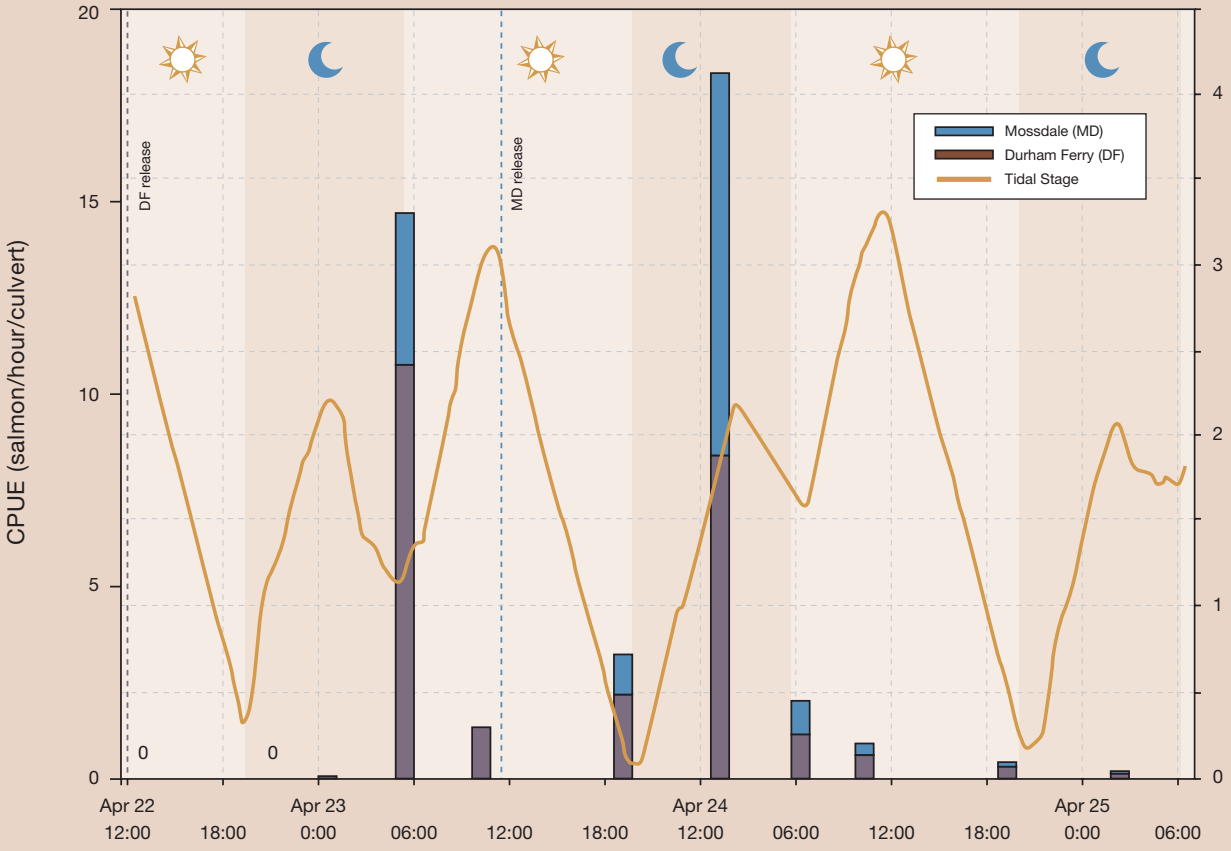


FIGURE 4-5

The total number of Unmarked, Mossdale and Durham Ferry salmon caught, by culvert, for the first eight days of monitoring: April 20 to April 28, 2004. Culverts 1–3 were closed during this time.

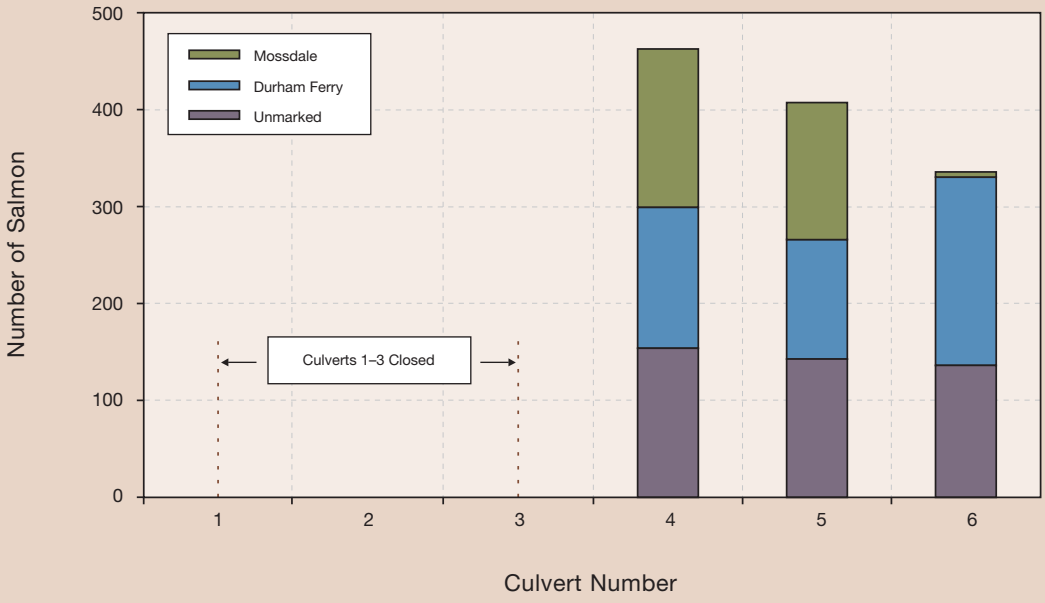


FIGURE 4-6

The total number of Unmarked, Mossdale and Durham Ferry released salmon caught, by culvert, from April 28 to May 14, 2004 when all 6 of the culverts were scheduled to be open. Culvert 2 broke and was never opened.

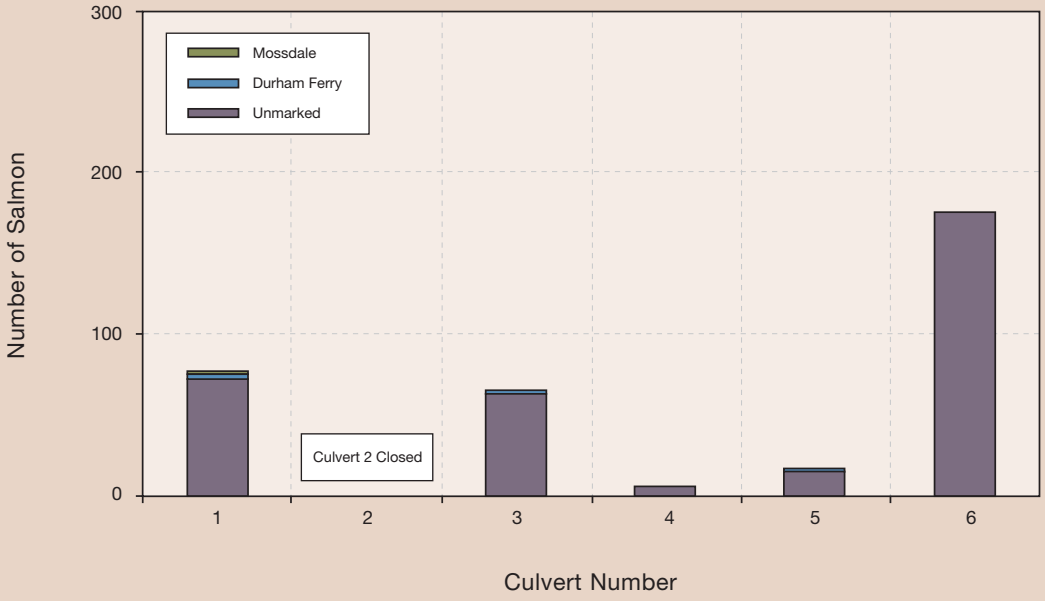
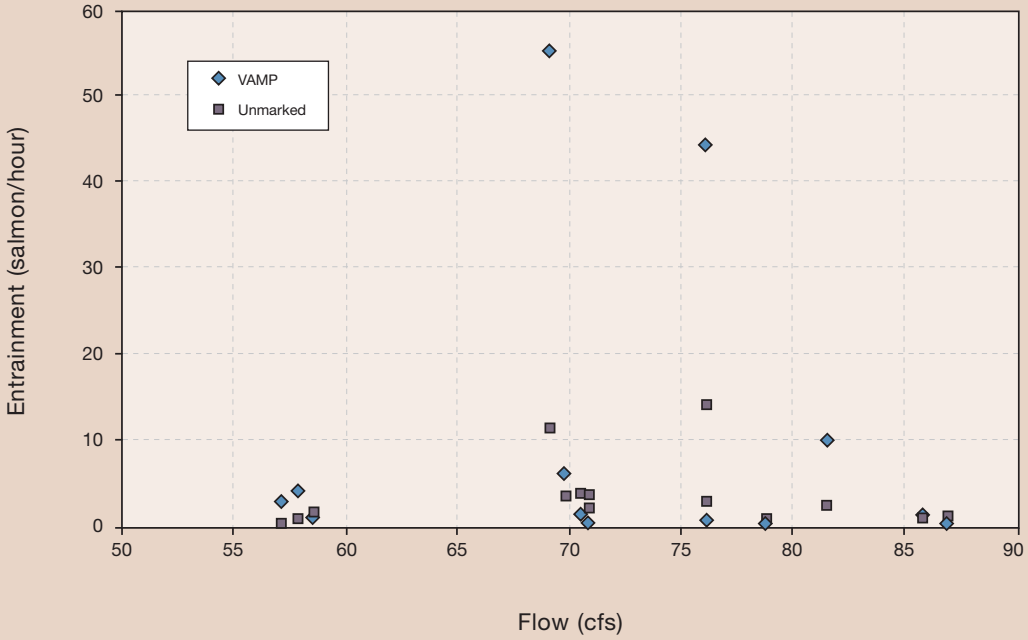


FIGURE 4-7

The relationship between flow and salmon entertained in culvert 4 from midnight April 23 to 8:45 am on April 26, 2004



This is similar to 2002 when about 75% of both the VAMP and unmarked salmon were caught at night. Approximately 52% of the VAMP salmon and 43% of the unmarked salmon were entrained on the flood tide in 2004.

DWR installed a flow meter in culvert number 4. Flow data for culvert number 4 was recorded throughout the monitoring period (Table 4-3). Due to low salmon entrainment, entrainment-flow analyses were limited to the period when most VAMP salmon passed by the barrier: from midnight on April 23 to 8:45 am on April 26. Simple linear regression analysis indicated CWT salmon showed no significant relationship between entrainment and flow (degrees of freedom (df) = 13, Probability (P) = 0.82, Coefficient of Correlation (r^2) < 0.01). Similarly, unmarked salmon showed no significant relationship between entrainment and flow (df = 13, P = 0.86, r^2 = 0.08) (Figure 4-7).

DISCUSSION

The lower catch and broken slide gates made data comparisons among years, as well as within the 2004 VAMP period, difficult. The number of culverts fully open varied throughout the monitoring period. The culvert slide gate gear-boxes became stripped during the monitoring period, causing several of the gates to remain in the partially closed position. Because some fish were able to pass through the partially closed culverts, those culverts were still monitored for fish entrainment. Another problem arose after the CWT salmon were processed. Apparently, 65 Mossdale CWT salmon were caught before they were supposedly released upstream (Figure 4-4). We were unable to determine where the catch error occurred. The processed CWT salmon could have been misdated or labeled but all the salmon are accounted for when compared to the original field sheets. The Mossdale and Durham Ferry CWTs could have been mixed but there is no evidence of cross-contaminated tags. There is no doubt the CWT salmon were entrained in the culverts. There is only a question about when the entrainment occurred. Consequently, the questionable data was retained since the loss index calculations are not affected by when the salmon are entrained.

The color-marked salmon releases conducted in previous years were discontinued in 2004. The 2000 to 2003 color-marked study results were useful but continuing these releases

was thought to provide little additional information. It was felt that the color-marked results were similar to the larger Durham Ferry and Mossdale salmon release results and more information could be gained by using the VAMP salmon releases. However, color-marked salmon might be used in future special studies at the HORB.

More white catfish were entrained then all the other species combined. The 2004 total catfish catch was the second highest. The highest catfish catch (7,485) occurred in 2002. Over the past several years, the field crews have observed partially digested salmon smolts and catfish regurgitating smolts in the live-boxes. Most of the regurgitated salmon appear to be recently consumed which suggests catfish are preying upon salmon in the nets and in the live-boxes, or in front of the culverts. Catfish entrainment tends to increase in May after the VAMP CWT salmon have already passed the HORB. However, salmon entrained in May could be affected by catfish predation. Catfish gut content analysis is the only effective method for determining the extent of catfish predation on salmon smolts at the HORB.

Salmon entrainment appears proportional to the number of fish released upstream. In 2004, roughly half as many VAMP salmon were released upstream of the HORB than in previous years. Likewise, half as many salmon were entrained at the HORB than in previous years. Interestingly, about half as many unmarked salmon were also entrained this year compared to 2003 and about a quarter as many as in 2002. The unmarked catch is comprised of both MRFF and wild salmon. The decline in unmarked catch could be the result of fewer returning adult salmon in the fall of 2003. This resulted in lower MRFF production and lower in-stream spawning which may have caused the decline in outmigrating salmon. Also, unmarked salmon catch tends to increase around the VAMP releases. Since there was no second release, the associated unmarked salmon increase was also absent.

The HORB is fairly effective in keeping salmon on the San Joaquin side of the barrier. Less than one percent of the VAMP CWT salmon released upstream was entrained at the HORB. Salmon entrainment patterns are similar to previous years.

Approximately 85 percent of the entrained VAMP salmon were caught at night. Of the unmarked salmon entrained at the HORB, 80 percent were also caught at night. The data collected over the past four years strongly suggests salmon are more vulnerable to entrainment at night. As mentioned in previous reports, the timing of the salmon releases and the distance the fish must travel to the HORB probably affects diel entrainment patterns. A change in the VAMP salmon release times so that salmon pass the barrier midday probably would not result in the same spiked increase seen at night. This assumption could be tested with an early morning salmon release at Mossdale.

Entrainment between the flood and ebb tides were similar. Salmon entrainment is highest soon after the salmon releases at Durham Ferry and Mossdale. Peak entrainment of the fish released at Durham Ferry occurred after midnight on an ebb tide, and peak entrainment of the Mossdale-released fish occurred before midnight, the following day, on a flood tide. The tide should affect entrainment since the head difference between upstream and downstream water levels at the HORB determines flow through the culverts. If entrainment is affected by the amount of flow through the culvert, then higher salmon entrainment should occur at higher flows at a given salmon density. In culvert number 4, there was no relationship between CWT or unmarked salmon entrainment and flow. Most of the data collected to date suggest entrainment is probably more a function of the number of salmon passing the barrier. The number of VAMP salmon passing the HORB is affected by the size, timing and location of the upstream releases.

This year, the differences in overall entrainment among culverts were affected more by culvert gate operation than in previous years. The partially closed culverts made comparisons among culverts difficult. During the Durham Ferry release, culvert numbers 4, 5, and 6 were operating and entrainment was slightly higher in culvert number 6. Culvert number 6 broke just before the Mossdale release occurred. Subsequently, few Mossdale fish were entrained in that culvert. After culvert number 6 was repaired the following week, it entrained the most salmon. Culvert number 4's entrainment declined to almost nothing after it broke on May 6. The opening of additional culverts, as well as slide gate breakdowns may have changed the hydrodynamics in front of the culverts. This change could effect salmon entrainment among the culverts.

In summary, 2004 culvert gate operation differed from the previous three years. The number of culverts fully open varied throughout the monitoring period due to scheduled gate openings and gates breaking near the closed position. Entrainment results from the past four years and this year's results suggest salmon are more vulnerable to entrainment at night. Diel changes in salmon out-migration patterns are probably a factor in entrainment vulnerability. At night, salmon might be lower in the water column and pass closer to the culverts. The tidal effects on entrainment are still unclear. Water velocities through the culverts are greatest on a low tide, near slack water. However, no significant relationship was found between CWT or unmarked salmon entrainment and flow through culvert number 4. Salmon smolt behavior and relative abundance near the barrier plays an important role in entrainment vulnerability. The highest entrainment has always occurred soon after the upstream VAMP CWT salmon releases.

It is recommended that VAMP continue delaying the first salmon release by at least 5 days after the closure of the HORB. The delay allows for completion of the barrier and minimizes the field crew's exposure to heavy equipment operation. It also allows time for any loose material near the barrier to pass through the culverts before the nets are attached. The 2003 day and evening releases at Mossdale showed markedly different entrainment rates at the HORB. Another paired day-night or early morning salmon release at Mossdale would be useful in further illuminating diel entrainment patterns at the HORB. Flow monitoring on all six culverts is desirable to fully evaluate the flow versus entrainment relationship. Additional flow meters would allow comparison of flow and salmon entrainment rate among culverts.

It is recommended that VAMP continue delaying the first salmon release by at least 5 days after the closure of the HORB. The delay allows for completion of the barrier and minimizes the field crew's exposure to heavy equipment operation.