Entrainment Sampling at the Browns Creek Conduit Intake Structure

Crane Valley Project
FERC No. 1354

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1.0 Executive Summary

In accordance with FERC's July 9, 2004, Order Modifying and Approving Fish Entrainment Study Plan Under Article 407 and FERC's October 28, 2004, Order Denying Rehearing, Pacific Gas and Electric Company (PG&E) consulted with the California Department of Fish and Game (CDFG), the United States Forest Service (USFS), and the U.S. Fish and Wildlife Service (FWS) to identify the water-year type and conducted the first year of fish entrainment monitoring at the Browns Creek Conduit Intake Structure, a part of the Crane Valley Project, FERC No. 1354. PG&E met with representatives of the resource agencies on November 4, 2004, to review the upcoming water-year type and agree on the initiation of fish entrainment monitoring. Though consensus was not reached on a forecast of water-year type, all of the participants agreed that fish entrainment monitoring should proceed.

PG&E designed, built, and tested a custom-fabricated net and a method of securing it to the Browns Creek Conduit walls immediately downstream of the Intake Structure. The net was designed to capture any fish entrained in the flow diverted into the Conduit. A live-car attached to the cod end of the net was used to hold any captured fish for identification.

Fish entrainment monitoring was conducted for up to five consecutive days and nights in the months of January, March, April, June, and July 2005. A lack of flow in the conduit prevented sampling in October 2004 or October 2005. Storm activity and operational constraints limited the monitoring to mostly daylight hours during the winter months. Continuous 24-hour monitoring was possible during April, June, and July when natural flows were lower. Visual encounter surveys of the Browns Creek Conduit were conducted prior to the onset of each sampling period and at the end of each sampling period.

Total fish entrainment was minimal throughout the study. Only three fish were captured in approximately 300 hours of sampling between the months of January and July 2005. No fish were observed stranded in the conduit downstream of the sampling location prior to or following entrainment sampling.

The calculated and measured flow velocities at the Intake Structure were found to be generally less than the swimming and burst speeds of the trout species found in South Fork Willow Creek (SFWC), presenting little risk of entrainment for fish greater than 2 inches in length. The measured water quality parameters (temperature, pH, dissolved oxygen, and conductivity) were within an acceptable range for coldwater salmonid streams.

The conduit provides poor habitat for salmonid populations. In contrast the natural stream channels of SFWC and its upstream tributaries (Browns Creek and Sand Creek) provide adequate to good habitat for salmonid populations. Both brown trout and rainbow trout of various sizes were regularly observed during the entrainment study in SFWC upstream of the Intake Structure.

Only three fish (two brown trout and one rainbow trout) were captured during the entrainment sampling periods, even though 2005 was an above normal water year. The captured fish and other species (three newts and three garter snakes) were in good to excellent physical condition. No mortality was observed and the captured specimens were returned to SFWC in suitable habitat below the Browns Creek Diversion Dam. Entrainment at the Intake Structure does not appear to influence mortality. During a below normal year flow magnitudes and velocities would be lower, and entrainment potential would be decreased.

The Browns Creek Conduit diverts water from SFWC to Bass Lake which provides suitable habitat for the few fish that may be entrained in the canal. The results of the 2005 fish entrainment monitoring show that fish entrainment is insignificant at the Browns Creek Conduit Intake Structure. Any subsequent entrainment sampling in a below normal water year is unlikely to modify this result.

A meeting took place between PG&E, CDFG and USFS on January 20, 2006, in which the participants agreed that the existing results were satisfactory to document low entrainment at the Brown's Creek Diversion and that there was limited value in a second year of data (appendix E).

2.0 Background

PG&E completed one year of entrainment sampling at the Browns Creek Conduit Intake Structure in accordance with FERC's July 9, 2004, Order Modifying and Approving Fish Entrainment Study Plan Under Article 407 and FERC's October 28, 2004, Order Denying Rehearing. Pacific Gas and Electric Company (PG&E) conducted the Fish Entrainment Study (henceforth referred to as the study) to assess the impact of the Intake Structure on aquatic resources at the Crane Valley Project. The study site is located at the Browns Creek Diversion Dam near South Fork Willow Creek in Madera County, California on land managed by the Sierra National Forest. PG&E developed the Fish Entrainment Study Plan to assess the level of fish entrainment at the intake to the Browns Creek Conduit in collaboration with the United States Forest Service (USFS), California Department of Fish and Game (CDFG), and the United States Fish and Wildlife Service (FWS). The proposed study plan was reviewed by the above agencies and approved by FERC. The study was initiated on November 4, 2004, after a meeting with USFS and CDFG during which water year predictions were discussed[1].

1 PG&E met with USFS and CDFG staff on November 4, 2004 to review the water year type and agree on study initiation. A water year lasts from October 1 through September 30 with official forecasts of water year conditions published in May by the California Department of Water Resources. An early water year prediction was attempted by having the participants venture a guess. This resulted in one "wet", one "dry", one "normal", and one "I don't know" forecast of water year type.. However, all of the participants agreed that the sampling should begin in December 2004 or January 2005.

3.0 Browns Creek Diversion Structure Description

The Browns Creek diversion structure is part of the Crane Valley Project (FERC 1354). The structure is located in Madera County, California on lands managed by the Sierra National Forest. The Browns Creek Development consists of the Browns Creek Diversion Dam, the Browns Creek Conduit Intake Structure, the 2-mile-long Browns Creek Conduit, and the Browns Creek Conduit spill channel (a map of the study area was included in the study plan). The Intake Structure diverts water from the South Fork Willow Creek (SFWC), through the Browns Creek Conduit, and into the Browns Creek Conduit spill channel that flows into Bass Lake.

Water is diverted into the Browns Creek Conduit when the unimpeded flow in the SFWC exceeds 20 cfs. The capacity of the canal is limited to 100 cfs and typically operates between 15 and 75 cfs. If the unimpeded flow above the diversion exceeds 75 cfs, the diversion dam spills into SFWC (Merck *pers. comm.* 2005). The FERC license requires a minimum flow of 4.5 cfs or the natural flow (if less than 4.5 cfs) in SFWC below the diversion dam. The necessary flow releases are made from valve in the Intake Structure and are returned to the stream slightly downstream of the Diversion Dam. Water from SFWC is released into the Conduit by two manually-operated, 3'-3" wide by 3'-0" high slide gates located at the right abutment of the Browns Creek Intake Structure. The invert of each slide gate is at El. 3522.3 feet. The dam spill crest elevation is at El 3526.3 feet.

Aquatic habitat within the conduit is unsuitable for sustaining fish populations, because of the semi-circular steel flume or concrete-lined rectangular channel. Flow within the Browns Creek Conduit ranges from 0 to 90 cfs, depending on the daily operating procedures of the Crane Valley Project and natural stream flow variation upstream of the diversion dam. Sand Creek and Browns Creek form the headwaters of the SFWC. Their confluence is just upstream of the Browns Creek Diversion Dam.

4.0 Methods and Materials

PG&E designed, built, and tested a custom-fabricated net and secured it to the conduit walls immediately downstream of the diversion intake. The net was designed to capture any fish entrained in the flow diverted into the conduit. A live-car attached to the cod end of the net was used to hold any captured fish for identification. The net measured approximately 25 feet in length with a mouth opening dimension of 6' L by 4'-3" H and a uniform mesh size of 1/8 inch. The net was secured between a metal frame attached to the conduit walls immediately downstream of the intake (Figure 1). For each sampling event, the net was fished throughout the day and evening[2] to capture diel (daily) variation in entrainment. The net and livecar were checked once in the morning and once during the late afternoon, before dusk. "Daytime" sampling periods continued from the morning net check to late afternoon/dusk net check. The

2 Safety and operational requirements limited sampling periods to daylight hours during storm runoff events. A qualified operator was required to assess safety and operational requirements prior to giving clearance for the sampling to continue.

“nighttime” sampling period began at dusk (the end of the daytime period) and continued through the night until the morning net check. Monitoring of the sampling apparatus was conducted throughout the day and periodically in the evening. Prior to the onset of each sampling period, the conduit was dewatered to install the net. Before flow was returned to the conduit to initiate entrainment sampling, the entire conduit length was assessed to account for any stranded fish.

The net was fished during both daylight and nighttime hours during January, March, April, June, and July to sample conduit flow during significant biological events (i.e., spawning, fry emergence, and fish migration periods). The specific sampling periods and durations were dictated by project operations and natural flows in SFWC. A lack of flow in the conduit prevented sampling in October of 2004 which corresponded with brown trout spawning activity. The first data collection occurred in January 2005. Adequate flows were available for sampling in January, March, April, June, and July. Shortly after the July sampling, the conduit was taken out of service due to the lack of sufficient flow.

Figure 1. Entrainment net and livecar in operation (Photo taken April 2005).

Modifications were made to the net design following a net failure during the January sampling. During this sample event, the net tore open as a result of excessive debris loading and net chaffing on the conduit floor. Modifications to improve the net included constructing a new net with heavier-tear resistant materials, addition of a PVC chafe skirt along the entire bottom length, and bridal rope attachments to relieve weight stress on the cod-end attachment point. These modifications allowed continued sampling

and eliminated subsequent net failures. The original net was repaired for use as a potential backup, but was not used.

The livecar was secured to the cod-end of the net to capture and maintain entrained organisms and debris. The design of the livecar created a low velocity holding environment for fish, while providing sufficient open area for adequate water circulation within the enclosure. During the January net failure, several problems were noted with the connection of the livecar to the net. Several modifications were made to the live car set-up prior to the next sample period. These included strengthening the net to livecar connection by machining knurls into the connecting pipe, adding additional clamps, and suspending the live car within the conduit on cross-beams to alleviate weight stress on the net attachment point. These modifications improved sampling and eliminated subsequent livecar failures.

The contents of the livecar were thoroughly sorted to locate specimens collected and to document debris type and quantity. Fish collected during each sampling period were identified to species, and length and weight measurements were taken. The general condition of captured fish was also noted. Following specimen documentation, all captured individuals were released into SFWC, downstream of the diversion dam in areas of ample water depth. Physical parameters of the water, including velocity, temperature, dissolved oxygen concentration, conductivity, and pH were also measured.

Conduit flows were measured at PG&E gage W-1 located downstream of the sampling location. Diversion point velocities were measured immediately upstream of the intake gates on a daily basis for each sample event with a Marsh-McBurney velocity meter mounted on a modified top-set rod. Point velocities were recorded every 0.25 meters across the face of the intake structure walkway and were measured at three depths: just below the water surface, at 6/10 of total depth, and just above the stream substrate interface. Velocity at the intake structure was also estimated by dividing the flow (in cfs) by the area of the intake opening (in square feet).

5.0 Results

5.1 Sample Periods

The Browns Creek Conduit was sampled for fish entrainment in the months of January, March, April, June, and July, 2005. A tabulation of the sampling periods and weather conditions is shown in Table 1.

The conduit was fished for three days in January 2005. During the first day (January 24, 2005) both day and night sets were conducted. Precipitation, which began at approximately noon on the second day, created a two-fold problem that resulted from increased debris flow. First, debris build-up in the net

Table 1. Summary of sampling periods, duration, total catch, and concurrent weather conditions for entrainment sampling at Browns Diversion Dam (2005). (CL = Clear, PC = Partial Clouds, ST = Storm, RN = Rain).

Set #	Sample Period	Start Date	Start Time	End Date	End Time	Number of fish captured	Daily Total (hours)	Weekly Total (hours)	Weather
1	Day	24-Jan-05	1115	24-Jan-05	1630	0	5.3		PC
2	Night	24-Jan-05	1505	25-Jan-05	0830	0	17.4		PC
3	Day	25-Jan-05	0850	25-Jan-05	1600	0	7.1		ST
4	Day	26-Jan-05	0850	26-Jan-05	1145	0	3.9	33.7	RN
1	Day	29-Mar-05	1030	29-Mar-05	1430	0	4.0		RN
2	Day	30-Mar-05	0920	30-Mar-05	1540	0	6.3		ST
3	Day	31-Mar-05	0855	31-Mar-05	1555	0	7.0		ST
4	Day	1-Apr-05	0900	1-Apr-05	1600	0	7.0	24.3	RN
1	Day	25-Apr-05	1000	25-Apr-05	1630	0	6.5		RN
2	Day	26-Apr-05	0900	26-Apr-05	1620	0	7.3		PC
3	Day	27-Apr-05	0900	27-Apr-05	1615	0	7.3		RN
4	Day	28-Apr-05	0920	28-Apr-05	1615	0	5.6		ST
5	Day	29-Apr-05	1215	29-Apr-05	1620	0	4.1	30.7	RN
1	Day	20-Jun-05	1040	20-Jun-05	1615	1	5.9		CL
2	Night	20-Jun-05	1630	21-Jun-05	0835	1	16.1		CL
3	Day	21-Jun-05	0840	21-Jun-05	1605	0	7.8		PC
4	Night	21-Jun-05	1615	22-Jun-05	0840	0	16.5		PC
5	Day	22-Jun-05	0850	22-Jun-05	1605	0	7.3		CL
6	Night	22-Jun-05	1615	23-Jun-05	0838	0	16.4		CL
7	Day	23-Jun-05	0850	23-Jun-05	1607	0	7.3		PC
8	Night	23-Jun-05	1618	24-Jun-05	0830	0	16.2		PC
9	Day	24-Jun-05	0843	24-Jun-05	1602	0	7.3	100.7	CL
1	Day	25-Jul-05	1030	25-Jul-05	1630	0	6.0		CL
2	Night	25-Jul-05	1650	26-Jul-05	0855	0	16.1		CL
3	Day	26-Jul-05	0900	26-Jul-05	1600	0	7.0		CL
4	Night	26-Jul-05	1630	27-Jul-05	0855	1	16.4		CL
5	Day	27-Jul-05	0910	27-Jul-05	16:01	0	6.3		CL
6	Night	27-Jul-05	1620	28-Jul-05	9:00	0	16.7		CL
7	Day	28-Jul-05	0915	28-Jul-05	16:06	0	6.9		PC
8	Night	28-Jul-05	1615	29-Jul-05	8:55	0	16.7		CL
9	Day	29-Jul-05	0900	29-Jul-05	16:00	0	7.0	99. 6	CL

impeded downstream flow in the conduit downstream of the net; and second, the impeded flow and build-up of debris resulted in net failure. Further night sets where cancelled due to continued precipitation. On the third day, large amounts of debris caused total net failure and the sampling was canceled. As a result, sampling scheduled in February did not occur as the net was being replaced and modified.

In March 2005 the conduit was fished for four days. Sampling did not start on the typical first day of sampling (Monday) due to operational constraints, which were caused by severe storm flow conditions throughout the Crane Valley Project. During this period, flow through Browns Creek Conduit was shut

off to eliminate additional water conveyance into Bass Lake. As a result March sampling began on Tuesday when storm flows subsided in SFWC to a point where water conveyance operation was feasible. Continued precipitation and high debris loads only allowed for daytime sampling when the net could be continually monitored.

The Browns Creek Conduit was fished for five days in April 2005. Security restrictions precluded nighttime sampling. A USFS representative, Kevin Williams, was in attendance to observe one morning of set-up and sampling. In both June and July the Browns Creek Conduit was fished for five days. Both daytime and nighttime sets were conducted during each sampling period.

5.2 Visual Surveys

Visual encounter surveys of the conduit were conducted prior to the onset of each sampling period and at the end of each sampling period, when the conduit was dewatered in order to install and/or remove the net and livecar. During these surveys, two biologists walked the entire length of the conduit in an effort to locate stranded fish that had been entrained into the conduit prior to net installation. No fish were observed stranded in the conduit during the visual encounter surveys.

5.3 Water Quality

Water temperature, dissolved oxygen, conductivity, and pH were measured daily during entrainment sampling in South Fork Willow Creek just upstream of the intake slide gates. Monthly averages of the water quality measurements are shown in Table 2. Water temperature ranged from a mean low of 4.9˚C in January to a mean high of 12˚C in June. The pH ranged from a mean of 8.4 to 8.7 during the months in which measurements were taken (March and April). Dissolved oxygen was high, ranging from a mean of 12.5 mg/L in January to 8.1 mg/L in June. Conductivity was low, ranging from a mean of 14.6 µS in January to 19.2 µS in June. Water quality measurements were not taken in July due to equipment failure.

Table 2. Browns Creek diversion intake water quality measurements, averages by month, 2005 (NA=not available).

	Jan	March	April	June	July
Water Temperature (ºC)	4.9	6.1	7.2	12.0	NA
pH	NA	8.4	8.7	NA	NA
Dissolved Oxygen (mg/L)	12.5	12.4	10.5	8.1	NA
Conductivity (µS)	14.6	14.2	16.1	19.2	NA

5.4 Velocity Measurements

Water velocities were collected daily on all sampling dates and were measured every 0.25 meters across the 3.50 meter face of the intake structure walkway, for a total of 45 individual point velocity measurements. Mean, minimum, and maximum daily measurements just below the water surface, at 6/10 of total depth, and just above the stream substrate interface are reported in Appendix B. Overall mean

water velocities were lowest in January[3], highest in April, and decreased for the remainder of the spring and summer. Mean water velocities per sampling period (calculated as the mean of the daily means for up to sixty point-velocities) were as follows: 0.46 ft/sec (January), 0.59 ft/sec (March), 0.82 ft/sec (April), 0.56 ft/sec (June), and 0.56 ft/sec (July) (Appendix B).

5.5 Flow Measurements

Water level (stage height) and flow was monitored at PG&E gage W-1, located in the Browns Creek Conduit immediately downstream of County Road 274. Mean daily flows (cfs) were calculated by averaging 15 measurements per day. Flows for water year 2005, (October 2004 through September 2005) are tabulated in Appendix B. Flows ranged from a high monthly mean of 62 cfs in March 2005, to a low monthly mean of 0 cfs in October 2004 and September 2005. Flows recorded during fish entrainment sampling periods ranged from 10 cfs (July 29, 2005) to 71 cfs (March 31, 2005) (Appendix B).

Water from SFWC is manually released into the canal by two - 3'3"w x 3'0"h slide gates. Velocity at the slide gates was estimated by dividing the measured flow by the area of the intake opening. A low flow of 10 cfs therefore suggests a velocity of 0.51 ft/sec, while a maximum hypothetical flow of 100 cfs suggests a velocity at the intake of 5.1 ft/sec (Table 3). The highest recorded flows for water year 2004-2005, was 81 cfs suggesting a maximum estimated velocity at the intake of 4.15 ft/sec.

Table 3. Estimated velocity (f/s) at Browns Creek Conduit intake calculated from flow (cfs). Velocity = Flow/ Area of intake opening. Area of slide gate openings = 19.5 sq-ft.

Flow (cfs)	Velocity (ft/s)
10	0.51
20	1.03
30	1.54
40	2.05
50	2.56
60	3.08
70	3.59
80	4.10
90	4.62
100	5.13

5.6 Fish Species and Condition

A total of three fish were captured over the course of the study. Two of these fish were captured in the live car and one was found within the net following conduit dewatering. During the day set on June 20, 2005, one brown trout was captured in the livecar measuring 150 mm (standard length), and weighing 50 grams. The fish appeared in good physical condition with minor signs of fin fray (Figure 2A). A second brown trout was captured within the net during the night set on June 21, 2005. This fish measured

3 January velocity measurements were taken during increasing storm activity on the 24th and 25th with flows too high to safely measure on the 25th. Therefore, the mean January velocity is underestimated. See Appendix B.

209mm (standard length) and weighed 140 grams. This fish was in excellent physical condition (Figure 2B). On July 27, 2005, during the night set a rainbow trout was captured in the livecar. This fish measured 147 mm (total length) and weighed 30 grams. This fish had a severely bruised caudal peduncle (Figure 2C). Other organisms captured in the net over the course of the study included three newts and three garter snakes.

(A)

(B)

(C)

Figure 2. Photos of all the fish collected during entrainment sampling at Browns Creek Conduit (2005); (A) brown trout, 150 mm (SL), 50 g; (B) brown trout, 209 mm (SL), 140 g, (C) rainbow trout, 147 mm (SL), 30 g.

5.7 Salmonid Swimming Ability

The absolute swimming speed of fish increases with body size, because larger fish have both larger fins and greater muscle power. Also, larger fish have greater anaerobic capacity than small fish. Bainbridge (1960, 1962) found that fish swimming speed is generally proportional to body length. A similar relationship was described by Fry and Cox (1970) for salmonids. Fish activity levels may be classified into three major categories: sustained, prolonged and burst swimming. Burst capacity, generally defined as speeds which can be maintained for less than 20 seconds, is the most relevant measurement for determining a fish's ability to escape entrainment.

Numerous investigations have been carried out to determine the burst capacity of fish and possible escape speed. Bainbridge (1960) compared the relative burst speeds of three fish species, and demonstrated that burst speed was largely independent of the species. This finding was subsequently confirmed for salmonids by other investigations (Clay 1961, Ryland 1963) (Table 4).

Table 4. Cruising and burst speeds of salmonids. Cruising speed = about 4 fish lengths/second; burst speed = about 10 fish lengths/second (Clay 1961).

Length (mm)	Length (in)	Cruising Speed (f/s)	Burst Speed (f/s)
25	1	0.3	0.8
50	2	0.6	1.5
75	3	1.0	2.5
100	4	1.3	3.3
125	5	1.7	4.2
150	6	2.0	5.0
175	7	2.3	5.8

Swimming ability and speed are dependent on numerous factors including body size, morphology, temperature, dissolved oxygen concentrations, pollutants, and other environmental factors.

5.8 Catch per unit Effort

Time-based catch per unit effort (CPUE) estimates were calculated by dividing the number of fish captured by the length of time sampled per each collection period (day and night). Fish capture per hour ranged from a high of 0.2 to a low of 0.0 (Appendix B). Throughout the entire study, three fish were caught in 289 hours of sampling, yielding a mean fish per hour of 0.01.

5.9 General Site Observations

General site observations were made during each entrainment event. Juvenile and adult fish were observed swimming and feeding upstream of the Browns Creek intake structure during every sampling period. Only a few individuals were sighted above the intake structure during the colder months (January–April), but greater numbers were observed as stream temperature increased (June–July). For

example, six trout ranging from approximately 100 mm to 200 mm, were observed upstream of the intake during the June sample. These six fish were observed in close proximity to the intake gates (~3 feet) and along the dam wall and bedrock outcropping that abut either side of the intake structure. They were also frequently seen in the pool approximately ten meters upstream of the intake. Observed fish were free swimming individuals (sustained swimming) maintaining a feeding position in front of the intake and did not exhibit swimming stress. When startled, the fish typically darted out of sight into the upstream pool.

Aquatic habitat immediately upstream of the intake structure is highly supportive of salmonid populations. In this area, the diversion dam has created suitable pool habitat conditions in the main thalweg of Browns Creek. Additionally, the water diversion towards the intake structure also provides a suitable low velocity habitat area that changes morphology depending on water stage height. At high stage, this area forms a low velocity pool habitat; at low stage, the area becomes a moderate velocity riffle/run habitat. Trout were observed in both of these habitat areas.

Further upstream, Sand Creek and Browns Creek diverge into separate river systems. Both Sand Creek and Browns Creek exhibit high gradient channels dominated by large boulder substrates. Browns Creek is the major tributary to SFWC, so an upstream visual stream survey was conducted. Habitat in these sections can be generalized as step pool/pocket water habitat. The channels are typical of Rosgen channel types A2 to A2a+. Beyond the steep A-type channel observed just upstream of the dam, which extends approximately one-mile, the channel type changes to a lower gradient B4 channel type. In this area high numbers of salmonids of all life stages were observed.

6.0 DISCUSSION AND COMMENTS

6.1 Fish Community

Fish surveys conducted in SFWC identified four species; rainbow trout (*Oncorhynchus mykiss*); brown trout (*Salmo trutta*); Sacramento sucker (*Catostomus occidentalis*); and green sunfish (*Lepomis cyanellus*) (PG&E 1985, 1995). Rainbow trout and brown trout were the only species encountered upstream of the Diversion Dam (PG&E 1985, 1995). The fish ranged in size from 44 to 226 mm, with roughly half the catch comprising young-of-the-year fishes (PG&E 1985). Of 26 fish collected, 15 were rainbow trout and 11 were brown trout (PG&E 1985). In 1985, rainbow trout were found to be the dominant species upstream of the Diversion Dam (PG&E 1985), while brown trout were most dominant in samples collected in 1995 (PG&E 1995). Downstream of the Diversion Dam, trout comprised over 76% by number and 88% by biomass of 159 fishes collected from three locations in SFWC (PG&E 1985). Moderate numbers of Sacramento suckers and a single green sunfish were found as well (PG&E 1985).

Life stage histories of both rainbow trout and brown trout are relevant to the study of fish entrainment at the Browns Creek Diversion Dam. Rainbow and brown trout life history characteristics based on

descriptions outlined by Moyle (2002), are contained in Appendix C. Table 5 provides a general overview of the life stages that could be affected by entrainment and the timing of the stages by species. In order to maximize the catch probability of all potential life stages present in Browns Creek, sampling was targeted during months of highest mean flow, peak spawning periods, and young-of-year emergence.

Table 5. Life history stages and biological timing periods for fish species present upstream of Browns Creek Conduit. Highlighted months indicate occurrence of entrainment sampling.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
RAINBOW TROUT												
Spawn							X	X				
Young-of-year								X	X	X		
Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
Adult	X	X	X	X	X	X	X	X	X	X	X	X
BROWN TROUT												
Spawn	X											X
Young-of-year						X	X	X				
Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
Adult	X	X	X	X	X	X	X	X	X	X	X	X

Total fish entrainment was minimal throughout the study. Only three fish were captured in approximately 300 hours of sampling between the months of January and July, 2005. No fish were observed stranded in the conduit downstream of the sampling location prior to or following entrainment sampling.

A potential for fish entrainment was suggested by the capture of 90 fish within the Browns Creek Conduit spill channel in surveys conducted in 1984 (p. 54 Supplemental EA). The conduit spill channel is located approximately two miles downstream of the diversion structures and terminates at Bass Lake. The results of this study indicate that fish in South Fork Willow Creek are subject to low entrainment rates. It is therefore likely that some fish enter the spill channel from Bass Lake when the lake is at or near full capacity rather than through the diversion at South Fork Willow Creek. At high lake levels the channel is inundated. The species captured in the spill channel, including rainbow trout, brown trout, green sunfish and prickly sculpin, show that many of the spill channel fish reside in the lake. Only rainbow trout and brown trout are known to occur upstream in the vicinity of the diversion structure.

6.2 Sampling Constraints

The higher than normal flows caused a number of sampling problems including high debris loading of the stream channel and the intake. The net was often quickly filled with leaf litter, branches, pine cones, pine needles, and other drift materials (Appendix A). This required constant attention as the net completely enclosed the conduit. Retardation of flow increased conduit water level and created the risk of overflow. An example of the flow retardation encountered during sampling activity is illustrated in Appendix B.

During extremely high runoff periods such as the January and March sampling periods, safety and operational reliability were major concerns. Another major safety concern was access to the diversion structure at night during storm conditions. Sampling was restricted to day time hours during significant storm events.

In addition to the safety and operational reliability concerns, there were security events that occurred during sampling that restricted the duration of samples. Increased security needs reduced the availability of qualified personnel to operate the intake equipment and provide safe clearances for the study personnel to enter the ditch to maintain the net and other study equipment.

6.3 Entrainment Potential

The entrainment potential of fish due to water velocity varies with fish body size. Early life history stages (young-of-year and 1+ individuals) likely face the greatest risk. No fish less than 5 inches (~125mm) were caught during the course of the study, although as many as six fish, (all less than 5 inches in length) were observed in the channel upstream of the intake during sampling. The three entrained fish ranged from 150 mm to 209 mm in total length. Trout of this size have estimated burst speeds greater than 5 ft/sec, which exceeds observed intake velocities.

Velocity measurements across the face of the intake suggest fish greater than 2 inches are rarely at risk of entrainment. The maximum measured point velocity in the water column throughout all sampling dates was 2.4 ft/sec, recorded in April near the water surface. This velocity roughly corresponds to the burst speed potential of a trout 3 inches in length. Average mean velocities were generally closer to 0.4 to 0.8 ft/sec, corresponding to burst speed potential of a trout one inch in length or less. The maximum estimated velocity at the intake opening based on flow was 3.6 ft/sec. This rate roughly corresponds to the burst speed of a trout greater than 4 inches in length. The fact that all entrained fish likely had the swimming capabilities to escape the intake approach velocities, and that no small fish were captured, suggests that intake velocity alone may not determine fish entrainment at the intake structure.

6.4 Water Temperature Effect

Water temperature and seasonality appears to be related to overall catch rates observed during the entrainment study. Temperature is an important environmental determinant of physiological activity and performance of ectothermic (cold-blooded) vertebrates (Cossins and Bowler 1987, Bennett 1990). Moreover, the interaction between temperature and swimming capacity is an important factor determining microhabitat use (Taylor 1988) and migration (Heggenes and Traaen 1988). Ambient water temperatures dictate a fish's internal body temperature. At temperatures in the range of 5°C to 10°C, which is similar to temperatures observed from January through April (Appendix B) in SFWC, individual performance potential of fish was between 10 and 30 percent (Ojanguren and Brana (2000)). Low physical

performance at low temperatures causes fish to be less active during cold periods. Furthermore, fish do not need to forage as frequently because low water temperatures reduce metabolic demand. As water temperatures increased in SFWC during June and July (~12°C), catch rates also increased. Due to the minimal catch rate observed, this relationship could not be confirmed.

6.5 Water Quality

Water quality conditions measured in the conduit were similar to South Fork Willow Creek and are within a typical range for streams in the study vicinity. No abnormalities were observed in measured water quality parameters. Monthly measures of dissolved oxygen, temperature, pH, and conductivity (Appendix B) are all within an acceptable water quality range for coldwater salmonid streams. Therefore, it is presumed that water quality factors did not significantly effect fish entrainment at Browns Creek during the study period.

6.6 Aquatic Habitat

Habitat within the conduit is not suitable for sustaining salmonid populations due to poor habitat quality (steel and concrete surfaces). Substrate materials are excluded from the conduit by a sand trap located just downstream of the intake structure. As a result, insufficient habitat complexity exists to support fish or invertebrate life. However, it has been observed in the past that fish do occasionally stray into the conduit, and therefore experience a limited degree of entrainment[4]. Whether entrained fish continue downstream to Bass Lake is unknown, but the lack of any barriers or holding areas in the conduit and the rapid travel time would likely support a successful transit.

Aquatic habitat immediately upstream of the diversion dam supports a viable trout population. Aside from the habitat area immediately upstream of the diversion dam, the stream channel type (Rosgen A-type) observed beyond this point for approximately one-mile is not conducive to high levels of salmonid biomass due to steep stream gradient (>4%) and low habitat complexity inherent to boulder/bedrock A-type channels. The presence of highly suitable habitat upstream of the A-type section allows for persistence of higher biomass. Consequently, fish migrating downstream from the upper stream reach encounter the high gradient section and likely continue downstream in search of more suitable habitat area. The first suitable habitat is encountered just upstream and downstream of the diversion dam. At this point, fish may hold in the pool area upstream of the diversion dam, travel over the diversion dam with the primary thalweg, or continue voluntarily or involuntarily through the intake gates.

4 Dale Mitchell, a Senior Fisheries Biologist with the California Department of Fish and Game, observed a brown trout in the sand trap just below the intake structure during project relicensing studies.

7.0 CONCLUSIONS

Entrainment studies typically attempt to assess the number of fish carried to a powerhouse, and their fate after passing through it. The entrainment study for the Browns Creek Conduit is atypical, in that the conduit does not deliver water to a powerhouse, but to Bass Lake, which can provide suitable habitat for the fish transported to it.

The ability to sample fish entrainment varies significantly with flow and debris load conditions, which is a direct function of season and precipitation. High flows generally caused by precipitation and snowmelt create substantial suspended debris loads that lessen sampling effectiveness.

Low mean water velocities measured upstream of the intake gates compared to burst speeds of trout indicate little risk to even the smallest age classes of fish. Small trout, including young-of-year and juveniles (1+), would have to be extremely close to the intake gates to be entrained. Large trout can easily avoid entrainment based on swimming performance literature. Considering that only trout greater than 5 inches in length were captured, which have the capabilities to easily escape the intake approach velocities, water velocity alone may not determine fish entrainment at the intake structure. Entrainment may be voluntary by larger individuals while juveniles may be able to adequately avoid entrainment. For all the fish collected, physical condition was good to excellent; no mortalities were observed, therefore, it is assumed that entrainment at the intake does not directly influence mortality.

Very few fish were captured during entrainment sampling periods, even though it was a wetter than normal water year. Given the high magnitude flows encountered in 2005 and the insignificant results obtained from sampling activities at the intake, additional sampling during a dry year does not appear to be warranted as entrainment potential would be expected to decrease under lower flow conditions.

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