1995 EVALUATION OF JUVENILE CHINOOK SALMON TRANSPORT TIMING IN THE VICINITY OF THE NEW FISH SCREENS AT THE GLENN-COLUSA IRRIGATION DISTRICT'S SACRAMENTO RIVER PUMP STATION

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PROJECT LOCATION

The Glenn-Colusa Irrigation District's (GCID) Sacramento River pumping station is located near Hamilton City approximately 100 miles north of the city of Sacramento on the west side of the main-stem Sacramento River and 206 river miles upstream from San Francisco Bay (Figure 1). The pumping station is located on an oxbow off the main-stem river with fish screens positioned upstream of the pumping station (Figure 2). Water flows from the river into the oxbow, through the fish screens and is pumped up into GCID's main irrigation canal as shown in Figure 3. The remaining flow in the oxbow passes in front of the screens or through two fish bypasses (when the bypasses are open) and then back to the main-stem Sacramento River via a return flow channel (Figure 2).

BACKGROUND

In 1994, GCID initiated biological investigations of new interim flat-plate screens installed near the GCID Sacramento River pumping station. The new screens were installed as a measure to increase fish survival at the site until a long-term solution for fish protection and water supply could be developed and implemented. The report on the 1994 investigation provided a history of fish protection at the site and described in detail the results of biological evaluations performed during the spring and summer of 1994. For information on those investigations, readers of this report should refer to Vogel and Marine (1995). As a result of the 1994 studies, conclusions and recommendations were formulated to reduce fish passage problems and fish mortality in the vicinity of the new fish screens. In particular, as related to this report, the following applicable findings were made and recommendations were implemented prior to the 1995 investigations:

> "*The roadway and culverts downstream of the screens present a significant problem to downstream migrant salmonids. The configuration of the roadway and culverts dramatically altered the natural downstream migratory behavior of salmonids and caused young fish to be more susceptible to predation. It is also probable that the roadway affects the presence of predatory fish. For example, the roadway may cause predatory fish to accumulate in the channel leading to the roadway culverts and possibly in much of the upstream channel in front of the fish screens. We recommend the roadway, culverts, and channel leading to and from the roadway be reconfigured with the following objectives:*
>
> - *Provide uninterrupted surface flow to minimize downstream migration delay. The intent should be to allow unimpeded migration of both young salmonids and larger predatory fish.*
>
> - *Avoid placement of structures across the channel which may alter the natural downstream migratory behavior.*

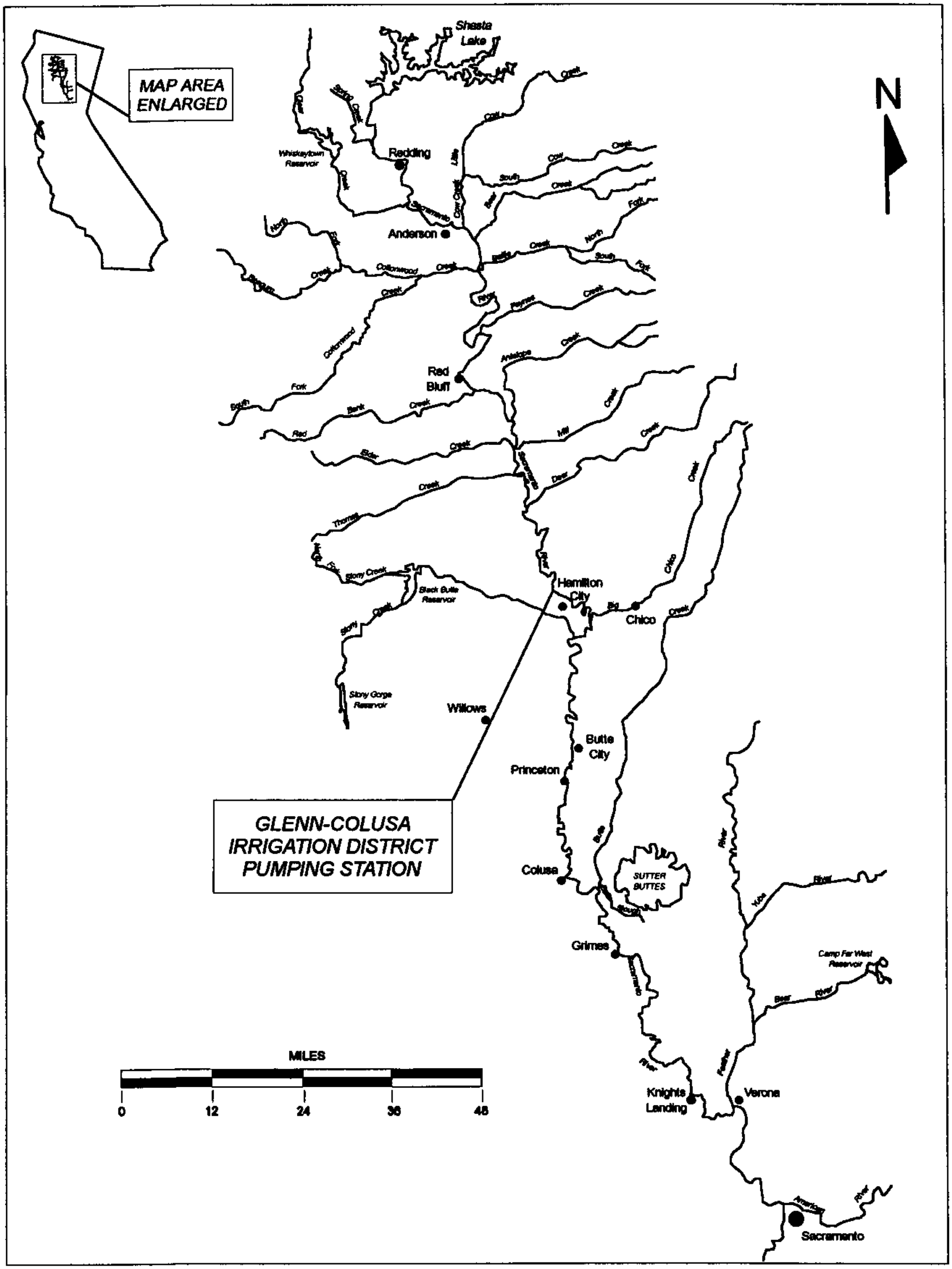

Figure 1. Sacramento River showing location of Glenn-Colusa Irrigation District's pumping station.

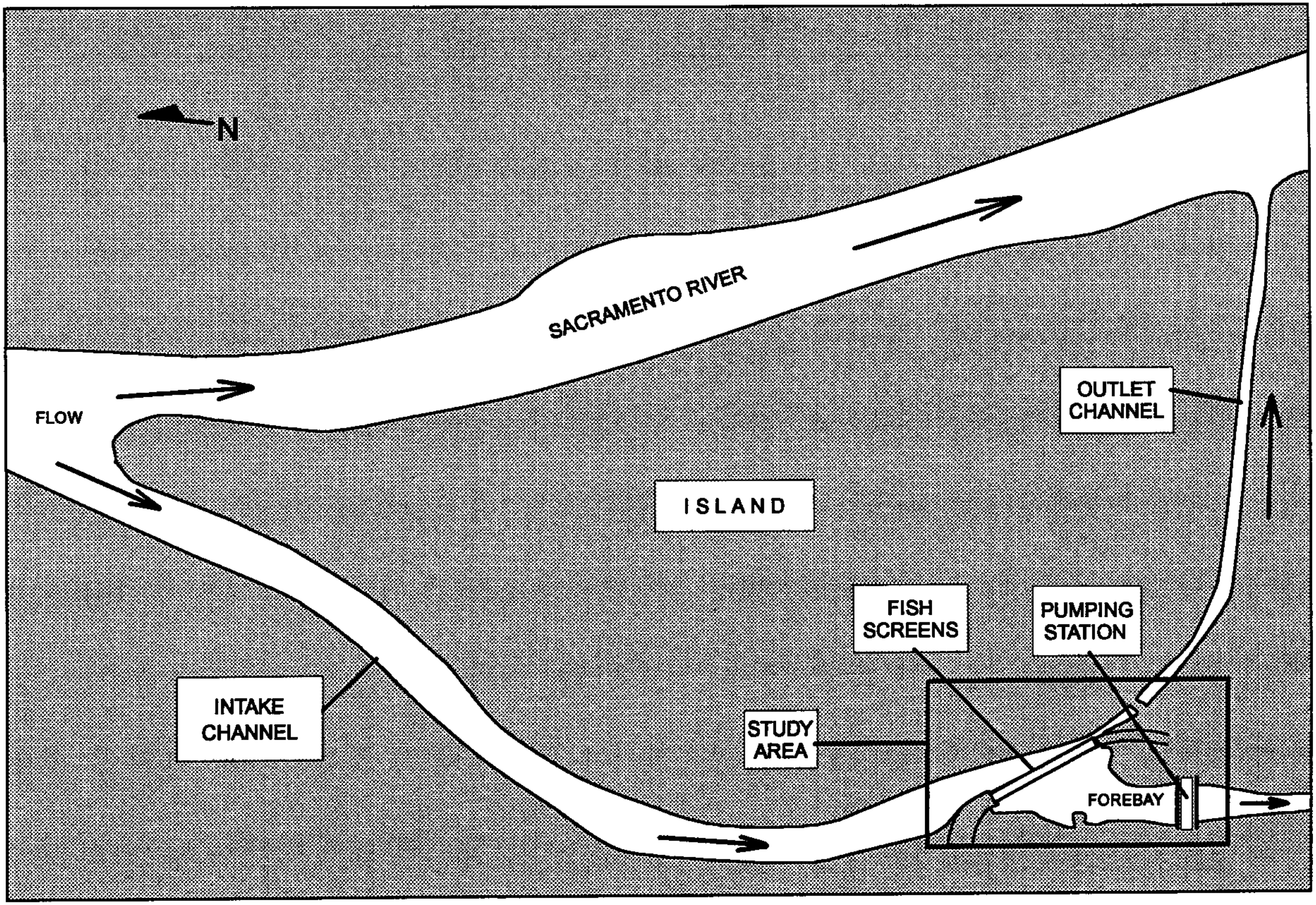

Figure 2. Sacramento River in the vicinity of Glenn-Colusa Irrigation District's pumping station showing the location of the 1995 fish protection investigations.

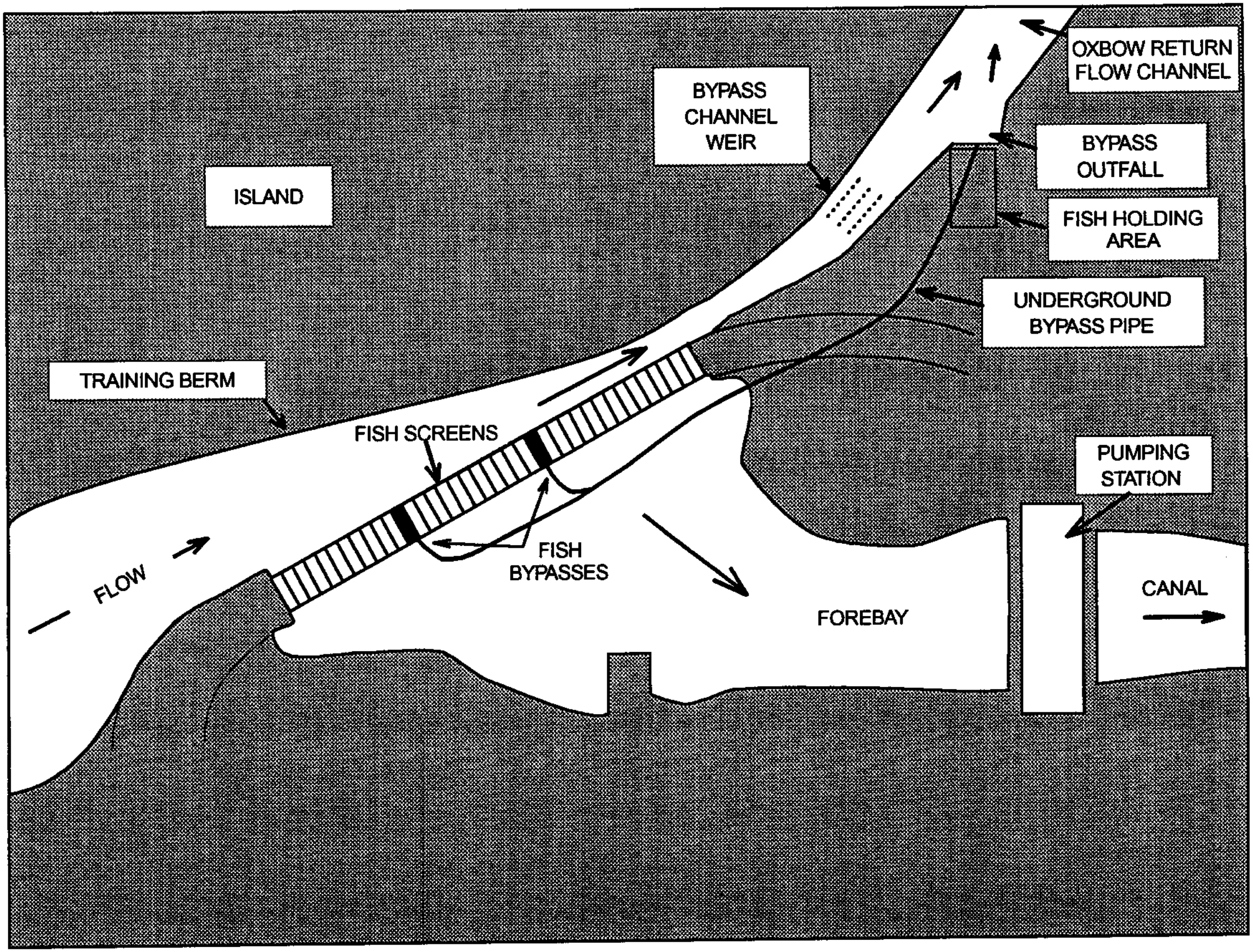

Figure 3. Layout of the Glenn-Colusa Irrigation District fish screens.

- *Minimize any eddies where natural downstream salmonid migration may be delayed and which predatory fish may utilize as holding/feeding habitat.*

- *Minimize turbulence to minimize any disruption in natural downstream migrant salmonid migratory behavior. The intent should be to avoid disorientation of downstream migrants and disruption of fish schooling behavior. We believe that maintaining natural fish shoaling behavior as fish migrate unimpeded past the site is one of the best natural defense mechanisms to minimize fish losses to predation.*

The feasibility of eliminating the backeddy in front of screen panels 39 and 40 should be examined. Elimination of this backeddy will reduce hazards for downstream migrant salmonids by minimizing disruption in their natural migratory behavior and reducing predatory fish holding/feeding habitat. If the backeddy and problems at the roadway are eliminated, additional fish transit timing tests could be easily conducted and compared to 1994 tests to determine if and how fish migration rates are improved." (Vogel and Marine 1995)

Evaluations performed during the 1994 biological evaluations using chinook salmon with passive integrated transponders (PIT tags) provided dramatic evidence of specific fish transport timing at various locations in the vicinity of the new fish screens. Use of the PIT tags at GCID was one of the first successful applications of this technology for this type of fishery resource investigation in California. The 1994 results clearly demonstrated that the roadway and culverts downstream of the fish screen structure and the large eddy at the upstream portion of the screens (i.e., at screen panels 39 and 40 in front of the dredge bay) created significant problems impeding the natural downstream migration of fish. These areas were also observed to harbor substantial numbers of predatory fish.

Once modifications previously described were completed, the follow-up evaluations were performed to determine the biological effectiveness of the measures for downstream migrant salmon. Because of the successful performance of the approach used in the 1994 biological study, the techniques to assess fish transport timing in 1995 were the same as those employed during 1994. Results of the 1995 tests would help determine if fish protection at the site was improved by decreases in fish transit timing (e.g., reduced exposure time to predators).

This 1995 report describes the results of the biological evaluation of the new screens conducted during the summer of 1995.

PURPOSE OF THIS EVALUATION

The purpose of the 1995 fish screen evaluation was to determine travel time of juvenile salmon past the new screens following channel and screen modifications recommended from the 1994 study. This information on specific attributes and biological performance features of the new fish screens would be useful for evaluating proposed future fish screen designs and for identifying a long-term solution for fish protection at the GCID pumping station. The information would also be used to improve the interim fish screen performance until such time as the long-term solution is in place near the pumping station.

METHODS

Source of Fish Used for Tests

Juvenile chinook salmon used for these investigations were obtained from the California Department of Fish and Game's (CDFG) Feather River Fish Hatchery. Juvenile salmon were selected to be generally of a size in the range 80-110 millimeter (mm) fork length (FL), which was similar in size to those fish used in the 1994 study.

Fish Marking/Tagging Procedures

A tagging station at the hatchery was set up in the hatchery building with four 8-foot x 3-foot x 1.9-foot rectangular, aluminum, flow-through tanks with access to the hatchery cold-water supply and floor trough drains. A manifold with individual valves for each tank provided water to each tank. Stand pipes were used to regulate water levels in the tanks. Tables were set up at one end of each of the holding tanks for organizing marking equipment and to provide work stations for fish taggers. Net pens constructed of 1/4-inch diameter stainless steel rod frames with knotless-nylon, 1/8-inch- or 1/4-inch-Delta mesh netting were used to hold tagged fish.

Passive Integrated Transponder (PIT) Implantation

Implantation of PIT tags in juvenile salmon for investigations of individual fish behavior was conducted at Feather River Fish Hatchery. Because of the surgical methods required for this procedure, fish were tagged at the hatchery where water temperature was cooler than at the pumping plant and transport stresses could be avoided prior to tagging. The procedure of Prentice *et al.* (1990) was followed for PIT tag implantation. A spring-loaded injector with a 12-gauge veterinary vaccinating needle loaded with a PIT tag, both sterilized with an activated iodophor (Veterinary grade Betadine) for at least 3 minutes and rinsed with sterile physiological saline (9 grams (g)/liter sodium chloride), was used to implant the tag in the peritoneal cavity of the fish. Fish were anesthetized before PIT implantation in groups of 25 to 30 fish in aerated solutions containing 100 milligrams (mg)/liter 2,2,2 tricaine methanesulfonate buffered with an equal weight of sodium bicarbonate, 2 milliliters (ml) of PolyAqua, and about 5 to 7 g/liter sodium chloride. Water temperature of the anesthetic solution was monitored during PIT implant sessions and maintained within 2° F.

Upon sedation, fish were placed with their ventral surface facing up in a foam tagging cradle which supported the entire body of the fish (Figure 4). The tagging cradle was saturated with a solution containing PolyAqua and about 5 to 7 g/liter sodium chloride. The injector needle tip was gently partially inserted posteriorly into the salmon's abdomen at a point just posterior to the pectoral girdle to create an incision. The PIT tag was pushed from the barrel of the injector needle through the incision simultaneously as the needle was retracted from the incision leaving the PIT tag in the peritoneal cavity (Figure 4). The PIT code number, read with an AVID[1] multi-tag reader, along with a tagging quality code ranging from 1 for good to 5 for poor were recorded for each fish tagged. Fish were immediately placed in a five-gallon recovery bucket containing an aerated solution of 3 ml PolyAqua and about 5 to 7 g/liter sodium chloride. Upon regaining full equilibrium and stable ventilation, fish were placed in a 300-gallon circular flow-through tank salted to about 5 to 7 g/liter sodium chloride to complete recovery. Salting of the anesthetic and recovery water was used to reduce physiological, osmotic, and acid-base disequilibria associated with fish sedation and handling and to improve overall fish condition upon recovery from handling (Long *et al.* 1977, Summerfelt and Smith 1990, Wedemeyer 1992). Salinity gradually decreased as fresh water flowed through the tank. PIT-tagged salmon remained at the hatchery for approximately one week to fully recover from the implantation surgery prior to transport to the fish screens. Fish were fed several times every one to two days after tagging. Post-tagging mortalities were monitored, removed, and the PIT codes of dead fish recorded every one to two days. Tags in dead fish were removed and archived.

Fish Transport Protocol

Fish were transported between the hatchery, the GCID fish screen holding facility, and the fish release site using a 500-gallon, insulated fiberglass hauling tank with two electric agitation-circulation aerators. The tank was mounted on a flat bed utility truck. Fish were transported to the fish screens in water obtained at the hatchery. Transit time between the hatchery and the fish screens was approximately 45 minutes. Water temperatures were measured at departure from the hatchery and arrival at the pump station and never changed more than 2° F. Differences in water temperatures between the hatchery and the Sacramento River at the pump station never exceeded about 4° F and therefore no tempering was considered necessary when transferring fish to the holding tanks. Tagged fish were kept in a net pen placed in the hauling tank when transported. Transportation of tagged fish between the fish holding facility and the upstream release platform was conducted using river water pumped from the oxbow channel to the hauling tank. Tagged fish were transferred between the holding tanks and the hauling tank in net pens as previously described. Transit time to the release platform was generally less than 15 minutes between loading and transfer from the hauling tank to the fish release platform upstream of the fish screens.

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[1] AVID, Norco, California

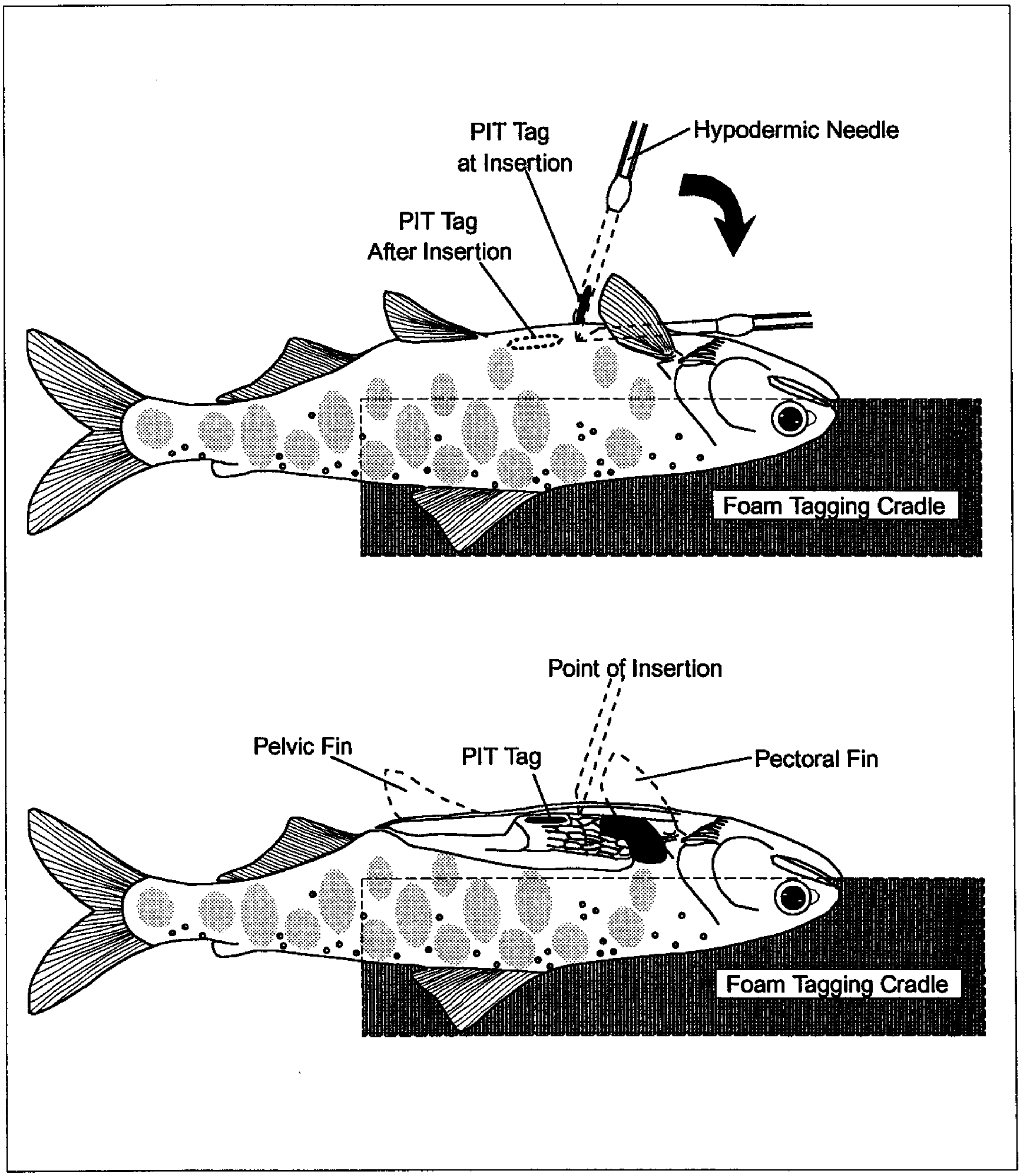

Figure 4. Illustrated implantation of a PIT tag in an anesthetized juvenile chinook salmon, showing point of insertion through the body wall musculature (cutaway view), needle injection angle to implantation site, and position of the implanted PIT tag within body cavity. (Adapted from Prentice *et al.* 1990)

GCID Fish Holding Facility

The fish holding facility at the GCID pump station used for maintaining tagged test fish at the diversion's fish screen site was located adjacent to the oxbow bypass channel just downstream from the bypass weir (Figure 3). River water was pumped to four rectangular flow-through tanks with an electric submersible pump connected to a water delivery manifold. Three of the tanks were constructed of aluminum with dimensions of 8 feet x 3 feet x 1.9 feet and one 1.5-inch diameter PVC stand pipe in each tank was used to regulate water depth in the tanks. Water was delivered to each of these tanks through a 1-inch diameter by 8-foot long PVC spray bar running the full length of each holding tank. The fourth tank, provided by CDFG, was constructed of stainless steel with dimensions of 18 feet x 3 feet x 1.8 feet and a 2-inch diameter stand pipe was used to regulate water depth in the tank. Water was delivered to this tank through a 3-inch diameter steel spray bar running the full length of the tank. A control valve was provided on each of the tanks' spray bars for controlling the rate of water flow. Tanks were flushed and cleaned every one to two days while fish were being held in them. Tanks were thoroughly brushed and cleaned of accumulated debris between test periods when no fish were being held in them. A canopy of nursery shade cloth was erected over the entire fish holding facility to moderate sunlight intensity.

Fish Release and Recovery

After a minimum of a 2-hour acclimation period in a net pen at the upstream fish release platform, PIT-tagged fish were transferred by dip net into 5-gallon buckets. During the transfer, individual PIT-tagged salmon had their tag code read with the AVID reader (the transponder activator) and recorded. The buckets of fish were then transferred into a 14-foot boat powered by an outboard motor and moved to specific sites of release. The release sites were upstream, adjacent to, and downstream of the screens. When PIT-tagged fish were released, the fish bypasses were closed. Tests were conducted by releasing PIT-tagged fish immediately adjacent to the fish screens to maximize their exposure to the screens. Fish released upstream of the screens were released directly from the upstream release platform. The exact time to the nearest second was recorded for each PIT-tagged fish released. Control PIT-tagged fish were released directly into the three downstream-most rotary fish traps to obtain "background" data on individual fish transport times once a fish entered a trap until it was recovered from the trap's live box. The fish traps were checked continuously immediately following each fish release to determine transport times from the release location to the recovery site. During the tests, technicians continuously monitored fish entering the live boxes, netted the fish, read the individual tag codes with the AVID reader and recorded the exact time (to the nearest second) of recovery. Persons recovering the PIT-tagged fish used watches synchronized with persons releasing the PIT-tagged fish at upstream locations.

RESULTS AND DISCUSSION

Fish Transport Timing

Figure 5 shows the release locations for PIT-tagged salmon during the 1994 study and Figure 6 shows the release locations for PIT-tagged salmon during the 1995 investigations. We chose to use some different release locations in 1995 to allow for a greater dispersal between release sites. In particular, we were most interested in acquiring additional detailed data on potential fish behavior influenced by the newly installed eddy deflector at the upstream end of the fish screens (Figure 6). Table 1 gives the approximate straight-line distances for each release location (fish bypasses were closed) to the live boxes in the rotary fish traps for the tests performed in 1995. Results of evaluating the transport timing for individual PIT-tagged chinook salmon released at the locations shown in Figure 6 are given in Appendix 1.

Table 1. Straight-line distances measured from PIT-tagged chinook salmon release locations to the live boxes in the rotary fish traps operated immediately downstream of the bypass channel weir in the oxbow return flow channel at GCID (see Figure 6 for specific locations).

Mouth of rotary traps	**10 feet**
Upstream of bypass weir	**147 feet**
Downstream end of fish screens	**299 feet**
Downstream fish bypass entrance (closed)	**433 feet**
Upstream fish bypass entrance (closed)	**609 feet**
In front of screen #35	**680 feet**
Upstream of screens off fish release platform	**805 feet**

The median timing rather than average timing is presented in the following discussion. Use of the average would result in distorted values attributable to one or several fish exhibiting atypical behavior. As an illustrative example, if the first 9 fish of 10 PIT-tagged fish released at one location at the same time were recovered in consecutive one minute intervals following their release but the remaining fish was not recovered until six hours later, the average recovery time for that group of fish would be 64.5 minutes but the median recovery time would be 5.5 minutes. In this instance, the median time is more indicative of general behavior for the group than is the average recovery time. The minimum (min.), maximum (max.), and standard deviation (S.D.) values are also presented in the following discussion. The minimum values are valuable because they provide empirical evidence of what is achievable in terms of transport timing. Because a recovery for each PIT-tagged fish represented one datum, we found that it was particularly

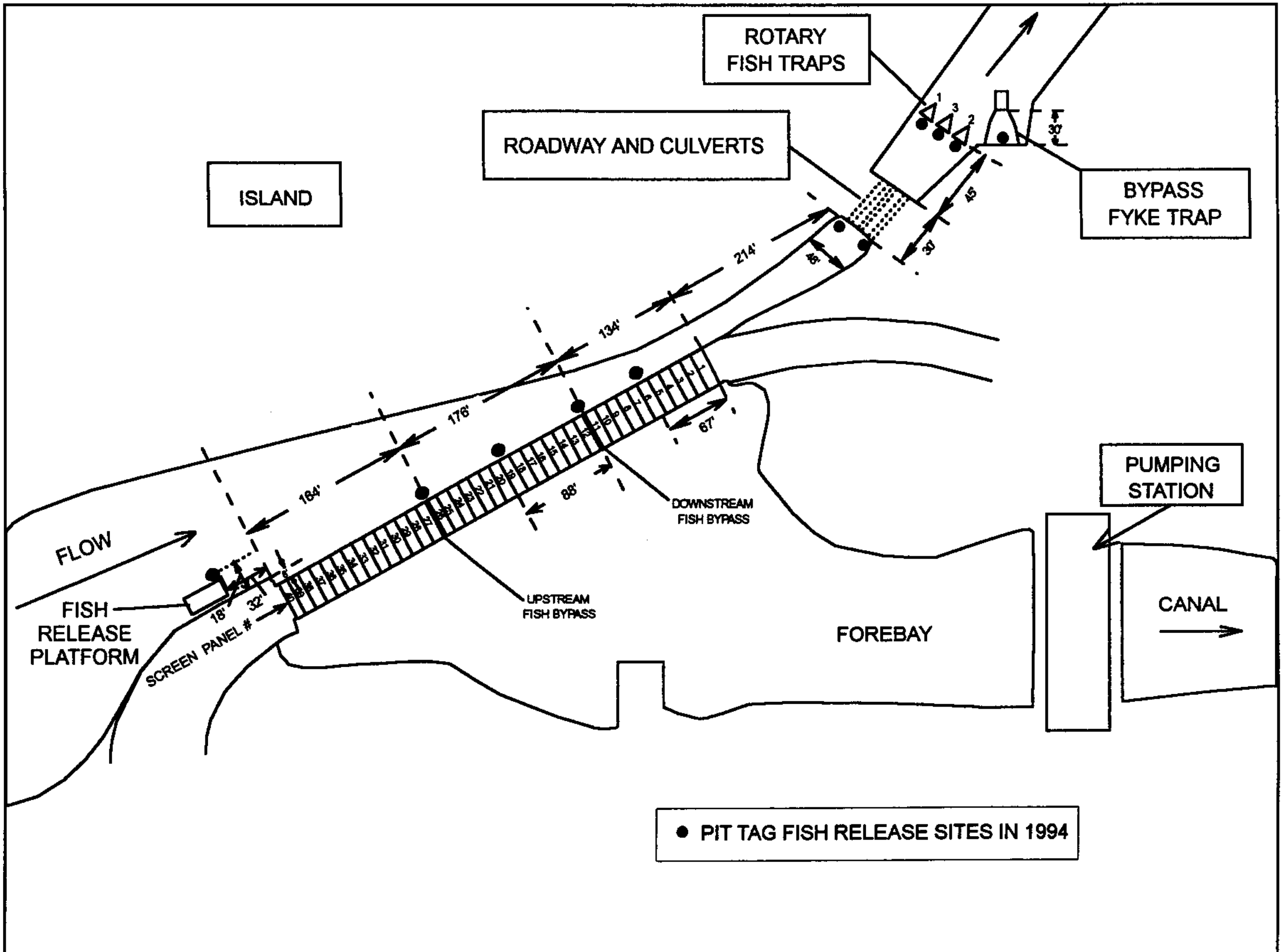

Figure 5. Layout of the Glenn-Colusa Irrigation District fish screens showing distances from PIT-tagged fish release locations in 1994 to fish recapture locations.

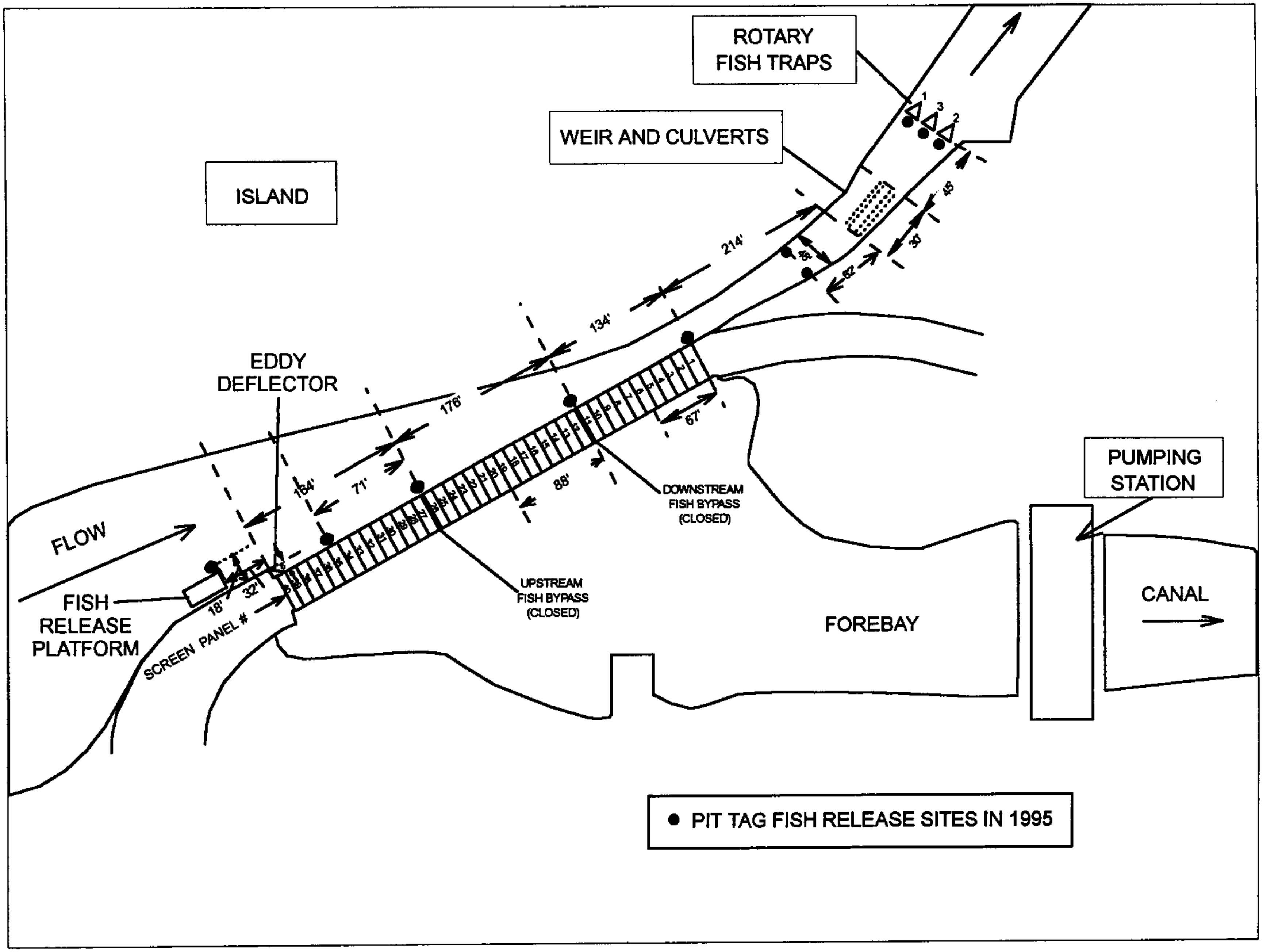

Figure 6. Layout of the Glenn-Colusa Irrigation District fish screens showing distances from PIT-tagged fish release locations in 1995 to fish recapture locations.

useful to present as much of the "raw" data as possible in graphic format instead of only tabulating a compiled statistical summary of all data. A data summarization negates much of the benefit in observing individual fish behavior. The graphic presentation of individual fish transport timing displays the considerable dispersion of data from each release location.

Because the physical process of recapturing fish was not instantaneous[2], we released PIT-tagged fish directly into each of the rotary traps and timed their individual transport timing within the traps. The median transport timing for 30 fish released within the three traps was 25 seconds (min. = 12 sec., max. = 1 min. 35 sec., S.D. = 21 sec.). This median transport timing and recovery in the rotary fish traps was the same as that observed in the 1994 tests. Figure 7 shows the individual transport timing for each of the 30 fish released into the rotary fish traps. These timing data represent "background" data for assessing the transit timing for other fish released at upstream locations. As the data demonstrate, there was very little time associated with the procedure in recovering PIT-tagged fish. Eighty-seven percent of the fish were recovered within one minute after the PIT-tagged fish were introduced into the fish traps.

As stated earlier, the focus of the tests performed during 1995 was to compare results between years as related to potential changes in hydraulic features in the vicinity of the new fish screens. One important change to channel hydraulics was the alteration of the roadway to the island which originally only allowed water to flow through culverts into the bypass outlet channel. The modifications resulted in a combination of water flowing over the top of the earthen weir and through two of the three culverts with the intent of improving downstream migration timing for young salmonids.

Several groups of fish were released around 10 PM on July 14 and 15, 1995 just upstream of the bypass channel weir. The median recovery time for 20 recaptured PIT-tagged fish in these nighttime releases was 2 minutes 55 seconds (min. = 55 sec., max. = 25 min. 26 sec., S.D. = 5 min. 38 sec.). Three-fourths of those fish were recovered in less than 5 minutes with two fish exhibiting markedly slower downstream migration timing (Figure 8). Several releases were also performed on July 15 and 16 shortly before daylight. Although fish releases were also performed on the left bank facing downstream, only those fish released on the right bank were recaptured. The median recovery time for 12 fish recaptured from these latter releases was 2 minutes 50 seconds (min. = 1 min. 11 sec., max. = 46 min. 21 sec., S.D. = 14 min. 34 sec.). Sixty-seven percent of the fish were recaptured in less than 5 minutes (Figure 9). The last set of these releases was performed at approximately 6 AM July 15 and 16 after sunrise. The median recovery time for 20 recaptured PIT-tagged fish in the daytime release was 4 minutes 39 seconds (min. = 1 min. 5 sec., max. = 5 hr., S.D. = 1 hr. 4 min. 32 sec.) (Figure 10) which compared to a median transport time of 24 minutes 17 seconds for those fish released in 1994. Figure 11 simply shows additional transport timing detail for 18 of the most rapidly moving fish among

[2] There is a certain amount of time from when the fish first enter the trap, are rotated back through the spirals in the screw trap, a person nets the fish in the live box, and the PIT tags are read with the AVID reader.

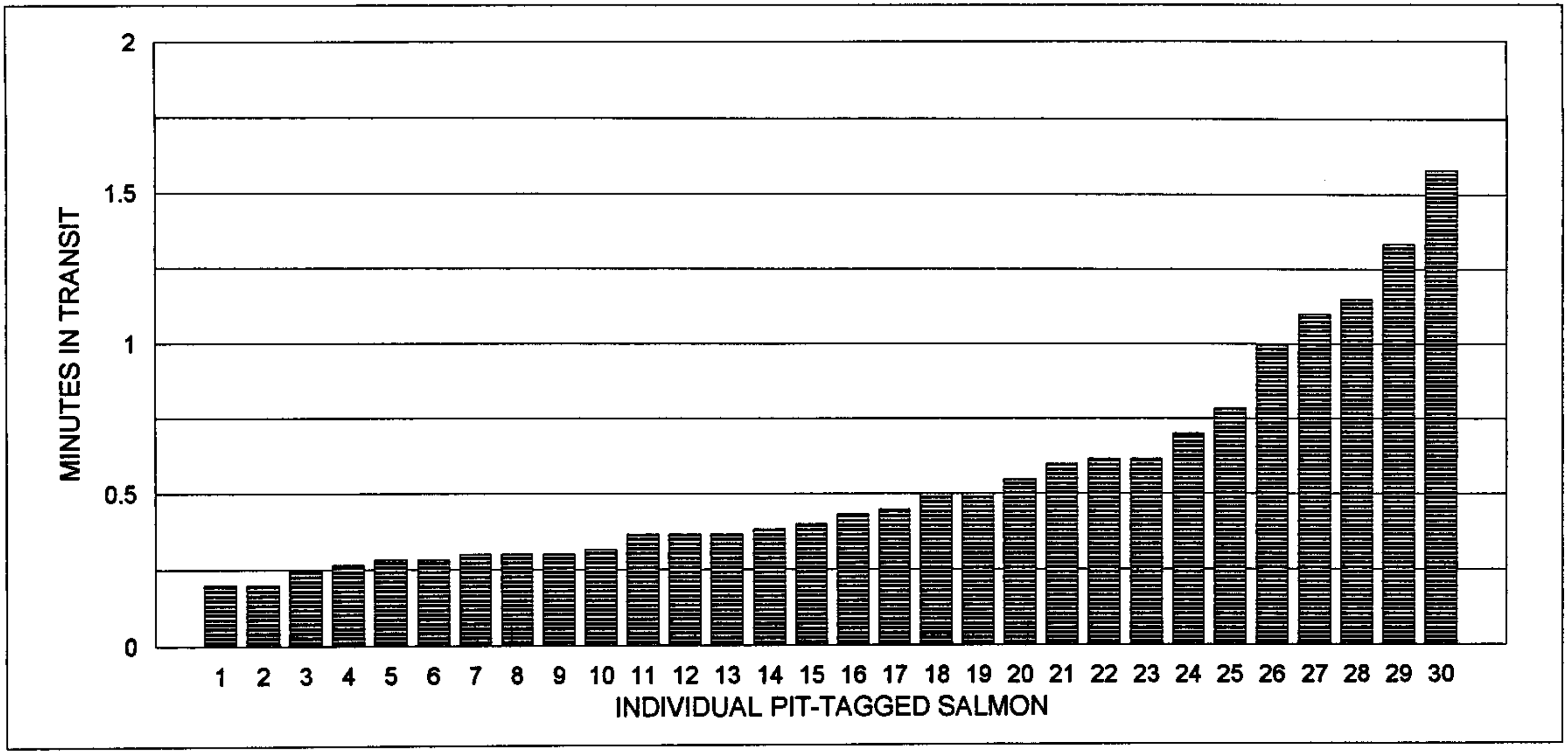

Figure 7. Individual transit time for each of 30 PIT-tagged chinook salmon released directly into the three rotary fish traps downstream of the bypass channel weir (utilized as the downstream fish recapture site) to the rotary trap live boxes - a distance of 10 feet.

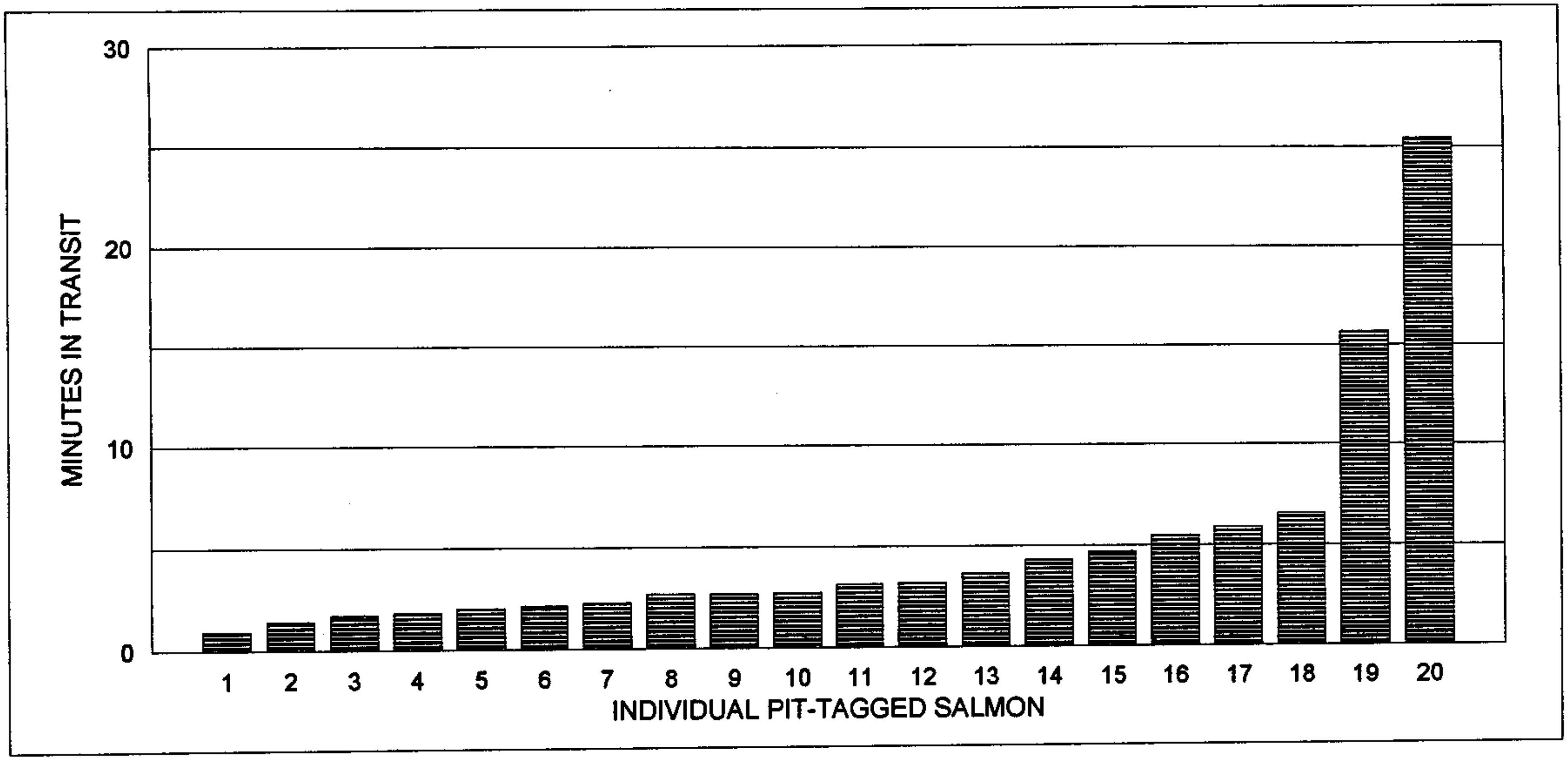

Figure 8. Individual transit time for each of 20 PIT-tagged chinook salmon released during late night hours (approximately 2200 hours) upstream of the bypass channel weir to the downstream recapture site (below weir - a distance of 147 feet).

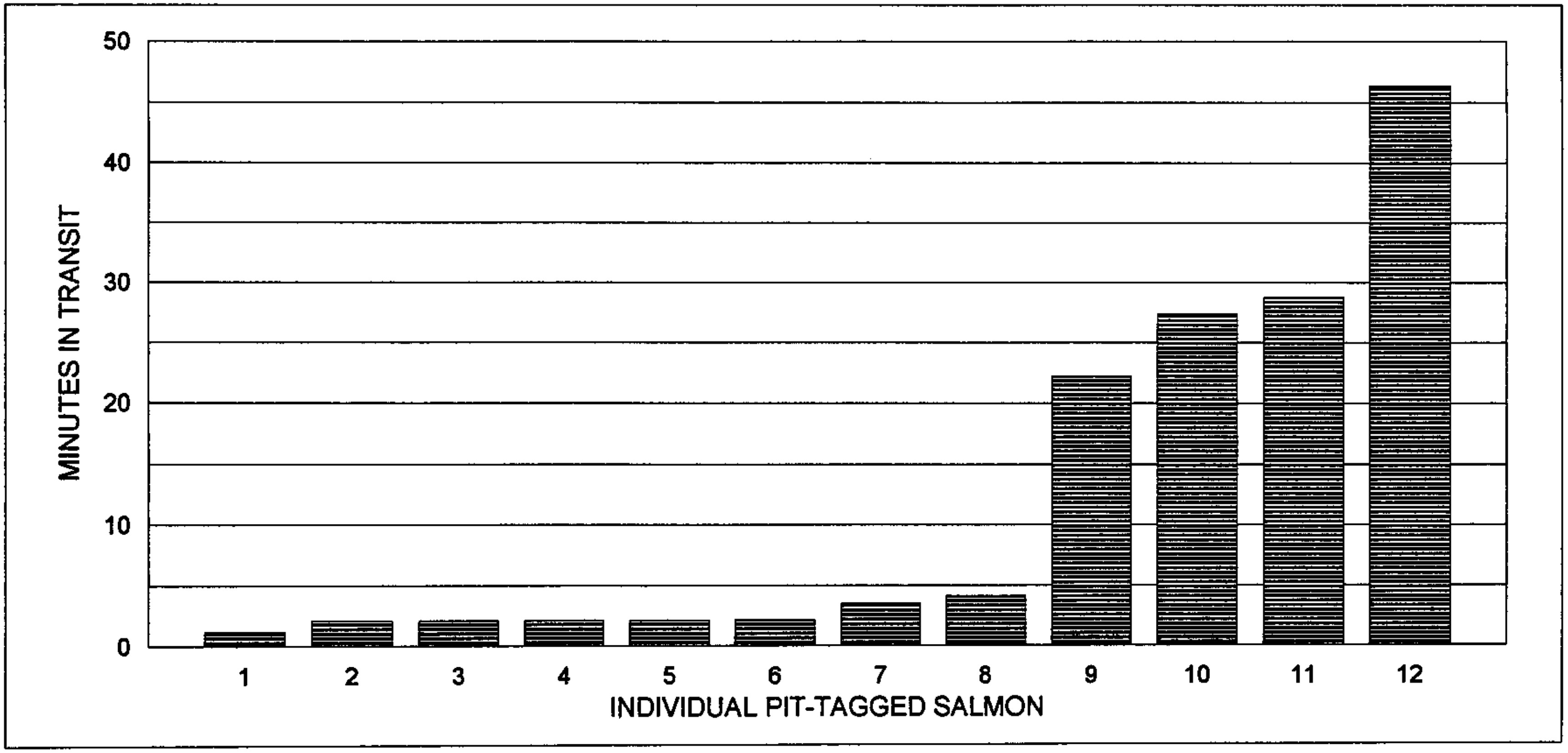

Figure 9. Individual transit time for each of 12 PIT-tagged chinook salmon released during pre-dawn hours (approximately 0500 hours) upstream of the bypass channel weir to the downstream recapture site (below weir - a distance of 147 feet).

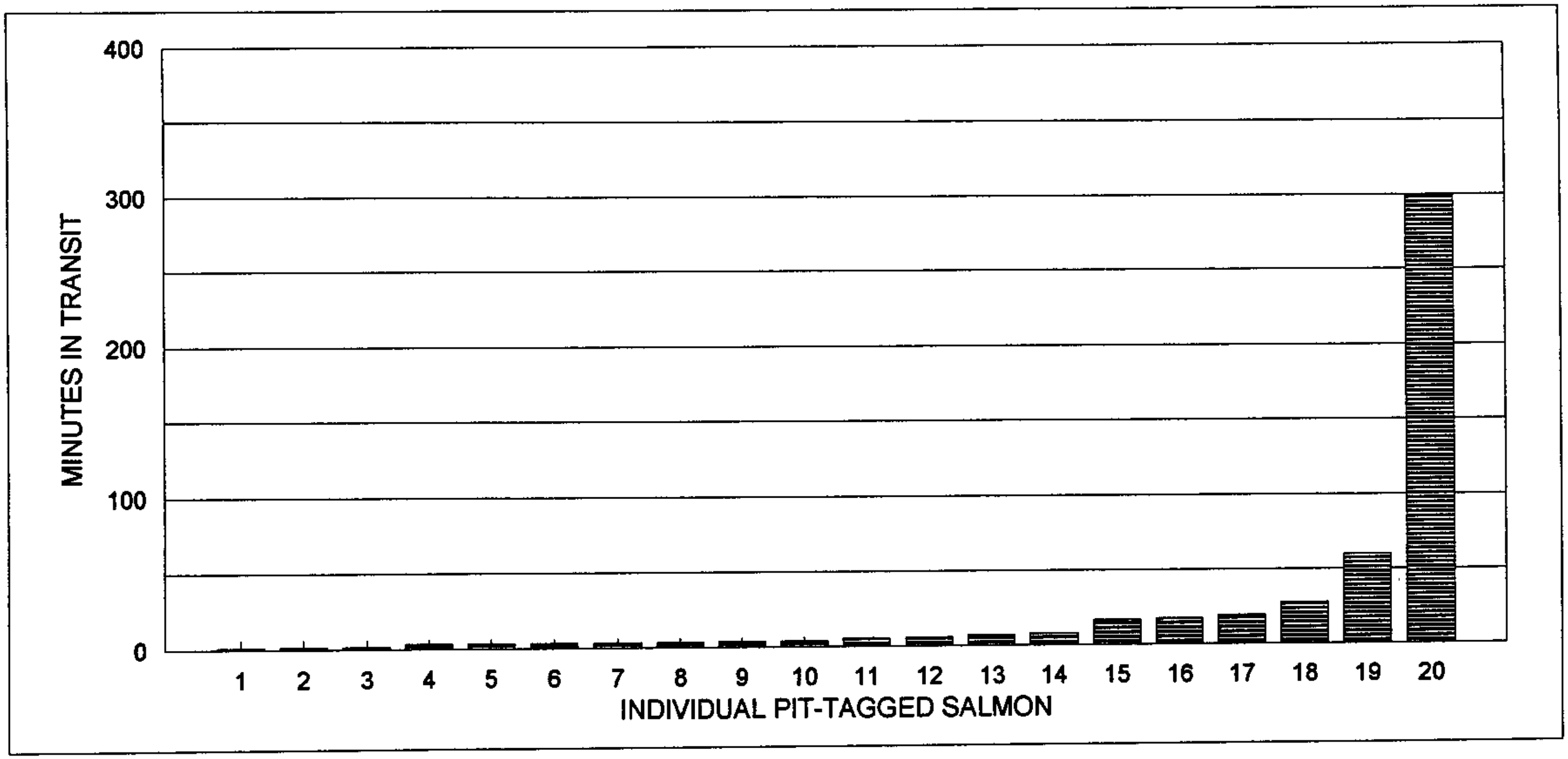

Figure 10. Individual transit time for each of 20 PIT-tagged chinook salmon released during daylight hours (approximately 0600 hours) upstream of the bypass channel weir to the downstream recapture site (below weir - a distance of 147 feet).

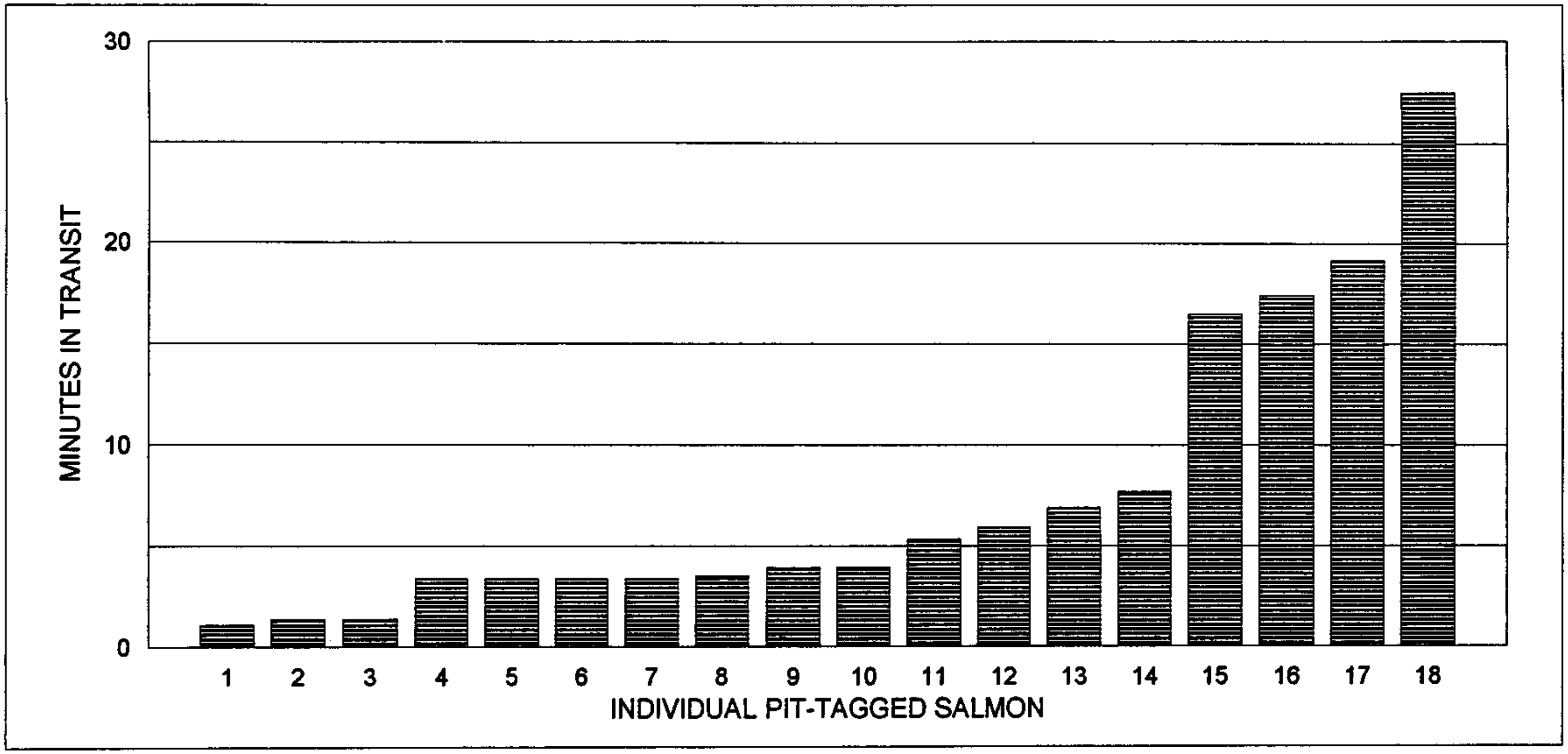

Figure 11. Individual transit time for each of 18 PIT-tagged chinook salmon released during daylight hours (approximately 0600 hours) upstream of the bypass channel weir to the downstream recapture site (below weir - a distance of 147 feet).

the 20 fish recaptured. Although the transport timing for fish released above the weir was slower than those fish released at the same site during darkness (either because of daytime/nighttime behavioral differences or behavior effects of the weir during daylight) (Figure 12), the results demonstrate markedly improved (less) transport timing which we attribute to alterations of the weir (Figure 13).

Releases of PIT-tagged fish were performed just downstream of the fish screens to obtain background information of transport timing from that location to the rotary fish traps. These data allowed for quantification of timing in this latter reach. These fish releases also allowed for subsequent assessment of fish transport timing in upstream reaches (i.e., when PIT-tagged fish were released at upstream locations in front of and upstream of the new fish screens). The 28 salmon recaptured after release at the downstream end of the screens exhibited a median transport time to the rotary fish traps of 3 minutes 3 seconds (min. = 1 min. 53 sec., max. = 6 min. 30 sec., S.D. = 1 min. 9 sec.). As expected, the timing for these fish was only slightly longer than those fish released at night further downstream near the bypass weir. Nearly 80 percent of the fish released just downstream of the fish screens were recaptured in the rotary fish traps downstream of the weir in less than 4 minutes (Figure 14).

Fish released at night between screen panels 11 and 12 (in front of the closed downstream bypass) (Figure 6) also exhibited relatively rapid downstream movement. The 23 recaptured fish had a median transit time of 3 minutes 33 seconds (min. = 2 min. 40 sec., max. = 7 min. 1 sec., S.D. = 1 min. 3 sec.) which was 30 seconds longer than the median transport timing for fish released at the downstream end of the screens. Nearly 90 percent of these fish were recaptured in less than 5 minutes following their release (Figure 15).

For those PIT-tagged fish released at night between screen panels 26 and 27 (in front of the closed upstream fish bypass) (Figure 6), 14 recaptured fish had a median transit time of 4 minutes 56 seconds (min. = 3 min. 31 sec., max. = 17 min. 36 sec., S.D. = 3 min. 22 sec.) for a distance of 609 feet to the recapture site (Figure 16).

PIT-tagged fish were released at night in front of screen panel 35 to acquire detailed information on potential effects of the newly installed eddy deflector. It was believed that detailed data could be derived from examining differences in transport timing for fish released just upstream and downstream of the eddy deflector. During the 1994 tests, this general area was determined to significantly retard fish movement. For 32 fish recaptured from the releases in front of screen 35, their median transit time was 5 minutes 58 seconds (min. = 3 min. 39 sec., max. = 9 min. 30 sec., S.D. = 1 min. 15 sec.). Nearly 80 percent of these fish were recaptured downstream of the weir in less than 7 minutes (Figure 17).

PIT-tagged salmon releases were performed during night-time just upstream of the fish screens in the same location as in 1994 (Figure 6). The group of 24 PIT-tagged fish recovered from these releases showed a median transport time to the fish traps downstream of the weir

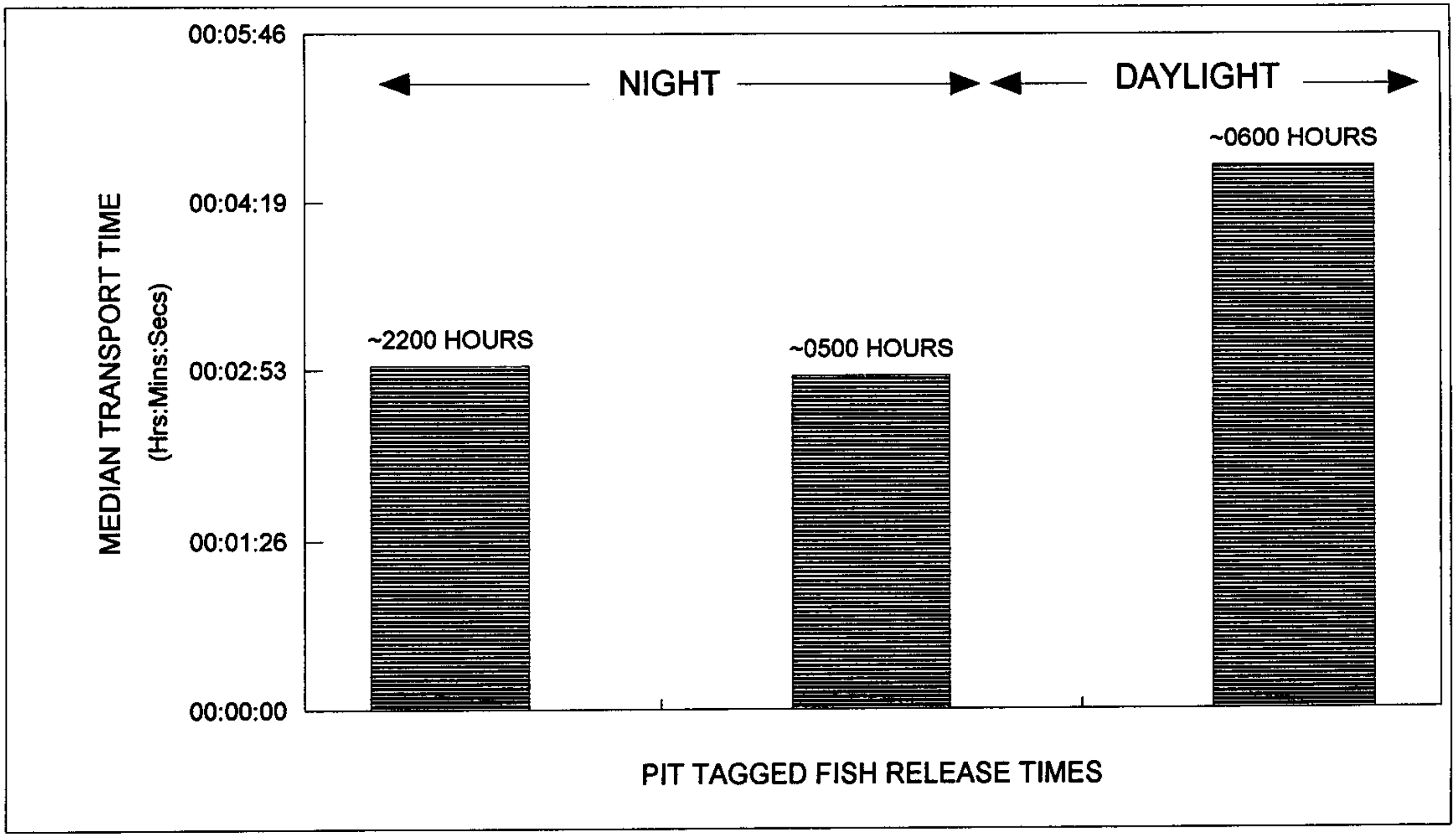

Figure 12. Median transport time for groups of PIT-tagged chinook salmon released upstream of the bypass channel weir to the downstream recapture site (below weir).

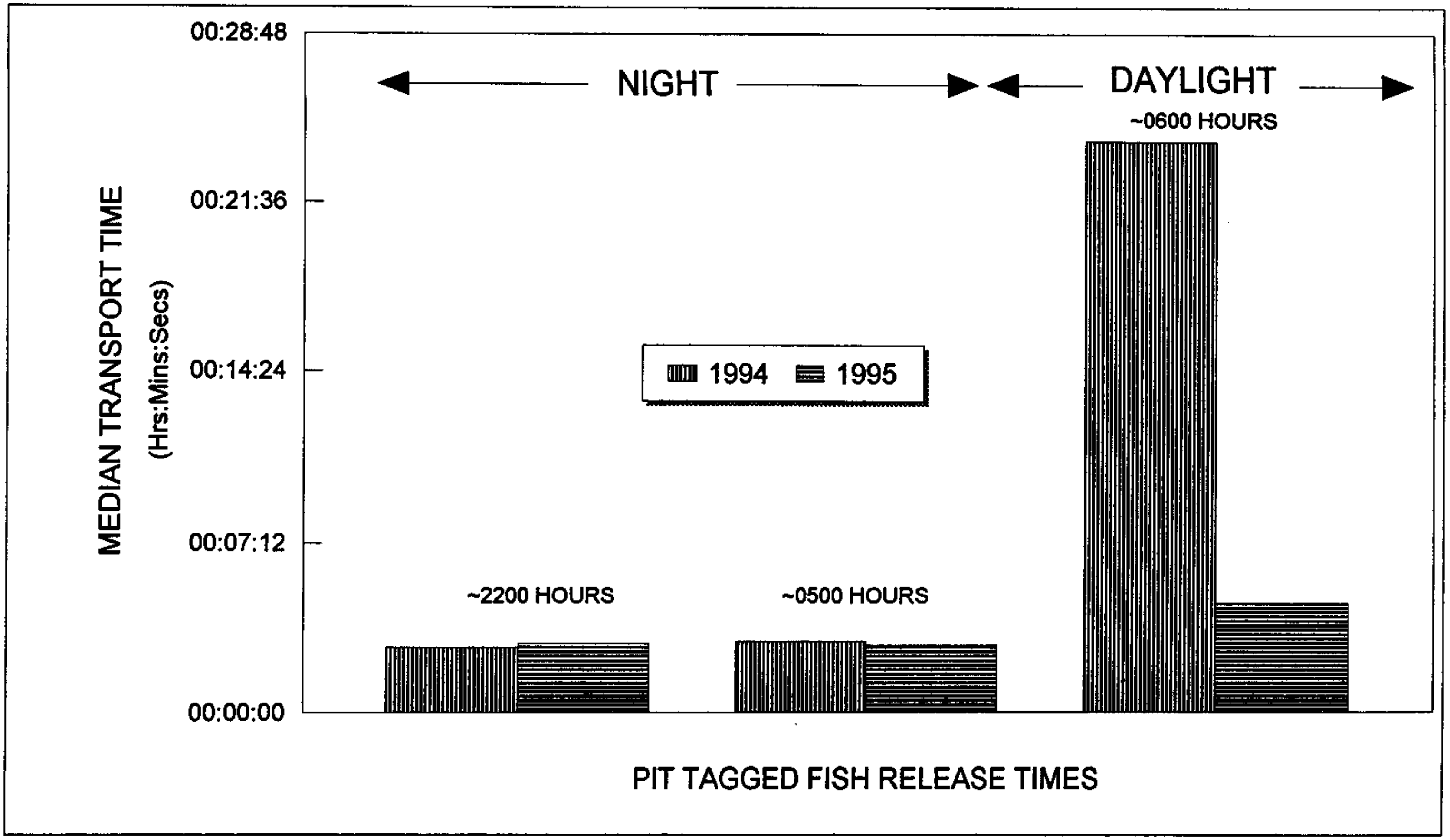

Figure 13. Comparison of 1994 and 1995 median transport time for groups of PIT-tagged chinook salmon released upstream of the bypass channel weir to the downstream recapture site (below weir).

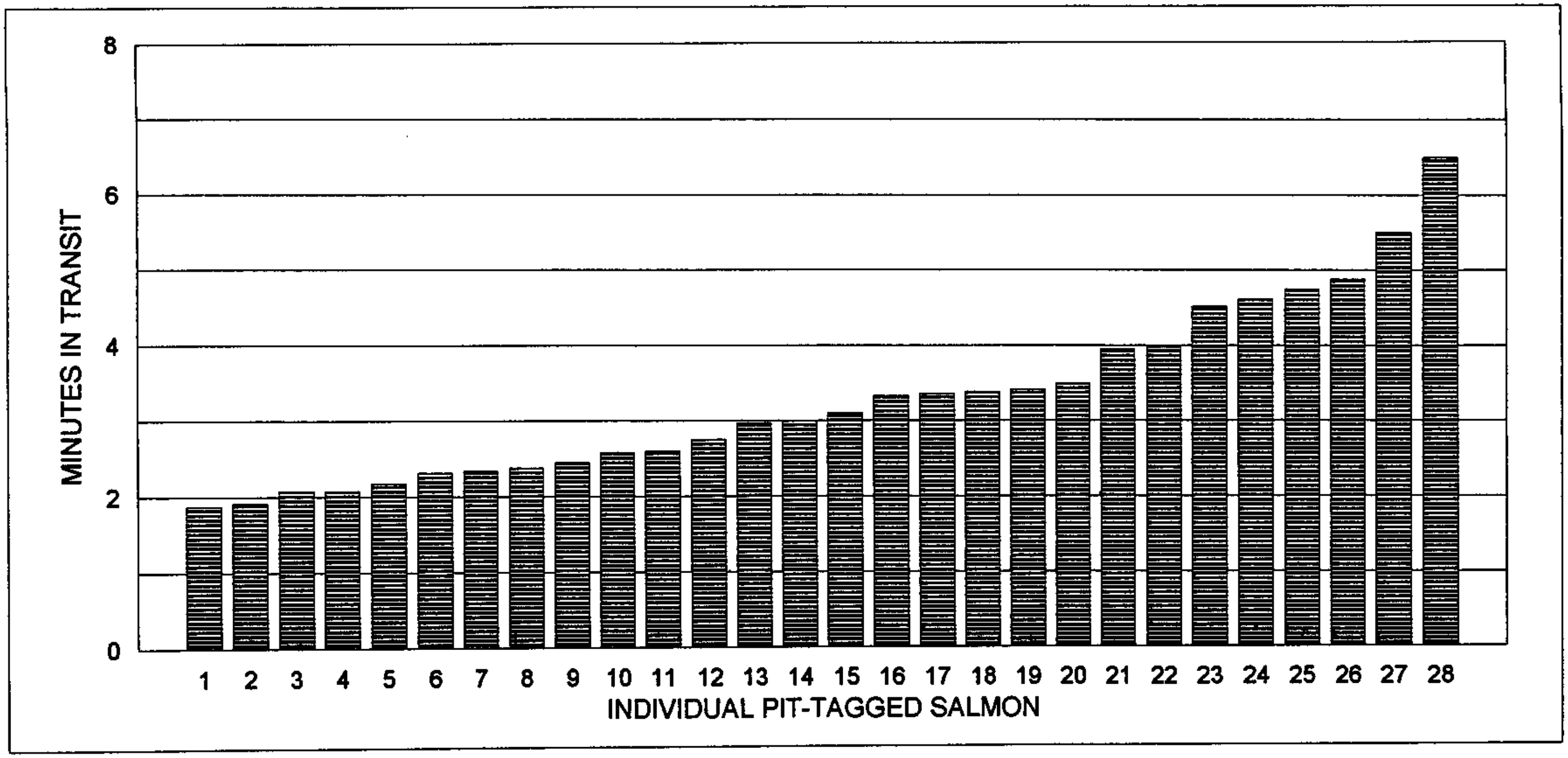

Figure 14. Individual transit time for each of 28 PIT-tagged chinook salmon released at the downstream end of fish screens to the recapture site downstream of the screens (below bypass channel weir - a distance of 299 feet).

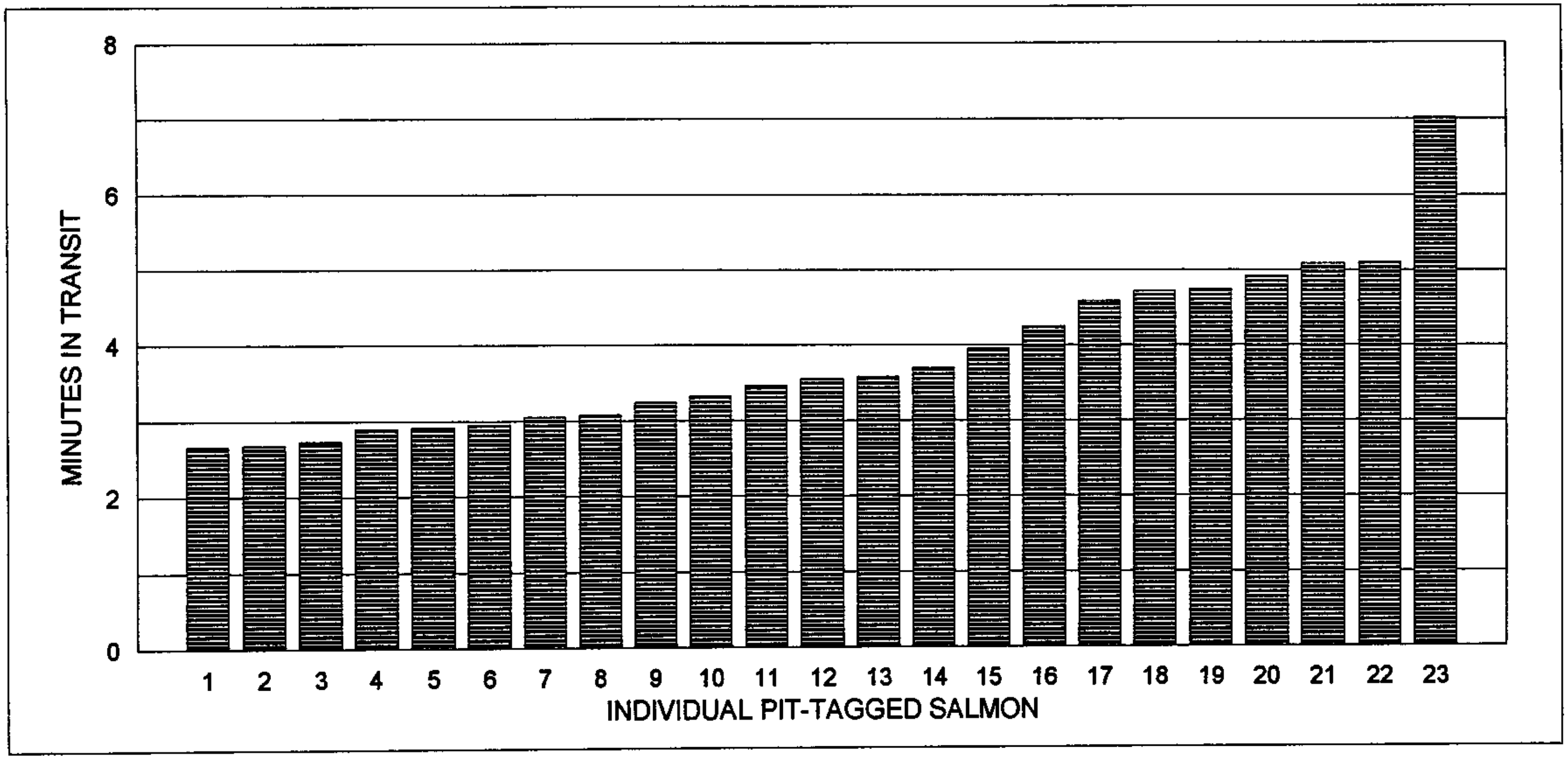

Figure 15. Individual transit time for each of 23 PIT-tagged chinook salmon released in front of the closed downstream fish bypass to the recapture site downstream of the screens (below bypass channel weir - a distance of 433 feet).

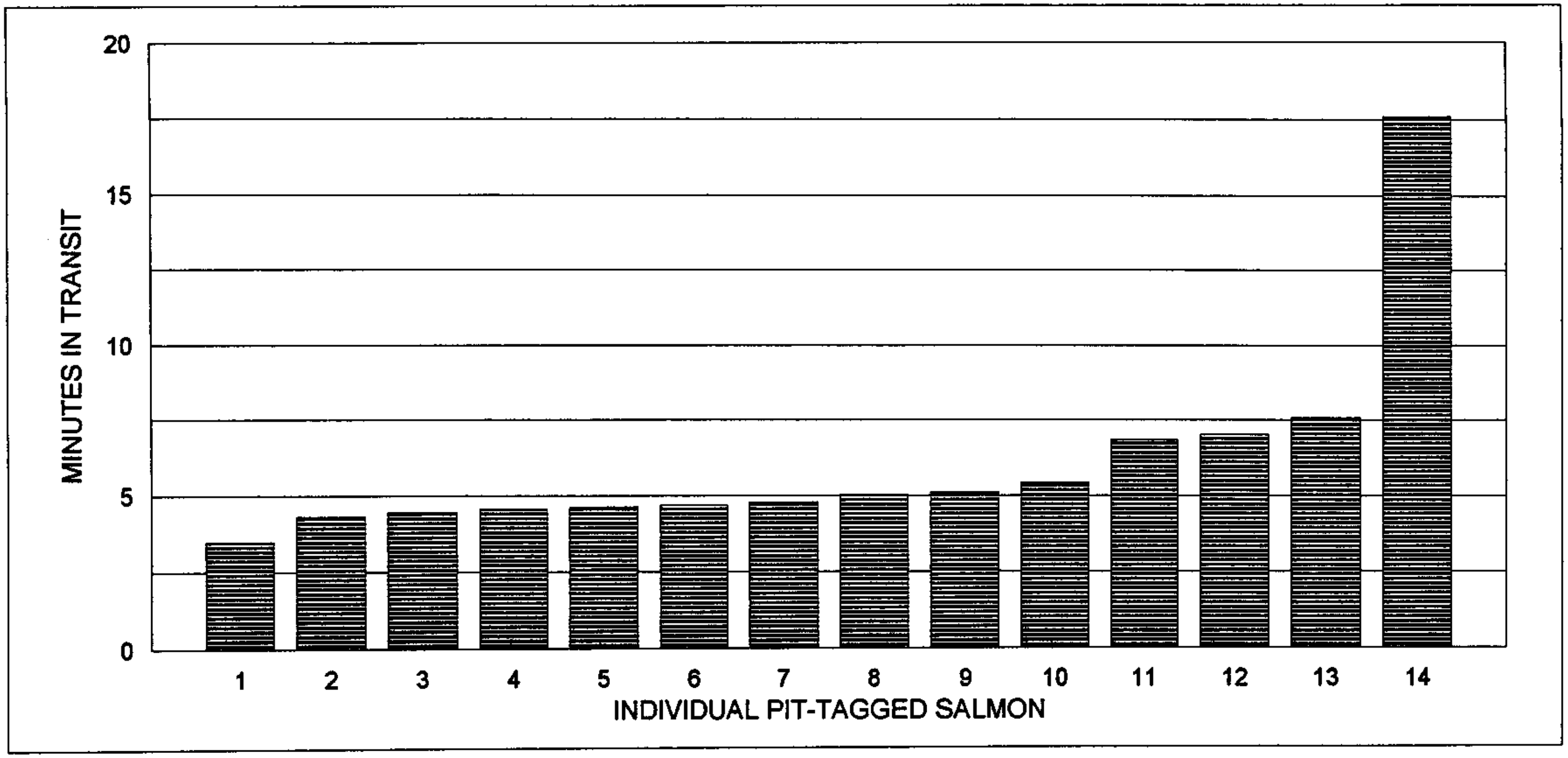

Figure 16. Individual transit time for each of 14 PIT-tagged chinook salmon released in front the closed upstream fish bypass to the recapture site downstream of the screens (below bypass channel weir - a distance of 609 feet).

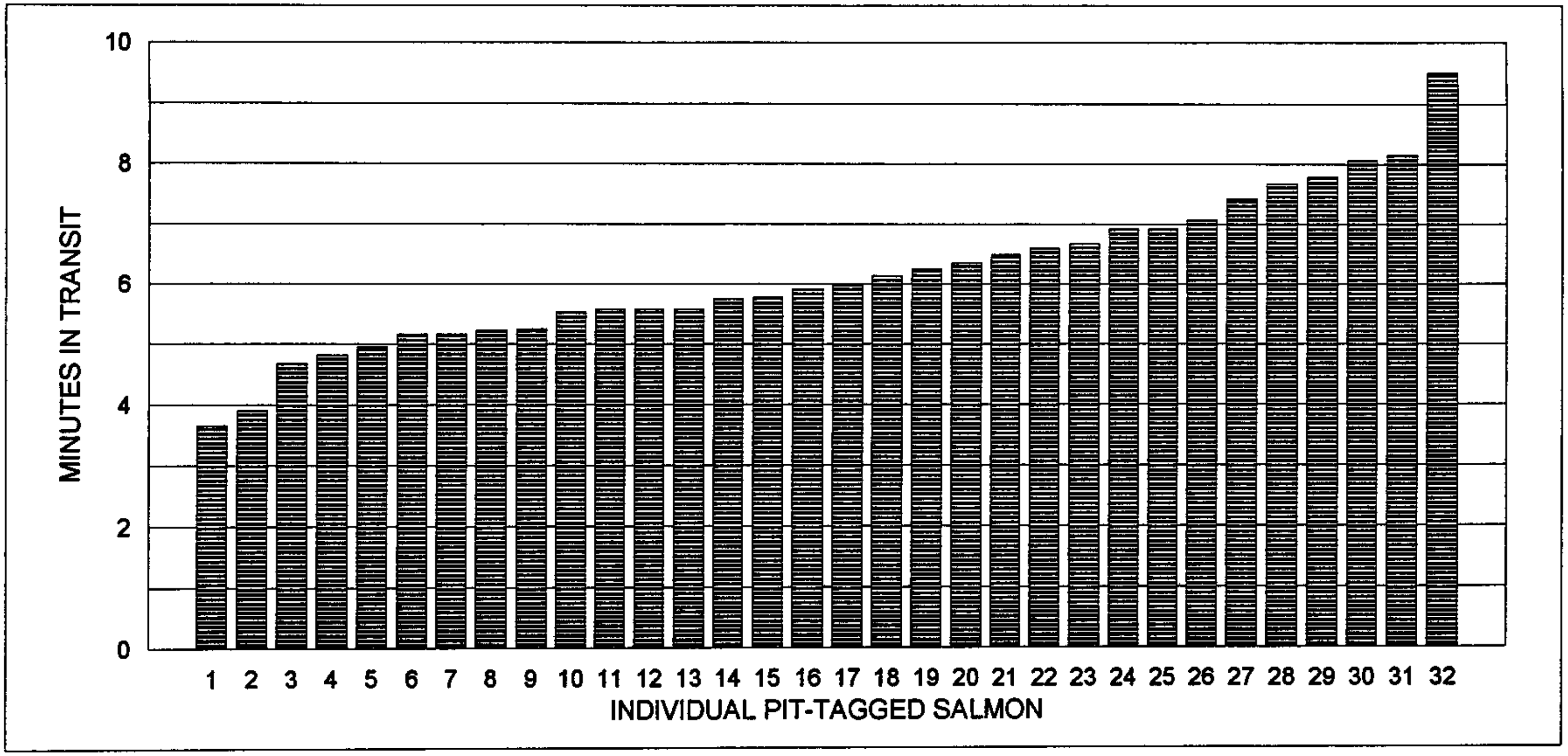

Figure 17. Individual transit time for each of 32 PIT-tagged chinook salmon released in front of screen panel 35 (upstream of the upstream fish bypass) to the recapture site downstream of the screens (below bypass channel weir - a distance of 680 feet).

of 7 minutes 25 seconds (min. = 6 min. 18 sec., max. = 13 min. 54 sec., S.D. = 2 min.). Nearly 80 percent of these fish were recaptured in less than 9 minutes (Figure 18).

Figure 19 shows a summary of the data previously described. It is evident from the median timing data that the slowest migration rates (i.e., distance traveled within a given time) occurred at the upstream portion of the fish screens and near the bypass channel weir. The minimum timing data demonstrate that migratory timing was relatively uniform for all traversed reaches except for those fish released just upstream of the screens (Figure 20).

Based on median transport timing results, these data demonstrate that the PIT-tagged chinook salmon could traverse the distance of the fish screens[3] in 4 minutes 22 seconds[4]. Using the minimum transport timing results, the data indicate the transport timing past the screens was 4 minutes 25 seconds. These results show that the approximate migration ***rate*** of young chinook salmon past the screens was 1.9 feet per second.

We assessed fish migration rates in relation to hydraulic data collected at the fish screens in the summer of 1995 by CH2M HILL. Among those hydraulic data, the data sets compiled on July 17 and 18, 1995 provided the most relevant information to compare with PIT-tagged fish migration rates. Because the downstream bypass weir was not modified into a combination overflow weir with culverts until July 14, 1995, prior hydraulic data sets could not be used. Hydraulic conditions on July 17 and 18, 1995 were similar to those conditions present during the fish migration tests on July 14-16, 1995 (Table 2).

Table 2. Hydraulic conditions* at the GCID fish screens during the fish migration tests on July 14-16, 1995 and during hydraulic measurements on July 17 and 18, 1995.

	July 14-16, 1995	July 17-18, 1995
GCID Pumping Flow	**1900 cfs**	**2000 cfs**
Bypass Channel Flow	**808 cfs**	**769 cfs**
North Island River Flow	**16,860 cfs**	**16,640 cfs**
River Stage at Screen 40	**138.78 feet**	**138.68 feet**

*** Average daily flows and river stages**

[3] i.e., the distance from the upstream release platform to the end of the fish screens - a distance of 506 feet.

[4] The difference between the median transport time for those fish released just downstream of the screens and the median transport time for those fish released upstream of the screens.

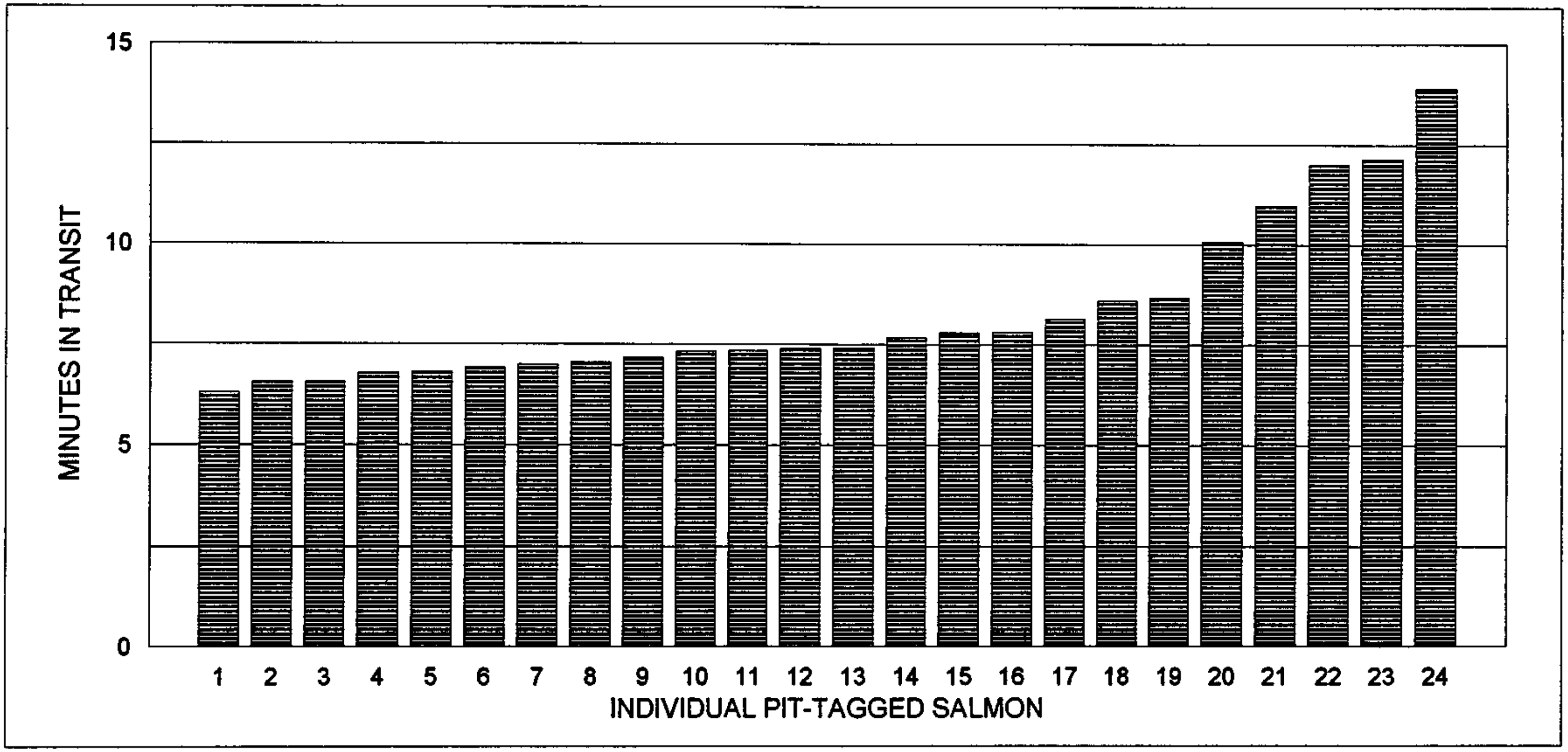

Figure 18. Individual transit time for each of 24 PIT-tagged chinook salmon released upstream of the GCID fish screens to the recapture site downstream of the screens (below bypass channel weir - a distance of 805 feet).

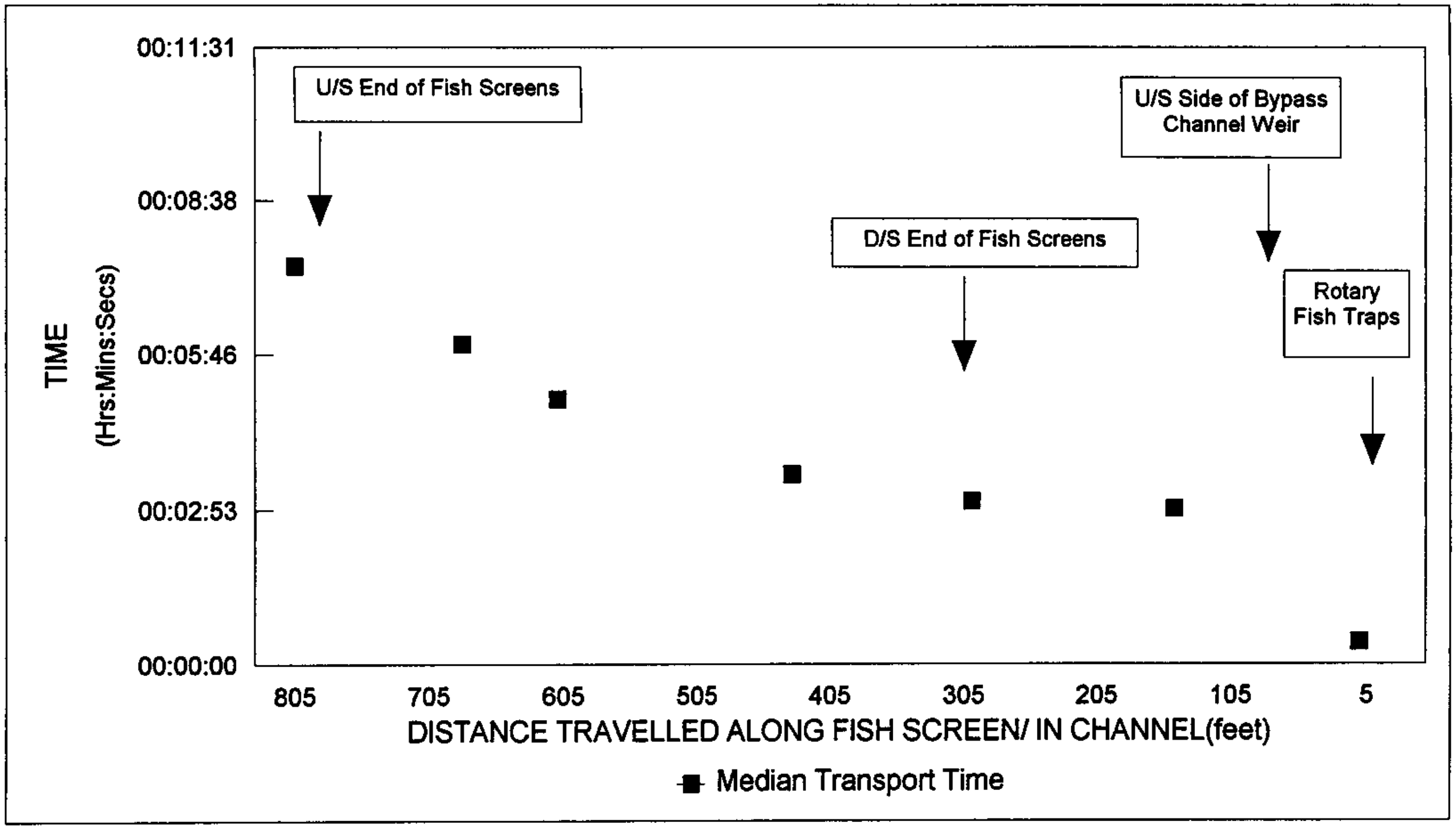

Figure 19. Median transport time for groups of PIT-tagged chinook salmon released at various locations in the vicinity of the GCID fish screens to the recapture site downstream of the bypass channel weir (night-time releases only).

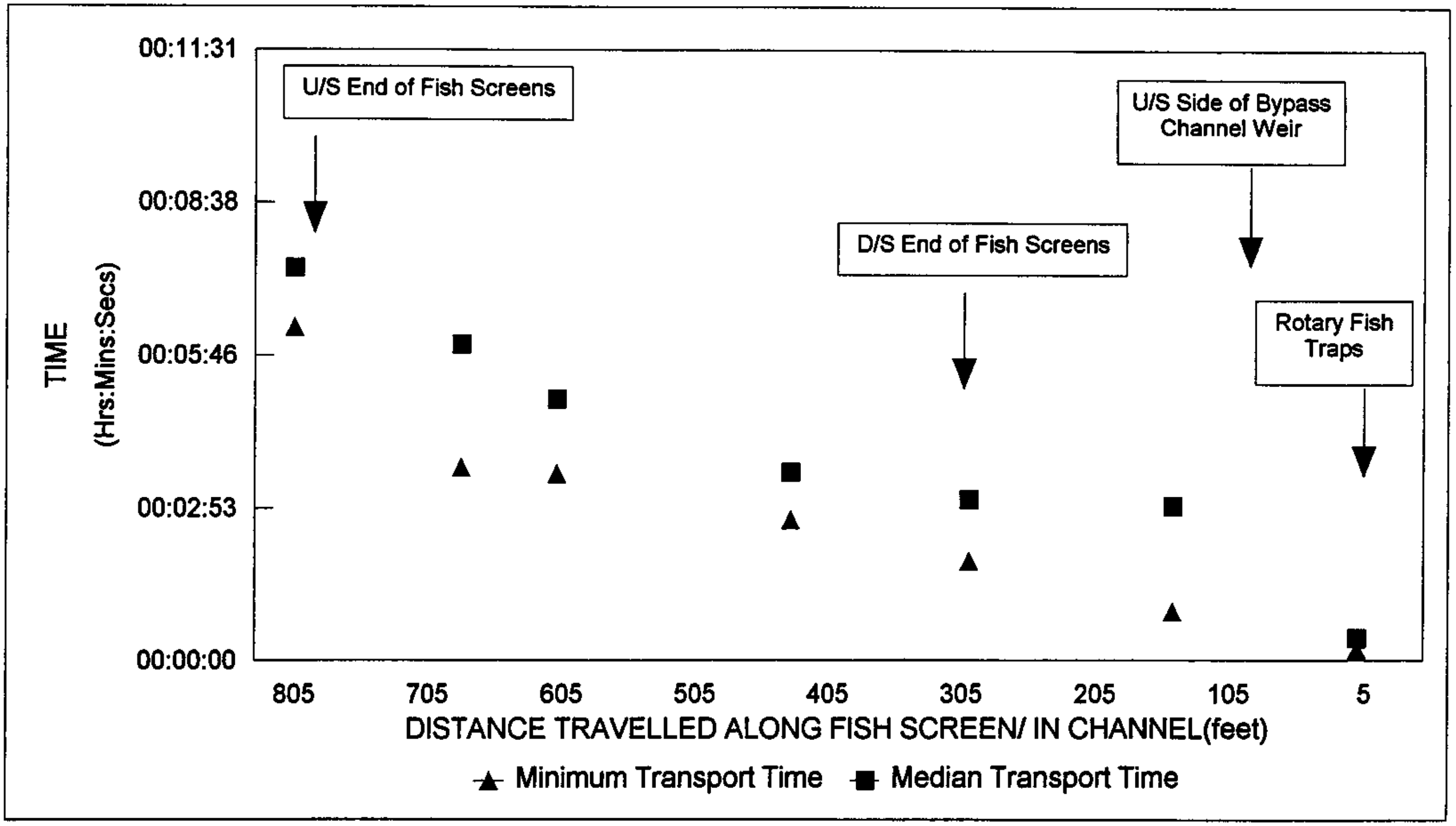

Figure 20. Comparison of minimum transport time with median transport time for individual PIT-tagged chinook salmon released at various locations in the vicinity of the GCID fish screens to the recapture site downstream of the bypass channel weir (night-time releases only).

The average sweeping velocity at the fish screens on July 17-18, 1995 was 1.9 feet/second which was the same as the median transport rate for fish released upstream of the screens on July 14-16, 1995. As shown in Figure 19, fish released at downstream areas in front of the fish screens exhibited a faster migration rate than those released in upstream areas. This phenomenon corresponded to the higher sweeping velocities measured at downstream areas. In general, sweeping velocities were found to increase in a downstream direction (Figure 21) (CH2M HILL 1995).

Comparisons of the 1995 transport timing data with the 1994 data show that significant improvements in fish passage occurred (i.e., more rapid migration). This was particularly evident for those fish released just upstream of the fish screens which we believe was primarily attributable to the newly installed eddy deflector (Figure 22). Although some decrease in transport timing was evident for fish released at other locations along the fish screens, this phenomenon could have been attributable to different riverine conditions in 1995 as compared to 1994. In particular, bypass channel flows were higher in 1995 when the tests were conducted (approximately 800 cfs) as compared to 1994 (approximately 500 cfs). Alteration of the roadway into an overflow weir also resulted in visibly different conditions (increased water velocities) in 1995 than 1994, so we could not determine the principal contributing factor causing more rapid fish movements. However, an examination of data collected for fish released during nighttime and daylight conditions in 1994 and 1995 just upstream of the bypass channel weir provides dramatic evidence of improved conditions for fish passage as a result of the roadway modifications (Figure 13). Although fish migration is expected to be affected by fish behavior changes between nighttime and daylight conditions[5], it was readily apparent that modifications of the roadway from those conditions present in 1994 (i.e., only submerged flow through culverts) to the overflow weir (combined with culvert flow) in 1995 significantly improved fish passage at this locality in 1995.

[5] e.g., Vogel (1989) and Vogel and Marine (1994) found that juvenile salmon downstream migration principally occurs at night on the Sacramento and Mokelumne Rivers, respectively.

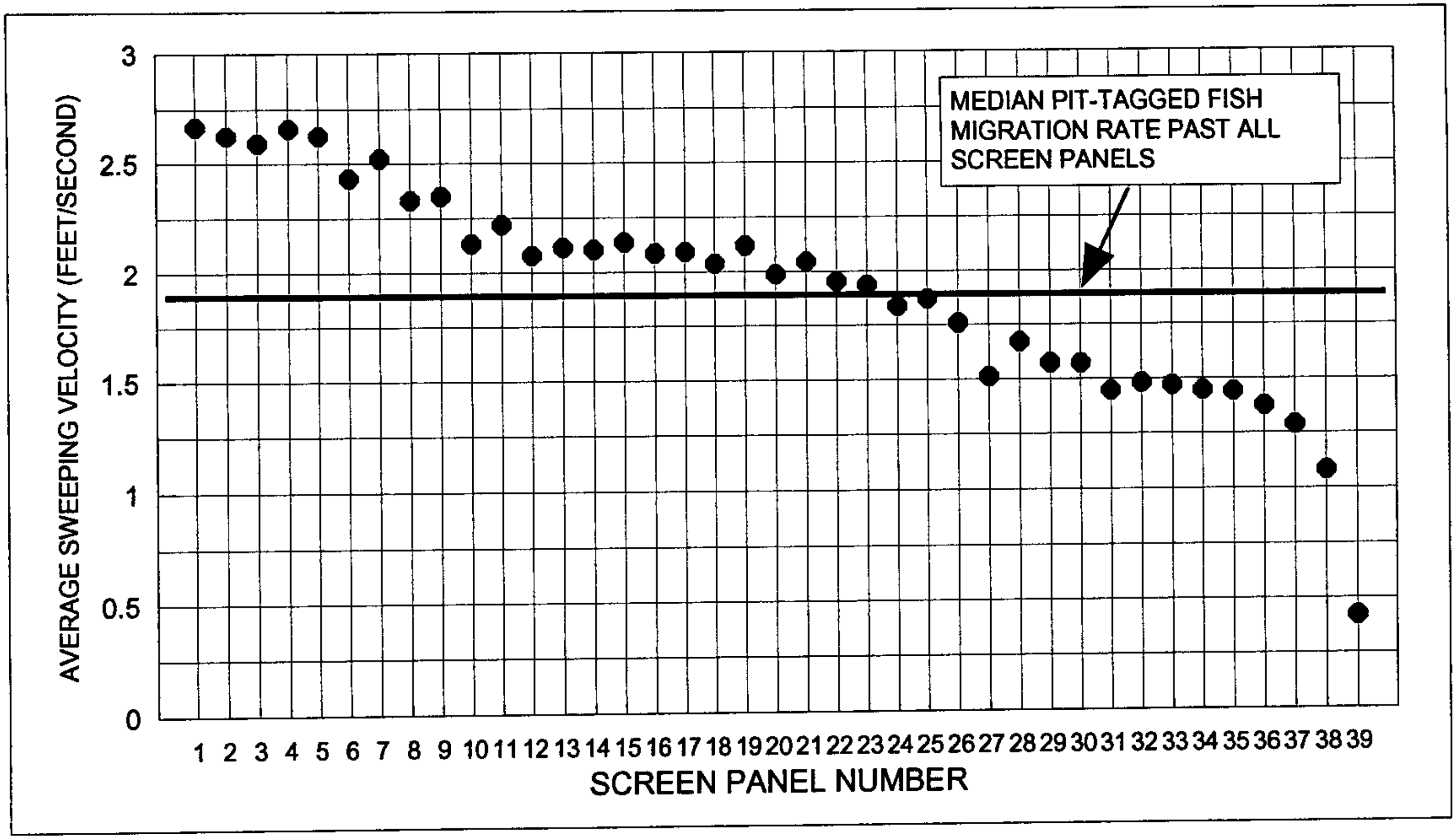

Figure 21. Average sweeping velocities at each GCID screen panel (July 17-18, 1995); screen panel no. 1 is the downstream-most panel; no measurements taken at panel no. 40 because of the eddy deflector (data from CH2M HILL 1995).

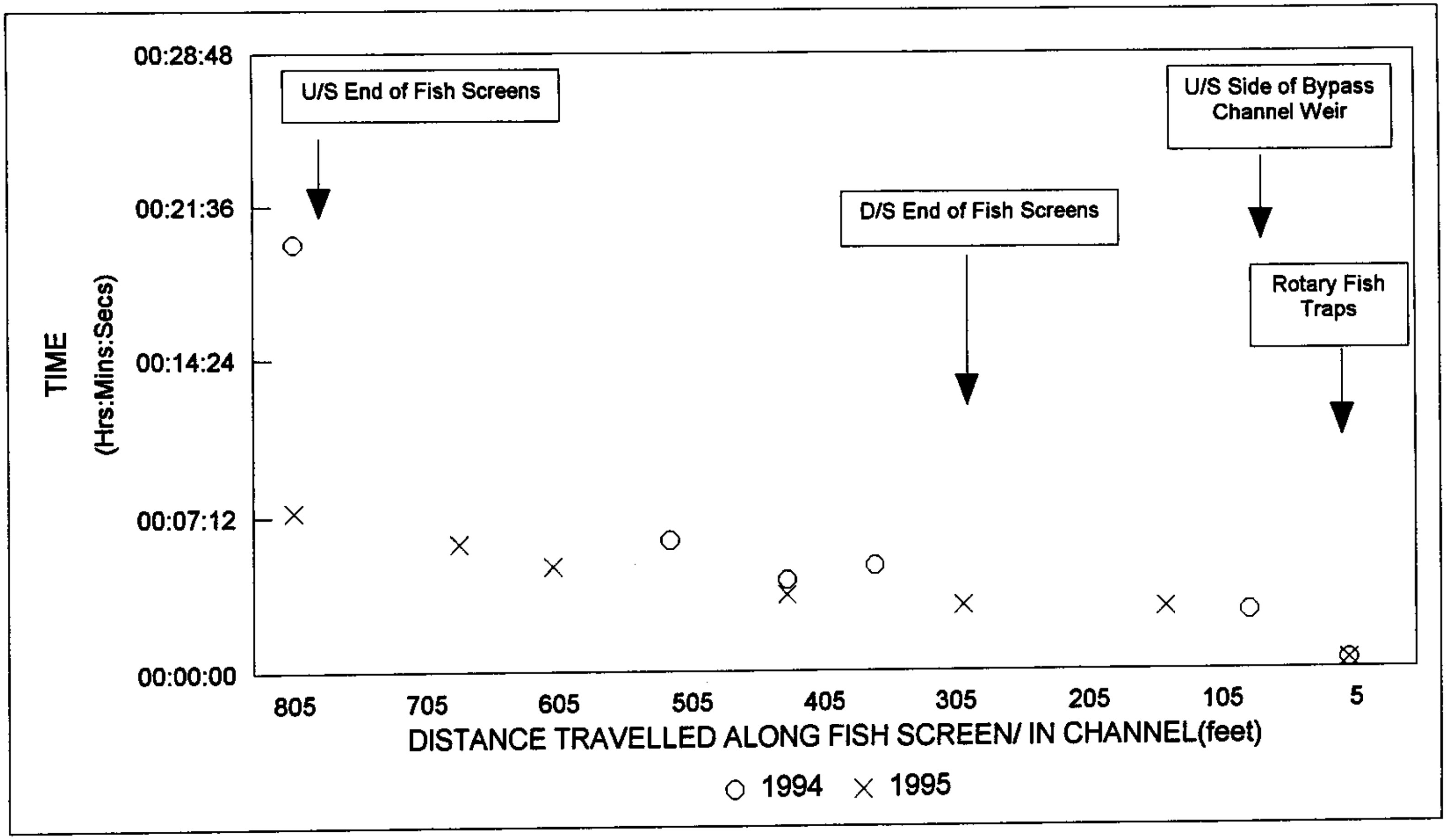

Figure 22. Comparison of 1994 and 1995 median transport time for groups of PIT-tagged chinook salmon released at various locations in the vicinity of the GCID fish screens to the recapture site downstream of the bypass channel weir (night-time releases only).

CONCLUSIONS

Based on detailed data on fish transport timing in the vicinity of the new interim flat-plate fish screens at the GCID Hamilton City pumping station, it was determined that modifications made to or near the facility with the objective of improving hydraulic conditions for downstream migrant salmonid passage were effective in reducing fish passage timing. Specifically, installation of an eddy deflector in front of screen panel 40 and alteration of the roadway into an overflow weir improved downstream migrant fish passage timing.

ACKNOWLEDGEMENTS

Formal recognition should be given to the GCID Board of Directors and members of GCID for their foresight and pro-active approach toward resolving fish passage problems near the GCID Sacramento River pumping station. Their continued sincere desire to minimize natural resource conflicts is evident by their actions to reduce fish mortality at the site with the installation and evaluation of the new interim fish screens while concurrently and aggressively pursuing a long-term solution to fish passage issues. Numerous GCID staff persons contributed considerable time and effort to improving fish passage conditions for salmon at the site and in evaluating the effectiveness of those measures. Rick Moncreif of GCID and other staff at the pumping station deserve special recognition for their extensive efforts in day-to-day operations at the fish screen facility. The CDFG Region 2 staff and Feather River Fish Hatchery staff deserve special gratitude for making the 1995 biological evaluations possible. These persons are thanked for making fish available to perform tests during 1995 and for providing support for the studies.

REFERENCES

CH2M HILL. 1995. Glenn-Colusa Irrigation District, 1995 Hydraulic Monitoring Report, Volume I, Prepared for Glenn-Colusa Irrigation District.

Long, C.W., J.R. McComes, and H. Monk. 1977. Use of salt (NaCl) water to reduce mortality of chinook salmon smolts, *Oncorhynchus tshawytscha*, during handling and hauling. Marine Fisheries Review 39:6-9.

Prentice, E.F., T.A. Flagg, C.S. McCutcheon, D.F. Brastow, and D.C. Cross. 1990. Equipment, methods, and an automated data-entry station for PIT tagging. American Fisheries Society Symposium 7:335-340.

Summerfelt, R.C. and L.S. Smith. 1990. Anesthesia, surgery, and related techniques. Pages 213-334 in C.B. Schreck and P.B. Moyle (editors). *Methods for Fish Biology*. American Fisheries Society. Bethesda, Maryland.

Vogel, D.A. 1989. Tehama-Colusa Canal Diversion and Fishery Problems Study. Final Report. U.S. Fish and Wildlife Service Report No. AFF/FAO-89-06. 33 pp. with appendices.

Vogel, D.A. and K.R. Marine. 1994. Evaluation of the Downstream Migration of Juvenile Chinook Salmon and Steelhead in the Lower Mokelumne River and the Sacramento-San Joaquin Delta (January through July 1993). Vogel Environmental Services. April 1994. 59 pp. with appendices.

Vogel, D.A. and K.R. Marine. 1995. 1994 biological evaluation of the new fish screens at the Glenn-Colusa Irrigation District's Sacramento River pump station. Natural Resource Scientists, Inc. February 1995. 77 pp. plus appendices.

Wedemeyer, G. 1992. Transporting and handling smolts. World Aquaculture 23:47-50.

APPENDIX 1. GLENN-COLUSA IRRIGATION DISTRICT - 1995 FISH PROTECTION INVESTIGATIONS

PASSIVE-INTEGRATED TRANSPONDER DATA FOR JUVENILE CHINOOK SALMON

TRANSPONDER TAG ID NUMBER	TAGGING DATE	RELEASE DATE	RELEASE TIME	RELEASE LOCATION	RECOVERY LOCATION	RECOVERY DATE	RECOVERY TIME	ELAPSED TIME HR:MIN:SEC	NUMBER OF FISH RELEASED	NUMBER OF FISH RECOVERED	AVERAGE TIME RECOVERY	STANDARD DEVIATION TIME RECOVERY	MINIMUM TIME RECOVERY	MAXIMUM TIME RECOVERY	MEDIAN TIME RECOVERY
020600115	07/05/95	07/16/95	00:32:00	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 3	07/16/95	00:40:36	00:08:36							
020693033	07/05/95	07/16/95	00:38:28	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 3	07/16/95	00:46:09	00:07:41							
019617822	07/05/95	07/15/95	01:11:22	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 3	07/15/95	01:20:02	00:08:40							
019527084	07/05/95	07/16/95	00:38:28	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 3	07/16/95	00:45:02	00:06:34							
020689016	07/05/95	07/15/95	01:33:31	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 3	07/15/95	01:45:40	00:12:09							
020263042	07/05/95	07/15/95	01:28:00	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 2	07/15/95	01:35:21	00:07:21							
020628343	07/05/95	07/16/95	00:47:39	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 2	07/16/95	01:01:33	00:13:54							
019328526	07/05/95	07/15/95	01:28:00	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 2	07/15/95	01:35:47	00:07:47							
019604005	07/05/95	07/15/95	01:33:31	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 2	07/15/95	01:40:05	00:06:34							
018040892	07/05/95	07/15/95	01:22:44	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 2	07/15/95	01:29:02	00:06:18							
019522008	07/05/95	07/15/95	01:11:22	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 2	07/15/95	01:18:22	00:07:00							
021769086	07/05/95	07/15/95	01:16:32	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 2	07/15/95	01:27:30	00:10:58							
018040882	07/05/95	07/16/95	00:47:39	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 2	07/16/95	00:59:40	00:12:01							
021536570	07/05/95	07/16/95	00:47:39	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 1	07/16/95	00:54:26	00:06:47							
021020585	07/05/95	07/16/95	00:22:55	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 1	07/16/95	00:29:50	00:06:55							
020381033	07/05/95	07/16/95	00:22:55	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 1	07/16/95	00:30:20	00:07:25							
019522292	07/05/95	07/15/95	01:33:31	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 1	07/15/95	01:40:51	00:07:20							
018827583	07/05/95	07/16/95	00:55:27	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 1	07/16/95	01:02:30	00:07:03							
012356833	07/05/95	07/15/95	01:16:32	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 1	07/15/95	01:24:20	00:07:48							
019514328	07/05/95	07/15/95	01:28:00	OFF U/S END OF SCREENS AT RELEASE PLATFORM	TRAP 1	07/15/95	01:35:10	00:07:10							
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020601519	07/05/95	07/15/95	00:52:10	IN FRONT OF SCREEN #35	TRAP 1	07/15/95	00:59:57	00:07:47							
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019531293	07/05/95	07/15/95	00:52:10	IN FRONT OF SCREEN #35	TRAP 1	07/15/95	00:58:18	00:06:08							
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APPENDIX 1. GLENN-COLUSA IRRIGATION DISTRICT - 1995 FISH PROTECTION INVESTIGATIONS
PASSIVE-INTEGRATED TRANSPONDER DATA FOR JUVENILE CHINOOK SALMON

TRANSPONDER TAG ID NUMBER	TAGGING DATE	RELEASE DATE	RELEASE TIME	RELEASE LOCATION	RECOVERY LOCATION	RECOVERY DATE	RECOVERY TIME	ELAPSED TIME HR:MIN:SEC	NUMBER OF FISH RELEASED	NUMBER OF FISH RECOVERED	AVERAGE TIME RECOVERY	STANDARD DEVIATION TIME RECOVERY	MINIMUM TIME RECOVERY	MAXIMUM TIME RECOVERY	MEDIAN TIME RECOVERY
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019379121	07/05/95	07/15/95	00:25:22	IN FRONT OF U/S BYPASS - CLOSED	TRAP 3	07/15/95	00:32:56	00:07:34							
019342335	07/05/95	07/15/95	00:12:32	IN FRONT OF U/S BYPASS - CLOSED	TRAP 2	07/15/95	00:17:06	00:04:34							
020883313	07/05/95	07/15/95	00:20:50	IN FRONT OF U/S BYPASS - CLOSED	TRAP 2	07/15/95	00:25:28	00:04:38							
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020004576	07/05/95	07/15/95	00:20:50	IN FRONT OF U/S BYPASS - CLOSED	TRAP 1	07/15/95	00:25:32	00:04:42							
019327038	07/05/95	07/15/95	00:25:22	IN FRONT OF U/S BYPASS - CLOSED	TRAP 1	07/15/95	00:29:42	00:04:20							
										STATISTICS FOR RELEASES IN FRONT OF U/S BYPASS - CLOSED					
									76	14	00:06:07	00:03:22	00:03:31	00:17:36	00:04:56
018555045	07/05/95	07/14/95	23:41:17	IN FRONT OF D/S BYPASS - CLOSED	TRAP 3	07/14/95	23:44:32	00:03:15							
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020554060	07/05/95	07/14/95	23:29:55	IN FRONT OF D/S BYPASS - CLOSED	TRAP 3	07/14/95	23:34:50	00:04:55							
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021796790	07/05/95	07/15/95	23:11:40	IN FRONT OF D/S BYPASS - CLOSED	TRAP 3	07/15/95	23:16:15	00:04:35							
021768610	07/05/95	07/14/95	23:29:55	IN FRONT OF D/S BYPASS - CLOSED	TRAP 3	07/14/95	23:33:30	00:03:35							
021076546	07/05/95	07/14/95	23:41:17	IN FRONT OF D/S BYPASS - CLOSED	TRAP 3	07/14/95	23:44:01	00:02:44							
019800319	07/05/95	07/14/95	23:41:17	IN FRONT OF D/S BYPASS - CLOSED	TRAP 3	07/14/95	23:44:50	00:03:33							
019036893	07/05/95	07/14/95	23:21:15	IN FRONT OF D/S BYPASS - CLOSED	TRAP 3	07/14/95	23:24:12	00:02:57							
018118012	07/05/95	07/14/95	23:21:15	IN FRONT OF D/S BYPASS - CLOSED	TRAP 3	07/14/95	23:24:09	00:02:54							
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021605811	07/05/95	07/14/95	23:21:15	IN FRONT OF D/S BYPASS - CLOSED	TRAP 2	07/14/95	23:26:21	00:05:06							
018649301	07/05/95	07/14/95	23:21:15	IN FRONT OF D/S BYPASS - CLOSED	TRAP 2	07/14/95	23:26:00	00:04:45							
020789378	07/05/95	07/14/95	23:41:17	IN FRONT OF D/S BYPASS - CLOSED	TRAP 2	07/14/95	23:43:58	00:02:41							
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019519581	07/05/95	07/14/95	23:41:17	IN FRONT OF D/S BYPASS - CLOSED	TRAP 2	07/14/95	23:44:12	00:02:55							
020693033	07/05/95	07/14/95	23:21:15	IN FRONT OF D/S BYPASS - CLOSED	TRAP 2	07/14/95	23:25:58	00:04:43							
018602382	07/05/95	07/15/95	23:24:50	IN FRONT OF D/S BYPASS - CLOSED	TRAP 1	07/15/95	23:28:10	00:03:20							
020526372	07/05/95	07/15/95	23:11:40	IN FRONT OF D/S BYPASS - CLOSED	TRAP 1	07/15/95	23:15:55	00:04:15							
020066030	07/05/95	07/14/95	23:21:15	IN FRONT OF D/S BYPASS - CLOSED	TRAP 1	07/14/95	23:24:43	00:03:28							
019043280	07/05/95	07/14/95	23:29:55	IN FRONT OF D/S BYPASS - CLOSED	TRAP 1	07/14/95	23:33:52	00:03:57							
018859870	07/05/95	07/14/95	23:29:55	IN FRONT OF D/S BYPASS - CLOSED	TRAP 1	07/14/95	23:33:00	00:03:05							
										STATISTICS FOR RELEASES IN FRONT OF D/S BYPASS - CLOSED					
									150	23	00:03:50	00:01:03	00:02:40	00:07:01	00:03:33
020529888	07/05/95	07/14/95	23:09:35	D/S END OF SCREENS	TRAP 3	07/14/95	23:11:54	00:02:19							
021099306	07/05/95	07/14/95	22:26:00	D/S END OF SCREENS	TRAP 3	07/14/95	22:28:05	00:02:05							
021040832	07/05/95	07/14/95	23:05:05	D/S END OF SCREENS	TRAP 3	07/14/95	23:08:11	00:03:06							
019789383	07/05/95	07/14/95	22:26:00	D/S END OF SCREENS	TRAP 3	07/14/95	22:30:00	00:04:00							
021358768	07/05/95	07/14/95	22:26:00	D/S END OF SCREENS	TRAP 3	07/14/95	22:29:00	00:03:00							
012573851	07/05/95	07/14/95	23:01:40	D/S END OF SCREENS	TRAP 3	07/14/95	23:04:07	00:02:27							
018044884	07/05/95	07/14/95	22:57:05	D/S END OF SCREENS	TRAP 3	07/14/95	22:59:00	00:01:55							
019810089	07/05/95	07/15/95	22:52:55	D/S END OF SCREENS	TRAP 3	07/15/95	22:56:20	00:03:25							
021845087	07/05/95	07/15/95	22:52:55	D/S END OF SCREENS	TRAP 3	07/15/95	22:56:52	00:03:57							
019811105	07/05/95	07/14/95	23:09:35	D/S END OF SCREENS	TRAP 2	07/14/95	23:11:56	00:02:21							
021323808	07/05/95	07/14/95	22:26:00	D/S END OF SCREENS	TRAP 2	07/14/95	22:28:38	00:02:38							
020024521	07/05/95	07/14/95	22:57:05	D/S END OF SCREENS	TRAP 2	07/14/95	22:59:16	00:02:11							
018047804	07/05/95	07/15/95	22:45:15	D/S END OF SCREENS	TRAP 2	07/15/95	22:48:00	00:02:45							
012113014	07/05/95	07/14/95	22:26:00	D/S END OF SCREENS	TRAP 2	07/14/95	22:27:53	00:01:53							
019805042	07/05/95	07/14/95	23:05:05	D/S END OF SCREENS	TRAP 2	07/14/95	23:08:26	00:03:21							
018874319	07/05/95	07/14/95	23:05:05	D/S END OF SCREENS	TRAP 2	07/14/95	23:09:42	00:04:37							
019804771	07/05/95	07/15/95	22:59:50	D/S END OF SCREENS	TRAP 2	07/15/95	23:03:13	00:03:23							
020085289	07/05/95	07/14/95	22:31:07	D/S END OF SCREENS	TRAP 2	07/14/95	22:33:30	00:02:23							
019088832	07/05/95	07/14/95	22:26:00	D/S END OF SCREENS	TRAP 1	07/14/95	22:28:58	00:02:58							
020848519	07/05/95	07/14/95	22:57:05	D/S END OF SCREENS	TRAP 1	07/14/95	22:59:40	00:02:35							

APPENDIX 1. GLENN-COLUSA IRRIGATION DISTRICT - 1995 FISH PROTECTION INVESTIGATIONS

PASSIVE-INTEGRATED TRANSPONDER DATA FOR JUVENILE CHINOOK SALMON

TRANSPONDER TAG ID NUMBER	TAGGING DATE	RELEASE DATE	RELEASE TIME	RELEASE LOCATION	RECOVERY LOCATION	RECOVERY DATE	RECOVERY TIME	ELAPSED TIME HR:MIN:SEC	NUMBER OF FISH RELEASED	NUMBER OF FISH RECOVERED	AVERAGE TIME RECOVERY	STANDARD DEVIATION TIME RECOVERY	MINIMUM TIME RECOVERY	MAXIMUM TIME RECOVERY	MEDIAN TIME RECOVERY
019530256	07/05/95	07/14/95	23:05:05	D/S END OF SCREENS	TRAP 1	07/14/95	23:10:35	00:05:30							
021095332	07/05/95	07/15/95	22:52:55	D/S END OF SCREENS	TRAP 1	07/15/95	22:55:00	00:02:05							
019374858	07/05/95	07/15/95	22:52:55	D/S END OF SCREENS	TRAP 1	07/15/95	22:57:40	00:04:45							
019852809	07/05/95	07/14/95	23:05:05	D/S END OF SCREENS	TRAP 1	07/14/95	23:09:58	00:04:53							
021841639	07/05/95	07/15/95	23:36:50	D/S END OF SCREENS	TRAP 1	07/15/95	23:43:20	00:06:30							
019790005	07/05/95	07/14/95	22:26:00	D/S END OF SCREENS	TRAP 1	07/14/95	22:30:31	00:04:31							
020049328	07/05/95	07/15/95	22:59:50	D/S END OF SCREENS	TRAP 1	07/15/95	23:03:20	00:03:30							
019324074	07/05/95	07/15/95	23:36:50	D/S END OF SCREENS	TRAP 1	07/15/95	23:40:10	00:03:20							
										STATISTICS FOR RELEASES AT THE D/S END OF SCREENS					
									145	28	00:03:18	00:01:09	00:01:53	00:06:30	00:03:03
020096845	07/05/95	07/15/95	22:02:33	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 3	07/15/95	22:04:50	00:02:17							
021099034	07/05/95	07/14/95	21:56:23	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 3	07/14/95	21:59:30	00:03:07							
020602591	07/05/95	07/14/95	22:10:36	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 3	07/14/95	22:12:00	00:01:24							
021541546	07/05/95	07/15/95	22:02:33	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 3	07/15/95	22:18:15	00:15:42							
021772294	07/05/95	07/15/95	22:02:33	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/15/95	22:27:59	00:25:26							
019580324	07/05/95	07/14/95	21:56:23	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/14/95	22:02:16	00:05:53							
019616570	07/05/95	07/14/95	21:56:23	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/14/95	21:57:18	00:00:55							
020289104	07/05/95	07/14/95	21:56:23	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/14/95	21:59:34	00:03:11							
020283115	07/05/95	07/15/95	22:02:33	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/15/95	22:04:34	00:02:01							
019516580	07/05/95	07/15/95	22:25:49	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/15/95	22:27:32	00:01:43							
021557578	07/05/95	07/15/95	22:02:33	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/15/95	22:06:12	00:03:39							
020049817	07/05/95	07/14/95	22:10:36	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/14/95	22:12:45	00:02:09							
020080794	07/05/95	07/14/95	22:10:36	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/14/95	22:13:17	00:02:41							
020258529	07/05/95	07/14/95	22:10:36	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/14/95	22:14:54	00:04:18							
019854293	07/05/95	07/15/95	22:25:49	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/15/95	22:30:30	00:04:41							
014559631	07/05/95	07/15/95	22:25:49	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/15/95	22:28:32	00:02:43							
019614086	07/05/95	07/14/95	21:56:23	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 2	07/14/95	22:02:58	00:06:35							
018319038	07/05/95	07/15/95	22:25:49	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 1	07/15/95	22:28:30	00:02:41							
021602539	07/05/95	07/14/95	22:10:36	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 1	07/14/95	22:16:06	00:05:30							
020377821	07/05/95	07/14/95	21:56:23	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-NIGHT	TRAP 1	07/14/95	21:58:13	00:01:50							
										STATISTICS FOR RELEASES U/S OF CULVERTS & D/S OF SCREENS					
										RIGHT BANK FACING D/S - NIGHT					
									81	20	00:04:55	00:05:38	00:00:55	00:25:26	00:02:55
020315011	07/05/95	07/15/95	05:04:20	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-PRE-DAWN	TRAP 3	07/15/95	05:06:30	00:02:10							
019848349	07/05/95	07/15/95	05:04:20	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-PRE-DAWN	TRAP 2	07/15/95	05:06:27	00:02:07							
019000262	07/05/95	07/16/95	05:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-PRE-DAWN	TRAP 2	07/16/95	05:03:30	00:03:30							
020614871	07/05/95	07/16/95	05:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-PRE-DAWN	TRAP 2	07/16/95	05:28:50	00:28:50							
020531098	07/05/95	07/16/95	05:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-PRE-DAWN	TRAP 2	07/16/95	05:22:12	00:22:12							
019557636	07/05/95	07/15/95	05:04:20	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-PRE-DAWN	TRAP 2	07/15/95	05:06:27	00:02:07							
019576272	07/05/95	07/15/95	05:04:20	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-PRE-DAWN	TRAP 2	07/15/95	05:50:41	00:46:21							
021368108	07/05/95	07/15/95	05:04:20	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-PRE-DAWN	TRAP 2	07/15/95	05:06:27	00:02:07							
020825103	07/05/95	07/15/95	05:04:20	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-PRE-DAWN	TRAP 2	07/15/95	05:06:27	00:02:07							
019788639	07/05/95	07/16/95	05:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-PRE-DAWN	TRAP 2	07/16/95	05:01:11	00:01:11							
019563587	07/05/95	07/15/95	05:04:20	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-PRE-DAWN	TRAP 1	07/15/95	05:08:27	00:04:07							
021536570	07/05/95	07/15/95	05:04:20	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-PRE-DAWN	TRAP 1	07/15/95	05:31:46	00:27:26							
										STATISTICS FOR RELEASES U/S OF CULVERTS & D/S OF SCREENS					
										RIGHT BANK FACING D/S - PRE-DAWN					
									84	12	00:12:01	00:14:34	00:01:11	00:48:21	00:02:50
019516604	07/05/95	07/15/95	08:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-DAYLIGHT	TRAP 3	07/15/95	08:16:30	00:16:30							
020381033	07/05/95	07/15/95	06:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-DAYLIGHT	TRAP 2	07/15/95	07:00:00	[illegible]							
021518822	07/05/95	07/16/95	08:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-DAYLIGHT	TRAP 2	07/16/95	08:03:31	00:03:31							
020775030	07/05/95	07/15/95	08:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-DAYLIGHT	TRAP 2	07/15/95	08:07:41	00:07:41							
020006008	07/05/95	07/16/95	08:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-DAYLIGHT	TRAP 2	07/16/95	08:05:21	00:05:21							
019376041	07/05/95	07/15/95	08:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-DAYLIGHT	TRAP 1	07/15/95	08:17:28	00:17:28							
011349032	07/05/95	07/16/95	06:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-DAYLIGHT	TRAP 1	07/16/95	11:00:00	[illegible]							
020600115	07/05/95	07/15/95	08:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-DAYLIGHT	TRAP 1	07/15/95	08:18:11	00:18:11							
019626320	07/05/95	07/16/95	08:00:00	U/S OF CULVERTS & D/S OF SCREENS - RIGHT BANK FACING D/S-DAYLIGHT	TRAP 1	07/16/95	08:27:30	00:27:30							
020533084	07/05/95	07/15/95	08:07:00	U/S OF CULVERTS & D/S OF SCREENS - LEFT BANK FACING D/S-DAYLIGHT	TRAP 3	07/15/95	08:10:56	00:03:56							
020261562	07/05/95	07/15/95	08:07:00	U/S OF CULVERTS & D/S OF SCREENS - LEFT BANK FACING D/S-DAYLIGHT	TRAP 3	07/15/95	08:10:57	00:03:57							

APPENDIX 1. GLENN-COLUSA IRRIGATION DISTRICT - 1995 FISH PROTECTION INVESTIGATIONS
PASSIVE-INTEGRATED TRANSPONDER DATA FOR JUVENILE CHINOOK SALMON

TRANSPONDER TAG ID NUMBER	TAGGING DATE	RELEASE DATE	RELEASE TIME	RELEASE LOCATION	RECOVERY LOCATION	RECOVERY DATE	RECOVERY TIME	ELAPSED TIME HR:MIN:SEC	NUMBER OF FISH RELEASED	NUMBER OF FISH RECOVERED	AVERAGE TIME RECOVERY	STANDARD DEVIATION TIME RECOVERY	MINIMUM TIME RECOVERY	MAXIMUM TIME RECOVERY	MEDIAN TIME RECOVERY
019373068	07/05/95	07/15/95	08:07:00	U/S OF CULVERTS & D/S OF SCREENS - LEFT BANK FACING D/S-DAYLIGHT	TRAP 2	07/15/95	08:08:23	00:01:23							
020328614	07/05/95	07/15/95	08:07:00	U/S OF CULVERTS & D/S OF SCREENS - LEFT BANK FACING D/S-DAYLIGHT	TRAP 2	07/15/95	08:10:22	00:03:22							
020533538	07/05/95	07/15/95	08:07:00	U/S OF CULVERTS & D/S OF SCREENS - LEFT BANK FACING D/S-DAYLIGHT	TRAP 2	07/15/95	08:10:22	00:03:22							
020534328	07/05/95	07/15/95	08:07:00	U/S OF CULVERTS & D/S OF SCREENS - LEFT BANK FACING D/S-DAYLIGHT	TRAP 2	07/15/95	08:10:22	00:03:22							
021015885	07/05/95	07/15/95	08:07:00	U/S OF CULVERTS & D/S OF SCREENS - LEFT BANK FACING D/S-DAYLIGHT	TRAP 2	07/15/95	08:10:22	00:03:22							
018827583	07/05/95	07/15/95	08:07:00	U/S OF CULVERTS & D/S OF SCREENS - LEFT BANK FACING D/S-DAYLIGHT	TRAP 2	07/15/95	08:08:23	00:01:23							
021515618	07/05/95	07/16/95	08:06:00	U/S OF CULVERTS & D/S OF SCREENS - LEFT BANK FACING D/S-DAYLIGHT	TRAP 1	07/16/95	08:07:05	00:01:05							
020894633	07/05/95	07/15/95	08:07:00	U/S OF CULVERTS & D/S OF SCREENS - LEFT BANK FACING D/S-DAYLIGHT	TRAP 1	07/15/95	08:13:55	00:06:55							
020289604	07/05/95	07/15/95	08:07:00	U/S OF CULVERTS & D/S OF SCREENS - LEFT BANK FACING D/S-DAYLIGHT	TRAP 1	07/15/95	08:12:55	00:05:55							
										STATISTICS FOR RELEASES U/S OF CULVERTS & D/S OF SCREENS					
										RIGHT & LEFT BANKS FACING D/S - DAYLIGHT					
									64	20	00:24:46	01:04:32	00:01:05	05:00:00	00:04:39
019625276	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 1	TRAP 1	07/15/95	SEE NOTE	00:01:20							
019382617	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 1	TRAP 1	07/15/95	SEE NOTE	00:00:30							
021301539	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 1	TRAP 1	07/15/95	SEE NOTE	00:00:22							
019516364	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 1	TRAP 1	07/15/95	SEE NOTE	00:00:15							
021542782	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 1	TRAP 1	07/15/95	SEE NOTE	00:00:22							
021020565	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 1	TRAP 1	07/15/95	SEE NOTE	00:00:17							
019615589	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 1	TRAP 1	07/15/95	SEE NOTE	00:00:23							
021114087	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 1	TRAP 1	07/15/95	SEE NOTE	00:00:18							
018871583	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 1	TRAP 1	07/15/95	SEE NOTE	00:00:18							
020532792	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 1	TRAP 1	07/15/95	SEE NOTE	00:00:22							
										STATISTICS FOR RELEASES DIRECTLY INTO TRAP 1					
									10	10	00:00:27	00:00:18	00:00:15	00:01:20	00:00:22
019527084	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 2	TRAP 2	07/15/95	SEE NOTE	00:00:12							
020608010	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 2	TRAP 2	07/15/95	SEE NOTE	00:00:19							
019540282	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 2	TRAP 2	07/15/95	SEE NOTE	00:01:35							
021020021	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 2	TRAP 2	07/15/95	SEE NOTE	00:01:08							
020368122	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 2	TRAP 2	07/15/95	SEE NOTE	00:00:37							
019621542	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 2	TRAP 2	07/15/95	SEE NOTE	00:00:12							
019317269	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 2	TRAP 2	07/15/95	SEE NOTE	00:00:24							
021538034	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 2	TRAP 2	07/15/95	SEE NOTE	00:00:30							
021368332	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 2	TRAP 2	07/15/95	SEE NOTE	00:00:42							
020577360	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 2	TRAP 2	07/15/95	SEE NOTE	00:00:16							
										STATISTICS FOR RELEASES DIRECTLY INTO TRAP 2					
									10	10	00:00:36	00:00:28	00:00:12	00:01:35	00:00:27
019357576	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 3	TRAP 3	07/15/95	SEE NOTE	00:00:17							
020362355	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 3	TRAP 3	07/15/95	SEE NOTE	00:01:08							
019849889	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 3	TRAP 3	07/15/95	SEE NOTE	00:00:33							
013257526	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 3	TRAP 3	07/15/95	SEE NOTE	00:00:36							
021775282	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 3	TRAP 3	07/15/95	SEE NOTE	00:00:37							
019358519	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 3	TRAP 3	07/15/95	SEE NOTE	00:00:47							
018860357	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 3	TRAP 3	07/15/95	SEE NOTE	00:01:00							
020283287	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 3	TRAP 3	07/15/95	SEE NOTE	00:00:27							
020002368	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 3	TRAP 3	07/15/95	SEE NOTE	00:00:18							
020108347	07/05/95	07/15/95	SEE NOTE	RELEASED DIRECTLY INTO TRAP 3	TRAP 3	07/15/95	SEE NOTE	00:00:26							
										STATISTICS FOR RELEASES DIRECTLY INTO TRAP 3					
									10	10	00:00:37	00:00:16	00:00:17	00:01:08	00:00:35
NOTE: TIMING FOR THESE PIT TAGGED FISH WAS BASED ON DIRECT TIMING BY STOP WATCH															
										STATISTICS FOR RELEASES INTO ALL THREE ROTARY TRAPS					
									30	30	00:00:33	00:00:21	00:00:12	00:01:35	00:00:25