FIELD EVALUATION OF ENGINEERED CULVERTS

Prepared by:
Douglas L. Kane and Charles E. Behlke

Water and Environmental Research Center
Institute of Northern Engineering
University of Alaska Fairbanks

February 1998

Prepared for:
Alaska Department of Transportation
Statewide Research Office
3132 Channel Drive
Juneau, AK 99801-7898

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Using information garnered from research results, design engineers and biologists are now designing hydraulic structures to enhance fish passage. Many of these structures have been in place for several years; however, there has not been a critical examination of these structures. In this study, field visits to numerous engineered-culverts were made throughout the State of Alaska during the past two summers (1996 and 1997) with the sole intention of evaluating the capability of each culvert to pass fish. In most cases the culverts evaluated had received special attention in the design phase by the AK Department of Transportation and Public Facilities (AKDOT&PF) design engineers, AK Department of Fish and Game (AKF&G) biologists, or, in the case of the culverts on Prince of Wales Island, by a third party.
## METRIC (SI*) CONVERSION FACTORS

### APPROXIMATE CONVERSIONS TO SI UNITS

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These factors conform to the requirement of FHWA Order 5190.1A *SI is the symbol for the International System of Measurements.
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FINAL REPORT

by

Douglas L. Kane and Charles E. Behlke

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INTRODUCTION

During the past few years, researchers have revisited the issues surrounding the interaction between fish and hydraulic structures. Initial efforts were directed at an improved and more physically based quantification of fish swimming performance by various species. Most of this work was directed at adult fish. On the hydraulic side, laboratory studies were performed on numerous hydraulic structures (culverts, fish ladders, turbines, etc.) with the goal of enhancing fish passage. More recently, researchers have directed their efforts toward juvenile fish to both ensure that they can reach upstream habitat and, in the case of anadromous fish, successfully return to the sea.

Using information garnered from research results, design engineers and biologists are now designing hydraulic structures to enhance fish passage. Many of these structures have been in place for several years; however, there has not been a critical examination of these structures. In this study, field visits to numerous engineered-culverts were made throughout the State of Alaska during the past two summers (1996 and 1997) with the sole intention of evaluating the capability of each culvert to pass fish. In most cases the culverts evaluated had received special attention in the design phase by the AK Department of Transportation and Public Facilities (AKDOT&PF) design engineers, AK Department of Fish and Game (AKF&G) biologists, or, in the case of the culverts on Prince of Wales Island, by a third party.

STUDY PLAN

Alaska streams are utilized by both resident and anadromous fish that range from those classified as weak to strong swimmers. Currently, commercial and sport fishing are important components of the Alaskan lifestyle. The ability of these fish populations to move upstream and downstream to habitat and spawning areas unimpeded is necessary for maintaining population levels. The objective of this study was to conduct a field review of culverts (≈12) that had been designed with the intent of improving fish passage. These culverts were chosen to be representative of a range of streams, from northern to southeastern Alaska, for streams inhabited by primarily weak-swimming adult fish to those with just strong-swimming adult fish. In between those two extremes, there is a mixture of both weak and strong-swimming fish, including juveniles. By the end of the two summer field seasons, we had examined 33 culverts. Data collected at each site could range from just photos and video footage to a number of measurements, including geometry of culvert (slope, diameter, length, baffle spacing, etc.), stream slope upstream and downstream of culvert, water surface profile from upstream of culvert to downstream of culvert, stream discharge, velocity profiles, and numerous miscellaneous observations (bed material, fish, obstructions such as ice and woody materials, etc.). For a thoroughly investigated site, we followed the data collection format used by Kane and Wellen (1985) and Wellen and Kane (1985) in an earlier study.
LIMITATIONS OF STUDY

The principle limitation of this study was that most sites were visited only once. Flow conditions through a culvert can vary substantially from low flows to high flows. High flows occur following snowmelt events and major rainfall events. For streams inhabited with Arctic Grayling (Thymallus arcticus), the snowmelt period coincides with upstream movement for spawning purposes. Therefore, streams with Arctic Grayling should be visited during high flows from snowmelt. The only northern stream not visited during snowmelt was Rosie Creek at Mile Post 170 Dalton Highway. Most salmon species spawn after the snowmelt period; upstream migration could be hampered by both low and high flow conditions, the latter being caused by rain-generated runoff. Juvenile fish searching for suitable habitat in the stream system were assumed to move when flow conditions allowed, which generally occurs in the range of lower flows. The assumption was that they could withstand a short delay in moving from one area to another for purposes of feeding. All of the salmon-dominated streams in southcentral and southeastern Alaska were visited during the summer months of July, August and September.

CASE STUDIES

South Fork of the West Fork of the Dall River
Mile Post 91.1 Dalton Highway

This culvert was visited three times during the course of this study. The site consists of two circular culverts, 10 foot and 5 foot diameters (Figure 1). The larger culvert was installed at ground level at approximately the same slope as the stream. The smaller overflow culvert was elevated about five feet, roughly parallel to the top of the 10 foot diameter culvert. The smaller culvert had three galvanized steam pipes running through the top of the culvert and the main culvert had one flexible tube running through it. The overflow culvert was added, apparently to take some of the flow when the main culvert was full of aufeis.

On May 14, 1996, a visit to the site revealed that the main culvert was basically blocked by aufeis and almost all of the flow was going through the smaller culvert. Upstream of the road, water was backed up and the culvert inlets were submerged. The flow in the smaller culvert was supercritical (we could not hold a current meter in the flow); we estimated the average velocity at 15 fps. Aufeis upstream of the culvert did not appear to be a problem. On May 18, 1996, we revisited the site. There was now flow passing through both culverts. Some melting of the aufeis in the larger culvert had occurred, allowing for the flow of water. Another visit to this site later in the summer, after all the ice had ablated (August 2), revealed a properly functioning culvert.

If Arctic Grayling utilize this stream for spawning, they would have been delayed several days by the lack of flow because of ice in the larger culvert and the high velocity flow in the smaller, overflow culvert. Because the smaller culvert is elevated above the streambed about five feet, flows accelerate at the downstream outlet, producing supercritical flow. The solution to this problem is to install permanent steam pipes in the larger culvert to initiate flow through this culvert that will erode the ice. With no ice in the larger culvert,
fish would be able to migrate upstream through this culvert according to the predictions of the FISHPASS model (Behlke et al., 1991).

![Figure 1. Culverts on South Fork of the West Fork of the Dall River, May 14, 1996 show all of the flow going through the left culvert.](image)

**Middle Fork of the West Fork of the Dall River**
**Mile Post 93.2 Dalton Highway**

An older arched culvert (8 feet 10 inches by 6 feet 1 inch) with a perched outlet had been replaced by an 8 foot circular pipe that was depressed about 1½ feet at the outlet (Figure 2). This site was visited on May 14, 1996. Snowmelt runoff was in recession and the measured discharge was 30.0 cfs. Velocity profiles were taken at both the inlet where the maximum centerline depth was 1.75 feet and the outlet where the maximum depth was 3.0 feet. Velocities at the upstream culvert inlet were relatively high (3.5 fps @ 0.25 feet from wall, \(V_{\text{max}} = 5.5 \text{ fps} @ 0.75 \text{ feet from wall}\)). These high velocities extended about 30 feet into culvert. Velocities at the outlet were 2.5 fps or less.

There was some aufeis remaining in the culvert on May 14, but the blockage did not seem to alter water velocities significantly. The ends of the culvert were anchored down to prevent ice from pushing the culvert end up and producing an adverse slope. Three steam pipes extended through the culvert. This culvert was installed with the same slope as the upstream channel. Visits on May 30 and August 2 confirmed that this culvert was operating properly for fish passage. **We could find no problems with fish passage on this culvert.**
culvert is quite adequate for passage of weak swimming fish during the spring flood according to the FISHPASS model (Behlke et al., 1991)

Figure 2: Outlet of the Middle Fork of the West Fork of Dall River with depressed outlet on May 14, 1996. Also note the tie-down cables and steam pipes.

Finger Mountain Creek
Mile Post 96.3 Dalton Highway

A 5 foot diameter circular culvert, 112 feet long, was installed at this crossing. Above the road the stream is very small and lacks any deep pools for fish habitat during dry periods. Because we felt that this headwater drainage was too small for fish we only gave it a cursory inspection. The only visible problem was that the fill material from the large roadway embankment was eroding into the stream; this could impact fish habitat below the road.

Olsen Lake’s Creek
Mile Post 99.8 Dalton Highway

The culverts installed at this site prior to the upgrade were deemed a barrier to the upstream movement of Arctic Grayling. After the upgrade, an existing arched culvert (7 ft by 5 ft 1 in, 136 ft long) remained in place. A 36 inch diameter culvert (214 ft long) was replaced by a 10 foot diameter culvert (184 ft long). The new culvert was equipped with three thaw pipes, whereas the pre-existing pipe had none. Aufeis is a major problem at this site, both upstream and inside of the culvert. We visited this site in the spring on May 14 and May 30, 1996.
On May 14, both culverts had flow through them, although both were partially blocked with ice. The older and smaller culvert (without thaw pipes) had ice in the bottom. This was particularly evident at the outlet where the water flowing over the ice was in the supercritical range as it dropped about three feet in elevation with very high velocities. Because of the ice and the high flow velocities we did not take any hydraulic measurements. The new 10 foot diameter culvert was almost completely filled with ice (Figure 3).

Figure 3: The new 10 foot diameter culvert at Olsen Lake’s Creek in foreground, with older culvert in background on May 14, 1996. Because of aufeis in new culvert, most of the flow passes through older culvert.

Two obstacles existed at this site that would have been detrimental to fish passage. During the early snowmelt runoff, most of the flow passed through the smaller arched culvert. Both the ice in the culvert and the fact that at the downstream outlet the channel is rather steep (until the flow reaches the channel emanating from the larger culvert) produce quite high velocities. Also, the flow entering the larger 10 foot diameter culvert first flowed over the top of the aufeis upstream from the roadway, then dropped vertically down about 6 feet into the culvert (Figure 4).

A visit to this site on May 30 revealed that 90% of the flow was still going into the smaller culvert, and this water drops several feet between the outlets of the two culverts. Although this culvert was aligned with the stream upstream it was not downstream; the result was that this culvert terminated several feet above the stream channel. There was still a large amount of ice in the 10 foot culvert. On August 2, 1996, a visit to this site showed everything in order. Of course the main cause of all the problems, aufeis, was totally ablated. We have insufficient data to evaluate this culvert with the FISHPASS model.
There is no simple solution to the problems at this site. The older culvert was not properly installed and the aufeis at the site redirects flow into this pipe rather than the new pipe. The new pipe is adequately equipped with thaw pipes and, as our late summer observations show, it is not a barrier to fish when all the flow passes through this culvert. However, because the aufeis upstream redirects most of the flow to the other culvert, a barrier to fish passage exists until the ice in and around the culverts melts. This culvert should have been removed when the new one was installed.

Rosie Creek
Mile Post 170.0 Dalton Highway

On August 16, 1997 we visited this site to examine the performance of the large riprap placed in the stream downstream of the culvert to minimize the amount of perching that was occurring. Seven large boulders (Figure 5) had been placed in a line across the stream about 25 to 30 feet below the culvert. At the time of our visit, bank erosion had taken place, allowing water to flow around both ends of the riprap. The culvert was not perched as yet, although the channel width had increased substantially over that of the culvert or stream channel some distance downstream. We did not take any measurements at this site. Had we had some original measurements during the installation, we could have made comparisons of bed slope, channel width and bed material. It appears that there has been some deposition of bed material below the culvert outlet and above the riprap. A small riffle has developed below the riprap. Some of the large boulders appear to have been moved downstream. Bank erosion is the main problem here. When obstructions are placed in the stream channel
to raise the upstream water level, the banks require protection. Otherwise, the flow slowly erodes the banks. Most of this erosion occurs at higher flows.

Figure 5: A view looking upstream at the outlet of the culvert on Rosie Creek, August 16, 1997. This view shows both the riprap placed in the channel and the stream bank erosion around the ends of the riprap.

Answer Creek
Mile 5.3 Talkeetna Spur Road

This site was visited on August 16, 1996. Five log weirs had been placed across the creek downstream of the culvert to minimize perching of the culvert. The spacing of these logs ranged from 13 to 15 feet and the drops (water surface to water surface) ranged from 0.25 to 0.55 feet except at the last drop transitioning into the undisturbed channel where the change was 1.6 feet. The culvert was arched (11.25 ft wide by 13.0 ft high, length equals 112 ft) and had a large rock at the outlet (Figure 6). The downstream channel slope is relatively steep, 0.044, and this produces the conditions that are favorable for culverts to perch.

The modification to this culvert appeared to be working except for the large drop between the farthermost downstream log weir and the undisturbed channel. When the logs were placed in the channel, the width of this channel was constructed wider than the normal channel. Unlike Rosie Creek on the Dalton Highway, the banks were protected with riprap. As the flow transitions from the wider and shallower channel of the log weirs to the narrower and deeper natural channel the flow accelerates. This has produced some scouring at this transition point. Each log had been notched, and velocities in these openings were around 3
to 3.5 fps, except for the lower log weir, where the velocity was around 5 fps. At a flow of 15 cfs, no excessive velocities existed in the culvert.

The only problem at this site appears to be the large drop at the lowest weir log. We do not know if it has existed since the installation or if it is progressively getting worse. This drop may prevent some juvenile fish from moving upstream, although we do not yet have good data on the leaping ability of these fish. A smoother transition in width from the constructed channel to the natural channel could alleviate some of this problem. It appears that a significant change of slope occurs at the site of the culvert. The channel slope downstream of the culvert is much greater than upstream of the culvert. Upstream of the culvert the channel width is quite similar to the rehabilitated channel with the log weirs.

Figure 6: A view looking upstream at the Answer Creek culvert outlet on August 16, 1996 with four of the log weirs in the foreground.

Trapper Creek
Mile Post 115.7 Parks Highway

Three arched culverts (9.7 ft w and 10.7 ft h, length 100 ft) carry the water of Trapper Creek under the Parks Highway. Three rows of riprap were placed across the stream below the outlet to minimize perching (Figure 7). The stream drains a wetland area with very little gradient (0.0064) upstream of the culvert and the slope increases downstream to 0.012. On August 16, 1996 at a flow rate of 50.0 cfs, the velocities entering the culvert were relatively low. At the outlet, the average velocities approached 6 fps and the culverts were slightly perched.
Figure 7: Installation of riprap at the downstream end of the Trapper Creek Culvert. The bottom two rows of riprap are visible, but not the top row, which has washed away (August 13, 1996).

The first row of riprap downstream of the culvert outlet had been partly dislodged. Evidence of this riprap was only visible from above on the road (Figure 8) as there was essentially no change in water surface elevation as the water flowed over it. After the second row of riprap (34 ft downstream) the water level dropped 0.6 feet, and 50 feet downstream at the third row of riprap it dropped another 0.45 feet. Most of the riprap was 1 to 2 feet in the longest dimension. There was nothing holding the riprap in place.

The culvert is slightly perched but not so severely that fish, even juveniles, would be impacted. The riprap appears to be undersized as it was obviously displaced during high flows. If the riprap had been anchored it would have been of sufficient size to minimize perching. Perching at this site will get worse with time as high flows further dislodge the riprap.

Un-named Creek
Mile Post 121 Parks Highway

Below the culvert outlet of this small stream, two logs had been placed across the stream that resulted in drops of 0.5 and 0.8 feet. Three culverts were used at this site (Figure 9). A nice pool existed at the outlet of the culvert. Everything seemed to be functioning correctly at this site regarding fish passage. The banks looked to be stabilized.
Figure 8: Riprap on Trapper Creek as viewed looking downstream from the above roadway. The remains of the upper row of riprap can be seen in the foreground below the water. There is also no observable change in the water surface such as can be seen for the lower two rows of riprap (August 13, 1996).

Un-named Creek
Mile Post 126 Parks Highway

At this site, visited on August 16, 1996, 3 log weirs were placed downstream of the culvert with drops of 1.0 foot, 0.5 feet, 0.6 feet (Figure 10). The site seemed to be functioning quite nicely, as the velocities in the culvert were low at the entrance and exit and in the barrel. The banks had also stabilized with vegetation.
Figure 9: Looking upstream at culvert outlet at Mile Post 121 with two log weirs in foreground (August 16, 1996).

Figure 10: View looking downstream at the three log weirs on the creek at Mile Post 126 (August 16, 1996).
Spokane Creek
Mile Post 61 Seward Highway

This site was visited on August 14, 1996. Two culverts exist at this site, an overflow culvert (5.6 ft w by 4.3 ft h) and the main culvert that has a width of 8.8 feet, but its height could not be determined because of sediment in the culvert. Six baffles were installed in the culvert; starting upstream the water surface at the baffles dropped 1.0, 0.0, 0.8, 0.8, 0.2 and 0.0 feet. Ideally, it would be best to have more uniform drops. The problem is due to the fact that the culvert does not have a constant slope. Some riprap appeared to have been placed across the stream downstream of the outlet; this enhances pool conditions below the outlet (Figure 11) and helps to minimize perching. Other than this, the culvert was performing adequately.

![Outlet of culvert on Spokane Creek showing enhanced pool conditions (August 14, 1996).](image)

Petes Creek
Mile Post 64.0 Seward Highway

This site was visited on August 14, 1996. This is another baffled culvert (6.8 ft w by 5.0 ft h). Baffles 1.6 feet high at the centerline were spaced 15 feet apart throughout the culvert. The top of these baffles were not placed horizontally, but at an angle (Figure 12). Baffle slopes alternate, so the flow meanders back and forth across the culvert. This appeared to be effective at the low flows that existed during our visit. The space between the baffles was filled with gravel. Large boulders had been strategically placed in the channel downstream, these were effective also. This was a well designed and installed installation.
Figure 12. View looking upstream through culvert at Pete’s Creek on August 14, 1996, showing the varying slope on baffles.

Silvertip Creek
Mile Post 61.2 Seward Highway

An arched culvert (16.3 ft w by 11.0 ft h) with baffles was installed at this site. The baffles are 2.4 feet high at the centerline and are installed at an angle (Figure 13). The upper cell between baffles is filled with gravel, the remaining cells are only partially full. Concrete headwalls are in-place at both ends of the culvert and some riprap was placed in the channel downstream to minimize perching. Everything seemed to be functioning properly at this structure.

Soldotna Creek
Sterling Highway near Soldotna

This culvert was visited on August 14, 1996 and August 2, 1997. This 298 foot long culvert has 13 baffles that are irregularly spaced. The drop in the water surface at each baffle ranges from 0.2 to 0.8 feet. This culvert is potentially only a barrier to young of the year juvenile salmon that cannot get over the baffles. There is also a weir at the upstream end of the culvert constructed of sheet piling (Figure 14). It is not known what the purpose of this structure is. The baffles are basically horizontal, although some are tilted slightly to one side or the other (no recognizable pattern). The water surface drops over 4.0 feet from the upper end of the culvert to the lower. The stream flows through a wetland before entering the culvert (0.002 slope) and the downstream slope is 1.3 feet per 100 feet. This culvert has been identified as a field study site for juvenile coho salmon. In the summer of 1998 we will study whether juveniles have any problems traveling upstream in this culvert.
Slikok Creek  
Mile Post 20.2 Kalifornski Beach Road

This site was visited on August 15, 1996. This road is apparently scheduled for an upgrade that will result in widening of the road. The present 8 feet diameter culvert (plus 4 ft diameter overflow culvert) is functioning properly at this time. The gradient here is very flat with low velocities at the entrance, exit, and barrel of the culvert. Extending the present culvert or installing a longer new culvert should present no problems. There is some bank erosion due to the heavy fishing pressure at this site.

Crooked Creek  
South of Kasilof River on Sterling Highway

We visited this site on August 15, 1996 to review potential problems regarding fish passage rather than because the culvert had been altered. This stream is heavily used by salmon and sport fishing is very popular here. Also, a fish hatchery exists upstream of the culvert. Two 100 foot long, 8 foot diameter culverts with concrete headwalls exist at this site (Figure 15). These culverts have two problems; they are perched and the slope in the lower 40 feet is greater than in the upstream segment of the culvert. Maximum velocities at the inlet are 4.5 fps, with velocities around 2.0 to 2.5 fps along the walls. Outlet velocities were measured between 8.0 and 11.0 fps. Both juvenile and adult salmon were observed trying to enter the
Figure 14: Conditions at the upstream end of the Soldotna Creek culvert. The weir just above the culvert is visible (August 15, 1996).

Figure 15: Outlet conditions at Crooked Creek (August 15, 1996) showing the perched conditions and the high velocity of the water exiting the culvert.
downstream end of culvert. The adults made it with considerable difficulty and the juveniles all appeared to have failed. The juveniles would leap from under the culvert into the high velocity jet of water coming out of the culvert. All appeared to be swept back into the downstream pool. Because of the large number of adult fish in the stream above the culvert, it appeared that they were relatively successful at getting through the culvert. Observations of adult fish (Sockeye) entering downstream and exiting upstream of the culvert showed that they spent considerable time in the culvert (20 minutes or more). On exiting the culvert, they moved very slowly upstream and spent considerable time resting in the pools.

Putting structures (riprap or log weirs) downstream in the channel could significantly help the perching problem. This would also back the water up some and reduce the outlet velocities. Because of the high velocities in the lower section of the culvert we were unable to take measurements there. A more uniform slope through the culvert would reduce the high velocities near the outlet of the culvert but increase them at the other end.

Beaver Creek
Kenai Spur Road

This creek, like Crooked Creek, is a major salmon stream where it had been previously reported that the culvert (9.0 ft w by 10.0 ft h) could be a barrier to juvenile Coho (Elliot and Nelson, 1985). Numerous measurements of discharge, velocity profiles at inlet and outlet, and water and culvert slopes were made on August 15, 1996. Measurements of the water surface through the culvert reveal that there is a 1.0 foot drop through the culvert and that most of this drop occurs in the upper 20 feet of the 116 foot long culvert. Water surface slopes in the stream approaching the culvert are rather flat (0.004), increase in the top 20 feet of culvert (0.04), decrease in the remaining 96 feet of culvert (0.002), decrease in the outlet pool (0.001) and then again increase in the downstream channel (0.01). All of the problems in this culvert are caused by the steep slope in the upper 20 feet of the culvert. The flow in the upstream segment of the culvert is supercritical with a small hydraulic jump in the culvert (Figure 16). Velocities in this section exceed 8.0 fps with velocities near the wall of almost 6 fps. These velocities were measured at a moderately low flow of 22.5 cfs. Velocities were rather low in the remainder of the culvert.

This site was selected as one for more detailed observations of juvenile Coho behavior and was visited again from July 31 to August 4, 1997. We anticipated after our first visit that juvenile fish would have difficulty with the upper reaches of this culvert. Subsequent detailed observations of juvenile coho demonstrated that this culvert posed no problems for these fish at the flows observed.

Duke Creek Tributary No. 1
Mile 6.2 Big Salt Lake Road, Prince of Wales Island

This arched culvert (8 ft h) was observed on July 13, 1997 (Figure 17). The water entering, exiting and in the barrel had relatively low velocities at the discharge observed. There was some gravel in the bottom of the culvert, although no baffles to hold it in place. No problems for fish passage.
Figure 16: View of Beaver Creek looking downstream through the culvert on August 15, 1996. The flow is supercritical just inside the culvert.

Figure 17: View looking upstream into Duke Creek Tributary No.1 culvert.
Duke Creek Tributary No. 2  
Mile 6.2 Big Salt Lake Road, Prince of Wales Island

An 8 foot high elliptical culvert was installed at this crossing. Nothing special was done to enhance fish passage in this culvert. Culvert slope is much flatter than stream gradient. Maximum velocities in the culvert were 2.0 fps for the low flow conditions that prevailed. Rocky stream channel with a 2.0 foot drop at the inlet (Figure 18). There is no gravel in culvert invert. **Again, no problems for fish passage.**

Control Creek Tributary  
Mile Post 2.3 Thorne Bay Road, Prince of Wales Island

This site was visited on July 14, 1997. A depressed culvert with concrete headwalls was installed at this crossing. The site has a moderate slope, therefore no baffles were required to retain gravel in the culvert. The bottom of the culvert was covered with gravel throughout its length (Figure 19). This culvert blended in nicely with the stream channel. No fish problems were identified at this site.

Control Creek Tributary  
7.9 Mile Thorne Bay Road, Prince of Wales Island

This culvert has Canadian offset baffles where the right side is slanting upstream at an angle of 45º and the left side is normal to the alignment of the culvert (Figure 20). The diameter of the culvert is 7.0 feet with 25 baffles at 5 foot spacing. Baffles are 0.8 feet high at the end of each with the slanted segment being 4.0 feet long and the straight segment 1.6 feet long. The culvert slope (0.096) is steeper than both the upstream (0.048) and the downstream (0.009) slopes. Except for some branches that have caught in the opening in the baffle, all was working well at the low observed flow on July 14, 1997.

Stellar Jay Creek  
Kasaan Road, Prince of Wales Island

This site was visited on August 14, 1997. The culvert (Figure 21) was depressed slightly when recently installed. Some gravel had been placed in the culvert at the time of the installation. From Figure 21 it can be seen that most is still there. The facts that the culvert is only slightly depressed and nothing is holding the gravel leads one to believe that during high flows this material will be washed out. The slope is relatively mild here, which may alleviate the washout somewhat. At present the installation looks good. It blends in nicely with the channels upstream and downstream.

NT2 Creek  
Kasaan Road, Prince of Wales Island

To enhance fish passage, riprap was placed in this culvert, although it has no baffles and is not depressed. In the outlet channel additional riprap was placed (Figure 22). A board was also placed across the bottom of the culvert on the upstream end. At the time of the visit, July 14, 1997, the flows were quite low. While the culvert was operating properly when we visited it, the likelihood of the board and riprap remaining in the culvert are slim during high
Figure 18: View looking upstream through Duke Creek Tributary No. 2 culvert on July 13, 1997.

Figure 19: Depressed culvert outlet on Control Creek tributary (Mile Post 2.3 Thorne Bay Road).
flows. The riprap downstream is considerably larger than that in the culvert and may persevere through large storms. The slope on the culvert is not great, and, even if the riprap washes out, the corrugations may provide sufficient roughness for juvenile fish to move successfully upstream.
Figure 21: View of the barrel of the slightly depressed culvert on Stellar Jay Creek.

Figure 22: Riprap placed downstream of the culvert on NT2 Creek (July 14, 1997).
Control Lake Creek Tributary No. 1  
Mile Post 53.6 North Prince of Wales Road

This culvert and the following one are located on two closely spaced upstream tributaries of Control Lake (Figure 23). The slope of this 9.5 ft w and 7.0 ft h culvert is 0.066. There are 7 baffles in this 70 foot long culvert at 10 foot spacings. The water surface drop at each baffle is 0.7 feet. Most cells have some gravel in them, plus some juvenile fish were observed. This site was visited during low flows on August 15, 1997. The stream channel is very steep. It appears that natural controls on habitat availability exist just a short distance upstream from the culvert inlet. The observation of juvenile fish in the culvert would imply that they can leap 0.7 feet at the baffles, unless they hatched in the culvert or the very short section upstream (about 50 ft) of the culvert. A visit to this culvert four years earlier after a major storm revealed much less gravel in the culvert, so some gravel has been replaced.

Figure 23: Inlet conditions at the baffled Control Lake Tributary No. 1 (Mile Post 53.6 North Prince of Wales Road). Flow conditions at the time of this visit were quite low (July 15, 1997).

Control Lake Creek Tributary No. 2  
Mile Post 53.65 North Prince of Wales Road

This site was visited on July 15, 1997. A 132 foot long, 8.0 foot diameter circular baffled culvert is installed at this site at a slope of 0.072. The situation is quite similar to the previous one, with natural slopes upstream limiting available habitat. With baffles spaced every 10 feet, the average drop is about 0.7 feet at each baffle. Juvenile fish were observed in the cells between the baffles. We understand that this culvert was designed to hold gravel
in the cells. Katapodis and Rajaratnam (1989) recommend that the best hydraulic flow conditions exist when the height of the baffles is 0.15D and baffle spacing is 0.6D. The spacing for this culvert is 1.25D. **More baffles closer together would help to retain more gravel thus reducing the drop at each baffle.**

**Steelhead Creek**  
Mile 55 North Prince of Wales Island Road

This 7.5 foot diameter baffled culvert was visited on July 13, 1997 (Figure 24). This culvert is installed at a slope of 0.058 while the upstream and downstream slopes are 0.098 and 0.081 respectively. The culvert is perched 1.4 feet. Baffles are 1 foot high at the centerline, and most are tilted to the left side. At the time of the visit the flows were quite low. There is some gravel in the cells between baffles. **Again, more baffles would ensure more gravel in the culvert and reduce the drop at each baffle. The perched outlet is the main problem at this culvert.**

![Figure 24: Perched outlet conditions on the baffled Steelhead Creek culvert.](image)

**Un-named Tributary**  
Mile Post 55.6 North Prince of Wales Road

Like all streams on North Prince of Wales Road, streamflow was quite low (1.2 cfs) during our visit on July 14, 1997. This 8 foot diameter circular culvert with baffles was operating satisfactorily (Figure 25). The maximum drop at the baffles was 0.8 feet. Velocities
between the baffles were 1.0 to 2.0 fps. Spacing of baffles was 9 feet with a height of 1.0 foot at centerline. It was our understanding that these culverts had been designed to hold gravel in the cells. This culvert, like many of the neighboring culverts had little gravel in them because the spacing of the baffles is too large. During storms, this gravel is flushed out. Reducing the distance between baffles would increase the capability of the culvert to retain gravel in the cells and also reduce the maximum drop in water surface at each baffle.
Several culverts near Gustavus were visited July 16, 1997. All of the older culverts had the same problem; the land surface is still rebounding from glaciation. As the land rebounds, the stream erodes a more incised channel in the sandy soils. This results in the culverts’ becoming perched on the downstream end. On the upstream end, water backs up behind the culvert until it can flow through. This is causing artificial impoundments in the channels between the culverts where the water is probably both warmer and slower than it would be without the obstruction. Glen’s Ditch west of the airport (Figure 26) is such an example. Along the north-south segment of Main road several culverts have been raised, but only the farthest downstream culvert is perched. The ecological impact on adult or juvenile fish is not known. However, large numbers of juvenile fish were observed swimming above the culverts. The solution to this problem is to depress all culverts about 0.2D of the culvert. This will ensure that at the present rebound rate that the culverts will not become perched during their lifetimes. The new culvert installed at Glen’s Ditch No. 2 at the south end of the runway on the east side is a good example of how to do it correctly (Figure 27).

Figure 26: Glen’s Ditch No. 1 where rebound has left the culvert slightly perched.
Figure 27: Glen’s Ditch No. 2, a new culvert that was depressed when it was installed.

REFERENCES


APPENDIX

Field Evaluation Forms
FIELD EVALUATION FORM
DRAINAGE STRUCTURES

DATE OF VISIT: 5/14/96
LOCATION: Middle Fork of West Fork of Dall River, Milepost 93.2 Dalton Highway
DIMENSIONS:
- DIAMETER: 8 ft.
- LENGTH: 92 ft. (old culvert length)
- SLOPE:
  - CULVERT: 0.0198
  - CULVERT WS: 0.006
  - UPSTREAM: 0.019
  - DOWNSTREAM: 0.0044

VELOCITY PROFILES

<table>
<thead>
<tr>
<th>OUTLET DEPTH (ft)</th>
<th>OUTLET VELOCITY (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>1.00</td>
<td>2.09</td>
</tr>
<tr>
<td>1.50</td>
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<td>0.25</td>
<td>0.32</td>
</tr>
<tr>
<td>0.35</td>
<td>0.47</td>
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<table>
<thead>
<tr>
<th>INLET DEPTH (ft)</th>
<th>INLET VELOCITY (ft/sec)</th>
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</thead>
<tbody>
<tr>
<td>0.25</td>
<td>3.46</td>
</tr>
<tr>
<td>0.50</td>
<td>4.63</td>
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<tr>
<td>0.75</td>
<td>5.52</td>
</tr>
<tr>
<td>1.10</td>
<td>5.46</td>
</tr>
</tbody>
</table>

DISCHARGE: 30.02 cfs
TOTAL DEPTH OUTLET: 3.0 ft
TOTAL DEPTH INLET: 1.75 ft
DATE OF VISIT: 5/14/96
LOCATION: Middle Fork of West Fork of Dall River, Milepost 93.2 Dalton Highway

FISH FACILITIES
CULVERT CONDITIONS
Functioning properly, no obstacles to fish
Culvert ends anchored down
High velocities at inlet and extended 25-35 ft. into culvert
Some ice in culvert, mostly above waterline in center of culvert.
Aufeis apparently half-filled culvert during past winter.
DATE OF VISIT: 8/16/96
LOCATION: Answer Creek, Mile 5.3 Talkeetna Spur Road

DIMENSIONS:
- SPAN: 11.25 ft
- RISE: 13 ft
- LENGTH: 112 ft
- SLOPE: UPSTREAM 0.014, DOWNSTREAM 0.044, CULVERT 0.011, CULVERT WS 0.004

VELOCITY PROFILES

<table>
<thead>
<tr>
<th>Inlet Centerline</th>
<th>Center of Culvert</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DEPTH (ft)</strong></td>
<td><strong>VELOCITY (ft/sec)</strong></td>
</tr>
<tr>
<td>Bottom</td>
<td>2.00</td>
</tr>
<tr>
<td>Surface</td>
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</tbody>
</table>

Outlet Lip

<table>
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<tr>
<th><strong>DEPTH (ft)</strong></th>
<th><strong>VELOCITY (ft/sec)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>RB</td>
<td>1.00</td>
</tr>
<tr>
<td>LB</td>
<td>1.50</td>
</tr>
</tbody>
</table>
DATE OF VISIT: 8/16/96  
LOCATION: Answer Creek, Mile 5.3 Talkeetna Spur Road  
DISCHARGE: 14.83 cfs  

**FISH FACILITIES**  
Five vertical drops formed by log weirs. Velocities in the range of 3 - 3.5 fps over the upper four log weirs, while velocity of the water over the lower weir is closer to 5 fps.  
Big rock blocking outlet  
High inlet velocity, also 18 inch drop 80 ft. downstream where channel constricts  
Top of culvert cut back 16 ft.
FIELD EVALUATION FORM
DRAINAGE STRUCTURES

DATE OF VISIT: 8/16/96
LOCATION: Trapper Creek, Milepost 115.7 Parks Highway

DIMENSIONS:
- SPAN: 9.7 ft
- RISE: 10.7 ft.
- LENGTH: 100 ft.
- SLOPE: UPSTREAM 0.0064
  DOWNSTREAM 0.012
  CULVERT 0.0043
  CULVERT WS 0.0115

VELOCITY PROFILES
Velocity profiles taken along centerline of outlet

<table>
<thead>
<tr>
<th>Outlet Centerline</th>
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<tbody>
<tr>
<td><strong>DEPTH (ft)</strong></td>
</tr>
<tr>
<td>Bottom</td>
</tr>
<tr>
<td>Avg. Depth</td>
</tr>
<tr>
<td>Edges</td>
</tr>
</tbody>
</table>

DISCHARGE: 49.74 cfs

FISH FACILITIES
Top row of rocks has been dislodged such that there is minimal drop in water surface across the rocks
Some drop at second and third row of rocks
Velocities at inlet not excessive, top of culvert cut back 14 ft.
Adult salmon upstream
FIELD EVALUATION FORM
DRAINAGE STRUCTURES

DATE OF VISIT: 8/14/96
LOCATION: Soldotna Creek

DIMENSIONS:
LENGTH 298 ft
SLOPE
CULVERT 0.0135
CULVERT WS 0.0157
UPSTREAM 0.002
DOWNSTREAM 0.013

TOTAL DEPTH OUTLET: 3.0 ft
TOTAL DEPTH INLET: 1.75 ft
DISCHARGE: 13.04 cfs

FISH FACILITIES
BAFFLES: 13 baffles, not evenly spaced

OTHER: Low gradient stream, clean and clear
Small weir upstream

<table>
<thead>
<tr>
<th>Baffle No.</th>
<th>Starting from Outlet</th>
<th>Drop at Baffles</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0.4</td>
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</tr>
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</tr>
<tr>
<td>10</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>
DATE OF VISIT: 8/2/97
LOCATION: Soldotna Creek Culvert on Sterling Highway

VELOCITY PROFILES

All velocity profiles taken 10 ft. from inlet edge of culvert

Meter: Montedoro-Whitney

<table>
<thead>
<tr>
<th>DEPTH (ft)</th>
<th>VELOCITY (ft/sec)</th>
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<td>4.54</td>
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<tr>
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<td>4.98</td>
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<td>0.30</td>
<td>5.97</td>
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<tr>
<td>0.40</td>
<td>5.78</td>
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<tr>
<td>0.50</td>
<td>6.11</td>
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<table>
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<tr>
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</tr>
<tr>
<td>0.35</td>
</tr>
<tr>
<td>0.45</td>
</tr>
<tr>
<td>0.55</td>
</tr>
</tbody>
</table>

| DEPTH (ft) | VELOCITY (ft/sec) |
| 0.15       | 3.17              |
| 0.25       | 6.28              |
| 0.35       | 7.42              |
| 0.45       | 7.63              |
| 0.55       | 7.39              |
| 0.65       | 7.4               |

<table>
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<td>DEPTH (ft)</td>
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<td>0.65</td>
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</tbody>
</table>

Velocity Profile

![Velocity Profile Graph](image-url)
DATE OF VISIT: 8/2/97
LOCATION: Soldotna Creek Culvert on Sterling Highway

TOTAL DEPTH STATION 0  0 ft  right edge of water looking downstream
TOTAL DEPTH STATION 0.5  0.35 ft
TOTAL DEPTH STATION 1.1  0.6 ft
TOTAL DEPTH STATION 2.1  0.8 ft
TOTAL DEPTH STATION 3.1  0.65 ft
TOTAL DEPTH STATION 4.0  0.35 ft
TOTAL DEPTH STATION 4.3  0 ft  left edge of water looking downstream

FISH FACILITIES
BAFFLES IN BARREL:  13
REST AREAS: Corrugations 2 in. by 6 in.

Baffles 4, 12 and 13 (from bottom) may pose problem for juvenile fish, they may have to jump to get over the baffles.
FIELD EVALUATION FORM  
DRAINAGE STRUCTURES 

DATE OF VISIT: 8/15/96  
LOCATION: Beaver Creek, Kenai Spur Road  

DIMENSIONS:  
SPAN: 9 ft  
RISE: 10 ft.  
LENGTH: 116 ft.  
SLOPE  
UPSTREAM: 0.0072  
DOWNSTREAM: 0.0036  
CULVERT: 0.0126  
CULVERT WS: 0.01  

VELOCITY PROFILES  

<table>
<thead>
<tr>
<th>10 ft from DS of Inlet Lip</th>
<th>Inlet Lip</th>
</tr>
</thead>
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<td><strong>VELOCITY (ft/sec)</strong></td>
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<td>5.78</td>
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<td>8.22</td>
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<td>0.80</td>
<td>8.03</td>
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<tr>
<td>1.05</td>
<td>1.71</td>
</tr>
<tr>
<td>1.30</td>
<td>2.10</td>
</tr>
</tbody>
</table>

Culvert and Water Surface Survey
**DATE OF VISIT**: 8/15/96  
**LOCATION**: Beaver Creek

<table>
<thead>
<tr>
<th>DEPTH (ft)</th>
<th>VELOCITY (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20</td>
<td>1.72</td>
</tr>
<tr>
<td>0.40</td>
<td>2.54</td>
</tr>
<tr>
<td>0.60</td>
<td>2.68</td>
</tr>
<tr>
<td>0.80</td>
<td>2.84</td>
</tr>
<tr>
<td>1.00</td>
<td>2.93</td>
</tr>
<tr>
<td>1.30</td>
<td>2.91</td>
</tr>
<tr>
<td>1.70</td>
<td>2.92</td>
</tr>
</tbody>
</table>

**TOTAL DEPTH DOWNSTREAM**: 1.9 ft.  
**TOTAL DEPTH UPSTREAM**: 1.1 ft.  
**TOTAL DEPTH 10 ft DOWNSTREAM OF INLET LIP**: 1.1 ft.  
**TOTAL DEPTH @ INLET LIP**: 1.5 ft.  
**TOTAL DEPTH @ OUTLET LIP**: 1.9 ft.

**FISH FACILITIES**  
Downstream pool 100 ft. long  
Upstream channel grassy with very mild slope  
Dilapidated beaver dam approximately 100 ft. upstream  
Second smaller culvert with no flow, debris blocking entrance  
High velocity water extends 25 ft. into upstream end of culvert
FIELD EVALUATION FORM
DRAINAGE STRUCTURES

DATE OF VISIT: 7/14/97
LOCATION: Control Creek Tributary, 7.9 mile Thorne Bay Rd.

DIMENSIONS:
- DIAMETER: 7.0 ft
- LENGTH: 130 ft.
- SLOPE:
  - CULVERT: 0.096
  - CULVERT WS: 0.095
  - UPSTREAM: 0.048
  - DOWNSTREAM: 0.009

DISCHARGE: 1.93 cfs

FISH FACILITIES

BAFFLES:
- Yes, 25 baffles, 5 ft. spacing
  Width 4 ft. and 1.6 ft., 0.8 ft. high at ends

  Baffles clean except for one large log and one medium sized log
FIELD EVALUATION FORM
DRAINAGE STRUCTURES

DATE OF VISIT: 7/14/97
LOCATION: NT2 Creek, Kasaan Rd.

DIMENSIONS: SPAN: 9.3 ft
RISE: 6.5 ft +/- 0.5 ft. gravel
LENGTH: 61 ft
SLOPE: CULVERT 0.035
CULVERT WS 0.037
UPSTREAM 0.064
DOWNSTREAM 0.014

DISCHARGE: 1.44 cfs

FISH FACILITIES

Culvert not depressed. Fish passage okay at this stage.
Rocks placed in culvert, nothing holding them in place.
Some large rocks 20 ft. downstream.
FIELD EVALUATION FORM
DRAINAGE STRUCTURES

DATE OF VISIT: 7/15/97
LOCATION: Control Lake Creek Trib #1, Mile 53.6 North Prince of Wales Road

DIMENSIONS:
- SPAN: 9.5 ft
- RISE: 7.0 ft
- LENGTH: 70 ft
- SLOPE: CULVERT 0.066
  CULVERT WS 0.07

Culvert and Water Surface Survey

![Culvert and Water Surface Survey Graph](image-url)
FIELD EVALUATION FORM
DRAINAGE STRUCTURES

DATE OF VISIT: 7/15/97
LOCATION:  Control Lake Creek Trib #2, Mile 53.65 North Prince of Wales Road

DIMENSIONS:
- DIAMETER: 8.0 ft
- LENGTH: 132 ft.
- SLOPE: CULVERT 0.072
  UPSTREAM steep
  DOWNSTREAM steep

DISCHARGE: None taken because low flow
**FIELD EVALUATION FORM**

**DRAINAGE STRUCTURES**

**DATE OF VISIT:** 7/13/97  
**LOCATION:** Steelhead #1, Milepost 55 <0.1 Mile North

**DIMENSIONS:**
- **DIAMETER:** 7.5 ft  
- **LENGTH:** 93.5 ft  
- **SLOPE:**
  - CULVERT: 0.067  
  - CULVERT WS: 0.058  
  - UPSTREAM: 0.098  
  - DOWNSTREAM: 0.081

<table>
<thead>
<tr>
<th>Relative Distance (ft)</th>
<th>Relative Elevation (ft)</th>
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<tbody>
<tr>
<td>-200</td>
<td>110</td>
</tr>
<tr>
<td>-100</td>
<td>100</td>
</tr>
<tr>
<td>0</td>
<td>90</td>
</tr>
<tr>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>200</td>
<td>70</td>
</tr>
<tr>
<td>300</td>
<td>60</td>
</tr>
</tbody>
</table>

**TOTAL DEPTH DOWNSTREAM:** 0.17 ft  
**OUTLET VELOCITY:** 0.53 ft/sec  
**DISCHARGE:** 1.44 cfs

**FISH FACILITIES**

**BAFFLES:** 1 ft. high at center line  
Baffles are tilted so at low stages water flows over one side

No gravel at lower end of culvert. Some cells have gravel, others clean (no pattern).  
5 ft. of culvert at each end with no baffle.

**CULVERT:** Perched at outlet 1.4 ft.
FIELD EVALUATION FORM
DRAINAGE STRUCTURES

DATE OF VISIT: 7/14/97
LOCATION: Un-named Tributary, 55.6 mile North POW Road

DIMENSIONS:
- DIAMETER: 7.8 ft.
- LENGTH: 76.5 ft.
- SLOPE:
  - CULVERT: 0.038
  - UPSTREAM: 0.098
  - DOWNSTREAM: 0.061

VELOCITY PROFILE
Velocity profile taken at culvert outlet centerline

<table>
<thead>
<tr>
<th>DEPTH (ft)</th>
<th>VELOCITY (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10</td>
<td>1.84</td>
</tr>
<tr>
<td>0.20</td>
<td>2.37</td>
</tr>
</tbody>
</table>

TOTAL DEPTH @ CULVERT OUTLET: 0.3 ft.

DISCHARGE: 1.22 cfs

FISH FACILITIES

BAFFLES: Yes, 9 ft. spacing, 1 ft. high at Centerline
0.8 ft. drop from water to top of baffle
FIELD EVALUATION FORM
DRAINAGE STRUCTURES

DATE OF VISIT: 9/13/97
LOCATION: No Name Creek, Prince of Wales Island

DIMENSIONS:
- LENGTH: 84 ft
- SLOPE:
  - CULVERT: 0.0034
  - UPSTREAM: 0.014
  - DOWNSTREAM: 0.0029

Culvert and Water Surface Survey

VELOCITY PROFILES

Meter: Montedoro-Whitney

All velocity profiles were taken 6 ft. upstream from outlet, from the top of corrugation. All measurements from right edge of water are made while facing downstream.

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Velocity (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>1.55</td>
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<tr>
<td>0.15</td>
<td>1.78</td>
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<tr>
<td>0.25</td>
<td>2.36</td>
</tr>
<tr>
<td>0.35</td>
<td>2.20</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Velocity (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>1.55</td>
</tr>
<tr>
<td>0.15</td>
<td>1.95</td>
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<tr>
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<td>2.53</td>
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<tr>
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<tr>
<td>0.55</td>
<td>2.94</td>
</tr>
<tr>
<td>0.65</td>
<td>2.82</td>
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<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Velocity (ft/sec)</th>
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<td>1.29</td>
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<td>0.35</td>
<td>2.45</td>
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<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Velocity (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>2.00</td>
</tr>
<tr>
<td>0.25</td>
<td>2.28</td>
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<tr>
<td>0.35</td>
<td>2.56</td>
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<tr>
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<td>2.69</td>
</tr>
<tr>
<td>0.55</td>
<td>2.76</td>
</tr>
</tbody>
</table>

DISCHARGE:
- 9.97 cfs on 9/13/97
- 4.68 cfs on 9/15/97
DATE OF VISIT: 9/13/97
LOCATION: No Name Creek, Prince of Wales Island

FISH FACILITIES
REST AREAS: Corrugations 2 in. by 6 in.