Alaska Department of Transportation & Public Facilities

Research & Technology Transfer

Investigating Fish Passage Through Culvert Sliplines Using Passive Integrated Transponder Tags

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The focus of this study was to investigate fish behavior and passage rates through smooth-wall HDPE culvert sliplines. Passive integrated transponder (PIT) tags were implanted in 741 juvenile coho salmon and 463 Dolly Varden. Swim trials were conducted in Juneau, Alaska through entire culvert, half culvert, or a natural stream reach of comparable gradient and length.

Eight trials were conducted at Ninemile Creek culvert; a 153 ft, 4.0% gradient slipline with V-shaped weir baffles located every 9 ft. Coho salmon and Dolly Varden pass the culvert at significantly lower rates than the control reach. Smaller fish could not traverse the culvert. Findings suggest high-gradient culverts can provide fish passage for larger juvenile fish at limited flow ranges. Half-culvert trials suggest a shorter culvert with no entry challenge may not improve passage rates or eliminate size discrimination for coho salmon but may for Dolly Varden.

Two trials were conducted at the Egan Drive Creek culvert; a 150 ft, 0.03% gradient slipline that is fully backwatered. Trials here show no significant difference in passage rates, size composition, or passage time at low and high stream flows. The low-gradient, backwatered culvert does not appear to restrict fish passage except perhaps at peak flows.

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Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm
nanometer	nm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
inch of mercury	inHg
kilowatt	kW
Kilopascal	kPa
Nephelometric Turbidity Unit	NTU
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
etalii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
idest (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log$_2$, etc.
minute (angular)	'
no data	ND
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

TECHNICAL REPORT NO. 24-10

INVESTIGATING FISH PASSAGE THROUGH CULVERT SLIPLINES USING PASSIVE INTEGRATED TRANSPONDER TAGS

By

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June 2024

Funding for this investigation was provided by the Alaska Department of Transportation and Public Facilities.

Cover: Ninemile Creek culvert slipline with PIT tag antenna at high flow (outlet upper left; inlet upper right) and at low flow (outlet lower left; inlet lower right) stage.

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ACKNOWLEDGEMENTS

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Habitat Section Southeast Regional Supervisor Kate Kanouse assisted with developing the study design, procured the funding, provided field support, participated in the advisory group, and reviewed and edited the report. Habitat Biologists Dylan Krull, Flynn Casey, Erika King, Jesse Lindgren, Claire Delbecq, and Nick Jensen provided field support. ADF&G Division of Commercial Fisheries Biometrician Alexandra Reich provided biometric review. Habitat Section peers reviewed the report, including Operations Manager Dr. Al Ott, Dylan Krull, and Habitat Regional Supervisor Ron Benkert.

EXECUTIVE SUMMARY

The Alaska Department of Transportation and Public Facilities (DOT&PF) requested the Alaska Department of Fish and Game (ADF&G) Habitat Section investigate fish passage through smooth-wall culvert sliplines, which can be an economic means of extending the life of a failing culvert, but sometimes present fish passage challenges. The Habitat Section works in concert with DOT&PF to evaluate and permit culvert replacements on State highways, a process centered around providing proper fish passage[a] according to site-specific environmental conditions and needs. The focus of this study was to investigate fish behavior and passage rates through two culvert sliplines, with the results to be used by Habitat Section in the permitting process.

In this study, we used passive integrated transponder (PIT) tags implanted in 741 juvenile coho salmon *Oncorhynchus kisutch* and 463 Dolly Varden *Salvelinus malma* (fork lengths by species ranged 54–150 mm and 50–169 mm) sourced from nearby drainages to investigate fish passage rates through two culvert sliplines on roadways managed by DOT&PF in Juneau, Alaska. For each trial, 103–138 fish were tagged, randomly assigned to one of three groups and submitted to swim trials through either the entire culvert or half the culvert, or a natural stream reach of comparable gradient and length (as a control reach). We placed disinfected salmon eggs at the top of each reach to encourage upstream fish movement. Eight replicate trials were conducted at the Ninemile Creek culvert slipline, which is a 153 ft long, 4.0% gradient high-density polyethylene (HDPE) smooth-wall slipline outfitted with V-shaped weir baffles welded in place every 9 ft. Two trials were conducted at the Egan Drive Creek culvert, which is a 150 ft long, 0.03% gradient HDPE smooth-wall slipline that is fully backwatered by a downstream hydraulic control.

Results from the Ninemile Creek trials indicate that both coho salmon and Dolly Varden pass the culvert at significantly lower rates (2.5% and 18.8%) than the control reach (18.0% and 40.8%). Furthermore, coho salmon smaller than 85 mm fork length (FL) and Dolly Varden smaller than 79 mm FL did not pass the culvert, but were recorded passing the control reach at lengths as small as 61 mm FL and 64 mm FL. These findings suggest the Ninemile Creek culvert provides fish passage for larger juvenile fish at a limited range of flows. Results from fish released halfway down the culvert suggest that a shorter culvert with no initial entry challenge from the outlet jump pool may not improve passage rates or eliminate size discrimination for coho salmon, but may for Dolly Varden.

Trials at the Egan Drive Creek site show no significant difference in passage rates, size composition, or passage time for both species at low and high streamflows. The low gradient, backwatered culvert does not appear to restrict fish passage except perhaps at peak flows.

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[a] As required by Alaska Statutes 16.05.841 and 16.05.871, the Fishway and Anadromous Fish Acts, which are responsibilities of the ADF&G commissioner.

INTRODUCTION

Between 2021 and 2024, DOT&PF provided funding and support for ADF&G Habitat Section to investigate juvenile fish passage through smooth-wall culvert sliplines. A smooth-wall culvert slipline is a method of culvert rehabilitation that involves the insertion, and grouting in place, of a smaller diameter non-corrugated HDPE plastic pipe within a failing host culvert. This rehabilitation option is typically less expensive than structure replacement, requires no excavation or traffic interruption, and can be employed as a short or long-term fix. The smooth wall of the slipline reduces roughness and maintains hydraulic capacity for flood conveyance, despite the reduction in diameter. However, the increased water velocity, decreased water depth, and raised culvert invert elevation can create impediments to upstream fish movement.[b] Two ways to mitigate these effects are to install weir baffles in the slipline or ensure the slipline is fully backwatered, assuming the reduced hydraulic capacity is an acceptable risk. Fish passage under these two conditions is the focus of this study.

The DOT&PF and the ADF&G Habitat Section work cooperatively to evaluate, design, and permit culvert replacements on State highways guided by a Memorandum of Agreement[c] that addresses culvert design criteria, but provides little guidance for smooth-wall culverts and sliplines, which are assessed on a case-by-case basis. Since culvert sliplines can provide cost savings, but pose fish passage issues, understanding passage rates and fish behavior is needed to determine when the method may or may not be appropriate. While peer-reviewed literature on fish passage and culvert design is abundant, this investigation offers a comparison of juvenile fish passage at in-situ test and control sites using wild fish monitored by passive integrated transponder (PIT) tags, which is otherwise not documented in the literature (an annotated bibliography is in Appendix A).

PURPOSE

The purpose of this study was to investigate upstream passage of juvenile coho salmon and Dolly Varden through two culvert sliplines in Juneau, Alaska: at Ninemile Creek[d] and Egan Drive Creek[e]. The study goals were to test the general hypothesis that upstream fish passage rates in the culvert test groups would differ from the control reach group and to compare passage time and flow conditions among groups. Results from the investigation may be considered during the design and permitting of culvert rehabilitation projects in fish-bearing waterbodies in Alaska.

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[b] Natural stream geomorphic processes such as sediment and debris transport also are impacted with sliplines; however, the focus of this investigation is fish passage.

[c] ADF&G and DOT&PF. 2001. Memorandum of Agreement between Alaska Department of Fish and Game and Alaska Department of Transportation and Public Facilities for the design, permitting, and construction of culverts for fish passage; dated 8/3/2001. Unpublished document can be obtained from the Regional Supervisor at 802 3rd Street, Douglas, Alaska.

[d] ADF&G Stream no. 111-50-10670; cataloged for chum, coho, and pink salmon and Dolly Varden.

[e] ADF&G Stream no. 111-50-10625; cataloged for coho salmon.

STUDY SITES

Fish passage trials were conducted at two culvert slipline sites and test fish were captured from drainages proximate to the test sites. Test site and fish source drainages all flow into the Gastineau Channel (Figure 1).

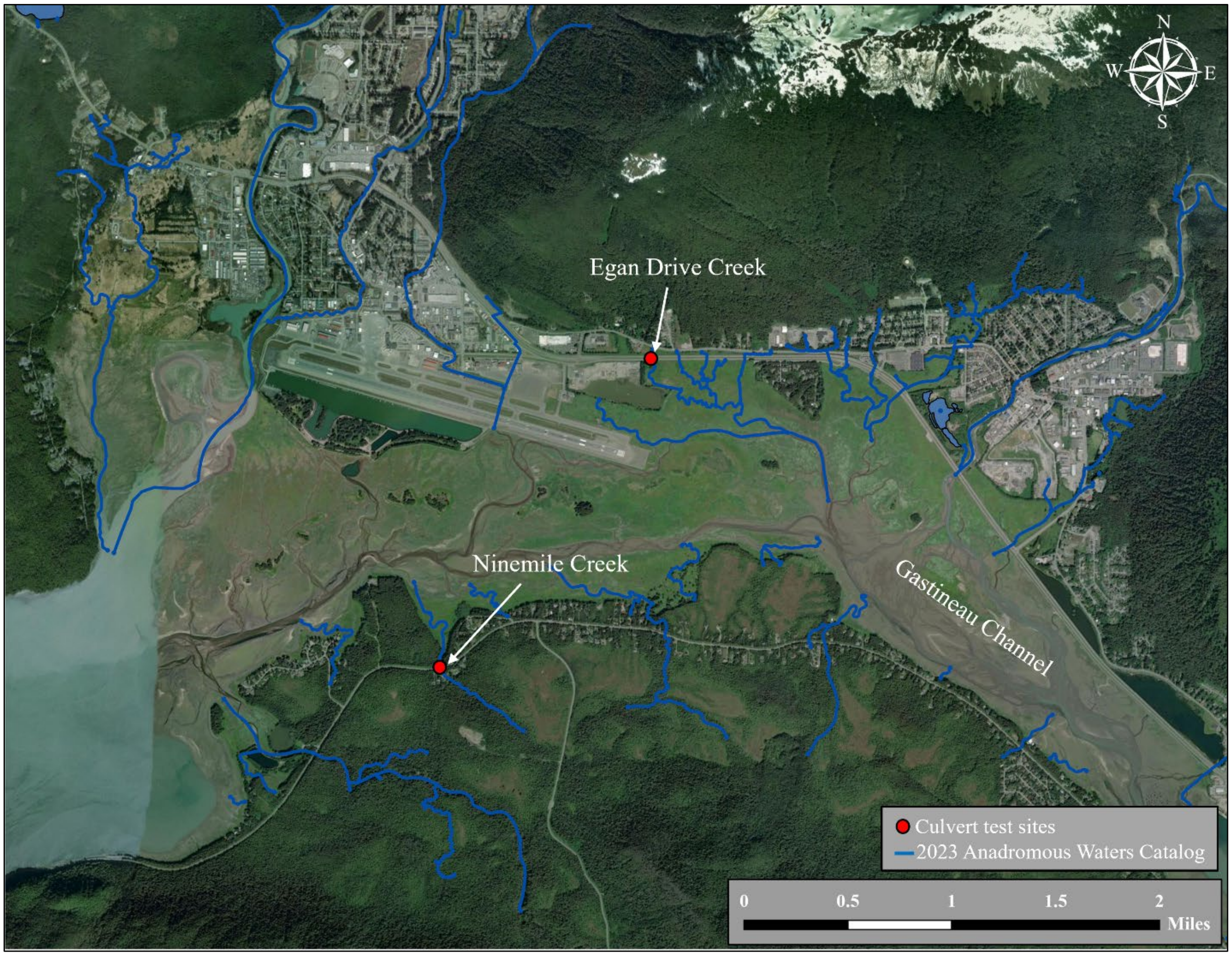

Figure 1.–Map showing study sites and general area from which test fish were collected.

Ninemile Creek

Ninemile Creek drains a roughly 0.49 mi^2 basin of forested peat bog mosaic on the north side of Douglas Island. The Ninemile Creek culvert (Figure 2) is buried about 35 ft in the North Douglas Highway roadbed and situated at the top of a 75 ft long reach of log weir step-pools terminating at tidewater in the Gastineau Channel. The log step-pools were constructed to partially backwater the original perched culvert in 2002 as mitigation for wetland fill on the island.[f] Culvert gradient was thought to create a fish passage barrier, so metal baffles were retrofitted into the 5 ft diameter corrugated pipe sometime around 2004; however, they were not sealed and provided limited fish passage. Juvenile coho salmon were captured upstream of the culvert in 1997, but repeated attempts beginning in 2010 failed to capture anadromous fish until October 2019, 11 months after

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[f] Original log weir construction was completed by DOT&PF under ADF&G Special Area Permit No. FG 01-I(J)-40.

the failing culvert was retrofitted with a baffled HDPE culvert slipline, when adult coho salmon were observed spawning upstream of the culvert.[g]

The 153 ft long, 4.5 ft diameter, 4.0% gradient HDPE smooth-wall culvert has 17 factory-welded V-shaped weirs spaced 9 ft,[h] which are 12 inches tall at the invert. Gradient varies slightly throughout the culvert, but in general, the backwater effect from each weir provides a 7.7-inch-deep jump pool and a 4.3-inch jump from the water surface to the weir crest at low flow. Sediment wedges are present upstream of the top five baffles and the remainder of the culvert is mostly bare. The outlet is backwatered by the downstream log weir; however, water drains subsurface during extended low flow conditions creating a perched condition, though this did not occur during fish passage trials. At the inlet, the streambed is continuous gravel extending to the upper-most weir (Figure 3).

Figure 2.–Ninemile Creek culvert outlet with PIT tag antenna installed; low flow 5/28/2023 (left), high flow 10/19/2023 (right).

Figure 3.–Ninemile Creek culvert inlet with PIT tag antenna installed; low flow 5/28/2023 (left), high flow 10/19/2023 (right).

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[g] Madison Bargas, Fish and Wildlife Technician, to Kate Kanouse, Southeast Regional Supervisor, ADF&G Habitat Section. Memorandum: Ninemile Creek–Adult Salmon Survey; dated 12/7/2019. Unpublished document can be obtained from the Regional Supervisor at 802 3rd Street, Douglas, Alaska.

[h] The terminal baffle was a retrofit secured with brackets, which is not water-tight and is 5 ft downstream of the upper subsequent baffle.

Egan Drive Creek

Egan Drive Creek drains a roughly 0.07 mi^2 basin that includes a small wetland directly upslope of the highway and developed and undeveloped forested hillside on the south-facing Juneau mainland, terminating at the Gastineau Channel. The original 36 inch diameter culvert at the study site is about 4 ft beneath Egan Drive, which has four travel lanes and a median. The 150 ft long, 2.5 ft diameter culvert slipline is 0.3% gradient and entirely backwatered[i] by a tailwater control point about 20 ft downstream in the salt marsh channel which is flooded by 21 ft tides (Figures 4, 5). The retrofit of the smooth-wall HDPE culvert with no baffles was completed in 2018. Sand and gravel have recruited into the culvert since installation and juvenile coho salmon and Dolly Varden are present year-round upstream.

Figure 4.–Egan Drive Creek culvert outlet with PIT tag antenna installed; low flow 9/20/2023 (left), high flow 9/21/2023 (right).

Figure 5.–Egan Drive Creek culvert inlet; low flow 9/20/2023 (left), high flow 9/21/2023 (right).

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[i] The tailwater control degraded prior to the study, rendering the upper 30 ft of the culvert not backwatered during low flow. Therefore, we used sandbags to raise the water elevation at the tailwater control point and backwater the culvert. Complete culvert backwatering is a condition of DOT&PF's Fish Habitat Permit FH15-I-0129A issued for the culvert slipline.

METHODS

FISH CAPTURE AND TAGGING

Juvenile coho salmon (54–150 mm FL) and Dolly Varden (50–169 mm FL) were captured at drainages proximate to the study sites using galvanized steel minnow traps baited with disinfected salmon roe[j] within finely-perforated containers to avoid fish consumption, or a Smith-Root LR-24 backpack electrofisher. Fish were transferred into a 25-gallon cooler with an aeration device and transported to the study site where they were anesthetized in batches in 9 mg/L AQUI-S® 20E (10% eugenol), weighed (nearest 0.1 g), measured (nearest 1 mm FL), injected with a 12 mm half-duplex PIT tag in the intraperitoneal cavity,[k,l] and randomly assigned to one of three test or control groups. Fish were then placed in the appropriate group livewell (30-gallon perforated totes anchored in the creek) for recovery and acclimation to study site conditions for 18–24 hours. After recovery and acclimation, fish were netted, checked for tag retention using a tag reader, and transported to their assigned group release location in a 5-gallon bucket. Mortalities and fish that did not retain tags were excluded from the trial.

EXPERIMENTAL DESIGN

Fish were transported in a 5-gallon bucket to the three assigned test or control locations with no more than 40 fish per location and 120 fish per trial. PIT tag antenna arrays, using hardware manufactured by ORFID,[m] were constructed at the inlet and outlet of the culvert and the top of the control reach (Figure 6). About 600 g of salmon roe was placed in a perforated container upstream of the culvert and control reaches to motivate fish to move upstream and was refreshed every 18–24 hours. Release locations included the culvert outlet plunge pool (group 1), the midpoint of the culvert (group 2), and the bottom of the control reach (control group). At the Ninemile Creek site, when high streamflow prevented hand-delivery of fish inside the culvert, they were floated downstream from the inlet in a closed bucket with a rope-operated release mechanism triggered halfway through. At the Egan Drive Creek site, fish were carefully poured through a storm drain grate in the highway median directly into the center of the culvert. At each location, an unaltered stream reach of comparable length and gradient to the test culvert was used to control for effects related to fish movement in response to the salmon roe scent.

Fish passage trials in 2022 and 2023 were conducted between April and November, when fish were more likely to respond to bait scent and move upstream due to increased seasonal water temperature. Eight replicate 48 hour trials were conducted at Ninemile Creek over two seasons and two trials were conducted at Egan Drive Creek within the same month with an effort to capture varied flow conditions. Several fish passage trials were fraught with issues from tag collision[n] and

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[j] Following methods in Magnus et al. (2006).

[k] Injection needles and tags sterilized in a 1:1 solution of betadine and water.

[l] McCann (1993) found fish smaller than 65 mm FL can have reduced tag retention and swimming abilities; however, we included them since they are a target fish of interest and experimental design resulted in random distribution of small fish in all groups.

[m] Arrays consisted of an ORSR Single reader antenna, ATC auto tuner, 12v marine deep cycle battery, and 8 ga. wire loop antenna. Wire loop antennas were originally housed within PVC encircling the stream, but later adjusted to bare wire either be suspended over the creek or partially buried within the creek, to reduce back eddies.

[n] Tag collision occurs when two or more tags enter the detection field and only one tag can be recorded.

battery failure at the culvert outlet antennas. Therefore, culvert outlet data were not available for all trials and is incorporated in a qualitative manner.

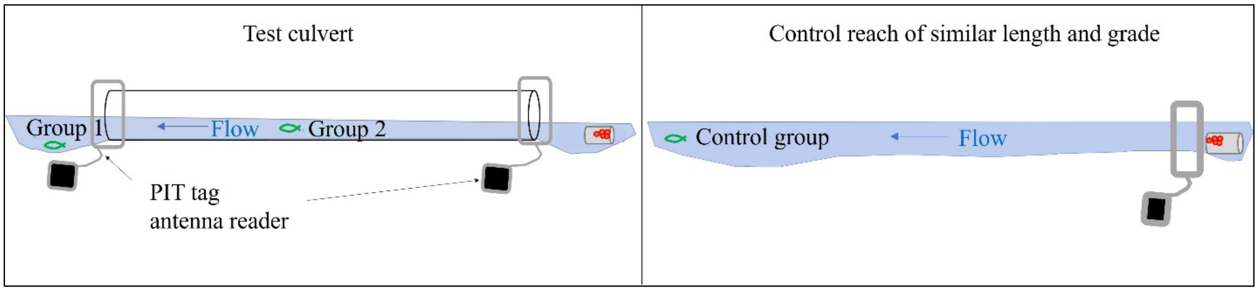

Figure 6.–Experimental design for Ninemile Creek.

STREAM GAGING

Stream discharge was measured with a SonTek Flowtracker® acoustic doppler velocimeter following standard procedures from Rantz (1982) and SonTek (2007) 1–3 times over the course of each trial and water level and temperature were recorded every 30 min with a data logger[o] installed in the stream. Stage-discharge datapoints were used to generate a rating curve, expressed by the following equation:

$$Q = c(h + a)^n$$

Where Q equals discharge, h equals the gage height, a equals the gage height at zero flow, and c and n are constants (Herschy 1995). An additional water level logger, recording at 2 h intervals placed about 10 ft upstream, was maintained in Ninemile Creek from March 4, 2021 to November 3, 2023 to record stream stage over a wider range of conditions and provide hydrologic context for flow conditions during the passage trials. A propeller-driven flow meter[p] was used to record representative velocities in at least two locations at each culvert inlet.

Bankfull stage discharge and peak flows (Q) on October 1, 2022, and August 12, 2023, were estimated by surveying a channel cross-section at the gage location and applying the U.S. Geological Survey slope-conveyance method, which uses Manning's equation (Dalrymple and Benson 1968):

$$Q = \left(\frac{1.486}{n}\right) AR^{2/3}S^{1/2}$$

Where n equals the channel roughness coefficient, A equals the cross-sectional area, R equals the hydraulic radius, and S equals channel slope. These high flow estimates were included in the wide range stage-discharge dataset to produce mean daily flow values and exceedance statistics.

Egan Drive Creek was not gaged outside of experimental trials and high flow discharge estimates were not attempted. A datalogger was anchored in the stream at the same location for both trials recording water level and temperature every 30 min.

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[o] Onset® UL-20 Hobo water level logger, corrected for atmospheric pressure with a second logger above water using HoboPro software.

[p] Global Water® flow probe.

Statistical analysis

Due to the inherent differences in swimming abilities and the length frequency distributions of coho salmon and Dolly Varden sample fish, data from each species were analyzed separately. By species, chi-squared statistical analyses were used to test whether group assignment affected passage rate and identify which pairwise comparisons were significant at the 0.017 significance level, following a Bonferroni correction for multiple comparisons.

At the Egan Drive study site, where sample size was low and data distribution non-normal, a non-parametric Mann-Whitney U-test was used to detect significant differences in FL among groups, discharge at moment of passage among groups, and passage time among groups. At Ninemile Creek where sample size was larger, a Student's t-test or Welch's t-test[q] was used to compare sample means. A Pearson correlation coefficient was used to test for a relationship between FL and passage time of successful individuals in groups. A one-way ANOVA was used to test for significant difference in FL. Significant comparison results were obtained for t-tests when the *p*-value was less than 0.05 and for U-tests when the critical value, as obtained from the critical value table at the 0.05 significance level, was exceeded by the U-test statistic.

On occasion, fish tagged in a previous trial were recorded passing antennas on later trial dates. We did not compare these "legacy" fish with "contemporary" trial fish, since they have had greater recovery and acclimation time and were not recently captured, measured or weighed (i.e., experienced stress); however, their passage through the culvert and FL at time of tagging was included in the assessment of minimum size of fish observed to pass the culvert and at what flow stages.

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[q] Welch's T-test was used to compare coho salmon FL between groups, Student's T-test was used for all other comparisons.

RESULTS

NINEMILE CREEK

Trial Conditions

Eight trials at Ninemile Creek were conducted between March 29, 2022 and November 1, 2023 in which estimated discharge ranged from 0.1 to 37.0 ft^3/s and water temperature ranged from 2.6 to 11.6°C (Table 1). We captured and tagged 594 juvenile coho salmon (54–150 mm FL) and 396 Dolly Varden (58–169 mm FL) for the trials with total fish per trial ranging from 103 to 138 individuals (Appendices B, C). An effort to maintain even numbers of both species in each trial was made; though some trials were conducted with primarily coho salmon when Dolly Varden were not readily captured. Fork length frequency distribution among groups within species did not differ significantly (Table 2).

Table 1.–Ninemile Creek culvert fish passage trial summary data.

Date	Trial Duration (h)	Min Q (ft^3/s)	Max Q (ft^3/s)	Water Temperature (˚C)	Group 1 CO *Group 1 DV* pass/total (%)	Group 2 CO *Group 2 DV* pass/total (%)	Control Group CO *Control Group DV* pass/total (%)
04/29/22	44.5	0.9	3.9	2.6–3.1	1/38 (2.6%) *0/2 (0.0%)*	0/40 (0.0%) *0/1 (0.0%)*	0/37 (0.0%) *0/2 (0.0%)*
06/22/22	46.5	0.3	1.8	8.8–9.7	0/27 (0.0%) *6/19 (31.6%)*	0/27 (0.0%) *7/20 (35.0%)*	4/26 (15.4%) *6/19 (31.6%)*
07/29/22	50.0	0.6	8.7	11.2–11.3	0/29 (.00%) *6/13 (46.2%)*	5/30 (16.7%) *10/14 (71.4%)*	14/30 (46.7%) *11/14 (78.6%)*
10/07/22	48.0	0.5	0.7	9.2–9.5	4/32 (12.5%) *1/14 (7.1%)*	3/30 (10.0%) *5/14 (35.7%)*	16/30 (53.3%) *10/14 (78.6%)*
05/28/23	48.0	0.1	1.4	8.2–8.9	0/12 (0.0%) *2/23 (8.7%)*	0/13 (0.0%) *10/23 (43.5%)*	0/11 (0.0%) *6/21 (28.6%)*
06/25/23	48.0	0.2	0.3	10–11.6	0/19 (0.0%) *9/25 (36.0%)*	1/19 (5.3%) *15/25 (60.0%)*	1/17 (5.9%) *11/25 (44.0%)*
10/17/23	48.0	1.3	37.6	8.3–8.9	0/18 (0.0%) *1/24 (4.2%)*	0/19 (0.0%) *1/24 (4.2%)*	0/18 (0.0%) *8/23 (34.8%)*
11/01/23	48.0	0.1	0.4	3.3–3.9	0/24 (0.0%) *0/13 (0.0%)*	0/24 (0.0%) *2/12 (16.7%)*	0/24 (0.0%) *1/12 (8.3%)*
Totals					5/199 (2.5%) *25/133 (18.8%)*	9/202 (4.5%) *50/133 (37.6%)*	35/193 (18.1%) *53/130 (40.8%)*

Note: coho salmon = CO, Dolly Varden = DV.

Table 2.–Fork length frequency distribution among groups and results from ANOVA comparison.

Group	Count	Average FL (mm)	Standard deviation	Minimum FL (mm)	Maximum FL (mm)	*P*-value
Coho salmon group 1	199	94.8	17.3	58	146	0.424
Coho salmon group 2	202	92.6	17.5	54	150	
Coho salmon control	193	93.8	15.2	60	140	
Dolly Varden group 1	133	105.4	24.5	60	165	0.359
Dolly Varden group 2	133	109.3	24.2	58	169	
Dolly Varden control	130	105.9	23.9	62	163	

Fish Passage

Coho salmon and Dolly Varden passage rates in individual trials ranged 0–53% and 0–79% (Table 1). Combining the Ninemile Creek trial data, there were several significant differences which are presented in Tables 3–4 and Figures 7–8: mean group 1 passage rates for coho salmon and Dolly Varden (2.5% and 18.8%) were significantly lower than mean control group rates (18.0% and 40.8%; CO and DV: $P = 0.000$); the mean passage rate of group 2 coho salmon (4.5%) was significantly lower than the control group rate (18.0%; $P = 0.000$); and the mean passage rate of group 1 Dolly Varden (18.8%) was significantly lower than group 2 Dolly Varden (37.6%; $P = 0.001$). Mean FLs for passing fish in group 1 of both species were higher than control group means, but not significantly different. There was no significant negative correlation with FL and passage time for any group (Table 4). The mean culvert passage time for group 1 Dolly Varden (19.2 h) was significantly different than the mean control group passage time (7.5 h; $P = 0.000$). Average discharge at the moment of reach ascent was significantly different for group 1 Dolly Varden (0.6 ft^3/s) compared to the controls (2.1 ft^3/s; $P = 0.013$). Coho salmon passed the control reach at higher discharges (up to 5.9 ft^3/s) than the culvert (3.3 ft^3/s); however, these discharges were not significantly different. The maximum discharges experienced by coho salmon and Dolly Varden while successfully ascending the culvert were 3.9 ft^3/s and 37.0 ft^3/s[r] and control group maximums were 8.7 ft^3/s and 37.0 ft^3/s. Mean streamflow recorded every 30 min during successful passage for coho salmon and Dolly Varden in group 1 were 1.0 ft^3/s and 16.4 ft^3/s and control group means were 1.2 ft^3/s and 4.9 ft^3/s.

Table 3.–Chi-squared comparisons of mean passage rates between groups.

	Group 1	Control		Group 1	Group 2		Group 2	Control	
Species	% passing	% passing	*P*-value	% passing	% passing	*P*-value	% passing	% passing	*P*-value
Coho salmon	2.5%	18.1%	**0.000**	2.5%	4.5%	0.289	4.5%	18.1%	**0.000**
Dolly Varden	18.8%	40.8%	**0.000**	18.8%	37.6%	**0.001**	37.6%	40.8%	0.598

Note: Bold values indicate a statistically significant test result below 0.017, after Bonferroni correction.

Table 4.–Summary statistics for group comparisons.

Species	Group 1			Control group			
	FL mean (mm)	FL range (mm)	*n*	FL mean (mm)	FL range (mm)	*n*	*P*-value
Coho Salmon	106.0	85-131	5	91.2	61-120	35	0.118
Dolly Varden	110.5	79-165	25	102.2	64-140	53	0.084
	Passage time mean	Passage time range	*n*	Passage time mean	Passage time range	*n*	*P*-value
Coho Salmon	15.4	6.5-24.5	5	11.4	0.5-45.5	35	0.501
Dolly Varden	19.2	4.5-47	25	7.5	0.5-48	53	**0.000**
	Mean Q ascent (ft^3/s)	Q ascent range	*n*	Mean Q ascent	Q ascent range (ft^3/s)	*n*	*P*-value
Coho Salmon	1.1	0.5-3.3	5	0.9	0.2-5.9	35	0.711
Dolly Varden	0.6	0.1-3.7	25	2.1	0.1-21.0	53	**0.013**
	FL vs. time Pearson correlation			FL vs. time Pearson correlation			
	FL vs. time	FL vs. time		FL vs. time	FL vs. time correlation		
Coho Salmon	0.30	0.617		0.21	0.050		
Dolly Varden	0.12	0.574		0.14	0.328		

Note: Bold values indicate a statistically significant test result.

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[r] Antenna recorder data suggests a 138 mm Dolly Varden transited the culvert in 35.5 hours during which time flow ranged 3.7–37.0 ft^3/s; however, it is more likely the fish entered the culvert after the peak flow had subsided, but was missed due to tag collision, then passed within a few hours at lower flow.

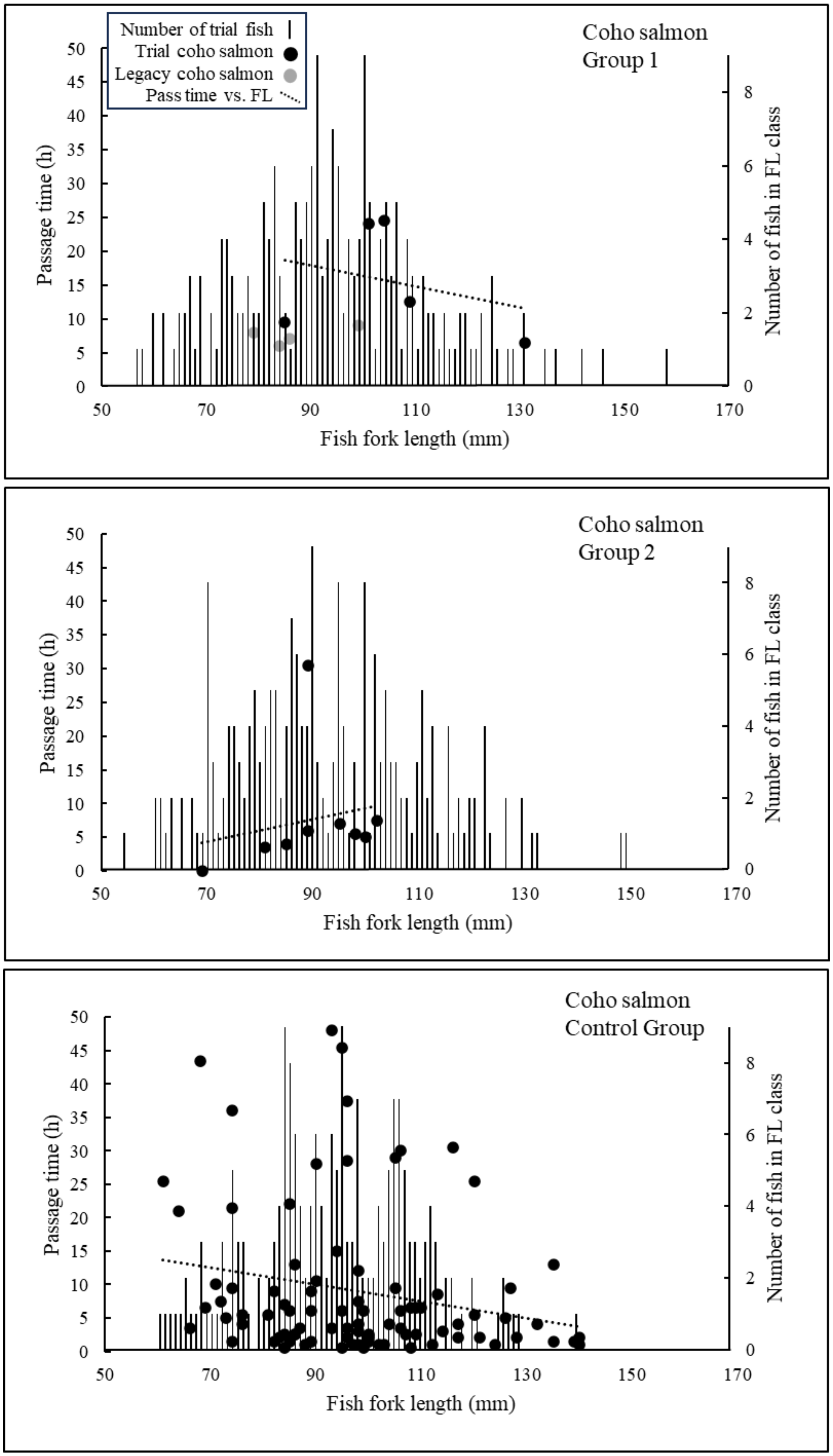

Figure 7.–Coho salmon FL vs. passage time by group.

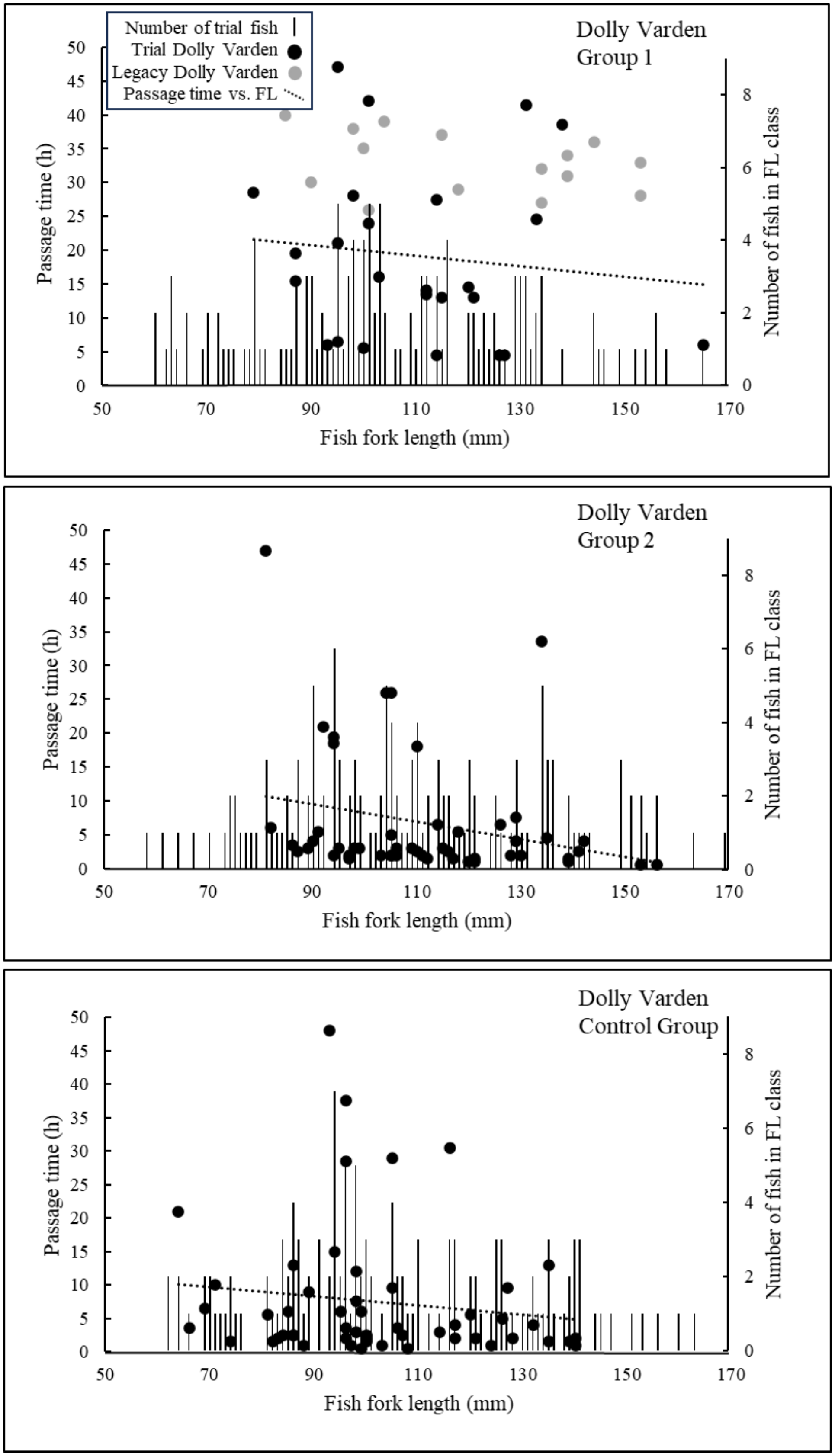

Figure 8.–Dolly Varden passage time vs. FL by group.

Hydrology

Twenty-seven discharge measurements ranging 0.13–17.7 ft^3/s were taken during the March 4, 2021 to November 3, 2023 stream gaging period (Table 5). Culvert inlet velocities were recorded on 11 occasions and ranged 0.7–4.8 ft/s. The channel downcut on October 1, 2022, when a near-bankfull flow event washed out a log jam downstream. Subsequently, different rating curve equations were used before and after the event. Bankfull discharge and peak discharges on October 1, 2022 and August 12, 2023 were estimated at 42.7 ft^3/s, 37.6 ft^3/s, and 25.1 ft^3/s using a channel cross section and Manning's equation and were incorporated into rating curves (Appendix D). The estimated mean annual discharge was 2.1 ft^3/s and mean monthly streamflow ranged 0.9–3.4 ft^3/s (Table 6). Estimates of daily exceedances and streamflow frequencies are presented in Figures 9 and 10, annual discharge graph is presented in Figure 11, and trial discharge hydrographs are in Appendix E. Peak discharge, estimated from stage height recorded on the wide–range data logger recording during the March 4, 2023 to November 3, 2023 period was estimated at 37.6 ft^3/s and bankfull discharge, which did not occur during the recording period, but is relevant for streamflow context, was estimated at 42.7 ft^3/s.

Table 5.–Stage, discharge, and culvert inlet velocity data.

Date	Time	Water level - wide range (ft)	Water level - trial range (ft)	Discharge estimate (ft^3/s)	Staff gage height (ft)	Mean culvert inlet velocity (ft/s)	Notes
03/04/21	9:20	0.648	ND	1.1	ND		Staff gage not installed
04/15/21	10:30	0.709	ND	3.5	ND		Staff gage not installed
08/10/21	11:00	0.572	ND	1.1	ND		Staff gage not installed
09/02/21	13:30	0.915	ND	10.1	ND		Staff gage not installed
09/03/21	10:00	0.637	ND	2.6	ND		Staff gage not installed
04/27/22	9:20	0.732	0.778	3.3	3.02	2.0	
04/28/22	9:30	0.619	0.725	2.1	2.97	2.3	
04/29/22	10:00	0.510	0.601	0.9	2.85	0.8	
06/23/22	9:00	0.491	0.746	0.9	3.00	0.8	
06/24/22	9:00	0.411	0.450	0.4	2.75	0.9	
07/27/22	10:30	0.494	0.580	1.0	ND	0.7	
07/28/22	10:00	0.910	1.040	8.6	3.29	2.2	
07/29/22	11:30	0.756	0.829	3.7	3.10	1.3	
10/01/22	7:00	1.606	ND	37.6	ND		Manning's equation estimate
10/05/22	12:00	0.372	0.383	0.6	2.62		Channel downcut 10/1/22
10/06/22	9:00	0.342	0.363	0.6	2.61	0.7	
10/07/22	12:00	0.315	0.349	0.5	2.60		
05/24/23	13:05	0.259	0.245	0.2	2.58		
05/25/23	11:00	0.262	0.237	0.1	2.50	0.2	
05/26/23	12:00	0.483	0.454	0.7	2.81		
05/28/23	12:00	0.733	0.628	3.4	2.89		
06/21/23	8:50	0.295	0.275	0.2	2.52		
06/23/23	12:00	0.262	0.228	0.1	2.50		
06/26/23	7:45	0.367	0.311	0.3	2.55		
08/12/23	15:00	1.322	0.639	25.1	ND		Manning's equation estimate
10/18/23	8:52	0.837	1.177	4.0	ND		
10/19/23	11:50	1.101	1.023	17.7	3.31	4.8	Creek above OHW stage
10/20/23	14:10	0.570	0.530	2.5	2.74		
11/01/23	9:26	0.377	0.326	0.4	2.53		

Note: ND = no data.

Table 6.–Mean annual and monthly flow statistics.

Time period	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean discharge (ft^3/s)	2.1	2.5	3.0	1.8	2.6	1.2	1.2	0.9	1.9	3.3	3.4	1.9	1.1

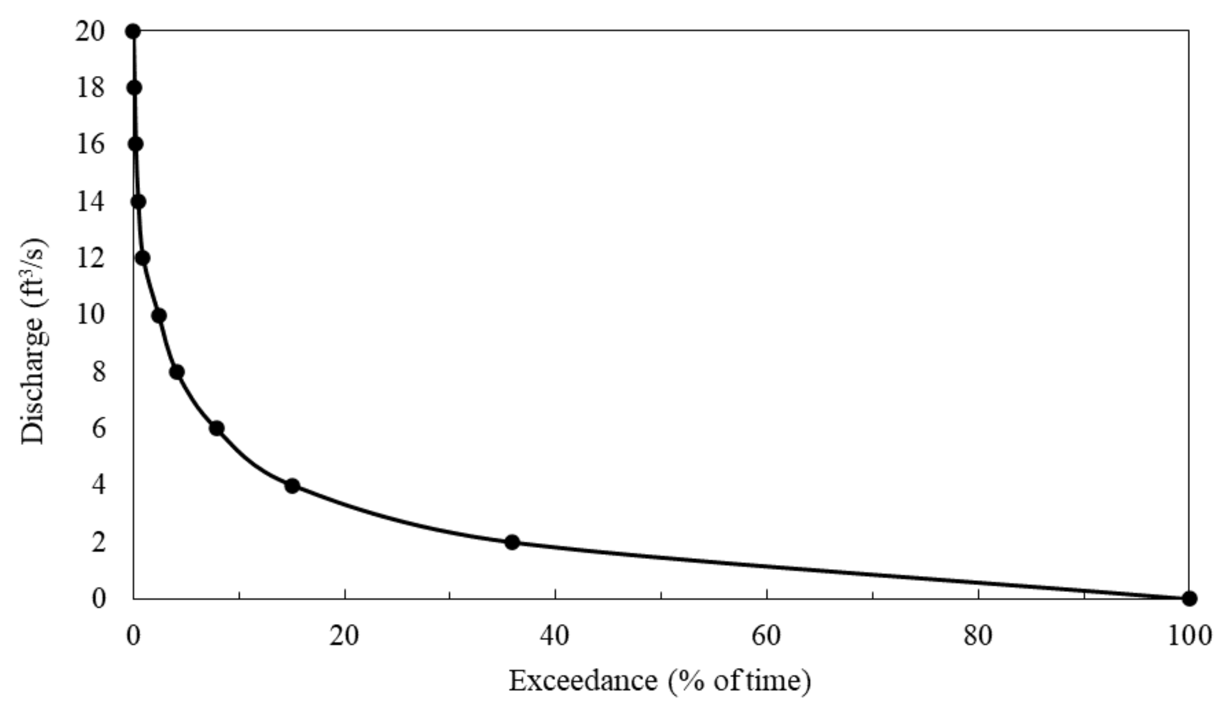

Figure 9.–Flow exceedance based on mean daily flows from 3/04/2021 to 11/03/2023.

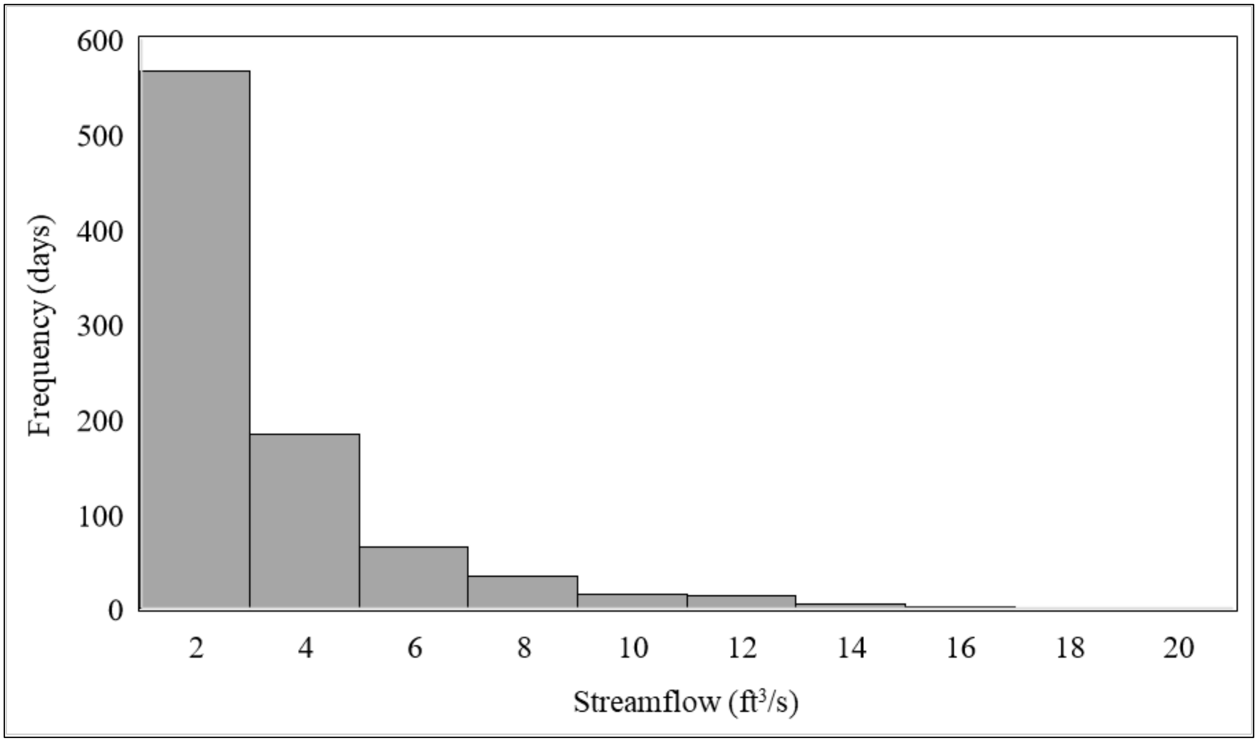

Figure 10.–Flow frequency based on mean daily flows from 3/04/21 to 11/03/23.

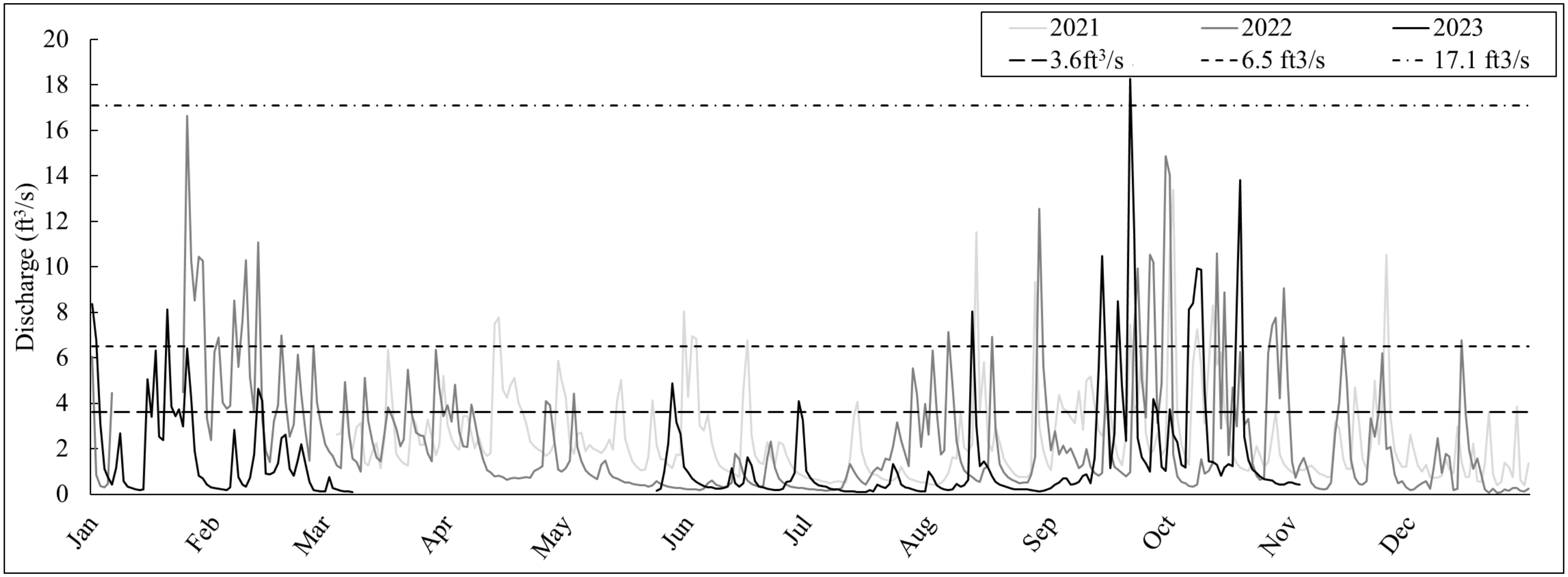

Figure 11.–Mean daily flow hydrograph 3/04/21–11/03/23, with select flow levels illustrated.

EGAN DRIVE CREEK

Trial conditions

The two trials at Egan Drive Creek were conducted and timed to coincide with low and high streamflow events, between which results are presented discretely. Stream discharge remained relatively steady at 0.4–0.6 ft^3/s during the September 7, 2023 low flow trial and ranged 0.4–14.5 ft^3/s during the September 20, 2023 high flow trial, which exceeded bankfull stage (Table 7). Mean velocity at the culvert inlet ranged 0.8–0.9 ft/s during low flow and 2.5–3.2 ft/s during high flow, at which time a vortex formed at the inlet. Lapses in recording data at the culvert outlet antenna were due to battery failure during the low flow trial and there was a high rate of tag collision at the culvert outlet antenna during both trials, resulting in little useful data. Water temperatures ranged 10.7–11.1˚C during the low flow trial and 9.3–9.9˚C during the high flow trial. Species composition for both trials was more heavily weighted towards coho salmon (coho salmon n = 147, Dolly Varden n = 67)—similar to composition of some of the Ninemile Creek fish passage trials—and FL frequency distribution did not differ significantly among groups for each species (Table 8).

Table 7.–Egan Drive Creek culvert fish passage trial summary data.

	Trial duration (h)	Min Q (ft^3/s)	Max Q (ft^3/s)	Water Temperature (˚C)	Group 1 CO *Group 1 DV* pass/total (%)	Group 2 CO *Group 2 DV* pass/total (%)	Group 3 CO *Group 3 DV* pass/total (%)
09/07/23	48	0.4	0.6	10.7–11.1	5/21 (23.8%)	3/22 (13.6%)	5/20 (25.0%)
					7/11 (63.6%)	*5/11 (45.5%)*	*4/9 (44.4%)*
09/20/23	48	0.4	14.5	9.3–9.9	3/29 (10.3%)	3/27 (11.1%)	10/28 (35.7%)
					4/13 (30.8%)	*6/12 (50.0%)*	*5/11 (45.5%)*

Table 8.–Fork length frequency distribution among groups and results from ANOVA comparison.

Group	Count	Average FL (mm)	Standard deviation	Minimum FL (mm)	Maximum FL (mm)	P-value
Coho salmon Group 1	50	99.9	17.0	67	129	0.965
Coho salmon Group 2	49	100.8	15.4	67	126	
Coho salmon Control	48	100.5	16.7	69	132	
Dolly Varden Group 1	24	96.8	29.7	55	148	0.116
Dolly Varden Group 2	23	112	27.1	57	148	
Dolly Varden control	20	94.5	31.9	50	154	

Fish Passage: Low Flow Trial

During the September 7, 2023 trial, which was marked by steady low flow conditions, chi-squared analysis of all test groups among species indicated that mean passage rate across trials and among species was not affected by group assignment (CO: $P = 0.601$; DV: $P = 0.610$) and all pairwise comparisons between groups were non-significant (Table 9). The difference between FL for passing fish in group 1 and the control group was not significant, as was the correlation for FL and passage time in all groups for both species (Table 10). However, the average culvert passage time for group 1 Dolly Varden (11.1 h) was significantly different than the average control group time (1.4 h). Due to flow remaining constant through the trial, discharge at moment of passage for each fish in each group was not investigated.

Table 9.–Chi-squared comparisons between group mean passage rates.

		Group 1	Control		Group 1	Group 2		Group 2	Control	
Trial date	Stream stage (sp)	% passing	% passing	*P*-value	% passing	% passing	*P*-value	% passing	% passing	*P*-value
09/07/23	Low flow (CO)	23.8%	25.0%	0.929	23.8%	13.6%	0.391	13.6%	25.0%	0.349
09/07/23	Low flow (DV)	63.6%	44.4%	0.391	63.6%	45.5%	0.392	45.5%	44.4%	0.964
09/20/23	High flow (CO)	10.3%	35.7%	0.022	10.3%	11.1%	0.926	11.1%	35.7%	0.032
09/20/23	High flow (DV)	30.8%	45.5%	0.459	30.8%	50.0%	0.327	50.0%	45.5%	0.827

Note: Significance level of 0.017 after Bonferroni correction for multiple comparisons was used.

Fish Passage: High Flow Trial

During the September 20, 2023 trial, marked by a bankfull flow event, chi-squared analysis of all test groups among species indicated that mean passage rate across trials and among species was not affected by group assignment (CO: $P = 0.023$; DV: $P = 0.594$) and all pairwise comparisons between groups were not significant (Table 9). The difference between FL for passing fish in group 1 and the control group was not significant, as was the correlation coefficient for FL versus passage time in all groups for both species (Table 10). Culvert passage times between group 1 and the control were also not significantly different. Comparison of discharge at the moment of passage through the upstream antenna at the culvert inlet during the high flow passage trial revealed no significant difference between groups within species (Table 10).

Table 10.–Statistical analysis for coho salmon and Dolly Varden between groups by trial date.

Trial date	Stream stage (sp)	Group 1			Control group				
		FL mean (mm)	FL range (mm)	*n*	FL mean (mm)	FL range (mm)	*n*	U-statistic	U-critical value
09/07/23	Low flow (CO)	81.4	67-92	5	104.0	76-132	6	6	2
09/07/23	Low flow (DV)	100.4	62-135	7	88.5	50-117	4	9	3
09/20/23	High flow (CO)	112.7	108-116	3	111.1	103-132	9	12	3
09/20/23	High flow (DV)	124.5	101-148	4	99.8	88-122	5	3	1
		Passage time mean (h)	Passage time range (h)	*n*	Passage time mean (h)	Passage time range (h)	*n*	U-statistic	U-critical value
09/07/23	Low flow (CO)	18.1	8.5-26.5	5	38.0	7.0-16.5	2	4	2
09/07/23	Low flow (DV)	11.1	2.0-26.5	7	1.4	0.5-2.5	3	**2**	**3**
09/20/23	High flow (CO)	11.8	3.5-28.0	3	5.5	3.0-11.5	10	14	3
09/20/23	High flow (DV)	3.4	2.0-4.0	5	14.0	1.5-45.5	5	9	1
		Mean Q ascent (ft^3/s)	Q ascent range (ft^3/s)	*n*	Mean Q ascent (ft^3/s)	Q ascent range (ft^3/s)	*n*	U-statistic	U-critical value
09/20/23	High flow (CO)	4.9	2.2-10.4	3	3.4	2.1-8.3	10	14	3
09/20/23	High flow (DV)	2.2	2.1-2.2	5	4.7	2.0-11.0	5	9	1
		FL vs. time Pearson correlation			FL vs. time Pearson correlation				
		r-value	*P*-value		*r*-value	*P*-value			
09/07/23	Low flow (CO)	0.85	0.071		0.74	0.150			
09/07/23	Low flow (DV)	0.43	0.338		0.63	0.373			
09/20/23	High flow (CO)	0.68	0.524		0.19	0.592			
09/20/23	High flow (DV)	0.50	0.500		0.10	0.875			

DISCUSSION

FISH PASSAGE

Ninemile Creek

Average group 1 culvert passage rates of 2.5% and 18.8% for coho salmon and Dolly Varden are low. However, control group passage rates of 18.1% and 40.8% for each species still don't approach what would be expected under free passage conditions. This suggests factors other than swimming obstacles (e.g., lack of motivation by food, predator-prey dynamics, etc.) were involved. When test group passage rates are calibrated to respective control group passage rates (by dividing the test group rate by the control rate), group 1 coho salmon and Dolly Varden passage rates are 13.9% and 46.1% and 24.6% and 92.2% in group 2 (Table 11). These rates; however, must be further qualified by consideration of fish FL, passage time, and the discharge data.

Table 11.–Fish passage rates calibrated to the control group rate.

Species	Group 1 % passing	Group 2 % passing	Control % passing
Coho Salmon	13.9%	24.6%	100.0%
Dolly Varden	46.1%	92.2%	100.0%

Mean FL of passing fish was not significantly different between experimental groups; however, it is notable that coho salmon smaller than 85 mm and Dolly Varden smaller than 79 mm passed the control reach, but not the culvert. Furthermore, of the 19 legacy fish (4 CO, 15 DV) recorded passing the culvert, none were originally recorded[s] at less than 79 mm (coho salmon) and 85 mm (Dolly Varden) FL. When coho less than 85 mm FL and Dolly Varden less than 79 mm FL are removed from the group 1 and control group passing fish datasets,[t] the resulting mean group 1 fish FLs (CO:106 mm FL; DV: 111 mm FL) are still larger than passing control group mean FLs (CO: 98 mm FL, DV: 106 mm FL). This suggests that among fish of a sufficient FL to pass the culvert, passage conditions appear to favor larger fish; an intuitive trend supported by common understanding of fish swimming ability as a function of size (Wardle 1975).

Group 2 fish provide a unique insight in that they were not subjected to making the initial leap from the outlet pool to enter the culvert and were challenged with passing only 77 ft of culvert, rather than 153 ft. While not all comparisons with group 2 are appropriate, the result of similar group 1 and group 2 passage rates by coho salmon (2.5% and 4.5%) indicate that a shorter, baffled slipline with a smooth outlet transition may still not result in fish passage rates similar to the control reach. In contrast, group 2 Dolly Varden showed a higher passage rate (37.6%) than group 1 (18.8%) which also indicates better passage rates could be expected in a shorter, baffled slipline; however, fish less than 81 mm FL still did not pass, even from halfway up.

Mean passage times for both species in the control group were lower than group 1 mean passage times (significantly so for Dolly Varden only); however, it is possible a given fish could have summited most of the reach rapidly, then loitered for hours just downstream of the upper antenna prior to passing. When passage times for group 1 are truncated to include only the time from last detection at the culvert outlet antenna to the first detection at the inlet antenna, the average passage times for coho salmon and Dolly Varden drop from 15.4 h and 19.2 h to 7.7 h and 10.1 h.

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[s] Original FL recording dates vary for each fish. Legacy fish were not recaptured and measured in subsequent trials and could have increased length between trials.

[t] Legacy fish not included.

Unfortunately, without an antenna at the downstream end of the control reach, the passage times from last attempt cannot be compared. Future studies would benefit from incorporating additional antennas at the beginning of each reach and potentially within the reach to assess fish movement patterns.

A similar caution is needed for comparing discharge at moment of reach ascent as that point in time does not represent discharge during the duration of fish movement, unless the ascent was made in rapid time or under unchanging flow conditions. Subsequently, mean flow rate (sampled every 30 min) was calculated for each passing fish, then averaged within groups and compared. The overall mean discharges experienced by group 1 coho salmon and Dolly Varden were 1.0 ft^3/s and 1.8 ft^3/s, which are lower than control group means of 1.2 ft^3/s and 4.9 ft^3/s. Dolly Varden would have shown a similar pattern; however, a 138 mm FL fish appeared to remain in the culvert for 35.5 hours through a peak flow of 37.0 ft^3/s prior to summitting (though it is more likely the fish entered the culvert after the peak flow undetected due to tag collision). Regardless of this single potential outlier, seven control group fish ascended during times when peak flows ranged 8.7–37.0 ft^3/s, suggesting control reach passage is easier than culvert passage during high flow conditions.

Flow during successful passage of coho salmon (including legacy fish), from their last detection at the outlet antenna until their first detection at the inlet, ranged 0.5–3.9 ft^3/s and 0.1–6.5 ft^3/s for Dolly Varden (aside from the 138 mm fish transiting during 37.0 ft^3/s, aforementioned). Discharge levels of 3.9 ft^3/s and 6.5 ft^3/s were exceeded 17.5% and 6.9% of the time during the 32-month stream gaging period.[u] The majority of coho salmon and Dolly Varden passed the culvert when flows were below 1.0 ft^3/s and 1.5 ft^3/s, which were exceeded 58.8% and 45.1% of the time.

Egan Drive

Group 1 passage rates for coho salmon and Dolly Varden, when divided by control group passage rates for the sake of calibration, were 95.2% and 143.2% during the low flow trial[v] and 29.0% and 67.7% during the high flow trial (Table 12). Due to low sample size and a lack of replicate trials, these results should be interpreted with caution. Given the low streamflow velocity, backwatered state, and the observation of rapid culvert ascent by some Dolly Varden, the significantly longer transit time shown by group 1 fish may be a result of behavioral factors, rather than swim difficulty. High flow may present a partial barrier for coho salmon, though it is worth noting one of the three passing coho from group 1 (116 mm FL) did so in less than 30 min when discharge was near a peak of 10.8 ft^3/s. All other group 1 and group 2 passages for both species occurred within the first 6 h of the trial, when discharge ranged 1.8–2.1 ft^3/s. Control group passages occurred over a wider time range and flows up to 11.7 ft^3/s.

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[u] For context, bankfull discharge was estimated at 42.7 ft^3/s.

[v] More fish passed in group 1 than then the control group, resulting in the greater (relative) passage success rate of 143%.

Table 12.–Fish passage rates calibrated to the control group.

Trial date	Stream stage (sp)	Group 1 % passing	Group 2 % passing	Control group % passing
09/07/23	Low flow (CO)	95.2%	54.5%	100.0%
09/07/23	Low flow (DV)	143.2%	102.3%	100.0%
09/20/23	High flow (CO)	29.0%	31.1%	100.0%
09/20/23	High flow (DV)	67.7%	110.0%	100.0%

CONCLUSIONS

In this study, coho salmon less than 85 mm and Dolly Varden less than 79 mm did not pass the Ninemile Creek baffled culvert slipline. Coho salmon and Dolly Varden juveniles generally passed the control reach at higher flow stages and in a shorter time. Overall, the Ninemile Creek culvert can be passed by larger juvenile salmonids, which is an improvement over the previous culvert condition for a fraction of the estimated culvert replacement cost (R. Trousil, Regional Materials Engineer, DOT&PF, Juneau, personal communication).

Unlike coho salmon, Dolly Varden challenged with only swimming half the pipe (group 2) showed a similar rate of passage to control group fish. This finding suggests either cumulative culvert length and/or the initial entry jump may be of higher importance than baffle form and gradient for Dolly Varden. Absent baffles, the Ninemile Creek culvert would block all upstream fish migration due to low water depth, high velocity, and culvert length.

While sample size limits conclusions at the Egan Drive Creek site, the high culvert passage rates during base flow suggest the culvert does not constitute a complete barrier for either species. Additional trials at differing flow levels at this site would be needed to understand fish behavior at higher streamflows.

Future PIT tag passage studies should include a fourth antenna at the downstream end of the control reach and if desired, antennas halfway up each reach, to understand passage dynamics and reduce uncertainty and data loss from tag collision at outlet antennas where fish may loiter. Additionally, targeting smaller fish and timing flow with weather forecasted over the course of trial (i.e., delaying trial start until flow has risen to minimum desired stage) could shine light on finer details of fish passage through culvert sliplines.

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Wardle, C.S. 1975. Limit of fish swimming speed. Nature. 255:725-727.

APPENDIX A: ANNOTATED BIBLIOGRAPHY

1. **Birnie-Gauvin, K., P. Franklin, M. Wilkes, and K. Aarestrup. 2017. Moving beyond fitting fish into equations: progressing the fish passage debate in the Anthropocene. Aquatic Conservation: Marine and Freshwater Ecosystems. 29:1095–1105.**

Abstract - Realization of the importance of fish passage for migratory species has led to the development of innovative and creative solutions ('fishways') to mitigate the effects of artificial barriers in freshwater systems in the last few decades. 2. In many instances, however, the first move has been to attempt to engineer a solution to the problem, thus attempting to 'fit fish into an equation'. These fishways are often derived from designs targeting salmonids in the Northern Hemisphere. They are rarely adequate, even for these strong-swimming fish, and certainly appear to be unsuitable for most other species, not least for those of tropical regions. 3. Fishway design criteria do not adequately account for natural variation among individuals, populations and species. Moreover, engineered solutions cannot reinstate the natural habitat and geomorphological properties of the river, objectives that have been largely ignored. 4. This article discusses the most prominent issues with the current management and conservation of freshwater ecosystems as it pertains to fish passage. It is not intended as a review on fish passage, but rather a perspective on the issues related to fishways, as seen by practitioners.

2. **Cabonce, J., H. Wang, and H. Chanson. 2018. Smart baffles to assist upstream culvert passage of small-bodied fish. 7th International Symposium on Hydraulic Structures. Aachen Germany. May 2018.**

Abstract - Current culvert designs have little evolved since ancient designs. Some recognition of the ecological impact of culverts on natural streams and rivers led to changes in culvert design guidelines, too often associated with un-economical design recommendations. A simple small triangular corner baffle system may assist upstream passage of small body-mass fish in box culvert structures on very flat bed slope, while inducing little reduction in discharge capacity at design flow conditions and creating sizeable slow flow regions at less-than-design flow conditions. The system was tested systematically in a near full-scale physical model, 0.5 m wide and 12 m long. The present investigation delivered a detailed characterization of the flow field in smooth and triangular baffled channels, at a scale comparable to a small standard box culvert barrel. Tests showed that small-bodied fish preferred to swim in slow-velocity regions, typically in the baffle corner. To be most effective, the corner baffle size has to be comparable with the fish dimensions, and strong flow reversal must be avoided, since it might confuse fish attempting upstream passage. Finally, design guidelines of fish-friendly culverts must be re-thought, with a focus on fish passage for less-than-design flows and maximizing the discharge capacity at design flow. Current design practices must evolve from a semi-empirical approach based heavily on simplistic observations and educated guesses to advanced physics-based theoretical considerations and sound engineering guidelines.

Additional notes – Experimental trials consisted of silver perch subjected to a 40 ft long by 1.5 ft wide flume with isosceles triangle shaped corner baffles with and without vent holes and discharge creating velocities at maximum capability of test. Passage success was greatly improved by venting baffles with a hole to reduce the flow reversal effect behind each corner baffle. However, holes would be subject to clogging in natural environment.

3. **Cabonce, J., H. Wang, and H. Chanson. 2019. Using small triangular baffles to facilitate upstream fish passage in standard box culverts. Environmental Fluid Mechanics. 19:157–179.**

Abstract - A culvert is a covered channel to pass streams and floodwaters through an embankment. The ecological impact of culverts has been recognized, in particular in terms of stream connectivity, but existing guidelines lead often to un-economical culvert design. Herein, a small triangular corner baffle system was tested physically in a near-full-scale fish-friendly facility of a box culvert barrel. Experiments were repeated with several configurations to characterize the flow properties for a range of less-than-design flows, baffle sizes and spacings. In presence of triangular corner baffles, the flow was asymmetrical, owing to the wake behind each baffle. The presence of triangular corner baffles had a moderate effect on the flow resistance and discharge capacity, albeit the data indicated the combined effect of relative baffle height and spacing on the friction factor. With triangular baffles, the surface area of slow velocity regions increased by a factor of two to three. Such low velocity regions are preferential swimming zones for fish, beneficial to small-bodied fish passage. Testing with small-bodied fish showed that fish preferred to swim upstream in slow-velocity regions, typically next to the sidewalls and in the left corner where the triangular baffles were located. The presence of small triangular baffles facilitated substantially the upstream passage of small fish, including in terms of endurance, compared to a smooth un-baffled box culvert barrel, when the baffle size was comparable to the fish length. The present findings highlighted the importance of physical modelling at near full-scale for the development of fish-friendly culvert designs.

4. **Castro-Santos, T., A. Cotel, and P. Webb. 2009. Fishway evaluations for better bioengineering: an integrative approach. American Fisheries Society Symposium. 69:557–575.**

Abstract - Effective fishway design requires extensive integration of biological and hydraulic data. Many relevant biological parameters remain poorly characterized, however, and the lack of adequate biological data has long been recognized as a central weakness in fish passage technology. This is of particular concern given the growing recognition of the importance of passing a broad diversity of species. Part of the reason for this weakness is the difficulty of identifying relevant biological, hydraulic, and other physical parameters. We propose that by both exploring questions suggested by current knowledge, and also by increasing the frequency and refining the methods with which fishways are evaluated, two results can be achieved: our understanding of design effectiveness can be improved, and research questions can be prioritized through adaptive management. We describe a framework and rationale for fishway evaluations that identifies several promising avenues of research. Understanding correlates of passage performance is increasingly important as fish passage needs expand on a global scale.

Additional notes – Velocity, kinetic energy (or energy dissipation factor), and dimensions describing pools chutes, and weirs are currently used to inform criteria for fish passage. The author suggests literature indicates other factors must be considered such as turbulence, fishway morphology, behavior, and energetic cost.

5. **Chanson, H and W. Uys. 2016. Baffle designs to facilitate fish passage in box culverts: a preliminary study. In B. Crookston & B. Tullis (Eds.), Hydraulic Structures and Water Systems Management. 6th IAHR International Symposium on Hydraulic Structures, Portland, OR, 27-30.**

Abstract – Waterway culverts and road crossings are very common structures along water systems, ranging from rural roads to national highways and urban drainage networks. Present expertise in environmental hydraulics of culverts is deficient because of the many empirically-based design guidelines, which are sometimes outdated and often inadequate for fish passage. Engineers and biologists need better, more reliable prediction 'tools' during the design stages to compare the bio-engineering performances of a range of design options. In all the cases, the turbulence of the flowing waters must be optimized efficiently to maximize fish migration. This project focused on the development of simple solutions to retrofit existing box culverts, with the aim to maximize slow flow regions suitable for small fish passage and to minimize the afflux increase. Herein, a physical study of a standard box culvert was performed under controlled flow conditions, and six baffle designs were tested. Two baffle configurations presented promising results: the corner baffles and the streamlined diagonal baffles. The streamlined diagonal baffles assisted with the development of a large recirculation region immediately downstream of each baffle, with a moderate increase in afflux for a given discharge. The optimum design appeared to be the corner baffle system. It produced little additional afflux, while creating excellent recirculation both upstream and downstream of each baffle. However, further testing must be conducted to develop quantitative design guidelines and to assess the impact on real fish passage.

6. **Cotel, A.J. and P.W. Webb. 2015. Living in a turbulent world – A new conceptual framework for the interactions of fish and eddies. Integrative and Comparative Biology. 55(4):662-672.**

Abstract – The natural habitats of fishes are characterized by movements of water driven by a multitude of physical processes of either natural or human origin. The resultant unsteadiness is exacerbated when flow interacts with surfaces, such as the bottom and banks, and protruding objects, such as corals, boulders, and woody debris. There is growing interest in the impacts on performance and behavior of fishes swimming in ‘‘turbulent flows’’. The ability of fishes to stabilize their postures and their swimming trajectories is thought to be important in determining species’ distributions and densities, and hence the resultant assemblages in various habitats. A theoretical framework is proposed to quantify the interactions of fish and flows. Dimensionless parameters are derived based on a physical description of the flow structures and different regimes are predicted describing fishes’ responses to a wide range of physical perturbations. We found the ratio of eddy size to fish size, the ‘‘momentum ratio’’ (ratio between momentum of the eddy and the momentum of the fish), as well as the time of interaction between eddy and fish to be especially important in determining thresholds for the fish’s posture and trajectory.

7. **Duguay, J. and J. Lacey. 2014. Numerical validation of an innovative fish baffle design in response to fish passage issues at perched culverts. CSPI Technical Bulletin. 1/14/2014.**

Abstract – The hydraulic characteristics of a half-round corrugated steel fish ladder is investigated by means of an advanced numerical model. The objective of this study was to develop an innovative baffle design which produces an appropriate flow field for fish passage over a wide range of seasonal flow rates. The baffle consists of a lower main passageway, to accommodate fish passage at low flow rates, and a higher secondary passageway, which presents an auxiliary option for fish passage as well as debris at higher discharges. The elevated center arch of the baffle develops pool depth, thus minimizing the volumetric dissipative power in the pools at high flow rates. The velocities at the passageways respect critical swim speeds for a wide range of fish species of socioeconomic importance to North America. Turbulence metrics (turbulent kinetic energy and volumetric dissipative power) within the 3D dimensional flow structure of the pool are also investigated and discussed. The presence of a large hydraulic refuge zone was identified in the upstream section of the pools which fish may use to stage jumping attempts. The proposed fish ladder, made of polymer coated corrugated steel is a lightweight, durable and low cost solution to the problem of aquatic habitat fragmentation at perched culverts.

A*dditional notes* – The Hannaford weir design can split the flow during high discharge and concentrates velocity and turbulence on the culvert wall, leaving a larger low energy area in the center of the culvert, while the Department of Fisheries and Oceans standard weir, with only a single passageway in the center creates two smaller low turbulence zones on either side. It's important to note that since this fish ladder is not constrained to fit within an existing pipe, the Hannaford weir design may create too much hydraulic roughness within a given culvert for conveying flood flows adequately. Design slopes tested were 8.5% and 10%.

8. **Duguay, J. and R.W. J. Lacey. 2015. Effect of fish baffles on the hydraulic roughness of slip-lined culverts. Journal of Hydraulic Engineering. 141(1):1-10.**

Abstract – The use of fish baffles in HDPE slipliners is growing in popularity to improve hydraulic conditions for fish passage, yet little is known on how baffles affect the outlet-controlled discharge capacity of these types of culverts. To fill this gap in knowledge, roughness coefficient (Manning's n and friction factor f values) were experimentally determined for weir baffle, slotted weir baffle, and spoiler baffle configurations at four relative spacings ($\lambda^+ = 0.6, 1.2, 1.8, 2.4$) and three values of relative roughness height ($h^+ = 0.15, 0.10, 0.05$). Relative roughness height ($h^+ = h/D$ where D is the pipe diameter) was found to be the determinant geometric parameter affecting energy losses. Relative spacing ($\lambda^+ = \lambda/D$) was found to play an important secondary role. An analytical model was developed and analyzed to determine the effects of the following: roughness reduction between the Manning's coefficients of the host and baffle equipped slipline culvert; diameter reduction between the diameters of the host and slipline culverts; relative length; and inlet treatments on the hydraulic capacity of corrugated steel culverts after being sliplined with baffled high-density polyethylene (HDPE) culverts. Results demonstrate that many HDPE slipliner culverts can house baffles with α values in the range of 0.5 to 0.9. Design recommendations for the use of baffles in slipline culverts are discussed.

Additional notes – Relative height was determined to be the primary geometric parameter affecting roughness, with baffle spacing taking a secondary role. Slotted-weir baffles consistently created lower roughness than the other two configurations.

9. **Duguay, J., R.W. Jay Lacey, and T. Castro-Santos. 2018. Influence of baffles on upstream passage of brook trout and brown trout in an experimental box culvert. Canadian Journal of Fisheries and Aquatic Sciences. 00:1-14.**

Abstract – There is much to learn about improving baffle designs to increase successful fish passage through culverts. A fish's motivation to attempt entry into the culvert is essential. Upon entry, successful passage will largely depend on the physiological ability of the fish to navigate the entire culvert length. In this study, the motivation of brook trout (*Salvelinus fontinalis* (Mitchill, 1814)) and brown trout (*Salmo trutta* Linnaeus, 1758) to attempt ascent of an experimental flume, which mimics a roadway culvert left bare (smooth) or fitted with either spoiler or weir baffles, is assessed. Performance, measured as maximum distance of ascent within the flume, is also quantified. The bare flume was the most motivating for brook trout, and the weirs were most motivating for brown trout. As a rule, brown trout showed less motivation to stage attempts than brook trout, except within the weir baffle treatments. Performance was greatest in the weirs for smaller trout and in the spoiler baffles for larger trout. Our findings
suggest that baffle form influences passage rates at road crossings in ways previously unknown and further stresses the importance of considering fish motivation and performance together when assessing the efficacy of baffle forms.

Additional notes – Trials were conducted during the spawning migration periods, though an unexpected 8 day hold and decreased water temperatures may have had a minor impact on the results. The author suspected the hydraulic jump present at outlet of bare flume trials may have attracted brook trout, but ultimately the passage conditions favorable to motivation are often detrimental to performance. Weir baffles were only 2 inches tall, which may explain increased max ascent performance for smaller fish vs larger.

10. **Duguay, J., B. Foster, J. Lacey, and T. Castro-Santos. 2018. Sediment infilling benefits rainbow trout passage in a baffled culvert. Ecological Engineering. 125:38–49.**

Abstract – Fish are thought to exploit low velocity recirculation zones in the wakes of baffles to take refuge from challenging hydraulic conditions in baffled culverts. Here, we investigate how sediment deposition in the wakes of baffles affects passage and behaviors of juvenile rainbow trout in a baffled experimental flume. High temporal resolution 3D fish tracking provided detailed kinematics of adopted trajectories. Stereoscopic particle image velocimetry permitted a finely resolved description of the flow over a clear baffle configuration and the same configuration with sediment wedges placed in their wakes. Controlled station-holding, suggestive of flow-refuging, only occurred when sediment wedges were blocking the baffles' recirculation region. Also, maximum distances of ascent were higher, and slower ground-speeds were employed in the sediment condition. The results of this study suggest the turbulent recirculatory wakes of the clear bed condition caused postural instabilities and were in many ways detrimental to passage performance. Additional research is required to understand the relationships existing between baffle height, hydrodynamic recirculatory wake metrics, sediment deposition and the behavioral responses of fish interacting with weir baffle wakes.

Additional notes – Laboratory setup included a 6 ft long, 6 inch wide, 0% slope box flume with watertight top and pressurized flow at 0.37 ft/s and rainbow trout with mean FL 86 mm. While conclusions demonstrate fish could not make use of the eddies, caution should be applied when scaling to larger culverts, in which postural stability is not costly when holding in a large enough eddy. Formula for evaluating eddy size and velocity relative to fish length is offered as an analysis tool. Additionally, plunging flow condition was not tested, only streaming flow.

11. Ead, S.A., N. Rajaratnam, and C. Katopodis. 2002. Generalized study of hydraulics of culvert fishways. Journal of Hydraulic Engineering. 128(11):1018–1022.

Abstract – This study presents a comprehensive analysis of the experimental observations, collected previously in an extended project on culvert fishways with offset baffle, slotted weir baffle, weir baffle, spoiler baffle, Alberta fishweir, and fishbaffle systems. It has been found that a general correlation exists between the dimensionless discharge $\mathbf{Q*}5Q/\mathrm{A}(gS0D5)$ and the relative depth of flow ($y0$ /D) for each value of the relative baffle height (h/D). Furthermore, for relative baffle heights in the practical range of 0.1–0.15, longitudinal baffle spacing should be limited to a maximum of D. The velocity field in the centerplane of each of these culvert fishways was analyzed and was found to be similar with the similarity profiles having different shapes for different baffle systems. A general correlation was also found for the normalized velocity scale. Even though most of the baffle systems worked reasonably well in the range of parameters recommended, the weir and slotted weir baffle systems are simpler yet equally effective. The results presented in this paper will hopefully facilitate the design and building of successful culvert fishways.

12. Enders, E.C., T. Castro-Santos, and R.W.J. Lacey. 2017. The effects of horizontally and vertically oriented baffles on flow structure and ascent performance of upstream-migrating fish. Journal of Ecohydraulics. 2(1):38-52.

Abstract – Considerable effort has been expended to construct culverts and fishways that allow for fish passage. However, the designs have seldom considered behavior, energetics, and biomechanics of fish. In this study, we performed controlled experiments, in which upstream-migrating Alewife (Alosa pseudoharengus) and Brook Trout (Salvelinus fontinalis) were allowed to volitionally enter either one of two open channels. These channels were outfitted with horizontally and vertically oriented baffles. The flow structure was characterized using acoustic Doppler velocimeter measurements. The added baffles had a marked influence on the flow field, which was distinct between horizontal and vertical baffles, indicative of horizontally and vertically orientated vortices, respectively. Passage success was measured, both in terms of attraction and ascent performance under each flow condition. The results indicated that Alewife and Brook Trout staged significantly more attempts into the vertical baffled channel compared to the horizontal baffled channel. However, Alewife traversed greater distances swimming in the channel with the horizontal baffles at the lower flow condition. Brook Trout also swam further under low flow but traversed similar distances in both channels. This information furthers our understanding of both ascent performance and behavioral responses of fish in relation to turbulent flow and roughness orientation.

Additional notes – Tests were performed in parallel wooden 60 ft long, 32 inch wide box culverts set at 3.5% gradient with vertical and horizontal weirs under about 1 and 2 cfs flow conditions. Results corroborate other findings suggesting salmonids take advantage of vertically oriented vortices to move upstream through obstacles.

13. **Feurich, R, J. Boubee, and N.R.B. Olsen. 2012. Improvement of fish passage in culverts using CFD. Ecological Engineering. 47(2012):1–8.**

Abstract – Upstream migration of fish through circular culverts is often prevented by velocities in the barrel being higher than that of the natural channel. In this investigation a computational fluid dynamic (CFD) model has been used to test the effects of various spoiler baffle geometries in culverts of varying size to reduce water velocity and increase water depth and thus increase the upstream passage of small fish species. Results indicated that standard baffles designed for specific fish species or groups could be successfully retrofitted to culverts of varying dimensions. Subsequent field tests have confirmed the effectiveness of the design.

Additional notes – The standard block size of 5 x 5 x 10 inches was the ideal balance of creating low velocities while minimizing the number of baffle installations. Authors recommend linking the size of baffles to the size of fish to minimize potential for debris blockage. Culvert capacity loss decreases with size of pipe when the standard baffle was installed. Losses were 8%, 7%, 5%, and 3% for 4.1, 6.5, 9.8, and 13.1 ft diameter pipes.

14. **Freire, R., C. Sailema, and H. Chanson. 2018 On ventilated corner baffles for box culvert barrel: a physical investigation. Hydraulic Model Report No. CH112/18. University of Queensland, School of Civil Engineering, August, 2018.**

Abstract – During the last decades, concerns regarding the ecological impact of standard culverts have led to some evolution in design. The installation of baffles along the culvert barrel invert and walls may be a fish friendly technique to decrease velocities in the barrel and increase flow depths. The resulting flow conditions may be potentially more suitable for upstream fish passage. Small triangular corner baffles were proposed to facilitate the upstream passage of small-body-mass fish, without compromising the discharge capacity of the culvert at design flow conditions. Although fish benefited from low velocity regions for resting and sheltering, small-body-mass fish were observed to turn around and could become disoriented by the adverse effect of flow reversal regions in the wake of plain baffles (CABONCE et al. 2017,2018,2019). This study presents the design and hydrodynamic testing of ventilated triangular corner baffles for standard box culverts. The ventilated baffles were developed to address the issue of negative wake behind the baffles, previously observed to affect adversely small-bodied fish. Two designs were tested: a baffle with three holes and a brush baffle. Detailed physical modelling in a near-full-scale culvert barrel showed that the ventilated corner baffles created a smaller negative wake region. A lesser negative velocity magnitude was observed behind the ventilated baffles, in comparison to plain baffles, for the same flow rate, baffle height and spacing. With ventilated corner baffles, the longitudinal distribution of low-velocity zone (LVZ) was more uniform, yielding a better longitudinal connectivity for upstream passage, compared to plain baffles. A comparison between detailed hydrodynamic measurements suggested however that the requirements for continuous, sizeable low positive velocity zone (LPVZ) suitable to small-bodied fish might be better fulfilled with an asymmetrically roughened culvert barrel than with triangular baffles, even with ventilation.

15. **Goerig, E. and T. Castro-Santos. 2017. Is motivation important to brook trout passage through culverts? Canadian Journal of Fisheries and Aquatic Sciences. 74:885–893.**

Abstract – Culverts can restrict movement of stream-dwelling fish. Motivation to enter and ascend these structures is an essential precursor for successful passage. However, motivation is challenging to quantify. Here, we use attempt rate to assess motivation of 447 brook trout (*Salvelinus fontinalis*) entering three culverts under a range of hydraulic, environmental, and biological conditions. A passive integrated transponder system allowed for the identification of passage attempts and success of individual fish. Attempt rate was quantified using time-to-event analysis allowing for time-varying covariates and recurrent events. Attempt rate was greatest during the spawning period, at elevated discharge, at dusk, and for longer fish. It decreased during the day and with increasing number of conspecifics downstream of the culvert. Results also show a positive correlation between elevated motivation and successful passage. This study enhances understanding of factors influencing brook trout motivation to ascend culverts and shows that attempt rate is a dynamic phenomenon, variable over time and among individuals. It also presents methods that could be used to investigate other species' motivation to pass natural or anthropogenic barriers.

Additional notes – 447 test fish (FL 90–263 mm) were caught primarily upstream of the culverts and placed in groups of ~25 fish in a spacious cage with resting habitat connected to the culvert outlets. PIT tag arrays were spaced throughout the culverts and flow ranged 2-25 cfs during trials. Attempt rate was 1.8 times higher when testing fell within 2 weeks of spawning. Discharge had positive relation to attempt with 60% of fish attempting at 3.5 cfs, 80% at 10.6%, and 90% at 17.7%. Attempts were 25% higher at dusk than dawn.

16. **Goodrich, H.R., J.R. Watson, R.L. Cramp, M.A. Gordos, and C.E. Franklin. 2018. Making culverts great again: Efficacy of a common culvert remediation strategy across sympatric fish species. Ecological Engineering. 116:143–153**.

Abstract – Culverts are instream structures that act as hydrological barriers to fish movement by altering water turbulence, increasing water velocities and disrupting connectivity. Hydrological barriers like culverts have led to the fragmentation and decline of freshwater fish populations worldwide. Culvert remediation strategies such as bed roughening have proved effective at increasing the likelihood of fish passage in a variety of fish species. However, little is known about whether culvert roughening is efficacious for Australian small bodied fishes and if so, whether bed roughening is comparably beneficial to all species that may utilize remediated culverts. This study assessed the effect of roughened bed substrates on the swimming performance and behaviour of four small bodied or juvenile Australian fishes (*Hypseleotris compressa* and *Melanotaenia duboulayi*, and juvenile *Tandanus tandanus* and *Maccullochella peelii*) that exist in sympatry over parts of their distribution. Results showed that bed roughening increased water turbulence and the size of low velocity regions within fluid flow and that all fish species displayed the same positive behavioral preferences for these zones. However, the effect of bed roughening on swimming endurance and traversability was found to only benefit *Mel. duboulayi* and *Mac. peelii*. Roughening decreased endurance and traversability in *T. tandanus* and had no effect on performance in *H. compressa*. These data indicate that sympatric species may respond differently to culvert remediation actions, highlighting the need for a holistic approach to culvert remediation and a comprehensive understanding of all species' requirements within the affected environment.

Additional notes – Laboratory trials consisted of a 10.5 x 0.8 x 1 ft flume either smooth or lined with river stone cemented in place and velocities ranging 1–1.5 ft/s. Cementing river stone into culverts is a remediation strategy in Australia.

17. **Gregory, S. and J. McEnroe. 2004. Fish passage through retrofitted culverts. Oregon Department of Transportation, Technical Report No. FHWA-OR-RD-05-05, Salem, OR.**

Abstract – Long term and short term studies of fish movement were conducted at several retrofitted culverts within Oregon. This was done to assess the effectiveness of retrofitting culverts with baffles to improve fish passage. The long term results showed that the baffle equipped culverts do in fact allow fish passage, even though the fish in the study areas did not appear to move a great deal in any part of the study reaches. The short term results indicated a definite improvement in the ability of juvenile steelhead trout to move upstream after the addition of certain baffle configurations. Measurements of hydraulic conditions showed that the baffles do create areas of lower flow velocity, deepen the flow, and create resting pools. These observations indicate that fish can and do move through culverts retrofitted with baffles and that the addition of baffles can improve the ability of juvenile fish (especially steelhead trout) to move upstream through a culvert.

Additional notes – The short term study consisted of placing hatchery steelhead within the retrofitted 8 ft wide concrete box culvert with enclosures at each end, then electrofishing within the culvert to locate fish after given several hours to move. With no baffles, 98% of fish moved downstream of the culvert, 29% moved in an upstream direction with 30º baffles, 39%% moved in an upstream direction with 45º baffles, and 38% moved in an upstream direction with 90º baffles. Authors determined incentives such as bait or scaring fish upstream had no effect on fish movement. Long term studies consisted of marking hundreds of fish in 7 drainages with retrofitted culverts, then resampling for them both up and downstream of the culvert and provides only a snap shot at two points in time.

18. **Hinch, S.G and P.S. Rand. 2000. Optimal swimming speeds and forward-assisted propulsion: energy-conserving behaviors of upriver-migrating adult salmon. Canadian Journal of Fisheries and Aquatic Sciences. 57(12):2357–2362.**

Abstract - Anadromous salmon migrations are energetically expensive. Long-distance migrants should be efficient in their use of energy and minimize swimming costs wherever possible. We explore swimming strategies and energy-saving tactics employed by three long-distance-migrating sockeye salmon (*Oncorhynchus nerka*) stocks in the Fraser River watershed, British Columbia. We used stereovideography and bank-side observations to estimate swimming speeds (from tailbeat frequency) and ground speeds (using distance traveled and duration) for individuals at several sites. Salmon were highly efficient at migration (i.e., ground speeds equaled or exceeded swimming speeds) through reaches with relatively low encountered currents (<0.25 $m \cdot s^{-1}$). We speculate that salmon exploit small reverse-flow vortices to achieve this feat. With low encountered currents, most salmon migrated according to an optimal swimming speed model: migrants minimized transport costs per unit distance traveled. Generally, salmon were less efficient at migration with fast currents, although the Chilko stock were superoptimal migrants, possibly owing to unique morphology and (or) behaviors. The risk of significant delays is enhanced when fast currents are encountered. Under these conditions, relatively fast swimming speeds could minimize travel time, despite high costs. Migrants may be balancing energetic costs of migration against the fitness costs of spawning delays

19. **Hotchkiss, R.H. and C.M. Fei. 2007. Design for fish passage at roadway-stream crossings: synthesis report. U.S. Department of Transportation Federal Highway Administration, Publication No. FHWA-HIF-07-033, McLean, VA.**

Abstract – Cataloging and synthesizing existing methods for the design of roadway-stream crossings for fish passage began in January 2005 with an extensive literature review covering the topics of culvert design and assessment to facilitate fish passage. A survey was posted online to gather input from design professionals across the country, and a Culvert Summit Meeting was held in Denver Colorado from February 15-16, 2006, to allow presentation and discussion of state-of-practice design and assessment techniques. Following the Summit meeting, a Technical Advisory Committee was developed with individuals specifically knowledgeable in the topics of interest. Members were crucial in shaping and reviewing the direction of these guidelines.

This document places current culvert design techniques into four categories based on design premise and objectives. These categories include: No Impedance techniques, which span the entire stream channel and floodplain; Geomorphic Simulation techniques, which create fish passage by matching natural channel conditions within the culvert crossing; Hydraulic Simulation techniques, which attempt to closely resemble hydraulic diversity found in the natural channels through the use of natural and oversized substrate; and Hydraulic Design techniques, which may utilize roughness elements such as baffles and weirs to meet species specific fish passage criteria during periods of fish movement.

Preliminary chapters covering the topics of fish biology and capabilities, culverts as barriers, fish passage hydrology, and design considerations aid in the selection of appropriate design techniques based on hydraulic, biologic, and geomorphic considerations. A further section presents examples of design techniques fitting the defined design categories. Design examples and case histories for a selection of design techniques are presented next, and are followed by a discussion on construction, maintenance, monitoring, and future research needs.

20. **Kane, D.L., C.E. Behlke, R.E.Gieck, and R.F. McLean. 2000. Juvenile fish passage through culverts in Alaska: a field study. Final Report, June 2000, Fairbanks, Prepared for the Alaska Department of Transportation, Juneau, AK.**

Abstract – In the past, culvert designs for fish passage generally has been based on the weakest-swimming adult fish in a river system. It has also been recognized for some time that juvenile fish are very active throughout the year, moving upstream and downstream in response to a number of environmental factors. The objective of this study was to examine the behavior of juveniles when attempting to ascend a culvert. It was hypothesized that vertical obstacles or high velocity of opposing flow may prevent juvenile fish from moving upstream. Four culverts were selected for intensive study regarding juvenile fish passage: Beaver and Soldotna Creeks on Kenai Peninsula and No-name and Pass Creek Tributary on Prince of Wales Island. In general, observations of fish attempting to move upstream through the culvert revealed that they swam very close to the culvert wall, and in the case of high velocities they swam near the surface along the sidewall where velocities are reduced.

Additional notes – Fish were captured locally, marked with dye, then released with baited traps in place upstream of the culvert which were checked in the following 48 hours. Soldotna Creek culvert was 298 ft long, 14 x 10 ft wide, 1.9% gradient with baffles. 92 of 299 juvenile coho were recaptured upstream and included young-of-year fish. Observations indicated fish swam through openings between baffles and the culvert wall. All other culverts were corrugated with no baffles and observations indicated fish rested in the 2 x 6 inch corrugations, but could not do so in 1 x 3 inch corrugations.

21. **Khodier, M.A. and B.P. Tullis. 2014. Fish passage behavior for severe hydraulic conditions in baffled culverts. Journal of Hydraulic Engineering. 140(3):322–327.**

Abstract – Laboratory tests were conducted with brown trout to evaluate their ability to pass through a small, baffled prototype-scale culvert under a variety of culvert slopes and discharge conditions. The culvert was 60 ft long and 2 ft in diameter with 0.15D baffle height and 0.9D spacing, where D is the culvert inside diameter. An inverse relationship was observed between fish passage success and flow rate and/or culvert slope. The influence of the sample fish population and the length of the individual fish on passage rates were investigated; the data showed that the brown trout fish passage sample size evaluated in this study (25 per test) was sufficiently large to minimize sample size dependency. The elapsed time required for fish to traverse the culvert decreased with increasing hydraulic difficulty primarily owing to diminishing resting zones. The behavior of fish traversing the culvert was observed and reported, including resting/staging zone locations.

Additional notes – Passage rates ranging 12–24% were observed under 1 cfs discharge trials of 5% and 6% slopes, while no fish passed 5% and 6% slopes under 3 cfs discharge trials. Passage rates ranging 76–85% were observed at 3–4% slopes under 1 cfs discharge trial and fell to 60–64% and 4–52% under 2 and 3 cfs trials.

22. **Khodier, M. A. and B.P. Tullis. 2016. Experimental and computational comparison of baffled-culvert hydrodynamics for fish passage. Journal of Applied Water Engineering and Research. 6(3)191–199.**

Abstract – For some applications, fish passage through culverts may be enhanced by adding weir baffles along the culvert invert. In an effort to evaluate the effectiveness of computation techniques as a design tool for baffled-culvert design, turbulent freesurface flow conditions through a weir-baffled-lined culvert were simulated numerically using a three-dimensional numerical model utilizing three different turbulence models: k–ε, renormalized group k–ε, and large Eddy simulation. Experimental data from a small prototype-scale baffled-lined culvert, measured using particle image velocimetry, were used to assess the ability of these turbulence models to predict the turbulent flow characteristics for various culvert slopes and discharges. Allcomputer simulations struggled in the regions of high shear and reverse flow, independent of the specific turbulence model used. Comparisons between the measured and computed flow field velocity and turbulent kinetic energy data, however, found that the renormalized group k–ε model provided the best approximation of the flow field, which included undulating supercritical flow profiles with recirculating eddies downstream of each baffle. Despite the limitations found in this study, computational fluid flow modeling represents a reasonable design tool-baffled-culvert design.

23. Lang, M. and E. Cashman. 2008. Influence of fish passage retrofits on culvert hydraulic capacity. Final Report for California Department of Transportation.

Abstract – Barriers to migration affect the ease and extent to which fish and other aquatic organisms access required habitat conditions and may affect an organism's survival and ultimately, a population's viability. Road-stream crossings, such as culverts bridges and fords, can create passage barriers due to their inherent design or as a result of geomorphic response of streams to their installation. Addressing fish passage at road-stream crossings requires inventorying, assessing and prioritizing retrofit or replacement of existing culvert barriers, and proper design and installation of new culverts and culvert retrofits.

Laboratory and field analysis of the effects of fish passage retrofits, such as baffles and weirs, on culvert hydraulic performance has focused primarily on whether the retrofit meets the hydraulic conditions needed for fish passage over the range of flows at which fish are present and attempting to migrate. Retrofitting a culvert barrel to improve fish passage may also alter the hydraulic performance of the culvert at all flows. Few studies have been conducted to specifically measure and quantify the impact of retrofits on culvert hydraulic capacity at flood flows. In these studies, laboratory and field measurements were collected to quantify high flow hydraulic performance of retrofit culverts, develop model parameters and identify appropriate design and analysis methods. Sample applications, updated design parameters and recommended analysis assumptions are described for common design tools (HY8, HEC-RAS, and FishXing V3).

Laboratory physical model experiments were also conducted to evaluate sediment transport and trapping characteristics of these retrofit designs over a range of flows. Generally, experimental results indicate trapped sediment in culverts retrofit to improve fish passage decreases the effectiveness of the retrofit due to sediment deposition in areas with lower velocities (where fish can rest). Other observations include:

1. Trapped sediment reduced the effective culvert barrel roughness and, thus, decreased water depths and increased velocities through the culvert, compared to clear water experiments with the retrofit baffles.
2. High flows (culvert barrel water depth/culvert height > 0.5) successfully cleared trapped sediment under conditions of minimal sediment transport from upstream
3. Preliminary results indicate moderate flows (culvert barrel water depth/culvert height ~ 0.25 to 0.5) in combination with moderate sediment feed rates caused the greatest accumulation of trapped sediment

Additional notes – Experimental trials highlight the importance of including sediment accumulation in design and analysis and the importance of calculating and understanding the hydraulic and biological implications of a baffled culvert at plunging flow vs. stream flow conditions. Field experiments to relate discharge to depth of flow were carried out by skim-coating the culvert barrel with a clay layer to record high water mark during discharge events.

24. Liao, J.C., D.N. Beal, G.V. Lauder, M.S. Triantafyllou. 2003. Fish exploiting vortices decrease muscle activity. Science. 302:1566–1569.

Abstract – Fishes moving through turbulent flows or in formation are regularly exposed to vortices. Although animals living in fluid environments commonly capture energy from vortices, experimental data on the hydrodynamics and neural control of interactions between fish and vortices are lacking. We used quantitative flow visualization and electromyography to show that trout will adopt a novel mode of locomotion to slalom in between experimentally generated vortices by activating only their anterior axial muscles. Reduced muscle activity during vortex exploitation compared with the activity of fishes engaged in undulatory swimming suggests a decrease in the cost of locomotion and provides a mechanism to understand the patterns of fish distributions in schools and riverine environments.

25. Macdonald, J.I. and P.E. Davies. 2007. Improving the upstream passage of two galaxiid fish species through a pipe culvert. Fisheries Management and Ecology. 14:221–230.

Abstract – Movement between habitats in river fish assemblages is often restricted by instream structures such as culverts. The ability of diadromous common jollytail, Galaxias maculatus (Jenyns), and spotted galaxias, Galaxias truttaceus (Val.), to pass upstream through an in situ pipe culvert modified through the installation of baffles was assessed. Spoiler baffles (3.9· 2.8 · 1.1 or 2.2 inch) were installed in three spatial arrangements along a 18 ft section of the pipe, and individual fish passage assessed at three flow velocities (1.1, 2.3 and 3.3 ft/s). Common jollytails (43–169 mm fork length, FL) were 10 times more successful in passing when baffles were present than under control conditions (baffles absent). Baffle size did not influence success, which increased with the spatial complexity of the baffle arrangement. Across all velocities, common jollytails (46–132 mm FL) and spotted galaxias (55–190 mm FL) were, respectively, 86 and 73 times more successful with the most complex baffle arrangement (overall 80% success) compared with control conditions (overall 13.5% success). Success for both species decreased at higher velocities under control conditions; however, when baffles were present, this trend persisted only for common jollytails. Installing small spoiler baffles may provide a simple, cost-effective solution to passage problems at culverts.

Additional notes – Common jollytails are a salmoniform fish with slower burst swimming speeds (1.5 ft/s) than juvenile coho salmon (2.6 ft/s). Parallel 5 ft diameter smooth concrete culverts set at 1.3% gradient were fitted with spoiler baffles screwed into the barrel and single fish trials were conducted.

26. **Olsen, A.H. and B.P. Tullis. 2013. Laboratory study of fish passage and discharge capacity in slip-lined, baffled culverts. Journal of Hydraulic Engineering. 139(4): 424–432.**

Abstract – Culvert rehabilitation is a cost-effective alternative to culvert replacement for many applications where the culvert has reached the end of its useful life. When a profile-walled existing (host) culvert is relined with a smooth-walled pipe, the culvert flow velocities typically increase, the corresponding flow depths decrease, and the resulting flow conditions can create a potential barrier to fish passage. In an effort to provide some baseline data for fish passage through baffled culvert liners, fish passage behaviors of wild brown trout through prototype-scale 24 inch diameter, 60 ft long smooth-walled baffled and non-baffled culverts were observed in the laboratory under a variety of culvert slopes and discharges. The baffles significantly increased the range of culvert slopes and discharges over which the fish could successfully pass. The baffled culvert hydraulic roughness coefficient (Manning's n) increased 274% (approximately equivalent to corrugated metal pipe values) relative to the non-baffled culvert.

Additional notes – Trials included smooth-wall, weir baffled, and corner baffled culvert tested at 0.5, 1, 1.5, 2, 2.5, 3, and 3.5% slopes at 1, 2, and 3 cfs discharge. Trials suggest corner baffled and weir baffled culverts performed similarly for passage, though sample sizes were low (*n = 6-13* trial fish). Fish were encouraged through the culvert with bright light disturbance at ports along the way.

27. **Pearson, W.H., S. L. Southard, C.W. May, J.R. Skalski, R.L. Townsend, A.R. Homer-Devine, D.R. Thurman, R.H. Hotchkiss, R.R. Morrison, M.C. Richmond, and D. Deng. 2006. Research on the upstream passage of juvenile salmon through culverts: retrofit baffles. Final report, April 2006, Richland, WA. Prepared for the Washington State Department of Transportation WSDOT.**

Abstract – This report provides data from biological tests conducted November 2005 through January 2006 by Battelle for the WSDOT at the Culvert Test Bed Facility located at the WDFW Skookumchuck Hatchery near Tenino, Washington. Fish tests evaluated passage success in a 40-ft corrugated culvert without baffles or with three weir baffles at one culvert slope (1.14%) and over five flows (1.5, 3, 6, 8, and 12 cfs). The 3- and 8-cfs flows were tested under an additional backwatering condition. The relationships between natural logarithm of passage success of juvenile coho salmon (94 mm to 104 mm) and culvert discharge were statistically significant and curvilinear for all three configurations. For the configuration without baffles, passage success was about 40% at 1.5 cfs, increased to about 70% at 3 cfs, and then decreased to less than 10% at 12 cfs. The curves for configurations without baffles and with baffles and elevated backwatering condition did not differ significantly. Both these curves were significantly greater than the curve for the configuration with baffles and standard backwatering condition. Backwatering influences passage success through baffled culverts and needs to be considered as an experimental variable in future studies. Behavioral observations indicate the fish used low-velocity pathways and that these pathways differed between the baffled and unbaffled conditions and perhaps differed with flow for the baffled condition.

Additional notes – Thirty-four 3-hour trials with 100 hatchery fish in each trial were conducted. Visual and video monitoring were used to qualitatively document fish behavior and generally showed fish used the lowest velocity pathways, which changed under various discharge scenarios.

28. **Smith, D.L., A. Goodwin, and J.M. Nestler. 2014. Relating turbulence and fish habitat: a new approach for management and research. Reviews in Fisheries Science and Aquaculture. 22(2):123–130.**

Abstract – Understanding how fish perceive turbulence characteristics to utilize complex habitats (large wood, rock, channel bedforms, etc.) is a critical, but poorly understood component of aquatic habitat restoration. Many recent studies attempt to relate turbulence characteristics to habitat utilization, but results are inconsistent for two reasons. First, turbulence is a complex, multi-scale manifestation of fluid flow that can be characterized in different ways with different interpretations. Second, fish behavioral response to flow field features is also complex because both acclimation and learning are important. For example, some studies show that turbulence decreases swimming stability, increases energy expenditure for a given swimming speed, and alters feeding behavior, whereas others show turbulence to decrease energy needed to swim at a given speed and correlates with fish abundance. We describe a Turbulence Attraction and Avoidance (TAA) hypothesis to reconcile inconsistent, even seemingly contradictory, findings. The TAA hypothesis creates a new perspective of turbulence, habitat complexity, and fish habitat occupancy by acknowledging that fish, like all animals, perceive their environment at their own relevant scales and in a conditional manner, dependent on their prior exposure history.

29. **Thurman, D.R., A.R. Horner-Devine, R.R. Morrison, and R.H. Hotchkiss. 2007. Juvenile salmon passage in sloped-baffled culverts. International Conference on Ecology and Transportation, May, 2007.**

Abstract – The connectivity of river drainages has been decreased by the installation of roadway culverts, particularly for the salmonids of the Pacific Northwest. Thousands of culverts within the State of Washington have been designated by the state DOT as fish passage barriers. Though it is well known that the anadromous salmon travel upstream to spawn, recent evidence suggests that juvenile salmon also travel upstream to seek preferred habitats for feeding, which may ultimately improve their survival at sea. Retrofitting culverts is an economical solution that has been initially implemented to improve adult salmon passage. Baffles increase water depth for low flow conditions and reduce velocities for higher flowrates. To determine the effect of baffles on upstream passage of juveniles, sloped-baffles were studied at a culvert test bed near Tenino, Washington. Using an Acoustic Doppler Velocimeter (ADV), 3-D velocity fields were collected in a full-sized 12.2 m (40') long, 1.8 m (6') diameter corrugated culvert. The culvert slope, baffle spacing, and baffle height were varied to observe flow regime trends that describe conditions suitable for fish passage. This project is unique from other hydraulic studies in that biological testing was conducted in conjunction with the hydrodynamic measurements. Biologists randomly selected 100 juvenile Coho salmon from the on-site rearing facility and allowed the fish to ascend the culvert during a three hour period. The movement of the fish was recorded with video cameras and the passage rate was determined.

Results indicate that there is considerable spatial variability in the flow created by the baffles within the culvert. The flow is asymmetric, consisting of a jet traveling over the low side of the baffle and an area of re-circulating water on the high side of the baffle. The asymmetry decreases as the discharge increases and the mean water height surpasses the baffle height. The diversity of flow structures created by this asymmetry is important because it increases the number of reduced velocity paths that fish may travel. The fish passage success rates are also consistent with the trends of asymmetry: as the culvert discharge increases fish are limited to fewer possible paths, and passage rates decrease. The results suggest that both the structure of the flow and the average speed of the flow affect the passage rate. We present a scaling equation that relates the occurrence of flow structures to the independent study parameters in order to provide guidance in baffle implementation. Recommendations for future work include further biological interpretation and testing, so that the hydraulic and biological results may be more closely coupled.

Additional notes – Weir baffles were offset from horizontal a few degrees. Researchers indicate fish passage is best under jet flow regime "J2", where the baffle is fully submerged, but plunging flow is still present. They suggest baffle design should be conducted to optimize the J2 regime at the most common flow. See Pearson et al. 2006 for more in depth analysis of fish passage in this study.

30. Webb, P.W. 2004. Response latencies to postural disturbances in three species of teleostean fishes. Journal of Experimental Biology. 207:955–961.

Flow in aquatic systems is characterized by unsteadiness that creates destabilizing perturbations. Appropriate correction responses depend on response latency. The time between a disturbance induced by either removal of a flow refuge or striking various parts of the body with a narrow water jet was measured for three species, chosen as examples of modes in teleostean body/fin organization that are expected to affect stability. Creek chub *Semotilus atromaculatus* is representative of fusiform-bodied soft-rayed teleosts, smallmouth bass *Micropterus dolomieu* of fusiform-bodied spiny-rayed forms and bluegill *Lepomis macrochirus* of deep-bodied spiny-rayed forms. Observations were made at 23°C. Loss of refuge resulted in a surge that fish corrected by starting to swim within 129±29 ms (mean ± 2 S.E.M.) for chub, which was significantly shorter than minimal times of approximately 200 ms for bluegill and bass. Slips and heaves induced by water jets initially resulted in extension of the median and paired fins that would damp growth of the disturbance, but otherwise these disturbances were ignored. Yaws and pitches were more likely to cause fish to swim away from the stimulus, making corrections as they did so. There were no differences in latencies for slip, heave, yaw and pitch disturbances within each species, but latencies varied among species. For these disturbances, responses averaged 123±19 ms for chub, again significantly smaller than those of 201±24 ms for bass and 208±52 ms for bluegill. Values for the two centrarchids were not significantly different ($P>0.08$). The response latency for rolling disturbances did not differ among species but was significantly smaller than that for other disturbances, with an overall latency of 70±15 ms. The greater responsiveness to hydrostatic rolling instability is attributed to functions requiring an upright posture and differences among species in habitat preferences.

31. Webb, J.R. 2009. Slip lined culvert retrofit and passage. Master of Science Thesis, Brigham Young University, Provo, UT.

Abstract – Culverts throughout the country are approaching or are past their original design lives. These 'baby boomer' culverts will need to be repaired, rehabilitated, or replaced. Because entire culvert replacement is so expensive and intrusive, alternate measures to extend the culvert project life are growing increasingly popular. One such method is slip lining, where a 'sleeve' is installed within an existing culvert barrel and stabilized. Plastic pipe sleeves are very popular for slip lining primarily because the plastic material's lower Manning's roughness values allow for the culvert capacity to be maintained despite a reduction in culvert size. Unfortunately, the reduced friction within the barrel can create a barrier to fish passage due to increased water velocities. The increased velocities also cause greater outlet scour which can result in further obstacles to fish passage. These new fish barriers can greatly affect aquatic ecosystems by limiting the access that fish have to smaller tributaries used for spawning and rearing access that is critical to the life cycles of many fish. It is suggested that mitigation of the increased velocities should go hand-in-hand with slip lined culvert design projects where fish passage (present or future) is to be considered. Can the demand for hydraulic capacity as well as the demand for fish passage be satisfied?

Careful design and installation, coupled with post-project monitoring can result in slip lined culvert retrofits which successfully pass fish. Investigation of federal and state laws and various agency guidelines has informed the creation of a list of culvert conditions which should prompt consideration of slip lined culvert retrofit among other design alternatives. Additionally, a literature review and survey of all U.S. state Departments of Transportation as well as state Fish and Wildlife Departments has shown that there has been very limited experience in providing for fish passage through slip lined culverts. Literature and practice has pointed to the use of baffles and tailwater control weirs for velocity mitigation. Site visits have been made to the few states with this experience to assess developing technologies and record successful and unsuccessful installations. Additional hydraulic analysis using current software suggests general trends in the effects slip lined culvert retrofits on flow type, headwater, velocity as well as the effects of tailwater control weirs. Issues of sustainability, constructability and maintenance, as well as monitoring are addressed.

Additional notes – Utah Division of Water Rights and Army Corps of Engineers lists following conditions where slip lines can be considered: 1) present culvert is oversized and can be backwatered 2) No fish present 3) Existing barrier present 4) Exemption from fish passage laws, culvert failure, 5-10 year full replacement planned, experimental trial. Recommends tailwater control structures over baffles which are easier to maintain and more visible.

APPENDIX B: TEST FISH METRICS AND PASSAGE DATA

Appendix A1.–Ninemile Creek fish passage trial data.

Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
04/27/22	7869	CO	85	4	1	ND	6	0	y					9.5	3.3		
04/27/22	7600	CO	88	6	1	ND	0	0	n								
04/27/22	7601	CO	106	8	1	ND	0	0	n								
04/27/22	7605	CO	110	9	1	ND	0	0	n								
04/27/22	7607	CO	85	5	1	ND	0	0	n								
04/27/22	7613	CO	110	10	1	ND	0	0	n								
04/27/22	7625	CO	94	6	1	ND	0	0	n								
04/27/22	7640	CO	75	3	1	ND	0	0	n								
04/27/22	7651	CO	101	8	1	ND	0	0	n								
04/27/22	7652	CO	82	4	1	ND	0	0	n								
04/27/22	7654	CO	105	9	1	ND	0	0	n								
04/27/22	7657	CO	105	9	1	ND	0	0	n								
04/27/22	7672	CO	125	14	1	ND	0	0	n								
04/27/22	7675	CO	116	12	1	ND	0	0	n								
04/27/22	7694	CO	102	8	1	ND	0	0	n								
04/27/22	7696	CO	119	11	1	ND	0	0	n								
04/27/22	7698	CO	98	7	1	ND	0	0	n								
04/27/22	7802	CO	88	5	1	ND	0	0	n								
04/27/22	7809	CO	97	9	1	ND	0	0	n								
04/27/22	7810	CO	100	7	1	ND	0	0	n								
04/27/22	7812	CO	85	5	1	ND	0	0	n								
04/27/22	7813	CO	99	7	1	ND	0	0	n								
04/27/22	7817	CO	83	4	1	ND	0	0	n								
04/27/22	7823	CO	111	9	1	ND	0	0	n								
04/27/22	7829	CO	93	6	1	ND	0	0	n								
04/27/22	7836	CO	114	11	1	ND	0	0	n								
04/27/22	7838	CO	100	7	1	ND	0	0	n								
04/27/22	7841	CO	96	7	1	ND	0	0	n								
04/27/22	7843	CO	135	18	1	ND	0	0	n								
04/27/22	7845	CO	92	6	1	ND	0	0	n								
04/27/22	7846	CO	93	7	1	ND	0	0	n								
04/27/22	7848	CO	129	13	1	ND	0	0	n								

Note: ND = no data

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
04/27/22	7853	CO	82	5	1	ND	0	0	n								
04/27/22	7875	CO	94	6	1	ND	0	0	n								
04/27/22	7877	CO	107	9	1	ND	0	0	n								
04/27/22	7881	CO	87	5	1	ND	0	0	n								
04/27/22	7886	CO	108	10	1	ND	0	0	n								
04/27/22	7899	CO	105	9	1	ND	0	0	n								
04/27/22	7601	CO	130	15	2	ND	0	0	n								
04/27/22	7606	CO	92	6	2	ND	0	0	n								
04/27/22	7617	CO	90	6	2	ND	0	0	n								
04/27/22	7618	CO	83	4	2	ND	0	0	n								
04/27/22	7620	CO	96	6	2	ND	0	0	n								
04/27/22	7621	CO	96	7	2	ND	0	0	n								
04/27/22	7633	CO	100	7	2	ND	0	0	n								
04/27/22	7636	CO	95	7	2	ND	0	0	n								
04/27/22	7643	CO	97	7	2	ND	0	0	n								
04/27/22	7648	CO	107	8	2	ND	0	0	n								
04/27/22	7649	CO	113	10	2	ND	0	0	n								
04/27/22	7650	CO	113	11	2	ND	0	0	n								
04/27/22	7653	CO	108	9	2	ND	0	0	n								
04/27/22	7682	CO	90	6	2	ND	0	0	n								
04/27/22	7683	CO	82	4	2	ND	0	0	n								
04/27/22	7690	CO	100	7	2	ND	0	0	n								
04/27/22	7804	CO	102	8	2	ND	0	0	n								
04/27/22	7808	CO	106	9	2	ND	0	0	n								
04/27/22	7811	CO	76	4	2	ND	0	0	n								
04/27/22	7818	CO	130	13	2	ND	0	0	n								
04/27/22	7819	CO	110	9	2	ND	0	0	n								
04/27/22	7820	CO	70	3	2	ND	0	0	n								
04/27/22	7821	CO	101	7	2	ND	0	0	n								
04/27/22	7822	CO	111	10	2	ND	0	0	n								
04/27/22	7827	CO	77	4	2	ND	0	0	n								
04/27/22	7832	CO	70	3	2	ND	0	0	n								

Note: ND = no data

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Appendix A1.–Page 3 of 33.

Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
04/27/22	7834	CO	112	9	2	ND	0	0	n								
04/27/22	7835	CO	77	4	2	ND	0	0	n								
04/27/22	7837	CO	111	10	2	ND	0	0	n								
04/27/22	7839	CO	123	15	2	ND	0	0	n								
04/27/22	7850	CO	103	8	2	ND	0	0	n								
04/27/22	7855	CO	121	13	2	ND	0	0	n								
04/27/22	7871	CO	98	7	2	ND	0	0	n								
04/27/22	7872	CO	80	4	2	ND	0	0	n								
04/27/22	7889	CO	120	14	2	ND	0	0	n								
04/27/22	7891	CO	85	5	2	ND	0	0	n								
04/27/22	7892	CO	106	8	2	ND	0	0	n								
04/27/22	7896	CO	73	3	2	ND	0	0	n								
04/27/22	7898	CO	79	4	2	ND	0	0	n								
04/27/22	7612	CO	95	6	Control	ND	1	0	n					0.5	3.8		
04/27/22	7623	CO	84	5	Control	ND	1	0	n					0.0	3.3		
04/27/22	7631	CO	79	4	Control	ND	1	0	n					0.0	3.3		
04/27/22	7637	CO	103	7	Control	ND	1	0	n					0.5	3.8		
04/27/22	7639	CO	112	10	Control	ND	1	0	n					0.5	3.8		
04/27/22	7641	CO	104	7	Control	ND	1	0	n					0.5	3.8		
04/27/22	7647	CO	102	8	Control	ND	6	0	n					0.5	3.8		
04/27/22	7655	CO	98	8	Control	ND	1	0	n					0.0	3.3		
04/27/22	7659	CO	111	10	Control	ND	0	0	n								
04/27/22	7660	CO	112	11	Control	ND	1	0	n					0.0	3.3		
04/27/22	7668	CO	83	6	Control	ND	1	0	n					10.5	3.1		
04/27/22	7669	CO	105	9	Control	ND	1	0	n					0.0	3.3		
04/27/22	7671	CO	95	6	Control	ND	1	0	n					0.0	3.3		
04/27/22	7685	CO	116	10	Control	ND	1	0	n					0.5	3.8		
04/27/22	7695	CO	103	8	Control	ND	1	0	n					24.0	1.8		
04/27/22	7699	CO	83	5	Control	ND	1	0	n					0.0	3.3		
04/27/22	7805	CO	86	5	Control	ND	1	0	n					0.5	3.8		
04/27/22	7807	CO	90	6	Control	ND	1	0	n					0.5	3.8		
04/27/22	7825	CO	94	6	Control	ND	1	0	n					0.0	3.3		

Note: ND = no data

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
04/27/22	7828	CO	91	6	Control	ND	0	0	n								
04/27/22	7830	CO	118	13	Control	ND	1	0	n					0.0	3.3		
04/27/22	7831	CO	102	9	Control	ND	1	0	n					9.0	3.4		
04/27/22	7840	CO	113	10	Control	ND	1	0	n					9.0	3.4		
04/27/22	7842	CO	105	9	Control	ND	1	0	n					0.0	3.3		
04/27/22	7847	CO	140	18	Control	ND	0	0	n								
04/27/22	7858	CO	128	15	Control	ND	3	0	n					0.0	3.3		
04/27/22	7859	CO	95	9	Control	ND	1	0	n					0.5	3.8		
04/27/22	7860	CO	96	6	Control	ND	0	0	n								
04/27/22	7861	CO	116	11	Control	ND	0	0	n								
04/27/22	7863	CO	111	10	Control	ND	0	0	n								
04/27/22	7865	CO	86	5	Control	ND	0	0	n								
04/27/22	7866	CO	96	7	Control	ND	0	0	n								
04/27/22	7867	CO	93	6	Control	ND	0	0	n								
04/27/22	7870	CO	89	5	Control	ND	0	0	n								
04/27/22	7894	CO	108	7	Control	ND	1	0	n					0.5	3.8		
04/27/22	7895	CO	82	3	Control	ND	0	0	n								
04/27/22	7615	DV	158	30	1	ND	0	0	n								
04/27/22	7806	DV	152	24	1	ND	0	0	n								
04/27/22	7614	DV	149	24	2	ND	0	0	n								
04/27/22	7629	DV	84	4	Control	ND	0	0	n								
04/27/22	7897	DV	125	15	Control	ND	0	0	n								
06/22/22	7677	CO	102	11.1	1	0	0	0	n								
06/22/22	7701	CO	93	9	1	0	0	0	n								
06/22/22	7705	CO	101	13.4	1	0	0	0	n								
06/22/22	7724	CO	92	9	1	15	0	0	n	34.5	0.3	34.5	0.3				
06/22/22	7796	CO	83	6.7	1	0	0	0	n								
06/22/22	7816	CO	94	11	1	0	0	0	n								
06/22/22	7864	CO	96	9.9	1	0	0	0	n								
06/22/22	7868	CO	92	8.3	1	0	0	0	n								
06/22/22	7882	CO	77	5	1	0	0	0	n								
06/22/22	7884	CO	89	7.7	1	0	0	0	n								

Note: ND = no data

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
06/22/22	7885	CO	118	16.1	1	0	0	0	n								
06/22/22	7888	CO	89	8	1	0	0	0	n								
06/22/22	7904	CO	96	10	1	0	0	0	n								
06/22/22	7913	CO	90	7.6	1	0	0	0	n								
06/22/22	7914	CO	88	7.9	1	0	0	0	n								
06/22/22	7919	CO	84	7.3	1	0	0	0	n								
06/22/22	7925	CO	86	7.1	1	0	0	0	n								
06/22/22	7927	CO	86	6.6	1	0	0	0	n								
06/22/22	7928	CO	91	8.1	1	0	0	0	n								
06/22/22	7929	CO	92	9.5	1	0	0	0	n								
06/22/22	7942	CO	76	7.8	1	0	0	0	n								
06/22/22	7948	CO	95	10.1	1	0	0	0	n								
06/22/22	7966	CO	97	11.2	1	0	0	0	n								
06/22/22	7974	CO	94	8.8	1	0	0	0	n								
06/22/22	7990	CO	101	12.4	1	0	0	0	n								
06/22/22	7991	CO	92	8.8	1	0	0	0	n								
06/22/22	7996	CO	74	4.1	1	0	0	0	n								
06/22/22	7656	CO	88	6.6	2	9	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7754	CO	74	4	2	3	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7766	CO	83	6.7	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7777	CO	95	11	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7803	CO	75	3.9	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7826	CO	95	9.1	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7844	CO	79	5.6	2	3	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7876	CO	90	6.7	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7879	CO	71	4.6	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7901	CO	78	4.9	2	2	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7908	CO	90	10.2	2	5	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7931	CO	70	4.2	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7934	CO	78	5.7	2	3	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7937	CO	75	5	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7941	CO	100	11.6	2	12	0	0	n	0.0	1.8	34.5	0.3				

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
06/22/22	7954	CO	83	6.4	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7955	CO	79	5.3	2	2	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7965	CO	81	7.3	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7973	CO	95	9.6	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7980	CO	91	7.9	2	2	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7982	CO	86	7.2	2	3	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7988	CO	103	11.7	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7995	CO	87	7.4	2	1	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7737	CO	102	11.9	2	9	0	0	n	0.5	1.7	0.5	1.7				
06/22/22	7833	CO	87	7.8	2	0	0	0	n								
06/22/22	7883	CO	86	7.5	2	0	0	0	n								
06/22/22	7947	CO	91	8.5	2	0	0	0	n								
06/22/22	7905	CO	85	6.3	Control	0	0	1	y							22.0	0.6
06/22/22	7989	CO	74	4.1	Control	0	0	2	y							21.5	0.6
06/22/22	7878	CO	76	5	Control	0	0	3	y							5.5	1.3
06/22/22	7930	CO	76	4.8	Control	0	0	1	y							4.0	1.4
06/22/22	7608	CO	93	7.8	Control	0	0	0	n								
06/22/22	7717	CO	87	7.3	Control	130	1	0	n	17.5	0.7	26.0	0.4	10.5	0.9		
06/22/22	7740	CO	95	10.1	Control	0	0	0	n								
06/22/22	7784	CO	88	8	Control	0	0	0	n								
06/22/22	7815	CO	87	7.6	Control	0	113	0	n					6.0	1.3		
06/22/22	7852	CO	93	8.7	Control	0	7	0	n					16.5	0.7		
06/22/22	7873	CO	72	3.9	Control	1	1	0	n	25.0	0.5	25.0	0.5	4.0	1.4		
06/22/22	7887	CO	84	7.7	Control	1	2	0	n	0.5	1.7	0.5	1.7	0.5	1.7		
06/22/22	7900	CO	99	11.5	Control	1	10	0	n	4.5	1.4	4.5	1.4	2.0	1.6		
06/22/22	7910	CO	93	6.7	Control	0	1	0	n					0.0	1.8		
06/22/22	7916	CO	84	6.7	Control	0	0	0	n								
06/22/22	7918	CO	85	6.5	Control	0	0	0	n								
06/22/22	7945	CO	93	9.5	Control	0	0	0	n								
06/22/22	7946	CO	86	8.2	Control	1	18	0	n	12.0	0.8	12.0	0.8	6.5	1.2		
06/22/22	7950	CO	92	7.5	Control	0	0	0	n								
06/22/22	7951	CO	87	7.7	Control	1	9	0	n	3.0	1.6	3.0	1.6	0.0	1.8		

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
06/22/22	7959	CO	90	8.1	Control	0	3	0	n					0.5	1.7		
06/22/22	7962	CO	94	9.9	Control	0	0	0	n								
06/22/22	7975	CO	95	10.1	Control	0	0	0	n								
06/22/22	7981	CO	91	8.6	Control	0	0	0	n								
06/22/22	7994	CO	75	5.6	Control	0	0	0	n								
06/22/22	7953	DV	131	21.3	1	18	2	0	y	36.5	0.4	36.5	0.4	41.5	0.3		
06/22/22	7997	DV	79	4.7	1	10	1	0	y	10.0	0.9	10.0	0.9	28.5	0.4		
06/22/22	7940	DV	114	14	1	1	32	0	y	3.5	1.5	3.5	1.5	27.5	0.4		
06/22/22	7958	DV	133	21.3	1	1	2	0	y	10.0	0.9	10.0	0.9	24.5	0.5		
06/22/22	7849	DV	101	9.8	1	8	131	0	y	10.5	0.9	10.5	0.9	24.0	0.5		
06/22/22	7963	DV	127	19.2	1	10	13	0	y	3.5	1.5	3.5	1.5	4.5	1.4		
06/22/22	7801	DV	84	5.8	1	0	0	0	n								
06/22/22	7909	DV	145	33.2	1	0	0	0	n								
06/22/22	7911	DV	103	9.7	1	0	0	0	n								
06/22/22	7921	DV	99	10.4	1	23	0	0	n	10.0	0.9	10.5	0.9				
06/22/22	7924	DV	156	36.7	1	0	0	0	n								
06/22/22	7926	DV	103	12.4	1	0	0	0	n								
06/22/22	7933	DV	90	6.8	1	0	0	0	n								
06/22/22	7943	DV	134	28.1	1	0	0	0	n								
06/22/22	7969	DV	81	4.9	1	0	0	0	n								
06/22/22	7971	DV	75	4	1	0	0	0	n								
06/22/22	7976	DV	87	6.7	1	0	0	0	n								
06/22/22	7977	DV	158	38	1	0	0	0	n								
06/22/22	7993	DV	102	11.1	1	11	0	0	n	10.0	0.9	26.0	0.4				
06/22/22	7890	DV	153	37.3	2	0	120	0	y					0.5	1.7		
06/22/22	7893	DV	94	8	2	0	50	0	y					18.5	0.7		
06/22/22	7902	DV	118	15.9	2	0	173	1	y					5.5	1.3	34.0	0.3
06/22/22	7952	DV	139	27.3	2	0	141	0	y					1.5	1.7		
06/22/22	7957	DV	92	8.2	2	0	19	0	y					21.0	0.6		
06/22/22	7964	DV	121	18.6	2	0	6	0	y					1.5	1.7		
06/22/22	7987	DV	156	38.9	2	0	31	0	y					0.5	1.7		
06/22/22	7915	DV	119	16.2	2	1	0	0	n	0.5	1.7	0.5	1.7				

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
06/22/22	7979	DV	153	38	2	1	0	0	n	0.5	1.7	0.5	1.7				
06/22/22	7985	DV	149	37	2	1	0	0	n	0.5	1.7	0.5	1.7				
06/22/22	7998	DV	94	8.1	2	1	0	0	n	0.5	1.7	0.5	1.7				
06/22/22	7922	DV	94	8.7	2	1	0	0	n	1.0	1.7	1.0	1.7				
06/22/22	7938	DV	81	7.1	2	15	0	0	n	1.0	1.7	2.5	1.5				
06/22/22	7999	DV	89	6.8	2	1	0	0	n	1.5	1.7	1.5	1.7				
06/22/22	7935	DV	134	22.1	2	0	0	0	n								
06/22/22	7939	DV	81	5.5	2	0	0	0	n								
06/22/22	7949	DV	90	7.2	2	0	0	0	n								
06/22/22	7960	DV	156	36.4	2	0	0	0	n								
06/22/22	7968	DV	134	24.3	2	0	0	0	n								
06/22/22	7983	DV	96	8.3	Control	0	0	2	y							37.5	0.3
06/22/22	7920	DV	96	8.3	Control	0	0	1	y							3.5	1.5
06/22/22	7856	DV	84	6.9	Control	0	0	1	y							2.5	1.5
06/22/22	7972	DV	128	20.7	Control	0	0	56	y							2.0	1.6
06/22/22	7906	DV	97	9.4	Control	0	0	5	y							1.0	1.8
06/22/22	7907	DV	100	10.3	Control	0	0	3	y							1.5	1.7
06/22/22	7880	DV	94	8.1	Control	0	10	0	n					17.0	0.7		
06/22/22	7901	DV	91	8.3	Control	2	0	0	n	0.0	1.8	0.0	1.8				
06/22/22	7903	DV	153	32.9	Control	12	67	0	n	4.5	1.4	41.5	0.3	3.0	1.6		
06/22/22	7917	DV	144	29.6	Control	0	6	0	n					9.5	1.0		
06/22/22	7923	DV	106	12.6	Control	1	7	0	n	1.5	1.7	1.5	1.7	1.0	1.7		
06/22/22	7932	DV	117	14.7	Control	0	0	0	n								
06/22/22	7936	DV	93	8.8	Control	1	15	0	n	2.0	1.6	2.0	1.6	1.5	1.7		
06/22/22	7944	DV	140	29.2	Control	0	26	0	n					4.0	1.4		
06/22/22	7961	DV	91	10.2	Control	0	18	0	n					10.0	0.9		
06/22/22	7967	DV	138	27.9	Control	0	42	0	n					11.5	0.9		
06/22/22	7975	DV	136	25.2	Control	0	0	0	n								
06/22/22	7984	DV	147	38	Control	0	0	0	n								
06/22/22	7986	DV	101	9.4	Control	0	0	0	n								
07/29/22	7704	CO	68	3.2	1	0	0	0	n								
07/29/22	7706	CO	115	17.4	1	0	0	0	n								

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
07/29/22	7713	CO	74	4.8	1	0	0	0	n								
07/29/22	7714	CO	106	13.7	1	14	0	0	n	31.0	6.5	31.0	6.5				
07/29/22	7730	CO	66	3.3	1	0	0	0	n								
07/29/22	7736	CO	91	9.2	1	0	0	0	n								
07/29/22	7739	CO	75	4.9	1	0	0	0	n								
07/29/22	7752	CO	100	10.8	1	0	0	0	n								
07/29/22	8011	CO	78	5.7	1	0	0	0	n								
07/29/22	8019	CO	103	12.1	1	0	0	0	n								
07/29/22	8022	CO	70	3.6	1	0	0	0	n								
07/29/22	8023	CO	101	12.9	1	0	0	0	n								
07/29/22	8024	CO	68	3.2	1	0	0	0	n								
07/29/22	8027	CO	99	11.6	1	507	0	0	n	9.5	0.6	18.0	2.1				
07/29/22	8028	CO	109	13.5	1	0	0	0	n								
07/29/22	8031	CO	81	6.9	1	0	0	0	n								
07/29/22	8036	CO	101	12.5	1	0	0	0	n								
07/29/22	8038	CO	95	10.4	1	644	0	0	n	11.0	0.6	48.0	3.5				
07/29/22	8043	CO	76	4.4	1	0	0	0	n								
07/29/22	8051	CO	70	3.9	1	0	0	0	n								
07/29/22	8059	CO	95	9.4	1	0	0	0	n								
07/29/22	8065	CO	84	7.3	1	0	0	0	n								
07/29/22	8072	CO	98	12	1	0	0	0	n								
07/29/22	8078	CO	104	13	1	0	0	0	n								
07/29/22	8079	CO	82	5.9	1	394	0	0	n	5.5	0.6	18.5	3.2				
07/29/22	8082	CO	105	13.6	1	267	0	0	n	12.0	0.6	29.5	5.7				
07/29/22	8087	CO	73	4.3	1	0	0	0	n								
07/29/22	8092	CO	80	5.8	1	0	0	0	n								
07/29/22	8094	CO	95	10.1	1	0	0	0	n								
07/29/22	7749	CO	81	6.6	2	0	210	404	y					3.5	0.7	7.0	0.6
07/29/22	8030	CO	89	7.5	2	6	2169	0	y	31.0	6.5	31.0	6.5	6.0	0.6		
07/29/22	8044	CO	102	12.3	2	0	10	0	y					7.5	0.6		
07/29/22	8057	CO	98	10	2	0	6	0	y					5.5	0.6		
07/29/22	8081	CO	85	7.9	2	7	306	0	y	19.0	4.7	19.0	4.7	4.0	0.6		

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
07/29/22	7734	CO	70	4.2	2	4	0	0	n	0.0	0.8	0.0	0.8				
07/29/22	7750	CO	79	6	2	196	0	0	n	0.0	0.8	18.0	2.1				
07/29/22	7764	CO	104	14.6	2	3	0	0	n	0.0	0.8	0.0	0.8				
07/29/22	8015	CO	82	6.5	2	6	0	0	n	0.0	0.8	0.0	0.8				
07/29/22	8063	CO	100	12.2	2	24	0	0	n	0.5	0.8	0.5	0.8				
07/29/22	8049	CO	92	9.5	2	4	0	0	n	1.5	0.7	1.5	0.7				
07/29/22	8062	CO	80	5.7	2	1060	0	0	n	1.5	0.7	1.5	0.7				
07/29/22	8010	CO	94	9.1	2	5	0	0	n	2.0	0.7	2.0	0.7				
07/29/22	8047	CO	94	10	2	14	0	0	n	2.0	0.7	2.0	0.7				
07/29/22	8075	CO	88	7.3	2	130	0	0	n	2.0	0.7	4.0	0.6				
07/29/22	8001	CO	80	6.2	2	13	0	0	n	3.5	0.7	3.5	0.7				
07/29/22	8066	CO	95	12.3	2	3	0	0	n	4.5	0.6	4.5	0.6				
07/29/22	8090	CO	109	13.9	2	38	0	0	n	4.5	0.6	5.0	0.6				
07/29/22	7715	CO	88	7.9	2	6	0	0	n	5.0	0.6	5.0	0.6				
07/29/22	8009	CO	104	13.6	2	14	0	0	n	5.0	0.6	5.0	0.6				
07/29/22	7760	CO	94	9.2	2	28	0	0	n	5.5	0.6	5.5	0.6				
07/29/22	8004	CO	70	4	2	16	0	0	n	5.5	0.6	6.0	0.6				
07/29/22	7755	CO	86	7.8	2	3	0	0	n	8.0	0.6	8.0	0.6				
07/29/22	8069	CO	95	9.6	2	970	0	0	n	8.5	0.6	35.0	8.0				
07/29/22	8008	CO	65	2.8	2	1150	0	0	n	16.0	0.8	16.0	0.8				
07/29/22	8045	CO	104	12.1	2	101	0	0	n	17.5	1.5	17.5	1.5				
07/29/22	8086	CO	100	12	2	6	0	0	n	18.0	2.1	18.0	2.1				
07/29/22	7742	CO	72	4.1	2	5	0	0	n	19.5	6.0	19.5	6.0				
07/29/22	8050	CO	74	4.4	2	0	0	0	n								
07/29/22	8056	CO	79	5.1	2	0	0	0	n								
07/29/22	8003	CO	90	9	Control	0	0	612	y							28.0	5.9
07/29/22	8074	CO	95	10.1	Control	0	0	7	y							45.5	4.4
07/29/22	7732	CO	74	4.1	Control	0	0	3292	y							9.5	0.6
07/29/22	7712	CO	104	12.6	Control	0	0	3483	y							4.0	0.6
07/29/22	8060	CO	98	11	Control	0	0	1790	y							4.0	0.6
07/29/22	8054	CO	93	8.7	Control	0	0	50	y							3.5	0.7
07/29/22	8091	CO	87	6.3	Control	0	0	25	y							3.5	0.7

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
07/29/22	7895	CO	112	16.4	Control	0	0	142	y							1.0	0.7
07/29/22	8018	CO	98	11.3	Control	0	0	4250	y							1.0	0.7
07/29/22	8021	CO	85	7.7	Control	0	0	145	y							1.5	0.7
07/29/22	8052	CO	89	8.3	Control	0	0	98	y							1.5	0.7
07/29/22	8029	CO	102	11.5	Control	0	0	116	y							1.0	0.7
07/29/22	7707	CO	84	6.7	Control	0	0	297	y							0.5	0.8
07/29/22	8083	CO	95	10.4	Control	0	0	586	y							0.5	0.8
07/29/22	7703	CO	99	12	Control	12	398	0	n	6.5	0.6	6.5	0.6	1.0	0.7		
07/29/22	7723	CO	70	4.1	Control	0	0	0	n								
07/29/22	7726	CO	88	8.2	Control	28	215	0	n	7.0	0.6	7.0	0.6	5.5	0.6		
07/29/22	7759	CO	106	14.3	Control	6	684	0	n	20.5	6.9	20.5	6.9	1.0	0.7		
07/29/22	7762	CO	85	7.6	Control	33	51	0	n	5.0	0.6	5.0	0.6	0.5	0.8		
07/29/22	7779	CO	104	14	Control	14	8	0	n	18.0	2.1	18.0	2.1	12.0	0.6		
07/29/22	7798	CO	86	7.7	Control	0	0	0	n								
07/29/22	8006	CO	75	5	Control	0	18	0	n					36.0	7.8		
07/29/22	8007	CO	98	8.9	Control	6	8	0	n	19.0	4.7	19.0	4.7	1.0	0.7		
07/29/22	8037	CO	83	6.5	Control	5	20	0	n	18.0	2.1	18.0	2.1	6.0	0.6		
07/29/22	8048	CO	65	3.2	Control	0	0	0	n								
07/29/22	8076	CO	68	3	Control	0	0	0	n								
07/29/22	8077	CO	105	14.2	Control	0	0	0	n								
07/29/22	8088	CO	102	13	Control	2	23	0	n	19.0	4.7	19.0	4.7	3.0	0.7		
07/29/22	8093	CO	84	6.2	Control	0	0	0	n								
07/29/22	8097	CO	85	7.1	Control	0	197	0	n					1.0	0.7		
07/29/22	8067	DV	115	17.2	1	276	1168	0	y	10.0	0.6	10.0	0.6	13.0	0.6		
07/29/22	8026	DV	103	11.4	1	131	185	2	y	12.5	0.6	12.5	0.6	16.0	0.8	33.5	7.9
07/29/22	8039	DV	93	7.9	1	21	608	23	y	2.5	0.7	2.5	0.7	6.0	0.6	26.0	6.8
07/29/22	8098	DV	95	9.6	1	21	19	0	y	1.0	0.7	1.0	0.7	6.5	0.6		
07/29/22	8040	DV	114	17.5	1	63	46	303	y	1.0	0.7	1.0	0.7	4.5	0.6	8.5	0.6
07/29/22	8096	DV	126	18	1	77	23	0	y	1.5	0.7	1.5	0.7	4.5	0.6		
07/29/22	7700	DV	94	9.2	1	0	0	0	n								
07/29/22	7720	DV	106	12.3	1	403	0	0	n	10.0	0.6	18.5	3.2				
07/29/22	7733	DV	156	38.2	1	603	0	0	n	13.0	0.6	17.0	1.2				

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
07/29/22	8033	DV	103	11.6	1	94	0	0	n	12.0	0.6	18.0	2.1				
07/29/22	8068	DV	154	37	1	0	0	0	n								
07/29/22	8084	DV	80	5.6	1	93	0	0	n	5.0	0.6	5.0	0.6				
07/29/22	8099	DV	134	25.8	1	232	0	0	n	21.0	7.1	47.5	3.7				
07/29/22	7748	DV	105	12.3	2	0	15	7	y					2.0	0.7	6.0	0.6
07/29/22	7790	DV	94	8.6	2	0	139	17	y					19.5	6.0	33.0	7.6
07/29/22	7793	DV	98	10	2	0	870	0	y					3.0	0.7		
07/29/22	8000	DV	103	12.2	2	0	12834	0	y					2.0	0.7		
07/29/22	8013	DV	105	12.4	2	0	25	0	y					2.0	0.7		
07/29/22	8017	DV	109	14.2	2	0	27	0	y					3.0	0.7		
07/29/22	8042	DV	130	19.5	2	0	13	0	y					2.0	0.7		
07/29/22	8064	DV	99	9.6	2	0	12	294	y					3.0	0.7	5.5	0.6
07/29/22	8071	DV	117	18.2	2	0	6	317	y					1.5	0.7	6.5	0.6
07/29/22	8073	DV	105	12	2	0	93	0	y					5.0	0.6		
07/29/22	8080	DV	95	10.3	2	144	0	0	n	2.0	0.7	7.0	0.6				
07/29/22	8095	DV	102	11.4	2	364	0	0	n	6.5	0.6	8.0	0.6				
07/29/22	8012	DV	90	7.2	2	10	0	0	n	18.0	2.1	18.0	2.1				
07/29/22	8002	DV	120	16.9	2	29	0	0	n	18.5	3.2	18.5	3.2				
07/29/22	8070	DV	98	10.8	Control	0	0	53	y							12.0	0.6
07/29/22	8025	DV	105	10.2	Control	52	23	56	y	17.0	1.2	17.0	1.2	13.0	0.6	9.5	0.6
07/29/22	7769	DV	120	18.3	Control	0	0	345	y							5.5	0.6
07/29/22	8046	DV	98	9.7	Control	0	0	606	y							3.0	0.7
07/29/22	7921	DV	107	13.4	Control	8	28	100	y	18.5	3.2	18.5	3.2	18.5	3.2	2.5	0.7
07/29/22	8005	DV	100	13.1	Control	0	0	66	y							2.0	0.7
07/29/22	8032	DV	100	10.9	Control	0	0	3779	y							2.5	0.7
07/29/22	7743	DV	103	11.5	Control	0	0	4890	y							1.0	0.7
07/29/22	8085	DV	88	6.2	Control	0	0	11	y							1.0	0.7
07/29/22	7787	DV	99	9.6	Control	0	0	12	y							0.5	0.8
07/29/22	8035	DV	108	13.1	Control	0	0	48	y							0.5	0.8
07/29/22	7702	DV	160	40.6	Control	0	32	0	n					17.5	1.5		
07/29/22	8014	DV	125	24.4	Control	0	906	0	n					15.5	0.8		
07/29/22	8061	DV	95	9.7	Control	0	0	0	n								

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
10/07/22	8576	CO	104	12.4	1	430	12	0	y	5.5	0.5	19.5	0.5	24.5	0.5		
10/07/22	8513	CO	101	12.2	1	76	20	0	y	5.5	0.5	12.5	0.6	24.0	0.5		
10/07/22	8597	CO	131	26.1	1	210	31	0	y	2.0	0.6	4.5	0.5	6.5	0.6		
10/07/22	8501	CO	109	10.6	1	13	36	0	y	5.5	0.5	6.0	0.6	12.5	0.6		
10/07/22	8406	CO	102	12.5	1	0	0	0	n								
10/07/22	8414	CO	65	3.2	1	49	0	0	n	23.0	0.6	27.5	0.5				
10/07/22	8419	CO	122	20.1	1	0	0	0	n								
10/07/22	8422	CO	104	12.8	1	43	0	0	n	5.5	0.5	30.5	0.5				
10/07/22	8424	CO	78	5.4	1	92	0	0	n	7.5	0.6	27.0	0.5				
10/07/22	8435	CO	79	5.4	1	0	0	0	n								
10/07/22	8446	CO	88	7.9	1	0	0	0	n								
10/07/22	8448	CO	72	4.1	1	0	0	0	n								
10/07/22	8449	CO	58	2.3	1	4	0	0	n	12.0	0.6	12.0	0.6				
10/07/22	8464	CO	84	7.2	1	10	0	0	n	42.5	0.5	43.0	0.5				
10/07/22	8466	CO	67	3.6	1	144	0	0	n	5.5	0.5	43.0	0.5				
10/07/22	8468	CO	91	8.6	1	0	0	0	n								
10/07/22	8469	CO	66	3.1	1	7	0	0	n	13.5	0.6	13.5	0.6				
10/07/22	8474	CO	67	3.7	1	0	0	0	n								
10/07/22	8475	CO	92	8.8	1	0	0	0	n								
10/07/22	8483	CO	74	4.6	1	3	0	0	n	30.0	0.5	30.0	0.5				
10/07/22	8487	CO	72	4.8	1	0	0	0	n								
10/07/22	8492	CO	79	5.6	1	0	0	0	n								
10/07/22	8505	CO	91	8.6	1	0	0	0	n								
10/07/22	8531	CO	116	16.4	1	0	0	0	n								
10/07/22	8535	CO	119	17.9	1	34	0	0	n	18.5	0.6	30.0	0.5				
10/07/22	8560	CO	59	2.8	1	0	0	0	n								
10/07/22	8563	CO	84	6.6	1	78	0	0	n	21.5	0.5	24.0	0.5				
10/07/22	8573	CO	61	2.7	1	0	0	0	n								
10/07/22	8583	CO	79	5.9	1	3	0	0	n	30.0	0.5	30.0	0.5				
10/07/22	8585	CO	61	29.3	1	0	0	0	n								
10/07/22	8587	CO	82	6.4	1	0	0	0	n								
10/07/22	8590	CO	63	2.6	1	7	0	0	n	42.0	0.5	42.0	0.5				

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
10/07/22	8467	CO	69	3.8	2	0	2	0	y					0.0	0.6		
10/07/22	8526	CO	95	9.2	2	0	15	0	y					7.0	0.6		
10/07/22	8575	CO	89	8.1	2	0	8	0	y					30.5	0.5		
10/07/22	8484	CO	74	4.2	2	2	0	0	n	0.0	0.6	0.0	0.6				
10/07/22	8524	CO	81	5.8	2	4	0	0	n	0.0	0.6	0.0	0.6				
10/07/22	8568	CO	83	6.2	2	11	0	0	n	0.0	0.6	41.5	0.5				
10/07/22	8574	CO	127	23.1	2	4	0	0	n	0.0	0.6	0.0	0.6				
10/07/22	8586	CO	96	10.6	2	9	0	0	n	0.0	0.6	6.0	0.6				
10/07/22	8400	CO	86	7.4	2	12	0	0	n	0.5	0.6	31.5	0.5				
10/07/22	8420	CO	62	2.7	2	9	0	0	n	0.5	0.6	0.5	0.6				
10/07/22	8534	CO	61	2.5	2	4	0	0	n	0.5	0.6	0.5	0.6				
10/07/22	8553	CO	78	5.2	2	4	0	0	n	0.5	0.6	0.5	0.6				
10/07/22	8599	CO	71	4.3	2	4	0	0	n	0.5	0.6	0.5	0.6				
10/07/22	8497	CO	90	8.7	2	4	0	0	n	1.5	0.5	1.5	0.5				
10/07/22	8516	CO	93	8.9	2	8	0	0	n	2.5	0.6	30.0	0.5				
10/07/22	8589	CO	78	5.2	2	2	0	0	n	2.5	0.6	2.5	0.6				
10/07/22	8572	CO	86	8.2	2	25	0	0	n	3.5	0.6	31.5	0.5				
10/07/22	8416	CO	70	4	2	5	0	0	n	4.0	0.6	23.0	0.6				
10/07/22	8412	CO	89	8.9	2	6	0	0	n	5.0	0.5	30.0	0.5				
10/07/22	8410	CO	60	2.5	2	2	0	0	n	6.5	0.6	6.5	0.6				
10/07/22	8447	CO	116	16.7	2	5	0	0	n	12.0	0.6	13.5	0.6				
10/07/22	8442	CO	71	4.5	2	12	0	0	n	15.0	0.5	18.5	0.6				
10/07/22	8495	CO	90	9.6	2	5	0	0	n	15.5	0.6	24.0	0.5				
10/07/22	8451	CO	121	21	2	5	0	0	n	19.5	0.5	20.0	0.5				
10/07/22	8561	CO	113	17	2	4	0	0	n	21.5	0.5	21.5	0.5				
10/07/22	8578	CO	74	4.4	2	11	0	0	n	26.0	0.5	26.0	0.5				
10/07/22	8429	CO	61	2.3	2	3	0	0	n	36.0	0.5	36.0	0.5				
10/07/22	8486	CO	75	7.4	2	3	0	0	n	48.0	0.5	48.0	0.5				
10/07/22	8459	CO	70	3.8	2	0	0	0	n								
10/07/22	8465	CO	75	5.2	2	0	0	0	n								
10/07/22	8423	CO	68	4.2	Control	0	0	7	y							43.5	0.5
10/07/22	8426	CO	106	14	Control	0	0	5	y							30.0	0.5

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
10/07/22	8545	CO	74	4.5	Control	0	0	665	y							36.0	0.5
10/07/22	8485	CO	61	3	Control	0	0	2	y							25.5	0.5
10/07/22	8588	CO	120	19.1	Control	0	0	61	y							25.5	0.5
10/07/22	8437	CO	82	6.5	Control	0	0	916	y							9.0	0.6
10/07/22	8479	CO	89	9	Control	0	0	15	y							6.0	0.6
10/07/22	8496	CO	108	13.8	Control	0	0	3	y							6.5	0.6
10/07/22	8509	CO	72	4.6	Control	0	0	559	y							7.5	0.6
10/07/22	8542	CO	106	12.9	Control	0	0	3	y							6.0	0.6
10/07/22	8558	CO	110	15.5	Control	0	0	4	y							6.5	0.6
10/07/22	8577	CO	109	14	Control	0	0	23	y							6.5	0.6
10/07/22	8581	CO	84	6.8	Control	0	0	7	y							7.0	0.6
10/07/22	8584	CO	113	16.3	Control	0	0	10	y							8.5	0.5
10/07/22	8430	CO	73	4.4	Control	223	6	6	y	37.0	0.5	40.5	0.5	30.0	0.5	5.0	0.5
10/07/22	8476	CO	109	14.9	Control	0	0	4	y							2.5	0.6
10/07/22	8408	CO	62	2.7	Control	0	0	0	n								
10/07/22	8421	CO	74	5.5	Control	0	0	0	n								
10/07/22	8425	CO	91	8.1	Control	0	0	0	n								
10/07/22	8450	CO	80	5.6	Control	0	0	0	n								
10/07/22	8454	CO	63	2.9	Control	0	10276	0	n					18.5	0.6		
10/07/22	8458	CO	67	3.5	Control	0	0	0	n								
10/07/22	8482	CO	86	7.6	Control	45	3	0	n	17.0	0.5	31.0	0.5	5.5	0.5		
10/07/22	8490	CO	60	2.6	Control	30	8	0	n	7.0	0.6	16.0	0.6	5.0	0.5		
10/07/22	8494	CO	69	3.6	Control	0	0	0	n								
10/07/22	8519	CO	81	6.1	Control	0	0	0	n								
10/07/22	8538	CO	127	20.5	Control	0	0	0	n								
10/07/22	8539	CO	107	13.3	Control	0	0	0	n								
10/07/22	8550	CO	120	20	Control	0	0	0	n								
10/07/22	8590	CO	64	2.9	Control	7	0	0	n	42.0	0.5	42.0	0.5				
10/07/22	8559	DV	165	42.1	1	37	8	4	y	2.0	0.6	2.5	0.6	6.0	0.6	9.5	0.6
10/07/22	8403	DV	125	18.3	1	34	0	0	n	2.0	0.6	2.5	0.6				
10/07/22	8433	DV	116	14.8	1	64	0	0	n	0.5	0.6	41.5	0.5				
10/07/22	8439	DV	129	23.2	1	361	0	0	n	4.0	0.6	41.5	0.5				

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
10/07/22	8440	DV	66	2.5	1	0	0	0	n								
10/07/22	8441	DV	89	3.3	1	10	0	0	n	1.0	0.6	4.0	0.6				
10/07/22	8457	DV	131	21.8	1	220	0	0	n	6.0	0.6	42.0	0.5				
10/07/22	8461	DV	70	3.1	1	0	0	0	n								
10/07/22	8462	DV	69	3	1	37	0	0	n	21.5	0.5	42.5	0.5				
10/07/22	8463	DV	63	2.4	1	0	0	0	n								
10/07/22	8489	DV	130	22.3	1	115	0	0	n	1.0	0.6	40.5	0.5				
10/07/22	8491	DV	70	3.2	1	67	0	0	n	5.5	0.5	42.5	0.5				
10/07/22	8548	DV	72	3.3	1	0	0	0	n								
10/07/22	8566	DV	64	2.4	1	0	0	0	n								
10/07/22	8402	DV	141	28.1	2	0	3	3	y					2.5	0.6	4.5	0.6
10/07/22	8413	DV	120	16.4	2	0	8	0	y					1.0	0.6		
10/07/22	8444	DV	105	11.7	2	0	26	0	y					26.0	0.5		
10/07/22	8499	DV	115	13.7	2	0	149	0	y					3.0	0.6		
10/07/22	8521	DV	142	29.5	2	6	544	0	y	27.0	0.5	38.0	0.5	4.0	0.6		
10/07/22	8498	DV	135	24.6	2	2	0	0	n	0.5	0.6	0.5	0.6				
10/07/22	8481	DV	151	30	2	3	0	0	n	3.5	0.6	3.5	0.6				
10/07/22	8478	DV	74	3.7	2	4	0	0	n	10.0	0.6	10.0	0.6				
10/07/22	8477	DV	74	3.8	2	5	0	0	n	23.0	0.6	23.0	0.6				
10/07/22	8445	DV	73	3.8	2	3	0	0	n	44.5	0.5	44.5	0.5				
10/07/22	8411	DV	70	3.2	2	0	0	0	n								
10/07/22	8473	DV	75	4.3	2	0	0	0	n								
10/07/22	8530	DV	83	5.4	2	0	0	0	n								
10/07/22	8594	DV	67	2.9	2	0	0	0	n								
10/07/22	8418	DV	71	3.4	Control	0	0	20	y							10.0	0.6
10/07/22	8452	DV	127	21.5	Control	38	8	10	y	18.5	0.6	18.5	0.6	10.0	0.6	9.5	0.6
10/07/22	8460	DV	64	2.2	Control	0	0	3	y							21.0	0.6
10/07/22	8543	DV	69	3	Control	0	0	2	y							6.5	0.6
10/07/22	8401	DV	74	4.3	Control	0	0	31	y							1.5	0.5
10/07/22	8404	DV	140	26.7	Control	0	0	3337	y							2.0	0.6
10/07/22	8493	DV	82	5	Control	0	0	516	y							1.5	0.5
10/07/22	8564	DV	66	2.9	Control	0	0	1272	y							3.5	0.6

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
10/07/22	8417	DV	140	27	Control	0	0	2	y							1.0	0.6
10/07/22	8470	DV	124	15.3	Control	0	0	912	y							1.0	0.6
10/07/22	8427	DV	84	5.3	Control	0	0	0	n								
10/07/22	8428	DV	62	2.3	Control	0	0	0	n								
10/07/22	8431	DV	156	37.1	Control	72	0	0	n	14.0	0.6	41.0	0.5				
10/07/22	8549	DV	70	3	Control	0	0	0	n								
05/28/23	8114	CO	89	6.8	1	2	0	0	n	33.0	0.6	33.5	0.7				
05/28/23	8126	CO	107	10.6	1	0	0	0	n								
05/28/23	8139	CO	121	15.3	1	0	0	0	n								
05/28/23	8140	CO	107	13.4	1	0	0	0	n								
05/28/23	8145	CO	120	18.4	1	0	0	0	n								
05/28/23	8158	CO	82	5.4	1	0	0	0	n								
05/28/23	8162	CO	109	14.7	1	0	0	0	n								
05/28/23	8178	CO	88	4.5	1	0	0	0	n								
05/28/23	8409	CO	76	4.7	1	0	0	0	n								
05/28/23	8443	CO	109	11.9	1	0	0	0	n								
05/28/23	8456	CO	77	5.2	1	0	0	0	n								
05/28/23	8488	CO	146	25.3	1	0	0	0	n								
05/28/23	8192	CO	116	13.3	2	3	0	0	n	1.0		1.0					
05/28/23	8407	CO	132	20.6	2	6	0	0	n	1.5	0.1	2.0	0.1				
05/28/23	8434	CO	123	17.9	2	5	0	0	n	1.5	0.1	1.5	0.1				
05/28/23	8157	CO	63	2.7	2	1	0	0	n	15.5	0.1	15.5	0.1				
05/28/23	8160	CO	60	2.4	2	2	0	0	n	15.5	0.1	15.5	0.1				
05/28/23	8436	CO	67	3.6	2	2	0	0	n	16.0	0.1	16.0	0.1				
05/28/23	8121	CO	87	5.9	2	1	0	0	n	22.0	0.2	22.0	0.2				
05/28/23	8106	CO	70	2	2	2	0	0	n	31.5	0.4	31.5	0.4				
05/28/23	8111	CO	102	11.8	2	1	0	0	n	33.5	0.7	33.5	0.7				
05/28/23	8128	CO	54	1.5	2	4	0	0	n	34.5	0.8	34.5	0.8				
05/28/23	8182	CO	96	9.7	2	2	0	0	n	34.5	0.8	34.5	0.8				
05/28/23	8119	CO	73	4.8	2	0	0	0	n								
05/28/23	8155	CO	63	3.3	2	0	0	0	n								
05/28/23	8117	CO	84	6.5	Control	0	0	0	n								

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
05/28/23	8123	CO	81	5.9	Control	5	1	0	n	33.5	0.7	38.0	0.6	33.0	0.6		
05/28/23	8127	CO	85	5.5	Control	2	1	0	n	34.5	0.8	34.5	0.8	15.5	0.1		
05/28/23	8152	CO	71	3.5	Control	0	0	0	n								
05/28/23	8153	CO	125	17.6	Control	0	0	0	n								
05/28/23	8177	CO	79	5.2	Control	0	0	0	n								
05/28/23	8186	CO	77	5	Control	0	0	0	n								
05/28/23	8191	CO	68	4	Control	0	0	0	n								
05/28/23	8415	CO	97	8.7	Control	0	0	0	n								
05/28/23	8455	CO	84	6.2	Control	0	0	0	n								
05/28/23	8472	CO	90	7.8	Control	2	7	0	n	44.5	1.4	44.5	1.4	42.5	1.2		
05/28/23	8151	DV	95	7.9	1	7	1	0	y	5.0	0.1	6.0	0.1	47.0	1.2		
05/28/23	8110	DV	100	8.4	1	30	27	0	y	1.0	0.1	2.5	0.1	5.5	0.1		
05/28/23	8100	DV	62	2.6	1	0	0	0	n								
05/28/23	8104	DV	129	21.7	1	3	0	0	n	40.0	0.8	40.0	0.8				
05/28/23	8112	DV	101	10.7	1	0	0	0	n								
05/28/23	8113	DV	97	8.2	1	0	0	0	n								
05/28/23	8125	DV	130	17.4	1	7	0	0	n	34.5	0.8	34.5	0.8				
05/28/23	8129	DV	116	13	1	1	0	0	n	32.0	0.4	32.0	0.4				
05/28/23	8132	DV	101	9.5	1	0	0	0	n								
05/28/23	8141	DV	100	11.9	1	0	0	0	n								
05/28/23	8142	DV	66	2.7	1	1	0	0	n	2.0	0.1	2.0	0.1				
05/28/23	8159	DV	98	11.2	1	0	0	0	n								
05/28/23	8164	DV	77	4.5	1	0	0	0	n								
05/28/23	8168	DV	79	4.6	1	0	0	0	n								
05/28/23	8171	DV	90	7	1	2	0	0	n	31.0	0.3	31.0	0.3				
05/28/23	8174	DV	101	8.8	1	0	0	0	n								
05/28/23	8175	DV	114	14.1	1	0	0	0	n								
05/28/23	8187	DV	89	7.7	1	0	0	0	n								
05/28/23	8188	DV	131	21.7	1	11	0	0	n	33.0	0.6	33.0	0.6				
05/28/23	8194	DV	96	7.4	1	0	0	0	n								
05/28/23	8438	DV	92	6.8	1	16	0	0	n	32.5	0.4	34.0	0.7				
05/28/23	8461	DV	79	3.7	1	0	0	0	n								

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
05/28/23	8471	DV	78	4.5	1	0	0	0	n								
05/28/23	8101	DV	89	6.2	2	72	24	0	y	29.0	0.2	35.5	0.7	3.0	0.1		
05/28/23	8108	DV	95	7.7	2	0	18	0	y					3.0	0.1		
05/28/23	8118	DV	97	8	2	0	7	0	y					1.5	0.1		
05/28/23	8122	DV	104	10.5	2	0	3	0	y					26.0	0.2		
05/28/23	8135	DV	81	6.3	2	0	2	0	y					47.0	1.2		
05/28/23	8144	DV	134	25.3	2	7	2	0	y	35.0	0.7	35.5	0.7	33.5	0.7		
05/28/23	8176	DV	90	6.8	2	0	15	0	y					4.0	0.1		
05/28/23	8183	DV	106	11	2	1	5	0	y	28.0	0.2	28.0	0.2	3.0	0.1		
05/28/23	8195	DV	94	7.1	2	0	11	0	y					2.0	0.1		
05/28/23	8491	DV	82	4.9	2	0	42	0	y					6.0	0.1		
05/28/23	8198	DV	114	14	2	5	0	0	n	1.0	0.1	1.0	0.1				
05/28/23	8173	DV	108	11.2	2	9	0	0	n	1.5	0.1	7.5	0.1				
05/28/23	8134	DV	103	9.7	2	2	0	0	n	3.0	0.1	3.0	0.1				
05/28/23	8105	DV	154	32.1	2	13	0	0	n	9.5	0.1	10.0	0.1				
05/28/23	8102	DV	149	32.3	2	11	0	0	n	16.0	0.1	16.5	0.1				
05/28/23	8190	DV	85	5.9	2	7	0	0	n	19.5	0.1	19.5	0.1				
05/28/23	8154	DV	58	1.8	2	8	0	0	n	31.5	0.4	33.0	0.6				
05/28/23	8161	DV	136	20.9	2	5	0	0	n	33.0	0.6	33.0	0.6				
05/28/23	8131	DV	94	9.5	2	0	0	0	n								
05/28/23	8146	DV	85	7	2	0	0	0	n								
05/28/23	8169	DV	107	11.6	2	0	0	0	n								
05/28/23	8197	DV	61	2	2	0	0	0	n								
05/28/23	8480	DV	143	27.3	2	0	0	0	n								
05/28/23	8138	DV	93	7.9	Control	0	0	2	y							48.0	1.2
05/28/23	8156	DV	99	7.2	Control	0	0	3	y							6.0	0.1
05/28/23	8107	DV	96	8	Control	0	0	6	y							2.0	0.1
05/28/23	8124	DV	114	13.6	Control	0	4	3	y					46.0	1.2	3.0	0.1
05/28/23	8165	DV	86	5.6	Control	0	0	3	y							2.5	0.1
05/28/23	8432	DV	83	4.9	Control	0	0	16	y							2.0	0.1
05/28/23	8103	DV	94	7	Control	0	0	0	n								
05/28/23	8109	DV	131	22.4	Control	34	3	0	n	15.5	0.1	34.0	0.7	10.0	0.1		

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
05/28/23	8115	DV	130	19	Control	1	1	0	n	16.0	0.1	16.0	0.1	14.0	0.2		
05/28/23	8120	DV	87	7.9	Control	0	0	0	n								
05/28/23	8130	DV	76	5	Control	0	0	0	n								
05/28/23	8137	DV	81	5.3	Control	0	0	0	n								
05/28/23	8143	DV	141	27.9	Control	6	1	0	n	14.0	0.2	14.5	0.2	10.5	0.1		
05/28/23	8147	DV	163	43.9	Control	1	1	0	n	36.0	0.6	36.0	0.6	34.5	0.8		
05/28/23	8149	DV	86	7.1	Control	0	0	0	n								
05/28/23	8150	DV	87	7.4	Control	0	0	0	n								
05/28/23	8166	DV	141	22.8	Control	4	1	0	n	31.5	0.4	31.5	0.4	16.0	0.1		
05/28/23	8181	DV	110	11.2	Control	0	1	0	n					8.5	0.1		
05/28/23	8185	DV	89	7.5	Control	0	0	0	n								
05/28/23	8193	DV	105	11.1	Control	0	0	0	n								
05/28/23	8405	DV	98	8.7	Control	1	2	0	n	1.5	0.1	1.5	0.1	1.0	0.1		
06/25/23	8163	CO	98	10.7	1	0	0	0	n								
06/25/23	8172	CO	84	7.3	1	1	0	0	n	1.5	0.2	1.5	0.2				
06/25/23	8179	CO	80	6.1	1	0	0	0	n								
06/25/23	8202	CO	90	9	1	1	0	0	n	38.5	0.2	38.5	0.2				
06/25/23	8205	CO	70	3.8	1	0	0	0	n								
06/25/23	8231	CO	68	3.4	1	0	0	0	n								
06/25/23	8233	CO	83	6	1	0	0	0	n								
06/25/23	8235	CO	63	2.6	1	2	0	0	n	13.0	0.2	13.0	0.2				
06/25/23	8241	CO	75	4.5	1	0	0	0	n								
06/25/23	8249	CO	101	12.3	1	17	0	0	n	13.5	0.2	17.0	0.2				
06/25/23	8262	CO	84	6.6	1	0	0	0	n								
06/25/23	8265	CO	69	3.7	1	1	0	0	n	12.0	0.2	12.0	0.2				
06/25/23	8266	CO	75	4.8	1	0	0	0	n								
06/25/23	8272	CO	95	9	1	0	0	0	n								
06/25/23	8280	CO	95	10.3	1	0	0	0	n								
06/25/23	8284	CO	74	4.8	1	0	0	0	n								
06/25/23	8293	CO	90	8.7	1	1	0	0	n	1.5	0.2	1.5	0.2				
06/25/23	8296	CO	83	6.3	1	0	0	0	n								
06/25/23	8456	CO	81	6.2	1	0	0	0	n								

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
06/25/23	8225	CO	100	11.6	2	0	30	0	y					5.0			
06/25/23	8133	CO	89	8.1	2	1	0	0	n	1.0	0.2	1.0	0.2				
06/25/23	8238	CO	105	12.5	2	1	0	0	n	1.0	0.2	1.0	0.2				
06/25/23	8281	CO	100	11.6	2	1	0	0	n	1.5	0.2	1.5	0.2				
06/25/23	8287	CO	87	8.9	2	1	0	0	n	1.5	0.2	1.5	0.2				
06/25/23	8263	CO	81	6.1	2	1	0	0	n	2.0	0.2	2.0	0.2				
06/25/23	8275	CO	91	7.4	2	1	0	0	n	2.0	0.2	2.0	0.2				
06/25/23	8180	CO	87	8.1	2	1	0	0	n	2.5	0.2	2.5	0.2				
06/25/23	8268	CO	83	6.2	2	3	0	0	n	2.5	0.2	2.5	0.2				
06/25/23	8203	CO	65	3.3	2	2	0	0	n	3.0	0.2	3.0	0.2				
06/25/23	8207	CO	82	6.7	2	3	0	0	n	4.0	0.2	9.5	0.1				
06/25/23	8232	CO	76	5	2	2	0	0	n	5.0	0.2	13.5	0.2				
06/25/23	8189	CO	86	8.3	2	1	0	0	n	5.5	0.2	5.5	0.2				
06/25/23	8157	CO	67	3.3	2	2	0	0	n	6.0	0.2	6.0	0.2				
06/25/23	8177	CO	84	6.2	2	9	0	0	n	6.0	0.2	46.0	0.2				
06/25/23	8363	CO	68	3.7	2	2	0	0	n	10.0	0.2	10.5	0.2				
06/25/23	8274	CO	87	7.3	2	3	0	0	n	13.5	0.2	13.5	0.2				
06/25/23	8357	CO	76	4.4	2	3	0	0	n	25.0	0.2	25.0	0.2				
06/25/23	8290	CO	85	7.4	2	0	0	0	n								
06/25/23	8222	CO	90	8.3	Control	0	0	1	y							10.5	0.2
06/25/23	8148	CO	92	8.9	Control	3	9	0	n	14.0	0.2	38.0	0.2	12.0	0.2		
06/25/23	8170	CO	101	10.4	Control	2	1	0	n	13.0	0.2	13.5	0.2	12.5	0.2		
06/25/23	8196	CO	65	3	Control	0	1	0	n					12.5	0.2		
06/25/23	8204	CO	100	11.3	Control	1	1	0	n	20.0	0.2	20.0	0.2	13.5	0.2		
06/25/23	8229	CO	75	5.1	Control	0	0	0	n								
06/25/23	8234	CO	76	5.2	Control	0	0	0	n								
06/25/23	8236	CO	72	3.9	Control	0	0	0	n								
06/25/23	8239	CO	89	8.3	Control	2	2	0	n	2.5	0.2	12.5	0.2	1.0	0.2		
06/25/23	8246	CO	96	10.8	Control	0	0	0	n								
06/25/23	8247	CO	74	4.1	Control	0	1	0	n					37.5	0.2		
06/25/23	8264	CO	90	8.2	Control	1	10	0	n	14.5	0.2	14.5	0.2	12.5	0.2		
06/25/23	8270	CO	95	9.5	Control	3	1	0	n	9.0	0.2	13.5	0.2	1.0	0.2		

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
06/25/23	8271	CO	66	3.4	Control	1	1	0	n	26.0	0.2	26.0	0.2	13.5	0.2		
06/25/23	8277	CO	86	8.6	Control	2	1	0	n	13.5	0.2	13.5	0.2	12.5	0.2		
06/25/23	8283	CO	85	6.3	Control	1	1	0	n	13.5	0.2	13.5	0.2	12.5	0.2		
06/25/23	8285	CO	83	6.1	Control	0	1	0	n					5.0	0.2		
06/25/23	8136	DV	101	9.6	1	4	2	0	y	12.5	0.2	12.5	0.2	42.0	0.2		
06/25/23	8206	DV	98	8.8	1	5	5	0	y	12.5	0.2	12.5	0.2	28.0	0.2		
06/25/23	8146	DV	87	6.4	1	5	4	0	y	12.0	0.2	12.0	0.2	15.5	0.2		
06/25/23	8297	DV	112	13.5	1	45	66	0	y	12.0	0.2	12.0	0.2	14.0	0.2		
06/25/23	8299	DV	112	13.3	1	5	4	3	y	12.0	0.2	12.0	0.2	13.5	0.2	17.5	0.2
06/25/23	8311	DV	120	15.8	1	6	14	2	y	10.5	0.2	12.5	0.2	14.5	0.2	38.5	0.2
06/25/23	8215	DV	121	16.5	1	1	4	0	y	12.0	0.2	12.0	0.2	13.0	0.2		
06/25/23	8220	DV	95	7.6	1	31	1	0	y	13.5	0.2	15.0	0.2	21.0	0.2		
06/25/23	8289	DV	87	5.9	1	4	1	0	y					19.5	0.2		
06/25/23	8208	DV	129	19.2	1	59	0	0	n	0.5	0.2	42.5	0.2				
06/25/23	8219	DV	85	5.5	1	69	0	0	n	13.0	0.2	43.5	0.2				
06/25/23	8223	DV	124	18.8	1	11	0	0	n	13.0	0.2	13.5	0.2				
06/25/23	8228	DV	79	4.3	1	0	0	0	n								
06/25/23	8237	DV	98	8.2	1	0	0	0	n								
06/25/23	8240	DV	130	20.9	1	8	0	0	n	13.5	0.2	15.5	0.2				
06/25/23	8242	DV	91	7	1	1	0	0	n	13.0	0.2	13.0	0.2				
06/25/23	8248	DV	116	16.3	1	0	0	0	n								
06/25/23	8257	DV	123	17.8	1	1	0	0	n	14.5	0.2	14.5	0.2				
06/25/23	8260	DV	90	7	1	0	0	0	n								
06/25/23	8278	DV	144	30	1	0	0	0	n								
06/25/23	8298	DV	120	15.9	1	16	0	0	n	2.0	0.2	37.5	0.2				
06/25/23	8318	DV	97	8.8	1	2	0	0	n	13.5	0.2	13.5	0.2				
06/25/23	8333	DV	100	10.3	1	0	0	0	n								
06/25/23	8387	DV	109	12.4	1	0	0	0	n								
06/25/23	8392	DV	95	7.6	1	0	0	0	n								
06/25/23	8124	DV	116	16.8	2	0	5	0	y					2.5	0.2		
06/25/23	8200	DV	106	11.7	2	0	1	2	y					2.0	0.2	28.5	0.1
06/25/23	8201	DV	128	19.2	2	0	2	0	y					2.0	0.2		

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
06/25/23	8211	DV	87	6	2	0	65	4	y					2.5	0.2	26.0	0.2
06/25/23	8212	DV	129	19.2	2	10	20	0	y	40.0	0.2	42.0	0.2	7.5	0.2		
06/25/23	8217	DV	112	12.4	2	0	1	1	y					1.5	0.2	10.5	0.2
06/25/23	8221	DV	126	14.3	2	0	12	0	y					6.5	0.2		
06/25/23	8226	DV	86	5.9	2	0	1	2	y					3.5	0.2	30.5	0.2
06/25/23	8230	DV	97	7.8	2	0	2	1	y					2.0	0.2	7.5	0.2
06/25/23	8252	DV	110	14.9	2	73	2	0	y	13.0	0.2	15.5	0.2	18.0	0.2		
06/25/23	8259	DV	121	20	2	0	2	1	y					1.0	0.2	10.0	0.2
06/25/23	8282	DV	111	13.4	2	0	6	0	y					2.0	0.2		
06/25/23	8295	DV	114	14.8	2	0	44	1	y					6.5	0.2	18.0	0.2
06/25/23	8351	DV	91	7	2	0	3	3	y					5.5	0.2	18.5	0.2
06/25/23	8373	DV	110	13.3	2	0	9	0	y					2.5	0.2		
06/25/23	8227	DV	104	11.3	2	2	0	0	n	1.5	0.2	1.5	0.2				
06/25/23	8322	DV	76	4.9	2	35	0	0	n	2.0	0.2	44.5	0.2				
06/25/23	8209	DV	90	6.7	2	4	0	0	n	6.0	0.2	12.0	0.2				
06/25/23	8245	DV	114	14.8	2	3	0	0	n	20.0	0.2	40.5	0.2				
06/25/23	8255	DV	104	10.6	2	3	0	0	n	22.0	0.2	39.0	0.2				
06/25/23	8214	DV	101	10.2	2	4	0	0	n	29.0	0.2	29.0	0.2				
06/25/23	8167	DV	120	16.4	2	1	0	0	n	39.0	0.2	39.0	0.2				
06/25/23	8210	DV	109	11.5	2	0	0	0	n								
06/25/23	8286	DV	109	15.9	2	0	0	0	n								
06/25/23	8395	DV	87	2	2	0	0	0	n								
06/25/23	8291	DV	94	6.9	Control	0	0	1	y							15.0	0.2
06/25/23	8292	DV	86	6.2	Control	0	0	52	y							13.0	0.2
06/25/23	8116	DV	89	6.3	Control	0	0	1	y							9.0	0.2
06/25/23	8253	DV	98	8.7	Control	0	0	1	y							7.5	0.2
06/25/23	8254	DV	95	7.8	Control	0	0	2	y							6.0	0.2
06/25/23	8261	DV	81	4.5	Control	0	0	3	y							5.5	0.2
06/25/23	8273	DV	85	5.9	Control	0	0	7	y							6.0	0.2
06/25/23	8276	DV	117	16.4	Control	0	0	3	y							4.0	0.2
06/25/23	8213	DV	106	10.7	Control	0	0	5	y							3.5	0.2
06/25/23	8324	DV	86	6	Control	0	0	1	y							2.5	0.2

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
06/25/23	8216	DV	135	21.4	Control	0	0	2	y							1.5	0.2
06/25/23	8224	DV	110	13	Control	0	0	0	n								
06/25/23	8243	DV	101	9.3	Control	18	165	0	n	12.5	0.2	13.0	0.2	21.5	0.2		
06/25/23	8244	DV	72	3.5	Control	0	0	0	n								
06/25/23	8250	DV	73	3.4	Control	0	0	0	n								
06/25/23	8251	DV	94	8.4	Control	0	18	0	n					13.5	0.2		
06/25/23	8256	DV	70	2.9	Control	0	0	0	n								
06/25/23	8258	DV	112	13.5	Control	0	30	0	n					12.5	0.2		
06/25/23	8267	DV	105	10.2	Control	0	0	0	n								
06/25/23	8279	DV	87	6.5	Control	23	22	0	n	32.0	0.1	37.5	0.2	12.0	0.2		
06/25/23	8288	DV	126	19.1	Control	1	2	0	n	19.5	0.2	19.5	0.2	16.0	0.2		
06/25/23	8294	DV	96	8.5	Control	0	0	0	n								
06/25/23	8336	DV	109	12.6	Control	1	1	0	n	6.0	0.2	6.0	0.2	3.5	0.2		
06/25/23	8349	DV	116	14.4	Control	25	6	0	n	24.0	0.2	45.5	0.2	14.5	0.2		
06/25/23	8382	DV	125	18.7	Control	0	0	0	n								
10/17/23	3202	CO	99	10.5	1	0	0	0	n								
10/17/23	3245	CO	112	16.1	1	0	0	0	n								
10/17/23	3258	CO	110	15.6	1	0	0	0	n								
10/17/23	3306	CO	101	10	1	0	0	0	n								
10/17/23	3309	CO	112	14.8	1	0	0	0	n								
10/17/23	3315	CO	102	12.5	1	0	0	0	n								
10/17/23	3318	CO	113	15.7	1	0	0	0	n								
10/17/23	3319	CO	107	13.6	1	0	0	0	n								
10/17/23	3331	CO	107	13.1	1	0	0	0	n								
10/17/23	3343	CO	96	10.1	1	0	0	0	n								
10/17/23	3346	CO	117	17.8	1	0	0	0	n								
10/17/23	3355	CO	91	8.1	1	0	0	0	n								
10/17/23	3370	CO	102	11.5	1	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3371	CO	114	16.6	1	21	0	0	n	30.0	9.2	32.0	6.9				
10/17/23	3390	CO	100	11	1	0	0	0	n								
10/17/23	3391	CO	96	8.3	1	0	0	0	n								
10/17/23	3395	CO	98	10.5	1	0	0	0	n								

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
10/17/23	3399	CO	91	8.8	1	0	0	0	n								
10/17/23	3227	CO	110	13.9	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3246	CO	118	19.5	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3254	CO	90	8.3	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3307	CO	103	11.9	2	3	0	0	n	0.5	4.3	3.5	10.9				
10/17/23	3308	CO	133	24.5	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3313	CO	106	14.3	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3322	CO	123	19.8	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3339	CO	113	15	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3361	CO	123	19.3	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3363	CO	86	6.7	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3373	CO	112	14.3	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3383	CO	108	15.1	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3265	CO	119	19.1	2	0	0	0	n								
10/17/23	3266	CO	104	11.8	2	0	0	0	n								
10/17/23	3310	CO	114	15.2	2	0	0	0	n								
10/17/23	3314	CO	84	5.6	2	0	0	0	n								
10/17/23	3375	CO	124	20.4	2	0	0	0	n								
10/17/23	3382	CO	110	15.1	2	0	0	0	n								
10/17/23	3384	CO	116	17.7	2	0	0	0	n								
10/17/23	3204	CO	100	11.3	Control	0	0	0	n								
10/17/23	3208	CO	113	17	Control	0	1	0	n					43.0	2.9		
10/17/23	3264	CO	104	12.8	Control	0	1	0	n					2.0	6.2		
10/17/23	3275	CO	129	23.8	Control	1	1	0	n	0.0	3.8	0.0	3.8	0.0	3.8		
10/17/23	3281	CO	112	16.5	Control	1	0	0	n	1.5	5.0	1.5	5.0				
10/17/23	3303	CO	98	11	Control	1	1	0	n	0.5	4.3	0.5	4.3	0.5	4.3		
10/17/23	3320	CO	115	16.6	Control	0	1	0	n					2.0	6.2		
10/17/23	3325	CO	105	12.8	Control	1	1	0	n	0.5	4.3	0.5	4.3	0.5	4.3		
10/17/23	3332	CO	106	12.7	Control	1	1	0	n	0.5	4.3	0.5	4.3	0.5	4.3		
10/17/23	3333	CO	106	13.4	Control	1	1	0	n	0.5	4.3	0.5	4.3	0.5	4.3		
10/17/23	3336	CO	104	12.6	Control	1	1	0	n	0.5	4.3	0.5	4.3	0.5	4.3		
10/17/23	3338	CO	105	12.8	Control	1	2	0	n	7.5	20.7	7.5	20.7	7.0	22.2		

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
10/17/23	3344	CO	107	11.9	Control	0	0	0	n								
10/17/23	3360	CO	110	15.3	Control	1	1	0	n	0.5	4.3	0.5	4.3	0.5	4.3		
10/17/23	3368	CO	107	13.9	Control	0	1	0	n					0.0	3.8		
10/17/23	3380	CO	97	9	Control	1	5	0	n	4.0	15.3	4.0	15.3	4.0	15.3		
10/17/23	3385	CO	103	11.6	Control	0	10	0	n					2.0	6.2		
10/17/23	3389	CO	101	10.8	Control	1	65	0	n	2.5	7.0	2.5	7.0	2.0	6.2		
10/17/23	3222	DV	138	23.7	1	2	1	1	y	1.0	4.7	3.0	9.0	38.5	3.7	46.5	
10/17/23	3211	DV	107	11.4	1	0	0	0	n								
10/17/23	3219	DV	97	9.2	1	10	0	0	n	1.5	5.0	39.0	3.8				
10/17/23	3230	DV	149	32.5	1	11	0	0	n	1.0	4.7	6.0	21.4				
10/17/23	3231	DV	111	12.3	1	1	0	0	n	3.5	10.9	3.5	10.9				
10/17/23	3240	DV	125	19.8	1	17	0	0	n	1.0	4.7	35.5	4.8				
10/17/23	3242	DV	60	2.1	1	0	0	0	n								
10/17/23	3244	DV	112	13.6	1	10	0	0	n	1.5	5.0	31.0	8.4				
10/17/23	3253	DV	63	2.4	1	0	0	0	n								
10/17/23	3262	DV	86	6.8	1	3	0	0	n	3.5	10.9	3.5	10.9				
10/17/23	3285	DV	122	17.5	1	0	0	0	n								
10/17/23	3287	DV	63	2.5	1	0	0	0	n								
10/17/23	3289	DV	111	13.5	1	2	0	0	n	1.0	4.7	1.0	4.7				
10/17/23	3293	DV	144	26.3	1	26	0	0	n	0.5	4.3	5.0					
10/17/23	3299	DV	98	9.1	1	2	0	0	n	3.0	9.0	3.5					
10/17/23	3302	DV	72	3.4	1	0	0	0	n								
10/17/23	3324	DV	116	14.3	1	0	0	0	n								
10/17/23	3328	DV	103	10.2	1	0	0	0	n								
10/17/23	3329	DV	132	21.9	1	17	0	0	n	1.0	4.7	2.5	7.0				
10/17/23	3354	DV	110	14.4	1	0	0	0	n								
10/17/23	3357	DV	111	12.4	1	13	0	0	n	28.5	11.4	33.5	6.0				
10/17/23	3364	DV	133	21.3	1	4	0	0	n	1.0	4.7	2.0	6.2				
10/17/23	3367	DV	134	23.6	1	0	0	0	n								
10/17/23	3386	DV	121	16.5	1	10	0	0	n	1.0	4.7	2.0	6.2				
10/17/23	3327	DV	139	27.5	2	0	41	1	y					1.0	4.7	3.0	9.0
10/17/23	3200	DV	64	2.5	2	1	0	0	n	0.5	4.3	0.5	4.3				

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
10/17/23	3221	DV	129	18.8	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3270	DV	125	19.9	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3298	DV	98	7.4	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3362	DV	131	22.2	2	4	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3365	DV	140	25	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3370	DV	92	8.4	2	1	0	0	n	0.5	4.3	0.5	4.3				
10/17/23	3205	DV	136	21.4	2	1	0	0	n	1.0	4.7	1.0	4.7				
10/17/23	3224	DV	112	13.3	2	2	0	0	n	1.0	4.7	10.0	24.3				
10/17/23	3283	DV	134	22.3	2	5	0	0	n	1.0	4.7	1.0	4.7				
10/17/23	3284	DV	104	12.1	2	1	0	0	n	1.0	4.7	1.0	4.7				
10/17/23	3321	DV	134	23.6	2	12	0	0	n	1.0	4.7	32.5	6.4				
10/17/23	3277	DV	116	14.3	2	2	0	0	n	2.0	6.2	5.5	23.3				
10/17/23	3295	DV	104	9.6	2	2	0	0	n	2.0	6.2	2.5	7.0				
10/17/23	3323	DV	124	18.2	2	10	0	0	n	25.5	24.1	33.5	6.0				
10/17/23	335	DV	99	9.7	2	0	0	0	n								
10/17/23	3214	DV	79	5	2	0	0	0	n								
10/17/23	3239	DV	125	19.3	2	0	0	0	n								
10/17/23	3250	DV	78	4.2	2	0	0	0	n								
10/17/23	3252	DV	110	12.1	2	0	0	0	n								
10/17/23	3312	DV	95	9.1	2	0	0	0	n								
10/17/23	3349	DV	136	26.8	2	0	0	0	n								
10/17/23	8344	DV	84	5.6	2	0	0	0	n								
10/17/23	3220	DV	117	17.1	Control	0	0	5	y							2.0	6.2
10/17/23	3226	DV	132	22.3	Control	0	2	5	y					0.5	4.3	4.0	15.3
10/17/23	3248	DV	96	8.4	Control	0	0	3	y							28.5	11.4
10/17/23	3263	DV	121	16.7	Control	0	0	1	y							2.0	6.2
10/17/23	3269	DV	116	15.6	Control	0	0	1	y							30.5	9.1
10/17/23	3271	DV	105	11.4	Control	0	0	3	y							29.0	10.5
10/17/23	3359	DV	126	16.6	Control	0	0	1	y							5.0	21.0
10/17/23	3470	DV	139	22.7	Control	1	1	5	y	4.0	15.3	4.0	15.3	4.0	15.3	1.5	5.0
10/17/23	3215	DV	62	2.1	Control	0	0	0	n								
10/17/23	3225	DV	141	30.8	Control	1	13	0	n	2.5	7.0	2.5	7.0	2.5	7.0		

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
10/17/23	3239	DV	122	17.4	Control	0	0	0	n								
10/17/23	3259	DV	98	9.2	Control	0	0	0	n								
10/17/23	3279	DV	69	2.7	Control	0	0	0	n								
10/17/23	3286	DV	64	2.4	Control	0	0	0	n								
10/17/23	3291	DV	134	22.6	Control	0	1	0	n					1.5	5.0		
10/17/23	3317	DV	132	19.7	Control	1	1	0	n	1.0	4.7	1.0	4.7	1.0	4.7		
10/17/23	3326	DV	126	20.5	Control	1	7	0	n	1.5	5.0	1.5	5.0	1.5	5.0		
10/17/23	3342	DV	135	23.9	Control	1	1	0	n	1.5	5.0	1.5	5.0	1.0	4.7		
10/17/23	3347	DV	116	17.3	Control	1	7	0	n	1.0	4.7	1.0	4.7	0.5	4.3		
10/17/23	3377	DV	145	30.1	Control	0	1	0	n					0.5	4.3		
10/17/23	3379	DV	94	8.7	Control	0	0	0	n								
10/17/23	3397	DV	94	8.6	Control	0	0	0	n								
10/17/23	8368	DV	151	31.3	Control	2	9	0	n	3.5	10.9	3.5	10.9	1.5	5.0		
11/03/23	3101	CO	96	7.2	1	8	0	0	n	1.5	0.4	8.5	0.4				
11/03/23	3105	CO	101	10.8	1	1	0	0	n	0.5	0.4	0.5	0.4				
11/03/23	3107	CO	112	12	1	0	0	0	n								
11/03/23	3118	CO	123	18.2	1	0	0	0	n								
11/03/23	3123	CO	92	7.1	1	7	0	0	n	2.0	0.4	8.0	0.4				
11/03/23	3129	CO	128	23.6	1	5	0	0	n	24.0	0.4	34.5	0.4				
11/03/23	3146	CO	95	9	1	11	0	0	n	32.0	0.3	38.5	0.4				
11/03/23	3165	CO	90	5.9	1	18	0	0	n	1.5	0.4	24.0	0.4				
11/03/23	3185	CO	113	15.1	1	1	0	0	n	1.0	0.4	1.0	0.4				
11/03/23	3195	CO	123	21.7	1	0	0	0	n								
11/03/23	3203	CO	89	5.8	1	5	0	0	n	1.0	0.4	7.5	0.4				
11/03/23	3206	CO	125	17.7	1	2	0	0	n	1.5	0.4	2.5	0.4				
11/03/23	3210	CO	137	22.9	1	1	0	0	n	5.0	0.3	5.0	0.3				
11/03/23	3216	CO	131	16.2	1	1	0	0	n	0.5	0.4	0.5	0.4				
11/03/23	3238	CO	105	10.1	1	0	0	0	n								
11/03/23	3247	CO	142	25.9	1	1	0	0	n	44.0	0.3	44.0	0.3				
11/03/23	3249	CO	106	12	1	2	0	0	n	8.0	0.4	8.0	0.4				
11/03/23	3254	CO	90	7.7	1	743	0	0	n	8.0	0.4	33.0	0.3				
11/03/23	3255	CO	120	15.6	1	4	0	0	n	1.0	0.4	2.5	0.4				

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
11/03/23	3256	CO	125	16.1	1	1	0	0	n	22.0	0.4	22.0	0.4				
11/03/23	3261	CO	126	18.9	1	0	0	0	n								
11/03/23	3267	CO	104	9.7	1	1	0	0	n	1.0	0.4	1.0	0.4				
11/03/23	3268	CO	92	7.2	1	4	0	0	n	1.0	0.4	8.0	0.4				
11/03/23	3282	CO	92	7.4	1	0	0	0	n								
11/03/23		CO	111	10.7	2	0	0	0	n	0.0	0.4	0.0	0.4				
11/03/23	3110	CO	85	5	2	48	0	0	n	1.0	0.4	9.0	0.4				
11/03/23	3120	CO	90	7.9	2	4	0	0	n	1.0	0.4	5.0	0.3				
11/03/23	3179	CO	107	11.7	2	2	0	0	n	1.0	0.4	1.0	0.4				
11/03/23	3207	CO	95	7.2	2	12	0	0	n	1.5	0.4	9.0	0.4				
11/03/23	3235	CO	102	9.4	2	4	0	0	n	1.5	0.4	8.0	0.4				
11/03/23	3257	CO	118	14.7	2	33	0	0	n	2.0	0.4	35.5	0.4				
11/03/23	3126	CO	105	12.8	2	3	0	0	n	2.5	0.4	5.0	0.3				
11/03/23	3213	CO	117	14.4	2	3	0	0	n	2.5	0.4	2.5	0.4				
11/03/23	3273	CO	120	16.3	2	4	0	0	n	2.5	0.4	2.5	0.4				
11/03/23	3274	CO	111	12.1	2	5	0	0	n	2.5	0.4	22.5	0.4				
11/03/23	3294	CO	104	8.7	2	111	0	0	n	2.5	0.4	8.5	0.4				
11/03/23	3116	CO	90	7.8	2	7	0	0	n	3.0	0.4	5.0	0.3				
11/03/23	3158	CO	90	7.5	2	1	0	0	n	3.0	0.4	3.0	0.4				
11/03/23	3217	CO	150	23.1	2	7	0	0	n	3.0	0.4	8.5	0.4				
11/03/23	3124	CO	102	9.2	2	127	0	0	n	3.5	0.3	35.5	0.4				
11/03/23	3131	CO	88	6.7	2	13	0	0	n	4.0	0.3	39.5	0.4				
11/03/23	3191	CO	100	9.2	2	2	0	0	n	5.0	0.3	5.0	0.3				
11/03/23	3251	CO	105	11.2	2	3	0	0	n	7.5	0.4	7.5	0.4				
11/03/23	3297	CO	82	4.4	2	20	0	0	n	9.5	0.4	9.5	0.4				
11/03/23	3127	CO	98	7.5	2	15	0	0	n	10.0	0.4	46.5	0.3				
11/03/23	3260	CO	127	16	2	0	0	0	n								
11/03/23	3272	CO	82	4.7	2	0	0	0	n								
11/03/23	3371	CO	111	16.2	2	0	0	0	n								
11/03/23	3109	CO	97	11.5	Control	0	0	0	n								
11/03/23	3119	CO	85	5.1	Control	0	1	0	n					11.5	0.4		
11/03/23	3135	CO	84	5.6	Control	0	0	0	n								

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
11/03/23	3151	CO	111	12.2	Control	0	0	0	n								
11/03/23	3156	CO	95	9	Control	2	1	0	n	23.0	0.4	24.0	0.4	8.0	0.4		
11/03/23	3159	CO	94	10.1	Control	0	0	0	n								
11/03/23	3166	CO	95	9.5	Control	3	1	0	n	9.0	0.4	22.5	0.4	9.0	0.4		
11/03/23	3169	CO	94	7.1	Control	5	4	0	n	13.5	0.4	18.5	0.4	8.0	0.4		
11/03/23	3182	CO	98	10	Control	18	1	0	n	10.0	0.4	16.5	0.4	8.0	0.4		
11/03/23	3183	CO	82	4.8	Control	14	1	0	n	10.0	0.4	20.5	0.4	9.5	0.4		
11/03/23	3188	CO	107	13.6	Control	2	1	0	n	9.0	0.4	9.5	0.4	8.0	0.4		
11/03/23	3190	CO	107	14.2	Control	26	1	0	n	24.5	0.4	26.0	0.4	8.5	0.4		
11/03/23	3198	CO	126	20.8	Control	1	1	0	n	9.0	0.4	9.0	0.4	8.0	0.4		
11/03/23	3201	CO	91	6.3	Control	0	1	0	n					9.0	0.4		
11/03/23	3209	CO	105	9.9	Control	0	0	0	n								
11/03/23	3233	CO	121	19.3	Control	0	0	0	n								
11/03/23	3234	CO	106	9.7	Control	4	1	0	n	5.0	0.3	8.0	0.4	0.5	0.4		
11/03/23	3236	CO	108	10.9	Control	0	0	0	n								
11/03/23	3241	CO	126	15.6	Control	10	1	0	n	8.5	0.4	9.0	0.4	8.0	0.4		
11/03/23	3276	CO	109	10.4	Control	0	0	0	n								
11/03/23	3280	CO	106	10	Control	3	1	0	n	12.5	0.4	13.0	0.4	8.5	0.4		
11/03/23	3288	CO	98	8.2	Control	3	1	0	n	22.5	0.4	46.5	0.3	10.0	0.4		
11/03/23	3290	CO	94	6.5	Control	0	0	0	n								
11/03/23	3296	CO	115	12.5	Control	0	0	0	n								
11/03/23	3100	DV	74	3.5	1	0	0	0	n								
11/03/23	3114	DV	60	2.2	1	0	0	0	n								
11/03/23	3122	DV	89	6.8	1	36	0	0	n	1.5	0.4	39.0	0.3				
11/03/23	3136	DV	73	3.5	1	16	0	0	n	0.5	0.4	32.0	0.3				
11/03/23	3149	DV	104	11.2	1	3	0	0	n	0.5	0.4	8.0	0.4				
11/03/23	3174	DV	100	9.4	1	1	0	0	n	1.0	0.4	1.0	0.4				
11/03/23	3176	DV	95	8.8	1	2	0	0	n	4.5	0.3	6.0	0.3				
11/03/23	3192	DV	123	17.7	1	0	0	0	n								
11/03/23	3196	DV	109	11.9	1	11	0	0	n	1.0	0.4	21.0	0.4				
11/03/23	3212	DV	146	24.1	1	0	0	0	n								
11/03/23	3237	DV	92	6.8	1	2	0	0	n	8.0	0.4	46.0	0.3				

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
11/03/23	3259	DV	102	8.7	1	2	0	0	n	3.5	0.3	6.0	0.3				
11/03/23	3284	DV	104	11.2	1	38	0	0	n	0.5	0.4	39.5	0.4				
11/03/23	3130	DV	129	20.7	2	0	1	0	y					4.0	0.3		
11/03/23	3229	DV	135	21	2	0	1	0	y					4.5	0.3		
11/03/23		DV	75	4.2	2	0	0	0	n	0.0	0.4	0.0	0.4				
11/03/23	3243	DV	169	39.6	2	10	0	0	n	0.5	0.4	9.0	0.4				
11/03/23	3357	DV	115	11.7	2	11	0	0	n	4.5	0.3	19.5	0.4				
11/03/23	3181	DV	163	42	2	10	0	0	n	6.5	0.3	22.5	0.4				
11/03/23	3199	DV	98	9.8	2	22	0	0	n	25.5	0.4	27.0	0.4				
11/03/23	3104	DV	135	25.3	2	0	0	0	n								
11/03/23	3132	DV	77	4.2	2	0	0	0	n								
11/03/23	3161	DV	110	12	2	0	0	0	n								
11/03/23	3170	DV	87	5.8	2	0	0	0	n								
11/03/23	3194	DV	90	6.7	2	0	0	0	n								
11/03/23	3133	DV	135	25.9	Control	0	0	2	y							13.0	0.4
11/03/23	3102	DV	110	13.6	Control	0	0	0	n								
11/03/23	3106	DV	94	7.9	Control	0	0	0	n								
11/03/23	3145	DV	75	4.5	Control	0	0	0	n								
11/03/23	3152	DV	85	5.8	Control	0	0	0	n								
11/03/23	3154	DV	74	3.6	Control	0	0	0	n								
11/03/23	3162	DV	91	7.2	Control	0	0	0	n								
11/03/23	3168	DV	120	18.3	Control	0	0	0	n								
11/03/23	3218	DV	107	9.7	Control	0	0	0	n								
11/03/23	3223	DV	139	23.5	Control	0	0	0	n								
11/03/23	3278	DV	121	15	Control	0	0	0	n								
11/03/23	8084	DV	133	22.1	Control	0	0	0	n								
07/29/22	7919(L)	CO	84	7.3	1	206	251	0	y	8.0	0.6	8.5	0.6	10.5	0.6		
07/29/22	7844(L)	CO	79	5.6	1	15823	157	0	y	1.0	0.7	4.5	0.6	6.0	0.6		
07/29/22	7925(L)	CO	86	7.1	1	186	6	63	y	0.5	0.8	0.5	0.8	3.0	0.7	6.5	0.6
07/29/22	7849(L)	DV	101	9.8	1	104	118	9067	y	2.0	0.7	2.0	0.7	5.0	0.6	7.5	0.6
07/29/22	7949(L)	DV	90	7.2	1	192	127	0	y	0.0	0.8	0.5	0.8	3.0	0.7		
07/29/22	7952(L)	DV	139	27.3	1	37	655	0	y	0.5	0.8	1.0	0.7	2.0	0.7		

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
07/29/22	7902(L)	DV	118	15.9	1	27	4	0	y	44.5	4.6	44.5	4.6	47.5	3.7		
07/29/22	7890(L)	DV	153	37.3	1	122	3850	0	y	19.0	4.7	27.0	6.1	29.0	5.7		
07/29/22	7943(L)	DV	134	28.1	1	150	1278	12	y	19.0	4.7	28.5	5.5	30.0	5.9	47.0	3.7
07/29/22	7968(L)	DV	134	24.3	1	73	62	0	y	20.0	6.5	29.5	5.7	31.0	6.5		
10/07/22	8027(L)	CO	99	11.6	1	138	16	0	y	0.0	0.6	0.5	0.6	2.5	0.6		
10/07/22	7952(L)	DV	139	27.3	1	94	13	0	y	16.0	0.6	26.0	0.5	27.0	0.5		
10/07/22	8067(L)	DV	115	17.2	1	144	5	3	y	16.0	0.6	26.0	0.5	27.0	0.5	27.5	0.5
10/07/22	7907(L)	DV	100	10.3	1	92	30	0	y	5.5	0.5	25.0	0.5	26.0	0.5		
10/07/22	7793(L)	DV	98	10	1	34	24	11	y	0.5	0.6	0.5	0.6	2.0	0.6	3.5	0.6
10/07/22	7917(L)	DV	144	29.6	1	36	22	11	y	7.0	0.6	7.0	0.6	8.0	0.6	9.5	0.6
10/07/22	7890(L)	DV	153	37.3	1	196	148	0	y	2.0	0.6	2.0	0.6	3.0	0.6		
06/25/23	8122(L)	DV	104	10.5	1	8	2	0	y	42.5	0.2	25.0	0.2	43.5	0.2		
06/25/23	8146(L)	DV	85	7	1	5	4	0	y	12.0	0.2	12.0	0.2	15.5	0.2		

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Appendix A2.–Egan Drive Creek fish passage trial data.

Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
09/07/24	3469	CO	115	14	1	ND	0	0	n								
09/07/24	8300	CO	85	6.7	1	ND	0	0	n								
09/07/24	8308	CO	80	6.8	1	ND	0	0	n								
09/07/24	8314	CO	91	9.3	1	ND	5	0	y					13.0	0.5		
09/07/24	8320	CO	115	19	1	ND	0	0	n								
09/07/24	8337	CO	97	9.8	1	ND	0	0	n								
09/07/24	8338	CO	75	5.4	1	ND	0	0	n								
09/07/24	8339	CO	102	14.1	1	ND	0	0	n								
09/07/24	8340	CO	75	4.9	1	ND	0	0	n								
09/07/24	8343	CO	90	10.2	1	ND	0	0	n								
09/07/24	8347	CO	69	4.2	1	ND	0	0	n								
09/07/24	8348	CO	87	7.7	1	ND	1	0	y					8.5			
09/07/24	8353	CO	119	18.9	1	ND	0	0	n								
09/07/24	8358	CO	70	3.9	1	ND	5	0	y					26.5	0.6		
09/07/24	8359	CO	124	22.3	1	ND	0	0	n								
09/07/24	8360	CO	99	12.5	1	ND	0	1	n							12.5	0.5
09/07/24	8362	CO	67	3.5	1	ND	2	0	y					25.5	0.6		
09/07/24	8376	CO	121	19.8	1	ND	0	0	n								
09/07/24	8389	CO	88	5.7	1	ND	0	0	n								
09/07/24	8397	CO	92	10.5	1	ND	0	0	n								
09/07/24	8398	CO	92	8.9	1	ND	2	0	y					17.0	0.5		
09/07/24	3460	CO	95	10.5	2	ND	0	0	n								
09/07/24	3478	CO	100	11	2	ND	0	0	n								
09/07/24	8302	CO	84	6.7	2	ND	0	0	n								
09/07/24	8303	CO	97	10.9	2	ND	0	0	n								
09/07/24	8310	CO	86	8.8	2	ND	1	0	y			0.0	0.5	13.0	0.5		
09/07/24	8315	CO	100	11.7	2	ND	0	0	n								
09/07/24	8316	CO	120	15.6	2	ND	0	0	n								
09/07/24	8321	CO	115	13.1	2	ND	3	0	y			0.0	0.5	14.5	0.5		
09/07/24	8326	CO	78	6	2	ND	0	0	n								
09/07/24	8328	CO	75	4.8	2	ND	0	0	n								
09/07/24	8334	CO	126	24.5	2	ND	0	0	n								

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
09/07/24	8342	CO	69	4	2	ND	0	0	n								
09/07/24	8345	CO	67	3.6	2	ND	0	0	n								
09/07/24	8350	CO	115	18	2	ND	0	0	n								
09/07/24	8354	CO	79	6.8	2	ND	0	0	n								
09/07/24	8364	CO	103	13.1	2	ND	0	0	n								
09/07/24	8369	CO	103	13.9	2	ND	0	0	n								
09/07/24	8372	CO	70	3.8	2	ND	0	0	n								
09/07/24	8375	CO	89	8.6	2	ND	1	0	y			0.0	0.5	15.0	0.5		
09/07/24	8384	CO	91	8.2	2	ND	0	0	n								
09/07/24	8388	CO	88	7.8	2	ND	0	0	n								
09/07/24	8399	CO	118	18.7	2	ND	0	0	n								
09/07/24	8304	CO	75	4.5	Control	ND	0	0	n								
09/07/24	8305	CO	102	12.4	Control	ND	1	0	n					38.0	0.5		
09/07/24	8307	CO	85	7.3	Control	ND	0	0	n								
09/07/24	8309	CO	81	6.5	Control	ND	0	0	n								
09/07/24	8313	CO	120	21.3	Control	ND	0	0	n								
09/07/24	8319	CO	114	16.1	Control	ND	0	2	y							16.0	0.5
09/07/24	8341	CO	82	6.7	Control	ND	0	0	n								
09/07/24	8352	CO	69	3.7	Control	ND	0	0	n								
09/07/24	8355	CO	88	7.2	Control	ND	0	0	n								
09/07/24	8356	CO	78	6.2	Control	ND	0	0	n								
09/07/24	8361	CO	76	5.1	Control	ND	0	0	n								
09/07/24	8365	CO	120	21.5	Control	ND	0	2	y							8.0	0.5
09/07/24	8366	CO	120	20.6	Control	ND	0	0	n								
09/07/24	8377	CO	76	5	Control	ND	0	0	n								
09/07/24	8378	CO	119	21.2	Control	ND	0	0	n								
09/07/24	8380	CO	132	27.4	Control	ND	0	2	y							16.5	0.5
09/07/24	8383	CO	80	5.6	Control	ND	0	1	y							7.0	
09/07/24	8386	CO	109	14.1	Control	ND	0	0	n								
09/07/24	8390	CO	76	5.2	Control	ND	0	1	y							7.0	
09/07/24	8394	CO	102	12	Control	ND	0	0	n								
09/07/24	3440	DV	81	5.2	1	ND	2	0	y				0.5	2.5	0.5		

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
09/07/24	3483	DV	93	9	1	ND	0	0	n				0.5				
09/07/24	3487	DV	124	18.2	1	ND	1	0	y				0.5	8.5			
09/07/24	8329	DV	130	29.2	1	ND	0	0	n				0.5				
09/07/24	8330	DV	90	7.5	1	ND	1	0	y				0.5	2.0	0.5		
09/07/24	8335	DV	62	2.5	1	ND	4	0	y				0.5	12.5	0.5		
09/07/24	8344	DV	79	4.4	1	ND	0	0	n				0.5				
09/07/24	8346	DV	120	19	1	ND	1	0	y				0.5	9.0	0.5		
09/07/24	8367	DV	91	8.3	1	ND	12	0	y				0.5	17.0	0.5		
09/07/24	8391	DV	135	21.2	1	ND	4	0	y				0.5	26.5	0.6		
09/07/24	8396	DV	82	5.7	1	ND	0	126	n				0.5			13.0	0.5
09/07/24	3417	DV	82	5.6	2	ND	3	0	y				0.5	2.5	0.5		
09/07/24	3465	DV	148	35.5	2	ND	6	0	y				0.5	39.0	0.6		
09/07/24	8312	DV	95	8	2	ND	0	0	n								
09/07/24	8323	DV	104	9.8	2	ND	3	0	y			0.0	0.5	13.0	0.5		
09/07/24	8332	DV	115	9	2	ND	3	0	y			0.0	0.5	1.5	0.5		
09/07/24	8368	DV	140	32.3	2	ND	0	0	n								
09/07/24	8374	DV	121	21.7	2	ND	0	0	n								
09/07/24	8381	DV	130	22	2	ND	0	1	n							2.0	0.5
09/07/24	8385	DV	95	7.6	2	ND	0	4	n							1.0	0.5
09/07/24	8393	DV	95	8.1	2	ND	3	0	y			0.0	0.5	1.0	0.5		
09/07/24	3400	DV	135	29.8	2	ND	0	0	n								
09/07/24	3430	DV	117	17.1	Control	ND	0	3	y							0.5	0.5
09/07/24	3439	DV	58	1.8	Control	ND	0	0	n								
09/07/24	8306	DV	154	10.9	Control	ND	0	0	n								
09/07/24	8317	DV	150	32.8	Control	ND	0	0	n								
09/07/24	8325	DV	78	4.6	Control	ND	0	2	y							2.5	0.5
09/07/24	8327	DV	109	11.7	Control	ND	0	2	y							1.0	0.5
09/07/24	8331	DV	65	3.1	Control	ND	0	0	n								
09/07/24	8370	DV	64	2.8	Control	ND	0	0	n								
09/07/24	8371	DV	50	ND	Control	ND	5	7	y					9.5	0.5	1.5	0.5
09/23/24	3301	CO	88	8.4	1	11	0	2	n	30	13.9	44.5	6.1				
09/23/24	3305	CO	124	20.1	1	0	0	7	n								

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
09/23/24	3330	CO	117	17.4	1	0	0	1	n								
09/23/24	3335	CO	99	11.5	1	0	0	1	n								
09/23/24	3345	CO	104	15.9	1	2	0	0	n	0.5	0.5	33.0	13.1				
09/23/24	3348	CO	108	14.4	1	2	7	1	y	1	1.9	1.5	0.6	4.0	0.8		
09/23/24	3351	CO	122	20.5	1	0	0	3	n								
09/23/24	3392	CO	122	20	1	0	0	4	n								
09/23/24	3393	CO	109	16.6	1	1	0	1	n	1	1.9	1.0	1.9				
09/23/24	3398	CO	118	20.1	1	0	0	21	n								
09/23/24	3403	CO	114	19.7	1	1	1	0	y	1.5	0.6	1.5	0.6	3.5	0.7		
09/23/24	3416	CO	126	23.7	1	0	0	3	n								
09/23/24	3422	CO	96	10.2	1	43	0	5	n	2	0.6	44.0	7.0				
09/23/24	3432	CO	104	13.4	1	43	0	0	n	25	9.7	32.0	13.4				
09/23/24	3433	CO	92	9.7	1	2	0	0	n	30.5	14.5	44.5	6.1				
09/23/24	3441	CO	88	8.6	1	75	0	0	n	25	9.7	44.5	6.1				
09/23/24	3442	CO	93	10.1	1	1	0	1	n	3.5	0.7	3.5	0.7				
09/23/24	3446	CO	75	6.3	1	1	0	13	n	3	0.7	3.0	0.7				
09/23/24	3448	CO	76	5.6	1	12	0	0	n	26.5	9.8	44.5	6.1				
09/23/24	3450	CO	110	17	1	7	0	0	n	30.5	14.5	44.5	6.1				
09/23/24	3453	CO	119	20.6	1	0	0	0	n								
09/23/24	3454	CO	78	4	1	0	0	5	n								
09/23/24	3459	CO	99	12.6	1	150	0	4	n	1.5	0.6	31.5	13.9				
09/23/24	3475	CO	109	15.9	1	1	0	2	n	25.5	9.8	25.5	9.8				
09/23/24	3484	CO	129	23.2	1	180	0	1	n	25	9.7	45.5	5.5				
09/23/24	3486	CO	99	11.7	1	1	0	3	n	1.5	0.6	1.5	0.6				
09/23/24	3490	CO	112	18	1	5	0	0	n	33	13.1	33.0	13.1				
09/23/24	3492	CO	116	18.7	1	14	1	1	y	28	10.8	45.5	5.5	28.0	10.8		
09/23/24	3493	CO	97	9.7	1	0	0	7	n								
09/23/24	3300	CO	103	12.7	2	0	0	1	n								
09/23/24	3316	CO	108	14.8	2	10	0	0	n	26	9.8	30.5	14.5				
09/23/24	3337	CO	122	20.2	2	0	402	0	y					6.0	1.9		
09/23/24	3341	CO	100	11.6	2	22	0	3	n	26	9.8	32.0	13.4				
09/23/24	3353	CO	100	12	2	3	0	0	n	1	1.9	44.0	7.0				

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
09/23/24	3356	CO	107	15.1	2	0	0	14	n								
09/23/24	3374	CO	119	21.8	2	0	0	1	n								
09/23/24	3387	CO	112	17.6	2	0	6	0	y					3.0	0.7		
09/23/24	3396	CO	106	14.9	2	1	0	0	n	26	9.8	26.0	9.8				
09/23/24	3406	CO	67	4.5	2	2	0	0	n	8	6.0	19.0	12.6				
09/23/24	3412	CO	104	13.1	2	0	0	1	n								
09/23/24	3418	CO	102	15.6	2	0	0	11	n								
09/23/24	3419	CO	120	20.7	2	0	0	1	n								
09/23/24	3423	CO	108	15	2	0	0	5	n								
09/23/24	3436	CO	112	17.1	2	0	1968	0	y					4.0	0.8		
09/23/24	3443	CO	94	9.8	2	0	0	0	n								
09/23/24	3445	CO	108	14.3	2	0	0	5	n								
09/23/24	3449	CO	94	9.6	2	1	0	0	n	26	9.8	26.0	9.8				
09/23/24	3455	CO	108	14.3	2	0	0	0	n								
09/23/24	3462	CO	114	18.4	2	0	0	2	n								
09/23/24	3464	CO	116	19.7	2	1	0	1	n	3	0.7	3.0	0.7				
09/23/24	3468	CO	102	12.7	2	0	0	1	n								
09/23/24	3482	CO	118	18.8	2	0	0	3	n								
09/23/24	3485	CO	97	11	2	1	0	2	n	1.5	0.6	1.5	0.6				
09/23/24	3495	CO	121	23.1	2	57	0	0	n	25	9.7	44.5	6.1				
09/23/24	3498	CO	112	16.2	2	2	0	1	n	2	0.6	2.0	0.6				
09/23/24	3499	CO	97	11.8	2	0	0	1	n								
09/23/24	3304	CO	110	14.3	Control	0	0	0	n								
09/23/24	3311	CO	104	13.4	Control	0	0	0	n								
09/23/24	3334	CO	114	17.2	Control	0	6	3	y							5.5	1.4
09/23/24	3358	CO	110	15.8	Control	0	0	0	n								
09/23/24	3372	CO	104	14.1	Control	0	4	6	y							4.5	0.9
09/23/24	3376	CO	110	16.6	Control	0	0	0	n								
09/23/24	3378	CO	126	26.5	Control	0	0	0	n								
09/23/24	3388	CO	116	20.1	Control	1275	0	18	y							3.0	0.7
09/23/24	3394	CO	118	18.7	Control	186	0	0	n								
09/23/24	3407	CO	103	12.3	Control	71	0	1	y							3.5	0.7

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
09/23/24	3408	CO	78	5.1	Control	0	0	0	n								
09/23/24	3410	CO	132	25.9	Control	0	0	2	y							6.0	1.9
09/23/24	3413	CO	120	23.1	Control	0	3	4	y							4.5	0.9
09/23/24	3420	CO	88	8.6	Control	0	0	0	n								
09/23/24	3421	CO	103	12	Control	0	0	1	y							11.5	7.8
09/23/24	3425	CO	104	14.7	Control	1	0	15	y							6.0	1.9
09/23/24	3427	CO	109	15.2	Control	29	0	2	y							3.5	0.7
09/23/24	3431	CO	96	11.6	Control	0	0	0	n								
09/23/24	3434	CO	106	12.6	Control	31	0	4	y							6.5	2.7
09/23/24	3435	CO	108	15.3	Control	0	0	0	n								
09/23/24	3437	CO	88	7.8	Control	0	0	0	n								
09/23/24	3452	CO	87	6.7	Control	0	0	0	n								
09/23/24	3461	CO	106	14.6	Control	0	0	0	n								
09/23/24	3467	CO	114	15.7	Control	0	0	0	n								
09/23/24	3481	CO	91	8.6	Control	0	0	0	n								
09/23/24	3489	CO	104	15.4	Control	0	0	0	n								
09/23/24	3497	CO	92	6.8	Control	0	0	0	n								
09/23/24	8338	CO	78	6.3	Control	0	0	0	n								
09/23/24	3340	DV	130	22.1	1	3	0	1	n	2.5	2.1	3.5	0.7				
09/23/24	3366	DV	55	1.6	1	0	0	0	n								
09/23/24	3369	DV	61	2.8	1	0	0	0	n								
09/23/24	3402	DV	78	5.3	1	48	0	0	n	1.5	0.6	8.5	7.1				
09/23/24	3404	DV	58	2.4	1	0	0	0	n								
09/23/24	3405	DV	116	16.6	1	2	7	17	y	1	1.9	2.0	0.6	4.0	0.8		
09/23/24	3409	DV	58	2	1	0	0	0	n								
09/23/24	3438	DV	92	7.2	1	375	0	0	n	1.5	0.6	45.5	5.5				
09/23/24	3457	DV	143	28.7	1	0	0	0	n								
09/23/24	3466	DV	148	43.8	1	1	2	2	y	2.5	2.1	2.5	2.1	3.5	0.7		
09/23/24	3473	DV	101	12.7	1	3	1	0	y	1.5	0.6	2.0	0.6	2.5	2.1		
09/23/24	3476	DV	62	2.5	1	0	0	0	n								
09/23/24	3477	DV	133	27.7	1	11	2	2	y	1	1.9	4.5	0.9	3.5	0.7		
09/23/24	3429	DV	126	18.2	2	2	2	1	y	2	0.6	2.5	2.1	3.5	0.7		

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Trial date	Tag no. (Legacy: L)	Species	FL (mm)	Weight (g)	Group	No. outlet antenna detects.	No. intlet antenna detects.	No. contr. antenna detects.	Passed (y/n)	Outlet ant. 1st det. (h)	Q at detect. (ft^3/s)	Outlet ant. last det. (h)	Q at detect. (ft^3/s)	ant. 1st detect. (h)	Q at detect. (ft^3/s)	Control ant. 1st det. (h)	Q at detect. (ft^3/s)
09/23/24	3350	DV	57	2	2	2	0	0	n	2	0.6	2.0	0.6				
09/23/24	3401	DV	71	3.8	2	16	0	1	n	1.5	0.6	3.0	0.7				
09/23/24	3411	DV	114	14.6	2	0	0	2	n								
09/23/24	3414	DV	82	5.8	2	0	0	0	n								
09/23/24	3428	DV	125	23.7	2	2	3	1	y	1	1.9	3.0	0.7	4.0	0.8		
09/23/24	3456	DV	58	2.1	2	0	0	0	n								
09/23/24	3470	DV	131	24.2	2	3	6	24	y	2	0.6	34.5	11.8	4.0	0.8		
09/23/24	3472	DV	137	29.3	2	1	2	1	y	4	0.8	4.0	0.8	1.0	1.9		
09/23/24	3474	DV	136	25.5	2	2	6	3	y	1.5	0.6	2.5	2.1	3.0	0.7		
09/23/24	3491	DV	136	26.1	2	0	0	21	n								
09/23/24	3494	DV	143	28.1	2	3	3	19	y	1.5	0.6	35.5	11.6	1.0	1.9		
09/23/24	3381	DV	64	2.5	Control	0	0	0	n								
09/23/24	3415	DV	59	2.7	Control	0	0	0	n								
09/23/24	3424	DV	58	2.3	Control	0	0	0	n								
09/23/24	3426	DV	141	28	Control	0	0	0	n								
09/23/24	3458	DV	88	7.2	Control	13	0	1	y							1.5	0.6
09/23/24	3463	DV	97	9.5	Control	77	5	0	n								
09/23/24	3471	DV	92	7.1	Control	0	0	7	y							1.5	0.6
09/23/24	3479	DV	93	8.1	Control	1	0	3	y							18.5	11.7
09/23/24	3480	DV	127	25.7	Control	0	0	0	n								
09/23/24	3488	DV	122	19.2	Control	0	0	6	y							3.0	0.7
09/23/24	8323	DV	104	10.5	Control	0	0	11	y							45.5	5.5

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APPENDIX C: WATER LEVEL DATA BY PASSAGE TRIAL

Appendix B1.–Water level data for 04/27/22 and 06/22/22 trials at Ninemile Creek.

Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)	Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)
4/27/22 12:00	0.0	0.824	3.3	37.1	6/22/22 11:30	0.0	0.710	1.8	47.6
4/27/22 12:30	0.5	0.826	3.8	37.1	6/22/22 12:00	0.5	0.705	1.7	47.6
4/27/22 13:00	1.0	0.829	3.4	37.3	6/22/22 12:30	1.0	0.700	1.7	47.6
4/27/22 13:30	1.5	0.823	3.3	37.3	6/22/22 13:00	1.5	0.698	1.7	47.6
4/27/22 14:00	2.0	0.831	3.4	37.3	6/22/22 13:30	2.0	0.695	1.6	47.6
4/27/22 14:30	2.5	0.838	3.6	37.3	6/22/22 14:00	2.5	0.684	1.5	47.8
4/27/22 15:00	3.0	0.833	3.5	37.5	6/22/22 14:30	3.0	0.686	1.6	47.8
4/27/22 15:30	3.5	0.856	3.9	37.5	6/22/22 15:00	3.5	0.677	1.5	47.8
4/27/22 16:00	4.0	0.850	3.8	37.5	6/22/22 15:30	4.0	0.673	1.4	48.0
4/27/22 16:30	4.5	0.851	3.8	37.5	6/22/22 16:00	4.5	0.668	1.4	48.0
4/27/22 17:00	5.0	0.855	3.9	37.5	6/22/22 16:30	5.0	0.663	1.4	48.0
4/27/22 17:30	5.5	0.851	3.8	37.5	6/22/22 17:00	5.5	0.655	1.3	48.2
4/27/22 18:00	6.0	0.855	3.9	37.5	6/22/22 17:30	6.0	0.654	1.3	48.2
4/27/22 18:30	6.5	0.849	3.8	37.5	6/22/22 18:00	6.5	0.642	1.2	48.2
4/27/22 19:00	7.0	0.848	3.7	37.5	6/22/22 18:30	7.0	0.639	1.2	48.2
4/27/22 19:30	7.5	0.845	3.7	37.5	6/22/22 19:00	7.5	0.640	1.2	48.2
4/27/22 20:00	8.0	0.838	3.6	37.5	6/22/22 19:30	8.0	0.619	1.0	48.0
4/27/22 20:30	8.5	0.832	3.5	37.5	6/22/22 20:00	8.5	0.621	1.0	48.0
4/27/22 21:00	9.0	0.831	3.4	37.5	6/22/22 20:30	9.0	0.616	1.0	48.0
4/27/22 21:30	9.5	0.824	3.3	37.5	6/22/22 21:00	9.5	0.612	1.0	48.0
4/27/22 22:00	10.0	0.830	3.4	37.3	6/22/22 21:30	10.0	0.608	0.9	48.0
4/27/22 22:30	10.5	0.810	3.1	37.3	6/22/22 22:00	10.5	0.605	0.9	48.0
4/27/22 23:00	11.0	0.809	3.1	37.3	6/22/22 22:30	11.0	0.597	0.9	48.0
4/27/22 23:30	11.5	0.808	3.1	37.3	6/22/22 23:00	11.5	0.599	0.9	48.0
4/28/22 0:00	12.0	0.803	3.0	37.3	6/22/22 23:30	12.0	0.590	0.8	47.8
4/28/22 0:30	12.5	0.799	2.9	37.1	6/23/22 0:00	12.5	0.587	0.8	47.8
4/28/22 1:00	13.0	0.792	2.8	37.1	6/23/22 0:30	13.0	0.591	0.8	47.8
4/28/22 1:30	13.5	0.785	2.7	37.1	6/23/22 1:00	13.5	0.581	0.8	47.8
4/28/22 2:00	14.0	0.784	2.7	36.9	6/23/22 1:30	14.0	0.583	0.8	47.6
4/28/22 2:30	14.5	0.790	2.8	36.9	6/23/22 2:00	14.5	0.566	0.7	47.6
4/28/22 3:00	15.0	0.774	2.6	36.9	6/23/22 2:30	15.0	0.564	0.7	47.6
4/28/22 3:30	15.5	0.778	2.6	36.9	6/23/22 3:00	15.5	0.570	0.7	47.6
4/28/22 4:00	16.0	0.764	2.4	36.9	6/23/22 3:30	16.0	0.574	0.7	47.6
4/28/22 4:30	16.5	0.762	2.4	36.7	6/23/22 4:00	16.5	0.563	0.7	47.6
4/28/22 5:00	17.0	0.749	2.2	36.7	6/23/22 4:30	17.0	0.565	0.7	47.6
4/28/22 5:30	17.5	0.749	2.2	36.7	6/23/22 5:00	17.5	0.561	0.7	47.6
4/28/22 6:00	18.0	0.749	2.2	36.7	6/23/22 5:30	18.0	0.564	0.7	47.6
4/28/22 6:30	18.5	0.738	2.1	36.5	6/23/22 6:00	18.5	0.558	0.7	47.6
4/28/22 7:00	19.0	0.736	2.1	36.5	6/23/22 6:30	19.0	0.548	0.6	47.6
4/28/22 7:30	19.5	0.732	2.0	36.5	6/23/22 7:00	19.5	0.553	0.6	47.6
4/28/22 8:00	20.0	0.728	2.0	36.7	6/23/22 7:30	20.0	0.544	0.6	47.8
4/28/22 8:30	20.5	0.727	2.0	36.7	6/23/22 8:00	20.5	0.546	0.6	47.8
4/28/22 9:00	21.0	0.728	2.0	36.9	6/23/22 8:30	21.0	0.539	0.6	47.8
4/28/22 9:30	21.5	0.725	2.0	36.9	6/23/22 9:00	21.5	0.545	0.6	47.8
4/28/22 10:00	22.0	0.716	1.9	37.1	6/23/22 9:30	22.0	0.542	0.6	48.0
4/28/22 10:30	22.5	0.707	1.8	37.1	6/23/22 10:00	22.5	0.529	0.5	48.2
4/28/22 11:00	23.0	0.704	1.7	37.3	6/23/22 10:30	23.0	0.527	0.5	48.3
4/28/22 11:30	23.5	0.706	1.8	37.5	6/23/22 11:00	23.5	0.533	0.5	48.7
4/28/22 12:00	24.0	0.708	1.8	37.7	6/23/22 11:30	24.0	0.519	0.5	49.1
4/28/22 12:30	24.5	0.701	1.7	37.9	6/23/22 12:00	24.5	0.513	0.5	49.4
4/28/22 13:00	25.0	0.693	1.6	38.1	6/23/22 12:30	25.0	0.516	0.5	49.6
4/28/22 13:30	25.5	0.685	1.5	38.1	6/23/22 13:00	25.5	0.507	0.4	49.9
4/28/22 14:00	26.0	0.676	1.5	38.1	6/23/22 13:30	26.0	0.506	0.4	50.1
4/28/22 14:30	26.5	0.682	1.5	38.3	6/23/22 14:00	26.5	0.505	0.4	50.3
4/28/22 15:00	27.0	0.682	1.5	38.3	6/23/22 14:30	27.0	0.504	0.4	50.5

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Appendix B1.–Page 2 of 2.

Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)	Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)
4/28/22 15:30	27.5	0.673	1.4	38.4	6/23/22 15:00	27.5	0.498	0.4	50.8
4/28/22 16:00	28.0	0.670	1.4	38.4	6/23/22 15:30	28.0	0.497	0.4	50.6
4/28/22 16:30	28.5	0.672	1.4	38.4	6/23/22 16:00	28.5	0.499	0.4	50.8
4/28/22 17:00	29.0	0.670	1.4	38.4	6/23/22 16:30	29.0	0.487	0.4	50.8
4/28/22 17:30	29.5	0.662	1.3	38.4	6/23/22 17:00	29.5	0.489	0.4	50.6
4/28/22 18:00	30.0	0.667	1.4	38.4	6/23/22 17:30	30.0	0.487	0.4	50.6
4/28/22 18:30	30.5	0.665	1.4	38.4	6/23/22 18:00	30.5	0.486	0.4	50.6
4/28/22 19:00	31.0	0.657	1.3	38.4	6/23/22 18:30	31.0	0.485	0.4	50.6
4/28/22 19:30	31.5	0.657	1.3	38.4	6/23/22 19:00	31.5	0.488	0.4	50.6
4/28/22 20:00	32.0	0.654	1.3	38.3	6/23/22 19:30	32.0	0.477	0.3	50.5
4/28/22 20:30	32.5	0.650	1.2	38.3	6/23/22 20:00	32.5	0.480	0.4	50.5
4/28/22 21:00	33.0	0.646	1.2	38.3	6/23/22 20:30	33.0	0.479	0.4	50.5
4/28/22 21:30	33.5	0.645	1.2	38.1	6/23/22 21:00	33.5	0.478	0.3	50.3
4/28/22 22:00	34.0	0.648	1.2	38.1	6/23/22 21:30	34.0	0.476	0.3	50.3
4/28/22 22:30	34.5	0.644	1.2	37.9	6/23/22 22:00	34.5	0.473	0.3	50.1
4/28/22 23:00	35.0	0.639	1.2	37.9	6/23/22 22:30	35.0	0.473	0.3	50.1
4/28/22 23:30	35.5	0.645	1.2	37.7	6/23/22 23:00	35.5	0.471	0.3	49.9
4/29/22 0:00	36.0	0.637	1.1	37.7	6/23/22 23:30	36.0	0.470	0.3	49.9
4/29/22 0:30	36.5	0.638	1.2	37.5	6/24/22 0:00	36.5	0.479	0.4	49.8
4/29/22 1:00	37.0	0.630	1.1	37.3	6/24/22 0:30	37.0	0.471	0.3	49.8
4/29/22 1:30	37.5	0.630	1.1	37.3	6/24/22 1:00	37.5	0.473	0.3	49.6
4/29/22 2:00	38.0	0.619	1.0	37.1	6/24/22 1:30	38.0	0.465	0.3	49.6
4/29/22 2:30	38.5	0.624	1.1	36.9	6/24/22 2:00	38.5	0.474	0.3	49.4
4/29/22 3:00	39.0	0.619	1.0	36.7	6/24/22 2:30	39.0	0.476	0.3	49.2
4/29/22 3:30	39.5	0.621	1.0	36.7	6/24/22 3:00	39.5	0.472	0.3	49.2
4/29/22 4:00	40.0	0.619	1.0	36.5	6/24/22 3:30	40.0	0.473	0.3	49.1
4/29/22 4:30	40.5	0.615	1.0	36.5	6/24/22 4:00	40.5	0.476	0.3	49.1
4/29/22 5:00	41.0	0.617	1.0	36.3	6/24/22 4:30	41.0	0.475	0.3	48.9
4/29/22 5:30	41.5	0.618	1.0	36.1	6/24/22 5:00	41.5	0.471	0.3	48.9
4/29/22 6:00	42.0	0.612	1.0	36.1	6/24/22 5:30	42.0	0.465	0.3	48.7
4/29/22 6:30	42.5	0.619	1.0	36.1	6/24/22 6:00	42.5	0.465	0.3	48.7
4/29/22 7:00	43.0	0.615	1.0	36.1	6/24/22 6:30	43.0	0.461	0.3	48.7
4/29/22 7:30	43.5	0.612	1.0	36.1	6/24/22 7:00	43.5	0.466	0.3	48.7
4/29/22 8:00	44.0	0.603	0.9	36.1	6/24/22 7:30	44.0	0.465	0.3	48.7
4/29/22 8:30	44.5	0.609	1.0	36.1	6/24/22 8:00	44.5	0.445	0.3	48.7
					6/24/22 8:30	45.0	0.457	0.3	48.9
					6/24/22 9:00	45.5	0.450	0.3	49.1

Appendix B2.–Water level data for 07/27/22 and 10/5/22 trials at Ninemile Creek.

Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)	Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)
7/27/22 10:00	0.0	0.584	0.8	51.9	10/5/22 12:30	0.0	0.373	0.6	48.2
7/27/22 10:30	0.5	0.584	0.8	51.9	10/5/22 13:00	0.5	0.364	0.6	48.2
7/27/22 11:00	1.0	0.568	0.7	51.7	10/5/22 13:30	1.0	0.364	0.6	48.3
7/27/22 11:30	1.5	0.572	0.7	51.9	10/5/22 14:00	1.5	0.355	0.5	48.3
7/27/22 12:00	2.0	0.566	0.7	52.2	10/5/22 14:30	2.0	0.362	0.6	48.5
7/27/22 12:30	2.5	0.570	0.7	52.4	10/5/22 15:00	2.5	0.360	0.6	48.7
7/27/22 13:00	3.0	0.558	0.7	52.6	10/5/22 15:30	3.0	0.361	0.6	48.9
7/27/22 13:30	3.5	0.557	0.7	52.8	10/5/22 16:00	3.5	0.359	0.6	48.9
7/27/22 14:00	4.0	0.552	0.6	52.9	10/5/22 16:30	4.0	0.358	0.6	49.1
7/27/22 14:30	4.5	0.554	0.6	52.9	10/5/22 17:00	4.5	0.358	0.6	49.1
7/27/22 15:00	5.0	0.555	0.6	52.9	10/5/22 17:30	5.0	0.355	0.5	49.1
7/27/22 15:30	5.5	0.550	0.6	52.9	10/5/22 18:00	5.5	0.351	0.5	49.1
7/27/22 16:00	6.0	0.554	0.6	52.9	10/5/22 18:30	6.0	0.360	0.6	49.1
7/27/22 16:30	6.5	0.551	0.6	52.9	10/5/22 19:00	6.5	0.362	0.6	49.1
7/27/22 17:00	7.0	0.547	0.6	52.9	10/5/22 19:30	7.0	0.364	0.6	49.1
7/27/22 17:30	7.5	0.546	0.6	52.9	10/5/22 20:00	7.5	0.357	0.6	49.1
7/27/22 18:00	8.0	0.545	0.6	52.9	10/5/22 20:30	8.0	0.367	0.6	49.1
7/27/22 18:30	8.5	0.546	0.6	52.8	10/5/22 21:00	8.5	0.354	0.5	48.9
7/27/22 19:00	9.0	0.539	0.6	52.8	10/5/22 21:30	9.0	0.360	0.6	48.9
7/27/22 19:30	9.5	0.542	0.6	52.8	10/5/22 22:00	9.5	0.360	0.6	48.9
7/27/22 20:00	10.0	0.545	0.6	52.8	10/5/22 22:30	10.0	0.359	0.6	48.9
7/27/22 20:30	10.5	0.543	0.6	52.6	10/5/22 23:00	10.5	0.358	0.6	48.9
7/27/22 21:00	11.0	0.538	0.6	52.6	10/5/22 23:30	11.0	0.356	0.6	48.9
7/27/22 21:30	11.5	0.541	0.6	52.6	10/6/22 0:00	11.5	0.364	0.6	48.9
7/27/22 22:00	12.0	0.538	0.6	52.6	10/6/22 0:30	12.0	0.357	0.6	48.9
7/27/22 22:30	12.5	0.544	0.6	52.6	10/6/22 1:00	12.5	0.357	0.6	48.9
7/27/22 23:00	13.0	0.548	0.6	52.6	10/6/22 1:30	13.0	0.358	0.6	48.9
7/27/22 23:30	13.5	0.550	0.6	52.6	10/6/22 2:00	13.5	0.359	0.6	48.9
7/28/22 0:00	14.0	0.552	0.6	52.6	10/6/22 2:30	14.0	0.360	0.6	48.9
7/28/22 0:30	14.5	0.559	0.7	52.6	10/6/22 3:00	14.5	0.355	0.5	48.9
7/28/22 1:00	15.0	0.570	0.7	52.6	10/6/22 3:30	15.0	0.351	0.5	48.9
7/28/22 1:30	15.5	0.576	0.8	52.6	10/6/22 4:00	15.5	0.359	0.6	48.9
7/28/22 2:00	16.0	0.585	0.8	52.6	10/6/22 4:30	16.0	0.362	0.6	48.9
7/28/22 2:30	16.5	0.597	0.9	52.4	10/6/22 5:00	16.5	0.362	0.6	48.9
7/28/22 3:00	17.0	0.645	1.2	52.4	10/6/22 5:30	17.0	0.354	0.5	48.9
7/28/22 3:30	17.5	0.684	1.5	52.4	10/6/22 6:00	17.5	0.365	0.6	48.9
7/28/22 4:00	18.0	0.740	2.1	52.4	10/6/22 6:30	18.0	0.361	0.6	48.9
7/28/22 4:30	18.5	0.819	3.2	52.2	10/6/22 7:00	18.5	0.361	0.6	48.9
7/28/22 5:00	19.0	0.894	4.7	52.1	10/6/22 7:30	19.0	0.358	0.6	48.9
7/28/22 5:30	19.5	0.952	6.0	52.1	10/6/22 8:00	19.5	0.352	0.5	48.9
7/28/22 6:00	20.0	0.969	6.5	52.1	10/6/22 8:30	20.0	0.353	0.5	48.9
7/28/22 6:30	20.5	0.984	6.9	51.9	10/6/22 9:00	20.5	0.363	0.6	48.9
7/28/22 7:00	21.0	0.989	7.1	51.9	10/6/22 9:30	21.0	0.356	0.6	49.1
7/28/22 7:30	21.5	1.000	7.4	51.9	10/6/22 10:00	21.5	0.348	0.5	49.1
7/28/22 8:00	22.0	0.988	7.0	51.9	10/6/22 10:30	22.0	0.357	0.6	49.1
7/28/22 8:30	22.5	0.993	7.2	51.9	10/6/22 11:00	22.5	0.351	0.5	49.1
7/28/22 9:00	23.0	0.993	7.2	51.9	10/6/22 11:30	23.0	0.356	0.6	49.2
7/28/22 9:30	23.5	1.009	7.7	51.9	10/6/22 12:00	23.5	0.352	0.5	49.2
7/28/22 10:00	24.0	1.040	8.7	51.9	10/6/22 12:30	24.0	0.352	0.5	49.4
7/28/22 10:30	24.5	1.001	7.4	51.9	10/6/22 13:00	24.5	0.341	0.5	49.4
7/28/22 11:00	25.0	0.993	7.2	51.9	10/6/22 13:30	25.0	0.343	0.5	49.6
7/28/22 11:30	25.5	0.994	7.2	51.9	10/6/22 14:00	25.5	0.343	0.5	49.6
7/28/22 12:00	26.0	0.979	6.8	51.9	10/6/22 14:30	26.0	0.342	0.5	49.8
7/28/22 12:30	26.5	0.970	6.5	51.9	10/6/22 15:00	26.5	0.342	0.5	49.8
7/28/22 13:00	27.0	0.953	6.1	51.9	10/6/22 15:30	27.0	0.341	0.5	49.8

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Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)	Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)
7/28/22 13:30	27.5	0.953	6.1	51.9	10/6/22 16:00	27.5	0.342	0.5	49.8
7/28/22 14:00	28.0	0.945	5.9	52.1	10/6/22 16:30	28.0	0.341	0.5	49.8
7/28/22 14:30	28.5	0.930	5.5	52.1	10/6/22 17:00	28.5	0.342	0.5	49.8
7/28/22 15:00	29.0	0.941	5.7	52.1	10/6/22 17:30	29.0	0.340	0.5	49.6
7/28/22 15:30	29.5	0.940	5.7	52.1	10/6/22 18:00	29.5	0.349	0.5	49.6
7/28/22 16:00	30.0	0.947	5.9	52.2	10/6/22 18:30	30.0	0.343	0.5	49.6
7/28/22 16:30	30.5	0.943	5.8	52.2	10/6/22 19:00	30.5	0.342	0.5	49.4
7/28/22 17:00	31.0	0.970	6.5	52.2	10/6/22 19:30	31.0	0.349	0.5	49.4
7/28/22 17:30	31.5	0.973	6.6	52.2	10/6/22 20:00	31.5	0.350	0.5	49.2
7/28/22 18:00	32.0	0.991	7.1	52.2	10/6/22 20:30	32.0	0.358	0.6	49.2
7/28/22 18:30	32.5	1.001	7.4	52.2	10/6/22 21:00	32.5	0.350	0.5	49.2
7/28/22 19:00	33.0	1.008	7.6	52.2	10/6/22 21:30	33.0	0.355	0.5	49.2
7/28/22 19:30	33.5	1.015	7.9	52.1	10/6/22 22:00	33.5	0.352	0.5	49.2
7/28/22 20:00	34.0	1.013	7.8	52.1	10/6/22 22:30	34.0	0.346	0.5	49.2
7/28/22 20:30	34.5	1.026	8.2	52.1	10/6/22 23:00	34.5	0.343	0.5	49.2
7/28/22 21:00	35.0	1.018	8.0	52.1	10/6/22 23:30	35.0	0.350	0.5	49.2
7/28/22 21:30	35.5	1.011	7.7	52.1	10/7/22 0:00	35.5	0.347	0.5	49.2
7/28/22 22:00	36.0	1.012	7.8	52.1	10/7/22 0:30	36.0	0.353	0.5	49.2
7/28/22 22:30	36.5	1.014	7.8	52.1	10/7/22 1:00	36.5	0.350	0.5	49.2
7/28/22 23:00	37.0	0.999	7.4	52.1	10/7/22 1:30	37.0	0.342	0.5	49.2
7/28/22 23:30	37.5	0.992	7.1	51.9	10/7/22 2:00	37.5	0.352	0.5	49.2
7/29/22 0:00	38.0	0.985	6.9	51.9	10/7/22 2:30	38.0	0.345	0.5	49.2
7/29/22 0:30	38.5	0.965	6.4	51.9	10/7/22 3:00	38.5	0.344	0.5	49.2
7/29/22 1:00	39.0	0.971	6.5	51.9	10/7/22 3:30	39.0	0.348	0.5	49.1
7/29/22 1:30	39.5	0.960	6.2	51.9	10/7/22 4:00	39.5	0.346	0.5	49.1
7/29/22 2:00	40.0	0.955	6.1	51.9	10/7/22 4:30	40.0	0.347	0.5	49.1
7/29/22 2:30	40.5	0.938	5.7	51.9	10/7/22 5:00	40.5	0.352	0.5	49.1
7/29/22 3:00	41.0	0.934	5.6	51.9	10/7/22 5:30	41.0	0.347	0.5	49.1
7/29/22 3:30	41.5	0.926	5.4	51.9	10/7/22 6:00	41.5	0.352	0.5	49.1
7/29/22 4:00	42.0	0.920	5.2	51.9	10/7/22 6:30	42.0	0.355	0.5	48.9
7/29/22 4:30	42.5	0.927	5.4	51.7	10/7/22 7:00	42.5	0.354	0.5	48.9
7/29/22 5:00	43.0	0.909	5.0	51.7	10/7/22 7:30	43.0	0.349	0.5	48.9
7/29/22 5:30	43.5	0.908	5.0	51.7	10/7/22 8:00	43.5	0.345	0.5	48.9
7/29/22 6:00	44.0	0.905	4.9	51.7	10/7/22 8:30	44.0	0.353	0.5	48.7
7/29/22 6:30	44.5	0.893	4.6	51.7	10/7/22 9:00	44.5	0.350	0.5	48.7
7/29/22 7:00	45.0	0.890	4.6	51.7	10/7/22 9:30	45.0	0.349	0.5	48.7
7/29/22 7:30	45.5	0.880	4.4	51.7	10/7/22 10:00	45.5	0.355	0.5	48.7
7/29/22 8:00	46.0	0.872	4.2	51.7	10/7/22 10:30	46.0	0.348	0.5	48.9
7/29/22 8:30	46.5	0.862	4.0	51.7	10/7/22 11:00	46.5	0.349	0.5	48.9
7/29/22 9:00	47.0	0.848	3.7	51.9	10/7/22 11:30	47.0	0.342	0.5	48.9
7/29/22 9:30	47.5	0.847	3.7	51.9	10/7/22 12:00	47.5	0.349	0.5	48.9
7/29/22 10:00	48.0	0.837	3.5	51.9	10/7/22 12:30	48.0	0.344	0.5	49.1

Appendix B3.–Water level data for 05/24/23 and 06/21/23 trials at Ninemile Creek.

Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)	Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)
5/24/23 13:00	0.0	0.245	0.2	46.9	6/21/23 9:00	0.0	0.275	0.2	49.8
5/24/23 13:30	0.5	0.243	0.2	47.3	6/21/23 9:30	0.5	0.279	0.2	49.8
5/24/23 14:00	1.0	0.237	0.1	47.4	6/21/23 10:00	1.0	0.269	0.2	49.9
5/24/23 14:30	1.5	0.239	0.1	47.8	6/21/23 10:30	1.5	0.268	0.2	50.1
5/24/23 15:00	2.0	0.236	0.1	48.0	6/21/23 11:00	2.0	0.265	0.2	50.5
5/24/23 15:30	2.5	0.234	0.1	48.3	6/21/23 11:30	2.5	0.259	0.2	50.6
5/24/23 16:00	3.0	0.236	0.1	48.2	6/21/23 12:00	3.0	0.265	0.2	50.8
5/24/23 16:30	3.5	0.234	0.1	47.8	6/21/23 12:30	3.5	0.266	0.2	51.2
5/24/23 17:00	4.0	0.233	0.1	47.6	6/21/23 13:00	4.0	0.254	0.2	51.5
5/24/23 17:30	4.5	0.230	0.1	47.6	6/21/23 13:30	4.5	0.258	0.2	51.7
5/24/23 18:00	5.0	0.233	0.1	47.6	6/21/23 14:00	5.0	0.252	0.2	51.9
5/24/23 18:30	5.5	0.230	0.1	47.4	6/21/23 14:30	5.5	0.254	0.2	52.6
5/24/23 19:00	6.0	0.237	0.1	47.4	6/21/23 15:00	6.0	0.256	0.2	53.3
5/24/23 19:30	6.5	0.234	0.1	47.3	6/21/23 15:30	6.5	0.247	0.2	52.9
5/24/23 20:00	7.0	0.235	0.1	47.1	6/21/23 16:00	7.0	0.249	0.2	52.8
5/24/23 20:30	7.5	0.230	0.1	47.1	6/21/23 16:30	7.5	0.249	0.2	52.9
5/24/23 21:00	8.0	0.226	0.1	46.9	6/21/23 17:00	8.0	0.249	0.2	52.8
5/24/23 21:30	8.5	0.233	0.1	46.7	6/21/23 17:30	8.5	0.244	0.2	52.9
5/24/23 22:00	9.0	0.232	0.1	46.7	6/21/23 18:00	9.0	0.247	0.2	52.9
5/24/23 22:30	9.5	0.231	0.1	46.7	6/21/23 18:30	9.5	0.239	0.1	52.8
5/24/23 23:00	10.0	0.232	0.1	46.7	6/21/23 19:00	10.0	0.245	0.2	52.6
5/24/23 23:30	10.5	0.237	0.1	46.5	6/21/23 19:30	10.5	0.247	0.2	52.4
5/25/23 0:00	11.0	0.237	0.1	46.5	6/21/23 20:00	11.0	0.244	0.2	52.2
5/25/23 0:30	11.5	0.237	0.1	46.5	6/21/23 20:30	11.5	0.247	0.2	52.1
5/25/23 1:00	12.0	0.239	0.1	46.4	6/21/23 21:00	12.0	0.249	0.2	51.9
5/25/23 1:30	12.5	0.249	0.2	46.4	6/21/23 21:30	12.5	0.248	0.2	51.9
5/25/23 2:00	13.0	0.235	0.1	46.2	6/21/23 22:00	13.0	0.251	0.2	51.7
5/25/23 2:30	13.5	0.233	0.1	46.2	6/21/23 22:30	13.5	0.246	0.2	51.5
5/25/23 3:00	14.0	0.242	0.2	46.2	6/21/23 23:00	14.0	0.247	0.2	51.5
5/25/23 3:30	14.5	0.240	0.2	46.2	6/21/23 23:30	14.5	0.249	0.2	51.3
5/25/23 4:00	15.0	0.242	0.2	46.2	6/22/23 0:00	15.0	0.253	0.2	51.3
5/25/23 4:30	15.5	0.236	0.1	46.2	6/22/23 0:30	15.5	0.250	0.2	51.3
5/25/23 5:00	16.0	0.236	0.1	46.0	6/22/23 1:00	16.0	0.250	0.2	51.2
5/25/23 5:30	16.5	0.233	0.1	46.0	6/22/23 1:30	16.5	0.251	0.2	51.0
5/25/23 6:00	17.0	0.237	0.1	45.8	6/22/23 2:00	17.0	0.251	0.2	51.0
5/25/23 6:30	17.5	0.236	0.1	46.0	6/22/23 2:30	17.5	0.258	0.2	51.0
5/25/23 7:00	18.0	0.239	0.1	46.0	6/22/23 3:00	18.0	0.262	0.2	50.8
5/25/23 7:30	18.5	0.237	0.1	46.2	6/22/23 3:30	18.5	0.258	0.2	50.8
5/25/23 8:00	19.0	0.226	0.1	46.2	6/22/23 4:00	19.0	0.259	0.2	50.6
5/25/23 8:30	19.5	0.231	0.1	46.4	6/22/23 4:30	19.5	0.260	0.2	50.6
5/25/23 9:00	20.0	0.235	0.1	46.4	6/22/23 5:00	20.0	0.259	0.2	50.5
5/25/23 9:30	20.5	0.236	0.1	46.5	6/22/23 5:30	20.5	0.260	0.2	50.5
5/25/23 10:00	21.0	0.236	0.1	46.7	6/22/23 6:00	21.0	0.257	0.2	50.5
5/25/23 10:30	21.5	0.243	0.2	46.9	6/22/23 6:30	21.5	0.261	0.2	50.5
5/25/23 11:00	22.0	0.237	0.1	47.1	6/22/23 7:00	22.0	0.264	0.2	50.5
5/25/23 11:30	22.5	0.241	0.2	47.3	6/22/23 7:30	22.5	0.254	0.2	50.5
5/25/23 12:00	23.0	0.245	0.2	47.3	6/22/23 8:00	23.0	0.263	0.2	50.5
5/25/23 12:30	23.5	0.237	0.1	47.3	6/22/23 8:30	23.5	0.255	0.2	50.6
5/25/23 13:00	24.0	0.240	0.2	47.3	6/22/23 9:00	24.0	0.254	0.2	50.6
5/25/23 13:30	24.5	0.239	0.1	47.1	6/22/23 9:30	24.5	0.258	0.2	50.8
5/25/23 14:00	25.0	0.243	0.2	47.3	6/22/23 10:00	25.0	0.252	0.2	50.8
5/25/23 14:30	25.5	0.242	0.2	47.3	6/22/23 10:30	25.5	0.255	0.2	51.0
5/25/23 15:00	26.0	0.244	0.2	47.3	6/22/23 11:00	26.0	0.250	0.2	51.0
5/25/23 15:30	26.5	0.244	0.2	47.3	6/22/23 11:30	26.5	0.250	0.2	51.2
5/25/23 16:00	27.0	0.239	0.1	47.3	6/22/23 12:00	27.0	0.247	0.2	51.3

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Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)	Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)
5/25/23 16:30	27.5	0.239	0.1	47.1	6/22/23 12:30	27.5	0.245	0.2	51.3
5/25/23 17:00	28.0	0.243	0.2	47.1	6/22/23 13:00	28.0	0.244	0.2	51.5
5/25/23 17:30	28.5	0.246	0.2	47.1	6/22/23 13:30	28.5	0.236	0.1	51.5
5/25/23 18:00	29.0	0.256	0.2	47.1	6/22/23 14:00	29.0	0.255	0.2	51.7
5/25/23 18:30	29.5	0.268	0.2	47.4	6/22/23 14:30	29.5	0.247	0.2	51.7
5/25/23 19:00	30.0	0.278	0.2	47.4	6/22/23 15:00	30.0	0.247	0.2	51.9
5/25/23 19:30	30.5	0.287	0.3	47.4	6/22/23 15:30	30.5	0.243	0.2	51.9
5/25/23 20:00	31.0	0.298	0.3	47.6	6/22/23 16:00	31.0	0.235	0.1	52.1
5/25/23 20:30	31.5	0.307	0.3	47.3	6/22/23 16:30	31.5	0.246	0.2	52.2
5/25/23 21:00	32.0	0.321	0.4	47.1	6/22/23 17:00	32.0	0.239	0.1	52.2
5/25/23 21:30	32.5	0.320	0.4	45.8	6/22/23 17:30	32.5	0.252	0.2	52.6
5/25/23 22:00	33.0	0.333	0.4	45.8	6/22/23 18:00	33.0	0.248	0.2	52.6
5/25/23 22:30	33.5	0.365	0.6	46.2	6/22/23 18:30	33.5	0.237	0.1	52.6
5/25/23 23:00	34.0	0.379	0.7	46.2	6/22/23 19:00	34.0	0.240	0.2	52.4
5/25/23 23:30	34.5	0.384	0.7	46.4	6/22/23 19:30	34.5	0.242	0.2	52.4
5/26/23 0:00	35.0	0.396	0.8	46.4	6/22/23 20:00	35.0	0.245	0.2	52.4
5/26/23 0:30	35.5	0.386	0.7	46.5	6/22/23 20:30	35.5	0.244	0.2	52.2
5/26/23 1:00	36.0	0.380	0.7	46.7	6/22/23 21:00	36.0	0.241	0.2	52.2
5/26/23 1:30	36.5	0.373	0.6	46.7	6/22/23 21:30	36.5	0.239	0.1	52.1
5/26/23 2:00	37.0	0.372	0.6	46.7	6/22/23 22:00	37.0	0.244	0.2	52.1
5/26/23 2:30	37.5	0.378	0.7	46.7	6/22/23 22:30	37.5	0.246	0.2	51.9
5/26/23 3:00	38.0	0.374	0.7	46.7	6/22/23 23:00	38.0	0.242	0.2	51.9
5/26/23 3:30	38.5	0.370	0.6	46.7	6/22/23 23:30	38.5	0.246	0.2	51.9
5/26/23 4:00	39.0	0.366	0.6	46.7	6/23/23 0:00	39.0	0.245	0.2	51.7
5/26/23 4:30	39.5	0.387	0.7	46.7	6/23/23 0:30	39.5	0.250	0.2	51.7
5/26/23 5:00	40.0	0.390	0.7	44.4	6/23/23 1:00	40.0	0.249	0.2	51.5
5/26/23 5:30	40.5	0.404	0.8	44.4	6/23/23 1:30	40.5	0.253	0.2	51.5
5/26/23 6:00	41.0	0.411	0.9	45.3	6/23/23 2:00	41.0	0.246	0.2	51.5
5/26/23 6:30	41.5	0.426	1.0	46.2	6/23/23 2:30	41.5	0.244	0.2	51.3
5/26/23 7:00	42.0	0.431	1.0	46.4	6/23/23 3:00	42.0	0.245	0.2	51.3
5/26/23 7:30	42.5	0.448	1.2	45.8	6/23/23 3:30	42.5	0.252	0.2	51.3
5/26/23 8:00	43.0	0.456	1.2	46.0	6/23/23 4:00	43.0	0.246	0.2	51.2
5/26/23 8:30	43.5	0.452	1.2	46.0	6/23/23 4:30	43.5	0.244	0.2	51.2
5/26/23 9:00	44.0	0.460	1.3	46.0	6/23/23 5:00	44.0	0.245	0.2	51.2
5/26/23 9:30	44.5	0.467	1.3	45.8	6/23/23 5:30	44.5	0.245	0.2	51.0
5/26/23 10:00	45.0	0.469	1.4	45.8	6/23/23 6:00	45.0	0.248	0.2	51.0
5/26/23 10:30	45.5	0.460	1.3	45.8	6/23/23 6:30	45.5	0.249	0.2	51.0
5/26/23 11:00	46.0	0.461	1.3	45.8	6/23/23 7:00	46.0	0.245	0.2	51.2
5/26/23 11:30	46.5	0.456	1.2	45.8	6/23/23 7:30	46.5	0.245	0.2	51.2
5/26/23 12:00	47.0	0.454	1.2	45.8	6/23/23 8:00	47.0	0.241	0.2	51.2
5/26/23 12:30	47.5	0.453	1.2	45.8	6/23/23 8:30	47.5	0.242	0.2	51.3
5/26/23 13:00	48.0	0.455	1.2	45.8	6/23/23 9:00	48.0	0.244	0.2	51.3

Appendix B4.–Water level data for 10/18/23 and 11/01/23 trials at Ninemile Creek.

Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)	Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)
10/18/23 9:00	0.0	0.639	3.8	47.6	11/1/23 9:30	0.0	0.326	0.4	38.8
10/18/23 9:30	0.5	0.665	4.3	47.6	11/1/23 10:00	0.5	0.327	0.4	38.8
10/18/23 10:00	1.0	0.683	4.7	47.6	11/1/23 10:30	1.0	0.327	0.4	38.8
10/18/23 10:30	1.5	0.698	5.0	47.6	11/1/23 11:00	1.5	0.322	0.4	39.0
10/18/23 11:00	2.0	0.743	6.2	47.6	11/1/23 11:30	2.0	0.320	0.4	39.0
10/18/23 11:30	2.5	0.770	7.0	47.6	11/1/23 12:00	2.5	0.314	0.4	39.0
10/18/23 12:00	3.0	0.832	9.0	47.8	11/1/23 12:30	3.0	0.312	0.4	39.2
10/18/23 12:30	3.5	0.882	10.9	47.8	11/1/23 13:00	3.5	0.307	0.3	39.2
10/18/23 13:00	4.0	0.980	15.3	47.8	11/1/23 13:30	4.0	0.309	0.3	39.4
10/18/23 13:30	4.5	1.060	19.9	48.0	11/1/23 14:00	4.5	0.307	0.3	39.4
10/18/23 14:00	5.0	1.079	21.0	48.0	11/1/23 14:30	5.0	0.308	0.3	39.4
10/18/23 14:30	5.5	1.113	23.3	48.0	11/1/23 15:00	5.5	0.301	0.3	39.4
10/18/23 15:00	6.0	1.084	21.4	48.2	11/1/23 15:30	6.0	0.305	0.3	39.6
10/18/23 15:30	6.5	1.070	20.5	48.2	11/1/23 16:00	6.5	0.304	0.3	39.6
10/18/23 16:00	7.0	1.097	22.2	48.2	11/1/23 16:30	7.0	0.305	0.3	39.4
10/18/23 16:30	7.5	1.074	20.7	48.2	11/1/23 17:00	7.5	0.315	0.4	39.4
10/18/23 17:00	8.0	1.078	21.0	48.3	11/1/23 17:30	8.0	0.326	0.4	39.4
10/18/23 17:30	8.5	1.060	19.9	48.3	11/1/23 18:00	8.5	0.318	0.4	39.2
10/18/23 18:00	9.0	1.108	23.0	48.3	11/1/23 18:30	9.0	0.323	0.4	39.2
10/18/23 18:30	9.5	1.130	24.5	48.3	11/1/23 19:00	9.5	0.313	0.4	39.2
10/18/23 19:00	10.0	1.127	24.3	48.3	11/1/23 19:30	10.0	0.317	0.4	39.2
10/18/23 19:30	10.5	1.136	24.9	48.3	11/1/23 20:00	10.5	0.320	0.4	39.2
10/18/23 20:00	11.0	1.128	24.4	48.3	11/1/23 20:30	11.0	0.320	0.4	39.2
10/18/23 20:30	11.5	1.134	24.8	48.3	11/1/23 21:00	11.5	0.318	0.4	39.2
10/18/23 21:00	12.0	1.106	22.8	48.3	11/1/23 21:30	12.0	0.321	0.4	39.0
10/18/23 21:30	12.5	1.106	22.8	48.3	11/1/23 22:00	12.5	0.326	0.4	39.0
10/18/23 22:00	13.0	1.089	21.7	48.3	11/1/23 22:30	13.0	0.319	0.4	39.0
10/18/23 22:30	13.5	1.044	18.9	48.3	11/1/23 23:00	13.5	0.319	0.4	38.8
10/18/23 23:00	14.0	1.024	17.7	48.3	11/1/23 23:30	14.0	0.319	0.4	38.8
10/18/23 23:30	14.5	1.019	17.4	48.3	11/2/23 0:00	14.5	0.315	0.4	38.8
10/19/23 0:00	15.0	1.022	17.6	48.3	11/2/23 0:30	15.0	0.314	0.4	38.8
10/19/23 0:30	15.5	1.036	18.4	48.3	11/2/23 1:00	15.5	0.315	0.4	38.8
10/19/23 1:00	16.0	1.033	18.2	48.3	11/2/23 1:30	16.0	0.320	0.4	38.8
10/19/23 1:30	16.5	1.056	19.6	48.3	11/2/23 2:00	16.5	0.311	0.4	38.8
10/19/23 2:00	17.0	1.044	18.9	48.3	11/2/23 2:30	17.0	0.318	0.4	38.8
10/19/23 2:30	17.5	1.040	18.7	48.3	11/2/23 3:00	17.5	0.320	0.4	38.6
10/19/23 3:00	18.0	1.044	18.9	48.3	11/2/23 3:30	18.0	0.318	0.4	38.6
10/19/23 3:30	18.5	1.035	18.4	48.3	11/2/23 4:00	18.5	0.314	0.4	38.6
10/19/23 4:00	19.0	1.041	18.7	48.3	11/2/23 4:30	19.0	0.318	0.4	38.6
10/19/23 4:30	19.5	1.052	19.4	48.3	11/2/23 5:00	19.5	0.319	0.4	38.6
10/19/23 5:00	20.0	1.052	19.4	48.3	11/2/23 5:30	20.0	0.317	0.4	38.6
10/19/23 5:30	20.5	1.092	21.9	48.3	11/2/23 6:00	20.5	0.326	0.4	38.6
10/19/23 6:00	21.0	1.148	25.8	48.3	11/2/23 6:30	21.0	0.320	0.4	38.4
10/19/23 6:30	21.5	1.207	30.4	48.3	11/2/23 7:00	21.5	0.316	0.4	38.4
10/19/23 7:00	22.0	1.212	30.8	48.3	11/2/23 7:30	22.0	0.324	0.4	38.3
10/19/23 7:30	22.5	1.271	36.0	48.3	11/2/23 8:00	22.5	0.317	0.4	38.3
10/19/23 8:00	23.0	1.242	33.4	48.3	11/2/23 8:30	23.0	0.320	0.4	38.1
10/19/23 8:30	23.5	1.281	37.0	48.3	11/2/23 9:00	23.5	0.325	0.4	38.1
10/19/23 9:00	24.0	1.220	31.5	48.3	11/2/23 9:30	24.0	0.320	0.4	37.9
10/19/23 9:30	24.5	1.177	28.0	48.3	11/2/23 10:00	24.5	0.324	0.4	37.9
10/19/23 10:00	25.0	1.155	26.3	48.3	11/2/23 10:30	25.0	0.322	0.4	37.9
10/19/23 10:30	25.5	1.124	24.1	48.3	11/2/23 11:00	25.5	0.324	0.4	38.1
10/19/23 11:00	26.0	1.089	21.7	48.3	11/2/23 11:30	26.0	0.319	0.4	38.1
10/19/23 11:30	26.5	1.062	20.0	48.3	11/2/23 12:00	26.5	0.320	0.4	38.1
10/19/23 12:00	27.0	1.023	17.7	48.3	11/2/23 12:30	27.0	0.315	0.4	38.1

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Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)	Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)
10/19/23 12:30	27.5	0.976	15.1	48.3	11/2/23 13:00	27.5	0.319	0.4	38.1
10/19/23 13:00	28.0	0.954	14.1	48.3	11/2/23 13:30	28.0	0.311	0.4	38.3
10/19/23 13:30	28.5	0.896	11.4	48.3	11/2/23 14:00	28.5	0.308	0.3	38.3
10/19/23 14:00	29.0	0.874	10.5	48.3	11/2/23 14:30	29.0	0.309	0.3	38.3
10/19/23 14:30	29.5	0.860	10.0	48.3	11/2/23 15:00	29.5	0.308	0.3	38.3
10/19/23 15:00	30.0	0.839	9.2	48.3	11/2/23 15:30	30.0	0.306	0.3	38.3
10/19/23 15:30	30.5	0.835	9.1	48.3	11/2/23 16:00	30.5	0.304	0.3	38.4
10/19/23 16:00	31.0	0.815	8.4	48.3	11/2/23 16:30	31.0	0.309	0.3	38.4
10/19/23 16:30	31.5	0.788	7.5	48.3	11/2/23 17:00	31.5	0.312	0.4	38.4
10/19/23 17:00	32.0	0.769	6.9	48.3	11/2/23 17:30	32.0	0.305	0.3	38.4
10/19/23 17:30	32.5	0.752	6.4	48.2	11/2/23 18:00	32.5	0.312	0.4	38.4
10/19/23 18:00	33.0	0.748	6.3	48.2	11/2/23 18:30	33.0	0.305	0.3	38.4
10/19/23 18:30	33.5	0.737	6.0	48.2	11/2/23 19:00	33.5	0.319	0.4	38.4
10/19/23 19:00	34.0	0.720	5.6	48.0	11/2/23 19:30	34.0	0.313	0.4	38.4
10/19/23 19:30	34.5	0.700	5.1	48.0	11/2/23 20:00	34.5	0.317	0.4	38.4
10/19/23 20:00	35.0	0.689	4.8	48.0	11/2/23 20:30	35.0	0.317	0.4	38.4
10/19/23 20:30	35.5	0.689	4.8	47.8	11/2/23 21:00	35.5	0.310	0.4	38.3
10/19/23 21:00	36.0	0.673	4.5	47.8	11/2/23 21:30	36.0	0.308	0.3	38.4
10/19/23 21:30	36.5	0.664	4.3	47.8	11/2/23 22:00	36.5	0.309	0.3	38.4
10/19/23 22:00	37.0	0.662	4.2	47.6	11/2/23 22:30	37.0	0.316	0.4	38.3
10/19/23 22:30	37.5	0.659	4.2	47.6	11/2/23 23:00	37.5	0.309	0.3	38.4
10/19/23 23:00	38.0	0.649	4.0	47.6	11/2/23 23:30	38.0	0.311	0.4	38.4
10/19/23 23:30	38.5	0.635	3.7	47.4	11/3/23 0:00	38.5	0.314	0.4	38.4
10/20/23 0:00	39.0	0.643	3.8	47.4	11/3/23 0:30	39.0	0.308	0.3	38.4
10/20/23 0:30	39.5	0.640	3.8	47.4	11/3/23 1:00	39.5	0.310	0.4	38.4
10/20/23 1:00	40.0	0.624	3.5	47.4	11/3/23 1:30	40.0	0.301	0.3	38.4
10/20/23 1:30	40.5	0.619	3.4	47.3	11/3/23 2:00	40.5	0.305	0.3	38.4
10/20/23 2:00	41.0	0.622	3.5	47.3	11/3/23 2:30	41.0	0.307	0.3	38.4
10/20/23 2:30	41.5	0.617	3.4	47.3	11/3/23 3:00	41.5	0.298	0.3	38.4
10/20/23 3:00	42.0	0.615	3.3	47.3	11/3/23 3:30	42.0	0.307	0.3	38.6
10/20/23 3:30	42.5	0.605	3.2	47.1	11/3/23 4:00	42.5	0.313	0.4	38.6
10/20/23 4:00	43.0	0.592	2.9	47.1	11/3/23 4:30	43.0	0.303	0.3	38.6
10/20/23 4:30	43.5	0.591	2.9	47.1	11/3/23 5:00	43.5	0.304	0.3	38.6
10/20/23 5:00	44.0	0.593	3.0	47.1	11/3/23 5:30	44.0	0.301	0.3	38.6
10/20/23 5:30	44.5	0.584	2.8	47.1	11/3/23 6:00	44.5	0.300	0.3	38.6
10/20/23 6:00	45.0	0.581	2.8	47.1	11/3/23 6:30	45.0	0.308	0.3	38.6
10/20/23 6:30	45.5	0.572	2.6	46.9	11/3/23 7:00	45.5	0.309	0.3	38.8
10/20/23 7:00	46.0	0.575	2.7	46.9	11/3/23 7:30	46.0	0.303	0.3	38.8
10/20/23 7:30	46.5	0.569	2.6	46.9	11/3/23 8:00	46.5	0.307	0.3	38.8
10/20/23 8:00	47.0	0.567	2.5	46.9	11/3/23 8:30	47.0	0.297	0.3	38.8
10/20/23 8:30	47.5	0.565	2.5	46.9	11/3/23 9:00	47.5	0.303	0.3	38.8
10/20/23 9:00	48.0	0.561	2.5	46.9	11/3/23 9:30	48.0	0.295	0.3	38.8

Appendix B5.–Water level data for 09/07/23 and 09/20/23 trials at Egan Drive Creek.

Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)	Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)
9/7/23 7:00	0.0	0.716	0.5	51.3	9/20/23 13:00	0.0	0.714	0.5	49.4
9/7/23 7:30	0.5	0.716	0.5	51.3	9/20/23 13:30	0.5	0.720	0.5	49.4
9/7/23 8:00	1.0	0.716	0.5	51.3	9/20/23 14:00	1.0	0.753	0.5	49.4
9/7/23 8:30	1.5	0.719	0.5	51.3	9/20/23 14:30	1.5	0.766	0.6	49.6
9/7/23 9:00	2.0	0.715	0.5	51.3	9/20/23 15:00	2.0	0.784	0.6	49.6
9/7/23 9:30	2.5	0.710	0.5	51.3	9/20/23 15:30	2.5	0.802	0.7	49.6
9/7/23 10:00	3.0	0.702	0.5	51.3	9/20/23 16:00	3.0	0.808	0.7	49.6
9/7/23 10:30	3.5	0.698	0.4	51.5	9/20/23 16:30	3.5	0.831	0.7	49.6
9/7/23 11:00	4.0	0.700	0.4	51.5	9/20/23 17:00	4.0	0.846	0.8	49.4
9/7/23 11:30	4.5	0.707	0.5	51.5	9/20/23 17:30	4.5	0.880	0.9	49.4
9/7/23 12:00	5.0	0.696	0.4	51.5	9/20/23 18:00	5.0	0.942	1.1	49.4
9/7/23 12:30	5.5	0.701	0.5	51.5	9/20/23 18:30	5.5	1.032	1.4	49.4
9/7/23 13:00	6.0	0.697	0.4	51.5	9/20/23 19:00	6.0	1.123	1.9	49.2
9/7/23 13:30	6.5	0.702	0.5	51.5	9/20/23 19:30	6.5	1.243	2.7	49.2
9/7/23 14:00	7.0	0.707	0.5	51.5	9/20/23 20:00	7.0	1.373	3.9	49.2
9/7/23 14:30	7.5	0.721	0.5	51.5	9/20/23 20:30	7.5	1.466	5.0	49.1
9/7/23 15:00	8.0	0.738	0.5	51.5	9/20/23 21:00	8.0	1.539	6.0	49.1
9/7/23 15:30	8.5	0.730	0.5	51.5	9/20/23 21:30	8.5	1.602	7.1	49.1
9/7/23 16:00	9.0	0.727	0.5	51.5	9/20/23 22:00	9.0	1.642	7.8	49.1
9/7/23 16:30	9.5	0.728	0.5	51.5	9/20/23 22:30	9.5	1.675	8.5	49.1
9/7/23 17:00	10.0	0.716	0.5	51.5	9/20/23 23:00	10.0	1.677	8.5	49.1
9/7/23 17:30	10.5	0.721	0.5	51.5	9/20/23 23:30	10.5	1.655	8.1	49.1
9/7/23 18:00	11.0	0.726	0.5	51.5	9/21/23 0:00	11.0	1.656	8.1	49.1
9/7/23 18:30	11.5	0.721	0.5	51.5	9/21/23 0:30	11.5	1.640	7.8	49.1
9/7/23 19:00	12.0	0.718	0.5	51.5	9/21/23 1:00	12.0	1.639	7.8	49.1
9/7/23 19:30	12.5	0.719	0.5	51.5	9/21/23 1:30	12.5	1.661	8.2	49.1
9/7/23 20:00	13.0	0.715	0.5	51.5	9/21/23 2:00	13.0	1.669	8.4	49.2
9/7/23 20:30	13.5	0.713	0.5	51.5	9/21/23 2:30	13.5	1.686	8.7	49.2
9/7/23 21:00	14.0	0.720	0.5	51.5	9/21/23 3:00	14.0	1.701	9.1	49.2
9/7/23 21:30	14.5	0.724	0.5	51.5	9/21/23 3:30	14.5	1.725	9.6	49.2
9/7/23 22:00	15.0	0.723	0.5	51.5	9/21/23 4:00	15.0	1.749	10.2	49.2
9/7/23 22:30	15.5	0.726	0.5	51.5	9/21/23 4:30	15.5	1.757	10.4	49.2
9/7/23 23:00	16.0	0.724	0.5	51.5	9/21/23 5:00	16.0	1.743	10.0	49.2
9/7/23 23:30	16.5	0.722	0.5	51.5	9/21/23 5:30	16.5	1.750	10.2	49.2
9/8/23 0:00	17.0	0.722	0.5	51.5	9/21/23 6:00	17.0	1.746	10.1	49.2
9/8/23 0:30	17.5	0.716	0.5	51.5	9/21/23 6:30	17.5	1.749	10.2	49.2
9/8/23 1:00	18.0	0.715	0.5	51.5	9/21/23 7:00	18.0	1.762	10.5	49.4
9/8/23 1:30	18.5	0.712	0.5	51.5	9/21/23 7:30	18.5	1.809	11.7	49.4
9/8/23 2:00	19.0	0.711	0.5	51.5	9/21/23 8:00	19.0	1.838	12.6	49.4
9/8/23 2:30	19.5	0.711	0.5	51.5	9/21/23 8:30	19.5	1.825	12.2	49.4
9/8/23 3:00	20.0	0.718	0.5	51.3	9/21/23 9:00	20.0	1.835	12.5	49.4
9/8/23 3:30	20.5	0.721	0.5	51.5	9/21/23 9:30	20.5	1.832	12.4	49.4
9/8/23 4:00	21.0	0.714	0.5	51.5	9/21/23 10:00	21.0	1.829	12.3	49.4
9/8/23 4:30	21.5	0.714	0.5	51.5	9/21/23 10:30	21.5	1.800	11.5	49.4
9/8/23 5:00	22.0	0.710	0.5	51.5	9/21/23 11:00	22.0	1.814	11.9	49.6
9/8/23 5:30	22.5	0.705	0.5	51.5	9/21/23 11:30	22.5	1.796	11.4	49.6
9/8/23 6:00	23.0	0.719	0.5	51.3	9/21/23 12:00	23.0	1.784	11.1	49.6
9/8/23 6:30	23.5	0.747	0.5	51.3	9/21/23 12:30	23.5	1.765	10.6	49.6
9/8/23 7:00	24.0	0.768	0.6	51.5	9/21/23 13:00	24.0	1.764	10.6	49.6
9/8/23 7:30	24.5	0.750	0.5	51.5	9/21/23 13:30	24.5	1.749	10.2	49.6
9/8/23 8:00	25.0	0.771	0.6	51.5	9/21/23 14:00	25.0	1.727	9.7	49.6
9/8/23 8:30	25.5	0.767	0.6	51.5	9/21/23 14:30	25.5	1.732	9.8	49.8
9/8/23 9:00	26.0	0.760	0.6	51.5	9/21/23 15:00	26.0	1.735	9.8	49.8
9/8/23 9:30	26.5	0.759	0.6	51.5	9/21/23 15:30	26.5	1.735	9.8	49.8
9/8/23 10:00	27.0	0.757	0.6	51.5	9/21/23 16:00	27.0	1.749	10.2	49.9

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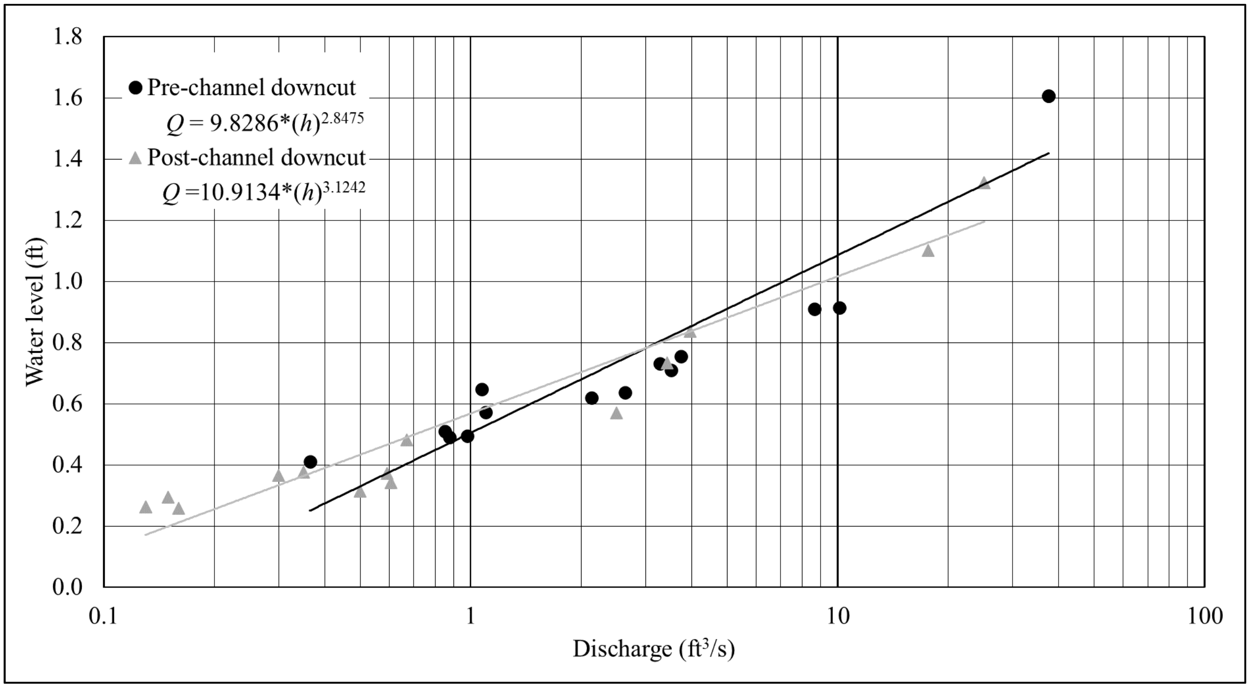
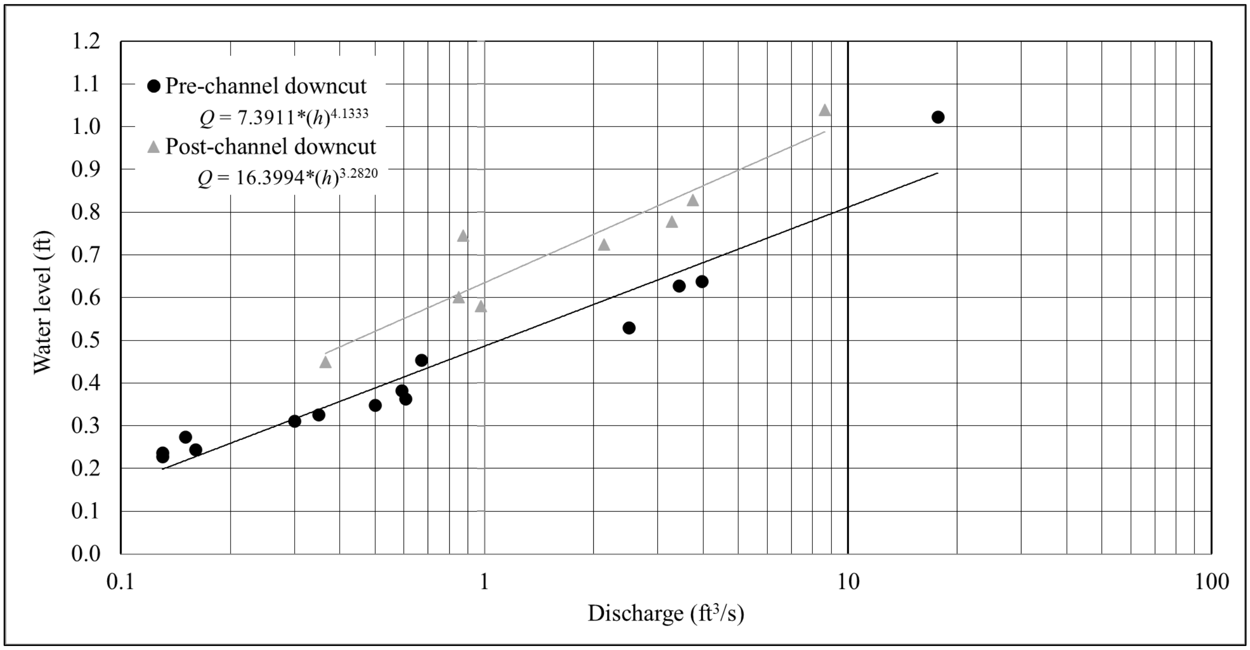
Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)	Trial date and time	Trial hour	Water level (ft)	Q estimate (ft^3/s)	Temperature (°F)
9/8/23 10:30	27.5	0.767	0.6	51.5	9/21/23 16:30	27.5	1.775	10.8	49.9
9/8/23 11:00	28.0	0.734	0.5	51.5	9/21/23 17:00	28.0	1.775	10.8	49.9
9/8/23 11:30	28.5	0.753	0.5	51.5	9/21/23 17:30	28.5	1.772	10.8	49.9
9/8/23 12:00	29.0	0.762	0.6	51.7	9/21/23 18:00	29.0	1.796	11.4	49.9
9/8/23 12:30	29.5	0.758	0.6	51.7	9/21/23 18:30	29.5	1.830	12.3	49.9
9/8/23 13:00	30.0	0.762	0.6	51.7	9/21/23 19:00	30.0	1.882	13.9	49.9
9/8/23 13:30	30.5	0.754	0.5	51.7	9/21/23 19:30	30.5	1.900	14.5	49.9
9/8/23 14:00	31.0	0.759	0.6	51.7	9/21/23 20:00	31.0	1.898	14.4	49.9
9/8/23 14:30	31.5	0.759	0.6	51.7	9/21/23 20:30	31.5	1.880	13.9	49.8
9/8/23 15:00	32.0	0.766	0.6	51.9	9/21/23 21:00	32.0	1.867	13.4	49.8
9/8/23 15:30	32.5	0.750	0.5	51.9	9/21/23 21:30	32.5	1.863	13.3	49.8
9/8/23 16:00	33.0	0.738	0.5	51.9	9/21/23 22:00	33.0	1.854	13.1	49.8
9/8/23 16:30	33.5	0.745	0.5	51.9	9/21/23 22:30	33.5	1.842	12.7	49.8
9/8/23 17:00	34.0	0.741	0.5	51.9	9/21/23 23:00	34.0	1.820	12.1	49.6
9/8/23 17:30	34.5	0.744	0.5	51.9	9/21/23 23:30	34.5	1.810	11.8	49.6
9/8/23 18:00	35.0	0.752	0.5	51.9	9/22/23 0:00	35.0	1.807	11.7	49.6
9/8/23 18:30	35.5	0.745	0.5	51.9	9/22/23 0:30	35.5	1.803	11.6	49.6
9/8/23 19:00	36.0	0.750	0.5	51.9	9/22/23 1:00	36.0	1.802	11.6	49.6
9/8/23 19:30	36.5	0.751	0.5	51.9	9/22/23 1:30	36.5	1.809	11.7	49.6
9/8/23 20:00	37.0	0.752	0.5	51.9	9/22/23 2:00	37.0	1.830	12.3	49.6
9/8/23 20:30	37.5	0.753	0.5	51.9	9/22/23 2:30	37.5	1.824	12.2	49.4
9/8/23 21:00	38.0	0.750	0.5	51.9	9/22/23 3:00	38.0	1.823	12.1	49.4
9/8/23 21:30	38.5	0.760	0.6	51.9	9/22/23 3:30	38.5	1.801	11.5	49.4
9/8/23 22:00	39.0	0.767	0.6	51.9	9/22/23 4:00	39.0	1.771	10.7	49.4
9/8/23 22:30	39.5	0.760	0.6	51.9	9/22/23 4:30	39.5	1.768	10.7	49.2
9/8/23 23:00	40.0	0.763	0.6	51.9	9/22/23 5:00	40.0	1.756	10.4	49.2
9/8/23 23:30	40.5	0.764	0.6	51.9	9/22/23 5:30	40.5	1.759	10.4	49.2
9/9/23 0:00	41.0	0.760	0.6	51.9	9/22/23 6:00	41.0	1.748	10.2	49.2
9/9/23 0:30	41.5	0.767	0.6	51.9	9/22/23 6:30	41.5	1.726	9.6	49.2
9/9/23 1:00	42.0	0.762	0.6	51.9	9/22/23 7:00	42.0	1.718	9.5	49.2
9/9/23 1:30	42.5	0.771	0.6	51.7	9/22/23 7:30	42.5	1.698	9.0	49.2
9/9/23 2:00	43.0	0.772	0.6	51.7	9/22/23 8:00	43.0	1.667	8.3	49.1
9/9/23 2:30	43.5	0.767	0.6	51.7	9/22/23 8:30	43.5	1.634	7.7	49.1
9/9/23 3:00	44.0	0.768	0.6	51.7	9/22/23 9:00	44.0	1.596	7.0	49.1
9/9/23 3:30	44.5	0.765	0.6	51.7	9/22/23 9:30	44.5	1.543	6.1	48.9
9/9/23 4:00	45.0	0.767	0.6	51.7	9/22/23 10:00	45.0	1.524	5.8	48.9
9/9/23 4:30	45.5	0.760	0.6	51.7	9/22/23 10:30	45.5	1.500	5.5	48.9
9/9/23 5:00	46.0	0.762	0.6	51.7	9/22/23 11:00	46.0	1.471	5.0	48.7
9/9/23 5:30	46.5	0.768	0.6	51.7	9/22/23 11:30	46.5	1.433	4.6	48.7
9/9/23 6:00	47.0	0.763	0.6	51.7	9/22/23 12:00	47.0	1.413	4.3	48.7
9/9/23 6:30	47.5	0.777	0.6	51.7	9/22/23 12:30	47.5	1.380	3.9	48.7
9/9/23 7:00	48.0	0.776	0.6	51.7	9/22/23 13:00	48.0	1.366	3.8	48.7

APPENDIX D: RATING CURVES AND CHANNEL CROSS-SECTION

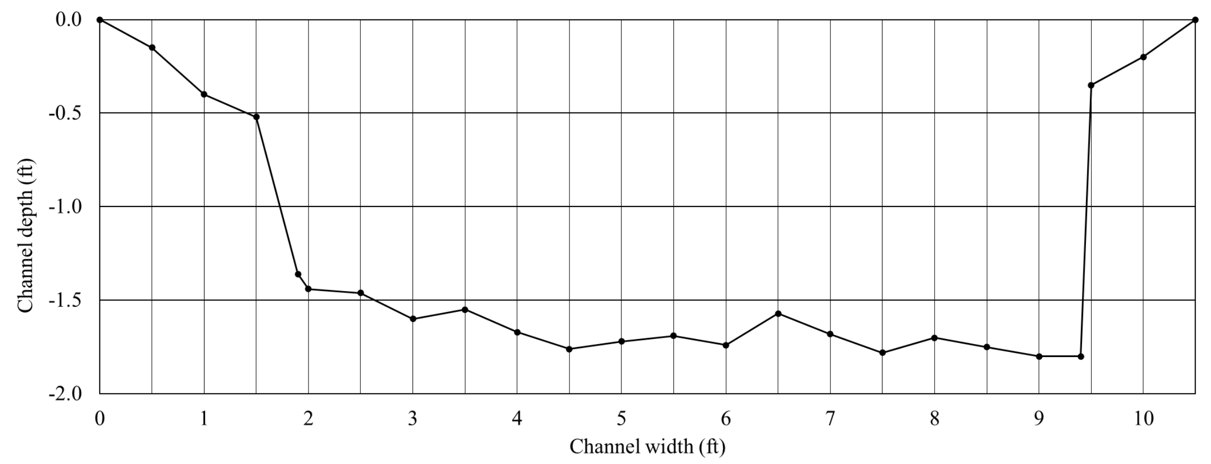
Appendix C1.–Rating curve plot for wide-range data logger, 04/15/21–11/03/23.



Appendix C2.–Rating curve plot for trial data only, 04/27/22–11/03/23.



Appendix C3.–Gage site channel cross section to bankfull stage looking upstream.



APPENDIX E: MEAN DAILY WATER LEVEL DATA

Appendix D.–Mean daily water level and discharge estimates from 3/4/21–11/3/23 period.

Day	2021 mean daily water level	2021 Q estimate (ft^3/s)	2022 mean daily water level	2022 Q estimate (ft^3/s)	2023 mean daily water level	2023 Q estimate (ft^3/s)
1-Jan			0.843	6.1	0.918	8.4
2-Jan			0.422	0.8	0.859	6.8
3-Jan			0.316	0.4	0.668	3.1
4-Jan			0.292	0.3	0.484	1.1
5-Jan			0.339	0.5	0.424	0.7
6-Jan			0.758	4.5	0.357	0.4
7-Jan			ND	ND	0.488	1.2
8-Jan			ND	ND	0.638	2.7
9-Jan			ND	ND	0.389	0.6
10-Jan			ND	ND	0.329	0.3
11-Jan			ND	ND	0.303	0.3
12-Jan			ND	ND	0.280	0.2
13-Jan			ND	ND	0.272	0.2
14-Jan			ND	ND	0.285	0.2
15-Jan			ND	ND	0.782	5.1
16-Jan			ND	ND	0.689	3.4
17-Jan			ND	ND	0.840	6.3
18-Jan			ND	ND	0.628	2.5
19-Jan			ND	ND	0.615	2.4
20-Jan			ND	ND	0.910	8.1
21-Jan			ND	ND	0.717	3.9
22-Jan			ND	ND	0.690	3.4
23-Jan			ND	ND	0.710	3.8
24-Jan			ND	ND	0.660	3.0
25-Jan			1.203	16.6	0.844	6.4
26-Jan			1.015	10.3	0.735	4.2
27-Jan			0.951	8.5	0.571	1.9
28-Jan			1.021	10.4	0.434	0.8
29-Jan			1.015	10.3	0.417	0.7
30-Jan			0.684	3.3	0.351	0.4
31-Jan			0.608	2.4	0.319	0.3
1-Feb			0.854	6.3	0.304	0.3
2-Feb			0.883	6.9	0.295	0.2
3-Feb			0.731	4.0	0.283	0.2
4-Feb			0.714	3.8	0.273	0.2
5-Feb			0.722	3.9	0.317	0.3
6-Feb			0.952	8.5	0.650	2.8
7-Feb			0.820	5.6	0.428	0.8
8-Feb			0.915	7.6	0.352	0.4
9-Feb			1.017	10.3	0.330	0.3
10-Feb			0.797	5.2	0.423	0.7
11-Feb			0.705	3.6	0.556	1.7
12-Feb			1.043	11.1	0.761	4.7
13-Feb			0.682	3.3	0.731	4.1
14-Feb			0.565	1.9	0.451	0.9
15-Feb			0.508	1.4	0.446	0.9
16-Feb			0.677	3.2	0.462	1.0
17-Feb			0.723	3.9	0.513	1.4
18-Feb			0.887	7.0	0.622	2.5
19-Feb			0.735	4.1	0.633	2.6
20-Feb			0.622	2.5	0.482	1.1
21-Feb			0.664	3.1	0.434	0.8
22-Feb			0.848	6.1	0.530	1.5
23-Feb			0.753	4.4	0.599	2.2
24-Feb			0.643	2.8	0.514	1.4
25-Feb			0.516	1.5	0.385	0.6
26-Feb			0.866	6.5	0.270	0.2
27-Feb			0.732	4.0	0.255	0.2
28-Feb			0.662	3.0	0.243	0.1

Note: ND = no data

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Day	2021 mean daily water level	2021 Q estimate (ft^3/s)	2022 mean daily water level	2022 Q estimate (ft^3/s)	2023 mean daily water level	2023 Q estimate (ft^3/s)
2-Mar			0.557	1.9	0.423	0.7
3-Mar			0.540	1.7	0.310	0.3
4-Mar	0.628	2.6	0.489	1.3	0.281	0.2
5-Mar	0.633	2.7	0.469	1.1	0.249	0.1
6-Mar	0.740	4.2	0.785	4.9	0.240	0.1
7-Mar	0.620	2.5	0.634	2.7	0.235	0.1
8-Mar	0.569	2.0	0.524	1.6	0.217	0.1
9-Mar	0.656	3.0	0.507	1.4	ND	ND
10-Mar	0.670	3.1	0.448	1.0	ND	ND
11-Mar	0.502	1.4	0.795	5.1	ND	ND
12-Mar	0.488	1.3	0.677	3.2	ND	ND
13-Mar	0.560	1.9	0.602	2.3	ND	ND
14-Mar	0.596	2.3	0.531	1.6	ND	ND
15-Mar	0.472	1.2	0.510	1.4	ND	ND
16-Mar	0.619	2.5	0.640	2.8	ND	ND
17-Mar	0.858	6.4	0.717	3.8	ND	ND
18-Mar	0.737	4.1	0.690	3.4	ND	ND
19-Mar	0.549	1.8	0.652	2.9	ND	ND
20-Mar	0.520	1.5	0.582	2.1	ND	ND
21-Mar	0.498	1.4	0.610	2.4	ND	ND
22-Mar	0.487	1.3	0.815	5.5	ND	ND
23-Mar	0.692	3.4	0.696	3.5	ND	ND
24-Mar	0.664	3.1	0.637	2.7	ND	ND
25-Mar	0.588	2.2	0.626	2.6	ND	ND
26-Mar	0.590	2.2	0.624	2.6	ND	ND
27-Mar	0.680	3.3	0.552	1.8	ND	ND
28-Mar	0.621	2.5	0.510	1.4	ND	ND
29-Mar	0.544	1.7	0.858	6.3	ND	ND
30-Mar	0.588	2.2	0.770	4.7	ND	ND
31-Mar	0.801	5.2	0.691	3.4	ND	ND
1-Apr	0.665	3.1	0.724	3.9	ND	ND
2-Apr	0.613	2.4	0.674	3.2	ND	ND
3-Apr	0.584	2.1	0.778	4.8	ND	ND
4-Apr	0.566	1.9	0.641	2.8	ND	ND
5-Apr	0.691	3.4	0.583	2.1	ND	ND
6-Apr	0.692	3.4	0.578	2.1	ND	ND
7-Apr	0.630	2.6	0.727	4.0	ND	ND
8-Apr	0.572	2.0	0.675	3.2	ND	ND
9-Apr	0.620	2.5	0.593	2.2	ND	ND
10-Apr	0.562	1.9	0.520	1.5	ND	ND
11-Apr	0.539	1.7	0.459	1.1	ND	ND
12-Apr	0.551	1.8	0.441	1.0	ND	ND
13-Apr	0.909	7.5	0.410	0.8	ND	ND
14-Apr	0.921	7.8	0.419	0.8	ND	ND
15-Apr	0.766	4.6	0.409	0.8	ND	ND
16-Apr	0.744	4.2	0.385	0.6	ND	ND
17-Apr	0.777	4.8	0.394	0.7	ND	ND
18-Apr	0.795	5.1	0.400	0.7	ND	ND
19-Apr	0.730	4.0	0.393	0.7	ND	ND
20-Apr	0.705	3.6	0.402	0.7	ND	ND
21-Apr	0.670	3.1	0.404	0.7	ND	ND
22-Apr	0.602	2.3	0.402	0.7	ND	ND
23-Apr	0.582	2.1	0.450	1.0	ND	ND
24-Apr	0.567	2.0	0.465	1.1	ND	ND
25-Apr	0.557	1.9	0.482	1.2	ND	ND
26-Apr	0.538	1.7	0.736	4.1	ND	ND
27-Apr	0.557	1.9	0.723	3.9	ND	ND
28-Apr	0.592	2.2	0.610	2.4	ND	ND
29-Apr	0.834	5.9	0.461	1.1	ND	ND
30-Apr	0.788	5.0	0.448	1.0	ND	ND

Note: ND = no data

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Day	2021 mean daily water level	2021 Q estimate (ft^3/s)	2022 mean daily water level	2022 Q estimate (ft^3/s)	2023 mean daily water level	2023 Q estimate (ft^3/s)
2-May	0.595	2.2	0.514	1.5	ND	ND
3-May	0.547	1.8	0.756	4.4	ND	ND
4-May	0.632	2.7	0.581	2.1	ND	ND
5-May	0.637	2.7	0.510	1.4	ND	ND
6-May	0.562	1.9	0.458	1.1	ND	ND
7-May	0.588	2.2	0.430	0.9	ND	ND
8-May	0.571	2.0	0.407	0.8	ND	ND
9-May	0.565	1.9	0.387	0.7	ND	ND
10-May	0.551	1.8	0.493	1.3	ND	ND
11-May	0.573	2.0	0.514	1.5	ND	ND
12-May	0.610	2.4	0.438	0.9	ND	ND
13-May	0.567	2.0	0.408	0.8	ND	ND
14-May	0.733	4.1	0.397	0.7	ND	ND
15-May	0.790	5.0	0.377	0.6	ND	ND
16-May	0.614	2.4	0.357	0.5	ND	ND
17-May	0.556	1.8	0.354	0.5	ND	ND
18-May	0.508	1.4	0.343	0.5	ND	ND
19-May	0.480	1.2	0.332	0.4	ND	ND
20-May	0.458	1.1	0.323	0.4	ND	ND
21-May	0.463	1.1	0.321	0.4	ND	ND
22-May	0.535	1.7	0.310	0.3	ND	ND
23-May	0.737	4.1	0.326	0.4	ND	ND
24-May	0.589	2.2	0.369	0.6	0.262	0.2
25-May	0.521	1.5	0.341	0.5	0.294	0.2
26-May	0.523	1.6	0.324	0.4	0.459	1.0
27-May	0.491	1.3	0.307	0.3	0.601	2.2
28-May	0.470	1.1	0.300	0.3	0.774	4.9
29-May	0.544	1.7	0.290	0.3	0.672	3.2
30-May	0.544	1.7	0.282	0.3	0.636	2.7
31-May	0.932	8.0	0.276	0.3	0.493	1.2
1-Jun	0.747	4.3	0.264	0.2	0.462	1.0
2-Jun	0.885	6.9	0.261	0.2	0.413	0.7
3-Jun	0.880	6.8	0.260	0.2	0.386	0.6
4-Jun	0.661	3.0	0.251	0.2	0.359	0.4
5-Jun	0.643	2.8	0.273	0.2	0.336	0.4
6-Jun	0.696	3.5	0.348	0.5	0.323	0.3
7-Jun	0.594	2.2	0.379	0.6	0.322	0.3
8-Jun	0.529	1.6	0.330	0.4	0.297	0.2
9-Jun	0.486	1.3	0.311	0.4	0.297	0.2
10-Jun	0.465	1.1	0.298	0.3	0.307	0.3
11-Jun	0.453	1.0	0.313	0.4	0.329	0.3
12-Jun	0.443	1.0	0.358	0.5	0.486	1.1
13-Jun	0.426	0.9	0.550	1.8	0.368	0.5
14-Jun	0.406	0.8	0.522	1.5	0.325	0.3
15-Jun	0.764	4.6	0.431	0.9	0.370	0.5
16-Jun	0.878	6.8	0.377	0.6	0.545	1.6
17-Jun	0.625	2.6	0.341	0.5	0.503	1.3
18-Jun	0.543	1.7	0.324	0.4	0.388	0.6
19-Jun	0.507	1.4	0.305	0.3	0.331	0.3
20-Jun	0.494	1.3	0.311	0.4	0.317	0.3
21-Jun	0.600	2.3	0.529	1.6	0.296	0.2
22-Jun	0.539	1.7	0.601	2.3	0.284	0.2
23-Jun	0.487	1.3	0.473	1.2	0.267	0.2
24-Jun	0.600	2.3	0.394	0.7	0.265	0.2
25-Jun	0.592	2.2	0.352	0.5	0.301	0.3
26-Jun	0.543	1.7	0.329	0.4	0.382	0.5
27-Jun	0.493	1.3	0.309	0.3	0.389	0.6
28-Jun	0.456	1.0	0.291	0.3	0.455	0.9
29-Jun	0.432	0.9	0.284	0.3	0.730	4.1
30-Jun	0.416	0.8	0.284	0.3	0.678	3.2

Note: ND = no data

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Day	2021 mean daily water level	2021 Q estimate (ft^3/s)	2022 mean daily water level	2022 Q estimate (ft^3/s)	2023 mean daily water level	2023 Q estimate (ft^3/s)
2-Jul	0.394	0.7	0.264	0.2	0.420	0.7
3-Jul	0.387	0.7	0.261	0.2	0.377	0.5
4-Jul	0.380	0.6	0.253	0.2	0.348	0.4
5-Jul	0.369	0.6	0.244	0.2	0.334	0.4
6-Jul	0.364	0.6	0.240	0.2	0.325	0.3
7-Jul	0.351	0.5	0.242	0.2	0.292	0.2
8-Jul	0.363	0.5	0.254	0.2	0.291	0.2
9-Jul	0.370	0.6	0.265	0.2	0.283	0.2
10-Jul	0.361	0.5	0.288	0.3	0.260	0.2
11-Jul	0.352	0.5	0.393	0.7	0.247	0.1
12-Jul	0.524	1.6	0.496	1.3	0.242	0.1
13-Jul	0.693	3.5	0.449	1.0	0.240	0.1
14-Jul	0.733	4.1	0.407	0.8	0.227	0.1
15-Jul	0.565	1.9	0.362	0.5	0.220	0.1
16-Jul	0.493	1.3	0.333	0.4	0.209	0.1
17-Jul	0.444	1.0	0.400	0.7	0.274	0.2
18-Jul	0.429	0.9	0.446	1.0	0.244	0.1
19-Jul	0.423	0.8	0.476	1.2	0.352	0.4
20-Jul	0.398	0.7	0.459	1.1	0.330	0.3
21-Jul	0.384	0.6	0.525	1.6	0.305	0.3
22-Jul	0.376	0.6	0.517	1.5	0.363	0.5
23-Jul	0.375	0.6	0.583	2.1	0.511	1.3
24-Jul	0.404	0.7	0.672	3.2	0.458	1.0
25-Jul	0.478	1.2	0.605	2.3	0.356	0.4
26-Jul	0.429	0.9	0.544	1.7	0.317	0.3
27-Jul	0.394	0.7	0.483	1.2	0.306	0.3
28-Jul	0.384	0.6	0.817	5.5	0.284	0.2
29-Jul	0.368	0.6	0.754	4.4	0.263	0.2
30-Jul	0.359	0.5	0.580	2.1	0.242	0.1
31-Jul	0.352	0.5	0.727	4.0	0.238	0.1
1-Aug	0.340	0.5	0.628	2.6	0.466	1.0
2-Aug	0.336	0.4	0.856	6.3	0.423	0.7
3-Aug	0.334	0.4	0.704	3.6	0.344	0.4
4-Aug	0.346	0.5	0.546	1.8	0.313	0.3
5-Aug	0.384	0.6	0.566	1.9	0.284	0.2
6-Aug	0.438	0.9	0.894	7.1	0.269	0.2
7-Aug	0.532	1.6	0.779	4.8	0.287	0.2
8-Aug	0.525	1.6	0.602	2.3	0.365	0.5
9-Aug	0.703	3.6	0.511	1.5	0.333	0.3
10-Aug	0.577	2.1	0.458	1.1	0.343	0.4
11-Aug	0.562	1.9	0.429	0.9	0.404	0.6
12-Aug	0.590	2.2	0.405	0.7	0.907	8.0
13-Aug	1.057	11.5	0.375	0.6	0.663	3.0
14-Aug	0.709	3.7	0.364	0.6	0.500	1.3
15-Aug	0.831	5.8	0.465	1.1	0.523	1.4
16-Aug	0.601	2.3	0.484	1.2	0.492	1.2
17-Aug	0.563	1.9	0.885	6.9	0.429	0.8
18-Aug	0.655	2.9	0.652	2.9	0.385	0.6
19-Aug	0.601	2.3	0.496	1.3	0.350	0.4
20-Aug	0.523	1.6	0.442	1.0	0.339	0.4
21-Aug	0.486	1.3	0.406	0.8	0.319	0.3
22-Aug	0.451	1.0	0.381	0.6	0.302	0.3
23-Aug	0.424	0.9	0.367	0.6	0.283	0.2
24-Aug	0.408	0.8	0.349	0.5	0.285	0.2
25-Aug	0.406	0.8	0.353	0.5	0.281	0.2
26-Aug	0.405	0.7	0.356	0.5	0.290	0.2
27-Aug	0.443	1.0	0.425	0.9	0.274	0.2
28-Aug	0.982	9.3	0.534	1.6	0.260	0.2
29-Aug	0.659	3.0	1.090	12.6	0.246	0.1
30-Aug	0.565	1.9	0.822	5.6	0.252	0.1
31-Aug	0.496	1.3	0.682	3.3	0.283	0.2

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Day	2021 mean daily water level	2021 Q estimate (ft^3/s)	2022 mean daily water level	2022 Q estimate (ft^3/s)	2023 mean daily water level	2023 Q estimate (ft^3/s)
2-Sep	0.645	2.8	0.641	2.8	0.357	0.4
3-Sep	0.752	4.4	0.544	1.7	0.380	0.5
4-Sep	0.713	3.8	0.586	2.1	0.415	0.7
5-Sep	0.708	3.7	0.551	1.8	0.412	0.7
6-Sep	0.688	3.4	0.574	2.0	0.355	0.4
7-Sep	0.669	3.1	0.530	1.6	0.362	0.5
8-Sep	0.763	4.5	0.469	1.1	0.384	0.5
9-Sep	0.646	2.8	0.491	1.3	0.435	0.8
10-Sep	0.789	5.0	0.570	2.0	0.448	0.9
11-Sep	0.798	5.2	0.479	1.2	0.372	0.5
12-Sep	0.723	3.9	0.439	0.9	0.541	1.6
13-Sep	0.644	2.8	0.418	0.8	0.807	5.6
14-Sep	0.624	2.6	0.438	0.9	0.987	10.5
15-Sep	0.698	3.5	0.791	5.0	0.796	5.3
16-Sep	0.701	3.6	0.563	1.9	0.485	1.1
17-Sep	0.603	2.3	0.477	1.2	0.638	2.7
18-Sep	0.532	1.6	0.460	1.1	0.923	8.5
19-Sep	0.488	1.3	0.440	1.0	0.766	4.7
20-Sep	0.623	2.6	0.415	0.8	0.612	2.4
21-Sep	0.908	7.5	0.443	1.0	1.179	18.3
22-Sep	0.709	3.7	0.900	7.3	1.016	11.5
23-Sep	0.728	4.0	1.003	9.9	0.622	2.5
24-Sep	0.859	6.4	0.792	5.1	0.544	1.6
25-Sep	0.635	2.7	0.686	3.4	0.514	1.4
26-Sep	0.552	1.8	1.025	10.5	0.466	1.0
27-Sep	0.564	1.9	1.013	10.2	0.737	4.2
28-Sep	0.635	2.7	0.669	3.1	0.702	3.6
29-Sep	0.542	1.7	0.782	4.9	0.493	1.2
30-Sep	0.574	2.0	1.157	14.9	0.471	1.0
1-Oct	1.023	10.5	1.133	14.0	0.709	3.7
2-Oct	1.115	13.4	0.561	1.8	0.632	2.6
3-Oct	0.688	3.4	0.432	0.8	0.607	2.3
4-Oct	0.592	2.2	0.383	0.5	0.507	1.3
5-Oct	0.534	1.6	0.368	0.5	0.488	1.2
6-Oct	0.491	1.3	0.340	0.4	0.910	8.1
7-Oct	0.830	5.8	0.323	0.3	0.919	8.4
8-Oct	0.899	7.3	0.355	0.4	0.971	9.9
9-Oct	0.820	5.6	0.535	1.5	0.969	9.9
10-Oct	0.666	3.1	0.451	0.9	0.754	4.5
11-Oct	0.828	5.7	0.471	1.0	0.526	1.5
12-Oct	0.943	8.3	0.517	1.4	0.519	1.4
13-Oct	0.826	5.7	0.991	10.6	0.506	1.3
14-Oct	0.852	6.2	0.653	2.9	0.436	0.8
15-Oct	0.701	3.6	0.936	8.9	0.489	1.2
16-Oct	0.644	2.8	0.553	1.7	0.510	1.3
17-Oct	0.546	1.8	0.763	4.7	0.498	1.2
18-Oct	0.500	1.4	0.661	3.0	0.916	8.3
19-Oct	0.475	1.2	0.837	6.3	1.078	13.8
20-Oct	0.460	1.1	0.664	3.0	0.625	2.5
21-Oct	0.454	1.0	0.684	3.3	0.530	1.5
22-Oct	0.504	1.4	0.514	1.4	0.478	1.1
23-Oct	0.582	2.1	0.435	0.8	0.456	0.9
24-Oct	0.543	1.7	0.400	0.6	0.433	0.8
25-Oct	0.480	1.2	0.422	0.7	0.411	0.7
26-Oct	0.506	1.4	0.835	6.2	0.400	0.6
27-Oct	0.625	2.6	0.884	7.4	0.395	0.6
28-Oct	0.704	3.6	0.897	7.8	0.371	0.5
29-Oct	0.546	1.8	0.737	4.2	0.352	0.4
30-Oct	0.494	1.3	0.942	9.1	0.358	0.4
31-Oct	0.466	1.1	0.766	4.7	0.379	0.5

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Day	2021 mean daily water level	2021 Q estimate (ft^3/s)	2022 mean daily water level	2022 Q estimate (ft^3/s)	2023 mean daily water level	2023 Q estimate (ft^3/s)
2-Nov	0.427	0.9	0.420	0.7	0.366	0.5
3-Nov	0.460	1.1	0.504	1.3	0.355	0.4
4-Nov	0.456	1.0	0.541	1.6		
5-Nov	0.476	1.2	0.473	1.0		
6-Nov	0.487	1.3	0.373	0.5		
7-Nov	0.462	1.1	0.314	0.3		
8-Nov	0.433	0.9	0.294	0.2		
9-Nov	0.421	0.8	0.287	0.2		
10-Nov	0.407	0.8	0.301	0.3		
11-Nov	0.405	0.8	0.374	0.5		
12-Nov	0.673	3.2	0.639	2.7		
13-Nov	0.650	2.9	0.729	4.1		
14-Nov	0.520	1.5	0.863	6.9		
15-Nov	0.464	1.1	0.777	5.0		
16-Nov	0.465	1.1	0.533	1.5		
17-Nov	0.772	4.7	0.422	0.7		
18-Nov	0.670	3.1	0.362	0.5		
19-Nov	0.526	1.6	0.356	0.4		
20-Nov	0.468	1.1	0.392	0.6		
21-Nov	0.578	2.1	0.686	3.4		
22-Nov	0.788	5.0	0.626	2.5		
23-Nov	0.592	2.2	0.704	3.6		
24-Nov	0.722	3.9	0.834	6.2		
25-Nov	1.025	10.5	0.581	2.0		
26-Nov	0.689	3.4	0.589	2.1		
27-Nov	0.565	1.9	0.445	0.9		
28-Nov	0.517	1.5	0.370	0.5		
29-Nov	0.477	1.2	0.393	0.6		
30-Nov	0.478	1.2	0.316	0.3		
1-Dec	0.629	2.6	0.278	0.2		
2-Dec	0.566	1.9	0.285	0.2		
3-Dec	0.488	1.3	0.333	0.4		
4-Dec	0.447	1.0	0.366	0.5		
5-Dec	0.490	1.3	0.391	0.6		
6-Dec	0.405	0.8	0.293	0.2		
7-Dec	0.400	0.7	0.482	1.1		
8-Dec	0.403	0.7	0.621	2.5		
9-Dec	0.416	0.8	0.454	0.9		
10-Dec	0.521	1.5	0.558	1.8		
11-Dec	0.466	1.1	0.549	1.7		
12-Dec	0.432	0.9	0.269	0.2		
13-Dec	0.658	3.0	0.292	0.2		
14-Dec	0.506	1.4	0.859	6.8		
15-Dec	0.404	0.7	0.699	3.6		
16-Dec	0.406	0.8	0.578	2.0		
17-Dec	0.593	2.2	0.481	1.1		
18-Dec	0.367	0.6	0.537	1.6		
19-Dec	0.362	0.5	0.441	0.8		
20-Dec	0.499	1.4	0.284	0.2		
21-Dec	0.703	3.6	0.189	0.1		
22-Dec	0.430	0.9	0.293	0.2		
23-Dec	0.324	0.4	0.190	0.1		
24-Dec	0.362	0.5	0.218	0.1		
25-Dec	0.503	1.4	0.281	0.2		
26-Dec	0.478	1.2	0.262	0.2		
27-Dec	0.409	0.8	0.304	0.3		
28-Dec	0.720	3.9	0.305	0.3		
29-Dec	0.384	0.6	0.248	0.1		
30-Dec	0.326	0.4	0.240	0.1		
31-Dec	0.501	1.4	0.300	0.3		

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