Evaluation of an Electric Barrier as a Seal Deterrent on the Puntledge River

Prepared For

Pacific Salmon Commission
Southern Boundary Restoration & Enhancement Fund Committee
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DRAFT

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1. INTRODUCTION

In 2007 Smith-Root Inc, in partnership with the Pacific Salmon Commission (PSC) and the Department of Fisheries and Oceans (DFO) Puntledge River Hatchery, conducted a series of tests to determine the effectiveness of electrical barriers to deter seal predation on salmonids. Results from the two trials in 2007, one conducted at the Vancouver Aquarium, and the other in the Puntledge River in Courtenay, BC indicated that seals avoided the electrified zone (Cave et al. 2008). The low levels of electricity used in these trials (voltage gradient < 0.32 volts/cm, pulse width of 1 msec, frequency of 2 Hz) were considerably below levels capable of causing injury to fish (NMFS 2000), and appeared to be effective in preventing the upstream movement of seals to their established predation site in the Punteldge River study.

In response to the encouraging results obtained in 2007, a more comprehensive evaluation was carried out in the Puntledge River in 2008. The 2008 study examined more closely the potential impacts of an electrical array on the migratory behaviour of salmonid fish in the river. Preliminary results from studies conducted in the Fraser River suggested that this technology had the potential for deterring marine mammal predation without affecting fish migration, thus contributing to the overall protection and conservation of both fish and marine mammal species (Cave et al. 2008).

The primary goal of the 2008 study in the Puntledge River was to test and further refine a non-lethal marine mammal deterrent technology that would not adversely affect the migrational behaviour of salmonid fishes.

The objectives of this study were to assess and determine:

i. whether an electrical array will serve as an effective long term deterrent in displacing seals from localized foraging areas (such as along the light shadow at the 5th Street bridge, and as a barrier in blocking seal movements upstream of the array;

ii. whether the strength of the electric field sufficient to deter seals affects the migratory behaviour of juvenile and adult salmon; and

iii. whether there is a difference in the efficacy of the two types of arrays tested in this study (perpendicular or parallel arrangement) in preventing upstream seal passage, while allowing unobstructed salmon migration.

Three observational phases were incorporated in the study design; Phase I - baseline observations; Phase II - operation of electric barrier during juvenile outmigration; and Phase III - operation of electric barrier during adult migration. The electric barrier will be considered an effective deterrent if it displaces seals from foraging along the light shadow on the upriver side of the 5th Street Bridge at power levels that do not adversely affect the migratory behaviour of salmon. The electric array will be considered effective in reducing upriver predation on adult salmon if it blocks the movements of seals at power levels that do not affect the migration of adult salmon. If successful, this technology will assist to resolve predation issues on stocks of concern without lethal removal of the marine mammal predators, and may be applied to other systems in the Pacific Northwest.

2. BACKGROUND

The Puntledge River Summer chinook stock is one of only two summer-returning stocks on Vancouver Island. DNA analysis has confirmed that this stock is genetically distinct from the Puntledge fall-run stock and from other Georgia Basin stocks, and its status is one of ongoing concern under the Pacific Salmon Treaty. Chinook fisheries in Canada and the United States are currently limited, resulting in conservation concerns for these stocks. The Puntledge River Summer stock is the only escapement and exploitation indicator (PSC Chinook Technical Committee) for Georgia Strait Summer Chinook stocks. This genetically unique population, recently identified by DFO as its own Conservation Unit under the Wild Salmon Policy, is considered to be at risk. Key issues affecting the re-building of this stock have been identified as low freshwater productivity, poor marine survival, excessive fishery exploitation and marine mammal predation during freshwater migration.

Seal predation has been identified as a significant contributor to juvenile and adult salmonid mortality within the Courtenay River and the lowest reaches of the Puntledge River. Detailed assessments conducted in 1990 and 1995 estimated that seals consumed 24% of the returning summer chinook adults and 15% of the out-migrating juvenile salmonids respectively in the river (Olesiuk et al. 1995 and 1996). One of the key findings during these assessments was that a significant proportion of the total consumption of fry and smolts was performed by a small number of seals (of the larger population that inhabit the Courtenay River estuary during April-May) that had developed a specialized foraging behaviour at the 5th and 17th Street bridges whereby they would utilize light cast from the bridges to silhouette and capture outmigrating salmon fry and smolts (Olesiuk et al. 1995).

In response to these concerns a lethal cull was carried out in the late 1990's removing habituated seals from the river. An increasing trend in Summer Chinook returns was realized until recently, when the abundance of seals predating in-river increased again to pre-cull numbers, once again impacting escapement.

A successful seal deterrent technology may provide the opportunity to assist in protecting threatened or endangered stocks as part of a restoration / recovery plan for these fisheries without the need to reinstate a lethal cull of seals in the Courtenay River.

3. METHODS

Between April 27 and June 5, 2008 three different electric arrays were tested in the lower Puntledge River. Each of the electric barrier configurations were installed just upstream of the 5th Street bridge in approximately a 24 metre stretch of river between the upstream edge of the bridge and a metal retaining wall located on the west side of the river (Figure 1). Each array was securely anchored to both shorelines as well as in several locations in the river bottom. Anchors were placed upstream and lines ran from arrays to anchors to hold positioning of arrays throughout the test period (Appendix A).

The electrodes of the first array consisted of 3 copper cables 12.7 mm (½-inch) in diameter strung across the river perpendicular to the stream flow, held at even spacing 3 meters apart by securing the cables to PVC pipes each 6 meters long (Figure 2). This configuration is referred to as "**3-cable**" array. The second array consisted of 17 copper pipes each one 19 mm (¾-inch) in diameter and 6 metres long, laid parallel to the stream flow every 3 meters across the 49 m (160 ft) of river. Although this configuration was originally designed with 17 copper electrodes, four electrodes were eventually disconnected (see Section 4.2). Wire cables connected the copper electrodes to the power source and served to maintain 3-meter spacing. This array is referred to as "**17-element**" array (Figure 2). The third array was an exact duplication of the array used in 2007, consisting of 4 copper cables 12.7 mm (½-inch) in diameter strung across the river perpendicular to the stream flow, held at even spacing 2 meters apart by securing the cables to PVC pipes each 6 meters long (Figure 3). This is referred to as "**4-cable**" array.

DFO provided a secure metal building on the west side of the river to house all electronic and computer components necessary for the project (Appendix C - Photo 4). This included Smith-Root BP-1.5 Programmable Output Waveform (POW) pulsators, computer components needed to produce and control electrical output to the arrays, and computers to record DIDSON images. The 1.5 POW barrier pulsators were powered by 220V, 30 Amp circuit obtained from a neighbouring apartment building. Heavy gauge wires encased in conduit transmitted power to the array cables at the water's edge. The arrays laid flat on the river bottom and, when energized at a frequency of 2.25 Hz, filled the volume of water directly over the cables with an electric field of no more than 0.32 V/cm at the surface (Appendix B). The electric field bowed out 2-3 meters above and below the array, but quickly decreased to undetectable levels several meters upstream and downstream of the array. Field strength measurements were taken for all three arrays using the Smith-Root, Inc. EFP-2 Electric Field Probe. This consisted of taking voltage gradient measurements at the water surface from a boat. These measurements were used to assess whether the array was functioning properly and within operational parameters. Water conductivity varied from 28 – 37 microSiemens/cm between April 27th and May 1st, 2008. Conductivity measurements taken at high tide underneath the 5th St. bridge on the river bottom on June 4, verified the lack of saltwater intrusion.

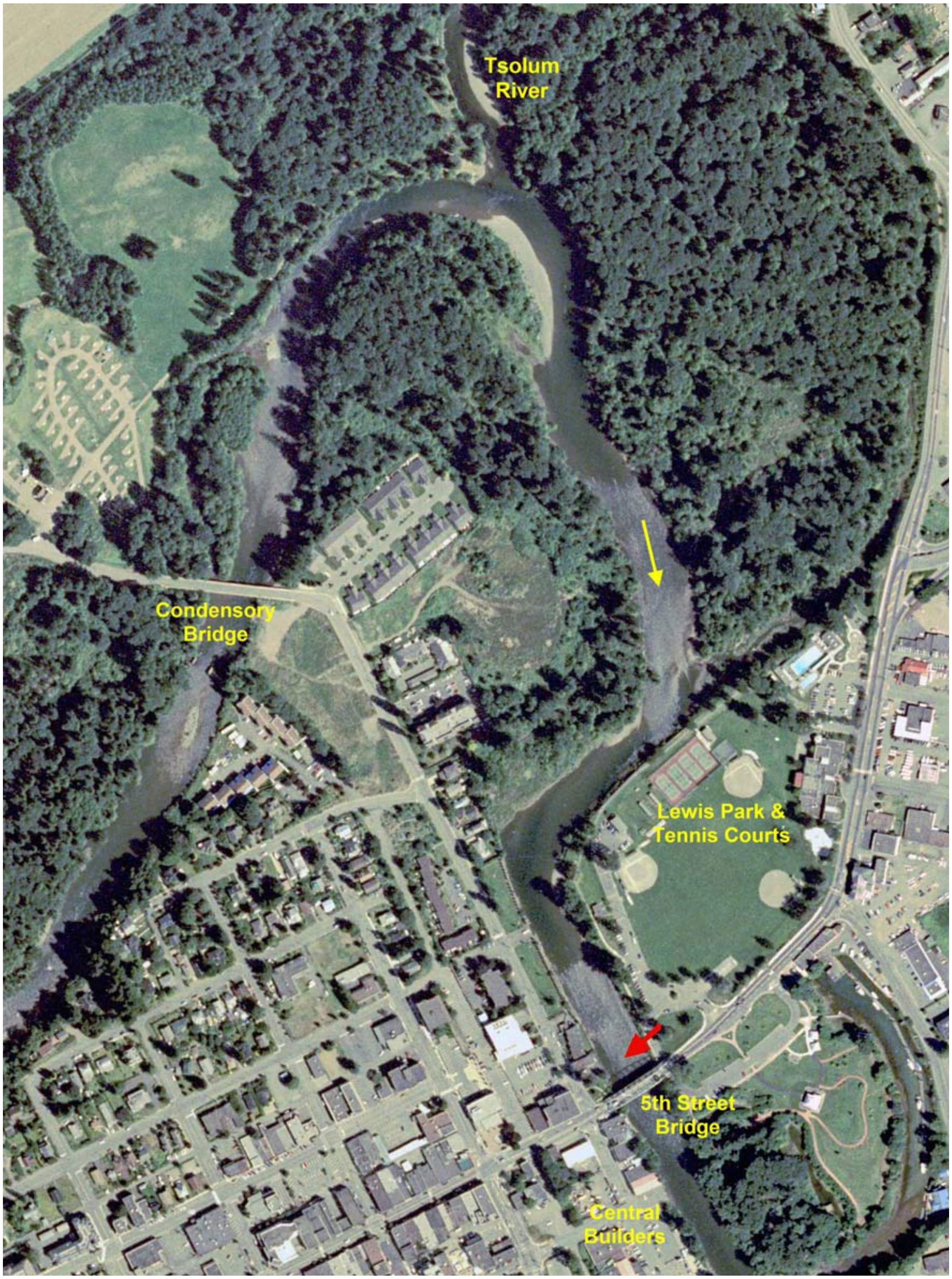

Figure 1. Location of the 2008 Electric Seal Deterrent Trials (red arrow) in the Courtenay River, and other key features associated with the study. The 17th Street bridge (not shown) is located ~1km downstream of the 5th Street bridge.

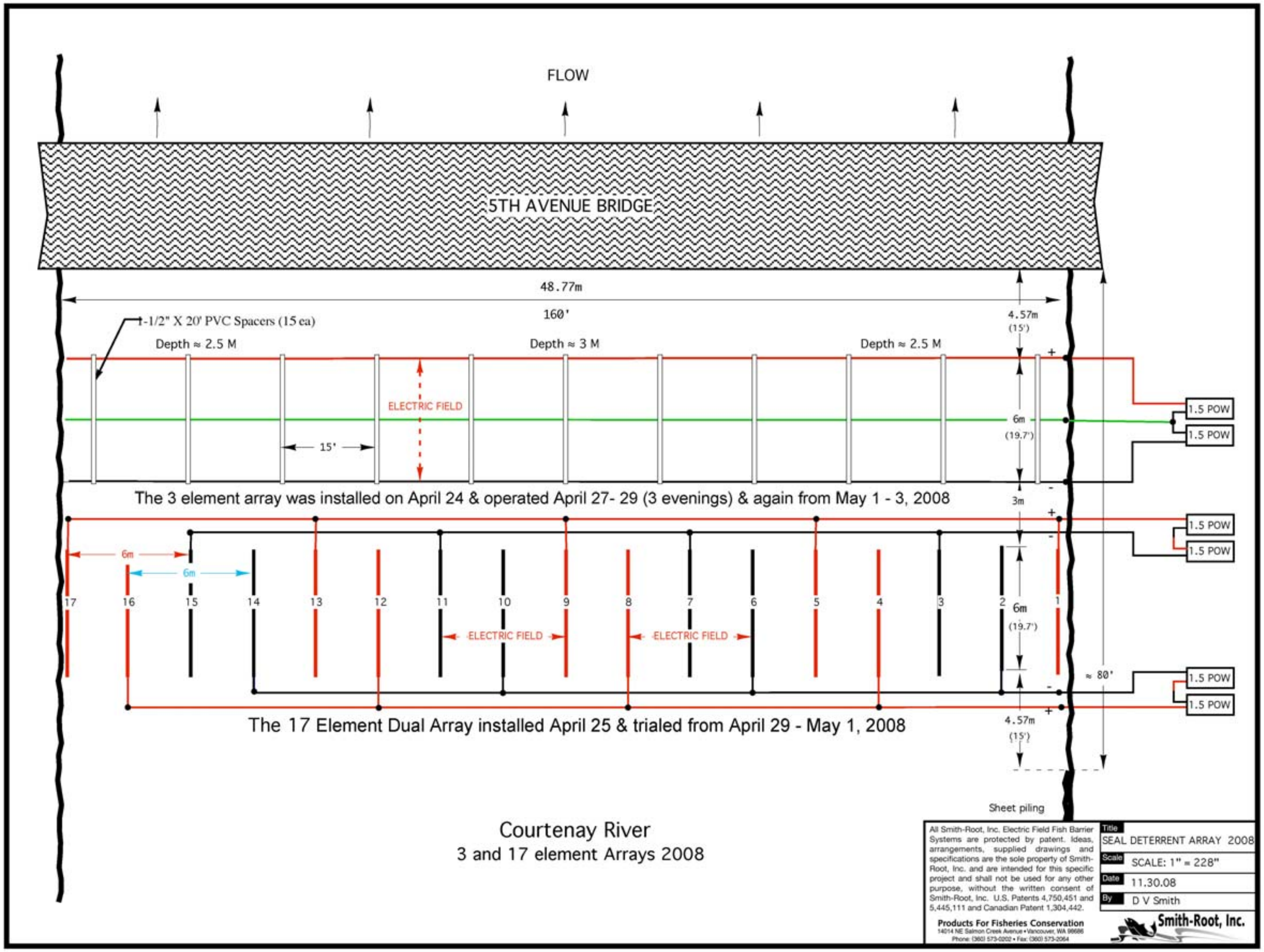

Figure 2. Schematic of the 3-cable and the 17-element arrays tested in the Courtenay River upstream of the 5th Street bridge between April 27 and May 3, 2008.

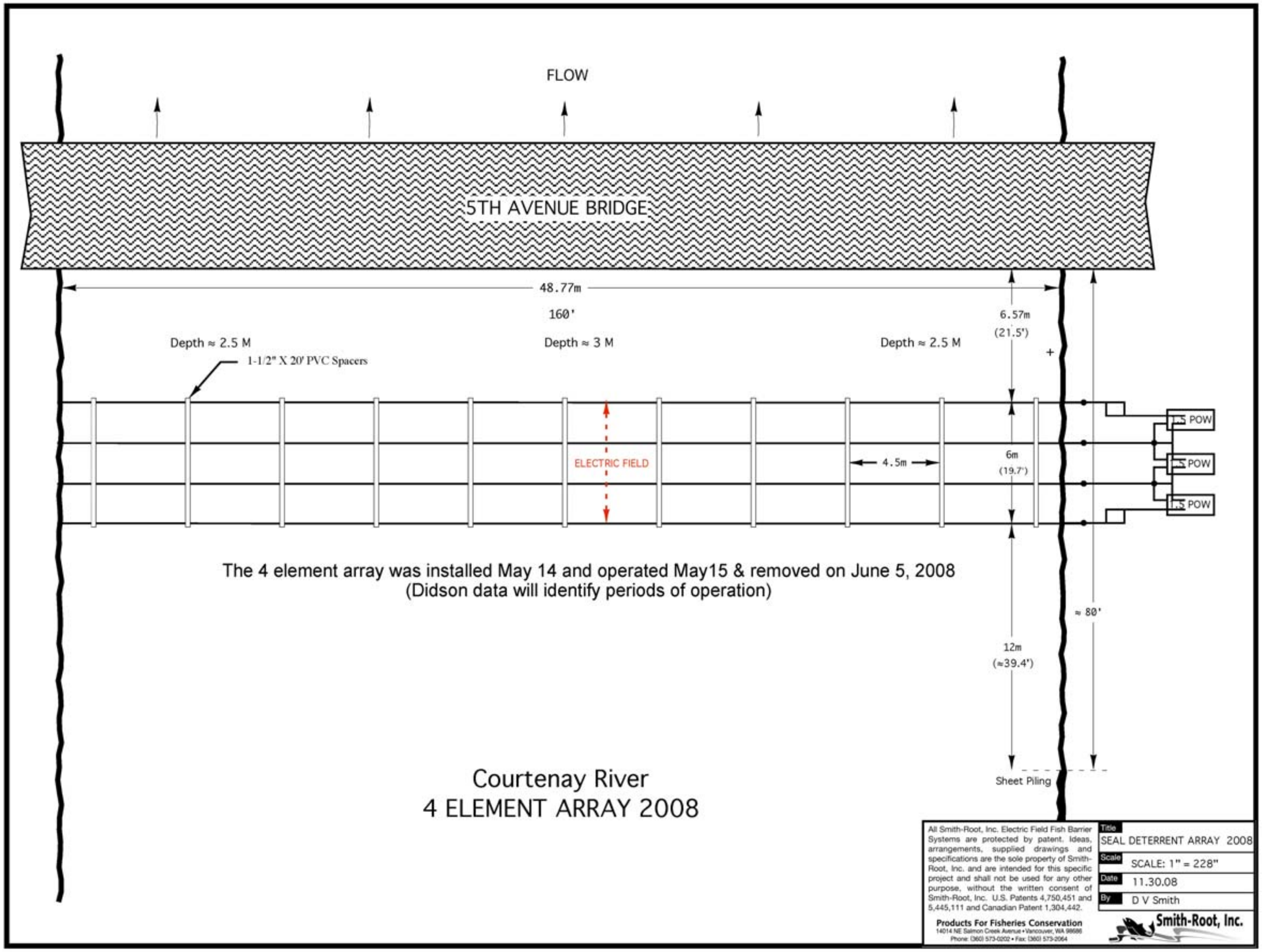

Figure 3. Schematic of the 4-cable array tested in the Courtenay River upstream of the 5th Street bridge between May 14 and June 5, 2008.

The “3-cable” and “17-element” arrays were installed during the week of April 21 - April 26, 2008. The 3-cable array was situated approximately 4 meters upstream of the 5th St bridge and the “17-element” array was placed approximately 3 meters upstream of the top of the “3-cable” array. Both of these arrays were in the water and operational from April 27th – May 3rd. The “3-cable” array was operated on April 27- 29 (3 evenings). The “17-element” array was trialed from April 29 - May 1. During the period of May 5th – 9th the “17-element” array was pulled out and the “3-cable” was converted into the “4-cable” array. This was done in-situ by adding an additional cable and repositioning two other cables so as to maintain even spacing of 2 meters between cables. The “4-cable” array was operated from May 14 to May 22 and was removed from the river on June 5, 2008.

Two DIDSON (Dual-frequency IDentification SONar) acoustic cameras, a Short-range (30 m) and a Long-range (80 m), were used to record behaviour of seals and fish in the area of the active electrical array. Two ramps were constructed on the west shoreline to guide and position the DIDSON acoustic cameras in the water (Appendix C - Photo 3). This additionally allowed easy installation and removal, as the DIDSONs could not be left permanently in position due to security concerns. One was located downstream of the lower array and the other was located upstream of the upper array (Appendix A). The positioning of these ramps was not changed throughout the testing. The Long-range DIDSON initially was placed at the downstream ramp with the Short-range DIDSON at the upstream ramp, however the downstream ramp was located in water too shallow to allow continual operation of the DIDSON throughout the tidal cycle. As the Long-range DIDSON provided the best coverage of the interactions between seals and the electric array, it was moved to the upstream ramp after a few days. DIDSON imagery was collected during each evening the electric array was operated with the exception of the initial trial period of the 3-cable array.

During the field trials, a minimum of two safety observers were on site stationed near shore where visibility of the electrified zone was unobstructed. The electrical system for operating the arrays was equipped with a kill switch which the safety observer could have next to them while at the shoreline. The observer could turn off power to the array at a moments notice if there was any potential for a human interaction with the electrical field in the water. Signs were placed above and below the electrical arrays to alert water users of the presence of electricity in the water during the trial periods (Appendix C - Photo 5). The observers were also equipped with an air horn to get the attention of humans wanting to pass through the array location. Power was always turned off whenever humans approached the array.

At various times during initial start-up of the electric deterrent trails, when array configurations were changed and/or when pulse width settings were increased, Dr. M. Haulena, Vancouver Aquarium veterinarian; Peter Olesiuk, DFO Marine Mammal Biologist; and staff from DFO Puntledge Hatchery and Smith-Root Inc. were also present to review parameters of the electric field and monitor seal behaviour in response to the electric field at various pulse width settings. Approval was obtained from the Animal Care Committee (ACC) to operate the array at 0.3 v/cm and 2 Hz with pulse widths varying from 1 to 5 msec by 1 msec increments. The latter required the full consent of Dr. Haulena and P. Olesiuk before implementing.

4. RESULTS

4.1 Baseline Observations

Following observations and assessments conducted in the 1990s on seal predation on outmigrating fry and smolts (Olesiuk et al. 1995), it was strongly recommended that shielding of the lights at the 5th and 17th Street bridges should be evaluated as a mitigative measure to deter seals from foraging beneath them. Predation on outmigrants was determined to be a relatively localized behaviour. With assistance from the City of Courtenay, modifications to the lights on the 5th Street bridge were finally completed in the fall of 2007. This included turning off every second light on the bridge truss above the road, and erecting a shield around the remaining lights to prevent light from spilling beyond the bridge deck and into the river, significantly reducing the light shadow used by foraging seals.

Observations of seal foraging behaviour were collected by Puntledge Hatchery personnel during the months of April and May 2008 (before the arrays began operating and during their operation) at 5 main areas of the Puntledge / Courtenay River: Condensory Road bridge, Lewis Park tennis courts, 5th Street bridge, Central Builders, and the 17th Street bridge using night vision equipment (see Figure 1). Observations were conducted between dusk and dawn and during favourable tides (when seals typically enter the river for foraging at the 5th Street bridge). The 2008 observations are compared to 2007 observations collected during the same months and illustrated in Figure 4.

It appears that the light shields were effective in reducing the number of seals feeding under the 5th Street bridge. For the period prior to the start of the electric fence trial on April 27, the maximum number of seals observed on any given monitoring event was 4 in 2008 compared to 9 in 2007 and 10 in 2006. The average number of seals observed during this period was 5.2 in 2006, 3.7 in 2007 and 0.7 in 2008. It was noted that the light shields appeared to have eliminated the distinct shadow line where seals have congregated to feed on outmigrating juveniles in past years. Seals may have been displaced to other well lit areas of the river to feed such as the tennis courts (upstream) or the area adjacent Central Builders (downstream). A comparison of 2007 and 2008 observations at the Lewis Park Tennis Courts provides limited information due to the disproportion in sampling effort between the 2 years (Figure 5). No observations were collected at the Central Builders site downstream of the 5th Street bridge in 2007 for comparison. These comparisons do not take into account other variables that may have influenced seal activity such as tide level and river discharge.

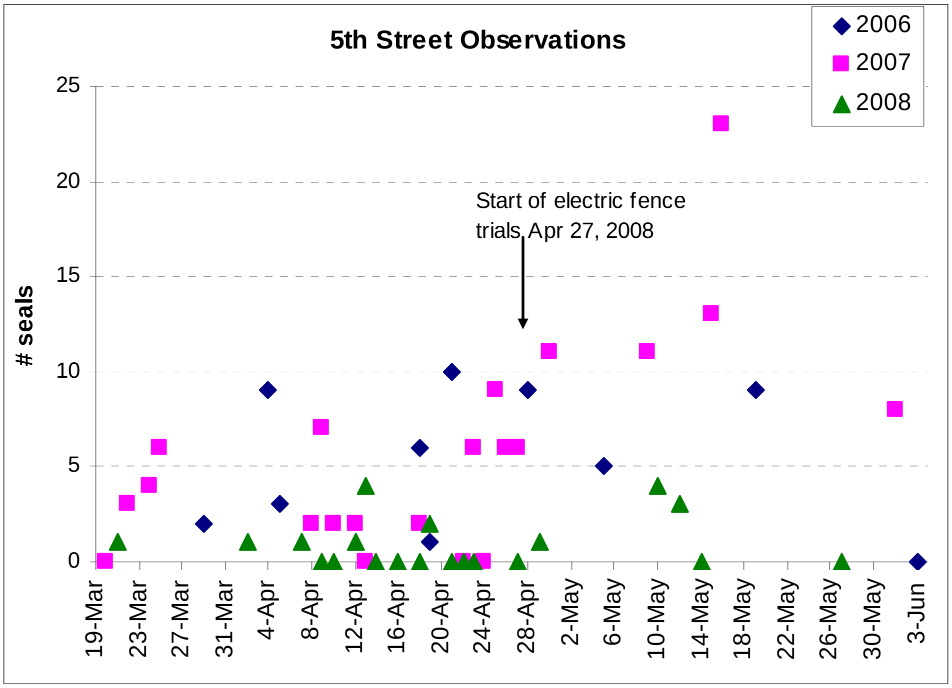

Figure 4. Observations of seals in the Courtenay River at the 5th Street bridge between April and June before lights were shielded (2006-2007) and after (2008). Commencement of the 2008 electric deterrent trials is noted. Trials in 2007 were conducted on April 12-13 and April 23-25

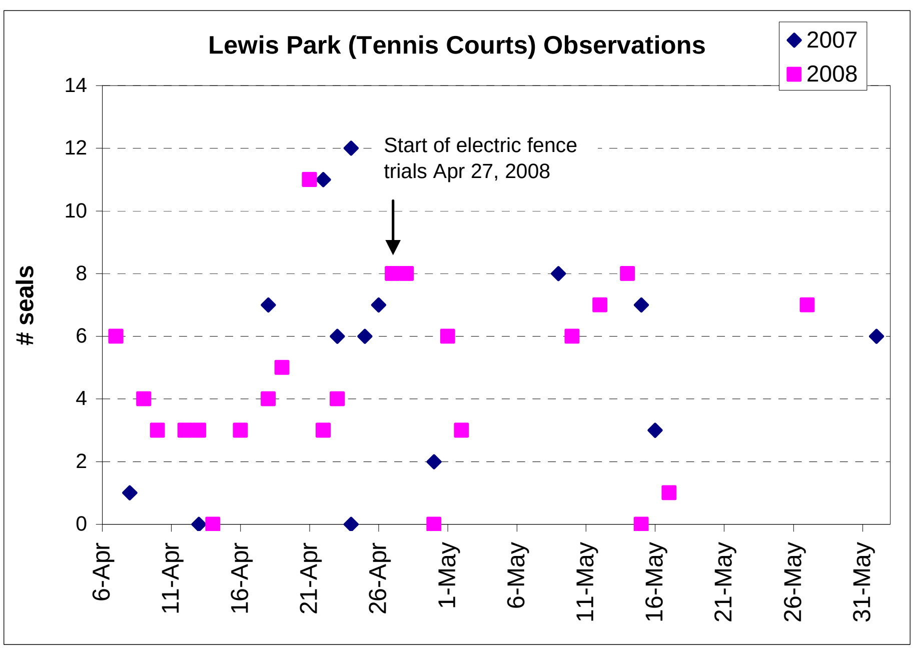

Figure 5. Observations of seals in the Courtenay River at the Lewis Park Tennis Courts (upstream of the 5th Street bridge), between April and June before lights were shielded (2007) and after (2008). Commencement of the 2008 electric deterrent trials is noted. Trials in 2007 were conducted on April 12-13 and April 23-25.

4.2 Phase II – electric deterrent trials during juvenile outmigration

“3 cable” Array – electrodes perpendicular to stream flow

Tests of the “3-cable” array commenced on April 27, 2008 at 0.3 v/cm and 2 Hz at the 1 msec pulse width setting and ramping up to a maximum of 3 msec by the third evening. This array configuration was similar to the array tested in the Puntledge River in 2007, but with only 3 cables placed perpendicular to the river flow rather than 4 as in 2007. Seals were observed to easily move upstream through the array at the lower pulse width settings while at the highest setting some seals exhibited more distinctive avoidance behaviours. Measurements of the voltage gradient at the water surface within the array found gaps in the voltage (voltage drop) in the centre of the array. Tests using this configuration were terminated when the inconsistencies in the electric field could not be rectified. One explanation for these inconsistencies was the potential presence of metal in the streambed since the location of the array differed slightly from its position in the 2007 study.

“17-element” Array – electrodes parallel to stream flow

Operation of the 17-element array commenced on April 29, 2008 at the 1 msec pulse width setting, ramping up to the 5 msec pulse width setting by the fourth and final evening of testing. The parallel electrode orientation was considered to be less likely to affect adult fish, or potentially disrupting their upstream migration. The electric field lines created between the electrodes in a parallel orientation would flow horizontally through the fish (side to side) rather than from snout to tail as would occur with perpendicular orientations, when fish are swimming against the flow. However, when the electric field was tested, inconsistencies and gaps in the voltage across the field were again discovered and the new design did not perform as expected from the models. Some of the electrodes at the shoreline were exposed at low tide. These were disconnected in an attempt to resolve the voltage problems with no success. At the highest 5 msec pulse width setting, results from DIDSON sonar imagery revealed that approximately 68% of the seals that approached the barrier from downstream were turned back compared to between 30 and 50 % at the lower pulse width settings (Table 1). Observers also noted distinctive behavioural responses in seals during both upstream and downstream passage through the array, such as hesitation, splashing or porpoising at the surface, and circling within the array.

Schools of juvenile salmon were observed drifting passively over the array at night during these trials but did not appear to be affected by the electric field. The operation of the 17-element array was terminated on May 2, 2008 when various wiring configurations failed to resolve the voltage gaps in the electric field.

“4 cable” Array – electrodes perpendicular to stream flow

Operation of the 4-cable array commenced on May 14, 2008 at the 1 msec pulse width setting and ramping up to 3 msec on the first evening. Only 1 seal was observed during the time the fence was operated at the 1 msec pulse width setting (30 minutes), and successfully passed through the array with some hesitation. At the 2 msec pulse width setting which was tested for 1 hour and 18 minutes, 4 of 6 seals (67%) were blocked from upstream passage (Table 1). For the remainder of the trial on May 14 (2043 – 0200 hrs) at 3 msec, a total of 6 of the 8 seals (75%) that were observed approaching the array were prevented from continuing upstream.

The first trial at the 4 msec pulse width setting was conducted on the evening of May 15. During this test, the array was activated over one hour before dusk and before seals moved into the area. Dr. Olesiuk was present during this trial and observed 3 seals approaching the array from downstream at dusk. One passed quickly through the array without difficulty. A second seal appeared to experience involuntary muscle contractions while trying to swim through the array and was unsuccessful at making further upstream progress and moved downstream. The third seal also entered the array and experienced physical difficulty swimming through it. After climbing on shore the seal was observed exhibiting the same muscle contractions as the second seal, but managed to proceed upstream. Based on the physiological responses observed in these seals it was recommended that further testing of the array at the 4 msec pulse setting be postponed until Dr. Haulena could be present. Tests continued at the 3 msec setting for the remainder of that evening until May 22.

The second trial at the 4 msec pulse width setting was conducted on May 22. The array was activated at 1900 hrs and within a few minutes one seal surfaced upstream of the array suggesting it likely passed through the array. A few minutes later two more seals approached the array from downstream. One entered the array and became immobilized, experiencing the distinctive whole-body muscle contractions as seen previously. This seal remained in the array for close to one minute before it was able to proceed upstream. The second seal made a few attempts to enter the array but was turned back and disappeared downstream. About 10 minutes later two more seals approached and passed through the array successfully, possibly due to the weakening field strength as the tide height increased. Many other seals that had been staging downstream of the array were observed passing upstream through the array as the tide increased during the evening. High tide of 4.8 m or 15.7 feet was at 21:00 hrs.

One final test of the electric field was conducted on June 4th though a large tide cycle (5.1 m / 16.7 ft.). During this test, Smith-Root collected measurements of the electric field over the array at the surface throughout the tide cycle and confirmed that the strength of the electric field weakened over the array as the river depth increased from the rising tide (data to be included in Final Report by SR). During this high tide cycle, conductivity measurements confirm that there was no salt water intrusion into the area (no change in river conductivity readings at peak tide height), though at the 17th Street bridge, full strength sea water was measured. Therefore the 5th Street bridge location likely is the closest site to the estuary that could accommodate an electric deterrent installation.

Table 1. Summary of seal occurrences at electrical arrays on the Courtenay River, based on DIDSON sonar images collected from April 28 - May 22, 2008.

Date	Didson Operational Time (24 hr clock)	Pulse Width (msec)	Array Config.	Upstream Blocks / Attempts	Downstream Blocks / Attempts	Approx. Discharge Gauge 8 + Tsolum (cms)	Tide Level During Period (m)	Direction	Comments
Apr 28	2245 - 0045	2	3-cable	15 / 22 (68%)	0 / 9 (0%)	37	3.6 - 4.4	rising	high tide (4.6m) occurred at 0200 on Apr29
Apr 30	1736-0047	2	17-element	4 / 13 (31%)	1 / 2 (50%)	25	2.65 - 3.9	falling then rising	low tide (2 m) occurred at 20:00
May 1	2015 - 2132	3	17-element	2 / 5 (40%)	0 / 9 (0%)	23	2.4 - 2.35	low tide	low tide (2.3 m) occurred at 21:00
	2132 - 0025	4	17-element	6 / 12 (50%)	0 / 8 (0%)	23	2.35 - 3.3	rising	high tide (4.6m) occurred at 0300 on May 2
May 2	1849 - 0236	5	17-element	32 / 47 (68%)	0 / 15 (0%)	24	3.5 - 4.3	falling then rising	low tide (2.5 m) occurred at 22:00
May 14	1855 - 1924	1	4-cable	0 / 1 (0%)	0	59	2.8 – 2.7	falling	data from visual and DIDSON
	1925 - 2042	2	4-cable	4 / 6 (67%)	0 / 1 (0%)	59	2.7 – 2.6	falling	data from visual and DIDSON
	2043 - 0200	3	4-cable	6 / 8 (75%)	0 / 9 (0%)	59	2.6 - 4.5	falling then rising	low tide (2.5 m) occurred at 21:00
May 15	1819 - 2145	4	4-cable	1 / 2 (50%)	0 / 1 (0%)	70	3.6 - 2.9	falling	2.9 m low tide at 21:00
	~2145 - 0130	3	4-cable	11 / 11 (100%)	0 / 3 (0%)	75	2.9 - 4.0	rising	4.5 m high tide at 03:00 May 16
May 16	1830 - 0500	3	4-cable	15 / 23 (65%)	0 / 17 (0%)	83	4.0 - 4.3	falling then rising	low tide (3.1 m) occurred at 23:00.
May 17	2034 - 0615	3	4-cable	16 / 20 (80%)	0 / 24 (0%)	99	3.95 - 3.85	falling - rising - falling	low tide (3.4 m) occurred at 23:00.
May 18	2028 - 0615	3	4-cable	23 / 32 (72%)	0 / 11 (0%)	88	4.35 - 3.9	falling - rising - falling	low tide (3.5 m) occurred at 24:00
May 19	2020 - 0615	3	4-cable	20 / 25 (80%)	0 / 23 (0%)	87	4.6 - 4.0	falling - rising - falling	low tide (3.6 m) occurred at 01:00 May 20
May 20	2028 - 0614	3	4-cable	62 / 72 (86%)	0 / 20 (0%)	59	4.75 - 4.2	falling then rising	low tide (3.7 m) occurred at 01:00 May 21
May 21	2022 - 0600	3	4-cable	25 / 33 (76%)	3 / 20 (15%)	56	4.75 - 4.1	falling then rising	low tide (3.7 m) occurred at 02:00 May 22
May 22	1957 - 2308	4	4-cable	13 / 25 (52%)	0 / 2 (0%)	53	4.5 - 4.6	rising then falling	high tide (4.8 m) occurred at 21:00
	2315 - 0300*	4	4-cable	1 / 1 (100%)	0 / 2 (0%)	54	4.55 - 3.7	falling	low tide (3.7 m) at 03:00

Notes: Array operation commenced Apr 27, 2008 during which time issues with the electric fields and DIDSON operation were worked out. Occasionally visual observations were made during these two days, however they were insufficient to include in this summary. A Short-range and a Long-range DIDSON were used at various times throughout the testings. Data from the Long-range DIDSON were used for summarizing unless not available in which case data were used from the Short-range DIDSON. DIDSON images for April 28th were read by Lisa Harlan (Smith-Root, Inc.) and images for April 30 - May 22 were read by T. Defeo (DFO). Data were not verified by a second reader. Data summarized by L. Harlan and only includes occurrences where species and final direction of seal movement were positively identified

* 2315-0300 Long Range operated at 20m to observe smolts. Seal passage during this time included in count.

DIDSON imagery collected during operation of the 4-cable array from May 15 to May 21 at the 3 msec pulse width setting indicate that between 65% and 100% of seals that approached the array from the downstream end were turned away (average = 79%). Similar to operation of the 17-element array, there appeared to be no adverse effect on outmigrating juveniles passing through the array, either from DIDSON imagery or from visual observations made on shore. The original study design proposed to assess potential physiological affects on juveniles by conducting fish health examinations on juveniles after passing through the array, and conducting a bioassay to assess seawater adaptability on chinook smolts after passing though the energized and disconnected array. However, this component was not completed after discussion with DFO veterinarian Dr. Christine MacWilliams. It was felt that any sublethal effects on juvenile salmonids exposed to the array would be extremely difficult to assess, and would not likely provide any meaningful information to the study.

4.3 Phase III – electric deterrent trials during adult migration

This component of the study was terminated following a review of DIDSON imagery collected on May 18, 2008 during operation of the 4-cable array at the 3 msec pulse width setting. The imagery identified 14 adult salmon targets approaching the array. Three adults proceeded upstream through the array, 6 turned around and went downstream and the remaining 5 fish appeared to stall at the downstream periphery of the array, but their eventual migration direction was inconclusive. The DIDSON sonars were operated on May 24 with the electric fence shut off to observe adult migration. Nine adult salmon targets were confirmed with 8 proceeding upstream over the disconnected array and one turning back downstream. DIDSON images were verified by I. Matthews and G. Cronkite (DFO). Since summer chinook are the main migrating population during this time period, it was agreed that any observed obstruction to their upstream migration would result in an immediate suspension of further testing of the electric barrier.

4.4 Environmental Data

Flows (hourly averages) during the study period (April 1 – June 5, 2008) were obtained from Environment Canada for Puntledge River station WSC Gauge No. 08HB006 located below the BC Hydro Puntledge Generating station (3.7 km upstream from the Puntledge/Tsolum River confluence) and for the Tsolum River (WSC Gauge No. 08HB011) located approximately 2 km upstream of the confluence. Discharge from these two stations were totalled to provide an estimate of the discharge observed at the 5th Street bridge with no correction for lag time for distances between gauge locations and the bridge location (Figure 6). Discharge in the river below the confluence was highest during the testing period of the 4-cable array from May 14 to May 22, 2008 (average discharge = 68.8 cms) and lowest during the baseline observations (average discharge = 21cms).

The mouth of the Courtenay River becomes accessible to seals at tides above 1.7 meters and as the tide rises, seals move progressively further upstream. At tides above 3.5 meters seals may be distributed along the entire lower 3.5 km of the river under tidal influence. Testing periods of the 3 arrays from dusk to dawn corresponded to tide levels typically greater than 1.7 m (Table 1).

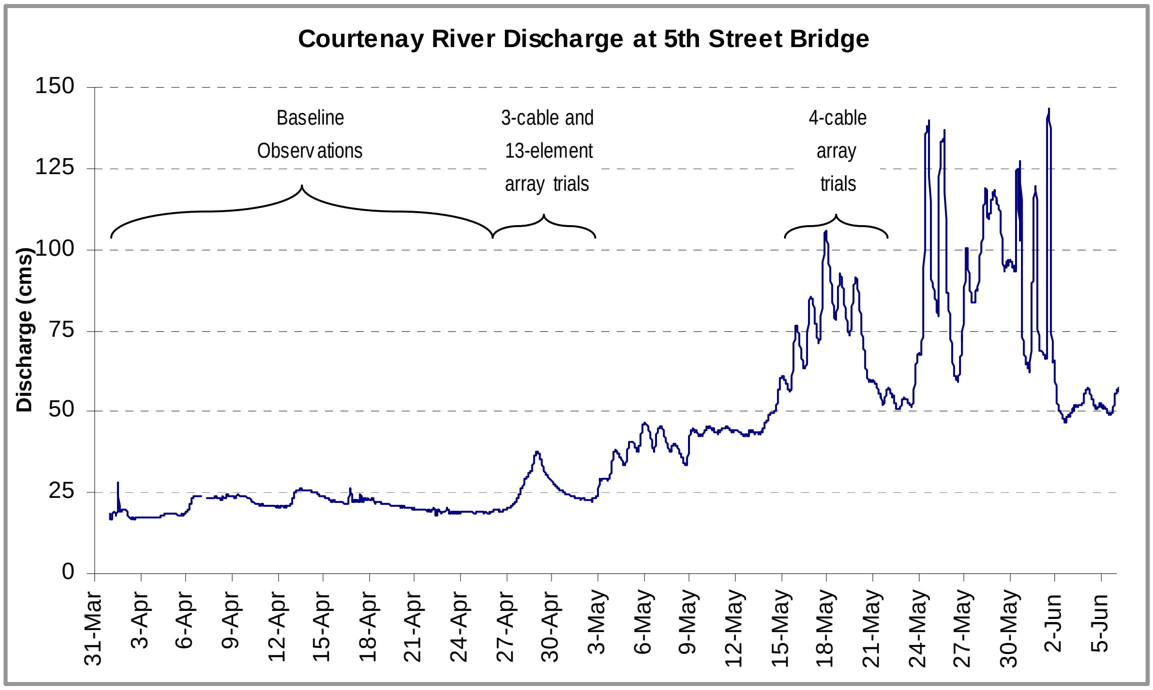

Figure 6. Hourly average discharge for the Courtenay River (below the Puntledge/Tsolum River confluence) from April 1 – June 5, 2008, derived from the sum of Puntledge River discharge below the BC Hydro powerhouse and the Tsolum River discharge.

5. DISCUSSION

The key objectives of this study were to assess 1) whether an electrical array will serve as an effective barrier in blocking seal movements upstream of the array; 2) whether the strength of the electric field sufficient to deter seals affects the migratory behaviour of juvenile and adult salmon; and 3) whether there is a difference in the efficacy of the two types of arrays tested in this study.

With respect to the first and the third objectives, the observational data obtained from this study indicates that the establishment of an electric field at the 5th Street bridge in the Courtenay River had a varying effect on upstream seal movement. Of the three array configurations tested in this study the 4-cable array with the electrodes positioned perpendicular to the river flow provided the most consistent electric field across the channel width and for this reason appeared to be the most effective in preventing the upstream passage of seals in the Courtenay River. At pulse width settings of 3 msec, an average of 79% of the seal attempts to migrate upstream through the array were blocked.

Pulse width settings greater than 3 msec appeared to cause physiological stress in the seals that were exposed to this electric field, leading the project team to recommend an upper threshold of 3 msec for future trials.

The effectiveness of the barrier was dependent on the strength of the field provided by the pulse width parameter, but may also have been dependent on the environmental conditions during which the array was operated. As the river depth over the array increased due to tidal inundation and increased discharge, the electric field weakened at the surface, potentially creating openings in the electric barrier that seals would quickly learn and habituate to. (data pending from SR).

While the barrier may be considered effective at deterring the upstream movement of a large proportion of seals that approached it, it was noted that even at the highest electrical field strengths tested some seals continued to challenge the array exposing themselves to significant physiological stress and potentially harmful levels. The commencement of trials at the lowest pulse width setting (1 msec) and ramping up gradually to higher levels (4-5 msec) has been criticized by Dr Jennifer Hurley, who has considerable experience with captive sea lions, as essentially training seals to tolerate the electrical stimulus, and charge through the array at levels that may be harmful. However, the gradual ramping up of field strength was necessary to determine the upper threshold for invoking an acceptable behavioural response in seals.

Based on the DIDSON images and shoreline observations there was no apparent effect of the electrical field on juvenile salmon migration behaviour at the levels tested. Conversely, upstream migrating adults appeared to have been obstructed at levels that were considered effective at deterring seals. The delay and/or obstruction of 11 of 14 adult salmon targets in DIDSON imagery recorded on May 18 lead to the conclusion that operation of the electric deterrent at a setting that affects the upstream passage of seals (3msec) adversely affects the migratory behaviour of adult salmon. Therefore, with respect to the second objective, the current technology may only be useful at reducing seal predation on juvenile salmon smolts and fry in localized foraging areas and preventing naive seals from accessing feeding areas further upstream during a brief operating window (late April to mid May). Even during this period, there remains the potential that operation of an electric barrier in the Courtenay River to reduce predation on outmigrating juvenile salmonids will overlap with migrating adults (late steelhead migrants and early summer chinook migrants).

The displacement of seals from the 5th Street bridge area to other foraging areas downstream continues to be an issue where lighting provides the distinctive shadow that seals utilize to their advantage such as the Central Builders parking lot downstream of the 5th Street bridge and the 17th Street bridge. Periodic observations at these two locations identified between 8 and 24 seals. Light shielding at the 5th Street bridge installed in 2007 appears to have significantly reduced the number seals foraging at this location. Efforts to design similar solutions in other well lit sections of the river should be explored with the City of Courtenay, Ministry of Transportation and other riverside property owners as this treatment seems to have a positive effect at reducing the number of seals from these areas.

6. RECOMMENDATIONS

Based on what was learned from the 2008 trials in the Courtenay River, the project team recommends the following modifications to the study if further investigation of an electrical barrier is proposed:

1. Conduct a survey of the river bottom in an area upstream of the 5th Street bridge to determine the presence and extent of “scrap” metal that may be embedded in the sediment. Results from this survey will provide direction for re-location of the electrical array or removal of metal debris in order to ensure optimum operation of the array.
2. Deploy the most successful of the arrays tested in 2008 (4-cable array with electrodes perpendicular to stream flow) and increase the length of the electric field from 6 metres to 15 metres. A seal swimming quickly through a 6 m electric field operating at a pulse frequency of 2 Hz would only feel 1-2 electrical pulses and may become habituated to this stimulus.
3. Commence trials at the maximum recommended pulse width setting of 3 msec to prevent seals from adapting to the electric field. Increase the pulse frequency from 2 Hz to 5 Hz (beginning with 3 Hz). These levels are still significantly lower than levels known to injure fish (NMFS 2000).
4. Incorporate a secondary stimulus such as a visual strobe light or acoustic sensor downstream of the array so that seals can recognize the location of the array and choose to avoid the area.
5. Incorporate a water level sensor and relay that will automatically adjust the electrical power of the barrier with varying water depths. Such a mechanism must be able to increase electric field strength at the surface, where the field is weaker, without increasing the strength of the array below (nearer to the electrodes) to levels that may be potentially harmful to seals.
6. Incorporate an experimental design to any future studies so that comparisons of seal behaviour at different electrical field strengths can be made with greater precision than simply examining the overall observations (J. Taylor pers. comm.).

7. REFERENCES

Cave, J., K. Forrest, D. Smith, L. Harlan, C. Burger, L. Carstensen, K. Smith, C. Beggs, B. Munro, M. Haulena. 2008. Evaluation of the use of an electrical gradient as a seal deterrent. Prepared for: Pacific Salmon Commission Southern Boundary Restoration & Enhancement Fund Committee.

NMFS 2000. Guidelines for electrofishing in waters containing salmonids listed under the endangered species act, June 2000. National Marine Fisheries Service, Portland, OR. 5 pp.

Olesiuk, P.F., G. Horonowitsch, G.M. Ellis, T.G. Smith, L. Flostrand and S.C. Warby. 1996. An assessment of harbour seal (*Phoca vitulina*) predation on outmigrating chum fry (*Oncorhynchus keta*) and coho smolts (*O. kisutch*) in the lower Puntledge River, British Columbia. PSARC Working Paper S95-10.

Olesiuk, P.F., P.E. Cottrell and C.E. Neville. 1996. An assessment of harbour seal (*Phoca vitulina*) predation on pre-spawning adult salmon (*Oncorhynchus spp*.) in Comox Harbour and the lower Puntledge River, British Columbia. PSARC Working Paper S96-18.

Personal Communications

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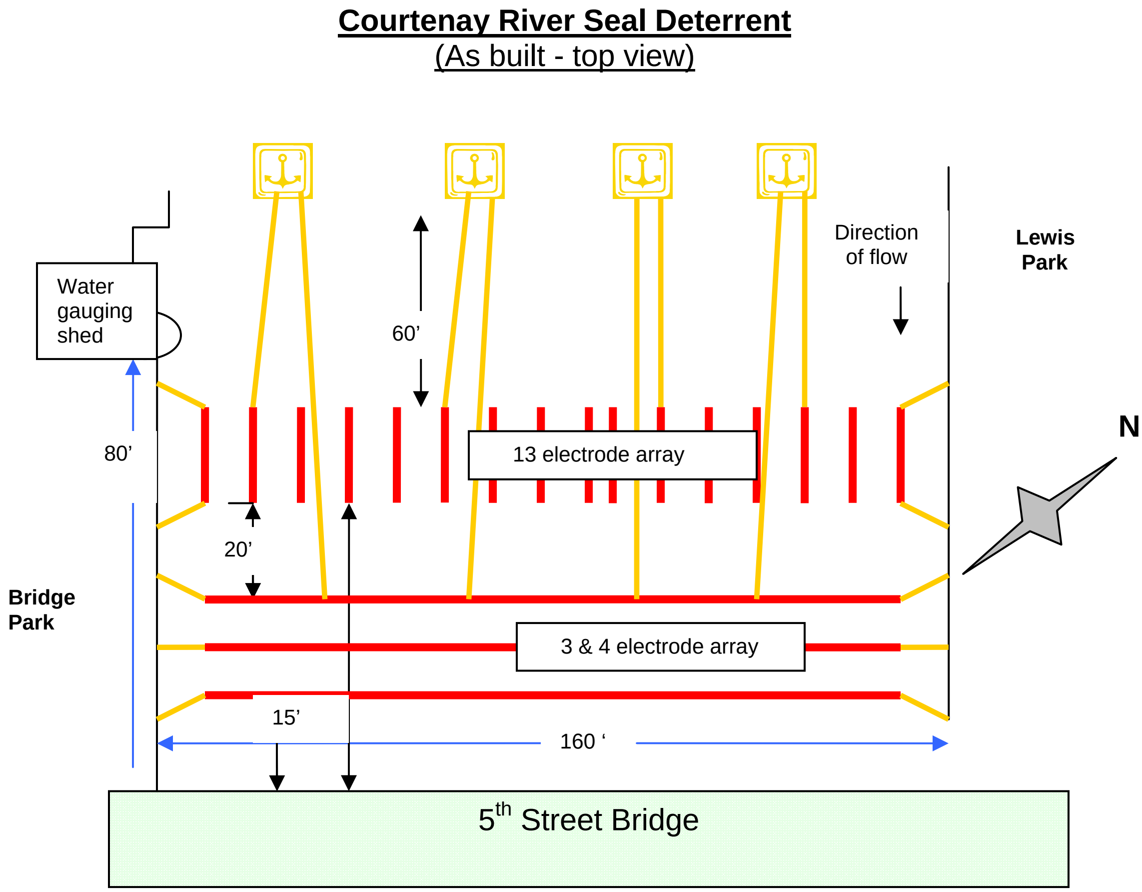
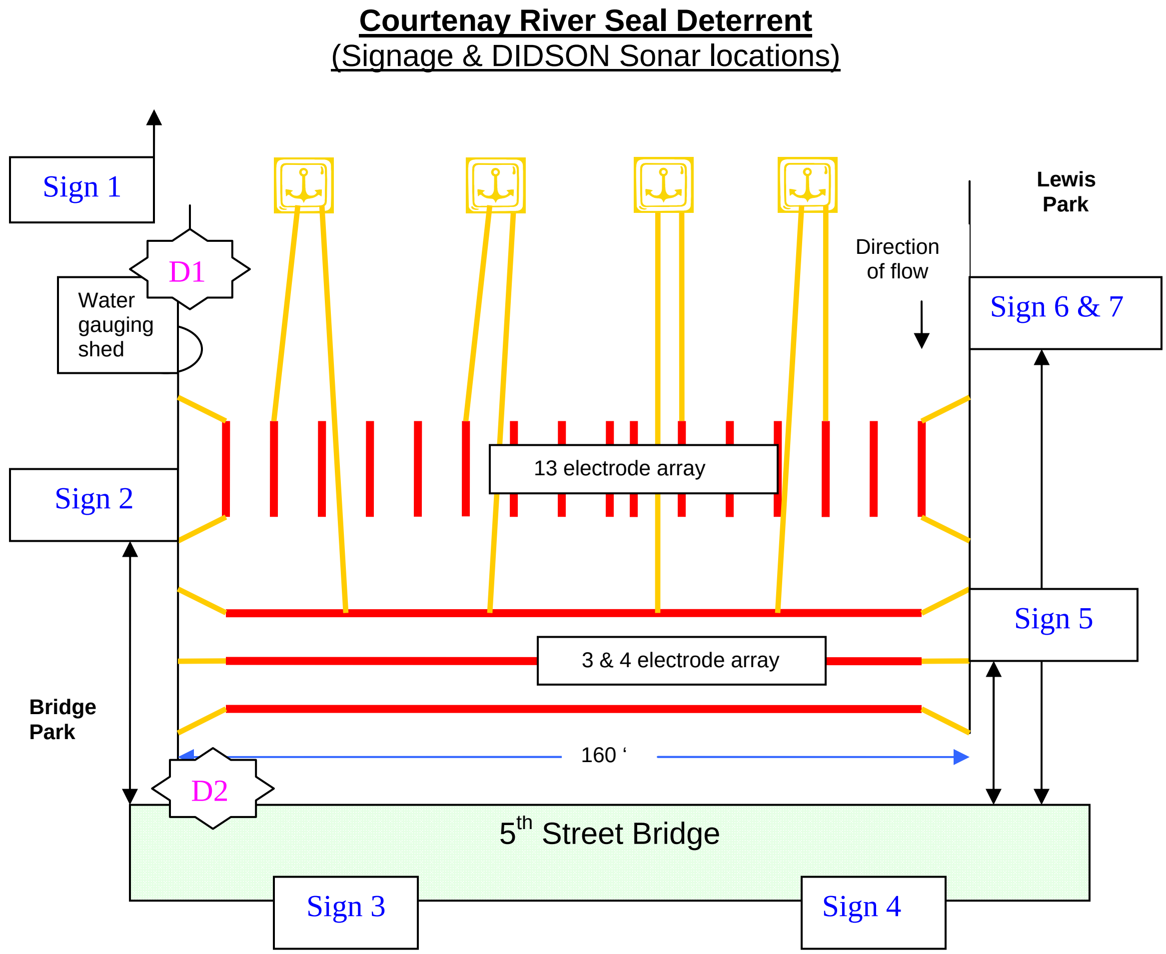
Appendix A. Anchor, signage and DIDSON location schematics.



Anchoring set-up

- 4 anchors (30# ground line / halibut) spaced across river approximately 80'above the top end of the upstream array (new design - 13 electrode).
- Each anchor had 2 lines attached. 1 line was attached to upstream array & 1 line was attached to downstream array.
- Arrays were also attached to shore locations directly adjacent.

Appendix A cont'd. Anchor, signage and DIDSON location schematics.



Sign location:

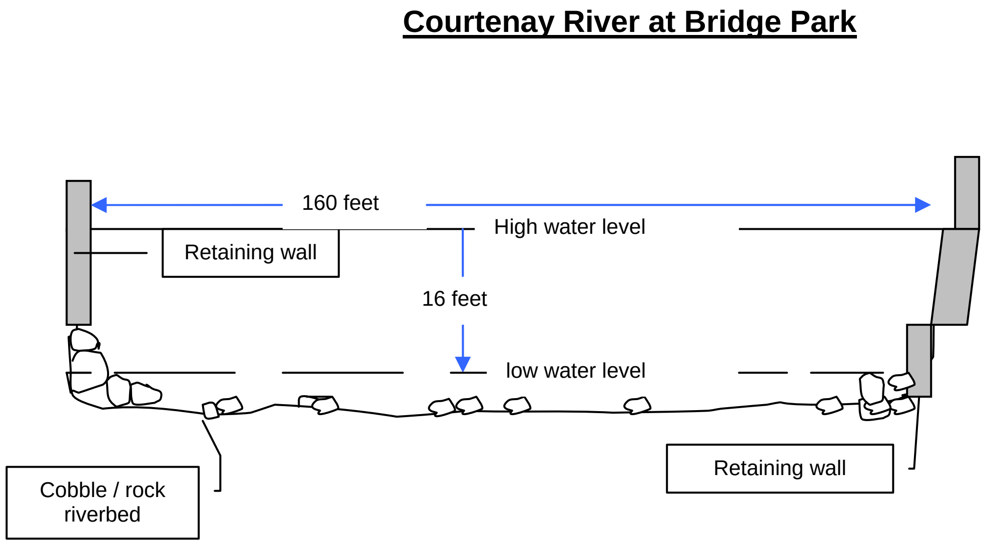
1) 125 ft. upstream from water gauging shed.
2) Immediately adjacent to arrays (river right)
3) Hanging from 5th St. Bridge walkway railing – river right.
4) Hanging from 5th St. Bridge walkway railing – river left.
5) Attached to railing adjacent to arrays.
6) Attached to stairway railing – downstream rail.
7) Attached to stairway railing – upstream rail.

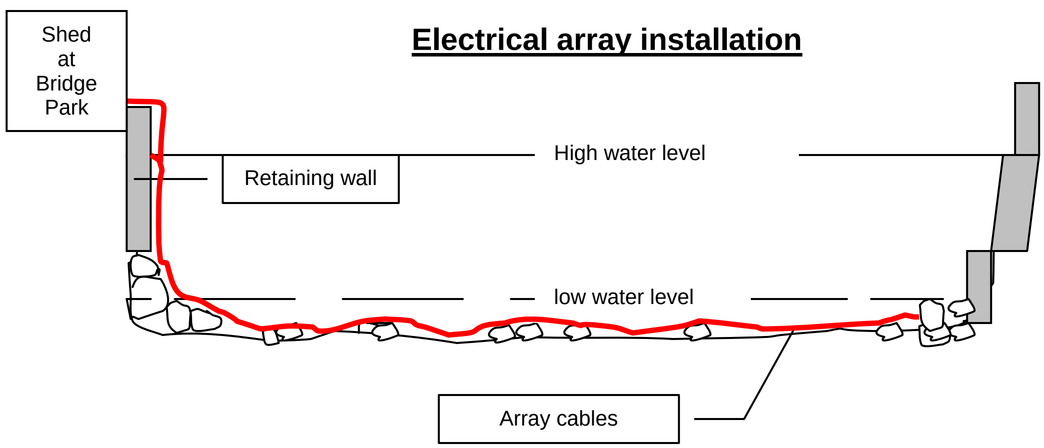
Signs 1, 2, 5, 6 & 7 were 1.5 ft. x 2 ft.
Signs 3 & 4 were 2 ft. x 3 ft.

Didson Location

D1 –Short range model - immediately upstream from survey shed
D2 – Long range model – directly below upstream edge of bridge

Appendix B - Cross section view of Courtenay River at electric array location looking upstream from 5th St. Bridge





Appendix C. Selected Photos

Photo 1. Assembling and installing the 3-cable array, April 2008. Photo looking from east to west shore (river left to river right) at low tide.

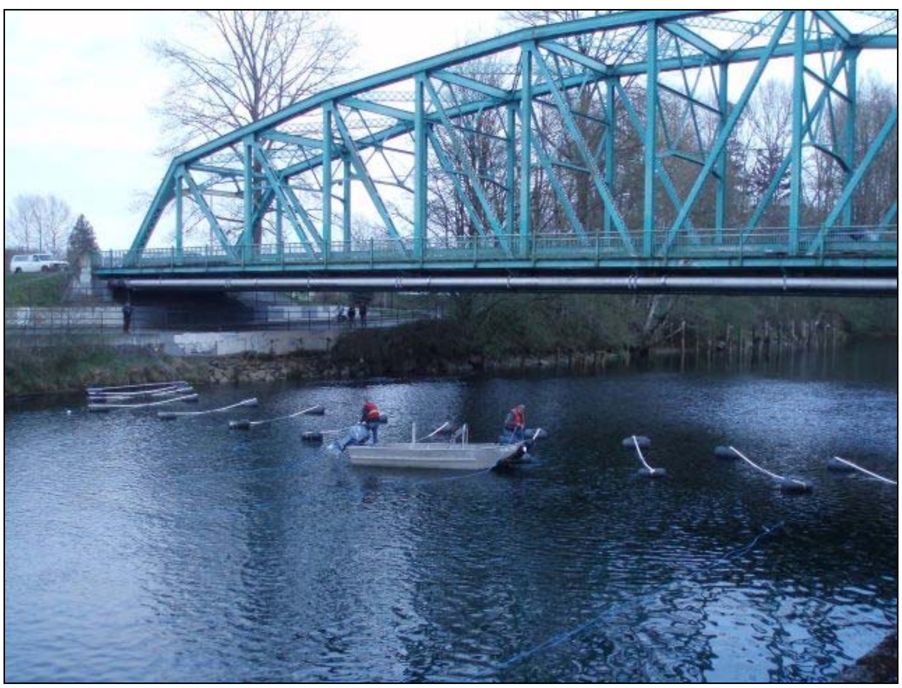


Photo 2. Placement of the 3-cable array upstream of the 5th Street bridge prior to anchoring, April 2008. Photo looking downstream from west to east shore (river right to river left).

Photo 3. Placement of one of two DIDSON sonars and ramp upstream of the 5th Street bridge

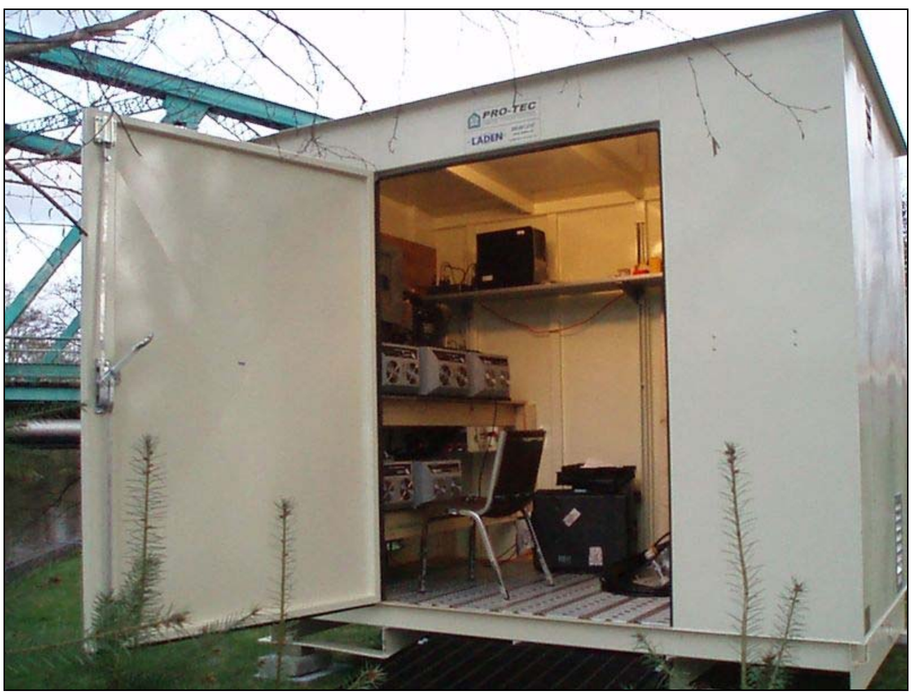


Photo 4. Secure metal building temporarily installed on the west side of the river to house all electronic and computer components necessary for the project.

Photo 5. Example of signage posted upstream, downstream and within the testing area of the electric deterrent in the Courtenay River from April – June 2008.