Columbia River Project Water Use Plan

Kinbasket Reservoir Fish and Wildlife Information Plan

Implementation Year 1

Reference: CLBMON-07

Kinbasket Reservoir Rainbow Trout Life History and Habitat Use Assessment

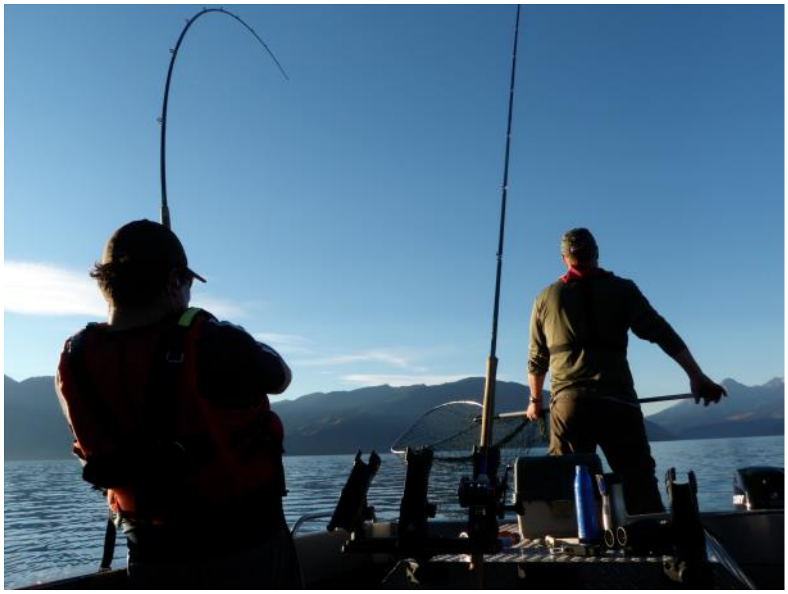
Study Period: September 2014 – August 2015

Canadian Columbia River Inter-tribal Fisheries Commission

7468 Mission Rd, Cranbrook, BC, V1C 7E5

February 19, 2016

WLR Monitoring Study No. CLBMON-07 (Year 1)
Kinbasket Reservoir Rainbow Trout Life History and Habitat Use Assessment



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Cover Photo:

Angling for Rainbow Trout on the Kinbasket Reservoir in September 2014.

Suggested citation:

Caley, K.A., Warnock, W.G. 2015. WLR Monitoring Study No. CLBMON-07 (Year 1) Kinbasket Reservoir Rainbow Trout Life History and Habitat Use Assessment. Prepared for BC Hydro by the Canadian Columbia River Inter-tribal Fisheries Commission. Cranbrook, B.C.

EXECUTIVE SUMMARY

Rainbow Trout (*Onchorhyncus mykiss*) were historically distributed throughout the Columbia and Canoe Rivers, and historic Kinbasket Lake, which were impounded by the construction of Mica Dam in 1973. Mica Dam created Kinbasket Reservoir, a 216 km long, 43,200 ha ultraoligotrophic water body. Rainbow Trout are present throughout Kinbasket Reservoir; this is a technical report that summarizes the findings of Year 1 (2015) of a three year monitoring study of their life history and habitat use.

Kinbasket Reservoir has a normal operating range of approximately 35 m, and during periods below full pool, a large shoreline drawdown zone is exposed. Typical Reservoir operations drawdown during the winter months beginning in January and reach low pool level by approximately the end of April. The timing of low pool level coincides with when Rainbow Trout are migrating to tributaries to spawn which may restrict access to suitable spawning habitats. Rainbow Trout have specific spawning habitat requirements in tributaries, preferring a range of stream gradient, depths, velocities, gravel substrate and thermal regime suitable for spawning and egg development. It is currently unknown whether suitable Rainbow Trout spawning habitat is found in tributaries specifically within the drawdown zone, or if any fish migration barriers are exposed which would limit access to upstream spawning areas.

This study uses a combination of biotelemetry and habitat surveys to determine biological characteristics and movement of Rainbow Trout during the suspected spawning time period, as well as the habitat characteristics of potential spawning streams within the drawdown zone. Rainbow Trout were captured by angling over 12 days beginning in mid-September 2014. Representative areas of the reservoir were angled; however, areas that have been identified as having higher Rainbow Trout occupancy were targeted.

A total of 36 Rainbow Trout (mean size 420 +/- 87.6 mm; 0.95 +/- 0.76 kg) were caught in 12 days of angling, yielding an overall catch-per-unit-effort (CPUE) of 0.08 fish/rod hour (95% CI of 0.05-0.11 fish/rod hour). Capture success varied between the four capture areas targeted in the reservoir. Ten (10) fish of sufficient size were surgically implanted with combined acoustic-radio transmitters (CART). Fixed acoustic receivers revealed large scale movement patterns of 5 out of the 10 tagged Rainbow Trout through the fall and winter months. Mobile radio tracking by fixed-wing aircraft will occur during the spawning season beginning in April 2016, assuming a sufficient sample size of tagged fish is available from 2015 tagging efforts.

Fourteen (14) tributaries with the potential to support Rainbow Trout were identified from the literature review, and the drawdown zone of five of these streams was surveyed during low pool in late April 2015. Low pool elevations in 2015 were much higher than average, so only the drawdown zone between the high pool mark (754 m) and ~738 m could be surveyed. Three of the five surveyed tributaries either had migration barriers, too coarse of substrate or too steep gradients to support Rainbow Trout spawning. The exception was Succour Creek, a low gradient tributary to the southern portion of the reservoir with high Rainbow Trout spawning potential. This stream contained gentle gradients (0.4% slope) pool-riffle channel morphology and gravel substrate through most of the drawdown zone (1,428 lineal m of 4,200 m of horizontal stream length). Temperature data will augment habitat suitability

analysis in future years, and tributaries will be re-visited if reservoir operations result in lower elevations than were encountered in 2015.

Management Question	**Hypotheses**	**Status**
What are some basic biological characteristics of Rainbow Trout populations in Kinbasket Reservoir (e.g., distribution, abundance, growth and age structure)?		To be addressed in years 2 and 3 when more data is available.
Does operation of Kinbasket Reservoir result in blockage or reduced success of upstream migration of Rainbow Trout spawners in tributary streams?	H1: The productivity of Rainbow Trout populations is limited by habitat impacts directly related to operation of Kinbasket Reservoir. H1A: Operation of the reservoir restricts upstream passage of Rainbow Trout spawners to reservoir tributaries due to low water elevations.	Drawdown zones in five of 14 tributaries with the potential to support Rainbow Trout were surveyed to 738 m in late April 2015. Barriers were present in the drawdown zone of Windfall and an unnamed creek, which may restrict upstream passage for Rainbow Trout spawners. Further habitat surveys at lower reservoir elevations and on unsurveyed tributaries will be addressed in years 2 and 3.
Does operation of Kinbasket Reservoir cause the flooding of Rainbow Trout spawning habitat within the drawdown zone and lower sections of tributaries, causing adverse effects on egg and fry survival?	H1B: Operation of the reservoir reduces Rainbow Trout egg and fry survival due to inundation of spawning habitats within the drawdown zone.	Habitat surveys in 5 of 14 surveyed tributaries revealed extensive reaches of possible suitable spawning substrate and habitat characteristics in the drawdown zone of Succour Creek to 738 m elevation. Limited reaches of suitable spawning substrates were also present in Harvey Creek and the upper, above-barrier portion of Windfall Creek. Further habitat surveys and tributary use by biotelemetry and redd surveys to be addressed in years 2 and 3.

Can modifications be made to the operation of Kinbasket Reservoir to protect or enhance spawning success of these Rainbow Trout populations?		To be addressed in years 2 and 3.

ACKNOWLEDGEMENTS
We thank Bill Green, Karen Bray, Guy Martel, and Gerry Oliver for review and discussion of methodology and safety programs for this project.

Jim Clarricoates, JoAnne Fisher, Kenton Andreashuk, Jaime Cristales and Misun Kang provided technical field, logistics and administrative support for this project. José Galdamez provided support for mapping. Angela Prince and Scott Cope of Westslope Fisheries Ltd provided useful background information and advice on project methodology and Kinbasket Rainbow Trout capture and telemetry.

Jamie Tippe provided guiding services for Rainbow Trout capture and use of his boat. We thank him for his expert knowledge in boat operation and fish capture from years of experience on the Kinbasket Reservoir.

Last but not least, thank you to Jason Watson at BC Hydro for management of this project.

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INTRODUCTION

Background

Kinbasket Reservoir was created by the construction of Mica Dam in 1973, under the terms of the Columbia River Treaty. The purposes of the creation of this earthfill, high head dam and reservoir were for optimized, coordinated power generation between Columbia River mainstem dams in the US and Canada and for downstream flood control. The reservoir inundated 216 km of the length of the Columbia River between Mica and Donald, and is among the largest reservoirs in British Columbia, with a maximum surface area of 43,200 ha. Prior to dam construction, the majority of this habitat was free flowing, with the exception of a lacustrine portion known as Kinbasket Lake that was 13km long and had a surface area of 2,250 ha (Prince 2011). The reservoir can be coarsely segregated into two main reaches, with the Columbia and Canoe reaches meeting at the historic confluence of the Canoe and Columbia rivers, where the Columbia River turns southward approximately where Mica Dam is currently situated. The reaches of the reservoir are typically bounded by steep valleys and are narrow, with stretches becoming riverine at low pool. Thee large lacustrine portions of the reservoir occur at the confluence of the Canoe and Columbia Reaches, at the historic location of Kinbasket Lake near the confluence with the Sullivan River, and at the confluence with the Bush River. Stream inputs are largely glacial, draining the high elevation northern tips of the Selkirk and Monashee mountains from the West, and the extensively glaciated West slopes of the Canadian Rockies from the East.

Operations of Mica dam result in extreme annual fluctuations of the reservoir levels. Kinbasket Reservoir elevations may vary between a maximum of 754.38 m and a minimum 707.41 m, and may occasionally be brought up to a maximum elevation of 754.68 m on application to the Comptroller of Water Rights if there is a high probability of spill (BC Hydro 2007). Normal operating level for the 2008-2012 period was from a mean maximum of 753.26 m and a minimum of 718.12 m, with a normal operating range of 35.14 m. Drawdown from full pool normally begins slowly in September, and draft rate increases through the winter, with a levelling off of drafting and normal low pool occurring in mid-late April. During the spring period, discharge from Mica dam decreases, which coincides with the normal spring freshet, which rapidly refills the reservoir through the spring and early summer.

Interior populations of Rainbow Trout spawn in the spring in streams, during periods of rising water temperatures consistently exceeding 6-8 °C and the ascending limb of the hydrograph (Behnke 2002, Muhlfeld 2002, McPhail 2007) (Figure 1). This timing for inland populations may occur in late April-July, depending on hydrographic characteristics of the spawning stream, the latitude and elevation. Spawning is followed by egg incubation in gravels before emerging as fry. This process typically takes 1-2 months depending on incubation temperature (McPhail 2007). Rainbow Trout spawning and incubation timing thus coincides with the period that Kinbasket Reservoir is refilling from low pool elevation. This timing can result in two potential alternatives in which reservoir operations can limit Rainbow Trout recruitment, and thus productivity, for this population. Firstly, pre-spawning migrations into critical spawning habitat may be obstructed by barriers formed during low pool elevations of the reservoir. Since Rainbow Trout may initiate spawning migrations shortly after ice off, they are likely to encounter barriers if they are present at especially low reservoir elevations prior to being flooded. Secondly, Rainbow Trout may spawn in alluvial fan outlets of streams immediately adjacent to the reservoir in low pool periods. These habitats may be inundated in some years of reservoir operation when reservoir elevations do not reach typical low pool, or fill rapidly or early, or else they may be inundated subsequent to spawning. Inundation of gravels where eggs are incubating will likely result in stagnant water, reducing egg to fry survival due to lack of oxygen or removal of waste products. In addition, emergence of fry directly into an open water lentic habitat may increase predation. This study is designed to detect whether Rainbow Trout are susceptible to these potential limitations on recruitment success in the years of study.

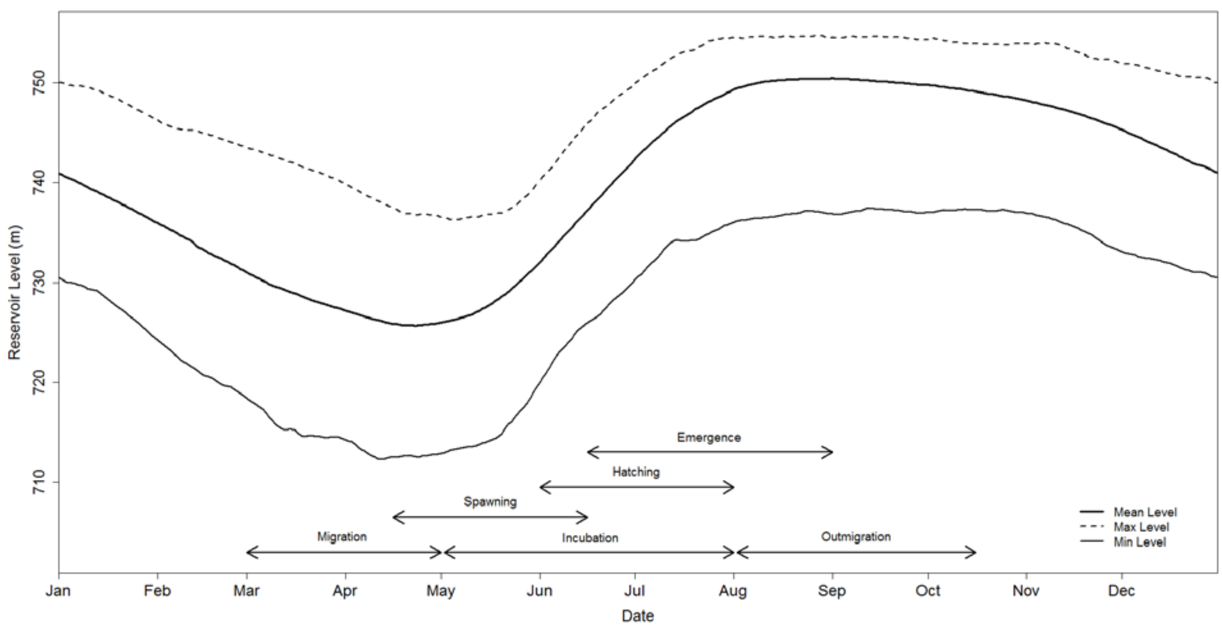

Figure 1: Life history timing of Rainbow Trout compared with the minimum, maximum and mean reservoir elevations in the Kinbasket Reservoir, 1976-2015

Rainbow Trout

Kinbasket Reservoir holds a modestly popular, but productive fishery for Rainbow Trout (Pole 1995, Bray 2002). The origin of indigenous Rainbow Trout is redband Columbia River trout that were locally adapted to the upper Columbia River complex from Arrow Lakes, upstream to Columbia Lake. The indigenous strain included a large piscivorous form, colloquially referred to as yellowfin trout, which was largely adfluvial from the Arrow Lakes, and spawned in the Canoe River and its tributaries (Peterson and Withler 1965, Prince 2001). Post-reservoir phenotypic and genetic surveys indicate that current strains appear to be a cross between indigenous forms and introduced hatchery origin, which source from the Lardeau River, a tributary to Kootenay Lake (“Gerrard” strain) (Fidler 1994, Taylor 2000).

A large amount of habitat was inundated for Columbia River Rainbow Trout upstream from Mica Dam, resulting in a shift of valley bottom habitat from primarily riverine to lacustrine. The life history form that now inhabits the reservoir is adfluvial. Spawning and rearing habitat may be limited in tributaries to the reservoir, as most streams provide poor habitat for Rainbow Trout spawning and rearing, or have suitable sections that are seasonally inundated (Fielden et al. 1992, Oliver 2001). Based on the slightly higher elevation and latitude of Kinbasket Reservoir, spawn timing for adfluvial Rainbow Trout is likely to mirror that or be slightly later than Arrow Lakes Reservoir. Spawning and associated migration occurs in Arrow Lake populations between April and June (inclusive), with peak migration and spawn timing of the final week in May (Toth and Tsumura 1996, Drieschner et al. 2008). Emergence periods follow, from mid-June to early September, although most fry outmigrate shortly after emergence in late June to early August (Drieschner et al. 2008, Hawes and Drieschner 2013). Although many fish emigrate as fry, juveniles may rear within the stream for an additional time period, as they do in tributaries to Arrow Lakes Reservoir (Decker and Hagen 2007).

Few tributaries in Kinbasket Reservoir are likely to support resident Rainbow Trout populations or a large spawning population of adfluvial forms above the full pool mark, due to physical habitat characteristics that are limiting for this species. Limiting habitat characteristics include low productivity and cold water temperatures due to glacial origin, high stream gradients or barriers above the drawdown zone and large freshet discharges that interfere with optimal flow stability that are conducive to Rainbow Trout spawning ecology (Fielden et al. 1992, Fausch et al. 2001, Oliver 2001, Golder 2003). Of direct tributaries to the reservoir that are possibly impacted by drawdown, Succour Creek has consistently been identified as having the highest abundance and densities of Rainbow Trout (Fielden et al. 1992, Oliver 2001). This stream was theorized to have greater Rainbow Trout abundance due to its lower gradient, stable flows, non-glacial origin (low turbidity and warmer temperatures) and suitable rearing habitat. Rainbow Trout have also been observed occupying the drawdown zone in the spring, during the generalized regional spawn timing window for the species. In addition, Camp Creek near Valemount may have historically been, and may continue to be an important Rainbow Trout spawning stream, particularly for indigenous Columbia River yellowfin Rainbow Trout (Peterson and Withler 1965, Fidler 1994, Prince 2001). This tributary does not flow directly into the Kinbasket Reservoir, but flows into the Canoe River shortly above its confluence with the reservoir. Other various tributaries support low densities of Rainbow Trout and thus may support adfluvial spawning and juvenile rearing. The drawdown zone has been theorized to possibly support Rainbow Trout spawning, but this has not been confirmed by any study (Fielden et al. 1992; Oliver 2001). Arndt (2009) speculates that adfluvial Rainbow Trout from Kinbasket Reservoir are likely to migrate into tributaries to the Columbia River upstream from the reservoir, rather than tributaries directly feeding the reservoir due to more favorable spawning habitat.

Management Questions

The management questions (MQs) associated with this monitoring program are (BC Hydro 2007):

1) What are some of the basic biological characteristics of Rainbow Trout in Kinbasket Reservoir?

2) Does operation of Kinbasket Reservoir result in blockage or reduced success of upstream migration of Rainbow Trout spawners in tributary streams?

3) Does operation of Kinbasket Reservoir cause the flooding of Rainbow Trout spawning habitat within the drawdown zone and lower sections of tributaries, causing adverse effects on egg and fry survival?

4) Can modifications be made to the operation of Kinbasket Reservoir to protect or enhance these Rainbow Trout populations?

The monitoring program will provide a quantitative baseline dataset to establish basic biological characteristics of the Rainbow Trout populations in Kinbasket Reservoir. It will provide information on habitat use, life history and rough estimates of abundance, and possible factors affecting Rainbow Trout productivity.

Management Hypothesis

The primary aim of this monitoring program is to provide baseline information on the Rainbow Trout population in Kinbasket Reservoir to better inform on the relationship between reservoir operations and recruitment. It is designed to specifically test the following hypotheses using assumptions of spring (April-June) habitat use being linked to spawning activity:

H_1: The productivity of Rainbow Trout populations is limited by habitat impacts directly related to operation of Kinbasket Reservoir.

$H_{1A:}$ Operation of the reservoir restricts upstream passage of Rainbow Trout spawners to reservoir tributaries due to low water elevations.

$H_{1B:}$ Operation of the reservoir reduces Rainbow Trout egg and fry survival due to inundation of spawning habitats within the drawdown zone.

Key Water Use Decision Affected

Implementation of the proposed monitoring program will provide information to support more informed decision making with respect to the need to balance storage in Kinbasket Reservoir with impacts on fish populations in the reservoir. Specifically, it will provide the information that is required to support future decisions around maintaining the current operating regime or modifying operations to protect reservoir Rainbow Trout populations.

METHODS

Overview, study objectives and limitations

The general approach of this study draws upon the design of a previous Water Use Planning tributary fish migration access assessment, CLBMON-32A (Drieschner et al. 2008, Hawes et al. 2010, 2011, 2012, 2013, 2014) and refines it to apply to Kinbasket Reservoir.

The study is designed to answer the management questions (MQs), as outlined in the previous section. Unfortunately, the main drawback of work on the Kinbasket Reservoir is the size of the system. While the full area of the reservoir is included in the study design (Figure 2), areas which have been documented as having higher Rainbow Trout capture rates will be focused on during the capture and tagging programs (more details provided in the “Rainbow Trout capture and tagging” section). In addition, the remoteness of the reservoir requires extensive travel with limited safe access and contact points. Given these safety and logistical constraints, angling effort was focused in the northern end of

Columbia Reach and the southern end of the Canoe Reach, while time spent in the northern end of the Canoe Reach and the southern end of the Columbia Reach was limited.

Rainbow Trout capture and tagging

Standardized capture techniques (i.e., time of year, depth and equipment) using angling equipment were used to target Rainbow Trout. A fall capture time of year was chosen, as Rainbow Trout distribution shifts to shallower habitats as they follow spawning kokanee (Ford 1995) and capture rates still remain high relative to other times of year (Pole 1995, 1996). Temperatures also begin to drop during this time of year, which decreases stress on fish due to capture and surgery.

The initial capture period was conducted from September 16 to 27, 2014. Angling effort was focused in four reservoir areas where Rainbow Trout efficiency was reported as high during creel surveys (Pole 1995, 1996). The use of these areas was further justified based on past experiences of our fishing guide, Jamie Tippe. The four areas are in the Canoe Reach, confluence and Mica Dam headpond, Wood Arm and Old Kinbasket Lake. A professional guide was employed for all capture efforts. Trolling was the angling method employed, which primarily targets large bodied piscivorous fish. Large bodied piscivorous Rainbow Trout size and capture success make them ideal candidates to target for tagging with large biotelemetry tags. Shorelines as well as open water pelagic zones were targeted.

Our capture methodology was impractical for estimating total abundance in Kinbasket Reservoir. We provide basic capture-per-unit-effort (CPUE) metrics as rough, relative estimates of abundance for MQ1 from a targeting angling sampling approach. Mean CPUE was expressed as number of fish per rod hour.

Transmitters (Lotek CART11, 16 g in air, Lotek CART16, 28 g in air) were surgically implanted at the location of capture, according to the 2% tag-to-body weight ratio in water rule (Brown et al. 1999, Harrison et al. 2013). Lotek CART11 tags were implanted in smaller fish and have an estimated battery life of 479 days; whereas CART16 tags can be implanted in larger fish and have an estimated life of 780 days.

Sufficiently sized fish in good condition were selected and anaesthetized in a 100 L bath of lake water, with a 0.4 mL/L concentration of clove oil. Clove oil was first dissolved in ethanol before being added to water to ensure proper mixture of anaesthetic. Fish were transferred to surgery once they reached level four anaesthesia (total loss of movement and weak opercular motion; Cope 2009). Times to anaesthesia, surgery and recovery of fish were recorded for quality assurance.

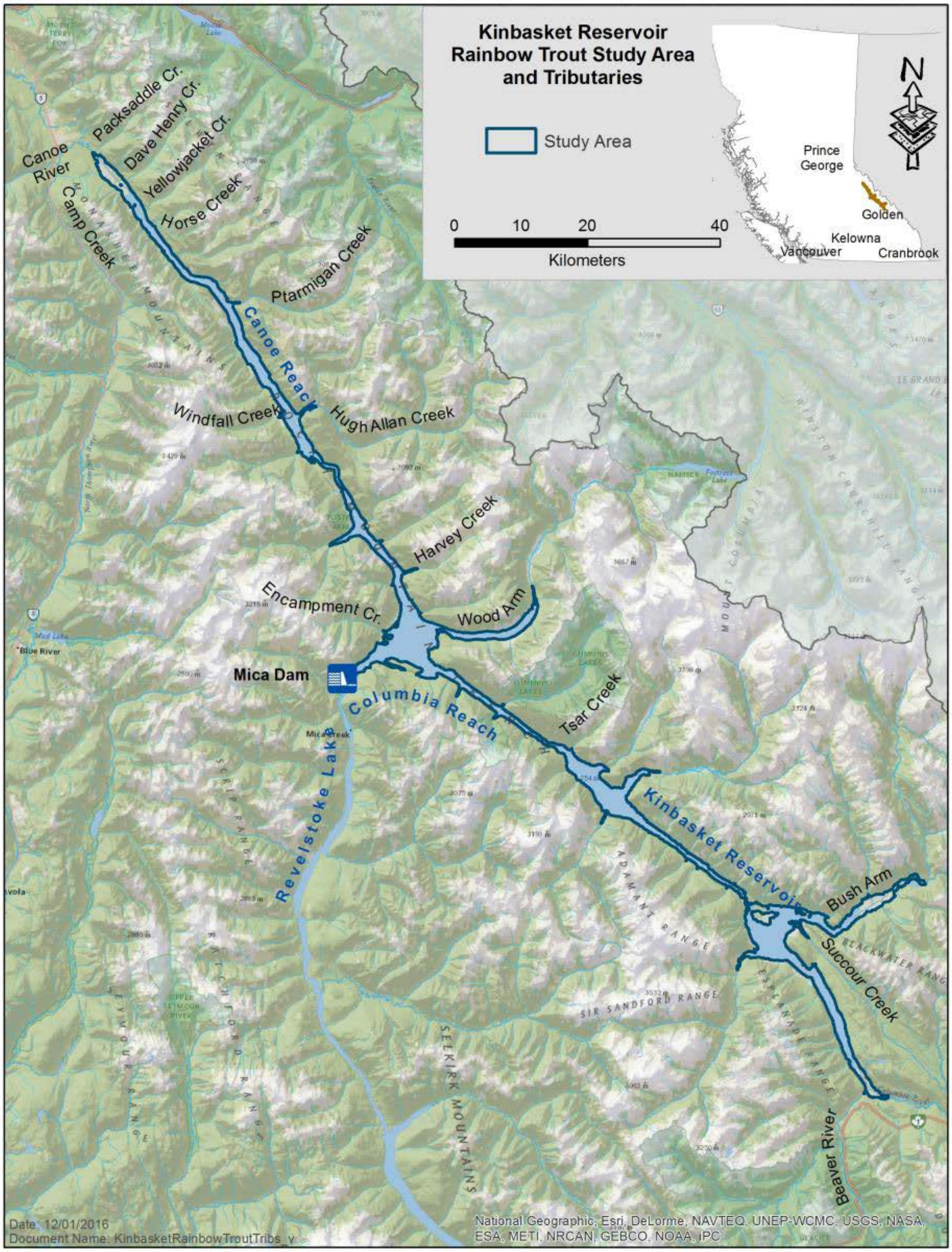

Figure 2: Locations of study area and tributaries in the Kinbasket Reservoir

Fish were transferred to a surgical table with a V-shaped cradle constructed of Coroplast™ board (Figure 3). A technician provided a continuous supply of oxygenated water to the fish by hydrating the gills throughout the procedure. A small incision was made 3-4 cm posterior to the pectoral fin and just below the mid-ventral line. A catheter was inserted at a point 1 cm posterior to the pelvic fin which then exited through the incision. The antenna wire was fed through the catheter, which was pulled through the body wall, and the transmitter was simultaneously placed within the body cavity (Figure 4). The incision was then closed using independent and permanent monofilament sutures (4/0 Ethicon). Fish were transferred to a 120 L live well supplied with oxygen (0.2 to 0.5 L/min) (Figure 5). Rainbow Trout were typically allowed 20 minutes to fully recover (i.e., attainment of fear response) before being returned to the reservoir at the surface.

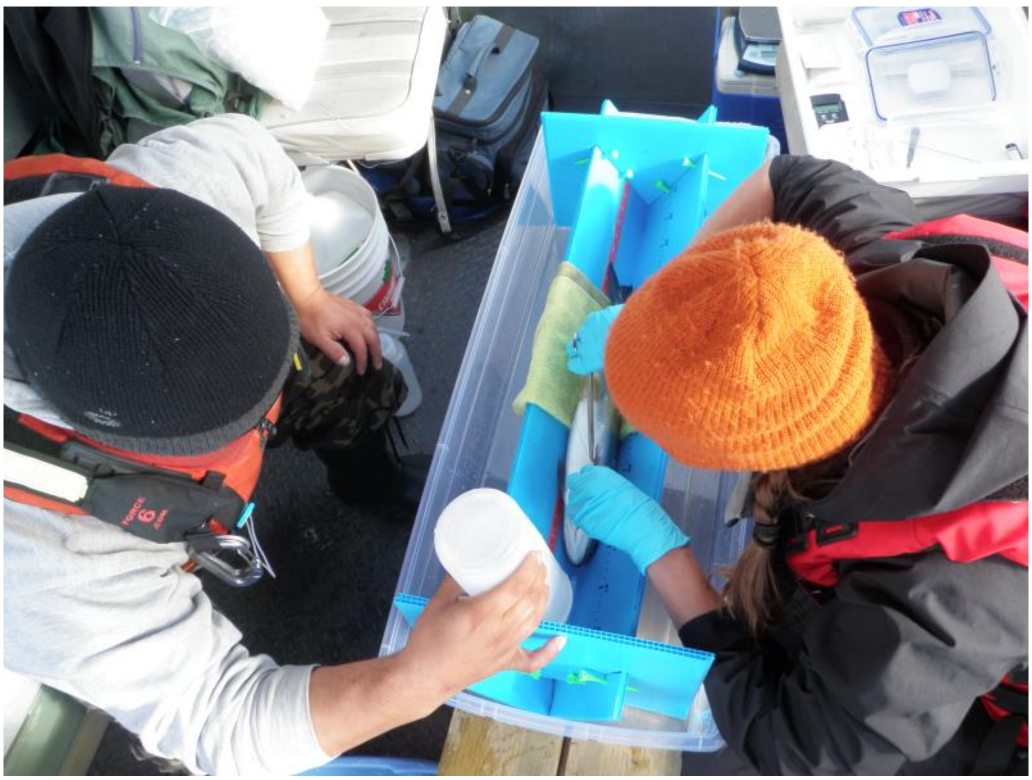

Figure 3: Surgical setup for transmitter implantation


Figure 4: Incision and antenna placement for Rainbow Trout transmitter surgery


Figure 5: Rainbow Trout in oxygenated recovery tank

A second capture and tagging session was held July 21-23, 2015. This session will not be discussed in subsequent sections as no Rainbow Trout were caught over the three day period.

Mobile and fixed receiver tracking

This study is designed to detect year-round habitat use of Rainbow Trout and aspects of their migratory life history (e.g., adfluvial movements; MQ1), as well as tributary use during the spawning season (MQs 2 and 3). These movements will be assessed using a combined approach of data collection from mobile tracking radio frequencies of CART tags from a fixed-wing aircraft, and acoustic frequencies of the same CART tags from a series of fixed receivers placed throughout the study area. The study period for tagging and tracking will occur over two years. CART transmitters use a coded radio (codes 111-160) frequency of 150.21 MHz for individual tag identification and an acoustic transmission of 76 KHz. The radio burst rate is 4.5 or 5.0 seconds continuous and acoustic pulses are transmitted every 60.5 s (CART16) or 100.5s (CART11).

Fixed receiver tracking

As part of the CLBMON-05 Kinbasket Reservoir Burbot Life History and Habitat Use Assessment (Warnock et al. 2014), multiple fixed acoustic receivers (n = 16) were deployed through 10 areas in the study area from June 2-5, 2014 (Figure 6). Receiver locations were selected such that constrictions in the valley were “gated” to track movement amongst areas (Gutowsky et al. 2013). An additional receiver (Lotek WH3250E 76 KHz underwater hydrophone datalogger) was deployed on May 1st, 2015 near the mouth of Succour Creek to supplement the existing array and provide better coverage for the Rainbow Trout life history and habitat use assessment. Succour Creek has previously been identified as having high quality Rainbow Trout spawning habitat and consistently has had the highest densities and abundance of Rainbow Trout of any tributaries flowing directly into Kinbasket Reservoir (Fielden et al. 1992, Oliver 2001). Receiver deployment procedures generally followed those used by Warnock et al. (2014). One additional consideration was that reservoir elevation was approximately 738 m which was 13 m higher than mean reservoir level at that time of year. As well, at the time of deployment the water depth at the Succour Creek location was approximately 16 m. It was therefore important to adjust the length of the mooring system to account for the unusually high low pool reservoir elevation.

Retrieval of the CLBMON-05 acoustic receivers was conducted April 27 - May 15 and July 20-26, 2015. Due to the higher than usual low pool reservoir level it was only possible to retrieve 11 of the 16 receivers that were deployed in 2014. Additional efforts will be made in the future to retrieve those receivers. During the data download it was discovered that the receivers’ batteries did not last the full tracking period, with records generally available only until late winter, prior to pre-spawn migration season for Rainbow Trout. Therefore, it will not be possible to discuss Rainbow Trout movements during their spawning season; however, general descriptions of detected Rainbow Trout will be provided for the period during which the acoustic receivers were active. To ensure that battery life lasts the full tracking period in year 2, the on/off cycle of the receivers has been adjusted to conserve battery power.

Mobile tracking

Mobile fixed-wing aircraft tracking will start in 2016 and will follow a methodology similar to that used by Oliver (2001b), assuming a significant number of fish are tagged during capture efforts in 2015.

Opportunistic radio tracking of tagged fish was conducted during the tributary surveys, April 25 to May 1, 2015.

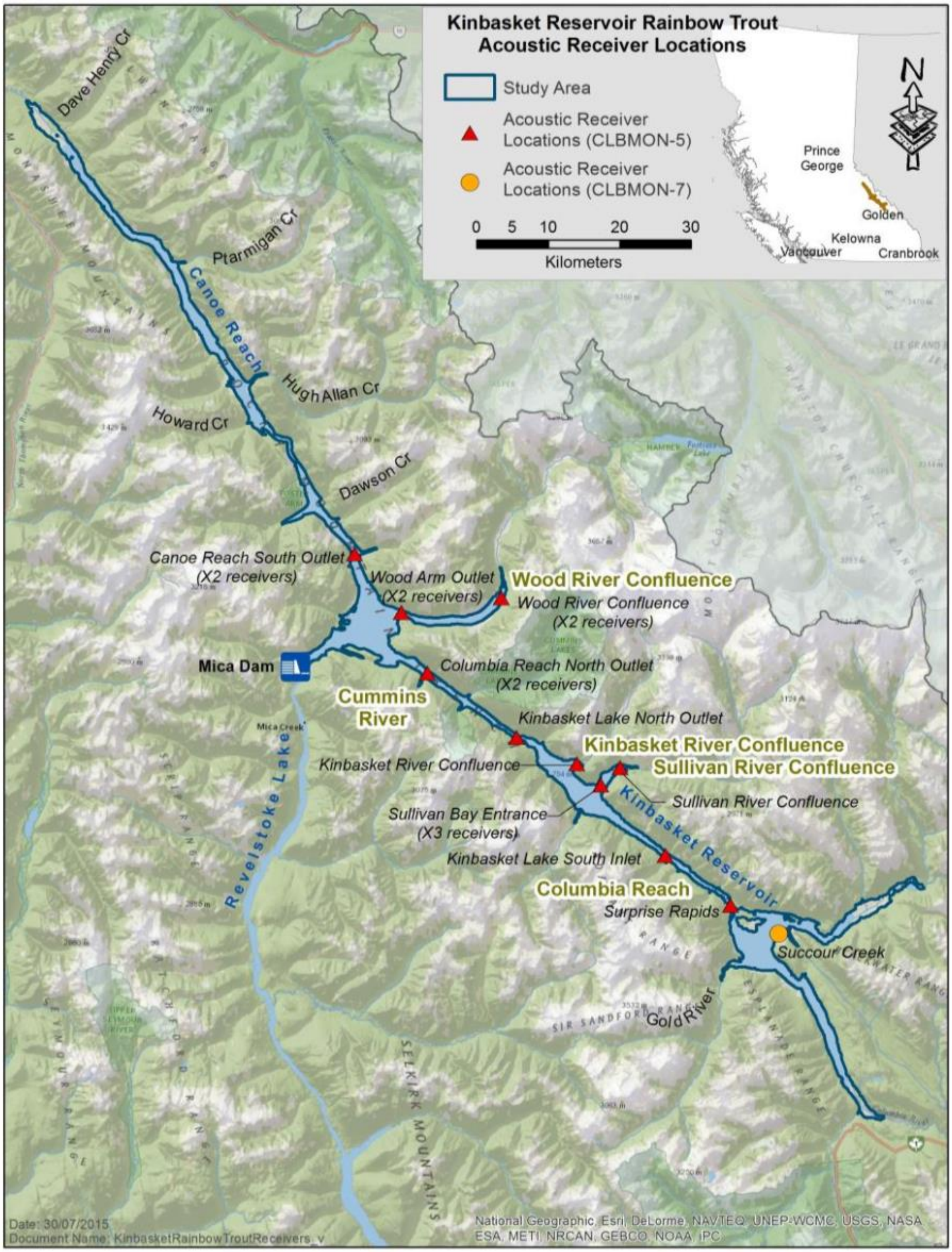

Figure 6: Locations of 17 acoustic receivers within Kinbasket Reservoir (16 from CLBMON-05 and 1 from CLBMON-07)

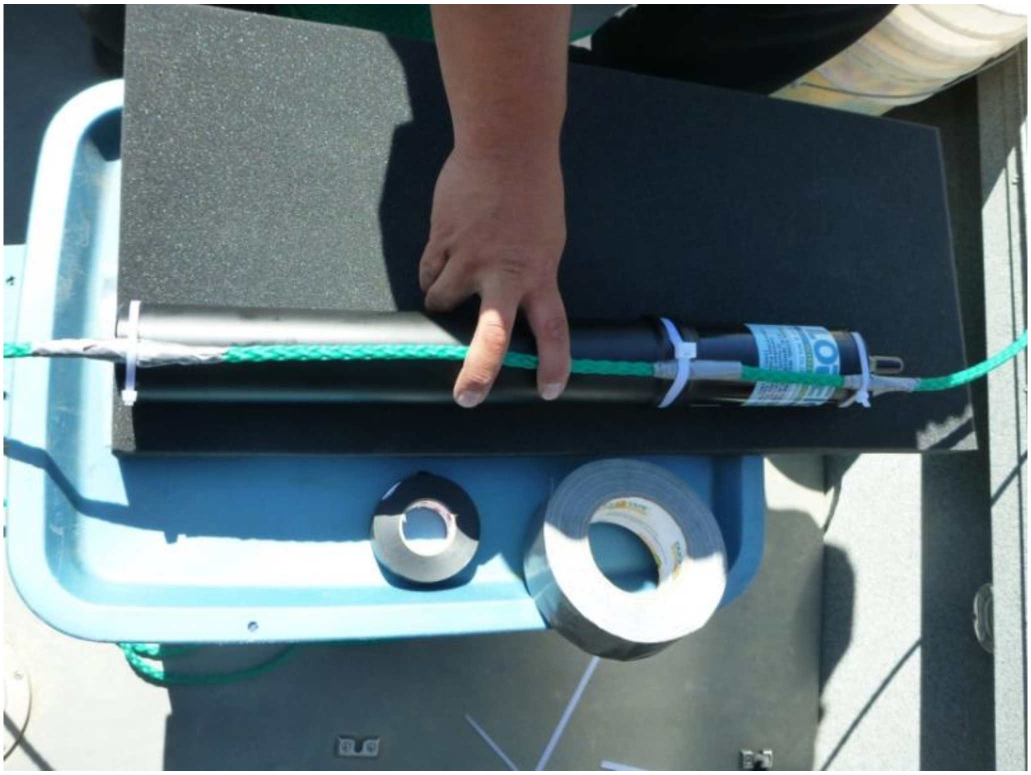

Figure 7: Receivers used in study, attached to floating line (Photo: Scott Cope, 2014)

Tributary access and stream habitat surveys

Detailed surveys and habitat assessments of selected tributaries were completed between April 25th and May 1st, 2015. The purpose of the surveys was to: i) identify potential barriers to upstream movement of adult Rainbow Trout; ii) measure stream elevation in the drawdown zone; and iii) record stream habitat characteristics to identify potential Rainbow Trout spawning habitat.

Earlier sampling efforts in the Kinbasket Reservoir have identified limited distributions of Rainbow Trout in tributaries, as well as a limited number of tributaries with the potential to support spring spawning salmonids such as Rainbow Trout (Fielden et al. 1992, Oliver 2001, Golder 2003). A total of 14 tributaries were selected based on those previously identified as having potential Rainbow Trout spawning habitat (Figure 2). A summary of the tributary surveys completed in 2015 is provided in Table 1.

Stream elevation was measured using a Sokkia GRX2 RTK-accurate GPS at the boundaries of consistently measured reaches along the full length of the stream beginning at the top of the drawdown zone (~754 m). Typical elevation accuracy using this equipment is +/- 30 cm. The length of each reach depended on the total horizontal length of the drawdown zone. Horizontal reach length was determined on-site using an angle compensating digital rangefinder. Any barriers encountered were also surveyed. Elevation was recorded at the top and bottom of the barrier so that length and height could be calculated. The type of barrier (i.e., woody debris, boulders) was also noted. Elevations obtained from the Sokkia were verified by taking daily reference measurements at the reservoir level and comparing them to known reservoir levels provided by BC Hydro. Any differences between the recorded and known reservoir elevations were used to correct stream elevation measurements.

Stream habitat characteristics were recorded at a transect perpendicular to the stream taken at each reach boundary using methods similar to Oliver (2001a). Parameters measured included: gradient, water depth, wetted and bankfull widths, water velocity, dominant and sub-dominant bed material, cover type, and habitat unit type. Gradient was calculated as a % slope based on the total measured horizontal length of the drawdown zone and total elevation lost from the top to bottom of the drawdown zone, Stream width was measured with a survey tape, and depth was measured by averaging three meter stick measurements across the transect. The Velocity-Head Rod method was also used to roughly determine velocity at each of the depth measurement locations by observing the degree of deflection of water on the meter stick (Carufel 1980). Substrate, cover type and habitat unit type were determined by visual inspection along each reach. Substrate was classified according to Wentworth scale particle classifications, and potential spawning gravels were considered if they were in the 4-64 mm size range. The lineal distance of suitable spawning gravel outcroppings was noted wherever they were encountered, unless they occurred in a small patch that could not support a single Rainbow Trout redd (<0.2 m^2; Bjornn and Reiser 1991).

Habitat characteristics will be used to determine if streams contain general habitat suitable for Rainbow Trout spawning. Qualitative accounts will be made for the year 1 report, but a more thorough quantitative analysis using stream gradient, substrate, channel morphology and thermal regime will be conducted in subsequent years to determine the extent of drawdown zone suitability within each examined tributary.

Table 1: Summary of tributary surveys completed in 2015

Tributary	Tributary Survey	Temperature Logger	To be completed in 2016
Canoe River			X
Packsaddle Creek			X
Dave Henry Creek			X
Yellowjacket Creek			X
Horse Creek			X
Ptarmigan Creek			X
Hugh Allan Creek	X	X	
Windfall Creek	X	X	
Harvey Creek	X	X	
Encampment Creek		X	X
Tsar Creek			X
Unnamed tributary north of Gold River	X	X	
Beaver River			X
Succour Creek	X	X	

A temperature logger (Hobo Pendant® Data Logger) was installed at the top of the drawdown zone for each surveyed tributary. Each logger was placed in a housing unit constructed of PVC pipe which was secured to a 1 m length of t-post. The t-post was used to anchor the housed logger which was buried at the approximate depth that Rainbow Trout redds are excavated (15-30 cm; see Irvine et al. 2013). Temperature data will be downloaded during the 2016 and 2017 surveys. These data will be used to determine the amount of accumulated thermal units (ATU) that developing eggs will be exposed to and subsequently model an approximate range of fry emergence dates for each stream (Irvine et al. 2013), using generalized or observed spawning dates. This information can be used to model the date of emergence relative to reservoir operations that would potentially flood suitable spawning areas in each stream. Temperature profiles will be used to determining whether tributaries are thermally suitable for Rainbow Trout spawning and egg incubation.

Biological observations were made in streams during habitat surveys, and presence of any fishes or redds were noted as they were encountered.

Statistical analysis

Rainbow Trout biological attributes were assessed by examining the mean weight and length according to each of the four reservoir areas and across all sampling areas. Descriptive statistics were run in the program R 3.2.1.

RESULTS

Rainbow Trout capture and tagging

Rainbow Trout capture summary statistics by reservoir area are shown in Table 2 and Table 3. Detailed capture data can be found in the Appendix A.1. A total of 519.25 rod hours were spent across the four areas of the reservoir from September 16th to 27th, 2014. Rainbow Trout capture success varied between different areas of the reservoir with the highest capture success in the Canoe Reach. 36 Rainbow Trout were caught, ranging from 285 to 736 mm (Figure 8). 10 of these Rainbow Trout were surgically implanted with CART tags (see methods). Tagged fish size ranged from 0.75 kg (419 mm) to 3.3 kg (736 mm). Released fish were either too small for minimum tag burden or in to poor of condition for surgery due to hooking and capture stress. In addition, eight mortalities occurred during the sampling program. High water temperatures were regarded as responsible for stress and mortalities for fish that met minimum size thresholds for tagging; tagged fish were caught at lower temperatures (mean = 14.2 °C) than those that died or were in too poor of condition for surgery (mean = 14.8 °C) (t_{15} = -2.2, p <0.05). All mortalities were post-capture and were not a result of the fish surgery. Surgeries were minimally invasive, with quick surgery and recovery times (Appendix A.2). Bycatch made up 27% (n=14) of the fishes caught and included only Bull Trout.

The maturity and stomach contents of the seven Rainbow Trout mortalities were examined. These fish ranged in size from 0.60 kg (365 mm) to 2.3 kg (539 mm). All fish were found to be mature at the time of capture. Stomach contents of five of the seven fish were comprised entirely of insects. The stomachs of the other two fish contained only kokanee. The insectivorous fish were also found to have the smaller body sizes (0.60-1.0 kg), while the piscivorous Rainbow Trout were larger bodied (2.1-2.3 kg).

Table 2: Summary statistics of Rainbow Trout captured across four general areas of Kinbasket Reservoir

Reservoir area	Mean Water Temp (°C)	N RT caught	N RT tagged	N RT mortalities	Mean CPUE (fish/hr)	S.D. CPUE (fish/hr)	95% CI CPUE (fish/hr)
Confluence/Forebay	14.2	13	4	4	0.06	0.04	0.03
Old Kinbasket Lake	14.4	4	2	1	0.04	0.04	0.05
Canoe Reach	14.6	15	4	3	0.11	0.08	0.07
Wood Arm	14.4	4	0	0	0.19[a]	n/a	n/a
All sites		36	10	8	0.08	0.07	0.03

[a] A single visit was made to the Wood Arm, therefore the value presented is not a mean, and S.D. and 95% CI cannot be calculated.

Table 3: Summary statistics of Rainbow Trout (RT) catches and individual fish data across 4 general areas of Kinbasket Reservoir

Reservoir area	N	Mean length (mm)	S.D. length (mm)	Mean weight (kg)	S.D. weight (kg)
Confluence/Forebay	13	441	119	1.16	1.00
Old Kinbasket Lake	4	472	40.4	1.33	0.522
Canoe Reach	15	413	51.8	0.838	0.556
Wood Arm	4	328	46.8	0.323	0.223
All sites	36	420	87.6	0.950	0.761

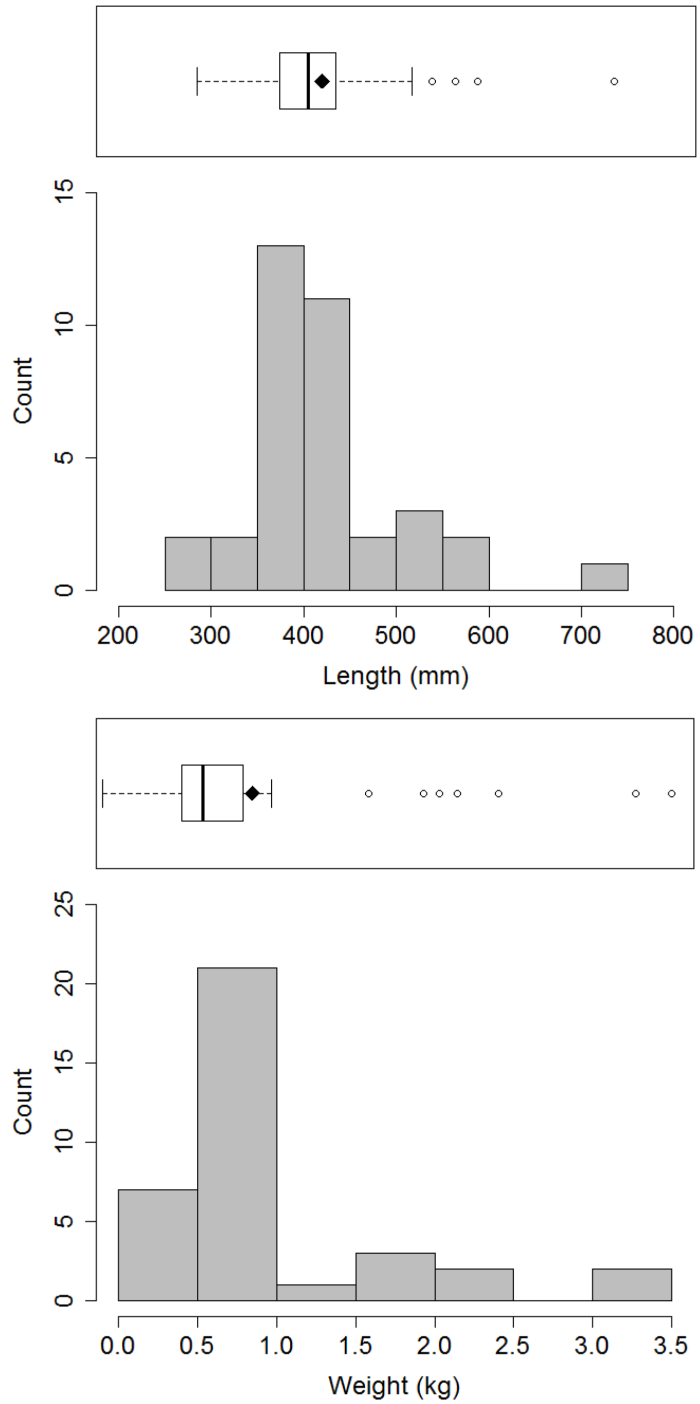

Figure 8: Size (length and weight) distributions and box plots of Rainbow Trout (n=36) caught and measured in Kinbasket Reservoir. Boxes represent interquartile range, diamonds represent the sample mean, while the middle line in the box is the median sample value. Whiskers represent observations outside of the interquartile range, with outlier data points.

Mobile tracking
Mobile tracking by fixed-wing aircraft was not conducted in 2015 due to the low number of Rainbow Trout tagged during the September 2014 capture and tagging session. Mobile tracking sessions will occur between early April and early July 2016 and 2017.

The tributary survey program in late April and early May 2015 provided an opportunity for ground tracking to be conducted during the pre-spawn and early spawning periods. No tagged fish were detected in any of the five tributaries that were surveyed.

Fixed receiver tracking
Of the 10 Rainbow Trout tagged in September 2014, five were detected by the acoustic receivers installed for CLBMON-05. Movement patterns of Rainbow Trout are described for each detected fish below. See Appendix A.3 for maps showing the locations of acoustic receivers that detected tagged fish. All physical characteristics recorded at the time of capture are summarized in Appendix A.1.

112:
Captured on September 22nd, 2014 in the Confluence and first detected on September 23rd, 2014 by the Wood Arm outlet receivers (east and west). Movements between the Wood Arm and Canoe Reach outlet were recorded until October 5th. From October 6th until April 2nd, 2015, this tagged fish was consistently detected between Kinbasket Lake inlet and the Sullivan entrance.

113:
Captured on September 24th, 2014 in Old Kinbasket Lake and was first detected on September 24th, 2014 at the Sullivan Bay entrance receiver and stayed in that area until September 30th. It was recorded again on September 30th at the Kinbasket Lake outlet and was then consistently recorded by this receiver until November 19th. Until the end of January 2015 the fish regularly used the area around the Sullivan Bay entrance receiver and Kinbasket Lake receivers (inlet and outlet). Between January 31st and March 27th, this fish was detected by the Columbia Reach outlet, Wood Arm outlet, Canoe Reach outlet, Wood Arm outlet and Kinbasket Lake inlet receivers.

115:
Captured on September 26th, 2014 in the confluence and was first detected on September 27th, 2014 at the Columbia Reach outlet receiver (east). It stayed in the area until September 28th and then moved to the Wood Arm outlet on October 2nd. On October 3rd and 4th it was recorded by the Canoe Reach outlet receiver. After October 4th this fish was not re-detected at any of the other receivers for the remaining period that the acoustic receivers were active.

152:
Captured on September 20th, 2014 in the Mica Dam forebay and was first detected on September 22nd, 2014 by the Wood Arm outlet (east) receiver. It moved to the Canoe Reach outlet on September 27th and generally stayed in the area until October 9th. Between October 10th and March 29th, regular detections of this fish were made at the Wood Arm outlet, Wood River outlet and Canoe Reach outlet receivers.

153:

Captured on September 21st, 2014 in Canoe Reach (near the confluence) and was first detected on September 29th, 2014 by the Columbia Reach outlet (east) receiver. It moved north to the Kinbasket River outlet on October 2nd, and then to the Sullivan Bay entrance on the same day. On October 5th it was recorded at Kinbasket Lake inlet and then was not re-detected by any of the receivers for the remaining period that the acoustic receivers were active.

Tributary access and stream habitat surveys

A total of five tributaries were surveyed during the spring 2015 program. A summary of key tributary measurements and observations is provided in Table 4. The full set of parameters can be found in Appendix B.1 and barrier survey information is given in Appendix B.2. Photographs of surveyed tributaries are shown in Appendix B.3.

Two out of the five assessed tributaries had potential fish migration barriers within their respective drawdown zones at the time of the surveys. Windfall Creek had a total of four barriers. Three of those barriers were created from large woody debris (Figure 11), and the fourth was a combination of boulders and large woody debris. A single barrier was observed on the unnamed west tributary north of Gold Creek which was made of boulders and large woody debris (Figure 13). Longitudinal elevation profiles for Harvey Creek (Figure 9), Hugh Allan Creek (Figure 10) and Succour Creek (Figure 12) are also provided below.

In addition to the tributary access surveys, suitable spawning substrates within the drawdown zone were identified and surveyed. Suitable spawning substrates were found in all tributaries except for Hugh Allan Creek. Only 2 m of lineal spawning gravels were identified in the unnamed creek. A total of 1,561 m of spawning gravel was found in the drawdown zones of Succour Creek, Harvey Creek and Windfall Creek. Throughout the study area, the vast majority of potentially suitable spawning substrate was found in Succour Creek (91.4%; 1,428 m) while 4.5% (70 m) and 4.1% (64 m) were found in Harvey Creek and Windfall Creek, respectively. Figure 14 shows the locations of the suitable spawning substrate within the drawdown zone of Succour Creek.

Where potential barriers to fish migration exist on tributaries with suitable spawning substrate it is important to relate the position of the barriers to the spawning substrate. Windfall Creek was the only tributary that was observed to have both spawning gravels and barriers. A total of 24 m (37.5%) of spawning gravels were upstream of all barriers. The remaining 40 m (62.5%) were between barriers 2 and 3 (160-200 m below the top of the drawdown zone).

Water clarity was generally high on all tributaries, so visual surveys to collect opportunistic biological data were possible. Fish presence in the drawdown zone was only observed in Succour Creek, with Rainbow Trout observed in the upper section of the drawdown zone (Figure 15). No redds were observed in any streams.

As low pool reservoir elevation was approximately 13 m higher than average, it is anticipated that future low pool reservoir levels will be lower, exposing more of the drawdown zone. It will be necessary to return to all tributaries to extend the surveys into the newly exposed area of the drawdown zone. These surveys will be continued in the spring of 2016 and 2017. As well, any tributaries that were not surveyed during the 2015 program will be completed in 2016.

Table 4: Summary of key tributary measurements and observations during April-May survey 2015

Parameter	Harvey Creek	Hugh Allan Creek	Windfall Creek	Succour Creek	Unnamed Creek
Survey Date	April 25, 2015	April 26, 2015	April 27, 2015	April 28-30, 2015	May 1, 2015
Water Temp (°C)	5.0	4.0	7.0	10.5	7.0
Length of DDZ Surveyed (m)	440	580	340	4,200	180
No. of Reaches	23	30	18	29	13
Reach Length (m)	20	20	20	150	15
Channel Type	Step-pool	Bedrock forced pool riffle	Step-pool	Pool-riffle	Cascade
Mean Depth (cm)	31.3	Too deep and swift to wade	31.6	50.6	16.0
Mean Bankfull Width (m)	26.2	37.5	17.5	9.7	12.2
Mean Wetted Width (m)	13.0	19.9	10.3	8.2	4.9
Gradient (%)	3.5	2.7	4.7	0.4	8.8
Mean Velocity (m/s)	0.87	Too deep and swift to wade	0.75	0.61	0.68
Dominant Substrate	Gravel	Boulder	Boulder	Gravel	Cobble
Spawning Gravels (m)	70	0	64	1,428	2
Fish Present	None observed	None observed	None observed	Juvenile Rainbow Trout	None observed
Redds Observed	None observed	None observed	None observed	None observed	None observed
Fish detected during opportunistic radio tracking?	No	No	No	No	No
Barriers / Type	None	None	4 (coarse woody debris, boulders)	None	1 (coarse woody debris, boulders)

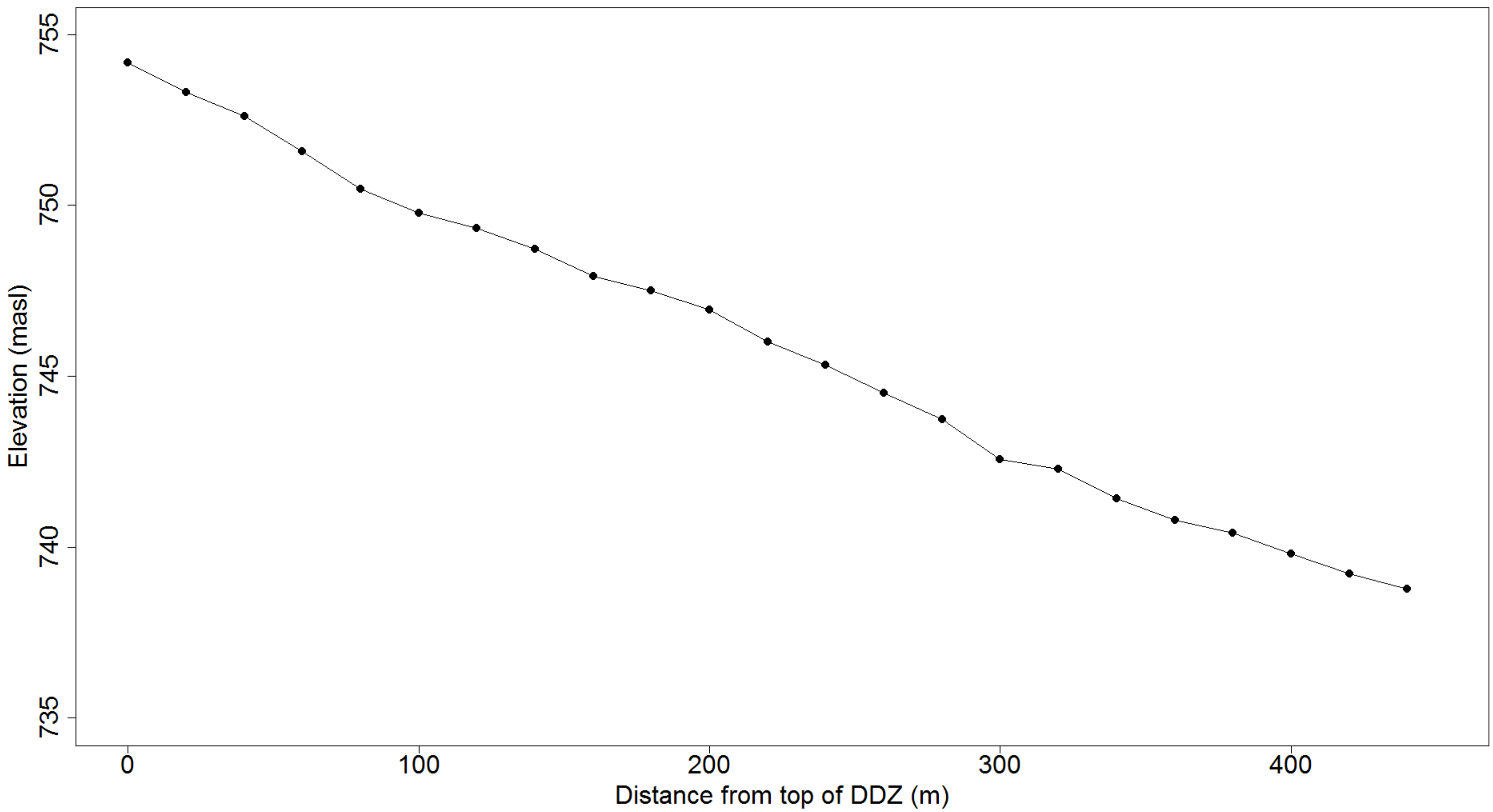

Figure 9: Longitudinal profile of stream elevation for Harvey Creek

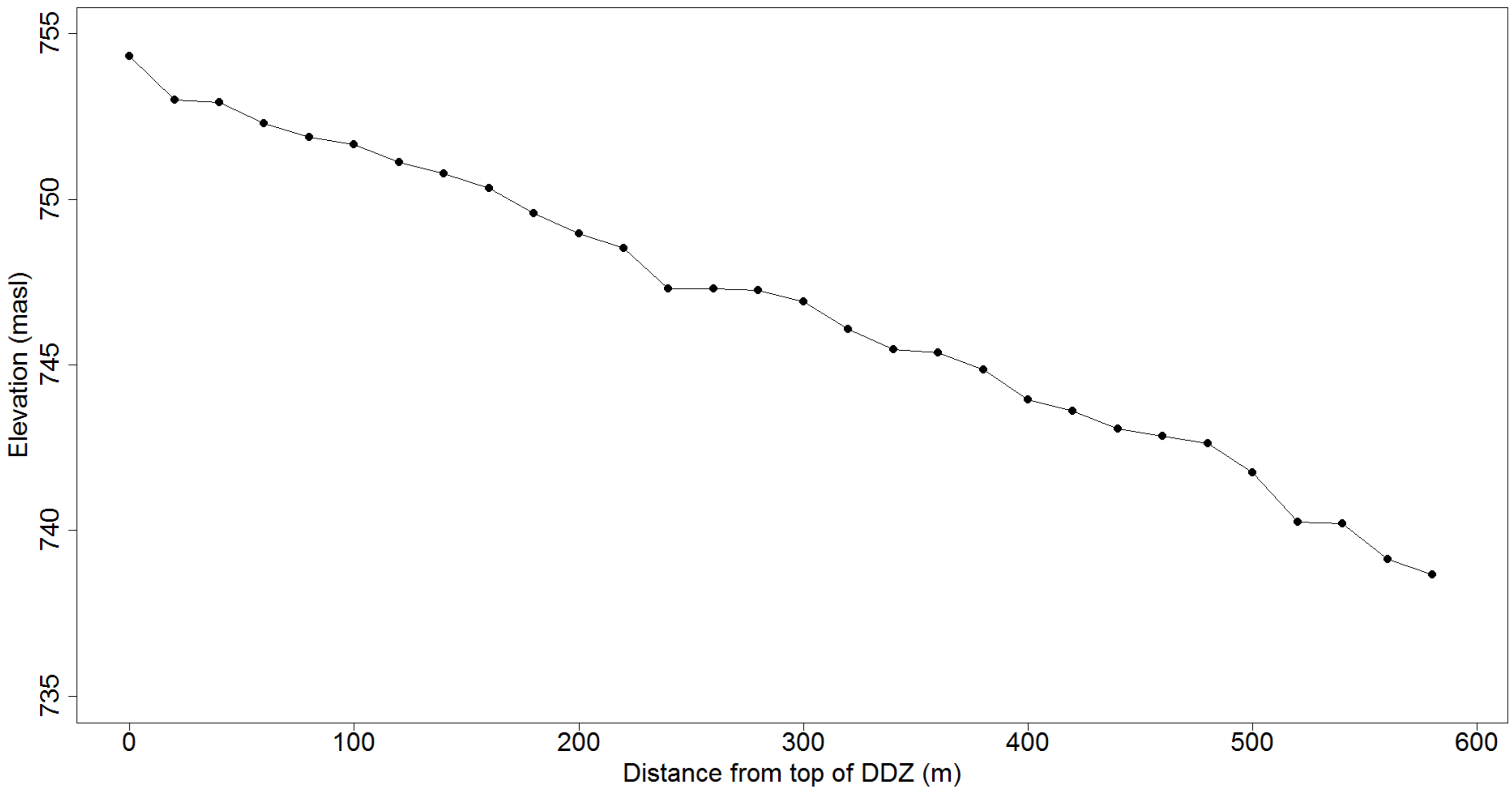

Figure 10: Longitudinal profile of stream elevation for Hugh Allan Creek

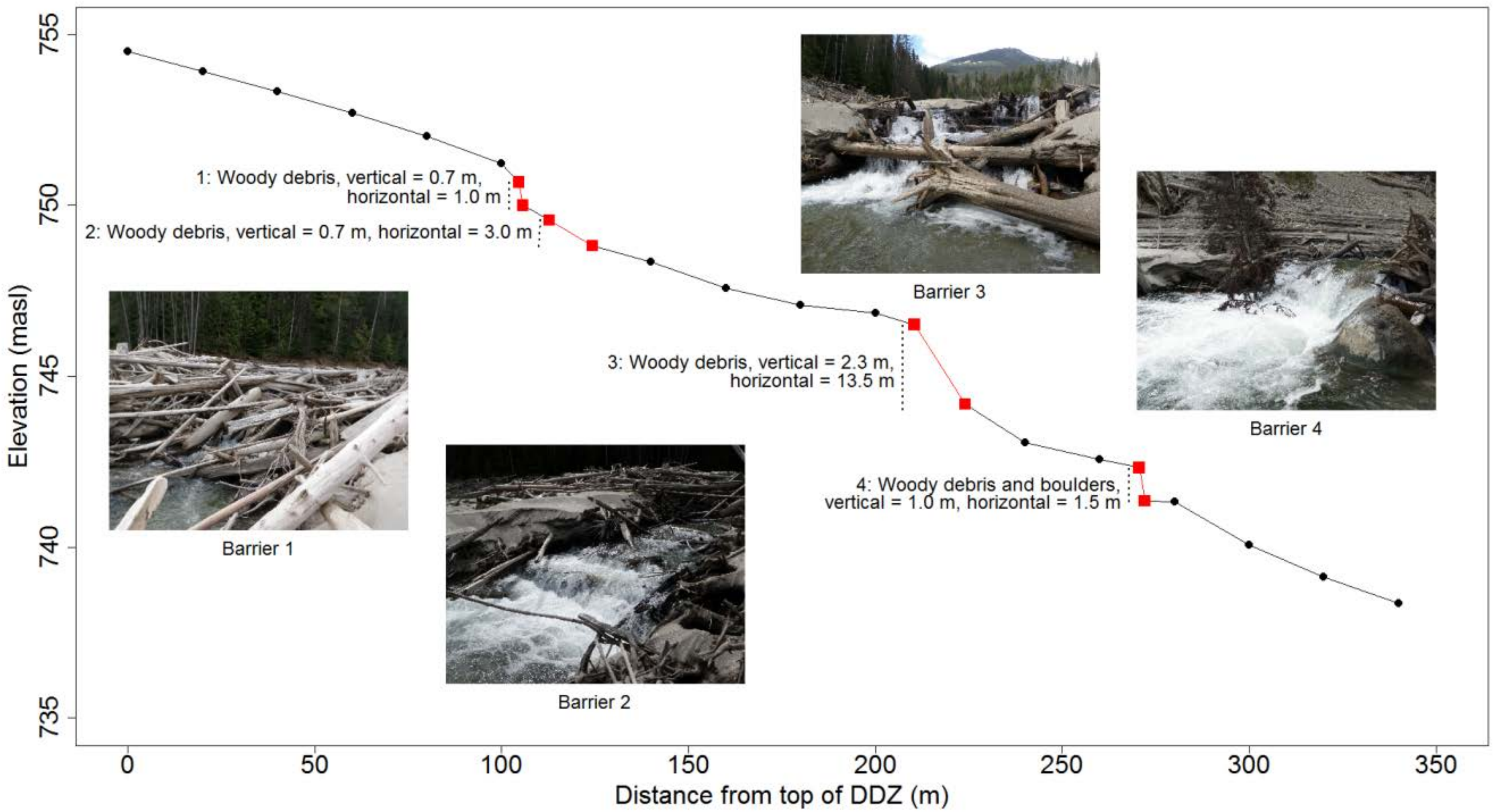

Figure 11: Longitudinal profile of stream elevation for Windfall Creek. Information on the vertical and horizontal dimensions of the barriers are provided along with photographs.

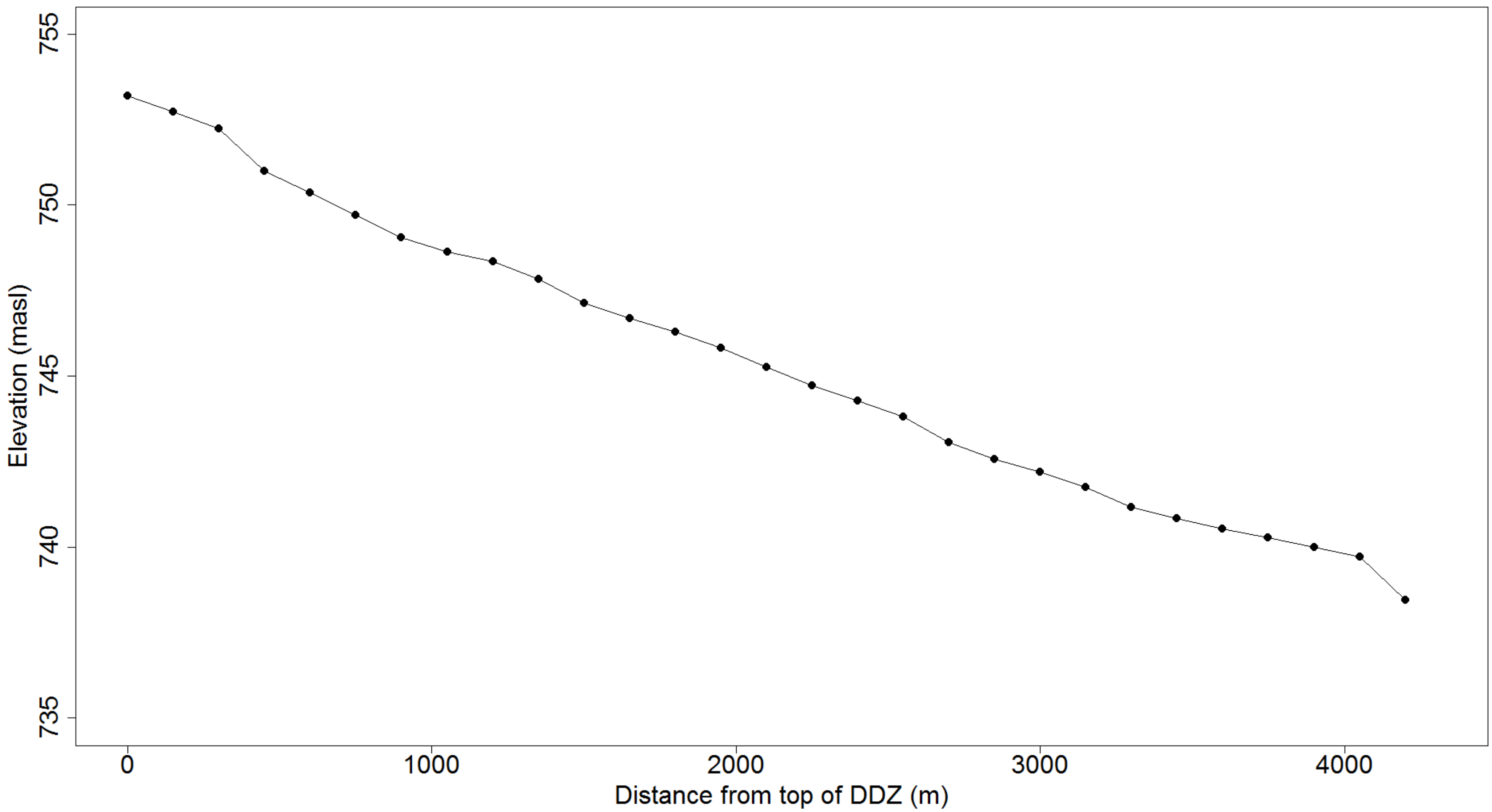

Figure 12: Longitudinal profile of stream elevation for Succour Creek

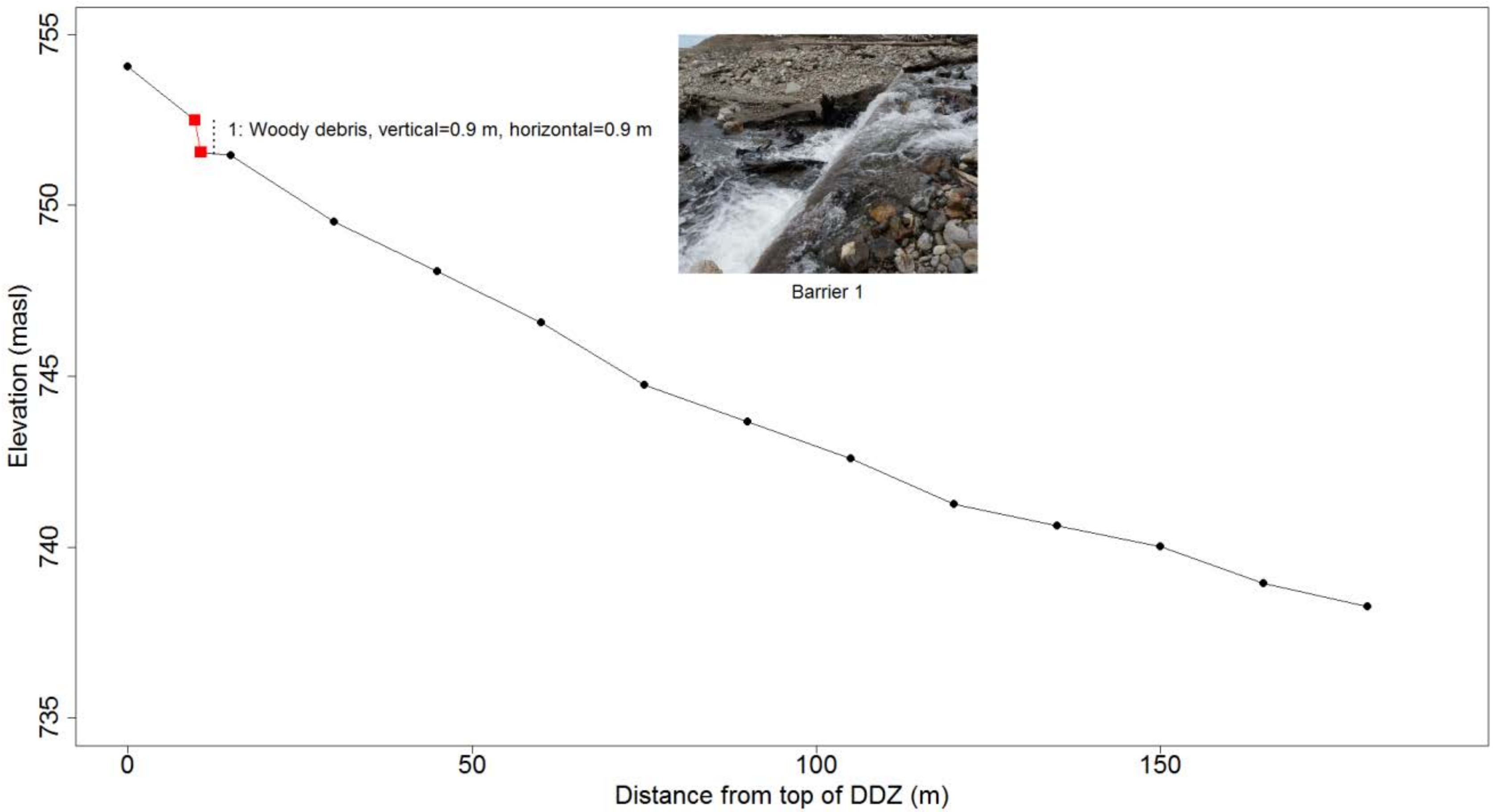

Figure 13: Longitudinal profile of stream elevation for Unnamed Creek. Information on the vertical and horizontal dimensions of the barrier is provided along with a photograph.

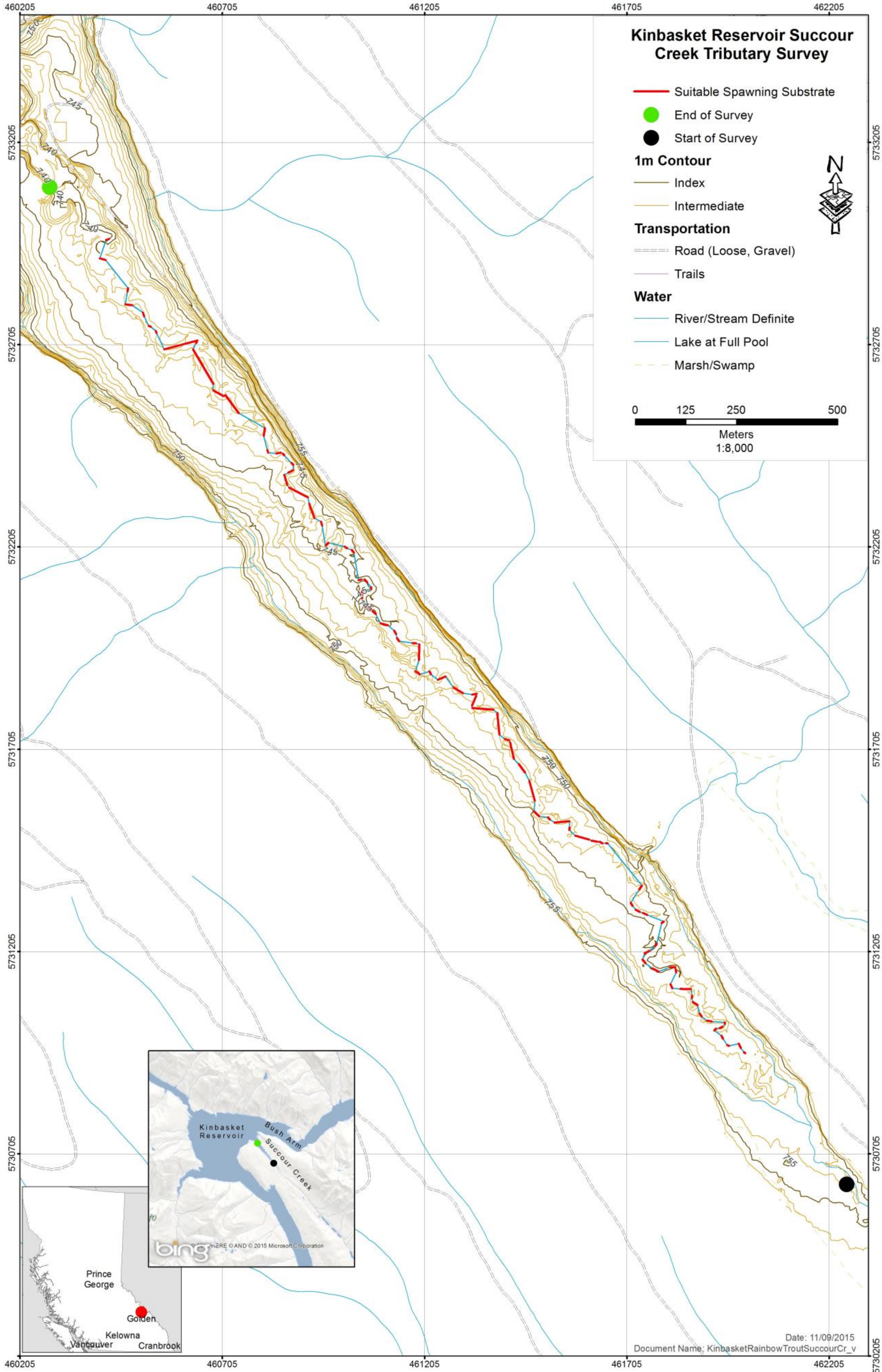

Figure 14: Locations of suitable spawning substrate within the drawdown zone of Succour Creek

Figure 15: Rainbow Trout in Succour Creek

DISCUSSION and RECOMMENDATIONS

Rainbow Trout capture, biological characteristics and tagging

Overall abundance of Rainbow Trout in Kinbasket Reservoir appears low from circumstantial interpretation of the results of other studies. Rainbow Trout were absent in bycatch from gillnet sets (Sebastien and Weir 2014) or angling targeting other large predators in the reservoir (Gutowsky et al. 2013), and their low abundance in the Mica Dam tailrace (Bisset et al. 2015) may imply that few Rainbow Trout are entrained through Mica Dam. Relative to other large lakes in the Kootenay region, the abundance of Rainbow Trout appears to be moderate in Kinbasket Reservoir based on comparison of overall CPUE. CPUE of 0.117 (Gazey 1994) and 0.07 (Bray and Campbell 2001) have been documented for Rainbow Trout in the Revelstoke Reservoir. Arrow Lakes Reservoir has had CPUE between 0.03 and 0.104 (Arndt 2004, 2014), while Kootenay Lake was found to have a CPUE of 0.08 (Andrusak and Andrusak 2012). Kinbasket Reservoir is generally data poor relative to other large lakes, but catch appears to have declined from levels seen in previous decades (CPUE of 0.15-0.19 depending on method of creel data collected; Pole 1995, 1996, Bray 2002). The declining abundance of Rainbow Trout in Kinbasket Reservoir observed in this study could be due to a variety of reasons that are beyond the scope of this study. Reasons for decline may include: naturally low productivity; increased access and angler effort, resulting in increased harvest over the last two decades; poor reproductive success due to reservoir operations or natural limiting conditions in spawning areas; cessation of stocking programs (Rainbow Trout were stocked in Kinbasket Reservoir with Lardeau River "Gerrard" strain from 1984-1992); poor capture success during capture session and insufficient capture expended to provide an accurate CPUE estimate. Kokanee abundance is unlikely to explain decreased abundance of Rainbow Trout due to high and sustained abundance of kokanee and zooplankton densities in recent years (Bray et al. 2014; Sebastien and Weir 2014) and high catch of bull trout, an alternate predator in the reservoir (Gutowsky et al. 2013). Low water transparency is also not likely a limiting factor for visually acute Rainbow Trout predators in Kinbasket Reservoir (see Beauchamp et al. 1999), as Secchi depth in Kinbasket Reservoir is similar to that found in Kootenay Lake (Bray et al. 2014, Schindler et al. 2014).

Large lakes in the Kootenay region may have sympatric insectivorous and piscivorous morphs of Rainbow Trout (Arndt 2009), which may represent reproductively segregated stocks (Andrusak and Andrusak 2012). The angling method employed in this study was biased to preferentially target the piscivorous morph. Large bodied piscivorous fish were targeted due to their ability to take large tag burdens, as large tags with long battery life was required for this study. Examining stomach contents of select fish confirms that insectivorous Rainbow Trout are present, and these fish may mature at small sizes (365-468 mm) relative to large bodied forms. Indeed, this study reveals a subtle bimodal size distribution with the larger distribution peak occurring at smaller sizes. A more comprehensive, unbiased sampling program would be needed to determine the relative abundance of the two forms. Small, insectivorous Rainbow Trout production may be limited because littoral productivity in Kinbasket Reservoir is limited by dam operations which cause fluctuating water levels. Some limited littoral foraging areas may be seasonally inundated or contiguous with the greater reservoir in areas where wetlands and ponds occur within the drawdown zone near the full pool (753-754 m) elevation, and these indeed contain macroinvertebrates and macrophyte growth (Adama et al. 2014); however, the extent of these areas is not a significant proportion of the perimeter of the reservoir and they are only contiguous with the greater reservoir area at limited times of year and only in years when reservoir elevations near the full pool mark. Pelagic and benthic macroinvertebrates, terrestrial insects and lotic invertebrates at stream mouths may provide other forage sources for this insectivorous morph, with terrestrial insects typically being the most important for large lakes in the Kootenay region (Arndt 2009). Future sampling efforts should attempt to use gear and techniques to target small bodied fish in subsequent years of this study, but our ability to examine their habitat use by biotelemetry is currently limited by our inability to tag smaller fish. Studies in the future may take advantage of smaller tags which continue to become available.

Dates for the capture and tagging program will be selected based on when surface water temperatures begin to drop and remain consistently below 15°C. Water temperatures during the fall 2014 capture session were higher than normal leading to fish hooking and capture stress and mortality, and some fish were in too poor of condition for surgical tag implantation. Surface water temperature measurements will be taken from the Mica Dam headpond which will be provided by BC Hydro.

Mobile tracking

Opportunistic mobile radio tracking was conducted during low pool tributary habitat surveys in late April 2015, but failed to detect any of the 10 fish tagged. This tracking does coincide with supposed spawn timing window of Rainbow Trout (April – June), but may largely precede the spawn timing, since other populations of Rainbow Trout in the Arrow Lakes, a nearby and similar system, tend to have peak spawn timing in late May (Toth and Tsumura 1996, Drieschner et al. 2008). Further opportunistic tracking will take place during tributary surveys in years 2 and 3 of the study.

If a sufficient number of Rainbow Trout are tagged in 2015, the first aerial tracking period will occur in the spring of 2016, coinciding with the generalized regional spawning period. Mobile radio tracking will be exclusively conducted by fixed-wing aircraft, and thus be limited to detecting fish that are using shallow depths and/or tributaries during the day. Low catches of large bodied fish may continue to limit sample sizes of fish due to majority of catch being under sized for the maximum tag weight.

Fixed-wing tracking is advantageous because of the large spatial coverage and ability to track fish into tributaries, as well as relatively strong detection efficiency when fish are present in shallow water. In order to further maximize probability of detection, flights will be concentrated in areas where fish are suspected to be spawning, based on a literature survey of areas that appear to have had high Rainbow Trout use during the past (Oliver 2001). Flights will occur bi-weekly within the spawning period in 2016.

Fixed receiver tracking

Due to the limited number of Rainbow Trout tagged and subsequently detected by the acoustic receivers, it is not possible to extrapolate Rainbow Trout movements to a population level. The five Rainbow Trout that were detected appeared to use a large area when the acoustic receivers were active. In particular, Rainbow Trout 112 and 113 were detected from Canoe Reach down to Kinbasket Lake inlet during the tracking period. It unknown whether or not any of the Rainbow Trout moved southeast of the Kinbasket Lake inlet as the receiver at Surprise Rapids could not be retrieved. These large-scale movements of Rainbow Trout have been documented in other large systems where seasonal movements are made to access suitable habitat for feeding, overwintering or spawning (Ford et al. 1995). Large, piscivorous Rainbow Trout in Kootenay Lake have been found to move over distances of 60-100 km during a 6-12 month detection period. On average, Rainbow Trout had a movement rate of approximately 2.7 km per day (Andrusak and Thorley 2013). The movement patterns of large piscivorous Rainbow Trout, relative to smaller insectivorous morphs are unknown.

With another two downloads scheduled for the acoustic receivers and a capture and tagging session in year 2 (September-October 2015), it is anticipated that the additional data will help better our understanding of the year-round movements made by Rainbow Trout throughout the Kinbasket Reservoir, especially in areas of the reservoir used during the pre-spawn and spawning periods. As well, this information will allow us to adjust our fixed-wing radio tracking plan to focus on areas that are more regularly occupied by tagged Rainbow Trout.

If Rainbow Trout migrate up the Columbia River to spawn, a fixed acoustic receiver which was deployed in summer 2015 for the BC Hydro WLR study CLBMON-05 may be able to track their movement towards the head of the reservoir. It is also possible that Rainbow Trout move up other large tributaries, including the Canoe, Bush, Sullivan, Wood or Kinbasket Rivers. The deployment of fixed acoustic receivers may detect pre-spawn movement towards all of these tributaries, as well as Succour Creek.

Tributary access and stream habitat surveys
Tributaries were surveyed during the general low pool period of late April, but 2015 was an unusual year in that reservoir operations resulted in a pool elevation of ~13 m higher than normal. Surveys in this first year of study were conducted at ~738 m elevation, which did not capture the full drawdown zone of tributaries. Tributaries surveyed in 2015 may be re-visited in 2016 and 2017 to capture more of the drawdown zone.

For the tributaries surveyed, fish migration barriers may be present in Windfall and the unnamed tributary north of Gold Creek. These barriers may restrict upstream movement to these streams above the drawdown zone, and in the case of Windfall Creek, restrict access to some potentially suitable spawning substrates at the upper end of the drawdown zone. It is important to note that fish may negotiate barriers with varying degrees of success based on fish size and stream flow (Bjornn and Reiser 1991). Most barriers encountered were <2 m vertical height and some larger fish may be able to pass these during periods of higher flow. More barriers may be exposed lower in the drawdown zone when tributaries are surveyed in subsequent years if reservoir elevations drop lower than those encountered in 2015.

From a qualitative perspective, stream habitat was rarely considered suitable for Rainbow Trout spawning in all streams except in Succour Creek. Rainbow Trout spawning requirements include gradients <5% (Miller et al. 2002) and gravel substrate that is approximately no larger than 10% of female spawner body length (Kondolf 2000). The unnamed tributary north of Gold Creek had gradients far too steep for Rainbow Trout preference, and Windfall creek approached the upper limits for gradient suitability. The drawdown zones of these two streams, when also considering migration barriers, are likely currently unsuitable for Rainbow Trout spawning. Substrate suitability is a function of spawner size. Based on maturity of examined mortalities, Rainbow Trout in Kinbasket Reservoir may mature at a large range of sizes (365-539 mm) indicating a wide range of suitable gravel substrate sizes and possibly bimodal in nature if both piscivorous and non-piscivorous morphs are present; however, despite the large range in substrate suitability, few tributaries contained gravel outcroppings sufficient to support large spawner aggregations in the drawdown zone. Harvey Creek contained a very limited 70 m of lineal stream distance which could potentially support Rainbow Trout spawning. The exception was Succour Creek, which had gentle stream gradient and suitable gravels over 34% (1,428 lineal m) of its total drawdown zone length surveyed.

Rainbow Trout spawn in the spring, and the redds of these resident species are generally shallow, and thus extremely sensitive to scour in snowmelt dominated watersheds with steep channel (>3%) morphology and spring flood disturbance (Montgomery 1999, Fausch et al. 2001). The hydrology of tributaries in Kinbasket Reservoir is, without exception, snowmelt dominated. Most tributaries of Kinbasket Reservoir contain step-pool channel morphology with steep (>3%) gradients (Fielden et al. 1992) that likely limit the suitability of spawning habitat due to spring scour.

The major exception to this is Succour Creek, which has a lower elevation watershed and much gentler stream gradient (<1%). Channel morphology is riffle-pool, and it is likely that this stream contains large amounts of habitat physically suitable for Rainbow Trout spawning within the drawdown zone. Rainbow

Trout have been observed in the drawdown zone, both in this study, and referenced in previous studies (Fielden et al. 1992) during the generalized regional spawn time window. Future study should focus more strongly on Succour creek due to its higher habitat use potential for Rainbow Trout.

Rainbow Trout have specific thermal requirements for spawning and egg incubation. For the purposes of this study, temperature loggers were installed in streams to determine if surveyed streams are thermally suitable for spawning, and egg incubation for Rainbow Trout within the drawdown zone. This will be quantitatively analyzed in year 2 of the study.

Conclusions and recommendations

Large bodied piscivorous Rainbow Trout abundance appears to be low in Kinbasket Reservoir, based on catch data from the first year of study. Catch was much lower than figures reported from creel surveys in previous decades for Kinbasket Reservoir, and catch was lower for large bodied morphs relative to Kootenay Lake (Pole 1995, 1996, Bray 2002, Andrusak and Andrusak 2012). The abundance of small bodied, insectivorous Rainbow Trout is unknown, but limited littoral production due to reservoir operations likely limits the productivity of this morph. Future sampling efforts should target both morphs of Rainbow Trout, and sampling time period should coincide with reduction of water temperatures in the fall when fish will be less stressed by capture and tagging.

Year one of this study provided the opportunity to only survey a limited range of tributaries in the drawdown zone (754-738 m), since low pool elevations were much higher than average. Tributaries will be re-visited, in addition to as-yet unsurveyed tributaries in the second and third years of study, which may capture more of the drawdown zone. Tributaries visited which were deemed unsuitable may be lower priority for sampling in future years.

Of the five streams surveyed in Kinbasket Reservoir during this first year, three were found to have no significant migration barriers, and three had suitable substrate to support Rainbow Trout spawning between drawdown zone elevations of 754 and 738 m. Windfall Creek has some potentially suitable spawning substrates at the upper section of the drawdown zone, but access to this area is restricted by migration barriers. Harvey Creek had small outcroppings of gravel which may be suitable for Rainbow Trout spawning over 70 lineal m, but the surveyed area does not have the capacity to support large spawning aggregations. Succour Creek was identified as having the highest potential for Rainbow Trout spawning in the drawdown zone, with suitable channel morphology, substrate and stream gradient over 1,428 lineal m, and confirmed occupancy by Rainbow Trout from visual survey. The high suitability of this tributary supports the conclusions of previous studies, and previous observations of Rainbow Trout occupancy in the drawdown zone during the generalized regional spawn timing window (Oliver 2001, Fielden et al. 1992). Succour Creek should therefore receive more extensive sampling effort to determine Rainbow Trout spawning use of the tributary and its drawdown zone. In addition to sampling more of the drawdown zone in subsequent years it is recommended that redd surveys and opportunistic ground radio tracking be conducted throughout the spawning season (April-June) to determine presence and extent of spawning in the drawdown zone. Redd surveys and opportunistic radio tracking were conducted in the late April survey in 2015, but this survey timing may precede peak Rainbow Trout spawn timing.

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APPENDIX A.1 – INDIVIDUAL FISH CAPTURE AND TAGGING DATA

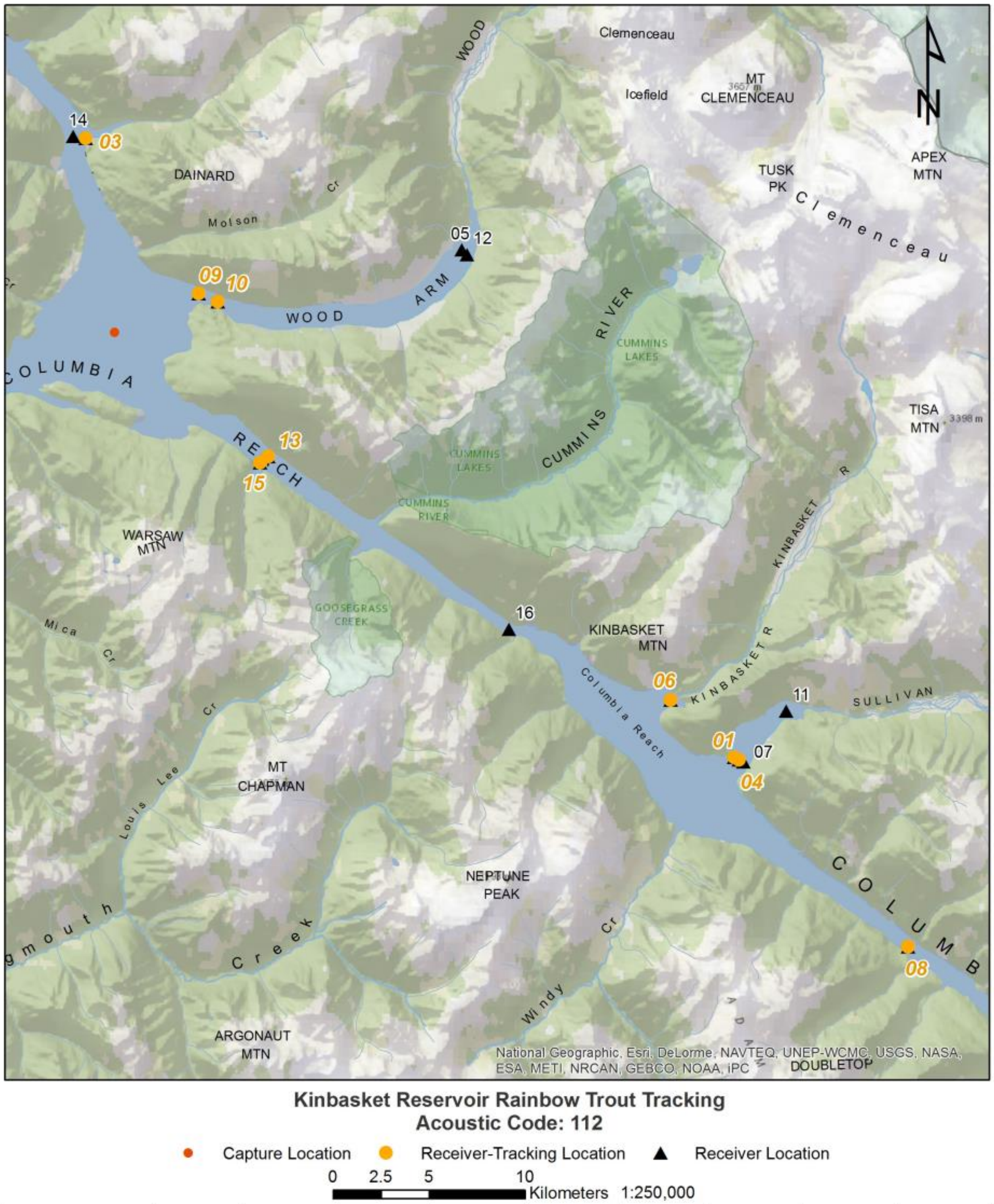
Record	Capture Date/Time		Capture Location			Species	RECAP	Acoustic Code	Radio Code	Radio Freq	Length	Weight	MORT	Sex	Tissue	Otolith	Fish Comments	H_2O	Weather & Water
#	Date	Time	Easting	Northing	General Description	Code	(Y/N)				(mm)	(kg)	(Y/N)	(M/F)	(Y/N)	(Y/N)		^0C	Conditions
1	16-Sep-14	14:00	404175	5773655	Confluence	BT	N				370		N	U	Y	N			clear, calm
2	16-Sep-14	17:49	406814	5771111	Confluence	RB	N				437	0.840	Y	U	Y	Y	mature yellowfin	14.9	clear, calm
3	17-Sep-14	11:50	402758	5780024	Canoe Reach	RT	N				320	0.370	N	U	Y	N	too small for tag	14.7	overcast, calm
4	17-Sep-14	13:03	402429	5780599	Canoe Reach	RB	N				380	0.590	N	U	Y	N	too small for tag	14.9	overcast, calm
5	17-Sep-14	16:30	402488	5780624	Canoe Reach	RB	N				405	0.740	N	U	Y	N	poor condition, hooked in eye	14.5	overcast, calm
6	17-Sep-14	16:59	402487	5780571	Canoe Reach	RB	N				385	0.550	N	U	Y	N	too small for tag; hooked in back	14.5	overcast, calm
7	17-Sep-14	17:30	402420	5780664	Canoe Reach	RB	N				415	0.660	Y	F	Y	Y	mature, hook broke off in head	14.5	overcast, calm
8	17-Sep-14	17:35	402564	5780495	Canoe Reach	BT	N				520	1.380	N	U	Y	N	hooked in belly, shallow wound	14.7	overcast, calm
9	18-Sep-14	10:15	410968	57777050	Wood Arm	RB	N				366	0.450	N	U	Y	N		14.5	light rain, calm
10	18-Sep-14	10:17	411064	5777079	Wood Arm	RB	N				370	0.570	N	U	Y	N	hooked in head	14.5	light rain, calm
11	18-Sep-14	11:30	416467	5776879	Wood Arm	RB	N				289	0.160	N	U	Y	N	hooked in eye	14.3	rain, calm
12	18-Sep-14	11:45	417386	5777323	Wood Arm	RB	N				285	0.110	N	U	Y	N	too small for tag	14.3	overcast, calm
13	18-Sep-14	14:32	402667	5780273	Canoe Reach	RB	N				388	0.500	N	U	Y	N	too small for tag	14.7	overcast, calm
14	18-Sep-14	15:20	402279	5778357	Canoe Reach	RB	N				413	0.500	N	U	Y	N	poor condition, head wound	14.7	overcast, calm
15	19-Sep-14	10:14	429804	5756212	Old Kinbasket Lake	RB	N	151	151	150.210	420	0.750	N	U	Y	N	good condition	14.5	partly cloudy, calm
16	19-Sep-14	12:10	435054	5755266	Old Kinbasket Lake	BT	N				460	0.848	N	U	Y	N		14.8	partly cloudy, calm
17	19-Sep-14	16:16	418779	5762967	Old Kinbasket Lake	BT	N				390	0.623	N	U	Y	N	hooked lower jaw, air in belly	14.5	partly cloudy, calm
18	20-Sep-14	9:18	393195	5772457	Mica Dam Forebay	BT	N				488	1.110	Y	F	Y	Y	hooked below gills, air in belly	13.3	partly cloudly, calm, light wind
19	20-Sep-14	9:37	394045	5773108	Mica Dam Forebay	RB	N				369	0.563	N	U	Y	N	hooked in eye, too small for tag	13.4	partly cloudly, calm, light wind
20	20-Sep-14	9:40	394422	5773217	Mica Dam Forebay	RB	N	152	152	150.210	409	0.811	N	U	Y	N		13.6	clear, calm
21	20-Sep-14	10:30	394920	5773793	Mica Dam Forebay	BT	N				350	0.400	N	U	Y	N		13.6	clear, calm
22	20-Sep-14	11:23	393330	5771490	Mica Dam Forebay	RB	N				365	0.603	Y	F	Y	Y	poor condition, mature	13.3	clear, calm
23	20-Sep-14	13:14	399994	5780253	Confluence	RB	N				372	0.616	N	U	Y	N	too small for tag	14.3	clear, calm
24	20-Sep-14	16:42	401714	5772787	Confluence	RB	N				376	0.609	N	U	Y	N	too small for tag	15.4	clear, calm
25	21-Sep-14	11:34	404559	5775543	Canoe Reach	RB	N	153	153	150.210	412	0.788	N	U	Y	N	good condition	14.8	clear, calm
26	21-Sep-14	12:38	404139	5774888	Canoe Reach	RB	N				400	0.766	Y	F	Y	Y	hooked through eye and into gills, mature	14.9	clear, calm
27	21-Sep-14	13:11	405241	5775292	Canoe Reach	RB	N				406	0.663	N	U	Y	N	hooked through eye, too small for tag	15.6	clear, calm
28	21-Sep-14	17:03	401517	5773882	Canoe Reach	RB	N	111	111	150.210	510	2.000	N	U	Y	N		15.3	clear, calm
29	21-Sep-14	17:20	401843	5773577	Canoe Reach	BT	N				455	1.100	N	U	Y	N	good condition	15.3	clear, calm
30	21-Sep-14	17:39	402168	5773271	Canoe Reach	RB	N				539	2.330	Y	F	Y	Y	injury on side where hooked	15.2	clear, calm
31	22-Sep-14	15:55	401476	5776504	Confluence	RB	N	112	112	150.210	588	3.100	N	U	Y	N	good condition	14.6	rain, small waves
32	22-Sep-14	16:02	401438	5776296	Confluence	RB	N				564	2.100	Y	F	Y	Y	stomach full of kokanee, mature	14.6	rain, small waves
33	23-Sep-14	9:05	397966	5775800	Confluence	BT	N				550	1.560	N	U	Y	N	good condition	14.0	overcast, small waves
34	23-Sep-14	10:05	398934	5775358	Confluence	RB	N				394	0.680	N	U	Y	N	too weak for surgery, borderline weight and length	14.0	overcast, small waves
35	24-Sep-14	12:10	429792	5753887	Old Kinbasket Lake	RB	N				468	1.060	Y	F	Y	Y		14.6	rain, small waves
36	24-Sep-14	13:24	433053	5753091	Old Kinbasket Lake	RB	N				484	1.600	N	U	Y	N	too weak for surgery	14.5	rain, small waves
37	24-Sep-14	14:25	432911	5753517	Old Kinbasket Lake	BT	N				438	0.810	N	U	Y	N		14.4	rain, small waves
38	24-Sep-14	14:34	433225	5753303	Old Kinbasket Lake	RB	N	113	113	150.210	517	1.910	N	U	Y	N		14.4	rain, small waves
39	24-Sep-14	15:05	433507	5752905	Old Kinbasket Lake	BT	N				438	0.830	N	U	Y	N		14.2	rain, small waves
40	24-Sep-14	15:27	433686	5752383	Old Kinbasket Lake	BT	N				512	1.410	N	U	Y	N		14.1	rain, small waves
41	25-Sep-14	11:18	384628	5807490	Canoe Reach	RB	N				387	0.588	N	U	Y	N	too small for tag, hooked through eye	13.3	rain, calm
42	25-Sep-14	15:26	356980	5845934	Canoe Reach	RB	N	154	154	150.210	422	0.780	N	U	Y	N	good condition	13.1	light rain, calm
43	26-Sep-14	10:00	394502	5794260	Canoe Reach	RB	N	155	155	150.210	419	0.745	N	U	Y	N	good condition, hooked through operculum	13.7	overcast, calm
44	26-Sep-14	14:45	401482	5779104	Confluence	BT	N				498	1.110	N	U	Y	N		13.7	rain, choppy
45	26-Sep-14	15:57	401435	5774852	Confluence	BT	N				424	0.750	N	U	Y	N		13.8	light rain, choppy
46	26-Sep-14	16:46	401919	5773220	Confluence	RB	N	114	114	150.210	736	3.300	N	F	Y	N	good condition	14.0	overcast, slightly choppy
47	26-Sep-14	18:06	401265	5773366	Confluence	RB	N	115	115	150.210	432	0.956	N	U	Y	N		13.9	overcast, slightly choppy
48	27-Sep-14	14:41	402424	5773533	Confluence	BT	N				488	1.275	N	U	Y	N	parasite (lice) on fins	15.4	clear, calm
49	27-Sep-14	15:06	401268	5773685	Confluence	RB	N				375	0.519	N	U	Y	N	too small for tag	15.4	clear, calm
50	27-Sep-14	17:46	402440	5772789	Confluence	RB	N				310	0.337	N	U	Y	N	too small for tag	14.8	clear, calm
51	27-Sep-14	18:12	401252	5773253	Confluence	BT	N				543	2.182	N	U	Y	N		14.5	clear, calm

APPENDIX A.2 – FISH SURGERY DATA

Record #	Acoustic Code	Radio Code	Radio Freq	Anaesthesia (min:sec)	Surgery (min:sec)	Recovery (min:sec)	Release (min:sec)	H_2O ^0C
1								
2								14.9
3								14.7
4								14.9
5								14.5
6								14.5
7								14.5
8								14.7
9								14.5
10								14.5
11								14.3
12								14.3
13								14.7
14								14.7
15	151	151	150.21	3:45	5:00	13:08	30:00	14.5
16								14.8
17								14.5
18								13.3
19								13.4
20	152	152	150.21	6:23	6:12	20:00	40:00	13.6
21								13.6
22								13.3
23								14.3
24								15.4
25	153	153	150.21	4:17	9:08	22:00	43:00	14.8
26								14.9
27								15.6
28	111	111	150.21	4:11	5:45	10:16	35:00	15.3
29								15.3
30								15.2
31	112	112	150.21	4:11	5:20	20:00	43:00	14.6
32								14.6
33								14.0
34								14.0
35								14.6
36								14.5
37								14.4
38	113	113	150.21	4:47	4:44	20:00	50:00	14.4
39								14.2
40								14.1
41								13.3
42	154	154	150.21	2:32	6:45	20:28	39:00	13.1
43	155	155	150.21	2:54	4:13	23:00	35:00	13.7
44								13.7

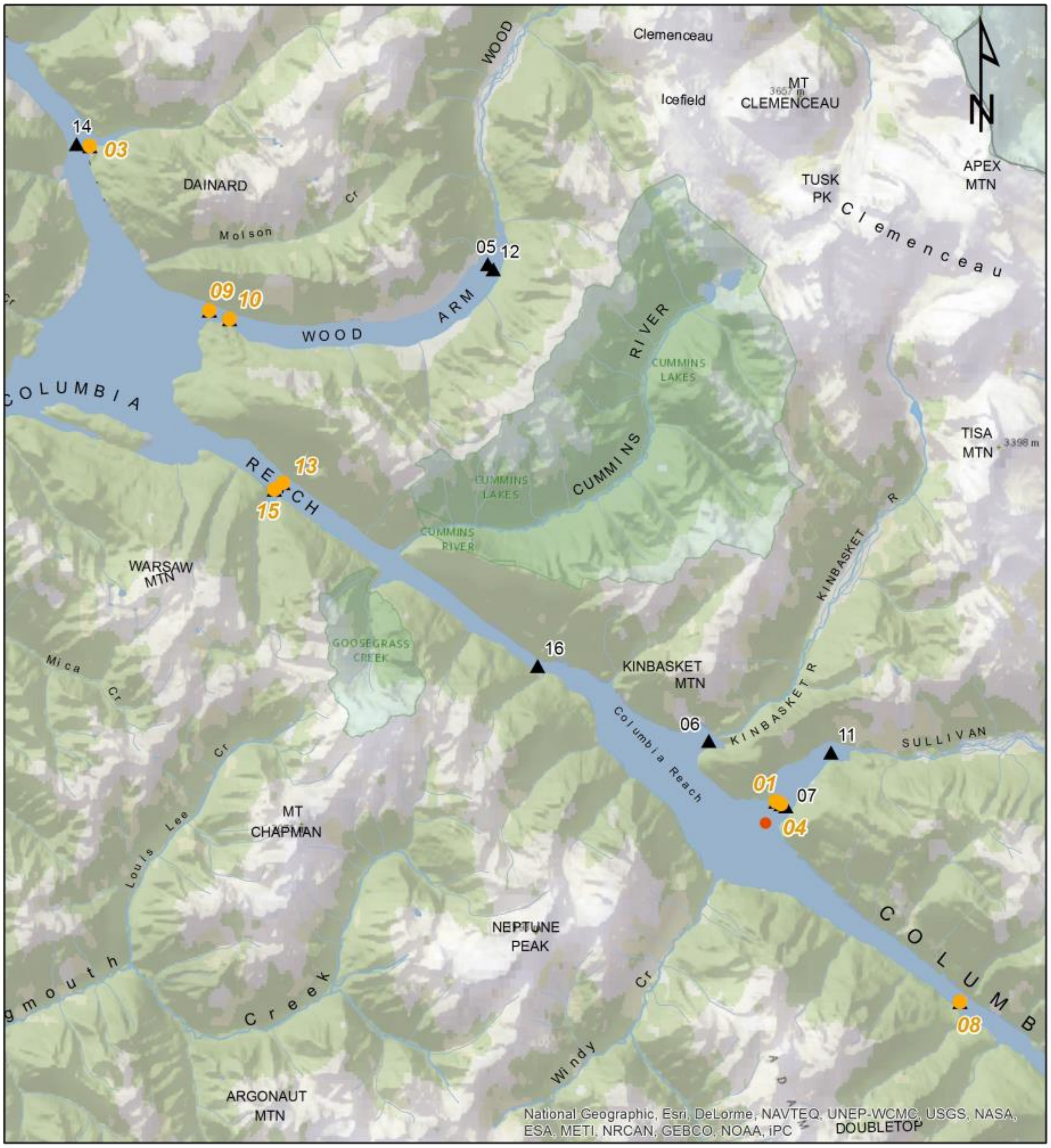
Record #	Acoustic Code	Radio Code	Radio Freq	Anaesthesia (min:sec)	Surgery (min:sec)	Recovery (min:sec)	Release (min:sec)	H_2O ^0C
45								13.8
46	114	114	150.21	3:30	5:24	25:03	46:00	14.0
47	115	115	150.21	4:37	4:50	14:39	38:00	13.9
48								15.4
49								15.4
50								14.8
51								14.5

APPENDIX A.3 – RAINBOW TROUT TRACKING MAPS



Receiver ID	1	3	4	6	8	9	10	13	15
Tracking Count	2001	305	2875	233	5978	314	202	508	475
Tracking Date Range	20/10/2014 - 30/01/2015	30/09/2014 - 04/10/2014	20/10/2014 - 16/02/2015	19/10/2014 - 02/11/2014	04/11/2014 - 02/04/2014	23/09/2014 - 05/10/2014	24/09/2014 - 26/09/2014	06/10/2014 - 09/10/2014	06/10/2014 - 09/10/2014

Figure A.3-1. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 112 and their tracking date ranges.



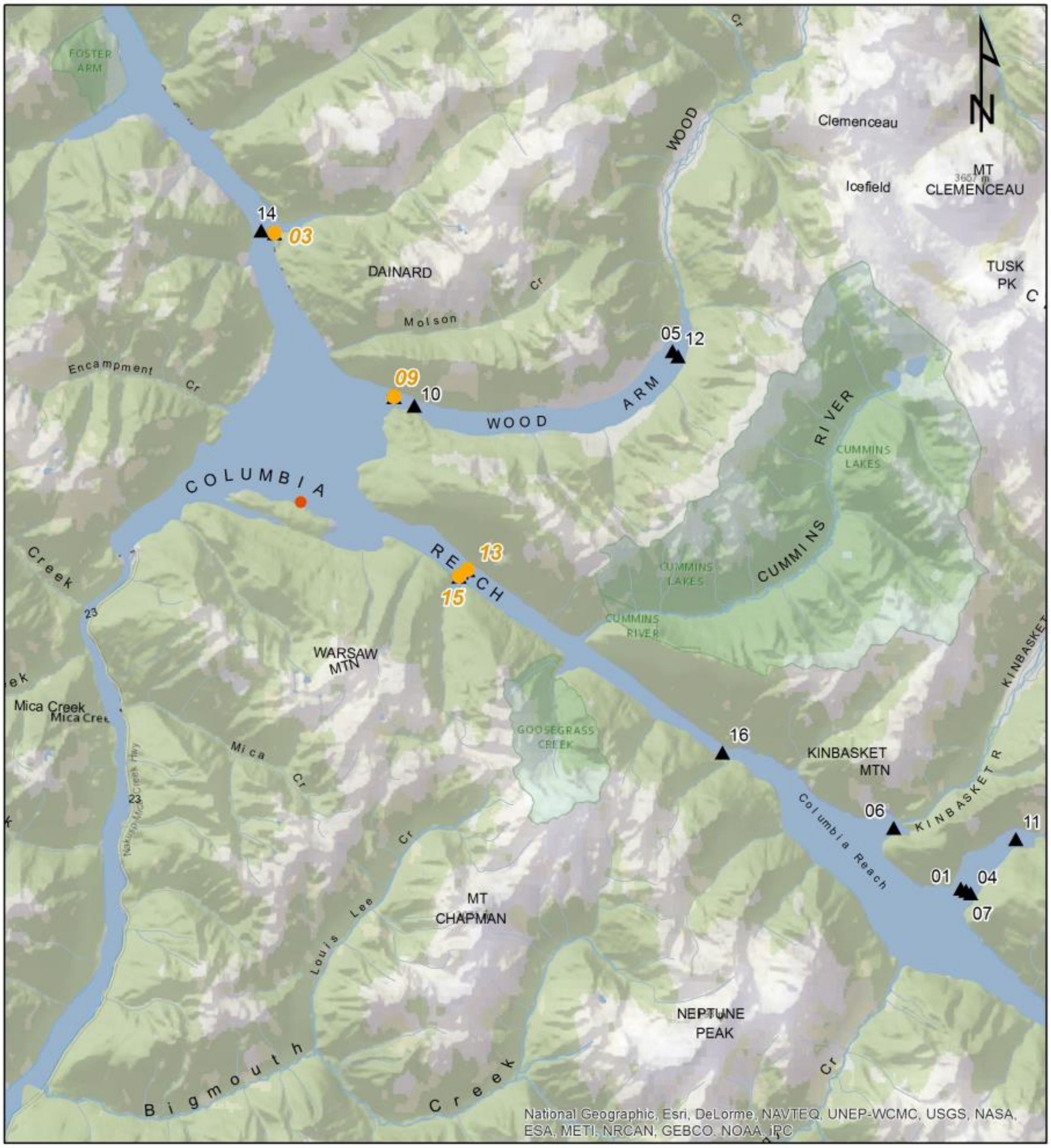
Kinbasket Reservoir Rainbow Trout Tracking
Acoustic Code: 113

● Capture Location ● Receiver-Tracking Location ▲ Receiver Location

0 2.5 5 10 Kilometers 1:250,000

Receiver ID	1	3	4	8	9	10	13	15
Tracking Count	4288	519	4676	5876	92	28	148	77
Tracking Date Range	24/09/2014 - 28/01/2015	14/02/2015 - 16/02/2015	24/09/2014 - 28/01/2015	30/09/2014 - 27/03/2014	05/02/2015 - 16/02/2015	05/02/2015 - 17/02/2015	02/02/2015 - 03/02/2015	31/01/2015 - 02/02/2015

Figure A.3-2. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 113 and their tracking date ranges.



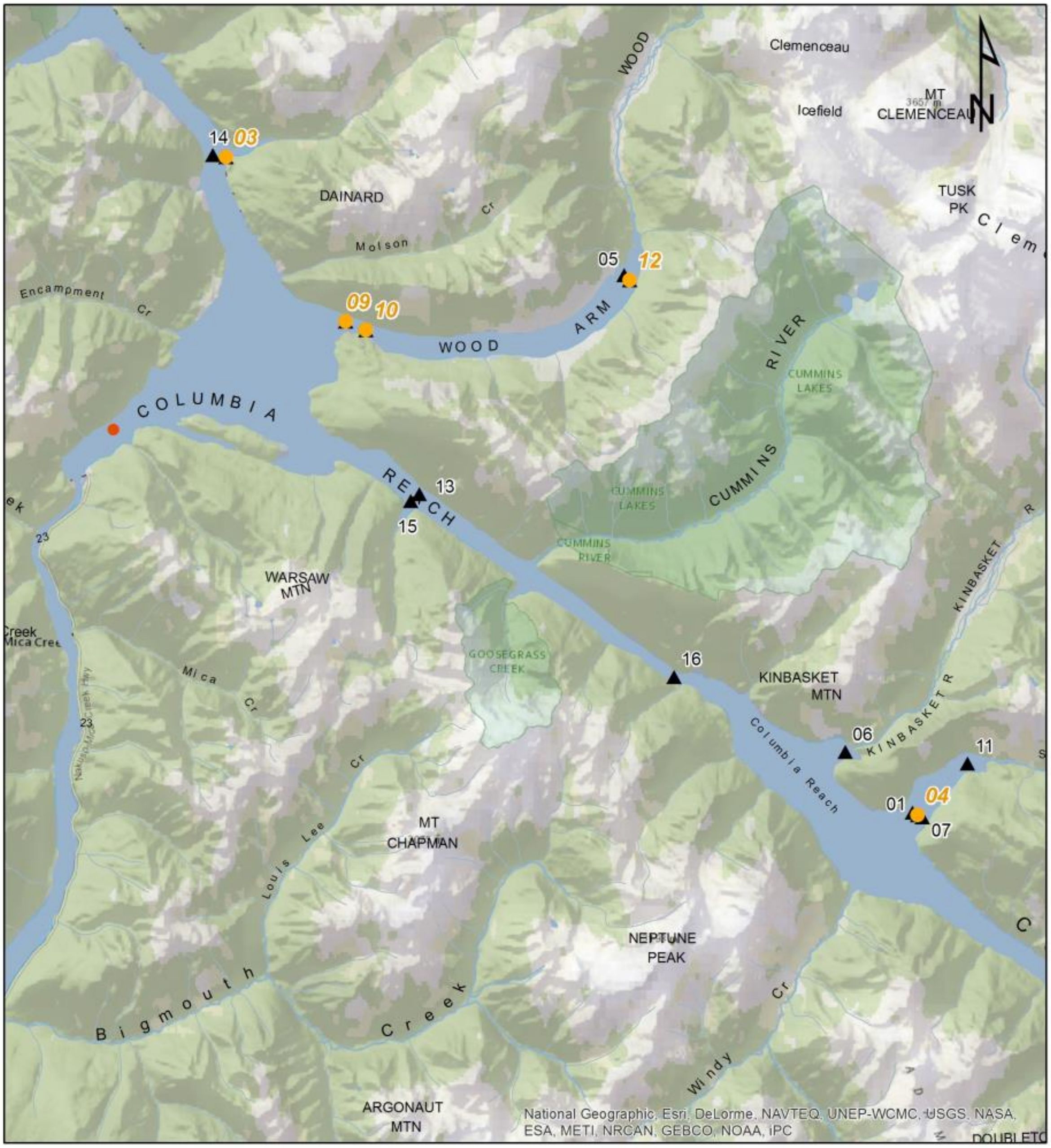
Kinbasket Reservoir Rainbow Trout Tracking
Acoustic Code: 115

- Capture Location
- Receiver-Tracking Location
- Receiver Location

0 2.5 5 10 Kilometers
1:250,000

Receiver ID	3	9	13	15
Tracking Count	90	38	166	27
Tracking Date Range	03/10/2014 - 04/10/2014	02/10/2014 - 02/10/2014	27/09/2014 - 28/09/2014	28/09/2014 - 28/09/2014

Figure A.3-3. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 115 and their tracking date ranges.



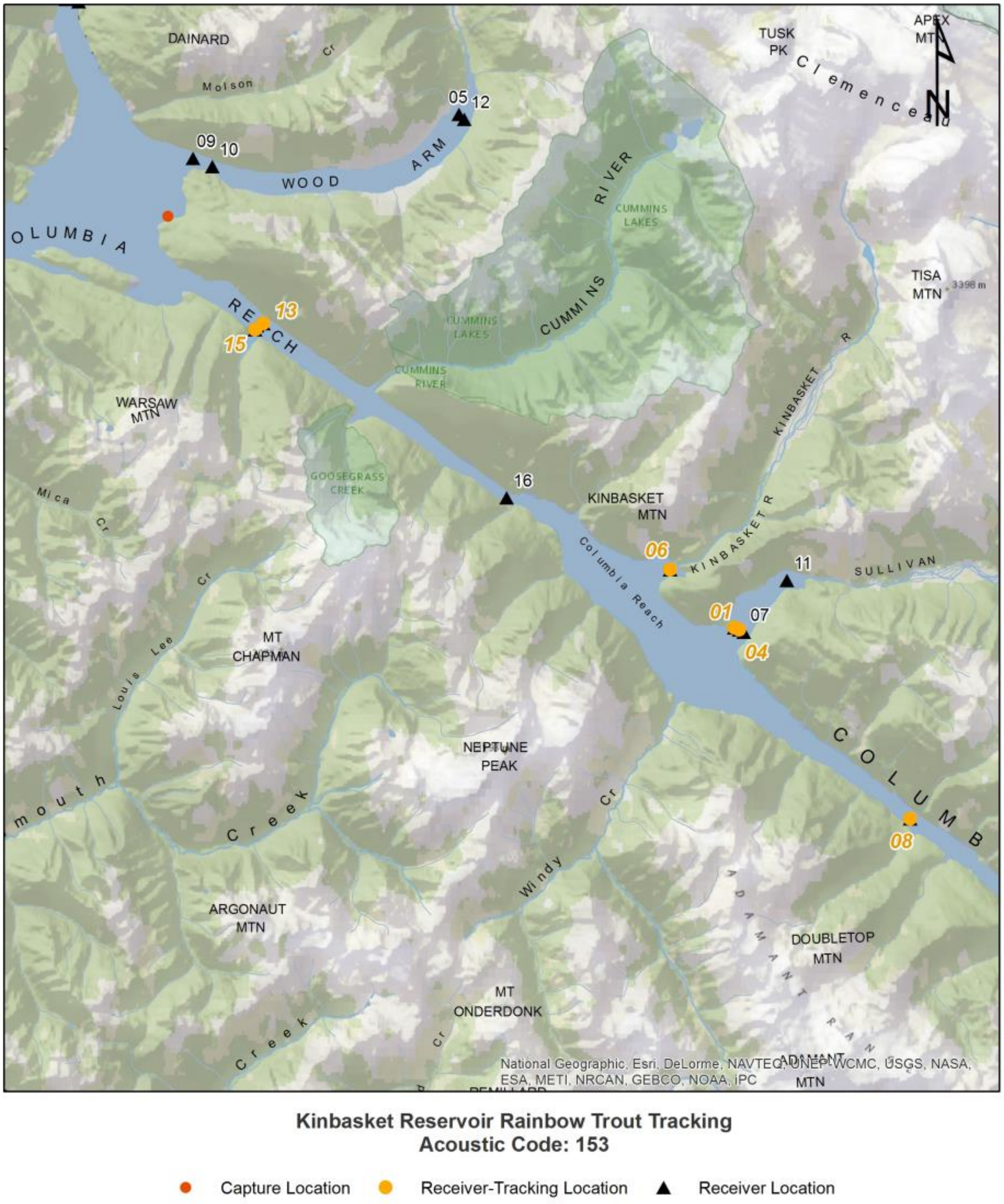
Kinbasket Reservoir Rainbow Trout Tracking
Acoustic Code: 152

● Capture Location ● Receiver-Tracking Location ▲ Receiver Location

0 2.5 5 10 Kilometers
1:250,000

Receiver ID	3	4	9	10	12
Tracking Count	638	448	277	216	217
Tracking Date Range	27/09/2014 - 04/11/2014	09/02/2015 - 29/03/2015	22/09/2014 - 19/11/2014	10/10/2014 - 19/11/2014	12/01/2015 - 12/02/2015

Figure A.3-4. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 152 and their tracking date ranges.



Receiver ID	1	4	6	8	13	15
Tracking Count	34	34	10	6	6	2
Tracking Date Range	02/10/2014 - 05/10/2014	02/10/2014 - 05/10/2014	02/10/2014 - 02/10/2014	05/10/2014 - 05/10/2014	29/09/2014 - 29/09/2014	29/09/2014 - 29/09/2014

Figure A.3-5. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 153 and their tracking date ranges.

APPENDIX B.1 – TRIBUTARY SURVEY DATA

Tributary Name	No	Date	Distance (m)	Habitat Type	Northing	Easting	Elevation (m)	Gradient (%)	Vel. 1 (m/s)	Vel. 2 (m/s)	Vel. 3 (m/s)	Mean Velocity (m/s)	Water Depth 1 (m)	Water Depth 2 (m)	Water Depth 3 (m)	Mean Water Depth (cm)	Bankfull Width (m)	Wetted Width (m)	Dom. Bed Material Type*	Sub-dom. Bed Material Type**	Cover Type***	Barrier Ref #
Harvey Creek	1	25-Apr-15	0	R	5787433	402672.4	754.1823		1.40	0.77	0.63	0.93	17	28	39	28.0	14.89	14.89	B	C	B	
Harvey Creek	2	25-Apr-15	20	R	5787427	402653.5	753.3184	4.3	0.99	0.63	0.99	0.87	29	9	35	24.3	16	16	C	B	WD	
Harvey Creek	3	25-Apr-15	40	R	5787419	402635.2	752.6110	3.5	0.77	0.44	1.66	0.96	19	14	50	27.7	17	15	B	C	WD, B	
Harvey Creek	4	25-Apr-15	60	R	5787412	402616.3	751.5863	5.1	0.44	1.53	1.08	1.02	14	38	38	30.0	16	14	B	C	WD, B	
Harvey Creek	5	25-Apr-15	80	C	5787408	402596.9	750.4808	5.5	0.99	0.89	0.00	0.63	40	30		35.0	14	10	B	C	WD, B	
Harvey Creek	6	25-Apr-15	100	P	5787405	402579.4	749.7663	3.6	0.77	1.17	0.99	0.98	45	85	70	66.7	14.4	8.9	B	C	WD, B	
Harvey Creek	7	25-Apr-15	120	R	5787403	402558.3	749.3407	2.1	1.17	0.77	0.77	0.90	57	22	20	33.0	19	12	C	G	WD, B	
Harvey Creek	8	25-Apr-15	140	R	5787398	402540.9	748.7302	3.1	0.99	0.00	0.44	0.48	41	30	14	28.3	21	15	G	S	WD, B	
Harvey Creek	9	25-Apr-15	160	R	5787396	402519.3	747.9350	4.0	0.63	0.77	0.89	0.76	15	40	31	28.7	29	16	C	G	WD, B	
Harvey Creek	10	25-Apr-15	180	R	5787396	402505	747.5132	2.1	0.44	1.25	1.08	0.93	10	27	18	18.3	27	19	G	C	WD, B	
Harvey Creek	11	25-Apr-15	200	R	5787391	402486.2	746.9531	2.8	0.44	0.63	1.72	0.93	13	6	61	26.7	28	16	G	B	WD, B	
Harvey Creek	12	25-Apr-15	220	R	5787376	402469.7	746.0137	4.7	0.77	1.08	0.89	0.91	26	53	30	36.3	44	9.7	G	B	WD, B	
Harvey Creek	13	25-Apr-15	240	R	5787366	402449.9	745.3224	3.5	0.63	0.77	2.26	1.22	9	15	30	18.0	46	9.2	G	B	WD, B	
Harvey Creek	14	25-Apr-15	260	R	5787356	402431.8	744.5086	4.1	0.44	0.99	0.77	0.73	40	50	32	40.7	22	8	B	C	WD, B	
Harvey Creek	15	25-Apr-15	280	R	5787348	402418.6	743.7348	3.9	0.89	0.99	0.00	0.63	35	30	10	25.0	26	15	G	B	WD, B	
Harvey Creek	16	25-Apr-15	300	C	5787345	402404.9	742.5721	5.8	* Too deep and swift to wade								26	9	B	C	WD, B	
Harvey Creek	17	25-Apr-15	320	R	5787354	402388.6	742.2874	1.4	0.77	1.17	0.99	0.98	34	57	33	41.3	25	10	C	G	WD, B	
Harvey Creek	18	25-Apr-15	340	R	5787367	402377.3	741.4215	4.3	1.33	1.33	0.44	1.03	38	55	15	36.0	29	13	G	B	WD, B	
Harvey Creek	19	25-Apr-15	360	R	5787384	402367.5	740.7849	3.2	0.44	0.63	1.77	0.95	18	35	37	30.0	41	17	G	B	WD, B	
Harvey Creek	20	25-Apr-15	380	R	5787395	402352	740.4048	1.9	0.44	1.17	0.89	0.83	10	27	40	25.7	36	16	G	C	WD, B	
Harvey Creek	21	25-Apr-15	400	R	5787404	402332.2	739.8022	3.0	1.08	0.99	0.63	0.90	30	20	22	24.0	32	19	G	B	WD, B	
Harvey Creek	22	25-Apr-15	420	R	5787410	402314.4	739.2113	3.0	0.63	1.25	0.63	0.84	39	56	11	35.3	24	10	G	C	WD, B	
Harvey Creek	23	25-Apr-15	440	R	5787422	402298.4	738.7875	2.1	1.08	1.08	0.00	0.72	19	50	22	30.3	35	6.2	G	C	WD, B	
Hugh Allan Creek	1	26-Apr-15	0	C	5811813	387421	754.3332		* Too deep and swift to wade								28	20	Bd	S	B	
Hugh Allan Creek	2	26-Apr-15	20	P			752.9940	6.7									21	19	B	Bd	B	
Hugh Allan Creek	3	26-Apr-15	40	R	5811835	387383.7	752.9357	0.3									26	17	B	Bd	B, WD	
Hugh Allan Creek	4	26-Apr-15	60	R	5811846	387364.7	752.3020	3.2									31	15	B	Bd	B, WD	
Hugh Allan Creek	5	26-Apr-15	80	R	5811853	387345.8	751.8785	2.1									25	20	B	Bd	B, WD	
Hugh Allan Creek	6	26-Apr-15	100	R	5811855	387325.9	751.6512	1.1									28	21	B	C	B, WD	
Hugh Allan Creek	7	26-Apr-15	120	R	5811851	387307.4	751.1178	2.7									26	21	B	Bd	B, WD	
Hugh Allan Creek	8	26-Apr-15	140	R	5811846	387287.9	750.7686	1.7									36	22	Bd	Bd	B, WD	
Hugh Allan Creek	9	26-Apr-15	160	R	5811840	387269.6	750.3247	2.2									33	21	B	Bd	B, WD	
Hugh Allan Creek	10	26-Apr-15	180	R	5811829	387249.3	749.5667	3.8									34	21	Bd	B	B, WD	
Hugh Allan Creek	11	26-Apr-15	200	R	5811825	387229.5	748.9714	3.0									34	19	Bd	B	B, WD	

Tributary Name	No	Date	Distance (m)	Habitat Type	Northing	Easting	Elevation (m)	Gradient (%)	Vel. 1 (m/s)	Vel. 2 (m/s)	Vel. 3 (m/s)	Mean Velocity (m/s)	Water Depth 1 (m)	Water Depth 2 (m)	Water Depth 3 (m)	Mean Water Depth (cm)	Bankfull Width (m)	Wetted Width (m)	Dom. Bed Material Type	Sub-dom. Bed Material Type	Cover Type	Barrier Ref #
Hugh Allan Creek	12	26-Apr-15	220	R	5811826	387209.4	748.5138	2.3									27	18	Bd	B	B, WD	
Hugh Allan Creek	13	26-Apr-15	240	R	5811830	387188	747.3016	6.1									31	12	Bd	B	B, WD	
Hugh Allan Creek	14	26-Apr-15	260	P	5811825	387167.8	747.3105	0.0										20	G	B	B, WD	
Hugh Allan Creek	15	26-Apr-15	280	R	5811826	387149.9	747.2626	0.2										21	B	Bd	B, WD	
Hugh Allan Creek	16	26-Apr-15	300	R	5811825	387127	746.9032	1.8									42	22	Bd	B	B, WD	
Hugh Allan Creek	17	26-Apr-15	320	R	5811831	387105.4	746.0896	4.1									45	18	B	Bd	B, WD	
Hugh Allan Creek	18	26-Apr-15	340	Run	5811833	387084.4	745.4701	3.1									39	18	B	S	B, WD	
Hugh Allan Creek	19	26-Apr-15	360	R	5811837	387067.4	745.3677	0.5									38	21	B	Bd	B, WD	
Hugh Allan Creek	20	26-Apr-15	380	R	5811836	387047.3	744.8611	2.5									42	20	B	C	B, WD	
Hugh Allan Creek	21	26-Apr-15	400	Run	5811842	387030.1	743.9432	4.6									43	16	B	S	B, WD	
Hugh Allan Creek	22	26-Apr-15	420	R	5811848	387010.1	743.5993	1.7									34	18	B	S	B, WD	
Hugh Allan Creek	23	26-Apr-15	440	Run	5811854	386992.3	743.0626	2.7									43	20	B	S	B, WD	
Hugh Allan Creek	24	26-Apr-15	460	Run	5811862	386973.5	742.8460	1.1									40	18	B	S	B, WD	
Hugh Allan Creek	25	26-Apr-15	480	R	5811859	386957	742.6184	1.1									47	24	B	C	B, WD	
Hugh Allan Creek	26	26-Apr-15	500	C	5811849	386940.5	741.7550	4.3									62	27	B	Bd	B, WD	
Hugh Allan Creek	27	26-Apr-15	520	C	5811841	386918.4	740.2590	7.5									50	25	Bd	B	B, WD	
Hugh Allan Creek	28	26-Apr-15	540	P	5811841	386899.5	740.2179	0.2									44	17	Bd	B	B, WD	
Hugh Allan Creek	29	26-Apr-15	560	R	5811845	386879.3	739.1333	5.4									50	22	Bd	B	B, WD	
Hugh Allan Creek	30	26-Apr-15	580	R	5811847	386857.2	738.6634	2.3									51	23	Bd	B	B, WD	
Windfall Creek	1	27-Apr-15	0	R	5810287	381346.9	754.5014		0.63	1.08	0.77	0.83	38	35	33	35.3	12	7.3	B	C	B, WD, D	
Windfall Creek	2	27-Apr-15	20	R	5810272	381360.7	753.9182	2.9	0.89	0.89	0.00	0.59	26	42	24	30.7	15	10	C	B	B, WD, D	
Windfall Creek	3	27-Apr-15	40	R	5810284	381380.3	753.3441	2.9	0.77	0.44	0.63	0.61	32	5	10	15.7	32	32	C	S	B, WD, D	
Windfall Creek	4	27-Apr-15	60	R	5810291	381397.5	752.7116	3.2	0.77	0.63	0.99	0.79	7	13	30	16.7	26	6.5	G	S	WD	
Windfall Creek	5	27-Apr-15	80	R	5810285	381418.1	752.0202	3.5	0.63	0.77	0.77	0.72	36	34	23	31.0	25	17	G	S	WD	
Windfall Creek	6	27-Apr-15	100	R	5810277	381432.9	751.2237	4.0	0.44	1.25	0.77	0.82	33	70	33	45.3		5.6	G	S	WD	1, 2
Windfall Creek	7	27-Apr-15	120	Run	5810291	381447.4	748.8253	12.0	1.08	1.08	0.00	0.72	27	32	50	36.3		6.7	G	S	WD, B	
Windfall Creek	8	27-Apr-15	140	R	5810292	381469.5	748.3604	2.3	1.53	1.17	0.89	1.20	33	33	18	28.0	7.9	5.3	C	B	WD, B	
Windfall Creek	9	27-Apr-15	160	R	5810280	381483.3	747.5683	4.0	0.00	0.99	1.17	0.72	3	27	27	19.0	14	12	G	C	WD, B	
Windfall Creek	10	27-Apr-15	180	R	5810274	381500.8	747.0771	2.5	0.44	0.77	0.89	0.70	14	32	24	23.3	17	12	G	C	WD, B	
Windfall Creek	11	27-Apr-15	200	Run	5810273	381516.9	746.8610	1.1	0.44	0.44	0.63	0.50	35	17	15	22.3	22	13	S	G	WD	3
Windfall Creek	12	27-Apr-15	220	R	5810263	381538.8	743.7268	15.7	0.63	0.63	0.44	0.57	25	18	14	19.0	27	18	C	B	WD, B	
Windfall Creek	13	27-Apr-15	240	R	5810262	381555.8	743.0541	3.4	0.44	1.08	0.63	0.72	53	57	32	47.3	14	6.5	B	S	WD, B	
Windfall Creek	14	27-Apr-15	260	R	5810252	381573.3	742.5597	2.5	0.44	0.99	0.63	0.69	20	34	24	26.0	14	7.9	B	C	WD, B	4
Windfall Creek	15	27-Apr-15	280	Run	5810248	381588.3	741.3252	6.2	1.83	0.99	0.63	1.15	57	46	53	52.0	14	8	B	S	WD, B	
Windfall Creek	16	27-Apr-15	300	Run	5810251	381605.6	740.0599	6.3	1.17	0.89	0.00	0.69	37	54	9	33.3	11	6	B	S	WD, B	
Windfall Creek	17	27-Apr-15	320	Run	5810248	381625.9	739.1244	4.7	1.33	0.44	0.44	0.74	65	45	27	45.7	15	6.6	B	S	WD, B	
Windfall Creek	18	27-Apr-15	340	R	5810238	381645.5	738.3575	3.8	1.17	0.89	0.44	0.83	45	51	32	42.7	14	5.8	B	S	WD, B	

Tributary Name	No	Date	Distance (m)	Habitat Type	Northing	Easting	Elevation (m)	Gradient (%)	Vel. 1 (m/s)	Vel. 2 (m/s)	Vel. 3 (m/s)	Mean Velocity (m/s)	Water Depth 1 (m)	Water Depth 2 (m)	Water Depth 3 (m)	Mean Water Depth (cm)	Bankfull Width (m)	Wetted Width (m)	Dom. Bed Material Type	Sub-dom. Bed Material Type	Cover Type	Barrier Ref #
Succour Creek	1	28-Apr-15	0	Run	5730630	462249	753.1968		0.89	0.63	0.63	0.71	44	36	23	34.3	5.3	5.3	G	S	WD, D	
Succour Creek	2	28-Apr-15	150	Run	5730715	462162.3	752.7186	0.3	0.63	0.63	0.44	0.57	76	67	29	57.3	11	11	S	G	WD	
Succour Creek	3	28-Apr-15	300	Run	5730826	462094.6	752.2309	0.3	* Too deep to wade									9	S	G	WD	
Succour Creek	4	28-Apr-15	450	Run	5730936	462023.6	751.0005	0.8	0.00	0.00	0.00	0.00						5.5	S	G	WD	
Succour Creek	5	29-Apr-15	600	Run	5731014	461930	750.3575	0.4	0.63	0.89	0.44	0.65	80	87	68	78.3	4.8	4.8	S	G	WD	
Succour Creek	6	29-Apr-15	750	Run	5731108	461872.6	749.6994	0.4	0.99	0.99	0.77	0.92	58	30	26	38.0	6.4	6.4	G	S	WD	
Succour Creek	7	29-Apr-15	900	Run	5731162	461770.8	749.0451	0.4	0.63	0.77	0.89	0.76	35	45	42	40.7	6.2	6.2	G	S	WD	
Succour Creek	8	29-Apr-15	1050	Run	5731272	461782.7	748.6361	0.3	0.44	0.63	0.63	0.57	51	75	79	68.3	5.3	5.3	S	G	WD	
Succour Creek	9	29-Apr-15	1200	Run	5731357	461734.9	748.3410	0.2	0.44	0.63	0.63	0.57	79	75	68	74.0	5.9	5.9	G	S	WD	
Succour Creek	10	29-Apr-15	1350	Run	5731468	461667.7	747.8280	0.3	0.63	0.89	0.63	0.71	58	49	48	51.7	8.7	8.7	G	S	WD	
Succour Creek	11	29-Apr-15	1500	Run	5731529	461554.3	747.1439	0.5	0.44	0.89	0.63	0.65	64	57	66	62.3	8.5	8.5	G	S	WD	
Succour Creek	12	29-Apr-15	1650	R	5731598	461473.2	746.6785	0.3	1.08	0.77	0.00	0.62	45	24	9	26.0	12	12	G	S	WD	
Succour Creek	13	29-Apr-15	1800	Run	5731727	461415.6	746.2984	0.3	1.08	0.63	0.44	0.72	94	68	30	64.0	5.4	5.4	G	S	WD	
Succour Creek	14	29-Apr-15	1950	Run	5731814	461323	745.8195	0.3	0.00	0.44	0.77	0.40	40	39	68	49.0	9.9	9.9	G	F	WD	
Succour Creek	15	29-Apr-15	2100	R	5731880	461241.6	745.2580	0.4	0.89	0.99	0.89	0.92	40	33	15	29.3	14	8.4	G	S	WD	
Succour Creek	16	29-Apr-15	2250	R	5731960	461192.2	744.7123	0.4	0.63	0.63	0.89	0.71	49	30	49	42.7	9.6	9.6	G	S	WD	
Succour Creek	17	29-Apr-15	2400	P	5732040	461085.3	744.2724	0.3	0.44		0.00	0.22	70	1.1	93	54.7	10.5	6.7	G	S	WD	
Succour Creek	18	29-Apr-15	2550	R	5732125	461028.1	743.8143	0.3	0.44	0.63	0.44	0.50	51	75	48	58.0	9.3	8.6	G	S	WD	
Succour Creek	19	29-Apr-15	2700	G	5732215	460965.2	743.0694	0.5	0.63	0.63	0.44	0.57	65	67	37	56.3	10.1	8.9	G	S	WD	
Succour Creek	20	29-Apr-15	2850	R	5732319	460916	742.5747	0.3	0.00	0.63	0.63	0.42	15	48	70	44.3	17.4	10.6	G	S	WD	
Succour Creek	21	29-Apr-15	3000	R	5732417	460873.4	742.1822	0.3	0.89	0.89	1.17	0.98	36	45	46	42.3	9.3	7.5	G	C	WD	
Succour Creek	22	29-Apr-15	3150	Run	5732515	460802.3	741.7503	0.3	0.89	0.89	0.63	0.80	60	53	27	46.7	9.4	8	G	S	WD	
Succour Creek	23	29-Apr-15	3300	R	5732574	460701.8	741.1525	0.4	0.77	0.63	0.44	0.61	49	39	34	40.7	11.2	8.3	G	S	WD	
Succour Creek	24	29-Apr-15	3450	R	5732701	460634	740.8412	0.2	0.00	0.63	0.63	0.42	16	43	57	38.7	11	9.8	G	S	WD	
Succour Creek	25	30-Apr-15	3600	R	5732721	460537.2	740.5425	0.2	0.00	0.63	0.44	0.36	29	35	52	38.7	15	13	G	S	WD	
Succour Creek	26	30-Apr-15	3750	Run	5732822	460462.9	740.2684	0.2	0.63	0.63	0.44	0.57	46	73	71	63.3	11.3	7.9	F	G	WD	
Succour Creek	27	30-Apr-15	3900	P	5732934	460386.5	740.0018	0.2	0.63	0.00	0.44	0.36	86	50	57	64.3	11.1	9.8	G	F	WD	
Succour Creek	28	30-Apr-15	4050	Run	5732996	460358.8	739.7177	0.2	0.89	0.63	0.44	0.65	50	61	58	56.3	11.2	10	C	S	WD	
Succour Creek	29	30-Apr-15	4200	R	5733095	460278.9	738.4576	0.8	0.99	1.25	0.99	1.08	40	62	35	45.7	10.7	7.6	C	S	WD	
Unnamed west tributary north of Gold Creek	1	1-May-15	0	R	5733613	451985	754.0604		0.89	0.89	0.63	0.80	33	11	13	19.0	4.9	3.4	G	B	B, WD	1
Unnamed west tributary north of Gold Creek	2	1-May-15	15	R	5733616	451998.4	751.4659	17.3	0.77	0.44	0.77	0.66	18	19	10	15.7	7	5.6	G	C	B, WD	
Unnamed west tributary north of Gold Creek	3	1-May-15	30	R	5733625	452008.4	749.5287	12.9	0.44	0.77	0.44	0.55	4	23	7	11.3	14.7	10.3	G	C	B, WD	
Unnamed west tributary north of Gold Creek	4	1-May-15	45	R	5733628	452024.1	748.0668	9.7	0.89	0.77	0.00	0.55	31	13	5	16.3	10.5	3.9	B	C	B, WD	
Unnamed west tributary north of Gold Creek	5	1-May-15	60	R	5733629	452038	746.5591	10.1	0.63	0.44	0.63	0.57	11	4	5	6.7	21	12	B	C	B, WD	

Tributary Name	No	Date	Distance (m)	Habitat Type	Northing	Easting	Elevation (m)	Gradient (%)	Vel. 1 (m/s)	Vel. 2 (m/s)	Vel. 3 (m/s)	Mean Velocity (m/s)	Water Depth 1 (m)	Water Depth 2 (m)	Water Depth 3 (m)	Mean Water Depth (cm)	Bankfull Width (m)	Wetted Width (m)	Dom. Bed Material Type	Sub-dom. Bed Material Type	Cover Type	Barrier Ref #
Unnamed west tributary north of Gold Creek	6	1-May-15	75	R	5733621	452053.1	744.7416	12.1	0.44	1.40	0.77	0.87	6	18	15	13.0	15	5	B	C	B, WD	
Unnamed west tributary north of Gold Creek	7	1-May-15	90	P	5733623	452066.4	743.6722	7.1	0.63	0.00	0.44	0.36	13	14	26	17.7	14	4.1	B	G	B, WD	
Unnamed west tributary north of Gold Creek	8	1-May-15	105	R	5733621	452081.8	742.5883	7.2	0.77	0.63	0.77	0.72	18	34	16	22.7	13	3.4	C	G	B, WD	
Unnamed west tributary north of Gold Creek	9	1-May-15	120	R	5733625	452094.8	741.2587	8.9	1.25	0.77	0.00	0.67	18	10	8	12.0	15	3.4	C	G	B, WD	
Unnamed west tributary north of Gold Creek	10	1-May-15	135	R	5733629	452109.9	740.6266	4.2	0.44	0.77	1.33	0.85	10	8	21	13.0	13	3	C	G	B, WD	
Unnamed west tributary north of Gold Creek	11	1-May-15	150	R	5733631	452124.8	740.0214	4.0	0.89	0.77	0.00	0.55	25	26	8	19.7	16	3.3	C	B	B, WD	
Unnamed west tributary north of Gold Creek	12	1-May-15	165	R	5733630	452137.3	738.9482	7.2	0.44	0.89	1.33	0.89	12	43	24	26.3	5.9	2.4	C	B	B, WD	
Unnamed west tributary north of Gold Creek	13	1-May-15	180	R	5733627	452153.2	738.2598	4.6	0.99	0.89	0.63	0.83	14	19	10	14.3	8	3.4	C	B	B, WD	

* Dominant bed material type refers to the type of bed material that covers the largest percentage of the area of the reach. F – fines (silts, clays, or fine organic material), S – sands, G – gravels, C – cobbles, B – boulders, Bd – bedrock.

** Sub-dominant bed material type refers to the type of bed material that covers the second largest percentage of the area of the reach.

*** Cover type refers to the type of material overlying the wetted surface area. WD – woody debris, B – boulders, D – deciduous.

APPENDIX B.2 – TRIBUTARY BARRIER DATA

Tributary	Barrier Ref #	Top of Barrier			Bottom of Barrier			Material*
		Northing	Easting	Elevation (m)	Northing	Easting	Elevation (m)	
Windfall Creek	1	5810277	381437.5	750.6739	5810277	381438.4	750.0007	WD
Windfall Creek	2	5810285	381444.2	749.5602	5810287	381446	748.8228	WD
Windfall Creek	3	5810267	381525.7	746.5096	5810254	381529.4	744.1865	WD
Windfall Creek	4	5810246	381581.7	742.3226	5810245	381583.1	741.3495	WD, B
Unnamed west tributary north of Gold Creek	1	5733612	451995.3	752.4944	5733612	451996	751.5607	WD

* Material refers to the type of material that makes up the barrier. WD – woody debris, B – boulders.

APPENDIX B.3. – TRIBUTARY PHOTOGRAPHS

Photograph 1. Harvey Creek at the top of the drawdown zone (April 25th, 2015).

Photograph 2. Harvey Creek, approximately 220 m below the top of the drawdown zone (April 25th, 2015).


Photograph 3. Hugh Allan Creek at the top of the drawdown zone (April 26th, 2015).


Photograph 4. Hugh Allan Creek, approximately 320 m below the top of the drawdown zone (April 26th, 2015).

Photograph 5. Windfall Creek at the top of the drawdown zone (April 27th, 2015).

Photograph 6. Windfall Creek, looking downstream from approximately 100 m below the top of the drawdown zone (April 27th, 2015).

Photograph 7. Windfall Creek, approximately 200 m below the top of the drawdown zone (April 27th, 2015).

Photograph 8. Succour Creek at the top of the drawdown zone (April 28th, 2015).

Photograph 9. Succour Creek, approximately 2,100 m below the top of the drawdown zone (April 29th, 2015).

Photograph 10. The unnamed west tributary north of Gold Creek at the top of the drawdown zone (May 1st, 2015).

Photograph 11. The unnamed west tributary north of Gold Creek, approximately 175 m below the top of the drawdown zone (May 1st, 2015).