Columbia River Project Water Use Plan

Kinbasket Reservoir Fish And Wildlife Information Plan

Kinbasket Reservoir Rainbow Trout Life History and Habitat Use Assessment

Implementation Year 2

Reference: CLBMON-7

Kinbasket Reservoir Rainbow Trout Life History and Habitat Use Assessment (Year 2)

Study Period: September 2015 – August 2016

Canadian Columbia River Inter-tribal Fisheries Commission
7468 Mission Rd, Cranbrook, BC, V1C 7E5

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Kinbasket Reservoir Rainbow Trout Life History and Habitat Use Assessment (Year 2)

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Snorkel survey on Succour Creek in May 2016. Photos in this document © Katrina Caley, CCRIFC.

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EXECUTIVE SUMMARY

Rainbow Trout (*Oncorhyncus mykiss*) were historically distributed throughout the Columbia and Canoe Rivers, and historic Kinbasket Lake, which were impounded by the construction of the Mica Dam in 1973. Mica Dam created Kinbasket Reservoir, a 216 km long, 43,200 ha ultraoligotrophic water body. This is a technical report that summarizes the findings of Year 2 (2016) of a three year monitoring study of the life history, habitat use, and potential operational impacts of the Mica Dam on the spawning ecology of Rainbow Trout in Kinbasket Reservoir.

Kinbasket Reservoir has a normal annual operating range of approximately 35 m, and during periods below full pool, a large shoreline drawdown zone is exposed. Typical reservoir drawdown occurs during the winter months, beginning in January, reaching low pool level by approximately the end of April. The timing of low pool level coincides with the general timing of Rainbow Trout migration to tributaries to spawn. Rainbow Trout have specific spawning habitat requirements in tributaries, preferring a range of stream gradients, depths, and velocities, in addition to gravel substrate and a thermal regime suitable for spawning and embryo development. Locations of Rainbow Trout spawning are currently unknown in tributaries to Kinbasket Reservoir. If suitable spawning habitat is present in the portion of tributaries that traverse the drawdown zone or migration barriers are exposed in these portions during the spawning migration, dam operations may potentially impact the success of Rainbow Trout spawning or subsequent embryo incubation.

Year 2 of this study continued to use a combination of biotelemetry and habitat surveys to determine biological characteristics and movement of Rainbow Trout during the suspected prespawn and spawning time period, as well as the habitat characteristics of potential spawning streams through the portions that traverse the drawdown zone. Snorkel surveys were conducted through the spring in the drawdown zone of Succour Creek, a stream with high potential to support spawning of Rainbow Trout.

Large bodied Rainbow Trout were targeted by angling (trolling) with a professional guide over 10 days beginning at the end of September 2015. A total of 22 Rainbow Trout (mean size 419 +/- 70.3 mm; 0.96 +/- 0.68 kg) were caught in 10 days of angling, yielding an overall catch-per-unit-effort (CPUE) of 0.06 fish/rod hour (95% CI of 0.03-0.09 fish/rod hour). Overall capture success for Rainbow Trout vulnerable to the capture method during both years of study was low to moderate (0.06 fish/rod hour; 1043.75 rod hours effort), relative to comparisons with creel survey data from other large lakes in the region. The species was distributed throughout the reservoir, and biological data from a limited number of captured fish (diet, size distribution, maturity and length at age) lead us to hypothesize there may be a large-bodied, piscivorous form, as well as a small-bodied, insectivorous form.

Seven fish of sufficient size were captured for surgical implantation with combined acoustic-radio transmitters (CART), increasing the total number of tagged fish to 17 for the study. Fixed acoustic receivers revealed large scale movement patterns of 11 of 17 Rainbow Trout throughout the course of the study from September 2014 to May 2016. Fish detected by acoustic receivers had a variety of home range size and location preferences. Directed pre-spawn and/or post-spawn movements to and from home ranges appeared to occur in five tagged fish in late March-late April, and late May, respectively. Several fish migrated to the upstream end of the Columbia Reach of the reservoir during these forays.

Tributaries with the potential to support Rainbow Trout spawning were identified from literature review, and the drawdown zone of six of these streams was surveyed during low pool in mid-April to early May 2016. Low pool elevations in 2016 were similar to the mean low pool elevation for Kinbasket Reservoir between 1977 and 2014, so it was possible to survey a large portion of the drawdown zone in each tributary. Surveys extended from the top of the drawdown zone at the high pool mark (754 m) to the reservoir at ~731 m. One tributary (Beaver River) had a cascade that may be a full or partial barrier for migrating fish. Three tributaries had extensive reaches with undefined, shallow braided channels that could reduce tributary access for migrating fish in base flows. Within the drawdown zone, three of the six tributaries had gradients shallow enough to support Rainbow Trout spawning. However, only two of these (Dave Henry Creek and Succour Creek) had suitable spawning substrate. Of the surveyed tributaries, Succour Creek provides the most extensive reaches of suitable spawning habitat for Rainbow Trout, as it has gentle gradients (0.4% slope), pool-riffle channel morphology and gravel substrate through most of the drawdown zone (1,539 m of 5,421 m of surveyed stream length in the drawdown zone). Preliminary analysis of water temperature data from Succour Creek indicate the creek was thermally suitable in the drawdown zone for spawning in 2015 beginning in late April, and reservoir operations have the potential to inundate suitable spawning habitat prior to earliest times of modeled fry emergence. Despite the apparent suitability of the drawdown zone for Rainbow Trout spawning in Succour Creek, three snorkel surveys (conducted in April, May and June) did not reveal the presence of redds in 2016.

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)?		Two Rainbow Trout morphs may be present in Kinbasket Reservoir – a smaller insectivorous morph and a larger piscivorous morph. The size classes or form vulnerable to the capture method may be less abundant than in comparable large lakes. Rainbow Trout are distributed throughout the reservoir; this question will be addressed more thoroughly in year 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 six tributaries with the potential to support Rainbow Trout were surveyed to low pool elevations of ~731 m in mid-April to early May 2016. One possible migration impediment is present on the Beaver River, at the top of the drawdown zone. Possible shallow barriers formed by channel braiding may be present in the drawdown zones of three surveyed tributaries during periods of low flow. Further habitat surveys at lower reservoir elevations and on unsurveyed tributaries will be addressed in year 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 six surveyed tributaries revealed extensive reaches of possible suitable spawning substrate and habitat characteristics in the drawdown zone of Succour Creek to 731 m elevation. Limited reaches of suitable spawning substrates were also present in Dave Henry and Yellowjacket Creeks. Preliminary analysis of temperature data suggests that reservoir operations inundated potentially suitable spawning habitat in the lower reaches of Succour Creek during the thermally suitable time for spawning and embryo incubation, and prior to earliest modeled fry emergence timing. No Rainbow Trout spawning activity or redds were observed during snorkel surveys. Further

		habitat and redd surveys, as well as a more detailed analysis of temperature data to be addressed in year 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 year 3.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY iii
ACKNOWLEDGEMENTS vii
LIST OF FIGURES ix
LIST OF TABLES x
INTRODUCTION 1
Background 1
Rainbow Trout – life history and biological characteristics in Kinbasket Reservoir 2
Management Questions 3
Management Hypotheses 4
Key Water Use Decision Affected 4
METHODS 4
Overview, study objectives and limitations 4
Rainbow Trout capture and tagging 5
Mobile and fixed receiver tracking 8
Fixed receiver tracking 8
Mobile tracking 11
Tributary access, stream habitat and thermal suitability 11
Snorkel surveys 13
Statistical analysis 13
RESULTS 13
Rainbow Trout capture and tagging 13
Mobile tracking 16
Fixed receiver tracking 16
Tributary access, stream habitat and thermal suitability 19
Snorkel surveys 22
DISCUSSION and RECOMMENDATIONS 25
Rainbow Trout capture, biological characteristics and tagging 25
Mobile tracking 26
Fixed receiver tracking 26

Tributary access, stream habitat and thermal suitability 27
Snorkel surveys 29
Conclusions and recommendations 30
REFERENCES 31
APPENDIX A.1 – INDIVIDUAL FISH CAPTURE AND TAGGING DATA 37
APPENDIX A.2 – FISH SURGERY DATA 38
APPENDIX A.3 – RAINBOW TROUT TRACKING MAPS 39
APPENDIX B.1 – TRIBUTARY SURVEY DATA 50
APPENDIX B.2. – TRIBUTARY PHOTOGRAPHS 55
APPENDIX B.3. – STREAM ELEVATION PROFILES THROUGH DRAWDOWN ZONE 61

LIST OF FIGURES

Figure 1: Life history timing of Rainbow Trout compared with the minimum, maximum and mean reservoir elevations in the Kinbasket Reservoir, 1976-2015 2
Figure 2: Locations of study area and tributaries in the Kinbasket Reservoir 6
Figure 3: Surgical setup for transmitter implantation 7
Figure 4: Incision and antenna placement for Rainbow Trout transmitter surgery 7
Figure 5: Rainbow Trout in oxygenated recovery tank 8
Figure 6: Locations of 27 acoustic receivers within Kinbasket Reservoir (26 from CLBMON-05 and 1 from CLBMON-07), and general areas of reservoir sampling for Rainbow Trout and delineating home ranges. 10
Figure 7: Size (length and weight) distributions and box plots of Rainbow Trout (n=22) caught and measured in Kinbasket Reservoir in September and October 2015. 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. 15
Figure 8: Length at age of Rainbow Trout, as examined from otoliths of piscivorous (closed circles; n = 2) and non-piscivorous (open circles; n = 6) individuals, taken from incidental mortalities in both Year 1 and Year 2 of the study. 16
Figure 9: Daily mean water temperature of Succour Creek and spring/summer reservoir elevations (dashed line) in 2015. The dotted line is modeled temperatures, and the solid line into which it merges is measured temperatures. The upper and lower horizontal lines are the upper and lower temperature suitability thresholds for Rainbow trout spawning and incubation. The left vertical line represents the earliest date of spawning according to the lower suitability threshold for the species and the right vertical line represents the earliest date of emergence modeled from the accumulated thermal units of the initial spawn date. 22
Figure 10: Juvenile Rainbow Trout observed in Succour Creek 23
Figure 11: Largescale suckers observed in Succour Creek during the May 18th, 2016 snorkel survey 23
Figure 12: Longitudinal profile of stream elevation for Succour Creek 61

Figure 13: Longitudinal profile of stream elevation for Horse Creek 62
Figure 14: Longitudinal profile of stream elevation for Ptarmigan Creek 63
Figure 15: Longitudinal profile of stream elevation for Dave Henry Creek 64
Figure 16: Longitudinal profile of stream elevation for Yellowjacket Creek 65
Figure 17: Longitudinal profile of stream elevation for Beaver River 66

LIST OF TABLES

Table 1: Summary of tributary surveys conducted in 2015 and 2016 12
Table 2: Summary statistics of Rainbow Trout captured across four general areas of Kinbasket Reservoir, 2015. 14
Table 3: Summary statistics of Rainbow Trout (RT) catches and individual fish data across 4 general areas of Kinbasket Reservoir 14
Table 4: Summary of key tributary measurements and observations during the 2016 surveys 21
Table 5: Summary of snorkel survey observations, Succour Creek. 24

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 13 km long and had a surface area of 2,250 ha (Prince 2001a). 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. Three 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, 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 (*Oncorhynchus mykiss*) spawn in the spring in streams, during periods of rising water temperatures consistently exceeding 6-8 °C and the ascending limb of the hydrograph (McPhail 2007)(Figure 1). Spawn 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 lasts 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 can result in two potential alternatives in which reservoir operations can limit Rainbow Trout recruitment, and thus productivity. Firstly, the pre-spawning migration period into critical spawning habitat may be obstructed by in-stream migration barriers exposed during the coinciding low pool elevations of the reservoir. Secondly, Rainbow Trout may spawn in the drawdown zone of streams immediately upstream from their confluence with 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 embryos are incubating changes the nature of the incubation environment; Rainbow Trout require flowing water to constantly provide developing embryos with oxygen and to remove metabolic waste products. In addition, emergence of fry directly into an open water lentic habitat may increase predation and reduce foraging opportunities. This study is designed to detect whether Rainbow Trout are susceptible to these potential limitations on recruitment success in the years of study, as these uncertainties have been identified by the Water Use Plan Consultative Committee.

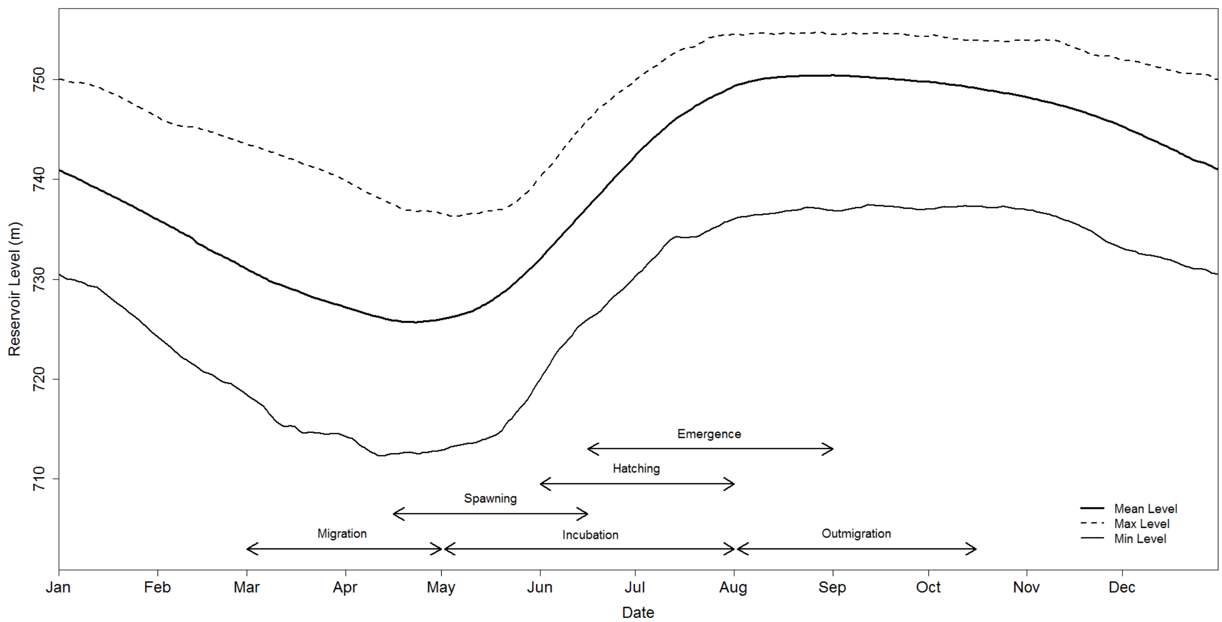

Figure 1: Life history timing of Rainbow Trout compared with the minimum, maximum and mean reservoir elevations in the Kinbasket Reservoir, 1976-2015

Rainbow Trout – life history and biological characteristics in Kinbasket Reservoir

Kinbasket Reservoir holds a modestly popular, but productive fishery for Rainbow Trout (Pole 1995, Bray 2002). The origin of indigenous Rainbow Trout in Kinbasket Reservoir is from 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 2001b). 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 of these 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 similar but slightly higher elevation and latitude of Kinbasket Reservoir, spawn timing for adfluvial Rainbow Trout may 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 by prior research 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 2001b). 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 for the tributary portions that traverses this shoreline, 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 may migrate into tributaries to the Columbia River upstream from the reservoir, rather than tributaries directly feeding into 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 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 Hypotheses

The primary aim of this monitoring program is to provide baseline information on Rainbow Trout in Kinbasket Reservoir to better inform 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 partially 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. 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, sampling effort to capture fish is biased to focus on central and southern portions of the reservoir.

Rainbow Trout capture and tagging

Capture techniques and timing used in Year 2 of the study were similar to those used in Year 1 (Caley and Warnock 2015). Trolling was the angling method employed, which 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. The capture period was from September 25th until October 3rd, 2015. The capture program was scheduled approximately two weeks later than the 2014 program to ensure that water temperatures were cooler. It was suspected that higher water temperatures during the 2014 program were contributing to fish stress and higher than anticipated mortality. Water temperatures in the Kinbasket Reservoir were confirmed with BC Hydro prior to starting the capture program.

Angling effort focused on four reservoir areas: the Canoe Reach, the confluence and Mica Dam forebay, Kinbasket Lake and the Upper Columbia (Figure 6). The Wood Arm was not visited and instead angling effort was expended in the Upper Columbia where visits were not made in 2014. A professional guide with extensive local knowledge and prior experience in capture of fish for biotelemetry in Kinbasket Reservoir (Martins et al. 2013) was employed for all capture efforts.

Due to the large area of the reservoir, 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. All mortalities were examined for gut contents and biological samples of otoliths were removed from mortalities for aging.

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 (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. The same surgical techniques that were used by Caley and Warnock (2015) were employed in Year 2 of this study. Figure 3 to Figure 5 show the main steps of the tag implantation and recovery process.

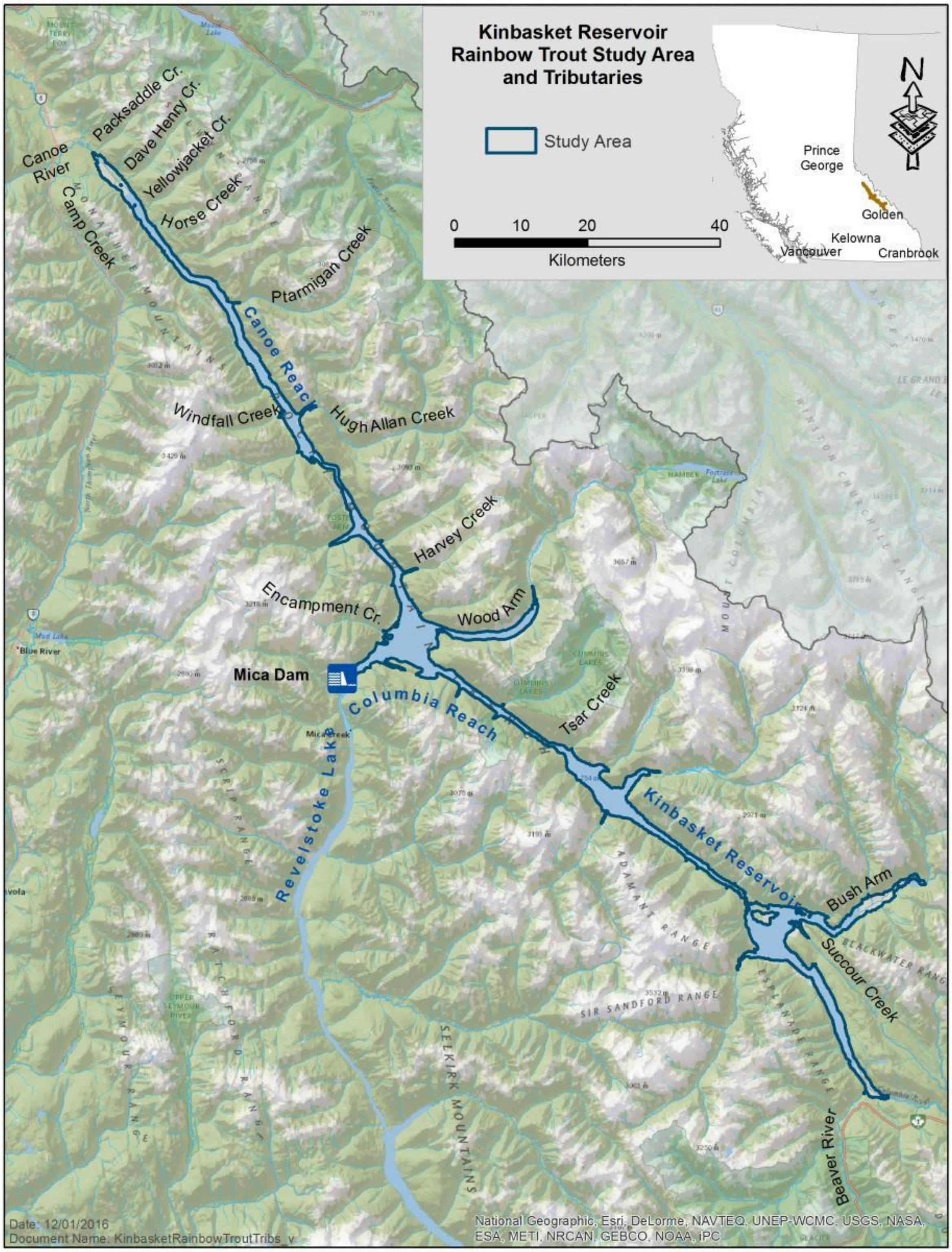

Figure 2: Locations of study area and tributaries in the Kinbasket Reservoir

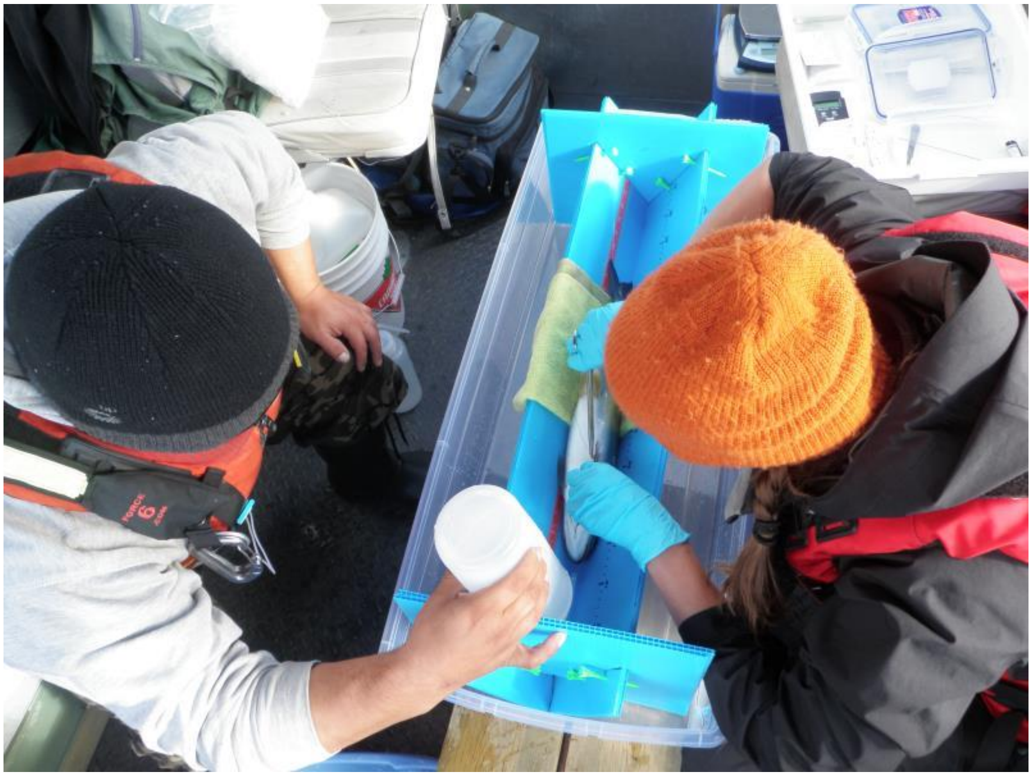

Figure 3: Surgical setup for transmitter implantation

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

Figure 5: Rainbow Trout in oxygenated recovery tank

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 pre-spawn and spawning season (MQs 2 and 3). Originally mobile radio tracking CART tags from fixed-wing aircraft was to be used to detect movements during the spawning season (Caley and Warnock 2015); however, due to low numbers of tagged Rainbow Trout, mobile radio tracking from fixed-wing aircraft was removed from the study. Opportunistic ground tracking and fixed acoustic receiver tracking continued to be used throughout Year 2 to assess movements of tagged Rainbow Trout. The CART transmitters use a coded radio (codes 111-160) frequency of 150.210 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, Kang et al. 2015), multiple fixed acoustic receivers were deployed in the study area in June 2014 (n=16) and July 2015 (n=14) (Figure 6). Four of the receivers deployed in 2015 were replacements for the 2014 receivers that could not be retrieved due to loss or high reservoir levels. Therefore, a total of 26 receivers were actively tracking during Year 2 of the CLBMON-07 study. See reports of CLBMON-05 for more information on receiver set timings and active tracking periods. Receiver locations were selected such that constrictions in the valley were "gated" to track movement amongst areas (Gutowsky et al. 2013). Fish were considered to use a "home range" by reviewing the quantity and duration of detections in a specific reservoir area (Figure 6). Where the majority of detections occurred over a sustained period of several months, within one or more large reservoir areas, this was considered the home range for the tagged fish. Fish were assessed as making potential pre or post-spawn movements if they appeared to make a directed movement to or from a preferred home range during the months of March, April, May or June, which coincides with the generalized timing window for pre and post-spawn movements in Rainbow Trout.

On May 1st, 2015 an additional acoustic receiver was deployed 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. At the time of deployment the elevation of the Kinbasket Reservoir was 737.99 m. The receiver was deployed in a location where the water depth was approximately 16 m and the buoy attached to the receiver was placed at approximately 12 m above the bottom of the reservoir. Retrieval of the receiver was attempted on May 2nd, 2016, however, the reservoir elevation had risen to 733.57 m and it was not possible to locate the receiver. We will attempt to locate and retrieve the receiver during the spring 2017 tributary survey program.

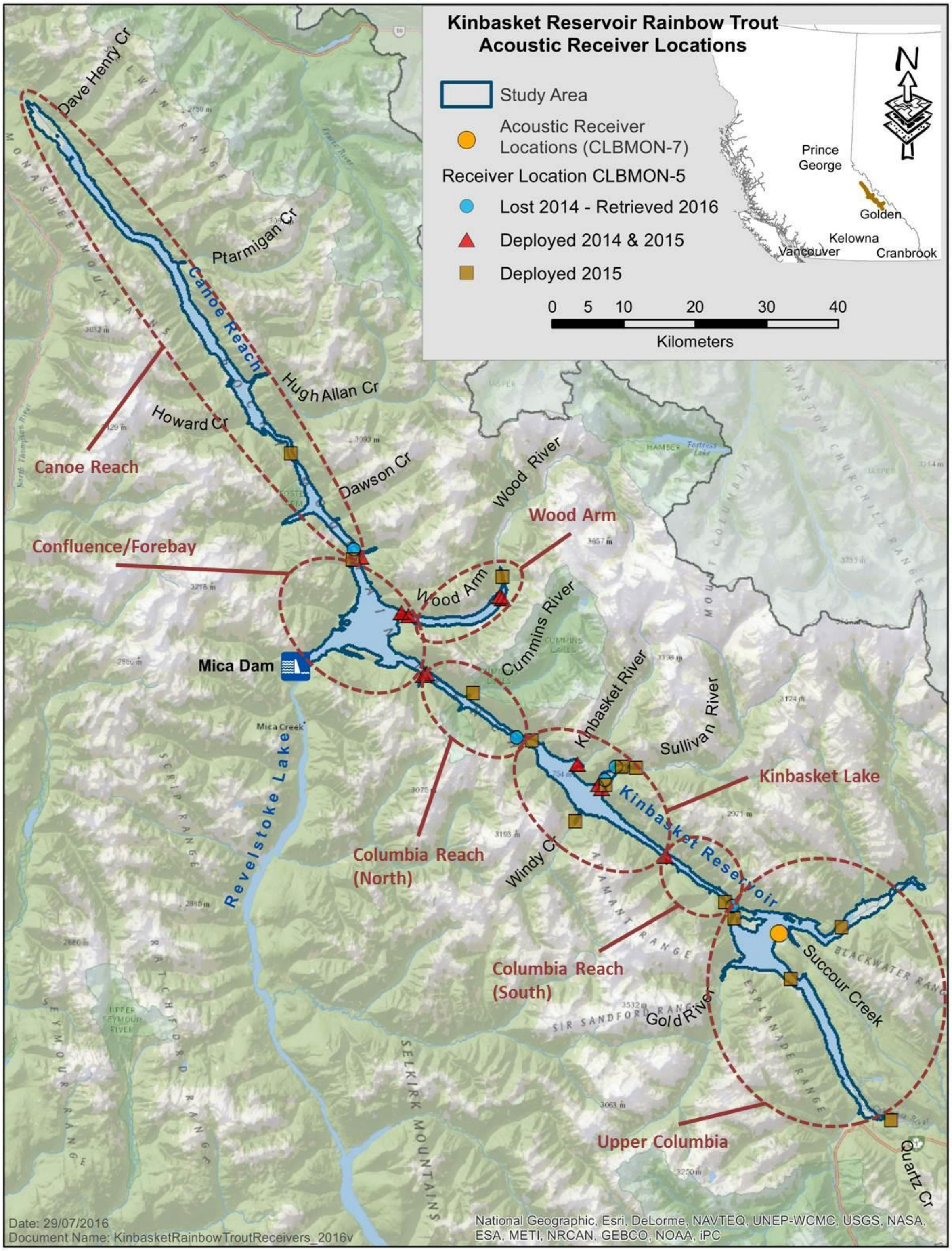

Figure 6: Locations of 27 acoustic receivers within Kinbasket Reservoir (26 from CLBMON-05 and 1 from CLBMON-07), and general areas of reservoir sampling for Rainbow Trout and delineating home ranges.

Mobile tracking
At the end of the Year 2 capture and tagging program, 17 tags had been surgically implanted in Rainbow Trout captured in the Kinbasket Reservoir. By the spring of 2016 when the first tracking flight was scheduled, the five small tags implanted in 2014 were no longer active; therefore, only 12 active tags would have been available for tracking. Also, during the first year of acoustic tracking (September 2014 until approximately the beginning of April 2015), only five of the ten tags were detected. No additional capture/tagging sessions were planned for the remainder of the study. The CCRIFC and BC Hydro team decided that radio tracking flights were not an effective use of the remaining budget. Furthermore, there was concern that aerial radio tracking of 12 tags (assuming no additional mortality) would not provide a high enough sample size to meaningfully test the management hypotheses. As a result, mobile tracking was removed from the CLBMON-07 program.

Opportunistic radio tracking of tagged fish was conducted during the tributary and snorkel surveys which occurred between April 17th and May 18th, 2016.

Tributary access, stream habitat and thermal suitability
Detailed surveys and habitat assessments of selected tributaries were completed between April 17th and May 4th, 2016. The purpose of the surveys was to: i) identify potential barriers to upstream movement of adult Rainbow Trout; and ii) record stream habitat characteristics to identify potential Rainbow Trout spawning habitat.

These surveys built on those that were completed in Year 1 (Caley and Warnock 2015). Reservoir elevation dropped to between 730.36 m and 734.09 m during the survey period which was approximately 8 m lower than during a similar time period in 2015. It was therefore possible to extend the survey on Succour Creek. Tributaries located in the Canoe Reach at the north end of Kinbasket Reservoir were accessed by road. A summary of the tributary surveys completed in 2016 is provided in Table 1. A map showing tributary locations is provided in Figure 2.

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 stream through the drawdown zone; we estimated reach length in order to provide a total number of over 15 measured transects so that stream habitat would be adequately characterized. Since a large number of reaches were surveyed in 2015 in Succour Creek, we extended the reach length in this stream from 150 m to 350 m for the continuation of this survey in 2016. 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 (2001). 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).

Table 1: Summary of tributary surveys conducted in 2015 and 2016

Tributary	Lowest Elevation Surveyed (m)	Tributary Survey	Temperature Logger	To be completed in 2017
Canoe River	n/a			X
Packsaddle Creek	n/a		X	X
Dave Henry Creek	731.19	X	X	
Yellowjacket Creek	731.41	X	X	
Horse Creek	731.14	X	X	
Ptarmigan Creek	731.80	X	X	
Hugh Allan Creek	738.66	X	X	
Windfall Creek	738.36	X	X	
Harvey Creek	738.79	X	X	
Encampment Creek	n/a		X	X
Tsar Creek	n/a			X
Unnamed tributary north of Gold River	738.26	X	X	
Beaver River	734.47	X		
Succour Creek	730.41	X X	X X	

X = 2015 tributary survey conducted, X = 2016 tributary survey conducted

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). Succour Creek had an especially long drawdown zone, thus in addition to a logger installed at the top of the drawdown zone, two additional loggers were installed, at 2 km intervals downstream.

Rainbow Trout initiate spawning when mean daily water temperatures exceed 6 ^{o}C, optimal incubation temperatures occur between 7 and 10 ^{o}C, and acute mortality for developing embryos is encountered at 16 ^{o}C (McCullough et al. 2001, Muhlfeld 2002, Carter 2008). We thus used lower and upper thresholds of 6 and 16 ^{o}C to determine if and when the thermally suitable time period occurred for spawning and incubation. Where water temperature was available, we modeled fry emergence assuming a regionally developed threshold of 480 accumulated thermal units for incubation (Irvine et al. 2013). Emergence dates were then compared to reservoir elevations to determine the severity of reservoir inundation over suitable habitat for Rainbow Trout spawning within the stream.

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

Snorkel surveys

Snorkel surveys were conducted monthly from April until June 2016 to assess the presence and abundance of Rainbow Trout during the spawning period. Snorkel surveys started at the top of the drawdown zone and progressed downstream until the reservoir was reached. Fish species and numbers observed during the survey, as well as the presence of redds were recorded. Succour Creek was selected for snorkel surveys, as it has the highest potential to support Rainbow Trout spawning (Caley and Warnock 2015, Oliver 2001). The stream originates from a lake, and unlike most snowmelt dominated or glacial fed stream in the region, stream clarity remains high throughout the spring freshet period. Habitat surveys in Year 1 of the study indicated potential for the drawdown zone portion of Succour Creek to provide extensive spawning habitat for Rainbow Trout (Caley and Warnock 2015). Snorkel surveys were selected as the most appropriate method to monitor Succour Creek for Rainbow Trout spawning activity as they cause minimal disturbance to the habitat and fish, are low cost, and have modest equipment requirements, which is ideal for remote locations (O'Neal 2007).

A crew of two people was used to complete the surveys. One person snorkeled while the other person supervised the survey from the stream bank. The supervising crew member recorded data and ensured that any potential hazards were mitigated for (e.g., woody debris, wildlife).

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 360.75 rod hours were spent across the four areas of the reservoir from September 25th until October 3rd, 2015. 22 Rainbow Trout were caught, ranging from 285 to 575 mm in length and 0.24 to 2.64 kg in weight (Figure 7). Seven of these Rainbow Trout were surgically implanted with CART tags (see Methods). Tagged fish size ranged from 0.90 kg (423 mm) to 2.5 kg (547 mm). Released fish were either too small for minimum tag burden or in too poor of condition for surgery due to hooking and capture stress. A total of four mortalities occurred during the sampling program. All mortalities were a result of foul hooking and were not a result of the fish surgery. Surgeries were minimally invasive, with quick surgery and recovery times (Appendix A.2). Average water temperature throughout the four areas was 12.7°C. Bycatch made up 33% (*n*=11) of the fishes caught and included only Bull Trout.

The maturity and stomach contents of the four Rainbow Trout mortalities were examined. These fish ranged in size from 0.44 kg (340 mm) to 0.95 kg (442 mm). All fish were found to be mature at the time of capture. Stomach contents of all four fish were comprised entirely of insects. Combining results of Year 1 and Year 2, eleven mortalities were examined for state of maturity and gut contents. Two fish were piscivorous (539-564 mm; 2.1-2.3 kg), nine fish were insectivorous (340-468 mm; 0.44-1.1 kg) and all eleven were mature. Eight of the Rainbow Trout mortalities from both Year 1 and Year 2 of the study had otoliths that were in appropriate condition for aging. These fish ranged from three to six years of age (Figure 8).

Table 2: Summary statistics of Rainbow Trout captured across four general areas of Kinbasket Reservoir, 2015.

Reservoir area	Mean Water Temp (°C)	N RT caught	N RT tagged	Mean CPUE (fish/hr)	S.D. CPUE (fish/hr)	95% CI CPUE (fish/hr)
Confluence/Forebay	12.9	15	5	0.08	0.03	0.03
Kinbasket Lake	12.6	3	2	0.07	n/a[a]	n/a
Canoe Reach	12.5	2	0	0.07	0.12	0.13
Upper Columbia	11.5	2	0	0.04	0.05	0.04
All sites	12.7	22	7	0.06	0.06	0.03

[a] A single visit was made to Kinbasket Lake, 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	15	415	47.4	0.871	0.540
Kinbasket Lake	3	535	47.2	2.01	0.777
Canoe Reach	2	385	10.6	0.615	0.064
Upper Columbia	2	311	36.8	0.348	0.153
All sites	22	419	70.3	1.00	0.680

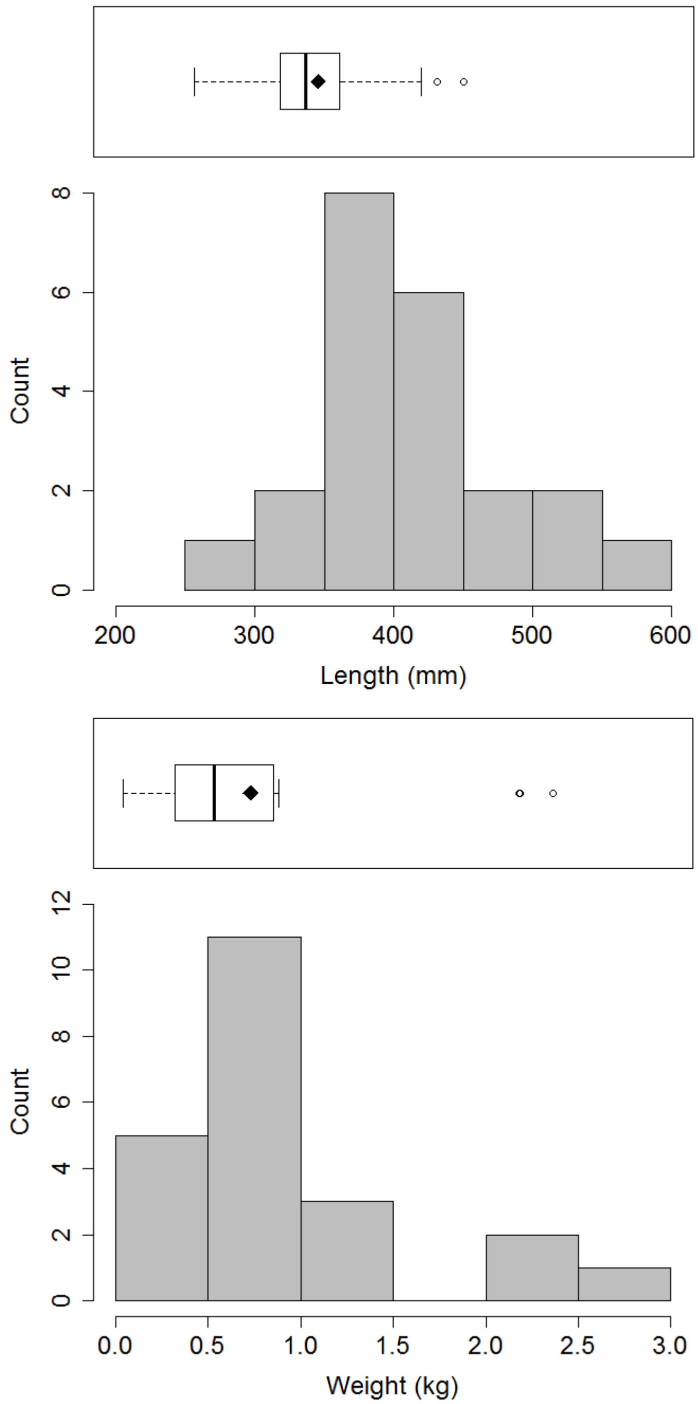

Figure 7: Size (length and weight) distributions and box plots of Rainbow Trout (n=22) caught and measured in Kinbasket Reservoir in September and October 2015. Boxes represent interquartile range, diamonds represent the sample mean, while the middle line in the box is the median sample value. Whiskers represent observations outside of the interquartile range, with outlier data points.

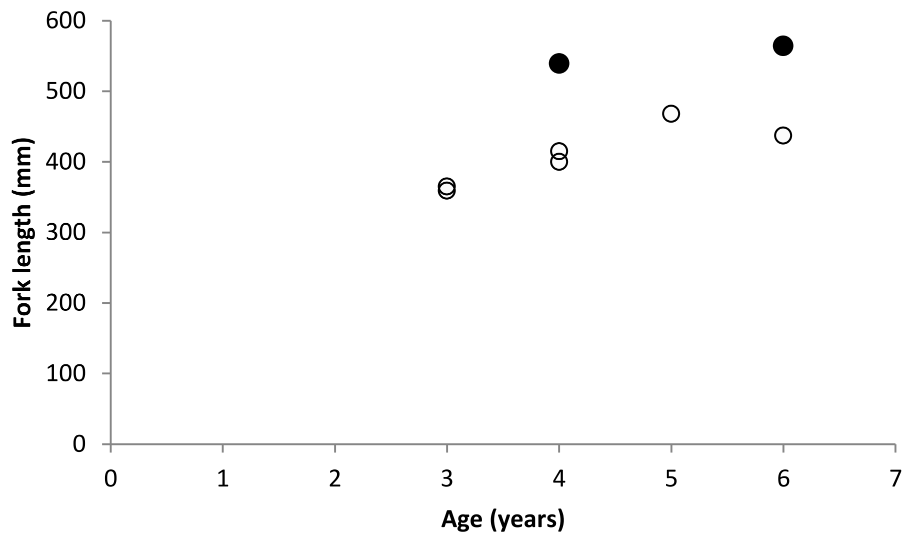

Figure 8: Length at age of Rainbow Trout, as examined from otoliths of piscivorous (closed circles; n = 2) and non-piscivorous (open circles; n = 6) individuals, taken from incidental mortalities in both Year 1 and Year 2 of the study.

Mobile tracking

Mobile tracking by fixed-wing aircraft was not conducted in 2016 due to the low number of Rainbow Trout tagged during the Fall 2015 capture and tagging session. As a result, mobile tracking by fixed-wing aircraft has been removed from the CLBMON-07 study.

The tributary survey and snorkel survey programs that occurred between April and June 2016 provided an opportunity for mobile ground tracking to be conducted during the pre-spawn and spawning periods. No tagged fish were detected in any of the tributaries that were surveyed.

Fixed receiver tracking

Eleven of 17 implanted tags were detected by acoustic receivers during the course of this program. Two of the five tagged fish that were detected in Year 1 were not detected again in Year 2. Movement patterns of Rainbow Trout tagged in this program are described below for the entire period of tracking data available. Greater detail is given to describe movements during periods of presumed pre-spawning or spawning periods (March to June). Reservoir areas and detection locations can be visually cross referenced with descriptions by consulting Figure 6.

Nine of the 11 fish tracked by fixed receivers provided data during the presumed pre-spawning and spawning period, and five of these appeared to make directed movements that were interpreted as possible pre or post-spawn migrations. Of these five fish that made possible spawning forays, four appeared to make directed movements upstream from the Columbia Reach and into the Upper Columbia area, and two of these four appeared to head towards the inlet of the Reservoir, at the upstream end of the Upper Columbia area. The timing of these movements was between late March and late April. Two of these fish returned to their home ranges by late May. One of the five fish that made a possible spawning foray appeared to move towards the north end of the Canoe Reach in late April, indicating a pre or post-spawn movement. See Appendix A.3 for maps showing the locations of acoustic receivers that detected each tagged fish. All physical characteristics recorded at the time of capture are summarized in Appendix A.1.

Acoustic tag 112 (possible spawning migration detected):
Captured on September 22nd, 2014 in the Confluence, its last detection in the first year of tracking was on April 2nd at the Kinbasket Lake outlet. Throughout the pre-spawning period in 2015 it was detected by the Sullivan Bay entrance receiver (March 1-3) and then only by the Kinbasket Lake inlet receiver (March 4th to April 2nd). It was next detected on May 24th, 2015 by the Kinbasket Lake south inlet receiver. Throughout most of May 2015 it remained near the Kinbasket River outlet and then moved to the Sullivan Bay entrance and the outlet of the Kinbasket River at the end of May. It was last detected on June 13th, 2015 at the entrance to Sullivan Bay. Since the fish left its preferred home range of the Kinbasket Lake area, in an upstream direction between April 2nd and May 24th, it is possible that the fish travelled upstream to an unknown location to spawn and returned.

Acoustic tag 113:
Captured on September 24th, 2014 in Kinbasket Lake, its last detection in the first year of tracking was on March 27th, 2015 at the Sullivan Bay entrance receiver. The fish's preferred home range appeared to be in the Kinbasket Lake area. This tag was not re-detected after this date or in the second year of tracking. Although this fish was detected in the pre-spawn period in both 2014 and 2015, no inferences can be made about directed movements since it did not appear to make any directed movements.

Acoustic tag 115 (possible spawning migration detected):
Captured on September 26th, 2014 in the confluence, its last detection in the first year of tracking was on October 4th, 2014 at the south outlet of the Canoe Reach. It was not detected again until July 17th, 2015 at the north outlet of the Columbia Reach. Therefore, movement information is not available for the pre-spawn and spawning periods. This fish remained near the north outlet of the Columbia Reach until July 21st where it was detected by the one of the Canoe Reach receivers. From the beginning of August until the end of October it moved between the Wood Arm outlet, Canoe Reach and north outlet of Columbia Reach. It was not re-detected until April 30th, 2016 at the most upstream receiver in the Canoe Reach. Given the timing of detection, it is possible that this indicated a pre or post-spawn movement out of its preferred home range in the Confluence, to an area upstream in the Canoe Reach.

Acoustic tag 116:
Captured on October 2nd, 2015 in Kinbasket Lake and was first detected on October 2nd, 2015 by one of the receivers in the Sullivan Bay entrance. Detections were made by the Sullivan Bay entrance receivers until December 3rd. It was not re-detected until April 2nd, 2016 where it was again in the Sullivan Bay entrance. The final detection was on April 27th, 2016 in the Sullivan Bay entrance. The home range of

this fish for tracking information available was restricted to the Kinbasket Lake area. Tracking information is not available for the remainder of the pre-spawning period or the spawning period.

Acoustic tag 117 (possible spawning migration detected):
Captured on October 2nd, 2015 in Kinbasket Lake and was first detected on October 10th, 2015 by one of the receivers in the Sullivan Bay entrance. It remained in the area of the Sullivan Bay entrance until October 6th, and then moved to the Kinbasket Lake outlet. Regular movements were then made between the outlet of Kinbasket Lake, the Kinbasket River outlet and the Sullivan Bay entrance between October 6th and February 11th, 2016. On February 19th it was detected at the south inlet of Kinbasket Lake where it stayed for the remainder of February. On March 15th it was detected at the Surprise Rapids outlet, and then regular detections occurred at both the outlet and inlet of Surprise Rapids until the end of March. On April 17th and 18th it was detected at the south inlet of Kinbasket Lake and Surprise Rapids, respectively. The final detection was made on April 19th in Esplanade Bay. This fish thus moved out of its preferred home range of the Kinbasket Lake area by Mid-March and was making a directed movement upstream towards the inlet of the Reservoir by mid-April, which could indicate a pre-spawn movement to an upstream spawning area.

Acoustic tag 152 (possible spawning migration detected):
Captured on September 20th, 2014 in the Mica Dam forebay, its last detection in the first year of tracking was on March 29th, 2015 at the outlet of the Sullivan River after having spent the previous winter in the Wood Arm, ~50 km away . It was re-detected on May 26th and 27th, 2015 at the south inlet of Kinbasket Lake. Its final detection was recorded by both receivers gating the north outlet of the Columbia Reach on May 30th. This fish thus made a directed movement in the pre-spawn period of late March upstream, either to or passing beyond Kinbasket Lake to the Upper Columbia area of the reservoir, then returned towards its preferred home range of the Confluence and Wood Arm in late May of the same year.

Acoustic tag 153:
Captured on September 21st, 2014 in the Confluence, its last detection in the first year of tracking was on October 5th, 2014 in Kinbasket Lake. This tag was not re-detected in the second year of tracking. No inferences can be made about spawning movements or home range.

Acoustic tag 155:
Captured on September 26th, 2014 in the Canoe Reach and was first detected on July 28th, 2015 at the most upstream receiver in the Canoe Reach. Regular detections were made by receivers throughout the Canoe Reach September 16th and then again on January 29th, 2016. From February 2nd until the 19th it was detected at the outlet of the Wood Arm. The preferred home range of this fish appeared to be concentrated in the Confluence and southern portions of the Canoe Reach. The final detection was in the outlet of the Canoe Reach on April 6th, 2016. No inferences can be made on spawning movements.

Acoustic tag 157 (possible spawning migration detected):
Captured on September 28th, 2015 in the confluence and was first detected on October 10th, 2015 in the outlet of the Canoe Reach. From October 13th until November 14th regular detections were recorded at

the outlet of the Wood Arm. It was then found at the north outlet of Columbia Reach on November 15th and 16th, and then in Cummins River from November 17th until the 19th. Throughout December it traveled between the outlet of Kinbasket Lake, Sullivan Bay entrance and the inlet of Kinbasket Lake. It was next detected on March 7th, 2016 at the entrance of Sullivan Bay. From the beginning of March until mid-April it continued to be detected between the same three receiver locations. On April 18th it was recorded at the inlet of the southern Columbia Reach and then finally at Esplanade Bay (the penultimate receiver location in the upstream portion of the Upper Columbia) on April 25th. This fish thus moved out of its preferred, extensive home range of the Kinbasket Lake/Columbia Reach/Confluence area, making a directed movement upstream towards the inlet of the Reservoir by late April, which could indicate a pre-spawn movement to an upstream spawning area.

Acoustic tag 158:
Captured on September 28th, 2015 in the confluence and was first detected on October 29th, 2015 in the Canoe Reach. It was regularly detected in the Canoe Reach until mid-November. In mid-December it was detected at the north outlet of the Columbia Reach and then in the Cummins River until the end of December. It was then recorded at the Sullivan Bay entrance at the end of January 2016, and again at the beginning of April. Limited detections are available to make inferences of home range. No additional tracking information is available for the pre-spawning period.

Acoustic tag 159:
Captured on September 28th, 2015 in the confluence and was first detected on October 17th, 2015 in the Canoe Reach. It was regularly detected in the Canoe Reach until the end of October, and then again from December 20th until the 23rd. Between December 29th, 2015 and January 2nd, 2016 it was recorded at the north outlet of the Columbia Reach. It then traveled to the outlet of Kinbasket Lake, then Cummins River and Surprise Rapids throughout January. Its final detection was on January 20th, 2016 at the inlet of Surprise Rapids. Limited detections are available to make inferences of home range. No inferences can be made on spawning movements.

Tributary access, stream habitat and thermal suitability
A total of six tributaries were surveyed during the spring 2016 program in late April to early May. 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. With respect to barrier surveys, the Beaver River had a swift flowing cascade that may be a velocity barrier to fish migration (Appendix B.2.; photograph 11). Horse, Dave Henry and Yellowjacket Creeks have poorly defined channel morphology, with alluvial fans that create multiple, shallow migration corridors, many of which may be unpassable during low stream flows. Photographs of surveyed tributaries are shown in Appendix B.2. Longitudinal elevation profiles for each surveyed stream can be found in Appendix B.3.

Water clarity was generally high for most of the tributaries (except the Beaver River), so visual surveys to collect opportunistic biological data were possible. Fish presence in the drawdown zone was only observed in Succour Creek, with juvenile Rainbow Trout observed in the upper section of the drawdown zone. An additional 111 m of spawning gravels and potentially suitable spawning habitat was found between 4,200 m and 5,241 m (below the top of the drawdown zone) on Succour Creek. This brings the total 1,539 linear distance of reaches with gravels potentially suitable for spawning of 5,421 m of horizontal stream length surveyed in the drawdown zone of Succour Creek. Reaches containing patches of gravel were also observed in Dave Henry and Yellowjacket Creeks. No redds were observed in any streams.

Temperature data was only available for Succour Creek. The logger installed at the top of the drawdown zone could not be retrieved in 2016, thus data from the logger installed 2 km downstream from the top of the drawdown zone was used to model thermal suitability and emergence timing. Stream temperature data was only available from the deployment date of May 1, 2015, to the date at which the reservoir inundated the logger, which occurred on June 11, 2015 (Figure 9). Temperatures were thermally suitable for Rainbow Trout spawning as of the deployment date of May 1 in 2015, as temperatures well exceeded the lower spawning suitability threshold of 6 ^{o}C. It is possible that the stream was thermally suitable before this date as well, thus we back-casted temperatures in mid-April by fitting a linear equation to measured temperatures encountered in the month of May (R^2 = 0.97; Temperature = 7.87 ^{o}C + 0.201* date). A back-casted date of April 22, 2015 was calculated at the time in which temperatures likely became suitable for spawning (>6 ^{o}C) in Succour Creek (Figure 9). Temperatures remained suitable for spawning and incubation for the full period of measurement, but were approaching the upper threshold of suitability by the date the logger was inundated. Using the measured and modeled temperature data that was available, we calculated a date of June 7, 2015 as the earliest possible date of fry emergence. The reservoir elevation on this date was 744.3 m and rising rapidly. Because of missing stream temperature data after June 11, 2015, we could not model the full window of spawning and emergence timing.

Table 4: Summary of key tributary measurements and observations during the 2016 surveys

Parameter	Succour Creek[a]	Horse Creek	Ptarmigan Creek	Dave Henry Creek	Yellowjacket Creek	Beaver River
Survey Date(s)	April 28-30, 2015 & April 18, 2016	April 20, 2016	April 21, 2016	April 22, 2016	April 22, 2016	May 4, 2016
Reservoir Elevation (m)	730.36	730.96	730.92	731.19	731.19	734.09
Length of DDZ Surveyed (m)	5,241	520	600	900	690	2,076[b]
No. of Reaches	32	27	25	19	24	22
Reach Length (m)	150 / 350	20	25	50	30	100
Channel Type	Pool-Riffle	Plane Bed / Step Pool	Step Pool	Plane Bed	Plane Bed	Upper: Cascade / Lower: Pool- Riffle
Mean Depth (cm)	50.0	21.0	n/a[c]	n/a[c]	n/a[c]	n/a[c]
Mean Bankfull Width (m)	9.9	98.7	27.0	58.0	58.0	65.2[b]
Mean Wetted Width (m)	8.7	17.4[b]	21.2	17.1	23.8	79.6
Gradient (%)	0.39	4.49	3.31	2.21	3.31	0.30[b]
Mean Velocity (m/s)	0.67	0.82	n/a[c]	n/a[c]	n/a[c]	n/a[c]
Dominant Substrate	Gravel	Cobble	Cobble	Cobble	Cobble	[d]
Spawning Gravels (m)	1,539	0	10	355	210	[d]
Fish Present	Juvenile Rainbow Trout	None observed	None observed	None observed	None observed	[d]
Redds Observed	None observed	None observed	None observed	None observed	None observed	None observed
Fish detected during opportunistic radio tracking?	No	No	No	No	No	No
Barriers / Type	None	Possible – Alluvial fan	None	Possible – Alluvial fan	Possible – Alluvial fan	Possible for some fish - Cascade

[a] Values presented reflect information collected from both the 2015 and 2016 surveys.
[b] Measurements are only available for a section of the drawdown zone.
[c] Stream/river was too deep and swift to wade.
[d] High turbidity. Information not available.

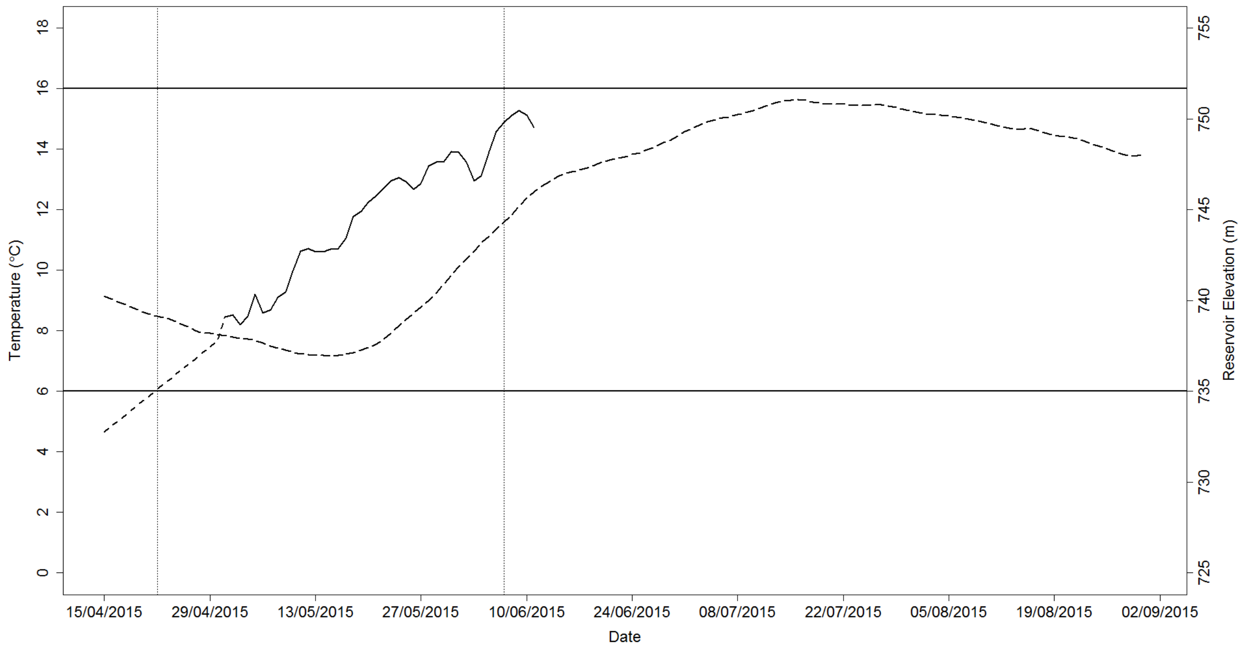

Figure 9: Daily mean water temperature of Succour Creek and spring/summer reservoir elevations (dashed line) in 2015. The dotted line is modeled temperatures, and the solid line into which it merges is measured temperatures. The upper and lower horizontal lines are the upper and lower temperature suitability thresholds for Rainbow trout spawning and incubation. The left vertical line represents the earliest date of spawning according to the lower suitability threshold for the species and the right vertical line represents the earliest date of emergence modeled from the accumulated thermal units of the initial spawn date.

Snorkel surveys

Snorkel surveys on Succour Creek were conducted on April 19th, May 18th and June 17th, 2016. A summary of fish counts for all surveys is provided in Table 5. Generally very few Rainbow Trout were observed throughout Succour Creek during all three surveys. Peak Rainbow Trout counts occurred during the May 18th survey and the majority of the observed fish were approximately 0-10 cm in length and thus immature (Figure 10). Large numbers of Mountain Whitefish and Largescale Suckers (Figure 11) were also found during this survey. In terms of diversity, the greatest number of fish species was observed on June 17th (N=7). No redds were observed during any of the surveys.

Figure 10: Juvenile Rainbow Trout observed in Succour Creek

Figure 11: Largescale suckers observed in Succour Creek during the May 18th, 2016 snorkel survey

Table 5: Summary of snorkel survey observations, Succour Creek.

	April 19, 2016					May 18, 2016					June 17, 2016				
	Counts (cm)				Total Count	Counts (cm)				Total Count	Counts (cm)				Total Count
Species	0-10	10-20	20-30	30-40		0-10	10-20	20-30	30-40		0-10	10-20	20-30	30-40	
Rainbow Trout		5	1	1	7	30	17			47		5			5
Mountain Whitefish			1		1	62	60	8	1	131		4			4
Brook Trout	1				1	4	2			6		4	3	1	8
Largescale Sucker								756	464	1,220					
Bull Trout								1		1					
Sculpin											4				4
Kokanee												1			1
Redside Shiner												1			1

DISCUSSION and RECOMMENDATIONS

Rainbow Trout capture, biological characteristics and tagging

Similar to Year 1, Rainbow Trout catch per unit effort was low. Catch of Rainbow Trout by other metrics in Kinbasket Reservoir has similarly been low by in recent years from 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 low or moderate in Kinbasket Reservoir based on comparison of overall CPUE. Despite a very high effort in fall capture sessions of 519.25 rod hours in 2014 and 360.75 in 2015, a mean CPUE of 0.08 and 0.06 were found, respectively. . A short exploratory capture session in summer of 2015 resulted in a CPUE of 0.0 fish/rod hour, despite 163.75 rod hours of effort (Caley and Warnock 2015). During the course of the two years of this study, a mean CPUE of 0.06 fish/rod hour was found (1043.75 rod hours of effort), employing professional guiding services, using a targeted sampling program. CPUE of 0.117 fish/rod hour (Gazey 1994) and 0.07 fish/rod hour (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 fish/rod hour (Arndt 2004, 2014), while Kootenay Lake was found to have a CPUE of 0.08 fish/rod hour (Andrusak and Andrusak 2012). All of these reported values are generated from angler surveys, encompassing multiple seasons and a range of angler abilities and multiple angling techniques which may have efficiency biases to either insectivorous or piscivorous forms of Rainbow Trout. Kinbasket Reservoir is generally data poor relative to other large lakes, but may have have declined from levels seen in previous decades (CPUE of 0.15-0.19 fish/rod hour depending on method of creel data collected; Pole 1995, 1996, Bray 2002). If Rainbow Trout have declining in abundance in Kinbasket Reservoir, this 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; FFSBC 2015), poor capture success during capture session and insufficient capture expended to provide an accurate CPUE estimate. Prey availability is unlikely to explain decreased abundance of Rainbow Trout due to high and sustained abundance of Kokanee and zooplankton densities in recent years (Bray 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 2014, Schindler et al. 2014). Rainbow trout were captured throughout the reservoir, thus they are distributed throughout it.

In Year 1 we observed a subtle bimodal size distribution of captured fish and stomach samples examined led us to hypothesize that there are likely two forms of Rainbow Trout in Kinbasket Reservoir (Caley and Warnock 2015); despite small sample size, biological data in Year 2 of the study are consistent with those in Year 1 and provide further support for this hypothesis. Data on length-at-age also suggest that piscivorous fish were larger for equivalent age than non-piscivorous forms (Figure 8), which is consistent with this hypothesis, but sample size was not sufficient to test statistically. Large lakes in the Kootenay region may have sympatric insectivorous and piscivorous morphs of Rainbow Trout (Arndt 2009), which may be easily distinguished by their size, and represent reproductively segregated stocks (Andrusak and Andrusak 2012). The existence of separate, reproductively isolated populations of these two forms is possible in Kinbasket Reservoir, but beyond the scope of this study. The angling method employed in this study was biased to preferentially target the larger piscivorous morph. Large bodied piscivorous fish were targeted due to their ability to receive large tag burdens, as large tags with long battery life were required for this study. A more comprehensive, unbiased sampling program would still be needed to determine the relative abundance of the two forms or abundance of either form.

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 foraging areas may be seasonally inundated or contiguous with the continuously inundated pool of the 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 macrophytes (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 connected 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 benthic invertebrates at stream mouths may provide other forage sources for the insectivorous morph, with terrestrial insects typically being the most important food source for large lakes in the Kootenay region (Arndt 2009).

Mobile tracking

Opportunistic mobile radio tracking was conducted during tributary surveys, as well as during the snorkel surveys in April and May. Ground tracking failed to detect any fish with active tags. Opportunistic tracking will continue to be carried out during the 2017 tributary and snorkel surveys. However, as no further capture and tagging programs are scheduled and all tags from the Year 1 capture program will no longer be active, the likelihood of detecting a tag with ground tracking will decrease.

Fixed receiver tracking

Similar to the results from the Year 1 period of this study, a limited number of fish were available for tracking, thus inferences are based on a small sample size (Caley and Warnock 2015).

Generally, the majority of detections for most of the summer, fall or overwintering periods were between the outlet of Canoe Reach and the Sullivan Bay entrance. Rainbow Trout 157 had the greatest coverage of the reservoir, traveling between the outlet of Canoe Reach to Esplanade Bay at the southeast end of Kinbasket Lake. 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, Andrusak and Thorley 2013). Rainbow Trout 116 traveled the least of the tagged fish, with detections only at the entrance of Sullivan Bay. Thus, Rainbow Trout likely have great variety in home range size in Kinbasket Reservoir, with individuals ranging from relatively resident to their capture location to highly mobile (Harrison et al. 2014).

Some limited information is available from this program for tagged Rainbow Trout movements during the pre-spawn and spawning seasons. Most fish that were detected by acoustic receivers were tracked between early March and late June in either year. Five of these fish appeared to make directed movements away from their estimated home range between late March and late April. Two of these fish were redetected in their home range by late May. This conditionally indicates a pre-spawn movement period of late March and through the month of April, and post-spawn movement by late May for the limited number of fish tracked. This is similar to the timing of migration and spawning observed in tributaries to Arrow Lakes Reservoir (Toth and Tsumura 1996, Drieschner et al. 2008). Location of spawning is not possible to determine from this study, but it appears that several fish made directed movements to the most upstream portions of the Columbia Reach of the Reservoir in the pre-spawn period. Arndt (2009) speculated that Rainbow Trout may migrate upstream entirely from the Reservoir, up the Columbia River to spawn in tributaries; however, the receiver installed on Kinbasket Reservoir at Quartz Creek (close to the confluence of the Columbia River) did not detect any of the tagged Rainbow Trout.

Data from the acoustic receiver installed at the mouth of Succour Creek are not available as it was not possible to retrieve the receiver in Year 2. Tracking information will be presented in the Year 3 report if it is possible to retrieve the receiver during low pool levels in 2017. Acoustic receivers for the CLBMON-05 study (Kang et al. 2015) have been re-deployed for an additional year of tracking and will be retrieved in spring 2017. These data may help better understand year-round movements made by Rainbow Trout throughout the Kinbasket Reservoir, especially during the pre-spawn and spawning periods.

Tributary access, stream habitat and thermal suitability

Tributaries were surveyed during the general low pool period from April 18th to May 4th, 2016. Reservoir elevation ranged from 730.36 m to 734.09 m. Historically (1977 to 2014), the reservoir has experienced a mean reservoir elevation of 730.95 m, with a minimum elevation of 712.53 m and a maximum elevation of 737.14 m for this same low pool time period. As reservoir elevation was approximately 13 m higher than normal in 2015, surveys needed to be extended in future years with lower low pool elevations. In 2016 it was possible to extend the survey of Succour Creek by 1,241 m. The other five tributaries visited had not been previously surveyed, but it is expected that follow-up surveys will not be conducted unless the reservoir elevation drops significantly below 731 m, exposing more of the drawdown zone.

Several tributaries surveyed in 2016 may have at least partial fish migration barriers. A cascade is present at the top of the drawdown zone on the Beaver River, which may restrict fish migration (Appendix B.2.; Photograph 11). This barrier has been exposed during the potential pre-spawn migration period (early spring) during all years of the operation of Mica Dam (Figure 1). Bull Trout have been observed actively ascending the upper portion of the cascade, and large bodied, presumably adfluvial, Bull Trout spawn in tributaries to the Beaver River (Thorley 2013), thus the barrier may not restrict passage of all fish (Thorley 2013). It is possible that the barrier may restrict movement of Rainbow Trout, particularly smaller size classes, as smaller salmonid fish cannot ascend equivalent vertical barriers as successfully as larger conspecifics (Kondratieff and Myrick 2006). Horse, Dave Henry and Yellowjacket Creeks flow into northeast shore of the Canoe Reach and all have similar, undefined channel morphologies. These streams flow through alluvial fans, braiding into multiple, shallow channels through extensive sections of the drawdown zone. Reservoir operations likely contribute to the instability of these channels, and fish access impacts have been observed in tributaries to nearby Arrow Lakes Reservoir during periods of low stream discharge (Hawes and Drieschner 2013, 2014). It is possible that under some low flow regimes, the channels in similar streams surveyed in this study may be too shallow to navigate. In 2016 at the time of our surveys, we did not observe depths that would be considered too shallow to pass migratory fish in these streams, but flows were much higher than average for the time of year. These streams may therefore contain fish passage barriers depending on flow, especially as Rainbow Trout immigration may occur during pre-freshet base flow conditions, which coincides with the period of lowest pool in Kinbasket Reservoir. It is unknown if any of these streams contain runs of adfluvial Rainbow Trout and would thus be impacted. A large, impassable and natural fish migration barrier occurs on Dave Henry Creek within 250 m upstream from the high pool elevation of Kinbasket Reservoir (Fielden et al. 1992), and thus may be unlikely to support a migratory population in any case.

During the tributary surveys, the presence of suitable spawning substrates and their linear length were recorded. Gravel substrate that is approximately no larger than 10% of female spawner body length (Kondolf 2000) is considered suitable for spawning Rainbow Trout to construct their redds. An additional 111 m of suitable spawning gravels were observed in Succour Creek in 2015. Taking into account the 2015 observations, 28% (1,549 m) of the total drawdown length surveyed contains gravels of suitable size for spawning. This is the most extensive total reach length of suitable substrate found in any of the tributaries surveyed to date. Scattered spawning gravels were also observed in the lower alluvial fan reaches of Dave Henry and Yellowjacket Creeks, but these patches were not extensive. Gravel suitability could not be assessed in the Beaver River due to high flows at the time of the survey.

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. Most tributaries surveyed in 2016 were on the border of the 3% steepness threshold, with mostly plane-bed channel morphology. Three of the six tributaries surveyed in 2016 have average gradients of approximately 3-5% in the surveyed portion of the drawdown zone and thus are likely to have marginal suitability for spawning. The Beaver River has a gentle gradient in its lower reaches, but high discharge and turbidity during the survey date prevented safe access, so we could not determine more detailed data on suitability.

Succour Creek was thermally suitable for Rainbow Trout spawning and incubation in the spring of 2015, during the period of lowest reservoir elevation (736.9 m), and continuing through the spring period of reservoir refilling. No Rainbow Trout spawning activity was observed in this stream during the tributary survey in Year 1, even though the survey dates were during a thermally suitable period for spawning. Reservoir operations during 2015 refilled the reservoir to 744 m by the earliest possible modeled emergence date in Succour Creek, indicating that reservoir operations have the potential to inundate suitable Rainbow Trout spawning habitat. As reservoir water level elevations continue to rise rapidly, it is likely that inundation of suitable spawning habitat would continue to occur prior to emergence. Temperatures measured in 2015 indicated that stream temperature was beginning to rise to the upper level of suitability by the time the temperature logger was inundated by the reservoir. Temperature data were not complete, thus a more thorough modeling exercise could not be conducted in this year of study to determine the full range of impacts. Temperature data for the 2016 season will be available in the subsequent year of study.

Snorkel surveys

Succour Creek was selected for snorkel surveys, in order to determine spring occupation of the drawdown zone and spawning by Rainbow Trout. Three survey dates were selected as early (April), mid (May) and late (June) periods within the generalized possible spawning window for Rainbow Trout. Although the extensive drawdown zone of Succour Creek contains habitat that should be supportive of spawning during the periods of the survey, Rainbow Trout spawning was not observed in 2016. Salmonid spawn timing is selected for in order to optimize survival to emergence and ensure that emergence timing occurs during a favorable period for growth (Brannon 1987, Quinn 2005). Given the modeled timing of first emergence, it is possible that Rainbow Trout are limited by rapidly escalating temperatures or inundation prior to emergence for most spawning dates, and for most locations in the drawdown zone. It is also possible that the drawdown zone suffers from extremely poor productivity of benthic invertebrates and does not provide initial first feeding opportunities for emergent fry (Brännäs 1995). Rainbow Trout, like all salmonids, return back to natal areas to spawn. It is possible that the habitat is severely limited (for any of the above reasons) to the extent that the local spawning population has been extirpated and cannot re-establish in the drawdown zone. Monitoring should be continued in subsequent years to determine if any spawning activity is present in the drawdown zone of this stream.

Fish abundance and diversity in the drawdown zone of Succour Creek was highly dependent on the survey date, with few numbers observed in the first and third survey and many fishes observed in the second survey. On the date of the second survey (May 18, 2016), but neither the first or third surveys, very large numbers of Largescale Sucker were observed. These fish were large bodied, and exhibited coloration indicative of secondary sex characteristics displayed during spawning. Habitat characteristics in the stream are consistent with those reported as preferred by Largescale Sucker, and water temperatures in late May are likely within the optimal temperature range for spawning of this species (McPhail 2007). It is likely that Succour Creek supports a large population of adfluvial Largescale Sucker, a life history form that has not previously been reported to our knowledge. An interesting observation is the relatively high abundance of other species, particularly juvenile Rainbow Trout and Mountain Whitefish, during the same survey. The higher abundance of these species at this time could be explained by preference for the habitat at this time of year, migration through the drawdown zone, or feeding opportunities for eggs released during Largescale Sucker spawning events.

Conclusions and recommendations

In the second year of this study, several observations were made to further our understanding of Rainbow Trout life history and habitat use in Kinbasket Reservoir and its tributaries. Rainbow Trout susceptible to trolling angling techniques did not appear to be abundant in the reservoir during the two years of study, although they were distributed throughout it. Overall catch per unit effort was generally lower than most values reported from creel surveys in previous decades for Kinbasket Reservoir, and lower for large bodied fish susceptible to the sampling method, relative to those reported for most other large lakes in the region (Pole 1995, 1996, Bray 2002, Andrusak and Andrusak 2012). Biological data from fish captured during the two years of study indicate that there is likely a large bodied, piscivorous morph, and a small bodied, insectivorous morph present in the reservoir, but this hypothesis should be tested by further study. Low abundance is unlikely to be related to the availability of prey for piscivorous morphs, as Kokanee populations have been stable and abundant in Kinbasket Reservoir in the years of study and those leading up to it (Sebastien and Weir 2015). The abundance of small bodied, insectivorous Rainbow Trout is unknown, as capture methods were not specialized to target this morph.

Fish that were tagged with biotelemetry tags were observed to have individual differences in home range size and location, with the most frequent occupation of home ranges between the Confluence of the Columbia and Canoe Reaches, and the inlet into Kinbasket Lake (Figure 6). Some directed spawning migrations to and from home ranges appeared to occur, with several fish migrating upstream from Surprise Rapids in the Columbia Reach of the Reservoir in late March to early April, and returning by late May. This may indicate a directed movement of fish to spawning locations at the upstream end of the reservoir, and provides some data on the possible timing of pre and post spawn movements. Fish already tagged will continue to provide data to these receivers in the subsequent year of study. Owing to low capture success of larger fish, few Rainbow Trout were of sufficient size to be surgically implanted with biotelemetry tags, limiting sample size for tracking movements throughout the course of this study. Home range characteristics, and the timing and locations of pre and post spawn movements should be interpreted with caution in extrapolating to the population-level until further study is conducted.

Tributary surveys in 2016 helped determine potential fish migration barriers that may be exposed and suitability of tributaries for spawning during the spring low pool period. Five additional tributaries were surveyed in Year 2 of the study, and one tributary was revisited in order to capture a more extensive portion of the drawdown zone, as low pool reservoir elevations were lower in 2016 than in 2015. Three tributaries (Horse, Dave Henry and Yellowjacket Creeks) with undefined, braided channels were found at the north east portion of the reservoir, and may provide challenges to upstream fish migration during periods of base flow and low reservoir elevations. These systems may warrant further study to determine the impacts of reservoir operations on fish migration. A possible fish migration impediment may be present in the drawdown zone of the Beaver River, although the barrier is assumed to not preclude passage of all fish.

We did not find a significant amount of habitat suitable for Rainbow Trout spawning in the drawdown zone of tributaries surveyed, as most tributaries either contained unsuitable spawning substrate over the majority of the drawdown zone, or channel slopes exceeded those typically associated with spawning for the species. Supporting the findings of Year 1 of this study, the exception was in Succour

Creek, which contained extensive habitat and a thermal regime predicted to be suitable for spawning throughout the drawdown zone. The thermal regime in Succour Creek indicates that the stream likely became thermally suitable for spawning in late April, 2015, and remained suitable throughout the month of May and into early June. The earliest theoretical date of fry emergence given the thermal regime in the stream in 2015 was modeled to be in early June, during a period of rapid reservoir refilling, thus reservoir operations have the potential to inundate suitable Rainbow Trout embryo incubation habitat prior to fry emergence and thus impact egg to fry survival in this stream. The Beaver River also may contain suitable habitats, but could not be thoroughly assessed in the year of study due to high flows, and should be revisited in a subsequent year. Thermal suitability analysis appears promising to determine if tributaries provide a thermal regime that supports Rainbow Trout spawning and incubation. More data will be forthcoming in the final year of study.

Snorkel surveys and detailed redd surveys did not reveal any spawning activity of Rainbow Trout in the drawdown zone of Succour Creek in 2016 despite the apparent physical suitability of the habitat. It is possible that reservoir operations or some other factor limit the establishment of a local spawning population in this habitat by interrupting the processes that support embryo and fry development or early growth. An additional year of surveys should be completed to increase the monitoring effort on Succour Creek, as well as refine the thermal suitability analysis to compare theoretical spawning and emergence timing to reservoir operations.

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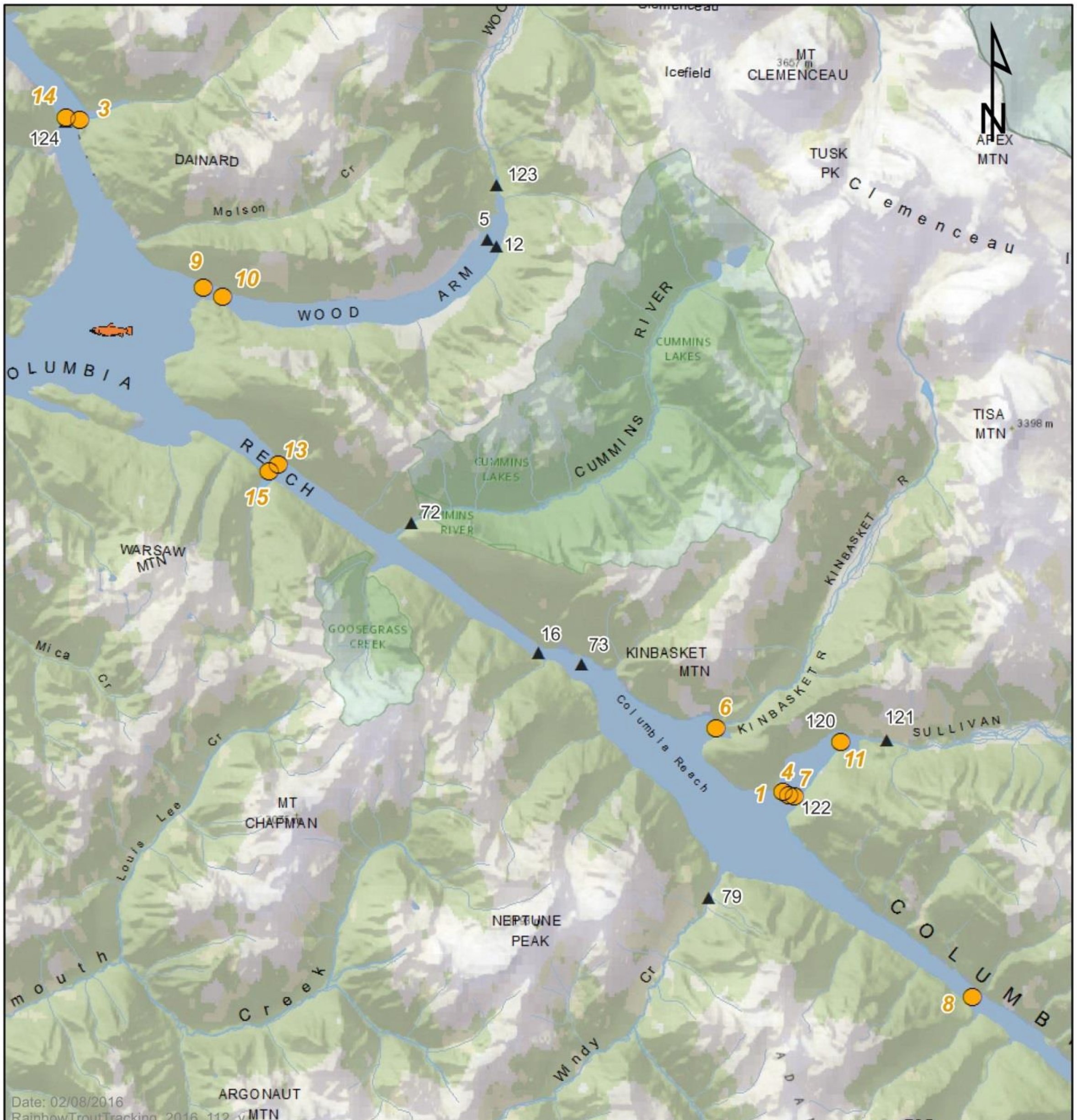
APPENDIX A.1 – INDIVIDUAL FISH CAPTURE AND TAGGING DATA

Capture Date/Time		Capture Location			Species	RECAP	Acoustic	Radio	Radio	Length	Weight	MORT	Sex	Fish Comments	H_2O	Weather & Water
Date	Time	Easting	Northing	General Description	Code	(Y/N)	Code	Code	Freq	(mm)	(kg)	(Y/N)	(M/F/U)		^0C	Conditions
27-Sep-15	10:33	451187	5728407	Upper Columbia - Gold Cr	RB	N				285	0.240	N	U	good condition	11.3	overcast, calm
27-Sep-15	12:22	453744	5729708	Upper Columbia - Gold Cr	RB	N				337	0.456	N	U	good condition	11.6	overcast, calm
28-Sep-15	11:48	401525	5772931	Confluence	RB	N				400	0.650	N	U	good condition	12.9	mixed, calm
28-Sep-15	12:32	400775	5773247	Confluence	RB	N	157	157	150.210	441	0.950	N	U	damage to one eye	13.1	mixed, calm
28-Sep-15	14:11	400644	5773341	Confluence	RB	N	158	158	150.210	423	0.900	N	U	good condition	13.2	mixed, calm
28-Sep-15	14:44	400983	5773171	Confluence	RB	N	159	159	150.210	472	1.100	N	U	good condition	13.3	mixed, calm
28-Sep-15	16:06	400710	5773280	Confluence	RB	N				429	0.850	N	U	hooked in top of mouth and eye	13.3	mixed, calm
28-Sep-15	18:25	401356	5773522	Confluence	RB	N	160	160	150.210	442	0.950	Y	U	hooked in eye	13.2	mixed, calm
29-Sep-15	16:02	402838	5773012	Confluence	RB	N				371	0.400	N	U	good condition	13.0	overcast, calm
29-Sep-15	16:35	401667	5772814	Confluence	RB	N				434	0.790	N	U	good condition	13.0	overcast, calm
29-Sep-15	17:48	400721	5773414	Confluence	RB	N				409	0.710	N	U	good condition	12.7	overcast, calm
30-Sep-15	8:59	398863	5776668	Confluence	RB	N				359	0.450	Y	U	hooked under tongue	12.3	overcast, wind
30-Sep-15	12:19	400052	5778365	Confluence	RB	N	156	156	150.210	530	1.080	N	U	good condition	12.8	overcast, calm
30-Sep-15	14:37	404893	5777899	Confluence	RB	N				395	0.630	N	U	good condition	13.1	overcast, calm
30-Sep-15	15:13	404922	5777849	Confluence	RB	N				382	0.530	Y	F	hooked in gill	13.3	overcast, calm
01-Oct-15	17:40	394061	5793962	Canoe Reach - Foster	RB	N				392	0.660	N	U	lost one eye	12.5	clear, calm
01-Oct-15	17:49	394165	5793970	Canoe Reach - Foster	RB	N				377	0.570	N	U	signs of previous injuries	12.4	clear, calm
02-Oct-15	11:46	432485	5753529	Old Kinbasket Lake	RB	N	116	116	150.210	547	2.460	N	M	good condition	12.6	overcast, calm
02-Oct-15	12:52	433323	5753375	Old Kinbasket Lake	RB	N				483	1.110	N	U	good condition	12.6	overcast, calm
02-Oct-15	16:23	433171	5753284	Old Kinbasket Lake	RB	N	117	117	150.210	575	2.450	N	U	good condition	12.5	rain, wind
03-Oct-15	12:42	404972	5778208	Confluence	RB	N				340	0.440	Y	F	hooked in head; insects in stomach	12.6	clear, calm
03-Oct-15	16:34	397325	5773855	Confluence	RB	N				393	2.640	N	U	hooked in head	12.4	clear, wind
25-Sep-15	13:26	455165	5730819	Upper Columbia - Succour Cr	BT	N				530	1.250	N	U	good condition	12.4	rain, wind
26-Sep-15	13:32	454997	5728697	Upper Columbia - Gold Cr	BT	N				415	0.670	N	U	slight bleeding from gills	12.2	overcast, calm
27-Sep-15	10:11	451234	5728549	Upper Columbia - Gold Cr	BT	N				306	0.246	N	U	good condition	11.3	overcast, calm
29-Sep-15	16:46	400926	5773160	Confluence	BT	N				464	0.980	N	U	good condition; lice	12.9	overcast, calm
30-Sep-15	10:26	399736	5779114	Confluence	BT	N				715	3.450	N	M	good condition	12.3	clear, wind
30-Sep-15	16:00	404968	5778135	Confluence	BT	N				685	3.850	N	M	good condition	13.0	overcast, calm
30-Sep-15	16:49	404533	5777428	Confluence	BT	N				582	2.670	N	F	good condition	13.4	overcast, calm
01-Oct-15	10:28	384193	5809754	Canoe Reach - Hugh Allan	BT	N				508	1.240	N	U	good condition	12.0	mixed, wind
02-Oct-15	10:18	433140	5753139	Old Kinbasket Lake	BT	N				508	1.400	N	U	good condition	12.5	overcast, calm
02-Oct-15	11:33	431711	5753954	Old Kinbasket Lake	BT	N				548	1.450	N	F	good condition	12.6	overcast, calm
03-Oct-15	14:00	403937	5773929	Confluence	BT	N				492	1.180	N	U	good condition; lice	12.5	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								12.4
2								12.2
3								11.3
4								11.3
5								11.6
6								12.9
7	157	157	150.21	4:49	5:52	20:07	30:48	13.1
8	158	158	150.21	5:15	5:56	17:18	28:29	13.2
9	159	159	150.21	4:59	5:31	18:59	29:29	13.3
10								13.3
11	160	160	150.21	4:40	6:04	17:08	37:48	13.2
12								13.0
13								13.0
14								12.9
15								12.7
16								12.3
17								12.3
18	156	156	150.21	6:16	5:25	18:18	29:59	12.8
19								13.1
20								13.3
21								13.0
22								13.4
23								12.0
24								12.5
25								12.4
26								12.5
27								12.6
28	116	116	150.21	3:25	5:08	22:12	30:45	12.6
29								12.6
30	117	117	150.21	3:15	6:01	20:34	29:50	12.5
31								12.6
32								12.5
33								12.4

APPENDIX A.3 – RAINBOW TROUT TRACKING MAPS



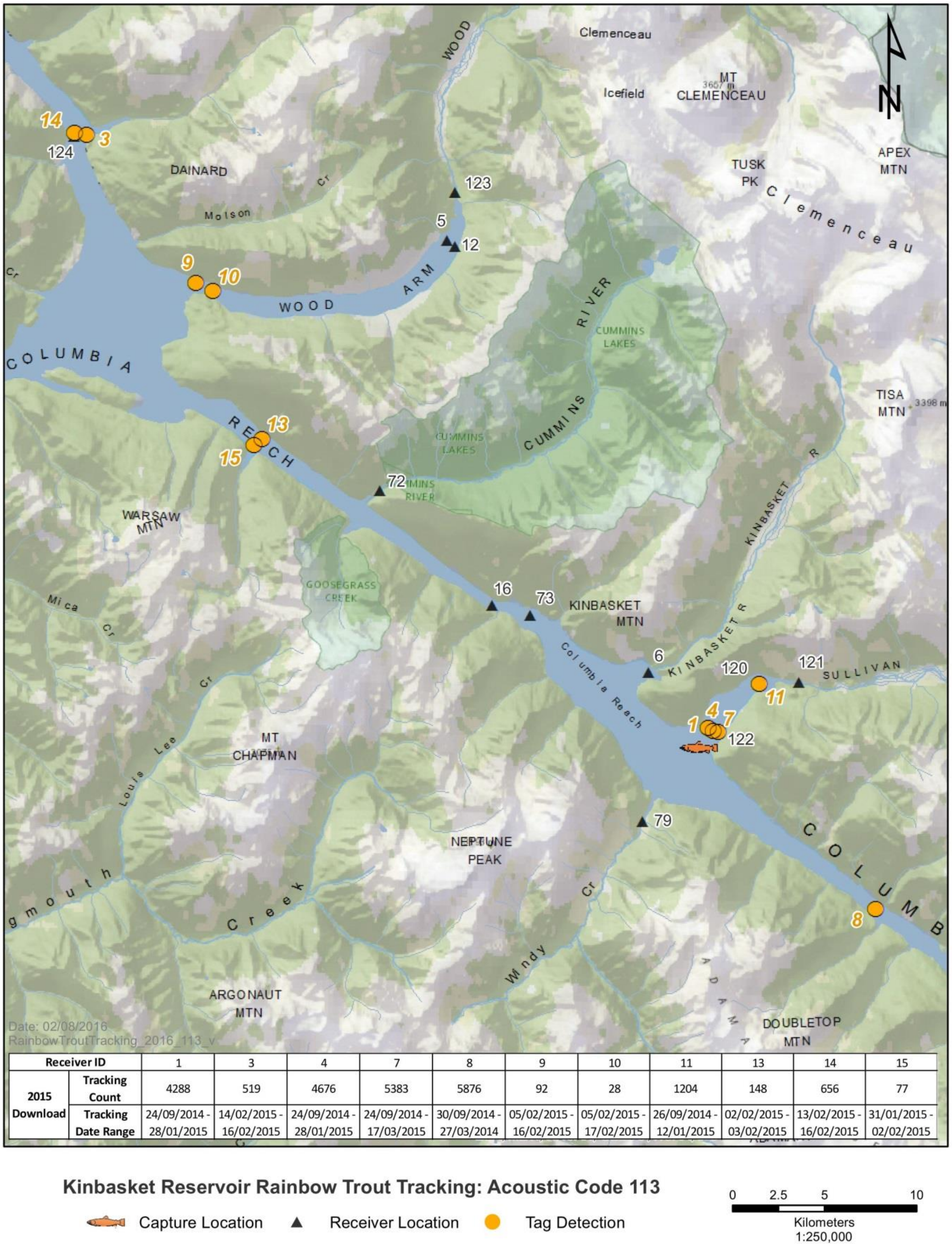
Receiver ID		1	3	4	6	7	8	9	10	11	13	14	15
2015 Download	Tracking Count	2001	305	2875	233	4328	5978	314	202	125	508	255	475
	Tracking Date Range	20/10/2014 - 30/01/2015	30/09/2014 - 04/10/2014	20/10/2014 - 16/02/2015	19/10/2014 - 02/11/2014	20/10/2014 - 03/03/2015	04/11/2014 - 02/04/2014	23/09/2014 - 05/10/2014	24/09/2014 - 26/09/2014	20/10/2014 - 06/01/2015	06/10/2014 - 09/10/2014	30/09/2014 - 04/10/2014	06/10/2014 - 09/10/2014
2016 Download	Tracking Count	36		32	132		1						
	Tracking Date Range	28/05/2015 - 13/06/2015		28/05/2015 - 13/06/2015	26/05/2015 - 04/06/2015		24/05/2015						

Kinbasket Reservoir Rainbow Trout Tracking: Acoustic Code 112

Capture Location ▲ Receiver Location ● Tag Detection

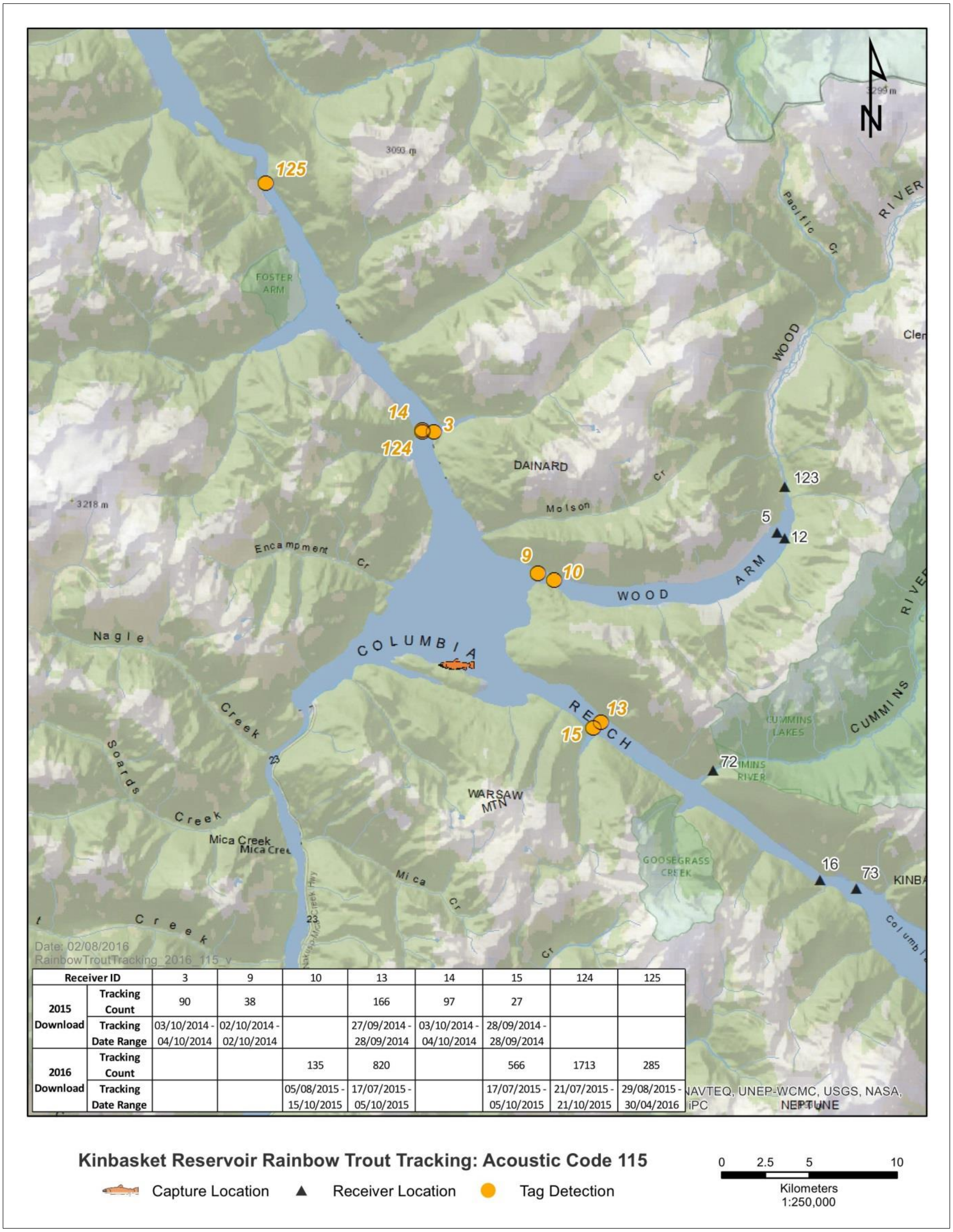
0 2.5 5 10
Kilometers
1:250,000

Figure A.3-1. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 112 and their tracking date ranges. Capture and tag implantation occurred on September 22, 2014.



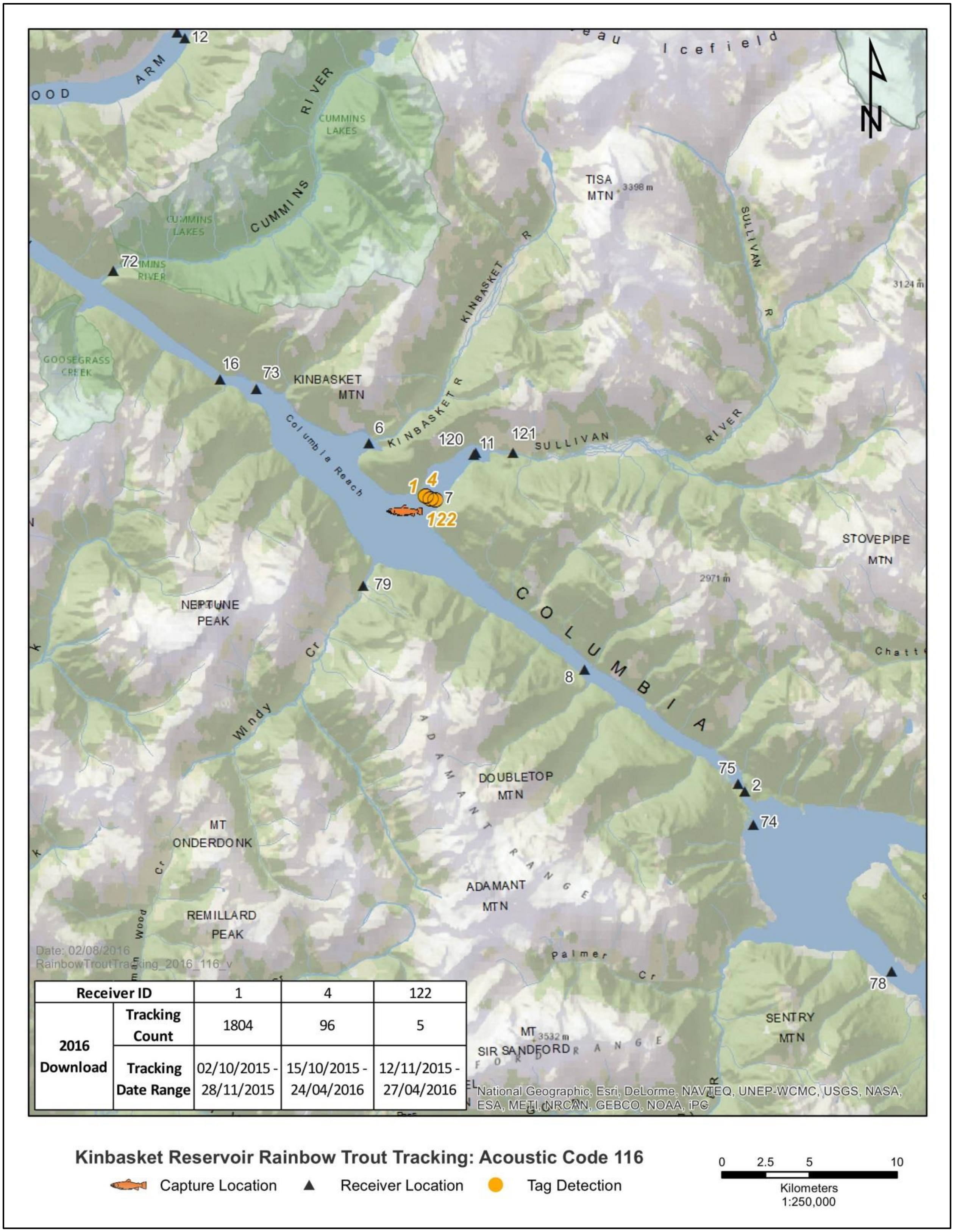
Receiver ID		1	3	4	7	8	9	10	11	13	14	15
2015 Download	Tracking Count	4288	519	4676	5383	5876	92	28	1204	148	656	77
	Tracking Date Range	24/09/2014 - 28/01/2015	14/02/2015 - 16/02/2015	24/09/2014 - 28/01/2015	24/09/2014 - 17/03/2015	30/09/2014 - 27/03/2014	05/02/2015 - 16/02/2015	05/02/2015 - 17/02/2015	26/09/2014 - 12/01/2015	02/02/2015 - 03/02/2015	13/02/2015 - 16/02/2015	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. Capture and tag implantation occurred on September 24, 2014.



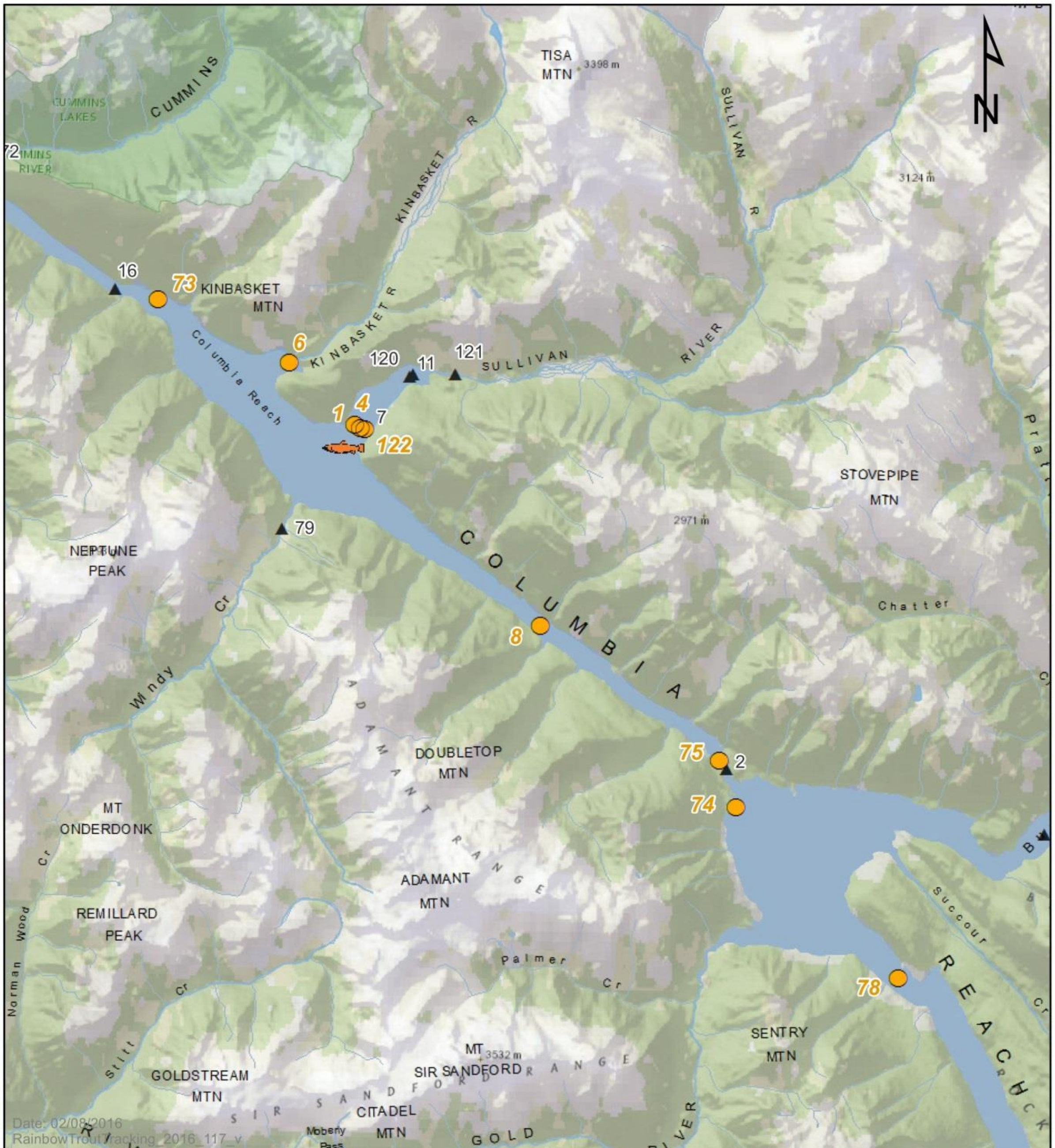
Receiver ID		3	9	10	13	14	15	124	125
2015 Download	Tracking Count	90	38		166	97	27		
	Tracking Date Range	03/10/2014 - 04/10/2014	02/10/2014 - 02/10/2014		27/09/2014 - 28/09/2014	03/10/2014 - 04/10/2014	28/09/2014 - 28/09/2014		
2016 Download	Tracking Count			135	820		566	1713	285
	Tracking Date Range			05/08/2015 - 15/10/2015	17/07/2015 - 05/10/2015		17/07/2015 - 05/10/2015	21/07/2015 - 21/10/2015	29/08/2015 - 30/04/2016

Figure A.3-3. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 115 and their tracking date ranges. Capture and tag implantation occurred on September 26, 2014.



Receiver ID		1	4	122
2016 Download	Tracking Count	1804	96	5
	Tracking Date Range	02/10/2015 - 28/11/2015	15/10/2015 - 24/04/2016	12/11/2015 - 27/04/2016

Figure A.3-4. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 116 and their tracking date ranges. Capture and tag implantation occurred on October 2, 2015.



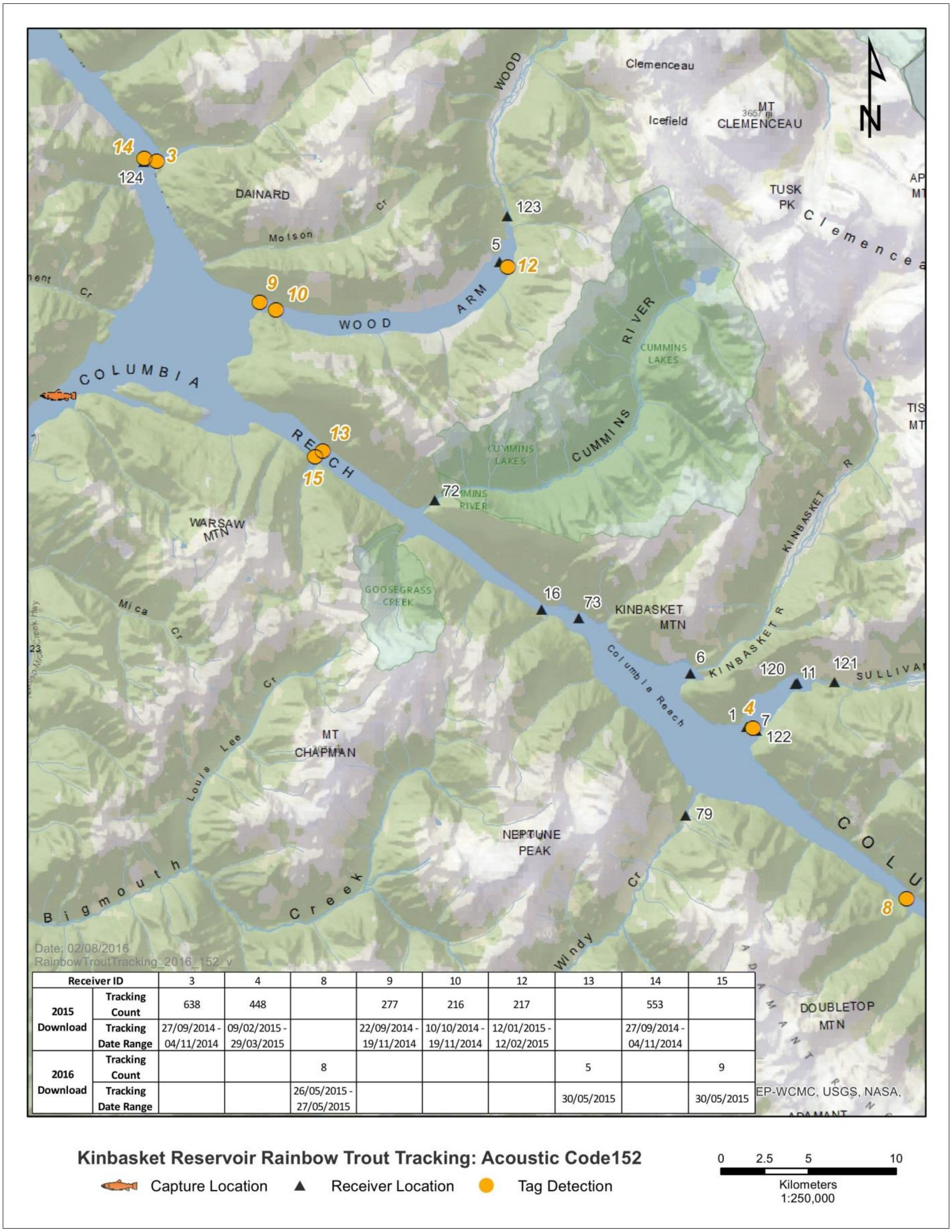
Receiver ID		1	4	6	8	73	74	75	78	122
2016 Download	Tracking Count	1061	1256	816	2035	783	92	404	2	664
	Tracking Date Range	02/10/2015 - 11/02/2016	02/10/2015 - 10/06/2016	09/10/2015 - 09/01/2016	21/10/2015 - 17/04/2016	06/10/2015 - 10/01/2016	15/03/2016 - 19/04/2016	15/03/2016 - 18/04/2016	19/04/2016	02/10/2015 - 09/02/2016

Kinbasket Reservoir Rainbow Trout Tracking: Acoustic Code117

Capture Location ▲ Receiver Location ● Tag Detection

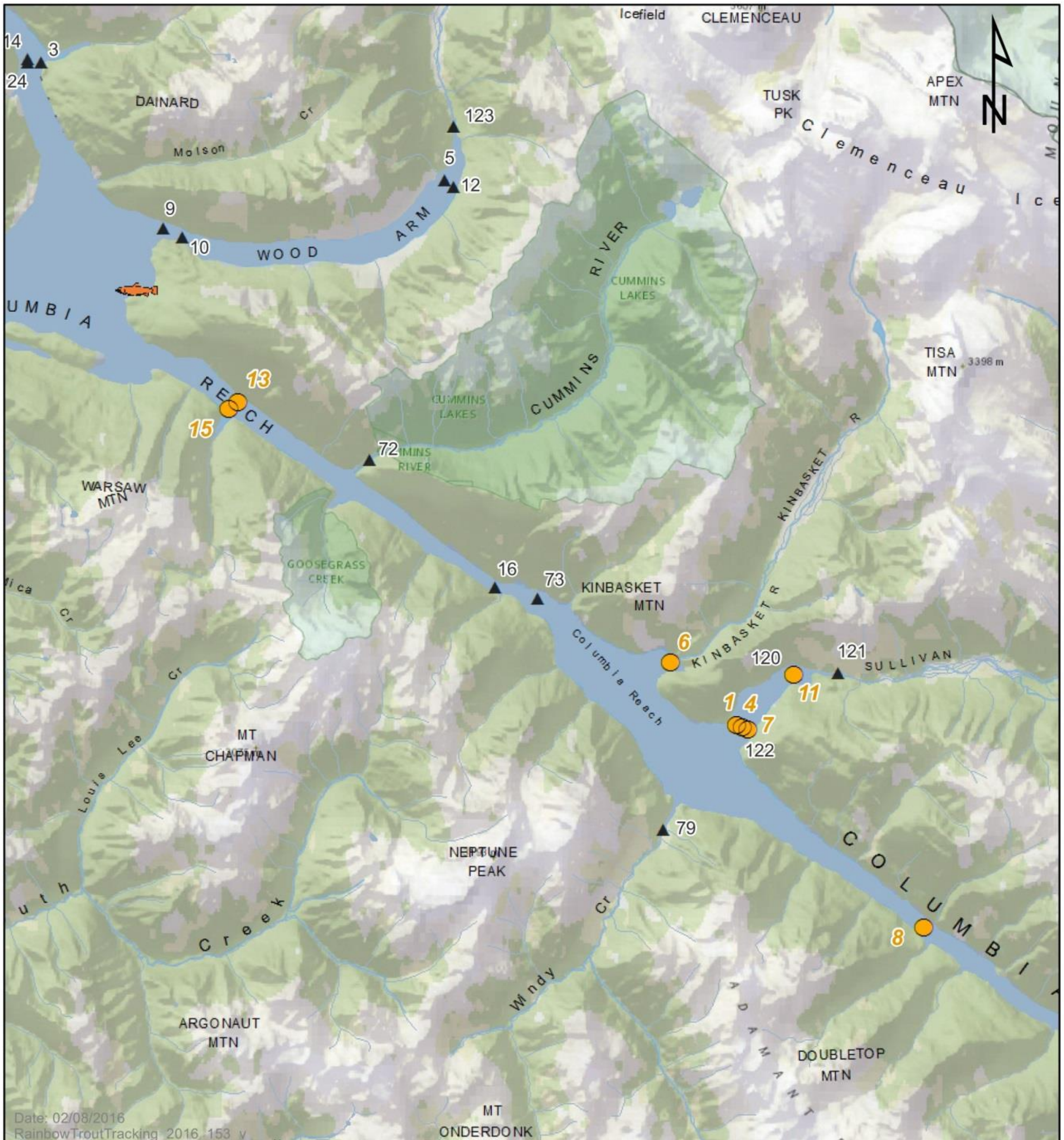
0 2.5 5 10 Kilometers 1:250,000

Figure A.3-5. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 117 and their tracking date ranges. Capture and tag implantation occurred on October 2, 2015.



Receiver ID		3	4	8	9	10	12	13	14	15
2015 Download	Tracking Count	638	448		277	216	217		553	
	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		27/09/2014 - 04/11/2014	
2016 Download	Tracking Count			8				5		9
	Tracking Date Range			26/05/2015 - 27/05/2015				30/05/2015		30/05/2015

Figure A.3-6. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 152 and their tracking date ranges. Capture and tag implantation occurred on September 20, 2014.



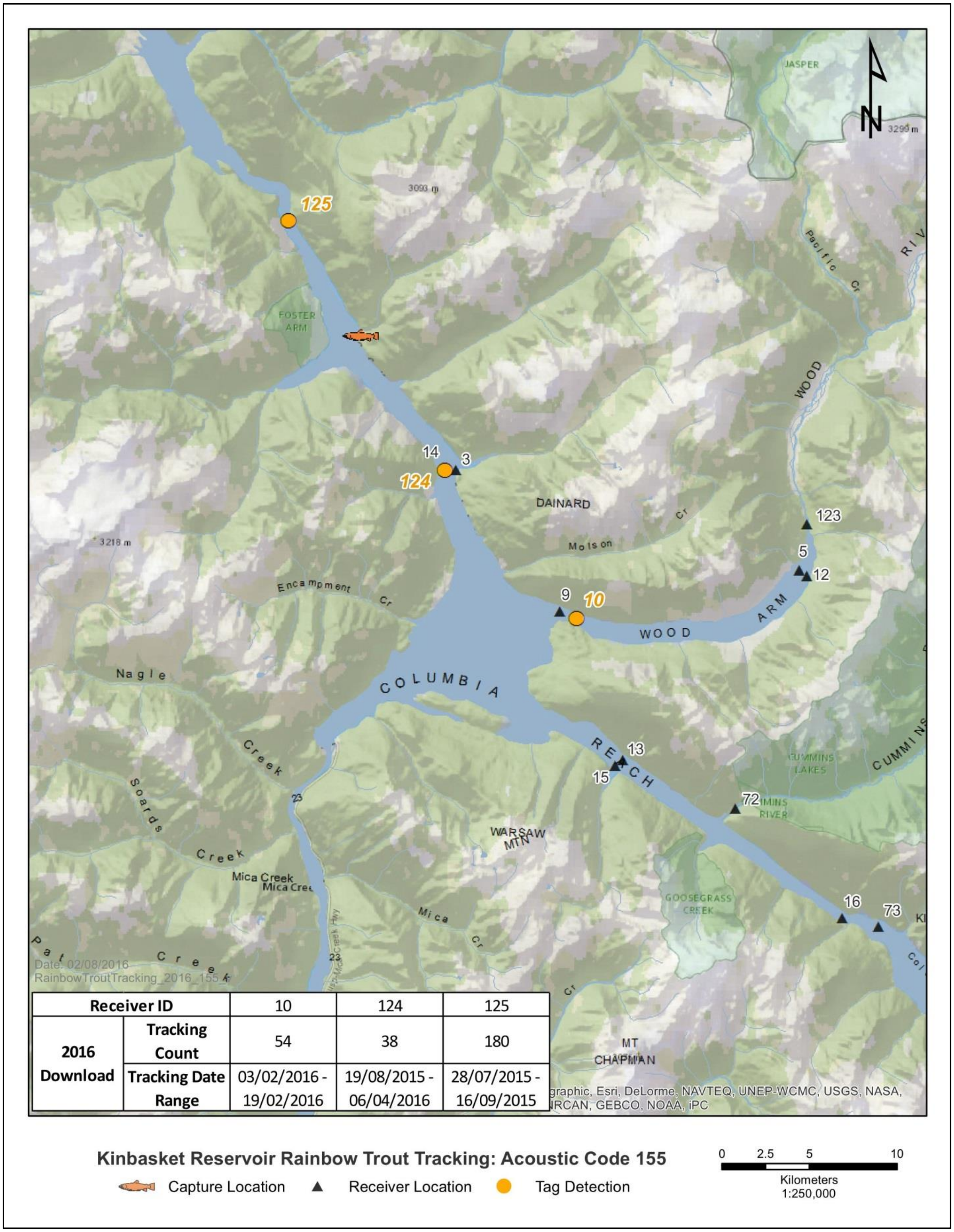
Receiver ID		1	4	6	7	8	11	13	15
2015 Download	Tracking Count	34	34	10	27	6	54	6	2
	Tracking Date Range	02/10/2014 - 05/10/2014	02/10/2014 - 05/10/2014	02/10/2014 - 02/10/2014	02/10/2014 - 05/10/2014	05/10/2014 - 05/10/2014	03/10/2014 - 04/10/2014	29/09/2014 - 29/09/2014	29/09/2014 - 29/09/2014

Kinbasket Reservoir Rainbow Trout Tracking: Acoustic Code 153

Capture Location ▲ Receiver Location Tag Detection

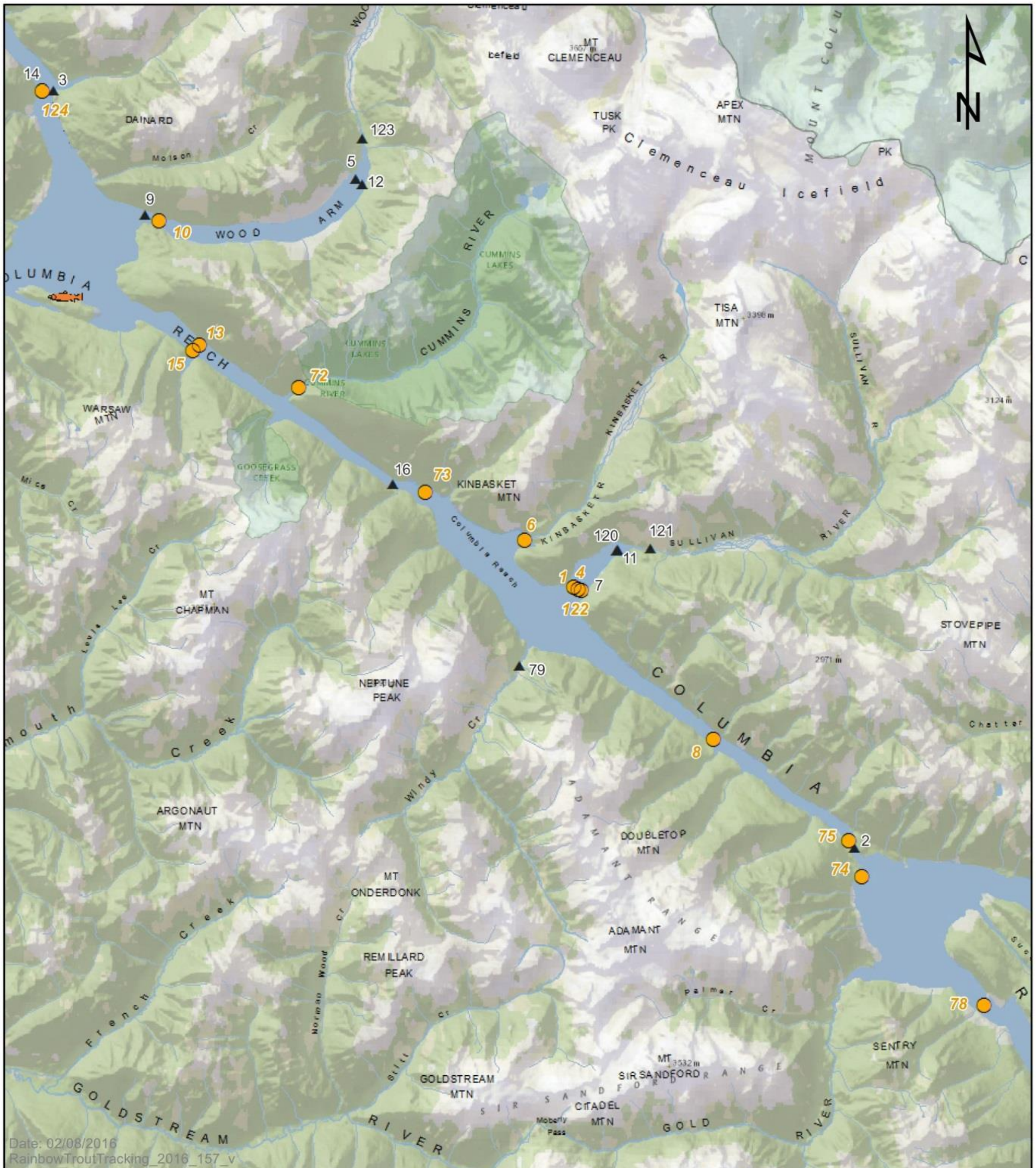
0 2.5 5 10
Kilometers
1:250,000

Figure A.3-7. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 153 and their tracking date ranges. Capture and tag implantation occurred on September 21, 2014.



Receiver ID		10	124	125
2016 Download	Tracking Count	54	38	180
	Tracking Date Range	03/02/2016 - 19/02/2016	19/08/2015 - 06/04/2016	28/07/2015 - 16/09/2015

Figure A.3-8. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 155 and their tracking date ranges. Capture and tag implantation occurred on September 26, 2014.



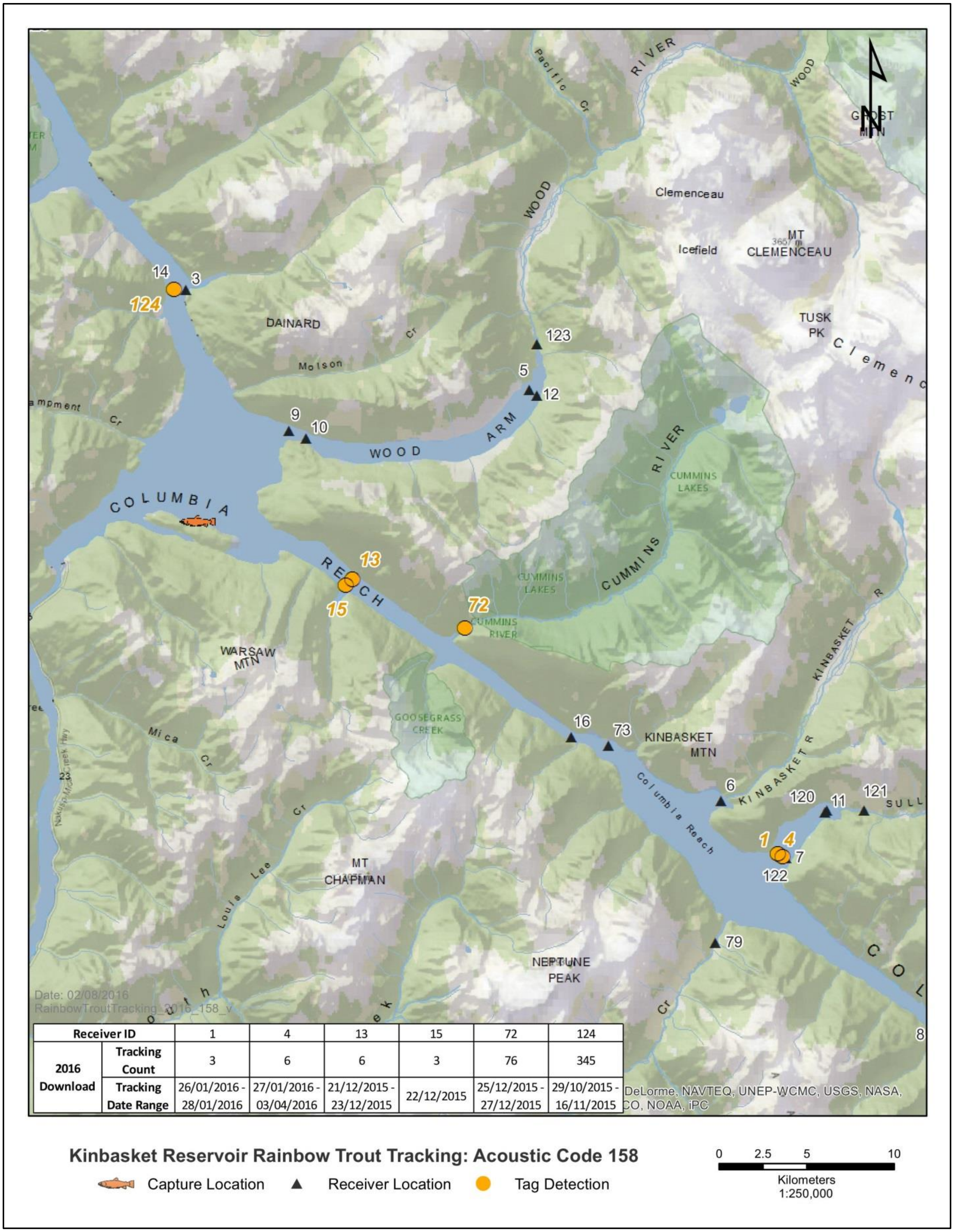
Receiver ID		1	4	6	8	10	13	15	72	73	74	75	78	122	124
2016 Download	Tracking Count	193	319	6	158	665	36	2	79	42	1	6	15	188	30
	Tracking Date Range	08/12/2015 - 11/03/2016	08/12/2015 - 12/04/2016	08/12/2015	18/12/2015 - 17/04/2016	13/10/2015 - 14/11/2015	15/11/2015 - 16/11/2015	16/11/2015 - 21/11/2015	17/11/2015 - 05/12/2015	07/12/2015 - 28/03/2016	23/04/2016	18/04/2016	25/04/2016	08/12/2015 - 12/04/2016	10/10/2015 - 11/10/2015

Kinbasket Reservoir Rainbow Trout Tracking: Acoustic Code 157

Capture Location ▲ Receiver Location ● Tag Detection

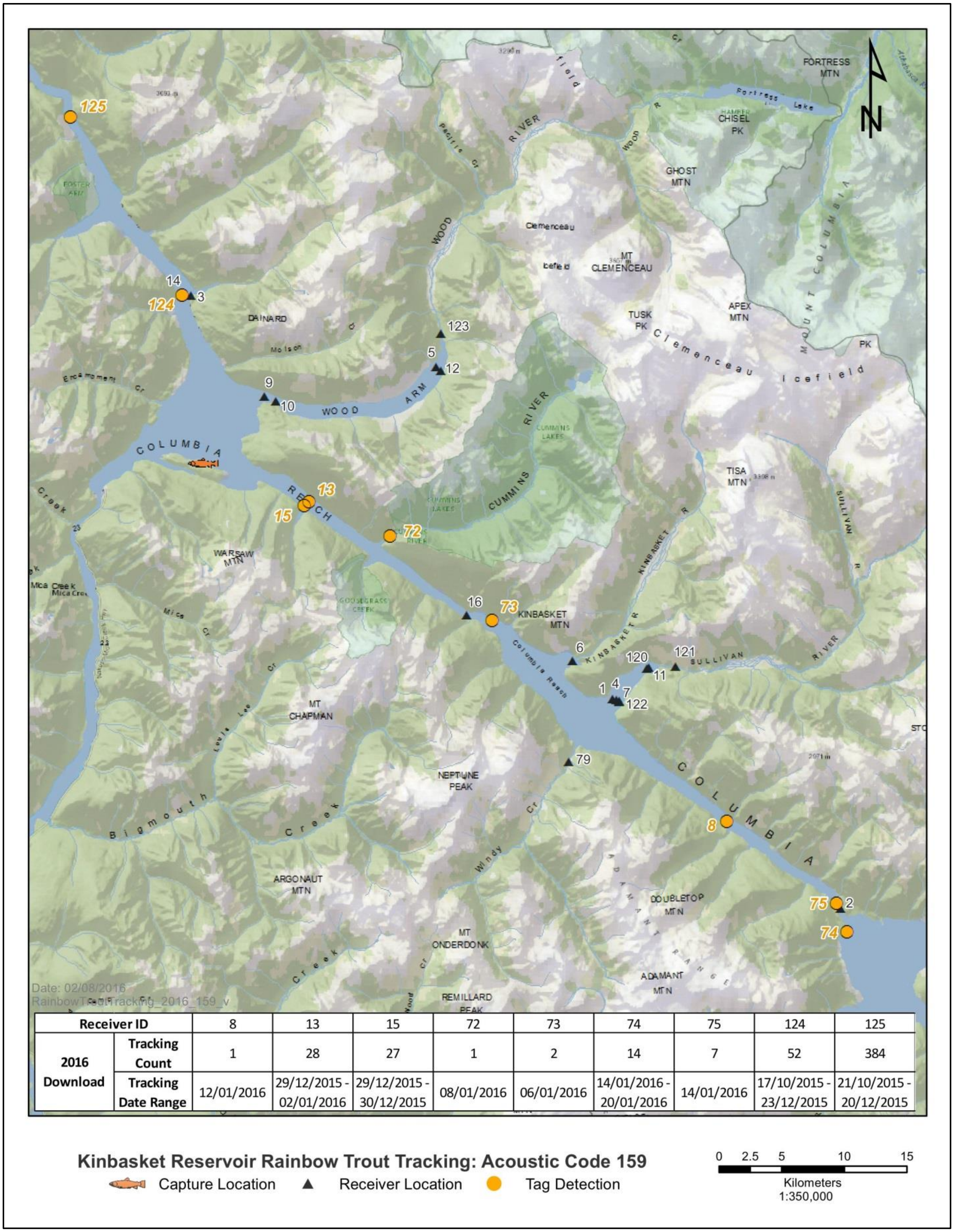
0 2.5 5 10 15
Kilometers
1:325,000

Figure A.3-9. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 157 and their tracking date ranges. Capture and tag implantation occurred on September 28, 2015.



Receiver ID		1	4	13	15	72	124
2016 Download	Tracking Count	3	6	6	3	76	345
	Tracking Date Range	26/01/2016 - 28/01/2016	27/01/2016 - 03/04/2016	21/12/2015 - 23/12/2015	22/12/2015	25/12/2015 - 27/12/2015	29/10/2015 - 16/11/2015

Figure A.3-10. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 158 and their tracking date ranges. Capture and tag implantation occurred on September 28, 2015.



Receiver ID		8	13	15	72	73	74	75	124	125
2016 Download	Tracking Count	1	28	27	1	2	14	7	52	384
	Tracking Date Range	12/01/2016	29/12/2015 - 02/01/2016	29/12/2015 - 30/12/2015	08/01/2016	06/01/2016	14/01/2016 - 20/01/2016	14/01/2016	17/10/2015 - 23/12/2015	21/10/2015 - 20/12/2015

Figure A.3-11. Map showing the acoustic receivers in Kinbasket Reservoir that detected tag 159 and their tracking date ranges. Capture and tag implantation occurred on September 28, 2015.

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 (cm)	Water Depth 2 (cm)	Water Depth 3 (cm)	Mean Water Depth (cm)	Bankfull Width (m)	Wetted Width (m)	Dom. Bed Material Type *	Sub-dom. Bed Material Type **	Cover Type ***	Comments
Succour Creek	1	28-Apr-15	0	Run	5730630	462249	753.20		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	752.72	0.32	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	462095	752.23	0.33	Note: Reach too deep and swift to wade									9	S	G	WD	
Succour Creek	4	28-Apr-15	450	Run	5730936	462024	751.00	0.82	Note: Reach too deep and swift to wade									5.5	S	G	WD	
Succour Creek	5	29-Apr-15	600	Run	5731014	461930	750.36	0.43	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	461873	749.70	0.44	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	461771	749.05	0.44	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	461783	748.64	0.27	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	461735	748.34	0.20	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	461668	747.83	0.34	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	747.14	0.46	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	746.68	0.31	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	461416	746.30	0.25	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	745.82	0.32	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	461242	745.26	0.37	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	744.71	0.36	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	744.27	0.29	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	743.81	0.31	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	743.07	0.50	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	742.57	0.33	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	742.18	0.26	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	741.75	0.29	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	460702	741.15	0.40	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	740.84	0.21	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	740.54	0.20	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	460463	740.27	0.18	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	740.00	0.18	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	460359	739.72	0.19	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	460279	738.46	0.84	0.99	1.25	0.99	1.08	40	62	35	45.7	10.7	7.6	C	S	WD	
Succour Creek	1	18-Apr-16	4200	Run	5733095	460280	738.45		1.40	1.40	1.40	1.40	48	60	37	48.3	10	10	G	C		
Succour Creek	2	18-Apr-16	4560	Run	5733300	460205	735.42	0.84	0.63	0.99	1.33	0.98	15	30	81	42.0	13	13	S	G		A
Succour Creek	3	18-Apr-16	4910	Run	5733415	459992	732.21	0.92	1.17	1.47	1.08	1.24	27	56	59	47.3	11	11	C	G	WD	
Succour Creek	4	18-Apr-16	5241	Run	5733556	459846	730.41	0.55	0.44	0.44	0.63	0.50	32	33	61	42.0	12	12	G	C		A

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 (cm)	Water Depth 2 (cm)	Water Depth 3 (cm)	Mean Water Depth (cm)	Bankfull Width (m)	Wetted Width (m)	Dom. Bed Material Type *	Sub-dom. Bed Material Type **	Cover Type ***	Comments
Horse Creek	1	20-Apr-16	0	R	5839205	362680	754.48		0.63	0.77	0.99	0.79	35	24	30	29.7	23	11	B	C	B	A
Horse Creek	2	20-Apr-16	20	R	5839185	362679	753.04	7.22	1.40	1.08	0.99	1.16	55	65	40	53.3	21	6.7	B	C	B	A
Horse Creek	3	20-Apr-16	40	R	5839166	362679	752.38	3.28	1.33	1.40	1.66	1.46	40	60	50	50.0	20	6.3	B	C	B	
Horse Creek	4	20-Apr-16	60	R	5839145	362680	751.81	2.88	1.83	1.40	0.89	1.37	48	45	43	45.3	21	7.8	B	C	B	A
Horse Creek	5	20-Apr-16	80	R	5839129	362681	750.88	4.64	1.47	1.08	1.17	1.24	54	28	33	38.3	33	6.4	B	C	B	
Horse Creek	6	20-Apr-16	100	R	5839113	362669	749.96	4.60	0.99	1.40	1.72	1.37	48	55	65	56.0	41	5.4	B	C	B	B
Horse Creek	7	20-Apr-16	120	R	5839096	362654	749.16	4.01	1.72	0.89	0.63	1.08	60	8	15	27.7	40	21	C	B	B	B
Horse Creek	8	20-Apr-16	140	R	5839082	362641	748.50	3.29	0.63	1.17	0.99	0.93	5	28	30	21.0	49	24	B	C	B	B
Horse Creek	9	20-Apr-16	160	R	5839059	362636	747.28	6.09	1.53	0.89	1.08	1.17	30	20	35	28.3	46	10	B	C	B	
Horse Creek	10	20-Apr-16	180	R	5839043	362625	746.63	3.23	1.40	0.44	0.89	0.91	30	10	18	19.3	48	17	C	B	B	
Horse Creek	11	20-Apr-16	200	R	5839024	362618	745.80	4.16	1.25	0.44	0.89	0.86	28	11	23	20.7	58	17	C	B	B	
Horse Creek	12	20-Apr-16	220	R	5839004	362615	744.97	4.15	0.63	1.40	0.89	0.97	15	20	18	17.7	71	16	C	B	B	
Horse Creek	13	20-Apr-16	240	R	5838990	362601	744.32	3.25	1.47	1.08	0.00	0.85	41	25	4	23.3	64	29	C	B	B	
Horse Creek	14	20-Apr-16	260	R	5838973	362597	743.67	3.26	0.44	1.47	0.63	0.85	5	15	10	10.0	81	50	C	B	B	
Horse Creek	15	20-Apr-16	280	R	5838954	362588	742.51	5.80	0.63	0.77	0.00	0.46	20	5	5	10.0	96	34	C	B	B	C
Horse Creek	16	20-Apr-16	300	R	5838930	362588	741.41	5.51	0.44	0.44	0.00	0.30	5	10	3	6.0	112		C	G	B	C
Horse Creek	17	20-Apr-16	320	R	5838911	362586	740.34	5.35	0.44	1.08	0.44	0.66	7	18	3	9.3	131		C	G	B	
Horse Creek	18	20-Apr-16	340	R	5838889	362583	739.14	5.98	0.44	0.63	0.77	0.61	6	4	22	10.7	126		S	G	B	
Horse Creek	19	20-Apr-16	360	R	5838870	362580	738.10	5.23	0.44	0.99	0.44	0.63	4	14	5	7.7	118		G	S	B	
Horse Creek	20	20-Apr-16	380	R	5838851	362582	737.26	4.17	0.44	1.25	0.44	0.71	6	15	10	10.3	118		S	C	B	
Horse Creek	21	20-Apr-16	400	R	5838836	362567	736.23	5.16	0.00	0.77	0.63	0.46	2	17	8	9.0	160		C	S	B, WD	
Horse Creek	22	20-Apr-16	420	R	5838819	362556	735.56	3.34	0.00	0.89	0.44	0.44	9	18	5	10.7	205		G	C	B, WD	
Horse Creek	23	20-Apr-16	440	R	5838802	362544	734.45	5.55	0.44	0.00	1.08	0.51	5	8	13	8.7	181		G	C	B	
Horse Creek	24	20-Apr-16	460	R	5838786	362532	733.73	3.61	0.63	0.63	0.63	0.63	11	16	4	10.3	184		G	C	B	C
Horse Creek	25	20-Apr-16	480	R	5838767	362525	732.89	4.22	0.44	0.77	0.00	0.40	7	24	5	12.0	178		G	C	B	C
Horse Creek	26	20-Apr-16	500	R	5838756	362508	732.06	4.14	0.63	0.89	0.63	0.71	5	20	8	11.0	213		G	C	B	C
Horse Creek	27	20-Apr-16	520	R	5838754	362484	731.14	4.62	0.63	0.99	0.00	0.54	5	22	3	10.0	226		G	S	B	C
Ptarmigan Creek	1	21-Apr-16	0	P	5827534	375761	751.67		Note: Creek too deep and swift to wade								30	25	B	G	D	C
Ptarmigan Creek	2	21-Apr-16	25	C	5827524	375738	750.50	4.68									25	21	B	Bd		C
Ptarmigan Creek	3	21-Apr-16	50	R	5827519	375717	749.81	2.75									22	20	B	C		C
Ptarmigan Creek	4	21-Apr-16	75	R	5827524	375692	748.83	3.94									25	21	B	C		C
Ptarmigan Creek	5	21-Apr-16	100	R	5827536	375671	748.07	3.04									27	21	B	C		C
Ptarmigan Creek	6	21-Apr-16	125	C	5827544	375646	746.95	4.47									22	20	B	C		C
Ptarmigan Creek	7	21-Apr-16	150	C	5827545	375620	745.83	4.49									21	15	B	C		C
Ptarmigan Creek	8	21-Apr-16	175	R	5827540	375594	744.96	3.49									25	20	B	C		C
Ptarmigan Creek	9	21-Apr-16	200	R	5827530	375569	744.51	1.79									23	21	B	C		
Ptarmigan Creek	10	21-Apr-16	225	P	5827512	375552	743.43	4.31									22	21	B	G		

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 (cm)	Water Depth 2 (cm)	Water Depth 3 (cm)	Mean Water Depth (cm)	Bankfull Width (m)	Wetted Width (m)	Dom. Bed Material Type *	Sub-dom. Bed Material Type **	Cover Type ***	Comments
Ptarmigan Creek	11	21-Apr-16	250	R	5827498	375530	742.55	3.53									25	24	B	C		
Ptarmigan Creek	12	21-Apr-16	275	C	5827476	375512	741.76	3.16									29	20	B	C		
Ptarmigan Creek	13	21-Apr-16	300	C	5827455	375495	740.53	4.92									26	15	B	C		
Ptarmigan Creek	14	21-Apr-16	325	R	5827443	375472	739.95	2.33									22	19	B	C		
Ptarmigan Creek	15	21-Apr-16	350	R	5827434	375450	739.47	1.93									23	20	B	C		
Ptarmigan Creek	16	21-Apr-16	375	R	5827427	375426	738.67	3.20									23	21	B	C		
Ptarmigan Creek	17	21-Apr-16	400	R	5827427	375407	738.22	1.80									22	21	B	C		
Ptarmigan Creek	18	21-Apr-16	425	R	5827430	375384	737.30	3.66									36	21	B	C		
Ptarmigan Creek	19	21-Apr-16	450	R	5827445	375359	735.99	5.22									42	28	B	C		
Ptarmigan Creek	20	21-Apr-16	475	R	5827459	375341	735.30	2.78									41	26	B	C		
Ptarmigan Creek	21	21-Apr-16	500	C	5827473	375313	734.48	3.27									38	21	B	C		
Ptarmigan Creek	22	21-Apr-16	525	C	5827486	375289	732.97	6.05									24	19	B	S		A
Ptarmigan Creek	23	21-Apr-16	550	P	5827498	375270	732.84	0.50									26	17	B	C		
Ptarmigan Creek	24	21-Apr-16	575	R	5827510	375248	732.27	2.28									21	20	B	C		
Ptarmigan Creek	25	21-Apr-16	600	R	5827518	375226	731.80										34	34	B	C		
Dave Henry Creek	1	22-Apr-16	0	R	5845830	358433	751.07		Note: Creek too deep and swift to wade								18	10	B	C	WD	
Dave Henry Creek	2	22-Apr-16	50	R	5845809	358389	750.02	2.09									16	19	B	C	WD	
Dave Henry Creek	3	22-Apr-16	100	Run	5845799	358340	748.33	3.39									23	9	B	C		
Dave Henry Creek	4	22-Apr-16	150	R	5845780	358291	746.36	3.93									42	26	B	C	WD	
Dave Henry Creek	5	22-Apr-16	200	Run	5845765	358244	744.50	3.72									47	20	B	C		
Dave Henry Creek	6	22-Apr-16	250	R	5845764	358199	743.52	1.98									37	17	B	C		
Dave Henry Creek	7	22-Apr-16	300	R	5845742	358155	742.40	2.24									54	19	B	C		
Dave Henry Creek	8	22-Apr-16	350	R	5845700	358128	741.07	2.65									63	18	B	C		
Dave Henry Creek	9	22-Apr-16	400	R	5845669	358092	739.89	2.37									108	20	B	C		
Dave Henry Creek	10	22-Apr-16	450	R	5845634	358069	738.51	2.75									81	25	B	C		
Dave Henry Creek	11	22-Apr-16	500	R	5845614	358022	736.99	3.04									146		B	C		C
Dave Henry Creek	12	22-Apr-16	550	Run	5845579	357986	735.63	2.73									133		C	G	WD	C
Dave Henry Creek	13	22-Apr-16	600	Run	5845567	357940	734.83	1.58									105		C	G	WD	C
Dave Henry Creek	14	22-Apr-16	650	Run	5845552	357895	733.90	1.87									48	20	B	C		
Dave Henry Creek	15	22-Apr-16	700	Run	5845517	357864	733.35	1.09									12	10	B	C		
Dave Henry Creek	16	22-Apr-16	750	Run	5845470	357850	732.57	1.57									35	13	B	C		
Dave Henry Creek	17	22-Apr-16	800	Run	5845438	357819	731.92	1.29									31	14	C	G		
Dave Henry Creek	18	22-Apr-16	850	Run	5846424	357782	731.64	0.56									30	10, 4.5	C	G		
Dave Henry Creek	19	22-Apr-16	900	Run	5845391	357732	731.19	0.90									73	10, 19	C	G		
Yellowjacket Creek	1	22-Apr-16	0	R	5841306	361337	754.22	2.56									15	10	B	C		
Yellowjacket Creek	2	22-Apr-16	30	Run	5841289	361313	753.60	2.06									16	12	B	C	WD	
Yellowjacket Creek	3	22-Apr-16	60	R	5841267	361289	752.39	4.03									35	29	B	C		

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 (cm)	Water Depth 2 (cm)	Water Depth 3 (cm)	Mean Water Depth (cm)	Bankfull Width (m)	Wetted Width (m)	Dom. Bed Material Type *	Sub-dom. Bed Material Type **	Cover Type ***	Comments
Yellowjacket Creek	4	22-Apr-16	90	Run	5841255	361259	750.69	5.66									34	15	B	C		A
Yellowjacket Creek	5	22-Apr-16	120	R	5841233	361237	749.65	3.46									49	28	B	C		A
Yellowjacket Creek	6	22-Apr-16	150	R	5841210	361218	747.83	6.07									55	32	B	C		A
Yellowjacket Creek	7	22-Apr-16	180	R	5841231	361189	746.29	5.14									35	25	B	C		A
Yellowjacket Creek	8	22-Apr-16	210	Run	5841227	361159	745.01	4.25									29	10	B	C		
Yellowjacket Creek	9	22-Apr-16	240	R	5841232	361131	744.61	1.33									39	18	B	C		A
Yellowjacket Creek	10	22-Apr-16	270	R	5841215	361106	743.67	3.14									40	17	B	C		
Yellowjacket Creek	11	22-Apr-16	300	R	5841205	361077	742.79	2.92									50	14	B	C		
Yellowjacket Creek	12	22-Apr-16	330	R	5841206	361049	741.96	2.79									41	21	B	C		A
Yellowjacket Creek	13	22-Apr-16	360	R	5841216	361020	740.92	3.47									88	27	B	C		A
Yellowjacket Creek	14	22-Apr-16	390	R	5841225	360990	739.53	4.63									84		B	C		C
Yellowjacket Creek	15	22-Apr-16	420	R	5841221	360960	738.43	3.65									88		B	C		C
Yellowjacket Creek	16	22-Apr-16	450	R	5841218	360929	737.43	3.34									74	27	B	C		
Yellowjacket Creek	17	22-Apr-16	480	R	5841207	360901	736.49	3.14									83	52	C	B		
Yellowjacket Creek	18	22-Apr-16	510	R	5841192	360873	735.44	3.49									79	29	B	C		
Yellowjacket Creek	19	22-Apr-16	540	R	5841186	360841	735.01	1.44									78	22	B	C		
Yellowjacket Creek	20	22-Apr-16	570	R	5841184	360811	734.12	2.94									44	22	C	B		
Yellowjacket Creek	21	22-Apr-16	600	R	5841168	360783	733.63	1.66									71	43	C	G		
Yellowjacket Creek	22	22-Apr-16	630	R	5841162	360757	732.64	3.30									80		C	B		C
Yellowjacket Creek	23	22-Apr-16	660	R	5841158	360728	732.19	1.49									100		G	C		C
Yellowjacket Creek	24	22-Apr-16	690	R	5841159	360698	731.41	2.60									85		G	C		C
Beaver River	1	04-May-16	0	Run					Note: River too deep and swift to wade								49	26				
Beaver River	2	04-May-16	100	Run													45	25				
Beaver River	3	04-May-16	200	Run													47	23				
Beaver River	4	04-May-16	300	Run													54	21				
Beaver River	5	04-May-16	400	Run													54	26				
Beaver River	6	04-May-16	500	Run													59	29				
Beaver River	7	04-May-16	600	Run													59	42				
Beaver River	8	04-May-16	700	Run													61	24				
Beaver River	9	04-May-16	800	Run													74	25				
Beaver River	10	04-May-16	900	Run	5708358	469687	738.01										63	27				
Beaver River	11	04-May-16	1000	Run	5708425	469758	737.45	0.56									82	32				
Beaver River	12	04-May-16	1100	Run	5708519	469808	737.16	0.29									94	43				
Beaver River	13	04-May-16	1200	Run	5708586	469879	736.89	0.27									107	43				
Beaver River	14	04-May-16	1300	Run	5708636	469971	736.62	0.27										67				
Beaver River	15	04-May-16	1400	Run	5708660	470072	736.36	0.26										218				C
Beaver River	16	04-May-16	1500	Run	5708743	470140	735.86	0.50										220				C

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 (cm)	Water Depth 2 (cm)	Water Depth 3 (cm)	Mean Water Depth (cm)	Bankfull Width (m)	Wetted Width (m)	Dom. Bed Material Type *	Sub-dom. Bed Material Type **	Cover Type ***	Comments
Beaver River	17	04-May-16	1600	Run	5708828	470222	735.43	0.43										270				C
Beaver River	18	04-May-16	1700	Run	5708906	470296	734.98	0.46										180				C
Beaver River	19	04-May-16	1800	Run	5708975	470367	734.77	0.21										124				
Beaver River	20	04-May-16	1900	Run	5709056	470411	734.61	0.16										71				
Beaver River	21	04-May-16	2000	Run	5709136	470469	734.52	0.08										66				
Beaver River	22	04-May-16	2076	P	5709199	470512	734.47	0.07										150				

* 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.

A – Scattered spawning gravels throughout the reach.

B – Extensive spawning gravels throughout the reach.

C – Channel highly braided and irregular.

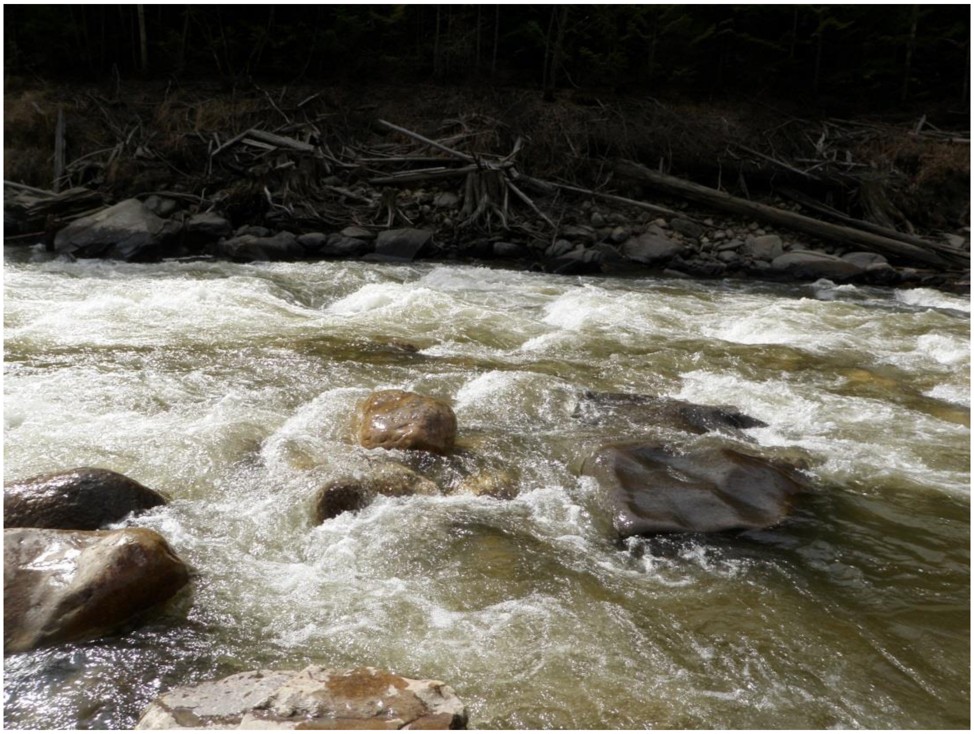
APPENDIX B.2. – TRIBUTARY PHOTOGRAPHS

Photograph 1. Succour Creek at the top of the drawdown zone (April 28th, 2015).

Photograph 2. Looking downstream Succour Creek, approximately 4,910 m below the top of the drawdown zone (April 18th, 2016).

Photograph 3. Horse Creek at the top of the drawdown zone (April 20th, 2016).

Photograph 4. Horse Creek, approximately 340 m below the top of the drawdown zone (April 20th, 2016).



Photograph 5. Ptarmigan Creek at the top of the drawdown zone (April 21st, 2016).

Photograph 6. Looking downstream Ptarmigan Creek, approximately 525 m below the top of the drawdown zone (April 21st, 2016).

Photograph 7. Dave Henry Creek at the top of the drawdown zone (April 22nd, 2016).

Photograph 8. Looking downstream Dave Henry Creek, approximately 500 m below the top of the drawdown zone (April 22nd, 2016).

Photograph 9. Looking upstream from the top of the drawdown zone on Yellowjacket Creek (April 22nd, 2016).

Photograph 10. Yellowjacket Creek, approximately 390 m below the top of the drawdown zone (April 22nd, 2016).

Photograph 11. Cascade at the top of the drawdown zone on the Beaver River (May 4th, 2016).

Photograph 12. Beaver River, approximately 1,500 m below the top of the drawdown zone (May 4th, 2016).

APPENDIX B.3. – STREAM ELEVATION PROFILES THROUGH DRAWDOWN ZONE

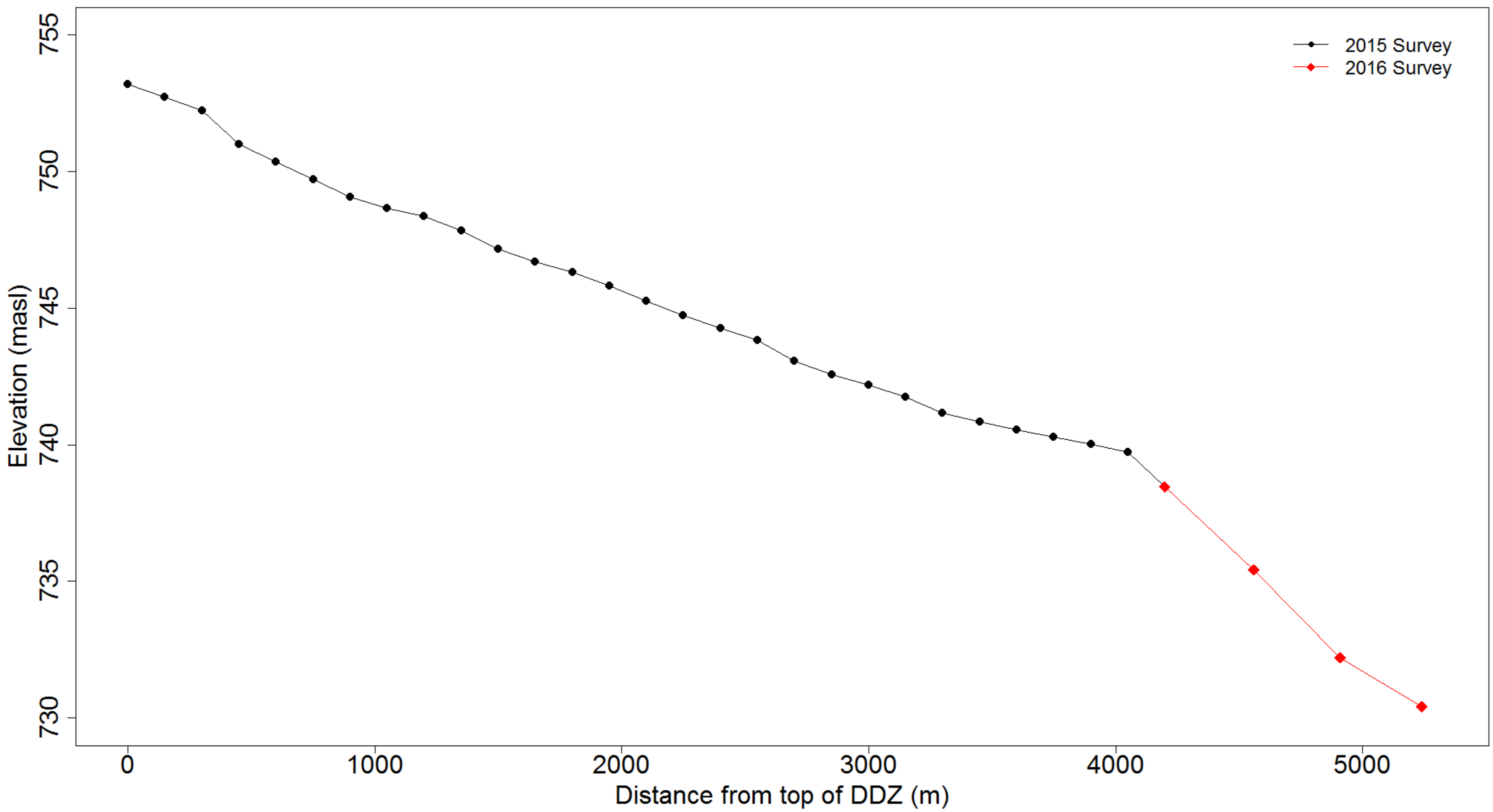


Figure 12: Longitudinal profile of stream elevation for Succour Creek

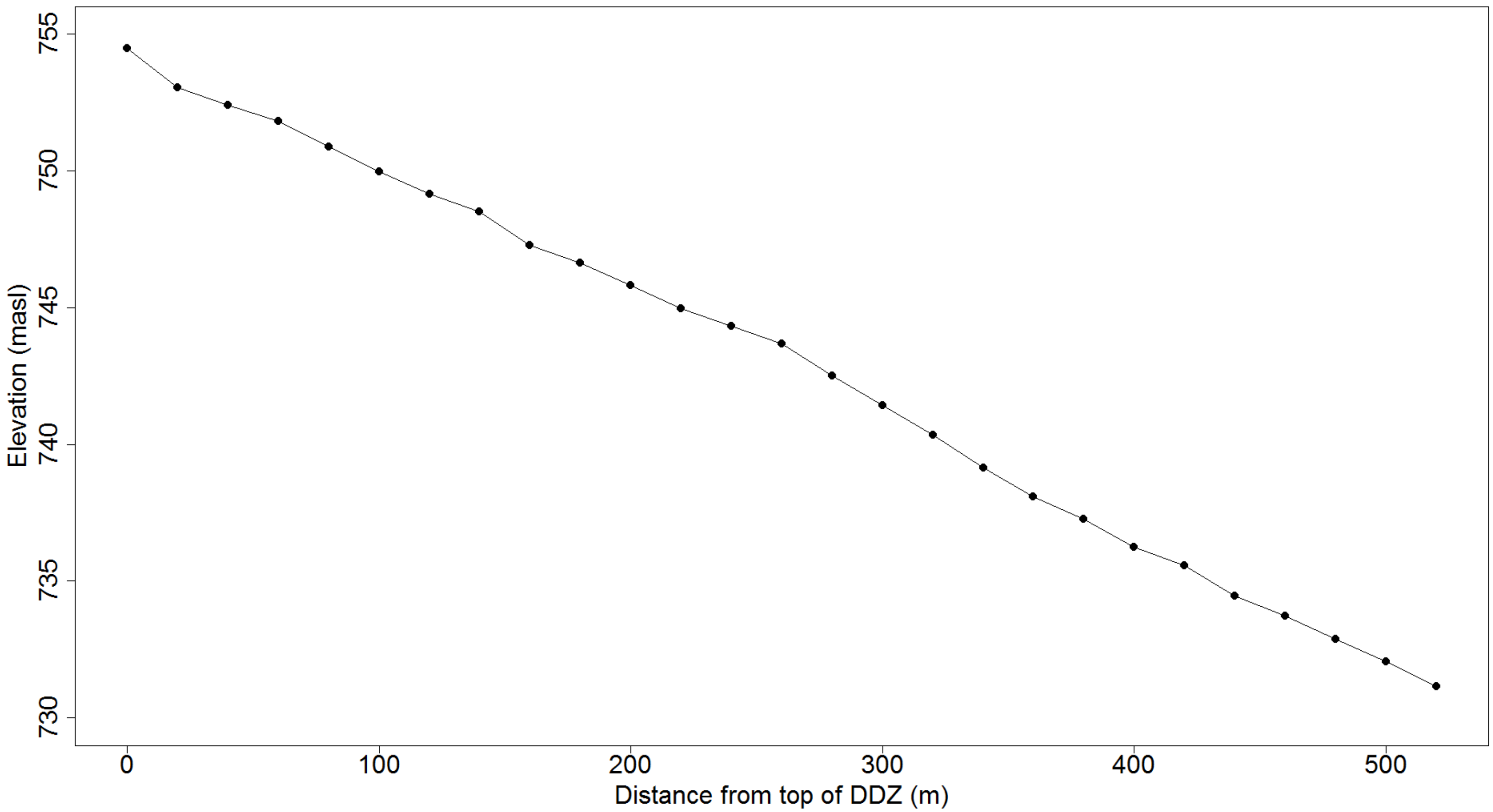


Figure 13: Longitudinal profile of stream elevation for Horse Creek

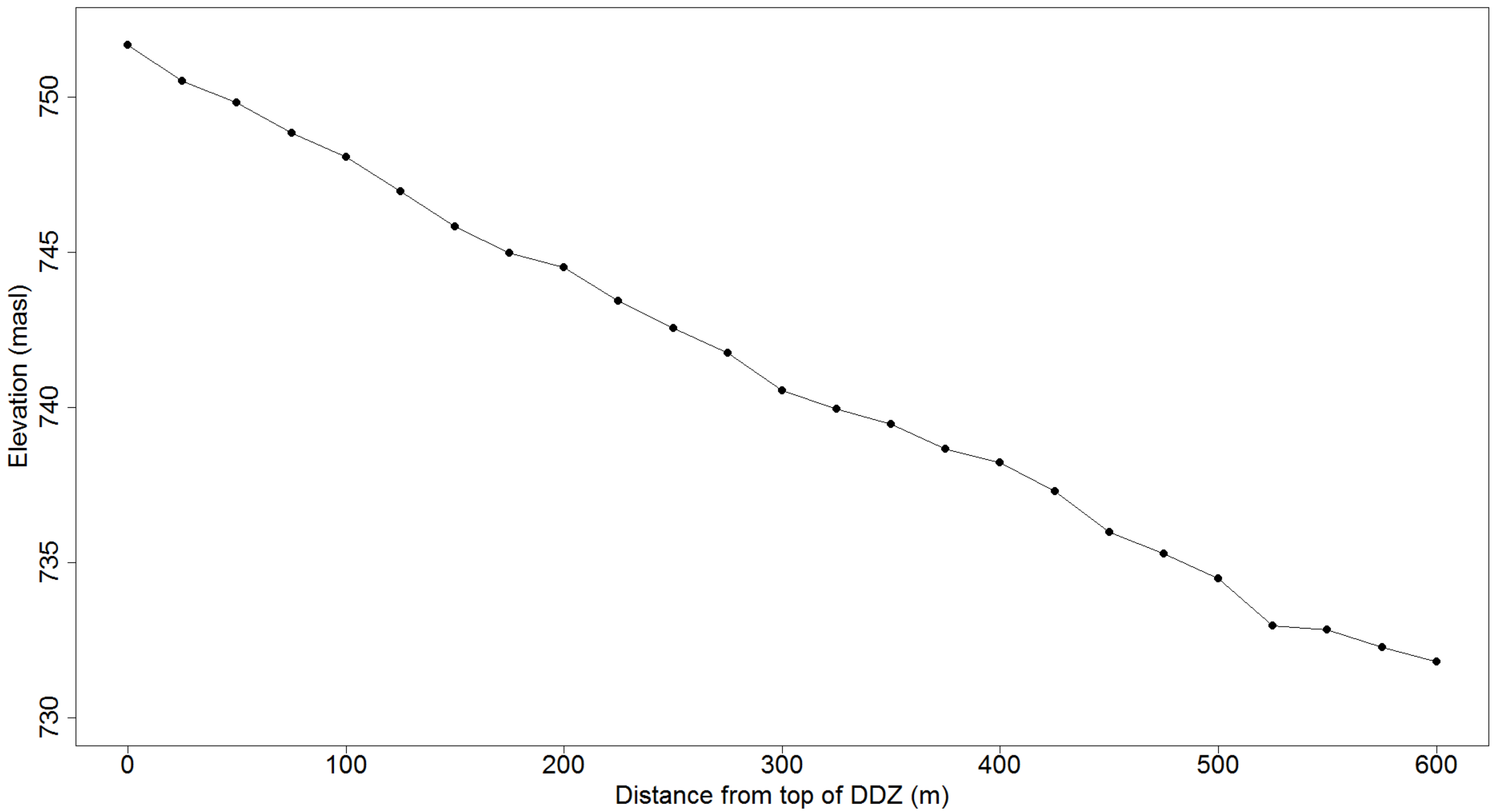


Figure 14: Longitudinal profile of stream elevation for Ptarmigan Creek

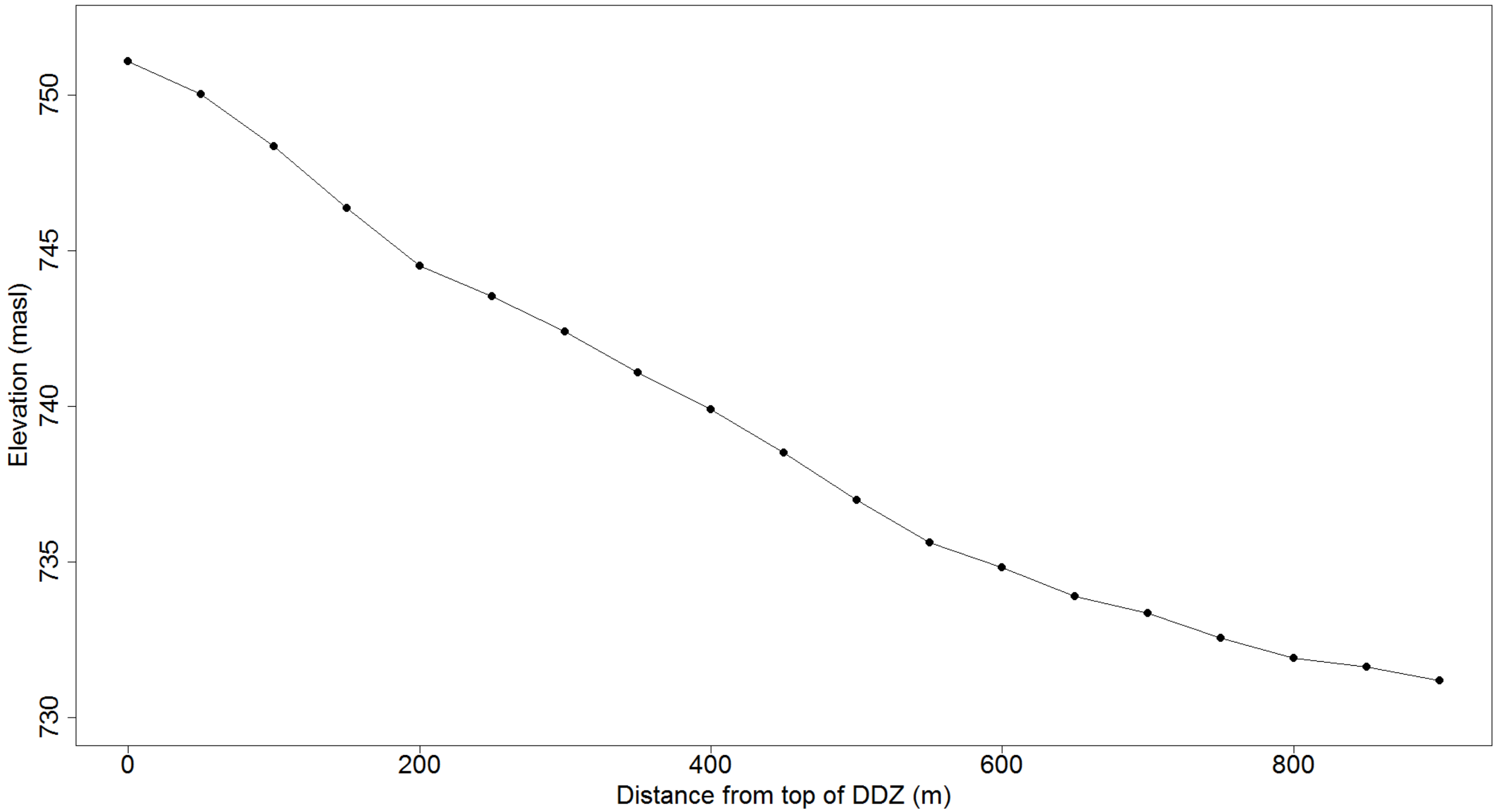


Figure 15: Longitudinal profile of stream elevation for Dave Henry Creek

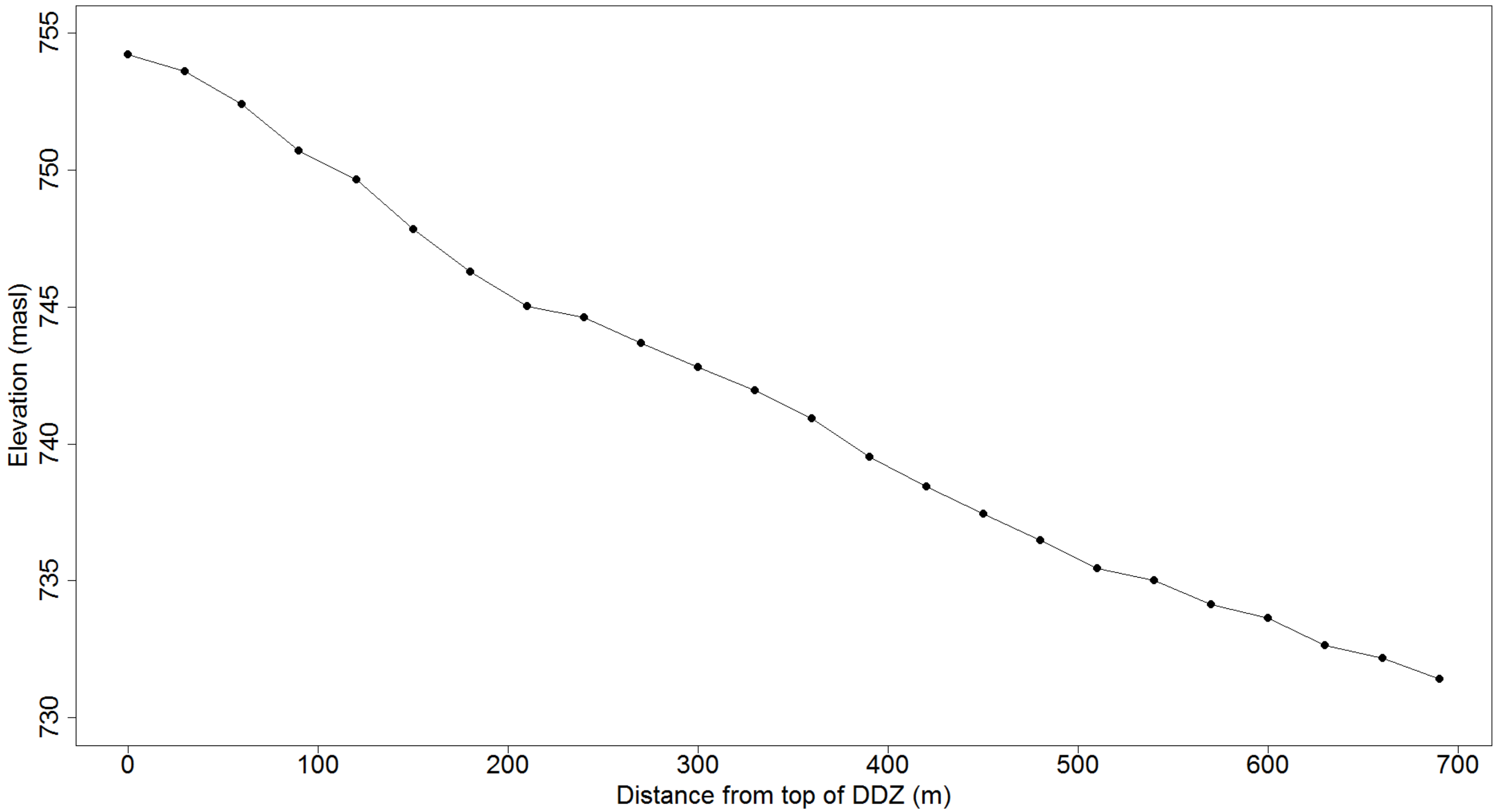


Figure 16: Longitudinal profile of stream elevation for Yellowjacket Creek

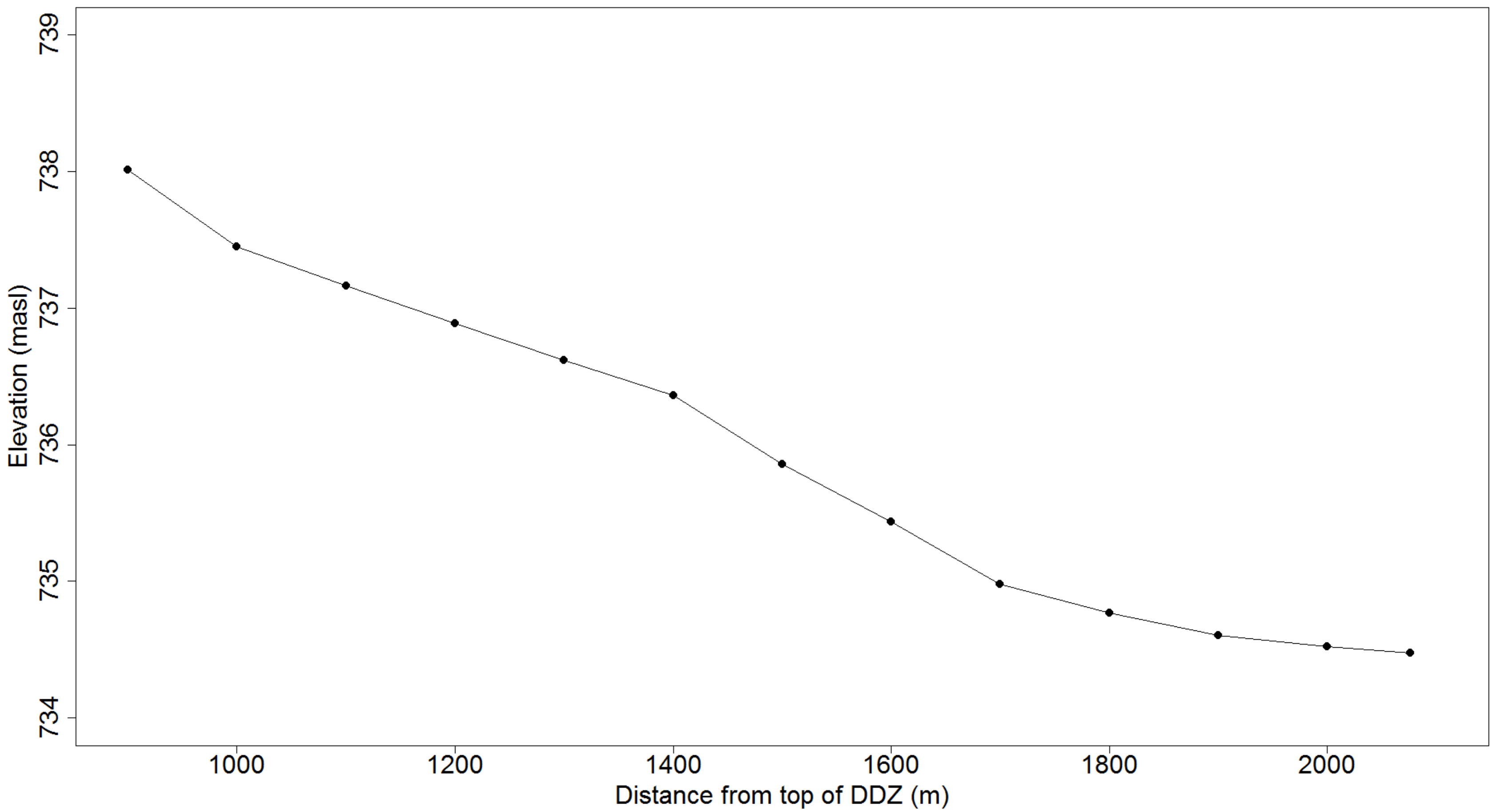


Figure 17: Longitudinal profile of stream elevation for Beaver River