Columbia River Project Water Use Plan

BCH RESERVOIR

Reference: CLBMON-05

Kinbasket Reservoir Burbot Life History and Habitat Use Assessment

Study Period: 2014 – 2018

Ktunaxa Nation Council Society

and

Westslope Fisheries Ltd.

February 15, 2019

EA3533

BCH RESERVOIR

Monitoring Program No. CLBMON-05
Kinbasket Reservoir Burbot Life History and Habitat Use Assessment




Final Report

Prepared for

BC Hydro Generation
Water Licence Requirements
6911 Southpoint Drive
Burnaby, BC

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Prepared by

Ktunaxa Nation Council Society

Technical Contact: Misun Kang, PhD, RPBio.
email; mkang@ktunaxa.org

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Cover photos:

From Clockwise from top left: Cod trap with Burbot caught from Kinbasket Reservoir during spring capture session 2014 (photo credit: Scott Cope, Westslope Fisheries, Ltd.); view of Kinbasket Reservoir at the entrance of the Columbia Reach located north of Encampment Creek, May 27, 2017 (photo credit: Misun Kang, Ktunaxa Nation Council); looking out over Kinbasket Reservoir and cod traps at low pool during spring capture session of burbot, May 2014 (photo credit: Scott Cope, Westslope Fisheries, Ltd.); looking upstream at Wood River with cod traps in foreground at low pool during spring capture session of Burbot, May 2015 (photo credit: Scott Cope, Westslope Fisheries, Ltd.).

EXECUTIVE SUMMARY

Burbot (*Lota lota*) were historically distributed throughout the Columbia and Canoe Rivers, and Kinbasket Lake, which were impounded by the construction of Mica Dam in 1973. Mica Dam created Kinbasket Reservoir, a 216 km long, 43,200 ha ultra-oligotrophic water body. Burbot are present throughout Kinbasket Reservoir. This technical report summarizes the findings of the five year monitoring study (2014-2018) of their life history and habitat use.

Kinbasket reservoir has a normal operating range of approximately 35 m. The reservoir experiences rapid drawdown during the winter months from January to April, when reservoir elevations decline by an average of 4.3 m/month. Burbot spawn during this time period, and the success of their spawning may be affected by declining water levels. Burbot often spawn in shallow water, and fertilized eggs require several weeks to develop before hatching, at which time larvae spend several days resting in substrate before becoming planktonic. It is during this time period that optimal spawning habitat, developing eggs or newly hatched larvae may become stranded by declining water levels in Kinbasket Reservoir. The fact that Burbot still exist in Kinbasket Reservoir implies that their population persists, however, anecdotal evidence suggests there has been a declining population trend over the last two decades. One hypothesis is that spawning success of a component of the population may be affected by operations.

This study used biotelemetry to determine biological characteristics, movement and depth preferences of Burbot when spawning is expected to occur. Previous data on capture rates and logistical constraints limited the capture locations to seven areas focused between the Canoe Arm and Surprise Rapids. Burbot were captured by baited cod traps during the immediate post-spawning period of late April and early May, 2014 and 2015, shortly after ice-off and during the period of minimum reservoir elevation. Capture was conducted in 48 h soaks, in shallow depths (< 20 m) to minimize decompression trauma of captured fish.

A total of 223 Burbot were caught over two seasons of sampling, yielding a catch per unit effort (CPUE) of 0.83 fish/48 hr in Year 1 and a CPUE of 0.64 fish/trapset in Year 2. CPUE was moderate compared to other lakes in British Columbia. Capture success varied between the capture areas targeted in the reservoir, indicating that Burbot abundance is not spatially uniform throughout the study area during their post-spawning period. Burbot size also varied between capture locations. Most Burbot captured were in post-spawning condition.

Ninety-eight (98) Burbot of a broad size range (0.84 – 4.60 kg) were surgically implanted (Spring 2014 and Spring 2015) with combined acoustic-radio transmitters (CART) that transmit depth (accuracy ± 1.4 m) and temperature (accuracy ± 0.8 °C) sensor data. These fish were tracked year-round by fixed acoustic receivers from Spring 2014 to Spring 2018. Aerial radio tracking had been attempted in Winter/Spring 2015 but was discontinued due to poor detection rates. Receivers were placed in areas designed to detect broad scale movements and in the vicinity of stream confluence areas suspected of being spawning areas. Burbot depth and water temperature data were recorded by receivers year-round and used to determine movements towards spawning areas and depths used during the spawning season.

Mobile and fixed receiver tracking data collected from 2014 to 2018 indicated no clear movement pattern towards a specific congregation location in the pre-spawning and early spawning season. Most detections were made at Wood River, Sullivan River, Kinbasket River, and Kinbasket Outlet/Inlet. While data from fixed acoustic receivers

indicated variability in the depths occupied by Burbot, significant differences among seasonal depth occupation patterns were observed in shallower habitat (approximately <16 m) use during assumed periods of spawning (spring) and deeper habitat use (approximately >20 m) during fall/early winter.

Final status of CLBMON-05

Management Question	Hypothesis	Summary of Key Monitoring Results
MQ-1 What are some basic biological characteristics of Burbot populations in Kinbasket Reservoir (e.g., distribution, abundance, growth and age structure)?		• Burbot are not evenly distributed throughout the study area; • Burbot were captured in a variety of benthic habitats and do not have microhabitat preferences; • Kinbasket Reservoir appeared to have moderate trap CPUE relative to other BC lakes that have been studied. Comparison of CPUE must consider spatial and depth scaling, as well as gear saturation; • Burbot captured in 2014 had a mean length of 666.7 ± 101.07 mm (n = 79) and mean weight of 1.6 ± 0.70 kg (n= 80) while Burbot captured in 2015 had a mean length of 659.1 ± 115.40 mm (n= 94) and mean weight of 1.5 ± 0.67 kg (n=93). For both year, mean length was 662.7 ± 108.85 mm (n=73) and mean weight was 1.6 ± 0.69 kg (n=173); • Clear seasonal patterns in depth occupation and field observations of Burbot suggest that spawning occurs during March-April
MQ-2 Does winter drawdown of Kinbasket Reservoir cause the dewatering of Burbot spawning habitat and affect spawning success?	H1: Does winter drawdown of Kinbasket Reservoir cause the dewatering of Burbot spawning habitat and affect spawning success?	The hypothesis could not be directly tested due to safety hazards. Field observations indicated that high turbidity, fine sediment transport, and sub-optimal water temperatures (greater than 6.0 °C) potentially created by reservoir operations during the suspected spawning period might affect egg incubation and/or spawning success.
	H2: Winter drawdown of Kinbasket Reservoir causes dewatering of access to Burbot spawning habitat in some years.	The hypothesis could not be directly tested due to safety hazards. Field observations indicated that high water velocity and backwatering created by reservoir operations during the suspected spawning period might affect Burbot access to suitable spawning habitat.

Management Question	Hypothesis	Summary of Key Monitoring Results
MQ-3 Can modifications be made to the operation of Kinbasket Reservoir to protect or enhance spawning success of these Burbot populations?		Further assessment would be required to confirm spawning areas of Burbot in Kinbasket Reservoir, as well as identify key spawning habitat that may be impacted by dam operations. If spawning habitat is confirmed to occur within the drawdown zone, further work would be required to assess the feasibility of works to improve access to suitable spawning habitat and egg incubation conditions, such as adapting an operational regime that minimizes sediment transport, high flows, and backwatering.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Burbot (*Lota lota*) were identified by the Columbia River Water Use Plan Consultative Committee (WUP CC) as a key fish species of concern in Kinbasket Reservoir given 1) their importance to the sport fishery, 2) the potential for links between reservoir operations and Burbot population productivity, and 3) the dearth of information regarding Burbot biology in the reservoir (Harrison et al., 2013). The WUP CC hypothesized that the greatest potential impact of reservoir operations on Burbot populations may be the dewatering effect of winter drawdown on spawning success and egg survival in sites along the shoreline and in lower sections of tributaries. The WUP CC also had concerns that winter drawdown could affect the quality of Burbot spawning habitat in tributary streams of Kinbasket Reservoir. To address these concerns, the WUP CC recommended that a life history and habitat use assessment be undertaken in Kinbasket Reservoir to gain a better understanding of how the current operating regime might be affecting Burbot populations.

Burbot typically spawn between late January and April, with timing on major Columbia River system reservoirs (Duncan and Arrow) occurring in mid-February to early April (Arndt and Hutchinson, 2000; Bisset and Cope, 2002; Prince and Cope, 2008; Cope, 2011; Robichaud et al., 2013). Burbot spawn in both in lacustrine and lotic habitats (Taylor and McPhail, 2000; McPhail, 2007). Burbot have been observed to spawn on sand, gravel, cobble, and bedrock in Beaton Arm/Flats of Arrow Reservoir (Robichaud et al., 2013), as well as on silt, fine sand, gravel, and cobble in Upper Duncan River (Westslope, 2010). Although there is no site preparation as eggs are broadcast into the water column above the substrate, the drifting, semi-buoyant eggs eventually settle into interstitial spaces of substrate (Taylor and McPhail, 2000; McPhail, 2007). Eggs incubation occurs over a period of 30-60 days (Taylor and McPhail, 2000; McPhail, 2007). After hatching, lacustrine larvae spend several days resting on the bottom before becoming free-swimming and planktonic in the water column. Newly hatched lotic larvae drift downstream from spawning tributaries to quiet water areas, which provide important nursery sites (McPhail 1997). It can be expected that the period of spawning and egg and early larval development occurs between February and May-June in Kinbasket Reservoir, which coincides with the period when reservoir water levels can decline by an average of 4.3 m/month before reaching low pool elevation (Figure 1).

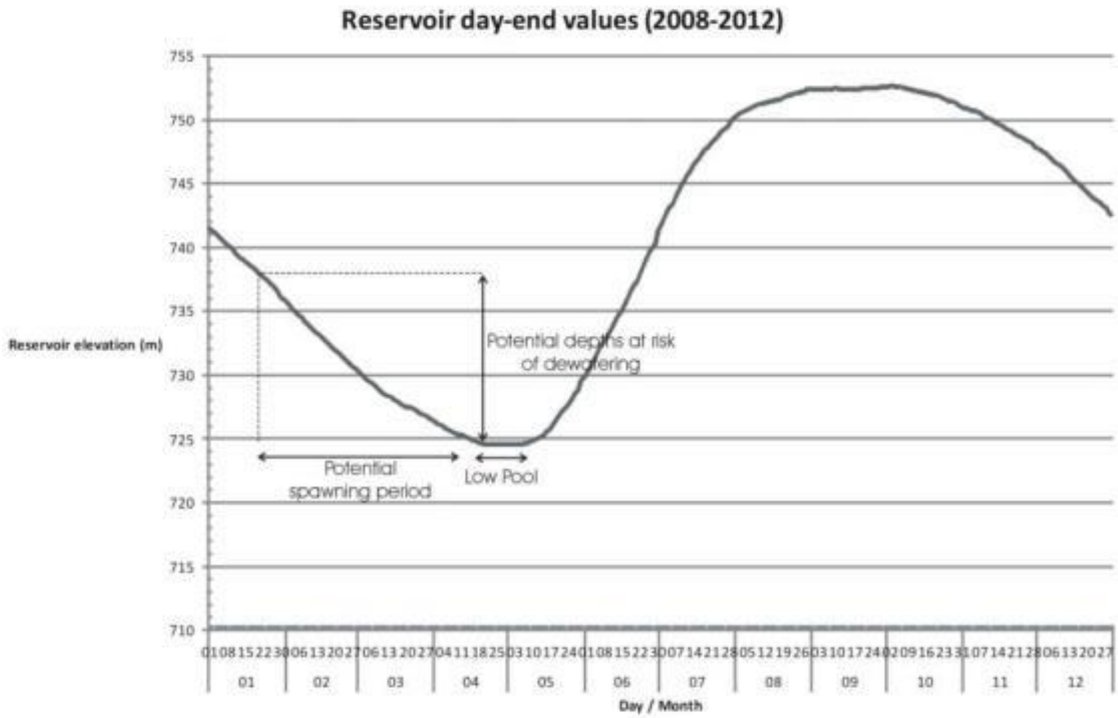

Figure 1: Potential elevations used by Burbot during the spawning period that are at risk of dewatering in an average year of reservoir operation. Lower elevations are at less risk for dewatering as the spawning season progresses. Line represents mean water elevation from 2008 to 2012.

The greatest potential impact of reservoir operations on Burbot populations may be the dewatering effect of winter drawdown on spawning success and egg survival in sites along the shoreline and in lower sections of tributaries. Burbot spawn in aggregations, often at night (McPhail, 2007), and vocalization appears to be a key behaviour that may aid Burbot in locating each other for spawning (Cott et al., 2014). In lakes and reservoirs, spawning may occur over near-shore shallows or over shallow offshore reefs and shoals (Ford et al., 1995; McPhail, 2007; Spence, 1999; Prince and Cope, 2008); however, deeper spawning (>20m) may also take place (Robichaud et al., 2013). In rivers and tributaries, Burbot spawn in low velocity areas in main channels and in side channels behind depositional bars (McPhail, 2007). In many cases, spawning in lakes is often associated with tributary confluences or upwelling but is not associated with specific microhabitats, as Burbot may select a range of substrate, habitat characteristics and depths to spawn (Ford et al., 1995; McPhail, 2007; Andrusak, 1998; Baxter et al., 2002; Spence and Neufeld, 2002; Prince and Cope, 2008; Cope, 2011). Spawning occurs above the substrate and eggs are broadcast into the water column, which eventually settle into interstices in the substrate (McPhail, 1997). The depth at which spawning takes place, coupled with the timing of spawning until the period of maximum drawdown in April, dictates whether there is a risk of spawning failure due to dewatering of eggs from reservoir operations (Figure 1).

Declining water levels may also interfere with Burbot spawning migration and spawning activity. In a radio telemetry study of adult Burbot in Duncan Reservoir, the extent of spawning migration into the upper Duncan River appeared to be influenced by reservoir water levels and their impacts on back-flooding and stream velocity (Spence and Neufeld, 2002; Cope, 2011). As back flooding from Duncan Reservoir declined, Burbot tended to move downstream into areas with lower water velocities than the locations they had abandoned. Since stream spawning Burbot tend to spawn in low velocity stream habitats (McPhail, 2007), these fish may have been moving downstream to more suitable lower velocity spawning sites. Burbot are known to have low swimming endurance and biotelemetry results in the Kootenay River below Libby Dam suggest that spawning migrations of Burbot in the Kootenay River may be disrupted by high flows produced during hydropower production and flood control (Paragamian, 2000).

The operational impacts of Mica Dam depend on the life history strategy of resident Burbot populations. As there is no pre-dam life history information available for Burbot populations in this area, assessment of impacts must rely on estimation based on habitat features, other species, and other Burbot populations. What is known is that there was habitat connectivity between the historic Kinbasket Lake and the upper Columbia watershed prior to dam construction and operation. The literature suggests that all three life history forms of Burbot (lacustrine, adfluvial, fluvial) often co-exist within the same system (McPhail, 2007) and this may have been the case for Burbot occupying the historic Kinbasket Lake and upper Columbia system that is now inundated by Kinbasket Reservoir. Adfluvial and lacustrine remnant life history forms may still be present, the population may be supported by fluvial immigrants from upstream sources, or a combination of life history forms may exist. The relative contributions or existence of these three life history forms to the current Kinbasket Burbot population is unknown.

While the life history and population status of Kinbasket Lake and Columbia River Burbot before dam construction are largely unknown, recent studies have provided some insights into important habitats and distribution of remnant stocks (Prince, 2001; Harrison et al., 2013). Growth rate is highly variable, as within other populations (Cope, 2011). Burbot capture is relatively consistent and successful in the Canoe Reach confluence, Bush pool, and historic Kinbasket Lake areas of the reservoir, as well as near tributary confluences in the Sullivan, Bush and Wood arms and Hugh Allan Creek (Figure 2; Prince, 2001; Prince, 2011; Harrison et al., 2013). Most Burbot (~2/3 of fish captured in the confluence area between the Columbia and Canoe Reaches) appear to make limited seasonal movements, as well, diel vertical migration and shifts to shallower habitats in winter are common (Harrison et al., 2013). This suggests that there may be many, non-central spawning areas, and/or that fish may not spawn annually, a common observation for Burbot (Paragamian and Wakkinen, 2008), especially those in reservoirs (Dunnigan and Sinclair, 2008). Burbot that move out of the confluence area do not appear to migrate towards a central spawning area (Harrison, pers. comm.).

This monitoring program was to provide a quantitative baseline dataset to establish basic biological characteristics of the Burbot populations in Kinbasket Reservoir. It also provided information on habitat use, life history and rough estimates of abundance, and possible factors affecting Burbot productivity. Specifically, the assessment addressed uncertainty regarding the extent to which Burbot are present in the drawdown zone during the spawning season, and if these areas are at risk for dewatering during the operational years of the study.

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

The monitoring program provides 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 provides information required to support future decisions around maintaining the current operating regime or modifying operations to protect reservoir Burbot populations.

2.0 MANAGEMENT QUESTIONS AND HYPOTHESES

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

1) What are some basic biological characteristics of Burbot populations in Kinbasket Reservoir (e.g., distribution, abundance, growth and age structure)?

2) Does winter drawdown of Kinbasket Reservoir cause the dewatering of Burbot spawning habitat and affect spawning success?

3) Can modifications be made to the operation of Kinbasket Reservoir to protect or enhance spawning success of these Burbot populations?

The monitoring program provides a quantitative baseline dataset to establish basic biological characteristics of the Burbot populations in Kinbasket Reservoir. It provides information on habitat use, life history and rough estimates of abundance, and possible factors affecting Burbot productivity. Specifically, the assessment addresses uncertainty regarding the extent to which Burbot are present in the drawdown zone during the suspected spawning season, and if these areas are at risk for dewatering during the operational years of the study.

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

H1: Winter drawdown of Kinbasket Reservoir causes dewatering of Burbot spawning habitat, which reduces egg survival and Burbot spawning success.

H2: Winter drawdown of Kinbasket Reservoir causes dewatering of access to Burbot spawning habitat in some years.

3.0 STUDY AREA

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, 2011). The reservoir can be coarsely segregated into two main reaches, with the Columbia and Canoe reaches meeting at the historic confluence of the Canoe and Columbia rivers, where the Columbia River turns southward approximately where Mica Dam is currently situated. The reaches of the reservoir are typically bounded by steep valleys and are narrow, with stretches becoming riverine at low pool. 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 Kinbasket reservoir elevations varying between a maximum of 754.38 m and a minimum 707.41 m, and being occasionally brought up to a maximum elevation of 754.68 m if there is a high probability of spill. Normal operating level for the 2008-2012 period was from a mean maximum of 753.26 m and a minimum of 718.12 m, with a normal operating range of 35.14 m. Drawdown from full pool normally begins slowly in September, and draft rate increases through the winter, with a levelling off of drafting and normal low pool occurring in mid-late April. During the spring period, discharge from Mica dam decreases, which coincides with the normal spring freshet, which rapidly refills the reservoir through the spring and early summer.

4.0 METHODS

4.1 *Overview*

The general approach of this study draws upon the designs of previous Water Use Planning Burbot life history and habitat use studies, particularly CLBMON-31 (Glova et al., 2009, 2010; Robichaud et al., 2011, 2012, 2013) and DDMMON-11 (Cope; 2009, 2010, 2011), and refines them.

See Section 8.2 in Appendix 2 for further details on methodology for the study.

4.2 *Datasets*

Table 1: Summary of datasets assessed for CLBMON-05

Dataset	Reference	Management Question	URL
Year 1 Burbot capture and tagging	Year 1 Report (2014)	MQ-1	https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/clbmon-5-yr1-2014-10-01.pdf
Year 1 opportunistic radio tracking	Year 1 Report (2014)	MQ-1	https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/clbmon-5-yr1-2014-10-01.pdf
Year 1 helicopter radio tracking	Year 2 Report (2016)	MQ-1	https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/clbmon-5-yr2-2016-03-14.pdf
Year 1 fixed receiver tracking	Year 2 Report (2016)	MQ-1	https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/clbmon-5-yr2-2016-03-14.pdf

Year 2 Burbot capture and tagging	Year 2 Report (2016)	MQ-1	https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/clbmon-5-yr2-2016-03-14.pdf
Year 2 fixed receiver tracking	Year 3 Report (2017)	MQ-1	https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/clbmon-5-yr3-2017-02-20.pdf
Year 3 fixed receiver tracking	Year 4 Report (2018)	MQ-1	https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/corporate/environment-sustainability/water-use-planning/southern-interior/clbmon-5-yr4-2018-07-03.pdf
Year 4 fixed receiver tracking	Year 5 Report (2019)	MQ-1, MQ-2	This report

4.3 *Data relevant to Management Questions*

The main body of this report summarizes the synthesis of data analyses conducted for the 5-year study to answer the MQs. The synthesis of data analyses are presented in Appendix 2 (Section 9.4). Table 1 provides an overview of data relevant to MQ 1 and 2. Due to logistical and safety constraints in collection of data during the suspected spawning period, we were not able to directly assess dewatering of spawning habitat and access to spawning habitat but we used observational data of habitat to answer MQ3. We provide recommendations in Section 5.0 to address knowledge gaps to further address the MQs.

The study was designed to answer three management questions (MQs). Unfortunately, the main drawbacks of work on Kinbasket reservoir are the size of the system, and inability to conduct on-reservoir work during Burbot spawning season in January-March. During that time, Kinbasket reservoir has unpredictable, dynamic ice conditions that make on-reservoir winter work unsafe. In addition, the remoteness of the reservoir requires extensive travel with limited safe access and contact points.

The study was concentrated between the Wood Arm and Columbia Reach (Figure 2). This area was chosen based on previous information of Burbot occurrence and logistical considerations for working from the only accessible boat launch near Mica Dam during the low pool period. Given the safety and logistical constraints, the study design attempted to answer MQs without working on-reservoir during the spawning season, and used a combination of fixed receiver and mobile helicopter tracking. These methods attempted to infer whether fish were present and congregating in shallow drawdown habitats during the spawning season.

This approach cannot confirm spawning activity. Presence of aggregations of Burbot and occupation of relatively shallow depths over multiple days during the potential spawning period were treated as indicative of potential spawning activity when addressing the management hypotheses outlined in Section 2.0. See Appendix 2 (Section 9.2) for details on the Burbot capture/tagging and fixed receiver tracking.

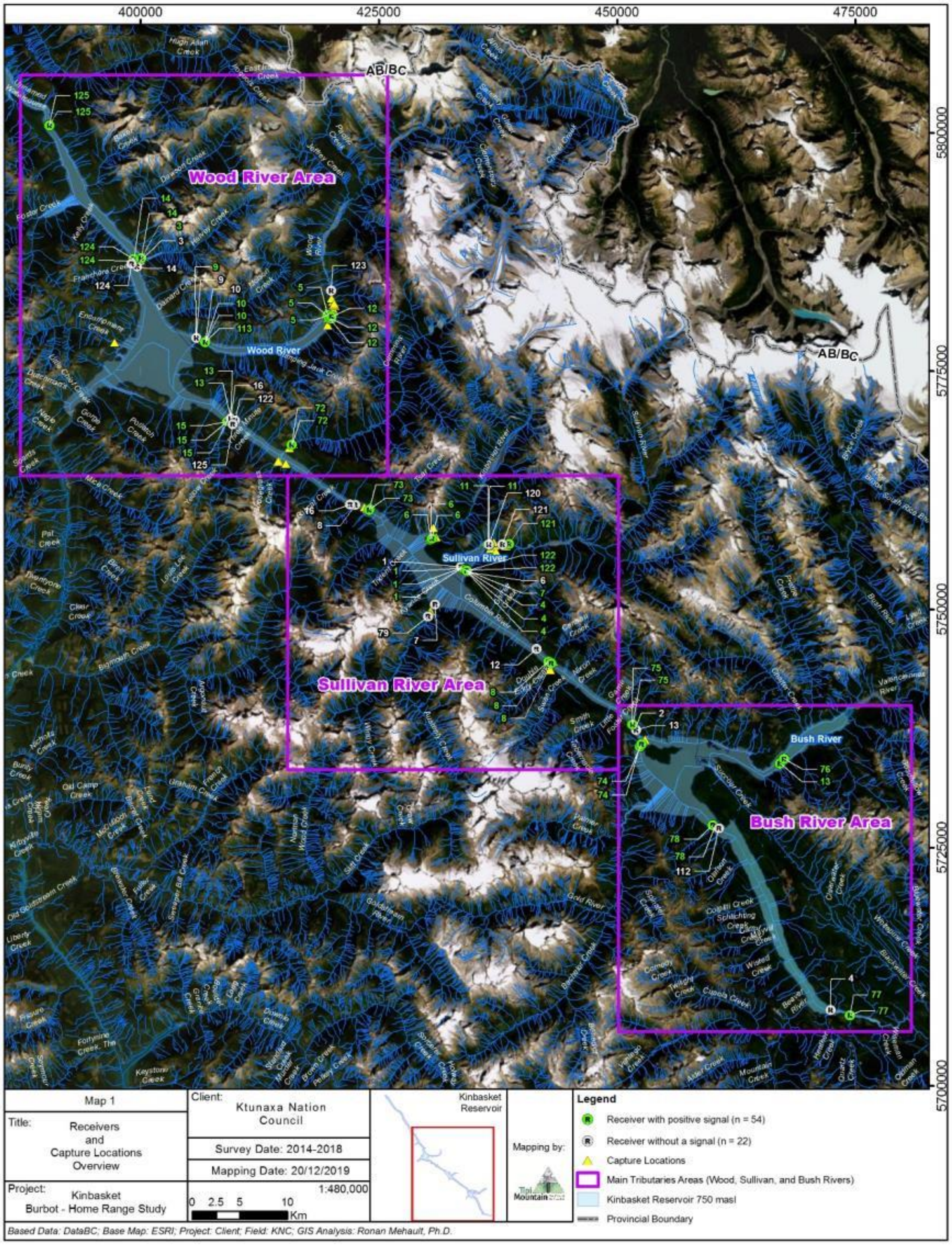

Figure 2: Locations of Burbot captures (yellow triangles) and acoustic receivers (symbols and numbers; n=30) within the Kinbasket Reservoir study area.

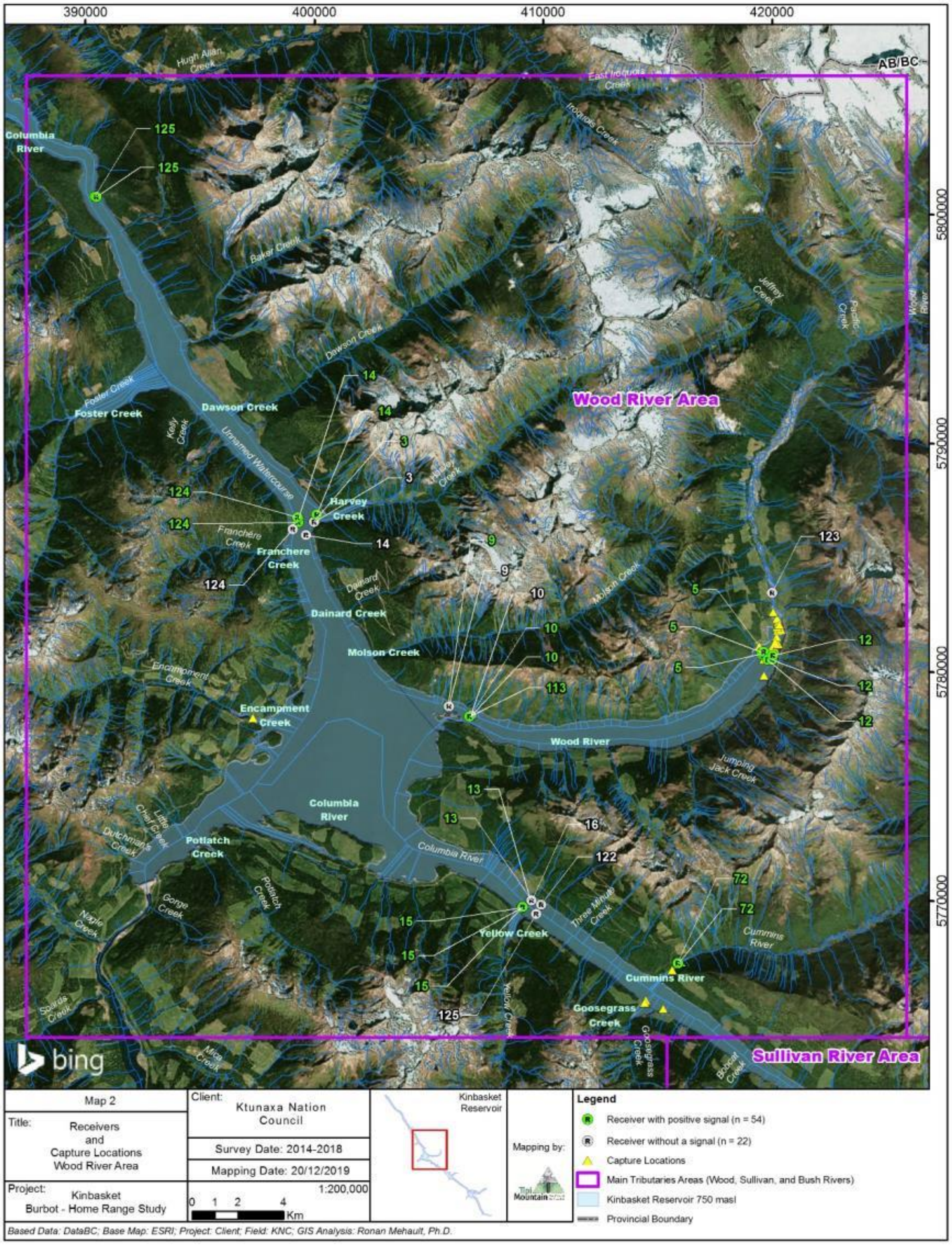

Figure 3:Locations of Burbot captures (yellow triangles) and acoustic receivers (symbols and numbers) within the Wood River study area of Kinbasket Reservoir.

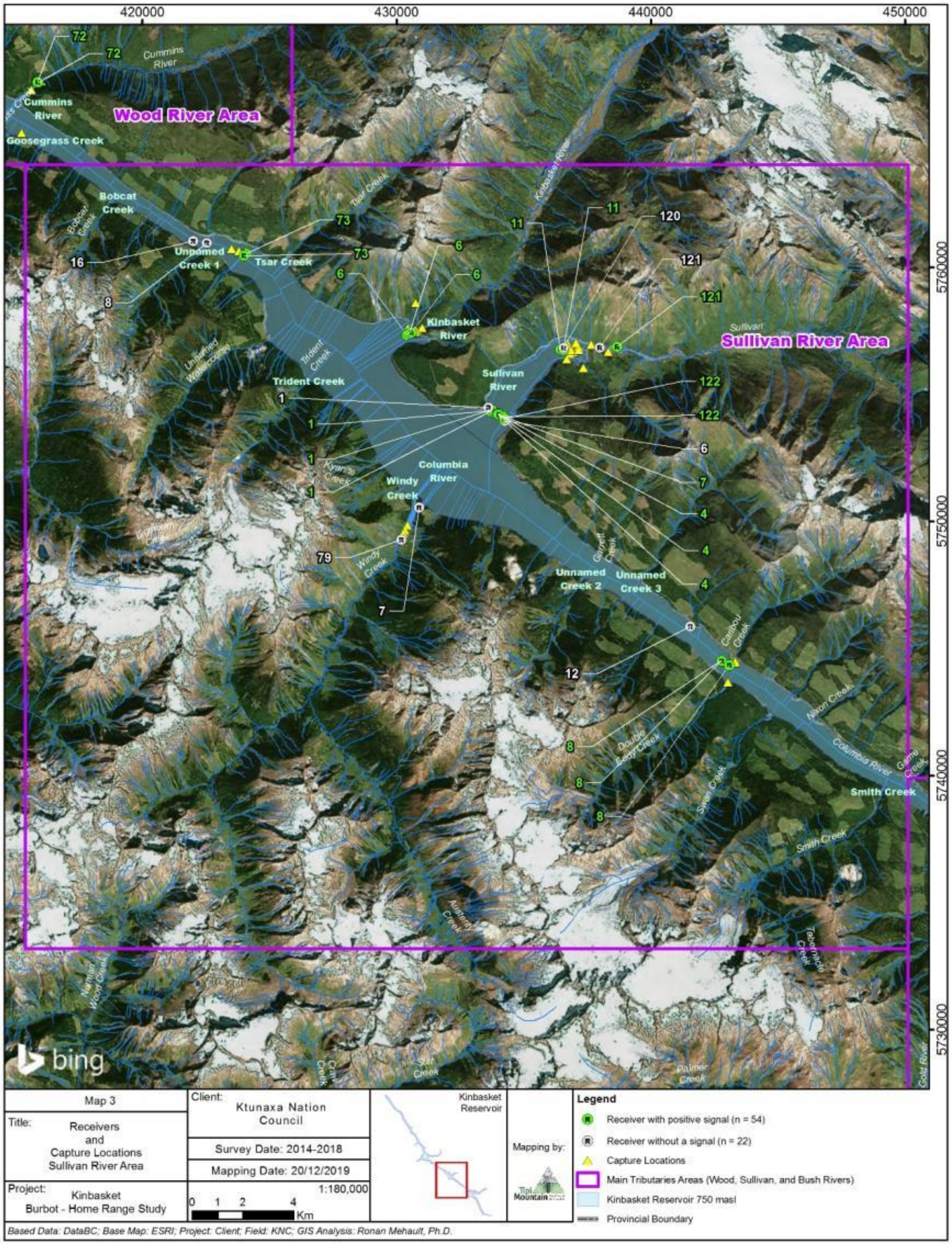

Figure 4:Locations of Burbot captures (yellow triangles) and acoustic receivers (symbols and numbers) within the Sullivan River study area of Kinbasket Reservoir.

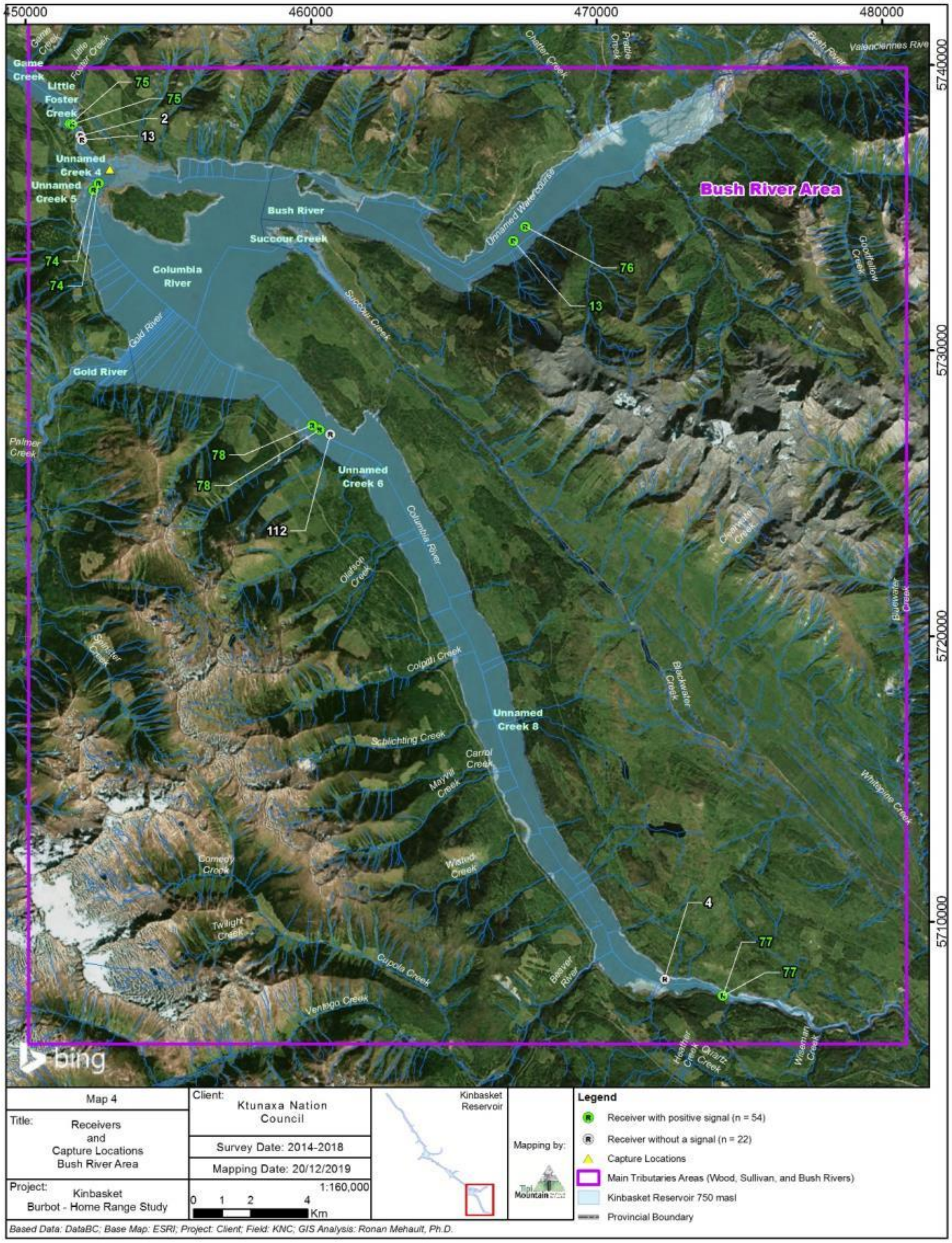

Figure 5: Locations of Burbot captures (yellow triangles) and acoustic receivers (symbols and numbers) within the Bush River study area of Kinbasket Reservoir.

5.0 Results and Discussion

The primary aim of this monitoring program was to provide baseline information on the Burbot population in Kinbasket Reservoir to better inform the relationship between reservoir operations and recruitment. We discuss conclusions related to each management question and associated management hypotheses based on findings from this and other Water Use Planning studies using a weight of evidence approach.

5.1 MQ1: What are some basic biological characteristics of Burbot populations in Kinbasket Reservoir (e.g., distribution, abundance, growth and age structure)?

5.1.1 Burbot capture and tagging

Distribution. Burbot capture success varied amongst sampling areas in Kinbasket Reservoir. This implies that Burbot are not evenly distributed throughout the reservoir, a common observation in other lakes (Cope 2011; Robichaud et al., 2012). Over the two years of study (2014 and 2015), the Wood Arm had the highest catch and the Kinbasket River confluence the lowest catch. New reservoir areas sampled in Year 2 of the study, particularly those focused around the perimeter of historic Kinbasket Lake, did not have different capture rates than the majority of other areas sampled that year. This area was suspected to have higher capture rates prior to undertaking the study because of the potential for persistence of an historic lacustrine morph that may have been present prior to the construction of Mica Dam (Warnock et al., 2014).

Qualitative observations of habitat at capture locations indicate that Burbot were captured in a variety of habitats. This supports the observation that Burbot are benthic, but specific microhabitat preferences of adults for substrate are not necessarily specialized (McPhail 2007).

Abundance. Kinbasket Reservoir appeared to have moderate trap CPUE relative to other lakes that have been studied in British Columbia (Kang et al., 2016). It is important to note that sampling effort for this study was neither randomized spatially nor by depth, and CPUE estimates reflect the targeted approach taken to maximize catch based on suspected spawn timing and known Burbot locations. It is also important to note that the study area covered 43% of the total area of the reservoir, thus the estimate should not be a reflection of the reservoir as a whole. Other possible confounding factors that may affect capture success include soak time (gear saturation), bait type and quality, trap placement, study design and effort, season, crew experience, depth and trap type used (Prince 2007). Thus, extreme caution is recommended when comparing CPUE estimates among lakes or studies. Randomized grid trap placement, stratified both spatially and by depth is the most preferable for comparisons to evaluate relative abundance, as spatial and depth biases are minimized. Effort must be scaled to the size of the system, as high error may result in large lakes if sufficient effort cannot be expended on trapping for a sufficient spatial coverage.

This study's finding of a negative relationship between $CPUE_{day}$ and soak time implies that estimates of $CPUE_{day}$ decreases with increased soak time. The reasons for this are unknown, but may be due to gear saturation, whereby a successful capture event reduces the probability of a subsequent capture event. Traps may become saturated for a variety of reasons, including reluctance to enter the trap if fish are already present or decreased quantity/quality of bait over time. Saturation may also occur if the gear samples a small fishing area rapidly and no fish recruit into the fishing area over the length of the soak. This suggests that $CPUE_{day}$ is sensitive to soak time, and that standardized trapset length is necessary if $CPUE_{day}$ is to be used as a metric for comparison purposes or indexing. Alternatively, a minimum trapset soak time may be employed, using capture as a binary response variable, or CPUE should preferentially be reported as $CPUE_{set}$. The two years of capture data suggested that longer soak times do not result in higher probability of Burbot capture once saturation is reached. This supports the use of Burbot capture success as a binary response variable when comparing relative abundance of Burbot in Kinbasket Reservoir with other systems, providing traps are set for a minimum of 24 hours.

Length and weight of Burbot captured in 2014 and 2015 are summarized in Table 2 (Warnock et al., 2014; Kang et al., 2016). Burbot size was weakly correlated with the year of sampling (Burbot were larger in Year 1 than in Year 2) and with reservoir area, when controlling for depth in a linear model (Kang et al., 2016). Using 2014 data alone, we found that Burbot size was weakly, but positively associated with increasing sampling depth (Warnock et al., 2014). Greater depths were sampled in 2015, and the trend was no longer significant when these data were included (Kang et al., 2016).

Table 2: Summary of length and weight of Burbot captured in Kinbasket Reservoir for CLBMON-5 study (2014-2015).

Capture Data	Mean Length ± SD (mm), n	Length Interquartile Range (mm)	Length Min/Max (mm)	Mean Weight ± SD (kg), n	Weight Interquartile Range (mm)	Weight Min/Max (mm)
2014	666.7 ± 101.07, 79	590 - 726	465/950	1.6 ± 0.70, 80	1.2 - 1.9	0.58/4.6
2015	659.1 ± 115.40, 94	574 - 738	383/939	1.5 ± 0.67, 93	1.1 – 1.9	0.29/4.0
All	662.7 ± 108.85, 173	587 - 735	383/950	1.6 ± 0.69, 173	1.14 - 1.86	0.29/4.6

5.1.2 Mobile and fixed receiver tracking

Fixed acoustic tracking information (2014-2017) showed clear seasonal patterns in depth occupation, as the sample sizes of detections in the suspected spawning period (i.e., January to April) supported robust statistical tests from Year 2 to Year 4 during which receivers retained suitable battery life for the monitoring periods. While there was variability in the depths occupied by Burbot, they generally occupied relatively shallow areas during the suspected spawning period and deeper areas in Fall/Winter (see Appendix 2).

The timing and sequence of occupation from the deep to the shallowest depths (See Depth Occupation discussion in Appendix 2; A2 Figure 7) is associated with a time period that could coincide with Burbot spawning (January to April; Harrison et al., 2013). This may reflect true movement to shallower depths during the suspected period for spawning, some other activity, or it may indicate occupation of shallower depths at this time of year as the spatial extent of the reservoir becomes constricted by reservoir drawdown. Receivers were installed so their locations were fixed in relation to the water surface so detections provide an indication of Burbot depth in relation to the reservoir elevation; however, this cannot provide an indication of position in relation to the reservoir bottom. Burbot are well known to be benthic (Fischer 2000a, 2000b), hence, we expect that depth detections likely reflect benthic behaviour, which might be influenced by winter reservoir drawdown. The high proportion of detections at Wood, Sullivan, and Kinbasket rivers all-year-round suggests that these areas provide preferred Burbot habitat and that occupation at Wood River is especially predominant during Fall and the suspected spawning period (see section 9.5 Results)..

Aerial radio tracking was conducted from February to April 2015 and indicated that Burbot use shallow water habitat during these months (Kang et al., 2016). The highest number of Burbot detected by radio tracking was on March 22, 2015 (n=12), indicating a possible peak time of shallow habitat use (Kang et al., 2016). There were also several observations of river habitat occupation from radio tracking data during this time period (Kang et al., 2016). These fish were detected at the Sullivan River (identified by local anglers as a historic location for large Burbot capture; Prince, 2001) and Cummins River. They made limited movements (<2 km) upriver. It is hypothesized that this behaviour is indicative of a segment of the population that engages in an adfluvial life history, undertaking limited movements up large spawning tributaries. Burbot were also located in confluence areas of Bobcat Creek, Kinbasket, Smith, Sullivan rivers and in mainstem areas (e.g., upstream of Surprise Rapids; Kang et al., 2016).

Burbot spawning occurs during winter months in most populations (McPhail 2007). Our assumption of a spawning period from January to April in Kinbasket Reservoir was supported by depth occupation detections from fixed acoustic and aerial radio tracking and requires confirmation. However, Burbot were observed to occupy shallow depths during March through to Spring, suggesting spawning may occur during the latter part of the suspected spawning period, perhaps beyond April into spring, and/or that Burbot may occupy shallow areas during the post-spawn period during Spring (Harrison et al., 2013). As well, over the two years of trapping in Kinbasket Reservoir during late April-early May, several Burbot were observed in spawning condition, and many were in post-spawn condition (Warnock et al., 2014; Kang et al., 2016). These findings suggest that spawning in Kinbasket Reservoir might start in March and end around late April-early May. In the nearby and southern Arrow Lakes Reservoir, spawning also occurs over a later period, beginning in late February or early March and continuing to the end of March or early April (Robichaud et al., 2013). In a concurrent study on Kinbasket Reservoir (CLBMON-6), adult Burbot were captured in nearshore fyke nets set during April 2016 in the Canoe Reach of (post-spawn condition; Kang and Warnock, 2017), May 2017 at Encampment Creek (Kang and Warnock, 2018), and June 2018 at Yellowjacket and Dave Henry creeks (Kang and Warnock, in review), further corroborating the finding that Burbot occupy shallow areas during the post-spawn period. These were the only observations of Burbot made during the bi-weekly and monthly sampling sessions, which concluded in August.

The observation of sustained Burbot occupation at shallow depths during Spring near confluences might also be an indication of an activity other than spawning, such as feeding. Burbot depth occupation was shallowest during Spring and a high proportion of Burbot were detected at Wood, Sullivan, and Kinbasket rivers (see section 9.5 Depth Occupation), suggesting that Burbot may be taking advantage of feeding opportunities. Kokanee (*Oncorhynchus nerka*), a preferred prey of Burbot in Lake Roosevelt, which is a similar Columbia River reservoir system, and Mountain Whitefish (*Prosopium williamsoni*) may provide foraging opportunities to Burbot during Spring as juveniles emigrate from tributaries and explain the maintenance of shallow depth occupations past the suspected spawning period (Black et al., 2003). Burbot may also be foraging on spring spawners and/or eggs.

Burbot have also been documented to exhibit seasonally plastic behaviour in terms of thermal habitat selection. Harrison et al. (2016) reported selection by Burbot for cold temperatures (<2 °C) during the spawning period for optimal reproduction while selection for warmer temperatures (12-14 °C) occurred during non-reproductive periods for optimal hunting and feeding. Sustained cool reservoir temperatures at shallow depths throughout Spring may provide optimal thermal habitat for hunting and feeding for Kinbasket Burbot prior to reservoir stratification. Turbidity levels may also influence movement to the pelagic zones and diel vertical migration behaviour (Probst and Eckmann, 2009; Harrison et al., 2013).

Aerial tracking was conducted over the entire length of the Columbia River from the headwaters at Columbia Lake and no Burbot were detected upstream, or anywhere else outside of the study area, except for a single entrainment event (Kang et al., 2016). Although these patterns of detection could not be corroborated by acoustic tracking, the lack of Burbot detections upstream of the Kinbasket Reservoir study area in the Columbia Reach during the aerial tracking period suggests that this area is not preferred habitat for Burbot during this time, likely due to lack of spawning habitat. Conversely, Burbot may have been occupying depths out of range for radio tracking in these areas. Fixed acoustic tracking detected movement of two Burbot (Acoustic Codes 33900 and 38300) upstream of the study area during August 2016 and September 2015, 2016, which is concurrent with timing of Kokanee mobilization for spawning, suggesting Burbot movement following prey. Fluvial Burbot have been reported to migrate into tributaries during fall (McPhail and Paragamian, 2000).

Data collected from fixed acoustic receivers also showed clear Diel Vertical Migration (DVM) during all seasons in some Burbot (Appendix 1). DVM has previously been demonstrated in adult Burbot from Kinbasket Reservoir (Harrison et al., 2013; Martins et al., 2013). The function of DVM has been attributed to a trade-off among bioenergetics advantage (i.e., fitness gains from foraging in warmer water at night and digesting in cooler, deeper waters in the day), foraging opportunity (i.e., migration aligned with prey movement), and predation threat (i.e., avoidance of predators by smaller individuals within gape size limits) (Harrison et al., 2013).

One Burbot was tracked by radio receiver in the tailrace of Mica dam (Acoustic Code: 31500; Kang et al., 2016) that demonstrated clear adfluvial behaviour and entrainment. It was tagged >20 km from the dam at the Sullivan River (Kang et al., 2016) and remained at the capture location until Jan. 21 2015 after which it was detected at the Mica forebay on Jan. 25, 2015. Although the timing of entrainment cannot be confirmed with receiver data, the date of first observation in the Mica tailrace occurred in March 22, 2015, highlights that entrainment occurred during the suspected spawning migration period. Our ability to detect entrainment was constrained because there were only five radio tracking sessions during the winter months and no receiver in the tailrace. A more thorough investigation of Burbot entrainment was conducted as part of the BC Hydro Fish Entrainment Strategy Action Plan for Mica Dam (Martins et al., 2013). Although use of the Mica forebay and entrainment rates were reported to be low, the authors recognized that life history would result in unequal entrainment vulnerabilities and Harrison et al. (2013) tagged forebay residents with few adfluvials in their study as individuals exhibited sedentary behaviour with high site fidelity. Burbot were more likely to be entrained in the fall (Martins et al., 2013).

Most movement detections occurred at the Wood, Sullivan, and Kinbasket rivers, near the location of capture, suggesting that Burbot have small home ranges. Estimation of home ranges sizes (see section 9.5 ‘Home Range Estimation’) indicated that there were no significant differences among home range sizes and season, however, a number of outlier individuals with larger home ranges were observed. Although most Burbot were relatively sedentary, a number of individuals were highly mobile, illustrating that tagged Burbot exhibited different life strategies.

We assessed Burbot mortality during this 5-year study (see Section 8.5 Burbot Mortality) and determined that 15.3% of tagged Burbot were suspected to be dead or had expelled tags based on tracking of depth (constant elevation over a long period of time) or temperature data (>0 °C) (13.3%); or confirmed dead (retrieved tags; 2.0%).

5.1.3 Challenges and Opportunities

This study showed that Burbot are not evenly distributed throughout the study area of Kinbasket Reservoir. This assessment cannot be extended to the whole reservoir as the size and remoteness of the reservoir restricted our ability to sample all areas of the reservoir due to logistical and safety constraints.

The suspected spawning period coincides with the low pool period during which conditions make on-reservoir work unsafe. Our inability to conduct field work during the suspected spawning period limited our ability to confirm spawning activity, as well as their timing and locations.

Our targeted sampling approach that maximized catch rate prevented comparisons of relative abundance of Burbot with other studies. As discussed in Section 5.1.1, Burbot sampling was not conducted randomly across the total area of the reservoir and focused on areas where Burbot were previously observed so comparisons of relative abundance must be scaled to areas covered for a given CPUE using a standardized trapset soak time.

Burbot home range estimations exhibited considerable spatial autocorrelation where detection data were not independent of on another, as is to be expected in data characterizing movement and migration patterns. However, detections were recorded at constant time intervals and illustrate true movement of Burbot in the reservoir.

Numerous discrete home ranges were pervasively identified for an individual Burbot rather than a spatial continuum. This likely reflects the patchy distribution of receivers across the large study area as it was not possible to deploy receivers at equally spaced intervals. Some receivers did not detect tagged Burbot despite being along the pathway of adjacent receivers that provided detections, indicating the receiver location was not effectively utilizing receiver ranges of detection and/or Burbot passed during the lag of receivers transmissions. Despite these sampling and methodological shortcomings, the identification of discrete home ranges reflect where Burbot were detected illustrating home range shifts and multiple preferred areas of occupation.

5.2 MQ2: Does winter drawdown of Kinbasket Reservoir cause the dewatering of Burbot spawning habitat and affect spawning success?

Due to safety hazards associated with field assessments and accessing spawning habitat during the suspected spawning period, no information was collected to directly assess the impacts of dam operation on dewatering of spawning habitat and access by Burbot. We discuss observations made by this study and other Water Use Planning studies that provide insights to quality of spawning habitat and access for Burbot. The timing of winter reservoir drawdown coincides with Burbot movements into shallow areas during their suspected spawning period, suggesting that dewatering of spawning habitat might occur during this time (see section 9.5 Depth Occupation; Appendix 2 Figure 8).

Field observations of areas of high Burbot activity during spring for this study and CLBMON-6 are summarized below:

Wood River

Substrate at the confluence of Wood River (Figure 6) was dominated by boulders and cobbles overlain by silt. This silt deposition is likely the result of decreased flow when backwatering occurs in lower reaches during rising reservoir levels in July and August. The silt is remobilized during winter/spring with decreasing reservoir levels and the return of downstream flows.

Figure 6: Upstream view of Wood River during late April-early May 2015 capture session. Photo by Scott Cope, Westslope Fisheries Ltd.

Kinbasket River

Clay and silt were the dominant substrate at the confluence of Kinbasket River and Kinbasket Reservoir (Figure 7). Habitat was assessed for CLBMON-6 when high sediment transport and turbid water were also observed.

Figure 7: Confluence of Kinbasket River with Kinbasket Reservoir during low pool conditions. Photo taken on April 19, 2018 during surveys for CLBMON-6.

Sullivan River

Substrate at Sullivan River was dominated by clay and silt during low pool conditions in late April (Figure 8). There is evidence of high sediment transport during rising (July/August) and lowering (suspected spawning period/spring) reservoir levels.

Figure 8: Confluence of Sullivan River with Kinbasket Reservoir during late April 2018 low pool conditions. Photo taken on April 28, 2018 during habitat assessments for CLBMON-6.

High turbidity and fine sediment transport were observed at all three sites where high Burbot activity has been detected during low pool conditions in late April, a time that has been identified as overlapping with the suspected spawning and post-spawning period. Sediment transport into interstitial spaces likely impairs egg and larval survival during egg incubation and larval rearing.

Water temperatures extend outside optimal temperatures for egg incubation during the suspected spawning period (A2 Figure 9, 10, 11; A2 Table 2), which might impact egg incubation success. Discrete recordings of temperatures exceeded 6 °C during the suspected spawning period (A2 Figure 10, 11; A2 Table 2), which is lethal to Burbot embryos (Taylor and McPhail 2000, Vught et al. 2007) and prevents induction of spawning in adults (Zarski et al. 2010). Temperatures <3 °C were also recorded and time to egg hatching is increased significantly at temperatures <3 °C (Taylor and McPhail 2000) so embryos with a 70 day incubation period would be potentially at risk of desiccation if eggs were incubated in the drawdown zone and the drawdown rate was high during this period.

Burbot have been documented to spawn in areas with low velocity in main channels and behind deposition bars in side channels (McPhail and Paragamian, 2000). Burbot were observed in the CLBMON-6 study during surveys conducted April, May, and as late as June near tributary mouths. Burbot may have moved to habitat with suitable water velocity to avoid high flows and backwatering created by operations.

5.2.1 Challenges

The suspected spawning period coincides with the low pool period during which conditions make on-reservoir work unsafe. Our inability to conduct field work during the suspected spawning period limited our ability to directly assess dewatering of and access to Burbot spawning habitat.

5.3 MQ3: Can modifications be made to the operation of Kinbasket Reservoir to protect or enhance spawning success of these Burbot populations?

The current operation of Kinbasket Reservoir creates conditions for fine sediment transport that could impede Burbot egg incubation success. Moreover, velocity barriers at tributary mouths and sediment wedges at confluences resulting from backwatering during drawdown could impede access to spawning areas. Given these conditions, spawning areas (potentially Wood, Kinbasket, Sullivan rivers) may have shifted to areas with suitable water velocity but might not provide suitable habitat conditions for egg incubation. Examples of suitable habitat conditions include water temperature range of 1-4 °C, presence of ice/woody debris cover, presence of interstitial spaces.

Further assessment would be required to confirm that Wood, Kinbasket, and Sullivan rivers are spawning areas of Burbot in Kinbasket Reservoir, as well as identify key spawning habitat that may be impacted by dam operations. If spawning habitat is confirmed to occur within the drawdown zone, the assessment should also confirm details such as i) spawning depth (our data suggest shallowest occupation at 9.3 to 18.4 m during March); ii) frequency of spawning habitat dewatering due to dam operations; iii) area of spawning habitat that is dewatered due to dam operations; iv) opportunities to improve access by Burbot to spawning habitat and egg incubation conditions, such as adapting an operational regime that minimizes sediment transport, high flows, and backwatering.

6.0 Recommendations

1. Confirm that Wood, Kinbasket, and Sullivan rivers are Burbot spawning locations and confirm timing of spawning by conducting surveys during the suspected spawning period (January to April) using an underwater camera or hydrophones to record Burbot vocalizations, which have been observed to be coincident with the onset of spawning (Cott et al., 2014);

2. If #1 confirms that spawning occurs in the drawdown zone, the following should be assessed: a) spawning depth (our data suggest shallowest occupation at 9.3 to 18.4 m during March) and area; b) frequency of spawning habitat dewatering; c) area of spawning habitat dewatered; d) opportunities to improve access by Burbot to suitable spawning habitat and egg incubation conditions;

3. Using information from 2b and 2c, develop a bathymetry model to evaluate seasonal habitat availability and reservoir levels.

4. Re-evaluate home range estimations using Brownian Bridge Movement Models (BBMM; Bullard 1999; Horne et al., 2007) to incorporate time between successive detections into Utilization Distribution (UD) estimations to address autocorrelation.

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8.0 APPENDIX 1. Timeline of CLBMON-05

Milestone	Timeline	Reference
Year 1 Burbot capture and tagging	Apr 29 – May 9, 2014	Year 1 Report (2014)
Year 1 opportunistic radio tracking	June 3, 5, 2014	Year 1 Report (2014)
Year 1 helicopter radio tracking	Feb 17 – Apr 8, 2015	Year 2 Report (2016)
Year 1 fixed receiver tracking	Jun 2, 2014 – Apr 3, 2015	Year 2 Report (2016)
Year 2 Burbot capture and tagging	Apr 28 - May 10, 2015	Year 2 Report (2016)
Year 2 fixed receiver tracking	May 11, 2015 – May 6, 2016	Year 3 Report (2017)
Year 3 fixed receiver tracking	May 1, 2016 - May 13, 2017	Year 4 Report (2018)
Year 4 fixed receiver tracking	Oct 5, 2017- Jun 29, 2018	Year 5 Report (2019)

9.0 Appendix 2. Burbot Capture/Tagging and Fixed Receiver Tracking

9.1 *Introduction*

The Burbot capture/tagging and fixed receiver tracking assessment was used to infer whether fish are present and congregating in shallow drawdown habitats during the spawning season. This approach cannot confirm spawning activity. Presence of aggregations of Burbot and occupation of relatively shallow depths over multiple days during the potential spawning period are treated as indicative of potential spawning activity when addressing the management hypotheses outlined in the previous section.

9.2 *Methods*

Capture, tagging and mobile/fixed receiver tracking methodologies are outlined in the Year 1 and Year 2 reports (Warnock et al. 2014; Kang et al., 2016). A total of 48 Burbot were tagged in 2014 (Year 1) and 50 Burbot were tagged in 2015 (Year 2). See Figure 2 to Figure 5 for capture locations.

Analyses of both mobile and fixed receiver tracking were conducted in Year 2 of the project. Due to limited detection of Burbot from mobile tracking in Year 1, mobile tracking was discontinued and 16 more receivers were deployed during redeployment of original receivers in 2015 (total number of receivers was 30) for subsequent analyses. See Figure 2 to Figure 5 for receiver locations.

Fixed receivers were deployed from October 4-8, 26, 2017 to June 26, 2018 for CLBMON-07 and provided information on Burbot that still had remaining battery life in tags. A reduced acoustic receiver network was deployed in 2017 due to limited budget and window of opportunity for deployments. A total of 12 receivers were deployed for tracking in 2017-18. Batteries were programmed to transmit every 100.5 s.

9.3 *Dataset*

All twelve receivers deployed with 2017-2018 data were retrieved and their data are summarized below (A2 Table 1). Only 1 receiver (#113) located in the Wood Arm detected two Burbot (Acoustic codes 36500 and 36600). Detections for these Burbot occurred during a limited period of time (Oct 2018 to January 2019) and were not representative of general movements so were not included in statistical analyses of detections, however, were incorporated in graphs for illustrative purposes of depth occupation.

A2 Table 1: Summary of monitoring period of fixed acoustic receivers deployed in Kinbasket Reservoir (listed according to locations from North to South).

Receiver ID	Location	Start of Monitoring	End of Monitoring
14	Lower Canoe River	26-Oct-17	26-Jun-18
124	Lower Canoe River	26-Oct-17	26-Jun-18
113	Wood Arm	26-Oct-17	26-Jun-18

125	Columbia Reach Entrance	26-Oct-17	27-Jun-18
122	Columbia Reach Entrance	05-Oct-17	27-Jun-18
8	Kinbasket Lake Outlet	05-Oct-17	26-Jun-18
12	Kinbasket Lake Inlet	04-Oct-17	27-Jun-18
1	Sullivan Arm	05-Oct-17	26-Jun-18
6	Sullivan Arm	05-Oct-17	
13	Surprise Rapids	08-Oct-17	29-Jun-18
112	Esplanade Bay	07-Oct-17	29-Jun-18
4	Columbia River	07-Oct-17	29-Jun-18

Data collected from receivers were compiled in the dataset of all years of depth detection data collected for the study.

9.4 *Analysis*

Depth Occupation and Water Temperature

Two-way ANOVA was used to compare i) differences in depth occupation of Burbot across study years, seasons, and months; and ii) differences in water temperature across study years. Test were deemed statistically significant using an alpha of 0.05. Assumptions of normality were often violated so nonparametric tests (Wilcoxon Kruskal-Wallis rank sums) were also conducted. Analyses of Burbot depth occupation were conducted using depths in relation to water surface level rather than reservoir elevation to provide a clear illustration of Burbot depth distributions during reservoir fluctuations.

Home Range Estimation

Burbot home range was estimated using Home Range Tools for ArcGIS using Kernel Density Estimations (KDE; Rodgers and Kie 2011). Calculations used the reference bandwidth approach (*Href*) for the bandwidth or smoothing parameter. KDE resolution was set at 10 m and a scaling factor of 10, 000, 000. KDEs were clipped to distinct Kinbasket Reservoir rasters that reflect water level fluctuations to calculate Utilization Distribution (UD) with four levels of probability (i.e., isopleths at 50, 75, 90, and 95%).

9.5 *Results*

Fixed Receiver Tracking

Of 98 Burbot tagged in 2014 and 2015, 85 (87%) were detected by acoustic receivers during the 5 year study. Detection rates for Burbot tagged in 2014 was 90% (43/48) while detection rates for BB tagged in 2015 was 84 % (42/50).

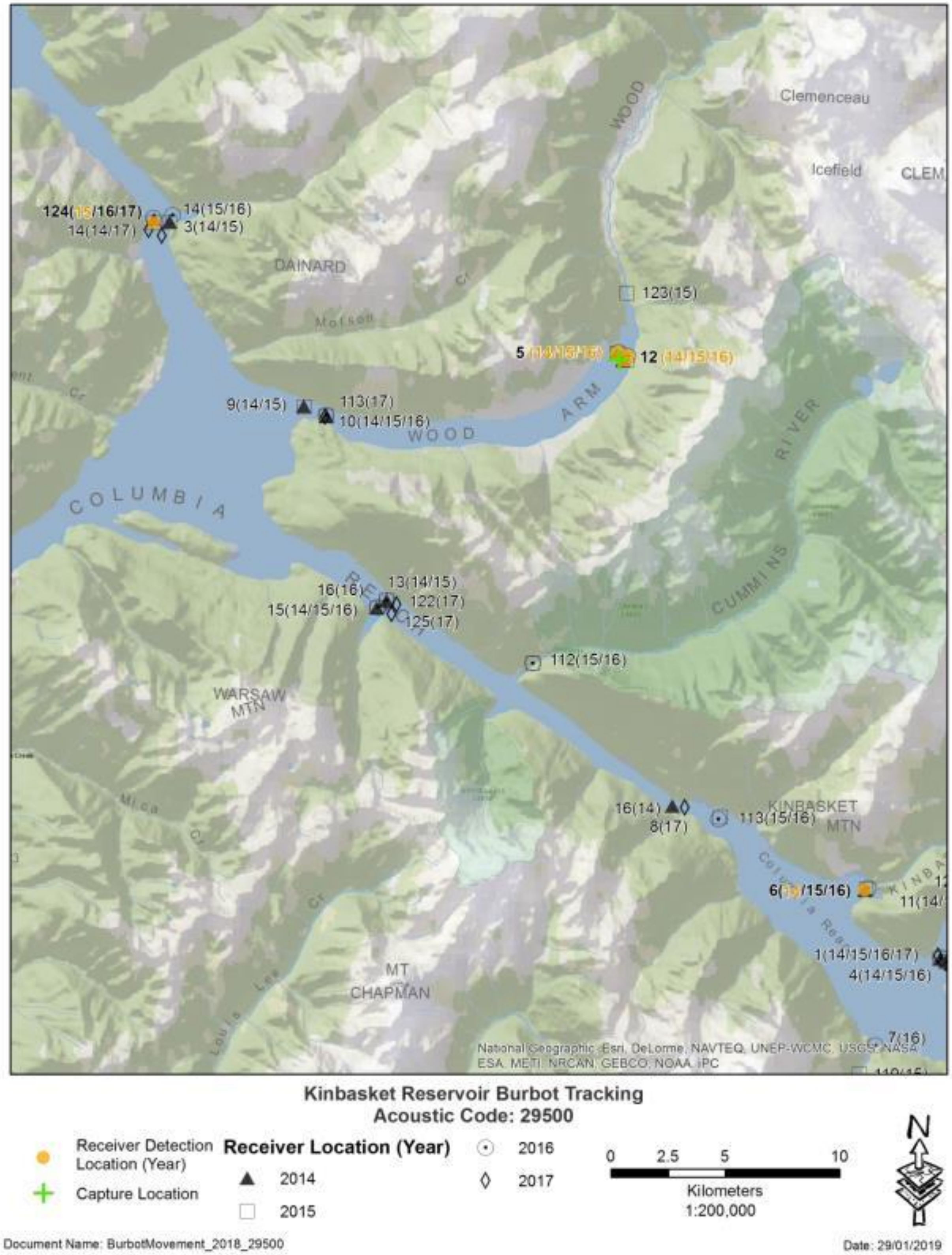
Most movement detections occurred near the location of capture (A2 Table 2; A2 Figure 1) with most detections occurring at receivers #12 (24%; Wood River), #5 (19%; Wood River), #11 (19%; Sullivan River), and #6 (15%; mouth of Kinbasket River). These locations also correspond to the locations of capture of 70% of the detected Burbot, suggesting small home ranges for some individuals. Home range estimation is discussed further below.

A2 Table 2: Summary of locations of detection for each Burbot (listed left to right according to locations from North to South). Yellow circles = capture location; black checks = 2014-2015 detection; red checks = 2015-2016 detection; blue checks = 2016-2017 detection; orange checks = 2017-2018 detections. Bolded acoustic codes represent Burbot that have not yet been detected during the study.

Acoustic Code	Upper Canoe Reach	Lower Canoe Reach	Wood Arm	Wood River	Columbia Reach Entrance	Columbia Reach Mid	Kinbasket Lake Outlet	Kinbasket River	Kinbasket Lake Inlet	Sullivan Arm	Sullivan River	Surprise Rapids	Bush Arm	Esplanade Bay	Columbia River
2014 IMPLANTS															
29500		✓(red)	●	✓ ✓(red) ✓(blue)				✓							
29600		✓	● ✓	✓	✓				✓	✓	✓				
29800		✓	● ✓	✓	✓ ✓(red)		✓(red)	✓(red)	✓ ✓(red)	✓ ✓(red)	✓ ✓(red)				
29900			✓ ✓(red)	✓ ✓(red)	✓ ✓(red)	●									
30100	✓(blue)	✓(blue)	● ✓(red)	✓ ✓(red) ✓(blue)	✓(red)										
30200					✓ ✓(red)	● ✓(red) ✓(blue)									
30300							✓(red) ✓(blue)	● ✓ ✓(red) ✓(blue)		✓ ✓(red)	✓				
30400								● ✓		✓	✓				
30500							✓(red)			● ✓ ✓(red) ✓(blue)	✓ ✓(red) ✓(blue)				
30600				✓				● ✓		✓					
30700								✓		✓	● ✓				
30800								✓		✓	● ✓				
30900		✓(red)	✓(red)	✓(red)					✓	✓	● ✓				
31000											● ✓ ✓(red)				
31100								● ✓	✓(red)	✓	✓				
31200		✓(red)		✓	✓(red)			● ✓		✓	✓				
31300								✓ ✓(red) ✓(blue)		✓ ✓(red)	● ✓				
31400									✓	✓	● ✓				
31600				✓(red)							● ✓				
31700					✓				✓		●				
31900															
32000															
32200															
32300															
32500	✓(red)	✓(red)	● ✓	✓ ✓(red)											
32600			● ✓	✓	✓(red)										
32700															
33000					✓	●		✓	✓	✓	✓				
33100								● ✓							
33200								✓		✓	● ✓				
33300								✓ ✓(red)		✓ ✓(red)	● ✓				
33400			● ✓	✓											
33500	✓(red)		● ✓		✓				✓	✓					
33600					●				✓						
33700							✓(red)	●		✓(red)					
33900									✓			●			✓(red)
34000										✓	● ✓				
34100					✓	●									

Acoustic Code	Upper Canoe Reach	Lower Canoe Reach	Wood Arm	Wood River	Columbia Reach Entrance	Columbia Reach Mid	Kinbasket Lake Outlet	Kinbasket River	Kinbasket Lake Inlet	Sullivan Arm	Sullivan River	Surprise Rapids	Bush Arm	Esplanade Bay	Columbia River
34200		✓	●	✓✓											
34300			●	✓			✓		✓	✓					
34400								●✓✓	✓						
34500					✓	●									
2015 IMPLANTS															
34 600					✓		✓	✓	✓✓	✓✓	●	✓✓	✓	✓✓	
34 700										✓✓	●✓✓				
34 800															
34 900															
35 000	✓	✓		✓	✓	✓	✓✓		✓	●✓	✓	✓			
35 100								✓		●	✓				
35 200							✓✓	●✓✓	✓	✓✓	✓				
35 300							✓✓	●✓✓		✓	✓				
35 400										✓	●✓				
35 500										✓	●✓				
35 600											●✓				
35 700											●✓				
35 800		✓	✓	●✓✓	✓										
35 900								●✓							
36 000								●✓							
36 100									✓	✓	●✓				
36 200	✓✓	✓✓	●✓	✓✓											
36 300	✓	✓		●✓✓											
36 400			●	✓											
36 500		✓	✓	●✓✓	✓✓										
36 600	✓✓	✓✓	●✓	✓✓✓											
36 700					✓	●	✓								
36 800			●✓												
36 900			✓	●✓	✓										
37 200												✓			
37 300							✓✓	●							
37 400															
37 600												●✓✓			
37 700															
37 800										✓	●✓				
37 900					●				✓			✓			
38 000															
38 100					●				✓✓						
38 200										✓	●✓✓				
38 300									✓	✓	●✓	✓		✓✓	✓
38 400							✓			●					
38 600															

Acoustic Code	Upper Canoe Reach	Lower Canoe Reach	Wood Arm	Wood River	Columbia Reach Entrance	Columbia Reach Mid	Kinbasket Lake Outlet	Kinbasket River	Kinbasket Lake Inlet	Sullivan Arm	Sullivan River	Surprise Rapids	Bush Arm	Esplanade Bay	Columbia River
38 700							●	✓							
38 800															
38 900				●✓											
39 000							✓	●✓	✓	✓✓	✓✓				
39 100		✓			●✓										
39 200			✓	●✓✓											
39 300	✓✓	✓	●✓	✓											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WOOD
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5
12
9(14/15)
113(17)
10(14/15/16)
WOOD
ARM
RIVER
COLUMBIA
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16(16)
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125(17)
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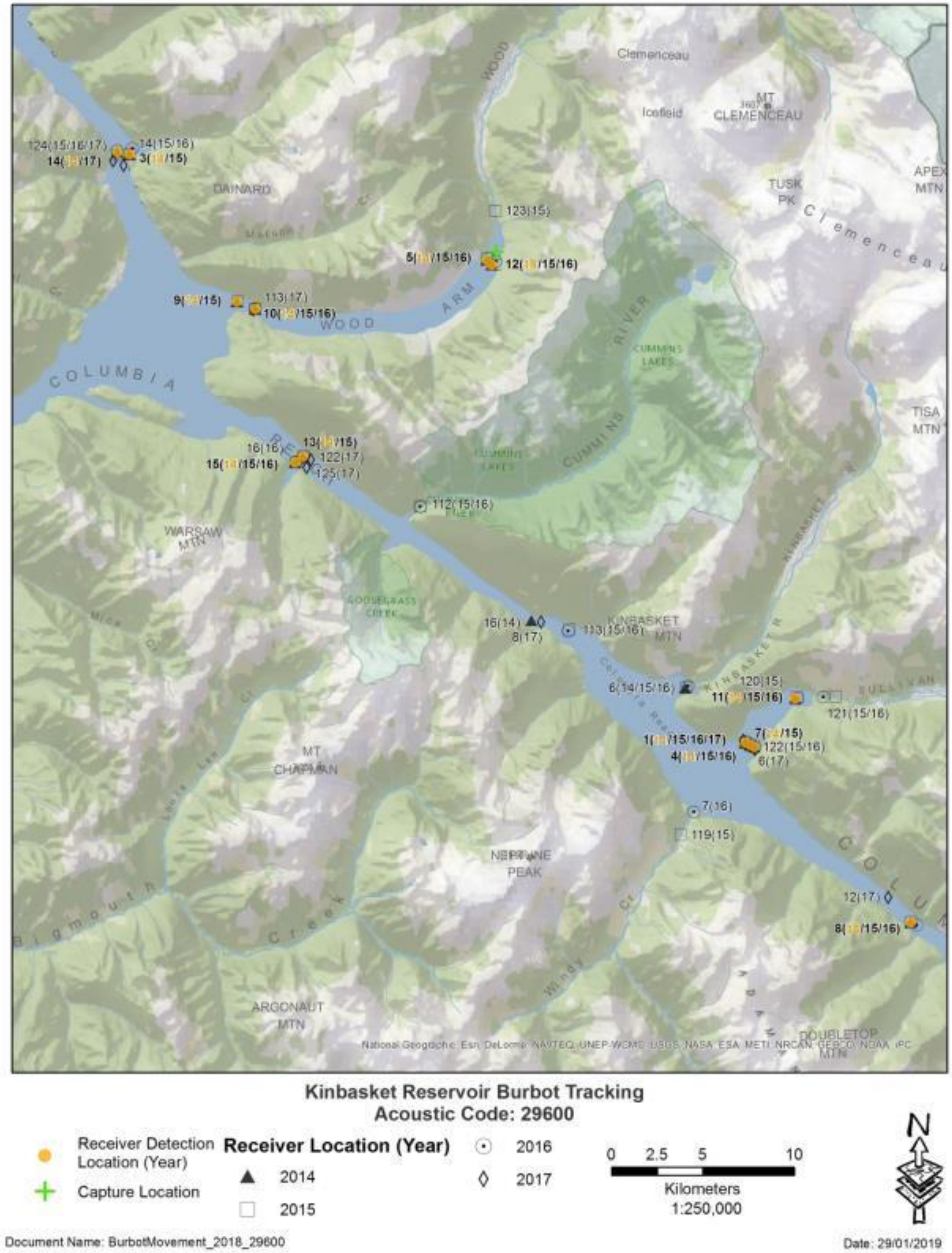
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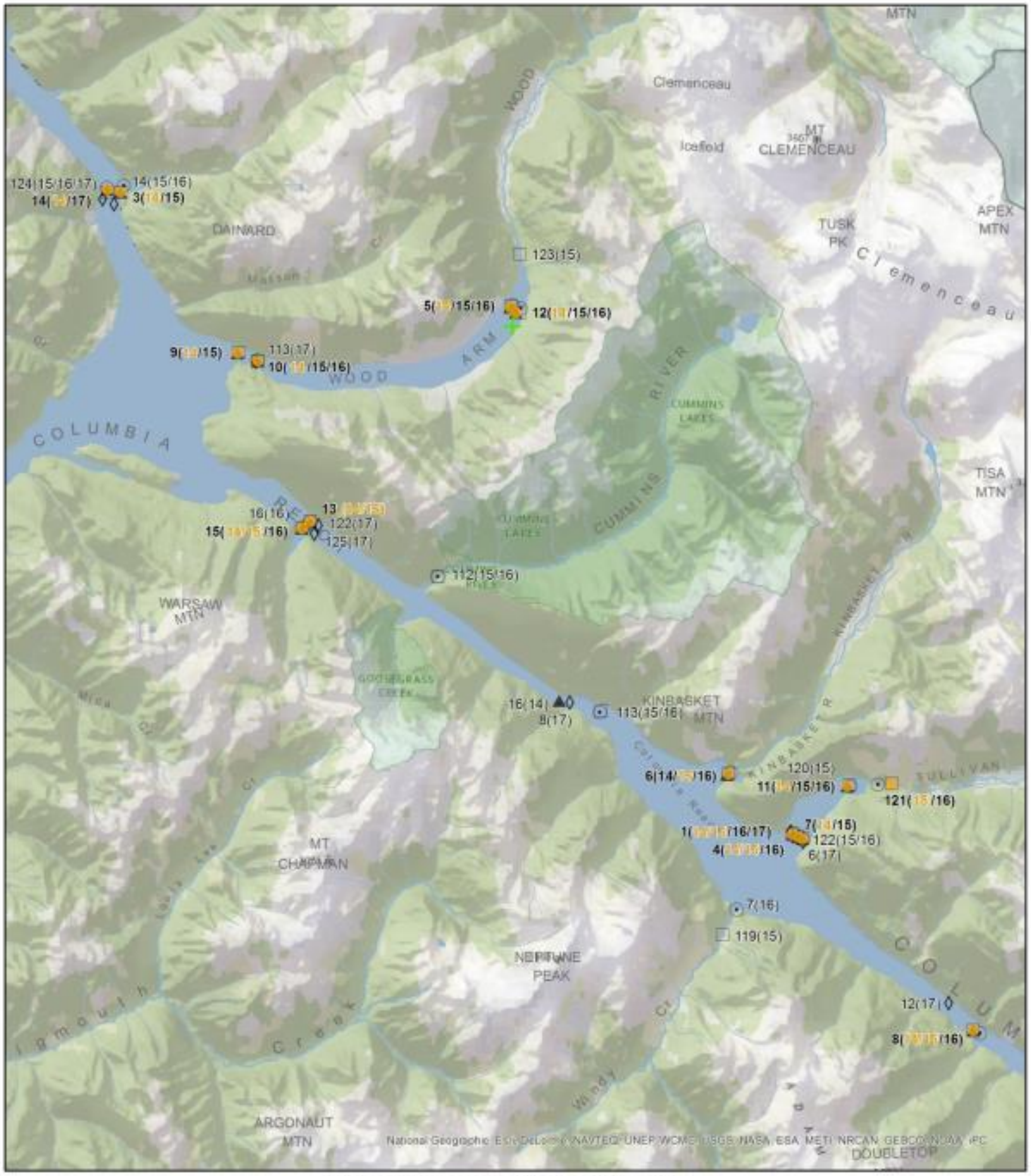

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Capture Location

Receiver Location (Year)
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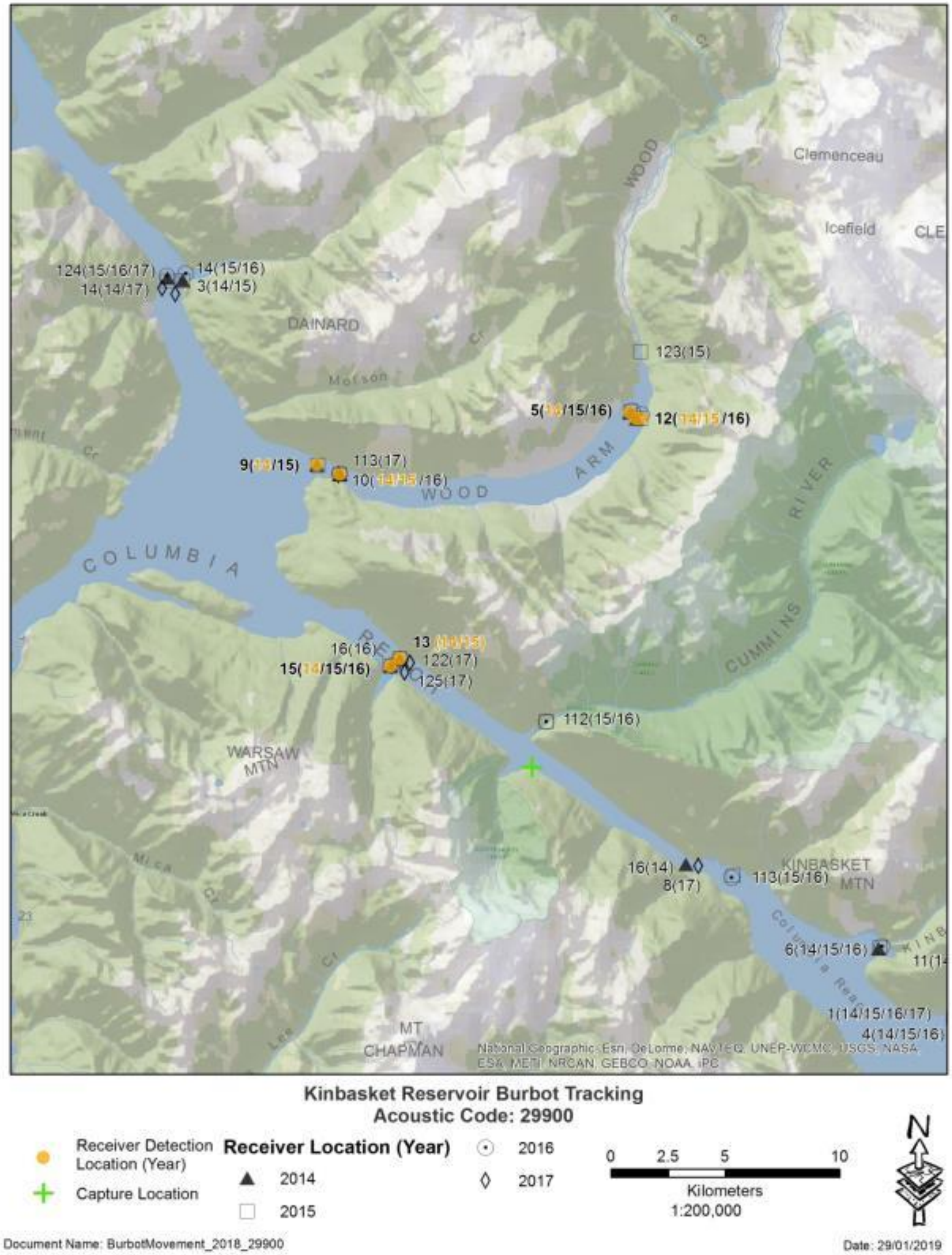
Document Name: BurbotMovement_2018_29800

Date: 29/01/2019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COLUMBIA
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Capture Location
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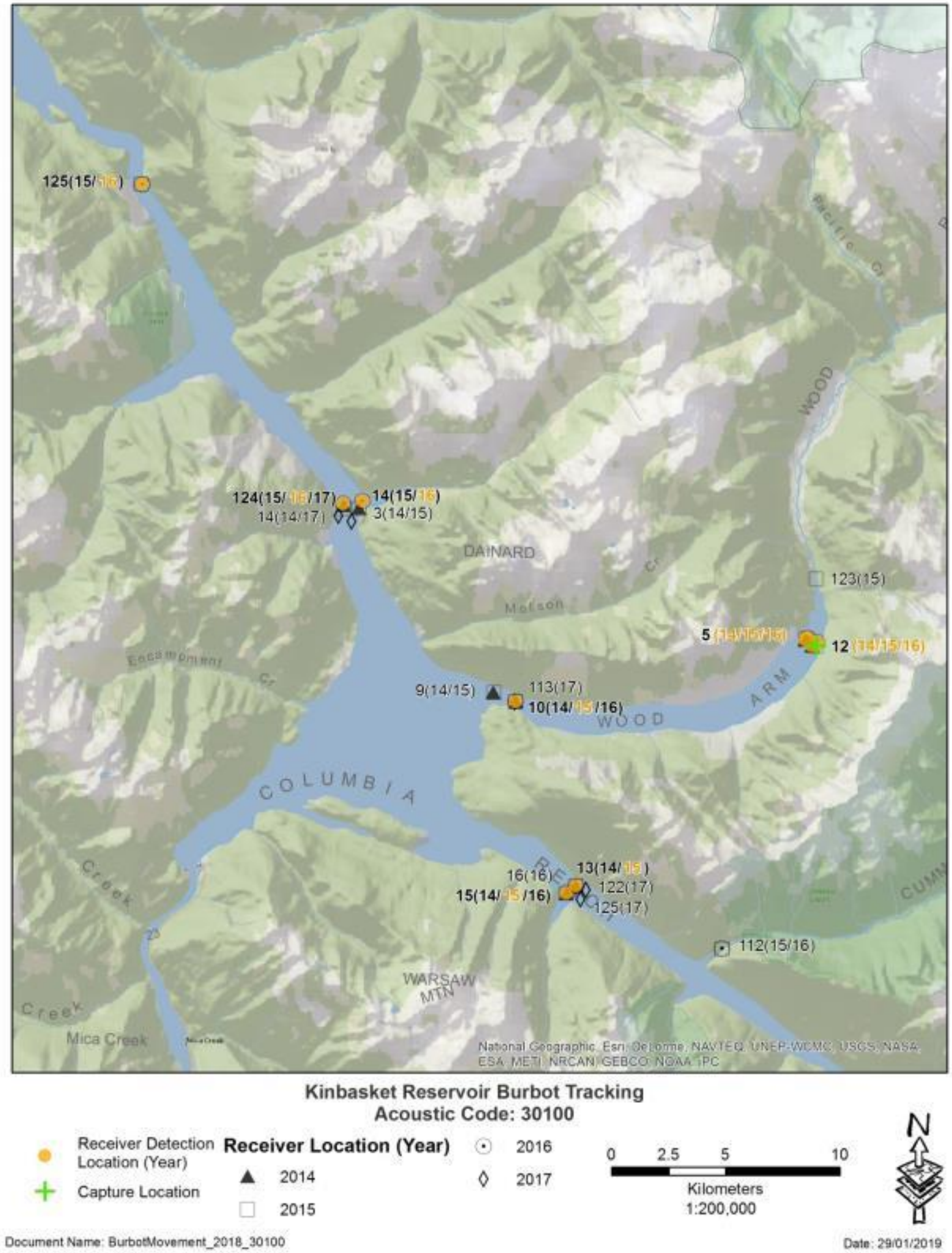
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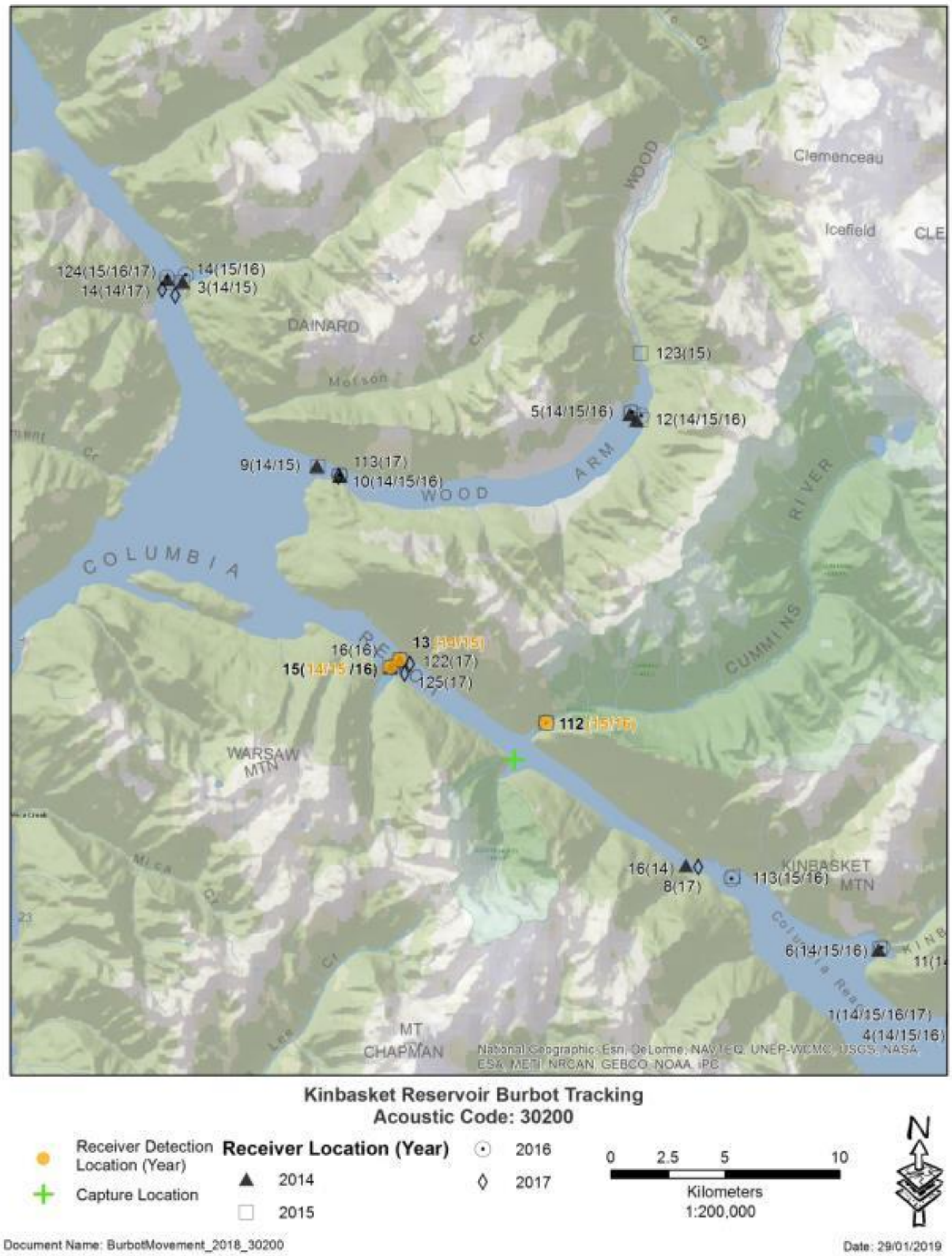
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ARM
RIVER
COLUMBIA
CUMMINS
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13
15(14/15 /16)
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125(17)
112
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Mica
Cr
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
1(14/15/16/17)
4(14/15/16)
MT CHAPMAN
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
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Receiver Location (Year)
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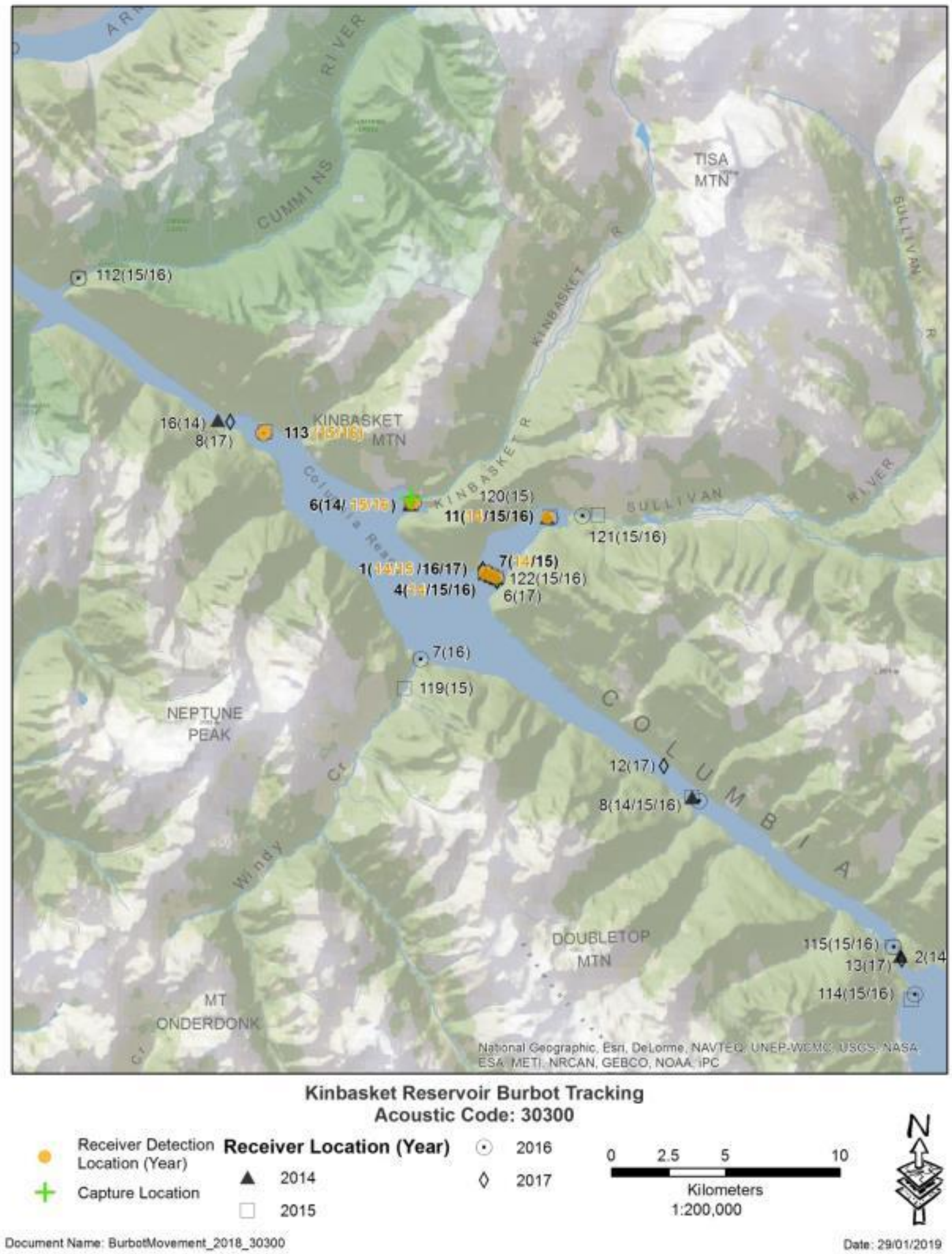
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1(
/16/17)
4(
/15/16)
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/15)
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DOUBLETOP MTN
MT ONDERDONK
115(15/16)
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114(15/16)
TISA MTN
COLUMBIA
SULLIVAN
RIVER
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
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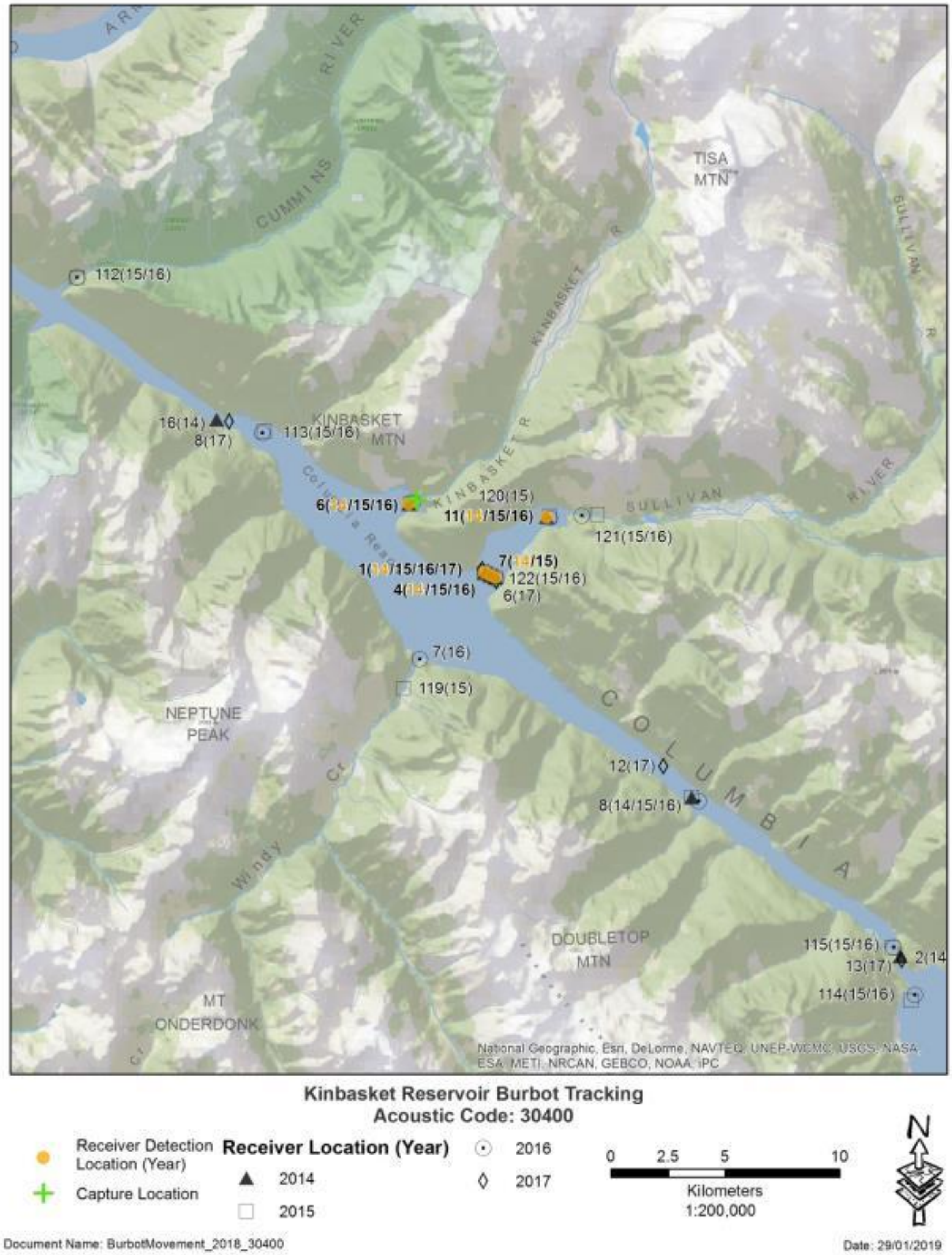
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12(17)
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MT ONDERDONK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
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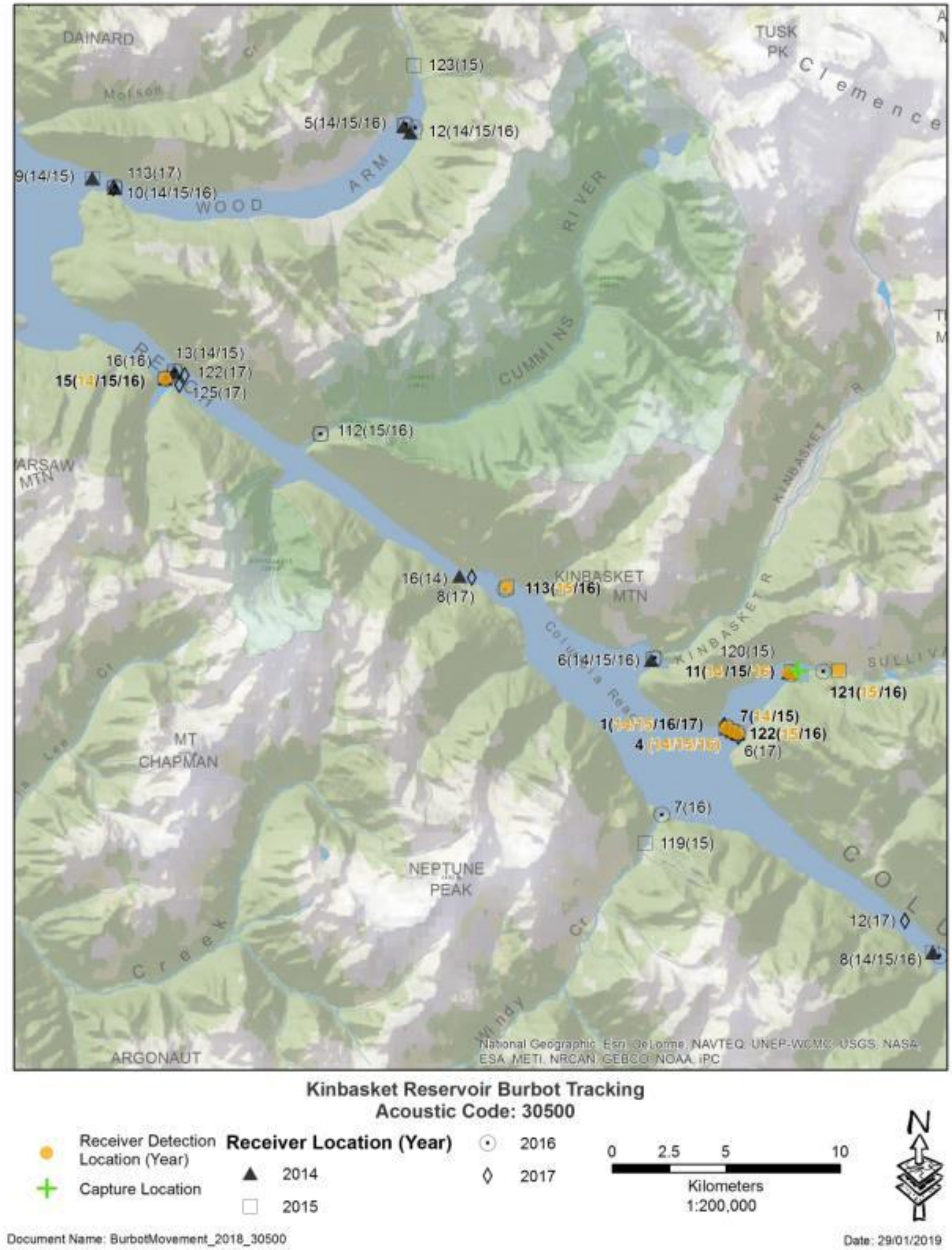
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WOOD ARM
RIVER
CUMMINS
16(16)
13(14/15)
122(17)
125(17)
112(15/16)
ARSAW MTN
16(14)
8(17)
KINBASKET MTN
6(14/15/16)
120(15)
6(17)
MT CHAPMAN
7(16)
119(15)
NEPTUNE PEAK
12(17)
8(14/15/16)
ARGONAUT
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 30500
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
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2016
2017
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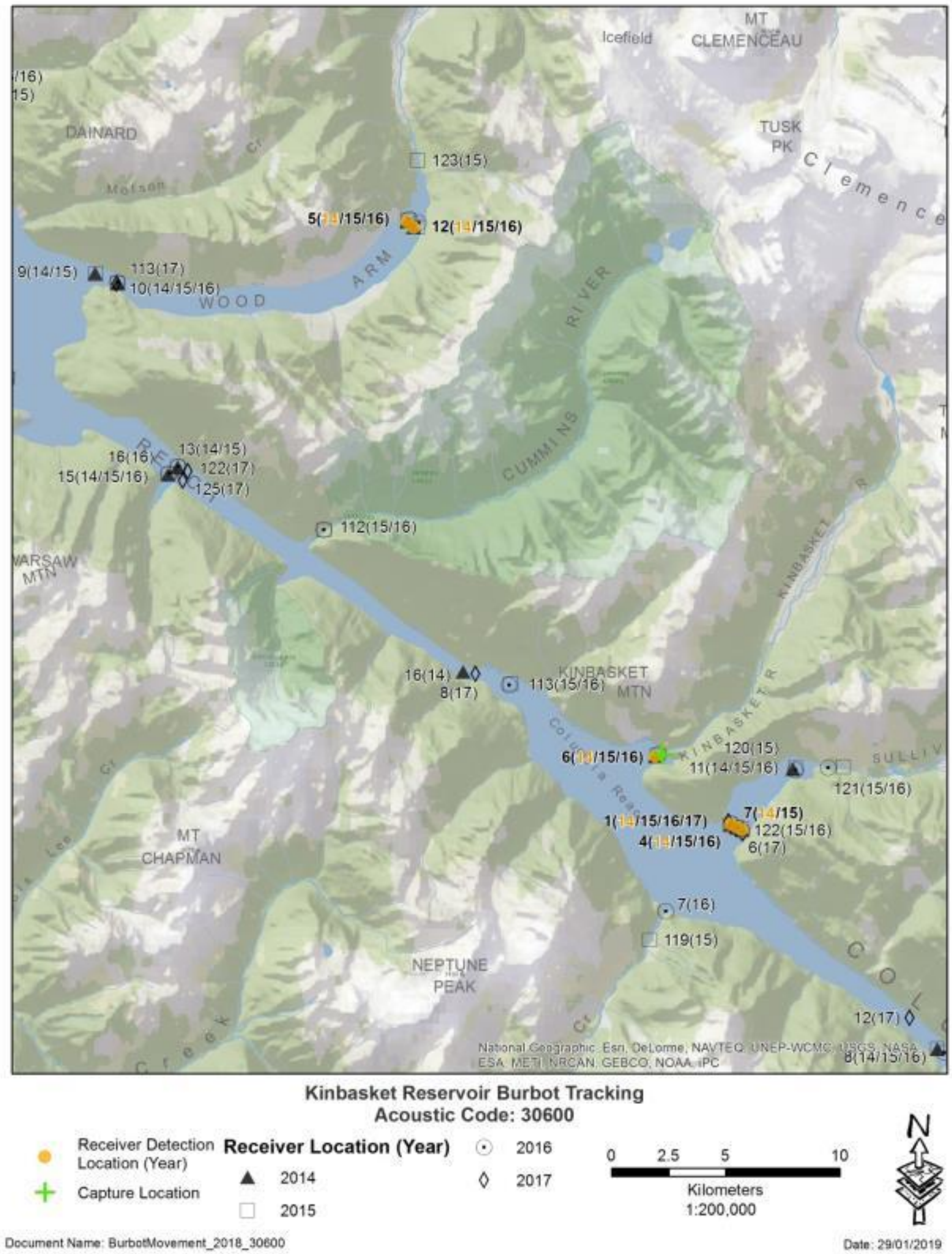
Date: 29/01/2019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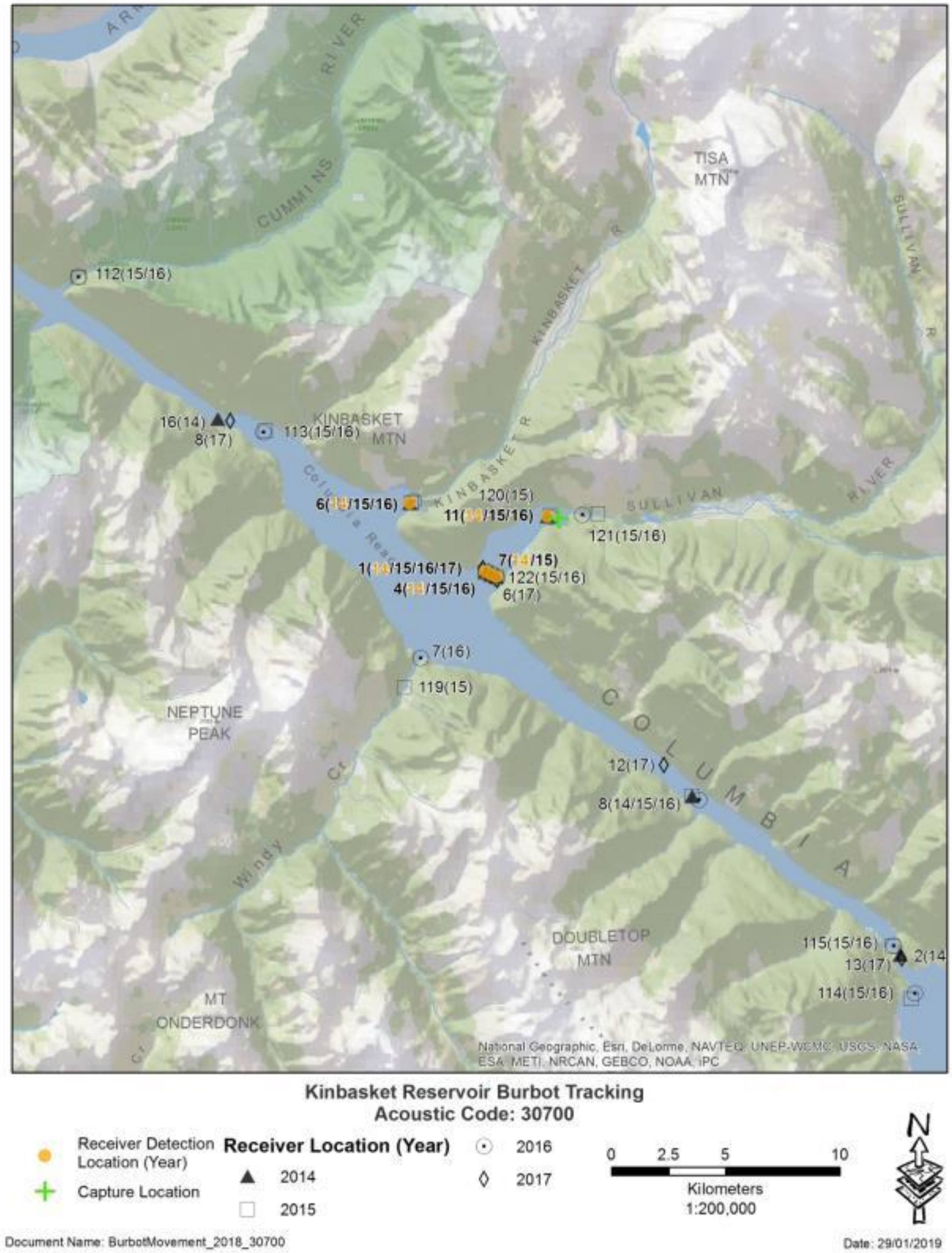
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7(16)
119(15)
NEPTUNE PEAK
12(17)
8(14/15/16)
COLUMBIA
DOUBLETOP MTN
115(15/16)
13(17)
114(15/16)
MT ONDERDONK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 30700
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
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2015
2016
2017
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Kilometers
1:200,000
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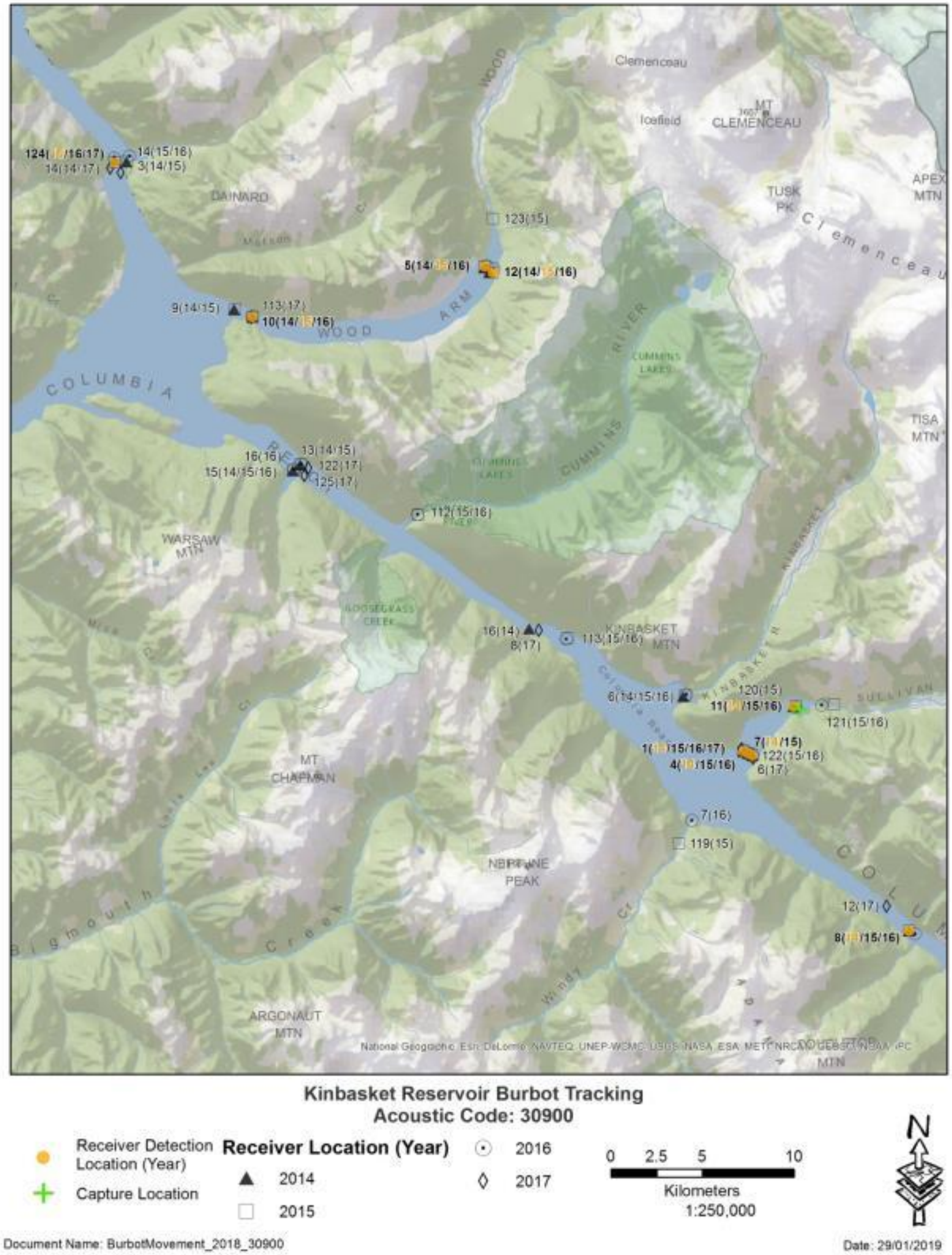
Document Name: BurbotMovement_2018_30700
Date: 29/01/2019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Capture Location
Receiver Location (Year)
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2015
2016
2017
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Kilometers
1:250,000
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DAINARD
Clemenceau
Icefield
MT CLEMENCEAU
TUSK PK
APEX MTN
TISA MTN
CUMMINS
KINBASKET MTN
WARSAW MTN
MT CHAPMAN
NEPTUNE PEAK
ARGONAUT MTN
SULLIVAN
14(15/16)
3(14/15)
14(14/17)
123(15)
9(14/15)
113(17)
13(14/15)
122(17)
125(17)
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6(14/15/16)
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12(17)
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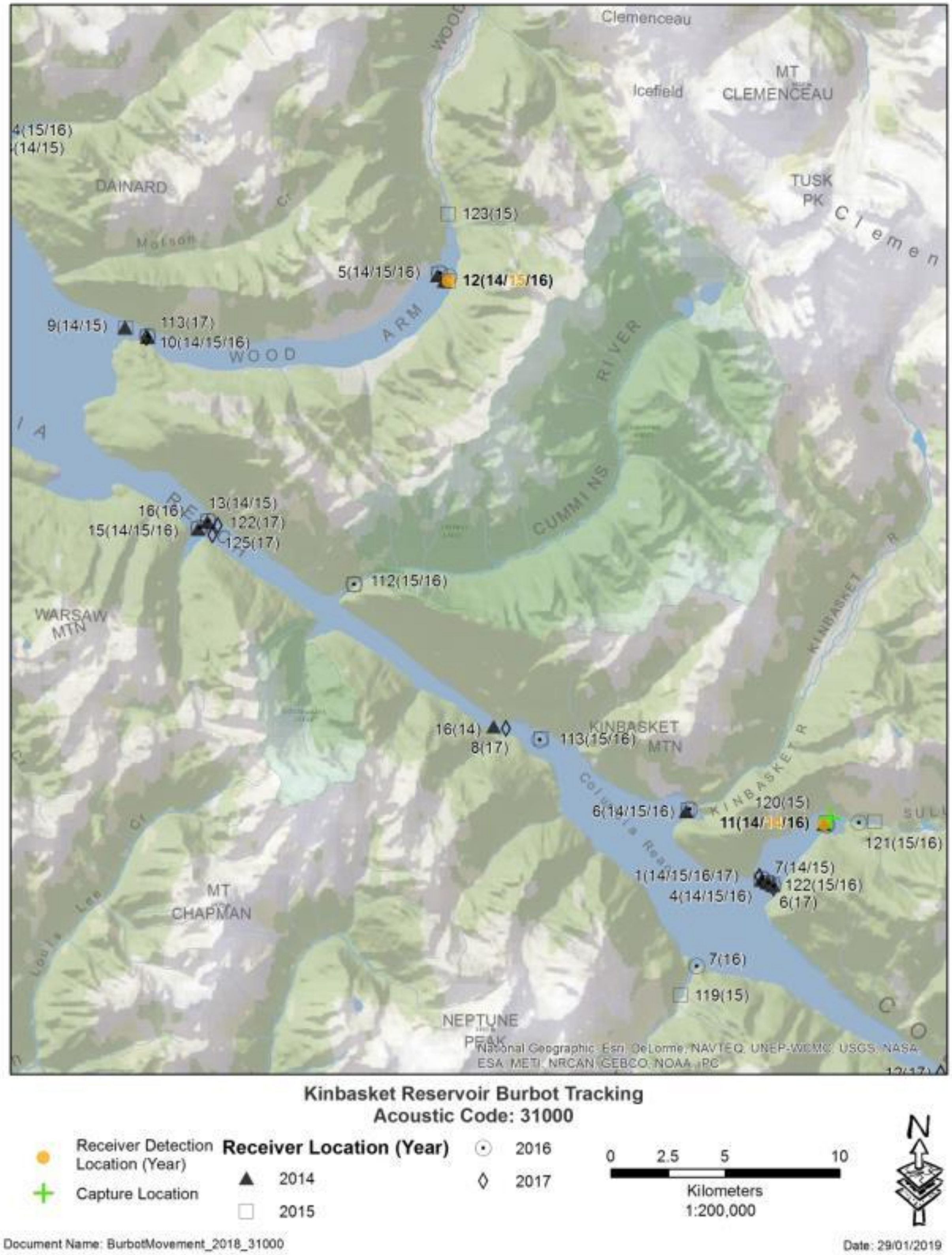
Document Name: BurbotMovement_2018_30900
Date: 29/01/2019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Icefield
MT CLEMENCEAU
TUSK PK
DAINARD
WOOD ARM
RIVER
CUMMINS
WARSAW MTN
KINBASKET MTN
MT CHAPMAN
NEPTUNE PEAK
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
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13(14/15)
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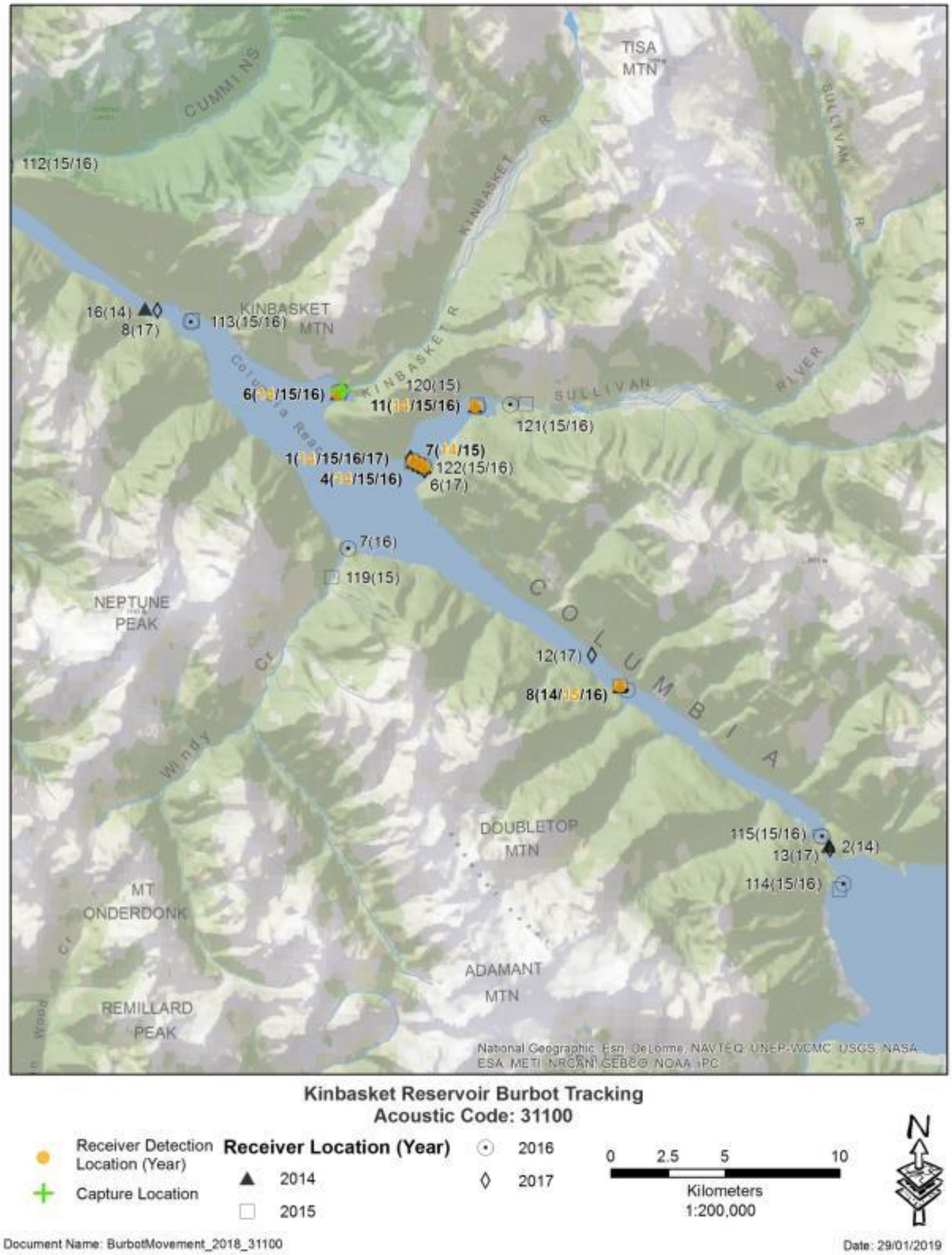
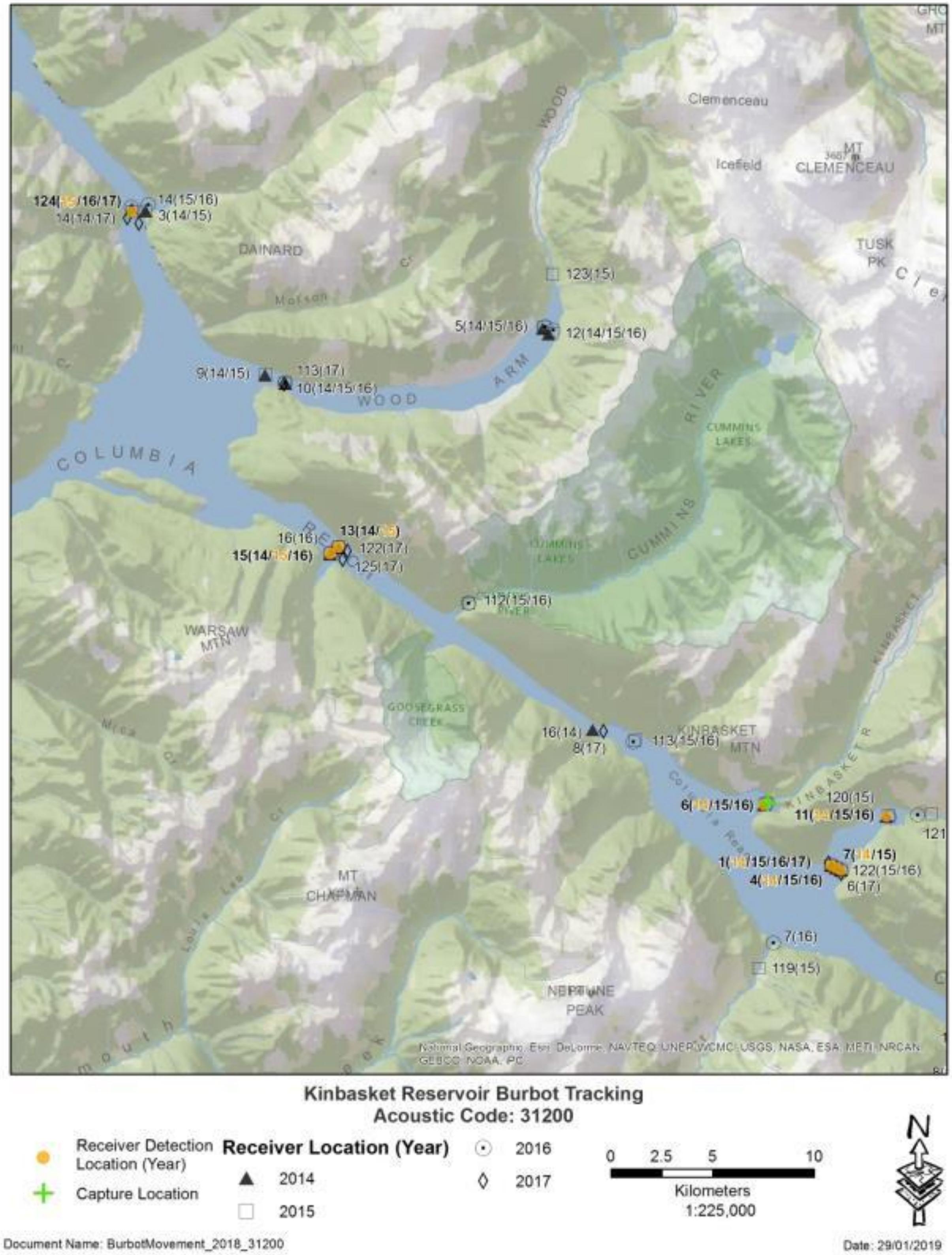
122(15/16)
4(14/15/16)
6(17)
7(16)
119(15)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 31000
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_31000
Date: 29/01/2019


TISA MTN
CUMMINS
KINBASKET R
SULLIVAN R
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
120(15)
SULLIVAN
RIVER
121(15/16)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
12(17)
COLUMBIA
Windy Cr
DOUBLETOP MTN
115(15/16)
2(14)
13(17)
114(15/16)
MT ONDERDONK
ADAMANT MTN
REMILLARD PEAK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 31100
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_31100
Date: 29/01/2019


Clemenceau
Icefield
MT CLEMENCEAU
TUSK PK
WOOD
DAINARD
124(/16/17)
14(14/17)
14(15/16)
3(14/15)
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
WOOD ARM
COLUMBIA
RIVER
CUMMINS LAKES
CUMMINS
13(14/)
16(16)
15(14/ /16)
122(17)
125(17)
112(15/16)
WARSAW MTN
GOOSEGRASS CREEK
16(14)
8(17)
113(15/16)
KINBASKET MTN
KINBASKET R
6(/15/16)
120(15)
11(/15/16)
121
1(/15/16/17)
4(/15/16)
7(/15)
122(15/16)
6(17)
7(16)
119(15)
MT CHAPMAN
NEPTUNE PEAK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 31200
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:225,000
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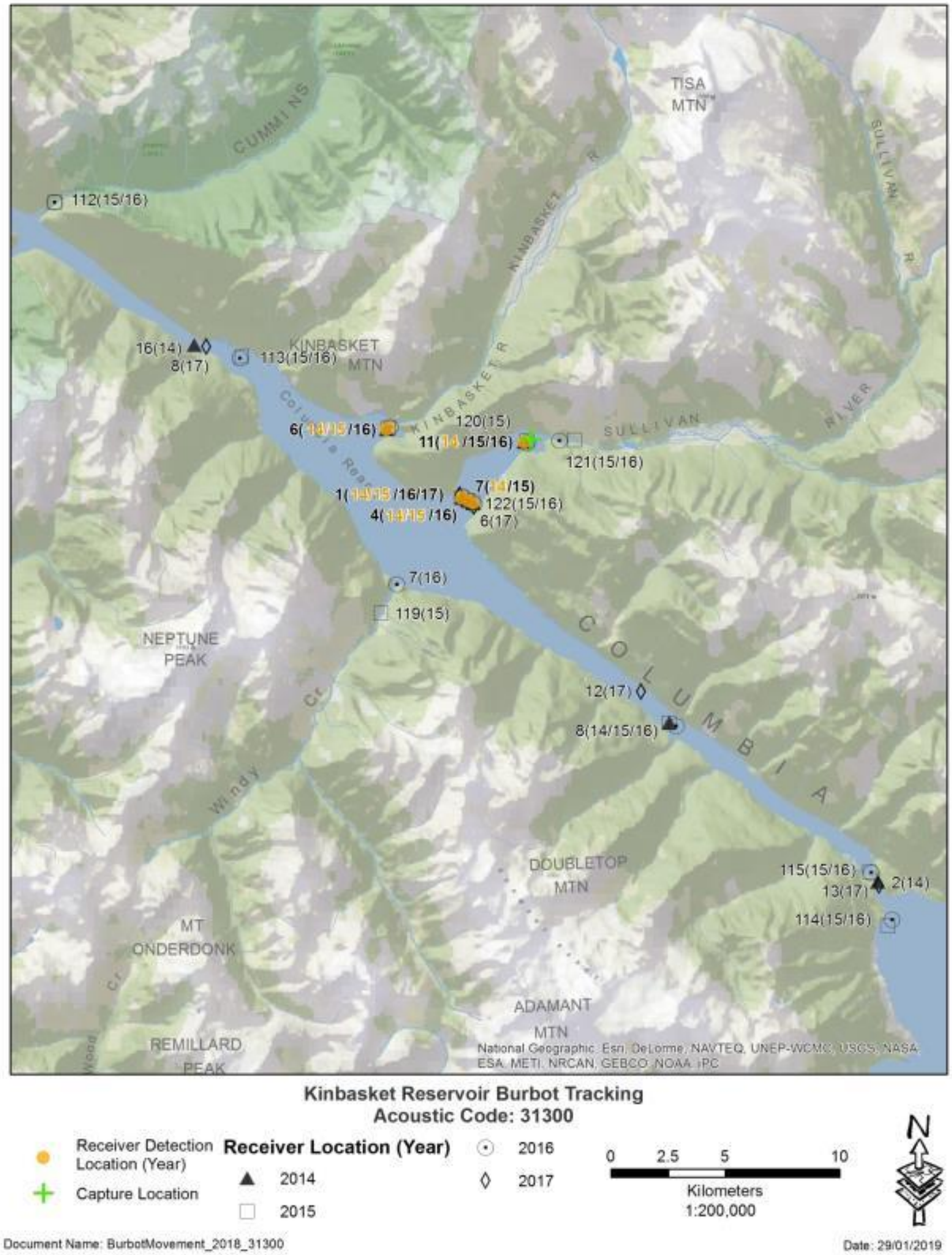
Document Name: BurbotMovement_2018_31200
Date: 29/01/2019


TISA MTN
CUMMINS
SULLIVAN R.
KINBASKET R.
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
SULLIVAN RIVER
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
COLUMBIA
12(17)
8(14/15/16)
Windy Cr
DOUBLETOP MTN
115(15/16)
13(17)
2(14)
114(15/16)
MT ONDERDONK
ADAMANT MTN
REMILLARD PEAK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 31300
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
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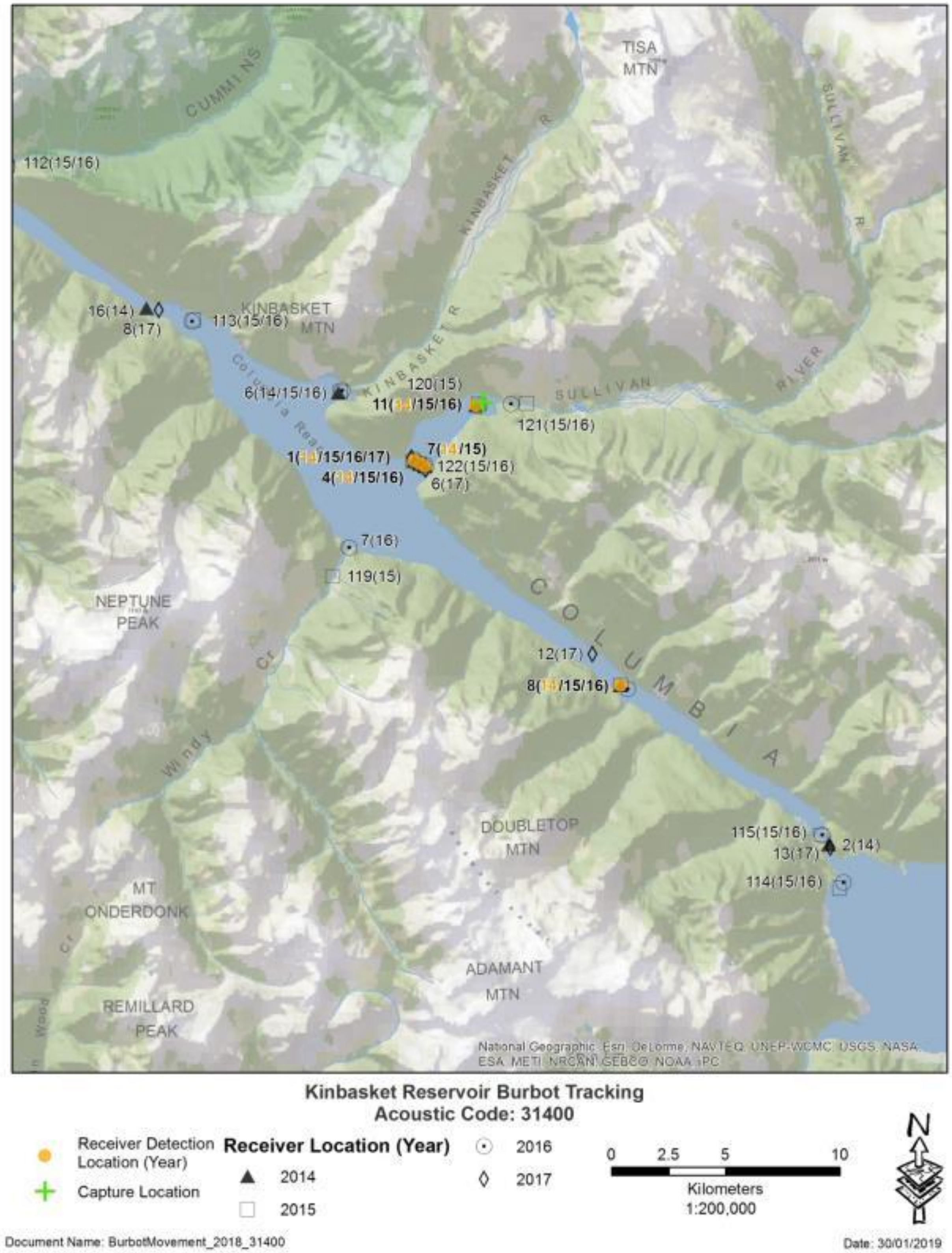
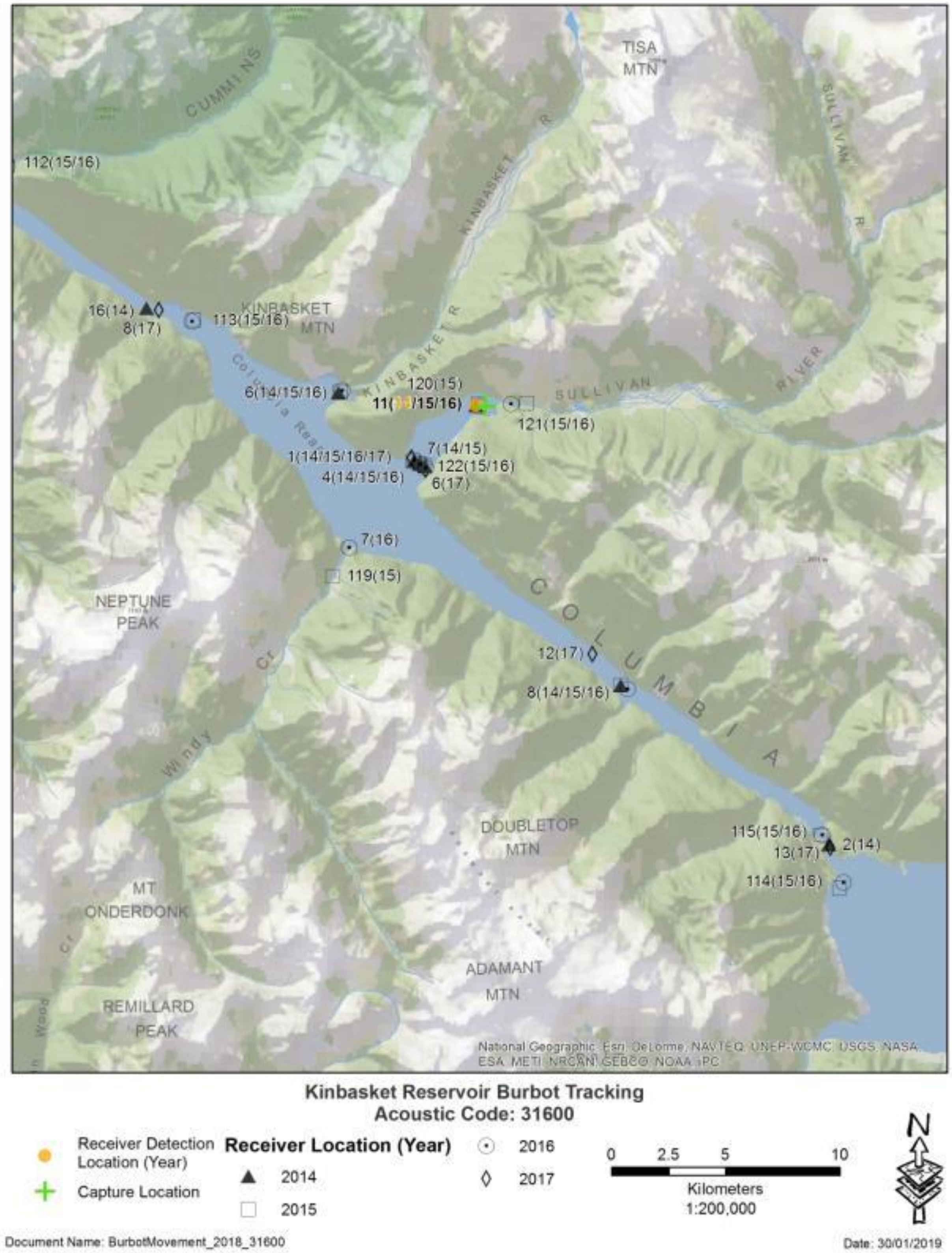
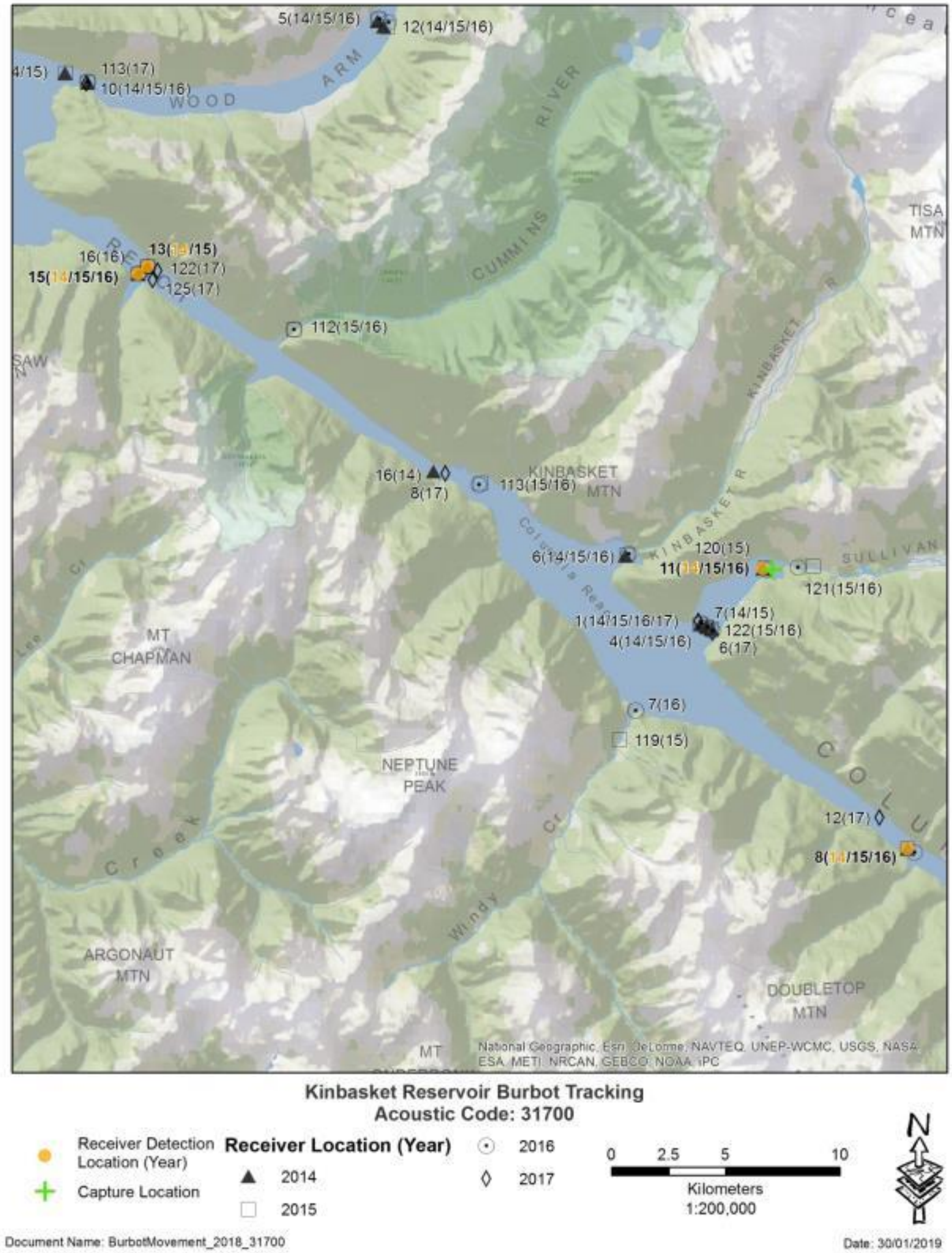
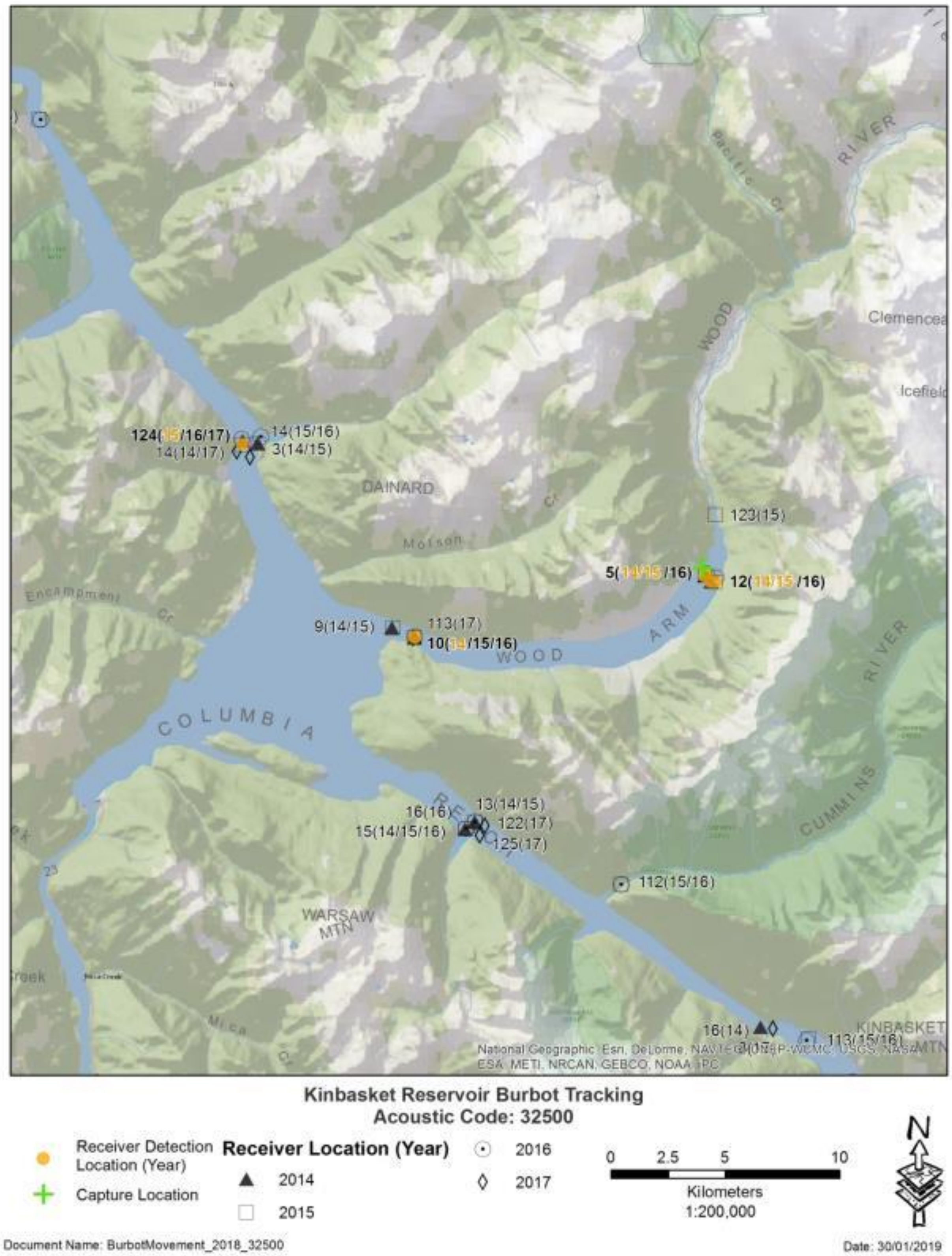
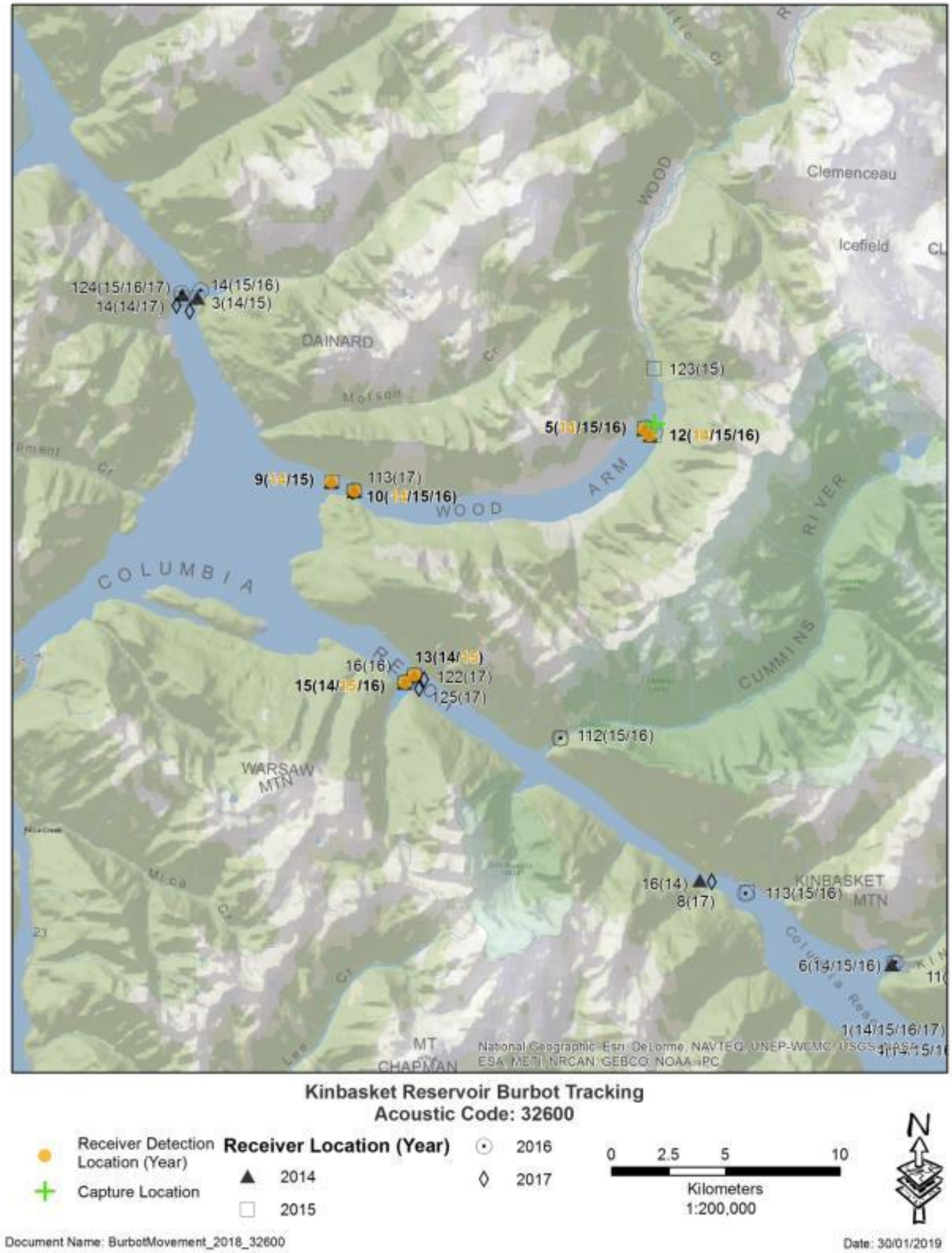
Document Name: BurbotMovement_2018_31300
Date: 29/01/2019

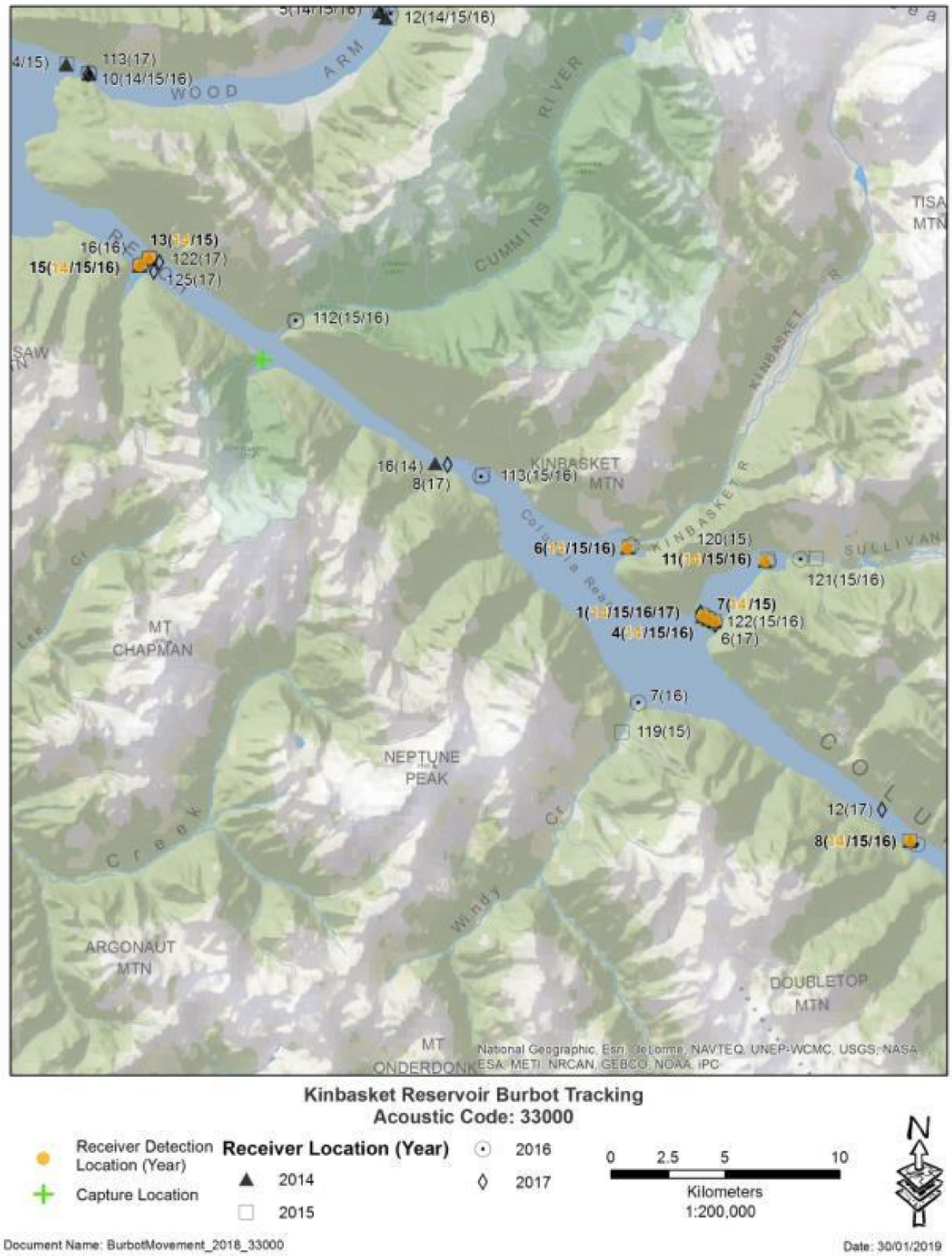

TISA MTN
CUMMINS
SULLIVAN R
KINBASKET R
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
Columbia Reach
6(14/15/16)
120(15)
SULLIVAN
121(15/16)
RIVER
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
COLUMBIA
12(17)
Windy Cr
DOUBLETOP MTN
115(15/16)
13(17)
2(14)
114(15/16)
MT ONDERDONK
ADAMANT MTN
REMILLARD PEAK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 31400
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_31400
Date: 30/01/2019

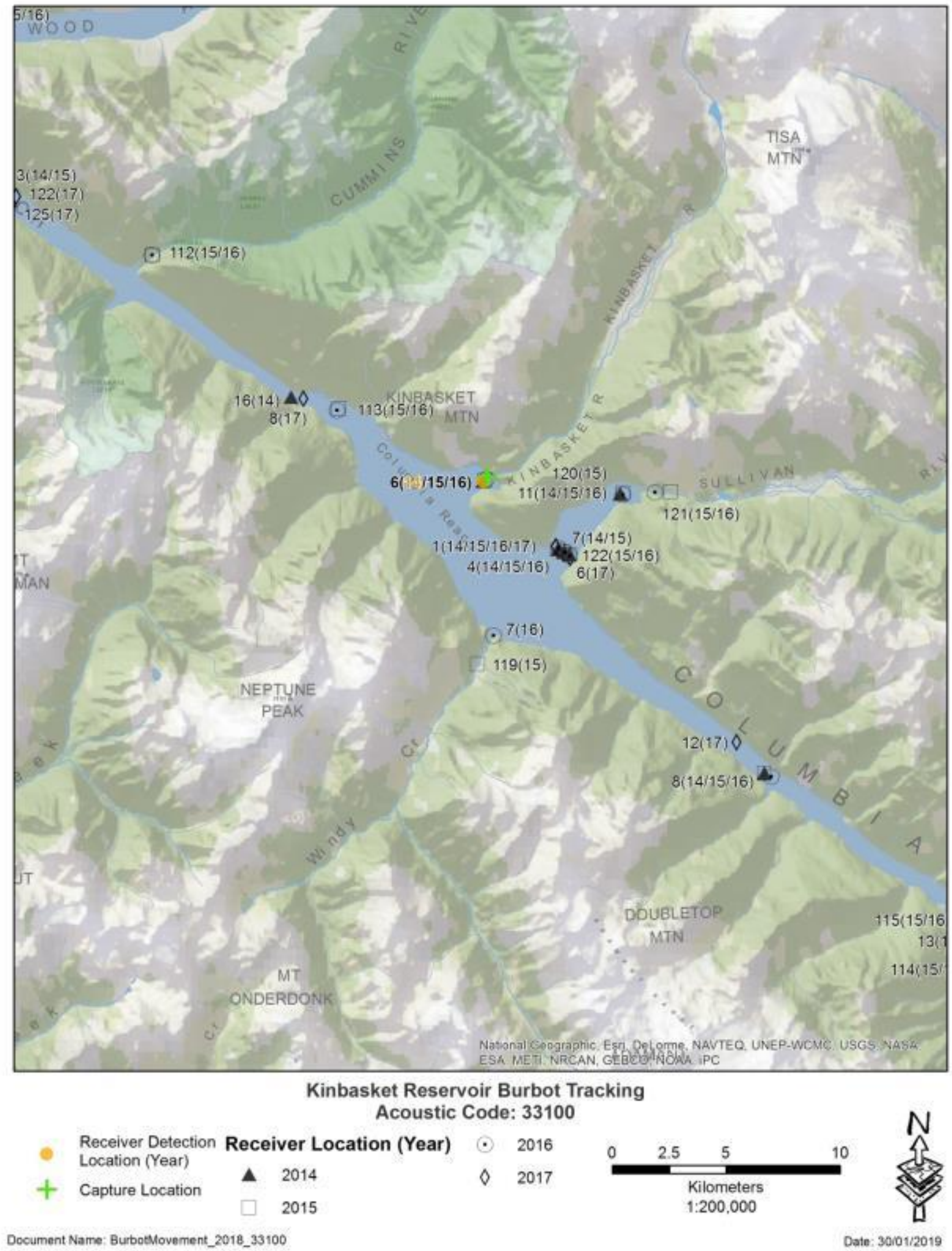

TISA MTN
CUMMINS
SULLIVAN R
KINBASKET R
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
Columbia Reach
6(14/15/16)
120(15)
/15/16)
121(15/16)
SULLIVAN
RIVER
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
Windy Cr
COLUMBIA
12(17)
8(14/15/16)
DOUBLETOP MTN
115(15/16)
13(17)
2(14)
114(15/16)
MT ONDERDONK
ADAMANT MTN
REMILLARD PEAK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 31600
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_31600
Date: 30/01/2019


5(14/15/16)
12(14/15/16)
113(17)
10(14/15/16)
WOOD
ARM
RIVER
CUMMINS
TISA MTN
13(14/15)
16(16)
15(14/15/16)
122(17)
125(17)
112(15/16)
KINBASKET R
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
SULLIVAN
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
MT CHAPMAN
7(16)
119(15)
NEPTUNE PEAK
COLU
12(17)
8(14/15/16)
Creek
Windy
ARGONAUT MTN
DOUBLETOP MTN
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 31700
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_31700
Date: 30/01/2019


124(15/16/17)
14(15/16)
14(14/17)
3(14/15)
DAINARD
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
WOOD
ARM
COLUMBIA
16(16)
13(14/15)
122(17)
15(14/15/16)
125(17)
112(15/16)
WARSAW MTN
16(14)
113(15/16)
Clemenceau
Icefield
RIVER
CUMMINS
KINBASKET
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 32500
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_32500
Date: 30/01/2019


124(15/16/17)
14(14/17)
14(15/16)
3(14/15)
DAINARD
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
WOOD ARM
COLUMBIA
CUMMINS
RIVER
Clemenceau
Icefield
16(16)
13(14/15)
122(17)
15(14/15/16)
125(17)
112(15/16)
WARSAW MTN
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
1(14/15/16/17)
MT CHAPMAN
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 32600
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_32600
Date: 30/01/2019


12(14/15/16)
113(17)
10(14/15/16)
WOOD
ARM
RIVER
CUMMINS
13(14/15)
16(16)
122(17)
15(14/15/16)
125(17)
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
120(15)
11(14/15/16)
SULLIVAN
121(15/16)
7(14/15)
1(14/15/16/17)
122(15/16)
4(14/15/16)
6(17)
MT CHAPMAN
7(16)
119(15)
NEPTUNE PEAK
12(17)
8(14/15/16)
ARGONAUT MTN
DOUBLETOP MTN
TISA MTN
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 33000
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_33000
Date: 30/01/2019


WOOD
TISA MTN
3(14/15)
122(17)
125(17)
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
SULLIVAN
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
12(17)
8(14/15/16)
COLUMBIA
DOUBLETOP MTN
MT ONDERDONK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 33100
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
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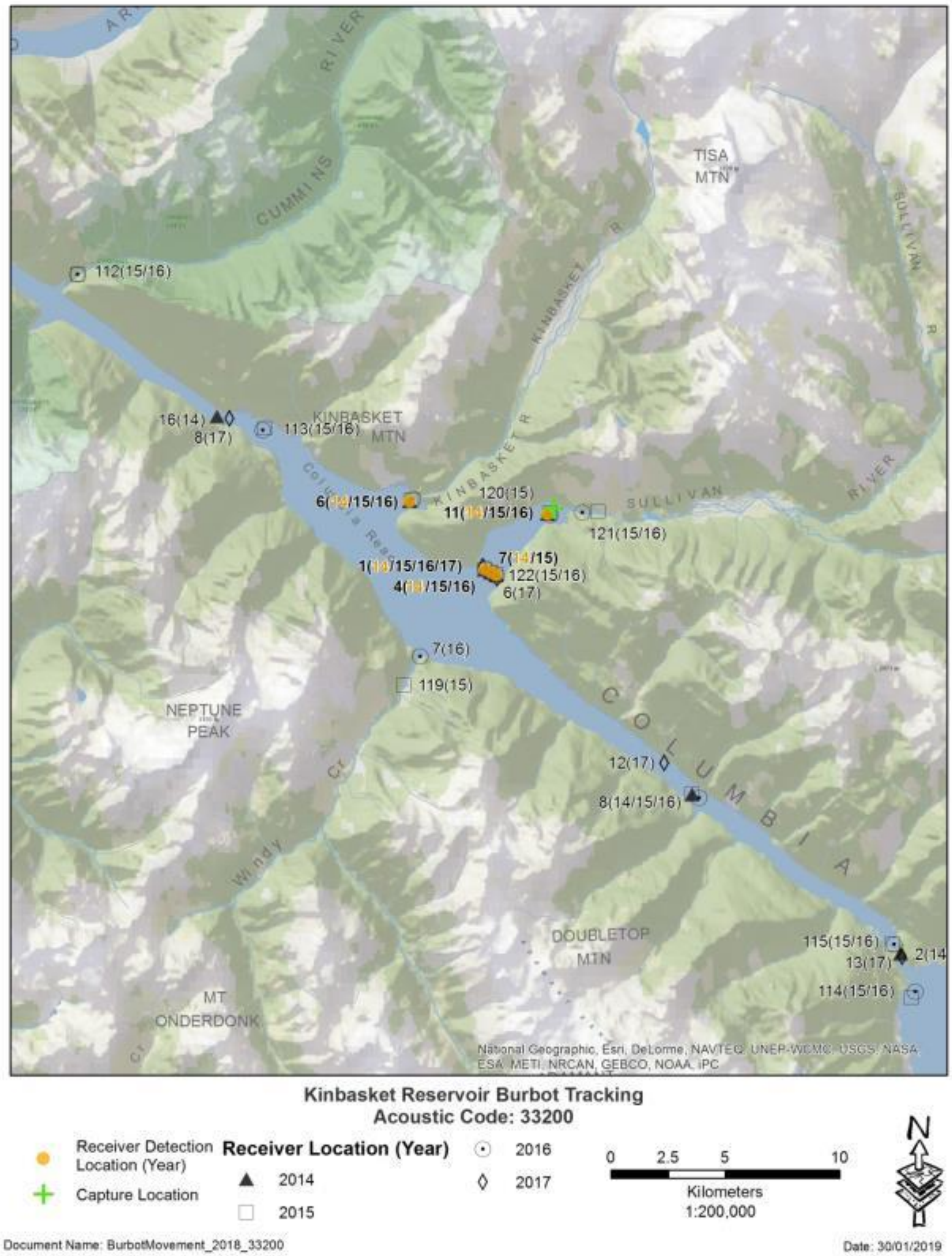
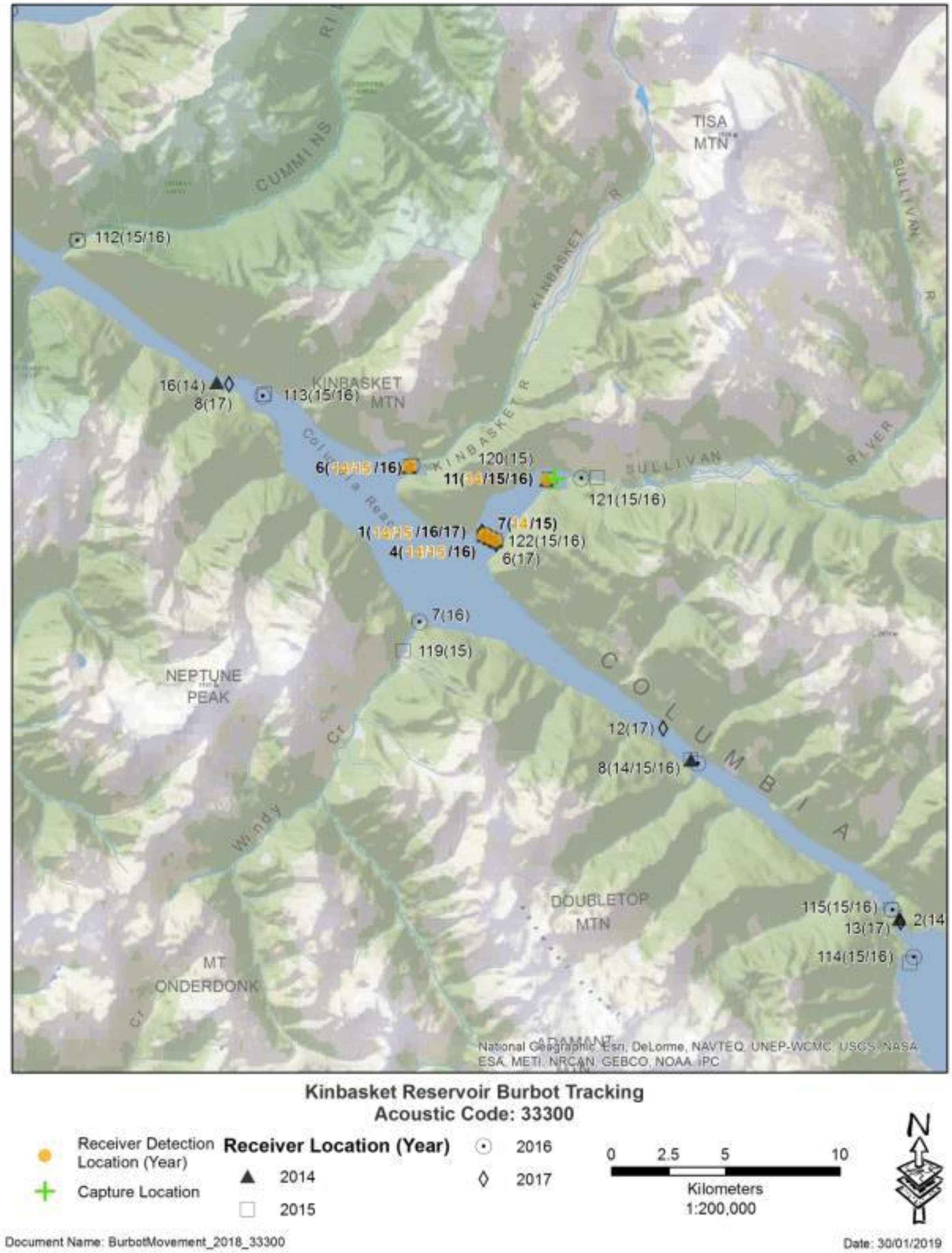
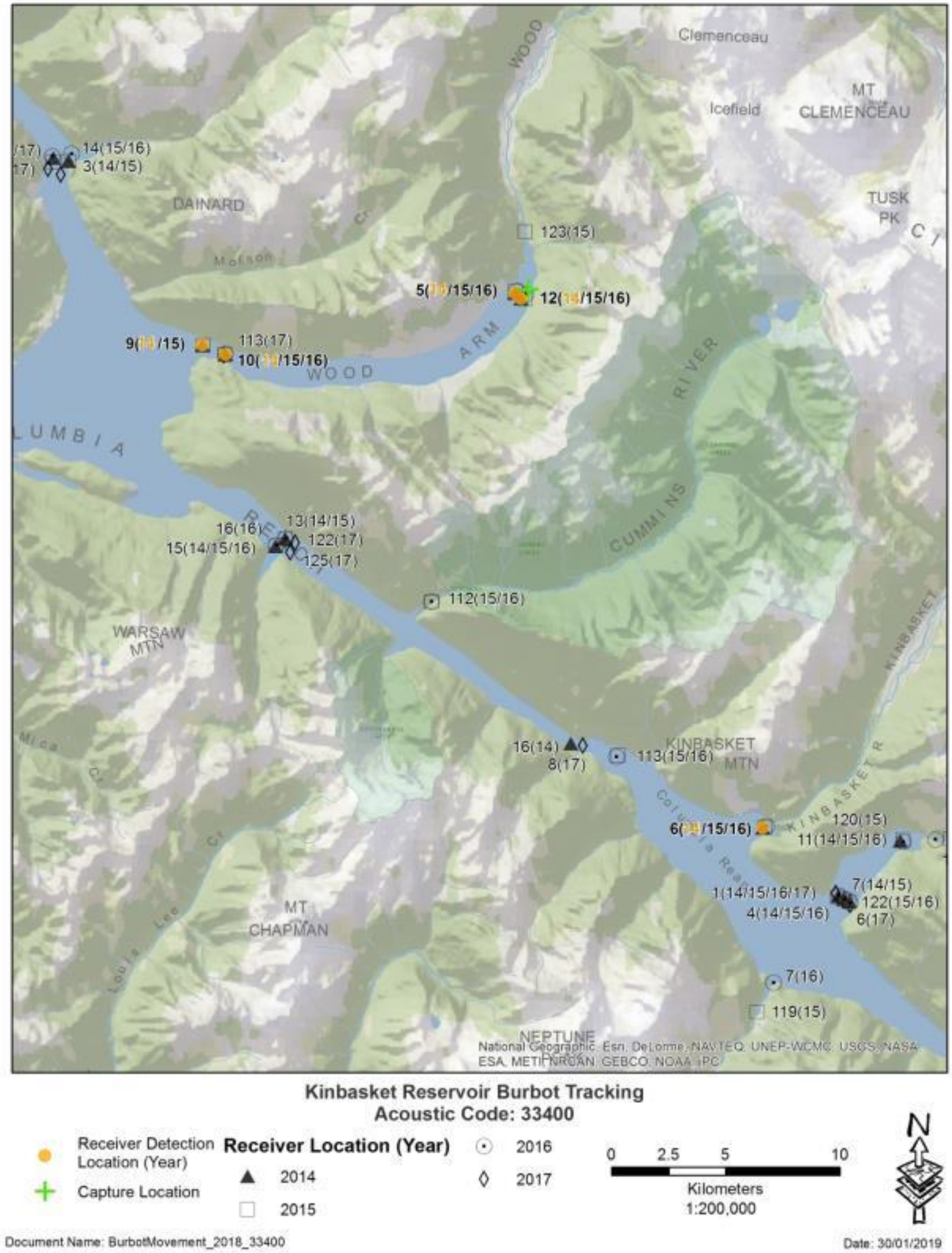
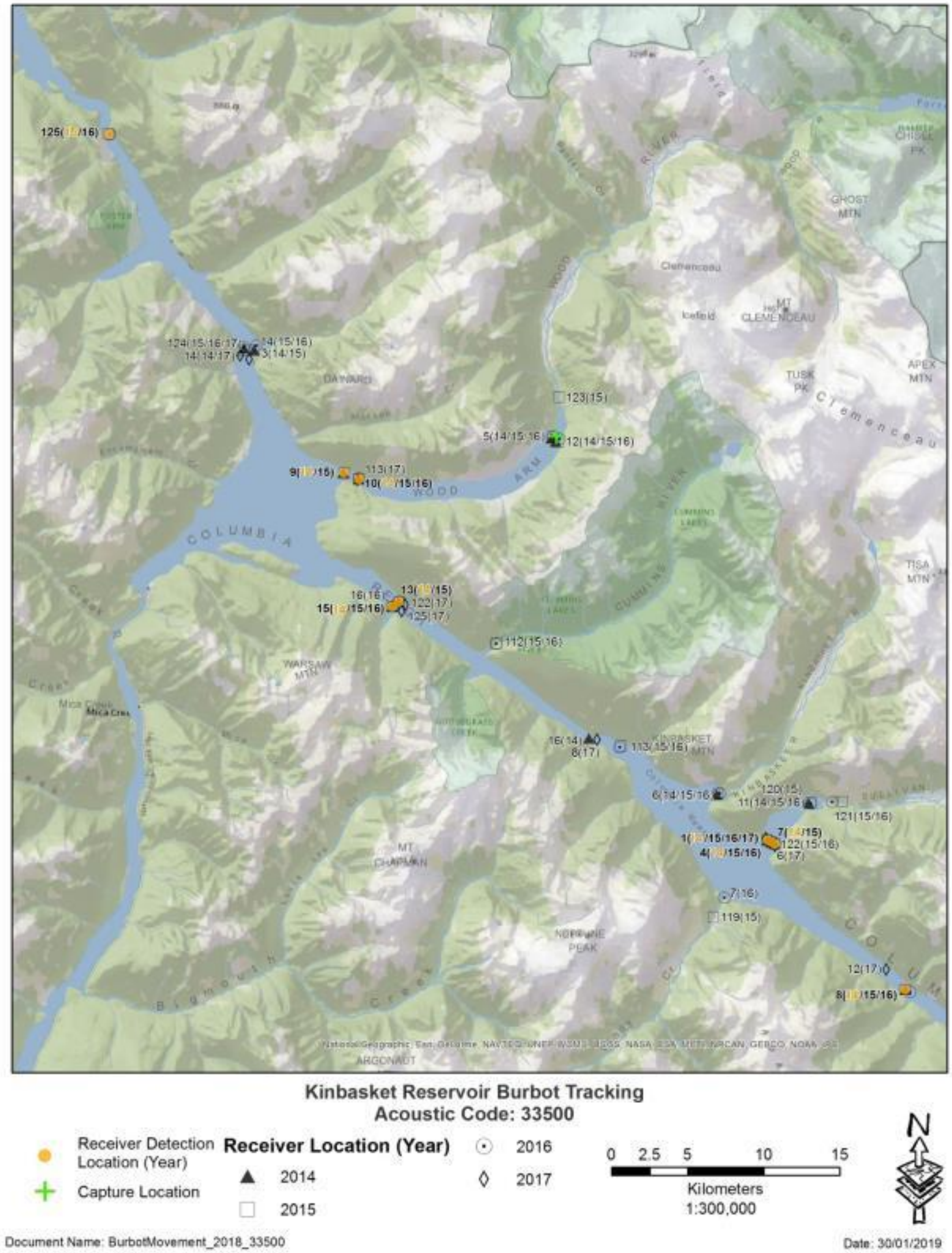
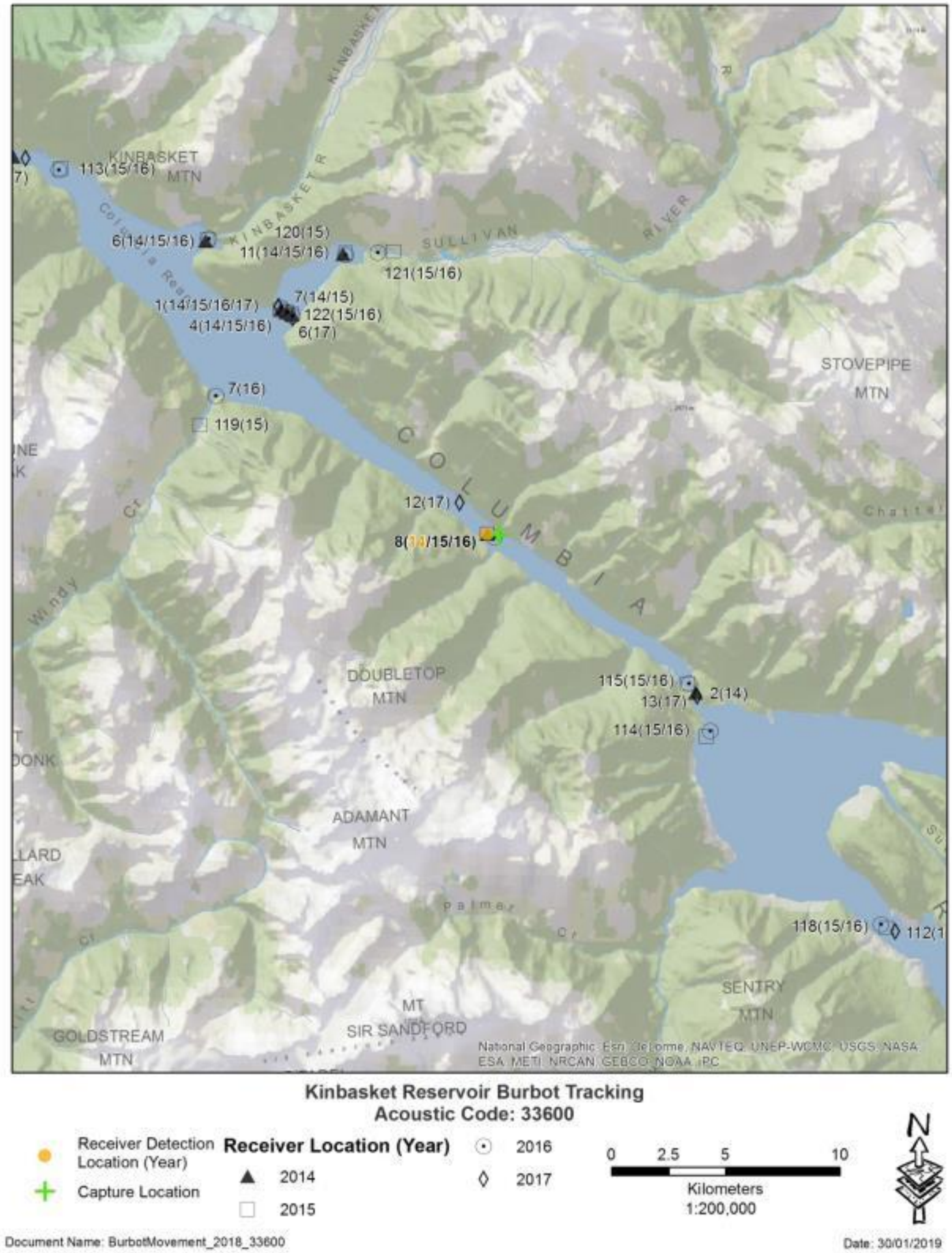
Document Name: BurbotMovement_2018_33100
Date: 30/01/2019

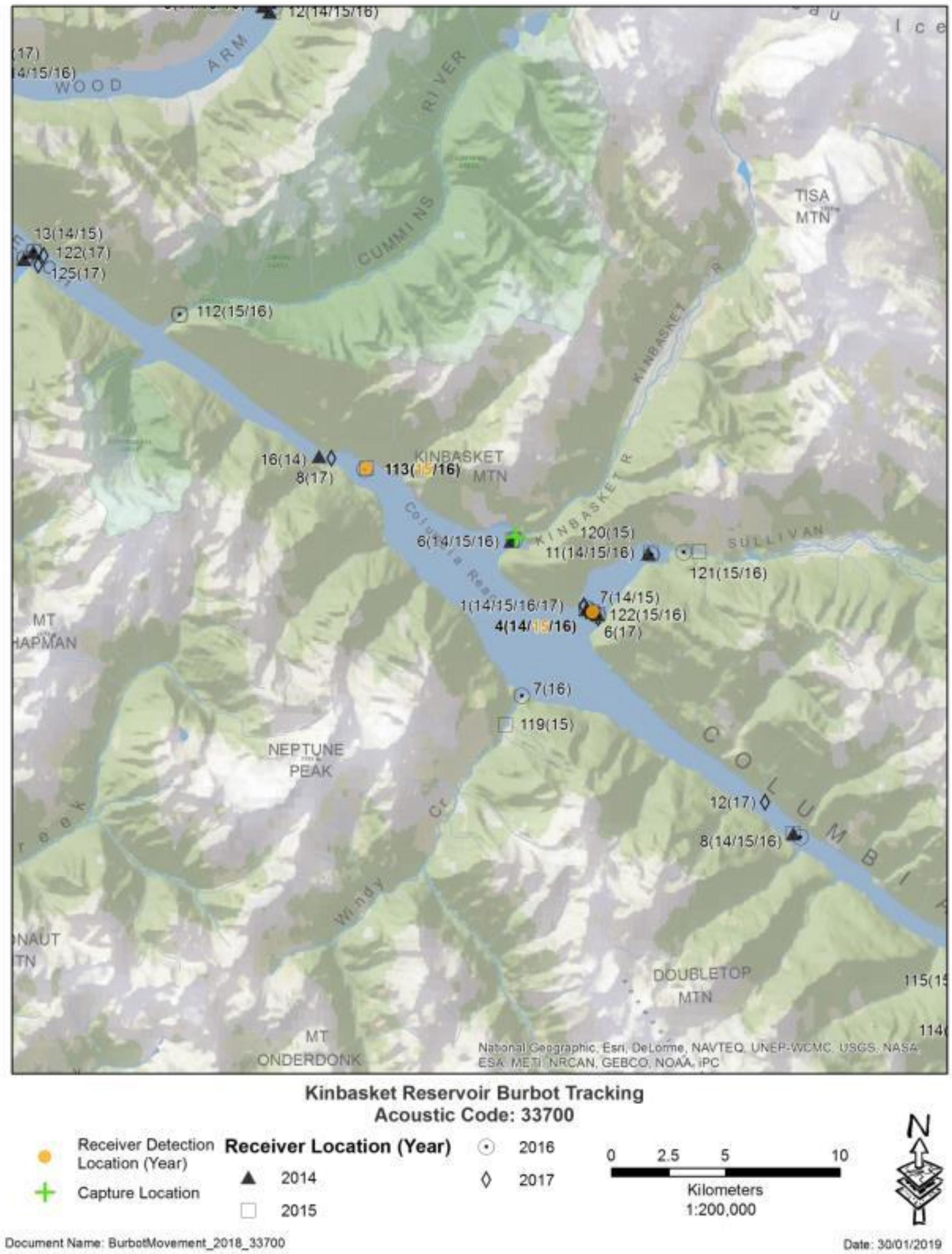

TISA MTN
SULLIVAN R
KINBASKET R
CUMMINS RIVER
SULLIVAN RIVER
KINBASKET MTN
112(15/16)
16(14)
8(17)
113(15/16)
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
COLUMBIA
12(17)
8(14/15/16)
Windy Cr
DOUBLETOP MTN
MT ONDERDONK
115(15/16)
13(17)
114(15/16)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 33200
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0
2.5
5
10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_33200
Date: 30/01/2019

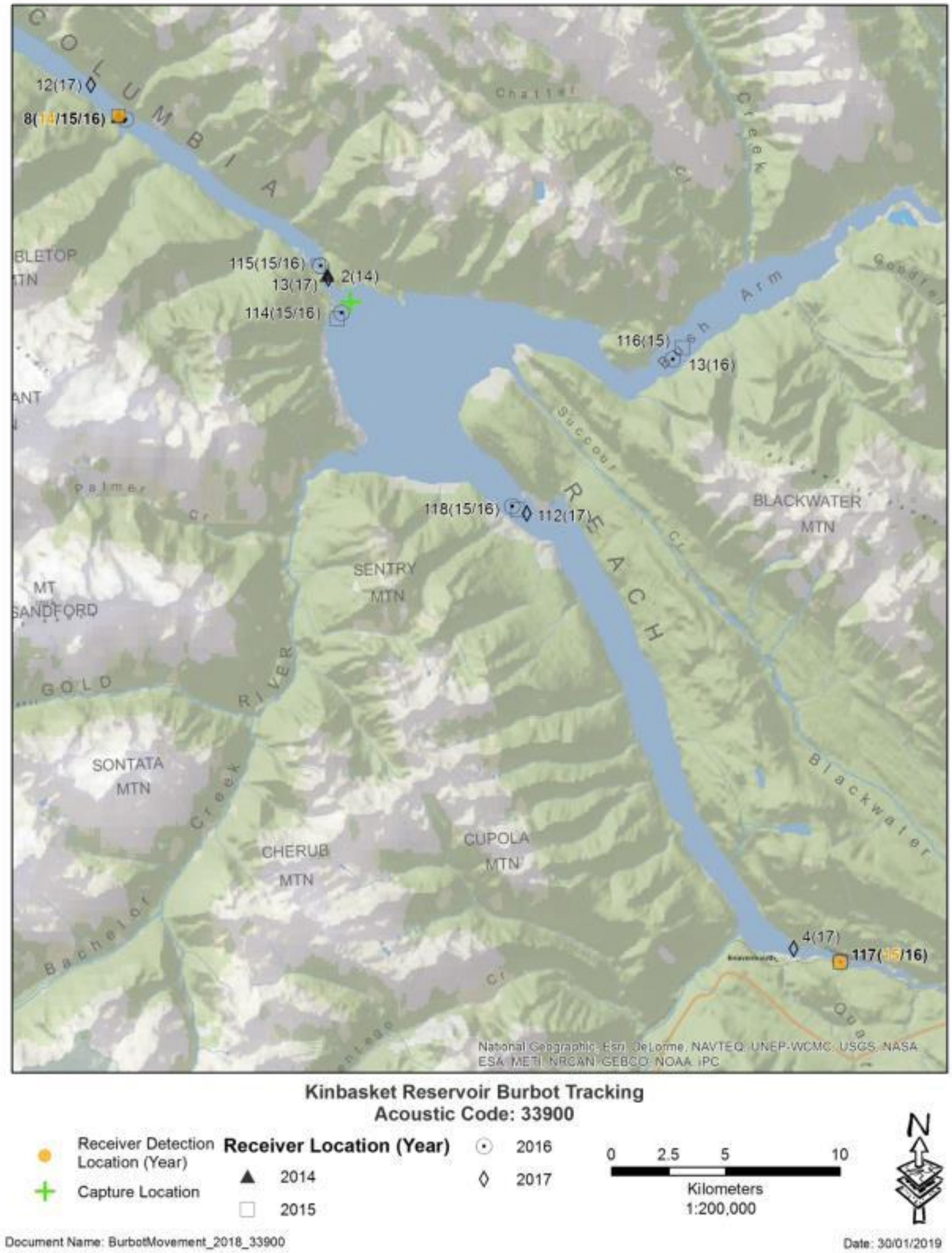

TISA MTN
CUMMINS
KINBASKET R
SULLIVAN R
SULLIVAN RIVER
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
Columbia Reach
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
COLUMBIA
12(17)
8(14/15/16)
Windy Cr
DOUBLETOP MTN
MT ONDERDONK
115(15/16)
13(17)
2(14
114(15/16)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 33300
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_33300
Date: 30/01/2019

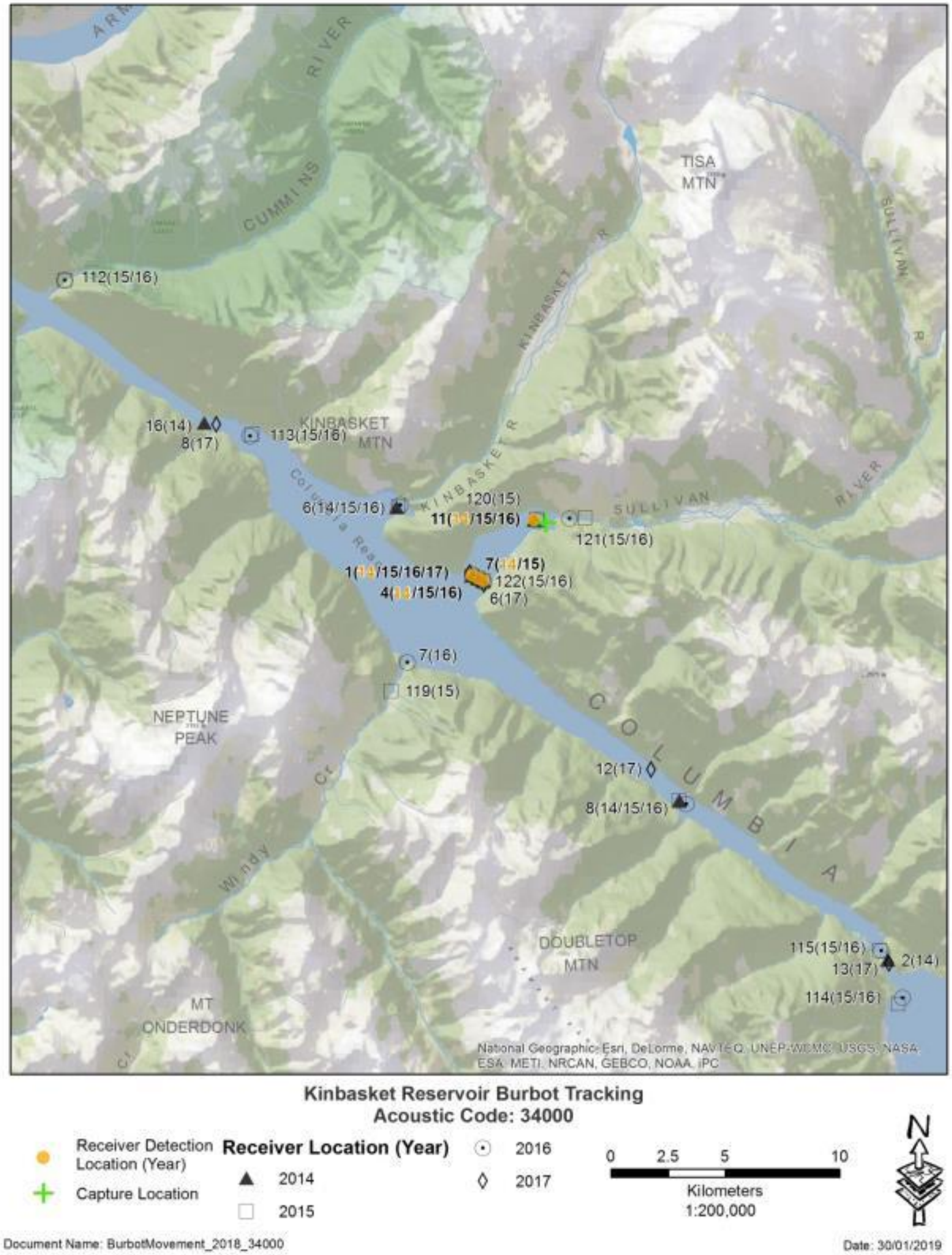

Clemenceau
MT CLEMENCEAU
Icefield
TUSK PK
DAINARD
WOOD
WOOD ARM
RIVER
CUMMINS
WARSAW MTN
KINBASKET MTN
MT CHAPMAN
NEPTUNE
14(15/16)
3(14/15)
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
13(14/15)
16(16)
122(17)
15(14/15/16)
125(17)
112(15/16)
16(14)
8(17)
113(15/16)
6(14/15/16)
120(15)
11(14/15/16)
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 33400
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_33400
Date: 30/01/2019

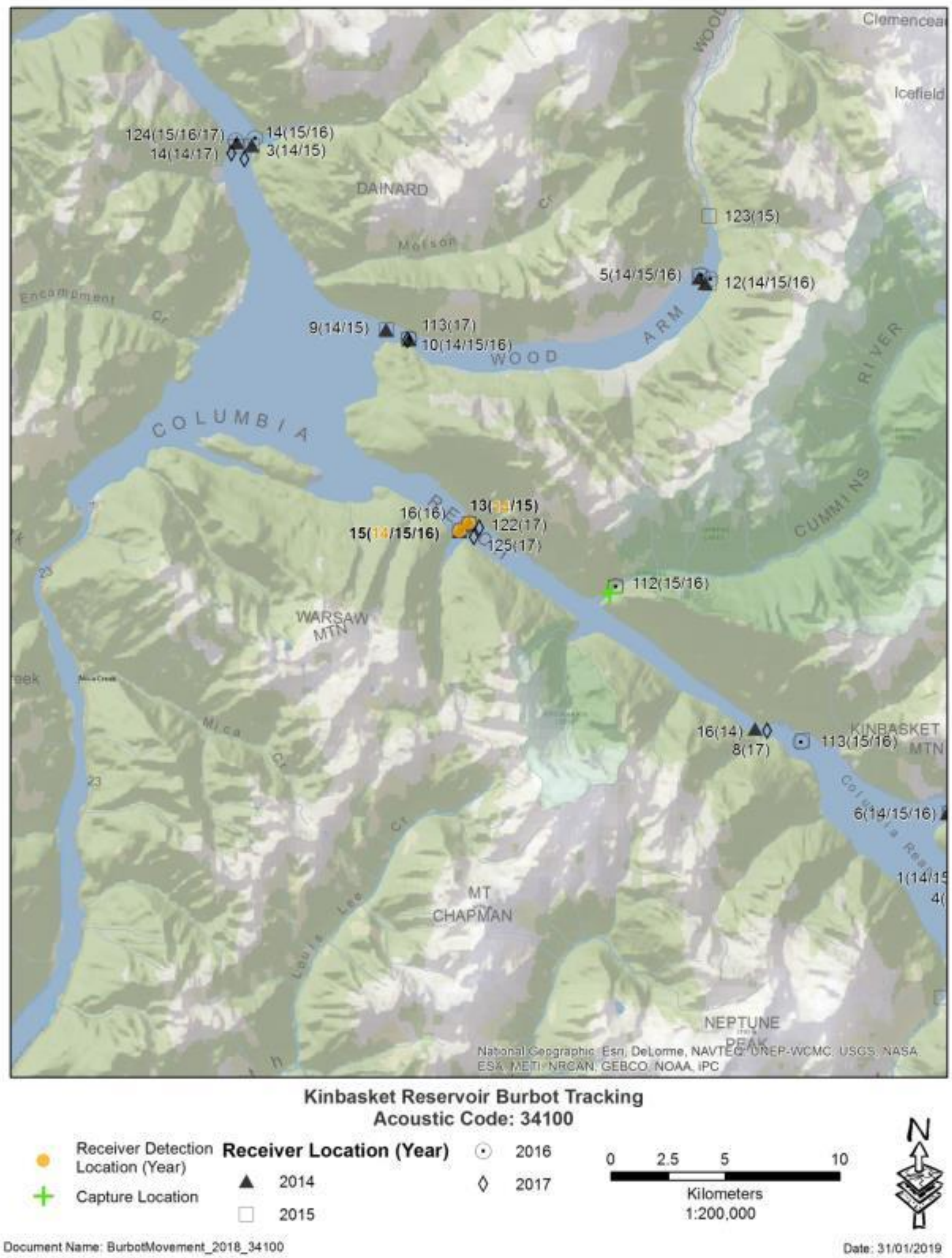

Kinbasket Reservoir Burbot Tracking
Acoustic Code: 33500
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10 15
Kilometers
1:300,000
N
Document Name: BurbotMovement_2018_33500
Date: 30/01/2019


113(15/16)
KINBASKET MTN
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
SULLIVAN RIVER
KINBASKET R
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
STOVEPIPE MTN
COLUMBIA
12(17)
8(14/15/16)
DOUBLETOP MTN
115(15/16)
13(17)
2(14)
114(15/16)
ADAMANT MTN
118(15/16)
SENTRY MTN
GOLDSTREAM MTN
MT SIR SANDFORD
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 33600
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_33600
Date: 30/01/2019


12(14/15/16)
13(14/15)
122(17)
125(17)
112(15/16)
16(14)
8(17)
113(15/16)
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
1(14/15/16/17)
7(14/15)
122(15/16)
6(17)
4(14/15/16)
7(16)
119(15)
12(17)
8(14/15/16)
KINBASKET MTN
TISA MTN
NEPTUNE PEAK
DOUBLETOP MTN
MT ONDERDONK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 33700
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_33700
Date: 30/01/2019


COLUMBIA
12(17)
8(14/15/16)
115(15/16)
13(17)
2(14)
114(15/16)
116(15)
13(16)
Bush Arm
118(15/16)
112(17)
REACH
BLACKWATER MTN
SENTRY MTN
MT SANDFORD
GOLD RIVER
SONTATA MTN
CHERUB MTN
CUPOLA MTN
4(17)
117(15/16)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 33900
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_33900
Date: 30/01/2019


TISA MTN
KINBASKET MTN
NEPTUNE PEAK
DOUBLETOP MTN
MT ONDERDONK
CUMMINS RIVER
KINBASKET R
SULLIVAN RIVER
COLUMBIA
112(15/16)
16(14)
8(17)
113(15/16)
6(14/15/16)
120(15)
121(15/16)
122(15/16)
6(17)
7(16)
119(15)
12(17)
8(14/15/16)
115(15/16)
13(17)
2(14)
114(15/16)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 34000
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_34000
Date: 30/01/2019


124(15/16/17)
14(14/17)
14(15/16)
3(14/15)
DAINARD
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
WOOD
ARM
COLUMBIA
RIVER
16(16)
122(17)
125(17)
112(15/16)
WARSAW MTN
CUMMINS
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
MT CHAPMAN
NEPTUNE PEAK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 34100
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
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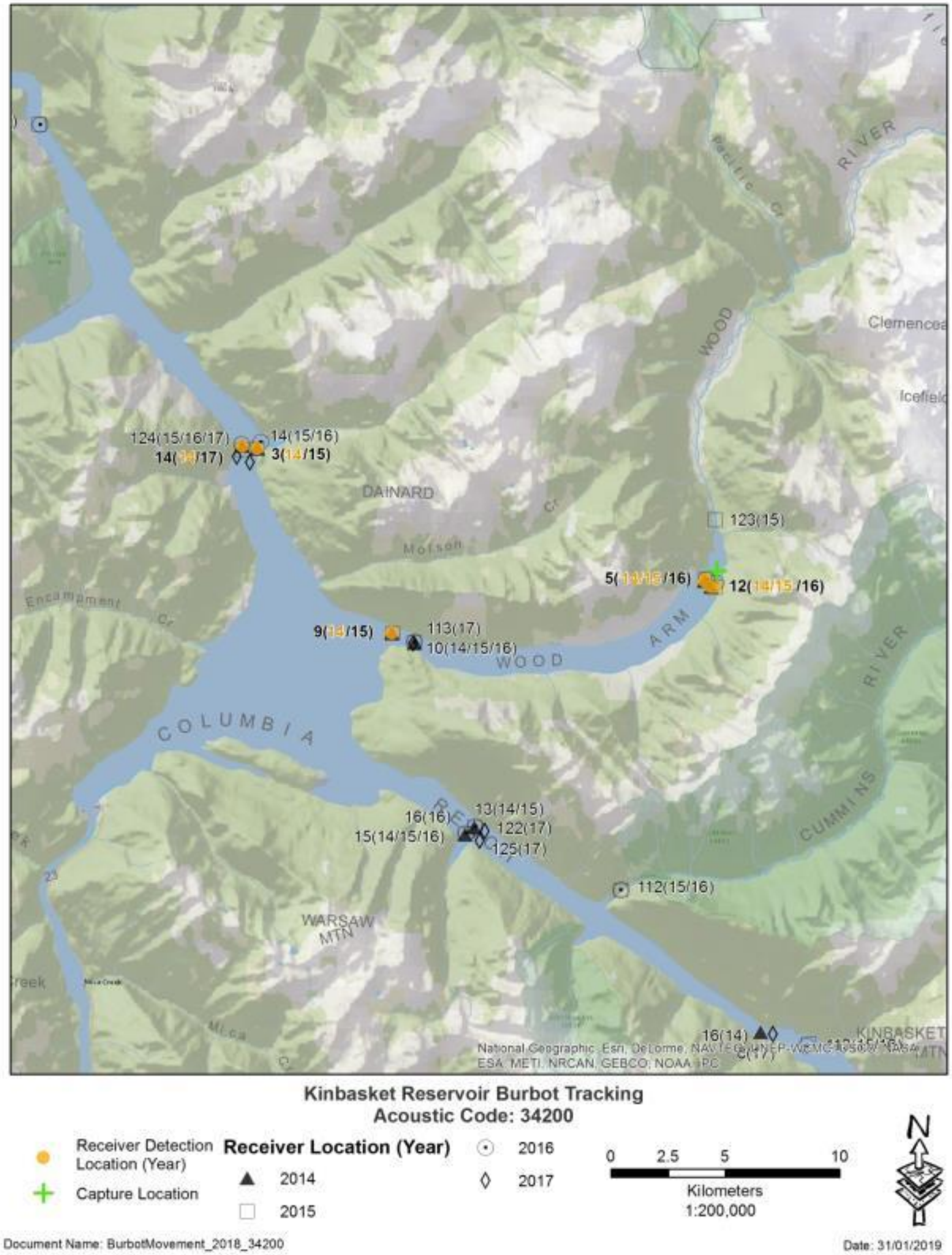
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_34100
Date: 31/01/2019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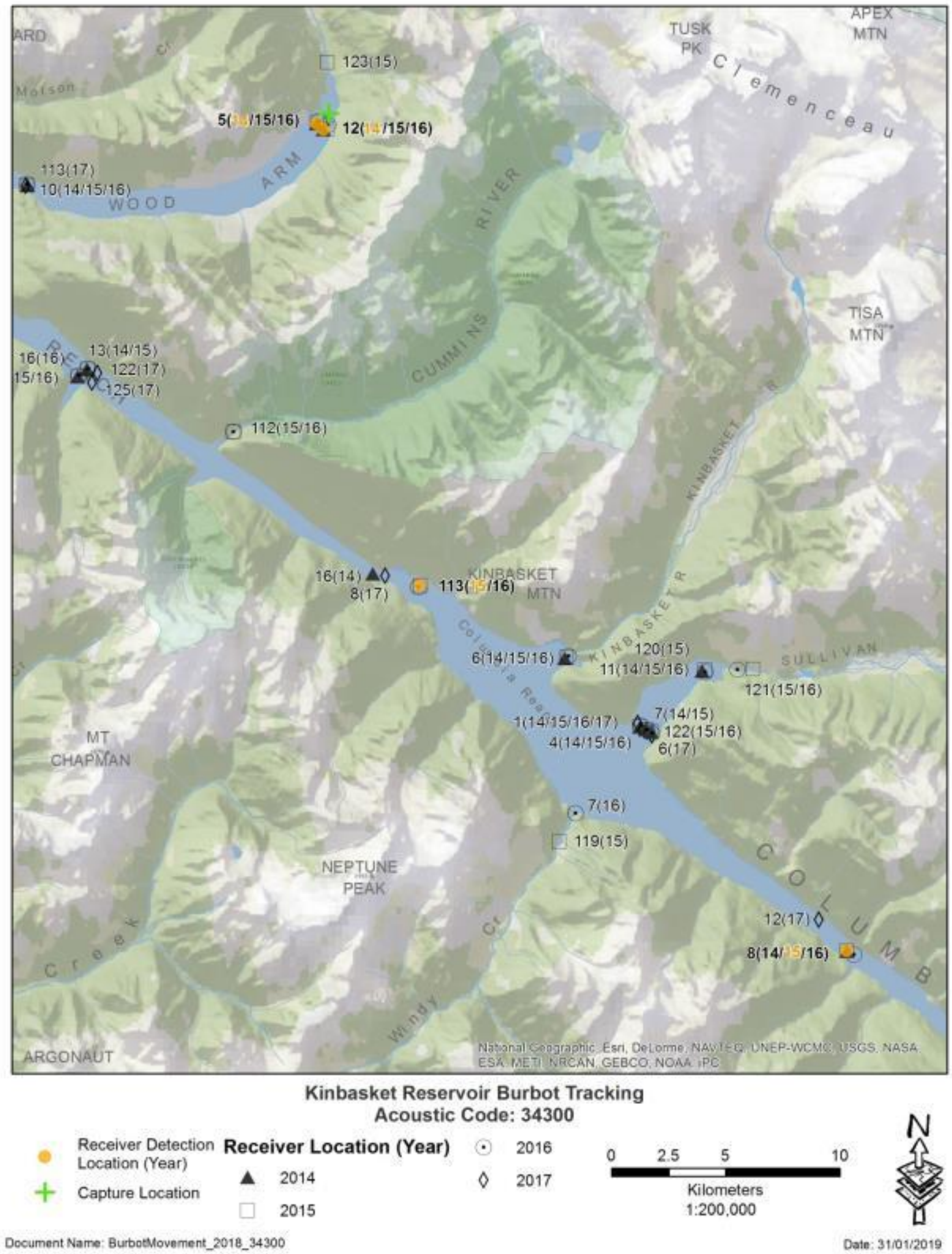
14(15/16)
14(14/17)
3(14/15)
DAINARD
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
WOOD ARM
COLUMBIA
WOOD RIVER
Clemenceau
Icefield
13(14/15)
16(16)
122(17)
15(14/15/16)
125(17)
112(15/16)
WARSAW MTN
CUMMINS
16(14)
KINBASKET MTN
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, IPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 34200
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0
2.5
5
10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_34200
Date: 31/01/2019


Kinbasket Reservoir Burbot Tracking
Acoustic Code: 34300
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
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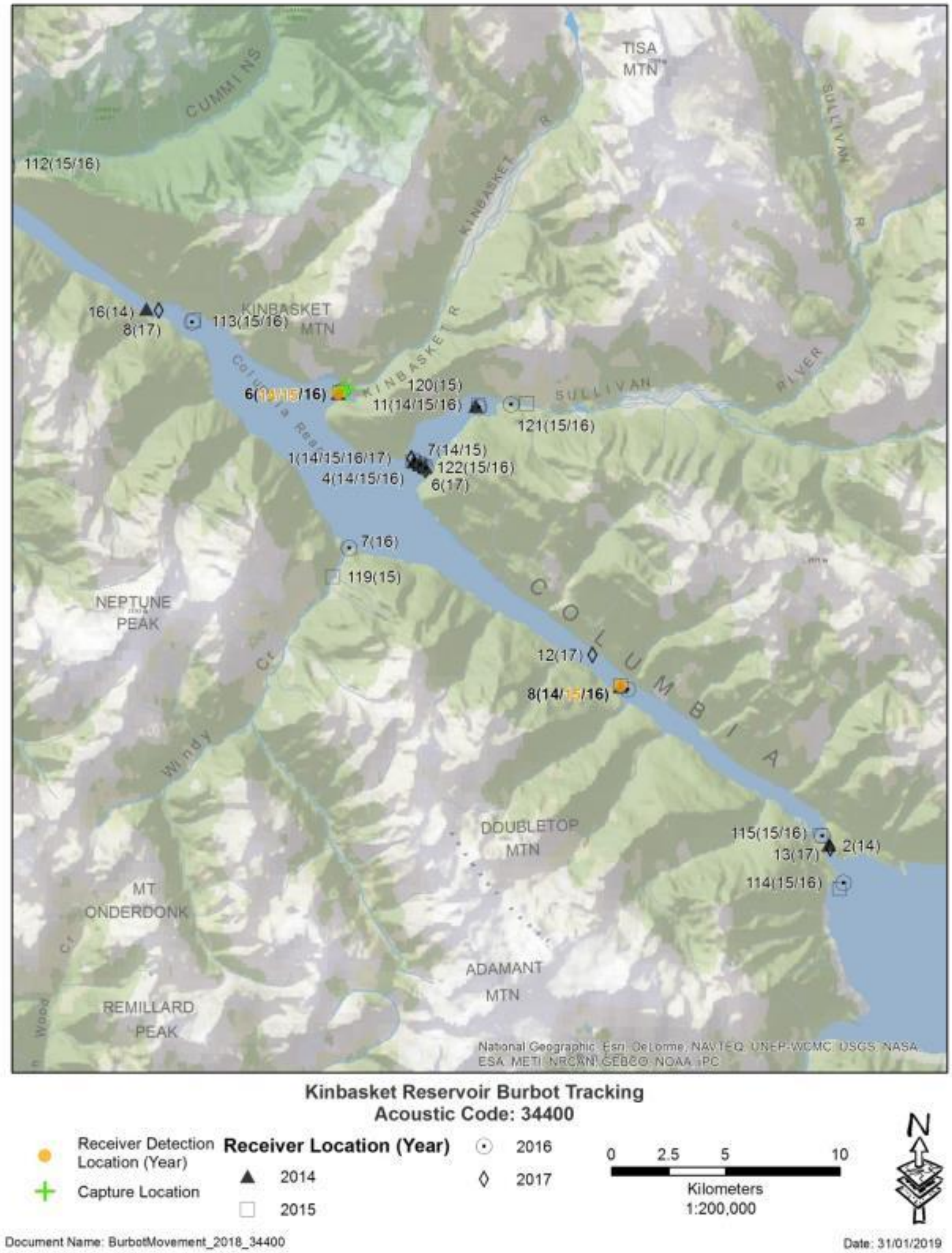
2015
2016
2017
Kilometers
1:200,000
Document Name: BurbotMovement_2018_34300
Date: 31/01/2019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CUMMINS
KINBASKET R
SULLIVAN R
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
Columbia Reach
KINBASKET R
6(14/15/16)
120(15)
11(14/15/16)
SULLIVAN RIVER
121(15/16)
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
COLUMBIA
12(17)
8(14/15/16)
Windy Cr
DOUBLETOP MTN
115(15/16)
13(17)
2(14)
114(15/16)
MT ONDERDONK
ADAMANT MTN
REMILLARD PEAK
Wood Cr
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 34400
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
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2.5
5
10
Kilometers
1:200,000
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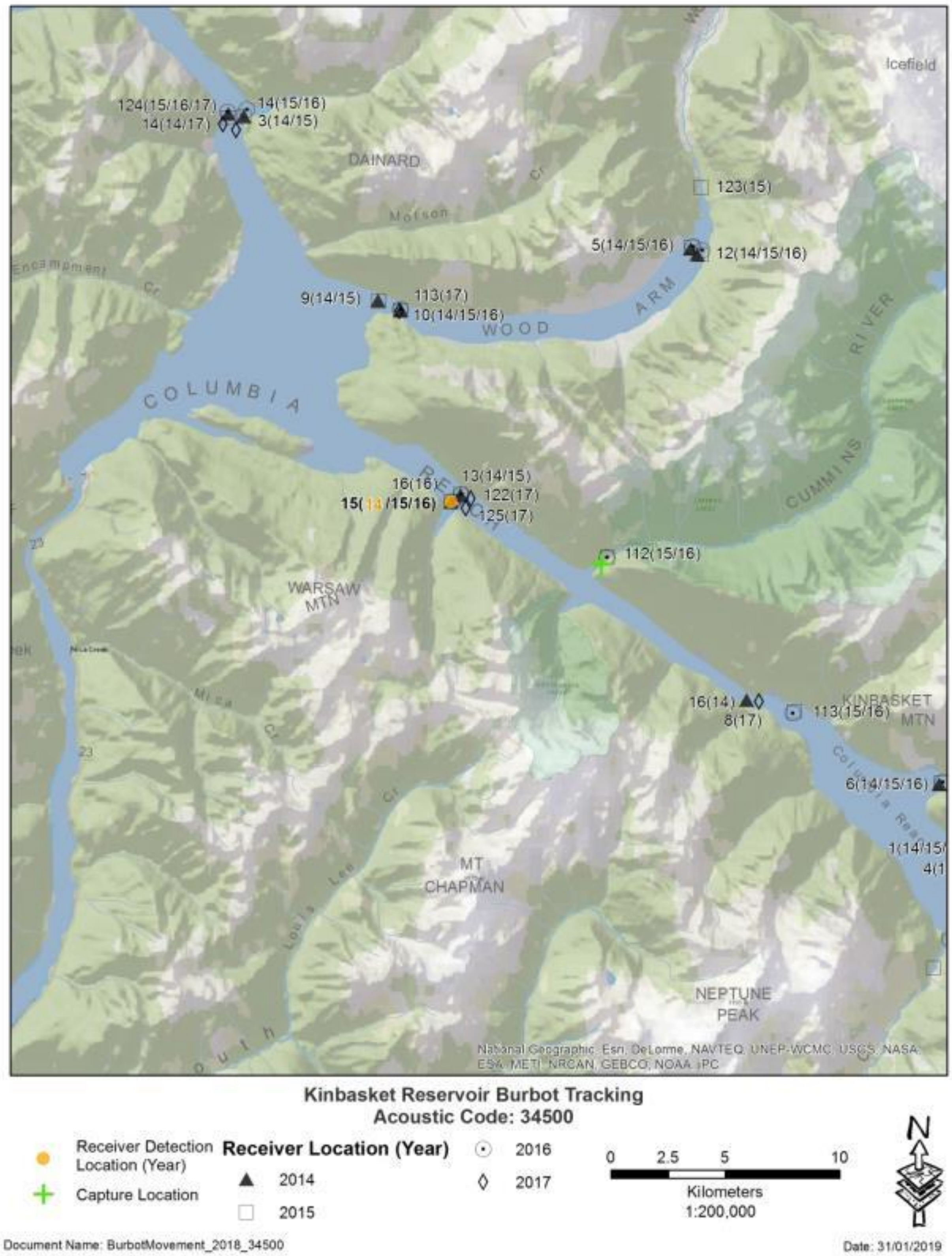
Document Name: BurbotMovement_2018_34400
Date: 31/01/2019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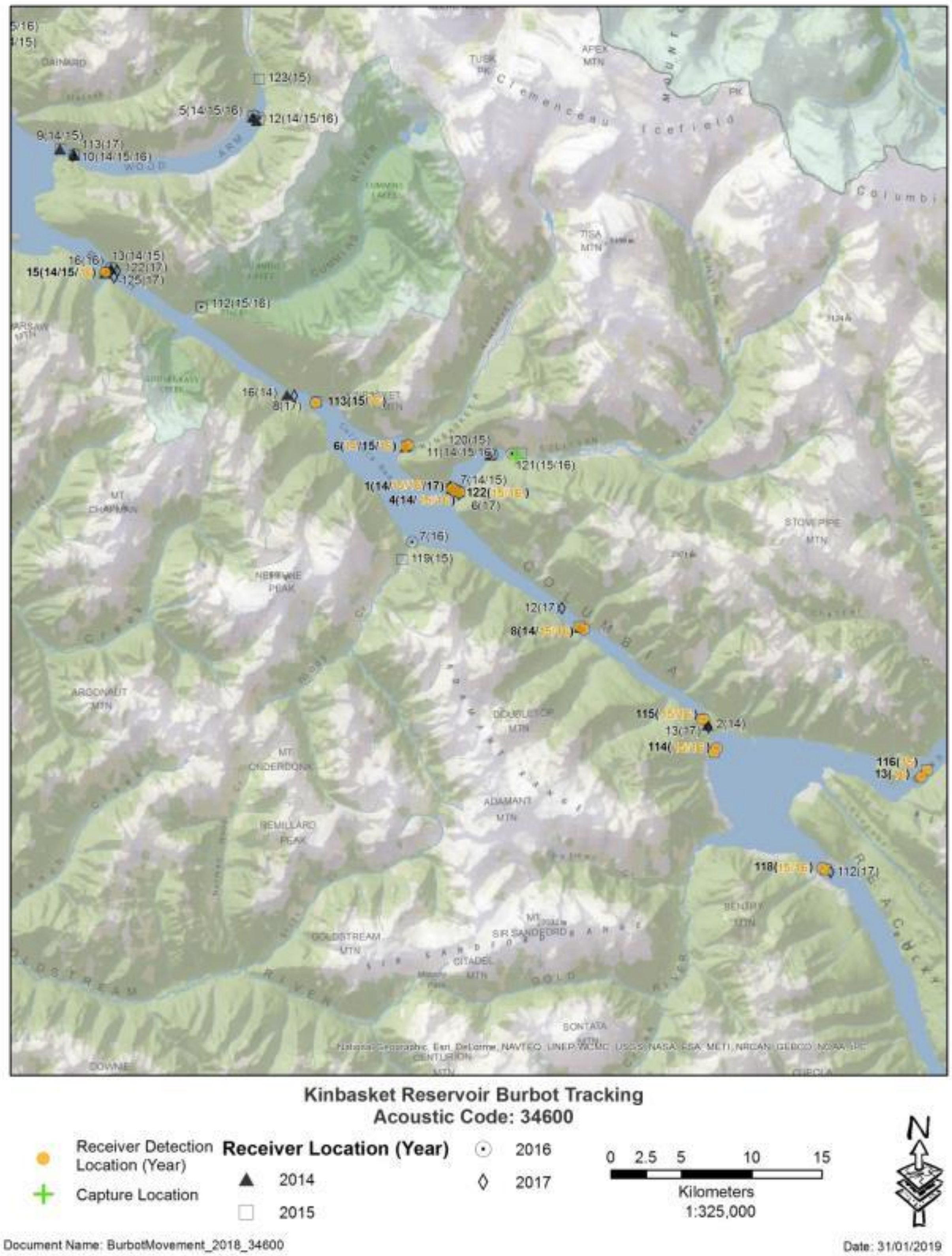
14(15/16)
3(14/15)
DAINARD
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
WOOD
ARM
RIVER
COLUMBIA
CUMMINS
16(16)
13(14/15)
15(14/15/16)
122(17)
125(17)
112(15/16)
WARSAW MTN
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
MT CHAPMAN
NEPTUNE PEAK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 34500
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0
2.5
5
10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_34500
Date: 31/01/2019


Kinbasket Reservoir Burbot Tracking
Acoustic Code: 34600
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
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2015
2016
2017
0 2.5 5 10 15
Kilometers
1:325,000
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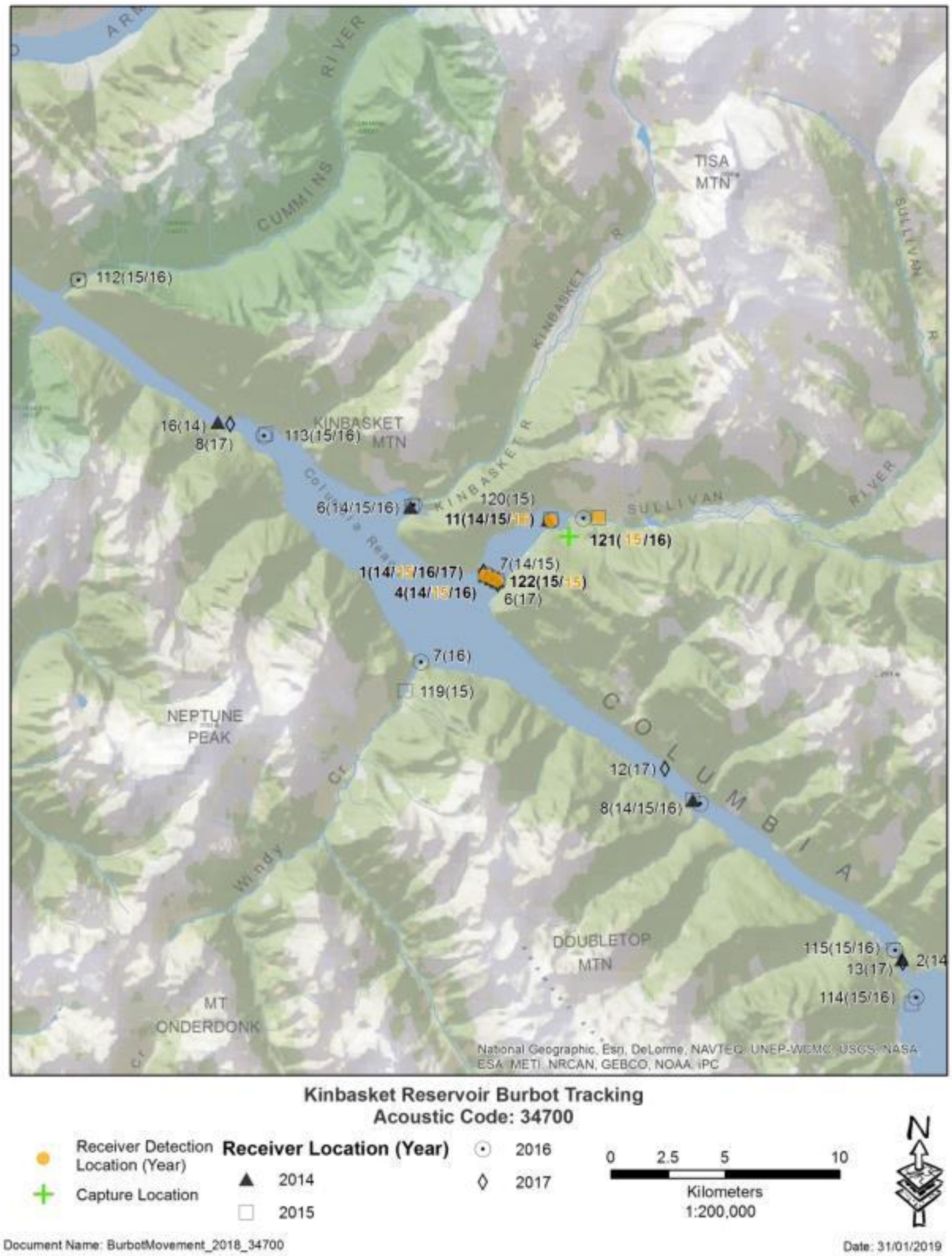
Document Name: BurbotMovement_2018_34600
Date: 31/01/2019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16(14)
8(17)
113(15/16)
KINBASKET MTN
TISA MTN
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
7(14/15)
1(14/15/16/17)
4(14/15/16)
122(15/15)
6(17)
7(16)
119(15)
NEPTUNE PEAK
12(17)
8(14/15/16)
COLUMBIA
DOUBLETOP MTN
115(15/16)
13(17)
114(15/16)
MT ONDERDONK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 34700
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
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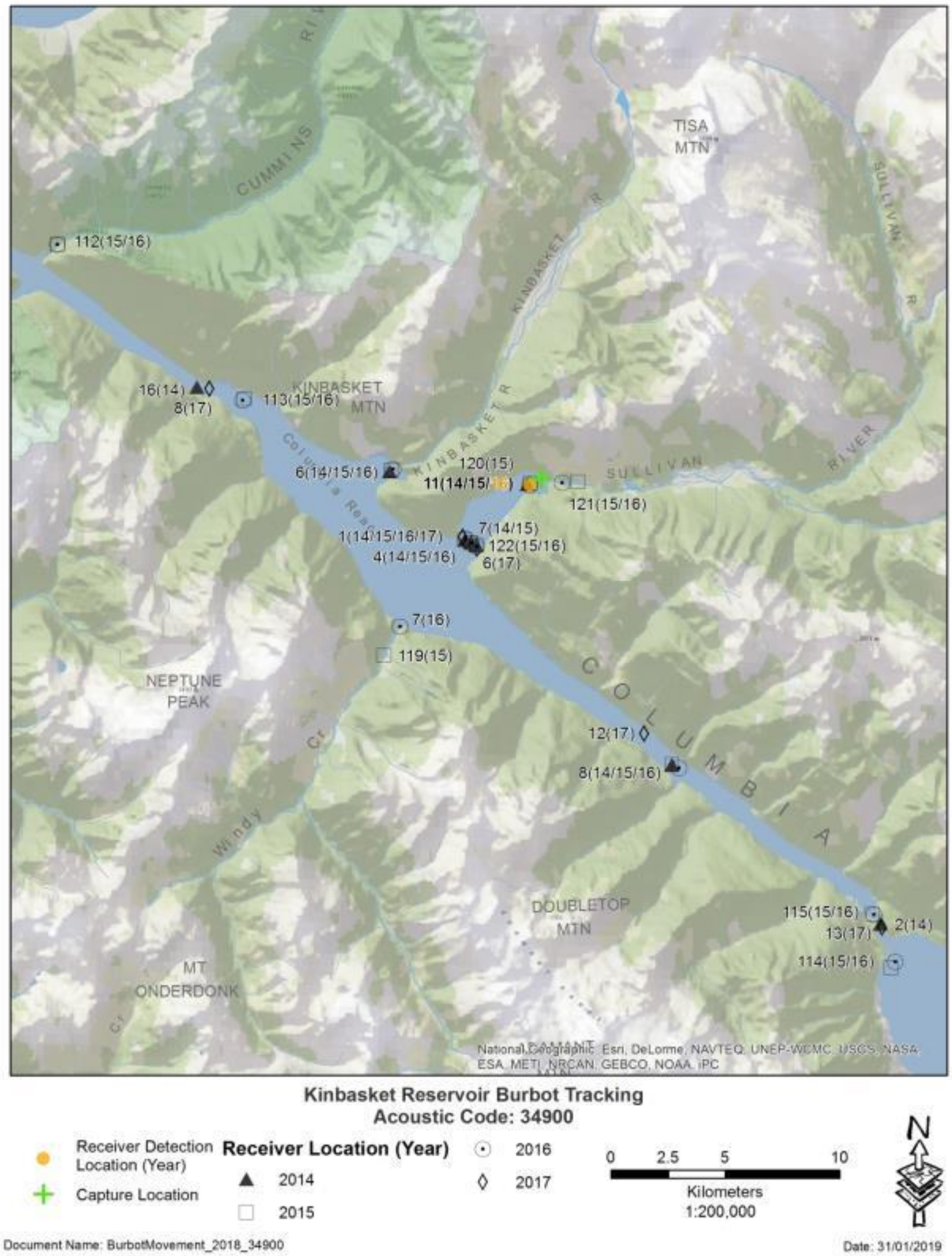
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_34700
Date: 31/01/2019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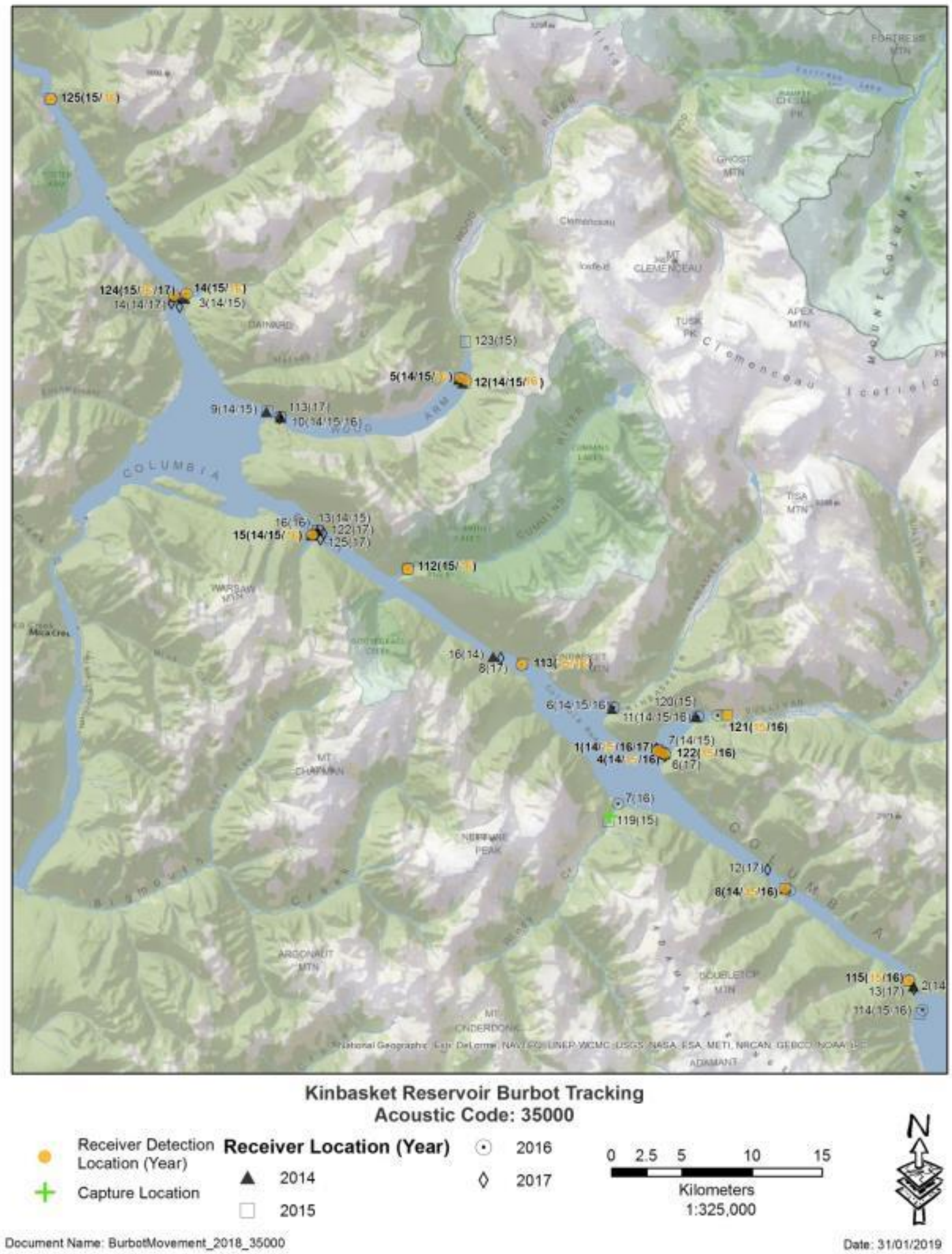
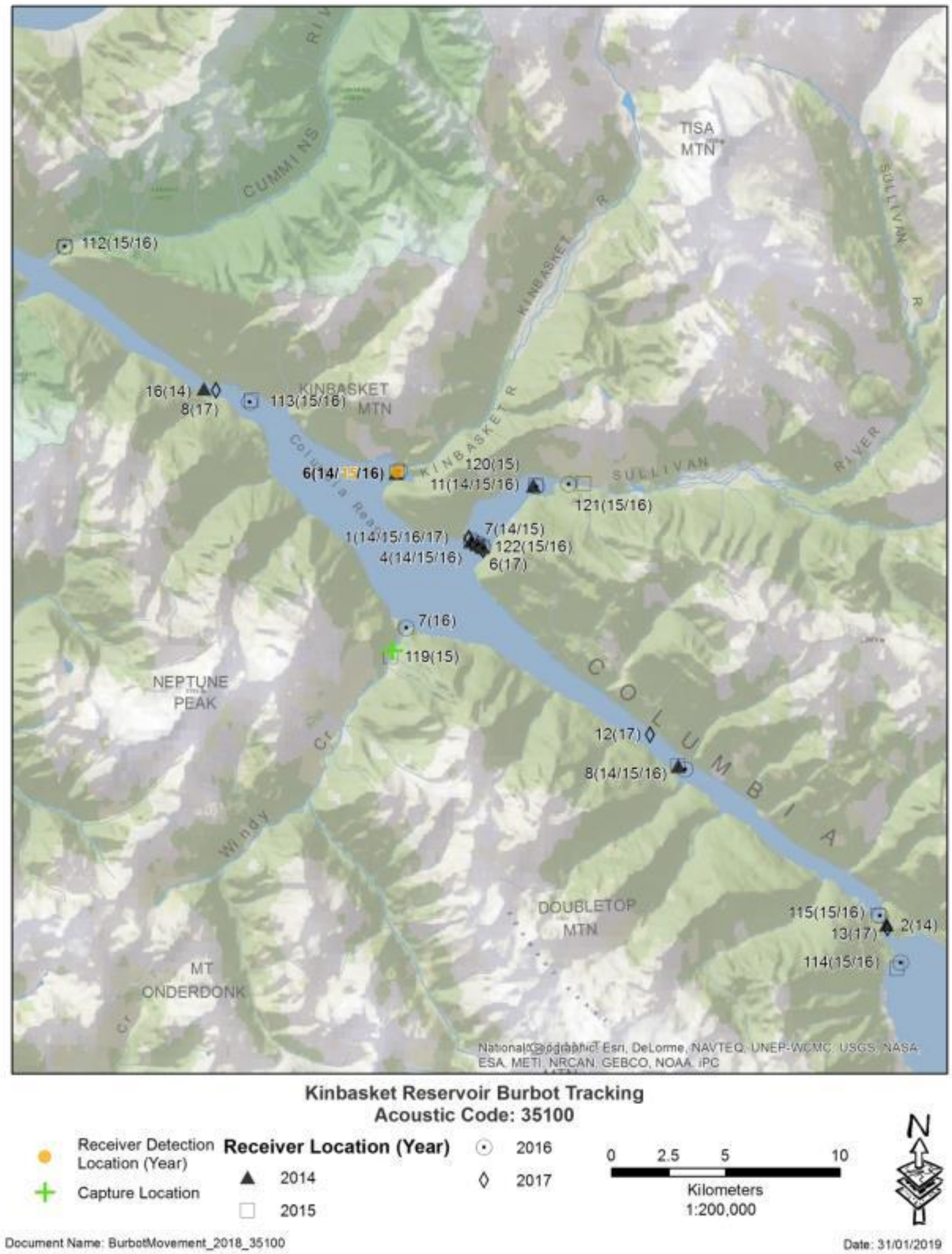
TISA MTN
CUMMINS
KINBASKET R
SULLIVAN R
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
SULLIVAN RIVER
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
COLUMBIA
12(17)
8(14/15/16)
Windy Cr
DOUBLETOP MTN
115(15/16)
13(17)
2(14)
114(15/16)
MT ONDERDONK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 34900
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_34900
Date: 31/01/2019


Kinbasket Reservoir Burbot Tracking
Acoustic Code: 35000
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10 15
Kilometers
1:325,000
N
Document Name: BurbotMovement_2018_35000
Date: 31/01/2019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SULLIVAN R
KINBASKET R
CUMMINS
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
SULLIVAN RIVER
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
COLUMBIA
12(17)
8(14/15/16)
Windy Cr
DOUBLETOP MTN
MT ONDERDONK
115(15/16)
13(17)
2(14)
114(15/16)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 35100
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
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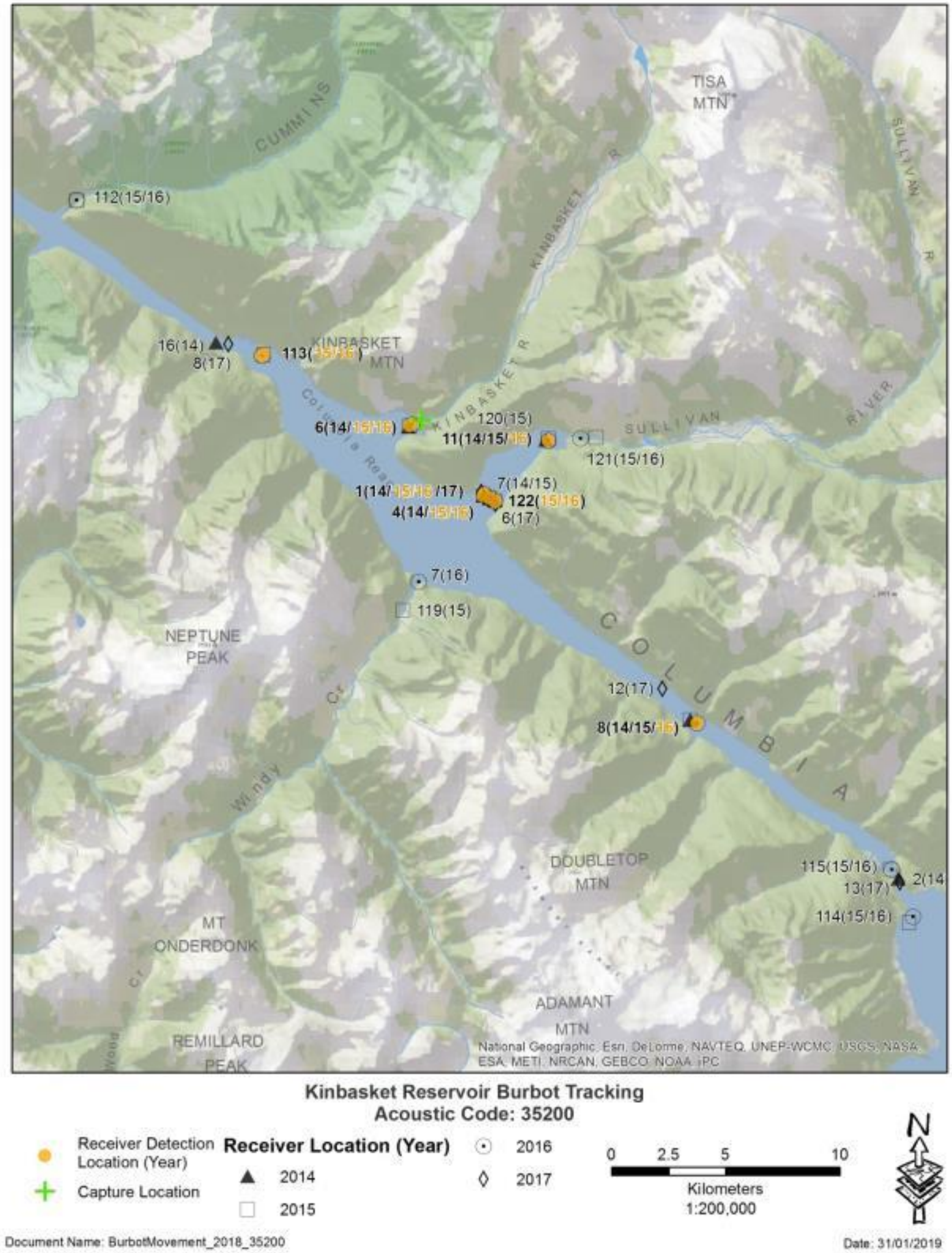
Document Name: BurbotMovement_2018_35100
Date: 31/01/2019


112(15/16)
16(14)
8(17)
113(
KINBASKET MTN
6(14/
120(15)
11(14/15/
121(15/16)
1(14/
/17)
4(14/
7(14/15)
122(
6(17)
7(16)
119(15)
NEPTUNE PEAK
12(17)
8(14/15/
COLUMBIA
115(15/16)
13(17)
2(14
114(15/16)
DOUBLETOP MTN
MT ONDERDONK
ADAMANT MTN
REMILLARD PEAK
TISA MTN
CUMMINS
KINBASKET R
SULLIVAN RIVER
SULLIVAN R
Windy Cr
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 35200
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
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2015
2016
2017
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Kilometers
1:200,000
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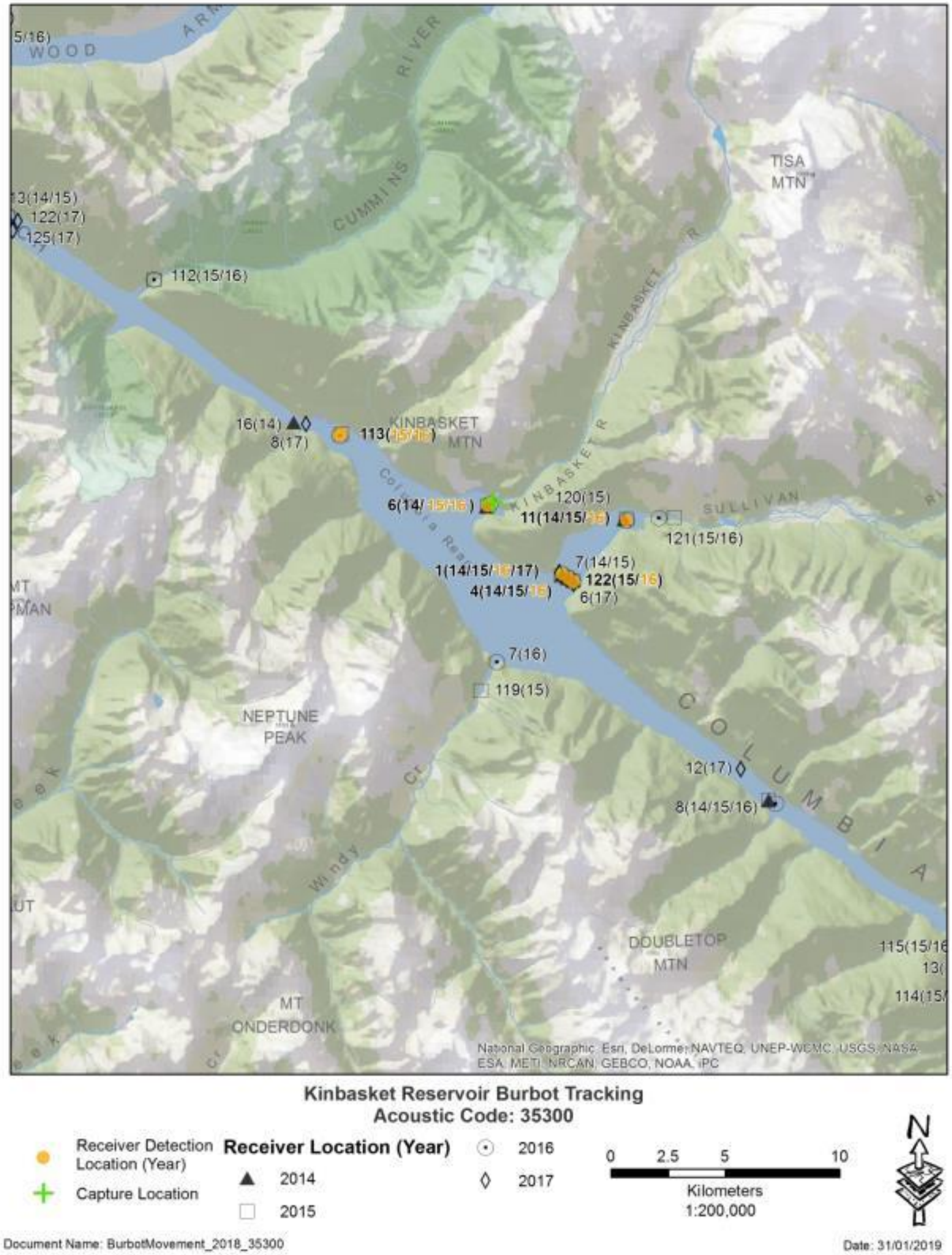
Document Name: BurbotMovement_2018_35200
Date: 31/01/2019


WOOD
RIVER
CUMMINS
TISA MTN
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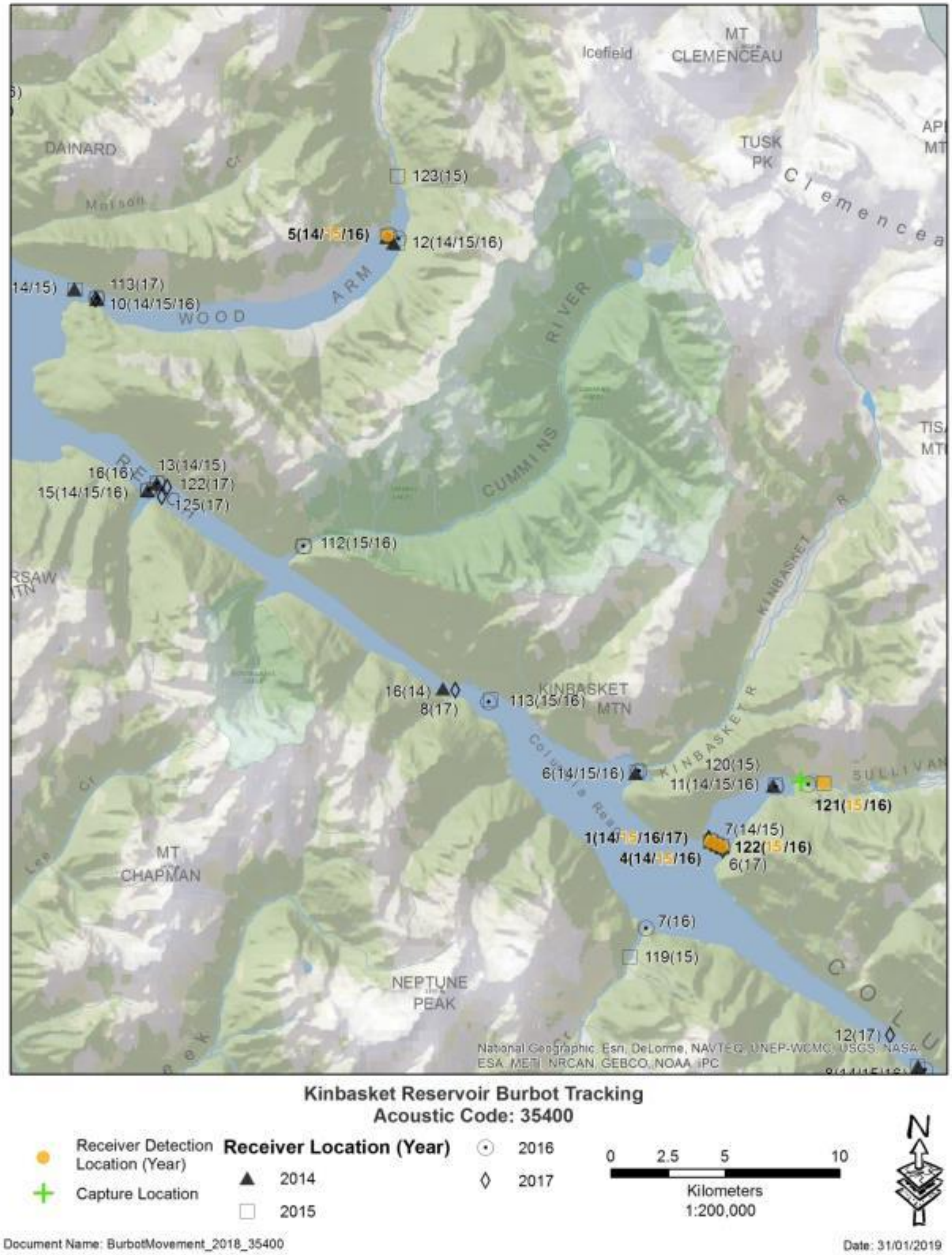
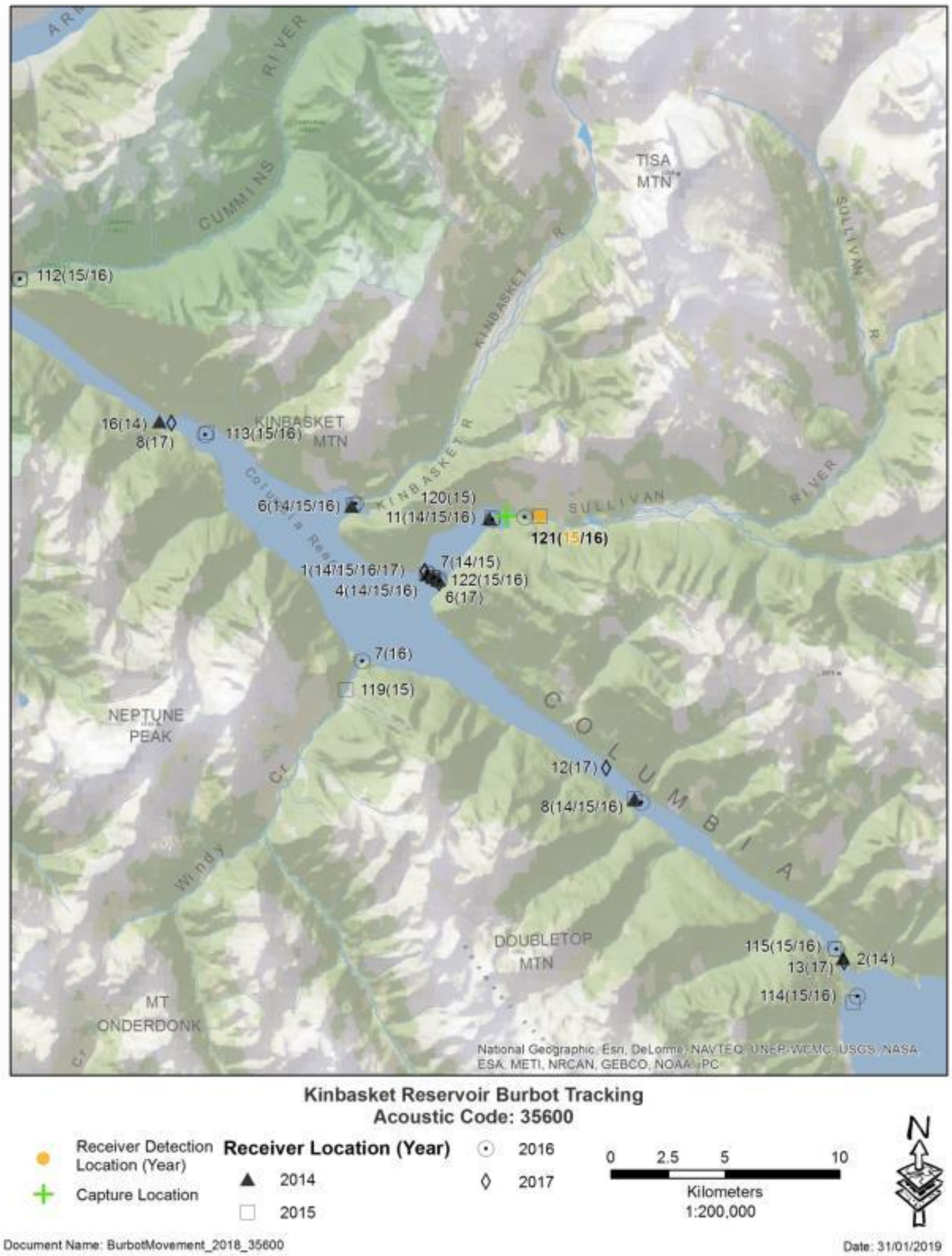
122(17)
125(17)
112(15/16)
KINBASKET
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
120(15)
11(14/15/16)
SULLIVAN
121(15/16)
7(14/15)
1(14/15/16/17)
122(15/16)
4(14/15/16)
6(17)
MT
7(16)
119(15)
NEPTUNE PEAK
COLUMBIA
12(17)
8(14/15/16)
Windy Cr
DOUBLETOP MTN
115(15/16
114(15
MT ONDERDONK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 35300
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_35300
Date: 31/01/2019



Kinbasket Reservoir Burbot Tracking
Acoustic Code: 35400


TISA MTN
SULLIVAN R
CUMMINS RIVER
KINBASKET R
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
120(15)
11(14/15/16)
SULLIVAN RIVER
121(15/16)
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
COLUMBIA
12(17)
8(14/15/16)
Windy Cr
DOUBLETOP MTN
115(15/16)
13(17)
2(14)
114(15/16)
MT ONDERDONK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 35600
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
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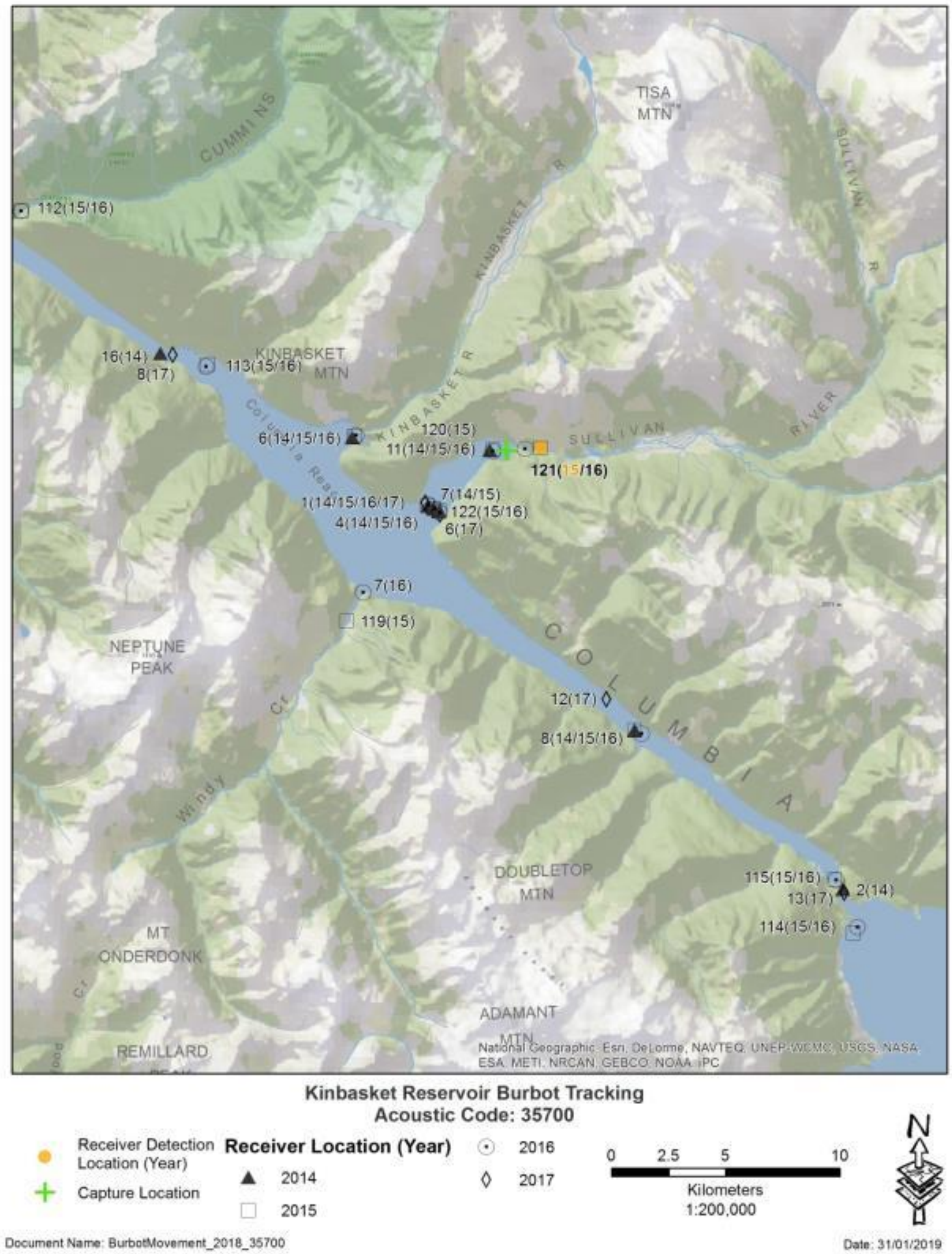
Document Name: BurbotMovement_2018_35600
Date: 31/01/2019


TISA MTN
CUMMINS
KINBASKET R
SULLIVAN R
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
Columbia Reservoir
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
SULLIVAN RIVER
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
COLUMBIA
12(17)
8(14/15/16)
Windy Cr
DOUBLETOP MTN
115(15/16)
13(17)
2(14)
114(15/16)
MT ONDERDONK
ADAMANT MTN
REMILLARD
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 35700
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
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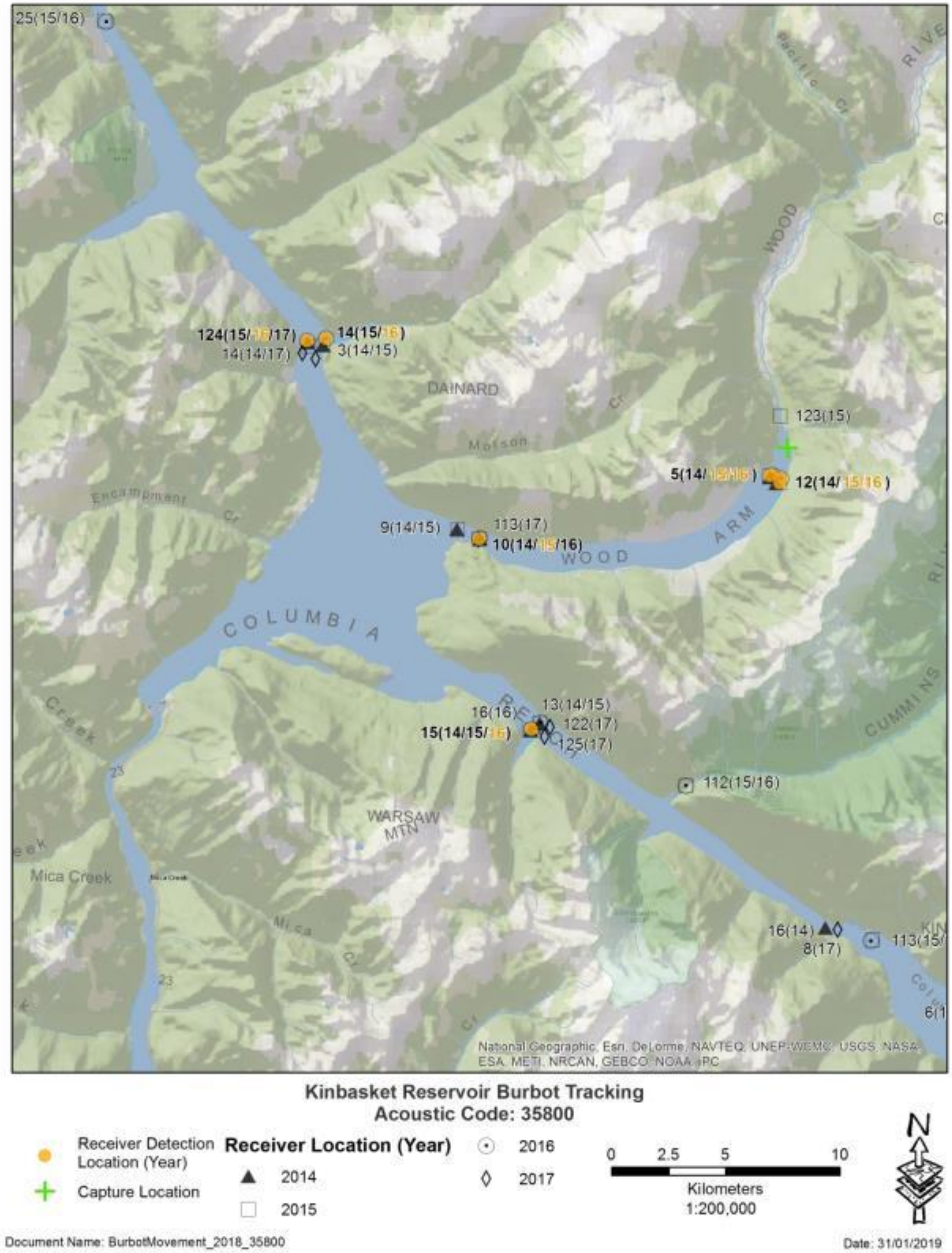
Document Name: BurbotMovement_2018_35700
Date: 31/01/2019


25(15/16)
124(15/16/17)
14(14/17)
14(15/16)
3(14/15)
DAINARD
Molson
WOOD
123(15)
5(14/15/16)
12(14/15/16)
Encampment Cr
9(14/15)
113(17)
10(14/15/16)
WOOD ARM
COLUMBIA
Creek
13(14/15)
16(16)
122(17)
15(14/15/16)
125(17)
CUMMINS
112(15/16)
WARSAW MTN
Mica Creek
Mica Cr
16(14)
8(17)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 35800
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
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2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
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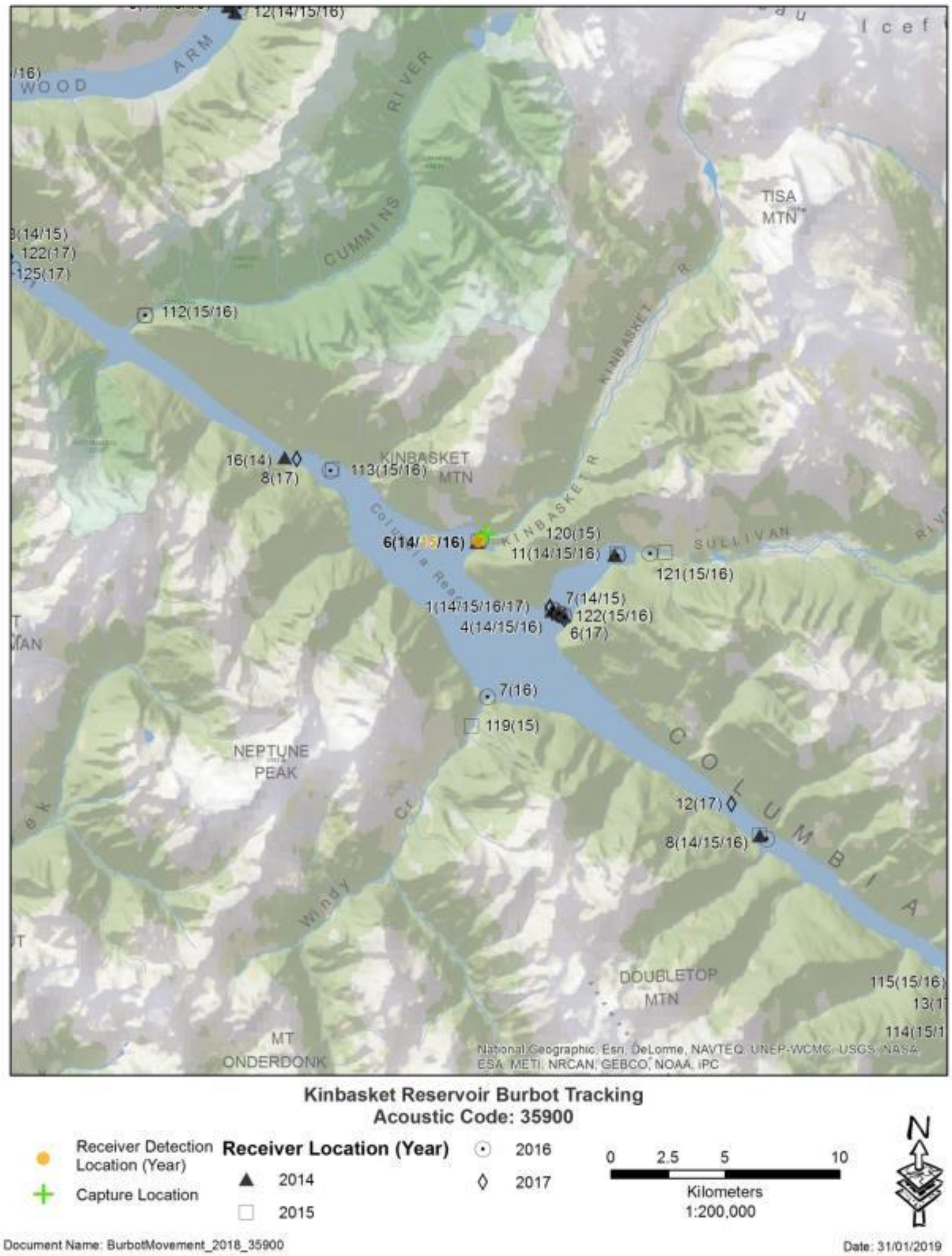
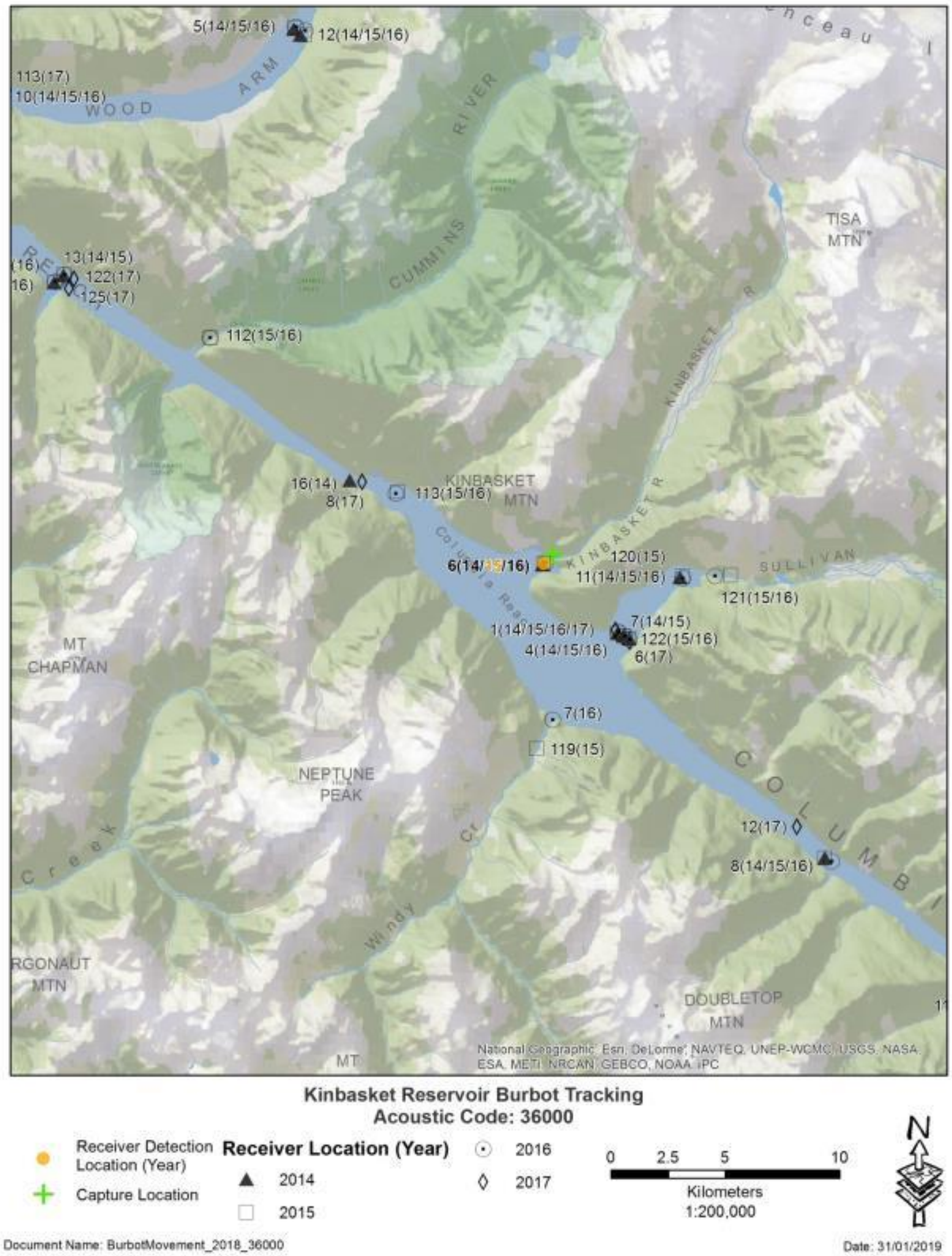
Document Name: BurbotMovement_2018_35800
Date: 31/01/2019


12(14/15/16)
WOOD ARM
RIVER
CUMMINS
TISA MTN
122(17)
125(17)
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
KINBASKET R
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
SULLIVAN
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
COLUMBIA
12(17)
8(14/15/16)
Windy Cr
DOUBLETOP MTN
115(15/16)
MT ONDERDONK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 35900
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_35900
Date: 31/01/2019


5(14/15/16)
12(14/15/16)
113(17)
10(14/15/16)
WOOD
ARM
RIVER
CUMMINS
TISA
MTN
13(14/15)
122(17)
125(17)
112(15/16)
KINBASKET R
16(14)
8(17)
113(15/16)
KINBASKET
MTN
6(14/15/16)
120(15)
11(14/15/16)
SULLIVAN
121(15/16)
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
MT
CHAPMAN
7(16)
119(15)
NEPTUNE
PEAK
12(17)
8(14/15/16)
COLUMBI
Creek
Windy
Cr
RGONAUT
MTN
DOUBLETOP
MTN
MT
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 36000
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
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2.5
5
10
Kilometers
1:200,000
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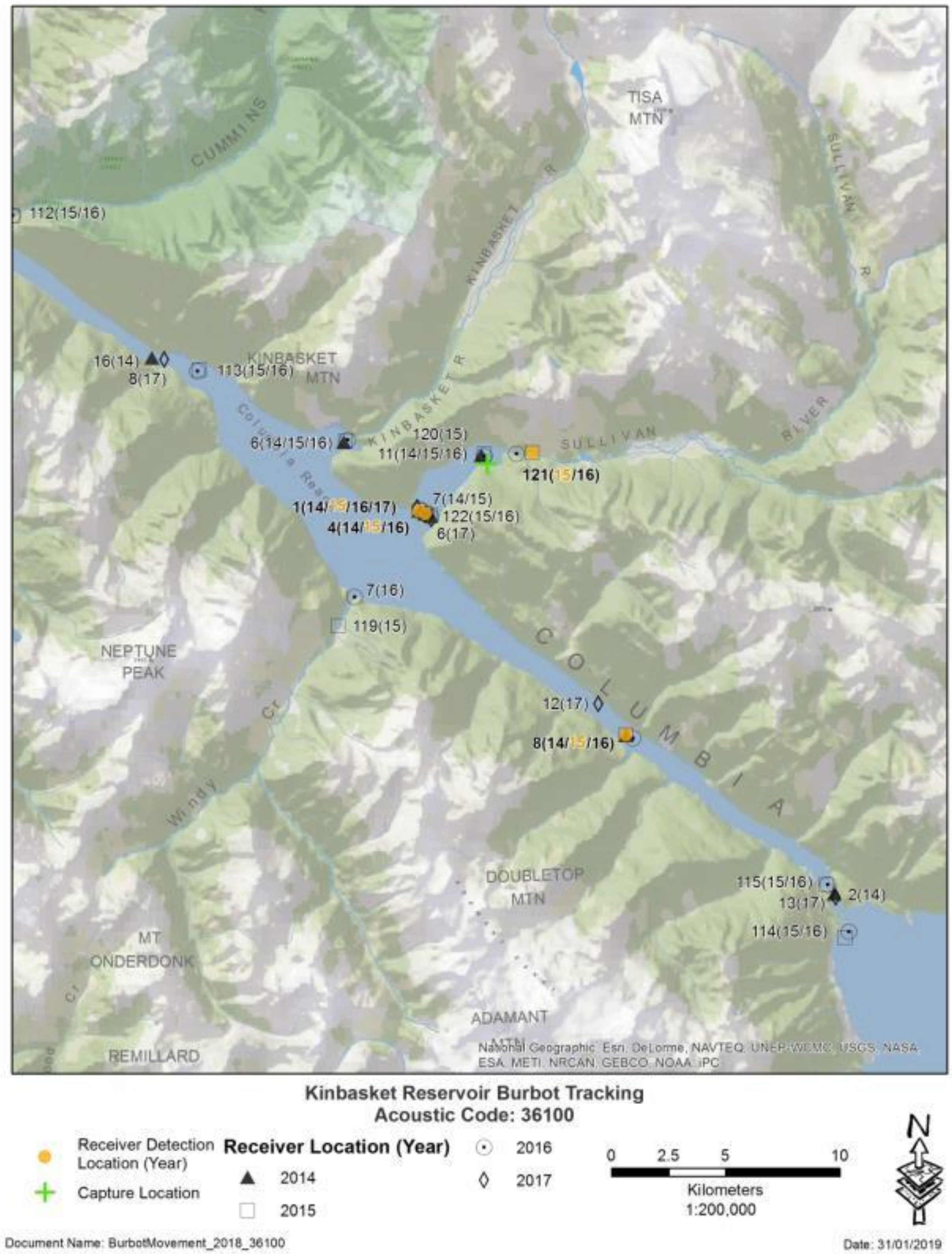
Document Name: BurbotMovement_2018_36000
Date: 31/01/2019


112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
12(17)
8(14/15/16)
COLUMBIA
TISA MTN
SULLIVAN RIVER
KINBASKET R
DOUBLETOP MTN
115(15/16)
13(17)
2(14)
114(15/16)
MT ONDERDONK
ADAMANT MTN
REMILLARD
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 36100
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
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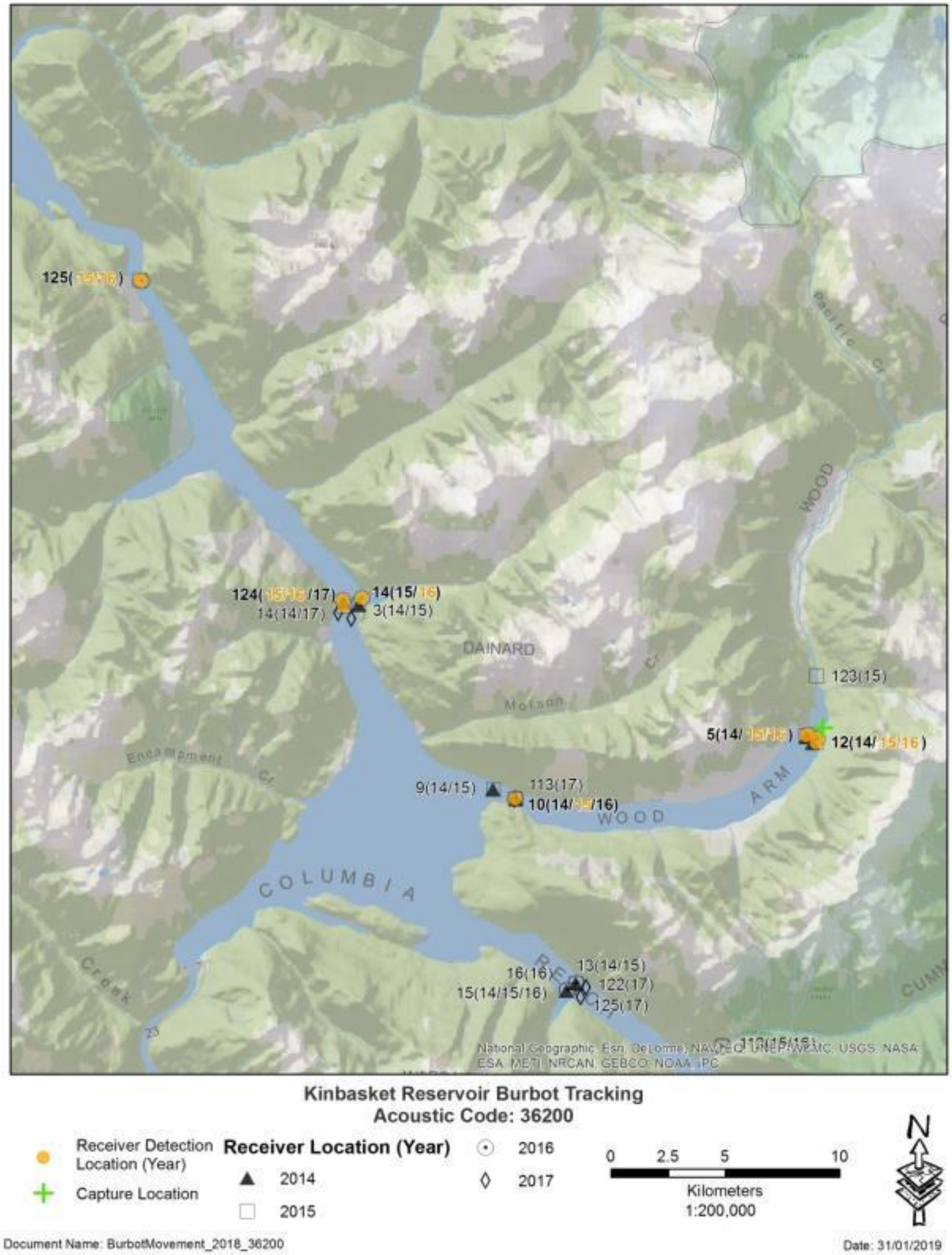
N
Document Name: BurbotMovement_2018_36100
Date: 31/01/2019


14(14/17)
3(14/15)
DAINARD
Molson
Cr
123(15)
Encampment
Cr
9(14/15)
113(17)
WOOD
ARM
WOOD
Pacific
Cr
COLUMBIA
REACH
Creek
16(16)
13(14/15)
15(14/15/16)
122(17)
125(17)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 36200
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
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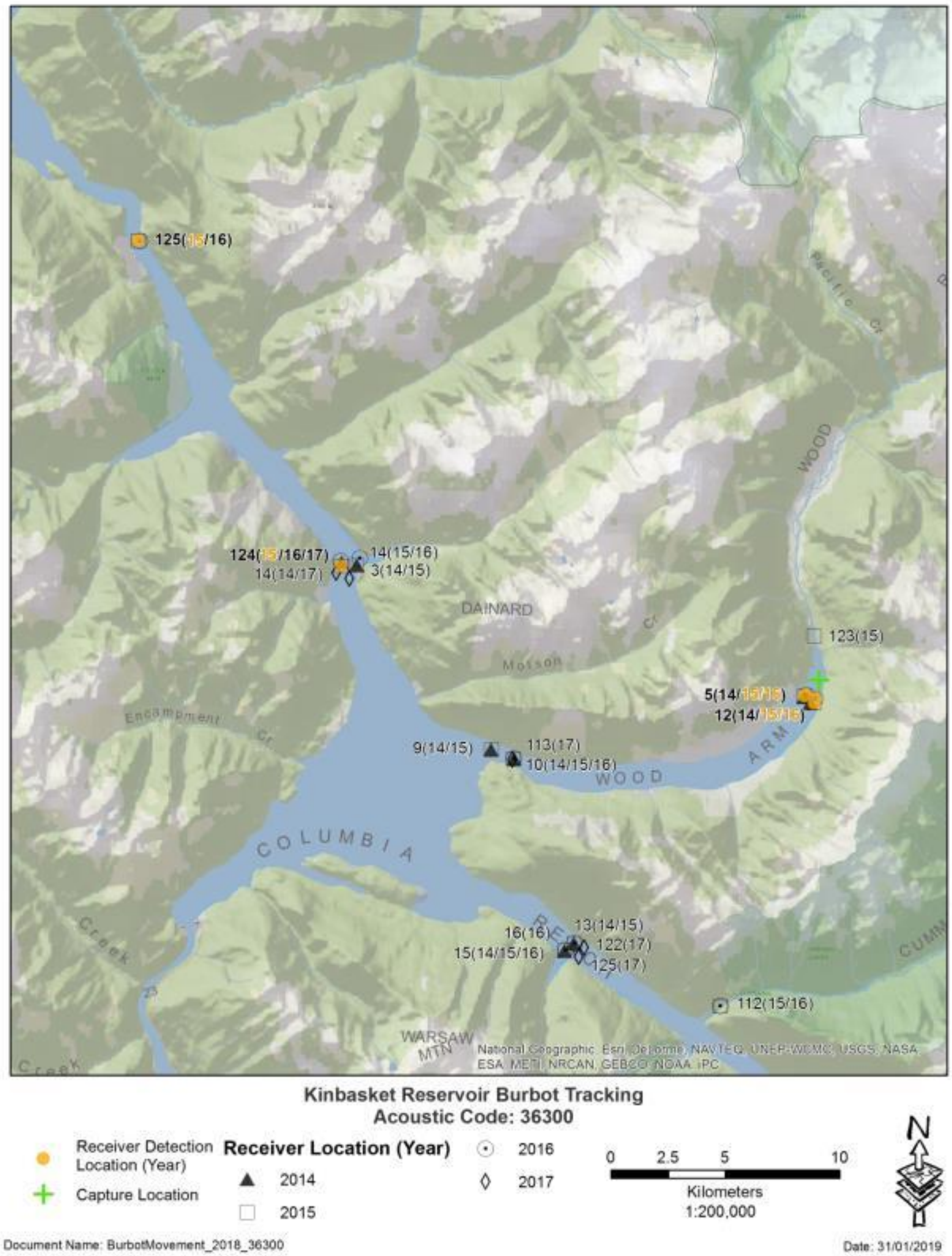
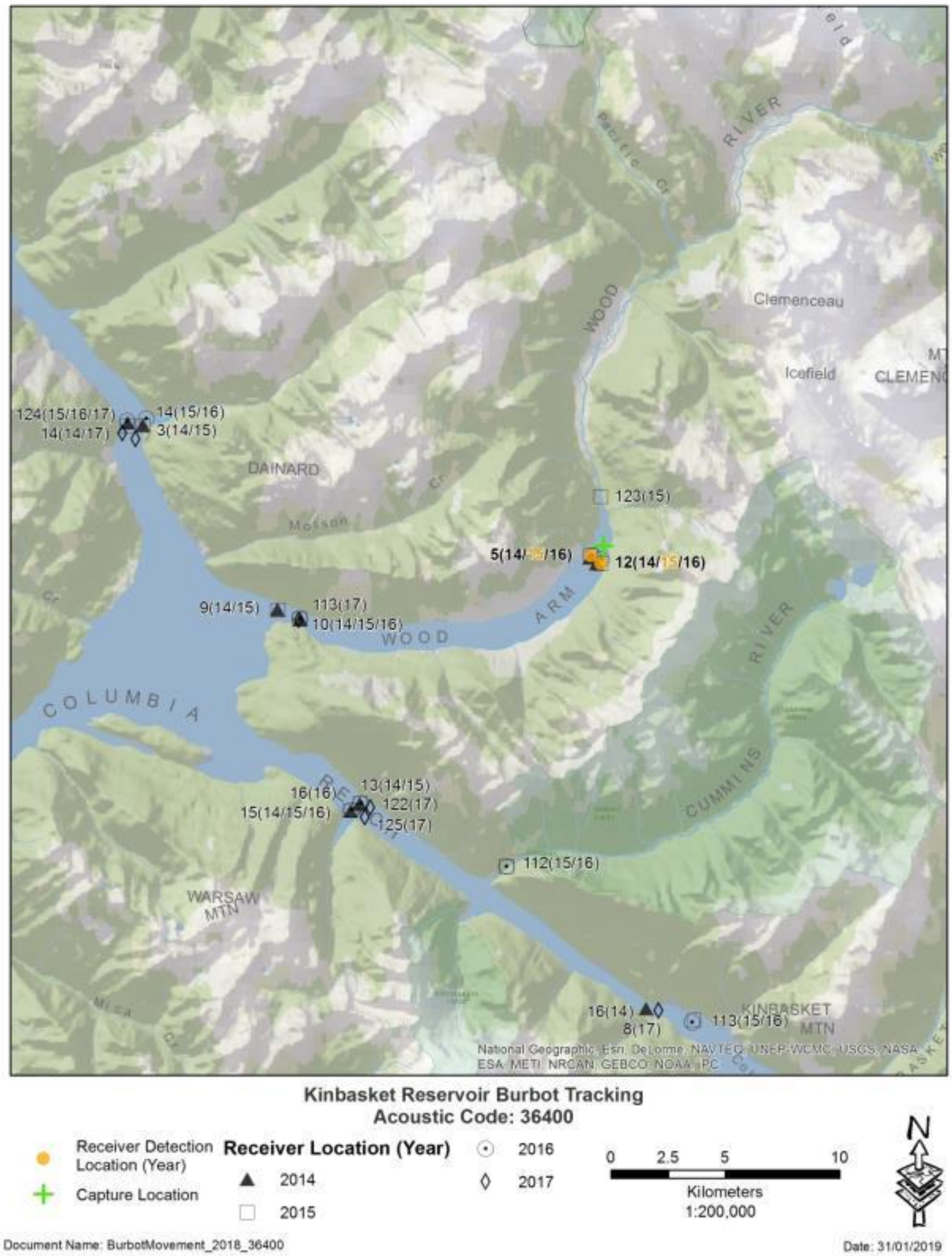
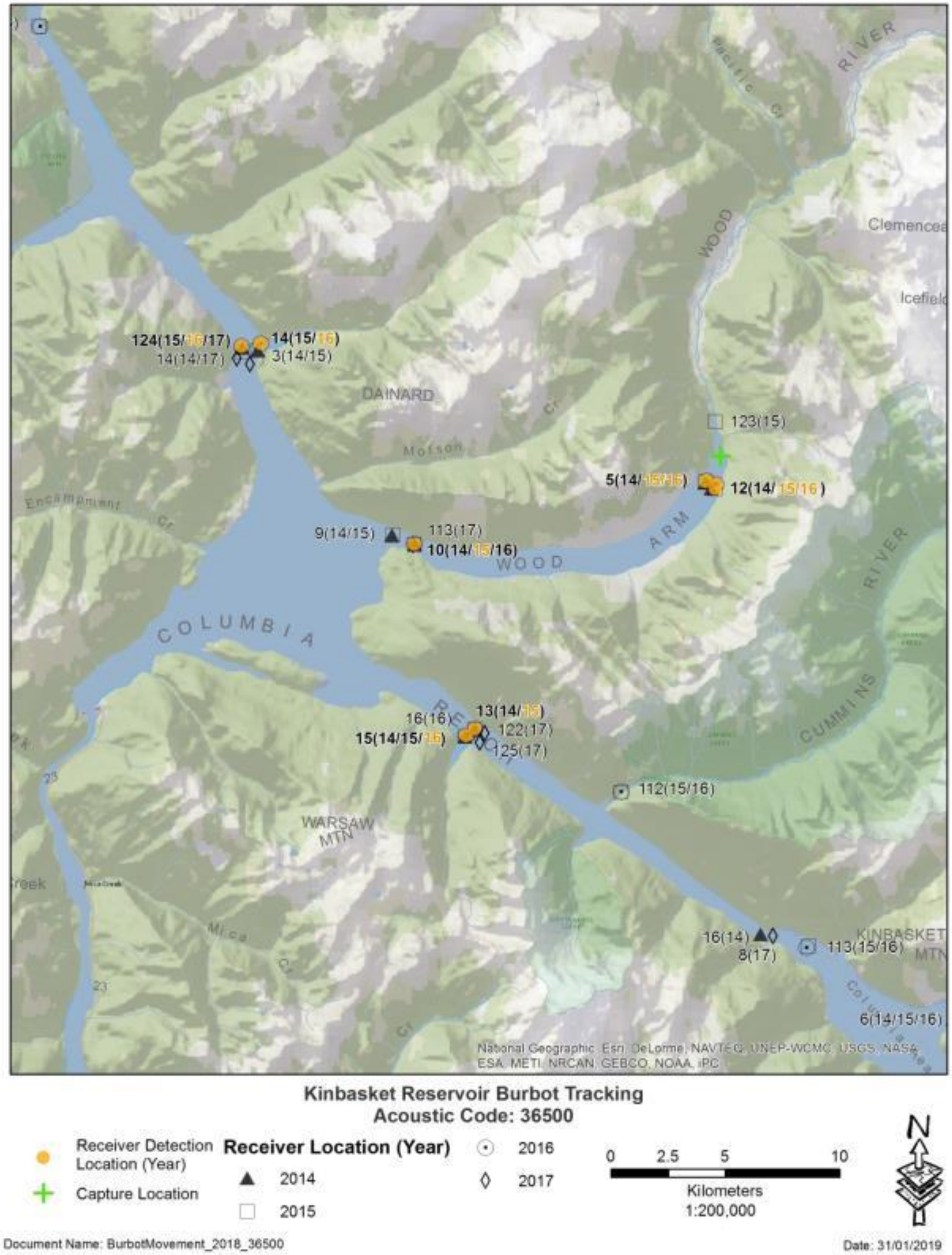
2.5
5
10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_36200
Date: 31/01/2019


125(15/16)
124(15/16/17)
14(14/17)
14(15/16)
3(14/15)
DAINARD
Mica
WOOD
Pacific Cr
123(15)
5(14/15/16)
12(14/15/16)
Encampment Cr
9(14/15)
113(17)
10(14/15/16)
WOOD ARM
COLUMBIA
Creek
16(16)
13(14/15)
122(17)
15(14/15/16)
125(17)
REACH
112(15/16)
WARSAW MTN
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 36300
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_36300
Date: 31/01/2019


Kinbasket Reservoir Burbot Tracking
Acoustic Code: 36400
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0
2.5
5
10
Kilometers
1:200,000
124(15/16/17)
14(14/17)
14(15/16)
3(14/15)
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
16(16)
15(14/15/16)
13(14/15)
122(17)
125(17)
112(15/16)
16(14)
8(17)
113(15/16)
COLUMBIA
WOOD
ARM
DAINARD
WARSAW MTN
KINBASKET MTN
Clemenceau
Icefield
RIVER
CUMMINS
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Document Name: BurbotMovement_2018_36400
Date: 31/01/2019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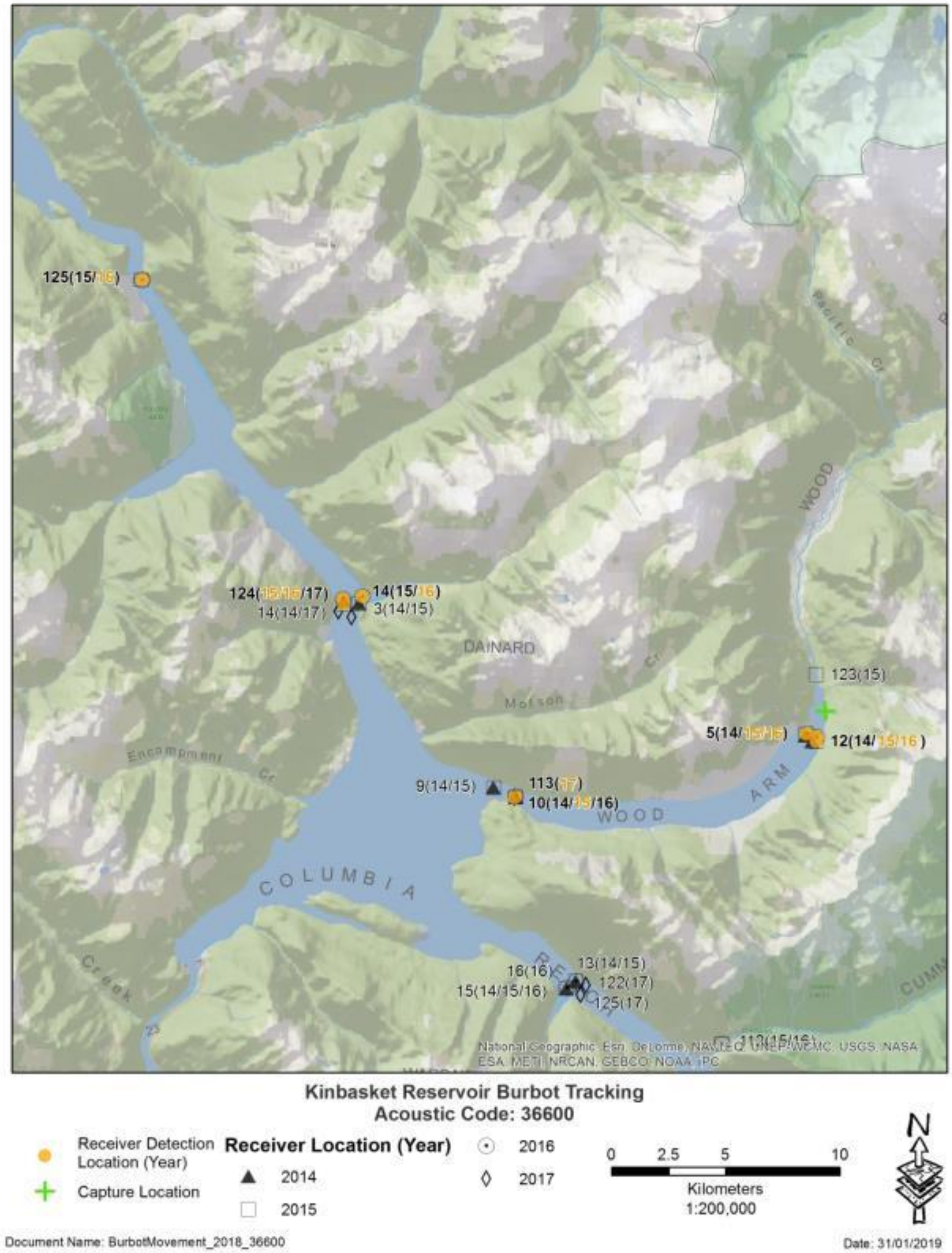
14(14/17)
14(15/16)
3(14/15)
DAINARD
Molson
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
WOOD
ARM
Encampment Cr
COLUMBIA
13(14/15)
16(16)
122(17)
15(14/15/16)
125(17)
112(15/16)
WARSAW MTN
Mica
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
RIVER
Clemencea
Icefield
CUMMINS
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 36500
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_36500
Date: 31/01/2019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124(15/16/17)
14(14/17)
14(15/16)
3(14/15)
DAINARD
Molson
Encampment Cr
COLUMBIA
WOOD ARM
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
16(16)
15(14/15/16)
13(14/15)
122(17)
125(17)
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 36600
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
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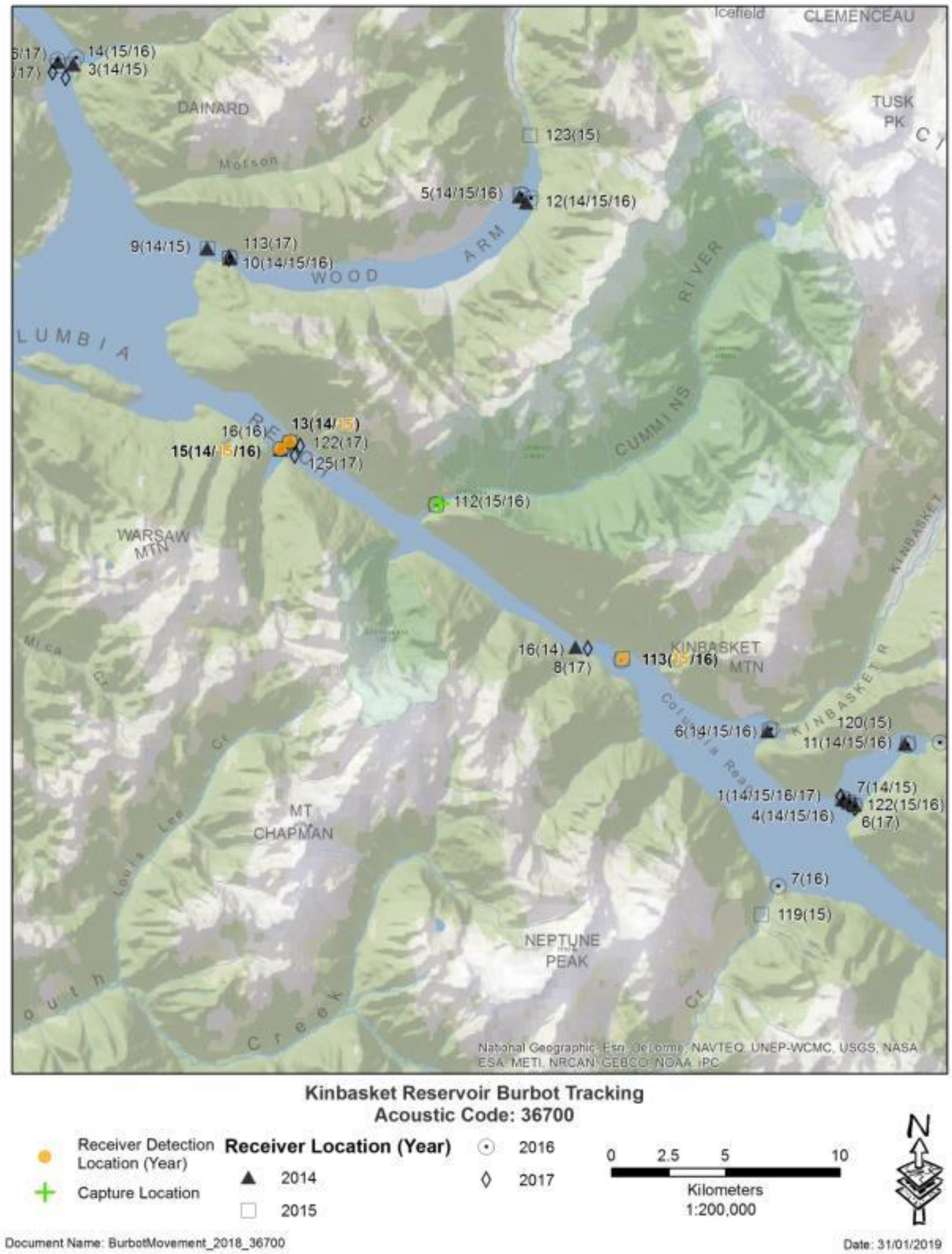
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_36600
Date: 31/01/2019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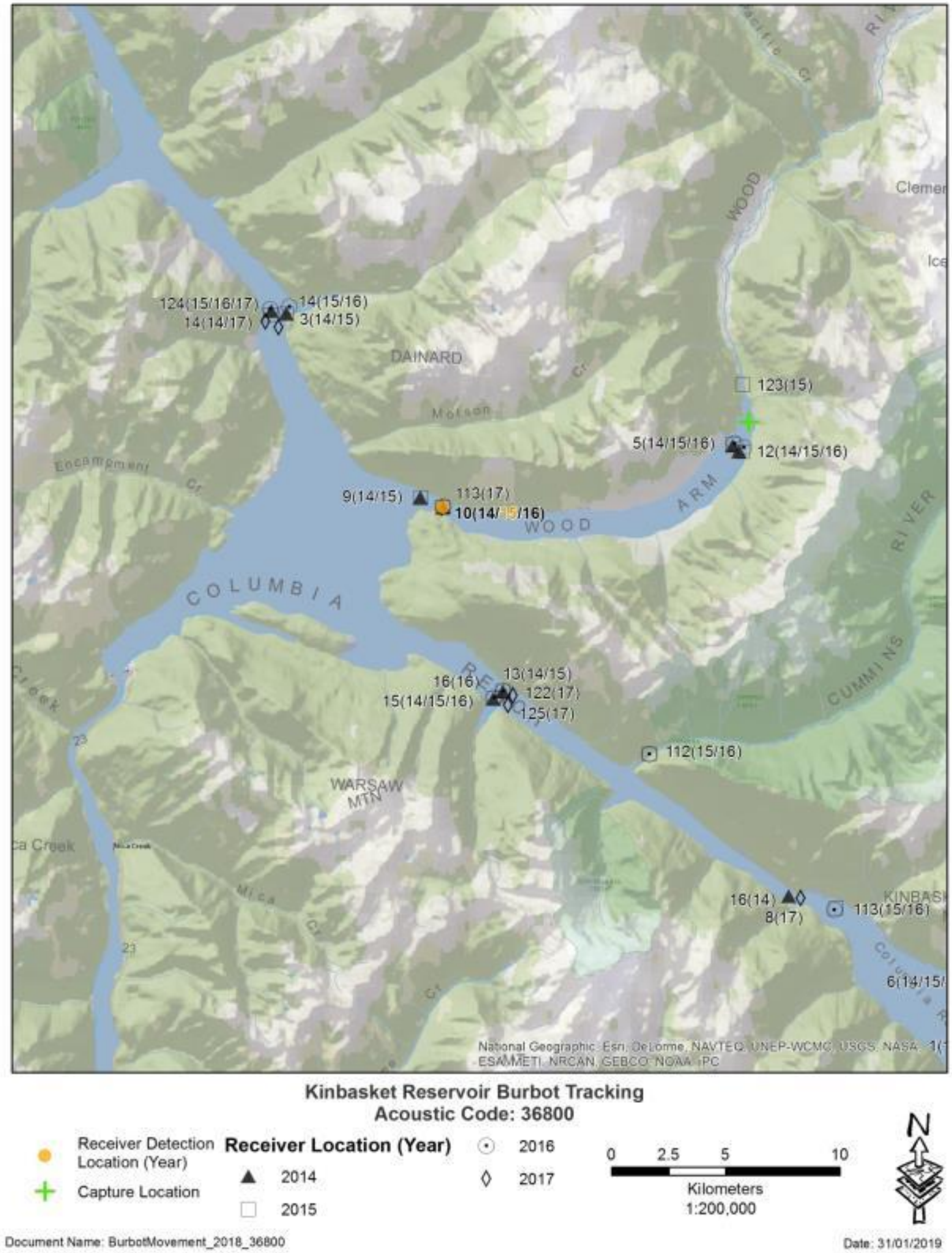
3(14/15)
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
WOOD ARM
13(14/15)
16(16)
122(17)
15(14/15/16)
125(17)
112(15/16)
16(14)
8(17)
113(15/16)
6(14/15/16)
120(15)
11(14/15/16)
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 36700
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_36700
Date: 31/01/2019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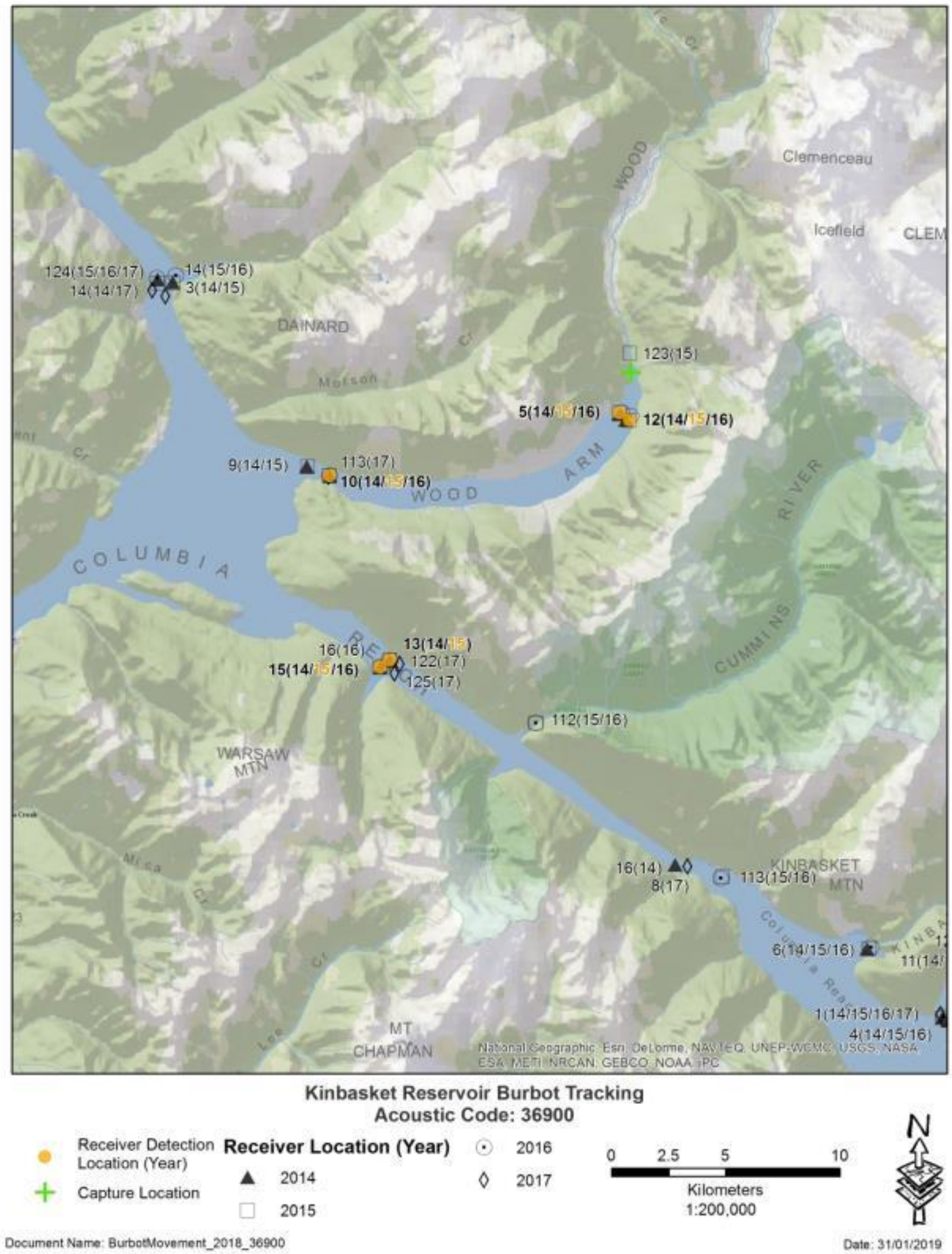
14(15/16)
14(14/17)
3(14/15)
DAINARD
Molson
Encampment Cr
WOOD
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
WOOD ARM
COLUMBIA
13(14/15)
16(16)
122(17)
15(14/15/16)
125(17)
112(15/16)
WARSAW MTN
CUMMINS
RIVER
16(14)
8(17)
113(15/16)
Mica Cr
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 36800
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0
2.5
5
10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_36800
Date: 31/01/2019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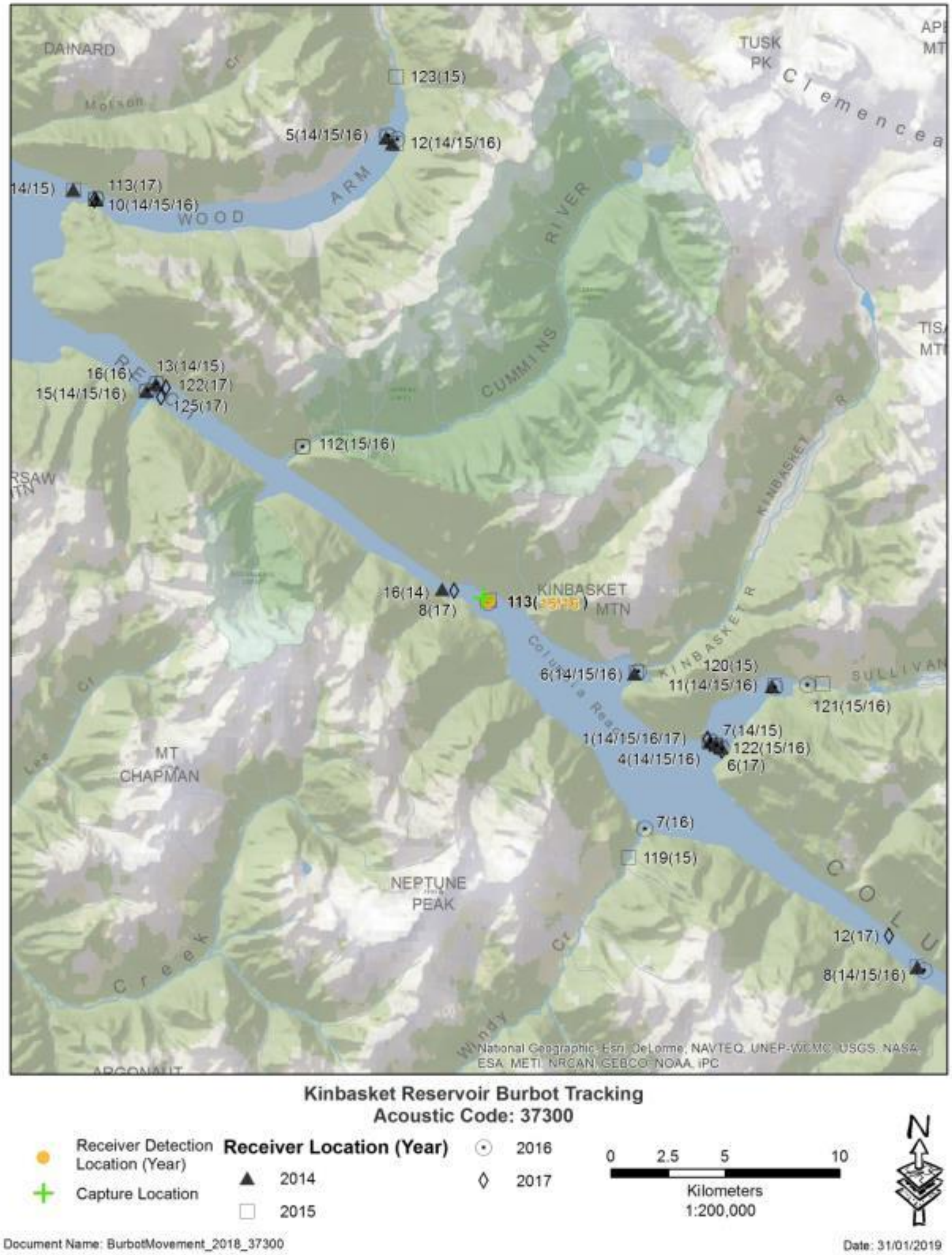
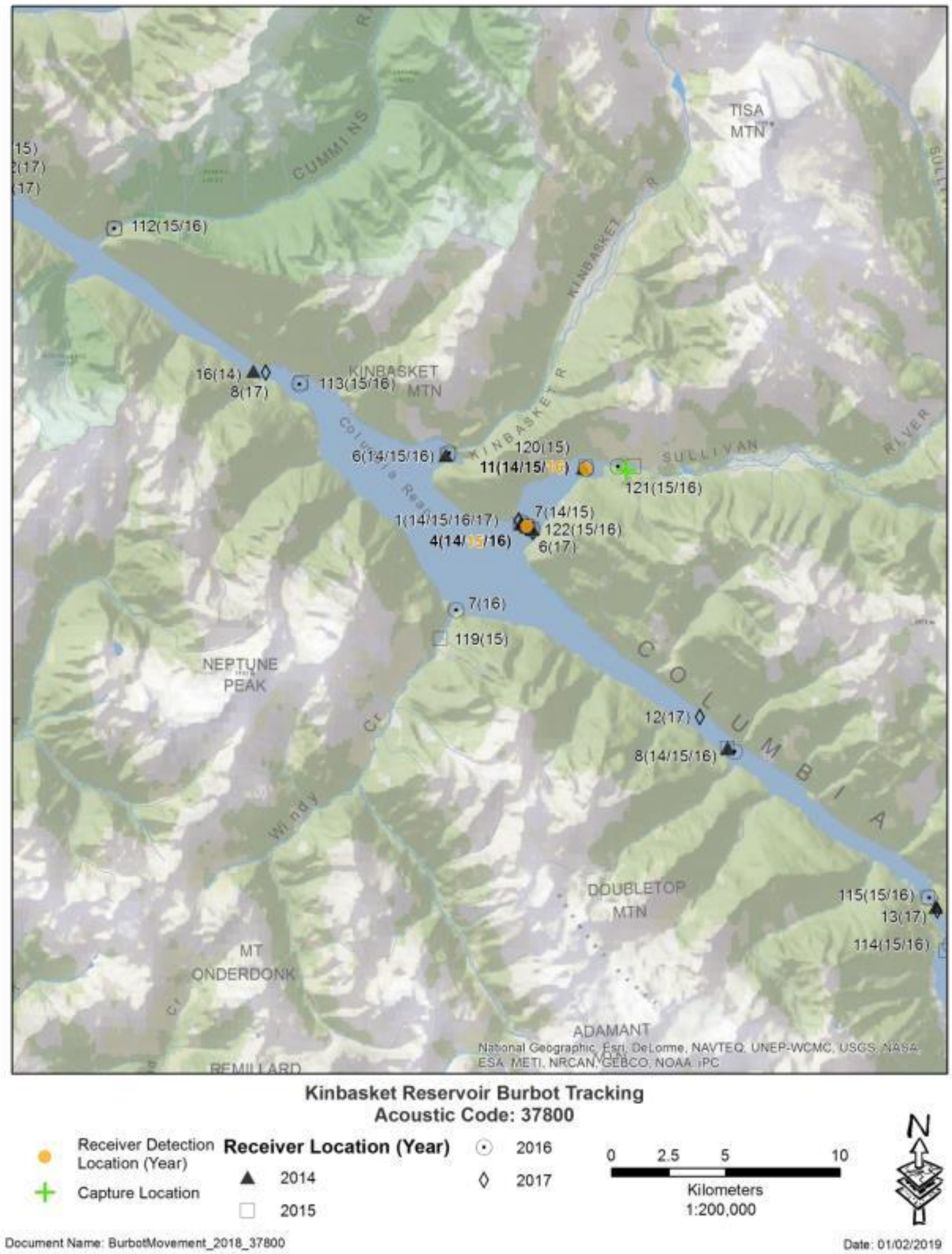
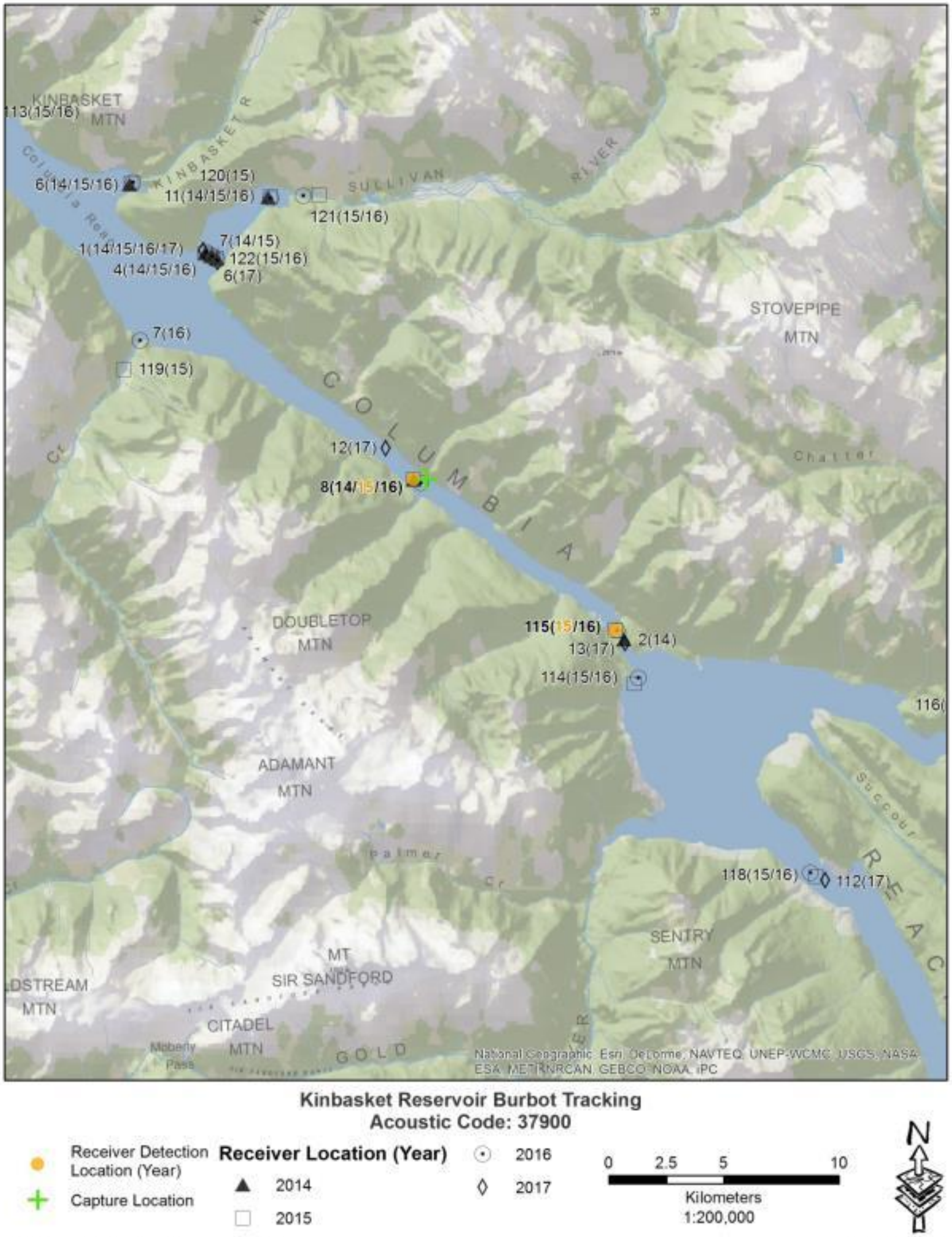
14(14/17)
14(15/16)
3(14/15)
DAINARD
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
WOOD ARM
COLUMBIA
13(14/15)
16(16)
15(14/15/16)
122(17)
125(17)
112(15/16)
WARSAW MTN
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
1(14/15/16/17)
4(14/15/16)
MT CHAPMAN
Clemenceau
Icefield
CUMMINS RIVER
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 36900
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_36900
Date: 31/01/2019

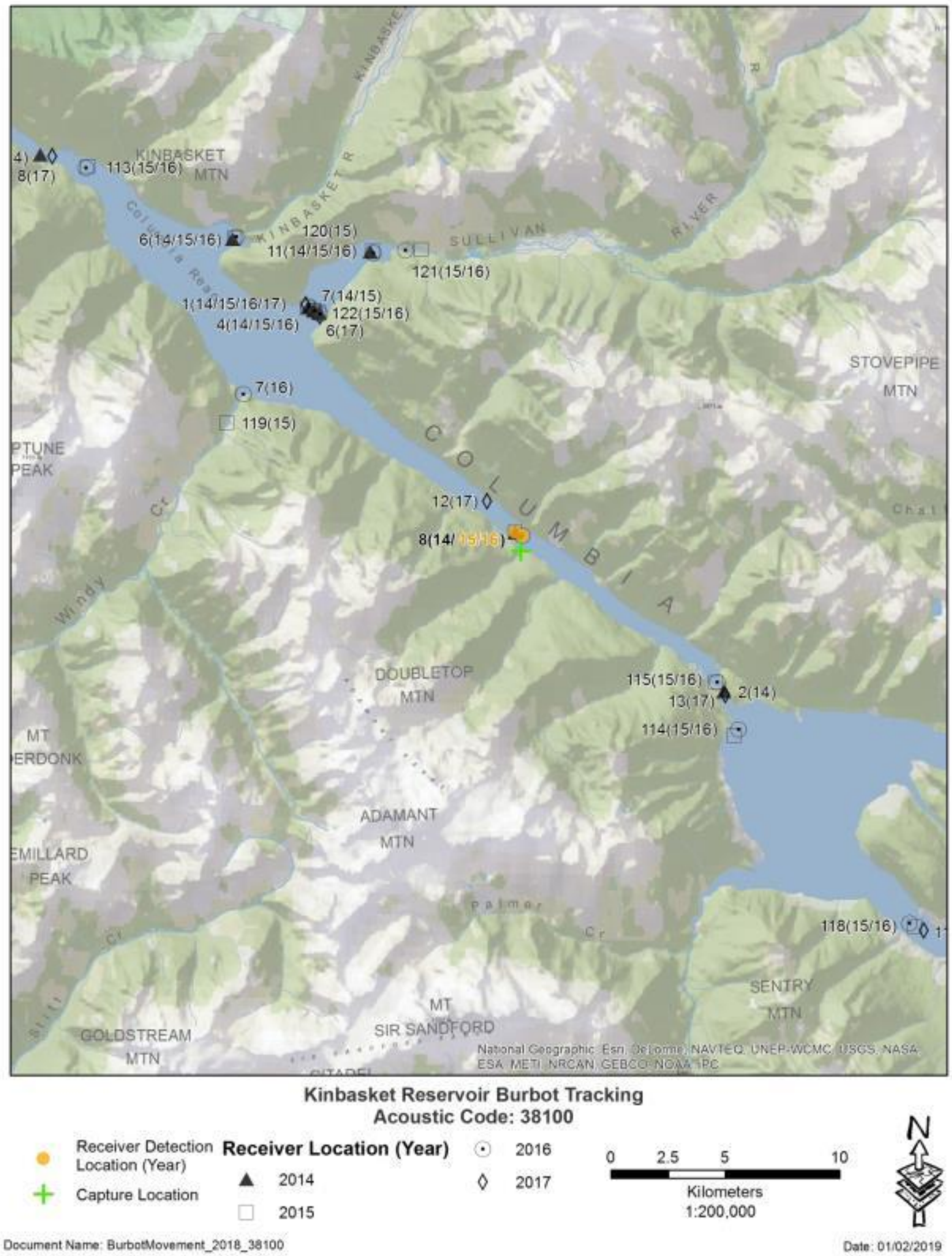

DAINARD
TUSK PK
Clemencea
123(15)
5(14/15/16)
12(14/15/16)
14/15)
113(17)
10(14/15/16)
WOOD ARM
RIVER
CUMMINS
13(14/15)
16(16)
122(17)
15(14/15/16)
125(17)
112(15/16)
KINBASKET R
16(14)
8(17)
KINBASKET MTN
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
SULLIVAN
1(14/15/16/17)
7(14/15)
122(15/16)
4(14/15/16)
6(17)
MT CHAPMAN
7(16)
119(15)
NEPTUNE PEAK
12(17)
8(14/15/16)
COLU
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 37300
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_37300
Date: 31/01/2019


112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE PEAK
TISA MTN
COLUMBIA
12(17)
8(14/15/16)
DOUBLETOP MTN
115(15/16)
13(17)
114(15/16)
MT ONDERDONK
ADAMANT
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 37800
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_37800
Date: 01/02/2019



Document Name: BurbotMovement_2018_37900

Date: 01/02/2019


4)
8(17)
113(15/16)
KINBASKET
MTN
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
SULLIVAN
RIVER
KINBASKET R
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
STOVEPIPE
MTN
PTUNE
PEAK
COLUMBIA
12(17)
8(14/15/16)
Windy
Cr
DOUBLETOP
MTN
115(15/16)
13(17)
2(14)
114(15/16)
MT
ERDONK
ADAMANT
MTN
EMILLARD
PEAK
Palmer
Cr
118(15/16)
SENTRY
MTN
MT
SIR SANDFORD
GOLDSTREAM
MTN
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 38100
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
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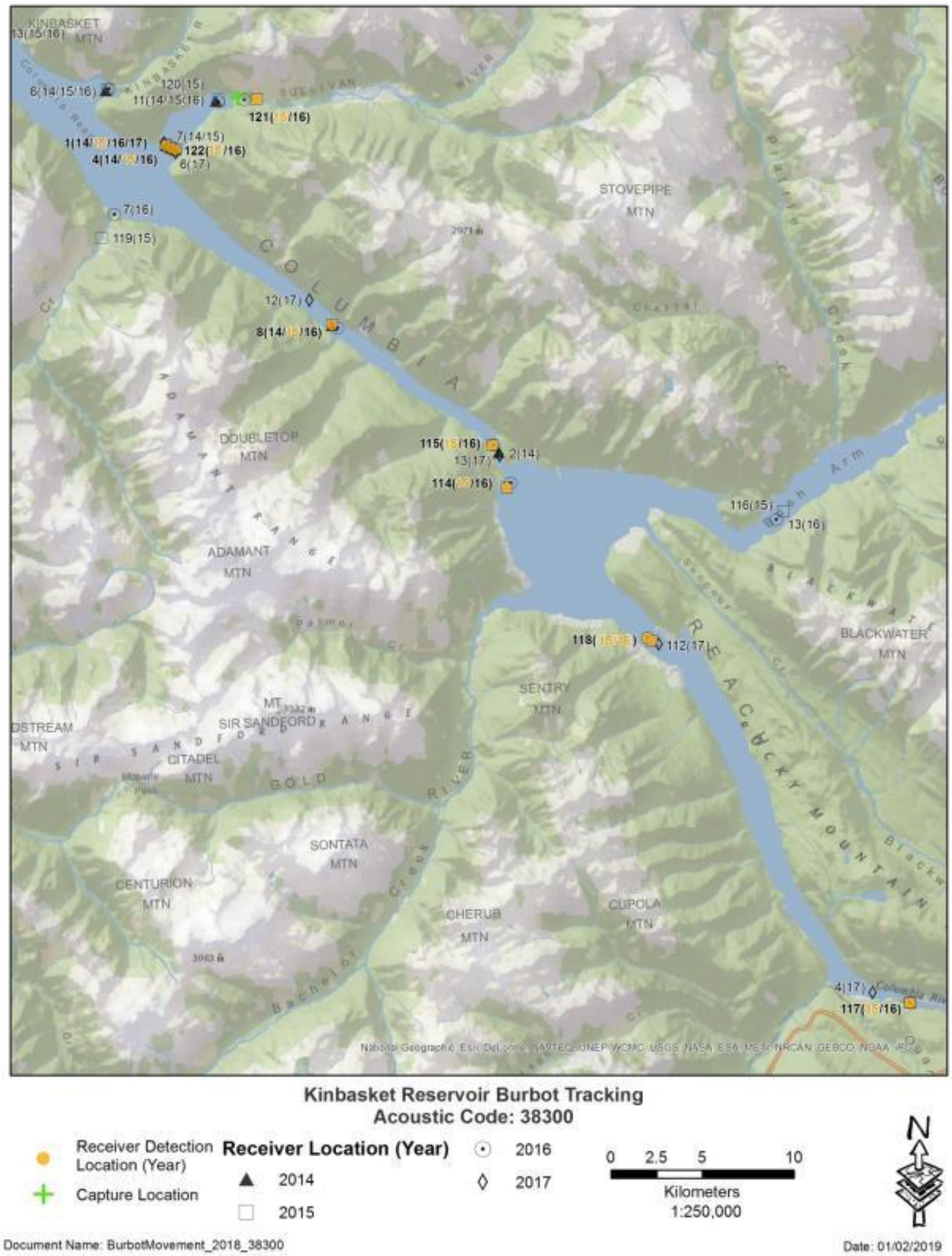
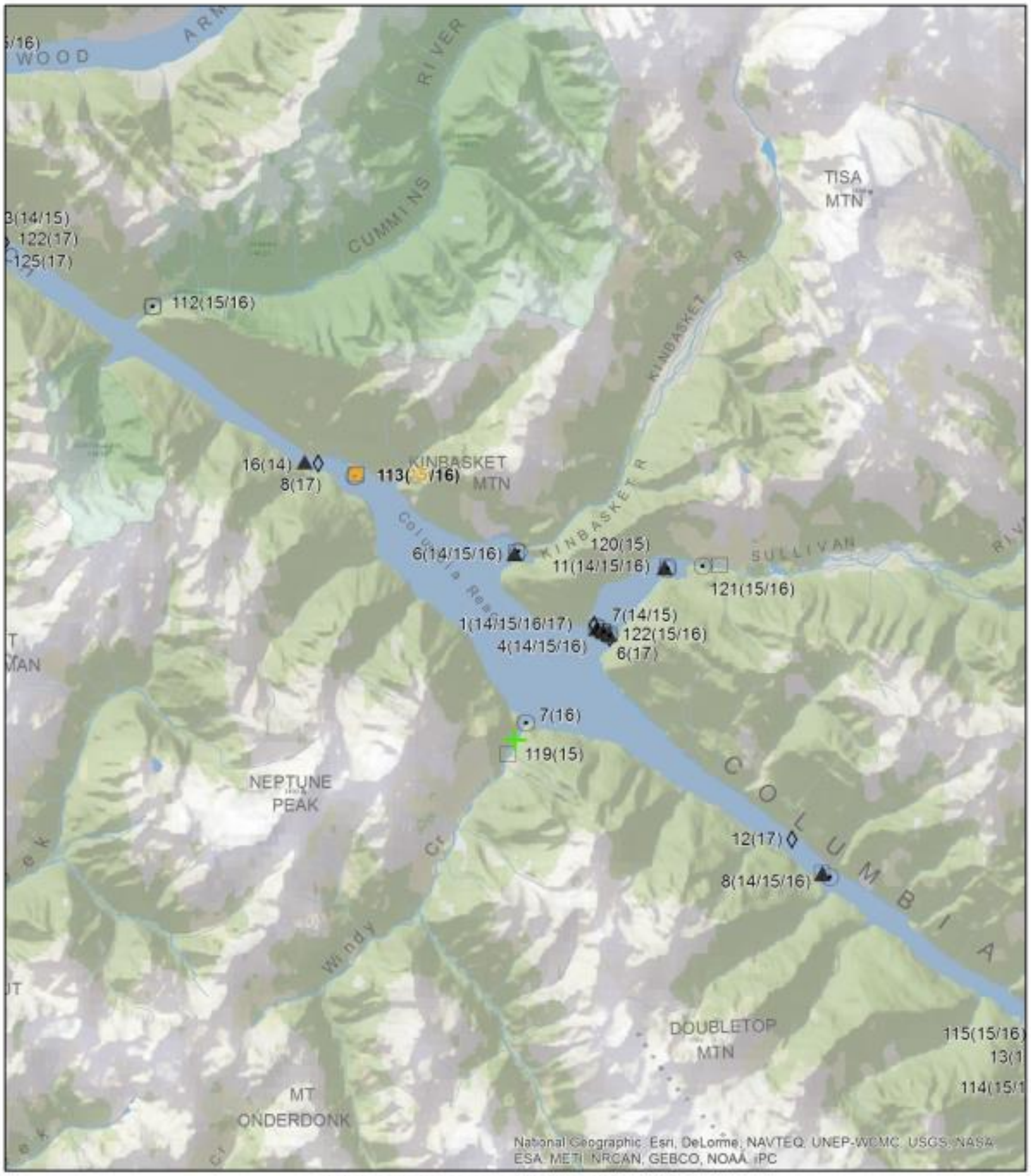
2.5
5
10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_38100
Date: 01/02/2019


Kinbasket Reservoir Burbot Tracking
Acoustic Code: 38300
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:250,000
N
COLUMBIA
STOVEPIPE MTN
DOUBLETOP MTN
ADAMANT MTN
SIR SANDFORD
CITADEL MTN
SENTRY MTN
BLACKWATER MTN
SONTATA MTN
CENTURION MTN
CHERUB MTN
CUPOLA MTN
GOLD RIVER
REACH
Document Name: BurbotMovement_2018_38300
Date: 01/02/2019



Kinbasket Reservoir Burbot Tracking
Acoustic Code: 38400

Receiver Detection Location (Year)
Capture Location

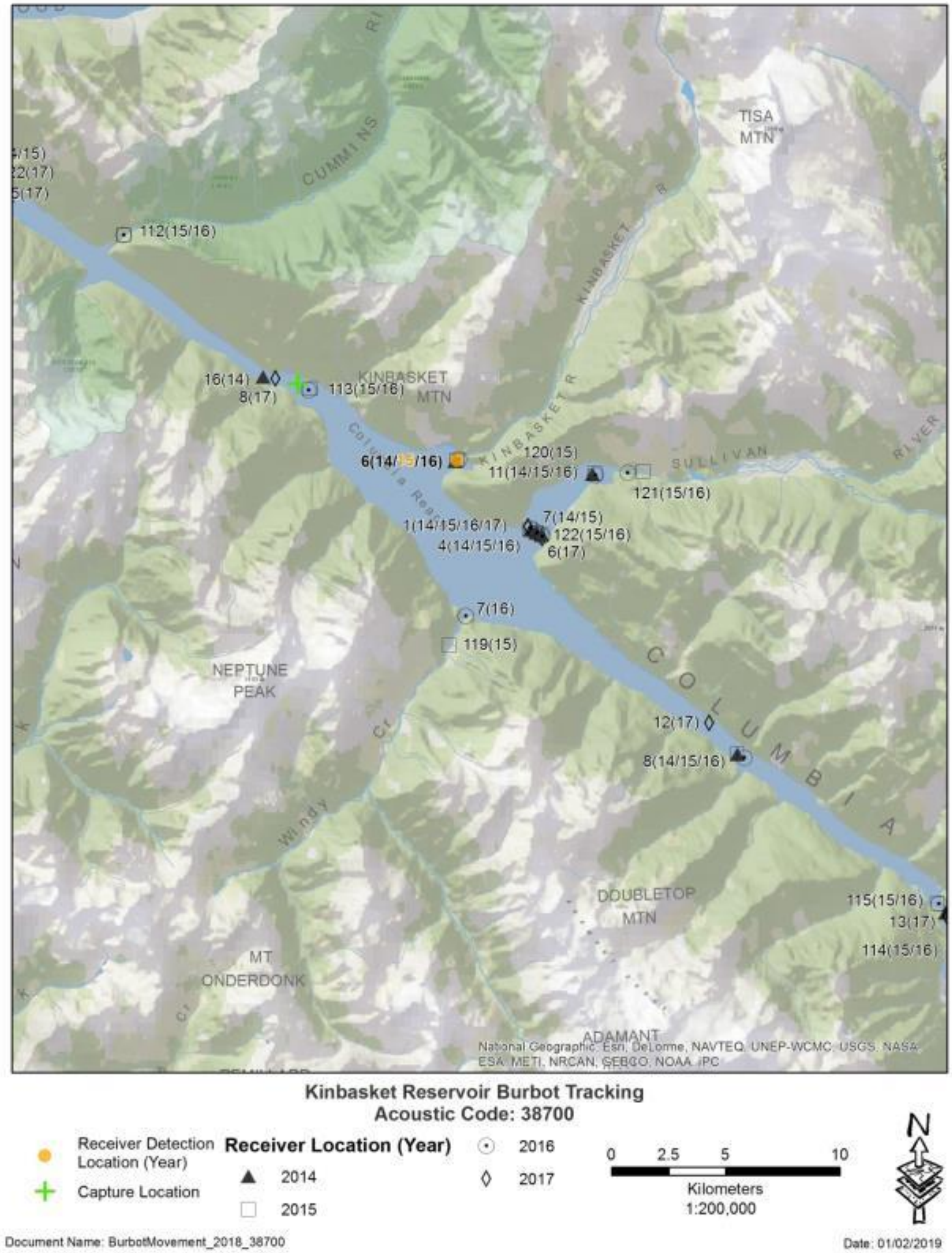
Receiver Location (Year)
- 2014
- 2015
- 2016
- 2017

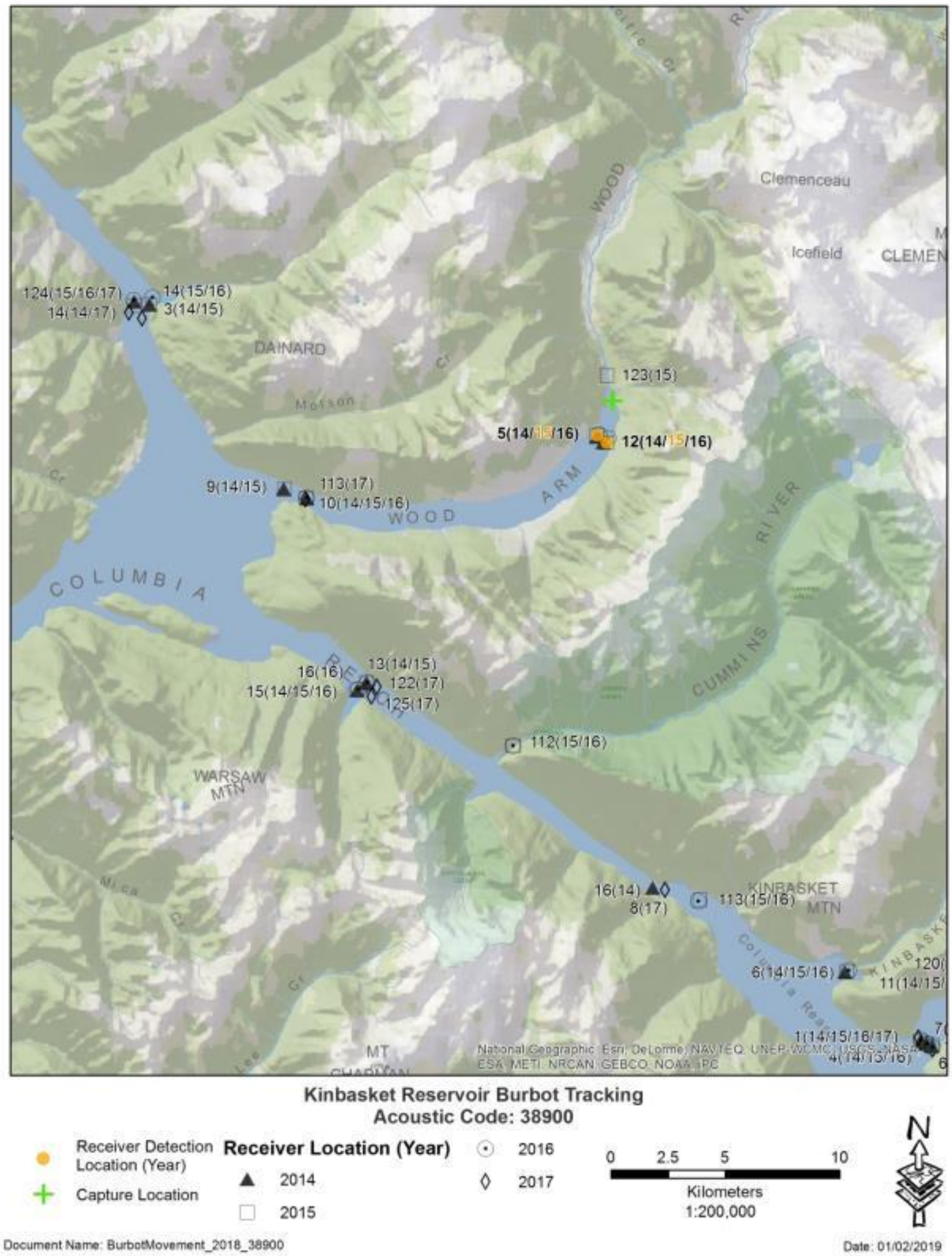
0 2.5 5 10
Kilometers
1:200,000

N

Document Name: BurbotMovement_2018_38400

Date: 01/02/2019


TISA MTN
CUMMINS
KINBASKET R
KINBASKET MTN
SULLIVAN RIVER
COLUMBIA
NEPTUNE PEAK
Windy Cr
DOUBLETOP MTN
MT ONDERDONK
ADAMANT
112(15/16)
16(14)
8(17)
113(15/16)
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
12(17)
8(14/15/16)
115(15/16)
13(17)
114(15/16)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 38700
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_38700
Date: 01/02/2019


124(15/16/17)
14(14/17)
14(15/16)
3(14/15)
DAINARD
Clemenceau
Icefield
WOOD
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
WOOD ARM
RIVER
COLUMBIA
CUMMINS
16(16)
15(14/15/16)
13(14/15)
122(17)
125(17)
112(15/16)
WARSAW MTN
16(14)
8(17)
113(15/16)
KINBASKET MTN
6(14/15/16)
1(14/15/16/17)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 38900
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
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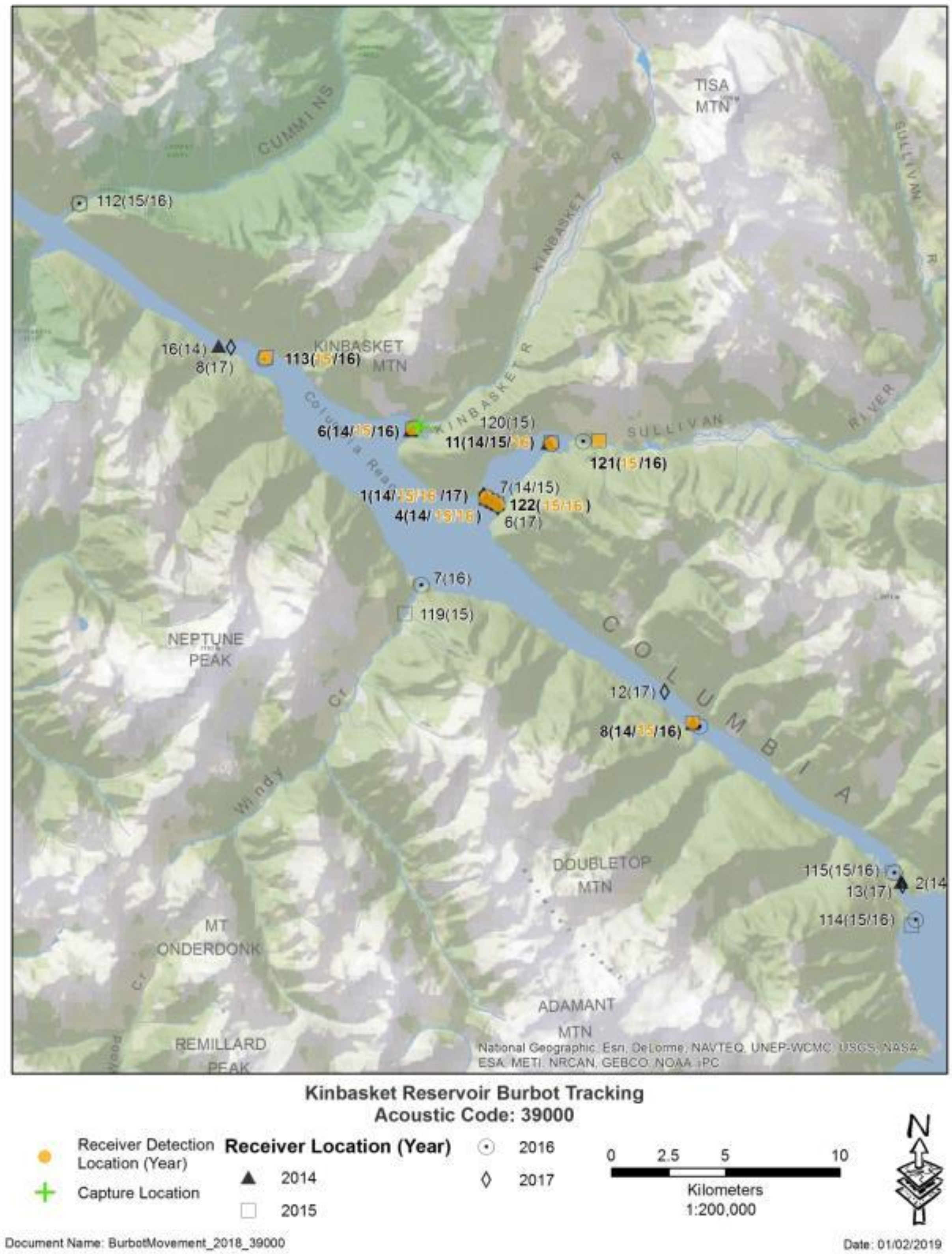
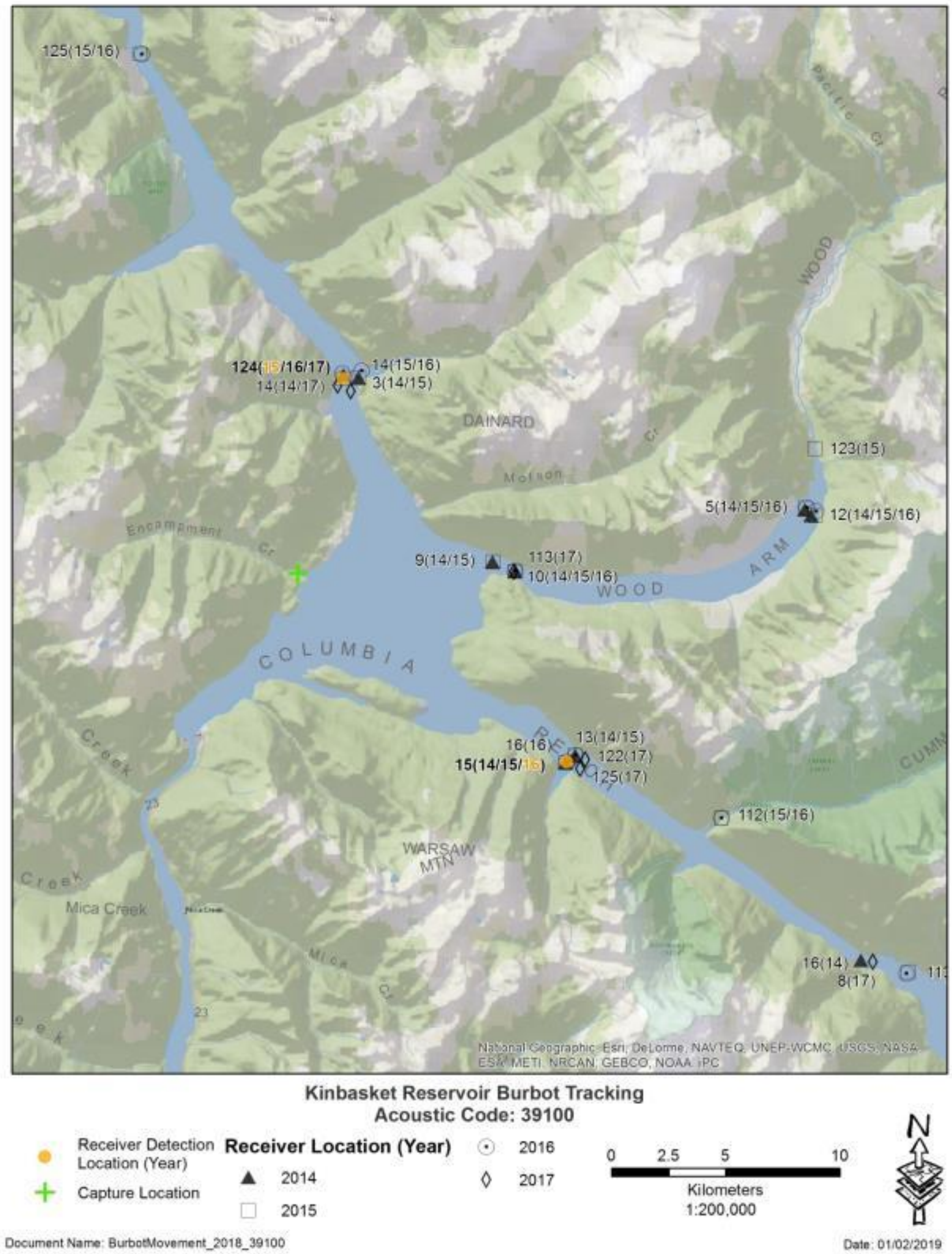
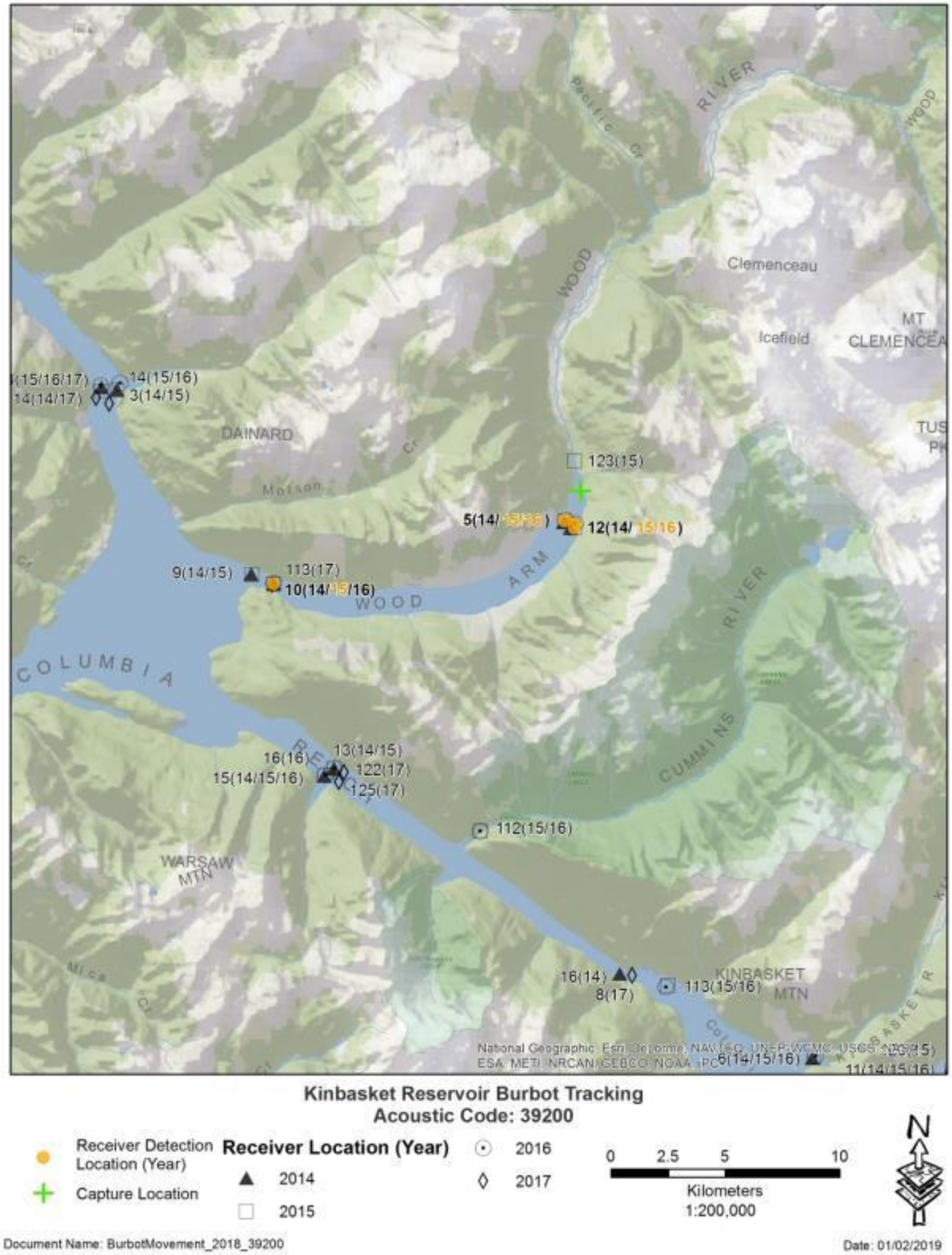
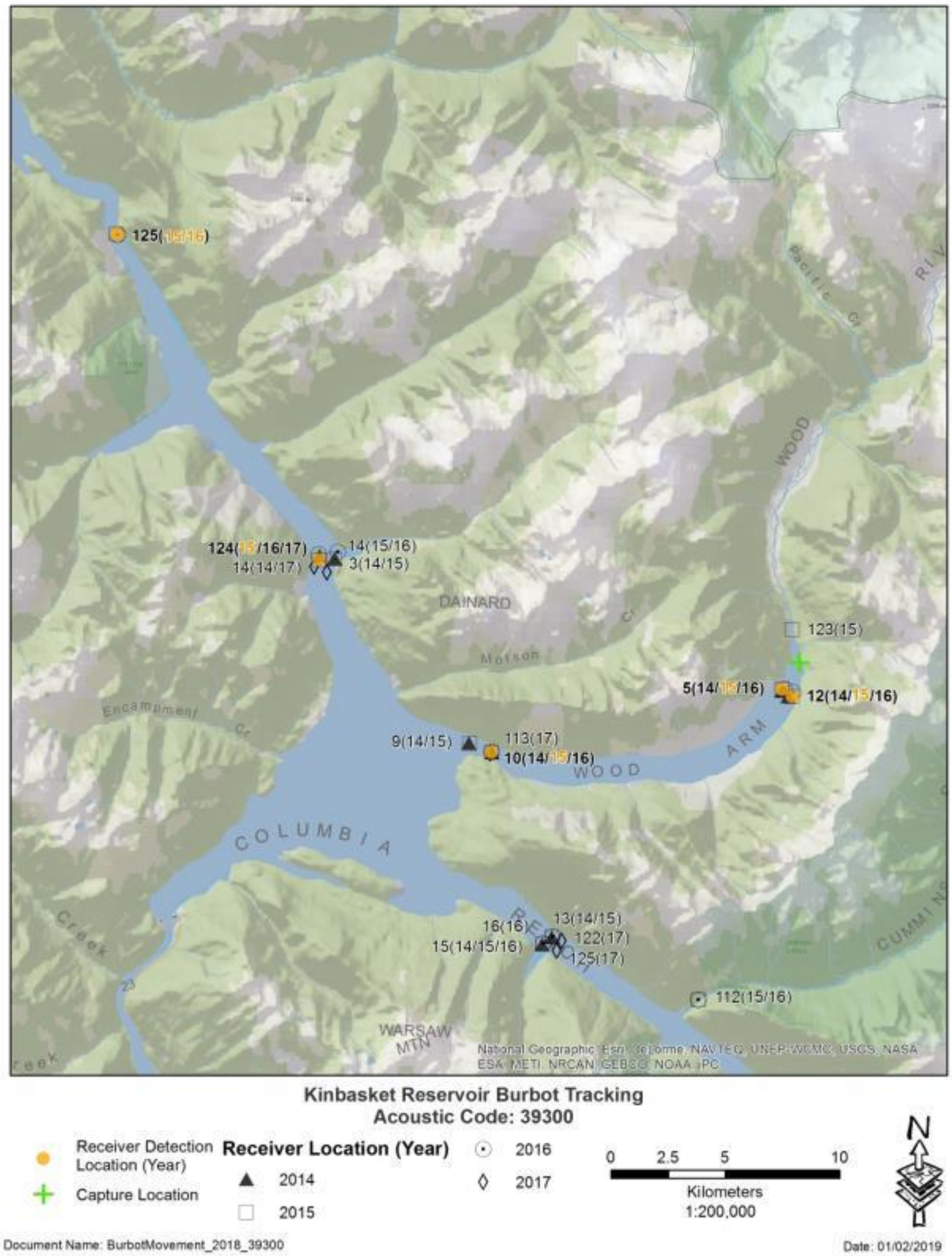
2.5
5
10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_38900
Date: 01/02/2019


TISA
MTN
CUMMINS
SULLIVAN
R
KINBASKET
112(15/16)
16(14)
8(17)
113(15/16)
KINBASKET
MTN
6(14/15/16)
120(15)
11(14/15/16)
121(15/16)
SULLIVAN
RIVER
1(14/15/16/17)
4(14/15/16)
7(14/15)
122(15/16)
6(17)
7(16)
119(15)
NEPTUNE
PEAK
COLUMBIA
12(17)
8(14/15/16)
Windy
Cr
DOUBLETOP
MTN
115(15/16)
13(17)
114(15/16)
MT
ONDERDONK
ADAMANT
MTN
REMILLARD
PEAK
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 39000
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0
2.5
5
10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_39000
Date: 01/02/2019


125(15/16)
124(15/16/17)
14(14/17)
14(15/16)
3(14/15)
DAINARD
Molson
123(15)
5(14/15/16)
12(14/15/16)
Encampment Cr
9(14/15)
113(17)
10(14/15/16)
WOOD ARM
COLUMBIA
REACH
13(14/15)
16(16)
15(14/15/16)
122(17)
125(17)
112(15/16)
WARSAW MTN
Creek
Mica Creek
Mica Cr
16(14)
8(17)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 39100
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_39100
Date: 01/02/2019


Kinbasket Reservoir Burbot Tracking
Acoustic Code: 39200
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0
2.5
5
10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_39200
Date: 01/02/2019
RIVER
WOOD
Clemenceau
Icefield
MT
CLEMENCEA
DAINARD
14(15/16)
3(14/15)
14(14/17)
123(15)
5(14/15/16)
12(14/15/16)
9(14/15)
113(17)
10(14/15/16)
WOOD
ARM
COLUMBIA
RIVER
13(14/15)
16(16)
122(17)
15(14/15/16)
125(17)
112(15/16)
CUMMINS
WARSAW
MTN
16(14)
8(17)
113(15/16)
KINBASKET
MTN
6(14/15/16)
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC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COLUMBIA
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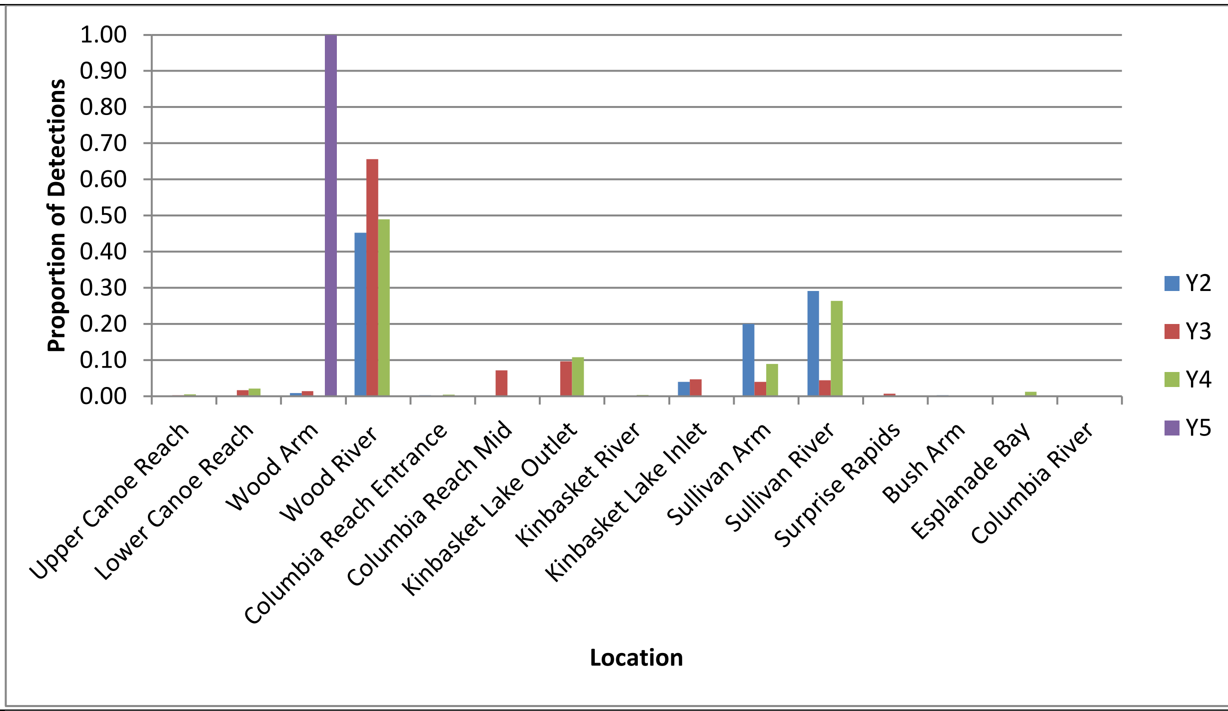
WARSAW MTN
National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Kinbasket Reservoir Burbot Tracking
Acoustic Code: 39300
Receiver Detection Location (Year)
Capture Location
Receiver Location (Year)
2014
2015
2016
2017
0 2.5 5 10
Kilometers
1:200,000
N
Document Name: BurbotMovement_2018_39300
Date: 01/02/2019

A2 Figure 1: Maps of capture and detection locations for each Burbot tracked for CLBMON-05 (2014 to 2018; n= 85). Number labels represent the receiver number with receiver deployment years in parentheses (yellow highlighting indicates the individual was detected by that receiver during that year).

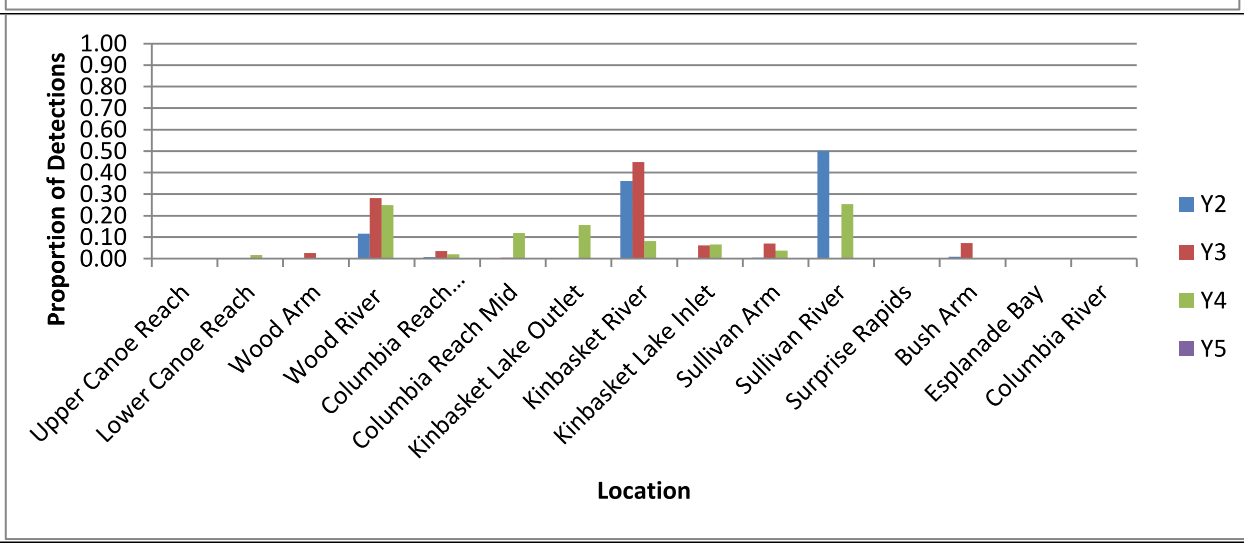
While the majority of detections were made at Wood River year-round (>40%), detections did vary seasonally (A2 Figure 2). Wood River detections made up >50% of detections during the suspected spawning period and Fall/Winter but >20% of detections during Spring and Summer. Sullivan River detections made up >25% of detections during Spring and Summer, as well as >20% of detections during Fall and the suspected spawning period. Kinbasket River detections were also high (27, 34, 10% during Spring, Summer, and Fall, respectively). The high proportion of detections at Wood River, Sullivan River, and Kinbasket River during the suspected spawning period and Spring suggests that Burbot congregate at these locations for spawning.

Spawning

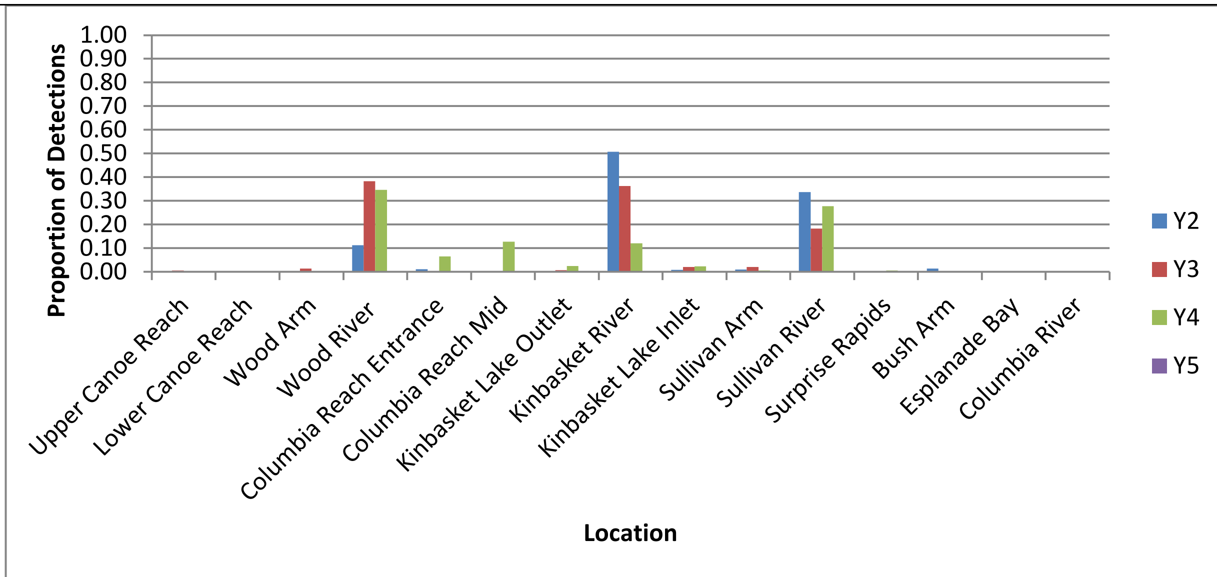
(Jan-Apr)



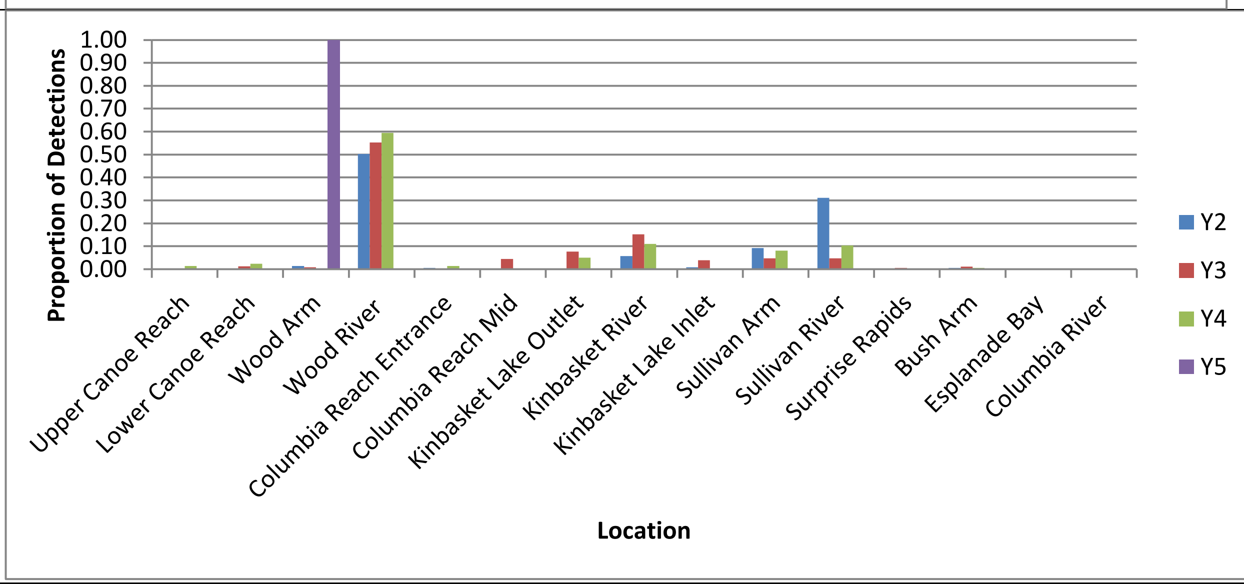
Spring (May - Jun)



Summer (Jul -Sep)



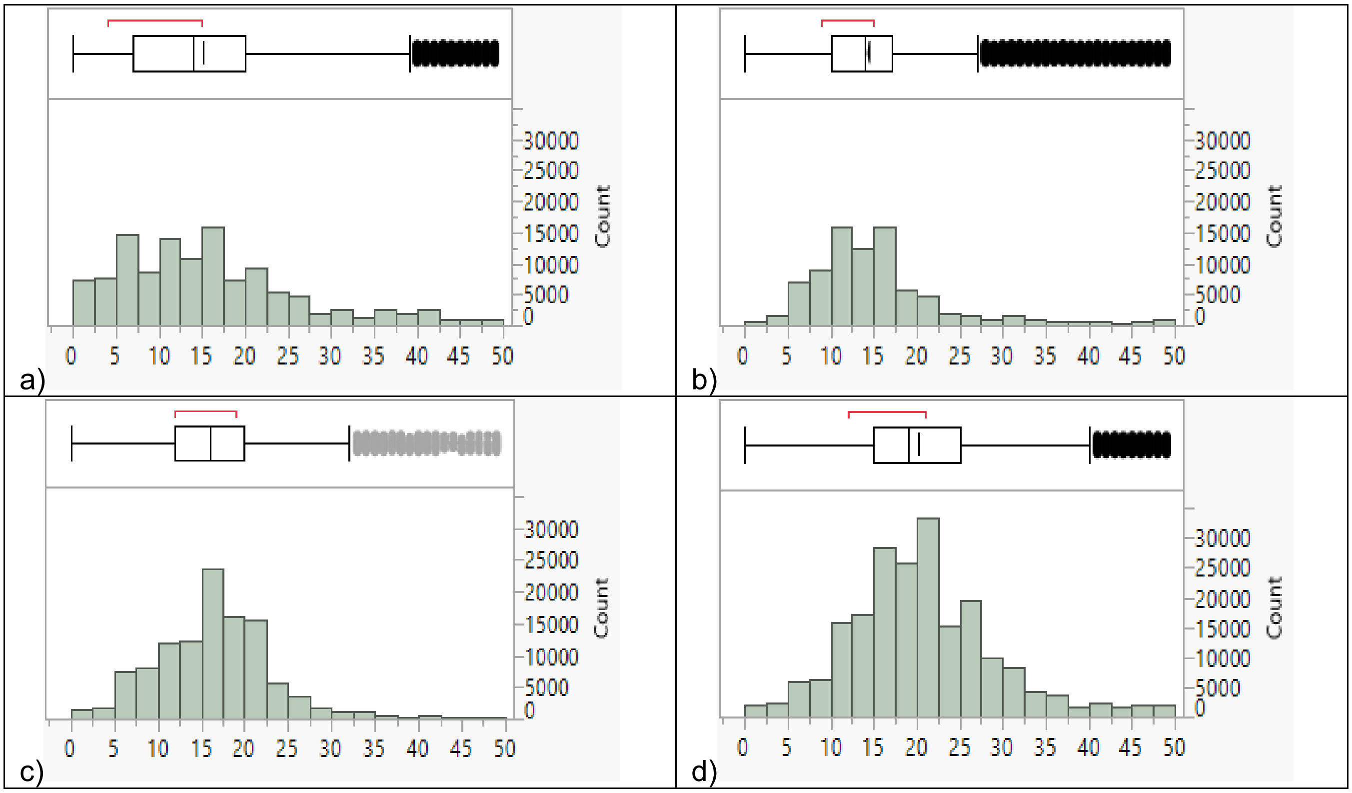
Fall-Winter (Oct – Dec)



A2 Figure 2: Summary of proportion of seasonal detections of Burbot at receiver locations (listed left to right according to locations from North to South) in Kinbasket Reservoir. The spawning period is expected to occur from January to April.

Depth Occupation

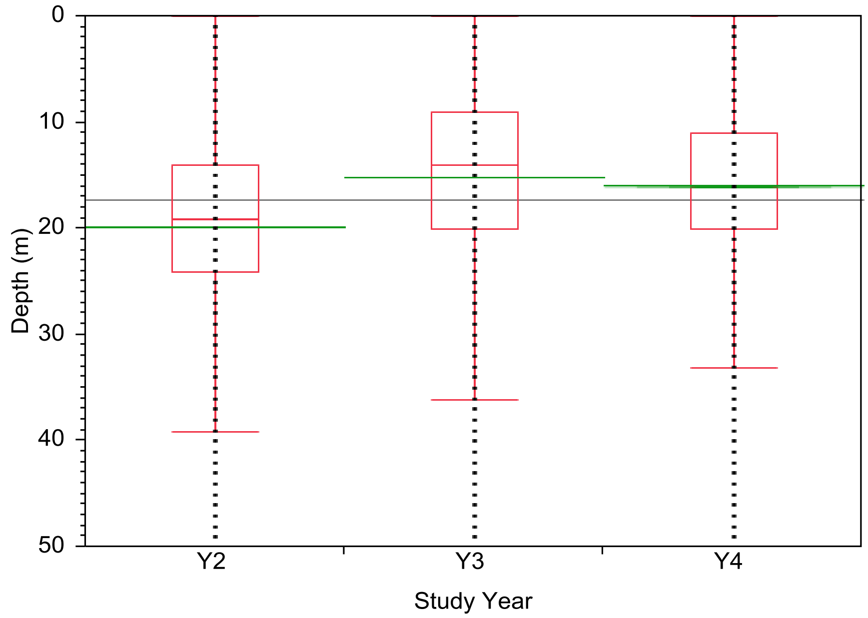
Mean depth of Burbot across all years (2014-2018) was 17.3 ±8.60 m, with most Burbot distributed in the depth range of 12.0 to 22.0 m (A2 Figure 3).



A2 Figure 3: Seasonal distribution (histogram and box plot) of depth (m) for Burbot detected by acoustic tracking (n = 76) in Kinbasket Reservoir during 2014-2018 – a) Suspected Spawning Season, b) Spring, c) Summer, d) Fall/Winter. Boxes represent interquartile range, diamonds represent the sample mean and 95% confidence interval, while the middle line in the box is the median sample value. Whiskers represent observations outside of the interquartile range, with outlier data points. The red line indicates the densest 50% of the observations.

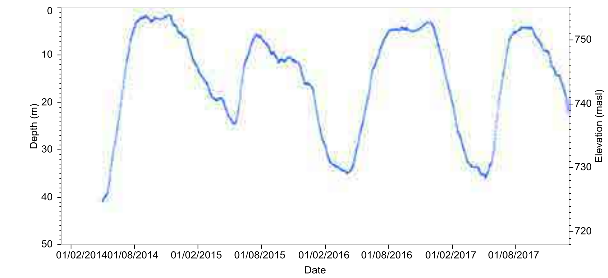
Burbot mean elevation during the 2014-2015 monitoring period was significantly lower than during the 2015-2016 and 2016-2017 monitoring periods (A2 Figure 4; median depths: 2014-2015 = 19.0 m; 2015-2016 = 14.0 m; 2016-2017: 16.0 m; df = 2). The median depth during 2017-2018 was 25 m and since detections were for only two individuals (Acoustic Code 36500, 36600) during a shortened study period, they were not included in analyses.

Depths occupied during the study years were shallower than those reported by Harrison et al. (2013; day-time and night-time mean depths ± SE were 37.09 ± 1.30 m and 25.9 ± 1.52 m, respectively; data from May 2010 to May 2012, corresponding to this study's timing), which might reflect general differences in dam operations (as the spatial extent of the reservoir goes through periods of contraction and expansion) or natural variation. Burbot are benthic (Fischer 2000a, 2000b) and depth detections likely reflect this behaviour.



A2 Figure 4: Mean depth (m) of Burbot for each study year (Year 2: May 2014 - May 2015, n= 206,505, Year 3: May 2015 – May 2016, n = 183,653, Year 4: May 2016 – May 2017, n = 111,809). Boxes represent interquartile range with the middle line representing the median sample value. Green diamonds represent the 95% confidence interval with the middle line representing the mean. Whiskers represent observations outside of the interquartile range, with outlier data points. Data from June 2014 to January 2018.

Depth profiles illustrate the variability in depth occupation among Burbot, with individuals occupying a range of depths (A2 Figure 5). Some general trends are apparent such as shifts from shallow to deeper areas from June/July to November/December and subsequent shifts to shallower depths from January to April-May (movements are discussed further below). Diel vertical migration (DVM) is illustrated by the vertical pattern of multiple points within a day. Of the 70 detected and living Burbot, 39% of individuals appeared to move into areas deeper than the transducer range limit of 50 m, as illustrated by numerous data points along the 50 m mark (A2 Figure 5).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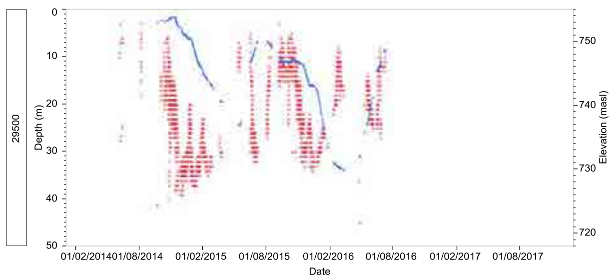
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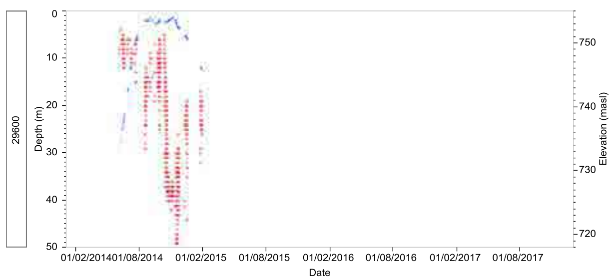
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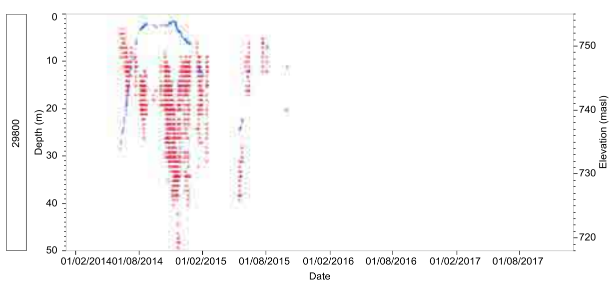
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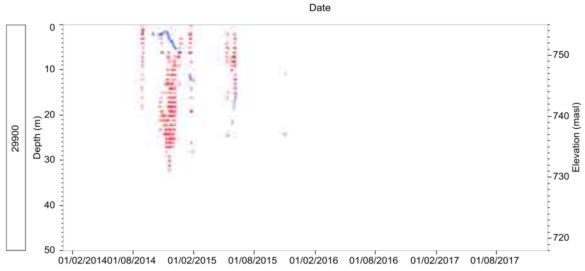
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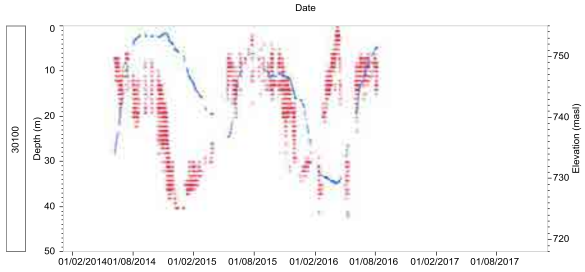
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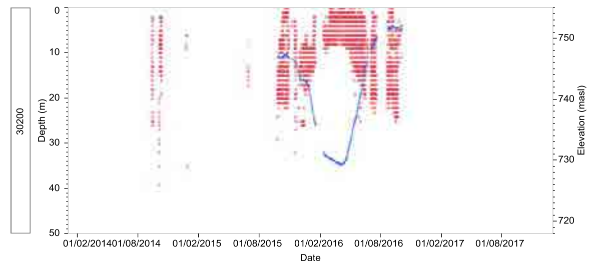
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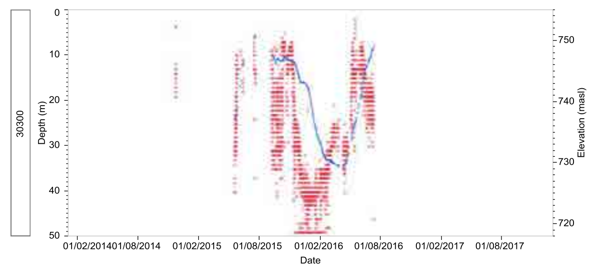
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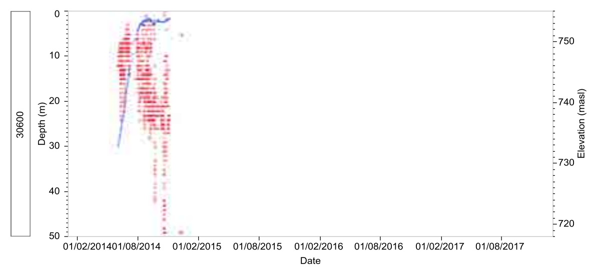
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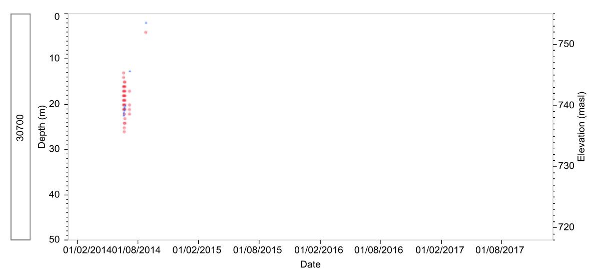
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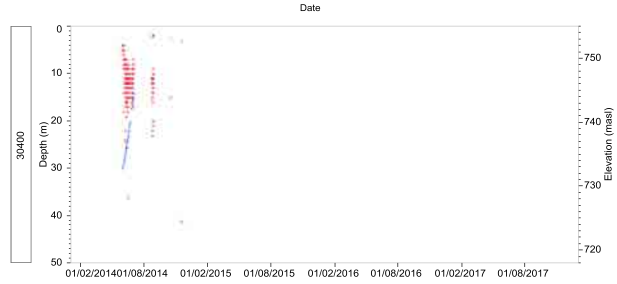
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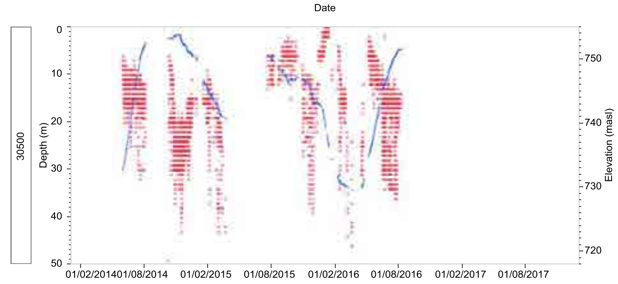
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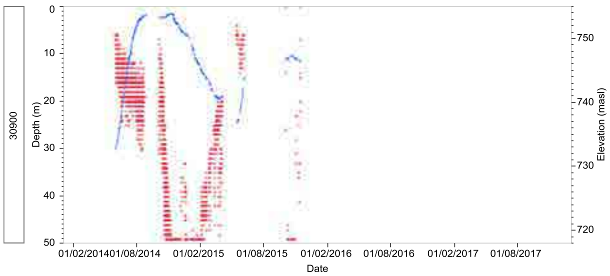
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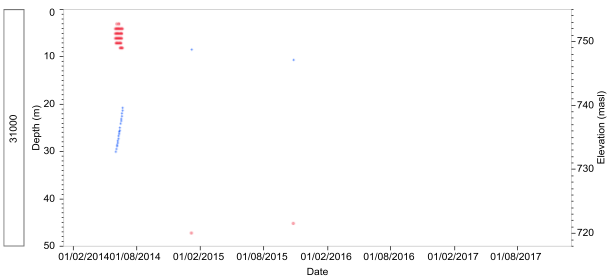
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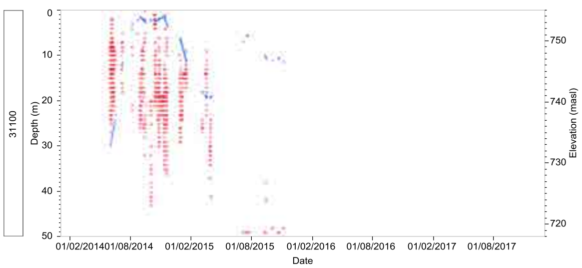
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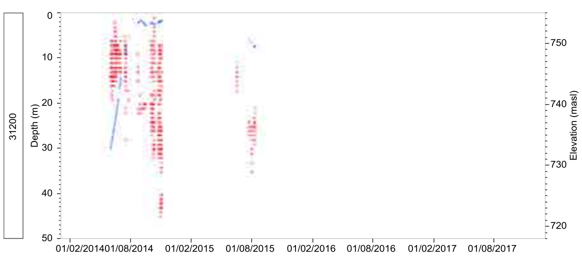
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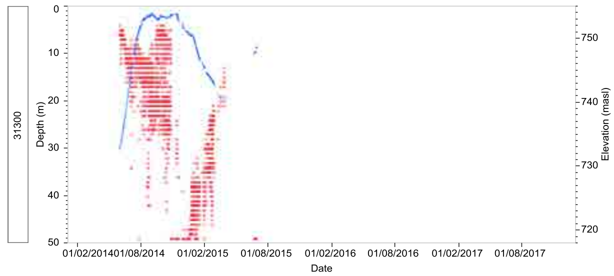
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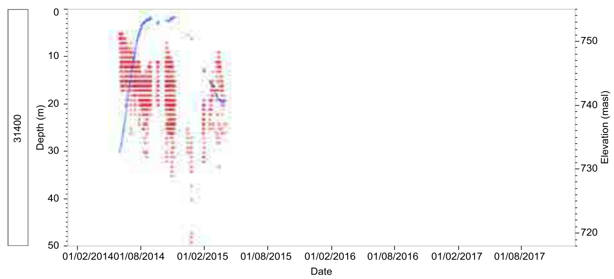
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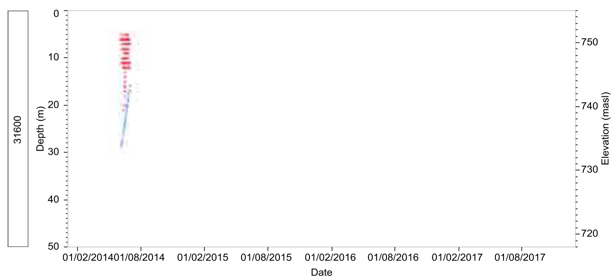
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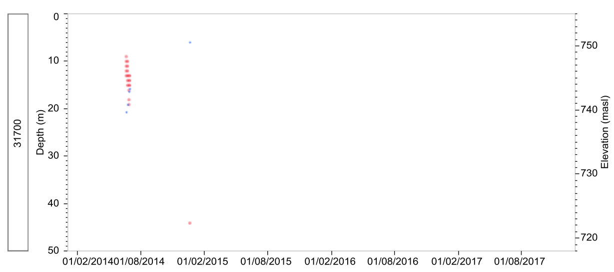
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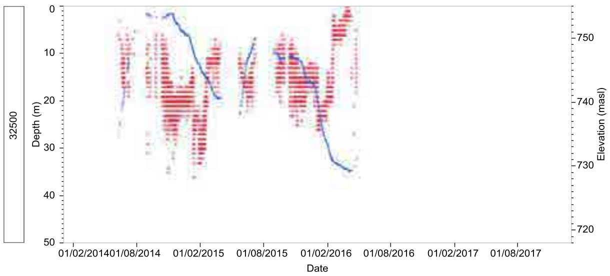
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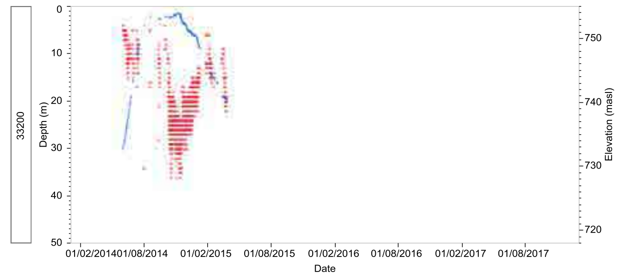
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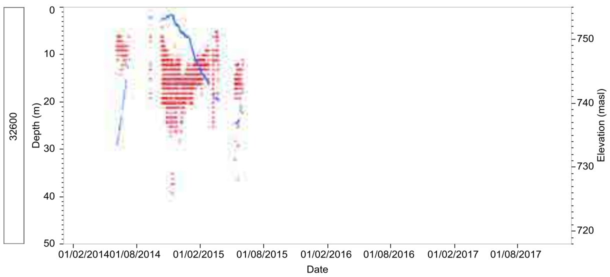
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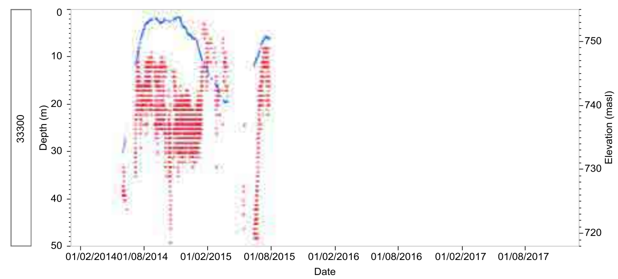
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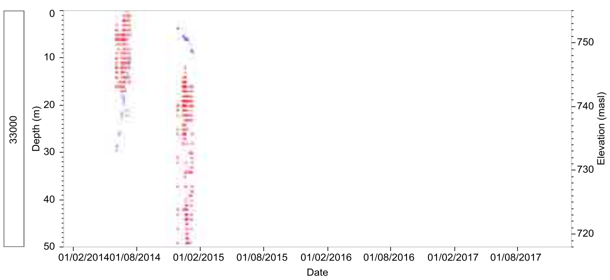
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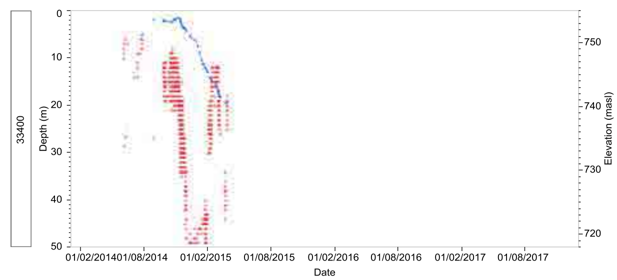
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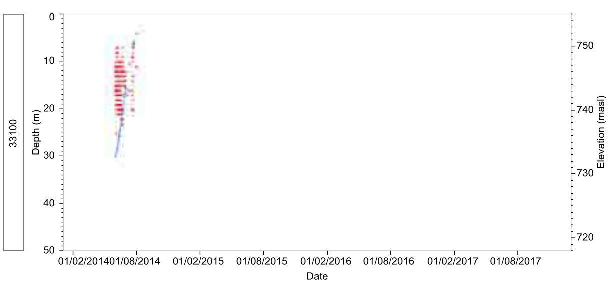
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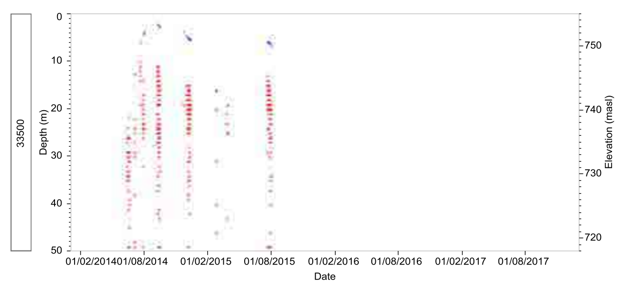
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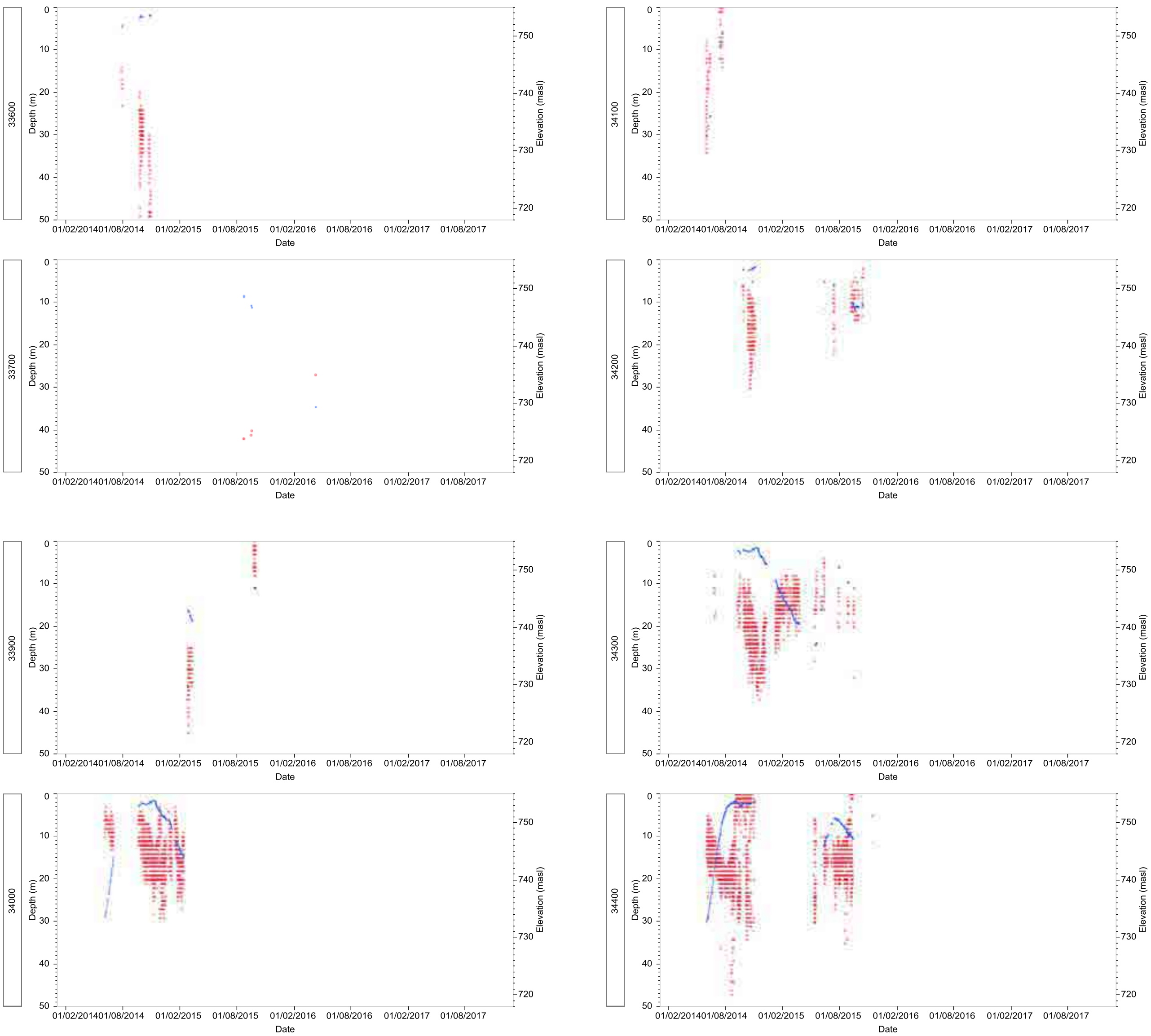
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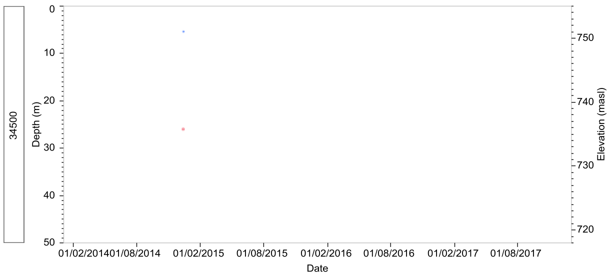
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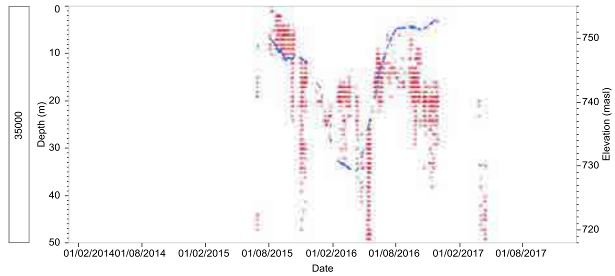
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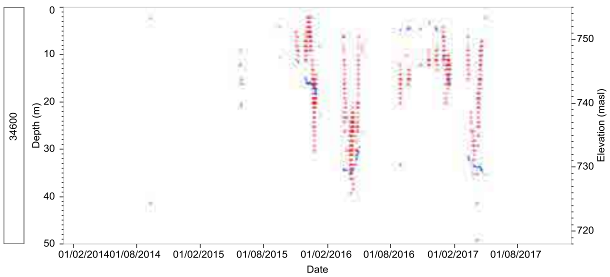
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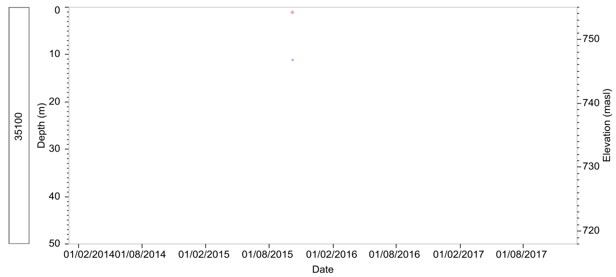
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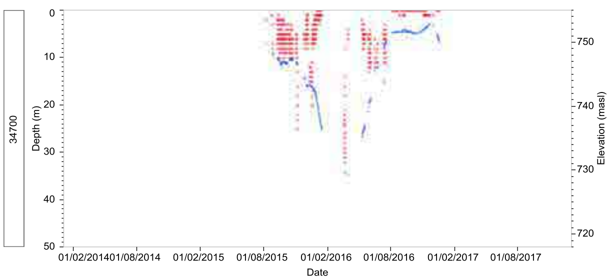
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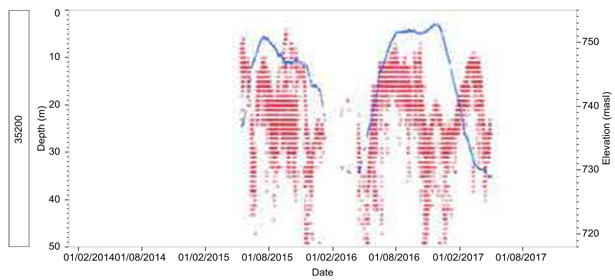
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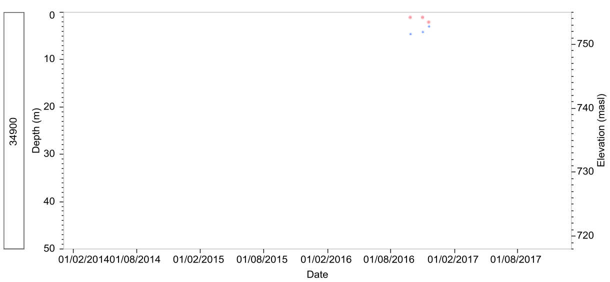
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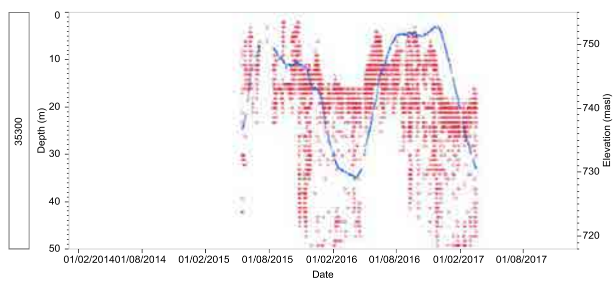
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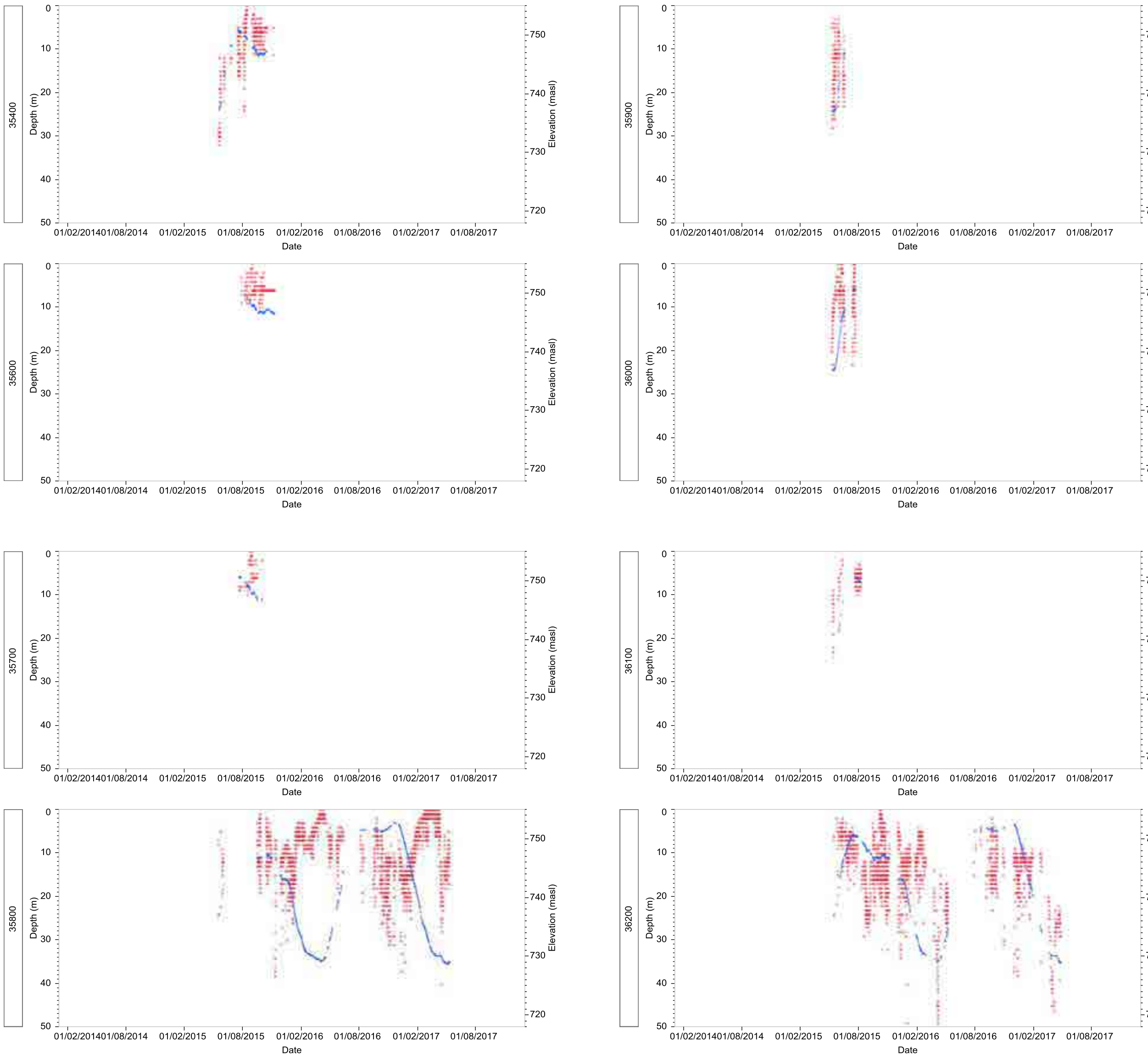
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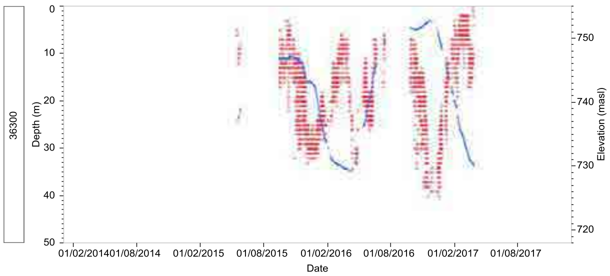
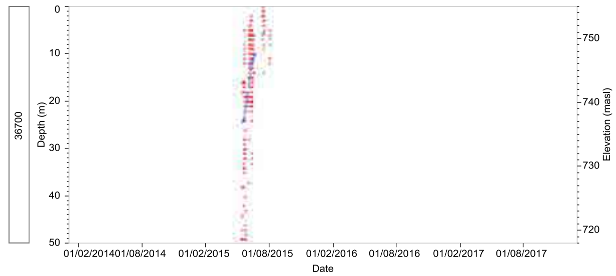
01/02/2017
01/08/2017


36300
Depth (m)
Elevation (masl)
Date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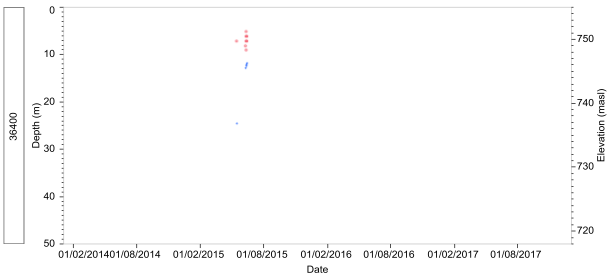
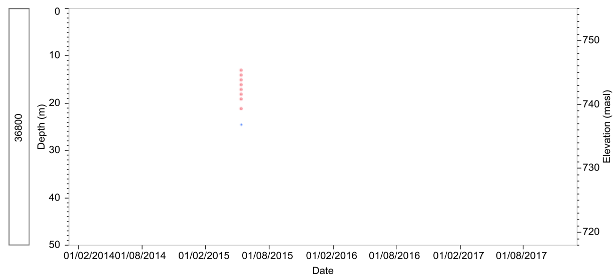
Depth (m)
Elevation (masl)
Date


36400
Depth (m)
Elevation (masl)
Date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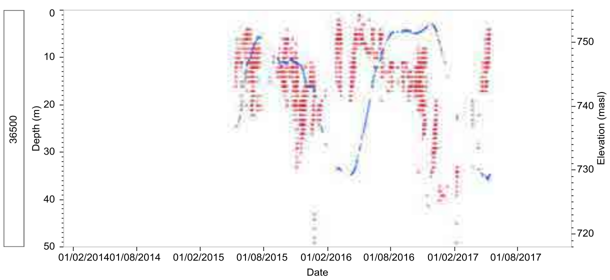
Depth (m)
Elevation (masl)
Date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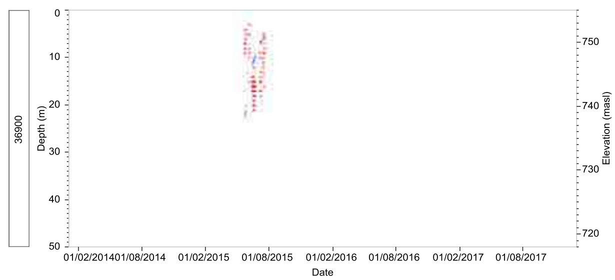
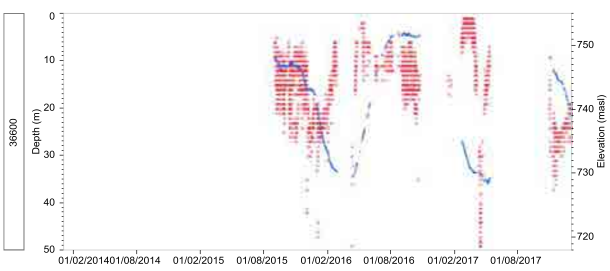
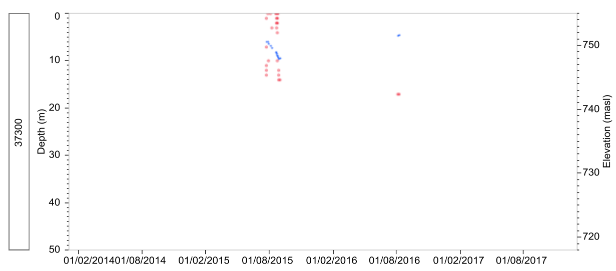
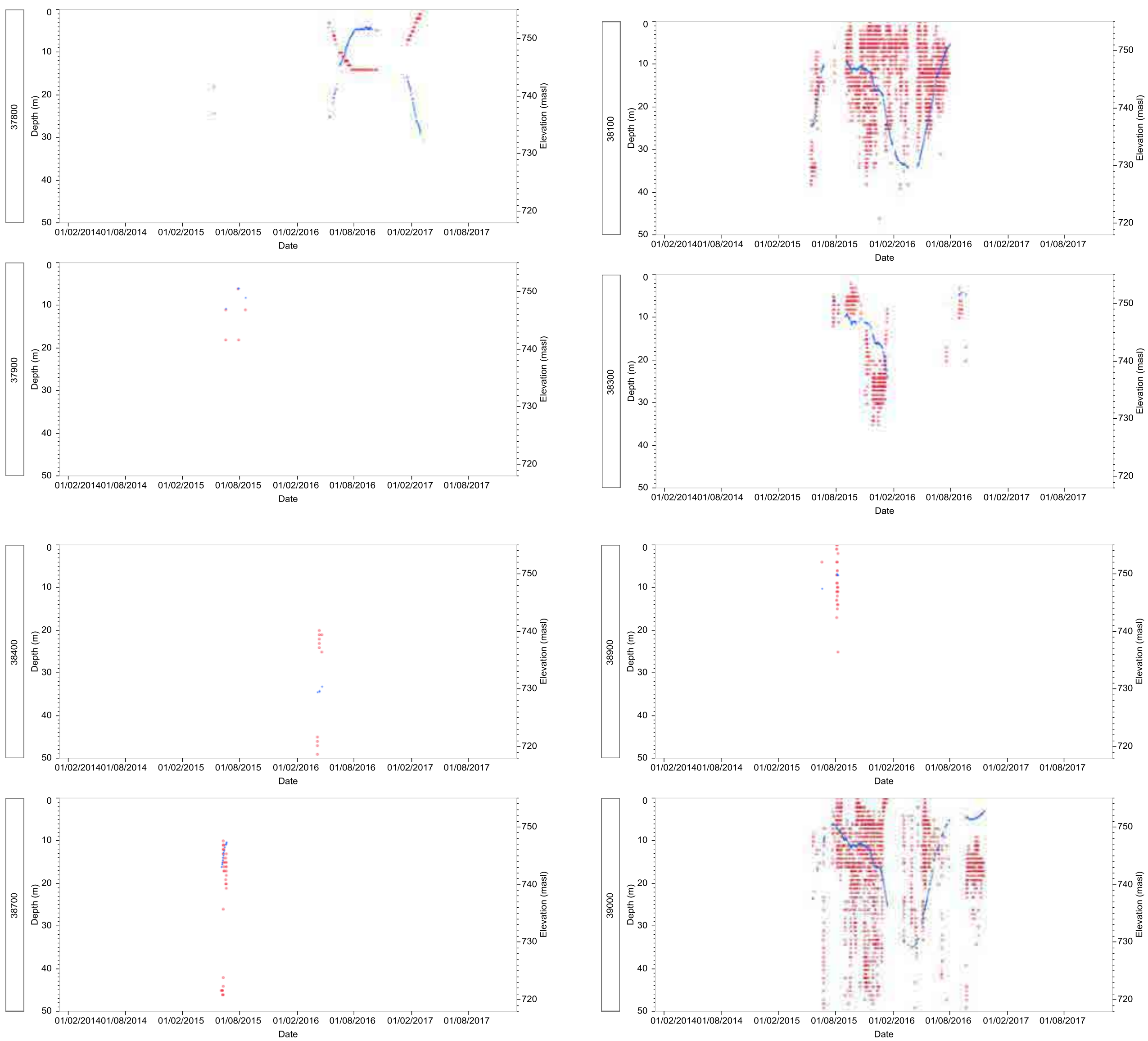
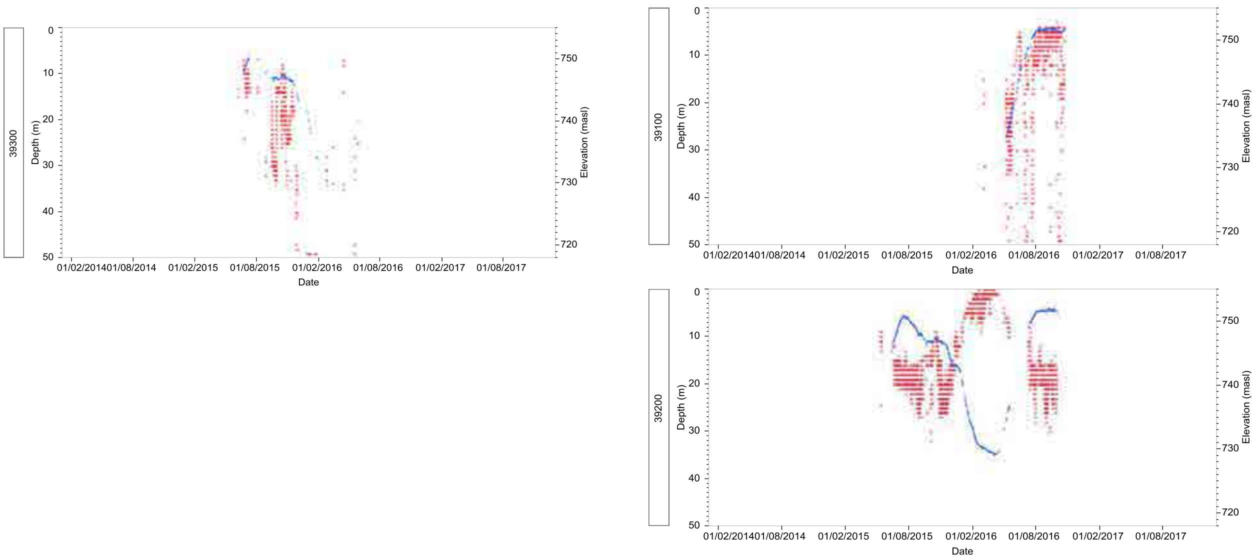
Depth (m)
Elevation (masl)
Date


36900
Depth (m)
Elevation (masl)
Date


36600
Depth (m)
Elevation (masl)
Date


37300
Depth (m)
Elevation (masl)
Date

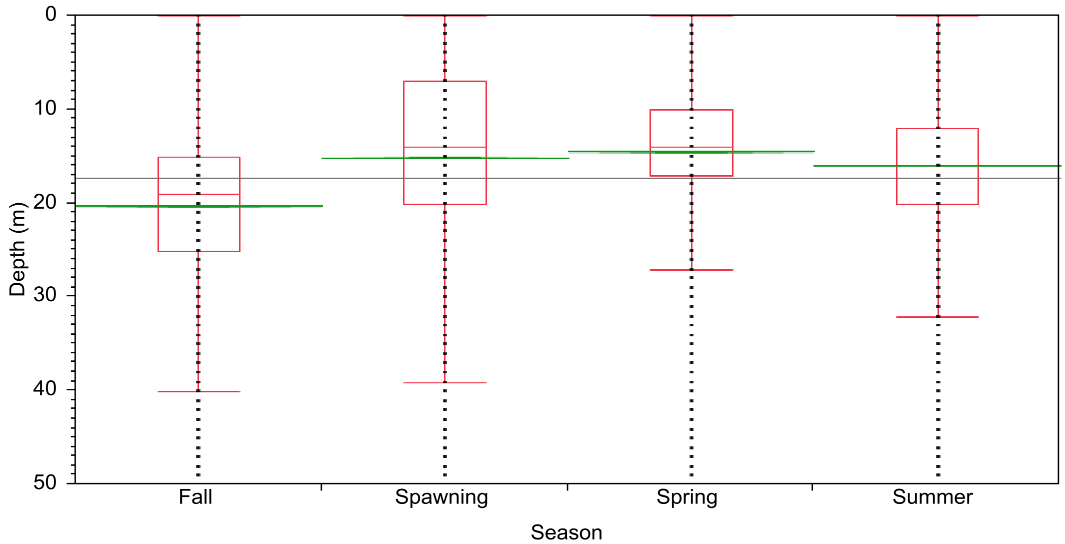

37800
37900
38400
38700
38100
38300
38900
39000
Depth (m)
Elevation (masl)
Date
01/02/2014
01/08/2014
01/02/2015
01/08/2015
01/02/2016
01/08/2016
01/02/2017
01/08/2017



A2 Figure 5: Summary of depth detections of individual Burbot tracked using CART tags in Kinbasket Reservoir (2014 to 2019). Red lines highlight Burbot depth detections and blue lines highlight reservoir elevations (note different scales).

Depths occupied by Burbot during the Spring (May to June, mean ± SE = 14.50 ± 0.03, n=77,364) were significantly shallower than in other seasons (suspected spawning period - January to April: 15.15 ± 0.02 m, n=114,849; Summer: July to September, 15.98 ± 0.03, n=108,376; Fall/Winter: October to December 20.26 ± 0.02, n=201,819; A2 Figure 6).

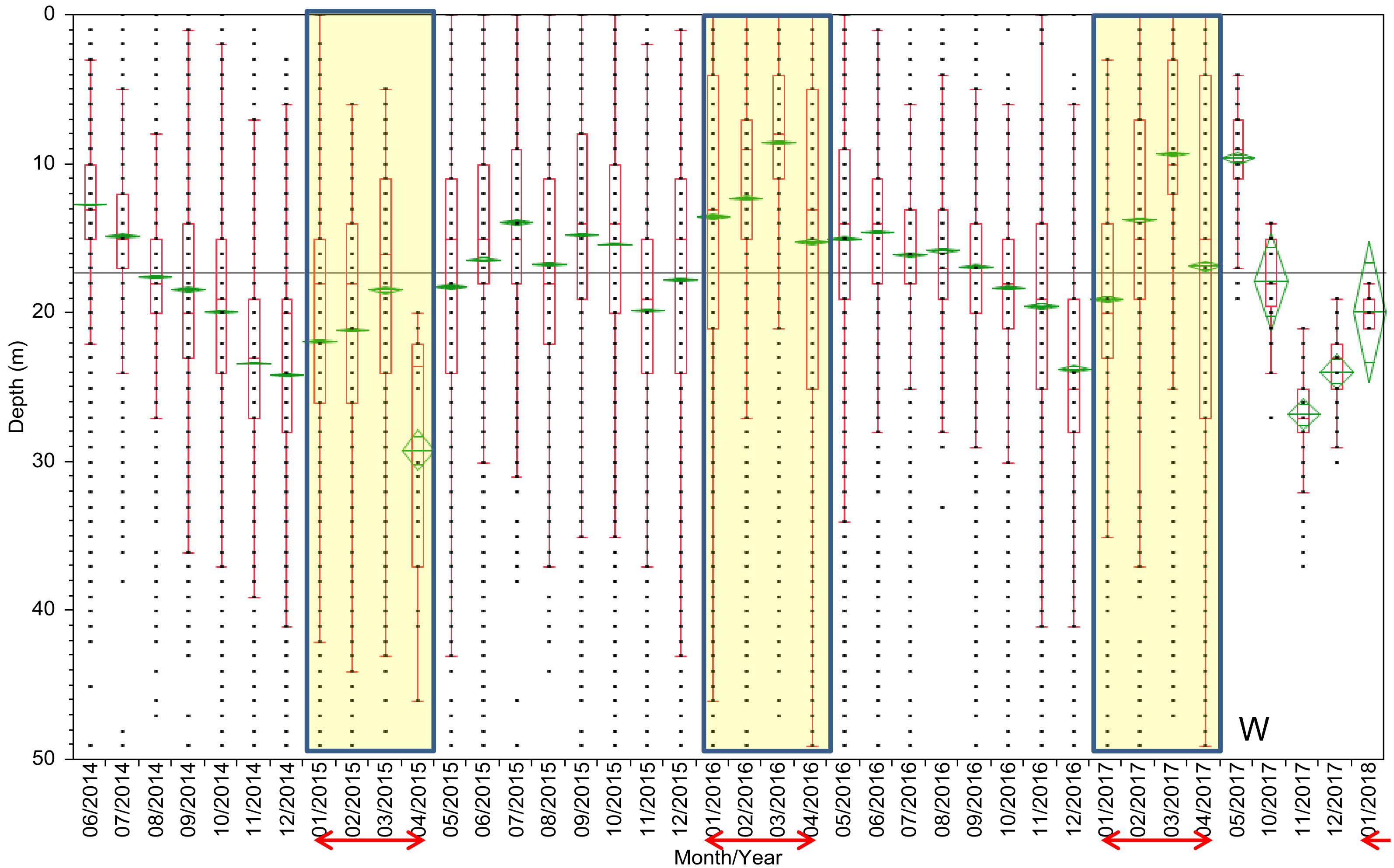
All depths occupied during each season were significantly different from each other (A2 Figure 6). This suggests that the suspected spawning period might extend past April into the Spring months or that Burbot remain in shallow habitats during the post-spawn period (A2 Figure 6 and 7).



A2 Figure 6: Mean seasonal depth (m) of Burbot for all monitoring periods. Boxes represent interquartile range with the middle line representing the median sample value. Diamonds represent the 95% confidence interval with the middle line representing the mean. Whiskers represent observations outside of the interquartile range, with outlier data points. Data from June 2014 to May 2017.

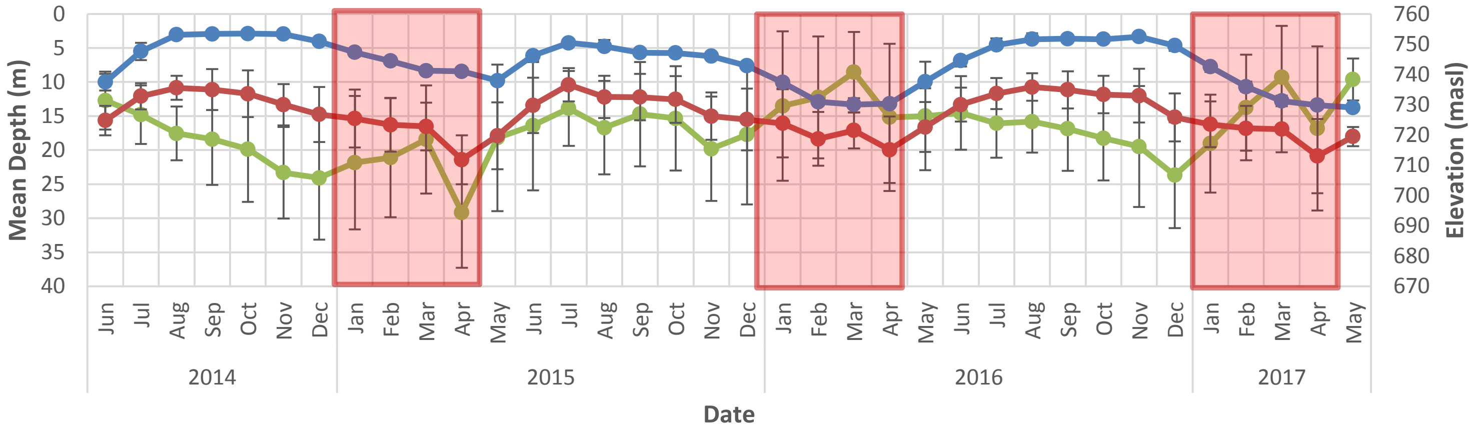
Burbot occupation at the deepest depths occurred during Fall (mean depth ± SE: Dec 2014 = 24.1 ± 0.05 m; Nov 2015 = 19.8 ± 0.05 m; Dec 2016 = 23.7 ± 0.11 m; Nov 2017 = 26.8 ± 0.52 m; A2 Figure 7) and was followed by occupation at shallower depths during the Suspected Spawning period (mean depth ± SE: March 2015 = 18.4 ± 0.11 m; March 2016 = 10.9 ± 0.51 m; March 2017 = 9.3 ± 0.51 m; A2 Figure 7). Similarly, observations of Burbot detection at depths <10 m have been made in Duncan Reservoir during February to March (Cope, 2011).

Occupation at shallow depths was sustained during Spring, corroborating the earlier observation that findings suggest that the suspected spawning period might extend past April into the Spring months or Burbot remain in shallow habitats during the post-spawn period (A2 Figure 6 and 7).



A2 Figure 7: Mean daily depth (m) of Burbot detected each month of the year in all monitoring periods. Boxes represent interquartile range with the middle line representing the median sample value. Diamonds represent the 95% confidence interval with the middle line representing the mean. Whiskers represent observations outside of the interquartile range, with outlier data points. Red double arrows mark the expected spawning periods. Data from June 2014 to January 2018. Note the break in sampling data during 2017 (highlighted with ‘W’ on the x-axis).

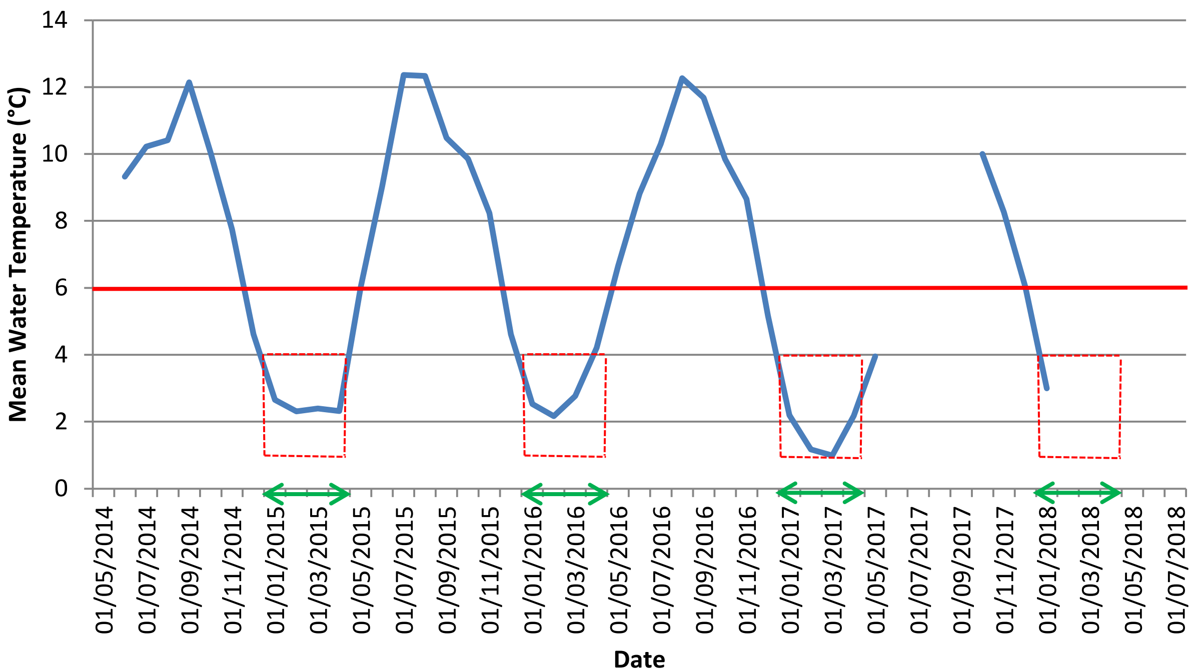
A comparison of mean daily Burbot depth occupation (corrected for reservoir elevation, masl) and mean daily reservoir elevation indicated that the timing of reservoir drawdown coincided with the suspected spawning periods when Burbot occupy the shallowest depths (A2 Figure 8). Overlap of standard deviation bars suggests that some spawning habitat may be dewatered during reservoir drawdown.



A2 Figure 8: Comparison of mean daily Burbot depth (red line represents Burbot depth corrected for reservoir elevation, masl; green line represents Burbot depth in relation to water surface, m) and mean daily reservoir elevation (blue line). Red shaded boxes mark the suspected spawning periods. Bars represent standard deviation. Data from June 2014 to May 2017.

Water Temperature

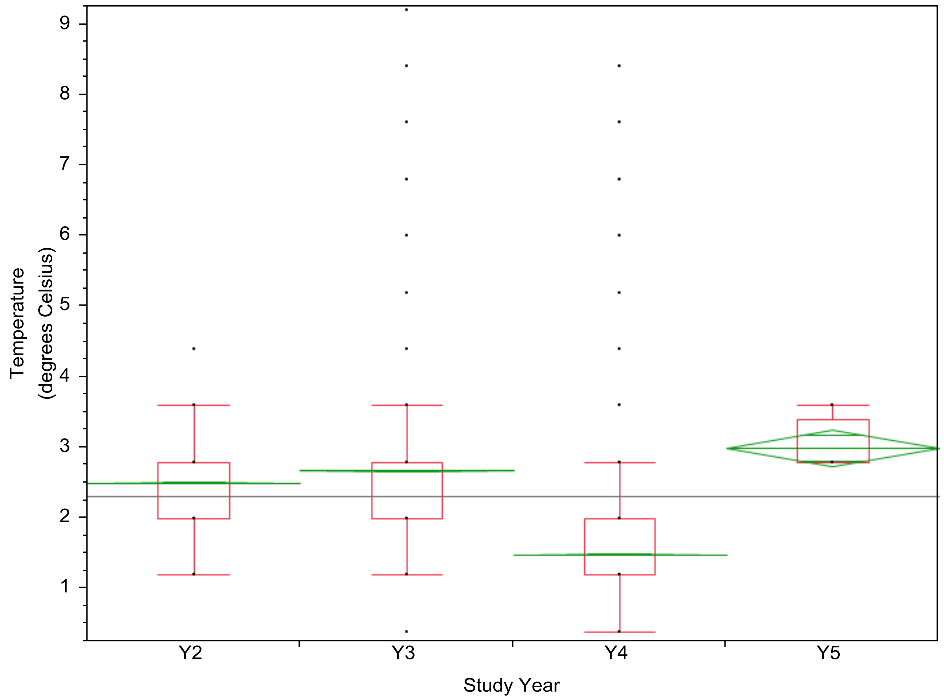
Although mean daily water temperatures during the suspected spawning period occurred within the optimal temperatures for egg incubation (1-4 °C; McPhail and Paragamian, 2000; A2 Figure 9), records of temperatures outside the optimal range occurred during the study (A2 Table 2, A2 Figure 10). Sustained temperatures above 4 °C were recorded in 2016 for over 20 consecutive days in Wood River, an area with the highest number of Burbot detections (A2 Figure 11).



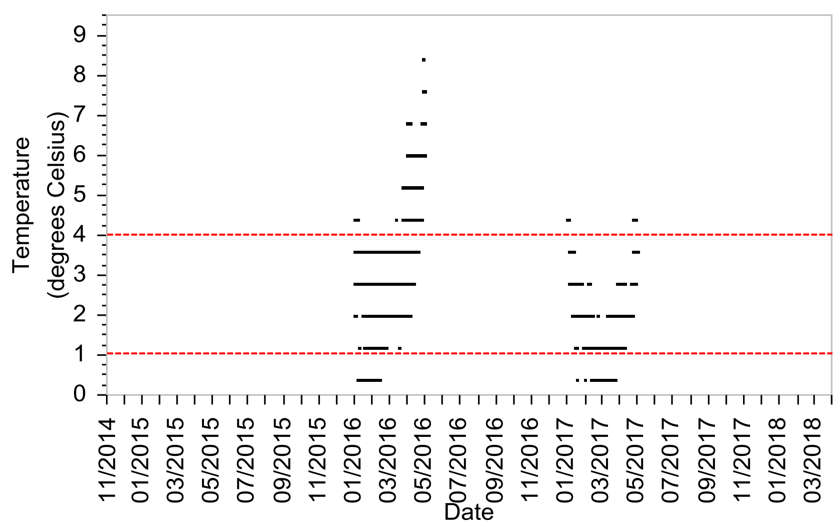
A2 Figure 9: Mean daily water temperature (°C). Green double arrows mark the suspected Burbot spawning periods. Red dashed boxes bound the optimal Burbot egg incubation temperature range. Red line marks the temperature above which Burbot embryos die (Taylor and McPhail 2000, Vught et al. 2007) and spawning cannot be induced (Zarski et al. 2010). Data from June 2014 to January 2018.

A2 Table 2: Summary of water temperature recorded during the suspected spawning period (January to April). Data from June 2014 to May 2017.

Study Year	Min. Temperature (°C)	Median Temperature (°C)	Max. Temperature (°C)
Y2 (2014-2015)	1.2	2	4.4
Y3 (2015-2016)	0.4	2.8	9.2
Y4 (2016-2017)	0.4	1.2	8.4



A2 Figure 10: Mean daily water temperature (°C) for each study year (Year 2: May 2014 - May 2015; Year 3: May 2015 – May 2016; Year 4: May 2016 – May 2017; Year 5: May 2017 – Jan 2018). Boxes represent interquartile range with the middle line representing the median sample value. Green diamonds represent the 95% confidence interval with the middle line representing the mean. Whiskers represent observations outside of the interquartile range, with outlier data points. Data from June 2014 to January 2018.



A2 Figure 11: Water temperatures recorded during the suspected spawning period (January to April) in Wood River. Dashed red lines bound the optimal egg incubation temperature range (1-4 °C; McPhail and Paragamian, 2000). Data from June 2014 to May 2017.

Home Range Estimation

A total of 185 KDEs were calculated and processed for area calculations. Assessment of mean seasonal water surface elevations indicated two distinct seasons: one of “Low Pool” (735 masl; 350.18 km²; used for Spawning and Spring seasons) and another or “High Pool” (750 masl; 412.89 km²; used for Summer and Fall seasons). These mean

Low Water and High Water elevation rasters were used to clip with KDEs to calculate UDs for the 50, 75, 90, and 95% isopleths (A2 Tables 3 to 6).

A2 Table 3: Utilization distributions (in km²) of Kinbasket burbots at 50% probability (i.e. Core Range) and per seasons.

Acoustic Code	Area of Utilization Distribution at 50% probability (Core Range) per Season (in Km²)				
	Fall	Spawning	Spring	Summer	Mean
29500	0.030457487	0.096281384	0.03712681	0.028076265	0.047985486
29600	6.329420449	51.86671307	0.022256697	0.010631791	14.5572555
29800	3.434989922	104.734626	5.929482179	3.661681325	29.44019486
29900	1.342969993	0.063680644	0.43315329	1.160192262	0.749999047
30100	0.017399913	0.459699235	0.72129768	0.044481764	0.310719648
30200	0.098436534		0.007435818	0.051538563	0.052470305
30300	1.158467715		0.626960842	1.043536732	0.94298843
30400			0.291936192		0.291936192
30500	0.555371876	1.06256797	0.00050703	0.052051511	0.417624597
30600	0.098472556		0.023103515	0.035061115	0.052212396
30700			0.998481825		0.998481825
30900	8.216858912	5.831375432	1.719079488		5.255771277
31000			8.29738E-05		8.29738E-05
31100	0.416612999	0.527893277	5.26733E-06	0.955526575	0.47500953
31200	1.690744385		2.048675516	33.24689897	12.32877296
31300	1.514598818	0.103518713	0.124760364	0.107038197	0.462479023
31400	0.30277175	0.700390293	4.55426E-06		0.334388866
31600			6.573E-06		6.573E-06
31700			15.10001634	0.02450973	7.562263035
32500	0.013290686	0.038752001	0.034741326	0.031200088	0.029496026
32600	0.172921989	0.527893277	6.134785871	0.014900705	1.712625461
33000	4.495094409		10.51744343	1.280571776	5.431036539
33100			2.01135E-05		2.01135E-05
33200	0.0572303	0.188177851	2.62633E-05	0.011033156	0.064116893
33300	0.459287717	0.361651359	0.064961675	0.447368538	0.333317322
33400	0.49230007	1.213053556	0.019409915	1.26471873	0.747370568
33500	0.470759873	3.579057463	1.662029118	21.03801084	6.687464324
34000	0.000724075	0.03582549	8.22325E-05		0.012210599
34100			0.175274442	0.031182577	0.10322851
34200	0.327128989		0.565493	0.045150454	0.312590815
34300	0.008717082	0.009197858	8.339503178	8.962525241	4.32998584
34400	0.129178189		0.00059947	0.000433513	0.043403724
34600	6.228738055	51.58246635	114.9350386	4.32770103	44.26848602
34700	0.322200267	0.057500495	0.000246298	0.02224495	0.100548002
35000	60.32217111	12.37629482	2.475979951	8.248616265	20.85576554
35200	0.775824756	0.61180708	1.889492213	0.337879526	0.903750894
35300	2.021475119	0.088902682	1.411243987	0.201146158	0.930691987
35400	0.253401149		0.06710103	0.466726973	0.262409717
35800	0.231793211	0.37162013	0.021609259	0.038660033	0.165920658
35900			8.08765E-05		8.08765E-05
36000			4.56071E-05		4.56071E-05
36100			3.925521761		3.925521761
36200	1.976497288	3.914717509	4.611482191	0.992840385	2.873884343
36300	0.024157839	0.485715384	0.011162703	0.038861392	0.139974329
36400			0.09578538		0.09578538
36500	0.08227816	1.100859	0.034297309	0.03006046	0.311873732
36600	0.610266642	1.299667187	0.016666938	0.025866508	0.488116819
36700			0.045862658	3.355576091	1.700719375
36800			1.056989312		1.056989312
36900			2.541361461	14.37958533	8.460473398
37300				3.8903E-05	3.8903E-05
37800			0.188284654		0.188284654
37900			0.019366066		0.019366066
38100			0.006091815	0.008786547	0.007439181
38300	9.708289801	1.526204467		15.10783414	8.780776136
38700			0.067293166		0.067293166
38900			0.715205583	0.01549741	0.365351496

39000	0.622696959	0.395122367	0.913076347	0.542520807	0.61835412
39100			0.086762362		0.086762362
39200	0.570546209	0.02381234	0.048452143	0.202494389	0.21132627
39300	0.758701579	15.83106092	9.642812712	0.038976788	6.567888
Mean	2.908581121	8.1583158	3.397051786	2.771141694	3.998660802

A2 Table 4:Utilization distributions (in km²) of Kinbasket burbots at 75% probability and per seasons.

Acoustic Code	Area of Utilization Distribution at 75% probability per Season (in Km²)				
	Fall	Spawning	Spring	Summer	Mean
29500	0.062820554	0.187042321	0.075020524	0.063148482	0.09700797
29600	21.16450958	110.7542504	0.044399565	0.024014233	32.99679345
29800	4.930743664	143.7993657	12.16499437	4.967017225	41.46553023
29900	2.919791939	0.125959737	0.658714337	1.813526779	1.379498198
30100	0.03531843	0.722987641	1.114544602	0.087651293	0.490125491
30200	0.908545343		0.01197899	0.069296269	0.329940201
30300	2.33200874		1.191376514	2.216018056	1.913134437
30400			0.559551411		0.559551411
30500	1.260501672	2.03148632	0.001005271	0.11236635	0.851339903
30600	0.198836034		0.045455004	0.070167833	0.104819624
30700			1.894918001		1.894918001
30900	13.35610801	9.711767903	2.262071814		8.443315909
31000			0.000159093		0.000159093
31100	0.987423611	1.138804808	1.35767E-05	1.478445721	0.901171929
31200	3.297787946		3.941026173	55.7138871	20.98423374
31300	2.636458707	0.203533854	0.255825052	0.21922753	0.828761286
31400	0.729184757	1.354079031	1.0861E-05		0.694424883
31600			1.09894E-05		1.09894E-05
31700			47.40633877	0.054078738	23.73020875
32500	0.027452103	0.07617668	0.069139524	0.065498243	0.059566638
32600	0.318147143	1.138804808	9.377625443	0.036068797	2.717661548
33000	7.347081284		24.85597791	1.949987943	11.38434904
33100			3.94584E-05		3.94584E-05
33200	0.119197546	0.399456278	6.46295E-05	0.023528085	0.135561635
33300	1.071213953	0.797516703	0.131500563	0.849615915	0.712461783
33400	0.751932157	2.703406223	0.043194074	1.973749369	1.368070456
33500	0.800724097	5.556483872	2.520864632	45.43306539	13.5777845
34000	0.001755935	0.072785317	0.000163142		0.024901465
34100			0.321818223	0.071971276	0.196894749
34200	0.574306153		0.889365164	0.095218852	0.519630056
34300	0.018662039	0.019019868	12.66845486	17.44083956	7.53674408
34400	0.259126168		0.00124037	0.000859901	0.08707548
34600	15.54964882	86.02324682	137.614655	7.245248711	61.60819985
34700	0.889560672	0.083666875	0.000510831	0.042022674	0.253940263
35000	86.16293439	19.93203431	8.234796139	11.89205119	31.55545401
35200	1.873018042	1.375316692	3.459971752	0.605577722	1.828471052
35300	4.258103969	0.178517737	2.351748093	0.369763666	1.789533366
35400	0.321495489		0.126716313	1.290011113	0.579407638
35800	0.376578902	0.616484942	0.045461831	0.07709576	0.278905359
35900			0.000166654		0.000166654
36000			9.94749E-05		9.94749E-05
36100			6.962351639		6.962351639
36200	4.544763242	6.077696043	5.002582697	2.092985593	4.429506894
36300	0.048431211	0.760831697	0.022792792	0.077043946	0.227274911
36400			0.219871284		0.219871284
36500	0.164973587	1.586892342	0.067772889	0.060171613	0.469952608
36600	0.944866348	2.61333272	0.033888893	0.051974961	0.91101573
36700			0.094089365	7.72427538	3.909182373
36800			2.04213232		2.04213232
36900			3.594197559	27.79935619	15.69677688
37300				7.10448E-05	7.10448E-05
37800			0.388114059		0.388114059
37900			0.032419784		0.032419784
38100			0.013217134	0.018160818	0.015688976
38300	21.13073097	2.890633315		59.23741453	27.75292627
38700			0.134934417		0.134934417
38900			0.996734996	0.036725414	0.516730205
39000	1.287813255	4.441236636	1.825149313	1.062486887	2.154171523
39100			0.16632493		0.16632493
39200	0.844386724	0.048954681	0.10387313	0.347867787	0.33627058
39300	1.163173616	25.59137977	18.95876297	0.078701602	11.44800449
Mean	5.14175292	13.531661	5.338986427	5.794051262	6.906409849

A2 Table 5:Utilization distributions (in km²) of Kinbasket burbots at 90% probability and per seasons.

Acoustic Code	Area of Utilization Distribution at 90% probability per Season (in Km²)				
	Fall	Spawning	Spring	Summer	Mean
29500	0.101259941	0.295797011	0.12493652	0.114310664	0.159076034
29600	56.48838047	159.3202467	0.074365203	0.041167029	53.98103986
29800	12.80297252	172.5827861	39.21117446	6.270702575	57.71690892
29900	4.622082365	0.204766419	1.519718077	2.83169389	2.294565188
30100	0.059666106	0.970794586	1.480174401	0.138105736	0.662185207
30200	1.595175243		0.015312993	0.090635365	0.5670412
30300	3.02063991		2.393575822	3.608284011	3.007499914
30400			1.041982819		1.041982819
30500	2.163242383	2.856696668	0.001648906	0.185342801	1.301732689
30600	0.332612747		0.075237727	0.116563603	0.174804692
30700			3.487187268		3.487187268
30900	25.85474409	14.23472557	2.98878143		14.35941703
31000			0.000273214		0.000273214
31100	2.194387713	1.883120822	1.68359E-05	1.981634507	1.514789969
31200	5.338748648		5.230348144	70.28924738	26.95278139
31300	3.696671225	0.3289441	0.447374791	0.381640584	1.213657675
31400	1.388013438	2.503036016	1.93032E-05		1.297022919
31600			2.30056E-05		2.30056E-05
31700			80.38238419	0.108057782	40.24522099
32500	0.045955976	0.120304456	0.109220993	0.10678409	0.095566379
32600	0.465234516	1.883120822	11.77877989	0.065302707	3.548109485
33000	10.85256362		30.30200778	3.90940691	15.0213261
33100			5.95315E-05		5.95315E-05
33200	0.21421156	0.760116582	0.000103075	0.0377876	0.253054704
33300	2.168349623	1.39168183	0.223024887	1.773527855	1.389146049
33400	1.047933905	4.096401697	0.098984096	2.553273909	1.949148402
33500	1.117420941	13.48460498	3.389880657	79.87131374	24.46580508
34000	0.002483474	0.12453967	0.000255176		0.042426107
34100			0.481155559	0.126355867	0.303755713
34200	0.801326331		1.235762279	0.157208024	0.731432211
34300	0.030870293	0.03202401	23.91822915	38.57322749	15.63858774
34400	0.415507302		0.002110097	0.001446095	0.139687831
34600	25.82424302	128.1735549	146.1166944	18.48468939	79.64979542
34700	1.874189318	0.119673004	0.000857297	0.071857369	0.516644247
35000	125.5038867	64.16297775	18.30569544	16.22829365	56.05021338
35200	3.640401146	2.187638996	5.008424493	0.893783746	2.932562095
35300	6.082174029	0.30196958	3.207675715	0.625213044	2.554258092
35400	0.378456259		0.199719875	2.050955259	0.876377131
35800	0.520336334	0.830701439	0.083553401	0.124809691	0.389850216
35900			0.000257556		0.000257556
36000			0.000169653		0.000169653
36100			12.57028695		12.57028695
36200	6.669303665	9.498085995	3.854363469	3.496418434	5.879542891
36300	0.079178237	0.993825724	0.039185071	0.121680158	0.308467298
36400			0.474425546		0.474425546
36500	0.25158836	2.251900155	0.105628449	0.097346581	0.676615886
36600	1.581833736	4.429747689	0.056310665	0.085057684	1.538237444
36700			0.154420219	9.322021253	4.738220736
36800			2.958986057		2.958986057
36900			6.653369368	42.72326338	24.68831637
37300				0.000128731	0.000128731
37800			0.665201038		0.665201038
37900			0.04950579		0.04950579
38100			0.021942108	0.03095556	0.026448834
38300	31.58230341	7.784979145		113.7646446	51.04397571
38700			0.221950852		0.221950852
38900			1.155702785	0.068973458	0.612338122
39000	1.960389611	9.641362385	2.814548539	2.358701888	4.193750606
39100			0.274657997		0.274657997
39200	1.163254724	0.081923604	0.174164161	0.477477425	0.474204979
39300	1.591585062	38.55659128	31.5141545	0.131608047	17.94848472

Mean	8.638089448	20.19026999	7.57111796	9.647520444	10.64456615

A2 Table 6: Utilization distributions (in km²) of Kinbasket burbots at 95% probability (i.e. Home Range) and per seasons.

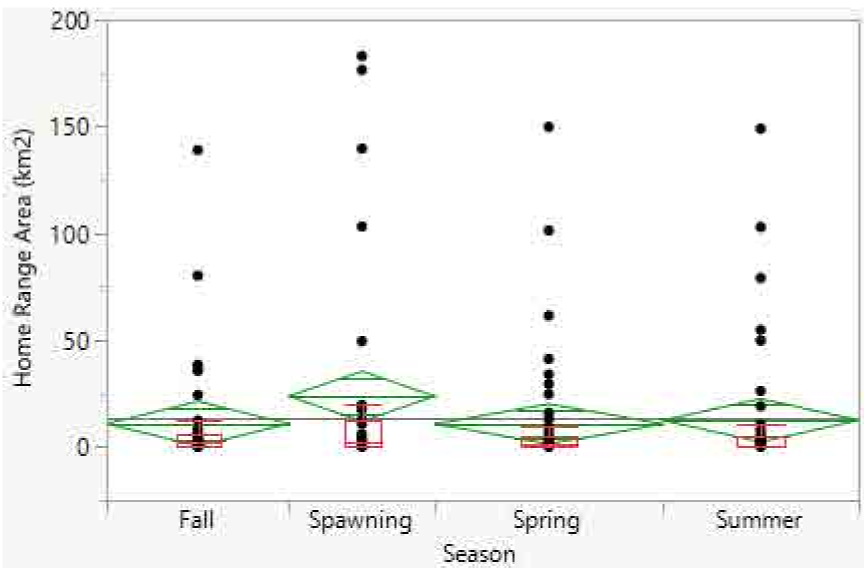
Acoustic Code	Area of Utilization Distribution at 95% probability (Home Range) per Season (in Km²)				
	Fall	Spawning	Spring	Summer	Mean
29500	0.12796712	0.367607636	0.165071856	0.153912615	0.203639807
29600	80.10289278	176.5071972	0.097268338	0.053747815	64.19027653
29800	24.43370678	183.0056094	61.61308208	7.665860284	69.17956464
29900	5.533709325	0.259957181	2.014587352	3.386796656	2.798762629
30100	0.076694103	1.126677667	1.730528921	0.17190737	0.776452015
30200	1.984728364		0.01686177	0.314058975	0.771883037
30300	3.528131726		2.988977165	4.242895591	3.586668161
30400			1.47193947		1.47193947
30500	2.662185837	3.374179639	0.002110989	0.227521294	1.56649944
30600	0.429342072		0.098207124	0.149927617	0.225825604
30700			4.572322786		4.572322786
30900	36.97259726	17.60828656	4.619010367		19.73329806
31000			0.000355115		0.000355115
31100	3.001980738	2.361956329	2.72867E-05	2.388917932	1.938220571
31200	6.804599062		6.446304935	78.96619709	30.7390337
31300	4.348902158	0.438169109	0.636176343	0.54578648	1.492258522
31400	1.829814795	3.233429474	2.11363E-05		1.687755135
31600			2.99828E-05		2.99828E-05
31700			101.2819478	0.149406278	50.71567705
32500	0.058739574	0.149406305	0.139142745	0.136909806	0.121049608
32600	0.554202641	2.361956329	13.11504435	0.087685781	4.029722276
33000	12.43282336		33.99685312	5.212255994	17.21397749
33100			7.24699E-05		7.24699E-05
33200	0.34007124	1.039222923	0.000135021	0.046622686	0.356512967
33300	2.891963209	1.770458572	0.291386292	2.638675857	1.898120982
33400	1.651172244	4.787461132	0.149750688	2.924501513	2.378221394
33500	1.32923495	19.76929281	3.973147957	102.8050923	31.969192
34000	0.003245872	0.172143498	0.000310848		0.058566739
34100			0.584978644	0.167475898	0.376227271
34200	0.927390895		1.451933768	0.201657883	0.860327515
34300	0.040823314	0.04168821	29.45710397	49.88038031	19.85499895
34400	0.517005482		0.002739886	0.001881811	0.173875726
34600	35.7491606	139.6572669	149.8147069	26.23964521	87.8651949
34700	2.526326013	0.36034564	0.001096789	0.095702798	0.74586781
35000	138.9142995	103.1098752	24.7949628	19.16131332	71.49511273
35200	4.918266121	2.673897184	6.433373967	1.053141736	3.769669752
35300	8.193305183	0.40617274	3.769841026	0.899161093	3.31712001
35400	0.418074639		0.254517689	2.557023774	1.0765387
35800	0.601759046	0.965404103	0.113027689	0.158404579	0.459648854
35900			0.000324542		0.000324542
36000			0.000202189		0.000202189
36100			16.04812997		16.04812997
36200	5.45696145	11.12565618	3.874495126	4.590768495	6.261970312
36300	0.100694415	1.142091513	0.052684346	0.155346934	0.362704302
36400			0.644599425		0.644599425
36500	0.301066954	3.107494081	0.135585568	0.123972816	0.917029855
36600	2.028953395	6.034037224	0.073171246	0.109804471	2.061491584
36700			0.195191912	10.61360787	5.404399891
36800			3.9196057		3.9196057
36900			9.405532601	54.90309846	32.15431553
37300				0.000161049	0.000161049
37800			0.946993987		0.946993987
37900			0.056098066		0.056098066
38100			0.029271059	0.039238524	0.034254791
38300	38.62764521	10.73760112		148.9702077	66.111818
38700			0.279627779		0.279627779
38900			1.226820556	0.093864976	0.660342766
39000	2.650066344	12.61590506	3.387127462	3.395161731	5.512065148
39100			0.363736988		0.363736988

39200	1.647330208	0.107604127	0.224783473	0.553245365	0.633240793
39300	1.918711076	49.59578781	41.29405428	0.170911342	23.24486613
Mean	10.91591363	23.75043246	9.122999894	12.19099677	12.97892135

A2 Table 7 summarizes the mean 50, 75, 90, and 95% kernel home ranges. There were no significant differences among home range sizes (95% UD) and season (n = 165; A2 Figure 12), however, a number of outliers (n=13) were observed of individuals with large home ranges.

A2 Table 7: Summary of Utilization Distributions (km^2) for 50, 75, 90, and 95% kernel estimate probabilities for each season.

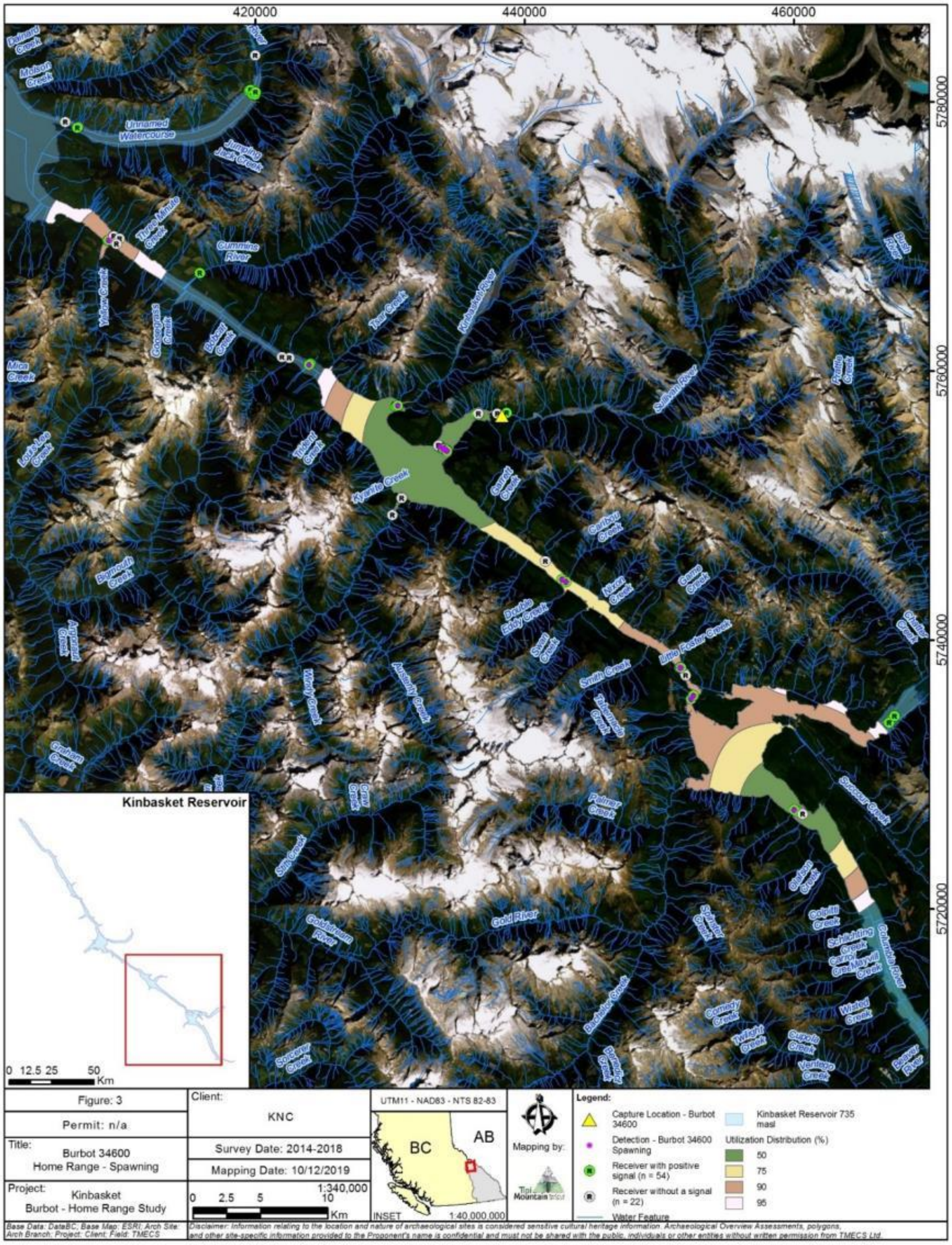
Kernel Estimate Probability (%)	Utilization Distribution Season (km^2)			
	Fall	Spawning	Spring	Summer
50	2.91	8.16	4.01	2.84
75	5.14	13.53	6.30	5.93
90	8.64	20.19	8.93	9.87
95	10.92	23.75	10.77	12.47
n	40	32	50	4



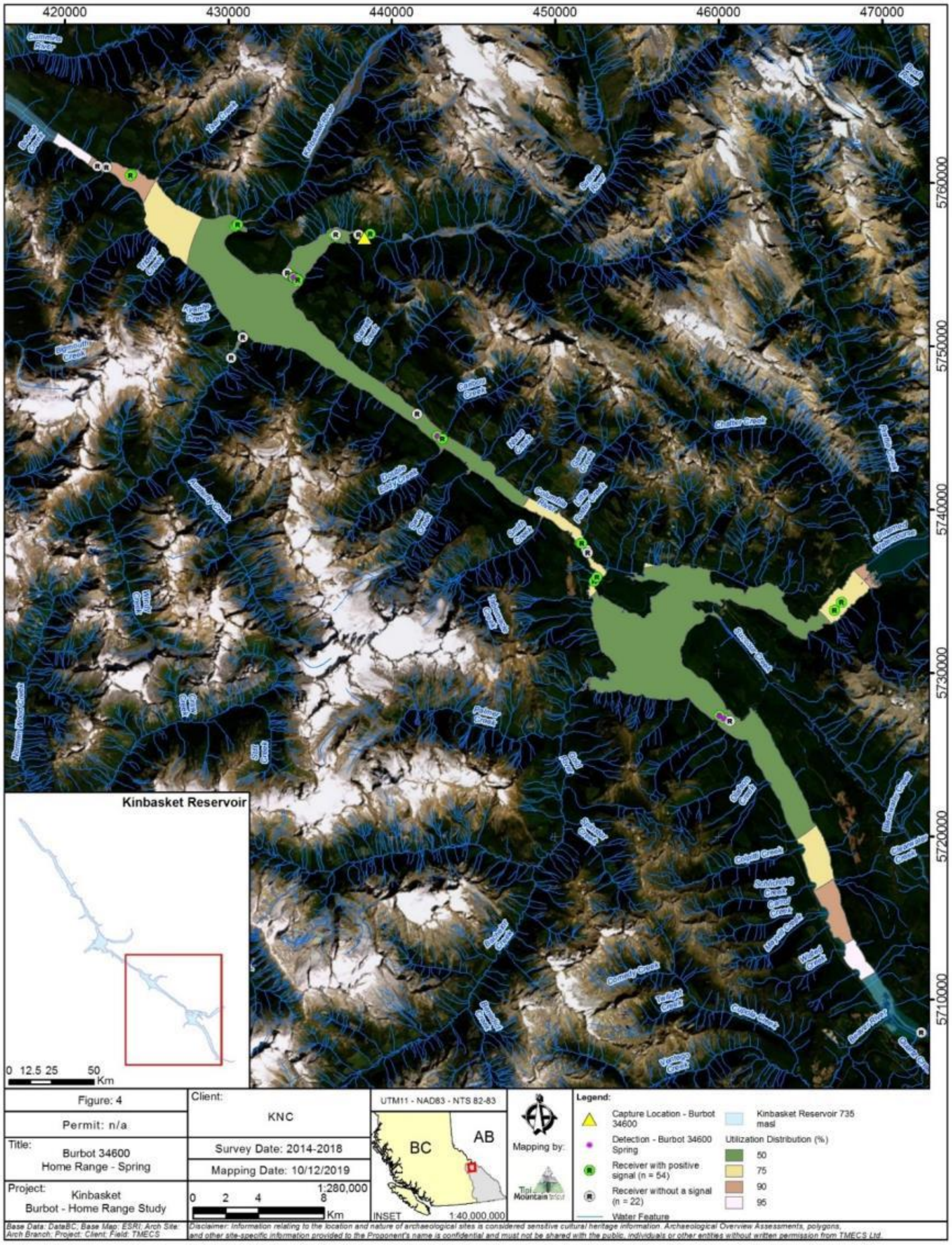
A2 Figure 12: Mean home range area (utilization distribution at 95% probability; km^2) for each season. Boxes represent interquartile range with the middle line representing the median sample value. Green diamonds represent the 95% confidence interval with the middle line representing the mean. Whiskers represent observations outside of the interquartile range, with outlier data points. Data from June 2014 to January 2018.

Maps of the seasonal home ranges of all Burbot for which UDs could be calculated can be found in Supplementary Information[1]. Here, we highlight the life strategies of tagged Kinbasket Burbot for illustrative purposes: the energetic and mobile Burbot with Acoustic Code 34600 (A2 Figures 13-16) and the sedentary Burbot with Acoustic Code 32500 that exhibited high site fidelity to the Wood Arm (A2 Figures 17-20).

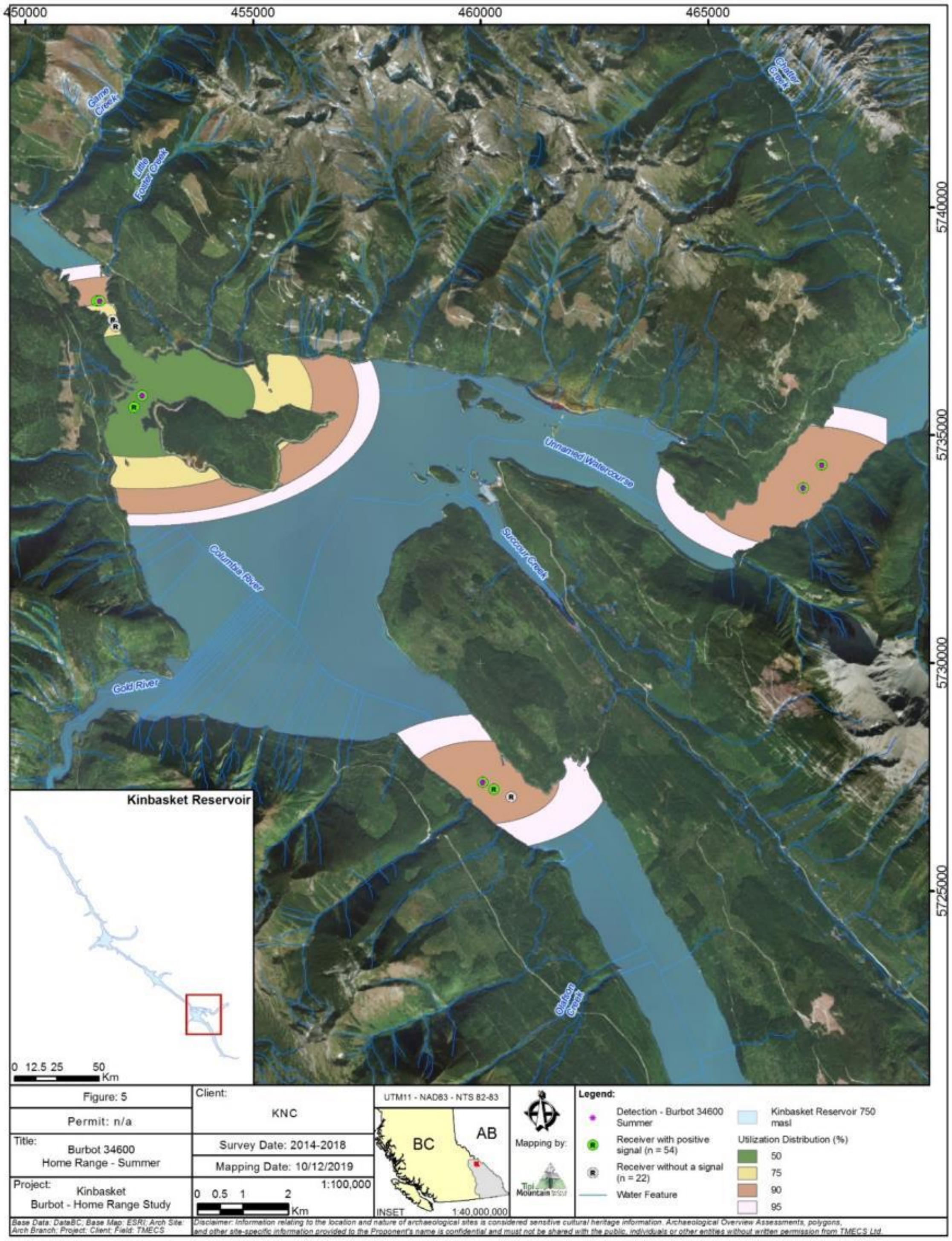
[1] Supplementary information can be obtained by contacting BC Hydro Water Licence Requirements at WaterLicenceRequirements@bchydro.com



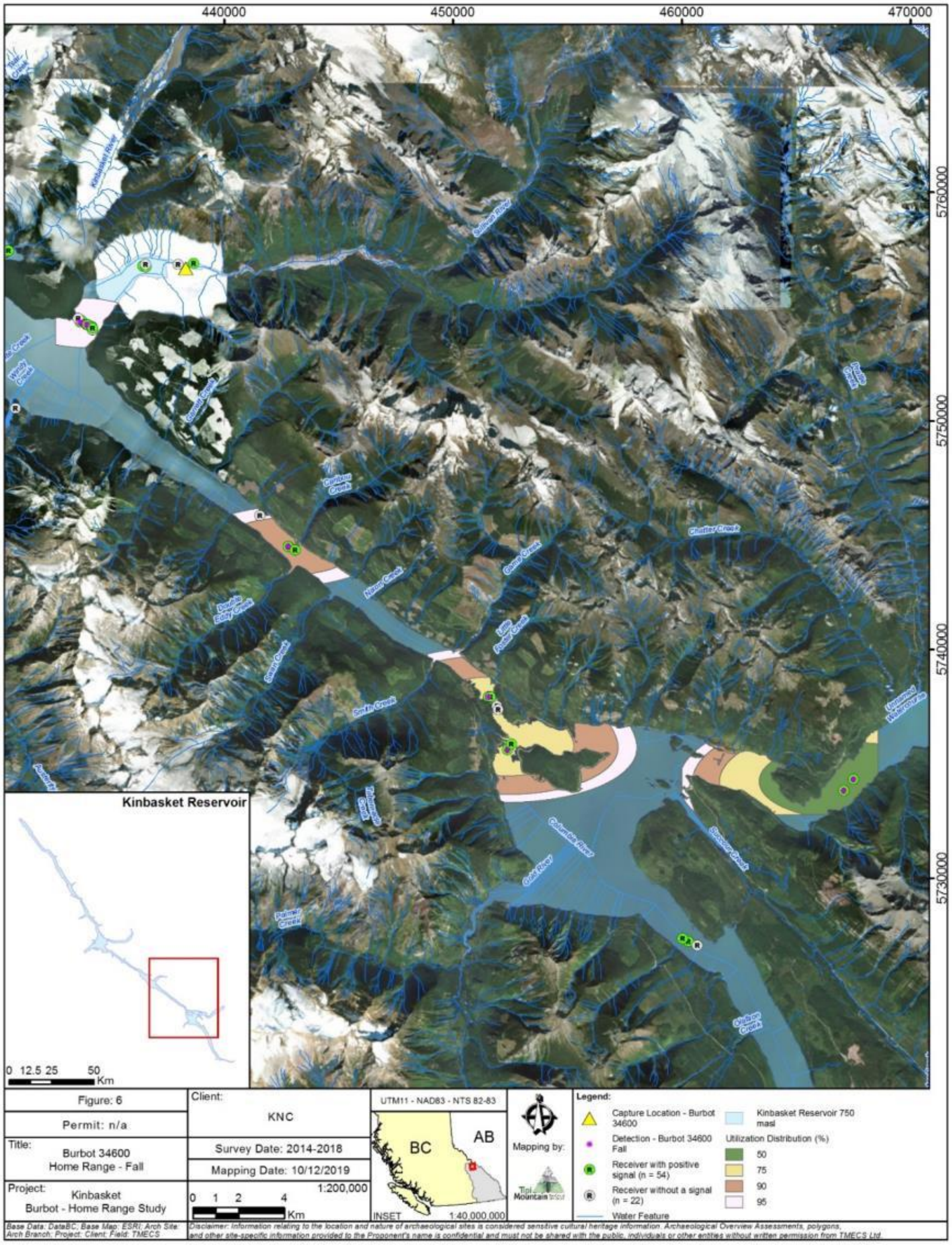
A2 Figure 13: Utilization distribution (UD) of Burbot with tag Acoustic Code 34600 during the suspected spawning season.



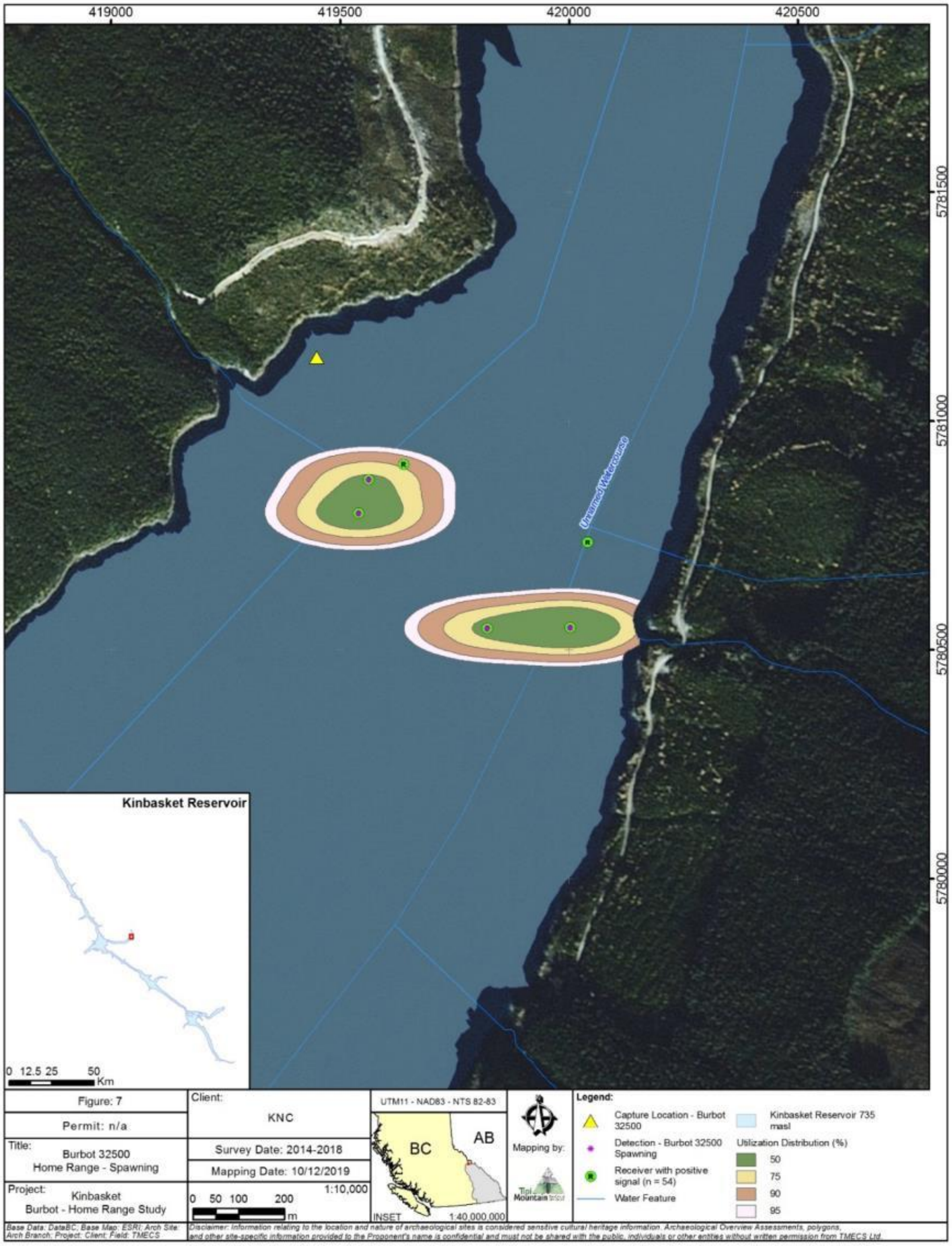
A2 Figure 14: Utilization distribution (UD) of Burbot with tag Acoustic Code 34600 during spring.



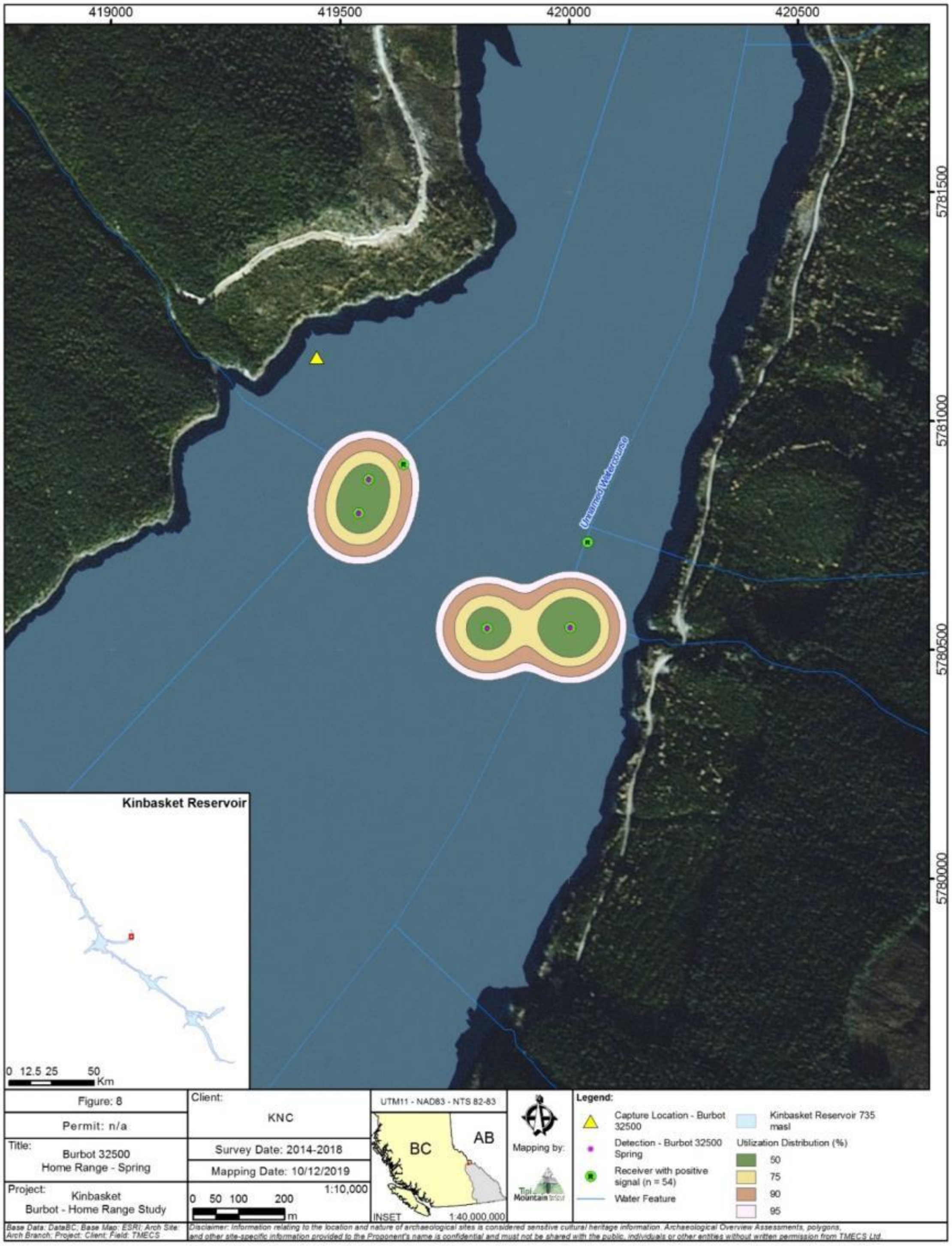
A2 Figure 15: Utilization distribution (UD) of Burbot with tag Acoustic Code 34600 during summer.



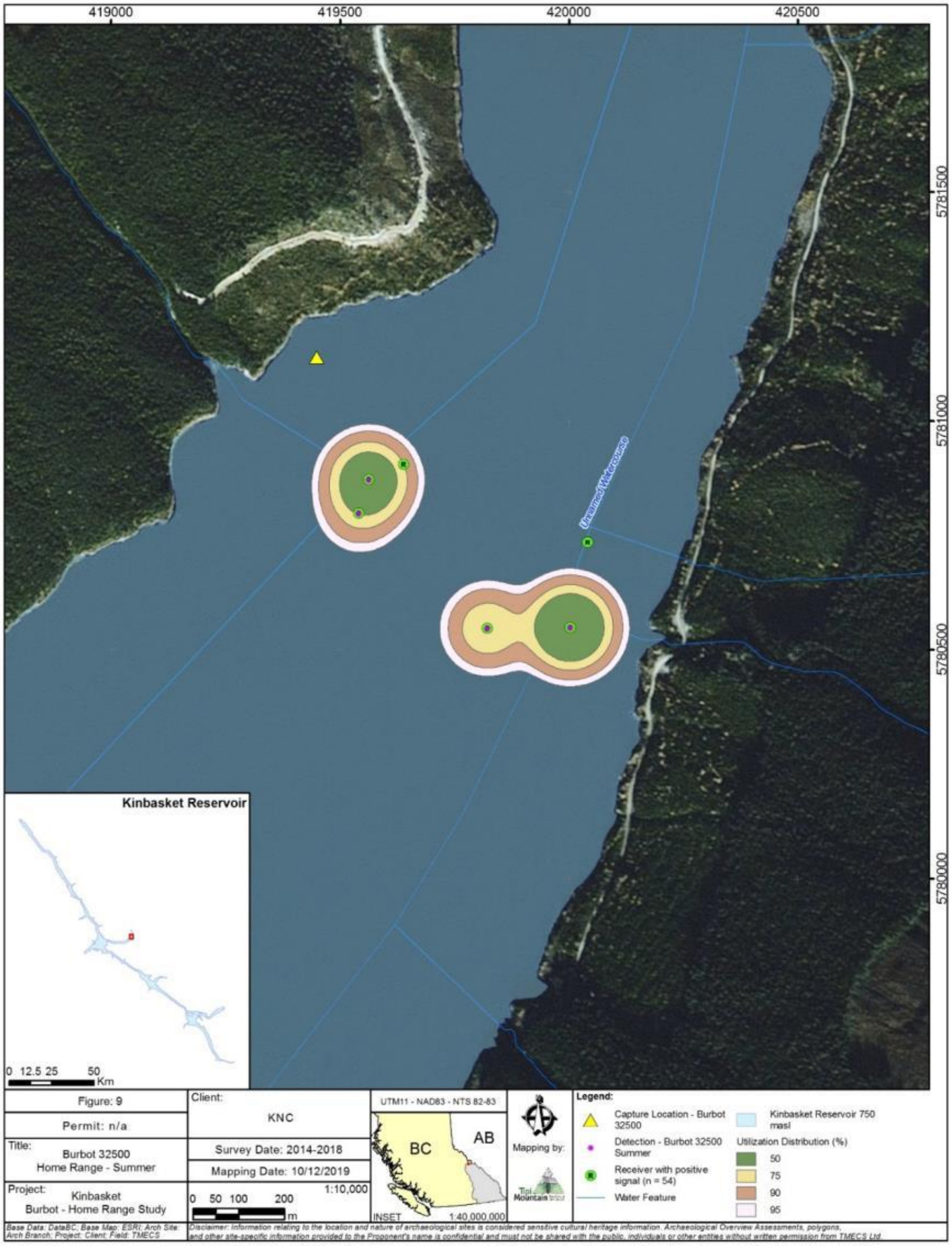
A2 Figure 16: Utilization distribution (UD) of Burbot with tag Acoustic Code 34600 during fall.



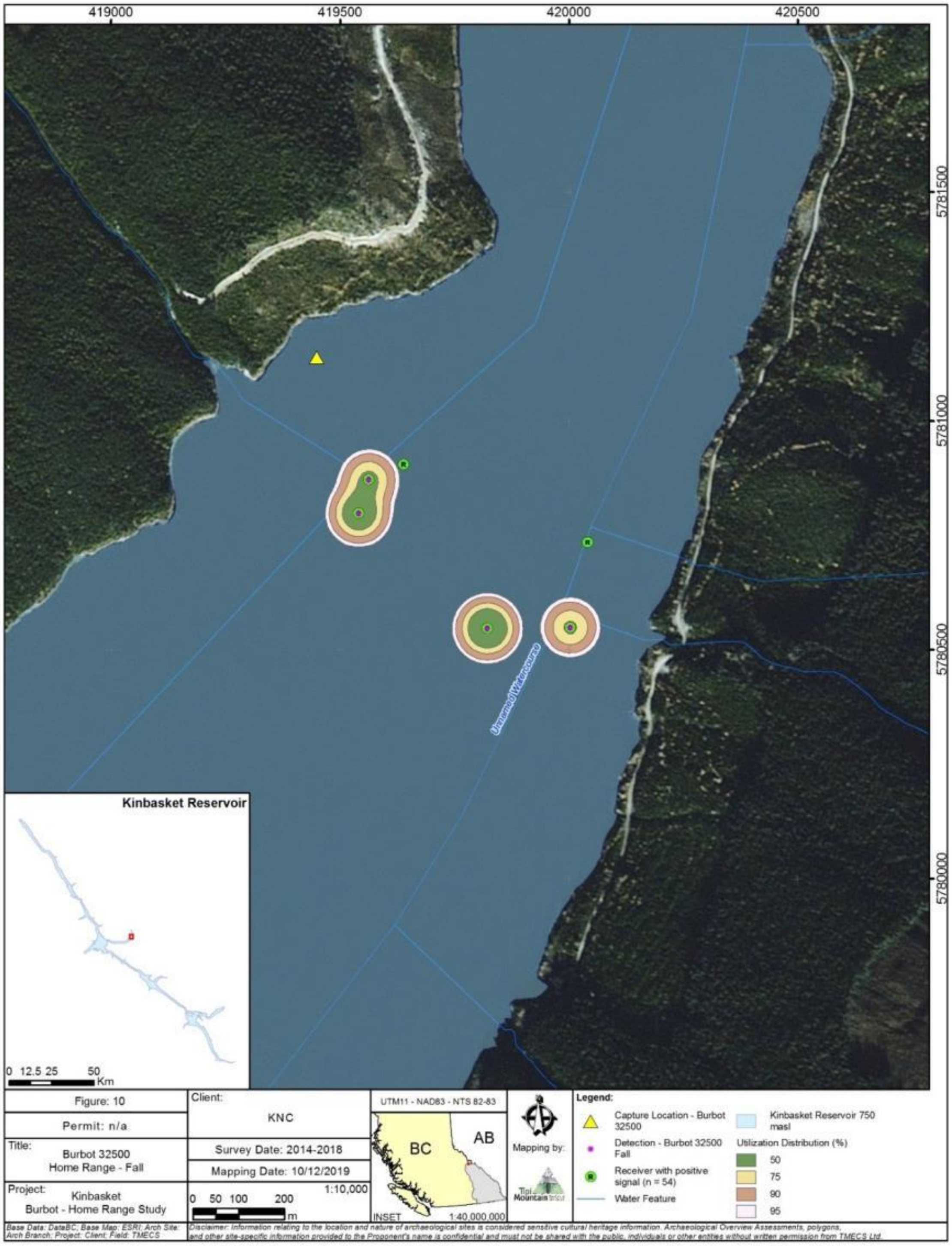
A2 Figure 17: Utilization distribution (UD) of Burbot with tag Acoustic Code 32500 during the Suspected Spawning season.



A2 Figure 18: Utilization distribution (UD) of Burbot with tag Acoustic Code 32500 during spring.



A2 Figure 19: Utilization distribution (UD) of Burbot with tag Acoustic Code 32500 during summer.



A2 Figure 20: Utilization distribution (UD) of Burbot with tag Acoustic Code 32500 during fall.

Burbot Mortality

Fifteen Burbot were either suspected (n=13) or confirmed dead (n=2) by the end of the 5 years of study (A2 Table 3). Data indicated that 13 Burbot have either died or expelled their tags based on repeated patterns of detection at the same depth over a number of days (A2 Table 3; Burbot with Acoustic Codes, 29700, 30000, 31800, 32900, 35500, 37000, 37200, 37500, 37600, 38200, and 38500). The Burbot with acoustic tag 32800 was found by a trapper who found the tag on a rock ledge 1m above the water level on Aug. 23, 2015. Teeth marks (possibly from an otter) on the broken tag indicated that the Burbot had died from predation. The Burbot with acoustic tag 30800 died from harvesting on Jul. 30, 2014 by a fisherman who returned the tag.

A2 Table 3: Summary of suspected or confirmed mortality of tagged Burbot in Kinbasket Reservoir.

Acoustic Code	Tag Year	Location tagged	Date mortality determined	Location of mortality	UTM E	UTM N	Cause of mortality	Method used to determine mortality	Mortality Confirmed?
29700	2014	Wood Arm	5-Jun-14	Wood Arm	419541	5780798	Unknown	Depth data	No
30000	2014	Surprise Rapids	25-Jul-15	Surprise Rapids	451616	5737839	Unknown	Depth data	No
30800	2014	Kinbasket River confluence	30-Jul-14	Kinbasket River confluence	436934	5756668	Angler harvest	Angler return of tag	Yes
31500	2014	Sullivan River confluence	22-Mar-15	Mica Dam tailrace	390817	5767174	Entrainment	Sensor data from aerial tracking	No
31800	2014	Columbia Reach	13-Jun-15	Kinbasket Lake inlet	443248	5743798	Unknown	Depth data	No
32400	2014	Columbia Reach south	18-Apr-15	Columbia Reach south; surprise rapids	453133	5735739	Unknown	Sensor data from aerial tracking	No
32800	2015	Kinbasket River confluence	23-Aug-15	Kinbasket River confluence	431480	5757714	Predator	Tag found with teeth marks	Yes
32900	2015	Wood River confluence	15-May-15	Wood River confluence	420315	5782027	Unknown	Depth data	No
35500	2015	Sullivan River confluence	04-May-16	Sullivan River	436576	5756745	Unknown	Depth data	No
37000	2015	Surprise Rapids	25-Jul-15	Surprise Rapids	451724	5737999	Unknown	Depth data	No
37200	2015	Surprise Rapids	25-Jul-15	Surprise Rapids	449108	5739467	Unknown	Depth data	No
37500	2015	Sullivan River confluence	18-May-15	Kinbasket Lake inlet	437063	5756831	Unknown	Depth data	No
37600	2015	Surprise Rapids	25-Jul-15	Surprise Rapids	452559	5735868	Unknown	Depth data	No
38200	2015	Sullivan River confluence	04-May-16	Sullivan River	436576	5756745	Unknown	Depth data	No
38500	2015	Sullivan River confluence	23-Jul-15	Sullivan River	438673	5756887	Unknown	Depth data	No

9.6 *Discussion*

- See Section 5.0.