



## Keeyask Generation Project Aquatic Effects Monitoring Plan

# Lake Whitefish Movement Monitoring Report

AEMP-2019-03



# **KEEYASK GENERATION PROJECT**

## **AQUATIC EFFECTS MONITORING PLAN**

REPORT #AEMP-2019-03

### **LAKE WHITEFISH MOVEMENT MONITORING IN THE NELSON RIVER BETWEEN CLARK LAKE AND THE LIMESTONE GENERATING STATION, OCTOBER 2017 TO OCTOBER 2018: YEAR 5 CONSTRUCTION**

Prepared for

Manitoba Hydro

By

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June 2019



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# SUMMARY

## Background

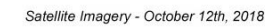
The Keeyask Hydropower Limited Partnership (KHLP) was required to prepare a plan to monitor the effects of construction and operation of the Keeyask Generating Station (GS) on the environment. Besides measuring the accuracy of the predictions made and actual effects of the GS on the environment, monitoring results will provide information on how construction and operation of the GS will affect the environment and if more needs to be done to reduce harmful effects.

Construction of the Keeyask GS began in mid-July 2014 with the construction of cofferdams that blocked flow in the north and central channels of Gull Rapids (see map). During the winter of 2015/2016, the Spillway Cofferdam, which partially blocks the south channel, was constructed. Beginning late in 2016 and continuing in 2017, the Tailrace Cofferdam was constructed. Work was completed in fall 2017 with the exception of an opening that was left to allow fish movement into and out of the cofferdam over the 2017/18 winter. This opening was closed in spring 2018, and the area was dewatered. The spillway was commissioned in August 2018. The South Dam Cofferdam was completed in fall 2018, blocking the channel and forcing the entire flow of the river through the spillway.

The movements of Lake Whitefish over Birthday Rapids and Gull Rapids were monitored prior to construction, but because different methods are being used to collect data under the Aquatic Effects Monitoring Plan (AEMP), the results of the two programs can't be compared. Pre-construction movement studies demonstrated that Lake Whitefish were able to move upstream and downstream over both Gull Rapids and Birthday Rapids. Lake Whitefish also congregated in the area below Gull Rapids during the fall spawning season.

This report presents results of Lake Whitefish movement monitoring from October 2017 to October 2018 and provides a summary of data collected since the monitoring program was initiated in the fall of 2014. Monitoring fish movements is an important component of the overall plan to monitor the impacts of construction and operation of the Keeyask GS on fish. Lake Whitefish were identified as one of the key species to monitor because they are: of commercial and domestic importance; known to pass through Gull Rapids in either direction; and resilient enough to survive the acoustic tagging procedure.





**Why is the study being done?**

Monitoring during construction is being done to answer two questions:

*Are there Lake Whitefish close to the construction site, particularly during spawning?*

If Lake Whitefish are in the river close to the construction area, they could be harmed by high amounts of mud in the water.

*How many Lake Whitefish are moving through and/or away from Gull Rapids during construction and how far are they going?*

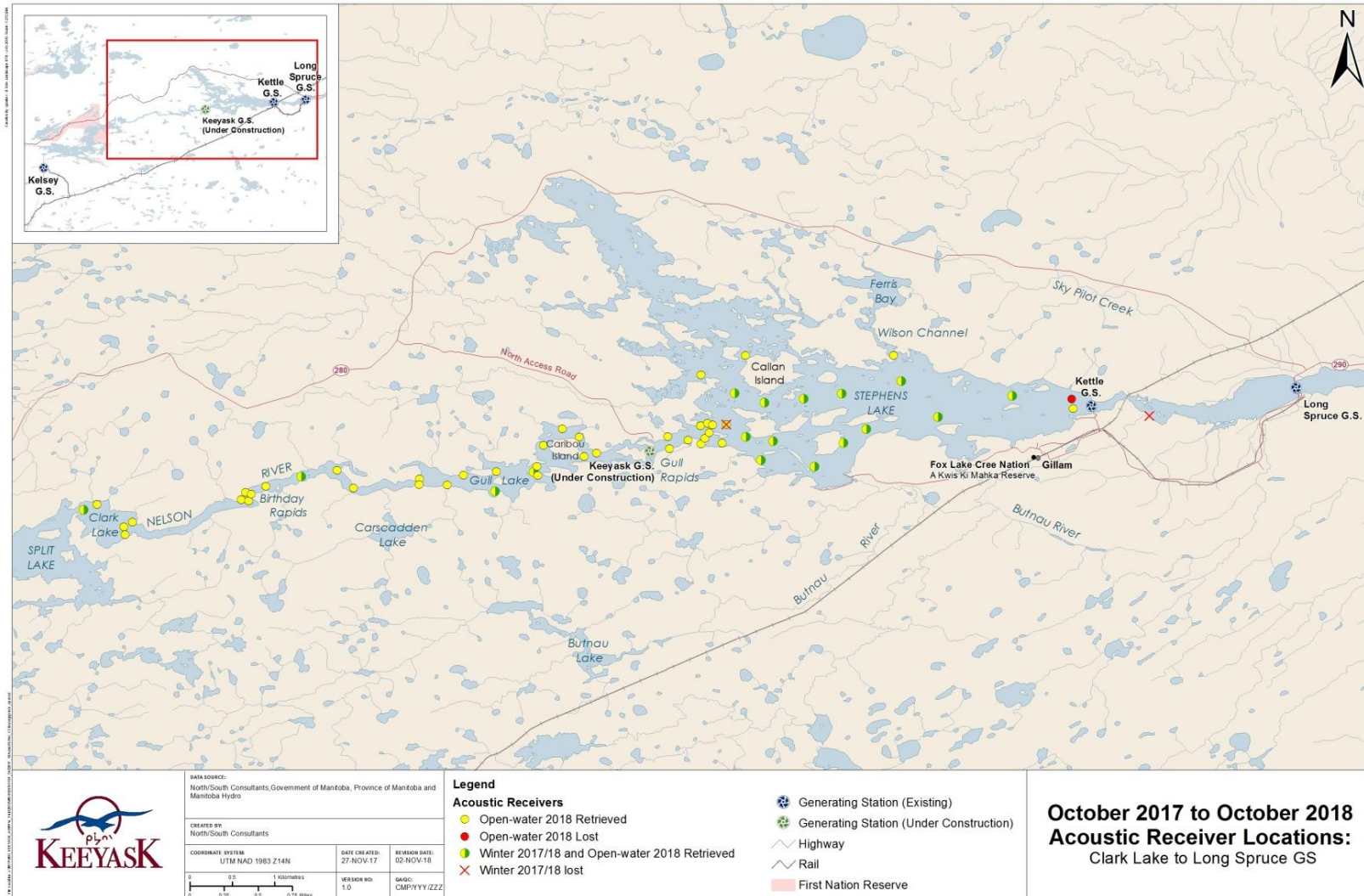
Movement studies tell us how many whitefish are moving up or down through Gull Rapids, how far they travel up or downstream away from the site, whether they are leaving the Keeyask area completely and when they are making these movements. The distance they travel is monitored as far upstream as the inlet to Clark Lake and downstream as far as the Limestone reservoir.

**What was done?**

Movements of Lake Whitefish were tracked using acoustic telemetry. This is a technique in which a tag (transmitter) is surgically implanted inside a fish. Each tag sends out a sound signal (called a “ping”) that is picked up by receivers that were placed along the Nelson River between Clark Lake and the Limestone Generating Station (see the study area map below). Each fish is given a transmitter that sends out a unique ping, and pings can be detected up to 1 kilometre (km) away from a receiver. By looking at the detections recorded by different receivers, the movement of each fish can be tracked.

Sixty Lake Whitefish were tagged in 2014, 20 upstream and 40 downstream of Gull Rapids. Because the batteries in these transmitters expired in winter 2017, 62 additional transmitters were implanted into Lake Whitefish in October 2017. This will extend the tracking of Lake Whitefish movements until summer 2022.





**Map showing the study area. The dots represent the locations of receivers in the river. The different colours represent receivers that were in the river at different times of the year.**

**What was found?**

Results from four years of tracking the movements of Lake Whitefish suggest that movement through Gull Rapids is rare. Of the 60 whitefish tagged in 2014 and tracked until the end of the 2017 open-water period, only two moved downstream. Of the 62 whitefish tagged in 2017, only three moved downstream, one of which may be related to tagging stress. No tagged whitefish have moved upstream through Gull Rapids since the start of the study.

Upstream of Gull Rapids, fish spent a large part of their time in the upper section of Gull Lake during the open-water period and do not appear to be using habitat directly upstream of the construction site. In the fall, some of the detected fish made upstream movements out of Gull Lake to the base of Birthday Rapids. These upstream movements are believed to be for spawning. Unlike in previous years, whitefish did not move upstream of Birthday Rapids in 2018.

In Stephens Lake, Lake Whitefish were more evenly spread throughout the lake. Many tagged whitefish were located closer to the base of Gull Rapids in the fall, presumably to spawn. Based on detections in the north part of Stephens Lake, it is suspected that some fish spend most of their time in the North Arm of Stephens Lake, and some of these fish move to Gull Rapids in the fall to spawn. During 2018, Lake Whitefish were detected at the mouth of Ferris Bay before the spawning period for the first time since monitoring began.

**What does it mean?**

Lake Whitefish are using habitat immediately downstream of the construction site at Gull Rapids. Movements through Gull Rapids have been rare as only five tagged fish have moved downstream through Gull Rapids during the four-year study. Some of these movements may be related to tagging stress or mortality. Similarly, no Lake Whitefish have moved downstream through the Kettle GS since the study began.

**What will be done next?**

The additional Lake Whitefish tagged in October 2017 will allow movement data to be collected until summer 2022. Ongoing tracking of fish during construction will provide additional information about where the fish are moving, what kinds of habitats these fish need to use over several years, when they are spawning, and where they are feeding. Tracking will also show where fish are relative to instream construction and if there is the potential that they could be at risk as a result of various construction activities.



# ACKNOWLEDGEMENTS

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The collection of biological samples described in this report was authorized by Manitoba Conservation and Water Stewardship, Fisheries Branch, under terms of the Scientific Collection Permit #22-18.

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# 1.0 INTRODUCTION

The Keeyask Generation Project (the Project) is a 695-megawatt (MW) hydroelectric generating station at Gull (Keeyask) Rapids on the lower Nelson River in northern Manitoba. The Project is approximately 725 kilometres (km) northeast of Winnipeg, 35 km upstream of the existing Kettle Generating Station, where Gull Lake flows into Stephens Lake, 60 km east of the community of Split Lake, 180 km east-northeast of Thompson and 30 km west of Gillam (Map 1). Construction of the Project began in July 2014.

The *Keeyask Generation Project: Response to EIS Guidelines*, completed in June 2012, provides a summary of predicted effects and planned mitigation for the Project. Technical supporting information for the aquatic environment, including a description of the environmental setting, effects and mitigation, and a summary of proposed monitoring and follow-up programs, is provided in the *Keeyask Generation Project Environmental Impact Statement: Aquatic Environment Supporting Volume* (AE SV). As part of the licensing process for the Project, an Aquatic Effects Monitoring Plan (AEMP) was developed detailing the monitoring activities of various components of the aquatic environment including the focus of this report, Lake Whitefish (*Coregonus clupeaformis*) movements, for the construction and operation phases of the Project.

Pre-construction (baseline) movements of Lake Whitefish were monitored from 2001 to 2005 (Barth *et al.* 2003; Murray *et al.* 2005; Murray and Barth 2007). Radio and acoustic telemetry studies focused specifically on detecting the upstream and downstream movements of fish over rapids in the study area (Birthday Rapids and Gull Rapids). Pre-construction movement data revealed that a proportion (28%) of Lake Whitefish did make movements both upstream and downstream over Gull or Birthday rapids. The pre-construction movement data also recorded Lake Whitefish congregating in the area below Gull Rapids during the fall, presumably for spawning. As pre-Project studies were not designed to record detailed movement patterns of Lake Whitefish in the Clark Lake to Stephens Lake reach as a whole, results are not directly comparable to the movement data being collected under the AEMP.

In fall 2014, 60 adult Lake Whitefish were implanted with acoustic transmitters to assess the frequency of movement through Gull Rapids and to monitor the potential impact construction of the Keeyask GS may have on Lake Whitefish. Annual reports detailing the 2014 to 2017 results are provided in Hrenchuk and Barth (2015), Lavergne and Hrenchuk (2016), Burnett and Hrenchuk (2017), and Lacho and Hrenchuk (2018). Results from October 17, 2017 to October 10, 2018 are presented in this report.

Lake Whitefish movements in the main flow of the Nelson River near the construction site may be affected by the installation of cofferdams that block upstream and downstream movements (Map 2), altered flow patterns, and disturbances such as blasting that may increase emigration from the construction area. Previous studies have shown that Lake Whitefish congregate in the area below Gull Rapids to spawn (Pisiak 2005a, b; Murray and Barth 2007). The broad objective of Lake Whitefish movement monitoring is to better understand their movements and habitat

use during generating station construction, with particular focus on movements in the vicinity of Gull Rapids.

The key questions (presented in the AEMP) related to Lake Whitefish movement monitoring during construction of the Keeyask GS are:

- What number (or proportion) of tagged Lake Whitefish move past the construction site?
- Are whitefish utilizing habitat in the vicinity of the construction site (particularly during spawning)?

## 2.0 STUDY SETTING

The study area encompasses an approximately 110 km long reach of the Nelson River from Clark Lake to the upstream end of the Limestone Reservoir (Map 1). This section of river offers a diversity of physical habitat conditions, including a variety of substrate types, and variable water depths (range 0–30 m) and velocities. Water velocities were classified as low (0.2–0.5 metres per second [m/s]), moderate (0.5–1.5 m/s), or high (greater than 1.5 m/s), as described in the Keeyask AE SV.

Clark Lake is located immediately downstream of Split Lake, and approximately 42 km upstream of Gull Rapids (Map 1). Current is restricted to the main section of the lake, with off-current bays outside the main channel. The Assean River is the only major tributary to Clark Lake, and flows into the north side. Downstream from the outlet of Clark Lake, the Nelson River narrows and water velocity increases for a 3 km stretch, known as Long Rapids. For the next 7 km, the river widens, and water velocity decreases.

Birthday Rapids is located approximately 10 km downstream of Clark Lake and 30 km upstream of Gull Rapids (Maps 1 and 3). The drop in elevation from the upstream to downstream side of Birthday Rapids is approximately 2 m. The 14 km reach of the Nelson River between Birthday Rapids and Gull Lake is characterized as a large and somewhat uniform channel with medium to high water velocities. There are a few large bays with reduced water velocity and a number of small tributaries that drain into the Nelson River.

Gull Lake is a section of the Nelson River where the river widens, with moderate to low water velocity. Gull Lake is herein defined as the reach of the Nelson River beginning approximately 17 km upstream of Gull Rapids and 14 km downstream of Birthday Rapids, where the river widens to the north into a bay around a large point of land (Maps 1 and 3), and extending to the downstream end of Caribou Island, approximately 3 km upstream of Gull Rapids. Gull Lake has three distinct basins, the first extending from the upstream end of the lake downstream approximately 6 km to a large island; the second extending from the large island to Morris Point (a constriction in the river immediately upstream of Caribou Island); and the third extending from Morris Point to the downstream end of Caribou Island (Map 3).

Gull Rapids is located approximately 3 km downstream of Caribou Island on the Nelson River (Map 1). The rapids are approximately 2 km in length, and the river elevation drops approximately 11 m along its 2 km length. Two large islands and several small islands occur within the rapids, prior to the river narrowing; these features are within the Project footprint and have been substantially altered during construction (Map 2). A summary of construction activities at Gull Rapids is provided in Section 2.1.

Just below Gull Rapids, the Nelson River enters Stephens Lake (Map 5). Stephens Lake was formed in 1971 by construction of the Kettle GS. Between Gull Rapids and Stephens Lake, there is an approximately 6 km long reach of the Nelson River that, although affected by water regulation at the Kettle GS, remains riverine habitat with moderate velocity. Construction has altered the flow distribution immediately downstream of Gull Rapids as all flow now passes via



the south channel of Gull Rapids. In August 2018, flow was further constricted when the spillway was commissioned (see Section 2.1).

Construction of the Kettle GS flooded Moose Nose Lake (north arm) and several other small lakes that previously drained into the Nelson River, as well as the old channels of the Nelson River that now lie within the southern portion of the lake (Map 4). Major tributaries of Stephens Lake include the North and South Moswakot rivers that enter the north arm of the lake. Looking Back Creek is a second order stream that drains into the north arm of Stephens Lake (Map 1). Kettle GS is located approximately 40 km downstream of Gull Rapids.

The Long Spruce reservoir was formed in 1979 by the construction of the Long Spruce GS. It is a 16 km reach of the Nelson River extending from Long Spruce GS upstream to Kettle GS (Manitoba Hydro Public Affairs 1999). Kettle River and Boots Creek are the only major tributaries flowing into Long Spruce reservoir, with both tributaries entering the reservoir on the south shore (Maps 1 and 6).

The Limestone Reservoir was formed in 1990 by the construction of the Limestone GS. It is a 23 km reach of the Nelson River extending from Limestone GS upstream to Long Spruce GS. Four tributaries of the Nelson River enter the reservoir; Wilson Creek and Brooks Creek enter from the south, and Sky Pilot Creek and Leslie Creek enter from the north. Aquatic habitat within the reservoir ranges from a riverine environment in the upper reach, to more lacustrine conditions just upstream of the Limestone GS.

## 2.1 CONSTRUCTION SUMMARY

Construction of the Keeyask GS began in mid-July 2014 with the construction of cofferdams in the north and central channels of Gull Rapids (Map 2). These cofferdams resulted in the dewatering of the north and central channels and the diversion of all flow to the south channel. Construction of the Spillway Cofferdam (SWCD), which extends into the south channel of Gull Rapids, was completed in 2015. The rock placement for the inner and outer groins of the Tailrace Cofferdam (TRCD) started in late 2016 and the impervious fill placement was completed in fall 2017. An opening was created to allow fish to move freely over the winter of 2017-2018. The opening was closed in spring 2018 and dewatering of the TRCD occurred in July, at which time a fish salvage was completed. In preparation for commissioning of the spillway, the SWCD was watered-up on both sides of the structure in June 2018. Removal of the SWCD started in early July and continued into August. The spillway was commissioned between August 3 and 7, 2018. Closing the south channel with the upstream South Dam Cofferdam (SDCD) commenced at the beginning of August and river closure was achieved on August 16. This closure and the work that continued to seal the cofferdam forced the entire river flow through the spillway. The downstream SDCD was completed in September and the area between the two cofferdams was dewatered, allowing for fish salvage to be completed by late September 2018. Work continued on the upstream SDCD until it was complete in late fall 2018.

## 2.2 FLOWS AND WATER LEVELS

From October 2017 to October 2018, Split Lake outflow ranged from about 2,800-4,000 m<sup>3</sup>/s. Flow typically fell in the range of about 3,000-3,500 m<sup>3</sup>/s, which is near the historical annual median flow of approximately 3,300 m<sup>3</sup>/s. Flow was generally higher during the 2017-2018 winter period, gradually declining from about 3,800 m<sup>3</sup>/s at the end of February 2018 to about 2,800 m<sup>3</sup>/s by the beginning of May. From early May 2018 to the beginning of July, flow gradually increased to about 3,500 m<sup>3</sup>/s and remained at that level to the end of July. The flow subsequently declined to about 2,800 m<sup>3</sup>/s by the end of September. Water levels varied in conjunction with the flows, ranging from about 153.4-155.2 m ASL on Gull Lake.

## 3.0 METHODS

### 3.1 ACOUSTIC TELEMETRY

Acoustic telemetry involves tracking movements of fish surgically implanted with internal acoustic transmitters (tags). Each transmitter emits a unique signal, recognizable by stationary receivers. When tagged fish come into range (generally within 500 m to 1 km, depending on conditions), the transmitter code number, as well as the date and time, are stored in the receiver. Initially, the receiver array was designed to monitor adult Lake Sturgeon (Hrenchuk and Lacho 2019a); however, the same array is also used to monitor juvenile Lake Sturgeon (Lacho and Hrenchuk 2019), Walleye (Hrenchuk and Lacho 2019b), and Lake Whitefish (the focus of this report).

#### 3.1.1 ACOUSTIC TRANSMITTER APPLICATION

Acoustic transmitters (Vemco V13-1x, estimated 1,141 day battery life) were applied to 60 fish in September and October, 2014; 20 upstream and 40 downstream of Gull Rapids (Tables 1 and 2). Tagged Lake Whitefish had fork lengths ranging from 372 to 565 mm. As the batteries in these tags were due to expire during winter 2017/2018, an additional 62 tags (V13-1x, estimated 1,737 day battery life) were applied to Lake Whitefish in October 2017; 22 upstream and 40 downstream of Gull Rapids (described in Lacho and Hrenchuk 2018). These were captured by both gillnetting and boat electroshocking. Upstream of Gull Rapids, 22 Lake Whitefish were tagged below Birthday Rapids at rkm -33.5 (Map 3). These fish had a mean fork length of 480 mm (standard deviation [StDev] = 29 mm; range: 432–533 mm) and a mean weight of 1,425 g (StDev = 531 g; range: 1,425–3,425). In Stephens Lake, 40 Lake Whitefish were tagged at rkm 0.4 (Map 3). These fish had a mean fork length of 482 mm (StDev = 38 mm; range: 406–540 mm) and a mean weight of 1,999 g (StDev = 469 g; range: 1,000–2,900 g).

#### 3.1.2 ACOUSTIC RECEIVERS

Since 2014, stationary acoustic receivers (VEMCO model VR2 and VR2W) were used to continuously monitor tagged Lake Whitefish between Clark Lake and the Keeyask GS construction site, Stephens Lake, and the Long Spruce reservoir. In spring 2016, the receiver array was extended to the upper Limestone reservoir. The intent of these receivers was to determine whether fish that had moved into the Long Spruce reservoir the preceding year had continued to move downstream.

During the open-water period, receivers were deployed in calm water with a flat bottom free of large debris to maximize detection range, and spaced along the main river channel throughout the study area to maximize spatial coverage. At constrictions within the river channel, a series of

receivers were deployed to create “gates” with the intent of recording all fish that passed by the river cross-section (described in Section 3.1.2.2).

The retrieval of receivers deployed during winter has proved challenging; several were lost in previous winters, likely because of ice (Hrenchuk and Barth 2013). Because it appears that receivers will only remain safe from ice if deployed at depths greater than 10 m, the number of possible receiver locations during winter, especially in Gull Lake, is limited.

### **3.1.2.1 WINTER 2017/2018**

The stationary acoustic receiver array for the winter 2017/2018 (October 17, 2017 to April 30, 2018) period consisted of 20 receivers. Four were set upstream of Gull Rapids, 15 throughout Stephens Lake, and one in the Long Spruce Reservoir (Maps 3, 4, and 5). A single receiver lost during winter 2016/2017 (rkm 23.5) was not reset during winter 2017/2018. Due to low water levels, the receiver in the Long Spruce Reservoir could not be retrieved at the end of the 2017/2018 winter period.

### **3.1.2.2 OPEN-WATER 2018**

An array of 56 receivers was used during the 2018 open-water period (defined as May 1 to October 10, 2018). Twenty-seven were set upstream of Gull Rapids and 29 were set in Stephens Lake (Maps 6 and 7).

The 2018 open-water array differed slightly from arrays used in previous years. One receiver (#108002) was set in a new location upstream of Gull Rapids, closer to construction, at rkm -4.8 (Map 6). In Stephens Lake, one receiver set during open-water 2017 (rkm 23.5) was not reset due to its proximity to an additional receiver (#114241 at rkm 24.7; Map 7).

Due to low water levels, receivers could not be set in the Long Spruce or Limestone reservoirs during the 2018 open-water period. Several attempts were made to access the sites throughout the open-water period; however, a boat could not be safely launched in either area. Receivers will be set in both locations during open-water 2019 provided conditions are suitable.

Receiver “gates” were established in several key areas selected based on river morphology (channel restrictions) and characteristics of habitat (areas with low velocity adjacent to the main flow of the river). Receiver “gates” consisted of two or more acoustic receivers set parallel to flow to provide complete (or nearly complete) signal coverage of a river cross-section. Areas between the “gates” were referred to as river zones. Receiver gates provide confidence that movements past key points are being detected, which allows for extrapolation of coarse-scale positions (*i.e.*, which zone) during periods when fish remain undetected. When analyzing data, fish detected within a zone that subsequently go undetected for a period of time without passing through a gate, are assumed to be within the zone they were last detected.

Four gates were established between Clark Lake and Gull Rapids (44.0, 34.0, 19.0, and 10.0 rkms upstream of Gull Rapids), and two were established in Stephens Lake (4.5 and 40.0 rkms

downstream of Gull Rapids) (Maps 6 and 7). The area upstream of Gull Rapids was divided into five zones (Map 6; Zones 1–5), while Stephens Lake was divided into two zones (Map 7; Zones 6 and 7). The Long Spruce Reservoir is referred to as Zone 8 and the Limestone Reservoir as Zone 9. The location of the “gates” has remained consistent since first set in 2013.

Water temperature within the Nelson River mainstem was recorded with a HOBO Water Temperature Pro data logger from October 17, 2017 to October 10, 2018. Lake Whitefish spawn during fall when water temperatures are between 6 and 9°C, often forming pre-spawning aggregations (Green and Derksen 1987; Scott and Crossman 1998; Stewart and Watkinson 2004). Thus, data collected when water temperature measured less than 12°C (when movements to spawning areas may be occurring) were considered as “spawning period”.

On October 10, 2018, the majority of receivers were removed and a subset ( $n = 19$ ) were redeployed to monitor movements during winter 2018/2019.

### 3.1.3 DATA ANALYSIS

False detections can arise on acoustic telemetry receivers due to code collisions and/or environmental noise (Pincock 2012). To filter out false detections, a fish was required to be detected at least two times within a 30-minute interval at a given stationary receiver. Single detections were filtered and not used in most analyses; however, in instances when fish went undetected for lengthy periods, and/or rapid movements were suspected, raw data were also explored. In no instance did examination of raw data suggest that consideration of a single detection would result in a different behaviour or movement pattern compared with the result when single detections were removed.

Movements were analysed in terms of rkm distance, with the base of Gull Rapids representing a distance of 0 rkm. The area located downstream of Gull Rapids (*i.e.*, Stephens Lake and the Long Spruce Reservoir) were given positive (+) distance values from Gull Rapids, while the area located upstream (*i.e.*, Gull and Clark lakes) were given negative (-) distance values (Figures 1 and 2). The average rkm distance from Gull Rapids was calculated over a 4-hour interval and plotted versus time for each fish. Total detection ranges were calculated by subtracting the furthest downstream detection location from the location of the furthest upstream detection. The proportion of time that all fish spent within each river zone was calculated and plotted.

## 4.0 RESULTS

Tagging and biological information for Lake Whitefish tagged in October 2017 upstream and downstream of Gull Rapids can be found in Tables 1 and 2. Table 3 summarizes the time fish spent in each river zone during the four years Lake Whitefish have been monitored, including fish tagged in both 2014 and 2017. Figures 1 and 2 show the receiver locations upstream and downstream of Gull Rapids during winter 2017/18 and the 2018 open-water period. Figure 3 provides water temperatures in the Nelson River mainstem between October 2017 and October 2018. Figures 4 to 16 provide movement range, and proportional distribution of tagged fish both upstream and downstream of the construction site by season. A detection summary by season and year, including the farthest upstream and downstream detection locations for each tagged whitefish, are presented in Appendix 1. Individual movement summaries for each Lake Whitefish tagged in 2017 are presented in Appendices 2 and 3.

### 4.1 WINTER 2017/2018

#### 4.1.1 UPSTREAM OF GULL RAPIDS

The winter receiver array consisted of four receivers deployed at rkms -48.2, -29.4, -12.4, and -10.3 (Figure 1). All four receivers were retrieved (Map 3). Twenty-one of the 22 (95%) available whitefish were located a total of 8,628 times (range: 3–5,914 detections per individual) (Figure 4; Appendix A1-1). Fish were detected on one to 16 days of the 196 day period. The majority of detections occurred downstream of Birthday Rapids (rkm -29.4) in October and November, 2017 (Figure 5). No detections were logged by any receiver after January 21, 2018.

A single fish (#31740) moved downstream through Gull Rapids into Stephens Lake (Appendix A2-16). After it was tagged at rkm -32.5 on October 11, 2017, it was detected at rkm -29.4 until October 24, then at rkm -10.3 in Gull Lake on October 27. It was detected in Stephens Lake on November 1 at rkm 5.2, then continued to move downstream until it was last detected at rkm 18.6 on November 7. Based on the lack of upstream movements, this fish likely represents a tagging mortality and is not discussed for the remainder of this report.

#### 4.1.2 STEPHENS LAKE

Fifteen receivers were deployed in Stephens Lake during the 2017/2018 winter period, between rkms 5.2 and 36.1 (Figure 1). Fourteen of the 15 acoustic receivers were retrieved; the receiver at rkm 5.8 could not be located and was likely moved by ice (Map 4).

Twenty-six of the 40 (60%) available Lake Whitefish were located a total of 114,472 times (range: 6–52,985 detections per individual) (Figure 6; Appendix A1-2). Fish were detected on one to 179 days of the 196 day winter period (1–91% of the time) for an average of 28 days, or



14% of the study period (StDev = 47.8 days). The farthest upstream detections occurred at rkm 5.2 (by 13 fish; 50%), while the farthest downstream occurred at rkm 36.1 (by two fish; 8%) (Figure 6; Appendix A1-2). The average, overall movement range was 9.2 rkm (range: 0.0–30.9 rkm).

The majority of detections ( $n = 64,499$ ; 56%) were logged in the southern portion of Stephens Lake at rkm 13.9 (Figure 7). Twenty-three fish moved into the northern portion of Stephens Lake and were detected at rkms 6.5 ( $n = 12,138$ ; 11%), 8.4 ( $n = 14,485$ ; 13%), 13.0 ( $n = 7,459$ ; 7%), and 16.8 ( $n = 2,472$ ; 2%) (Figure 7).

## **4.2 OPEN-WATER 2018**

### **4.2.1 ACOUSTIC RECEIVER RETRIEVAL**

All stationary acoustic receivers deployed upstream of Gull Rapids ( $n = 27$ ) during the 2018 open-water period were successfully retrieved (Map 6). For the first time in 2018, a receiver was successfully deployed and retrieved closer to Keeyask construction at rkm -4.8 (#108002; Map 6). One of the 29 receivers deployed in Stephens Lake (#102966) at rkm 40.8 went missing part way through the study period (Map 7). No data were retrieved from this receiver after July 26, 2018; therefore, the “gate” at the downstream end of Stephens Lake was no longer effective after this date. Due to low water levels, no receivers were set or retrieved in the Long Spruce or Limestone reservoirs.

### **4.2.2 UPSTREAM OF GULL RAPIDS**

All of the 21 available Lake Whitefish in Gull Lake were detected during the 2018 open-water period. Fish were detected 105–26,627 times for 7–121 days of the 163 day open-water period (4–74% of the time; Appendix A1-3). The average movement range was 14.6 rkm (StDev = 8.5 rkm; range: 0–29 rkm). The farthest upstream detections occurred just below Birthday Rapids at rkms -33.8 (by nine fish; 47%), while the farthest downstream detections (not including the two fish that moved through the rapids) occurred at the receiver closest to Gull Rapids at rkm -4.8 (by two fish; 11%; Figure 8). Two fish moved downstream through Gull Rapids into Stephens Lake in 2018 (discussed in Section 4.2.2.2; Table A1-3).

#### **4.2.2.1 PROPORTIONAL DISTRIBUTION**

Individual Lake Whitefish were detected most often in Zone 4 (upper basin of Gull Lake) in 2018, spending an average of 55% of the study period in this zone (StDev = 45%, range: 0–100%; Figure 9). Lake Whitefish were detected for an average of 21% of the study period in Zone 3 (river reach from Birthday Rapids to Gull Lake; StDev = 35%; range: 0–100%) and 23% in Zone 5 (lower basin of Gull Lake; StDev = 18%, range: 1–43%). No Lake Whitefish were

detected in Zones 1 (Clark Lake) or 2 (the riverine area between Clark Lake and Birthday Rapids) (Figures 9 and 10). Fish were detected in Gull Lake (Zones 4 and 5) for a greater proportion of time during the spring and summer than in the fall (Table 3; Figure 9). A greater proportion of detections occurred in Zone 3 at the end of the open-water period. Zone 3 was used:

- 14% of the time between June 6 and September 9;
- 51% of the time between September 9 and 26; and
- 71% of the time between September 27 and October 10.

#### 4.2.2.2 MOVEMENT PATTERNS

In general, detections were spread out between Zones 3, 4, and 5 during the 2018 open-water period, with the highest number of detections logged immediately downstream of Birthday Rapids (rkm -33.8; n = 51,034; 26%) and in lower Gull Lake east of Caribou Island (rkm -9.3; n = 34,954; 18%) (Figure 10). Few detections were recorded at the three closest receivers to Gull Rapids (n = 705; 0.4%; Figure 11). During the spawning period (September 25 to October 10 based on water temperatures of less than 12°C), 70% of all detections were logged immediately downstream of Birthday Rapids on the north side of the river (rkm -33.8; n = 37,727; Figure 12). Unlike fish tagged in 2013, no fish tagged in 2017 moved upstream over Birthday Rapids.

Of the 21 fish detected during the open-water period:

- Seven remained exclusively in Gull Lake:
  - Two (#31732 and #31737) moved between the upper and lower basins of Gull Lake (Zones 4 and 5)
  - Four (#31726, #31731, #31734, and #31739) were only detected in Zone 4 (upper basin of Gull Lake), moving as far upstream as rkm -19.5.
  - One (#31735) remained exclusively in lower Gull Lake (Zone 5), between rkm -9.3 and -4.8.
- Nine remained in Gull Lake for the majority of the open-water period but made distinct upstream movements in fall:
  - Seven (#31729, #31730, #31736, #31741, #31742, #31743, and #31745) moved as far upstream as Birthday Rapids (rkm -33.8),
  - One (#31722) was detected as far upstream as rkm -29.4.
  - One (#31746) moved as far upstream as a small set of rapids at rkm -19.5.
- Two (#31728 and #31733) remained exclusively in the riverine area between Birthday Rapids and Gull Lake (Zone 3). Both made upstream movements to Birthday Rapids in the fall.

- One (#31744) was detected in Gull Lake at the beginning of the open-water period, but moved upstream to Zone 3 (as far as rkm -26.5) in June.
- Two moved downstream into Stephens Lake. All movements were made prior to spillway commissioning.
  - #31727 was last detected in Gull Lake at rkm -10.3 on November 10, 2017, and was next detected in Stephens Lake on May 30, 2018. It moved between rkms 1.2 and 18.6 for the remainder of the 2018 open-water period.
  - #31738 was detected consistently at the receiver at rkm -9.3 until July 26, 2018. It then moved downstream and was detected in Stephens Lake at rkm 1.2 until August 8.

### 4.2.3 STEPHENS LAKE

Of the 40 fish in Stephens Lake at the beginning of the 2018 open-water period, 27 (68%) were detected. These fish were detected between 15 and 34,874 times over one to 113 days of the 163 day open-water period (1–69% of the time) (Appendix A1-4). The average total movement range was 8.8 rkm (StDev 9.4 rkm; range: 0.0–34.9 rkm) (Figure 13). The farthest upstream detections occurred at the receivers closest to Gull Rapids at rkm 1.2 (by 11 fish; 42%), while the farthest downstream detections were at rkm 36.1 (by two fish; 8%).

Of the 13 fish that were not detected during the 2018 open-water period:

- One (#31701) has not been detected since tagging;
- Seven (#31698, #31706, #31713, #31719, #31720, #31721, and #31755) were only detected briefly after tagging; and
- Five (#31711, #31717, #31723, #31752, and #31756) were last detected during the winter.

#### 4.2.3.1 PROPORTIONAL DISTRIBUTION

Overall, Lake Whitefish spent more time in Zone 7 (farther away from Gull Rapids) than Zone 6 during the 2018 open-water period (Figures 9 and 14; Table 3). On average, fish spent 57% of the time in Zone 7 (StDev = 42%; range: 0 – 100%) and 43% in Zone 6 (StDev = 42%, range: 0–100%). By the end of September, however, time spent in Zone 6 started to increase:

- Zone 6 was used an average of 40% of the time (StDev = 45%; range: 0–100%) between June 6 and September 24; and
- 63% of the time (StDev = 45%; range: 0–100%) between September 25 and October 10.

### 4.2.3.2 MOVEMENT PATTERNS

During the 2018 open-water period, the highest number of detections ( $n = 13,387$ ; 28%) were recorded just below Gull Rapids, near the south shore at rkm 1.2 (Figure 15; Map 8). An additional 17% were logged at the boundary between Zones 6 and 7 (Figure 15, Map 8). A greater number of detections were logged in the northern portion of Stephens Lake than in the southern (Figure 15; Map 8). During the spawning period (September 25 to October 10 based on water temperature less than 12°C), no fish were detected downstream of rkm 21.6, and 90% of the detections were logged within 4.5 rkm of Gull Rapids (Figure 16).

Of the 27 Lake Whitefish detected in Stephens Lake during the 2018 open-water period:

- Eighteen remained in the upstream portion of Stephens Lake, moving only as far downstream as rkm 10.3.
  - Three (#31708, #31716, and #31751) remained exclusively in the southern portion of the lake.
  - Six (#31707, #31710, #31714, #31718, #31725, and #31753) remained exclusively in the northern portion of the lake.
  - Nine (#31700, #31702, #31703, #31705, #31709, #31715, #31747, #31750, and #31757) moved between the northern and southern portions of the lake.
- Two (#31712 and #31749) were detected exclusively in lower Stephens Lake (Zone 7).
- The remaining seven fish moved more extensively throughout Stephens Lake, using both the northern and southern portions.
  - Three were last detected at the mouth of Ferris Bay (rkm 20.0) in June (#53762) and October (#31704 and #53761), and likely continued to move into the bay, Four (#31699, #31724, #31748, and #31754) moved throughout Stephens Lake during the open water season but moved upstream to within 3.8 rkm of Gull Rapids in the fall.

### 4.2.4 LONG SPRUCE AND LIMESTONE RESERVOIRS

Due to low water levels, no receivers could be set in the Long Spruce or Limestone reservoirs during open-water 2018. Since no fish were detected farther downstream in Stephens Lake than rkm 36.1, it is unlikely that any fish moved downstream over the Kettle GS in 2018. Provided conditions are suitable, receivers will be set in this area in open-water 2019 to monitor potential fish passage.

## 5.0 DISCUSSION

### 5.1 EVALUATION OF METHODOLOGY

Fish movement monitoring, via acoustic telemetry, is a significant component of the AEMP for the Keeyask GS Project used to assess potential impacts of GS construction on several fish species including Lake Sturgeon (adults and juveniles), Walleye, and Lake Whitefish. Of these fish species/life stages, the methodology is most effective for monitoring movements of adult and juvenile Lake Sturgeon. Lake Sturgeon have a low natural mortality rate, occupy main channel habitats where the receivers are located, and in the case of juveniles, rarely move. Monitoring movements of Walleye and Lake Whitefish via acoustic telemetry has been less effective relative to Lake Sturgeon. This is because: i) tagged individuals are detected less frequently due to more frequent utilization of shallow water habitat outside the detection range of receivers; ii) potential use of tributaries and off-current embayments where receivers are not located; iii) stress from the tagging procedure may cause an initial downstream movement of some individuals which complicates data interpretation; and iv) a higher natural mortality rate relative to Lake Sturgeon causes a greater proportion of tags to go missing. Despite this, the data collected to date (2014 to 2018) provide a good understanding of Lake Whitefish movements. This has been facilitated by the extensive array of stationary acoustic receivers spread over a ~100 km length of the Nelson River between Clark Lake and the Limestone GS, and the inclusion of receiver gates which provide confidence that movements of Lake Whitefish past key points are being detected.

One additional receiver was added to the receiver array during the open-water 2018 period. A receiver was deployed at rkm -4.8 (upstream of Gull Rapids) in order to monitor movements in close proximity to the Keeyask GS construction site. During open-water 2018, two fish (not including those that moved downstream through Gull Rapids) were detected at this receiver (discussed further in Section 5.4). This receiver will continue to be deployed as part of the upstream receiver array.

The proportion of Lake Whitefish detected during the 2018 open-water season was higher than any other year of study. All of the 21 fish available in Gull Lake were detected during the 2018 open water season, higher than the 47–80% detection rates in previous years. In Stephens Lake, 60% of fish were detected, which is similar to 49%–68% in previous years (Lavergne and Hrenchuk 2016; Burnett and Hrenchuk 2017; Lacho and Hrenchuk 2018).

### 5.2 WINTER MOVEMENT

A limited amount of winter movement data has been collected from Lake Whitefish upstream of Gull Rapids since the study commenced in 2014. During the winter 2017/2018 period, although 95% of fish were detected, they were only detected for an average of four days (2% of days).

Similarly, in previous years, average detection days have been very low in the winter (4 days in 2014/15, 7 days in 2015/16, and 6 days in 2016/17). In all study years, the majority of detections have occurred during October and November downstream of Birthday Rapids (rkm -33.8). These detections are likely related to spawning and post-spawning movements. Due largely to the limited receiver array, overwintering habitat and locations for Lake Whitefish upstream of Gull Rapids remain poorly understood.

The winter receiver array in Stephens Lake is more extensive, and thus more fish can be tracked for a greater proportion of the period. The majority of detections during the 2017/2018 winter period occurred at rkm 13.9, in the southern part of Stephens Lake. Lake Whitefish tagged in 2014 were also detected in this area during all previous years. However, 60% of fish also moved into the northern portion of Stephens Lake during the 2017/2018 winter period. Based on detection summaries, it is suspected that Lake Whitefish may also overwinter in the North Arm of Stephens Lake, out of the detection range of the receiver array.

### 5.3 OPEN-WATER MOVEMENT

Acoustic telemetry continues to provide a relatively good understanding of open-water Lake Whitefish movement patterns despite the (relative to Lake Sturgeon) low number of detections and relatively long gaps between detection events. As in previous years, Lake Whitefish tended to spend most of the open-water period in Gull Lake, with some fish staying in the lake for the entire open-water period and some making upstream movements out of the lake during the fall. Similar to those tagged in 2014, Lake Whitefish tagged in 2017 were detected at the base of Birthday Rapids during the spawning period (*i.e.*, when water temperatures fell below 12°C).

The movement pattern of fish tagged in 2017 did differ from those tagged in 2014 in one respect: no fish were detected upstream of Birthday Rapids in 2018. In the three previous study years, fish were detected as far upstream as Clark Lake during the open-water season. A receiver placed at the mouth of the Assean River in 2016 detected Lake Whitefish during the spawning periods of both 2016 and 2017, and hoopnetting studies also suggested that Lake Whitefish spawn in the Assean River (Johnson 2005; Lavergne and Hrenchuk 2016; Burnett and Hrenchuk 2017; Lacho and Hrenchuk 2018). Continued monitoring will reveal if fish tagged in 2017 continue to exclusively inhabit the area downstream of Birthday Rapids, or if fish will move upstream as time progresses.

Lake Whitefish in Stephens Lake spent slightly less time in Zone 6 than during previous years; however, as in the first three years of the study, the proportion of time spent in Zone 6 increased during the fall. The majority of Lake Whitefish were detected within the northern portion of Stephens Lake, some of which likely moved into the North Arm outside of the receiver array. For the first time since monitoring began, Lake Whitefish were detected at the receiver at the mouth of Ferris Bay during the spawning period. Despite this area being a known spawning site (Michaluk *et al.* 2011; Keeyask Hydropower Limited Partnership 2014), none of the fish tagged in 2014 were detected here during the spawning period.



## 5.4 KEY QUESTIONS

The AEMP identified key questions for Lake Whitefish movement monitoring, two of which are relevant to the construction period and are addressed in the discussion below.

*What is the number (or proportion) of tagged Lake Whitefish that move past the construction site?*

Monitoring the movement of Lake Whitefish for four years has shown that movements past Gull Rapids are rare. Three of the 22 (14%) Lake Whitefish tagged upstream of Gull Rapids in 2017 have moved downstream into Stephens Lake (one in 2017 and two in 2018). It is likely that at least one of these fish is a tagging mortality. Of the 20 fish tagged upstream in 2014, two (10%) moved downstream during the three-years the tags were active. No Lake Whitefish have moved upstream over Gull Rapids since the study was initiated in 2014. The Keeyask GS spillway was commissioned in August 2018, after which upstream movements were no longer possible.

*Are Lake Whitefish utilizing habitat in the vicinity of construction activities (particularly during spawning)?*

Upstream of Gull Rapids, Lake Whitefish do not frequently use habitat in the vicinity of the construction site. With the exception of the two fish that moved through Gull Rapids, only two Lake Whitefish were detected at the receiver closest to Gull Rapids in 2018. This is similar to the observations of fish tagged in 2014, as no fish were detected at the receiver closest to Gull Rapids in 2015 and only one was detected in this area in both 2016 and 2017.

In contrast, a large proportion of Lake Whitefish tagged in Stephens Lake have consistently been detected immediately downstream of Gull Rapids in all study years. In 2018, 42% of fish in Stephens Lake were detected at the receiver closest to Gull Rapids during the open-water period. During the 2018 spawning period, 90% of all detections occurred within 4.5 rkm of the rapids. High proportions ( $\geq 80\%$ ) of detections have been recorded near Gull Rapids during the spawning period since the study began, indicating that Lake Whitefish are spawning in this area. This means that Lake Whitefish in Stephens Lake may be especially susceptible to construction-related activities like sedimentation and flow alteration during the fall spawning period.

## 6.0 SUMMARY AND CONCLUSIONS

- Although Lake Whitefish may go undetected for long periods of time and the number of detections are low compared to Lake Sturgeon, acoustic monitoring continues to provide enough data to meet the objectives of the AEMP.
- In open-water 2018, as in previous years, Lake Whitefish upstream of Gull Rapids spent the majority of the open-water period in Gull Lake, with some fish making upstream movements out of the lake during the fall, likely related to spawning. As in all previous years of the study, Lake Whitefish were detected at Birthday Rapids during the spawning period. No fish tagged in 2017 has been detected upstream of Birthday Rapids since tagging; in contrast, fish tagged in 2014 were detected as far upstream as Clark Lake during all three open-water seasons that they were monitored. Further monitoring will reveal if fish tagged in 2017 will expand their upstream ranges as their movements are tracked for a longer period of time.
- In Stephens Lake, movement patterns were similar to those observed in previous years, with fish spending more time closer to Gull Rapids during the fall and a large proportion of detections occurring near Gull Rapids during the spawning period. As in previous years, Lake Whitefish were detected frequently in the northern portion of the lake. For the first time in 2018, fish were detected at the mouth of Ferris Bay (a known spawning location) during the spawning period.
- The key questions as described in the AEMP for Lake Whitefish movement monitoring during construction of the Keeyask GS are:

- *What is the number (or the proportion) of tagged Lake Whitefish that move past the construction site?*

Results of four years of monitoring suggest that a small proportion of Lake Whitefish tagged in Gull Lake move downstream through Gull Rapids. Of the fish tagged upstream of Gull Rapids, two of 20 (10%) tagged in 2014 and three of 22 (14%) tagged in 2017 moved downstream into Stephens Lake. At least one of the movements in 2017 may have been related to tagging stress. There have been no upstream movements through the rapids.

- *Are tagged Lake Whitefish utilizing habitat in the vicinity of construction activities (particularly during spawning)?*

So far, Lake Whitefish tagged upstream of Gull Rapids rarely utilized habitat directly upstream of the construction site. A large proportion of whitefish tagged downstream in Stephens Lake continue to use the area immediately downstream of Gull Rapids, especially during the spawning period.

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## **TABLES**



**Table 1: Acoustic-tag and biological information for each Lake Whitefish tagged with an acoustic transmitter in the Nelson River upstream of Gull Rapids, fall 2017.**

Acoustic Tag ID	Floy Tag #	Date Tagged	Tag Life (days)	Expiry Date	Fork Length (mm)	Weight (g)
31722	101750	07-Oct-17	1737	10-Jul-22	460	2275
31726	109695	12-Oct-17	1737	15-Jul-22	468	2575
31727	109696	12-Oct-17	1737	15-Jul-22	465	2075
31728	109688	14-Oct-17	1737	17-Jul-22	486	2550
31729	109689	14-Oct-17	1737	17-Jul-22	483	2350
31730	109690	14-Oct-17	1737	17-Jul-22	448	1850
31731	109691	14-Oct-17	1737	17-Jul-22	490	2500
31732	109697	12-Oct-17	1737	15-Jul-22	455	1750
31733	109692	14-Oct-17	1737	17-Jul-22	488	2725
31734	109693	14-Oct-17	1737	17-Jul-22	435	1925
31735	109694	12-Oct-17	1737	15-Jul-22	495	2250
31736	109698	12-Oct-17	1737	15-Jul-22	528	3425
31737	109699	12-Oct-17	1737	15-Jul-22	454	1500
31738	109700	11-Oct-17	1737	14-Jul-22	432	1425
31739	109654	11-Oct-17	1737	14-Jul-22	491	2475
31740	109652	11-Oct-17	1737	14-Jul-22	509	2950
31741	109653	11-Oct-17	1737	14-Jul-22	467	1725
31742	109655	11-Oct-17	1737	14-Jul-22	482	2525
31743	109656	11-Oct-17	1737	14-Jul-22	529	3050
31744	109657	11-Oct-17	1737	14-Jul-22	501	2350
31745	109658	11-Oct-17	1737	14-Jul-22	533	2675
31746	109659	11-Oct-17	1737	14-Jul-22	450	1500

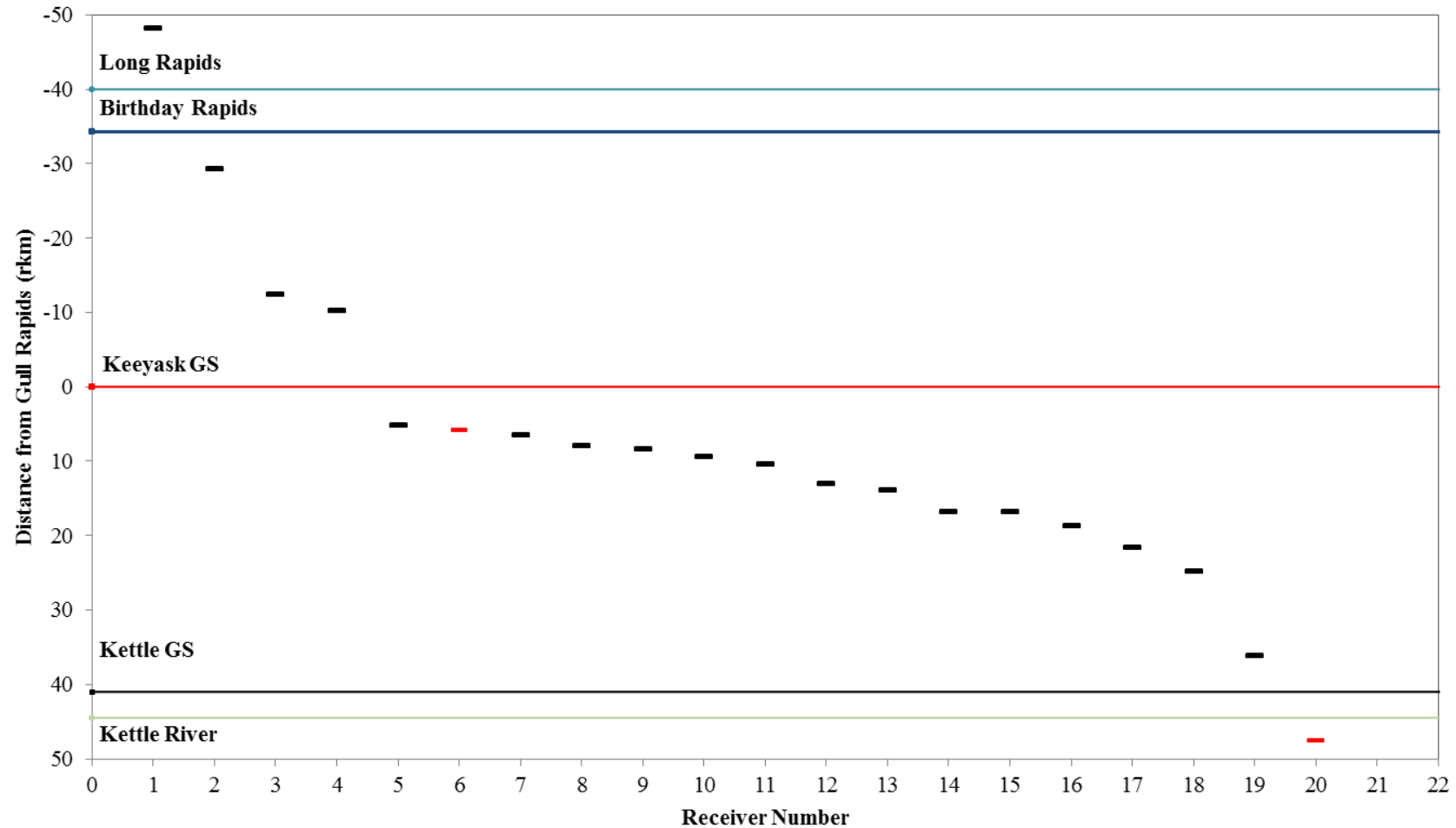
**Table 2: Acoustic-tag and biological information for each Lake Whitefish tagged with an acoustic transmitter in Stephens Lake, fall 2017.**

Acoustic Tag ID	Floy Tag #	Date tagged	Tag life (days)	Expiry date	Fork length (mm)	Weight (g)
31698	101729	09-Oct-17	1737	12-Jul-22	476	1900
31699	101728	09-Oct-17	1737	12-Jul-22	423	1375
31700	101727	09-Oct-17	1737	12-Jul-22	446	2125
31701	101726	09-Oct-17	1737	12-Jul-22	524	2450
31702	101744	09-Oct-17	1737	12-Jul-22	406	1100
31703	101730	09-Oct-17	1737	12-Jul-22	525	2400
31704	101731	09-Oct-17	1737	12-Jul-22	504	2600
31705	101732	09-Oct-17	1737	12-Jul-22	495	2375
31706	101733	09-Oct-17	1737	12-Jul-22	522	2300
31707	101734	09-Oct-17	1737	12-Jul-22	456	1750
31708	101740	09-Oct-17	1737	12-Jul-22	455	1500
31709	101738	09-Oct-17	1737	12-Jul-22	480	2050
31710	101737	09-Oct-17	1737	12-Jul-22	426	1250
31711	101736	09-Oct-17	1737	12-Jul-22	494	2075
31712	101735	09-Oct-17	1737	12-Jul-22	413	1400
31713	101739	09-Oct-17	1737	12-Jul-22	519	2450
31714	101743	09-Oct-17	1737	12-Jul-22	455	1725
31715	101745	09-Oct-17	1737	12-Jul-22	490	2500
31716	101747	08-Oct-17	1737	11-Jul-22	417	1075
31717	101749	08-Oct-17	1737	11-Jul-22	504	2100
31718	101741	09-Oct-17	1737	12-Jul-22	486	2050
31719	101742	09-Oct-17	1737	12-Jul-22	505	2000
31720	101746	09-Oct-17	1737	12-Jul-22	512	2300
31721	101748	08-Oct-17	1737	11-Jul-22	519	2900
31723	109673	10-Oct-17	1737	13-Jul-22	511	2250
31724	109664	10-Oct-17	1737	13-Jul-22	494	2150
31725	109663	10-Oct-17	1737	13-Jul-22	447	1525
31747	109660	10-Oct-17	1737	13-Jul-22	490	2525
31748	109661	10-Oct-17	1737	13-Jul-22	410	1000
31749	109662	10-Oct-17	1737	13-Jul-22	422	1250
31750	109665	10-Oct-17	1737	13-Jul-22	499	2150
31751	109666	10-Oct-17	1737	13-Jul-22	540	2550
31752	109667	10-Oct-17	1737	13-Jul-22	537	2250
31753	109668	10-Oct-17	1737	13-Jul-22	468	2175
31754	109669	10-Oct-17	1737	13-Jul-22	471	1875
31755	109670	10-Oct-17	1737	13-Jul-22	512	2350
31756	109671	10-Oct-17	1737	13-Jul-22	496	1775
31757	109672	10-Oct-17	1737	13-Jul-22	516	2125
53761	109674	10-Oct-17	1737	13-Jul-22	502	1975
53762	109675	09-Oct-17	1737	12-Jul-22	508	2275

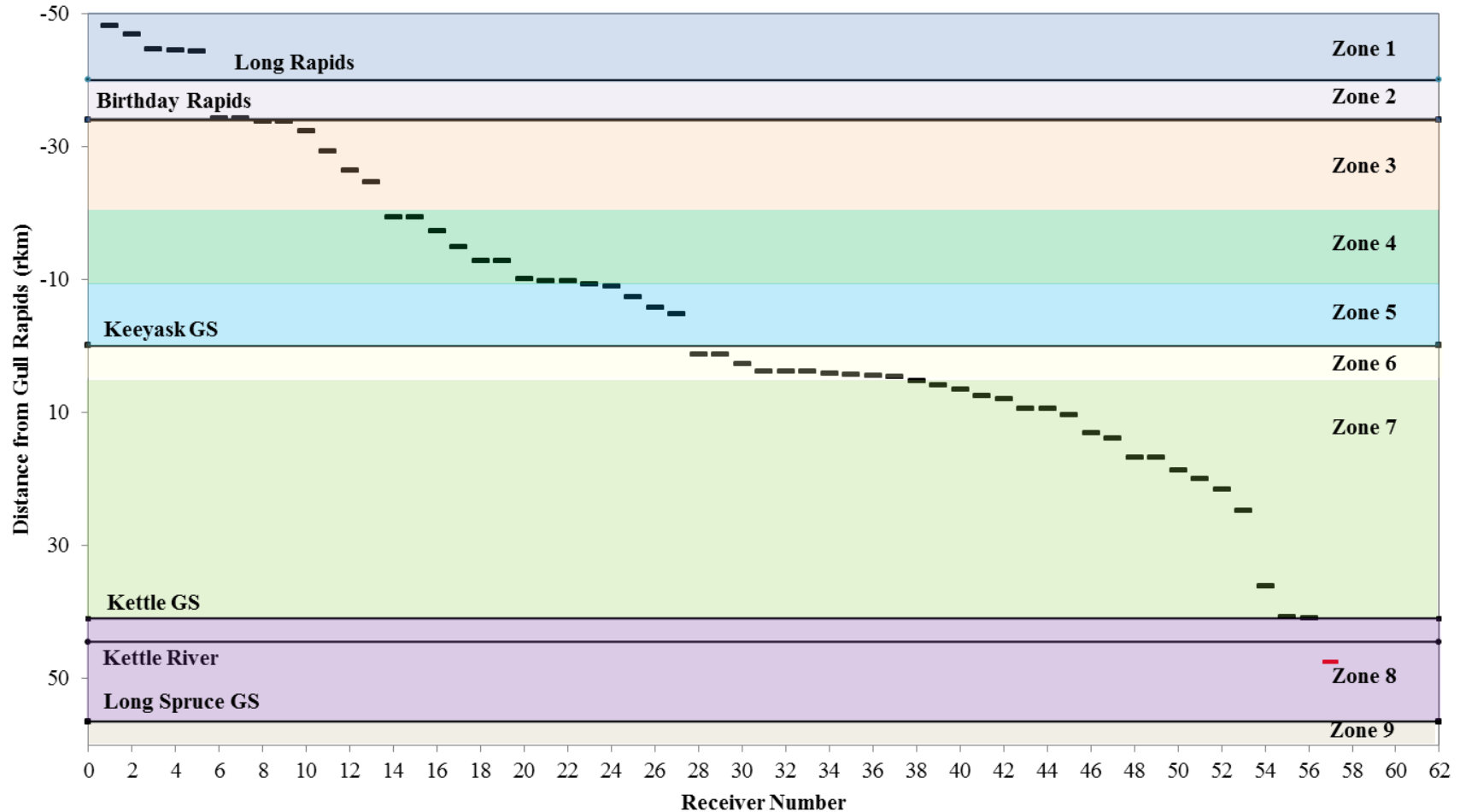
**Table 3: Proportion of time spent in each river zone by Lake Whitefish implanted with acoustic transmitters upstream of Gull Rapids and in Stephens Lake during a portion of the 2015 (June 4 to October 11), 2016 (June 4 to October 19), 2017 (June 7 to October 16), and 2018 (June 6 to October 10) open-water periods.**

Tagging Year	Study Year	Upstream of Gull Rapids					Stephens Lake	
		1	2	3	4	5	6	7
<b>2014</b>	2015	0.2	0.5	32.0	45.4	21.9	66.4	45.2
	2016	6.6	5.6	20.8	50.3	16.6	55.3	44.7
	2017	18.8	0.5	19.1	51.3	10.2	52.4	47.6
<b>2017</b>	2018	0.0	0.0	21.6	55.0	23.4	43.2	56.8

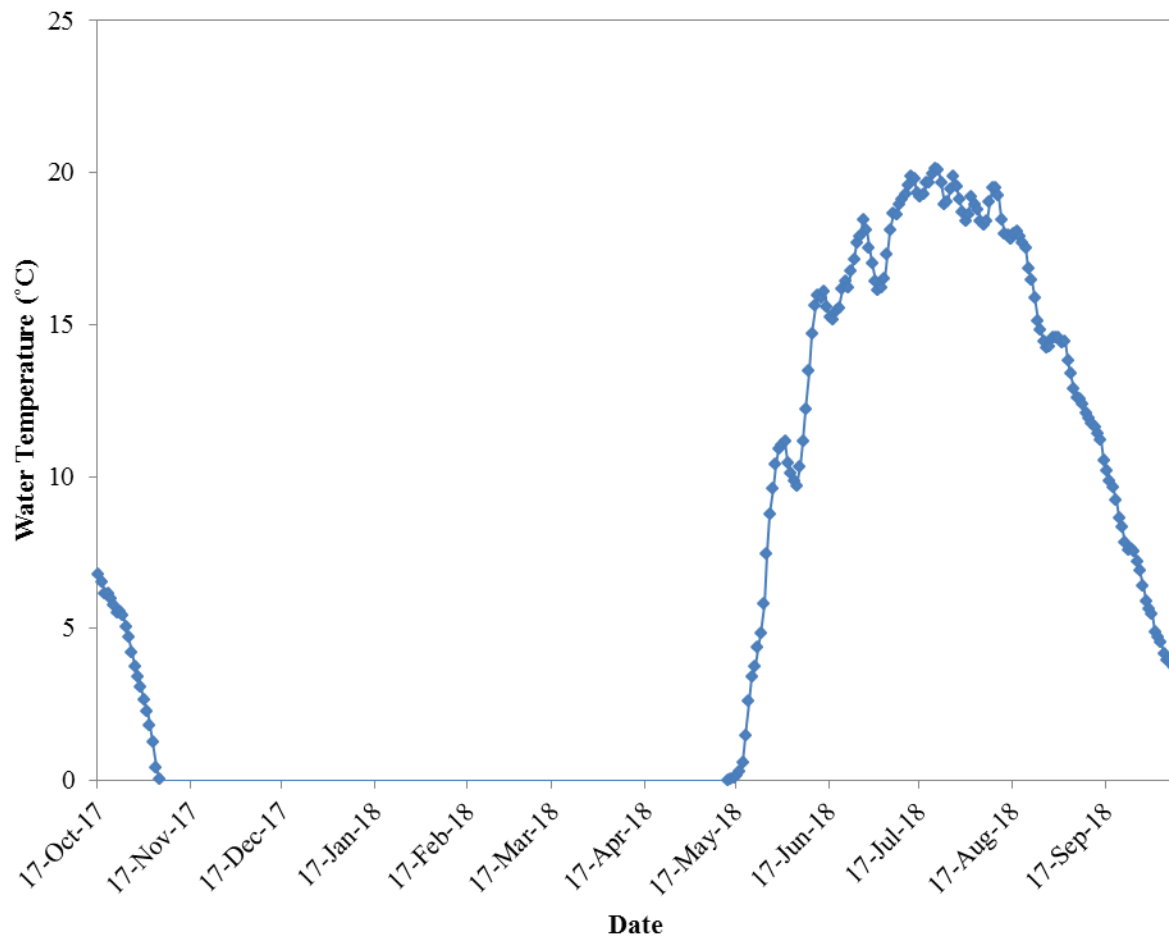
## FIGURES



**Figure 1:** Locations of stationary acoustic receivers (dashes) in relation to the base of Gull Rapids (rkm 0) and other major landmarks (lines) in the Nelson River between Clark Lake and the Limestone GS between October, 2017 and June, 2018. A red dash indicates a receiver that was lost.

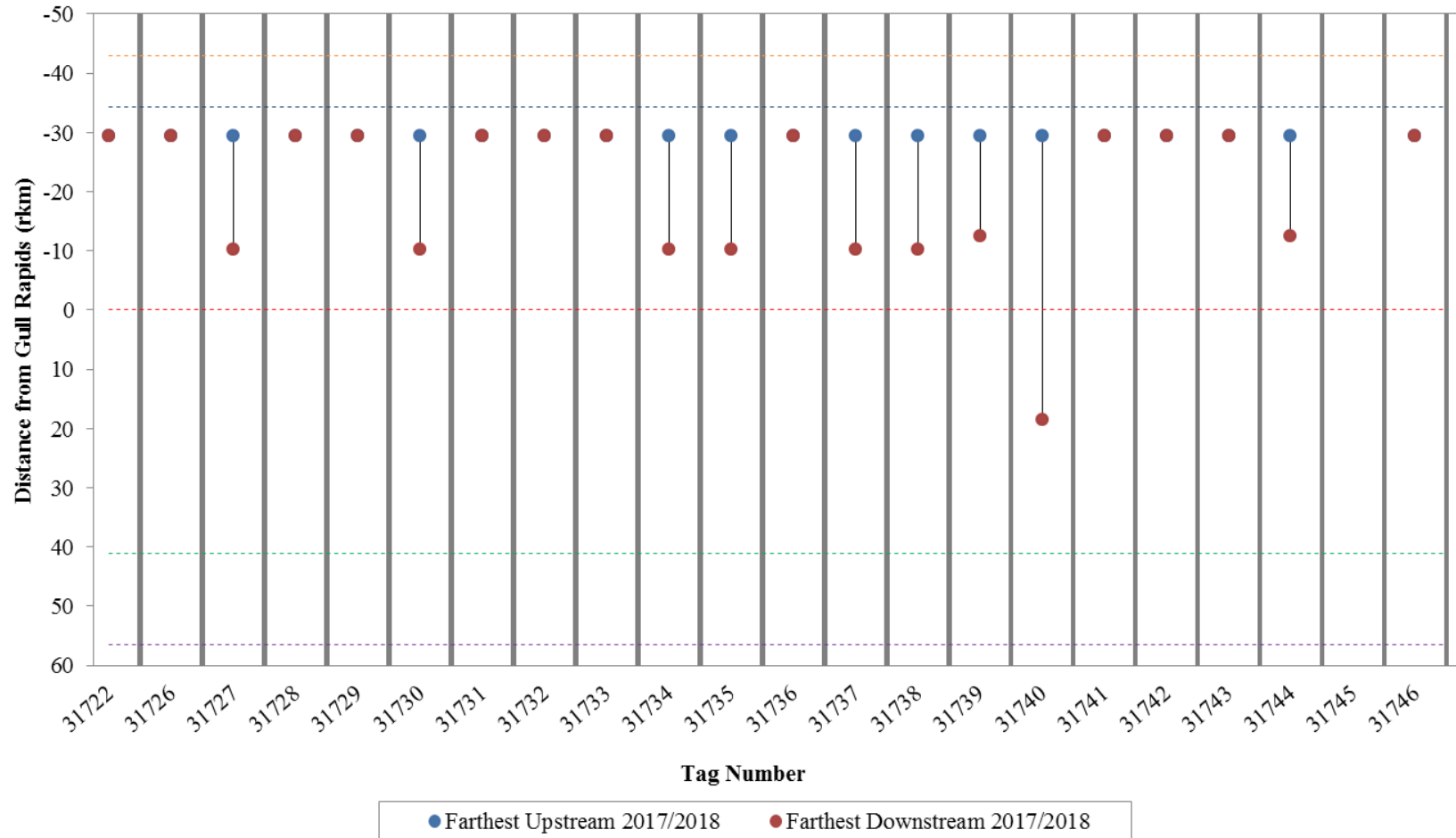


**Figure 2:** Locations of stationary acoustic receivers (dashes) in relation to the base of Gull Rapids (rkm 0) and other major landmarks (lines) in the Nelson River between Clark Lake and the Limestone GS between June and October, 2018. River zones upstream and downstream of Gull Rapids are indicated by shading. A red dash indicates a receiver was lost.

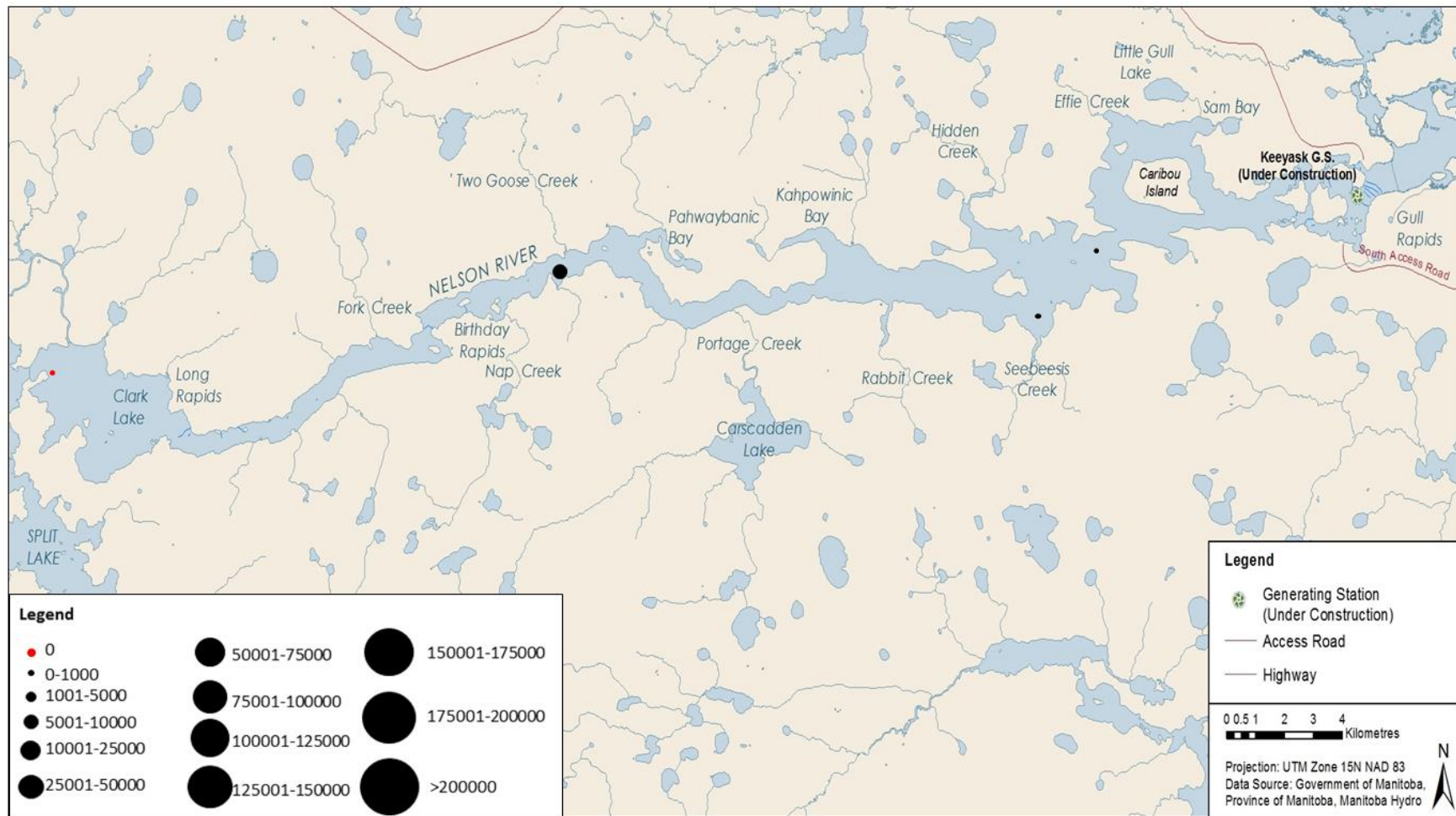


**Figure 3: Water temperature in the Nelson River mainstem from October 17, 2017, to October 10, 2018.**

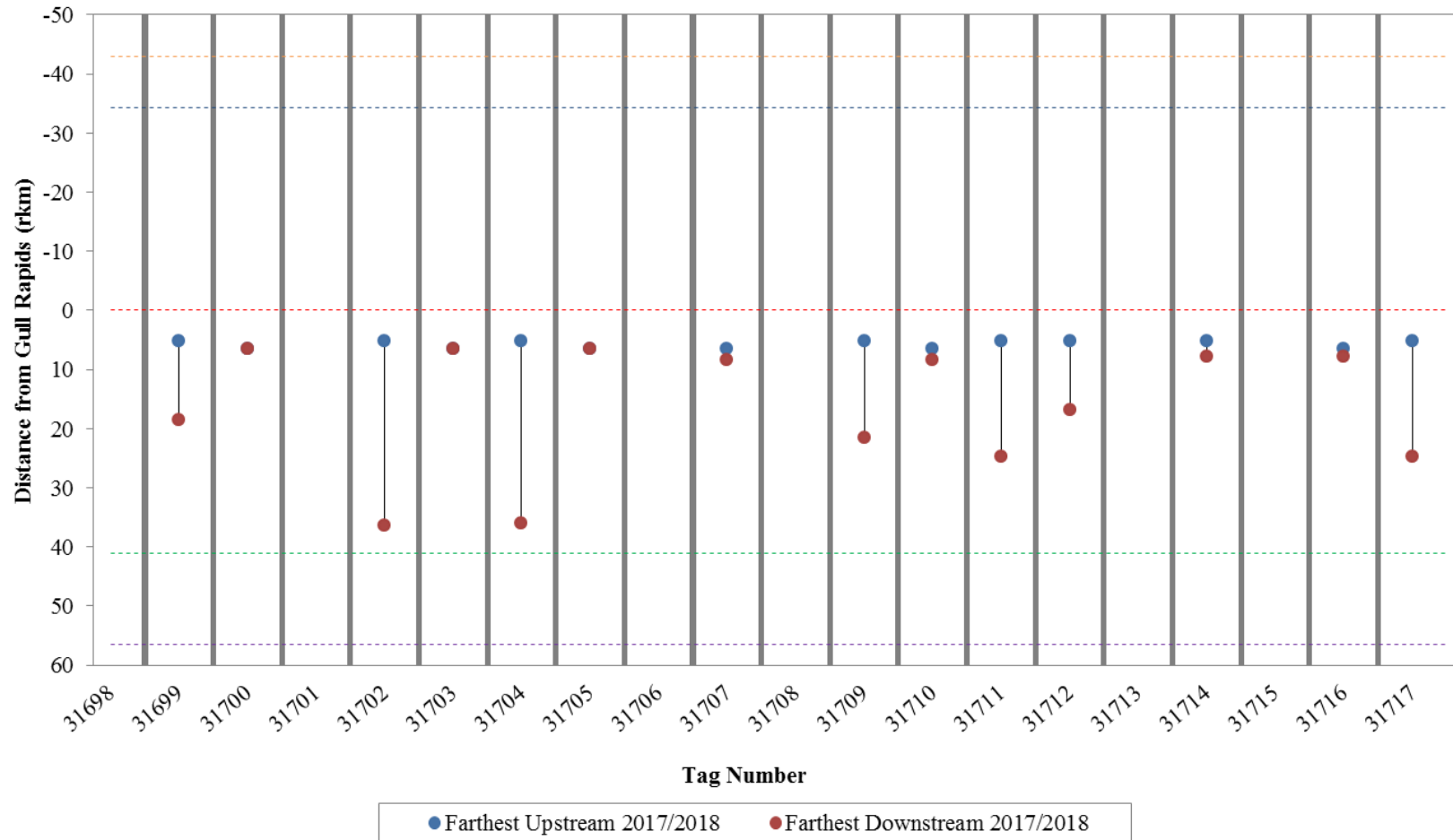




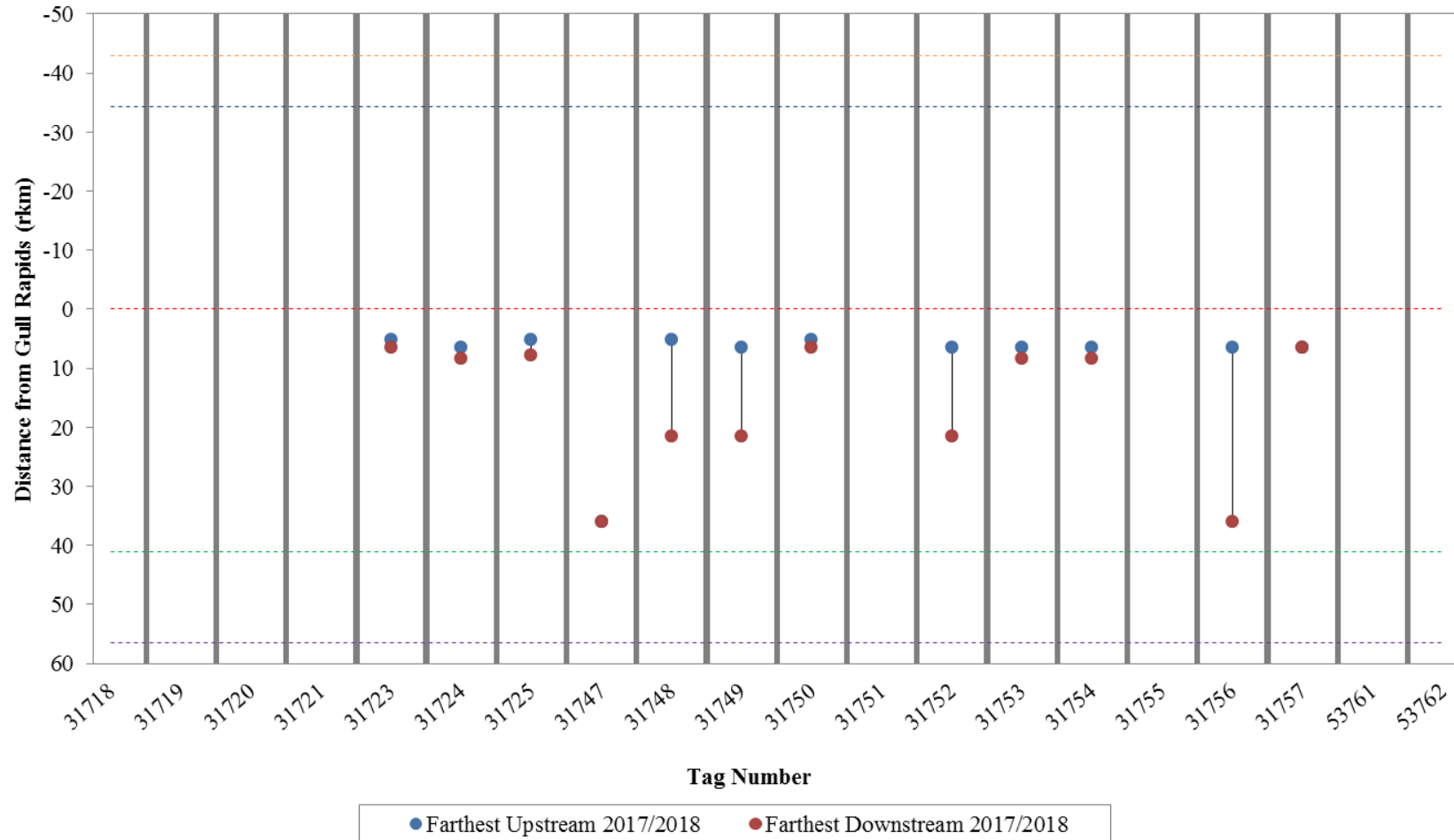
**Figure 4:** Detection ranges for individual Lake Whitefish (n = 20) tagged with acoustic transmitters upstream of Gull Rapids during the 2017/18 (October 17, 2017 to April 30, 2018) winter period. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids; red = Gull Rapids; green = Kettle GS; purple = Long Spruce GS).



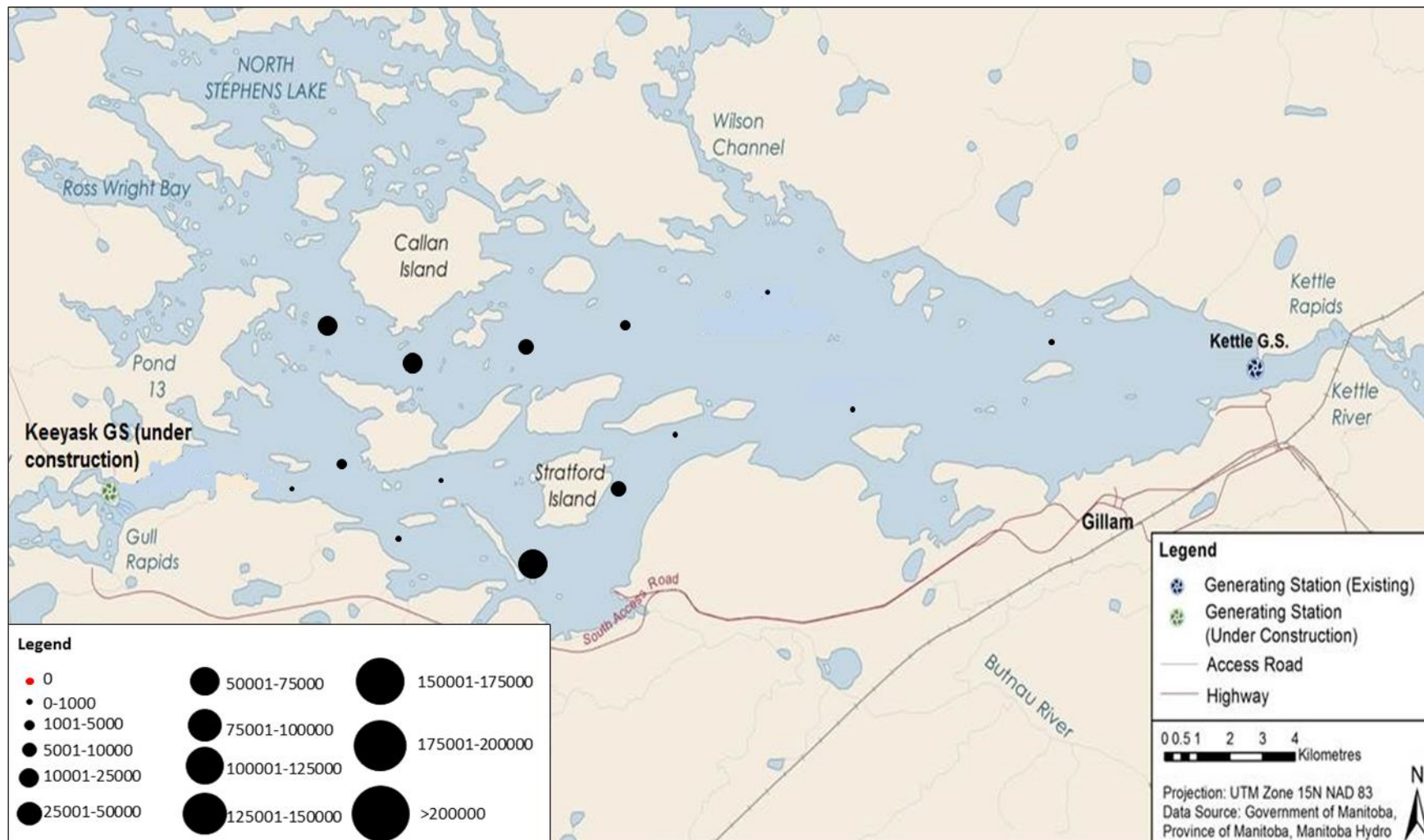
**Figure 5:** Relative number of detections at each acoustic receiver set between Clark Lake and Gull Rapids during winter 2017/2018 (October 17, 2017, to April 30, 2018). Number of detections indicated by size of bubble (defined in legend). Receivers with no detections indicated with red dot.



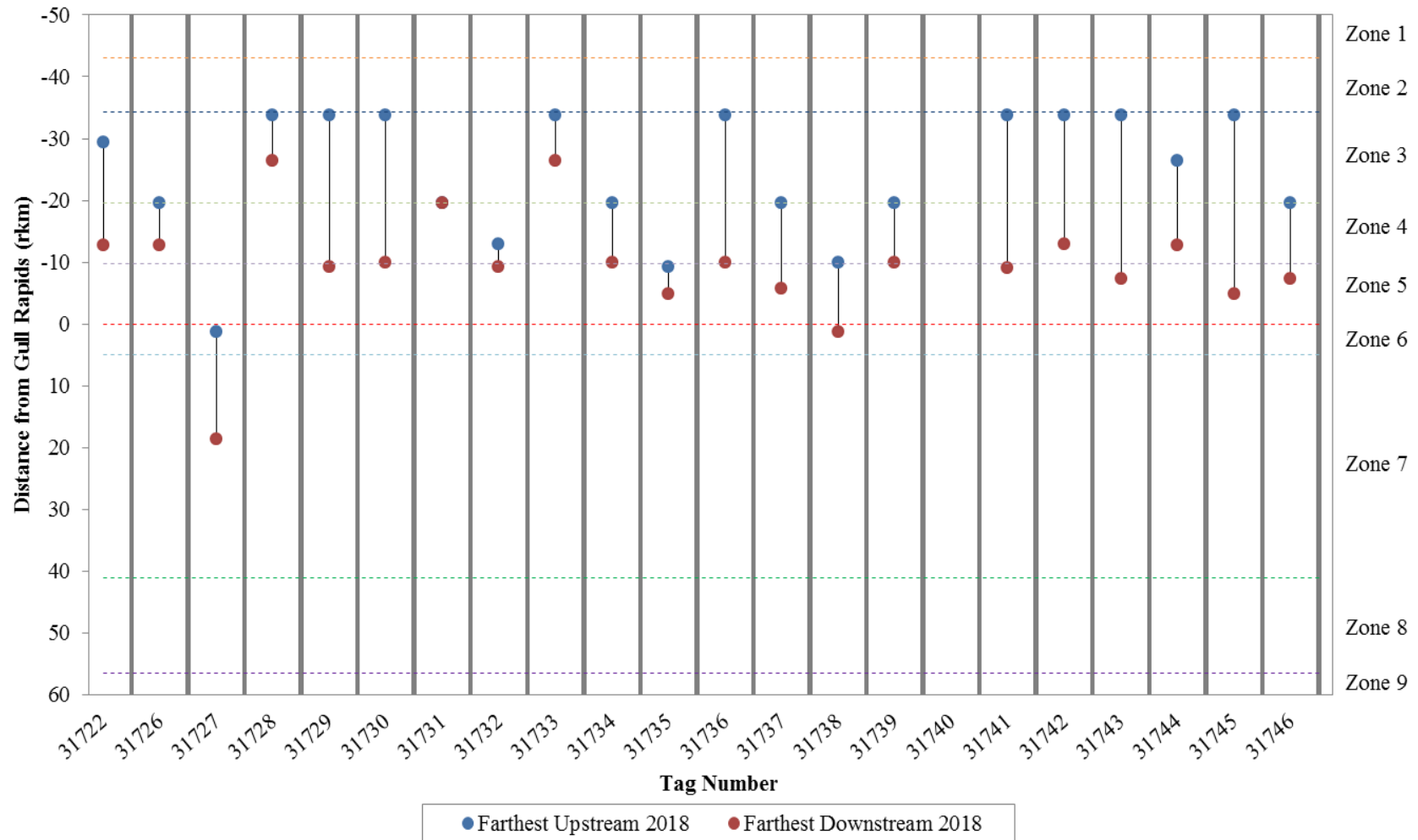
**Figure 6:** Detection ranges for individual Lake Whitefish (n = 40) tagged with acoustic transmitters in Stephens Lake during the 2017/18 (October 17, 2017 to April 30, 2018) winter period. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids; red = Gull Rapids; green = Kettle GS; purple = Long Spruce GS).



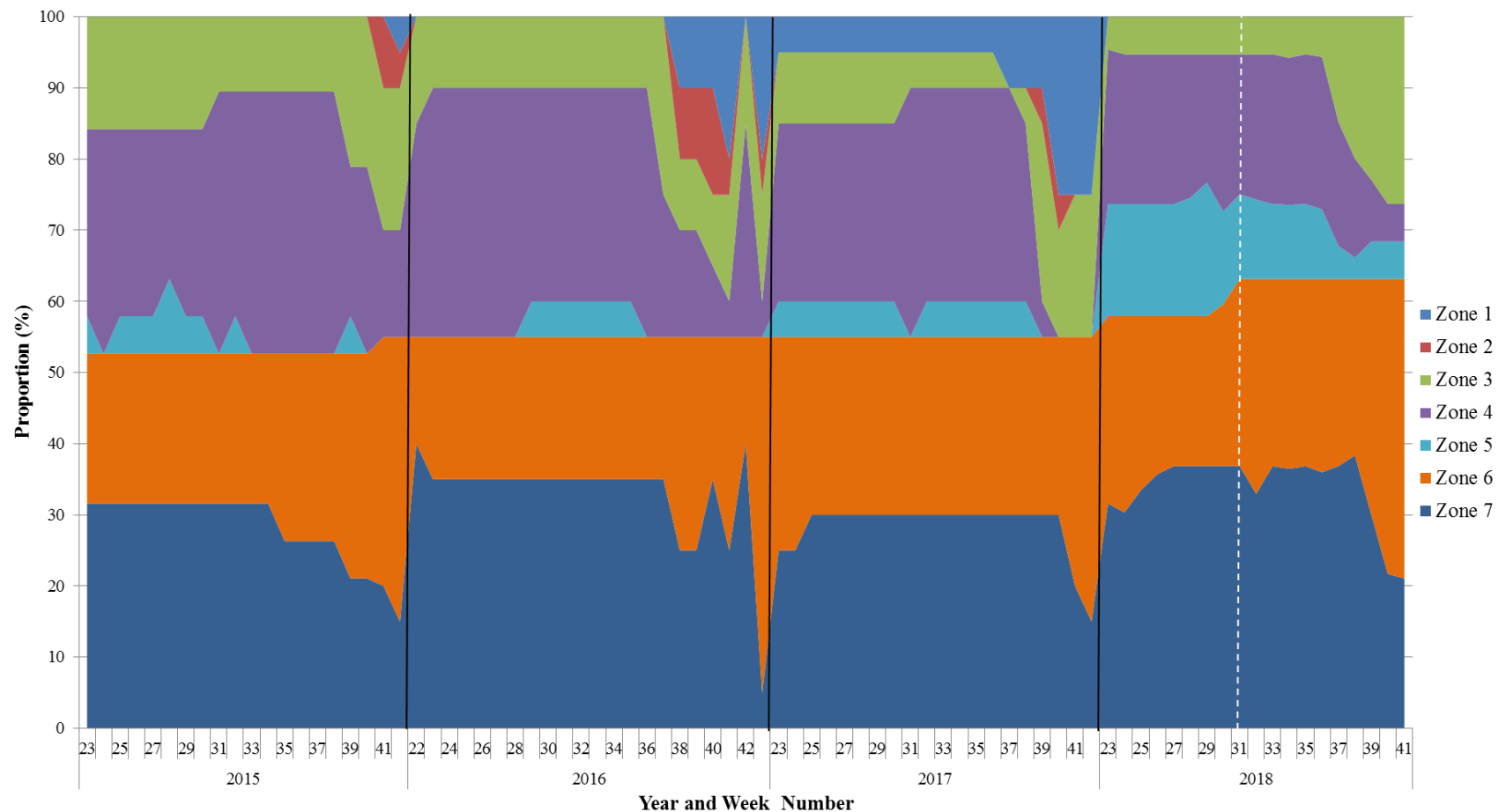
**Figure 6:** Detection ranges for individual Lake Whitefish (n = 40) tagged with acoustic transmitters in Stephens Lake during the 2017/18 (October 17, 2017 to April 30, 2018) winter period. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids; red = Gull Rapids; green = Kettle GS; purple = Long Spruce GS) (continued).



**Figure 7:** Relative number of detections at each acoustic receiver set in Stephens Lake during winter 2016/2017 (October 17, 2017, to April 30, 2018). Number of detections indicated by size of bubble (defined in legend). Receivers with no detections indicated with red dot.

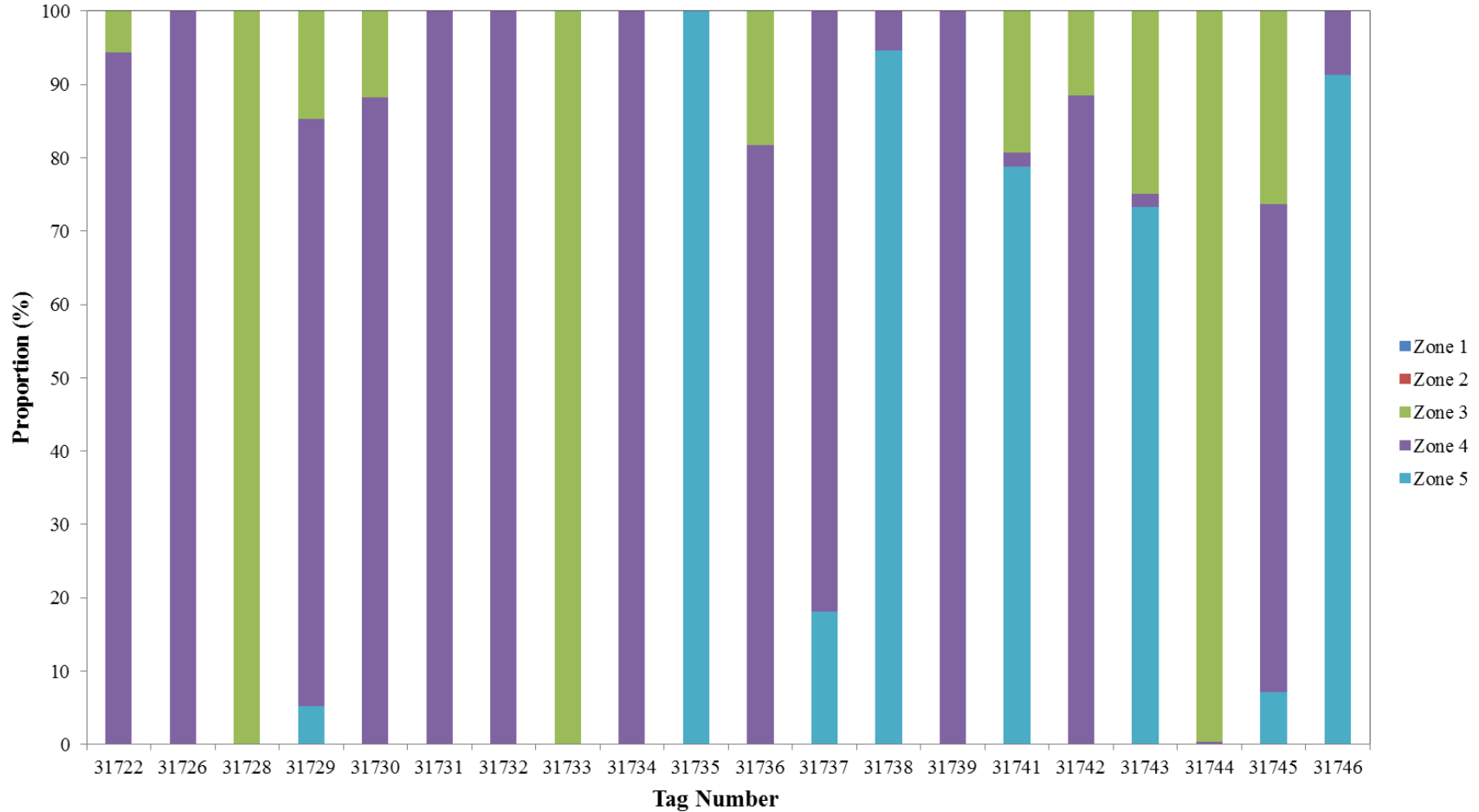


**Figure 8:** Detection ranges for individual Lake Whitefish ( $n = 22$ ) tagged with acoustic transmitters in Gull Lake during the 2018 (May 1 to October 10) open-water period. Horizontal dotted lines demarcate zones. Orange represents the outlet of Clark Lake, blue represents Birthday Rapids, red represents Gull Rapids, green represents the Kettle GS, and purple represents the Long Spruce GS.

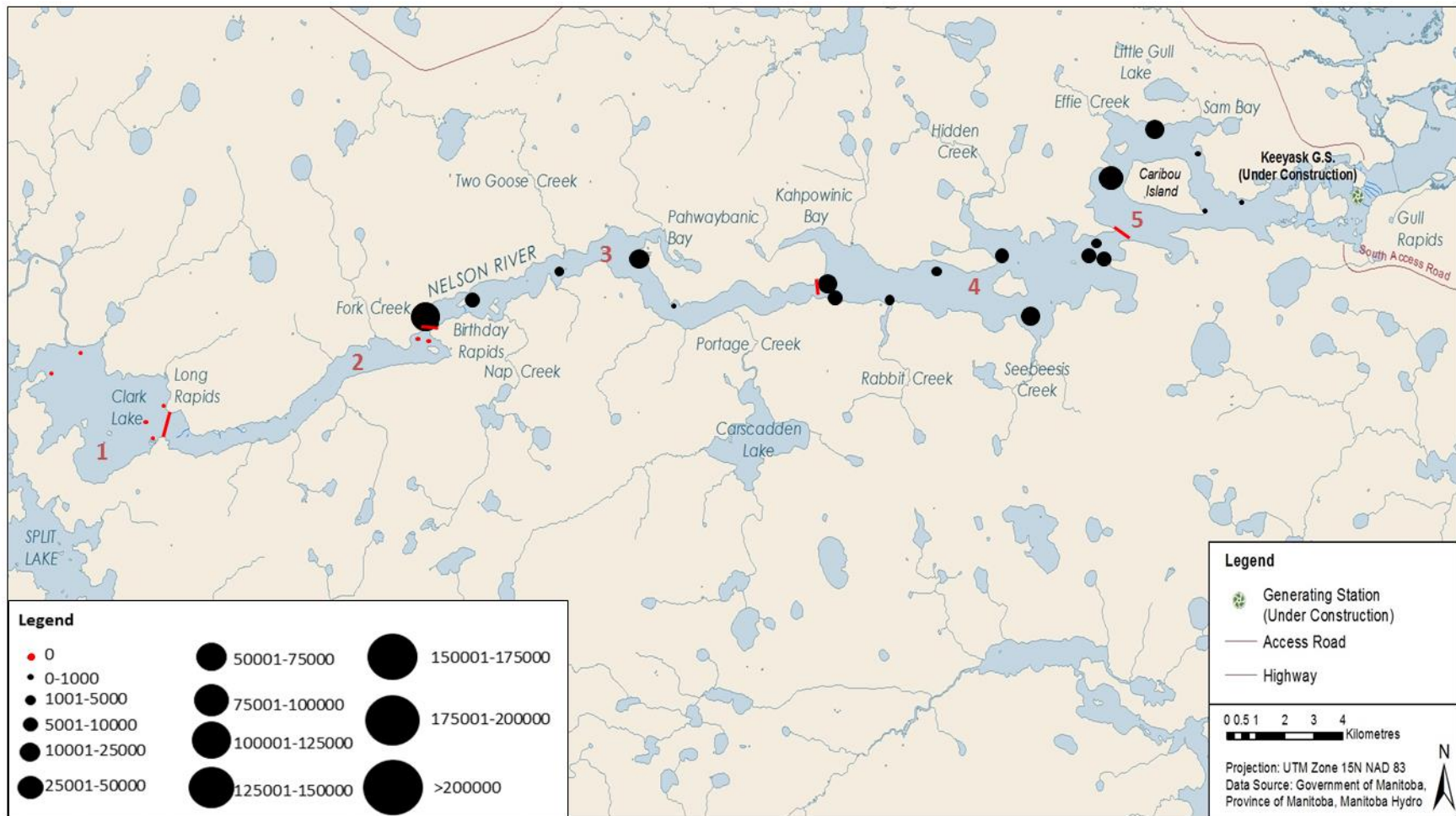


**Figure 9:** Proportional distribution of Lake Whitefish with acoustic transmitters tagged in 2014 and 2017 within seven river zones between Clark Lake and the Kettle GS during a portion of the 2015 (June 4 to October 11), 2016 (June 25 to October 19), 2017 (June 7 to October 16) and 2018 (June 6 to October 10) open-water periods. Black lines demarcate years and white dashed line indicates start of spillway operation.

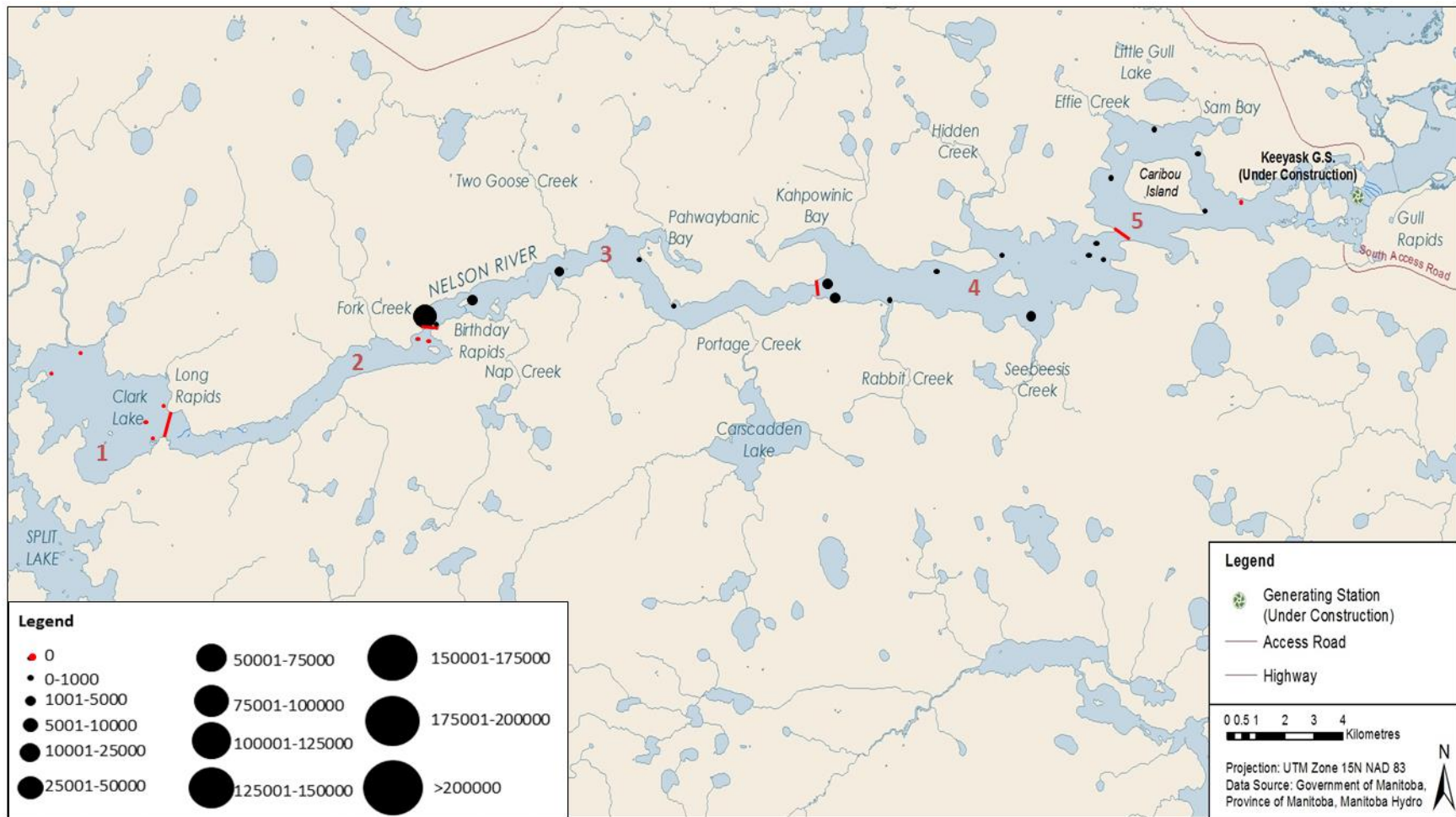




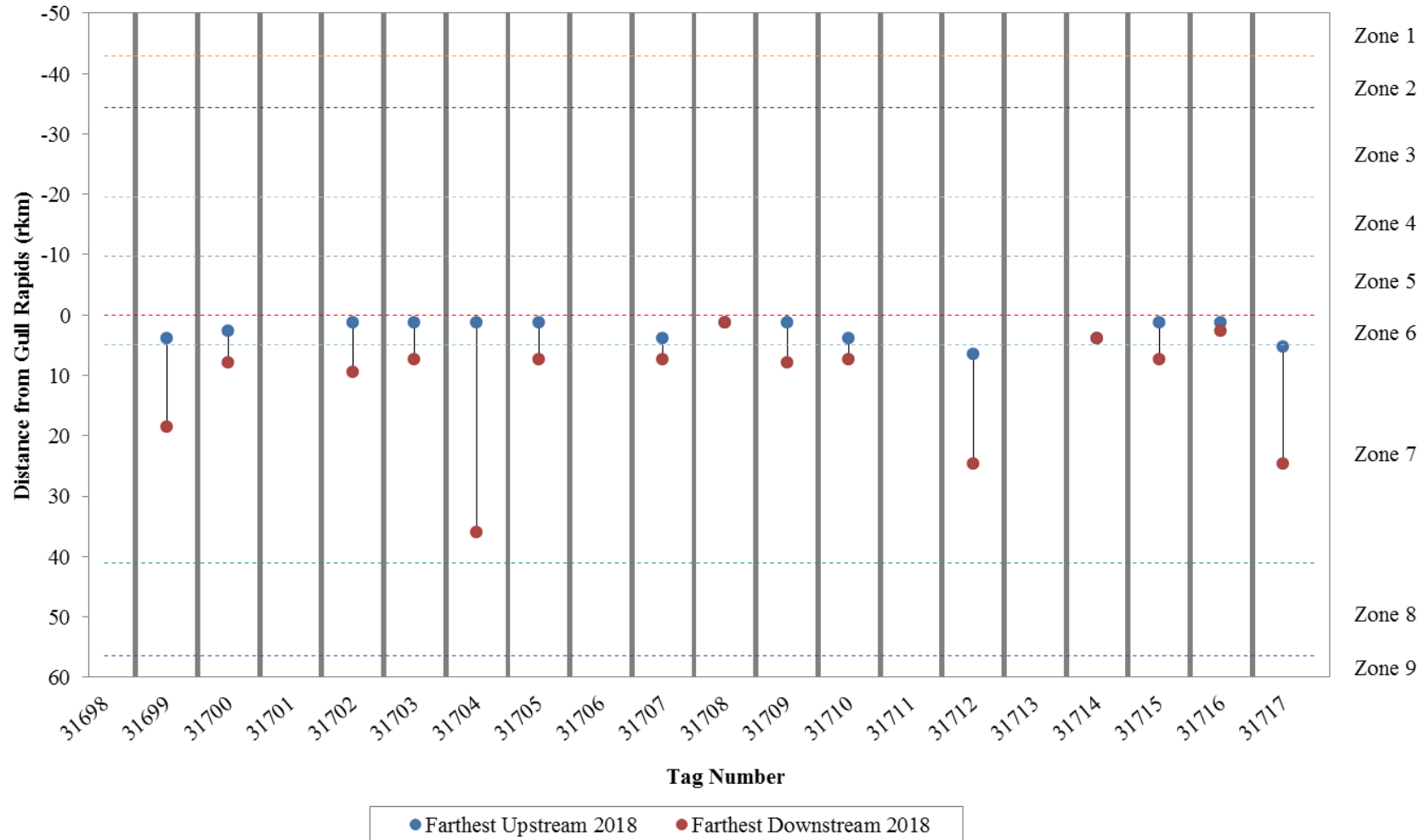
**Figure 10: Proportion of time spent within five river zones between Clark Lake and Gull Rapids by individual acoustic-tagged Lake Whitefish during the 2018 open-water period (June 6 to October 10).**



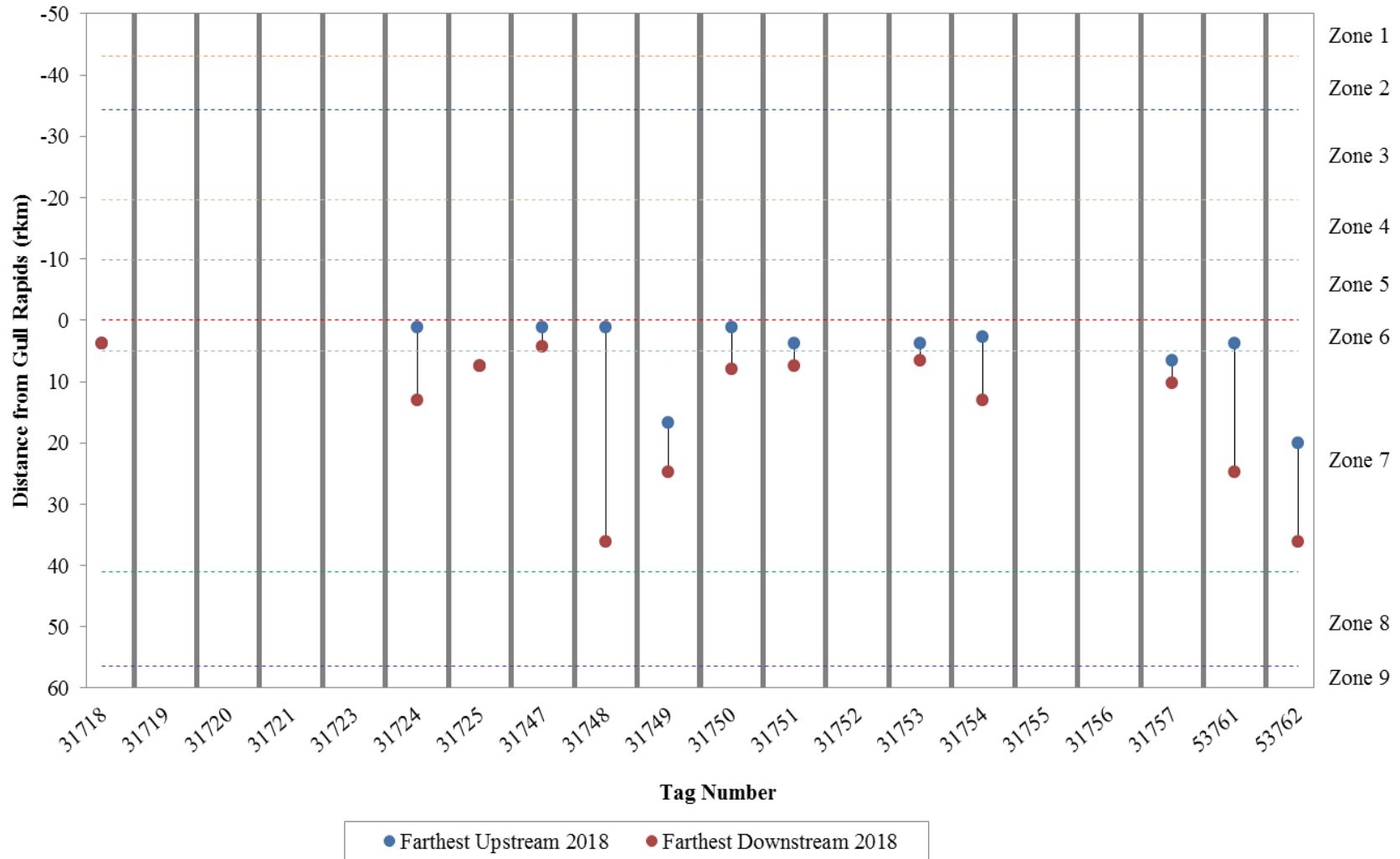
**Figure 11:** Relative number of detections at each acoustic receiver set in the Nelson River between Clark Lake and Gull Rapids during the 2018 open-water period (May 1 to October 10). Number of detections indicated by size of bubble (defined in legend). Receivers with no detections indicated with red dot. The river is divided into five "zones" based on placement of receiver "gates."



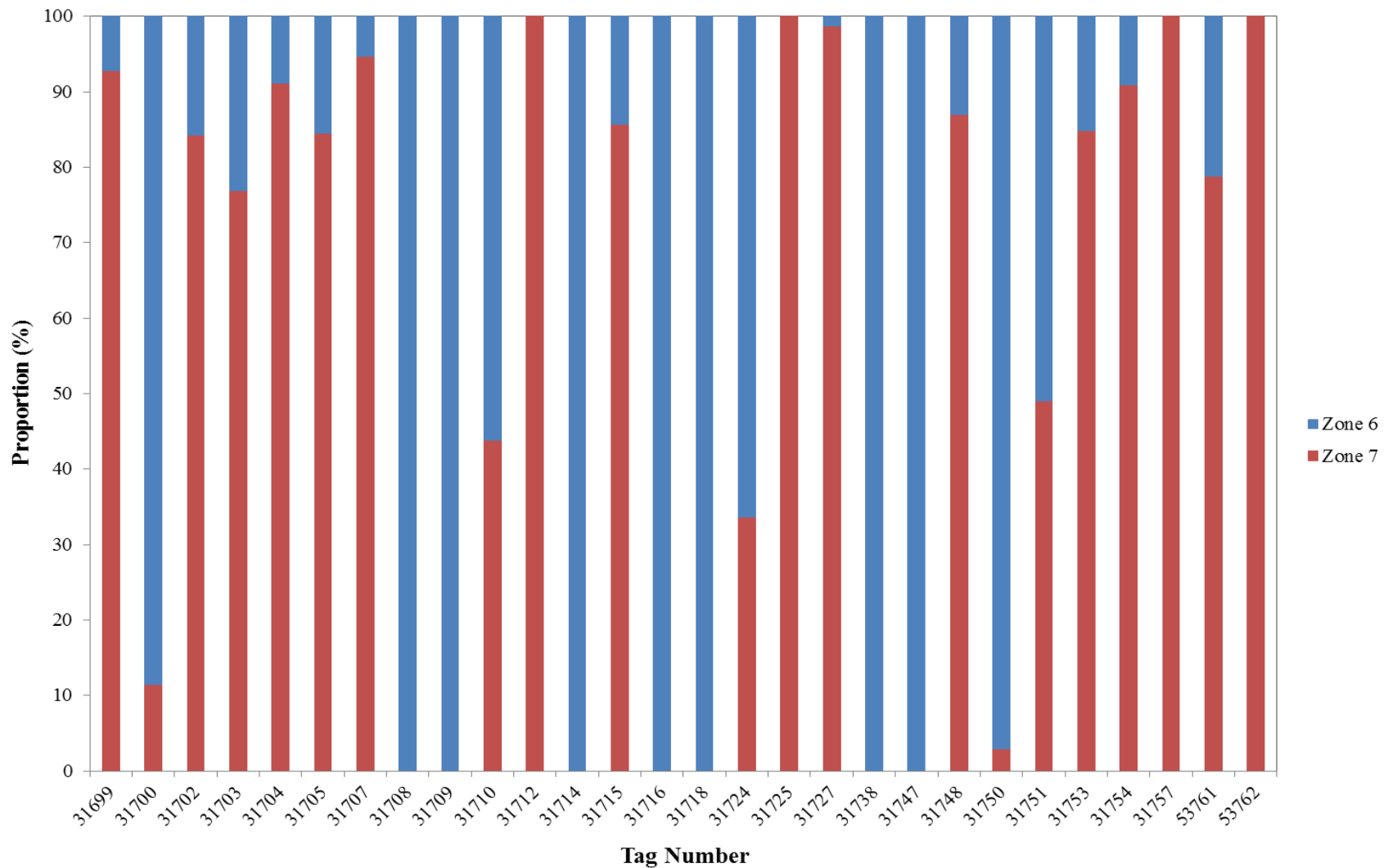
**Figure 12:** Relative number of detections at each acoustic receiver set in the Nelson River between Clark Lake and Gull Rapids during the 2018 spawning period (September 25 to October 10). Spawning period was defined as the period when water temperature fell below 12°C (in order to capture movement of Lake Whitefish to spawning sites) to the end of the study period. Relative number of detections indicated by size of bubble. Receivers with no detections indicated with red dot. The river is divided into five "zones" based on placement of receiver "gates."



**Figure 13: Detection ranges for individual Lake Whitefish (n = 40) tagged with acoustic transmitters in Stephens Lake during the 2018 (May 1 to October 10) open-water period. Horizontal dotted lines demarcate zones. Orange represents the outlet of Clark Lake, blue represents Birthday Rapids, red represents Gull Rapids, green represents the Kettle GS, and purple represents the Long Spruce GS.**

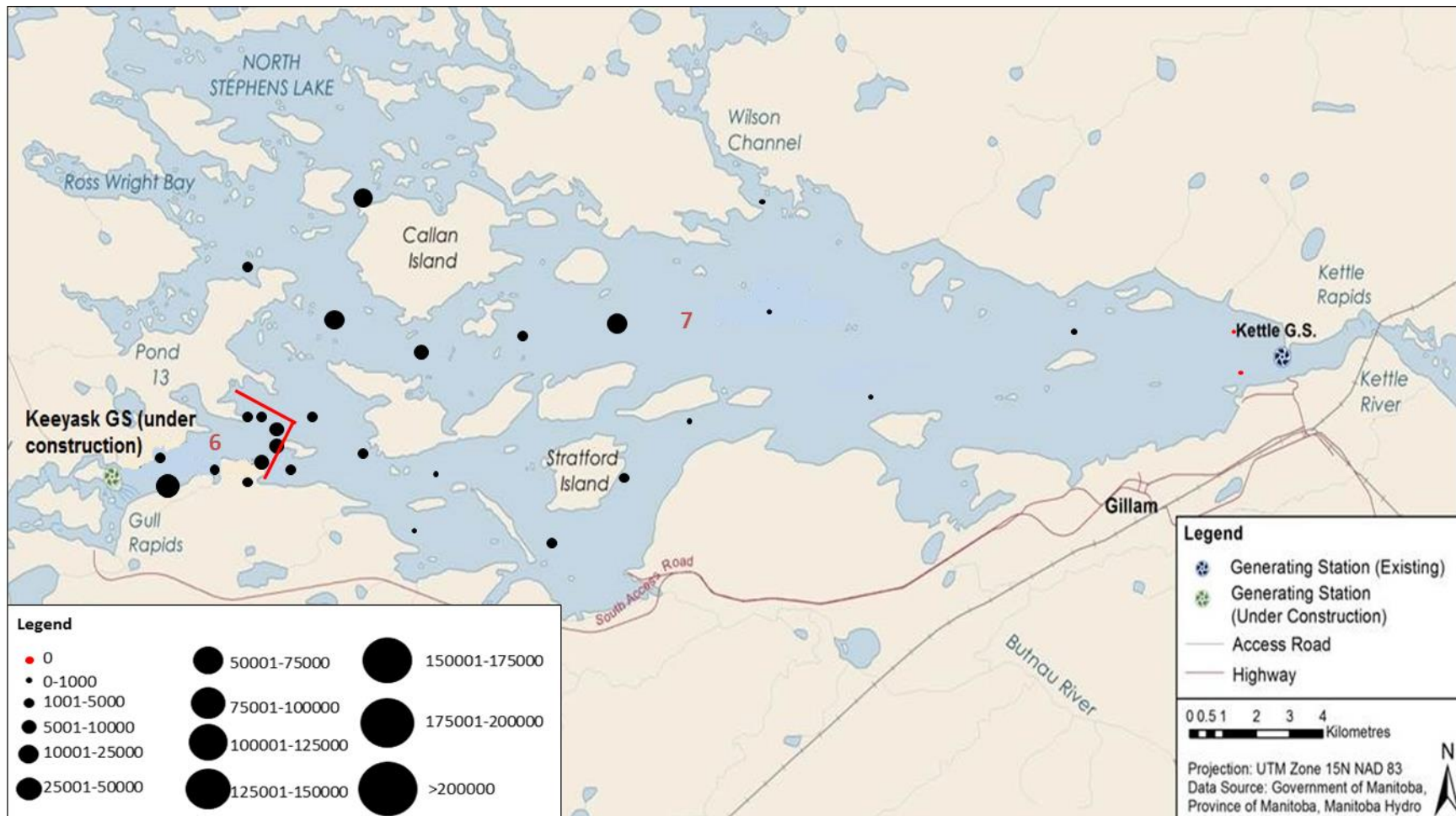


**Figure 13: Detection ranges for individual Lake Whitefish (n = 40) tagged with acoustic transmitters in Stephens Lake during the 2018 (May 1 to October 10) open-water period. Horizontal dotted lines demarcate zones (continued).**



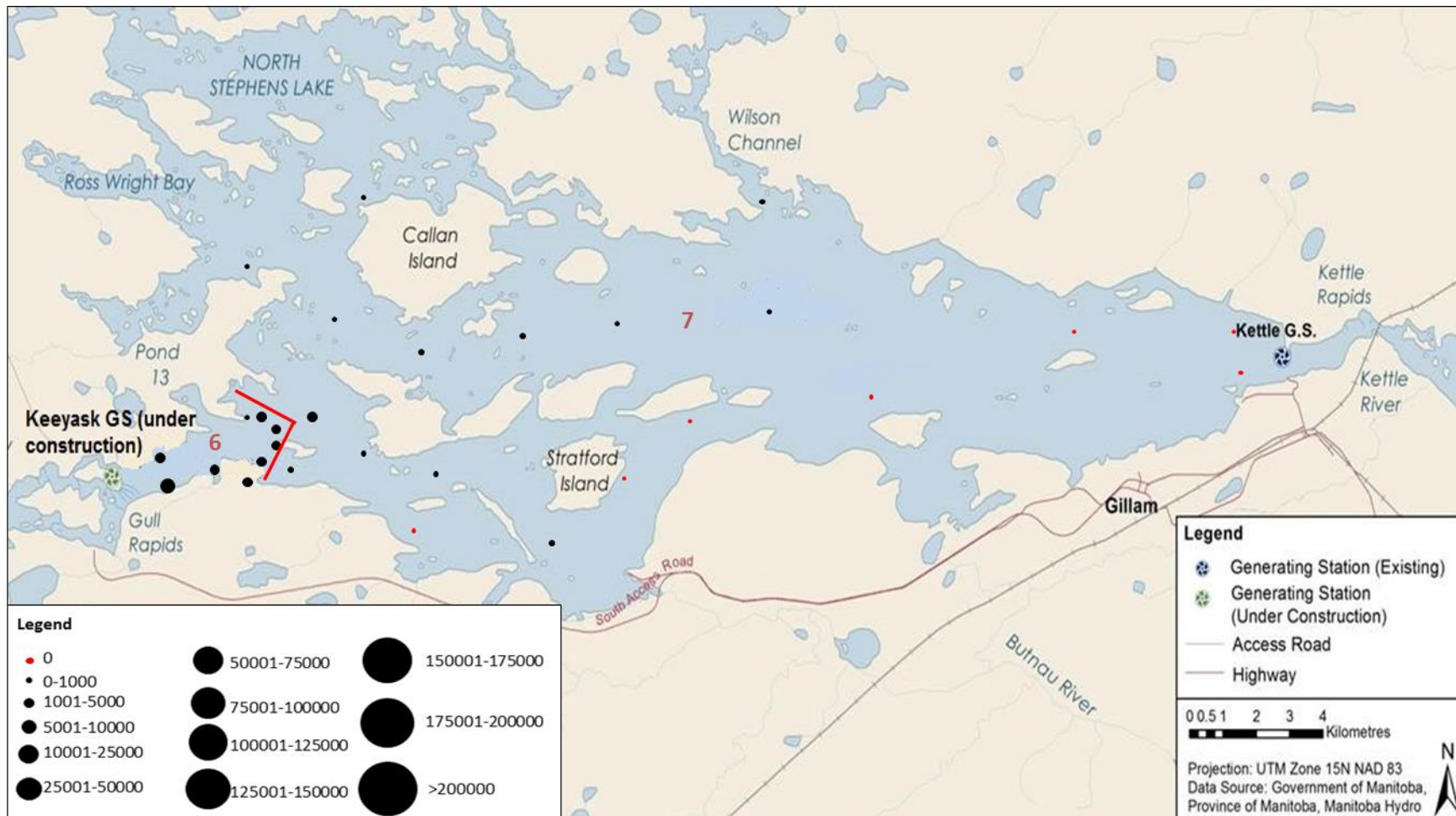
**Figure 14: Proportion of time spent in Stephens Lake between Gull Rapids and the Kettle GS by individual acoustic-tagged Lake Whitefish during the 2018 open-water period (June 6 to October 10).**





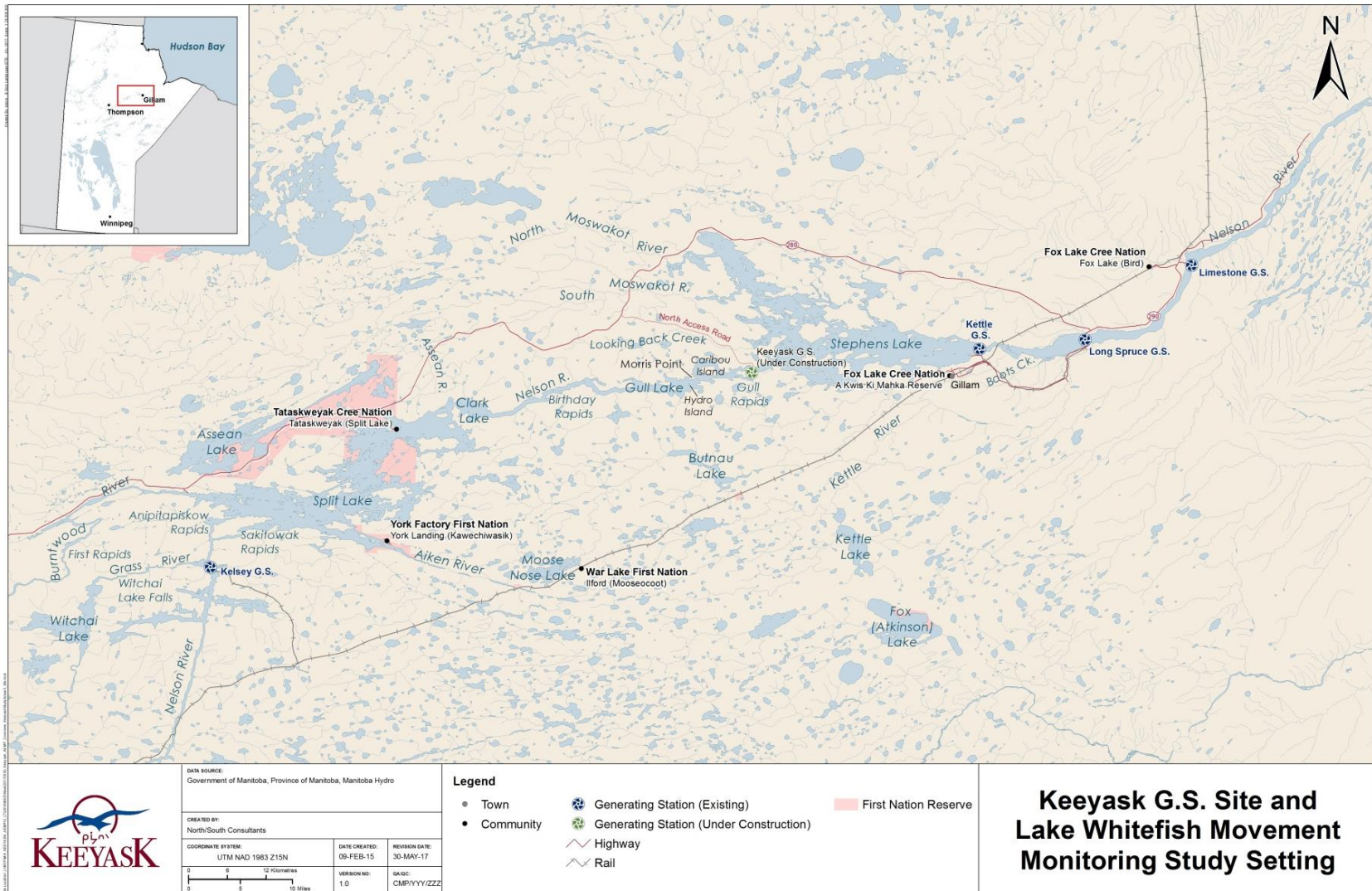
**Figure 15:** Relative number of detections at each acoustic receiver set in Stephens Lake during the 2018 open-water period (May 1 to October 10). Relative number of detections indicated by size of bubble. Receivers with no detections indicated with red dot. The river is divided into two "zones" based on placement of receiver "gates."





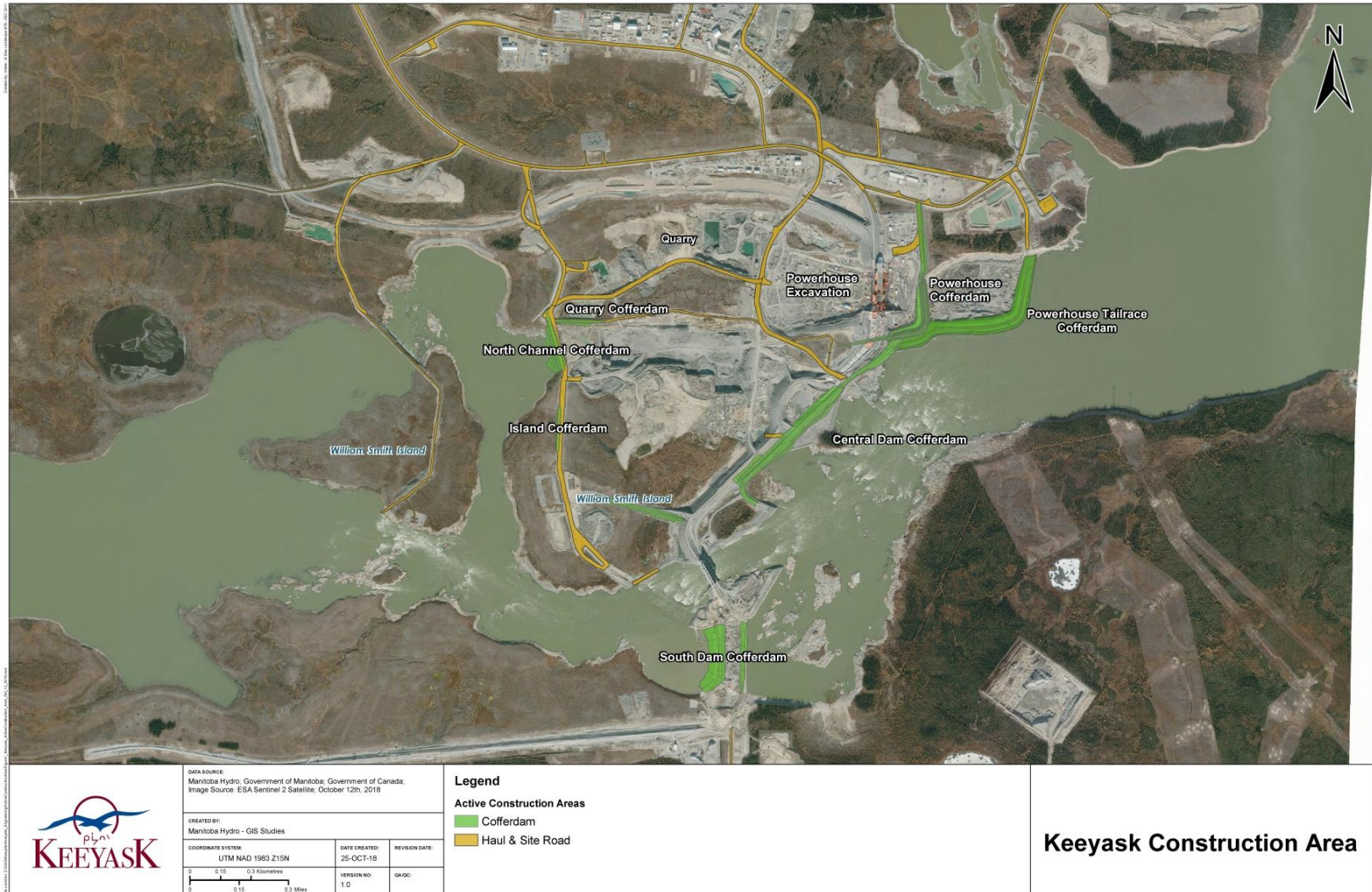
**Figure 16:** Relative number of detections at each acoustic receiver set in Stephens Lake during the 2018 spawning period (September 25 to October 10). Spawning period was defines as the period when water temperature fell below 12°C (in order to capture movement of Lake Whitefish to spawning sites) to the end of the study period. Relative number of detections indicated by size of bubble. Receivers with no detections indicated with red dot. The river is divided into two "zones" based on placement of receiver "gates."

## MAPS

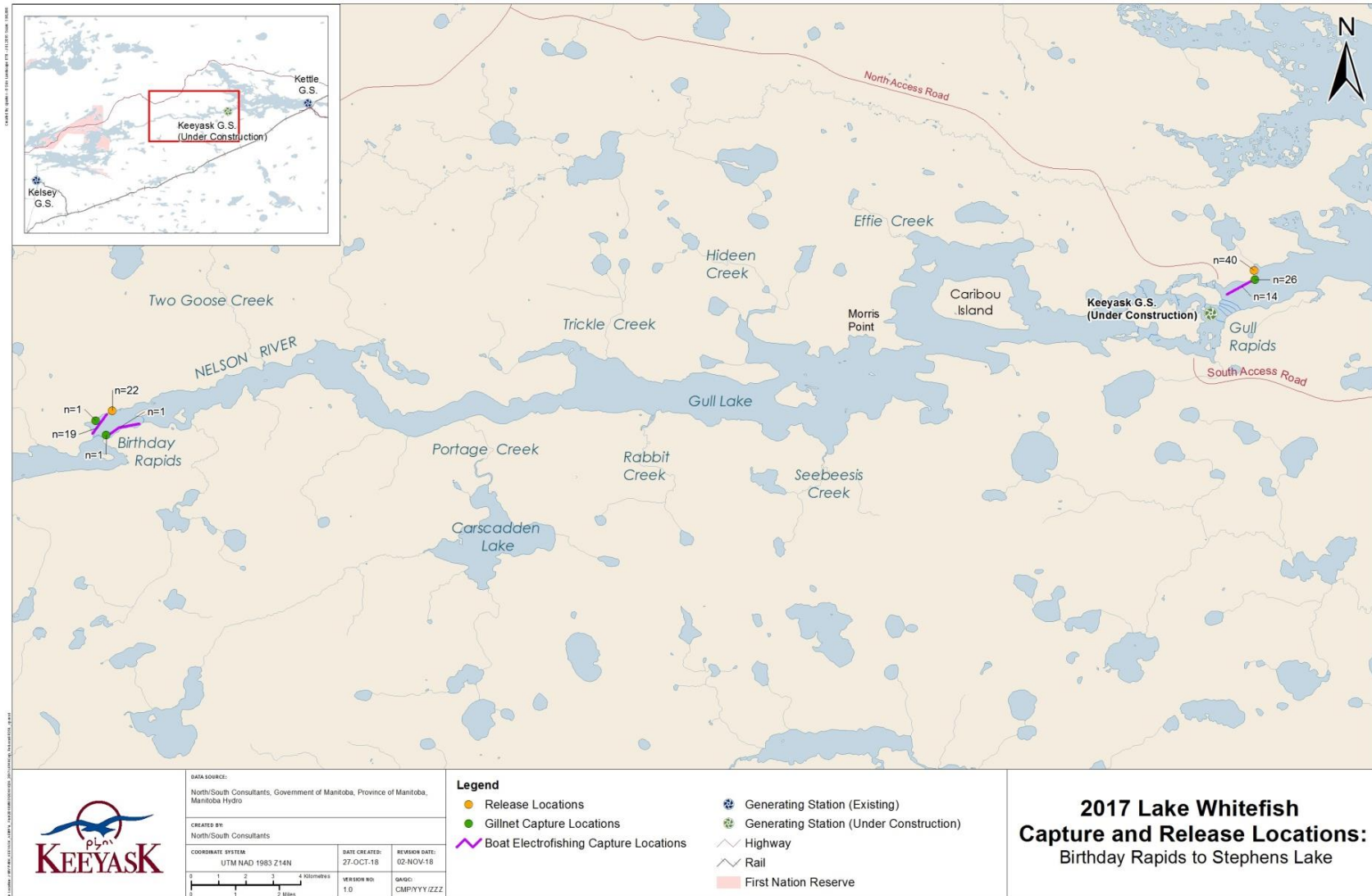


**Map 1: Map of the Nelson River showing the site of the Keeyask Generating Station and the Lake Whitefish movement monitoring study setting.**



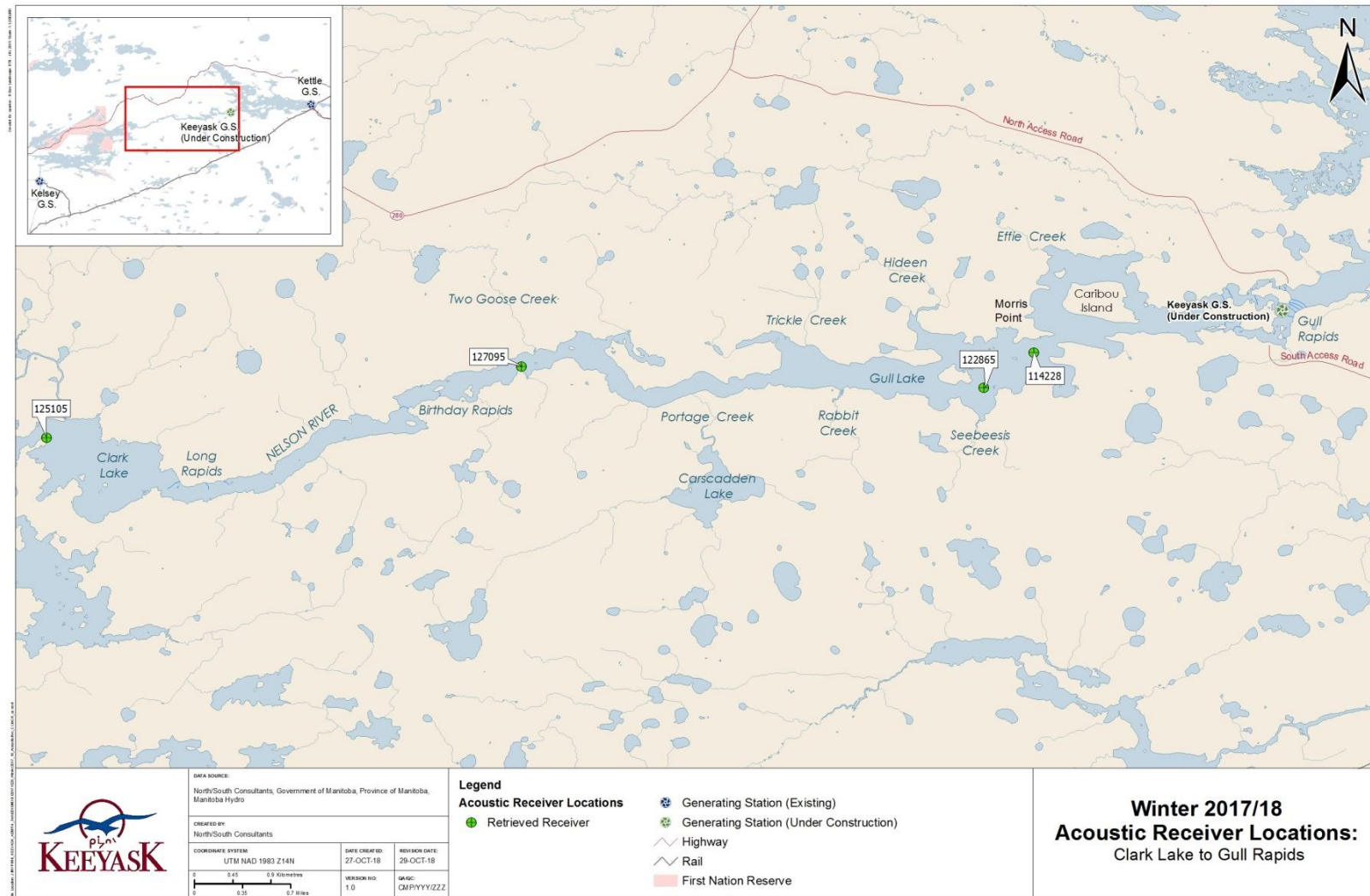


**Map 2: Map of instream structures at the Keeyask Generating Station site, October 2018.**

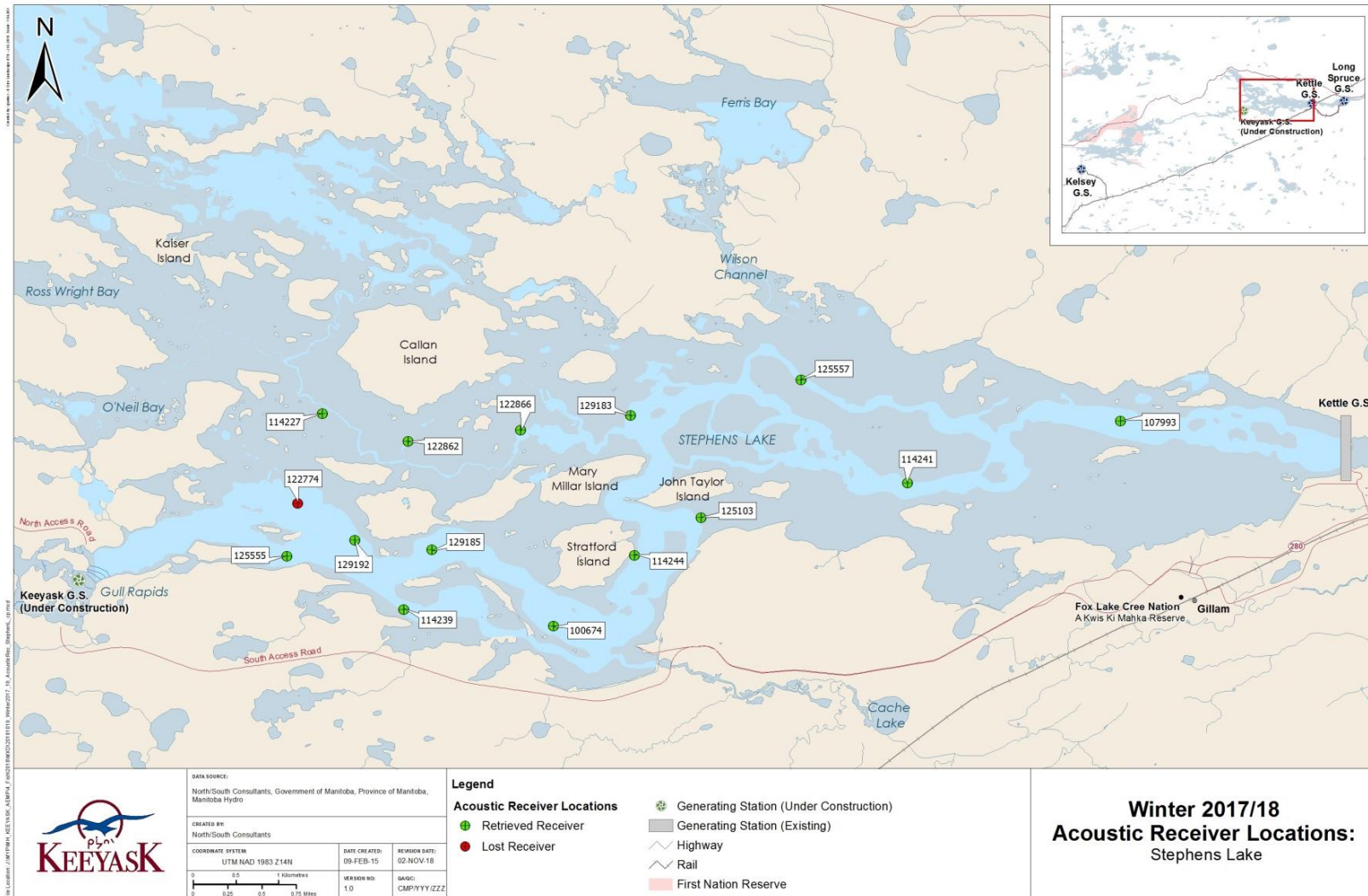


**Map 3: Location of Lake Whitefish acoustic tagging locations, October 2017.**



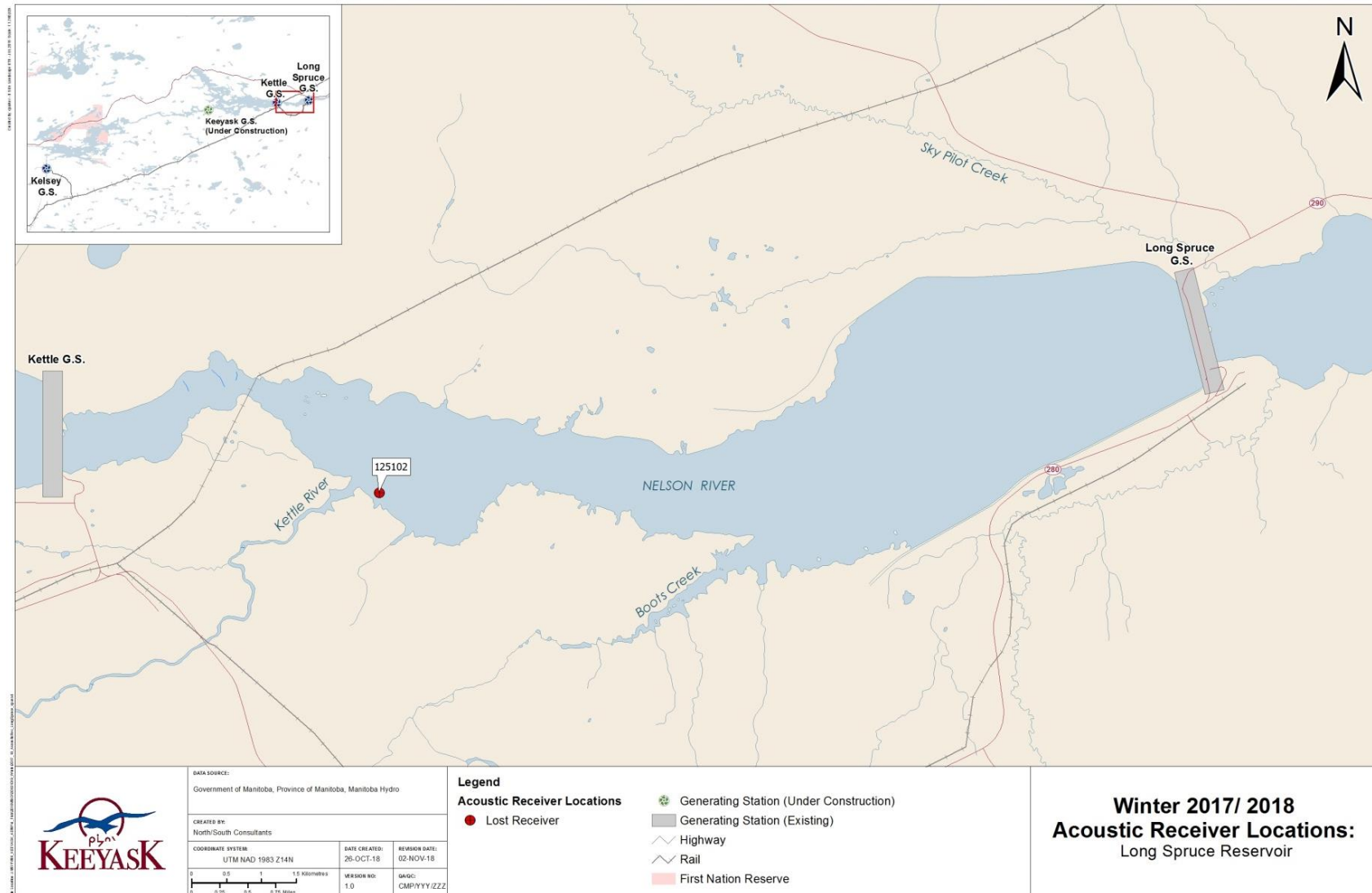


**Map 4: Location of stationary receivers set in the Nelson River from Clark Lake to Gull Rapids between October 2017 and June 2018.**

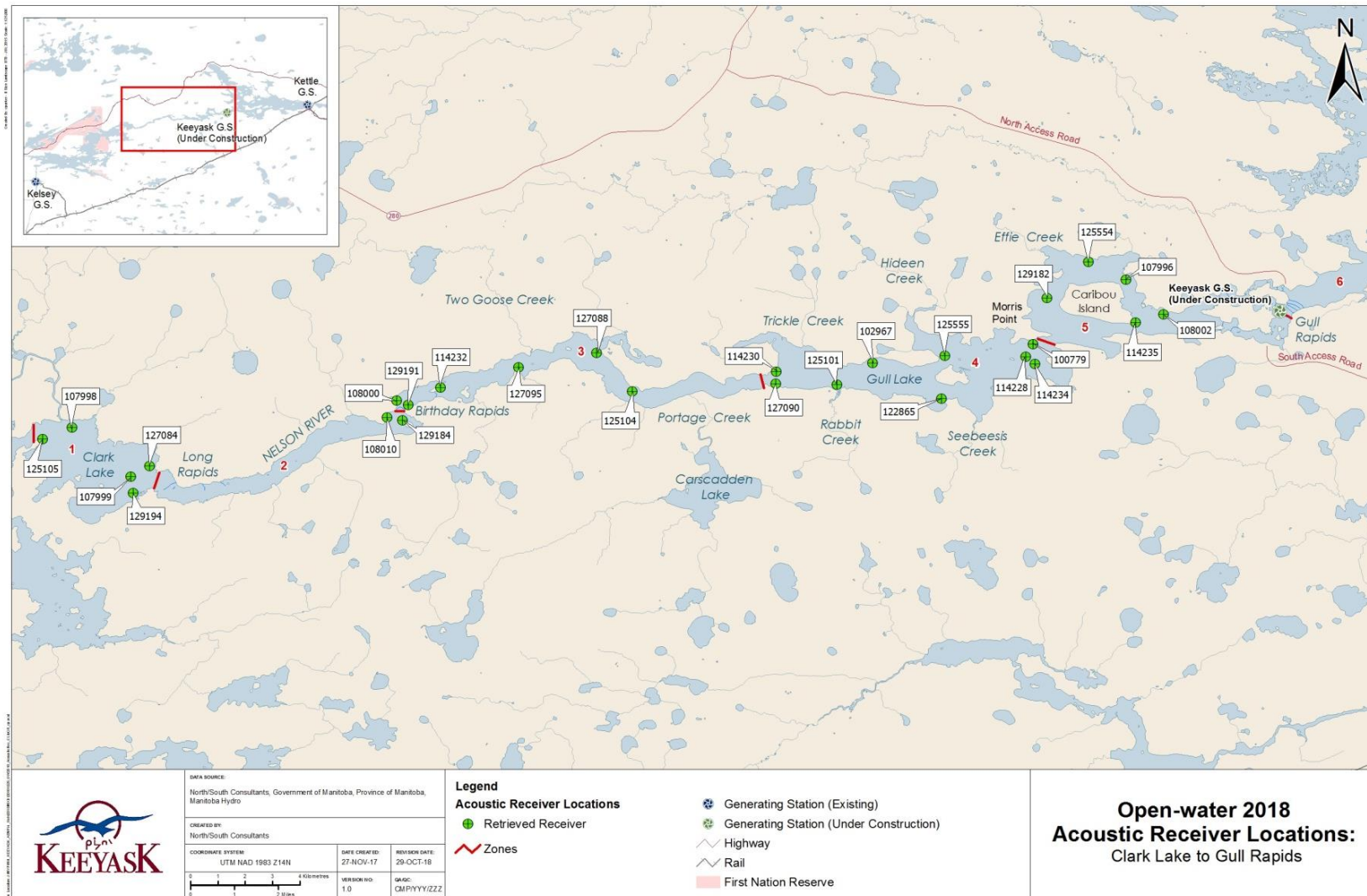


**Map 5: Location of stationary receivers set in Stephens Lake from Gull Rapids to Kettle GS between October 2017 and June 2018. The former (pre-impoundment) river channel is shown in light blue.**

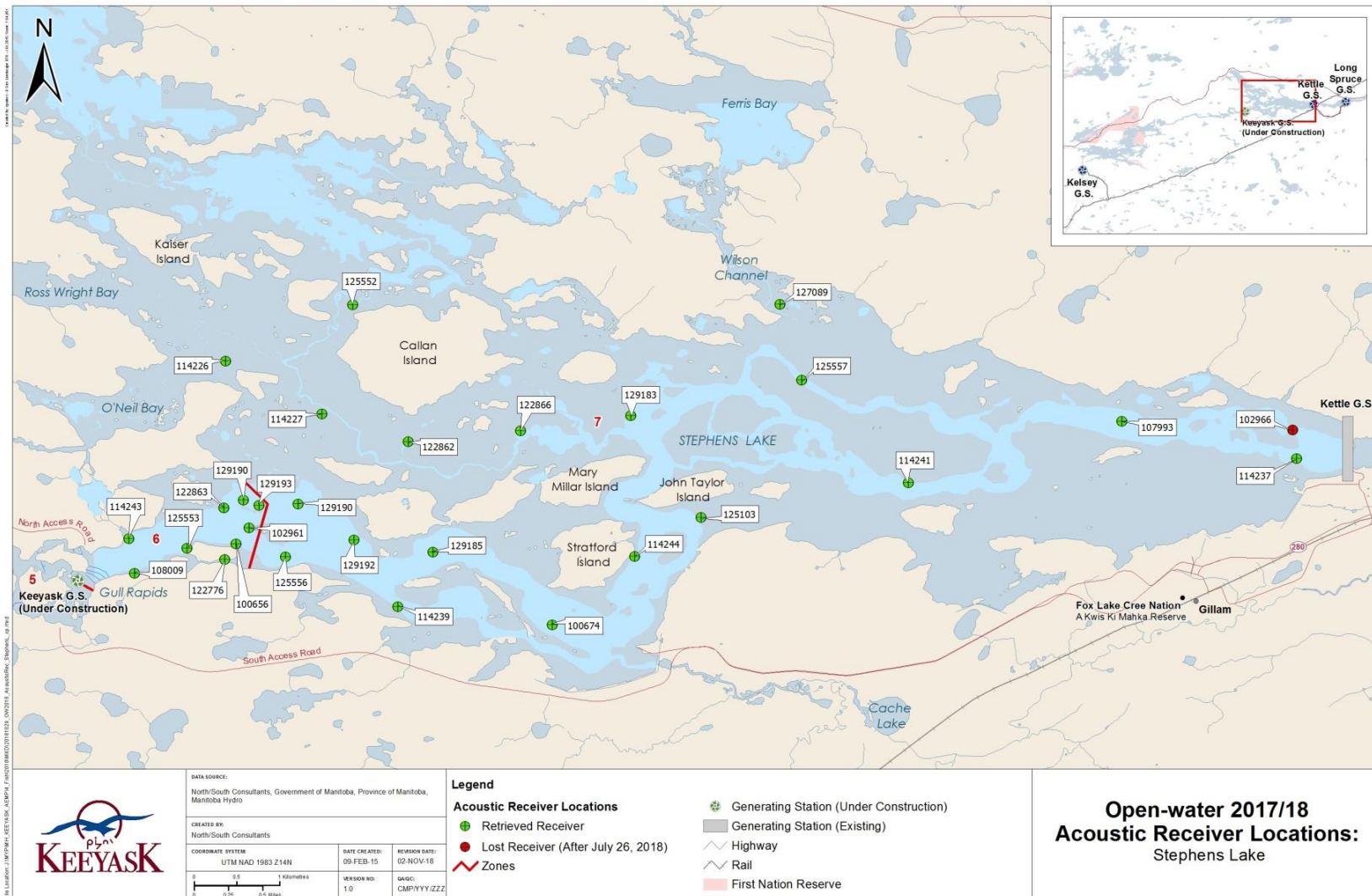




**Map 6: Location of the stationary receiver set in the Long Spruce Reservoir between October 2017 and June 2018.**



**Map 7: Locations of stationary receivers set in the Nelson River from Clark Lake to Gull Rapids between June and October 2018. The river is divided into five "zones" based on placement of receiver "gates."**



**Map 8: Locations of stationary receivers set in Stephens Lake between June and October 2018. The river is divided into two "zones" based on placement of receiver "gates." The pre-impoundment river channel is shown in light blue.**

# APPENDICES

# APPENDIX 1:

## DETECTION SUMMARIES FOR LAKE WHITEFISH TAGGED AND MONITORED IN THE KEEYASK STUDY AREA BETWEEN 2014 AND 2017.

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Table A1-1:	Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometre (rkm) detection sites, and detection range for Lake Whitefish tagged upstream of Gull Rapids during the 2017/2018 (October 17 to April 30) winter period. ....	55
Table A1-2:	Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometre (rkm) detection sites, and detection range for Lake Whitefish tagged in Stephens Lake during the 2017/18 (October 12, 2015 to April 30, 2016) winter period. ....	56
Table A1-3:	Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometre (rkm) detection sites, and detection range for Lake Whitefish tagged upstream of Gull Rapids during the 2018 (May 1 to October 10) open-water periods. ....	58
Table A1-4:	Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometre (rkm) detection sites, and detection range for Lake Whitefish tagged in Stephens Lake during the 2018 (May 1 to October 6) open-water period. ....	59



**Table A1-1: Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometre (rkm) detection sites, and detection range for Lake Whitefish tagged upstream of Gull Rapids during the 2017/2018 (October 17 to April 30) winter period. Fish that moved downstream through Gull Rapids are highlighted in blue.**

Tag ID	Date Tagged	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)
31722	07-Oct-17	3	1	-29.4	-29.4	0.0
31726	12-Oct-17	13	2	-29.4	-29.4	0.0
31727	12-Oct-17	132	5	-29.4	-10.3	19.1
31728	14-Oct-17	8	1	-29.4	-29.4	0.0
31729	14-Oct-17	5	1	-29.4	-29.4	0.0
31730	14-Oct-17	106	3	-29.4	-10.3	19.1
31731	14-Oct-17	153	5	-29.4	-29.4	0.0
31732	12-Oct-17	14	1	-29.4	-29.4	0.0
31733	14-Oct-17	9	1	-29.4	-29.4	0.0
31734	14-Oct-17	5914	16	-29.4	-10.3	19.1
31735	12-Oct-17	50	2	-29.4	-10.3	19.1
31736	12-Oct-17	26	1	-29.4	-29.4	0.0
31737	12-Oct-17	138	4	-29.4	-10.3	19.1
31738	11-Oct-17	227	7	-29.4	-10.3	19.1
31739	11-Oct-17	145	3	-29.4	-12.4	17.0
31740	11-Oct-17	948	11	-29.4	18.6	48.0
31741	11-Oct-17	9	1	-29.4	-29.4	0.0
31742	11-Oct-17	3	1	-29.4	-29.4	0.0
31743	11-Oct-17	4	1	-29.4	-29.4	0.0
31744	11-Oct-17	280	14	-29.4	-12.4	17.0
31745	11-Oct-17	-	-	-	-	-
31746	11-Oct-17	434	5	-29.4	-29.4	0.0

**Table A1-2: Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometre (rkm) detection sites, and detection range for Lake Whitefish tagged in Stephens Lake during the 2017/18 (October 12, 2015 to April 30, 2016) winter period.**

Tag ID	Date Tagged	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)
31698	09-Oct-17	-	-	-	-	-
31699	09-Oct-17	16567	160	5.2	18.6	13.4
31700	09-Oct-17	69	3	6.5	6.5	0.0
31701	09-Oct-17	-	-	-	-	-
31702	09-Oct-17	8556	66	5.2	36.1	30.9
31703	09-Oct-17	7	2	6.5	6.5	0.0
31704	09-Oct-17	1111	22	5.2	36.1	30.9
31705	09-Oct-17	44	1	6.5	6.5	0.0
31706	09-Oct-17	-	-	-	-	-
31707	09-Oct-17	7193	61	6.5	8.4	1.9
31708	09-Oct-17	-	-	-	-	-
31709	09-Oct-17	841	18	5.2	21.6	16.4
31710	09-Oct-17	34	3	6.5	8.4	1.9
31711	09-Oct-17	154	5	5.2	24.7	19.5
31712	09-Oct-17	12134	73	5.2	16.8	11.6
31713	09-Oct-17	-	-	-	-	-
31714	09-Oct-17	77	3	5.2	7.9	2.7
31715	09-Oct-17	-	-	-	-	-
31716	08-Oct-17	426	3	6.5	7.9	1.4
31717	08-Oct-17	173	2	5.2	24.7	19.5
31718	09-Oct-17	-	-	-	-	-
31719	09-Oct-17	-	-	-	-	-
31720	09-Oct-17	-	-	-	-	-
31721	08-Oct-17	-	-	-	-	-
31723	10-Oct-17	36	2	5.2	6.5	1.3
31724	10-Oct-17	35	2	6.5	8.4	1.9
31725	10-Oct-17	29	1	5.2	7.9	2.7
31747	10-Oct-17	46	2	36.1	36.1	0.0
31748	10-Oct-17	52985	179	5.2	21.6	16.4
31749	10-Oct-17	1100	13	6.5	21.6	15.1



**Table A1-2: Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometre (rkm) detection sites, and detection range for Lake Whitefish tagged in Stephens Lake during the 2017/18 (October 12, 2015 to April 30, 2016) winter period (continued).**

Tag ID	Date Tagged	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)
31750	10-Oct-17	503	5	5.2	6.5	1.3
31751	10-Oct-17	-	-	-	-	-
31752	10-Oct-17	736	16	6.5	21.6	15.1
31753	10-Oct-17	1414	10	6.5	8.4	1.9
31754	10-Oct-17	9850	73	5.2	8.4	3.2
31755	10-Oct-17	-	-	-	-	-
31756	10-Oct-17	346	5	6.5	36.1	29.6
31757	10-Oct-17	6	2	6.5	6.5	0.0
53761	10-Oct-17	-	-	-	-	-
53762	09-Oct-17	-	-	-	-	-

**Table A1-3: Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometre (rkm) detection sites, and detection range for Lake Whitefish tagged upstream of Gull Rapids during the 2018 (May 1 to October 10) open-water periods. Fish that moved downstream through Gull Rapids are highlighted in blue.**

Tag ID	Date Tagged	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)
31722	07-Oct-17	6868	62	-29.4	-12.8	16.6
31726	12-Oct-17	13454	93	-19.5	-12.8	6.7
31727	12-Oct-17	6891	86	1.2	18.6	17.4
31728	14-Oct-17	16398	77	-33.8	-26.5	7.3
31729	14-Oct-17	11540	70	-33.8	-9.3	24.5
31730	14-Oct-17	18066	73	-33.8	-9.9	23.9
31731	14-Oct-17	105	13	-19.5	-19.5	0.0
31732	12-Oct-17	3780	73	-12.9	-9.3	3.6
31733	14-Oct-17	14460	74	-33.8	-26.5	7.3
31734	14-Oct-17	2432	26	-19.5	-9.9	9.6
31735	12-Oct-17	2746	25	-9.3	-4.8	4.5
31736	12-Oct-17	16257	82	-33.8	-9.9	23.9
31737	12-Oct-17	4807	62	-19.5	-5.8	13.7
31738	11-Oct-17	4222	73	-9.9	1.2	11.1
31739	11-Oct-17	4182	40	-19.5	-9.9	9.6
31740	11-Oct-17	-	-	-	-	-
31741	11-Oct-17	17796	113	-33.8	-9.0	24.8
31742	11-Oct-17	1990	36	-33.8	-12.9	20.9
31743	11-Oct-17	19757	92	-33.8	-7.4	26.4
31744	11-Oct-17	440	7	-26.5	-12.8	13.7
31745	11-Oct-17	9343	93	-33.8	-4.8	29.0
31746	11-Oct-17	26627	121	-19.5	-7.4	12.1

**Table A1-4: Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometre (rkm) detection sites, and detection range for Lake Whitefish tagged in Stephens Lake during the 2018 (May 1 to October 6) open-water period.**

Tag ID	Date Tagged	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)
31698	09-Oct-17	-	-	-	-	-
31699	09-Oct-17	13497	113	3.8	18.6	14.8
31700	09-Oct-17	1789	46	2.7	7.9	5.2
31701	09-Oct-17	-	-	-	-	-
31702	09-Oct-17	11844	65	1.2	9.4	8.2
31703	09-Oct-17	2854	19	1.2	7.4	6.2
31704	09-Oct-17	1888	24	1.2	36.1	34.9
31705	09-Oct-17	932	5	1.2	7.4	6.2
31706	09-Oct-17	-	-	-	-	-
31707	09-Oct-17	13071	31	3.8	7.4	3.6
31708	09-Oct-17	21	5	1.2	1.2	0.0
31709	09-Oct-17	7230	11	1.2	7.9	6.7
31710	09-Oct-17	361	14	3.8	7.4	3.6
31711	09-Oct-17	-	-	-	-	-
31712	09-Oct-17	5045	43	6.5	24.7	18.2
31713	09-Oct-17	-	-	-	-	-
31714	09-Oct-17	77	4	3.8	3.8	0.0
31715	09-Oct-17	1024	5	1.2	7.4	6.2
31716	08-Oct-17	34874	75	1.2	2.7	1.5
31717	08-Oct-17	-	-	-	-	-
31718	09-Oct-17	64	2	3.8	3.8	0.0
31719	09-Oct-17	-	-	-	-	-
31720	09-Oct-17	-	-	-	-	-
31721	08-Oct-17	-	-	-	-	-
31723	10-Oct-17	-	-	-	-	-
31724	10-Oct-17	11143	54	1.2	13	11.8
31725	10-Oct-17	62	1	7.4	7.4	0.0
31747	10-Oct-17	249	4	1.2	4.4	3.2
31748	10-Oct-17	8800	94	1.2	36.1	34.9
31749	10-Oct-17	52	6	16.8	24.7	7.9

**Table A1-4: Number of detections (n), number of days detected, farthest upstream (U/S) and downstream (D/S) river kilometre (rkm) detection sites, and detection range for Lake Whitefish tagged in Stephens Lake during the 2018 (May 1 to October 6) open-water period (continued).**

Tag ID	Date Tagged	n	# Days	U/S (rkm)	D/S (rkm)	Range (rkm)
31750	10-Oct-17	5820	21	1.2	7.9	6.7
31751	10-Oct-17	15	2	3.8	7.4	3.6
31752	10-Oct-17	-	-	-	-	-
31753	10-Oct-17	5106	53	3.8	6.5	2.7
31754	10-Oct-17	4662	53	2.7	13.0	10.3
31755	10-Oct-17	-	-	-	-	-
31756	10-Oct-17	-	-	-	-	-
31757	10-Oct-17	404	6	6.5	10.3	3.8
53761	10-Oct-17	1817	46	3.8	24.7	20.9
53762	09-Oct-17	61	4	20.0	36.1	16.1

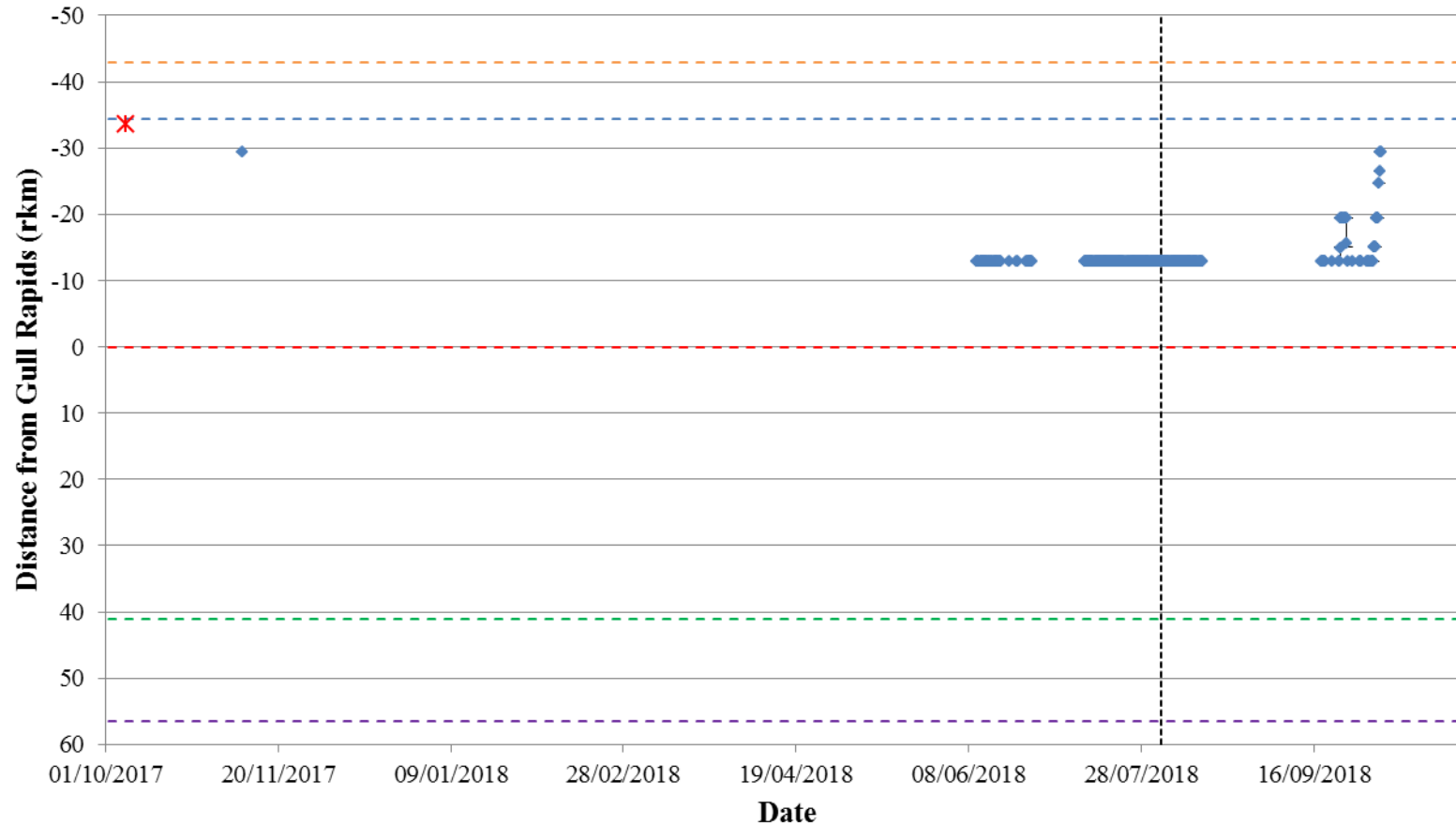
## APPENDIX 2:

# LOCATION SUMMARY FOR INDIVIDUAL ACOUSTIC-TAGGED LAKE WHITEFISH IN GULL LAKE, OCTOBER 2017 TO OCTOBER 2018

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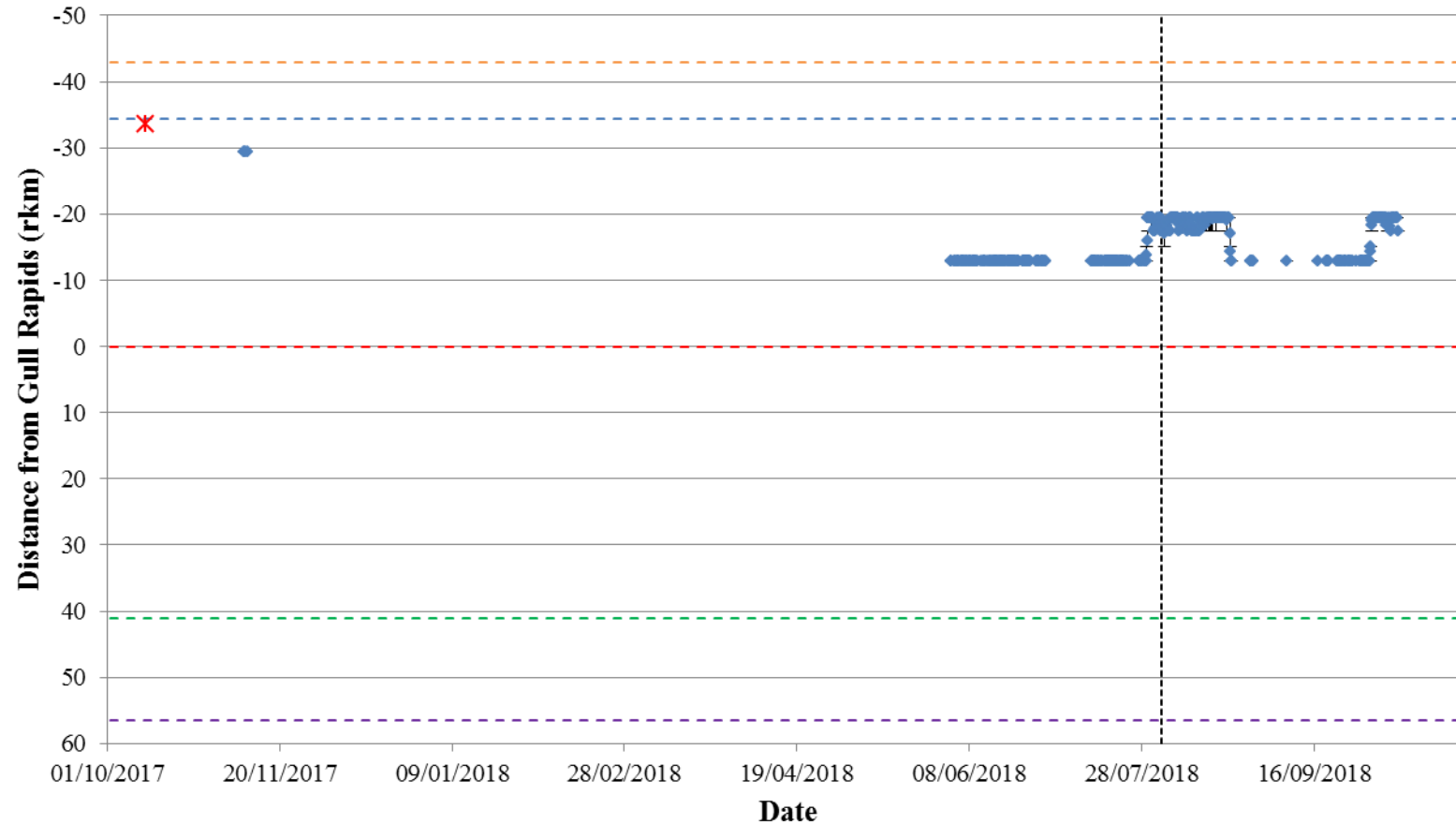
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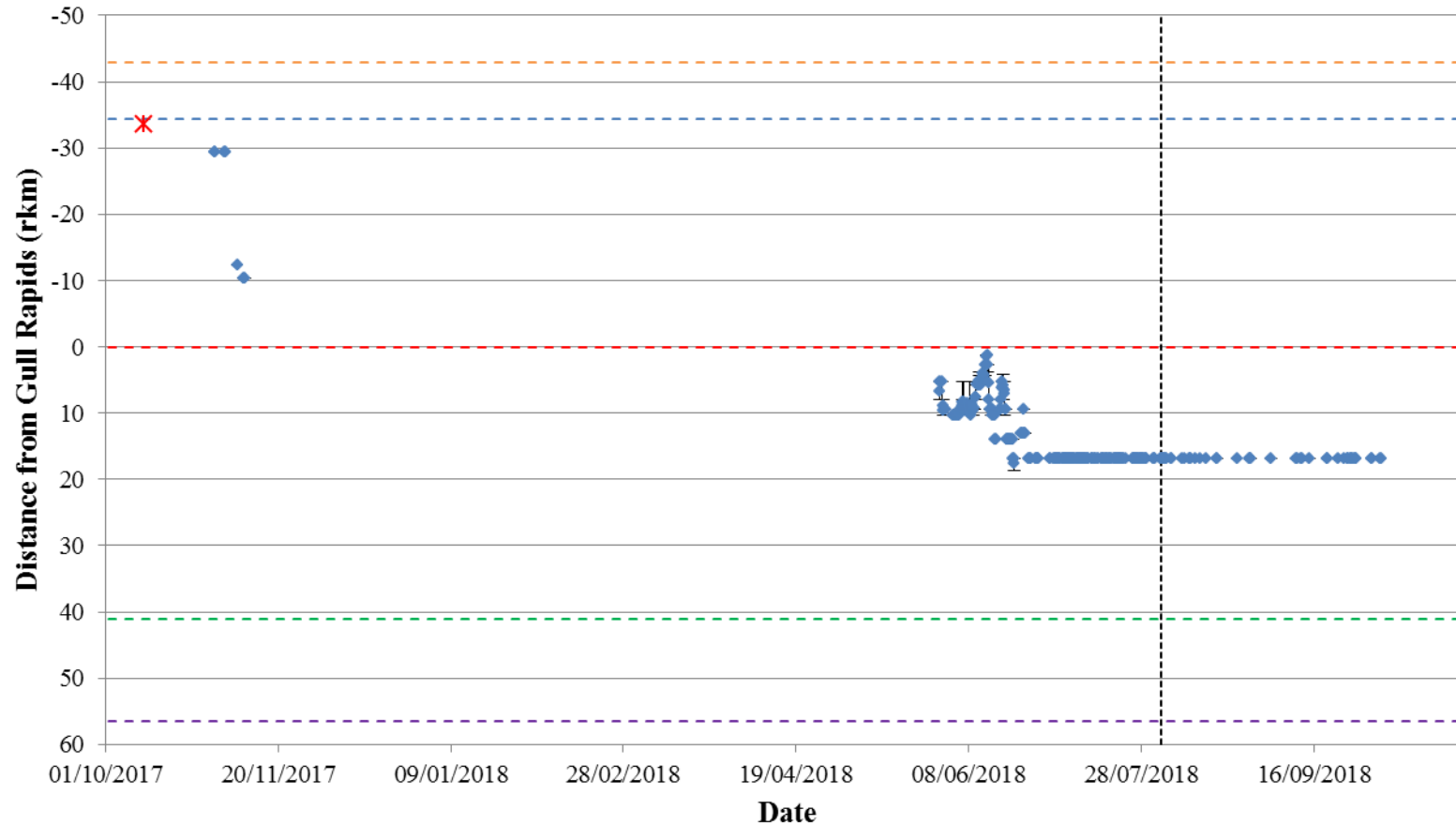


**Figure A2-1: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31722) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

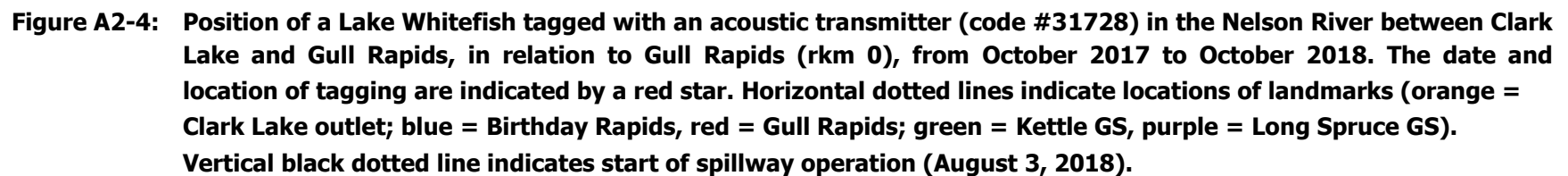


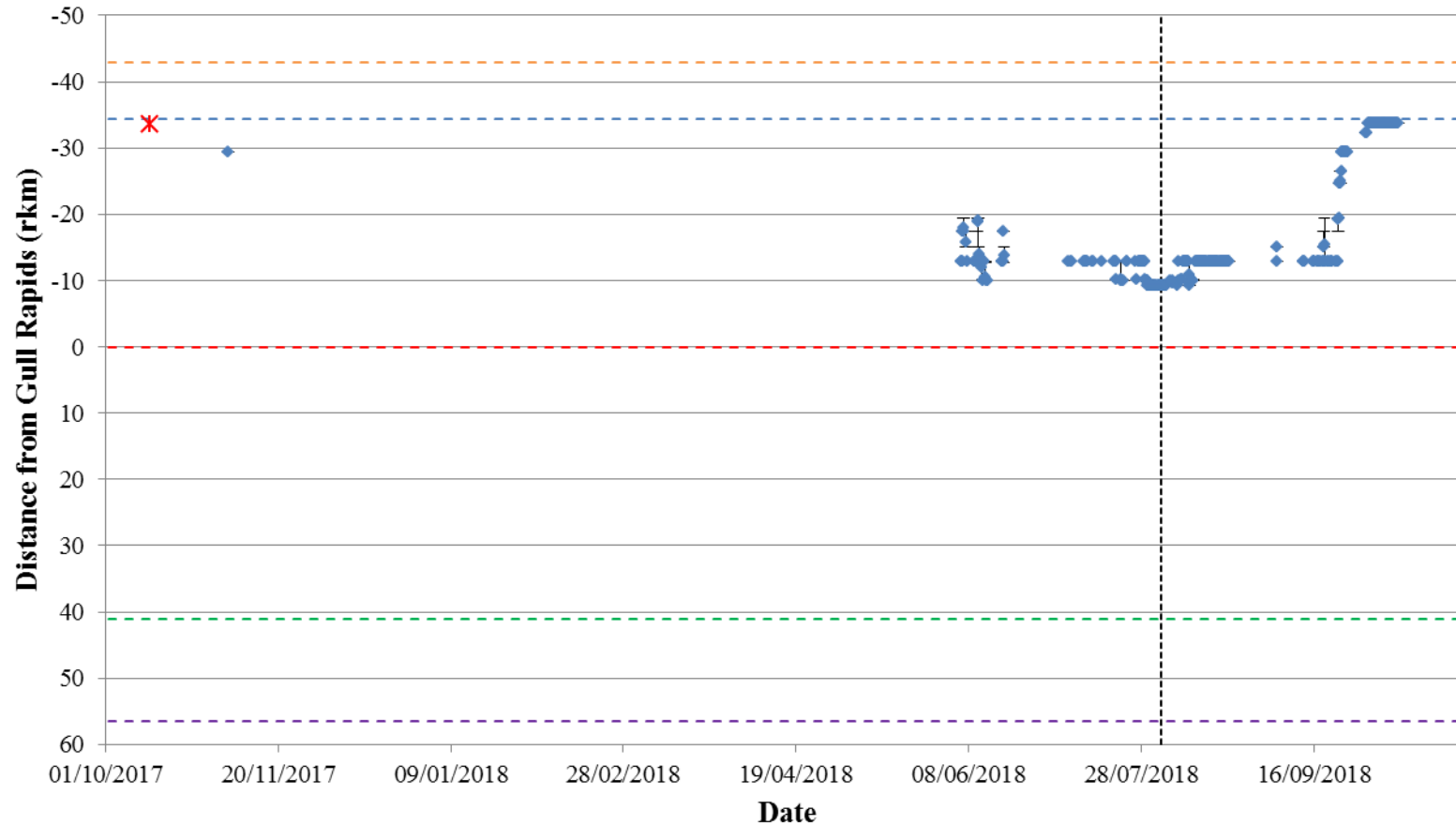


**Figure A2-2: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31726) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

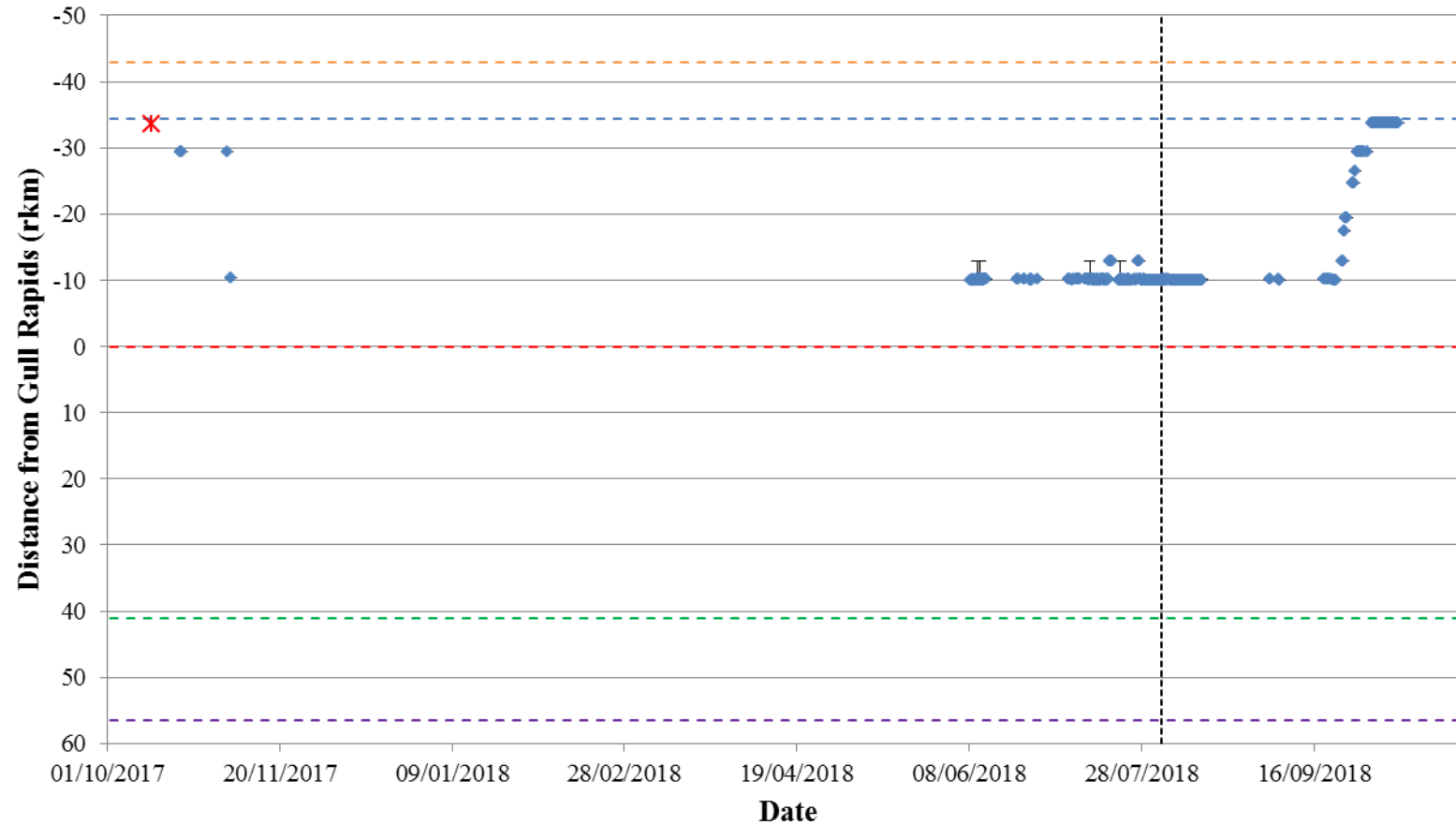


**Figure A2-3: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31727) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

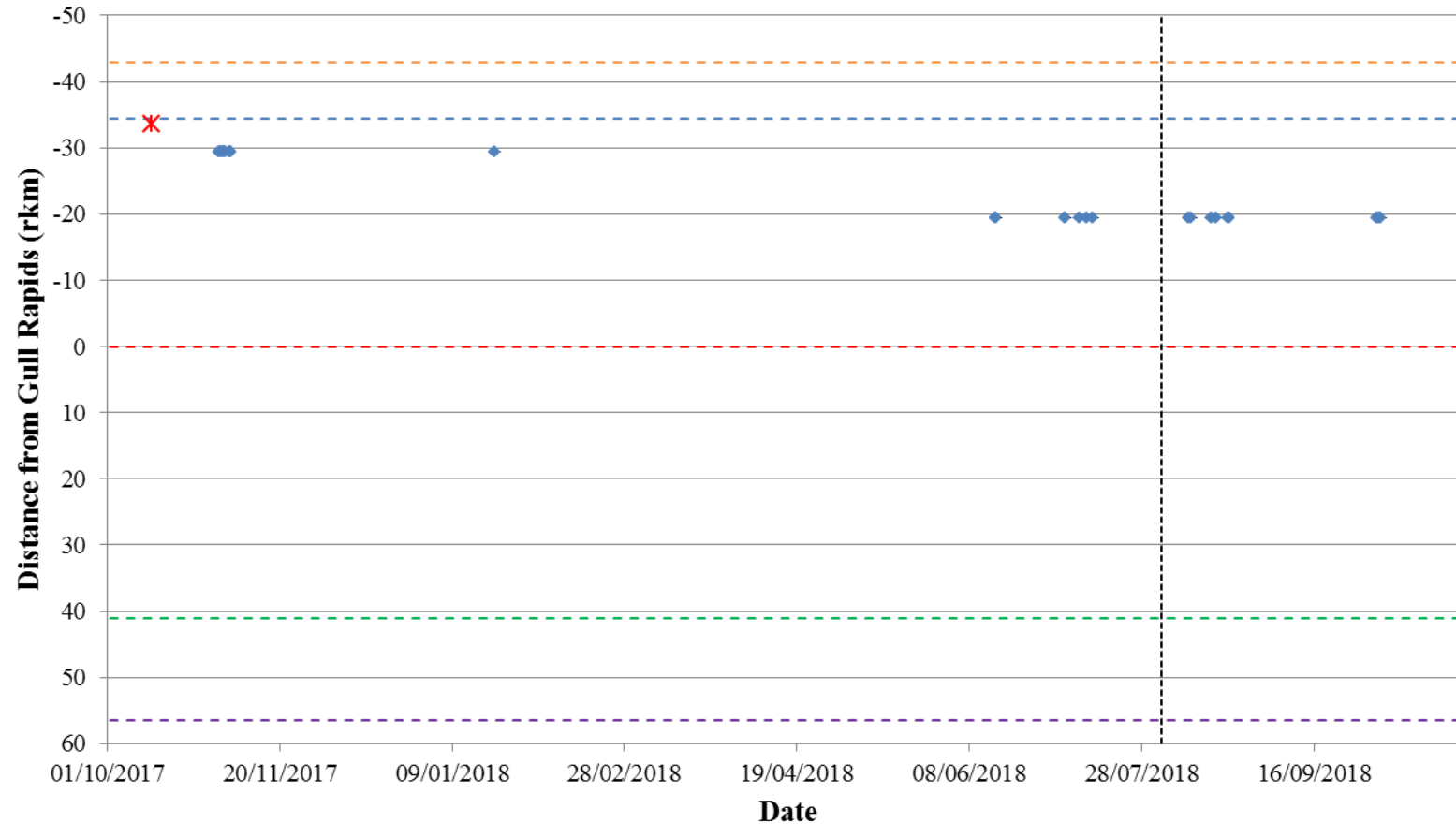




**Figure A2-5: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31729) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

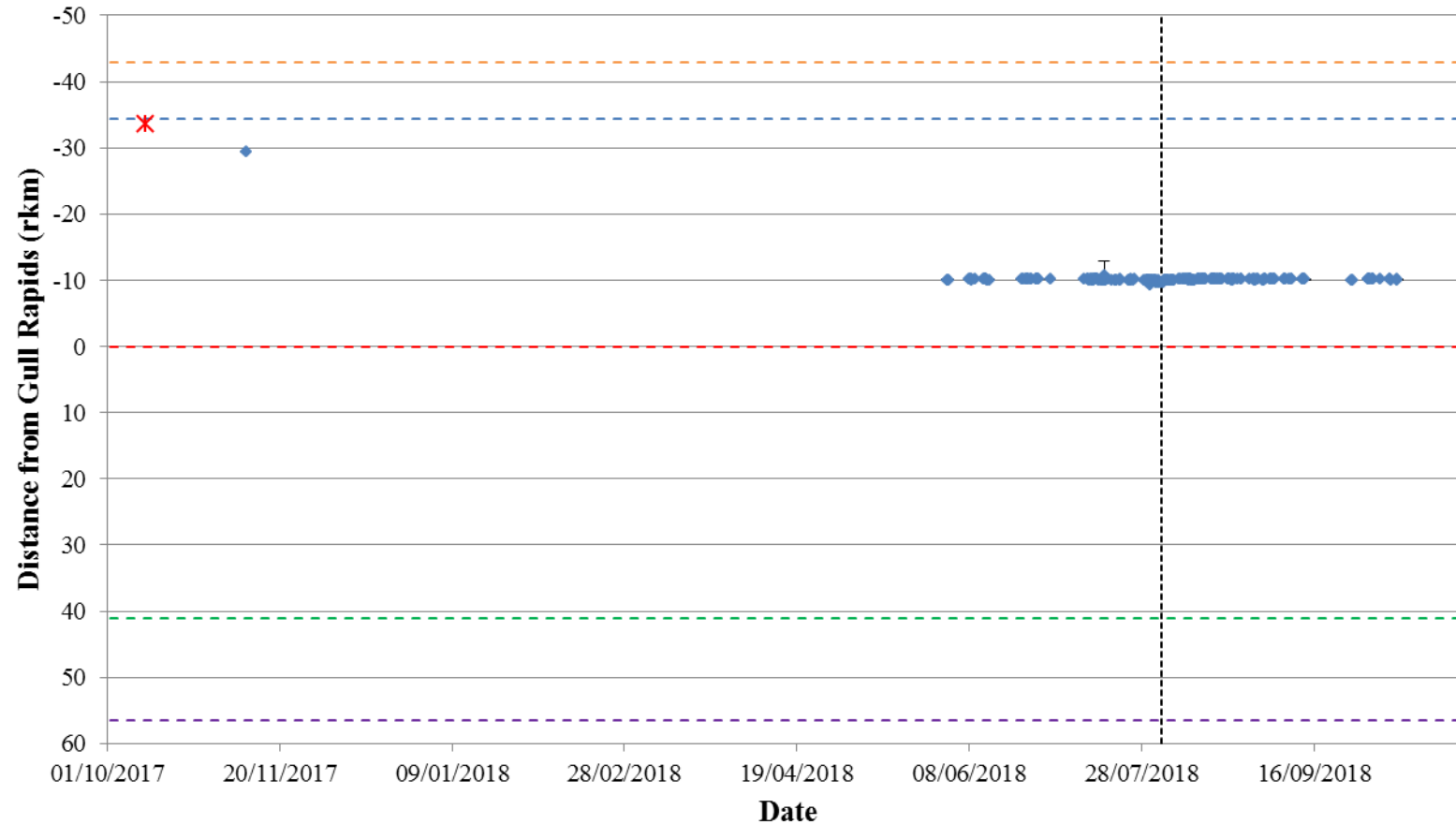


**Figure A2-6: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31730) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

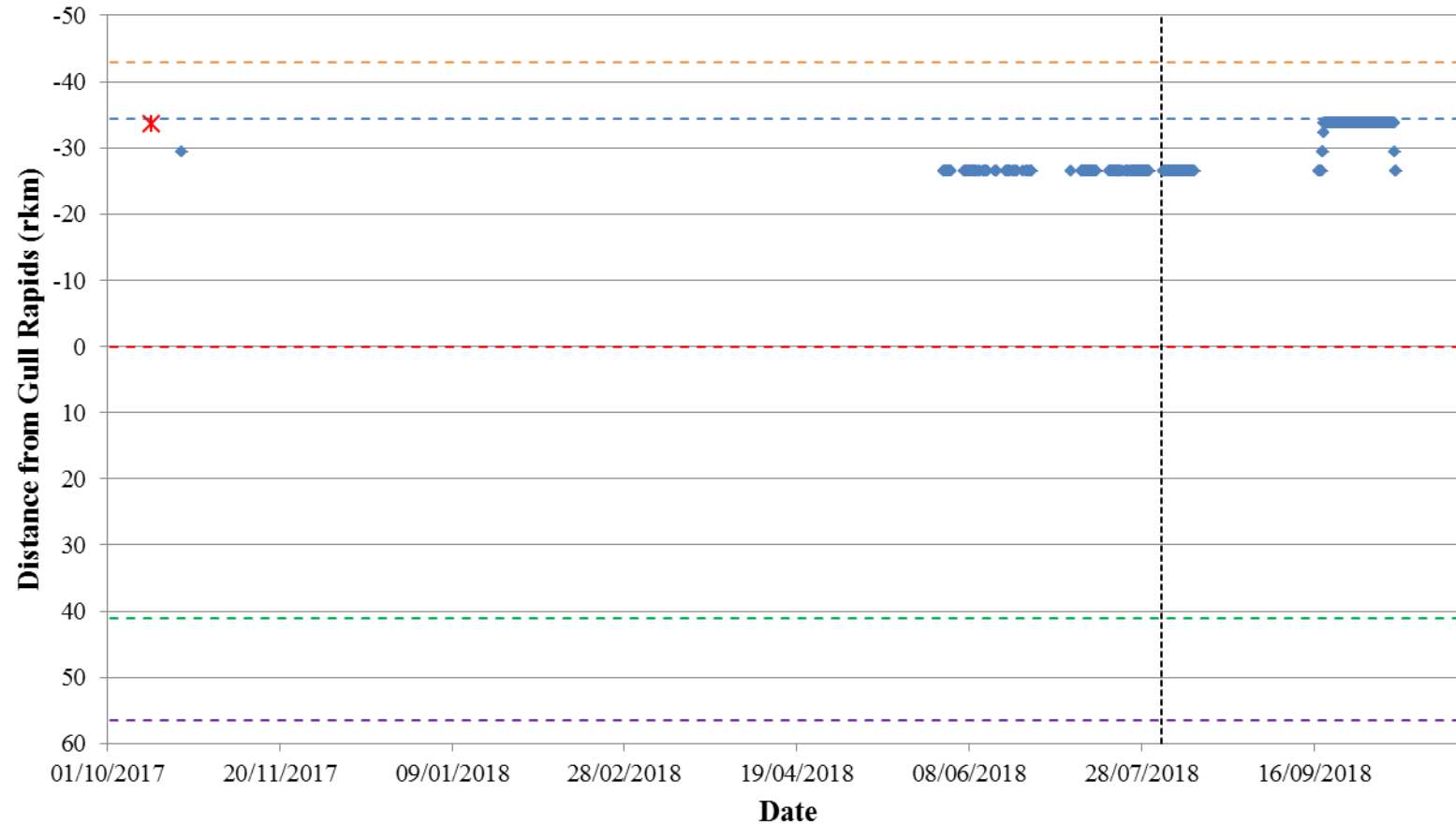


**Figure A2-7: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31731) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

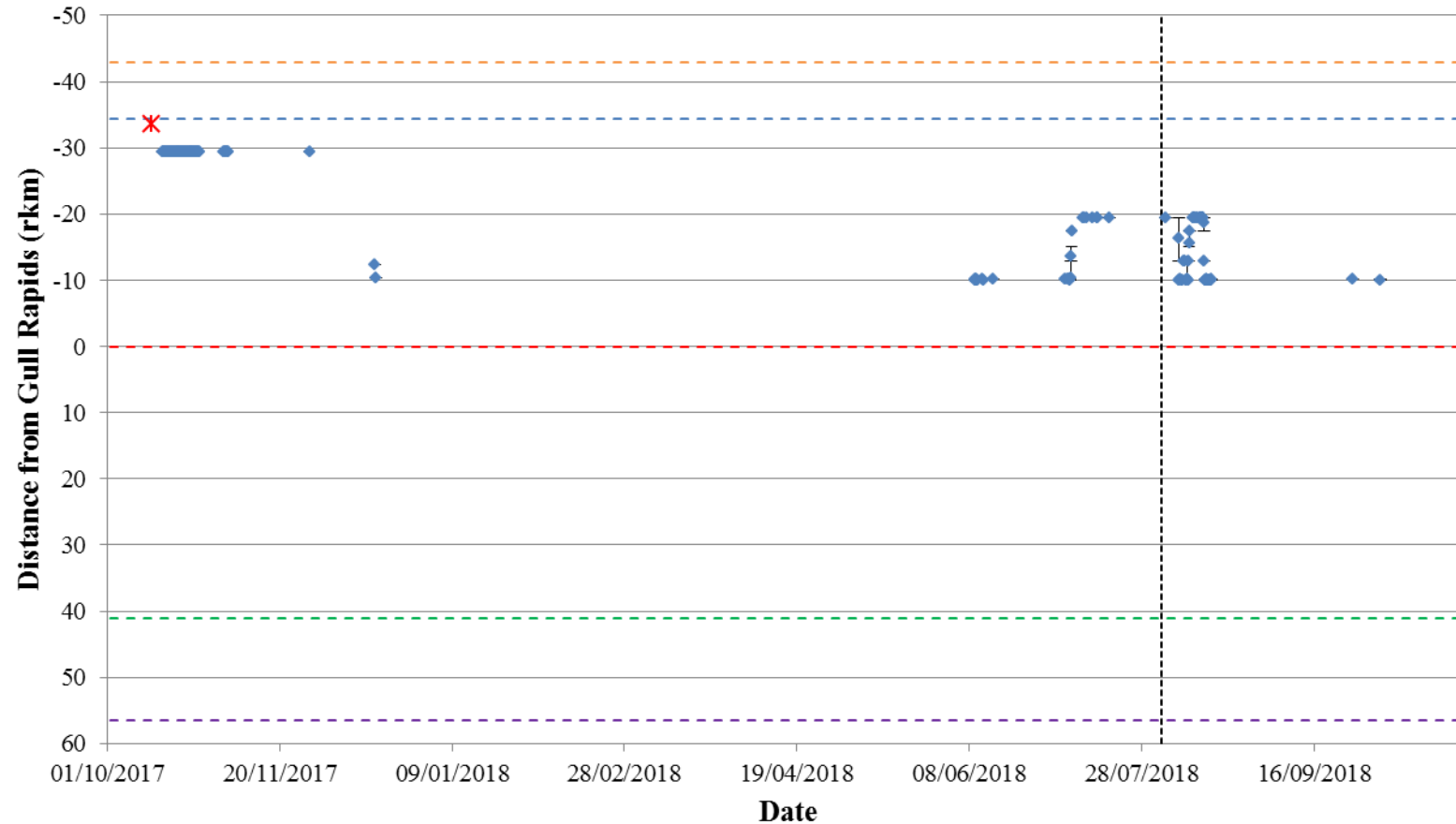




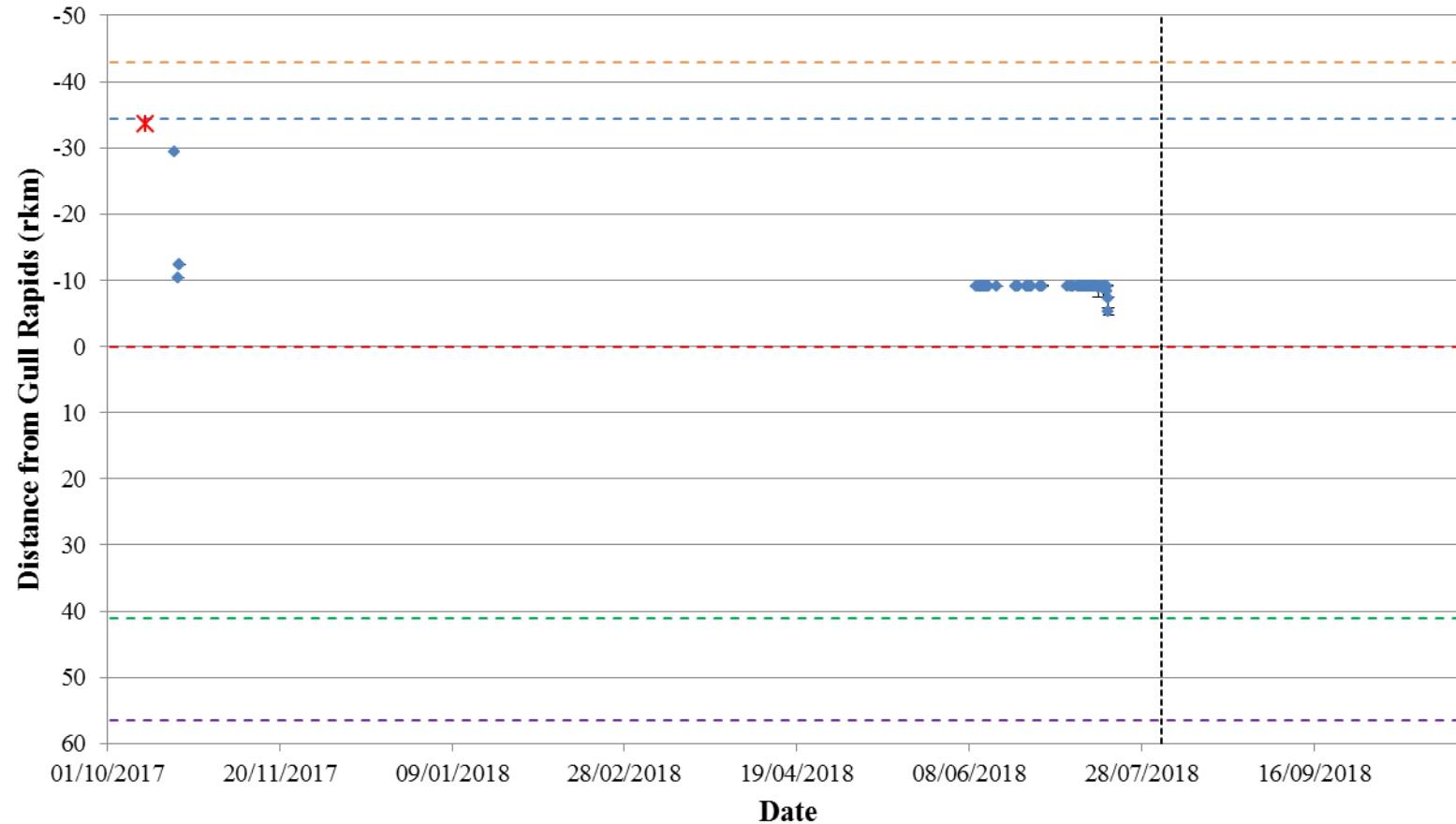
**Figure A2-8: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31732) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



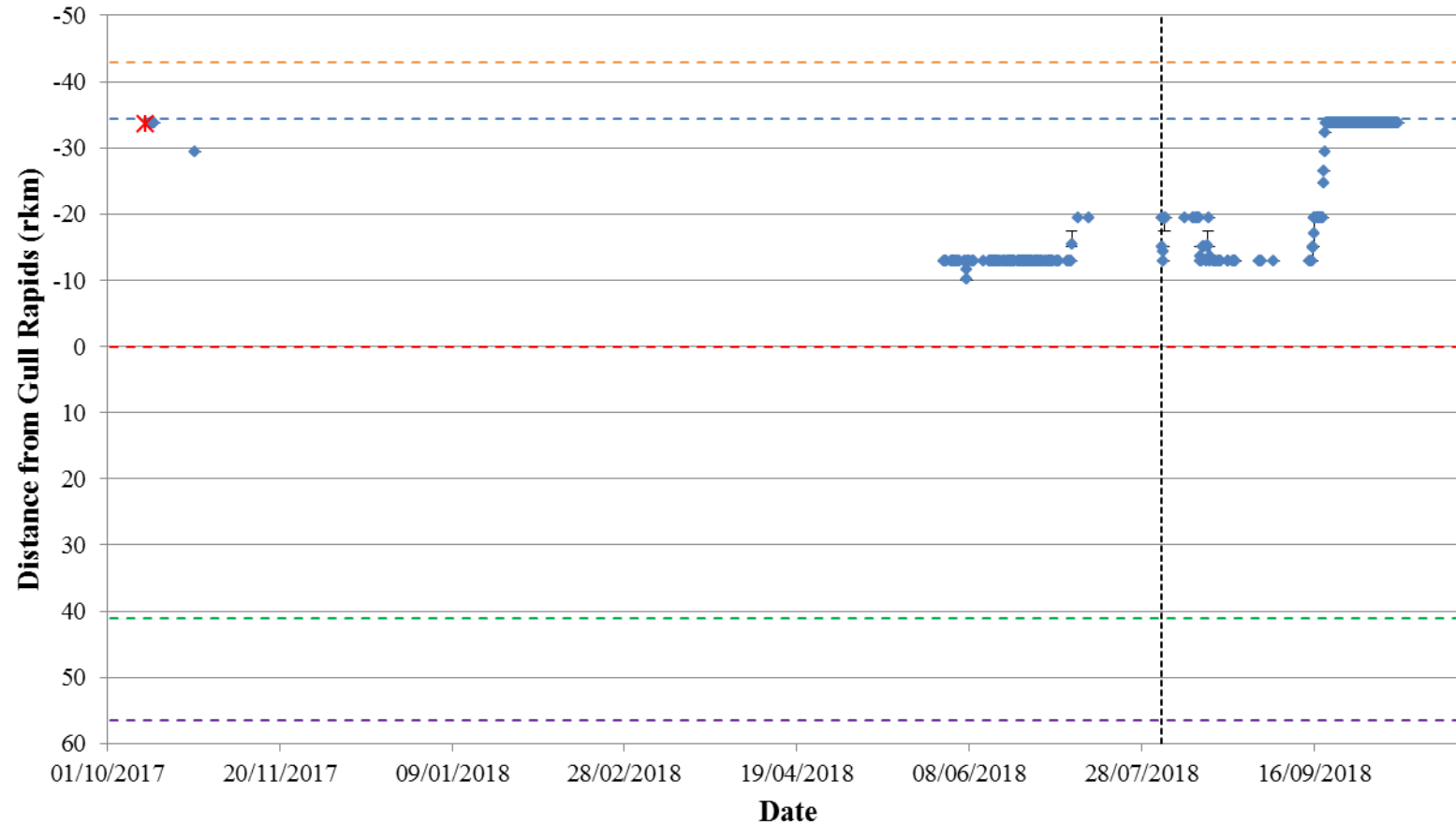
**Figure A2-9: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31733) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



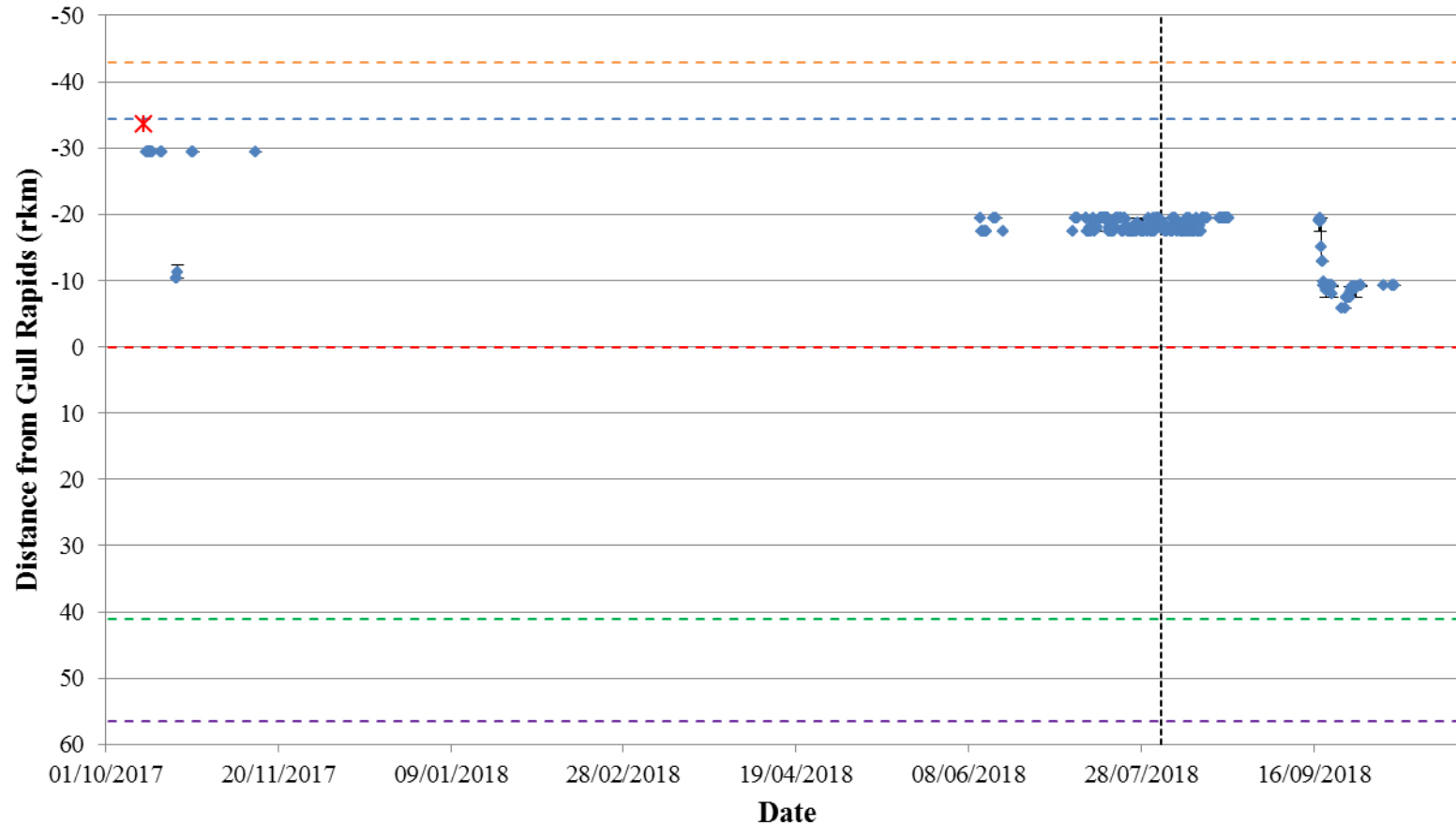
**Figure A2-10: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31734) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



**Figure A2-11: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31735) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

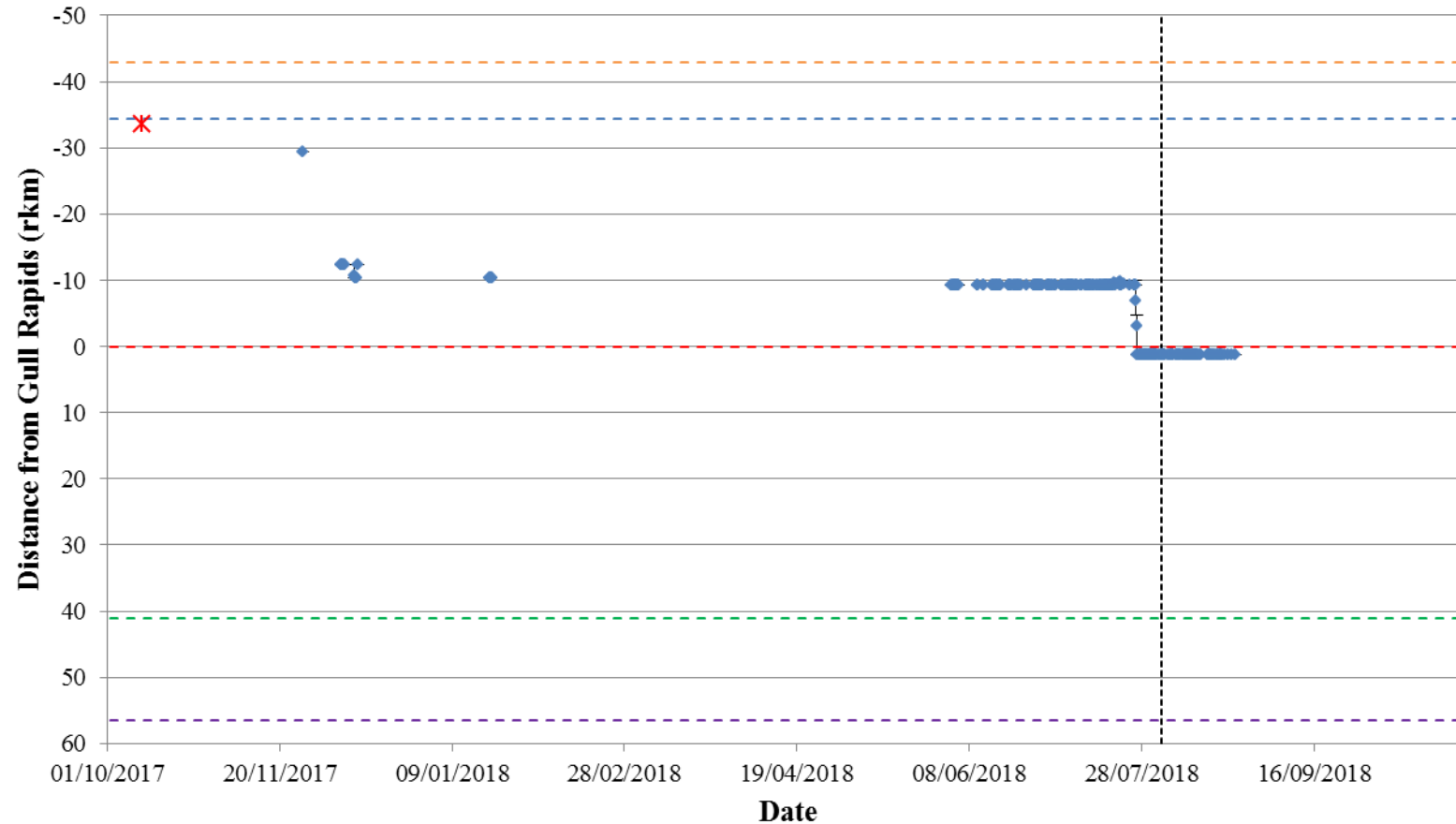


**Figure A2-12: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31736) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

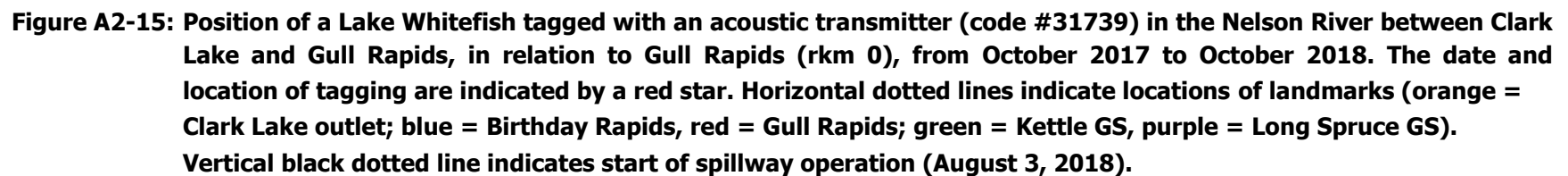


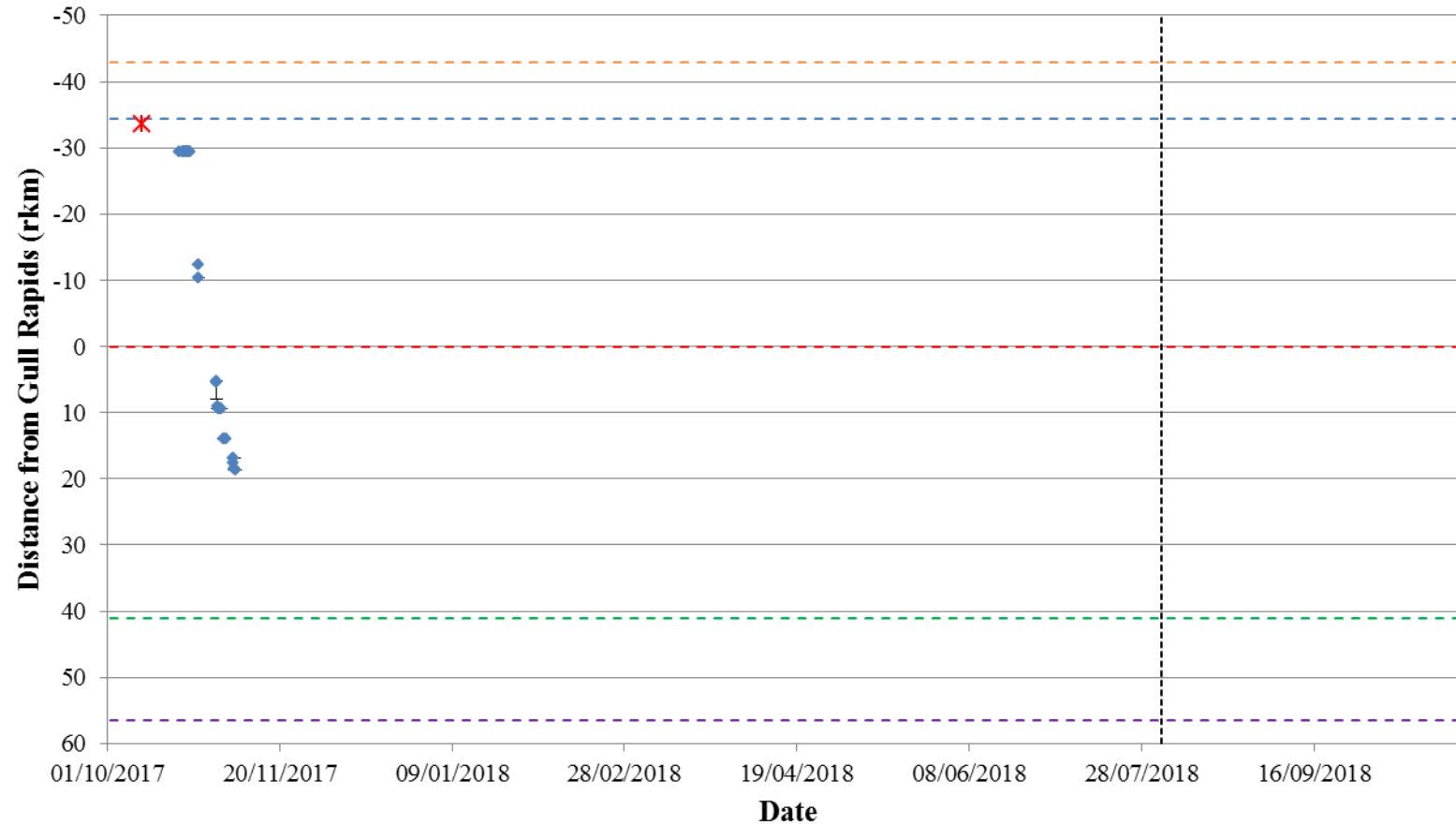
**Figure A2-13: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31737) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



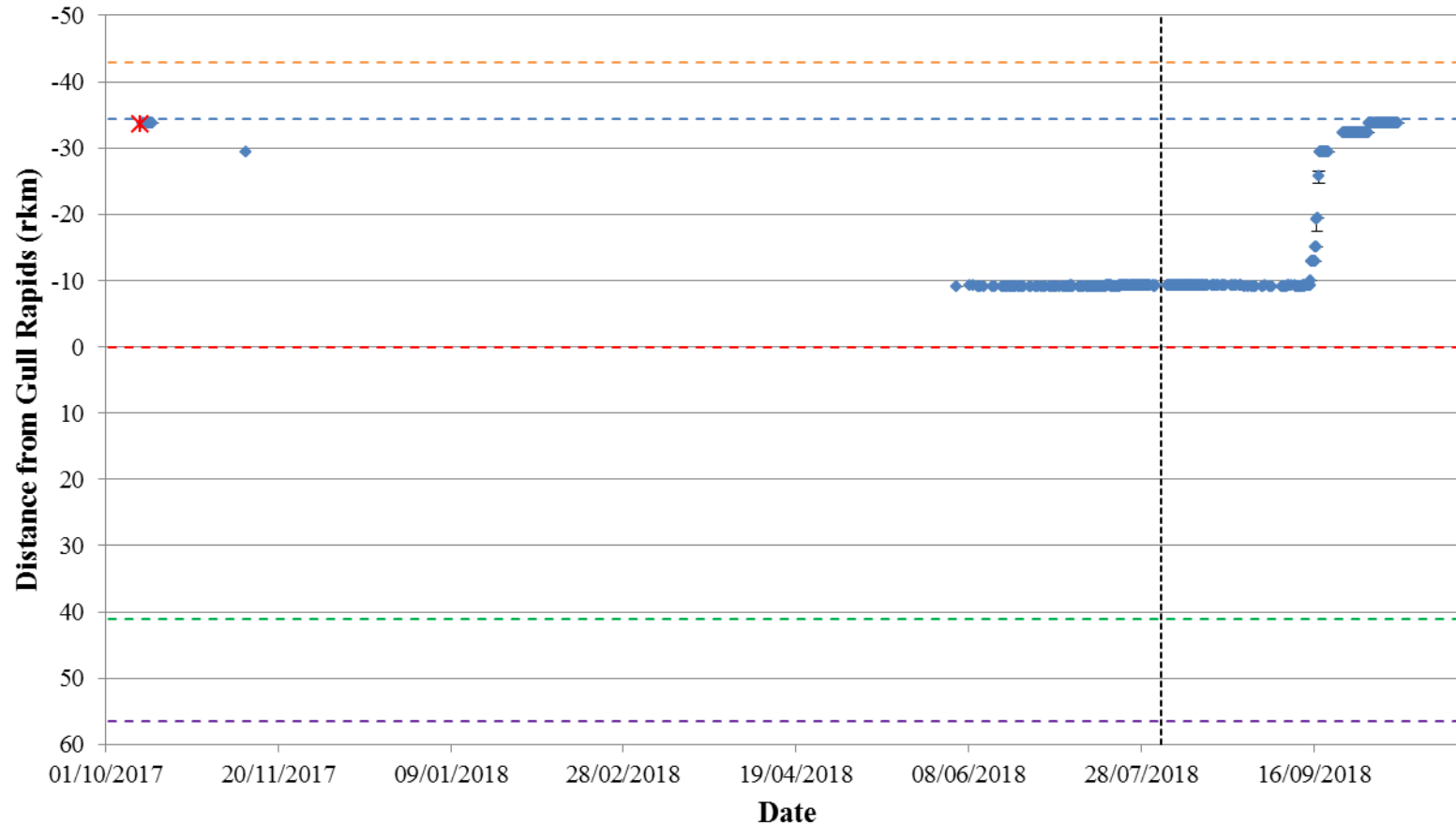


**Figure A2-14: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31738) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

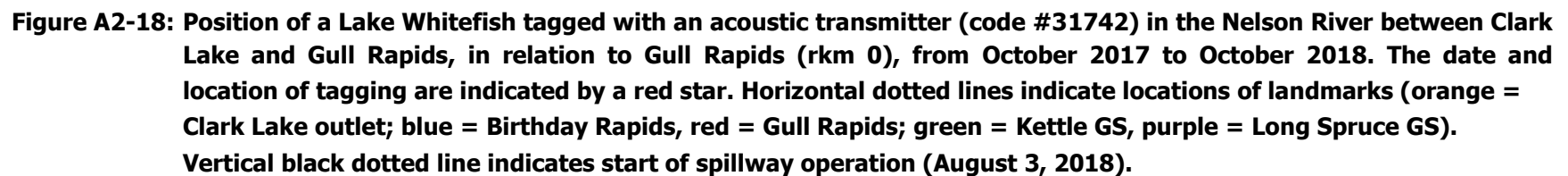


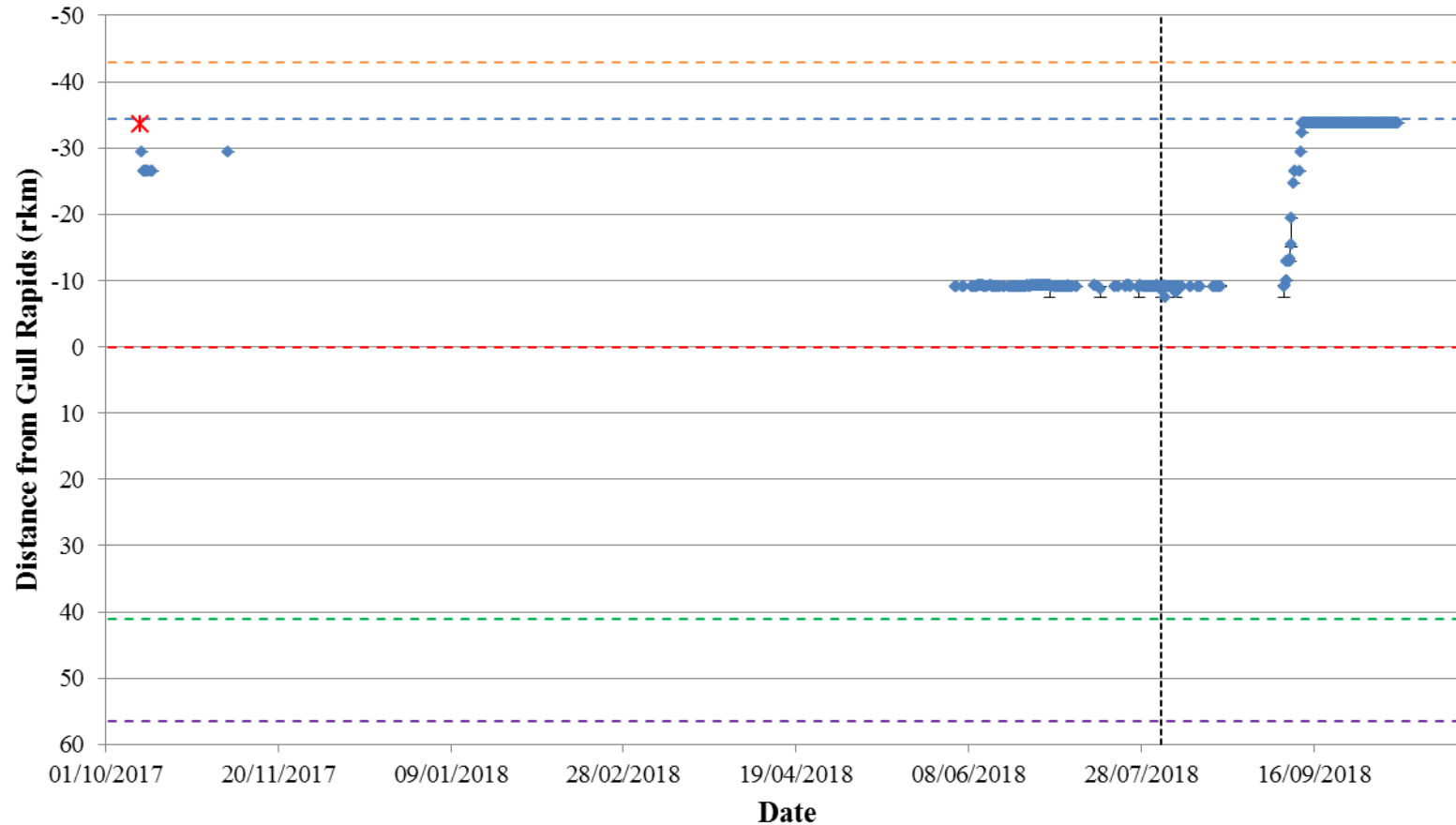


**Figure A2-16: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31740) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



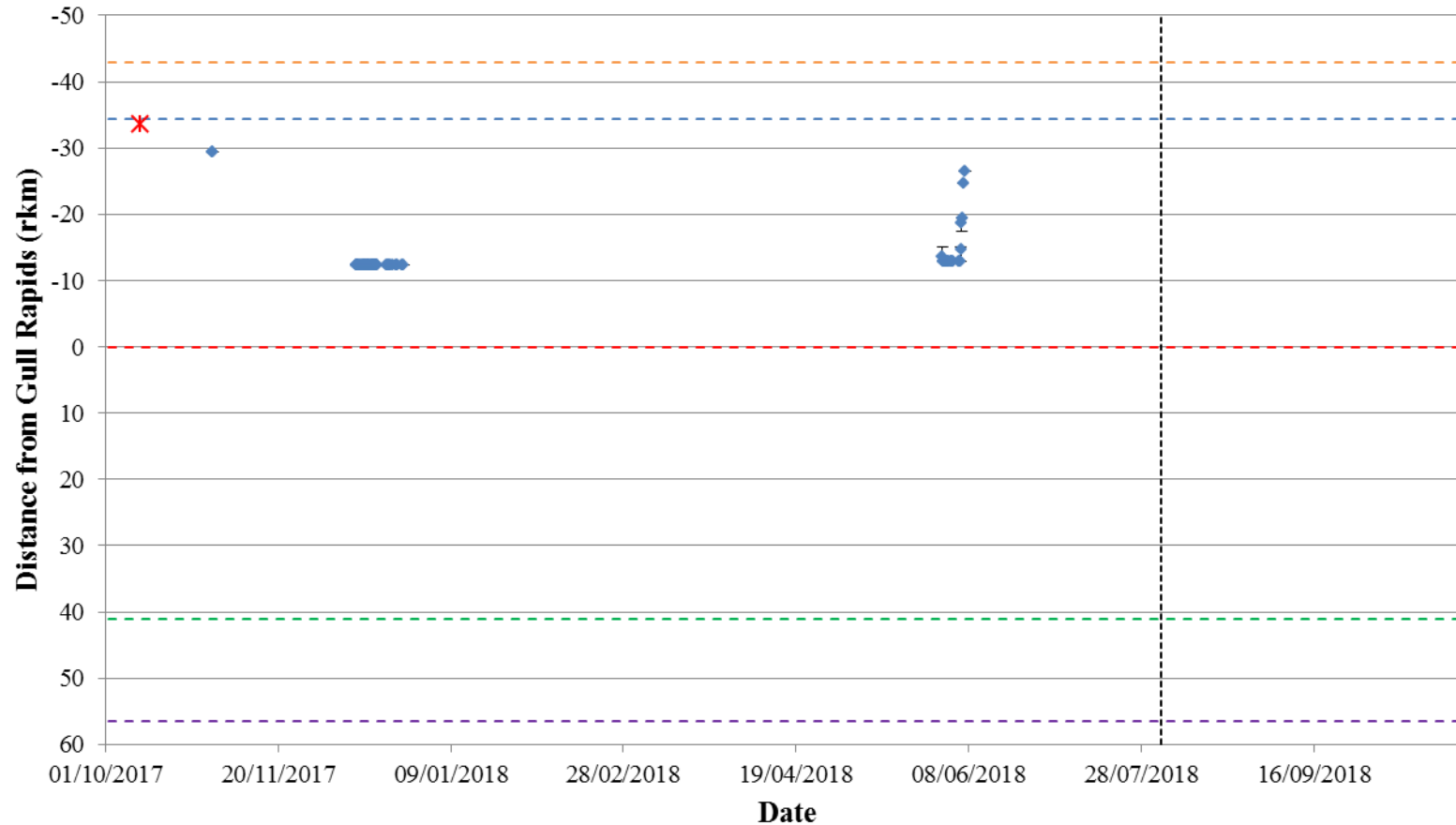
**Figure A2-17: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31741) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



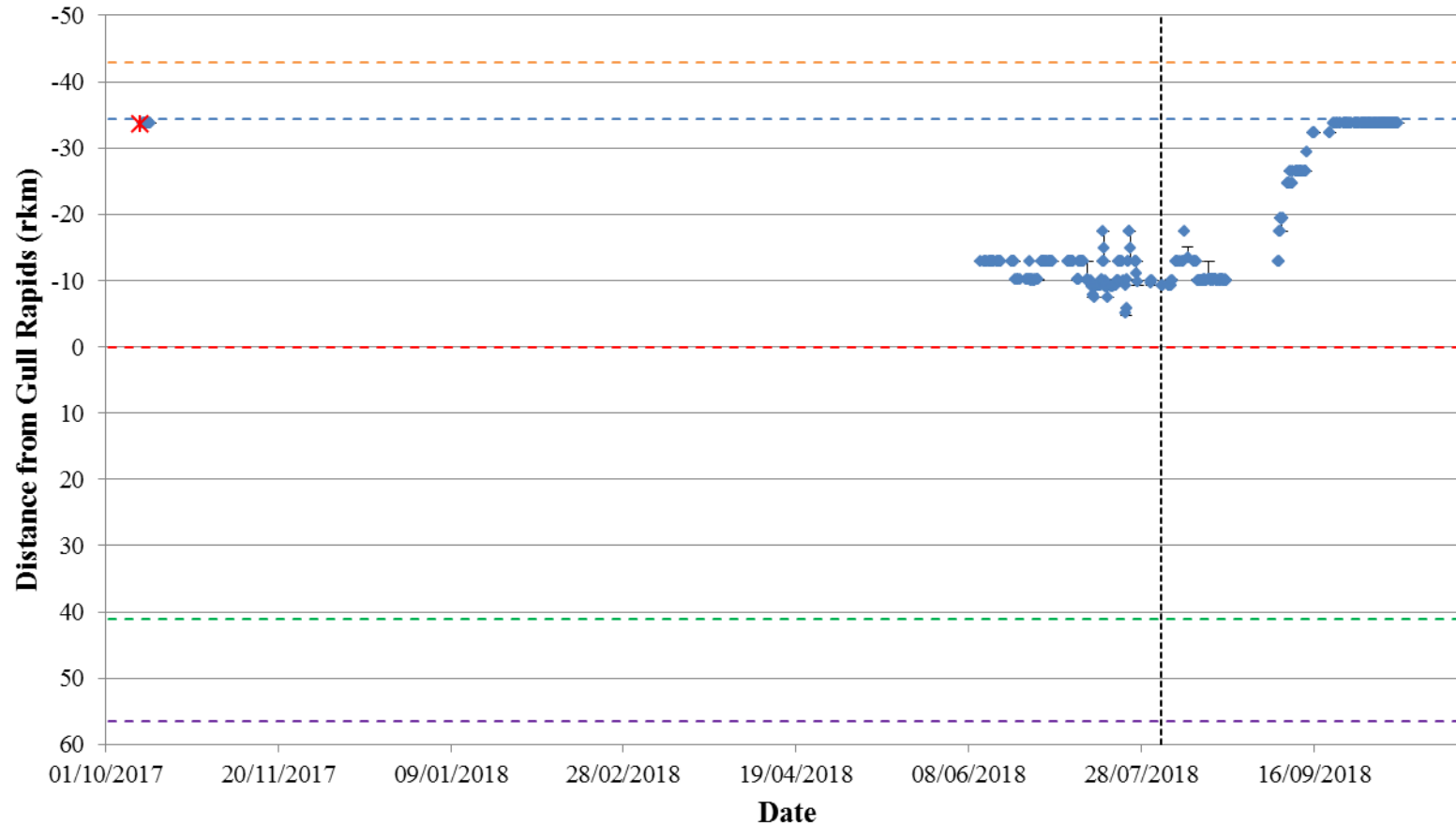


**Figure A2-19: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31743) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

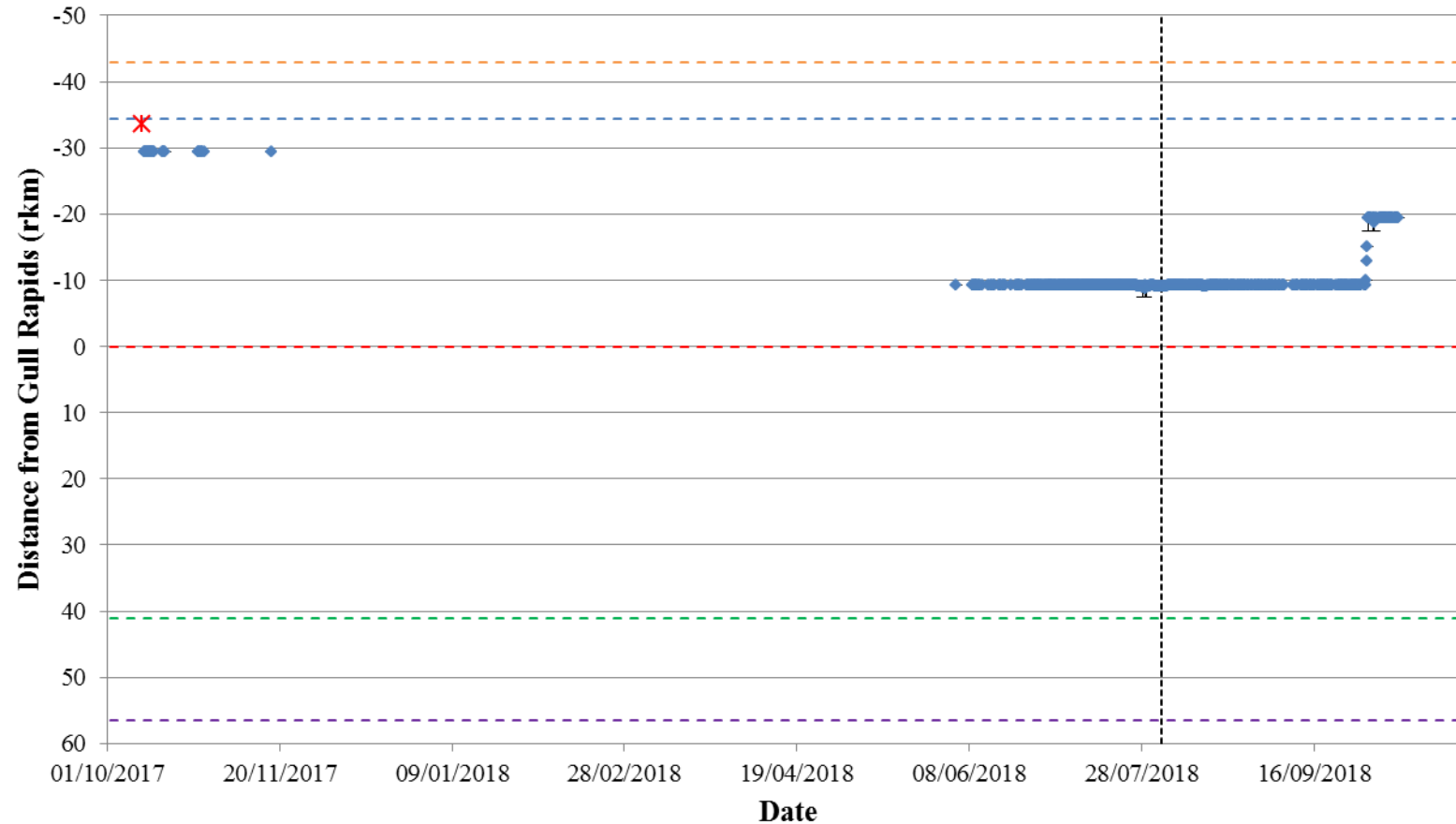




**Figure A2-20: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31744) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



**Figure A2-21: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31745) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



**Figure A2-21: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31746) in the Nelson River between Clark Lake and Gull Rapids, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

## **APPENDIX 3:**

# **LOCATION SUMMARY FOR INDIVIDUAL ACOUSTIC-TAGGED LAKE WHITEFISH IN STEPHENS LAKE, OCTOBER 2017 TO OCTOBER 2018**

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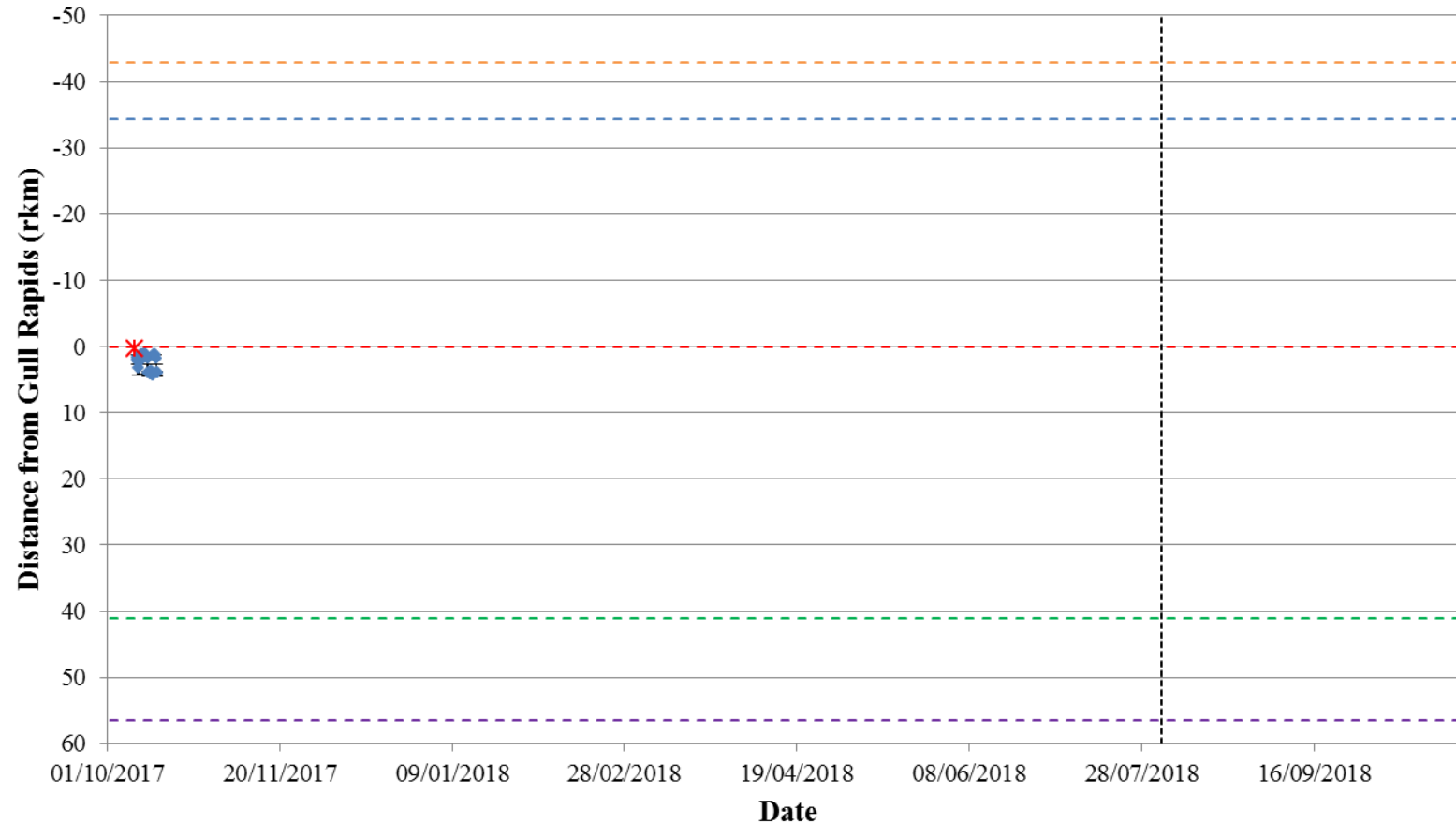
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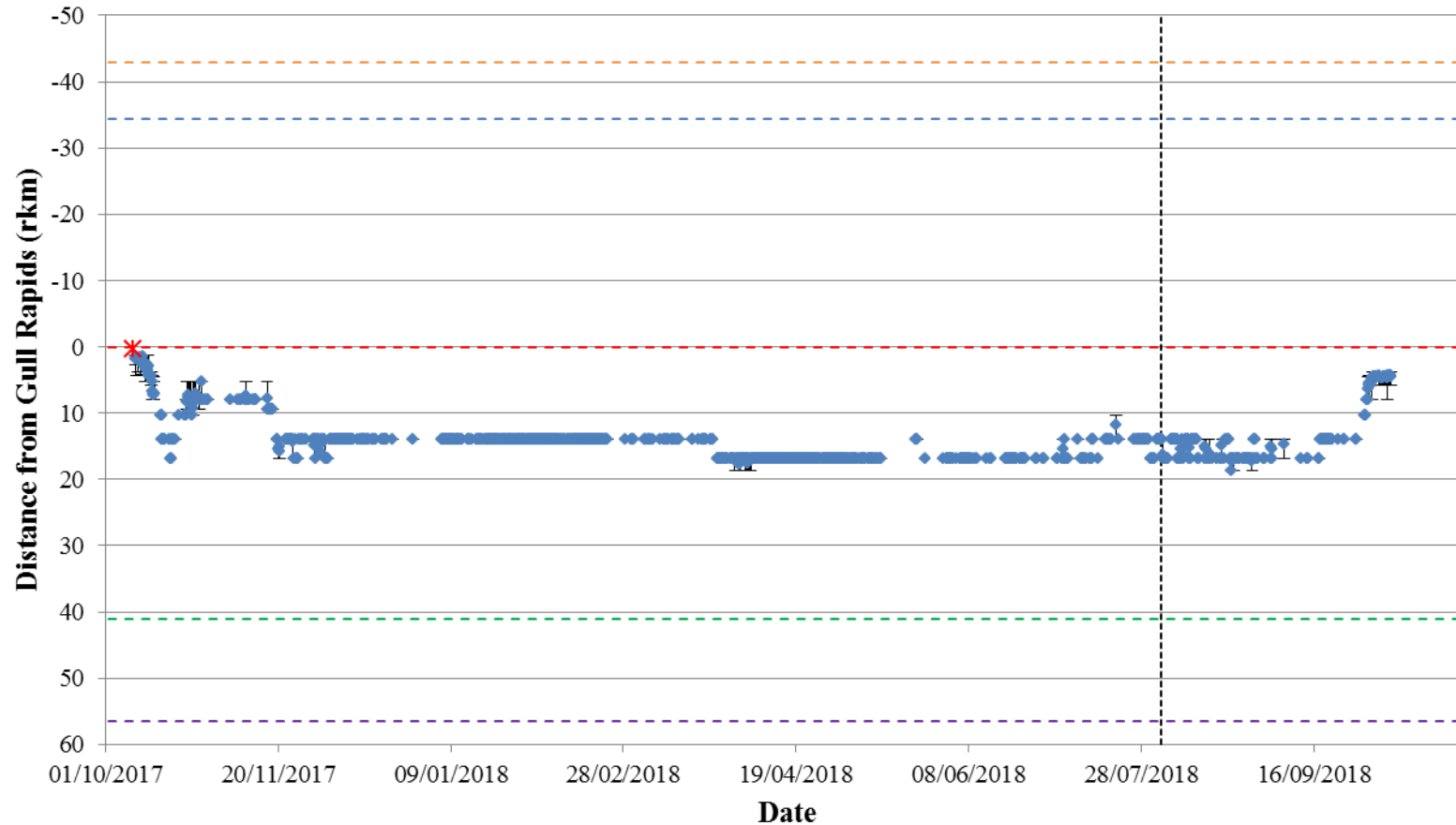
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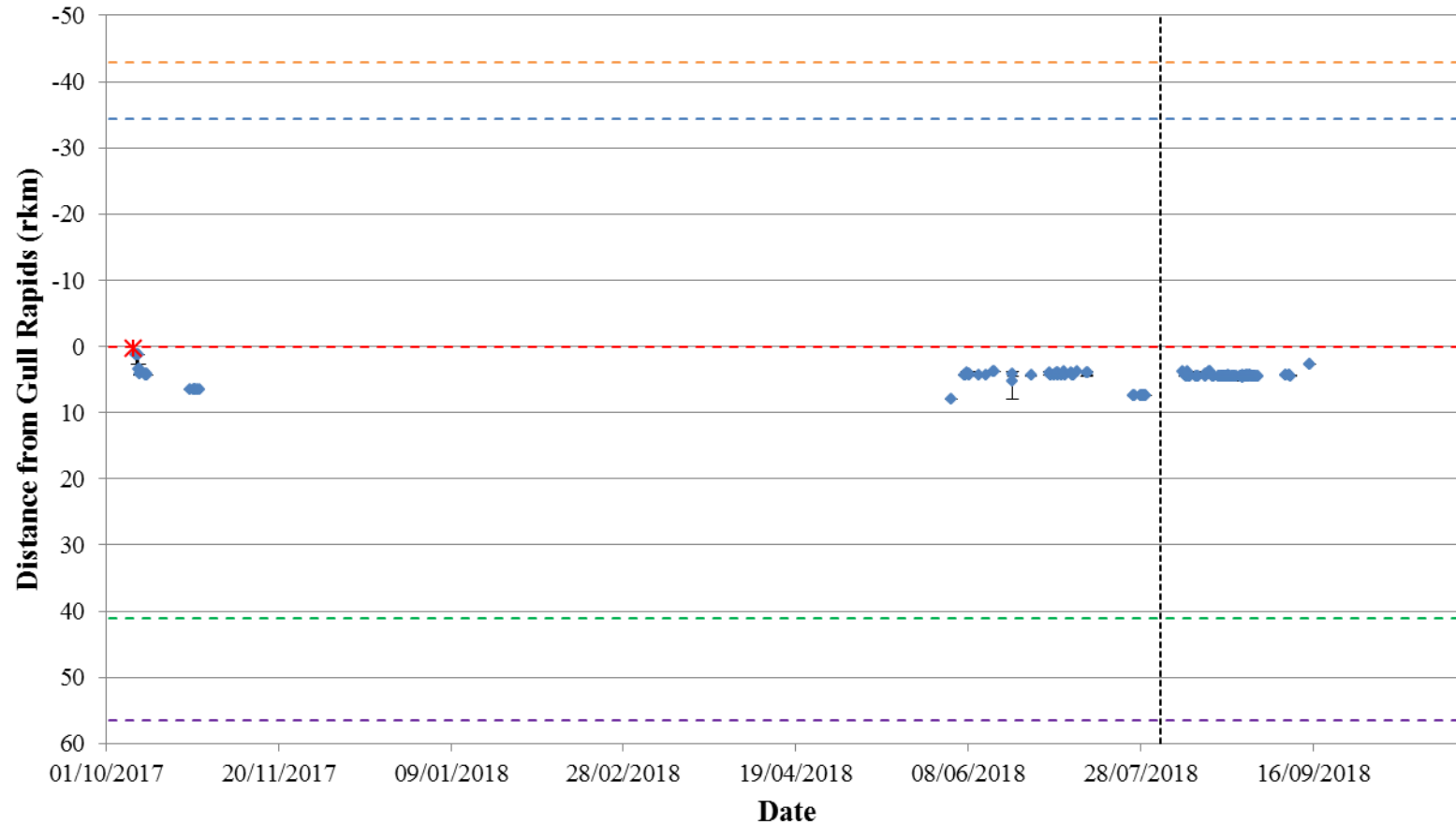
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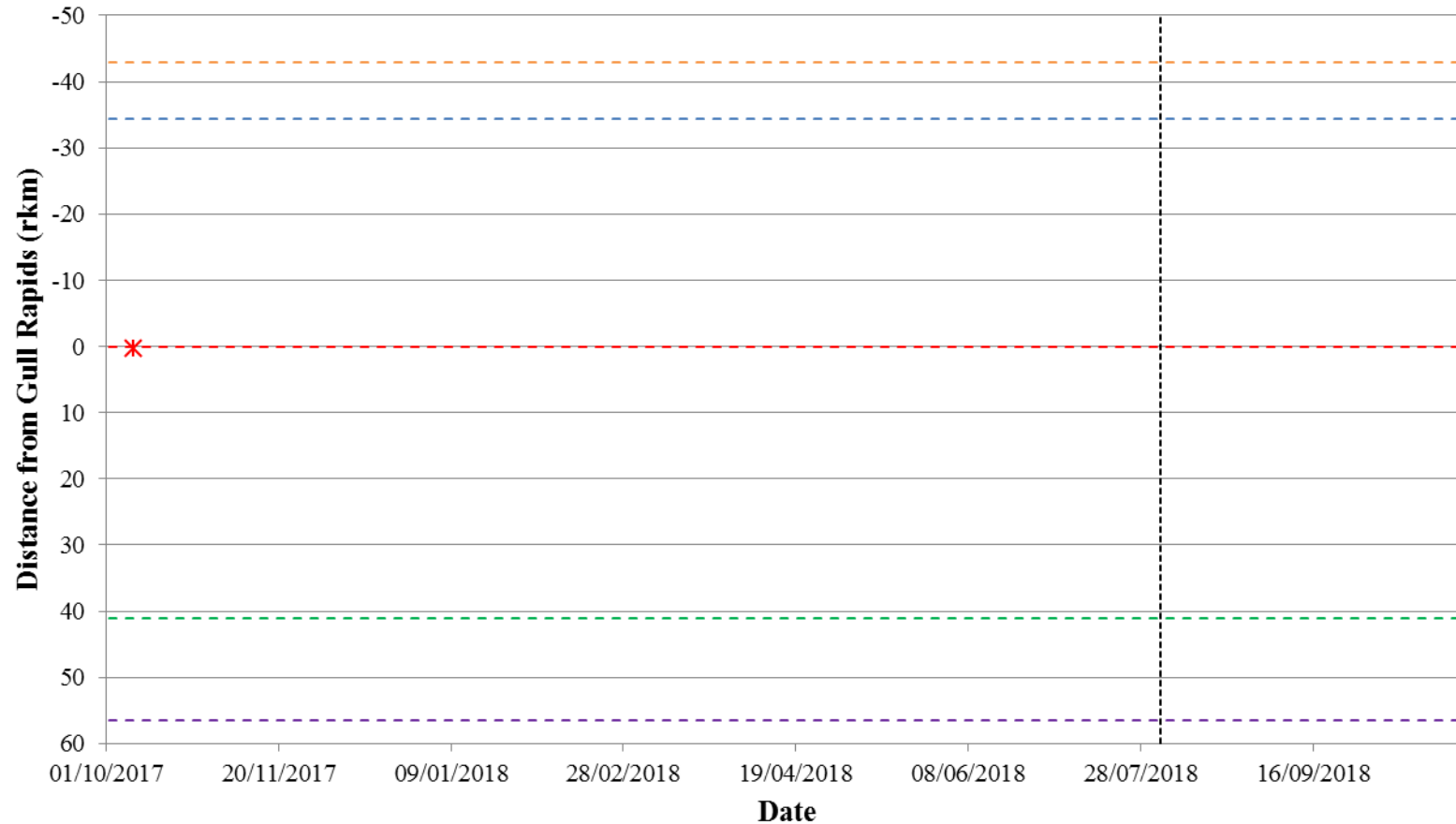
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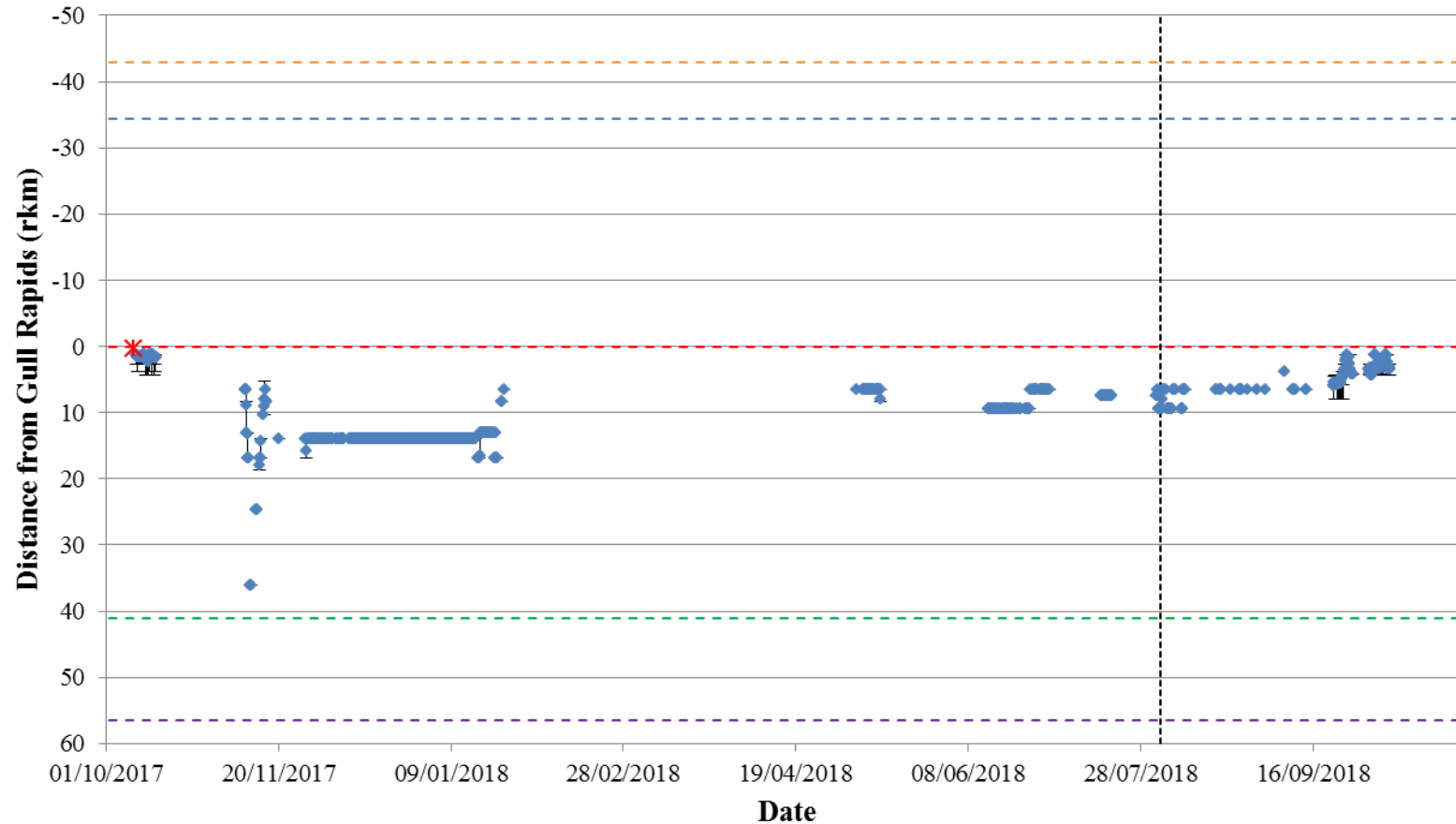
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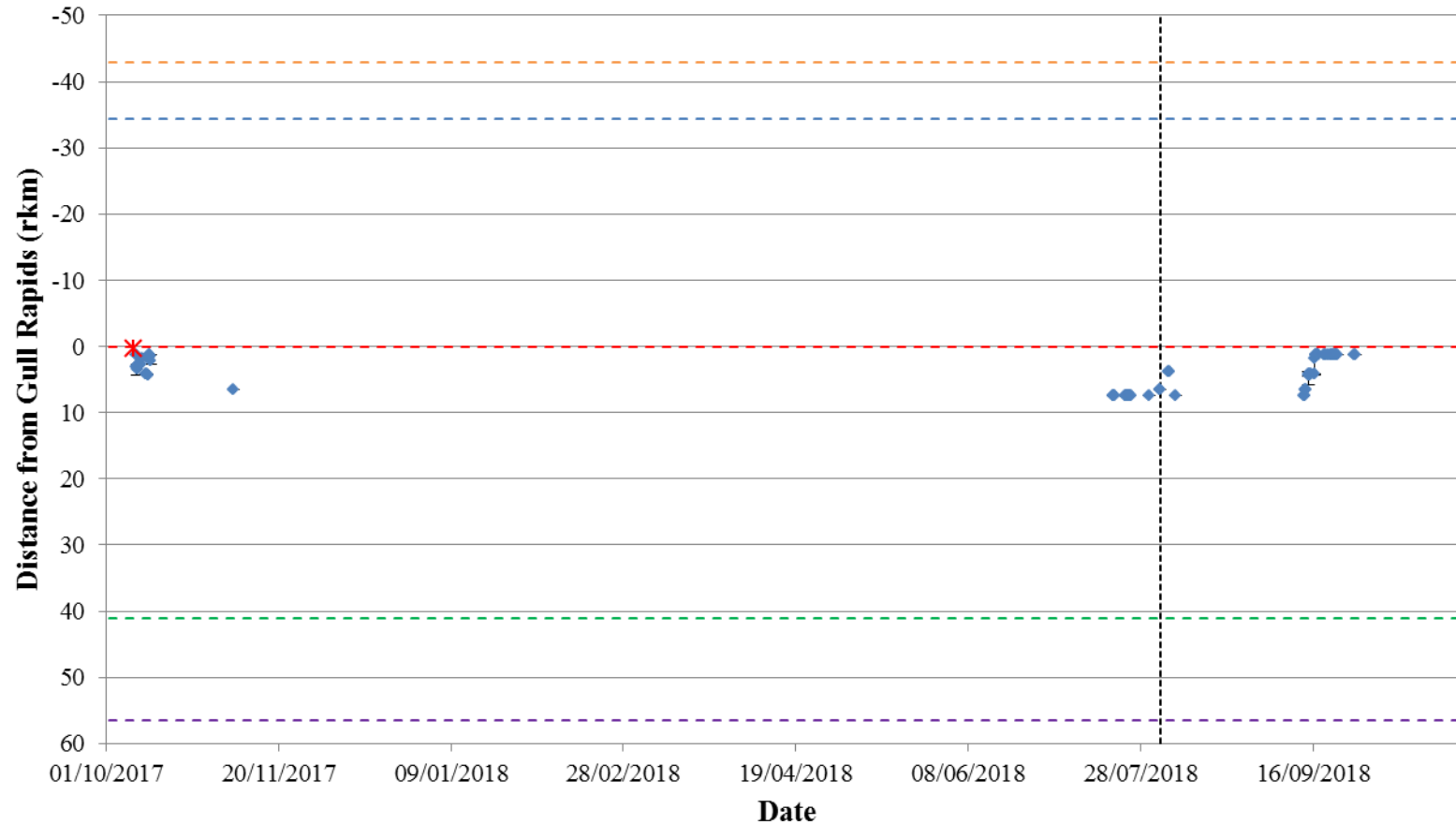
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**Figure A3-4: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31701) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

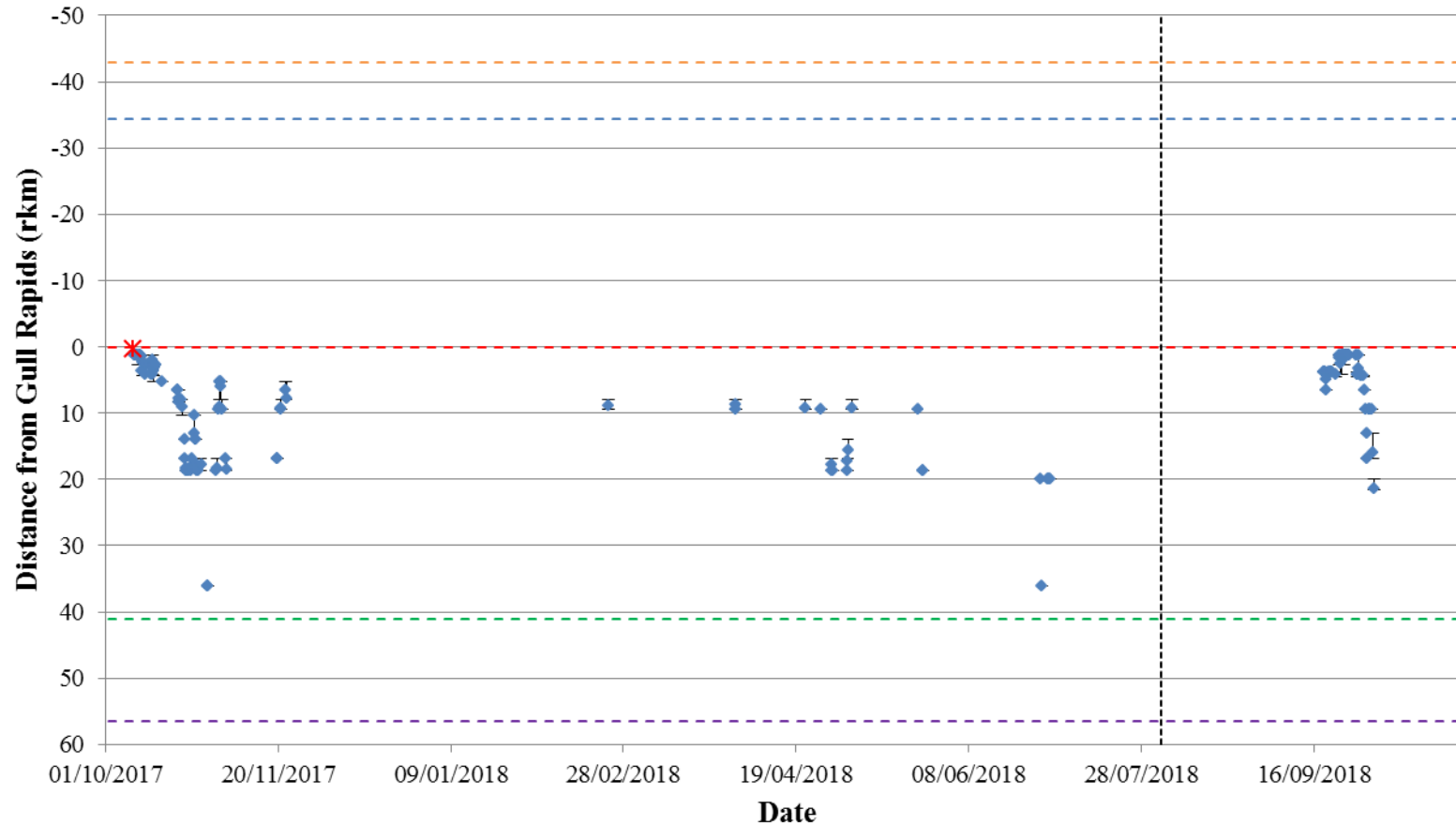


**Figure A3-5: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31702) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

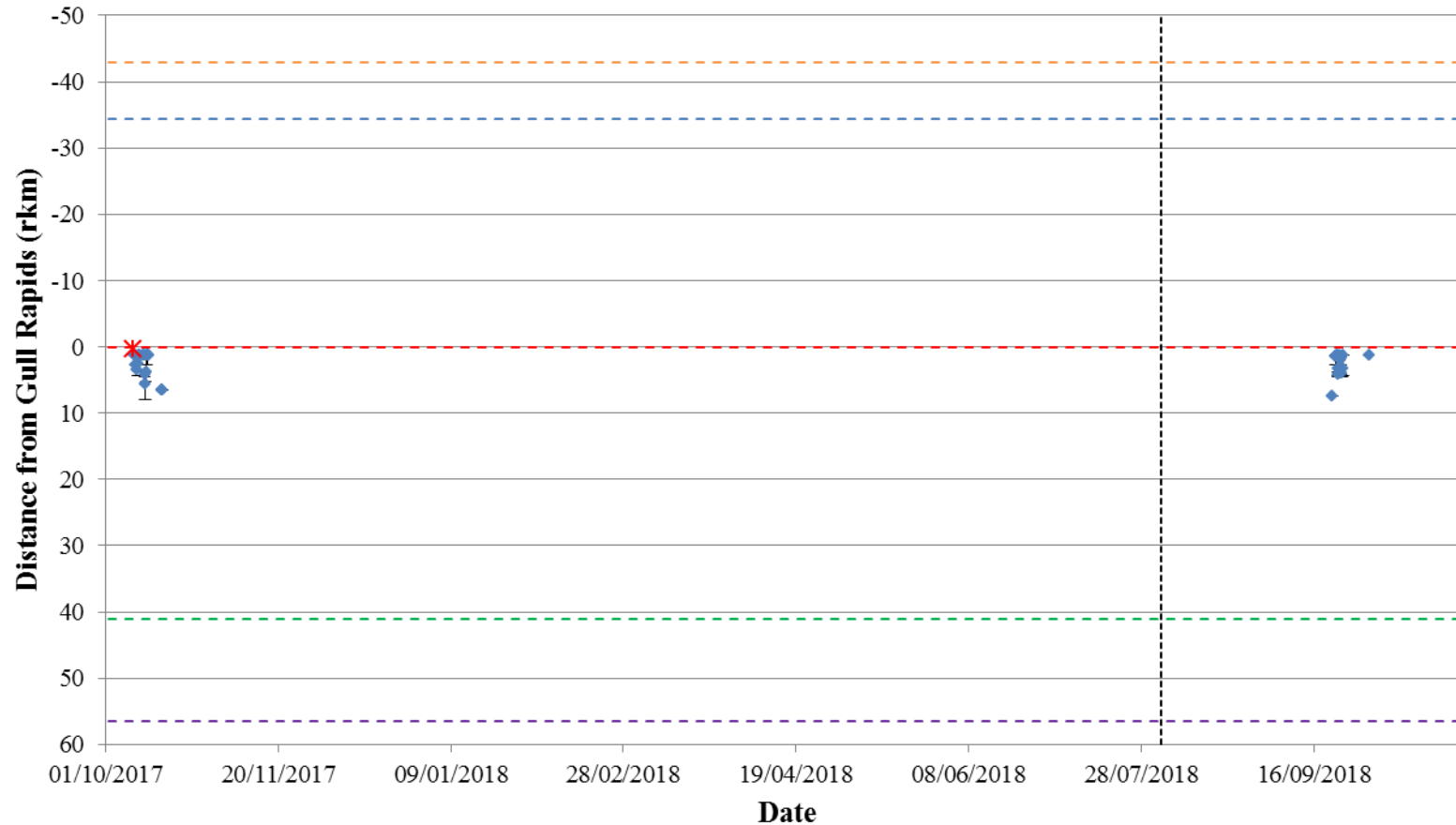


**Figure A3-6: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31703) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

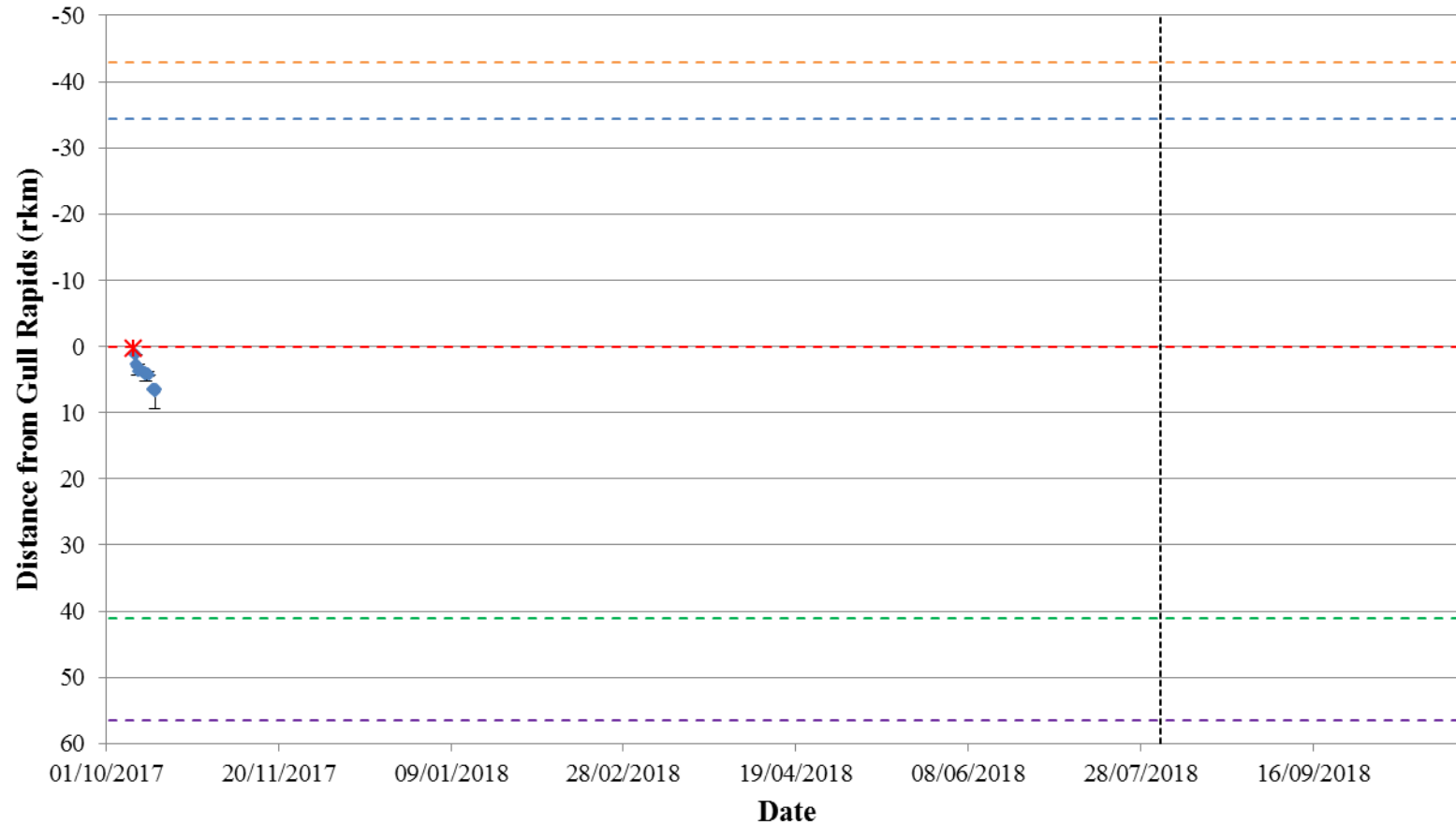




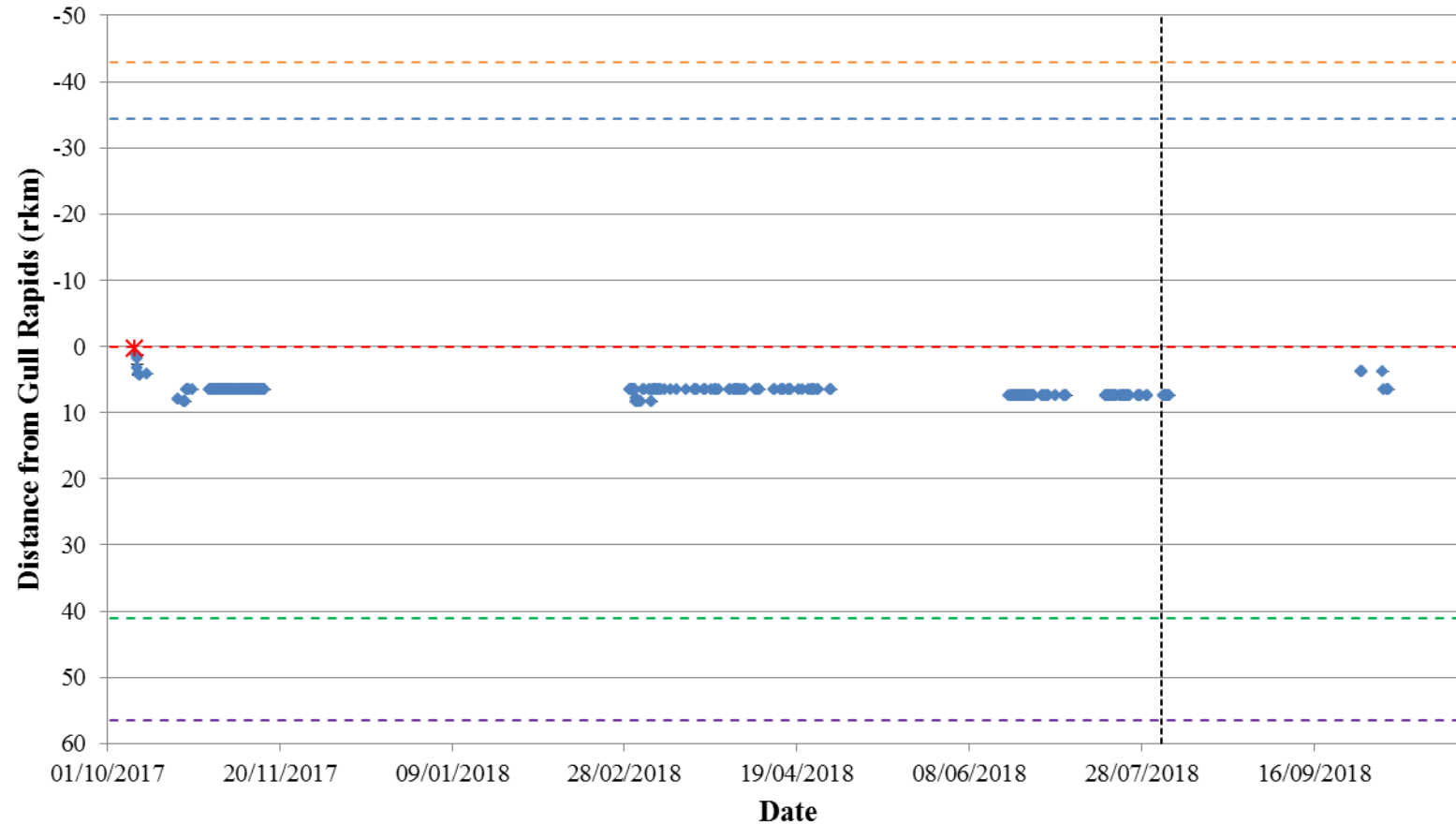
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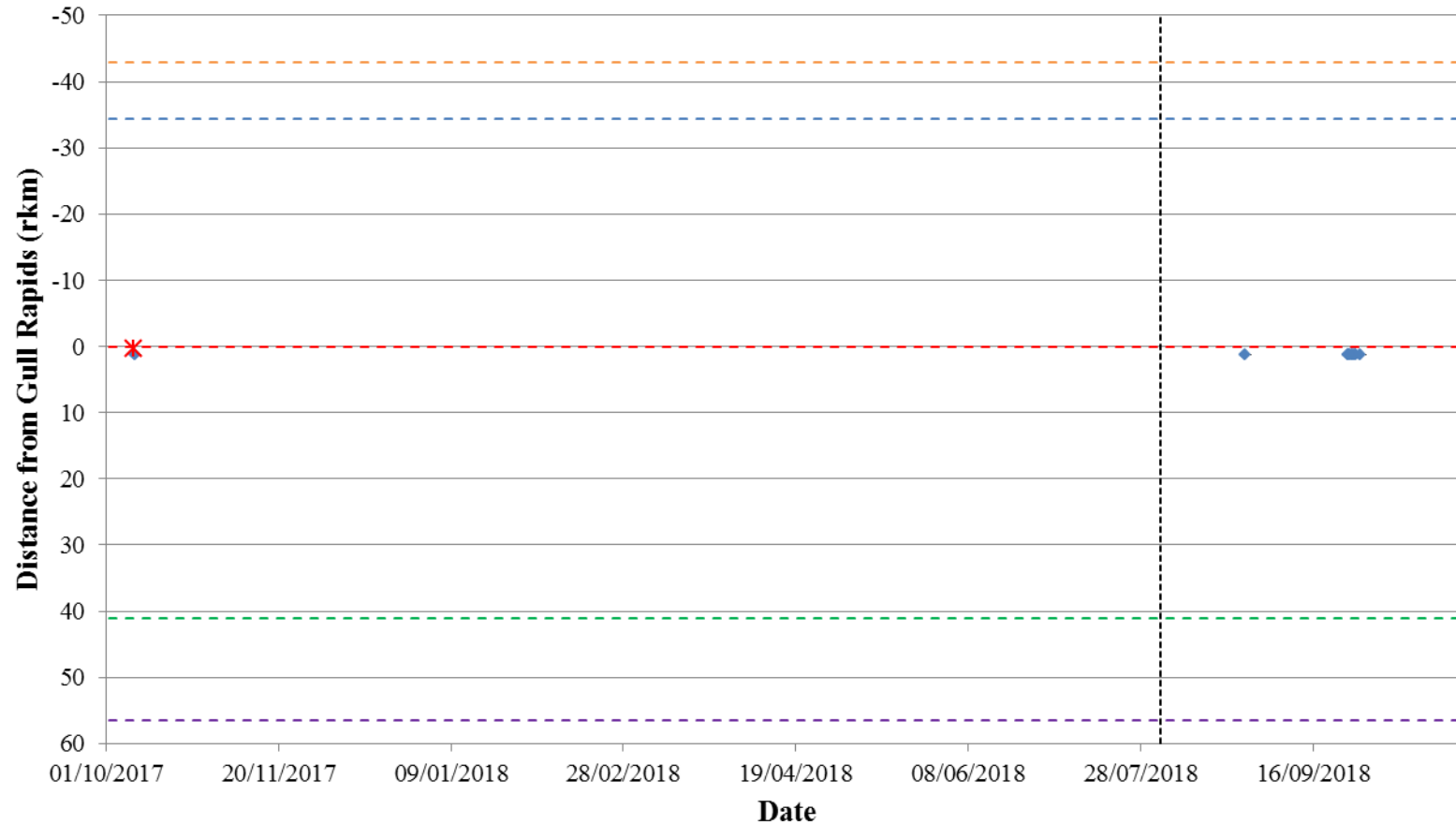
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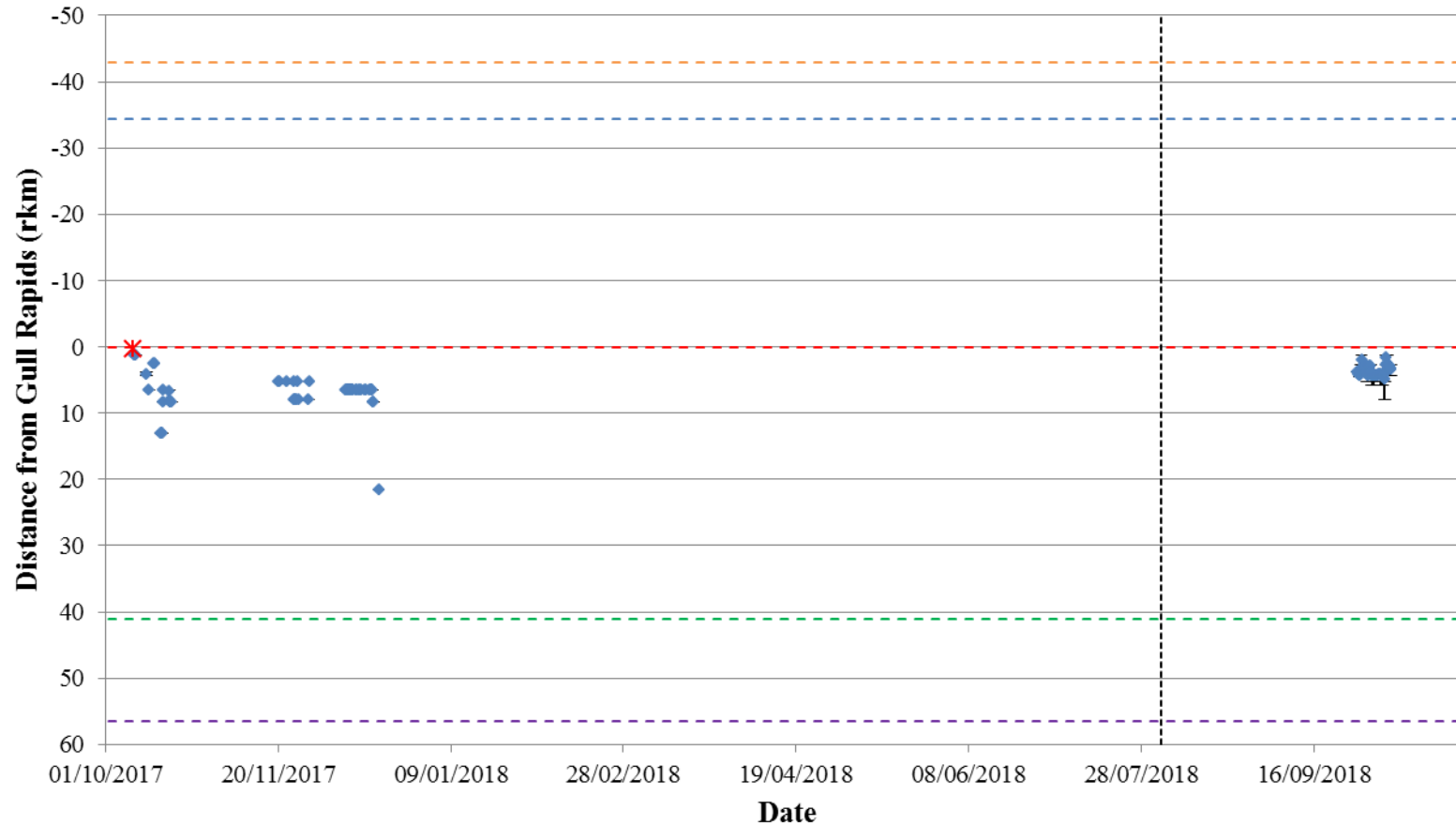
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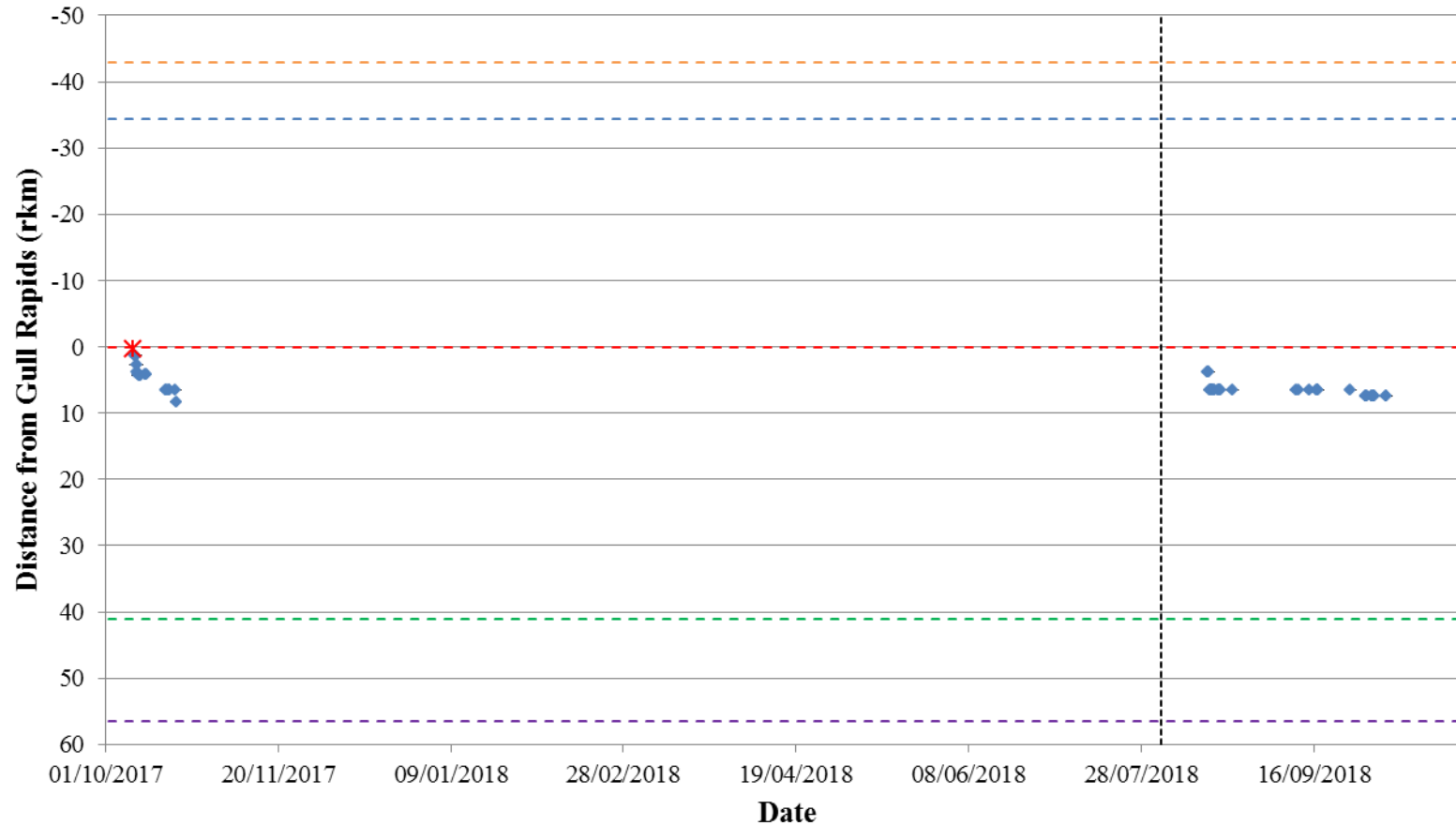
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**Figure A3-11: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31708) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

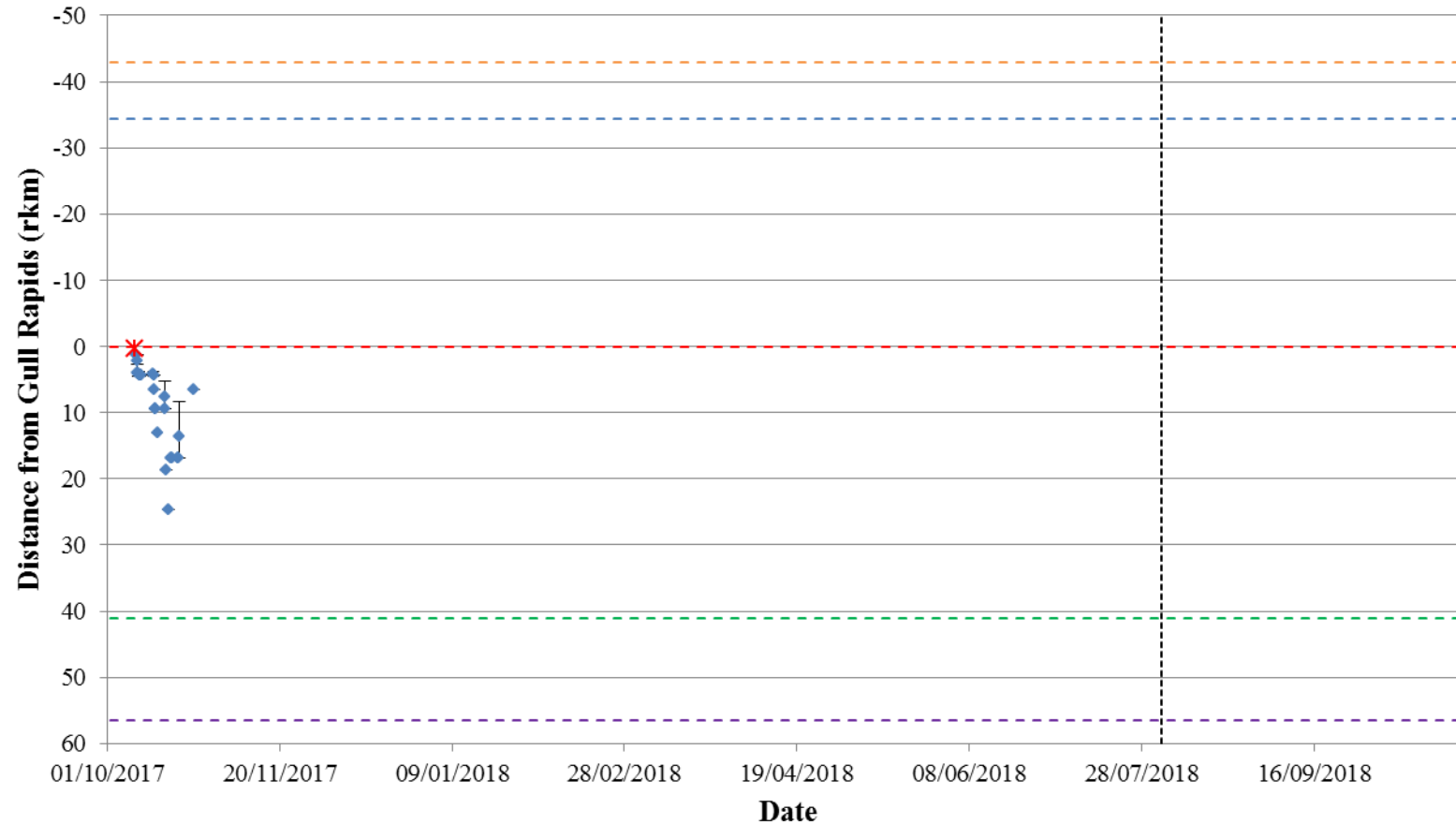


**Figure A3-12: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31709) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

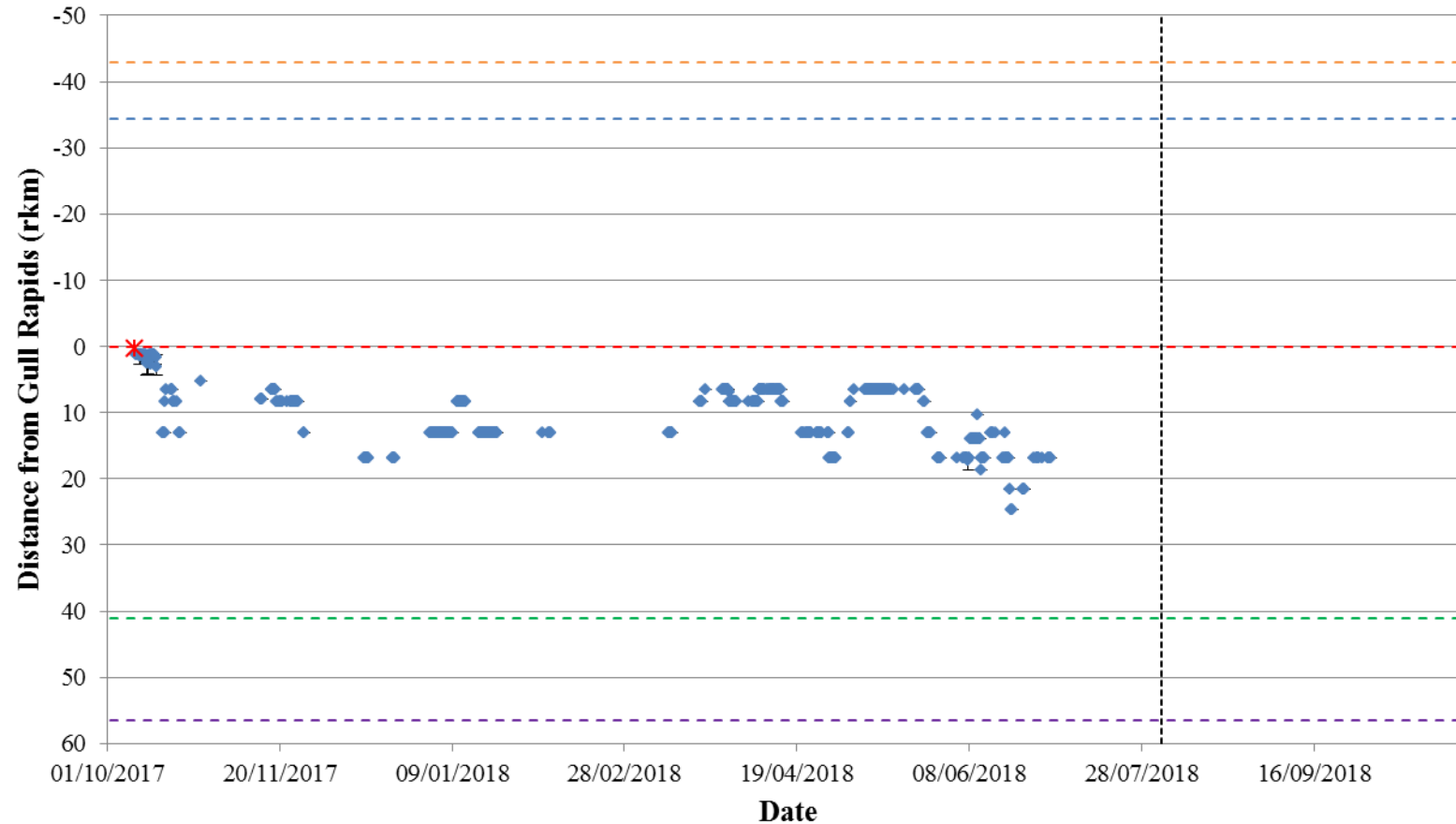


**Figure A3-13: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31710) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

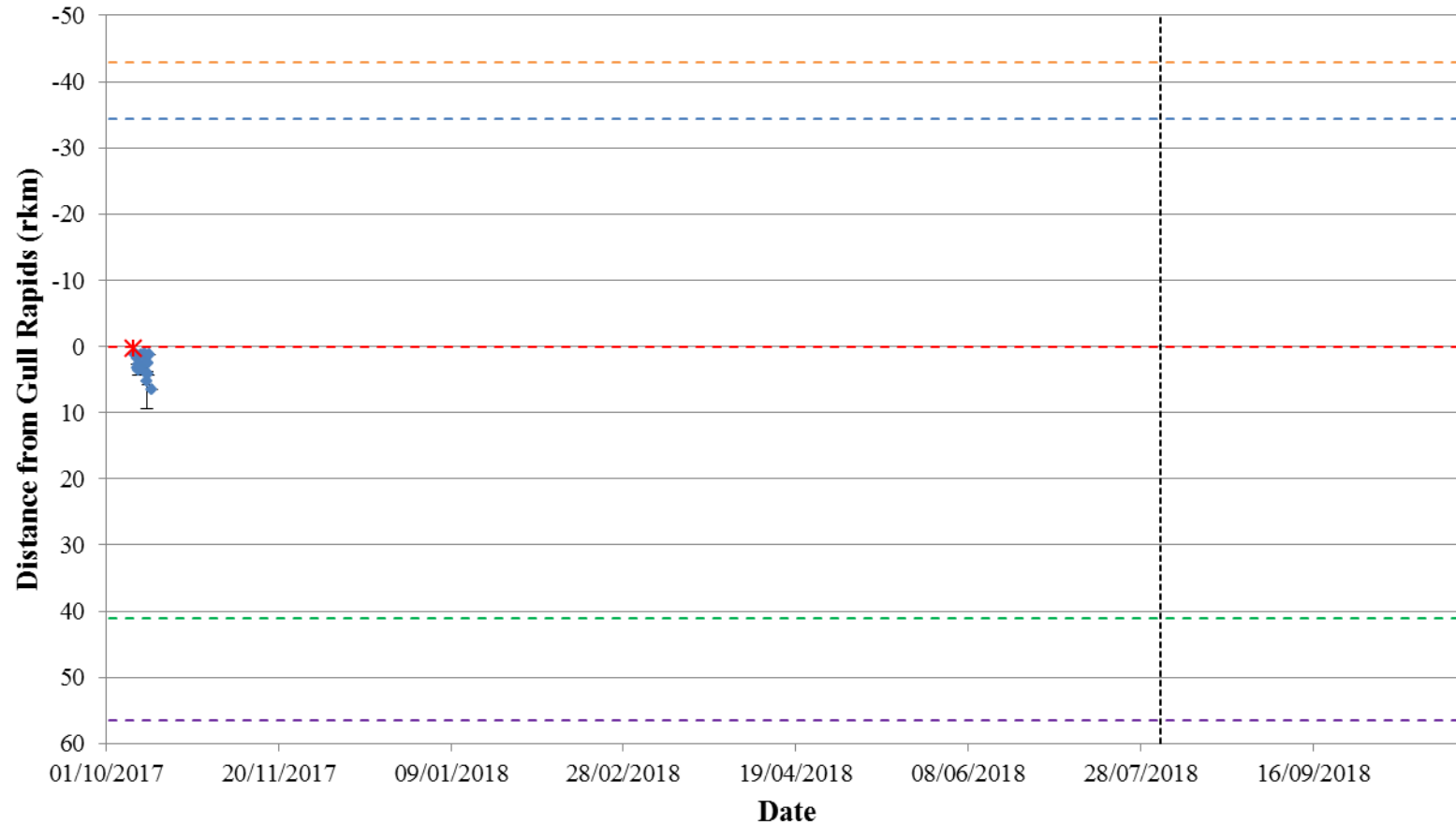




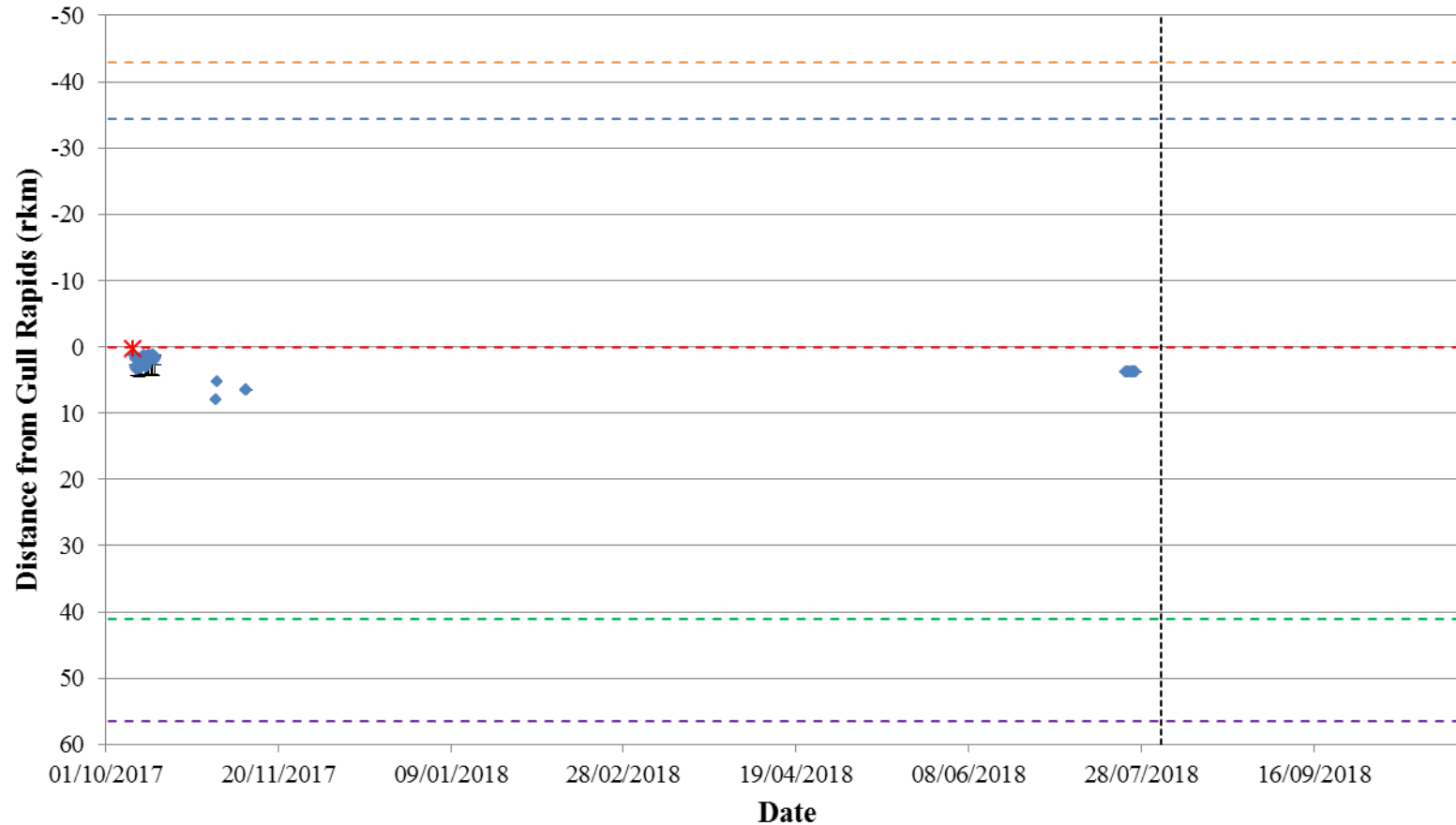
**Figure A3-14: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31711) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



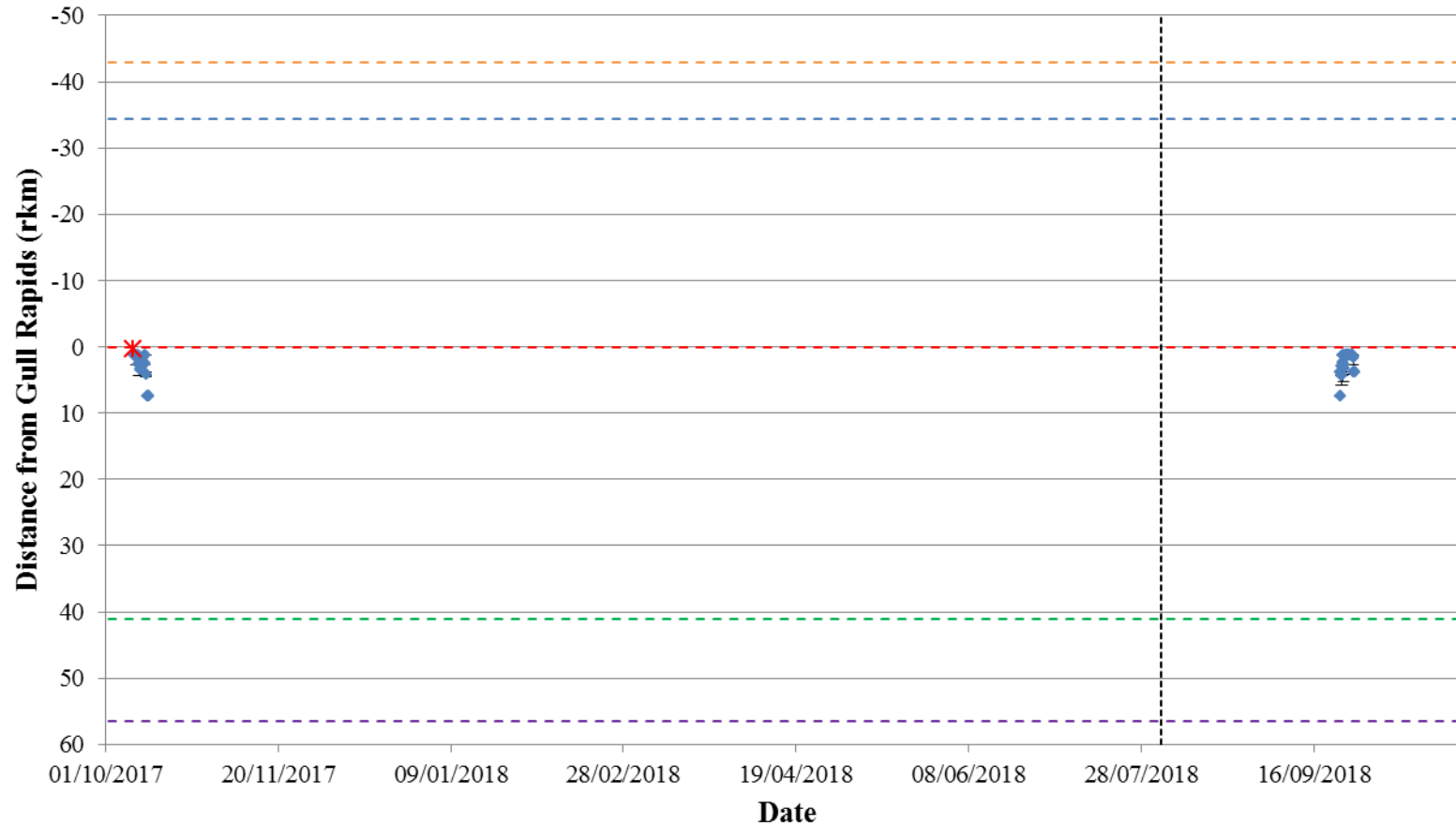
**Figure A3-15: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31712) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



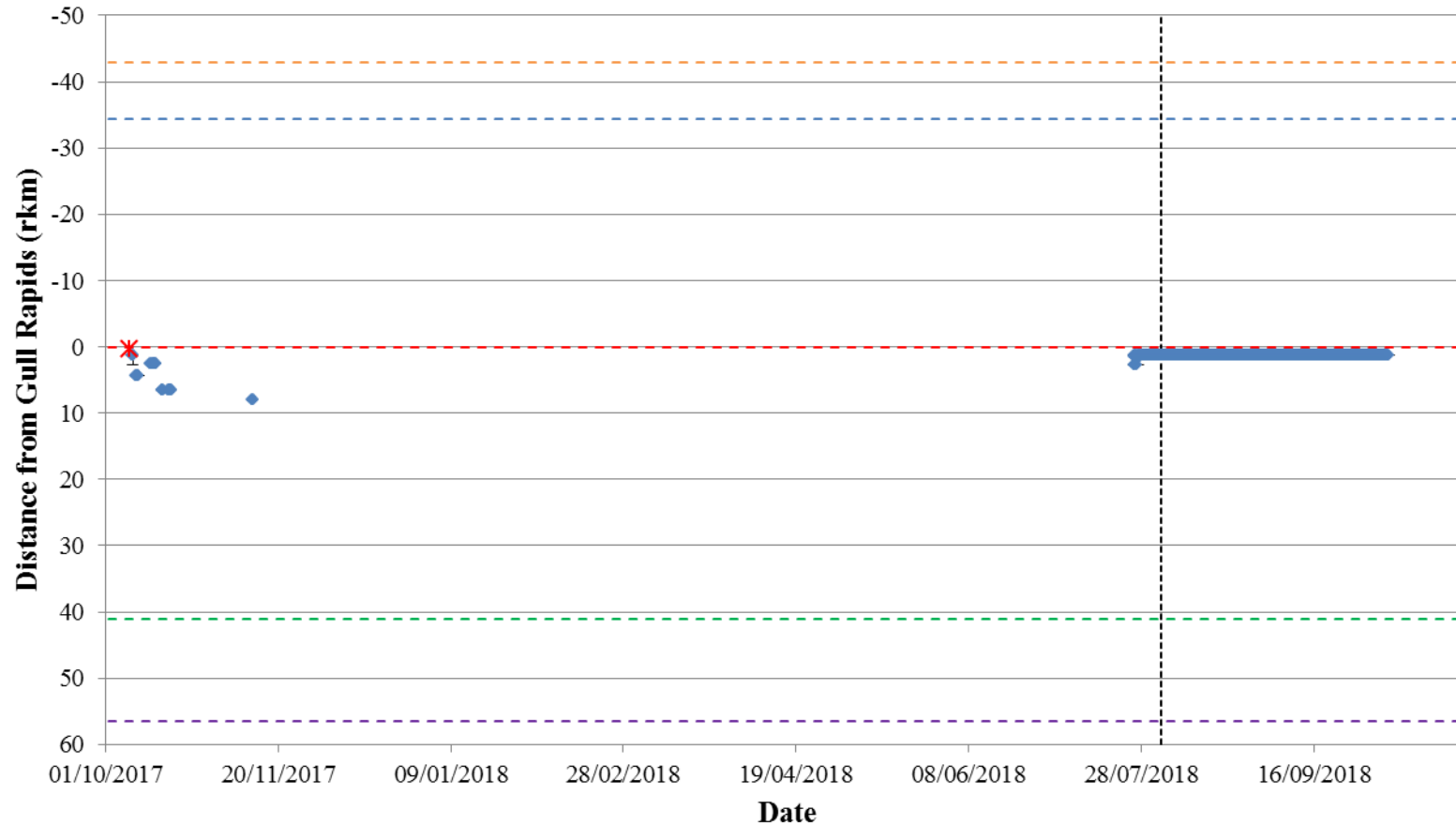
**Figure A3-16: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31713) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



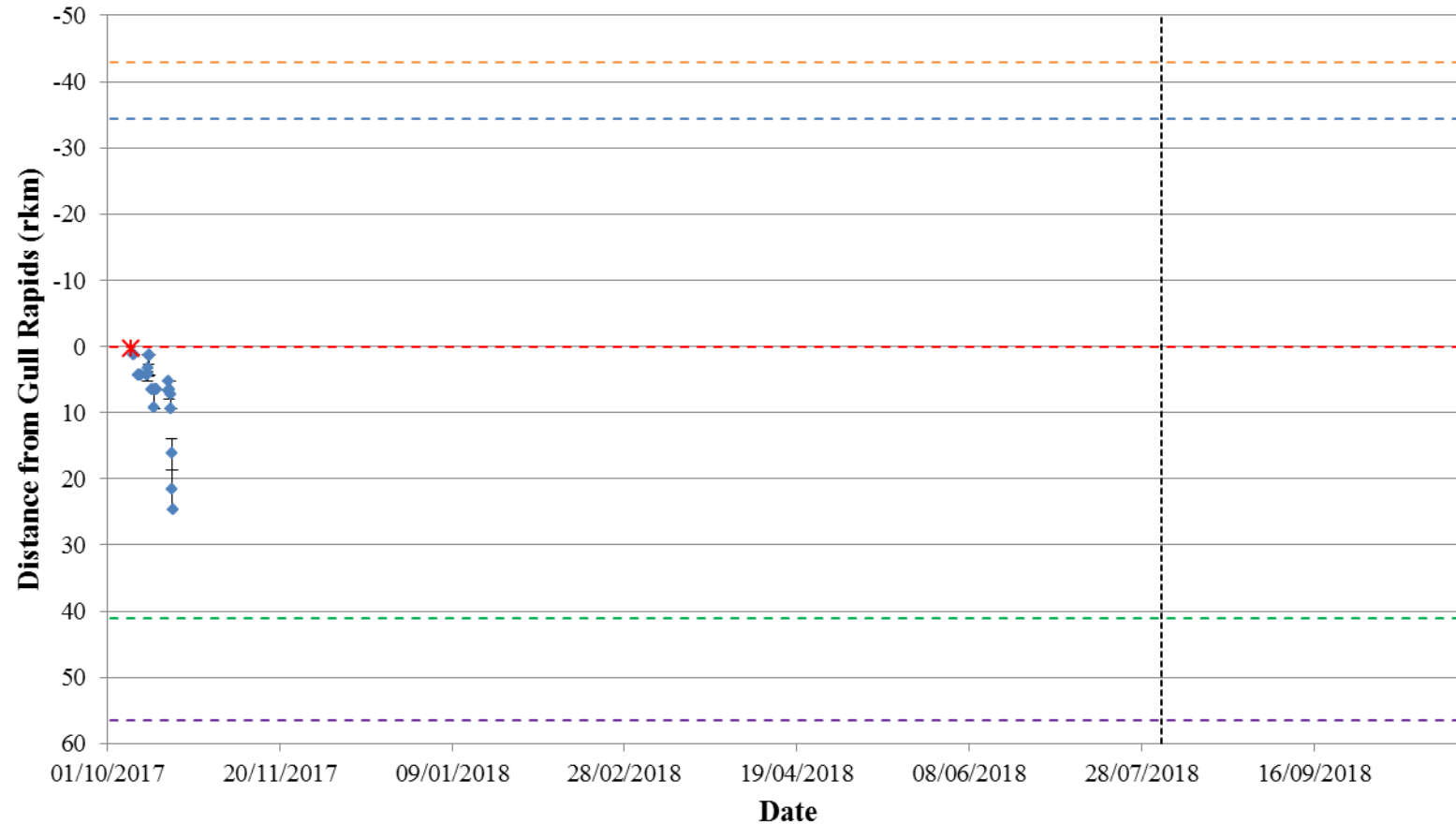
**Figure A3-17: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31714) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



**Figure A3-18: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31715) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

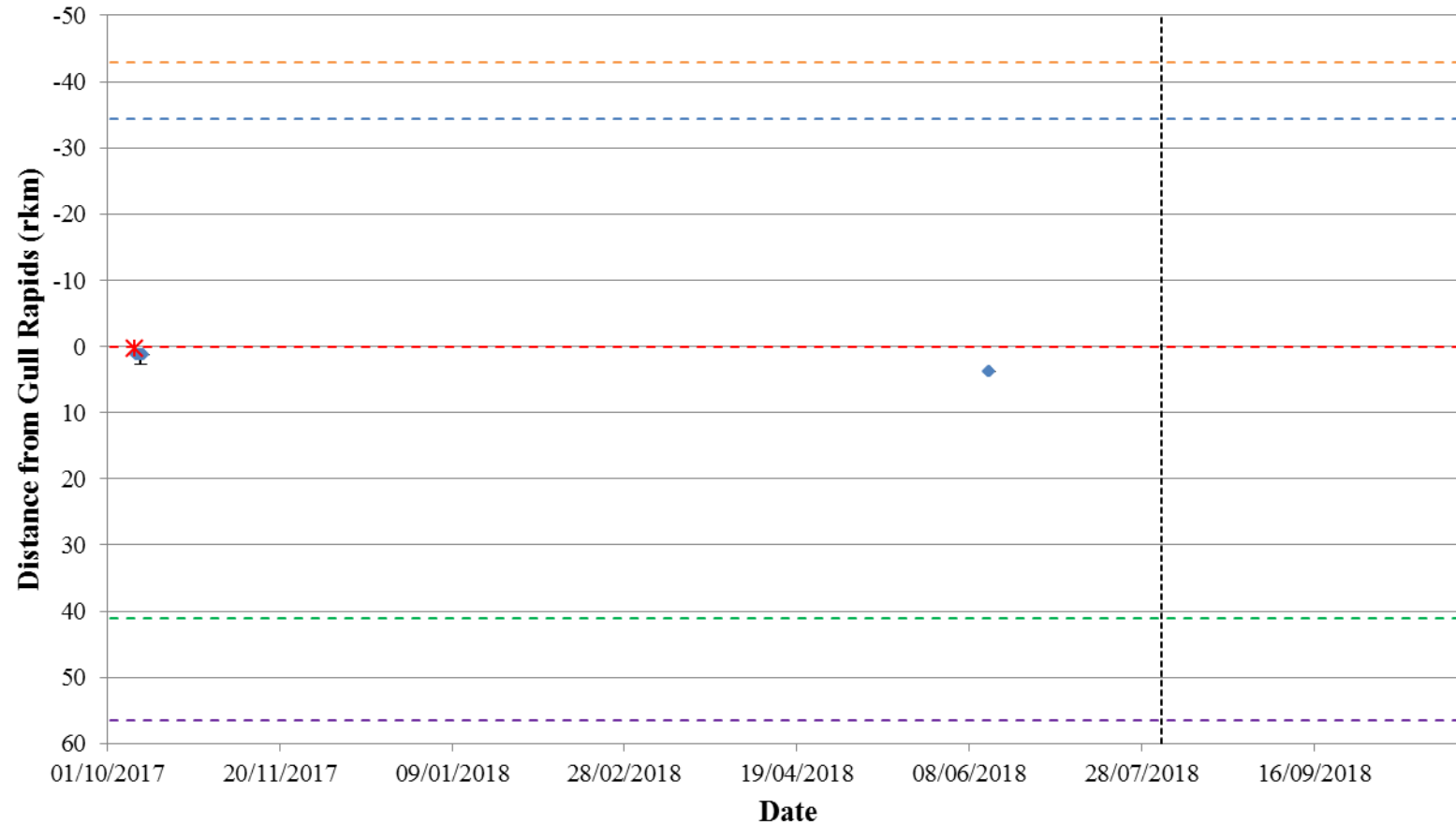


**Figure A3-19: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31716) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

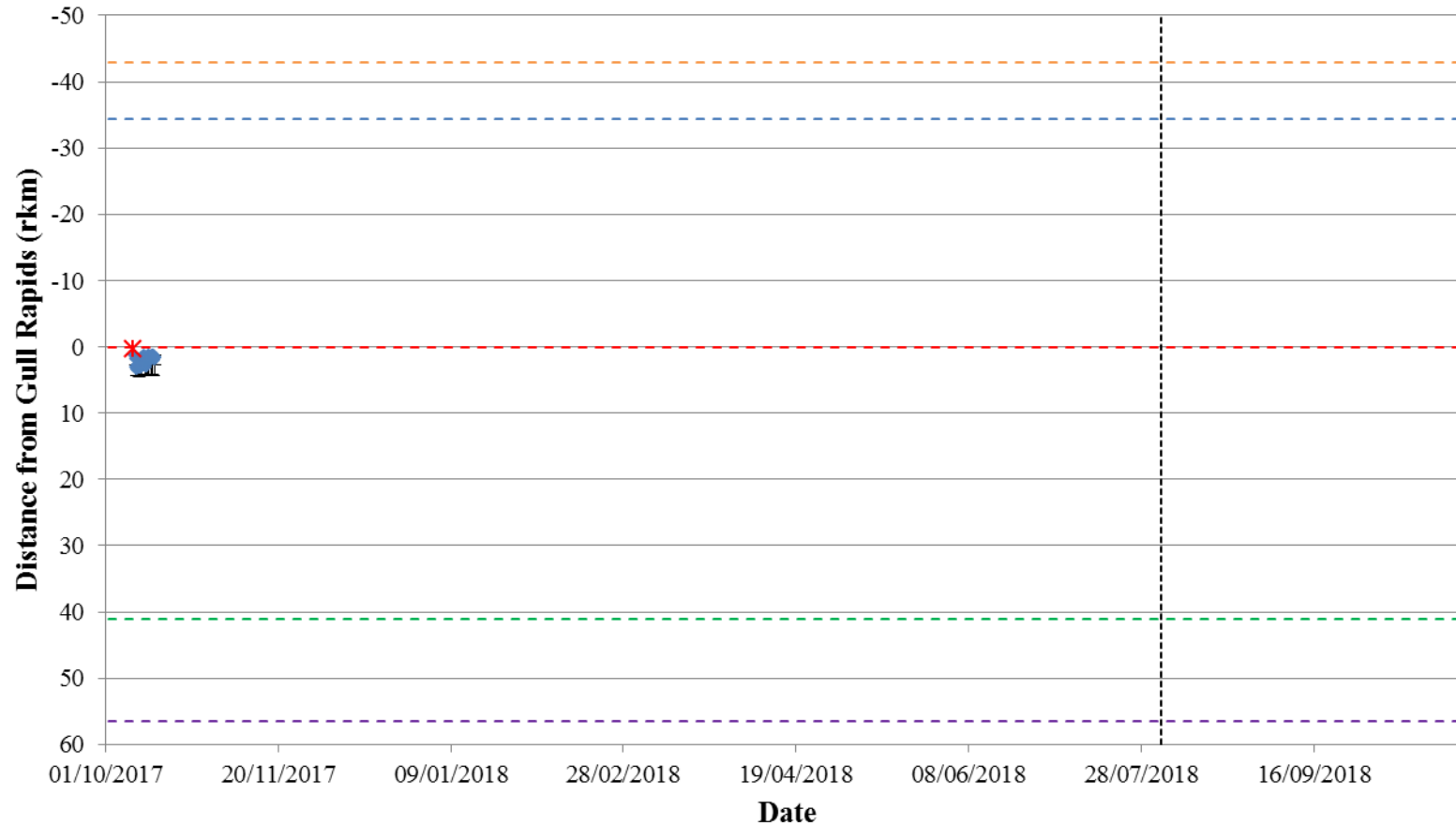


**Figure A3-20: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31717) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

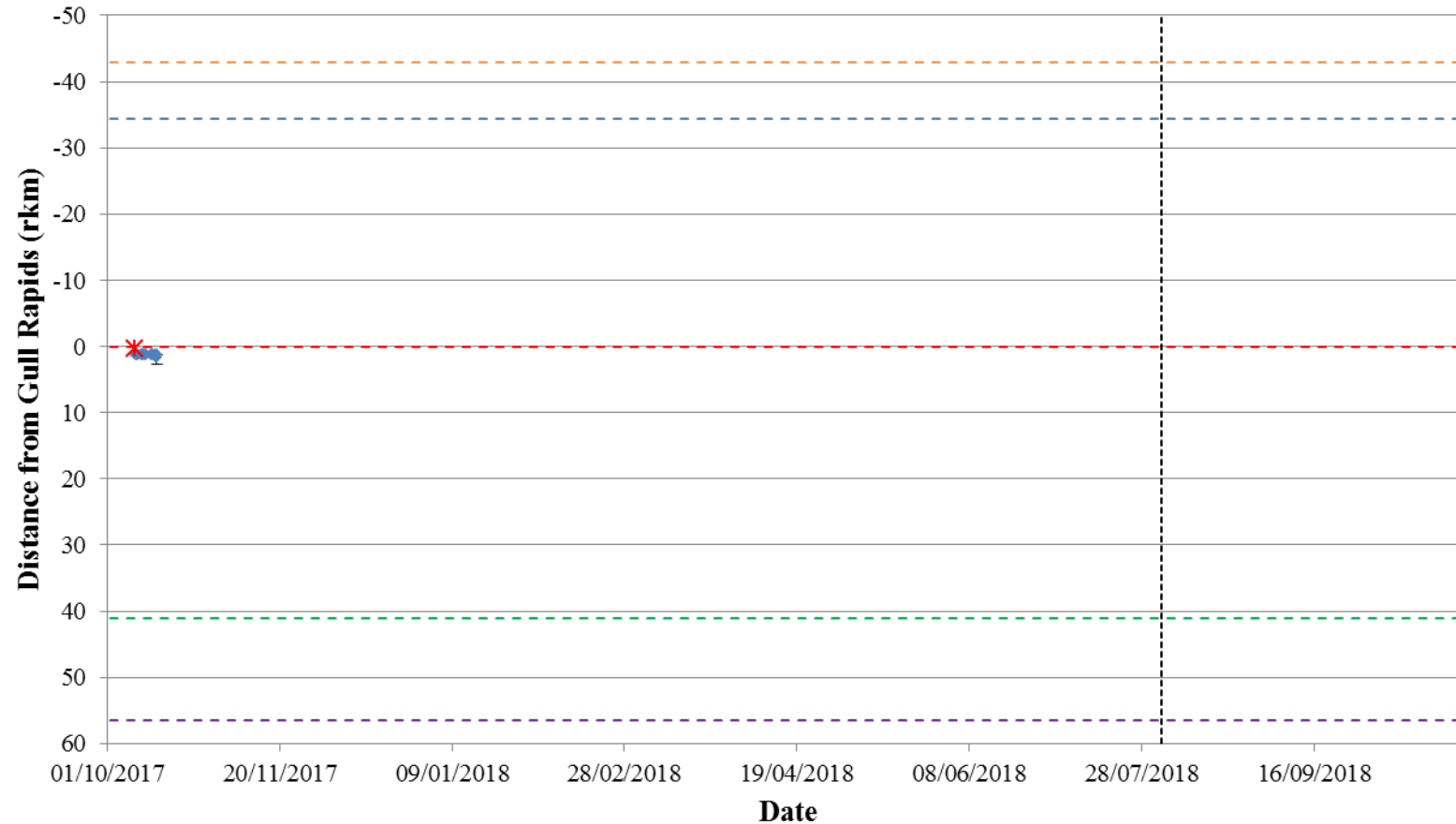




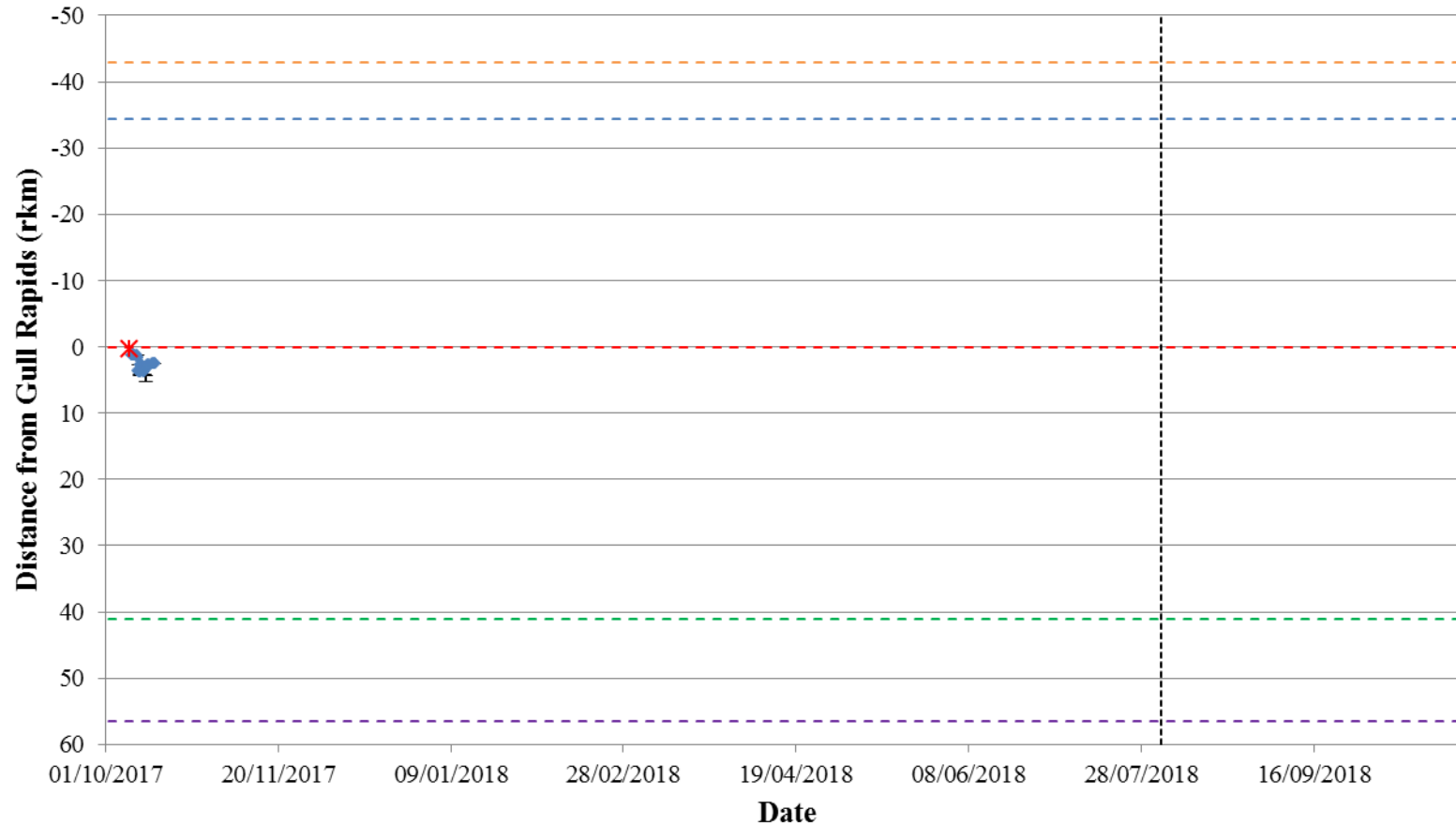
**Figure A3-21: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31718) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



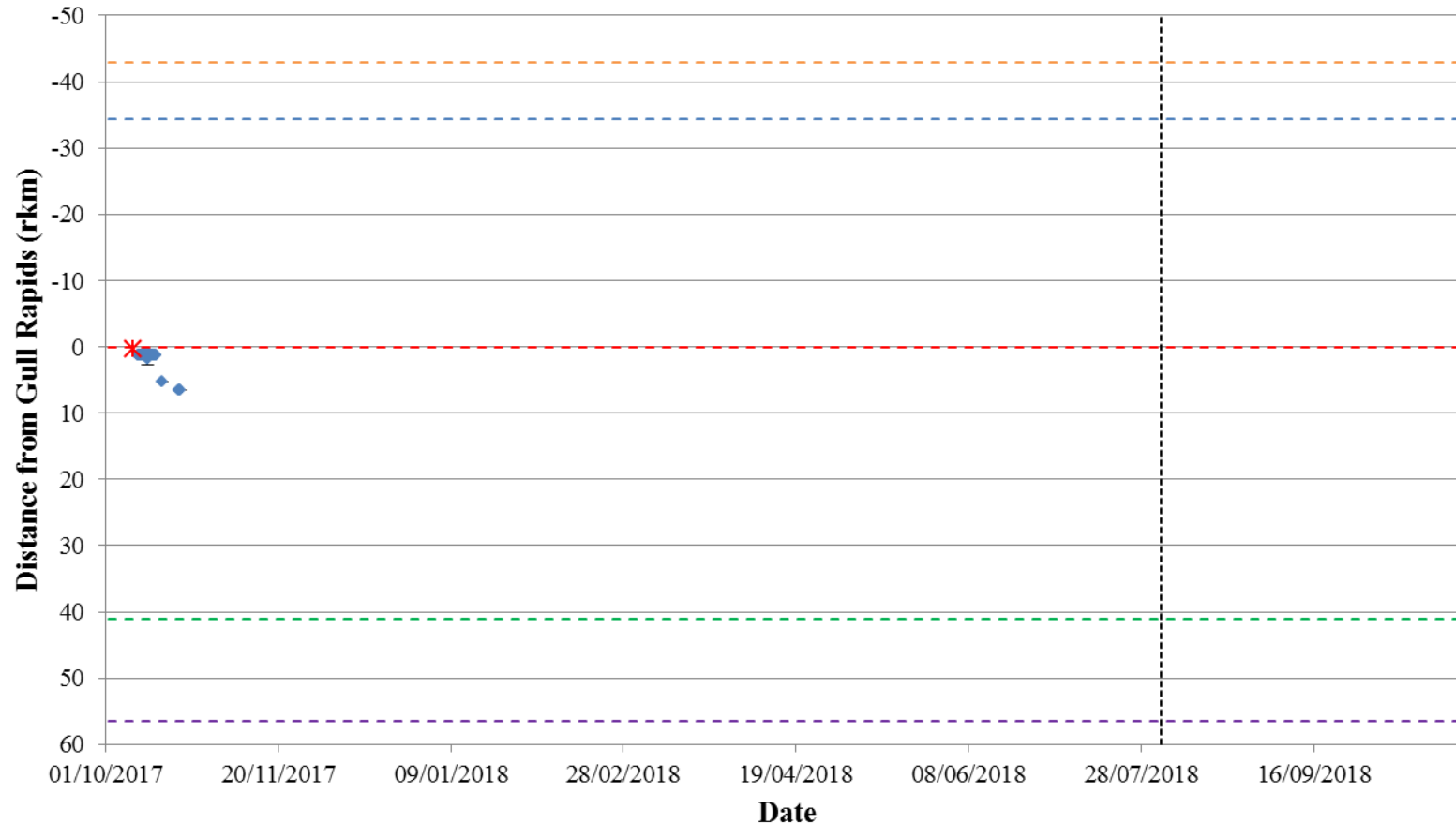
**Figure A3-22: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31719) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



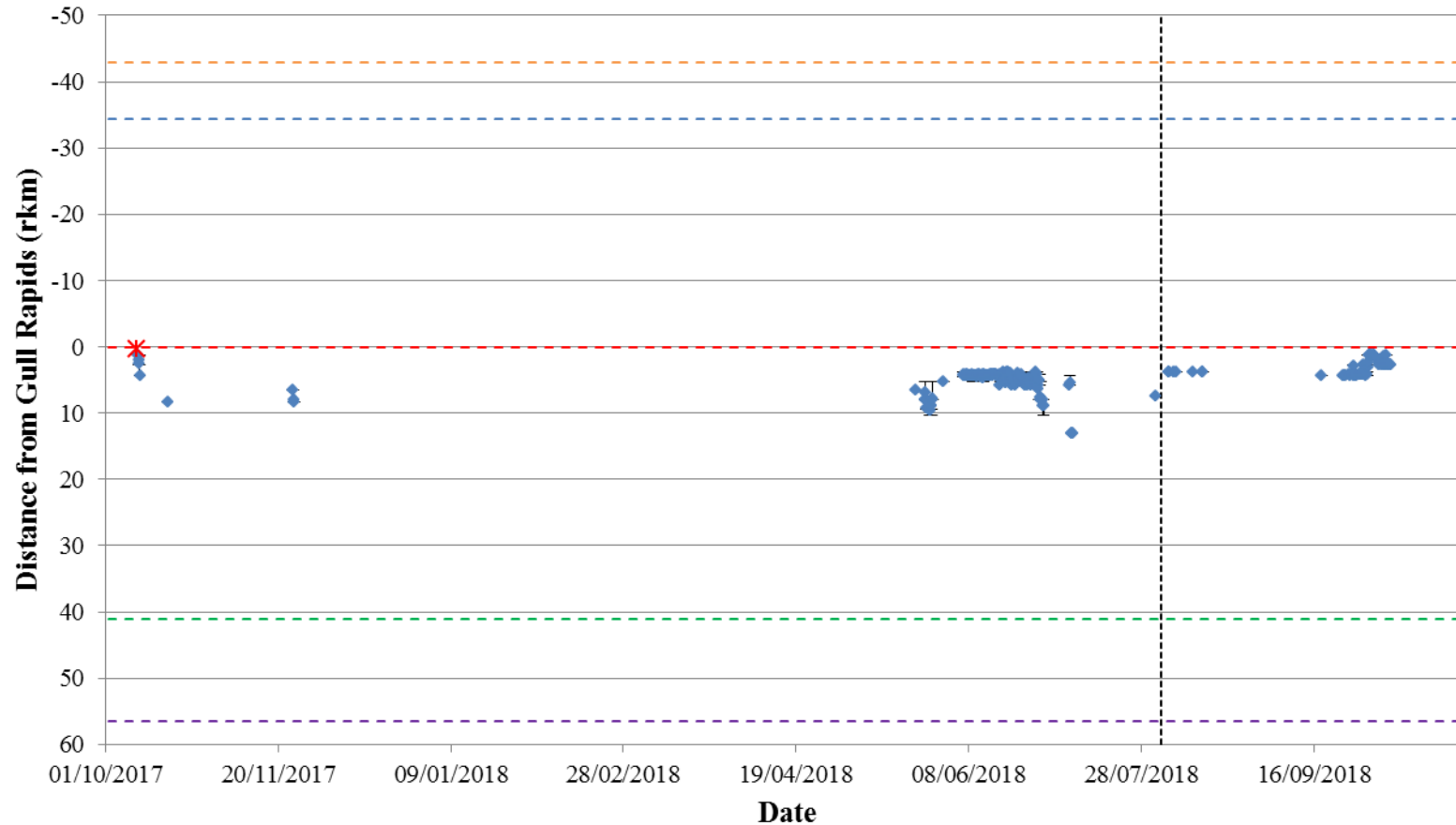
**Figure A3-23: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31720) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



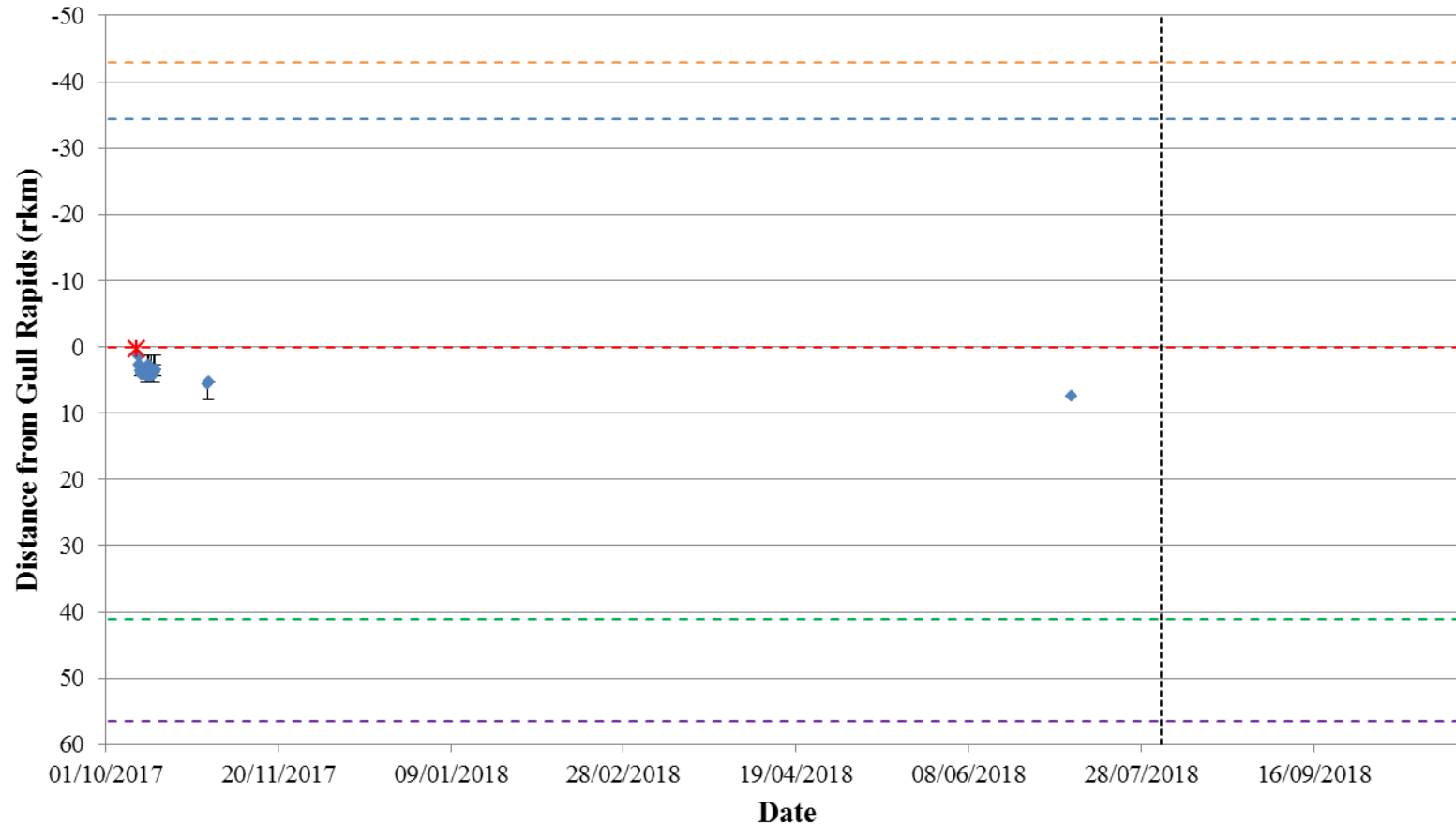
**Figure A3-24: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31721) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



**Figure A3-25: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31723) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

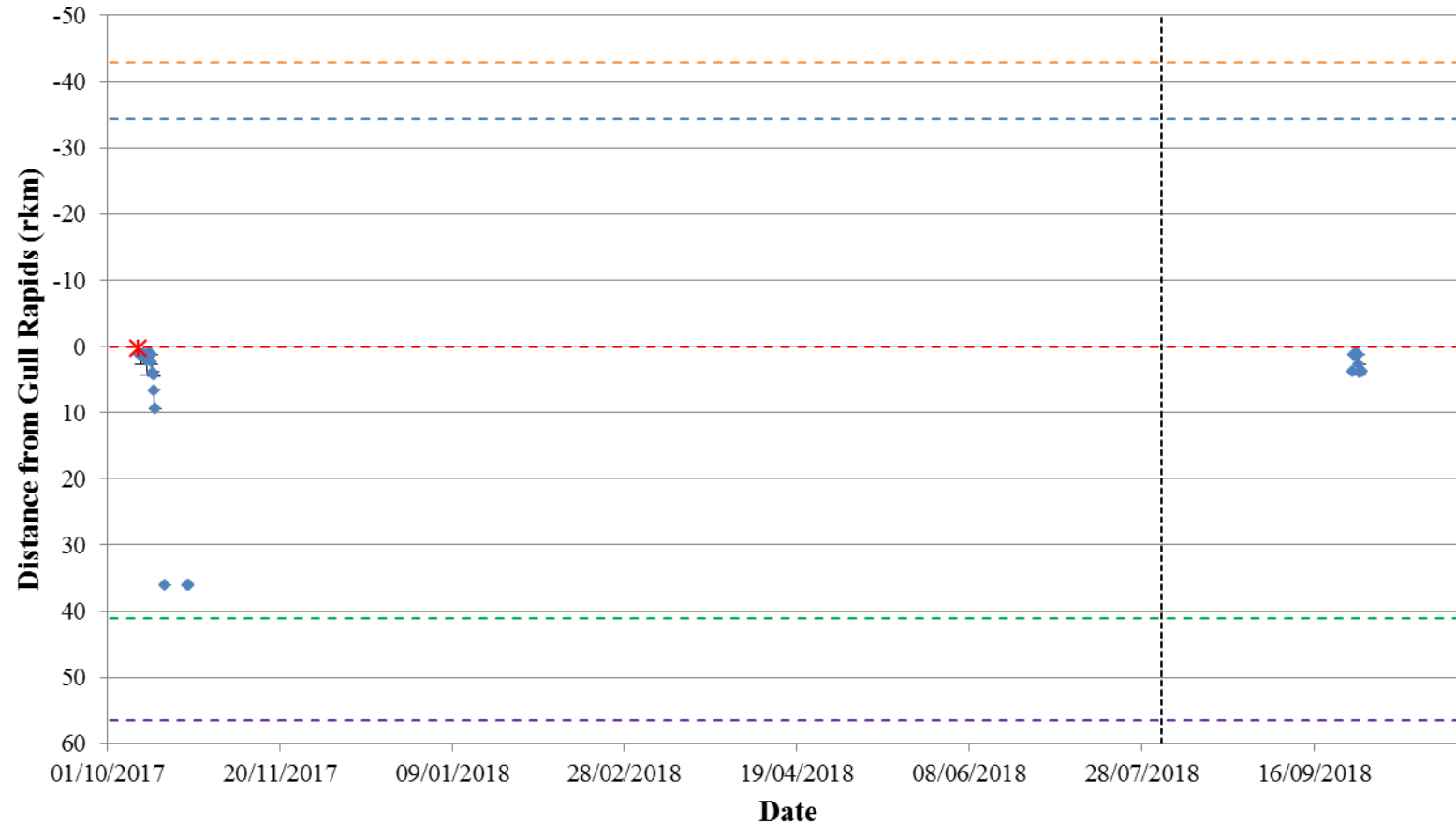


**Figure A3-26: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31724) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

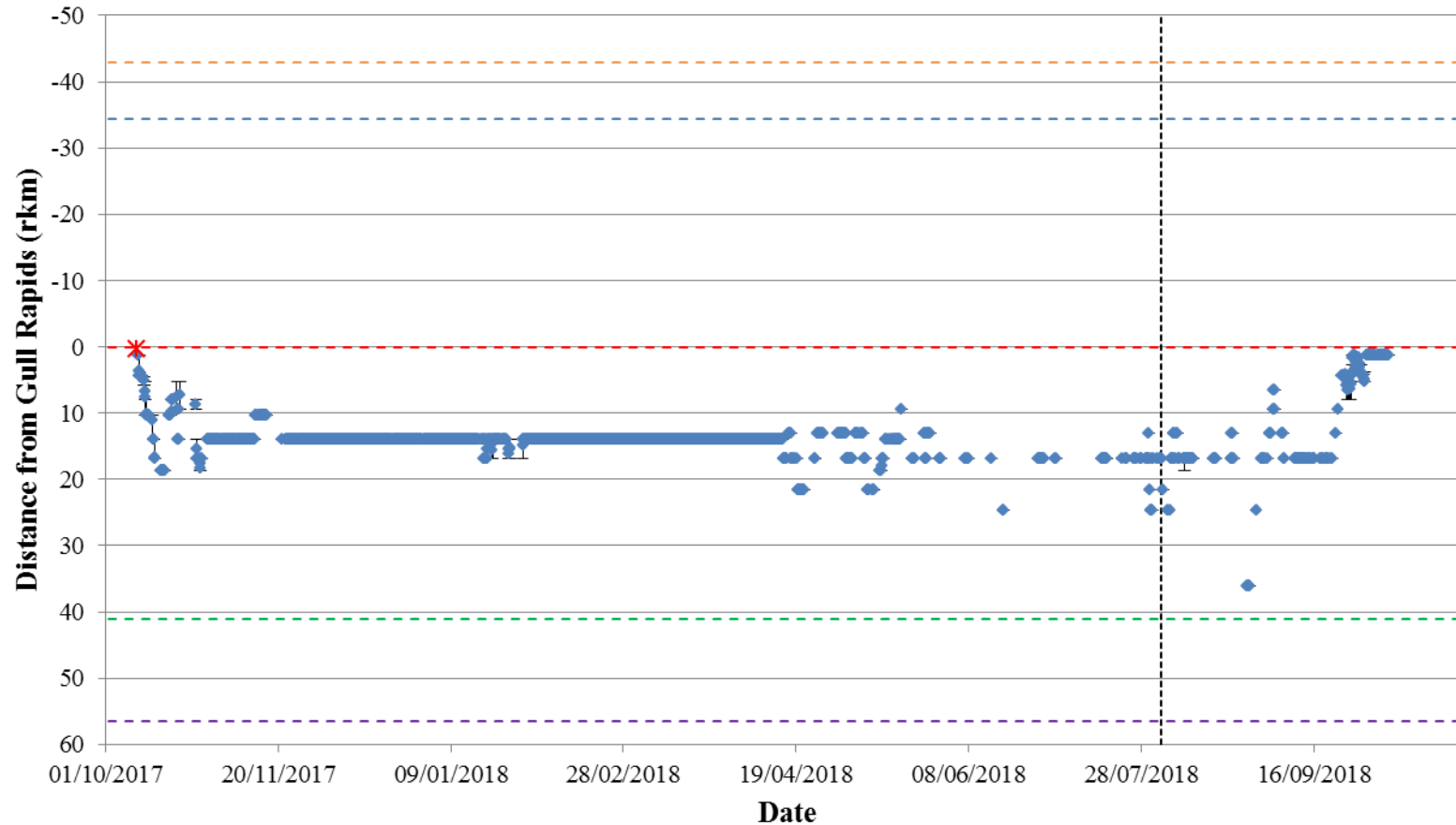


**Figure A3-27: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31725) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

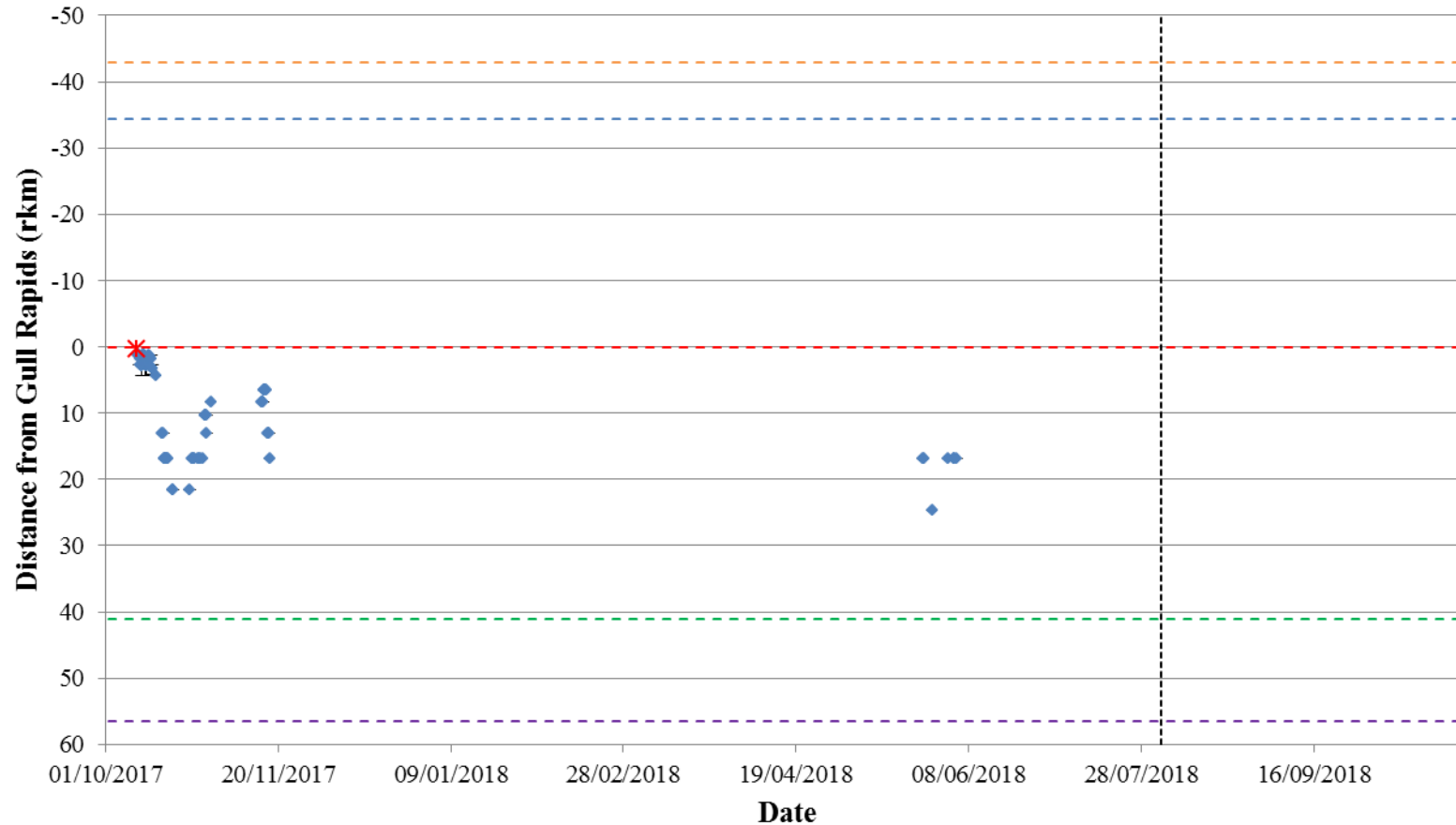




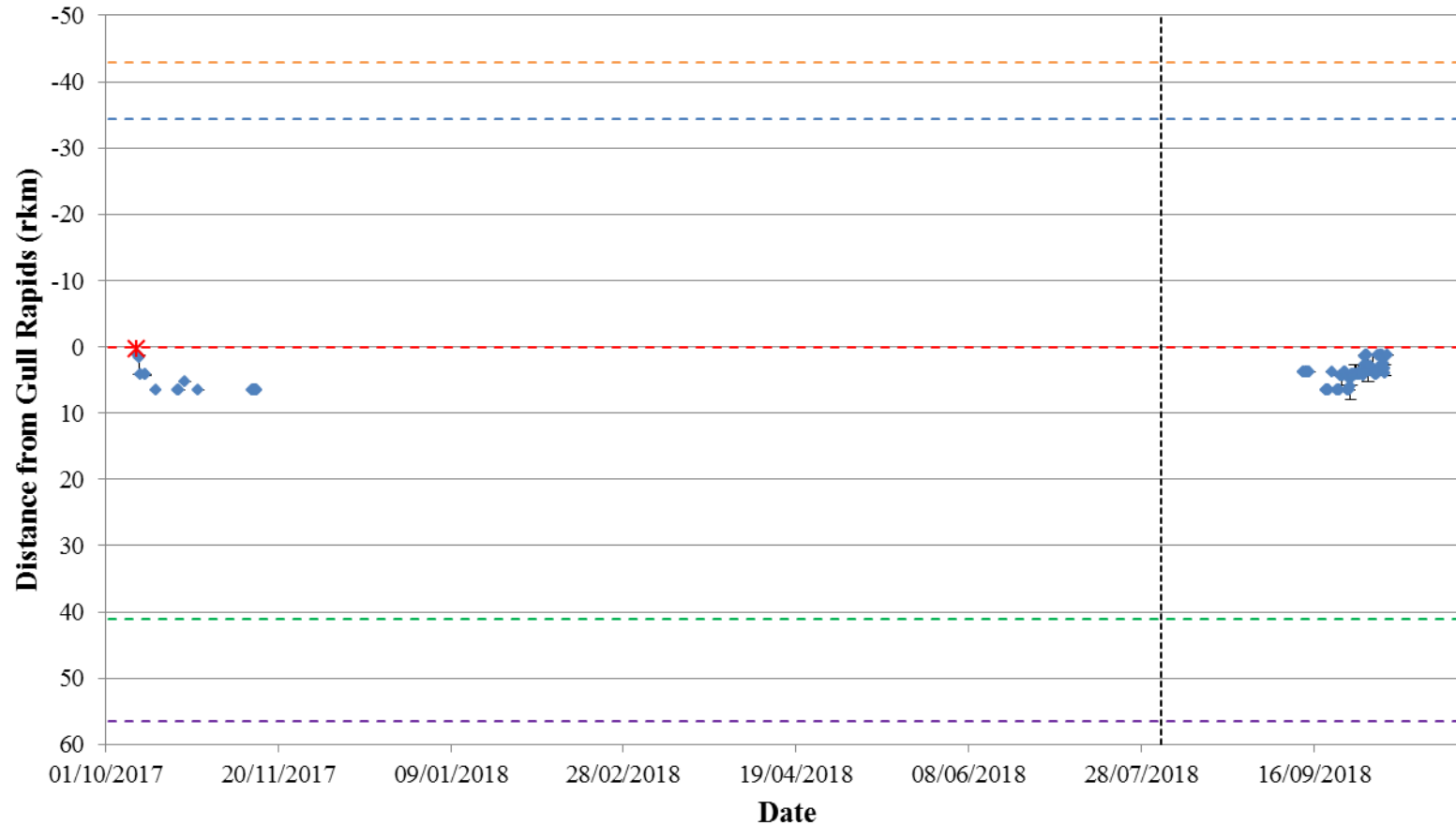
**Figure A3-28: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31747) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



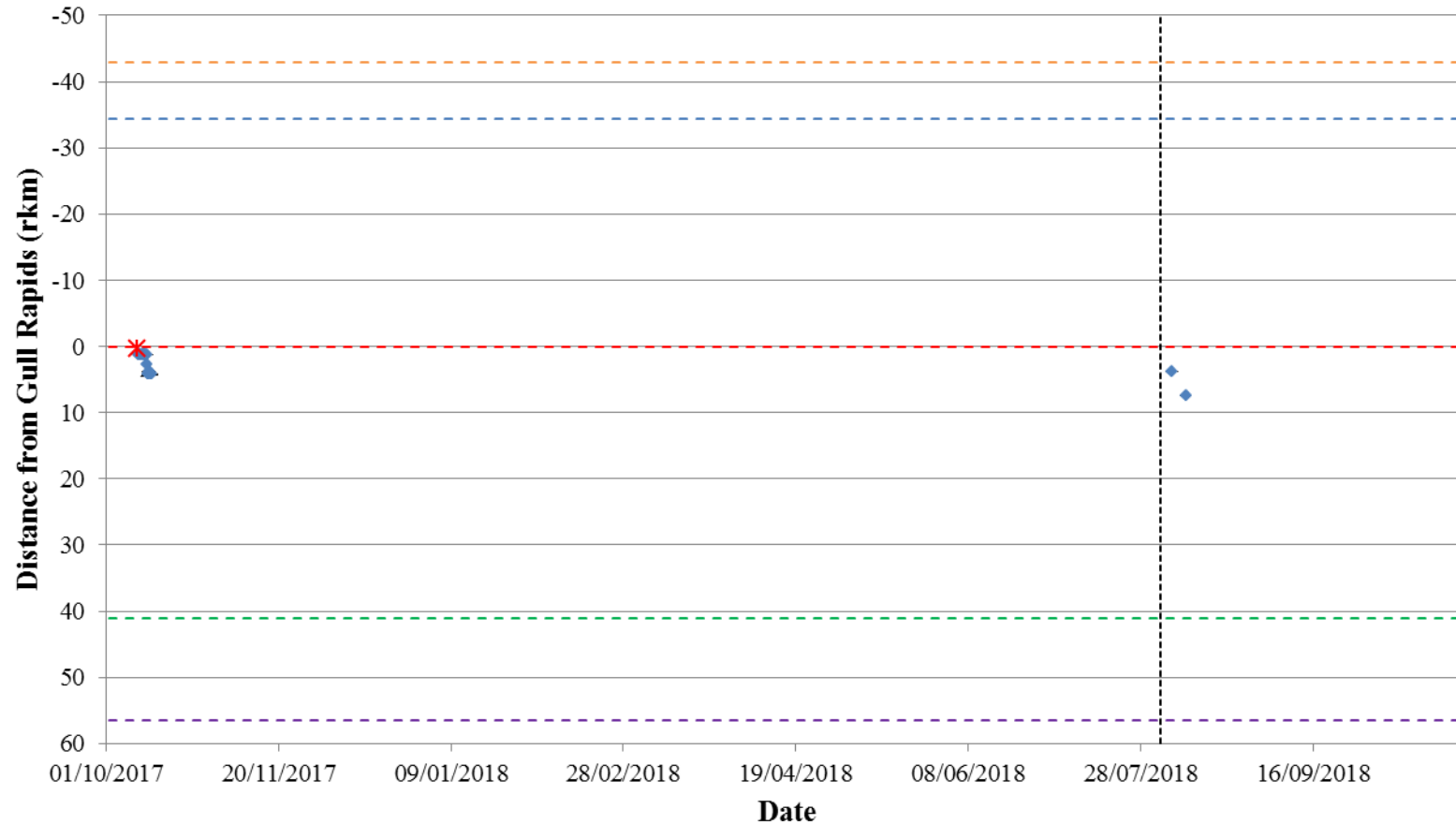
**Figure A3-29: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31748) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



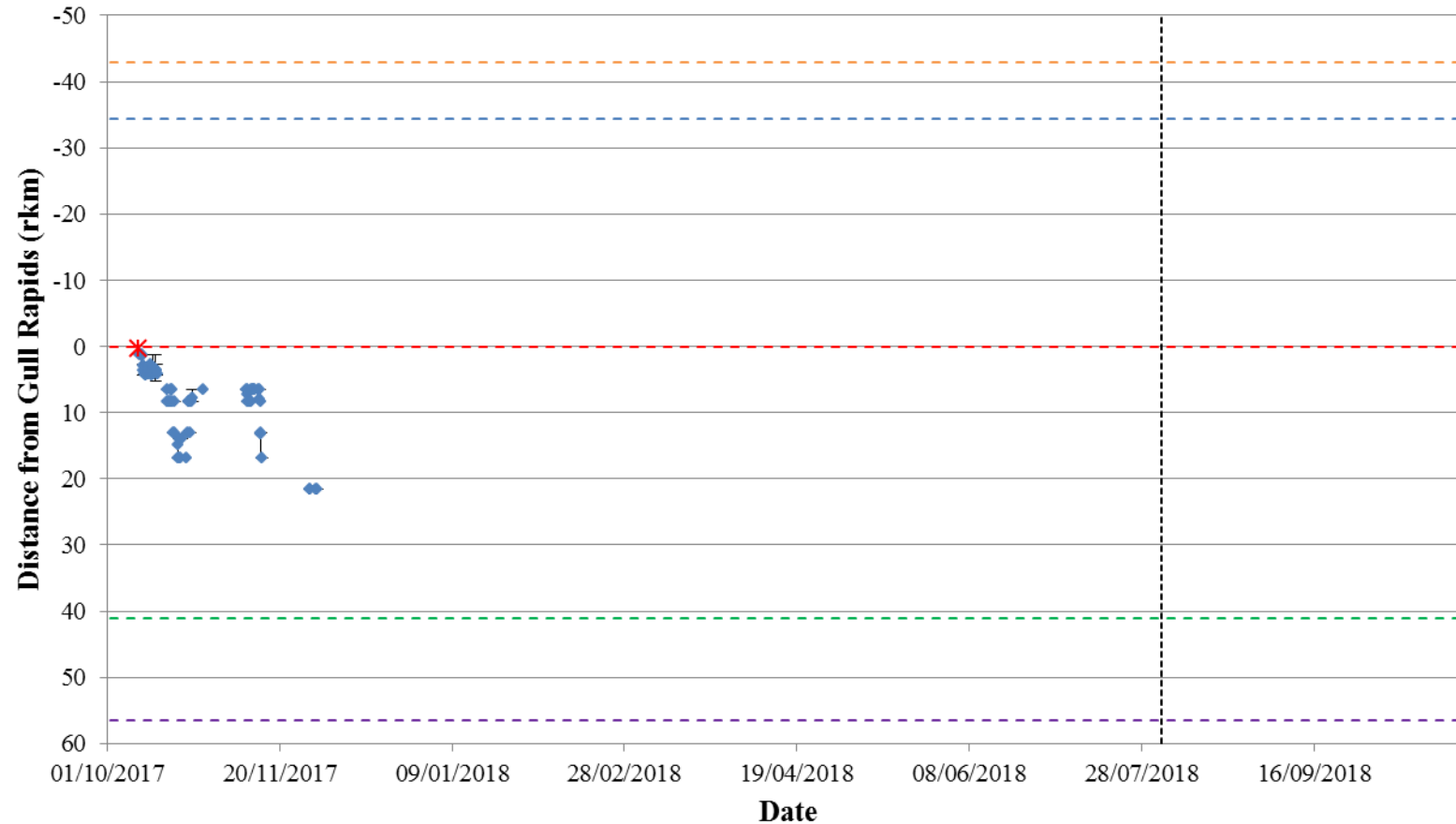
**Figure A3-30: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31749) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



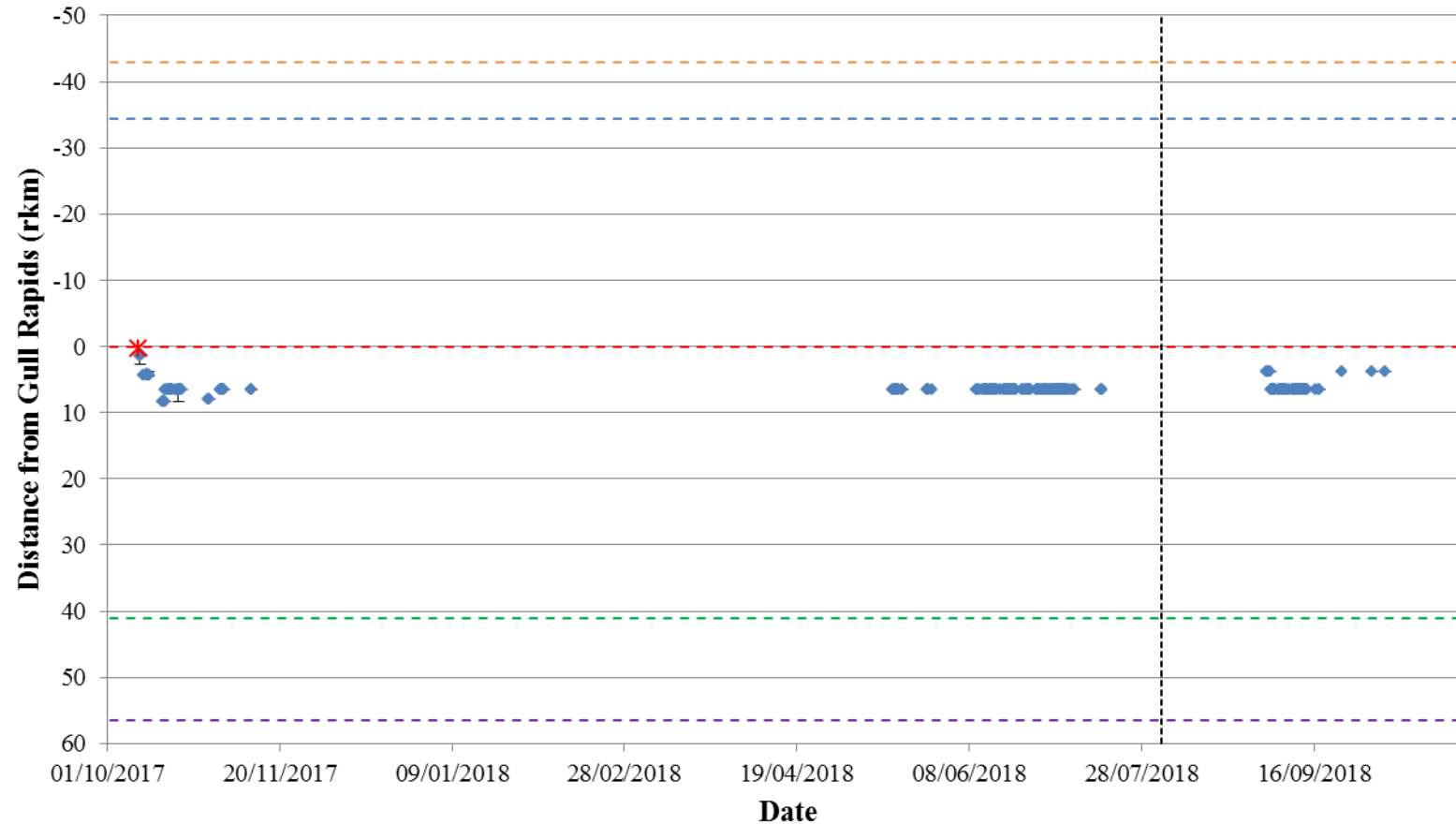
**Figure A3-31: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31750) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



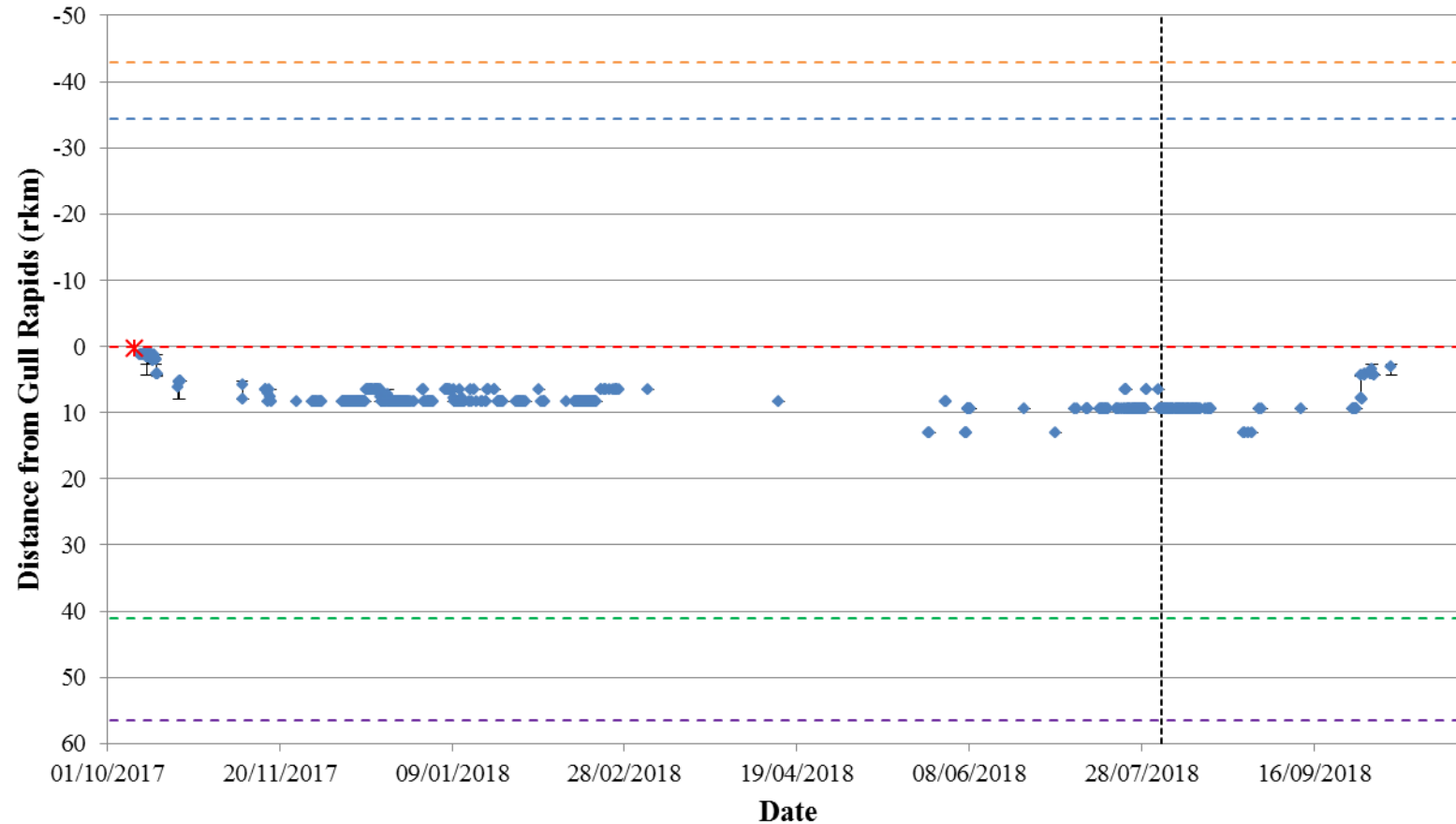
**Figure A3-32: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31751) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



**Figure A3-33: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31752) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

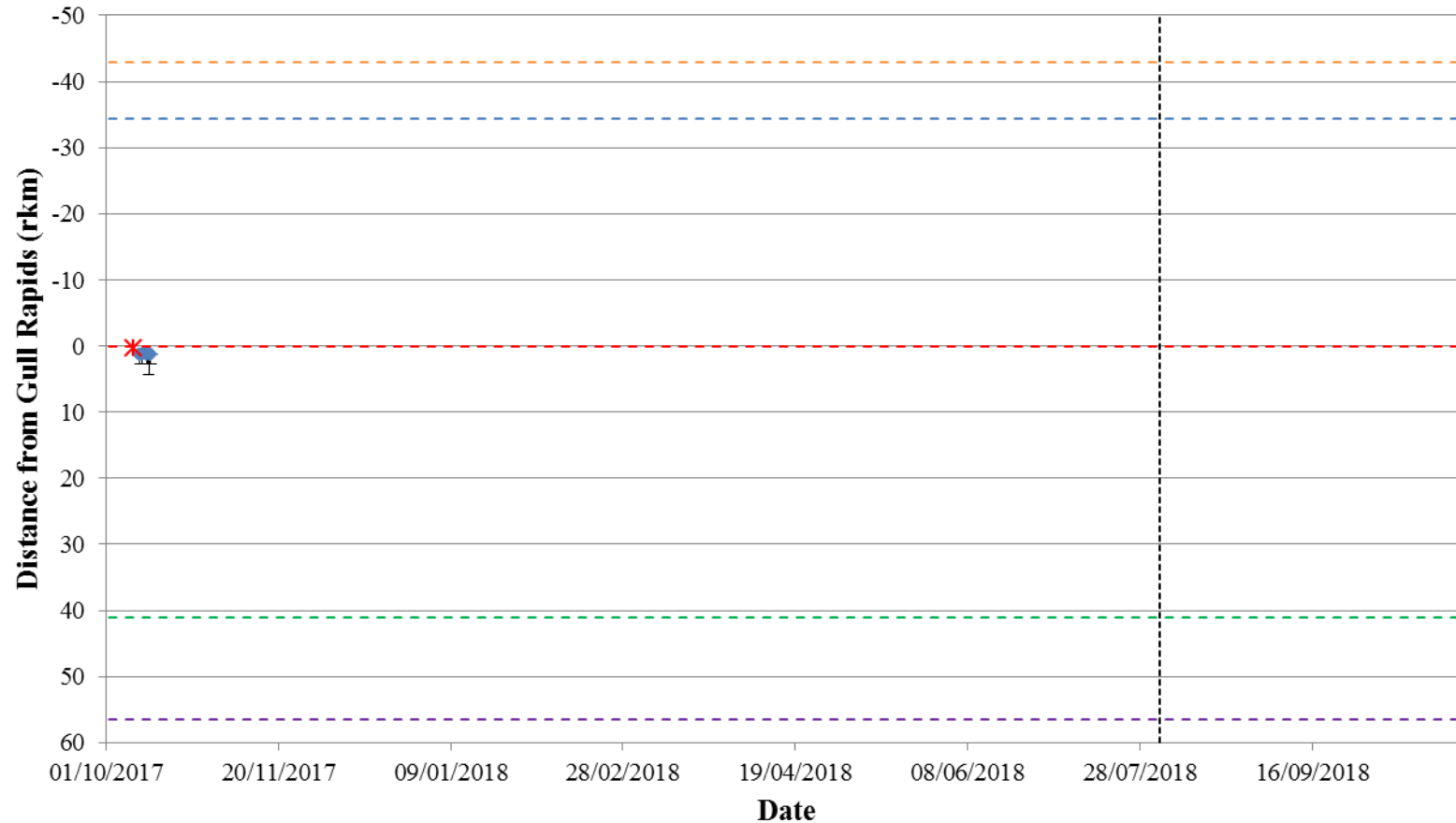


**Figure A3-34: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31753) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

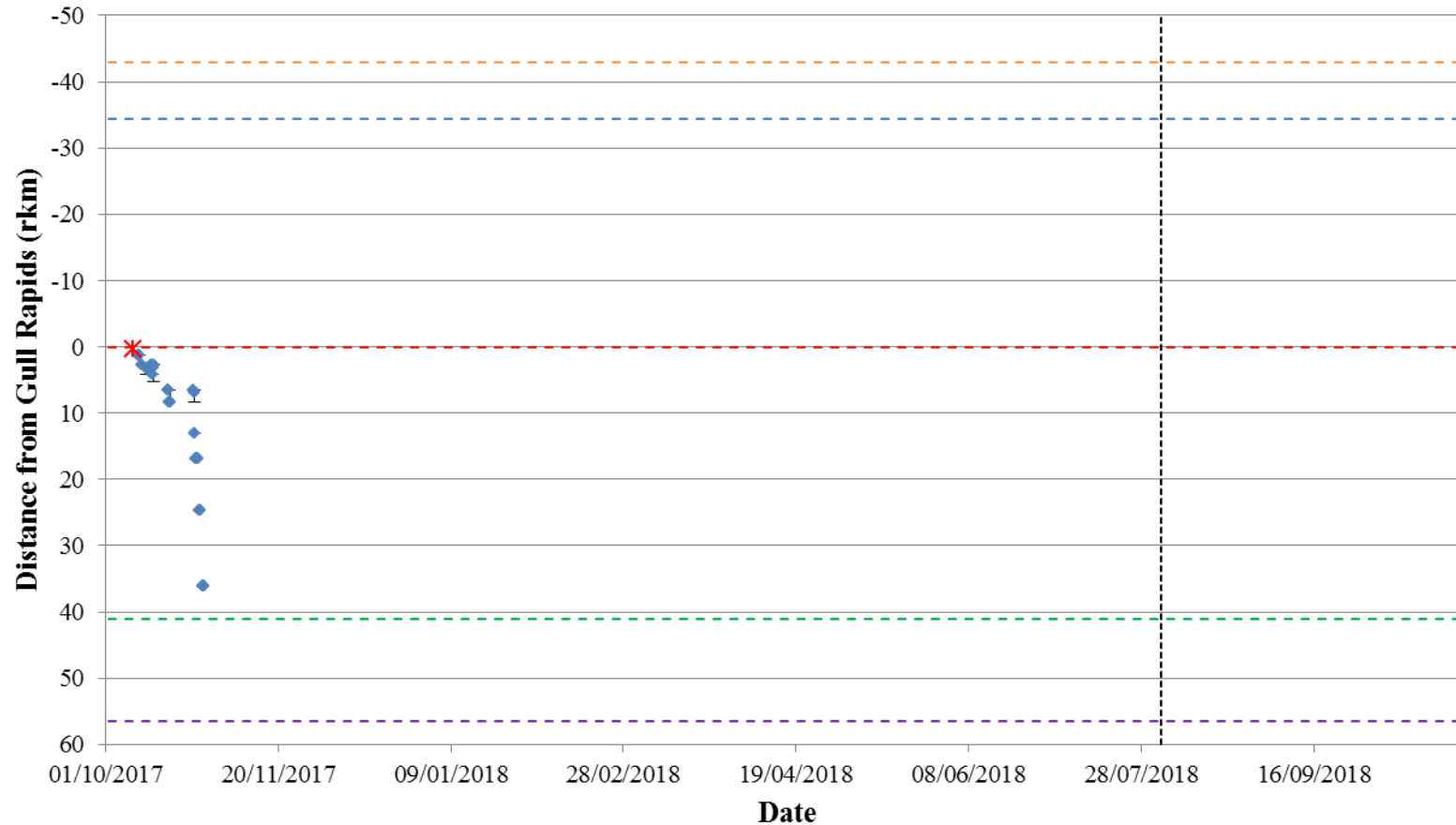


**Figure A3-35: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31754) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**

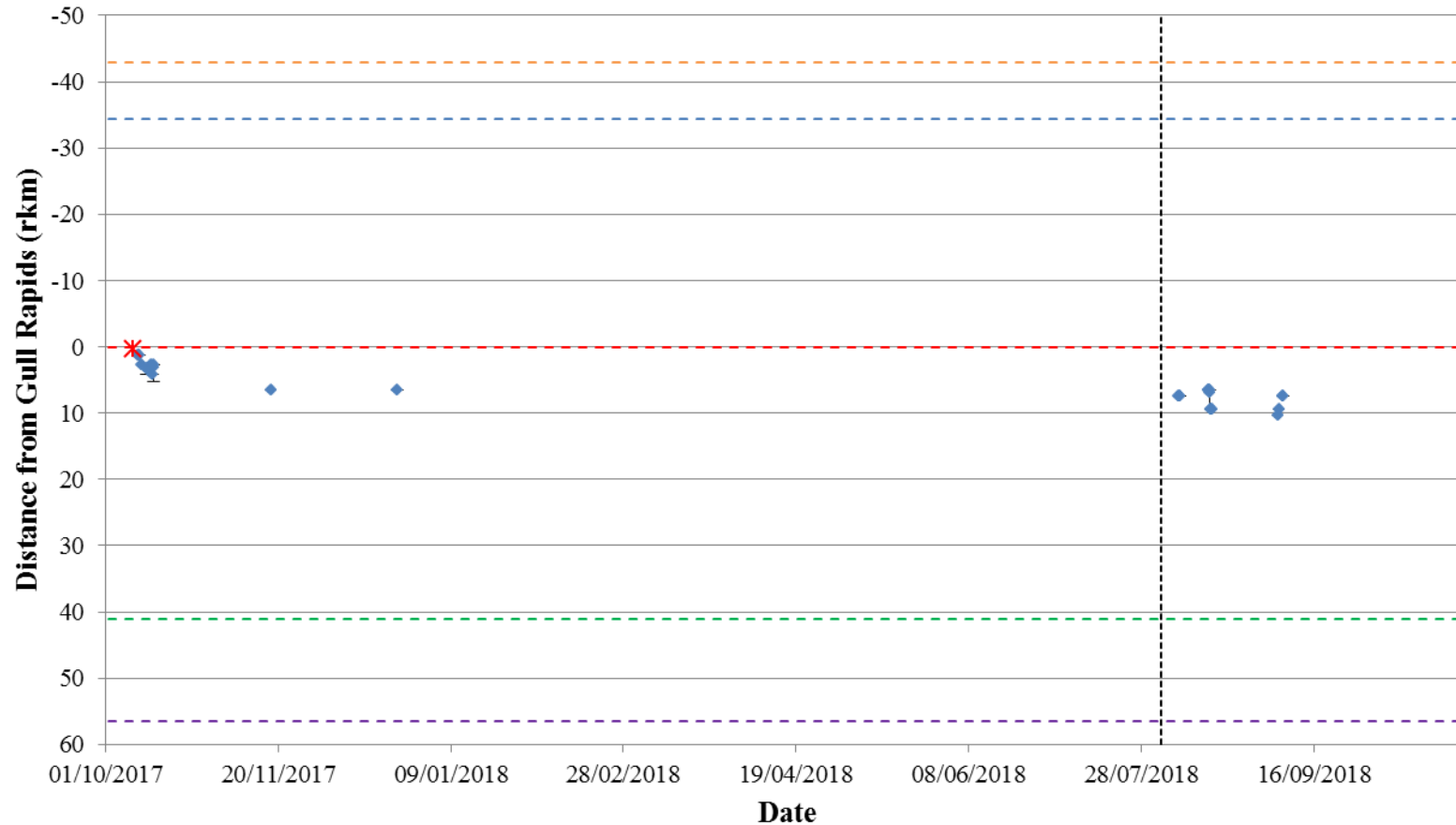




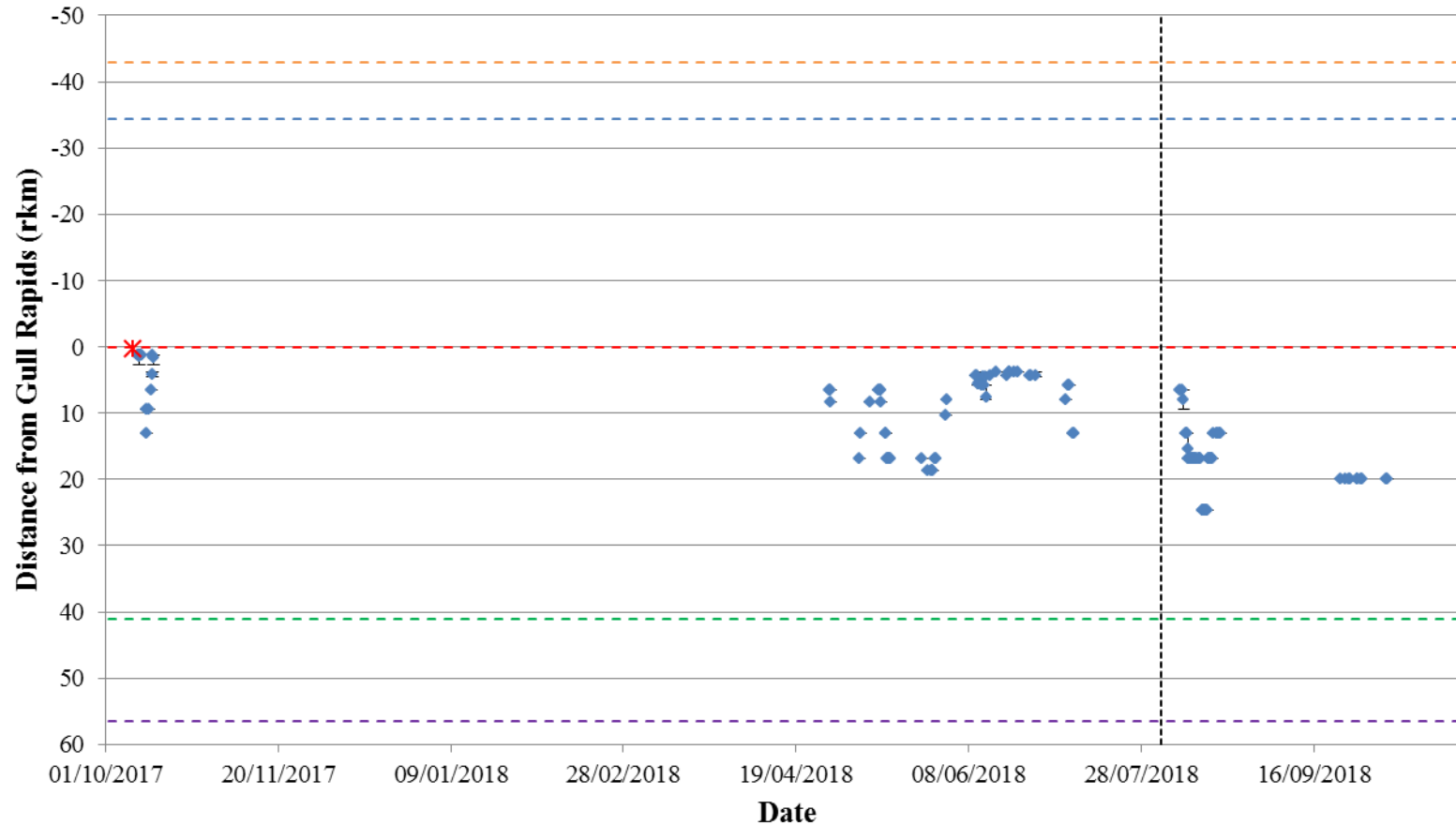
**Figure A3-36: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31755) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



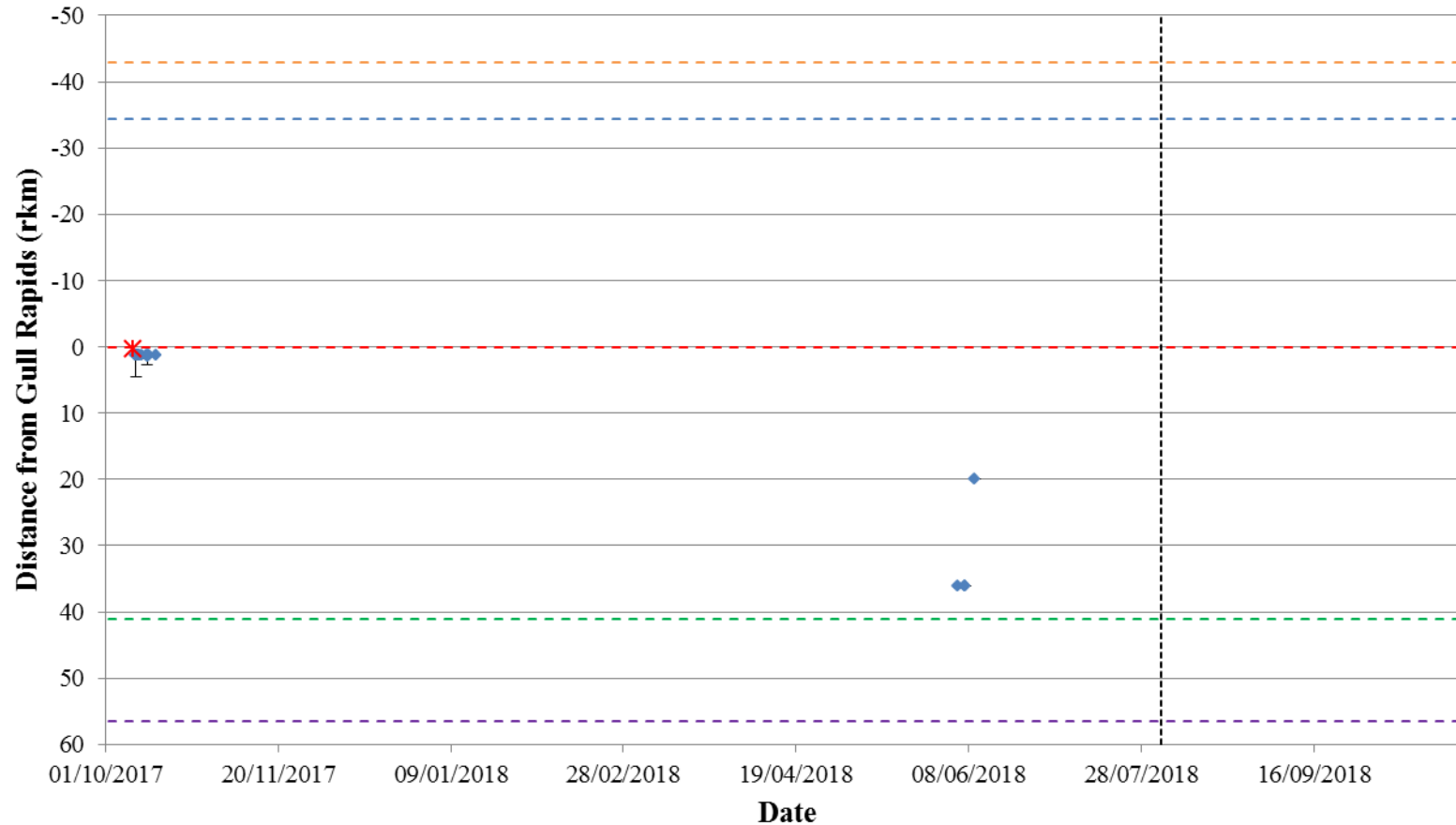
**Figure A3-37: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31756) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



**Figure A3-38: Position of a Lake Whitefish tagged with an acoustic transmitter (code #31757) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



**Figure A3-39: Position of a Lake Whitefish tagged with an acoustic transmitter (code #53761) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**



**Figure A3-40: Position of a Lake Whitefish tagged with an acoustic transmitter (code #53762) in Stephens Lake, in relation to Gull Rapids (rkm 0), from October 2017 to October 2018. The date and location of tagging are indicated by a red star. Horizontal dotted lines indicate locations of landmarks (orange = Clark Lake outlet; blue = Birthday Rapids, red = Gull Rapids; green = Kettle GS, purple = Long Spruce GS). Vertical black dotted line indicates start of spillway operation (August 3, 2018).**