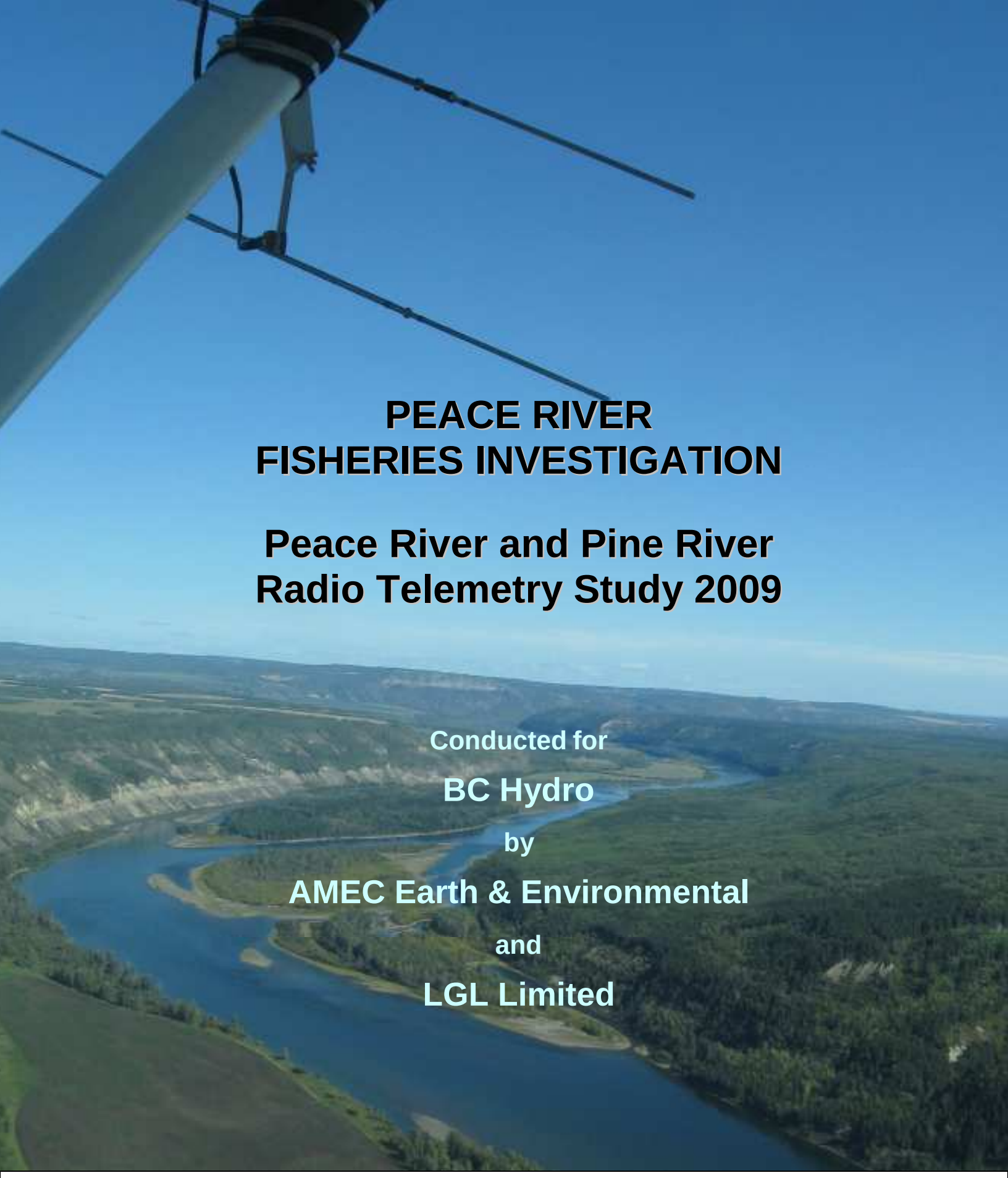

PEACE RIVER FISHERIES INVESTIGATION

Peace River and Pine River Radio Telemetry Study 2009

Conducted for

BC Hydro

by

AMEC Earth & Environmental

and

LGL Limited

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May 2010

VE51567

EXECUTIVE SUMMARY

Since 2005, AMEC and LGL have been commissioned annually by BC Hydro to conduct radio telemetry studies on the movements of sportfish species in the upper Peace River watershed from the Peace Canyon Dam to the vicinity of the potential Site C dam location. The movements of radio-tagged fish were tracked each year from early spring through autumn by strategically located fixed-station receivers and aerial surveys conducted at given intervals. Spring-spawning species (rainbow trout, Arctic grayling, walleye) were tagged and released in the Peace River mainstem in autumn 2005, whereas mountain whitefish (autumn spawner) were tagged in the following summer in the Peace mainstem, with some additional tagging of rainbow trout and Arctic grayling. In addition, tagging and release of bull trout, rainbow trout and Arctic grayling in the Pine River drainage were performed in 2006 (by Golder) and in 2007 and 2008 (by AMEC & LGL, and MOE). In total, 422 fish were tagged in the Peace River watershed below Peace Canyon Dam: 116 mountain whitefish, 82 Arctic grayling, 61 rainbow trout, 58 walleye and 105 bull trout. The findings from 2005 to 2008 have been described in annual reports.

This report summarizes the findings of the movements in 2009 of the Pine-tagged fish, compares them to previous results, and provides a synopsis of the overall results to date. Briefly, the main findings are as follows:

1. **Bull trout**

- The majority of bull trout in the Pine River watershed appear to be resident fish that do not move extensively; migratory fish probably constitute a minor proportion (perhaps <5%) of the overall population
- The migratory form appears to consist of two life history types: one that spawns in the Halfway and forages/overwinters in the Pine mainstem (2%; 2/104 fish in 2007; none in 2008 and 2009), the other spawns in the Pine and forages/overwinters in the Peace mainstem (2%, 4% and 2% in 2007, 2008 and 2009 respectively)
- Very few bull trout were detected in the Peace River mainstem, and none were recorded between July and September;
- The distribution of bull trout in the Pine River watershed was relatively stable over time: 51-64% were in the Pine mainstem, 18-30% in the Burnt/Sukunka rivers, and 18-24% in the Murray/Wolverine drainage;
- The median distance moved by bull trout became progressively shorter with each successive year: 51, 27 and 12 km in 2007, 2008 and 2009, respectively; fewer movements were recorded outside of the Pine watershed in 2008 (4 fish) and 2009 (2 fish) than in 2007 (5 fish);

- Of the fish that did not exit the Pine watershed, some made annual forays between the Burnt/Sukunka drainage and the Pine mainstem, spending late summer-autumn in the Burnt/Sukunka area and winter-summer period in the Pine mainstem.

2. Arctic grayling

- Movement distances among Arctic grayling generally were not extensive (median movement 7.4 km); none was detected outside of the Pine River watershed, consistent with the findings of the MOE 1996-1999 radio-tracking study;
- In all months, the majority of Arctic grayling detected were in the Pine mainstem below the Murray River, and invariably their movement was progressively downstream from release to site of last detection.

3. Rainbow trout

- Movement distances among rainbow trout were variable, consisting of minor, moderate and extensive movers (median distance 6.9 km); a few fish exited the Pine, but, with one exception (one fish moved ~10 km past the Moberly, then downstream to near the Beatton, and returned to the Pine), did not move far from the river's mouth;
- During all months, rainbow trout were proportionally distributed fairly evenly between the Burnt/Sukunka drainage and the lower Pine mainstem.

4. Walleye

- Of the few walleye detected in 2009 (due to battery end of life), their locations in the Peace mainstem and tributaries (Beatton and Pine rivers) were consistent with those identified previously (2006-2008)

The overall results of three years of tracking of the Pine-tagged fish populations suggest:

- It is very unlikely that Arctic grayling will exit the Pine River and move past Site C;
- A few rainbow trout may exit the Pine, but in most instances will probably not move upstream past Site C;
- Movement past Site C may be limited to a few bull trout that move between the Pine and Halfway rivers in either direction to complete their life cycle.

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1.0 INTRODUCTION

BC Hydro currently operates the G. M. Shrum and Peace Canyon generating stations on the Peace River in northern British Columbia. The province of British Columbia has forecast a growing electricity gap and has been investigating ways to meet the province's future power demands. One option that BC Hydro has been investigating is another hydroelectric development on the Peace River at Site C, in the vicinity of Fort St. John (Figure 1).

Within the Site C study area, the proposed dam has the potential to alter upstream and downstream migrations of fish in the Peace River. Inundation of the Peace River and the lower reaches of upstream tributaries by Site C dam would change fish habitat from riverine to more lacustrine and alter the upstream fish community as it adapts to the new environment. The inundation of these tributaries has the potential to change local fish populations (i.e., species composition, abundance and distribution) by changing hydraulic conditions of their habitat, and increasing sedimentation in inundated areas.

Over the last 30 years, BC Hydro has conducted baseline fisheries studies and investigated the potential environmental impacts of Site C dam. Some of these previous studies have provided information on the movements of bull trout (*Salvelinus confluentus*) Arctic grayling (*Thymallus arcticus*), rainbow trout (*Oncorhynchus mykiss*), mountain whitefish (*Prosopium williamsoni*), and walleye (*Sander vitreus*) in the Peace River and its tributaries (Burrows et al. 2001; R.L.&L. 1991a, 1991b; AMEC & LGL 2010). These studies suggested:

- Bull trout move between the Halfway River and the Peace River and a portion of bull trout that spawn in the Halfway River make extensive migrations in the Peace River, including downstream movements past the proposed Site C dam location (Burrows et al. 2001; R.L.&L. 1991a, 1991b; AMEC & LGL 2010).
- Peace River Arctic grayling are found primarily in the reach between the confluences of the Halfway and Moberly rivers and appear to exhibit only localized movements (R.L.&L. 1991a, 1991b);
- Rainbow trout are most abundant in the Peace River upstream of Farrell Creek and move into tributaries in the spring to spawn, particularly Maurice and Lynx creeks (R.L.&L. 1991a, 1991b);

- Mountain whitefish are ubiquitous in the Peace River and a proportion of this population moved from the Peace River into the Halfway River in the fall to spawn (R.L.&L. 1991a, 1991b); and,
- Walleye are generally found downstream of the Pine River (R.L.&L. 1991a, 1991b). They concentrate near the mouth of the Beatton River and use the Beatton River for spawning (R.L.&L. 1991a, 1991b). A portion of the walleye population concentrated near the Beatton River moved upstream past the proposed Site C Dam location in the summer, but returned downstream in the fall (R.L.&L. 1991a, 1991b).

BC Hydro has also conducted a number of literature reviews and gap analyses regarding the Peace River fish community. These reviews by AMEC and others (Valenius 2001; Pottinger Gaherty 2001) identified additional information that was needed to develop a defensible baseline database for any future environmental impact assessment of Site C dam. Two of these potential information requirements included determining further information about how the proposed Site C dam would affect fish migrations and the utilization of tributaries upstream of the potential Site C dam. In 2005, AMEC and LGL initiated long-term baseline studies to address these concerns which have continued annually to present (AMEC & LGL 2008a, 2008b, 2008c, 2009, 2010).

A radio telemetry study was initiated in 2005 to expand on previous movement studies and to determine the potential impact Site C dam would have on migrations of large-bodied fish in the Peace River (AMEC & LGL 2008a, 2008b, 2008c, 2009). The specific objectives were to determine the magnitude, direction, and seasonality of fish movements in the mainstem and into Peace River tributaries with a focus on movements past the potential Site C dam location and above the potential zone of inundation in the tributaries. Radio-tagging of fish included Arctic grayling, walleye and rainbow trout in fall 2005, and Arctic grayling, rainbow trout and mountain whitefish in early summer 2006 in the mainstem of the Peace River between the Peace Canyon Dam and the Kiskatinaw River. From 2005 until the tags expired, movements of tagged fish were tracked each year using fixed stations and aerial tracking surveys.

The telemetry results for the Peace River-tagged fish (AMEC & LGL 2008a, 2008b and 2008d) suggested that:

- Walleye are distributed in the Peace River, downstream of the Moberly River, and approximately 50% move extensively within and between the Peace River mainstem and the Beatton River to spawn and some use the Pine River to forage in summer;

- Mountain whitefish are widely distributed in the Peace River and their spawning locations are also widespread, including the Peace River mainstem and lower reaches of most tributaries upstream of the potential Site C dam;
- Arctic grayling spend most of their time in the Peace River between the Halfway and Beatton rivers but spawn in Peace River tributaries, mainly the Moberly River. As a result of their distribution, Peace River Arctic grayling is the species most likely to pass the potential Site C Dam location; and,
- Rainbow trout are found mainly from the Peace Canyon Dam to the vicinity of the Halfway River, and spawning occurs primarily in the smaller streams upstream of the Halfway River (e.g., Maurice, Lynx, Farrell creeks).

Bull trout are known to move between the Halfway River and the Peace River and a portion of Halfway River bull trout made extensive migrations in the Peace River including downstream movements past the proposed Site C dam location (AMEC & LGL 2010). However, movement of the Pine River bull trout population among the Pine, Peace and Halfway rivers was previously unknown. In 2007 and 2008, the radio telemetry program was expanded to tag and track sportfish in the Pine River and to investigate how Pine River fish utilize the Peace River and its tributaries upstream and downstream of the potential Site C dam location. Bull trout, Arctic grayling and rainbow trout were also tagged in the Pine River system in the fall of 2006.

Based on 2007 and 2008 tracking results, it appears likely that Arctic grayling in the upper Pine River watershed are resident populations that remain in the drainage year round. No radio-tagged Arctic grayling moved from the Pine River into the Peace River in 2007 or 2008 (AMEC & LGL 2008c, 2009). As for rainbow trout, no fish moved out of the Pine River watershed in 2007; however, two fish moved into the Peace River mainstem in 2008 (AMEC & LGL 2008c, 2009). It should be noted that only limited numbers of rainbow trout (15) and Arctic grayling (8) were radio-tagged in the Pine River system in 2006 (and subsequently tracked in 2007). The 2008 fish were not tagged until the summer, so spawning movements of the spring-spawners (Arctic grayling, rainbow trout) were not observed in 2008

Radio-tagged bull trout showed considerable variation in movements over the duration tracked. From March to October 2007, some fish, particularly those in the upper Pine River watershed, moved relatively short distances (average 51 km; AMEC & LGL 2008c). In contrast, two bull trout made extensive migrations of more than 450 km, moving from the Pine River system to the upper Halfway River drainage in late summer 2007, remained in the Halfway

River system until the end of the spawning period, and then returned to the Pine River in late fall (AMEC & LGL 2008c).

In 2007, it was noted that the proportion of fish that moved from the Pine River to the Halfway River may have been under-represented in our study, because 2006 tagging was conducted primarily in Burnt/Sukuka drainage in mid-August, after the date when bull trout may have migrated to spawning locations outside the Pine River watershed (AMEC & LGL 2008c). This criticism led to additional tagging efforts in 2008 to examine bull trout migrations from other locations in the Pine River system. In 2008, bull trout were detected in the Peace River mainstem, but none of the tagged bull trout at large migrated into the Halfway River drainage in fall to spawn (AMEC & LGL 2009).

The results to date suggest that there may be two populations of bull trout in the Pine River drainage. It is possible that one population (the numerically dominant one) is resident in the Pine River drainage, while the other undertakes large scale migrations from the Pine River watershed to the Halfway River watershed. The 2007 and 2008 data suggest that the resident population spawns in the Burnt/Sukunka, Wolverine and upper Pine River drainage, and rears and forages primarily in the Pine River system. On the other hand, the migratory population appears to be a mix of two types: one that spawns in the upper Halfway River drainage, and overwinters/forages in the Pine River; the other, spawns in the lower Wolverine watershed and overwinters/forages in the Peace mainstem near the Alberta border. The relative proportion of resident versus migratory bull trout in the Pine River system is not currently known. Movements of bull trout among the Pine and Peace and Halfway rivers from the 2007 and 2008 surveys are not consistent.

1.1 Objectives

To report on the findings of radio telemetry studies conducted by AMEC and LGL on sportfish species (primarily bull trout, rainbow trout and Arctic grayling) in the Peace River Site C study area in 2009, with comparisons of relevance to findings of earlier reports by AMEC & LGL (2008b, 2008c , 2009), and others. The specific objectives of the 2009 program were:

- To monitor the magnitude, direction of movement, and seasonal variability of movements of Pine River bull trout, Arctic grayling and rainbow trout tagged from 2006 to 2008; and,
- To determine the extent of movements of Pine River fish into the Peace River mainstem and its tributaries upstream of Site C.

1.2 Study Area

The overall study area includes the Peace River mainstem and its tributaries from the Peace Canyon Dam downstream to the town of Peace River, Alberta (Figure 1).

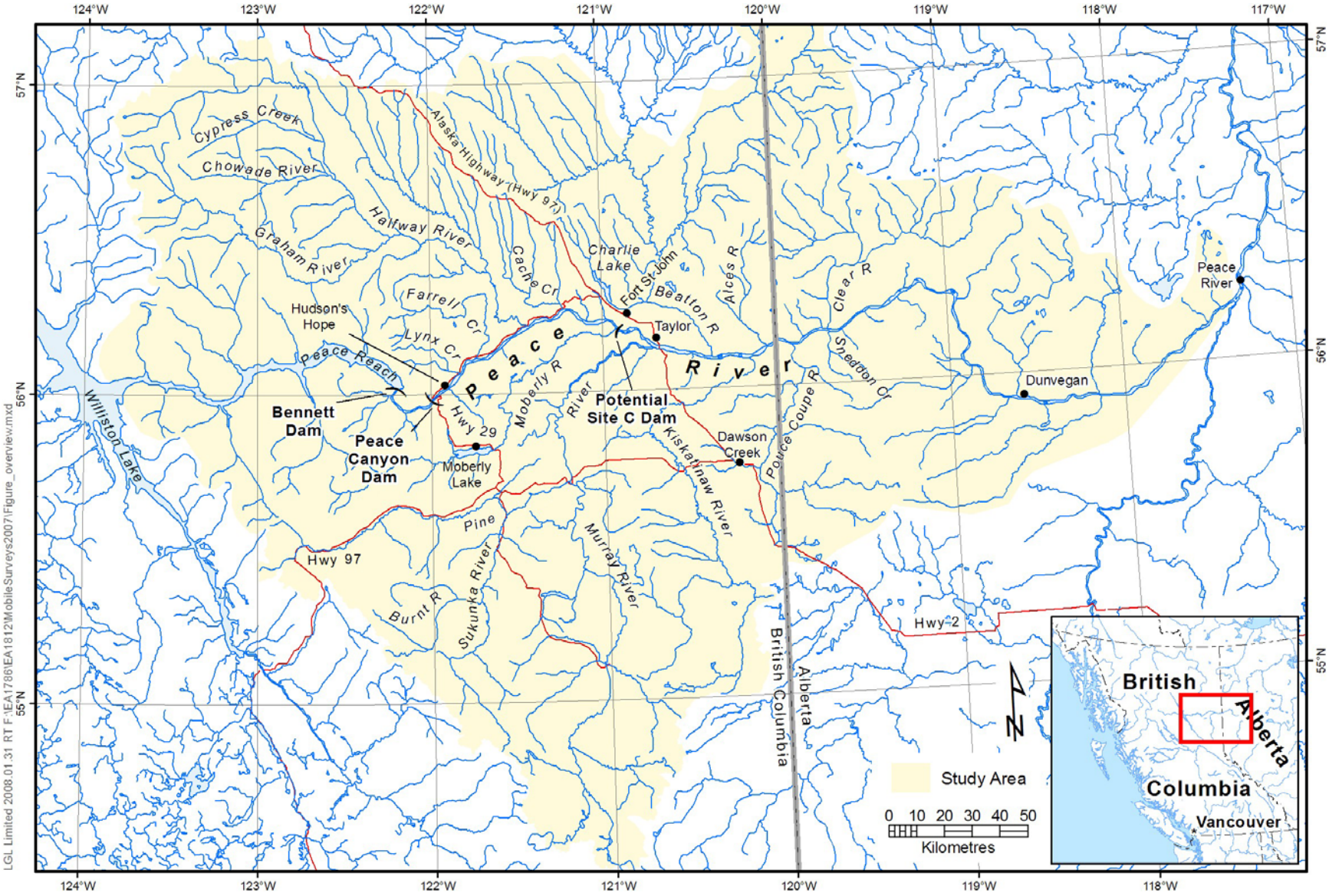


Figure 1: Peace River and its tributaries in northeast British Columbia

2.0 METHODS

2.1 Discharge

Discharge information for the Peace (near Taylor, BC; station 07EF001), Pine (station 07FB001), Moberly (station 07FB008), Halfway (station 07FA006) and Beatton (07FC001) rivers was obtained from the Water Survey of Canada (WSC 2008, 2009). Average daily maximum and minimum discharge was calculated for a 10 year period of record (1996-2005). Discharge records were also compared among years: 2006, 2007, 2008, and 2009, where available. The 2009 real time discharge data were made available by Water Survey of Canada (WSC 2009) but the data have not been calibrated and many values are more extreme than expected.

2.2 Water Temperature

Tidbit® temperature loggers were placed in the Peace River mainstem at the proposed Site C Dam location and in all of the major tributaries of the Peace River from Peace Canyon Dam to the Beatton River. Most of the loggers in the tributaries were located within 1 km of the confluence with the Peace River. Water temperatures were logged every hour from the onset of deployment to retrieval. The timing of deployment varied among sites because of high discharge and debris, which resulted in some loggers being lost or having to be relocated during the period of study. Final downloading of all temperature loggers occurred during October 2009. In 2009, temperature loggers were only available for Cache, Farrell, Lynx and Maurice creeks. Data for additional locations are available in previous reports (see AMEC & LGL 2009).

Data from all temperature loggers were carefully reviewed to ensure data quality and eliminate outliers/erroneous data. Daily mean, minimum and maximum water temperatures were graphed to identify any time periods where the loggers were out of water as a result of desiccation or tampering. All suspicious data were eliminated from the data set. Daily means for the remaining data were graphed by day for fall 2005 to fall 2009.

2.3 Radio Telemetry

2.3.1 Radio Transmitters

Pulse-coded microprocessor radio transmitters were used to monitor fish movements in all four years of tracking (2006, 2007, 2008 and 2009; refer to AMEC & LGL 2008a, 2008b, and 2008c). Radio transmitters were fabricated by Lotek Wireless. Two transmitter sizes (see below) were used depending on the size of the fish, with both having a 400 mm long antenna and a 3 volt battery to transmit a pulsed signal every 5 to 5.5 seconds (set by the manufacturer).

Smaller fish (<400 mm fork length) were tagged with model MCFT-3FM tags, which were 11 mm in diameter, 59 mm in length, and weighed 10 g in air (4.6 g in water). Larger fish (>400 mm fork length) were tagged with model MCFT-3A, which were 16 mm in diameter, 46 mm long, and weighed 16 g in air (6.7 g in water); in all instances, the tags implanted did not exceed 5% of the wet body weight of the fish. The estimated operational life was 378 and 761 days for small and large tags, respectively. For additional information on the transmitters including tag specifications, delayed activation in some years (depending on timing of tagging of some species), expected battery life, etc, refer to previous AMEC & LGL reports (2008a, 2008b, 2008c, 2009).

2.3.2 Mobile Zones and Fixed-Stations

The upper Peace River watershed- and associated-watershed zones used during mobile tracking are illustrated in Figure 2. The watershed zones and delineations are further described in AMEC & LGL 2008b and 2008c, 2009.

In addition to mobile tracking, fixed-station receivers were installed at various locations to monitor fish movements: nine stations were deployed and used in 2006, 10 in 2007, seven in 2008, and six in 2009 (Figure 3). The fixed-station at the mouth of the Chowade River was discontinued in 2009 as virtually no detections were recorded at this site in previous years. For explanation of the fixed stations operated in preceding years, and of installation, testing of detection range and directionality, and decommissioning of the receivers in all years, refer to previous AMEC & LGL reports (2008a, 2008b, 2008c).

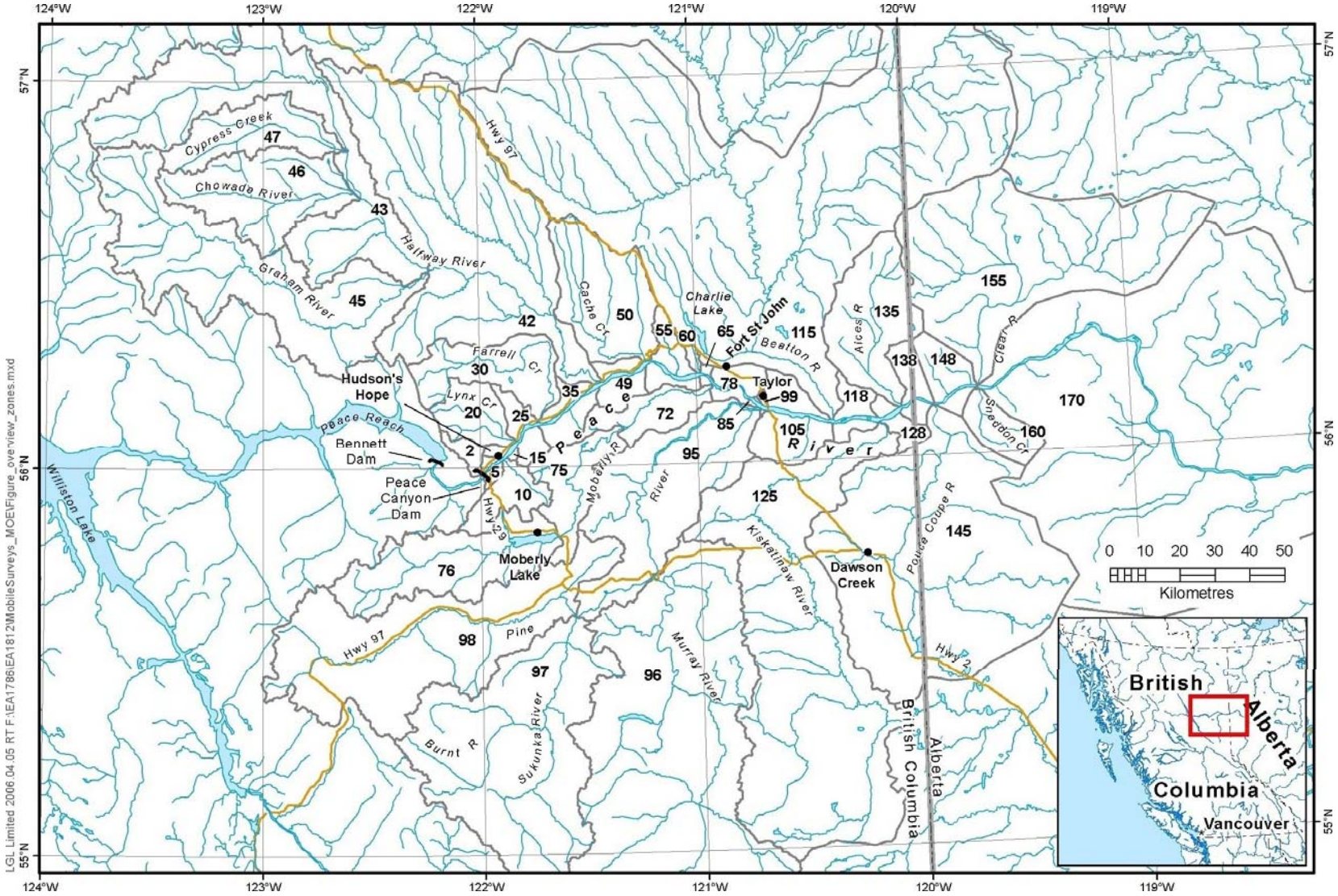


Figure 2: **Upper Peace River system showing the zones of watersheds used in fish mobile tracking; numbered watershed zones are listed in Appendix B. See Figure 4 for sites used in fixed-station tracking**

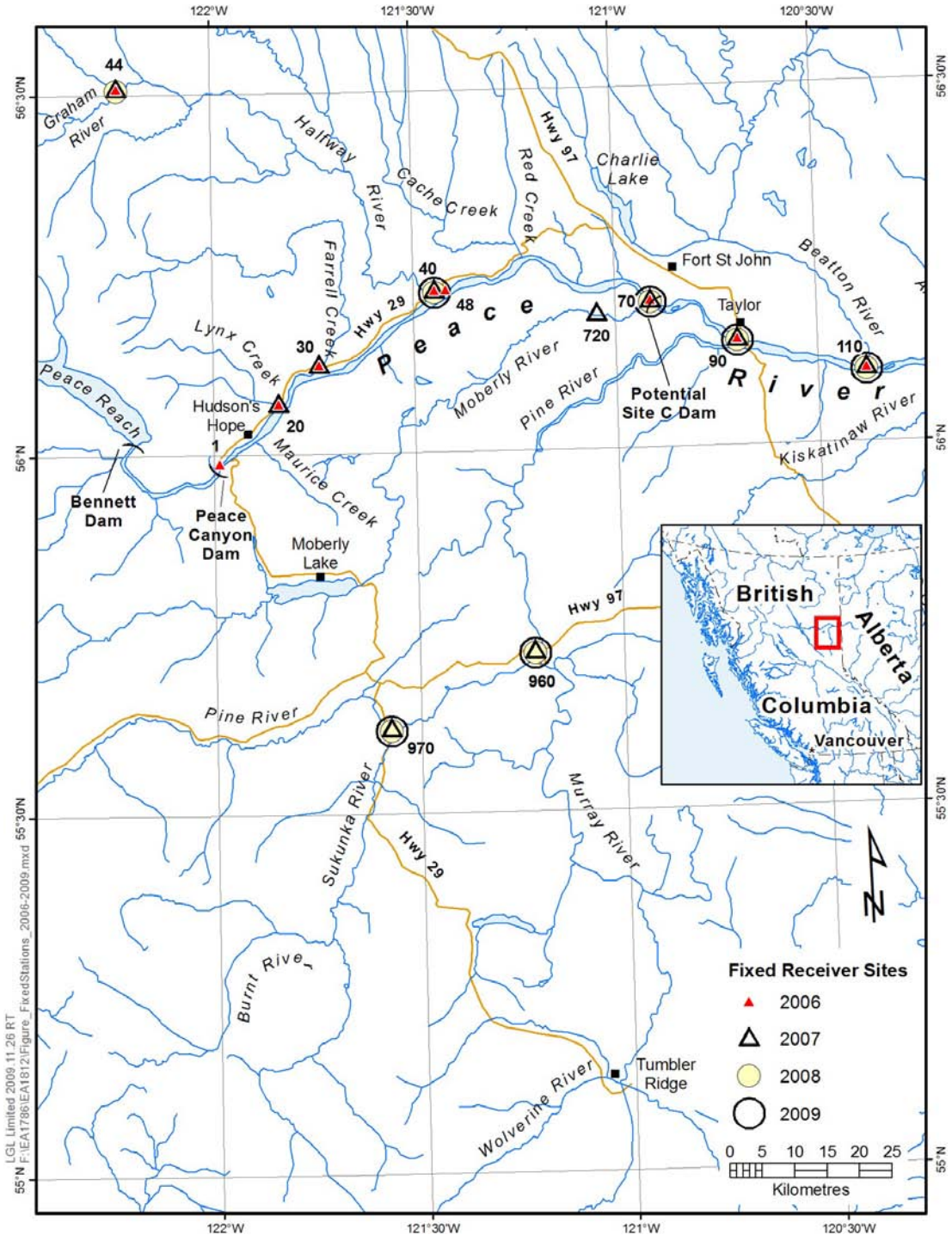


Figure 3: **Locations of fixed-station receivers in the Peace River watershed during the 2006-2009 tracking period; in 2009, there were 6 fixed-station receivers. Each station is identified by a specific number.**

2.3.3 Fish Capture, Tagging and Release

The total number of fish radio-tagged in the Peace and Pine rivers from 2005 to 2008 is presented in Table 1. In total, 422 fish were tagged during that period: 126, 206, 9, and 81 fish in 2005, 2006, 2007 and 2008, respectively, as per the numbers by species listed in the table. The locations and numbers of radio-tagged fish released from 2005-2008 inclusive are presented in Figure 4, Figure 5, Figure 6 and Figure 7. The mean lengths and weights of radio-tagged fish are shown, by species, in Table 2. Detailed information for each tagged fish is provided in Appendix B (Table B-1).

AMEC/LGL- and Golder-tagged fish were collected with the use of a boat-mounted electrofisher and by angling; MOE-tagged fish were collected solely by angling. For further details on fish measurements, tag-implantation, and holding/releasing procedures refer to previous AMEC & LGL reports (2008a, 2008b, 2008c, 2009).

Table 1: Summary of radio-tagged fish released in the upper Peace River watershed, 2005-2008 inclusive.

Species	Number of fish				
	2005	2006	2007	2008	Total
Mountain whitefish	0	116	0	0	116
Arctic grayling	39	10, 8[1]	0	25	82
Rainbow trout	29	3, 15[1]	0	14	61
Walleye	58	0	0	0	58
Bull trout	0	54[1]	9[2]	17, 25[3]	105
Total	126	206	9	81	422

Notes: [1] fish tagged by Golder Associates in the Pine River system, August-September, 2006; [2] fish tagged by MOE in Wolverine River (8) and upper Moberly River (1), July-September, 2007; [3] fish tagged by MOE in the Pine and Wolverine Rivers, August, 2008

Table 2 Summary of lengths and weights of radio-tagged fish released in the upper Peace River system, 2005-2008

Species	n	Fork Length (mm)		Mean Weight (g)[1]
		Mean	Range	
Mountain whitefish	116	336	252-480	476
Arctic grayling	82	314	251-400	425
Rainbow trout	61	337	256-452	505
Walleye	58	416	275-574	919
Bull trout	105	456	348-684	1059
Total	422			

Note: [1]Golder-tagged Arctic grayling and rainbow trout and MOE-tagged bull trout were not weighed.

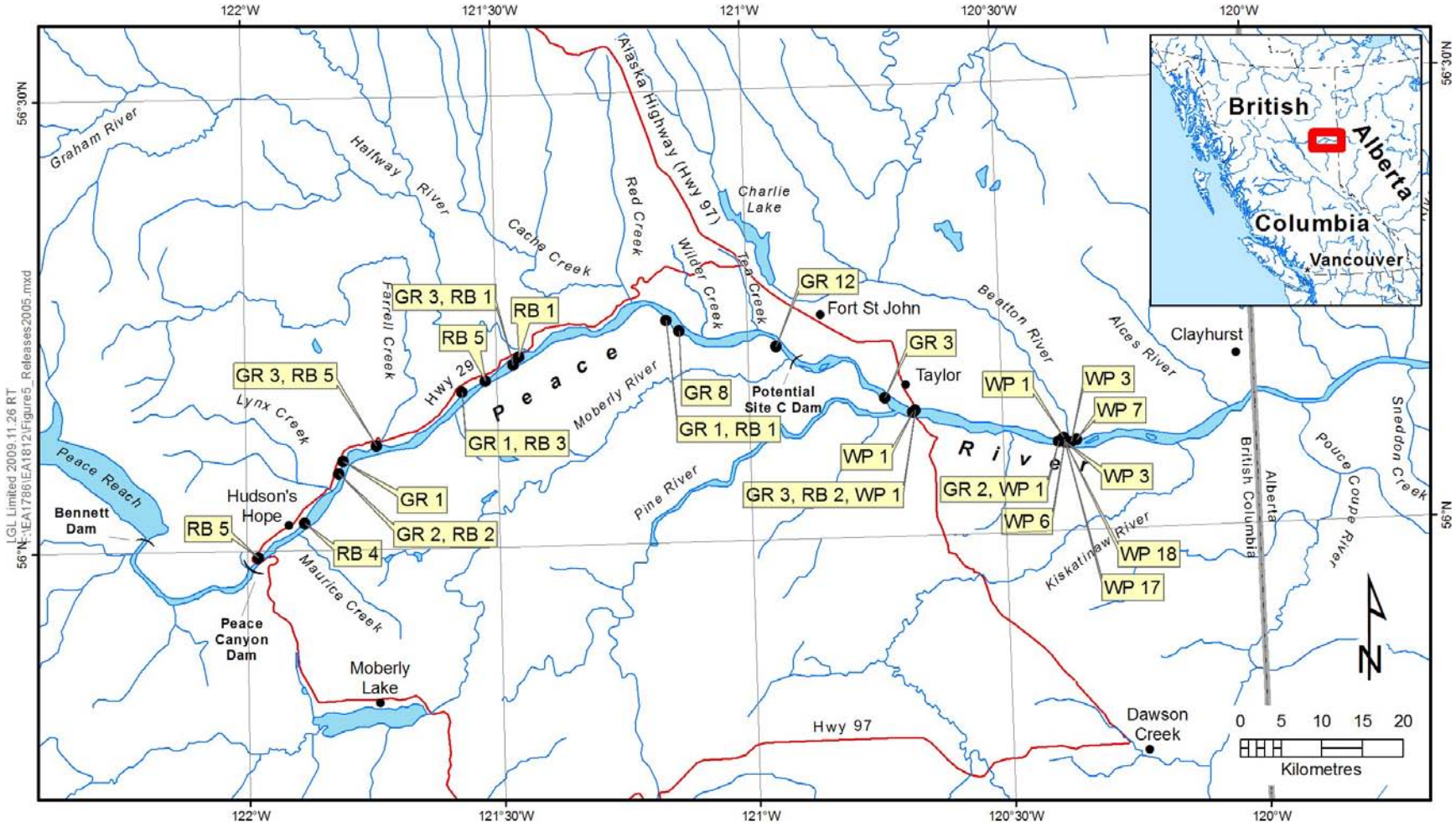


Figure 4: Locations and numbers of radio-tagged Arctic grayling, rainbow trout and walleye released in the Peace River mainstem, September 2005.

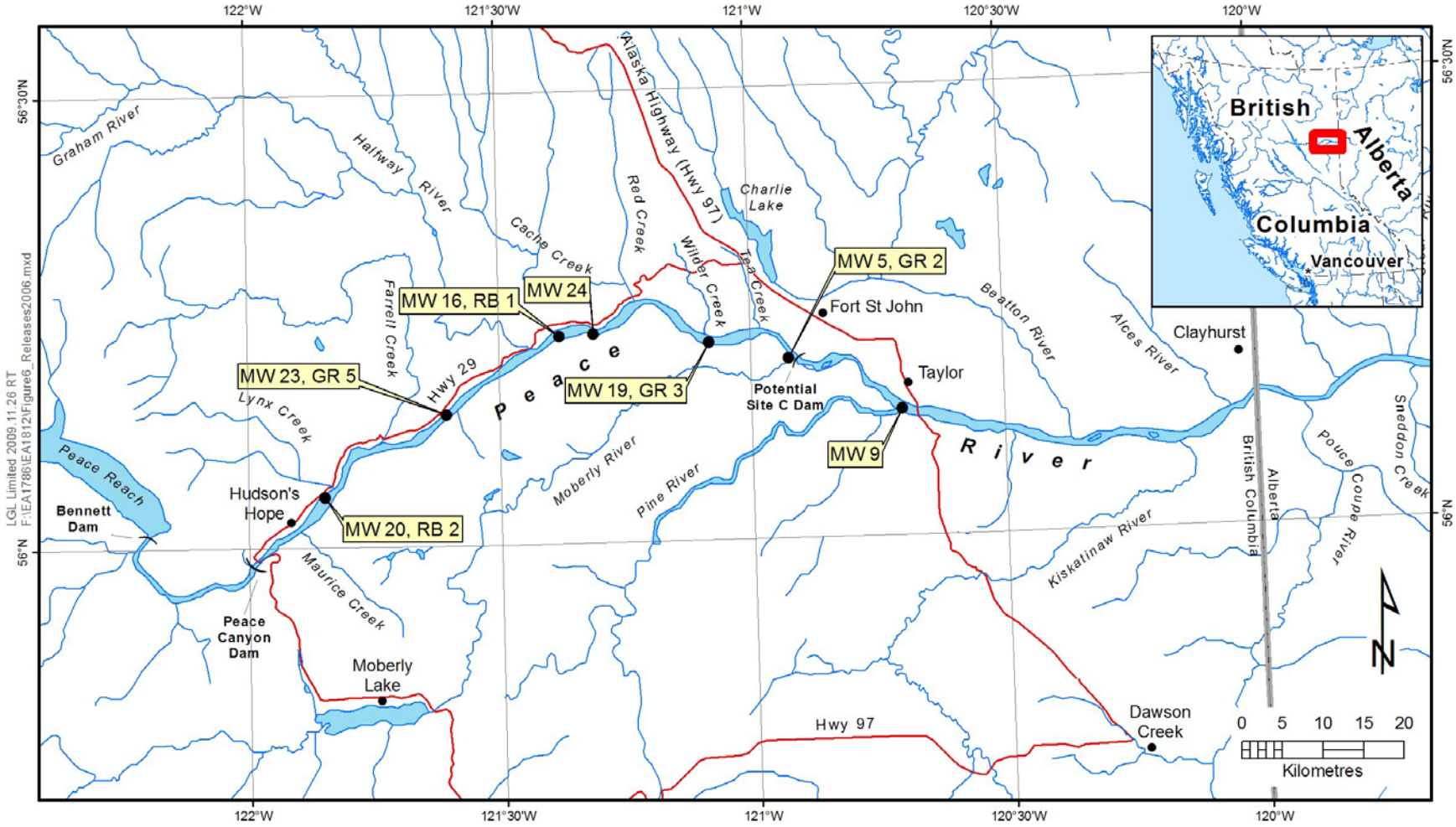


Figure 5: Locations and numbers of radio-tagged mountain whitefish, Arctic grayling and rainbow trout released in the Peace River mainstem, June 2006.

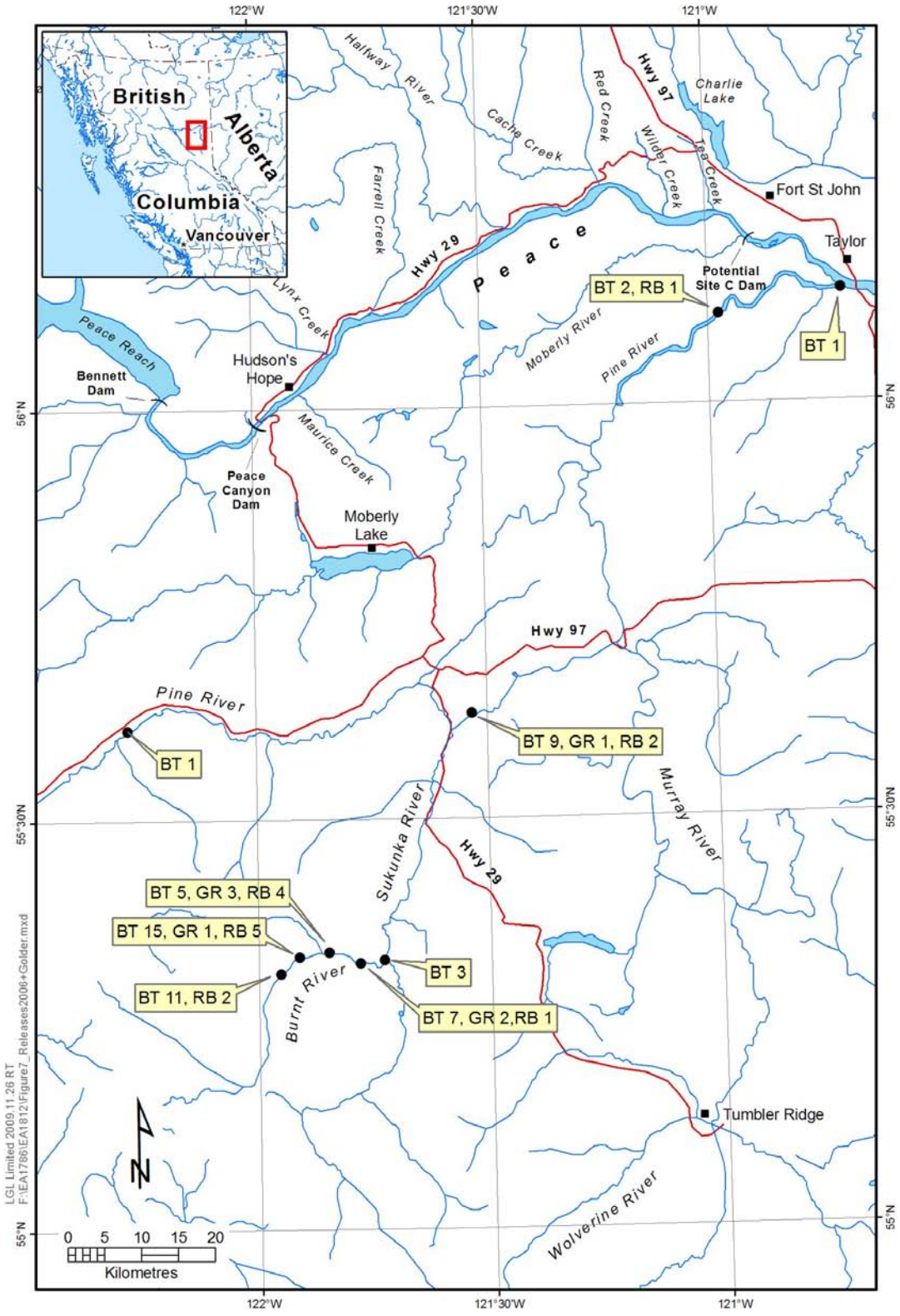


Figure 6: **Locations and numbers of radio-tagged bull trout, Arctic grayling and rainbow trout released in the Pine River watershed, August-September, 2006.**

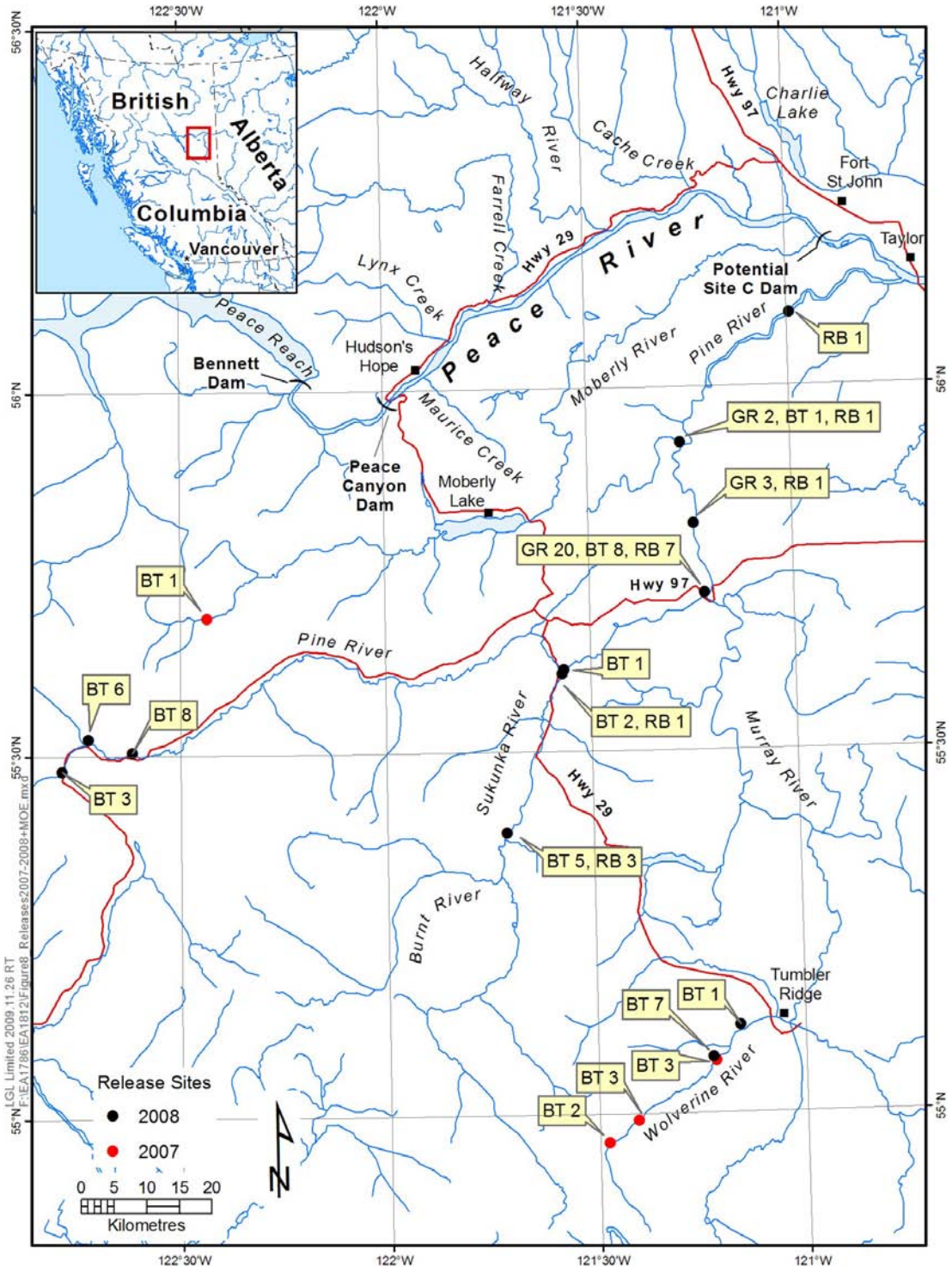


Figure 7: **Locations and numbers of radio-tagged bull trout, Arctic grayling and rainbow trout released in the Pine River watershed, July-September, 2007 and June-August, 2008. In total, only 9 fish (bull trout) were released in 2007.**

The fish tracked in 2009 comprised mostly bull trout, rainbow trout and Arctic grayling that were radio-tagged in the Pine River watershed in 2007 and 2008 (refer to Figure 7). Others included a small number of bull trout that were tagged in the Pine River watershed in 2006, and a few walleye that were tagged in the Peace River mainstem in 2005 for which, surprisingly, the tags were still intermittently active in 2009.

2.3.4 Monitoring Fish Movement

2.3.4.1 Fixed-stations

For the 2009 monitoring period, all fixed-stations were set up in late March, similar to procedures used in previous years. Lotek SRX600 receivers were installed at the mouths of the Moberly and Halfway rivers, while all other fixed stations were equipped with an SRX400 receiver. The receivers were downloaded every third week from the third week in April to the second week in October. Although the frequency was reduced, downloading procedures were similar to those deployed in previous years and are detailed in AMEC & LGL 2008c and 2009.

2.3.4.2 Mobile Tracks

In total, 10 aerial tracks of the Peace River mainstem (from Peace Canyon Dam to Peace River, Alberta) and its major tributaries were conducted from late March/early April to early October 2008. Flights were conducted approximately every three weeks.

For all surveys, mobile tracks were conducted using a fixed-wing aircraft equipped with receivers, antennas, GPS unit, and data logger. Three Lotek SRX400 receivers were used in mobile tracking (see below). Other tracking procedures were the same as those used in 2008 (AMEC & LGL 2009). As in previous years, surveying the whole study area often required multiple days. For surveys that could not be completed in one day, the detections for all days were combined to produce a single synoptic map of the areas covered in total for that survey.

Typically, mobile surveys were conducted along the Peace River mainstem from the Peace Canyon Dam to the Alberta border and along the Pine River mainstem and its two major tributaries (the Burnt/Sukunka and Murray/Wolverine rivers). For the first survey in spring (end March/early April) and last two surveys in autumn (September/October), tracking was extended to Peace River, Alberta, to ensure coverage of possible fish movements further downstream. Strategically located fixed-station receivers were

downloaded prior to flights, so that the information and that of previous tracks could be used to determine which tributaries were likely to have fish present. Although no fish were detected moving into the Halfway River during the 2009 study period, during the first survey in spring and the September flight, tracking was extended into the headwaters to confirm the absence/presence of tagged fish in the upper reaches of this major tributary. Also, occasionally, variable distances (10-30 km) were tracked up the Beatton River to check for possible fish.

All radio-tagged fish detected during mobile surveys were assigned to zones of the Peace River watershed as outlined in Figure 2. Data were accessed for analysis with LGL's *Telemetry Manager* software and with scripts written in Visual FoxPro; and Arc-GIS software was used to plot the distribution of fish detections on maps for each of the mobile surveys.

2.3.5 Data Processing

Telemetry Data Processing

The data from mobile tracks and fixed-station downloads were processed and analyzed using LGL's custom database software, "*Telemetry Manager*". *Telemetry Manager* facilitates data organization, record validation, and analysis through the systematic application of user-defined criteria. Raw data were archived so that the temporal or spatial resolution and noise filtering criteria could be changed by the user at any time without altering the raw data.

An important aspect of radio telemetry is the removal of false records in receiver files, for example, those that arise from electronic noise. In this study, the following criteria were set for records to be considered valid:

- Power levels had to be greater than 50 (on a 1 to 232 scale);
- For fixed-station data, multiple detections had to be recorded within a single zone, within 20 minutes of each other, and with no records at other zones interspersed (i.e., single records, or records separated by more than 20 minutes were rejected); and
- Detections could not be at zones disparate from similarly-timed sequences of valid detections (i.e., each tag could only be in one place at a time).

Once false records were removed, *Telemetry Manager* created a compressed "operational" database of sequential detections for each fish. Each record included the tag number, zone number (antenna number, fixed-station number, or a general location), the first and last time and date for

sequential detections in a specific zone, and the maximum power for all detections in that interval. The compressed operational database was used for all subsequent analyses of fish behaviour and survival.

Distance Calculations and Data Cleanup

The result of data processing was an operational database file containing a summary of all release and recovery information, with all valid fixed-station and mobile track detections in chronological order for each fish. For each location record in the database, UTM coordinates were appended. For mobile detections, the position of the fish was assumed to be that of the aircraft (downloaded from the GPS unit) at the time of the most powerful detection event. Fish detections recorded by the fixed-station receiver were assigned the coordinates of the receiver. From the dataset containing sequential positions for each fish, movements, displacements and travel speeds could be calculated.

Movement distances were estimated using a FoxPro script, which either connected sequential UTM coordinates with a straight line, or, when sequential positions were in different zones, via a series of nodes thereby forcing the movements to approximately follow the geography of the river system. For each movement event, the start and end timestamps were used to determine the “time at large” (i.e., the duration) of the movement event. Also, the start and end positions of each movement event were used to determine if the direction of movement was upstream or downstream. On occasion, a fish would move both downstream and upstream within the same movement event (e.g., a fish detected in the Beatton River and subsequently in the Pine River had to move downstream in the Beatton River, upstream in the Peace River, and then upstream into the Pine River). In these events, the direction of the final leg of the movement was assigned to the whole of the movement.

For each movement, a displacement was calculated as the magnitude of the movement multiplied by 1 for upstream movements, or by -1 for downstream movements. Movement rates were calculated for all sequential detections as the distance moved divided by the time at large. Similarly, displacement rates were calculated as the displacement divided by the time at large.

Once the distance, direction, and duration were calculated, invalid records became apparent. Detection sequences that made fish appear to move too quickly were examined more closely. Also, detection sequences that made fish appear to move too far, especially without being detected by fixed-station receivers in between, were also examined. Most of the unrealistic movements resulted from simultaneous mobile and fixed-station detections.

Fish that remained in the detection field of a fixed-station receiver at the time of a mobile track would show artificially high displacement rates because they would be recorded at the UTM coordinates of the fixed-station receiver, then instantly appear at the UTM coordinates of the mobile survey aircraft, and then immediately return to the UTM of the fixed-station receiver. To avoid this problem, mobile detections were ignored (for the purposes of movement and displacement analyses) if they occurred simultaneously with a series of fixed-station detections.

Once all of the artificial movements were cleared out of the database, the movement distances, directions, and durations were recalculated. For these final calculations, movement distances were estimated using ARC-GIS software. For each fish, all detection positions were plotted, and each sequential position was connected with a line (making *n-1* lines joining *n* detection positions). Tracking tools in the software were used to confine each of these connector-lines to within the river contours, hence taking all river-curvatures into account. Time at large, movement distance and movement direction (and hence movement rates, displacement, and displacement rates) were all re-calculated using the methods as previously described.

All movement events, with their associated direction, displacement, time at large, and displacement rate, were linked to an individual fish (and hence a species) and a timestamp for subsequent analyses. Analyses included comparisons among species, among years, and among months of displacement rates, overwinter movement and total movements. Also, the effect of time at large on displacement was examined.

Displacement and Movement Calculations

Various metrics were calculated to describe the movements and displacements of the radio-tagged fish. As described above, ARC-GIS was used to determine the along-river distance between each sequential detection of each fish. To add directionality to the distances, they were multiplied by -1 if the fish moved in the downstream direction, or by +1 for the upstream direction. Distances without directionality were called ‘movements’, those with directional information were called ‘displacements’.

Displacements

Basic displacement rates were calculated for each sequential detection of each fish by dividing the observed displacement by the time between those sequential detections. For each radio-tagged fish, the median overall study-

period displacement was calculated. Also, median displacement was calculated for each month for each radio-tagged fish.

Within-species differences among years, and within-year differences among species were calculated using Kruskal Wallis H tests (one-way ANOVA non-parametric equivalent; Zar 1984). In each case, year and species-specific median displacement rates were used as the dependent variable in order to ensure that each individual was included only once in each analysis.

For each species, differences in displacement rates among months were calculated using Kruskal Wallis H tests, with median monthly displacements as the dependent variable, again to ensure that each individual was included in the analysis only once per month.

Displacement rates were also examined by plotting displacement versus time at large. For each species, the displacement between each sequential detection of each fish was plotted against the time between those sequential detections. The slope of the relationship was calculated for each species. If the slope was negative, then the species tended to move downstream over time, with farther downstream movements observed with longer periods of time-at-large. Differences in slopes among species and among years were tested using ANCOVA, where significant interaction terms indicated a difference in displacement behaviour.

Movements

For each radio-tagged fish, overall movement was calculated by summing all of the observed movements over the duration of each study year. Note that movements (non-directional) were summed, not displacements. Differences in overall movements among species or among years were calculated using Kruskal Wallis H tests.

Statistical Analyses

For all analyses, statistical significance was declared when *P* values were less than 0.05.

Basis for Tag Exclusion

Radio-tagged fish confirmed or presumed to be dead and those that were never detected were filtered from the dataset and excluded from further analysis.

Potential Mortality

From position-based telemetry data, it is not possible to determine if a fish is living or dead. A live, sedentary fish would "track" the same as a dead fish, or as an expelled tag on the riverbed. It is generally acceptable to assume, when movements are observed, that an individual is alive. It should be noted, however, that there is error associated with our position estimates (based on the speed of the aircraft used for tracking, the frequency of the tag's signal transmission, etc) and a tag can appear to "move" from survey to survey even if it is motionless on the riverbed. It is therefore necessary to determine the minimum movement threshold below which any observed "movements" might be spurious.

In prior studies on the Peace River, the minimum movement threshold that was used was 350 m (AMEC and LGL 2008b, 2008c, 2009). In the 2009 tracking, all fish were observed to move at least 550 m (Figure 8), thus it was decided that no tags would be treated as potential mortalities.

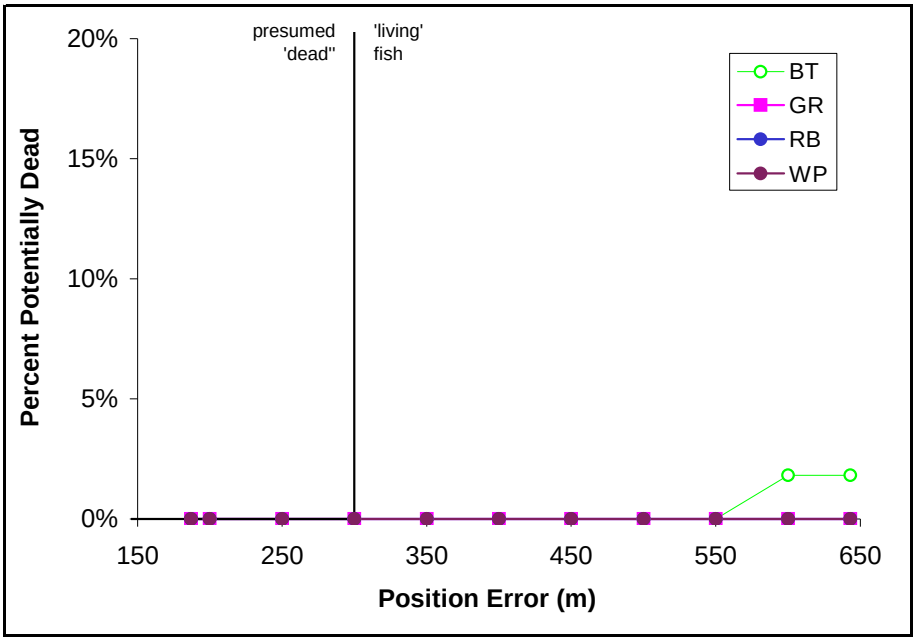


Figure 8: Potential mortalities of radio-tagged fish in 2009, by species. Note that fish detected only once, never detected, or recovered by fishermen were excluded from this analysis

Known Mortalities

All fish (or tags) that were recovered from anglers (or found on the riverbed) and returned to us were classified as "known mortalities". These fish were

excluded from all subsequent analyses. In total, 16 fish were excluded (Table 3) for reasons of mortality.

Undetected Tags

Several tags were not detected during the 2009 tracking (Appendix B, Table B3). Of the tags deployed in 2005, 98% (124 of 126) were not detected in 2009, largely as a result of the expected decay in battery life of the transmitters. Similarly, for fish tagged in 2006, 92% (189 of 206) were not detected in 2009.

In contrast, the fish that were tagged in 2007 and 2008 were expected to have fully-functional batteries during the 2009 survey year. Only six of these 90 tags were never detected in 2009 (2 tagged in 2007 and 4 tagged in 2008), and of these 5 had been detected in 2008. These six fish may have moved out of the study area, may have been removed by a predator or an angler, or some of these tags may have failed prematurely. Expected tag failure based on information from past LGL studies is approximately 0.3%. Note that the survey efforts were adequately intense to expect that tags associated with dead fish would be detected at least once. For this reason, tags that were never detected were not considered as ‘mortalities’, but were nevertheless censored from subsequent analyses.

Table 3: Radio-tagged fish confirmed dead[1]

Species	Tag #	Date Tagged	Tag Site	FL (mm)	Weight (g)	Recovery Date	Comments[1]
Bull Trout	303	08/21/06	Pine	44	740	09/03/07	Caught by an angler
	304	08/20/06	Pine	47	1010	09/19/07	Caught by an angler
Mountain Whitefish	139	06/24/06	Peace	372	575	09/09/06	Eaten by bull trout, caught by angler
	232	06/27/06	Peace	337	425	09/02/06	Tag found on riverbed
	252	06/26/06	Peace	326	350	07/15/06	Tag found on riverbed
Rainbow Trout	74	09/26/05	Peace	276	300	05/17/06	Tag found on riverbed
	88	09/27/05	Peace	396	825	08/28/06	Eaten by bull trout, caught by angler
	95	09/28/05	Peace	341	450	06/01/06	Caught by an angler
Walleye	3	09/21/05	Beatton mouth	473	1350	06/08/07	Caught by an angler
	10	09/21/05	Beatton mouth	411	800	02/10/06	Fish found dead at Pouce Coupe River
	28	09/21/05	Beatton mouth	439	1100	01/31/06	Caught by an angler
	102	09/29/05	Beatton mouth	361	575	07/08/06	Fish found dead at Beatton River mouth
	104	09/29/05	Beatton mouth	478	1400	10/15/09	Caught by an angler
	113	09/29/05	Beatton mouth	441	1050	04/07/06	Caught by an angler
	116	09/29/05	Beatton mouth	389	675	08/26/08	Caught by an angler
	126	09/29/05	Beatton mouth	507	1725	10/11/07	Caught by an angler

Note: [1]Confirmed deaths are based on tag recoveries.

Fish Movement Past Site C

The fixed-station receiver that was closest to the potential Site C Dam location was deployed about 0.5 km upstream from it, at the confluence of the Moberly River with the Peace River. For each fish, any sequence of movements that showed detections both upstream and downstream of the Moberly River mouth was included as a Site C Dam passage event. Passage events were associated with a date and an individual (and hence a species) for subsequent analyses. Fish that approached the Moberly River mouth from upstream, but immediately returned back upstream (without being detected downstream of the Moberly River mouth) were not considered to have passed Site C, since Site C is located downstream of the fixed-station receiver. Conversely, fish that approached the Moberly River mouth from downstream must have passed Site C, regardless of their subsequent movements. Analyses included comparisons of movement events among species, among years and among months.

3.0 RESULTS

3.1 Environmental Characteristics

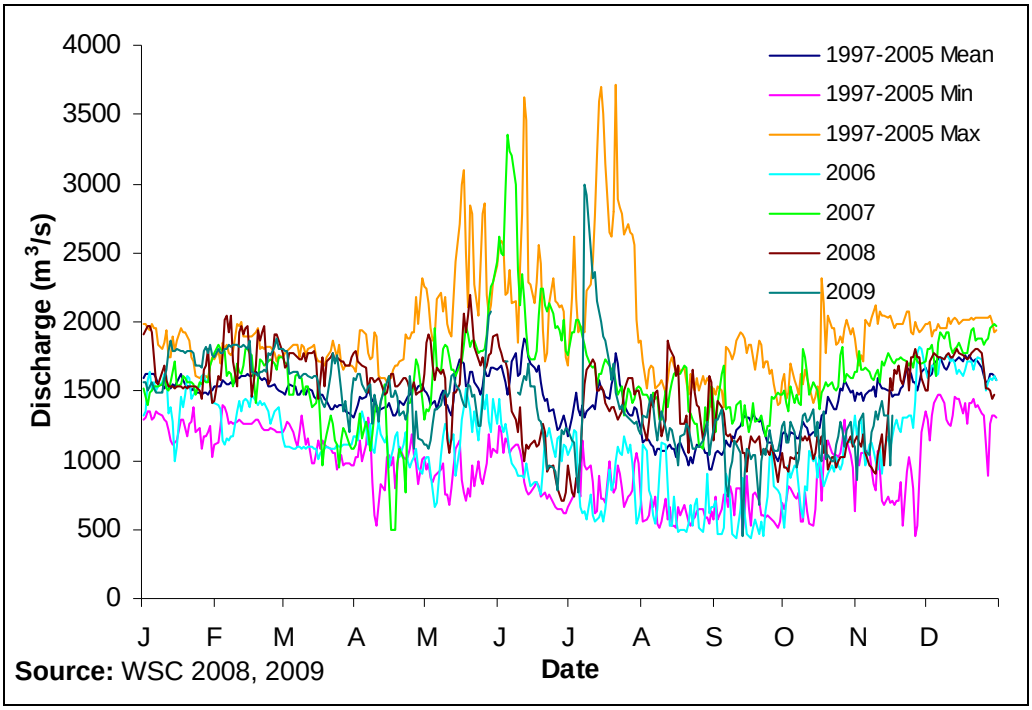
3.1.1 Discharge

Flow data at Water Survey of Canada stream gauges on the Peace River at Taylor, Halfway, Moberly, Pine and Beatton rivers for 1996 to 2009 (WSC 2008, 2009) are presented in Figures 9 to 13, respectively and Appendix A (Table A-1). The 1996 discharge for the Peace River is not included in Figure 10 because there was a spill event from W.A.C. Bennett Dam in the summer of that year which does not reflect natural flow conditions. In 2009, WSC real-time data were available for all the tributaries (see Appendix A). However, this data has not been validated by WSC and for most of the sites and the values are well outside of expected maximum and minimum ranges. The 2009 discharge is only shown for the Peace River mainstem graph (Figure 9) as these values fall within expected ranges; however, this data is still preliminary and may be updated by WSC in 2010.

Peace River discharge in 2009 was generally close to the 1997-2005 mean, with the exception of a large discharge increase in early-July. The 2009 flows peaked at almost 3000 m^3/s on 8 July and then receded quickly to values similar to the 1997-2005 mean. In 2008, daily mean discharge was relatively similar to the 1997-2005 maximum during winter and spring. However, 2008 water discharge lowered to 1997-2005 mean levels in late-May and June and then lowered again toward the 1997-2005 minimum in the summer.

Discharge in 2007 was generally between the 1997-2005 daily mean and daily maxima indicating higher overall flows in 2007. In contrast, Peace River discharge in 2006 generally ranged between the 1997-2005 daily mean and daily minima (Figure 9). Although flow regulation is attenuated downstream by discharge from unregulated tributaries, Peace River flows at Taylor, B.C. are largely dictated by flows out of Peace Canyon Dam.

In the major Peace River tributaries, flow patterns were similar among tributaries but varied among years (Figures 10-13). The discharge in 2008 was between the 2006 and 2007 values and was similar to the 1997-2005 mean most of the year, with the exception of spring when it was closer to the 1997-2005 maxima. In 2007, the major tributaries had discharge between the 1996-2005 daily mean and maxima in the spring while flows after June fluctuated around the daily mean. In 2006, discharge was consistently below the 1996-2005 daily mean flow; they were slightly above the 10 year minima in spring, but frequently less than the minima following June.



Source: WSC 2008, 2009

Figure 9: **Daily discharge (m^3/s) of the Peace River near Taylor, BC for 2006, 2007, 2008 and 2009 compared to 1997 to 2005**

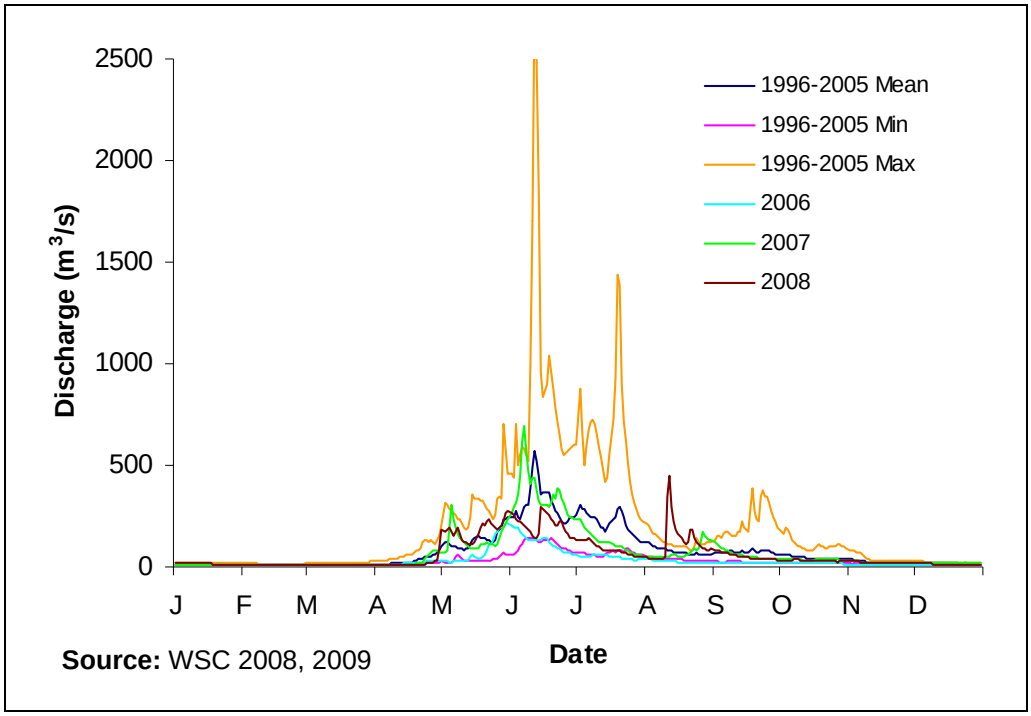


Figure 10: **Daily discharge (m^3/s) of the Halfway River for 2006, 2007 and 2008, compared to 1996 to 2005**

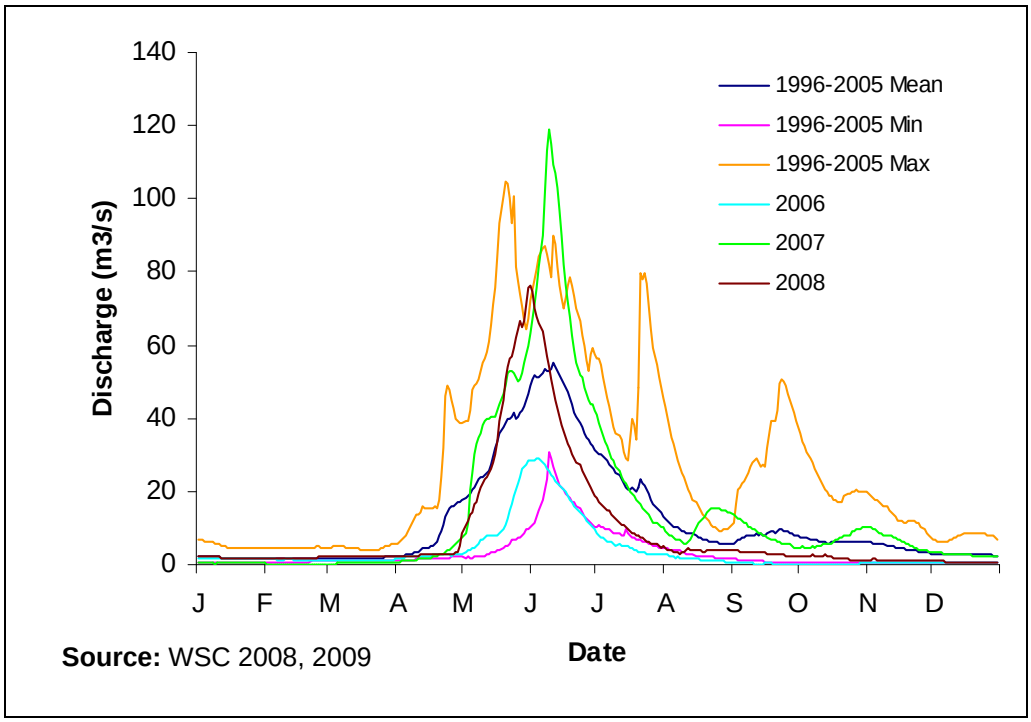


Figure 11: **Daily discharge (m^3/s) of the Moberly River for 2006, 2007 and 2008, compared to 1996 to 2005**

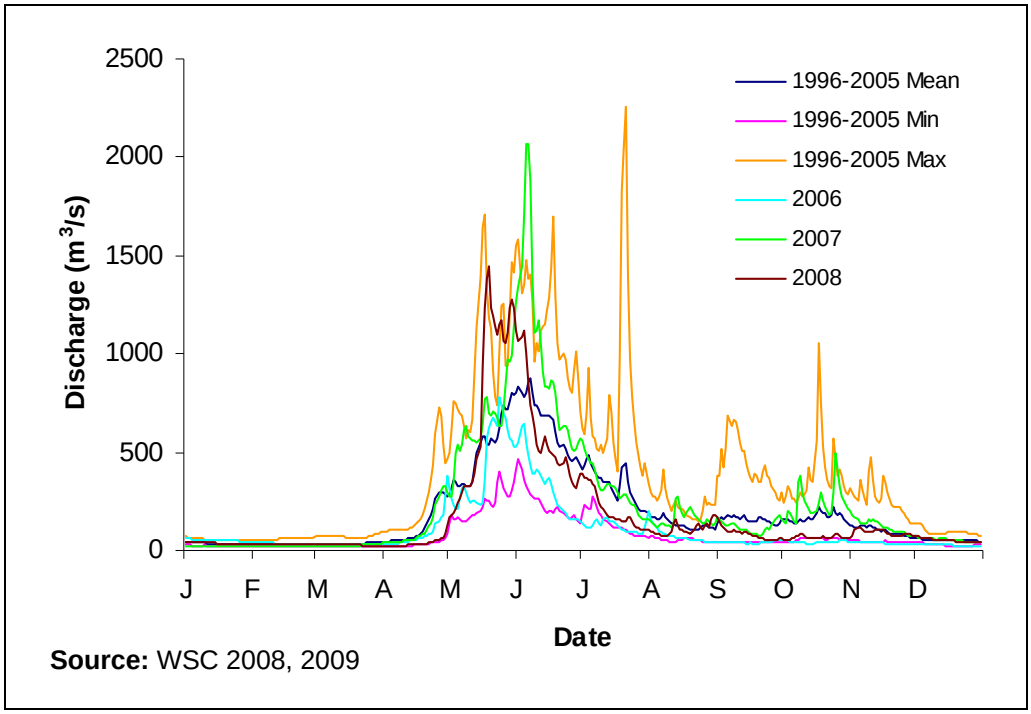


Figure 12: **Daily discharge (m^3/s) of the Pine River for 2006, 2007 and 2008, compared to 1996 to 2005**

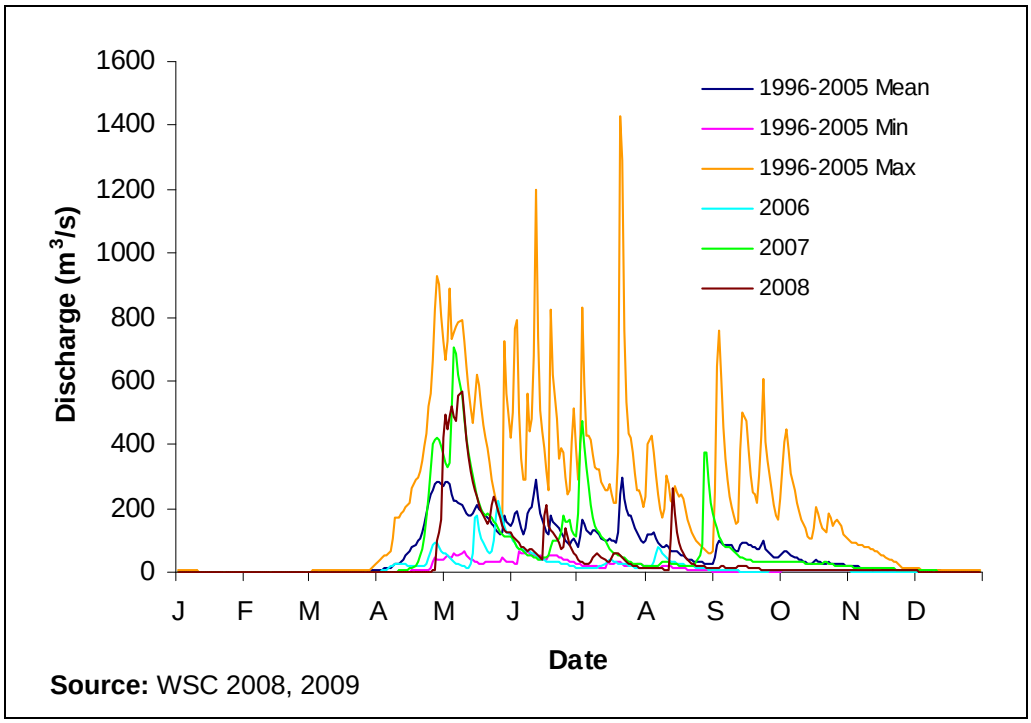


Figure 13: **Daily discharge (m^3/s) of the Beatton River for 2006, 2007 and 2008, compared to 1996 to 2005**

3.1.2 Water Temperatures

Mean daily water temperatures near the mouths of Cache, Farrell, Lynx, and Maurice creeks for the period between fall 2005 and fall 2009 are presented in Appendix A (Table A-2), and in Figures 14 to 17, respectively.

In the smaller tributaries, Cache, Farrell, Lynx and Maurice creeks, water temperatures were similar between 2005 and 2009. In 2008, water temperatures were similar to the other years but temperatures were slightly cooler in April suggesting a later spring melt than in 2005 and 2006. In 2009, water temperatures were similar to other years except in late-May and early-July, when temperatures were cooler than in all other years. Water temperatures were highest in Farrell and Cache creeks in all years monitored.

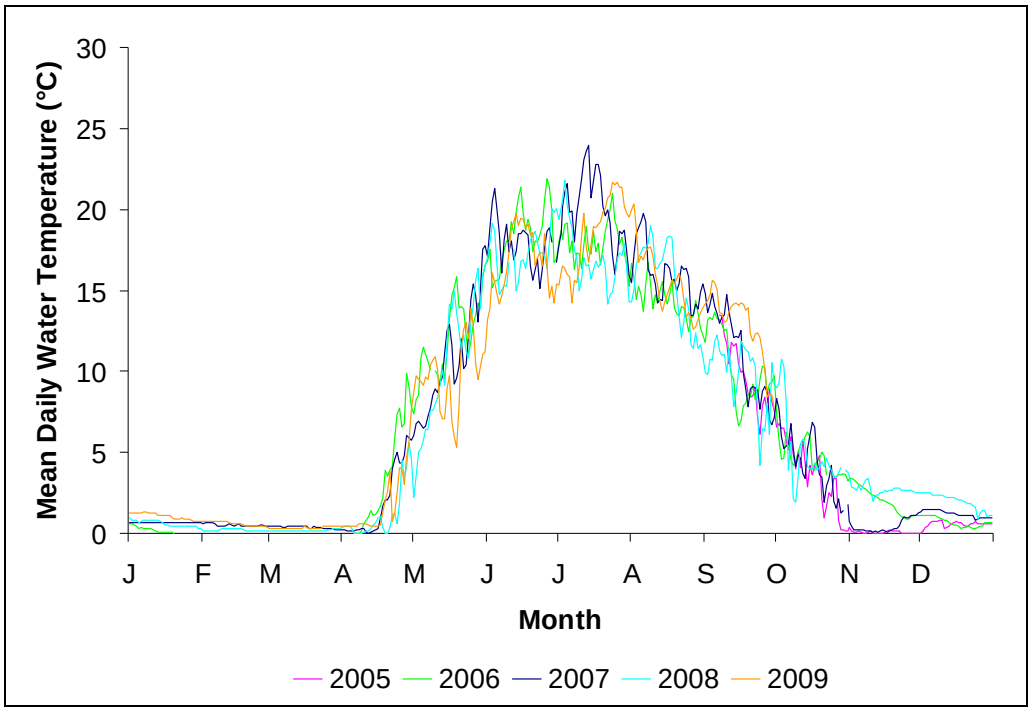


Figure 14: Water temperatures for Cache Creek

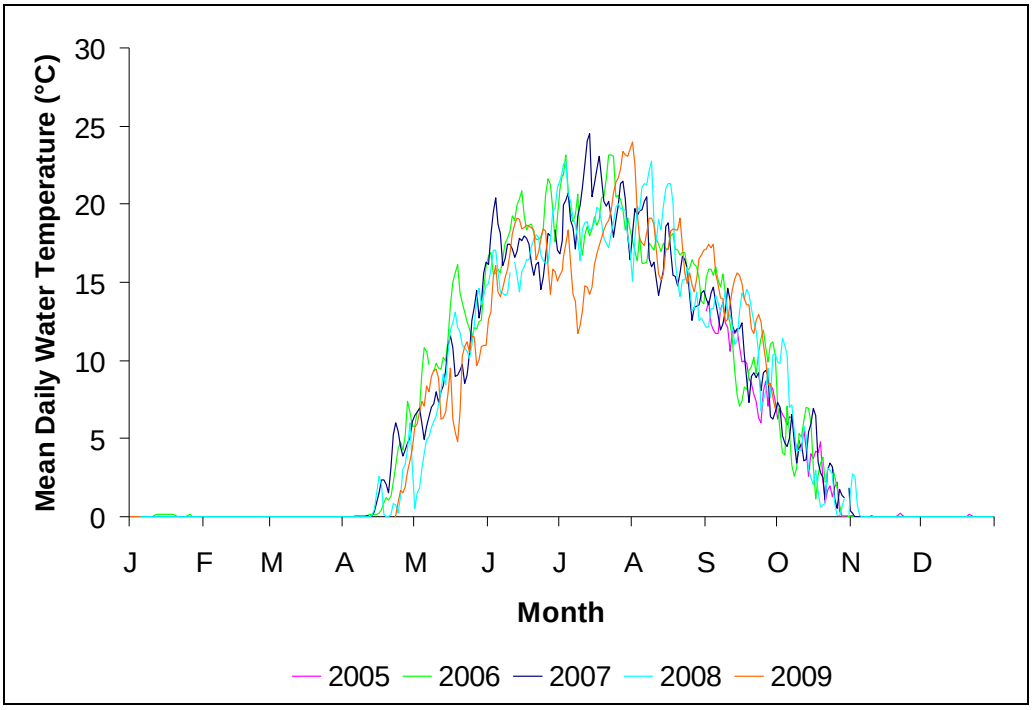


Figure 15: Water temperatures for Farrell Creek

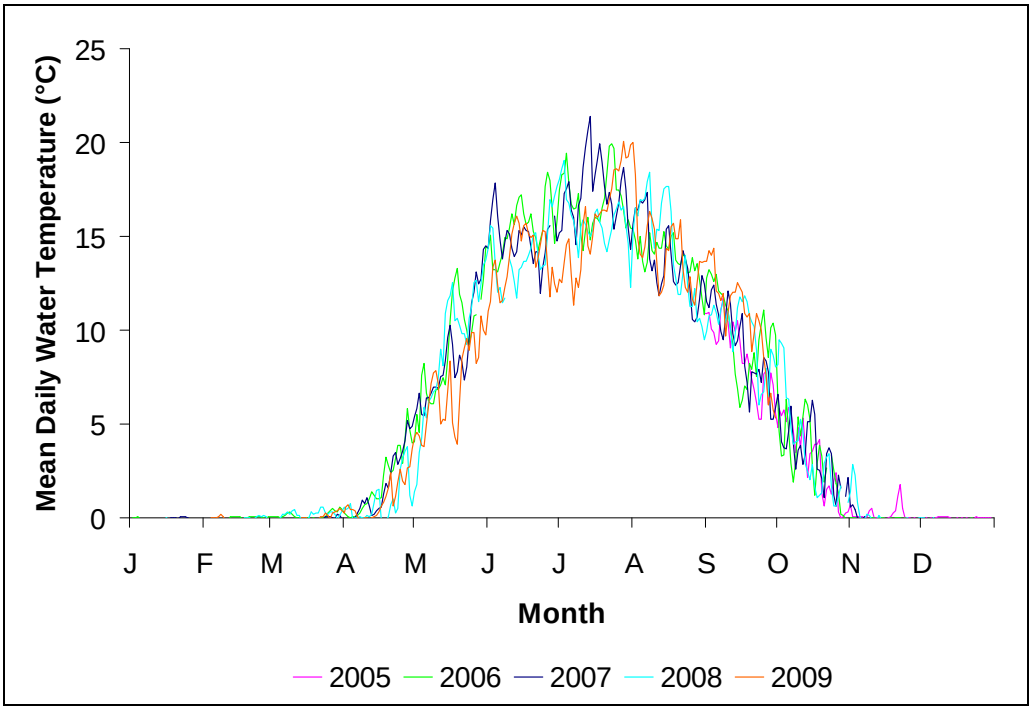


Figure 16: Water temperatures for Lynx Creek

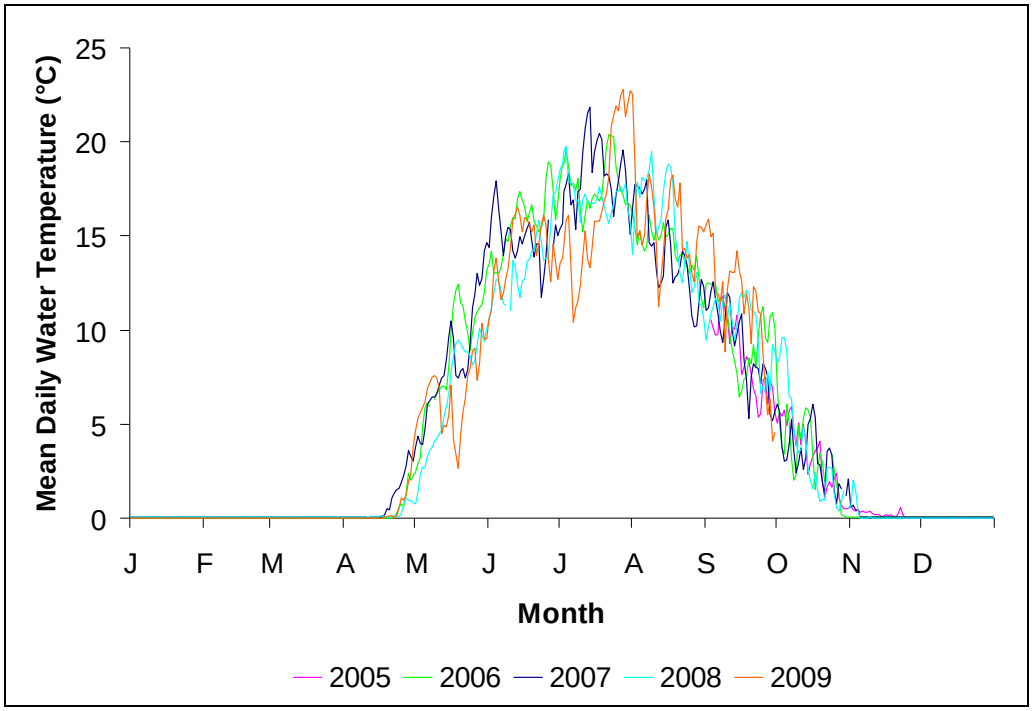


Figure 17: Water temperatures for Maurice Creek

3.2 Radio Telemetry

None of the Arctic grayling or mountain whitefish, and few of the rainbow trout that were released in the Peace River mainstem during the 2005-2006 period were detected in 2009 as the tags were beyond the expected battery life. A summary of the date, time, location and distance moved for all fish detected in 2009 is available in Appendix B (Table B-4).

3.2.1.1 Fixed-stations

During the 2009 study period, a total of 19 of the 103 fish (18%) were detected at the fixed-station receiver sites. The percentage of radio-tagged fish that was detected at each of the fixed-station receivers is presented by species in Table 4. A greater proportion of bull trout was detected at stations located within the Pine River system compared with elsewhere. Most of the detections of Arctic grayling were at the Pine-Murray confluence, and those of rainbow trout were at the Pine-Murray and Pine-Sukunka confluences. For the most part, the bulk of the detections for each species was in the vicinity of the tagging and release locations, indicating that the fish moved relatively little.

Table 4: The percent of radio-tagged fish that was detected at each fixed-station receiver, 2009

	Species			
Fixed-station	Bull trout n=61	Arctic grayling n=23	Rainbow trout n=17	Walleye n=2
Halfway River				
Moberly River			6%	
Pine River	2%		6%	
Beatton River	2%			50%
Pine at Murray	10%	13%	24%	
Pine at Sukunka	8%		35%	

3.2.1.2 Mobile Tracks

The number and percentage of tags detected at large in each of the 10 mobile tracks conducted in 2009 are summarized in Table 5. Owing to progressive decay of battery life in the transmitters, the number of detections between the first (March/April) and last (October) surveys declined for each species, though most pronounced for bull trout: bull trout decreased from 53 to 29 fish, Arctic grayling from 21 to 17 fish, and rainbow trout from 17 to 10 fish.

The flight path and distribution of tag detections by species for each track are illustrated on Maps 1 to 10. For clarity purposes, flight paths and tag detections are divided among three maps for each of the 10 tracks: i) flight paths on Maps A; ii) detections of bull trout on Maps B; and, iii) detections of the remaining species on Maps C; on occasion, a few walleye were detected.

During the first survey (31 March-2 April), ice and snow cover was present in all Peace River tributaries in the study area. During the second survey (21-23 April), ice and snow persisted over most of the Pine River and Maurice Creek, and in some upper sections of the Halfway River and Farrell Creek; all other tributaries were ice-free. A comparison among years for spring conditions in the study streams for the period 2006-2009 is provided in Appendix A (Plates 1 to 15).

Table 5: Number and percentage of radio tagged fish detected by species for each mobile track, 2009

	Bull trout (n=61)		Arctic grayling (n=23)		Rainbow trout (n=17)		Walleye (n=2)	
Survey Date	%	$n^{detections}$	%	$n^{detections}$	%	$n^{detections}$	%	$n^{detections}$
Mar 31 - Apr 2	87%	53	91%	21	100%	17	0%	0
April 21-23	84%	51	91%	21	88%	15	0%	0
May 14	84%	51	91%	21	94%	16	0%	0
June 3-4	75%	46	87%	20	88%	15	0%	0
June 24	77%	47	87%	20	88%	15	50%	1
July 15	70%	43	91%	21	88%	15	0%	0
Aug 5-6	69%	42	83%	19	88%	15	50%	1
Aug 26	62%	38	87%	20	82%	14	0%	0
Sept 16-17	52%	32	83%	19	71%	12	0%	0
Oct 6-10	48%	29	74%	17	59%	10	0%	0

Note: Percentages are based on the total number of known active tags remaining in the tagged population at the time of survey (ignoring known and 'potential' mortalities).

March/April Tracks (Maps 1 & 2)

First Track, 31 March-2 April (Map 1)

With ice and snow still widely present in the tributaries, the detections during the March/April track are indicative of the winter distribution of the radio-tagged fish. Coverage during this survey was extensive to ensure that the distribution of fish was adequately documented. The area included the Peace mainstem from the Peace Canyon Dam to Peace River, Alberta, and both the mainstem and headwater tributaries of the Pine and Halfway rivers. For all species combined, most (96%, 91) of the fish were in the Pine River watershed, with a few individuals (4) widely scattered in the Peace mainstem downstream of Cache Creek to the Alberta border. Those detected outside of the Pine River watershed included two bull trout (tags 340 & 457) and two rainbow trout (tags 364 & 384).

Bull trout detected in the Pine River drainage (55 in all) were widely distributed: 20% (11) were in the Pine mainstem below the Sukunka River confluence, 24% (13) in each of the Murray/Wolverine and Burnt/Sukunka rivers, and 32% (18) in the upper Pine mainstem. In contrast, both rainbow trout and Arctic grayling were less widely distributed in the Pine River drainage: 60% (8) and 95% (20), respectively, were in the lower Pine mainstem. The rest of the rainbow trout (40%, 5) were in the Burnt/Sukunka drainage, and one Arctic grayling was in the Murray River.

Second Track, 21-23 April (Map 2)

For this track, and all others, except the last two tracks in 2009, aerial coverage was restricted to the Pine River watershed and the Peace River mainstem from Peace Canyon Dam to the Alberta border. Fish detections from the first track (March/early April) and first fixed-station data download (late April) indicated it was unlikely that radio-tagged fish would be present outside these areas and was confirmed by checking all fixed stations prior to flights.

Overall, although fewer tags were detected in this survey (87) than in the previous one (95), the distribution of detections by species was similar between surveys. Of the 87 fish detected for all three species combined, 95% were in the Pine River watershed; the remaining 5% (2 bull trout and 2 rainbow trout) were in the Peace mainstem from below Cache Creek to the Alberta border - one of these fish (a bull trout, tag 457) had moved approximately 6 km upstream from where it was previously located (near mouth of Alces River).

Of the 49 bull trout detected in the Pine River drainage, 22% were in each of the Pine mainstem below the Sukunka confluence and the Murray/Wolverine rivers, 23% in the Burnt/Sukunka watershed, and 33% in the upper Pine mainstem. There was no major change in the distribution of detections for rainbow trout and Arctic grayling between surveys; the majority of both species (rainbow trout 62%, Arctic grayling 90%) were in the lower Pine mainstem.