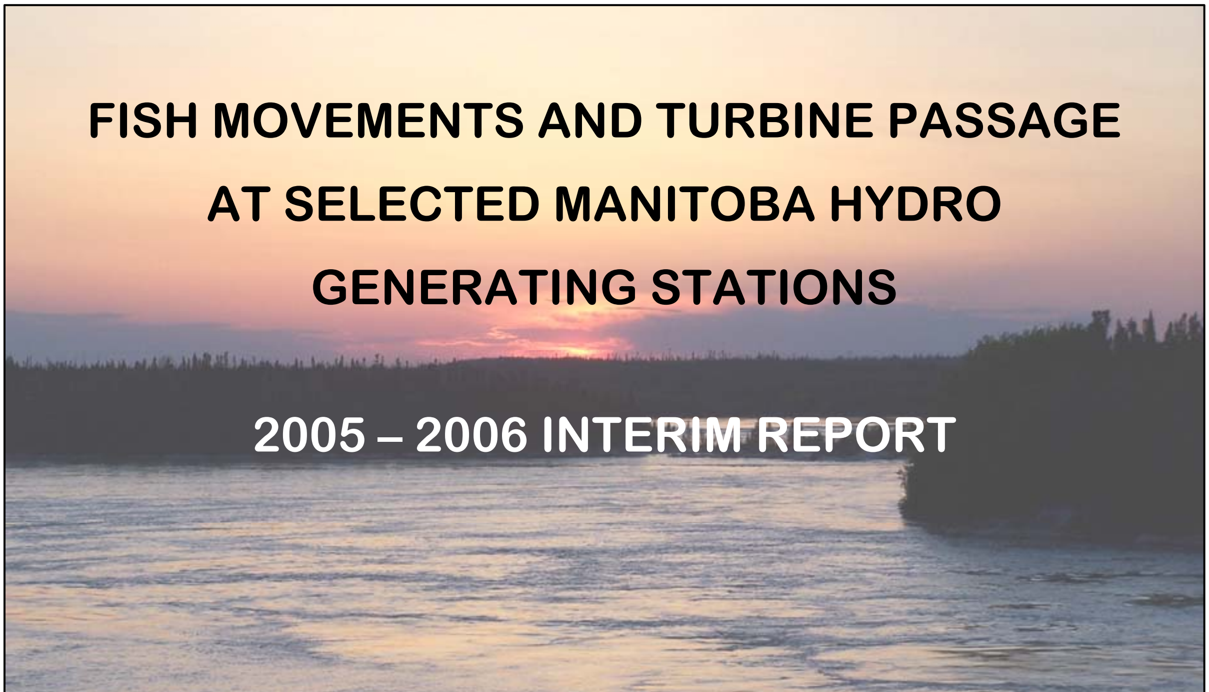
FISH MOVEMENTS AND TURBINE PASSAGE AT SELECTED MANITOBA HYDRO GENERATING STATIONS

2005 – 2006 INTERIM REPORT



North/South Consultants Inc.
Aquatic Environment Specialists

NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

FISH MOVEMENTS AND TURBINE PASSAGE AT SELECTED MANITOBA HYDRO GENERATING STATIONS

2005 – 2006 INTERIM REPORT

Prepared
for
Manitoba Hydro

by

North/South Consultants Inc. and Normandeau Associates Inc.

May 2007

North/South Consultants Inc.
Aquatic Environment Specialists

83 Scurfield Blvd.
Winnipeg, Manitoba, R3Y 1G4
Website: www.nscons.ca

Tel.: (204) 284-3366
Fax: (204) 477-4173
E-mail: nscons@nscons.ca

NORMANDEAU ASSOCIATES
ENVIRONMENTAL CONSULTANTS

EXECUTIVE SUMMARY

This report presents preliminary results of an ongoing study investigating natural fish movements and experimental turbine passage at selected Manitoba Hydro hydroelectric generating stations (GSs) in northern Manitoba. Results are presented in two parts: 1) results of the first two years of a three-year fish movement study conducted at the Limestone GS; and 2) results of a pilot study conducted to provide preliminary estimates of injury/mortality rates of fish intentionally passed through a turbine at the Kelsey GS (presented as two reports detailing: (a) immediate, or short-term (≤ 48 hours) effects; and (b) long-term (up to three months) effects).

Part 1 Limestone fish movements: In September, 2005, 37 walleye, 30 northern pike, 20 lake whitefish, 13 white sucker, and one lake sturgeon surgically implanted with acoustic tags were released in the upper section of the Limestone forebay. After an initial period of greater rates of downstream movements (as is commonly observed immediately after capturing and handling fish for tagging), the majority of tagged fish remained within the forebay. Of the 84 fish relocated in the forebay in May, 2006, only two fish moved through the Limestone GS during the open-water season (May-November 2006). Location data indicated that most fish spent the majority of the open-water season in the upper end of the forebay. Gillnetting studies from previous years support this observation, likely due to lower quality habitat immediately upstream of the GS. Movement data also indicated that most fish that moved downstream in the forebay showed a tendency to return upstream.

Part 2 Kelsey turbine passage: Results of the turbine passage pilot study indicated that the 48-hour survival probability of fish experimentally introduced into a turbine was 66% for northern pike and 80% for walleye. These tests, conducted in June, 2006, focused on larger walleye (314-651 mm) and northern pike (455-1,085 mm). Estimates of survival probabilities may be modified after further study in 2007 when the lower size limit of fish tested will be reduced to more realistically represent the overall size range of the resident walleye and northern pike populations. The further testing of northern pike, walleye, and potentially lake whitefish, scheduled for fall 2007, will also provide the opportunity to conduct fish passage tests using a new turbine currently being installed at the Kelsey GS.

Taken together, results to date of Parts 1 and 2 suggest that turbine mortality does not have a substantial effect on walleye and northern pike in the Nelson River within the size range tested, as the number of larger individuals of these species moving downstream through generating stations is small and, of these, the majority survive.

TECHNICAL SUMMARY

Background and Introduction to the Study

Since construction of the first hydroelectric GSs in the 19th century, there have been few studies concerning the effects of turbine passage on non-anadromous boreal fish species. Additionally, little information exists about the frequency with which these fish species naturally pass downstream through hydroelectric GSs. Most studies concerned with fish passage through hydroelectric stations have focused on anadromous species (see review by Cada 2001). Two North American studies (Navarro et al. 1996 and Matousek et al. 1994) have looked at fish movements and turbine passage for some of the species of concern in Manitoba; however, the type(s) of turbines examined by these authors are substantially different from those used in Manitoba Hydro plants.

Recent concerns expressed by provincial and federal regulatory agencies and local stakeholders (primarily First Nation communities) regarding the scarcity of information on the fate of fish that pass through Manitoba Hydro's hydroelectric GSs prompted the utility to initiate a pilot study examining:

- the frequency of naturally occurring movements of fish through hydroelectric GSs; and
- the rate of injury/mortality of larger individuals of fish species of domestic or commercial importance as a result of turbine passage.

This study was conducted in two parts. The first component of this study (hereafter referred to as Part 1: Limestone fish movements) used acoustic telemetry to investigate the frequency of naturally occurring movements of fish through a Manitoba Hydro GS. The Limestone GS forebay was selected as the location for this investigation because the relatively narrow shape of the forebay allowed for effective monitoring of fish movements throughout its entire length using a series of stationary receivers. Also, fish are contained in the forebay between the Long Spruce and Limestone GSs, so tagged fish can only leave the system by moving downstream. Fish passing through the Limestone GS (both past the turbines and over the spillway) were effectively monitored using a series of stationary receivers downstream of the GS. Part 1 of this report documents results for years 1 and 2 of the movements study for lake sturgeon (*Acipenser fulvescens*), lake whitefish (*Coregonus clupeaformis*), northern pike (*Esox lucius*), walleye (*Sander vitreus*), and white sucker (*Catostomus commersoni*).

The second component of this study (hereafter referred to as Part 2: Kelsey turbine passage) investigated: (a) short-term (≤ 48 hrs); and (b) long-term (up to three months) survival of walleye, northern pike, and lake whitefish as a result of intentionally passing fish through a turbine at the Kelsey GS. Short term survival of fish after turbine passage was studied with the use of "HI-Z" tags (Heisey et al. 1992). Long-term survival and post-passage movements of fish were assessed using a sub-sample of "HI-Z"-tagged northern pike and walleye internally implanted with acoustic transmitters. The Kelsey GS was a suitable location to conduct Part 2 as it is representative of many of the GSs in the Manitoba Hydro system. Also, Manitoba Hydro is in the process of replacing the turbine units at the Kelsey GS, providing an opportunity to conduct tests on both "old" and "new" turbine designs.

The following sections provide a summary of the methods and preliminary findings of the two study parts: Part 1 Limestone fish movements; and Part 2 Kelsey turbine passage.

Part 1 – Limestone Fish Movements, 2005 - 2006

Specific objectives of Part 1 were: a) to acquire a better understanding of species-specific fish movements within the Limestone forebay; and b) to acquire a better understanding of species-specific fish movements through the Limestone GS, either by passage through the turbines or over the spillway (i.e., movements of fish downstream out of the Limestone forebay).

In September, 2005, a total of 101 fish, including 37 walleye, 30 northern pike, 20 lake whitefish, 13 white sucker, and one lake sturgeon were captured in gill nets set in the upper reach of the Limestone GS forebay and surgically implanted with acoustic transmitters. These acoustic tags identify each fish individually. All fish were released in the forebay 1–2 km downstream of the Long Spruce GS, approximately 21 km upstream of the Limestone GS.

Fish movements were monitored using stationary acoustic receivers positioned throughout the Limestone GS forebay from September to November, 2005, and from May to November, 2006. Manual tracking from a boat was also conducted on three occasions during these time periods. Receivers were removed during the winter months due to ice conditions. As part of a separate study, stationary receivers were positioned along the length of the Nelson River immediately below the Limestone GS downstream to Port Nelson. These receivers would monitor downstream movements of tagged fish in the event of fish passage through the Limestone GS.

Within two weeks of tagging, three fish (one each of lake whitefish, walleye, and white sucker) had moved downstream past the Limestone GS. Given that these fish moved downstream immediately following tagging, with no intervening upstream movements, it is thought that this occurred as a result of stress due to capture and handling and does not represent natural behaviour (similar movements have been observed during other tagging studies). By November, 2005, one additional fish (a northern pike) was detected by stationary receivers below the Limestone GS.

In May 2006, 84 acoustic-tagged fish were relocated in the forebay. During spring 2006, two acoustic-tagged northern pike passed through the Limestone GS and one walleye was harvested by a local angler. In November 2006, 81 of the 84 acoustic-tagged fish located in May 2006 remained within the forebay. Data for thirteen of the original tags are sparse or non-existent; these fish may have left the forebay, been in regions of the forebay which were out of the receivers' range, or the tags may have failed.

It is unknown if fish passed through the Limestone GS via the spillway or through the turbines. At least five of the six fish known to have moved through the GS did so during times when the spill gates were open. It is likely that the six acoustic-tagged fish that passed through the Limestone GS in 2005 and 2006 survived passage based on observed movements in the downstream environment.

The transmitters applied to fish in the Limestone GS forebay have a life expectancy of approximately 2-2.5 years (4 years for lake sturgeon); therefore additional data will be collected in 2007 to provide a better understanding of overall fish movements within and downstream out of the Limestone forebay.

Part 2 – Kelsey Turbine Passage Study:

Specific objectives of Part 2 were: a) to determine the rates of short-term (≤ 48 hr) survival and injury/mortality to lake whitefish, northern pike, and walleye, experimentally passed through the Unit 2 turbine at the Kelsey GS; and b) to examine the long-term (up to three months) survival and movements following turbine passage. North/South Consultants Inc., under contract to Manitoba Hydro, sub-contracted Normandeau Associates Inc. to conduct the short term turbine passage survival and condition studies.

A total of 267 fish were used in this study, of which 202 were "treatment" fish and 65 were "control" fish. Treatment fish consisted of those fish that were intentionally passed through the Unit 2 turbine. Control fish consisted of those fish that were released directly into the tailrace downstream of the turbulent eddies below the GS (i.e., fish that were not intentionally passed through the turbine). Treatment fish and control fish were captured and handled using identical techniques prior to their release. "HI-Z" tags and radio tags were attached to all fish to allow for their retrieval following testing (i.e., to allow study team members to recapture fish and assess their condition within minutes of their release).

The treatment fish (99 walleye, 88 northern pike, and 15 lake whitefish) were released through an induction system into the intake area of the Unit 2 turbine at a discharge of approximately 227.9 m^3/s (8,000 cfs). Although the study design called for equal numbers of walleye, northern pike, and lake whitefish to be released through the turbine, more walleye and northern pike were released due to the limited availability of lake whitefish during spring in the vicinity of the Kelsey GS. Average total length for treatment fish was 446 mm (range 314-651 mm) for walleye, 660 mm (range 455-1,085 mm) for northern pike, and 503 mm (range 448-565 mm) for lake whitefish.

The control fish (30 walleye, 30 northern pike, and five lake whitefish) were released through an induction system directly downstream of the tailrace. Average total length for control fish was 458 mm (range 341-610 mm) for walleye, 629 mm (range 500-990 mm) for northern pike, and 498 mm (range 475-533 mm) for lake whitefish.

Recapture rates (physical retrieval of fish following testing) were high for all species: 97.9% for walleye; 97.7% for northern pike; and 93.3% for lake whitefish. Retrieval times were short (average <8 min) and comparable to those recorded in other similar investigations. Tag detachment was minimal. None of the control fish died or suffered visible injuries, indicating that mortality and injury observed was due to passage through the turbine and not other handling associated with the study.

Survival probabilities (≤ 48 hr) for treatment fish across all entrainment depths (shallow, mid, and deep) were 0.804 (SE=0.040) and 0.659 (SE=0.050) for walleye and northern pike, respectively. The difference in survival rate between walleye and northern pike was most likely related to difference in fish size; walleye averaged 446 mm and northern pike averaged 660 mm total length. This finding is consistent with several recent literature reports; survival decreases with increased fish lengths. However, due to the relatively small sample size in each length group, an overall predictive relationship between survival rate and fish lengths was not established. Survival rates were not calculated for lake whitefish due to an insufficient sample size; however, 13 of the 14 tested and recaptured lake whitefish survived passage.

Malady rates (fish with visible injuries and/or scale loss, or loss of equilibrium, including all mortalities) of treatment fish passed through the turbine also showed species-specific differences: northern pike passage-related malady rates were 52.9% compared to 30.5% for walleye. Similar to the results for survival estimates, this difference was most likely due to the generally larger size of northern pike compared to walleye, although the observed differences in the frequency of injured and non-injured fish between length groups were only significant (P=0.001) for walleye but not for northern pike (P=0.685). The probable injury source for almost all fish was mechanical (i.e., contact with structural components of the turbine).

Clean fish estimates (fish free of maladies) differed between species. The clean fish estimate was 47.1% for northern pike and 67.4% for walleye. Again, the difference was attributed to differences in lengths between species.

This turbine passage study focused on larger walleye and northern pike. Further testing of northern pike, walleye, and potentially lake whitefish, scheduled for fall 2007, will provide the opportunity to conduct fish passage tests using a new turbine currently being installed at the Kelsey GS. Estimates of survival probabilities may be modified after the 2007 study, when the lower size limit of fish tested will be reduced to more realistically represent the overall size range of the resident walleye and northern pike populations and testing will be conducted on a modern turbine.

Long-term (up to three months) survival and subsequent movements of treatment and control fish was studied using a sub-sample consisting of 26 walleye (24 treatment and 2 control fish) and 26 northern pike (22 treatment and 4 control fish) surgically implanted with acoustic transmitters. The mean length of acoustic-tagged northern pike (653 mm) and walleye (446 mm) used as treatment fish approximated the mean length of all treatment fish of the respective species.

Fish locations were monitored from the time of release until 3 September, 2006, using five stationary receivers positioned up to 7.7 km downstream of the Kelsey GS in the two reaches of the Nelson River extending towards Split Lake. Stationary receivers were removed on 18 August. Manual tracking was conducted with a mobile receiver for two 3-4 day periods in June and September.

Of the 46 treatment fish equipped with acoustic transmitters, six northern pike (27.3 % of the pike) and four walleye (16.7% of the walleye) did not survive turbine passage. These mortality rates were similar to those observed for the entire sample of pike (24.4%) and walleye (17.7%) that were released as treatment fish through the turbine. A total of 20 northern pike and 22 walleye (including all six control fish) were released back into the Nelson River below the Kelsey GS with acoustic tags. Of these, 18 northern pike and 21 walleye were tracked and confirmed to be alive based on the spatial and temporal pattern of signal reception. The status of two of these fish, one pike and one walleye, was initially unknown because they were never visually detected or located by radio tracking after turbine passage. Confirmation that these fish were alive based on subsequent acoustic tracking provided information that affected the outcome of the survival estimates.

The acoustic data provided no conclusive evidence that any of the fish released into the river immediately after turbine passage died within the 1-91 days they were tracked. At least half of the fish were still confirmed present and alive in the Study Area 10-13 weeks (i.e., to the end of stationary and manual tracking, respectively) after passing through the turbine or being released as control fish. However, for one third of all fish, an acoustic signal was last received within 10 days and the long-term fate of these fish is largely unknown. Based on the spatial and temporal pattern of relocations, just over half of the fish that were tracked for less than 11 days likely moved beyond the range of the receivers shortly after being released back into the river. Others may have avoided signal detection, and some of these pike and walleye may have died due to predation or as a delayed effect of turbine passage.

To our knowledge no other studies have documented the long term survival or movements of northern pike or walleye after turbine passage. The movement patterns of northern pike and walleye observed in this study are largely in agreement with literature results and other data obtained from pike and walleye in the Nelson River system. This suggests that the movements of these two species at Kelsey GS fall within the patterns regularly observed in walleye and pike after Floy-tagging from similar habitats and do not suggest a pronounced effect of turbine passage on the movement patterns of these two species.

Preliminary Conclusions and Next Steps

Taken together, results to date suggest that turbine mortality does not have a substantial effect on walleye and northern pike in the Nelson River within the size range tested, as investigations conducted indicated that the number of larger individuals of these species moving downstream through generating stations was small and, of these, survival was approximately 66% for northern pike and 80% for walleye. However, these results are preliminary as additional studies are planned to document the incidence of fish movements past GSs, and the evaluation of mortality/injury rates has been limited to larger individuals of two species. The data presented herein should not be used to extrapolate effects of fish passage at Manitoba Hydro's hydroelectric GSs to the fish community of the Nelson River at large, or even to the entire population of the study species.

Monitoring of fish movements in the Limestone forebay will continue through 2007 as the tags have one more year of battery life.

The Kelsey turbine passage study will continue in 2007 when the lower size limit of test fish will be reduced to more realistically represent the overall size range of resident populations of walleye, northern pike and, potentially, lake whitefish. Testing will be conducted on a new turbine currently being installed at the Kelsey GS. It is hypothesized that the new turbines will have less impact on fish passing through them, given the reduced number of blades (five versus six in older turbines).

NON-TECHNICAL SUMMARY

WHY WAS THIS STUDY DONE?

- This study was done to start to answer three questions:
  - Do adult fish of domestic or commercial importance naturally move downstream through a typical Manitoba Hydro Generating Station (GS), and if yes, what proportion of the fish in the forebay?
  - What happens to adult jackfish, pickerel, and whitefish when they move through a typical Manitoba Hydro GS turbine?
  - What effect does the movement of adult fish downstream through a typical Manitoba Hydro GS have on numbers of those fish species upstream and downstream of the GS?

WHO DID THE STUDY?

- This study was done for Manitoba Hydro by a large team made up of people from North South Consultants Inc., Normandeau Associates Inc., York Factory First Nation (YFFN), Tataskweyak Cree Nation (TCN), and Fox Lake Cree Nation (FLCN), with help from the Manitoba Hydro staff of the Kelsey and Limestone Generating Stations and several other people from Manitoba Hydro. Evelyn Beardy (YFFN), Douglas Kitchekeesik (TCN), and Ray Mayham (FLCN) helped co-ordinate First Nation participation in the study. Jonah Anderson (FLCN), Stewart Anderson (FLCN), Isaac Beardy (YFFN), Marcel Beardy (TCN), Robert Beardy (FLCN), Ron Beardy (TCN), Russell Beardy (TCN), William Beardy (FLCN), Frank Colomb (FLCN), Michael John Garson (TCN), Saul Mayham (TCN), Randy Naismith Jr. (FLCN), Franklin Ponask (YFFN), and Jeremy Saunders (YFFN) assisted in the collection of data during the study.

WHERE AND WHEN WAS THE STUDY DONE?

- One part of the study was done at the Limestone GS forebay during 2005 and 2006 (Limestone fish movements study) and the other part was done at Kelsey GS during 2006 (Kelsey turbine passage study).

WHY WAS THE STUDY DONE IN TWO PARTS AND PLACES?

- The Limestone GS forebay was one of the best places to try to answer the question "Do adult fish naturally move downstream through a typical Manitoba Hydro GS and, if so, what proportion of the fish in the forebay?" The Limestone GS forebay is relatively short and narrow, which means that it is much easier to monitor fish movements throughout the entire length of the forebay than in a much longer, wider forebay such as the one at Kelsey. Fish are contained in the forebay between the Long Spruce and Limestone GSs preventing the loss of tagged fish due to upstream movement. Additionally, any tagged fish that did move downstream out of the Limestone GS forebay could be tracked in the Nelson River by receivers that were already in place as part of other studies.

- The Kelsey GS was chosen as the site to determine what happens to adult jackfish, pickerel, and whitefish that do move through a typical Manitoba Hydro GS turbine for the following reasons:

  - The Kelsey GS is similar to many of Manitoba Hydro's GSs; and

  - Kelsey GS is in the process of replacing the turbine units, providing an opportunity to conduct tests on both "old" and "new" turbine designs.

HOW WAS THE STUDY DONE?

- Limestone fish movements study: During fall 2005, acoustic (sonic or sound) tags were surgically implanted into 101 fish that were captured and released at the upstream end of the Limestone Forebay: 37 pickerel; 30 jackfish; 20 whitefish; 13 white sucker; and 1 sturgeon. Fish movements were monitored during fall 2005 and May to November 2006 using manual tracking and receivers that were anchored in certain parts of the forebay. Receivers had to be removed during the winter due to ice conditions.

- Kelsey turbine passage study: The objectives were: to determine "short-term" (up to 48 hours) survival and injury rates of adult pickerel, jackfish, and whitefish passed through the Unit 2 turbine; and to assess "long-term" (up to three months) survival and movement of some of the pickerel and jackfish that were passed through the turbine. Fish were captured downstream of the Kelsey GS during June 2006, held in pools for approximately 24 hours, tagged with balloon and radio tags, and released directly into the Unit 2 turbine. Some of the pickerel and jackfish were also surgically implanted with acoustic tags before being released into the turbine. Fish were recaptured immediately after passage through the turbine, assessed for turbine related injuries, and released back into the river if acoustic-tagged, or held in pools for an additional assessment after 48 hours. All live fish were released back into the Nelson River following 48 hour assessments.

WHAT WAS FOUND?

- Limestone fish movement study: After the first two years of the fish movement study, most of the tagged fish were still in the Limestone forebay. Most of these fish preferred to be in the upper part of the forebay (just below the Long Spruce GS). Most fish that did start to move downstream tended to move back upstream rather than pass through the Limestone GS.

- Kelsey turbine passage study: Preliminary results of the turbine passage study indicated that approximately 66% of the jackfish and 80% of the pickerel that were introduced directly into the turbine survived passage. The surviving fish continued to do well for the three months that they were acoustically tracked. Within the size range of fish tested, larger fish appeared to be more likely to be injured or killed when they passed through the turbine. Since only fish longer than 30 cm (12 inches) were tested, the effect on younger, smaller fish is not known. Studies planned for 2007 will test smaller fish as well to get a better estimate of overall survival rates.

The studies so far suggest that turbine mortality does not have a large effect on pickerel and jackfish in the Nelson River within the sizes of fish tested, as the number of larger individuals moving downstream through GSs is small and, of these, survival was approximately 66% for jackfish and 80% for pickerel. However, these results are preliminary as additional studies are planned to document the frequency of fish movements past GSs, and the evaluation of mortality/injury rates has been limited to larger individuals of two species. At this time, these results should not be used to determine the effects of turbine passage at Manitoba Hydro's hydroelectric GSs on all fish living in the Nelson River.

IS THE STUDY FINISHED?

- The tags used in the Limestone forebay fish movements study have one more year of battery life and the movements of these fish will be monitored for one more year.

- The part of the study conducted at Kelsey GS is proposed to be repeated in fall 2007 if one or more of the turbines have been replaced. It is thought that it will be easier to catch and test whitefish during fall. In addition, smaller fish of the species of interest will be included to get a better idea of potential effects to a larger size range of these species.

ACKNOWLEDGMENTS

We would like to thank Manitoba Hydro for the opportunity and resources to conduct this study. We wish to specifically thank Roy Bukowsky, Bill Brown, and Shelley Matkowski for their support of this project.

Part 1 – Movements of fish tagged with acoustic transmitters in the Limestone Generating Station forebay, 2005 - 2006:

Chief and Council of the Fox Lake Cree Nation (FLCN) are gratefully acknowledged for their support of this program. We would like to thank Ray Mayham of FLCN for arranging logistical support and personnel needed to conduct the field work. Appreciation is extended to Robert Beardy, Stewart Anderson, Randy Naismith Jr., Frank Colomb, William Beardy, and Jonah Anderson of FLCN for their assistance in the collection of field data during the study.

This study was authorized by Manitoba Water Stewardship under terms of Scientific Collection Permits # 34-05 and #22-06.

Part 2 – Fish turbine passage through the Kelsey GS:

The fish induction system was modified and constructed by Acres Manitoba Ltd. based on a design provided by Normandeau Associates Inc. and was installed by Glen Middleton (Acres), Roy Bukowsky (Manitoba Hydro), Ron Beardy (TCN), Jeremy Saunders (YFFN), and staff of the Kelsey Generating Station, in particular Doug Boe, Dave Bruderer, and Kim Young. The Manitoba Hydro staff of the Kelsey GS are thanked for providing help wherever and whenever needed. The support and encouragement provided by Tom MacGowan and Kevin Stimpson was greatly appreciated. Finally, Roy Bukowsky, Kim Young, and Dave Bruderer are sincerely thanked for their problem solving abilities and willingness to do whatever it took to get the job done, whether it was fixing a loose hose, finding a way to get fish out of the gatewell, or getting the last fish out of a holding pool.

Chief and Council of York Factory First Nation (YFFN) and Tataskweyak Cree Nation (TCN) are gratefully acknowledged for their support of this program. We would also like to thank Evelyn Beardy (YFFN) and Douglas Kitchekeesik (TCN) for coordinating First Nation participation in the study.

Don Macdonald of Manitoba Water Stewardship, Thompson, and Bev Ross and Rob Tkach of DFO Winnipeg provided comments on study design and interest in the conduct of the study. This study was authorized by Manitoba Water Stewardship under terms of Scientific Collection Permit # 28-06.

STUDY TEAM

Part 1 - Movements of fish tagged with acoustic transmitters in the Limestone Generating Station forebay, 2005 - 2006

Data collection

North/South Consultants Inc.	First Nations
Ken Ambrose	Jonah Anderson (FLCN)
Cam Barth	Stewart Anderson (FLCN)
Mark Blanchard	Robert Beardy (FLCN)
Rochelle Gnanapragasm	William Beardy (FLCN)
Stacy Hnatiuk	Frank Colomb (FLCN)
Lee Murray	Randy Naismith Jr. (FLCN)
Darcy Pisiak	

Data analysis, report preparation, and report review

North/South Consultants Inc.
Cam Barth
Leanne Dolce
Wolfgang Jansen
Lee Murray
Darcy Pisiak
Richard Remnant

Part 2 - Fish turbine passage through the Kelsey GS

Data collection

North/South Consultants Inc.	Normandeau Associates, Inc.	First Nations
Colin Dyck	Steve Adams	Isaac Beardy (YFFN)
Wolfgang Jansen	Joanne Fulmer	Marcel Beardy (TCN)
Lee Murray	Paul Heisey	Ron Beardy (TCN)
Darcy Pisiak	Steve Kauffman	Russell Beardy (TCN)
Richard Remnant		Michael John Garson (TCN)
Vicki Richardson		Saul Mayham (TCN)
		Franklin Ponask (YFFN)
		Jeremy Saunders (YFFN)

Data analysis, report preparation, and report review

North/South Consultants Inc.	Normandeau Associates, Inc.
Leanne Dolce	Sidney Graver
Wolfgang Jansen	Susan Haney
Michelle Lavergne	Paul Heisey
Lee Murray	Steve Kauffman
Darcy Pisiak	Michael Martinek
Richard Remnant	Dilip Mathur

PART 1

MOVEMENTS OF FISH TAGGED WITH ACOUSTIC TRANSMITTERS IN THE LIMESTONE GENERATING STATION FOREBAY

2005 – 2006 INTERIM REPORT

Prepared

for

Manitoba Hydro

by

D.J. Pisiak and L. Murray

May 2007

North/South Consultants Inc.
Aquatic Environment Specialists
83 Scurfield Blvd.
Winnipeg, Manitoba, R3Y 1G4
Website: www.nscons.ca
Tel.: (204) 284-3366
Fax: (204) 477-4173
E-mail: nscons@nscons.ca

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF APPENDICES

Page

1.0 INTRODUCTION

This study, initiated during fall, 2005, in the Limestone GS forebay, investigates the species-specific behaviour and movement of fish in the vicinity of a dam, as well as the frequency of fish passage through a hydroelectric GS. This study represents Part 1 of a larger study investigating the impacts to fish passing through Manitoba Hydro's hydroelectric GSs. Results complement Part 2 of the study conducted in 2006 at the Kelsey GS (see parts 2a and 2b of this report), which investigate short term and long term survival, respectively, of fish experimentally passed through a hydroelectric GS turbine.

This report presents preliminary results of the second year of a three-year fish movement study conducted in the Limestone GS Forebay during the 2006 open-water season. Where applicable, results are presented and interpreted cumulatively with data collected during fall, 2005. One final year of data collection is planned for the 2007 open-water season, upon which time a comprehensive analysis of fish movements will be conducted.

2.0 STUDY AREA

With a 1340 MW capacity, the Limestone GS is the largest single producer of electricity in the province of Manitoba. The Limestone GS was completed in 1990 and resulted in the formation of the Limestone forebay. The forebay extends 23 km upstream to the base of the Long Spruce GS on the Nelson River (Manitoba Hydro 2002).

Four tributaries of the Nelson River enter the forebay; Wilson Creek and Brooks Creek enter from the south, and Sky Pilot Creek and Leslie Creek enter from the north. Aquatic habitat within the forebay ranges from a riverine environment in the upper reach, to more lacustrine conditions just upstream of the Limestone GS. Aquatic macrophytes do not occur along the shoreline of the forebay or within the tributary mouths.

The Limestone forebay was determined to be a suitable location to conduct this study for several reasons. Fish are contained in the forebay between the Long Spruce and Limestone GSs; therefore fish can only leave the forebay by moving downstream. There is also less potential for fish to move downstream due to tagging stress as fish released in the upper region of the forebay would have to move over 20 km through calmer water before passing through the Limestone GS. Fish movements could be effectively monitored throughout the entire length of the forebay with 8 – 10 stationary receivers. Receivers placed downstream of the Limestone GS can monitor fish movements in the lower Nelson River. Fish movements in the Limestone forebay may be considered representative of the situations anticipated at Manitoba Hydro’s proposed future developments.

3.0 METHODS

During fall, 2005, acoustic transmitters were surgically implanted into 101 fish captured at the upstream end of the Limestone forebay, including walleye (n=37), northern pike (n=30), lake whitefish (n=20), white sucker (n=13), and lake sturgeon (n=1). Fish were released 1 – 2 km downstream of the Long Spruce GS (approximately 21 km upstream of the Limestone GS) at either Site 1, near the confluence of Sky Pilot Creek and the Nelson River, or at Site 2, near the confluence of Wilson Creek and the Nelson River (Figure 1).

3.1 Gillnetting

During spring, 2006, four 50 yd (45.7 m) large mesh gillnet gangs were set adjacent to the Long Spruce GS spillway from 20 – 23 May in an attempt to capture and acoustic tag additional lake sturgeon. Gillnet gangs consisted of two 25 yd (22.9 m) panels of some combination of 8, 9, 10, or 12 inch (203, 228, 254, or 305 mm) twisted nylon mesh and were checked approximately every 24 hours. No additional lake sturgeon were captured during spring, 2006. For descriptions of fish capture methods, acoustic transmitter application procedures, and transmitter specifications, refer to Pisiak and Barth (2006).

3.2 Acoustic telemetry

Acoustic transmitters were monitored via two methods: a) stationary receivers; and b) a portable ultrasonic receiver. For a detailed description of the equipment used, methods of stationary receiver deployment, data retrieval, and methods of manual tracking, refer to Pisiak and Barth (2006).

3.2.1 Stationary receivers

During fall, 2005, movements of acoustic-tagged fish were monitored using nine stationary VR2 receivers positioned throughout the Limestone forebay (Figure 1). All receivers were removed from the Nelson River on 1 and 2 November, 2005, to prevent being lost or damaged over winter.

On 17 and 18 May, 2006, ten stationary receivers were deployed in the Limestone forebay, including one receiver (R10) set in a shallow, off-current bay approximately 1.5 km downstream of the R1 receiver (Figure 2). Receiver R10 was deployed in 2006 in response to results of manual tracking data obtained in fall, 2005 (i.e., several acoustic-tagged fish were located in this bay, which was determined to be out of range of the R1 receiver). In 2006, receiver R4 was positioned downstream of its 2005 location, as it was determined that R3 and R4 were overlapping in detection ranges (Figure 2). By repositioning R4, greater overall coverage within the forebay was obtained. As part of a separate and ongoing study, fifteen stationary receivers, including three directly below the Limestone GS, were positioned along the length of the Nelson River downstream of the Limestone GS to Port Nelson (Figure 3). It was anticipated that these receivers would monitor fish movements in the event of fish passage through the Limestone GS.

For the purposes of this report, the range of detection for all stationary acoustic receivers in the forebay was estimated at 500 m. Receivers deployed in 2006 likely had a higher range of detection than those in 2005, as spillage through both the Long Spruce and Limestone GSs was much lower in 2006 resulting in less turbulent waters and reduced levels of "noise". Based on the assumed 500 m range of detection for each receiver, detection ranges were delineated for receivers in the forebay (Figure 2).

Stationary receivers were downloaded approximately once every two to four weeks. As in the previous year, all receivers were removed from the Nelson River on 2 November, 2006, to prevent being lost or damaged over winter.

3.2.2 Manual tracking

Manual tracking in the Limestone forebay was conducted from a boat using a portable ultrasonic receiver on 17 and 18 May and 4 and 5 September, 2006. Manual tracking sites in 2006 are illustrated in Figure 4.

3.3 Data analysis

During fall, 2005, movements of acoustic-tagged fish were quantified by measuring the minimum distance of movement (MDM). The MDM was calculated by adding the distance between original tagging location and the locations of receivers where a fish was detected on a daily basis. As stationary receivers were removed from the Nelson River between November 2005 and May 2006, it is not possible to quantify individual fish movements due to the chronological gap in the data. In addition, three stationary receivers were lost during the 2006 open-water season; R2 was lost shortly after deployment in spring, 2006, resulting in the loss of data between 18 May and 12 June for this location, R1 was lost between 10 July and 3 September, 2006, and R9 was lost from 3 September to the end of the program.

Fish movement data collected in 2006 were analyzed and presented on a more general and qualitative basis than those in 2005. In 2006, the forebay was considered to consist of three regions or zones, for which the boundaries were arbitrarily delineated: 1) the upper forebay (Zone A); 2) the middle forebay (Zone B); and 3) the lower forebay (Zone C) (Figure 2).

4.0 RESULTS AND DISCUSSION

Nelson River discharge data, collected at the Long Spruce and Limestone GSs from 1 September, 2005, to 31 December, 2006, are provided in Appendix 1. During fall, 2005, the spill gates at the Limestone GS were open throughout the entire tracking period. Initially in spring, 2006, the spill gates were open at the start of the tracking period on 17 May, to approximately 4 July. From 4 July to 2 August, the spill gates were open periodically, and following 2 August the gates were closed for the remainder of the open-water season.

4.1 Fish movements

A species-specific summary of fish movement data collected during fall, 2005, and the open-water season in 2006, is presented in Table 1. In fall, 2005, within approximately two weeks of tagging, three fish (one each of lake whitefish, walleye, and white sucker) had moved downstream past the Limestone GS. Given that these fish moved downstream immediately following tagging, with no intervening upstream movements, it is likely that this occurred as a result of stress due to capture and handling and does not represent natural behaviour (similar movements have been observed during other tagging studies). By November, 2005, one additional fish (a northern pike) was detected by stationary receivers below the Limestone GS.

In spring 2006, 84 acoustic-tagged fish were relocated in the forebay. During spring 2006, two acoustic-tagged northern pike passed through the Limestone GS and one walleye was harvested by a local angler. In November 2006, 81 of the 84 acoustic-tagged fish located in spring remained within the forebay. Data for thirteen of the original tags are sparse or non-existent; these fish may have left the forebay, been in regions of the forebay which were out of the receivers' range, or the tags may have failed.

Movements of individual fish in 2006, presented in terms of zones delineated within the forebay, are provided in Table 2. Table 3, which provides an outline of fish movements within the forebay on a monthly basis in 2006, describes the species-specific seasonal distribution of fish (i.e., upper, middle, or lower areas) within the forebay. These data are also illustrated in figures 5 through 9. The data indicate that areas within Zone A (upper forebay) are preferred by most species throughout the majority of the open-water season.

4.1.1 Lake sturgeon

One lake sturgeon was implanted with an acoustic transmitter in the Limestone forebay during fall, 2005. Efforts to capture additional lake sturgeon in 2006 were unsuccessful.

During fall, 2005, this lake sturgeon remained in the upper region of the forebay (Zone A), in the vicinity of receivers R1 and R2 (Figure 1). This fish was relocated in Zone A in May, 2006, and moved downstream to Zone C by mid-June. On 5 September, 2006, this fish was located by manual tracking in the vicinity of sites 1 and 4 in Zone B (Figure 4). In late fall, 2006, this lake sturgeon returned upstream where it was last located in Zone A in late October (Table 3; Figure 5). Due to the small sample size (n=1 fish), an extensive analysis of lake sturgeon movements is not warranted.

4.1.2 Lake whitefish

During fall, 2005, twenty lake whitefish were implanted with acoustic transmitters in the Limestone forebay. Twelve of the nineteen lake whitefish for which data were obtained moved downstream during fall, 2005, of which five returned upstream. Initial downstream movements of at least eight of these fish may have been a result of post-operative stress. Of the five species implanted with acoustic transmitters, lake whitefish appeared most sensitive to the surgical procedure and consequently may have been more likely to move downstream in the days following their release.

Prior to freeze-up in fall, 2005, one lake whitefish was confirmed to have passed through the Limestone GS. This fish likely survived passage as it was located near a stationary receiver positioned at Broten Creek South (Figure 3), approximately 60 km downstream of the Limestone GS. Passive drifting of a fish over such a great distance is unlikely. Four additional lake whitefish were suspected to have passed through the GS following their detection in the lower forebay, and at least fourteen lake whitefish remained in the forebay; there were no data collected for one fish.

In spring, 2006, twelve acoustic-tagged lake whitefish were relocated in the forebay, of which ten were initially relocated by manual tracking. Among the fish located by manual tracking was the fish that was undetected in 2005. Eight lake whitefish were undetected throughout the entire 2006 open-water season, among which are the four fish suspected to have passed through the Limestone GS during fall, 2005, and the one lake whitefish that was known to have passed through the GS in 2005. The remaining three lake whitefish that were undetected may still be in the forebay, as there are no data to suggest otherwise.

As of November, 2006, at least twelve (60%) of the acoustic-tagged lake whitefish remain in the forebay. Overall, lake whitefish were most often found in Zone A, and six lake whitefish did not move downstream of Zone A throughout the entire open-water season (tables 2 and 3; Figure 6).

4.1.3 Northern pike

Thirty northern pike were implanted with acoustic transmitters in the Limestone forebay during fall, 2005. One pike passed through the Limestone GS approximately six weeks following its release. This fish likely survived passage through the GS as it was detected by a receiver approximately 60 km downstream of the Limestone GS. It is unlikely that a fish would drift passively over such a great distance. Two northern pike were undetected following their release in fall, 2005; however these pike were detected in the upper forebay throughout the 2006 open-water season. Overall, it is probable that 29 of the 30 northern pike remained in the forebay throughout the 2005 open-water season.

In spring 2006, twelve northern pike were initially relocated in the forebay by manual tracking, and an additional twelve pike were detected by stationary receivers. There were no data for four pike that were known to be in the forebay throughout fall, 2005; however there are no data to suggest that these fish passed through the Limestone GS.

During 2006, two pike are known to have passed through the Limestone GS and the data suggest that both fish survived passage. One pike (code 1279) was initially relocated below the Limestone GS on 5 June, 2006; therefore the approximate date of passage for this fish is unknown. This fish was first detected near the Limestone spillway and was later detected near the mouth of Sundance Creek. The data indicate that this fish was not stationary while in the vicinity of these receivers (i.e., this fish moved in and out of the receivers' range of detection), likely indicating active movement of the fish. The second fish (code 213) passed through the GS between 27 and 31 May, 2006. This pike survived passage through the GS as it demonstrated upstream movements following passage.

It is unknown if the three pike that passed through the Limestone GS did so through the turbines or through the spillway. However, the approximate dates of passage are known for two of these pike, and during these times the spill gates at the GS were open.

As of November, 2006, at least 23 (77%) and possibly as many as 27 (90%) of the 30 acoustic-tagged northern pike remain in the Limestone forebay. Most of these fish were located in Zone A for the majority of the open-water season (tables 2 and 3; Figure 7).

4.1.4 Walleye

Thirty-seven walleye were acoustic-tagged in the Limestone forebay during fall, 2005. One fish passed through the Limestone GS approximately one week after being tagged, likely a result of post-operative stress. The spill gates at the Limestone GS were in operation during the time this fish passed, therefore it is unknown whether this walleye passed with the spill or through the turbines. Following passage through the GS, this fish was relocated on multiple occasions near the confluence of the Angling and Nelson rivers, suggesting that this fish survived passage. This walleye was not relocated downstream of the GS in 2006. No additional walleye were suspected to have passed through the GS in fall, 2005.

In spring 2006, data were obtained for the remaining 36 walleye in the Limestone forebay. Eighteen walleye were initially detected by manual tracking and eighteen were first detected by stationary receivers. All 36 walleye were initially detected in Zone A of the forebay (Table 2). One walleye was harvested by a local angler in Wilson Creek at its confluence with the Nelson River on 23 May, 2006.

Only one walleye is suspected to have passed through the Limestone GS during the 2006 open-water season, as it was last detected in Zone C on 30 June. However, no detections were recorded downstream of the Limestone GS throughout the remainder of the tracking period. Overall, as of November 2006, at least 34 (92%) of the acoustic-tagged walleye remain in the Limestone Forebay (Table 1). The majority of these fish were last located in late fall in Zone A (Table 3; Figure 8).

4.1.5 White sucker

Of the 13 white sucker acoustic-tagged in the Limestone forebay during fall, 2005, one fish passed through the Limestone GS approximately two weeks after its release, possibly a result of post-operative stress. One additional white sucker, suspected to have passed through the GS during fall, 2005, was relocated in the forebay during the 2006 open-water period. Data collected in 2006 confirm that only one white sucker passed through the Limestone GS during fall, 2005.

White sucker were found to move throughout the forebay during fall, 2005, including the middle and lower regions. During spring 2006, nine of the eleven white sucker were initially relocated in Zone A (Table 2; Figure 9). Of these nine fish, six moved throughout the middle and lower reaches throughout the season, resulting in a distribution in fall, 2006, similar to that of 2005. The data appear to indicate that white sucker have a preference for the upper forebay in spring, with a tendency to be distributed throughout the forebay during summer and fall (Figure 9).

Overall, at least eleven (85%), and possibly twelve of the thirteen acoustic-tagged white sucker remain in the Limestone forebay, as one fish went undetected throughout the 2006 open-water season (Table 1).

5.0 DISCUSSION

5.1 Nelson River discharge

During fall, 2005, high water levels required the spill gates at the Long Spruce and Limestone GSs to be in operation on a daily basis. Discharge measured at each GS was considerably higher than in previous years. Passive drifting of fish released in the upper region of the Limestone GS forebay may have increased due to higher than normal discharge from the Long Spruce GS. It is unknown if the four fish that were confirmed to have moved out of the Limestone forebay did so via the spillway or through the turbines. As a result, fish passage through the Limestone GS during fall, 2005, does not necessarily indicate turbine passage.

Water levels in the Nelson River were considerably lower during the 2006 open-water season in comparison to fall, 2005. The spill gates at both Long Spruce and Limestone GSs were in operation at the start of the monitoring program, from 17 May to approximately 4 July, after which time spilling occurred periodically until 2 August. From 3 August and throughout the remainder of the open-water season, the spill gates at Long Spruce and Limestone GSs were closed (Appendix 1). One of the fish confirmed to have passed through the Limestone GS during the 2006 open-water season did so when the spill gates were open. The approximate date of passage of the other fish is unknown.

5.2 Fish movements

Data collected during fall, 2005, indicate that at least one lake whitefish, one northern pike, one walleye, and one white sucker passed through the Limestone GS. The lake whitefish (code 225) and the walleye (code 1276) passed through the Limestone GS approximately one week after being tagged, and the white sucker (code 227) passed through the GS approximately two weeks after being tagged. The northern pike (code 1230) showed some upstream movement before passing through the GS approximately six weeks after being tagged. At the conclusion of the 2005 open-water season, four additional lake whitefish and one additional white sucker were suspected to have passed through the Limestone GS. These four lake whitefish were not located during the open-water season in 2006; however, the white sucker was relocated by manual tracking in Zone B.

During the 2006 open-water season, two additional northern pike (codes 1279 and 213) passed through the Limestone GS and one walleye (code 228) is suspected to have passed through, as it was last detected in Zone C on 30 June, 2006. Data collected during fall, 2005, and the open-water season in 2006, indicate that at least 60% of lake whitefish, 77% of northern pike, 92% of walleye, and 85% of white sucker, implanted with acoustic transmitters, remain in the Limestone forebay as of November, 2006. The only acoustic-tagged lake sturgeon also remains in the forebay.

When considering only data collected in the 2006 open-water season, 84 acoustic-tagged fish were located in the forebay at the start of the open-water season. Of these fish, one walleye was harvested, two northern pike passed through the Limestone GS, and the remaining 81 fish were located in the forebay as of November, 2006.

Of the six fish known to have passed through the Limestone GS, five passed during times when the Limestone GS spill gates were open. The exact date of passage of the sixth fish is unknown. As a result, it is unknown if these fish passed through the GS via the turbines or the spillway. There is no conclusive evidence to suggest that any of the fish that passed through the GS did not survive. It is likely that most fish survived passage through the GS as the data indicate either: a) upstream movements following passage through the GS; b) a sufficient length of time in the vicinity of a receiver to rule out the possibility of passive drifting with the current; or c) temporal gaps in the data indicating a fish is moving in and out of the range of a particular receiver. Additionally, it is unlikely that any of these fish would have passively drifted downstream in the Nelson River over such great distances (40 – 60 km downstream in some cases).

The transmitters applied to fish discussed in this report have a life expectancy of approximately 2 – 2.5 years (4 years for lake sturgeon); therefore, further monitoring of the acoustic-tagged fish during the open-water season in 2007 will provide greater insight into fish movement over time. Following the 2007 open-water season, a comprehensive analysis of data collected from 2005 – 2007 will synthesize the results of fish movements within the Limestone forebay and through the Limestone GS.

6.0 REFERENCES

CADA, G. F. 2001. The development of advanced hydroelectric turbines to improve fish passage survival. Fisheries 26: 14 – 23.

MANITOBA HYDRO. 2002. http://www.hydro.mb.ca/our_facilities/gs_limestone.shtml

MATOUSEK, J. A., A. W. WELLS, J. H. HECHT, and S. G. METZGER. 1994. Reporting survival results of fish passing through low-head turbines. Hydro Review, May 1994: 58 – 65.

NAVARRO, J. E., D. J. McCAULEY, and A. R. BLYSTRA. 1996. Turbine passage at four low-head hydroelectric facilities in northeast Michigan. N. Am. J. Fish. Manage. 16: 182 – 191.

PISIAK, D.J. and C.C. BARTH. 2006. Movements of fish tagged with acoustic transmitters in the Limestone Generating Station Forebay, fall 2005. A draft report prepared for Manitoba Hydro by North/South Consultants Inc. 55 pp.

TABLES AND FIGURES

Table 1. Summary of movements of acoustic-tagged fish in the Limestone forebay, 2005 - 2006.

	2005						2006					
Species	**# tagged**	**# passed through GS[1]**	**# potentially passed through GS[2]**	**no data**	**# remaining in forebay[3]**	**% of tagged fish remaining in forebay[4]**	**# relocated in forebay**	**# passed through GS**	**# potentially passed through GS**	**no data**	**# remaining in forebay**	**% of tagged fish remaining in forebay**
LKST	1	0	0	0	1	100.0	1	0	0	0	1	100.0
LKWH	20	1	4	1	14	70.0	12	0	0	7	12	60.0
NRPK	30	1	0	2	27	90.0	24	2	0	4	23	76.7
WALL	37	1	0	0	36	97.3	36	0	1	0	34**	91.9
WHSC	13	1	1	0	11	84.6	11	0	0	1	11	84.6
Total	**101**	**4**	**5**	**3**	**89**	**88.1**	**84**	**2**	**1**	**12**	**81**	**80.2**

1 - number of acoustic-tagged fish confirmed to have passed through the Limestone GS
2 - number of additional fish suspected to have passed through the Limestone GS, but unconfirmed based on available data (i.e., status unknown)
3 - number of fish confirmed to be remaining in the Limestone forebay; may be an underestimate due to fish with status unknown and fish for which no data were collected
4 - minimum % of tagged fish confirmed to be remaining in the Limestone forebay
** - one walleye was harvested by a local angler during spring, 2006

Table 2. Detection locations of fish marked with acoustic transmitters in the Limestone forebay, 2005 - 2006.

								Detection Zones / Receivers[2] - May to November 2006								
		2005		2006				Zone A			Zone B		Zone C			
Species[1]	Code	Zone of last detection[2]	Date	Zone of first detection	Date	Zone of last detection	Date	R1	R10	R2	R3	R4	R5 & R6	R7, R8, & R9	Passage[3]	VR-60 Location[4]
LKST	1072	A	Oct-29	A	May-18	A	Oct-30	X	X	X	X	X	X	X	-	1, 4
LKWH	149	no data	-	A	May-18	A	Jul-04	X	X	X	-	-	-	-	-	23
LKWH	146	A	Oct-11	A	Jun-11	A	Oct-31	X	X	X	-	-	-	-	-	-
LKWH	147	A	Nov-02	A	May-18	A	Nov-02	-	-	X	-	-	-	-	-	23
LKWH	212	A	Oct-27	A	May-18	A	Sep-26	X	-	X	-	-	-	-	-	24
LKWH	224	A	Nov-02	B	May-17	A	Nov-01	X	X	X	X	X	-	-	-	13, 20
LKWH	210	A	Nov-01	A	May-18	A	Oct-31	X	-	X	-	-	-	-	-	24
LKWH	148	A	Oct-21	A	May-18	A	Oct-25	X	X	X	-	-	-	-	-	23
LKWH	233	B	Sep-15	B	May-18	B	May-18	-	-	-	-	-	-	-	-	17
LKWH	218	A	Oct-29	B	May-18	A	Oct-22	X	X	X	X	X	-	-	-	19
LKWH	206	C	Nov-01	C	May-31	C	Nov-02	-	-	-	-	-	X	X	-	-
LKWH	1245	C	Nov-01	C	May-17	C	Sep-04	-	-	-	-	-	-	-	-	9
LKWH	1223	C	Sep-10	no data	-	-	-	-	-	-	-	-	-	-	-	-
LKWH	1212	C	Sep-15	no data	-	-	-	-	-	-	-	-	-	-	-	-
LKWH	1247	C	Sep-11	no data	-	-	-	-	-	-	-	-	-	-	-	-
LKWH	217	A	Nov-02	no data	-	-	-	-	-	-	-	-	-	-	-	-
LKWH	145	A	Nov-02	no data	-	-	-	-	-	-	-	-	-	-	-	-
LKWH	232	C	Oct-09	no data	-	-	-	-	-	-	-	-	-	-	-	-
LKWH	211	C	Oct-14	no data	-	-	-	-	-	-	-	-	-	-	-	-
LKWH	1275	C	Oct-31	B	May-18	C	Nov-02	X	X	X	X	X	X	-	-	18
LKWH	225	Broten Cr. South	Oct-08	no data	-	no data	-	-	-	-	-	-	-	-	-	-

Table 2. Continued.

		2005		2006				Detection Zones / Receivers[2] - May to November 2006								
								Zone A			Zone B		Zone C			
Species[1]	**Code**	**Zone of last detection[2]**	**Date**	**Zone of first detection**	**Date**	**Zone of last detection**	**Date**	**R1**	**R10**	**R2**	**R3**	**R4**	**R5 & R6**	**R7, R8, & R9**	**Passage[3]**	**VR-60 Location[4]**
NRPK	1241	no data	-	A	Jun-18	A	Oct-25	X	X	X	-	-	-	-	-	12
NRPK	1234	no data	-	A	Jun-15	A	Oct-05	X	X	-	-	-	-	-	-	-
NRPK	1279	A	Oct-31	Limestone Spillway	Jun-05	Sundance Creek	Oct-28	-	-	-	-	-	-	-	X	-
NRPK	1248	A	Sep-07	no data	-	no data	-	-	-	-	-	-	-	-	-	-
NRPK	1219	A	Sep-24	A	May-18	A	Oct-19	X	X	X	-	-	-	-	-	23
NRPK	1221	A	Oct-25	B	May-19	A	Oct-31	X	X	X	X	X	X	-	-	-
NRPK	1227	A	Nov-02	A	May-17	A	Jun-01	X	-	-	-	-	-	-	-	15
NRPK	213	A	Oct-31	C	May-18	Sundance Creek	Oct-26	-	-	-	-	-	X	X	X	-
NRPK	1211	A	Oct-20	A	May-18	A	May-29	X	-	X	-	-	-	-	-	23
NRPK	1267	A	Oct-27	A	May-18	A	Nov-02	X	X	X	-	-	-	-	-	-
NRPK	1255	A	Nov-02	A	May-17	A	Nov-02	X	X	X	X	-	-	-	-	15, 13
NRPK	1214	A	Oct-14	no data	-	no data	-	-	-	-	-	-	-	-	-	-
NRPK	1228	A	Nov-02	no data	-	no data	-	-	-	-	-	-	-	-	-	-
NRPK	1232	A	Nov-02	A	May-17	A	May-17	-	-	-	-	-	-	-	-	14
NRPK	1210	A	Oct-06	A	May-18	B	Nov-02	X	X	X	X	X	-	-	-	23
NRPK	1240	A	Nov-02	A	May-21	A	Nov-02	X	X	X	-	-	-	-	-	-
NRPK	1265	B	Nov-01	A	May-31	A	Oct-07	X	X	X	-	-	-	-	-	-
NRPK	1246	B	Nov-01	B	May-17	A	Oct-21	X	X	-	-	-	-	-	-	12
NRPK	1249	B	Oct-10	A	May-21	A	Nov-02	X	X	X	-	-	-	-	-	-
NRPK	1220	B	Sep-17	no data	-	no data	-	-	-	-	-	-	-	-	-	-
NRPK	1264	B	Sep-12	B	May-17	B	May-17	-	-	-	-	-	-	-	-	11

Table 2. Continued.

		2005		2006				Detection Zones / Receivers[2] - May to November 2006								
								Zone A			Zone B		Zone C			
Species[1]	Code	Zone of last detection[2]	Date	Zone of first detection	Date	Zone of last detection	Date	R1	R10	R2	R3	R4	R5 & R6	R7, R8, & R9	Passage[3]	VR-60 Location[4]
NRPK	1243	B	Oct-06	B	May-18	B	Sep-02	-	-	X	X	X	-	-	-	19
NRPK	1213	B	Nov-01	A	May-18	A	Oct-23	X	X	X	X	-	-	-	-	24
NRPK	1257	A	Nov-02	A	May-17	A	Oct-16	X	-	-	-	-	-	-	-	15
NRPK	1269	A	Oct-31	A	May-19	A	Oct-22	X	X	-	X	-	-	-	-	-
NRPK	1237	A	Oct-26	A	May-19	A	Nov-02	X	X	X	-	-	-	-	-	-
NRPK	1216	B	Oct-27	A	May-18	A	May-18	-	-	-	-	-	-	-	-	23
NRPK	1239	A	Nov-02	A	May-18	A	Oct-21	X	X	X	X	-	-	-	-	-
NRPK	1218	B	Nov-01	A	May-19	B	Nov-02	X	X	X	X	X	X	-	-	-
NRPK	1230	Broten Cr. South	Oct-24	no data	-	no data	-	-	-	-	-	-	-	-	-	-
WALL	1242	A	Sep-24	A	Jun-10	A	Nov-02	X	X	X	-	-	-	-	-	-
WALL	1236	A	Sep-16	A	May-17	A	Nov-02	X	X	X	-	-	-	-	-	15
WALL	1268	A	Sep-19	A	May-17	A	Nov-02	-	X	-	-	-	-	-	-	16
WALL	1271	A	Sep-08	A	May-30	A	Nov-02	X	X	X	-	-	-	-	-	-
WALL	1222	A	Sep-21	A	May-18	A	Nov-02	X	X	X	-	-	-	-	-	23
WALL	1226	A	Sep-08	A	Jun-13	A	Oct-31	X	X	X	-	-	-	-	-	-
WALL	1231	A	Sep-09	A	May-31	A	Nov-02	X	X	X	-	-	-	-	-	2
WALL	1233	A	Sep-17	A	May-17	A	Nov-02	X	X	X	X	-	-	-	-	16
WALL	1261	A	Sep-14	A	May-18	A	Nov-02	X	X	X	-	-	-	-	-	2
WALL	219	A	Sep-09	A	May-18	A	Oct-02	X	X	X	X	X	-	-	-	23
WALL	221	A	Sep-09	A	Jun-08	A	Nov-02	X	X	X	-	-	-	-	-	-
WALL	234	A	Nov-02	A	May-18	A	Nov-02	X	X	X	X	-	-	-	-	23

Table 2. Continued.

		2005		2006				Detection Zones / Receivers[2] - May to November 2006								
								Zone A			Zone B		Zone C			
Species[1]	Code	Zone of last detection[2]	Date	Zone of first detection	Date	Zone of last detection	Date	R1	R10	R2	R3	R4	R5 & R6	R7, R8, & R9	Passage[3]	VR-60 Location[4]
WALL	208	A	Sep-29	A	Jun-12	A	Nov-02	X	X	X	-	-	-	-	-	-
WALL	222	A	Sep-13	A	May-18	A	Nov-02	X	X	X	-	-	-	-	-	23
WALL	1273	A	Sep-14	A	Jun-13	A	Oct-03	X	-	X	-	-	-	-	-	-
WALL	1278	A	Sep-24	A	May-23	A	Oct-17	X	X	X	X	-	-	-	-	-
WALL	1224	A	Oct-29	A	May-17	A	Oct-29	X	X	X	X	X	X	X	-	15, 22
WALL	1235	A	Oct-06	A	Jun-09	A	Nov-02	X	X	X	-	-	-	-	-	-
WALL	1217	A	Oct-06	A	May-19	A	Nov-02	X	X	X	-	-	-	-	-	-
WALL	1225	A	Oct-06	A	May-27	A	Nov-02	X	X	X	-	-	-	-	-	-
WALL	228	A	Oct-06	A	May-18	C	Jun-30	X	X	X	X	X	X	X	?	22
WALL	1252	A	Oct-06	A	May-18	A	Nov-02	X	X	X	-	-	-	-	-	25, 3
WALL	1260	A	Oct-06	A	May-17	A	Nov-02	-	X	-	-	-	-	-	-	16
WALL	1244	A	Nov-02	A	May-18	C	Nov-02	-	X	-	X	X	X	-	-	23
WALL	215	B	Oct-28	A	Jun-13	B	Oct-17	X	X	X	X	-	-	-	-	-
WALL	1262	B	Oct-10	A	May-18	LRU Harvest in Wilson Ck.	May-23	-	-	X	-	-	-	-	-	23
WALL	1277	B	Sep-23	A	May-18	A	Nov-02	X	X	X	X	-	-	-	-	21
WALL	1253	B	Nov-01	A	May-18	A	Oct-26	-	X	X	-	-	-	-	-	23
WALL	1274	B	Oct-27	A	May-18	A	Oct-23	X	X	X	-	-	-	-	-	23
WALL	1238	A	Oct-08	A	May-19	A	Oct-17	X	X	X	-	-	-	-	-	3
WALL	1266	A	Oct-31	A	May-18	A	Oct-23	X	X	X	X	X	-	-	-	23
WALL	229	A	Oct-22	A	Jun-13	A	Nov-02	X	X	X	-	-	-	-	-	-
WALL	1250	A	Oct-18	A	Jun-09	A	Nov-01	X	X	X	-	-	-	-	-	-
WALL	1259	A	Nov-01	A	May-18	A	Oct-31	X	X	X	-	-	-	-	-	22

Table 2. Continued.

		2005		2006				Detection Zones / Receivers[2] - May to November 2006								
								Zone A			Zone B		Zone C			
Species[1]	Code	Zone of last detection[2]	Date	Zone of first detection	Date	Zone of last detection	Date	R1	R10	R2	R3	R4	R5 & R6	R7, R8, & R9	Passage[3]	VR-60 Location[4]
WALL	1272	B	Nov-01	A	May-20	A	Nov-02	X	X	X	X	-	-	-	-	-
WALL	1254	B	Oct-27	A	May-18	A	Nov-01	X	X	X	-	-	-	-	-	3
WALL	1276	Frank's Is.	Sep-16	no data	-	no data	-	-	-	-	-	-	-	-	-	-
WHSC	205	A	Nov-02	A	May-18	A	Nov-02	-	-	X	-	-	-	-	-	23
WHSC	207	A	Nov-01	A	May-19	A	Nov-01	X	-	X	X	-	-	-	-	-
WHSC	209	A	Oct-26	A	May-18	A	Nov-02	-	-	X	X	X	X	X	-	23
WHSC	1256	A	Oct-26	A	May-18	A	Oct-05	-	-	X	-	-	-	-	-	23
WHSC	1215	A	Oct-06	A	Jun-15	A	Aug-08	-	X	X	X	-	-	-	-	-
WHSC	214	B	Oct-30	A	Jun-13	A	Oct-02	-	-	X	-	-	-	-	-	-
WHSC	1263	B	Sep-12	B	May-18	B	May-18	-	-	-	-	-	-	-	-	17
WHSC	1270	C	Oct-06	A	May-18	A	Nov-02	X	X	X	X	X	X	-	-	23, 10
WHSC	1258	C	Oct-06	B	May-17	B	May-17	-	-	-	-	-	-	-	-	10
WHSC	220	C	Oct-22	A	Jun-10	C	Oct-26	X	X	-	X	X	X	X	-	-
WHSC	1229	C	Nov-01	A	May-23	C	Nov-02	X	X	-	X	X	X	X	-	-
WHSC	226	B	Oct-10	no data	-	no data	-	-	-	-	-	-	-	-	-	-
WHSC	227	Angling R.	Sep-25	no data	-	no data	-	-	-	-	-	-	-	-	-	-

1 - LKST - lake sturgeon; LKWH - lake whitefish; NRPK - northern pike; WALL - walleye; WHSC - white sucker
2 - refer to Figure 1 (2005) and Figure 2 (2006) for zone delineations and stationary receiver locations; refer to Figure 3 for locations below the Limestone GS
3 - refer to Figure 4 for manual tracking locations using a VR-60 receiver

Table 3. Locations of acoustic-tagged fish in the Limestone forebay, 17 May to 2 November, 2006.

	Forebay Zones[1]								
Lake sturgeon	A	B	C	A / B	B / C	A / B / C	C / Passage	Passage	No data[2]
May	1	-	-	-	-	-	-	-	-
June	-	-	-	-	-	1	-	-	-
July	-	-	-	-	1	-	-	-	-
August	-	-	-	-	1	-	-	-	-
September	-	-	-	-	-	1	-	-	-
October	-	-	-	1	-	-	-	-	-

Lake whitefish	A	B	C	A / B	B / C	A / B / C	C / Passage	Passage	No data
May	5	2	2	1	1	-	-	-	8
June	8	-	1	-	-	1	-	-	9
July	6	-	1	2	-	-	-	-	10
August	4	-	1	2	-	-	-	-	12
September	7	-	1	1	-	-	-	-	10
October	7	-	1	-	-	1	-	-	10

Northern pike	A	B	C	A / B	B / C	A / B / C	C / Passage	Passage	No data
May	15	3	-	2	-	1	1	1	6
June	13	1	-	3	-	-	-	-	10
July	13	-	-	-	-	-	-	-	14
August	11	-	-	-	-	-	-	-	16
September	18	2	-	-	-	-	-	-	7
October	17	-	-	1	-	1	-	-	8

Walleye	A	B	C	A / B	B / C	A / B / C	C / Passage	Passage	No data
May	27	-	-	-	-	-	-	-	9
June	32	-	-	1	-	2	-	-	-
July	31	-	-	2	-	-	-	-	2
August	28	-	-	2	-	-	-	-	5
September	29	-	1	4	-	-	-	-	1
October	28	-	1	4	-	1	-	-	1

White sucker	A	B	C	A / B	B / C	A / B / C	C / Passage	Passage	No data
May	5	2	-	1	-	-	-	-	4
June	4	-	-	1	1	3	-	-	3
July	2	1	1	1	1	1	-	-	5
August	3	1	1	1	-	2	-	-	4
September	6	-	1	1	-	-	-	-	4
October	6	-	1	-	-	1	-	-	4

1 - refer to Figure 2 for delineation of regions; data indicate number of fish in each zone(s) on a monthly basis
2 - receiver R2 located at Wilson Creek (Zone A) was lost between 18 May and 12 June; receiver R1 located at Sky Pilot Creek (Zone A) was lost between 10 July and 3 September; receiver R9 (Zone C) was lost after 3 September

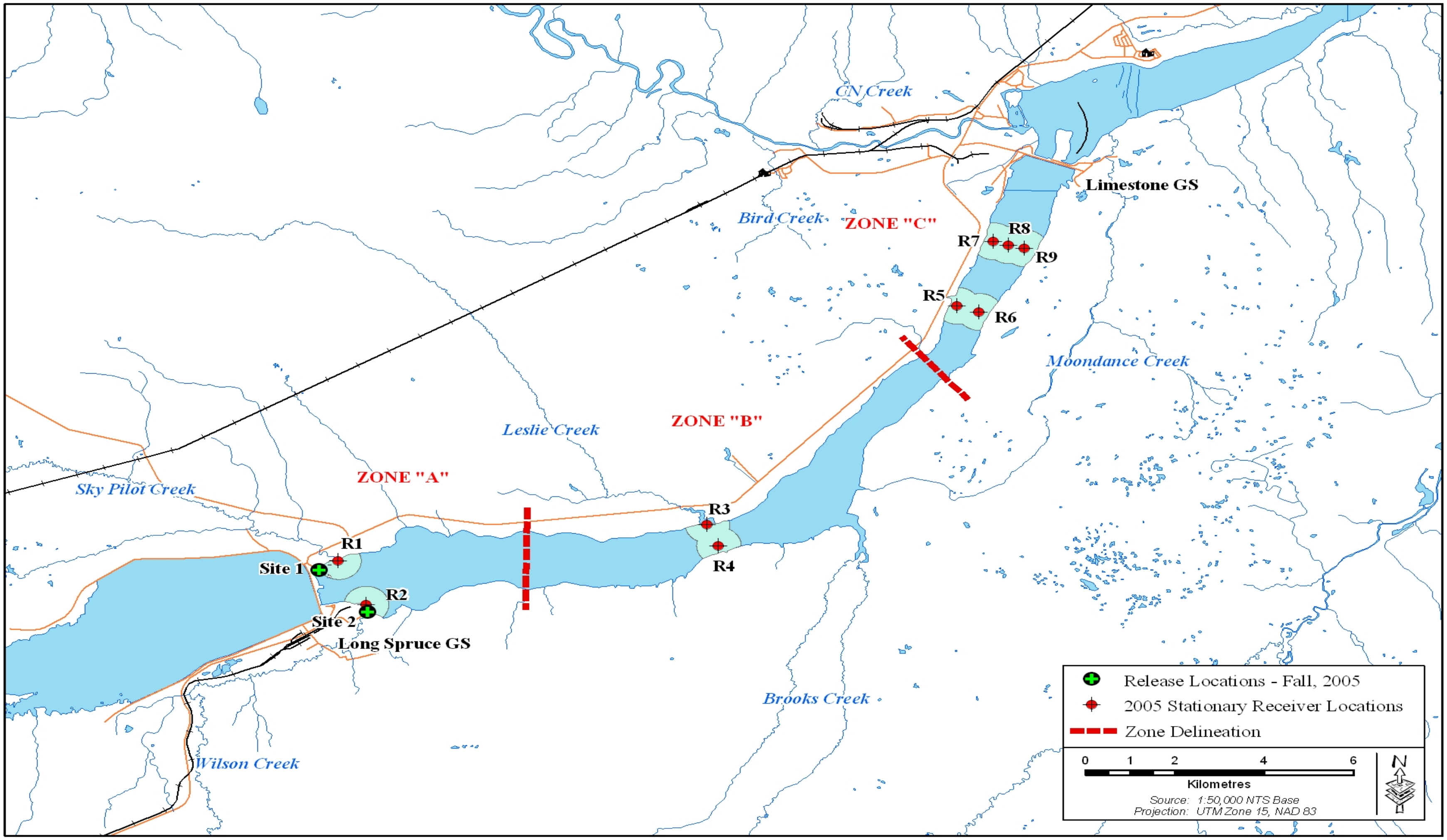


Figure 1. Locations of release sites of fish, stationary acoustic receivers, and estimated minimum range of detection of receivers in the Limestone GS forebay, fall 2005.

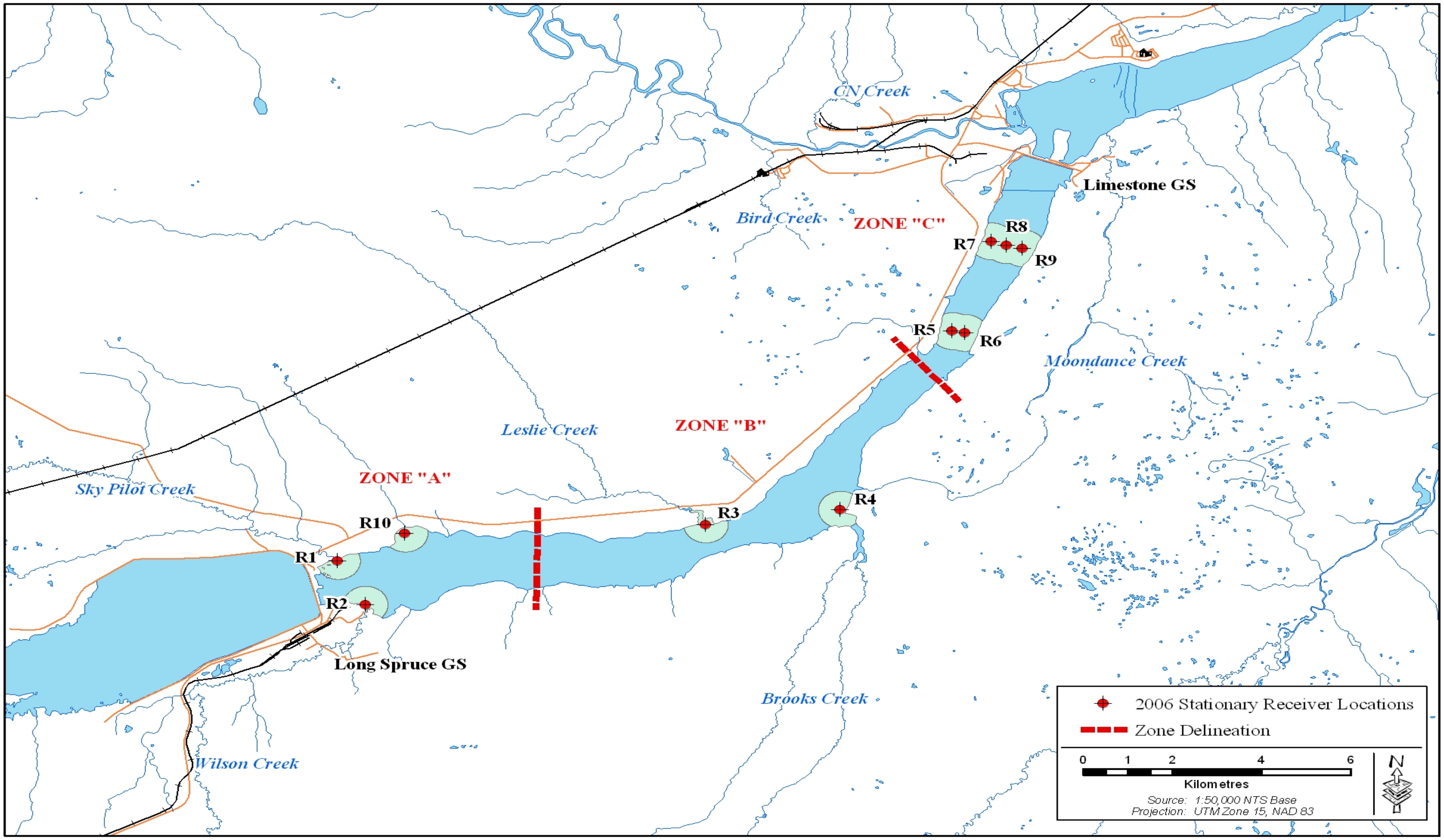


Figure 2. Locations of stationary acoustic receivers and their estimated minimum range of detection (green shading) in the Limestone GS forebay, May to November, 2006.

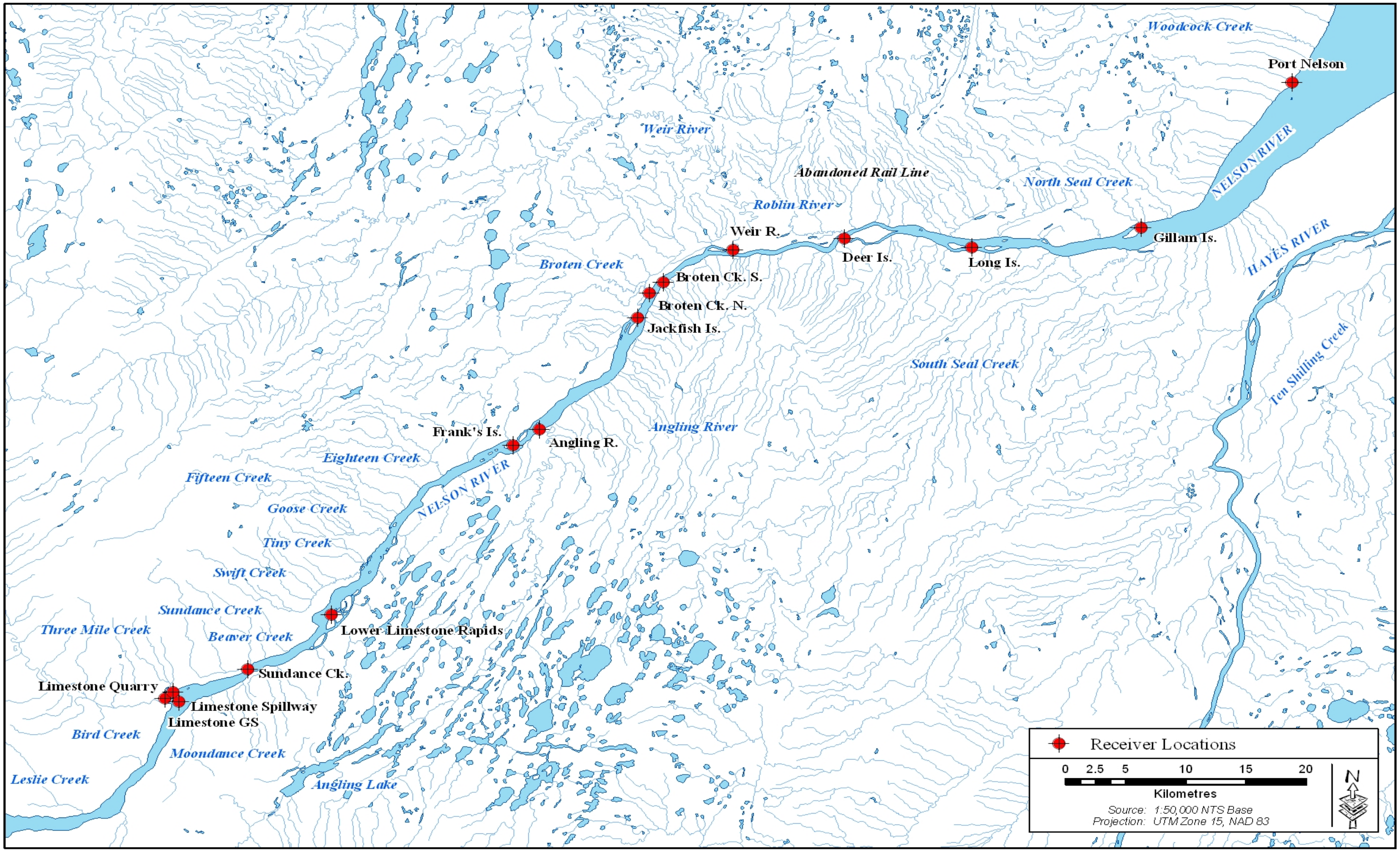


Figure 3. Locations of stationary acoustic receivers downstream of the Limestone GS, May to November, 2006.

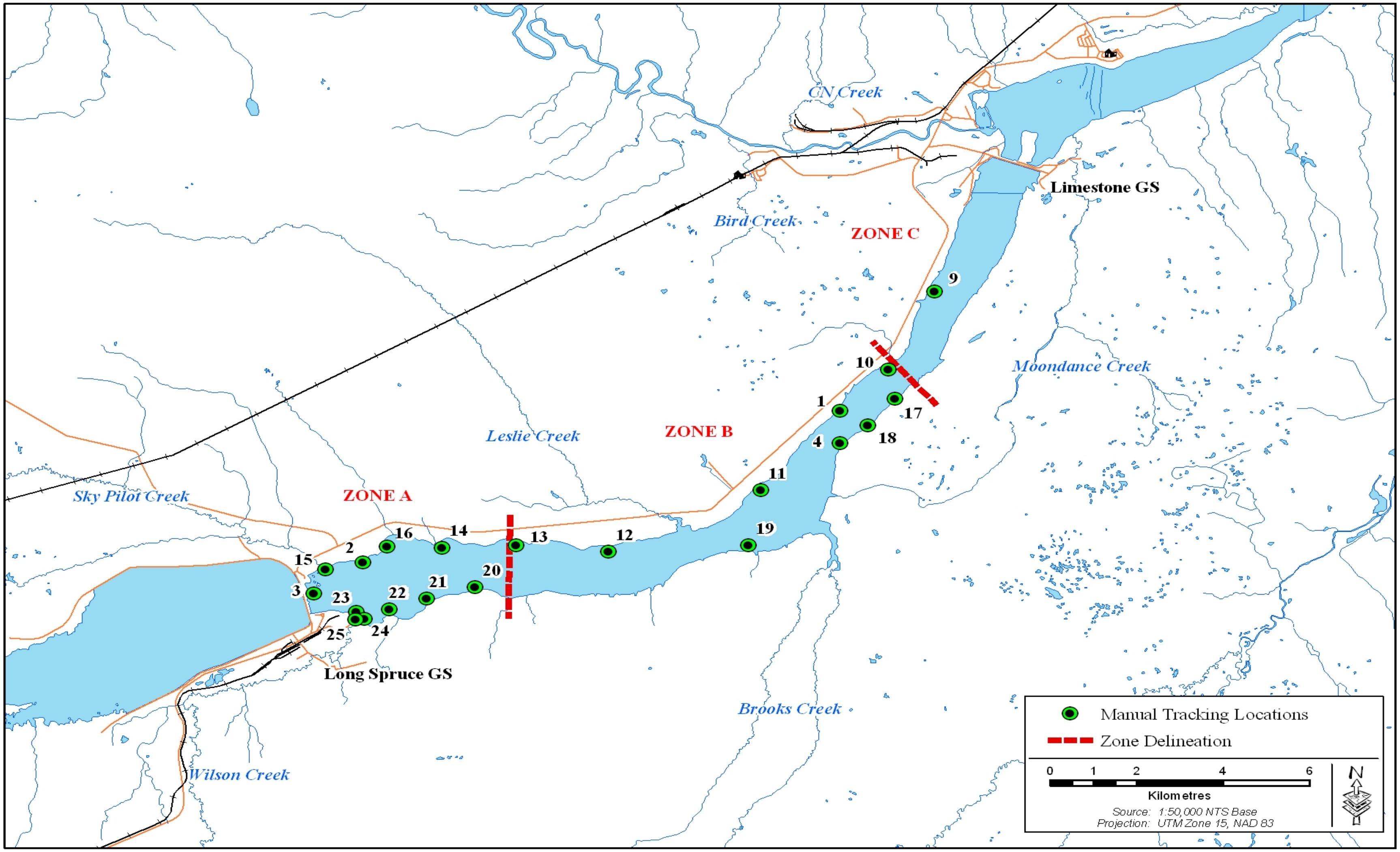


Figure 4. Manual tracking (VR60) locations in the Limestone forebay during the open-water season in 2006.

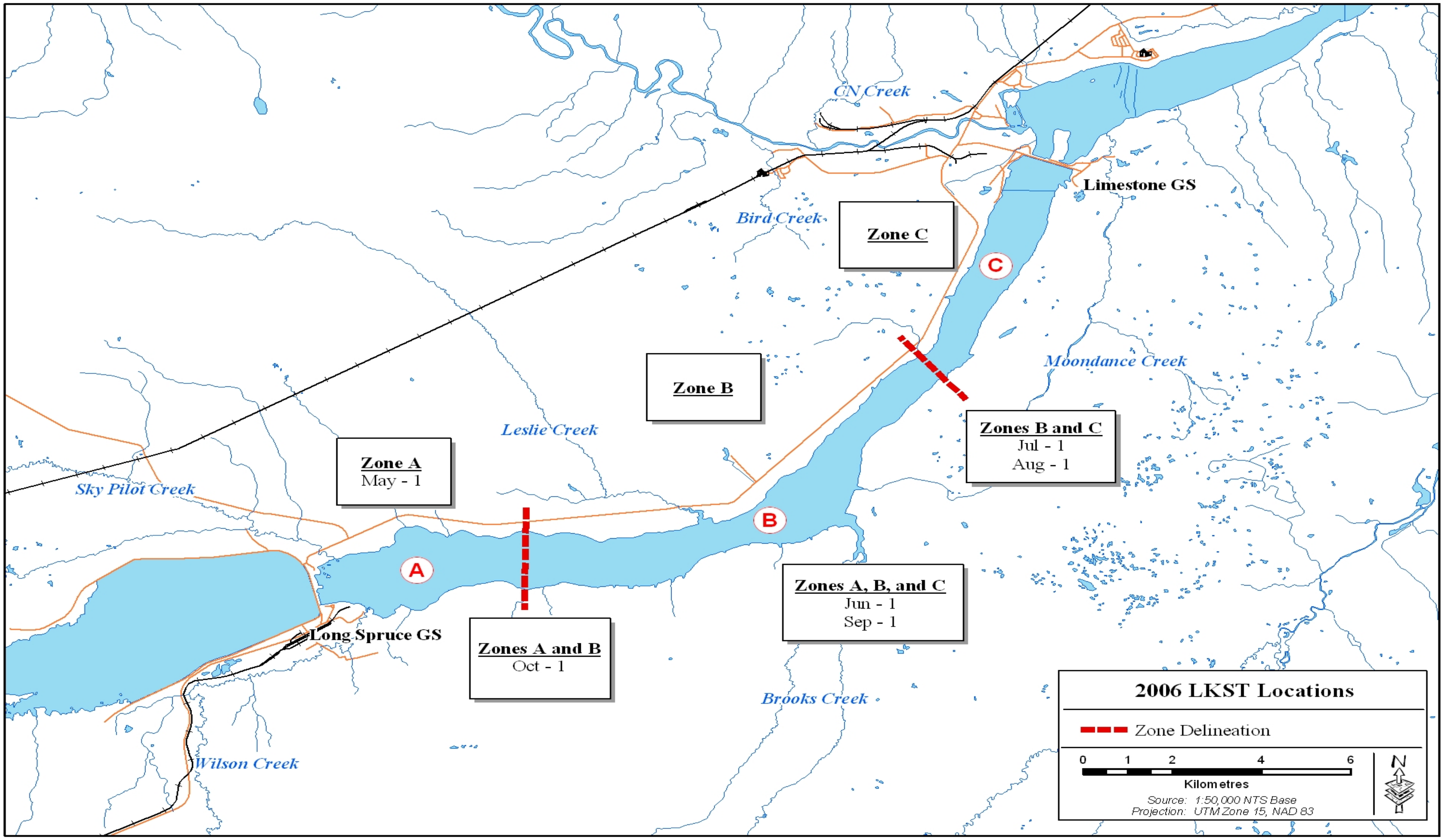


Figure 5. Monthly relocation data, by zone, for the acoustic-tagged lake sturgeon in the Limestone forebay during the open-water season in 2006.

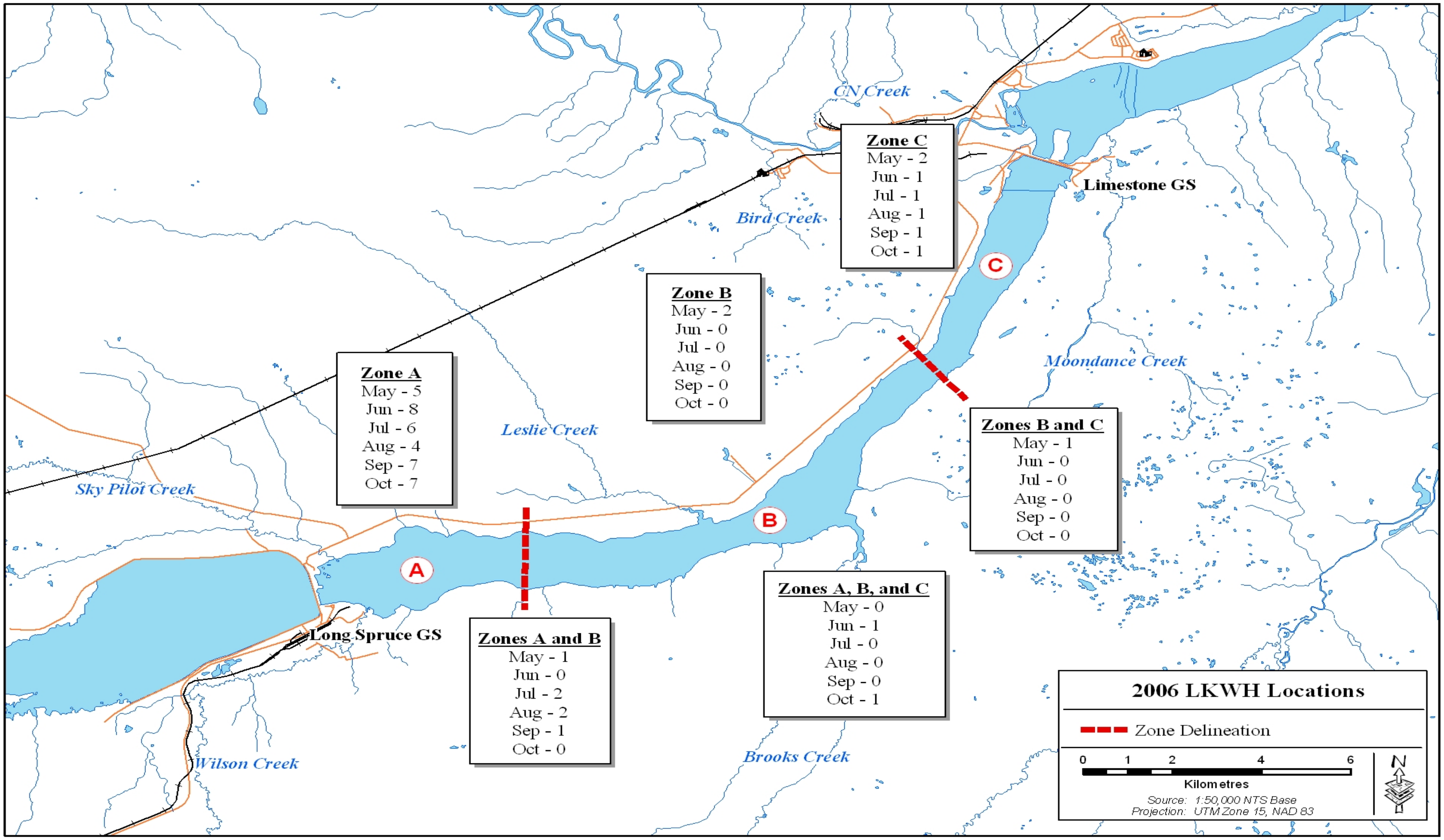


Figure 6. Monthly relocation data, by zone, for acoustic-tagged lake whitefish in the Limestone forebay during the open-water season in 2006.

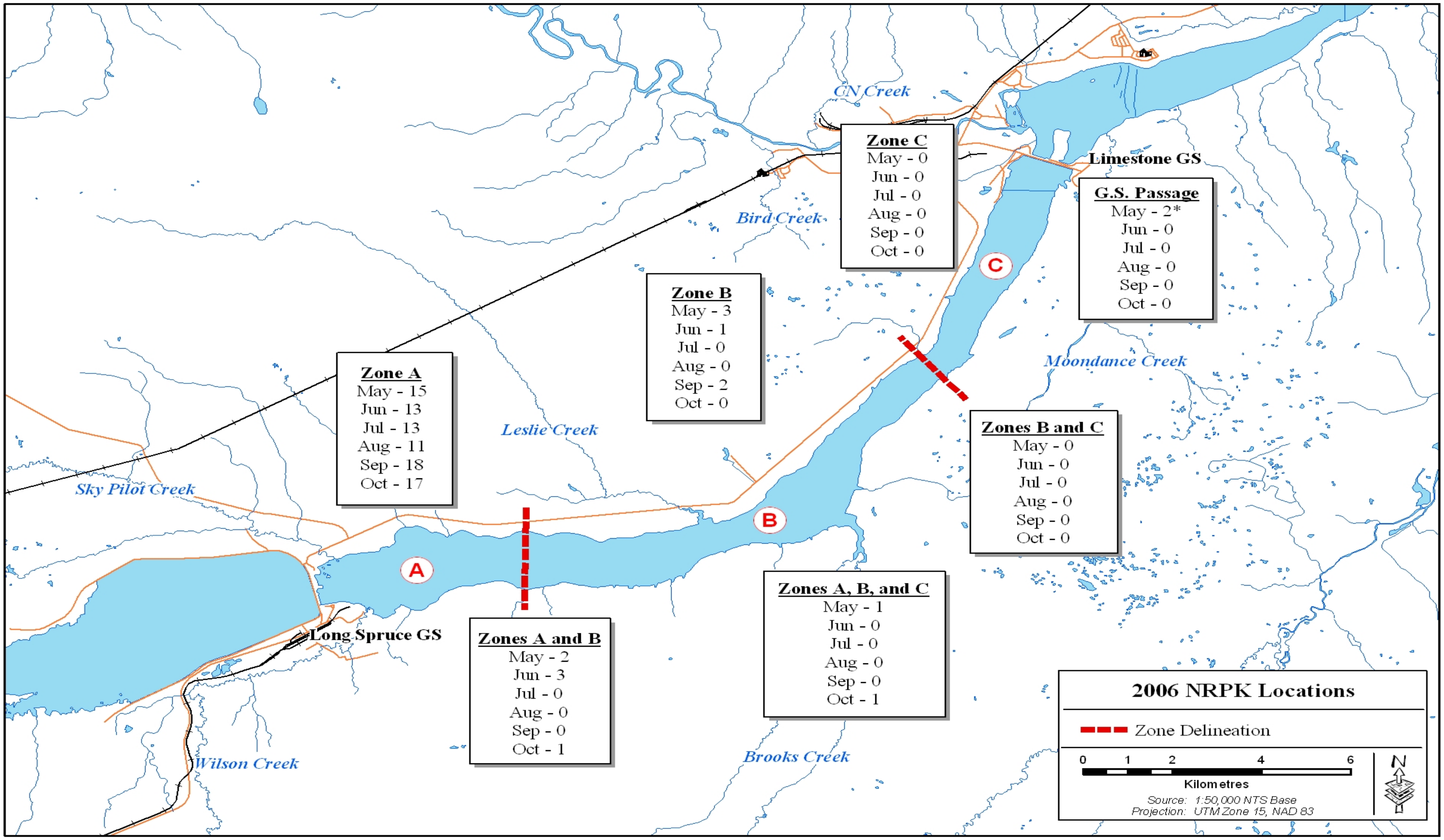


Figure 7. Monthly relocation data, by zone, for acoustic-tagged northern pike in the Limestone forebay during the open-water season in 2006.

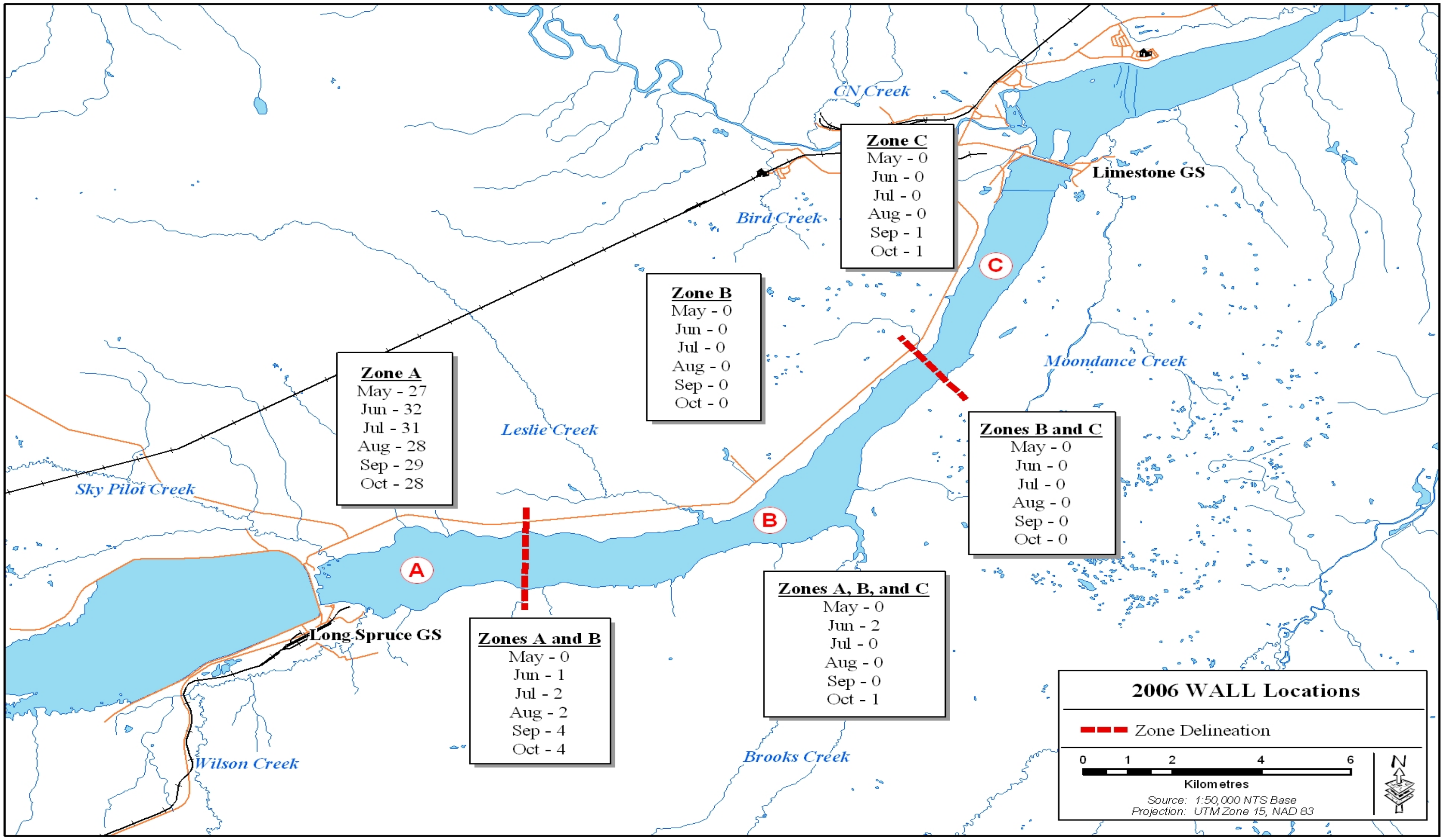


Figure 8. Monthly relocation data, by zone, for acoustic-tagged walleye in the Limestone forebay during the open-water season in 2006.

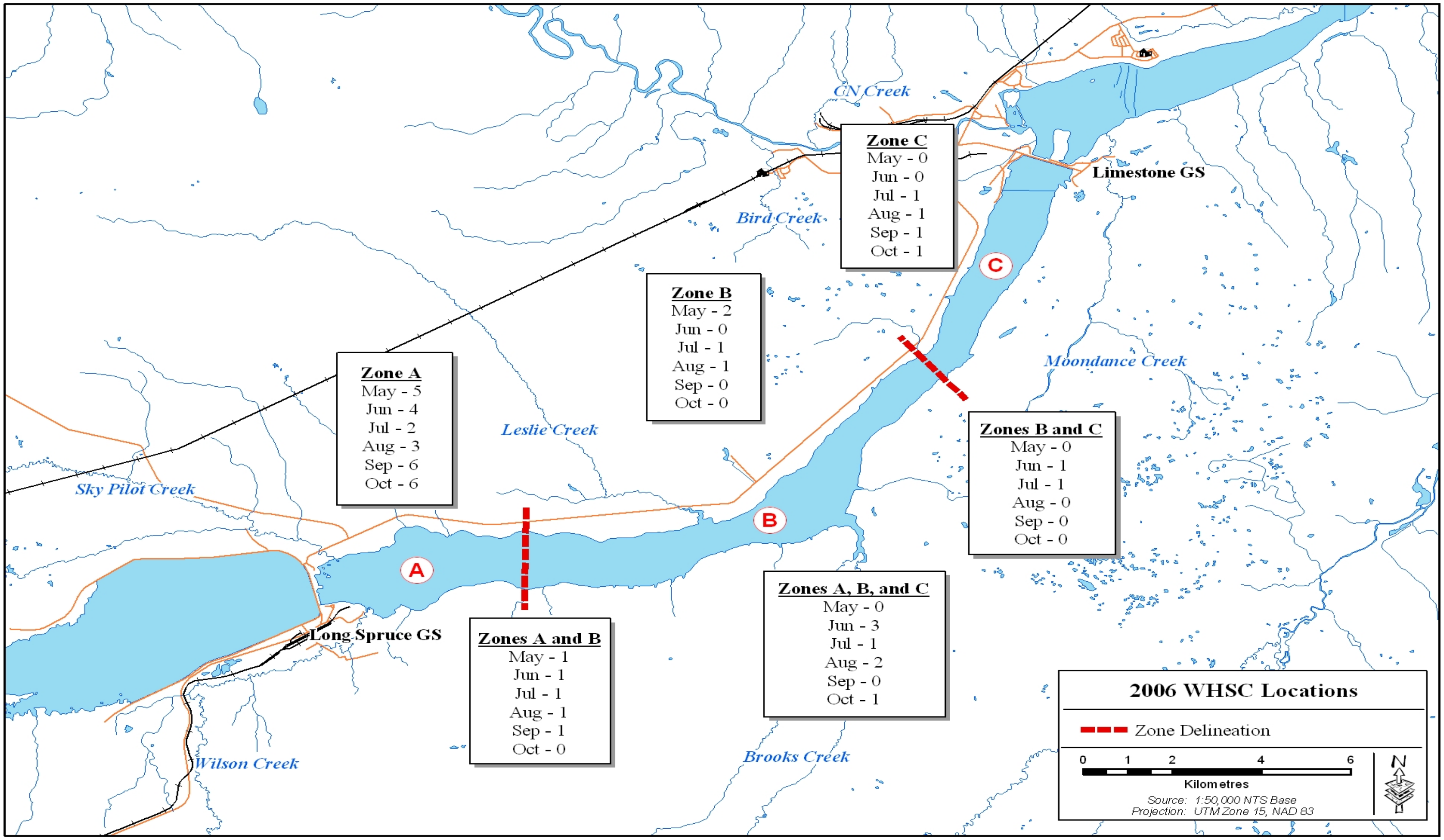


Figure 9. Monthly relocation data, by zone, for acoustic-tagged white sucker in the Limestone forebay during the open-water season in 2006

APPENDIX 1

DAILY DISCHARGE THROUGH THE LONG SPRUCE AND LIMESTONE GENERATING STATIONS

Table A1-1. Daily discharge (m^3/s) through the Long Spruce and Limestone Generating Stations, September 1, 2005 to December 31, 2006.

	Long Spruce GS			Limestone GS		
Date	Total Discharge	Spillage	Turbines	Total Discharge	Spillage	Turbines
1-Sep-05	6564	2825	3740	6721	2943	3778
2-Sep-05	6466	2787	3679	6631	3026	3605
3-Sep-05	6531	3099	3432	6647	3289	3357
4-Sep-05	6673	3333	3340	6781	3329	3453
5-Sep-05	6545	2999	3546	6649	2987	3662
6-Sep-05	6742	2816	3926	6917	2698	4219
7-Sep-05	6319	2315	4004	6491	2001	4490
8-Sep-05	6661	2970	3691	6798	2685	4113
9-Sep-05	6701	2988	3713	6884	3008	3876
10-Sep-05	6557	2498	4059	6787	2552	4236
11-Sep-05	6365	2521	3843	6541	2126	4415
12-Sep-05	6653	2514	4140	6752	2414	4339
13-Sep-05	6675	2952	3723	6886	2824	4062
14-Sep-05	6658	2880	3778	6815	2812	4002
15-Sep-05	6815	3001	3814	7025	3071	3954
16-Sep-05	6579	2884	3695	6826	2936	3890
17-Sep-05	6699	3004	3695	6898	3192	3706
18-Sep-05	6671	3564	3106	6933	3640	3292
19-Sep-05	6567	3275	3291	6694	2885	3810
20-Sep-05	6958	3618	3340	7173	3391	3782
21-Sep-05	6638	3150	3488	6803	2602	4200
22-Sep-05	6525	2945	3580	6701	2953	3748
23-Sep-05	6486	3027	3459	6686	3110	3577
24-Sep-05	6767	3454	3313	6991	3556	3435
25-Sep-05	6539	2590	3949	6670	2525	4145
26-Sep-05	6729	2909	3820	6897	2815	4082
27-Sep-05	6732	3019	3713	6887	2978	3908
28-Sep-05	6564	3104	3460	6707	3205	3502
29-Sep-05	6476	3003	3473	6599	3304	3294
30-Sep-05	6643	3413	3230	6736	3257	3479
1-Oct-05	6626	3411	3215	6762	3138	3624
2-Oct-05	6430	3067	3363	6587	2920	3668
3-Oct-05	6649	3024	3625	6779	2780	3998
4-Oct-05	6503	2817	3685	6587	2429	4158
5-Oct-05	6424	2849	3576	6633	2552	4081
6-Oct-05	6441	2959	3481	6533	2546	3987

Table A1-1. Continued.

	Long Spruce GS			Limestone GS		
Date	**Total Discharge**	**Spillage**	**Turbines**	**Total Discharge**	**Spillage**	**Turbines**
7-Oct-05	6419	3094	3325	6570	2224	4347
8-Oct-05	6577	3079	3499	6762	2262	4500
9-Oct-05	6347	2787	3560	6507	2406	4101
10-Oct-05	6395	2572	3823	6567	2089	4477
11-Oct-05	6323	2634	3689	6433	1910	4523
12-Oct-05	6272	2527	3744	6407	1872	4535
13-Oct-05	6272	2583	3689	6407	2000	4407
14-Oct-05	6353	2538	3815	6490	2408	4082
15-Oct-05	6133	2657	3475	6294	2142	4152
16-Oct-05	6139	3023	3117	6248	2567	3682
17-Oct-05	6226	2726	3501	6327	2479	3848
18-Oct-05	6225	2991	3234	6408	2880	3528
19-Oct-05	6011	2654	3357	6245	2696	3549
20-Oct-05	5893	1914	3979	6087	2302	3785
21-Oct-05	5951	1879	4072	6107	2110	3997
22-Oct-05	5989	2569	3421	6170	2739	3432
23-Oct-05	5845	1645	4201	6007	1980	4027
24-Oct-05	5818	1705	4112	5950	2124	3826
25-Oct-05	5706	1615	4090	5871	1832	4039
26-Oct-05	5671	1384	4288	5821	1792	4029
27-Oct-05	5510	1440	4070	5599	1345	4254
28-Oct-05	5576	1719	3858	5724	1801	3923
29-Oct-05	5391	2157	3233	5567	2147	3420
30-Oct-05	5285	2154	3130	5442	2451	2991
31-Oct-05	5337	1266	4070	5456	1636	3821
1-Nov-05	5218	913	4304	5344	1356	3988
2-Nov-05	4778	233	4544	4908	1023	3884
3-Nov-05	4959	367	4592	5063	919	4144
4-Nov-05	4882	327	4555	5003	880	4122
5-Nov-05	4793	612	4181	4817	852	3964
6-Nov-05	4896	559	4337	4960	667	4293
7-Nov-05	4610	185	4426	4619	210	4409
8-Nov-05	4626	323	4303	4438	0	4438
9-Nov-05	4794	446	4347	4820	0	4820
10-Nov-05	4544	115	4429	4492	55	4437
11-Nov-05	4883	516	4367	4941	532	4408
12-Nov-05	4785	634	4150	4865	640	4224
13-Nov-05	4548	663	3885	4550	562	3988
14-Nov-05	4601	179	4422	4663	142	4520

Table A1-1. Continued.

	Long Spruce GS			Limestone GS		
Date	**Total Discharge**	**Spillage**	**Turbines**	**Total Discharge**	**Spillage**	**Turbines**
15-Nov-05	4592	15	4577	4580	0	4580
16-Nov-05	4546	0	4546	4622	0	4622
17-Nov-05	4626	0	4626	4542	0	4542
18-Nov-05	4526	0	4526	4543	0	4543
19-Nov-05	4484	0	4484	4503	0	4503
20-Nov-05	4289	0	4289	4158	0	4158
21-Nov-05	4390	0	4390	4416	0	4416
22-Nov-05	4468	32	4437	4428	52	4376
23-Nov-05	4381	0	4381	4435	2	4433
24-Nov-05	4558	0	4558	4590	0	4590
25-Nov-05	4621	0	4621	4525	0	4525
26-Nov-05	4638	0	4638	4544	0	4544
27-Nov-05	4142	0	4142	4219	0	4219
28-Nov-05	4591	0	4591	4520	0	4520
29-Nov-05	4470	23	4447	4475	0	4475
30-Nov-05	4204	0	4204	4220	0	4220
1-Dec-05	4178	0	4178	4221	0	4221
2-Dec-05	4172	0	4172	4258	0	4258
3-Dec-05	3841	0	3841	3794	0	3794
4-Dec-05	3778	0	3778	3796	0	3796
5-Dec-05	4238	0	4238	4247	0	4247
6-Dec-05	4323	0	4323	4191	0	4191
7-Dec-05	4214	0	4214	4337	0	4337
8-Dec-05	4178	0	4178	4080	0	4080
9-Dec-05	3951	0	3951	3964	0	3964
10-Dec-05	3689	0	3689	3699	0	3699
11-Dec-05	3057	0	3057	2977	0	2977
12-Dec-05	3693	0	3693	3798	0	3798
13-Dec-05	3966	0	3966	3856	0	3856
14-Dec-05	4142	0	4142	4100	0	4100
15-Dec-05	4411	0	4411	4438	0	4438
16-Dec-05	4490	0	4490	4486	0	4486
17-Dec-05	4442	0	4442	4431	0	4431
18-Dec-05	4480	0	4480	4549	0	4549
19-Dec-05	4291	0	4291	4279	0	4279
20-Dec-05	4528	0	4528	4518	0	4518
21-Dec-05	4495	0	4495	4482	0	4482
22-Dec-05	4124	0	4124	4133	0	4133
23-Dec-05	4039	0	4039	3936	0	3936

Table A1-1. Continued.

	Long Spruce GS			Limestone GS		
Date	Total Discharge	Spillage	Turbines	Total Discharge	Spillage	Turbines
24-Dec-05	3223	0	3223	3225	0	3225
25-Dec-05	2724	0	2724	2663	0	2663
26-Dec-05	3700	0	3700	3722	0	3722
27-Dec-05	4040	0	4040	3983	0	3983
28-Dec-05	3886	0	3886	3963	0	3963
29-Dec-05	4185	0	4185	4137	0	4137
30-Dec-05	4005	0	4005	3988	0	3988
31-Dec-05	3406	0	3406	3383	0	3383
1-Jan-06	3033	0	3033	2961	0	2961
2-Jan-06	3828	0	3828	3841	0	3841
3-Jan-06	4054	0	4054	4069	0	4069
4-Jan-06	4146	0	4146	4141	0	4141
5-Jan-06	4241	0	4241	4219	0	4219
6-Jan-06	4284	0	4284	4335	0	4335
7-Jan-06	4143	0	4143	4082	0	4082
8-Jan-06	3987	0	3987	3998	0	3998
9-Jan-06	4282	0	4282	4250	0	4250
10-Jan-06	4212	0	4212	4121	0	4121
11-Jan-06	4192	0	4192	4149	0	4149
12-Jan-06	4183	0	4183	4241	0	4241
13-Jan-06	4246	0	4246	4215	0	4215
14-Jan-06	4564	0	4564	4499	0	4499
15-Jan-06	4495	0	4495	4524	0	4524
16-Jan-06	4535	0	4535	4512	0	4512
17-Jan-06	4276	0	4276	4272	0	4272
18-Jan-06	4446	0	4446	4442	0	4442
19-Jan-06	4328	0	4328	4363	0	4363
20-Jan-06	4223	0	4223	4163	0	4163
21-Jan-06	4241	0	4241	4350	0	4350
22-Jan-06	4183	0	4183	4081	0	4081
23-Jan-06	4253	0	4253	4284	0	4284
24-Jan-06	4084	0	4084	4091	0	4091
25-Jan-06	4304	0	4304	4335	0	4335
26-Jan-06	4392	0	4392	4282	0	4282
27-Jan-06	4384	0	4384	4313	0	4313
28-Jan-06	4474	0	4474	4438	0	4438
29-Jan-06	4095	0	4095	4172	0	4172
30-Jan-06	4444	0	4444	4448	0	4448
31-Jan-06	4414	0	4414	4367	0	4367

Table A1-1. Continued.

	Long Spruce GS			Limestone GS		
Date	**Total Discharge**	**Spillage**	**Turbines**	**Total Discharge**	**Spillage**	**Turbines**
1-Feb-06	4216	0	4216	4208	0	4208
2-Feb-06	4176	0	4176	4179	0	4179
3-Feb-06	4099	0	4099	4070	0	4070
4-Feb-06	4180	0	4180	4165	0	4165
5-Feb-06	3853	0	3853	3863	0	3863
6-Feb-06	4090	0	4090	4081	0	4081
7-Feb-06	4221	0	4221	4242	0	4242
8-Feb-06	4159	0	4159	4197	0	4197
9-Feb-06	4233	0	4233	4204	0	4204
10-Feb-06	4218	0	4218	4177	0	4177
11-Feb-06	4316	0	4316	4309	0	4309
12-Feb-06	4188	0	4188	4239	0	4239
13-Feb-06	4362	0	4362	4269	0	4269
14-Feb-06	4303	0	4303	4342	0	4342
15-Feb-06	4194	0	4194	4046	0	4046
16-Feb-06	4252	0	4252	4389	0	4389
17-Feb-06	4349	0	4349	4279	0	4279
18-Feb-06	4221	0	4221	4128	0	4128
19-Feb-06	4081	0	4081	4118	0	4118
20-Feb-06	4226	0	4226	4222	0	4222
21-Feb-06	4286	0	4286	4254	0	4254
22-Feb-06	4303	0	4303	4348	0	4348
23-Feb-06	4303	0	4303	4348	0	4348
24-Feb-06	4268	0	4268	4189	0	4189
25-Feb-06	4334	0	4334	4306	0	4306
26-Feb-06	4279	0	4279	4270	0	4270
27-Feb-06	4260	0	4260	4316	0	4316
28-Feb-06	4272	0	4272	4255	0	4255
1-Mar-06	4325	0	4325	4282	0	4282
2-Mar-06	4413	0	4413	4386	0	4386
3-Mar-06	4524	0	4524	4528	0	4528
4-Mar-06	4516	0	4516	4476	0	4476
5-Mar-06	4342	0	4342	4330	0	4330
6-Mar-06	4368	0	4368	4347	0	4347
7-Mar-06	4508	0	4508	4538	0	4538
8-Mar-06	4461	0	4461	4479	0	4479
9-Mar-06	4485	0	4485	4440	0	4440
10-Mar-06	4514	0	4514	4532	0	4532
11-Mar-06	4469	0	4469	4495	0	4495

Table A1-1. Continued.

	Long Spruce GS			Limestone GS		
Date	Total Discharge	Spillage	Turbines	Total Discharge	Spillage	Turbines
12-Mar-06	4531	0	4531	4488	0	4488
13-Mar-06	4637	0	4637	4632	0	4632
14-Mar-06	4628	0	4628	4671	0	4671
15-Mar-06	4610	0	4610	4632	0	4632
16-Mar-06	4503	0	4503	4421	0	4421
17-Mar-06	4540	109	4430	4500	0	4500
18-Mar-06	4728	429	4299	4705	0	4705
19-Mar-06	4647	508	4140	4635	0	4635
20-Mar-06	4699	354	4345	4701	0	4701
21-Mar-06	4716	200	4516	4711	0	4711
22-Mar-06	4701	125	4576	4724	0	4724
23-Mar-06	4657	0	4657	4612	0	4612
24-Mar-06	4550	0	4550	4583	0	4583
25-Mar-06	4511	0	4511	4495	0	4495
26-Mar-06	4443	0	4443	4434	0	4434
27-Mar-06	4413	0	4413	4441	0	4441
28-Mar-06	4600	0	4600	4615	0	4615
29-Mar-06	4368	0	4368	4434	0	4434
30-Mar-06	4034	0	4034	4002	0	4002
31-Mar-06	3391	0	3391	3327	0	3327
1-Apr-06	3290	0	3290	3287	0	3287
2-Apr-06	3133	0	3133	3140	0	3140
3-Apr-06	3472	0	3472	3430	0	3430
4-Apr-06	3304	0	3304	3363	0	3363
5-Apr-06	3261	0	3261	3286	0	3286
6-Apr-06	3219	0	3219	3125	0	3125
7-Apr-06	3282	0	3282	3302	0	3302
8-Apr-06	3090	0	3090	3069	0	3069
9-Apr-06	3976	1003	2973	3959	918	3041
10-Apr-06	4401	469	3932	4623	497	4125
11-Apr-06	4482	566	3916	4354	572	3782
12-Apr-06	4436	269	4168	4479	317	4163
13-Apr-06	4381	104	4277	4384	34	4351
14-Apr-06	4518	450	4068	4564	0	4564
15-Apr-06	4396	202	4194	4401	97	4304
16-Apr-06	4591	485	4106	4566	288	4278
17-Apr-06	4649	673	3976	4699	487	4211
18-Apr-06	4447	238	4208	4531	180	4351
19-Apr-06	4624	504	4120	4576	397	4179

Table A1-1. Continued.

	Long Spruce GS			Limestone GS		
Date	Total Discharge	Spillage	Turbines	Total Discharge	Spillage	Turbines
20-Apr-06	4744	710	4034	4755	452	4303
21-Apr-06	4668	386	4282	4795	138	4657
22-Apr-06	4812	408	4405	4674	124	4550
23-Apr-06	4881	908	3973	5048	630	4418
24-Apr-06	4875	529	4346	4875	245	4630
25-Apr-06	4865	571	4293	4812	375	4437
26-Apr-06	4853	720	4134	4973	754	4219
27-Apr-06	4809	596	4213	4793	336	4457
28-Apr-06	4814	723	4092	4800	445	4355
29-Apr-06	4820	658	4162	4890	417	4473
30-Apr-06	4856	694	4162	4939	478	4462
1-May-06	4906	1010	3896	4881	415	4465
2-May-06	4896	927	3969	4894	714	4180
3-May-06	4909	893	4016	4988	670	4318
4-May-06	4883	623	4260	4914	339	4576
5-May-06	4845	509	4336	4928	284	4644
6-May-06	4910	569	4340	4972	327	4645
7-May-06	4896	855	4042	4905	664	4241
8-May-06	4835	345	4490	4822	263	4559
9-May-06	4986	544	4442	5032	356	4675
10-May-06	5037	677	4360	5094	564	4530
11-May-06	5062	677	4385	5117	519	4598
12-May-06	5080	1319	3761	5247	1448	3799
13-May-06	5022	793	4230	5112	1088	4024
14-May-06	5067	512	4556	5262	1027	4235
15-May-06	5186	754	4431	5247	998	4249
16-May-06	5250	975	4275	5386	1336	4050
17-May-06	5116	840	4276	5267	1297	3970
18-May-06	5189	932	4257	5270	1163	4107
19-May-06	5262	1060	4201	5379	1253	4126
20-May-06	5154	1000	4154	5267	1083	4185
21-May-06	5189	970	4219	5260	785	4475
22-May-06	5237	1058	4179	5367	1119	4247
23-May-06	5284	1064	4220	5427	959	4468
24-May-06	5156	1107	4049	5205	819	4386
25-May-06	5153	1158	3995	5274	871	4403
26-May-06	5273	1080	4193	5383	1100	4283
27-May-06	5261	1199	4063	5317	983	4334
28-May-06	5169	1162	4007	5417	1392	4026

Table A1-1. Continued.

	Long Spruce GS			Limestone GS		
Date	Total Discharge	Spillage	Turbines	Total Discharge	Spillage	Turbines
29-May-06	5194	1052	4141	5191	820	4371
30-May-06	5828	1845	3983	6069	1725	4344
31-May-06	5060	943	4117	5107	837	4270
1-Jun-06	5207	968	4239	5254	1011	4242
2-Jun-06	5312	873	4439	5404	985	4419
3-Jun-06	5227	827	4400	5344	1150	4193
4-Jun-06	5563	1133	4431	5679	1245	4433
5-Jun-06	5141	669	4472	5143	671	4473
6-Jun-06	5408	1266	4142	5579	1030	4550
7-Jun-06	5353	1174	4179	5489	984	4504
8-Jun-06	5331	1289	4042	5352	970	4382
9-Jun-06	5240	1383	3857	5387	989	4398
10-Jun-06	5289	1901	3388	5287	1644	3643
11-Jun-06	5302	1908	3394	5429	1804	3626
12-Jun-06	5256	1264	3992	5387	1283	4103
13-Jun-06	5356	1039	4318	5477	955	4522
14-Jun-06	5363	1055	4309	5536	894	4642
15-Jun-06	5385	1153	4232	5463	964	4500
16-Jun-06	5049	693	4356	5119	601	4518
17-Jun-06	5289	1090	4199	5531	955	4576
18-Jun-06	5391	1159	4232	5294	604	4690
19-Jun-06	5409	962	4448	5338	668	4670
20-Jun-06	5289	817	4472	5293	649	4645
21-Jun-06	5285	771	4514	5287	575	4712
22-Jun-06	5260	821	4439	5283	608	4674
23-Jun-06	5126	740	4386	5219	604	4615
24-Jun-06	5132	1458	3674	5300	1167	4133
25-Jun-06	5029	1605	3425	5313	0	5313
26-Jun-06	4903	1081	3823	5027	795	4232
27-Jun-06	4843	732	4111	4948	607	4341
28-Jun-06	4811	536	4275	4831	403	4427
29-Jun-06	4676	309	4367	4713	21	4693
30-Jun-06	4759	222	4538	4671	123	4548
1-Jul-06	4777	437	4340	4822	145	4677
2-Jul-06	4457	41	4416	4522	0	4522
3-Jul-06	4466	202	4264	4450	58	4392
4-Jul-06	4357	240	4117	4333	60	4272
5-Jul-06	4398	12	4385	4421	0	4421
6-Jul-06	4442	0	4442	4414	0	4414

Table A1-1. Continued.

	Long Spruce GS			Limestone GS		
Date	Total Discharge	Spillage	Turbines	Total Discharge	Spillage	Turbines
7-Jul-06	4385	0	4385	4415	0	4415
8-Jul-06	4177	39	4138	4183	0	4183
9-Jul-06	4403	432	3970	4370	563	3807
10-Jul-06	4278	0	4278	4399	176	4224
11-Jul-06	4402	0	4402	4375	0	4375
12-Jul-06	4560	0	4560	4523	0	4523
13-Jul-06	4482	0	4482	4510	3	4506
14-Jul-06	4326	0	4326	4316	0	4316
15-Jul-06	4423	0	4423	4506	0	4506
16-Jul-06	4217	0	4217	4115	0	4115
17-Jul-06	4325	972	3352	4333	613	3720
18-Jul-06	4619	1178	3441	4720	1381	3339
19-Jul-06	4485	679	3807	4547	748	3799
20-Jul-06	4578	57	4521	4645	69	4576
21-Jul-06	4576	0	4576	4572	0	4572
22-Jul-06	4411	0	4411	4476	0	4476
23-Jul-06	4584	0	4584	4518	0	4518
24-Jul-06	4630	78	4552	4718	63	4655
25-Jul-06	4458	0	4458	4401	0	4401
26-Jul-06	4561	27	4535	4592	0	4592
27-Jul-06	4565	0	4565	4582	0	4582
28-Jul-06	4584	0	4584	4618	0	4618
29-Jul-06	4619	0	4619	4602	0	4602
30-Jul-06	4525	0	4525	4563	0	4563
31-Jul-06	4553	32	4521	4606	0	4606
1-Aug-06	4593	0	4593	4582	0	4582
2-Aug-06	4260	95	4165	4274	1	4274
3-Aug-06	4634	0	4634	4650	0	4650
4-Aug-06	4566	0	4566	4564	0	4564
5-Aug-06	4433	0	4433	4427	0	4427
6-Aug-06	4454	0	4454	4448	0	4448
7-Aug-06	4505	0	4505	4517	0	4517
8-Aug-06	4537	0	4537	4551	0	4551
9-Aug-06	4577	0	4577	4605	0	4605
10-Aug-06	4618	0	4618	4629	0	4629
11-Aug-06	4322	0	4322	4340	0	4340
12-Aug-06	4243	0	4243	4248	0	4248
13-Aug-06	4232	0	4232	4183	0	4183
14-Aug-06	4347	0	4347	4400	0	4400

Table A1-1. Continued.

	Long Spruce GS			Limestone GS		
Date	**Total Discharge**	**Spillage**	**Turbines**	**Total Discharge**	**Spillage**	**Turbines**
15-Aug-06	4430	0	4430	4471	0	4471
16-Aug-06	4272	0	4272	4223	0	4223
17-Aug-06	4352	0	4352	4389	0	4389
18-Aug-06	4341	0	4341	4359	0	4359
19-Aug-06	4213	0	4213	4209	0	4209
20-Aug-06	4264	0	4264	4184	0	4184
21-Aug-06	4339	0	4339	4405	0	4405
22-Aug-06	3982	0	3982	3908	0	3908
23-Aug-06	3904	0	3904	3974	0	3974
24-Aug-06	4274	0	4274	4239	0	4239
25-Aug-06	4268	0	4268	4226	0	4226
26-Aug-06	3913	0	3913	3949	0	3949
27-Aug-06	3842	0	3842	3822	0	3822
28-Aug-06	3964	0	3964	3997	0	3997
29-Aug-06	3894	0	3894	3863	0	3863
30-Aug-06	3816	0	3816	3774	0	3774
31-Aug-06	3699	0	3699	3729	0	3729
1-Sep-06	4126	0	4126	4106	0	4106
2-Sep-06	4302	0	4302	4253	0	4253
3-Sep-06	3796	0	3796	3793	0	3793
4-Sep-06	3360	0	3360	3343	0	3343
5-Sep-06	3755	0	3755	3696	0	3696
6-Sep-06	4242	0	4242	4258	0	4258
7-Sep-06	4039	0	4039	4021	0	4021
8-Sep-06	3677	0	3677	3640	0	3640
9-Sep-06	3454	0	3454	3459	0	3459
10-Sep-06	3251	0	3251	3196	0	3196
11-Sep-06	3914	0	3914	4013	0	4013
12-Sep-06	3700	0	3700	3555	0	3555
13-Sep-06	3719	0	3719	3718	0	3718
14-Sep-06	3586	0	3586	3566	0	3566
15-Sep-06	3392	0	3392	3493	0	3493
16-Sep-06	3140	0	3140	3012	0	3012
17-Sep-06	2436	0	2436	2412	0	2412
18-Sep-06	3253	0	3253	3312	0	3312
19-Sep-06	3401	0	3401	3362	0	3362
20-Sep-06	3434	0	3434	3411	0	3411
21-Sep-06	3389	0	3389	3388	0	3388
22-Sep-06	3414	0	3414	3371	0	3371

Table A1-1. Continued.

	Long Spruce GS			Limestone GS		
Date	**Total Discharge**	**Spillage**	**Turbines**	**Total Discharge**	**Spillage**	**Turbines**
23-Sep-06	2852	0	2852	2794	0	2794
24-Sep-06	2449	0	2449	2520	0	2520
25-Sep-06	3272	0	3272	3267	0	3267
26-Sep-06	3477	0	3477	3441	0	3441
27-Sep-06	3364	0	3364	3350	0	3350
28-Sep-06	3240	0	3240	3216	0	3216
29-Sep-06	2999	0	2999	3014	0	3014
30-Sep-06	2183	0	2183	2153	0	2153
1-Oct-06	1946	0	1946	1941	0	1941
2-Oct-06	3186	0	3186	3113	0	3113
3-Oct-06	3024	0	3024	3025	0	3025
4-Oct-06	2989	0	2989	2939	0	2939
5-Oct-06	2714	0	2714	2676	0	2676
6-Oct-06	2713	0	2713	2731	0	2731
7-Oct-06	1894	0	1894	1851	0	1851
8-Oct-06	1906	0	1906	1882	0	1882
9-Oct-06	2980	0	2980	2994	0	2994
10-Oct-06	2941	0	2941	2895	0	2895
11-Oct-06	3052	0	3052	3085	0	3085
12-Oct-06	3123	0	3123	3175	0	3175
13-Oct-06	2998	0	2998	3039	0	3039
14-Oct-06	1522	0	1522	1540	0	1540
15-Oct-06	1328	0	1328	1248	0	1248
16-Oct-06	2891	0	2891	2951	0	2951
17-Oct-06	3063	0	3063	2987	0	2987
18-Oct-06	3148	0	3148	3103	0	3103
19-Oct-06	3223	0	3223	3194	0	3194
20-Oct-06	2644	0	2644	2616	0	2616
21-Oct-06	1787	0	1787	1775	0	1775
22-Oct-06	1636	0	1636	1607	0	1607
23-Oct-06	3184	0	3184	3177	0	3177
24-Oct-06	2391	0	2391	2389	0	2389
25-Oct-06	2207	0	2207	2271	0	2271
26-Oct-06	2821	0	2821	2775	0	2775
27-Oct-06	3004	0	3004	2989	0	2989
28-Oct-06	2098	0	2098	2102	0	2102
29-Oct-06	2081	0	2081	2064	0	2064
30-Oct-06	3176	0	3176	3155	0	3155
31-Oct-06	2924	0	2924	2881	0	2881

Table A1-1. Continued.

Date	Long Spruce GS			Limestone GS		
	Total Discharge	**Spillage**	**Turbines**	**Total Discharge**	**Spillage**	**Turbines**
1-Nov-06	2843	0	2843	2843	0	2843
2-Nov-06	3248	0	3248	3221	0	3221
3-Nov-06	3328	0	3328	3338	0	3338
4-Nov-06	2884	0	2884	2838	0	2838
5-Nov-06	1609	0	1609	1648	0	1648
6-Nov-06	2814	0	2814	2760	0	2760
7-Nov-06	3064	0	3064	3078	0	3078
8-Nov-06	2912	0	2912	2892	0	2892
9-Nov-06	2683	0	2683	2639	0	2639
10-Nov-06	2967	0	2967	3007	0	3007
11-Nov-06	2225	0	2225	2167	0	2167
12-Nov-06	1786	0	1786	1772	0	1772
13-Nov-06	2940	0	2940	2931	0	2931
14-Nov-06	2606	0	2606	2569	0	2569
15-Nov-06	3100	0	3100	3134	0	3134
16-Nov-06	3429	0	3429	3429	0	3429
17-Nov-06	3305	0	3305	3316	0	3316
18-Nov-06	2741	0	2741	2691	0	2691
19-Nov-06	1978	0	1978	1966	0	1966
20-Nov-06	3127	0	3127	3159	0	3159
21-Nov-06	2773	0	2773	2781	0	2781
22-Nov-06	2510	0	2510	2426	0	2426
23-Nov-06	1854	0	1854	1816	0	1816
24-Nov-06	1981	0	1981	1989	0	1989
25-Nov-06	2305	0	2305	2333	0	2333
26-Nov-06	2210	0	2210	2207	0	2207
27-Nov-06	2744	0	2744	2708	0	2708
28-Nov-06	2523	0	2523	2499	0	2499
29-Nov-06	3002	0	3002	2973	0	2973
30-Nov-06	3272	0	3272	3303	0	3303
1-Dec-06	3012	0	3012	2989	0	2989
2-Dec-06	2374	0	2374	2319	0	2319
3-Dec-06	2316	0	2316	2296	0	2296
4-Dec-06	3221	0	3221	3230	0	3230
5-Dec-06	3056	0	3056	3032	0	3032
6-Dec-06	3336	0	3336	3361	0	3361
7-Dec-06	4002	0	4002	3989	0	3989
8-Dec-06	3421	0	3421	3347	0	3347
9-Dec-06	2338	0	2338	2279	0	2279

Table A1-1. Continued.

Date	Long Spruce GS			Limestone GS		
	Total Discharge	Spillage	Turbines	Total Discharge	Spillage	Turbines
10-Dec-06	2200	0	2200	2187	0	2187
11-Dec-06	3347	0	3347	3344	0	3344
12-Dec-06	3302	0	3302	3302	0	3302
13-Dec-06	3098	0	3098	3079	0	3079
14-Dec-06	3447	0	3447	3445	0	3445
15-Dec-06	3983	0	3983	3964	0	3964
16-Dec-06	3306	0	3306	3311	0	3311
17-Dec-06	3464	0	3464	3419	0	3419
18-Dec-06	4176	0	4176	4198	0	4198
19-Dec-06	3859	0	3859	3828	0	3828
20-Dec-06	3745	0	3745	3729	0	3729
21-Dec-06	3839	0	3839	3846	0	3846
22-Dec-06	3833	0	3833	3835	0	3835
23-Dec-06	2902	0	2902	2912	0	2912
24-Dec-06	2479	0	2479	2421	0	2421
25-Dec-06	2251	0	2251	2264	0	2264
26-Dec-06	3305	0	3305	3332	0	3332
27-Dec-06	3860	0	3860	3894	0	3894
28-Dec-06	3745	0	3745	3683	0	3683
29-Dec-06	3777	0	3777	3726	0	3726
30-Dec-06	3457	0	3457	3393	0	3393
31-Dec-06	3152	0	3152	3163	0	3163

Note: data provided by Manitoba Hydro (in raw format, not subject to quality control)

PART 2A

PART 2A

ESTIMATING DIRECT SURVIVAL AND INJURY OF ADULT WALLEYE, NORTHERN PIKE, AND LAKE WHITEFISH THROUGH A TURBINE AT MANITOBA HYDRO'S KELSEY GENERATING STATION

Prepared for

NORTH/SOUTH CONSULTANTS INC.
83 Scurfield Boulevard
Winnipeg MB
Canada R3Y 1G4

Prepared by

NORMANDEAU ASSOCIATES, INC.
1921 River Road
Drumore, Pennsylvania 17518

Normandeau Project Number 20013.001

May 2007

TABLE OF CONTENTS

1.0 INTRODUCTION

The behavior and mortality of boreal freshwater fish species of commercial interest passing through hydroelectric stations has not been quantified. Manitoba Hydro and the Department of Fisheries and Oceans Canada expressed interest in determining rates of mortality and injury to fish as a result of passage through turbines. Kelsey Generating Station (GS), in northern Manitoba, was selected as the site for a pilot study representing Part 2 of a larger study to investigate the impacts to fish passing through Manitoba Hydro's hydroelectric GSs. On July 28, 2004 personnel from Manitoba Hydro, Department of Fisheries and Oceans (DFO), Manitoba Conservation, Normandeau Associates Inc., and North/South Consultants Inc. visited the Kelsey GS to assess the feasibility and logistics of an investigation on fish turbine passage related mortality using fish with "HI-Z" tags (Heisey *et al*. 1992). As a result of the site visit and ensuing discussions, the study was conducted in early June, 2006.

The objectives of the "HI-Z" tag study as set forth by Manitoba Hydro and DFO were: (1) to determine the rates of direct survival and injury of adult fishes of domestic or commercial interest (northern pike, walleye, and lake whitefish) in passage through turbines; and (2) to evaluate the modifications to the HI-Z tag-recapture (Heisey *et al*. 1992) technique for adult-sized (>300 mm) fishes in passage experiments at the Manitoba Hydro's Kelsey GS.

1.1 Project Description

The Kelsey GS is located on the upper Nelson River in northern Manitoba, at latitude 55° 57' N and longitude 96° 32' W. It is approximately 137 km upstream of the Kettle GS and about 680 km north of Winnipeg (Figure 1-1). The Kelsey GS was built between 1957 and 1961 to supply electricity to the International Nickel Company's mining and smelting operations and also to the City of Thompson. Kelsey's original five turbine generators (units) were expanded to six in 1969 and a seventh unit was added in 1972. They operate with a 17.1 m head and the current total capacity is 225 MW with a discharge of 1,713 m^3 per second. All turbines are vertical propeller type with 6 fixed blades, a runner diameter of 7.92 m, and a rotational speed of 102.9 RPM. The powerhouse was built across a channel of the Nelson River and all generating equipment is housed inside the building, while the transformers are located outside of the generating station on the lower deck (Figure 1-2). The Kelsey GS Forebay water level is controlled by a spillway located a short distance away from the powerhouse. The spillway has nine vertical lift sluice gates with a total water discharge capacity of 7,082 m^3/s (approximately 250,000 cfs). The turbine discharge through the test Unit 2 was 227.9 m^3/s (approximately 8,000 cfs).

2.0 STUDY DESIGN AND METHODS

The study was designed to estimate the rates of survival and clean fish (fish without visible injuries, scale loss < 20% per side, and no loss of equilibrium) passed through turbine Unit 2 at the Kelsey GS. From 2-8 June 2006, northern pike, walleye, and lake whitefish were released at three entrainment depths; deep (1.5 m above the bottom), shallow (1.5m below the ceiling), and mid (middle of the turbine intake approximately 5.5 m below ceiling) (Figure 2-1). Although fish were released at three locations, survival and clean fish rates were estimated for the composite sample.

The rate of fish survival after passage through a specific obstruction or channel is affected by direct and indirect forces. Direct effects are manifested immediately after passage (e.g. instantaneous fish mortality, injury, or loss of equilibrium); indirect effects (e.g. predation, disease, or physiological stress) may occur over an extended period or distance after passage. The present study was designed to estimate direct effects by introducing HI-Z tagged (Heisey *et al*. 1992) fish into the turbine Unit 2 at the Kelsey GS (treatment) or directly into the tailrace downstream of the turbulent eddies (control), recapturing them after passage, enumerating the live and dead fish, and then carefully examining the condition of each fish. The latter information may be used to help assess the probable causal mechanisms for injury/mortality which may in turn be used to identify potential mitigative measures. Table 2-1 shows the summary of daily fish releases of each species.

2.1 Sample Size Calculations

Prior to initiating the study, the sample size requirement was determined to fulfill the primary objective of obtaining survival estimates that would be within a pre-specified precision (ε) level. The sample size is a function of the recapture rate (P_A), expected passage survival ($\hat{\tau}$) or mortality ($1-\hat{\tau}$), survival of control fish (S), and the desired precision (ε) at a given probability of significance (α). In general, sample size requirements decrease with an increase in control survival and recapture rates (Mathur *et al*. 1996, 2000). Only precision (ε) and α levels can be strictly controlled by an investigator. Results of turbine survival experiments from other sites indicate a sample size of approximately 100 (50 treatment and 50 control) fish per species may be sufficient to attain survival estimates within ± 0.10, 90% of the time (Table 2-2). This number assumes close to 100% control survival, a recapture rate of 95% and expected passage survival of > 90% for the study.

Initially, it was proposed that approximately 50 treatment individuals each of northern pike, walleye, and lake whitefish would be released into the intake of turbine Unit 2 at the Kelsey GS and 30 control fish of each of these species would be released into the tailrace (Figure 2-2) to estimate the rate of mortality and injury during passage. It was determined that fewer controls per species would be needed if all were recaptured free of injuries and survived 48 h. However, it was apparent during the initial phase of the study that not enough healthy lake whitefish could be captured to meet the sample size requirement for that species. Sample size adjustments were made during the course of the study by increasing the number of northern pike (88 treatment and 30 control) and walleye (99 treatment and 30 control) because of the small number of lake whitefish that were available for the study (15 treatment and 5 control) (Table 2-1). Appendix A provides data on individual fish and other measured parameters. Appendix C provides statistical output.

2.2 Source and Maintenance of Specimens

Fish for this study were obtained between 1 and 7 June, 2006 from locations downstream of the Kelsey GS. The majority of fish were captured by gill net sets in locations that have historically yielded good numbers of fishes and that facilitated rapid transport to the holding facilities. Additional fish were caught by angling and electrofishing in areas around the Kelsey GS. Mr. Don MacDonald from the Fisheries Branch of the Manitoba Water Stewardship Department and local fishermen were consulted regarding site selections for fish collection. Nets were checked at one and two-hour intervals, and fish were removed from the net as soon as possible after capture with minimal handling. Only fish in good physical condition were used. The size range of northern pike, walleye, and lake whitefish used in the study largely reflected the size range of captured fish. The fish were transported by boat to covered pools (Figure 2-3) located on the intake deck area of the dam near the turbine Unit 2 release location. In general, enough soft-walled pools were available to hold fish separately by species and date of capture.

A continual supply of ambient river water was supplied to each pool and all fish were held for a minimum of 12-24 h prior to tagging which allowed fish time to recover from initial capture and handling stress. Water temperature in the holding pools ranged from 10.0 to 15.5° C and river temperatures, measured in the tailrace, were 11.0 to 14.0 °C (Table 2-1).

Total length for northern pike ranged from 455-1,085 mm for the treatment fish (mean of 660 mm) and from 500-990 mm (mean of 629 mm) for the control fish (Figure 2-4). Total length for walleye ranged from 314-651 mm for the treatment fish (mean of 446 mm) and from 341 to 610 mm (mean of 458 mm) for the control fish (Figure 2-4). Total length for lake whitefish ranged from 448-565 mm (mean of 503 mm) for the treatment fish and from 475 to 533 mm (mean of 498 mm) for the control fish (Figure 2-4).

2.3 Tagging and Release

Due to the nature and size of the test fish (adult walleye, northern pike and lake whitefish), fish handling, tagging, and recapture techniques were adapted specifically for each species for this pilot investigation at Kelsey GS. In order to bring large fish to the surface for rapid recapture, as many as 12 HI-Z balloon tags (average 4-6) were attached with a small cable tie through the musculature beneath the pelvic, pectoral and dorsal fins via a curved canula needle (Figure 2-5). The conventional method of attaching HI-Z tags with a small stainless steel pin was used to attach tags at the base of the walleye's pelvic fins. Radio tags were attached in combination with one of the HI-Z balloon tags to aid in tracking released fish. Specially designed fish restraint devices were developed and built by Normandeau to aid in tagging test fish (Figure 2-6). In addition to attachment of HI-Z tags, Floy-tags and surgically implanted acoustic tags were also applied to a sub-sample of the treatment and control fish (see Part 2B of this report).

HI-Z tags were activated by injecting a small amount of water into the balloons which caused the tag to inflate in approximately 2 to 4 minutes. All treatment fish were released through an induction apparatus (Figure 2-7) that consisted of a holding basin attached to a 20.32 cm (8 inch) diameter flexible hose which led to a rigid 20.32 cm (8 inch) PVC pipe. This pipe was U-bolted onto a steel frame that could be raised or lowered to the desired release depth (Figure 2-8). The release hose was continuously supplied with river water to ensure fish were transported quickly to the desired release point. Control fish were released through the same induction apparatus attached to a 20.32 cm (8 inch) diameter flexible hose approximately 15 m (50 ft) long that released fish into the tailrace downstream of the turbulent eddies (Figure 2-2). Treatment fish were introduced into turbine Unit 2 at 3 depths, shallow (1.5 m below ceiling), mid (middle of turbine intake approx. 5.5 m below ceiling) and deep (1.5 m above the bottom) (Figure 2-1).

Procedures for handling, tagging, release and recapture of fish were similar for treatment and control groups. Fish were randomly selected from the holding pools, using small seines, dip nets, and wool gloves, and all fish releases were made during daylight hours.

2.4 Fish Recapture Methods

After release (either as treatment or control), fish were tracked and retrieved when they buoyed to the surface downstream of the Kelsey GS by one of three recapture boat crews (Figure 2-9). Boat crews were notified of the radio tag frequency of each fish upon its release. Only crew members trained in fish handling were used to retrieve tagged fish. To minimize crew bias, no crew was specifically assigned to retrieve either control or treatment fish.

Radio signals were received on a 5-element Yagi antenna or Loop antenna coupled to an Advanced Telemetry System receiver. The radio signal transmission enabled the boat crews to follow the movement of each fish after passage and position the boats downstream for retrieval when the HI-Z tags buoyed the fish to the surface.

Active radio tags which failed to surface were tracked for a minimum of 30 minutes and then periodically thereafter to determine whether the fish appeared to be alive (moving around) or whether the tag broke loose (stationary signal). Recaptured fish were placed into an on-board holding facility and tags were removed (Heisey *et al*. 1992). Each fish was immediately examined for maladies consisting of visible injuries, descaling, and loss of equilibrium and assigned appropriate condition codes, per the descriptions presented in Table 2-3. Tagging and data recording personnel were notified via a two-way radio system of each fish's recovery time and condition. Appendix tables A-1 and A-2 provide data on disposition of individual fish.

After recapturing an acoustically tagged fish, the fish was assessed for condition and any turbine related injuries. If no injuries were present, all HI-Z tags were removed and the fish was released back into the river so that any movements could be monitored by five stationary acoustic receivers. Any acoustically tagged fish that were recaptured injured were held in holding tanks to be monitored during the 48 h delayed assessment period. If injuries were not life-threatening, and the fish was alive at 48 h, the fish was released into the river. The results of the acoustic tag study are reported in Part 2B of this report.

2.5 Assessment of Fish Injuries

All recaptured fish, dead or alive, were examined for types of external injuries. A sub-sample of dead fish was also examined for internal injuries when there were no apparent external injuries. Each recaptured fish with a visible injury or scale loss was assigned a likely causal mechanism. Controlled laboratory experiments (Neitzel *et al*. 2000; PNNL et al. 2001) to replicate and correlate injury type and characteristic to a specific causative mechanism provides some indication of the cause of observed injuries in the field. Some injury symptoms can be manifested by two different sources which may lessen the probability of accurate delineation of a cause and effect relationship in the field (Eicher Associates 1987).

Injury and descaling were categorized by type, extent, and area of body. Fish without visible injuries that were not actively swimming or swimming erratically at recapture were classified as "loss of equilibrium". This condition has been noted in most past studies and often disappears within 10 to 15 min after recapture if the fish is not injured (Normandeau Associates *et al*. 1996, 2000, 2003). A malady classification was established to include fish with visible injuries, scale loss (greater than 20% on either side), or loss of equilibrium. Dead fish without any of these symptoms were not included in this category. Fish without maladies were designated "clean fish". Daily tag-recapture and daily malady data are presented in Appendix tables A-3 and A-4.

The clean fish metric was established to provide a standard way to depict a specific passage route's effects on the condition of entrained fish (Normandeau and Skalski 2006). The clean fish metric is based solely on fish physically recaptured and examined. Additionally, the clean fish metric in concert with site-specific hydraulic and physical data may provide insight into what passage conditions present safer fish passage.

2.6 Classification of Recaptured Fish

As in previous investigations (Mathur *et al*. 1996, 2000; Normandeau and Skalski 2006) the immediate post-passage status of an individual recaptured fish and recovery of inflated tags dislodged from fish was designated as alive, dead, tag and pin recovered, or unknown. The following criteria have been established to make these designations: (1) alive—recaptured alive and remaining so for 1 h; (2) alive—fish does not surface but radio signals indicate movement patterns; (3) dead—recaptured dead or dead within 1 h of release; (4) dead—only inflated dislodged tag(s) are recovered, and telemetric tracking or the manner in which inflated tags surfaced is not indicative of a live fish; and (5) unknown—no fish or dislodged tags are recaptured, or radio signals are received only briefly, and the subsequent status cannot be ascertained.

Each fish recaptured alive (except acoustically tagged) was immediately transferred to 5,000 liter holding pools on the lower deck for assessment of delayed effects (48 h). Each pool was continuously supplied with ambient river water and shielded to prevent potential fish escape and predation (otters, bears, *etc*.).

Mortalities of recaptured fish occurring after 1 h were assigned 48 h post-passage effects although fish were observed at approximately 12 h intervals. In such cases, the fish was examined for descaling and injury, and those that died without obvious injuries were necropsied to determine the probable cause of death. Additionally, all specimens alive at 48 h were closely examined for injury and descaling. The initial examination allows detection of some injuries, such as bleeding and minor bruising that may not be evident after 48 h due to natural healing processes (Normandeau Associates *et al*. 1996).

2.7 Acoustically Tagged fish

Generally, recaptured fish are held in pools for 48 h to assess any post passage effects and thereby are included in the 48h survival/injury probabilities (Heisey *et al*. 1992; Mathur *et al*. 1996). However, the acoustically tagged fish that were recaptured and released back into the Nelson River (minus HI-Z tags) were included in the 48 h survival calculation (Appendix B). Information from acoustically tracked fish (see Section 2.6 and Part 2B of this report) was considered in the final classification of fish that were not immediately recaptured and their status could not be assessed based on radio signals. This included two fish, one northern pike and one walleye of initially "unknown status" that were subsequently assigned "alive" status (after 48 h) because the acoustic data indicated that these fish were actively moving over several weeks.

2.8 Survival and Clean Fish Estimation

Separate survival probabilities (1 h and 48 h) and clean fish rates and their associated standard errors were estimated for northern pike and walleye using the likelihood model given in Mathur *et al*. (1996) and Normandeau Associates *et al*. (2000). The model outputs along with results of other statistical analyses are provided in Appendix C.

3.0 RESULTS

3.1 Recapture Rates

Recapture rates (physical retrieval of both live and dead fish) of treatment and control groups were high (Table 3-1). Recapture rate of all treatment groups (northern pike and walleye) exceeded 97%. Lake whitefish treatment recapture rate was 93.3%. Walleye, northern pike, and lake whitefish control recapture rates were 100%. There was low incidence of tag detachment.

3.2 Retrieval Times

Retrieval times (the interval between fish release through the induction system and physical retrieval) for all releases were short; a mean time of about 6-7 minutes for northern pike, 5-6 minutes for walleye and 7-8 minutes for lake whitefish (Figure 3-1).

3.3 Survival Estimates

Estimated 1 h and 48 h direct survival probabilities ($\hat{\tau}$) were calculated for northern pike and walleye (Table 3-2). Survival probability (1 h) for walleye across all release locations (shallow, mid and deep) was 0.814 (SE=0.040) and 48 h estimated survival was 0.804 (SE=0.040). Northern pike estimated 1 h survival probability was 0.742 (SE=0.046) and 48 h survival was 0.659 (SE=0.050) (Table 3-2). Lake whitefish survival probabilities were not calculated due to the small sample size (N=10).

3.4 Injury Rates and Probable Causal Mechanisms

Injury rates (%) are based on the total number of fish recaptured and examined, not on the total number of fish released and refer to only passage-related injuries and not tag-related or preexisting conditions such as gill net damage, handling, etc. Malady rates for treatment fish needed no adjustments since control fish were free of maladies.

Injury rates differed between the species (Table 3-3). Out of 95 walleye examined, 29 (30.5%) had visible injuries while the injury rate of northern pike was much higher at 52.9%. The injury rate of lake whitefish was 7.1%; 1 out of 14 fish examined (Table 3-3).

Probable sources of observed injuries for all species tested were mostly due to mechanical causes (Table 3-4). 48.2% of northern pike and 28.4% of walleye were mechanically injured. The common injury types were severed head/body or missing body parts and tears or lacerations to the head and body (Table 3-3).

Malady rate, which includes visible injuries plus loss of equilibrium and/or major scale loss, was almost identical to the visible injury rate (Table 3-5). The malady rate for walleye was 32.6% and it was 52.9% for northern pike.

Although the sample size by release location (shallow, mid and deep) was small, there was an indication that passage location affected injury rates (Table 3-3). The visible injury rates were higher for shallow-released fish than deep-released fish. The respective rates for shallow, mid and deep released walleye and northern pike were 46.4, 30.0 and 18.9% and 67.9, 36.7 and 55.6%, respectively.

3.5 Clean Fish Estimates (CFE)

Clean fish estimates (fish free of maladies) are presented in Table 3-6. Clean fish estimates differed between species. The CFE for walleye was 0.674 (SE=0.048) and for northern pike it was 0.471 (SE=0.054). The entrainment depth of fish seems to affect the magnitude of survival and injury based on absolute values; however, the sample size was not deemed adequate for further statistical analysis.

Injury rates appeared to be related to fish length with longer fish suffering a greater rate of injury in both species (Figure 3-2); length effect, however, appears more pronounced for walleye than northern pike. Species-specific injury rates related to length were analyzed by chi-square tests. However, because of small sample sizes adjacent length interval groups were pooled to have at least five fish in each length group. This resulted in the following length groups with sample sizes in parentheses. For the northern pike, they were: 451-550 mm (N=10), 551-600 mm (N=14), 601-650 mm (N=23), 651-700 mm (N=19), 701-800 mm (N=7), and 801-1,100 mm (N=12). For the walleye, the following five groups were formed: 301-400 mm (N=9), 401-450 mm (N=39), 451-500 mm (N=31), 501-550 mm (N=11), and 551-700 mm (N=5). Chi-square tests did not show a difference (P=0.685) between the frequency of injured and non-injured fish for the northern pike. However, differences in the frequency of injured and non-injured fish between length groups were significant (P=0.001) for the walleye; most of the variation to the chi-square was contributed by injured fish frequency in the 551-700 mm length group, only five fish were in this length range and all were injured.

Although the length effect on injury rates was evident, particularly on walleye, all injuries were not lethal over the 48 h period. Chi-square tests did not detect significant differences (P > 0.20) between length groups in the frequencies of dead and alive fish. Figure 3-

3a and Figure 3-3b shows the relationship between mortality rate of recaptured fish and length for each species. No clear relationships are evident for either species.

4.0 DISCUSSION

The primary objectives of the study were met. The first, estimation of survival of adult species of domestic or commercial interest (northern pike, walleye, and lake whitefish) within ≤ ± 0.10, 90% of the time, was successfully achieved. The precision (ε) on survival estimates of northern pike and walleye was within ± 0.10, 90% of the time; however, because of the small sample size of lake whitefish (N=10) survival rate for this species was not estimated. The estimated 48 h direct survival probability for walleye passage through turbine Unit 2 was 0.804 (SE=0.040, 90% CI=0.738-0.870); it was 0.659 (SE=0.050, 90% CI=0.577-0.741) for the northern pike. The second objective, the evaluation of HI-Z tag-recapture technique with modifications for adult fishes, was also successfully achieved. The recapture rates of both northern pike and walleye exceeded 95% and retrieval times averaged less than 8 minutes. Both these values are consistent with those generally observed for juvenile fishes (< 200 mm) in passage through turbines (Normandeau Associates *et al*. 1996; Normandeau Associates and Skalski 2006). In addition, the tag detachment was minimal.

A literature review (EPRI 1992, 1996; Franke *et al*. 1997) indicates that scant information exists on survival rates of fish larger than 300 mm in passage through relatively large Kaplan type turbines such as at Kelsey. In particular, comparable data for the two species and sizes tested herein in passage through Kaplan type turbines with characteristics similar to Kelsey GS are unavailable to provide a perspective on the results obtained herein. Although survival estimates have been reported for walleye of lengths up to > 300 mm (Navarro *et al*. 1996), and for northern pike of up to 456 mm length (Matousek *et al*. 1994), these are not deemed comparable to the results from the present study because they were obtained at Francis and Sampson type turbines. In general, the available data for Kaplan turbines are that fish size and shape (rather than species *per se*), number of runner blades, turbine runner diameter, and runner blade rotational speed affect survival rates.

Survival rates for large sized American shad (424 to 560 mm), somewhat similar in size and shape to walleye, in passage through Kaplan type turbines reported in the recent literature (Bell and Kynard 1985; Franke *et al* 1997; Normandeau Associates 1997) are available for comparisons. Bell and Kynard (1985) reported a survival rate (2-4 h) of 78.2% for radio-tagged American shad (average length 560 mm) in passage through a Kaplan turbine at the Hadley Falls Station on the Connecticut River. Normandeau Associates (1997) reported a survival rate (48 h) of 86% for post-spawned American shad (average length 424 mm) in passage through Kaplan type turbines at the Safe Harbor Station on the Susquehanna River. The 48 h survival rate (80.42%) for walleye with an average length of 446 mm found in the present study is relatively similar to that reported for American shad, particularly at Hadley Falls. Kelsey GS shares several structural characteristics with both the Hadley Falls and Safe Harbor Stations (5 to 7 runner blades, runner speeds of 78 to 128 RPM, and runner diameter of 170 to 223 in).

Even though literature is scant on survival of larger sized fish (> 300 mm) evidence is emerging that survival is more a function of fish size than species *per se* (Normandeau Associates 1997; Skalski *et al*. 2002). In studies of juvenile (≤ 150 mm) and adult post-spawned American shad (average length 424 mm) in passage through Kaplan type turbines at Safe Harbor Hydroelectric Station survival for juveniles was reported at > 97% and for adults at about 86% (Heisey *et al*. 1992; Normandeau Associates 1997). A retrospective analysis of survival data on several species by Skalski *et al*. (2002) showed fish length to be an important variable affecting survival more than other variables tested. Results from the present study support this relationship to a large extent. There was also an increasing trend in malady rates with increased fish length.

The species composition and size of the fish naturally passing through the Kelsey GS is unknown and it is difficult to predict the extent to which present survival estimates for northern pike and walleye apply to the fish community at large. However, because of the bias for larger fish chosen for this study, it is hypothesized that average survival rates for the entire population of northern pike and walleye and similar sized other species present at Kelsey GS will likely be higher than those estimated herein.

5.0 LITERATURE CITED

Bell, C. E., and B. Kynard. 1985. Mortality of adult American shad passing through a 17-megawatt Kaplan turbine at a low-head hydroelectric dam. N. Amer. J. Fish Mgt. 5: 33-38.

Eicher Associates, Inc. 1987. Turbine-related fish mortality: review and evaluation of studies. Research Project 2694-4. Prepared for Electric Power Research Institute, Palo Alto, CA.

Electric Power Research Institute (EPRI). 1992. Fish entrainment and turbine mortality review and guidelines. EPRI. TR-1011231, Palo Alto, CA.

Electric Power Research Institute (EPRI). 1996. Guidelines for hydro turbine fish entrainment and survival studies. EPRI. W04083-01, Palo Alto, CA.

Franke, G. F., and nine co-authors. 1997. Development of environmentally advanced hydropower turbine system design concepts. Prepared for the U.S. Department of Energy, DOE Idaho Operations Office, and Hydropower Research Foundation, Inc., Contract No. DE-AC07-96ID13382.

Heisey, P. G., D. Mathur, and T. Rineer. 1992. A reliable tag-recapture technique for estimating turbine passage survival: application to young-of-the-year American shad (*Alosa sapidissima*). Can. Jour. Fish. Aquat. Sci. 49:1826-1834.

Mathur, D., P. G. Heisey, E. T. Euston, J. R. Skalski, and S. Hays. 1996. Turbine passage survival estimation for Chinook salmon smolts (*Oncorhynchus tshawytscha*) at a large dam on the Columbia River. Can. Jour. Fish. Aquat. Sci. 53:542-549.

Mathur, D., P. G. Heisey, J. R. Skalski, and D. R. Kennedy. 2000. Salmonid smolt survival relative to turbine efficiency and entrainment depth in hydroelectric power generation. Jour. Amer. Water Resources Assoc. 36(4):737-747.

Matousek, J.A., A.W. Wells, J.H. Hecht, and S.G. Metzger. 1994. Reporting survival results of fish passing through low-head turbines. Hydro Review, May 1994: 58-65.

Navarro, J.E., D.J. McCauley, and A.R. Blystra. 1996. Turbine passage at four low-head hydroelectric facilities in northeast Michigan. N. Amer. J. Fish. Manage. 16: 182-197.

Neitzel, D. A., and nine co-authors. 2000. Laboratory studies of the effects of shear on fish. Prepared by the Pacific Northwest National Laboratory, Richland, WA for the Advanced Hydropower System Team, U. S. Dept. of Energy, Idaho Falls, ID. DOE/ID-1 of 22.

Normandeau Associates, Inc. 1997. Survival of adult American shad in passage through turbines at the Safe Harbor Station on the Susquehanna River, Pennsylvania. Report Prepared for Safe Harbor Water Power Corporation, Conestoga, Pennsylvania.

Normandeau Associates, Inc., and J. R. Skalski. 2006. Performance evaluation of the new Advanced Hydro Turbine System (AHTS) at Wanapum Dam, Columbia River, Washington. Report prepared for Public Utility District No. 2 of Grant County, Ephrata, WA.

Normandeau Associates, Inc., J. R. Skalski, and Mid Columbia Consulting, Inc. 1996. Fish survival investigation relative to turbine rehabilitation at Wanapum Dam, Columbia River, Washington. Report prepared for the Grant County Public Utility District No. 2, Ephrata, WA.

Normandeau Associates, Inc., J. R. Skalski, and Mid Columbia Consulting, Inc. 2000. Passage survival and condition of Chinook salmon smolts through an existing and new minimum gap runner turbine at Bonneville Dam First Powerhouse, Columbia River. Report prepared for Department of the Army, Portland District Corps of Engineers, Portland, OR.

Normandeau Associates, Inc., J. R. Skalski, and Mid Columbia Consulting, Inc. 2003. Survival/condition of Chinook salmon smolts under different turbine operations at McNary Dam, Columbia River. Prepared for the U.S. Department of the Army, Walla Walla District, Walla Walla, WA.

Pacific Northwest National Laboratory, BioAnalysts, ENSR International, Inc., and Normandeau Associates, Inc., 2001. Design guidelines for high flow smolt bypass outfalls: field laboratory, and modeling studies. Report prepared for Dept. of Army, Corps of Engineers, Portland, OR.

Skalski, J.R., D. Mathur, and P.G. Heisey. 2002. Effects of turbine operating efficiency on smolt passage survival N. Amer. Fish. Manage. 22: 1193-1200.

TABLES

Table 2-1

Daily schedule of releases for northern pike, walleye and lake whitefish into turbine Unit 2 intake at 227.9 m^3/s (8,000 cfs) at three release locations, shallow, mid, and deep. Control fish were released downstream of the turbine discharge at the Kelsey GS, June 2006.

		Species												
	Tailrace Temp.	Northern pike				Walleye				Lake whitefish				
Date	(°C)	Shallow	Mid	Deep	Control	Shallow	Mid	Deep	Control	Shallow	Mid	Deep	Control	Total
2-Jun	10.6							2						**2**
3-Jun	10.8							37						**37**
4-Jun	11.1			27					15			10		**52**
5-Jun	11.4				18	29							5	**52**
6-Jun	11.9	30							15	2				**47**
7-Jun	12.2				12		31							**43**
8-Jun	12.8		31								3			**34**
Total		**30**	**31**	**27**	**30**	**29**	**31**	**39**	**30**	**2**	**3**	**10**	**5**	**267**

Table 2-2

Required sample sizes for treatment and control fish releases for various combinations of control survival (S), recapture probability (P_A), and turbine related mortality ($\hat{\tau}$) to obtain a precision (ε) of ≤ ± 0.10 at 1-□=0.90.

Control Survival (S)	Recapture Rate (P_A)	Turbine Mortality (1-$\hat{\tau}$)	Number of Fish
1.00	0.99	0.05	18
		0.10	29
		0.15	39
	0.95	0.05	39
		0.10	49
		0.15	57
	0.90	0.05	69
		0.10	76
		0.15	82
0.95	0.99	0.05	45
		0.10	54
		0.15	61
	0.95	0.05	67
		0.10	74
		0.15	80
	0.90	0.05	98
		0.10	103
		0.15	107
0.90	0.99	0.05	74
		0.10	81
		0.15	87
	0.95	0.05	98
		0.10	103
		0.15	107
	0.90	0.05	130
		0.10	133
		0.15	134

Table 2-3

Condition codes assigned to fish and dislodged HI-Z tags for fish passage survival evaluation.

FISH CODES

Code	**Description**
*	Turbine/passage-related malady
5	Major scale loss, >20% Scaled
6	Severed body (tear/cut)
7	Decapitated; Head missing
8	Hemorrhaged, bulged or missing eye(s)
9	Hemorrhaged, torn, bent gill/operculum
A	No visible marks on fish
B	Flesh tear at tag site(s)
C	Minor scale loss, 3 to 20%
E	Laceration(s); tear(s) on body or head (not severed)
F	Torn Isthmus
G	Hemorrhaged, bruised head or body
H	LOE
I	Spasmodic movement of body
J	Very weak, barely gilling, died within 60 minutes of recovery
K	Failed to enter system
L	Fish likely preyed on (telemetry, circumstances relative to recapture)
M	Substantial bleeding at tag site
P	Observed Predator marks
Q	Manitoba only -Fish not recovered but counted as alive based on telem and/or visual
R	Replaced due to unrecoverable conditions
S	Manitoba only - acoustic tag inserted
T	Trapped inside tunnel/gate well
U	Manitoba only - floy tag only no acoustic tag"
V	Fins displaced, or hemorrhaged (ripped, torn, or pulled) from origin
W	Abrasion / Scrape

SURVIVAL CODES

1	Recovered - Alive
2	Recovered - Dead
3	Unrecovered – Tag and pin only – assigned dead
4	Unrecovered – Unknown – no information
5	Unrecovered – Radio telem or other information

DISSECTION CODES

1	Shear	E	Broken bones obvious
2	Mechanical	F	Hemorrhaged internally
3	Pressure	L	Organ displacement
4	Undetermined	N	Heart damage, rupture, hemorrhaged, etc.
5	Mechanical/Shear	O	Liver damage, rupture, hemorrhaged, etc.
6	Mechanical/Pressure	R	Necropsied, no obvious injuries
7	Shear/Pressure	S	Necropsied, internal injuries observed
B	Swim bladder ruptured or expanded	W	Head removed; i.e. otolith
D	Kidneys damaged (hemorrhaged)		

Table 3-1

Summary of tag-recapture data for three species northern pike, walleye and lake whitefish released into turbine Unit 2 intake at 227.9 m^3/s (8,000 cfs) at three release locations, shallow, mid, and deep. Control fish were released downstream of the turbine discharge at the Kelsey GS, June 2006.

	Release Location									
	Deep		Mid		Shallow		Total		Control Pipe	
Walleye										
Number released	39		31		29		99[a]		30	
Number recaptured alive	31	(0.795)	26	(0.867)	22	(0.759)	79	(0.806)	30	(1.000)
Number recaptured dead	6	(0.154)	5	(0.161)	6	(0.207)	17	(0.173)	0	(0.000)
Number assigned dead	1	(0.026)	0	(0.000)	0	(0.000)	1	(0.010)	0	(0.000)
Number unknown	1	(0.026)	0	(0.000)	1	(0.034)	2	(0.020)	0	(0.000)
Number held alive at 48h or released to river	30	(0.769)	26	(0.867)	22	(0.759)	77[b]	(0.786)	30	(1.000)
Northern pike										
Number released	27		31		30		88[c]		30	
Number recaptured alive	20	(0.741)	25	(0.806)	20	(0.667)	65	(0.739)	30	(1.000)
Number recaptured dead	7	(0.259)	6	(0.194)	8	(0.267)	21[d]	(0.239)	0	(0.000)
Number assigned dead	0	(0.000)	0	(0.000)	2	(0.067)	2	(0.023)	0	(0.000)
Number unknown	0	(0.000)	0	(0.000)	0	(0.000)	0	(0.000)	0	(0.000)
Number held alive at 48h or released to river	17	(0.630)	19	(0.613)	19	(0.633)	55	(0.625)	30	(1.000)

Table 3-1 Continued

	Release Location									
	Deep		**Mid**		**Shallow**		**Total**		**Control Pipe**	
	Lake whitefish									
Number released	10		3		2		15		5	
Number recaptured alive	8	(0.800)	3	(1.000)	2	(1.000)	13	(0.867)	5	(1.000)
Number recaptured dead	1	(0.100)	0	(0.000)	0	(0.000)	1	(0.067)	0	(0.000)
Number assigned dead	0	(0.000)	0	(0.000)	0	(0.000)	0	(0.000)	0	(0.000)
Number unknown	1	(0.100)	0	(0.000)	0	(0.000)	1	(0.067)	0	(0.000)
Number held	8	(0.800)	3	(1.000)	2	(1.000)	13	(0.867)	5	(1.000)
Number alive at 24 h	7	(0.700)	3	(1.000)	1	(0.500)	11	(0.733)	5	(1.000)
Number alive at 48 h	7	(0.700)	3	(1.000)	1	(0.500)	11	(0.733)	5	(1.000)

a Includes 24 acoustically tagged fish

b Includes one acoustically tagged fish released after 48 h

c Includes 24 acoustically tagged fish

d Includes one acoustic tagged fish unrecovered

Table 3-2

Estimated 1 h and 48 h direct survival probabilities ($\hat{\tau}$) and standard errors (SE) for northern pike and walleye released into turbine Unit 2 intake at 227.9 m^3/s (8,000 cfs) at three locations, shallow, mid, and deep. Control fish were released downstream of the turbine discharge at the Kelsey GS, June 2006.

	Northern pike	Walleye
Survival ($\hat{\tau}$)		
1 h	0.742	0.814
SE*	0.046	0.040
48 h	0.659	0.804
SE*	0.050	0.040

*Multiply standard errors (SE) by 1.645 to obtain 90% confidence intervals. For example, the highest SE (0.050) has 90% confidence limits of ±0.082.

Table 3-3

Summary of visible passage related injury types, excluding scale loss and loss of equilibrium observed on northern pike, walleye and lake whitefish released into turbine Unit 2 intake at the Kelsey GS, June 2006. Control fish were released downstream of the turbine discharge.

				Injury Type						
Release Location	**Number Released**	**Number Examined**	**Visible Injuries Related to Passage (Number of Fish)**	**Damaged Eyes***	**Torn/ Scraped Operculum, Gills Hemorrhaged**	**Bruise on Body/Head**	**Scrapes/ Abrasions on Body/Head**	**Severed Head/ Body and/or Missing Body Parts**	**Lacerations Body/Head**	**Internal Injury**
					Walleye					
Deep	39	37 (94.9%)	7 (18.9%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (16.2%)	1 (2.7%)	1 (2.7%)
Mid	31	30 (96.8%)	9 (30.0%)	0 (0.0%)	0 (0.0%)	1 (3.3%)	1 (3.3%)	5 (16.7%)	2 (6.7%)	0 (0.0%)
Shallow	29	28 (96.6%)	13 (46.4%)	0 (0.0%)	4 (14.3%)	0 (0.0%)	1 (3.6%)	2 (7.1%)	8 (28.6%)	1 (3.6%)
Total	**99**	**95 (96.0%)**	**29 (30.5%)**	**0 (0.0%)**	**4 (4.2%)**	**1 (1.1%)**	**2 (2.1%)**	**13 (13.7%)**	**11 (11.6%)**	**2 (2.1%)**
					Northern Pike					
Deep	27	27 (100.0%)	15 (55.6%)	2 (7.4%)	3 (11.1%)	1 (3.7%)	3 (11.1%)	6 (22.2%)	5 (18.5%)	1 (3.7%)
Mid	31	30 (96.8%)	11 (36.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (10.0%)	7 (23.3%)	2 (6.7%)	1 (3.3%)
Shallow	30	28 (93.3%)	19 (67.9%)	2 (7.1%)	2 (7.1%)	1 (3.6%)	2 (7.1%)	4 (14.3%)	13 (46.4%)	0 (0.0%)
Total	**88**	**85 (96.6%)**	**45 (52.9%)**	**4 (4.7%)**	**5 (5.9%)**	**2 (2.4%)**	**8 (9.4%)**	**17 (20.0%)**	**20 (23.5%)**	**2 (2.4%)**
					Lake Whitefish					
Deep	10	9 (90.0%)	1 (11.1%)	1 (11.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (11.1%)
Mid	3	3 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Shallow	2	2 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Total	**15**	**14 (93.3%)**	**1 (7.1%)**	**0 (0.0%)**	**0 (0.0%)**	**0 (0.0%)**	**0 (0.0%)**	**0 (0.0%)**	**0 (0.0%)**	**0 (0.0%)**
					Control					
Pipe	65	65 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

*Hemorrhaged, bulged, ruptured or missing eyes

Table 3-4

Probable sources of visibly observed injuries and scale loss (≥20% per side) on adult northern pike, walleye and lake whitefish after passage through Unit 2 at Kelsey GS, June 2006. Percentages are given in parentheses..

Treatment		Probable Injury Source							
Release Depth**	**No. of Fish Examined**	**Mechanical**	**Shear**	**Pressure**	**Shear/ Mechanical***	**Shear/ Pressure***	**Mechanical/ Pressure***	**Injury Mechanism Undetermined**	**Total**
					Northern pike				
Shallow	28	18 (64.3)			1 (3.6)				19 (67.9)
Mid	30	11 (36.7)							11 (36.7)
Deep	27	12 (44.4)	2 (7.4)		1 (3.7)				15 (55.6)
Total	**85**	**41 (48.2)**	**2 (2.4)**		**2 (2.4)**				**45 (52.9)**
					Walleye				
Shallow	28	10 (35.7)	2 (7.1)		1 (3.6)				13 (46.4)
Mid	30	9 (30.0)						1 (3.3)	10 (33.3)
Deep	37	8 (21.6)							8 (21.6)
Total	**95**	**27 (28.4)**	**2 (2.1)**		**1 (1.1)**			**1 (1.1)**	**31 (32.6)**

Table 3-4 Continued.

Treatment		Probable Injury Source							
Release Depth**	**No. of Fish Examined**	**Mechanical**	**Shear**	**Pressure**	**Shear/ Mechanical***	**Shear/ Pressure***	**Mechanical/ Pressure***	**Injury Mechanism Undetermined**	**Total**
					Lake whitefish				
Shallow	2							1 (50.0)	1 (50.0)
Mid	3								0 (0.0)
Deep	9	1 (11.1)							1 (11.1)
Total	**14**	**1 (7.1)**						**1 (7.1)**	**2 (14.3)**

*Mechanical, shear, or pressure injuries may have been due to multiple forces or one acting singularly.
**Distance below the ceiling intake

Table 3-5

Passage related maladies, including visibe injury, loss of equilibrium and scale loss (≥ 20% per side) on adult northern pike, walleye and lake whitefish after passage through Unit 2 at the Kelsey GS, June 2006. Percentages are given in parentheses.

Treatment		Number and (%)			
Release Depth	**No. of Fish Examined**	**Exclusively LOE**	**Exclusively Scale Loss**	**Visibly Injured**	**Total Maladies**
		Northern pike			
Shallow	28	0	0	19 (67.9%)	19 (67.9%)
Mid	30	0	0	11 (36.7%)	11 (36.7%)
Deep	27	0	0	15 (55.6%)	15 (55.6%)
Total	**85**	**0**	**0**	**45 (52.9%)**	**45 (52.9%)**
		Walleye			
Shallow	28	0	0	13 (46.4%)	13 (46.4%)
Mid	30	1 (3.3%)	0	9 (30.0%)	10 (33.3%)
Deep	37	0	1 (2.7%)	7 (18.9%)	8 (21.6%)
Total	**95**	**1 (1.1%)**	**1 (1.1%)**	**29 (30.5%)**	**31 (32.6%)**
		Lake whitefish			
Shallow	2	0	0	1 (50.0%)	1 (50.0%)
Mid	3	0	0	0 (0.0%)	0 (0.0%)
Deep	9	0	0	1 (11.1%)	1 (11.1%)
Total	**14**	**0**	**0**	**2 (14.3%)**	**2 (14.3%)**

*Mechanical, shear, or pressure injuries may have been due to multiple forces or one acting singularly.

Table 3-6

Estimated clean fish probabilities (CFE) for northern pike and walleye released into the intake of turbine Unit 2 at the Kelsey GS, June 2006.

	Species	
	Northern pike	**Walleye**
Clean Fish Estimate (CFE)	0.471	0.674
Standard Error (SE)	0.054*	0.048*

* Multiply standard errors (SE) by 1.645 to obtain 90% confidence intervals. For example, the confidence limits for highest SE of 0.054 is ± 0.089.

FIGURES

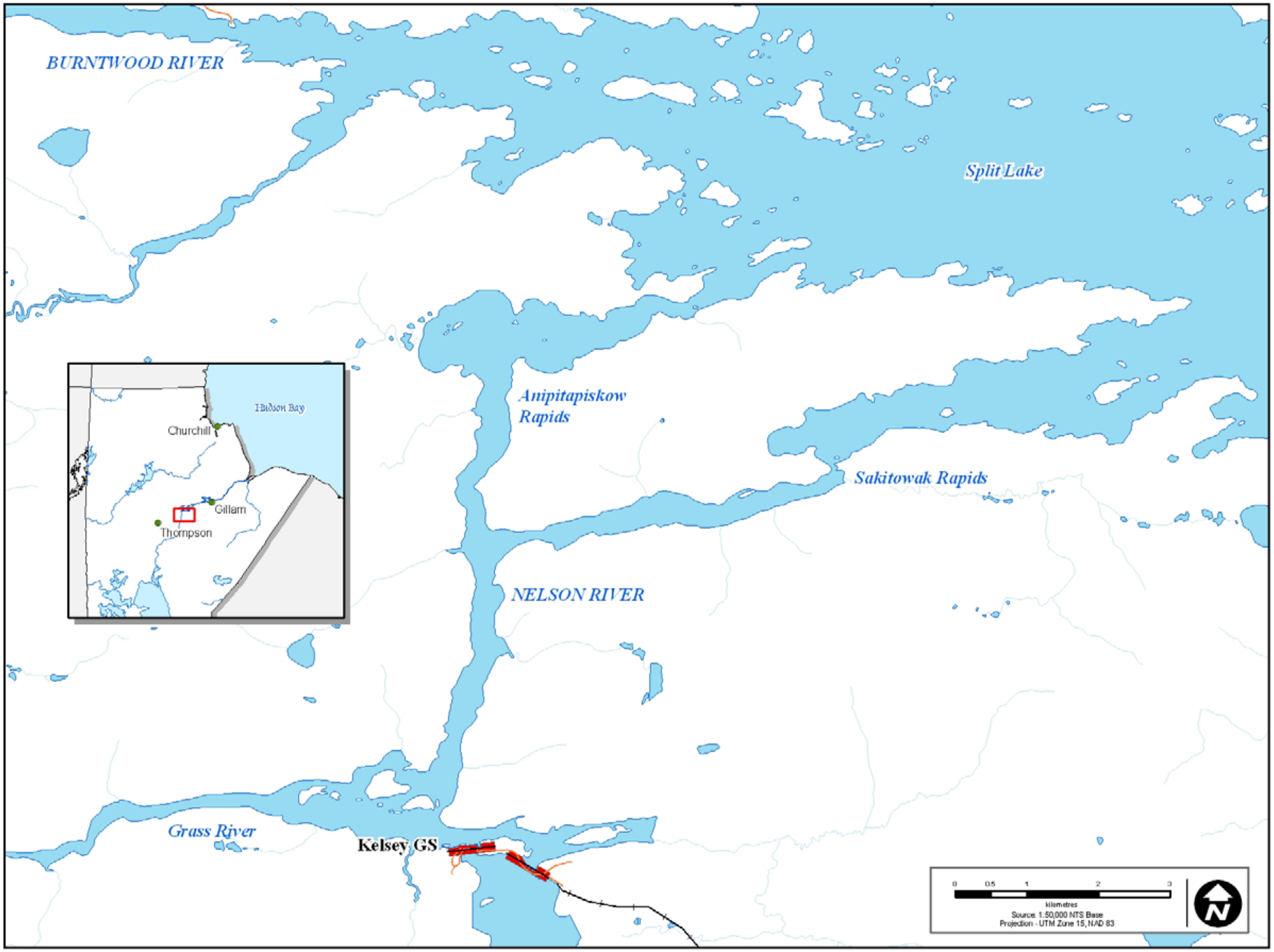


Figure 1-1 Location of Kelsey GS in northern Manitoba.

Figure 1-2

Overview of the Kelsey GS.

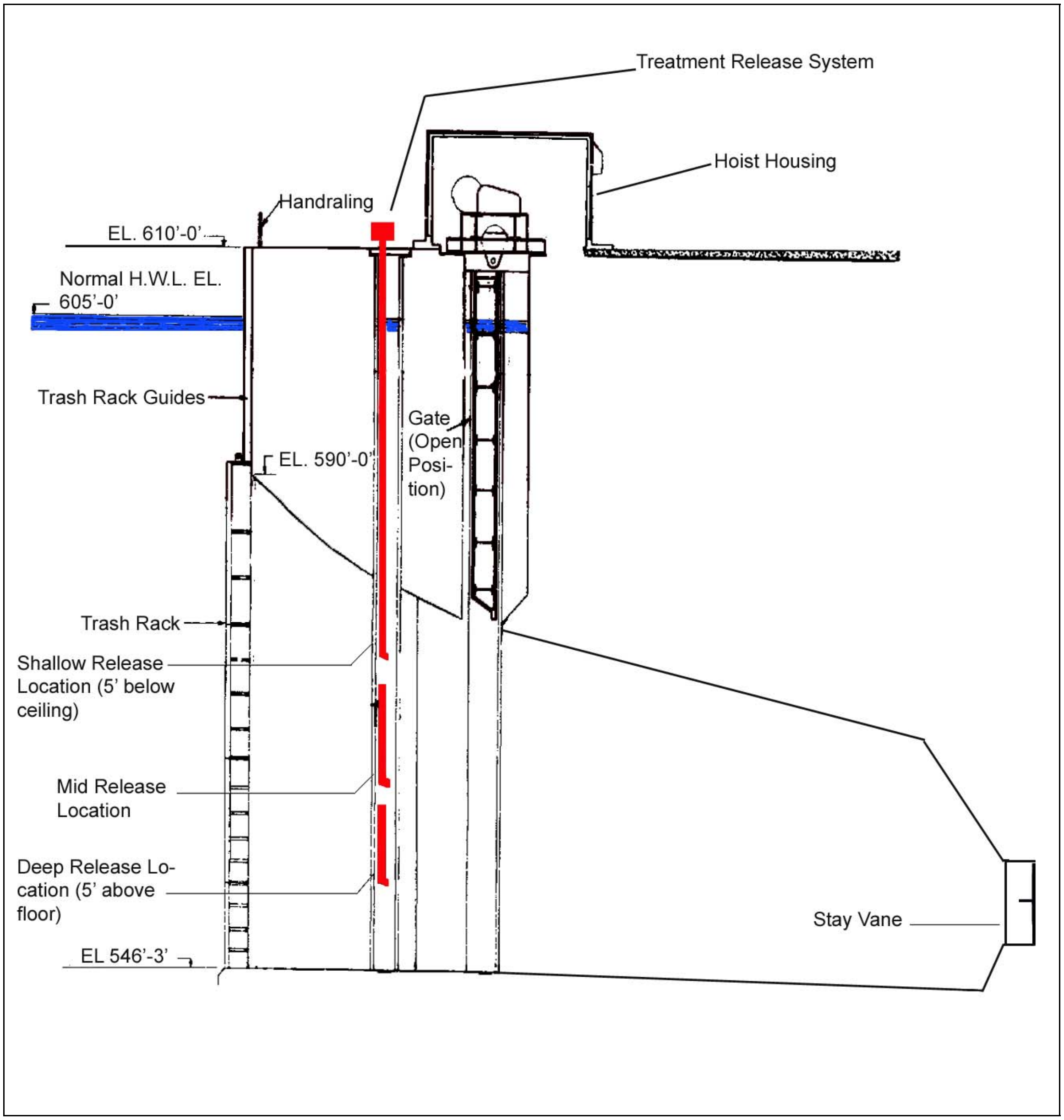


Figure 2-1

Cross-section of the Kelsey GS head works and intake with schematic of treatment fish release system and locations.

Figure 2-2

Control site and release hose extending into Nelson River.

Figure 2-3

Holding facility for transported fish located on the intake deck of the Kelsey GS.

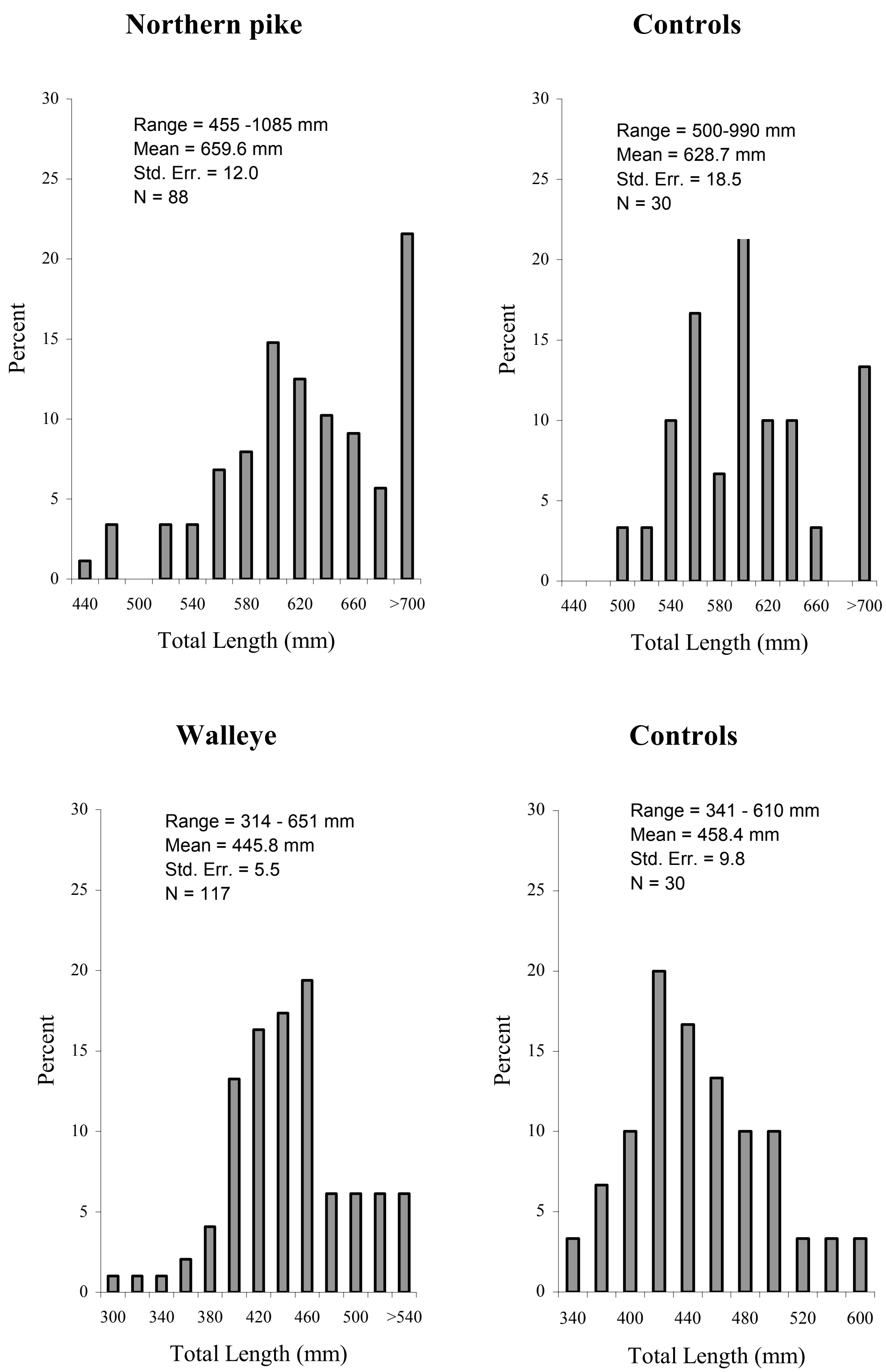


Figure 2-4

Total length (mm) frequency distribution of treatment and control northern pike and walleye released through Kelsey GS, June 2006.

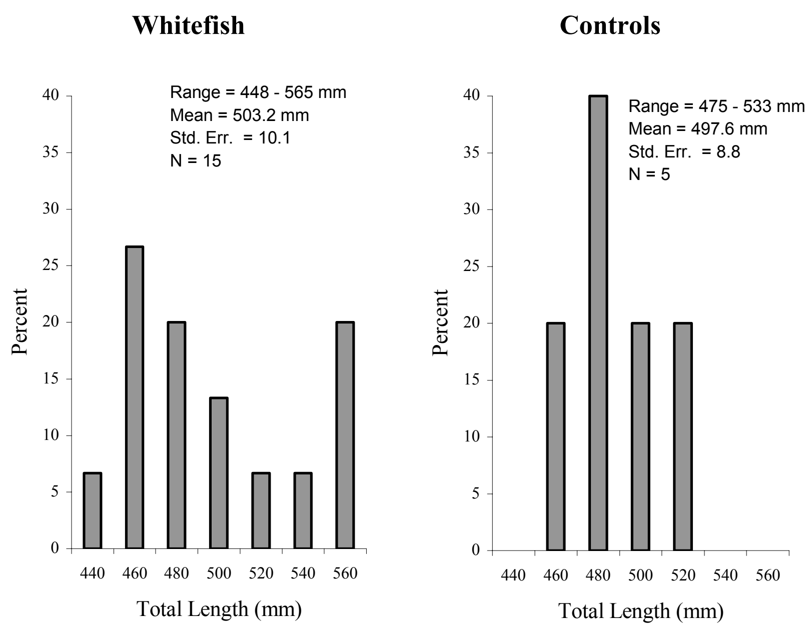


Figure 2-4 (cont.)

Total length (mm) frequency distribution of treatment and control lake whitefish released through the Kelsey GS, June 2006.

Figure 2-5

HI-Z balloon tagged fish. Upper photo uninflated; lower photo inflated balloons.

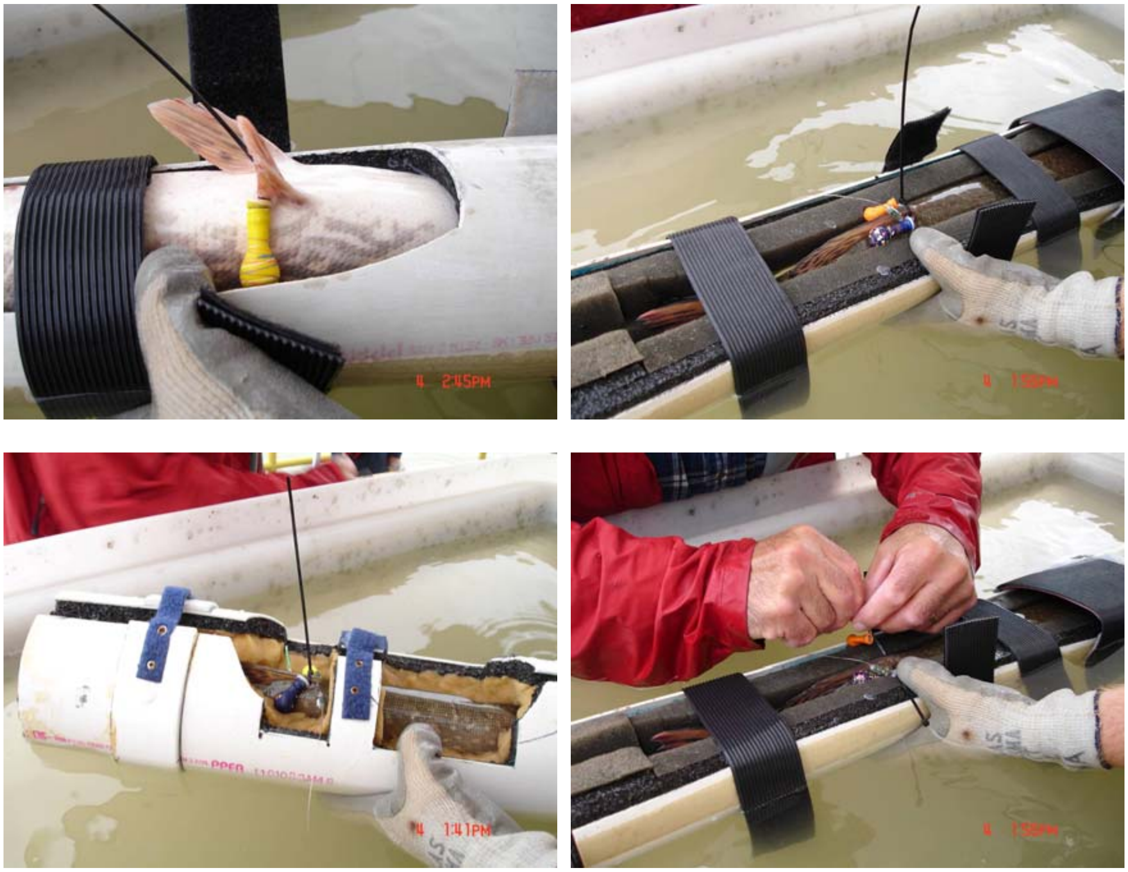


Figure 2-6

HI-Z tag attachment to adult fish while in restraint device at the Kelsey GS.

Figure 2-7

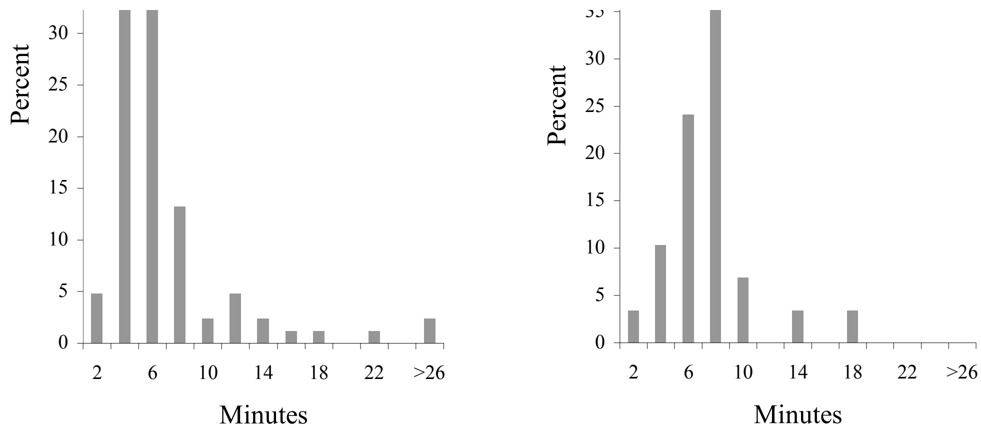
Induction apparatus (upper) and release pipe (lower) for introducing fish into turbine Unit 2 intake at the Kelsey GS.

Figure 2-8

Steel support frame and lower section of the 20 cm diameter PVC release pipe used to release fish into Unit 2 intake at the Kelsey GS.

Figure 2-9

Tracking boats and boat crews retrieving HI-Z tagged fish after being buoyed to the surface downstream of the Kelsey GS.



Walleye **Controls**

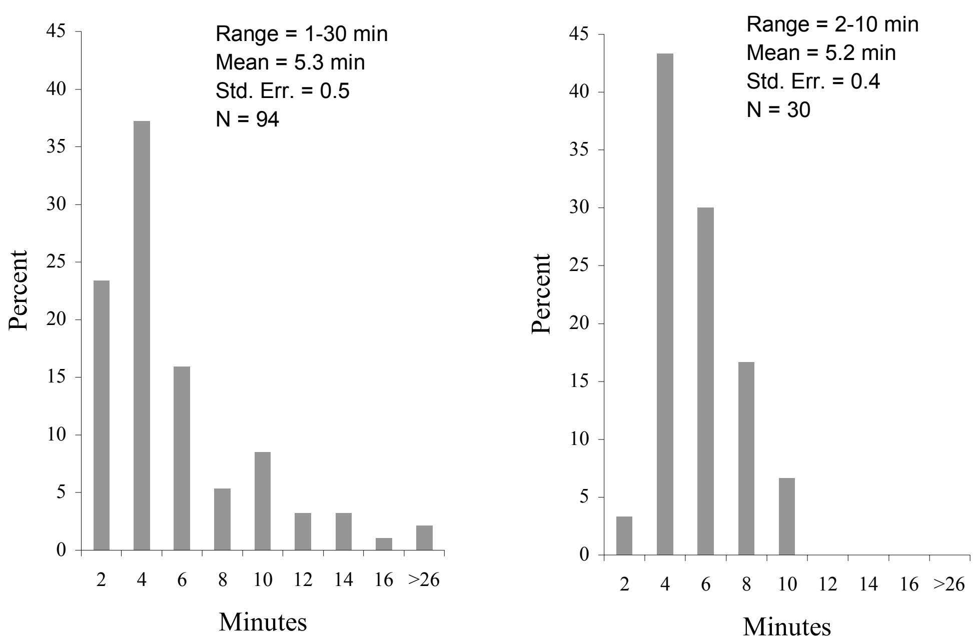


Figure 3-1

Frequency distribution of recapture times (minutes) of treatment and control northern pike and walleye released through the Kelsey GS, June 2006.

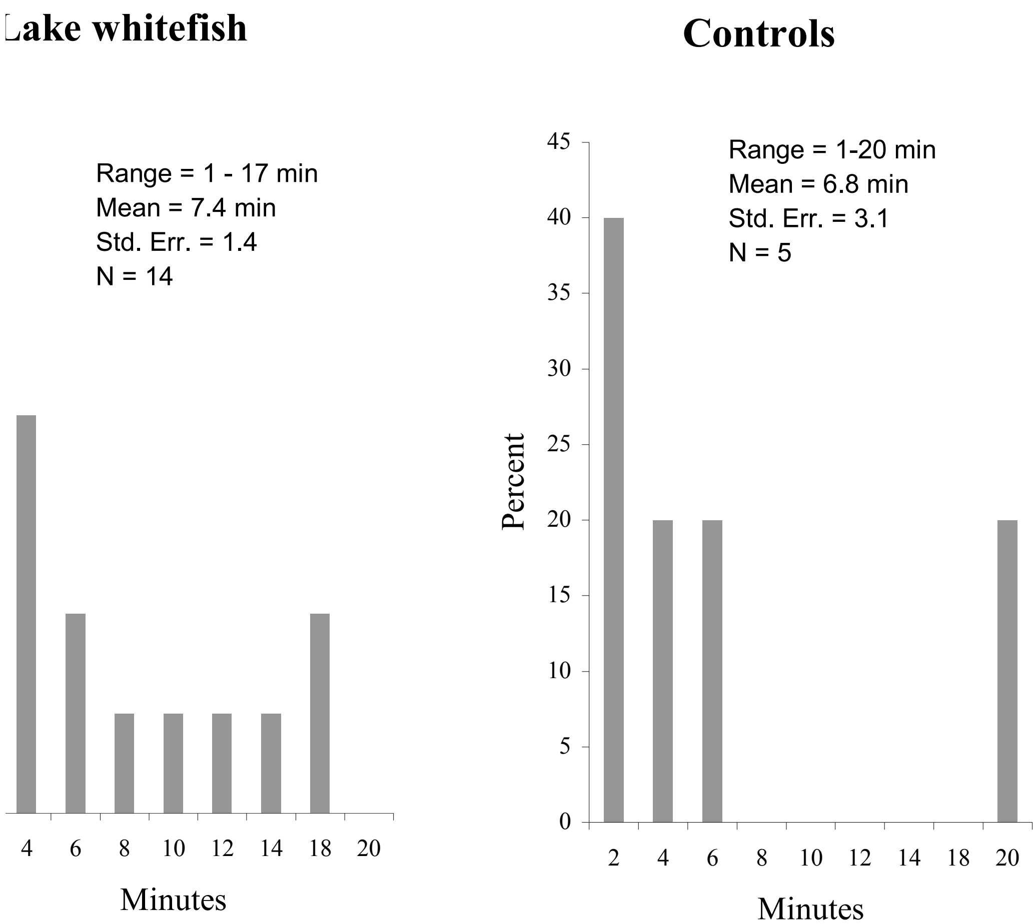
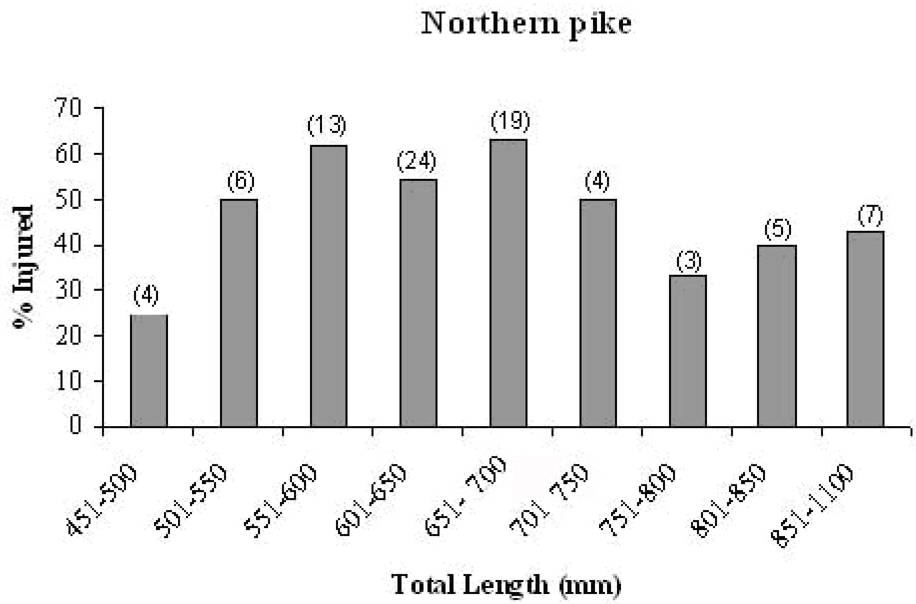


Figure 3-1 (cont.)

Frequency distribution of recapture times (minutes) of treatment and control lake whitefish released through the Kelsey GS, June 2006.



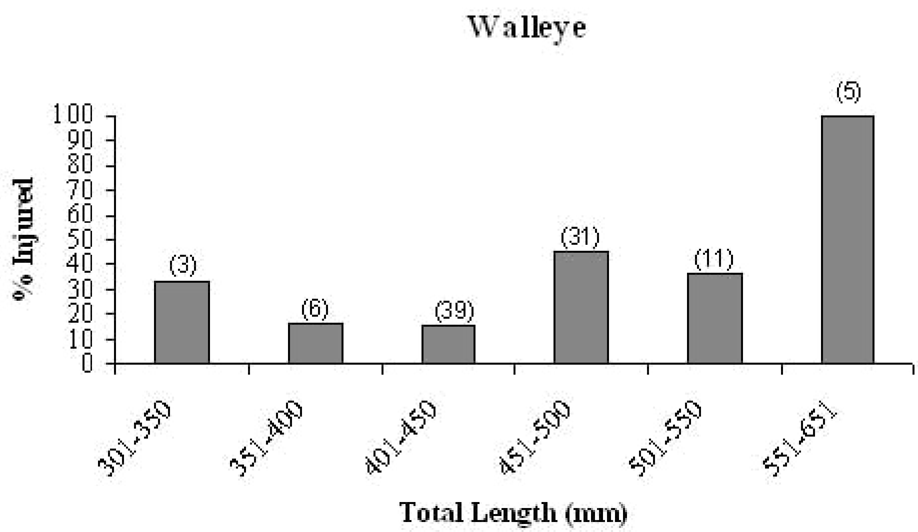


Figure 3-2

Relationship of turbine passage related injury versus total length of northern pike and walleye in passage through the Kelsey GS, June 2006. Number of fish examined post-passage in each length group is given in parentheses.

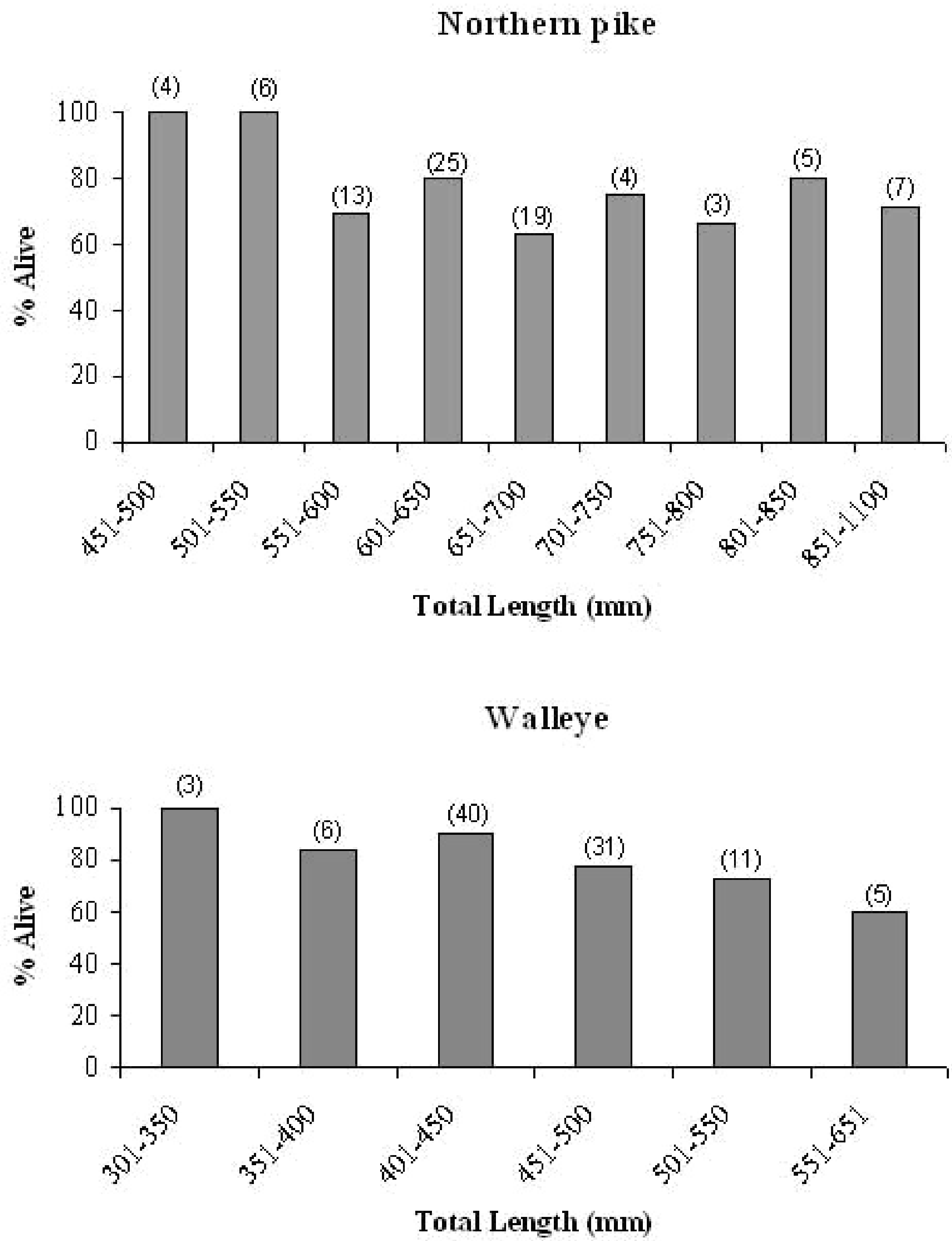


Figure 3-3b Relationship of turbine passed alive fish versus total length of northern pike and walleye in passage through Unit 2 of the Kelsey GS, June 2006. Number of fish examined post-passage in each length group is given in parentheses.

APPENDIX A
INDIVIDUAL FISH AND INJURY DATA

Appendix Table A-1

Short term passage survival data on individual fish for northern pike, walleye, and lake whitefish released into turbine Unit 2 intake at three release locations, shallow, mid, and deep; 1.5m below intake ceiling, midway above the turbine intake (approx. 5.5m) and 1.5m above the bottom, respectively. Control fish were released downstream of the turbine discharge at the Kelsey GS, June 2006. Description of codes and details on injured fish are presented in Table 2-3 and Appendix Table B.

	Total	Time					Status Codes			
Fish ID	Length (mm)	Released	Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	1	2	3	4
2-Jun		**Test Lot 1**		**Deep - Walleye**		**Water temp = 10.6 °C**				
1	465	18:07	18:10	3	3	1	A			*
2	440	18:05	18:10	5	3	1	A			
3-Jun		**Test Lot 2**		**Deep - Walleye**		**Water temp = 10.8 °C**				
3	445	9:08			0	4	S			
4	522	9:58	10:02	4	4	1	A			S
5	456	10:09	10:12	3	4	1	A			S
6	520	10:26	10:28	2	4	1	A			S
7	445	10:38	10:41	3	4	1	A			
8	422	10:47	10:50	3	4	1	A			
9	474	10:54	11:03	9	3	1	A			
10	420	11:18	11:20	2	4	1	A			
11	417	11:27	11:30	3	2	2	*	6		
12	530	11:35	11:42	7	4	1	A			
13	412	11:52	11:54	2	4	1	A			
14	430	12:00	12:03	3	4	1	A			

Appendix Table A-1 Continued

Fish ID	Total Length (mm)	Time Released	Time Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	Status Codes 1	Status Codes 2	Status Codes 3	Status Codes 4
18	413	12:36	12:41	5	4	1	A			
19	425	12:43	12:45	2	4	1	A			
20	434	12:56	13:00	4	2	2	*	6		
21	439	13:02	13:06	4	4	1	A			
22	474	13:08	13:12	4	4	1	A			
23	488	13:15	13:28	13	4	1	A			
24	504	13:20			0	3				
25	453	13:37	13:40	3	4	1	A			
26	446	13:50	14:00	10	4	1	A			
27	434	14:01	14:07	6	4	1	A			
28	500	14:13	14:20	7	4	1	A			
29	483	14:20	14:23	3	4	1	A			
30	445	14:26	14:30	4	4	1	A			
31	437	14:37	14:40	3	2	2	*	6		
32	492	14:42			0	5	R			
33	508	14:49	14:54	5	4	1	A			
34	393	14:55	14:59	4	4	1	A			
35	435	15:13	15:17	4	4	1	A			
36	444	15:20	15:22	2	4	1	A			
37	520	15:25	15:30	5	4	1	*	E		
38	470	15:33	15:36	3	2	2	*	6		

Appendix Table A-1 Continued

Fish ID	Total Length (mm)	Time Released	Time Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	Status Codes 1	Status Codes 2	Status Codes 3	Status Codes 4
39	423	15:37	15:42	5	4	1	A			
40	503	15:43	15:48	5	2	2	*	6		
4-Jun		**Test Lot 3**		**Deep -Northern pike**		**Water temp = 11.1 °C**				
16	590	11:55	11:58	3	4	1	A			
17	695	12:07	12:13	6	3	1	A			
18	733	12:25	12:30	5	4	2	*		6	
19	660	13:06	13:10	4	4	1	W	*		
20	602	13:15	13:18	3	4	1	*	E	W	
21	495	13:22	13:26	4	4	1		W		
22	657	13:34	13:37	3	4	1	H	*		S
23	493	13:41	13:45	4	4	1	G	9	*	S
24	455	13:49	13:53	4	4	1	W			
25	640	13:57	14:00	3	2	1	A			
26	685	14:07	14:12	5	4	2	*		6	
27	592	14:16	14:19	3	4	2	*	6		
29	665	14:31	14:37	6	4	1		9		
30	652	14:38	14:46	8	4	1	9			
28	521	14:23	14:31	8	4	1	E	*		
31	665	14:45	14:56	11	4	1	E	9	*	
32	540	14:53	15:09	16	2	1	A			
33	631	15:04	15:17	13	4	1	G			

Appendix Table A-1 Continued

Fish ID	Total Length (mm)	Time Released	Time Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	Status Codes 1	Status Codes 2	Status Codes 3	Status Codes 4
34	620	15:11	15:18	7	4	2	*	6		
35	905	15:20	15:25	5	4	2	*	6		
46	615	17:20	17:26	6	4	1	A			
47	600	17:26	17:30	4	4	2	H	G	*	
48	590	17:32	17:40	8	4	1	9			*
49	605	17:40	17:46	6	4	1	H	E	9	*
50	576	17:47	17:51	4	4	2	*	5	6	8
51	544	17:54	17:57	3	4	1	W			
52	575	17:59	18:20	21	4	1	A			
4-Jun		**Test Lot 3**		**Deep - Lake whitefish**		**Water temp = 11.1 °C**				
36	470	15:36			0	4	X			
37	470	15:44	15:55	11	3	1	5			
38	550	16:00	16:17	17	4	1	A			
39	448	16:27	16:44	17	2	2	8	G	W	*
40	490	16:39	16:44	5	4	1	A			
41	562	16:48	16:50	2	4	1	A			
42	565	16:53	16:56	3	4	1	9			
43	480	16:58	17:06	8	4	1	A			
44	470	17:05	17:06	1	4	1	A			
45	565	17:10	17:16	6	4	1	A			

Appendix Table A-1 Continued

Fish ID	Total Length (mm)	Time Released	Time Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	Status Codes 1	2	3	4
4-Jun		**Test Lot 3**		**Controls - Walleye**		**Water temp = 11.1 °C**				
1	426	8:56	8:58	2	4	1	A			
2	432	9:01	9:05	4	4	1	A			
3	435	9:08	9:12	4	4	1	A			
4	462	9:28	9:34	6	4	1	A			
5	435	9:34	9:39	5	4	1	A			
6	341	9:40	9:43	3	4	1	A			
7	538	9:47	9:53	6	4	1	A			
8	510	9:55	10:01	6	4	1	A			
9	441	9:58	10:05	7	4	1	A			
10	440	10:09	10:13	4	4	1	A			
11	430	10:15	10:18	3	4	1	A		S	
12	468	10:19	10:28	9	4	1	A			
13	395	10:23	10:28	5	4	1	A			
14	451	10:30	10:33	3	4	1	A			
15	415	10:36	10:44	8	4	1	A			
5-Jun		**Test Lot 4**		**Shallow - Walleye**		**Water temp = 11.4 °C**				
24	470	13:05	13:15	10	3	1	E	*		
25	427	13:16	13:18	2	4	1	A			
26	386	13:21	13:22	1	4	1	A			

Appendix Table A-1 Continued

Fish ID	Total Length (mm)	Time Released	Time Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	Status Codes 1	Status Codes 2	Status Codes 3	Status Codes 4
27	502	13:28	13:32	4	4	2	E	H	*	
28	460	13:34	13:36	2	4	1	A			
29	441	13:40	13:42	2	4	1	A			
30	415	13:44	13:46	2	4	1	A			
31	408	13:48	13:53	5	4	1	A			
32	451	13:54				4	X			
33	408	14:00	14:03	3	4	1	A			
34	370	14:08	14:11	3	4	1	A			
35	554	14:22	14:25	3	4	1	H	*	E	9
37	490	14:35	14:40	5	4	2	E	*	S	
38	486	14:41	14:45	4	4	2	*	6		
39	418	14:47	14:49	2	4	1	A			
40	473	14:57	14:59	2	4	1	A			S
41	466	15:02	15:07	5	4	1	A			
42	437	15:09	15:11	2	4	1		*	E	
43	461	15:15	15:18	3	4	1	A			S
44	414	15:22	15:24	2	4	1	A			
45	465	15:29	15:32	3	4	2	H	6	*	
46	470	15:34	15:44	10	4	1		*	E	
47	520	15:42	15:45	3	4	2	9	*		
48	593	15:50				5	R	T		

Appendix Table A-1 Continued

Fish ID	Total Length (mm)	Time Released	Time Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	Status Codes 1	Status Codes 2	Status Codes 3	Status Codes 4
49	635	15:56	16:10	14	4	2	*	7		
50	469	16:11	16:13	2	4	1	W	E	*	
51	375	16:26	16:29	3	4	1	A			
52	410	16:32	16:34	2	4	1	E	9	*	
53	468	16:37	16:44	7	4	1	H	*	9	
36	395	14:30	14:32	2	4	1	A			
5-Jun		**Test Lot 4**		**Controls - Lake whitefish**		**Water temp = 11.4 °C**				
1	475	8:23	8:26	3	4	1	A			
2	485	8:28	8:48	20	4	1	A			
3	495	8:34	8:36	2	4	1	A			
4	533	8:43	8:51	8	4	1	A			
5	500	8:59	9:00	1	4	1	A			
5-Jun		**Test Lot 4**		**Controls - Northern pike**		**Water temp = 11.4 °C**				
6	990	9:18	9:23	5		1	Q			
7	650	9:52	9:59	7	4	1	A			
8	611	10:00	10:05	5	4	1	A			
9	605	10:08	10:11	3	4	1	A			
10	590	10:14	10:20	6	4	1	A			
11	608	10:21	10:28	7	4	1	A			S
12	660	10:31	10:39	8	4	1	A			

Appendix Table A-1 Continued

Fish ID	Total Length (mm)	Time Released	Time Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	Status Codes 1	Status Codes 2	Status Codes 3	Status Codes 4
13	645	10:40	10:54	14	4	1	A			
14	600	10:48	10:55	7	4	1	A			
15	548	11:06	11:08	2	4	1	A			S
16	625	11:12	11:20	8	4	1	A			
17	530	11:22	11:27	5	4	1	A			
18	645	11:28	11:37	9	4	1	A			
19	618	11:34	11:41	7	4	1	A			
20	577	11:40	11:47	7	4	1	A			
21	578	11:47	11:54	7	4	1	A			
22	552	11:53	11:59	6	4	1	A			
23	570	12:00	12:04	4	4	1	A			S
6-Jun		**Test Lot 5**		**Shallow - Northern pike**		**Water temp = 11.9 °C**				
16	612	11:30	11:34	4	4	1	A			
17	632	11:34	11:40	6	4	1	E	5	*	
18	595	11:41	11:44	3	4	1	E	*		
19	659	11:46	11:52	6	1	2	*	E	9	
20	637	11:53	11:56	3	4	1	*	9	5	S
21	925	12:05	12:11	6	6	1	E	W	*	
22	650	12:12				3				
23	630	12:53	12:59	6	4	1	A			S
24	630	12:58	13:05	7	2	2	*	6		

Appendix Table A-1 Continued

Fish ID	Total Length (mm)	Time Released	Time Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	Status Codes 1	Status Codes 2	Status Codes 3	Status Codes 4
25	586	13:05	13:12	7	4	1	E	5	*	
26	812	13:15	13:18	3	4	1	*	E	5	
27	592	13:23	13:28	5	4	1	*	W		
28	710	13:30	13:35	5	4	1	A			
29	675	13:42	13:46	4	2	2	*	6		
30	620	13:47	13:52	5	4	1	E	*		
31	965	13:58	14:01	3	4	1	A			
32	680	14:04	14:09	5	4	1	A			
33	635	14:12				3				
34	678	14:34	14:38	4	4	2	*	6		
35	613	14:42	15:00	18	2	1	A			
36	692	14:49	14:55	6	4	2	S	E	W	*
37	613	14:59	15:03	4	4	2	H	E	8	*
38	640	15:04	15:10	6	4	2	*	6		
39	575	15:10	15:12	2	4	2	*	8	E	
40	670	15:16	15:22	6	4	1	A			
41	633	15:41	15:46	5	4	1	A			
42	603	15:46	15:51	5	4	1	E	*		
43	653	15:52	16:05	13	4	1	E	*		
44	481	16:00	16:12	12	4	1	A			
45	526	16:06	16:10	4	4	1	E	*		

Appendix Table A-1 Continued

Fish ID	Total Length (mm)	Time Released	Time Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	Status Codes 1	2	3	4
6-Jun		**Test Lot 5**		**Shallow - Lake whitefish**		**Water temp =11.9 °C**				
46	502	14:21	14:25	4	4	1	A			
47	528	14:27	14:41	14	4	1	H			
6-Jun		**Test Lot 5**		**Control - Walleye**		**Water temp = 11.9 °C**				
1	392	8:40	8:43	3	4	1	A			
2	410	8:45	8:49	4	4	1	A			
3	461	8:51	8:56	5	4	1	A			
4	452	8:56	9:00	4	4	1	A			
5	408	9:02	9:05	3	4	1	A			
6	485	9:09	9:13	4	4	1	A			
7	467	9:14	9:20	6	4	1	A			
8	458	9:20	9:24	4	4	1	A			
9	497	9:26	9:30	4	4	1	A			
10	610	9:42	9:49	7	4	1	A			
11	428	9:49	9:57	8	4	1	A			
12	488	9:54	10:04	10	4	1	A			
13	500	10:01	10:08	7	4	1	A			
14	572	10:09	10:15	6	4	1	A			
15	505	10:13	10:19	6	4	1	A			

Appendix Table A-1 Continued

Fish ID	Total Length (mm)	Time: Released	Time: Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	Status Codes: 1	2	3	4
7-Jun		**Test Lot 6**		**Mid - Walleye**		**Water temp = 12.2 °C**				
13	469	10:40	10:51	11	1	2	*	6	W	S
14	447	10:46	10:56	10	4	1	A			S
15	505	10:58				4	Q	T		S
16	440	11:06	11:14	8	4	1	A			S
17	545	11:12	11:41	29		1	Q	S		
18	651	11:23	11:35	12	4	1	9	*	E	W
19	460	11:30	11:36	6	4	1	A			
20	440	11:55	11:59	4	4	1	A			
21	484	12:05	12:08	3	4	1	A			
22	314	12:01	12:06	5	4	1	A			
23	457	13:27	13:31	4	4	1	A			
24	419	13:32	13:34	2	4	1	A			
25	576	13:38	13:40	2	4	2	*	6		
26	469	13:43	13:56	13	4	1	*	E		
27	341	13:47	13:48	1	2	1	A			
28	431	13:52	13:55	3	4	1	A			
29	495	13:58	14:03	5	4	1	W	*		
30	458	14:04	14:32	28	4	2	*	6		
31	460	14:10	14:22	12	4	1	A			S
32	414	14:15	14:24	9	4	1	A			S

Appendix Table A-1 Continued

Fish ID	Total Length (mm)	Time Released	Time Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	Status Codes 1	Status Codes 2	Status Codes 3	Status Codes 4
33	446	14:19	14:24	5	4	1	A			S
34	430	14:30	14:33	3	4	2	*	6		S
35	432	14:35	14:41	6	4	1	A			S
36	520	14:42	14:57	15	4	1	A			S
37	465	14:47	14:57	10	4	1	A			S
38	453	15:00	15:04	4	4	1	A			S
39	599	15:12	15:22	10	4	1	E	*		S
40	465	15:17	15:20	3	4	2	*	6		S
41	504	15:26	15:56	30	4	1	A		S	
42	413	15:31	15:38	7	4	1	A			S
43	320	15:36	15:40	4	4	1	H		*	
7-Jun		**Test Lot 6**		**Control - Northern pike**		**Water temp = 12.2 °C**				
1	612	8:30	8:40	10	3	1	A			
2	595	8:40	8:47	7	4	1	A			
3	635	8:46	8:53	7	4	1	A			
4	920	8:56	9:13	17	4	1	A			
5	638	9:05	9:09	4	4	1	A		S	
6	762	9:14	9:21	7	4	1	A			
7	547	9:21	9:27	6	4	1	A			
8	608	9:27	9:34	7	4	1	A			
9	706	9:33	9:41	8	4	1	A			

Appendix Table A-1 Continued

	Total	Time					Status Codes			
Fish ID	Length (mm)	Released	Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	1	2	3	4
10	570	9:39	9:45	6	4	1	A			
11	566	9:46	9:51	5	4	1	A			
12	500	9:52	10:00	8	4	1	A			
8-Jun		**Test Lot 7**		**Mid - Northern pike**		**Water temp = 12.8 °C**				
1	622	8:10	8:12	2	4	1	A			S
2	635	8:15	8:17	2	2	1	E	*	6	S
3	615	8:22	8:24	2	4	1	A			S
4	602	8:27	8:37	10	4	1	*	E	W	S
5	754	8:34	8:40	6	4	2	*	6		S
6	840	8:45	8:48	3	4	2	E	6	*	S
7	820	8:53	8:57	4	4	1	H			S
8	762	9:01	9:30	29		1	Q	S		
9	831	9:10	9:17	7	4	1	A			S
10	578	9:16	9:20	4	3	1	A			S
11	596	9:33	9:39	6	4	1		W		S
12	560	9:39	9:47	8	4	1	A			S
13	765	9:47	9:53	6	4	1	A			S
14	890	9:56	10:51	55	6	1	A		S	
15	651	10:02	10:08	6	4	1	A		S	
16	615	10:08				4	S			
17	664	10:15	10:22	7	2	2	*	6	S	

Appendix Table A-1 Continued

Fish ID	Total Length (mm)	Time Released	Recovered	Minutes at large	No. HI-Z tags recovered	Survival Code	Status Codes 1	2	3	4
18	724	11:01	11:09	8	4	1	A		U	*
19	692	11:07	11:10	3		2	6	U	*	
20	810	11:14	11:17	3	4	1		U		W
21	712	11:25	11:36	11	4	1	A			U
22	603	11:30	11:40	10	4	1	A			U
23	610	11:36	11:42	6	4	1	A			U
24	535	11:46	11:52	6	4	1	*	5		U
25	570	11:52	12:03	11	4	2	*	7		U
26	651	11:59	12:03	4	2	1	*	5		U
27	897	12:12	12:40	28		1				U
28	548	12:31	12:37	6	4	1	A			U
29	661	12:36	12:44	8	4	1	A			U
30	922	13:12	14:00	48		1	Q			S
34	1085	13:38	13:42	4	9	2	*	6	U	
8-Jun		**Test Lot 7**		**Mid - Lake whitefish**		**Water temp = 12.8 °C**				
31	488	12:48	12:51	3	4	1			5	U
32	460	12:53	13:03	10	4	1	A			U
33	500	12:59	13:02	3	4	1	A			U

Appendix Table A-2

Incidence of injury, scale loss, and temporary loss of equilibrium (LOE) observed on northern pike, walleye, and lake whitefish released into turbine Unit 2 intake at three release locations, shallow, mid, and deep (1.5m below intake ceiling, 5.5m below intake ceiling and 1.5m above the bottom, respectively). Control fish were released downstream of the turbine discharge at the Kelsey GS, June 2006.

Scenario	Species and Release Location	Date	Lot	ID #	Alive/ Dead	HR	Injury Description/Comments	Passage Related Malady	Photo	Mechanism	Severity
1	Walleye - Deep	6/2/06	1	1	alive	48h	Major scale loss on caudal peduncle	Yes	Yes	mechanical	minor
1	Walleye - Deep	6/3/06	2	11	dead	1h	Severed body at dorsal fin	Yes	Yes	mechanical	major
1	Walleye - Deep	6/3/06	2	17	dead	1h	Cut 3/4 through the body (nearly severed), Severed backbone	Yes	Yes	mechanical	major
1	Walleye - Deep	6/3/06	2	20	dead	1h	Severed body between dorsal fins, recovered both halves, cut between pelvic fins	Yes	Yes	mechanical	major
1	Walleye - Deep	6/3/06	2	31	dead	1h	Severed body just behind head	Yes	Yes	mechanical	major
1	Walleye - Deep	6/3/06	2	37	dead	24h	Severe laceration on dorsal side of caudal peduncle, broken backbone	Yes	Yes	mechanical	major
1	Walleye - Deep	6/3/06	2	38	dead	1h	Severed body at dorsal fin	Yes	Yes	mechanical	major
1	Walleye - Deep	6/3/06	2	40	dead	1h	Severed body at dorsal fin	Yes	Yes	mechanical	major
2	Northern Pike - Deep	6/4/06	3	18	dead	1h	Severed body at pelvic fins	Yes	Yes	mechanical	major
2	Northern Pike - Deep	6/4/06	3	19	dead	48h	Skin cut and abrasion on top of head, laceration on right side of caudal peduncle	Yes	Yes	mechanical	major
2	Northern Pike - Deep	6/4/06	3	20	alive	48h	Scrape on left mandible, small cut above left eye and operculum	Yes	Yes	mechanical	minor

Appendix Table A-2 **Continued**

Scenario	Species and Release Location	Date	Lot	ID #	Alive/ Dead	HR	Injury Description/Comments	Passage Related Malady	Photo	Mechanism	Severity
2	Northern Pike - Deep	6/4/06	3	22	dead	24h	Scraped left side behind operculum Acoustic tagged fish	Yes	Yes	mechanical	major
2	Northern Pike - Deep	6/4/06	3	23	alive	48h	Bruise on middle of back Torn right operculum Acoustic tag inserted	Yes	No	mechanical/ shear	major
2	Northern Pike - Deep	6/4/06	3	26	dead	1h	Severed body at pectoral fins	Yes	Yes	mechanical	major
2	Northern Pike - Deep	6/4/06	3	27	dead	1h	Severed body in front of pelvic fins	Yes	Yes	mechanical	major
2	Northern Pike - Deep	6/4/06	3	28	alive	48h	Laceration above anal fin left side	Yes	Yes	mechanical	minor
2	Northern Pike - Deep	6/4/06	3	31	alive	48h	Skin torn and missing on top of head, operculum damage	Yes	Yes	mechanical	major
2	Northern Pike - Deep	6/4/06	3	34	dead	1h	Severed body at dorsal fin	Yes	Yes	mechanical	major
2	Northern Pike - Deep	6/4/06	3	35	dead	1h	Severed body near pelvic fins	Yes	Yes	mechanical	major
2	Northern Pike - Deep	6/4/06	3	47	dead	1h	Left side of head crushed	Yes	No	mechanical	major
2	Northern Pike - Deep	6/4/06	3	48	alive	48h	Torn right operculum	Yes	Yes	shear	minor
2	Northern Pike - Deep	6/4/06	3	49	dead	48h	Torn right mandible, damaged right eye	Yes	Yes	shear	major
2	Northern Pike - Deep	6/4/06	3	50	dead	1h	Missing half of lower mandible and operculum left side, damaged right eye, Major scale loss left side below lateral line	Yes	Yes	mechanical	major

Appendix Table A-2 **Continued**

Scenario	Species and Release Location	Date	Lot	ID #	Alive/ Dead	HR	Injury Description/Comments	Passage Related Malady	Photo	Mechanism	Severity
3	Lake Whitefish - Deep	6/4/06	3	39	dead	1h	Crushed head on right side, damaged right eye	Yes	Yes	mechanical	major
3	Lake Whitefish - Deep	6/4/06	3	42	dead	24h	Hemorrhaged head, operculum and fins was pre-release	No	Yes	N/A	N/A
4	Walleye - Mid	6/7/06	6	13	dead	1h	Severed body between dorsal fins; Acoustic tagged fish	Yes	Yes	mechanical	major
4	Walleye - Mid	6/7/06	6	18	alive	48h	Damaged upper jaw right side, Abrasion and hemorrhaged around mouth	Yes	Yes	mechanical	minor
4	Walleye - Mid	6/7/06	6	25	dead	1h	Missing most of head	Yes	Yes	mechanical	major
4	Walleye - Mid	6/7/06	6	26	alive	48h	Cut on lower jaw left side	Yes	No	mechanical	minor
4	Walleye - Mid	6/7/06	6	29	alive	48h	Abrasion on snout	Yes	No	mechanical	minor
4	Walleye - Mid	6/7/06	6	30	dead	1h	Head missing eyes to front	Yes	Yes	mechanical	major
4	Walleye - Mid	6/7/06	6	34	dead	1h	Severed body at anal fin; Acoustic tag inserted	Yes	Yes	mechanical	major
4	Walleye - Mid	6/7/06	6	39	alive	48h	Cut in center of upper mandible; Acoustic tag inserted	Yes	Yes	mechanical	minor
4	Walleye - Mid	6/7/06	6	40	dead	1h	Missing left portion of head, Acoustic tag inserted	Yes	Yes	mechanical	major
4	Walleye - Mid	6/7/06	6	43	alive	48h	LOE	Yes	No	undetermined	

Appendix Table A-2 **Continued**

Scenario	Species and Release Location	Date	Lot	ID #	Alive/ Dead	HR	Injury Description/Comments	Passage Related Malady	Photo	Mechanism	Severity
5	Northern Pike - Mid	6/8/06	7	2	dead	24h	Severe cut (nearly severed) at caudal peduncle, Acoustic tag inserted	Yes	Yes	mechanical	major
5	Northern Pike - Mid	6/8/06	7	4	dead	24h	Broken upper jaw, scrape on middle of back; Floy tag and acoustic tag inserted	Yes	Yes	mechanical	major
5	Northern Pike - Mid	6/8/06	7	5	dead	1h	Severed body behind pectoral fins Acoustic tag inserted	Yes	Yes	mechanical	major
5	Northern Pike - Mid	6/8/06	7	6	dead	1h	Severed at dorsal fin, Acoustic tag inserted	Yes	Yes	mechanical	major
5	Northern Pike - Mid	6/8/06	7	17	dead	1h	Severed body at dorsal and anal fin, Acoustic tag inserted	Yes	Yes	mechanical	major
5	Northern Pike - Mid	6/8/06	7	18	alive	48h	2" cut in front of dorsal fin, Floy tag only	Yes	Yes	mechanical	major
5	Northern Pike - Mid	6/8/06	7	19	dead	1h	Spotted dead half of fish (visual); Acoustic tag inserted	Yes	No	mechanical	major
5	Northern Pike - Mid	6/8/06	7	24	dead	48h	Left side major scale loss/scrape; Floy tag only	Yes	Yes	mechanical	major
5	Northern Pike - Mid	6/8/06	7	25	dead	1h	Decapitated at pectoral fins; Floy tag only	Yes	Yes	mechanical	major
5	Northern Pike - Mid	6/8/06	7	26	alive	48h	Major scale loss left side, scrape resulting in tissue damage on left side, cut near dorsal and anal fins; Floy tag only	Yes	Yes	mechanical	major

Appendix Table A-2 **Continued**

Scenario	Species and Release Location	Date	Lot	ID #	Alive/ Dead	HR	Injury Description/Comments	Passage Related Malady	Photo	Mechanism	Severity
5	Northern Pike - Mid	6/8/06	7	34	dead	1h	Severed body by dorsal fin Floy tag only	Yes	Yes	mechanical	major
7	Walleye - Shallow	6/5/06	4	24	alive	48h	Small cut near caudal fin on left side	Yes	No	mechanical	minor
7	Walleye - Shallow	6/5/06	4	27	dead	1h	1" cut on left operculum LOE	Yes	Yes	mechanical	major
7	Walleye - Shallow	6/5/06	4	35	alive	48h	Severe laceration on upper mandible into head, LOE	Yes	Yes	mechanical	major
7	Walleye - Shallow	6/5/06	4	37	dead	1h	Upper mandible split back into the head, Lower jaw damage, Acoustic tag inserted	Yes	Yes	mechanical	major
7	Walleye - Shallow	6/5/06	4	38	dead	1h	Severed body at dorsal fin	Yes	Yes	mechanical	major
7	Walleye - Shallow	6/5/06	4	42	alive	48h	Laceration to front of jaw	Yes	No	mechanical	minor
7	Walleye - Shallow	6/5/06	4	45	dead	1h	LOE, Severe laceration from dorsal fin to caudal fin	Yes	Yes	mechanical	major
7	Walleye - Shallow	6/5/06	4	46	dead	24h	Small cut on left side of the upper mandible	Yes	Yes	mechanical	minor
7	Walleye - Shallow	6/5/06	4	47	dead	1h	Left operculum torn to eye, torn right operculum	Yes	Yes	shear	major
7	Walleye - Shallow	6/5/06	4	49	dead	1h	Decapitated at pectoral fins	Yes	Yes	mechanical/ shear	major

Appendix Table A-2 **Continued**

Scenario	Species and Release Location	Date	Lot	ID #	Alive/ Dead	HR	Injury Description/Comments	Passage Related Malady	Photo	Mechanism	Severity
7	Walleye - Shallow	6/5/06	4	50	alive	48h	Small scrape near second dorsal fin cut on upper jaw	Yes	No	mechanical	minor
7	Walleye - Shallow	6/5/06	4	52	alive	48h	Cut on lower jaw, damaged right operculum	Yes	No	mechanical	minor
7	Walleye - Shallow	6/5/06	4	53	alive	48h	LOE, damaged left operculum	Yes	No	shear	minor
8	Northern Pike - Shallow	6/6/06	5	17	alive	48h	Two small cuts on left side of body Major scale loss >20% on left side	Yes	No	mechanical	minor
8	Northern Pike - Shallow	6/6/06	5	18	alive	48h	Small cut on right side of lower jaw	Yes	No	mechanical	minor
8	Northern Pike - Shallow	6/6/06	5	19	dead	1h	Severe Laceration near pelvic fins Both operculi torn	Yes	Yes	mechanical	major
8	Northern Pike - Shallow	6/6/06	5	20	alive	48h	Left operculum torn, major scale loss >20% both sides; Acoustic tag inserted	Yes	No	mechanical/ shear	minor
8	Northern Pike - Shallow	6/6/06	5	21	alive	48h	Small cut near right operculum Some scrapes on body	Yes	No	mechanical	minor
8	Northern Pike - Shallow	6/6/06	5	24	dead	1h	Severed body at dorsal fin	Yes	Yes	mechanical	major
8	Northern Pike - Shallow	6/6/06	5	25	alive	48h	Cut in front of right pelvic fin Major scale loss >20% near cut	Yes	No	mechanical	major
8	Northern Pike - Shallow	6/6/06	5	26	alive	48h	Cut on left mandible Major scale loss >20% behind head on body	Yes	No	mechanical	major
8	Northern Pike - Shallow	6/6/06	5	27	alive	48h	Abrasion on lower and upper jaw	Yes	No	mechanical	minor

Appendix Table A-2 **Continued**

Scenario	Species and Release Location	Date	Lot	ID #	Alive/ Dead	HR	Injury Description/Comments	Passage Related Malady	Photo	Mechanism	Severity
8	Northern Pike - Shallow	6/6/06	5	29	dead	1h	Severed body behind anal fin	Yes	Yes	mechanical	major
8	Northern Pike - Shallow	6/6/06	5	30	alive	48h	Cut on lower jaw	Yes	No	mechanical	major
8	Northern Pike - Shallow	6/6/06	5	34	dead	1h	Severed body behind pectoral fins	Yes	Yes	mechanical	major
8	Northern Pike - Shallow	6/6/06	5	36	dead	1h	Left upper mandible damage/torn, bruise on top of head; Acoustic tag inserted	Yes	Yes	mechanical	major
8	Northern Pike - Shallow	6/6/06	5	37	dead	1h	severe cut on left side of head and lower mandible, ruptured left eye	Yes	Yes	mechanical	major
8	Northern Pike - Shallow	6/6/06	5	38	dead	1h	Severed body at pelvic fins	Yes	Yes	mechanical	major
8	Northern Pike - Shallow	6/6/06	5	39	dead	1h	Ruptured right eye, cut on bottom of both sides of lower mandible	Yes	Yes	mechanical	major
8	Northern Pike - Shallow	6/6/06	5	42	alive	48h	Cut on lower mandible	Yes	No	mechanical	minor
8	Northern Pike - Shallow	6/6/06	5	43	alive	48h	Laceration on right upper jaw into head	Yes	Yes	mechanical	minor
8	Northern Pike - Shallow	6/6/06	5	45	alive	48h	Cut on both upper and lower mandible	Yes	No	mechanical	major
9	Lake Whitefish - Shallow	6/6/06	5	47	dead	24h	LOE, no visible marks on fish	No	No	undetermined	major

*Hemorrhages, bulged, ruptured or missing eyes

Appendix Table A-3

Daily tag recapture data for northern pike, walleye, and lake whitefish released into turbine Unit 2 intake at three release locations, shallow, mid, and deep (1.5m below intake ceiling, 5.5m below intake ceiling and 1.5m above the bottom, respectively). Control fish were released downstream of the turbine discharge at the Kelsey GS, June 2006.

	6/2	6/3	6/4	6/5	6/6	6/7	6/8	Totals
			Walleye					
Deep								
Number released	2	37	--	--	--	--	--	39
Number recovered alive	2	29	--	--	--	--	--	31
Number recovered dead	0	6	--	--	--	--	--	6
Number Acoustic tagged	0	4	--	--	--	--	--	4
Number Acoustic tagged Fish returned to river	0	3	--	--	--	--	--	3
Number assigned dead*	0	1	--	--	--	--	--	1
Dislodged tags	--	1	--	--	--	--	--	1
Stationary signal	--	--	--	--	--	--	--	0
Unknown	0	1	--	--	--	--	--	1
Number held	2	26	--	--	--	--	--	28
Number alive at 48 h	2	25	--	--	--	--	--	27
Mid								
Number released	--	--	--	--	--	31	--	31
Number recovered alive	--	--	--	--	--	26	--	26
Number recovered dead	--	--	--	--	--	5	--	5
Number Acoustic tagged	--	--	--	--	--	16	--	16
Number Acoustic tagged Fish returned to river	--	--	--	--	--	12	--	12
Number assigned dead*	--	--	--	--	--	0	--	0
Dislodged tags	--	--	--	--	--	--	--	0
Stationary signal	--	--	--	--	--	--	--	0
Unknown	--	--	--	--	--	0	--	0
Number held	--	--	--	--	--	13	--	13
Number alive at 48 h	--	--	--	--	--	13	--	13

Appendix Table A-3

	6/2	6/3	6/4	6/5	6/6	6/7	6/8	Totals
Shallow								
Number released	--	--	--	29	--	--	--	29
Number recovered alive	--	--	--	22	--	--	--	22
Number recovered dead	--	--	--	6	--	--	--	6
Number Acoustic tagged	--	--	--	3	--	--	--	3
Number Acoustic tagged Fish returned to river	--	--	--	2	--	--	--	2
Number assigned dead*	--	--	--	0	--	--	--	0
Dislodged tags	--	--	--	--	--	--	--	0
Stationary signal	--	--	--	--	--	--	--	0
Unknown	--	--	--	1	--	--	--	1
Number held	--	--	--	20	--	--	--	20
Number alive at 48 h	--	--	--	20	--	--	--	20
			Northern pike					
Deep								
Number released	--	--	27	--	--	--	--	27
Number recovered alive	--	--	20	--	--	--	--	20
Number recovered dead	--	--	7	--	--	--	--	7
Number Acoustic tagged	--	--	2	--	--	--	--	2
Number Acoustic tagged Fish returned to river	--	--	0	--	--	--	--	0
Number assigned dead*	--	--	0	--	--	--	--	0
Dislodged tags	--	--	--	--	--	--	--	0
Stationary signal	--	--	--	--	--	--	--	0
Unknown	--	--	0	--	--	--	--	0
Number held	--	--	20	--	--	--	--	20
Number alive at 48 h	--	--	17	--	--	--	--	17
Mid								
Number released	--	--	--	--	--	--	31	31

Appendix Table A-3

	6/2	6/3	6/4	6/5	6/6	6/7	6/8	Totals
Number recovered alive	--	--	--	--	--	--	25	25
Number recovered dead	--	--	--	--	--	--	6	6
Number Acoustic tagged	--	--	--	--	--	--	18	18
Number Acoustic tagged Fish returned to river	--	--	--	--	--	--	11	11
Number assigned dead*	--	--	--	--	--	--	0	0
Dislodged tags	--	--	--	--	--	--	--	0
Stationary signal	--	--	--	--	--	--	--	0
Unknown	--	--	--	--	--	--	0	0
Number held	--	--	--	--	--	--	11	11
Number alive at 48 h	--	--	--	--	--	--	8	8
Shallow								
Number released	--	--	--	--	30	--	--	30
Number recovered alive	--	--	--	--	20	--	--	20
Number recovered dead	--	--	--	--	8	--	--	8
Number Acoustic tagged	--	--	--	--	3	--	--	3
Number Acoustic tagged Fish returned to river	--	--	--	--	2	--	--	2
Number assigned dead*	--	--	--	--	2	--	--	2
Dislodged tags	--	--	--	--	2	--	--	2
Stationary signal	--	--	--	--	--	--	--	0
Unknown	--	--	--	--	0	--	--	0
Number held	--	--	--	--	19	--	--	19
Number alive at 48 h	--	--	--	--	18	--	--	18
			Lake whitefish					
Deep								
Number released	--	--	10	--	--	--	--	10
Number recovered alive	--	--	8	--	--	--	--	8

Appendix Table A-3

	6/2	6/3	6/4	6/5	6/6	6/7	6/8	Totals
Number recovered dead	--	--	1	--	--	--	--	1
Number assigned dead*	--	--	0	--	--	--	--	0
Dislodged tags	--	--	--	--	--	--	--	0
Stationary signal	--	--	--	--	--	--	--	0
Unknown	--	--	1	--	--	--	--	1
Number held	--	--	8	--	--	--	--	8
Number alive at 48 h	--	--	7	--	--	--	--	7
Mid								
Number released	--	--	--	--	--	--	3	3
Number recovered alive	--	--	--	--	--	--	3	3
Number recovered dead	--	--	--	--	--	--	0	0
Number assigned dead*	--	--	--	--	--	--	0	0
Dislodged tags	--	--	--	--	--	--	--	0
Stationary signal	--	--	--	--	--	--	--	0
Unknown	--	--	--	--	--	--	0	0
Number held	--	--	--	--	--	--	3	3
Number alive at 48 h	--	--	--	--	--	--	3	3
Shallow								
Number released	--	--	--	--	2	--	--	2
Number recovered alive	--	--	--	--	2	--	--	2
Number recovered dead	--	--	--	--	0	--	--	0
Number assigned dead*	--	--	--	--	0	--	--	0
Dislodged tags	--	--	--	--	--	--	--	0
Stationary signal	--	--	--	--	--	--	--	0
Unknown	--	--	--	--	0	--	--	0
Number held	--	--	--	--	2	--	--	2
Number alive at 48 h	--	--	--	--	1	--	--	1
			Walleye					
Controls								
Number released	--	--	15	--	15	--	--	30

Appendix Table A-3

	6/2	6/3	6/4	6/5	6/6	6/7	6/8	Totals
Number recovered alive	--	--	15	--	15	--	--	30
Number recovered dead	--	--	0	--	0	--	--	0
Number Acoustic tagged	--	--	1	--	0	--	--	1
Number Acoustic tagged Fish returned to river	--	--	1	--	0	--	--	1
Number assigned dead*	--	--	0	--	0	--	--	0
Dislodged tags	--	--	--	--	--	--	--	0
Stationary signal	--	--	--	--	--	--	--	0
Unknown	--	--	0	--	0	--	--	0
Number held	--	--	14	--	15	--	--	29
Number alive at 48 h	--	--	14	--	15	--	--	29
			Northern pike					
Controls								
Number released	--	--	--	18	--	12	--	30
Number recovered alive	--	--	--	18	--	12	--	30
Number recovered dead	--	--	--	0	--	0	--	0
Number Acoustic tagged	--	--	--	3	--	1	--	4
Number Acoustic tagged Fish returned to river	--	--	--	3	--	1	--	4
Number assigned dead*	--	--	--	0	--	0	--	0
Dislodged tags	--	--	--	--	--	--	--	0
Stationary signal	--	--	--	--	--	--	--	0
Unknown	--	--	--	0	--	0	--	0
Number held	--	--	--	14	--	11	--	25
Number alive at 48 h	--	--	--	14	--	11	--	25
			Lake whitefish					
Controls								
Number released	--	--	--	5	--	--	--	5

Appendix Table A-3

	6/2	6/3	6/4	6/5	6/6	6/7	6/8	Totals
Number recovered alive	--	--	--	5	--	--	--	5
Number recovered dead	--	--	--	0	--	--	--	0
Number assigned dead*	--	--	--	0	--	--	--	0
Dislodged tags	--	--	--	--	--	--	--	0
Stationary signal	--	--	--	--	--	--	--	0
Unknown	--	--	--	0	--	--	--	0
Number held	--	--	--	5	--	--	--	5
Number alive at 48 h	--	--	--	5	--	--	--	5

* These fish added to "recovered dead" for survival estimates

Appendix Table A-4

Daily malady data for northern pike, walleye, and lake whitefish released into turbine Unit 2 intake at three release locations, shallow, mid, and deep (1.5m below intake ceiling, 5.5m below intake ceiling and 1.5m above the bottom, respectively). Control fish were released downstream of the turbine discharge at the Kelsey GS, June 2006.

	6/2	6/3	6/4	6/5	6/6	6/7	6/8	Totals
			Walleye					
Deep								
Released	2	37	--	--	--	--	--	39
Examined	2	35	--	--	--	--	--	37
Total with passage related maladies	1	7	--	--	--	--	--	8
Visible injuries	0	7	--	--	--	--	--	7
Scale loss only	1	0	--	--	--	--	--	1
Loss of equilibrium only	0	0	--	--	--	--	--	0
Dead from no apparent cause	0	0	--	--	--	--	--	0
Mid								
Released	--	--	--	--	--	31	--	31
Examined	--	--	--	--	--	31	--	31
Total with passage related maladies	--	--	--	--	--	10	--	10
Visible injuries	--	--	--	--	--	9	--	9
Scale loss only	--	--	--	--	--	0	--	0
Loss of equilibrium only	--	--	--	--	--	1	--	1
Dead from no apparent cause	--	--	--	--	--	0	--	0
Shallow								
Released	--	--	--	29	--	--	--	29
Examined	--	--	--	28	--	--	--	28
Total with passage related maladies	--	--	--	13	--	--	--	13
Visible injuries	--	--	--	13	--	--	--	13
Scale loss only	--	--	--	0	--	--	--	0
Loss of equilibrium only	--	--	--	0	--	--	--	0
Dead from no apparent cause	--	--	--	0	--	--	--	0
			Northern pike					
Deep								
Released	--	--	27	--	--	--	--	27
Examined	--	--	27	--	--	--	--	27
Total with passage related maladies	--	--	15	--	--	--	--	15

Appendix Table A-4 Continued

	6/2	6/3	6/4	6/5	6/6	6/7	6/8	Totals
Visible injuries	--	--	15	--	--	--	--	15
Scale loss only	--	--	0	--	--	--	--	0
Loss of equilibrium only	--	--	0	--	--	--	--	0
Dead from no apparent cause	--	--	0	--	--	--	--	0
Mid								
Released	--	--	--	--	--	--	31	31
Examined	--	--	--	--	--	--	31	31
Total with passage related maladies	--	--	--	--	--	--	11	11
Visible injuries	--	--	--	--	--	--	11	11
Scale loss only	--	--	--	--	--	--	0	0
Loss of equilibrium only	--	--	--	--	--	--	0	0
Dead from no apparent cause	--	--	--	--	--	--	0	0
Shallow								
Released	--	--	--	--	30	--	--	30
Examined	--	--	--	--	28	--	--	28
Total with passage related maladies	--	--	--	--	19	--	--	19
Visible injuries	--	--	--	--	19	--	--	19
Scale loss only	--	--	--	--	0	--	--	0
Loss of equilibrium only	--	--	--	--	0	--	--	0
Dead from no apparent cause	--	--	--	--	0	--	--	0
			Lake whitefish					
Deep								
Released	--	--	10	--	--	--	--	10
Examined	--	--	9	--	--	--	--	9
Total with passage related maladies	--	--	1	--	--	--	--	1
Visible injuries	--	--	1	--	--	--	--	1
Scale loss only	--	--	0	--	--	--	--	0
Loss of equilibrium only	--	--	0	--	--	--	--	0
Dead from no apparent cause	--	--	0	--	--	--	--	0
Mid								
Released	--	--	--	--	--	--	3	3
Examined	--	--	--	--	--	--	3	3
Total with passage related maladies	--	--	--	--	--	--	0	0

Appendix Table A-4 Continued

	6/2	6/3	6/4	6/5	6/6	6/7	6/8	Totals
Visible injuries	--	--	--	--	--	--	0	0
Scale loss only	--	--	--	--	--	--	0	0
Loss of equilibrium only	--	--	--	--	--	--	0	0
Dead from no apparent cause	--	--	--	--	--	--	0	0
Shallow								
Released	--	--	--	--	2	--	--	2
Examined	--	--	--	--	2	--	--	2
Total with passage related maladies	--	--	--	--	0	--	--	0
Visible injuries	--	--	--	--	0	--	--	0
Scale loss only	--	--	--	--	0	--	--	0
Loss of equilibrium only	--	--	--	--	0	--	--	0
Dead from no apparent cause	--	--	--	--	1	--	--	1
			Northern pike					
Controls								
Released	--	--	--	15	--	15	--	30
Examined	--	--	--	15	--	15	--	30
Total with passage related maladies	--	--	--	0	--	0	--	0
Visible injuries	--	--	--	0	--	0	--	0
Scale loss only	--	--	--	0	--	0	--	0
Loss of equilibrium only	--	--	--	0	--	0	--	0
Dead from no apparent cause	--	--	--	0	--	0	--	0
			Walleye					
Controls								
Released	--	--	15	--	15	--	--	30
Examined	--	--	15	--	15	--	--	30
Total with passage related maladies	--	--	0	--	0	--	--	0
Visible injuries	--	--	0	--	0	--	--	0
Scale loss only	--	--	0	--	0	--	--	0
Loss of equilibrium only	--	--	0	--	0	--	--	0
Dead from no apparent cause	--	--	0	--	0	--	--	0
			Lake whitefish					

Appendix Table A-4 Continued

	6/2	6/3	6/4	6/5	6/6	6/7	6/8	Totals
Controls								
Released	--	--	--	5	--	--	--	5
Examined	--	--	--	5	--	--	--	5
Total with passage related maladies	--	--	--	0	--	--	--	0
Visible injuries	--	--	--	0	--	--	--	0
Scale loss only	--	--	--	0	--	--	--	0
Loss of equilibrium only	--	--	--	0	--	--	--	0
Dead from no apparent cause	--	--	--	0	--	--	--	0

APPENDIX B
ACOUSTIC DATA

Appendix Table B

Status of acoustically tagged fish including 48 h survival (presumed survival probabilities based on acoustic tag information) on two species, northern pike, and walleye released into the intake of turbine Unit 2 at 227.9 m^3/s (8,000 cfs) at three release locations, shallow, mid and deep (1.5m below ceiling intake, 5.5m below ceiling intake and 1.5m above the bottom, respectively). Control fish were released downstream of the turbine discharge at the Kelsey GS, June 2006.

Date	Scenario	T/C	Species	Lot	ID	Length	Release	Recovery	Time out	# balloons	Survival	1	2	3	4	Comments	In river
4-Jun	2	deep	pike	3	22	657	13:34	13:37	*3*	4	2	H	*		S	Floy #84657 and acoustic tagged 24h mortality, scrape left side behind operculum	no
4-Jun	2	deep	pike	3	23	493	13:41	13:45	*4*	4	1	G	9	*	S	Floy #84658 and acoustic tagged Right operculum bruise, bruise in middle of back	yes
5-Jun	98	control	pike	4	11	608	10:21	10:28	*7*	4	1	A			S	Floy #84663 and acoustic tagged	yes
5-Jun	98	control	pike	4	15	548	11:06	11:08	*2*	4	1	A			S	Floy #84665 and acoustic tagged	yes
5-Jun	98	control	pike	4	23	570	12:00	12:04	*1*	4	1	A			S	Floy #84662 and acoustic tagged	yes
6-Jun	8	shallow	pike	5	20	637	11:53	11:56	*3*	4	1	*	9	5	S	Floy #84666 and acoustic tagged; Left operculum flared, major scale loss both sides	yes
6-Jun	8	shallow	pike	5	23	630	12:53	12:59	*6*	4	1	A			S	Floy #84669 and acoustic tagged	yes
6-Jun	8	shallow	pike	5	36	692	14:49	14:55	*6*	4	2	*	E	W	S	Floy #84667 and acoustic tagged; Left maxilary damage, hit on top of head, LOE	no
7-Jun	98	control	pike	6	5	638	9:05	9:09	*4*	4	1	A			S	Floy #84668 and acoustic tagged	yes
8-Jun	5	mid	pike	7	1	622	8:10	8:12	*2*	4	1	A			S	Floy #84698 and acoustic tagged	yes
8-Jun	5	mid	pike	7	2	635	8:15	8:17	*2*	2	2	E	*	6	S	Floy #84689 and acoustic tagged; tail almost severed	no
8-Jun	5	mid	pike	7	3	615	8:22	8:24	*2*	4	1	A			S	Floy #84201 and acoustic	yes
8-Jun	5	mid	pike	7	4	602	8:27	8:37	*10*	4	2	*	E	W	S	Floy #84203 and acoustic tag; split upper jaw, scrape on back middle to second set of balloons	no

Appendix Table B Continued.

Date	Scenario	T/C	Species	Lot	ID	Length	Release	Recovery	Time out	# balloons	Survival	1	2	3	4	Comments	In river
8-Jun	5	mid	pike	7	5	754	8:34	8:40	*6*	4	2	*	7		S	Floy # 84696 and acoustic tagged; decap	no
8-Jun	5	mid	pike	7	6	840	8:45	8:48	*3*	4	2	8	6	*	S	Floy # 84693 and acoustic tagged; severed at vent back, rigth front of mouth broken up, LOE	no
8-Jun	5	mid	pike	7	7	820	8:53	8:57	*4*	4	1	H			S	Floy #84692 and acoustic tagged; severe LOE at first and then came around	yes
8-Jun	5	mid	pike	7	8	762	9:01			0	1	Q			S	Floy #84694 and acoustic tagged; signal pattern that of an alive fish close to mouth of creek by cabin, (fish alive but not recovered)	yes
8-Jun	5	mid	pike	7	9	831	9:10	9:17	*7*	4	1	A			S	Floy #84695 and acoustic tagged	yes
8-Jun	5	mid	pike	7	10	578	9:16	9:20	*4*	3	1	A			S	Floy #84691 and acoustic tagged; lost a balloon tag	yes
8-Jun	5	mid	pike	7	11	596	9:33	9:39	*6*	4	1	*	W	G	S	Floy #84690 and acoustic tagged; scrape mark left side, bruising on top of head	yes
8-Jun	5	mid	pike	7	12	560	9:39	9:47	*8*	4	1	A			S	Floy #84202 and acoustic tagged	yes
8-Jun	5	mid	pike	7	13	765	9:47	9:53	*6*	4	1	A			S	Floy #84700 and acoustic tagged	yes
8-Jun	5	mid	pike	7	14	890	9:56	10:51	*55*	6	1	A			S	Floy #84687 and acoustic tagged; sat down at mouth of creek at cabin then floated up with 6 fully inflated tags	yes
8-Jun	5	mid	pike	7	15	651	10:02	10:08	*6*	4	1	A			S	Floy #84697 and acoustic tagged	yes
8-Jun	5	mid	pike	7	16	615	10:08			0	1	Q			S	Floy #84688 and acoustic tagged; tracked acoustically	yes
8-Jun	5	mid	pike	7	30	922	13:12			0	1	Q			S	Floy #84699 and acoustic tagged; had a full visual and then it dove; tracked acoustically	yes
3-Jun	1	deep	walleye	2	3	445	9:08			0	4				S	Floy #84651 and acoustic tagged	yes
3-Jun	1	deep	walleye	2	4	522	9:58	10:02	*4*	4	1	A			S	Floy #84653 and acoustic tagged	yes
3-Jun	1	deep	walleye	2	5	456	10:09	10:12	*3*	4	1	A			S	Floy #84654 and acoustic tagged	yes

Appendix Table B Continued.

Date	Scenario	T/C	Species	Lot	ID	Length	Release	Recovery	Time out	# balloons	Survival	1	2	3	4	Comments	In river
3-Jun	1	deep	walleye	2	6	520	10:26	10:28	*2*	4	1	A			S	Floy #84652 and acoustic tagged	yes
4-Jun	99	control	walleye	3	8	510	9:55	10:01	*6*	4	1	A			S	Floy #84656 and acoustic tagged	yes
4-Jun	99	control	walleye	3	11	430	10:15	10:18	*3*	4	1	A			S	Floy #84655 and acoustic tagged	yes
5-Jun	7	shallow	walleye	4	37	490	14:35	14:40	*5*	4	2	E	*		S	Floy #84660 and acoustic tagged; Split down the middle of head	no
5-Jun	7	shallow	walleye	4	40	473	14:57	14:59	*2*	4	1	A			S	Floy #84661 and acoustic tagged	yes
5-Jun	7	shallow	walleye	4	43	461	15:15	15:18	*3*	4	1	A			S	Floy #84659 and acoustic tagged	yes
7-Jun	4	mid	walleye	6	13	469	10:40	10:51	*11*	1	2	*	6	W	S	Floy #84683 and acoustic tagged; cut in half, right side of face at snout to before right pelvic fin hem and abrasion, hit below second dorsal fin left side	no
7-Jun	4	mid	walleye	6	14	447	10:46	10:56	*10*	4	1	A			S	Floy #84677 and acoustic tagged	yes
7-Jun	4	mid	walleye	6	15	505	10:58			0	1	Q	T		S	Floy #84681and acoustic tagged; Trapped in gatewell; balloons deflated, then acoustically tracked	yes
7-Jun	4	mid	walleye	6	16	440	11:06	11:14	*8*	4	1	A			S	Floy #84672 and acoustic tagged	yes
7-Jun	4	mid	walleye	6	17	545	11:12			0	1	Q			S	Floy #84678 and acoustic tagged; Fish located at the mouth of Grassy River alive, chased it around with a paddle	yes
7-Jun	4	mid	walleye	6	31	460	14:10	14:22	*12*	4	1	A			S	Floy #84676 and acoustic tagged	yes
7-Jun	4	mid	walleye	6	32	414	14:15	14:24	*9*	4	1	A			S	Floy #84685 and acoustic tagged	yes
7-Jun	4	mid	walleye	6	33	446	14:19	14:24	*5*	4	1	A			S	Floy #84684 and acousic tagged	yes
7-Jun	4	mid	walleye	6	34	430	14:30	14:33	*3*	4	2	*	6		S	Floy #84680 and acoustic tagged; back half of fish missing, 2nd dorsal fin and back	no
7-Jun	4	mid	walleye	6	35	432	14:35	14:41	*6*	4	1	A			S	Floy #84675 and acoustic tagged	yes
7-Jun	4	mid	walleye	6	36	520	14:42	14:57	*15*	4	1	A			S	Floy #84679 and acoustic tagged	yes

Appendix Table B Continued.

Date	Scenario	T/C	Species	Lot	ID	Length	Release	Recovery	Time out	# balloons	Survival	1	2	3	4	Comments	In river
7-Jun	4	mid	walleye	6	37	465	14:47	14:57	*10*	4	1	A			S	Floy #84671 and acoustic tagged	yes
7-Jun	4	mid	walleye	6	38	453	15:00	15:04	*4*	4	1	A			S	Floy #84682 and acoustic tagged	yes
7-Jun	4	mid	walleye	6	39	599	15:12	15:22	*10*	4	1	E	*		S	Floy #84673 and acoustic tagged; kept for observation 1" cut center of upper jaw; released after 48h	yes
7-Jun	4	mid	walleye	6	40	465	15:17	15:20	*3*	4	2	*	6		S	Floy #84674 and acoustic tagged; missing left portion of head	no
7-Jun	4	mid	walleye	6	41	504	15:26	15:56	*30*	4	1	A			S	Floy #84670 and acoustic tagged	yes
7-Jun	4	mid	walleye	6	42	413	15:31	15:38	*7*	4	1	A			S	Floy #84686 and acoustic tagged	yes

APPENDIX C STATISTICAL OUTPUT

APPENDIX C

DERIVATION OF PRECISION, SAMPLE SIZE, AND MAXIMUM LIKELIHOOD PARAMETERS

The statistical description below is excerpted from Normandeau Associates and Skalski (2000a). For the sake of brevity, references within the text have been removed. However, interested readers can look up these citations in the report prepared by Normandeau Associates and Skalski (2000a).

The estimation for the likelihood model parameters and sample size requirements discussed in the text are given herein. Additionally, the results of statistical analyses for evaluating homogeneity in recapture and survival probabilities, and in testing hypotheses of equality in parameter estimates under the simplified (H_O:P_A=P_D) versus the most generalized model (H_A:$P_A \neq P_D$) are given.

The following terms are defined for the equations and likelihood functions which follow:

R_C	=	Number of control fish released
R_T	=	Number of treatment fish released
R	=	R_C=R_T
n	=	Number of replicate estimates $\hat{\tau}_i$ (*i*=1,…,n)
a_C	=	Number of control fish recaptured alive
d_C	=	Number of control fish recaptured dead
a_T	=	Number of treatment fish recaptured alive
d_T	=	Number of treatment fish recaptured dead
S	=	Probability fish survive from the release point of the controls to recapture
P_A	=	Probability an alive fish is recaptured
P_D	=	Probability a dead fish is recaptured
τ	=	Probability a treatment fish survives to the point of the control releases (*i.e.*, passage survival)
1-τ	=	Passage-related mortality.

The precision of the estimate was defined as:

$$P(-\varepsilon < \hat{\tau} - \tau < \varepsilon) = 1 - \alpha$$

or equivalently

$$P(-\varepsilon <| \hat{\tau} - \tau |< \varepsilon) = 1 - \alpha$$

where the absolute errors in estimation, *i.e.*, $|\hat{\tau} - \tau|$, is <ε (1-α) 100% of the time, $\hat{\tau}$ is the estimated passage survival, and ε is the half-width of a (1-α) 100% confidence interval for $\hat{\tau}$ or 1-$\hat{\tau}$. A precision of ±5%, 90% of the time is expressed as P($|\hat{\tau} - \tau|$<0.05)=0.90.

Using the above precision definition and assuming normality of $\hat{\tau} - \tau$, the required total sample size (R) is as follows:

$$P\left(\frac{-\varepsilon}{\sqrt{Var(\hat{\tau})}} < Z < \frac{\varepsilon}{\sqrt{Var(\hat{\tau})}}\right) = 1 - \alpha$$

$$P\left(Z < \frac{-\varepsilon}{\sqrt{Var(\hat{\tau})}}\right) = \alpha / 2$$

$$\Phi\left(\frac{-\varepsilon}{\sqrt{Var(\hat{\tau})}}\right) = \alpha / 2$$

$$\frac{-\varepsilon}{\sqrt{Var(\hat{\tau})}} = Z_{\alpha/2}$$

$$Var(\hat{\tau}) = \frac{\varepsilon^2}{Z^2_{1-\frac{\alpha}{2}}}$$

$$\frac{\tau}{SP_A}\left[\frac{(1 - S\tau P_A)}{R_T} + \frac{(1 - SP_A)\tau}{R_C}\right] = \frac{\varepsilon^2}{Z^2_{1-\frac{\alpha}{2}}} \ .$$

where Z is a standard normal deviate satisfying the relationship $P(Z>Z_{1-\alpha/2})=\alpha/2$, and Φ is the cumulative distribution function for a standard normal deviate.

If data can be pooled across trials and letting $R_C=R_T=R$, the sample size for each release is

$$R = \frac{\tau}{SP_A}\left[1 + \tau - 2S\tau P_A\right]\frac{Z^2_{1-\alpha/2}}{\varepsilon^2} \ .$$

By rearranging, this equation can be solved to predetermine the anticipated precision given the available number of fish for a study. In most previous investigations (Normandeau Associates and Skalski 2000a) this equation has been used to calculate sample sizes because of homogeneity between trials; in the present investigation sample size was predetermined using this equation.

If data cannot be pooled across trials the precision is based on

$$\sum_{i=1}^{n}(1 - \hat{\tau}_i)/n = 1 - \sum_{i=1}^{n}\hat{\tau}_i / n = 1 - \bar{\hat{\tau}} \ .$$

Precision is defined as

$$P(|\bar{\hat{\tau}} - \bar{\tau}| < \varepsilon) = 1 - \alpha$$

$$P(-\varepsilon < \bar{\hat{\tau}} - \bar{\tau} \,|< \varepsilon) = 1 - \alpha$$

$$P\left(\frac{-\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}} < t_{n-1} < \frac{\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}}\right) = 1 - \alpha$$

$$P\left(t_{n-1} < \frac{-\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}}\right) = \alpha / 2$$

$$\Phi\left(\frac{-\varepsilon}{Var(\bar{\hat{\tau}})}\right) = \alpha / 2$$

$$\frac{-\varepsilon}{\sqrt{Var(\bar{\hat{\tau}})}} = t_{\alpha/2, n-1}$$

$$Var(\bar{\hat{\tau}}) = \frac{\varepsilon^2}{t^2_{1-\alpha/2, n-1}}$$

$$\frac{\sigma^2_\tau + \frac{\tau}{SP_A}\left[\frac{(1 - S\tau P_A)}{R_T} + \frac{(1 - SP_A)\tau}{R_C}\right]}{n} = \frac{\varepsilon^2}{t^2_{1-\alpha/2, n-1}}$$

where σ_τ^2=natural variation in passage-related mortality.

Now letting R_T=R_C

$$\frac{\sigma^2_\tau + \frac{\tau}{SP_A}\left[\frac{(1 - S\tau P_A)}{R} + \frac{(1 - SP_A)\tau}{R}\right]}{n} = \frac{\varepsilon^2}{t^2_{1-\alpha/2, n-1}}$$

which must be iteratively solved for n given R. Or R given n where

$$R = \frac{\frac{\tau}{SP_A}\left[(1 - S\tau P_A) + (1 - SP_A)\tau\right]}{\left[\frac{n\varepsilon^2}{t^2_{1-\alpha/2, n-1}} - \sigma^2_\tau\right]}$$

$$R = \frac{\dfrac{\tau(1+\tau)}{SP_A}}{\left[\dfrac{n\varepsilon^2}{t^2_{1-\alpha/2,n-1}} - \sigma^2_\tau\right]}$$

$$R = \frac{\tau(1+\tau)}{SP_A}\left[\frac{t^2_{1-\alpha/2,n-1}}{n\varepsilon^2 - \sigma^2_\tau t^2_{1-\alpha/2,n-1}}\right].$$

The joint likelihood for the passage-related mortality is:

$$L\,(S,\ \tau,\ P_A,\ P_D \mid R_C,\ R_T,\ a_C,\ a_T,\ d_C,\ d_T)=$$

$$\binom{R_C}{a_c d_C}(SP_A)^{a_C}((1-S)P_D)^{d_C}(1-SP_A-(1-S)P_D)^{R_C-a_C-d_C}$$

$$\times\binom{R_T}{a_T d_T}(S\tau P_A)^{a_T}((1-S\tau)P_D)^{d_T}(1-S\tau P_A-(1-S\tau)P_D)^{R_T-a_T-d_T}\quad .$$

The likelihood model is based on the following assumptions: (1) fate of each fish is independent, (2) the control and treatment fish come from the same population of inference and share that same survival probability, (3) all alive fish have the same probability, P_A, of recapture, (4) all dead fish have the same probability, P_D, of recapture, and (5) passage survival (τ) and survival (S) to the recapture point are conditionally independent. The likelihood model has four parameters (P_A, P_D, S, τ) and four minimum sufficient statistics (a_C, d_C, a_T, d_T).

Because any two treatment releases were made concurrently with a single shared control group we used the likelihood model which took into account dependencies within the study design (Normandeau Associates *et al.* 1995). For any two treatment groups (denoted T_1 and T_2), the likelihood model is as follows:

$$L(S,\tau_1,\tau_2,P_A,P_D \mid R_C,R_{T_1},R_{T_2},a_C,d_c,a_{T_1},d_{T_1},a_{T_2},d_{T_2}) =$$

$$\binom{R_C}{a_c d_C}(SP_A)^{a_C}((1-S)P_D)^{d_C}(1-SP_A-(1-S)P_D)^{R_C-a_C-d_C}$$

$$\times\binom{R_{T_1}}{a_{T_1} d_{T_1}}(S\tau_1 P_A)^{a_{T_1}}((1-S\tau_1)P_D)^{d_{T_1}}(1-S\tau_1 P_A-(1-S\tau_1)P_D)^{R_{T_1}-a_{T_1}-d_{T_1}}$$

$$\times\binom{R_{T_2}}{a_{T_2} d_{T_2}}(S\tau_2 P_A)^{a_{T_2}}((1-S\tau_2)P_D)^{d_{T_2}}(1-S\tau_2 P_A-(1-S\tau_2)P_D)^{R_{T_2}-a_{T_2}-d_{T_2}}\quad .$$

This likelihood model has the same assumptions as stated in Normandeau Associates and Skalski (2000a) but has five estimable parameters (S, τ_1, τ_2, P_A, and P_D). The survival rate for treatment T_1 is estimated by τ_1 and for treatment T_2, by τ_2. A likelihood ratio test with 1 degree of freedom was used to test for equality in survival rates between treatments τ_1 and τ_2 based on the hypothesis H_O: $\tau_1 = \tau_2$ versus H_a: $\tau_1 \neq \tau_2$.

Likelihood models are based on the following assumptions: (a) the fate of each fish is independent; (b) the control and treatment fish come from the same population of inference and share the same natural survival probability, S; (c) all alive fish have the same probability, P_A, of recapture; (d) all dead fish have the same probability, P_D, of recapture; and (e) passage survival (τ) and natural survival (S) to the recapture point are conditionally independent.

The estimators associated with the likelihood model are:

$$\hat{\tau} = \frac{a_T R_C}{R_T a_C}$$

$$\hat{S} = \frac{R_T d_C a_C - R_C d_T a_C}{R_C d_C a_T - R_C d_T a_C}$$

$$\hat{P}_A = \frac{d_C a_T - d_T a_C}{R_T d_C - R_C d_T}$$

$$\hat{P}_D = \frac{d_C a_T - d_T a_C}{R_C a_T - R_T a_C} \quad .$$

The variance (Var) and standard error (SE) of the estimated passage mortality ($1 - \hat{\tau}$) or survival ($\hat{\tau}$) are:

$$Var(1-\hat{\tau}) = Var(\hat{\tau}) = \frac{\tau}{SP_A}\left[\frac{(1-S\tau P_{A)}}{R_T} + \frac{(1-SP_A)\tau}{R_C}\right]$$

$$SE(1-\hat{\tau}) = SE(\hat{\tau}) = \sqrt{Var(1-\hat{\tau})} \quad .$$

DERIVATION OF VARIANCE FOR WEIGHTED AVERAGE SURVIVAL ESTIMATE

The variance of a weighted average is estimated by the formula

$$\hat{\bar{\theta}}_W = \frac{\sum_{i=1}^{n} W_i \hat{\theta}_i}{\sum_{i=1}^{n} W_i}$$

with

$$\text{Var}\left(\hat{\bar{\theta}}_W\right) = \frac{\sum_{i=1}^{n} W_i \left(\hat{\theta}_i - \hat{\bar{\theta}}_W\right)^2}{(n-1)\sum_{i=1}^{n} W_i}$$

where $\hat{\bar{\theta}}_W$ = the weighted average,

$\hat{\theta}_i$ = the parameter estimate for the *i*th replicate,

W_i = weight.

PART 2B

PART 2B

LONG-TERM SURVIVAL AND MOVEMENT OF ACOUSTIC-TAGGED NORTHERN PIKE AND WALLEYE FOLLOWING PASSAGE THROUGH A TURBINE AT THE KELSEY GENERATING STATION, 2006

An Interim Report Prepared

for

Manitoba Hydro

by

W. Jansen and L. Murray

May 2007

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF APPENDICES

Page

1.0 INTRODUCTION

Since the first hydroelectric generating stations (GS) were constructed in the 19th century, concerns have been expressed about the impact that dam construction and operation has on fish. Since then much more is known about the magnitude of fish movements through hydroelectric stations and the associated rate of injury/mortality. However, most studies on downstream fish passage through hydroelectric plants to date have focused on **anadromous*** species, such as salmon, trout, char, shad, and alewife, and **catadromous** species such as eels (see review by Cada 2001). These studies have, in most cases, been carried out in the United States and Europe and largely involve either **smolts** or adult salmon during their spawning migration. Information on the fate of **potamodromous** species (Lucas and Baras 2001), or so called "resident" fish populations when passing hydroelectric generating stations is largely absent. There is virtually no information regarding species of concern from reservoirs in boreal North America. Two North American studies (Navarro et al. 1996 and Matousek et al. 1994) have looked at fish movements and turbine passage for some cool, freshwater species; however, the type(s) of turbines examined by these authors were substantially different from those used in Manitoba Hydro plants. Furthermore, injury and mortality studies at hydroelectric GSs have mainly considered a time period of 48 hours or less after turbine passage. However, it has been recently shown that, at least for radio- and PIT-tagged juvenile Pacific salmon, delayed mortality (mainly due to predation) of successfully passed fish can be much higher than the direct turbine mortality rates as estimated by Hi-Z tags (Ferguson et al. 2006). Similar direct assessments of the longer-term survival of turbine-passed fish and the potential effects of turbine passage on the movement and behaviour of fish are lacking for larger fish and for boreal species.

In spring, 2006, North/South Consultants Inc. and Normandeau Associates Inc. collaborated to investigate fish injury and/or mortality due to passage through a hydroelectric GS. Injury rates and rates of short term (up to 48 hours) survival after turbine passage were estimated using "HI-Z" tags (see Part 2A of this study). This report summarizes results on the long-term survival (up to three months) and the post-passage movement and behaviour of a sub-sample of HI-Z-tagged northern pike and walleye obtained from internally implanted acoustic transmitters.

***** *for definitions of terms see glossary in Section 6.0***

2.0 STUDY AREA

The Kelsey GS is located on the upper Nelson River in northern Manitoba, at latitude 55° 57’ N and longitude 96° 32’ W. The station lies 137 km upstream of the Kettle GS and approximately 680 km north of Winnipeg. Kelsey GS was the first hydroelectric station built on the Nelson River. Construction of Kelsey GS commenced in 1957 and was completed in 1961 with five turbine generators (units), each producing 30 MW for a combined capacity of 160 MW. Additional units were added in 1969 and 1972 bringing the total capacity up to 211 MW. Kelsey GS was originally built to supply power to the International Nickel Company’s (INCO) mining and smelting operations in the area and also to the City of Thompson (Manitoba Hydro 2002).

Just downstream of the Kelsey GS the Nelson River is joined by the Grass River from the west (Figure 1). Past the confluence, the Nelson River flows north for approximately 5 km until it splits into two branches, one branch continues north around a large island and the other flows east around the island. Both branches have a set of rapids that must be passed before they enter into Split Lake where they are joined by water from the Burntwood River. The aquatic habitat within the area downstream of Kelsey ranges from a low velocity, relatively high water clarity riverine environment in the Grass River to a medium to high velocity, low water clarity riverine environment in the upstream portion of the Nelson River. More lacustrine conditions start to exist past the two sets of rapids on the Nelson River at the eastern edge of the Study Area (Figure 1) and continue to do so as the river enters Split Lake. Aquatic macrophytes are common in the Grass River but are not prominent along the shoreline of the Nelson River in the vicinity of Kelsey GS.

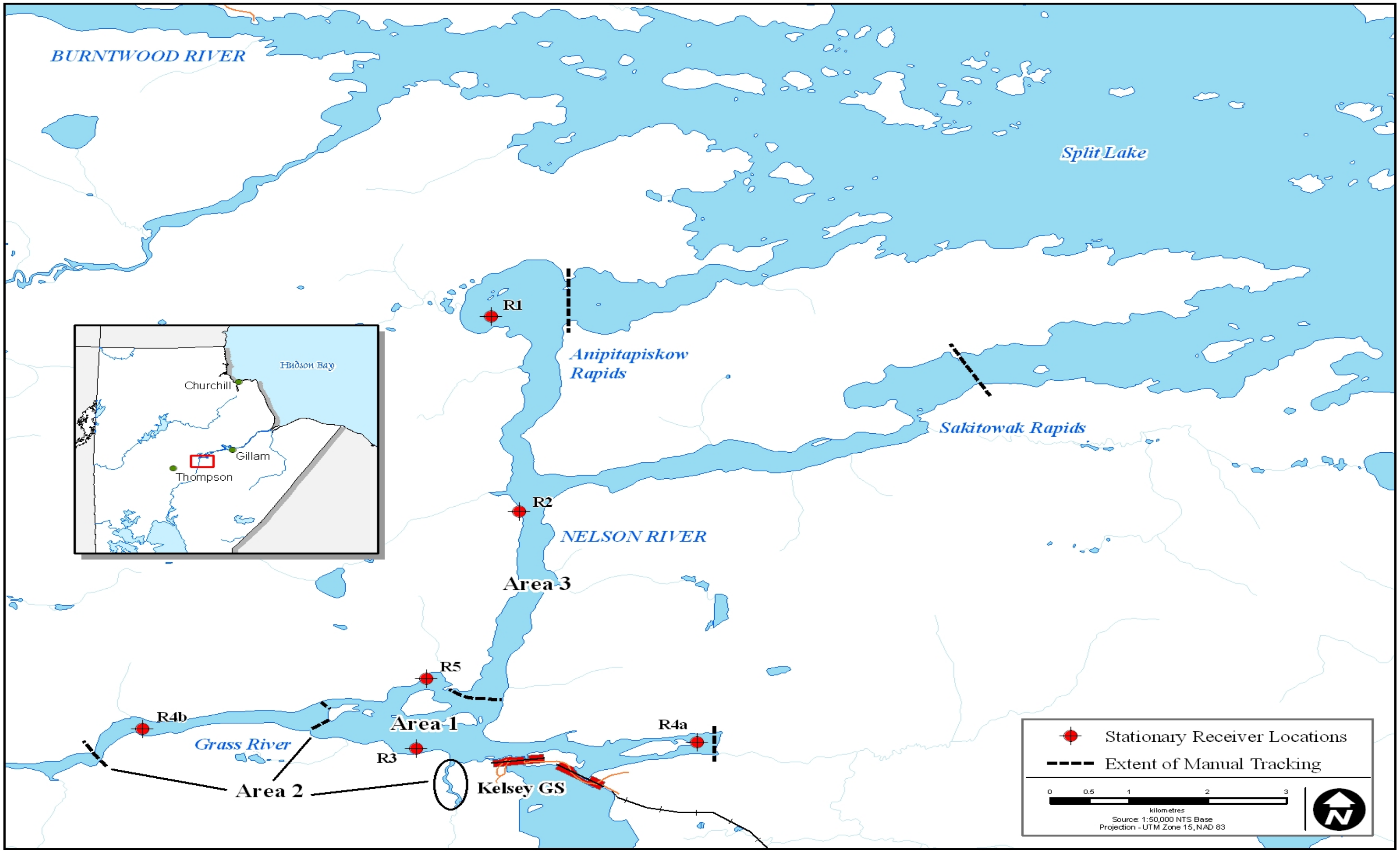


Figure 1. Overview of the Kelsey GS Study Area with locations of stationary acoustic receivers (stars), and the approximate extent of manual tracking (stipled lines) in June-August, 2006.

3.0 METHODS

3.1 FISH CAPTURE AND HANDLING

Northern pike (*Esox lucius*) and walleye (*Sander vitreus*) used in this study were captured from several locations (Figure 2) downstream of Kelsey GS by gillnetting (Figure 3), boat electrofishing (Figure 4), and angling. Captured fish were immediately placed in a tub of fresh water and transported to the Kelsey GS where fish were transferred to soft-walled pools of approximately 5000 L volume (see Part 2A of the study). Fish remained in these pools for a 24 hour monitoring period before acoustic transmitters were surgically implanted. Fish were monitored for 16-24 hours post-surgery before being released either as treatment or control fish. Prior to release each fish was externally fitted with a radio transmitter and "HI-Z Turb'N" tags to enable its relocation after turbine passage.

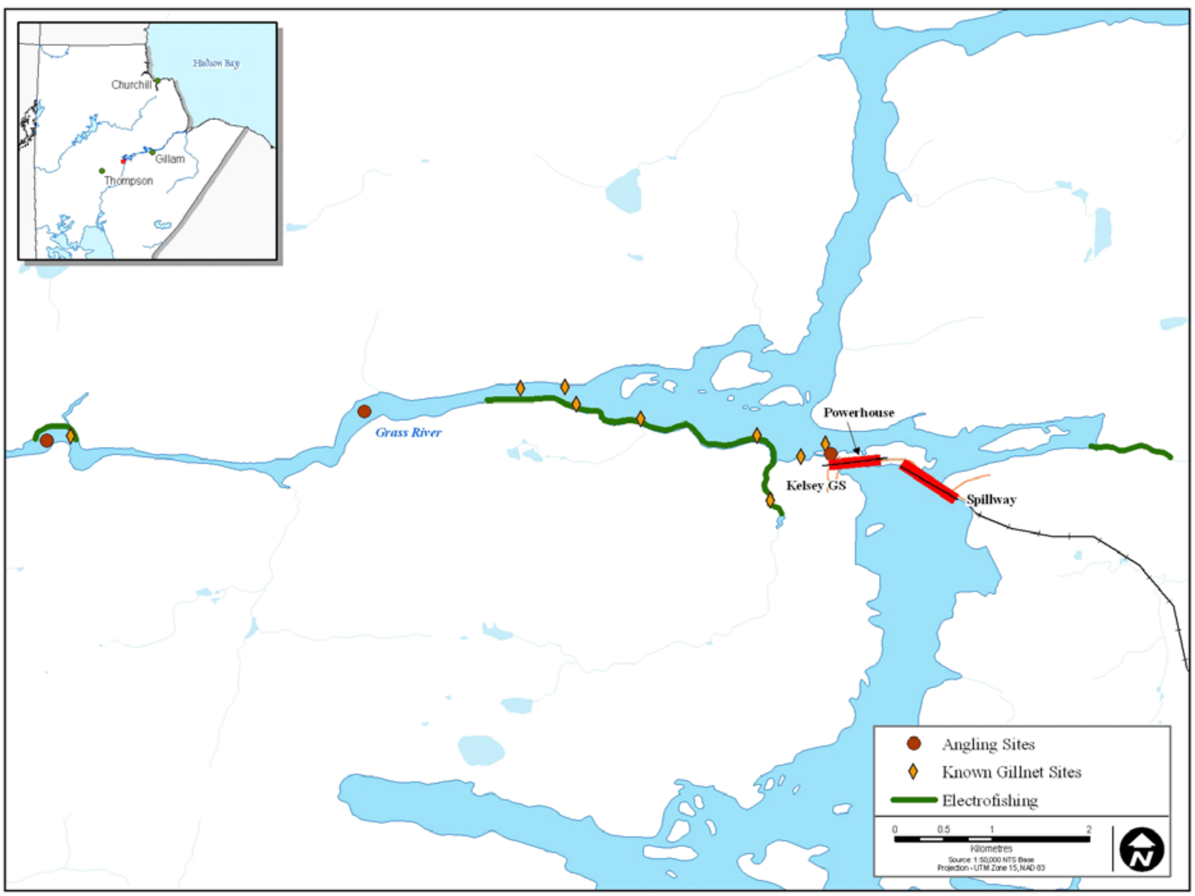


Figure 2. Areas where fish for the Turbine Passage Study were captured by either gillnetting (blue circles), electrofishing (green bands), or angling (red dots) from 1-7 June, 2006.

Figure 3. Gillnet capture of experimental fish near Kelsey GS, June, 2006.

Figure 4. Capture of experimental fish by electrofishing near the Kelsey GS. June 2006.

Fish that were physically recovered after turbine passage were placed into on-board holding tanks, where the radio transmitter and balloon tags were removed and the physical condition of the fish was assessed (see Part 2A of the study). Any injuries or mortalities were recorded and if the fish was in good condition they were released into the river. Injured acoustic-tagged fish were kept and transferred to a pool on the tailrace deck of the powerhouse to monitor survival for 48 hours. If, at that point, the fish was alive and behaved normally it was released into the river.

3.2 ACOUSTIC TRANSMITTER IMPLANTATION

Strong and healthy fish selected for acoustic tagging were measured for fork length (± 1 mm) and total weight (± 25 g; pan balance) prior to transmitter implantation. Fish were anaesthetized in a solution of clove oil and ethanol as described by Peake (1999). Clove oil was first dissolved in ethanol at a ratio of 1:10 (approximately 3 mL clove oil: 27 mL ethanol). This solution was mixed into approximately 30 L of river water. Fish were placed into the anaesthetic solution until immobile, then transferred to a V-

Figure 5. Implantation of a V13-1L acoustic transmitter into a walleye at Kelsey GS, June, 2006.

shaped surgical table, ventral side up (figures 5 and 6). As anaesthetized fish are unable to ventilate on their own, fresh water was continually pumped over the gills during the surgical procedure (Figure 6).

A mid-ventral incision, approximately 2 cm in length was made through the body wall of the fish using a sterilized 30 mm long scalpel. The acoustic transmitter, sterilized in alcohol, was inserted into the body cavity of the fish (Figure 5), and gently pushed forward to avoid stressing the incision after closure. The incision was closed using chromic #2 gut sutures (Figure 6) and a green, individually numbered Floy-tag (FD-94 T-bar anchor tags) was applied to each fish (Figure 7). Floy-tags were inserted at the base of the dorsal fin between the posterior basal pterygiophores with a Denison Mark II tagging gun. Fish were placed into a small enclosure formed by 5 mm mesh soft netting inside the recovery pool, and were monitored until they were able to maintain equilibrium and had regained mobility before being released into the main body of the pool.

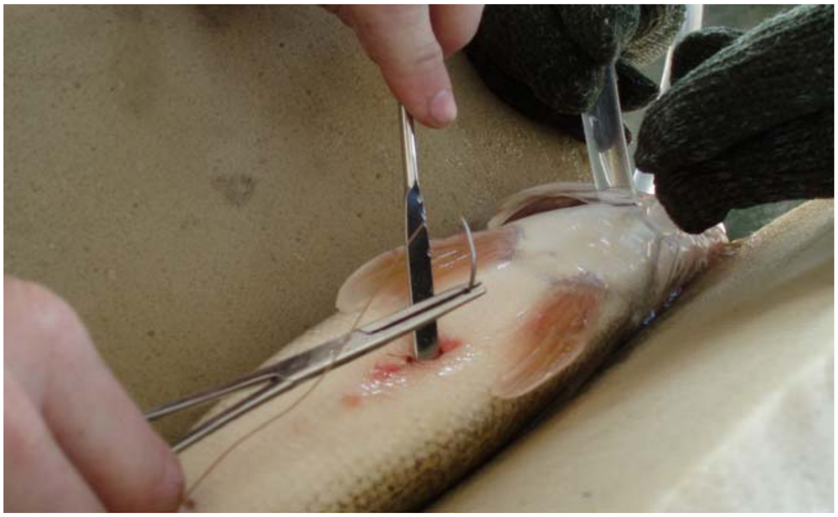


Figure 6. Suturing and gill irrigation of a walleye after implantation of an acoustic transmitter at Kelsey GS, June, 2006.

Figure 7. Walleye tagged with Floy-tag # 84654 in the dorsal musculature.

3.3 ACOUSTIC TELEMETRY

3.3.1 Acoustic transmitters and receivers

Fish were implanted with individually coded pinger V13-1L acoustic transmitters (VEMCO Ltd.; Figure 5). These transmitters measure 36 mm in length by 13 mm in diameter, weigh 6 g in water, and have a battery life expectancy of 790-900 days (approximately 2.2-2.5 years). V13-1L transmitters emit a pulse train every 50-150 seconds to minimize simultaneous pulse train transmissions by other acoustic transmitters in the immediate area. All transmitters operate on the same frequency (69 kHz), with each one transmitting a unique pulse train that can be recognized by either a submersible, stationary VR2 receiver, or a portable VR-60 ultrasonic receiver connected to a VH65 omni-directional hydrophone (VEMCO Ltd.; see below).

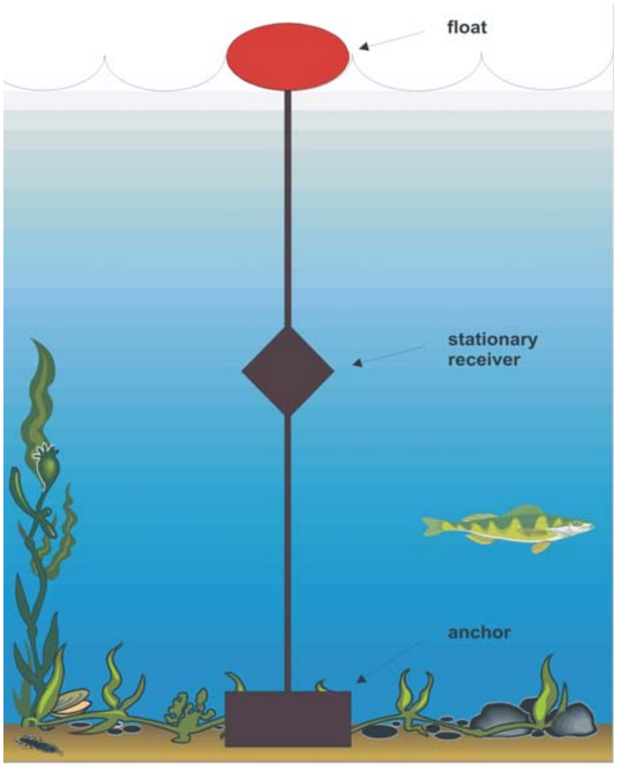


Figure 8. Schematic presentation of a deployed stationary acoustic receiver with anchor and float.

Stationary receivers operate with a built-in omni-directional hydrophone and an internal data logger. The omni-directional hydrophones of both the stationary and the portable receiver detect the pulse train transmitted from active transmitters within its range of detection, which may vary depending on environmental conditions (i.e., range of detection decreases with decreasing depths, increasing water velocity and turbulence or other “noise”). Based on preliminary field testing in the Study Area and on experience from other acoustic tagging studies (e.g., Pisiak and Barth 2006), the range of detection for all stationary receivers in this study was estimated at 500 m.

It should be noted that although transmitters emit pulse trains at variable intervals, the possibility exists of simultaneous transmissions reaching a receiver when a number of acoustic-tagged fish are within a receiver's range of detection. Receivers positioned in close proximity to the tagging / release sites are particularly susceptible to this. As such, receivers cannot distinguish individual signals and the possibility exists that signals were missed by stationary receivers and that a fish that left the area of the Kelsey GS immediately following its release remained undetected.

At each stationary receiver location, a coated steel cable attached to a king anchor was held vertically in the water column by a large float (Figure 8). Stationary receivers were attached via steel brackets to the cable and lowered into the water using a second float line (Figure 9). A U-bolt attached to the cable approximately 2 m off the river bottom served as a stopper. Tests performed for similar studies (e.g., Pisiak and Barth 2006) have shown that receivers positioned near the river bottom had a higher range of detection than those placed near the surface. This set-up allowed each receiver to be held vertically in the water column and allowed for the receivers to be pulled up the anchor cable with relative ease while eliminating the need to pull the anchor. This also ensured that following each download, receivers would be repositioned in the same location and at the same depth. Stationary receivers recorded the transmitter code number, date, and time of detection in an internal data logger until downloaded by an IBM/PC/AT computer (Figure 10). A VR2PC computer interface (VEMCO Ltd.) was used to transfer data between receiver and computer.

Figure 9. Deployment of a stationary receiver, showing steel cable, receiver, and float.

Figure 10. Downloading acoustic data from a stationary receiver onto a PC.

3.3.2 Fish tracking

Fish movements were monitored by five stationary VR2 receivers placed downstream of Kelsey GS (figures 1, 11-12) and by manual tracking from a boat with a portable VR-60 ultrasonic receiver connected to a VH65 omni-directional hydrophone (Figure 13). Stationary receivers were installed and tested for signal detection between June 1 and 2 and were removed from the Nelson River on 18 August, 2006. Initially, receivers were placed at locations R1, R2, R3, R4a, and R5 (Figure 1). Because no fish were detected by receiver R4a during the first week of the study, the receiver was relocated to location R4b on 9 June. Location R4b was chosen because manual tracking from 7-9 June indicated that several signals were received from locations west of receivers R3 and R5. Receiver R5 was removed on 9 July because this location provided only a very few relocations that were not recorded by receiver R3. A list of receiver locations with UTM coordinates and the periods of deployment is provided in Table 1. Stationary receivers were downloaded monthly.

Table 1. Locations (UTM 14 V coordinates) of stationary receivers, their dates of deployment, and the shortest in-water distance to other receivers.

Location			Deployment Date	Removal Date	Distance to (km)					
Receiver	**Easting**	**Northing**			R1	R2	R3	R4b	R5	Kelsey
R1	652452	6220131	1-Jun-06	18-Aug-06	-	3.5	7.8	11.0	7.5	7.7
R2	653065	6217142	1-Jun-06	18-Aug-06	3.5	-	4.5	7.5	3.7	4.2
R3	652087	6213356	1-Jun-06	18-Aug-06	7.8	4.5	-	3.5	1.3	1.3
R4a[1]	655598	6213733	1-Jun-06	9-Jun-06	-	-	-	-	-	2.3
R4b	648609	6213362	9-Jun-06	18-Aug-06	11.0	7.5	3.5	-	4.0	4.8
R5	652120	6214449	2-Jun-06	9-Jul-06	7.5	3.7	1.3	4.0	-	1.8

1 – R4a was not included in the between receiver distance calculation because it recorded no data before being relocated to location R4b.

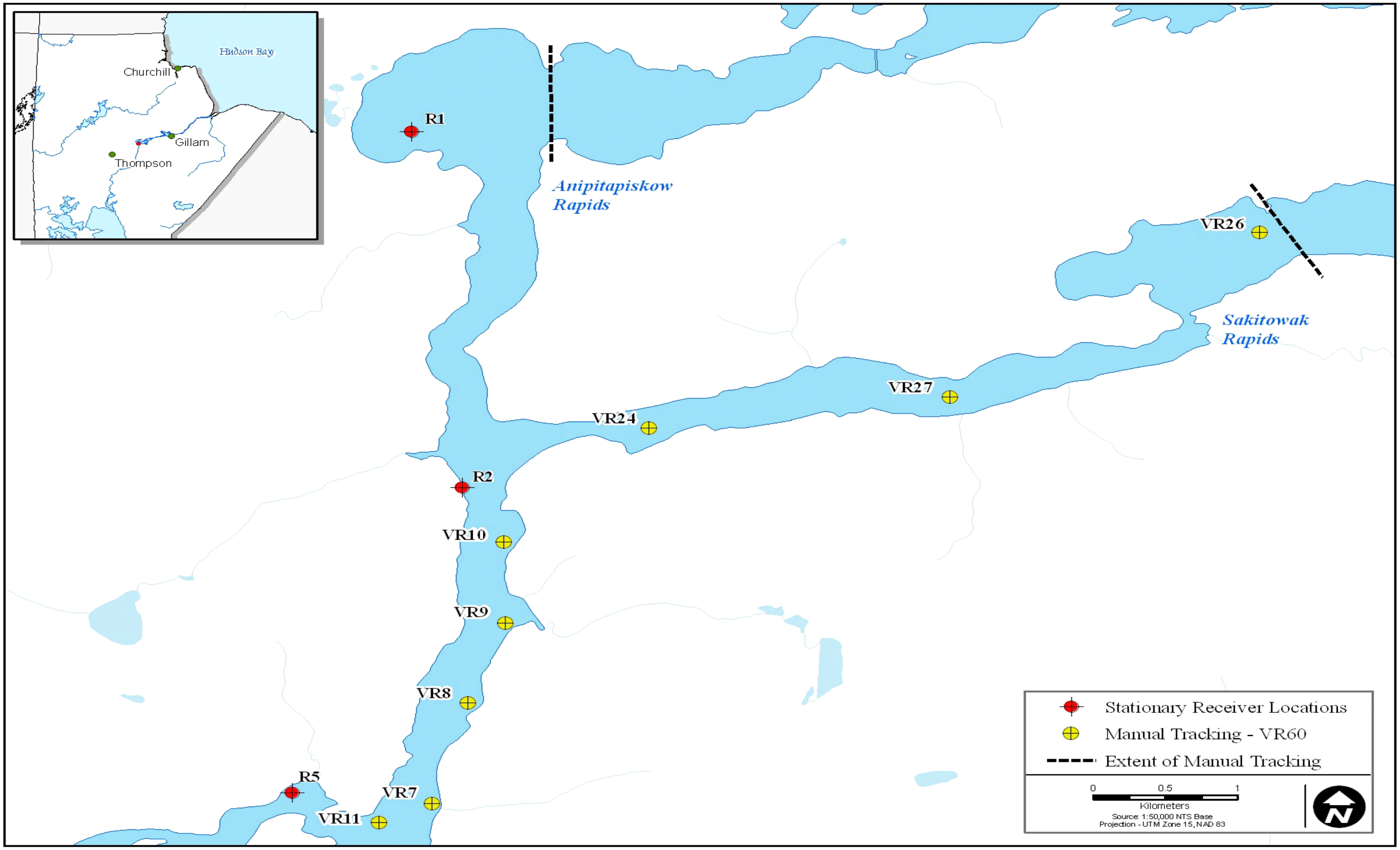


Figure 11. Sites with fish relocation(s) from manual tracking in the area north of the Kelsey Generating Station, June-September, 2006.

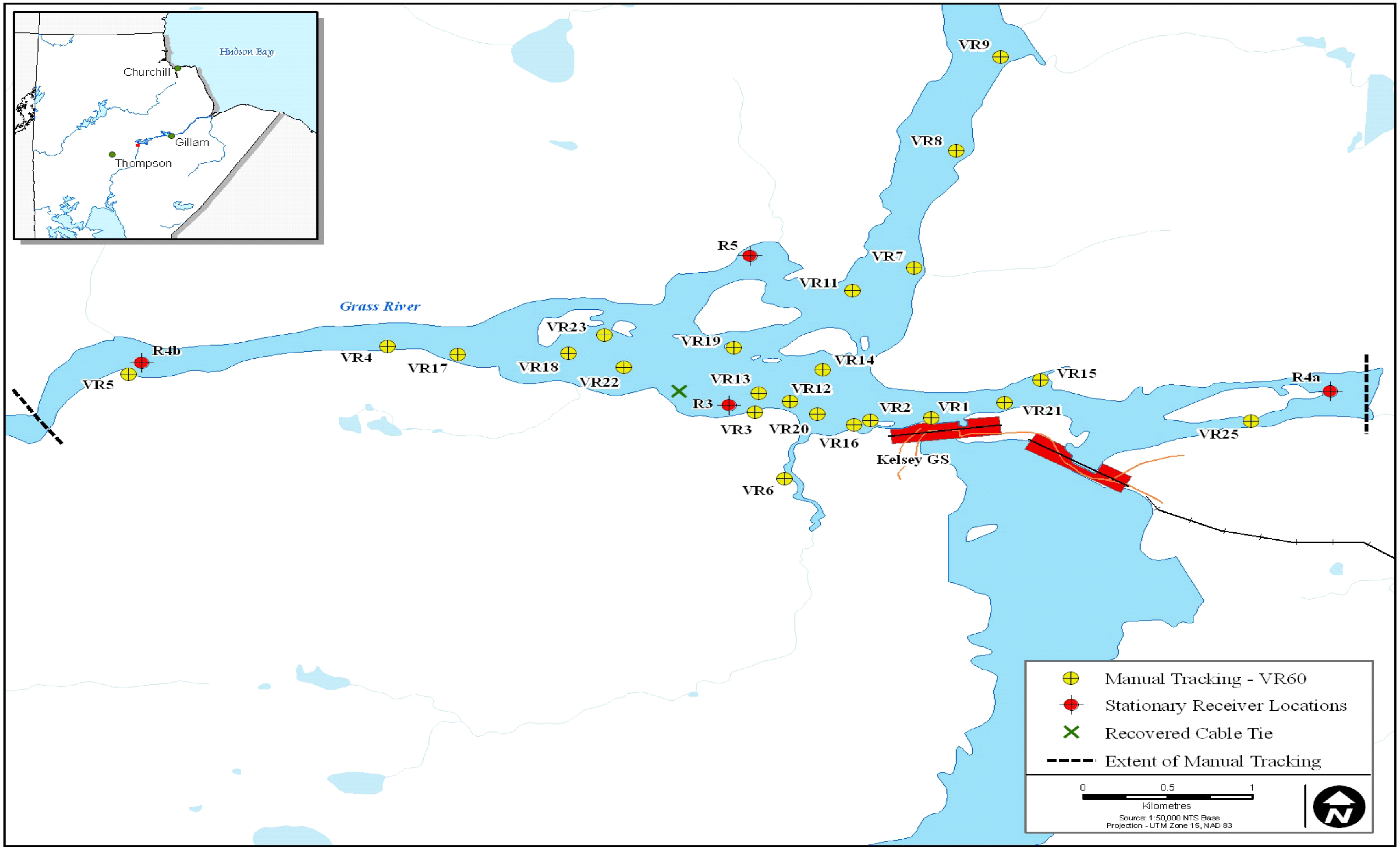


Figure 12. Sites with fish relocation(s) from manual tracking in the area near the Kelsey Generating Station, June-September, 2006.

Figure 13. VR-60 acoustic receiver used for manual tracking of fish at the Kelsey GS, June-September, 2006.

Manual tracking was intended to be done on a monthly basis. Due to VR-60 receiver malfunction or logistical problems, complete tracking runs were only available for the periods 7-9 June and 31 August-3 September. For each of these two runs, the boat followed a regular path within the boundaries of the tracking area (Figure 1), stopping every 300-500 m to check for acoustic signals. The hydrophone was lowered 1-2 m into the water and held there for approximately 3-5 minutes. If a number of signals were detected in the area, the hydrophone was held in the water for a longer period of time to ensure all signals in the area were detected.

If a weak signal was detected, the boat was maneuvered into the immediate area and acoustic readings were taken at shorter distances following a path of increasing signal strength until transmitter identification was obtained or could not be achieved. The time and location of tag identification was recorded. Although the actual position of the manual receiver at the time of transmitter identification sometimes differed by a couple of hundred meters between relocations on different days of a tracking period, or the signal for the same fish was sometimes received from several locations within a 30-45 min time span, it was assumed that the fish had remained ‘stationary’ between such relocations. A total of 27 distinct manual tracking locations were assigned (Appendix 1; figures 11-12). Tracking effort differed between areas. For the two tracking runs in June and September, the area near the Kelsey GS extending north to approximately location VR 7 on Figure 10 was searched for acoustic signals during every day of the manual tracking period, the area from location VR7 to R2 was searched twice, and the two arms of the Nelson River extending north and east from stationary receiver location R2 were searched once.

In Part 2A of this report, acoustic-tagged fish are identified by their Floy-tag number. To allow cross identification of fish between Part 2A and this report, text reference to individual fish in this document also uses their Floy-tag number.

3.4 DATA ANALYSIS

A conservative measure of the extent of movements of acoustic-tagged fish over the study period was calculated and referred to as the minimum distance of movement (MDM). The MDM was calculated by adding the distances between the downstream exit of turbine unit two and all subsequent relocations by either the stationary acoustic receivers (Table 1) or from manual tracking (Appendix 1) to the nearest 100 meters. Since both the time period and the frequency of relocations sometimes differed substantially between individuals, MDM has to be used with caution when comparing movements between individual fish. Another metric that was calculated to quantify fish movements was the maximum distance from the Kelsey GS that a fish was relocated (MaxD). Categories were established for both MDM (<6, 6-20, >20-50, >50 km) and MaxD (<4, >4-7, >7 km) to classify movement distances. These distance categories were arbitrary and were based on the distribution of the data.

Differences in mean MDM and MaxD between control and treatment fish and between northern pike and walleye were ascertained employing one-way analysis of variance (ANOVA). Because the distribution of the MDM and MaxD data could not be normalized by transformation, an ANOVA on ranks according to Kruskal-Wallis was performed. Statistical analyses were run using Sigma Stat V. 3.0 (SPSS 2003) software.

4.0 RESULTS AND DISCUSSION

4.1 SURVIVAL OF ACOUSTIC-TAGGED FISH

Acoustic transmitters were surgically implanted into 26 of the 88 northern pike (29.5 %) and 26 of the 99 walleye (26.3 %) that were used in the Turbine Passage Study (see Part 2A of this report). Most of the acoustic-tagged fish were treatment fish, and only four northern pike and two walleye served as controls (Table 2, Appendix 2). Treatment fish were passed through the turbine at all three release depths, but more than half of the walleye and pike were released at mid depth on 7 and 8 June, respectively (Table 3).

Table 2. Number of acoustic-tagged northern pike and walleye that were released into the Nelson River as control and treatment fish, experienced different outcomes as treatment fish, and were tracked acoustically at Kelsey GS from June to September, 2006.

Group	Northern pike	Walleye
Acoustically tagged	26	26
Control	4	2
Treatment	22	24
Treatment: not recovered	3	3
Treatment: dead	6	4
Treatment: alive and released	13	17
Total released into river[1]	20	22
Released injured	3	0
Acoustically tracked	18	21

1 – Total released into river includes Control fish, Treatment: alive and released, and Treatment: not recovered.

Table 3. Number of fish, by species, release depth, and date, implanted with acoustic transmitters at the Kelsey GS in June, 2006.

	Northern Pike		Walleye	
	Number	Date	Number	Date
Control	4	5, 7-Jun-06	2	4-Jun-06
Treatment: shallow	3	6-Jun-06	3	5-Jun-06
Treatment: mid	17	8-Jun-06	17	7-Jun-06
Treatment: deep	2	4-Jun-06	4	3-Jun-06

The 22 acoustic-tagged northern pike that were treatment fish had a mean length of 653 mm and a mean weight of 2,291 g, compared to the mean length of 658 mm for all 88 treatment fish (Table 4).

Table 4. Comparison of the mean length (SE) and weight of northern pike and walleye used as treatment or control fish during the turbine passage study at Kelsey GS with the respective metrics of acoustic-tagged fish.

Species	Treatment			Control		
	Length (mm)		Weight (g)	Length (mm)		Weight (g)
	Mean (SE)	Range	Mean (SE)	Mean (SE)	Range	Mean (SE)
			Acoustic-tagged fish			
Northern Pike	653 (110)	475-880	2291 (1228)	564 (32)	528-602	1269 (168)
Walleye	446 (43)	384-568	1048 (337)	446 (51)	410-482	988 (336)
			All experimental fish			
Northern Pike	658	455-1085	-	629	500-990	-
Walleye	446	314-651	-	458	341-610	-

The four pike that were fitted with acoustic transmitters and that served as controls had a mean length of 564 mm and a mean weight of 1,269 g, compared to the mean length of 629 mm for all 30 control fish (Table 4). The 24 acoustic-tagged walleye had a mean length of 446 mm and a mean weight of 1,048 g, the length being identical to the mean length of all 98 treatment fish (Table 4). The two walleye that were fitted with acoustic transmitters and that served as controls also had a mean length of 446 mm and a mean weight of 988 g, compared to the mean length of 458 mm for all 30 control fish (Table 4).

Table 5. Frequency of occurrence, by number of days, between release and last acoustic signal reception for treatment and control northern pike and walleye.

Days	Northern Pike		Walleye	
2 - 10	7	(38.9)	6	(28.6)
16 - 26	1	(5.6)	3	(14.3)
34 - 52	0		2	(9.5)
63 - 75	3	(16.7)	2	(9.5)
85 - 91	7	(38.9)	8	(38.1)

All six acoustic-tagged control fish survived and were released into the Nelson River with their radio tag and HI-Z balloons removed. Of the 46 treatment fish equipped with acoustic transmitters, six northern pike (27.3 % of the pike) and four walleye (16.7% of the walleye) did not survive the turbine passage or died during the 48 hour assessment period in the pools (Table 2; also see Part 2A of this study). These mortality rates were similar to those observed for the entire sample of pike (24.4%) and walleye (17.7%) that were released as treatment fish through the turbine. Of the remaining 16 pike and 20 walleye that were equipped with acoustic tags, three fish of each species were not physically recovered after turbine passage (Table 2) and, consequently, their radio tag and HI-Z balloons were not removed. Of these six non-recovered fish, acoustic signals were obtained for two pike (#84694 and #84688) and two walleye (#84681 and #84678) from several locations and spanning a time period of 1-3 months, indicating that these fish were alive after turbine passage (Appendix 2). Two of the non-recovered but acoustically tracked fish, pike #84688 and walleye #84681 were not visually detected or located by radio signal shortly after turbine passage and were initially considered as mortalities (see Part 2A of this report). Thus, the acoustic data provided critical information about the status of two fish that affected the survival estimates.

The substantial movements of most of the non-recovered fish and particularly walleye # 84678, which was located by all stationary receivers and was manually tracked until 3 September - the last day of the study - for a MDM of 94 km (see section 4.2 below) suggest that these fish were not strongly impeded in their activity by the balloons and the radio tag. The HI-Z balloons usually deflate within 6-24 hours without being punctured (Paul Heisey, Normandeau Associates, pers. comm.; see Figure 14 for a picture of deflated balloons) and the small radio tag (see figures 2-6 in Part 2A of this report) weighs approximately 1 g in air. Based on their tracking record in this study (see below), and approximately 100% survival rate of fish equipped with acoustic tags in most fish movement studies performed by the study team (Murray et al. 2005; Pisiak and Barth 2006; also see Part 1 of this report), there is no indication that acoustic-tagged fish suffered mortalities due to the surgical procedure and tag implantation. At least one fish provides direct evidence that the sutures of acoustic-tagged fish had healed well, and that the fish were in excellent condition and actively feeding several months after being equipped with the transmitter. Walleye #84659 was angled from the dock near the Kelsey GS powerhouse (Figure 2) on 7 September, 2006 and was inspected by Manitoba Hydro staff and a study team member.

Two of the non-recovered fish, pike #84699 and walleye #84651 together with pike #84666 were the only fish of the 42 pike and walleye released to the Nelson River that were never tracked acoustically (Table 2, Appendix 2). Pike #84666 had been released injured, with a flared left operculum and substantial scale loss on both sides of the body (Appendix 2; also see Part 2A of this report). Pike #84699 surfaced alive soon after turbine passage in front of one of the tracking boats and is suspected to have been struck by the boat's propeller. Although no visual or other information is available on walleye #84651, the physical evidence from the other two fish suggests that all of the fish for which no acoustic signal was received had suffered some type of injury during or shortly after turbine passage. Some indirect evidence suggests that at least one of the three non-recovered fish may have died near the Kelsey GS fairly soon after its turbine passage. On 3 September, 2006, during an unrelated study, an intact cable tie with two attached deflated balloons (Figure 14) was recovered when pulling a bottom-set gillnet approximately 300 m northwest of stationary receiver R3 (Figure 14). Due to the interior placement of the cable ties within a fish's bony structures (see Part 2A of this report), it is very unlikely that the recovered cable tie could have been removed from the fish without causing a fatal injury. The recovery location suggests that the tagged fish actively moved to this spot before the cable tie with the balloons fell off, because this spot is several hundred meters away from the main current of the Nelson River as it moves north downstream of the Kelsey GS (Figure 12). Any passive transport of the fish with the cable tie attached or of the (detached) cable tie to this location is very unlikely. Furthermore, the heavy filamentous algae cover on the balloons that, at the time of recovery, measured more than 2 cm in length, suggests that the balloons (with the cable tie) must have detached from the fish for some considerable time prior to 3 September.

Figure 14. Intact cable tie and deflated "Hi-Z" balloons found on 2 September, 2006, west of stationary receiver location R3 (see Figure 12).

All of the 39 acoustic-tracked fish were considered to be alive over the time period of their tracking. This assessment was based on the temporal and spatial pattern of signal reception. The possible exception is pike #84658 which was only relocated once after its turbine passage on 4 June (Appendix 2). This fish was released injured (Appendix 2) and its acoustic signal was received during manual tracking on 8 June at location VR 7 (Figure 3). However, if this fish had been dead at this time, its signal should also have been received on 7 June, when location VR 7 was checked for acoustic signals. The lack of signal reception on these two days suggests that the fish was alive on 8 June and subsequently moved further north in the Nelson River where it must have avoided detection by the stationary and mobile receivers until it may have moved outside of the tracking area.

The number of tracked fish decreased with time post release: thirty-eight fish were tracked during the time period of turbine passage and the release of control fish (i.e., 3-9 June, Period 1); the signal of 33 fish, including the only signal sequence for pike #84202, was received during tracking Period 2 (10 June-9 July); 17 fish were relocated during Period 3 (10 July-8 August) when only stationary receivers were available for tracking; and the signals of 19 fish were obtained during Period 4 (9 August-3 September; Table 6). Thus, although Period 4 was shorter than periods 2 and 3, and acoustic signals could only be received by the stationary receivers for nine days, at least half of all acoustic-tracked fish were still confirmed present and alive in the Study Area between 10 and 13 weeks after passing through the turbine or being released as control fish. Of these, seven pike (i.e., 39% of all tracked pike) and eight walleye that were tracked manually during the last four days of the study are confirmed to have survived for 12-13 weeks post-turbine passage (n=13 fish) or control release (n=2) (Table 5). An additional three northern pike and two walleye were tracked until or shortly before the stationary receivers were removed on 18 August.

Table 6. Number of acoustic-tagged northern pike and walleye that were tracked by stationary or mobile receivers during four time periods between 3 June and 3 September, 2006.

	3-9 June [1]			10 June - 9 July [2]			10 Jul 9 Aug[3]	10 August - 3 September [4]		
Species	**Tracked manually**	**Stationary receiver**	**Total**	**Tracked manually**	**Stationary receiver**	**Total**	**Stationary receiver**	**Tracked manually**	**Stationary receiver [5]**	**Total**
Northern pike	14	16	17	0	13	13	8	7	7	9
Walleye	14	20	21	2	20	20	9	8	8	10
Total	28	36	38	2	33	33	17	15	15	19

1 - Manual tracking wasconducted from 7-9 June.
2 - Manual tracking was conducted on 9 July but only at three locations due to receiver malfunction.
3 - No manual tracking was conducted.
4 - Manual tracking was conducted from 31 August - 3 September.
5 - Receivers were removed from the water on 18 August with the exception of R5 which was removed on 9 July.

Except for two walleye whose signal was last received 34 and 52 days after turbine passage, the remaining fish (approximately 44% of all pike and walleye) were last relocated within 26 days of their release downstream of Kelsey GS, and for one third of all fish an acoustic signal was last received within 10 days (Table 5). An assessment of the long-term survival of those fish that were not tracked until the end of the study is difficult and can only be inferred based on the temporal and spatial pattern of relocations together with our knowledge about the 'normal' behaviour of the two study species. The available information suggests that just over half of the fish that were tracked for 10 days or less likely moved outside of the Study Area (see Section 4.2.3). There is no certainty regarding the fate of the remaining fish that were tracked for fewer than 10 days (approximately 15% of all pike and walleye). Possible explanations include avoiding signal detection (either remaining within or having moved outside of the Study Area) or mortality (either unrelated to turbine passage or with a delayed effect of turbine passage being a contributing factor).

4.2 FISH MOVEMENT AND BEHAVIOUR

4.2.1 Stationary receivers versus mobile tracking

For periods 1 and 4, manual tracking over several days supplemented the information obtained from the stationary receivers. During Period 1, when fish generally were still located in the immediate area near the generating station, more fish were being tracked by the stationary receivers (n=36) than by manual tracking (n=28). Furthermore, only one pike and one walleye, representing 5.3% of the tracked fish, were exclusively detected by manual tracking (Table 6, Appendix 2). During Period 4, when fish were more widely distributed within the Study Area, manual tracking was equally successful compared to the stationary receivers, with both methods identifying signals from 15 fish. Importantly, four fish (two pike and two walleye), representing 21.1% of the fish tracked in Period 4, were only detected by the mobile receiver (Table 6, Appendix 2). These data suggest that manual mobile tracking can be an important component of fish survival and movement studies such as the one at Kelsey GS, and that its importance will increase over time after fish release.

4.2.2 Treatment versus control fish

Because the main focus of the Turbine Passage Study was the survival of treatment fish, only a few control fish were equipped with acoustic tags. No major differences were obvious in the relocation statistics between the four pike and two walleye controls (Appendix 2). All control fish were compared to all treatment fish to evaluate potential differences in movement and behaviour between those two groups. Although the number of control fish with acoustic tags was small and a definitive statement is difficult to make, it seems that based on the observed tracking patterns these fish behaved much like the acoustic-tagged treatment fish, providing a first indication that turbine passage did not markedly affect subsequent fish movements. Similar to the treatment fish, the six control fish included individuals that were only detected by one receiver for a few days immediately after their release (#84668 and #84665), fish that were relocated by only one receiver but over most tracking periods until the end of the study (#84662), fish that were detected by multiple receivers within the immediate area of the Kelsey GS over an extended period of time (#84655 and #84656), and fish that ranged widely in the Study Area and likely left the area prior to the end of the last tracking period (#84663). Furthermore, although the sample size was much smaller, the MDM of control fish (mean 21.9 km, range 1.7-60.3 km) were similar to those observed for treatment fish (mean 16.6 km, range 1.3-94.0 km). These means were not significantly different ($P>0.75$). Because of the absence of obvious differences in the measured parameters, acoustic-tagged treatment and control fish were not treated separately in the following account of fish movements.

4.2.3 Quantitative and qualitative movement of northern pike and walleye

Except for one walleye (#84678), none of the acoustic-tagged fish were found east of the spillway gates. The strong, turbulent current that exits the spillway in a south-north direction, then flows westwards close to the opposite river bank, may have discouraged fish movement in this direction. This information is based on 5 days of monitoring by stationary receiver R4a, and three and four days of intensive mobile tracking from 7-9 June and 31 August-3 September, respectively. Due to the relatively simple morphometry of the river channel east of the spillway, it is unlikely that acoustic signals of resident fish in the above area would have been missed by the receivers. However, because of the long time period between the two tracking events in the Nelson River east of the spillway, and because the tributary entering the Nelson River at the eastern end of the area could not be accessed for acoustic tracking in late August/early September due to low water levels and the presence of dense macrophyte beds, the possibility that some of the acoustic-tagged fish moved into the unnamed tributary flowing into the east end of the bay (and were no longer tracked) cannot be excluded. This is also because some of the fish used in this study were captured from the above mentioned tributary (Figure 2).

Generally, walleye moved more and over larger distances than northern pike. At 26.0 km and 5.5 km both mean MDM and MaxD, respectively, of walleye were significantly (P#0.002) larger than for pike (Table 7). In addition to the statistical difference in mean distances, there were pronounced interspecific differences in the distribution of the different MDM and MaxD categories. For example, none of the pike had a MDM of >50 km and more than 60% had a MDM of <6 km, whereas three walleye (17%) had a MDM of >50 km and only 19% had a MDM of <6 km (Figure 15). Similarly, more than half of the pike had a MaxD of <4 km, whereas over 95% of all walleye had moved more than 4 km away from the station (Figure 15).

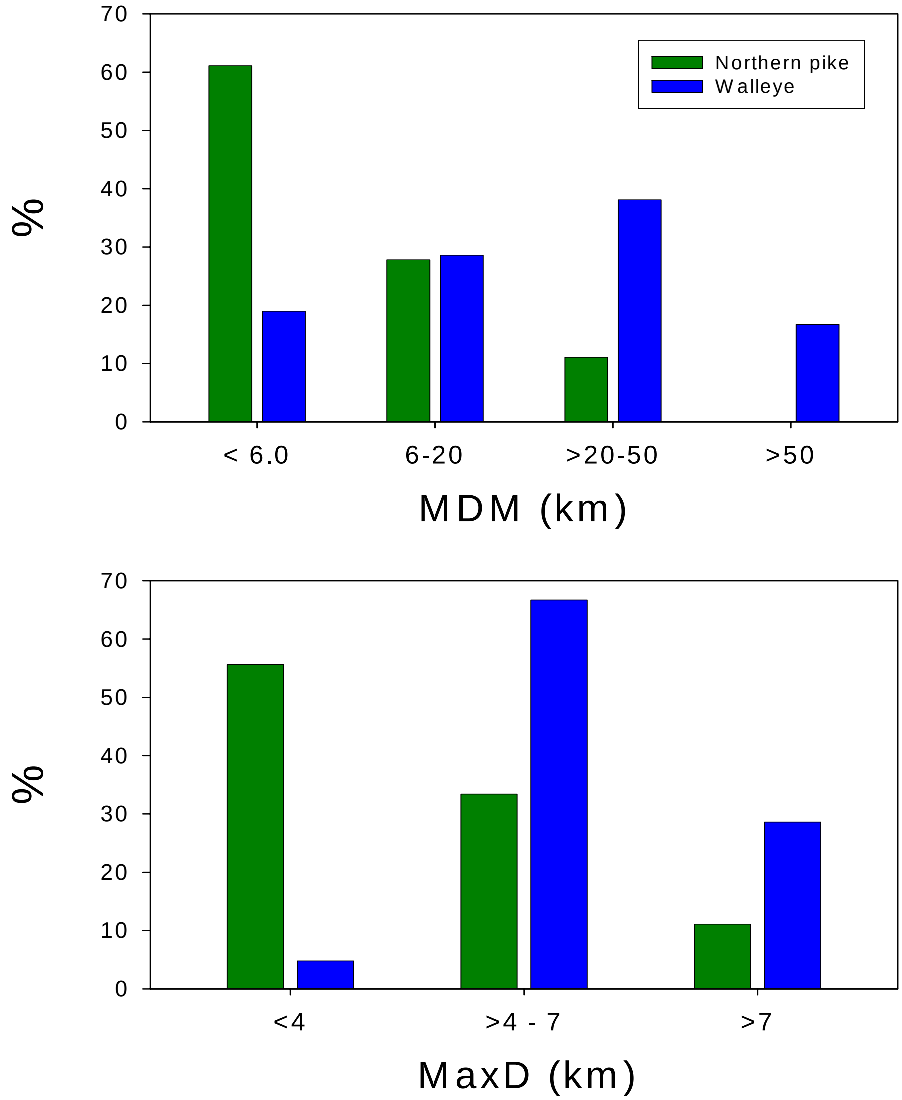


Figure 15. Proportion (%) of northern pike and walleye within each class of Minimum Distance of Movement (MDM) and Maximum Distance from Kelsey GS (MaxD) for 18 and 21 acoustic-tracked northern pike and walleye, respectively, after their release near the turbine outflow and subsequent tracking between 5 June and 3 September.

Table 7. Mean (SE) and number of fish in different distance classes for Minimum Distance of Movement (MDM) and Maximum Distance from Kelsey GS (MaxD) for acoustic-tracked northern pike and walleye, respectively, after their release near the turbine outflow.

Species	MDM (km)					MaxD (km)			
	Mean	**< 6.0**	**6 - 20**	**>20 - 50**	**>50**	**Mean**	**<4**	**4 - 7**	**>7**
Northern pike	7.5 ± 2.0	11	5	2	0	3.2 ± 0.5	10	6	2
Walleye	26.0 ± 5.3	4	6	8	3	5.5 ± 0.4	1	14	6

In addition to the above quantitative analysis, fish movements were also assessed qualitatively. For this, the Study Area was split up into three regions that differed in their distance from Kelsey GS but also in their physical characteristics and general habitat. Area 1 is the region close (#3 km) to the Kelsey GS extending west to the boundary with Area 2 and east to the edge of the Study Area (Figure 1). This area is mainly characterized by relatively shallow (<10 m depth), turbid waters over bedrock/boulder/hard mud substrate with a number of bays that feature some macrophyte growth and/or coarse woody debris including deadfalls. Area 2 includes the Grass River from the edge of the Study Area up to the limits of its plume as it extends into the Nelson River at the boundary with Area 1 (Figure 16). This area also includes the unnamed tributary of the Nelson River just west of the GS (Figure 1).

Figure 16. Mixing zone of the Grass River (dark coloured water) and the Nelson River (blue-grey coloured water) near the shore north of manual tracking location VR 17 (see Figure 12).

The area is characterized by generally shallow (<5 m), relatively clear but **DOC** rich waters indicating bog influence. Sediments consist mainly of sand or mud with local accumulations of organic debris and stands of submerged and/or emergent macrophytes. Water velocities are uniformly low (estimated at <0.4 m/s), the lowest of all three areas. Area 3 is the Nelson River mainstem as it flows north from its confluence with the Grass River to the northern extent of the Study Area (Figure 1). This area features a variety of habitats, but mainly has relatively fast flowing (≥ 1.0 m/s), deep (up to 20 m and more), mid-channel waters. The water is turbid and bottom substrates mainly consist of bedrock or boulders (overlain by compacted mud in places) with a few sandy shoreline areas within bays. Macrophyte growth is local and sparse except for the two large bays near Anipitapiskaw and Sakitowak rapids (Figure 1). One third of the 18 acoustic-tracked northern pike were exclusively relocated near the Kelsey GS, whereas the signal of only one of the 21 tracked walleye was exclusively received in Area 1 (Table 8).

Table 8. Number (%) of acoustic-tagged fish that were relocated at least once in four different sections of the Study Area.

Study Area Section	Northern Pike		Walleye	
Kelsey GS	6	(33.3)	1	(4.8)
Grass River	4	(22.2)	6	(28.6)
Nelson River, north	6	(33.3)	7	(33.3)
Grass and Nelson rivers	2	(11.1)	7	(33.3)

Approximately one third of the walleye moved at least temporarily into the Grass River, downstream on the Nelson River, or were relocated in both areas 2 and 3 (Table 8; also see figures 17-18, 21-22, 24). Substantial numbers of northern pike were relocated in the Grass River or downstream on the Nelson River, but only two individuals moved between both of these areas (also see Figure 20).

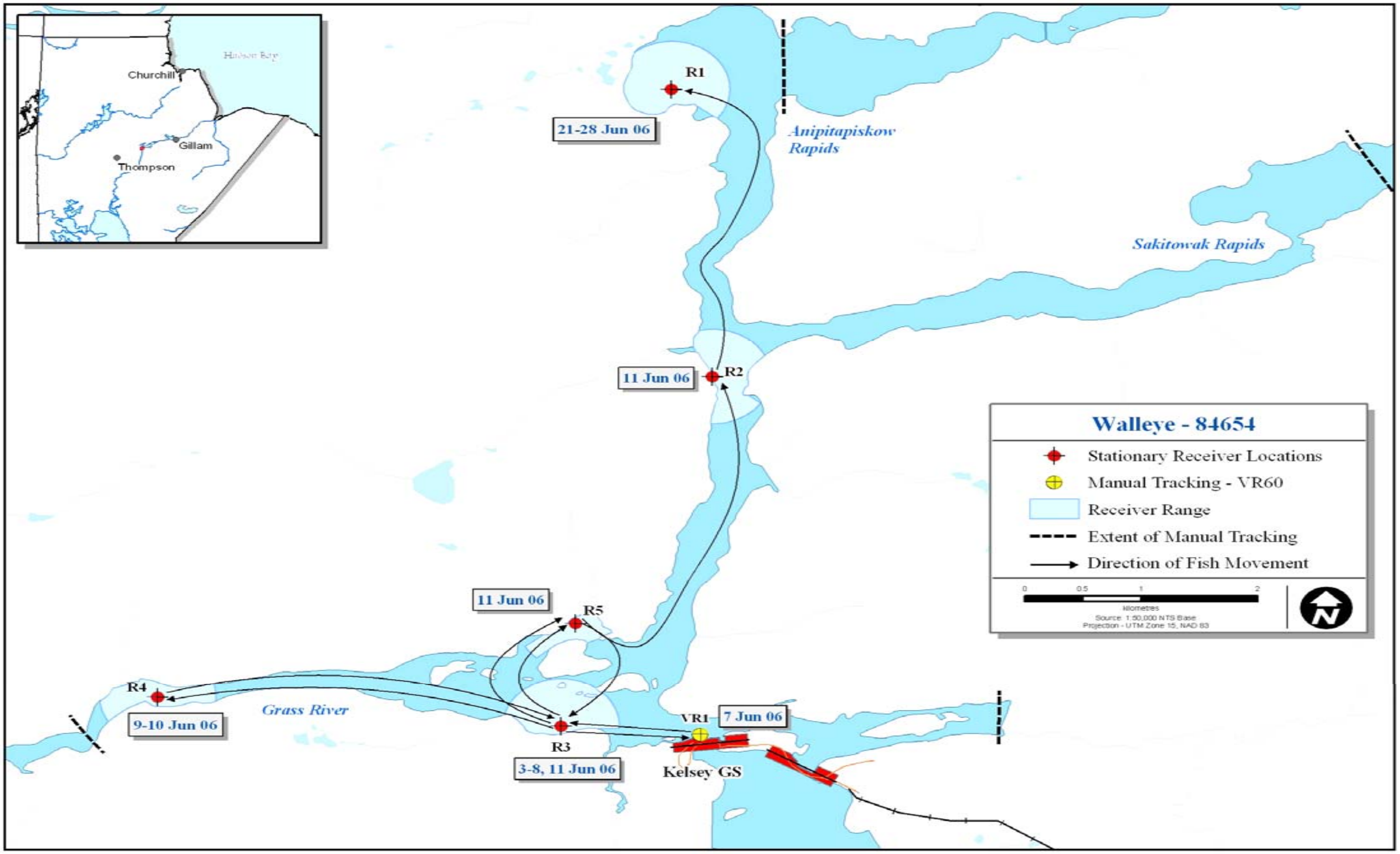


Figure 17. Movement of walleye #84654 between 3 and 21 June, 2006 after turbine passage on 3 June, 2006.

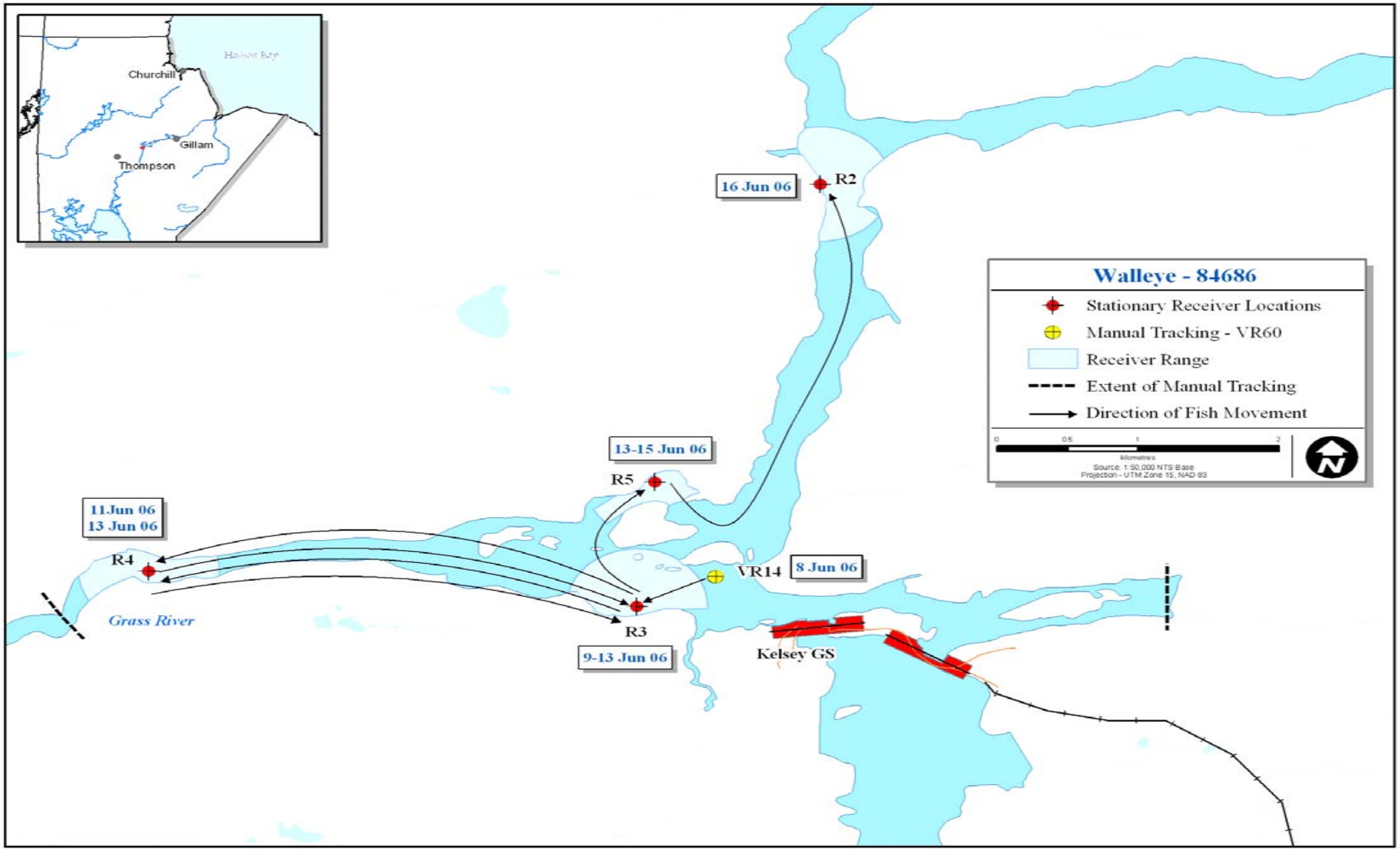


Figure 18. Movement of walleye #84686 between 8 and 16 June, 2006, after turbine passage on 7 June, 2006.

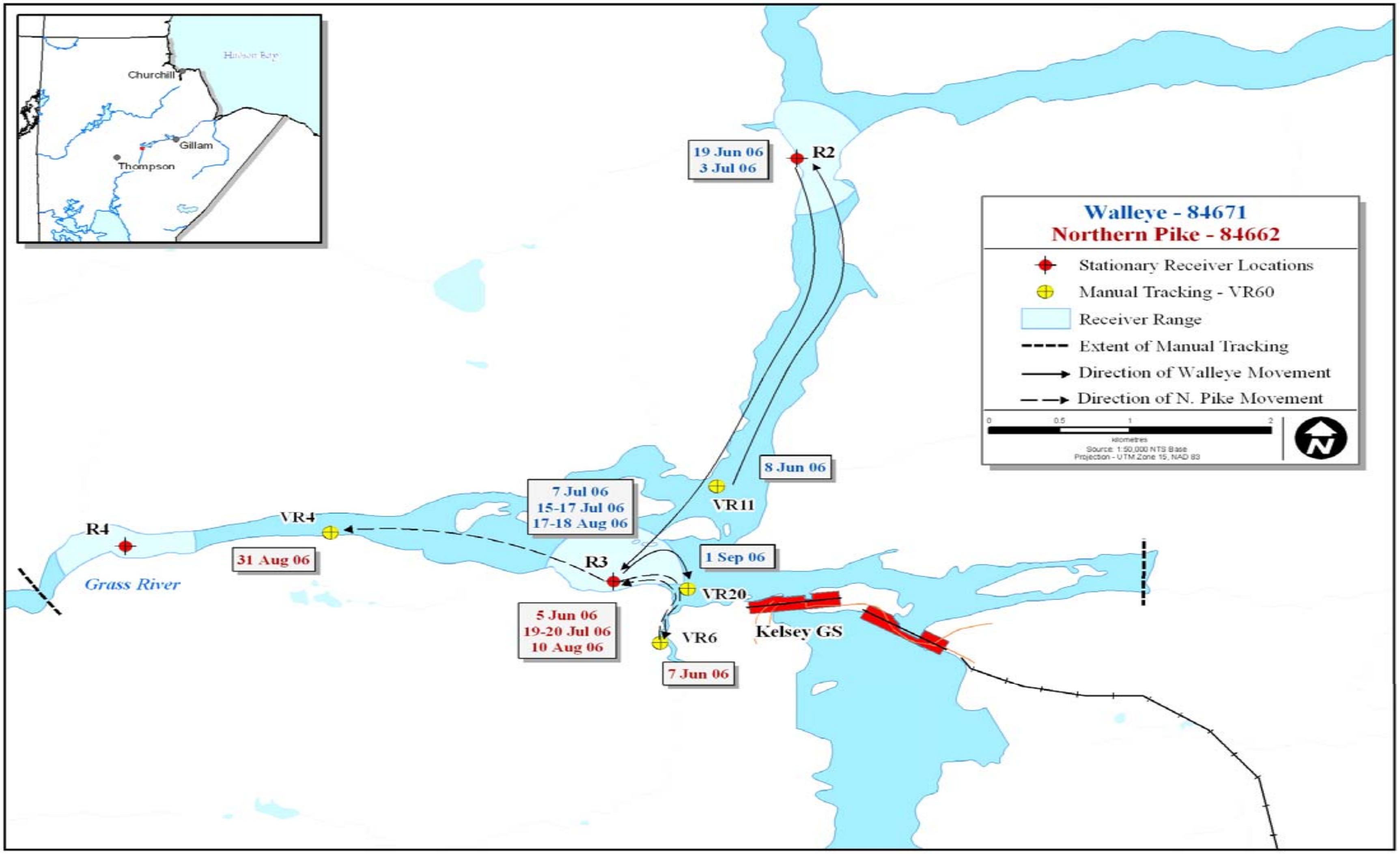


Figure 19. Movement of walleye # 84671 between 8 June and 1 September, 2006, after turbine passage on 7 June, 2006, and northern pike # 84662 between 5 June and 31 August, 2006, after being released as a control fish on 5 June, 2006.

In addition to a behaviour that can be best described as "long-term stationary near the Kelsey GS" and that was exhibited by three or possibly four pike (#84690, #84688, #84692, #84687) but none of the walleye (Appendix 2), individuals of both species showed four qualitatively distinct movement patterns. One group of fish that was comprised of walleye (#84672, #84682, #84675, #84654, #84686) and pike (#84700, #84695, #84665 and possibly #84658 [see discussion in section 4.1; Appendix 2]), exhibited "fast movement out of the Study Area". Although no definitive evidence that these fish left the Study Area exists, the movement pattern up to the last relocation strongly suggests that they did. Except for pike #84695, which had moved into the Grass River when its signal was lost, all of these fish were last relocated at either receiver R1 or R2, suggesting that they continued to move downstream on the Nelson River towards/into Split Lake (see below). This group includes two walleye (#84654 and #84686) that first moved around extensively in the southern part of the Study Area before moving relatively quickly downstream on the Nelson River (figures 17 and 18).

A second group of fish exhibited "fast movement into the Grass River with signal loss after several days of relocations". This group of fish consisted of one pike (#84691) and three walleye (#84670, #84677, #84679; Appendix 2). Walleye #84670 exhibited a slight variation from the general pattern of this group in that it moved several times between receivers R3 and R4. Together with pike #84695 (see previous paragraph), the fish from this group provided evidence that both pike and walleye moved upstream on the Grass River after turbine passage for time periods exceeding three months. A large proportion of the fish used in the current study were captured from the Grass River.

A third group of fish, consisting only of pike #84694 and walleye #84681 (Appendix 2), was "mainly stationary near Kelsey GS with one foray to location R2". Both these fish were relocated at R3, made one brief foray to R2 relatively early during tracking period 1 or 2, after which they returned to location R3.

With four pike and eleven walleye (Appendix 2), the fourth group of fish was the largest that could be identified. Its members showed "extensive movements between several locations and over an extended time period (1-3 months)". For one pike (#84662) and one walleye (#84671) this classification was tenuous because of the very sporadic nature of signal reception over the almost three months of successful tracking (Figure 19). This group included the one pike and the two walleye that were relocated at all five stationary receivers. After spending some time near Kelsey GS and in the Grass River, pike #84663 moved out of the Kelsey area downstream into the Nelson River between 21 June and 4 July, and was relocated at R1 from 6 July-18 August (Figure 20). During manual tracking on 2 September, a strong signal was obtained several times at locations downstream of Anipitapiskow Rapids and near the larger island at the eastern limit of the large bay where R1 was deployed. Although no acoustic code could be obtained, there is a strong possibility that the received signals belonged to pike #84663. Walleye #84678, which had not been recovered after turbine passage, not only moved into the vicinity of all stationary receivers, but also was the only fish that returned all the way to the Kelsey GS from location R1 and moved east past the spillway (Figure 21). Walleye #84676 also returned to the vicinity of the Kelsey GS after having moved downstream in the Nelson River to location R2 (Figure 22). Two walleye moved extensively within the northern portion of the Nelson River until the end of the last tracking period. Fish #84661 moved several times between R1 and R2 before entering the arm leading to Sakitowak Rapids (Figure 23). Fish #84684 also entered this section of the Nelson River after returning from location R1, swam past the rapids, and was relocated on 3 September near the easternmost extent of the tracking area (Figure 24).

It must be cautioned that the above assessment of northern pike movement and behaviour is somewhat limited by the fact that acoustic signals for most individuals were received for relatively short time periods. Ten pike were relocated on fewer than seven days out of the total of 88-93 (depending on the fish release date) available tracking days (Table 9), and of these, signals for five pike were only received for one or two days (Appendix 2). Most of the pike that were tracked for less than seven days were only relocated immediately after their turbine passage/release.

Table 9. Frequency of occurrence (n and % in parentheses), by number of days, an acoustic signal was received for treatment and control northern pike and walleye.

Days	Northern Pike		Walleye	
1 - 8	10	(55.6)	6	(28.6)
9 -21	2	(11.1)	7	(33.3)
22 - 71	6	(33.3)	8	(38.1)

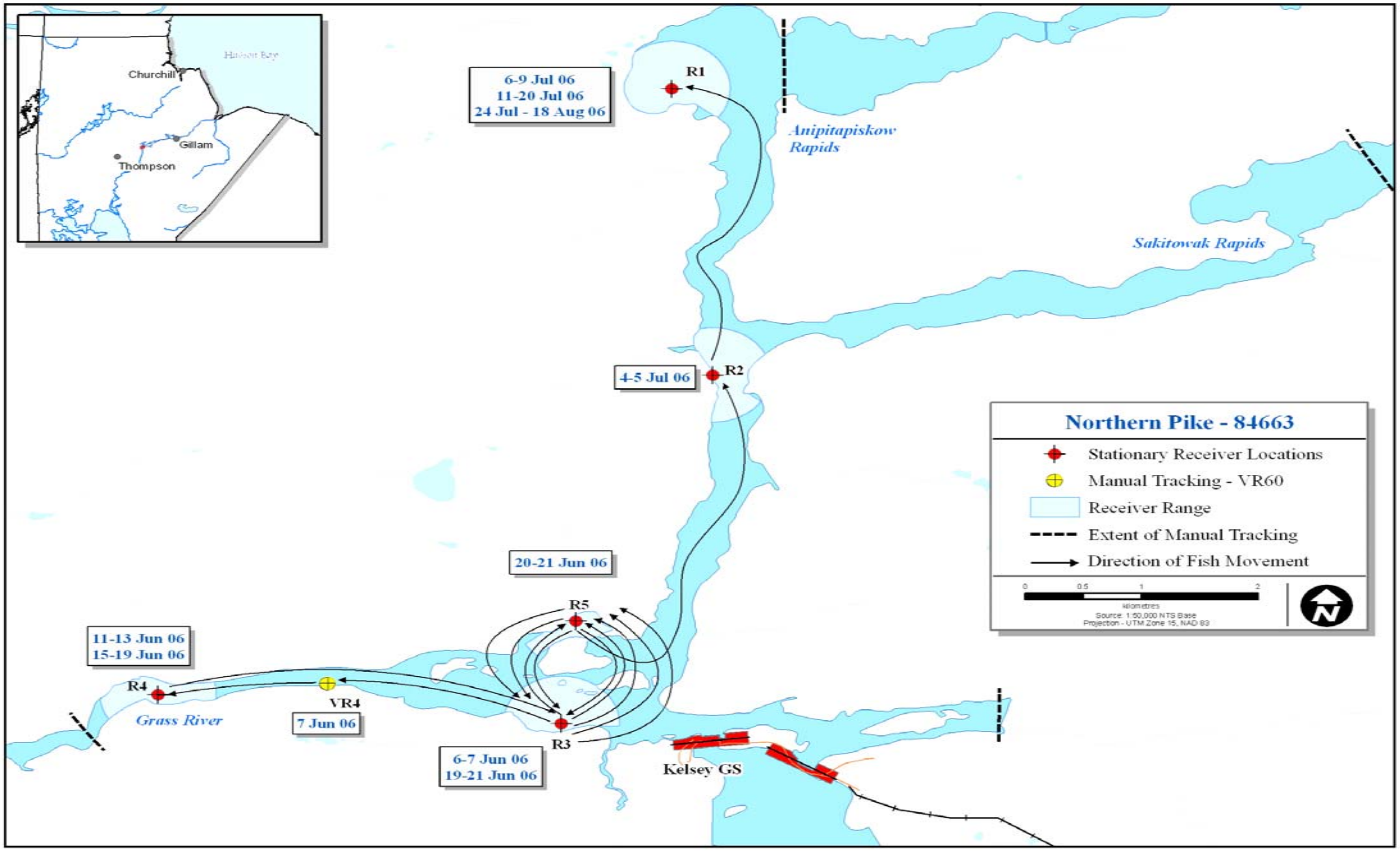


Figure 20. Movement of northern pike #84663 between 6 June and 18 August, 2006, after being released as a control fish on 5 June, 2006. Not all movements between R3 and R5 are shown.

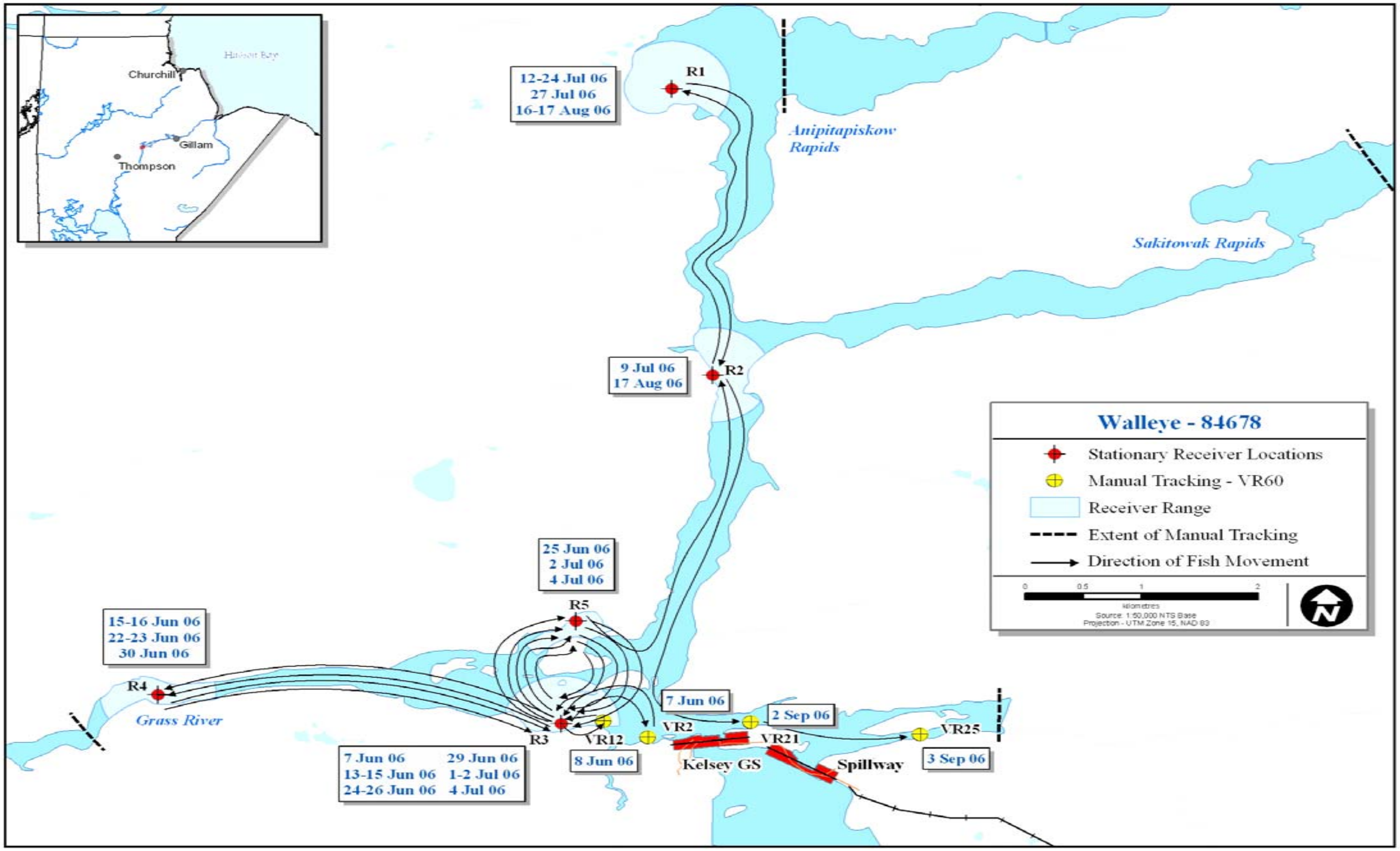


Figure 21. Movement of walleye #84678 between 7 June and 3 September, 2006, after turbine passage on 7 June, 2006. Not all movements between R3 and R5 are shown.

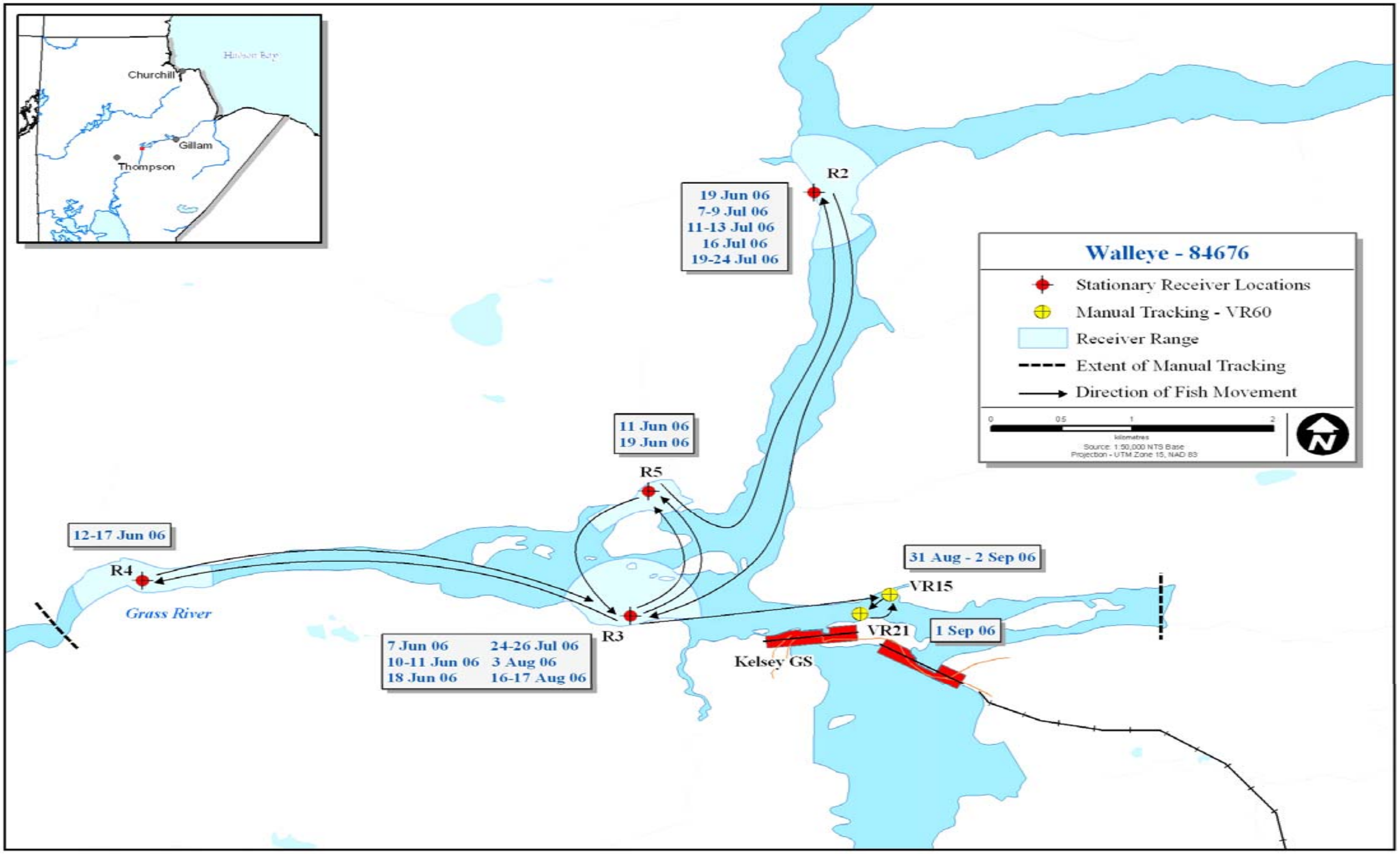


Figure 22. Movement of walleye #84676 between 7 June and 2 September, 2006 after turbine passage on 7 June, 2006.

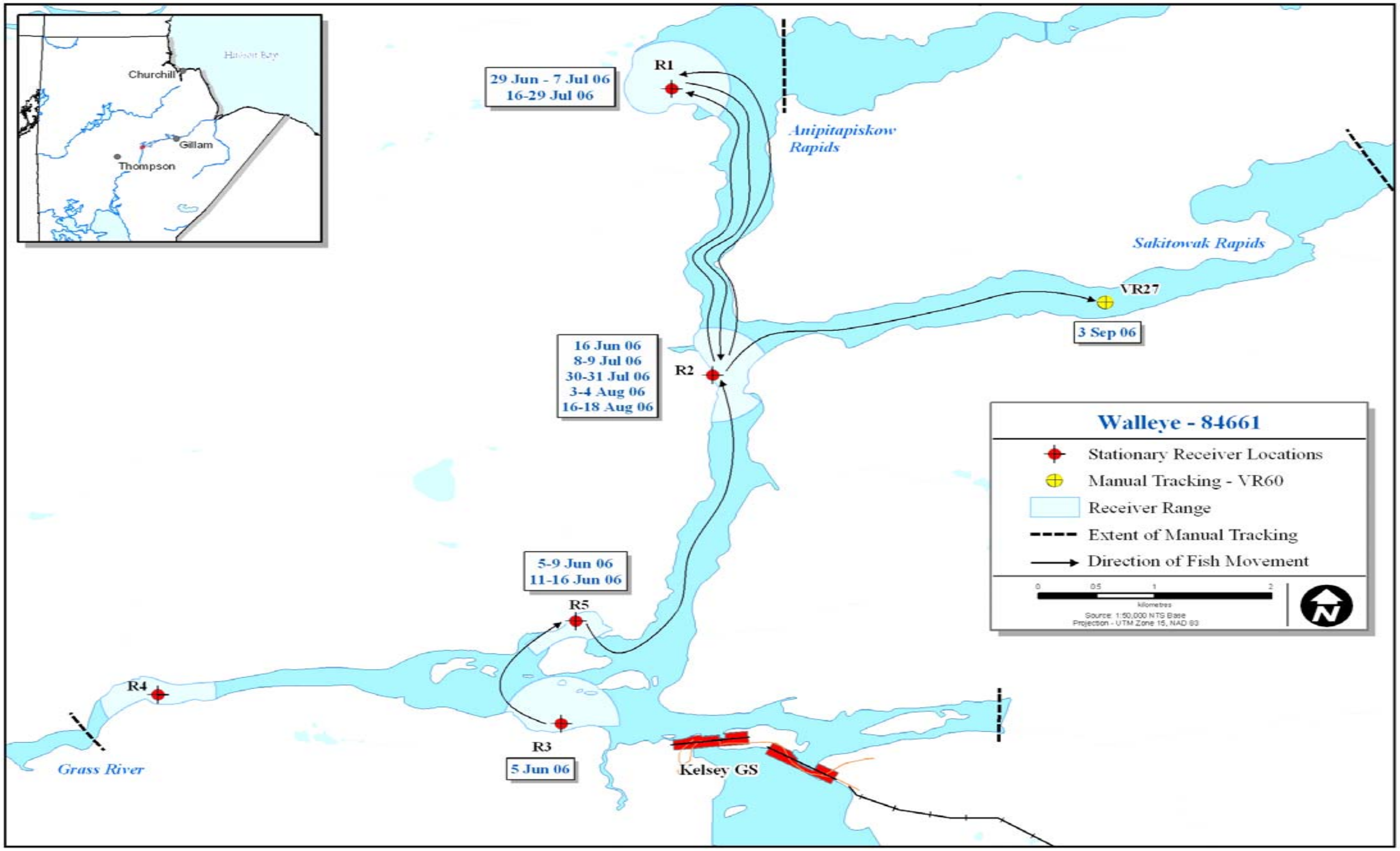


Figure 23. Movement of walleye #84661 between 5 June and 3 September, 2006 after turbine passage on 5 June, 2006.

Only the signal of pike #84662 was relocated (very sporadically) over almost the entire tracking period (Appendix 2). For four pike (and one walleye) the signal sequence and spatial distribution was inadequate to allow an assessment of a movement pattern (Appendix 2). Some of these pike, such as #84669, may have moved out of the tracking area quickly. Others may have died or their signal was no longer detected for other reasons (also see section 4.1). Northern pike are often found in vegetated shallows during the summer months (Diana et al. 1977; Chapman and MacKay 1984) where they can remain inactive for extended periods of time (Diana 1980). If northern pike in the current study behaved similarly, some of the acoustic-tagged individuals may have moved to and remained in small, shallow bays from where the signal could not be (stationary receivers) or was unlikely to be (mobile receiver) detected. Similar long-term stationary behaviour was displayed by three pike (#84690, #84688, #84692) for which signals were received from or near receiver R3 on 55-71 days over the entire study period (Appendix 2). In contrast to northern pike, the number of days over which walleye were relocated was much more evenly distributed, ranging between 2 and 69 days (Table 8).

To our knowledge no other studies documenting the movements of northern pike and walleye after turbine passage exist. Also little is known about the ‘normal’ summer movements of northern pike and walleye downstream of the Kelsey GS, although there is some evidence from Floy-tagging studies that at least some of these fish move into the area near Kelsey GS to spawn from Split Lake and tributaries to Split Lake (North/South Consultants Inc., unpubl. data). Some fish populations, including those of northern pike, have a (large) sedentary and a (small) mobile component (Malinin 1969; Mann 1980). Furthermore, there is no information about the movement history of those fish that were acoustic-tagged other than that spawning had been completed prior to the start of the study. For these and other reasons it is difficult to assess if the observed movement patterns were affected by turbine passage; nevertheless, some comparisons can be made.

Most walleye moved extensively (mean of 26 km) and widely after turbine passage. This pattern seems to deviate somewhat from general accounts of walleye movement. For example, in their review of freshwater fish migrations, Lucas and Baras (2001) state that adult walleye move less than 5 km over the summer, without providing a geographical location or the habitat of the study populations. The beginning of the present study coincided with the period of rapidly increasing water temperatures in the Nelson River, and between 1 July and the end of the study in early September river temperatures remained within 2.5EC of the observed maximum of 20.6EC (Figure 25). There was no obvious difference between walleye (and pike) movements prior to and post 1 July, and the data obtained in the current study mainly represent summer movements. Perhaps walleye populations from more southern waters or from lake environments (such as potentially presented in

Lucas and Baras (2001)) behave differently from those observed in this study. The existence of such interpopulation differences is supported by other studies in the Nelson River system that also indicate that walleye may move over larger distances (10-40 km) during the summer months (Barth et al. 2003; Murray et al. 2005).

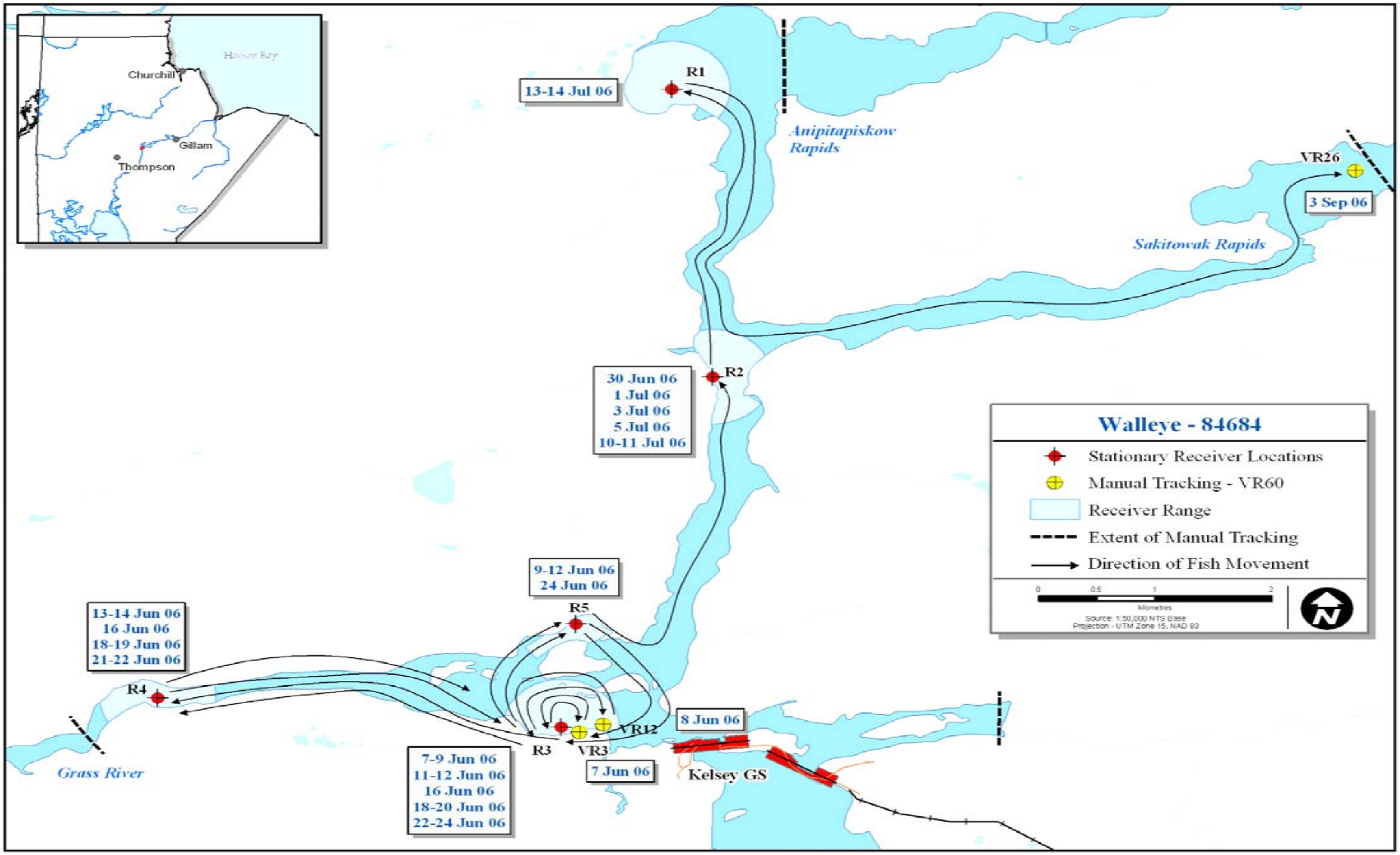


Figure 24. Movement of walleye #84684 between 7 June and 3 September, 2006 after turbine passage on 7 June, 2006.

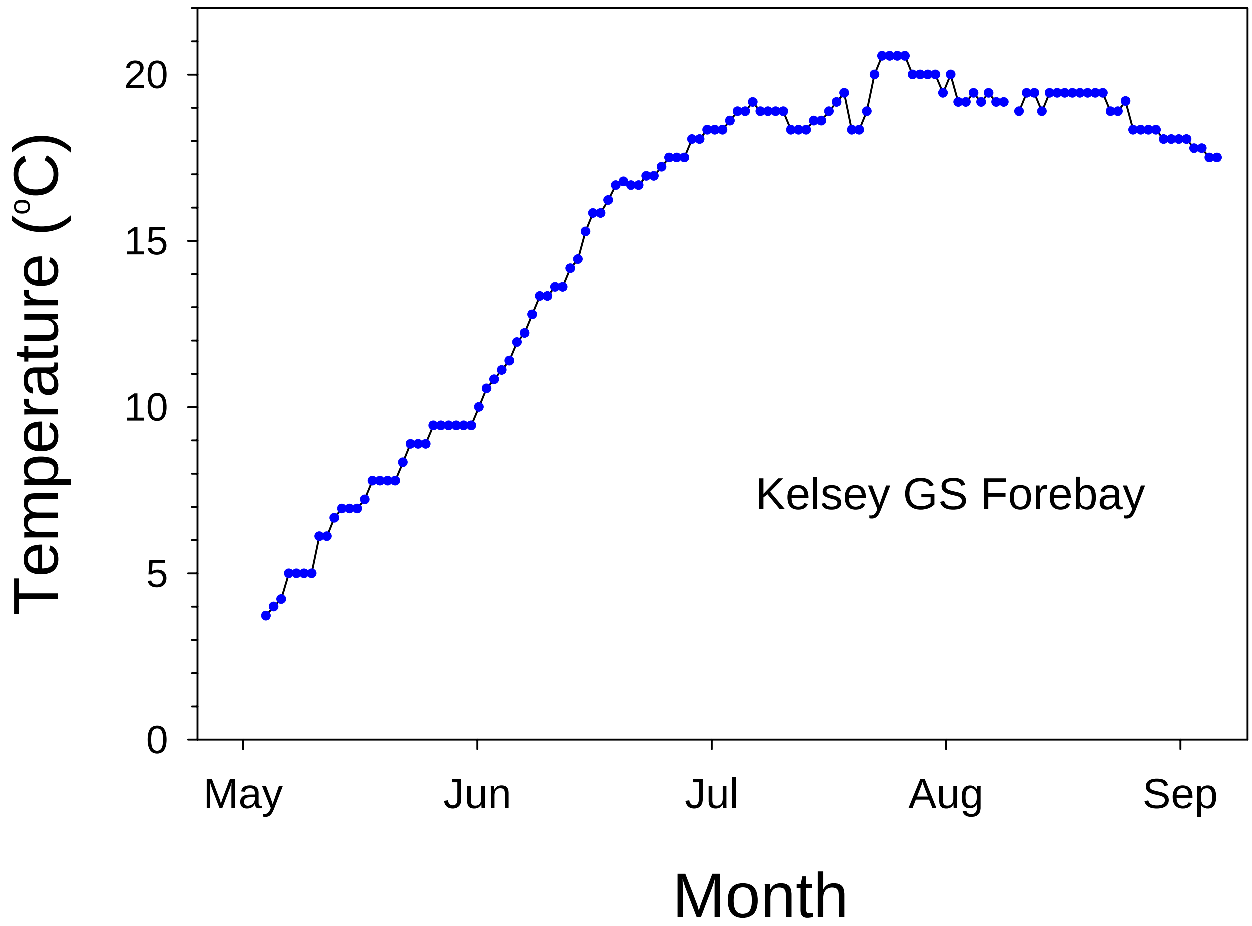


Figure 25. Daily Nelson River water temperatures from 4 May - 6 September, 2006, measured on the forebay side of the Kelsey GS powerhouse.

Adult northern pike have been described as rather sedentary (Diana 1980) during the summer months, but may also range widely with (Steinmann et al. 1937) or without (Diana et al. 1977) clear movement patterns. The pattern of pike movement observed at Kelsey GS is in agreement with these findings and also with results obtained from other pike populations in the Nelson River system (Barth et al. 2003; Murray et al. 2005; Murray and Barth 2007). Thus, the movements by walleye and northern pike at Kelsey GS seem to fall within the patterns regularly observed in walleye and pike populations from similar habitats and do not suggest a pronounced effect of turbine passage.

5.0 REFERENCES

CADA, G. F. 2001. The development of advanced hydroelectric turbines to improve fish passage survival. Fisheries 26: 14 – 23.

BARTH, C.C., L.J. NEUFELD, and J.R. OLYNIK. 2003. Movements of Northern Pike, Walleye, and Lake Whitefish Tagged with Radio and Acoustic Transmitters in the Gull (Keeyask) Study Area, 2001/2002. A draft report prepared for Manitoba Hydro by North/South Consultants Inc. 119 pp.

BRY, C. 1996. Role of vegetation in the life cycle of pike. In: "Pike: Biology and exploitation", Craig, J. F., ed., Chapman & Hall, London pp. 45-65.

CHAPMAN, C.A. and W.C. MACKAY. 1984. Versatility in habitat use by a top aquatic predator, Esoc lucius L. J. Fish Biol. 25:109-115.

CHAPMAN, C.A. and W.C. MACKAY. 1984. Direct observation of habitat utilization by northern pike. Copeia 1984:255-258.

DIANA, J. 1980. Diel Activity pattern and swimming speeds of northern pike (Esox lucius) in Lac Ste. Anne, Alberta. Can. J. Fish. Aquat. Sci. 37: 1454-1457.

DIANA, J.S., W.C. MACKAY, and M. EHRMAN. 1977. Movement and habitat preferences of northern pike (*Esox lucius* L.) in Lac St. Anne, Alberta. Trans. Am. Fish. Soc. 106:560-565.

FERGUSON, J.W., R.F. ABSOLON, T.J. CARLSON, and B.P. SANDFORD. 2006. Evidence of delayed mortality on juvenile Pacific salmon passing through turbines at Columbia River dams. Trans. Amer. Fish. Soc. 135:139-150.

LUCAS, M. C. and E. BARAS. 2001. Migration of Freshwater Fishes. Blackwell Science, Oxford, UK, 420 pp.

MALININ, L.K. 1969. Home range and homing instinct of fish. Zoologicheskii Zhurnal 48:381-391; Fisheries Research Board of Canada Translation Series 2050.

MANITOBA HYDRO 2002. http://www.hydro.mb.ca/our_facilities/gs_kelsey.shtml

MANN, R.H.K. 1980. The numbers and production of pike (Esox lucius) in two Dorset rivers. J. Anim. Ecol. 49:899-915.

MATOUSEK, J. A., A. W. WELLS, J. H. HECHT, and S. G. METZGER. 1994. Reporting survival results of fish passing through low-head turbines. Hydro Review, May 1994: 58 – 65.

MURRAY, L., C.C. BARTH, and J.R. OLYNIK. 2005. Movements of Radio- and Acoustic-Tagged Northern Pike, Walleye, and Lake Whitefish in the Keeyask Study Area: May 2002 to April 2003. A draft report prepared for Manitoba Hydro by North/South Consultants Inc. 107 pp.

MURRAY, L. and C.C. BARTH. 2007. Movements of Radio- and Acoustic-Tagged Northern Pike, Walleye and Lake Whitefish in the Keeyask Study Area: May 2003 to October 2004 and a Summary of Findings from 2001 to 2005. A draft report prepared for Manitoba Hydro by North/South Consultants Inc., 95 pp.

NAVARRO, J. E., D. J. McCAULEY, and A. R. BLYSTRA. 1996. Turbine passage at four low-head hydroelectric fascilities in northeast Michigan. N. Am. J. Fish. Manage. 16: 182 – 191.

PEAKE, S. 1999. Sodium bicarbonate and clove oil as potential anesthetics for non-salmonid fishes. N. Am. J. Fish. Man. 18: 919 – 924.

PISIAK, D.J., and C.C. BARTH. 2006. Movements of fish tagged with acoustic transmitters in the Limestone Generating Station Forebay, Fall 2005 Year 1. A draft report prepared for Manitoba Hydro by North/South Consultants Inc., 55 pp.

STEINMANN, P., W. KOCH, and L. SCHEURING. 1937. XII. Die Wanderungen unserer Süsswasserfische. Dargestellt aufgrund von Markierungsversuchen. Z. Fisch. 35:369-467.

6.0 GLOSSARY

Anadromous – a species of fish that spawn in freshwater but live part of their life in saltwater

Catadromous – a species of fish that spawn in saltwater but live primarily in freshwater

Diadromous – a species of fish that regularly migrate between fresh and salt water

DOC – Dissolved Organic Carbon

Potamodromous – a species of fish that migrates exclusively within freshwater

Smolts – A young salmon when it becomes covered with silvery scales and first migrates from fresh water to the sea.

APPENDICES

Appendix 1. Locations (UTM 14 V coordinates) of fish relocations from manual tracking. For each location, the number of tracked fish and the date(s) of tracking are provided.

Location ID	Location Easting	Location Northing	Distance From GS	Code	Detection Date(s)	Code	Detection Date(s)	Code	Detection Date(s)	Code	Detection Date(s)	Code	Detection Date(s)
VR1	653288	6213369	0.05	185	7, 8 Jun	1145	7 Jun	1140	7 Jun	1143	7 Jun	1149	8 Jun
VR2	652840	6213278	0.5	190	7 Jun								
VR3	652248	6213318	1.1	178	7 Jun	180	8 Jun	197	7 Jun				
VR4	650049	6213606	3.3	1136	7 Jun	1137	31 Aug	1149	1 Sep				
VR5	648542	6213274	4.9	1143	7 Jun								
VR6	652465	6212853	1.3	1137	7 Jun								
VR7	653095	6214443	1.5	1139	8 Jun								
VR8	653269	6215317	2.4	191	8 Jun	1142	8 Jun						
VR9	653468	6216018	3.1	1133	8 Jun								
VR10	653395	6216703	3.8	1135	8 Jun								
VR11	652746	6214248	1.4	1131	3 Sep	1134	8 Jun	1157	8 Jun				
VR12	652449	6213413	0.9	178	8 Jun	183	8 Jun	186	8 Jun	190	8 Jun	193	8 Jun
				193	31 Aug	193	2, 3 Sep	199	8 Jun	200	8 Jun	1132	8 Jun
				1140	31 Aug	1140	2 Sep	1148	8 Jun	1148	1 Sep	1251	8 Jun
VR13	652262	6213457	1.1	202	8 Jun								
VR14	652622	6213662	0.8	192	8 Jun	202	8 Jun						
VR15	653907	6213700	0.7	176	31 Aug	176	1, 2 Sep						
VR16	652931	6213319	0.4	1140	31 Aug								
VR17	650465	6213582	2.9	1149	31 Aug	1149	3 Sep						

Appendix 1. Continued.

Location ID	**Location Easting**	**Location Northing**	**Distance From GS**	**Code**	**Detection Date(s)**	**Code**	**Detection Date(s)**	**Code**	**Detection Date(s)**	**Code**	**Detection Date(s)**	**Code**	**Detection Date(s)**
VR18	651119	6213647	2.3	1143	31 Aug	1143	1 Sep	1149	1 Sep				
VR19	652085	6213776	1.4	199	31 Aug								
VR20	652617	6213336	0.7	193	1 Sep	1134	1 Sep	1140	1,2,3 Sep	1148	3 Sep		
VR21	653709	6213516	0.4	176	1 Sep								
VR22	651453	6213577	1.9	1143	1 Sep								
VR23	651315	6213802	2.1	1143	2 Sep	1149	2 Sep						
VR24	654311	6217756	5.7	185	2,3 Sep								
VR25	655173	6213510	1.9	190	3 Sep								
VR26	658375	6219785	9.4	178	3 Sep								
VR27	656359	6218204	7.8	1138	3 Sep								

Appendix 2. Biological, tagging, and relocation information for acoustic-tagged northern pike and walleye that were passed through a turbine or released as control fish at the Kelsey GS from 4-8 June, 2006.

									Period: 3-9 June [1]				Period: 10 Jun - 9 Jul [2]			Period: 10 Jul – 9 Aug [3]		Period: 10 Aug - 3 Sep [4]									
Species	Length (mm)	Weight (g)	Acoustic Code	Floy-tag number	Group	Date released	Release depth	Status Hi-Z Tag	Status acoustic	Tracked manually	Stationary receiver	Receiver number(s)	Tracked manually	Stationary receiver	Receiver number(s)	Stationary receiver	Receiver number(s)	Tracked manually	Stationary receiver [5]	Receiver number(s)	# of days with signal	# of days to last signal	Period(s) of relocation	Area	MDM (km)	MaxD (km)	Movement pattern
Pike	880	5500	179	84699	Turbine	8-Jun	mid	not recovered*	**no**	0	0	-	0	0	-	0	-	0	0	-	0	-	-	-	-	-	-
Pike	618	1800	180	84697	Turbine	8-Jun	mid	released	yes	1	1	R3, R5	0	1	R2, R3, R4	1	R3	0	0	-	48	63	8 Jun - 9 Aug	G, N	29.2	4.8	Extensive
Pike	576	1150	186	84201	Turbine	8-Jun	mid	released	yes	1	1	R3	0	1	R3	0	-	0	0	-	2	4	8 , 11 Jun	K	2.0	1.3	Short
Pike	715	2650	187	84700	Turbine	8-Jun	mid	released	yes	0	1	R1, R2, R3	0	1	R1	0	-	0	0	-	5	9	8, 9, 11, 13, 16 Jun	N	9.3	7.7	FD
Pike	563	1550	188	84690	Turbine	8-Jun	mid	released injured	yes	0	1	R3	0	1	R3	1	R3	1	1	R3	67	87	8 Jun - 2 Sep	K	1.8	1.3	Stat
Pike	724	3650	193	84694	Turbine	8-Jun	mid	not recovered	yes	1	1	R3	0	1	R2, R3	1	R3	1	1	R3	66	88	8 Jun - 3 Sep	N	7.4	4.2	Foray
Pike	565	1550	194	84203	Turbine	8-Jun	mid	dead at 48 hrs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pike	800	3850	195	84693	Turbine	8-Jun	mid	dead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pike	580	1350	199	84688	Turbine	8-Jun	mid	not recovered	yes	1	1	R3	0	1	R3	1	R3	1	1	R3	55	85	8 Jun - 31 Aug	K	2.5	1.4	Stat
Pike	790	3700	200	84695	Turbine	8-Jun	mid	released	yes	1	1	R3	0	1	R4, R5	0	-	0	0	-	4	4	8-11 Jun	G	7.3	4.8	FD
Pike	715	2900	201	84696	Turbine	8-Jun	mid	dead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pike	545	1225	202	84691	Turbine	8-Jun	mid	released	yes	1	1	R3	0	1	R3, R4	1	R4	0	1	R4	15	72	8-11 Jun, 5-8, 12-18 Aug	G	6.4	4.8	Grass R
Pike	604	1800	203	84689	Turbine	8-Jun	mid	dead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pike	600	1850	1130	84666	Turbine	6-Jun	shallow	released injured	**no**	0	0	-	0	0	-	0	-	0	0	-	0	-	-	-	-	-	-
Pike	650	1800	1131	84667	Turbine	6-Jun	shallow	dead-tag reused	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pike	841	4250	1131	84687	Turbine	8-Jun	mid	released	yes	0	1	R3	0	0	-	0	-	1	0	-	3	88	8-9 Jun, 3 Sep	N	2.4	1.4	(Stat)
Pike	602	1500	1132	84668	Control	7-Jun	-	released	yes	1	1	R3	0	0	-	0	-	0	0	-	2	2	7-8 Jun	K	1.7	1.3	Short
Pike	594	1450	1133	84669	Turbine	6-Jun	shallow	released	yes	1	1	R2, R3	0	0	-	0	-	0	0	-	2	3	6, 8 Jun	N	5.6	4.2	Short
Pike	528	1100	1135	84665	Control	5-Jun	-	released	yes	1	1	R2	0	1	R2	0	-	0	0	-	4	7	8-11 Jun	N	5.2	4.2	FD
Pike	574	1250	1136	84663	Control	5-Jun	-	released	yes	1	1	R3	0	1	R1, R2, R3, R4, R5	1	R1	0	1	R1	55	75	6 Jun - 18 Aug	G, N	27.3	7.7	Extensive
Pike	550	1225	1137	84662	Control	5-Jun	-	released	yes	1	1	R3	0	0	-	1	R3	1	1	R3	6	88	5, 7 Jun; 19-20 Jul; 10, 31 Aug	G	4.4	3.3	(Extensive)
Pike	475	800	1139	84658	Turbine	4-Jun	deep	released injured	yes	1	0	-	0	0	-	0	-	0	0	-	1	5	8 Jun	N	1.5	1.5	(FD)
Pike	641	2025	1144	84657	Turbine	4-Jun	deep	dead - tag reused	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pike	529	1250	1147	84202	Turbine	8-Jun	mid	released	yes	0	0	-	0	1	R3	0	-	0	0	-	1	23	30 Jun	K	1.3	1.3	short
Pike	775	2950	1148	84692	Turbine	8-Jun	mid	released	yes	1	1	R3	0	1	R3	1	R3	1	1	R3	71	88	8 Jun - 18 Aug, 1,3 Sep	K	2.6	1.3	Stat
Pike	587	1350	1149	84698	Turbine	8-Jun	mid	released	yes	1	1	R3	0	1	R3, R4	0	-	1	0	-	16	88	8-10,12-16,18-21 Jun; 31 Aug-3 Sep	G	16.4	4.8	Extensive

[1] Manual tracking was done from 7-9 June.
[2] Manual tracking was done on 9 July but only at three locations due to receiver malfunction.
[3] No manual tracking was done.
[4] Manual tracking was done from 31 August - 3 September.
[5] Receivers were taken out of the water on 18 August, except for R5 which was removed on 9 July.

MDM = Minimum Distance of Movement.
MaxD = Largest recorded distance from GS.
Receiver (R) 1-5 locations are provided in Table 1 and Figure 1.
R4 always refers to R4b.

Status Hi-Z = fate of a fish after treatment or control release**:**
not recovered (by recapture crew) = fate unknown; potentially survived for some time with balloons & radio tag attached.
released = released back into the Nelson R after balloons & radio tag were taken off and health status was assessed.
released injured = fish was released into the Nelson R with injuries that were deemed survivable.
dead = fish was killed during turbine passage (or died during 48h assessment); acoustic tag was either lost or reused.

Appendix 2. Continued.

									Period: 3-9 June [1]				Period: 10 Jun - 9 Jul [2]			Period: 10 Jul – 9 Aug [3]		Period: 10 Aug - 3 Sep [4]									
Species	**Length (mm)**	**Weight (g)**	**Acoustic Code**	**Floy-tag number**	**Group**	**Date released**	**Release depth**	**Status Hi-Z Tag**	**Status acoustic**	**Tracked manually**	**Stationary receiver**	**Receiver number(s)**	**Tracked manually**	**Stationary receiver**	**Receiver number(s)**	**Stationary receiver**	**Receiver number(s)**	**Tracked manually**	**Stationary receiver [5]**	**Receiver number(s)**	**# of days with signal**	**# of days to last signal**	**Period(s) of relocation**	**Area**	**MDM (km)**	**MaxD (km)**	**Movement pattern**
Walleye	405	750	175	84672	Turbine	7-Jun	mid	released	yes	0	1	R1, R2	0	0	-	0	-	0	0	-	2	3	7, 9 Jun	N	7.7	7.7	FD
Walleye	438	900	176	84676	Turbine	7-Jun	mid	released	yes	0	1	R3	0	1	R2, R3, R4, R5	1	R2, R3	1	1	R3	32	88	7 Jun-26 Jul; 3, 16-17 Aug; 31 Aug-2 Sep	G, N	18.8	4.8	Extensive
Walleye	401	750	177	84680	Turbine	7-Jun	mid	dead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Walleye	415	800	178	84684	Turbine	7-Jun	mid	released	yes	1	1	R3, R5	0	1	R2, R3, R4, R5	1	R1, R2	1	0	-	39	89	7 Jun -14 Jul; 3 Sep	G, N	74.4	9.4	Extensive
Walleye	568	1800	182	84673	Turbine	7-Jun	mid	released after 48 h	yes	0	1	R3	0	1	R3	0	-	0	0	-	4	5	7, 9-11 Jun	K	1.3	1.3	Short
Walleye	425	1075	183	84677	Turbine	7-Jun	mid	released	yes	1	1	R3	0	1	R3, R4	0	-	0	0	-	15	23	7-29 Jun	G	5.5	4.8	Grass R
Walleye	472	1150	184	84681	Turbine	7-Jun	mid	not recovered	yes	0	1	R2, R3	0	1	R3	0	-	0	0	-	16	52	7 Jun - 12 Jul, 27-28 Jul	N	10.3	4.2	Foray
Walleye	384	600	185	84685	Turbine	7-Jun	mid	released	yes	1	1	R3	0	1	R2, R3, R4, R5	0	-	1	0	-	18	89	7-26 Jun; 2-3 Sep	G, N	31.7	5.7	Extensive
Walleye	445	950	189	84674	Turbine	7-Jun	mid	dead - tag recovered	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Walleye	515	1800	190	84678	Turbine	7-Jun	mid	not recovered	yes	1	1	R3	0	1	R2, R3, R4, R5	1	R1	1	1	R1, R2	36	89	7 Jun - 27 Jul, 16-17 Aug, 2-3 Sep	G, N	94.0	7.7	Extensive
Walleye	412	750	191	84682	Turbine	7-Jun	mid	released	yes	1	1	R3	0	1	R1, R2	0	-	0	0	-	4	6	7-8, 11-12 Jun	N	9.0	7.7	FD
Walleye	388	600	192	84686	Turbine	7-Jun	mid	released	yes	1	1	R3	0	1	R2, R3, R4, R5	0	-	0	0	-	8	10	8-16 Jun	G, N	20.4	4.8	FD
Walleye	404	725	196	84675	Turbine	7-Jun	mid	released	yes	0	1	R3	0	1	R2	0	-	0	0	-	2	7	7, 13 Jun	N	5.8	4.2	FD
Walleye	488	1425	197	84679	Turbine	7-Jun	mid	released	yes	1	1	R3	0	1	R4	0	-	0	0	-	7	9	7, 9-15 Jun	G	5.1	4.8	Grass R
Walleye	439	900	198	84683	Turbine	7-Jun	mid	dead - tag lost	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Walleye	445	1025	1134	84671	Turbine	7-Jun	mid	released	yes	1	0	-	0	1	R2, R3	1	R3	1	1	R3	21	87	8, 19 Jun; 3-17 Jul; 17-18 Aug; 1 Sep	N	9.2	4.2	(Extensive)
Walleye	443	950	1138	84661	Turbine	5-Jun	shallow	released	yes	0	1	R3, R5	0	1	R1, R2, R5	1	R1, R2	1	1	R2	37	91	5 Jun - 18 Aug, 3 Sep	N	23.8	7.8	Extensive
Walleye	432	900	1140	84659	Turbine	5-Jun	shallow	released	yes	1	1	R3, R4	1	1	R3, R4, R5	1	R3, R4	1	1	R3, R4	69	91	5 Jun - 16 Aug, 31 Aug - 3 Sep	G	27.9	4.8	Extensive
Walleye	468	1050	1141	84660	Turbine	5-Jun	shallow	dead - tag lost	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
Walleye	410	750	1142	84655	Control	4-Jun	-	released	yes	1	1	R3	0	1	R3, R4, R5	1	R3	0	1	R3, R4	60	68	4 Jun - 10 Aug	G, N	16.6	4.8	Extensive
Walleye	482	1225	1143	84656	Control	4-Jun	-	released	yes	1	1	R3	1	1	R3, R4, R5	1	R3	1	1	R3, R4	62	91	4 Jun - 18 Aug, 31 Aug - 2 Sep	G	60.3	4.9	Extensive
Walleye	472	1400	1144	84670	Turbine	7-Jun	mid	released	yes	0	1	R3	0	1	R3, R4	0	-	0	0	-	14	16	7-22 Jun	G	32.8	4.8	Grass R
Walleye	429	1000	1145	84654	Turbine	3-Jun	deep	released	yes	1	1	R3, R4	0	1	R1, R2, R3, R5	0	-	0	0	-	17	26	3-11, 21-28 Jun	G, N	21.4	7.7	FD
Walleye	445	1000	1146	84651	Turbine	3-Jun	deep	not recovered	**no**	0	0	-	0	0	-	0	-	0	0	-	0	-	-	-	-	-	-
Walleye	490	1450	1157	84652	Turbine	3-Jun	deep	released	yes	1	1	R3, R5	0	1	R2, R3	1	R2	0	1	R2	37	69	3 Jun - 11 Jul, 25 Jul - 10 Aug	N	33.4	4.2	Extensive
Walleye	490	1400	1251	84653	Turbine	3-Jun	deep	released	yes	1	1	R3	0	1	R3, R4, R5	0	-	0	0	-	21	34	3-30 Jun, 6 Jul	G	36.0	4.8	Extensive

Area:
K= Kelsey GS (within VR 11, 18, 25).
G= Grassy River & S shore tributary (VR6).
N= Nelson River including, and north of VR 11.

Movement pattern: short= signal was received only for a few days, no pattern could be assessed.
FD= Fast movement to a distant location.
Extensive= Extensive movements between several locations over at least a 1-month period.
Stat= Stationary near Kelsey GS over the entire study period.
Foray= Mainly stationary near the Kelsey GS with one foray to location R2 or R1.
Grass R= Movement into the Grass River, signal lost after a few days.