Yukon River Lewes Reach Marshland Area Report

Prepared for Yukon Energy Corporation

Normandeau Associates, Inc.

December 2012

AECOM
2251 2nd Avenue 867 633 6474 tel
Whitehorse, YT, Canada Y1A 5W1 867 633 6321 fax
www.aecom.com

January 2, 2013

Travis Ritchie
Manager – Environment, Assessment and Licensing
Yukon Energy Corporation
2 Miles Canyon Road, Box 5920
Whitehorse, Yukon
Y1A 6S7

Dear Travis:

Project No: 60237818 – Task 2.2

Regarding: Marsh Lake Fall-Winter Storage Concept – Yukon River Lewes Reach Wetland Area Report

Please find attached the above noted report prepared by Normandeau Associates Inc. on behalf of AECOM.

We trust this report meets your current needs. If you have any questions regarding this report, or if we can be of further assistance, please do not hesitate to contact the undersigned.

Sincerely,
AECOM Canada Ltd.

Forest Pearson
Sr. Geological Engineer
Forest.Pearson@aecom.com

OM:om
Encl.
cc:

Contents

Table of Figures

Table of Acronyms

CSRS	Canadian Spatial Reference System
GPS	Global Positioning System
FSL	Full Supply Level
PPP	Precise Point Positioning
Q	Discharge
SA	Surface Area
TIN	Triangular Irregular Network
TRPA	Thomas R. Payne & Associates
YEC	Yukon Energy Corporation
WSEL	Water Surface Elevation

EXECUTIVE SUMMARY

Yukon Energy Corporation (YEC) has proposed changes to operation of Lewes Dam on the Yukon River to optimize the power produced during the wintertime at the Whitehorse Rapids Generating facility. The proposed operations, Southern Lakes Fall/Winter Storage Concept, will alter the timing and area of inundation for marshlands connected to the Yukon River downstream of the Lewes Dam. Marshlands (wetland type habitats) are important habitat for fish species that inhabit the Yukon River. Several marsh sites were selected and the flows at which the marshlands were connected to the Yukon River main channel were determined in a previous study (TRPA 2011). Findings from that study concluded that several sites remained connected at all but the lowest flows; in which case, the amount of marshland habitat would be determined by the river flow. Higher flows inundate more marshland area and create more off-channel habitat. This report provides an update to the previous report (TRPA 2011) by comparing the amount and timing of the marshland aquatic habitat in average, wet, and dry type years produced by current operations at Lewes Dam with the habitat that would be produced with the proposed Southern Lake Fall/Winter Storage Concept water management operations.

The results of this analysis show that the amount of aquatic habitat available during the ice-free period at the four marsh study sites under the proposed Southern Lakes Fall/Winter Storage Concept water management operations varies, along with Yukon River flows, depending on the water year and connectivity of the marsh areas. During the springtime, Concept flows create less marsh habitat than current operations; however, the decreased habitat only persists for an average of 4 days before attaining the amount of habitat produced by current operations. During the summer, until the gates at Lewes Dam are closed, the marsh habitat is similar under both the current and Concept conditions in all year types. During average and dry year types, when flow regulation begins at Lewes Dam in mid August, Concept flows reduce marsh habitat by 13% and 39%, respectively, compared to current conditions. During wet years, Concept flow regulation begins later in the season, decreasing the marsh habitat in October by an average of 47%. The main productivity period of the marshlands ends when the marshland water temperature falls below the mainstem water temperature. This typically occurs by early August, mitigating the impact of decrease in habitat area. The potential impact to marshland habitats further decreases in the fall, becoming positive by late fall under all water type years.

INTRODUCTION

This report describes the relationship of river flow with the marshland areas in the Lewes Reach of the Yukon River near Whitehorse for Yukon Energy Corporation (YEC). The study report “Yukon River Lewes Reach Marshland Connectivity”, (TRPA 2011), established the relationship of river flows to marshland connectivity but could not establish the relationship of flow to marshland area. Additional marshland bathymetric data was required to determine the relationship of marshland area to Yukon River Flow.

YEC engaged AECOM to assist with the assessment of increasing water storage in Marsh, Tagish and Bennett Lakes (collectively referred to as “the Southern Lakes”) to increase winter electrical production from the Whitehorse Rapids Hydroelectric Generating station. Under the proposed Project, the operating rules for the Lewes River Control Structure (also referred to as the “Marsh Lake Dam”, or “Lewes Dam”) would be modified to maintain a higher water level in Marsh Lake during the later summer and fall. Specifically, the current operating license would be modified to increase the Full Supply Level by 0.3 m from 656.234 m to 656.53 m, and lower the Low Supply Level by 0.1 m. The regulated period would generally remain unchanged from August 15th to May 15th. However, the goal of the proposed Project is to save water from the high-flow periods for use during the low-flow periods of the year. This will result in reduced flows in the late summer and early fall, and higher winter stream flow, with volumes varying by water year type. In wet years, Marsh Lake would remain normally high through the summer and fall and the flow regulation gates would not close and begin winter storage until the fall (e.g. October). In dry years, when the lake level is low, the gates would close earlier than the historical practice and cause Marsh Lake levels to rise.

Aquatic habitat downstream of Lewes Dam may be affected by the seasonal decreases and increases in flow. Rearing, feeding, and spawning habitat for some Yukon River fish species (e.g., northern pike, *Esox lucius*) is found in back-channels, littoral areas, and marshlands, particularly in marshlands immediately downstream of Marsh Lake below Lewes dam. Fish species mainly utilize these areas when the back-channel water temperature exceeds the main channel temperature corresponding to the period between mid-May and the end July (Don Toews, personal communication). These areas have the potential to be impacted by a new water management regime.

As per the recommendations in the “Yukon River Lewes Reach Marshland Connectivity” Report (TRPA 2011), this report examines four of the six previously identified marshland sites adjacent to the Yukon River between Lewes Dam and the Whitehorse Generating Facility, to determine the relationships of aquatic habitat area and flows in the Yukon River for each marshland site. When the marshlands become disconnected from the main river, water levels and areas of marshlands are independent of river flows and the habitat from these marshlands is no longer available to main channel fish and other aquatic organisms for feeding, rearing, or spawning. However, when these marshland areas are connected to the Yukon River, the amount of aquatic habitat available is determined by the water surface elevation, and flow in the Yukon River. Aquatic habitat area in the four sites during historic flows was compared to the aquatic habitat resulting from Concept flows.

STUDY AREA

The study area included the 27.6 kilometer portion of the Yukon River and adjacent marshlands downstream of Lewes Dam and upstream of Schwatka Lake and the City of Whitehorse in Southwestern Yukon, Canada. From this area, marshland sites were selected for analysis. The Southern Lake Concept Study area is depicted in Figure 1 and the marshlands studied in Figure 2.

METHODS

A previous study was conducted in 2010-11 in order to determine the connectivity of six marshland areas adjacent to the Yukon River (TRPA 2011). Site A was determined to have no connection to the Yukon River at any flow and was not assessed further and. Site E was also excluded from the current study due to time constraints during the field survey.

As part of a separate study for this project, 15 cross-sections (or transects) were distributed along this 27.6 kilometer length of the Yukon River, referred to as the Lewes Reach (AECOM and TRPA 2009). Figure 3 shows the transect locations. Data collected along these transects, included water velocity patterns, substrate characterization, and stage-discharge relationships which was for an instream flow study using physical habitat simulation (PHABSIM) methods (AECOM and TRPA 2009). The stage/discharge relationship of the PHABSIM transect nearest each marshland site was used to evaluate the relationship between Yukon River flow and marshland inundated area. All inundated area or wetted substrate is assumed to be aquatic habitat.

SAMPLE COLLECTION AND DATA ANALYSIS

MARSHLAND BATHYMETRIC SURVEYS

Marshland bathymetric surveys were completed by Underhill Geomatics Ltd of Whitehorse, Yukon. The location and scope of the surveys were discussed with AECOM staff in advance of initiating the field work. Additionally, one AECOM field staff accompanied the surveying team on the first day of the survey to confirm the location and area of interest for the Marshland surveys. The surveys were completed as a combination of topography surface surveys and boat-based bathymetric surveys. At each location, 2 to 3 GPS base stations were setup and allowed to gather data through the survey day. A total of 7 base station locations were used over the course of the surveys. The absolute position of survey points (both topographic and bathymetric) were determined from Real Time Kinematic GPS observations referencing the GPS base stations. These bathymetric surveys were carried out using Trimble R-8 dual frequency receivers connected to a Sonarmite V3 Echo sounder. Following the survey, the position of these base stations were derived using the CSRS Precise Point Positioning service (PPP, see http://www.geod.nrcan.gc.ca/products-produits/ppp_e.php for specifics). This allows for correction of the absolute (geodetic) accuracy of the survey. Overall survey accuracy is +/- 2cm in the horizontal plane and elevation accuracy of +/- 5cm.

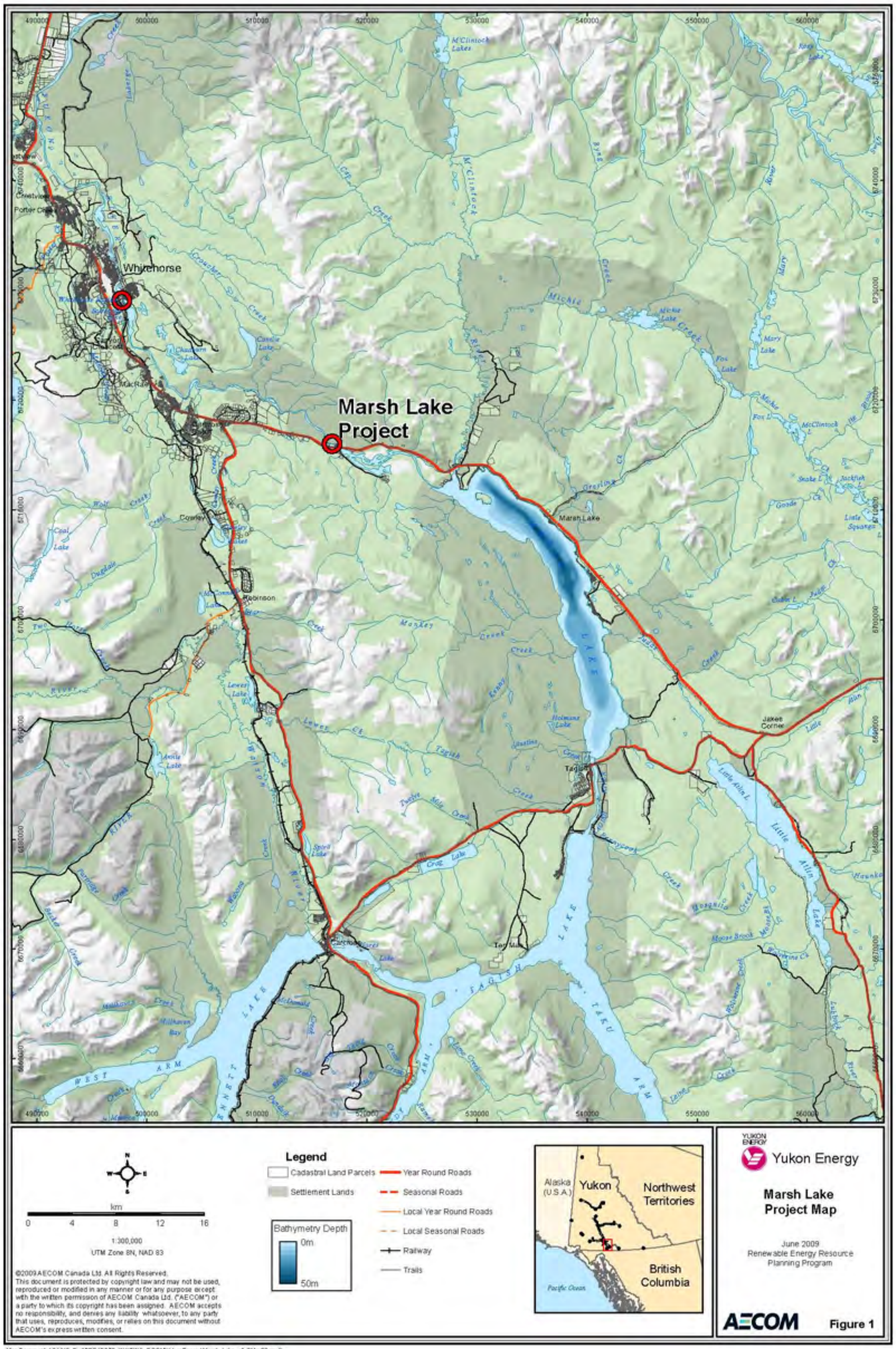

FIGURE 1. MARSH LAKE PROJECT STUDY AREA

.

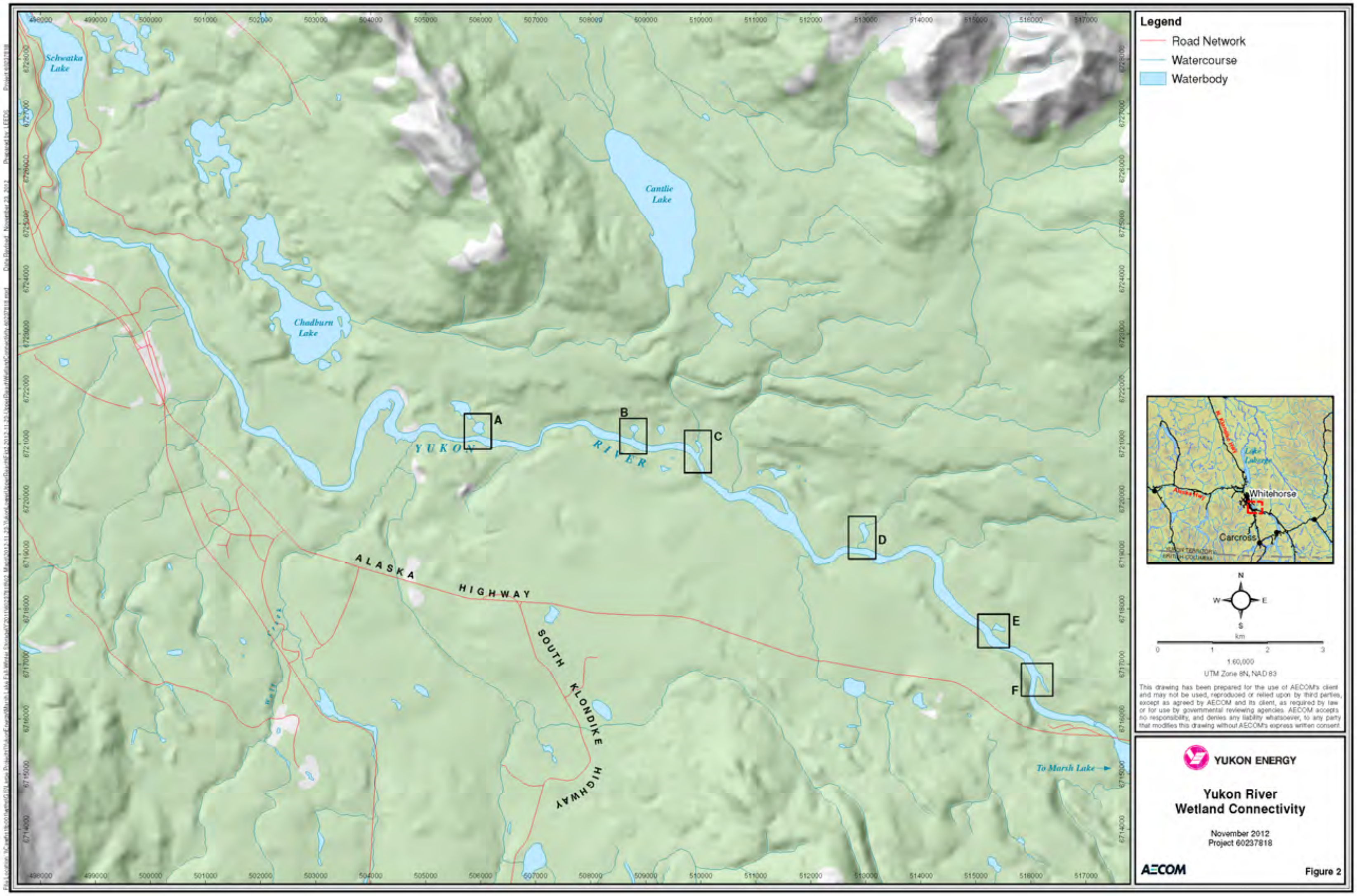

FIGURE 2. SIX MARSHLAND SITES ADJACENT TO THE YUKON RIVER LEWES REACH SELECTED FOR ANALYSIS OF CONNECTIVITY TO THE MAIN CHANNEL

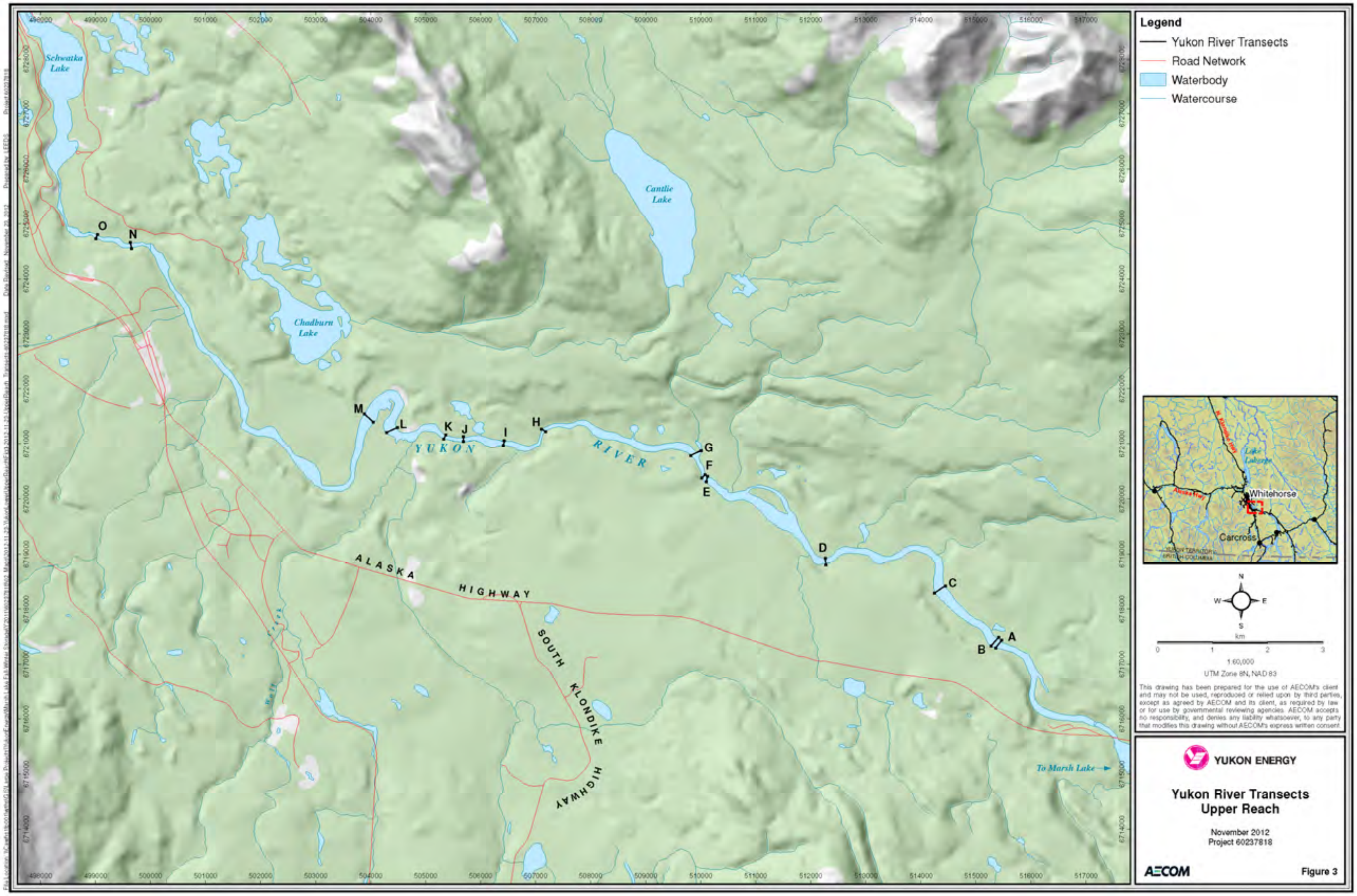

FIGURE 3. LOCATION OF PHABSIM TRANSECTS IN THE LEWES REACH OF THE YUKON RIVER (AECOM AND TRPA 2009).

DATA ANALYSIS

The relationships of the marshland aquatic habitat area with the flow of the Yukon River were calculated using GIS software. The water surface elevations from the rating curves established in the previous report (TRPA 2011) and the measured bathymetry/topography were used to determine relationship of aquatic habitat area with the flow on the Yukon River.

A triangulated irregular network (TIN) was created using the measured bathymetric data. Breaklines were added along the measured wetted edge and the resulting digital elevation model was clipped at the highest measured elevations. The 3D analyst tool in ArcMap 10 was used to calculate the aquatic habitat area available at each marshland over a range of flows at increments of 20cms. The range of flows simulated for each study site was determined by the flow at which each marshland becomes connected to the Yukon River and the highest elevations surveyed. For flows that resulted in water surface elevations above the surveyed topography, aquatic habitat was extrapolated from the existing curves using an equation that best fit the existing data and produced reasonable extrapolations.

Time series analysis incorporates the river hydrology with the marshlands/flow relationship to determine the change in habitat area over a period of time. Two scenarios, historical and Concept, using three water year types, were modeled. The term "historical" in this context refers to the hydrology that actually happened in the years simulated with the Lewes Dam as it is currently operated. The term "Concept" refers to the hydrology that would have occurred if the proposed Southern Lakes Fall/Winter Storage Concept had been in place at that time. Time series curves of inundated area (i.e. aquatic habitat) were created for each marshland site under historic conditions and Concept scenarios for the period from May 1st through November 30th (approximate time of ice free conditions) under the three different water year types. The historical average of daily flows for the period from 1984 through 2007 was used to represent an average water year. To represent a dry year, average daily flows from 1996 were used, and to represent an extreme wet year, average daily flows from 2007 were used. The percent change in area between historic and Concept conditions was calculated for each day between May 1 and November 30 by dividing the difference between the area under the proposed Southern Lakes Fall/Winter Storage Concept and the area under the historic flow conditions by the area under the historic flow conditions for the given water year types.

RESULTS

MARSH AREA RELATIONSHIP TO YUKON RIVER FLOW

The relationship of marsh area to Yukon River flow for each study site is presented separately with tabular values presented in Appendix A.

SITE B

The color shaded elevation map for Marsh Area Site B is shown in Figure 4. The surface area of Site B was calculated using the 3D Analyst tool in ArcGIS for elevations between 653 to 655.05 m, representing Yukon River flows between 50cms and 460cms. Above an elevation of 655.05 m there was not sufficient topographic data to calculate the area directly. For flows between 460cms to 650cms the surface area was extrapolated from the existing data using a polynomial equation. The equation derived from the surveyed data for this site is:

$$SA = 0.00033103 * Q^3 - 0.42999365 * Q^2 + 219.60686773 * Q - 12{,}174.57831376$$

SA is the surface area of the marsh and Q is the flow in the Yukon River.

Site B remains connected to the Yukon main channel until the flow drops to 71 cms, at which time the control becomes dewatered and the marshland habitat becomes isolated from the Yukon River (TRPA 2011). Figure 5 shows the relationship between Marshland Site B area and the Yukon River flow between 70 and 650 cms.

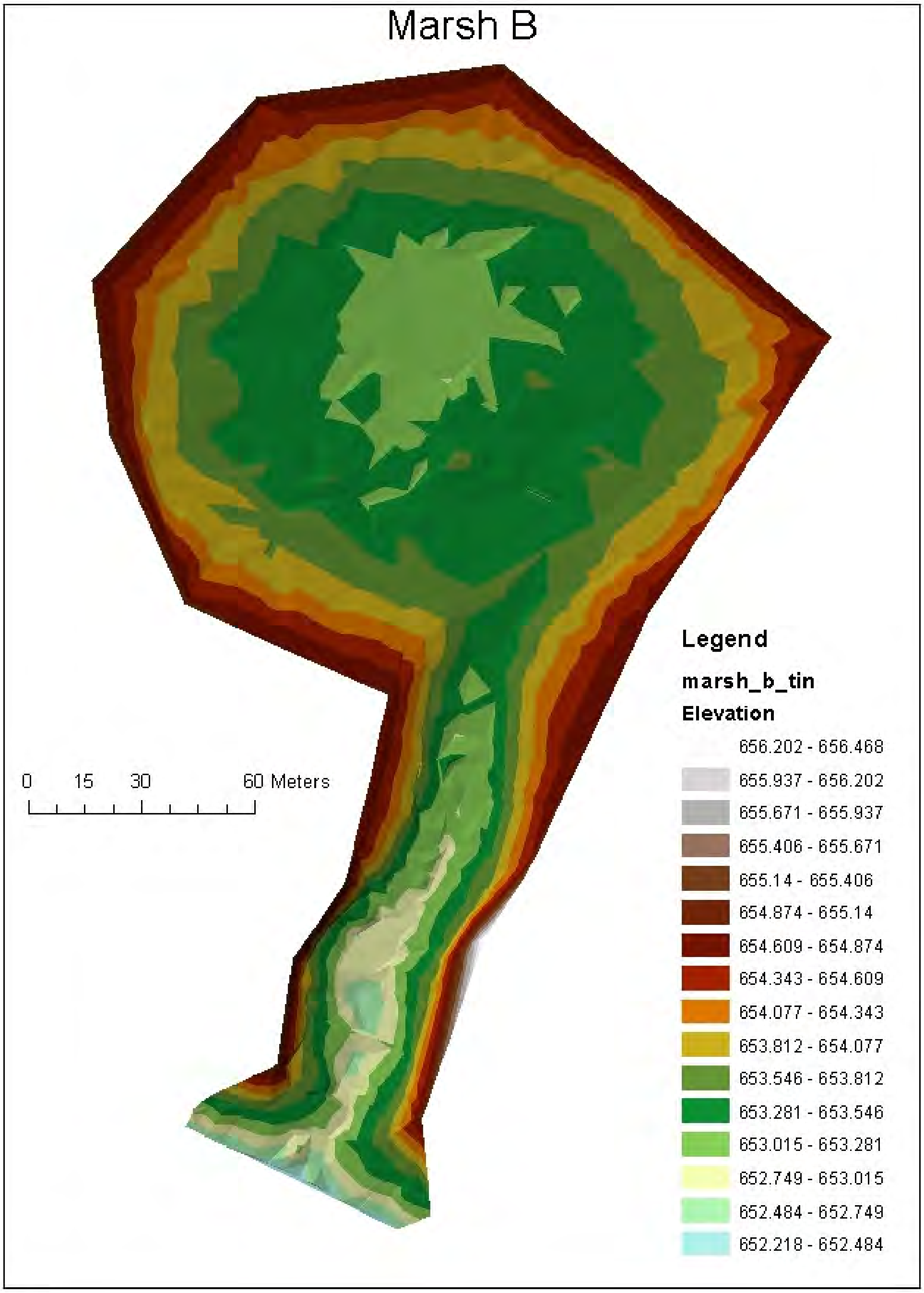

FIGURE 4. COLOR SHADED ELEVATION MAP OF MARSH AREA B.

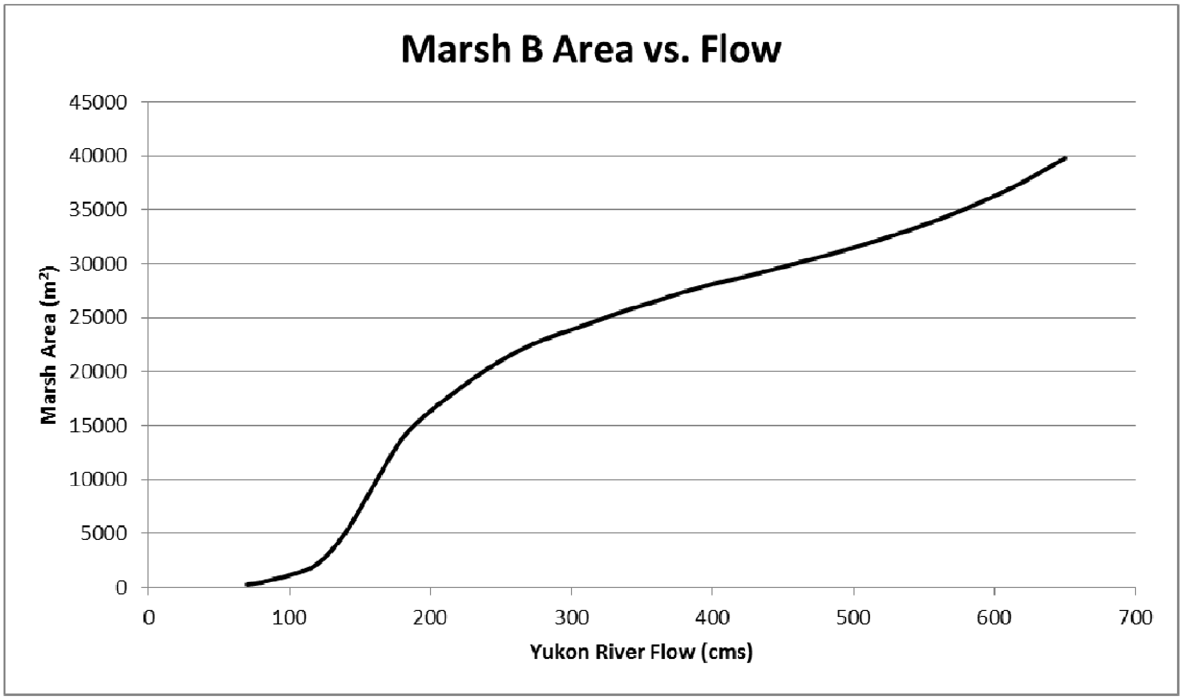

FIGURE 5. SITE B MARSH AREA RELATIONSHIP TO YUKON RIVER FLOW FOR FLOWS BETWEEN 70 AND 650 CMS.

SITE C

The color shaded elevation map of Marsh Area Site C is shown in Figure 6. The surface area of Site C was calculated using the 3D Analyst tool in ArcGIS for elevations between 652.5 to 654.98 m, or Yukon River flows between 50and 500 cms. Above an elevation of 655.98 m there was not sufficient topographic data to calculate the area directly. For flows between 500 to 650cms the surface area was extrapolated from the existing data using a polynomial equation. The equation derived from the surveyed data for this site is:

$$SA = 0.00003805 * Q^3 - 0.09000170 * Q^2 + 70.00555867 * Q - 3{,}340.50001195$$

The connecting channel to the Yukon River gradually decreases in depth into the marshland and the channel has no obvious hydraulic control (TRPA 2011). Figure 7 shows the relationship between Marsh Site C area and the Yukon River flow between 50 and 650 cms.

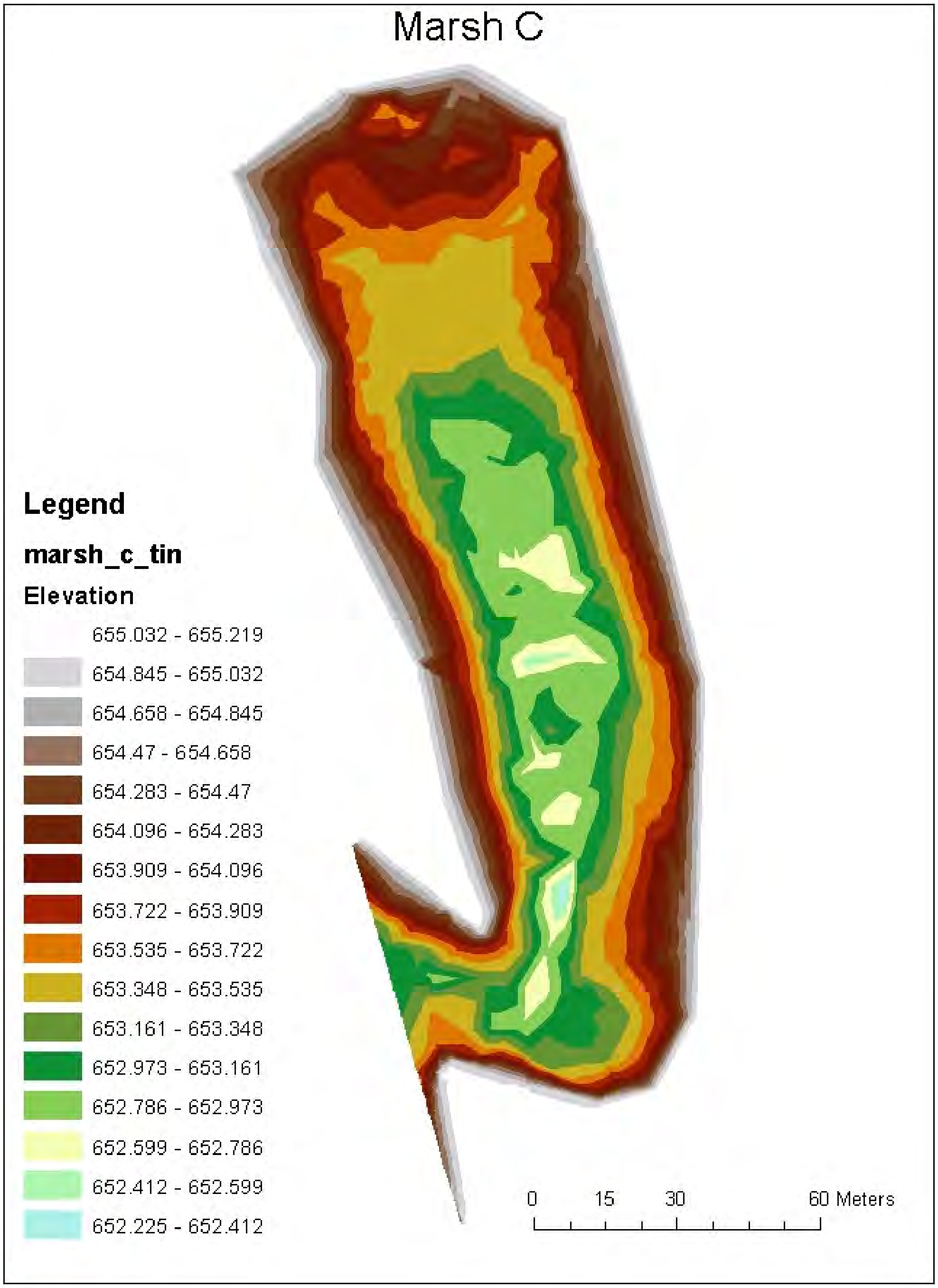

FIGURE 6. COLOR SHADED ELEVATION MAP OF MARSH AREA C.

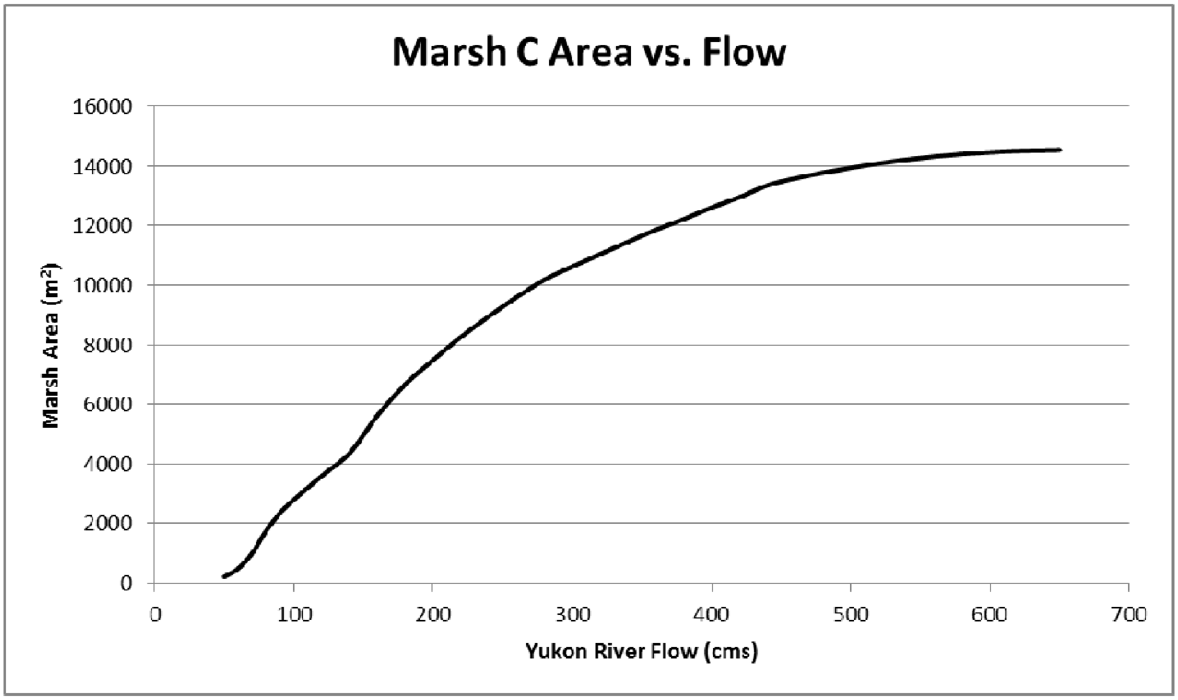

FIGURE 7. SITE C MARSH AREA RELATIONSHIP TO YUKON RIVER FLOW FOR FLOWS BETWEEN 50 AND 650 CMS.

SITE D

The color shaded elevation map of Marsh Area Site D is shown in Figure 8. The surface area of Site D was calculated using the 3D Analyst tool in ArcGIS for elevations between 653.12 to 655.56 m, or Yukon River flows between 50 and 500cms. Above an elevation of 655.56 m there was not sufficient topographic data to calculate the area directly. For flows between 480to 650 cms the surface area was extrapolated from the existing data using a linear equation. The equation derived from the surveyed data for this site is:

$$SA = 77.53207886 * Q + 26{,}034.63745808$$

The estimated flow at which Site D Marsh becomes connected to the Yukon River is 477 cms (TRPA 2011). Figure 9 shows the relationship between Marsh Site D area and the Yukon River flow between 480 and 650 cms.

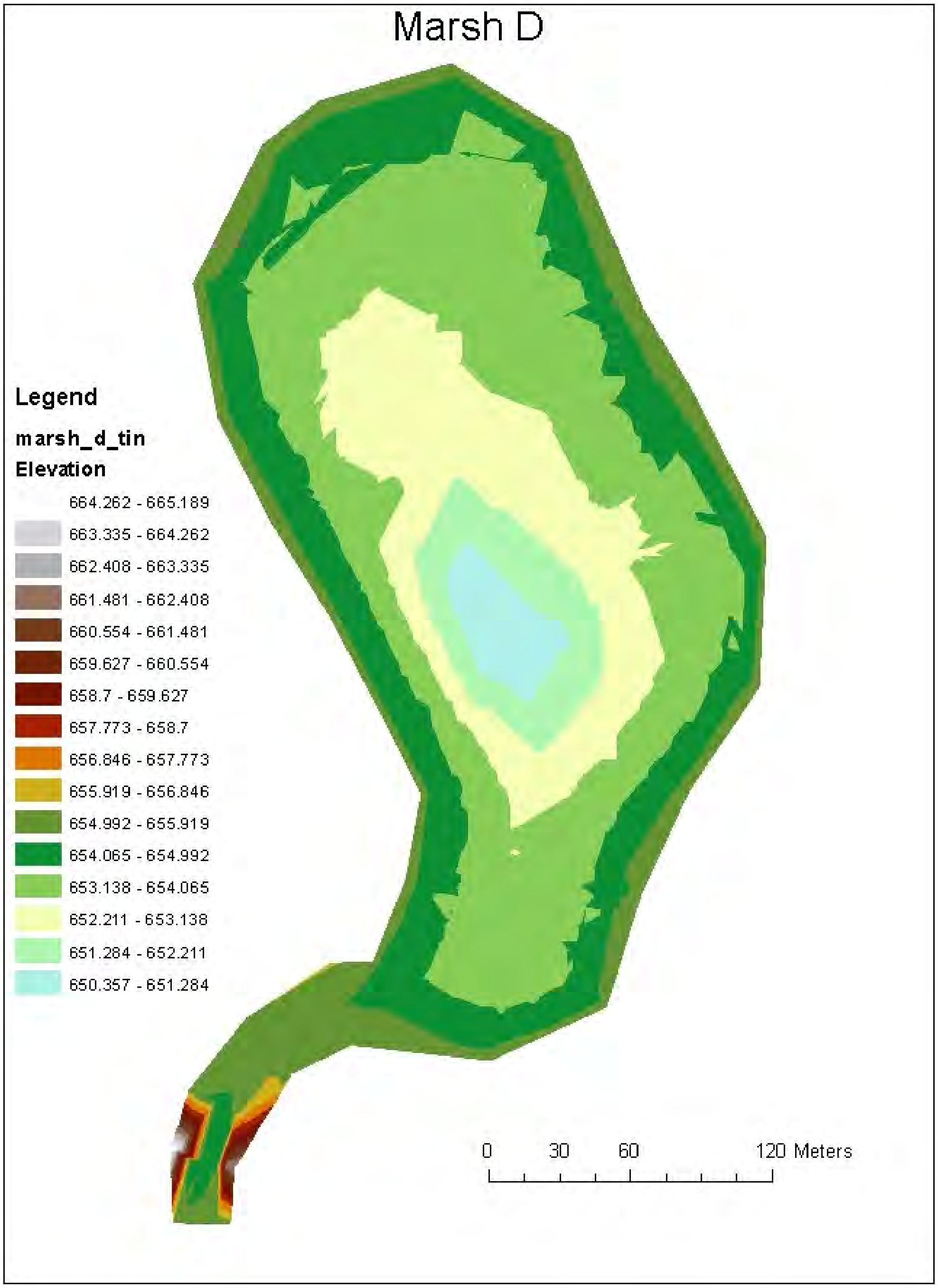

FIGURE 8. COLOR SHADED ELEVATION MAP OF MARSH AREA D.

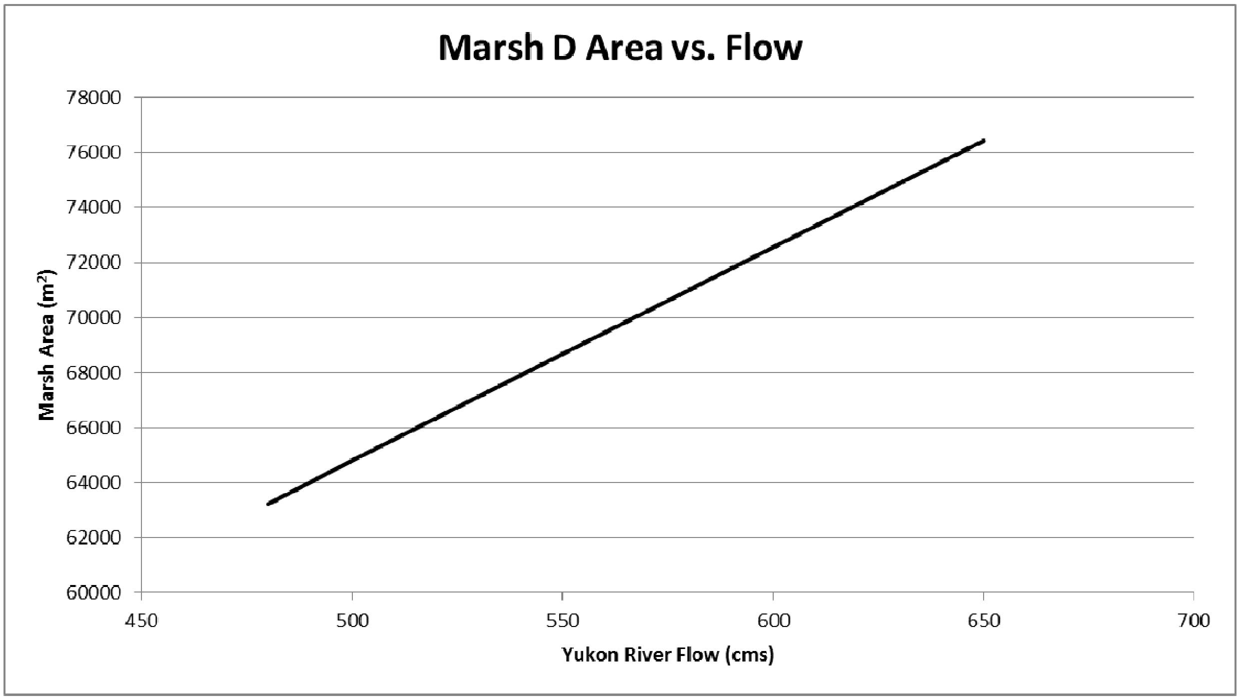

FIGURE 9. SITE D MARSH AREA RELATIONSHIP TO YUKON RIVER FLOW FOR FLOWS BETWEEN 480 AND 650 CMS.

SITE F

The color shaded elevation map of Marsh Area Site F is shown in Figure 10. The surface area of Site F was calculated using the 3D Analyst tool in ArcGIS for elevations between 652.50 to 654.98 m, or Yukon River flows between 50 and 560cms. Above an elevation of 655.56 m there was not sufficient topographic data to calculate the area directly. For flows between 580 to 650 cms the surface area was extrapolated from the existing data using a linear equation based on elevations at flows from 460 and 560 cms. The equation derived from the surveyed data for this site is:

$$SA = 8.70007942 * Q + 43{,}583.62350364$$

The Yukon River Lewes Reach Marshland Connectivity Report (TRPA 2011) indicated that Marsh F becomes disconnected at 183 cms with only marginal control; however, the more recent bathymetry measurements indicate that the marshland has no hydraulic control. The marshland area will change directly with the main channel flow. Figure 11 shows the relationship between Marsh Site F area and the Yukon River flow between 70 and 650 cubic meters per second.

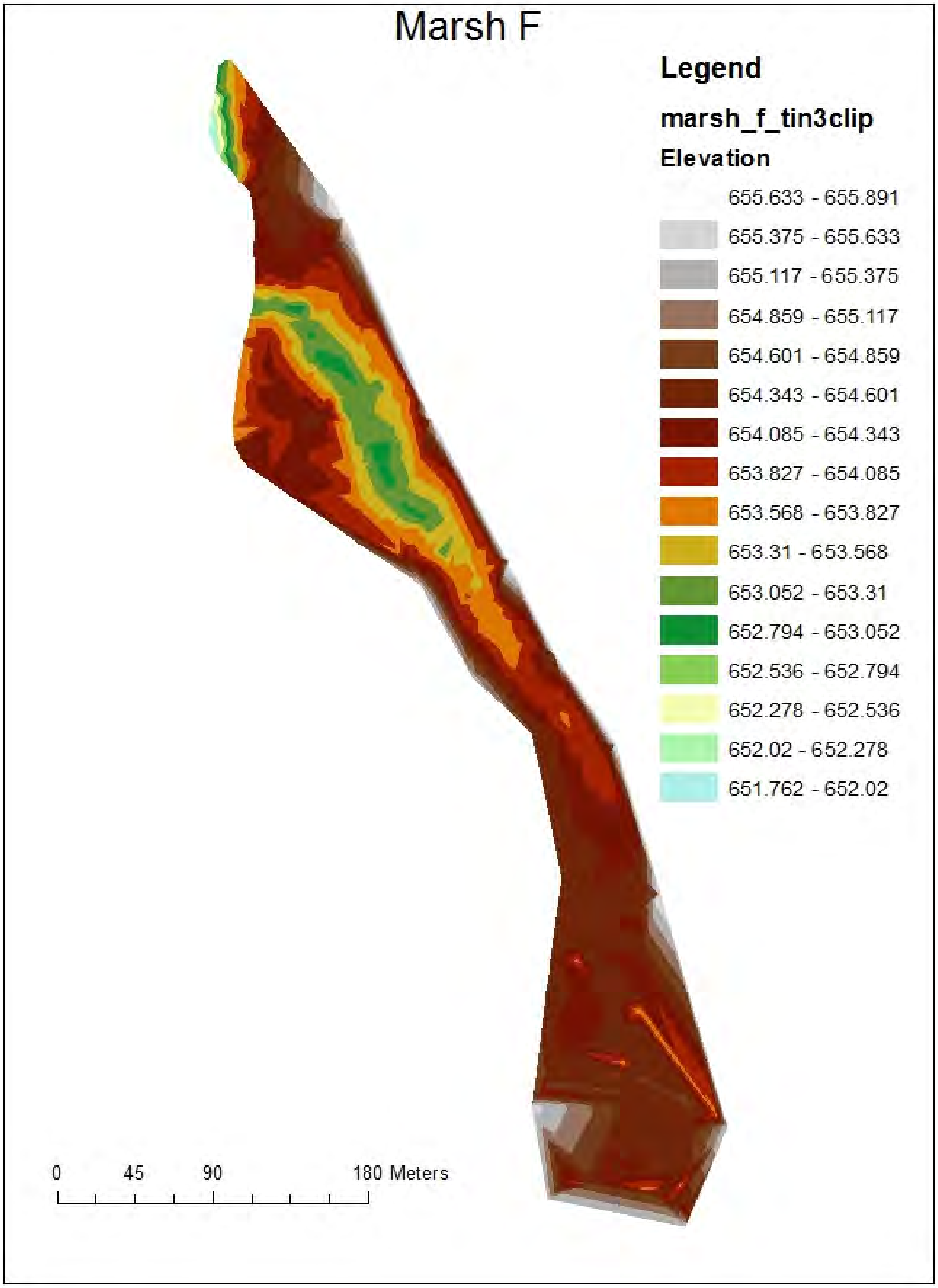

FIGURE 10. COLOR SHADED ELEVATION MAP OF MARSH AREA D.

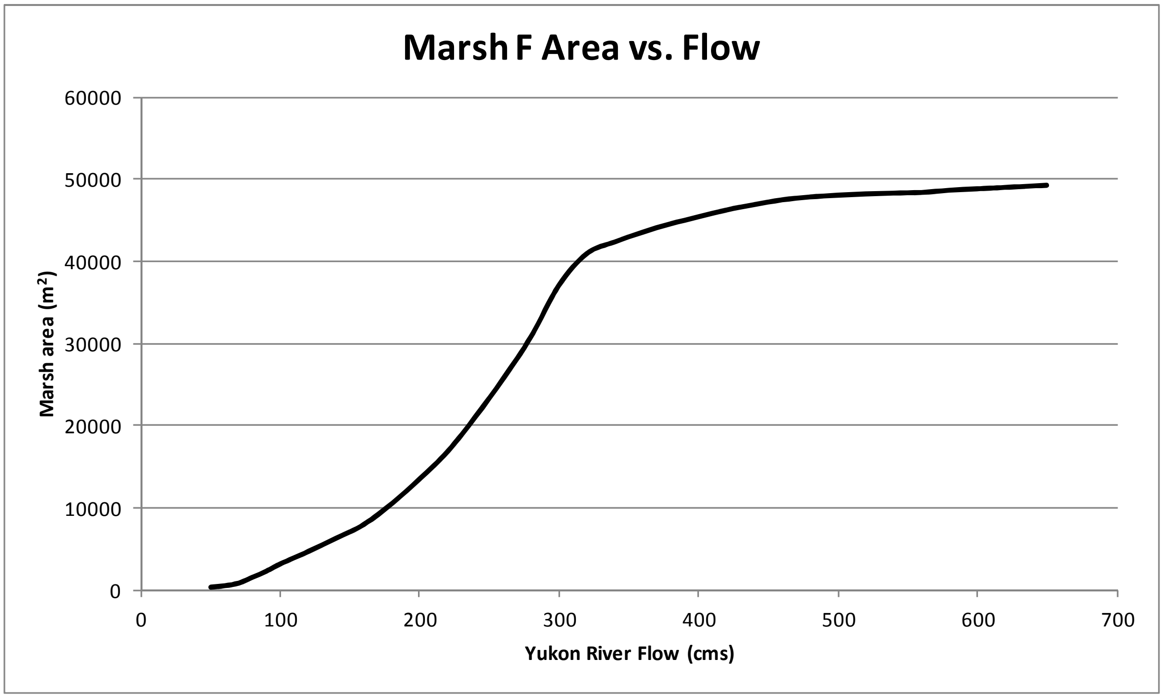

FIGURE 11. SITE F MARSH AREA RELATIONSHIP TO YUKON RIVER FLOW FOR FLOWS BETWEEN 70 AND 650 CMS.

TIME SERIES

For each site the daily habitat area for the historical and Concept scenarios are compared for average, wet, and dry year types with the results depicted graphically. The daily percent difference between the two operating scenarios is also depicted. On each graph the period of main productivity (May 15 to July 31) in the marshlands is highlighted.

SITE B

Figure 12 compares the aquatic habitat available at Marshland Site B during the ice-free period of May 1st through November 30th for the historic daily average flow condition from 1984 through 2007 and the Concept flow condition for the same time period. The percent change in aquatic habitat between the historical and Concept scenarios is shown in Figure 13. Marshland Site B is connected to the Yukon River throughout the entire year under the average historical flow (1984 - 2007) scenario and the Concept scenario for the same time period. Under historical conditions there is about 4,000m^2 of Marshland B aquatic habitat in the spring; this increases throughout the spring and summer to about 30,700m^2, and is maintained into the fall before beginning to drop to a total aquatic habitat area of about 8,600m^2 in the late fall/early winter. Under the Concept conditions on the Yukon River there is about 40% less aquatic habitat area in Marshland Site B in the spring, or about 2,500m^2. Both the river flow and marshland area increase throughout the spring and early summer. There is slightly less aquatic habitat area for the Concept conditions than there is under the historic average conditions until the first part of July when the aquatic habitat area under the Concept conditions peaks at about 30,000m^2. This level continues until about August 14th, at which time the aquatic habitat area drops to 26,000m^2, or about 15% less than under the historic conditions. In the late fall/early winter there would be about 5-10% more aquatic habitat area under the Concept conditions for an average year than under the historic conditions.

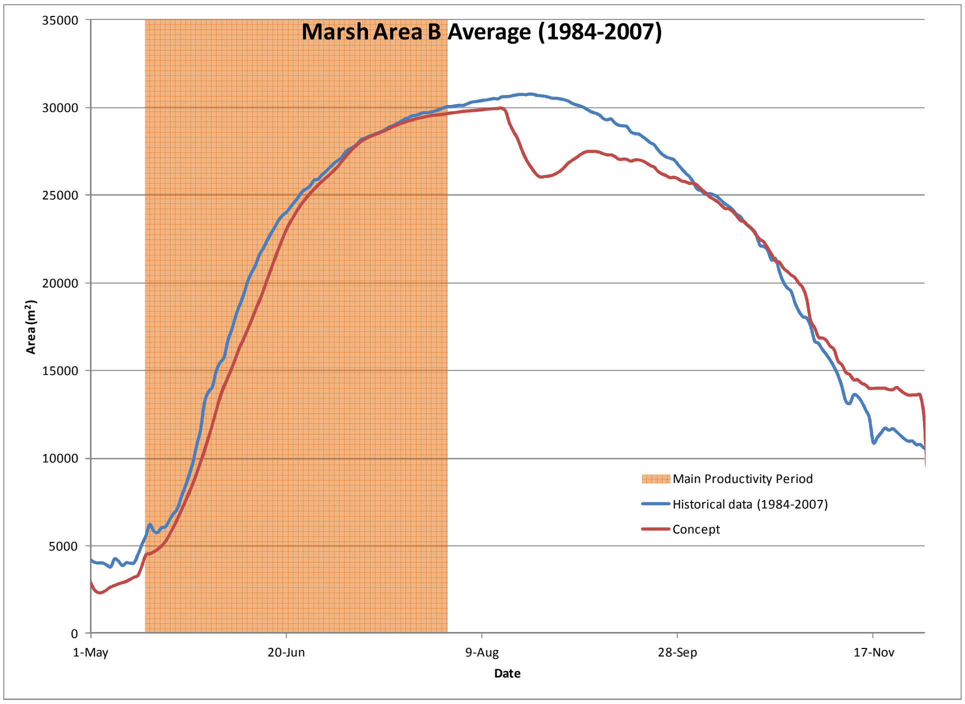

FIGURE 12. COMPARISON OF MARSH B AREA BASED ON HISTORICAL DAILY AVERAGE FLOW ON THE YUKON RIVER FROM 1984 THROUGH 2007 WITH THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME PERIOD.

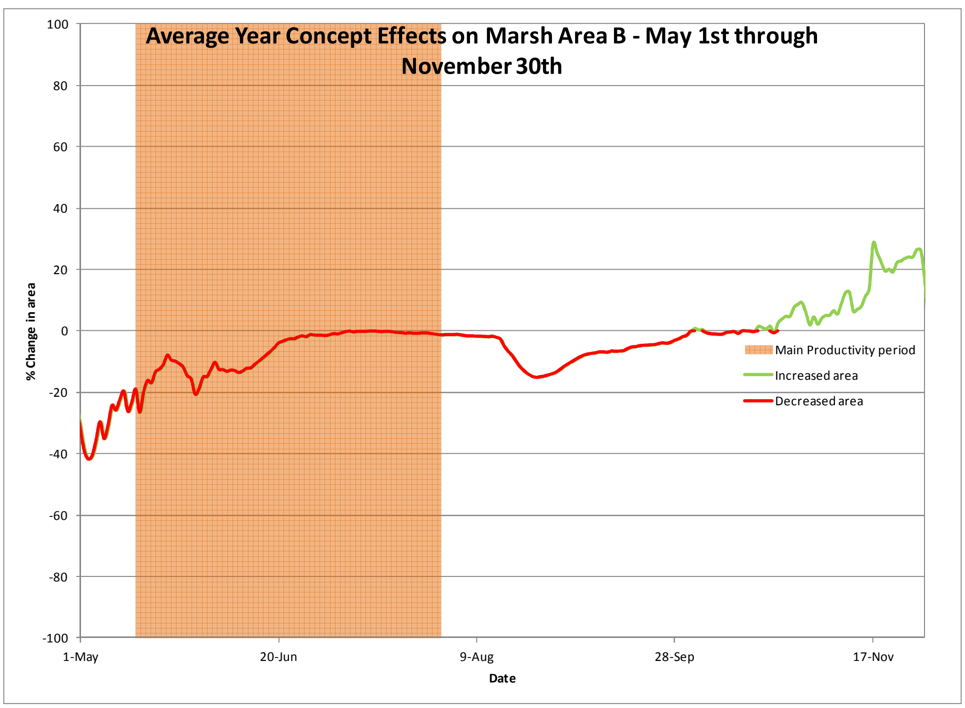

FIGURE 13. DIFFERENCE IN SITE B AREA BETWEEN THE HISTORICAL DAILY AVERAGE FLOW FROM 1984 THROUGH 2007 THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME TIME PERIOD.

Figure 14 compares the aquatic habitat of Marsh Site B available during the ice-free period of May 1st through November 30th for the historic daily average flow condition for an extreme wet year (2007) and the Concept scenario for the same time period. The percent change in aquatic habitat between the two scenarios is shown in Figure 15. During an extreme wet year, such as 2007, the aquatic habitat available at Marsh Site B is very similar under the historic and Concept conditions for most of the time from May 1st through October 1st, with the aquatic habitat available ranging from around 5,000m^2 in the spring to 39,000m^2 in mid to late summer. Around the first of October there is a decrease in the aquatic habitat available that occurs fourteen days earlier under the Concept conditions than would normally occur under the historic scenario. This accounts for the 33% decrease in area between the two scenarios shown in Figure 15 for this time period.

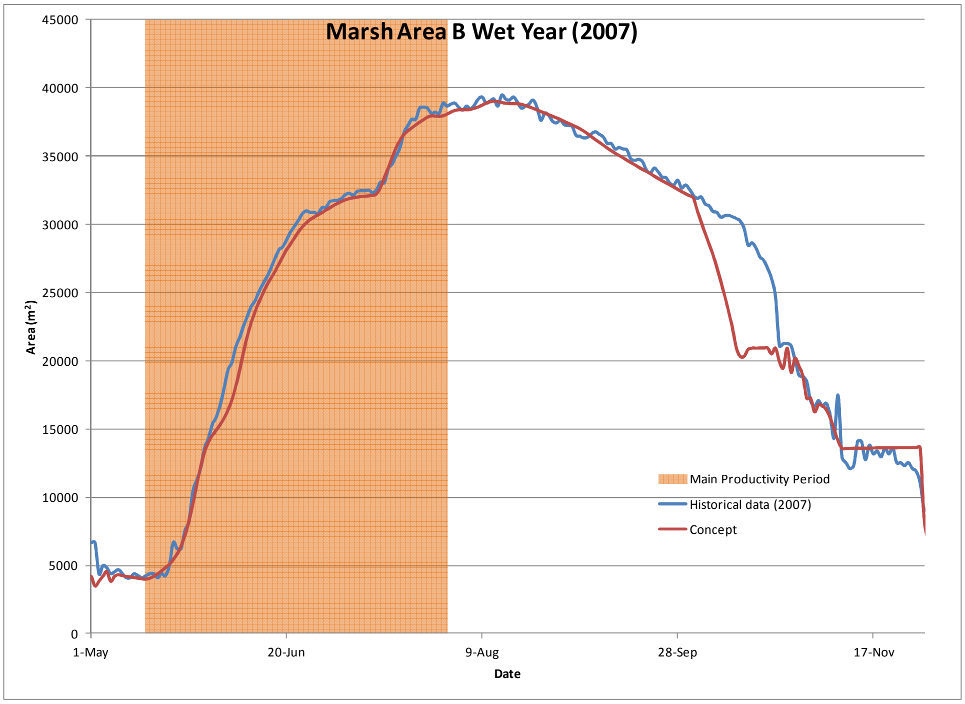

FIGURE 14. COMPARISON OF MARSH B AREA BASED ON HISTORICAL DAILY AVERAGE FLOW ON THE YUKON RIVER FOR THE EXTREME WET YEAR 2007 WITH THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME PERIOD.

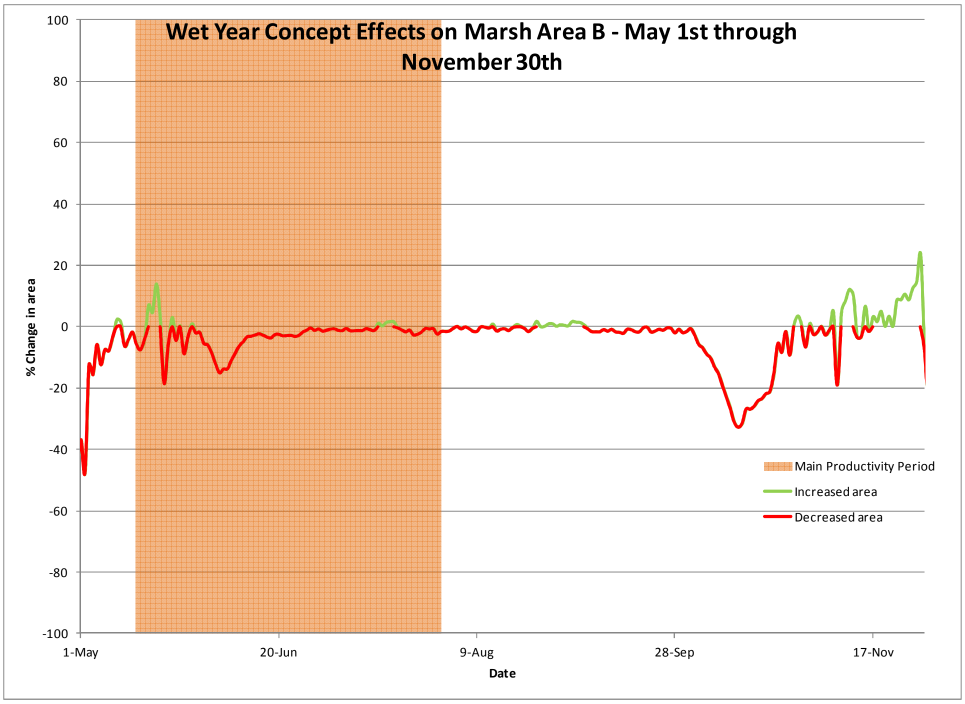

FIGURE 15. DIFFERENCE IN SITE B AREA BETWEEN THE HISTORICAL DAILY AVERAGE FOR THE WET YEAR 2007 AND THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME TIME PERIOD.

Figure 16 compares the aquatic habitat of Marsh Site B available during the ice-free period of May 1st through November 30th for the historic daily average flow condition for a dry year (1996) and the Concept condition under scenario 2b for the same time period. The percent change in aquatic habitat between the two scenarios is shown in Figure 17. In a dry year, such as 1996, the aquatic habitat at Marsh Site B ranges from a minimum of about 1,100m^2 in the spring to a maximum of 27,800m^2 in the summer. The minimum aquatic habitat in the Concept scenario is similar to the historic conditions, and the maximum is near 27,000m^2. Both scenarios follow the same general trend in flow patterns. The percent difference in the amount of habitat varies throughout the year. Under the proposed project conditions there is about 50% more aquatic habitat available between May 13th and May 27th. During the summer and early fall period the Concept scenario shows a decrease in aquatic habitat between 0% and 40%, with a few days with slight increases in aquatic habitat. In the fall, after October 19th, the proposed Concept operations would result in an increase in aquatic habitat up to 100% for the dry years.

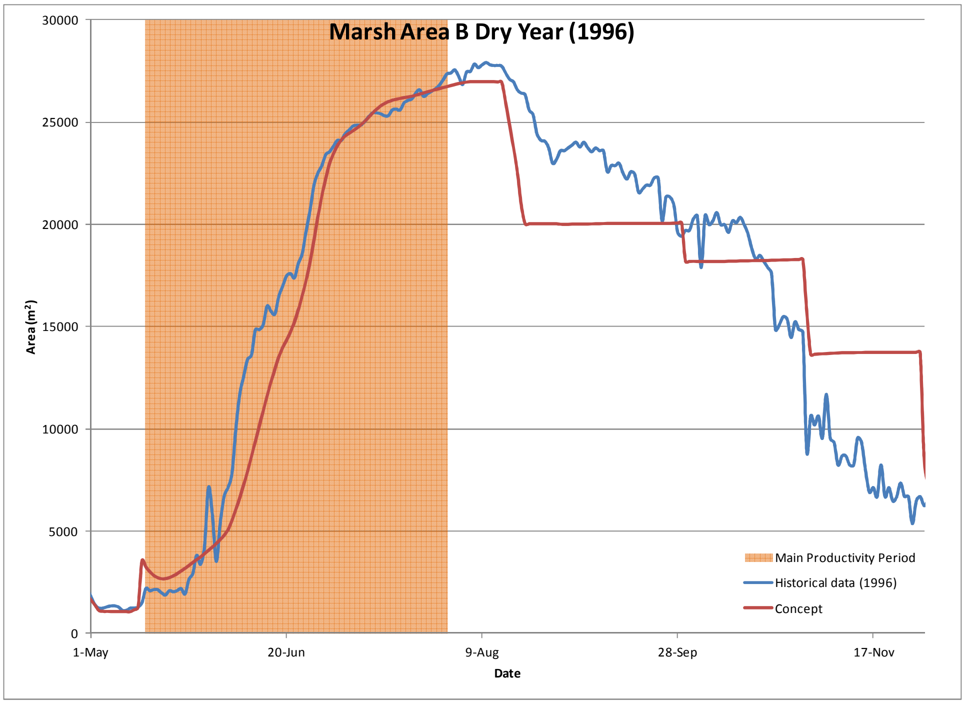

FIGURE 16. COMPARISON OF MARSH B AREA BASED ON HISTORICAL DAILY AVERAGE FLOW ON THE YUKON RIVER FOR THE DRY YEAR 1996 WITH THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME PERIOD.

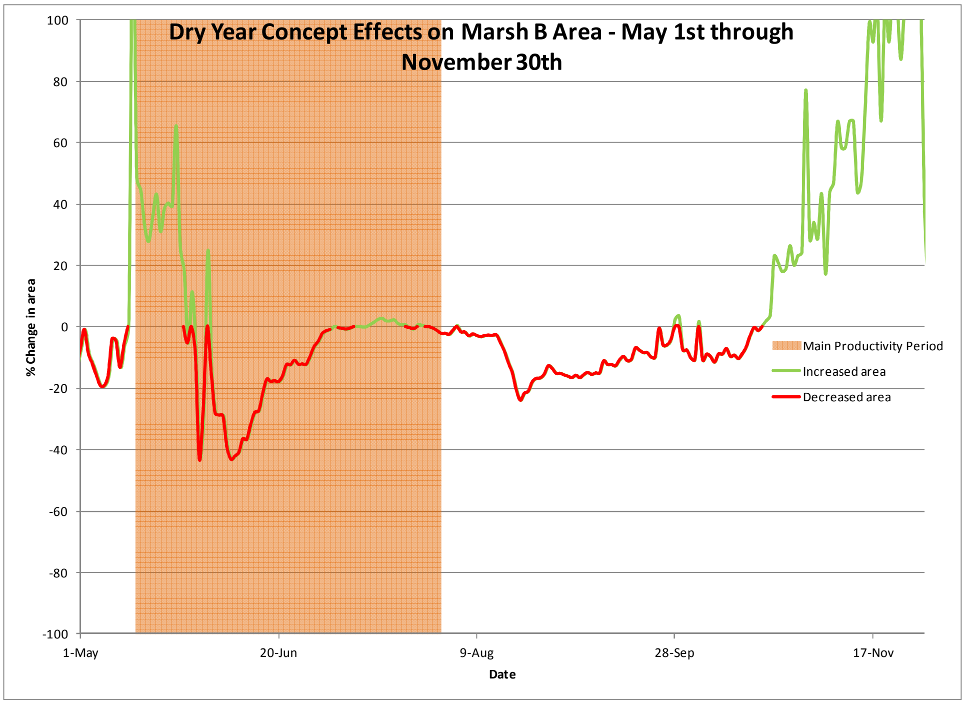

FIGURE 17. DIFFERENCE IN SITE B AREA BETWEEN THE HISTORICAL DAILY AVERAGE FOR THE DRY YEAR 1996 AND THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT CONDITIONS OVER THE SAME TIME PERIOD.

Site C

Marsh area Site C is connected to the Yukon River throughout the year under both flow scenarios. The amount of aquatic habitat in Site C, during an average flow year, ranges from 4,000m^2 to 13,750m^2 under the historical conditions, while under the Concept scenario the aquatic habitat at site C ranges from 3,700m^2 to 13,500m^2. Figure 18 compares the aquatic habitat of Marsh Site C available during the ice-free period of May 1st through November 30th for the historic daily average flow condition from 1984 through 2007 and the Concept scenario for the same time period. The percent change in aquatic habitat between the two scenarios is shown in Figure 19. The timing of the changes in aquatic habitat at Site C is very similar to those in Site B. Under the Concept conditions on the Yukon River there is about 11% less aquatic habitat available in Marsh Site C in the spring. As the flows on the Yukon River increase, there is slightly less aquatic habitat available under the Concept scenario than the historical scenario. Again, as in Site B, there is a sharp decrease in aquatic habitat in mid-August for the Concept scenario, resulting in a difference of 15% from the historic conditions. The aquatic habitat continues to decrease in the late summer and early fall for both scenarios, and after October 17th there is more aquatic habitat available under the Concept scenario than under the historic conditions.

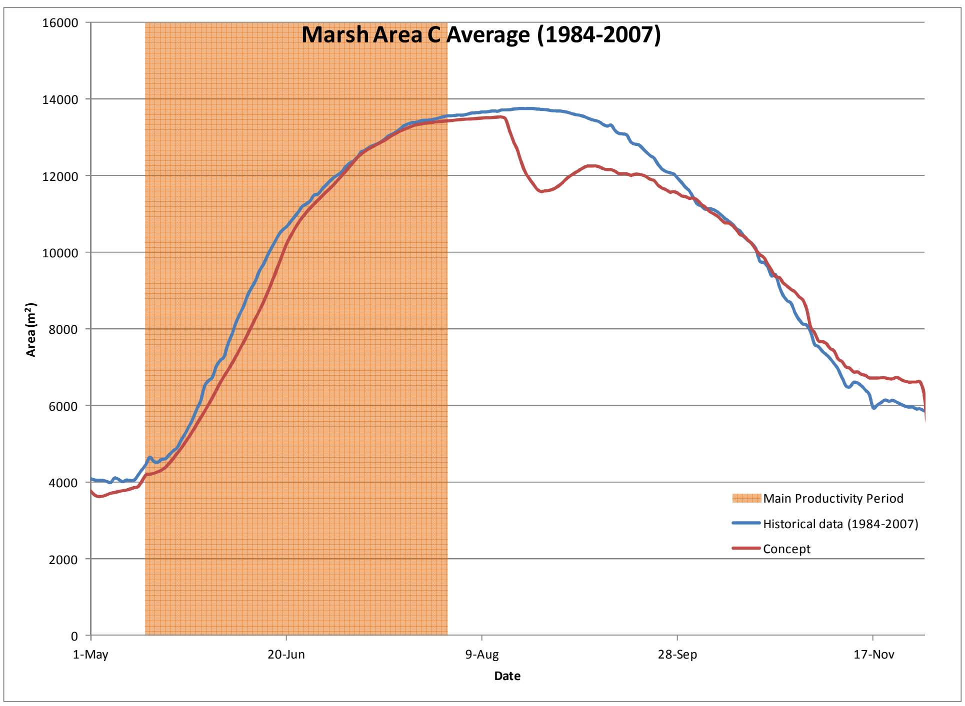

FIGURE 18. COMPARISON OF MARSH C AREA BASED ON HISTORICAL DAILY AVERAGE FLOW ON THE YUKON RIVER FROM 1984 THROUGH 2007 WITH THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME PERIOD.

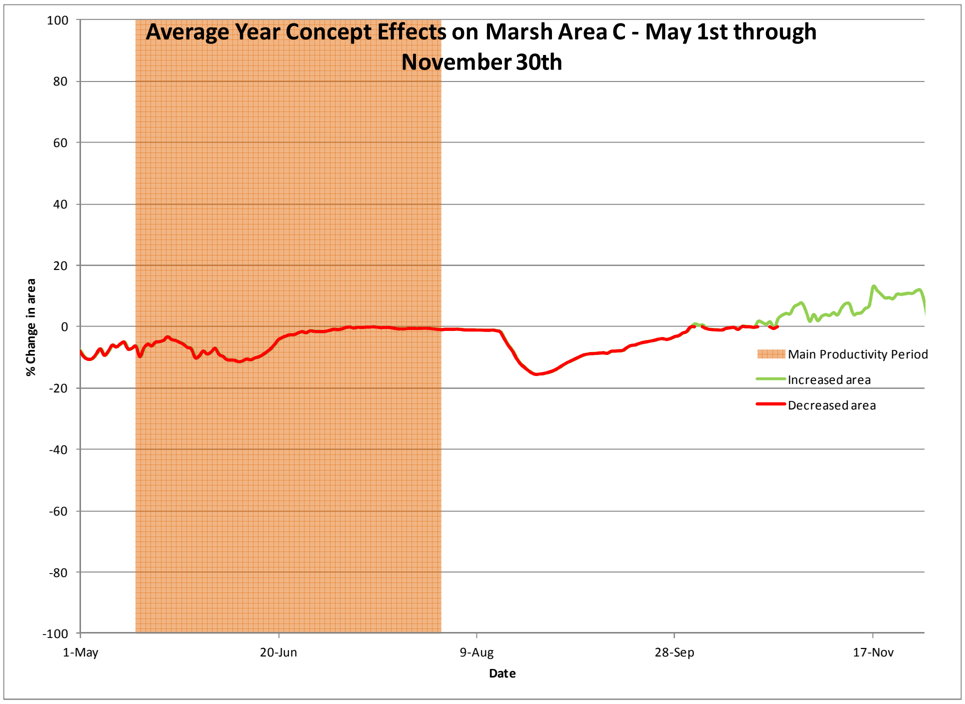

FIGURE 19. DIFFERENCE IN SITE C AREA BETWEEN THE HISTORICAL DAILY AVERAGE FLOW FROM 1984 THROUGH 2007 AND THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME TIME PERIOD.

Figure 20 compares the aquatic habitat of Marsh Site C available during the ice-free period of May 1st through November 30th for the historic daily average flow condition for an extreme wet year (2007) and the Concept scenario for the same time period. The percent change in aquatic habitat between the two scenarios is shown in Figure 21. During an extreme wet year, such as 2007, the aquatic habitat available at Site C is very similar under the historic and Concept conditions for most of the time from May 1st through October 1st, with the aquatic habitat available ranging from around 4,000m^2 in the spring to 14,500m^2 in mid to late summer. Around the first of October there is a decrease in the aquatic habitat that occurs about twelve days earlier under the Concept scenario than would normally occur under the historic scenario. This would account for the 34% decrease in aquatic habitat shown in Figure 21 for this time period. Throughout the rest of the late fall the two scenarios have similar amounts of aquatic habitat available.

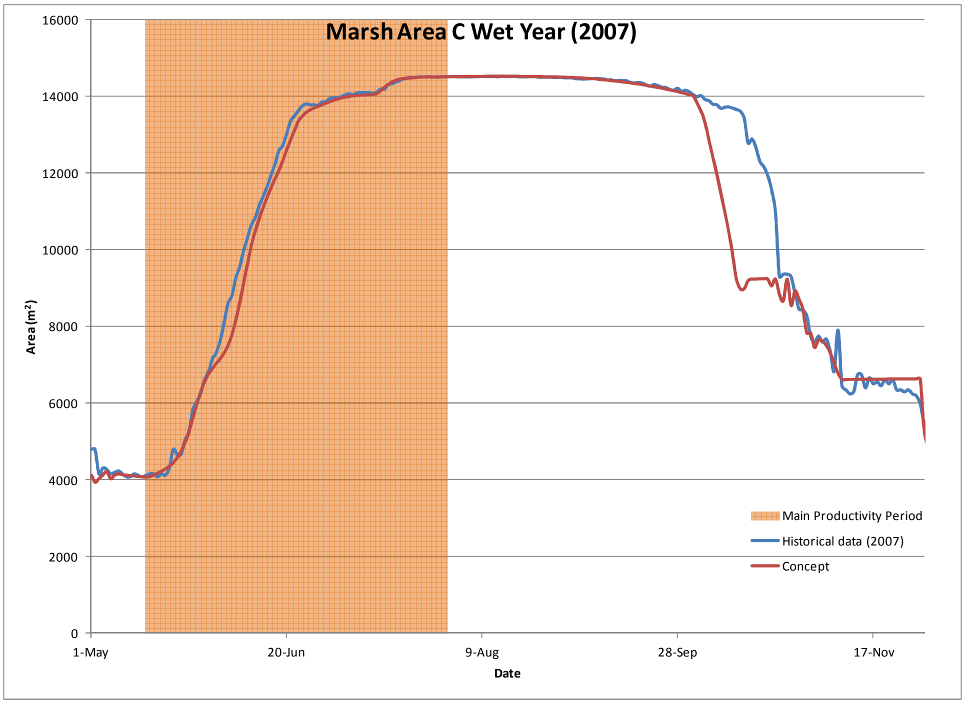

FIGURE 20. COMPARISON OF MARSH C AREA BASED ON HISTORICAL DAILY AVERAGE FLOW ON THE YUKON RIVER FOR THE EXTREME WET YEAR 2007 WITH THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME PERIOD.

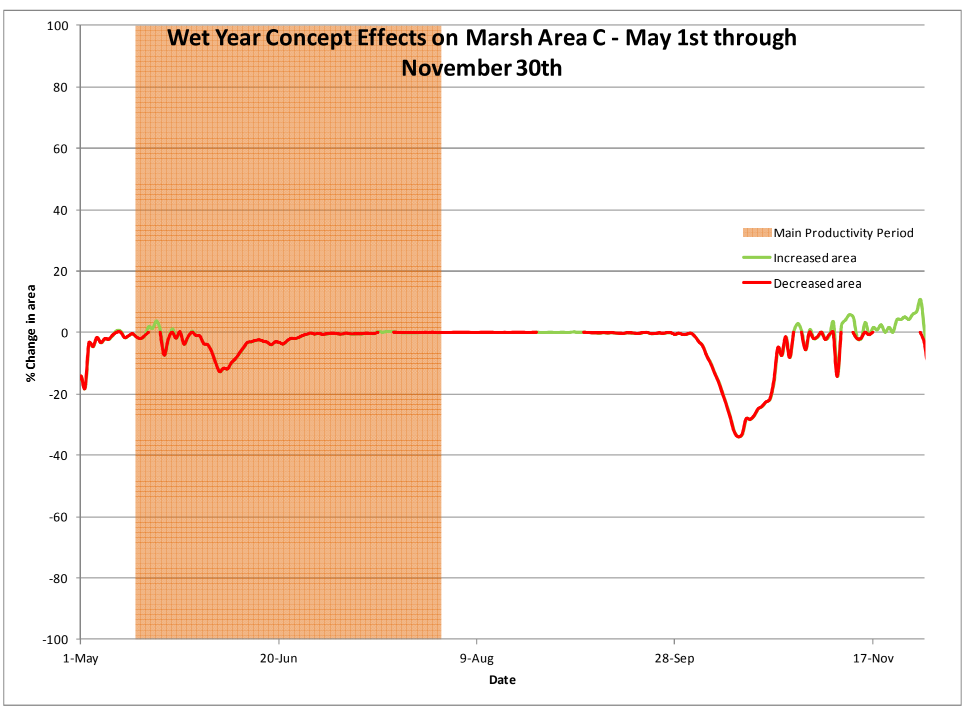

FIGURE 21. DIFFERENCE IN SITE C AREA BETWEEN THE HISTORICAL DAILY AVERAGE FOR THE WET YEAR 2007 AND THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME TIME PERIOD.

Figure 22 compares the amount of aquatic habitat available at Marsh Site C during the ice-free period of May 1st through November 30th for the historic daily average flow condition for a dry year (1996) and the Concept scenario for the same time period. The percent change in aquatic habitat between the two scenarios is shown in Figure 23. In a dry year, such as 1996, the aquatic habitat at marsh Site C ranges from a minimum of about 2700m^2 in the spring to a maximum of 12,300m^2 in the summer. The minimum aquatic habitat available in the Concept scenario is similar to the historic conditions, and the maximum is near 12,000m^2. Both scenarios follow the same general trend in aquatic habitat availability throughout the year. The percent difference in the amount of aquatic habitat available under the different scenarios varies throughout the year. Under the Concept conditions there is about a 10% increase in the aquatic habitat available between May 13th and May 28th. During the summer and early fall period the projected future operation condition shows a decrease in aquatic habitat between 0% and 20%, with a few days with slight increases in habitat. In the fall, after October 19th, the proposed Concept operations would result in an increase in aquatic habitat up to 40% for the dry years.

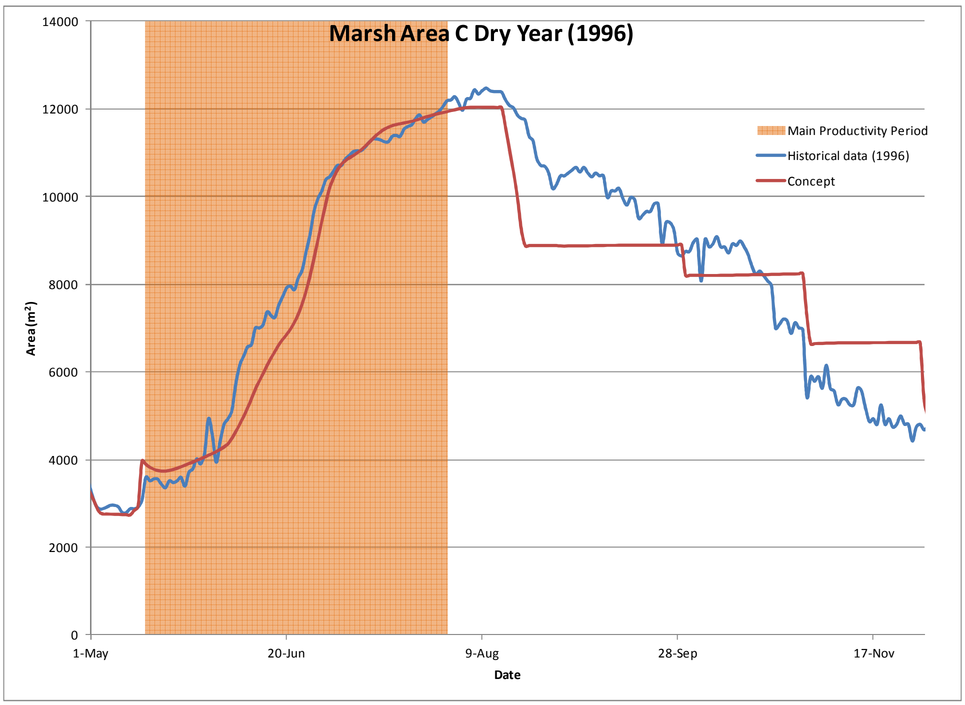

FIGURE 22. COMPARISON OF MARSH C AREA BASED ON HISTORICAL DAILY AVERAGE FLOW ON THE YUKON RIVER FOR THE DRY YEAR 1996 WITH THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME PERIOD.

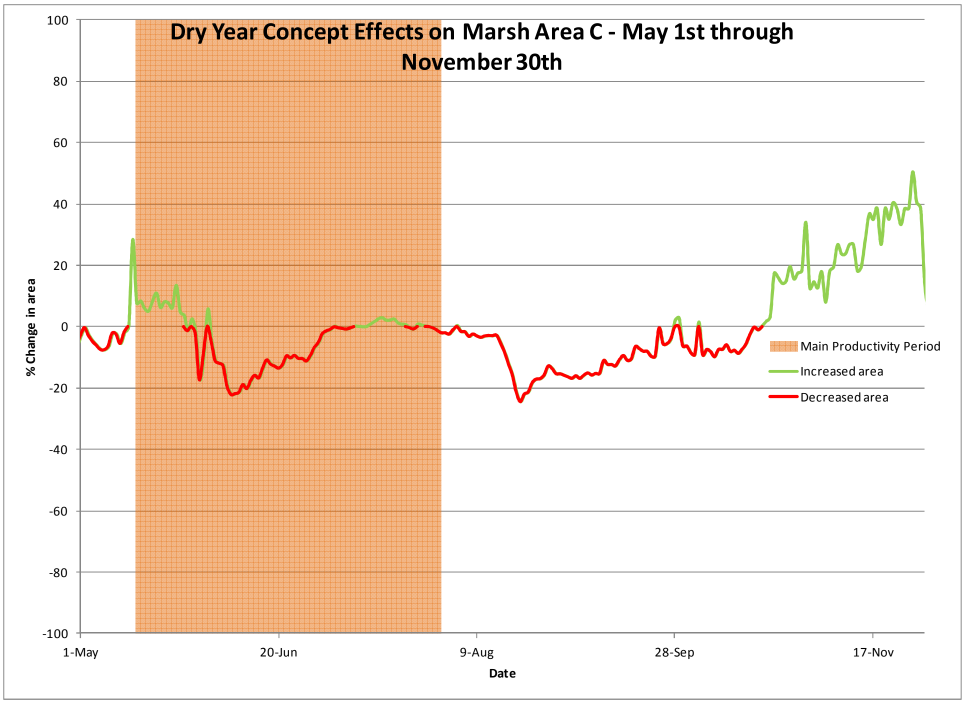

FIGURE 23. DIFFERENCE IN SITE C AREA BETWEEN THE HISTORICAL DAILY AVERAGE FOR THE DRY YEAR 1996 AND THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME TIME PERIOD.

SITE D

Marsh Site D becomes disconnected at a flow of 477cfs (TRPA 2011). During an average water year under historic conditions Marsh Site D is connected to the Yukon River for only eight days, and not at all under the Concept scenario. During the wet year 2007 it was connected for 106 days and would have been connected 97 days under the Concept scenario (Figure 24). The amount of aquatic habitat available is virtually identical under the historical and Concept scenarios, with differences generally less than 2% (Figure 25). During the dry year it would not have been connected at all under either scenario.

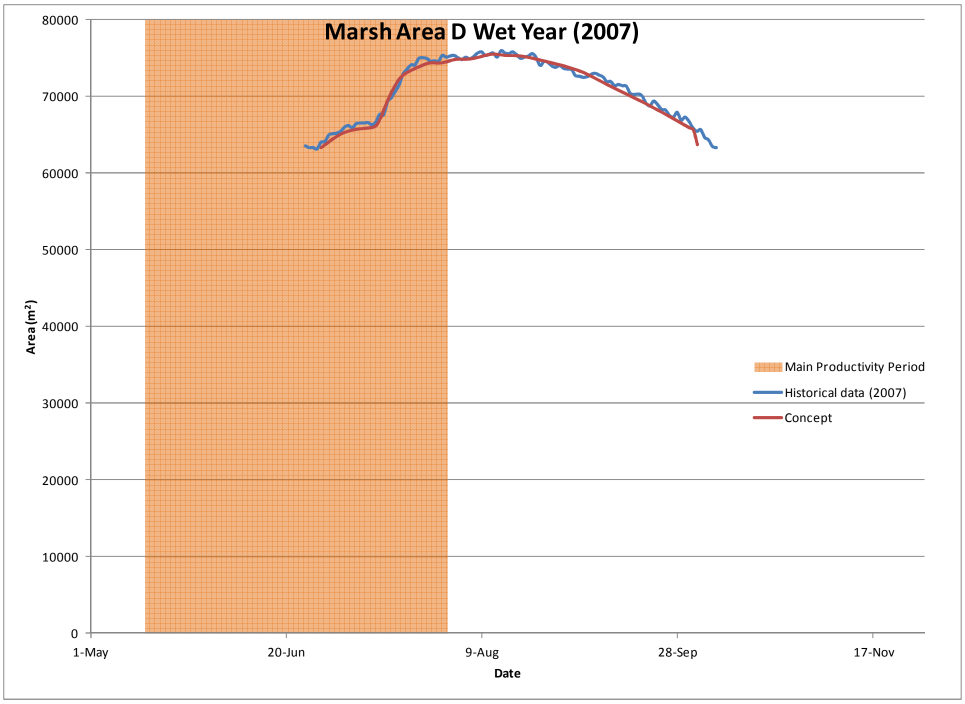

FIGURE 24. COMPARISON OF MARSH D AREA BASED ON HISTORICAL DAILY AVERAGE FLOW ON THE YUKON RIVER FOR THE EXTREME WET YEAR 2007 WITH THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME PERIOD.

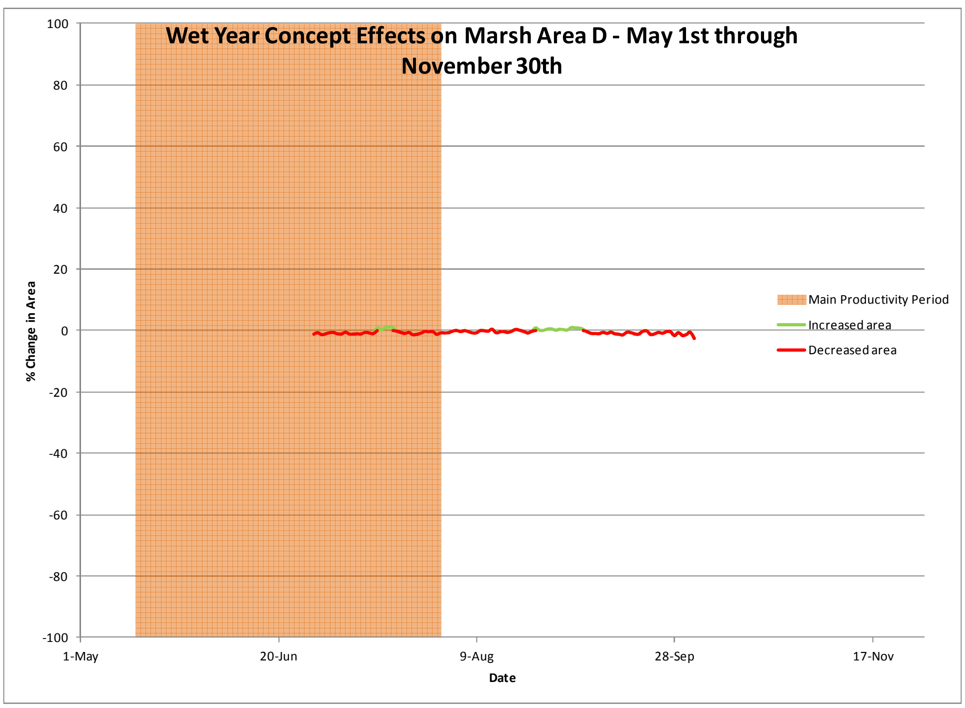

FIGURE 25. DIFFERENCE IN SITE D AREA BETWEEN THE HISTORICAL DAILY AVERAGE FOR THE WET YEAR 2007 AND THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME TIME PERIOD.

Site F

There is no hydraulic control on Marsh F that would retain water in the marshland and Marsh Site F remains connected to the Yukon River at all flows under both historic and future concept flows.

The amount of aquatic habitat available in Site F, during an average flow year, ranges from 5,500m^2 to 47,800m^2 under the historical conditions, while under the Concept scenario the aquatic habitat available at Site F ranges from 4,700m^2 to 47,300m^2. Figure 26 compares the aquatic habitat availability of Marsh Site F during the ice-free period of May 1st through November 30th for the historic daily average flow condition from 1984 through 2007 and the Concept scenario for the same time period. The percent change in aquatic habitat between the two scenarios is shown in Figure 27. The timing of the changes in aquatic habitat availability at site F is very similar to those in sites B and C. Under the Concept scenario there is about 5-27% less aquatic habitat available in Site F in the spring. As the flows on the Yukon River increase there is slightly less aquatic habitat available under the Concept conditions than the historical conditions. Again, as in sites B and C, there is a decrease in aquatic habitat area in mid-August for the proposed Concept scenario resulting in a difference of 10% from the historic conditions. The available aquatic habitat continues to decrease in the late summer and early fall for both scenarios, and after October 17th there is up to 20% more aquatic habitat available under the Concept conditions than under the historic conditions.

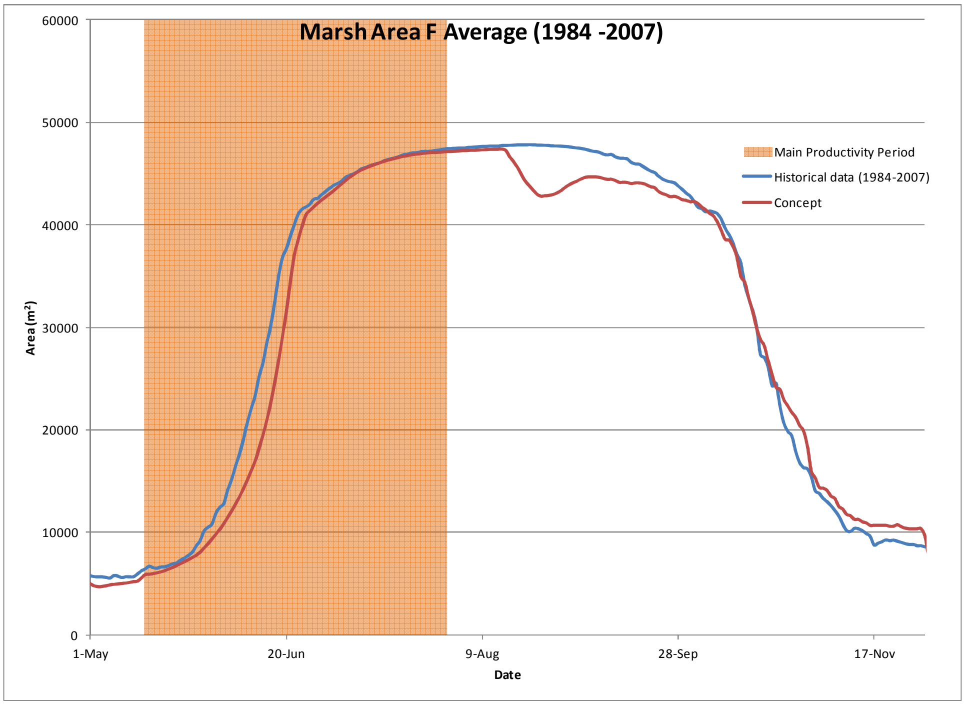

FIGURE 26. COMPARISON OF MARSH F AREA BASED ON HISTORICAL DAILY AVERAGE FLOW ON THE YUKON RIVER FROM 1984 THROUGH 2007 WITH THE PROPOSED MARSH LAKE FALL STOAGE CONCEPT OPERATIONS OVER THE SAME PERIOD.

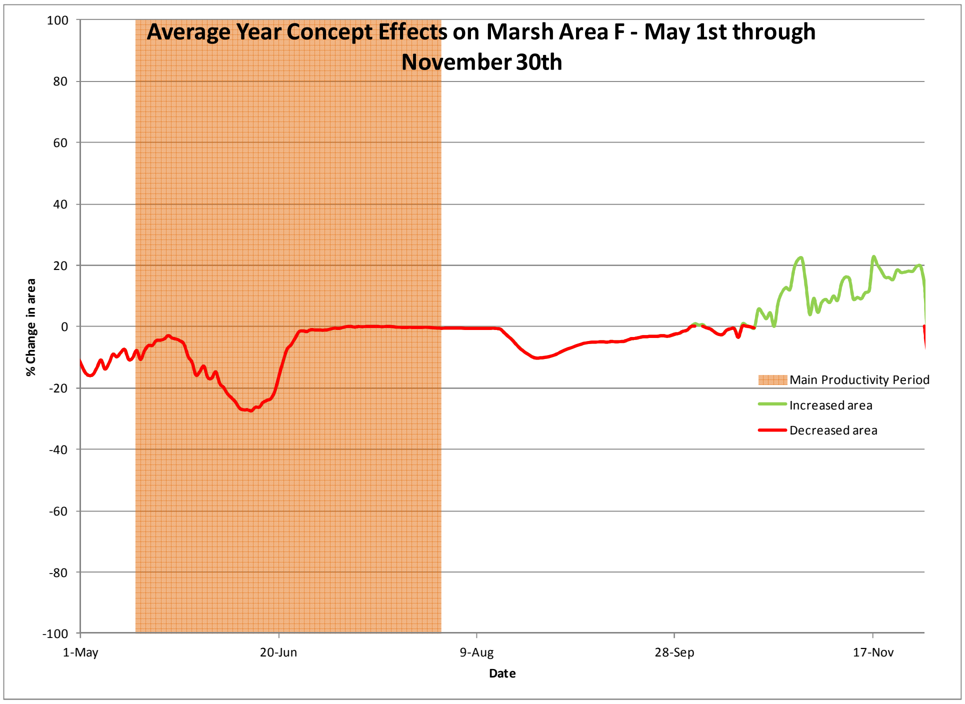

FIGURE 27. DIFFERENCE IN SITE F AREA BETWEEN THE HISTORICAL DAILY AVERAGE FLOW FROM 1984 THROUGH 2007 AND THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME TIME PERIOD.

Figure 28 compares the aquatic habitat available at Marsh Site F during the ice-free period of May 1st through November 30th for the historic daily average flow condition for an extreme wet year (2007) and the Concept scenario for the same time period. The percent change in aquatic habitat between the two scenarios is shown in Figure 29. During an extreme wet year, such as 2007, the aquatic habitat available at Site F is very similar under the Concept scenario for most of the time from May 1st through October 1st, ranging from around 5,300m^2 in the spring to 49,100m^2 in mid to late summer. Around the first of October there is a decrease in the aquatic habitat that occurs about twelve days earlier under the Concept scenario than occurred under the historic scenario. This would account for the sharp decrease, of about 55%, in aquatic habitat shown in Figure 29 for this time period. Throughout the rest of the late fall, the two scenarios have similar amounts of aquatic habitat available.

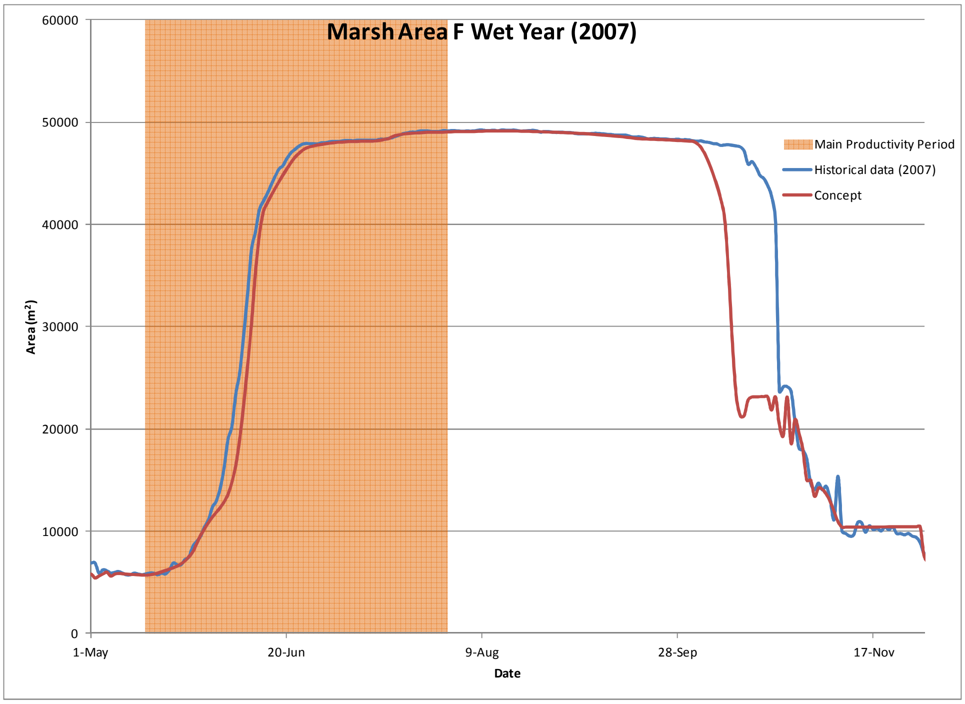

FIGURE 28. COMPARISON OF MARSH F AREA BASED ON HISTORICAL DAILY AVERAGE FLOW ON THE YUKON RIVER FOR THE EXTREME WET YEAR 2007 WITH PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME PERIOD.

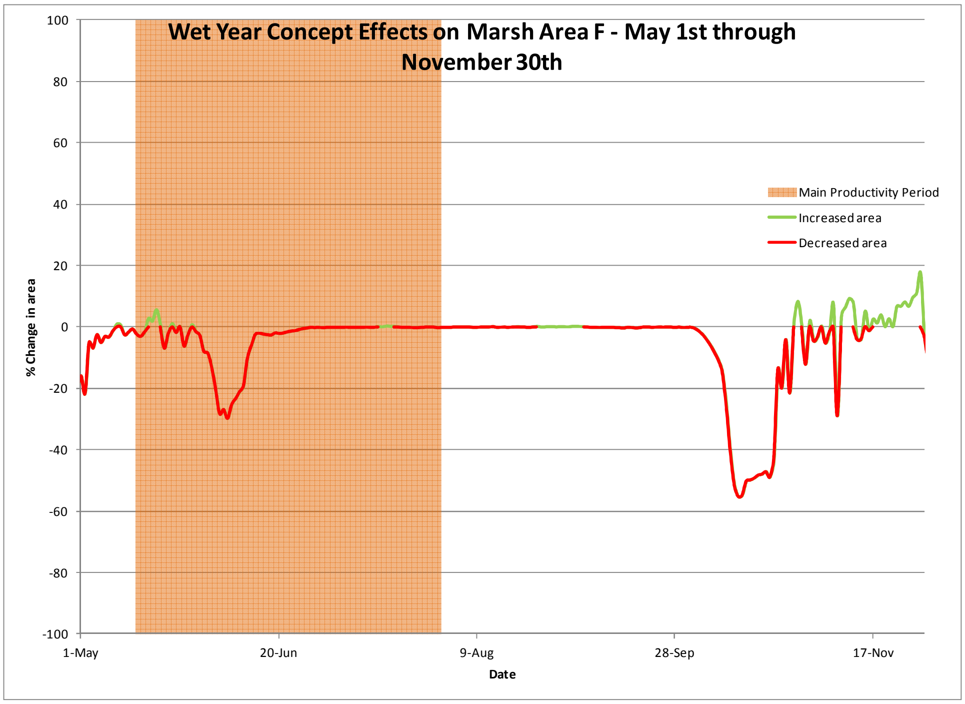

FIGURE 29. DIFFERENCE IN SITE F AREA BETWEEN THE HISTORICAL DAILY AVERAGE FOR THE WET YEAR 2007 AND PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME TIME PERIOD.

Figure 30 compares the aquatic habitat available at Marsh Site F during the ice-free period of May 1st through November 30th for the historic daily average flow condition for a dry year (1996) and the Concept scenario for the same time period. The percent change in aquatic habitat area available between the two scenarios is shown in Figure 31. In a dry year, such as 1996, the aquatic habitat available at Site F ranges from a minimum of about 3,125 m^2 to a maximum of 45,100 m^2 in the summer. The minimum aquatic habitat available in the Concept scenario is 3,000 m^2 and the maximum is near 44,000m^2 in mid-August. Under both scenarios there is sharp decrease in aquatic habitat after August 13th. Under the Concept conditions this decrease happens over a much shorter time period than under the historic conditions, resulting in the 52% decrease in aquatic habitat available between the two scenarios.

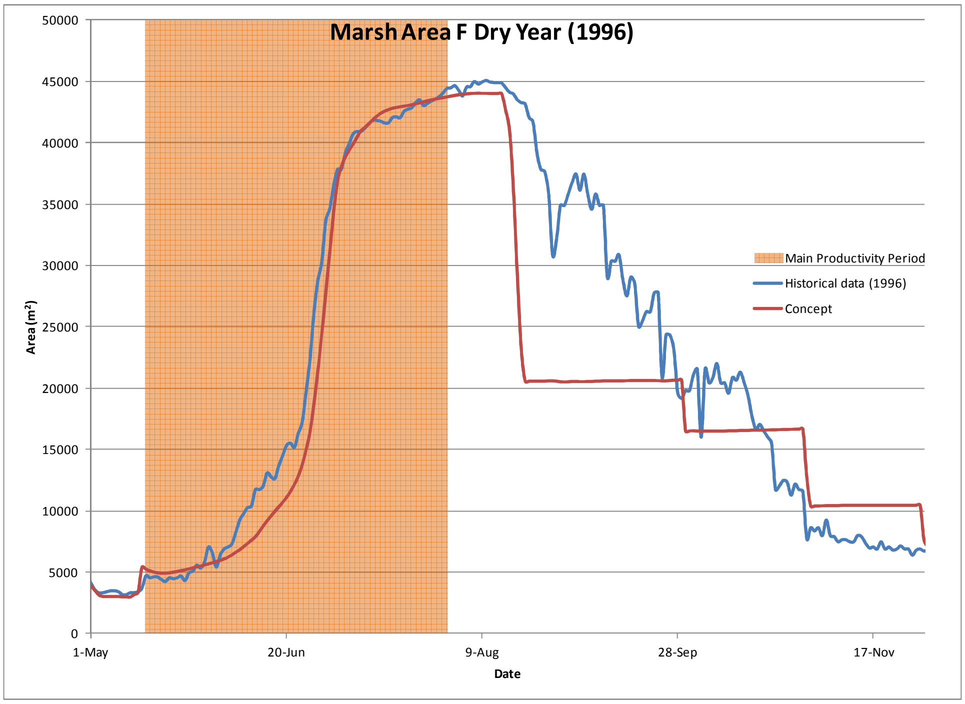

FIGURE 30. COMPARISON OF MARSH F AREA BASED ON HISTORICAL DAILY AVERAGE FLOW ON THE YUKON RIVER FOR THE DRY YEAR 1996 WITH PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME PERIOD.

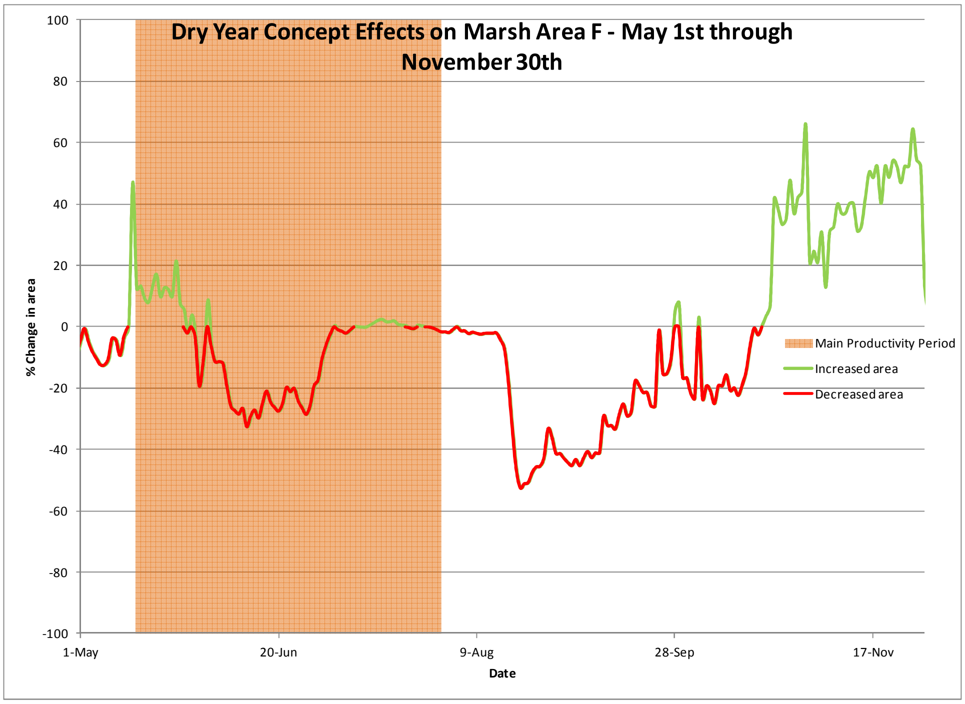

FIGURE 31. DIFFERENCE IN SITE F AREA BETWEEN THE HISTORICAL DAILY AVERAGE FOR THE DRY YEAR 1996 AND THE PROPOSED MARSH LAKE FALL STORAGE CONCEPT OPERATIONS OVER THE SAME TIME PERIOD.

Discussion

This analysis established the relationship of available aquatic habitat area for the four marsh sites with flow in the Yukon River. The Southern Lakes Fall/Winter Storage Concept will alter flows in the Yukon River downstream of Lewes Dam. The river flow records for three water-year types were used to compare the areas of wetted marshland aquatic habitat that occurred historically with that which would have occurred with the proposed Concept in place. Since the Yukon River and the marshland areas are ice covered for most of the winter, the time series analysis is restricted to the time period when the Yukon River and marshland areas are free of ice cover, and thereby usable by Yukon River fish species. The timing of freeze-up and break-up on the Yukon River varies from year to year depending on climatic conditions. Freeze-up near Whitehorse generally occurs sometime between mid-November and mid-December, and break-up generally occurs in the first few days of May. Shallow marshlands will be ice covered earlier than the main channel.

The changes in available aquatic habitat area at the marshland sites varies based on the water year type, but are quite similar between the marshland areas that are connected to the Yukon River. The Concept scenario decrease in available aquatic habitat during the spring results from the additional 0.1 meter draw down of Marsh Lake. From May through June there is an average of 4 days delay in the time it takes for the aquatic habitat available with the Concept scenario to reach the same levels as the historic scenario. In mid-August, during average years and dry years, the Southern Lakes Fall/Winter Storage Concept causes a sharp decrease in available aquatic habitat in the marshlands compared to the historic conditions (average of all sites of 13% and 39% for average and dry years). This reduction in aquatic habitat is a result of closing the flow regulation gates of Lewes Dam at the exit of Marsh Lake. The effect of the gate closing has more impact on the marshlands areas in dry years than in the average water years. During wet years the closing of the flow regulation gates occurs later in the year, around the first of October, with the ensuing decrease in aquatic habitat (average of all sites 47%) occurring about 7 days later. The effect of reduced marshland area in September and October on fisheries productivity would be negligible because fish would have moved out of the wetland by the end of August due to cooler water temperatures.

The use of the marshland area aquatic habitat along the Yukon River is not well documented; however, very high densities of adult northern pike are found every year in several wetlands in the Lewes Marshes upstream of the study area during June as they become wetted and July attracting a lot of angling activity (Don Toews, personal communication). McPhail and Lindsey (1970) note that northern pike spawn in shallow wetlands shortly after ice breakup. Electrofishing and gillnetting surveys of three wetlands in Lewes Marsh upstream of the Lewes Dam in Marsh Lake, conducted on August 3 and 4, 2011, the only specimens collected were four northern pike (AECOM field memorandum 2011). They ranged in size from 142mm to 740mm. The primary utilization period typically ends in mid to late July when marshland temperatures fall below the mainstem water temperature (Don Toews, personal communication). Von Finster *et al.* (1998) conducted extensive survey efforts for Chinook salmon on the main-stem Yukon River below the outlet of Marsh Lake. They employed an incline plane trap, minnow traps, and seining between May 30th and August 5th 1998. They report catching 32 Arctic grayling, 13 Chinook salmon, one Lake Chub, 147 longnose suckers, 21 northern pike, 111 slimy sculpin, 814 whitefish, and 28 unknown species over the course of their study. The use of non-natal tributaries of the Yukon River for Chinook salmon juvenile rearing has been well documented in several streams (Moody *et al*. 2000; Daum and Flannery 2011).

The primary impact to marshland aquatic habitat from the Concept flows will be the springtime delay in inundating the wetlands from the lower (delayed) flow in the main channel. The connectivity of the marshlands will not be impacted during the main productivity period. Marsh Site B connects to the main channel at a flow lower than the early spring flow and Marsh Site D at a higher flow. Marsh Sites C and F have no hydraulic controls, allowing the inundated marshland area to vary directly with the river flow. Although there would be a large decrease in wetted area in mid-August during average and dry years from Concept flows, the decrease would occur after the main period of marshland productivity. In wet years, the gate closure decrease of wetted marshland area would occur in October with less utilization of the marshland aquatic habitat than in August.

References

AECOM and TRPA 2009. Yukon River 2009 Instream Flow Summary Report. Prepared for Yukon Energy Corporation.

McPhail, J.D., and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fisheries Reseach Board of Canada Bulletin 173.

Daum, D. W. and B. G. Flannery 2011. Canadian-Origin Chinook Salmon Rearing in Nonnatal U. S. Tributary Streams of the Yukon River, Alaska. Trans. Amer. Fish. Soc. 140:207-220.

Moodie, S., J.A. Grout and A. von Finster. 2000. Juvenile chinook salmon (Oncorhynchus tshawytscha) utilization of Cruacher Creek, a small non-natal tributary of the upper Yukon River during 1993. Can. Manuscr. Rep. Fish. Aquat. Sci. 2531: 66 pp.

TRPA 2011. Yukon River Lewes Reach Marshland Connectivity Report. Prepared for Yukon Energy Corporation.

von Finster, A., W. R. Ricks, and J Viksten. 1998. Juvenile Chinook salmon downstream migration investigation. Yukon River Chinook Salmon Restoration and Enhancement project #RE-19-98. 41pp.

APPENDIX A. MARSH AREA TABLES

	Wetted Area			
Yukon River Flow (CMS)	Marsh B	Marsh C	Marsh D	Marsh F
50	*	211	*	310
60	*	491	*	487
70	270	1004	*	817
80	472	1756	*	1523
90	807	2356	*	2269
100	1140	2801	*	3142
120	2200	3598	*	4661
140	5151	4363	*	6268
160	9549	5631	*	7955
180	13818	6675	*	10499
200	16373	7489	*	13513
220	18378	8265	*	16816
240	20250	8954	*	21063
260	21780	9600	*	25722
280	22971	10184	*	30854
300	23902	10622	*	37075
320	24834	11041	*	40932
340	25751	11453	*	42344
360	26555	11858	*	43525
380	27419	12217	*	44554
400	28137	12607	*	45392
420	28711	12950	*	46221
440	29378	13349	*	46888
460	30079	13581	*	47458
480	30775	13772	63216	47817
500	31509	13933	64801	48023
520	32296	14086	66351	48178
540	33152	14213	67902	48284
560	34093	14317	69453	48364
580	35135	14398	71003	48630
600	36294	14460	72554	48804
620	37586	14503	74105	48978
650	39807	14537	76430	49239
*** indicates marsh not connected to the Yukon River**				