Whatshan Project Water Use Plan

Whatshan Reservoir Vegetation Monitoring (Year 6, 2011)

Reference: WGSMON#2

Whatshan Water Use Plan Monitoring Program: Reservoir Vegetation Monitoring

TECHNICAL REPORT

G3 Consulting Ltd.

May 2012

Whatshan Reservoir Vegetation Monitoring

2011 Technical Report

Prepared for:

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EXECUTIVE SUMMARY

G3 Consulting Ltd. (G3) was retained by BC Hydro to assess macrophyte communities on the Whatshan Reservoir. Whatshan Reservoir was impounded in 1951 by the British Columbia Power Commission and currently generates 121 GWh annually at the Whatshan generating station. A Water Use Planning Process was initiated for Whatshan Reservoir in 2002 and resulted in development of changes to water use at Whatshan Reservoir to promote recreational use of the waters. A three phase vegetation monitoring study (Baseline, 2006; 5-Year Post Changes, 2011; and, 10-Year Post Changes, 2016) was implemented to assess potential effects associated with changes to Water Use Plan WGSMON-2 which included the following:

- an increase in the minimum year-round water elevations to 636.5 m (previously 634 m); and,
- annual increases in minimum reservoir elevation occurring earlier in the year (i.e., minimum of 639 m by May 15th and a minimum of 640.35 m between June 15th and October 1st of each year).

Assessments were conducted as part of agreements made under the *Whatshan Reservoir Water Use Plan* and included satellite image acquisition and prediction of macrophyte size and location, using algorithm-based index modeling accompanied by ground-truthing (September 2011). Objectives and management questions were established prior to commissioning the Whatshan Reservoir Vegetation Monitoring Program. Study design and applied methodologies were developed to address study-specific objectives and management questions. The Objective of the Whatshan Reservoir macrophyte survey was to:

Reduce uncertainty related to the effects of reservoir operations on reservoir vegetation in the Whatshan Lake Reservoir. Monitoring will focus on key locations where aquatic vegetation is present (Bennett et al. 2002), and primarily examine large-scale changes in the boundaries of vegetation communities.

The key management question identified in the WGSMON-2 Terms of Reference (BC Hydro, 2005) is:

Do changes in the operation of the Whatshan Lake Reservoir affect reservoir vegetation? (Table 3-11)

TABLE 3-11: BC Hydro Status of Objectives Table

Objectives	Management Questions	Management Hypotheses	Year Six (2011) Status	Year Ten (2016) Status
Reduce uncertainty related to the effects of reservoir operations on reservoir vegetation in the Whatshan Lake Reservoir. Monitoring will focus on key locations where aquatic vegetation is present (Bennett et al. 2002), and primarily examine large-scale changes in the boundaries of vegetation communities.	Do changes in the operation of the Whatshan Lake Reservoir affect reservoir vegetation?	H1: The area of emergent vegetation will decrease as a consequence of extended inundation.	Tentatively Supported, to be confirmed in 2016	-
		H1a: The species composition of emergent vegetation will change as a consequence of extended inundation.	Not as yet addressed, to be assessed in 2016	-
		H2: The area of submerged vegetation will increase as a consequence of extended inundation.	Tentatively Supported, to be confirmed in 2016	-
		H2a: The species composition of submerged vegetation will change as a consequence of extended inundation.	Not as yet addressed, to be assessed in 2016	-

In situ vegetative community assessments and ground truthing were conducted from September 27 to 30, 2011. Macrophyte distribution was estimated from 72 quadrats distributed along transects through 8 study sites. Samples were collected from each transect and distribution apportioned by biomass and percent cover. Voucher specimens were identified to species level upon return from the field. Based on quadrat content, a mathematical model was generated to identify and delineate habitat type from multispectral satellite imagery.

In total, 42 taxa were identified during the 2011 Whatshan Reservoir Vegetation Monitoring Program. Twenty-six taxa were associated with emergent vegetation (i.e., aquatic vegetation partially or fully above the waterline but below the HHWM [i.e., full pool]), 20 submerged taxa (i.e., at or below the waterline) and 4 taxa in both submerged and emergent quadrats. Spectral analysis of satellite imagery was successful at classifying wetland habitats at all sites. Over 4.0 million m^2 of aquatic vegetation were identified and classified using spectral imaging techniques.

Due to unavailability of detailed results from Phase 1 (2006), Phase 2 (2011) required the establishment of a detailed baseline to enable the Phase 3 (2016) assessment to address the management questions and conduct detailed comparisons. The program and related detailed and final assessments addressing the specific management questions set forth for this program will be conducted in the fall of 2015 (Phase 3) with a final report delivered by March 31, 2016.

1.0 INTRODUCTION

On behalf of the British Columbia Hydro and Power Authority (BC Hydro), G3 Consulting Ltd. (G3) was retained to complete a vegetation monitoring program that evaluates potential effects of changes to water management practices, as outlined in the BC Hydro Water Use Plan (WUP) on aquatic vegetation, as a measure of fish and wildlife habitat. The overall program is comprised of three phases of assessment. Phase One was a baseline investigation conducted in 2006, prior to the changes outlined in the WUP coming into effect. Changes to the WUP, with the capacity to affect vegetative communities at Whatshan Reservoir, came into effect in 2007 and included:

- an increase in the minimum year-round water elevations to 636.5 m (previously 634 m); and,
- annual increases in minimum reservoir elevation occurring earlier in the year (i.e., minimum of 639 m by May 15th and a minimum of 640.35 m between June 15th and October 1st of each year).

Phase 2 field surveys, presented in this report, were conducted in September, 2011 and constitute a follow-up to the 2006 baseline assessment (Moody, 2007). Phase 3 is to be completed during a similar time period in mid to late August of 2015. Due to the unavailability of data derived from the 2006 study, data from this 2011 field study were also considered as a baseline assessment from which subsequent work will be compared.

The baseline investigation outlined in this report was developed as part of a hypothesis-driven, Multiple Before-After, Control-Impact-Paired (MBACIP) statistical design, which will take into account confounding influences posed by the dynamic and heterogeneous nature of the reservoir and natural spatial and temporal variability posed by both natural phenomena and anthropogenic activities. Further, this comparative investigation will examine current and past conditions of the reservoir and its macrophyte communities in an effort to map and compare surface area, composition and spatial location using high-resolution satellite imagery (Section 2.4.4) and ground-truthing (Section 2.3). Polygons generated from 2011 spectral data (current baseline) will be compared directly with those generated in 2016 to assess changes in size and distribution of macrophyte communities. Further, whole-reservoir modeled spectral data will be compared between years to assess changes in community composition and vigour as outlined in the management questions and objectives.

This report provides interpretive text and tables (Chapters 1 through 4), references and appendices. This chapter (Chapter 1) briefly outlines study objectives for the Vegetation Monitoring Program and summarizes important information on Whatshan Dam, general reservoir characteristics and ecology and the general study area. Chapter 2 provides an overview of the study design and methodology for field and laboratory work. Chapter 3 provides general study result and Chapter 4 summarizes information presented and provides recommendations for Phase 3 of the study. As this is intended only as a technical report, data interpretation is limited until 2016 data is available for a complete assessment. References and literature cited are provided in Chapter 5

Appendices provide figures (Appendix 1), photographs (Appendix 2), summary tables and charts (Appendix 3), site descriptions (Appendix 4), ecological characteristics of observed macrophytes (Appendix 5), base maps of reservoir vegetation (Appendix 6), the *Safety & Environmental Management Plan* (Appendix 7) and a sample of field forms used (Appendix 8). Photographic meta data, a vegetation reference collection and excel spreadsheet of field data were provided as an Annex to this report.

1.1 Study Objectives

To ensure that provincial water management decisions reflect changing public values and environmental priorities a water use planning process was initiated for Whatshan Reservoir in March, 2002. The Consultative Committee for the Whatshan Water Use Plan (WUP) agreed upon a water management strategy so as to improve and protect the recreational use of Whatshan Reservoir through improved access and improving fisheries habitat quality. As part of these changes BC Hydro would fill the reservoir earlier in the year (May 15) to enable use of the boat ramp earlier in the season, improving access and use of the reservoir.

The agreed upon strategy resulted in amendments to the BC Comptroller of Water Rights and implementation of the Whatshan Reservoir WUP, as specified in the Whatshan Reservoir Consultative Committee report (Consultative Committee, 2003). These amendments included operational constraints to the minimum year round reservoir elevation (previously 634 m) and the spring filling dates (previously mid May through early June). Due to a lack of information regarding potential effects of spring and winter reservoir elevation on vegetative communities and fisheries and wildlife resources and habitat, as well as a general concern expressed during the consultative process, a pre- (Phase 1), mid (Phase 2, this report) and post-project (Phase 3) assessment of vegetative communities was recommended, and subsequently approved, to verify predictions on changes to vegetative communities. This report (Phase 2) provides midpoint (2011) assessment results.

Objectives and management questions were established prior to commissioning the Whatshan Reservoir Vegetation Monitoring Program. Study design and field methodologies were specifically designed to address study-specific objectives and answer management questions. The Objective of the Whatshan Reservoir macrophyte survey was to:

> *Reduce uncertainty related to the effects of reservoir operations on reservoir vegetation in the Whatshan Lake Reservoir. Monitoring will focus on key locations where aquatic vegetation is present (Bennett et al. 2002), and primarily examine large-scale changes in the boundaries of vegetation communities.*

Key management questions included:

> *Do changes in the operation of the Whatshan Lake Reservoir affect reservoir vegetation?*

1.2 Background & Project Rationale

The Whatshan Reservoir hydroelectric project was designed and constructed by the British Columbia Power Commission and was completed in 1951. Whatshan Dam is a 12 m high and 82 m long concrete dam with a further 91 m of earth filled embankments. The Dam is located at the southern end of Whatshan Reservoir and fed primarily by Whatshan River at the north end (Figure 1, Appendix 1). Whatshan Reservoir has a storage capacity of 122,000,000 m^3 at maximum operating elevation (641.3 m). The penstock intake at the southeast side of Whatshan Lake is a 3.4 km tunnel that directs water to the powerhouse on the west side of the Arrow Lakes Reservoir. The Whatshan Powerhouse generates 121 GWh annually through a single Francis-type Turbine (50 MW, 33 m^3/s).

The three interconnected basins of Whatshan Reservoir flow north to south. The upper basin is the largest at 1,255 hectares (ha) with a maximum depth of 116 m. The middle basin is characterized by “The Narrows” and resembles a lentic riverine system. The maximum depth of the middle basin is 15.2 m and occupies only 99 ha. The lower basin has a surface area of 338 ha and has a maximum depth of 33 m. Water residency time is estimated at four months (Pettigiani, 1995; cited in Consultative Committee, 2003).

Whatshan Reservoir maintains a year-round alarm threshold level of 640.9 m elevation providing a 0.4 m buffer to maximum operating level. At the threshold level, power generation occurs at maximum capacity. The year round operating minimum is 636.5 m.

Monthly turbine flow and Whatshan Reservoir water elevation (minimum, maximum and average), from January 2000 to February 2012, are provided in Chart A1 (Appendix 3). During recreational use (May – Oct) minimum reservoir levels are established at -1.5 m of the maximum elevation (641.3 m). Between October 1 and May 15 the minimum operating level is 636.5 m.

1.2.1 Reservoir Characteristics

Reservoirs are typically described as occupying intermediate positions between rivers and natural lakes on a continuum of aquatic ecosystems (Kimmel and Groeger, 1984). River-flooded reservoirs, such as Whatshan Reservoir undergo fluctuation of water levels associated with drawdown of water for hydroelectric power generation. Water levels in Whatshan reservoir remain relatively constant within a season (fluctuation between 640.3 m and 641 m during summer months) with drawdown to the minimum level immediately after October 1st each year (Chart A1, Appendix 3).

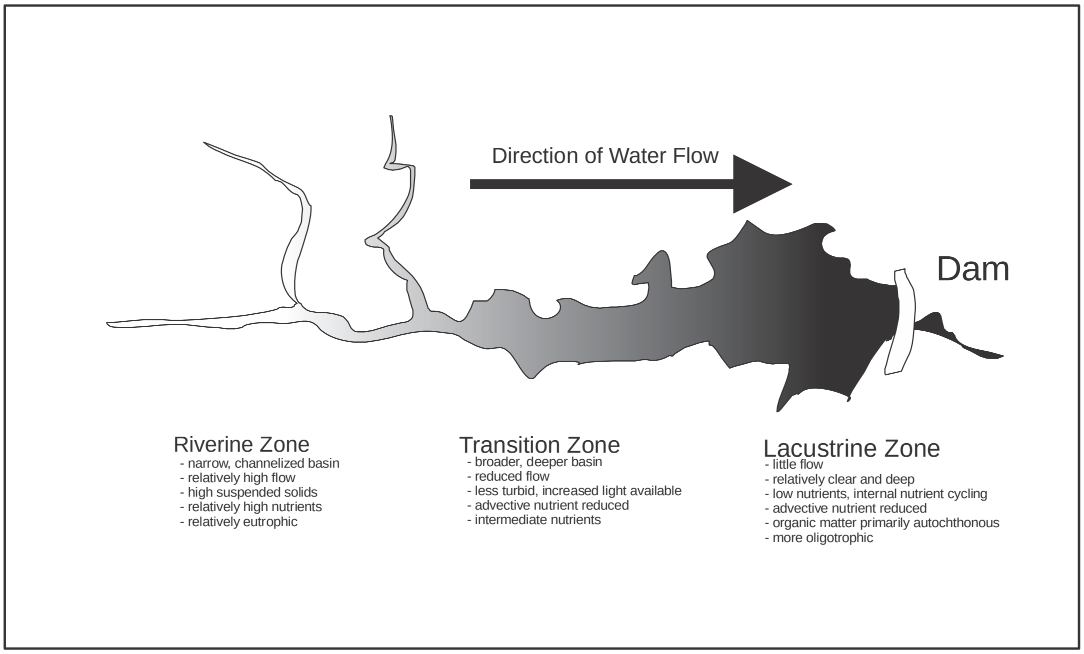
Compared with natural systems reservoirs are, in general, characterized by a large shore development ratio (SDR), dendritic shorelines (many-branched and convoluted), V-shapes bottom profiles, short retention times, large and unstable aridals (barren drawdown zones), high spatial and temporal heterogeneity, unidirectional flow and serial zonation, shorter lifespan and high allochthonous sediment loading due to high watershed-to-lake area ratio (Lind et al., 1993; Straskraba et al., 1993; Straškrábová et al., 2005). The euphotic zone in reservoirs is usually only a few metres deep (Morris and Jiahua, 1998). Sediment inflow and re-suspension of bottom sediments by wave action can increase water turbidity, most notably up reservoir.

Reservoirs are influenced by climatological, hydrological and anthropogenic parameters, with the degree of response depending on the size and volume of reservoirs and varying proportionately to the magnitude of environmental parameters. The different uses of reservoirs and their watersheds may have an impact on water quality, and thus, on aquatic life.

Reservoirs can typically be divided into three regions (Figure 1-1):

- **Riverine Zone:** the region of a reservoir where the types of processes (e.g., bank erosion, water flow, sedimentation) occurring are more comparable to a river than a lake. This zone is characterized by narrow geometry, shallow waters, significant flow velocities and the transport of silts and clays (Morris and Jiahua, 1998). Allochthonous (i.e., external) organic material predominates in this zone; however, water remains well-oxygenated due to low depths. Water transparency can be reduced by high sediments loading from rivers or high primary productivity (e.g., algae blooms caused by high nutrient inputs from rivers). Many of the original riverine invertebrate and fish species persist. Excessive silting may influence bottom living invertebrates that rely on clean, sediment-free conditions;
- **Transition Zone:** headwaters are often dominated or influenced by the riverine inputs to the region. If inflows have a density greater than lacustrine zone surface waters, the inflows will tend to plunge beneath the lacustrine zone surface. Often a “trash line” of floating debris will indicate such a plunge point. If the inflow water is less dense, it will flow over the lacustrine zone surface. If inflow density is greater than the lacustrine zone surface, but less dense than that of the lacustrine zone bottom waters, these flows may extend into the lacustrine zone or perhaps throughout the lacustrine zone. Such interflows are common where plunging inflows attain depths similar to the penstock opening depth on the dam impounding the lacustrine zone. Substantial inflows (e.g., high flows from occasional precipitation events) can greatly influence the lacustrine zone thermal structure. For example, inflows with high (or low) temperatures have the potential to change the thermocline depth and, thus, may be a primary factor influencing the thermal structure of the lacustrine zone; and,
- **Lacustrine Zone:** the deepest region, typically downstream from the transition area, where strictly limnetic processes dominate. This zone extends to the dam and has characteristics similar to lakes (e.g., clearer water, lower sediments loading, stratified water column, organic matter mostly produced by reservoir plankton, primary production limited by nutrients loading rather than lack of light; Morris and Jiahua, 1998). True lacustrine phyto- and zooplankton develop in this zone. Floating vegetation, such as the water fern and the water hyacinth, may form extensive mats covering large areas of the reservoir. Lacustrine insects, such as lake flies (chironomids and chaoborids), also colonize this zone.

Figure 1-1: Reservoir Zonation (adapted from Thornton *et al.,* 1981)



The region in which the lake gradually changes from riverine to limnetic dominance is aptly termed the transition area. This ecotone (i.e., ecological transition) is usually rich and diverse in biota, and dynamic and complex in hydrology. Mixing of riverine and lacustrine waters, when combined with reservoir drawdown cycles and seasonal influences (e.g., winds and related currents, winter freeze-up), result in complicated horizontal and vertical hydrological movements in the transition area. Changing seasonally, these forces produce differences in current and density between riverine and lacustrine waters.

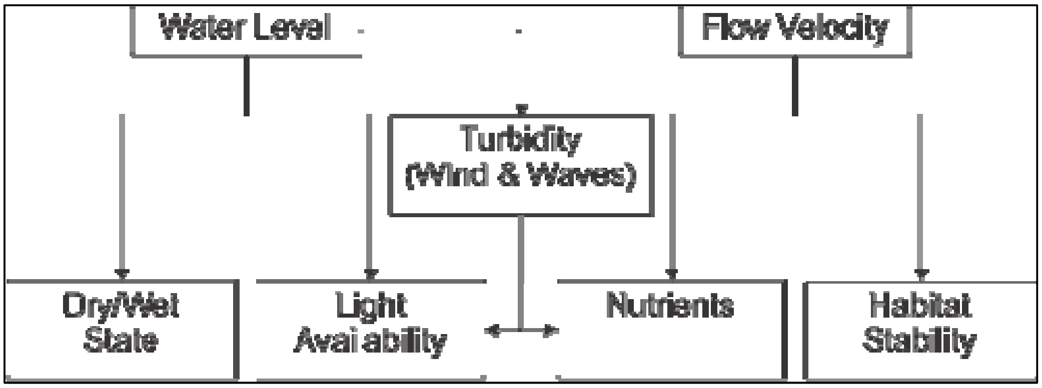
The theoretical retention time of a reservoir is the ratio of reservoir volume to inflow rate. Short retention times prevent significant settling of suspended particles (Cooke *et al*., 2005). Phytoplanktonic and macrophytic production depends greatly on reservoir retention time, specifically with regards to the settling of organic and inorganic suspended particles present in the water column. When retention time is low (e.g., a few days) and the reservoir is shallow, benthic algae dominate autotrophic production (Hargrave, 1969). In reservoirs with greater retention times, colonization by typical lake flora is favoured.

Whatshan Reservoir is dissimilar to typical reservoir zonation in that there are three distinct basins (Upper Basin, Middle Basin, Lower Basin) which each exhibit typical reservoir zonation on a localized scale (Figure A1, Appendix 1). Retention times of each basin vary with the level of hydroelectric power generation activity at a given time of year.

1.2.2 Reservoirs & Macrophyte Ecology

Macrophyte (i.e., emergent, submerged or floating-type plants) communities play an important role in fish and wildlife habitat. Macrophyte communities provide spawning, nesting, nursery and feeding habitat for a variety of organisms (i.e., fish, waterfowl, raptors, ungulates and other large herbivorous mammals, large carnivorous mammals, and small mammals, reptiles and amphibians). Upstream influx of nutrients can generate abundant levels of macrophyte growth which may cover fish habitat, causing decreased dissolved oxygen (DO) levels thereby reducing the quantity and quality of fish habitat (i.e., eutrophication). Macrophytes provide a number of ecosystem services (i.e., water purification, nutrient cycling, etc.) and are of critical importance to supporting fish, zooplankton and invertebrate populations (Cowx and Welcomme, 1998). Aquatic macrophytes are also a source of food for waterfowl, muskrats, beavers and moose (Mitchell and Prepas, 1990). Growth of macrophytes in reservoirs depends on several environmental parameters (e.g., light energy and nutrient availability, water temperature, water level fluctuations, water velocity; Figure 1-2):

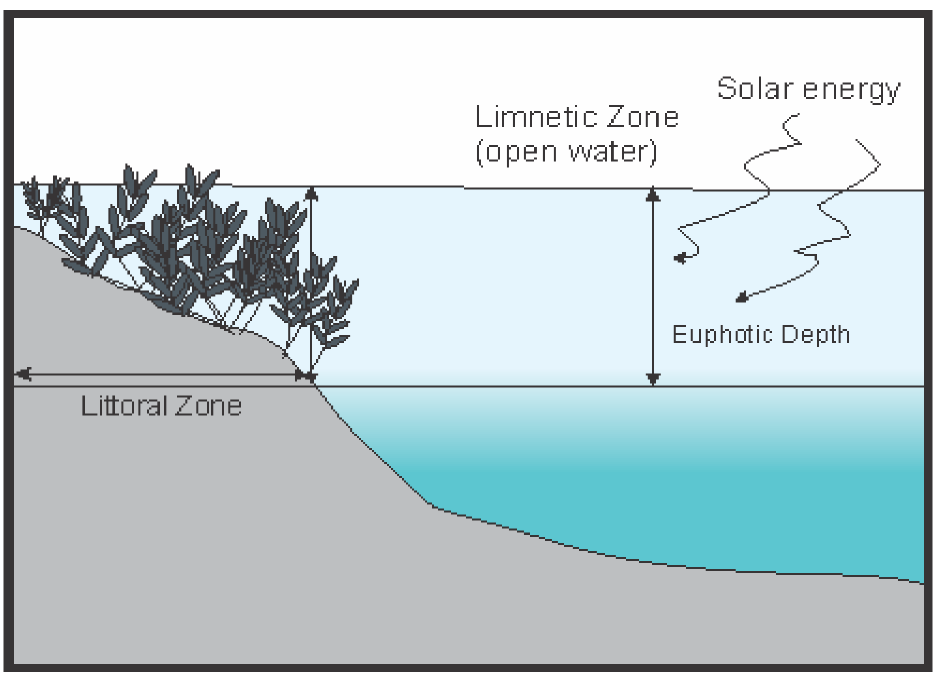
Figure 1-2: Environmental Parameters Influencing Macrophyte Growth



(Adapted from Stevenson; 1996)

The type of substrate and reservoir slope can also have an impact (positive or negative) on macrophytes growth (Cooke et al., 2005). Nearshore areas (i.e., littoral vs. limnetic, profundal and benthic) are characterized by better light availability and higher risk of desiccation (Figure 1-3), while deeper zones are characterized by lower light availability and higher flow velocity. The highest macrophyte biomass is typically observed in the littoral zone of reservoirs, especially during periods when water levels are constant (Wetzel, 2001).

Figure 1-3: Water Zonation within a Reservoir



Biophysical changes in the littoral zone of reservoirs associated with periodic drawdown and inundation typically have significant effects (positive or negative) on macrophyte development

(Wetzel, 1983; Baxter, 1985; Kimmel and Groeger, 1986; Northcote and Atagi, 1997). Macrophyte mobility is very limited with their development depending on environmental parameters in both reservoir water and sediments. Macrophyte species are sensitive to physical and chemical changes in the surrounding environment and are, thus, good indicators of both current environmental conditions and long-term environmental changes.

Water level fluctuations within a reservoir constitute a periodic disturbance regime to the littoral environment. Studies in Canada (Hill *et al.,* 1998) and northern Europe (Rørslett, 1991; Hellsten, 2001) demonstrated that macrophyte diversity was, in general, lower in reservoirs than in non-regulated lakes. The relationship between macrophyte diversity and disturbance is complex. The intermediate disturbance hypothesis states that species richness within an ecosystem is maximized at moderate levels of disturbance (Ward and Stanford, 1983; Hobbs and Huenneke, 1992). Murphy *et al.* (1990) suggested that a modest increase in disturbance had the potential to increase suitable habitats within a reservoir for European aquatic macrophytes. A survey of Scandinavian lakes (Rørslett, 1991) showed that macrophyte richness peaked with drawdown amplitudes of 1 m to 3 m. A similar phenomenon was reported for reservoirs regulated for hydropower in New Zealand where an increase in the range of monthly water level fluctuations appeared to increase biodiversity (Riis and Hawes, 2002). Inundated trees and brush seemed to enhance macrophyte colonization in water bodies with small level fluctuations (Judd and Taub, 1973; Nichols, 1974; Northcote and Atagi, 1997). Complex interactions between changes in water level, substrate, flow regimes and inundated terrestrial vegetation will ultimately determine the distribution and diversity of macrophyte communities within a reservoir. Changes in reservoirs cited above resulting from changes in water use may not be applied to all reservoirs. Similarly, changes in Whatshan Reservoir following changes in water use may be attributed to multiple factors within the reservoir.

1.3 Study Area & Sample Sites

The study area for Phase 2 (Year 5) of the Whatshan Reservoir Vegetation Monitoring Program included eight previously identified long-term monitoring sites as defined in Bennet *et al.* (2002; Figure 1, Appendix 1). The Whatshan dam is located approximately at UTM coordinates 419800 E 5530000 N 11U; 100 km southeast of Vernon, BC.

Whatshan Reservoir is primarily located in the Columbia-Shuswap Moist Interior Cedar-Hemlock (ICHmw2) Biogeoclimatic Zone with northern portions of the reservoir and headwaters located in the Selkirk Wet Cold Engelmann Spruce-Subalpine Fir (ESSFwc4) biogeoclimatic subzone (Bennet *et al.,* 2002). The upper basin of Whatshan Reservoir is bounded by Whatshan Peak to the west and Mount Ingersoll to the east.

Two of the long-term monitoring Sites 1-17 and 1-18 were situated at the north end of the upper basin on the west and east sites of the Whatshan River outlet, respectively (Figures A2-7 and A2-8, Appendix 1). Site 2-13 was located at the southern end of the upper basin, near the outlet of White Grouse Creek. Sites 3-7 and 3-8 were located immediately south of “The Narrows” separating the middle and lower basins. Sites 3-7 and 3-8 (Figures A2-4 and A2-5, Appendix 1) were situated on the west and east sides of the reservoir, respectively, with Site 3-7 also bounding Site 3-6, locally referred to as “Robin’s Lagoon” (Figure A2-3, Appendix 1). Site 4-4, locally referred to as “David’s Lagoon,” was situated near the middle of the lower basin and was bounded by the eastern shore of Whatshan Reservoir (Figure A2-2, Appendix 1). Site 6-3 was located at the southern extent of the Reservoir near the Penstock intake (Figure A2-1, Appendix 1). Detailed site descriptions are provided in Section 2.3.4

1.3.1 Fisheries

Whatshan Reservoir supports a healthy fish community dominated by salmonids and cyprinidae (Table 1-1). Wetland habitats consist of *Typha sp*. Dominated marshes, reed and sedge dominated marshes, sedge and shrub dominated wet meadows (fen), riparian vegetation and various transitional communities.

TABLE 1-1: Whatshan Reservoir Fisheries Resources		
Common Name	**Latin Name**	**Conservation Status**
Sport Fish		
Kokanee	*Oncorhynchus nerka*	No Status
Rainbow Trout	*Oncorhynchus mykiss*	No Status
Bull Trout	*Salvelinus confluentus*	Provincial Blue Listed
Mountain Whitefish	*Prosopium williamsoni*	No Status
Non-Sport Fish		
Northern Pikeminnow	*Ptychocheilus oregonensis*	No Status
Largescale Sucker	*Catostomus macrocheilus*	No Status
Peamouth Chub	*Mylocheilus caurinus*	No Status
Longnose Sucker	*Catostomus catostomus*	No Status
Longnose Dace	*Rhinichthys cataractae*	No Status
Slimy Sculpin	*Cottus cognatus*	No Status
Redside Shiner	*Richardsonius balteatus*	No Status

1.3.2 Wildlife

Extensive wetlands in and around Whatshan Reservoir, as described in Sections 2.3.4 and 3.2 of this report, support a diverse and abundant wildlife community. Species observed during Phase 2 (2011) field assessments are noted in Table 1-2, below. Elk (three cows and two calves) were observed in the Upper Basin at Site 1-17. The observed elk appeared to be avoiding a predator that field personnel were unable to observe. A muskrat lodge was identified at Site 6-3 in the Lower Basin and likely muskrat habitat was observed at Sites 3-7, 3-8, 2-13, 1-17 and 1-18. No amphibians were directly observed during Phase 2 (2011) field assessments; however, small green eggs/seeds/algae were noted floating in the water and were abundant inside cattail (*Typha sp.)* communities of Sites 3-7 and 3-8 (Photographs provided in database Appendix: P9300184 - P9300189).

TABLE 1-2: Potential Wildlife at Whatshan Reservoir

Common Name	Latin Name	Conservation Status	Local Status
Amphibians (*Amphibia*) & Reptiles (*Reptilia*)			
Columbia Spotted Frog	*Rana luteiventris*	Yellow Listed	Confirmed (Bennet *et al.* 2002)
Pacific tree frog	*Pseudacris regilla*	No Status	Confirmed (Bennet *et al.* 2002)
Western Toad	*Anaxyrus boreas*	Blue Listed	Confirmed (Bennet *et al.* 2002)
Common Garter Snake	*Thamnophis sirtalis*	No Status	Suspected (Bennet *et al.* 2002)
Long-toed Salamander	*Ambystoma macrodactylum*	Yellow Listed	Suspected (Bennet *et al.* 2002)
Western Garter Snake	*Thamnophis elegans*	No Status	Suspected (Bennet *et al.* 2002)
Northern Rubber Boa	*Charina bottae*	Yellow Listed	Suspected (Bennet *et al.* 2002)
Northern Leopard Frog	*Rana pipiens*	Red Listed	Potential (Bennet *et al.* 2002)
Blotched Tiger Salamander	*Ambystoma mavortium*	Red Listed	Potential (BC MOE)
Painted Turtle	*Chrysemys picta*	No Status	Potential (BC MOE)
Coeur d'Alene Salamander	*Plethodon idahoensis*	Yellow Listed	Potential (BC MOE)
Mammals (*Mammalia*)			
Elk	*Cervus canadensis*	No Status	Observed (2011)
Muskrat	*Ondatra zibethicus*	No Status	Confirmed (2011)
Black Bear	*Ursus americanus*	No Status	Reported (2011)
American Badger	*Taxidea taxus*	Red Listed	Suspected (2011)
Grizzly Bear	*Ursus arctos horribilis*	Blue Listed	Observed (Bennet *et al.* 2002)
Southern Mountain Caribou	*Rangifer tarandus*	Red Listed	Suspected (Bennet *et al.* 2002)
Wolverine, *luscus* subspecies	*Gulo gulo luscus*	Blue Listed	Suspected (Bennet *et al.* 2002)
Townsend's Big-eared Bat	*Corynorhinus (Plecotus) townsendii*	Blue Listed	Suspected (Bennet *et al.* 2002)
Fisher	*Martes pennanti*	Blue Listed	Potential (Bennet *et al.* 2002)
Grey Wolf	*Canis Lupus*	Yellow Listed	Potential (BC MOE)
Fringed Myotis	*Myotis thysanodes*	Blue Listed	Potential (BC MOE)
Red-tailed chipmunk; *simulans* subspecies	*Neotamia ruficaudus simulans*	Blue Listed	Potential (BC MOE)

Cont'd next page

TABLE 1-2: Whatshan Reservoir Wildlife Resources (cont'd)

Common Name	Latin Name	Conservation Status	Local Status
Avians (*Aves*)			
Great Blue Heron; *Herodias* subspecies	*Ardea Herodias herodias*	Blue Listed	Observed (2011)
Bald Eagle	*Haliaeetus leucocephalus*	Yellow Listed	Observed (2011)
Common Loon	*Gavia immer*	No Status	Observed (2011)
Prairie Falcon	*Falco mexicanus*	Red Listed	Confirmed (Bennet *et al.* 2002)
Lewis's Woodpecker	*Melanerpes lewis*	Red Listed	Suspected (Bennet *et al.* 2002)
Peregrine Falcon; *anatum* subspecies	*Falco peregrines anatum*	No Status	Suspected (Bennet *et al.* 2002)
Western Screech-Owl; *macfarlanei* subspecies	*Megascops kennicottii macfarlanei*	Red Listed	Suspected (Bennet *et al.* 2002)
White-throated swift	*Aeronautes saxatalis*	No Status	Suspected (Bennet *et al.* 2002)
American Bittern	*Botaurus lentiginosus*	Blue Listed	Suspected (Bennet *et al.* 2002)
Swainson's Hawk	*Buteo swainsoni*	Red Listed	Suspected (Bennet *et al.* 2002)
Boreal Owl	*Aegolius funereus*	Yellow Listed	Potential (BC MOE)
Short-eared Owl	*Asio flammeus*	Blue Listed	Potential (BC MOE)
Upland sandpiper	*Bartramia longicauda*	Red Listed	Potential (BC MOE)
Black Tern	*Chlidonias niger*	Yellow Listed	Potential (BC MOE)
Black Swift	*Cypseloides niger*	Yellow Listed	Potential (BC MOE)
Rusty Blackbird	*Euphagus carolinus*	Blue Listed	Potential (BC MOE)
Flammulated Owl	*Otus flammeolus*	Blue Listed	Potential (BC MOE)
White-headed Woodpecker	*Picoides albolarvatus*	Red Listed	Potential (BC MOE)
Williamson's Sapsucker	*Sphyrapicus thyroideus*	No Status	Potential (BC MOE)

1.4 Summary of Phase 1 (2006)

The 2006 Phase 1, baseline study was conducted by AIM Ecological Consultants Ltd. on September 7-12, 2006 (Moody, 2007). Moody (2007) used colour infrared aerial photography and ground truthing to delineate vegetation polygons within Whatshan Reservoir. The baseline study located 111.3 ha of wetland habitat with 26.8 ha of emergent and 84.5 ha of submerged vegetation. Moody (2007) identified 17 species of submerged macrophytes.

Moody (2007) designed the 2006 baseline study based on vegetation studies of similar nearby reservoirs. It was discovered upon arrival that Whatshan Reservoir was unlike other reservoirs at which other vegetation studies had been conducted. The elevation range of emergent vegetation was found to be very restricted as most emergent vegetation had developed on accumulations of woody debris along gently sloped shores.

During the 2006 baseline survey, reservoir elevation was 640.6 m. Emergent vegetation was found to be restricted to a range approximately equal to the summer operating level (640.9 m). Moody (2007) noted that submerged macrophyte communities appeared to be primarily associated with inflowing water sources (e.g., creek mouths). Moody (2007) also noted that the upper 1-2 m of the drawdown zone supported almost no macrophyte vegetation except along shallow grades and near water inputs.

The maximum depth of macrophyte vegetation was found to be 633 m which corresponded to the maximum depth of the euphotic zone (Moody, 2007). Vegetative growth was noted as greatly diminished at depths exceeding 635 m.

Moody (2007) identified 82 polygons of aquatic vegetation (submerged and emergent) occupying a total of 1,107,489.1 m^2. In total, 53 plant species were identified in various habitat types. Species distributions within sites were not published and not available during this Phase 2 (2011) assessment with which to compare current community structure and distribution. Further, no GPS data was available from BC Hydro to enable sampling along similar transects and/or quadrats. As a result, Phase 2 (2011) must be considered as a new baseline.

2.0 STUDY DESIGN & METHODS

The Whatshan Reservoir Vegetation Monitoring Program (VMP) adopted an MBACIP (Multiple Before-After, Control-Impact-Paired) statistical design from which to assess potential spatial and temporal effects on heterogeneous reservoir macrophyte communities associated with changes to the Water Use Plan (WUP). MBACIP designs use multiple impact and control sites, assessed over time (Downes *et al*., 2002). Phase 1 (2006) of this VMP was the first of three phases in a 11 year (2006 – 2016) program in which baseline data was to be established for comparison with subsequent field assessments (Phases 2 and 3). Phase 1 baseline data (species distributions) was not available, necessitating Phase 2 field assessments (2011) to establish baseline conditions for comparison in the next phase (i.e., Phase 3, Year 10).

Pre-field tasks for this baseline work phase included summarizing existing information, developing a site-specific *Environmental and Safety Plan*, tasking satellites and obtaining required imagery and preparing base maps. When, after several weeks of collection opportunities, we were unable to obtain the required data from the Digital-Globe satellite WorldView-2, 5 m resolution multispectral (Red, Green, Blue, Red-Edge, Near-Infrared) was requested from the German satellite constellation RapidEye. Imagery was collected on August 1, 2011 in two parts at 19:45 and 20:03 PDT.

Satellite data collected were subsequently used to generate False Colour Composite (FCC; Section) base maps to assist in field assessments. *In situ* vegetative community assessments and ground truthing were conducted from September 27 to 30, 2011. Methodology employed during office and baseline assessments followed those developed by G3 on other environmental and macrophyte assessment programs, those specified by the Request for Proposal (RFP) and those of the provincial Resource Inventory Committee (RIC, 1997).

2.1 Start-up Meeting & Communications

Prior to commencement of office and field activities, a project start-up meeting was convened by telephone (May 5, 2011). This meeting finalized the scope of work (e.g., project objectives, budget, timing, methods/approach), discussed environmental and safety planning and introduced project participants and responsibilities.

Ongoing communications for this project were generally conducted via email to maintain a record of discussions.

2.2 Pre-Field

Pre-field assessments were completed to familiarize personnel with the subject area and to develop a *Workplan* for Year 5 assessments. Pre-field assessments included:

- summary of existing information;
- review of current and historical air photos, satellite imagery, and site maps;
- acquiring high resolution monochromatic (WorldView-1) and multi-spectral satellite imagery (RapidEye, Ikonos);
- development of classification algorithms and False Colour Composite (FCC) imagery (Section 2.4.4);
- development and approval by BC Hydro of the *Workplan*; and,
- development and acceptance by BC Hydro of a site-specific Whatshan Reservoir *Environmental and Safety Plan* in accordance with criteria stipulated (i.e., *BC Hydro Water License Requirement Safety Requirements*).

2.2.1 Summary of Existing Information

Relevant available information on macrophytes in Whatshan Reservoir (e.g., species list, relative abundance, contributing factors, distribution, etc.) was collected and summarized. In addition, historic reports on similar reservoirs in the area, such as the Arrow Lakes and Revelstoke reservoirs were reviewed. Information was obtained from grey and peer reviewed literature, queries to agencies (i.e., BC Hydro, BC Ministry of Environment) and consultant reports.

Aerial photographs and assessments (where available) produced by Moody (2007) were collected and reviewed to identify potential locations and types of macrophyte species thought to be currently present in Whatshan Reservoir. Meta-analysis synthesized data from various sources and developed a historical background profile and current trend analysis. A comprehensive evaluation of various terrestrial and aquatic vegetation indices was completed with an iterative feedback and review cycle.

A priori vegetative survey maps were created in False-Colour-Composite (FCC) to establish thresholds for calibrating algorithms and distinguish between emergent, submerged, riparian and algal vegetative communities.

2.3 Field Work

Field assessments of submerged and emergent vegetation at Whatshan Reservoir were to be conducted in three phases:

Phase 1: Year 1 (2006) Baseline Assessment (Moody, 2007);

Phase 2: Year 5 (2011) Vegetation Monitoring, Baseline Re-Evaluation (Current); and,

Phase 3: Year 10 (2016) Final Vegetation Assessment.

Year 1 (2006) field activities were conducted by AIM Ecological Consultants Ltd. between September 7 and September 12, 2006 and are described in detail in Moody (2007) and summarized in Section 1.4 of this report.

Year 5 (2011) field activities at Whatshan Reservoir (this report) were conducted from September 26 to September 30, 2011 with detailed methodology described herein. Field activities were conducted in accordance with the *2011 Operational Workplan* to give BC Hydro the opportunity to comment and provide input on project planning activities and objectives for field and assessment activities.

2.3.1 Research Vessel

A 6.7 m aluminum boat powered by a 340 HP inboard jet drive engine (Photo 2-1, Appendix 2) was used to conduct field studies. The boat was launched at or near the Inonoaklin Recreational Site boat launch, along the western shoreline, in the southern basin of the reservoir each day. The vessel was transported using a single axle EZ-load trailer, rated for highway transport and compliant with Transport Canada regulations. The boat was equipped with an emergency kit that included six (6) life jackets, a survival kit, flashlights, a bail bucket, two oars, a rope, a life ring, flares, a VHF radio, cellular phone and satellite phone.

2.3.2 Whatshan Reservoir Environmental & Safety Plan

Prior to conducting baseline assessments, G3 developed a project-specific *Environmental and Safety Management Plan* in accordance with BC Hydro safety protocols. The *Safety & Environmental Management Plan* (Appendix 6) included detailed protocols on:

- radio and communication;
- job hazards;
- field emergencies;
- Emergency Action Plans;
- water rescue;

- field mobility and activities (i.e., boat safety);
- field check-in procedures; and,
- emergency and program contacts (e.g., local fire, SAR, police, medical, BC Hydro, G3, etc.).

This plan was submitted to, and subsequently accepted by, BC Hydro prior to field crew deployment and followed BC Hydro Standard Operating Procedures (SOPs) and Occupational Safety and Health (OSH) guidelines.

2.3.2 Locating & Confirming Study Sites

Study locations were selected based on sites identified in the 2002 *Whatshan Water Use Plan Wildlife Overview* (Bennett et al., 2002). Approximate locations were first established using maps published in Bennet *et al.* (2002), Moody (2007) and through use of new multispectral imagery. In the field, study sites were further delineated using GPS coordinates estimated from previously published imagery with locations ultimately confirmed by verifying site descriptions from Bennett *et al.* (2002). Original site transect markers (from 2006) could not be identified at any site and GPS coordinates for transects or sample quadrats from those Year 1 field assessments were unavailable for comparison.

2.3.3 Site Layout

Once a given study site was established using available map data (Bennet *et al,* 2002; Moody, 2007) and confirmed using site descriptions (Bennet *et al.*, 2002), northern, southern and furthest from shore boundaries of the macrophyte community were then delineated using a Garmin GPSmap60Cx (Garmin GPS) and through strategic site survey and bottom viewing and assessment. Nearshore emergent macrophyte community boundaries were delineated using GPS operated from the research vessel. Boundaries were determined through observation of distinct changes in vegetation or soil composition, by field technicians. The high-high water mark (HHWM) boundary was defined through visual cues and differences observed in vegetation communities by on-shore personnel.

Site boundaries and transect points of commencement (POCs) were permanently marked with wooden stakes (0.05 m x 0.05 m x 1.20 m), metal ID tags affixed to the nearest permanent structure and/or other permanent on-shore markers (e.g., tree, boulder, stump). Stakes and permanent markers were tagged with coded location identifiers and flagged with orange marking ribbon and paint. Locations of all boundaries and markers were recorded using the Garmin GPS.

POCs were situated at the HHWM. The centre transect POC of each site was positioned equidistant from the northern and southern (or eastern and western) extents and measured using the Garmin GPS. Outer transect POCs were placed equidistant from the Centre POC and the corresponding site boundary (i.e., northern extent for north transect). Transects at each site were run parallel to each other (along established compass bearings) to prevent crossover and ensure comparability of communities obtained from quadrat sampling. In some instances sites deviated from the prescribed sampling plan (e.g., transects at Site 2-13 were placed at obtuse angles to one another to accommodate an unusual and challenging orientation of the shoreline [Figure A2-6, Appendix 1] and transects at Site 6-3 were placed at right angles (90°) to better reflect the macrophyte community of an island [Figure A2-1, Appendix 1]). Transect orientations are discussed in further detail in subsections below.

Three 1 m^2 quadrats were established along each transect representing three separate ecological zones, associated with distance from the high-high water mark, visual observation of plant communities and depth. Ecological zones sampled at each study site were:

1. Near High-High-Water-Mark (HHWM; Zone A);

2. Mid-Distance from HHWM (Zone B); and,
3. Far from HHWM (Zone C).

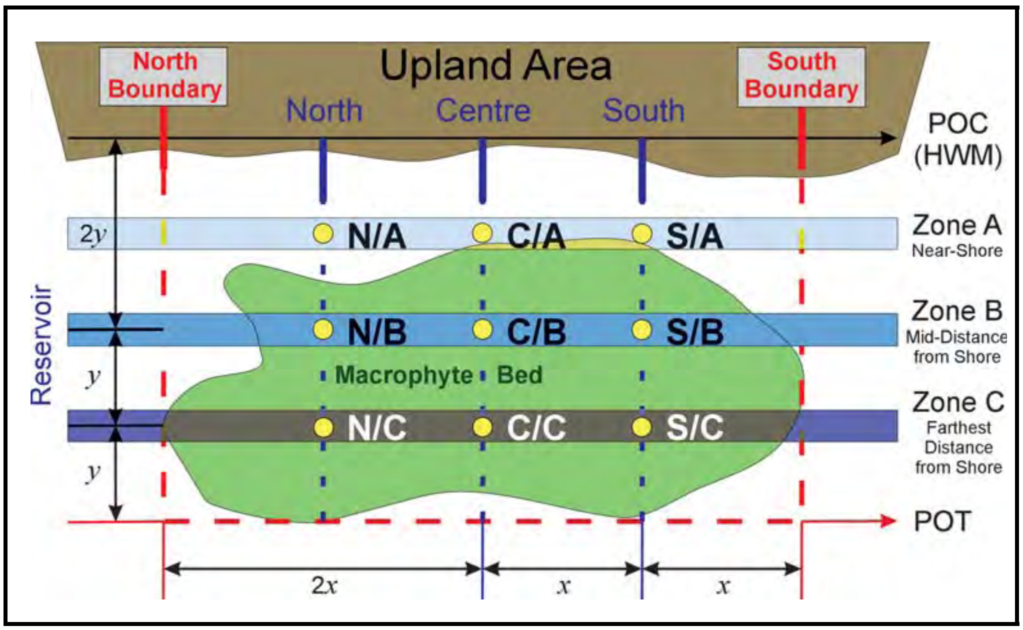
Sites were divided into quartiles as follows and illustrated in Figure 2-1. Zone B was established at the mid-point between the HHWM (i.e., POC) and the farthest point from shore where macrophytes were observed (i.e., Point of Termination [POT]. To provide consistency between transects at sites with expansive marshland (i.e., Sites 1-17, 1-18, 3-7 and 3-8) Zone B was positioned at the edge of marsh-grass communities. Zone A was set equidistant between B and the HHWM, and Zone C was equidistant between B and POT. Sites were comprised of nine sample quadrats.

TABLE 2-1: Quadrat Distribution

	north (or west)	Centre	south (or east)
Near HHWM (Zone A)	N(W)-Near	C-Near	S(E)-Near
Mid-Distance from HHWM (Zone B)	N(W)-Mid	C-Mid	S(E)-Mid
Far from HHWM (Zone C)	N(W)-Far	C-Far	S(E)-Far

UTM coordinates for each sample plot were recorded using GPS and waypoint numbers recorded into field notes. Full descriptions of each site are provided in Section 3.2.

Figure 2-2: ***Example Layout Schematic for Macrophyte Site Surveys***



2.3.4 Site Layout

Detailed site descriptions are provided in Section 3.2.

Site 6-3

As the macrophyte vegetation on and around the island could not be accurately described using parallel transect assessment techniques, the three transects at this site were radially-oriented. The Centre Transect POC was positioned on the west side of the island and extended southwest to the eastern bank of Whatshan Reservoir (POT). North and south transect POCs were positioned at the northern and southern-most HHWMs and extended along the axis of the island (NW to SE) to the distal extent of macrophyte communities (Figure A4-1, Appendix 4).

Site 4-4

Transects for this site were oriented north-south, perpendicular to the lagoon mouth. A fourth quadrat was established along each transect at this site, midway between the deepest part of the transect and the POT.

Sites 3-6, 3-7 & 3-8

Transects were established north-south and the sampling plan did not require modification to accurately describe the macrophyte community.

Site 2-13

The shoreline of Site 2-13 was contoured such that parallel transects were deemed inappropriate in the representation of the vegetative communities. Consequently, transects were oriented in a radial pattern to better represent the terrain and vegetative features of the monitoring location (Figure A2-6, Appendix 1).

Sites 1-17 & 1-18

Transects were established north-south at Site 1-17 and east-west at Site 1-18 and the sampling plan did not require modification to accurately describe the macrophyte community.

2.3.5 Bathymetry

Subsequent to macrophyte delineation, the extent of macrophyte communities within the water column was assessed using a digital Lowrance LCX-15MT depth sounder interfacing directly to an Omnistar differentially corrected DGPS receiver (measured in UTM coordinates, NAD83, Zone 11U). This particular sounder is particularly proficient even in highly turbid waters and able to distinguish between bottom substrate densities (i.e., gravel, sand, silt). The sounder was used to record depth, check for presence of submerged macrophytes and determine relative substrate condition and bottom slope. Information was stored in real-time and correlated with real-time collection of differentially-corrected GPS data. Bathymetric images of long-term monitoring sites were collected to enable subsequent comparative analysis, and to enable assessment of macrophyte distribution. At many sites, where macrophyte growth was continuous to a given depth, bathymetric data was used in post-field activities to determine the extent of macrophyte growth.

2.3.6 Collection of Biological & Physical Data

The main biophysical components assessed at each monitoring site were:

- macrophyte communities (i.e., community distribution, diversity and abundance, delineation of community types, and estimated percent (%) cover);
- *in situ* water quality; and,
- general sediment characteristics.

Distribution and size of macrophyte communities detected at the eight long-term monitoring sites identified in the *Whatshan Water Use Plan Wildlife Overview* (Bennet *et al.*, 2002) were predicted using several multispectral analysis techniques including False Colour Composite (FCC) imagery and a comprehensive vegetation algorithm applying twenty-one (21) vegetative indices (Section 2.4.4). Predicted distributions were assessed via *in situ* observations, with community perimeters mapped for post-field comparison and model refinement and calibration (Section 2.4.4.1).

2.3.6.1 Macrophyte Collection

Physical collection of macrophytes from quadrats employed two different methods. Depending on whether communities were submerged or emergent:

1. *Macrophyte Sampling Rake:* used in all submerged and partially submerged quadrats (typically zones ‘B’ and ‘C’). The macrophyte sampling rake consisted of two standard 0.5 m wide metal garden rakes bolted back to back with tines facing outwards and weighted at the collection end (Photo 2-7, Appendix 2). Braided nylon rope was fastened to the handle for easy deployment and retrieval; and,

2. *Direct Observation and Removal:* used for fully emergent quadrats, field personnel used bypass secateurs, trowels, and handheld garden rakes to remove macrophytes and root structures from quadrats for preservation and identification.

The primary collection method employed was the macrophyte sampling rake. The rake was lowered onto the sampling plot and dragged for one linear meter. This procedure was repeated three times within each quadrat regardless of whether macrophytes were collected. The sampling rake was effective in collecting all types of submerged macrophytes and used in most Zone B and all Zone C collections. An *Aqua-tiller*® (a commercial product used for collecting macrophytes from deep sampling zones, when necessary) was available but was not required for 2011 macrophyte collections at Whatshan Reservoir.

Once successfully collected, macrophyte specimens were brought to the surface, removed from the sampling device and placed in pre-labeled sample containers (specific to transect point) for processing. A small amount of site water accompanied each sample to prevent desiccation of macrophytes. Preliminary identification was completed *in situ* to establish relative densities within each quadrat and to ensure that at least one specimen of each species was retained from each study site.

Representative plant specimens from each plot were labeled and placed in a project-specific plant press and dried. Specimens included stem, leaves and reproductive structures (when present). Specimens were labeled according to site, transect, quadrat, depth and date. Photos were taken of each new species collected at a site and of each specimen prior to pressing. Observations were recorded in G3-developed biophysical field forms, including site locations, quadrat depths, transect distances, dominant and subdominant substrate and vegetation and site layout. A collection of voucher specimens was laminated, bound and submitted to BC Hydro as a separate annex to this report (*2011 Macrophyte Reference Collection*). The collection will be supplemented with any new plants identified in Phase 3 (2015).

2.3.6.2 Estimation of Percent (%) Macrophyte Cover

Estimates of per cent (%) vegetation coverage were made for each quadrat. Assessments were made through:

1. visual observation from the research vessel;

2. visual observations from shore-based field technicians; and,

3. estimations based on macrophyte sampling rake fullness and rate of success (when visual observations were not possible).

Through use of each method above, assessments were made with two field technicians separately estimating the extent of reservoir bottom covered by aquatic plants. Values were then averaged to yield the estimated per cent (%) coverage of a macrophyte community within a given quadrat. Estimates were recorded in field notebooks and on biophysical observation forms, photos were taken of each quadrat, where possible. Estimation methods were based on methods defined in Terry and Chilingar (1955).

Macrophytes collected from each site were sorted to taxa. Relative percent (%) biomass of each taxa was used to estimate percent (%) composition of each quadrat. Estimations were performed independently by three (3) field technicians with results discussed until a consensus was reached. Resulting distributions were recorded on biophysical observation forms.

2.3.6.3 Vegetation Perimeter Mapping

The delineations of different vegetative communities within a study site were conducted using a Garmin GPS. A field technician traversed the high-high water mark (HHWM) between the north and south (or east and west, as applicable) extents of each study site and identified and delineated any distinctive vegetative zones within the emergent and shallower-submerged portions of the study area.

Submerged vegetation community perimeters were defined through strategic sampling along transects, satellite spectral imagery, bathymetric data and visual observations. Macrophytes were sampled at random intervals along transects until no further vegetation was noted. The depth at which submerged macrophytes were no longer present was noted in project specific notebooks.

2.3.6.4 In Situ Water Quality

A YSI 6600 Sonde was used to assess *in situ* water quality. Readings were taken along the centre transects of each study site at each submerged quadrat. In total, 15 readings were performed. Water quality parameters assessed included temperature, conductivity, total dissolved solids (TDS), depth, pH, ORP, turbidity and dissolved oxygen (DO). Measurements were saved directly to the YSI, backed up each night, then to the G3 server upon return from the field. Data is presented in Charts A4-1 – A4-6, Appendix 3 and discussed in Section 3.4.1.

A Secchi disk was used to measure water clarity at the centre of each study site in cases where the bottom could not be visually observed. In such cases, Secchi disk measurements were completed in the centre transect within zone ‘C’ using a calibrated chain on the shaded side of the boat. Secchi depth was recorded independently by two observers and the results averaged. Recordings were documented in field notebooks and on project specific forms.

2.3.6.5 Sediment

A stainless steel 15 cm Ponar was used to collect sediment samples from each study area (Photo 2-10, Appendix 2-2). Samples were collected within each zone of the centre transect and deposited on a white tarpaulin for visual assessment and photographic documentation. Only sediment grabs more than approximately 75% full were considered acceptable for analysis.

Qualitative assessments of each sample were made *in situ* with descriptions documented according to criteria defined in sediment field forms developed by G3 specifically for this study (Appendix 4). In addition, qualitative nearshore evaluations were completed based on visual assessments. Gross sediment characteristics assessed, based on the Environmental Effects Monitoring (EEM) Working Group (EWG) and USEPA National Benthic Workshop (PTI, 1993), included:

- overall sediment characteristics (i.e., texture, colour, consistency, odour, presence of debris, and presence of fauna);
- vertical profile characteristics (i.e., homogeneity, layering, oily sheen, varves); and,
- other distinguishing features.

Photographs of each sediment sample are provided in Appendix 2-3.

2.3.7 Site Photos, Data & Observations

Photographs were taken of each study site (Appendix 2) using a 10-megapixel Olympus Stylus Tough waterproof camera. Photos captured images from a number of monitoring site vantage points including cardinal directions and site specific vantage points.

Photographic documentation was maintained for each new macrophyte species, substrate sampled along the centre transect, emergent vegetation quadrats and methodologies employed. Photographs were catalogued in a database as described in Section 2.4.3.

2.4 Post Field

2.4.1 Taxonomy

Following field surveys, macrophyte samples were transported to the G3 taxonomic laboratory, then unpacked for subsequent taxonomic analysis. Samples were checked against field forms and identifications confirmed by examining corresponding site photographs. Tracheophytes and aquatic algae were pressed and placed in a drying oven. Bryophytes were dried in paper sachets. Pressed and dried samples were then individually identified through examination of morphological structures and comparison with diagnostic characterizations in appropriate published keys (See Section 6.0, Taxonomy References).

Morphological structures were examined under a Nikon SMZ1000 dissecting microscope. Specimens were identified to the lowest possible taxonomic level and stored in a secure, cool, dry environment until all were identified. Quality assurance procedures during the identification of macrophytes involved a comparison of specimens with other confirmed verified specimens.

2.4.2 Reference Collection

The macrophyte specimens best preserved and most representative of a given species were compiled into a reference collection. Samples were pressed into 21.6 cm x 55.9 cm cardstock and laminated to preserve sample integrity. Each reference sample includes a site ID card listing the following:

- Latin name (*Genus species var.*);
- family name; and,
- collection site.

The reference collection was submitted to BC Hydro as an annex to this report (*2011 Macrophyte Reference Collection*). Any additional macrophyte species found during Phase 3 (2015) of the Whatshan Reservoir Macrophyte Monitoring program will be subsequently added to this reference collection.

2.4.3 Photographic Database

All G3 project photos were uploaded and entered into the 2011 Whatshan Reservoir Vegetation Assessment Photo Database. *Photo Collector Professional* was used to create the database and chosen based on a number of beneficial traits including: ease of use; compatibility; and, functionality. Key information about each photograph was attached as a tag and can be searched using a query tool. The information attached to each photo includes, but is not limited to:

- site name;
- photo date and time;
- photographer;
- photo caption;
- file details (format, file size, resolution and colour);
- camera details (type, flash, zoom, focal length and aperture); and,
- additional notes.

Photographs and meta database were submitted to BC Hydro on included DVD-ROM media. All photographs were included in both their native resolution and as lower resolution 800 x 600 versions.

2.4.4 Satellite Analyses

Satellite Imagery was assessed visually to evaluate the effectiveness of each spectral band and established vegetative indices at differentiating between vegetated classes identified during the field study. The classification was based on minute differences in chlorophyll a:b ratios, carotenoids and individual plant characteristics detectable through spectral differences (e.g., fitness, stress, water content, etc.).

2.4.4.1 Vegetation Classification & Satellite Model Refinement

Orthorectified multispectral satellite imagery obtained from RapidEye (GeoTIFF format) was imported into ArcGIS. RapidEye Satellite imagery was provided in Blue, Green, Red, Red Edge and Near-Infrared (NIR) bands. Ikonos satellite imagery was provided in Blue, Green, Red and NIR. The NIR channel (760 – 850 nm) cannot penetrate water and was used to create an outline of the current water level of Whatshan Reservoir. The outline was applied as a ‘clipping boundary’ to delineate between submerged and emergent vegetation in subsequent modeling stages. Each spectral band was corrected for “top-of-atmosphere” reflectance using manufacturer (RapidEye) provided constants and formulae and data were separated into emergent and submerged domains based on the established clipping boundaries.

25 spectral indices were calculated from the RapidEye multispectral data to broaden the feature input for the vegetation classification process. These included the following:

Table 2-2: Spectral Bands Considered in Analysis

Spectral Bands and Indices Considered	Submerged	Emergent
Blue (440 – 510 nm)	-	-
Green (520 – 590 nm)	Green (520 – 590 nm)	Green (520 – 590 nm)
Red (630 – 685 nm)	Red (630 – 685 nm)	-
RedEdge (690 – 730 nm)	RedEdge (690 – 730 nm)	RedEdge (690 – 730 nm)
Near Infra-Red (NIR; 760 – 850 nm)	Near Infra-Red (NIR; 760 – 850 nm)	-
Green / Blue	Green / Blue	Green / Blue
Green – Blue	Green - Blue	Green – Blue
Red – Green	Red – Green	Red – Green
RedEdge / Blue	RedEdge / Blue	RedEdge / Blue
RedEdge / Green	RedEdge / Green	RedEdge / Green
Red / Blue	Red / Blue	Red / Blue
(NIR – Red) / (NIR + Red)	(NIR – Red) / (NIR + Red)	-
(NIR – RedEdge) / (NIR + RedEdge)	(NIR – RedEdge) / (NIR + RedEdge)	-
Red / Green	Red / Green	-
Red – Blue	Red – Blue	-
(Red * Blue) – NIR	(Red * Blue) – NIR	-
RedEdge – Green	Red Edge – Green	-
(RedEdge – Red) / (RedEdge + Red)	(RedEdge – Red) / (RedEdge + Red)	-
RedEdge / Red	-	Red Edge / Red
RedEdge-Blue	-	Red Edge – Blue
(RedEdge – Green) / (RedEdge + Green)	-	(RedEdge – Green) / (RedEdge + Green)
RedEdge - Red	-	-
NIR - Red	-	-
NIR – RedEdge	-	-
NIR / Green	-	-
NIR / Blue	-	-
NIR / Red	-	-
NIR / RedEdge	-	-
NIR – Blue	-	-
NIR – Green	-	-

- eliminated from classification

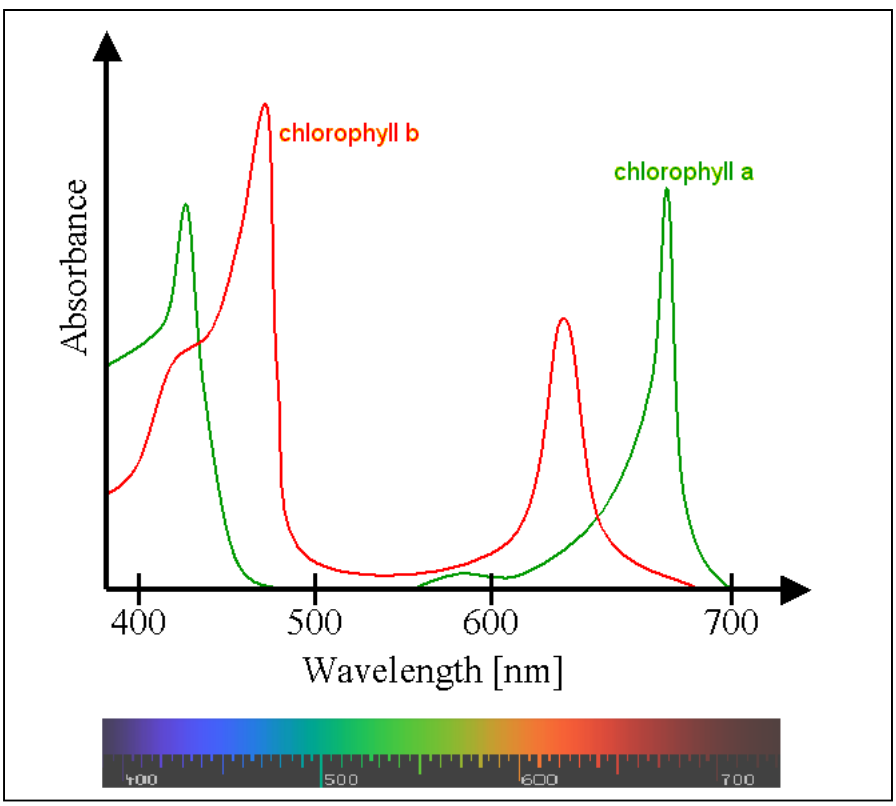
Each spectral index was assessed for noise (confounding data) and contrast of submerged and emergent vegetation types. Preliminary results were conducted via an iterative feedback process including field and technical personnel. Spectral classification proceeded using an applied forced trial and error approach resulting in the final selection of bands listed in Table 2-2 (above). Selected bands for each vegetation domain were composited into multi-channel GeoTIFF files (submerged and emergent). Due to wind conditions on the surface of Whatshan Reservoir during the RapidEye satellite collection, IKONOS satellite imagery was used for submerged classifications south of 5536700N and RapidEye was used for submerged classifications north of 5536700N.

Composited multi-channel data was classified using *MultiSpec* spectral analysis software created by Purdue Research Foundation (Landgrebe and Biehl, 2011). MultiSpec software performed a supervised classification using known vegetation areas derived from site visits to "train" the processor and aid in classification. *MultiSpec* generated a colour coded vegetation classification by grouping pixels with like spectral characteristics. Colour patterns were recorded in the model surrounding each field-marked quadrat. Quadrats with like-colours and like-vegetative characteristics were grouped into classes as per the *Canadian Wetland Classification System* (National Wetlands Working Group, 1997). ArcGIS was used to obtain areas of each class within the respective boundaries of each long-term study site.

GPS tracks and waypoints collected during field surveys were overlaid on geo-referenced satellite maps. Any offset between field and satellite data was rectified manually, based on field notes, photographs and consensus between field personnel.

Dominant and sub-dominant taxa within a quadrat (i.e., ≥ 20 % of quadrat) were correlated with the presence/absence of colour. Colours were then assigned habitat types based on dominant vegetation. Species composition of each quadrat was retained for comparison with the Year 10 (2016) survey information.

Figure 2-2: Chlorophyll Absorption Spectra (Aushulz, 2008; GNU Commons)



Bathymetry

Satellite studies of submerged macrophyte communities rely on light penetration to depth and accurate resolution of plant communities. Short wavelengths (400 – 450 nm) have the deepest water column penetration and are readily absorbed by chlorophyll a (peak absorption 430 nm and 662 nm in diethyl ether). The smallest spectral band of the RapidEye satellite encompassed 440 – 510 nm enabling good water column penetration and detection of substrate at depth.

The top-of-atmosphere reflectance-corrected dataset used for submerged vegetation classification was 'de-glinted' to minimize the effect of sun reflectance on water surfaces due to wave action. The spectral decay of the de-glinted dataset was linearized and multiple regressions were performed with *in situ* bathymetric measurements taken in the field. Spectral decay was modeled to create a processed depth raster map contoured to illustrate bathymetric depths.

2.4.5 Data Assessment

A Multiple Before-After, Control-Impact-Paired (MBACIP) design with multi-variate statistical analysis was adopted for this investigation. The MBACIP, which utilizes multiple impact and control sites over time (Downes *et al.*, 2002), improves on the insufficient spatial and temporal replication from which earlier BACI designs suffered (Underwood, 1994). Given that MBACIP designs assess spatial and temporal variation in matrices tested, potentially confounding influences are better accommodated. Each site becomes a comparative control (both spatially and temporally) to each other. This should result in more meaningful and relevant conclusions regarding effects of the enacted changes to the Whatshan Reservoir Water Use Plan on the heterogeneous macrophyte community and the reservoir community as a whole. This approach considers that the distribution of macrophytes is related to localized habitat conditions and reservoir spatial zonation.

Given the many interrelated environmental and anthropogenic factors that influence the distribution, structure and productivity of macrophyte communities in a dynamic system such as Whatshan Reservoir, it was imperative that any investigation designed to evaluate effects from a single stressor consider the system's natural variability and stressors that contribute to a community's characteristics. Factors which may affect macrophyte communities in the reservoir include both natural and anthropogenic influences, such as climate-related changes affecting water quality (e.g., temperature, light, flow), nutrient inputs from human activity (e.g., septic fields, municipal discharge, surface runoff), and changes to littoral slope and quality from shoreline activities, both natural and human-induced.

In the third, comparative phase of this project (2016), hypotheses involving multivariate factors (e.g., multi-species community data, multi-factor habitat tests; Status of Objectives, Table 3-11) will be used to assess variance patterns in overall macrophyte (or substrate) composition based on multiple factors (species or habitat factors). Exploratory analyses of this type are typically based on some form of pair-wise similarity measure of the overall macrophyte composition between samples/sites/times. In this study, Phase 1 was designed to provide baseline (i.e., 'Before') data that would be paired with data collected in Phases 2 and 3 (i.e., 'After') to assess the potential effects associated with the changes to the WUP on macrophyte communities in Whatshan Reservoir. Phase 1 'Baseline' data was not made available for comparisons with Phases 2 and 3 of this study; therefore, the Phase 2 design was modified to include this issue and will be used and assessed as a baseline for this study. From this pair-wise compilation of similarities, various graphical displays will be used to illustrate temporal and spatial floral patterns. The graphical method selected may be some form of spatial gradient plot, frequency plot, cluster analysis or ordination.

Cluster analyses provides a means for both a visual and interpretive review of information by combining all data from all sites into a 2-dimensional array. The cluster method is agglomerative, using an unweighted, pair group, mean-average sort (Sneath and Sokal, 1973).

TABLE 2-3: Whatshan Reservoir Management Hypotheses

Management Hypothesis	Null Hypotheses	Alternate Hypothesis
H1: The area of emergent vegetation will decrease as a consequence of extended inundation.	H_0: The area of emergent vegetation will not decrease as a consequence of extended inundation.	H_A: The area of emergent vegetation will decrease as a consequence of extended inundation.
H1a: The species composition of emergent vegetation will change as a consequence of extended inundation.	H_0: The species composition of emergent vegetation will not change as a consequence of extended inundation.	H_A: The species composition of emergent vegetation will change as a consequence of extended inundation.
H2: The area of submerged vegetation will increase as a consequence of extended inundation.	H_0: The area of submerged vegetation will not increase as a consequence of extended inundation.	H_A: The area of submerged vegetation will increase as a consequence of extended inundation.
H2a: The species composition of submerged vegetation will change as a consequence of extended inundation.	H_0: The species composition of submerged vegetation will not change as a consequence of extended inundation.	H_A: The species composition of submerged vegetation will change as a consequence of extended inundation.

Following Phase 3 (2016 reporting period) of the Macrophyte Assessment Program, the null hypotheses "*species composition of emergent vegetation will not change as a consequence of extended inundation*" and "*species composition of submerged vegetation will not change as a consequence of extended inundation*" will be tested using multiple ANOVA for macrophyte abundance, species number, Simpson's Diversity Index (1-D) and/or Shannon Weaver diversity (H') and abundance of dominant flora groups.

Multivariate statistical analyses will utilize dissimilarity coefficients (e.g., Bray and Curtis, 1957) and include multi-species community data with multi-factor (e.g., sediment and water quality, depth, spatial area in reservoir such as riverine or lacustrine zone). The null hypotheses (Table 2-3) would be tested using a "bootstrap" method called SIGTREE (Nemec and Brinkhurst, 1988).

As part of both the multivariate statistical analysis and ecological investigation, major factors within the reservoir's heterogeneous ecosystem, such as water quality, sediment quality, hydrological and biophysical dynamics, micro-climate and other environmental factors will be evaluated and included in the comparative assessment.

The Bray-Curtis (Bray and Curtis, 1957) dissimilarity coefficient will be used to compare pair-wise floral composition for each sample. This measure is strongly influenced by the most abundant species and, therefore, is sensitive to high dominance effects.

Using replicate data for each station, a statistical re-sampling or "bootstrap" method called SIGTREE (Nemec and Brinkhurst, 1988) will be used to generate multiple simulations to test the generalized null hypothesis (H_o) at each cluster linkage that two sampling site groups being linked together are homogeneous (not significantly different). The method is non-parametric and makes no assumptions about the underlying distribution of the multivariate data. The method examines the relative variability within and between sampling site groups independently for each linkage, to determine whether or not a cluster grouping is statistically valid.

2.4.6 Macrophyte Community Endpoints

Specific endpoints for macrophyte community analysis were calculated and used as part of the assessment of effects on the macrophyte community. Endpoints consisted of:

- density (% cover per species per site);
- taxon richness (taxa/station);
- diversity (Shannon-Weaver Index); and,
- similarity Index (to be selected *post hoc* following Phase 3).

The Shannon-Weaver diversity index $(H' = -\sum p_i \ln p_i)$ was selected over the more commonly used Simpson's index of diversity $(1 - D)$ based on the data type (i.e., percent distribution within a site). The Shannon-Weaver index is a measure of entropy (i.e., degree of uncertainty in predicting the next species encountered through random selection) and the index *H'* is more sensitive to the inclusion of an additional species than to the relative abundances of species within the community when compared with Simpson's (1-D). As not all families of vegetation could be resolved to the species level, diversity was calculated at the genera level to prevent over-representation of those families easily discernible to species (i.e., *Potamogeton sp.*) relative to families which could not be resolved to that level of detail (i.e., *Eleocharis sp., Isoetes sp.* etc.*).* In total, ten (10) species were removed and combined with broader *sp.* categories.

Community composition data was not available from the 2006 baseline (Phase 1) study from which to compare Phase 2 community compositions. Following Phase 3, available similarity indices (e.g., Bray-Curtis dissimilarity, Jaccard index, etc.), will be evaluated for suitability in assessing the data as collected.

2.5 QA/QC & Data management

A set of *Quality Assurance and Quality Control* (QA/QC) procedures and practices were implemented throughout this Year 5 assessment to ensure program integrity at every level. QA/QC objectives were incorporated into *Workplan*s, established in the management strategy, and included protocols for handling and recording information (in the field and office) and criteria used to confirm accuracy and precision of that information. QA/QC objectives included established protocols for literature management to ensure accurate citations and relevance based on date and source of publication.

Sampling was undertaken using both replication (i.e., multiple samples in each quadrat) and duplication (i.e., multiple representative individuals of each species identified in the laboratory, multiple water quality readings collected at each site) for measures taken in the field. Further, instrumentation was calibrated daily to ensure accurate performance, and alternate meters used to verify or support measures taken. Transcription or entry errors were checked through cross-referencing and review of original field notes and forms by alternate staff members on 20-25 % of entered data. When an error greater than five % was encountered the entire dataset was scrutinized.

In accordance with BC Hydro protocol, a quality assurance and safety field audit was conducted by a BC Hydro representative (September 27, 2011). The field audit evaluated a number of study elements which included, but were not limited to:

- project organization (e.g., schedule, field crew competency);
- study design (e.g., clearly stated objectives in project plan, field crew familiarity with study design and respective responsibilities);
- sampling methodology (e.g., sampling protocols consistent with regulatory standards, adherence to sampling protocols, appropriate field forms); and,
- data management (e.g., specific procedures for data entry and management, data storage compatible with BC Hydro).

Evaluation of study elements, safety and QA/QC procedures addressed BC Hydro requirements as defined by the program and original RFP.

3.0 RESULTS & DISCUSSION

The following provides baseline results for the 2011 (Phase 2) Whatshan Reservoir Vegetation Monitoring Program (i.e., multispectral image analysis and ground truthing). The extent of macrophyte distribution (i.e., location, depth, relative abundance, biodiversity, etc.) within Whatshan Reservoir was assessed at each of the eight long-term study sites following changes to the Whatshan WUP in 2006. The changes to the WUP are outlined in Section 1.0 and entailed filling of the reservoir earlier in spring each year and higher minimum winter elevations (636.5 m). Physical (i.e., water quality and sediment) and biological (i.e., macrophyte species identification and coverage) data were collected and will be used to aid in the understanding of macrophyte ecology within Whatshan Reservoir and to identify any changes to aquatic vegetation community structure or coverage that may have occurred as a result of the changes to the WUP since the 2006 (Phase 1) monitoring program.

Detailed results from the Phase 1 (2006) baseline assessment were not available to enable comparison of substrate, water quality and vegetative community compositions between years. Detailed comparisons of Phase 2 (2011) baseline results and Phase 3 (2016) follow-up results will be conducted subsequent to those field assessments.

3.1 Whatshan Reservoir Area

Anthropogenic activities in and around Whatshan Reservoir will be evaluated in greater detail following Phase 3 field assessments. The following provides a general summary of observed anthropogenic activities and general reservoir usage and should not be considered exhaustive.

Upland areas surrounding Whatshan Reservoir showed considerable evidence of current and historic logging activities. Primary access to forestry sites was via a network of visible logging roads. Little forestry activity was evident in areas immediately adjacent to Whatshan Reservoir with the exception of a clearing for BC Hydro High Voltage right-of-way near Whatshan Dam in the Lower Basin.

No permanent point or non-point waste discharges were observed along Whatshan Reservoir foreshore. Any waste generated at campsites, if present would be localized to a small bay in the Lower Basin (Old Coate’s Fish Camp) and no associated effects to water or habitat quality were observed at this site. Additional campgrounds in the Upper Basin (Stevens Creek and Richy Park; Figure B5, Appendix 6) were not observed during 2011 field assessments.

Recreational activities in and around Whatshan Lake are generally concentrated in the summer months with the peak period occurring between May and October. There are reportedly three boat launches in Whatshan Reservoir, one (Inonoaklin beach) was located and used during 2011 (Phase 2) field assessments. Boat launches and campgrounds at Steven’s Creek and Richy Park were not observed and may have been decommissioned, or were not visible from the water. The area surrounding the site locations illustrated in Figure B5 (Appendix 6), appeared otherwise undisturbed. The Whatshan guide outfitter recreational site was in use by out of province bear hunters during 2011 field assessments (September 29, 2011).

3.2 Site Observations

Whatshan Reservoir is distributed through three distinct basins described in detail in Section 1.2. Individual site layout descriptions are provided in Section 2.3.4, while the following provides detailed habitat descriptions of each site. Most emergent vegetation was identified in the mid and southern (lower) basins (Figure A3, Appendix 1). The northern (upper) basin featured extensive submerged aquatic vegetation at the northern-most locations surrounding the Whatshan River outlet into the reservoir. Most other areas of the northern basin did not appear to support appreciable macrophyte communities with the exception of Site 2-13 which also resides at a creek outlet (Section 2.3.4; Figures B4-6A through B4-6E, Appendix 6). Extensive marsh communities, noted at Sites 1-17, 1-18, 3-7 and 3-8 (Figures A2-[4,5,7,8]), tended to be associated with residual log debris that overtime has started to breakdown and become in-filled and facilitate ecological succession through plant development. Changes to noted emergent plant types at sites between 2006 and 2011 (Tables 3-2 to 3-9) appear to reflect this ongoing community succession (i.e., increased forestation of fen communities, shrubbery growth in marsh habitat, etc.) and not decreases in emergent cover in favour of submerged vegetation. Potential succession in plant communities between 2006 and 2011 could not be evaluated fully due to limited results from Phase 1 (2006) field assessments. This potential will be evaluated following Phase 3 (2016) assessments.

TABLE 3-1: 2011 Vegetative Community Area Assessment (m^2)

Vegetation Type	6-3	4-4	3-6	3-7	3-8	2-13	1-17	1-18
Emergent								
Low Marsh	900	200	725	4,100	11375	3,300	4,850	4,200
Marsh	400	475	975	11,400	21725	2,925	5,475	1,675
Fen	375	700	75	13,925	19100	1,350	7,400	1,775
Fen/Marsh Transitional	750	750	75	14,725	10075	3,925	7,025	2,050
Sum of emergent macrophytes	2,425	2,125	1,850	44,150	62275	11,500	24,750	9,700
Submerged								
Macrophyte Community (1)	2,150	1,150	4,725	2,875	3,250	3,485	11,440	3,871
Macrophyte Community (2)	4,150	2,050	7,950	5,025	9,875	15,059	39,465	9,308
Macrophyte Community (3)	3,050	150	400	3,200	12,700	20,983	55,625	1,770
Macrophyte Community (4)	6,400	1,000	4,700	7,575	25,275	49,952	3,391	142
Deep water Community (5)	21,450	725	35,700	26,175	9,600	44,114	0	0
Sum of Submergent macrophytes	37,200	5,075	53,475	44,850	60,700	133,594	109,920	15,090

Separations of submerged macrophyte communities are mathematical and related to spectral assessments from satellite data. Further, targeted studies are required to identify if any ecological differentiation exists between communities (Phase 3).

Site 6-3

Site 6-3 was located in the Lower Basin of Whatshan Reservoir and was a small island (approximately 30 m x 150 m) made up of Low Marsh (900 m^2), Marsh (400 m^2) and Fen (375 m^2) with an additional 750 m^2 classified as Transitional Fen/Marsh habitat (Figure B4-1A, Appendix 1). Emergent vegetation was characterized by *Typha sp.* and *Carex sp*. submerged vegetation was typical of most sites in Whatshan Reservoir and a detailed community distribution is provided in Appendix 4. A muskrat Lodge was observed on the south-eastern edge of the island.

Submerged macrophyte growth was prevalent between the western side of the island and the western shore of Whatshan Reservoir. Dominant vegetation included *Tolypella sp*. and *Potamogeton sp.* On the western side of the island, water depth (3.3 m) did not exceed the depth of the euphotic zone with macrophyte growth being extensive and uniform to the western shore of Whatshan Reservoir (37,200 m^2; Table 3-1). The eastern side of the island featured little aquatic vegetation with no observed macrophyte growth due to a steep drop off and substrate that appeared more gravelly. Phase 1 field studies classified the island as 100% marsh habitat; however, September (2011) field assessments and subsequent satellite analysis found the island to be partially dominated by fen and mature forest habitat. Large trees were present in the centre of the island and the fen and mature (non-aquatic) communities appeared to be separated by a distinctive HHWM.

TABLE 3-2: Site 6-3 Classified Vegetation Areas		
Vegetation Type	2006 Area (m^2)	2011 Area (m^2)
Low Marsh	-	900
Marsh	3,978.1	400
Fen	-	375
Fen/Marsh Transitional	-	750
Sum of Emergent Macrophytes	3,978.1	2,425
Sum of Submerged Macrophytes	32,531.7	37,200

Site 4-4

Site 4-4, locally referred to as David's Lagoon, was bounded by the eastern shore of Whatshan Reservoir and located in the southern basin (Figure A2-2, Appendix 1). Total area of submerged and emergent vegetation was 37,200 m^2 and 2,425 m^2(Tables 3-1, 3-2), respectively. Site 4-4 had two small and distinct sedge (*Carex sp.*) dominated marsh communities (900 m^2 Low Marsh and 400 m^2 Marsh) along the northern shore of the lagoon and submerged macrophytes were ubiquitous within the confines of the lagoon (i.e., substrates within the lagoon were completely covered in low-lying macrophyte growth). Two large nest-trees were present in the centre of the lagoon, although no wildlife was observed. There were two private docks within the lagoon and one private residence was visible from the water.

TABLE 3-3: Site 4-4 Classified Vegetation Areas		
Vegetation Type	2006 Area (m^2)	2011 Area (m^2)
Low Marsh	-	200
Marsh	269.8	475
Fen	-	700
Fen/Marsh Transitional	-	750
Sum of Emergent Macrophytes	269.8	2,125
Sum of Submerged Macrophytes	3,386.9	5,075

Site 3-6

Site 3-6, locally referred to as Robin's Lagoon, was located on the eastern shore of Whatshan Lake and confined by a small peninsula making up adjacent Site 3-7 (Figures A2-3, 4, Appendix 1). Along the northern edge of the lagoon were cattail (*Typha sp.*) and sedge (*Carex sp.*) marshes in a narrow strip adjacent to the shoreline (Figure A2-3, Appendix 1). Lagoon waters appeared dark due to bottom substrate colour and water quality (high dissolved organic materials) but Secchi disk readings were visible to bottom. Submerged macrophytes were dominated by *Potamogeton sp.* and *Chara sp.* Submerged macrophytes at deeper quadrats were not identifiable from the boat and required sampling to confirm presence. Artificial bird nesting platforms had been previously deployed at the site although no current nest activity was observed.

TABLE 3-4: Site 3-6 Classified Vegetation Areas

Vegetation Type	2006 Area (m^2)	2011 Area (m^2)
Low Marsh	-	725
Marsh	-	975
Fen	3,620	75
Fen/Marsh Transitional	-	75
Sum of Emergent Macrophytes	3,620	1,850
Sum of Submerged Macrophytes	50,986	53,475

Site 3-7 & 3-8

Sites 3-7 and 3-8 were primarily cattail (*Typha sp.*) dominated marshlands following the west and east shorelines of Whatshan Reservoir and occupying 15,500 m^2 and 33,100 m^2, respectively (Figures A3 and A2-4, Appendix 1). Submerged macrophyte communities at these sites were dominated by *Potamogeton sp.* and *Isoetes sp.* at Site 3-8 and *Chara sp.* and *Isoetes sp.* at Site 3-7. Sites were separated by the deeper, narrow, original river channel in which macrophytes were not present (Figures A2-4 and A2-5, Appendix 1). Submerged vegetation appeared to be restricted by water depth with no macrophytes observed below 6 m.

Emergent vegetation (i.e., *Typha sp.* marshes) appeared to rely on extensive log debris on the bottom which facilitated formation of existing marsh communities and associated habitat use. Sites 3-7 and 3-8 featured a clear and distinct zonation of Marsh and Fen habitats with significant habitat complexity resulting from woody debris. No direct wildlife observations were noted at either site; however, Cattails (*Typha sp.*) appeared depressed in many areas indicated ongoing and current use by wildlife.

TABLE 3-5: Site 3-7 Classified Vegetation Areas

Vegetation Type	2006 Area (m^2)	2011 Area (m^2)
Low Marsh	-	4,100
Marsh	29,699.2	11,400
Fen	26,424.1	13,925
Fen/Marsh Transitional	-	14,725
Sum of Emergent Macrophytes	56,123.3	44,150
Sum of Submerged Macrophytes	12,851	44,850

TABLE 3-6: Site 3-8 Classified Vegetation Areas		
Vegetation Type	**2006 Area (m^2)**	**2011 Area (m^2)**
Low Marsh	-	11,375
Marsh	40,253	21,725
Fen	29,294	19,100
Fen/Marsh Transitional	-	10,075
Sum of Emergent Macrophytes	69,547	62,275
Sum of Submerged Macrophytes	28,894	60,700

Site 2-13

Site 2-13 was comprised of habitat along the north and south sides of White Grouse Creek (BC Watershed Code 300-680400-36400) in the Upper Basin of Whatshan Reservoir (Figure A2-6, Appendix 1). Vegetation at this site consisted primarily of submerged macrophytes (*Ranunculus aquatilus, Potamogeton sp., Isoetes sp*.; 133,594 m^2) and wet meadow (Marsh, Fen and Fen/Marsh Transitional; 11,500 m^2) dominated by *Isoetes sp.* and *Carex sp.* south of the creek-mouth. Submerged vegetation was present from the current waterline to a depth of 6 m. Vegetation became patchy in cover as depth increased. No wildlife was observed at Site 2-13 during field assessments; however, due to proximity to Class A habitat in White Grouse Creek, and wetland coverage, potential use of habitat by wildlife is likely to be extensive.

TABLE 3-7: Site 2-13 Classified Vegetation Areas		
Vegetation Type	**2006 Area (m^2)**	**2011 Area (m^2)**
Low Marsh	5,000	3,300
Marsh	552.2	2,925
Fen	9,254	1,350
Fen/Marsh Transitional	-	3,925
Sum of Emergent Macrophytes	14,806.2	11,500
Sum of Submerged Macrophytes	85,738.6	133,594

Sites 1-17 & 1-18

Sites 1-17 and 1-18 featured diverse marsh communities each with distinctive sedge (*Carex sp.*), rush (*Juncus sp.*), cattail (*Typha sp.*) and macrophyte (*Potamogeton sp* and *Isoetes sp.*) communities. Elk were observed at Site 1-17 during field activities and wildlife use of the area appeared extensive. Sites were separated by the mouth of Whatshan River (5th Order; BC Watershed Code 300-680400). Marshland vegetation at both sites had historical log debris which was now overgrown. At these sites, successive wetland zones extended from the HHWM to wetted shorelines (total marsh cover 24,750 m^2 and 9,700 m^2 at sits 1-17 and 1-18, respectively). At 1-18, there was little submerged macrophyte growth surrounding the site.

TABLE 3-8: Site 1-17 Classified Vegetation Areas		
Vegetation Type	**2006 Area (m^2)**	**2011 Area (m^2)**
Low Marsh	16,986.3	4,850
Marsh	-	5,475
Fen	27,317.6	7,400
Fen/Marsh Transitional	-	7,025
Sum of Emergent Macrophytes	44,303.9	24,750
Sum of Submerged Macrophytes	15,0716	109,920

At 1-17 transect points of termination (POTs) there was submerged macrophyte growth which extended to 200 m from shore (Figure A2-6). Emergent growth (*Carex sp.* and *Eleocharis sp.* dominated) was very dense and habitat appeared delta-like with multiple rivulets and small islands extending from the outlet into the reservoir. Expansive Fen habitat at upland areas was reliant on log debris in-filled with river sediment.

TABLE 3-9: Site 1-18 Classified Vegetation Areas		
Vegetation Type	**2006 Area (m^2)**	**2011 Area (m^2)**
Low Marsh	-	4,200
Marsh	9,548	1,675
Fen	-	1,775
Fen/Marsh Transitional	-	2,050
Sum of Emergent Macrophytes	9,548	9,700
Sum of Submerged Macrophytes	5,231	15,090

3.3 Macrophyte Ecology

In total, 42 taxa were identified during the 2011 Whatshan Reservoir Vegetation Monitoring Program. Community endpoints (i.e., diversity, richness) were calculated at the genus level as described in Section 2.4.6. Emergent vegetation defined as aquatic vegetation partially or fully above the waterline but below the HHWM, was represented by 26 taxa. The most frequent taxa, as assessed at quadrats above the waterline (i.e., emergent quadrats), were *Carex sp.* and *Typha sp.* which occurred in 16 (64%) and 11 (44%) quadrats, respectively, of 25 total emergent quadrats. In quadrats at or below the waterline (submerged vegetation) 20 taxa were identified at 54 quadrats assessed. The most frequent taxa at submerged sites were *Potamogeton sp.* (39 quadrats, 72%), *Chara sp.* (32 quadrats, 59%), *Naja flexis* (31 quadrats, 57%) and *Isoetes sp.* (30 quadrats, 56%). The combined diversity (Shannon-Weaver diversity; H') of surveyed emergent and submerged vegetation at Whatshan Reservoir was calculated at each site. Macrophyte distributions and endpoints are summarized in Appendix 4.

Low sloping areas of Sites 1-17, 1-18, 3-7 and 3-8 which had substantial accumulated log debris, tended to have extensive marsh (*Typha sp., Eleocharis sp., Juncus sp. and Carex sp.*) communities. Macrophyte community area determinations were not comparable between years (i.e., 2006 to 2011) due to differences in methodology and a lack of detailed results from Phase 1 (2006). In general, decreases in the area of emergent vegetation were noted between years (Tables 3-2 through 3-9); however, it was unclear if the decreases were consistent with decreases predicted by the management hypotheses (i.e., loss of emergent vegetation to submerged vegetation with higher average annual water levels) or contrary to decreases predicted by the management hypotheses (i.e., loss of emergent aquatic vegetation to mature terrestrial communities). Phase 3 (2016) work will be used to identify and evaluated any trends.

From 2011 satellite data, approximately 4,076,864 m^2 of reservoir was attributed to aquatic vegetation (581,325 m^2 emergent and 3,495,539 m^2 submerged). The most abundant class of emergent vegetation was 'Marsh', occupying approximately 250,100 m^2, Fen/Marsh Transitional (~150,275 m^2), Low Marsh (~121,300 m^2) and Fen (~59.650 m^2). Submerged vegetation occupied approximately 415,054 m^2 within study sites.

Phase 3 (2016) will examine submerged macrophyte communities within Whatshan Reservoir and in conjunction with data from Phase 2 (2011) and provide a more detailed assessment of submerged vegetation.

3.4 Biophysical Observations

Data provided below is from *in situ* profiling of selected points. Data may not be representative of general reservoir conditions.

3.4.1 Water Quality

Water quality profiles as assessed in September 2011 at Whatshan Reservoir for temperature, conductivity, pH, redox (ORP), turbidity and dissolved oxygen (DO) are discussed below and depicted in Charts A4-1 to A4-6 provided in Appendix 3.

Temperature

Water temperature is an important variable that can affect the suitability of an ecosystem to support aquatic organisms. Factors which can influence water temperature include seasonal and daily changes in sunlight energy, shade, air temperature, stream flow, water depth, inflow of groundwater or surface water, and the colour and turbidity of the water. Optimal water temperatures for aquatic life (i.e., salmonids) are typically below 15°C (EPA, 1998). Water temperatures consistently outside of this range (i.e., 20+°C) may negative effect sensitive species. High water temperatures (up to an organism-specific limit) generally increase biological activity for many organisms (Fidler and Oliver, 2001; Haidekker, 2005). Temperature also affects biological activity by influencing water chemistry. Warm waters contain less dissolved oxygen (DO) than cooler waters, as solubility of oxygen in water is temperature-dependent (Mel'nichenko *et al.*, 2008). Such reduced DO levels may be insufficient to support development of macrophyte communities.

In Whatshan Reservoir, water temperatures were relatively consistent between sites with no discernible patterns noted with respect to specific location within the reservoir. Baseline assessments were conducted in late September, 2011 and temperatures ranged from 14.25 – 17.36 °C. The lowest temperature was measured at Site 2013 in the southern portion of the upper basin where temperatures ranged from 14.25°C to 14.75°C. Lower temperatures at Site 2-13 may have been influenced by input from White Grouse Creek, located within the study site or time of day as that station was measured in the early morning.

Dissolved Oxygen (DO)

Dissolved oxygen (DO) analysis is a measure of the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. Oxygen dissolves into water by diffusion from the surrounding air, by aeration (rapid movement) and as a by-product of photosynthesis (Poppe, 1987). Water at each of the eight long-term monitoring sites in Whatshan Reservoir was well oxygenated with DO levels ranging from approximately 9.3 mg/L (Sites 6-3 and 3-6) to 10.1 mg/L (Site 2-13) within the upper 4 m of the water column.

Riverine waters are usually more oxygenated than lacustrine waters, given that water movement tends to cause more oxygen to be introduced. Water temperatures in creeks from glacial, melting or upland sources may be lower than temperatures in receiving lacustrine environments. These effects may be why Site 2-13 waters, near the outlet of White Grouse Creek, were most oxygenated. Oxygen concentrations of water did not appear to be correlated with reservoir basins or position within those basins in Whatshan Reservoir.

Conductivity

Conductivity provides an estimate of the amount of total dissolved ions in water. Many factors influence the conductivity of freshwater, including geology, watershed size, input from point and non-point sources of nutrients and minerals, atmospheric fallout, evaporation rates, precipitation and bacterial metabolism (McNeil and Cox, 2000). Conductivity assessments during the 2011 field surveys ranged from 50 µS/cm (Site 4-4 and 6-3) to 57 µS/cm (Sites 1-17 and 1-18; Chart A2, Appendix 3). Conductivity was generally higher at reservoir sites in the Upper Basin (i.e., Sites 1-17, 1-18 and 2-13, 55-57 µS/cm) than in the Mid Basin (3-6, 3-7 and 3-8, 51-54 µS/cm) and Lower Basin sites (4-4 and 6-3, 50-51 µS/cm). Conductivity measurements remained comparatively low throughout the reservoir during field surveys. Conductivity was generally consistent between sites in 2011 field surveys and as such does not appear to be a distinguishing factor affecting macrophyte distribution or community structure in Whatshan Reservoir. Further measurements will be collected in 2016 (Phase 3) field assessments to confirm this assertion. Conductivity can influence the distribution and health of macrophytes, with some species being more sensitive to excessively high or low values than others. For example, Holmes and Whitton (1975) reported that *Ranunculus aquatilis* cover was negatively correlated to conductivity (i.e., increases in conductivity lead to corresponding decreases in *R. aquatilis* cover), while the cover of several species of *Potamogeton* can be positively correlated to conductivity. Correlations between species and specific environmental parameters were not assessed during this Phase (2) and will be examined in detail following Phase 3 (2015) field assessments.

pH

pH is a measure of the hydrogen ion concentration (or acidity) in water. A pH of 7 is considered neutral. Values lower than 7 are considered acidic, while values higher than 7 are basic. Many important chemical and biological reactions are strongly affected by pH. In turn, chemical reactions and biological processes (e.g., photosynthesis, respiration) can influence pH (CCME, 1999). In Phase 2 assessments (September 2011), pH values ranged from 7.38 pH units (Site 3-6) to 7.9 pH units (Site 6-3). There did not appear to be a relationship between reservoir location and water pH values (i.e., no apparent basin zonation, and not attributed to stream output nor log debris). If water becomes either too alkaline or acidic, it can be inhospitable to many species of macrophytes. The Canadian Council of Ministers of the Environment (CCME, 2012) states the optimum range of pH for the protection of aquatic life to be 6.5 to 9.0 pH units. Water profiles within the Whatshan Reservoir were noted to be within this ideal range. More integrated assessments will be conducted in 2016 (Phase 3).

Redox (ORP)

The decomposition of organic matter proceeds in a succession of redox reactions oxidizing an organic substance to yield carbon dioxide and water. Oxidation-reduction (i.e., redox) reactions are characterized by the flow of electrons between oxidized and reduced states toward equilibrium (Wetzel, 2001). When oxygen is dissolved in water, a redox potential (Eh) is generated. Dissolved organic compounds effectively lower redox potential in sediment and reduce the depth to the redox discontinuity (RPD) layer, a zone of rapid change from positive to negative Eh values (transition between oxic, oxidizing and anoxic reducing layers; Sampou and Oviatt, 1991; Levington, 1995). High rates of organic matter loading eventually create anoxic sediments with Eh levels of less than 0 mV and surface RPD (Hargrave *et al.*, 1997). In freshwater redox can range between +500 mV in the oxic zone to approximately -200 mV in the sulfidic- and methane-based zones (Mackie, 2004). The dimensions of these zones vary depending on the concentration of decomposed organic substances in sediment and turnover rates of those sediments. Redox values can often fluctuate in the range of ±50 mV (Schüring et al., 2000).

During Phase 2 field assessments (September 2011), ORP in water ranged from 134 mV (Site 3-7) to 203 mV (Site 1-17). Site 3-6 ORP appeared to decline notably below 5.5 m; however, this was attributed to contact of profiling instrumentation with bottom substrate at this site. Redox potential was similar between sites and no relationships between proximity within Whatshan Reservoir and ORP were noted. Redox values in freshwater ecosystems tend to rely on the type of rocks present in the watershed (Schüring et al., 2000). Reductive agents (e.g., organic compounds) are a contributing factor in the decrease of oxygen in water. Reductive agents also decrease the redox potential, indicating the deterioration of water quality. Follow-up surveys will be conducted during Phase 3 (2015) field assessments.

Turbidity

Turbidity is a measure of water clarity. Turbidity in water is caused by suspended matter (e.g., clay, silt, organic matter, plankton, other microscopic organisms) that interferes with the passage of light through water (APHA, 1998). Very clear water, however, is not necessarily a sign of good water quality, as suspended particles can be induced to fall (decreasing turbidity readings) by high acid or salt conditions. Turbidity of natural waters tends to increase during runoff events due to increased overland flow, stream flow and erosion. Increased turbidity reduces light penetration, thereby decreasing the growth of aquatic plants and organisms (Gradall and Swenson, 1982). Further, very turbid waters will reduce the diversity and coverage of macrophyte communities.

In September 2011, Whatshan Reservoir turbidity ranged from 0 NTU (Site 1-18) to 4.2 NTU (Site 1-17). Turbidity typically ranges from 0 to 1,000 NTU in freshwater ecosystems (i.e., lakes and rivers), with values exceeding 10 NTU considered turbid (Gradall and Swenson, 1982). Due to an equipment malfunction in the turbidity probe, turbidity readings at sites 2-13, 3-6, 3-7, 3-8, and 6-3 were considered unreliable and Secchi disk readings were used for inter-site comparisons (see below). Further assessments including inter- and intra-site comparisons will be conducted in Phase 3 (2015) field assessments.

Transparency

Water transparency (clarity) was based on *in situ* visual observations and Secchi disk readings, and was high in the reservoir. Macrophyte communities present at most sites were small and restricted to waters immediately above bottom substrates (~20 cm). As such, visual detection of macrophytes was not always possible even at sites where bottom substrates were visible. Secchi depths were measured at each site as summarized in Table 3-11 (below).

TABLE 3-10: Water Transparency by Calibrated Secchi Disk

Site	6-3	4-4	3-6	3-7	3-8	2-13	1-17	1-18
Secchi Depth	to bottom (2.3 m)	to bottom (3 m)	to bottom (6.4 m)	Mid Column 4.4 m	Mid Column 4.4 m	Mid Column 8.5 m	to bottom (6 m)	to bottom (6 m)

Water bodies with medium and dense macrophyte cover are characterized by a low concentration of suspended sediments and, thus, high water transparency. Such high water transparency enables light to penetrate deeper into the water column and decreases attenuation of photosynthetically active radiation (PAR) with depth, thereby facilitating colonization of macrophyte communities (usually adapted to low irradiances) in deeper areas (O’Sullivan and Reynolds, 2004). Conversely, water transparency decreases where coverage and density of aquatic macrophytes are reduced, such as in cases of eutrophication (Hargeby *et al*., 1994). In freshwater ecosystems, where macrophytes reappear after a period of absence, water transparency gradually improves with increasing vegetation cover. Trends in water transparency and turbidity will be further assessed in Phase 3 (2016) in conjunction with any observed differences in vegetative communities.

3.4.2 Substrate Characteristics

Qualitative substrate observations were made at the near-shore, mid-distance and farthest from shore zones of the Centre Transect (i.e., C/A, C/B, C/C) for each site and are tabulated in Appendix 4 (Site Descriptions).

Consistency and texture of substrates observed during baseline assessments varied throughout the reservoir ranging from ‘gritty’ and ‘gravelly’ to ‘silky’ and from ‘thick’, ‘pudding-like’ consistency to substrate that falls apart into pellets. No trends between qualitative sediment observations and zonation within the reservoir were reliably identified in this (2011) baseline phase of work. Variation in sediment quality was more consistent within a site than within a given reservoir zone. Site specific interactions (i.e., log deposition, bottom topography, proximity to streams) appeared to be related to substrate characteristics, quantification of this relationship in Phase 3 (2016) field assessments would require a more focussed sampling effort on this issue than requested during Phase 2 (2011).

Near-shore transect locations in the Lower Basin had gritty substrate in comparison with quadrats in the Middle and Upper Basins which were largely dominated by woody debris. All near-shore quadrats tended to have odourless substrates with substrate consistency being homogenous throughout. Near-shore sediment qualities were more attributed to site-specific factors than overall reservoir characteristics. Mid-distance from shore quadrats tended to have gritty substrates and were generally odourless and thick like pudding. Sites from the Middle Basin had a hydrogen sulphide (H_2S) odour at mid distance quadrats. Quadrats further from shore tended to reflect sediments with variable texture and consistency and with a distinct H_2S odour throughout the reservoir. Sediment was homogenous in 18 samples examined out of 22, while the remaining 4 samples were more heterogeneous in consistency.

Near-shore quadrats, in general, were found to be dark brown colour while Mid distance tended to be grey-green to brown-green colour and furthest from shore substrates were grey-green. Sediment colouration did not appear to vary with reservoir proximity in the reservoir and were likely a function of water depth. Phase 3 (2015) field activities will consider increased substrate sampling effort to further assess any relationship.

Hydrogen sulphide (H_2S) imparts sediments with a distinctive smell (i.e., odour reminiscent of rotten eggs), and usually indicates anoxic sediments (i.e., lack of oxygen). Anthropogenic activities are usually an important source of organic matter in reservoirs and can cause anoxic sediments. Sites 3-6 and 3-8 in the middle basin of Whatshan Reservoir had distinct H_2S odours and were not visibly impacted by anthropogenic activities.

During 2011 baseline assessments in Whatshan Reservoir, there was no obvious trend in sediment characteristics with reservoir zonation. Observed differences were attributed to site-specific factors (i.e., accumulation of woody debris) rather than specific reservoir characteristics or location (i.e., north to south flow).

3.5 Status of Objectives

BC Hydro's Management Objective to reduce the uncertainty of the effects of reservoir operations on reservoir vegetation in the Whatshan Lake Reservoir was addressed as substantially as could be achieved in Phase 2 (2011). Given the absence of detailed results from Phase 1 (2006) field assessments, this Phase 2 study established a baseline for Phase 3 (2016) comparisons and a framework for addressing each management hypothesis, as defined in Table 3-10, below.

Results of Phase 2 (2011) in general appeared to support management hypothesis H1. Confirmation is required and will be addressed in Phase 3 (2016). Similarly, management hypothesis H2 requires additional comparative field research to confirm that any assertions associated with an increase in submerged vegetation are, in fact, real and not a function of the methodologies employed.

TABLE 3-11: BC Hydro Status of Objectives Table

Objectives	Management Questions	Management Hypotheses	Year Six (2011) Status	Year Ten (2016) Status
Reduce uncertainty related to the effects of reservoir operations on reservoir vegetation in the Whatshan Lake Reservoir. Monitoring will focus on key locations where aquatic vegetation is present (Bennett et al. 2002), and primarily examine large-scale changes in the boundaries of vegetation communities.	Do changes in the operation of the Whatshan Lake Reservoir affect reservoir vegetation?	H1: The area of emergent vegetation will decrease as a consequence of extended inundation.	Tentatively Supported, to be confirmed in 2016	-
		H1a: The species composition of emergent vegetation will change as a consequence of extended inundation.	Not as yet addressed, to be assessed in 2016	-
		H2: The area of submerged vegetation will increase as a consequence of extended inundation.	Tentatively Supported, to be confirmed in 2016	-
		H2a: The species composition of submerged vegetation will change as a consequence of extended inundation.	Not as yet addressed, to be assessed in 2016	-

4.0 SUMMARY & RECOMMENDATIONS

Whatshan Reservoir was impounded in 1951 by the British Columbia Power Commission and currently generates 121 GWh annually. A Water Use Planning Process was initiated for Whatshan Reservoir in 2002 and resulted in recommendations that included:

- an increase in the minimum year-round water elevations to 636.5 m (previously 634 m); and,
- annual increases in minimum reservoir elevation occurring earlier in the year (i.e., minimum of 639 m by May 15th and a minimum of 640.35 m between June 15th and October 1st of each year).

Objectives and management questions were established prior to commissioning a Whatshan Reservoir Vegetation Monitoring Program. As part of this program study design and field methodologies were designed to address study-specific objectives and address these management questions. The Objective of the Whatshan Reservoir macrophyte survey was to:

> *Reduce uncertainty related to the effects of reservoir operations on reservoir vegetation in the Whatshan Lake Reservoir. Monitoring will focus on key locations where aquatic vegetation is present (Bennett et al. 2002), and primarily examine large-scale changes in the boundaries of vegetation communities.*

Key management questions included:

> *Do changes in the operation of the Whatshan Lake Reservoir affect reservoir vegetation?*

Phase 1 (2006) field assessments identified 53 aquatic plants and over 1.1 million m^2 of aquatic vegetation. Detailed results from this field assessment were unavailable during Phase 2 (2011). The current Phase 2 study results are to be used as a baseline for subsequent Phase 3 (2016) comparisons and results analysis to address specific management questions.

In total, 42 taxa were identified during the 2011 (Phase 2) Whatshan Reservoir Vegetation Monitoring Program. Emergent vegetation, defined as aquatic vegetation partially or fully above the waterline but below the HHWM, was represented by 26 taxa. The most frequent taxa, as assessed at quadrats above the waterline (i.e., emergent quadrats), were *Carex sp.* and *Typha sp.* which occurred in 16 (64%) and 11 (44%) quadrats, respectively, of 25 total emergent quadrats. In quadrats at or below the waterline (submerged vegetation) 20 taxa were identified at 54 quadrats assessed. The most frequent taxa at submerged sites were *Potamogeton sp.* (39 quadrats, 72%), *Chara sp.* (32 quadrats, 59%), *Naja flexis* (31 quadrats, 57%) and *Isoetes sp.* (30 quadrats, 56%).

Recommendations

Phase 3 (2015) field assessments would benefit from the following program modifications based on work done in Phase 2 (2011):

- conduct detailed *in situ* bathymetric modeling to complement and improve upon the limited DEM supplied by BC Hydro;
- additional effort should be applied to sampling substrates to enable comparisons of vegetation types by substrate characteristics;
- collection of low wavelength (i.e., coastal blue) spectral data to improve resolution of reservoir bottom and macrophyte communities at depth;
- use of drop-camera or similar technologies on transects to provide continuous observations of macrophytes *in situ*; and,
- application of the Phase 2 (2011) vegetation classification model to strategically select quadrat locations in Phase 3 (2015) in order to improve the capacity of the model for future vegetation surveys.

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Appendices

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Appendix 7 – Safety Plan
Appendix 8 – Sample Field Forms

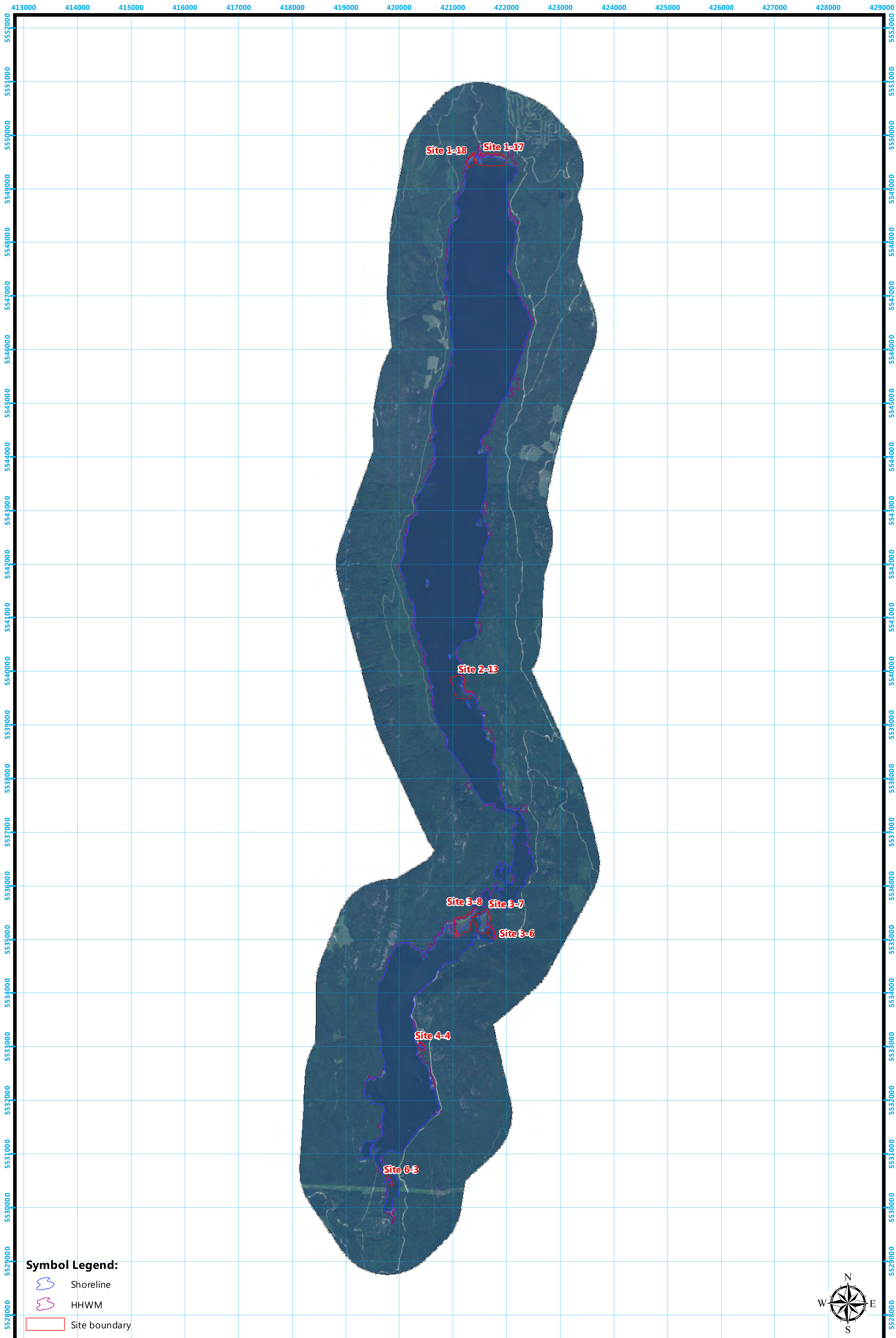
Appendix 1

Figures

1-1 Whatshan Reservoir
1-2 Site Maps

Appendix 1-1

Figures – Whatshan Reservoir



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Title: **Whole Reservoir True Colour**
Date/author: 18/05/2012 by K. Cupit
Coordinate system: WGS 1984 UTM Zone 11N
Scale: 1:65,000

0 500 1,000 2,000 3,000
Meters
1 centimeter = 650 meters

Appendix 1-2

Figures – Site Maps

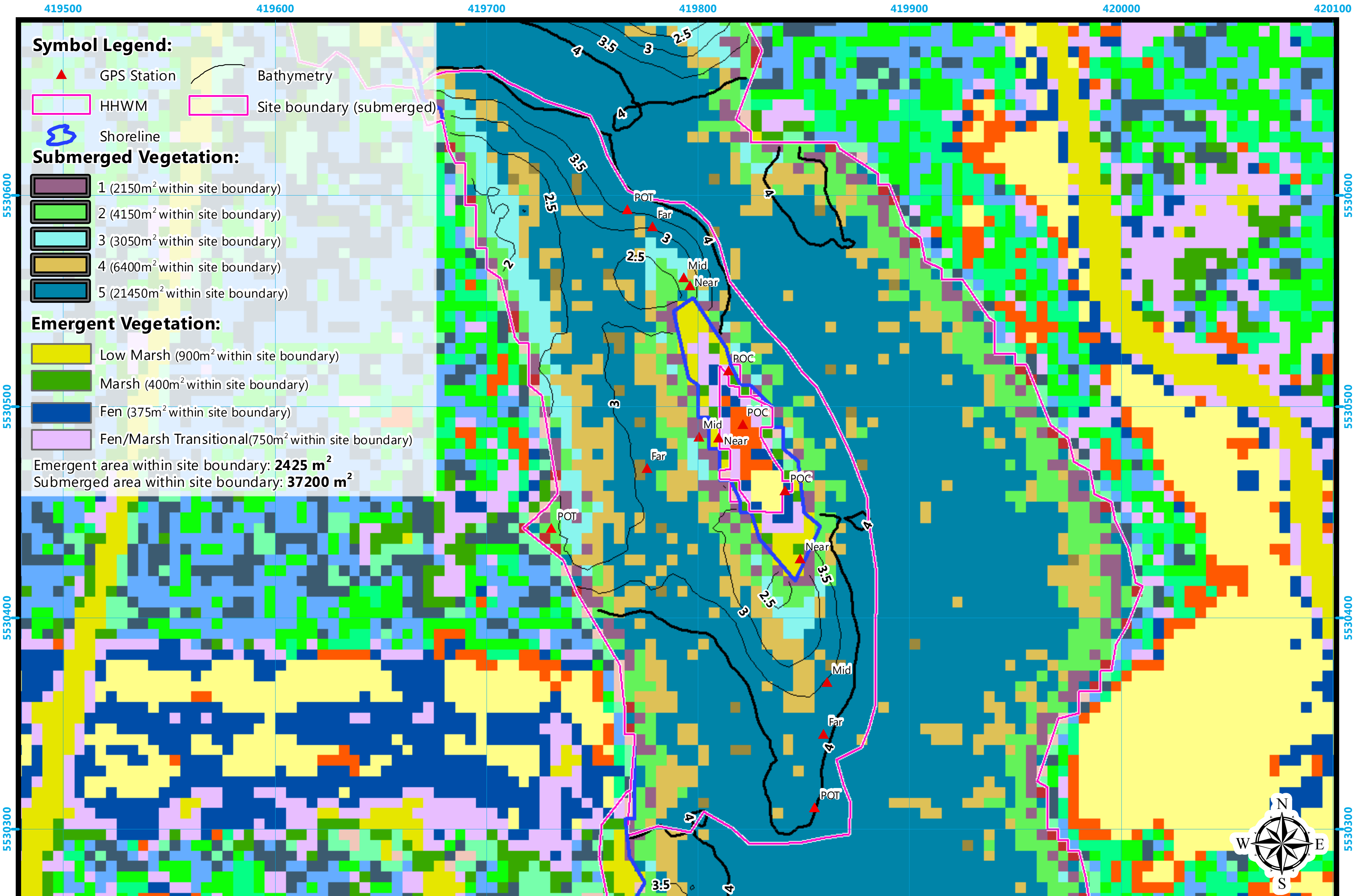

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Figure A2-1: Site 6-3 Spectral Vegetation Classifications

Date/author: 18/05/2012 by K. Cupit

Coordinate system: WGS 1984 UTM Zone 11N

Scale: 1:2,500

0 25 50 100 Meters

1 centimeter = 25 meters

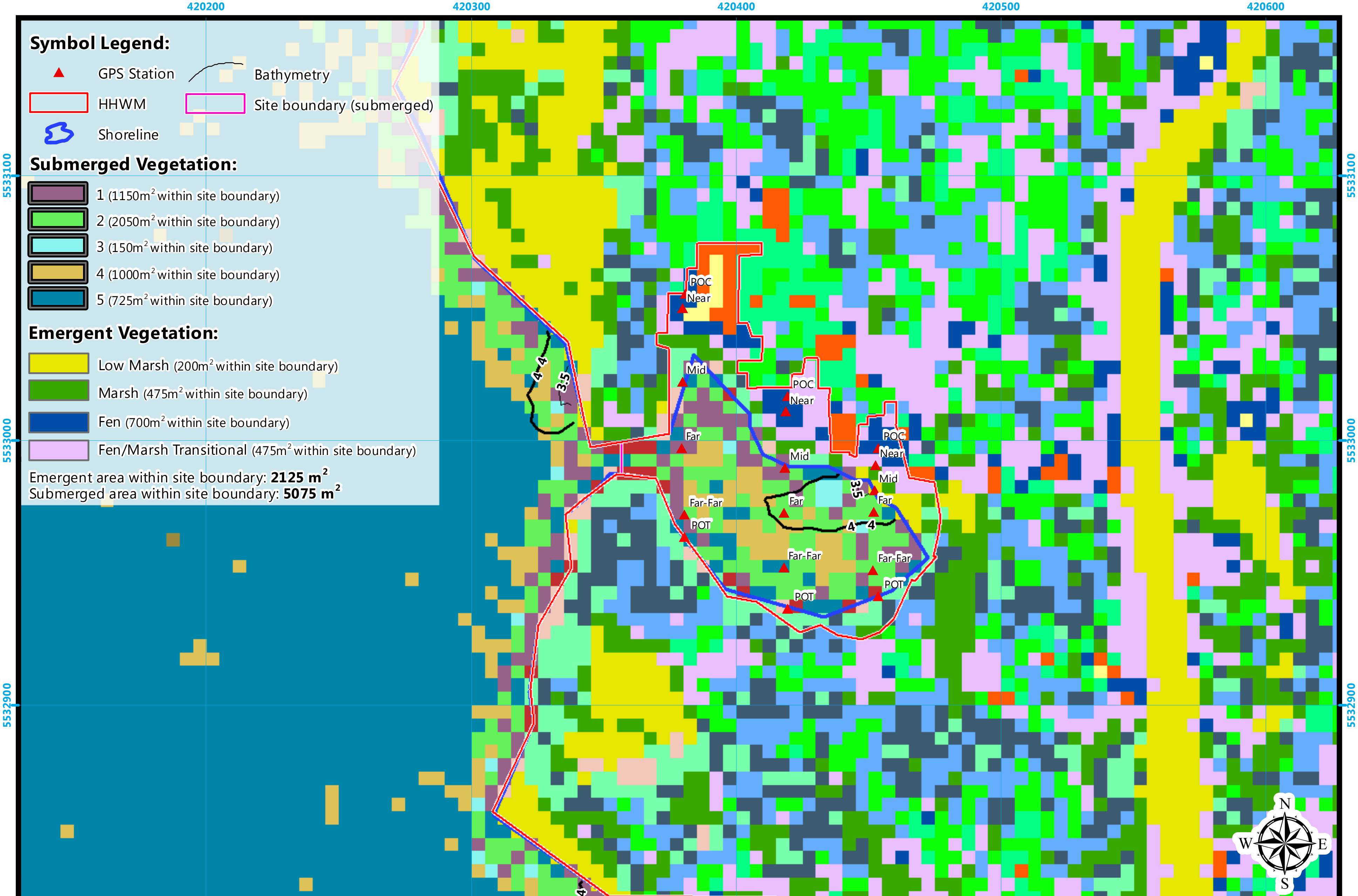

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Figure A2-2: Site 4-4 Spectral Vegetation Classifications
Date/author: 18/05/2012 by K. Cupit
Coordinate system: WGS 1984 UTM Zone 11N
Scale: 1:2,000

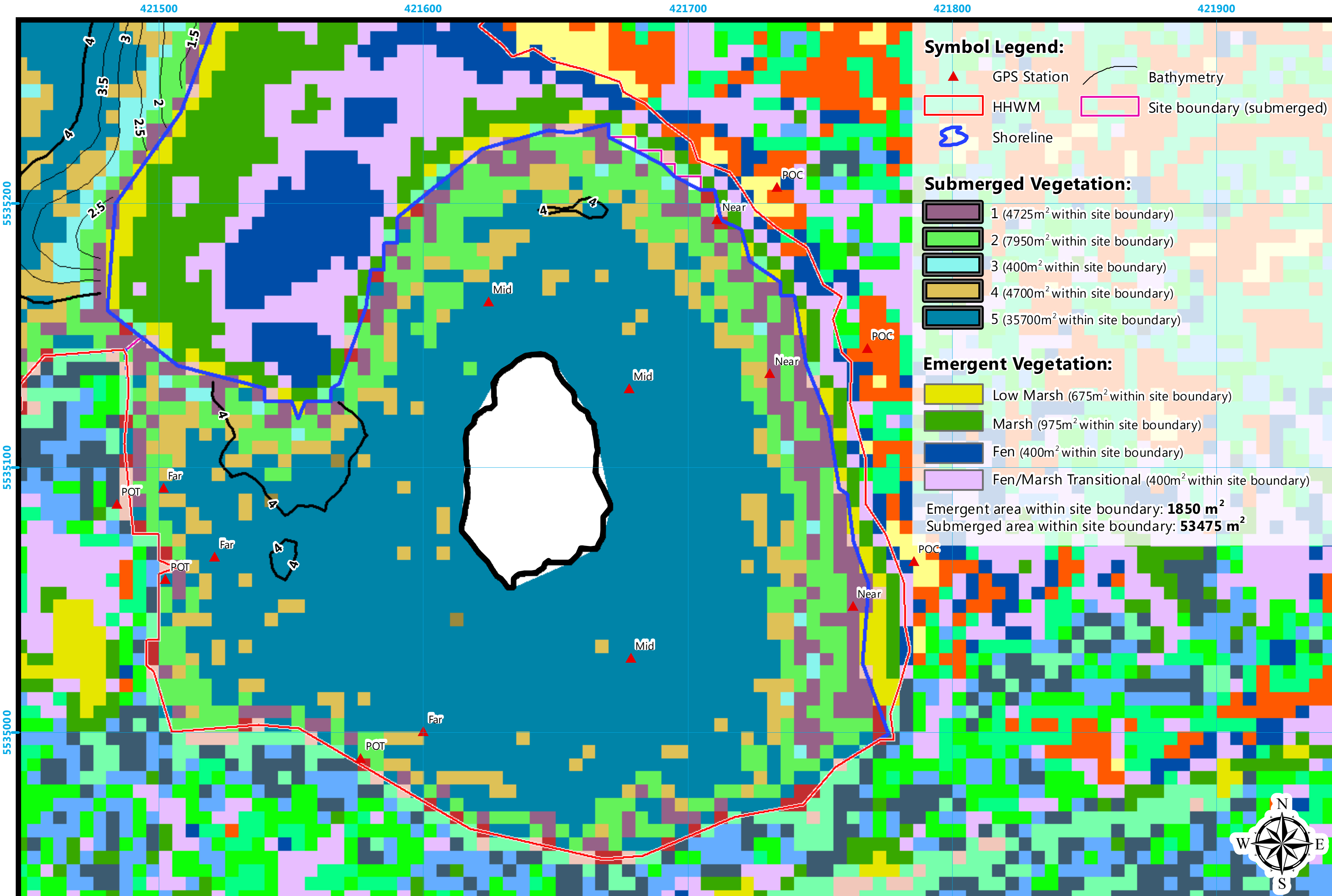

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Figure A2-3: Site 3-6 Spectral Vegetation Classifications
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Coordinate system: WGS 1984 UTM Zone 11N
Scale: 1:2,000

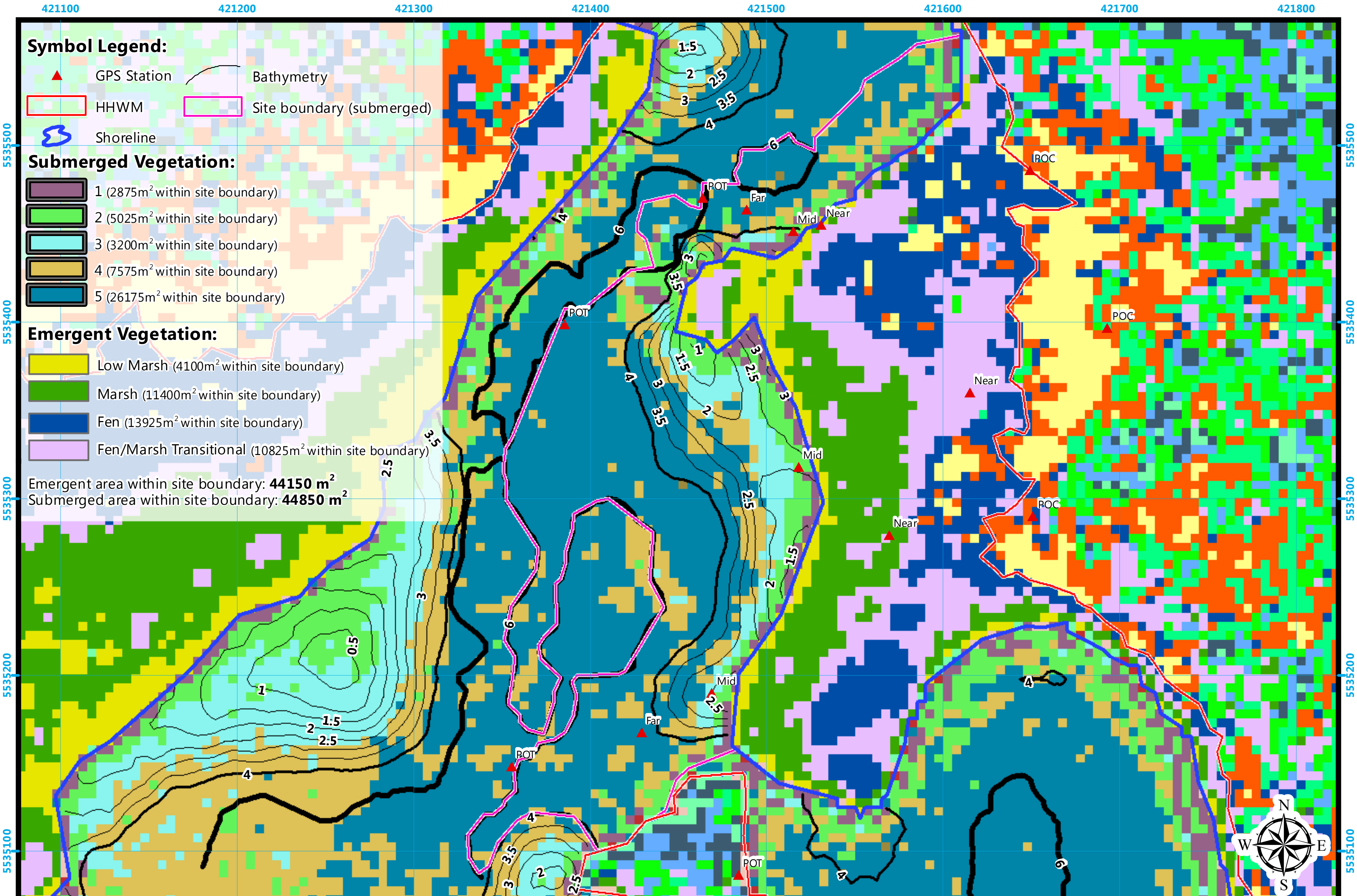

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Figure A2-4: Site 3-7 Spectral Vegetation Classifications
Date/author: 18/05/2012 by K. Cupit
Coordinate system: WGS 1984 UTM Zone 11N
Scale: 1:3,000

0 25 50 100 Meters
1 centimeter = 30 meters

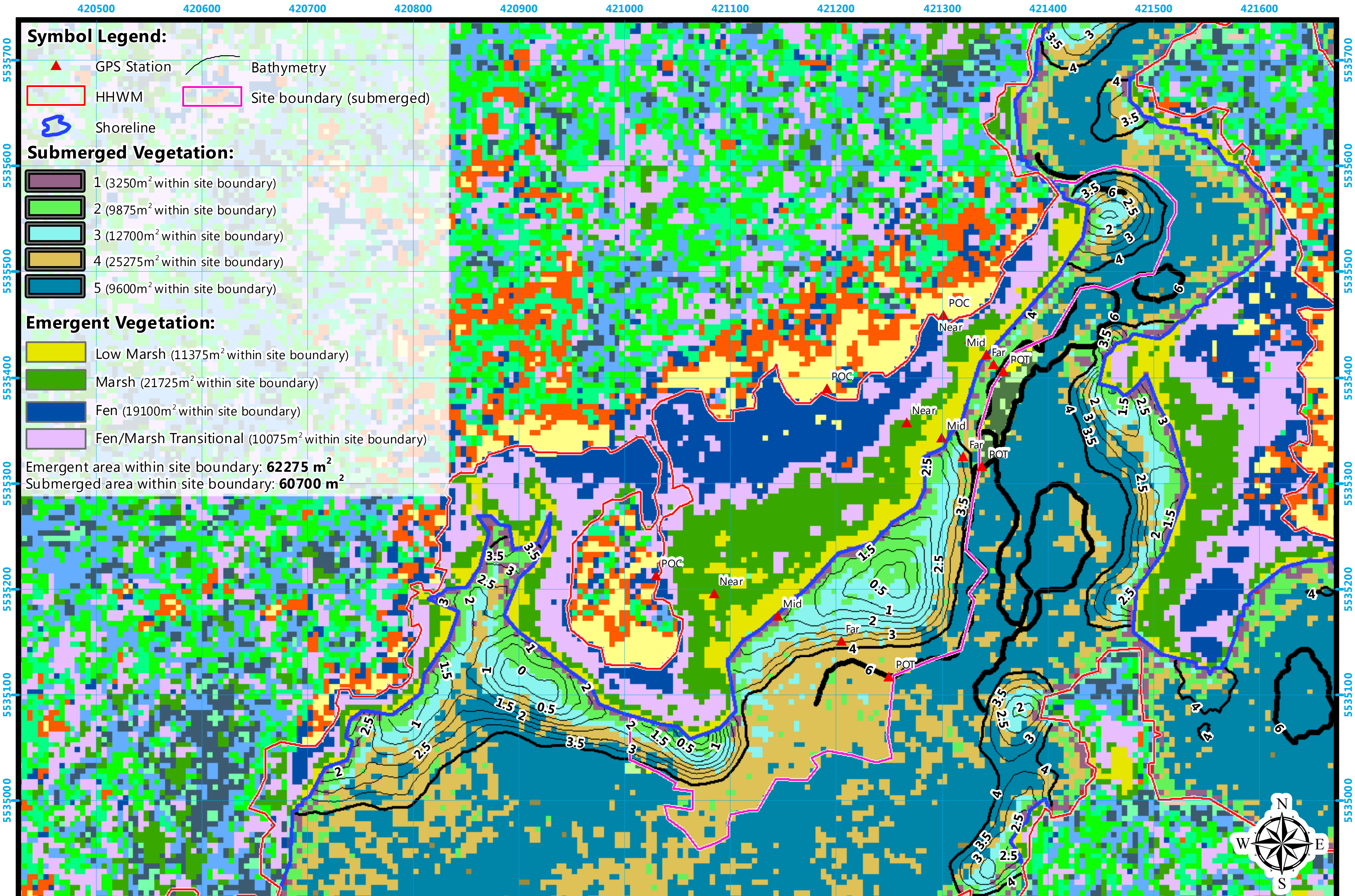

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Figure A2-5: Site 3-8 Spectral Vegetation Classifications
Date/author: 18/05/2012 by K. Cupit
Coordinate system: WGS 1984 UTM Zone 11N
Scale: 1:5,000

0 25 50 100 150 200 Meters
1 centimeter = 50 meters

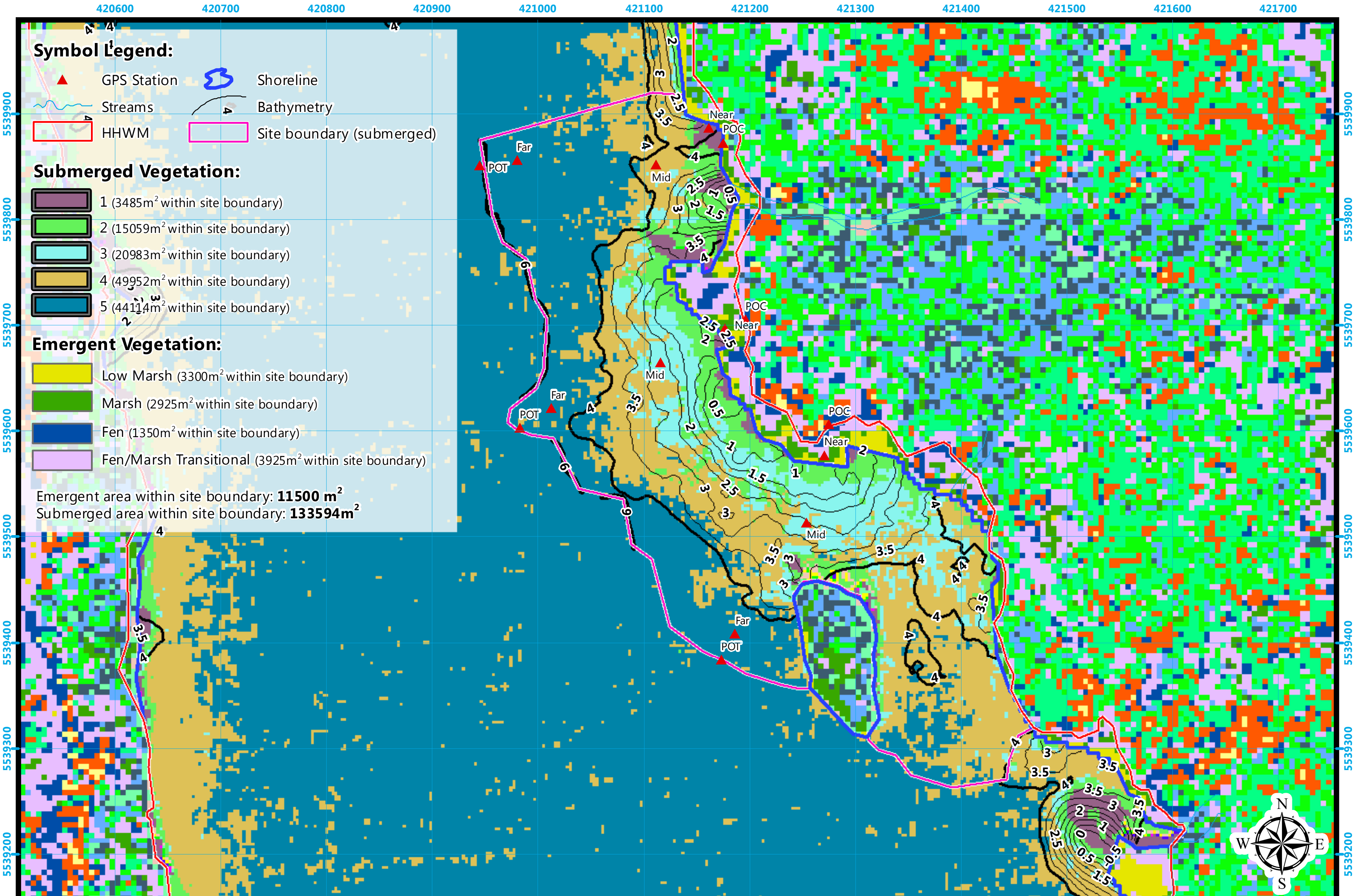

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Figure A2-6: Site 2-13 Spectral Vegetation Classifications
Date/author: 17/05/2012 by K. Cupit
Coordinate system: WGS 1984 UTM Zone 11N
Scale: 1:5,000

0 25 50 100 150 200 Meters
1 centimeter = 50 meters

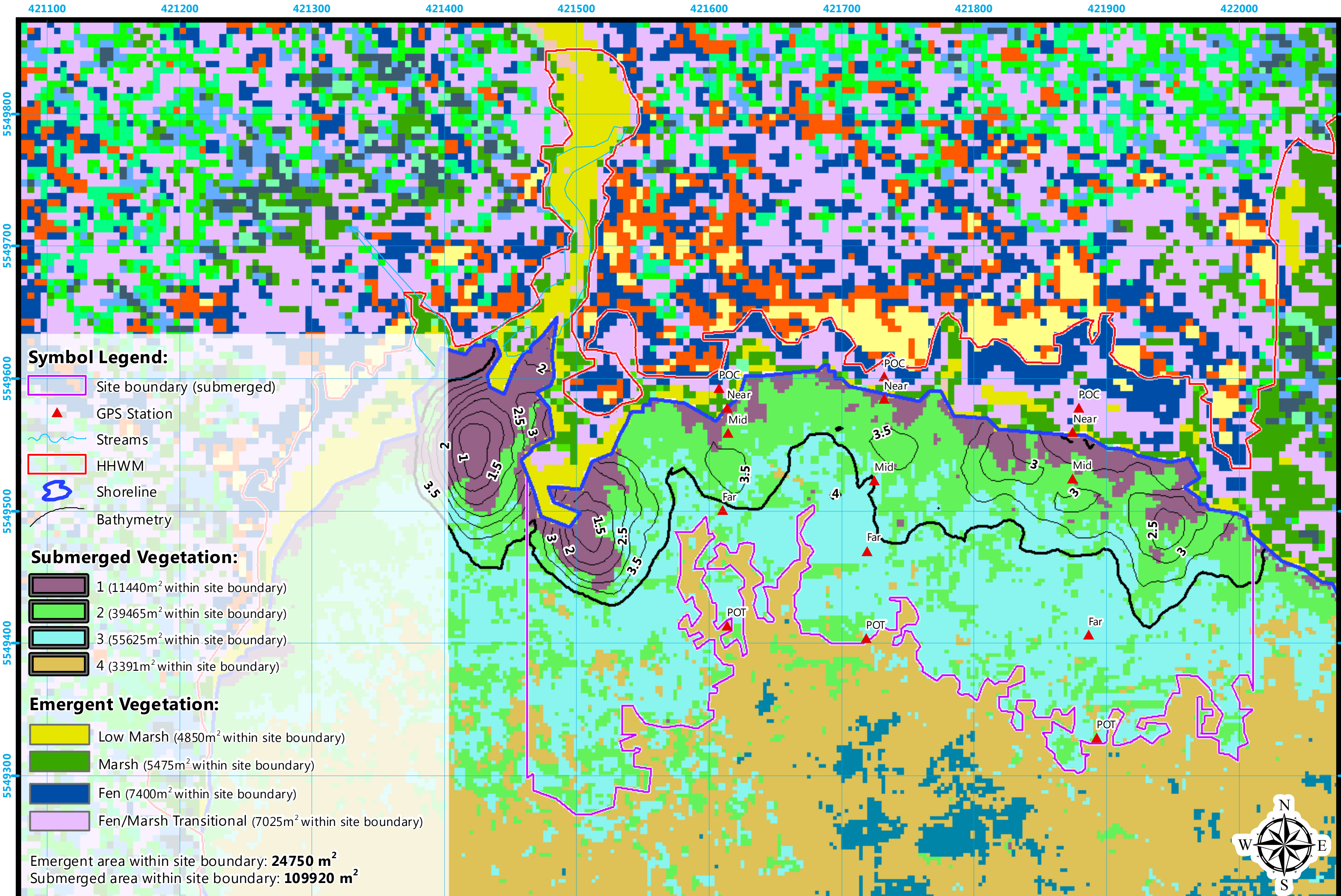

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Figure A7-2: Site 1-17 Spectral Vegetation Classifications
Date/author: 17/05/2012 by K. Cupit
Coordinate system: WGS 1984 UTM Zone 11N
Scale: 1:4,000

0 25 50 100 150 Meters
1 centimeter = 40 meters

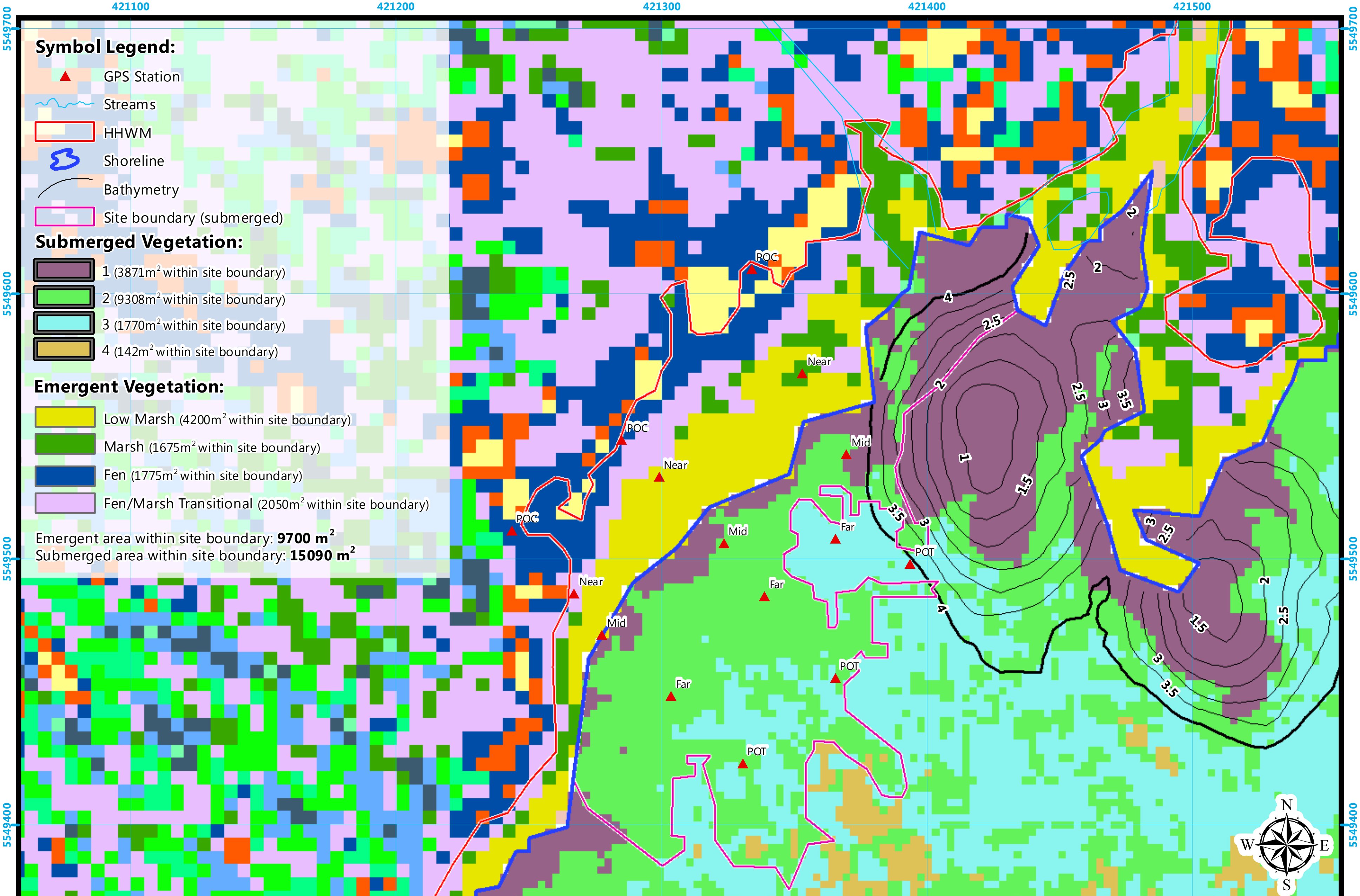

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Figure A2-8: Site 1-18 Spectral Vegetation Classifications
Date/author: 17/05/2012 by K. Cupit
Coordinate system: WGS 1984 UTM Zone 11N
Scale: 1:2,000

0 25 50 100 Meters
1 centimeter = 20 meters

Appendix 2

Photos

Appendix 2-1

Photos – Site Overview

Appendix 2-1: Site Description 6-3

Photo 1-1: Looking northwest at macrophytes on south side of Site 6-3 (September 30, 2011)

Photo 1-2: Looking north at the south side of Site 6-3 (September 30, 2011)

Photo 1-3: Looking south from Site 6-3 nearshore centre quadrat location (September 30, 2011)

Photo 1-4: Looking north from Site 6-3 nearshore centre quadrat location (September 30, 2011)

Photo 1-5: Looking north from Site 6-3 south nearshore quadrat (September 30, 2011)

Photo 1-6: Looking at macrophytes present at Site 6-3 north nearshore quadrat (September 30, 2011)

Appendix 2-1: Site Description 4-4

Photo 1-7: Looking east from Site 4-4 east POC (September 27, 2011)

Photo 1-8: Looking north at G3 survey vessel and G3 scientist preparing to collect macrophyte samples (September 27, 2011)

Photo 1-9: Looking south at macrophytes observed near the centre of Site 4-4 (September 27, 2011)

Photo 1-10: Looking north at standing dead trees within Site 4-4 (September 27, 2011)

Photo 1-11: Example nearshore quadrat with visible macrophytes (September 27, 2011)

Photo 1-12: Example of a permanent marker with identification tag at Site 4-4 (September 27, 2011)

Appendix 2-1: Site Description 3-6

Photo 1-13: Looking east from Site 3-6 centre POC (September 29, 2011)

Photo 1-14: Looking south from Site 3-6 centre POC (September 29, 2011)

Photo 1-15: Looking west from 3-6 east POC (September 29, 2011)

Photo 1-16: Looking west from 3-6 west POC (September 29, 2011)

Photo 1-17: Looking west from Site 3-6 centre POC (September 29, 2011)

Photo 1-18: Looking at Site 3-6 east POC (September 29, 2011)

Appendix 2-1: Site Description 3-7

Photo 1-19: Looking west from Site 3-7 south nearshore quadrat (September 29, 2011)

Photo 1-20: Looking east from Site 3-7 south nearshore quadrat (September 29, 2011)

Photo 1-21: Looking west from Site 3-7 centre transect permanent marker (September 29, 2011)

Photo 1-22: Looking east from 3-7 north POC (September 29, 2011)

Photo 1-23: Looking south from Site 3-7 north mid-distance quadrat (September 29, 2011)

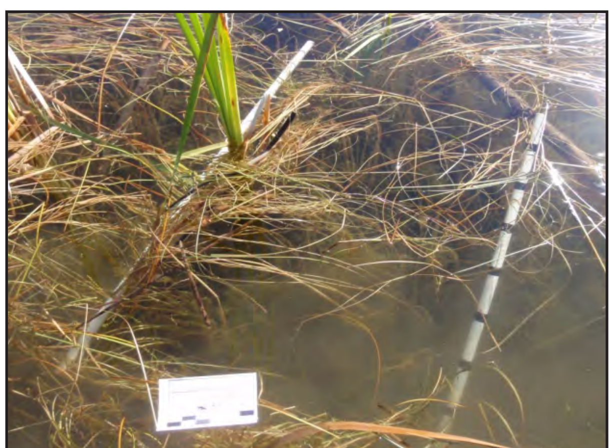


Photo 1-24: Looking at visible macrophytes within Site 3-7 north mid-distance quadrat (September 29, 2011)

Appendix 2-1: Site Description 3-8

Photo 1-25: Looking west at Site 3-8 across the reservoir from Site 3-7 (September 30, 2011)

Photo 1-26: Looking south from Site 3-8 centre POC (September 30, 2011)

Photo 1-27: Looking east from Site 3-8 south POC (September 30, 2011)

Photo 1-28: Looking west from Site 3-8 south POC (September 30, 2011)

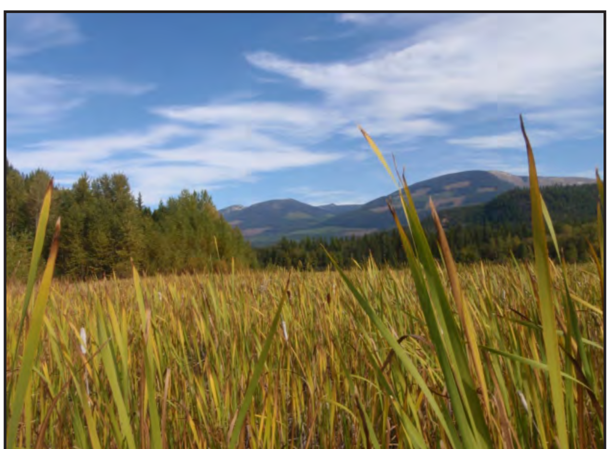


Photo 1-29: Looking north from Site 3-8 centre nearshore quadrat (September 30, 2011)

Photo 1-30: Looking at macrophytes within Site 3-8 north nearshore quadrat (September 30, 2011)

Appendix 2-1: Site Description 2-13

Photo 1-31: Looking south from Site 2-13 northern extent marker (September 30, 2011)

Photo 1-32: Looking north from Site 2-13 north POC (September 30, 2011)

Photo 1-33: Looking east from Site 2-13 east POC (September 30, 2011)

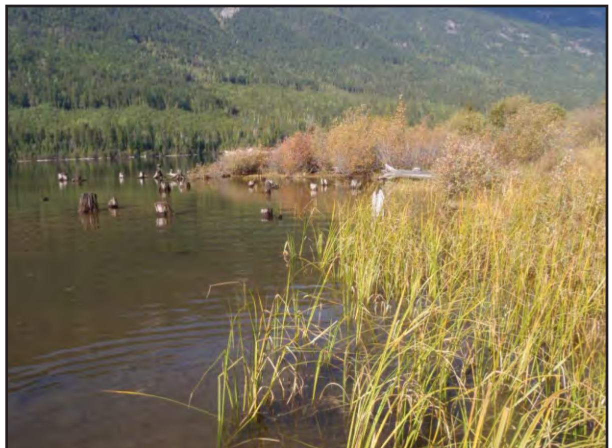


Photo 1-34: Looking north from Site 2-13 south nearshore quadrat (September 30, 2011)

Photo 1-35: Looking south from Site 2-13 south nearshore POC (September 30, 2011)

Photo 1-36: Looking east from Site 2-13 south nearshore POC (September 30, 2011)

Appendix 2-1: Site Description 1-18

Photo 1-37: Looking east from Site 1-18 northern extent at outflow of Whatshan River (September 28, 2011)

Photo 1-38: Looking northwest at Site 1-18 (September 28, 2011)

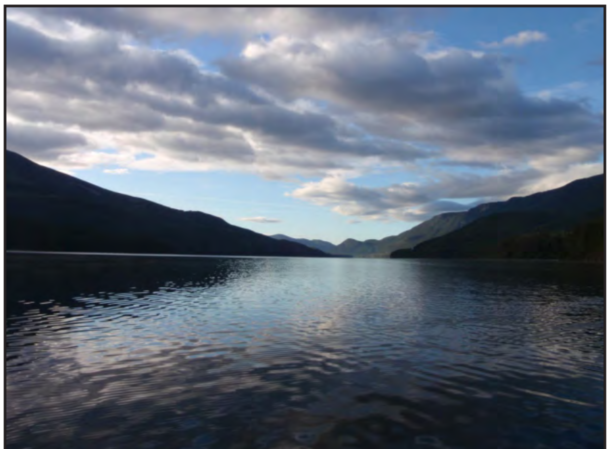


Photo 1-39: Looking south from Site 1-18 (September 28, 2011)

Photo 1-40: Looking southwest from Site 1-18 northern extent (September 28, 2011)

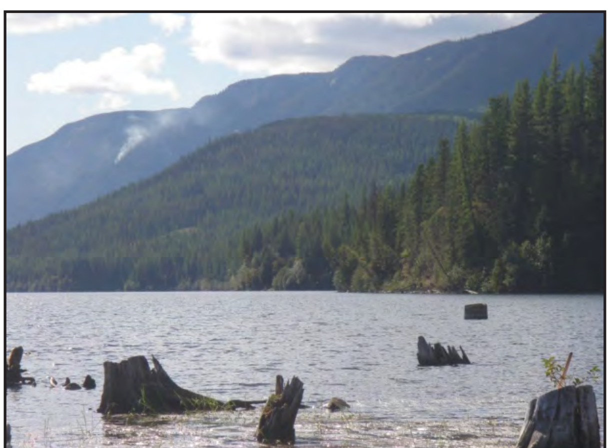


Photo 1-41: Looking southwest from Site 1-18 (September 28, 2011)

Photo 1-42: Looking at Site 1-18 north nearshore quadrat (September 28, 2011)

Appendix 2-1: Site Description 1-17

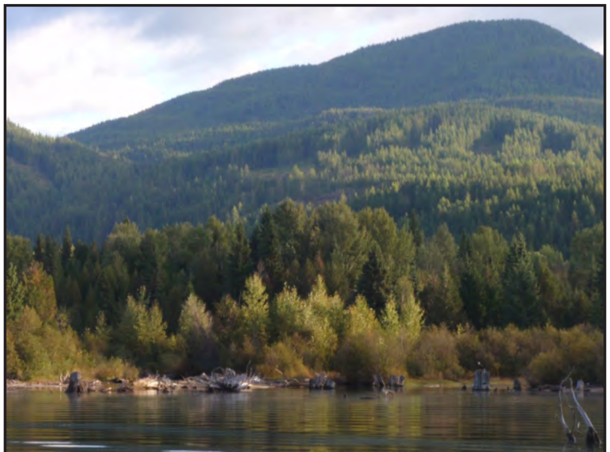


Photo 1-43: Looking north at the mouth of Watshan River (September 28, 2011)

Photo 1-44: Looking east from Site 1-17 (September 28, 2011)

Photo 1-45: Looking at cattail marsh near Site 1-17 eastern extent (September 28, 2011)

Photo 1-46: Looking at Site 1-17 centre nearshore quadrat (September 28, 2011)

Photo 1-47: Looking at Site 1-17 east nearshore quadrat (September 28, 2011)

Photo 1-48: Looking at Site 1-17 east POC permanent marker (September 28, 2011)

Appendix 2-2

Photos – Methodology

Appendix 2-2: Methodology

Photo 2-1: Looking at the 6.7 m aluminum field vessel powered by a 340 HP inboard jet drive engine

Photo 2-2: Preparing permanent markers at a site

Photo 2-3: Digital Lowrance LCX-15MT depth sounder interfacing directly to an omnistar DGPS receiver used to view and record bathymetry data

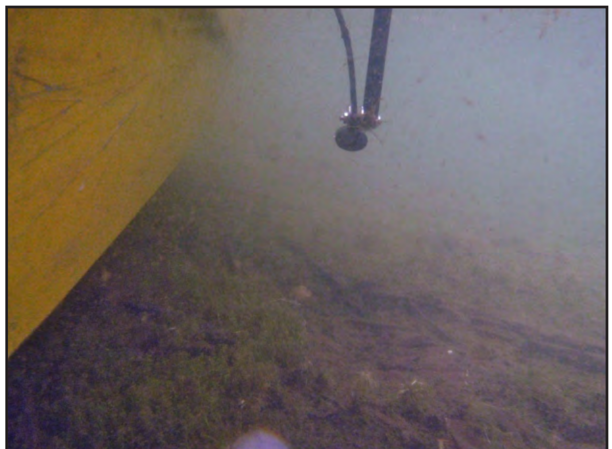


Photo 2-4: Transponder used to gather bathymetry data

Photo 2-5: Collecting submerged macrophytes using a macrophyte sampling rake

Photo 2-6: measuring depth at a quadrat

Appendix 2-2: Methodology (Con’d)

Photo 2-7: Collecting submerged macrophytes using a macrophyte sampling rake

Photo 2-8: Seperating macrophytes sampled with a macrophyte sampling rake

Photo 2-9: Preparing representative macrophytes for pressing

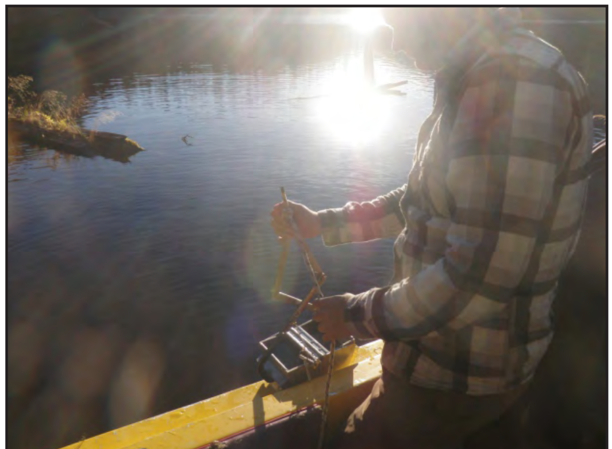


Photo 2-10: Stainless steel 15 cm ponar used for collecting sediment from depth

Appendix 2-3

Photos – Sediment Photos

Appendix 2-3: Sediment Grabs

Photo 3-1: Sediment sample taken from site 6-3 centre nearshore (September 30, 2011)

Photo 3-2: Sediment sample taken from site 6-3 centre furthest from shore (September 30, 2011)

Photo 3-3: Sediment sample taken from Site 4-4 centre mid distance from shore (September 28, 2011)

Photo 3-4: Sediment sample taken from Site 4-4 centre (September 28, 2011)

Photo 3-5: Sediment sample taken from Site 3-6 centre nearshore (September 29, 2011)

Photo 3-6: Sediment sample taken from Site 3-6 centre mid distance from shore (September 29, 2011)

Appendix 2-3: Sediment Grabs (Con'd)

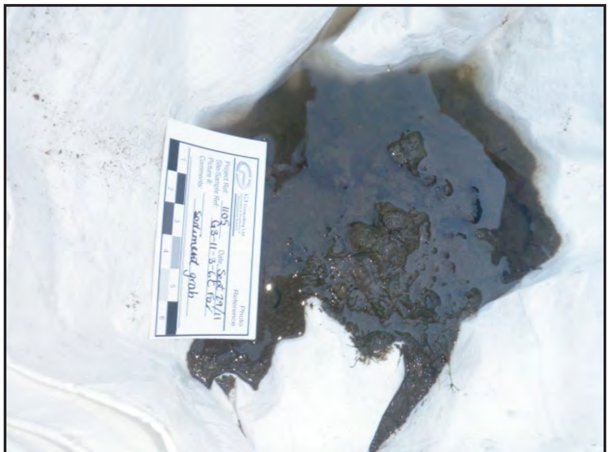


Photo 3-7: Sediment sample taken from Site 3-6 centre furthest from shore (September 29, 2011)

Photo 3-8: Sediment sample taken from Site 3-8 centre nearshore (September 30, 2011)

Photo 3-9: Sediment sample taken from Site 3-8 centre mid distance from shore (September 30, 2011)

Photo 3-10: Sediment sample taken from Site 3-8 centre furthest distance from shore (September 30, 2011)

Photo 3-11: Sediment sample taken from Site 3-7 centre nearshore (September 29, 2011)

Photo 3-12: Sediment sample taken from Site 3-7 centre mid distance from shore (September 30, 2011)

Appendix 2-3: Sediment Grabs (Con'd)

Photo 3-13: Sediment sample taken from Site 2-13 centre nearshore (September 30, 2011)

Photo 3-14: Sediment sample taken from Site 6-3 centre mid distance from shore (September 30, 2011)

Photo 3-15: Sediment sample taken from Site 2-13 centre furthest distance from shore (September 30, 2011)

Photo 3-16: Sediment sample taken from Site 1-18 centre mid distance from shore (September 28, 2011)

Photo 3-17: Sediment sample taken from Site 1-18 centre furthest distance from shore (September 28, 2011)

Photo 3-18: Sediment sample taken from Site 1-17 centre nearshore (September 28, 2011)

Appendix 2-3: Sediment Grabs (Con'd)

Photo 3-19: Sediment sample taken from Site 1-17 centre mid distance from shore (September 28, 2011)

Appendix 3

Tables & Charts

3-1 Tables
3-2 Charts

Appendix 3-1

Tables

A1: Macrophyte Distribution
A2: Sediment Characteristics
A3: Water Quality Profiles

TABLE A3–1: 6-3 Near Water Quality Profile

Depth (m)	Temp (°C)	Specific Conductivity (µS/cm)	pH	ORP (mV)	Dissolved Oxygen (mg/L)
0.012	17.36	50	7.8	187	9.59

TABLE A3–2: 6-3 Mid Water Quality Profile

Depth (m)	Temp (°C)	Specific Conductivity (µS/cm)	pH	ORP (mV)	Dissolved Oxygen (mg/L)
0.075	16.66	51	7.85	183	9.33
0.21	16.91	51	7.81	181	9.28
0.239	16.92	51	7.8	181	9.28
0.279	16.92	51	7.79	181	9.28
0.347	16.92	51	7.78	182	9.28
0.486	16.9	51	7.76	182	9.28
0.625	16.86	51	7.76	182	9.29
0.759	16.81	51	7.75	182	9.29
0.885	16.74	51	7.74	182	9.3
1.021	16.68	51	7.74	182	9.31
1.147	16.63	51	7.74	182	9.32
1.308	16.57	51	7.74	181	9.33
1.375	16.54	51	7.74	181	9.34
1.543	16.49	51	7.74	181	9.35
1.657	16.45	51	7.75	180	9.37
1.754	16.41	51	7.75	180	9.39
1.774	16.38	51	7.76	180	9.41

TABLE A3–3: 6-3 Far Water Quality Profile					
Depth (m)	Temp (°C)	Specific Conductivity (µS/cm)	pH	ORP (mV)	Dissolved Oxygen (mg/L)
0.045	16.92	51	7.9	168	9.33
0.175	16.75	51	7.68	172	9.46
0.236	16.75	51	7.69	172	9.46
0.342	16.73	51	7.68	173	9.46
0.441	16.72	51	7.68	173	9.46
0.646	16.7	51	7.67	173	9.46
0.908	16.67	51	7.66	174	9.45
1.175	16.62	51	7.65	174	9.45
1.462	16.56	51	7.65	174	9.45
1.722	16.5	50	7.66	174	9.45
1.869	16.46	50	7.66	174	9.45
2.132	16.4	50	7.66	173	9.46
2.295	16.35	50	7.67	173	9.48
2.325	16.32	50	7.68	173	9.49

TABLE A3–4: 4-4 Mid Water Quality Profile						
Depth (m)	Temp (°C)	Specific Conductivity (µS/cm)	pH	ORP (mV)	Turbidity (NTU)	Dissolved Oxygen (mg/L)
0	16.33	50	7.77	189	0.5	9.61
0.002	16.34	50	7.7	190	0.6	9.64
0.002	16.34	50	7.7	190	0.6	9.64
0.002	16.34	50	7.7	190	0.5	9.64
0.002	16.34	50	7.7	190	0.5	9.64
0.013	16.34	50	7.7	190	0.5	9.64
0.035	16.35	50	7.7	189	0.5	9.64
0.06	16.35	50	7.7	189	0.5	9.65
0.089	16.36	50	7.7	189	0.5	9.65
0.11	16.36	50	7.7	189	0.6	9.65
0.135	16.36	50	7.7	189	0.6	9.65
0.168	16.37	50	7.7	189	0.6	9.65
0.204	16.37	50	7.7	190	0.6	9.65
0.233	16.37	50	7.69	190	0.6	9.65
0.271	16.36	50	7.69	190	0.7	9.65
0.333	16.36	50	7.69	190	1.3	9.65
0.405	16.34	50	7.68	190	1.2	9.64
0.474	16.32	50	7.68	190	1.4	9.64
0.548	16.3	50	7.68	190	1.3	9.65
0.621	16.29	50	7.68	190	1.3	9.65

0.684	16.28	50	7.68	190	1.3	9.65
0.736	16.27	50	7.69	190	1.3	9.66
0.76	16.26	50	7.69	190	1.4	9.66
0.806	16.26	50	7.69	190	1.4	9.67
0.846	16.25	50	7.69	190	1.4	9.67
0.881	16.25	50	7.69	189	1.3	9.67
0.911	16.24	50	7.69	189	1.3	9.68
0.938	16.24	50	7.7	189	1.3	9.68
0.959	16.23	50	7.7	189	1.3	9.68
0.977	16.22	50	7.7	189	1.2	9.68
0.99	16.22	50	7.71	188	1.5	9.68
1	16.21	50	7.71	188	1.4	9.69
1.008	16.2	50	7.71	188	1.4	9.69
1.015	16.18	50	7.72	188	1.3	9.7
1.023	16.17	50	7.72	188	1.2	9.71
1.028	16.16	50	7.72	187	1.5	9.72
1.032	16.14	50	7.73	187	1.4	9.72
1.035	16.13	50	7.73	187	1.3	9.73
1.036	16.13	50	7.73	187	1.3	9.73
1.038	16.13	50	7.73	187	1.3	9.74
1.043	16.13	50	7.73	187	1.3	9.75
1.05	16.14	50	7.74	187	1.3	9.75
1.055	16.14	50	7.74	187	1.2	9.76

TABLE A3–5: 3-8 Far Water Quality Profile

Depth (m)	Temp (°C)	Specific Conductivity (µS/cm)	pH	ORP (mV)	Dissolved Oxygen (mg/L)
0.41	16.17	51	7.67	166	9.79
0.386	16.17	51	7.66	168	9.71
0.392	16.18	51	7.66	168	9.71
0.405	16.18	51	7.66	168	9.71
0.415	16.18	51	7.66	168	9.71
0.45	16.18	51	7.65	168	9.71
0.479	16.17	51	7.65	168	9.7
0.512	16.15	51	7.65	168	9.7
0.55	16.14	51	7.65	168	9.7
0.674	16.11	51	7.64	168	9.7
0.81	16.09	51	7.63	169	9.7
0.951	16.07	51	7.63	169	9.69
1.12	16.05	51	7.62	169	9.68
1.31	16.03	51	7.62	169	9.68
1.512	16.01	51	7.62	170	9.67

1.713	15.99	52	7.61	170	9.67
1.945	15.97	52	7.61	170	9.66
2.127	15.95	52	7.61	170	9.65
2.304	15.94	52	7.6	170	9.64
2.509	15.92	52	7.6	170	9.63
2.743	15.91	52	7.59	170	9.62
2.954	15.89	52	7.59	171	9.62
3.135	15.87	52	7.59	171	9.61
3.228	15.86	52	7.59	171	9.6
3.339	15.84	52	7.59	171	9.6
3.438	15.83	52	7.58	171	9.61
3.527	15.81	52	7.58	171	9.61
3.601	15.8	52	7.58	171	9.6
3.75	15.79	52	7.57	171	9.6
3.92	15.78	52	7.57	171	9.59
4.12	15.77	52	7.57	171	9.58
4.335	15.75	52	7.56	172	9.57
4.565	15.73	52	7.56	172	9.57
4.803	15.7	52	7.56	172	9.56
4.935	15.68	53	7.56	172	9.56
5.059	15.66	53	7.56	172	9.57
5.097	15.63	53	7.55	172	9.58
5.071	15.62	53	7.55	172	9.58

TABLE A3–6: 3-7 Far Water Quality Profile

Depth (m)	Temp (°C)	Specific Conductivity (µS/cm)	pH	ORP (mV)	Dissolved Oxygen (mg/L)
0.527	16.54	51	7.52	134	9.43
0.509	16.57	51	7.53	134	9.42
0.506	16.57	51	7.53	134	9.42
0.495	16.57	51	7.53	134	9.42
0.507	16.57	51	7.52	134	9.42
0.599	16.56	51	7.52	135	9.42
0.696	16.55	51	7.51	135	9.42
0.759	16.54	51	7.51	135	9.43
0.833	16.52	51	7.51	135	9.43
0.877	16.51	51	7.51	135	9.42
0.919	16.49	51	7.52	135	9.41
0.948	16.48	51	7.52	135	9.41
1.036	16.47	51	7.51	135	9.41
1.138	16.45	51	7.51	136	9.41
1.318	16.43	51	7.5	136	9.4

1.498	16.4	52	7.5	136	9.41
1.627	16.38	52	7.5	136	9.41
1.713	16.36	52	7.5	136	9.42
1.756	16.35	52	7.5	136	9.42
1.791	16.33	52	7.5	136	9.42

TABLE A3–7: 3-6 near Water Quality Profile

Depth (m)	Temp (°C)	Specific Conductivity (μS/cm)	pH	ORP (mV)	Dissolved Oxygen (mg/L)
0.307	16.47	52	7.42	132	9.66

TABLE A3–8: 3-6 Mid Water Quality Profile

Depth (m)	Temp (°C)	Specific Conductivity (μS/cm)	pH	ORP (mV)	Dissolved Oxygen (mg/L)
0.016	15.02	54	7.51	190	10.05
0.113	16.1	53	7.49	189	9.82
0.197	16.22	53	7.48	189	9.77
0.333	16.29	53	7.47	190	9.71
0.484	16.31	53	7.47	189	9.66
0.655	16.28	52	7.47	189	9.61
0.773	16.23	52	7.47	189	9.6
0.959	16.14	52	7.47	189	9.59
1.148	16.04	52	7.47	189	9.57
1.381	15.92	52	7.47	189	9.56
1.634	15.82	52	7.46	189	9.55
1.875	15.74	52	7.46	189	9.54
2.133	15.66	52	7.45	189	9.52
2.382	15.59	52	7.45	189	9.51
2.556	15.55	52	7.45	189	9.5
2.806	15.49	52	7.44	189	9.48
3.002	15.44	52	7.44	189	9.47
3.162	15.39	52	7.44	188	9.46
3.324	15.34	52	7.45	188	9.45
3.433	15.31	52	7.45	188	9.44
3.552	15.29	52	7.45	188	9.42
3.675	15.26	52	7.44	188	9.4
3.783	15.24	52	7.44	188	9.38
3.939	15.23	52	7.43	188	9.37
4.063	15.22	52	7.43	188	9.35
4.284	15.21	52	7.42	188	9.34
4.485	15.2	52	7.42	189	9.33

4.68	15.19	52	7.41	189	9.31
4.893	15.18	52	7.41	189	9.29
5.148	15.17	52	7.4	189	9.28
5.361	15.16	52	7.4	189	9.27
5.626	15.15	52	7.39	189	9.26
5.746	15.15	53	7.38	184	9.25
5.989	15.14	53	7.34	111	9.21
6.163	15.13	53	7.29	108	9.11
6.302	15.13	53	7.24	106	8.96
6.377	15.13	53	7.22	105	8.84
6.434	15.13	54	7.18	103	8.55

TABLE A3–9: 3-6 Far Water Quality Profile

Depth (m)	Temp (°C)	Specific Conductivity (µS/cm)	pH	ORP (mV)	Dissolved Oxygen (mg/L)
0.096	15.67	52	7.25	196	9.59
0.123	16.34	52	7.49	180	9.37
0.122	16.36	52	7.5	179	9.36
0.127	16.37	52	7.5	179	9.34
0.188	16.36	52	7.5	179	9.32
0.309	16.32	52	7.49	179	9.33
0.491	16.27	52	7.48	180	9.32
0.76	16.19	52	7.47	180	9.3
0.881	16.15	52	7.47	180	9.3
1.166	16.05	52	7.47	180	9.29
1.417	15.94	52	7.47	180	9.29
1.62	15.83	52	7.47	180	9.29
1.718	15.71	52	7.47	180	9.3

TABLE A3–10: 2-13 Mid Water Quality Profile

Depth (m)	Temp (°C)	Specific Conductivity (µS/cm)	pH	ORP (mV)	Dissolved Oxygen (mg/L)
0.144	14.33	55	7.64	185	0
0.315	14.25	55	7.71	180	10.09
0.315	14.25	55	7.71	180	10.08
0.314	14.24	55	7.71	179	10.08
0.312	14.24	55	7.71	179	10.08
0.314	14.24	55	7.71	180	10.08
0.324	14.24	55	7.71	180	10.07
0.357	14.24	55	7.71	180	10.08
0.424	14.24	55	7.71	180	10.07

0.452	14.24	55	7.71	180	10.08
0.539	14.24	55	7.71	180	10.07
0.656	14.25	55	7.71	179	10.07
0.708	14.24	55	7.71	179	10.07
0.844	14.24	55	7.71	180	10.07
0.98	14.24	55	7.7	180	10.07
1.065	14.24	55	7.71	180	10.07
1.249	14.23	55	7.71	179	10.05
1.375	14.21	55	7.71	179	10.04
1.486	14.18	55	7.72	179	10.02
1.542	14.15	55	7.72	179	10.02
1.588	14.11	55	7.72	179	10.02
1.611	14.07	55	7.72	179	10.03

TABLE A3–11: 2-13 Far Water Quality Profile

Depth (m)	Temp (°C)	Specific Conductivity (μS/cm)	pH	ORP (mV)	Dissolved Oxygen (mg/L)
0.153	14.63	56	7.76	189	10.08
0.168	14.63	56	7.78	187	10.06
0.177	14.63	56	7.78	187	10.06
0.193	14.63	56	7.79	187	10.06
0.228	14.63	56	7.79	187	10.06
0.301	14.63	56	7.78	187	10.06
0.465	14.63	56	7.78	188	10.06
0.645	14.63	56	7.78	188	10.06
0.779	14.63	56	7.77	188	10.05
1.044	14.63	56	7.77	188	10.05
1.192	14.63	56	7.77	188	10.05
1.307	14.63	56	7.77	188	10.04
1.372	14.62	56	7.78	188	10.04
1.47	14.62	56	7.78	187	10.04
1.509	14.62	56	7.79	187	10.04
1.568	14.62	56	7.79	187	10.04
1.63	14.62	56	7.79	187	10.03
1.658	14.61	56	7.79	187	10.03
1.726	14.61	56	7.78	187	10.02
1.873	14.61	56	7.78	187	10.03
1.985	14.61	56	7.77	188	10.03
2.251	14.61	56	7.77	188	10.03
2.427	14.6	56	7.76	188	10.02
2.762	14.59	55	7.76	188	10.02
2.993	14.58	55	7.76	188	10.01
3.15	14.57	55	7.76	189	10.01

3.423	14.56	55	7.76	189	10.01
3.662	14.55	55	7.76	189	10.01
3.823	14.54	55	7.75	189	10
4.095	14.51	55	7.75	189	10
4.344	14.46	55	7.75	189	10
4.458	14.44	55	7.76	189	10
4.617	14.4	55	7.76	188	10.01
4.701	14.38	55	7.76	187	10
4.742	14.35	55	7.76	186	10
4.744	14.34	55	7.77	185	10.01

TABLE A3–12: 1-17 Mid Water Quality Profile

Depth (m)	Temp (°C)	Specific Conductivity (µS/cm)	pH	ORP (mV)	Turbidity (NTU)	Dissolved Oxygen (mg/L)
0.261	17.06	57	7.65	169	0.8	9.79

TABLE A3–13: 1-17 Far Water Quality Profile

Depth (m)	Temp (°C)	Specific Conductivity (µS/cm)	pH	ORP (mV)	Turbidity (NTU)	Dissolved Oxygen (mg/L)
0.257	16.43	56	7.71	205	4.2	9.94
0.226	16.45	56	7.73	203	2.7	9.92
0.25	16.45	56	7.73	203	2.6	9.92
0.345	16.45	56	7.73	203	2.4	9.91
0.473	16.45	56	7.72	203	2.2	9.91
0.592	16.45	56	7.72	203	2	9.9
0.766	16.45	56	7.72	202	1.8	9.89
0.893	16.46	57	7.72	202	1.7	9.88
0.984	16.46	57	7.72	202	1.5	9.87
1.034	16.46	57	7.72	202	1.4	9.87
1.042	16.46	57	7.72	202	1.3	9.87

TABLE A3–14: 1-18 Water Quality Profile

Depth (m)	Temp (°C)	Specific Conductivity (µS/cm)	pH	ORP (mV)	Turbidity (NTU)	Dissolved Oxygen (mg/L)
0.238	16.22	57	7.76	182	0	9.8
0.391	16.21	56	7.73	155	1.4	9.44

Table A2: Sediment Characteristics							
Site #	**Depth (m)**	**Colour**	**Texture**	**Smell**	**Consistency**	**Homogeneous throughout**	**Description of Debris Present**
1-18C Mid	1	dark brown	Woody debris	odourless	Loose, woody debris	yes	Wood Chips; a few long sticks; organic detritus; fine woody debris
1-18C Far	1.5	gray-green	Gritty	H_2S	Thick like pudding	yes	Fine organic detritus on surface layer; Macrophytes; small woody debris; Brown surface Layer
1-17C Near	emergent	dark brown	Woody debris	odourless	Thick like pudding	yes	Organic debris/detritus, roots throughout; surface covered in macrophytes (small sedges)
1-17C Mid	0.75	brown-green	Gritty	odourless	Thick like pudding	yes	Fine gravel; surface plant layer; aquatic macrophytes
1-17C Far	2.4	gray-green	Gritty	odourless	Thick like pudding	no	Macrophytes; small organic debris; very few woodchips
3-6C Near	0.45	dark brown	Woody debris	Wood Chips	Loose	yes	Wood Chips; macrophytes
3-6C Mid	6	brown-green	Silky	H_2S, algae	Falls apart into fluffy pellets	yes	Few sticks
3-6C Far	2	gray-green	Woody debris	H_2S	Falls apart into fluffy pellets	no	Lots of wood chips; some macrophytes; macrophyte layer followed by fluffy Layer followed by woodchip Layer
3-7C Near	emergent	dark brown	Rooty	Soil	Thick like pudding	yes	Lots of organic debris, roots + detritus
3-7C Mid	0.2	brown-green	Gritty	odourless	Thick like pudding	yes	Organic debris/detritus, roots throughout; some wood chunks; surface covered in macrophytes (small sedges)
3-7C Far	3	gray-green	Gravelly	H_2S	Loose	yes	some macrophytes; small woodchips
3-8C Near	emergent, but wet	dark brown	Woody debris	odourless	Woody debis	yes	Almost entirely roots & woody debris; some moss on surface
3-8C Mid	0.45	gray-green	Gritty	H_2S	Thick like pudding, debris laden	no	Many macrophytes on surface- subsurface decaying macrophytes; wood & large sticks; very thick macrophyte layer.
3-8C Far	5.5	gray-green	Gritty	H_2S	Thick like pudding	yes	Sticks (small); macrophytes.
4-4C Centre	1.5	brown-green	Gritty	odourless	Thick like pudding	yes	Macrophyte vegetation; stick; 1 pebble

Table A2: Sediment Characteristics (Con'd)							
Site #	**Depth (m)**	**Colour**	**Texture**	**Smell**	**Consistency**	**Homogeneous throughout**	**Description of Debris Present**
4-4C Mid	0.5	dark brown	Silky	odourless	Thick like pudding	yes	Macrophytes; woody debris; grey/white sediments (inclusion) streaked throughout
6-3C Near	0.15	dark brown	Gritty	odourless	Thick like pudding	yes	Large pebbles in surface ~5mm to 30mm; below surface layer consists of brown mud; some woody debris present
6-3C Mid	2	brown-green	Gritty	odourless	Thick like pudding	yes	Macrophytes in surface layer; fluffy subsurface layer then gravelly
6-3C Far	3	gray-green	Gritty	H_2S	Falls apart into fluffy pellets	yes	Some organic debris; some parts of the profile are thicker (globular masses)
2-13C Near	0.15	gray-green	Silky, some grit	odourless	Falls apart into fluffy pellets	yes	Dense macrophytes and roots; some white inclusions throughout sediment
2-13 Mid	2.1	gray-green	Gravelly	odourless	Thick like pudding	yes	Macrophytes; black organic flecking throughout
2-13C Far	5.8	dark brown	Woody debris	odourless	Loose	no	Woodchips and small sticks; fish in sample; brown-green subsurface; gravelly

Site	Point	Transect	Easting	Northing	Distance from POC (m)	Elevation (m)	Depth (m)	Total Cover (%)	Calliergonella cuspidata Amblystegiaceae	Leptodictyum riparium Amblystegiaceae	unidentified (chick weed) Caryophyllaceae	Chara sp. Characeae	Tolypella sp. Characeae	Climacium dendroides Climaciaceae	Crassula aquatica (L.) Sch Crassulaceae	Carex exsiccata L.H. Baile Cyperaceae	Carex sp. Cyperaceae	Eleocharis sp. Cyperaceae	Eleocharis palustris (L.) R Cyperaceae	Schoenoplectus tabernae Cyperaceae	Equisetum sp. Equisetaceae	Equisetum fluviatile L. Equisetaceae	Equisetum pratense Ehrh. Equisetaceae	Rhododendron groenland Ericaceae	Myriophyllum verticillatu Haloragaceae	Isoetes sp. Isoetaceae	Juncus sp. Can't ID with Juncaceae	Mentha arvensis L. Lamiaceae	Utricularia macrorhiza Le Lentibulariaceae	Utricularia minor L. Lentibulariaceae	Najas flexilis (Willd.) Rost Najadaceae	Nuphar lutea (L.) Sm. Nymphaeaceae	Poaceae Poaceae	Persicaria amphibia var. e Polygonaceae	Potamogeton sp. Potamogetonaceae	Potamogeton epihydrus F Potamogetonaceae	Potamogeton foliosus Raf Potamogetonaceae	Potamogeton gramineus Potamogetonaceae	Potamogeton natans L. Potamogetonaceae	Potamogeton pusillus L. Potamogetonaceae	Ranunculus aquatilis var. Ranunculaceae	Comarum palustre L. Rosaceae	Fragaria virginiana Duche Rosaceae	Typha angustifolia L. Typhaceae	Viola orbiculata Geyer ex Violaceae	Beluta sp.	Athyrium felix-femina	unidentified aquatic moss	unidenfied Leafy pond-we	Purple Leaf	
6-3	Near	N	419796.05 m E	5530557.45 m N		641	emergent	60							0.30											0.10																	0.60							1.00
6-3	Near	C	419809.84 m E	5530485.63 m N		637	0.15	50									0.80																						0.20												1.00
6-3	Near	S	419848.40 m E	5530428.34 m N		639	0.1	70							0.30											0.10																	0.60							1.00
6-3	Mid	N	419793.02 m E	5530561.17 m N		641	0.3	60							0.10											0.20												0.40						0.30							1.00
6-3	Mid	C	419800.30 m E	5530485.99 m N		631	2	100					0.60													0.05					0.15				0.05	0.10		0.05													1.00
6-3	Mid	S	419861.03 m E	5530369.99 m N		632	0.5	40				0.04	0.01		0.05											0.90																									1.00
6-3	Far	N	419778.38 m E	5530585.40 m N		0	3	10																		1.00																									1.00
6-3	Far	C	419775.67 m E	5530471.24 m N		631	3.2	80					0.15												0.20						0.15				0.30	0.20															1.00
6-3	Far	S	419859.30 m E	5530345.11 m N		632	3	20																							0.80				0.10													0.10			1.00
4-4	Near	E	420452.46 m E	5532990.88 m N	6		0.22	100		0.03					0.90				0.05							0.03																									1.00
4-4	Near	C	420418.61 m E	5533011.00 m N	6		emergent	85									0.75																	0.01										0.24							1.00
4-4	Near	W	420379.68 m E	5533050.10 m N	5		emergent	75			0.02						0.90						0.03																			0.05									1.00
4-4	Mid	E	420452.16 m E	5532981.49 m N	15		0.5	95		0.01		0.07	0.15		0.65											0.10					0.02																				1.00
4-4	Mid	C	420418.42 m E	5532989.93 m N	27		0.91	100		0.25			0.01		0.55											0.04					0.15																				1.00
4-4	Mid	W	420379.66 m E	5533022.41 m N	34		0.76	80		0.01		0.04	0.05		0.80											0.05					0.05																				1.00
4-4	Far	E	420451.84 m E	5532973.24 m N	23		1.5	100		0.03		0.10	0.01		0.05				0.01						0.01	0.01					0.58								0.20												1.00
4-4	Far	C	420418.04 m E	5532972.71 m N	44		1.83	60		0.03		0.03	0.15		0.30											0.30					0.15					0.02					0.02										1.00
4-4	Far	W	420379.28 m E	5532997.19 m N	59		1.52	80				0.55	0.10													0.05					0.30																				1.00
4-4	Far-Far	E	420451.66 m E	5532951.08 m N	53		1.22	85				0.34	0.35													0.10					0.20						0.01														1.00
4-4	Far-Far	C	420417.90 m E	5532952.11 m N	65		1.37	100				0.60	0.20													0.03					0.10							0.05	0.01		0.01										1.00
4-4	Far-Far	W	420380.42 m E	5532972.03 m N	86		0.91	65		0.02		0.35	0.05		0.15											0.42					0.01																				1.00
3-6	Near	E	421762.44 m E	5535047.89 m N	28	648	1	60				0.05																			0.30				0.60													0.05			1.00
3-6	Near	C	421731.00 m E	5535136.00 m N	36		0.8	95				0.30																			0.05				0.05	0.60															1.00
3-6	Near	W	421711.00 m E	5535194.00 m N	24		0.5	100				0.60														0.30					0.04	0.05			0.01																1.00
3-6	Mid	E	421678.29 m E	5535028.10 m N	112	646	4	85																											1.00																1.00
3-6	Mid	C	421677.63 m E	5535129.97 m N	91	632	5.5	75				0.60																							0.40																1.00
3-6	Mid	W	421624.45 m E	5535162.89 m N	117	644	4.5	40				1.00																																							1.00
3-6	Far	E	421599.98 m E	5535000.44 m N	196	643	2.2	20																							0.60				0.40																1.00
3-6	Far	C	421521.03 m E	5535066.43 m N	259	645	2.2	85				0.60																			0.30				0.03	0.05					0.02										1.00
3-6	Far	W	421501.47 m E	5535092.51 m N	256	632	2.2	100				0.70	0.10																		0.10				0.05			0.05													1.00
2-13	Near	N	421161.60 m E	5539887.31 m N	20	650	1.2	80				0.10	0.01				0.01									0.07					0.10				0.01				0.70												1.00
2-13	Near	C	421176.65 m E	5539697.48 m N	22	637	0.15	90							0.30		0.30	0.10								0.30																									1.00
2-13	Near	S	421270.15 m E	5539577.56 m N	29	635	0.3	80									0.50									0.50																									1.00
2-13	Mid	N	421111.41 m E	5539852.13 m N	67	648	2.2	60					0.05																							0.95															1.00
2-13	Mid	C	421115.33 m E	5539665.13 m N	91	646	2.1	65					0.01													0.65					0.02					0.30					0.02										1.00
2-13	Mid	S	421253.44 m E	5539513.98 m N	95	640	1.9	100				0.01	0.01													0.15					0.03										0.80										1.00
2-13	Far	N	420980.04 m E	5539856.73 m N	195	644	5.9	30				0.85	0.05																						0.10																1.00
2-13	Far	C	421012.26 m E	5539621.61 m N	202	642	5.3	85				0.95																							0.05																1.00
2-13	Far	S	421186.17 m E	5539408.65 m N	216	639	3.2	30				0.70	0.01																		0.20				0.04	0.05															1.00
1-18	Near	N	421353.00 m E	5549570.00 m N	45		emergent	70									0.89				0.01			0.01																		0.02	0.01		0.01			0.05			1.00
1-18	Near	C	421299.00 m E	5549531.00 m N	21		emergent	85	0.03					0.02			0.80																0.10									0.02			0.01					0.02	1.00
1-18	Near	S	421267.00 m E	5549487.00 m N	35		emergent	60	0.08		0.01			0.07			0.70																									0.01		0.10		0.01	0.02				1.00
1-18	Mid	N	421369.67 m E	5549539.71 m N	78	640	0.4	80							0.02		0.85																					0.02			0.01		0.10								1.00
1-18	Mid	C	421323.46 m E	5549506.14 m N	54	643	1	25																														0.05	0.90				0.05								1.00
1-18	Mid	S	421277.45 m E	5549471.56 m N	52	639		60											0.85												0.05							0.05											0.05		1.00
1-18	Far	N	421365.62 m E	5549507.85 m N	107	635		20							0.01											0.38												0.60										0.01			1.00
1-18	Far	C	421338.76 m E	5549486.23 m N	79	643	1.52	80				0.03	0.03													0.40					0.05					0.10		0.40													1.00
1-18	Far	S	421303.51 m E	5549448.38 m N	87	645		20																		0.01													0.99												1.00
1-17	Near	E	421874.62 m E	5549559.66 m N	20	630	).1 / emerg	80		0.25									0.70							0.05																									1.00
1-17	Near	C	421732.04 m E	5549584.77 m N	17	630	ergent but	80									1.00																																		1.00
1-17	Near	W	421613.12 m E	5549578.06 m N	16	625	05 /emerg	50									1.00																																		1.00
1-17	Mid	E	421874.18 m E	5549524.75 m N	55	629	0.5	60					0.10		0.01		0.40		0.40							0.01					0.07										0.01										1.00
1-17	Mid	C	421724.63 m E	5549523.15 m N	79	626	0.75	100							0.30				0.20							0.30			0.05		0.10																		0.05		1.00
1-17	Mid	W	421614.06 m E	5549559.36 m N	35	625	0.4	100		0.25					0.25				0.15							0.25												0.10													1.00
1-17	Far	E	421886.47 m E	5549406.47 m N	172	643	1.83	40							0.03											0.25					0.02					0.10		0.60													1.00
1-17	Far	C	421718.92 m E	5549469.97 m N	132	631	2.44	65				0.09			0.10											0.80												0.01													1.00
1-17	Far	W	421609.91 m E	5549500.70 m N	95	629	1	100		0.20					0.30											0.50																									1.00
3-7	Near	N	421530.88 m E	5535455.05 m N	122	634	emergent	70									0.40				0.10																							0.50							1.00
3-7	Near	C	421615.00 m E	5535360.00 m N	85	0	emergent	95									0.02											0.02					0.05											0.90				0.01			1.00
3-7	Near	S	421569.34 m E	5535279.12 m N	73	640	emergent	90			0.03						0.40											0.07																0.50							1.00
3-7	Mid	N	421514.90 m E	5535451.51 m N	139	633	0.5	100				0.20	0.10		0.03												0.40				0.03										0.04			0.20							1.00
3-7	Mid	C	421518.00 m E	5535318.00 m N	192	0	0.2	100							0.05							0.03			0.01	0.15					0.48							0.02		0.01	0.05			0.20							1.00
3-7	Mid	S	421468.97 m E	5535190.07 m N	198	0	0.61	100				0.10	0.05		0.20											0.62												0.01						0.02							1.00
3-7	Far	N	421488.47 m E	5535463.79 m N	162	645	3	10				0.25																							0.15			0.60													1.00
3-7	Far	C	421454.00 m E	5535430.00 m N	245	0	2.74	100				0.60													0.09										0.30			0.01													1.00
3-7	Far	S	421351.01 m E	5535133.97 m N	250	0	3	100				0.40	0.35																		0.15				0.10																1.00
3-8	Near	N	421325.75 m E	5535436.82 m N	38	643	emergent	90		0.05						0.25																												0.70							1.00
3-8	Near	C	421266.56 m E	5535357.62 m N	83	642	emergent	90		0.05							0.25																											0.70							1.00
3-8	Near	S	421084.71 m E	5535196.26 m N	58	646	0.2	50																						0.05														0.95							1.00
3-8	Mid	N	421342.25 m E	5535422.45 m N	55	633	0.8	100				0.05			0.30											0.30				0.05	0.07				0.03			0.15			0.05										1.00
3-8	Mid	C	421299.92 m E	5535343.56 m N	119	631	0.46	100				0.04	0.01		0.05					0.10																		0.30			0.10			0.40							1.00
3-8	Mid	S	421144.66 m E	5535175.25 m N	122	636	0.7	100				0.04	0.01		0.05											0.90																									1.00
3-8	Far	N	421357.00 m E	5535411.00 m N	70	0	5.2	100				0.05			0.30											0.05				0.10					0.05			0.10			0.05			0.30							1.00
3-8	Far	C	421316.00 m E	5535338.00 m N	166	0	5.5	100				0.30																			0.01				0.25			0.30			0.14										1.00
3-8	Far	S	421204.64 m E	5535151.58 m N	186	638	5.5	100					0.05												0.10										0.75			0.05			0.05										1.00

Appendix 3-2

Charts

A1: Reservoir Daily Elevations (2000-2012)
A2: Reservoir Daily Elevations (2006 & 2011)
A3: Reservoir Daily Elevations (September 2006 & 2011)
A4: Water Quality Profiles

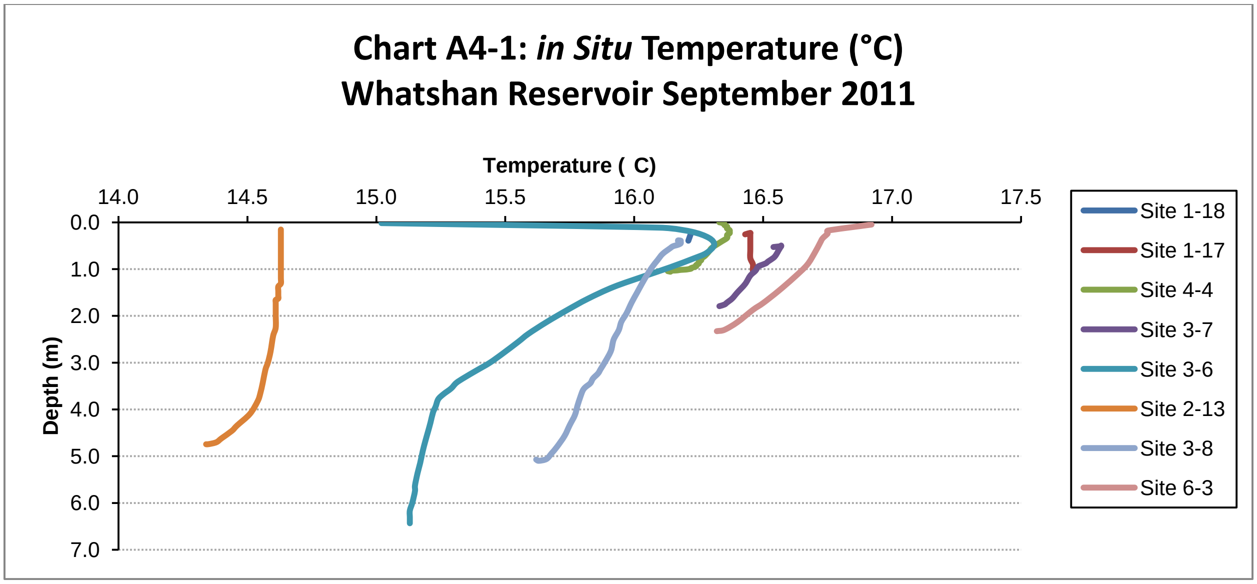


Chart A4-1: *in Situ* Temperature (°C)
Whatshan Reservoir September 2011
Temperature (C)
14.0
14.5
15.0
15.5
16.0
16.5
17.0
17.5
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Depth (m)
Site 1-18
Site 1-17
Site 4-4
Site 3-7
Site 3-6
Site 2-13
Site 3-8
Site 6-3

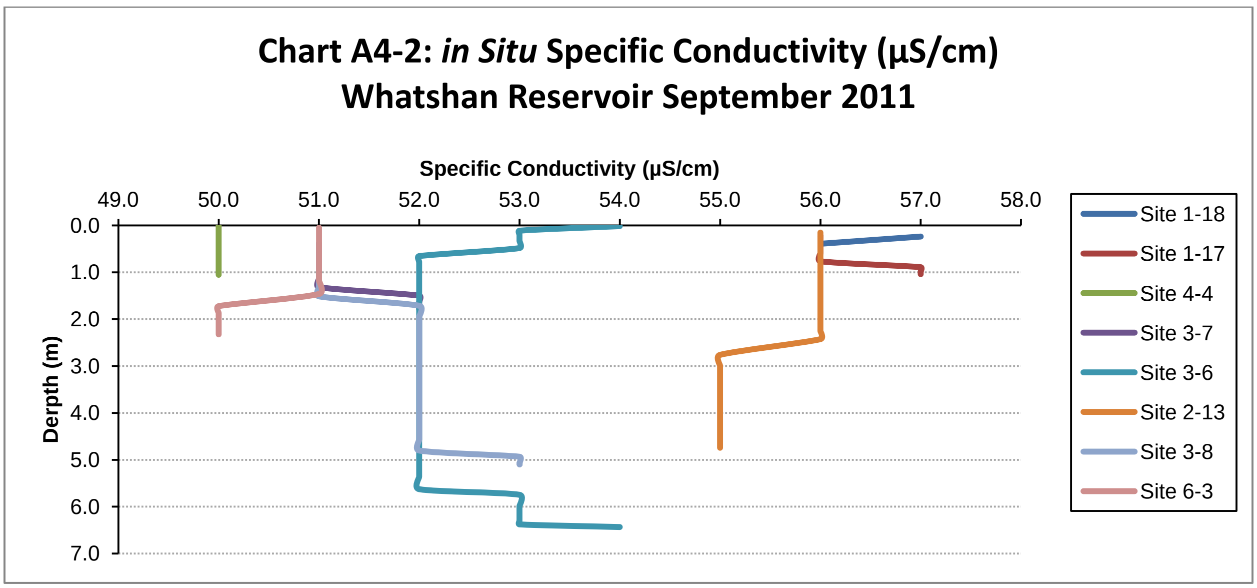


Chart A4-2: *in Situ* Specific Conductivity (µS/cm)
Whatshan Reservoir September 2011
Specific Conductivity (µS/cm)
49.0
50.0
51.0
52.0
53.0
54.0
55.0
56.0
57.0
58.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Derpth (m)
Site 1-18
Site 1-17
Site 4-4
Site 3-7
Site 3-6
Site 2-13
Site 3-8
Site 6-3

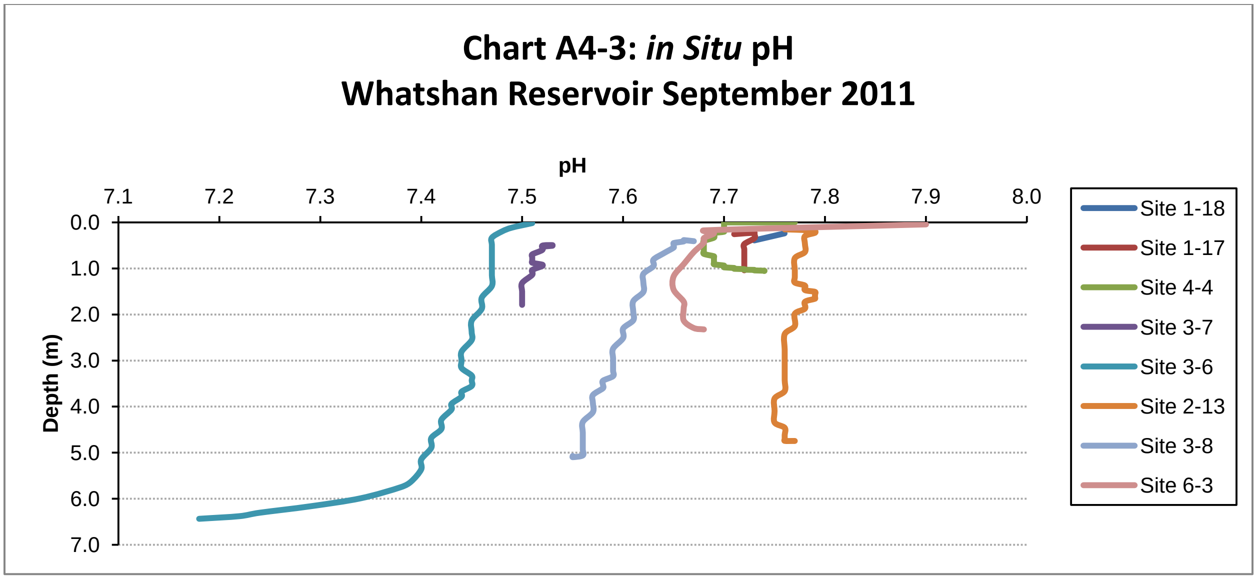


Chart A4-3: *in Situ* pH
Whatshan Reservoir September 2011
pH
7.1
7.2
7.3
7.4
7.5
7.6
7.7
7.8
7.9
8.0
Depth (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Site 1-18
Site 1-17
Site 4-4
Site 3-7
Site 3-6
Site 2-13
Site 3-8
Site 6-3

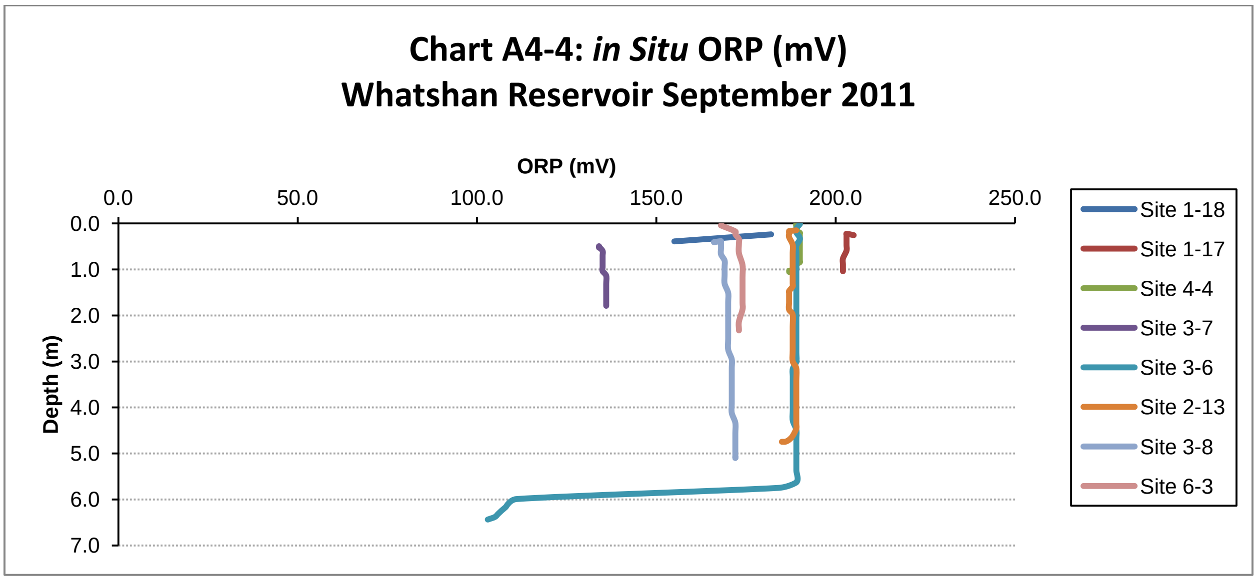


Chart A4-4: *in Situ* ORP (mV)
Whatshan Reservoir September 2011
ORP (mV)
0.0
50.0
100.0
150.0
200.0
250.0
Depth (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Site 1-18
Site 1-17
Site 4-4
Site 3-7
Site 3-6
Site 2-13
Site 3-8
Site 6-3

Chart A4-5: *in Situ* Turbidity (NTU) Whatshan Reservoir September 2011

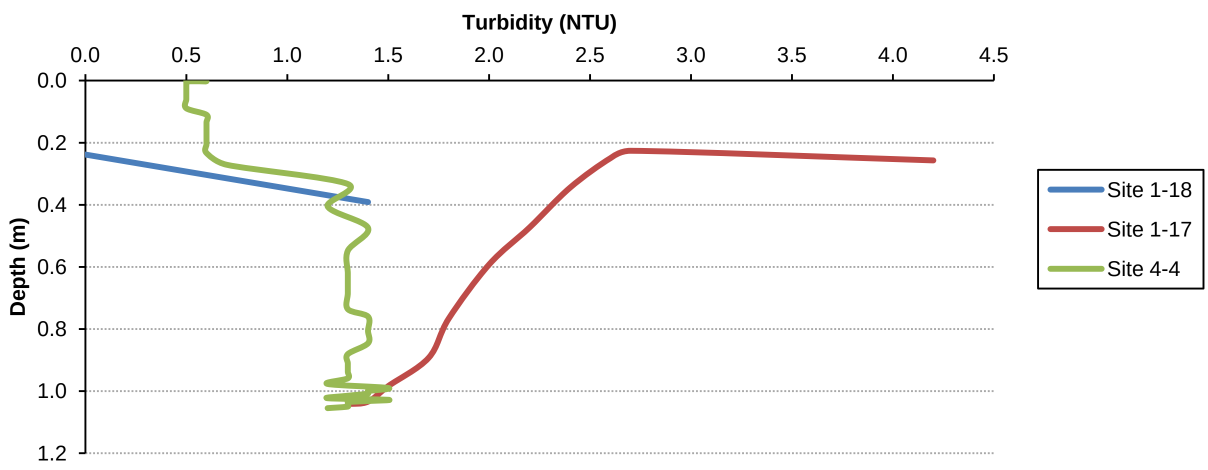
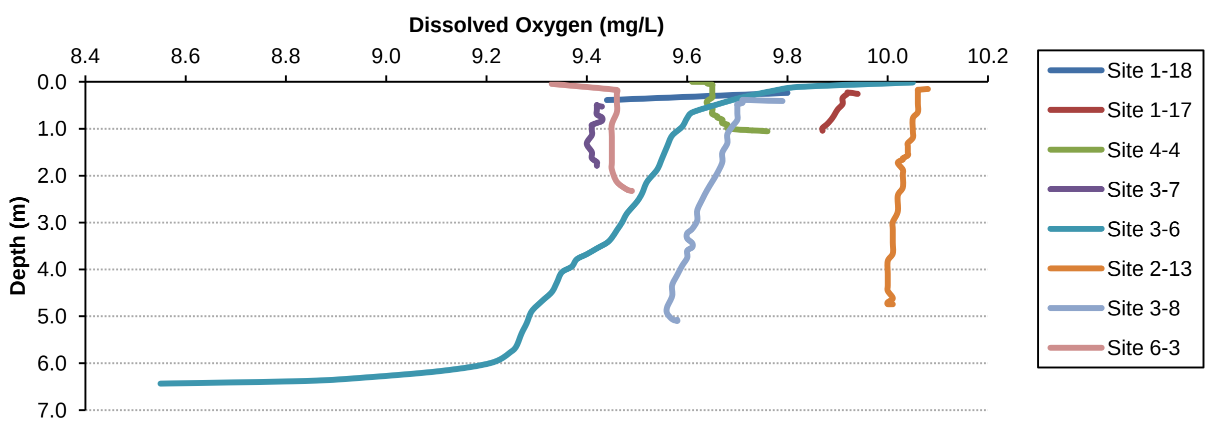


Chart A4-6: *in Situ* Dissolved Oxygen (mg/L) Whatshan Reservoir September 2011



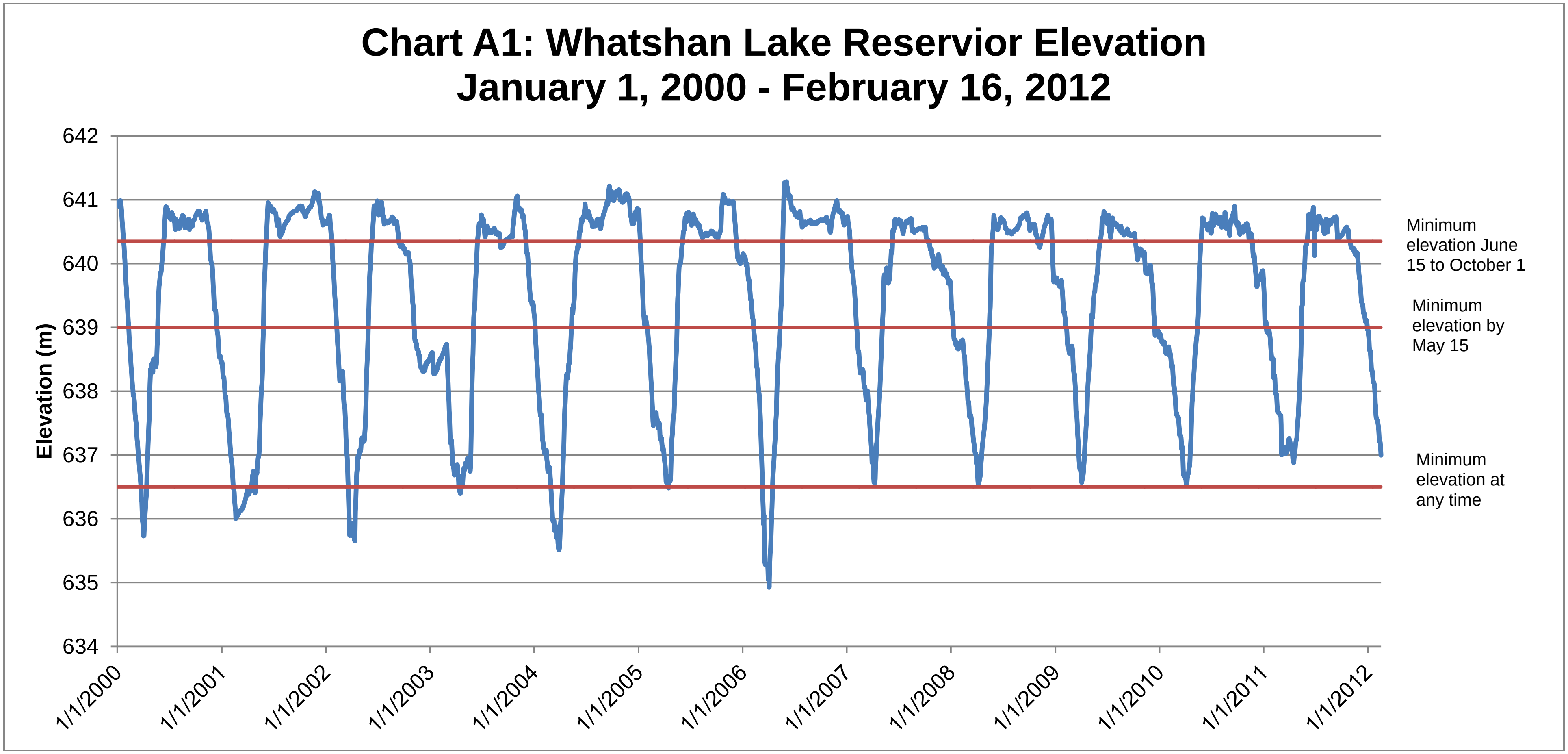


Chart A1: Whatshan Lake Reservior Elevation
January 1, 2000 - February 16, 2012
Elevation (m)
642
641
640
639
638
637
636
635
634
1/1/2000
1/1/2001
1/1/2002
1/1/2003
1/1/2004
1/1/2005
1/1/2006
1/1/2007
1/1/2008
1/1/2009
1/1/2010
1/1/2011
1/1/2012
Minimum elevation June 15 to October 1
Minimum elevation by May 15
Minimum elevation at any time

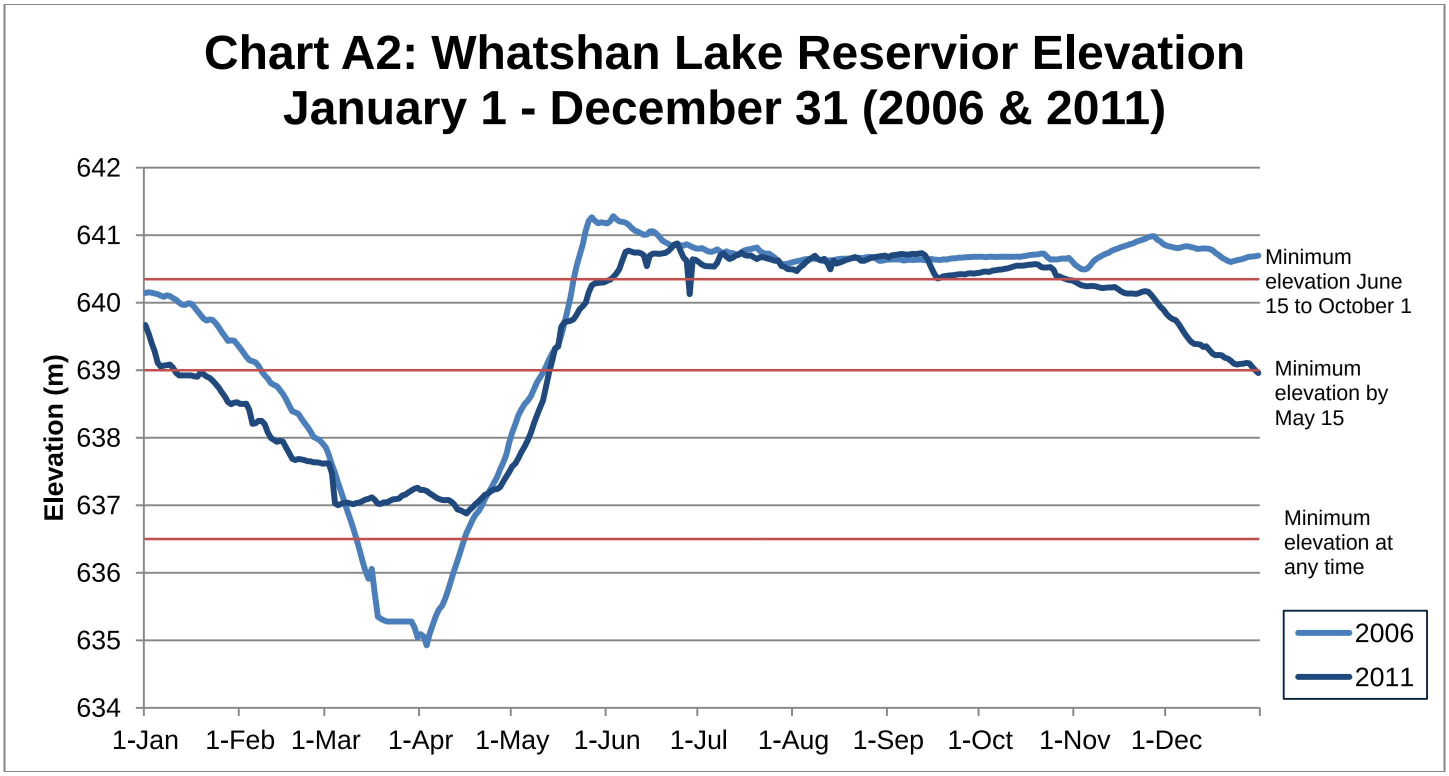


Chart A2: Whatshan Lake Reservior Elevation
January 1 - December 31 (2006 & 2011)
Elevation (m)
642
641
640
639
638
637
636
635
634
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
Minimum elevation June 15 to October 1
Minimum elevation by May 15
Minimum elevation at any time
2006
2011

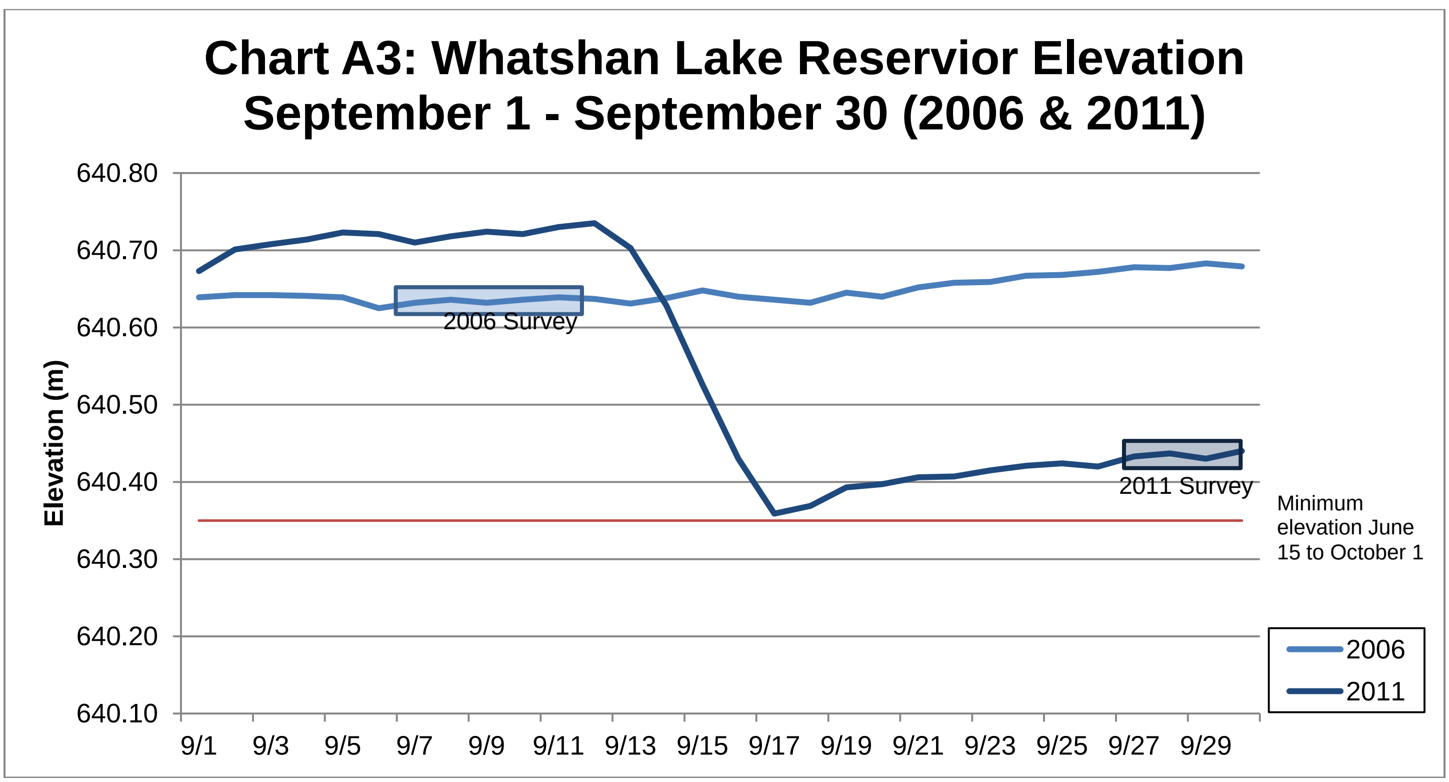


Chart A3: Whatshan Lake Reservior Elevation
September 1 - September 30 (2006 & 2011)
Elevation (m)
640.80
640.70
640.60
640.50
640.40
640.30
640.20
640.10
9/1
9/3
9/5
9/7
9/9
9/11
9/13
9/15
9/17
9/19
9/21
9/23
9/25
9/27
9/29
2006 Survey
2011 Survey
Minimum elevation June 15 to October 1
2006
2011

Appendix 4

Site Descriptions

4-1 Site 6-3
4-2 Site 4-4
4-3 Site 3-6
4-4 Site 3-7
4-5 Site 3-8
4-6 Site 2-13
4-7 Site 1-17
4-8 Site 1-18

TABLE A1-1: SITE 6-3 MACROPHYTE ECOLOGY

Near-Shore (Emergent)

Richness (# of taxa at genus level)	5	*Typha sp.* *Carex sp.* *Crassula aquatica* *Isoetes sp.* *Potamogeton sp.*	43.3% 22.2% 21.7% 7.2% 5.6%
Diversity (Shannon-Weaver H')	1.378		
Mean % Cover	60%		

Mid Distance from Shore (Transitional)

Richness (# of taxa at genus level)	7	*Tolypella sp.* *Isoetes sp.* *Potamogeton sp.* *Typha sp.* *Najas flexilis* *Crassula aquatica* *Chara sp.*	30.2% 26.5% 22.0% 9.0% 7.5% 4.0% 0.8%
Diversity (Shannon-Weaver H')	1.625		
Mean % Cover	66%		

Further from Shore (Submerged)

Richness (# of taxa at genus level)	6	*Potamogeton sp.* *Najas flexilis* *Myriophyllum sibiricum* *Tolypella sp.* *Isoetes sp.* unidentified aquatic moss	38.2% 25.5% 14.5% 10.9% 9.1% 1.8%
Diversity (Shannon-Weaver H')	1.529		
Mean % Cover	37%		

Site 6-3 Sediment Characteristics

Location	Depth (m)	Colour	Texture	Smell	Consistency	Homogeneous throughout
Near-Shore	0.15	dark brown	Gritty	odourless	Thick like pudding	yes
	Large pebbles in surface ~5mm to 30mm; below surface layer consists of brown mud; some woody debris present					
Mid Distance from Shore	2	brown-green	Gritty	odourless	Thick like pudding	yes
	Macrophytes in surface layer; fluffy subsurface layer then gravelly					
Further from Shore	3	gray-green	Gritty	H_2S	Falls apart into fluffy pellets	yes
	Some organic debris; some parts of the profile are thicker (globular masses)					

TABLE A1-2: SITE 4-4 MACROPHYTE ECOLOGY

Near-Shore (Emergent)

Richness (# of taxa at genus level)	6	*Carex sp.*	82.0%
Diversity (Shannon-Weaver H')	0.645	*Typha sp.*	12.8%
Mean % Cover	80%	*Comarum palustre L.*	2.3%
		Equisetum sp.	1.4%
		unidentified (chick weed)	0.9%
		Persicaria amphibia var. *emersa*	0.5%

Mid and Further distances from Shore (Submerged)

Richness (# of taxa at genus level)	10	*Crassula aquatica* (L.) Schoenl	28.7%
Diversity (Shannon-Weaver H')	1.781	*Chara sp.*	22.9%
Mean % Cover	78%	*Najas flexilis* (Willd.) Rostk. & Schmidt	18.0%
		Tolypella sp.	11.6%
		Isoetes sp.	10.3%
		Leptodictyum riparium	4.3%
		Potamogeton sp.	3.6%
		Ranunculus aquatilis	0.3%
		Eleocharis sp.	0.2%
		Myriophyllum sibiricum.	0.1%

Site 4-4 Sediment Characteristics

Location	Depth (m)	Colour	Texture	Smell	Consistency	Homogeneous throughout
Centre of Site	1.5	brown-green	Gritty	odourless	Thick like pudding	yes
	Macrophyte vegetation; stick; 1 pebble					
Mid Distance from Shore	0.5	dark brown	Silky	odourless	Thick like pudding	yes
	Macrophytes; woody debris; grey/white sediments (inclusion) streaked throughout					

TABLE A1-3: SITE 3-6 MACROPHYTE ECOLOGY			
Near-Shore (Emergent)			
Richness (# of taxa at genus level)	6	*Potamogeton sp.*	38.7%
Diversity (Shannon-Weaver H')	1.353	*Chara sp.*	35.9%
Mean % Cover	85%	*Isoetes sp.*	11.8%
		Najas flexilis	10.5%
		Nuphar lutea	2.0%
		unidentified aquatic moss	1.2%
Mid and Further distances from Shore (Submerged)			
Richness (# of taxa at genus level)	5	*Chara sp.*	50.9%
Diversity (Shannon-Weaver H')	1.077	*Potamogeton sp.*	34.5%
Mean % Cover	68%	*Najas flexilis*	11.7%
		Tolypella sp.	2.5%
		Ranunculus aquatilis	0.4%

Site 3-6 Sediment Characteristics

Location	Depth (m)	Colour	Texture	Smell	Consistency	Homogeneous throughout
Near-Shore	0.45	dark brown	Woody debris	Wood Chips	Loose	yes
	Wood Chips; macrophytes					
Mid Distance from Shore	6	brown-green	Silky	H_2S, algae	Falls apart into fluffy pellets	yes
	Few sticks					
Further from Shore	2	gray-green	Woody debris	H_2S	Falls apart into fluffy pellets	no
	Lots of wood chips; some macrophytes; macrophyte layer followed by fluffy Layer followed by woodchip Layer					

TABLE A1-4: SITE 3-7 MACROPHYTE ECOLOGY

Near-Shore (Emergent)

Richness (# of taxa at genus level)	7	*Typha sp.*	64.9%
Diversity (Shannon-Weaver H')	0.983	*Carex sp.*	25.8%
Mean % Cover	85%	*Mentha arvensis L.*	3.2%
		Equisetum sp.	2.7%
		Poaceae	1.9%
		unidentified (chick weed)	1.1%
		unidentified aquatic moss	0.4%

Mid Distance from Shore (Transitional)

Richness (# of taxa at genus level)	11	*Isoetes sp.*	25.7%
Diversity (Shannon-Weaver H')	2.023	*Najas flexilis*	17.0%
Mean % Cover	100%	*Typha sp..*	14.0%
		Juncus sp.	13.3%
		Chara sp.	10.0%
		Crassula aquatica	9.3%
		Tolypella sp.	5.0%
		Ranunculus aquatilis	3.0%
		Potamogeton sp.	1.3%
		Equisetum sp.	1.0%
		Myriophyllum sibiricum	0.3%

Further from Shore (Submerged)

Richness (# of taxa at genus level)	5	*Chara sp.*	48.8%
Diversity (Shannon-Weaver H')	1.311	*Potamogeton sp.*	23.1%
Mean % Cover	70%	*Tolypella sp.*	16.7%
		Najas flexilis	7.1%
		Myriophyllum sibiricum	4.3%

Site 3-7 Sediment Characteristics

Location	Depth (m)	Colour	Texture	Smell	Consistency	Homogeneous throughout
Near-Shore	emergent	dark brown	Rooty	Soil	Thick like pudding	yes
	Lots of organic debris, roots + detritus					
Mid Distance from Shore	0.2	brown-green	Gritty	odourless	Thick like pudding	yes
	Organic debris/detritus, roots throughout; some wood chunks; surface covered in macrophytes (small sedges)					
Further from Shore	3	gray-green	Gravelly	H_2S	Loose	yes
	some macrophytes; small woodchips					

TABLE A1-5: SITE 3-8 MACROPHYTE ECOLOGY

Near-Shore (Emergent)

Richness (# of taxa at genus level)	4	*Typha sp.*	75.4%
Diversity (Shannon-Weaver H')	0.708	*Carex sp.*	19.6%
Mean % Cover	77%	*Leptodictyum riparium*	3.9%
		Utricularia sp.	1.1%

Mid and Further distances from Shore (Submerged)

Richness (# of taxa at genus level)	11	*Potamogeton sp.*	33.0%
Diversity (Shannon-Weaver H')	1.912	*Isoetes sp.*	20.8%
Mean % Cover	100%	*Crassula aquatica*	11.7%
		Typha sp.	11.7%
		Chara sp.	8.0%
		Ranunculus aquatilis	6.5%
		Utricularia sp.	2.5%
		Schoenoplectus tabernaemontani	1.7%
		Myriophyllum sibiricum	1.7%
		Najas flexilis	1.3%
		Tolypella sp.	1.2%

Site 3-8 Sediment Characteristics

Location	Depth (m)	Colour	Texture	Smell	Consistency	Homogeneous throughout
Near-Shore	emergent, but wet	dark brown	Woody debris	odourless	Woody debis	yes
	Almost entirely roots & woody debris; some moss on surface					
Mid Distance from Shore	0.45	gray-green	Gritty	H_2S	Thick like pudding, debris laden	no
	Many macrophytes on surface- subsurface decaying macrophytes; wood & large sticks; very thick macrophyte layer.					
Further from Shore	5.5	gray-green	Gritty	H_2S	Thick like pudding	yes
	Sticks (small); macrophytes.					

TABLE A1-6: SITE 2-13 MACROPHYTE ECOLOGY

Near-Shore (Emergent)

Richness (# of taxa at genus level)	8	*Isoetes sp.*	29.0%
Diversity (Shannon-Weaver H')	1.648	*Carex sp.*	27.1%
Mean % Cover	83%	*Potamogeton sp.*	22.7%
		Crassula aquatica	10.8%
		Eleocharis sp.	3.6%
		Chara sp.	3.2%
		Najas flexilis	3.2%
		Tolypella sp.	0.3%

Mid Distance from Shore (Transitional)

Richness (# of taxa at genus level)	6	*Ranunculus aquatilis*	36.1%
Diversity (Shannon-Weaver H')	1.263	*Potamogeton sp.*	34.0%
Mean % Cover	75%	*Isoetes sp.*	25.4%
		Tolypella sp.	2.1%
		Najas flexilis	1.9%
		Chara sp.	0.4%

Further from Shore (Submerged)

Richness (# of taxa at genus level)	4	*Chara sp.*	87.8%
Diversity (Shannon-Weaver H')	0.485	*Potamogeton sp.*	6.9%
Mean % Cover	48%	*Najas flexilis*	4.1%
		Tolypella sp.	1.2%

Site 2-13 Sediment Characteristics

Location	Depth (m)	Colour	Texture	Smell	Consistency	Homogeneous throughout
Near-Shore	0.15	gray-green	Silky, some grit	odourless	Falls apart into fluffy pellets	yes
	Dense macrophytes and roots; some white inclusions throughout sediment					
Mid Distance from Shore	2.1	gray-green	Gravelly	odourless	Thick like pudding	yes
	Macrophytes; black organic flecking throughout					
Further from Shore	5.8	dark brown	Woody debris	odourless	Loose	no
	Woodchips and small sticks; fish in sample; brown-green subsurface; gravelly					

TABLE A1-7: SITE 1-18 MACROPHYTE ECOLOGY

Near-Shore (Emergent)

Richness (# of taxa at genus level)	15	*Carex sp.*	80.1%
Diversity (Shannon-Weaver H')	0.948	*Poaceae*	4.0%
Mean % Cover	72%	*Calliergonella cuspidata*	3.4%
		Typha sp.	2.8%
		Climacium dendroidies	2.7%
		Comarum palustre L.	1.7%
		unidentified aquatic moss	1.6%
		Unidentified *Rosaceae*	0.8%
		Viola orbiculata	0.7%
		Athyrium felix-femina	0.6%
		Equisetum sp.	0.3%
		Rhododendron groenlandicum	0.3%
		Fragaria virginiana	0.3%
		unidentified (chick weed)	0.3%
		Beluta sp.	0.3%

Mid Distance from Shore (Transitional)

Richness (# of taxa at genus level)	8	*Carex sp.*	41.2%
Diversity (Shannon-Weaver H')	1.409	*Eleocharis sp.*	30.9%
Mean % Cover	55%	*Potamogeton sp.*	17.2%
		Fragaria virginiana	5.6%
		Najas flexilis	1.8%
		unidenfied Leafy pond-weed	1.8%
		Crassula aquatica	1.0%
		Ranunculus aquatilis	0.5%

Further from Shore (Submerged)

Richness (# of taxa at genus level)	7	*Potamogeton sp.*	59.8%
Diversity (Shannon-Weaver H')	0.945	*Isoetes sp.*	33.2%
Mean % Cover	40%	*Najas flexilis*	3.3%
		Chara sp.	1.7%
		Tolypella sp.	1.7%
		Crassula aquatica	0.2%
		unidentified aquatic moss	0.2%

Site 1-18 Sediment Characteristics

Location	Depth (m)	Colour	Texture	Smell	Consistency	Homogeneous throughout
Mid Distance from Shore	1	dark brown	Woody debris	odourless	Loose, woody debris	yes
	Wood Chips; a few long sticks; organic detritus; fine woody debris					
Further from Shore	1.5	gray-green	Gritty	H_2S	Thick like pudding	yes
	Fine organic detritus on surface layer; Macrophytes; small woody debris; Brown surface Layer					

TABLE A1-8: SITE 1-17 MACROPHYTE ECOLOGY

Near-Shore (Emergent)

Richness (# of taxa at genus level)	4	Carex sp.	61.9%
Diversity (Shannon-Weaver H')	0.949	Eleocharis sp.	26.7%
Mean % Cover	70%	Leptodictyum riparium	9.5%
		Isoetes sp.	1.9%

Mid Distance from Shore (Transitional)

Richness (# of taxa at genus level)	11	Eleocharis sp.	22.7%
Diversity (Shannon-Weaver H')	1.978	Crassula aquatica	21.4%
Mean % Cover	87%	Isoetes sp.	21.4%
		Leptodictyum riparium	9.6%
		Carex sp.	9.2%
		Najas flexilis	5.5%
		Potamogeton sp.	3.8%
		Tolypella sp.	2.3%
		Utricularia sp.	1.9%
		unidenfied Leafy pond-weed	1.9%
		Ranunculus aquatilis	0.2%

Further from Shore (Submerged)

Richness (# of taxa at genus level)	6	Isoetes sp.	54.6%
Diversity (Shannon-Weaver H')	1.267	Crassula aquatica	18.4%
Mean % Cover	68%	Potamogeton sp.	14.0%
		Leptodictyum riparium	9.8%
		Chara sp.	2.9%
		Najas flexilis	0.4%

Site 1-17 Sediment Characteristics

Location	Depth (m)	Colour	Texture	Smell	Consistency	Homogeneous throughout
Near-Shore	emergent	dark brown	Woody debris	odourless	Thick like pudding	yes
	Organic debris/detritus, roots throughout; surface covered in macrophytes (small sedges)					
Mid Distance from Shore	0.75	brown-green	Gritty	odourless	Thick like pudding	yes
	Fine gravel; surface plant layer; aquatic macrophytes					
Further from Shore	2.4	gray-green	Gritty	odourless	Thick like pudding	no
	Macrophytes; small organic debris; very few woodchips					

Appendix 5

Macrophyte Ecology

Potamageton natans — Floating-leaved Pondweed

General Description

Classification

Kingdom Plantae – Plants
Subkingdom Tracheobionta – Vascular plants
Superdivision Spermatophyta – Seed plants
Division Magnoliophyta – Flowering plants
Class Liliopsida – Monocotyledons
Subclass Alismatidae
Order Najadales
Family Potamogetonaceae – Pondweeds
Genus Potamogeton L. – pondweed

Native Status

Native in Canada, Alaska, and Continental USA

Duration

Perennial

Threatened & Endangered Information

Not threatened

Habitat

Shallow lentic waters up to 3 m deep in fresh or brackish water, circumboreal

Growth Habit

Unknown

Morphology / Physiology

Active Growth Period

Summer

Growth Rate

Rapid

Growth Form

Rhizomatous

Growth Form

Long slender stems up to 2 mm thick and 1.5 m long extend from extensive submerged rhizomes.

Nitrogen Fixation

None

Foliage

Foliage is coppery-green. Floating Leaves are long and elliptical with a waxy – leathery texture. Submerged leaves are 1 - 2 mm wide and 5 - 20 cm long. Spirally arranged. Foliage is porous year-round.

Fruit/Seed Colour

Seeds are inconspicuous, semi-fleshy sessile Achenes; greenish brown in colour with a single diploid seed (2n = 52). Seeds are non-toxic.

Flowers

Produces inconspicuous green flowers which are tiny, stalkless, and whorled with 4 segments. There are 4 ovaries and 4 stamens present.

Growth Requirements

Soil Requirements

Rhizomous roots require 0 cm soil depth and are not adapted to a particular soil type. Requires submerged soils with medium fertility and medium C:N Ratios.

Hardiness

Minimum temperature tolerance of -38.9 °C; acceptable pH range of 5.8 – 7.0. High tolerance for anaerobic conditions. Requires 90 frost free days per annum and is shade intolerant. Found in regions with 30 – 140 cm of annual precipitation.

Reproduction

Bloom Period

Blooms in mid-summer and produces seeds from summer – fall.

Propagation Vectors

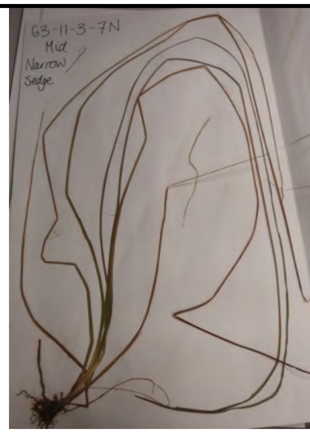
Can be propagated by bare roots, sprigs or seeds.
Forms extensive rhizomes that produce overwintering tubers.

Propagation Rate

Spread by seeds is slow due to low seed production and low seedling vigour. Vegetative spread is rapid.

Carex essicata, L.H. Bailey — Inflated Sedge

General Description



Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Liliopsida* – Monocotyledons
Subclass *Commelinidae*
Order *Cyperales*
Family *Cyperaceae* – Sedge family
Genus *Carex* L. – sedge

Native Status

Native to BC

Duration

Perennial

Threatened & Endangered Information

Not Threatened

Habitat

Found along shores of lakes, rivers, also in marshes, fens and wet meadows from 100 – 1890 m elevation. Typically within lowland and montane zones.

Synonyms

Synonymous with *Carex vesicaria* var. *major* Boott

Morphology / Physiology

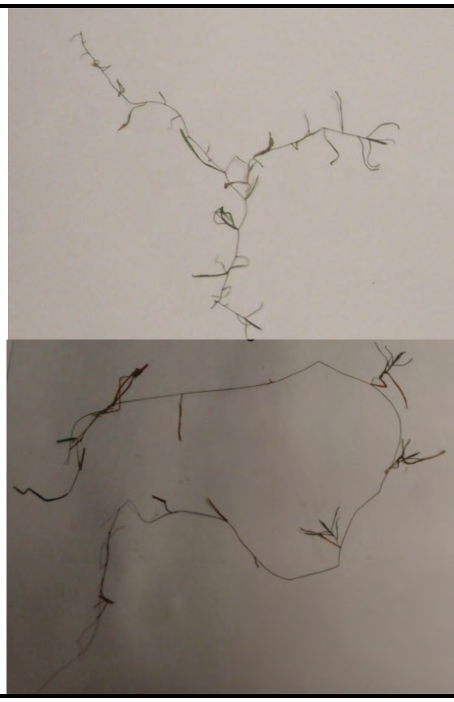
Foliage Texture	Inflorescence	Fruit/Seed Colour
Leaves are basal and cauline. Blades are flat and V shaped with a distinct midvein.	Stems protrude 30 – 100 cm from the base and are taller than leaves. Inflorescence are terminal with have 4 - 7 spikes.	Perigynia lanceolate, 7 - 10 mm long, 1.5 - 3 mm wide. Yellow-green to reddish-brown in colour Produces seeds from June – September.
Shape and Orientation		
Tufted herb with creeping rhizomes.		

Growth Requirements

Soil Texture (Coarse – Fine)	Cold Stratification Required	Temperature Tolerance (°C)
Not available	Not available	Not available
Anaerobic Tolerance	**Soil Fertility**	**pH Tolerance**
Not available	Rich	Not available
Precipitation, Min – Max	**Shade Tolerance**	**Submergence Tolerance**
Not available	Not available	Can persist in up to 0.50 m water

Potamogeton, Foliosus — Leafy Pondweed

General Description



Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Liliopsida* – Monocotyledons
Subclass *Alismatidae*
Order *Najadales*
Family *Potamogetonaceae* – Pondweeds
Genus *Potamogeton L.* – pondweed

Native Status

Native to BC, Canada and the US including Hawaii and Puerto Rico

Duration

Perennial

Threatened & Endangered Information

Endangered in Maryland and New Hampshire

Habitat

Submerged macrophyte existing in shallow water up to 1.2 m deep with soft sediments.

Growth Habit

Forb/Herb

Morphology / Physiology

Active Growth Period	**Flower Colour**	**Fruit/Seed Colour**
Spring and Summer	Green	Brown
Growth Rate	**Flower Conspicuous**	**Fruit/Seed Conspicuous**
Moderate	No	No
Growth Form	**Foliage Texture**	**Toxicity**
Single Crown	Fine	None
Shape and Orientation	**Foliage Colour**	**Fall Conspicuous**
Prostate	Green	No
C:N Ratio	**Foliage Porosity Summer**	**Known Allelopath**
Medium	Porous	No
Nitrogen Fixation	**Foliage Porosity Winter**	
None	Porous	

Growth Requirements

Soil Requirements	**Hardiness**
Rhizomous roots require 0 cm soil depth and are not adapted to a particular soil type. Requires submerged soils with medium fertility and medium C:N Ratios.	Minimum temperature tolerance of -38.9 °C; acceptable pH range of 5.5 – 7.0. High tolerance for anaerobic conditions. Requires 100 frost free days per annum and is shade intolerant. Found in regions with 30 – 140 cm of annual precipitation.

Reproduction

Bloom Period	**Propagated by Bare Root**	**Seed Spread Rate**
Late Spring	Yes	Moderate
Fruit/Seed Abundance	**Propagated by Sprigs**	**Seeding Vigor**
Medium	Yes	Medium
Fruit/Seed Period	**Propagated by Seed**	**Vegetative Spread Rate**
Summer	Yes	Slow
Fruit/Seed Persistence	**Propagated by Tubers**	
No	No	

Potamogeton epihydrous Ribbonleaf pondweed

General Description

Classification	Kingdom *Plantae* – Plants Subkingdom *Tracheobionta* – Vascular plants Superdivision *Spermatophyta* – Seed plants Division *Magnoliophyta* – Flowering plants Class *Liliopsida* – Monocotyledons Subclass *Alismatidae* Order *Najadales* Family *Potamogetonaceae* – Pondweeds Genus *Potamogeton* L. – pondweed
Native Status	Native to BC, Canada and the US including Hawaii and Puerto Rico
Duration	Perennial
Threatened & Endangered Information	BC Yellow listed, Endangered in parts of SE USA.
Habitat	Found in lakes, ponds, ditches in lowland to subalpine zones.
Growth Habit	Monocot Forb/Herb

Morphology / Physiology

Active Growth Period	Flower Colour	Foliage Texture
Summer and Fall	Inconspicuous and green. Inflorescence is spike-like with spikes 2 - 4 cm long containing 5 - 12 whorls.	Foliage is fine, green and remains porous in Winter and Summer. Leaves are ribbon-like, between 3 - 7 mm wide and 1 - 20 cm long. Broad translucent bands run along mid-veins.
Growth Rate		
Rapid, from a single crown.		
Shape and Orientation	**C:N Ratio**	
Prostrate	Medium	
Fruit/Seed Colour Fa	**ll Conspicuous**	
Globe shaped, brown achenes	No	

Growth Requirements

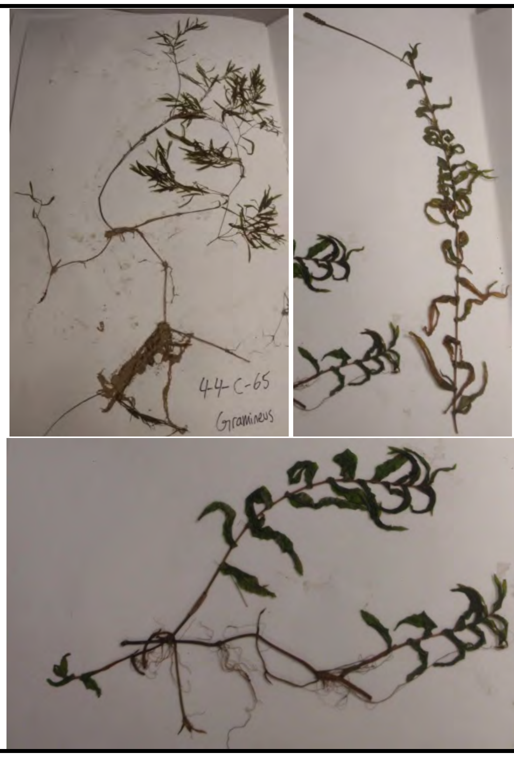
Soil Requirements	Hardiness
Rhizomous roots require 0 cm soil depth and are not adapted to a particular soil type. Requires submerged soils with medium fertility and medium C:N Ratios.	Minimum temperature tolerance of -33.0 °C; acceptable pH range of 5.4 – 7.0. High tolerance for anaerobic conditions. Requires 100 frost free days per annum and is shade intolerant. Found in regions with 35 – 140 cm of annual precipitation.

Reproduction

Bloom Period	Propagated by Bare Root	Seed Spread Rate
Mid Summer	Yes	Moderate
Fruit/Seed Abundance	**Propagated by Sprigs**	**Seeding Vigor**
Medium	Yes	Medium
Fruit/Seed Period	**Propagated by Seed**	**Vegetative Spread Rate**
Summer - Fall	Yes	Slow
Fruit/Seed Persistence	**Propagated by Tubers**	
No	No	

Potamogeton gramineus — Variable-leaf Pondweed

General Description



Classification

Kingdom Plantae – Plants
Subkingdom Tracheobionta – Vascular plants
Superdivision Spermatophyta – Seed plants
Division Magnoliophyta – Flowering plants
Class Liliopsida – Monocotyledons
Subclass Alismatidae
Order Najadales
Family Potamogetonaceae – Pondweeds
Genus Potamogeton L. – pondweed

Native Status

Native to BC and most of North America

Duration

Perennial

Threatened & Endangered Information

Not Threatened

Habitat

Lakes and lake margins, bogs and lentic water systems in all but the alpine zone. Primarily Interior Douglas Fir Biogeoclimatic zone.

Growth Habit

unknown

Morphology / Physiology

Active Growth Period	Flower Colour	Fruit/Seed Colour
Spring and Summer	Inflorescence are spike-like 2 - 4 cm long with 5 - 10 whorls	Globe shapes achenes with short beaks and sharp prominent keels.
Shape and Orientation	**Foliage Texture**	**Growth Rate**
Aquatic or semi-terrestrial herbaceous plant with strong rhizomes. Stems can extend up to 150 cm and are approximately circular. Prostrate.	Submerged leaves are lanceolate, thin, flat and green.	Rapid growth from a single crown.
		C:N Ratio
		Medium

Growth Requirements

Soil Requirements	Hardiness
Rhizomous roots require 0 cm soil depth and are not adapted to a particular soil types. Requires submerged soils with medium fertility and medium C:N Ratios.	Minimum temperature tolerance of -38.9 °C; acceptable pH range of 5.5 – 7.0. High tolerance for anaerobic conditions. Requires 90 frost free days per annum and is shade intolerant. Found in regions with 30 – 140 cm of annual precipitation.

Reproduction

Bloom Period	Propagated by Bare Root	Seed Spread Rate
Late Spring	Yes	Moderate
Fruit/Seed Abundance	**Propagated by Sprigs**	**Seeding Vigor**
Low	Yes	Low
Fruit/Seed Period	**Propagated by Seed**	**Vegetative Spread Rate**
Summer	Yes	Slow
Fruit/Seed Persistence	**Propagated by Tubers**	
No	No	

Eleocharis palustris (L.) Roem & J.A. Schoenl — Common Spikerush

General Description


Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Liliopsida* – Monocotyledons
Subclass *Commelinidae*
Order *Cyperales*
Family *Cyperaceae* – Sedge family
Genus *Eleocharis* R. Br. - Spikerush

Native Status

Native throughout North America

Duration

Perennial Monocot

Threatened & Endangered Information

Not Threatened

Habitat

Obligate wetland species, thrives in water up to 1 m deep and up to 30 cm above water table (seasonally). Found up to 3000 m elevation.

Growth Habit

Graminoid

Morphology / Physiology

Shape and Orientation	Flower Colour	Fruit/Seed Colour
Strongly rhizomatous, develops thick root mass resistant to erosion.	Stems 10 – 70 cm tall, topped with terminal spikelet with multiple inconspicuous brown flowers.	Yellow – Brown bristled achene, 1.5 – 2.5 mm long
Active Growth Period	**C:N Ratio**	**Foliage Colour**
Spring	High	Dark green fine foliage porous in winter and moderately porous in summer.

Growth Requirements

Soil Requirements	Hardiness
Suited to moisture saturated fine-textured soils. High tolerance for anaerobic conditions.	Tolerates temperatures down to -38.9 °C and is found in areas with 40 – 152 cm of annual precipitation. Tolerates pH ranges from 4.0 – 8.0

Reproduction

Bloom Period	Propagated by Bare Root	Seed Spread Rate
Late Spring	No	Moderate
Fruit/Seed Abundance	**Propagated by Sprigs**	**Seeding Vigor**
Medium	Yes	Medium
Fruit/Seed Period	**Propagated by Seed**	**Vegetative Spread Rate**
Fall	Yes	Moderate
Fruit/Seed Persistence	**Propagated by Tubers**	
No	No	

Typha angustifolia L. — Narrowleaf Cattail

General Description

Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Liliopsida* – Monocotyledons
Subclass *Commelinidae*
Order *Typhales*
Family *Typhaceae* – Cat-tail family
Genus *Typha L.* - Cattail

Native Status

Native to BC, MN, SK, ON, QC and maritime provinces. Introduced in US.
May also be *Typha latifolia*

Duration

Perennial, Monocot

Threatened & Endangered Information

Not Threatened

Habitat

Brackish - subsaline waters through 0 – 1900 m elevation

Growth Habit

Forb / Herb

Morphology / Physiology

Foliage Texture	Flower Colour	Fruit/Seed Colour
Foliage is green, coarse and porous year round.	Flowering shoots 5 – 12 mm thick, reduced to 2 – 3 mm thick in inflorescence. Flowers are brown and inconspicuous	Seeds/fruits are brown and conspicuous, 2n = 30.
Active Growth Period	**Growth Form**	**Toxicity**
Spring and Summer	Rhizomatous	None
Shape and Orientation	**C:N Ratio**	
Erect shoots, 150 – 300 cm.	High	

Growth Requirements

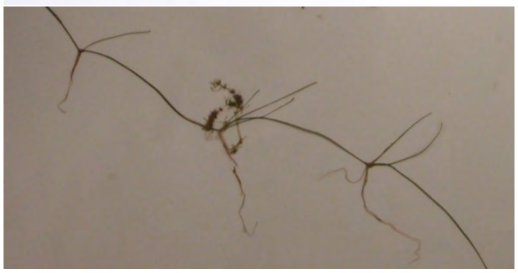
Soil Requirements	Hardiness
Adapted to coarse – fine sediment types. In soils with medium fertility. Roots require a minimum of 45 cm depth.	Requires 100 frost free days per annum and can tolerate temperatures to -37 °C. pHs of 5.5 – 8.7 are tolerated.
Anaerobic Tolerance	**Shade Tolerance**
High	Intermediate

Reproduction

Bloom Period	Propagated by Bare Root	Seed Spread Rate
Late Spring	Yes	Moderate
Fruit/Seed Abundance	**Propagated by Sprigs**	**Seeding Vigor**
High	Yes	Medium
Fruit/Seed Period	**Propagated by Seed**	**Vegetative Spread Rate**
Fall	Yes	Rapid
Fruit/Seed Persistence	**Propagated by Tubers**	
Yes	No	

Isoetes sp. Quillworts

General Description



Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Division *Lycopodiophyta* – Lycopods
Class *Lycopodiopsida* – Monocotyledons
Order *Isoetales*
Family *Isoetaceae* – Quillwort family
Isoetes L. – quillwort
Most Likely Species: *I. occidentalis* or *I. howelli,*
Also possibilities: *I. minima, I. xpseudotruncata, I. tenella.*
In area, but not ID'd: *I. nuttallii, I. maratima*

Native Status

Several Native species in BC

Duration

Perennial

Threatened & Endangered Information

Most species not threatened
Isoetes nuttallii is listed as sensitive in Washington.
Other threatened/endangered taxa are not present in BC.

Habitat

Lakes in lowland to subalpine zones, lacustrine or lentic waters. Habitat is used to delineate taxa. Mostly submerged individuals in Whatshan Reservoir.

Growth Habit

Graminoid, fern allies

Morphology / Physiology

Shape and Orientation	Fruit/Seed Colour	Flower Colour
Small and upright with short-lobed rootstock.	Spores stored within rootstock. Sporangia ovoid to ellipsoid. Spores cristulate with distinctive tri-lateral ridge	n/a
Growth Form	**Foliage Colour**	**Foliage Texture**
Propagated by spores	Green	Fine

Crassula aquatic (L.) Schoenl — Water Pygmyweed

General Description

Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Magnoliopsida* – Dicotyledons
Subclass *Rosidae*
Order *Rosales*
Family *Crassulaceae* – Stonecrop family
Genus *Crassula L.* - pygmyweed

Native Status

Native to North America, widespread in southern BC.

Duration

Annual, usually co-dominant

Threatened & Endangered Information

Not threatened in Canada
Endangered/extirpated in Connecticut, Maryland, New York, New Hampshire and Pennsylvania.
Threatened in Massachusetts and Minnesota.

Habitat

Brackish mudflats, pools, margins of ponds, coastal marshes and stream sides. 0 – 3000 m elevation.

Growth Habit

Weak annual herb, nodal roots.

Morphology / Physiology

Shape and Orientation	Foliage Texture	Fruit/Seed Colour
Roots at basal nodes, branching at the base.	Succulent opposite leaves, Oblancoleate leaf blades 2 - 6 mm	Oblong ellipsoid seeds (2n=42) from follicles (6-12 seeds per follicle).
Bloom Period	**Foliage Colour**	**Fruit/Seed Conspicuous**
Late Spring - Summer	Green	No

Ranunculus aquatilis L. White Water-crowsfoot

General Description

Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Magnoliopsida* – Dicotyledons
Subclass *Magnolidae*
Order *Ranunculales*
Family *Ranunculaceae* – Buttercup family
Genus *Ranunculus L.* - Buttercup

Native Status

Native to Canada, Alaska and the continental US.

Duration

Perennial

Threatened & Endangered Information

Not threatened

Habitat

Ponds, lakes, streams, ditches and river edges form 0 – 3,200 m.

Growth Habit

Forb/Herb

Morphology / Physiology

Shape and Orientation	Foliage Texture	Toxicity
Rooting from nodes of lower stems. Stems are weak with few branches, creeping and mat forming.	Filiform dissected, connate leaves. Leaves are all alternate stemmed, typically kidney shaped with three parts (5 – 8 mm long).	All parts of plant are poisonous when fresh. Leaves of *R. aquatilis capillaceous* are used to treat fevers and asthma in India.
Known Allelopath	**Flower Colour**	**Fruit/Seed Colour**
Inhibits growth of nearby plants, particularly legumes	White , self compatible, hermaphroditic flowers	Fruiting pedicles recurved, producing hemispheric achenes. Taxonomy unclear.

Growth Requirements

Soil Texture (Coarse – Fine)	Shade Tolerance	pH Tolerance
Suited to sandy, loamy and clay soils. Requires moist soils or submergence.	Semi-shade to full sun	Wide tolerance
Bloom Period		
Late Spring - Summer		

Najas flexilis — Nodding Waternymph

General Description

Classification

Kingdom Plantae – Plants
Subkingdom Tracheobionta – Vascular plants
Superdivision Spermatophyta – Seed plants
Division Magnoliophyta – Flowering plants
Class Liliopsida – Monocotyledons
Subclass Alismatidae
Order Najadales
Family Najadaceae – Water-Nymphs
Genus *Najas L.* - waternymph

Native Status

Native to Canada, Alaska, and parts of the USA

Duration

Annual Monocot

Threatened & Endangered Information

Not Threatened

Habitat

Shallow fresh or brackish waters, Lakes and Rivers 0 – 1,500 m. Obligate wetland species.

Growth Habit

Forb/Herb

Morphology / Physiology

Active Growth Period	Flower Colour	Fruit/Seed Colour
Spring, Summer, Fall	Solitary or paired inflorescence with unstalked axilary green flowers (monoecious). Male flowers have single-chambered anthers.	Spindle-shaped achenes, 3 mm, long green.
Growth Rate		**Foliage Porosity Summer**
Rapid		Porous
Growth Form	**Flower Conspicuous**	**Foliage Porosity Winter**
Colonizing	No	Porous
C:N Ratio	**Foliage Texture**	**Foliage Colour**
Low	Fine	Green

Growth Requireme

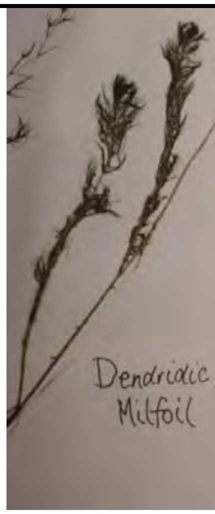
Soil Texture (Coarse – Fine)	Cold Stratification Required	Temperature Tolerance (°C)
Very tolerant of soil texture	Yes	Min -40°C
Anaerobic Tolerance	**Soil Fertility**	**pH Tolerance**
High	Medium	6.5 – 7.5
Precipitation, Min – Max	**Shade Tolerance**	
Unknown	Intermediate	

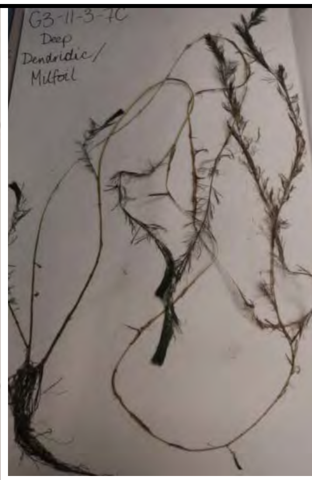
Reproduction

Bloom Period	Propagated by Bare Root	Seed Spread Rate
Late Summer	No	Moderate
Fruit/Seed Abundance	**Propagated by Sprigs**	**Seeding Vigor**
Medium	Yes	Medium
Fruit/Seed Period	**Propagated by Seed**	**Vegetative Spread Rate**
Summer to Fall	Yes	Slow
Fruit/Seed Persistence	**Propagated by Tubers**	
No	No	

Myriophyllum, sibiricum — Water milfoil

General Description





Classification

Kingdom *Plantae* – Plants
Subkingdom *Tracheobionta* – Vascular plants
Superdivision *Spermatophyta* – Seed plants
Division *Magnoliophyta* – Flowering plants
Class *Magnoliopsida* – Dicotyledons
Subclass *Rosidae*
Order *Haloragales*
Family *Haloragaceae* – Water milfoil
Genus *Myriophyllum L.* - watermilfoil

Native Status

Native to BC and North America
Indistinguishable from M. Verticillatum

Duration

Perennial

Threatened & Endangered Information

Endangered in New Jersey, Pennsylvania
Threatened in Ohio

Habitat

Lakes, ponds and sloughs in the lowland and montane zones. Frequent throughout BC

Growth Period

Forb/Herb

Morphology / Physiology

Shape and Orientation	Flower Colour	Foliage Texture
Short rhizomes producing stems 10 – 150 cm long.	Spikes emergent, 15 cm long. Male flowers pink-red in *sibiricum*, yellow in *M. verticillatum.*	Foliage in whorls of 3 – 4. Leaves pinnate with 4 - 14 segments.
Growth Form	**Flower Conspicuous**	**Foliage Colour**
Herbaceous	Yes	Green
Fruit/Seed Colour Fruit/Se	**ed Conspicuous**	
4 brown Mericarps, wrinkled	No	

Growth Requirements

Soil Texture (Coarse – Fine)	Soil Fertility	Temperature Tolerance (°C)
Sandy to loamy soils	Unknown	Suspected -40 °C
Anaerobic Tolerance	**Shade Tolerance**	**pH Tolerance**
Unknown	Intolerant	High alkaline tolerance

Reproduction

Bloom Period	Propagated by Bare Root	Propagated by Seed
Monoescious flowers, wind pollinated. Blooms July - August	unknown	Yes
Fruit/Seed Period	**Propagated by Sprigs**	**Propagated by Tubers**
Seeds present Fall	unknown	Unknown
Fruit/Seed Persistence		
Sessile until following spring.		

References Used for Database:

E-Flora BC: Electronic Atlas of the Plants of British Columbia

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Plants For a Future

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Flora of North America

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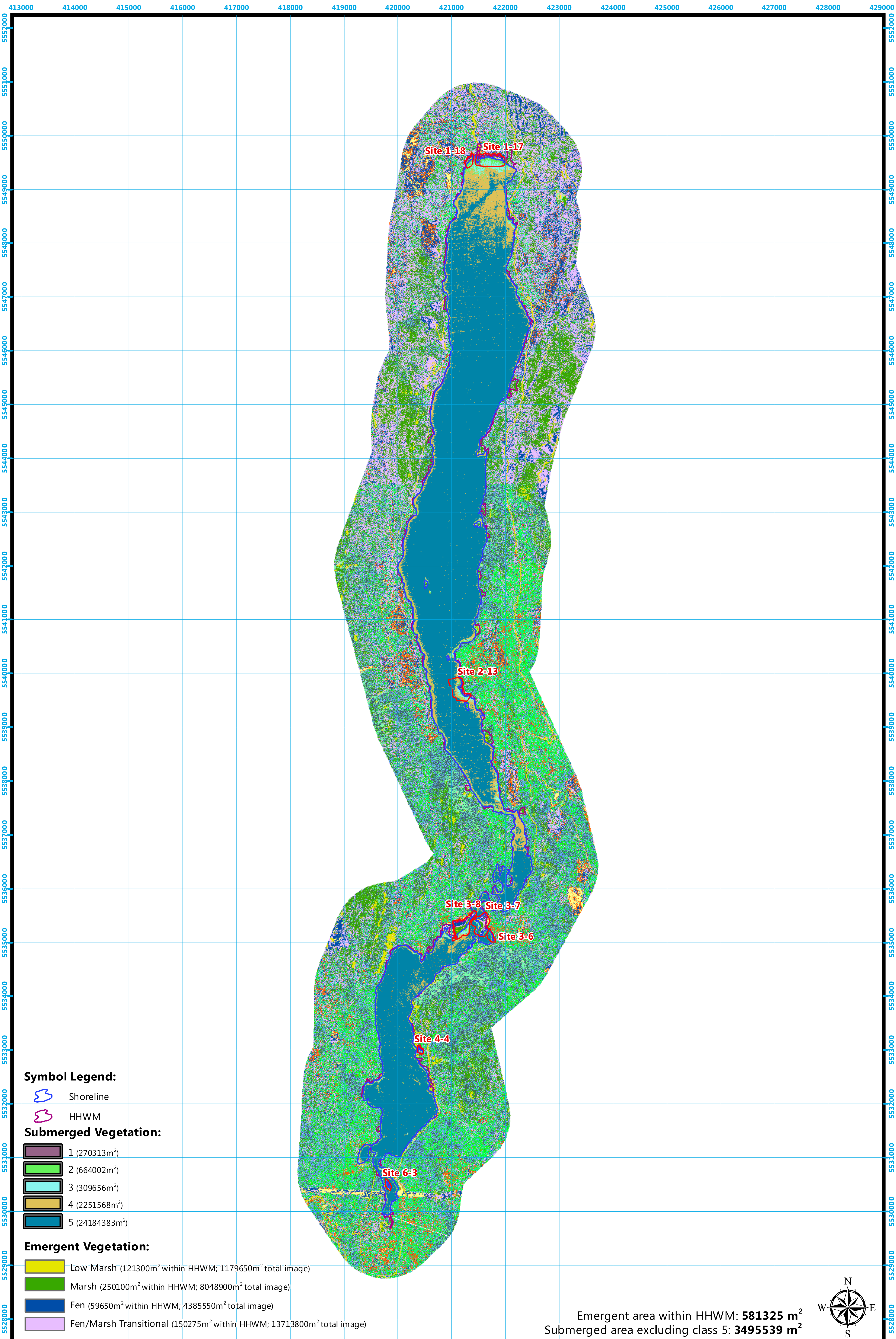
http://www.rook.org/earl/bwca/nature/aquatics/myriophyllumver.html

Appendix 6

Base maps

B1: Whole Reservoir Classification
B2: Emergent Vegetation FCC Field Map
B3: Submerged Vegetation FCC Field Map
B4: Site maps
B5: Whatshan Vegetation Map
B6: Whole Reservoir NVDI



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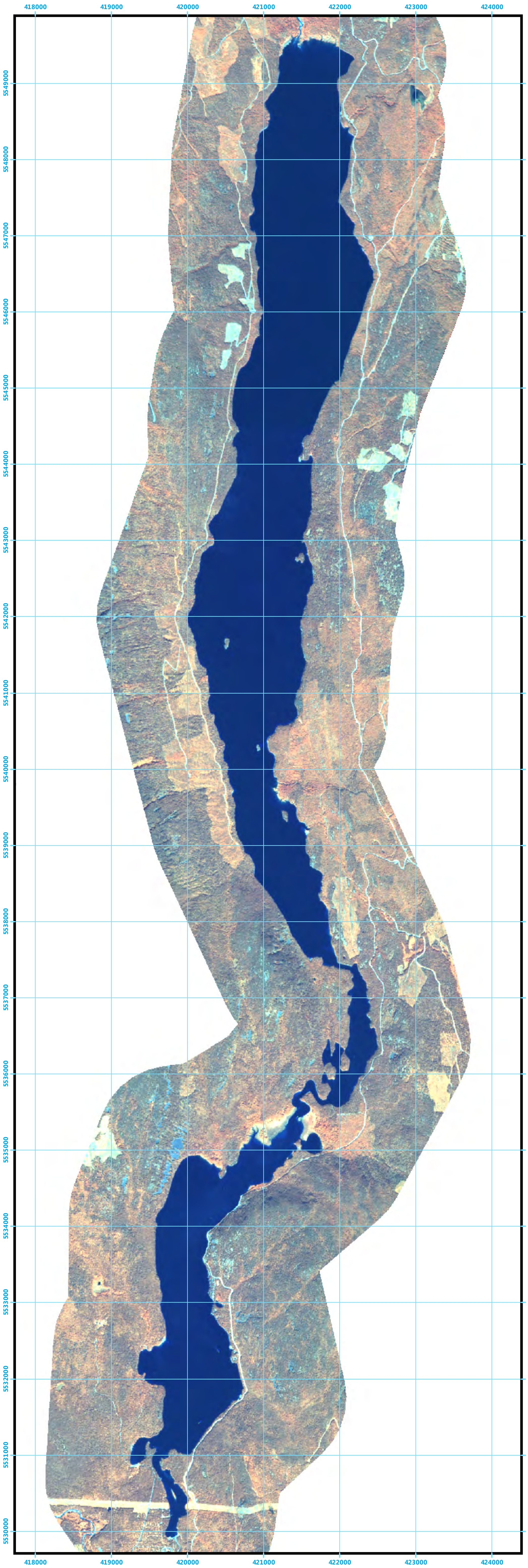
Innovation & Excellence in Environmental Science

Title: **Whole Reservoir Classification**
Date/author: 18/05/2012 by K. Cupit
Coordinate system: WGS 1984 UTM Zone 11N
Scale: 1:65,000

0 500 1,000 2,000 3,000 Meters
1 centimeter = 650 meters

Figure B1



Whatshan Reservoir

Emergent Vegetation FCC Field Map
NIR-Red Edge-Green

Symbol legend

Roads

Stream

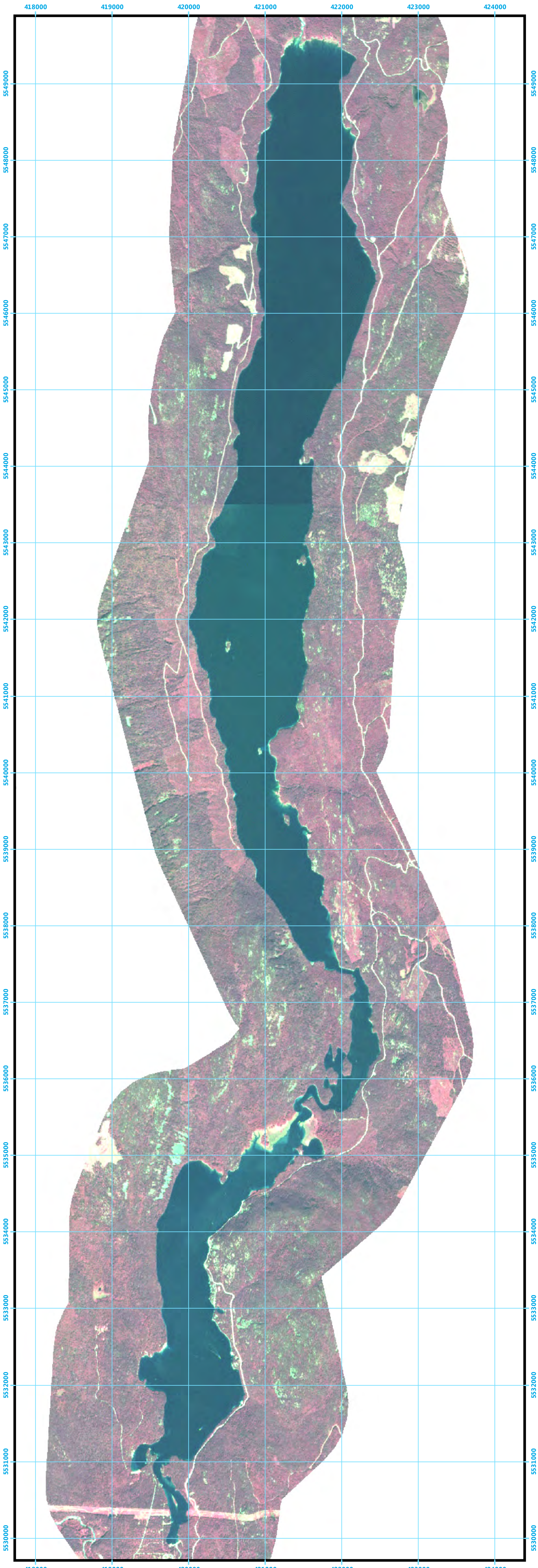
N W E S

1 centimeter = 500 meters

0 500 1,000 2,000 3,000 4,000 Meters

Date produced: September 23, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01

Figure B2



Whatshan Reservoir

Submerged Vegetation FCC Field Map
Red Edge-Red-Green

Symbol legend

Roads

Stream

N

W E

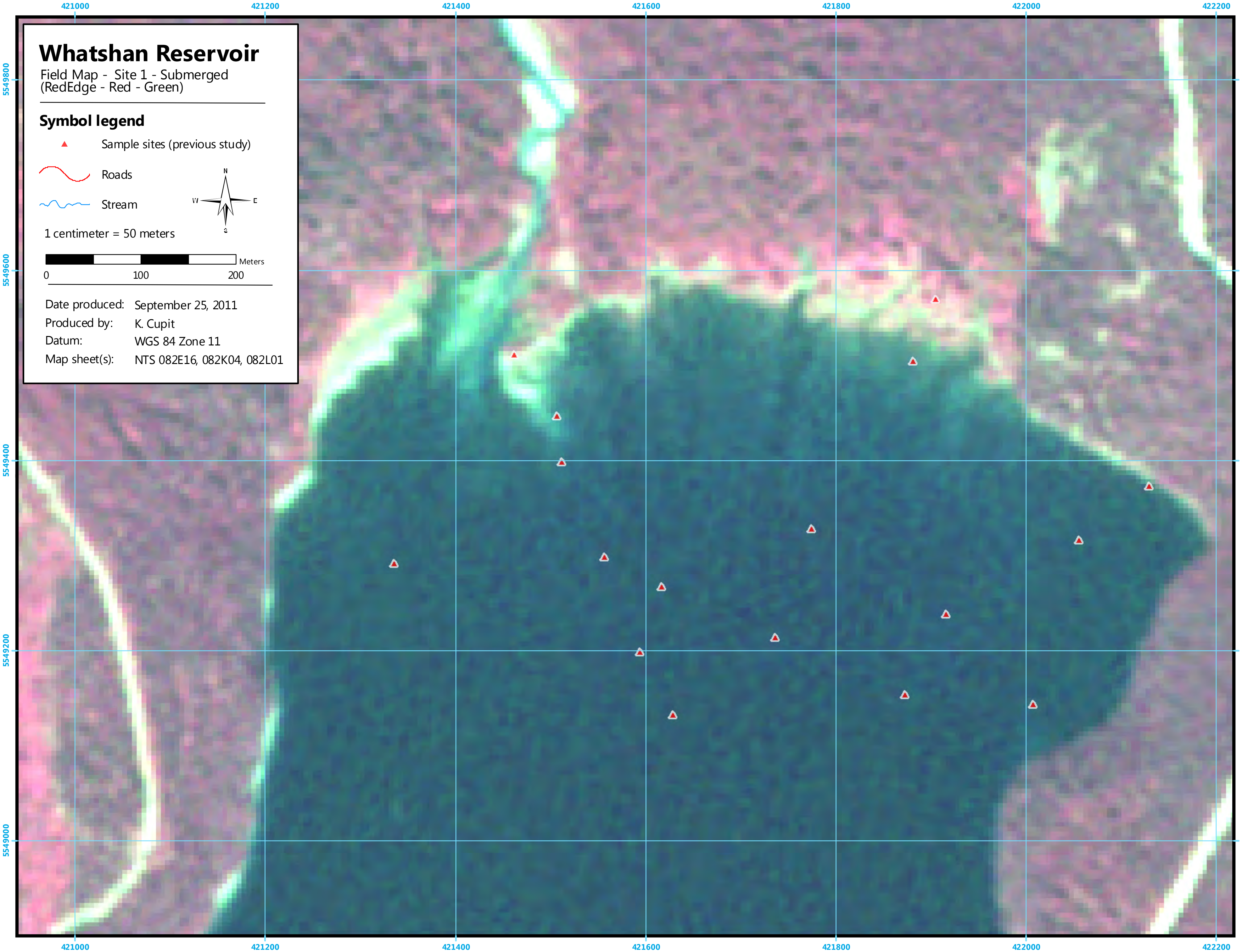
S

1 centimeter = 500 meters

0 500 1,000 2,000 3,000 4,000 Meters

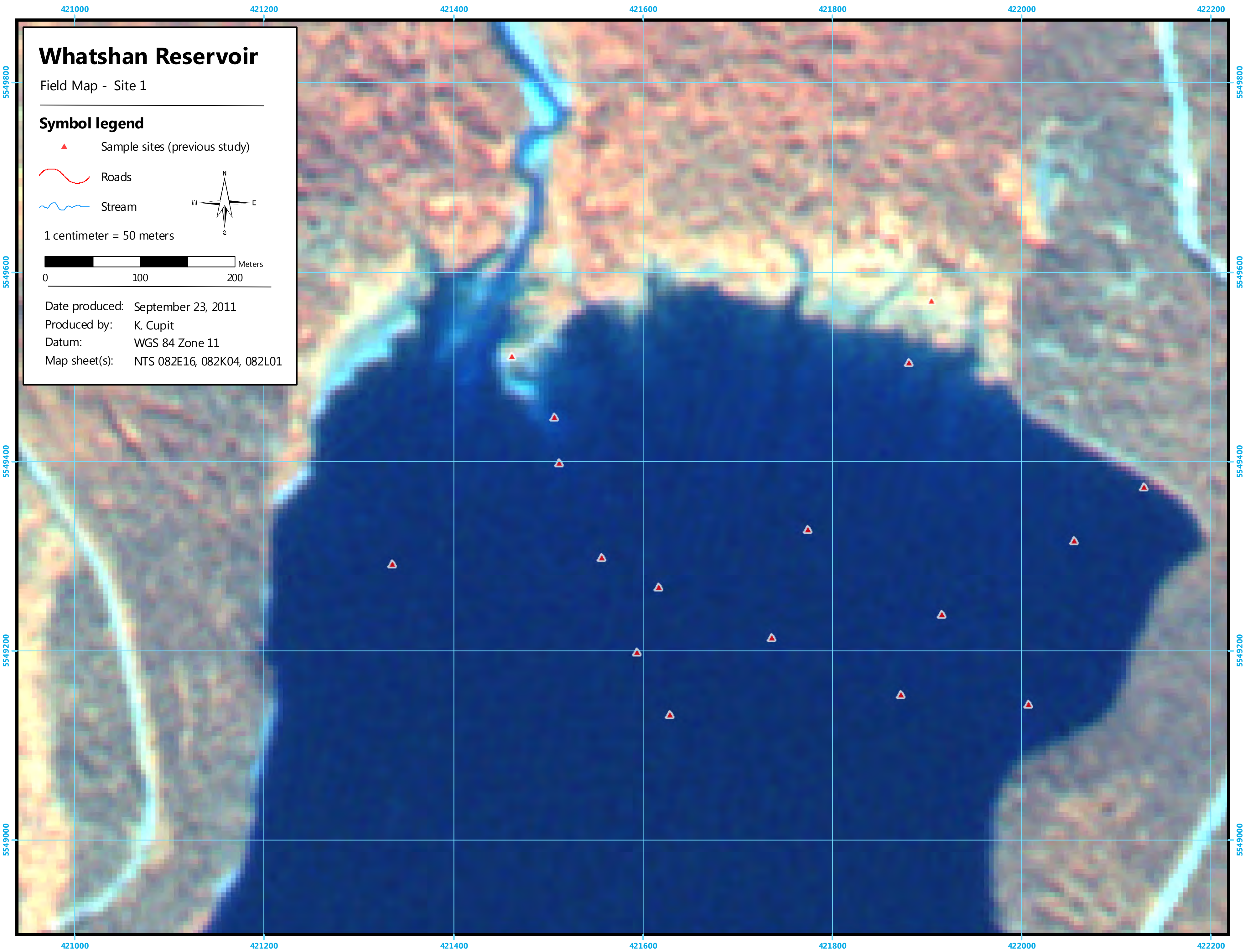
Date produced:	September 25, 2011
Produced by:	K. Cupit
Datum:	WGS 84 Zone 11
Map sheet(s):	NTS 082E16, 082K04, 082L01

Figure B3



Whatshan Reservoir
Field Map - Site 1 - Submerged
(RedEdge - Red - Green)
Symbol legend
Sample sites (previous study)
Roads
Stream
N
W
E
S
1 centimeter = 50 meters
Meters
0
100
200
Date produced: September 25, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01
421000
421200
421400
421600
421800
422000
422200
5549800
5549600
5549400
5549200
5549000

Figure B4-1a



Whatshan Reservoir
Field Map - Site 1
Symbol legend
Sample sites (previous study)
Roads
Stream
N
W
E
S
1 centimeter = 50 meters
Meters
0
100
200
Date produced: September 23, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01
421000
421200
421400
421600
421800
422000
422200
5549800
5549600
5549400
5549200
5549000

Figure B4-1b

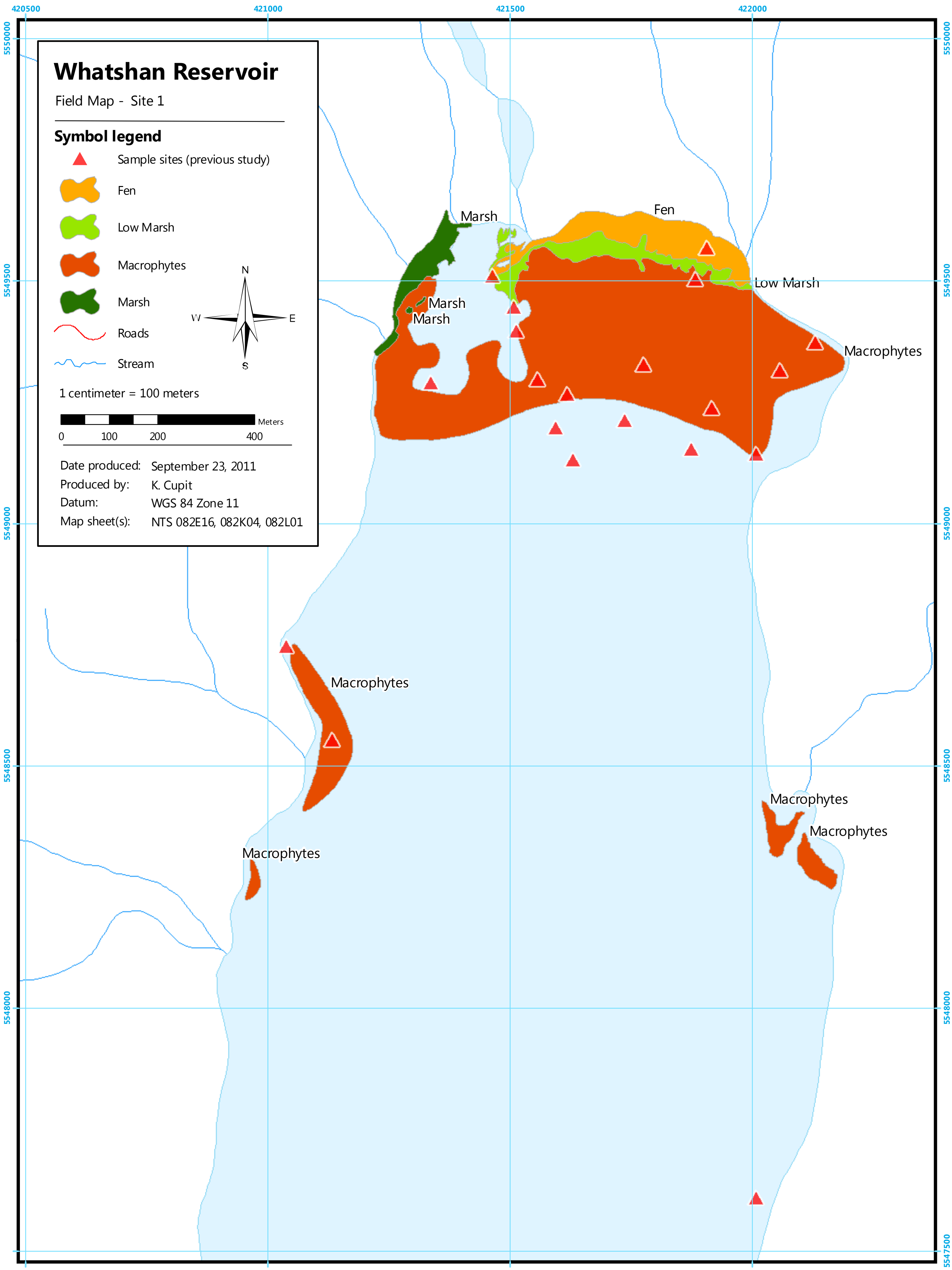
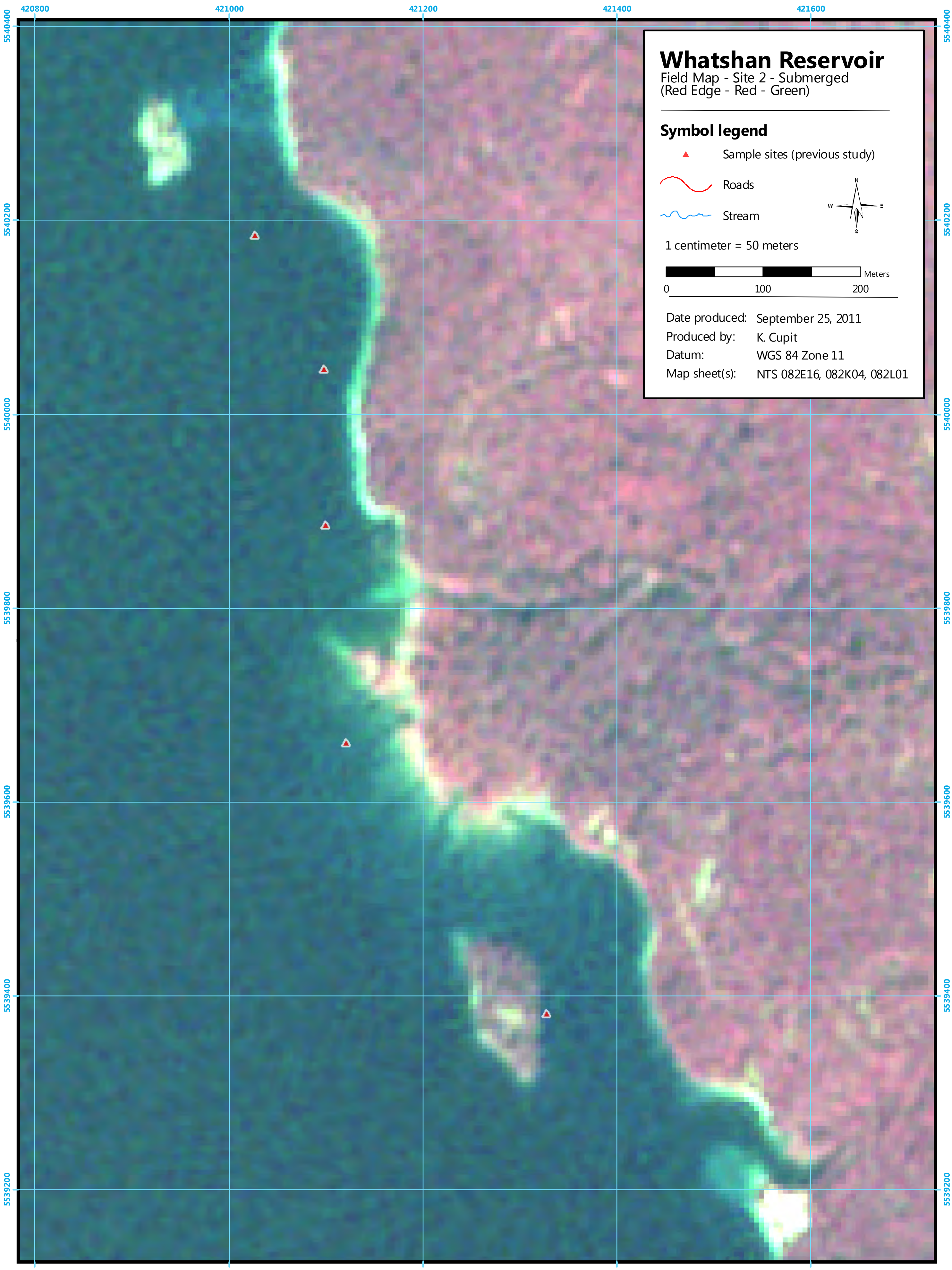

Whatshan Reservoir
Field Map - Site 1
Symbol legend
Sample sites (previous study)
Fen
Low Marsh
Macrophytes
Marsh
Roads
Stream
1 centimeter = 100 meters
Meters
0
100
200
400
Date produced: September 23, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01
N
W
E
S
Marsh
Fen
Low Marsh
Marsh
Marsh
Macrophytes
Macrophytes
Macrophytes
Macrophytes
Macrophytes
420500
421000
421500
422000
5550000
5549500
5549000
5548500
5548000
5547500

Figure B4-1c



Whatshan Reservoir
Field Map - Site 2 - Submerged
(Red Edge - Red - Green)
Symbol legend
Sample sites (previous study)
Roads
Stream
1 centimeter = 50 meters
Meters
0
100
200
Date produced: September 25, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01
420800
421000
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421400
421600
5540400
5540200
5540000
5539800
5539600
5539400
5539200

Figure B4-2a

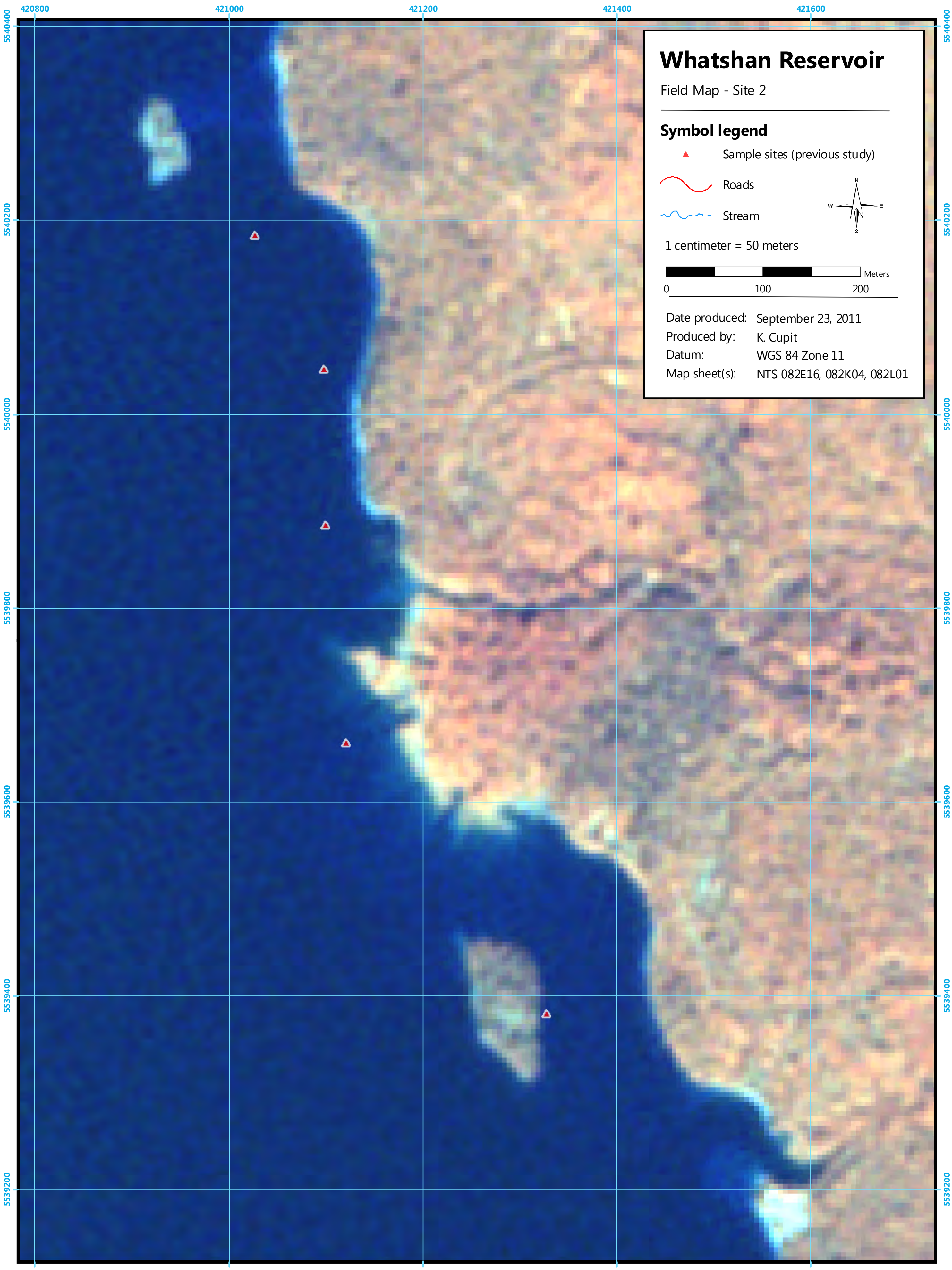

Whatshan Reservoir
Field Map - Site 2
Symbol legend
Sample sites (previous study)
Roads
Stream
1 centimeter = 50 meters
Meters
0
100
200
Date produced: September 23, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01
420800
421000
421200
421400
421600
5540400
5540200
5540000
5539800
5539600
5539400
5539200

Figure B4-2b

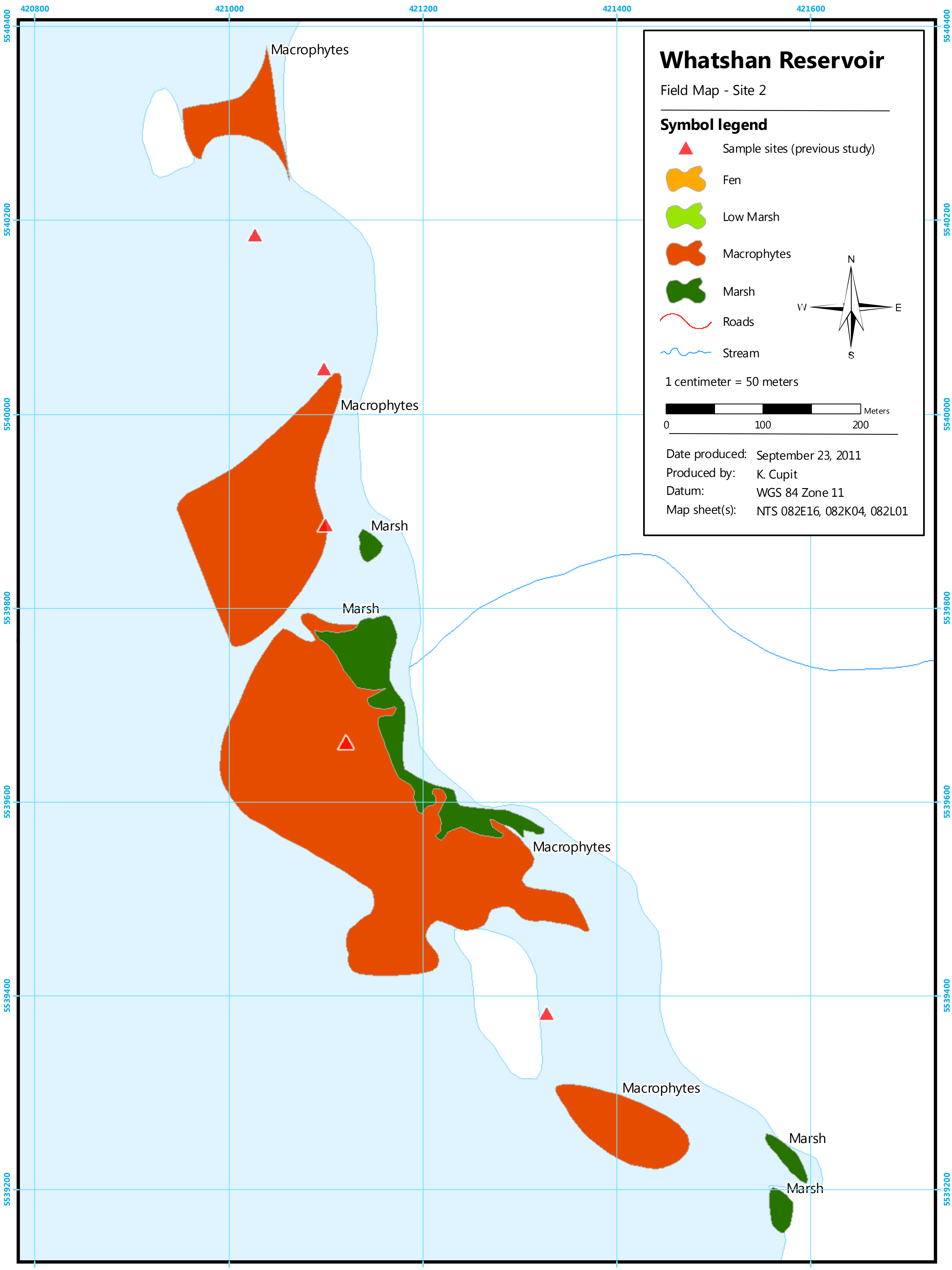
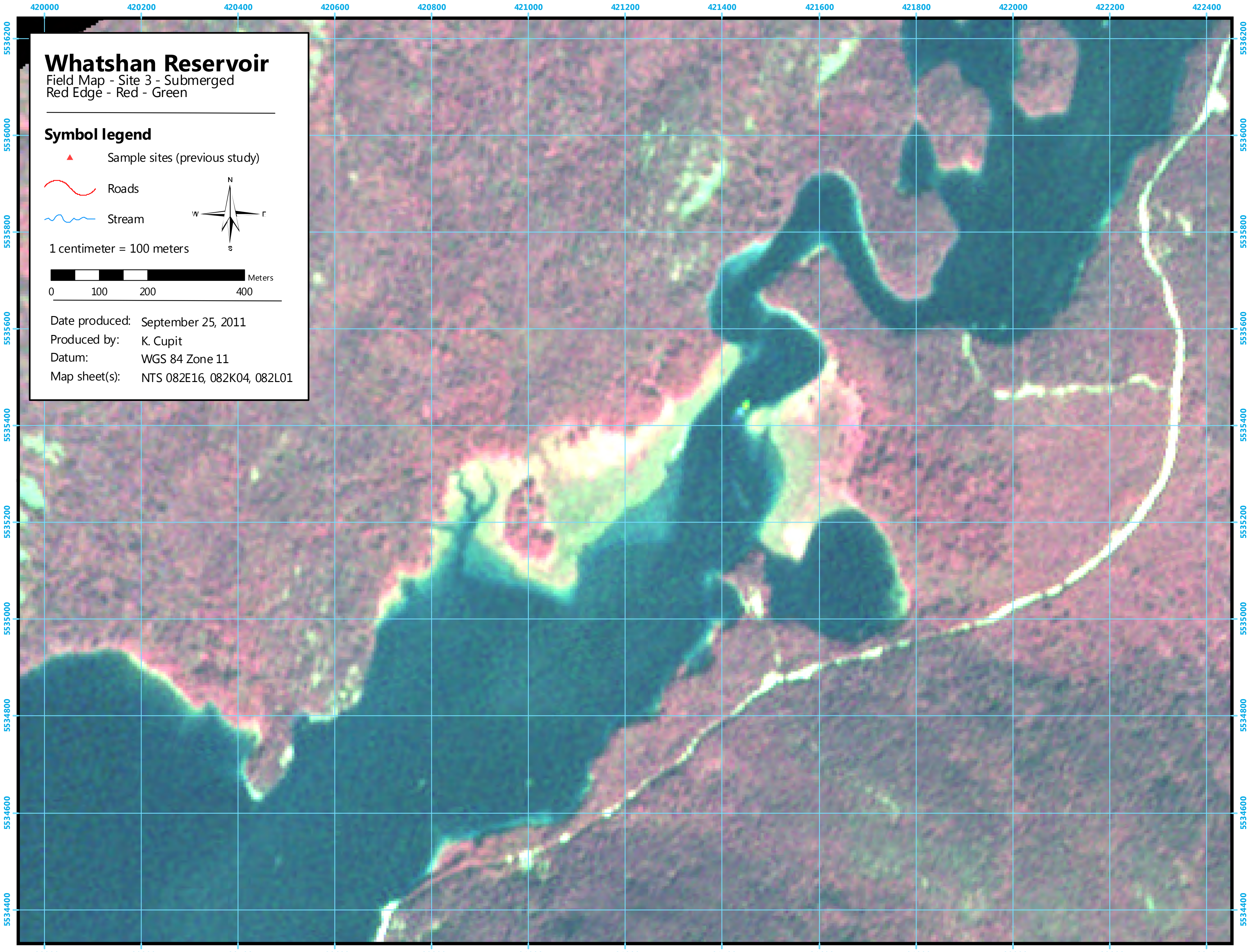

Whatshan Reservoir
Field Map - Site 2
Symbol legend
Sample sites (previous study)
Fen
Low Marsh
Macrophytes
Marsh
Roads
Stream
1 centimeter = 50 meters
Meters
0
100
200
Date produced: September 23, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01
N
W
E
S
Macrophytes
Macrophytes
Marsh
Marsh
Macrophytes
Macrophytes
Marsh
Marsh
420800
421000
421200
421400
421600
5540400
5540200
5540000
5539800
5539600
5539400
5539200

Figure B4-2c



Whatshan Reservoir
Field Map - Site 3 - Submerged
Red Edge - Red - Green
Symbol legend
Sample sites (previous study)
Roads
Stream
1 centimeter = 100 meters
Meters
0
100
200
400
N
W
E
S
Date produced: September 25, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01
420000
420200
420400
420600
420800
421000
421200
421400
421600
421800
422000
422200
422400
5536200
5536000
5535800
5535600
5535400
5535200
5535000
5534800
5534600
5534400

Figure B4-3a

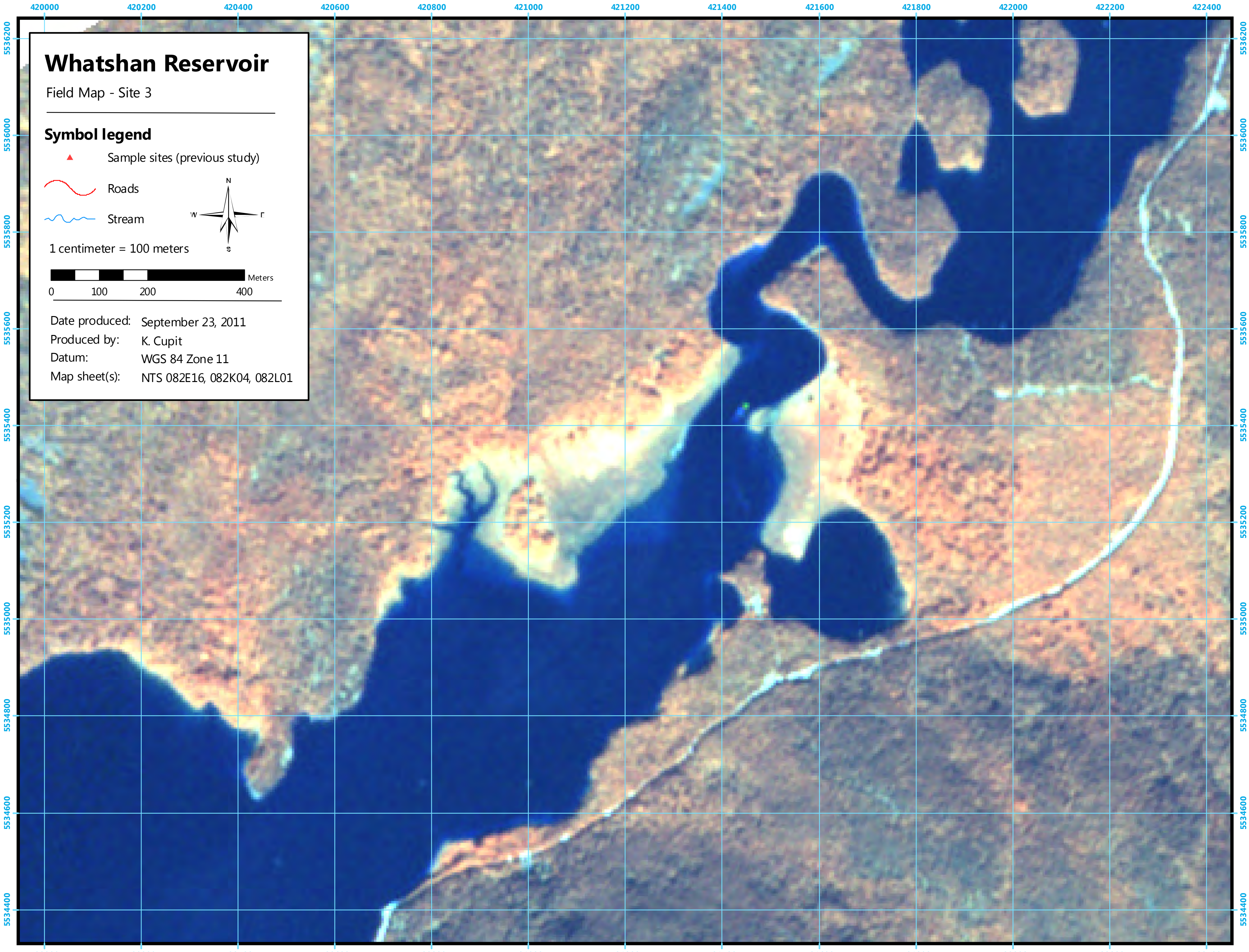
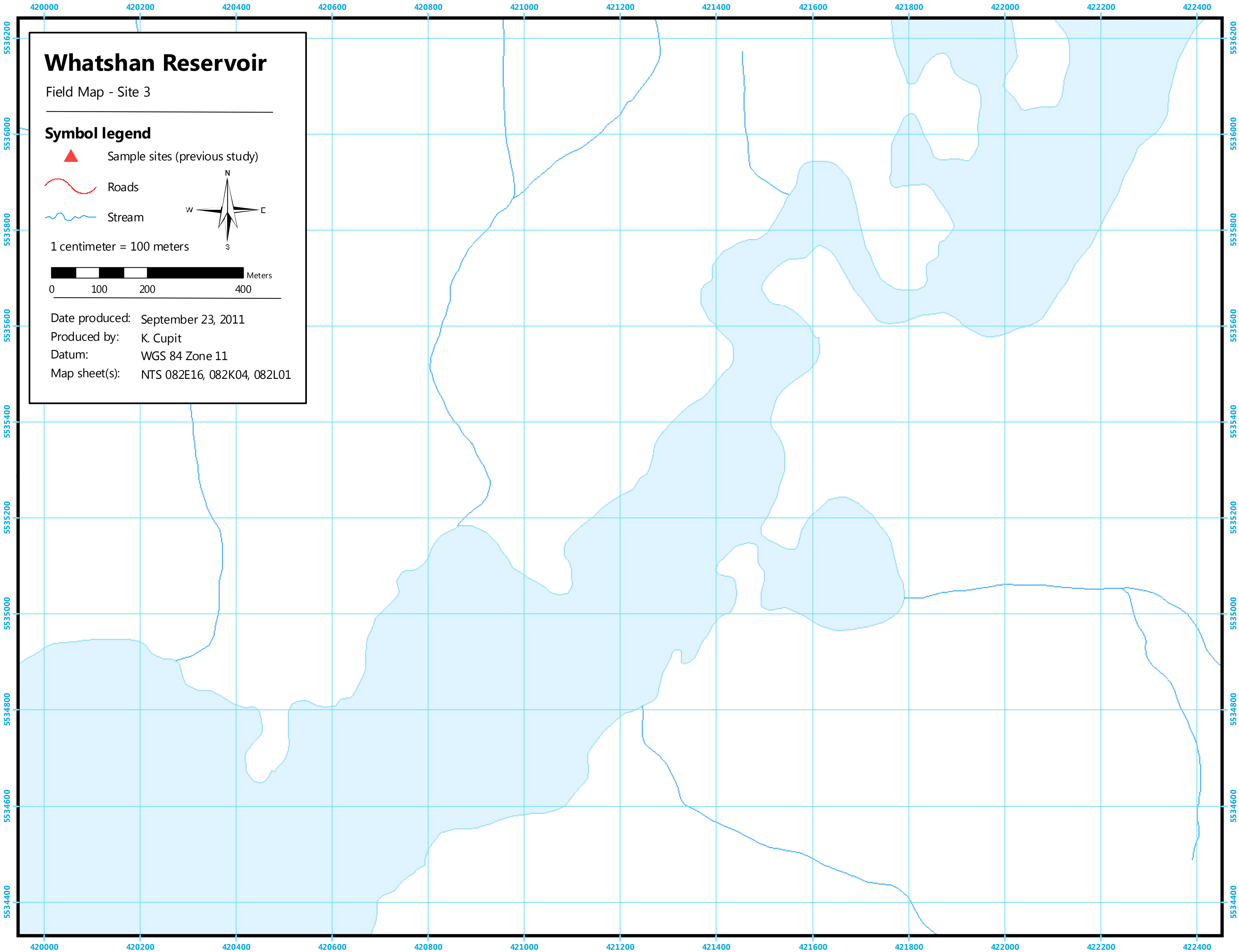

Whatshan Reservoir
Field Map - Site 3
Symbol legend
Sample sites (previous study)
Roads
Stream
1 centimeter = 100 meters
0 100 200 400 Meters
N
S
W
E
Date produced: September 23, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01
420000
420200
420400
420600
420800
421000
421200
421400
421600
421800
422000
422200
422400
5536200
5536000
5535800
5535600
5535400
5535200
5535000
5534800
5534600
5534400

Figure B4-3b



Whatshan Reservoir
Field Map - Site 3
Symbol legend
Sample sites (previous study)
Roads
Stream
1 centimeter = 100 meters
Meters
0
100
200
400
N
W
E
S
Date produced: September 23, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01
420000
420200
420400
420600
420800
421000
421200
421400
421600
421800
422000
422200
422400
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5536000
5535800
5535600
5535400
5535200
5535000
5534800
5534600
5534400

Figure B4-3c

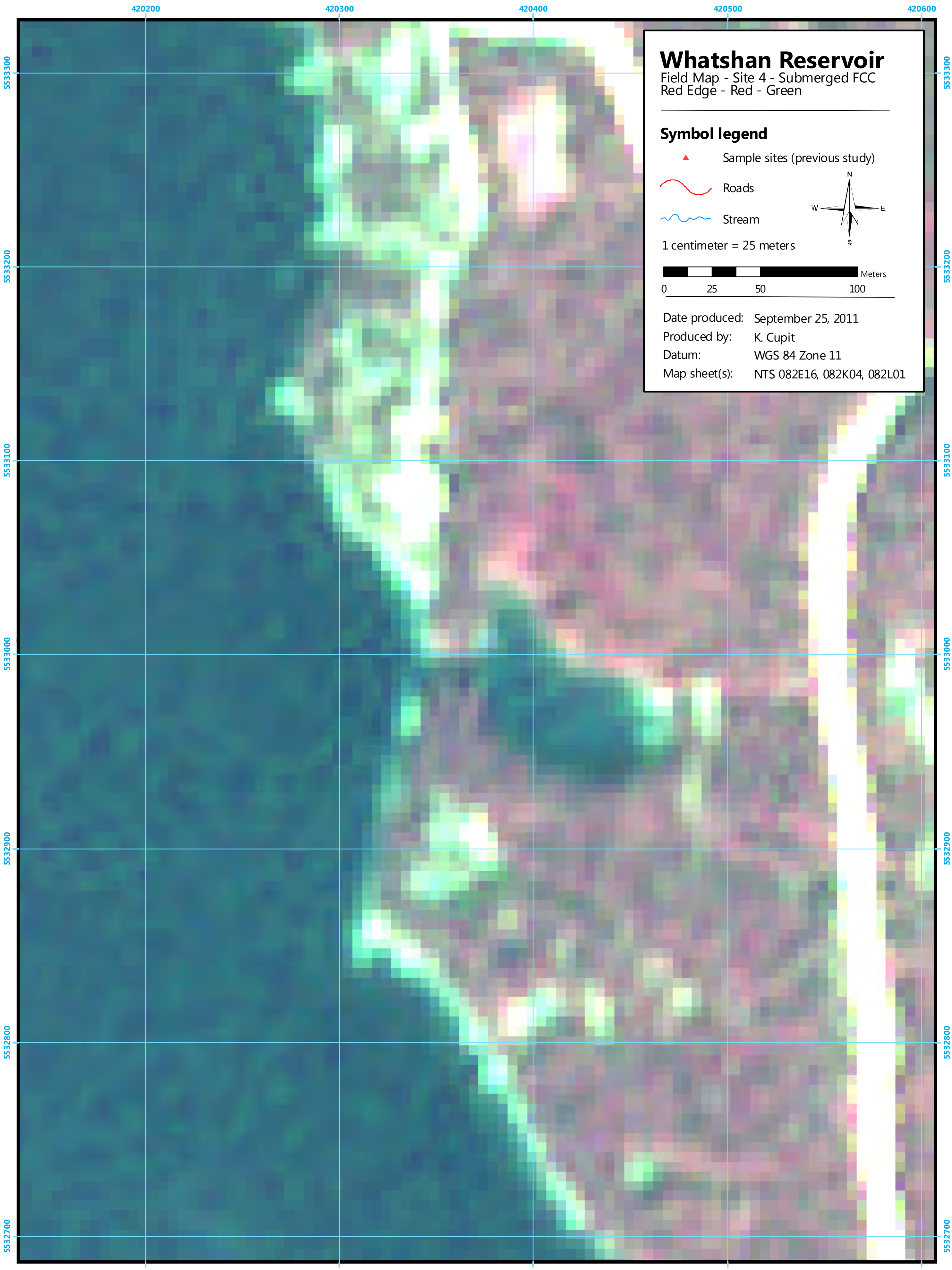
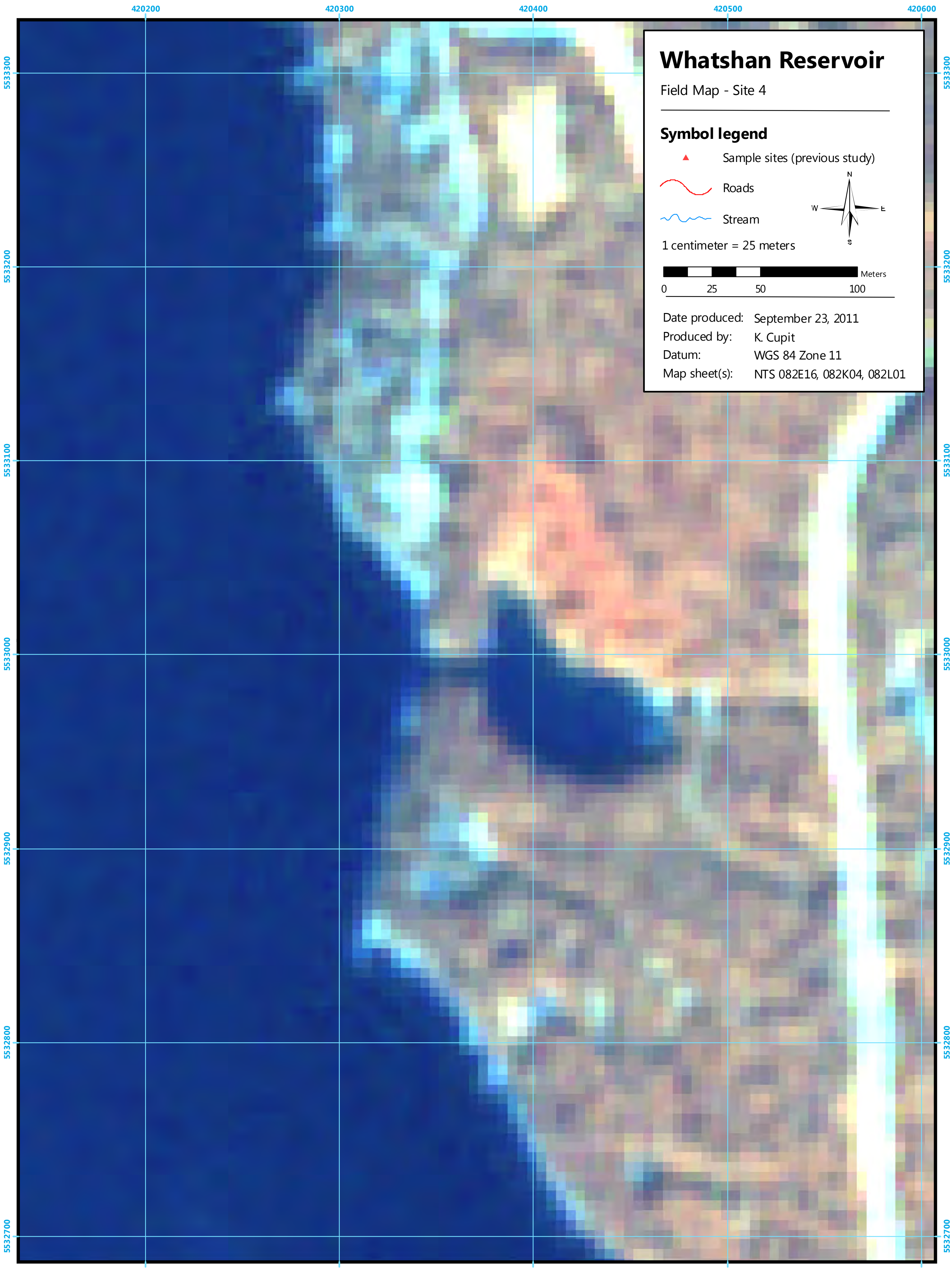

Whatshan Reservoir
Field Map - Site 4 - Submerged FCC
Red Edge - Red - Green
Symbol legend
Sample sites (previous study)
Roads
Stream
1 centimeter = 25 meters
N
W
E
S
Meters
0
25
50
100
Date produced: September 25, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01
420200
420300
420400
420500
420600
5533300
5533200
5533100
5533000
5532900
5532800
5532700

Figure B4-4a



Whatshan Reservoir
Field Map - Site 4
Symbol legend
Sample sites (previous study)
Roads
Stream
1 centimeter = 25 meters
N
S
E
W
Meters
0
25
50
100
Date produced: September 23, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01
420200
420300
420400
420500
420600
5533300
5533200
5533100
5533000
5532900
5532800
5532700

Figure B4-4b

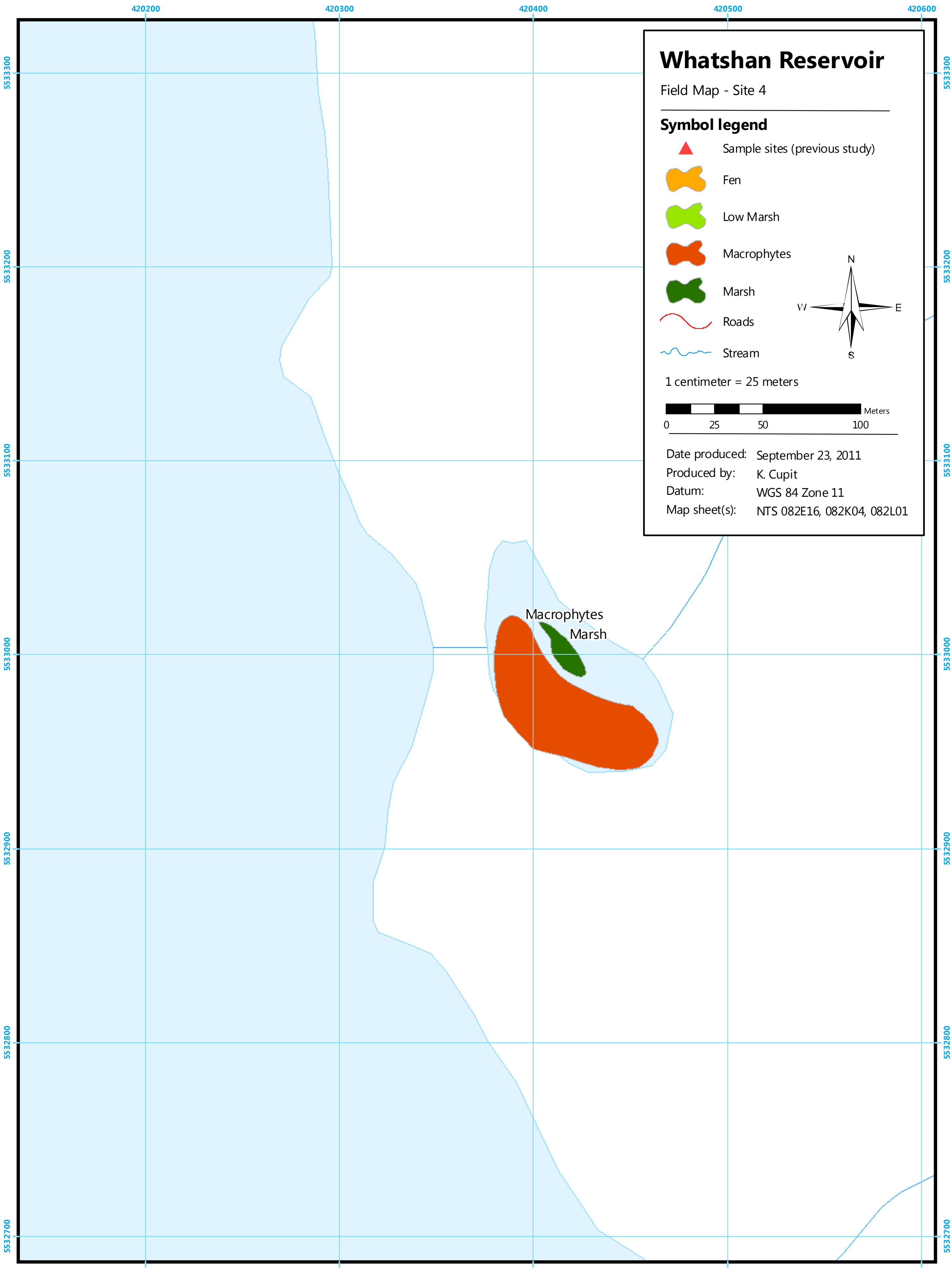
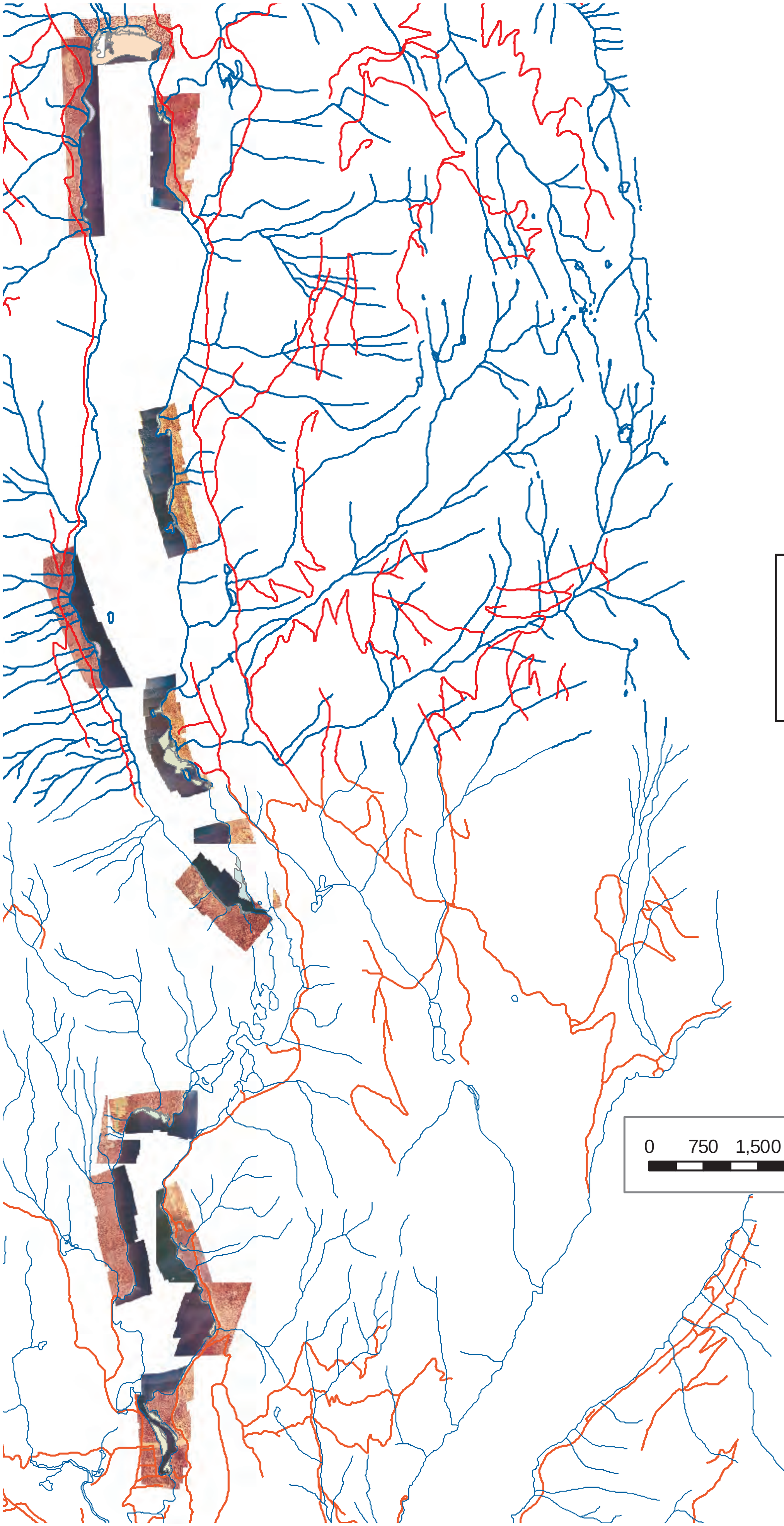

Whatshan Reservoir
Field Map - Site 4
Symbol legend
Sample sites (previous study)
Fen
Low Marsh
Macrophytes
Marsh
Roads
Stream
N
W
E
S
1 centimeter = 25 meters
Meters
0
25
50
100
Date produced: September 23, 2011
Produced by: K. Cupit
Datum: WGS 84 Zone 11
Map sheet(s): NTS 082E16, 082K04, 082L01
Macrophytes
Marsh
420200
420300
420400
420500
420600
5533300
5533200
5533100
5533000
5532900
5532800
5532700

Figure B4-4c

Whatshan Vegetation

Figure B5



Legend

Streams/Lake

Roads

0 750 1,500 3,000 4,500 6,000 Meters

G3 CONSULTING LTD.
Innovation & Excellence in Environmental Science

Title: **Whole Reservoir NVDI**
Date/author: 18/05/2012 by K. Cupit
Coordinate system: WGS 1984 UTM Zone 11N
Scale: 1:65,000

0 500 1,000 2,000 3,000 Meters
1 centimeter = 650 meters

Figure B6

Appendix 7

Safety and Environmental Plan

Safety & Environmental Management Plan

Field Operations
(2011 Field Season)

WHATSHAN RESERVOIR MACROPHYTE MONITORING

G3Consulting Ltd.
Innovation & Excellence in Environmental Science

1.0 RADIO & COMMUNICATION PROTOCOL

Radio frequencies are unsecured, allowing public and industry monitoring of transmissions. For this reason the following radio protocol will be followed (if required) to maintain a professional, functional line of communication between field crews and transportation/monitoring service providers (aircrafts, boat, etc.) or other stations as required. Once permission to use the assigned frequency has been granted by the client (if requested and required), all G3 field radios will have this channel programmed into their channel list.

1.1 Radio Frequencies

G3 will operate on industry or Marine two-way VHF radio frequencies within the study area.

1.1.1 Frequencies

Central Kootenay Regional Communications Frequencies:

BC Hydro F2	165.93000
BC Hydro F3	165.30000
BC Hydro F7	165.21000
BC Hydro Heli	173.32500
Nakusp EMS	149.68000
Nakusp Fire	153.83000
Central Kootenay RCMP	139.44000
	139.53000
	139.56000

BC Hydro Frequencies will be used only as directed. Internal communications will be conducted using G3 handheld radios and following the protocols outlined below. All personel will be familiar with radio protocols.

Air service providers often monitor radio frequencies, however their channels may not be the same as those used by field crews and radio communication is not always successful.

CYCG Traffic	122.10000

1.1.2 Key issues

- Operating Names will be assigned for each group;
- Location Codes will be assigned to each survey site;
- radio communication will be kept to the minimum pertinent information required for safe work planning; and,
- **SAFETY CONCERNS WILL OVER RIDE THIS PROTOCOL IMMEDIATELY.**

1.2 Implementation

- each field crew will be identified with a unique field name;
- location codes will be assigned according to sample/reach sites and field members will communicate with office personnel using these codes; and,
- radios will be tested during field operations to ensure operating condition and will be returned at the end of each day to the Safety Officer for proper charging and testing.

Radio Call procedure

1. Radio Callsign of the station you are calling;
2. “This is <Give Radio Callsign>”;
3. Clearly Spoken Message;
4. “Over” (if reply is expected) or “<Radio Callsign> Out” (if no reply is expected).

Radio Voice Procedure	Meaning
Affirmative	Yes
Negative	No
Over	I have finished talking and am listening for reply
Out	I have finished talking and do not expect a reply
Roger	I understand what you have said
Copy	I heard what you have said
Wilco	Will Comply
Go Ahead	Send your transmission
Say Again	Please repeat your last message

1.2.1 Safety

- during any type of medical or perceived emergency, radio protocol will be adjusted and site specific data will be given directly over the air;
- data is to be directed to other field crews, the pilot (if applicable), or other operating stations by their given field operating name,
- information should include (in this order):
    - Group Operating Name;
    - Location, (location point);
    - Water System Name;
    - Geographic Location;
    - Nature of Emergency; and,
    - Assistance Required.

1.2.2 Emergency Procedures (See Section 7.0)

Emergency Radio frequencies and procedures are referenced in detail in section:

7.0 EMERGENCY PHONE AND RADIO PROCEDURES on Page 14 of this EAP

1.3 UN Phonetic Alphabet

CHARACTER	*MORSE CODE*	*TELEPHONY*	*PHONIC (PRONUNCIATION)*
A	• —	Alfa	(AL-FAH)
B	— • • •	Bravo	(BRAH-VOH)
C	— • — •	Charlie	(CHAR-LEE) or (SHAR-LEE)
D	— • •	Delta	(DELL-TAH)
E	•	Echo	(ECK-OH)
F	• • — •	Foxtrot	(FOKS-TROT)
G	— — •	Golf	(GOLF)
H	• • • •	Hotel	(HOH-TEL)
I	• •	India	(IN-DEE-AH)
J	• — — —	Juliet	(JEW-LEE-ETT)
K	— • —	Kilo	(KEY-LOH)
L	• — • •	Lima	(LEE-MAH)
M	— —	Mike	(MIKE)
N	— •	November	(NO-VEM-BER)
O	— — —	Oscar	(OSS-CAH)
P	• — — •	Papa	(PAH-PAH)
Q	— — • —	Quebec	(KEH-BECK)
R	• — •	Romeo	(ROW-ME-OH)
S	• • •	Sierra	(SEE-AIR-RAH)
T	—	Tango	(TANG-GO)
U	• • —	Uniform	(YOU-NEE-FORM) or (OO-NEE-FORM)
V	• • • —	Victor	(VIK-TAH)
W	• — —	Whiskey	(WISS-KEY)
X	— • • —	Xray	(ECKS-RAY)
Y	— • — —	Yankee	(YANG-KEY)
Z	— — • •	Zulu	(ZOO-LOO)
1	• — — — —	One	(WUN)
2	• • — — —	Two	(TOO)
3	• • • — —	Three	(TREE)
4	• • • • —	Four	(FOW-ER)
5	• • • • •	Five	(FIFE)
6	— • • • •	Six	(SIX)
7	— — • • •	Seven	(SEV-EN)
8	— — — • •	Eight	(AIT)
9	— — — — •	Nine	(NIN-ER)
0	— — — — —	Zero	(ZEE-RO)

2.0 FIELD EMERGENCY PROCEDURES

In accordance with G3 Field Protocol, a Safety Officer will be assigned for the duration of the field program. The Safety Officer will make final decisions on issues regarding individuals or group safety as related to work tasks. In addition the Safety Officer will be responsible for the Spill Management (Section 2.2) and ensuring any and all Best Management Practices (BMPS)'s are followed when conducting field activities. Activities will be abandoned if deemed, by the Safety Officer, as too great a risk. The safety officer will possess a fist aid and, transportation (if required) certificate valid for the number of personnel under their supervision.

The field portion of this program will require the use of boats and four-wheel drive vehicles. Work will involve sampling and observations on or about water, and may include: water quality measurements; water column sampling; macrophyte sampling; and/or, sediment sampling. Work may be conducted on or around flowing water or reservoirs and has the potential for wildlife encounters. Appropriate personal gear (i.e. footwear, waders, life vest, rainwear and appropriate clothing, etc.) is the responsibility of each individual crew member. Personnel will not be permitted to participate in field activities if the Safety Officer deems personal equipment to be inadequate.

2.1 Roles & Responsibilities

It is the Safety Officers responsibility to ensure each that crew member has reviewed this EAP prior to conducting fieldwork, and to ensure the team is equipped with the following supplies:

- WCB Level I First Aid Kit and associated supplies. (Each G3 crew member will have completed at least the WCB level one first aid course and selected crew members would have the transportation endorsement, if required);
- Hand Held Radio (appropriate map/code)/Cell Phone & Charger;
- Survival Gear;
- Rescue gear (as required);
- Bear Knowledge, Bear Spray, and Bear Deterrents (if deemed necessary);
- Firearms training, and Firearm (only if required for a given project);
- Signaling Devices; and,
- **THIS EMERGENCY ACTION PLAN**

Any concerns regarding safety should be addressed directly to the Safety Officer.

2.2 Spill Management Procedures

Field work may involve the re-fueling of equipment (boat, generators etc.) in addition to managing this equipment over a sensitive waterbody. The procedures below are to be followed to prevent and manage a spill should one occur.

2.2.1 Preventing Spills in the Field

- The refueling of boats and or equipment while on the water is prohibited. Any and all refueling will take at an appropriate fueling station or at a distance >100 m from the shoreline.
- Any portable fuel containers used in the field must be < 20 L and be CSA (or equivalent) approved.
- Fuel containers will not be left unattended at any time while on the water.
- An appropriately sized spill kit will be kept with the boat during the course of the field work.

2.2.2 Dealing with a Spill

If a spill does occur while in the field the following procedures will be implemented by the Safety Officer to ensure proper containment and clean-up:

- **Assess safety** – Ensure the spill does not pose a health safety risk to crew members.
- **Contain and Clean the Spill** – Locate the spill kit and contain the spill using spill booms (if in water), ditches and spill rags. All of the contaminated soil and rags should be put into buckets.
- **Report the Spill** – If the spill is on land and greater then 10 L, report the spill to the Provincial Emergency Program (PEP). Notify BC Hydro and G3 Head office of any spill that occurs on site. All spills into a waterbody are to be reported to the PEP and BC Hydro.
- Prevent Future Spills – Assess how and why the spill occurred and rectify the problem so that it does not occur in the future.

3.0 SAFETY PLAN

In the event of an emergency, the Safety Plan is to be followed according to criteria described below. A first aid/rescue post is to be established at a readily accessible site (e.g., vehicle, launch site, etc.). It is the Safety Officers responsibility to ensure that this post is appropriately stocked and s upplies are maintained in good condition.

The closest and most direct route from the study area to an emergency medical centre is BC Highway 6 "Vernon Slocan Hwy," accessed via Whatshan Lake Rd. or Whatshan River Rd. from the sampling sites. Highway 6 would be used for any emergency requiring ground transportation to Arrow Lakes Hospital in Nakusp, BC that does not require air evacuation. If an ambulance is not required or immediate transport is required for transportation, G3 would use the field vehicle equipped with spine board and blankets, to transport any injured personnel.

Contents of the first aid/rescue post include:

- Level 1 first aid kit and spine board;
- survival gear;
- VHF and/or satellite phone (optional);
- swift water rescue equipment (where applicable); and,
- rescue/extraction equipment (e.g., ax, winch, etc.).

This post is to serve as the emergency gathering point in the event of crew separation at the work site. A log will be maintained at this site to leave and receive messages in the event that communication by radio/phone is not established. A copy of this Plan is to remain at the post at all times.

At all time you must know:

- WHERE YOU ARE;
- WHERE YOU ARE IN RELATION TO THE POST;
- NEAREST BOAT/TRUCK ACCESS; and,
- LOCATION OF NEAREST FIRST AID/RESCUE EQUIPMENT.

3.1 Life Threatening Work Place Emergency

In the event of a LIFE THREATENING work place emergency.

- Cease work action;
- Identify danger;
- Assess situation;
- Make area safe to administer or offer help;
- Begin life saving first aid;
- Stabilize victim; and,
- Radio crew members and contact **Emergency Services (911)** or other available station for assistance / evacuation.

Tell Them:

- LOCATION;
- DETAILS OF INJURY; and,
- ASSISTANCE REQUIRED.

3.2 Extreme Danger, Life Threatening Injuries:

Circumstances will determine the appropriate action.

3.2.1 Helicopter Available for Evacuation

DO NOT MOVE FROM REPORTED LOCATION.

- Remain Calm;
- At First Aid Attendants discretion of patients stability, transport patient to:
- Nearest First Aid Post; or,
- Nearest Hospital.

3.2.2 Helicopter Not Available for Evacuation

DO NOT MOVE FROM REPORTED LOCATION UNLESS UNSAFE.

- Remain Calm;
- Stabilize victim. You may be there for several minutes to several hours. In all cases prepare mentally and physically for several hours or overnight; and,
- Relay Radio to nearest radio station, to send transportation and first aid attendant.

3.2.3 If No Evacuation Is Available

- Remain Calm;
- Stabilize victim;
- MAKE ALL EFFORTS TO CONTACT OR ARRANGE EVACUATION;
- DO NOT MOVE FROM REPORTED LOCATION UNLESS UNSAFE;
- Maintain scheduled radio reports every 15 minutes with the other group or nearest radio. Keep help informed of situation. Keep radio use to minimum safe level to save battery and aid rescue attempts; and,
- Use Survival Gear to await help, prepare a signal device to attract attention from passing; boats or aircrafts.

3.2.4 If No Radio Contact Is Established

- Stabilize Victim;
- Remain Calm;
- MAKE ALL EFFORTS TO CONTACT OR ARRANGE EVACUATION;
- DO NOT MOVE FROM LOCATION UNLESS UNSAFE TO REMAIN;
- Use Survival Gear to await help, prepare a signal device to attract attention from passing, boats or aircrafts; and,
- The Safety Plan will be implemented and a search will begin within the designated time. If you are not heard from an emergency will be assumed and assistance will be sent.

3.2.5 Minor Emergency Care

Sprains, twists, small cuts.

- Coordinate crew consolidation, return to predetermined established safety point (i.e. the vehicle or launch point);
- Crew size will never be below two (2) persons;
- If necessary a first aid attendant will accompany the injured worker to the nearest first aid post or hospital;

- Complete applicable WCB and field notes pertaining to the events; and,
- Report incident to the G3 Head Office as soon as possible.

During evacuation or in the event of a rescue time delay (where safety permits):

- All G3 crew will be advised of the situation immediately and offer assistance;
- Inform G3 Head office of all details and action taken or needed; and,
- Maintain communication with the G3 office.

After evacuation to medical center you must:

- Inform remaining crew and rescuers of evacuation completion;
- Inform G3 Head Office of all details and action taken or needed;
- Complete applicable WCB and field notes pertaining to the events; and,
- Report Incident to BC Hydro Project Contact at:

  http://www.bchydro.com/ex/contractor_safety/?WT.mc_id=incident
  username = contractor; pwd = safety

3.3 Tailgate Meetings

Tailgate meetings are an important aspect of field work. They are used to review safety procedures, project objectives and timelines, focus and discuss daily activities and benchmarks and a means by which to discuss and review project progress and any issues, complications or findings.

Tailgate meetings would be held each morning before commencement of field work. Each day's work plan would be discussed and crew obligations, QA/QC criteria, and specific expectations outlined. The safety officer would provide input as to any specific safety issues or concerns and overview any procedures needed for the day (e.g., boat protocol, aircraft procedures, etc.). Each field personnel will be provided a waterproof field book in which daily activities will be noted and specific instructions listed.

Additional evening tailgates would be held to review and compare daily objectives with those identified in the morning and to identify any follow-up or action items for the next day (e.g. safety concerns, purchase of supplies, re-testing, shipment of samples, etc.). Tailgate discussions would be recorded by the field coordinator for reference.

3.4 Check-In Procedures

During the field work all crew members will remain together and in close contact with each other. Everyone will leave the launch point, and return to it, together at the end of each day. To ensure management is aware that each day was successful and that each personnel is accounted for, the crew leader will report to the office manager at the end of each day by 7pm, or once all crew members have returned to the hotel. Status reports and data uploads will also be given to the office manager with crew check-ins.

In the event that a check-in is not completed, all attempts will be made to contact the field crew via cell phones and hotel staff. If no contact can be established by 10pm, G3 will contact emergency authorities and report them missing with their last know location and the location of all the study sites.

4.0 WATER RESCUE

In the event of a water rescue the Safety Officer will coordinate the rescue team until the point at which a professional SAR Tech. of higher qualification arrives on site.

To reduce the chance of requiring swift water rescue, personal floatation devices (PFDs) are to be worn by ALL crew members when working near any fast moving water. Throw bags will be situated at each sample site as required. PFDs must be worn by all crew members while in the boat at all times. At least one crew member should be trained in swift water rescue for all work in or near flowing water.

4.1 Rescue Equipment (As Required)

In the event that strong currents are observed at a sample site, equipment designed specifically for swift water rescue will be located at either the on shore the first aid/rescue post (where applicable) or on the sampling boat.

Rescue Equipment includes:

- Throw bag;
- assorted 1" rescue webbing;
- 1 Rescue life jacket;
- assorted prussic slings;
- assorted locking carabiners; and,
- Level 1 first aid kit.

THIS EQUIPMENT IS TO BE USED FOR RESCUE PURPOSES ONLY.

4.2 Rescue Procedures

Swift water rescue requires special training and skills. In-stream rescues are to be conducted by appropriately trained field members only (i.e., Swift Water Rescue Technician 1). Rescue procedures are to be conducted in accordance to Swift Water Rescue procedures described in the Swift Water Rescue Training (SRT) course. Refer to SRT literature for appropriate procedures.

REMEMBER:

THROW	Throw bag first;
ROW	Assist with a boat or raft; and,
GO	Properly equipped swimming rescue as final resort.

5.0 FIELD MOBILITY & ACTIVITIES

During the field portion of any program, mobility and transportation of crew members and equipment will be facilitated through the use of a variety of means, including but not limited to:

- two and four wheel drive vehicles;
- motorized boats; and,
- aircraft (if required, or in event of emergency).

Each of these means of transport has certain inherent risks associated with use. To minimize these risks each means of transportation is to be operated and/or used in accordance with manufacturer's specifications and established guidelines (e.g., Coast Guard, Department of Transportation, WCB, etc.).

5.1 Boat Safety

Boats and rafts are to be used in accordance to Canadian Coast Guard regulations. Specifically boats will be equipped with a minimum of the following equipment:

- PFDs for all passengers;
- 15 m floating line;
- paddles/oars; navigation lights when operated at night;
- a signaling device (i.e., flares); and,
- a bailer.

In addition to this equipment, boats will be equipped with a marine VHF radio (hand held), survival gear and a first aid kit. In accordance to swift water procedures life jackets will be worn in the boat at all times it is operating within a reservoir. Boats are to be used for the sole purpose of field work and related activities. Excessive speed and/or dangerous use of boats is prohibited.

5.2 Fixed Wing Aircraft Safety (If Required)

Aircraft will not be used during the study unless required for emergency procedures (injury, evacuation etc.) unless otherwise specified, reviewed and approved in advance. In case contracting of aircraft is required, the pilot will explain safety in and around aircraft and proper procedures for flight. The pilot will have ultimate authority over safety issues pertaining to aircraft use which must be approved in advance by BC Hydro.

5.2.1 Pre Flight Procedure

1. All flights must be approved by the Manager, Aircraft Operations Department, or their delegate, prior to the flight taking place.
2. All flights must be in compliance with Canadian Aviation Regulations (CARs) and Provincial (WorkSafe BC) regulations.
3. A Fixed Wing Aircraft Booking Form must be completed by the requesting manager and forwarded to the Manager, Aircraft Operations Department, for approval.
4. A *Risk Assessment* and *Hazard Barrier* plan for scientific aerial surveys will be completed by the Manager, Aircraft Operations Department.
5. Emergency surveys (If required) may be pre-authorized in advance by submitting an emergency flight request on the standard Helicopter or *Fixed Wing Aircraft Booking Form*, with details of the approved flight crew and aircraft. The flight crew would normally consist of an experienced scientific flight coordinator familiar with the area and an approved experienced pilot. The Fixed Wing Aircraft Booking Form must be returned to the Manager, Aircraft Operations Department, the next working day for review.

5.2.2 Training

1. Prior to commencing any scientific work using any aircraft, all workers involved shall be adequately trained and familiar with the WorkSafe BC Occupational Health and Safety Regulations(OHS), Canadian Aviation Regulations (CARs) and will review this Safety Plan.
2. All non-BC Hydro personnel or BC Hydro passengers on board will receive a Flight Safety Briefing and review of Crew Resource Management (CRM) principles from the pilot prior to embarking on the flight.
3. The pilot must have documented proof of training in Pilot Decision Making (PDM) and Emergency Procedures. Documented proof will be listed on the pilot database available on the Aircraft Operations website.

5.2.3 Aerial Survey Procedure (as required)

1. Scientific aerial survey flights should be limited to five (5) hours on survey, with a maximum eight (8) hours of flight time per day.
2. Workers performing aerial surveys must complete a person check at regular intervals as determined by the flight plan
3. Aircraft selection must meet or exceed the requirements set out in this procedure
4. All patrols that include flights over remote areas must have an approved BC Hydro Emergency Preparedness kit on board when the flight commences. The emergency kit will have enough supplies to support all persons on board in case of an emergency landing in a remote area.
5. All low level aerial surveys must have an initial reconnaissance flight prior to a detailed survey being started if:
    a. The pilot and crew are not familiar with the area(s) to be surveyed; or
    b. The area(s) have not been flown within the past 6 months.
6. When flying or working over water (i.e. aquatic vegetation survey) all flight crew must wear an approved PFD (Personal Floatation Device).
7. In the case it is known that no flight hazards exist, the reconnaissance flight may be waived by any of the two listed below who are in agreement;
    a. Area Manager or delegate
    b. General Manager.

5.2.4 Pre-flight Operations / Job Planning

Always ask the question – Can the job or task be completed using other methods?

The following factors should be considered as part of job planning:

- Aircraft Selection
- Pilot Selection
- Pilot and Crew Pre-Flight Discussions
- Flight approvals
- Weather Check
- Aircraft Pre-flight Checks
- Person Check Procedure
- Route Planning
- Flight Following Coordination – ability to track aircraft
- Flight Mapping
- Flight hazards reviewed
- Crew Health (mentally and physically fit with mind on task)
- Crew Experience
- PDM – Pilot Decision Making TrainingSecurity during flight – equipment properly stowed, flight permits in place if required
- Communications Equipment check
- Personal Protective Equipment (PPE) as required -All required safety gear available

6.0 ASSOCIATED RISKS

There are several risks associated with the nature of certain field portions of any program. For this reason it is imperative that field members use their best judgment and remain vigilant in their application of safety protocols. If a question or uncertainty related to field safety arises, it is the responsibility of each crew member to consult the Safety Officer or this SAFETY PLAN document.

Certain risks associated with field work can be limited through application of common sense and judgment. Remember where you are and think about the risk involved in the work task and the potential outcome in the event of an emergency. Emergency resources may be limited, requiring absolute caution during all aspects of field work.

Generators & Motors

Never refuel a running motor. Be sure that the appropriate fuel type is used when refueling.

Alert other crew members when starting a generator, particularly when using power tools or related electrical appliances.

Shore Sampling

Sample collections from shore are to be conducted by experienced field members equipped with appropriate safety gear. All crew members must have pfd if sampling near swift water, wading belt (if using chest waders), and appropriate footwear. There must be throw lines stationed nearby for all in water activities.

Swimming

Swims (if required) are to be conducted by experienced field members equipped with appropriate dry suits and floatation devices. Crew members are not to conduct swims alone unless accompanied by a drift raft equipped with appropriate rescue equipment and experienced personnel.

7.0 EMERGENCY PHONE AND RADIO PROCEDURES

****DIAL 911

The nature of the field work requires the use of boats and may require use of 4x4 vehicles. In the event of an emergency be sure to identify the following points to the response team:

the situation involves stranded/injured field member(s) (in the river, up a road) requiring a search and rescue; and/or,

the situation involves injured field member(s) requiring assistance from the first aid/rescue post (e.g., field camp, truck, etc.).

In the event of an emergency:

Describe the nature of the accident in sufficient detail to assist in appropriate response. Keep details to the essential points. Speak slowly and clearly to avoid confusion. Be decisive in your actions and requests and have your request repeated back to you for confirmation. Provide the following information to the response team:

1. Nature of emergency (Medical, Accident, Storm/Weather, etc.);
2. Number of persons involved;
3. Type of assistance required (Paramedic, SAR Team, Heli/Air evacuation, Emergency towing, etc.);
4. Field location; and,
5. Site Description (as viewed from the air, water, road, etc.).

Remember to use logic. If the field team is known to be at a specific location, assistance and searches should focus on that area first.

7.1 Radios

Ensure all crew members are familiar with radio operation and know where the radio is located. Establish the following:

- an appropriate relay station (i.e., nearest party);
- approximate range of radio signal; and,
- barriers to radio use (i.e., valleys, mountains, etc.).

Nakusp EMS	149.68000
Nakusp Fire	153.83000
Central Kootenay RCMP	139.44000
	139.53000
	139.56000

7.1.2 Emergency Radio Call Procedure

1. Radio Callsign of the station you are calling;
2. “This is” <Give Radio Callsign>;
3. “Do you Copy”;
4. “Over.”

Speak Slowly and clearly to avoid confusion. Talking across the face of the microphone may make communications more understandable. If the emergency **requires** interruption of non-emergency communication radio protocol “Break Break” requests the channel be cleared for your priority message.

Once communication has been established with emergency services, provide the following information:

- Nature of emergency (Medical, Accident, Storm/Weather, etc.);
- Number of persons involved;
- Type of assistance required (Paramedic, SAR Team, Heli/Air evacuation, Emergency towing, etc.);
- Field location; and,
- Site Description (as viewed from the air, water, road, etc.).

Remember to use logic. If the field team is known to be at a s pecific location, assistance and searches should focus on that area first.

8.0 EMERGENCY TELEPHONE NUMBERS (PROJECT SPECIFIC)

G3 Consulting Ltd.	604-598-8501	
G3 Field Cellular	604-836-8501	604-255-1451
Emergency Services	911	
Minor Emergency Care	Edgewood Health Centre 322 Monashee Ave, Edgewood, BC	1-250-269-7313
Nearest Hospital	Arrow Lakes Hospital 97 1st Ave NE, Nakusp, BC	1-250-265-3622
Advanced Care Hospital	Kelowna General Hospital 2268 Pandosy St, Kelowna, BC	1-250-862-4000
Regional RCMP	Nakusp RCMP	1-250-265-3677
Regional Search & Rescue	Arrow Lakes Search and Rescue	1-250-265-4370
Regional Fire	Nakusp Fire Department	1-250-265-3563
Forest Fire	1-800-663-5555	*5555
Spill Reporting (PEP)	1-800-663-3456	

Accommodation
(G3 Field Crew)

Employee	Hotel (room)	Telephone	Cellular

<u>Remember: Safety First</u>

Appendix 8

Sample Sediment Field Form
Field Forms
Sample Biophysical Observation Form

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Innovation & Excellence in Environmental Science

Biophysical Observation Form

Date (yy/mm/dd)	Proj. No.	Site Location	UTMs	Recorder
	1105			

Biophysical Observations

Zone	Transect	Depth (m)	Transect Distance (m)	Substrate		Vegetation			
				Dominant	Sub Dominant	Dominant		Sub Dominant	
						Type	%	Type	%
A	1								
	2								
	3								
B	1								
	2								
	3								
C	1								
	2								
	3								

Zone

Type	Symbol
Nearest to Shore	A
Mid-distance from Shore	B
Furthest from Shore	C

Bottom Substrate

Type	Symbol
Rocky Shore-Bedrock	R-b
Rocky Shore-Rubble	R-r
Unconsolidated Shore-Cobble Gravel	UG

Bed Material

Class	Symbol	Size	Description
Fines	F	<2 mm	Smaller than a ladybug
Gravels	G	2-64 mm	Ladybug to tennis ball
Cobbles	C	64-256 mm	Tennis ball to basketball
Boulders	B	>256 mm	Larger than a basketball
Rock	R	>4000 mm	Includes boulders and blocks >4 m and bedrock
Anthropogenic	A		Riprap or other structures

Site Location:	Date:	UTMs:	Sketch Artist:

Sketch:

Comments:

IN SITU SEDIMENT DATA FORM

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GRAB CHARACTERISTICS

Site #: G3-11-1-17C Mid | **Effort #:** 1 | **Recorder:** NC

Date: September 28, 2011 | **Time:** 16:30 | **Weather:** sunny

Depth of Water at Sampling Site: 0.75 m

GPS Coordinates (UTMs):

% Ponar Filled: 100%

Water Velocity:

Colour (check):
black ☐ dark brown ☐ brown-green ☑ gray-green ☐ blue-gray ☐ dull gray ☐ other:

Consistency (describe & check):
gel-like ☐ loose ☐ watery ☐ thick like pudding ☑ falls apart into fluffy pellets ☐ other:

Texture (check): silky ☐ talcomy ☐ gritty ☑ gravelly ☐ other:

Smell (check): odourless ☑ rotten egg ☐ acrid ☐ chlorine ☐ oil ☐ creosote ☐ other:

Description of Debris Present:

Fine gravel
Surface plant layer, aquatic macrophytes

Other Comments:

GROSS CHARACTERISTICS OF VERTICAL PROFILE

Penetration Depth of Grab (cm):

Homogeneous throughout? Yes ☐ No ☑

If not, describe (include any horizontal streaks of brown or black; presence of varves or other obvious vertical layers; presence of thin oxidized layer on surface):

Other Comments:

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IN SITU SEDIMENT DATA FORM

GRAB CHARACTERISTICS

Site #: G3-11-1-17C Mid	**Effort #:** 1	**Recorder:** NC
Date: September 28, 2011	**Time:** 16:30	**Weather:** sunny

Depth of Water at Sampling Site: 0.75 m

GPS Coordinates (UTMs):

% Ponar Filled: 100%

Water Velocity:

Colour (check):
black ☐ dark brown ☐ brown-green ☑ gray-green ☐ blue-gray ☐ dull gray ☐ other:

Consistency (describe & check):
gel-like ☐ loose ☐ watery ☐ thick like pudding ☑ falls apart into fluffy pellets ☐ other:

Texture (check): silky ☐ talcomy ☐ gritty ☑ gravelly ☐ other:

Smell (check): odourless ☑ rotten egg ☐ acrid ☐ chlorine ☐ oil ☐ creosote ☐ other:

Description of Debris Present:

Fine gravel
Surface plant layer, aquatic macrophytes

Other Comments:

GROSS CHARACTERISTICS OF VERTICAL PROFILE

Penetration Depth of Grab (cm):

Homogeneous throughout? Yes ☐ No ☑

If not, describe (include any horizontal streaks of brown or black; presence of varves or other obvious vertical layers; presence of thin oxidized layer on surface):

Other Comments:

G3 Consulting Ltd., 206-8501 162nd Street., Surrey, BC, V4N 1B2 Tel: (604) 598-8501

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IN SITU SEDIMENT DATA FORM

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Description of Debris Present:	**Other Comments:**
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GROSS CHARACTERISTICS OF VERTICAL PROFILE

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IN SITU BENTHOS DATA FORM

GRAB CHARACTERISTICS

Site #:	Effort #:	Recorder:
Date:	Time:	Weather:

Depth of Water at Sampling Site:

GPS Coordinates (UTMs):

% Ponar Filled:

Water Velocity:

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Description of Debris Present:	Other Comments:

GROSS CHARACTERISTICS OF VERTICAL PROFILE

Penetration Depth of Core (cm):

Homogeneous throughout? Yes ☐ No ☐

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