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Memo

To: Trevor Hutton, General Manager
North Salt Spring Waterworks District

Date: January 28th, 2011

From: Lynne Atwood

Subject : Predicting impacts of increased lake levels on riparian vegetation at St. Mary Lake

BACKGROUND

North Salt Spring Waterworks District (NSSWD) has held water licenses on St Mary Lake since the 1960s. A water storage weir was constructed in 2006 and additional demand requires raising the weir crest height by 0.3 m, to elevation 41.0 m. This increase was anticipated during construction and can be accommodated with minor modifications to the existing structure.

On December 14th, 2010 a survey of the riparian vegetation around the lakeshore was conducted. The lake level was 40.8m at that time. The survey was done from the water and was qualitative; no vegetation transects were conducted. The impact scenarios presented in this memo are considered preliminary. Accurate data on species composition of the existing plant communities as well as the expected timing and duration of the high water level would be required to make quantitative predictions. The following items are included in this memo: a discussion of the ecological conditions that determine riparian vegetation patterns; a brief description of the riparian vegetation communities that occur around St. Mary Lake, and; a list of impacts that may occur to these communities if lake levels are increased 0.3 m.

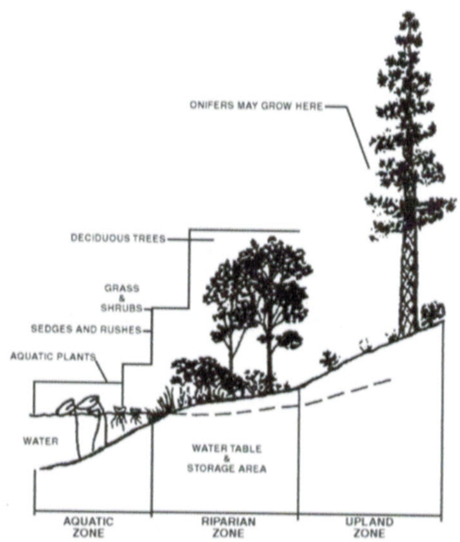
RIPARIAN ECOSYSTEMS

Riparian ecosystems are plant communities that occur adjacent to a water body; they are ecotones between aquatic and terrestrial, upland ecosystems that contain some aquatic and upland terrestrial species as well as vegetation that is distinct from the surrounding area. The form and structure of riparian ecosystems are influenced by: fluctuations in the water table caused by flood frequency, duration and intensity; variation in rates of sediment deposition, substrate type and texture; associated slope of both the lake bottom and adjacent shoreline, and; land use within and around the riparian area(Elmore 1988, Evenden 1989, Busch and Smith 1995, Fetherston et al. 1995). These influences create a series of habitat islands within a relatively small geographic area that may vary in general appearance, vegetative complexity, and ecosystem function (Odum 1979).

The water-related habitats have extremely high productivity. Increased plant biomass creates a complex vegetation form and structure that ameliorates shoreline climatic conditions and provides food, cover and nesting habitat for a disproportionately high number of both terrestrial and aquatic wildlife species (Bond el al. 1992, Hollis el al. 1988). The linear nature of natural riparian areas also maximizes the development of edge habitat, vegetation strata that are exposed in a step-like fashion. Edge habitat has an abundance of cover, nesting and feeding opportunities, much more than adjacent plant communities (Morgan and Wetmore 1986). As well, the diverse root systems associated with riparian systems reinforce and protect banks and shorelines (Elmore 1988).

Soils in riparian areas are not always saturated and plant species change according to depth of soil saturation and the duration of saturation. In Riparian communities, there is a transition of plant species from aquatic to upland terrestrial species along a gradient of decreasing soil moisture (Figure 1).

At St. Mary Lake, aquatic shoreline species are dominated by emergent macrophytes, specifically cattails (*Typha* spp) and bulrushes (*Schoenoplectus* spp). Terrestrial riparian species vary depending on the slope of the adjacent lake bottom and shoreline. Slope influences soil moisture and soils on steeper slopes are drier than flat or slightly sloped areas. In general, flat or slightly sloped areas immediately adjacent to the waters edge contain species that are adapted to very wet soils during the winter and very moist soils during the growing season. In this area, the water table is at or above the ground surface in winter and typically more than 30 cm deep during the growing season (Green and Klinka 1995). St. Mary Lake vegetation in this zone is dominated by sedges, rushes, grasses, hardhack (*Spirea douglasii*) and willow (*Salix* spp), which are highly resilient swamp species that can survive in both water and on muddy substrates.



Source: The Impact of Federal Programs on Wetlands - Vol. II" http://www.doi.gov-/oepc/wetlands2/images/fig12-1.gif

Areas slightly above the lakeshore community are colonized by plant species adapted to wet winter soils, were the water table is between ground level and 30 cm below ground, and near field capacity during the summer (i.e., soils with no water deficit during the growing season). Grasses, herbs and shrubs are common in this middle-vegetation band. At St. Mary Lake the common species in this zone are salmonberry *(Rubus specabiliis)*, red osier dogwood (*Cornus stolonifera*) and willow species that do not like soils that are saturated year-round. These species do best in continually moist soils.

The upper band of riparian vegetation is adapted to drier soil conditions. Winter soils are very moist, the groundwater is > 30 cm below soil surface and summer soils are slightly dry (Klinka et al 1989). Slightly dry soils typically experience a water deficit of up to 1.5 months during the growing season (Klinka et al 1989), so plants in this zone must be able to tolerate this dry period. Indian plum (*Oemleria cerasiformis*), red-alder (*Alnus rubra*) and big-leaf maple (*Acer macrophylum*) are common in the upper riparian plant communities at St. Mary Lake. Western red-cedar (*Thuja plicata*) and Douglas-fir (*Pseudotsuga menziesii*) are also found in this upper riparian community, although Douglas-fir prefer the drier, upslope soils, and hence are relatively scarce in the upper riparian zone.

Determinants of Flood Tolerance

Fluctuating water levels are the most important factor affecting vegetation patterns in riparian areas and many species are particularly sensitive to the timing and duration of the soil water (Evenden 1989, Delong 1991, Busch and Smith 1995). In general, conifers are less tolerant of flooding than deciduous trees, shrubs and herbs. In all species, the ability to tolerate high water levels increases with age. Seedlings rarely survive flood events; even emergent macrophytes require a portion of their stems to be above the water level throughout the year (Patrick et al 1981, Wenger 1984, Middleton 1999). Of the common tree species in riparian areas around St. Mary Lake, Klinka and company (1998) list Douglas-fir as intolerant of flooding and red alder, big-leaf maple and western red-cedar as highly tolerant of flooding. Wenger (1984) agrees with Klinka's Douglas-fir and red alder classifications, but considers big-leaf maple and western red-cedar only weakly tolerant of flooding; the duration of the flooding likely being the factor that determines survival.

The degree of flood tolerance in all species is determined by physiological and morphological traits. Species may possess one or more of the traits.

<u>Physiological traits that determine flood tolerance:</u>

- Roots can carry on anaerobic respiration while maintaining metabolic control: plants contain aerenchyma root tissue (buoyant tissue with large inter-cellular spaces), which rapidly diffuse oxygen. Lodgepole pine (*Pinus contorta*) has this type of root tissue (Coutts and Philipson 1978, Stoecker et al. 1995).

- Plants are capable of oxidizing their rhizosphere (narrow region of soil immediately adjacent to the root): plants possess stomatal pores or lenticels that move oxygen down the stem and out the root into the rhizosphere. The area immediately adjacent to the root is oxidized and toxic substances are reduced; this technique is common in willows, alders and lodgepole pine (Philipson and Coutts 1980).

- Roots can tolerate high concentrations of soil toxins that are common in oxygen-deprived soils. Anaerobic respiration releases carbon dioxide, methane, hydrogen and nitrogen and organic acids into the soil, substances that are toxic to plants. Some plants, such as cottonwood form lenticels on the submerged portions of the stems. These facilitate stem aeration and also release toxic compounds (Hook 1984).

<u>Morphological traits that determine flood tolerance:</u>

- Secondary roots can survive inundation; roots may contain aerenchyma tissue that retains oxygen and provide buoyancy (Middleton 1992).

- New secondary roots develop at the dieback point of the original roots of flooded plants. The new roots can diffuse oxygen into the rhizosphere and detoxify the soil. The new secondary roots will also increase the supply of root hormones to the shoots, aiding photosynthesis (Kozlowski and Pallardy 1997).

- Adventitious water roots develop: maples, alders, poplars, willow and western red-cedar form adventitious water roots. The roots develop further up the stem of the plant, above the soil but near the water surface in the flood zone. This area contains water and oxygen but anaerobically generated toxins are absent. (Kozlowski 1984).

To survive in waterlogged soils plants must adapt to an oxygen-deprived root environment. To do this, swamp species develop new secondary roots, oxidize their rhizosphere, and carry on anaerobic respiration (Wenger 1984). However, the typical response of flood intolerant species is to accelerate anaerobic respiration to the point where the toxic substances kill the plant itself (Raju 2002). Some species of trees are killed by flood duration of less than one month, while others can survive continuous flooding for at least two growing seasons. However, inundation of soil for a few weeks or more during the growing season retards growth of most woody plants

(Kozlowski and Pallardy 1997). Standing water during the growing season typically has less oxygen, which increases soil microbial activity; and thereby increases exposure to toxic conditions for the the majority of species (Middleton 1999, Raju 2002, Malanson. 1993).

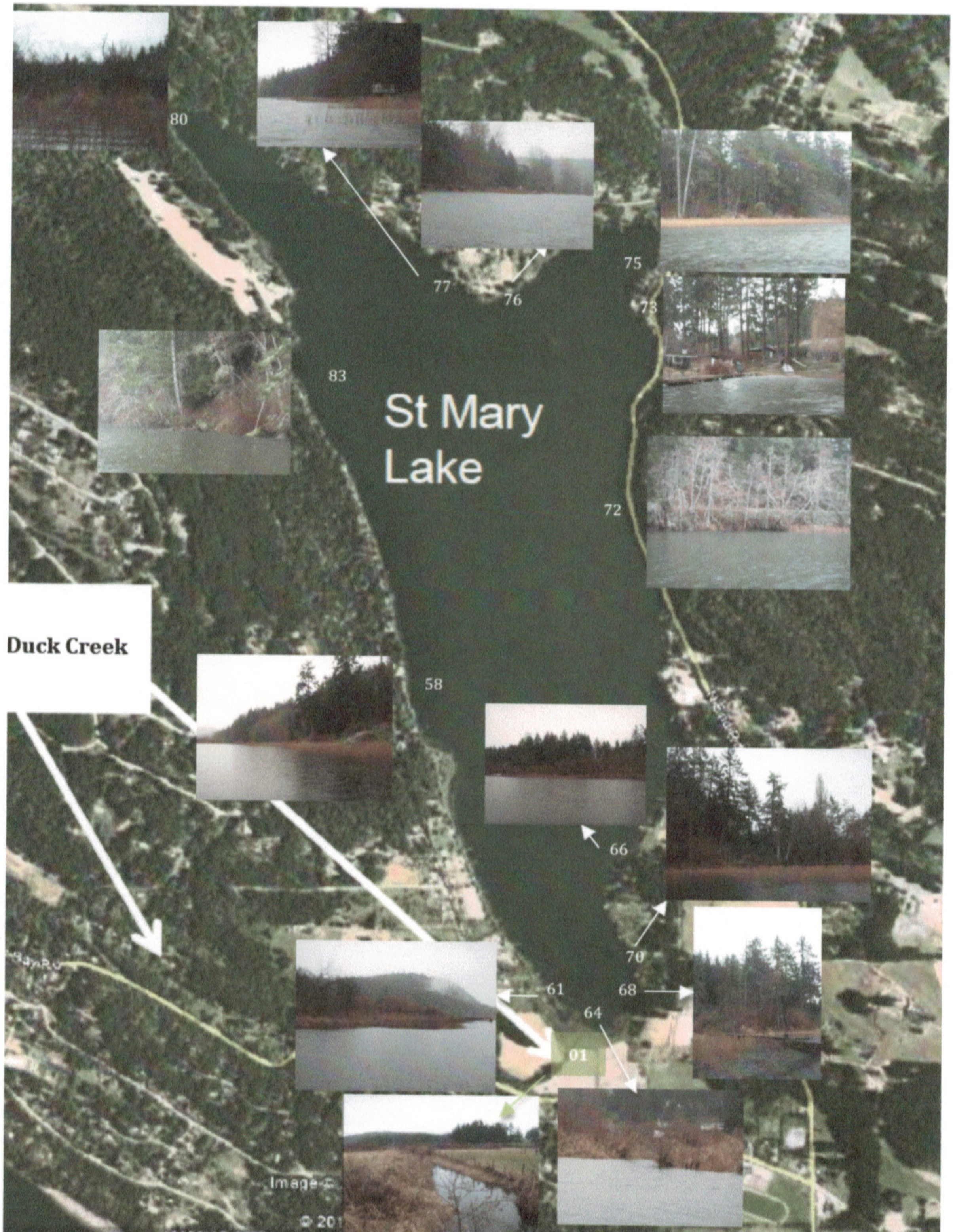
Riparian Vegetation at St. Mary Lake

The extent, type and dominant plant species of the St. Mary Lake riparian vegetation varies around the lake. The southern portion of the lake is more developed and riparian vegetation is limited; very little is in its natural, undisturbed state. The majority of the riparian vegetation in the developed areas has been removed and replaced with grasses, either lawn or pasture (Map 1, Photos 58 and 73). Occasionally, a thin shrub and deciduous tree strip remains between the aquatic macrophytes and the cleared lawns and pasture. Exceptions to this are the southwest corner, around Duck Creek. This area contains a wide macrophyte band and patches of shrubs adjacent to open pasture (Map 1, Photos 61 and 64). There are also pockets of upland forest in the south-east corner, although in many areas the conifer-dominated strips are perpendicular to the lakeshore along the property boundaries (Map 1, Photos 58, 66, 68 and 70). A deciduous tree band occurs along the north-east side of the lake where a very thin strip of red alder separates the lake from the road (Map 1, Photo 72).

The majority of the natural vegetation at St. Mary Lake is at the north end of the lake and differences in water table levels are evident by differences in plant species, relative to adjacent areas. The small bay on the northeast side of the lake contains a wide forested strip (Map 1, Photo 75) with some water-loving species, such as red-alder, but also Arbutus (*Arbutus menziesii)* and Douglas-fir, species that only tolerate very short-term flooding or no flooding, respectively. Along the northern most border of the lake are large patches of low and middle bench riparian vegetation, dominated by red alder, big-leaf maple, willow, and red-osier dogwood to name a few (Map 1, Photo 76). The northwest arm of the lake is dominated by conifers (Map 1, Photo 77) and ends in a swamp (Map 1, Photo 80). The west side of the northern arm is also dominated by coniferous forest and there is a very steep gradient from the water's edge to the top of the slope (Map 1, Photo 83). The steep-sided coniferous vegetation continues down the west side of the lake, narrowing where the road comes close to the lakeshore and giving way to landscaped lots and houses with a fringe of deciduous trees and shrubs, in the southern third of the west side (Map 1, photo 58). Between the lake and the weir on Duck Creek the mature riparian corridor has been removed. Weedy grasses, particularly reed-canary grass (*Phalaris arundinacea*) line this portion of the creek (Map 1, Photo 1).

Aquatic vegetation, rings most of the shoreline. The exception is along the steep slopes found along the north-west side of the lake (Map 1, Photo 83). The steep slopes in this area contain Plant communities that are not impacted by lake water levels, as most of the species present are flood-intolerant. Forests in this area are dominated by Douglas-fir with lesser amounts of western red-cedar and grand fir (*Abies grandis*), salal (*Gaultheria shallon*), dull Oregon grape (*Mahonia nervosa*) and oceanspray (*Holodiscus discolor*).

Map 1: Diversity of riparian plant communities around St. Mary Lake. Inset photos taken December 14, 2010.



Ecology of Riparian Species Common to St. Mary Lake

Emergent Macrophytes

Cattail and bulrush are the most common emergent macrophytes along the St. Mary Lake shoreline. The species are tolerant of fluctuating water levels, but neither prefers repeated and prolonged flooding (Currier et. al. 1978, Shay et. al. 1986, Lethto and Murphy 1989).

Optimum growth conditions for cattail and bulrush are in water that is < 1 m deep (Wetzel 2001, Magee and Kentula 2005). Cattail prefers shallow water and will grow in as little as 2.2 cm, in areas that dry out in the summer (July and August). Highest cattail density is attained in 22 cm deep water (Keith 1961, Grace and Wetzel 1981 and 1998, Hanson et al. 1988, Fickbohm and Wei-Zing 2006). Studies have shown that cattail died in all continuously flooded areas with water depths >46cm within 5 years (Steenis et al. 1959, Waters and Shay 1992). Bulrush grows in water that is too deep for cattail and when they grow together, bulrush will be found on the open-water side of cattail patches. Optimal water depth for bulrush is 30 cm, but it is found in water up to 1.5 m deep and very occasionally in water that is 2.5 m deep (Guard 1995, Harris and Marshall 1963, US Department of the Interior 1994). However, bulrush colonies will not survive for long when water levels are retained at 2.5 m (US Department of the Interior 1994).

Flood tolerance of cattail and bulrush is related to rhizome (underground runners that produce new shoots) production, season of flooding, age of the plant stems and surrounding vegetation (Currier et al 1978, Grace and Wetzel 1981 and 1998, Lethto and Murphy 1989). The primary mode of reproduction of both species is vegetative: they can spread rapidly from rhizomes. Vegetative reproduction occurs throughout the growing season, but will cease when water levels are too deep. Cattail rhizome production decreases substantially when water levels are >30 cm (Weller 1975, Dickerman et. al. 1985). Cattail rhizomes are highly productive at low water levels and can withstand some exposure, although they will not survive extended drought (Nelson and Dietz 1966, Hanson et al. 1988). Bulrush rhizomes are much more sensitive to water level fluctuations; they are very shallow and must be kept moist to survive (Harris and Marshal 1963, US Department of the Interior 1994).

Sexual reproduction does occur in both species, however both have precise germination requirements and cattail will not flower when its roots are submerged (Young and Young 1986, Grace 1989). Seedlings that do establish are very sensitive for the first two years. Cattail plants less than 1 year old died when water depths exceeded 46 cm and two-year old plants did not spread when water levels were 46 – 51 cm (Grace 1989, Grace and Wetzel 1981). Bulrush seedlings are equally sensitive and will not survive their first year if water levels are > 4 to 5 cm deep (Currier et al 1978; Lethto and Murphy 1989, Kerans 1990, US Department of Interior 1994). Seedling stems of both species must be above the water level to survive (Weller 1975, Sale and Wetzel 1983).

Cattails are more tolerant than bulrush to annual drawdown and flooding, and cattail will replace bulrush (Cooper 1978, Frolik 1941). However, cattail rhizomes are not as tolerant to drought as reed-canary grass (Grace and Wetzel 1981 and 1998).

Terrestrial shrubs and trees

Timing and duration of increased water levels are critical for terrestrial riparian plants (Wenger 1984, Middleton 1999). In general, species can withstand high water tables and standing water for longer periods of time during the winter months, when plants are not actively growing (Kozlowski 1984, Wenger 1984). Shoreline and middle riparian plant communities contain flood-tolerant species. However, further upslope species are less able to withstand saturated soils or inundation. Upper-level flood intolerant species shut down when soil water content is too high, and the typical response is a rapid reduction in the rate of photosynthesis (Kozlowski and Pallardy 1984, Zaerr 1983). Reduction in photosynthesis is caused by closure of stomata, resulting in decreased carbon dioxide absorption by the leaves (Pereira and Kozlowski 1977). Some flood-sensitive species lack a mechanism for reopening the stomata once water recedes, which in the long-term, can inhibit the plant's photosynthetic capacity (Kozlowski and Pallardy 1984).

One flood-adaptation strategy used by riparian shrubs and trees is a reliance on vegetative rather than sexual reproduction. Seeds require exposed, unsaturated mineral or organic soils to germinate, but vegetative growth, from root or stem fragments, rhizomes or stolons often prefer saturated conditions.

Willows, which are common to the lower riparian areas around St. Mary Lake are adapted to a range of soil moisture conditions and many willow species will tolerate standing water. Flood-tolerant willows form adventitious roots near the water surface and possess lenticels that oxidize the root system. They will reproduce from both stem and root fragments. However, for many willow species, growth can be severely reduced when water levels are retained at or above the root collar for extended periods of time (Brayshaw 1978, Knighton 1981).

Red-osier dogwood is another common shrub in the lower riparian areas at St. Marys Lake. Red-osier dogwood can live with its roots immersed in water. Reproduction from stolons (above-ground stems) are one of its' flood-tolerant adaptive techniques. In very moist to wet sites, above ground stems that come in contact with soil will root at the nodes and send up new shoots (Smithberg 1974).

Salmonberry spreads from underground rhizomes and it favours moist sites, where soils are moist but not saturated. Root growth is inhibited in saturated soils and standing water will stunt growth, slow respiration and eventually kill the plant (Barber 1976).

Red alder is the most common deciduous tree around St. Mary Lake and it occurs in all communities, from shoreline to upper-slope. It is a riparian species that relies on sexual rather than vegetative reproduction for population growth (Debell et al. 1984). Seed germination is best on moist, mineral soil that receives full sun. Red alder tolerates poorly drained soil and will survive prolonged periods of flooding but the best stands are found on deep, well-drained soils (Fowells 1965). However, it is considered one of the most tolerant species in coastal areas with high water tables (Minore 1979). Red alder survives standing water by developing adventitious roots near the water surface (Kozlowski 1984).

Big-leaf maple is not as common around St. Mary Lake as red alder, however it does prefer wetter soils than red alder. Its best growth occurs on sites with abundant seepage, although it will not withstand prolonged flooding (Krajina et al 1982, Minore 1979). Reproduction is primarily sexual, although it will sprout from dormant buds if the top of the tree is killed (Fowells 1965). Germination requires moist, mineral or organic soils.

There are two conifer species common to St. Mary Lake; western redcedar and Douglas-fir. Douglas-fir responds to gradients of elevation and soil moisture. Western redcedar responds to soil nutrients and elevation, and soil moisture has little effect on growth and survival (Gagnon 1995). Western redcedar is common in forested swamps and will tolerate stagnant winter water tables averaging < 15 cm below the soil surface (Minore and Smith 1971). Redcedar's extensive, shallow root system is an adaption to growing in wet environments; however, the root system is not as extensive as with species associated with dry soils (USDA Forest Service, 1990). The shallow root system makes western redcedar susceptible to wind-throw in wet environments (Minore 1983).

Douglas -fir are scattered along the St. Mary Lake shoreline and they dominate the upper elevation areas. Douglas-fir grows best on well-aerated, deep soils and does not thrive on poorly-drained soils (USDA Forest Service, 1990). Douglas-fir does not tolerate saturated soils or flooding and stops photosynthesis under these conditions. Studies have shown Douglas-fir photosynthesis shuts down within a day or two of root saturation and prolonged events can inhibit photosynthetic capacity of the tree (Kozlowski and Pallardy 1984, Zaerr 1983). High water tables also impact root morphology of Douglas-fir. In areas with a high water table Douglas-fir feeder roots are concentrated in the top 20cm of soil (Minore 1979, Klinka et al. 1998). Support roots are also concentrated above the water table, but will grow obliquely into deeper soil layers when possible. If support roots are in saturated soils for long periods of time, the tree is susceptible to wind throw (USDA Forest Service, 1990).

With changing water levels, species at the edge of their habitat preferences and species with adaptations that enable them to avoid the condition only temporarily are most at risk. In shrub environments water level regulation by dams has reduced flood- intolerant upland species growing adjacent to riparian communities. The species are replaced by willows and other pioneer riparian species (Williams and Wolman 1984; Harris et al. 1987; Johnson 1994). If willow seed or root fragments are not available for recruitment, annual forbs, grasses, horsetail and sedges are most likely to colonize the newly flooded areas (Harris and Lindquist 2000). When water levels are raised to intersect upland soils, studies have shown overall species diversity of the riparian system declines (Nilsson and Berggren 2000).

Many intolerant species use avoidance techniques to survive flood events. The intolerant species will either rely on short-term accelerated anaerobic respiration or ceasing photosynthesis. If flooding is prolonged, these strategies are ineffective and the plant will die. Large species, specifically trees can withstand poor conditions for a longer period of time, but when subjected to repeated prolonged or continual flooding, a slow death is typical (Werner 1984, Young et al 1995, Stahle and Cleaveland 1992, Fowells 1965).

Impact of Increased Water Levels on St. Mary Lake Riparian Plant Communities

The predicted frequency and duration of St. Mary Lake water levels is somewhat uncertain, but data presented by NSSWD suggest there is potential to retain the lake level at 41.0 m from early December to mid-July for durations of one to six months (Figure 1). The following conclusions are based on the predicted water level occurring between April and June, the growing season for the majority of plant species in the area.

1. Water level was at 40.8 m when the lake was surveyed in early December, which appears to be an average winter water level. At this height, there are no flood-intolerant species in standing water, although some individual plants may be in saturated soils.

2. It is difficult to predict what changes will occur in existing riparian communities and so potential impacts have been estimated, based on preferred water levels of aquatic species and flood tolerance of the species that dominate the shoreline.

3. Shoreline topography and lake bathymetry suggest there are three areas around the lake that may be susceptible to a 0.3 m increase in water level: the northeast bay, the northwest arm and the southern end of the lake (Figure 2). These areas have very shallow slope from lake to upland areas and currently support all three levels of riparian plant communities. The areas highlighted on Figure 2 likely have high water tables throughout the year.

4. Very little to no changes in existing shoreline plant communities are expected in other areas of the lake. The steep slope between the lake and upland areas will absorb the increase in water level without inundating the roots of shoreline plants. Changes in this area will likely be limited to a minor loss of mosses and ferns that have established on rocks adjacent to the waters edge (Map 1, photo 83).

5. It is likely an increase in lake level will result in an upland shift in riparian vegetation in the three susceptible areas (i.e. northeast bay, northwest arm and south end of the lake) and an upland shift in aquatic macrophytes throughout the lake.

6. A loss of all riparian plant species may occur on some private lands. Some landowners have retained a thin band or patches of riparian species between the lakeshore and their lawn or agricultural land. These species may not be able to adapt to the higher water table or to periodic inundation. Landowners may allow an upslope movement of the species, but if they are farming the area that seems unlikely.

7. Riparian species diversity may be reduced. Intolerant species will likely be displaced by water-tolerant species.

8. Areas with a lot of disturbance, such as the agricultural areas at the south end of the lake, may see an increase in invasive species adapted to wet soil conditions. Canda thistle *(Cirsium arvense)* is well suited to these conditions.

9. Portions of the agricultural land at the south end of the lake may convert to swamp. This will depend on how often the area is inundated and for how long. The area may become too wet to farm.

10. Pioneer species, such as grasses, herbs and willows may expand at the expense of shrubs and trees, species with slower reproductive and growth rates.

11. A shift in aquatic plant communities may be evident by a narrowing of bulrush colonies because water is too deep to support them and newly flooded areas are not inundated long enough to allow establishment.

12. Cattail may colonize the shoreline in bulrush areas. Cattail is more likely to establish in newly flooded areas that bulrush.

13. Weedy species, such as reed canary grass may colonize the shoreline in bulrush and cattail areas. Reed canary grass can withstand longer periods of drought than either cattail or bulrush and it may be favoured in newly flooded areas.

14. The willow - hardhack community may move upslope displacing salmonberry and red-osier dogwood. Depending on slope and soil type, salmonberry and red-osier dogwood may also move upslope, however they will not do as well in drier coarse textured soils.

15. The red alder, that is located between the lake and road, on the northeast side of the lake (Map 1, photo 72), may be replaced by more water-tolerant shrubs or weedy grasses. The trees are growing in marginal conditions and additional stress may kill them.

16. Some large-old Douglas-fir trees that occur in the three susceptible zones may die. It may be a slow death from compromised photosynthetic ability or wind-throw.

Figure 1: Graphed lake level data for St. Mary Lake for average years between 1981 - 1982 and 2006 - 2007. (Provided by NSSWD).

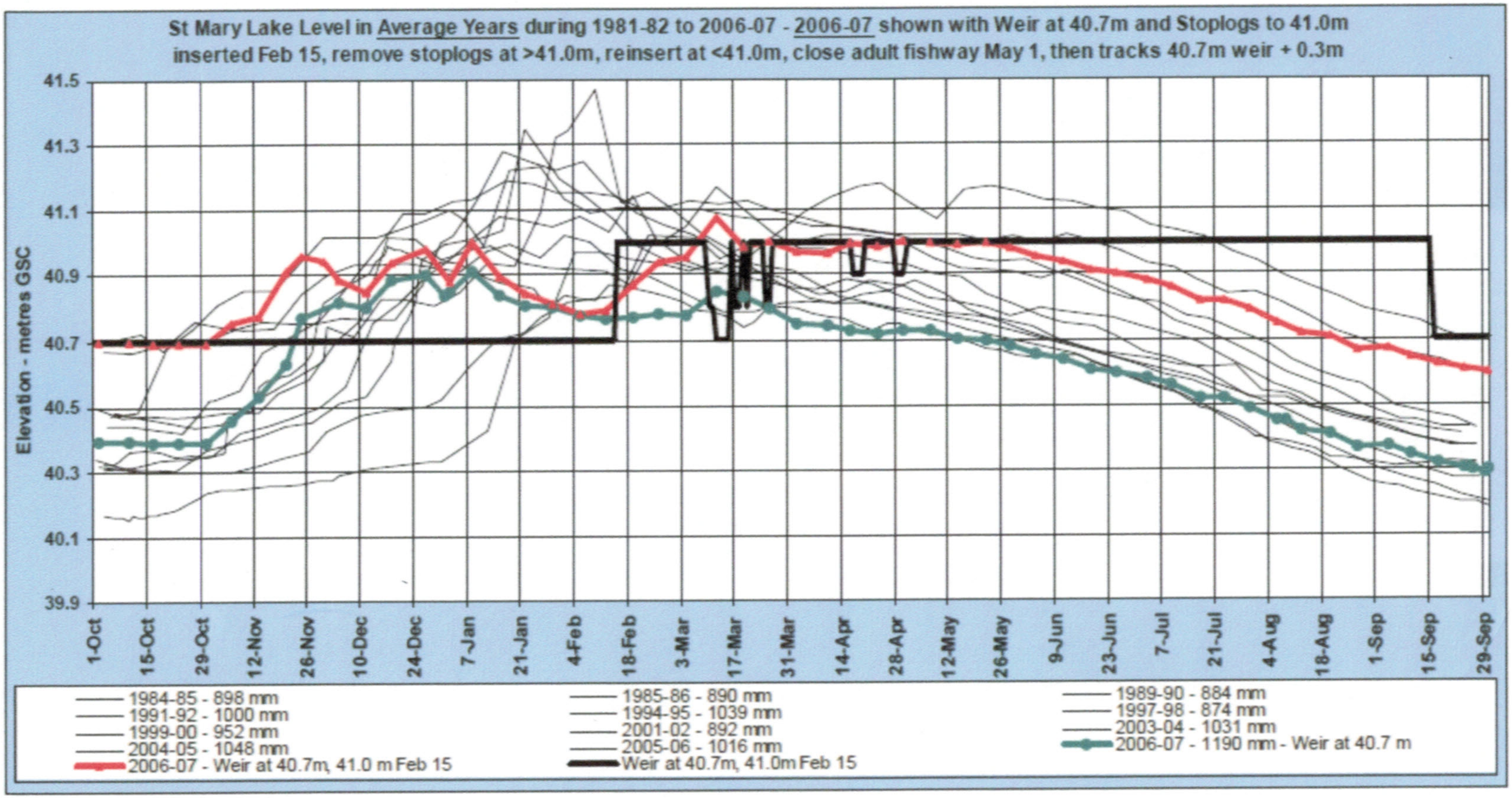
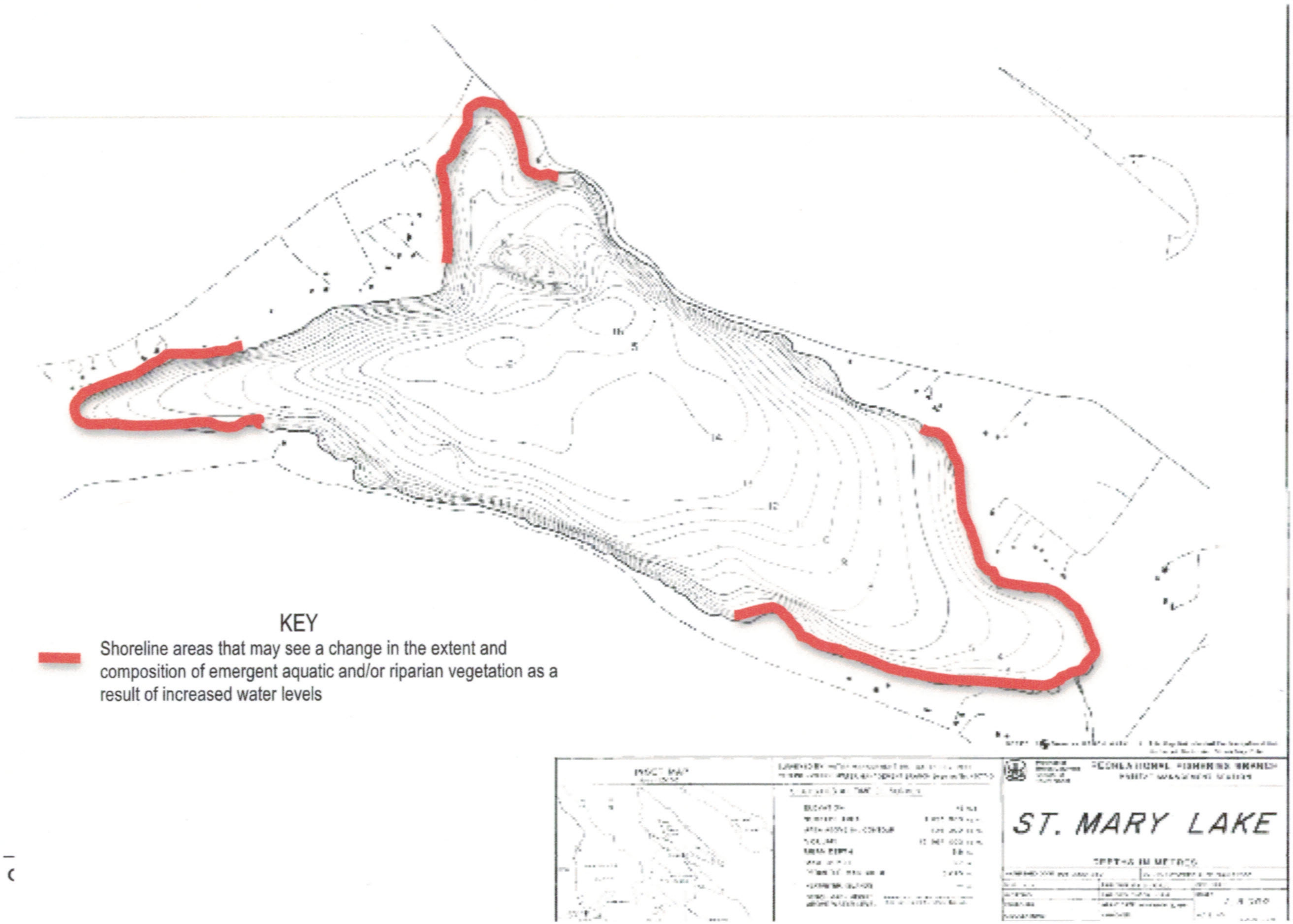


Figure 2: Areas of St. Mary Lake that may be susceptible to changes in riparian vegetation as a result of increased water levels. (Base map provided by NSSWD).



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