Lower Tawatinaw-Little Pine Creek Watershed Assessment

Prepared For:

For Crooked Creek Conservancy Society of Athabasca
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Little Fish Consulting Ltd.

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Tawatinaw Watershed Stewards and Keepers of the Athabasca

Kyle Ashmead,
Tawatinaw Watershed Stewards

1.0 INTRODUCTION

North Pine Environmental Ltd. was contracted by the Crooked Creek Conservancy Society of Athabasca to complete a watershed health assessment of the Tawatinaw River-Little Pine Creek Watersheds. The Tawatinaw River is a tributary of the Athabasca River in the Athabasca River Basin and is host to a rich and diverse myriad of flora and fauna. The Tawatinaw River-Little Pine watershed is an ecological oasis and invaluable resource to the people of Athabasca and surrounding communities for its traditional, historical, recreational, economic and intrinsic values.

Although the Tawatinaw-Little Pine watershed is currently regarded as a relatively unaltered ecosystem, the future health and maintenance of the river and surrounding riparian areas are increasingly being threatened by the encroachment of agriculture, oil and gas development, sand and gravel development, forestry, unregulated recreational use, urbanization, and infrastructure developments. The combination of anthropogenic activities adjacent to this watershed propagates a wide range of direct, indirect and cumulative impacts to the health of the watershed. Impacts are existential on local and landscape scales, such as stream-bank erosion, stream bed disruption, loss of riparian and aquatic vegetation, weed invasion, sedimentation, water pollution, decline of fish habitat quality, habitat fragmentation and linear disturbances. If current and future anthropogenic activities adjacent to this watershed are not controlled, monitored and in some cases prevented than the consequences of these activities will continue to accelerate and exacerbate.

The most recent development of concern to the health of this watershed is the Department of Transportation's proposed realignment of the Tawatinaw River that flows though the riverfront area in the town of Athabasca for the purpose of replacing the current bridge and developing a new Highway 55 and Highway 813 interchange. If this proposal is carried through it will pose a high risk to the biodiversity and health of the river system and riparian areas. Many riverbeds in North America were straightened or realigned in the 1960's and 1970's, many of which could no longer maintain themselves afterwards and became parched and dissipated as a result. Millions of dollars have been spent in efforts to re-establish native flora and fauna to ecosystems such as these, which would have been able to maintain themselves had they not been disturbed. A failed attempt at channelization also occurred in the town of Athabasca approximately 30 years ago when the Muskeg Creek meander that ran through Athabasca was straightened. Some of the negative impacts that resulted from this realignment included loss of woody species and decreased plant diversity, stream-bank degradation, loss of wildlife habitat and passage, and an increase of invasive plant species. The straightening of the Tawatinaw River would likely develop these same issues and likely on a larger scale since the Tawatinaw is a larger tributary to the Athabasca than the Muskeg Creek, and is host to a variety of fish species who are easily perturbed by disturbances to their normal passage, habitat and spawning sites.

The Athabasca River Basin and all of its interconnected tributaries and watersheds such as the Tawatinaw River-Little Pine Creek watersheds are host to a vast array of fauna and flora which contribute to the health and integrity of boreal ecosystems and thus are intrinsically invaluable. These watersheds are also important for a wide array of economic, recreational, historical and traditional values to locals. It is therefore necessary and urgent that all stakeholders of the watershed, including industry, agriculture, government, landowners, and recreational partakers, seek best management practices and mitigative measures addressing direct, indirect, and cumulative impacts in an effort to maintain watershed health now and in the future.

1.1 Watershed Assessment Objectives

The goals of this watershed assessment are to identify and interpret the following details:

- Background and description of the watershed
- Biophysical and socio-economic resources of the watershed
- Environmental parameter sampling, scope, and results
- Direct, indirect, and cumulative impacts affecting the watershed
- Recommended management strategies for stakeholders
- Recommended mitigation strategies and watershed stewardship

1.1 Background

The headwaters of the Tawatinaw River begin at Helliwell Lake in Township 61 Range 24 West of the 4th Meridian near the community of Nestow, Alberta. It flows north-east, converging with the Little Pine Creek and meeting its final destination at the Athabasca River after meandering through the town of Athabasca, Alberta in Township 66 Range 22 West of the 4th Meridian. The Little Pine Creek originates in Township 63 Range 22 West of the 4th Meridian and flows north-west, meeting its final destination near the town of Colinton, where it converges with the Tawatinaw River in Township 65 Range 22 West of the 4th Meridian. Refer to subsection 2.1 below for further details regarding the specific location and drainage patters of these watersheds. The town of Athabasca is a rural community nestled in the Athabasca River Basin approximately 150 km north of Edmonton on Highway 2. The communities of Tawatinaw, Rochester, Perryvale and Meanook are also situated along the Tawatinaw River. Refer to Figure 2 below for a large scale map of the extent of the Tawatinaw River-Little Pine Creek Watershed.

The Tawatinaw River-Little Pine Creek watershed is located within the Dry Mixedwood Natural Subregion of the Boreal Natural Region of Alberta. The Dry Mixedwood Natural Subregion is the second largest subregion in Alberta and is mapped in three separate units. The Tawatinaw River-Little Pine watershed is located in the most southerly portion which occupies a crescent shaped area in Central Alberta between the Central Parkland and Central Mixedwood Natural Subregions. The Boreal Region is characterized as subhumid and continental with short, cool summers and long, cold winters. The Dry Mixedwood features warmer summers and milder winters than other boreal subregions, with temperatures ranging approximately between -27.6 to 25.6 throughout the seasons of a year (Alberta Sustainable Resource Development, 2006). The average frost-free period is about 98 days in length, providing a longer growing season than other boreal subregions (Alberta Sustainable Resource Development, 2006). Annual precipitation averages about 460.6 millimetres per year with about 70 % of precipitation falling between April and August (Alberta Sustainable Resource Development, 2006). Overall the Dry Mixedwood subregion is warmer and faces higher moisture deficits than other boreal subregions. Refer to Figure 1 below for a small scale map depicting the location of the Tawatinaw River-Little Pine Creek Watershed within the Dry Mixedwood Subregion of Alberta.

The Tawatinaw River-Little Pine Creek Watershed

?- Could you show the whole Watershed

Figure 1. Map of the Subregions of Alberta, showing the location of the Tawatinaw River-Little Pine Creek Watershed within the Dry Mixedwood Subregion (Alberta Sustainable Resource Development, 2006).

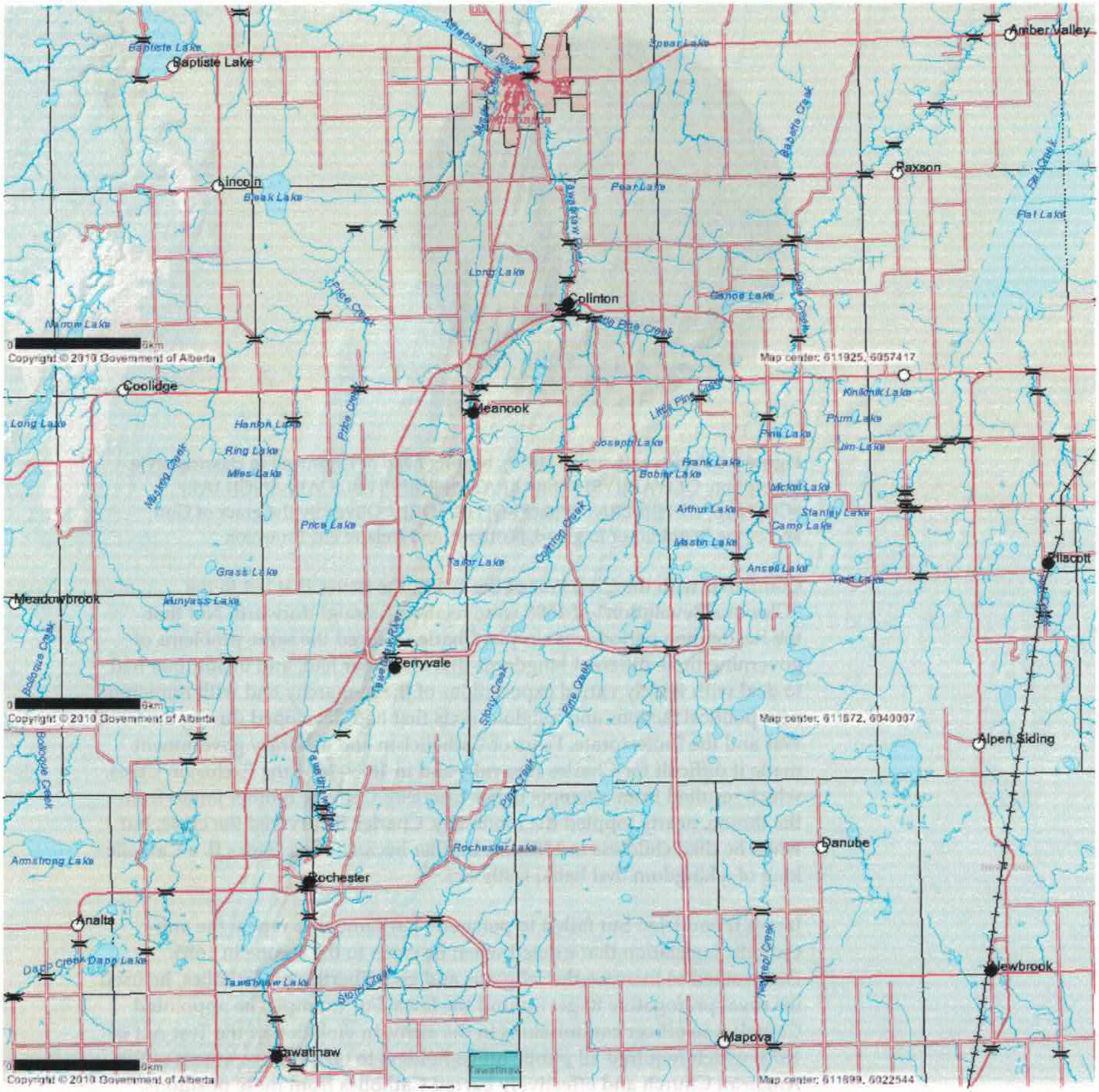

Figure 2. Lower Tawatinaw-Little Pine Creek Watershed (Alberta Sustainable Resource Development, 2011)

1.3 Study Area Description

The study area of this watershed health assessment encompasses the entire Tawatinaw River, from its headwaters at Helliwell Lake to its final conjunction point with the Athabasca River in the town of Athabasca as well as the entire Little Pine Creek. However, due to the extent of both watercourses and limited time and resources, the parameter

How should we relate these two studies?

sampling is more specifically focused on the lower portion of the Tawatinaw River and lower portion of the Little Pine Creek.

2.0 WATERSHED BIOPHYSICAL DESCRIPTION

On April 21 of 2011, North Pine Environmental Ltd. conducted a generic site visit that included recording spring breakup site conditions, landscape, vegetation, and wildlife data as well as areas of concern along the Tawatinaw River and Little Pine Creek watersheds. A total of 30 locations were sampled for specific parameters, including biological oxygen demand (BOD), total suspended solids (TSS), nitrates, phosphates, temperature, pH, and conductivity. Mean annual flow data was gathered from Wildlife Biologist Mark Spaffard's (Little Fish Consulting Ltd.) 2010 Lower Tawatinaw-Little Pine Watershed Assessment. The following watershed biophysical description was gathered on-site as well as through site specific research conducted during the field review.

2.1 Surface Hydrology

The Tawatinaw- Little Pine Creek Watershed is located in the greater Athabasca River Basin, which originates at the Columbia Glacier of the Columbia Ice Field in Jasper National Park, travelling 1,231 km before draining into the Peace-Athabasca Delta near Lake Athabasca south of Fort Chipewyan (Mitchell and Prepas, 1990). From there, its waters flow north and join the Peace River to form the Slave River that empties into Great Slave Lake and discharges through the Mackenzie River system into the Arctic Ocean. The cumulative drainage area of the extensive Athabasca River Basin is 95,300 km^2 (Mitchell and Prepas, 1990). Numerous communities are located on the banks of the Athabasca River, including Jasper, Brule, Entrance, Hinton, Whitecourt, Fort Assiniboine, Athabasca, Fort Smith, Fort McMurray, and Fort MacKay. Refer to Figure 3 below for a map of the Peace River-Athabasca River Basin within Alberta superimposed upon a map of the greater extent of the Peace River-Athabasca River Basin within Canada.

Locally, the headwaters of the Tawatinaw River begin at Helliwell Lake and flow north-east, draining the Tawatinaw Lake and eventually converging with the Little Pine Creek flowing north-west near Colinton, Alberta. The Tawatinaw meets its final destination at the Athabasca River, after meandering through the town of Athabasca, Alberta. The extent of the Tawatinaw River is approximately 66 km from the headwaters to where it meets the Athabasca River. The Little Pine Creek originates in Township 63 Range 22 West of the 4th Meridian and flows north, in-between the Colinton Creek to the west and Pine Creek to the East. It drains Gilbert Lake, Lee Lake, Frank Lake and Bobier Lake and converges with Colinton Creek, meeting its final destination near the town of Colinton where it converges with the Tawatinaw River in Township 65 Range 22 West of the 4th Meridian. The extent of the Little Pine Creek is approximately 26 km from its headwaters to where it meets the Tawatinaw River. The Muskeg Creek, Pine Creek, Price Creek, Colinton Creek, Stony Creek and many other small intermittent streams flow north adjacent to the Tawatinaw River-Little Pine Creek watercourses. Adjacent water bodies include Truman Lake, Tailor Lake, Joseph Lake, Canoe Lake, Pine Lake, Price Lake, Pear Lake and Long Lake among other small water bodies. Refer to Figure 2 above for a map representation of the Tawatinaw River – Little Pine Creek Watersheds on the landscape.

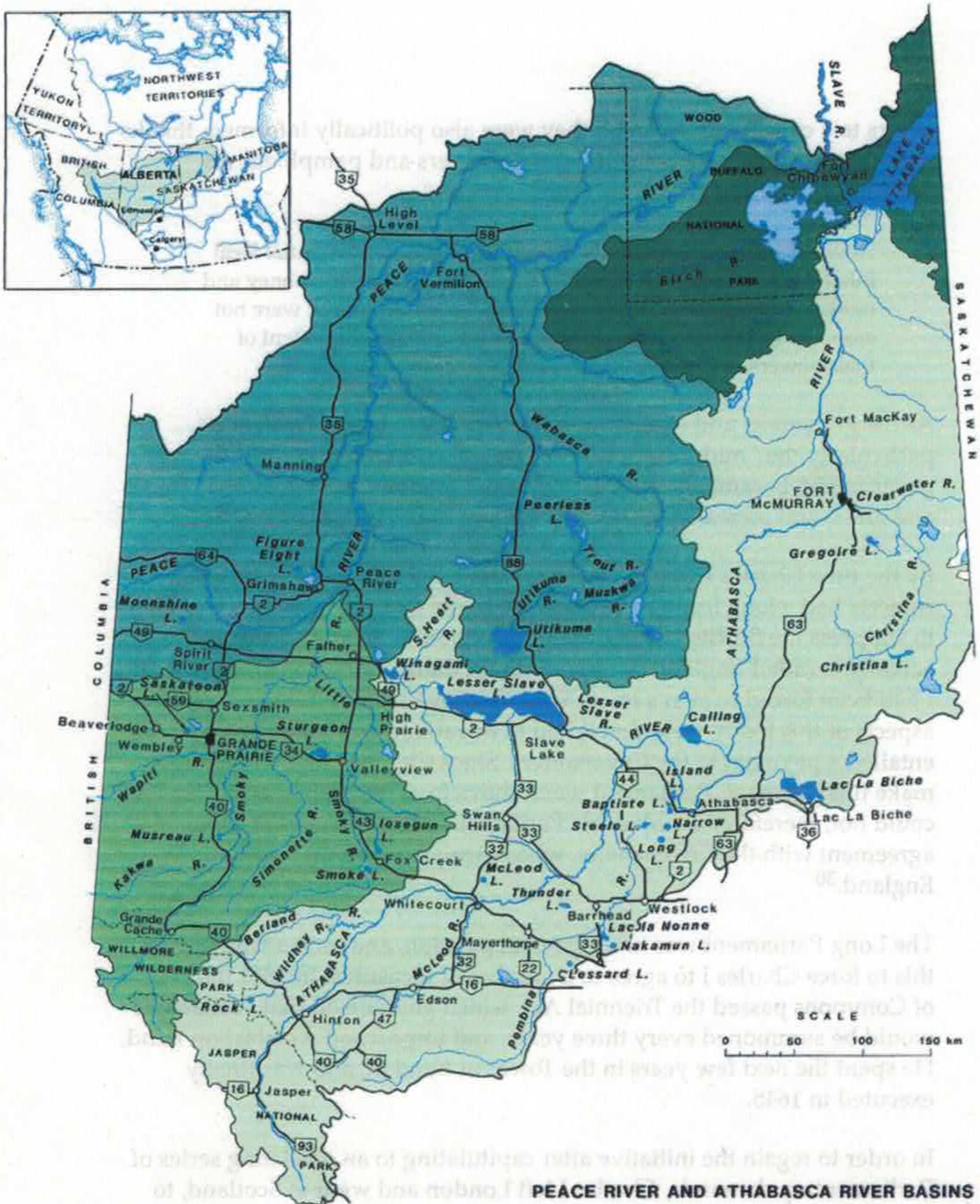

Figure 4. Peace River and Athabasca River Basin within Alberta (Natural Resources Canada, 2011)

2.2 Ground Hydrogeology

According to the Government of Albert (2011), the Tawatinaw River-Little Pine Creek watershed is located in the Western Plains hydrogeological region of Canada. Hydrogeological regions are classified based on similarities and differences of groundwater movement and distribution beneath the earth's surface. The factors affecting the distribution, recharge, and discharge of groundwater are the annual mean total precipitation (mm), moisture region, watershed, % wetland regions, surficial hydrogeological materials, relief, physiographic region, and land cover. According to Natural Resources Canada (2011) the annual mean total precipitation for the Tawatinaw River-Little Pine Creek watershed region is in-between 401-600 mm/year, the moisture region is classified as dry subhumid and is a part of the Arctic Ocean Watershed. Percent watershed region is 40-65% which is the second greatest in Alberta compared to the 65+ percent category (Natural Resources Canada, 2011). The surface hydrogeological material is sand/minor gravel (glacial lake/sea) as well as till blanket. Relief varies between 500 – 700 meters; the physiographic region is the interior plains; and the land cover is classified as a combination of mixed land use, crop land, aspen forest, and water (Natural Resources Canada, 2011). This hydrogeological region occurs in the Western Canadian Sedimentary Basin, a layered sedimentary wedge that thickens from the edge of the Canadian Shield to about 6 kilometres deep in the south-west of the basin. Surficial sediments in this basin alternate between till to sand and gravel to silt and clay, resulting in shallow groundwater systems. Shallow groundwater typically flows to streams or to prairie sloughs (Natural Resources Canada, 2011).

Hydrologic pathways and connections can conceivably extend from near surface to bedrock, and as a result human activities that impact shallower aquifer layers have the potential to affect larger, deeper layers as well (Campbell, 2008). Hence, oil sands production and sand and gravel extraction pose a significant concern for surface, and groundwater quality and quantity in this region. Refer to Section 3.0 for further details regarding stakeholder impacts on these watersheds.

2.3 Topography, Geology and Soils

The Central Alberta portion of the Dry Mixedwood Subregion mainly features undulating plains interspersed with hummocky uplands. Underlying bedrock formations include Upper Cretaceous shale, sandstone and siltstone formations. Elevations range from 225 m to 1225 m, averaging around 600 m (Alberta Sustainable Resource Development, 2006). Surficial materials are dominated by moderately fine textured, moderately calcareous glacial till. There is also a significant component of glaciofluvial sands and organic deposits. The predominant soils of this region are Orthic Grey Luvisols under moderately well drained aspen forests. Dark Grey Luvisols are also very common, especially in cultivated areas. Brunisols and weakly developed Grey Luvisols commonly occur on sandy glaciofluvial or eolian deposits. Organic soils underlaying wetlands are typically Terric Mesisols, and poor fens and bogs are typically associated with Fibric Mesisols.

Along the extent of the Tawatinaw River and Little Pine Creek the terrain ranges from gently to moderately rolling hills and steeply sloping ridges. The Tawatinaw River alternates between narrow channels to broad channels with an extensive floodplain. According to Alberta Agriculture and Food and Agriculture and Agri-Food Canada (2009) the Soils along the Tawatinaw River and Little Pine Creek are characterized by transitional areas; with the dominant soil group being Orthic Grey Luvisols. Intermittent Orthic Humic Gleysols and Organic soils, mainly in the form of Typic and Terric Mesisols, also occur along this watershed. Weakly developed Eluviated Eutric Brunisols are also present at the upper part of the Tawatinaw River where soils are very coarse textured and are typically occupied by jack pine. Orthic Regosols occur in an isolated area of the lower Tawatinaw River and Little Pine Creek. Soils along the extent of the Tawatinaw River and Little Pine Creek vary from moderately well to poorly drained. Soils are mainly very coarse textured sand (S) and sandy loam (SL) with intermittent intermediate to fine textured soils such as silty clay (SiC) and sandy clay loam (SCL). Bank erosion and slumping were commonly observed throughout the extent of the Tawatinaw River.

2.4 Vegetation

The vegetation of the Dry Mixedwood Subregion is similar to that of the adjacent Central Mixedwood Subregion as both share similar community types. The differences are largely in the proportion of various vegetation and other landscape features. The Dry Mixedwood Subregion landscape is generally dominated by aspen forests and cultivated lands with intermittent fens commonly occurring in low-lying areas.

The reference community type for the Central Alberta portion of the Dry Mixedwood Subregion is trembling aspen *(Populous tremuloides)* with understories of beaked hazelnut *(Corylus cornuta)*, prickly rose *(Rosa acicularis)*, wild sarsaparilla *(Aralia nudicaulis)*, cream-colored pea vine *(Lathyrus ochroleucus)*,and bluejoint *(Calamagrostis Canadensis)* (Alberta Sustainable Resource Development, 2006).

On moist, rich sites, balsam poplar *(Populous balsamifera)*, trembling aspen and white spruce *(Picea glauca)* occur as pure or mixed stands. Understories typically contain red-osier dogwood *(Cornus stolonifera)*, prickly rose, and a diverse array of forbs in deciduous and mixedwood stands, or a carpet of feathermosses and horsetails in coniferous stands (Alberta Sustainable Resource Development, 2006). This is the dominant community type found along the Tawatinaw River and Little Pine Creek watersheds.

Jack pine *(Pinus banksiana)* dominated stands typically occupy dry, course textured glaciofluvial or eolian deposits. These sites are often relatively open stands compared to other forest stands and usually contain a prominent groundcover of lichens (Alberta Sustainable Resource Development, 2006). Common understory species associated with jack pine stands include bearberry *(Actostaphylos uva-ursi)*, low billberry *(Vaccinium myrtillus)* bog cranberry *(Vaccinium oxycoccus)*, and prickly rose (Alberta Sustainable Resource Development, 2006). On coarse textured soil where water supply is somewhat better, jack pine occurs in mixed stands with aspen and white spruce. Common understory species for jack pine mixed stands includes bearberry, common blueberry *(Vaccinium myrtilliodes)*, green alder *(Alnus crispa)*, prickly rose, wild-lily-of-the-valley *(Maianthimum Canadensis)*, and hairy wild rye *(Elymus innovatus)* (Alberta Sustainable Resource Development, 2006).

Wet, poorly drained sites support a variety of bog and fen communities. The composition and structure of these communities depends on water levels and nutrient status. Treed and shrubby fens are most common, while sedge fens and bogs only occasionally occur on the landscape.

Refer to Table 1 for a list of plant species identified during the site investigations that took place on April 21, 2011 and May 2011.

According to the Atlas of Canada on the Natural Resources Canada (2011) website the Tawatinaw River-Little Pine Creek Watershed is situated in an area considered to have 1-3 endemic plant species; endemic referring to species that are only found in Canada. The majority of area in Canada and Alberta has 0 endemic plant species, suggesting that this area is unique since plants have genetically adapted to particular environmental conditions and thus should be protected for that inherent value. Endemic plants are impacted more heavily by disturbance because of the fact that they are so specialized in their habitat requirements and therefore are more vulnerable to changes to their habitat and needs. According to Natural Resources Canada (2011), the Tawatinaw River-Little Pine Creek Watershed is also located within a region of Canada that is considered to have 1 – 5 rare plant species, which are plants that naturally occur in very low numbers or occur in highly specialized areas. Some species have also become rare due to natural set-backs or excessive human pressure. Farming, deforestation, draining of wetlands and use of pesticides and herbicides has reduced the populations and areas of distribution for a number of plant species in Canada. Stantec Consulting Ltd (2009) conducted a rare plant survey on July 11, 2008 and identified the presence of false dragonhead (*Physostegia ledinghamii)* along the eastern banks of the Tawatinaw River near the confluence of the Athabasca River. False dragonhead is provincially listed as S2[1] and globally as G3[2] (Government of Alberta, 2010).

2.5 Wildlife

Characteristic mammals of this zone include woodland caribou, mule deer, moose, coyote, fisher and least chipmunk. Representative birds include boreal owl, great horned owl, blue jay, evening grosbeak, brown-headed cowbird and Canada warbler. The Boreal Plains Ecozone has widespread human activity such as logging, agriculture, and mining that have been shrinking wildlife habitat resulting in a number of native species, most notably the Whooping Crane *(Grus Americana)*, becoming threatened or endangered (Natural Resources Canada, 2011). Several species at risk from the mammals, birds, fish, mollusca, and Lepidoptera orders occur in the Boreal Plains region that are listed as Endangered, Threatened, or Special Concern.

The Canadian Wildlife Service's Website was accessed to identify if the Tawatinaw River-Little Pine Creek watershed is located in or adjacent to any National Wildlife Area (NWA), Migratory Bird Sanctuary (MBS), Wetland of International Importance (RAMSAR), or Important Bird Area (IBA). The search identified that the watershed is located in the Major Migratory Bird Flyway and near the Meanook National Wildlife Area (NWA) which was established in 1979 and is a total of 214 hectares. The Meanook NWA is located 15 kilometres SSW of Athabasca, approximately 550 meters north of a tributary stream of the Tawatinaw River and 1.6 km away from the Tawatinaw River. The Meanook NWA is operated as a zoological research field station by the University of Alberta of which one of the main study objectives was establishing a baseline inventory of the vegetation, vascular plant flora, bird, and mammal fauna in the area. The study involved a combination of transects and direct observation and resulted in the identification of 13 vegetation communities, 101 vascular plants species, 52 birds, and 11 mammals. Although the study was done in a relatively small area (214 ha) it serves as a good representation of the species that commonly occur in the Athabasca area and therefore the Tawatinaw River-Little Pine Creek Watershed. Within this NWA two provincially rare species were identified, both sedges: hidden sedge *(Carex umbellate sensu stricta)* and turned sedge *(Carex retrorsa)* (Environment Canada, 2011). One S3W *(vulnerable)* watch list species was also identified within the NWA, the woolly bulrush *(Scirpus atrovirons)* (Environment Canada, 2011).

Athabasca Regional ASRD Wildlife Biologist Kristina Norstrom was contacted to determine if the vicinity of the Tawatinaw River-Little Pine Creek watershed is located within any known critical wildlife habitat, or if any species at risk (SAR), or sensitive species inhabit the area. Norstrom (2011) confirmed that there is one species at risk inhabiting the area, the woodland caribou *(Rangifer tarandus)*, which is designated as a threatened species. There are also thirteen sensitive species identified in the area; sensitive species referring to species that rely on specific habitat conditions that are limited in abundance, limited in distribution, or are particularly sensitive to development. There are eight sensitive bird species inhabiting the area, the barred owl *(Strix varia)*, great grey owl *(Strix nebulosa),* American white pelican *(Pelecanus erythrorhynchos),* purple martin *(Progne subis),* great blue heron *(Ardea Herodias),* northern goshawk *(Accipiter gentilis)*, sharp-tailed grouse *(Tympanachus phasianellus)* and the sandhill crane *(Grus Canadensis).* There are two sensitive mammal species identified in the area; the American badger *(Taxidea taxus)* and the hoary bat *(Lasiurus cinereus).* Two sensitive amphibians were also identified to occupy the area; the boreal toad *(Anaxyrus boreas)* and the Canadian toad *(Bufo hemiophrys),* which is also designated as 'may be at risk'. Part of the upper Little Pine Creek also falls within a designated Wildlife Enhancement Area, in part of Township and Range 64, 21, 64, 22, 63, 21, and 63, 22 West of the 4th Meridian respectively, which are lands designated as critical habitat for wildlife ungulates and other wildlife.

The ASRD Fish and Wildlife Management Information System (FWMIS) internet mapping tool (IMF) was also accessed to identify fish and wildlife species in the Tawatinaw River-Little Pine Creek watershed, of which seven species of fish were identified. Refer to subsection 2.6 below for further details. Since there is little data on amphibians in the area it is recommended that a spring amphibian survey be conducted to identify if there are any provincial or federally listed amphibian species occupying these watersheds.

An on-site assessment of wildlife sightings and evidence was carried out during the site assessment of the Tawatinaw River-Little Pine Creek. Refer to Table 2 in the Appendices for a detailed list of wildlife sightings or evidence identified during the site visits that took place on April 21, 2011 and May 2011.

2.2 Fish and Aquatic Resources

The Tawatinaw River was identified by the Alberta Sustainable Resource Development (2011) FWMIS IMF to host six species of fish: white sucker *(Catostomus commersonii),* trout-perch *(Percopsis omiscomaycus),* longnose sucker *(Catostomus catostomus),* burbot *(Lota lota)*, northern pike *(Esox lucius)*, and spoonhead sculpin *(Cottus ricei)*. The Little Pine Creek was identified by the IMF to host one species of fish: white sucker. Walleye *(Sander vitreus)* and Arctic grayling *(Thymallus arcticus)* have also previously been identified in the Tawatinaw River (Little Fish Consulting, 2010).

Ten fish species were also documented by Stantec in the lower part of the Tawatinaw River although they claim there are as many as 29 species that have been reported in this area of the Athabasca River and could occur at various times in the confluence area of the rivers (Stantec Consulting Ltd, 2009). Wildlife Biologist Mark Spafford assessed the sport fish habitat potential for walleye, northern pike, and arctic grayling in the Tawatinaw River and Little Pine Creek from October 7-9, 2010 and determined that locations along the Little Pine Creek ranged from zero to low spawning, rearing, and overwintering potential for these species and locations along the Tawatinaw River ranged from zero to high spawning, rearing, and overwintering potential for this species.

3.0 SOCIAL AND ECONOMIC FACTORS

3.1 Historical Resources and Use

According to the Land Use Planning division of the Alberta Governments Culture and Community Spirit (ACCS) (2011) Human Resources Management Branch, nearly all of the land situated on the Tawatinaw River and most of the Little Pine Creek, with exception to a portion of the upper creek, are identified as having Historical Resources Value. These lands are classified as having a Historic Resource Value (HRV) of 5, which means these areas are believed to have historic value (Government of Alberta, 2011). The primary resource that the HRV is classified as is paleontological. Since most of the lands where these watersheds occur are in the HRV listing, activities proposed for these lands must be assessed by ACCS for their potential affect on any category of historic resource (Government of Alberta, 2011). Refer to subsection 7.3 for further details on how to manage the discovery of historical resources.

The Tawatinaw River watershed is important to the history of Athabasca and Alberta due to the Athabasca Landing Trail, which follows an important trading and settlement corridor which was the first overland route from Edmonton to the southern loop of the Athabasca River. The Athabasca Landing has significant historical value because it was the central point of transfer for all fur being moved along the Athabasca, Peace, and Mackenzie River Systems and central distribution point for all goods being shipped north by the end of 1880 (Alberta Trails to Try). In 1898, around 600 gold prospectors travelled along the Landing Trail journeying north to the gold fields in the Klondike (Alberta Trails to Try). A few years later the federal government declared the route a public right-of-way; homesteaders settled along the trail shortly thereafter. The current recreational Athabasca Landing Trail runs from the town of Athabasca municipal campground, proceeding south through Colinton to Perryvale, running parallel to the Tawatinaw River, for a total of 32 kilometers in length. The trail permits use for hiking, cycling, Nordic skiing, horseback riding, snowshoes and dogsleds. ATV's and snowmobiles are not permitted to use the trail. but, ...

During the site visits conducted on April 21, 2011 and May 2011 there was no identifiable evidence of historical artefacts or resources (tepee rings, arrowheads, structural remains, etc) observed within or adjacent to the Tawatinaw River-Little Pine Creek watershed.

3.2 Settlement

? See local community histories – Colinton, Meanook etc

3.3 Hunting and Trapping

Registered trap-line? Kevin ? or Mark ?

3.4 Recreational Land Use

As mentioned above in subsection 3.1, the 32 K Athabasca Landing Trail runs from the town of Athabasca municipal campground, proceeding south through Colinton to Perryvale, running parallel to the Tawatinaw River. The trail permits use for hiking, cycling, Nordic skiing, horseback riding, snowshoes and dogsleds. ATV's and snowmobiles are not permitted to use the trail. Although use of the trail by off-road vehicles is prohibited; it is not well enforced and is commonly used by recreational off-road vehicles. Refer to subsection 5.11 for details on the impacts of unregulated recreational land use.

3.5 Oil and Gas Activities

Natural gas and conventional oil exploration and development currently exist near the Tawatinaw River. There is a Mineral Surface Lease (MSL), which is a land disposition for an oil well lease, in the NW Quarter of Section 13 Township 61 Range 24 West of the 4th Meridian and is known to ASRD as MSL 0151925. This MSL is approximately 140 meters from a tributary stream flowing north into the Tawatinaw. In the same quarter section, a Pipeline Agreement (PLA) known to ASRD as PLA 072415 runs from this MSL and crosses the tributary stream mentioned above. There is also an MSL in the SW Quarter of Section 11 Township 64 Range 23 West of the 4th Meridian known to ASRD as MSL 91019 which is 130 meters and 300 meters away from two respective tributary streams of the Tawatinaw River. There is also a Licence of Occupation (LOC) known to ASRD as LOC 910170 which is associated with this MSL that crosses a tributary stream of the Tawatinaw.

There is also natural gas and oil exploration and development on the Little Pine Creek. There is an MSL in the SW Quarter of Section 19 Township 64 Range 21 West of the 4th Meridian that is approximately 160 meters away from Bobier Lake which is a drained by the Little Pine Creek, and is 130 meters from the tributary stream that drains Bobier Lake. There is an LOC known to ASRD as LOC 991570 operated by the same proponent and crossing the same tributary stream in the same Quarter Section as mentioned above. There is also a pipeline known to ASRD as PLA 770253 that crosses a tributary stream of the Little Pine Creek in the SE Quarter of Section 14 Township 64 Range 22 West of the 4th Meridian. Also, PLA 910686 crosses the Little Pine Creek in the NE Quarter of Section 1 Township 64 Range 22 West of the 4th Meridian and PLA 910106 crosses the Little Pine Creek in the NW Quarter of Section 6 Township 64 Range 21 West of the 4th Meridian. There is also an MSL located directly on the Little Pine Creek known to ASRD as MSL 942239 of which there is an LOC known as LOC 941535 that also crosses the Little Pine Creek. There is also an MSL known to ASRD as MSL 010995 that is located 125 meters from a tributary stream of the Little Pine Creek in the same Quarter Section. Refer to subsection 5.12 for details on the impacts of oil and gas activities.

3.6 Sand and Gravel Development

According to Alberta Sustainable Resource Development (2011), sand and gravel development currently exists adjacent to the Tawatinaw River in the NE Quarter of Section 14 Township 61 Range 24 West of the 4th Meridian. There are two Surface Material Leases (SML's) known to ASRD as SML 780138 and SML 080006 and one Surface Material License (SMC) in the described lands that is known to ASRD as SMC 080030. SML's are greater than 5 ha (12.36 acres) in size whereas SMC's are less than 5 ha in size. The nearest sand and gravel development to the Tawatinaw River is 1.2 km south-east of the river and 320 meters away from a tributary stream flowing north into the Tawatinaw. There are no sand and gravel developments adjacent to the Little Pine Creek. Refer to subsection 5.13 for details on the impacts of sand and gravel developments.

3.7 Forestry

The Tawatinaw River-Little Pine Creek watershed is located within Alberta's White Zone within the Upper Athabasca Land-use Framework Planning Region in Forest Management Unit L01, Lac La Biche. These lands are not held by a Forest Management Agreement (FMA). Forestry on private lands is occuring directly adjacent to the Tawatinaw River-Little Pine Creek watersheds. Photo # 6 in the Appendices shows forestry occurring on private lands directly adjacent to the Little Pine Creek watershed. Refer to subsection 5.14 for details on the impacts of forest developments.

3.8 Agriculture

A large extent of the lands directly adjacent to the Tawatinaw River and Little Pine Creek are privately owned agricultural lands consisting of pasture and tilled lands. The ASRD FWMIS (2011) also identified several agricultural public lands directly adjacent to these watersheds. There is a Farm Development Lease (FDL) known as FDL 7904071, and two Grazing Lease's (GRL) known as GRL 39243, and GRL 840159 which are all directly located on the Little Pine Creek watercourse and riparian areas. GRL 39243 is also directly located within the boundaries of two lakes, Lee Lake and Gilbert Lake, which are both drained by the Little Pine Creek into the Tawatinaw River and finally into the Athabasca River. Seven grazing leases known as GRL 40733, GRL 87088, GRL 850449, GRL 000019, GRL 000018, GRL 33487, and GRL 39604 occur directly on the Tawatinaw River or on direct tributary streams and riparian areas of the Tawatinaw River. GRL 960117 is also situated directly adjacent to Helliwell Lake, which are the headwaters of the Tawatinaw River. Evidently there is agricultural activity, mainly grazing leases which run cattle, directly within and adjacent to a large extent of the Tawatinaw River-Little Pine Creek Watershed. Refer to subsection 5.15 for details on the impacts of agricultural activities.

3.6 Government Developments

As mentioned in the introduction to this watershed health assessment, the most recent development of concern to the health of this watershed is the Department of Transportation's (DOT) proposed realignment of the Tawatinaw River that flows though the riverfront area in the town of Athabasca for the purpose of replacing the current bridge and developing a new Highway 55 and Highway 813 interchange. There is also a significant amount of infrastructure development on the Tawatinaw River-Little Pine Creek. According to FWMIS there are 16 bridges directly crossing the Tawatinaw River and numerous others on tributary streams of the Tawatinaw. There are also 6 bridges directly crossing the Little Pine Creek. There are many gravel roads and trails adjacent to both of these watersheds. Since there are so many infrastructures (bridges, roads etc) on and adjacent to the Tawatinaw River-Little Pine Creek watersheds there are also many culverts installed throughout the watercourses to divert flow. Refer to subsection 5.16 for details on the impacts of government developments.

4.0 SAMPLING PARAMETERS AND RESULTS

Site assessments were carried out on April 21, 2011 and May 00, 2011 at 29 locations along the extent of the Tawatinaw River and Little Pine Creek Watersheds. Refer to Figure 5 below for a map representation of the 29 locations that were sampled. On April 21, 2011 a generic site visit of the sampling locations was conducted to document seasonal spring breakup site conditions, vegetation, wildlife and landscape information, and identify anthropogenic impacts on the watershed. Several sites shown in Figure 5 below were not visited due to limited access and time constraints. The weather conditions were sunny with a light to moderate wind, with temperatures ranging from 1-9° C throughout the day. Snow cover ranged from zero on open, south facing slopes to moderately heavy in heavily forested areas and forested north facing slopes. The Tawatinaw River exhibited mostly open waters with high flow and volume; some heavily forested areas and shallower sections of the river still had ice cover and heavily snow covered banks. The Little Pine Creek exhibited mostly ice covered waters likely due to characteristics of a relatively narrower and shallower streambed dynamics, creating a more enclosed forest canopy with more shade; influencing a cooler habitat than that of the Tawatinaw River. Open water was identified in some areas, and snow covered banks were common along the Little Pine Creek watershed. Refer to Site Photos 1 – 12 in the Appendices for detailed descriptions of the locations visited along the Tawatinaw River and Little Pine Creek watersheds on April 21, 2011.

On May 00, 2011 a site assessment of the sampling locations was conducted to document the following parameters: Dissolved Oxygen (DO), Total Suspended Solids (TSS), Nitrogen, Phosphorus, Temperature, pH and Conductivity. Mean Annual Flow data was adapted from Little Fish Consulting Ltd. (2010) Lower Tawatinaw/Little Pine Watershed Assessment.

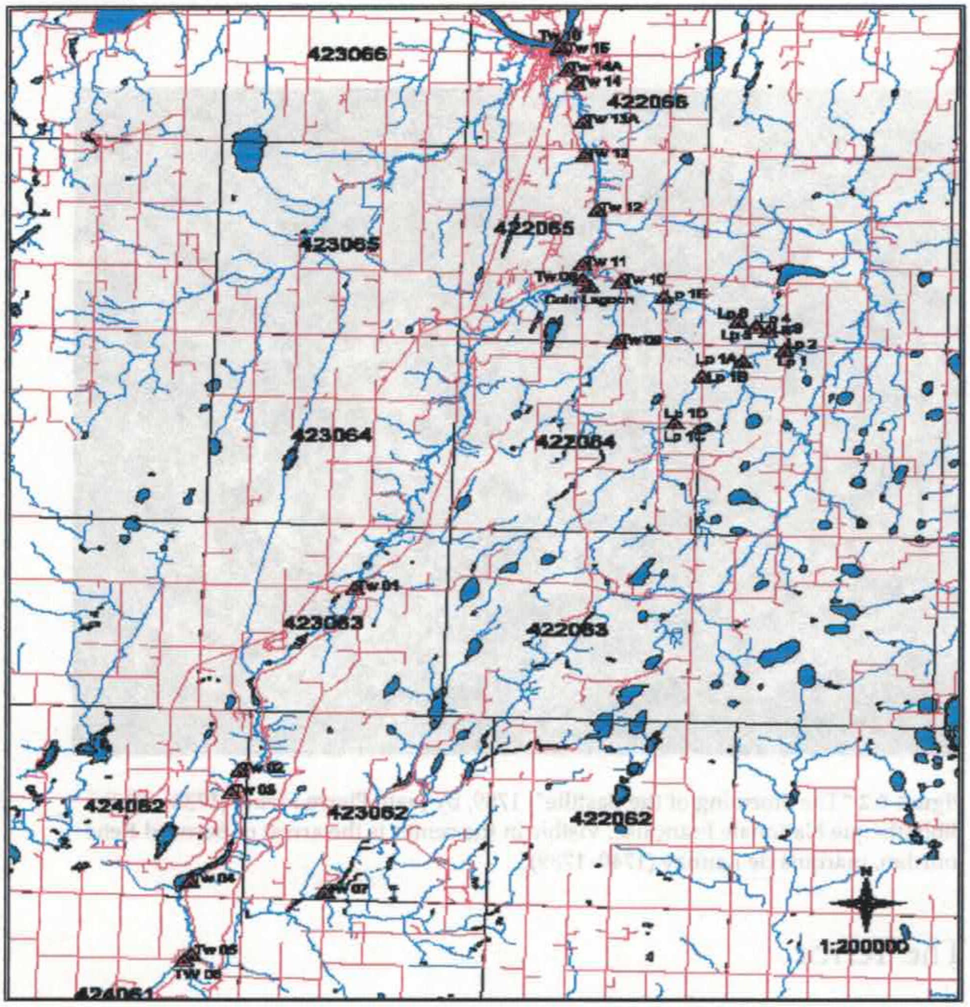

Figure 5. Sampling locations visited on April 21, 2011 and May 00, 2011 along the Tawatinaw River and Little Pine Creek watersheds (Map adapted from Little Fish Consulting Ltd., 2010).

4.1 Dissolved Oxygen

Dissolved oxygen (DO) refers to the volume of oxygen that is contained in water which is a function of the photosynthesis of aquatic biota and the transfer of oxygen between the water-air interface (Radwan, Willems, El-sadek and Berlamont, 2003). DO is higher in flowing waters than stagnant waters because oxygen-rich waters at the surface are continually being replaced by oxygen-depleted waters as a result of turbulence, which allows for greater exchange of oxygen between the air-water interface (Radwan, Willems, El-sadek and Berlamont, 2003).

Decreased dissolved oxygen is strongly correlated to eutrophication, which occurs as a result of nutrient enrichment (mainly N and P), which is linked to human activity (Diaz, 2000). Nutrient enrichment causes excessive production of autotrophs such as algae and cyanobacteria which increase respiration rates in the water and may lead to hypoxia or anoxia in poorly mixed bottom waters, shallow waters, and at night in surface waters under warm, calm conditions in the summer (Correll, 1998). In short, when dissolved oxygen levels are very low, hypoxia or anoxia may occur. Hypoxic waters refers to dissolved oxygen content of surface water that is reduced to a point that is detrimental to aerobic organisms; usually below 2-3 ppm (mg/L) compared with a normal level of 8-10 ppm (mg/L) (Stevenson and Wyman, 1991). Ecosystems that are stressed by hypoxic waters are at a severe threshold of fishery and ecosystem collapse and food web alteration (Diaz, 2000). Anoxic water refers to the complete depletion of dissolved oxygen from water; a severe case of hypoxia. As defined by the Surface Water Quality Guidelines for use in Alberta (1999) the guideline concentration of dissolved oxygen that is acute to freshwater aquatic life is 5 mg/L (1 day minimum) and the level that is chronic to freshwater aquatic life is 6.5 mg/L (7 day minimum). Acute levels refer to toxicity levels that are expressed in a short period of time relative to the lifespan of the organism, usually a few minutes or days. Chronic levels refer to toxicity levels that are expressed over a longer period of time and incorporate an organism's long term response to a toxicant.

4.2 Turbidity

According to Glysson, Gray and Conge (2000) fluvial sediment is the single most widespread pollutant in American rivers and streams, negatively impacting aquatic and riparian life, drinking water quality and recreational uses. The presence of sedimentation in surface waters is commonly referred to as turbidity; the cloudiness or haziness in water caused by individual particles (suspended solids).

Chapman (1996) summarizes the causes of high turbidity and the negative impacts associated with it. Turbidity naturally occurs from phytoplankton and the precipitation of a few minerals; mostly calcite. However turbidity is commonly directly related to human disturbances such as agriculture, mining, forestry etc which lead to high sediment levels entering water bodies during rainfall events. Areas prone to bank erosion such as the Tawatinaw River watershed are also highly susceptible to high turbidity rates. Storm water pollution from bridges, culverts and nearby roads also contribute to high turbidity. High turbidity levels of surface waters causes less light penetration into lower depths, which can inhibit the growth of submerged aquatic plants and negatively impact species such as fish that depend on them. High turbidity levels also affect fish's ability to absorb oxygen through their gills.

Turbidity may be determined using a number of different methods but is most commonly measured as nephelometric turbidity units (NTU). The concentration of suspended matter (SM) in rivers is usually measured as total suspended solids (TSS), usually measured after the filtration through 0.45µ m or 0.5 µm pore filters. TSS is one of the most variable characteristics of water quality with yearly averages in rivers varying anywhere between 1 to >10,000 mg/L, and for any given river it may vary in order of three magnitudes (Chapman, 1996).

4.3 Nitrogen

Nitrogen (N) is a major nutrient in forest ecosystems. Boreal forests generally tend to have limited N and N losses and strong N cycling patterns (Kreutzweiser, Hazlett, and Gunn, 2008). In forest ecosystems nitrogen is cycled from trees to litter layers to surface soils. Macro fauna (invertebrates that live in or on sediment) initiate decomposition of litter and release organic N, which is subsequently mineralized into inorganic N in the form of ammonium (NH_4^+) (Kreutzweiser, Hazlett, and Gunn, 2008). Some forest plants can also directly fix atmospheric N into ammonium in the soil. Further microbial activity further converts (NH_4^+) into nitrate (NO_3^-); both forms are readily available for plant uptake to support growth, however NO_3^- is readily lost from forest floors by leaching (Kreutzweiser, Hazlett, and Gunn, 2008). Denitrification occurs when these inorganic forms of N are transformed into nitrite (NO_2) and nitrogen gas (N_2) by microbes in wet soils and subsequently lost to the atmosphere (Kreutzweiser, Hazlett, and Gunn, 2008). Decomposing matter also leaches organic N in the form of dissolved organic nitrogen (DON) (Kreutzweiser, Hazlett, and Gunn, 2008).

Denitrification in riparian areas is particularly important to watershed health as nutrients are removed from soils via microbial activity, limiting nutrient leaching in the watercourse/body. Agriculture and to a lesser degree industry, are the main contributors of nitrogen to surface waters which cause eutrophication and hypoxia (Diaz, 2000). As defined by the Surface Water Quality Guidelines for use in Alberta (1999) the guideline concentration of total nitrogen (TN) that is chronic to freshwater aquatic life is 1 mg/L.

4.4 Phosphorus

Phosphorus (P) is the next most important nutrient to boreal forests after nitrogen and is available for uptake by plants in an inorganic form (Kreutzweiser, Hazlett, and Gunn, 2008). Kreutzweiser, Hazlett, and Gunn (2008) describe the P cycle in boreal forests. P is originally weathered from primary minerals near soil surface horizons to form soluble inorganic P or precipitate into secondary P minerals. Inorganic P may then be taken up by plants and microbes and converted into organic P. Subsequently, the decomposition of organic matter (such as livestock wastes) then releases a source of organic P that is mineralized into inorganic P available again for plant uptake or re-assimilated by microbes back into organic P. Organic forms of P readily leach out of soils and are exported in watersheds as dissolved organic P. Phosphates generally occur in low concentrations in soils; however phosphates often occur in high concentrations on farmlands due to P in fertilizers and livestock wastes (Siddique and Robinson, 2002). These soils may release environmentally significant levels of dissolved P into subsurface and surface waters, and have been linked to rising eutrophication in surface water bodies (Siddique and Robinson, 2002).

Phosphorus is most widely sampled in surface waters as Total Phosphorus (TP); generally there is no widely accepted concentration level of TP but for streams concentrations of 100 ug/L (0.1 mg/L) are unacceptably high and concentrations of 20ug/L (0.02 mg/L) are unacceptably low (Correll, 1998). As defined by the Surface Water Quality Guidelines for use in Alberta (1999) the guideline concentration for total phosphorus that is chronic to aquatic life is 0.05 mg/L.

4.7 Conductivity?

4.6 Mean Annual Flow

Environment Canada (2010) plotted the mean annual flow of the Stoney Creek between 1982-2009, which is an adjacent watercourse to the Tawatinaw River. The watercourse exhibited a steady decline in mean annual flow during this period (Figure 1). Since these streams share many similarities in terms of geographical, ecological, climatological characteristics and anthropogenic impacts, it is likely that the Tawatinaw River and Little Pine Creek exhibited the same decline in mean annual flow as the Stoney Creek (Little Fish Consulting Ltd, 2010).

Annual flow is very important to the long-term viability of a river system; a decrease in mean annual flow indicates year after year there is less water flowing through the river. Long term decreases in mean annual flow result in decreased mean water quantity, increased mean water temperatures, complete desiccation in some areas, and an overall decline in fish habitat quality (Little Fish Consulting Ltd, 2010). Causes for the phenomenon of steady decline in mean annual flow are typically linked to a decrease in mean annual precipitation, increase in mean average temperature and subsequent increase in evaporation, loss of connectivity to tributary streams due to culverts, diversion ditches, filling of channels, channel desiccation, and loss of connectivity in the main stream due to cattle crossing, off-road vehicles, bridge and culvert crossings.

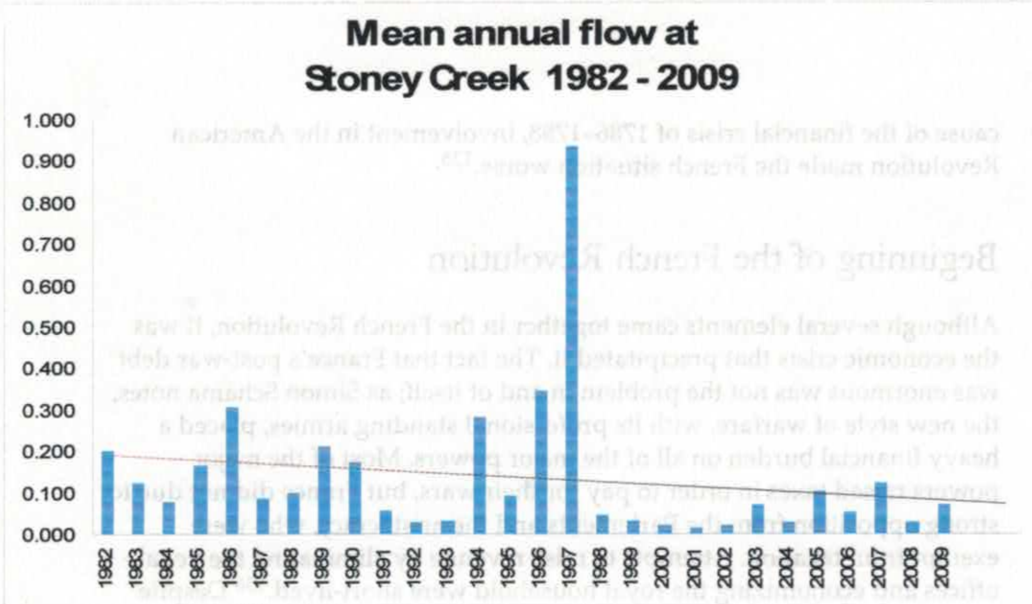

Figure 1. Mean Annual Flows at Stoney Creek from 1982 to 2009 (Environment Canada, 2010)

5.0 IMPACTS ON WATERSHED HEALTH

5.1 Direct & Indirect Impacts

5.11 Recreational

When a watercourse is crossed by off-road vehicles severe damage is caused to the stream/river bed, banks, and aquatic and riparian vegetation. The operation of off-road vehicles in the watercourse releases sediment which contributes to high turbidity rates and can destroy spawning beds; deterring fish from returning to these sites to use them again and thus altering the potential for these sites to support fisheries. As mentioned earlier, high turbidity rates also reduces available oxygen to fish and decreases light penetration to submerged aquatic vegetation which also affects fish species that depend on them.

Off road vehicles also transport invasive species to areas where they are not naturally found. Pollution from off-road riders is also a common problem; bottles, cans, plastic wrappers and other manufactured wastes are often left behind on the trail. These may disintegrate (over a very long time) and chemically pollute water, soils and organisms. Mobile animals are particularly affected by garbage because they may try to eat it or build a home with it and get trapped or wrapped up in it; causing disabilities, suffocation, and death.

5.12 Oil and Gas Development

Since there are oil and gas activities adjacent to and within the Tawatinaw River-Little Pine Creek watershed there is potential for hydrocarbon, salt, or heavy metal contamination to the watershed. Oil and gas activities may also directly contribute to increased turbidity levels if situated too close to the watershed. There are also indirect concerns associated with oil and gas acitivity such as weed invasion, and increased access for people to use the area for hunting and off-roading. Oil and gas development is a large contributor to local and landscape habitat fragmentation and linear disturbance since access roads, seismic lines, and pipelines are developed along with a well site or pad in order to develop oil and gas resources.

Oil sands production is a significant concern for surface, and groundwater quality and quantity in the Athabasca River Basin of Alberta. One of the most recent threats besides the destructive impacts of tar sands mining, is in-situ oil development, also referred to as SAGD (steam assisted gravity drainage). SAGD involves high pressure steam to extract bitumen, and poses a large concern for ground water quality due to the risks of accidental steam blowouts companied with inadequate monitoring and research on SAGD's effects on groundwater systems (Campbell, 2008). Although there are no SAGD operations directly in or near the Tawatinaw River-Little Pine Creek watershed, since SAGD blowouts can contaminate groundwater aquifers, the extent of contamination would be inconceivable due to unknown aquifer dynamics (Campbell, 2008). Since shallow groundwater runs into streams and sloughs, there is a potential for SAGD contamination to advance from the direct point source to ground and surface water aquifers throughout Alberta (Campbell, 2008)

5.13 *Sand and Gravel Development*

Sand and gravel extraction methods often encounter groundwater since sand and gravel deposits often extend deeper than the groundwater aquifers themselves. This can result in groundwater contamination and likewise surface water contamination, since as mentioned earlier in subsection 2.2 and 5.12; shallow groundwater often flows into streams and sloughs. Sand and gravel developments also pose a large concern for sedimentation which causes turbidity. The current sand and gravel developments on public lands are not close enough to the watershed to cause erosion or sedimentation issues. It is unknown if there are any sand and gravel developments on privates lands along these watersheds. Refer to subsection 6.3 below for details regarding recommended stakeholder management for sand and gravel developments.

5.14 *Forestry*

There are currently forestry disturbances directly associated with the Tawatinaw River-Little Pine Creek watershed on private lands. Forestry operations pose environmental concerns to the watershed due to the alteration of biogeochemical processes in soils that takes place by changing forest composition, soil conditions, soil microbial activity, plant uptake rates, moisture and temperature regimes, and water fluxes (Kreutzweiser, Hazlett, and Gunn, 2008). Forest landscapes that have a higher proportion of wetlands on the landscape face a higher risk of logging impacts on nutrient export and receiving water quality (Kreutzweiser, Hazlett, and Gunn, 2008). Logging increases nitrogen availability in soils due to increased mineralization, increased nitrification, and increased dissolved organic nitrogen (DON), affecting nitrogen cycling by increasing nitrogen exports to receiving waters and causing nitrogen losses from forest sites (Kreutzweiser, Hazlett, and Gunn, 2008). Forestry also contributes to erosion and high sedimentation rates into watersheds due to instability of soils after vegetation removal. Refer to photo # 6 in the Appendices for an example of forestry operations taking place on private lands directly adjacent to the Little Pine Creek watershed on a steep bank that has high potential for erosion and contribution to high turbidity in the surface waters. Refer to subsection 6.4 below for details regarding recommended stakeholder management for forestry operations.

5.15 *Agriculture*

Cattle or other livestock activity directly adjacent (riparian areas) and in the watercourse is the largest concern for destruction of this watershed. Cattle trampling and manure excretion induce the loss of riparian and aquatic vegetation, stream bank erosion, alteration of streambed dynamics, sedimentation (increased turbidity), and nutrient pollution (Chapman, 1996). Areas where cattle have access directly to the watercourse, widening and shallowing of the stream bed and banks occurs which reduces flow, increases turbidity, and subsequently increases temperature of the water (Little Fish Consulting Ltd, 2010). The removal of vegetation by trampling limits the ability of the stream to remain cool (no shade) and removes the natural ability of the stream to filter nutrients (such as phosphates and nitrates) and other organic matter. The deposition of manure directly into the stream and from run-off releases nutrients, mainly in the form of phosphates, that in the presence of warmer waters can produce algae and increase oxygen consumption downstream, subsequently decreasing the potential of the watercourse to support fisheries (Chapman, 1996).

Crop lands pose a concern for watercourses and riparian areas due to excess nutrient runoff as well as nutrient leaching, typically in the form of nitrates, into shallow groundwater aquifers which eventually run into streams and wetlands. Excessive nutrient runoff typically occurs when land is overly fertilized or lands are grazed by cattle and a major storm event occurs. Harmful pesticides and herbicides are also commonly sprayed on crop lands, which will also become a part of run-off, altering chemical and physical features of flora, fauna, water and soils and therefore altering entire ecosystems as well as human health (Chapman, 1996).

Cropped and grazed lands typically do not have much cover (vegetation) to stabilize the soil and are therefore more susceptible to soil erosion and runoff which cause sedimentation and pollution in the watercourse. This can be particularly detrimental to watercourses when there is not a sufficient buffer zone left between the watercourse and the tilled/grazed lands. A buffer zone is another term for a riparian area; the plant communities along the river/stream margins and banks, which is the most important area to maintaining a functional watershed. Riparian areas, or buffer zones, act as dissipaters of stream energy reducing soil erosion and sedimentation, filtering pollution in runoff, providing natural landscape irrigation, mitigation of water temperature change, and important wildlife habitat, corridors, and forage needs. These buffer areas are particularly important to water quality due to their ability to denitrify nitrates in fertilizers that run off of agricultural fields (Kreutzweiser, Hazlett, and Gunn, 2008). If there is no buffer zone to denitrify excessive nitrates from fertilizers then it will run directly into the watercourse/waterbody, stimulating increased vegetative growth and subsequent deprival of oxygen for fisheries (Diaz, 2000). This process is often called eutrophication, a process where excessive nutrients stimulate plant growth and decay that reduces water quality. Since Refer to subsection 6.5 for details regarding recommended stakeholder management for agricultural developers.

Rstues + Sites

5.16 *Government Developments*

The proposed realignment of the Tawatinaw River by the DOT would constitute straightening of the naturally occurring bend in the Tawatinaw River flood plain where it meets the Athabasca River by redirecting the flow through a canal (Tawatinaw Watershed Stewards, 2011). If this channelization proposal is carried through it will pose a high risk to the biodiversity and health of the river system and riparian areas. Channelization alters flow regimes by decreasing flow in certain streams and lowering water levels which negatively impacts fisheries (Hupp, 1992). Smaller waterways are important for fish spawning as they are 2-4° C warmer in the spring than larger rivers (Tawatinaw Watershed Stewards, 2011). Channelization involves extensive and intensive stream bed and stream bank disturbance which would cause increased erosion and sedimentation, increasing water turbidity and its associated impacts on the environment (Chapman, 1996).

A failed attempt at channelization occurred in the town of Athabasca approximately 30 years ago when the Muskeg Creek meander that ran through Athabasca was straightened. Some of the negative impacts that resulted from this realignment included loss of woody species and decreased plant diversity, stream-bank degradation, loss of wildlife habitat and passage, and an increase of invasive plant species (Tawatinaw Watershed Stewards, 2011). The straightening of the Tawatinaw River would likely develop these same circumstances and likely on a larger scale since the Tawatinaw is a larger tributary to the Athabasca than the Muskeg Creek and is, and is host to a variety of fish species who are easily perturbed by disturbances to their normal passage, habitat and spawning sites.

As mentioned earlier, there are many culverts and bridges crossing tributary streams and the main watercourse of the Tawatinaw River and Little Pine Creek. Culverts are contributing to erosion and sedimentation into the watercourse as many are partially blocked, hanging, or undersized. Many of the larger culverts have severely degraded fish habitat quality and spawning ability in the Tawatinaw and prohibition of passage to the Athabasca River. Many of the bridges are poorly built or degrading with age and are creating a number of issues in the watercourse. Deposition of sediment from bridge deck gaps and edges, ditching of roads to bridges directly into the stream, and cracked bridge support structures which are depositing concrete and rust into the stream channel are the main concerns. Refer to subection 6.6 below for details on recommended stakeholder management for government developments.

P. tws

5.7 Cumulative Impacts

The introduction of invasive species from all of the above anthropogenic activities can produce local and landscape scale alterations to a functional ecosystem. Invasive species are typically very durable and aggressive, with the ability to out-compete most native species to become the dominant plant. This has an effect on ecosystem dynamics because all components of a functional ecosystem depend on each other, and thus the removal of one native species may disturb the natural functioning of that ecosystem. Many species have specialized niches and may be considered sensitive, rare or endemic, and as mentioned previously in subsections 2.4 and 2.5, when these species face disturbances to their environments, their specialized habitats or forage requirements may no longer be suitable or available, causing the species to further decrease in abundance and distribution. This further stresses the viability of populations, contributing to further listing of special concern, threatened, extirpated, endangered and even extinct species.

The greatest cumulative impact on the landscape is habitat fragmentation and linear disturbances. Recreational, oil and gas, sand and gravel, forestry, agriculture, and government developments all cause habitat fragmentation and linear disturbances. Individually they may cause obvious local disturbances but cumulatively these anthropogenic activities have extensive and large-scale landscape impacts. Habitats which were once continuous become divided into separate fragments, and when the pressure is extensive and intensive, the separate fragments become small islands isolated from each other by pasture, croplands, roadways, seismic lines, pipelines, well sites and pads, towns, acreages and other human developments. One of the main impacts of habitat fragmentation on biodiversity is decreased available habitat for all organisms in an ecological niche. Small fragments of land can only support small populations of plants and animals which are more vulnerable to extinction. Plants and sessile organisms are often directly destroyed from localized impacts of human activities and can be cumulatively destructive to populations. Mobile animals such as birds and mammals tend to retreat into remnant patches of land leading to over-crowding and over-competition, further increasing the pressure on populations.

Many species, such as the woodland caribou, avoid linear tracts or cleared land because of a loss of cover and forage, and increased vulnerability to predation (Dyer, O'Neill, Wasel, and Boutin, 2001). Habitat fragmentation alters natural predator-prey interactions that developed over thousands of years of natural selection. Development creates cut blocks and cut lines that render remote habitat (which caribou prefer) easily accessible to hunters and wolves. Alberta studies showed that caribou were more likely to be killed by wolves in areas within 250 m of all recent cut-blocks and other developments, and that caribou used these areas much less than undisturbed forests (Adamczewski, Florkiewicz, and Loewen 2003). Consequently the woodland caribou populations in Alberta have suffered immensely and are designated as a threatened species (Dyer, O'Neill, Wasel, and Boutin, 2001). Habitat fragmentation also creates 'edge effects' which refers to the microclimatic changes in light, temperature and wind that alter the ecology in and around a fragment of land. This establishes an increased susceptibility to fire, invasion of exotic and pest species (mountain pine beetle, spruce bud worm etc) and unfavourable habitat.

Although habitat fragmentation is not as extensive and intensive near the Tawatinaw River-Little Pine Creek watersheds as it is along many other places in the Athabasca River Basin, there are still many risks to species as there are many sensitive species and some rare, endemic, endangered and threatened species inhabiting the area. It is likely that many of these species are finding a safe haven in areas such as this because the pressure of habitat fragmentation is too extensive and intensive in many other places along the Athabasca River Basin, such as the dense population and mineral mining upriver and the extensive in-situ and bitumen open pit mining downriver.

Surface water allocation is also becoming an extensive issue in Alberta; with the already parched surface waters of southern Alberta there is increasing pressure on groundwater systems. Surface and groundwater allocation in northern Alberta is also steadily increasing in order to fuel increasing industry demands and compensate for the high demand and little supply in southern Alberta. With demand of fresh water resources steadily increasing due to cumulative industrial development and urbanization throughout Alberta, surface and groundwater quantity and quality are becoming increasingly at risk.

implemented to prevent any further adverse environmental effects. Refer to Recommended Mitigation Measures and Watershed Stewardship in Section 7.0 below for further details regarding weed management, erosion control measures, spill prevention measures, seasonal constraints, and discovery of historical resources.

6.4 Forestry

In order to prevent the negative impacts of forestry on the Tawatinaw River-Little Pine Creek watershed, the most stringent operating guidelines and best management practices must be adhered to. Leaving buffer zones near forestry operations is critical, as mentioned in subsection 5.15, buffer zones, or riparian areas, act as dissipaters of stream energy reducing soil erosion and sedimentation, filtering pollution in runoff, providing natural landscape irrigation, mitigation of water temperature change, and important wildlife habitat, corridors, and forage needs.

The Tawatinaw River-Little Pine Creek watershed is protected under the Migratory Birds Convention Act. Thus, any industrial forest disturbances such as harvesting of standing timber and mulching must be avoided during the period from **May 1st to July 31st** to provide for the conservation of migratory birds and their nesting areas (Government of Alberta, 2011).

6.5 Agriculture

As a part of agricultural management, fencing setbacks around watercourses/water bodies should be implemented to allow for riparian area recovery and to promote the important natural functions that riparian areas provide. Instead of using the watercourse or water body as a watering source for livestock, a solar or wind powered water pump could be installed to pump water to a watering bowl outside of the riparian area. If there are sufficient funds, the agricultural manager could also dig a dugout outside of the riparian are to serve as a water source to replace the natural watercourse or waterbody. If there is currently no fencing off of the riparian area, salt blocks should not be placed near the watercourse or waterbody because this will result in more trampling and traveling near and into the watercourse/waterbody than is necessary. If the agricultural manager has no other option and must use the watercourse, riparian areas could be fenced off with one direct and limited area for the cattle to access the watercourse, companied by implementation of silt fencing in the watercourse/waterbody to limit the extent and impact of sedimentation and nutrient depositing into the water.

Fencing off of the riparian area is not only important as a buffer zone between livestock and the watercourse/waterbody but also as a buffer zone from cropped lands. These buffer areas are particularly important to water quality due to their ability to denitrify the nitrates in fertilizers that runs off of agricultural fields. Since buffer zones can naturally remove a high rate of nitrates they play a significant role in agricultural management. Refer to Recommended Mitigation Measures and Watershed Stewardship in Section 7.0 below for further details regarding weed management, erosion control measures, spill prevention measures, seasonal constraints, and discovery of historical resources.

6.6 Government

In the best interest of the ecosystem health of the Tawatinaw River-Little Pine Creek watershed, the proposed straightening of the naturally occurring bend in the Tawatinaw River flood plain where it meets the Athabasca River in the town of Athabasca should be terminated. In order to maintain the natural functioning of the river, riparian areas, and all of biotic and abiotic components, a less impactful proposal for the highway 55/813 interchange is necessary and urgent. The Tawatinaw River is generally an unaltered, naturally functioning watershed ecosystem and may serve as an important education tool for youth in the Athabasca area and also as a model for the restoration of the nearby Muskeg Creek. The Tawatinaw River is also an important historical feature to Athabasca and could play a role in bringing tourism to the area.

The costs incurred by the channelization of the Tawatinaw River meander that runs through Athabasca are not only ecological but economical as well. Bank stabilization, native plant establishment, invasive plant control, and re-developing a functional wildlife corridor and functional fish habitat will require expensive construction and maintenance costs.

Government officials should integrate regular culvert and bridge inspections, maintenance and repair into their infrastructure development and planning priorities now and in the future. If infrastructure is regularly maintained and repaired it will have a longer lifespan before need for replacement and less impact to the environment. Bridge, highway, and culvert designs should originally be designed to allow for natural stream meandering so that the risks of channel alteration are prevented to begin with. Refer to Recommended Mitigation Measures and Watershed Stewardship in Section 7.0 below for further details regarding weed management, erosion control measures, spill prevention measures, seasonal constraints, and discovery of historical resources.

6.7 Cumulative Impacts

Implementing proper practices may help mitigate habitat fragmentation, such as defined guidelines for wildlife corridor width, length, cover, vegetation cover and human use levels (White, Hurd, Hebbelwhite, and Pengally, 2007). Mobile wildlife are generally intimidated by wide, open corridors and predator-prey conflicts occur as a result. Andrews (1990) Found that bridges across rivers and gullies can be made into natural crossing if the bridge allows space alongside the banks, and particularly if natural vegetation is left as cover. Culverts could also be strategically placed as movement corridors for small mammals to minimize exposure to predators (Andrews, 1990). To minimize effects of linear disturbances, forest width clearance for roads could also be minimized because they are usually cleared wider than is sufficient, resulting in crossing levels less severe and traumatic for wildlife.

7.0 RECOMMENDED MITIGATIVE MEASURES & WATERSHED STEWARDSHIP

7.1 Weed Management

All stakeholders of the Tawatinaw River-Little Pine Creek Watershed, including industry, agriculture, government and recreation partakers are recommended to take weed management into consideration whether it be government or industry implementing a detailed weed management program or recreational users following best management practices to ensure prevention of weed problems. The following subsections detail the steps of effective weed management practices.

- Weed Prevention
- Weed Monitoring
- Weed Control

7.11 Weed Prevention

All equipment, vehicles, ATV's and other manufactured goods should be appropriately cleaned of any foreign (off-site) soils and vegetation before entering the site or watershed. This protocol is necessary because foreign soil and vegetation may foster weedy species of plants or organisms that are not native to the area and subsequently may inhabit that area and eliminate native species once brought in. Regarding industrial, agricultural or municipal development adjacent to the watershed, only Canada 1 Certified and SRD approved seed mixes should be applied to developments if seeding is required (Government of Alberta, 2011). If seed mixes are used that are not certified by the above two organizations the site could face a strong risk for weed invasion.

7.12 Weed Monitoring

During the growing season, industrial and agricultural lands as well as problem recreational and infrastructure areas, should be inspected regularly for weeds:

- Record weed type and location on Weed Survey Information Sheets
- As part of a weed survey, completion of a "weed documentation form"
    - Weed documentation forms can be found online at http://environment.gov.ab.ca/info/library/5929.pdf
- Determine if there is a risk of weeds spreading into the site if it is developed

- Prescribe weed prevention and control methods if necessary
    - Problematic weeds and required control methods are described in the *Weed Designation Regulation of the Weed Control Act.*
    - Such requirements are listed at the Alberta Agriculture and Food website: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/acts6156
- Prepare an annual weed monitoring report which details weed type, location, specific control measures and follow-up monitoring
- If you are an individual who identifies a weed concern on public lands then the County of Athabasca Weed Inspector should be notified immediately

7.13 Weed Control

Weed control should be conducted as soon as a weed problem is identified on site in order to ensure a greater success of weed management and end land-use objectives. Methods applicable to control further weed propagation and reduce or eliminate weeds on site include but are not limited to hand picking, mechanical (mowing) and chemical if required. Different types of weeds may require specific control methods or combinations of both in order to be successful. Each method also requires appropriate timing (seasonal constraints) and technique in order to be successful. Those conducting weed control methods should be appropriately educated to do so (i.e. obtain a pesticide applicator certificate or assistant applicator certificate) and operate under appropriate supervision if necessary. The weed applicant must conform to the provisions of:

- *Alberta Environmental Protection and Enhancement Act (AEPE), Pesticide Regulation AR 43/97*
- *Environmental Code of Practice for Pesticides; Water Resources Regulation*
- *Pesticide Sales, Handling, Use and Application Regulation AR 24/97*

7.2 Erosion Control Methods

Erosion control measures should be implemented to minimize the amount of sediment entering any watercourse or wetland, and preventing rutting and compaction from occuring. Appropriate erosion control measures include but are not limited to the following:

- Maintaining an appropriate buffer zone of vegetation surrounding watercourses and wetlands
- Special attention and monitoring of steep slopes for potential erosion problems
- Silt fencing and other erosion control devices (coconut matting, etc) installed in association with soil stockpiles and/or along the edge of a disturbance area adjacent to the watershed (s)
- "No Disturbance" limits, where required, will be identified and marked with tape or fenced off so that traffic may be diverted successfully
- Utilization of designated access routes on lease to ensure minimal disturbance
- Maintenance of appropriate surface drainage, and if necessary, installation of temporary culverts to maintain natural surface water drainage
- Regular checkups and maintenance of culvert and bridge conditions
- Prohibition of operating equipment within the wetted perimeter of any wetland
- Prohibition of operating equipment during/after unstable weather conditions
- Compliance with Best Management Practices

7.3 Spill Prevention Methods

Spill prevention measures include but are not limited to:

- Development of a site-specific spill response plan
- Training of spill response procedures to all on-site personnel
- Accessibility of spill response kits on site at all times
- Regular checks/maintenance of spill response kits/ fire extinguishers and other safety equipment
- Proper storage and disposal of partially empty drums and pails so that their contents do not come into contact with environmental factors in any way

    - These items are generally accepted at the local recycling center and at some sanitary landfills
- Proper storage of garbage such as in wildlife-proof containers and daily garbage removal
- Regular maintenance and performance checks of on-site equipment to lower the probability of future spills
- Appropriate capture and storage of fluids lost during repair and maintenance of equipment
- Reference to the Workplace Label or Materials Safety Data Sheet (MSDS) for specific handling and safety concerns related to the specific product being used
- Spills must be cleaned up, contained, and reported to the appropriate agency immediately if the spill is above the allowable volume as defined by spill guidelines

7.4 Seasonal Constraints

Fish and Wildlife (2011) recommends postponing all activities until fall or early winter in order to ensure successful wildlife nesting and rearing. As mentioned above, the Tawatinaw River-Little Pine Creek watershed is protected under the Migratory Birds Convention Act (1918) and therefore any industrial forest disturbances such as harvesting of standing timber and mulching must be avoided during the period from **May 1st to July 31st** to provide for the conservation of migratory birds and their nesting areas (Alberta Sustainable Resource Development, 2011). Caribou Zone?

7.5 Discovery of Historical Resources

Should any historic, prehistoric, and/or paleontological remains be discovered along the Tawatinaw River-Little Pine Creek watershed during industrial operations, operations are to cease immediately (Government of Alberta, 2011). If such an event should occur, the Alberta Historical Resources Foundation and ASRD should be notified as soon as possible. Operations are not to resume until access is granted by the appropriate regulatory body (Government of Alberta, 2011). Recreational and traditional land users should also notify the above contacts should they encounter any historic, prehistoric, and/or paleontological remains. Refer to the *Alberta Culture and Community Spirit Listing of Historic Resources Instructions for Use* manual on the Government of Alberta website for more detailed information, how to apply for *Historic Resources Act* clearance, recommended action matrices, as well as the appropriate government contacts.

7.6 Revegatation

6.0 RECOMMENDED STAKEHOLDER MANAGEMENT

6.1 Recreational

In order to mitigate the impacts of off-road vehicles, trails that enter the watercourse or riparian areas should be closed off and signs prohibiting use of the trails should be posted to educate riders. Signs could also be posted to educate off-roaders of the negative impacts that off-roading causes to watershed health. Garbage cans and recycling bins should be placed strategically along the trail to prevent littering. Fences could be installed in areas along the trails where there are identifiable areas that off-road vehicles are entering the watercourse or floodplain to prohibit entry. This would also likely influence off-roaders to avoid future use of the trail if part of it is inaccessible. It would also be beneficial to have enforcement of the trails during periods of intense use by off-roaders, such as during long weekends in the spring and summer. Refer to site photo # 12 which identifies an area along the Tawatinaw River where ATV's directly cross the watercourse. Refer to Recommended Mitigation Measures and Watershed Stewardship in Section 7.0 below for further details regarding weed management, erosion control measures, spill prevention measures, seasonal constraints, and discovery of historical resources.

6.2 Oil and Gas

Since there are is a potential for hydrocarbon, salt, or heavy metal contamination to the watershed from adjacent oil and gas activities it is important that due diligence is maintained during all phases of activity; from construction and operations to decommissioning. The Alberta Government requires that all oil and gas wells/pads are assessed by an accredited environmental outfit to determine if there is any potential contamination; referred to as a Phase I Environmental Site Assessment (ESA). If any potential contamination is identified it must then be fully characterized and delineated in a Phase II ESA and cleaned up and remediated in a Phase III ESA. Further cleanup and monitoring may be required depending on the nature and risks associated with the contamination. The following guidelines associated to contaminated oil and gas sites should be strictly adhered to:

- *Salt Contamination Assessment and Remediation Guidelines (AENV, 2001)*
- *Canada Wide Standards for Petroleum Hydrocarbons In Soil (CCME, 2001)*
- *Alberta Soil and Water Quality Guidelines for Upstream Oil and Gas Sites (AENV, 2001)*
- *Canadian Environmental Quality Guidelines (CCME, 2002)*
- *Guidance Manual on Sampling, Analysis, and Data Management for Contaminated Sites (CCME, 1993)*

Refer to Recommended Mitigation Measures and Watershed Stewardship in Section 7.0 below for further details regarding weed management, erosion control measures, spill prevention measures, seasonal constraints, and discovery of historical resources.

6.3 Sand and Gravel

If during operations material is mined below the water table and water becomes an issue for operations then dewatering areas within the lease may be required. In addition, proper drainage of the pit area will have to be considered for reclamation purposes. Pits on private or public land may require an approval under the *Water Resources Act* if water is used, such as for gravel washing, or diverted, such as for pit dewatering, or if the pit is within the floodplain of an identifiable watercourse or water-body (Alberta Sustainable Resource Development, 2008). If the conditions of the site require that water must be pumped off site, then ASRD must be contacted to provide authorization to do so prior to commencement of this activity (Alberta Sustainable Resource Development, 2008).

Groundwater should be actively and regularly monitored throughout the life of the pit to document pre- and post disturbance groundwater conditions should there be any concerns for contamination of groundwater from on or off-site activities. Sand and gravel managers are recommended to use piezometers at strategic locations throughout the SML to evaluate groundwater depth, gradient and chemistry over time (Alberta Sustainable Resource Development, 2008). Should contamination be suspected in the water on site, operations are to cease immediately and appropriate samples as defined by the appropriate regulatory body will be extracted and analyzed in a certified laboratory. If the analytical data proves there is contamination, appropriate mitigative measures defined by the appropriate regulatory body will be

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APPENDICES

Table 1. Plant species scientific name, common name, and type as identified along the Tawatinaw River and Little Pine Creek watersheds on April 21, 2011 and May 00, 2011.

Scientific Name	Common Name	Type	Comments
Populus balsamifera	Balsam poplar	Tree	Dominant
Populus tremuloides	Trembling aspen	Tree	
Picea glauca	White spruce	Tree	
Picea mariana	Black spruce	Tree	
Pinus banksiana	Jack pine	Tree	
Betula papyrifera	Paper birch	Tree	
Larix laricina	Tamarack	Tree	
Salix spp.	Willow sp.	Shrub	
Juniperus communis	Ground juniper	Shrub	
Artostaphylos uva-ursi	Common bearberry	Shrub	
Alnus crispa	Green alder	Shrub	
Rosa acicularis	Prickly rose	Shrub	
Shepherdia canadensis	Canada buffaloberry	Shrub	
Ledum groenlandicum	Common Labrador tea	Shrub	
Cornus stolonifera	Red osier dogwood	Shrub	
Viburnum edule	Low bush cranberry	Shrub	
Ribes lacustre	Black gooseberry	Shrub	
Rubus idaeus	Wild red rasberry	Shrub	
Amelanchier alnifolia	Saskatoon	Shrub	
Prunus virginiana	Chokecherry	Shrub	
Prunus pensylvanica	Pincherry	Shrub	
	Caragana	Shrub	
Cornus canadensis	Bunchberry	Forb	
Frageria vesca	Woodland strawberry	Forb	
Mitella nuda	Bishop's cap	Forb	
Linnaea borealis	Twinflower	Forb	
Lathyrus ochroleucus	Creamy pea-vine	Forb	
Orthilia secunda	Common pink wintergreen	Forb	
Astragulus agrestis	Purple milk vetch	Forb	
Viola adunca	Early blue violet	Forb	
Petasites frigidus var. palmatus	Palmate-leaved coltsfoot	Forb	
Galium boreale	Northern bedstraw	Forb	
	Cow parsnip	Forb	
	Common tansy	Forb	
Calamagrostis canadensis	Bluejoint	Grass	
	Western wheatgrass	Grass	
Cinna latifolia	Wood reed grass	Grass	

Phalaris arundinacea	Reed canary grass	Grass	
Phleum pratense	Timothy	Grass	Forage crop
	Alfalfa	Grass	Forage crop
Typha latifolia	Common cattail	Aquatics	
Cladina rangifera	Reindeer Lichen	Lichen	
	Leaf Lichen	Lichen	
	Lichen spp.	Lichen	
	Peat moss	Peat moss	
	Moss spp.	Moss	

Table 2. Wildlife evidence and sightings as identified along the Tawatinaw River and Little Pine Creek watersheds on April 21, 2011 and May 00, 2011.

Class	Specific Name	Common Name	Evidence/Sightings
Mammalian			
	Lontra canadensis	Northern river otter	E – bank slide
	Castor canadensis	Beaver	E – beaver dam, lodge and cuttings
	Lepus americanus	Snowshoe hare	E – hair remains
	Odocoileus virginianus	White tailed deer	S, E – droppings, tracks, browsed vegetation
	Odocoilues hemionus	Mule deer	S, E – droppings, tracks, browsed vegetation
	Alces alces	Moose	E – droppings, browsed vegetation
	Vulpes vulpes	Red fox	E - tracks
Birds			
	Buteo jamaicensis	Red tailed hawk	S
	Branta canadensis	Canada geese	S
	Ardea herodias	Great blue heron	S
	Archilochus colubris	Ruby throated hummingbird	E - nest
	Corvus corax	Common raven	S
	Falcipennise canadensis	Spruce grouse	S, E - audio
	Turdus migratorius	American robin	S
	Poecile hudsonicus	Boreal chickadee	S, E - audio
	Bucephala clangula	Common goldeneye	S
Insects			
	Vanessa cardui	Painted lady	S

SITE PHOTOS

Photo # 1. Looking NW at beaver lodge and cuttings on Little Pine Creek at location LP03 on April 21, 2011

Photo # 2. Looking S at inadequate silt fencing installation at location LP1B[1] on April 21, 2011

Photo # 3. Looking E at eroding wooden bridge and beaver dam constructed beneath bridge at location TW10 (conjunction point of Little Pine and Colinton Creek) on April 21, 2011

Photo # 4. Looking S from road over large culvert at beaver dam and heavily eroded E-NE facing slope at location TW09 (Colinton Creek) on April 21, 2011

Photo # 5. Looking N from road over culvert at diminished riparian area as a result of intensive beaver habitat and cattle grazing/trampling at TW09 on April 21, 2011

Photo # 6. Looking E-SE from road at clear-cut on private land S of Colinton, directly adjacent to tributary of Little Pine Creek on April 21, 2011

Photo # 7. Looking W-SW off bridge S of Colinton at Tawatinaw River where banks are not fenced off from pasture lands and riparian vegetation is minimal at TW08 on April 21, 2011

Photo # 8. Looking NE off bridge at proper fencing practices in pasture directly adjacent to Tawatinaw River at TW09[1] N of the town of Meanook on April 21, 2011

Photo # 9. Looking E at severely eroding cement bridge deck at location TW01 NW of Perryvale on April 21, 2011

Photo # 10. Looking E-SE at degrading Tawatinaw streambed and banks with no riparian vegetation left due to heavy cattle traffic at TW02 on April 21, 2011

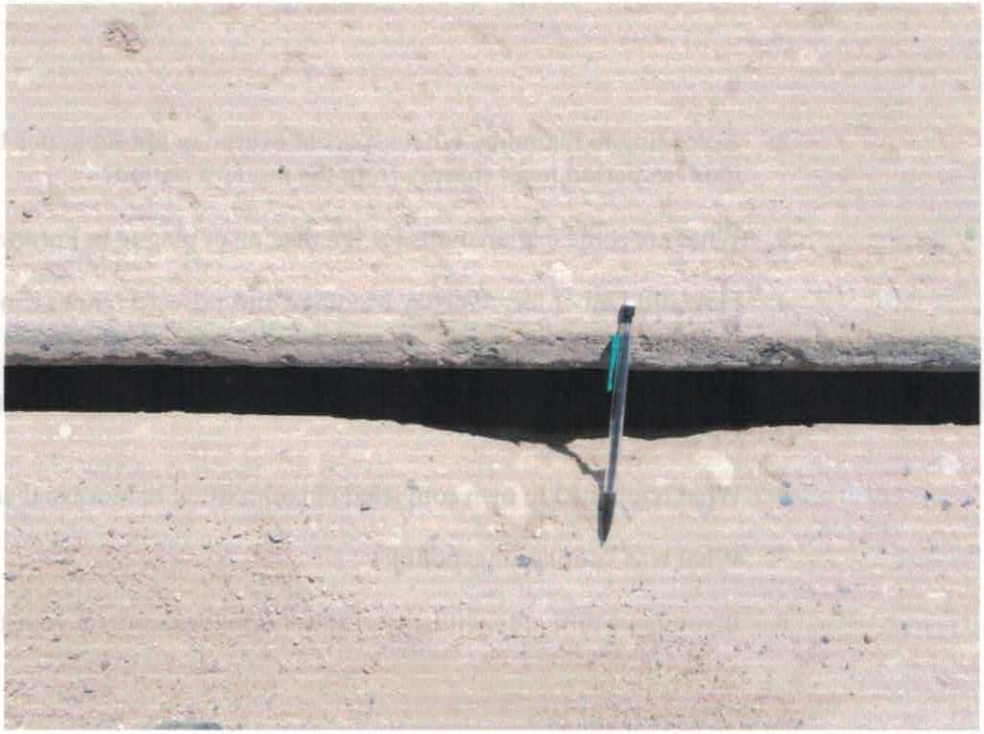

Photo # 11. Looking directly at one of several gaps in degrading cement bridge at location TW03 near Rochester on April 21, 2011

Photo # 12. Looking NE at quad trail that directly enters the streambed off of the east bank of the Tawatinaw River at TW03 on April 21, 2011

Photo # 13. Looking SE at degrading cement bridge deck at location TW05 in the village of Tawatinaw on April 21, 2011

Photo # 14. Looking N over large culvert at streambed where cattle have direct access and there is little riparian veg left and evidence of nutrient enrichment by presence of Lemmna duck-weed at location TW06 NW of Tawatinaw on April 21, 2011

Photo # 15. Looking W at upper Helliwell Lake, the headwaters of the Tawatinaw River, at evidence of nutrient enrichment causing eutrophication, on April 21, 2011

Photo # 16. Looking S-SE at heavily degrading cement bridge deck at location TW12 on April 21, 2011

Photo # 17. Looking NE off bridge on Trans-Canada Trail at erosion on S-facing bank of Tawatinaw River at location TW13 on April 21, 2011

Photo # 18. Looking N at lower Tawatinaw River in the town of Athabasca where Hwy 55/813 interchange is proposed to be removed and relocated to the S of its existing location, and the natural meander before the Athabasca River removed and straightened on April 21, 2011.