60 years of forest change in the Minesing Wetlands (1953-2013): Causal factors, ecological implications and recommendations for reforestation



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For the Nottawasaga Valley Conservation Authority and Friends of Minesing Wetlands

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Executive Summary

The Minesing Wetlands is an internationally significant wetland that provides local wetland benefits such as flood attenuation, nutrient cycling, wildlife habitat, and place for recreational activity and cultural learning.

The purpose of this report is to identify:

- the spatial extent of forest decline and composition of lost forests;
- potential causes and effects of forest decline;
- potential future trajectory of forest decline, and;
- potential means to mitigate forest loss

Forest decline was determined through analysis of a series of airphotos and orthoimagery available from 1953 to 2012. In 1953, forest cover in the Minesing Wetlands (core/study area) was estimated at 4,400 ha: about 70% of the core wetland landscape. This forest cover included approximately 3,000 ha of deciduous forest, which was dominant in the bottomland and lowland areas, along levees and on the periphery of the wetland. A mixed coniferous swamp covered an area greater than 1,400 ha along the base of the Algonquin Bluffs in the southeastern portion of the core wetland.

Between 1953 and 2013, 1,860 ha of deciduous forest cover was lost. Though partially offset by 240 ha of forest gain via regeneration (220 ha deciduous forest, 20 ha coniferous forest), this represents a 37% net decline in total forest cover and a loss of more than 56% of total deciduous cover during this time period. An analysis of historical reports prepared for and by the Ministry of Natural Resources showed that the main tree species lost was Silver Maple (Moriyama, 1974; AAA Consultants, 1977; MNR, 1979). Extensive emergent marsh and thicket swamp communities have replaced deciduous forest cover. Conversely, the mixed coniferous swamps associated with a stable groundwater regime in the southeast portion of the wetlands have remained relatively unchanged.

Forest die-off likely was initiated prior to 1953; however, the majority of forest cover loss between 1953 and 2013 occurred between 1978 and 2002, accounting for an estimated 1,100 ha of total forest loss of the total 1,800 ha lost during this period. Currently, deciduous floodplain forests are still in decline and based on long term trends along known forest loss fronts it is estimated that the Minesing Wetlands could lose an additional 180 ha of deciduous forest cover over the coming decades.

These observed changes in deciduous forest cover prompted an investigation into what could have caused such a significant decline in the last sixty years. Cumulative impacts from subwatershed-scale and local land clearing and drainage combined with subsequent impacts associated with Hurricane Hazel and Dutch Elm disease are linked to changes in the hydrology of the wetland (longer and more variable periods of inundation) and responsible for a shift in dominant ecosystem type from deciduous swamp forests to open marsh and swamp thickets. Innovative watershed planning is needed to ensure that future growth does not compound existing hydrological impacts. Continued wise stewardship on rural lands is also needed to control sediment loadings to watercourses tributary to the Minesing Wetlands.

The ecological implications associated with this vegetation shift are discussed. Open canopy species such as marsh birds appear to be benefitting from creation of extensive areas of marsh whereas core forest species such as forest interior birds appear to be declining from loss of forest cover. Invasive species, particularly Rough Manna Grass, have colonized extensive areas of former forest. Additional monitoring is required to better assess the ecological implications of ecosystem change as the Minesing Wetlands adjusts and responds to stressors such as climate change and invasive species.

Despite a trajectory for continued deciduous forest loss within remaining floodplain forest communities, there are significant opportunities to re-build floodplain forest cover within the Minesing Wetlands. Several reforestation project sites are identified that would bolster and reconnect remaining core floodplain forest habitat in the Minesing Wetlands. These sites are located on previously farmed levee areas and on public lands adjacent to the Minesing Wetlands in areas removed from observed hydrological impacts/forest loss. Development and implementation of detailed reforestation plans on these lands will help ensure the long term persistence of floodplain forests and their associated functions in the Minesing Wetlands.

Table of Contents

Contents

ACKNOWLEDGEMENTS	I
EXECUTIVE SUMMARY	II
1.0 INTRODUCTION	1
2.0 METHODS	4
2.1 DETERMINATION OF FOREST LOSS OVER TIME	
2.2 ANALYSIS OF FOREST LOSS BY FOREST TYPE	
2.3 CAUSAL FACTOR ANALYSES	5
3.0 RESULTS	6
3.1 Forest Cover Analysis	6
3.2 TOTAL FOREST LOSS	9
3.2.1 1953-1978	9
3.2.2 1979-2002	
3.2.3 2003-2013	
3.2.4 Future Forest Decline	
3.3 TOTAL FOREST GAIN	
3.4 FOREST COMMUNITY TYPE CHANGE IN THE MINESING WETLANDS	
3.5 Composition of Lost Forests	14
4.0 DISCUSSION	
4.1 Forest Loss – Causal Factors	
4.1.1 Historical Clearing and Drainage	
4.1.2 Levee Breaks/Crevasse Splays	
4.1.3 Dutch Elm Disease	
4.1.4 Hurricane Hazel	
4.1.5 Climate Change	
4.2 Forest Loss – Summary and Outlook	19
4.2.1 Emerald Ash Borer	21
4.3 VEGETATION COMMUNITY CHANGE – ECOLOGICAL IMPLICATIONS	21
4.3.1 Vegetation Communities	21
4.3.2 Wildlife	
4.3.3 Invasive Species	24
5.0 RECOMMENDATIONS	
5.1 WATERSHED PLANNING AND STEWARDSHIP	25
5.1.1 Watershed Planning	
5.1.2 Watershed Stewardship	27
5.2 Monitoring	27
5.3 Reforestation Options	29
5.3.1 Interior/Levee Reforestation Sites	

5.3.2Peripherv Reforestation Sites	
5.3.3 Reforestation Conclusions	
6.0 REFERENCES	
APPENDICES	

Table of Figures

Figure 1: Minesing Wetlands and Vicinity2
Figure 2: Historical and Current Wetland Coverage
Figure 3: Minesing Wetland Forest Cover 19537
Figure 4: Minesing Wetlands Forest Change 1953-2013
Figure 5: Rate of Forest Loss9
Figure 6: Current Forest Cover and Loss Fronts11
Figure 7: Forest Community Change (1953-2013)13
Figure 8: Vegetation Community Regime Shift13
Figure 9: Reforestation Options - Minesing Wetlands
Figure 10: Mad River Planting Sites
Figure 11: Nottawasaga River Planting Sites
Figure 12: Northern Minesing Wetlands Planting Sites
Figure 13: Baldwick Lane Planting Sites
Figure 14: Closed Canopy Silver Maple Swamp43
Figure 15: Declining Swamp Edge (note partial canopy, dead/declining trees and cattail understorey) .43
Figure 16: Drowned Swamp (note Rough Manna Grass marsh with dead standing timber)
Figure 17: Inundated Rough Manna Grass Marsh (spring conditions; only submerged stumps reminiscent of past forest)

1.0 Introduction

The Minesing Wetlands is internationally recognized as an area of unique biological diversity and ecological importance. Located in the heart of the Nottawasaga River watershed in Simcoe County (Figure 1), the wetland complex includes swamp, marsh, and fen communities, and is one of the largest wetlands in Southern Ontario.

The Minesing Wetlands have been evolving since the retreat of North American glaciers 11,000 years ago, which left a large glacial lake (Lake Algonquin) that covered much of the Nottawasaga Valley (Simcoe Lowlands). Over time this lake drained northeastwardly toward the Ottawa Valley. Approximately 5,000 years ago, the Minesing lowlands were again inundated by rising lake levels in Georgian Bay (Lake Edenvale - Nipissing transgression). With the opening of the St. Clair River outlet, lake levels receded to present day levels and vegetation communities dominated by floodplain swamp forests, boreal forest and fen evolved over the emerging lowlands forming the Minesing Wetlands.

Ducks Unlimited Canada (2010) estimated that the Minesing Wetlands would have covered an area nearly twice the size of the current wetland area of 7,250 ha prior to European Settlement (Figure 2). Drainage works were undertaken along much of the wetland periphery in the late 1800s and into the 1900s to facilitate drainage of agricultural fields. Agricultural clearing also occurred along the wider, drier river levees in the heart of the wetlands. In the mid-1900s, swamp forest cover was the dominant vegetation community type in the Minesing Wetlands. Floodplain deciduous swamps comprised the majority of wetland cover with a significant mixed coniferous swamp/fen complex present in the southeast portion of the wetland at the base of the Algonquin Bluffs. Fen, thicket swamp and marsh cover was also present.

Several reports have highlighted changes in forest cover and function in the Minesing Wetlands. A master plan for the wetlands was presented to the Ontario Ministry of Natural Resources (MNR) in 1974 that described the ecological and social history in the Minesing Wetlands (Moriyama, 1974) and ecological land classification of the deciduous and coniferous forest complexes across the wetland landscape (Bobbette, 1975). A study of the Willow Creek watershed (AAA Consultants, 1977) provided a detailed account of forest loss and hydrology changes along Willow Creek. Bowles et al. (2007) also reported the dieback of floodplain swamp forests and shift to open marsh. However, a systematic review of forest loss over time has not been undertaken for the core area of Minesing Wetlands (roughly bounded by County Road 90 to the south, Highway 26 to the north, County Road 10 to the west and George Johnston Road to the east). The purpose of this report is to:

- provide a review of forest loss over time;
- assess potential causal factors associated with forest loss;
- identify the implications of forest decline on wetland features and functions;
- assess the future trajectory of forest loss; and,

• provide recommendations for watershed planning and stewardship, wetland monitoring and floodplain forest reforestation



Figure 1: Minesing Wetlands and Vicinity

Figure 2: Historical and Current Wetland Coverage



2.0 Methods

The Minesing Wetlands complex is approximately 7,250 ha with a core (road-less) area approximately 6,150 ha. The analysis for this work was confined to the core, or study area (see Figure 3).

2.1 Determination of Forest Loss Over Time

Forest loss over time was analyzed for the sixty-year period of 1953-2013 as well as a prediction of forest loss over the next 15 years (2013-2028). Airphotos of the Minesing Wetlands were analyzed for changes in forest cover for the years 1953, 1971, 1978 and 1989. Aerial orthoimagery was evaluated in ArcGIS for 2002 and 2012. An inventory of all available airphotos of the Minesing Wetlands were catalogued for future reference (Appendix A), and scanned into the Nottawasaga Valley Conservation Authority (NVCA) geospatial data collection.

A trajectory of forest loss over the next 15 years has been determined based on the vulnerability of a particular area to forest die-off. Vulnerability of a forest stand was determined through existing ecological knowledge and results uncovered in this report. Therefore the existing forested area (A) is multiplied by the expected percent loss of the area, based on three vulnerability scores (V1: High – 30% predicted decline, V2: Medium – 15% predicted decline, and V3: Low – 7% decline) and then divided by time resulting in the predicted rate of forest loss for particular forest stands.

Predicted rate of forest loss = $(A_1 \times V_1) + (A_i \times V_i)$

time

This prediction is based on modelling to show an approximation of potential future forest loss over this time period. Actual forest loss could vary considerably based on storm events, disease, invasive species and other unforeseen events. Continued monitoring of forest change in the wetlands will verify actual extent and rate and forest loss over the coming years.

2.2 Analysis of Forest Loss By Forest Type

Several sources were reviewed to identify the key forest communities that were impacted by forest loss between 1953 and 2013.

The Ontario Ministry of Natural Resources carried out a forest resource inventory (FRI) of the Minesing Wetlands in 1979. The map created from this work was available from the NVCA forestry department as a hard copy and georeferenced copy in ArcGIS. This information provided a description of forest cover and composition, as well as other wetland community types. NVCA forestry records (Wood Land Reports 1960-1992, Boxes 0112, 0114) were also obtained and reviewed. Bobbette (1975) gives an overview of deciduous and coniferous stands based on extensive fieldwork and airphoto interpretation.

Ecological Land Classification (ELC) mapping conducted by NVCA staff provided a current assessment of vegetation communities in the Minesing Wetlands. This data, analyzed in ArcGIS, delineates (approximates) present-day forest community type and canopy cover and provided a useful comparison to past forest inventories (described above).

2.3 Causal Factor Analyses

Significant forest decline was identified early in the analysis process. This raised important questions as to what could have caused this decline. A number of sources were reviewed to assist with causal factor analyses – these included a review of broad scientific literature, local scientific studies, local history documents and an interview with a long-time resident of Minesing (Harold Parker).

A literature review of internal NVCA documents and other secondary sources, which included scientific journal articles and government publications, provided background information on the ecological and social conditions in and around the Minesing Wetlands. Of particular importance were the Master Plan for Minesing Swamp (Moriyama, 1974), Minesing Swamp Survey (Bobbette, 1975), Willow Creek Watershed Study (AAA Consultants, 1977) and the Minesing Wetlands Biological Inventory (Bowles et al. 2007).

"A History of Vespra Township" (Anderson and Anderson, 1987) provided important contextual information regarding the history of land use adjacent to the Minesing Wetlands and colourful anecdotal information that supports the findings of this study. Harold Parker - former Springwater Township Councillor, past-Chair of the NVCA and life-long resident of Minesing – kindly consented to an interview which provide the authors with a first-hand glimpse of changes in the Minesing Wetlands (as well as assorted shenanigans) over the past 60 years.

A full list of literature resources is available in the reference section.

3.0 Results

This section provides the results of forest cover analysis undertaken in support of this study. Broad forest cover analysis, using 1953 as a baseline, is provided. This includes a breakdown of forest cover change in the time intervals between analyzed air photo/orthophoto coverage. A breakdown of forest loss by forest community type follows. This, in turn, is followed by analysis of specific tree species most likely impacted by forest loss during the study period (1953-2013).

3.1 Forest Cover Analysis

The analysis of forest cover change is based on air photo interpretation for the years 1953, 1971, 1978, and 1989 and interpretation of aerial imagery for 2002 and 2012 (Simcoe County orthophotography). 1953 air photos provided baseline data for forest cover interpretation. Subsequent air photo and orthophotographic analysis allowed for the interpretation of change over time. A summary of total forest change from 1953-2013 is the overarching result from the work presented here. Although air photo analysis of forest decline requires some subjective interpretation (i.e. at what point is a forest area considered "dead"), significant forest cover change undeniably occurred over this 60-year period. This change is confirmed through "on the ground" vegetation inventories undertaken by NVCA staff (and others) over the past ten years.

The analysis of air photos from 1953 revealed that a mix of swamp forest communities covered much of the Minesing Wetlands and that these forests provided a thick tree canopy over much of the area. The total forested area was calculated to cover 4,385 ha (Figure 3), covering 71% of the core wetland. A deciduous swamp forest canopy dominated the forested landscape accounting for 67% of the total forest cover (2,951 ha) and nearly 50% of total core wetland cover. A large coniferous swamp community (boreal), encompassing a rare fen community type typically found in Northern Ontario, was present at the base of the Algonquin Bluffs in the southeast portion of the wetland. This boreal forest community represented 33% (1,434 ha) of the total (core) forest cover, and 23% of the core wetland area. The remaining 25% of the landscape in the Minesing Wetlands, in 1953, would have been a mix of open marsh, meadow and thicket communities (Figure 3).

Figure 3: Minesing Wetland Forest Cover 1953



Summary for 1953 Forest Cover in the Minesing Wetlands

- 4,400 ha of total forest cover within the study boundary
 - 3,000 ha of deciduous forest cover
 - 1,400 ha of coniferous forest cover
- 1,700 ha of non-forest wetland or agricultural land





Summary of Forest Change in the Minesing Wetlands 1953-2012

- 1,860 ha of deciduous forest loss within the study boundary
- 240 ha of forest gain within the study boundary (220 ha deciduous forest, 20 ha coniferous forest)

3.2 Total Forest Loss

An estimated 1,860 ha of forest cover was lost between 1953 and 2013 (see above Figure 4). This represents a 42% decrease in total forest cover in the Minesing Wetlands for this 60-year period. Forest cover loss was greatest between the years of 1979 and 2002 equalling nearly 50 ha lost per year, and totalling more than 1,100 ha during this time period (Figure 5). Although forest decline and dieback was occurring prior to 1979 the loss of forest cover was most evident during this period.



Figure 5: Rate of Forest Loss

3.2.1 1953-1978

It was estimated that 300 ha of forest cover was lost between 1953 and 1978. Initial examination of 1971 air photos revealed that approximately 43 ha of deciduous forest had been lost along portions of Willow and Black Creek, Concession XI Lot 12 (Willow Landing). In their Willow Creek Watershed Study, AAA Consultants (1977) reported that this die-off had begun in 1962 and was attributed to abnormal flooding and stagnant water. 1971 air photos revealed small pockets or breaks in the forest canopy – most notably at the confluence of the Mad River and Coates Creek (Concession VI, Lot 20) and to the west of Willow Creek at Concession VIII, Lots 10 and 11.

By 1978 these "pockets" of forest decline had grown visibly in size, especially around the abovementioned Mad River-Coates Creek confluence, where nearly 75 ha had become decadent or died off, and between the Mad River and Nottawasaga River where 55 ha of forest cover was lost. Continued forest dieback was occurring at Willow Landing with an observed 10 ha of forest die-off. By 1971 AAA Consultants (1977) reported that 81 ha of forest around Muskrat Creek had become decadent, and that by 1976 increased water diversion to this area had resulted in further flooding and rising tree decadence. The floodplain forests east of Willow Creek would subsequently be impacted by this increase in flooding, which appears to have accounted for an additional 150 ha of forest lost during the 1980s.

3.2.2 1979-2002

Rapid loss of forest cover occurred in Minesing Wetlands between 1979 and 2002 with an average loss of nearly 50 ha per year (see Figure 5). During this period approximately 1,137 ha of deciduous forest cover was lost. The largest area of tree die-off occurred west of the Nottawasaga River where forest loss was estimated to be 645 ha. The continued forest dieback around the Mad River and Coates Creek confluence was apparent in this area. This included an area of 94 ha east of Sunnidale Concession 3 in lots 19 and 20.

East of the Nottawasaga River approximately 550 ha of floodplain deciduous forest had died off. This included approximately 120 ha between the Nottawasaga River and Willow Creek and 420 ha east of Willow Creek. An additional 25 ha was lost north of Muskrat Marsh and 30 ha lost in the southeast portion of the Minesing Wetlands - in an area between the boreal swamp/fen and Highway 90.

3.2.3 2003-2013

In the last ten years, the rate of forest loss in the Minesing Wetlands has subsided in comparison to previous decades (likely because the cumulative forest loss over the years has left less floodplain forest to be impacted), but still large areas of forest continue to die off. Approximately 420 ha of floodplain deciduous forest was lost between 2003 and 2012 that included 250 ha west of the Nottawasaga River in the area between (and south) of the Mad River and Coates Creek, while approximately 200 ha was lost east of the Nottawasaga River levee.

3.2.4 Future Forest Decline

Floodplain forest decline is continuing in the Minesing Wetlands. Forest loss "fronts" are indicated by dead and declining trees along the forest edge and the colonization of emergent marsh species under the open canopy (Figure 6). These areas often have standing water even in late summer/early fall.

Based on historical rates of floodplain forest loss and identification of current floodplain forest proximal to the loss "front" a trajectory of future forest loss has been extrapolated based on the following assumptions:

- Drier forests on the Nottawasaga levees (which encompass the provincially rare Hackberry/mixed deciduous forest) would be minimally impacted
- The large Silver Maple/mixed deciduous swamp located east of the Nottawasaga River and east of McKinnon road would be minimally impacted (little historical loss in this community)
- The remainder of floodplain forest proximal to loss "fronts" extending out from the Willow Creek and Mad River would be at higher risk of die-off

Of the remaining deciduous forest cover in the Minesing Wetlands (Figure 6), the largest stands, and their predicted vulnerability to die off, include:

- 228 ha associated with the Mad River and Coates Creek; High vulnerability
- 130 ha west of the Nottawasaga River in the northern floodplains; Medium vulnerability
- 93 ha east of the Nottawasaga River in the northern floodplains; Medium vulnerability
- 178 ha centred around Willow Creek and Muskrat Marsh; Medium vulnerability

- 165 ha of floodplain forests adjacent to the Nottawasaga River levee; Medium vulnerability
- 227 ha east of McKinnon Road (south of Iron Bridge), which includes fragments of the southern Nottawasaga River levee; Low vulnerability
- 100 ha of forest cover on the Nottawasaga Levee north of the Iron Bridge; Low vulnerability
- 99 ha of deciduous cover in the southernmost portion of the wetlands; Low vulnerability

The 15-year prediction of forest loss estimates that deciduous floodplain forest will continue to decline by approximately 15 ha/year resulting in approximately 180 ha of forest die off by 2028.



Figure 6: Current Forest Cover and Loss Fronts

60 Years of Forest Change in the Minesing Wetlands (1953-2013) S. Rootham (NVCA/FOMW) & D. Featherstone (NVCA)

3.3 Total Forest Gain

Despite an overarching theme of forest loss during the study period, some swamp forest regeneration was noted during this analysis. Between 1953 and 2013 there was approximately 240 ha of forest gain within the core study area (Figure 4). Nearly all of this gain (220 ha) was deciduous forest cover. Deciduous forest regeneration, with the exception of the interior McKinnon fields, has generally occurred along the periphery of the core study area. A small area of conifer forest regeneration (20 ha) has occurred along the periphery of the Minesing fen.

3.4 Forest Community Type Change in the Minesing Wetlands

In 1953, the total area occupied by swamp forest cover was 4,385 ha, which represented 71% of the core wetland area. Deciduous floodplain forests covered 2,951 ha accounted for 67% of the total core forest cover and nearly half of core wetland cover within the Minesing Wetlands. The mixed coniferous swamp covered 1,434 ha, encompassing the Minesing Wetland fen ecosystem. This coniferous forest accounted for 33% of the forest landscape and 23% of core wetland cover. The remaining landscape elements were comprised of fen, marsh, wet meadow and swamp thicket communities.

The results of airphoto and orthoimagery analysis presented above showed that forest cover in the Minesing Wetlands declined from 4,385 ha to 2,765 ha over a 60-year period (1953-2012; Figures 7 and 8). Floodplain deciduous forest bore the full brunt of forest loss (1,860 ha) while recognizing some peripheral gains (220 ha). Coniferous forest remained relatively unchanged over this time period (20 ha gain). Swamp forest cover, once the dominant wetland type in Minesing (71% of total wetland cover), now constitutes less than half (45%) of core wetland vegetation cover (Figure 8).

Floodplain forest cover has been reduced from 48% of total (core) wetland cover to 21% total cover (from 2,951 ha to 1,311 ha). Emergent marshes and thicket swamp now dominate previously forested areas. Once the dominant vegetation community, floodplain deciduous forest has now been relegated to a secondary community type (though still significant in size) within Minesing Wetlands. Incremental loss is still occurring along the edges of most remaining floodplain forests as evidenced by Silver Maple decline and open canopy conditions along the forest edge and incursions by emergent marsh species such as *Glyceria maxima* (Rough Manna Grass - CVC, 2009, Great Manna Grass - Bobbette, 1975) and Cattail (*Typha latifolia*), which thrive under conditions of constant saturation/flooding.

Appendix B provides a pictorial "story" of floodplain forest decline – the edges of healthy closed canopy are inundated for prolonged periods resulting in tree decline/death, canopy opening and colonization of obligate marsh wetland species such as cattail and rough manna grass. Eventually, entire forest sections die off and a "drowned swamp" characterized by open marsh with numerous dead standing trees emerges. Over time, the dead standing timber collapses and only stumps remain within the marsh to remind one of the former closed canopy forest.

The mixed coniferous swamp forest did not experience any decline. Having represented only 33% of the forest mosaic in 1953, the boreal forest now represents more than half (53%) of the total forest remaining in the Minesing Wetlands (Figure 7). Unlike other areas of the wetland, the conifer swamps and fens are relatively isolated from water level fluctuations and sediment loading associated with the

floodplains. These communities are located at the base of an extensive area of groundwater discharge, which plays a significant role in their ecological integrity (Post et al, 2009). Relative to the floodplain forests and marshes where water levels can fluctuate by several metres over the course of the year, this groundwater-dominated regime is a steady-state system with relatively constant water table levels and relatively low nutrient inputs. Clearing and drainage alteration that is common along the remainder of the Minesing Wetland periphery has not been an issue here – adjacent upland areas are well-drained relative to the lowlands that surround the remainder of the core wetland and there was no need to improve drainage to facilitate farming.









60 Years of Forest Change in the Minesing Wetlands (1953-2013) S. Rootham (NVCA/FOMW) & D. Featherstone (NVCA)

3.5 Composition of Lost Forests

Department of Lands and Forest records describing forest composition in the Minesing Wetlands in 1962 were reviewed. They revealed a general description of stand area and species makeup for most of the Minesing Wetlands, but were not sufficiently detailed to provide mapping of forest makeup. According to their assessment the coniferous forest community contained a mix of Eastern White Cedar (*Thuja occidentalis*), Balsam Fir (*Abies balsamea*), Tamarack (*Larix laricina*), White Spruce (*Picea glauca*), and White Pine (*Pinus strobus*), while deciduous stands in the central and western portions of the Minesing Wetlands were composed mostly of Silver Maple (*Acer saccharinum*), Black Ash (*Fraxinus nigra*), White Ash (*Fraxinus americana*), and White Elm (*Ulmus americana*).

In 1979, the Ontario Ministry of Natural Resources conducted a remote sensing-based forest resource inventory (FRI) that provided more detail on tree species and landscape ecology. Their assessment included area classification, percent species per stand, and average age and height of trees in the stand. This FRI had been georeferenced into ArcGIS, which allowed for an analysis of the inventory in relation to forest loss identified through this study. The FRI data also sheds light on the key communities/species lost between 1953 and 2013 (Table 1). Silver Maple stands were most impacted by forest loss followed by Black Ash. Similarly, and through more detailed analyses within the Willow Creek portion of Minesing Wetlands, AAA Consultants (1977) identified Silver Maple as the major contributor to floodplain forest stands and Black Ash of secondary importance.

This information gives weight to the hypothesis that the species that experienced the greatest loss in the Minesing Wetlands was Silver Maple. Although Silver Maple stands are adapted to seasonal inundation, they do require a period of drying in late summer/early fall to persist. Extended periods of inundation – in excess of two years – will result in their decline and eventual senescence (Keddy, 2010). Other floodplain species such as Black Ash and White Elm are even more susceptible to decline based on wetter conditions. Based on floodplain forest decline and replacement with emergent marsh and thicket swamp communities (which are adapted to conditions of permanent/near permanent inundation), it is clear that hydrological conditions in the floodplain have been significantly altered over time. Conditions of near permanent inundation are no longer suitable for floodplain swamp forests in much of Minesing Wetlands. Multiple casual factors for this observed change are presented in Section 4.

Table 1. Composition of tree species lost based on 1979 Forest Resource Inventory (MNR, 1979)

Spacias Cada	Common Namo	Polativo Porcont Lost
species coue	Common Name	Relative Percent Lost
Ms	Silver Maple	57%
Ab	Black Ash	18%
Ро	Poplar	8%
Ce	Cedar	7%
Ew	White Elm	3%
Aw	White Ash	2%
Bd	Basswood	1%
Mh	Sugar Maple	1%
В	Balsam Fir	1%
Bw	White Birch	1%

4.0 Discussion

The Minesing Wetlands has undergone a vegetative regime shift with more than 1,800 ha of forest cover converted to open marsh and thicket swamp between 1953 and 2013. A number of factors appear to have contributed to the demise of floodplain forests in Minesing Wetlands. These factors are identified and discussed in the following subsections. These factors are then summarized and an outlook to future forest conditions is provided.

Loss of forest cover has resulted in significant shifts in wetland ecosystem structure. Formerly dominant deciduous floodplain forests have been relegated to a secondary (though still significant) status and have been replaced by open marsh and swamp thicket habitat. These open canopy habitats are now the dominant community form in the Minesing Wetlands. The ecological consequences of this change in ecosystem structure and dominance are not fully understood or documented, but a broad overview of these consequences is offered.

4.1 Forest Loss – Causal Factors

4.1.1 Historical Clearing and Drainage

Ducks Unlimited Canada (DUC) recently released a report that stated more than 72% of wetlands in Southern Ontario have been lost due to land use change (DUC, 2010). Prior to European settlement, the Minesing Wetlands were conservatively estimated to have covered an area greater than 12,000 ha (DUC, 2010). The current boundaries encompass an area just over half that size at 7,250 ha (Figure 2).

Forest loss in the Minesing Wetlands was initiated by European settlers who began settling and logging the area in 1833, and intensified with the coming of the railways in the 1850s (Anderson and Anderson, 1987). Some lands were cleared along the fringe of the wetlands for pasture by the late 1870s. Significant ditch and tile drainage along the fringes did not being until the 1890s but continued well into the 20th century (Anderson and Anderson, 1987). Drainage was accompanied by clearing of remaining timber and burning of muck and debris to facilitate farming.

Lumber firms during the 19th century removed mostly Pine, Hemlock and Cedar with the peak of exploitation occurring during the 1860s and operations gradually declining near the turn of the century (Moriyama, 1974). Between 1897 and 1954 the Minesing Basket Company removed more than ten million board feet of timber from the Minesing Wetlands comprised of mainly Ash species (Bowles et al., 2007; County of Simcoe; 2011; H. Parker, Personal communication 2013).

Settlement also induced land use change at the watershed and subwatershed scale. The Minesing Wetlands accepts drainage from an area of more than 2,600 km² (Bowles et al., 2007). Conversion of the majority of watershed forests and wetland to agricultural and urban uses impacted the hydrology of watershed streams and rivers resulting in "flashier" flow regimes and increased sediment loads. These significant flow and sediment load changes would have been transferred through the watershed to the Nottawasaga River, Mad River and Willow Creek, coming together cumulatively within the Minesing Wetlands and changing the overall hydrology. Changes in wetland communities were soon observed. The Barrie Northern Advance reported on March 24, 1904 (Anderson and Anderson, 1987) that the

timber in the Minesing Wetlands "was now beginning to die and the Swamp was becoming a menace to the health of the neighbourhood."

The 1964 Nottawasaga Valley Conservation Report (Department of Energy and Resources Management, 1964) describes post-settlement shifts in vegetation that likely reflected changing floodplain hydrology acting as a precursor to eventual forest loss. In particular the report notes that "The region drained by the Mad River where it flows into the main Nottawasaga was covered with a series of tamarack, cedar, spruce and birch swamps." "This has changed considerably since the original (presettlement – author's note) survey. The cover on this area is presently a hardwood forest, mainly of silver maple, elm and ash." This suggests a shift from mixed conifer swamp (with relatively stable flow and nutrient regimes) to a deciduous swamp adapted to fluctuating flow regimes and higher sediment/nutrient loading. Based on remnant conifer swamp cover along the east edge of the Minesing Wetlands near Fralick Road, similar changes may have been occurring concurrently within the Willow Creek portion of the wetland. Further research utilizing original pre-settlement surveys could shed further light on shifts in forest community composition.

AAA Consultants (1977) prepared an assessment of watershed conditions for Willow Creek that stated increases in water discharge and sedimentation was the result of upstream drainage alteration that had reduced the flood storage capacity and moisture regime of the wetland. They also observed that this change was beginning to impact plant biology, especially tree composition and viability as noted with the tree die-off of the bottomland forest around Willow Creek. Moriyama (1974) pointed out that due to historical land clearing and drainage alteration there was an increase in the intensity of sedimentation runoff into the Minesing Wetlands resulting in the formation of levees along forested areas and creating a backlog of water levels in lower lying areas. The result was longer periods of inundation and die-off of non-water tolerant plants (Moriyama, 1974). Decline of deciduous forests would have reduced evapotranspiration during the growing season resulting in greater persistence of wet conditions, which likely exacerbated floodplain forest decline.

4.1.2 Levee Breaks/Crevasse Splays

Building on Moriyama's (1974) work, the Minesing Wetlands has acted as a "delta" for receiving river systems since the recession of post-glacial Lake Algonquin (approximately ten thousand years ago). Naturally aggrading river systems would have developed from centuries of sediment transport into the wetlands. These systems are characterized by natural levee development and levee breaks (avulsions) often referred to as "crevasse splays" (Keddy, 2010). In some areas (i.e. along the Mad River north of Concession 2), levees were further enhanced by farmers to protect farmland from spring flooding.

Changes in land use during the settlement period increased sediment transport to the wetland and likely resulted in further channel bed aggradation. Increased channel bed aggradation may have increased incidences of levee breaks (crevasse splays), which, in turn, would have resulted in locally wetter conditions in floodplain forests beyond the levees.

In addition to channel bed aggradation, extreme floods as well as log and ice jams also trigger crevasse splays (Keddy, 2010). Hurricane Hazel in 1954 triggered extreme flooding/sediment deposition and no

doubt triggered crevasse splays and other stream form change particularly in Willow Creek where the watercourse was basically decoupled from its levee system (H. Parker, Personal communication 2013). Increases in log jam formation associated with senescence of floodplain White Elm within the broader drainage area may have also increased the frequency of levee breaks within Minesing Wetlands. These specific events are described in subsections below.

Active crevasse splays remain visible along the Nottawasaga River in the north portion of Minesing Wetlands as well as along the Mad River. A significant example of a crevasse splay is located on the Mad River upstream of Concession 2 where the river broke out of its levee in 2000 (B. Wesson, Personal communication 2014). In 2012 NVCA monitoring staff recorded that more than 70% of the Mad River's baseflow now flows east along the south side of Concession 2 to the Nottawasaga River (I. Ockenden, Personal communication 2014). Former agricultural fields in the vicinity of the splay are no longer workable and have been transformed into willow thicket swamp and emergent marsh habitat. The long-term effects of this diversion on the downstream portion of the Mad River within the core of the Minesing Wetlands are unclear.

River geomorphology is a highly complex science with a multitude of interacting parameters. This confounds interpretation of natural versus anthropogenic change in the system. Although it is quite likely that changes in river geomorphology are connected with forest decline in the Minesing Wetlands, significant additional research (far beyond the scope of this study) is required to change conjecture to solid science.

4.1.3 Dutch Elm Disease

Dutch Elm disease spread into south-central Ontario in the 1950s. By the 1970s Dutch elm disease had eliminated all mature White Elm from the Minesing Wetlands (Moriyama, 1974; AAA Consultants, 1977). White Elm was a significant component of the Silver Maple swamps and occasionally occurred in relatively pure stands along Willow Creek and the Nottawasaga River (Dept. of Energy and Resources Management, 1964). The loss of mature White Elm would have further reduced evapotranspiration from the Minesing floodplains during the growing season, and likely contributed to the increased duration of saturated/flooded conditions within the floodplain forests.

The loss of White Elm along watershed floodplains greatly increased the natural input of woody debris (trees, large branches) into watershed river systems. Although logjams are a natural part of streams and river systems, this large event increased the input of trees/logs well beyond natural loading levels resulting in numerous logjams along the Mad River and into the Minesing Wetlands – "several dozen" log jams were observed on the Mad River between its confluence with the Nottawasaga River and Glencairn in 1971 and 1972 (Ministry of Natural Resources, 1973). On steeper gradient systems, logjams would have resulted in additional bank erosion and associated sediment inputs. Within the relatively flat Minesing Wetlands, logjams may have resulted in levee breaks, which would have increased the extent and duration of flooding in the floodplain forests behind the levees.

4.1.4 Hurricane Hazel

Many of the impacts associated with forest cover loss are cumulative and have occurred over years or often decades. However, singular events can also play a role – particularly in stressed systems. In

October 1954 Hurricane Hazel brought record precipitation over an already saturated watershed resulting in a "hundred year" flood – a flood that would be expected, on average, only once in a one hundred year period.

Data retrieved from Environment Canada showed that water discharge at the Nottawasaga River and Baxter flow station was more than 7 times higher than the relative average for this month between 1953 and 2012. The high volume of discharge and extensive flooding would have been a stressor on vegetation such as tree saplings and older frail trees as well as those already stressed through other factors (i.e. Dutch elm disease and changing hydrology) impacting the succession, or natural regeneration, of the swamp forests. Significant flows, sediment loads and debris brought into the Minesing Wetlands during this event combined to change the drainage paths of watercourses, locally changing the hydrology of wetland communities particularly along Willow Creek where the watercourse was basically decoupled from its levee system. (H. Parker, Personal communication 2013).

4.1.5 Climate Change

Climate is a determining factor for biological and ecological conditions on earth. Climate is the behaviour of weather patterns over a long period of time, and includes average conditions as well as variation and extreme events (Zhang et al., 2011). Conservation Ontario (2011) and the Nottawasaga Valley Conservation Authority (NVCA, 2013) acknowledge that climate change will result in more intense periods of precipitation impacting social and ecological conditions at the watershed scale.

Wetland ecosystems are especially vulnerable to climate change impacts because of their sensitivity to precipitation change. From a floodplain forest perspective, flashier convective storm systems during the growing season would likely result in additional periods and longer duration of flooding, which would exacerbate current conditions of forest decline. Fen systems are heavily influenced by the relationship of precipitation to groundwater discharge and surface water run-off (Chu 2011). If changes in climate begin to impact groundwater, the boreal forest habitat that encompasses the fen community, now the dominant forest system of the Minesing Wetlands, would be at risk.

Of all the possible causes of forest loss in the Minesing Wetlands, climate change is the one overarching threat that has the ability to influence wetlands hydrology and forest form and composition. Intuitively one gets that sense that climate change should be the focus of wetland rehabilitation, yet addressing climate change through mitigation and adaption measures at the local scale typically involves focused actions such as minimizing invasive species, conserving forested land and adapting water strategies to benefit the small-scale system.

4.2 Forest Loss – Summary and Outlook

A multitude of causal factors appear to be associated with floodplain forest decline in the Minesing Wetlands. Broad landscape conversion of pre-settlement watershed forests and wetlands to agricultural land use and urban centres impacted the hydrology of rivers and streams within the watershed and increased the generation and delivery of sediments downstream to the Minesing Wetlands. These broad landscape-level changes were synergistically combined with local impacts along the periphery of the wetland associated with wetland clearing, tile drainage and construction of drains

that conveyed water efficiently into the remaining wetland areas rather than being held in storage by the former wetland.

It is difficult to tease out the relative importance of watershed versus local hydrological change, but it is worth comparing the relative impacts of forest decline in the Willow Creek and Mad River portions of the Minesing Wetlands to those along the Nottawasaga River itself. Significant forest loss and appears to be emanating outward from the Willow Creek and the Mad River toward the Nottawasaga River levees and the periphery of the wetland. Conversely, the floodplain swamps along the Nottawasaga River upstream of these influences are relatively unchanged. The floodplain swamps downstream of the Mad and Willow confluences are also relatively unchanged. The large silver maple swamps associated with Jack's Lake – a widening of the Nottawasaga River downstream of the Minesing Wetlands – show no sign of decline or loss. This suggests that land use change and drainage works along the Willow Creek and Mad River peripheries of the Minesing Wetlands are a significant causal factor associated with broader floodplain forest loss.

It is reasonable to assume that both watershed and local land use changes have cumulatively impacted hydrological conditions in the rivers and floodplains of the Minesing Wetlands. Floodplain forests that were adapted to seasonal inundation were exposed to longer periods of inundation beyond their moisture tolerance survival threshold. As floodplain forest weakened and declined, they became less resilient to specific events such as Hurricane Hazel and Dutch Elm Disease. Remaining floodplain forests are fragile and will be susceptible to future impacts associated with climate change and Emerald Ash Borer (*Agrilus planipennis*) and, possibly, imminent watershed development.

Floodplain forests continue to decline in the Minesing Wetlands. A possible future trajectory would see substantial core floodplain forest limited to the east side of the Nottawasaga River between the river and boreal forest system. The north floodplain forest along the Nottawasaga River downstream of the Willow Creek and Mad River confluences may also remain viable as core forest though this is less certain. Elsewhere in Minesing Wetlands, floodplain forests could be limited to narrow forest features along the levees of the Nottawasaga River, Willow Creek and Mad River.

By 2031, more than 100,000 new residents will live in the Nottawasaga watershed. Much of this growth is anticipated to occur within existing communities that eventually drain to the Minesing Wetlands. Monitoring in the Greater Toronto Area has shown that conventional stormwater management methods are still insufficient to avoid impacts associated with increased discharge (ICF Marbek, 2012). The cumulative impacts of growth could impact the Minesing Wetlands if innovative watershed planning is not utilized.

Although currently unaffected by hydrologic changes in the Minesing Wetlands floodplain, the relatively stable hydrological regime associated with the boreal swamp/fen complex could be impacted by proposed urban development in the Snow Valley Uplands, which acts as a "rain barrel" that feeds this groundwater-dominated ecosystem. The extent of development in this area needs to be carefully considered. Approved development should utilize "low impact development" (LID) strategies to ensure that water budgets and area hydrology are unaffected. Any changes to hydrological functions in this

headwater area could affect groundwater quality and quantity, which, in turn, could affect the boreal swamp/fen complex and its important ecological functions.

4.2.1 Emerald Ash Borer

Emerald Ash Borer (*Agrilus planipennis*) is advancing on the Nottawasaga watershed and will threaten Ash species within the Minesing Wetlands (S. Sampson, CVC Ecologist, Personal communication 2013). Though generally less dominant than Silver Maple in Minesing floodplain forests, Ash species are occasionally dominant and generally form at least a minor component of floodplain forest stands. The impact of Emerald Ash Borer will further reduce evapotranspiration rates, increase woody debris and reduce overall floodplain forest canopy cover in the Minesing Wetlands.

4.3 Vegetation Community Change – Ecological Implications

Floodplain forest decline has led to a significant shift in wetland structure in the Minesing Wetlands. Closed canopy swamp forest (floodplain and boreal) once constituted the majority of wetland habitat. Today, open canopy habitats (marsh, fen, thicket swamp) predominate. Deciduous floodplain forests were the principal habitat type, but have declined to less than half of their former extent. In terms of total forest cover, boreal swamp forest is now the dominant forest type.

Although the full ecological implications of these structural habitat shifts are not fully understood, available monitoring data and broader functional interpretation point to a number of implications for vegetation communities and wildlife.

4.3.1 Vegetation Communities

4.3.1.1 Boreal Swamp/Fen

The boreal swamp/fen complex downslope from the Algonquin Bluffs has remained relatively intact and has not experienced forest decline over the past sixty years. Rare vegetation communities and vascular plant species associated with this complex appear to be stable.

4.3.1.2 Floodplain Forest

Floodplain forests have been negatively impacted resulting in a significant loss of forest. Large core habitats continue to diminish in size and have become fragmented. Loss fronts generally extend outward from the Mad River and Willow Creek. A relatively stable stand of floodplain forest extends east of the Nottawasaga River toward the boreal swamp/fen complex. Provincially rare vegetation communities include the mixed Hackberry (*Celtis occidentalis*) levee forests and Bur Oak (*Quercus macrocarpa*) swamp at the north end of the Minesing Wetlands. The levee forests appear more resilient to changing hydrological conditions. The Bur Oak swamp located west of the Glengarry Road/Ronald Road corner also appears to be stable though could possibly become subject to the impacts of changing hydrology.

4.3.1.3 Marsh

Marsh habitat has increased concurrently with the loss of floodplain forest. Extensive core marsh habitats are now present along Willow Creek, between the Mad and Nottawasaga River and along portions of the Mad River. Presently, Rough Manna Grass is dominating much of this marsh habitat (see Section 4.3.3), though pockets of Cattails and other marsh vegetation are occasionally present. South of

the Mad River/Nottawasaga River junction, an interesting thicket/marsh community dominated by Buttonbush (*Cephalanthus occidentalis*)/Bur-reed (*Sparganium* sp.), and interspersed with open shallow marsh has developed. This community is likely provincially rare and supports an array of wildlife, including Species at Risk.

4.3.1.4 Swamp Thicket

Portions of the floodplain forest have been converted to open swamp thicket communities. Red Osier Dogwood (*Cornus sericea*), Willow species (*Salix* spp.), Elderberry (*Sambucus canadensis*), and Speckled Alder (*Alnus incana*) are variably dominant with stunted Green Ash (*Fraxinus pennsylvanica*) and Silver Maple often present. These are open canopy communities.

4.3.2 Wildlife

4.3.2.1 Herpetofauna

The Minesing Wetlands supports a diverse assemblage of turtle species. Population sizes and movement activities of the various species are generally not well known. Spotted Turtle (Clemmys *guttata*) is associated with the boreal swamp/fen complex and this habitat has remained relatively unchanged. Conversely, the Wood Turtle (*Glyptemys insculpta*), is typically associated with floodplain forests, which have experienced significant decline. Only one confirmed Wood Turtle has been observed in the Minesing Wetlands over the past ten years and it is possible that this population has declined in concert with its habitat (Bowles et al, 2007). Blanding's Turtle (Emydoidea blandingii) tends to be a significant traveller relative to other turtle species. Its movements and habitat requirements in the Minesing Wetlands are not well known and therefore it is difficult to ascertain what effects the change in vegetation community has had on the Blanding's population. Snapping Turtle (Chelydra serpentina) may be benefitting from larger marsh areas that are permanently saturated/inundated. Map Turtle (*Graptemys geographica*) is generally associated with larger river systems and may be relatively unaffected by vegetation community change. Generally wetter conditions with the wetlands may be incrementally affecting moisture conditions on the levees, which offer some opportunity for turtle nesting. Wetter levee conditions could negatively affect the nesting success of turtle species that nest there.

A variety of amphibians breed within the Minesing Wetlands. Vegetation community changes have likely benefitted some species while other species have declined. Loss of floodplain forest cover has likely reduced populations of forest species such as Wood Frog (*Rana sylvatica*) and Spring Peeper (*Pseudacris crucifer*). Increases in marsh cover and permanently inundated conditions have likely benefitted species such as Northern Leopard Frog (*Rana pipiens*) and Green Frog (*Lithobates clamitans*).

4.3.2.2 Birds

Boreal forest cover in the Minesing Wetlands has remained intact and relatively un-impacted by floodplain forest decline. This large core forest habitat continues to provide habitat for a suite of areasensitive/forest interior bird species that are adapted to conifer and mixed swamp habitats.

Floodplain forest decline has resulted in the substantial decline and fragmentation of core deciduous swamp forests. Area-sensitive/forest interior bird species adapted to this habitat type appear to have

declined. The provincially threatened Cerulean Warbler (*Setophaga cerulean*) requires large mature forests with deciduous cover, which is now limited in the Minesing Wetlands. Citizen scientist C. Harris (Ebird checklist S14538469) reported visiting a sizable population of Cerulean Warblers in the Minesing Wetlands during the 1970s. Although individual Cerulean Warbler territories are still present in Minesing, a sizeable population no longer appears to be present (D. Featherstone, Personal Communication 2013). Downes et al (2011) reported that although sample size was too small for trend analysis, the North American Breeding Bird Survey and Atlas of Breeding Birds in Ontario indicate the Cerulean Warbler is experiencing a significant long-term population decline in the Mixedwood Plains Ecozone, which has justified listing it as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Floodplain forest decline has created rotating opportunities for heronry development. The Minesing Wetlands has long been known to contain one of the oldest and largest heronry areas in southern Ontario. The Great Blue Heron (*Ardea herodias*) is the key species utilizing the heronries, however, some evidence for presence, (and breeding) of Black-crowned Night Heron (*Nycticorax nycticorax*) has also been observed (Bird Studies Canada et al., 2006). Herons often utilize recently dead trees for nesting. As the dead trees "fall apart", the branching structures used to support the herons' nests of loose sticks disappear and, eventually, the dead swamp areas no longer support viable heronry habitat. Within the Minesing Wetlands, the herons appear to be following the retreating floodplain forest edges, shifting their heronry colonies to locate "freshly" dead or declining swamp edges when older areas become no longer suitable for nesting.

Extensive marsh communities, which dominate areas previously covered by floodplain forest, are now providing expansive breeding opportunities for marsh birds. Although much of the marsh area is dominated by a Rough Manna Grass monoculture, NVCA Marsh Monitoring Program data suggests that these marshes are providing suitable habitat for a large, diverse marsh bird population including habitat for Species at Risk such as Black Tern (*Chlidonias niger*) and Least Bittern (*Ixobrychus exilis*). These extensive marshes also provide significant stopover habitat for migratory waterfowl and shorebirds, particularly during the spring migration period.

Less is known about bird activity within the thicket swamps, which have also developed over areas previously covered by floodplain forest. Additional monitoring to determine bird utilization of these habitats would be beneficial to better understand how they function as bird habitat.

4.3.2.3 Mammals

The boreal swamp/fen complex in the Minesing Wetlands supports one of the largest deeryards within the Nottawasaga River watershed. This area has remained relatively unchanged and significant numbers of white-tailed deer (*Odocoileus virginianus*) continue to use this habitat during the winter months.

Extensive new marsh habitats have likely increased populations of marsh-oriented mammals such as Muskrat (*Ondatra zibethicus*). Mink (*Mustela vison*) and River Otter (*Lontra canadensis*), may have also benefitted from vegetation community shifts. Loss of tree cover has likely reduced habitat opportunities for Porcupine (*Hystricomorph hystricidae*) and Beaver (*Castor canadensis*), however both

are still commonly observed along the river systems. Larger mammals such as the Black Bear (*Ursus americanus*), which have historically inhabited the Minesing Wetlands (and are present and possibly increasing in the watershed), may find it difficult to move through the inundated marshes relative to the closed canopy floodplain forests that were formerly predominant.

4.3.3 Invasive Species

Aggressive wetland plants have seized the opportunity to populate the now open marsh habitat. The swamp forest system could not absorb disturbance, collapsed and is now in a period of regeneration and exploitation. This change in ecological community exhibits characteristics of the adaptive cycle where drastic alterations to feedbacks create a regime shift, or collapse, and new resources are exploited by opportunistic species (Holling, 2001; Folke, 2006).

One of the most pressing concerns with the vegetation regime shift to open marsh has been the increase in non-native and highly invasive *Glyceria maxima* (Rough or Great Manna Grass) (CVC, 2009; Bobbette, 1975). Several threats have become apparent – the wetland invader is known to reduce biodiversity because of its competitive edge over other plants, which includes an aggressive mat-like root system and early growth in the spring leading to a monoculture type environment.

The presence of *Glyceria maxima* was noted by Bobbette (1975) as one of the plant invaders populating open areas where deciduous swamp forest was decadent, and surmised that this was an example of vegetative regime shift from swamp forest to thicket or marsh community. More than 30 years later D. Featherstone (Personal Communication, 2014) reports that *Glycercia maxima* is the dominant open marsh wetland plant invader in the Minesing Wetlands. Other aggressive wetland plants that have populated open marsh areas include the European Common Reed (*Phragmites australis var. australis*).

Reed Canary Grass (*Phalaris arundinacea*), an aggressive wetland meadow invader, has been observed along open, drier (previously farmed) areas of the Mad River and Nottawasaga River levees.

5.0 Recommendations

Change in ecosystems is a natural process. Change in ecosystems can also be created by human influences on the landscape. Human disturbance on the landscape has influenced the hydrology and composition of the Minesing Wetlands over a relatively short period of time. There has been a shift in wetland ecology from deciduous floodplain forests to open marsh and swamp thicket communities. We ascertain that this is a culmination of post-settlement changes in river and wetland hydrology combined with tree disease and extreme weather events over the last 60 years. Continued dieback of deciduous floodplain forests is expected. The extensive changes in floodplain hydrology appear to be permanent and opportunities to restore closed canopy forest cover in permanently inundated floodplains appear to be non-existent.

Recent and continuing shifts in vegetation communities have significant implications for management within the Minesing Wetlands and its broader drainage area. The work presented in this report should be used to inform future management/property plans for the Minesing Wetlands and as input for broader watershed planning.

Managing for ecological resilience where a regime shift has occurred has three general options described by Gundersson (2000) 1) do nothing, monitor the system for signs of natural succession 2) actively manage the system to encourage a return the original system state, and 3) concede that the system state is irreversibly altered and adapt to these changes. In the case of the Minesing Wetlands it seems reasonable to include elements of all three options as part of future management strategies.

Innovative watershed planning is required to address the potential cumulative impacts of urban growth pressure in the Minesing watershed to ensure that identified floodplain impacts are not exacerbated. Continued stewardship on private lands in rural portions of the watershed is needed to ensure that sediment and nutrient loadings are controlled.

Additional monitoring is required to better understand ecosystem change and its implications on ecological functions within the Minesing Wetlands. Though a full return of pre-settlement floodplain hydrological regimes appears unlikely, there are opportunities to offset floodplain forest loss and ensure the persistence and viability of the Minesing Wetlands forest community.

5.1 Watershed Planning and Stewardship

Changes in land use since European settlement have resulted in significant changes within the Minesing Wetlands. The floodplain-dominated ecosystems in the Minesing Wetlands have been particularly vulnerable to cumulative changes in flow regimes and sediment loading.

Conversion of the natural forest and wetland landscape to agricultural use and urban development – and coincident changes in watershed flow and sediment transport regimes – likely reached its peak in the 1920's. Similar to much of southern Ontario, a partial "re-wilding" of marginal agricultural lands occurring through the latter portion of the 20th century and into the new millennium.

Potential moderation of flow and sediment change associated with recent "wilding" is challenged by growth and agricultural intensification pressures. The NVCA Watershed Health Checks (2013) indicate a general trend of forest cover and wetland loss associated with urban development and agricultural conversion. In the 2002-2008 period, a net loss of 460 ha (0.39%) of forest cover and net loss of 254 ha (0.57%) of wetland cover occurred within the watershed.

5.1.1 Watershed Planning

The NVCA Strategic Plan 2014-2018 (NVCA, 2013) states that "Tremendous growth is at our doorstep. By 2031, more than 100,000 new residents will call the watershed home." Urban growth is anticipated in the following communities that eventually drain to Minesing Wetlands:

- Alliston
- Angus
- Barrie
- Beeton
- Bond Head
- Colgan
- Cookstown
- Craighurst

- Creemore
- Everett
- Midhurst
- Mono
- New Lowell
- Snow Valley
- Tottenham

Urban growth represents significant challenges and opportunities from a multitude of perspectives (NVCA, 2013). From a wetlands and watercourses perspective, two significant challenges/opportunities are associated with water management – stream/wetland hydrology and nutrient management. For the purposes of this study, impacts associated with hydrological and sediment regimes have been identified as the critical factor associated with floodplain forest loss. The following discussion; therefore, focuses on innovative means to address potential hydrological impacts associated with development. Nutrient management challenges associated with urban growth are outside the scope of this study.

Although management of stormwater from urbanized areas has improved significantly since the mid-1900's, monitoring has shown that conventional stormwater management methods are still insufficient to avoid impacts associated with increased discharge (ICF Marbek, 2012). "Conventional end-of-pipe approaches alone do not achieve all of the water quality, erosion and flood protection benefits they were intended to provide; nor are they fully protecting baseflows for assimilative capacity, ecosystems and biodiversity" (ICF Marbek, 2012).

With respect to Minesing Wetlands, a change to conventional stormwater approaches is needed to ensure that impacts to floodplain hydrology and sediment delivery are not exacerbated by new development. Further, it is critical that observed changes in floodplain communities do not spread into the relatively unimpacted boreal and fen communities, which support a range of Species at Risk including the globally endangered Hine's Emerald Dragonfly (*Somatochlora hineana*).

A recent study (ICF Marbek, 2012) commissioned by several south-central Ontario conservation authorities states that "Low impact development (LID) techniques offer an effective and affordable alternative to mitigate the environmental impacts of urbanization, while offering beneficial outcomes to developers, municipalities and the public. LID techniques manage rainfall at source – where it lands –

through site planning and physical installations that, together, mimic the predevelopment hydrologic conditions." LID techniques also offer the potential to mitigate some of the risks posed by climate change as these techniques (ICF Marbek, 2012).

Other forms of green infrastructure can be used to support ecological and hydrological functions and processes. The 2014 Provincial Policy Statement (MMAH, 2014; Policy 1.6.2) encourages municipalities promote green infrastructure. Green infrastructure can include components such as natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs (MMAH, 2014).

LID and other forms of green infrastructure are most often identified as a strategy to mitigate impacts on surface water flow. However, they are also of critical importance to maintain groundwater flow regimes. For example, use of these techniques will be essential in the Snow Valley Uplands to maintain groundwater flow regimes that outlet at the base of the Algonquin Bluffs. These significant seepage fronts support sensitive boreal forest and fen communities and their associated wildlife.

In addition to stormwater management, sediment and erosion control has historically been a significant issue for developing areas. The "Greater Golden Horseshoe Area Conservation Authorities' Erosion and Sediment Control Guideline for Urban Construction" (GGHACA, 2006) was prepared to include best management practices from an array of municipal and provincial agencies within the Greater Golden Horseshoe Area, which includes the NVCA. Continued implementation of these guidelines, including the need to update the guidelines to reflect most current best management erosion and sediment control practices, will serve to protect and preserve water quality, aquatic and terrestrial habitats, and form and function of their natural water resources.

5.1.2 Watershed Stewardship

Agriculture will continue to be a vital social and economic force in the Minesing Wetlands drainage area into the foreseeable future. New/more affordable technologies and expanding commodity markets are driving agricultural intensification in portions of the watershed. Recognizing that the farming community has a vested interest in retaining soils and nutrients on productive farmland, it will be important for NVCA (and others) to partner effectively with the agricultural community (NVCA, 2013) to advance stewardship on private lands.

Delivery of a comprehensive suite of restoration and protection programs including reforestation, stream bank stabilization and other erosion control and nutrient management projects in partnership with government and non-government groups will continue to be a high priority to assist in managing the watershed on a sustainable basis (NVCA, 2013). Focused delivery of these programs will be needed to continue progress on sediment and nutrient reduction in rural portions of the Minesing Wetlands drainage area.

5.2 Monitoring

Broad-based monitoring is required to understand the causes, implications and trajectory of forest change in the Minesing Wetlands. Long-term monitoring is also required to understand the potential impacts of climate change, invasive species and watershed growth on wetland features and functions.

The results of monitoring should be used to inform long-term management and stewardship in the Minesing Wetlands.

Section 4.1.2 notes that changes in river geomorphology (resulting from post-settlement changes in land use) are connected with forest decline in the Minesing Wetlands. Changes in flow regime and sediment loads appear to be driving changes in river geomorphology which, in turn, appears to be impacting wetland hydrology. Additional research and monitoring is required to better understand historical and present regimes with a view to interpreting future hydrological trajectories in the Minesing Wetlands. This information is important for medium to long-term management of the wetlands.

Monitoring of remaining deciduous floodplain forests is important to assess loss trends. Are loss fronts continuing to expand and increase in depth or will a "firm" forest edge be re-established? Reforested lands (see Section 5.3) will need to be monitored to assess the success of reforestation plantings and to inform future reforestation projects.

Portions of the northern stands east of the Nottawasaga River have recently been heavily logged. Open canopy conditions are sub-optimal for Cerulean Warbler; how will this clearing affect this Threatened species? Will opening of the canopy provide conditions suitable for invasive species? The regeneration trajectory of this site is unclear – will Silver Maple and other tree species regenerate rapidly or will conditions be too wet for this to occur? If tree regeneration does not occur, could this create another loss "front" in the deciduous floodplain forest? Monitoring is required to answer these questions. NVCA and NCC staff has initiated monitoring in this area (R.Grillmayer, Personal communication 2013).

Monitoring of Species at Risk in the remaining deciduous forests is potentially of critical importance, particularly with continuing deciduous forest decline. Cerulean Warbler, Wood Turtle and recent candidate species such as Wood Thrush (*Hylocichla mustelina*) and Eastern Wood-Pewee (*Contopus virens*) are all threatened by continued deciduous forest decline in the Minesing Wetlands. Monitoring is essential to track populations of these species and to inform potential stewardship actions.

Monitoring of Species at Risk in other forest types is also needed. Species at Risk turtles utilize the mixed coniferous swamp/fen communities at various times of the year but, at this point, we have little knowledge of their populations or seasonal movements. Hine's Emerald Dragonfly (Endangered) utilizes marsh and fen glades within these communities as larval/breeding habitat and also uses adjacent forests for foraging as adults; the full extent of their range and habitat utilization in the Minesing Wetlands is not fully known. Canada Warbler (*Cardellina canadensis*; Special Concern) has been observed in the mixed conifer swamps, but the extent of its activity i.e. number of breeding pairs is unknown. NVCA staff has initiated a groundwater monitoring program to monitor groundwater levels and quality from the base of the Algonquin Bluffs into the fen – this monitoring is vital since groundwater discharge literally underpins the ecology of this area.

Areas of floodplain forest loss have, in part, been colonized by mosaics of sparse, stunted Green Ash and Silver Maple forests intermixed with Alder, Willow and Dogwood thicket swamps. Wildlife functions associated with these open canopy, non-marsh habitats are largely unknown. Monitoring is required to better understand the functions of these extensive habitats.

5.3 Reforestation Options

Despite a likely trajectory of further floodplain forest decline in the Minesing Wetlands, there is a significant opportunity to offset and possibly reverse this trend over time. Reforestation of drier, previously farmed fields along the Mad River and Nottawasaga River and drier fringe areas adjacent to the wetland has the potential to improve long term forest connectivity and enhance core deciduous forest habitat within the Minesing Wetlands. Improved forest habitat has the potential to benefit Species at Risk such as Cerulean Warbler and Wood Turtle and would also enhance aquatic habitat along the Nottawasaga River, which provides habitat for the Threatened Lake Sturgeon (*Acipenser fulvescens*).

Four main sites have been identified for reforestation opportunities (Table 2; Figure 9). Two of these sites are located in the interior of the Minesing Wetlands, on conservation lands managed by the Nottawasaga Valley Conservation Authority (NVCA). The first site (three subsite areas) is located along the Mad River north of Concession 2. The second site (seven subsite areas) is located along the Nottawasaga River in the former farm fields north of McKinnon Road. The other two potential sites for reforestation projects are located on the wetlands periphery on land owned by the Province. One of these sites is located along a northern section of the Nottawasaga River (as it exits the Minesing Wetlands; two subsite areas) and the other in the southeastern portion of the wetland. This site listing should not be considered complete but, rather, a "first cut" of available opportunities. Other reforestation opportunities are likely present and may be identified/become available in the future. These may include opportunities to partner with private landowners along the wetland fringe in conjunction with other reforestation partners such as Trees Ontario.

The following subsections will review each site option in terms of biological and landscape characteristics, required stewardship efforts and tree planting logistics. This assessment will outline the benefits and drawbacks of each site option.

Table 2. Site recommendations for deciduous forest reforestation in the Minesing Wetlands

				Number of		
Site	Sub-			Trees	Land	Site
#	site	Site Area	На	Required	Ownership	Accessibility
1	А	Mad River	9	18000	NVCA	Yes
1	В	Mad River	9	18000	NVCA	Yes
1	C	Mad River	2	4000	NVCA	Yes
2	А	Nottawasaga River	10	20000	NVCA	Yes
2	В	Nottawasaga River	1.5	3000	NVCA	Yes
2	C	Nottawasaga River	3.7	7400	NVCA	Yes
2	D	Nottawasaga River	18	36000	NVCA	Limited
2	E	Nottawasaga River	1.9	3800	NVCA	Limited
2	F	Nottawasaga River	2.5	5000	NVCA	Limited
2	G	Nottawasaga River	2.7	5400	NVCA	Limited
3	А	North Minesing	10	20000	Provincial	Possible
3	В	North Minesing	5.2	10400	Provincial	Possible
4	A	Baldwick Lane	14	28000	Provincial	Unknown
			104.3	179000		

Minesing Wetlands Reforestation Options

Establishing tree cover at any of the proposed sites requires gathering background information including soil characterization as well as intensive site preparation. Successful hardwood establishment requires intensive site preparation and tending for at least three years to maintain a relatively weed free site. Particularly in old fields, herbaceous competition can limit tree growth for many years (White et al, 2005). Herbicides will be required for site preparation and follow-up treatments to maximize the success of reforestation projects in the Minesing Wetlands. Industry standard best management practices will be employed in their use and there will be close communication with NVCA ecological staff to ensure that sensitive natural heritage features and functions are not impacted by herbicide or site preparation works.

Depending on the sites chosen for rehabilitation, seed collection from trees native to the Minesing Wetlands is ideal, and would require up to 4 years in a nursery (for example Hackberry and Bur Oak). The success rates of planting deciduous trees is lower than that of conifer species so a high-density planting strategy of 2000 trees per hectare (800/acre) is recommended (R. Grillmayer, Personal communication 2013). There is a certain degree of uncertainty with reforestation work, but such large-scale experiments are useful for environmental managers to expose gaps in knowledge and to apply adaptive management (Walters and Holling, 1990) which will maximize the success of future plantings.

This assessment provides a framework for future reforestation only. Additional effort and coordination among NVCA staff and partners will be required to develop a full reforestation strategy based on detailed planting plans and identification of funding opportunities.

Figure 9: Reforestation Options - Minesing Wetlands



5.3.1 Interior/Levee Reforestation Sites

5.3.1.1 Mad River Sites

The Mad River site is located just north of Concession 2 (Sunnidale) near the waterfowl viewing platform and has been divided into three sub-sites. All sites are owned and managed by the NVCA. Tree planting here would support deciduous forests to the west and provide riparian habitat and bank stabilization for the Mad River. The adjacent forest is approximately 150 ha and is associated with a declining forest front. Establishing tree cover here, in a slightly elevated setting isolated from impacted floodplain hydrology would bolster remaining forest cover around this section of the Mad River. Currently site 1-A (9 ha) is on an annual 1-year lease for agriculture that would require termination. The typical crop is reported as soybeans, which will have enriched the soil making it ideal for tree planting (R. Grillmayer, Personal communication 2013).

Site 1-B is also 9 ha. This area is an abandoned farm field that has been overtaken with Reed Canary Grass, which suggests drier conditions fit for establishing tree cover. It would take a season to eliminate competitive vegetation in preparation for tree planting.

Site 1-C would provide more riparian habitat along the east banks of the Mad River and reconnect fragmented floodplain forest cover east of the Mad River. An assessment of flooding in this area would determine whether tree planting is possible.

There is potential for a 3-year plan to assess, plan, plant, and monitor on a rotational basis. First year plant site 1-A, second year plant site 1-B (monitor 1-A), and third year plant site 1-C and re-evaluate planting success and management goals (see Reforestation Planning section 6.3.3).





5.3.1.2 Nottawasaga River Sites

The Nottawasaga River site is divided into 7 sections, or sub-sites, for tree planting based on existing natural succession of the abandoned farmed fields and exclusion of areas deemed too wet for tree planting. These fields are located on the natural levees of the Nottawasaga River on both the east and west sides of the river, near the Iron Bridge. The land is owned and managed by the NVCA.

A November 2013 site inspection revealed an abundance of reed canary grass that would require multiple applications of herbicide to minimize competition. There has been some natural succession since these fields were abandoned in the 1970s with mainly Red-osier Dogwood thickets. Several species could be planted here including Silver Maple, Bur Oak and Hackberry. Although not desirable for

planting because of the encroaching Emerald Ash Borer, Ash tree species could provide a cover crop for other slower growing trees. Seed collection and nursery for Hackberry could require up to four years preparation before saplings are actually planted.

Reforestation of the McKinnon field sites would create a significant forested link between the core boreal forest east of the Nottawasaga River and the core floodplain forests in the north portion of Minesing Wetlands. Regeneration of forest here would also create a full-forested riparian corridor (>200 m width) along the Nottawasaga River levee in the Minesing Wetlands. Reforestation would significantly increase the extent of core floodplain forest habitat associated with the existing silver maple swamps east of the Nottawasaga River.

Sub-sites 2-A, 2-B and 2-C, located on the west levee of the Nottawasaga River, are accessible with tree planting machinery via the McKinnon Road access gate which would facilitate reforestation efforts. The Iron Bridge forms a significant constraint to planting on the east levee and sub-sites 2-D, 2-E and 2-F. This bridge allows for access on foot, but does not support the heavy machinery needed to plant such a large area. Reforestation in these areas would be a labour-intensive endeavour compared to the west levee sites.





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5.3.2Periphery Reforestation Sites

5.3.2.1 Northern Minesing Wetlands Sites – Connecting Bur Oak

These land parcels (Roll number 434101000702600 and 434101000701501; Concession 12 Pt Lot 4) are considered "crown land" and present an interesting opportunity to enhance a rare habitat type in the Minesing Wetlands – Bur Oak swamp (Bowles et al, 2007).

Although technically outside the Minesing Wetlands "boundary", the area is typically flooded during the spring freshet and appears to be a good candidate site for deciduous swamp restoration (D. Featherstone, Personal communication 2014). The properties are owned by the province (Management Secretariat) and are actively farmed. All parties would have to be approached as to the history and current land use, as well as potential for Bur Oak reforestation project.

Sub-site 3-A would add to the riparian habitat corridor along the Nottawasaga River creating a 10hectare block of forest linked to 3 ha of known Bur Oak habitat, which could serve as a seed source. Reforestation would result in an extension of existing core deciduous swamp habitat to the northeast.

Sub-site 3-B (5 ha) is connected to the northern deciduous forests of the Minesing Wetlands. Adjacent Bur Oak stands could be harvested for acorns for reforestation purposes. Reforestation would enhance existing core deciduous forest habitat in this portion of the Minesing Wetlands.

There may be efficiencies of scale and additional natural heritage benefits associated with planting both properties in their entirety.



Figure 12: Northern Minesing Wetlands Planting Sites

During the summer of 2014 existing Bur Oak stands should be identified and assessed for health. Seed collection of the native Minesing Wetlands Bur Oak should be conducted in the fall of 2014. Oaks have highly variable acorn production and it may take several years before a significant acorn crop is available for collection. Once a crop is collected, four years of nursery care is required for acorns to sprout and grow to planting size.

5.3.2.2 Baldwick Lane Site

This site (Site 4; Roll number 434101000807500) is vacant land owned by the Ministry of Natural Resources. The adjacent land to the west and north is primarily owned by NVCA. This site has 14 ha of potential land for tree planting. It lies adjacent to a stable mixed-coniferous swamp forest that runs along the base of the Algonquin Bluffs. The site's physiographic context suggests that mixed/conifer forest plantings may be more appropriate than deciduous floodplain forest plantings. Reforestation of this site would also connect to private forest cover to the southeast, reinforcing periphery wetland forest cover.

A site assessment should be undertaken in 2014 to determine soil type and confirm surrounding vegetation (ELC). Note should be taken of the ground contour as this site lies on the terrace between the Payette and Nippissing shorelines. The gullies could limit tree planting machinery access to the site.

Hine's Emerald Dragonfly has been reported within/proximal to this property. Reforestation of these lands would have to consider the potential short-term (planting preparation/physical planting) and long-term (conversion of open habitat to closed canopy forest) implications on Hine's Emerald Dragonfly habitat. This globally Endangered species is unique to the Minesing Wetlands in Canada – any potential impacts to its habitat would likely preclude reforestation on this property.



Figure 13: Baldwick Lane Planting Sites

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5.3.3 Reforestation Conclusions

The Mad River site has the best soil and access for an reforestation project. It would support deciduous forest cover proximal to an area that has been heavily impacted by forest loss, and continues to decline. The three sites provide for a 20 ha reforestation opportunity. Year 1 (2014) could see 9 ha planted (Subsite 1-A), which would require 18,000 trees. Sub-sites 1-B (9 ha) and 1-C (2 ha) would be assessed and prepared in 2014. Potential funding from NVCA and Trees Ontario still requires additional money that should be sought out from organizations such as the NCC, FOMW, DUC, EC and MNR. Outlined below is an estimation of planting costs and timeline of events to execute an reforestation project for the Mad River site. The final cost only represents current market prices in relation to the number of trees necessary to plant site 1-A. These numbers do not reflect seedling availability and until the site is properly assessed and a planting prescription is written it is impossible to determine the final cost.

Site 1-A Mad River (9ha)							Somerville 2014
	%	# of					
Tree	area	trees	age	height (cm)	Quantity	cost/tree	total cost
Silver Maple	100%	18000	1+0	25-40	1000+	0.6	\$10,800.00
Common Hackberry	0%	0	2+0	25-60	1000+	0.89	\$-
Basswood	0%	0					\$-
Swamp White Oak	0%	0	2+0	25-60	1000+	0.89	\$-
Trembling Aspen	0%	0					\$-
Bur Oak	0%	0	1+0	23-40	1000+	0.85	\$-
Black Maple	0%	0					\$-
	100%	18000					\$10,800.00

There are a number of factors that need to be considered for all potential reforestation sites.

Assessment of soils and other site characteristics such as flooding impacts should be undertaken to ensure viability for establishing tree cover, as well as monitoring for impacts from wildlife browsing, disease, competition from weeds and grass, and moisture or drought problems. Soil and flooding conditions are the primary determinants of site viability.

Typically a site is undergoes preparation measures to help ensure tree establishment. This includes spraying herbicides for undesirable plant control and possible wildlife fence exclusions (site dependent). Reed Canary Grass is generally dominant at all proposed sites, which means that site preparation would require multiple herbicide applications to reduce the population to a level where it would not outcompete plantings (R. Grillmayer, Personal Communication 2013). Live Willow staking has also proven successful as means of reducing Reed Canary Grass biomass (Kim et al., 2006; see also Lavergne and Molofsky, 2004).

Tree species selection is based on soil and moisture conditions of the site, and is reflective of tree species historically found in each respective area of the Minesing Wetlands. Seed sources would have to be re-evaluated after site analysis. Depending on seed availability collection will be necessary, which

would require 2-4 years of sapling growth in a nursery (R. Grillmayer, Personal Communication 2013).

Other important considerations for this proposed work includes the logistics in transporting materials and machinery to the site, and the availability of volunteers and staff for the labour. Volunteer support from groups such as the Friends of the Minesing Wetlands and the Nature Conservancy of Canada should be sought out, as well as in-kind support from the Nottawasaga Valley Conservation Authority.

A tabular framework for reforestation project planning and implementation is provided below. Additional effort and coordination among NVCA staff and partners will be required to develop a full reforestation strategy based on detailed planting plans and identification of funding opportunities.

	2014	2015	2016	
	Hackberry	Hackberry	Hackberry	
Seed Zone-appropriate	Bur Oak	Bur Oak	Bur Oak	
Stock	Silver Maple	Silver Maple	Silver Maple	
	Len Duckworth	Site 3 parties (?)	Site 1 follow-up	
	Site 1 neighbours	Site 4 parties (MNR)		
Landowner Outreach	NVCA	Site 1 follow-up		
	Site 3 parties (?)			
	Site 4 parties (MNR)			
Stewardship	NVCA,FOMW,NCC	NVCA,FOMW,NCC	NVCA,FOMW,NCC	
	Source grant funding			
Funding Partners	Trees Ontario	Trees Ontario	Trees Ontario	
	Other/Private			
Municipal Dentro and	Springwater Twp	Springwater Twp	Springwater Twp	
iviunicipal Partners	Clearview Twp			
	Site 1 (Completed)			
Site Magnetation Analysis	Site 2 (Completed)			
Sile vegetation Analysis	Site 3 (Refine)			
	Site 4 (Refine)			
	Site 1	Site 2		
Site Soil Analysis	Site 2	Site 3?		
	Site 4			
	Site 1	Site 1	Site 1	
Site Flooding Analysis	Site 2	Site 2	Site 2	
	Site 3	Site 3	Site 3	
Site preparation/				
monitoring	Mad River Sites	Mad River, Site 2?	Sites 3 or 4??	
Tree Planting		Site 1-A1-B	1-B; 1-C (2017?)	
		Other sites?	Other sites?	

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Appendices

Appendix A – Air Photo Series Maps Used for Minesing Analyses

NVCA air photos for the Minesing Wetlands.

Minesing Wetland Air Photos

	0		
<u>1953</u>	<u>1971</u>	<u>1978</u>	<u>1989</u>
53_4415_39_40	71_4415_20_10	78_4424_52_314	1989_89085_41
53_4415_39_42	71_4415_20_11	78_4424_52_315	1989_89085_42
53_4415_39_43	71_4415_20_12	78_4424_52_316	1989_89085_43
53_4416_39_11	71_4415_20_9	78_4425_10_53	1989_89089_380
53_4417_38_223	71_4416_76_59	78_4425_10_55	1989_89089_381
53_4417_38_225	71_4417_76_93	78_4425_10_59	1989_89089_382
53_4417_38_226	71_4417_76_94	78_4426_28_10	1989_89089_383
53_4417_38_227	71_4417_76_95	78_4426_28_12	1989_89089_384
53_4418_38_187	71_4417_76_96	78_4426_28_15	1989_89089_433
53_4418_38_189	71_4417_76_97	78_4426_29_8	1989_89089_435
53_4418_38_190	71_4418_5_10	78_4427_49_332	1989_89089_436
53_4418_38_191	71_4418_5_11	78_4427_49_334	1989_89089_437
53_4419_38_152	71_4418_5_12	78_4427_49_336	1989_89089_438
53_4419_38_155		78_4427_49_337	
53_4419_38_156		78_4427_49_341	
		78_4428_1_50	
		78_4428_1_51	
		78_4428_1_53	
		78_4428_1_54	
		78_4428_1_56	
		78_4428_1_57	
		78_4429_1_10	
		78_4429_1_12	
		78_4429_1_14	
		78_4429_1_16	
		78_4429_1_18	
		78_4430_18_10	
		78_4430_18_12	
		78_4430_18_14	
		78_4430_18_15	

Appendix B – Transition from Deciduous Swamp to Marsh

Figure 14: Closed Canopy Silver Maple Swamp



Figure 15: Declining Swamp Edge (note partial canopy, dead/declining trees and cattail understorey)



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Figure 16: Drowned Swamp (note Rough Manna Grass marsh with dead standing timber)

Figure 17: Inundated Rough Manna Grass Marsh (spring conditions; only submerged stumps reminiscent of past forest)

