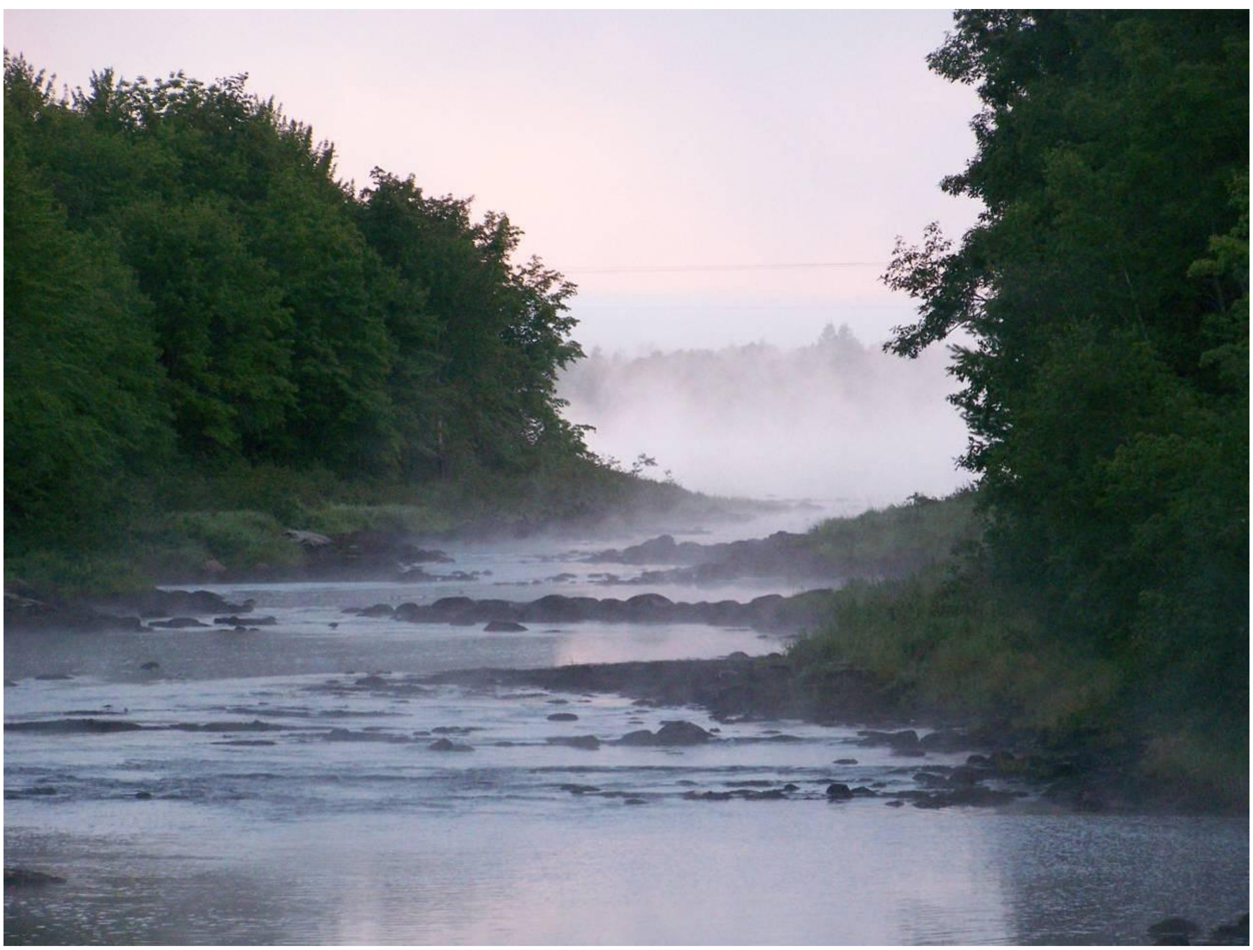
Mersey Tobeatic Research Institute

A geographic information system (GIS) approach for choosing terrestrial liming sites in the Gold, LaHave and Medway Watersheds



Brad Toms, Amanda Lavers and Jillian Barteaux

Contents

List of Tables and Figures

Contents

Introduction

In 2009 the Mersey Tobeatic Research Institute (MTRI) prepared a report for the Nova Forest Alliance and Environment Canada that identified eleven possible sites within the Gold, Lahave and Medway watersheds where terrestrial liming could take place (MTRI 2009). This study made tentative conclusions about candidate sites but recommended further data collection and analysis. The purpose of this report is to attempt to fulfill those recommendations.

The application of calcite (lime, calcium carbonate) to terrestrial habitats has been shown to improve water quality for a long period of time in a small stream catchment and the waters below it (Clair and Hindar 2005). Surface waters in southwestern Nova Scotia had historically low pH values but acid deposition and deforestation throughout the twentieth century created even more acid conditions (Clair 2007). Natural recovery is not likely to happen in the short term, even though acid deposition rates have decreased, because of the poor buffering capacity of the soil. Atlantic Salmon (*Salmo salar*) populations have been affected such that recreational fisheries are no longer viable on many rivers in the area. The rate of recovery of pH is not sufficient to ensure that Atlantic Salmon will persist in southwestern Nova Scotia. Several temporary mitigation options exist such as maintaining ex-situ populations of fish until waters recover, creating gene banks to preserve genetic information, and applying lime to water or to the land.

Sites chosen in a previous report produced by MTRI (2009) were based on five criteria using qualitative evaluations. Those criteria were as follows: the amount of wetlands, the forest capability/sensitivity, and the amount of private property, the amount of hardwood cover and the ds where terrestrial liming might be feasible. The purpose of this report is to make further recommendations on these previously identified sites using a GIS analysis of sub-catchments within the previously identified catchments to quantify values for each criterion.

The short-listed sites from last year's analysis are as follows (Figure 1):

- M1. Fifteen Mile Brook
- M2. Westfield River
- M3. Alma Lake
- L1. West River
- L2. North Branch
- L3. North River
- L4. Upper Main Branch
- G1. Lake Louis.
- G2. Larder River
- G3. Beech Hill Brook
- G4. Horseshoe Lake

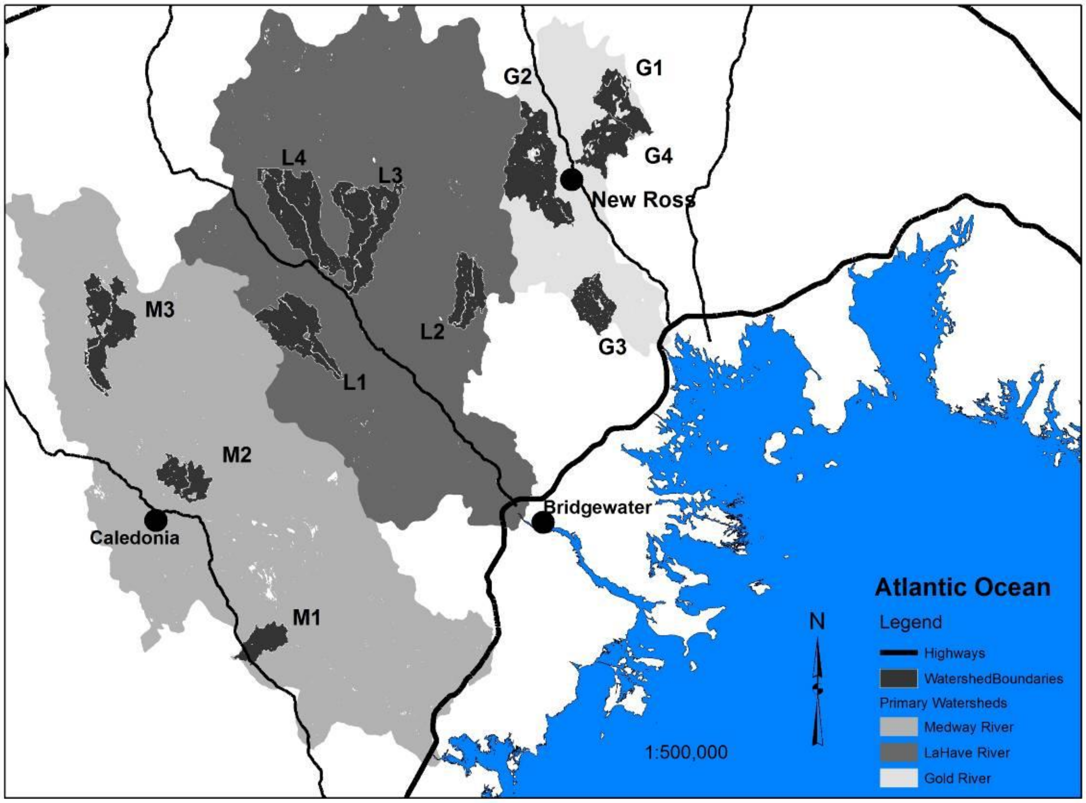


Figure 1: The Medway, Lahave and Gold Watersheds with catchment candidate sites for terrestrial liming. (Letter-number codes are provided in text).

Approach

This report will attempt to fulfill the following recommendations from last year's preliminary report: enhanced data collection, quantified selection criteria, and greater collaboration with other groups that would have a stake in the outcomes of this report. In 2009 and 2010 MTRI initiated several partnerships to further the goals of this report. These collaborations increased the number of salmon records and invasive species records from local anglers within the three primary watersheds of interest. Collaboration with other non-profit organizations and the Department of Fisheries and Oceans increased the number of water quality samples summarized in a GIS database. The Nova Scotia Department of Fisheries and Aquaculture provided their database of invasive species records and water quality data. The Nova Scotia Community College (NSCC) and Applied Geomatics Research Group (AGRG) provided training for delineating watersheds and catchments using existing data sources.

While a quantitative analysis of the size of catchments was recommended in the previous report (MTRI 2009) and was the initial goal for this report the sheer magnitude of the catchments that met the criteria (n=537, Table 2) did not correspond to the resources available for the project. A subsample of catchments were chosen using subjective recommendations from local anglers (MTRI 2009). With enough resources the raw data for entire watersheds could be analyzed further but conclusions would not likely differ from those in this report because the sites where terrestrial liming is practical appear to be limited within each candidate catchment.

Methods

Data Sources and Equipment:

GeoNOVA: Geographic Gateway to Nova Scotia – Data used in the creation of watershed, catchment and sub-catchment layers were compiled from shape files available for free download for the GeoNOVA website, accessed in Feburary of 2010. Data were downloaded in shapefile (.shp) format, projected in NAD 83 UTM Zone 20. The website address is as follows:
http://gov.ns.ca/GeoNova/home/products/softpage/data_locator.asp

ArcGIS 9.2: All geographic spatial analysis was completed within the ArcGIS 9.2 software suite. The Spatial Analysis extension was used to calculate hydrology for areas of interest and all maps were generated within ArcMap.

GIS Methodology

Digital Elevation Models (DEMs), watersheds, catchments and sub-catchments with associated data were created in ArcMap 9.2 using the Spatial Analyst extension- Hydrology modeling tools. Flow direction and flow accumulation rasters were generated from a 5 m DEM. The ArcMAP raster calculator was used to identify and extract streams by taking a threshold value of 2000 flow accumulation. Flow accumulation of 2000 and greater was identified as being cumulative enough to be representative of water volumes requiring a channel and therefore be named as streams.

To identify and measure sub-catchments within the catchments of interest, a threshold of at least 1600 cells (0.8 ha) was used to divide catchments into sub-catchments suitable for liming. It was evident from trials of differing threshold values that this best represented the true size of sub-catchments within the watersheds without creating excessively large or small sub-catchments.

DEMs used as inputs in the hydrology modeling tools were created from elevation values extracted from GeoNOVA data sets. DEMs for areas of interest were created using the interpolation tool "topo to raster" in the Spatial Analyst extensions. GeoNOVA data sets used in this processes are as follows: LF_DEM.shp, LF_LINE.shp, WA_POLY.shp, WA_LINE.shp, LF_SPOT.shp and boundary layers made to delineate the areas of interest.

An output raster cell size of 5 m was specified, and achieved due to the use of topographic contour data (LF_LINE.shp) measured at 5 m intervals. All sinks in the DEM were filled using the "identify and fill sinks" tools within the hydrology.

The DEMs used to calculate the catchments were used to calculate a raster image of slope within the catchment. This was achieved with the SLOPE tool in Spatial Analyst. This was then refined to eliminate zero values (lakes) and slope values above 2.87 degrees (5% gradient). This gradient was used to represent recharge areas within the catchment. The resulting raster images were used to generate shape files of recharge areas and overlay them with the catchment boundaries. The area within each catchment of recharge (low slope) and non-recharge (high slope) was then calculated. In the absence of reliably mapped soils or vegetation data to show soil permeability slope was considered as the lone factor when determining recharge area. The rational is that areas of a low slope will lose less water to surface runoff and retain a greater amount in the soil where it will permeate the soil.

Catchments were categorized into catchments that had >75% of their area covered in recharge area and catchments that had <75% of their area covered in recharge area.

DEM raster images for most of the candidate sites contained the entire catchment but others (West River and Upper Main Branch) were too large to include the entire area due to limitations of hardware and software. In these cases the largest area possible was used around the point of interest outlined by MTRI (2009).

A shapefile was made of invasive fish records by collecting records from anglers, salmon fishing groups, and the Nova Scotia Department of Fisheries and Aquaculture. These records were spatially proofed against their site names and then plotted alongside other spatial data.

Water quality data collected by MTRI, Bluenose Coastal Action Foundation (BCAF), and Environment Canada were merged into a single Microsoft Access database. A report was made that calculated the mean and minimum pH for each catchment and that datum was associated with the polygons in the watershed layer. These data were then clipped to the watershed borders created from DEMs as previously described.

Site Scoring

Several criteria were used for each of the eleven sites. Criteria were selected based on relevant factors and practical considerations for a physical application of lime to a restricted area. Five factors were considered in the previous report. Of those factors only the amount of wetlands was considered to be accurate at a fine scale. However, when the DEM's were analyzed for slope during the GIS analysis, zero values in the raster image were excluded to eliminate lakes from consideration as recharge areas. This had a side effect of eliminating most wetlands which also had a zero value for slope and finding areas that were recharge areas but not wetlands or lakes. To avoid redundancy, wetlands were therefore not assessed in this report to rank sites.

No new salmon records were collected from anglers or other organizations that fell within the candidate areas. The previous presence absence assessment was difficult to improve on. The rankings from MTRI 2009 were assigned numerical values of 2 for Low, 5 for Medium and 10 for High and used in the ranking of the candidate sites.

Sites were assigned a rank value based on the percentage of catchments that have >75% recharge area. The site with the highest value was given the rank of 11 and all others were given descending ranks to 1. Sites with the same value were assigned the same score.

Sites were also ranked by the percentage of the catchment owned by large landowners. The site with the highest value was given the rank of 11 and all others were given descending ranks to 1. Sites with the same value were assigned the same score. A letter was sent to large landowners to introduce the project and gauge interest in partnership opportunities (Appendix 1).

Minimum pH was used to rank each site. The site with the most acidic value was given the rank of 11 and all others were given descending ranks to 1. Sites with the same value were assigned the same score. Minimum pH was used because it is most likely to reflect the lowest pH that can be recorded at a site within a given year despite changing water levels and seasonal effects. Although very low pH values might imply that some sites are beyond recovery, the mean pH for all sites show that they could be recovered to a pH of 5.5 if liming produces an increase of 1 pH unit.

Sites were assigned a non-rank score based on the composition of invasive species presence (table 1). Invasive species data was obtained from Nova Scotia Fisheries and Aquaculture The scoring matrix is as follows:

Table 1. Scoring scheme for invasive species.

Condition	**Score**
Smallmouth Bass and Chain Pickerel inside the candidate area	0
Chain Pickerel only present inside the candidate area	2
Smallmouth Bass only present inside the candidate area	4
Smallmouth Bass and Chain Pickerel outside the candidate area	6
Only Chain Pickerel outside the candidate area	8
Only Smallmouth Bass outside the candidate area	10
Neither Chain Pickerel nor Smallmouth Bass in the primary area.	20

Sites were ranked based on the distance from the mouth of the candidate site to the mouth of the primary watershed following the course of the most direct route along the main river that flows to the outlet of the primary watershed. Sites closer to the mouth of the watershed are less prone to connectivity issues upstream meaning that the salmon are more likely to reach the watershed.

Results and Discussion

Catchment sizes varied from 1498 to 5569 ha with an mean catchment size of 3280 ha (n=11). Fifteen Mile Brook had the highest amount of recharge area (82%) and the highest proportion of catchments with greater than 75% recharge area (76%) (Table 2). Fifteen Mile Brook was followed by West River (59%) and Beach Hill Brook (50%) for the highest proportion of recharge area within each catchment. These three each are contained within three different primary watersheds. Recharge areas have been shown to be an efficient method of catchment liming (Clair and Hindar 2005). The high proportion of recharge areas in these Fifteen Mile Brook and West River catchments indicates that opportunities for terrestrial liming are most abundant at these sites. Inversely, the low proportion of catchments with >75% of the catchment area covered by recharge areas in the other catchments indicates that liming opportunities might be limited to only a select few areas.

Table 2: Summary of recharge areas and catchments within each catchment.

Site Name	Size (ha)	Total Recharge Area (ha)	Percent Recharge Area	Number of Catchments	Number of Catchments with > 75% Recharge area	Percent of Catchments with Greater than 75% Recharge Area
Lake Lewis (G1)	2154	1007	47	204	31	15
Larder River (G2)	5569	2383	43	543	60	11
Beech Hill Brook (G3)	2017	1009	50	206	43	21
Horseshoe Lake (Mill Brook) (G4)	2332	796	34	231	21	9
West River (L1)	3725	2187	59	328	98	30
North Branch (L2)	2217	931	42	198	23	12
North LaHave River (L3)	5183	2322	45	507	75	15
Upper Main LaHave (L4)	5375	2155	40	499	19	4
Fifteen Mile Brook (M1)	1498	1234	82	147	111	76
Westfield River(M2)	1922	908	47	175	22	13
Alma Lake (Medway Lake) (M3)	4094	1622	40	231	34	15
Total	**36086**	**16554**	**46**	**3269**	**537**	**16**

Table 3: A summary of land ownership in candidate sites. See Figures 2,5,7,9,11,13,15,17,19,21 and 23 for visual representations.

Site Name	Size (ha)	Crown Land (ha)	Bowater (ha)	J.D. Irving (ha)	Other Small forest companies (ha)	% ha. owned by Large Land Owners
Lake Lewis (G1)	2154	2	0	0	524	24
Larder River (G2)	5569	128	0	0	524	12
Beech Hill Brook (G3)	2017	1429	0	0	0	70
Horseshoe Lake (Mill Brook) (G4)	2332	22	0	0	32	2
West River (L1)	3725	1274	616	0	0	34
North Branch LaHave River (L2)	2217	92	0	0	0	4
North LaHave River (L3)	5183	333	279	0	751	26
Upper Main Branch Lahave (L4)	5375	357	0	0	0	48
Fifteen Mile Lake (M1)	1498	510	4	0	289	53
Westfield River (M2)	1922	148	0	0	198	18
Alma Lake (Medway Lake) (M3)	4094	216	3806	0	17	99

Table 4: A summary of mean and minimum pH values in the candidate sites.

Site Name	Mean pH	Minimum pH
Lake Lewis (G1)	4.69	4.23
Larder River (G2)	4.88	4.34
Beech Hill Brook (G3)	4.71	4.69
Horseshoe Lake (Mill Brook) (G4)	5.63	4.95
West River (L1)	5.05	3.98
North Branch LaHave River (L2)	5.56	4.23
North LaHave River (L3)	5.52	4.42
Upper Main Branch LaHave (L4)	5.56	5.02
Fifteen Mile Lake (M1)	5.64	5.49
Westfield River (M2)	4.86	4.74
Alma Lake (Medway Lake) (M3)	5.31	5.06

Candidate Site Summaries

M1. Fifteen Mile Brook (Medway)

The Fifteen Mile Brook catchment has a very low slope throughout the area that it covers (82%). Fifteen Mile Brook has the second highest proportion of land owned by large land owners (53%) of any candidate catchment. It is composed of 34% Crown land and 19% small forestry companies (Figure 2, Table 3). Smallmouth Bass have been caught above the catchment in Ponhook Lake (Figure 4). Although they have not been caught in 15 Mile Brook there are no barriers keeping them from migrating into this brook if they have not done so already. There are no records of Chain Pickerel upstream or downstream of Fifteen Mile Brook. Fifteen Mile Brook has an mean pH of 5.64 and is a relatively 'sweet water' site compared to other candidate areas (Table 4, Figure 3). Most of the large landowner parcels overlap with recharge areas. The already high pH makes this catchment a relatively low priority for recovery using terrestrial liming. The position of this catchment on the Medway system means that the benefit will only be seen in this catchment and the Medway River downstream. Access to this site is achieved via paved and unpaved municipal roads. An airfield (abandoned) nearby would make a convenient staging area for lime.

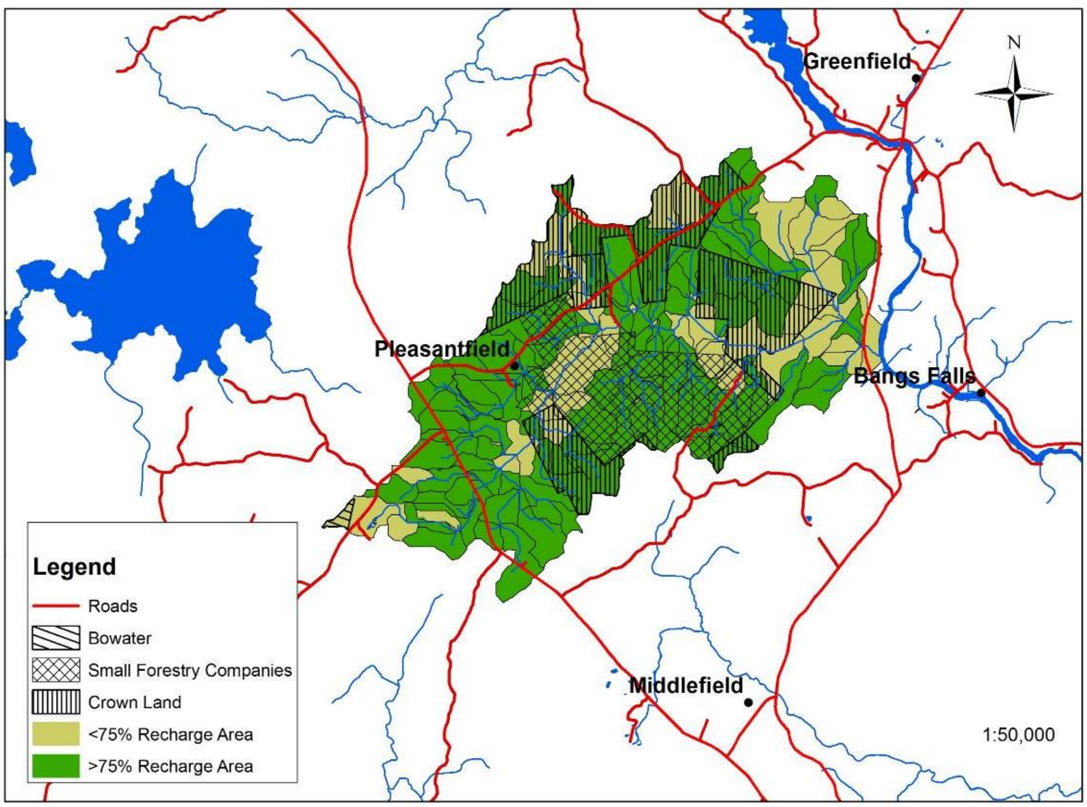


Figure 2: Catchments and property ownership within the Fifteen Mile Brook catchment. Dark areas represent catchments with > 75% recharge area (slope < 5%).

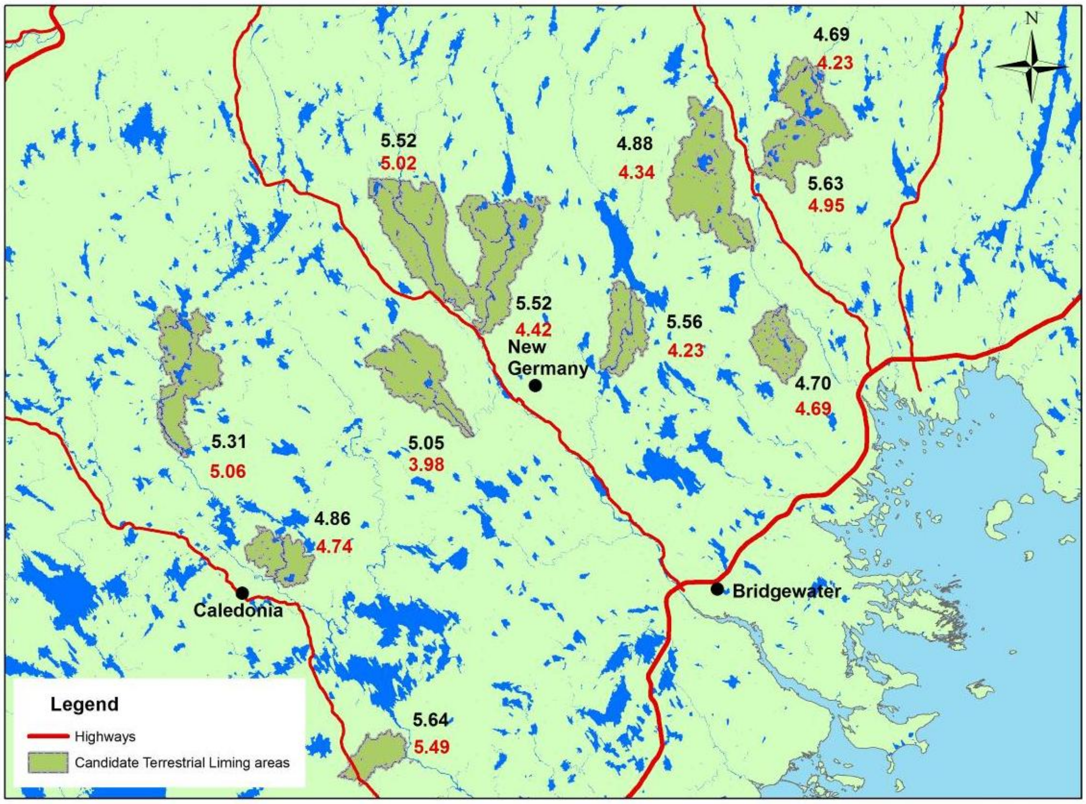


Figure 3: Minimum (in red font) and mean (in black font) pH values from water samples collected between 196 and 2009 for candidate catchments from MTRI, Bluenose Coastal Action Foundation, Department of Fisheries and Oceans and Environment Canada.

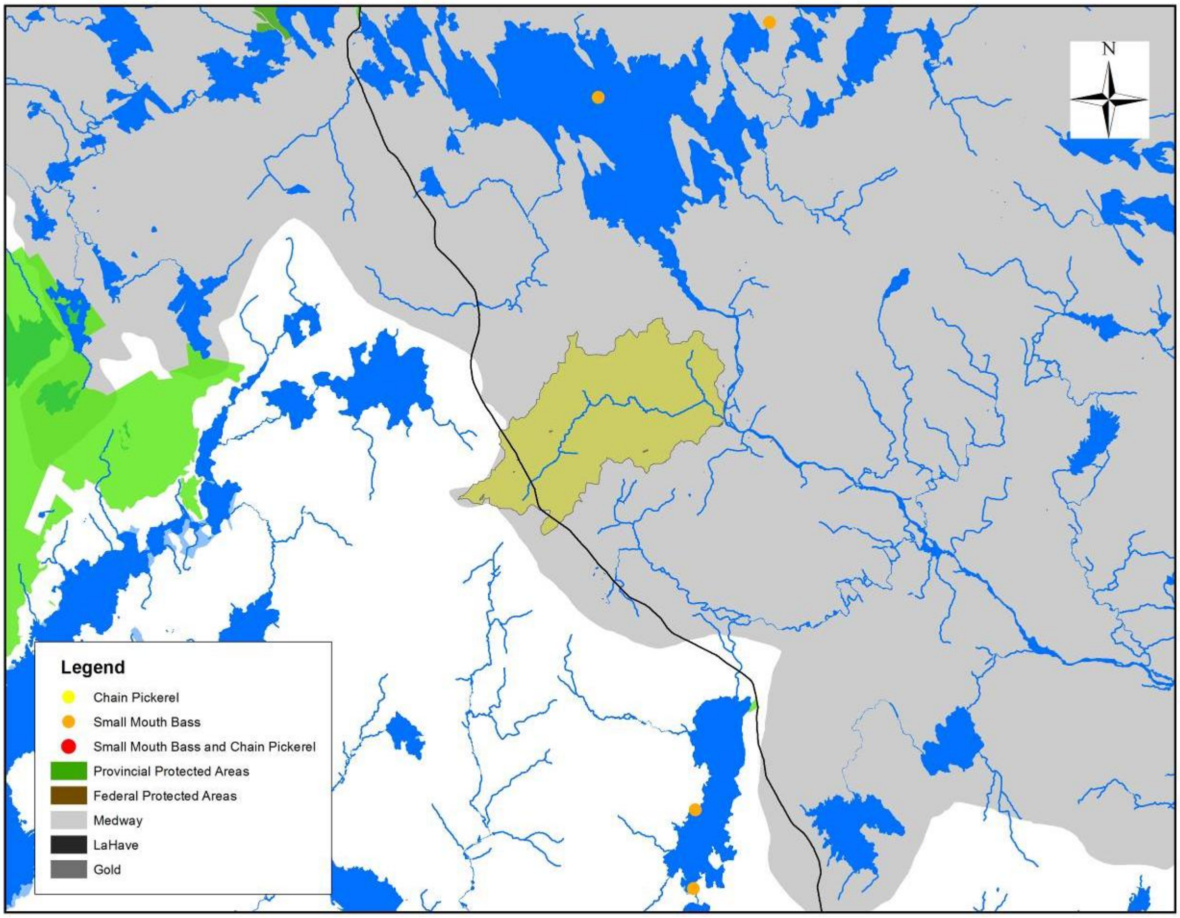


Figure 4: Location of invasive species relative to Fifteen Mile Brook catchment. Catchment highlighted in beige.

M2. Westfield River (Medway)

Despite having a large portion of its total area in a low slope (47%) only 22 of 175 catchments are composed of more than 75% recharge areas (Table 2, Figure 5). Eighteen percent of the area of the catchment is owned by large landowners (primarily small forestry companies). Smallmouth Bass are downstream of Westfield River and in Flynn Lake (Figure 6). There are few sites where recharge areas overlap with large landowners. This would make liming of recharge areas logistically more difficult but by no means insurmountable. Access to this catchment is achieved by local paved and unpaved municipal roads. Some existing log landing sites could be used as staging areas for lime but this would require the permission of a private landowner. The pH of the Westfield River catchment is not heavily impacted but in need of recovery (Table 4, Figure 3). Terrestrial liming would have a greater downstream benefit at this site than Fifteen Mile Brook by providing sweetened water to Ponhook Lake as well as the Medway River.

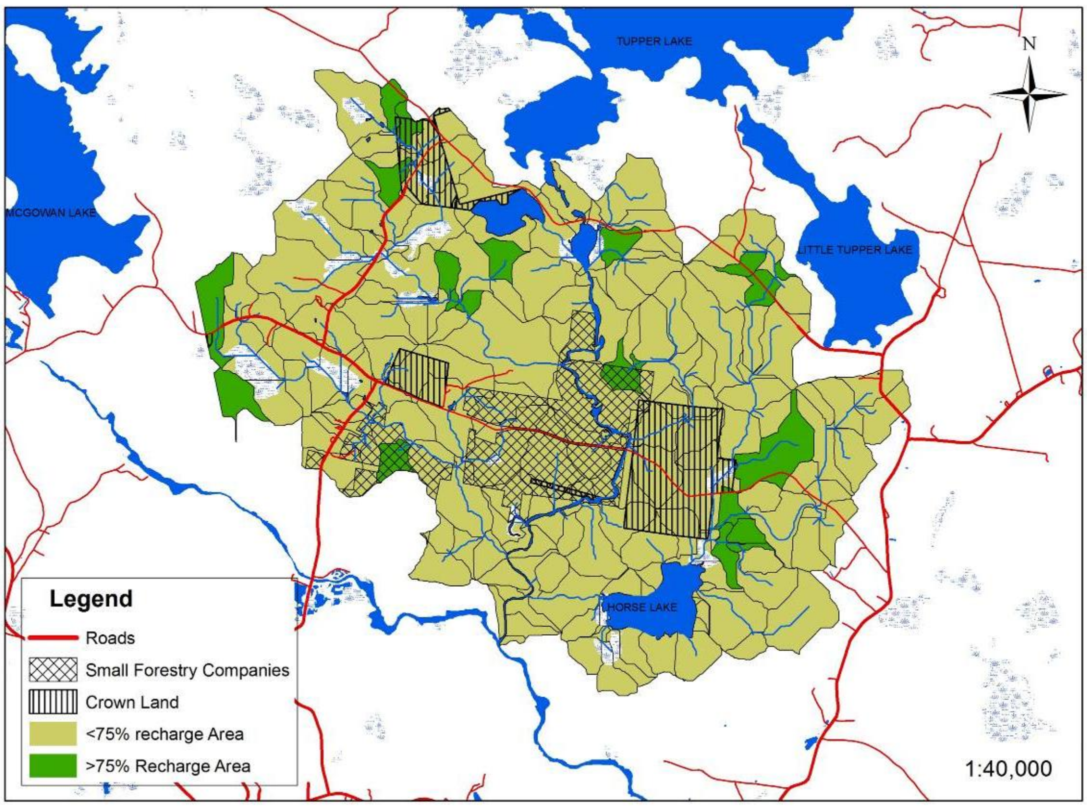


Figure 5: Catchments and property ownership within the Westfield River catchment. Dark areas represent catchments with > 75% recharge area (slope < 5%).

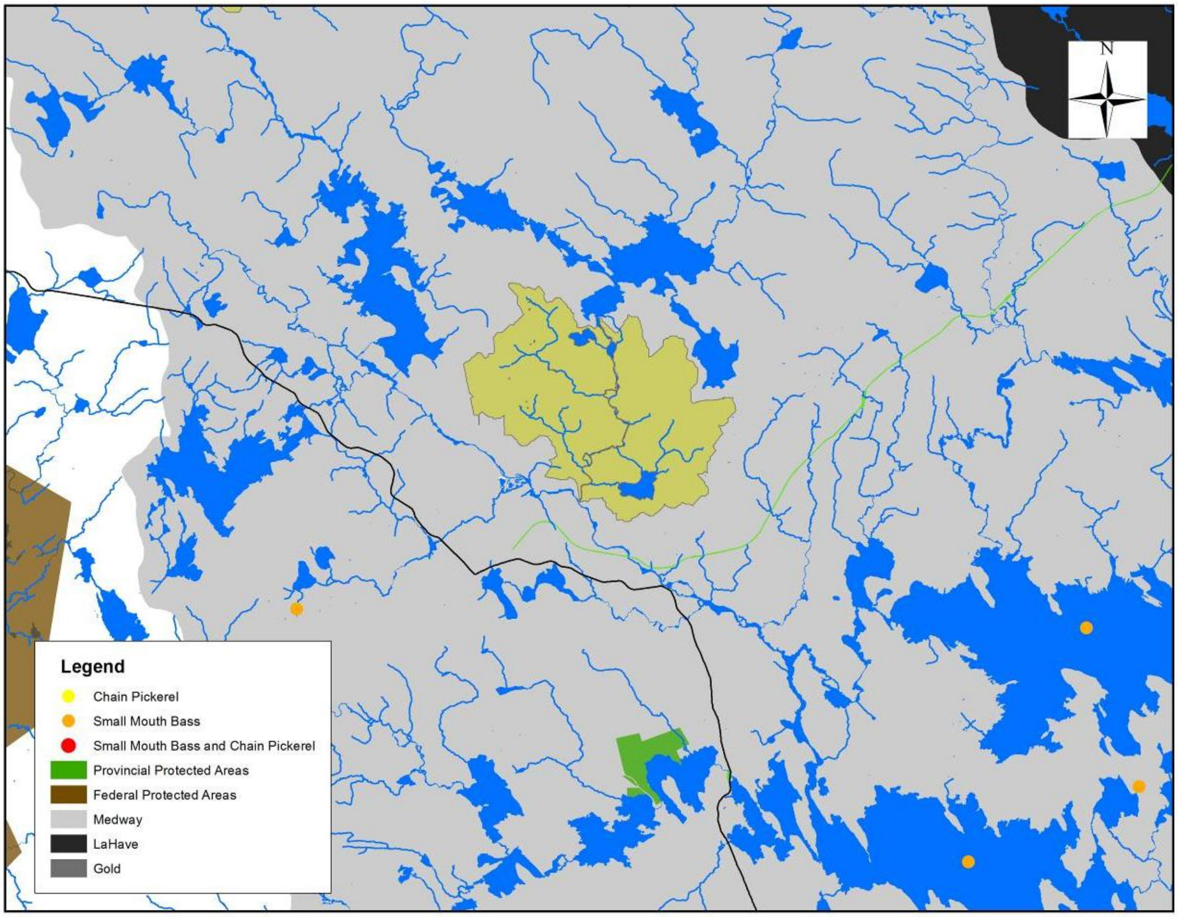
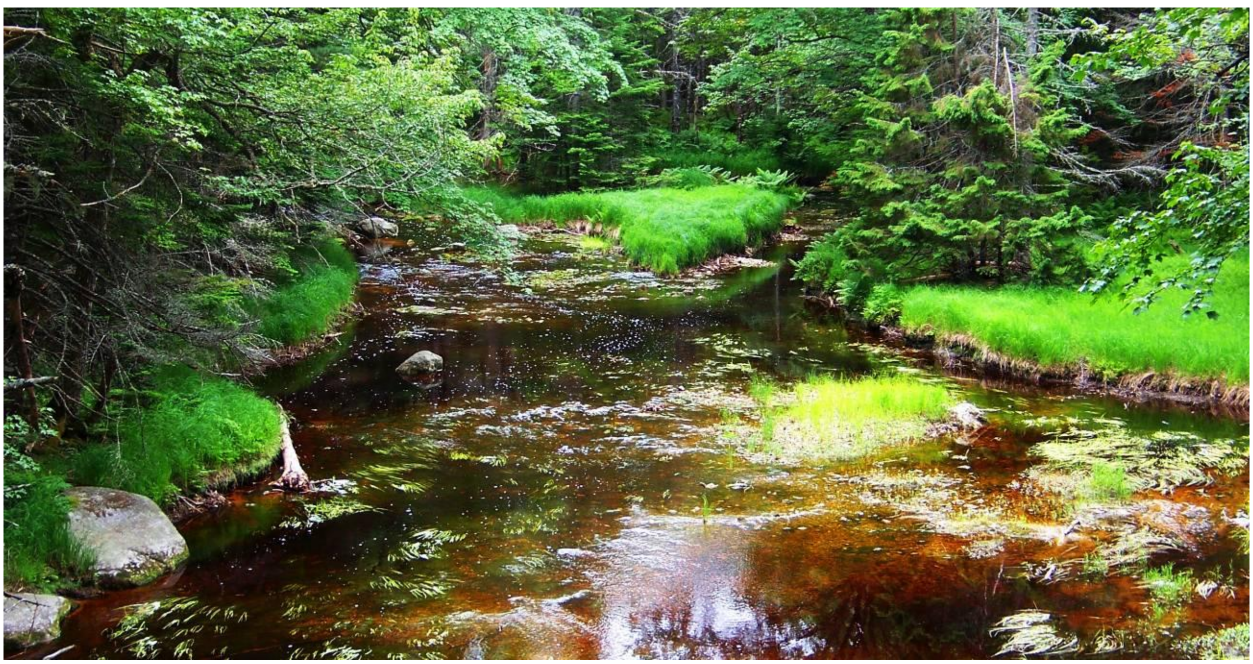


Figure 6: Location of invasive species relative to Westfield River catchment. Catchment highlighted in beige.

M3. Alma Lake (Medway Lake) (Medway)

The catchment below Alma Lake is less than half covered by recharge areas (40%) but few of the catchments are >75% recharge area (15%). This catchment is owned almost entirely by Bowater (93%) and almost all of the catchments with >75% recharge areas are encompassed by Bowater land or Crown land. The pH (Table 4, Figure 3) is mean for the area and would be a good candidate for recovery through terrestrial liming. Access to this site is restricted by Bowater but there are many staging areas and roads that can withstand heavy trucks. There are no invasive fish records upstream of this area (Figure 8). The nearest record of Smallmouth Bass is approximately 35km downstream in Ponhook Lake. There are relatively few records of salmon in this catchment; there is one recent record from electro-fishing collected by the Department of Fisheries and Oceans. The fish-way located at the power dam at McGowan Lake has acted as a barrier to some fish passage into Alma Lake although anglers have recorded salmon par at the fish-way in the past before the hydro generator was turned off and the flow was reduced. Until salmon are known to have consistent passage to this section of the Medway watershed terrestrial liming is not recommended for this site.



Typical dark water river in southwest Nova Scotia (Photo: Mersey Tobeatic Research Institute)

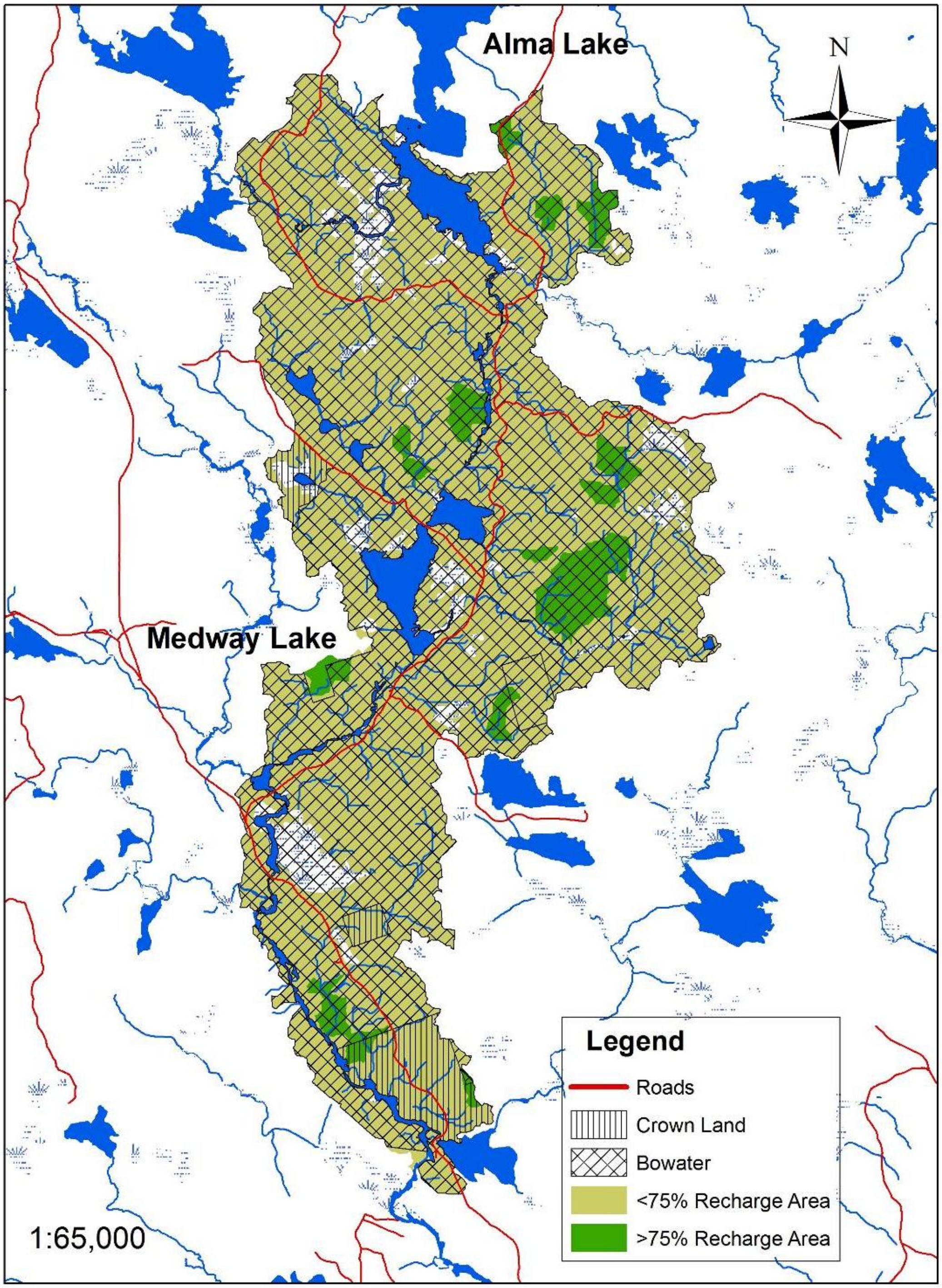


Figure 7: Catchments and property ownership within Alma Lake catchment (Medway Lake). Dark areas represent catchments with > 75% recharge area (slope < 5%).

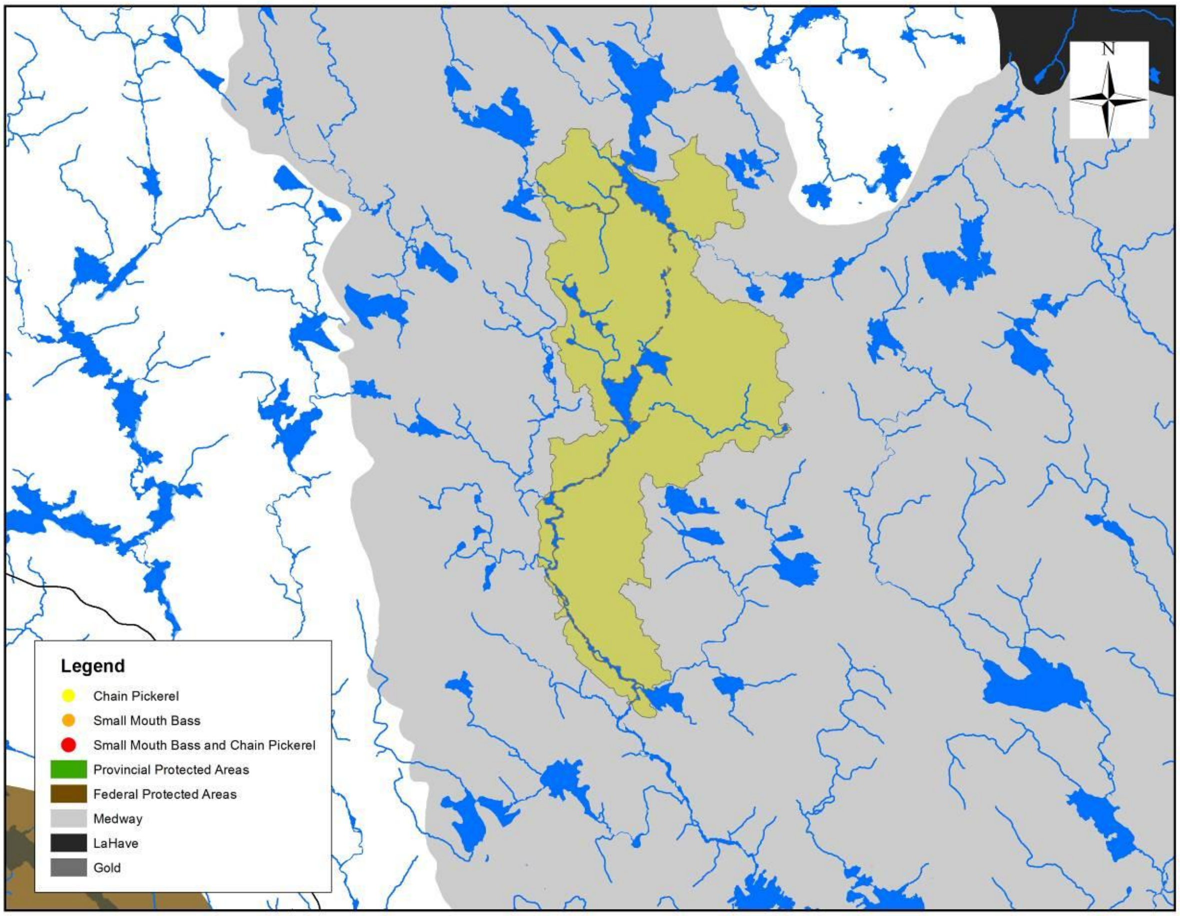


Figure 8: Location of invasive species relative to Alma Lake catchment. Catchment highlighted in beige.

L1. West River (LaHave)

The West River catchment has 59% recharge areas and 30% of the catchments have greater than 75% recharge areas (Table 2). Most of the catchments with >75% recharge areas are owned by large land owners (Table 3, Figure 9). Thirty four percent of the catchment is owned by large land owners, primarily the Crown and Bowater. Smallmouth Bass have been recorded at the mouth of this catchment. There are no barriers to suggest that they could not be more widely distributed throughout the catchment. Road access to the site is by municipal roads which are less numerous than many other candidate sites. The southernmost recharge areas have road access and potential staging areas where logging takes place (Figure 9). The pH in the West River is on mean in need of recovery but the minimum value recorded (3.98) suggest that some areas of this catchment are highly impacted (Table 4, Figure 3).

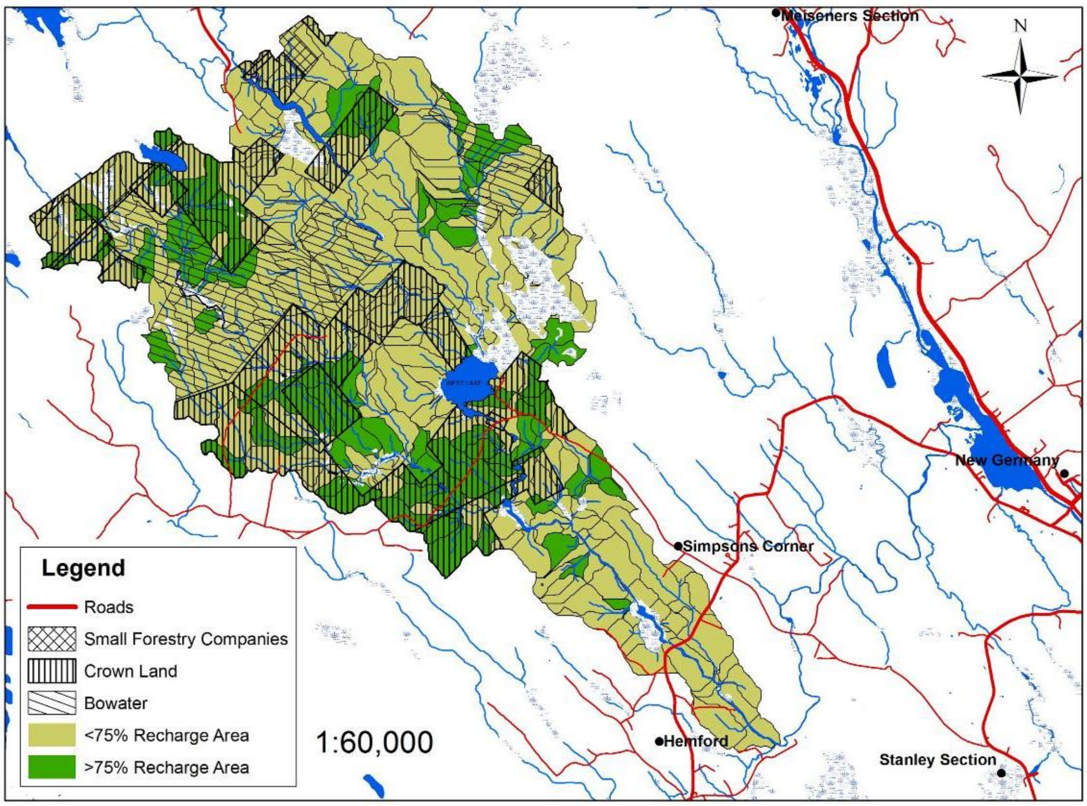


Figure 9: Catchments and property ownership within the West River catchment. Dark areas represent catchments with > 75% recharge area (slope < 5%).

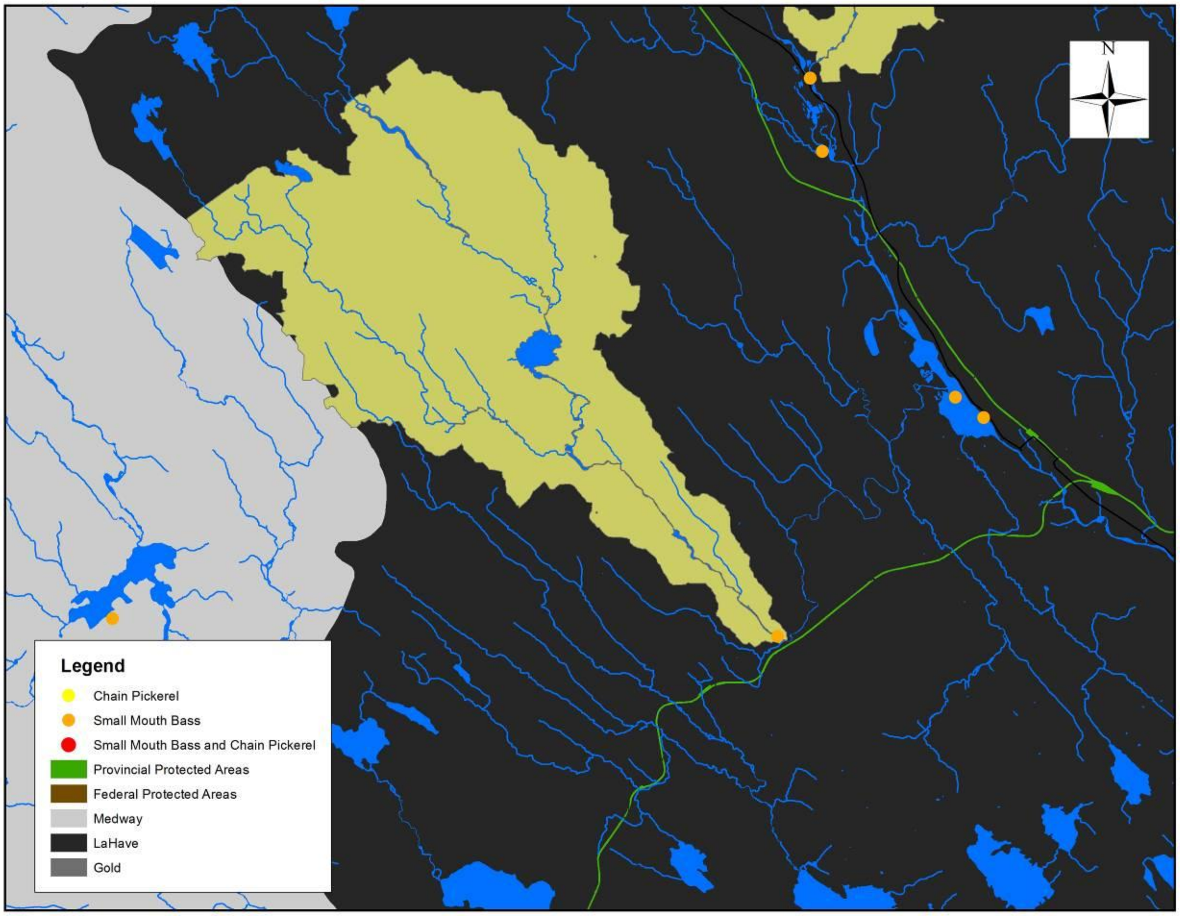


Figure 10: Location of invasive species relative to West River catchment. Catchment highlighted in beige.

L2. North Branch LaHave River (LaHave)

The North Branch catchment is composed of 42% recharge area but only 12% of catchments have >75% recharge area (Table 2). The North LaHave River catchment below Sherbrook Lake is largely privately owned in small parcels (Table 3). One area of Crown ownership overlaps with a recharge catchment close to Sherbrook Lake (Figure 11). Several records indicate the presence of Smallmouth Bass below above and within this catchment. Chain Pickerel have also been found in the catchment (Figure 12) and above Sherbrooke Lake (not shown on map). The mean pH in the catchment indicates a healthy level for Nova Scotia but the minimum pH (4.23) indicates that parts of the catchment are more impacted than others (Table 4, Figure 3). Municiple roads are abundant within this catchment. Staging areas may be less abundant on Crown and forestry land but agricultural fields could be used if a landowner was willing. A natural partial barrier exists at Indian Falls with a fish ladder built around it. The presence of Chain Pickerel combined with the small number of recharge areas and low land accessibility make this site not well suited for terrestrial liming.

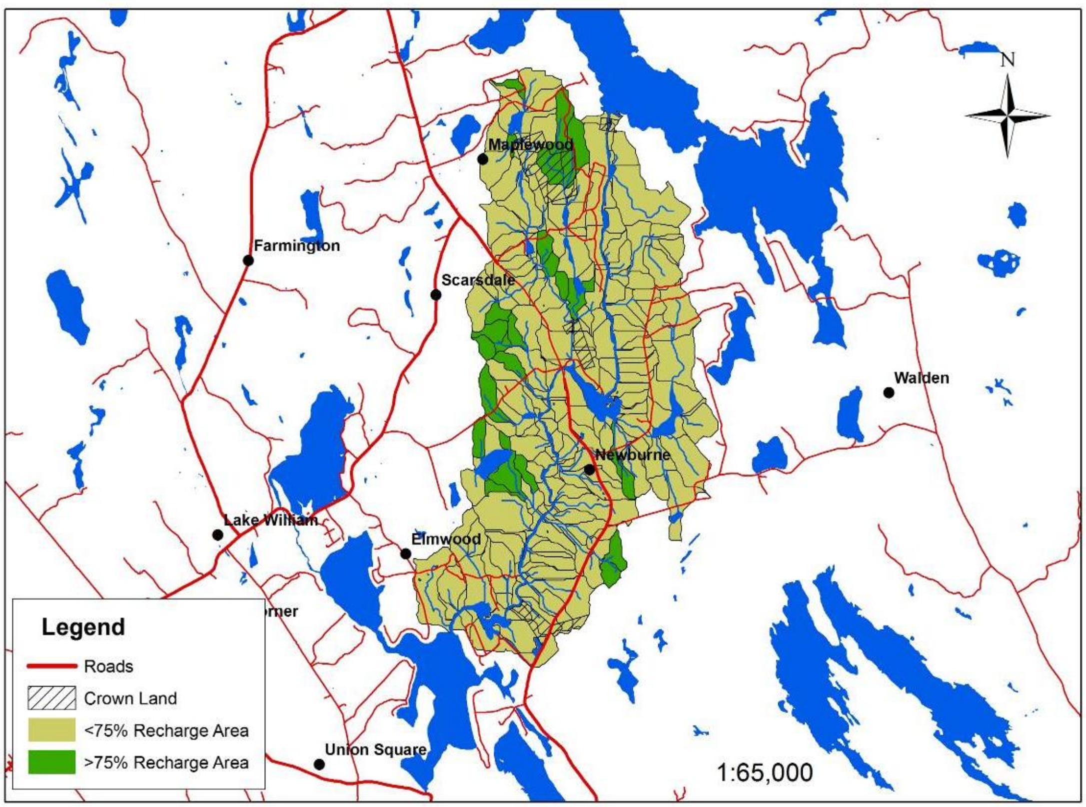


Figure 11: Catchments and property ownership within the North Branch Lahave River catchment. Dark areas represent catchments with > 75% recharge area (slope < 5%).

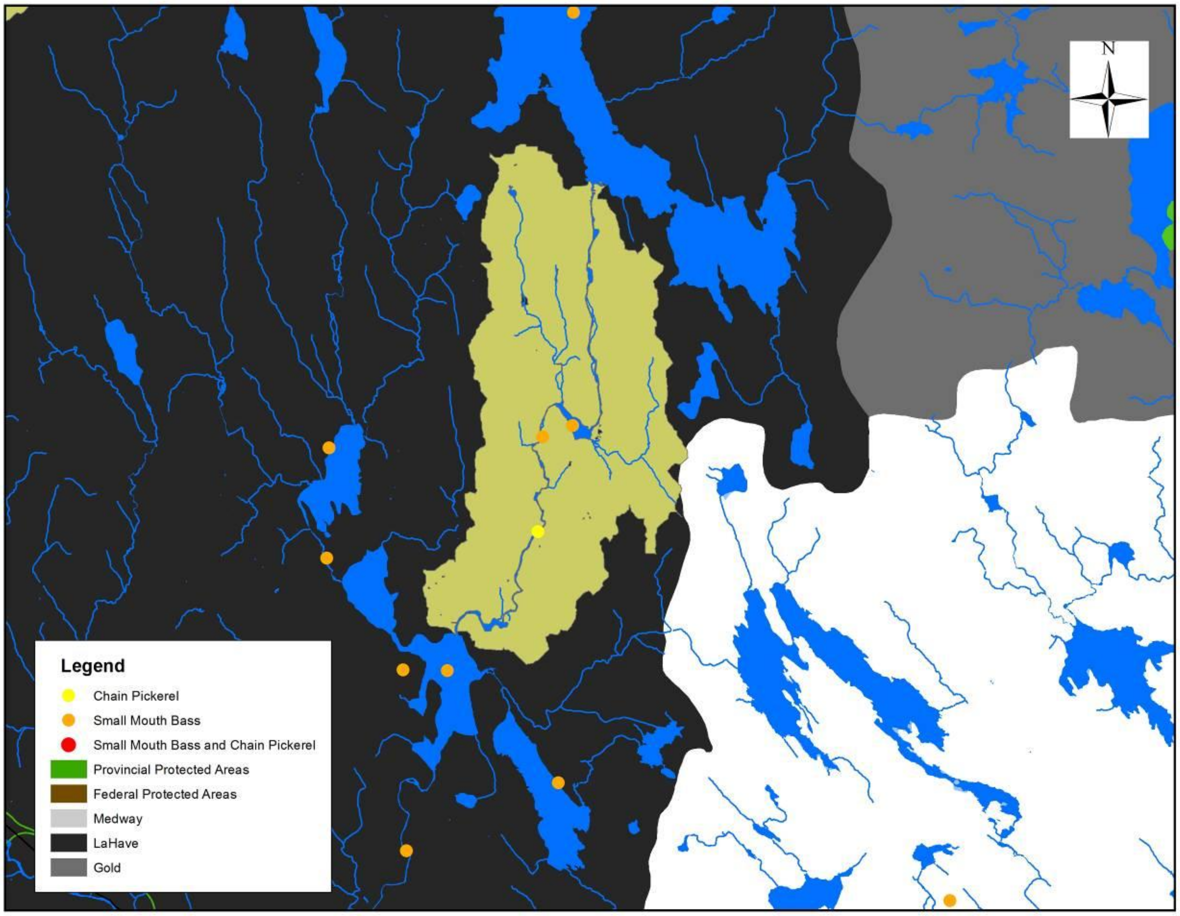


Figure 12: Location of invasive species relative to North Branch LaHave River catchment. Catchment highlighted in beige.

L3. North River (LaHave)

The North LaHave River Catchment has 45% of its area covered in recharge area but only 15% of catchments have >75% of their area covered by recharge areas (Table 2). The catchment has a low proportion of land owned by large land owners (Table 3) and only a few of those properties overlap with recharge areas (Figure 13). The areas around Saturday Lake in the northwest and the area northeast of Cherryfield are the best candidate areas within this catchment where recharge areas are owned by large land owners. Smallmouth Bass have been caught below the catchment in the main channel of the LaHave River (Figure 14). No barriers are known that could keep the bass from spreading further upstream if they have not done so already. The North LaHave has a moderate mean pH (5.52) but the minimum pH (4.74) suggests that parts of the catchment are more impacted than others (Table 4, Figure 3). Road access is largely composed of logging roads with one loose surface municipal road down the middle of the catchment. Quarries nearby west of Sherbrook Lake could act as staging areas with landowner permission. Active logging in the area means that there are likely staging areas for logs along forest roads as well.

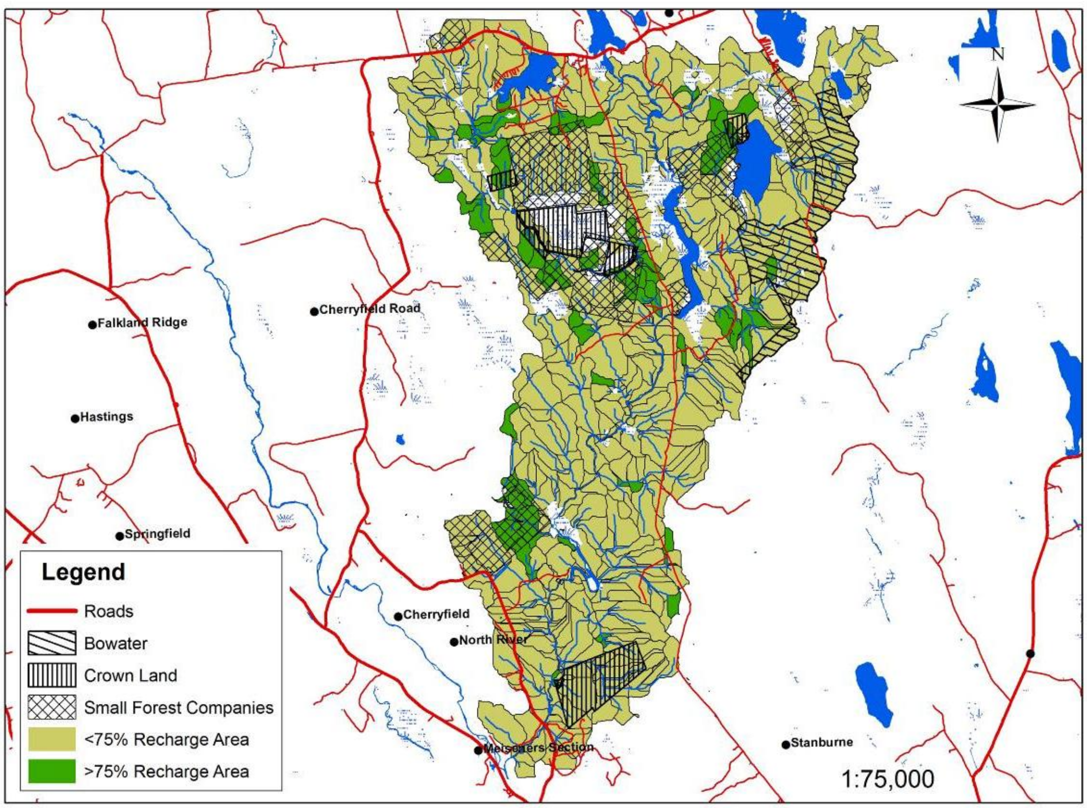


Figure 13: Catchments and property ownership within the North River catchment. Dark areas represent catchments with > 75% recharge area (slope < 5%).

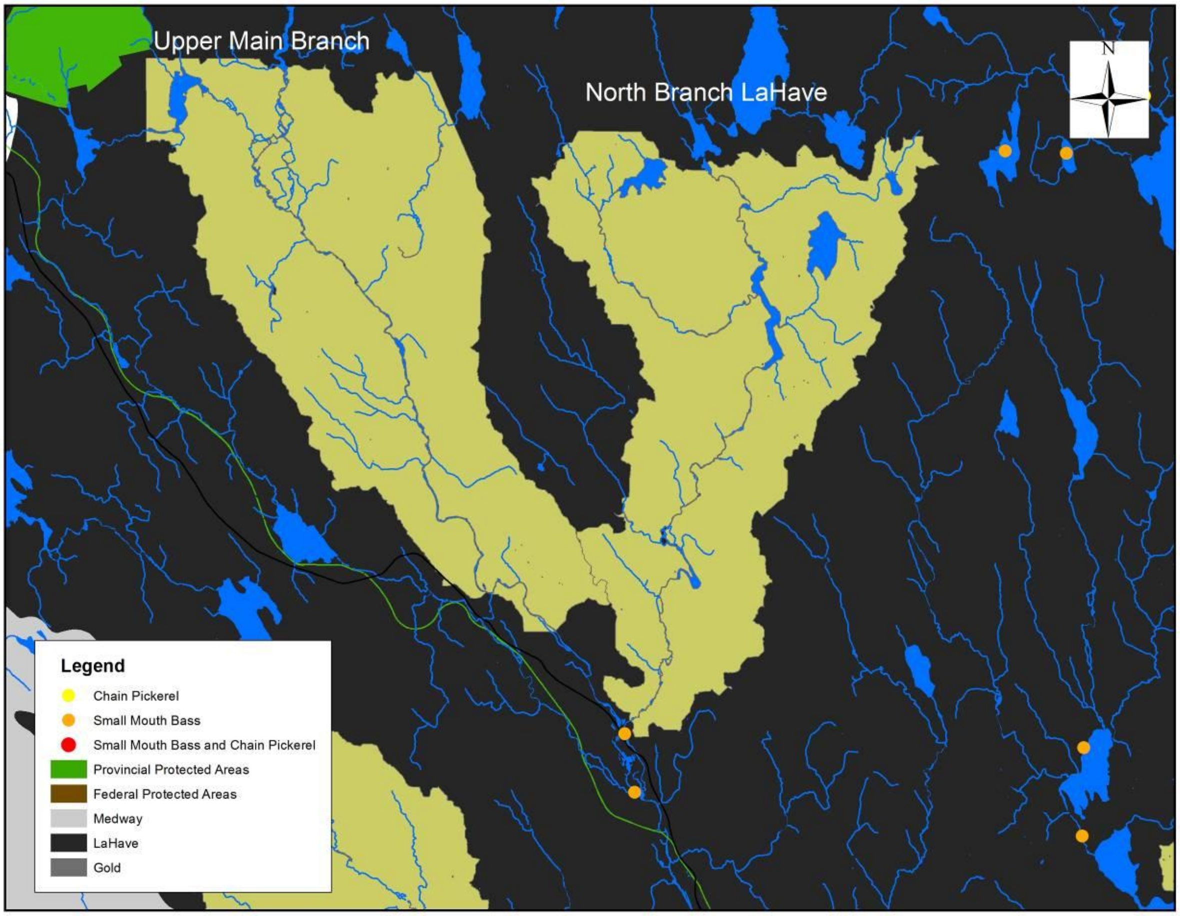


Figure 14: Location of invasive species relative to North River catchment. Catchment highlighted in beige.

L4. Upper Main Branch LaHave River (LaHave)

Forty percent of the Upper Main Branch catchment is recharge area while only four percent of the catchments are greater than 75% recharge area (Table 2). There are several recharge catchments in the Upper Main Branch catchment that are entirely within the boundaries of large land owners (Figure 15). Forty two percent of the catchment is owned by small forest companies and 7% by the Crown (Table 3). The mean (5.56) and minimum (5.02) pH indicate that the pH is moderately impacted (Table 4, Figure 3). Road access is plentiful throughout the catchment composed of several municipal roads and many private logging roads. There are no invasive species noted directly within the catchment but Smallmouth Bass are in close proximity and there are no barriers to keep them from moving upstream.

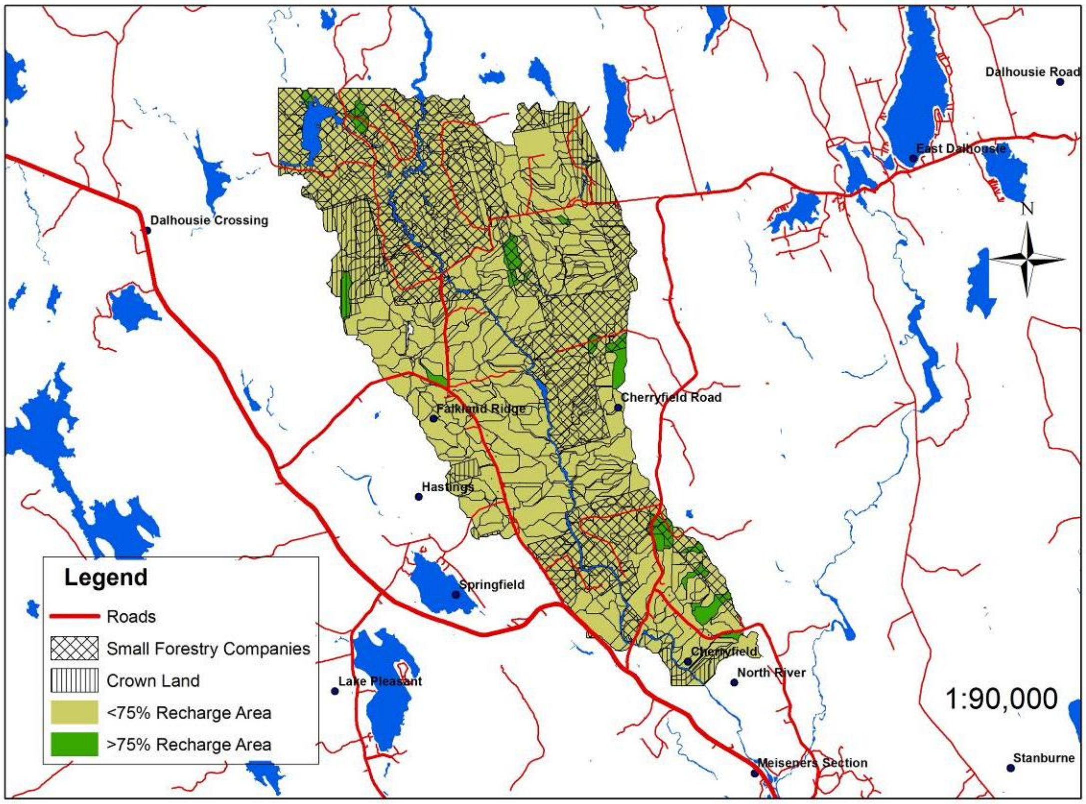


Figure 15: Catchments and property ownership within the Upper Main Branch LaHave River. Dark areas represent catchments with > 75% recharge area (slope < 5%).

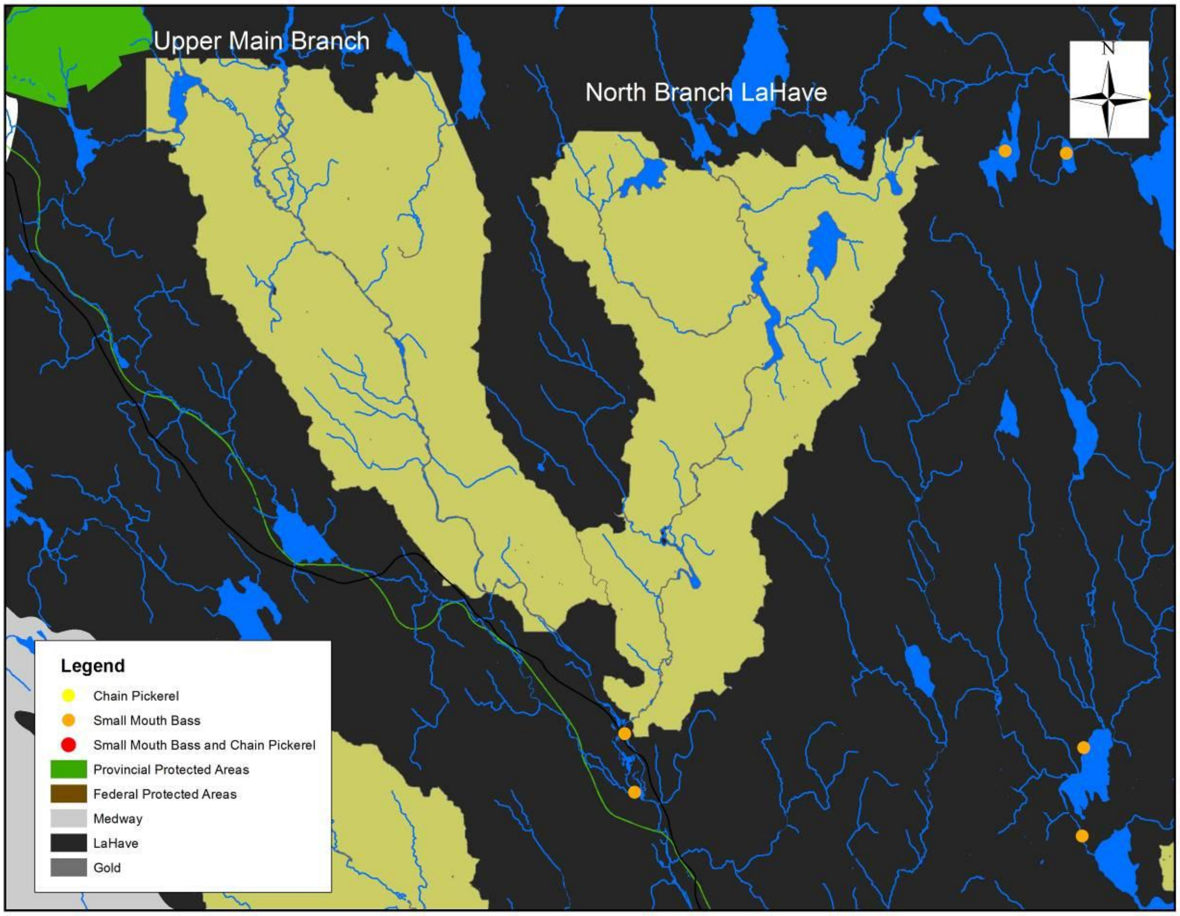


Figure 16: Location of invasive species relative to Upper Main Branch catchment. Catchment highlighted in beige.

G1. Lake Lewis (Gold)

Forty seven percent of the total catchment and 15% of the sub-catchments are covered by recharge areas (Table 3). The sub-catchments with > 75% recharge area overlap with large land parcels. The upper part of the catchment beyond Lake Lewis has several catchments that are fully within parcels of land owned by large land owners (Figure 17). There is also a site close to the outlet near Wallabak Lake where recharge catchments overlap with properties owned by large landowners (Figure 17). There are no records of Chain Pickerel in the watershed but there are records of Smallmouth Bass upstream approximately 5km (Figure 18). The mean pH (4.69) and the minimum (4.23) pH indicate that the catchment is highly impacted from acid rain and in need of rehabilitation (Table 4, Figure 3.) Road access to the recharge areas mentioned above is largely through logging roads. Gravel pits nearby can act as staging areas with permission of the landowners.

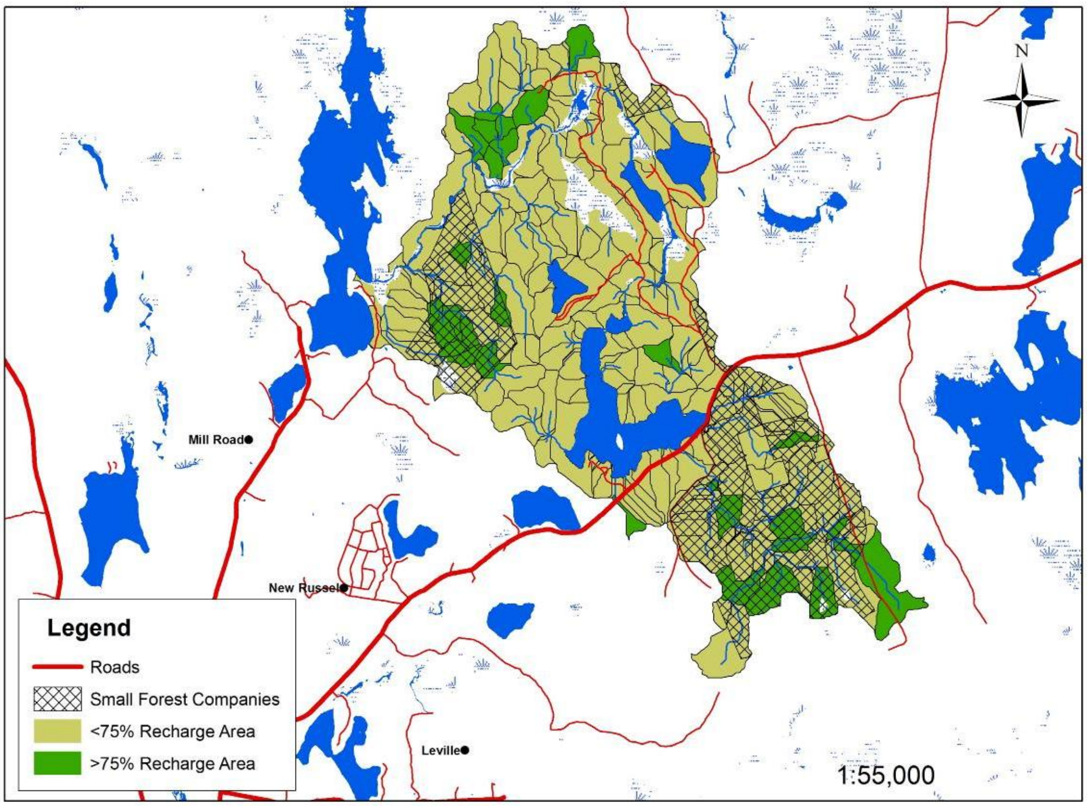


Figure 17: Catchments and property ownership within the Lake Lewis catchment. Dark areas represent catchments with > 75% recharge area (slope < 5%).

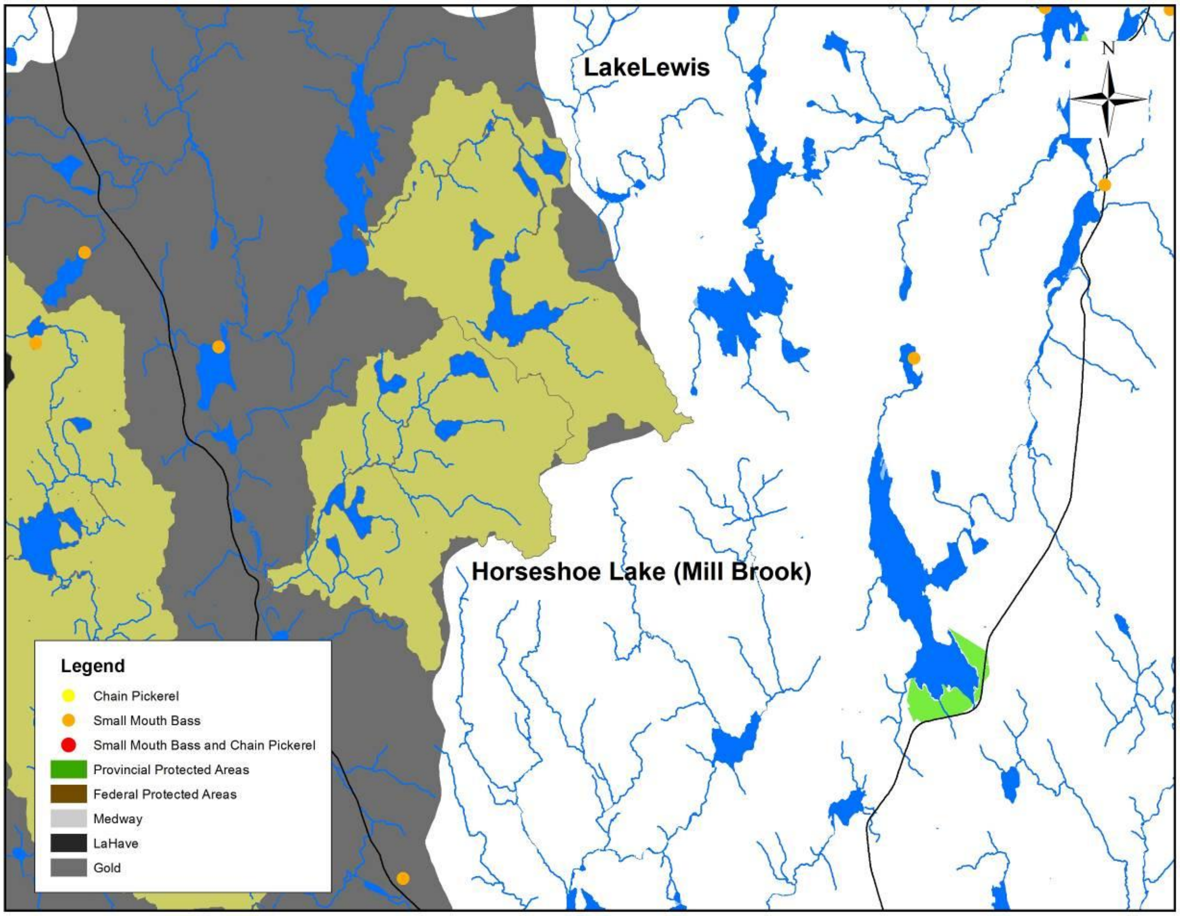


Figure 18: Location of invasive species relative to Lake Lewis catchment. It is the northernmost section of the two adjoining polygons.

G2. Larder River (Gold)

The Larder River catchment is composed of 43% recharge area but only 15% of catchments within the catchment have >75% recharge area (Table 2). There are three recharge catchments that are encompassed by large land parcels (Figure 19). This is consistent with the fact that only 11% of the catchment is owned by large landowners (Table 3). The mean pH (4.88) and the minimum pH (4.34) indicate that this catchment is highly acid and is in need of remediation (Table 4, Figure 3). Smallmouth Bass are known to exist within the catchment as well as downstream of the catchment (Figure 19). There are no Chain Pickerel sightings recorded in the Larder River catchment.

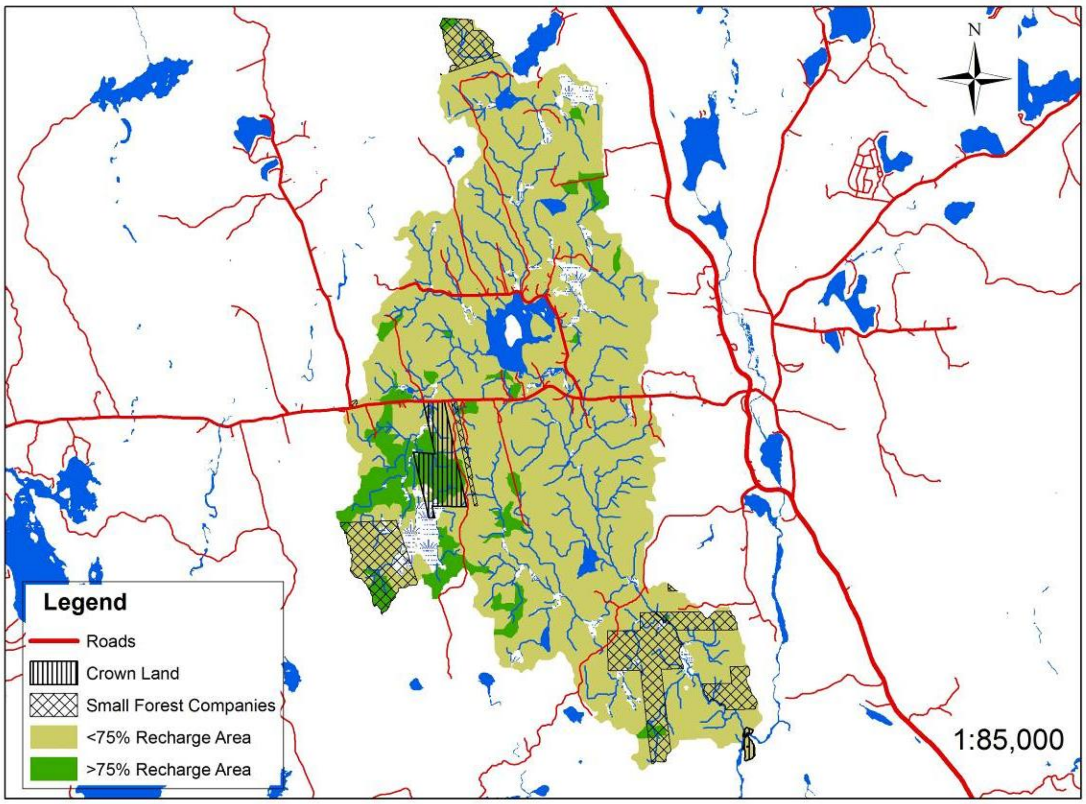


Figure 19: Catchments and property ownership within the Larder River catchment. Dark areas represent catchments with > 75% recharge area (slope < 5%).

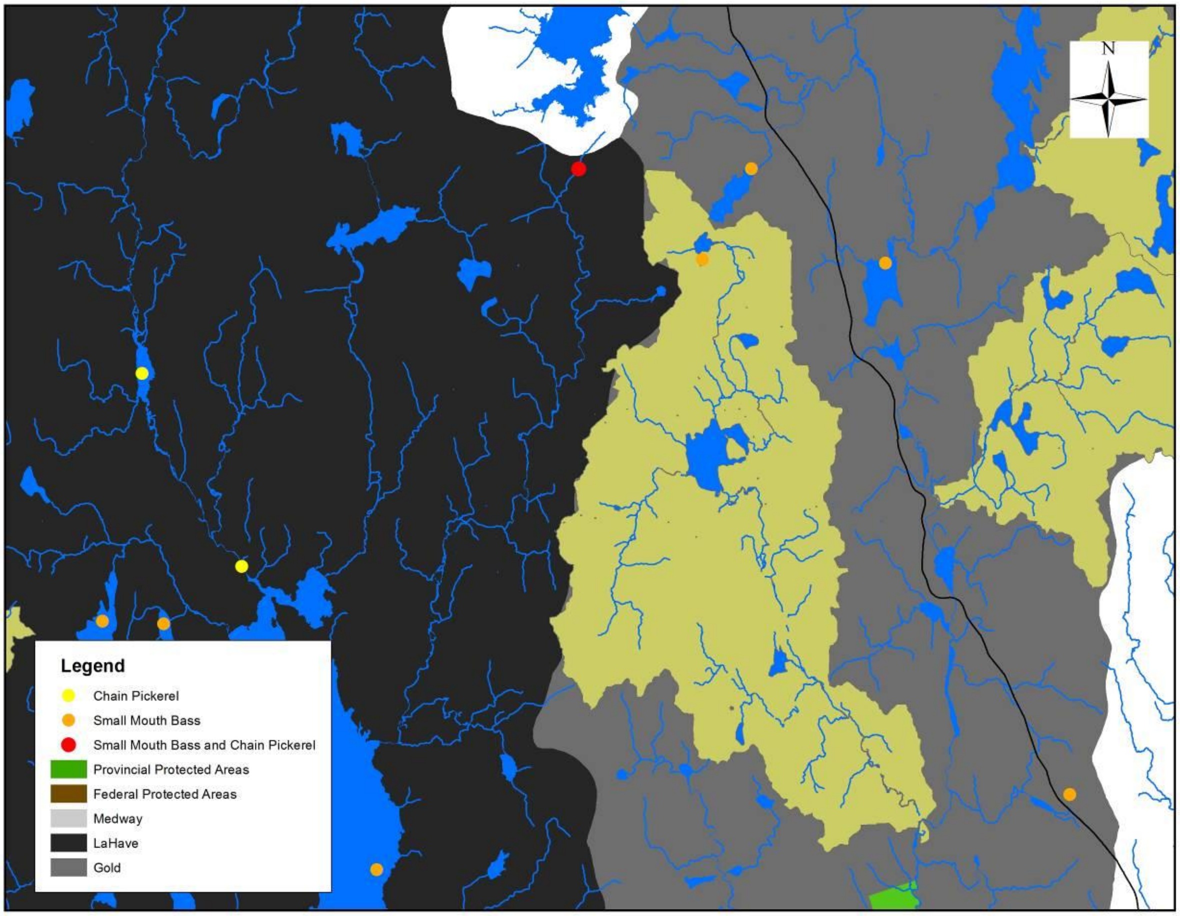


Figure 20: Location of invasive species relative to Larder River catchment. Catchment highlighted in beige.

G3. Beech Hill Brook (Gold)

Beech Hill Brook has half of its area covered by recharge area and 21% of catchments have >75% recharge areas (Table 2). Seventy one percent of the catchment is Crown land. Most of the catchments with >75% recharge area are on Crown land (Figure 21). Road access in the catchment is by municipal roads with some logging roads as well. The largest recharge areas can be accessed by municipal roads and a large gravel pit west of Beech Hill Lake could act as a staging area for lime. No invasive species are known to be in close proximity to this catchment (Figure 22). Smallmouth bass are the only invasive species know near this catchment and are located approximately 17km upstream north of the Horseshoe Lake (Mill Brook) catchment (Figure 24). The mean pH (4.71) and minimum pH (4.69) of this catchment suggest that it is acid impacted and in need of remediation (Table 4, Figure 3).

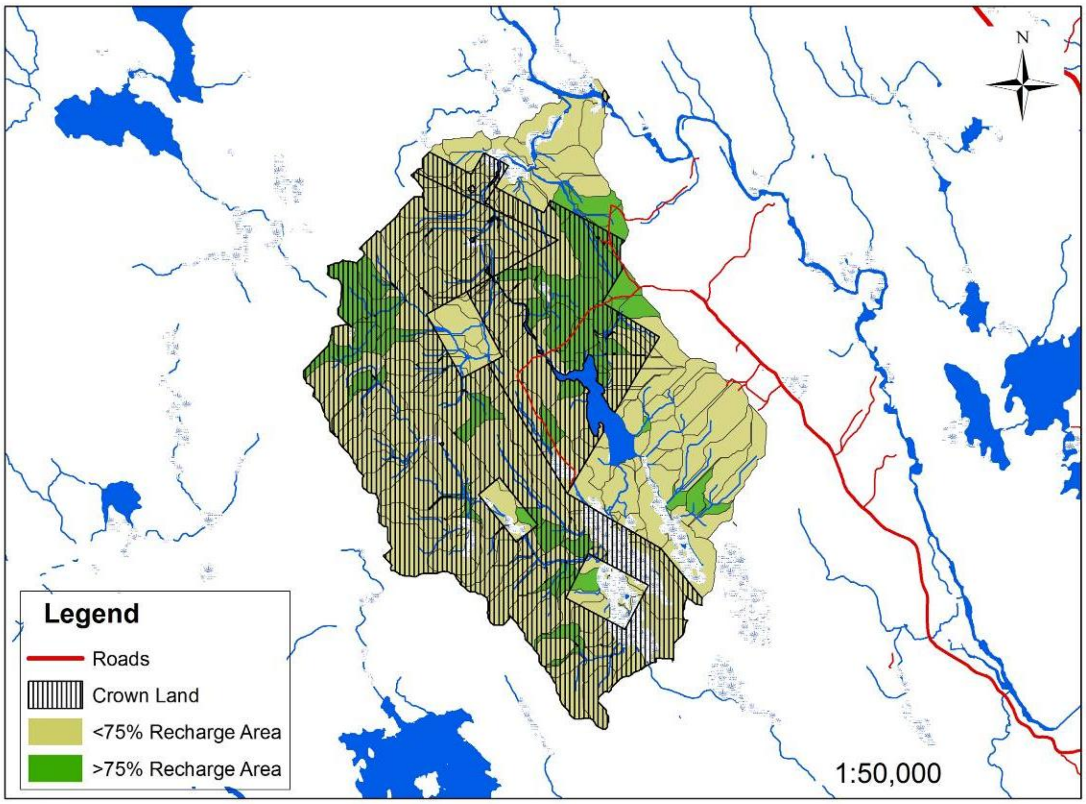


Figure 21: Catchments and property ownership within the Beech Hill Brook catchment. Dark areas represent catchments with > 75% recharge area (slope < 5%).

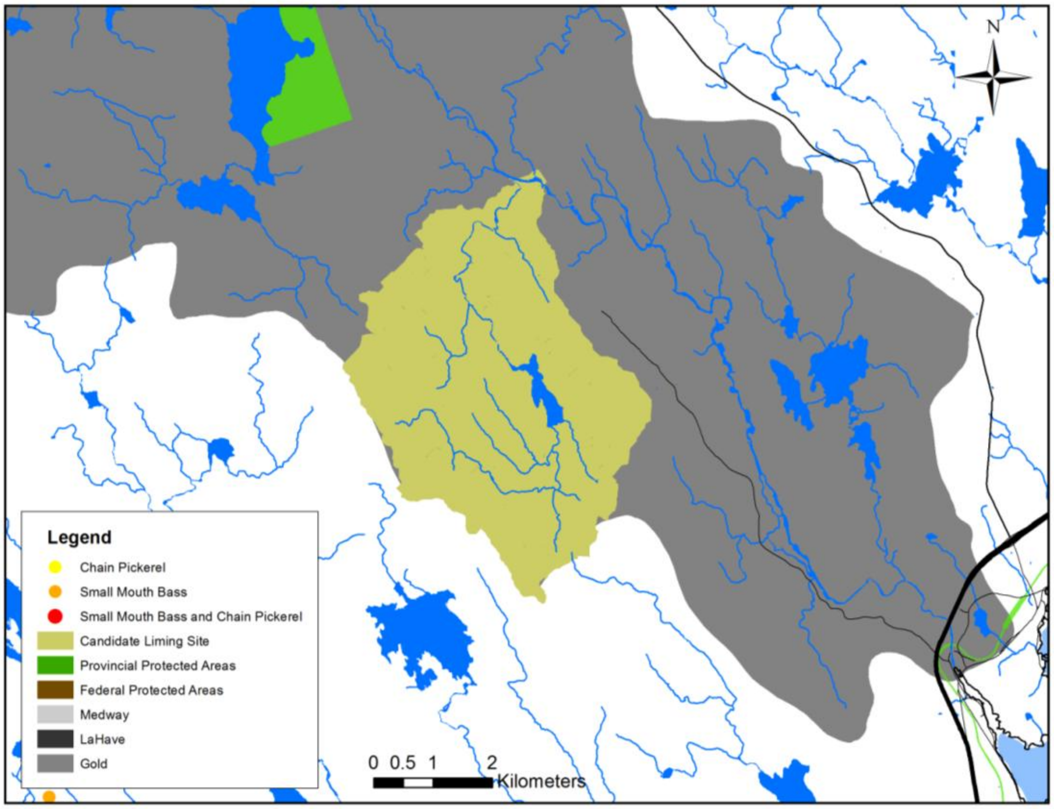


Figure 22: Location of invasive species relative to Beech Hill Brook catchment. Catchment highlighted in beige.

G4. Horseshoe Lake (Mill Brook) (Gold)

Horseshoe lake has the lowest proportion of recharge area of all candidate sites (34%) and only 9% of catchments have >75% recharge area (Table 2). Only 2.3% of land is owned within this catchment by large landowners (Table 3). A small area in the northeast and a small area in the southwest have recharge catchments that overlap with large landowners (Figure 23). The mean pH of this catchment (5.63) and the minimum pH (4.95) suggest that while it is not as impacted as other candidate sites it is a good candidate for remediation (Table 4, Figure 3). Access via municipal roads is abundant within the catchment with additional private trails and logging roads potentially giving access (with permission) to the recharge area. Agricultural field may lend themselves to staging areas for lime with landowner permission. Smallmouth Bass have been recorded above this catchment on the Gold River within approximately 5km (Figure 24).

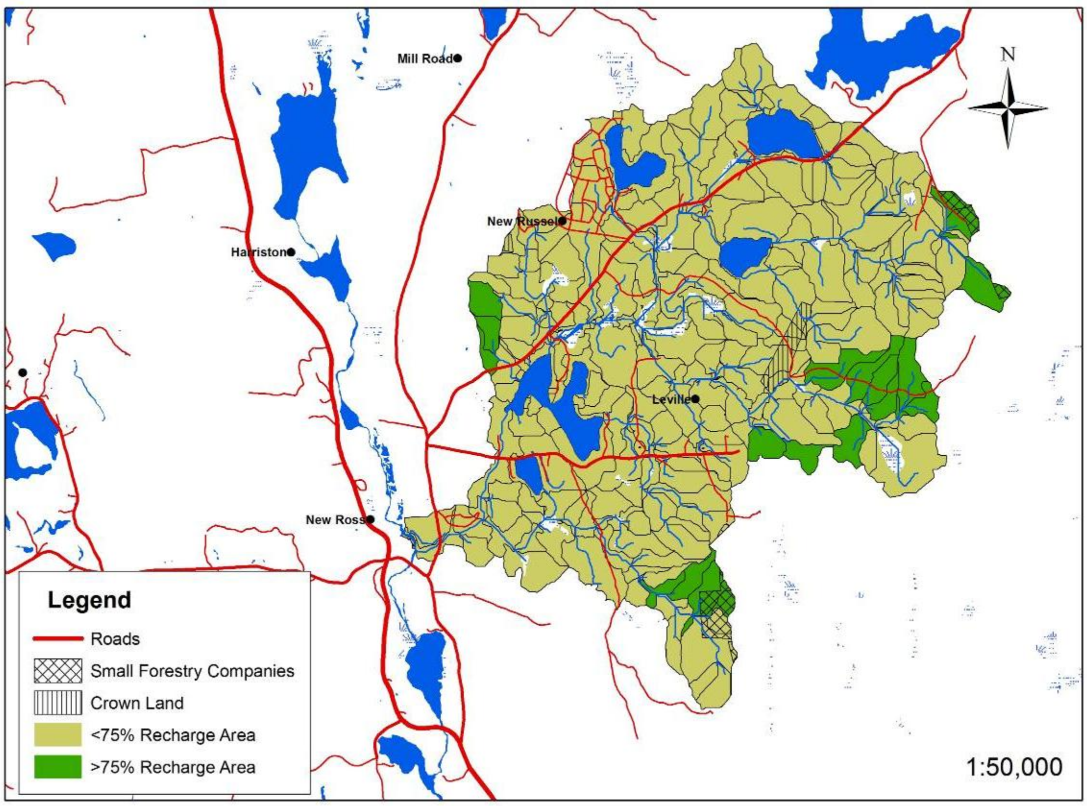


Figure 23: Catchments and property ownership within the Horseshoe Lake (Mill Brook). Dark areas represent catchments with > 75% recharge area (slope < 5%).

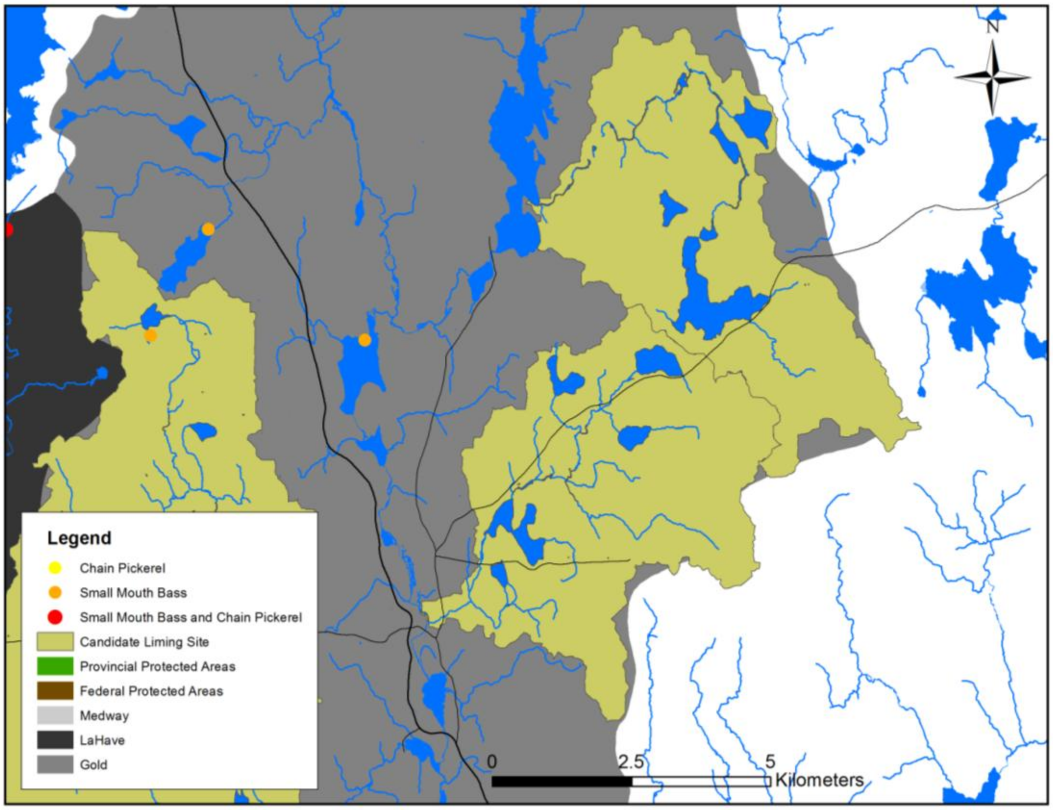
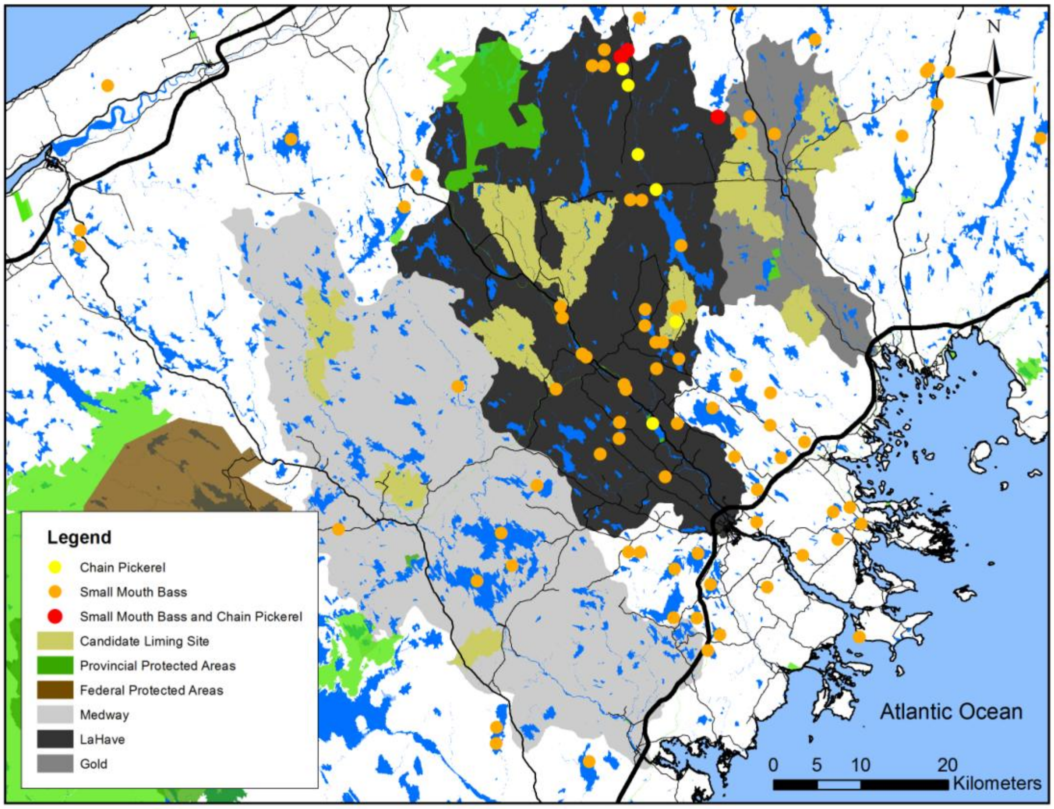


Figure 24: Location of invasive species relative to Horseshoe Lake (Mill Brook) catchment. It is the southernmost section of the two adjoining polygons.

The mobility of invasive species via human transportation or through waterways means that they must be considered on the macro scale. While they are not considered in the scoring of each sight they must be considered subjectively before any future terrestrial applications of lime. The locations of invasive fish species (Figure 24) show that the LaHave River watershed is the most impacted while the Gold and Medway River have only records of Smallmouth Bass. The restrictions and merits of barriers and fish passageways must be considered for both salmon and invasive species.

All sites were ranked relative to each other based on the proposed criteria (Table 5). The top five sites from the scoring exercise (Table 5) are: Beech Hill Brook, Gold River; West River, Lahave River; Fifteen Mile Brook, Medway River; North River, Lahave River; and Lake Lewis, Gold River.

Hindar (2005) notes that pH levels above 5.4 should support self-reproducing populations of Atlantic Salmon while levels between 5.4 and 4.7 will produce negative effects and values below 4.7 are associated with lost populations of salmon.



All boundaries are approximate. Geographic data courtesy of NSDNR. Fish Records courtesy of NS Fisheries and Aquaculture, Bluenose Coastal Actio
Department of Fisheries and Oceans and local fishermen.

Figure 25: Locations of invasive fish species in the Gold LaHave and Medway watersheds and surrounding areas.

Table 5: Table of values for terrestrial liming suitability score.

Site Name	Recharge Rank	Large Landowner Rank	Minimum pH Rank	Invasive Species Score	Distance to Watershed Outlet Rank	Salmon Presence Rank	Score	Rank
Lake Lewis (G1)	6	5	9	10	3	2	35	5
Larder River (G2)	3	3	8	4	9	2	29	10
Beech Hill Brook (G3)	9	10	6	10	10	2	47	1
Horseshoe Lake (Mill Brook) (G4)	2	1	4	10	6	10	33	6
West River (L1)	10	7	11	4	11	2	45	2
North Branch LaHave River (L2)	4	2	9	0	7	10	32	7
North River (L3)	6	6	7	10	5	5	39	4
Upper Main Branch LaHave (L4)	1	8	3	10	5	2	29	10
Fifteen Mile Brook (M1)	11	9	1	10	8	2	41	3
Westfield River (M2)	5	4	5	10	2	5	31	9
Alma Lake (Medway Lake) (M3)	6	11	2	10	1	2	32	7

Note: Tied scores account for two ranking spots (e.g. two sevens take spots seven and eight).

As noted in the summary for this site the Beech Hill Brook catchment has easily accessible Crown land that overlaps with recharge areas. Salmon were caught in the middle of the catchment (MTRI 2009). Beech Hill Brook has mean (4.71) and minimum (4.69) pH values that indicate that it is in need of remediation in order to sustain salmon populations.

West River has similar features but no salmon records in the middle of the catchment. Salmon were observed only at the mouth of the catchment. This could suggest data deficiency for the middle of the catchment or a blockage on the lower reaches of the catchment. West River has the lowest minimum pH (3.98) of all candidate sites and the mean pH (5.05) also indicates that remediation is necessary for self-sustaining salmon populations. Invasive species exist within this catchment.

Fifteen Mile Brook has a relatively healthy pH rank and according to Hindars' criteria it could support self reproducing populations of salmon. Salmon records are only for the mouth of the catchment and no sightings have been recorded further into the catchment.

The North River has only a few areas where land owned by large landowners overlaps with recharge areas. It is also lacking in salmon records from above the outlet of the catchment. The mean pH (5.52) indicates that it could support self-reproducing populations of salmon but the minimum pH (4.42) indicates that remediation is necessary in order to avoid any negative effects on the salmon population.

Lake Lewis has salmon records in the middle of the catchment and the mouth of the catchment. Lake Lewis has mean (4.69) and minimum (4.23) pH values that both indicate that remediation measures are necessary to avoid negative effects on salmon populations. The low "distance to watershed mouth" rank combined with salmon records implies that even though this catchment is at the top of the primary watershed salmon are still travelling the long distance to get there.

Recommendations for Monitoring

Hindar (2005) recommends a full chemical monitoring program that measures the efficacy of the liming strategy to produce satisfactory water quality. No detailed guidelines are given for a monitoring program. Monitoring of the sites is crucial to determine the effectiveness of terrestrial liming in Nova Scotia where it has never been attempted before. Water quality sampling sites should be established before the project begins and access to those sites should be secured via land or water. In order to determine the effect of the lime application on water quality we recommend that four water sampling sites should be established (at a minimum):

1. Within the catchment where lime will be applied
2. Immediately downstream from (but outside of) that same catchment
3. At the first downstream meeting of the river that leaves the catchment area
4. In the main branch of the main river in the watershed (Gold, LaHave or Medway)

Further sites can be established if budgets allow but these three are the minimum needed to assess the effect of the terrestrial liming. Control sites are also recommended (if feasible) within a different catchment but within the same watershed where no mixing of surface waters will occur with the catchment(s) being limed (i.e. an upstream or disjunct site).

We recommend that water samples should be collected before the application of terrestrial lime (preferably in the late summer or fall) to establish baseline levels of water quality. The lowest pH values of the year generally occur in September and October (Clair et al. 2007). Samples should then be collected within a month after the application of lime and then on a regular schedule after that. The frequency of sampling should be similar to other studies conducted but is likely to be dictated by budgets. In the face of restricted budgets annual collection of samples (preferably in the late summer or fall) would be adequate for tracking the effects of the lime application without documenting the effects of the seasonal variations. If this is the case the annual collection of samples should take place in a consistent manner (i.e. the same week each year).

The study will present a good opportunity for local community groups to partner with academia. While the project is on a scale (20+ years) that exceeds most post-graduate terms of study, shorter term studies during the initial years may provide a greater insight into the more immediate effects on forest plants, mosses, and soil chemistry. While these things have been included in some European studies, they have not yet been documented in Nova Scotia (Clair and Hindar, 2005).

If cost for helicopter application is excessive, alternative measures could be taken to lime a small catchment. Lime could be applied through the forest using handheld spreaders by a group of volunteers or behind all terrain vehicles or snowmobiles during the winter. While this might take more time to get full coverage, it might be done at a lower cost than aerial spreading. The recommended dosage of lime for catchment liming is between 5 and 10t/ha (Clair and Hindar, 2005). Using alternative application methods could be acceptable as long as the recommended dosage of 10t/ha is met with confidence. Several large landowners were contacted in the process of writing this document. Freeman's Lumber Company indicated that it was interested in liming on its lands. Abitibi Bowater and NSDNR have expressed interest in the project but need more information.

Acknowledgements.

The authors would like to thank Ashley Noto for organizing communications and meetings for the project. MTRI would also like to thank its partners in this project that shared data in order to enhance the outcome:

- Bluenose Coastal Action Programs (BCAF), for water quality data and collaboration with anglers.
- The Medway Salmon Association for invasive species and salmon records.
- Queens County Fish and Game Association for invasive species and salmon records as well as information on connectivity issues and blockages.
- Nova Scotia Department of Fisheries and Aquaculture for the use of invasive species records.
- Tom Clair of Environment Canada for guidance and expertise.

References

Clair, T and A. Hindar. 2005. Liming for the mitigation of acid rain effects: A review of recent results. Environmental Review 13: 91-128

Clair, T., Dennis, I.F., Scruton, D.A. and M. Gilliss. 2007. Freshwater Acidification research in Atlantic Canada: a review of results and predictions for the future. Environmental Review 15: 153-167.

Hindar, A., 2005. Recommended Liming Strategies for Salmon Rivers in Nova Scotia, Canada. Norwegian Institute for Water Research.

Mersey Tobeatic Research Institute (Lavers, A., Belliveau, A., and K. Rowter.) 2009. Recommended sites for terrestrial liming to improve salmonid habitat in the Medway, LaHave and Gold watersheds.

Appendix 1: Letter sent to large landowners

Dear ______

As you may be aware, the salmon and trout populations of Nova Scotia have been severely impacted through the acidification of our watersheds. Pollution from other areas of North America and the lack of natural rock containing high amounts of calcium in this area have created water quality conditions that can impact fish and fish habitat; specifically Atlantic salmon and Brook trout.

To ensure that we keep our salmon and trout populations healthy in Southwest Nova, options to improve water quality and fish habitat are being assessed by a number of organizations from non government organizations and river guardian groups, to federal government agencies. An option for increasing the buffering capacity of our soils and our freshwater systems is the application of lime either directly on the soil, referred to as Terrestrial Liming, or directly into the watercourse, which is often done through a timed-release dosier.

The Mersey Tobeatic Research Institute has been working in coordination with Environment Canada and the Nova Forest Alliance to devise a site selection tool that factors in a number of criteria in delineating areas for the application of lime. Within this project, our focal watersheds are the Gold, LaHave and Medway watersheds; watersheds in which your company currently operates. Terrestrial Liming hinges on co-operation with landowners where the lime will potentially be spread.

We'd like to be able to meet with you, at your convenience, to discuss this project in greater depth to gain a better understanding of the role of large landowners in the context of a liming project. Please contact me at (902) 682-2371 for more details and to arrange a meeting date. We'd be more than happy to come to your offices if that works best for your schedule.

Also, feel free to check out our website for more project details:

www.merseytobeatic.ca/projects-freshwater-liming.php