CRITERION 3.0

Conservation of Soil and Water Resources

Preamble

Local Level Indicators

3.1a Percentage of Harvested Area with Significant Soil Disturbance Resulting in Loss of Site Productivity (Soil Displacement, Erosion, Compaction, Impaired Drainage and Loss of Organic Matter)

3.1b Changes in Land Use Patterns by Individual Watersheds that have an Impact on Water Quality

3.1c Adherence to Canadian Water Quality Guidelines (Freshwater Aquatic Life, Drinking Water, Recreation, Agriculture and Industry)

3.1d Percentage of Watershed Area in Recent Cut Condition

3.1e Percentage of Harvested Area Affecting Nutrient Export

3.1f Status of Riparian Zones within the FMF Across the Landscape

3.2a Degree of Implementation of Guidelines For Soil and Water Protection

3.2b Implementation of Guidelines for Forest Class Road and Crossing Construction and Maintenance

References

"Soil and water are essential components of forests, sustaining the functioning and productive capacity of forest ecosystems. Criterion 3 discusses the conservation of soil and water resources. The primary reason for soil conservation is the maintenance of the living substrate for forest stands, whereas water conservation is important for the provision of potable water for humans and wildlife and the provision of suitable aquatic environments for plants and animals. Measures that maintain the quantity and quality of soil and water within and through forested ecosystems are addressed by this Criterion."

- CCFM (1997)

PREAMBLE

Criterion 3.0 – Conservation of Soil and Water Resources is one of six (6) criteria developed within the Montreal Process and subsequently adopted by the Canadian Council of Forest Ministers. A modified version (with fewer indicators than originally approved by the Montreal Process) was chosen by Fundy Model Forest as a means to evaluate the sustainability of forest management practices at the local level. Mrs. Jane Tims chaired meetings at which eight studies were approved and funded by the Soil and Water Conservation Subcommittee responsible for administering Criterion 3.

Started in 1997-98 the studies have attained varying levels of progress in identifying, quantifying and evaluating different indicators. This report refers to progress in these studies, some of which are considered complete, with final reports, while others still have knowledge or information gaps that need to be addressed. The indicators identified have, in some cases, been quantitatively described and are applicable to field conditions. Indicators such as these are used to describe Best Management Practices (BMPs). Several studies are involved in generating benchmark data for comparison with data gathered after certain silvicultural operations. Some of these studies are incomplete, though their work is continuing. Certain studies are involved in developing sampling protocols and, in some of these, monitoring of water quality, as affected by silvicultural activities, is to be continued. Useful interim conclusions have however, been generated from the available information. The investigations conducted by various researchers involved in this group, in general, have been very productive. The work should be continued in the future for the benefit of the partners of the FMF, and forestry in general.

Indicator 3.1a

Percentage of Harvested Area with Significant Soil Disturbance Resulting in Loss of Site Productivity (Soil Displacement, Erosion, Compaction, Impaired Drainage and Loss of Organic Matter)

Management Planning Objective - Maintain quality and quantity of soil and water resources

Justification for Selection

Preservation of soil and water resources is a prerequisite for sustainable forest management. Both soil and water quality may deteriorate to a varying degree as a result of forest harvesting. Less obviously, soil quality may also be lost under a forest cover of unfavorable species composition.

In the early regeneration phase, following forest harvesting, soil quality may be reduced by:

- compaction resulting from the movement of heavy equipment;
- erosion, following mineral soil exposure;
- loss of organic matter by mechanical action and accelerated decomposition at increased soil temperature;
- loss of nutrient reserves and accelerated leaching, resulting from slash removal in whole-tree harvesting, and
- road-side delimbing.

Change in forest cover type, including the introduction of predominantly shallow rooted species, may adversely affect water balance and nutrient cycles, and thereby gradually lower soil quality.

Harvesting of trees in a stable forest ecosystem is a severe perturbation that is bound to shock and affect equilibrium in the ecosystem, and the nature of regeneration and development of a subsequent forest. With the advent of modern machinery the disturbance of equilibrium extends to below ground portions of the ecosystem. This fact was recognized during the earlier phase of the FMF, and a number of projects were supported to investigate soil disturbance during harvests and its effects on site quality. Soil benchmark sites were also established to facilitate evaluation of soil disturbance as indicators of different forest management practices.

Data Sources

Projects undertaken in the Fundy Model Forest, including soil mapping, monitoring of benchmark soils and surveys of soil disturbance following harvesting and site preparation.

Monitoring Protocol

Some variables identified as useful for monitoring and evaluating include the following: off-road traffic pattern, determined by intensity (number of passes) and density (total area covered) of machine movement, intensity and extent of rutting, amount and distribution of logging slash, displacement and loss of organic matter, presence of chipping residue, frequency and intensity of soil erosion, accumulation of forest floor organic matter (slow nutrient cycling if excessive), and classification of forest floor.

Baseline Results

Figure 25 shows the interactions between eight tree species with respect to nutrient levels and aluminum tolerance. These species are commercially important in this region including the Fundy Model Forest area. In the Acadian forests of this region there is a definite sequence of species succession involved in the development of different stands. After the removal of trees, either by humans or due to natural causes like fire and insect epidemic, pioneer species (mainly aspen) colonize the area and condition the site for eventual succession by softwood.

jP – jack pine
bF – balsam fir
bS – black spruce
eL – eastern larch
wS– white spruce
tA – trembling aspen
wB - white birch
wP – white pine

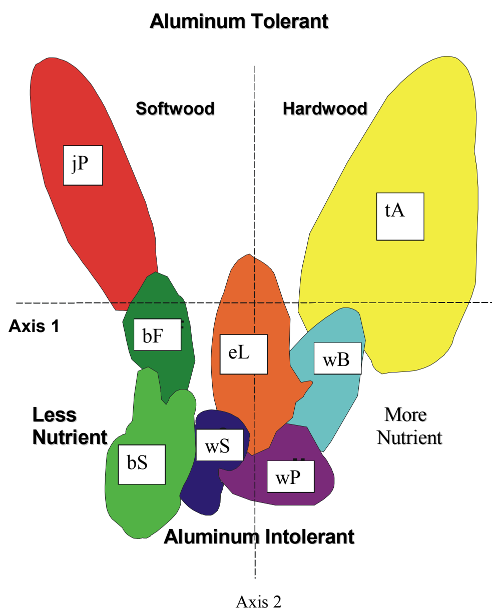


Figure 25. Delineation of tree species in the Acadian Forest based on interactions in the nutrient dynamics between trees and soil (Mahendrappa, M. K., and C. M. Pitt, 2000).

The majority of forests in this region consist of a mixture of softwood and hardwood species, which implies a need to maintain hardwood and softwood components in the stands. Every species has its niche that reflects its requirements for, and tolerances of, various soil, drainage, and temperature conditions. The sequence of stand development, the composition of the stands and the site requirements of different species are a function of synergism in the nutrient cycling between trees and soil. Mixed wood stand composition in particular is determined by the interactions among tree species. These interactions are guided by nutrient cycling processes in the soil.

The results from two projects, in particular, that address soil quality are presented below.

Benchmark Soils Project

Organic matter accumulation on the forest floor decreases, and nutrient concentrations increase, with increasing amount of hardwood in the forest canopy. Organic matter is lost in accelerated decomposition after clear-cutting and regained after canopy closure in the plantations. Accelerated decomposition of organic matter following cutting is associated with increasing pH and nutrient concentrations. Organic matter decomposition and nutrient release were retarded at the majority of black spruce plantation sites compared to sites of jack pine plantations of comparable age.

Soil Disturbance Survey

The amount and distribution of logging slash varied, according to the method of harvesting. Traffic patterns also varied with method of harvesting, with low density but high intensity traffic resulting from the shortwood system, employing processor and forwarder. In contrast, traffic was least intensive, but covered the largest proportion of land where trees were extracted for chipping. Thick deposits of chipping residue delayed re-vegetation and killed or retarded planted trees. Rutting was most prevalent under the shortwood harvesting system. Surface organic matter was displaced frequently, but on patches too small to threaten future productivity. Mineral soil exposure was limited regardless of harvesting method. Incipient and minor erosion, originating in rutted soil, was detected on cut blocks within landscapes of marked relief. The effects of traffic on sites were notable with respect to slope and drainage in this survey (Figure 26). As slope increased there was less area affected by heavy traffic, since numerous passes by heavy equipment are not made on such sites. On the other hand, there is greater disturbance on level ground since there is greater use of heavy traffic patterns when there is little to no slope. The opposite is true for light traffic methods of harvesting. Traffic is considered light in a random single pass, whereas heavy traffic is that which creates a major trail with numerous passes.

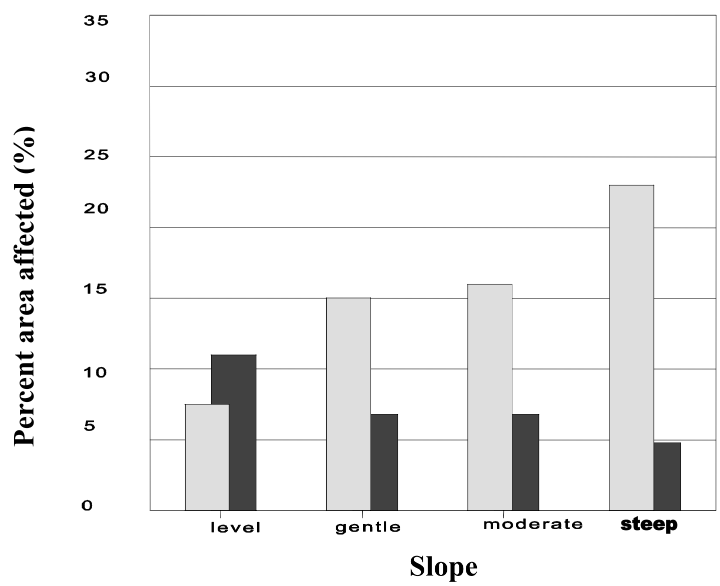


Figure 26. Effects of light and heavy traffic (percent of area affected) in relation to varying degrees of slope.

Soil disturbance is not excessive under present methods of harvesting in the FMF. However, concern is expressed over uncontrolled movement of harvesting equipment, unnecessarily increasing soil compaction and erosion. Fortunately, the erodibility of soils in the surveyed area is generally low and the vegetation of the region is resilient, responding to the disturbance of harvesting with a rapid growth of ground cover species and establishment of intolerant hardwoods. Reestablishment and quality of the succeeding forest will be adversely affected where chipping residue is deposited in thick layers. The large reduction of logging slash at hardwood sites after whole-tree harvesting is also of concern. Sustainability may be questioned under these conditions. It is well known, as has been demonstrated by the benchmark soils project, that nutrient cycling is slow and productivity low in coniferous forests with a high black spruce component on poorly drained soils. The condition is not only not remedied, but may further deteriorate when such sites are customarily planted to black spruce. A solution may be found in managing such sites through an increased diversity of compatible species, but no easy remedies are available at this time.

Best Management Practices

Soil conservation in forested areas can be accomplished not only by building roads and bridges cautiously to reduce loss of soil through erosion but also by implementing proper forest management practices. Some of these practices include harvesting with machinery appropriate for the site conditions and season of operation. Careful site preparation for plantation establishment also helps to conserve the soil resource.

The importance and significance of the need to match tree species to appropriate site is something that is not well understood. Planting of nutrient-demanding species on a nutrient poor site is certainly not going to be a productive venture. Conversely, planting a species that does not require a nutrient-rich site on land that supported nutrient demanding species, is counter productive. For example, planting jack pine on a productive site can lead to extensive acidification of the site and loss of nutrient reserves from the site. Because of the resulting deterioration of site quality it may not be possible to reintroduce the species that was originally present. Thus, it is extremely important, for sustainable forest management, to match the species to an appropriate site. The term Sustainable Forest Management (SFM) in this case should be considered synonymous with protection (conservation) of site quality.

Specific BMPs that will be effective in management planning to conserve soil quality include:

- Planning movement of harvesting equipment to minimize soil compaction, rutting and erosion.
- Scheduling operations to avoid cutting during wet seasons on land of low relief and soils with impeded drainage.
- Limiting whole-tree harvesting of hardwoods to the dormant season and prohibiting whole-tree harvesting of softwoods on low-quality sites.
- Limiting the thickness of chipping residue to 10 cm or less.
- Retaining volunteer species to contribute 15% or more to the stocking in a single species plantation.
- Aiming for maximum tree species diversity in the regeneration of former softwood sites with ericaceous ground cover.
- Applying forest site classification methods

Functionality and Application

This indicator (soil condition) can be measured and repeated annually and will reflect adherence to BMPs. Following best management practices will ensure the management planning objective of maintaining soil and water quality and quantity is met.

Southern New Brunswick Wood Co-op addresses the indicator of soil condition specifically through a policy to clear cut harvest no more than 2.0% of total productive forest on sites with slopes greater than 20%. The area of roads constructed in the 20% slope class is to be less than 1.0%.

J.D. Irving, Limited maintains soil and water quality by meeting objectives and targets developed through the ISO14001 certification standards program. In particular these objectives and targets are aimed at reducing the impacts of such conditions as rutting, siltation, and aquatic habitat destruction. These conditions are mitigated through the company's BMPs of designing harvesting prescriptions, systems, methods and schedules that consider environmental impacts.

Indicator 3.1b

Changes in Land Use Patterns by Individual Watersheds that have an Impact on Water Quality

Management Planning Objective - Maximize percentage of watershed in forested condition to reduce cumulative effects of disturbance

Justification for Selection

Many land use practices influence water quality. A watershed is the entire drainage area of all the surface and subsurface water that runs into a stream, lake, or groundwater area. A watershed therefore represents the most logical planning unit for water quality monitoring. To understand the processes that influence the water quality in a watershed, knowledge is required of land use and land cover. Note that all human activities that occur on the earth's surface, except perhaps for those in polar regions, are unavoidably performed in watersheds.

Data Sources

- Information compiled by NBDNRE on forest inventory (forest stands, water bodies and non-forest land classes) and line features (roads and streams).

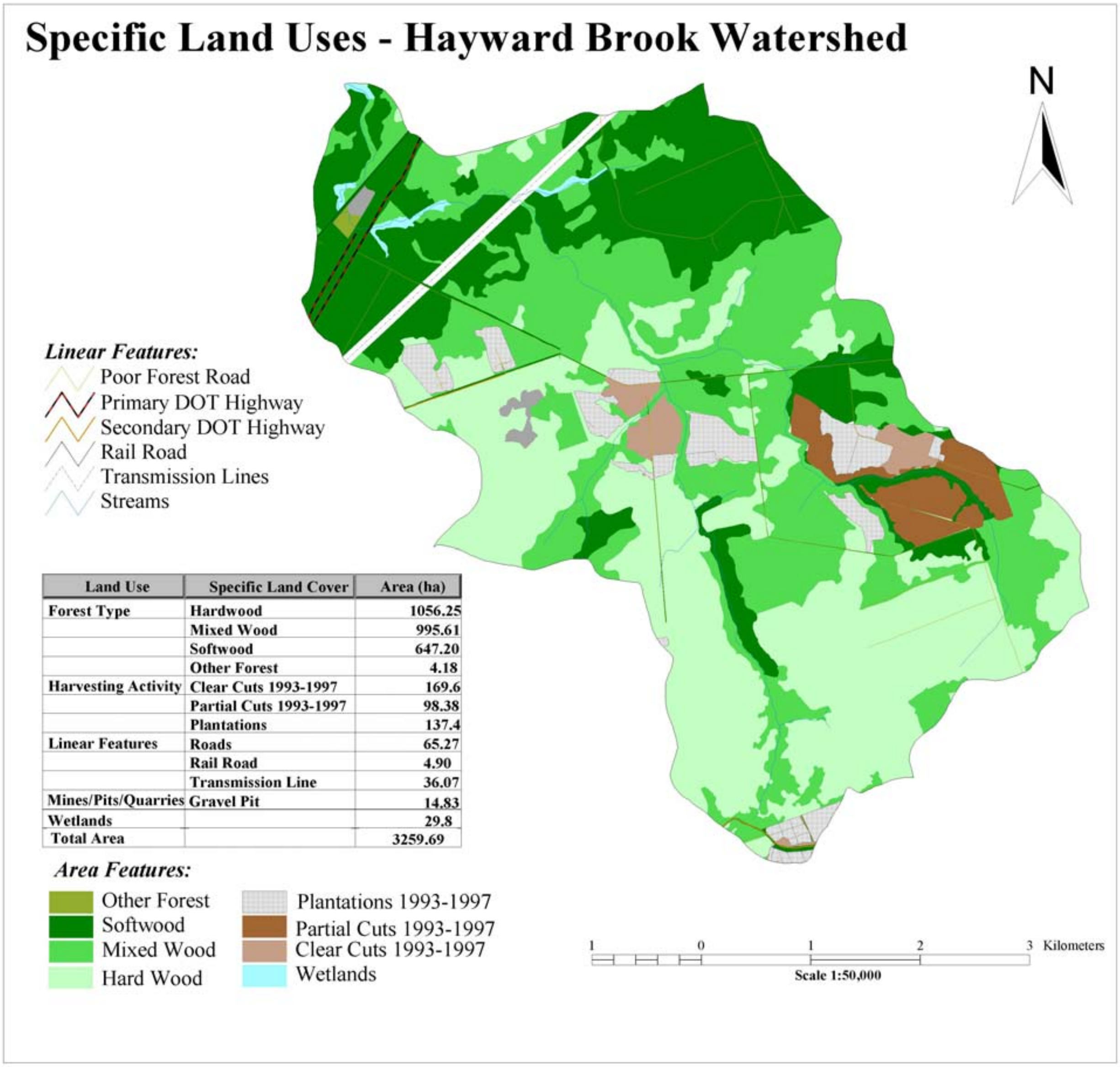
- Information from J.D. Irving, Limited on harvested and plantation areas.
- Information from NBDoT about the new highway Route 1: Saint John to Moncton, and the new Fredericton to Moncton highway project.
- Earlier information on Washademoak Lake (Manley, 1997).

Monitoring Protocol

Land use practices within any given watershed have an impact on water quality. Land use patterns can be identified from classification, summarization and presentation of geographic information systems (GIS) land cover features (i.e. 1993 GIS Forest Inventory). Categories of land use from the GIS can be produced to show their relation to hydrographic features.

Baseline Results

Using the 1993 digital GIS forest inventory, land use categories were determined for the entire Fundy Model Forest (FMF). Figure 27 (MacLaren, 1998) shows a sample of the different types of land use in one area of the Fundy Model Forest – the Hayward Brook Watershed. Table 12 (second page following) shows land use categories for the Fundy Model Forest, with associated BMPs to address the indicator and reduce the potential effects of disturbance.



Land Use	Specific Land Cover	Area (ha)
Forest Type	Hardwood	1056.25
	Mixed Wood	995.61
	Softwood	647.20
	Other Forest	4.18
Harvesting Activity	Clear Cuts 1993-1997	169.6
	Partial Cuts 1993-1997	98.38
	Plantations	137.4
Linear Features	Roads	65.27
	Rail Road	4.90
	Transmission Line	36.07
Mines/Pits/Quarries	Gravel Pit	14.83
Wetlands		29.8
Total Area		3259.69

Figure 27. Land use within the Hayward Brook Watershed.

Table 12. Land use area in the FMF and associated best management practices.

Land Use	Specific Land Use	Area (ha)	BMP	Tools/Techniques	Prevention
BMPs described here are associated with the major land use categories of agriculture, harvesting activity, and roads.					
Agriculture			Permanent vegetative cover	Used with activities such as: irrigation, pesticide application and animal waste storage	Prevents runoff; filters sediment and nutrients before reaching water
	Cultivated/Pasture	41653.74	Store animal waste away from rainfall and runoff	Plastic garbage can with lids or composters; wooden or concrete storage sheds; lined trenches	Decreases amount of bacteria and nutrients reaching water source
	Tree Crops	1639.57	Grazing practices	Fences; livestock crossing and water facilities	Minimize amount of water in contact with bacteria from livestock
			Suitable pasture	Animals graze at higher areas than water features; keep grazing away from wet fields	Keeps animals away from wet fields; minimizes erosion
			Responsible application of pesticides	Consider proximity to watercourse, surroundings and weather	Prevents contamination of water and leaching of pesticides through soil
		43293.31			
Harvesting Activity	Clear Cuts 1993-1997	3768.82	Sediment control devices	Check dams, straw bales, silt fences and sediment traps	Keeps sediment out of the stream system
	Selection Cuts 1993-1997	1428.18	Implementation of streamside management zones	Strip of unused land between water features and forestry operations	Controls erosion and protects wildlife habitats; acts as a barrier
	Plantations 1993-1997	3630.51	Silvicultural strategies	Responsible application of pesticides/herbicides; consider surroundings	Minimizes soil compaction and erosion
	Rights of Ways	0.78	Consider tree canopy height	Maintain canopy within 20% of natural range unless even-age management is appropriate	Reduces impact of rainfall falling on the soil
	Winter Roads	0.85	Wildlife tree management	Leave trees with special characteristics standing in riparian areas	Provides wildlife habitat; adds coarse woody debris to the stream system
			Pre-harvest planning	Consider slope, soil, organic matter, proximity to water and weather	Can prevent negative impacts to the environment
		8829.14			
Roads		5673.91	Minimize stream crossings	Knowledge of area's water features	Minimizes damage to forest and water features
			Installation of structures	Culverts, cross ditches, water turnouts, broad-based dips	Allows for good drainage
			Locate trails before harvesting	Build on grades less than 10%	Minimizes unnecessary compaction and erosion of soil
			Strategic placement of log landings	Log landings should be logged first	Minimizes number of times trail is travelled
			Best placement of logging roads	Locate roads allowing for natural drainage	Keeps roads from washing out; minimizes rutting.

The following land use categories do not have separate BMPs associated with them. BMPs which apply here are included with the broad land use categories (agriculture, harvesting activity and roads) listed above.					
Other Linear Features	Rail Roads	258.18			
	Transmission Lines	1097.92			
		1356.10			
Forest Type	Hardwood	104649.76			
	Mixed Wood	112376.97			
	Softwood	108216.81			
	Other Forest	11393.48			
		336637.02			
Mines/Pits/Quarries	Mines	236.00			
	Pits/Quarries	576.99			
		812.99			
Other	Air Strips	39.38			
	Barren Land	20.03			
	Rock Outcrops	18.90			
		78.31			
Occupied		5164.47			
Burns		166.32			
Wetlands		10947.06			
Water		6305.89			
Total		419264.52			

Best Management Practices

Some of the broad land use categories (agriculture, forestry, road construction) have been designated for further analysis for their impact on water quality. Once land use practices having adverse effects on water quality are identified, a best management practice can then be implemented to curb the impacts of a particular land use. A visual analysis of agricultural activities, forest harvesting techniques and road construction activities was performed to determine the potential effects on water quality and then each was associated with specific BMPs that could address negative impacts. These suggested BMPs were listed previously in Table 11. BMPs are derived from a number of sources. These include a brochure produced as a result of a report on the Washademoak Lake and its watershed (Manley, 1997), SNB's manual for private woodlot owners, J.D. Irving, Limited's BMP manual, and regulations set out by NBDNRE.

Functionality and Application

Using the same monitoring protocols as above, future patterns can be determined when the next aerial photo interpretation block is acquired for the FMF area in 2003. This will result in the subsequent production of a GIS map with attributes that can be used for land use mapping. A ten-year time series of changing land use percentages can be used to establish an observable trend over time. If negative trends are detected, best management practices (BMPs) can be implemented to rectify problems.

If the detection of more subtle changes is desirable, remote sensing technologies can be used for tracking on a yearly basis. Acquisition of Landsat TM7 imagery can be done annually to conduct a classification that will match the broad land use categories isolated from the GIS map-based attributes.

Managers can address the management planning objective through monitoring the prescribed patterns that are implemented on the landscape and adopting changes and practices that might be necessary to address water quality issues.

Indicator 3.1c

Adherence to Canadian Water Quality Guidelines (Freshwater Aquatic Life, Drinking Water, Recreation, Agriculture and Industry)

Management Planning Objective - Meet Canadian Water Quality Guidelines in the Fundy Model Forest

Justification for Selection

There is a need for clean water to fulfil societal demands to support different uses such as maintaining ecosystem function and human needs. Canadian Water Quality Guidelines (CCREM, 1987) have been established as part of a national initiative to represent a standard across Canada. These guidelines help to ensure the protection of aquatic health and drinking water supplies as well as addressing recreational, agricultural and industrial activities.

Water quality is essential to our well being and to all life that water sustains—including fish and wildlife species. Our appreciation of the aesthetic value of aquatic habitats also depends on water quality. These areas are fragile in nature and potentially subject to degradation by land based activities.

Data Sources

- Watershed Groups: Kennebecasis Watershed Restoration Committee, Petitcodiac Watershed Monitoring Group, Washademoak Environmentalists (Manley, 1997), and Hayward Brook Watershed Study
- Water quality: NB Department of Environment and Local Government (NBDELG)
- Monitoring agencies: Environment Canada (EC)
- Industry related sites: Potash Corporation of Saskatchewan
- Macro-invertebrate sampling sites: Grand Lake & Continental Lowlands ecoregions
- Canadian Water Quality Guidelines

Monitoring Protocol

Various organizations within the Fundy Model Forest (FMF) area undertake surface water quality monitoring. The data collected by these groups along with the baseline monitoring conducted by the provincial and federal departments of environment represent a wealth of information. These organizations follow sampling protocols used by the Department of Environment and Local Government (DELG) and by Environment Canada (EC). Chemical analyses are carried out at the certified laboratories of these departments. The FMF has accessed this established network of water sampling collections to determine the water quality within its boundaries and identify possible gaps in the sampling distribution for future monitoring.

Baseline Results

Surface water sampling data were gathered from the various monitoring groups, agencies and industries within the FMF (McLaughlin, 2000). The data cover the five major watersheds of the FMF (Canaan, Belleisle, Kennebecasis, Petitcodiac and Fundy Composite) (Appendix 5). Results indicate a limited number of sampling sites within the Belleisle and Fundy Composite regions and a need for future sampling on the Canaan Watershed (for which some data are now available in a new report; Rickard, 2001).

Macro-invertebrate assessment of water quality

Eight macro-invertebrate samples were collected by kick net from 30 randomly selected sites from the portion of the Grand Lake Ecoregion lying within the Fundy Model Forest (Chiasson, 1999). In addition pH, oxygen, specific conductivity and water temperature were assessed at each site. Macro-invertebrates were identified to Order for a sub-sample count of 300 organisms per sample. An analysis was used to determine if a correlation existed between land-based activities and macro-invertebrate indices.

Certain species of macro-invertebrates are used as indicators of water quality as they are most sensitive to habitat disturbance (Chiasson, 1999). They are Ephemeroptera, Plecoptera, and Trichoptera, hence the %EPT index (Figure 28).

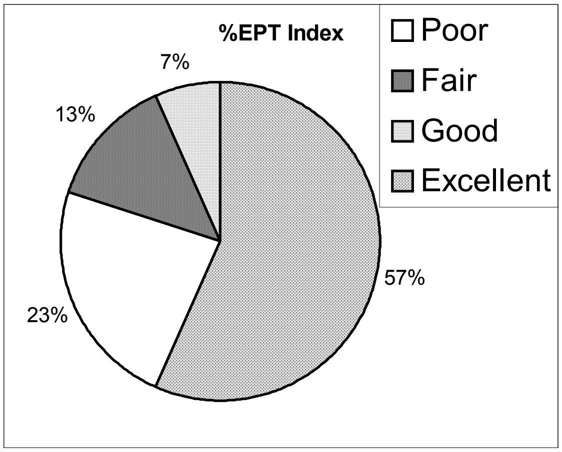


Figure 28. %EPT water quality index from the Grand Lake Ecoregion using macro-invertebrates as indicators of water quality (Chiasson, 1999).

Of the thirty sampling sites examined, 23% were below the reference site conditions and were classified as poor. An analysis revealed no correlation with forestry practices, but a correlation did exist with agriculture practices. Field observations suggested a relationship between inadequate riparian zones and sedimentation in the streams. Restoration of streamside vegetation, installation of digger logs and removal of sediment input are suggested as remedial measures.

Best Management Practices

Best management practices for the maintenance and protection of water quality have been supplied from numerous projects that have taken place in the Fundy Model Forest. The following projects have contributed to the promotion and implementation of various BMPs for preserving and protecting water quality.

Forestry Best Management Practices and Water Quality Video -Fundy Model Forest
Forest Best Management Practices for the Maintenance of Water Quality in the Fundy Model Forest is included in a report by John C. Jewitt, 1996.
BMPs were also compiled in the form of a brochure for public use, following the Washademoak Lake-Canaan River Watershed Study (Manley, 1997).

Functionality and Application

There is a need to determine the water quality status within the FMF to establish a baseline for future reference. Recent and historical water quality data compiled by McLaughlin (2000) should be analyzed, and compared to a previous study conducted by Jewett (1995). This would help determine the current state of the waterways, establish baseline levels, and verify adherence to the Canadian Water Quality Guidelines.

It is deemed unnecessary to establish a water quality sampling regime for the FMF, where many partnering groups and agencies conduct such sampling as part of their mandate. This information can be easily accessed and further analyzed to answer the FMF's needs.

Standards, protocol and sampling design developed for use on the FMF land base may surpass those of the Canadian Water Quality Guidelines. This indicator of water quality can be measured and repeated on one third of the land base as part of regulation compliance for land managers (J. D. Irving, Limited, crown land, Fundy National Park). The remaining two thirds are managed by private woodlot owners and more difficult to assess although the landowners are bound by regulation as well.

Explicit initiatives by National Parks Canada to address water quality in the area include: Fundy National Park and the enhancement of fish passage through culverts and bridges, Parks Canada actively drafting an interim policy on drinking water, and FNP's enhanced monitoring in response to the Walkerton, Ontario crisis.

Indicator 3.1d

Percentage of Watershed Area in Recent Cut Condition

Management Planning Objective - Conserve flow regimes; preserve nutrient cycles; no more than 1/5 of watershed harvested in a ten-year period in a watershed of third stream order

Justification for Selection

Forest harvesting within a watershed has been found to increase stream flows and nutrient exports. A study in central New Brunswick (Jewett, *et al*. 1995) reveals that approximately 10-12 years are required for complete hydrological rehabilitation following harvest, as judged by detailed comparisons between the before-and-after harvest stream discharge rates and watershed-wide albedo (surface reflectivity) levels. However, most of the recovery occurs within the first 4 to 5 years post-harvest.

Given that future forest harvest activity within the Fundy Model Forest is planned in a spatially explicit manner, the percentage of recent cut area within a given watershed is required to predict the potential impacts of harvesting.

Data Sources

- Harvest Coverage – JDI Freehold and Crown License 7
- Watersheds - NBDELG watershed coverage showing the major watersheds in the FMF
- Management Plan Blocking – spatial blocking plan of future harvest blocks by period
- Remote sensing change detection data for clear cuts and partial harvest areas

Monitoring Protocol

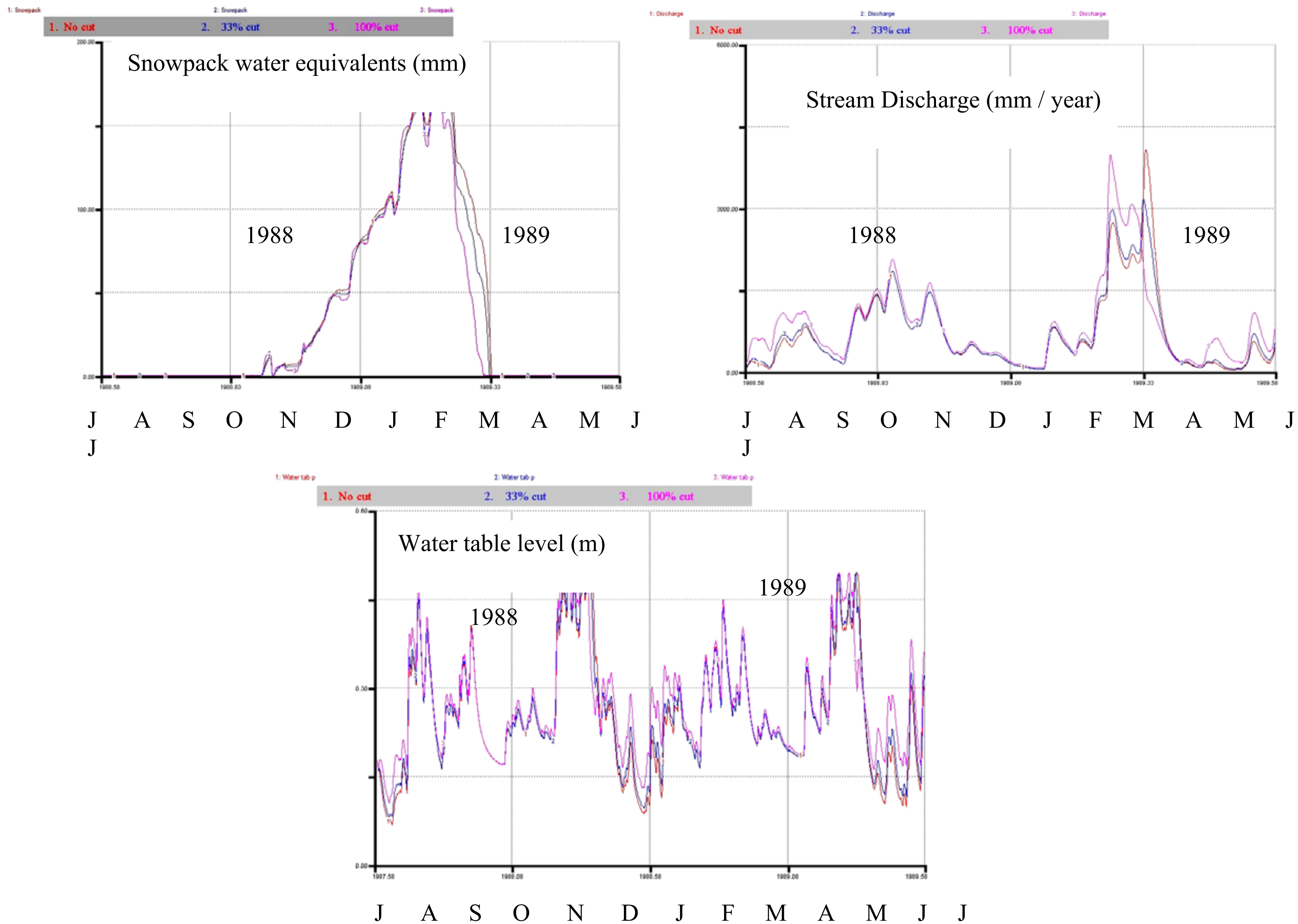
The ForHyM2 model can be used to model pre-and post-harvest water levels, snowpack depth and waterflows in primary zero to first order forest subcatchments from local daily weather records and rudimentary forest type and soil descriptions (Arp, 2000). The effects of percent basin cut can be modelled for each subcatchment as well.

Based on stream discharge records, and the extensive measurements taken for stream water quality at Hayward Brook and at Holmes Brook (N, P, K, Ca, Mg, etc.), estimates can now be made on total nutrients exported from each subcatchment. The results of doing so are documented in a forthcoming MScF thesis from UNB (Stanley, 2001).

Baseline Results

Figure 29 (next page) depicts the hydrological situation in conifer catchments cut at 0%, 33% and 100% for the Hayward Brook Watershed Study Area. Shown are snowpack water equivalents, water table depth variations in m (these need to be divided by pore space fraction of the soil substrate to get actual height variations), and stream discharge rate, as prorated on an annual basis (mm/ year). Note that clear cutting, as simulated, causes the snowpack to disappear earlier by about 2 weeks, causes the water table to rise (water table would rise more in compacted substrates), and stream discharge rates peak earlier. Even at 33%, impacts are simulated, although the impacts are much reduced.

Figure 29. The hydrological situation in conifer catchments cut at 0%, 33% and 100% for the Hayward Brook Watershed Study Area (Arp, 2001).



Best Management Practices

With the use of a Digital Terrain Model (DTM) and the Spatial Analyst extension in ArcView, zero or first order catchments can be delineated within each larger watershed (Figure 30). (See tabular results of harvest area by catchment in Appendix 6.) From this, cumulative impacts can then be calculated, subcatchment by subcatchment, based on simple routing algorithms and keeping track of nutrient concentrations and volumes of discharge per subcatchment basin.

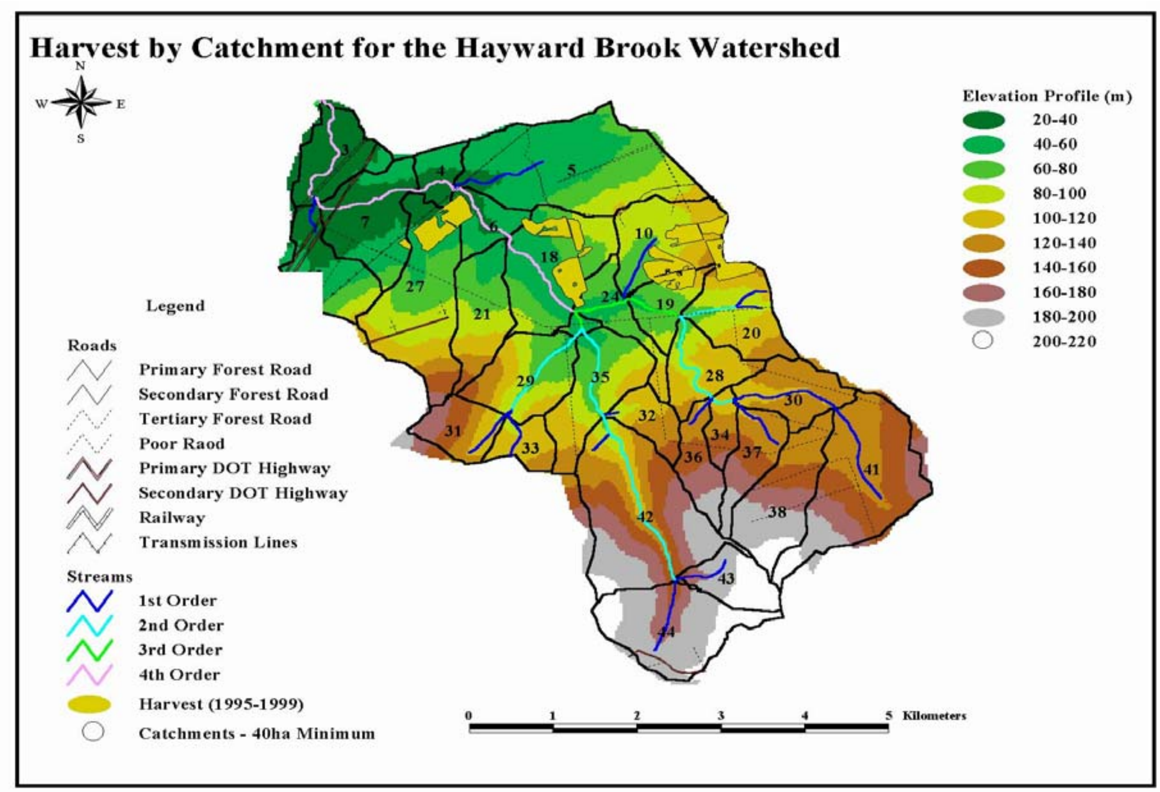


Figure 30. Delineation of harvest area in first order catchments.

Planned future harvest activity in the catchment areas can then be assessed by using the modeling process to compare hydrological impacts with past data, and with future projections, thus providing input for informed decision making with respect to likely impacts of forest harvesting on water yield.

Using this model and GIS information for the areas harvested, the potential impacts on water quality can then be calculated (modeled) for selected watersheds within the Hayward Brook experimental watershed area.

Functionality and Application

For more complete results of harvesting activities, remote sensing (RS) methods need to be employed for monitoring activities on small private woodlots. This would allow for more refined data than are provided by GIS. Further results for SNB will have to be determined from the partial harvest change detection methods established from remote sensing technology.

This indicator will facilitate land management at the watershed level. SNB Wood Co-op has undertaken a project, "Watershed-based Forest Sector Woodlot Management Planning" to attempt to establish some protocol for woodlot management planning across multiple land ownership within a particular watershed in the FMF. This indicator will be useful in spatial planning for activity in the watershed while protecting water quality.

Estimates will provide single and multiple landowners within a watershed a recommended amount of area for current forest harvest based on the previous five years of harvest. The total amount of recent cut area will be a prediction of the area of forest, which can be removed without causing a significant response in stream discharge and nutrient export.

Indicator 3.1e — Percentage of Harvested Area Affecting Nutrient Export

Management Planning Objective - Annual reduction in the amount of whole tree harvest with a target of 0%

Justification for Selection

A great deal of whole-tree harvesting is still being practiced in this region, although there is overwhelming evidence to show that such practices lead to site degradation if operations are continued for more than one rotation. In addition, if the slash is either burnt or allowed to decompose along the roadsides, the damage to the site will be exacerbated. One of the reasons for site degradation and the concomitant decrease in yield during subsequent rotations is the excessive loss of nutrients exported from the sites. Carbon sequestration and the balance of various nutrients associated with the organic matter will also be deleteriously affected by whole-tree harvesting. This will be an important indicator that can be quantitatively used for evaluating the sustainability of various harvesting methods.

Data sources

During Phase I of the FMF various studies were conducted to benchmark the status of nutrients and soil types in the model forest area. The results from these studies will constitute valuable data for the present study. Those studies include:

- Trends in soil and Vegetation Nutrient Contents for Sites Included in the forest Biomass Growth Project (Keys and Arp, 1996)
- Soil Disturbance Progress Report (Arp, 2000)
- Soils map of the Fundy Model Forest, (Fahmy, and Colpitts, 1995)
- Potential Forests of the Fundy Model Forest, (Zelazny, Veen, and Colpitts, 1997)

Additional data sources include:
- Harvest Coverage - GIS layer showing all harvest activity on JDI Freehold and Crown License 7
- Management Plan Blocking - GIS layer showing where future harvest blocks will be located and their associated prescriptions
- Soils - GIS layer showing forest soils according to NBDNRE –Timber Management Branch interpretation; see also Manley (1997) for Washademoak Lake soils
- Geology - GIS layer showing the bedrock geology for the FMF area

Monitoring Protocol

Trends have been shown for soil and vegetation nutrient content for sites included in the Forest Biomass Growth project (Keys and Arp, 1996) where nutrient levels in 15-20 year old black spruce and jack pine plantations approach those in mature natural stands of the same species. With greater biomass accumulation expected in plantations compared to natural stands, it is further expected that greater nutrient loss will occur at time of harvest.

Investigation into the nutrient supply and losses from intensively managed sites will be evaluated and further monitoring is required to accurately assess the nutrient sustainability of these sites.

Baseline Results

For the nutrients nitrogen (N), sulfur (S), potassium (K), and magnesium (Mg) jack pine plantations (measured at 15 to 20 years of age) are more aggressive in transforming available soil N, S, K, and Mg into biomass N, S, K, and Mg, than black spruce plantations (measured at the same age) (Keys and Arp, 1996). Planted jack pine stands measure approximately 2/3 to 3/4 the amounts of these nutrients that are normally found in the tree biomass of mature natural forest stands on benchmark sites, while black spruce nutrient content is approximately 1/3 to 1/2.

Best Management Practices

Aggressive nutrient uptake rates by plantations need to be monitored periodically. Jack pine plantations are aggressive in extracting nutrients from the soil. Black spruce plantations are somewhat slower in early growth rates, but are likely to accelerate their nutrient accumulations as these plantations approach an age of 20 years and more.

Pre-commercial thinning, with slash left on site, is likely to have a beneficial effect due to the return of nutrients to the soil, which in turn will be available to the remaining trees. Commercial thinning operations (several interventions) should each be monitored in terms of nutrient exports, and nutrients left on site. Slash (foliage and possibly also stem bark) should remain near the stump.

It is highly recommended that benchmark sites and plantations be monitored and reassessed for nutrient content in foliage, bark, stem, forest floor, and rooted portion of the mineral soil.

Results from the monitoring effort provide site-specific calibration data for simulation modeling with the ForSust and ForSVA forest productivity and nutrient cycling models that have been developed at UNB (Arp).

Functionality and Application

Achieving the management planning objective of annual reduction of whole tree harvest to 0% is a matter of choice and management planning for land managers and owners in the Fundy Model Forest. The functionality of this indicator is a matter of compliance to best management practices for the conservation of soil quality. The impacts of harvesting can be measured and BMPs implemented where necessary.

Industrial landowner J.D.Irving, Limited is managing this indicator through BMPs in which harvesting methods and processing equipment minimize product and residual stand damage. None of the company's harvesting methods use whole-tree removal (Gushue, pers. comm.). There is also an attempt to salvage timber loss caused by natural disturbances while recognizing that some downed trees must be left for biodiversity and habitat requirements.

Indicator 3.1f

Status of Riparian Zones within the FMF Across the Landscape

Management Planning Objective - An improvement in the presence and quality of riparian zone vegetation in the Fundy Model Forest

Justification for Selection

Functional riparian zones are a critical ecosystem component in terms of the aquatic health of streams. The presence or absence of adequately vegetated riparian zones can directly influence both water quality and fish habitat.

Water quality parameters such as temperature, sedimentation, and nutrient content are regulated to a large degree by healthy riparian zones. These areas provide shade, bank stability, and serve as filters for non-point source pollution that may occur due to adjacent land use activity.

The quality of fish habitat is similarly influenced in that stable vegetated stream banks provide a source of leaf litter and large woody debris (the basis of the invertebrate food chain) as well as act to keep stream widths narrow and the substrate clean.

As the width and nature of vegetated riparian zones (shrubs and trees) are physical landscape features that can be evaluated and tracked, their status is considered a valid indicator of stream health, and water quality.

Data Sources

- Service New Brunswick – enhanced hydrographic layer (Cowie, 1999) from report entitled "GIS Linkages for Water Quality Issues, Saint John River Basin".
- 1993 forest inventory GIS coverage
- Department of the Environment and Local Government (NBDELG) watershed coverages
- 1993 Department of Natural Resources (NBDNRE) line coverage
- NBDNRE enhanced wetland coverage
- Manley (1997) in report on Salmon Creek watershed of Washademoak Lake

Monitoring Protocol

To measure riparian status, the following steps were adopted: 1) Conversion of Service New Brunswick's hydrographic layer to route systems (Cowie, 1999), and conversion of NBDNRE wetlands layer for subsequent production of wetland route systems. 2) Use of aerial photo interpretation with a specific rule base to produce a table of attributes representing riparian status along the various watercourses, and 3) Integration of the attributes into the GIS for the generation of map products, graphs and tabular summaries (Appendix 7). A complete version of the above methodology is outlined in the "Status of Riparian Zones in the Anagance Watershed" (Pugh *et al*, 1999).

Baseline Results

Aerial photography interpretation of riparian zones in the FMF shows that the highest order streams (larger rivers) show the highest incidence of non-forest buffer condition (settlement and land clearing). The mid to lower order streams (smaller rivers, streams and brooks) have the highest incidence of forest cover. Of the forested buffers (Figure 31), most were comprised of mature timber. When infringement of the buffer zones in a forested environment occurred it was largely due to recent cutting. This occurred on small to mid-sized streams more than larger rivers. The most significant infringements along larger rivers are roads and railways.

Figure 31. Forested riparian zone.

Generally the nature of the forested buffers ranges from mature timber in the headwaters to alder/shrub in the mid-stretches, to a mixture at the confluence.

Relatively small amounts of regenerating stands, plantation stands and adjacent recent silviculture indicate that this watershed is healthy with respect to its riparian status. Although roads and railways are the major infringement on the larger rivers, a relatively small percentage of infringements-such as recent cut, railways, roads, etc-occur in forested areas.

The majority of non-forested buffers exist in agricultural areas among the higher order or larger streams. In the non-forested buffer environment, categories of bare, fringe and adequate were assigned (Figures 32-34). On highest and lowest stream orders in a non-forest condition, bare was the most common status of the buffer. Fringe status was more evident on the larger streams, while the areas where adequate vegetation grew tended to be along the smaller streams. Agriculture was the cause of highest incidence of infringement of all non-forest buffer conditions. This is reconfirmed by the adjacent land use patterns of agriculture, which is evident along bare, fringe, and adequate stream buffers.

Figure 32. Bare riparian status.

Figure 33. Fringe riparian status.

Figure 34. Adequate riparian status.

Best Management Practices

In the literature many BMPs have been suggested for the protection of fish habitat, as well as for forest harvesting techniques to ensure protection of stream bank stability, to guard against erosion, for filter capability, and stream crossing stability.

The effect of riparian zone management on fish community structure was studied in the Hayward Brook and Holmes Brook areas in the FMF, and BMPs were suggested for the enhancement and protection of fish communities (Chiasson, 1998).

Harvesting operations within buffer zones were also investigated in these watersheds (Krause, 1999). The BMPs recommended for forest operations address the concept that activities must not adversely affect water quality, jeopardize stability of stands, or alter stand succession. With a reduced vegetation layer at stream crossings, erosion problems could result and pose a threat to water quality and fish habitat.

Functionality and Application

Using the next set of aerial photography in 2003, this study can be repeated and comparisons made. When the initial stage is complete, compromised riparian zones in the FMF can be identified, and remedial action taken with the collaboration of the landowners. Best Management Practices could be implemented to improve the condition of any degraded riparian zone areas before the time of next measurement.

The current assessment could be compared to a second evaluation allowing a quantifiable statement to be made with regard to sustainability. Forecasting would provide managers with a tool to identify areas of concern and enable them to implement corrective BMPs in a proactive manner. The success of such actions would then be measurable in subsequent status reports.

The landowners and managers in the Fundy Model Forest are addressing the management planning objective of this indicator by employing best management practices and incorporating these into their management plans. Some specific examples of management strategies by FMF land managers are:

- Fundy National Park is discussing extending riparian buffer widths within watersheds that flow into the park,
- Pointe Wolf River Gorge has been designated as a conservation area by the province,
- SNB Wood Co-op prepares management plans based on a wood supply analysis where a treatment of selection harvest is prescribed for buffer zones with a maximum of 30% removal, and
- J.D. Irving, Limited's BMPs state that "riparian zones of a minimum width of 60 meters will be established on both banks of all fish bearing streams" (J.D. Irving Forestry Best Management Practices).

Indicator 3.2a

Degree of Implementation of Guidelines For Soil and Water Protection

Management Planning Objective - Full compliance to the standards and protocol for water quality monitoring

Justification for Selection

It is essential that policies outlined for water protection are being followed and enforced. Compliance is only a portion of total management. At this point, the FMF soil and water committee has not investigated the degree of implementation of any measures for the protection of soil.

Data Sources

- Watercourse alteration permits – NBDELG
- Pesticide applicators permits – NBDELG
- Forest Management Manual for Crown Lands
- Compliance Survey – Fundy Model Forest

Monitoring Protocol

Legislation and Guidelines for Protection of Water Quality in the Fundy Model Forest and New Brunswick (Wood, 1999) forms the cornerstone of the Compliance Survey work done by the soil and water technical group. The study was also designed to provide a sample of the kinds of activities that occur near or in streams that are regulated by laws and guidelines.

In order to sample the various watersheds, ecoregions, land use categories, land ownerships and road types, routes were selected along roads throughout the FMF. Activities along these roads were observed and measured with respect to compliance. The routes selected for study in the compliance report were representative of various sections of the FMF (Chase, 2000).

The compliance survey was designed to undertake a representative sub-sampling of activities in or near watercourses within the FMF. The activities observed and data gathered were from the following categories: 1) stream crossings, 2) agricultural, 3) industrial approvals, and 4) buffer operations.

Observations were made of activities, for which permits were issued within the last four years, and of activities which had no permits. It should be noted that many of the sites might have had permits issued at an earlier date. Greater detail of the survey is shown in Appendix 8.

Baseline Results

Of the 64 sites with permits that covered the previous four years, 69% met the conditions of compliance. There were 394 sites without permits. Of these 292 were culverts, 48 were bridges and there were 54 other activities. Table 13 shows the percentage of compliance for culvert and bridge activities without permits.

Table 13. Percentage of compliance for culvert and bridge activities without permits.

	Met requirements (%)	Minor departures from requirements (%)	Major departure from requirements (%)	Non-compliance (%)
Culverts	2	45	29	24
Bridges	71	23	4	2

Bridge activities without permits nevertheless comply with regulations, while culvert installation rarely met requirements.

It was also found that agriculture, residential, and municipal areas had a higher rate of non-compliance. There were 24 sites associated with agricultural activity of which 21 met no requirements. There were 15 sites in residential areas and none met any requirements.

Functionality and Application

The majority of Fundy Model Forest land managers including large industrial interests are obliged to follow, and are adhering to, standards set out by water quality guidelines and government regulation. There are instances however (as compliance study results show) when actions have been taken by others who carry out activities in or near watercourses without permits.

SNB Wood Co-op also has a specific mandate that the percent of land managed for soil and water protection will be maintained at 6% or 27,514 hectares. This is the area of SNB-managed land maintained in stream buffers.

This indicator can be measured and monitored as described, however the following suggestions are made in order to achieve the management plan objective of full compliance with standards and protocol for water quality monitoring:

- A letter from the Fundy Model Forest Partnership to the Department of Environment and Local Government should be written to suggest that permits include a clause requiring continued maintenance of the activity.
- There should be more follow up inspection of permitted activities by the Department of Environment and Local Government.
- Landowners should bear the responsibility for maintaining their property in agricultural or residential areas in a manner that follows a Best Management Practices approach, because of the prevailing high rate of failure to follow regulations and guidelines.
- Landowners wishing to undertake activities in or near the watercourses should obtain a permit.
- Any subsequent study should involve assessing compliance in a wider range of activities.

Indicator 3.2b — Implementation of Guidelines for Forest Class Road and Crossing Construction and Maintenance

Management Planning Objective – education strategy for land owners

Justification for Selection

This indicator was chosen because:
Roads can be identified as a major single source of adverse effects on water quality
Guidelines are available
Disruptive activities are often highly visible and may be easily dealt with

The Trout Creek Model Watershed of the Sussex Fish and Game Association developed a goal to assess potential and existing hazards to fish habitat, populations and overall water quality. It was therefore justified to conduct a watercourse crossing survey in the Kennebecasis watershed.

Data Sources

- Trout Creek watercourse crossing survey report – Trout Creek Model Watershed Committee of the Sussex Fish & Game Association
- Compliance Survey Microsoft Access database – contains water crossing survey information

Monitoring Protocol

Stream crossing areas were located using 1:12500 colour aerial photographs. Each crossing was also identified by landowner in order to obtain permission to do visual and analytical sampling. Crossings were located along tributaries and numbered from the headwaters down towards the discharge of each system. The types of crossings were also categorized. At each site stream characteristics were recorded for vegetative cover (%cover), substrate makeup (%constituent content), related evidence of erosion, approach condition, and the usage of each crossing.

Baseline Results

120 crossings were assessed on the tributaries and main stem of the Trout Creek system. Thirty-three of the 56 culverts assessed (59%) had outlet heights raised above the substrate, thus posing a problem for the migrations of salmonid species.

Vegetative cover played an important role in crossing stability. Forty-five (38%) of the crossings assessed showed depleted vegetation along their banks with grasses making up 50% or more of the cover. The loss of larger vegetation contributes to erosion. Of the crossings that were assessed, 5 showed severe erosion, 18 moderate and 47 were classified as having minimal erosion. In terms of substrate, 44 crossings (37%) had 25% substrate consisting of sands and fines. This caused many of the crossings to be unstable.

Results indicate that the Trout Creek watershed is largely composed of agricultural land, which has had detrimental impacts on the system. Loss of riparian vegetation, mining of gravel, and the use of unstable crossings have led to the current conditions. Improper construction and improper methods for maintenance of culverts and bridges have led to migration barriers to salmonid species.

Best Management Practices

As a follow-up to this study, recommendations were made and actions were taken to:

- re-establish vegetation along stream banks;
- replace unstable fording sites with stable ones;
- fence back cattle from stream banks (done to some degree);
- contact DoT about watercourse crossing problems;
- implement a public outreach and education program.

Functionality and Application

This indicator can be monitored and reported on using the sampling protocol described above. Education of the general public and small private land owners, as well as enforcement by regulatory agencies will help to improve the current conditions of crossings in the Fundy Model Forest.

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