Timber Harvesting and Forest Management Guidelines on Public and Private Forest Land in Various Watersheds in Minnesota

Photo courtesy of Mike Houser, Potlatch Corporation

2014 and 2015 Monitoring Implementation Results

A report by the Minnesota Department of Natural Resources,
Forest Management Guideline Implementation Monitoring Program
Respectfully submitted to the Minnesota Forest Resources Council

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Timber Harvesting and Forest Management Guideline Implementation on Public and Private Forest Land in Various Watersheds in Minnesota

Monitoring for Implementation 2014 & 2015

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March 2016

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Executive Summary

The Minnesota Forest Resources Council's (MFRC) *Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers,* establishes best management practices (guidelines) for timber harvesting and forest management (TH/FM) on forested lands in Minnesota. Implementation monitoring of these guidelines has been conducted on 1161 timber harvest sites across public and private forest lands since 2000. This report provides results for monitoring that occurred in summer and fall of 2014 and 2015 and attempts to assess trends in implementation levels over time.

For this reporting period, implementation of site-level guidelines were assessed on 172 sites randomly selected from within 6 watershed sample units (10 HUC-8 watersheds) in the forested portions of MN. Monitored sites had timber harvest occurring during summer of 2010 through summer of 2014. The distribution of sites among the primary ownership categories was in approximate proportion to the acres of timber harvest for each based on forest disturbance analysis for the same time window.

Overall implementation of key guidelines for this reporting period showed improvement in most areas compared to previous reports. Several key guidelines show continuous or substantial improvement when assessed at the statewide scale including RMZ management, filter strip management, retention of leave trees and snags, retention of fine woody debris on biomass harvest sites, avoiding rutting on wetland crossings, minimizing infrastructure, and coarse woody debris retention. Guidelines that demonstrate lower or no improvement of implementation include avoidance of wetland crossings, use of erosion control where needed, development of written management plans on NIPF lands, and implementation of some visual quality guidelines.

Conducting guideline monitoring at the watershed scale has proven valuable for the program by increasing understanding of the variation in guideline implementation across the state, and also increased efficiency and cost savings in the monitoring process. Implementation data at the watershed scale reveals interesting results and relationships not previously identified with statewide estimates. This additional information will help target outreach efforts to topics and audiences where best opportunities for innovation and improved implementation exist.

Recommendations for targeted outreach at the watershed scale include the guidelines with lower implementation levels mentioned above, as well as a variety of guidelines where opportunities exist within the specific conditions and operational cultures of localized watersheds. Several examples are offered where targeted outreach to land managers and loggers in specific watersheds may improve future compliance including:

- Outreach on the importance of riparian management zones to NIPF landowners in the RR watershed sample area where 6 of 7 did not meet guideline recommendations.
- Focusing on strategies for implementing leave tree guidelines in MGR where only 62% of sites met guidelines compared to the overall mean of 84%.
- Targeting outreach on avoiding unnecessary wetland crossings as well as methods to avoid rutting in wetland crossings in SUP and MH watershed sample units where over ½

of all avoidable crossings and 2/3 of all rutted crossings occurred.

Additional opportunities for improved implementation at the watershed scale are noted throughout this report. Recommendations include general introductory training for new foresters and loggers, outreach to stakeholders to increase awareness and implementation of revised (2012) guidelines, targeted training related to wetland identification to aid in avoidance of wetland crossings, and identification of situations where water diversion and erosion control practices need to be implemented. Continuing education programs, such as Minnesota Logger Education Program and the Sustainable Forestry Education Cooperative, are encouraged to continue their efforts related to these recommendations, and work to develop new educational opportunities to address the specific topics identified above.

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Introduction

This report is an update to the MFRC and forest management stakeholders on the implementation of sustainable forest management practices as required by the Sustainable Forest Resources Act (SFRA). The Minnesota Forest Resources Council (MFRC) was established under the SFRA to resolve important forestry policy issues through collaboration among a broad set of forest stakeholders. The SFRA requires the Council to develop and periodically revise voluntary guidelines for use on public and private forestland in Minnesota to minimize negative impacts of timber harvest and other forest management activities. This report summarizes the results of monitoring for the implementation of these guidelines.

The timber harvest and forest management (TH/FM) guidelines are a set of recommended voluntary practices designed to mitigate harvest-related impacts on water quality, wildlife, soil productivity, cultural resources, biodiversity, visual quality, and other forest resources. These guidelines were initially published in 1999 in the guidebook *Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers* (MFRC 1999). The guidelines have been revised twice since their inception, and new guidelines related to biomass harvesting were added in 2007. Substantial changes in recommendations related to riparian management zones (RMZs), allowable infrastructure, leave trees, and others, were made in the most recent revision (MFRC 2012). Most recently, a subset of the guidelines commonly used during timber harvesting were published in a condensed, user-friendly pocket field guide for use in operational settings.

The SFRA (89A.07, subd. 2.) requires the Minnesota Department of Natural Resources (DNR) to monitor implementation of the TH/FM guidelines on public and private forestlands. The DNR has monitored guideline implementation at over a 1,000 harvest sites since 2000 and has published six reports summarizing the findings through 2011. For those previous reports, monitoring sites were randomly selected from all harvest sites and findings were summarized to estimate statewide implementation levels. In 2013, the program was significantly modified by 1) focusing harvest site monitoring at the HUC-8 watershed scale compared to a statewide sample, and 2) incorporating forest disturbance estimates into the assessment, recognizing that the local level of disturbance and its configuration influences interpretation of implementation estimates. The overall objective of this new approach is to use the new assessment to conduct more targeted and effective education and outreach for improved guideline implementation.

The Council also recently conducted an in-depth review of past implementation levels to assess if forest resources were being protected (Slesak 2014). The review generally concluded that forest resources were being protected at current levels of guideline implementation, but several topics related to water quality, soil productivity, and wildlife were identified for further assessment and focus. This report summarizes the monitoring data for 172 harvest sites in 11 HUC-8 watersheds that were monitored during 2014-15, with emphasis on the key topics identified by the Council review. Statewide estimates calculated from the mean among watersheds are also presented for comparison to previous years and for application to statewide policy development.

Methods

This section outlines the forest cover change detection, site selection, and monitoring data collection methods for monitoring the implementation of forest management guidelines.

Watershed Sample Units

Starting in 2014, the guideline monitoring program (GMP) restructured monitoring efforts to focus on the US Geological Survey defined hydrologic unit code 8 (HUC-8) watershed scale. Sites monitored in 2014 and 2015 were selected from forest cover change detected within six watershed sample units, with each unit consisting of either a single watershed or a cluster of similar watersheds when forest management activity was low. Attempts were made to select watersheds that were concurrently being evaluated in the Minnesota Pollution Control Agency (MPCA) watershed Restoration and Protection Plan (WRAP) process. Where appropriate, results have been reported by watershed sample unit. Where no substantial difference in implementation data is observed, results may be presented in statewide summaries. The Appendix provides a series of in-depth maps and statistics related to each of the 6 watershed sample units. Future reports will focus on establishing stronger links between watersheds and implementation rates.

Throughout this document, watershed sample units will be abbreviated as follows: Mississippi River – Headwaters (MH); Lake Superior – North and South (SUP); Rum River (RR); Mississippi River – Grand Rapids (MGR); Vermillion River and Rainy River – Headwaters (VRR); and Red Lake, Red Lake River, Clearwater, and Wild Rice River (RLCW) watersheds.

Forest Cover Change Detection

Forest cover change detection was performed to 1) identify recent harvest sites for field monitoring (see below), and 2) provide overall estimates of forest disturbance by major watershed to provide additional context for field monitoring findings. Two methods of forest change detection were implemented in this reporting period. For monitoring year 2014, DNR Forestry Resource Assessment (RA) staff detected forest cover change within three HUC-8 watershed units, including: MH, SUP, and RR. For these watersheds, RA conducted change detection using aerial photographs from the National Agricultural Imagery Program (NAIP) acquired in 2010 and 2013 with focus on forest cover determined by the National Land Cover Database (NLCD 2011). Sites monitored in these units had timber harvest activity beginning in summer 2010 and up to summer 2013. For monitoring year 2015, RA staff detected forest cover change within all HUC-8 watersheds with greater than 20% forest cover, as determined by NLCD 2011, using Landsat 8 satellite images from summer 2013 – summer 2014. Sites monitored in these units had timber harvest activity between summer 2013 – summer 2014. For the six watershed sample units, RA image analysts visually inspected each area of detected forest change to refine the list of sites and modify their site boundaries as needed. In addition, RA staff provided ownership and contact information for a selection of sites (site selection procedure is described in more detail below).

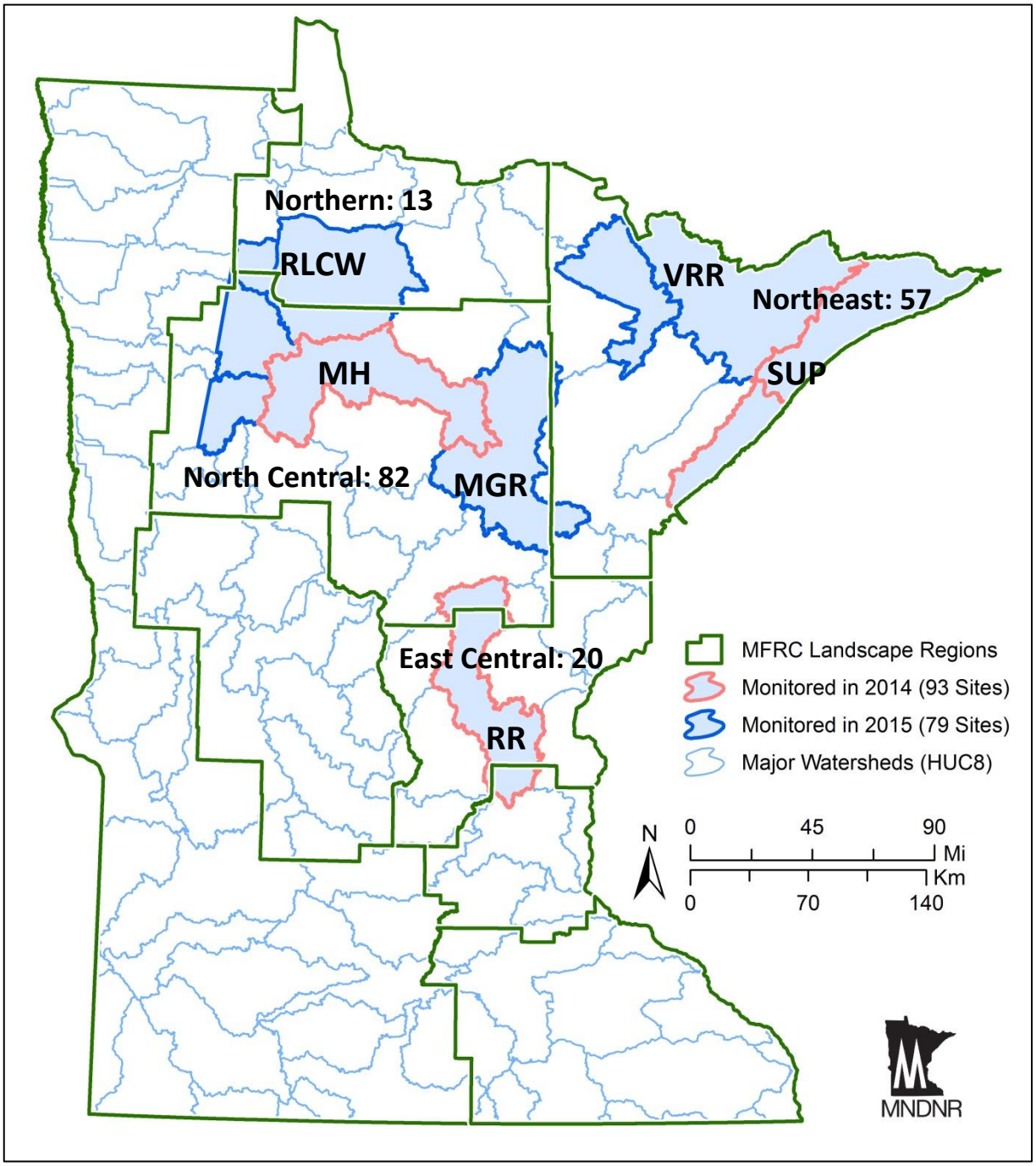


Figure 1. Watersheds where guideline implementation monitoring occurred in 2014 and 2015, and the relative number of sites per MRFC Landscape Region.

Site Selection

For both monitoring years, a subset of detected forest cover change site (and confirmed as harvest sites) were selected for monitoring. Within each watershed unit, monitoring sites were selected with effort to represent the relative proportion of harvest activity by ownership

categories. Bias was introduced into the sample population within each ownership category, to increase the number of sites with harvest activity within 200 feet of a known open water feature in an effort to monitor adequate number of sites near open water. Monitoring sites were selected from all forest ownerships. For purposes of this report, the ownerships have been grouped in the following categories: State: All lands owned by the state; County: All lands owned by a county; Federal: All lands owned by the U.S. Forest Service, Park Service, Fish and Wildlife Service, or Corps of Engineers; Forest Industry and Corporate: Lands owned by Blandin Paper, Potlatch, and Malpus and Rajala Companies; Nonindustrial Private Forests (NIPF): All privately owned non-industry or corporate lands and tribal lands.

Landowner and/or manager contact was attempted for every potential monitoring site to verify that harvest occurred within target dates, verify that harvest was completed, and secure permission to access the site. Final monitoring sites were selected from this initial pool. Alternate sites were selected to account for instances where sites had to be dropped for unanticipated reasons. A breakdown of site ownership per watershed unit is in Table 1 and site distribution across the seven MFRC landscapes is shown in Figure 1.

Table 1: Monitored watershed unit and number of monitored sites per ownership category.

Watershed Unit	Land Ownership Category					
	County	Federal	Forest Industry & Corporate Lands	State	NIPF & Tribal	Total
MH	12	4	2	6	11	35
SUP	8	8	2	8	4	30
RR	8	0	0	5	15	28
MGR	12	2	3	9	3	29
VRR	7	9	3	6	1	26
RLCW	10	0	0	8	6	24
Total	57	23	10	42	40	172

Monitoring Data Collection

For both field years represented in this report, DNR Forestry Guideline Monitoring Program (GMP) staff used monitoring protocols similar to those in the previous monitoring report (Rossman, 2011) with guideline monitoring application (GMA) software and equipment updates (ArcGIS 10.2; SurfacePro3 Tablets and Garmin Bluetooth GPS). Prior to field monitoring, GMP staff contacted agency, industry and tribal land managers to gather critical background information on the "pre-site data questionnaire" including information about timber harvest planning, harvest practices, season of harvest, and various guideline implementation strategies. An independent contractor was hired to contact all owners of potential NIPF sites to gather similar, but abbreviated pre-site information. The pre-site form provides the opportunity for landowners and managers to relate critical information on how guidelines were implemented on a site. Without this information, GMP staff and field contractors may not be aware of

specific reasoning or strategies for guideline implementation. Future program goals include interviewing loggers who conducted harvests on NIPF sites because they may be more aware of guideline implementation strategies than the landowner.

For field monitoring, a contract selected by competitive bid was administered to conduct the work. Bidding contractors were required to provide one or more teams of at least two people each, who collectively met several criteria including expertise and educational background in forestry, soil science, water resources science (including wetland delineation), and GIS and/or remote sensing skills. Contractors were also required to complete calibration training with GMP staff prior to the start of field monitoring. On-site field monitoring was conducted between June-September in both 20014 and 2015.

Monitoring contractors collected detailed information while on-site and delineated spatial features utilizing field observations, air photos, and site documentation. Data collection generally involved a ground survey of the entire site, with detailed measurements recorded for key features including leave trees, roads and landings, riparian management zones (RMZs), filter strips, surface water and wetlands, crossings, and others. On-site observations were entered into the GMA for analysis.

Quality Control

Both in-office and in-field review of site data was conducted by the GMP Coordinator on approximately 10% of monitoring sites to evaluate consistency and compliance with monitoring protocols. This process confirmed that data were being properly collected and provided useful insight for determining whether monitoring forms and field procedures needed additional modification. Where appropriate, changes were made to data based on quality control findings.

For sites without completed pre-site information, monitoring program staff attempted to gather relevant information through timber sale documents, maps and other public source evidence. Information gathered in this manner typically has gaps related to strategies used for guideline implementation because these considerations are rarely identified in supporting timber harvest documentation.

Results

Data referenced from previous monitoring reports may be found in Dahlman and Phillips (2004), Dahlman (2008), and Dahlman and Rossman (2010), Rossman 2012. See References on page 44.

Land and Water Characteristics by Watershed

The Appendix contains a wealth of information related to the characteristics of the six watershed sample units. Watershed characteristics such as frequency and types of streams and wetlands, lakes, developed acreage, and percent slope ultimately relate to the number of harvest sites triggering the need for specific BMPs or guidelines such as RMZs, filter strips, and erosion control on crossings, etc. Forest cover (including forested wetlands) varied considerably between watershed units from a high of 81% in SUP to a low of 29% in RR. Not surprisingly, RR

and RLCW had the highest percentages of crop/pasture or urban/open/barren lands at 41% and 15%, respectively, compared to 4% in SUP. These land cover types have been shown to have greater water quality impacts relative to forested land use, and both the RR and RLCW watersheds may be at higher risk of water quality degradation for this reason. In terms of water-related features, the VRR unit has the highest percent cover of lakes and ponds (20%) and is one of the units with the longest total length of rivers and streams (2245 miles). The SUP unit has the longest total length of rivers and streams (2397 miles) and the highest proportion of trout lakes/ponds and trout rivers/streams), but one of the lowest percent cover of lakes and ponds (5%). Given the high percentage of open water features and high percent forest cover in these watersheds, there is a higher chance of forest disturbances occurring near water features and presumably more riparian management zones (RMZ). Conversely, the MGR unit has one of the lowest percent cover of lakes and ponds (6%) and is one of the units with the shortest total length of rivers and streams (1101 miles). Given the high percent forest cover and the low amount of open water features in MGR, it is likely that the majority of disturbances will be relatively further away from water features. The two watershed units with the highest percent cover of emergent and open water wetlands are the RLCW and the RR units (13% and 11%, respectively), where the units with the lowest percent cover are SUP and VRR (1% and 2%, respectively). See the Appendix for detailed information related to land and water cover.

Forest Disturbances and Distance to Water Features

Forest cover change detection was done between summer 2010 – summer 2013 in the MH, SUP, and RR watershed units, and between summer 2013 – summer 2014 in the MGR, VRR, and RLCW watershed units. As a result of the longer time frame for change detection in the MH, SUP, and RR watershed units, the disturbance estimates for those units described here and in Table 2 are presented as annual averages for comparison purposes.

MH had relatively high forest disturbance compared to the SUP and RR units during the same detection period, due in-part to a high-wind storm event causing forest blowdown in July 2012. Of all the watershed units, the MH had the highest number of disturbed sites, largest total acreage of disturbance, and highest percent of the watershed area disturbed, though the average disturbance size was small (20.9 acres). The RR unit also had a small mean disturbance size, but the overall amount of forest disturbance was much lower and was the lowest of all the watershed units, which is expected with a lower percent forest cover in the watershed as a whole. The SUP watershed unit has the second highest number of sites, second largest acreage, and second highest percent of the watershed area. The watershed units with the largest average disturbance size are VRR and RLCW (45.7 acres and 40.0 acres, respectively), though these units have the fewest changes detected and the lowest percentages of the watershed disturbed (122 and 117, respectively; 0.2% of the watershed unit disturbed annually for both).

Table 2. Annual forest cover disturbance statistics by watershed.

Watershed Unit	Number of Detected Forest Disturbances	Mean disturbance Area (ac)	Standard Deviation of Area (ac)	Total Area (ac)	Disturbed Percent of Unit	Monitored Percent of Disturbances
MH*	428	20.9	35.7	8938.3	0.7%	12%
SUP*	226	28.8	50.8	6516.3	0.5%	18%
RR*	68	20.7	34.2	1046.7	0.1%	41%
MGR	180	34.5	29.4	6204.6	0.5%	15%
VRR	122	45.7	42.6	5569.9	0.2%	23%
RLCW	117	40.0	47.6	4681.5	0.2%	17%

*Number of detected disturbances, total area, disturbed percent of total area, and monitored percent of disturbances are presented as an annual average base on a three-year window of change detection.

Additional analyses have been done to summarize how close/far forest cover disturbances are from a water feature (ex., river/stream, lake/pond, open water wetland). The shortest distance between boundaries of a forest disturbance area and the nearest waterbody was calculated by using the "Near Tool" in ArcGIS. When a waterbody occurs within or touching the boundary of a disturbance feature, the distance between them is zero.

The watershed unit that has the highest percent of waterbodies within or nearest to disturbance features is the RR unit, where 30% of the disturbances have a water feature that touches or intersects the boundary of a disturbance and 45% of all RR disturbances are within 160 feet of a waterbody (the majority of which are open water wetlands). As expected based on the land cover characteristics described previously, the units with the second highest percent of disturbances nearest water features are SUP and VRR (23% and 28%, respectively, and 44% within 160 feet of a waterbody in both units). The RLCW watershed unit had the fewest disturbances near water features, where only 6% of the disturbances have a water feature that touches or intersects the boundary and more that 74% of the disturbances are greater than 640 feet away from a water feature. As expected, due to the high forest cover and low percentage of open water features, the MGR watershed unit is the only unit that has a majority of disturbance features greater than 640 feet from water features (53%). Histograms of these proximity analyses per watershed unit can be found in the Appendix.

Monitoring Site Characteristics

Monitoring Site Size

Table 3 reports statistics on monitoring site size by watershed and total. Mean site area of 37 acres is very similar to that reported in 2011 (34 acres), but there are clear differences in mean harvest size among the watershed units. Although not a guideline in itself, site size may influence implementation of other guidelines such as managing site infrastructure and acreage of leave tree clumps.

Table 3. Monitoring site size by watershed sample unit.

Watershed Unit	Number of Sites	Min Area (ac)	Max Area (ac)	Mean Area (ac)	Standard Deviation of Area (ac)	Total Area (ac)
MH	35	6.8	193.1	33.1	35.8	1157.6
SUP	30	13.9	234.3	78.9	60.0	1242.9
RR	28	6.3	392.8	34.8	70.9	975.5
MGR	29	6.0	162.6	31.8	32.8	922.4
VRR	26	29.9	271.7	96.6	69.5	1275.9
RLCW	24	51.5	154.4	94.2	40.9	774.2
Total	172	6.0	392.8	36.9	42.2	6348.5

Type and Distribution of Waterbodies

The types and numbers of waterbodies or wetlands associated with the monitoring sites are shown in Table 4. The majority of non-open water wetland (NOWW) types were located on-site, while the majority of open water wetlands (OWW) and streams were located adjacent to harvest sites, which may indicate that most harvests are designed to go around surface water features rather than containing them within the site. Over 92% of all monitoring sites had at least one waterbody or wetland on, adjacent, or along the logging road accessing the site. NOWW were more common than any other waterbody or wetland type, accounting for 88% of the total of which ~90% were mineral soil or shallow peat wetlands.

Table 4. Number of waterbodies by type and watershed sample unit.

	MH	SUP	RR	MGR	VRR	RLCW	Total
NOWW*	95	101	148	112	84	105	645
Intermittent Streams	-	1	-	2	6	-	9
Perennial Streams – Non-trout	1	3	-	5	14	3	26
Perennial Streams - Trout	-	14	-	-	2	-	16
OWW	3	-	7	7	-	-	17
Lakes	9	1	-	6	1	1	18
Total Waterbodies (#)	108	120	155	132	107	109	730
Sites with Waterbodies (#)	29	28	27	27	26	22	159
Sites with No Waterbodies (#)	6	2	1	2	0	2	13

*Includes Mineral soil wetlands, shallow peat wetlands, seeps and springs, beaver ponds, season ponds, wetlands or waterbodies where just a filter strip is recommended.

Harvest Methods and Planning

The percent of sites that were clear-cut remains similar to past reports at ~85%. Other methods reported include thinning, seed tree, single and group selection, and shelterwood. Some sites utilized mixed harvest methods. Almost all clear cuts included some reserve or leave trees on or adjacent to the clear cut.

Season of Harvest

As in past reports, the majority of sites (58%) conducted all or a significant portion of the harvest (75% or more) during winter season (Dec. 16 – Feb. 15). No substantial difference was evident between watersheds.

Guideline Version Used

For this reporting period, 130 of 133 agency and industry lands responding to the pre-site questionnaire indicated awareness that the site-level guidelines were revised in 2012. For NIPF sites, nine of 39 indicated they were aware. Only 24 respondents indicated that they used the 2012 version of the site-level guidelines, even though 47 indicated that harvests were agreed to or contracted after release of the revised guidelines in January 2013 or later. Regardless of when harvests were agreed to or contracted, 83 sites reported harvest beginning in 2013 or later. The reason(s) for this disparity between when revised guidelines were released and their use during subsequent harvests is unknown. The MFRC should explore this issue with partners to reinforce the need for implementation of the revised guidelines. Future monitoring will assume the implementation of 2012 revised guidelines on all sites.

Pre-harvest Planning

The TH/FM guidelines recommend the development of written plans for all forest management activities, including timber harvest. One of the most effective tools for communicating the details of a harvest plan is a site map identifying the location of critical site features. NIPF landowners reported that site maps were developed for only 36% of the sites, which is fairly consistent with past reports. Site maps were developed for 100% of county, federal, forest industry and state sites.

Approximately 50% of NIPF sites indicated that there was a general forest management plan for their property written by a forestry consultant or natural resource professional, and most of these also had a written timber harvest plan for the site. Of the NIPF sites without written plans, nine indicated an oral harvest plan was developed by the logger through discussion with the landowner, and 8 sites indicated no plan was developed. This emphasizes that for many NIPF harvests, the logging professional is key to informing landowners about site-level guidelines and is also the implementer of those guidelines on the site. Targeted outreach to loggers in watersheds with high NIPF harvest activity would be an effective approach to increase implementation of site-level guidelines.

Guideline Implementation Results

Visual Quality

After the development of visual quality BMPs in 1995, visual sensitivity classification maps were developed for the 16 northern counties with land departments and can be found at http://www.dnr.state.mn.us/forestry/visual_sensitivity/index.html. These maps identify features such as roads, rivers, lakes, or recreational trails that are rated as "most," "moderately," or "less," visually sensitive. Visual quality guideline implementation was based on these ratings. Note that the USFS utilizes an existing internal visual quality sensitivity rating that may be different.

Monitoring contractors rated sites for visual quality when components of a harvest site could be viewed from a location frequented by the public including roads, trails, lakes, navigable streams, or campgrounds. Visual quality guidelines were evaluated on 153 monitoring sites located within the 16 counties with established visual sensitivity ratings. For these 153 sites, 70% of state, county and industry sites indicated awareness of visual sensitivity ratings and 61% of the rated sites indicated the correct rating for the site.

About half (73) of these sites had one or more visually sensitive features (vistas), and visual quality guidelines were met for ~75% of these features. Common reasons for not meeting the guidelines were related to the apparent harvest size exceeding guideline recommendations or slash piles being visible from vistas, and landings located within ROW of roads or trails. Multiple methods were used to limit apparent harvest size including placement of leave tree clumps, creating narrow opening into the sale area, designing natural shaped harvests.

Endangered, Threatened and Special Concern Species

TH/FM guidelines recommend checking for the presence of endangered, threatened, or special concern species (ETS), sensitive communities, or sensitive sites on or near the site prior to the initiation of management activities and that appropriate actions are taken to protect known occurrences. Self-reported checking for ETS during the planning process was high (92%) for agency & industry lands. Checking for the presence of ETS species is unknown for NIPF lands because the pre-site questionnaire for this group was abbreviated and did not include a similar question. For all non-NIPF respondents, three indicated that an ETS species were known to occur on the monitoring site based on review of various sources, and two others reported discovery or occurrence of ETS species that were not identified on databases. Appropriate action was taken in these instances.

Guideline monitoring program staff independently queried if monitoring sites had ETS species (and other special concern sites) present using the DNR's Natural Heritage Information System (NHIS). The NHIS is a collection of databases that provides information on Minnesota's rare plants, animals, native plant communities, and other rare features. This query identified 19 monitoring sites with having a known ETS species on or adjacent (within 660 ft.) to the site. The NHIS identified three sites with known special concern species on the sites. For these three

sites, managers had indicated checking appropriate sources in the questionnaire, but failed to correctly identify the known species listed in the NHIS. For 12 sites identified as having known ETS species adjacent to the site, all but one indicated checking appropriate sources and 11 of these failed to correctly identify the known species of special concern identified in the NHIS query. One site correctly identified an endangered species (*Erigeron acris* var. *kamtschaticus*, Bitter Fleabane) occurring adjacent to the site. Four sites did not respond to the pre-site questionnaire. An additional two sites reported personal knowledge or the discovery of ETS species that were not listed in NHIS databases.

The reasons for disparity between sites that indicated checking appropriate sources for known ETS species, and the ability to correctly list species identified in the GMP query of NHIS database is unknown. DNR staff that manages the NHIS database indicated that this database is continually being updated, and there may be a time lag between species identification in the field and entry into the database. Because of this, staff recommend a second review of the NHIS database just prior to activity beginning if it has been more than one year since the initial review. Due to frequent updating in recent years, comparison of reported findings by land managers and recent queries by GMP staff may be inappropriate for the purposes of estimating guideline implementation.

The NHIS contains a wealth of information for landowners who utilize it. Outreach to NIPF landowners and loggers is recommended to improve use of the NHIS and implementation of related guidelines. It is unknown if loggers operating on NIPF lands conducted ETS inquiries due to abbreviated pre-site questionnaires.

Wetlands and Waterbodies

A major focus of the TH/FM guidelines is protecting wetlands and waterbodies, including non-open-water wetlands (NOWW), open-water wetlands (OWW), perennial and intermittent streams, lakes, seasonal ponds, and seeps and springs. The filter strip and RMZ guidelines are the primary tools for protecting wetlands and waterbodies by defining specified areas adjacent to a wetland or waterbody where management activities are to be less intrusive than in the general harvest area.

Filter Strips

The function of a filter strip adjacent to a waterbody is to trap and filter out suspended sediment, and chemicals attached to sediment, before it reaches the surface water. The guidelines recommend establishment of filter strips adjacent to all water features. The recommended width of a filter strip is 50 feet with an additional 2 feet for each 1% increase in slope over 10%, to a maximum of 150 feet. Harvesting and other forest management activities are permitted in a filter strip as long as the integrity of the filter strip is maintained and mineral soil exposure is kept to a minimum (MFRC 2012).

During field monitoring, detailed filter strip information is recorded for only those filter strips where contractors observed disturbance(s) that potentially resulted in a compromised filter

strip. All other filter strips are counted and labelled as meeting guideline recommendations. Not all filter strips that trigger full data set are determined to be "non-compliant" with the TH/FM guidelines. To be effective, soil disturbance should be minimized within a filter strip. The guidelines recommend limiting soil disturbance to less than 5% dispersed (not concentrated) soil exposure throughout the filter strip.

Of 838 total filter strips observed, 708 (84%) were adjacent to NOWW, 96 adjacent to streams, and 34 adjacent to OWW. Detailed filter strip data were recorded for 107 filter strips, 72 of which had no soil exposure recorded despite having roads, skid trails or landings within filter strips. A total of 26 filter strips had greater than 5% soil exposure, with17 of these caused by roads that existed prior to timber harvest activity. However, three of the 26 filter strips had observed erosion occurring due to newly constructed roads. Only one filter strip had observed sediment reaching a wetland (4.5 cubic feet) (Table 5). Future training efforts should include implementation of water diversion / erosion control (WD/EC) on all roads, whether new or existing. Landings were located in 59 of the filter strips, seven of which had greater than 5% exposed soil ranging from 25-95% exposed. None of the three filter strips with skid trails or the 59 filter strips with landings had erosion occurring. Continued emphasis should be placed on avoiding location of skid trails and landings within filter strips where practical.

Table 5. Soil exposure, erosion, and sediment reaching a waterbody observed in filter strips with and without roads, skid trails, or landings.

	Total Filter Strips	Filter Strips without Roads, Skid Trails, or Landings	Filter Strips with Roads, Skid Trails, or Landings	Filter Strips with Erosion	Filter Strips with Sediment Reaching a Waterbody
No Soil Exposure	812	757	72	0	0
<5% Dispersed	0	0	0	0	0
<5% Concentrated	0	0	0	0	0
≥5% Dispersed	19	1	18	1	0
≥5% Concentrated	7	0	7	2	1
Total	838	731	97	3	1

Despite the existence/placement of roads, skid trails, and landings in 97 filter strips, the guideline to limit disturbance to <5% dispersed was not met on only 26 filter strips, resulting in a 97% total compliance rate (Table 6), where the RLCW watershed unit had 100% compliance (zero filter strips with soil exposure and zero new roads) and the VRR watershed had the lowest compliance rate at 91% (13 filter strips with soil exposure, and 25 with roads, skid trails, or landings located within the filter strip).

Table 6. Soil exposure, erosion, and sediment reaching a waterbody observations, and overall compliance rates of filter strips per watershed unit.

Watershed Unit	Total Filter Strips	Filter Strips with ≥5% Soil Exposure	Filter Strips with Roads, Skid Trails, or Landings with No Soil Exposure	Filter Strips with Existing Roads	Filter Strips with Erosion	Filter Strips with Sediment Reaching a Waterbody	Overall Compliance*
MH	127	6	11	11	0	0	95%
SUP	149	3	12	12	0	0	98%
RR	163	2	1	1	0	0	99%
MGR	139	2	10	8	2	1	99%
VRR	146	13	25	15	1	0	91%
RLCW	114	0	13	13	0	0	100%
Total	838	26	72	60	3	1	97%

* Non-compliance is based on filter strips having ≥5% exposed soil.

Riparian Management Zones

Riparian area is defined as the area of land and water forming a transition from aquatic to terrestrial ecosystems along streams, lakes, and open water wetlands. RMZ guideline recommendations were modified in 2012 resulting in generally wider, but simplified RMZ recommendations. Current width and basal area recommendations for RMZs are based on type of waterbody and size of waterbody. Refer to the 2005 and 2012 version of the Site-Level guidelines for details on recommendations. In this reporting period, land managers reported using the 2012 revised RMZ guidelines on 6 RMZs (5 sites), and an additional RMZ occurred on a site where harvest began after the release of the revised guidelines. RMZ compliance evaluation for these sites was based on revised standards with remaining RMZs based on 2005 recommendations. For each RMZ, data were collected from three representative cross sections to characterize the composition of the full recommended RMZ width based on type and size of waterbody. Basal area (BA) within the RMZ was determined using a variable plot with 10 factor prism. Linear distances and BA were recorded for:

- Non-forest (sedge, brush, and scattered trees with a BA less than 25 ft^2/acre)
- Undisturbed forest (no apparent harvest with BA greater than 25 ft^2/acre)
- Partially harvested forest (harvest retained at least 25 ft^2/acre BA)
- Clear-cut (harvest retained less than 25 ft^2/acre BA) for the rest of the recommended RMZ width for the specific type and size of waterbody

Compliance was based on the combined width of the non-forest, undisturbed forest, and partially harvested forest from the water's edge landward. Basal area compliance was evaluated for the partially harvested portion based on the minimum BA recommended for the size and type (trout or non-trout) of waterbody. Some RMZs had significant areas of non-forest

vegetation (i.e., grass, sedge, brush, or shrubs) adjacent to water, while others were composed entirely of forest.

A total of 71 RMZs were identified on or adjacent to 54 sites monitored in 2014 and 2015 (Table 7). Overall, 57 of 71 (80%) RMZs met guideline recommendations for width and basal area of forest retention. Additionally 9 RMZs managed 50% or more of the recommended RMZ width and basal area representing an additional 13% of RMZs with significant partial compliance. These results represent a continuing trend of improved RMZ guideline implementation. For this report, authors considered RMZs meeting 95% or more of recommendation to be within our margin of error and considered compliant. This affected only two RMZs; one RMZ that managed 99' of a recommended 100' RMZ, and another RMZ that managed 48' of a recommended 50' RMZ. Data for RMZs utilizing 2012 guidelines indicates that five of seven RMZs met revised guideline recommendations, with the remaining 2 meeting 76% of the recommended width and BA. Nearly half (6) of the RMZs that did not meet guideline recommendations were in the RR watershed located on NIPF ownerships. Outreach targeting landowners and loggers in the RR watershed focusing on the benefits of implementing RMZs recommendations may improve compliance in this watershed.

RMZs provide direct shading to streams and lakes as well as shading to soils and ponded water that result in cooling or maintaining temperatures in runoff and internal drainage that is particularly important for cold water habitats. Compliance on trout streams was excellent for this reporting period; 14 of 15 RMZs fully met recommendations with the remaining RMZ meeting 93% of recommended width (Table 7).

Guidelines also recommend retention of CWD within RMZs where partial harvest is occurring. For 8 sites that conducted partial harvest (retained >25BA) within RMZs, only 1 retained 4 or more CWD/acre within the RMZ. Five of the RMZs that did not retain CWD are located within the RR watershed. Retaining CWD within RMZs can sometimes be confused with guidelines that recommend avoiding placement of slash within filter strips. Clear communication in guideline training could contribute to improved implementation.

Table 7. RMZs meeting guideline recommendations by watershed sample unit.

Watershed Unit	Total Sites	Sites with RMZs	Total RMZs (#)	Trout Streams (%)	Non-trout Streams (%)	Lakes & OWW (%)	Total Compliance (%)	Partial Compliance (>50%)
MH	35	8	12	-	-	100%	100%	-
SUP	30	16	17	92%	67%	100%	88%	12%
RR	28	3	7	-	0%	17%	14%	14%
MGR	29	12	14	-	100%	78%	86%	14%
VRR	26	11	17	100%	71%	100%	76%	24%
RLCW	24	4	4	-	100%	100%	100%	-
Total		54	71	93%	77%	77%%	80%	13%

Crossings

Crossings are sections of roads or skid trails, and in some instances landings, where equipment crosses a wetland or waterbody. Logging equipment crossings are the forest management features that have the greatest potential for disturbing wetlands and waterbodies.
The types and relative proportion of waterbodies and wetlands crossed changed little compared to the previous report. The majority of crossings (64%) occurred as a result of skid trials, with most crossings (96%) occurring on NOWW (Table 8). Frozen crossings continue to be the most frequently used type of crossing due to the high frequency of winter harvests.

One of the key guidelines to avoiding impacts to wetlands and waterbodies is to avoid crossings whenever practical. Contractors were asked to determine whether a crossing could have been avoided and site objectives still accomplished without unreasonable costs or reduced safety. Contractors reported that 28% of all observed crossings could have been avoided, with most occurring on skid trails (Table 8). No stream crossings were determined by the contractors as being avoidable. Continued and improved avoidance of unnecessary crossings will reduce wetland impacts and improve guideline implementation. Additionally, 20% of crossings identified as avoidable had rutting within the crossing. Situations where crossings were determined to be avoidable include: multiple crossings of a wetland were one crossing would suffice, cutting across the tip of a wetland rather than driving around the edge, or crossing small isolated wetlands that could easily have been avoided. With the exception of RR at 91%, all watersheds range from 62-76% compliance rate for avoidance of crossing wetlands suggesting an overall implementation rate of 72%, a drop from the 82% reported in 2011.

Table 8. Number of crossings by infrastructure component and avoidance potential.

	Crossings (#)	NOWW	Beaver Pond	OWW	Stream	Could Have Been Avoided
Roads	128	114	2	3	11	9
Landings	11	11	1	-	-	5
Skid trails	219	218	2	-	3	83
Total	358	343	5	3	15	97

At the watershed scale, number of crossings per site appears to be unrelated to implementation or ability to avoid crossings. Interestingly, the watersheds with the lowest (RLCW) and the highest (SUP) mean number of crossings per site share the lowest implementation rates (62% and 64% respectively) for avoiding crossings. Also the WS with the highest number of observed NOWW on or adjacent to sites (RR) had the highest compliance rate for avoidance of crossings.

The relationship between the number of wetlands on or adjacent to sites and the number of crossings is dependent on both care in avoiding crossings as well as the characteristics of those wetlands themselves. In most cases the number of crossings is much lower than the number of NOWWs observed indicating that many of the observed wetlands were not crossed and possibly avoided. This may reflect that small isolated wetlands (such as many in RR) are easier

to avoid than large linear or long narrow wetlands such as found in VRR or SUP. Outreach related to avoiding wetland crossings should consider the characteristics of wetlands and terrain in the targeted watershed to best relate to on-the-ground conditions.

Table 9. Non-open water wetland (NOWW) crossings by watershed sample unit.

Watershed Unit	# Sites	# Sites with Crossings	Total # of NOWW Observed	# of NOWW Crossings	Mean # CRS per site (all sites)	# of Crossings That Were Avoidable	# of Crossings Rutted
MH	35	20	95	74	2.3	20	18
SUP	30	21	101	97	3.3	36	13
RR	28	9	148	43	1.5	4	1
MGR	29	18	112	45	1.6	13	3
VRR	26	20	84	59	2.2	15	8
RLCW	24	13	105	25	1.0	9	2
Total	172	101	645	340	2.0	97	45

Figure 2 below is a common example where one of the two crossings was determined to be avoidable. The red line indicates the harvest site boundary, the blue polygon with hash marks indicate wetland boundaries, and inside the red circle the brown line with 'x' and the IDs FID:CRS5451 and FID:CRS5452 indicate crossings.

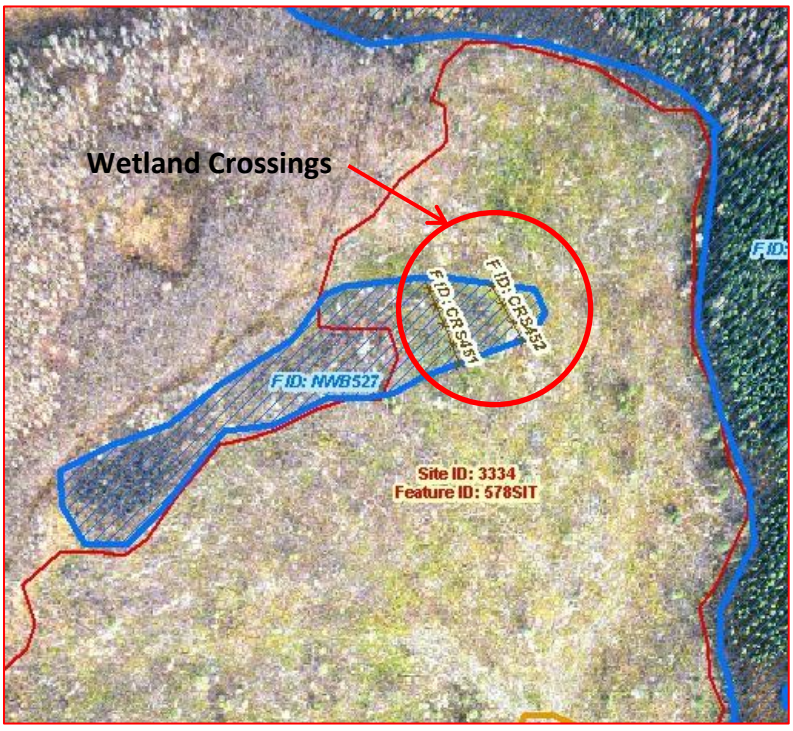


Figure 2. Example of multiple crossings of a wetland.

Rutting on NOWW Crossings

NOWW are the most frequently crossed wetlands during harvesting operations in MN. During this reporting period, 340 NOWW crossings were observed. Rutting occurred on 13% of all NOWW crossings (13% of sites as well). This is down substantially from the 33% reported in the last report. Three of these rutted crossings were due to ATV traffic presumably post-harvest. Of the crossings that were rutted, approximately 1/3 were identified as having rutting exceeding 50%. A substantial portion (51%) of the crossings that were rutted occurred on just 4 sites, with half of the severely rutted crossings ($\geq$50% rutted) occurring on just 2 sites. Although rutting did occur on sites harvested during winter season, the 4 sites with the majority of rutted crossings were harvested during non-frozen seasons. Skid trail crossings accounted for 85% of all rutted crossings.

Although substantially improved, this continues to be an opportunity for outreach focused on avoiding crossings and utilization of temporary crossing structures. Avoiding crossings of wetlands where possible would help to reduce the occurrence of rutting simply by reducing vehicle traffic in wetlands. Monitoring contractors indicated that 18 of the 45 rutted crossings could have been avoided.

Because 85% of rutted crossings occurred on skid trails, the use of slash mats, wood mats or other crossings structures may reduce occurrence of rutting when crossing non-frozen wetlands. Only 3 of the 45 rutted crossings used slash mats, wood mats, corduroy or other temporary crossings structures while 34 rutted crossings were unfrozen and did not use any temporary crossing structure that that was apparent.

The highest number of rutted NOWW crossings as well as the highest frequency of sites with some rutting on crossings occurred in the Mississippi Headwaters watershed. A severe blowdown event in July of 2012 increased harvest operations during summer and fall to clean up (salvage harvest) damaged stands and encourage regeneration. Two sites representing over half of rutted crossings in MH were salvage harvests conducted during non-frozen seasons. Salvage efforts may have inadvertently increased the incidence of rutting on crossings in MH watershed. Regardless, focusing outreach within this watershed (as well as others) on techniques to avoid rutting in NOWW crossings such as use of temporary crossings structures may improve future guideline implementation.

Stream Crossings

Guideline implementation at stream crossings is particularly important due to the potential to directly impact stream water quality. During this reporting period, contractors recorded 15 stream crossings occurring on 9 sites. Most (80%) of these crossings were as a result of forest roads, with the remaining 3 from skid trails. None of the 15 crossings were deemed as avoidable, indicating 100% compliance in avoiding stream crossings where possible. Additional stream crossings may have been avoided through site planning given that most streams were located adjacent to harvest sites.

One of the key guidelines related to crossings is implementation of water diversion and erosion control practices on approaches so that runoff and sediment does not move down the approach and into the waterbody. Four of the 15 stream crossings located on 3 of the 9 sites with stream crossings, did not meet guideline recommendations due to inadequate or poorly implemented erosion control and water diversion practices on approaches to the crossing. Three of these crossings were road crossings and one was a skid trail crossing. Three stream crossings also had evidence of minor amounts of sediment reaching the stream itself.

Most (11 of 15) stream crossings monitored occurred in the VRR watershed unit with 3 additional stream crossings in the SUP unit and one in the MH unit. Similarly, three of the four non-compliant crossings also occurred in the VRR watershed unit. The VRR and SUP watershed units appear to have a relatively higher stream density and therefore present the need to cross streams more frequently. Although stream crossing is relatively infrequent overall, outreach focusing on appropriate implementation of water diversion and erosion control practices in watersheds with a high stream density should continue to be a priority.

Approaches and Segments

Recommendations on the use of erosion control have been a primary component of the forest management guidelines related to maintaining water quality. In particular, use of erosion control at areas in close proximity to water resources is important in minimizing sedimentation of wetlands and streams. Approaches (APP) are the portion of a skid trail or road immediately leading into a wetland or waterbody, making them a key feature when assessing the use of erosion control because of potential to funnel surface water, sediment, organic debris, and contaminants into the water. Guidelines recommend that water diversion/erosion control (EC) practices be installed as soon as approaches are created and maintained until the location is stabilized.

Approximately 2/3 of sites had at least one approach that was identified by monitoring contractors. The vast majority (>90%) of these approaches did not require erosion practices for sediment control (Table 10), similar to what has been observed in previous reports (Rossman 2012). Generally, EC is not needed on approaches that have low slope (<2%), little or no exposed mineral soil, or where natural roughness and/or breaks in terrain negate the need. The high estimate of approaches not needing EC may reflect better guideline implementation through improved selection of crossing locations, or may be associated with the relatively forgiving operating conditions that occur in the state (ex., winter harvesting, level topography, etc.).

Fifty-two approaches that did require EC to be installed occurred at approximately 15% of all monitored harvest sites, with most of those approaches (~85%) associated with NOWW. Of those, only 1 in 5 had EC practices installed, which is similar to what was observed in the last report but much lower than earlier estimates. More importantly is that erosion was frequently observed when EC practices were needed but not installed, although the actual occurrence of sediment delivery to wetlands and streams was small (Table 10). Utilization of slash water bars

or scattered slash on approaches would reduce potential impacts to wetlands and surface water, but the establishment of vegetation appears to play an even larger role in minimizing erosion (Slesak et al. 2016). Regardless, the results reinforce the need to emphasize the importance of EC practices on approaches to minimize erosion potential, and a need to identify when EC practices are needed during training programs for loggers, land managers, and landowners. For example, only 2 of the watershed units (SUP and VRR) commonly had sites with approaches needing EC (Table 10), which is likely associated with differences in slope or soils. Targeted outreach to these watersheds on how to identify the need for EC installation would help to increase guideline implementation and reduce the potential for water quality impacts.

Table 10. Erosion control and occurrence on approaches for all water features by watershed unit.

Watershed Unit	Total Sites	Sites with APP	Total APP (#)	Sites Where EC on APP was Needed	For Sites with APP Needing EC			
					# APP Needing EC	# APP with EC Installed	# APP with Erosion	# APP Sediment Reached Waterbody
SUP	30	21	205	7	13	0	7	5
MH	35	21	161	6	12	0	12	8
SUP	30	21	205	7	13	0	7	5
RR	28	18	87	0	0	0	0	0
MGR	29	19	89	3	5	3	1	0
VRR	26	20	133	7	19	8	6	2
RLCW	24	12	49	2	3	0	2	1
Total	172	111	724	25	52	11	28	15

In addition to approaches, segments of skid trails and roads that are near wetlands or surface water also have higher potential to impact water quality compared to other portions of the harvest site. Because of their proximity, these “water quality (WC) segments” may impact water quality if erosion control practices are not properly installed. Only a small number of sites (<10%) have WQ segments present, which may reflect proper locating of roads and skid trails away from wetlands and surface water. However, similar to approaches, those WQ segments that needed EC installed generally did not have it and the occurrence of erosion in those situations was common (Table 11). There was only one occurrence where sediment actually reached a wetland or waterbody from a WQ segment, which may be because WQ segments are not a direct conduit to wetlands and waterbody’s like approaches are. Notably, the Mississippi Headwaters watershed had both a higher percentage of sites with WQ segments present and also the greatest number of WQ segments and occurrence of erosion compared to other watersheds, making it a prime candidate for targeted efforts to improve EC use and application. Although there is clearly a need to focus efforts on improving EC use in general, the small number of times that sediment reaches a wetland or waterbody from approaches and WQ segments limits water quality impacts associated with forest harvesting.

Table 11. Use of erosion control and erosion occurrence on skid trail and road segments that have potential to impact water quality (WQ) by watershed unit.

Watershed Unit	Total Sites	Sites with WQ Segments	For Sites with WQ Segments Present			
			# WQ Segments	# with EC Installed	# with Erosion	# Sediment Reached Waterbody
MH	35	9	16	0	16	0
SUP	30	3	5	1	1	0
RR	28	2	3	0	3	0
MGR	29	5	9	3	6	1
VRR	26	7	13	8	4	0
RLCW	24	1	3	1	3	0
Total	172	27	49	13	33	1

Infrastructure

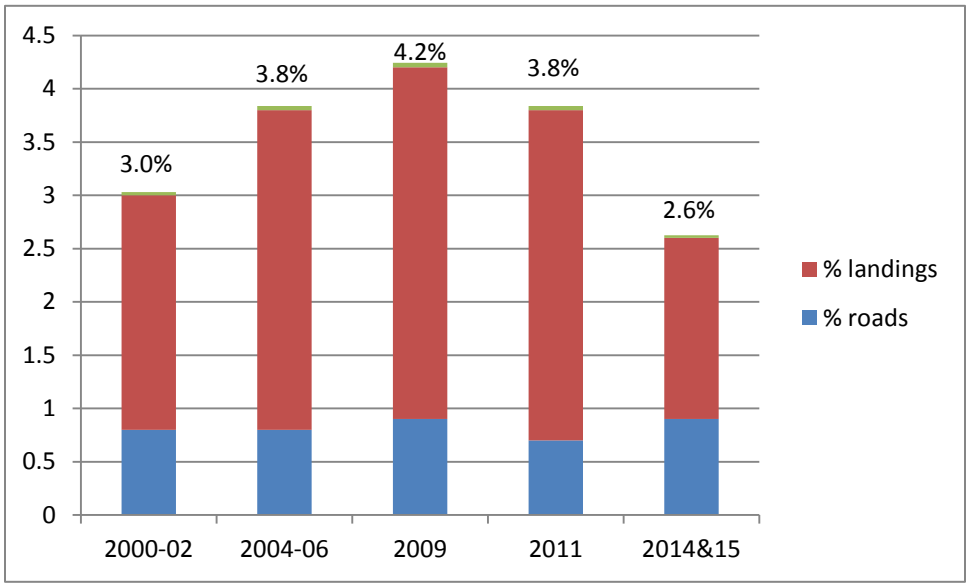
Equipment traffic can compact and rut soil, damage or remove vegetation whose root systems hold the soil in place, reduce movement of air and water into and through the soil, and redirect surface water flow. These impacts restrict plant root growth, reduce the availability of nutrients and moisture for plant growth, increase the potential for erosion, and can change surface and subsurface hydrology.

One way to minimize impacts of traffic on soil productivity during timber harvest operations is to limit the amount of high traffic area in roads and landings (i.e., infrastructure). Site-level guidelines recommend:

- Sites less than 20 acres should have 1 acre or less of the harvest site in infrastructure.
- Sites 20-30 acres should have less than 5% of the harvest area in infrastructure.
- Sites greater than 30 acres should have 3% or less of the harvest area in infrastructure.

Monitoring contractors determined total on-site infrastructure by measuring area occupied by landings and roads within the site. The estimated mean infrastructure per site for this report dropped to 2.6% (Figure 3) showing sharp decrease in percent of site occupied by infrastructure since the reported high of 4.2% in 2009. The decrease in percent infrastructure has occurred in both landing area and road infrastructure. Mean on-site total landing area per site in this reporting period was 0.76 acres (down from 1.0 acres in 2011). Mean on-site road acreage for this reporting period was 0.5 acres, also down from past reports. Fifty six of the 456 total landings observed were pre-existing landings utilized on 38 sites. Of the 38 sites that utilized pre-existing landings, 23 used only pre-existing, while 15 of them used a mix of old & new. Utilizing existing infrastructure is recommended in the site-level guidelines but is not always possible.

Figure 3. Mean Percent Infrastructure by reporting period.



Overall, 82% of sites monitored in 2014 and 2015 met the recommended infrastructure amounts based on 2012 guidelines. This is substantially higher than past reports and reflects revised guidelines as well as reduced mean infrastructure on monitoring sites. When comparing on-site infrastructure with site size, highest compliance to infrastructure guidelines was achieved on sites ≤20 acres in size, followed by sites in the 20-30 acre range, and finally sites greater than 30 acres.

At the watershed scale RR had 16 of 28 sites with on-site infrastructure. RR also had the smallest average on site infrastructure as well as the highest percent of sites meeting 2012 guideline recommendations for infrastructure. In contrast, VRR had 24 of 26 sites with on-site infrastructure, and the highest average on site infrastructure and mean site size, with one of the lowest compliance rates for meeting infrastructure guidelines. The VRR watershed is much more remote with less developed access than RR and this may suggest that the level of developed land with existing access may have influenced the need to develop on-site infrastructure for logging operations.

Landing Location

In addition to limiting the area occupied by landings within reasonable safety and operational limits, guidelines recommend locating landings outside of wetlands, filter strips, and RMZs to maintain water quality. Overall, 117 landings (26% of total) were located at least partially in a wetland or filter strip, with the majority of wetlands potentially affected being NOWW. Even in winter operations, wetlands should be avoided for landing locations if possible. Monitoring contractors judged whether suitable upland area was available for alternative location of landings that would still accomplish the site objectives without unreasonable costs or reduced safety. Of those landings located within wetlands and/or filter strips, 90 were judged to have upland locations available for landing, suggesting an overall implementation rate of 80% for

locating landings outside of wetlands and filter strips when possible (Table 13). This result is similar to the 76% reported in the 2011 report. When evaluating this information at the site scale; 34% of all sites had at least one landing located in a filter strip or wetland where an alternative upland location was deemed available. Several sites have multiple landings with only one within a wetland or filter strip.

Table 12. Acreage of on-site infrastructure by watershed sample unit.

Watershed Unit	Sites Meeting Infrastructure Guidelines (%)*	For sites with on-site infrastructure				
		Total # Sites with On-site Infrastructure	Mean On-site Infrastructure	Mean On-site Landing Size	Mean On-site Roads	Mean On-site Size
MH	74%	31	1.2	0.75	0.42	36
SUP	80%	24	1.3	0.82	0.48	47
RR	96%	16	0.71	0.49	0.22	38
MGR	83%	26	0.92	0.54	0.38	35
VRR	77%	24	1.62	1.1	0.52	51
RLCW	83%	23	1.03	0.6	0.44	33
Total	82%	144	1.15	0.76	0.50	37

*Compliance is based on 2012 infrastructure guidelines.

The majority of sites (77%) with landings located in wetlands were harvested during winter operations. Operating on landings under frozen conditions reduces the potential for rutting, but may not reduce the risk of depositing landing debris (i.e. slash, culls, and chipping debris) onto frozen wetland surfaces and subsequently into the wetland itself. Additionally, fueling, maintaining equipment or leakage from equipment, increases the potential to place contaminants directly into frozen wetland surfaces.

Table 13. Landing (LND) location related to wetlands and filter strips.

Watershed Unit	Total # Sites	Total # LND	LND Located in Wetlands or Filter Strips where Upland Available	Sites with a LND Located in Wetlands or Filter Strips where Upland Available
MH	35	117	13%	23%
SUP	30	76	8%	17%
RR	28	41	22%	32%
MGR	29	72	19%	34%
VRR	26	85	39%	58%
RLCW	24	62	19%	46%
Total	172	456	20%	34%

From the watershed perspective, VRR had the lowest number of total waterbodies observed on or adjacent to monitoring sites (Table 4), but has the highest percentage of landings located

within wetlands, waterbodies or filter strips (Table 13). It is unknown if this is related to ability to identify wetlands under variable harvest conditions, watershed characteristics, or harvest site planning and operations. Outreach addressing wetland identification tips and the importance of locating landings away from wetlands and waterbodies may improve awareness and implementation of guidelines in all watersheds.

Landing Conditions

Landings were generally in good condition. Two thirds of landings were more than 50% vegetated and only 4% had no vegetation at the time of monitoring. Although not a specific guideline, re-vegetated landings are less susceptible to erosion. Only 6 landings had evidence of rutting, with total rutting occupying less than 10% of the landing area in all cases. Only 5 landings had indication of erosion occurring, but no sediment reaching a wetland or water body in any of those cases.

Only 1.5% of all landings had evidence of fueling and equipment maintenance activity as evidenced by visible oil/petroleum product stains (oil spots) on the landing. Guidelines recommend keeping equipment in good repair, and that spills up to 5 gallons be thin spread over the upland part of a site, with spills over 5 gallons reported to MPCA duty officer for recommended action. Lack of observable evidence of spills on landings suggests high compliance to these guidelines.

Rutting Analysis at the Site Level

The TH/FM guidelines recommend minimizing rutting on roads, skid trails, and landings, and avoiding rutting in the general harvest area. Rutting occurs when tires or tracks of equipment displace and compact soil and tears the root mat when the soil is not strong enough to support the load applied by the vehicles.

The presence or absence of rutting 6 inches deep or deeper was recorded for a variety of features. In previous reports we have focused on the occurrence of rutting by various feature types (such as crossings, approaches, landings) across all sites. For this report, we also assessed the cumulative amount of rutting identified on all features of sites including the general harvest area. As in past reports the frequency of rutting was highest in NOWW skid trail crossings, but the highest surface area of rutting occurs when there is rutting identified in skid trails within the general harvest area (not associated with any one feature). This suggests that these sites have soils or soil conditions conducive to rutting (too wet for operations or weak soils).

When evaluated at the site level, rutting is clearly focused on a minority of monitored sites. Even then, sites that had some rutting identified had minor amounts when compared to the entire site. Of the 172 sites monitored, 34 sites had rutting identified somewhere on the site, and two thirds of these had rutting identified at more than one feature type. One site had total area rutted at ~7% of site, 3 additional sites had rutting estimated at 0.5-1% of site, and the remaining rutted sites had rutting estimated at less than 0.5%.

From the watershed perspective; some rutting occurred in all watersheds. The number of sites with rutting ranged from 1 in RR to 11 in MH. As mentioned previously, salvage operations

(salvage/regeneration harvests) triggered harvesting on several of the sites monitored in the MH watershed during summer/fall of 2012, resulting in a higher than normal amount of non-winter harvest operations which may have led to more frequent rutting.

The MFRC has established no threshold for guidelines related the % rutting on a site or specific features on a site. Guidelines recommend avoiding rutting through careful planning related to season of operation and monitoring of day to day conditions. Anecdotally, operations on sites with rutting at multiple feature locations (especially in general harvest area) likely occurred because operating conditions were conducive to rutting. In these situations, guidelines recommend changing operations or curtailing operations until conditions improve.

Biomass, Slash Management & Fine Woody Debris Retention

Retaining slash or fine woody debris (FWD) on harvest sites contributes to sustaining soil productivity, and provide habitat for small mammals, amphibians, and other organisms. Guidelines recommend favoring practices that allow for dispersed slash on the site, rather than piling slash, where dispersed slash does not conflict with management objectives or reforestation. For this report period, 150 of 156 sites not utilizing biomass had slash more or less evenly distributed on the site. Sixteen addition sites utilized slash as biomass product. Eleven of these sites retained at least 20% of tops and limbs from harvested trees as well as FWD from incidental breakage during harvest operations. The remaining 5 did not retain the intentional 20% of tops and limbs, but 3 of these did retain incidental breakage. Future monitoring protocols will estimate if about 1/3 of FWD is being retained at all harvest sites as recommended in the 2012 revised guidelines.

Wildlife Habitat

Coarse Woody Debris

Coarse woody debris (CWD) provides important habitat for forest animals and plants. The site-level guidelines recommend creating or retaining two to five bark-on down logs (>6 ft. pieces > 6 inches diameter) per acre in the general harvest area and at least four bark-on down logs per acre in riparian areas. General harvest areas met the guideline of two or more “sound” down logs per acre 99% of the time (Table 14). Only one site did not meet the minimum recommended number of CWD. Estimates reported here are substantially higher than numbers reported in previous reports, and may be partially due to a change in plot measurement protocols for CWD which includes inclusion of large branches as CWD rather than just logs (boles). Nearly half (48%) of sites monitored had 50 or more pieces of CWD/ acre in the general harvest area.

Table 14. Number of pieces of CWD in general harvest area of monitoring sites by ranges.

Watershed Unit	0-2	2-5	5-20	20-30	30-40	40-50	≥50	Total Sites
MH	1	0	2	1	4	8	19	35
SUP	0	1	2	4	5	6	12	30
RR	0	2	4	3	3	4	12	28
MGR	0	0	2	8	5	5	9	29
VRR	0	3	2	3	2	6	10	26
RLCW	0	0	0	0	1	2	21	24
Total	1	6	12	19	20	31	83	172

Leave Tree Distribution

The TH/FM guidelines recommend retaining mature, live trees on clear-cut timber harvests to provide vertical structure and habitat for wildlife while harvested stands regenerate. The guidelines provide two options for meeting the leave tree (or green tree retention) recommendations:

- Scattered - retain six or more scattered individual trees greater than 6" DBH per acre in the harvest area (scattered leave trees).
- Leave tree clumps (LTC) - retain at least 5% of a clear-cut harvest area in patches at least ¼ acre.

In both cases (scattered and LTC) leave trees should be at least six inches DBH. Leave tree clumps are most frequently located on site; however, areas adjacent to a harvest may be considered in evaluating leave tree acreage. Adjacent leave tree clumps are typically located between the harvest site and an adjacent RMZ, non-forested wetland, or previously harvested area, and where the leave tree clump is not large enough to be economically manageable by itself. In the 2012 revisions to the site-level guidelines, the MFRC modified the guidelines to include the area managed within RMZs as leave tree clumps. Of the 172 sites monitored, 158 sites were evaluated for implementation of the leave tree guidelines. The remaining 14 sites included selective harvest, thinning, seed tree and shelterwood harvests that retain abundant vertical structure and were therefor not evaluated for leave tree guideline compliance.

Overall, 129 (82%) of the 158 sites monitored for implementation of leave tree guidelines had adequate leave trees to meet recommended guidelines. Additionally 3 sites identified silvicultural or safety reasons for not retaining leave trees such as managing dwarf mistletoe (*Arceuthobium pusillum*) in black spruce stands. Considering these sites, the estimated compliance to leave tree retention guidelines was 84%. These statewide results show slight increase in implementation rates over numbers reported in 2011 (last report) and steadily increasing rates since 2004 (Table 15). Overall, the most common strategy utilized on sites meeting guideline recommendations continues to be through retention of scattered leave trees (47%) followed by sites using LTCs (38%). Statewide, a total of 27 sites (17%) did not meet the leave tree retention guidelines. Of these sites all but 2 had some leave trees retained, with

eleven (7%) of these 27 sites retaining 50% or more of the recommended leave trees by one or both methods demonstrating significant attempt at implementing guidelines.

Table 15. Percent of sites that meet or exceed leave tree guidelines.

Monitoring Year	Number of Sites for Which Guidelines Apply	Sites With ≥ 6 Scattered Leave Trees / Acre	Sites With ≥ 5% of Site in Leave Tree Clumps (at least ¼ acre)	Sites with ≥ 6 Scattered Leave Trees/ Acre or ≥ 5% of Site in Leave Tree Clumps, both, or in Combination	Sites Citing Silvicultural or Safety Reasons	Total
2000-02	293	49%	31%	61%	-	61%
2004-06	266	41%	13%	47%	-	47%
2009	74	50%	22%	61%	2	61%
2011	71	55%	32%	83%	1	83%
2014-15	158	47%	38%	82%	3	84%

At the watershed scale, rates of implementation ranged from a high of 100% in MH to a low of 62% in MGR which was substantially below the average. When looking at results by watershed unit, only the MGR and VRR sample units utilized LTCs more frequently than scattered on sites meeting guideline recommendations (Table 16). Three sites in the MGR unit utilized the 2012 guidelines and managed RMZs that also served as LTCs. Previous guideline versions did not include RMZs as leave tree retention. Considering these results, targeted outreach on leave tree guidelines to the MGR watershed would likely increase statewide implementation of leave tree guidelines.

Table 16. Number (%) leave tree compliance by watershed sample unit.

Watershed Unit	Total Sites	Sites Evaluated for LTs	Strategies used to Retain Leave Trees				% Sites Meeting Guidelines*
			Scattered	LTC	Both	Combination	
MH	35	33	22	0	8	0	91%
SUP	30	25	9	6	3	2	80%
RR	28	22	17	0	2	0	86%
MGR	29	29	3	10	1	5	62%
VRR	26	25	7	14	2	1	84%
RLCW	24	24	17	9	4	1	100%
Total	172	158	75	39	20	9	84%

Leave Tree Clumps

Contractors identified and evaluated 146 leave tree clumps (LTCs) on 63 sites (some of these did not meet 5% recommendation in guidelines); 12 additional LTCs were identified related to RMZs either as excess RMZ width resulting in a LTC or as RMZs managed under the 2012 guideline revisions. The average size of a LTC was reported as 0.9 acres – substantially larger than the minimum of 0.25 acres. Since 2004, the percentage of monitored sites utilizing LTCs to satisfy leave tree retention guidelines has increased steadily, but is still less than 50% (Table

16). Blowdown occurred in a third of LTC's, but the amount of blowdown in most (>85%) of these clumps was less than 5%. Overall average of blowdown in LTCs is ~3.6%.

Guidelines recommend that a mix of species is desirable for retention as leave trees and that preference should be given to particular species for their longevity, wind firmness, cavity potential and value to wildlife species. Guidelines also recommend that retention of a mix of naturally occurring species is desired, recognizing that it is necessary to work with what is available on a particular site. Table 17 shows the frequency of the most common mature tree species identified in LTCs. Four of the 5 most frequently occurring species in LTC's are ranked as having excellent or good value to wildlife.

Table 17. Common species identified in LTCs by frequency of occurrence, across all monitored sites.

Species	# of LTCs with Species Listed in 5 Most Frequent Species	% of LTCs	Rating of Species for Value to Wildlife
Paper birch	118	81%	Fair
Trembling aspen	83	57%	Excellent
Red maple	69	47%	Good
Black ash	46	32%	Excellent
Red pine	36	25%	Good
Balsam fir	24	16%	Fair
Burr oak	23	16%	Excellent
Jack pine	22	15%	Fair
Black spruce	22	15%	Fair
White pine	22	15%	Excellent

Scattered Leave Tree Characteristics

In addition to documenting presence or absence of scattered leave trees on monitoring sites, species composition of leave trees was also noted as well as additional characteristics including presence of cavity trees (or trees with rot in stem), and presence of dominant / co-dominants as leave trees (indicating that the larger trees were retained).

Scattered leave tree characteristics related to diversity, preference for wildlife suitability, and relative size were estimated from plot data at each site and averaged to determine mean values per watershed unit. A leave tree species preference metric for wildlife ranged from 1.9 to 2.6 with a statewide mean of 2.3, indicating that on average species with good or excellent wildlife characteristics are being retained at all watershed units. Both species richness and presence of large trees retained were variable across watershed units, being greatest in the RR and MH, intermediate in the SUP and RLCW, and lowest in the MGR and VRR. The Council has not established levels of suitability for these metrics, but the guidelines do suggest leaving a mix of species, size classes, and conditions. Given that the MGR unit had the lowest estimates for species preference, species richness, and presence of large trees, this unit is a likely candidate where improvements in implementation of leave tree guidelines could be attained with outreach and education efforts.

Although leave tree characteristics have not been included in previous reports, data was available to calculate these same metrics for a statewide sample conducted in 2011. Compared to 2011, the mean statewide estimates among HUC-8 watersheds for 2014-15 indicated greater retention of leave trees with more favorable characteristics (ex., sites on average had 30% more large tree coverage than 2011). For all years and watersheds, it appears that utilizing just single species retention is not common, as mean values for species richness were all greater than 3. Further interpretation and trends of leave tree characteristics will be possible as more data is collected and reported with time.

Table 18. Scattered leave tree and snag characteristics, where values in parentheses are standard error.

Watershed Unit	Snags (#/acre)		Species Richness (#) [a]		Species Preference Index [b]		Proportion of Plots with Large Trees [c]	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
MH	4.3 (0.7)	0–8.7	6.3 (0.6)	2–14	2.4 (0.1)	1.9–3.0	0.8 (0.06)	0.2–1.0
SUP	4.6 (0.9)	0.3–19.7	5.0 (0.4)	1–9	2.1 (0.1)	1.0–3.0	0.7 (0.05)	0.2–1.0
RR	3.7 (0.6)	0–14.4	6.6 (0.4)	0–10	2.6 (0.1)	0–3.0	0.9 (0.04)	0–1.0
MGR	2.7 (0.5)	0–10.0	3.1 (0.3)	0 - 6	1.9 (0.2)	0–3.0	0.3 (0.0)	0–0.9
VRR	2.0 (0.3)	0–6.3	3.6 (0.4)	0 - 7	2.3 (0.1)	0–3.0	0.4 (0.06)	0–1.0
RLCW	4.2 (0.6)	0–10.0	4.8 (0.5)	0 - 10	2.4 (0.1)	0–3.0	0.7 (0.07)	0–1.0
Total	3.6 (0.3)	0–19.7	5.0 (0.2)	0–14	2.3 (0.1)	0–3.0	0.6 (0.0)	0–1.0
2011	N/A	N/A	4.2 (0.3)	0–9	2.4 (0.1)	0–3.0	0.5 (0.0)	0–1.0

[a] Mean total number of species listed at each site.

[b] Calculated as the mean preference value per tree at each site, with values of 1, 2, and 3 corresponding to the categories “fair”, “good”, and “excellent” shown in Table GG-3 of the FMG Guidebook.

[c] The proportion of measurement plots at a given site where contractors indicated dominant or co-dominant trees were present.

Snag Distribution

Snags provide habitat for wildlife requiring tree cavities, perches, and bark foraging sites. For monitoring purposes a snag is defined as a dead tree stem standing at least 8 feet tall and $\geq$6 inches DBH. Snags were commonly recorded at nearly all harvest sites, ranging from a mean of 2.0 to 4.6 per acre across watersheds monitored this cycle. MFRC guidelines generally recommend leaving all snags possible, but also have recommendations to remove snags for visual quality concerns in some instances. Regardless, the suitability of these estimates is not clear, as guidance has not been provided on what level of snag density is needed to support snag-dependent wildlife populations. Based on FIA data, mean snag density for timberland in Minnesota is 18 per acre, indicating that these levels are lower than what exists in intact stands, but the implications of this difference is unclear.

Ninety six percent of the sites retained at least one snag per acre, and 62% had more than two (Table 18). Of those 7 sites that did not retain snags, only 2 indicated that snags were not retained due to specific silvicultural or safety reasons. The remaining sites had no further explanation. Since monitoring was initiated, snag retention has consistently increased.

Conclusions and Recommendations

Overall guideline implementation has improved in most of the focal areas evaluated in this report. One of the primary measures of success of the site-level guidelines is monitoring results that document continuous improvement in guideline implementation over time, and maintaining that high level once achieved. Results from this report show that statewide implementation of many guidelines is generally high with most reflecting continuous or substantial improvement including those related to managing RMZs , retaining leave trees and snags for wildlife, limiting disturbance in filter strips, minimizing total infrastructure, condition and location of landings (outside of wetlands and filter strips were uplands are available), occurrence of sites with rutting (primarily on wetland crossings), and retention of FWD on biomass harvest sites.

The use of HUC-8 watersheds to focus monitoring site selection and analysis has proven valuable to the guideline monitoring program by increasing our understanding of variation in guideline implementation levels across the state, and also by providing efficiencies and cost savings in the monitoring process such as reduced travel between monitoring sites. The guideline monitoring program is optimistic that additional benefits will be realized through targeted outreach resulting in improved levels of implementation.

Four guideline topics were found to show no improvement or decreasing level of implementation at the statewide scale including wetland crossings that could have been avoided, use of water diversion/erosion control on approaches, implementation of visual quality guidelines, and the use of written plans on NIPF lands. Given the critical role that the above guidelines play in mitigating impacts to water quality, wildlife, and soil productivity, landowners, managers and logging operators should strive to improve implementation to avoid negative impacts on Minnesota's forest resources. In particular, use of erosion control continues to be inadequate and there is a need for concerted effort to implement erosion control practices when potential impacts to water quality are high (e.g., on approaches and segments near wetlands and surface water. The following recommendations are intended to be used as a framework to improve the overall level of guideline implementation.

Implementation of Revised Guidelines

The MFRC published the revised site-level forest management guidelines in January of 2013. Implementation of the revised guidelines (as reported by landowners) was lower than expected for the proportion of sites monitored where harvesting was initiated after the publishing of the revised guidelines. The MFRC should explore this issue with partners to reinforce the need to use and implement revised guidelines and develop outreach as needed. Future monitoring will assume that the 2012 revised guidelines are being used on all sites.

Outreach and Education Statewide

Outreach is one of the primary tools available for improving guideline implementation and is essential to successful voluntary implementation. Future outreach should acknowledge successes in guideline implementation as well as focus on areas where opportunity for

improved implementation exists. Continued effort to publish and distribute the on-line introduction to site-level guidelines course will assist with this, but additional in-depth programs targeting specific guidelines should also be considered. Specific topics to consider for focused training could include 1) introduction of site-level guidelines to new land managers and loggers, 2) outreach to increase awareness and encourage implementation of the revised (2012) guidelines, 3) continued training for improved wetland identification, and 4) methods of effective water diversion and erosion control practices and how to recognize when these practices are needed. The above topics are recommended for all watershed units. Outreach efforts should include NIPF landowners, loggers who work on NIPF lands and natural resource professionals who advise NIPF landowners.

Summaries and Opportunities for Improvement at the Watershed Scale

The use of watershed scale monitoring introduces a structure to focus outreach and education efforts in localized areas with the highest opportunities for improved implementation. The following summaries provide an overall review of guideline implementation (rates provided) and opportunities for focused outreach for each watershed unit. Potential exists for Council staff, GMP staff, and others to work with local partners and efforts (e.g., MFRC's Regional Landscape Committees and the Minnesota Pollution Control Agencies' Watershed Restoration and Protection plans) to develop strategies and acquire funding for this outreach.

Mississippi River – Headwaters (MH):

Located prominently at the head of the Mississippi River, this unit is predominantly forested with several large lakes on the Mississippi chain. Sites in MH had high compliance in several categories, notably, implementing filter strips (95%), leave tree retention (91%), and RMZ management (100%). Opportunities to improve compliance exist for managing (minimizing) infrastructure (74%), avoiding wetland crossings (79%), use of erosion control on approaches and segments, and reducing rutting particularly in wetland crossings. Outreach related to use of temporary crossings structures on wetlands during non-frozen seasons would also be appropriate.

Lake Superior – North and South (SUP):

The Lake Superior Watersheds, encompassing the north shore area has the greatest total length of streams (many of them trout streams) in any of the watershed units. Sites in this watershed had high compliance for RMZ implementation especially on trout streams (92%). Implementation of filter strip guidelines and locating landings away from waterbodies was also high at 98% and 92%. Opportunities exist to improve implementation for avoiding wetland crossings (64% compliance), and emphasis on use of erosion control on approaches to stream crossings given the high density of trout streams that occur in this unit.

Rum River (RR):

The Rum River Watershed is the most southern watershed sample unit addressed in this report and has the highest component of developed and agricultural land use. This watershed has a high number of wetlands but fewer streams than other units. Sites in the RR watershed

accomplished exemplary performance in multiple categories. Despite having the highest number of observed wetlands of all sample units, RR had high implementation rates for filter strip implementation (99%), avoidance of wetland crossings (97%), and condition of approaches (100%). However, for RMZ management RR demonstrated very low compliance at only 14%. Outreach targeting NIPF landowners and loggers in the RR watershed focusing on the benefits of implementing RMZ recommendations may improve compliance in this watershed.

Mississippi River – Grand Rapids (MGR):

The second segment on the Mississippi River has one of the lowest percent cover of lakes and ponds (6%) and is one of the units with the shortest total length of rivers and streams. Sites in this watershed accomplished high compliance in filter strip implementation (99%), RMZ management (86%), and avoidance of wetland crossings (88%). Key areas of improvement in this watershed are related to retention of leave trees (only 62% compliant) with characteristics that are more desirable (i.e., higher species diversity/richness, retention of larger trees).

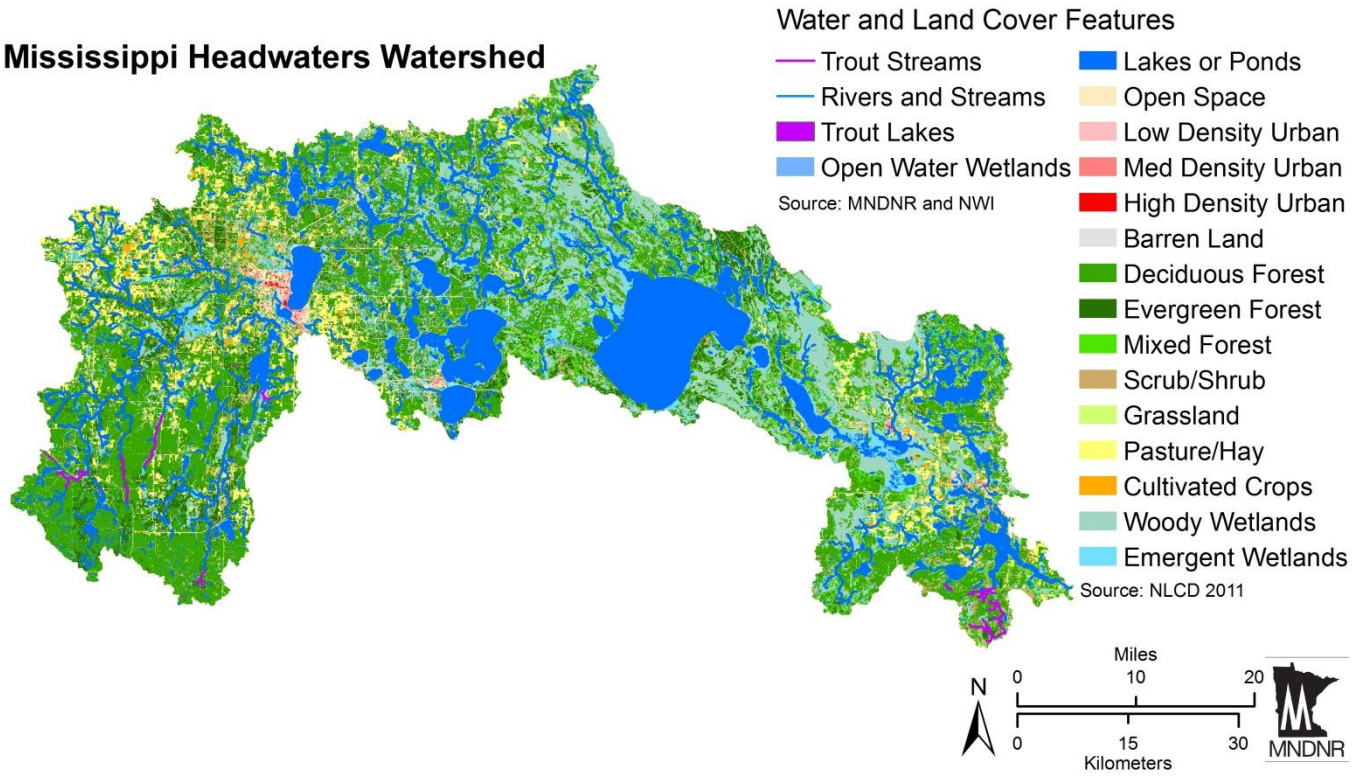
Vermillion River and Rainy River – Headwaters (VRR):

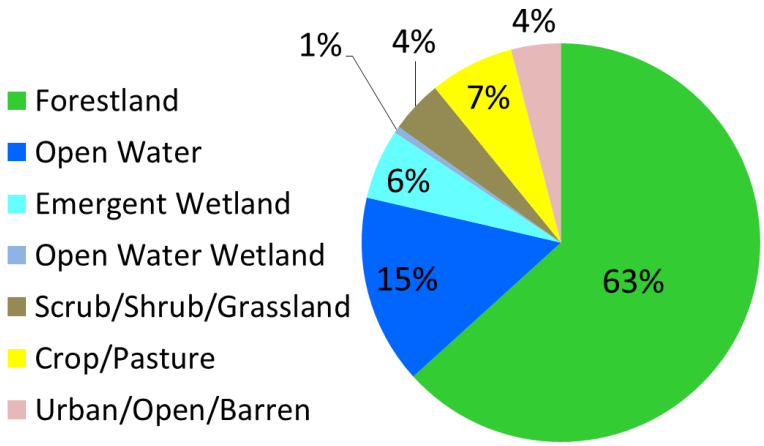
The VRR includes parts of the Boundary Waters Canoe Area (BWCA). VRR unit has the highest percent cover of lakes and ponds (20%) and is one of the units with the longest total length of rivers and streams and the majority of all stream crossings. Sites in this sample unit demonstrated high implementation rates for implementation of filter strips (91%), avoidance of wetland crossings (82%), and 84% leave tree compliance with over 50% of sites utilizing leave tree clumps. Sites also did better than average on avoiding wetland crossings and very good on avoiding rutting in crossings (90%). Opportunities for improvement include implementation of RMZs (76%), use of erosion control on stream approaches (73%), and locating landings away from wetlands and filter strips (61%). VRR also had the highest average on site infrastructure, with one of the lowest compliance rates for meeting infrastructure guidelines (77%). Outreach focus should also be placed on determining when erosion control is needed, as this unit had the highest proportion of sites where erosion control related to water quality was needed.

Red Lake, Clearwater River, and Wild Rice River (RLCW):

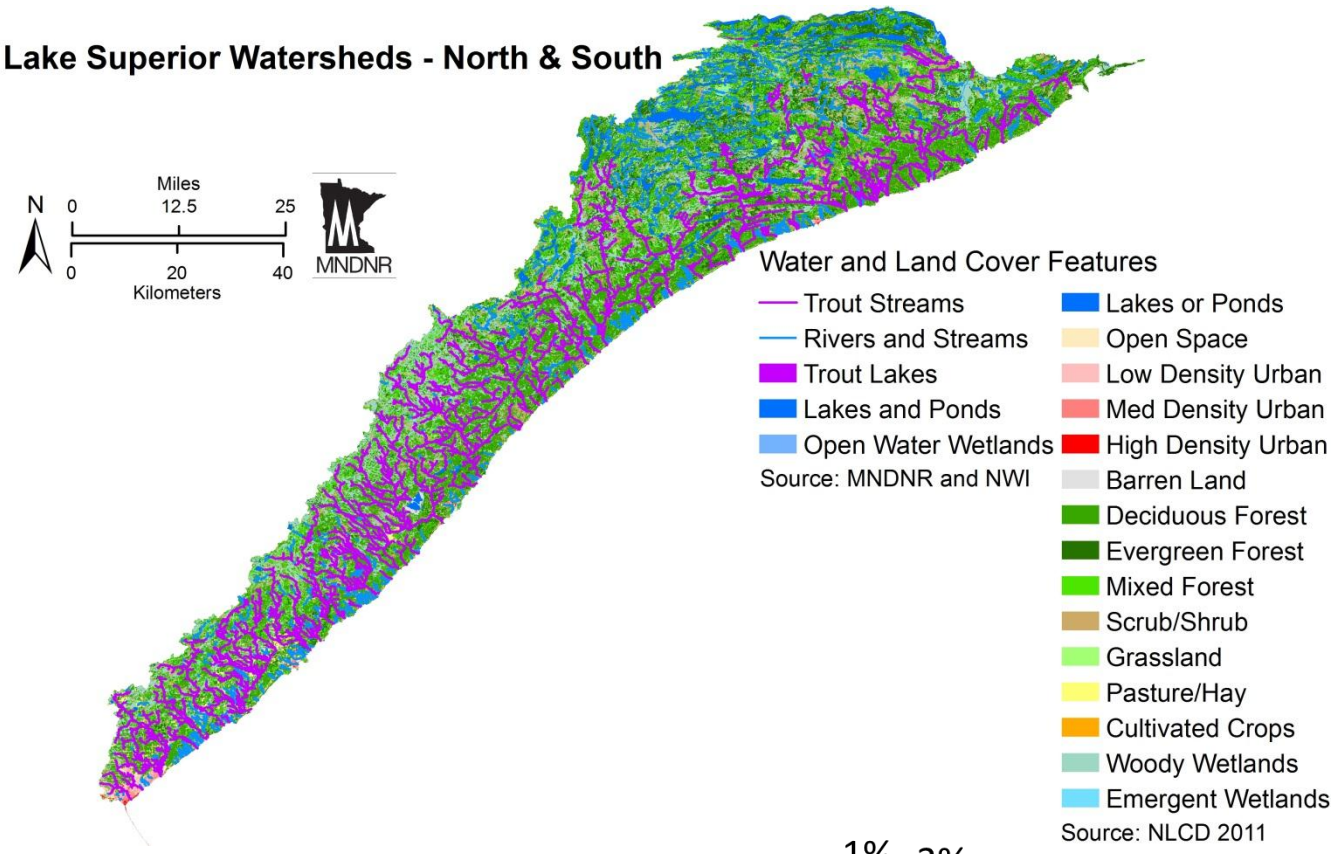
The RLCW watershed has the second highest percent of developed and agricultural land use and the highest percent cover in emergent and open water wetlands. This unit is critical to the health of one of the premier walleye fisheries in Minnesota as well as Clearwater River and Wild Rice River all flowing into the Red River of the North. Sites monitored in this watershed unit demonstrated excellent implementation rates in several categories including: filter strip implementation (100%), RMZ management (100%), avoidance of wetland crossings (92%), and leave tree retention (100%). Given that 46% of sites monitored in this unit had at least one landing located in wetland or filter strips were uplands were available, outreach addressing wetland identification and the importance of locating landings away from wetlands and waterbodies may improve awareness and implementation of this guidelines.

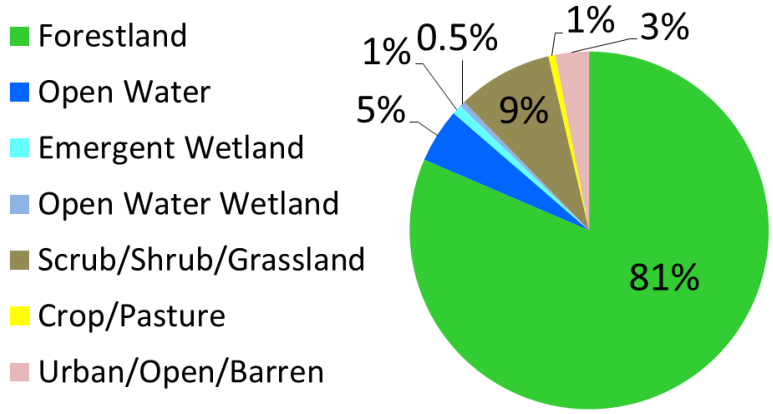
Appendix



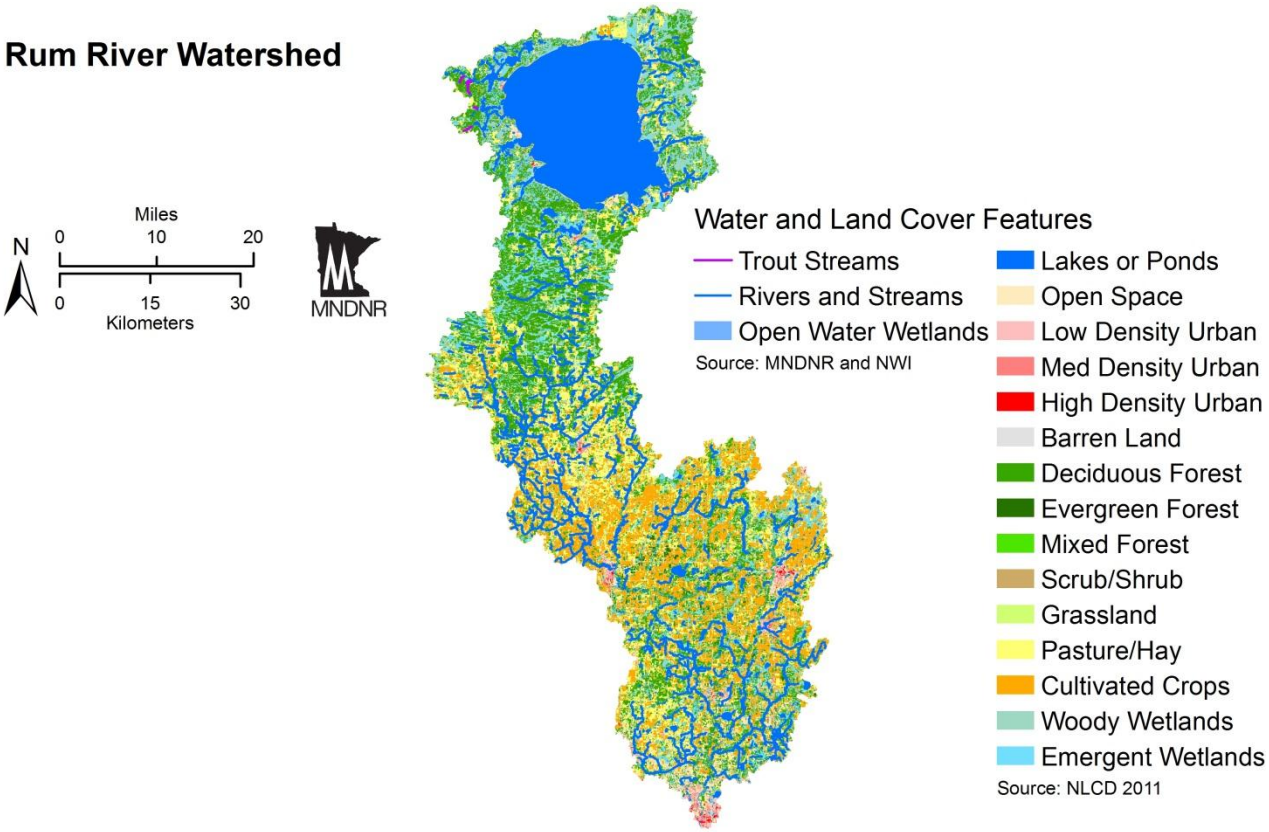


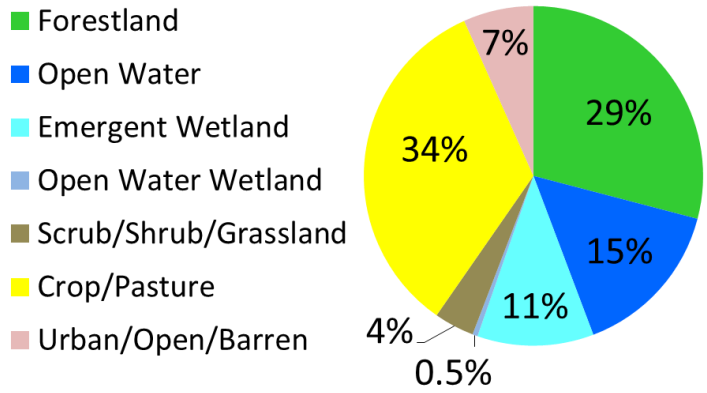
Total Area of Watershed (acres)	1,228,921
Slope (%; Mean, Standard Deviation)	3.2, 4.4
Rivers and Streams (length, mi)	1,575
Trout Lakes and Ponds (%)	0.2
Trout Rivers and Streams (%)	3
DOT/State Forest Roads (length, mi)	3,220
Forest Access Routes (length, mi)	1,729



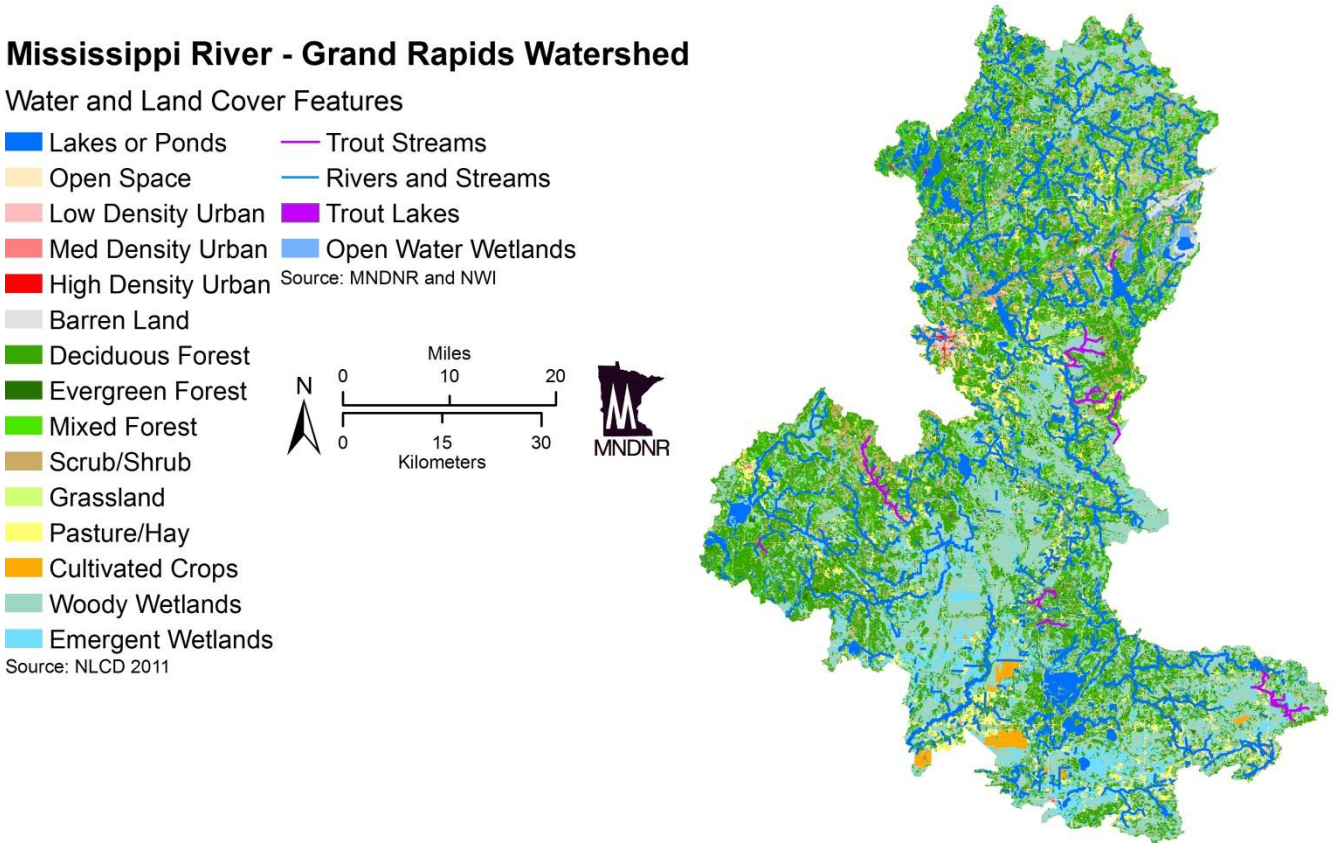


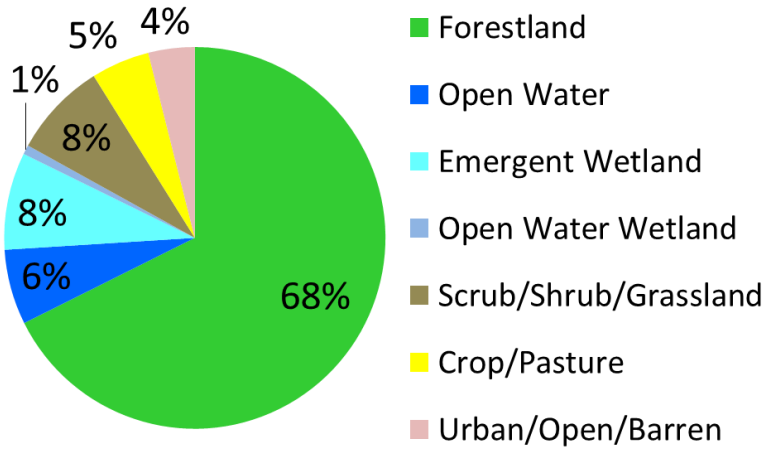
Total Area of Watershed (acres)	1,415,032
Slope (%; Mean, Standard Deviation)	6.9, 7.9
Rivers and Streams (length, mi)	2387
Trout Lakes and Ponds (%)	4
Trout Rivers and Streams (%)	81
DOT/State Forest Roads (length, mi)	1,967
Forest Access Routes (length, mi)	453



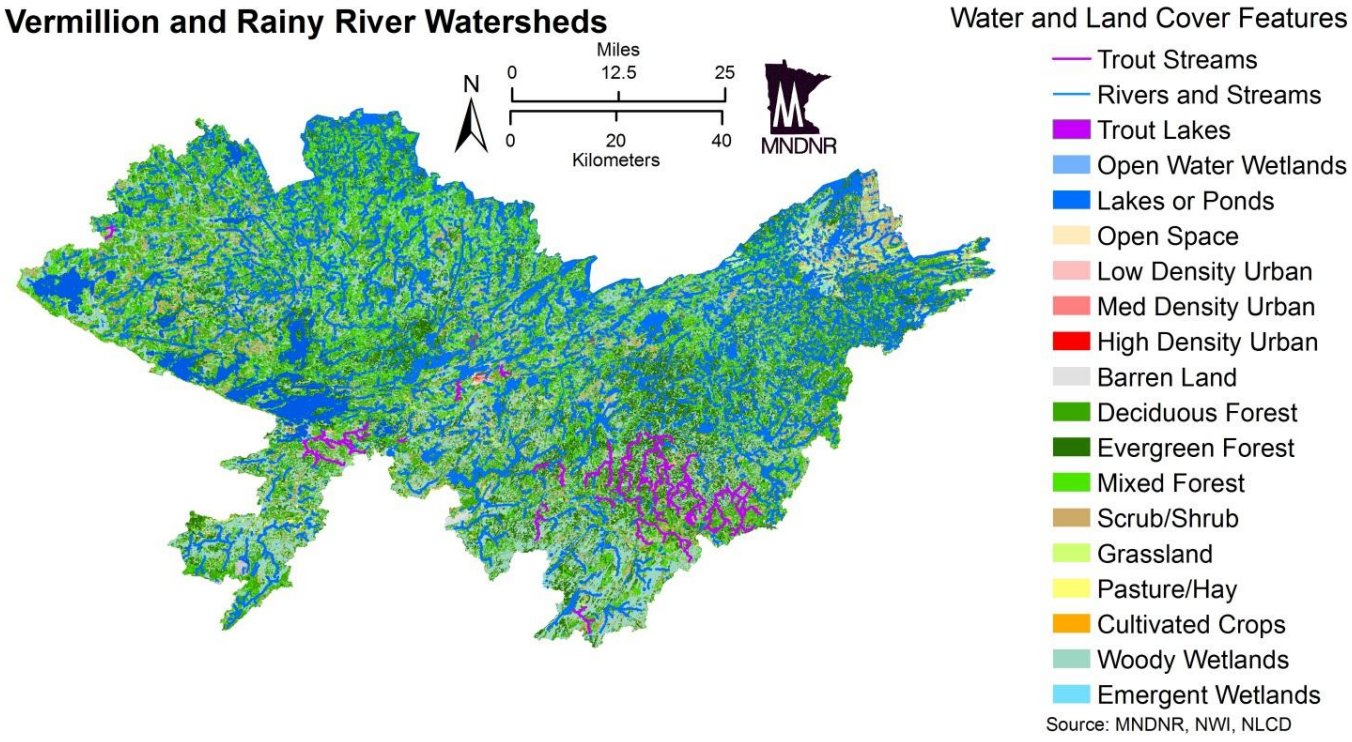


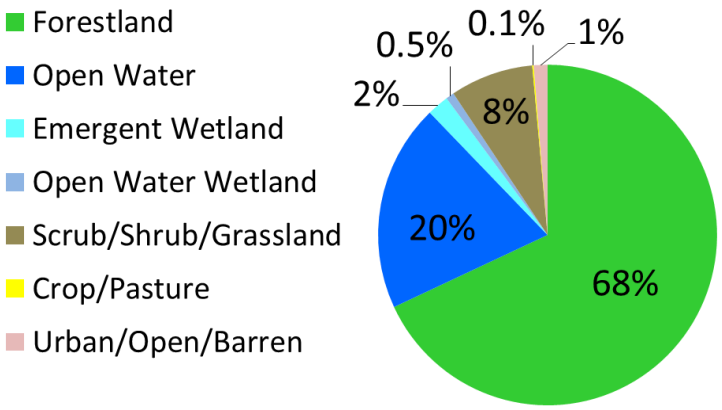
Total Area of Watershed (acres)	1,013,319
Slope (%; Mean, Standard Deviation)	2.6, 3.3
Rivers and Streams (length, mi)	885
Trout Lakes and Ponds (%)	0
Trout Rivers and Streams (%)	1
DOT/State Forest Roads (length, mi)	3,304
Forest Access Routes (length, mi)	9



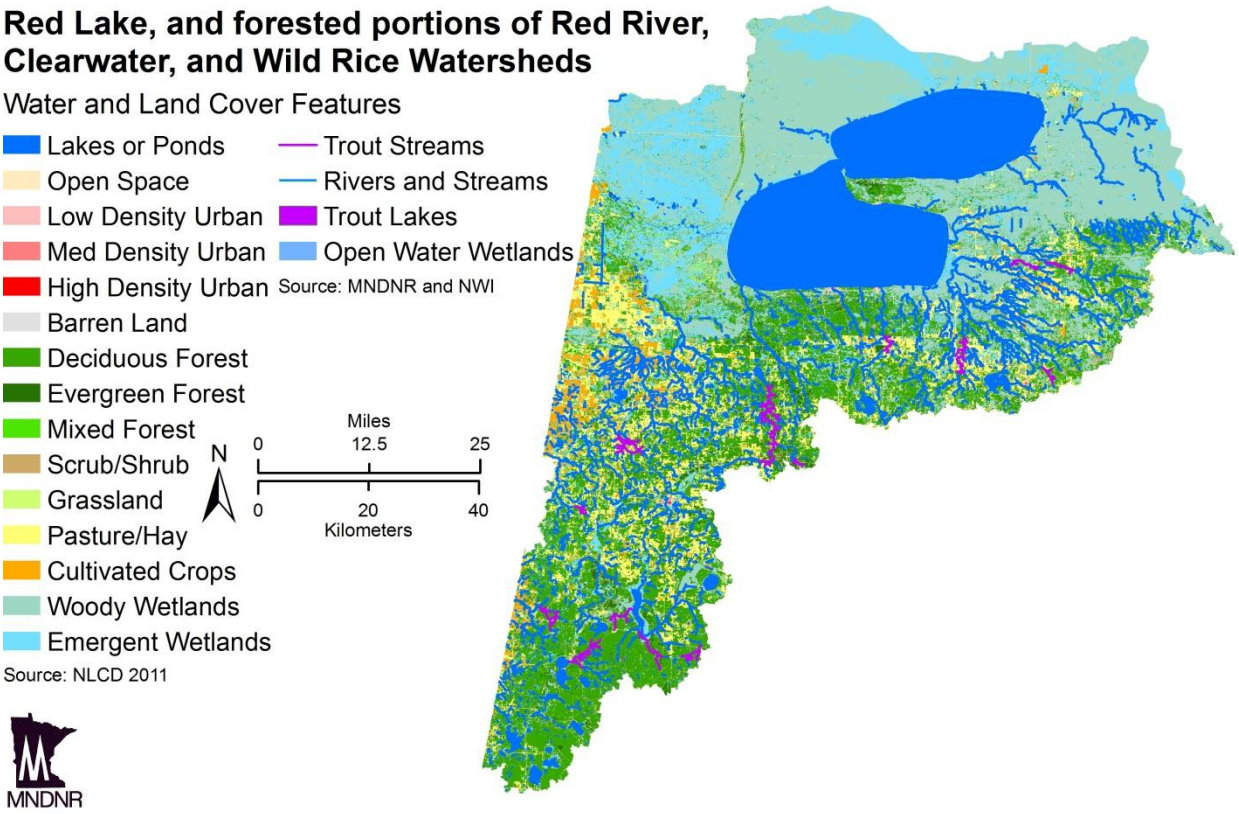


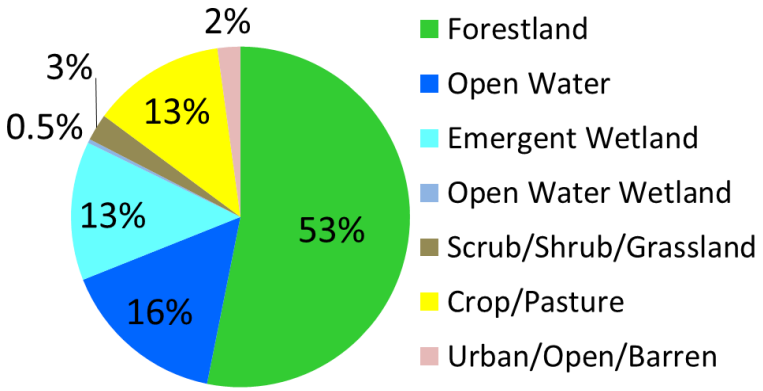
Total Area of Watershed (acres)	1,332,803
Slope (%; Mean, Standard Deviation)	3.1, 5.2
Rivers and Streams (length, mi)	1,101
Trout Lakes and Ponds (%)	0.3
Trout Rivers and Streams (%)	8
DOT/State Forest Roads (length, mi)	2,275
Forest Access Routes (length, mi)	1,852



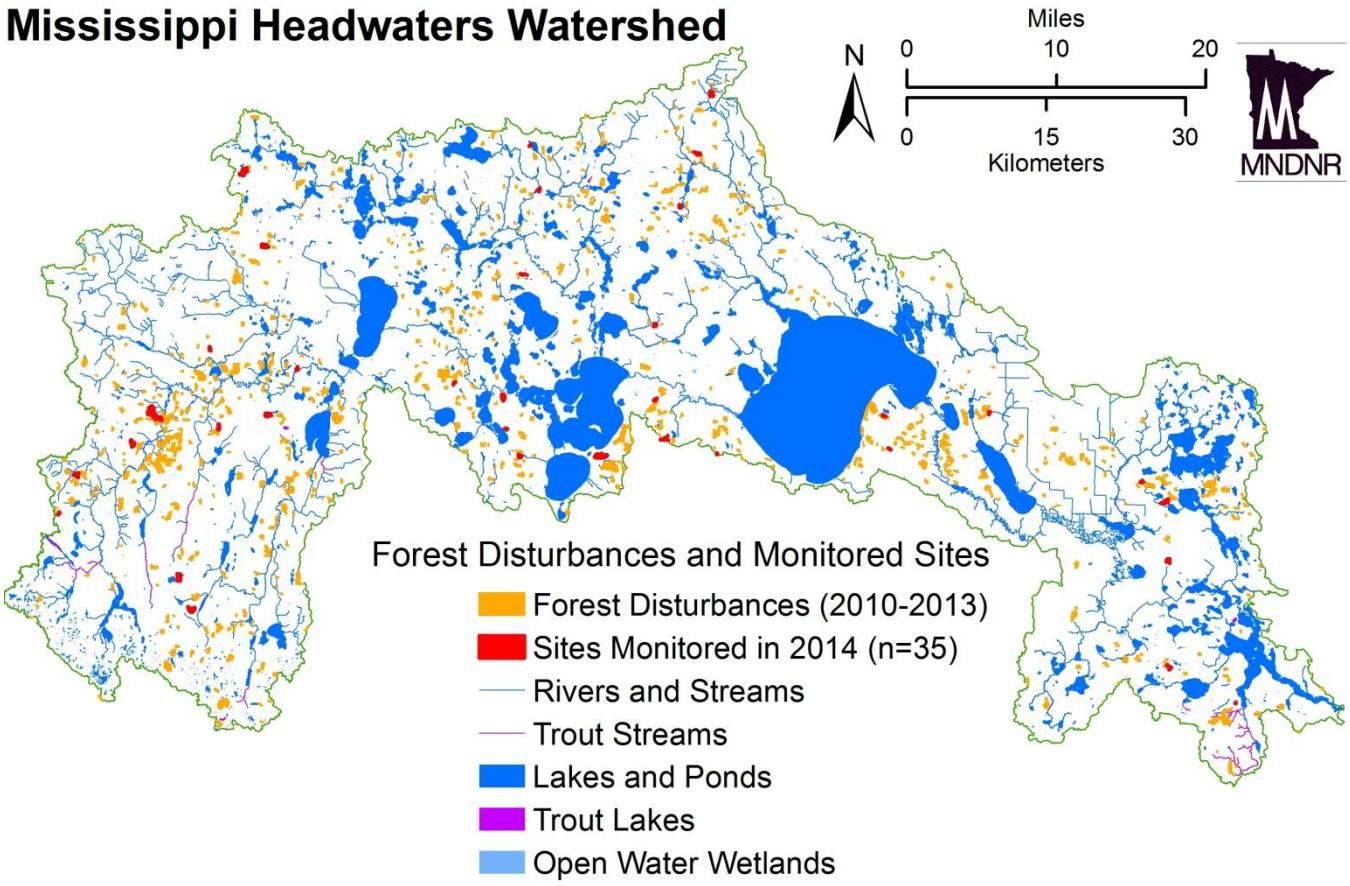


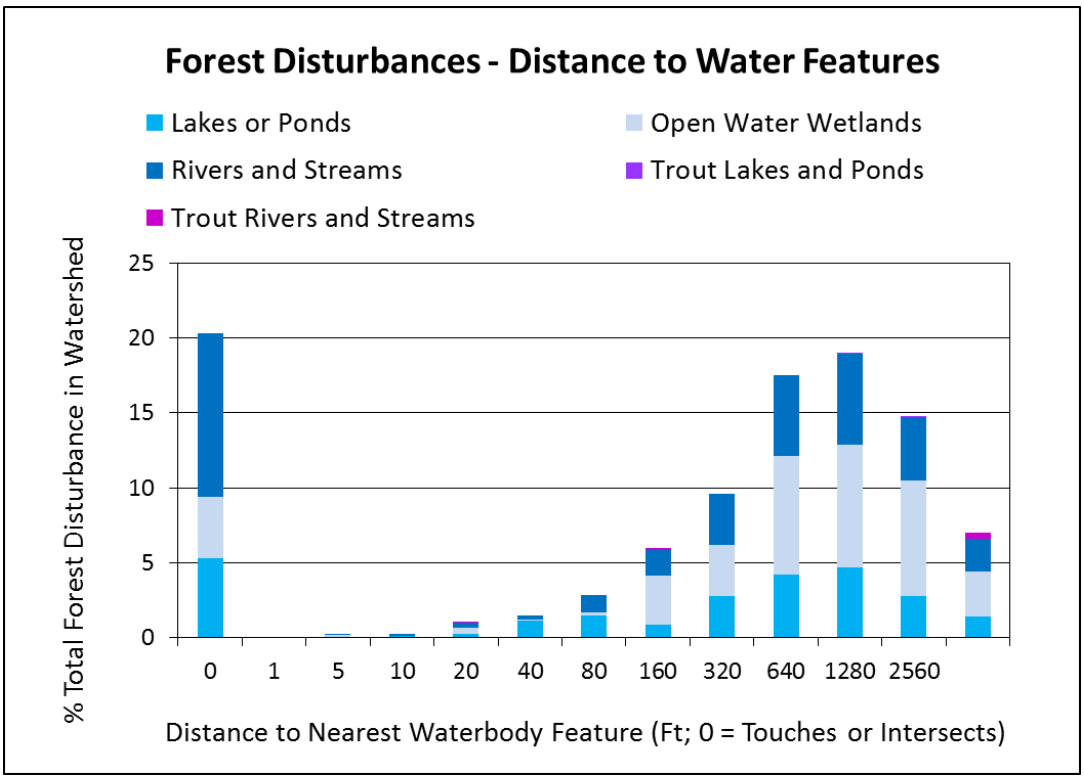
Total Area of Watershed (acres)	2,452,296
Slope (%; Mean, Standard Deviation)	6.8, 7.8
Rivers and Streams (length, mi)	2245
Trout Lakes and Ponds (%)	0
Trout Rivers and Streams (%)	12
DOT/State Forest Roads (length, mi)	1,498
Forest Access Routes (length, mi)	1,054

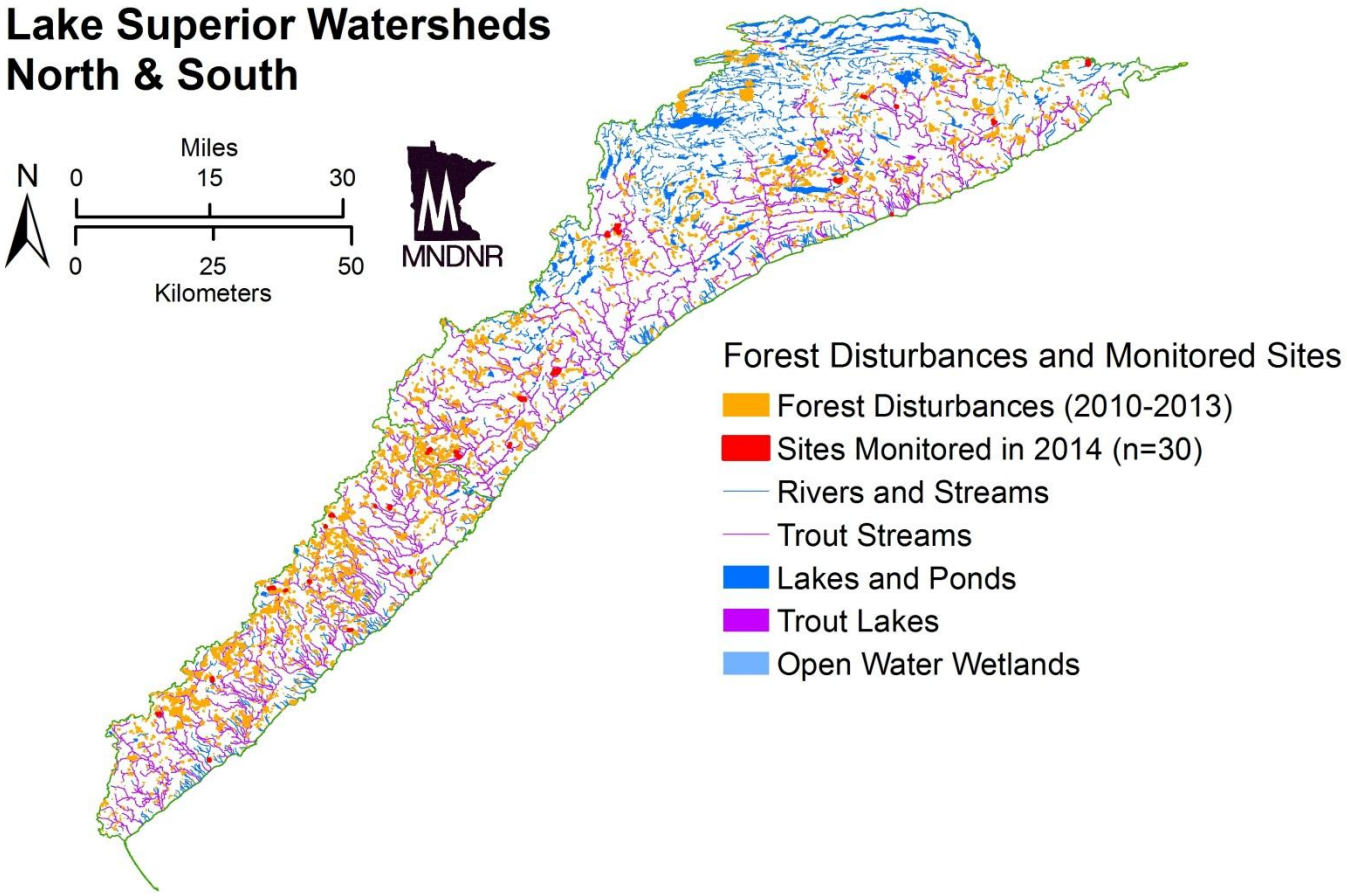


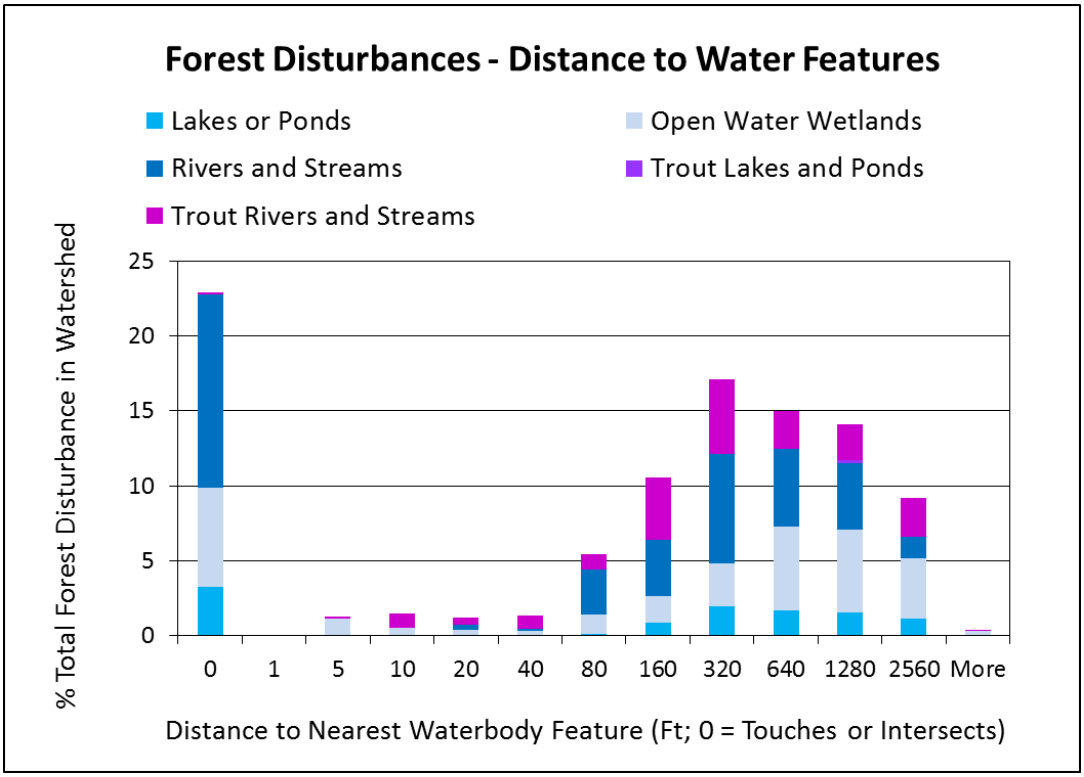


Total Area of Watershed (acres)	2,180,062
Slope (%; Mean, Standard Deviation)	2.1, 3.7
Rivers and Streams (length, mi)	1799
Trout Lakes and Ponds (%)	0
Trout Rivers and Streams (%)	7
DOT/State Forest Roads (length, mi)	2,912
Forest Access Routes (length, mi)	666

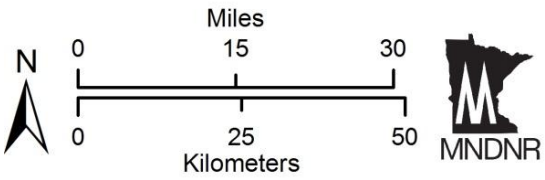

Mississippi Headwaters Watershed
N
Miles
0
10
20
0
15
30
Kilometers
MNDNR
Forest Disturbances and Monitored Sites
Forest Disturbances (2010-2013)
Sites Monitored in 2014 (n=35)
Rivers and Streams
Trout Streams
Lakes and Ponds
Trout Lakes
Open Water Wetlands


Forest Disturbances - Distance to Water Features
Lakes or Ponds
Open Water Wetlands
Rivers and Streams
Trout Lakes and Ponds
Trout Rivers and Streams
% Total Forest Disturbance in Watershed
25
20
15
10
5
0
0
1
5
10
20
40
80
160
320
640
1280
2560
Distance to Nearest Waterbody Feature (Ft; 0 = Touches or Intersects)


Lake Superior Watersheds
North & South
N
Miles
0
15
30
0
25
50
Kilometers
MNDNR
Forest Disturbances and Monitored Sites
Forest Disturbances (2010-2013)
Sites Monitored in 2014 (n=30)
Rivers and Streams
Trout Streams
Lakes and Ponds
Trout Lakes
Open Water Wetlands

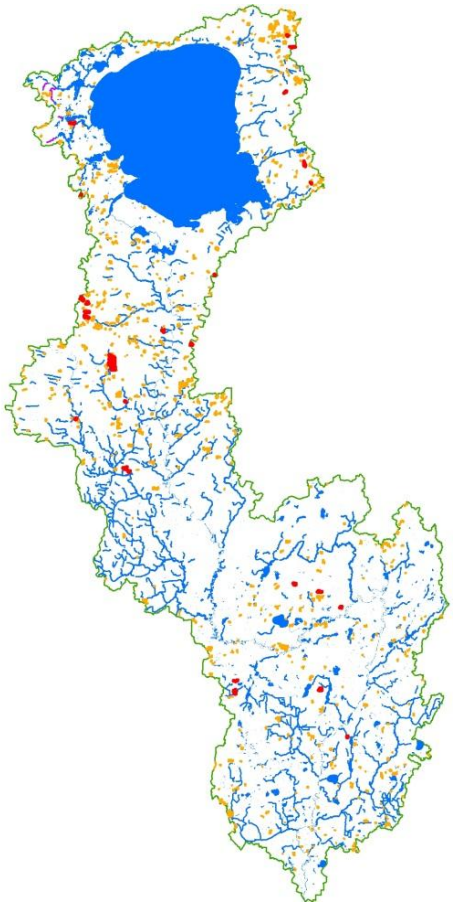

Forest Disturbances - Distance to Water Features
Lakes or Ponds
Open Water Wetlands
Rivers and Streams
Trout Lakes and Ponds
Trout Rivers and Streams
% Total Forest Disturbance in Watershed
25
20
15
10
5
0
0
1
5
10
20
40
80
160
320
640
1280
2560
More
Distance to Nearest Waterbody Feature (Ft; 0 = Touches or Intersects)

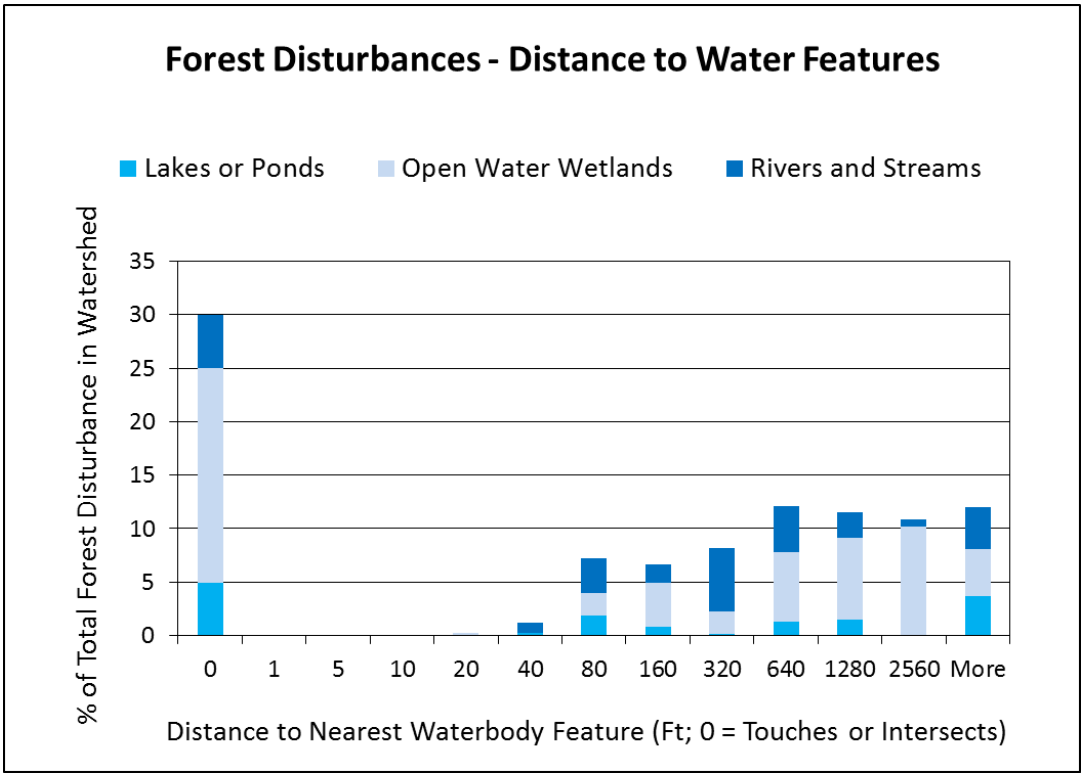
Rum River Watershed



Forest Disturbances and Monitored Sites

- Forest Disturbances (2010-2013)
- Sites Monitored in 2014 (n=28)
- Rivers and Streams
- Trout Streams
- Lakes and Ponds
- Open Water Wetlands

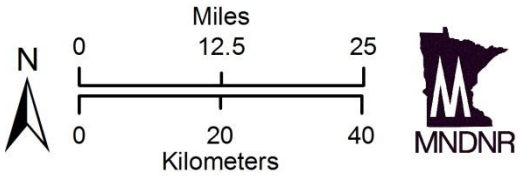


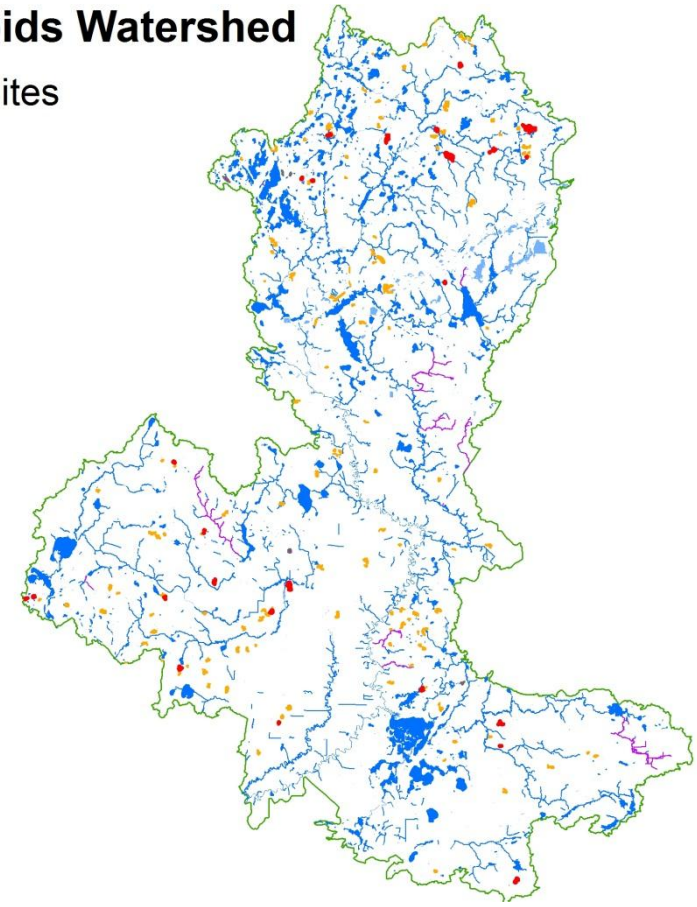


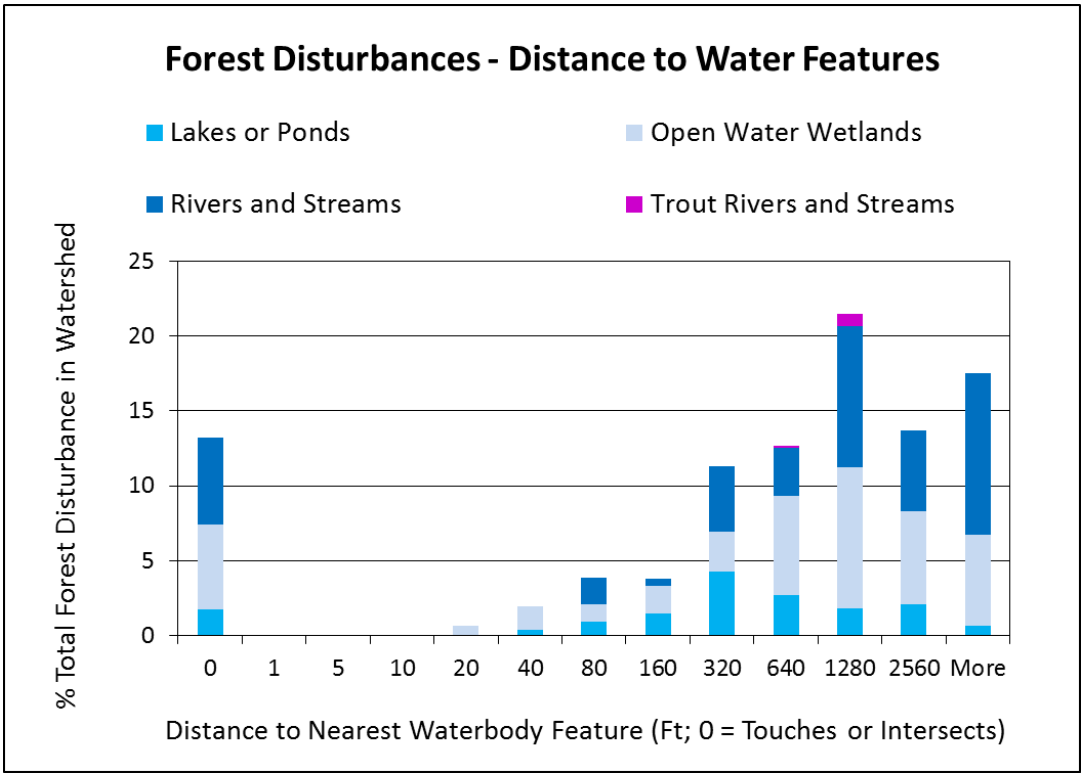
Mississippi River - Grand Rapids Watershed

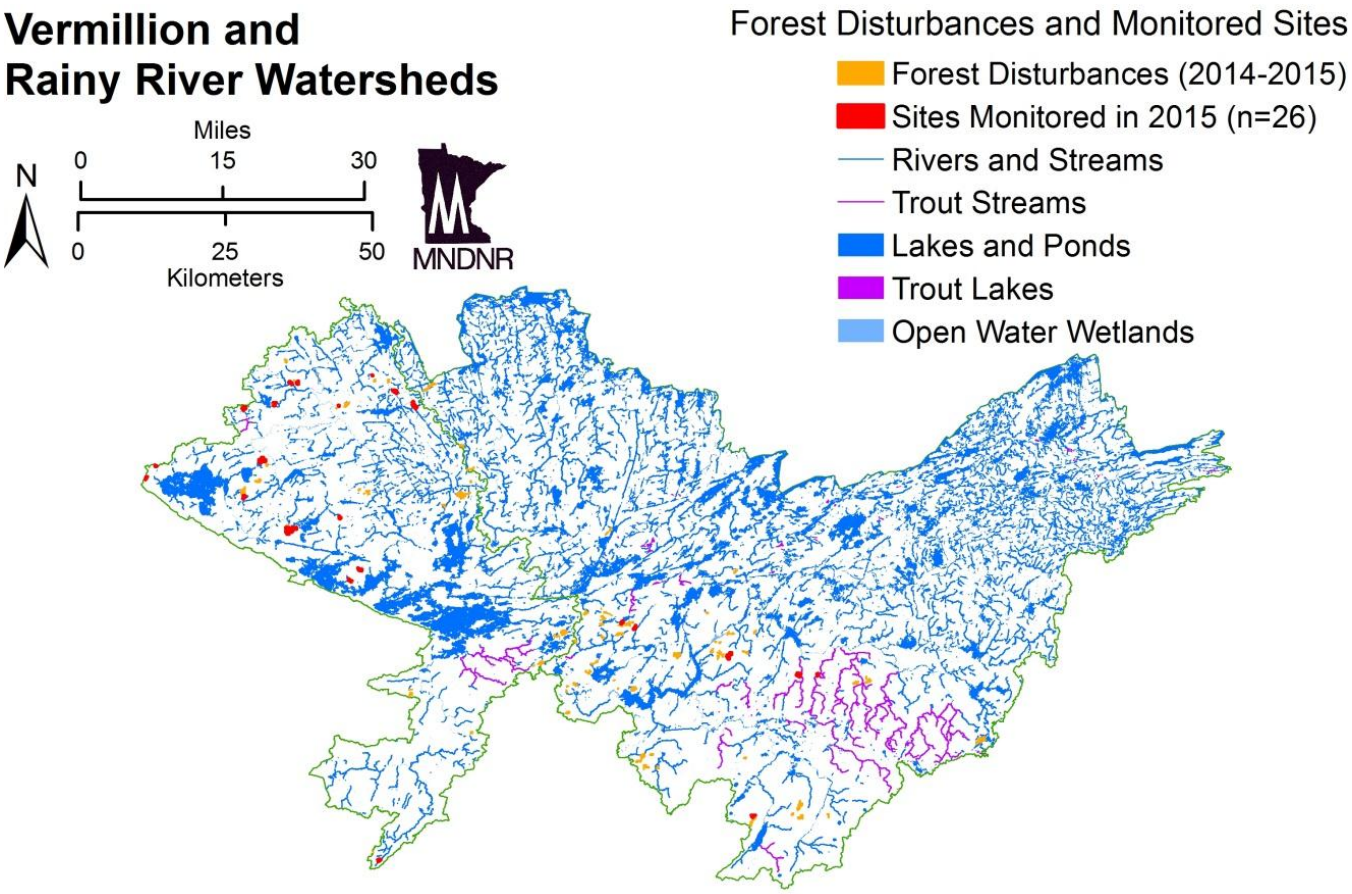
Forest Disturbances and Monitored Sites

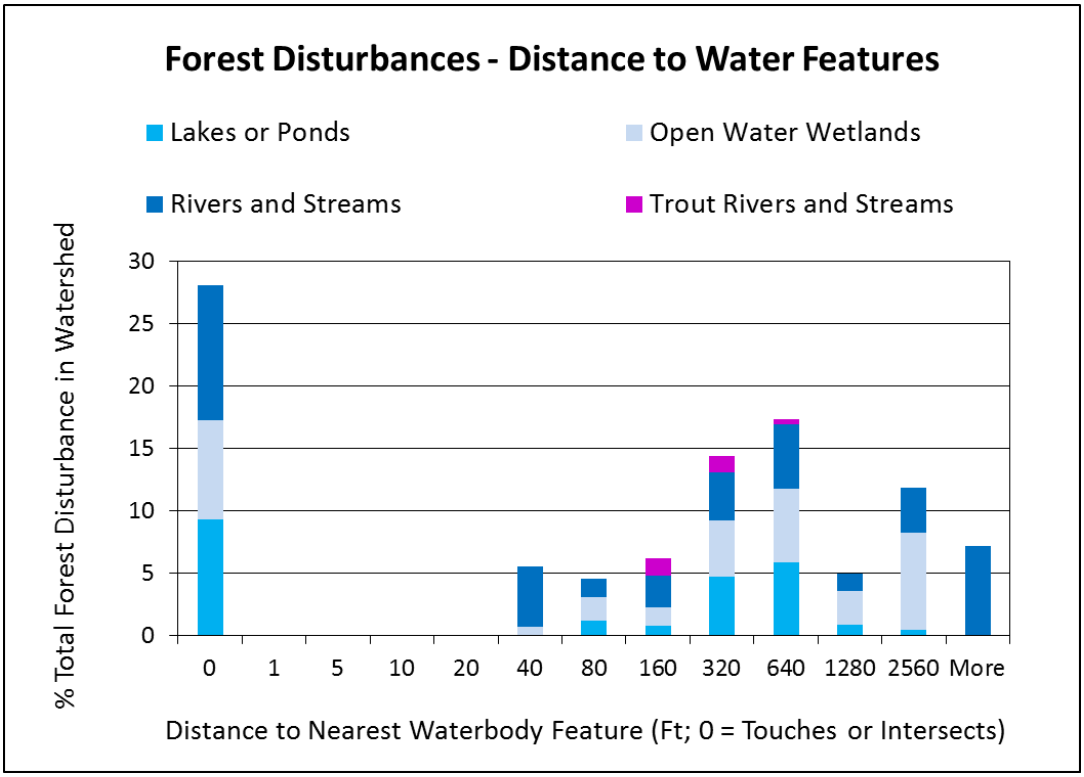
- Forest Disturbances (2014-2015)
- Sites Monitored in 2015 (n=29)
- Rivers and Streams
- Trout Streams
- Lakes and Ponds
- Trout Lakes
- Open Water Wetlands

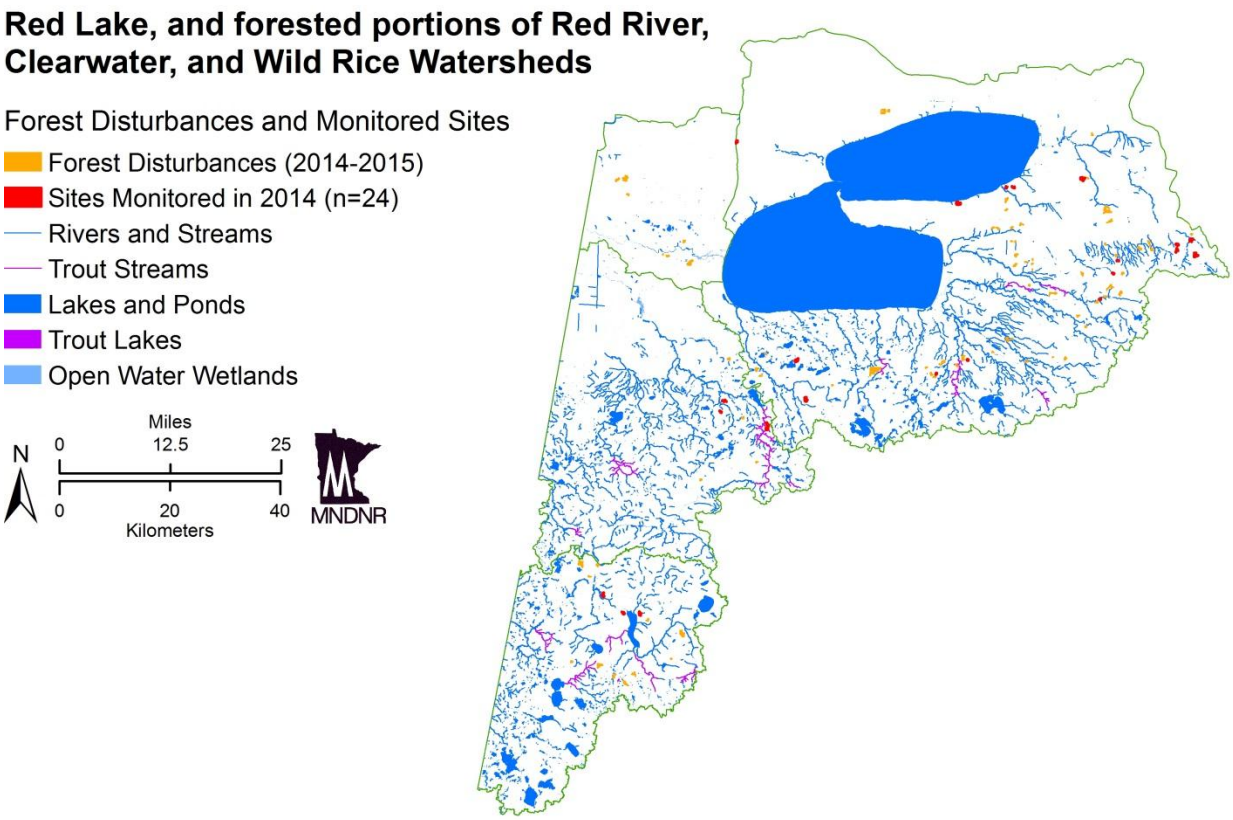


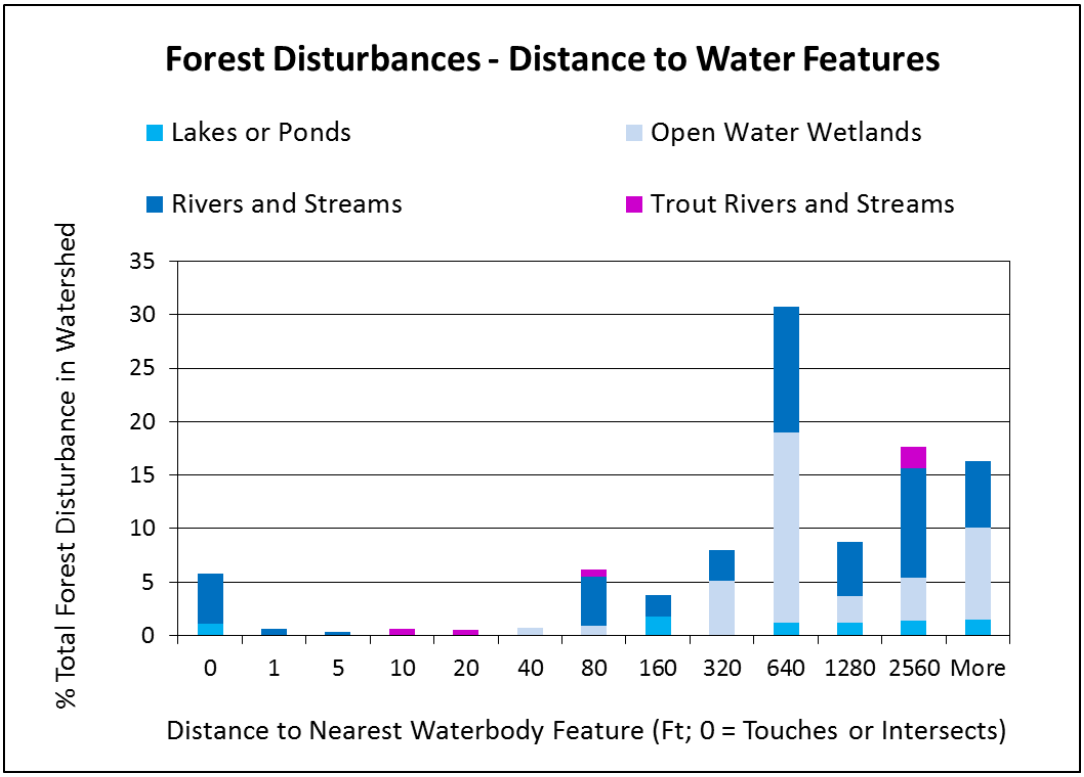





Vermillion and
Rainy River Watersheds
Miles
0
15
30
N
0
25
50
Kilometers
MNDNR
Forest Disturbances and Monitored Sites
Forest Disturbances (2014-2015)
Sites Monitored in 2015 (n=26)
Rivers and Streams
Trout Streams
Lakes and Ponds
Trout Lakes
Open Water Wetlands


Forest Disturbances - Distance to Water Features
Lakes or Ponds
Open Water Wetlands
Rivers and Streams
Trout Rivers and Streams
% Total Forest Disturbance in Watershed
30
25
20
15
10
5
0
0
1
5
10
20
40
80
160
320
640
1280
2560
More
Distance to Nearest Waterbody Feature (Ft; 0 = Touches or Intersects)


Red Lake, and forested portions of Red River, Clearwater, and Wild Rice Watersheds
Forest Disturbances and Monitored Sites
Forest Disturbances (2014-2015)
Sites Monitored in 2014 (n=24)
Rivers and Streams
Trout Streams
Lakes and Ponds
Trout Lakes
Open Water Wetlands
N
Miles
0
12.5
25
0
20
40
Kilometers
MNDNR


Forest Disturbances - Distance to Water Features
Lakes or Ponds
Open Water Wetlands
Rivers and Streams
Trout Rivers and Streams
% Total Forest Disturbance in Watershed
35
30
25
20
15
10
5
0
0
1
5
10
20
40
80
160
320
640
1280
2560
More
Distance to Nearest Waterbody Feature (Ft; 0 = Touches or Intersects)

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