Aquatic, Riparian, and Wetland Ecosystem Assessment

Bighorn National Forest, Wyoming

USDA Forest Service – Rocky Mountain Region

Report 2 of 3

Anthropogenic Influences Report

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The Bighorn Aquatic, Riparian and Wetland Ecosystem Assessment is presented in three separate reports. The reports can be cited as follows:

Winters, D.S. et al. 2004. Aquatic, riparian and wetland ecosystem assessment for the Bighorn National Forest. Report 1 of 3: Introduction and ecological driver analysis. Denver, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region.

Winters, D.S. et al. 2004. Aquatic, riparian and wetland ecosystem assessment for the Bighorn National Forest. Report 2 of 3: Anthropogenic influences report. Denver, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region.

Winters, D.S. et al. 2004. Aquatic, riparian and wetland ecosystem assessment for the Bighorn National Forest. Report 3 of 3: Ecological driver analysis and anthropogenic influence results: Synthesis and discussion. Denver, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region.

Table of Contents

List of Figures and Tables

Chapter 1
Introduction

The purpose of this report is to provide the results of the analysis of anthropogenic influences on aquatic, riparian, and wetland resources for the Bighorn National Forest and surrounding landscape. These analyses are based on the protocols described by Winters et al. (2003a). There have been minor modifications in this assessment that diverge from the original protocol documents. While we expected these modifications to occur with this pilot assessment the overall goal of the assessment has not changed.

Key Findings

1. The effects of several anthropogenic activities, including beaver removal and mining are still influencing aquatic, riparian, and wetland resources today, although they have not been actively occurring for sometime.
2. Railroad influences are the only activity identified which does not occur at the management scale.
3. Water uses are not as abundant within the Bighorn National Forest as outside of its boundaries, and appear to be less than other National Forests in the region where population centers are larger.
4. Transportation is well distributed in the Bighorn National Forests, with roads and trails often associated with the valley bottoms.
5. Recreational activities, especially dispersed camping, are closely related to streams, valley bottoms, and lakes in wilderness areas.
6. Native Yellowstone cutthroat populations occupy a relatively small proportion of their historic range on the Bighorn National Forest, and only partially within the areas of highest productivity.
7. There is a relationship between the percentage of HUBs burned since 1910 and the fact that they were historically impacted by tie-drives.

Analysis of anthropogenic influences are required by various federal laws, specifically the Endangered Species Act (1973), National Environmental Policy Act (1969), Clean Water Act (1977), and the National Forest Management Act (1976). In addition, specific funding is identified to conduct watershed assessments, monitor the effectiveness of land management plans and project implementation, develop new technology for managing resources, and pre-and post-habitat improvement projects. While there is limited funding and personnel to address the intent of these laws, this information is also important in maintaining and improving our working relationship with other federal agencies as well as state agencies and public groups. Individual administrative units of the Rocky Mountain Region have addressed the numerous regulations and demands that are increasing from the public relating to ecosystem sustainability and species viability with limited funding and personnel. These limitations have made it difficult to address these resource issues from a “regional” perspective. As a result, Forests within the Rocky Mountain Region have had to work independently to a large extent, and focused on critical issues rather than addressing these issues at several scales of importance throughout the region. The objective of this chapter is to supply the reader with current, defensible information on past and current anthropogenic influences that will facilitate sound resource management. This information will allow aquatic, riparian, and wetland specialists to focus on resource management with defensible, multi-scale assessment information that will allow them to address resource management challenges and the increased demands from the public.

A total of 24 different anthropogenic influences have been identified and organized into seven groups of similar activities and responses that influence aquatic, riparian, and wetland resources (table 1.1) (Winters et al. 2003b). We believe that the 24 different anthropogenic influences, defined in the seven different use categories, encompass the majority of influences found in the Rocky Mountain Region of the Forest Service. The seven different use categories were identified to start a process of “linking” activities with similar influences on aquatic, riparian, and wetland resources. This is an important step in addressing the additive influences of multiple activities on a particular resource.

Temporal and spatial influences of the specific topic for the three scales (basin, landscape, and management) are presented. Each section provides the results of the specific analysis, including statistical and graphical representation of the results. Maps are used to illustrate a particular influence at the basin scale, and to a lesser extent at the landscape scale. Figure 1.1 is an example of the template or the landscape map used throughout this chapter showing the 4th level HUBs intersecting the Bighorn National Forest boundary.

Following the analysis and discussion of the activity categories, a section will be devoted to the additive effects of that particular category on the aquatic, riparian, and wetland ecosystems of the management scale of the Bighorn National Forest. Only those activities with quantitative metrics were included in the additive effects analysis and discussion. We have chosen to use the terms "additive effects" for this analysis to reduce the confusion that cumulative effects may bring. Additive effect is a term specifically defined under National Environmental Policy Act (NEPA) of 1969 to describe the total effects of all management activities when addressing project level analysis (USDA 1993). While this analysis could be used in this context, we are addressing the additive effects within a particular Use Category. These use categories were selected based on their similar resource influences to aquatic, riparian, and wetland resources (Winters et al. 2003a). We developed a framework to quantify management-scale additive effects using two separate analyses. Both of these analyses have been provided to the Bighorn National Forest for their interpretation.

The first analysis is an agglomerative cluster analysis of measurements calculated for individual activities (e.g., measurements for diversions, transmission ditches, etc.; see Winters et al. 2003a for example of cluster analysis). The purpose of this analysis is to categorize the 74 6th level watersheds comprising the management scale into groupings based upon the statistical distribution of metric values within each category. These groupings allow for a simplified analysis of the potential influence of anthropogenic activities in that particular category. The clusters identified in the anthropogenic analyses are independent of those derived from the ecological driver analyses in Chapter 2 of Report 1 of this assessment.

The second analysis is based on the sum of quartile rank values for the individual activities analyses. We developed a framework for analyzing additive effects on aquatic, riparian, and wetland resources that utilized the results of the same five individual activity analyses used in the cluster analysis. The analysis procedure is as follows:

1. Each HUB has a ranking value (0 to 3) for a given individual activity (e.g., diversion ratio, transmission ditches, etc.).
2. Quartile ranking values for all activities were totaled for each HUB (e.g., rank sum). Rank sum values could range from a minimum of 0 (if the HUB had none of the five activities) to 15 (if the HUB had the top rank for each of the five activities).
3. The distribution of the rank sums was divided into quartiles. Group 1 identifies those HUBs within the lowest quartile of cumulative rankings. Group 2 identifies those HUBs within the 25th – 50th percentiles of cumulative rankings. Group 3 identifies those HUBs within the 50th – 75th percentiles of cumulative rankings. Group 4 identifies those HUBs within the highest quartile of cumulative rankings.
4. The distribution of these additive effects groups was mapped using GIS.

The purpose of this additive ranking analysis is to identify HUBs with the greatest and least potential to be influenced by the identified anthropogenic activities within each category. As data availability limits the scope of geographic information system analysis, not all activities had their percentile values and ranks calculated.

Interpretations of these analyses are intended to identify the spatial context of HUBs that have the greatest and the least potential to be influenced by anthropogenic activities, as well as the HUBs that are expected to have similar potentials for anthropogenic influence. The interpretation of the additive effects analysis in the context of the ecological driver analysis should provide valuable insight into the relationship between the ecological context, and the nature, extent and potential influences of anthropogenic activities across the management scale, thereby providing a framework for the creation, modification, and implementation of natural resource management strategies for the Bighorn National Forest.

Table 1.1. Twenty-four anthropogenic activities and seven use categories identified for this assessment based on Winters et al (2003a).

USE CATEGORY	ACTIVITY
Water Use	Stream Diversions
Water Use	Transmission Ditches
Water Use	Transbasin Diversions
Water Use	Reservoirs
Water Use	Spring Development
Transportation	Roads
Transportation	Trails
Transportation	Off-Road Vehicles
Transportation	Railroads
Recreation	Developed Recreation
Recreation	Dispersed Recreation
Recreation	Ski Area Development
Biological	Invasive Species
Biological	Beaver Removal
Biological	Pesticides
Mineral Extraction	Hardrock & Placer Mining
Mineral Extraction	Energy Development
Vegetation Management	Commercial Timber Harvest
Vegetation Management	Natural & Prescribed Fire
Vegetation Management	Tie Drives
Vegetation Management	Livestock Grazing
Vegetation Management	Large Wild Ungulates
Urbanization	Transmission Corridors
Urbanization	Urbanization

There are 248 6th level watersheds or HUBs encompassed at the landscape scale and 74 HUBs, which intersect the Bighorn National Forest boundary. These HUBs or watersheds conform to the hierarchical coding system adopted by the USDA Forest Service, and other federal and state agencies as a means of cataloging watersheds (Maxwell et al. 1995). These codes are used to identify 6th level HUBs in our analysis (fig. 1.2).

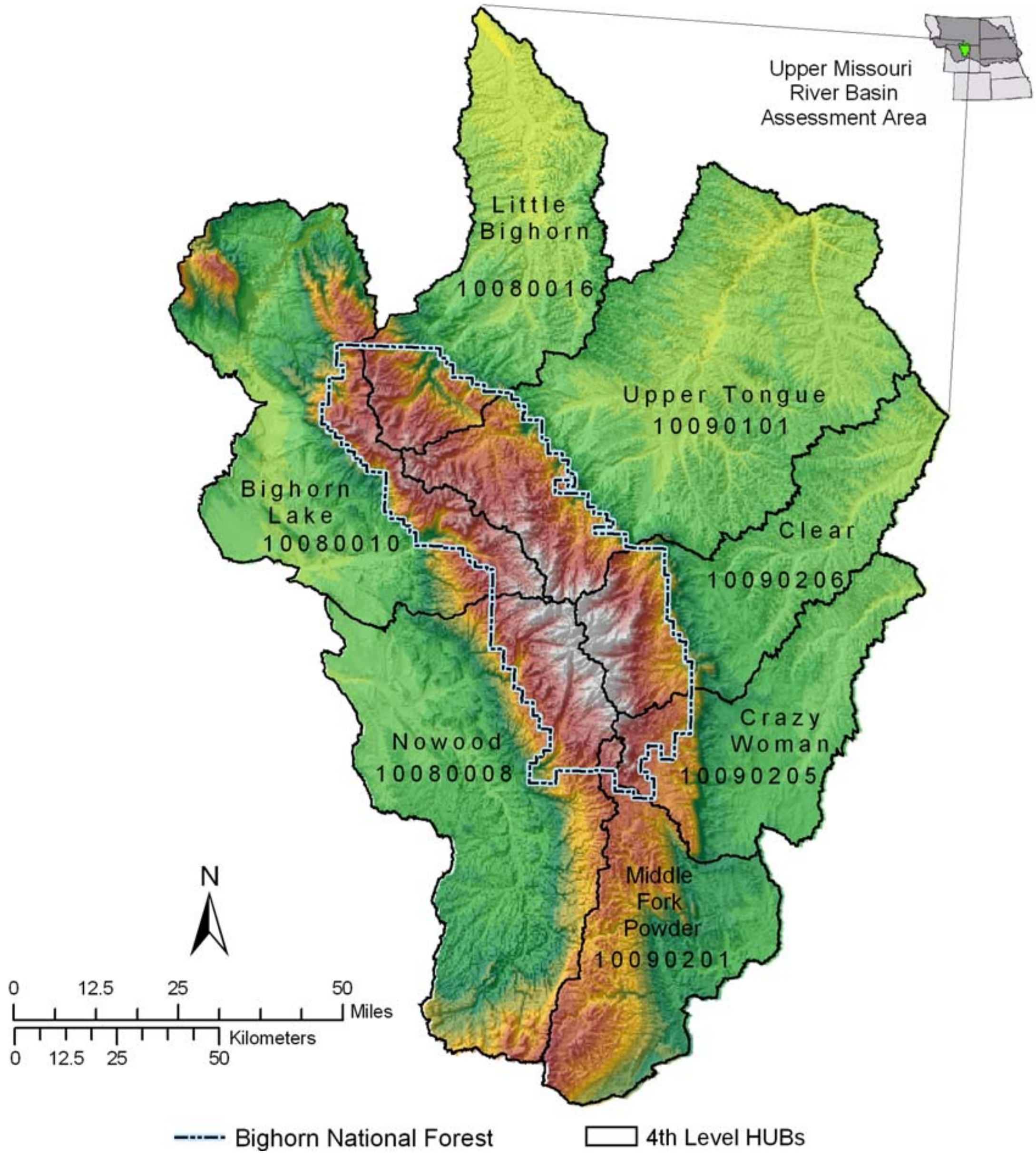

Figure 1.1. An example of the landscape scale map or template used throughout the anthropogenic influence chapter. The names and codes of the 4th level HUBs are shown.

The analysis of the effects of anthropogenic activities on aquatic, riparian, and wetland resources involves the use of three metrics: densities, ratios and percentages. A *density* metric is one that is concerned with the distribution of a given activity per unit area. An example of a density would be the number of points of water diversion per acre of a 6th level HUB.

A *ratio* metric involves the comparison of the amount of an activity to the amount of a different phenomenon. For example, the total length of road (in miles) is compared to the total length of streams (in miles) for each 6th level HUB. However, the ratio metric does not require that the phenomenon be in the same units. For example, the length of ditches (in feet) is compared to the total length of streams (in miles) per 6th level HUB. For this particular activity, the ratio of ditch length in miles to stream length (in miles) would yield an awkwardly low number. The use of different units (feet as opposed to miles) yields a number that is more meaningful because of the decrease in the number of significant digits.

A *percentage* metric involves the comparison of the amount of a particular subset of a phenomenon to the total amount of that phenomenon. For example, the percentage of streams that are affected by an upstream reservoir is a metric used in this assessment. This involves the computation of two components: the length of the streams affected by an upstream reservoir (in miles), and the total length of streams (in miles) per 6th level HUB.

In order to show the range of values comparatively between HUBs, and demographic area of each influence within this scale, values must be used that reflect the "density per unit area" of each area. For example, a 6th level HUB that has ten water diversions for 100 miles of stream has a ratio of 0.1, while a smaller watershed with five water diversions for 50 miles of stream also has a ratio of 0.1. Without addressing the relative size of the watershed (in this case with stream miles per HUB), a misleading result can be reached. Of course, other ways of looking at these values can occur, but this technique gives the reader measurable evaluation of where a particular anthropogenic activity "ranks" in relationship to the other 73 HUBs at this scale, and we can show the reader where it is located. The ranks of these ratios are divided into thirds, to give the reader an idea of the relative values across the rank continuum. The final step is to illustrate the 6th level HUBs spatially, with identification of the three levels of ratios identified. An example of the presentation of these results is presented in Figure 1.3.

As we proceeded through our analysis of effects, it became evident that there were data not available to complete a specific analysis. For example, a valuable analysis would be to determine how much water is available or is appropriated for water withdrawal and how much is available in a particular HUB. This information is difficult to determine throughout the region. However, it may be a high priority if we are to make decisions on potential future development. At the end of each chapter, we identified information needs that could help the Bighorn National Forest answer these questions in the future. Some information was not available for HUBs outside the National Forest boundary. For this analysis we were restricted to within boundary measurements, however still maintaining the comparative ranking procedure described previously.

A discussion at the end of each section on the relationship between the ecological driver results and the particular anthropogenic influence (e.g., ski areas) is also addressed. This information is valuable in helping specialists identify potential restoration watersheds (e.g., sensitive watersheds with high levels of activity) and reintroduction watersheds for rare species (e.g., HUBs with potentially high habitat and low activities). Finally, this information should prove valuable when determining project level feasibility when projects are identified.

Lastly, we did not conduct site or reach specific analysis in this assessment. This type of analysis requires intensive measurements of species population and habitat characteristics that are not appropriate for a multiple scale assessment. With this in mind, we are currently conducting validation studies within the assessment area at this scale to determine if the assumptions made for the assessment are correct. These results will be presented to the Bighorn National Forest for use in their planning efforts, as well as for determining the effectiveness of our assessment model. Future site and reach level inventories and monitoring efforts should take into consideration the results of this assessment when prioritizing inventory and monitoring efforts, and addressing characteristics of "reference conditions".

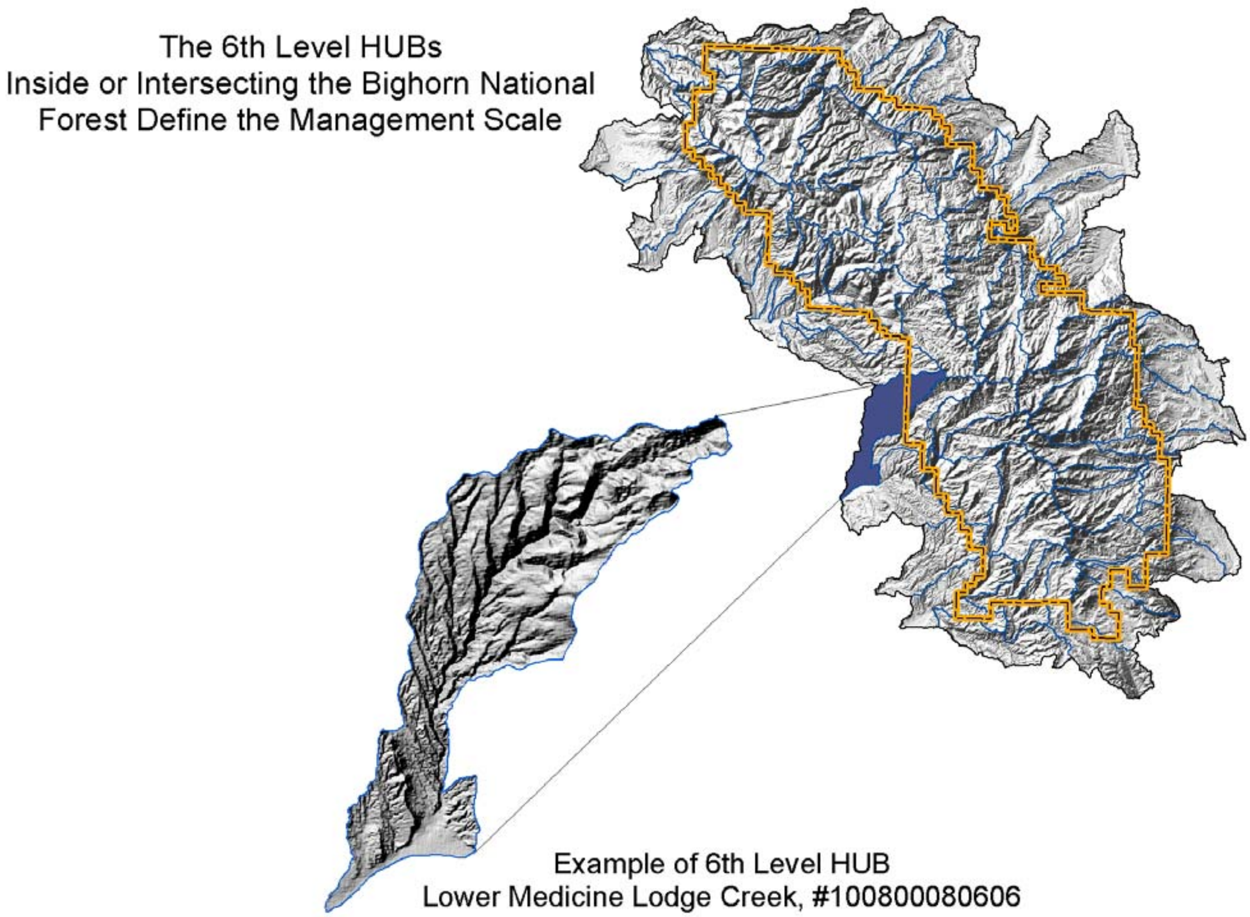

Figure 1.2. Management scale map of the Bighorn National Forest ecosystem showing a 6th level HUB identification number.

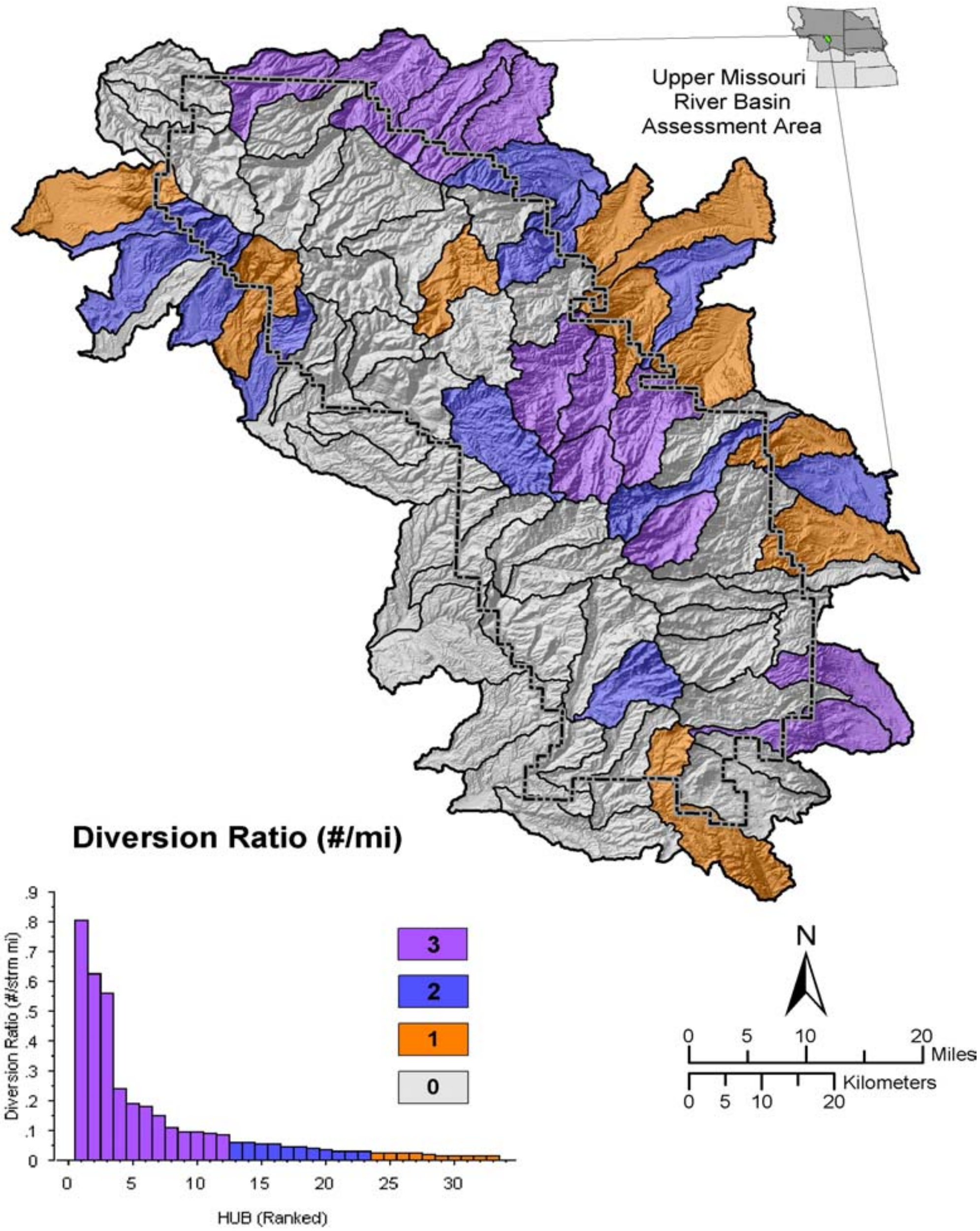

Figure 1.3. Rank and distribution of the ratio between numbers of diversions and stream length per 6th level HUB at the management scale.

Chapter 2
Water Use Category

The purpose of this chapter is to identify water uses that influence aquatic, riparian, and wetland resources within the Bighorn ecosystem and especially within lands managed by the Bighorn National Forest. In addition, analysis will be performed at the appropriate scales to address the extent of uses across the landscape, and improve the design of future site-specific projects and monitoring efforts.

Key Findings

1. At the landscape scale, there are a total of 3,267 water diversions identified. Only 27 (0.8%) diversions are located within the Bighorn National Forest (BNF).
2. The diversion ratios (number/ stream mile/ 6th level HUB) ranged from 0 to 0.8, with the highest values in HUBs that are located mostly outside the BNF.
3. A total of 41 of the 74 6th level HUBs at the management scale were not influenced by any water diversion structures.
4. There were over 467 miles of water transmission ditches identified at the landscape scale, with only 8 (1.7%) miles located in the BNF.
5. At the landscape scale, an estimated 47 miles of stream have been inundated by reservoirs, and only 0.7 (1.5%) located in the BNF.
6. Natural spring density (number/ acre/ 6th level HUB) was low, ranging from .0012 to 0. Most of the springs appear to be associated with calcareous geology in the northern region and around the outside borders of the BNF.
7. Only minor additive influences of water use impact the BNF. The HUBs that are impacted are located in the central – eastern section of the Forest.

Influence of Stream Diversions

For the purpose of this assessment, analysis of diversions will be restricted to the physical structure to divert water and upstream and downstream effects. The inundation created by an associated reservoir will be addressed in the Reservoir section. Transmission ditches to transport water from the diversion will also be addressed in another section of this chapter.

Basin Scale

Historic records indicate that diversions were constructed as early as the 1890s within the boundaries of and near the Bighorn National Forest (Walcott 1899). Other relatively small diversions were constructed throughout the area as towns grew and agricultural activity increased. Increasing populations and agricultural demands led to larger water diversion projects and construction of reservoirs (see Bureau of Reclamation Online: www.gp.usbr.gov/archive /glimpse /picksloane.htm).

The Upper Missouri River Basin and the Rocky Mountain Region of the USDA Forest Service is included in the Dry Domain portion of the continent (fig. 2.1). This expansive landscape has a relatively dry climate where evaporation rates exceed precipitation rates (Bailey 1995). Water is a valuable commodity in the Basin Region because of its scarcity. Demand quickly outstripped supply for recently established towns and farms in the arid Bighorn Mountain ecosystem. For example, Sheridan, Wyoming built a municipal pipeline to Goose Creek in 1901 to meet the needs of the local growth in population (Murray 1980). Similar strategies for storing and using water were developed during the same time period.

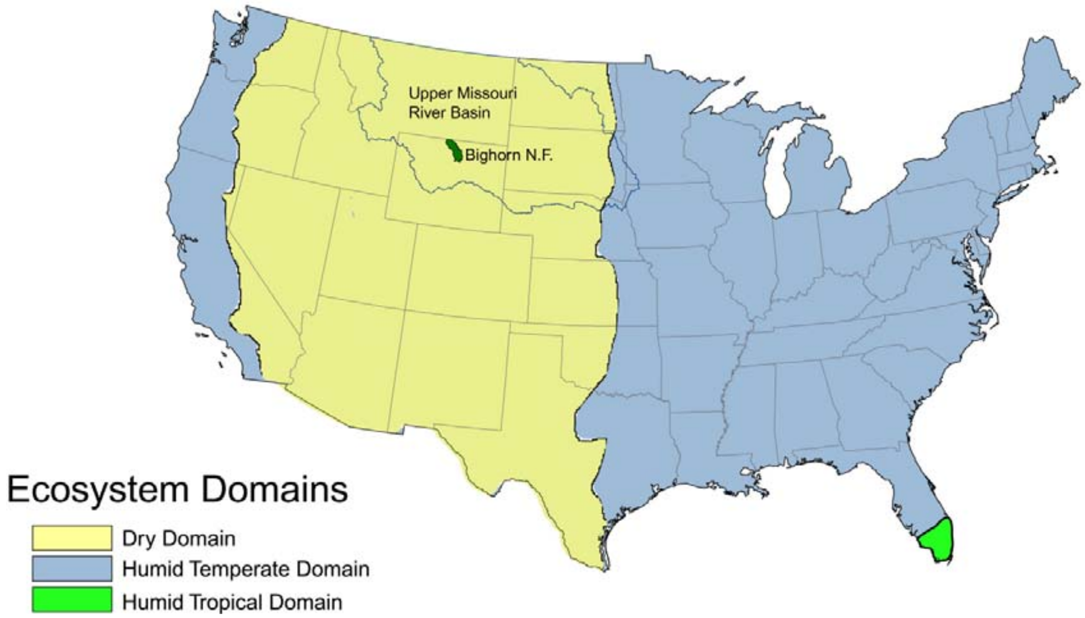

Figure 2.1. Location of the Bighorn National Forest within the Dry Humid Domain (map source: http://www.fs.fed.us/colorimagemap/ecoreg1_domains.html.)

Annual precipitation is not evenly distributed across the Basin. For example, the Big Horn Mountains have a much higher rate of precipitation than the surrounding ecosystems (fig. 2.2). Consequently, the area's major rivers (e.g., Tongue, Powder, and Big Horn Rivers) all have their headwaters in the Forest. Water diversion potential of headwater stream reaches may be high, because such projects could use the natural elevation gradient to transport water to high use and high demand areas downstream.

Regional per capita water use is very high. The population of Wyoming is low compared to other Western states, but its per capita water use (total water use per day/number of citizens) was the second highest for the all the states west of the Mississippi River in 1990 (16,700 gallons per person per day; Center of the American West 1997). Like other states in the West, most of this water was used for irrigation and livestock purposes (approximately 91% in 1990).

Landscape Scale

While reservoirs and water diversion structures are abundant on the Bighorn landscape (particularly on the Crow Indian Reservation in Montana), there are relatively few diversions within the Forest boundary (table 2.1 and fig. 2.3). Possible explanations for this pattern are: a) the lack of agricultural and municipal development within the Forest boundary, or b) the physical difficulty and expense of transporting water for primarily domestic and agricultural use in the lower elevations.

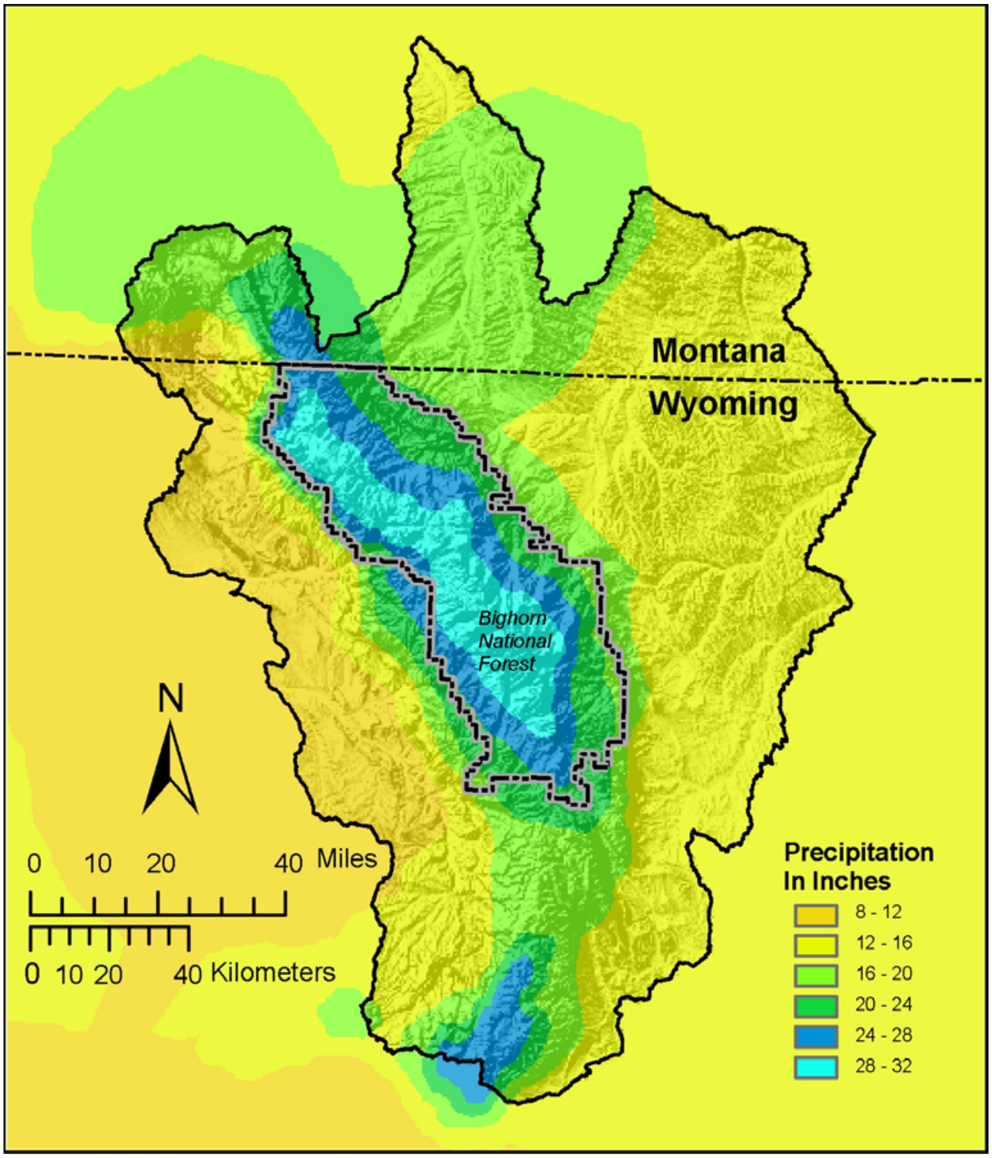

Figure 2.2. Distribution of average annual precipitation for the Big Horn Mountain ecosystem and Bighorn National Forest from 1970-2000 (from Regan et al. 2003).

The Big Horn Mountain foothills are quite steep, which makes construction of diversion transmission ditches difficult. Expensive conduits would need to be built to transport water from the higher mountain elevations in most areas. Moreover, most crop agriculture is conducted outside the National Forest boundary, and local diversions may be more cost effective than distant, upstream diversions.

While there are relatively few stream diversions within the Bighorn National Forest boundary (fig. 2.3), their influence can be apparent for some distance downstream. Finer-scaled analyses are required to detect these types of impacts. With the projected increase in population along the entire Front Range of the Rocky Mountains, it may not be too far in the future before there is an interest in utilizing additional water sources within National Forest boundaries. Population growth along the Rocky Mountain Front Range may lead to increased pressure to utilize water resources closer to their initial sources (e.g., in the headwaters).

Table 2.1. Ratio of diversions per stream length (# diversions/stream mile) within and outside of the Bighorn National Forest boundary in each 4th level HUB.

	Number of Diversions/Stream Mile		
4th Level HUB Name	**In National Forest**	**Outside National Forest**	**Total**
Nowood River	1	8	9
Big Horn Reservoir	3	257	260
Little Big Horn River	0	1,293	1,293
Upper Tongue River	19	1,567	1,586
Middle Fork Powder River	0	9	9
Crazy Woman Creek	0	58	58
Clear Creek	4	48	52
Total	27	3,240	3,267

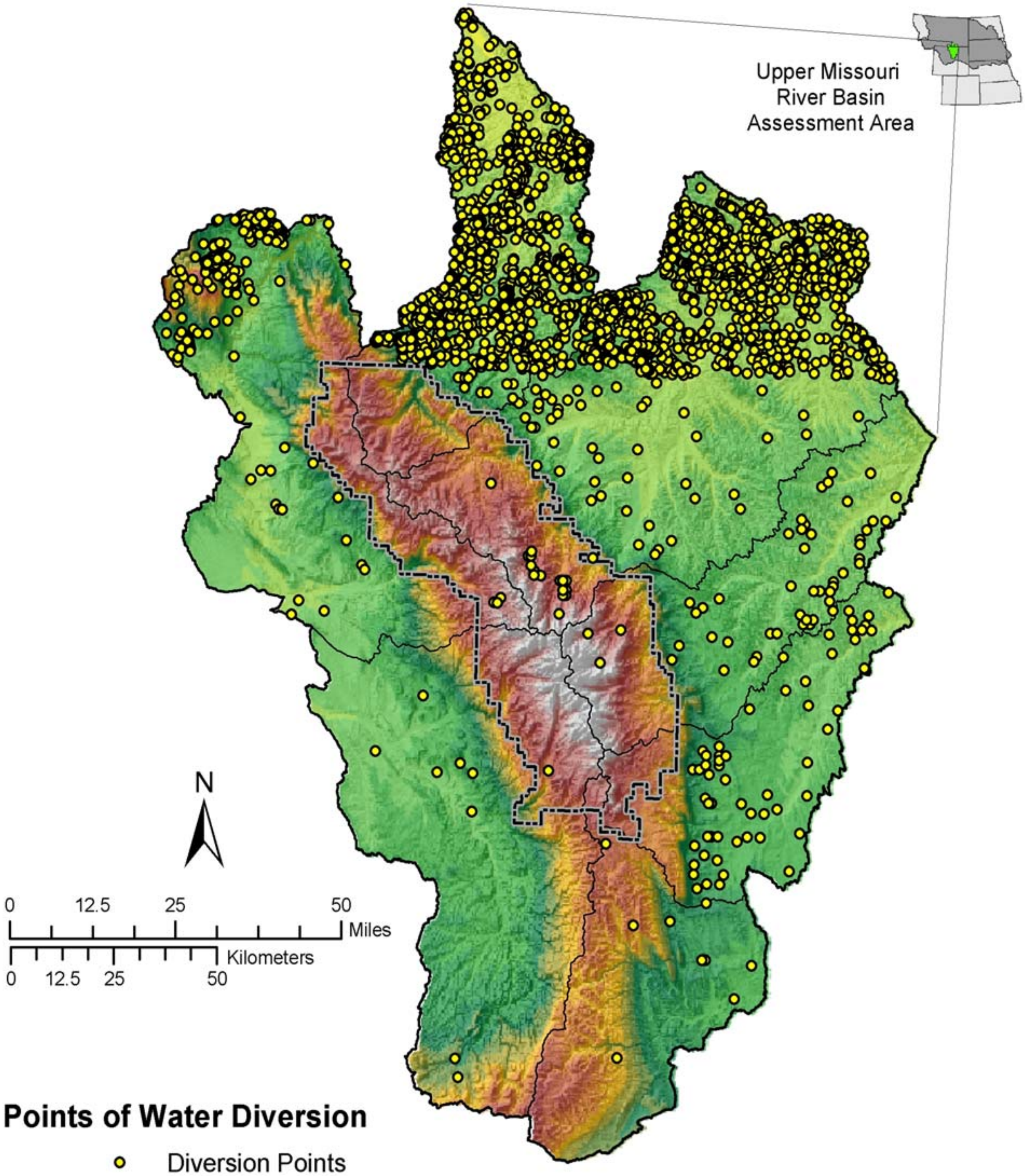

Figure 2.3. Locations of stream diversions at the landscape scale.

Management Scale

The viability of natural, self-sustaining populations of fish and other aquatic organisms depends on the size of the populations and their ability to migrate and interbreed. Population-level genetic diversity develops under the direction of natural selection programmed by environmental cues. These processes produce diverse and uniquely adapted local races of organisms should be viewed as a resource to be studied, protected, and used (Behnke 1979). Natural barriers are a part of Rocky Mountain streams, but their ephemeral character and the inherent connectivity of the system nonetheless permitted sufficient exchange of genetic material to allow resident species to persist and evolve. The presence of water diversions and other man-made structures that can "fragment" or isolate populations creates a challenge to manage existing populations of native and desired non-native fish and other aquatic fauna. Identifying the density of these structures at the 6th level HUB or small watershed scale, we will improve management by identifying watersheds: a) lacking man-made barriers, or b) with numerous barriers and a high degree of fragmentation. This information will be particularly useful to help manage populations of mobile organisms, such as fishes.

A total of twenty-seven diversions are located within the Bighorn National Forest boundary. The ratio of diversion structures for 6th level HUBs intersecting the Bighorn National Forest ranges from 0 to 0.8 diversions/stream mile/6th level HUB (fig. 2.4). While there are a number of 6th level HUBs associated with the Bighorn National Forest without diversions, there are three in particular that have ratio values clearly higher than the other 71 (HUBs 100800160103, 100800160107, and 100800160109). The diversions in these particular HUBs should be examined to determine their ability to fragment populations of aquatic, riparian, and wetland biota. The ranking of these ratio values was based on the 74 6th level HUBs associated only with the Bighorn National Forest, and are intended to provide a comparative analysis of the relative abundance of potential fragmentation of stream systems within the study area. These rankings do not reflect absolute impacts and may not be comparable with rankings in other geographic areas.

Additional measurements may be necessary to better define how diversions are affecting aquatic, riparian, and wetland habitats in the Forest. The diversion ratio (number of diversions/stream mile) measurement is an indication of potential barriers, but may not be as strongly correlated with actual water use. A more appropriate metric to measure diversion effects on aquatic habitat may be to determine the relationship between the amount of water appropriated under Wyoming State water law and the available water in each 6th level HUB. These data would provide a better measure of the quantity of water available for aquatic, riparian, and wetland habitats. Data on the amount of water adjudicated are available, but the ability to predict the discharge in a given watershed is presently limited.

A surrogate measurement that integrates water allocation with actual yield might be the amount of water adjudicated per acre of watershed. This measurement is predicated on the assumption that there is a relationship between watershed size and the amount of discharge available (Wohl 2001). Another complication is that water may be adjudicated, but not completely used. Overall, this surrogate measurement would at least give an estimation of the potential water use under present allocation levels. However, it is extremely important to note that this is not insinuating that there may not be significant reach/site level impacts from a particular diversion. The assessment results should be used to understand where the highest potential is for water removal on the Forest. Then the Forest can focus on more site-specific efforts to address the influence of these diversions on particular watersheds. In addition, if new permit applications are proposed, this information could be valuable in understanding the influence of existing water rights on a particular watershed.

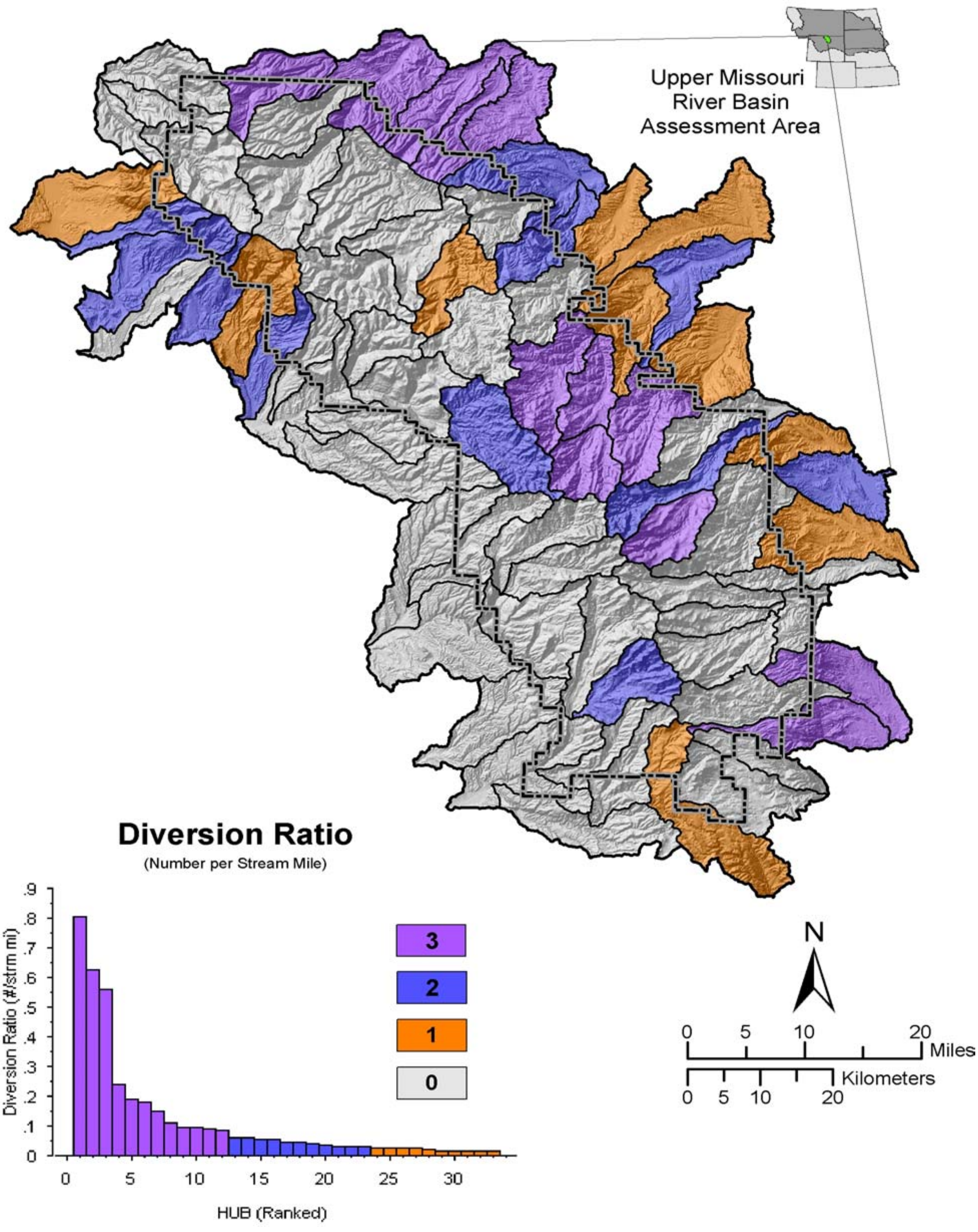

Figure 2.4. Ranking and distribution of stream diversion ratios (number of stream diversions/stream mile) for 6th level HUBs within and intersecting the Bighorn National Forest boundary. This ratio is noticeably higher for HUBs 100800160103, 100800160107, and 100800160109 respectively.

The location of a diversion in a watershed may determine the extent to which if affects downstream stream reaches. A measure of the influence of a particular diversion operation on the receiving segment is the percentage of the length of the receiving stream to the confluence of the next permanent stream segment in relationship to the total permanent stream miles in each 6th level HUB (stream mile influenced/total stream mile/6th level HUB). This value (percent stream miles affected) ranges from 0 to 55% per 6th level HUB (fig. 2.5). While there are several HUBs that do not influence downstream stream segments, three in particular (100800160109, 100800160107 and 100800160103) which exhibit considerably higher percent stream length affected than all the other HUBs. These three HUBs also had the three greatest diversion ratios (cf. figs. 2.4 and 2.5). While these values pertain only to HUBs intersecting the Bighorn National Forest, such data should be valuable in addressing future diversion projects, as well as aquatic management in these HUBs.

Reach/site scale measurements are still required to adequately measure the downstream impacts of water diversion.

<u>Reach/Site Scale</u>

Addressing the influence of water diversion structures and subsequent withdrawal on aquatic, riparian, and wetland resources at the reach/site scale is outside of the scope of this assessment. However, there are specific questions that should be addressed to identify influences on aquatic, riparian, and wetland resources for project level analysis related to Federal Land Policy and Management Act (FLPMA) on species viability and ecological sustainability. Listed below are specific questions that should be addressed, related to water diversions:

1. What aquatic, riparian, and wetland values should be addressed when evaluating a current or potential water diversion?

   a. Municipal needs
   b. Recreational needs
   c. Stream channel maintenance
   d. Riparian and aquatic vegetation
   e. Aquatic organism needs
   f. Terrestrial organism needs
   g. Water quality
   h. Others

2. What specific questions related to resource values should be addressed?

   a. Will flow modifications influence stream channel form and function?
   b. Will flow modifications influence riparian vegetation form and function?
   c. Will flow modifications influence aquatic organism life-history strategies and population size (e.g., water temperature, timing of spawning)?
   d. Will flow modifications influence recreational and aesthetic values?
   e. Will flow modifications influence habitat needs for terrestrial animals (e.g., beavers, southwest willow fly catchers)?
   f. Will altered instream flows provide a competitive advantage for invasive species?
   g. Will flow modifications influence adjacent wetland communities?
   h. Are changes in water quality acceptable?
   i. Will the structure allow passage of organisms necessary to maintain species/population viability?

Information Needs

The available information on the location of diversions on the Bighorn National Forest is fairly complete. Location and numbers of diversions was easily attainable. However, the actual amounts of water adjudicated for each diversion in each watershed was more difficult to identify and there are several groups of diversions where water rights appear to be shared between them, making it difficult to quantify.

In order to fully understand the relationship between potential water withdrawal and available water on aquatic, riparian, and wetland resources, an analysis of potential withdrawal and water yield for each 6th level HUB should be made.

However, the information on watershed yield is currently not available. This is an analysis that would be particularly valuable if future permit applications begin to be filed on the Forest.

Management Implications and Relationship to Ecological Drivers

The major influences of water diversions on stream and riparian ecosystems are migration barriers for aquatic biota through the structures and the influence that modified hydrology has on the downstream system. One of the aspects of this assessment that could not be addressed was the relationship between the location of diversion structures and their position in the 6th level HUB. The position of the structure in the watershed (if it is a migration barrier) can further promote isolation of populations upstream (Harig and Fausch 2002). In addition, there is a higher risk of riparian influence if the reach directly downstream is associated with a low gradient "adjustable" stream channel. This may be an additional analysis consideration for future planning purposes.

The results of this portion of the assessment shows that the majority of diversions at the landscape scale are located north and east of the Bighorn National Forest (fig. 2.3). While addressing diversions at the management scale, it is important to understand that some of the 6th level HUBs that have relatively high diversion ratios and affected stream densities are influenced by diversions outside of the Forest boundary. This information is important when addressing management considerations within the Forest boundary. For example, if a very small section of the HUB is located within the Forest and there is a diversion just downstream of the boundary, there may not be enough habitat to manage for self-sustaining populations of fish.

There are also HUBs with minor portions of land within the Forest boundary that exhibit no apparent influence from diversions. These HUBs may be areas of interest for reintroduction of native salmonids because of the warmer water temperature and increased productivity. However, all other anthropogenic influences would have to be taken into consideration, and ownership outside of the Forest boundary is a major logistical consideration. These lower elevation areas appear to be the primary habitat for rare plants, as pointed out in Chapter 2. Consideration for those plants associated with riparian areas may be made if future projects are identified.

The three 6th level HUBs identified with the highest "levels of influence" were the same for both the diversion ratio and the downstream reach analysis (figs. 2.4-2.5). Table 2.2 illustrates the cluster numbers with the three specific 6th level HUBs identified as the highest values in this analysis. In order to address these particular HUBs in more detail, the reader should review the sensitivity values and explanations for each cluster and resource area. It should also be noted that other HUBs maybe influenced more by water diversion related activities, based on the resource values identified in Chapter 2 of Report 1 of this assessment. Another often-overlooked analysis result is the absence of diversion influence within a 6th level HUB. Several of these HUBs do not have diversion influences and may be important for identification of "reference conditions". However, other anthropogenic influences should be considered in this type of analysis.

Table 2.2. Sixth level HUBs with the highest level of water diversion influence and associated cluster identification numbers.

6th Level HUB Code	Riparian Cluster Identification Numbers
100800160103	5r
100800160107	5r
100800160109	6r

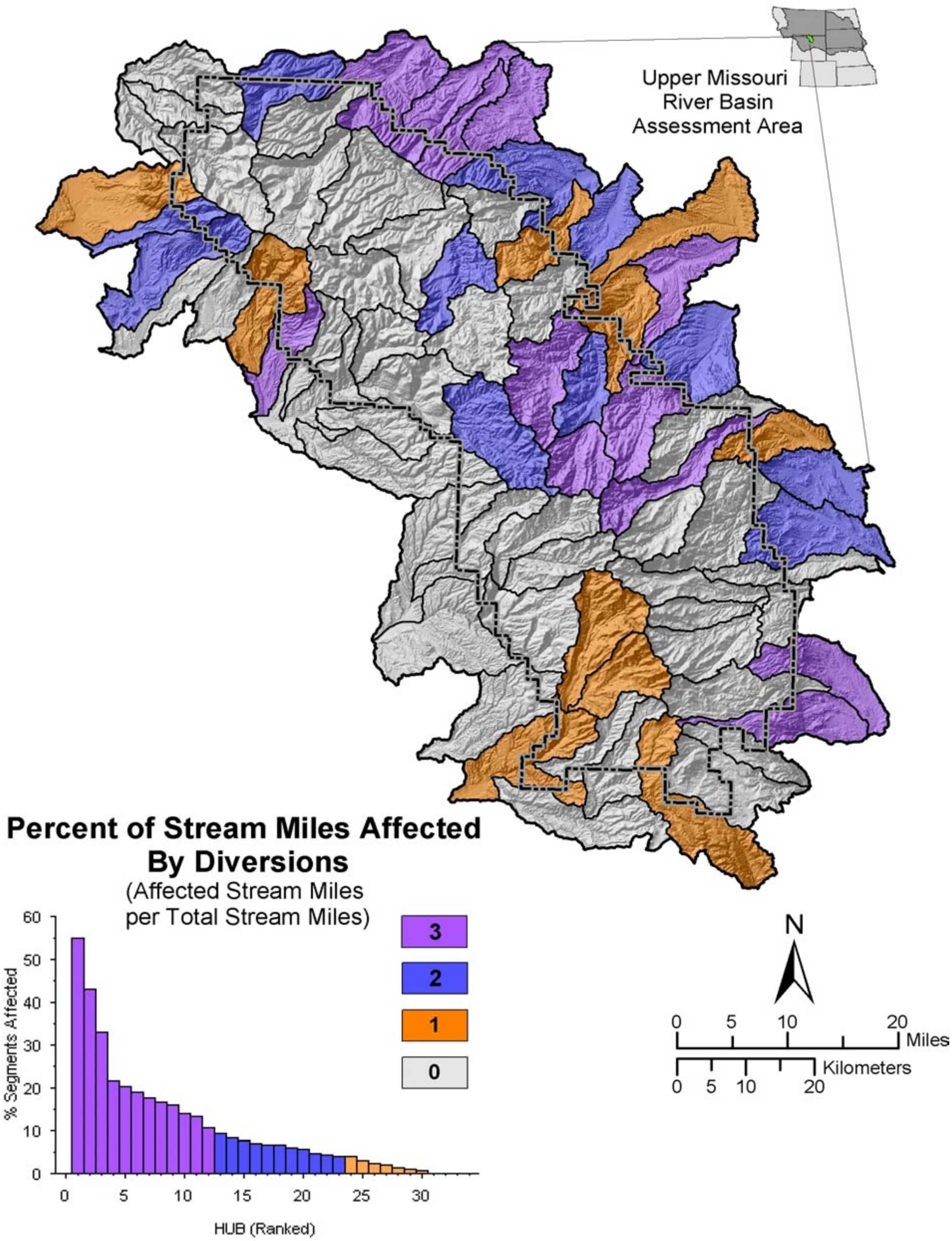

Figure 2.5. Percent and distribution of stream segments affected by stream diversion points for the management scale. This ratio is noticeably higher for the following three HUBs; 100800160109, 100800160107, and 100800160103 respectively.

Influence of Water Transmission Ditches

Water transmission ditches have the potential to significantly affect aquatic, riparian, and wetland resources. Ditches can change hydrology through water removals, which can range from minor to complete dewatering. The ditches themselves are designed to follow generally along contours with a small gradient drop. These ditches cut across slopes, intercepting overland and subsurface runoff, and disrupting natural runoff patterns. The ditches disrupt sediment dynamics by transporting sediment from one system to another (Wohl 2001). They may also be the vector for transport of invasive species or diseases. Perhaps the greatest potential impacts result from ditch wall failures and/or improperly designed structures, which can produce erosion, increased sediment production, and reduced water quality. While most ditches are not located directly in riparian or wetland areas, they frequently start and/or terminate in these areas, and they frequently run parallel to these habitats.

Basin Scale

Transmission ditches are associated with the movement of water from a diversion structure, or reservoir downstream to the target use (e.g., irrigation fields). Walcott (1899) noted that all the available water of the streams flowing out of the eastern side of these [Bighorn] mountains is utilized to irrigate the lands in the Sheridan Valley. Walcott also stated "It is obvious that these lands would be worthless without irrigation, and unless the supply of water is maintained irrigation will be impossible". By the 1890s all creeks exiting the mountains had small diversions with them (Murray 1980). The arid climate of the Upper Missouri River Basin necessitated the construction of diversions and transmission ditches to permit the irrigation of cropland and pasture. Improved technology and availability of heavy equipment resulted in construction of larger ditches and reservoirs.

By 1990, over 90% of the water use in Wyoming was used for agricultural purposes (Center of the American West 1997), and large irrigation canals are generally required to transport this water to downstream users (Wohl 2001). While large canals are found in other areas of the basin, most of the water conveyance systems in this portion of the basin are relatively small.

All of the early (pre-1900) transmission ditch construction occurred downstream of the Bighorn National Forest boundary because of excessive cost and difficult access (Murray 1980). However, by 1893 plans were already being developed to build reservoirs and associated transmission ditches within the mountainous areas of the Big Horn Mountains.

Regional demography also affects patterns of water use. For example, Brown (1999) noted that the population in the Missouri drainage might increase by as much as 40% between 1995 and 2040. Brown predicted that while irrigation needs would not increase significantly, livestock, domestic, industrial, and thermoelectric needs would continue to increase. If this is the case, there could be an increasing demand for water from the Bighorn National Forest in the future.

Landscape Scale

Most of the actual transmission ditch locations at the 4th level HUB or landscape scale are located outside the Bighorn National Forest boundary (table 2.3 and figs. 2.6-2.7). There are a total of approximately 343 miles of transmission ditches within the boundaries of the 4th level HUBs. However, a considerable portion of the ditches located outside of the National Forest boundary are adjacent to the base of the Big Horn Mountains in agricultural areas with a better growing season.

Ditch length ranges from approximately 0.1 miles in the Middle Fork Powder River to 250 miles in the Upper Tongue River 4th level HUB (table 2.3). The relatively high concentration of ditches just outside the eastern edge of the Forest boundary (e.g., near Sheridan, WY) is likely related to the intensive agriculture in these areas. There does not appear to be a considerable amount of transmission ditches on the Bighorn National Forest at the landscape scale, but these ditches may nonetheless influence

Table 2.3. Ditch length (miles) in 4th level HUBs.

4th Level HUB Name	Ditch Length (mi)		
	In National Forest	Outside National Forest	Total
Nowood River	0.83	6.82	7.65
Big Horn Reservoir	1.69	76.52	78.21
Little Big Horn River	0.77	39.81	40.58
Upper Tongue River	1.7	249.25	250.95
Middle Fork Powder River	0	0.12	0.12
Crazy Woman Creek	0.06	22.39	22.45
Clear Creek	3.02	64.43	67.45
Total	8.07	459.34	467.41

aquatic, riparian, and wetland resources at the reach/site scale.

Management Scale

Transmission ditches are scattered throughout the National Forest, with ratios ranging from 0 to 3,516 feet per stream mile of 6th level HUB (fig. 2.7). Very few of the HUBs analyzed lacked ditches, while at least 50% had more than 500 feet of ditches per stream mile. Three HUBs in particular, (100902060107, 100901010110 and 100901010204 respectively) exhibited ditch ratios higher than 2,500 feet of ditches/stream mile/6th level HUB. Ratio values may not include ditches that are abandoned, unrecorded, or located on private land. Assessing the abundance and distribution of transmission ditches at this scale can be used to prioritize management activities in areas subject to impact.

Reach/Site Scale

Many of the 6th level HUBs associated with the Bighorn National Forest contain diversion ditches. These structures can affect aquatic, riparian, and wetland resources whether or not they are currently being used to transport water. When evaluating the influences of each of these watersheds containing ditches the following questions should be considered:

1. What specific questions related to resource values should be addressed:
   a. Is the ditch abandoned or currently being used to transmit water?
   b. Has the ditch been maintained by the permittee or Forest Service?
   c. Does the ditch intercept surface flow that historically fed wetlands and other aquatic, riparian, and wetland habitats?
   d. Has the ditch wall breached, resulting in gullying and erosion?
   e. Has or does the ditch have the potential to transport undesirable plants and or animals?
   f. Is the transported water degrading water quality?
   g. Does the ditch intercept tributary flow that has not specifically allocated to it?

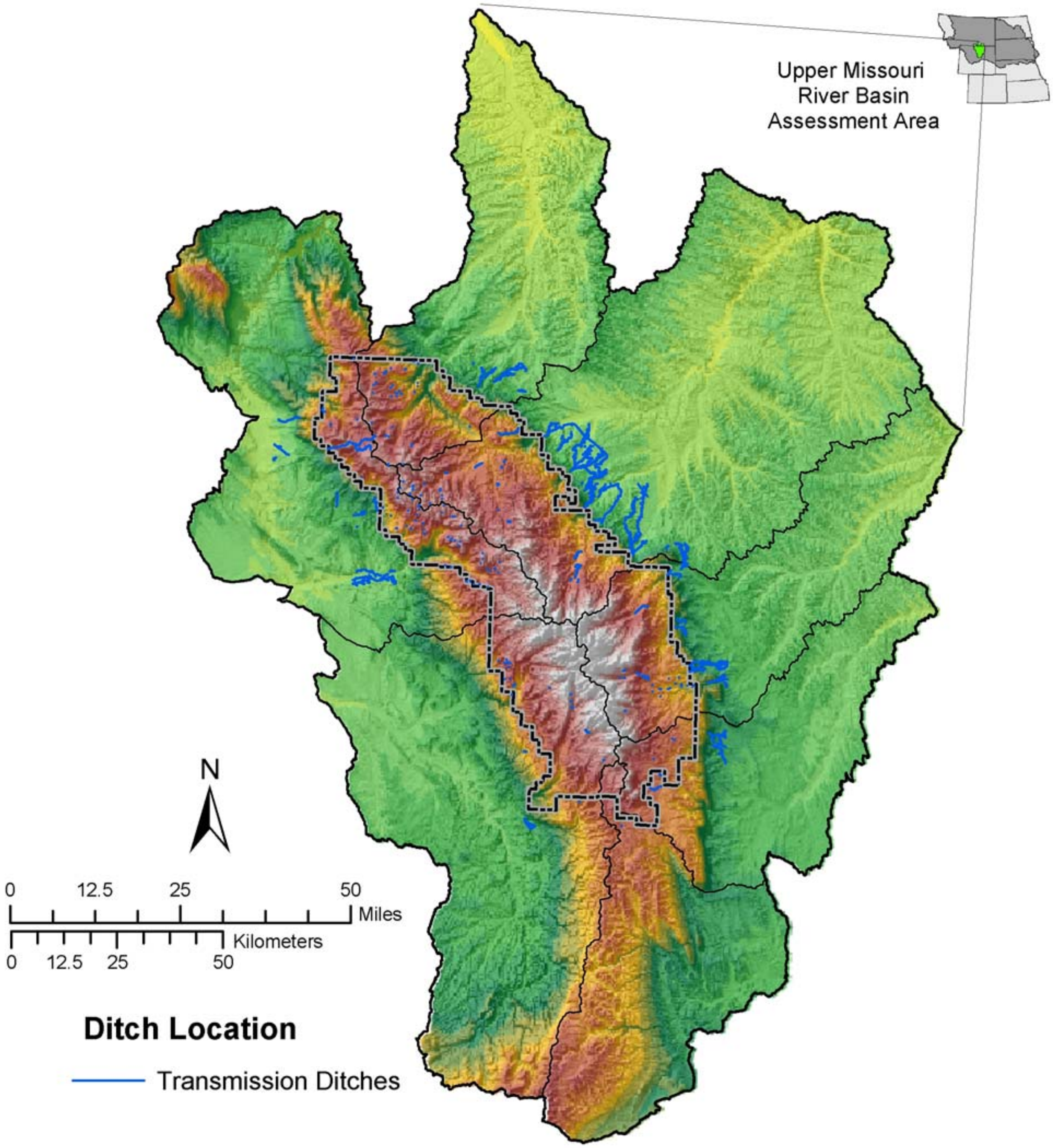

Figure 2.6. Locations of transmission ditches at the landscape scale for each 4th level HUB intersecting the Bighorn National Forest boundary.

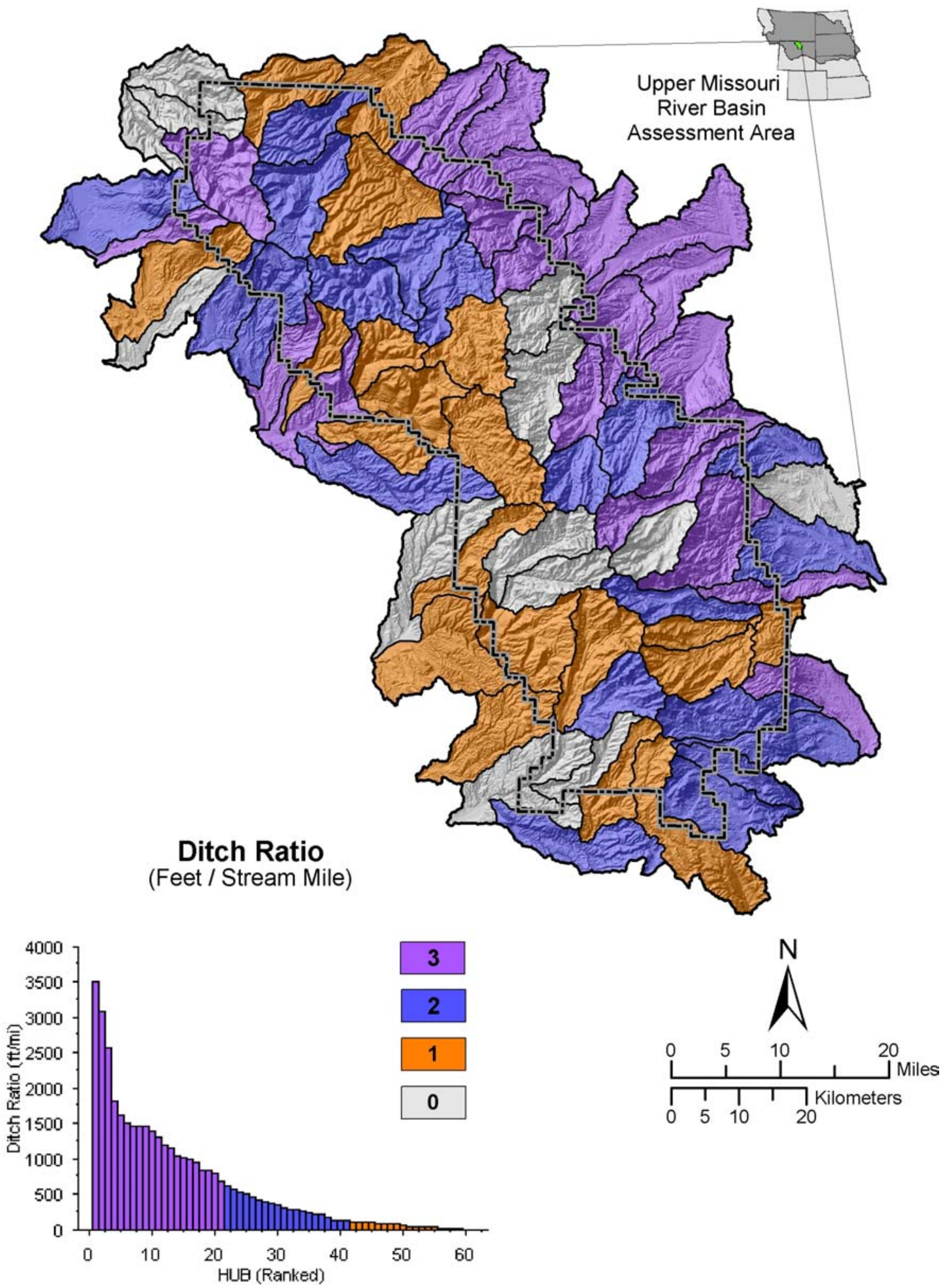

Figure 2.7. Ranking and distribution of transmission ditches at the management scale. The following three HUBs represent the highest ratios in this analysis: 100902060107, 100901010110, and 100901010204 (in order).

Information Needs

The information used for this analysis was derived from the Bighorn National Forest database, and appeared to be quite complete. The question could be asked "Is there confidence in the thoroughness of the data base, or are their ditch systems within the Bighorn National Forest which have not been inventoried?" We were not able to tell whether the ditches were abandoned or working ditches. This information might be valuable in prioritizing restoration efforts, and may be found in other databases than we used.

An analysis of ditches intersecting wetlands could also be valuable for this type of assessment. While these ditches may be quite old, and have possibly drained historic wetlands, remnants may be identified through the existing riparian and wetland inventory on the Forest.

Management Implications and Relationship to Ecological Drivers

Most of the ditches located within the Bighorn National Forest landscape scale are understandably at the fringe of or outside of the Forest boundary. These areas are economically better locations because they are closer to croplands. As discussed in the introduction to this section, even ditches that are no longer being used for management purposes may still be functioning to trap overland flow. One management consideration is to identify these "abandoned ditches" and restore them to the local topography. Identification of wetlands being influenced by these ditches could be conducted to prioritize restoration efforts.

Another management consideration might be to identify where ditches have breached the sidewalls, creating erosion through gullying. These breaches can cause considerable erosion to downslope wetlands and streams.

Influence of Transbasin Diversions

Transbasin diversions can have impacts similar to other diversion structures and transmission ditches. In addition, they add 'new water' to the receiving basin. Transbasin diversions can facilitate the invasion of non-native fish and other non-desirable species of plants and animals can enter a system where they can replace native species. Behnke (1979) found that several sub-species of cutthroat trout have been transported into other river basins where they would not normally occur. These introduced cutthroat trout subsequently hybridized with the native sub-species of cutthroat trout, leading to a loss of genetic diversity in native populations.

The diversion and transport of water from one watershed to another can result in physical, chemical, and biological changes to the receiving water body. For example, these activities can cause channel erosion, increased sediment transport, and deposition in reservoirs and channels (Glasser 2000). When the natural flow pattern of the receiving stream is altered, the ability to move stream channel material also changes (Rosgen 1996; Wohl 2000). Relatively steep, step-pool streams with large substrate may not be significantly affected by increased discharge, but lower gradient streams with smaller substrate can experience dramatic changes in channel geometry (Wohl 2001). Affected streams often exhibit elevated bank erosion, increased width-depth ratios, downcutting, and a dramatic loss in instream habitat for aquatic organisms. Since these low gradient stream reaches tend to be the most productive reaches for aquatic organisms in Rocky Mountain streams, water augmentation from transbasin diversions can have a dramatic effect on stream biota. Moreover, chemical and microbiological contamination can result from transbasin water transport.

Other elements of transbasin diversions effects are specifically addressed in the Water Use section (e.g., Stream Diversions and Water Transmission Ditches).

There are currently no transbasin diversions on the Bighorn National Forest. However, because of the potentially wide-ranging ecological impacts of transbasin diversions, any such proposed projects should be subject to close scrutiny.

Influence of Reservoirs

Reservoirs have been constructed in the Rocky Mountain Region for recreation, power production, snow-making, and flood control, but the predominant use for reservoirs has been to store water for irrigated agriculture and municipal consumption (Wohl 2001). Reservoirs were constructed as early as the mid-1800s to help facilitate the timing of downstream flows to coordinate with the agricultural growing season.

Reservoirs can have both beneficial and detrimental effects on aquatic, riparian, and wetland resources. Dams clearly have an immediate influence on local conditions, and can influence resources many miles in either direction. The most noticeable influence of dams is the water that is accumulated behind the dam. This standing water displaces the steam's riparian or wetland areas and creates a totally different environment. As the dam fills, riparian vegetation is inundated and plant diversity is reduced. Animal diversity can be increased or decreased, depending on the system. For example, stream aquatic invertebrate and algae communities are replaced with lake benthos, zooplankton, and phytoplankton. While many salmonids can exist in reservoirs, some fish species like darters (Percidae) and sculpins (Cottidae) cannot tolerate the conditions found in standing water (Baxter and Stone 1995). Reservoirs have several more influences on aquatic, riparian, and wetland resources that are explained in Winters et al. 2003b.

<u>Basin Scale</u>

Reservoirs have been built in the Upper Missouri River Basin since the early to mid-1800s when Euro-Americans settled the area (Murray 1980). Agricultural and municipal supply reservoirs were relatively small in the 1800s and early 1900s because of equipment and manpower limitations. Beginning in the 1930s, however, the federal government began to build large reservoirs to control floods and counteract the effects of the dust bowl (fig. 2.8). These major projects are located primarily on the mainstem of the Missouri River, with several large reservoirs being built through the 1960s.

The Bighorn Reservoir on the Bighorn River is probably the closest reservoir to the Big Horn Mountains. It was completed in 1966, covers approximately 70,000 acres, and is located in the Bighorn Reservoir 4th level HUB (10080010). Numerous smaller stock ponds and private reservoirs have been built in the Upper Missouri River Basin, data on their abundance and distribution are lacking.

<u>Landscape Level</u>

Bighorn Reservoir and Lake DeSmet are the two largest reservoirs at the landscape scale of the Bighorn assessment area (fig. 2.9). While numerous stock ponds and smaller reservoirs and manmade impoundments are found adjacent to the National Forest, relatively few manmade lakes and associated inundated stream miles are actually located within the Forest boundary.

Man-made reservoirs and lakes have inundated approximately 9% of the stream length (inside the Forest boundary) contained within the Middle Fork Powder River 4th level HUB (this data does not match with table 2.4). In contrast, three 4th level HUBs have no inundation in any portion of the HUBs. This information indicates that the inundation of aquatic, riparian, and wetland resources at this scale is quite limited. However, the effects of changed hydrology, channel morphology, riparian and wetlands, and introduced species cannot be evaluated at this scale.

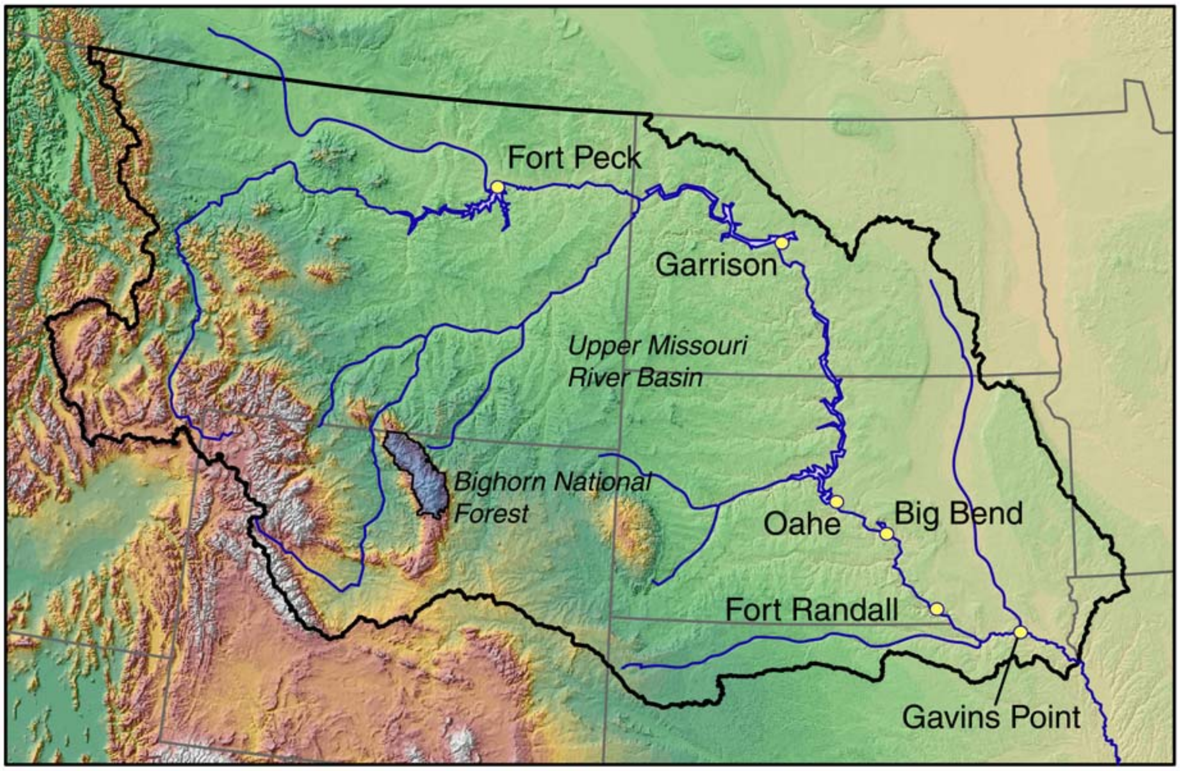

Figure 2.8. Location of the U.S. Bureau of Reclamation Pick-Sloan water management project in the Missouri Basin, with mainstem boundaries identified. (www.gp.usbr.gov/archive/ glimpse/picksloane.htm).

Table 2.4. Inundated stream length at the 4th level HUB within and outside the National Forest.

4th Level HUB Name	Inundated Stream Length (mi)		
	In National Forest	Outside National Forest	Total
Nowood River	0.0	0.0	0.0
Big Horn Reservoir	0.1	17.3	17.4
Little Big Horn River	0.0	0.0	0.0
Upper Tongue River	0.2	18.6	18.8
Middle Fork Powder River	0.1	1.1	1.2
Crazy Woman Creek	0.0	0.0	0.0
Clear Creek	0.3	9.5	9.8
Total	0.7	46.5	47.2

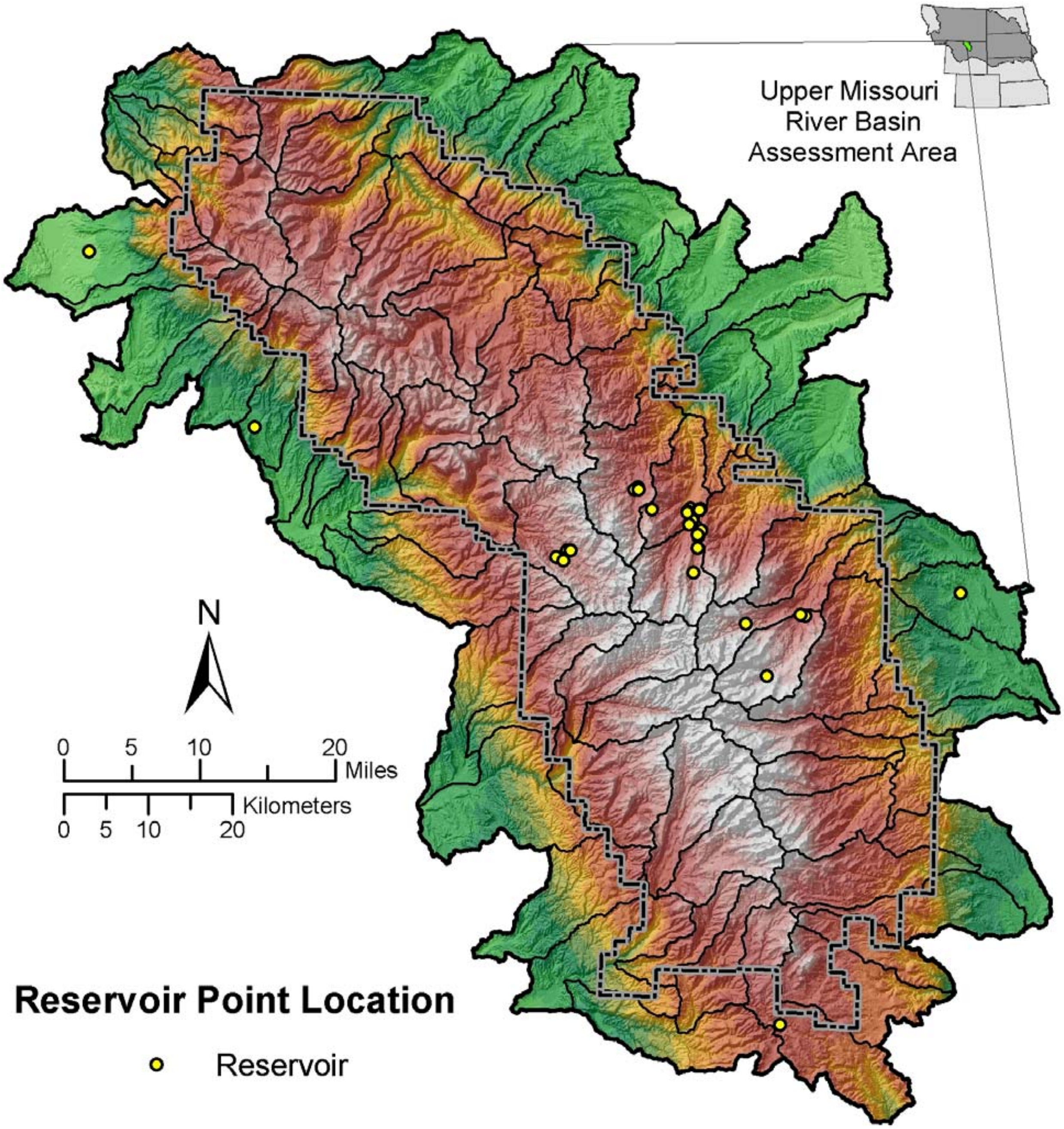

Figure 2.9. Locations of known reservoirs at the landscape scale.

Management Scale

Management scale analysis of reservoirs included a determination of: a) habitat directly inundated; and b) extent of possible downstream influences. A total of 65 6th level HUBs that intersect National Forest lands do not have any stream habitat directly inundated by reservoirs, whereas nine HUBs have some degree of inundation. Percent of inundated stream length per 6th level HUB ranges from 0 to 30% (fig. 2.10). The three HUBs with the highest percentage of inundated stream length are 100800100101, 100901010203 and 100902060302, respectively. Direct stream inundation does not appear to be a substantial problem for any 6th level HUB within the Bighorn National Forest boundary. For example, only 8% of the 74 6th level HUBs in the analysis were directly influenced by reservoir inundation (fig. 2.10). However, more site-specific analysis needs to occur to determine what effects such inundation may have on aquatic, riparian, and wetland resources. For instance, it would be expected that a reservoir inundating a broad valley with extensive riparian communities and aquatic habitat may have more of an impact than a reservoir inundating a narrow, steep valley with a narrow riparian habitat and with a more limited aquatic habitat. Nonetheless, those HUBs subject to inundation should be monitored at the reach/site level to detect significant indirect effects (e.g., related to trout viability concerns).

Thirteen of the 74 6th level HUBs intersecting the Forest have streams influenced by upstream reservoirs (fig. 2.11). These data indicate that is a considerable length of stream and associated riparian area that could be influenced by reservoir releases. One third of the watersheds influenced by reservoir releases have more than 50% of their entire permanent stream lengths potentially affected, and five HUBs have almost their entire stream lengths potentially affected (fig. 2.11). The effects of reservoirs on the receiving stream will change with distance, therefore reach/site scale analyses will be required to isolate these influences.

Reach/Site Scale

Reservoirs can influence ecological conditions upstream, downstream, and adjacent to their actual location. Listed below are specific questions that should be addressed when studying the influences of reservoirs on aquatic, riparian, and wetland resources.

1. What aquatic, riparian, and wetland values should be addressed when evaluating a current or potential water diversion?
   a. Municipal and recreational needs
   b. Stream channel maintenance needs
   c. Riparian and aquatic vegetation needs
   d. Aquatic organism needs
   e. Terrestrial organism needs
   f. Water quality influences
   g. Channel maintenance needs
   h. Aquatic habitat needs
   i. Invasive species introductions

2. What specific questions related to resource values should be addressed?
   a. Will the dam structure allow passage of organisms necessary to maintain species/population viability?
   b. Will flow modifications influence downstream channel form and function?
   c. Will flow modifications influence riparian vegetation form and function?
   d. Will flow modifications influence aquatic organism life-history strategies and population size (e.g., water temperature, timing of spawning)?
   e. Will flow modifications influence recreational and aesthetic values?
   f. Will flow modifications influence habitat needs for terrestrial animals (e.g., beavers, southwest willow fly catchers)?
   g. Will altered instream flows provide a competitive advantage for invasive species?
   h. Will flow modifications influence adjacent wetland communities?
   i. Are changes in water quality acceptable?
   j. Will/is inundation influence wetlands or rare ecosystem types such as fens?

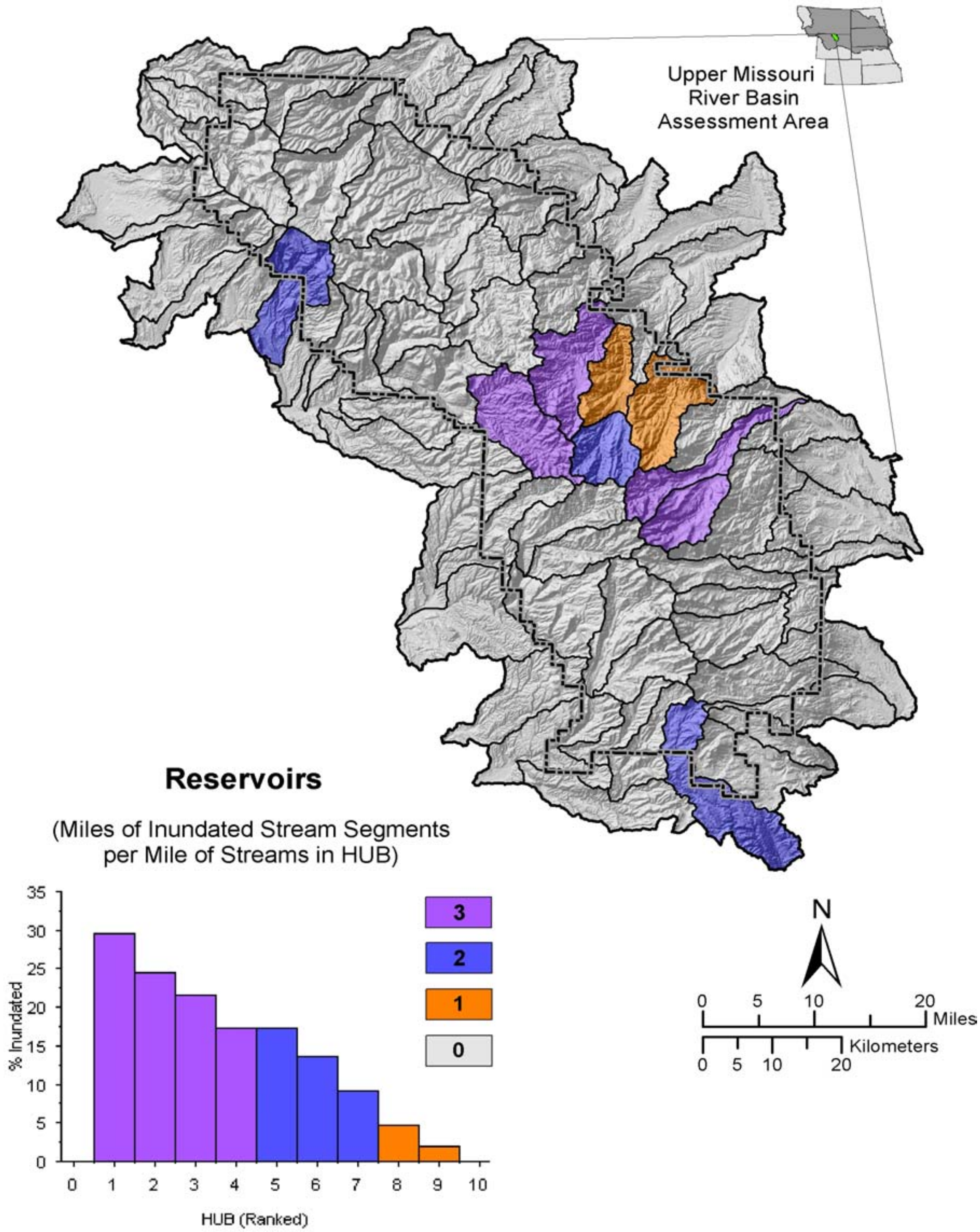

Figure 2.10. Rank and distribution of the percentage of streams inundated by reservoirs at the management scale. HUBs 100800100101, 100901010203, and 100902060302 contain the highest proportion of inundated stream miles, respectively.

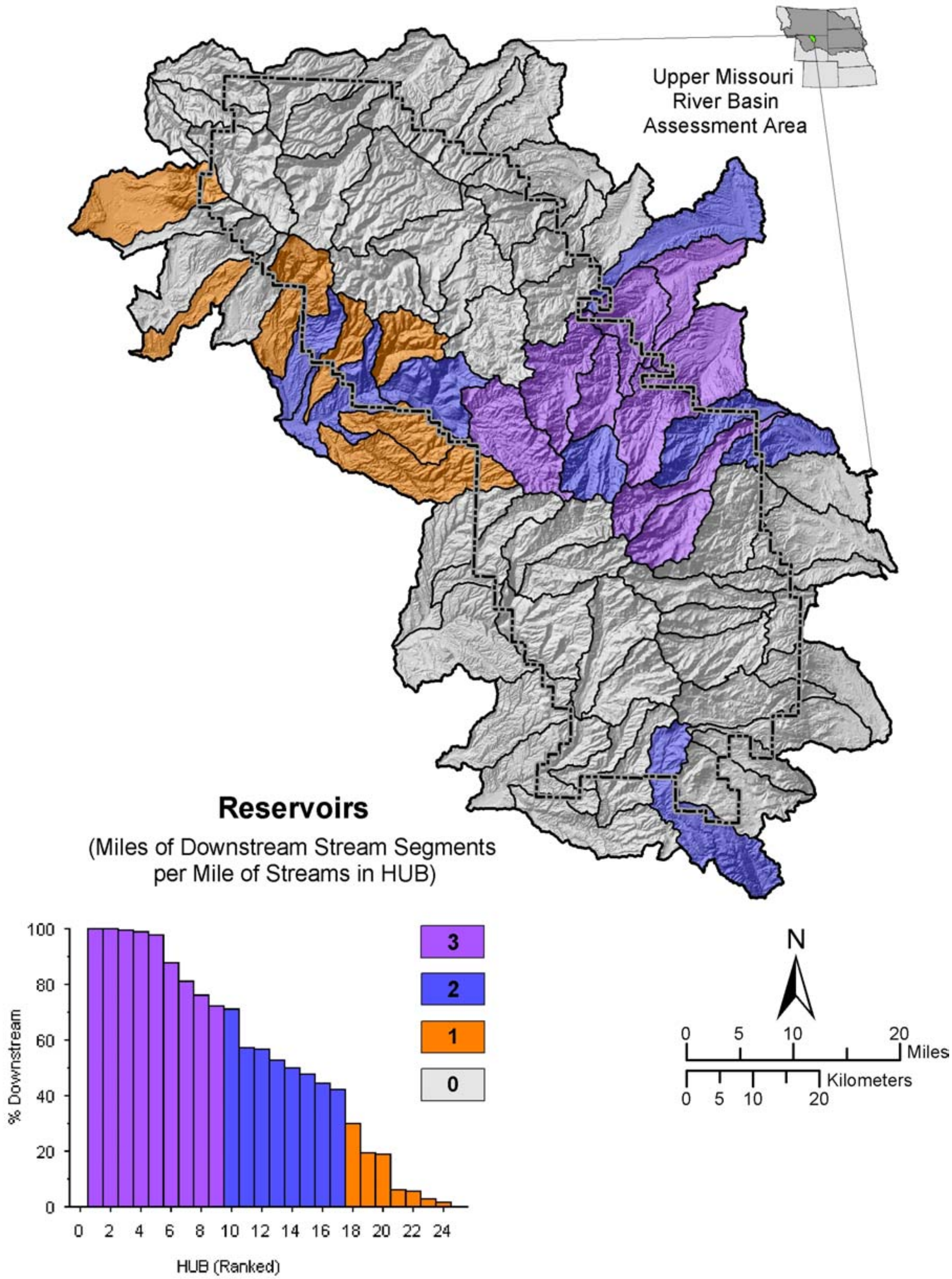

Figure 2.11. Rank and distribution of the percent of stream miles affected by upstream reservoirs at the management scale.

Information Needs

Information on the abundance and distribution of small impoundments such as stock ponds is lacking. These small impoundments can have large cumulative influences on watershed dynamics. These data will be necessary to understand the net cumulative influences of impoundments on aquatic, riparian, and wetland resources within the Bighorn National Forest.

Management Implications and Relationship to Ecological Drivers

Reservoirs can have profound influence on aquatic, riparian, and wetland resources. Often the recreational, domestic and agricultural needs have outweighed the natural processes they replace. In the past, inundation and dam construction have been mitigated. However, it has only been in the last few decades that the downstream influences have been thoroughly studied. In the highest one third of the 6th level HUBs at the management scale, all have a proportion of over 0.7 miles influenced for total length of stream segment. These results would indicate that aquatic biota, stream channel dynamics, and riparian ecology might have been influenced in a high proportion of the HUBs that receive water from them.

Understanding the relationship between reservoir releases and downstream influences, especially from a channel-morphology, riparian and aquatic biota perspective may be a consideration for future management. By understanding the influence that existing reservoirs have on aquatic, riparian, and wetland resources, the effects of future reservoirs could be better understood, especially within similar clusters.

There are relatively few 6th level HUBs associated with reservoirs within the Bighorn National Forest (fig. 2.10) with several more influenced from downstream flows (fig. 2.11). Clusters associated with stream and riparian habitats should be considered for this analysis. Inundation and dam construction could have a profound influence on reintroduction efforts for native species of salmonids and other fishes, as well as being habitat for non-native species that otherwise may not be found there. Clusters associated with a large proportion of low gradient stream channels and associated riparian areas could be influenced by modified stream flows. In addition, HUBs within the rain-and-snow driven hydrology and non-calcareous geology would be more prone to erosion and channel modification with fluctuating flows.

For future reservoir project consideration, the factors identified within specific clusters could be used for identifying resource values. HUBs in a cluster with a high percentage of glaciation would indicate a high chance of influencing wetlands, while a dam upstream of low gradient stream channels may have a high chance of stream channel and riparian modification.

Influence of Spring Developments

Grasslands of the Rocky Mountain Region are located in an arid to semi-arid landscape, with low total annual rainfall and high annual rainfall variability (Wohl 2001). Because permanent streams and ponds were often not readily accessible for human and livestock utilizing these grasslands, users had to seek other water sources. Across the Rocky Mountain landscape, both in the plains and mountains, springs and associated wetlands are found that are fed by groundwater (Winter et al. 1988). Wetlands not associated with streams are often fed by groundwater discharge and also form springs. As the number of settlers and domestic cattle increased in the 1800s and 1900s, utilization of springs likely increased. Typically, spring water was concentrated through pipes to fill watering tanks or ponds, which were subsequently used for watering livestock. Early settlers also used springs for drinking water.

Springs and associated wetlands provide unique and dramatic habitats on an arid landscape. Wetlands often have high biodiversity because of unique hydrologic, soil, and microclimatic conditions (Cooper 1986). Mosses, herbaceous plants, woody plants, combinations of all of these groups may dominate spring vegetation, and these communities are quite variable between distinct wetlands. Most plants associated with springs are highly sensitive to water chemistry, seasonality of water flow, and disturbance. Many invertebrates and amphibians also inhabit these environments because of the constant water temperatures, abundant food supplies, and general lack of predators (Hammerson 1986).

Development directly impacts springs and associated wetlands by altering the natural hydrologic regime. Developed springs often lose their unique hydrologic characteristics, and may be transformed to upland habitat. Direct influences such as ponding of springs can alter also the system's nutrients dynamics, making conditions unfavorable for endemic species. Indirectly, the concentration of domestic livestock at these watering places can alter the biological communities via intensive grazing activity, soil compaction, and nutrient addition.

Basin Scale

Spring development for livestock watering and domestic use has probably occurred since the early 1800s when settlers arrived in the Upper Missouri River Basin. While surface water from streams may have been adequate in some locations, it was insufficient in many others. In an effort to utilize pasture in areas lacking surface streams, ranchers dammed or piped water from springs to water their stock.

Areas adjacent to springs were also desirable homestead locations. The relatively clean and consistent water source was a necessity in the arid region. Many of the early spring developments are still used today, but most new homes receive their water from wells or municipal water sources

Although spring development in the Upper Missouri River Basin has frequently occurred during the last 200 years, data on the abundance and distribution of these developments is sparse.

Landscape Scale

At the landscape scale, springs were identified using U.S. Geological Survey topographic quadrangles (table 2.5 and fig. 2.12). While these data probably underestimate total spring locations, the major springs are most likely well represented. Most of the identified springs in the Bighorn assessment area are located within or adjacent to the National Forest boundary. Springs in this area tend to be associated with calcareous geology. For example, the northern portion of the Big Horn Mountains has predominantly calcareous geology and numerous springs. Springs are commonly formed when groundwater seeps through the calcareous bedrock found at the base of the Big Horn Mountains.

Approximately 67% of the springs identified in the Bighorn landscape are located on National Forest lands (table 2.5). Eighty-two percent of this total are located in the northern portion of the National Forest, within the Big Horn Reservoir, Little Big Horn River, and Upper Tongue 4^{th} level HUBs. The only area noticeably lacking springs is the Cloud Peaks Wilderness area (fig. 2.12), which is comprised primarily of non-calcareous geology.

Measuring the actual spring use strengthens this analysis, but currently there are no spatial data on the number of springs that have been developed for agricultural or domestic use and the amount of water extracted from them. These data could be used to more accurately assess the impact of spring development.

Management Scale

Springs are found throughout the management area, but are generally rare. The density of springs for each 6^{th} level HUB ranged from 0 to 0.0013 springs per acre (fig. 2.13). While few total springs are present, 80% of the 6^{th} level HUBs had at least one known spring. This information is important to determine the potential risk of various management activities on spring ecosystems. Sixth level HUBs with high spring densities may warrant special management consideration, but HUBs with fewer springs should not be neglected because springs are a relatively rare habitat feature.

Reach/Site Scale

In arid environments, springs tend to be small and rare, and larger springs are rarer still. Thus evaluating springs at the reach/site scale will be necessary to understand their influence on aquatic, riparian, and wetland biota. Specific questions to be answered when addressing spring influences include:

1. Has the spring been developed for domestic or livestock use?
2. Are rare native flora and fauna present that should be evaluated (e.g., northern leopard frogs)? And, are these taxa federal or state listed?
3. What are the influences that management activities have had on the spring ecosystem? Are ecologically similar springs present that could be used for comparative analyses?
4. What other resource values should be considered (e.g., recreational hunting)?

Table 2.5. Summary of springs and seeps for each 4th level HUBs within the Bighorn assessment area.

	Number of Springs and Seeps		
4th Level HUB Name	**Inside National Forest**	**Outside National Forest**	**Total**
Nowood River	37	34	71
Big Horn Reservoir	103	32	135
Little Big Horn River	73	2	75
Upper Tongue River	95	25	120
Middle Fork Powder River	0	8	8
Crazy Woman Creek	3	21	24
Clear Creek	18	32	50
Total	329	154	483

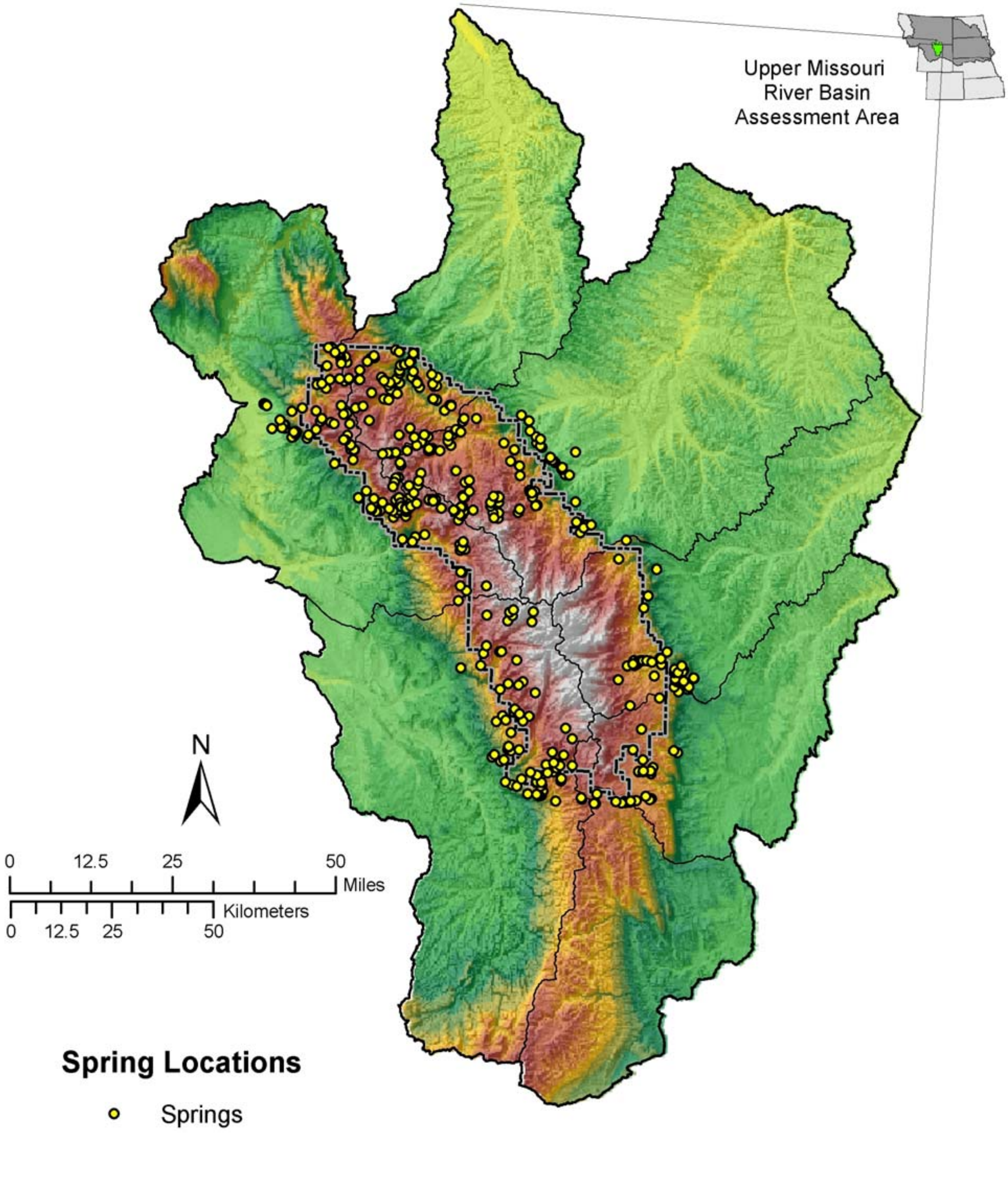

Figure 2.12. Locations of known springs at the landscape scale.

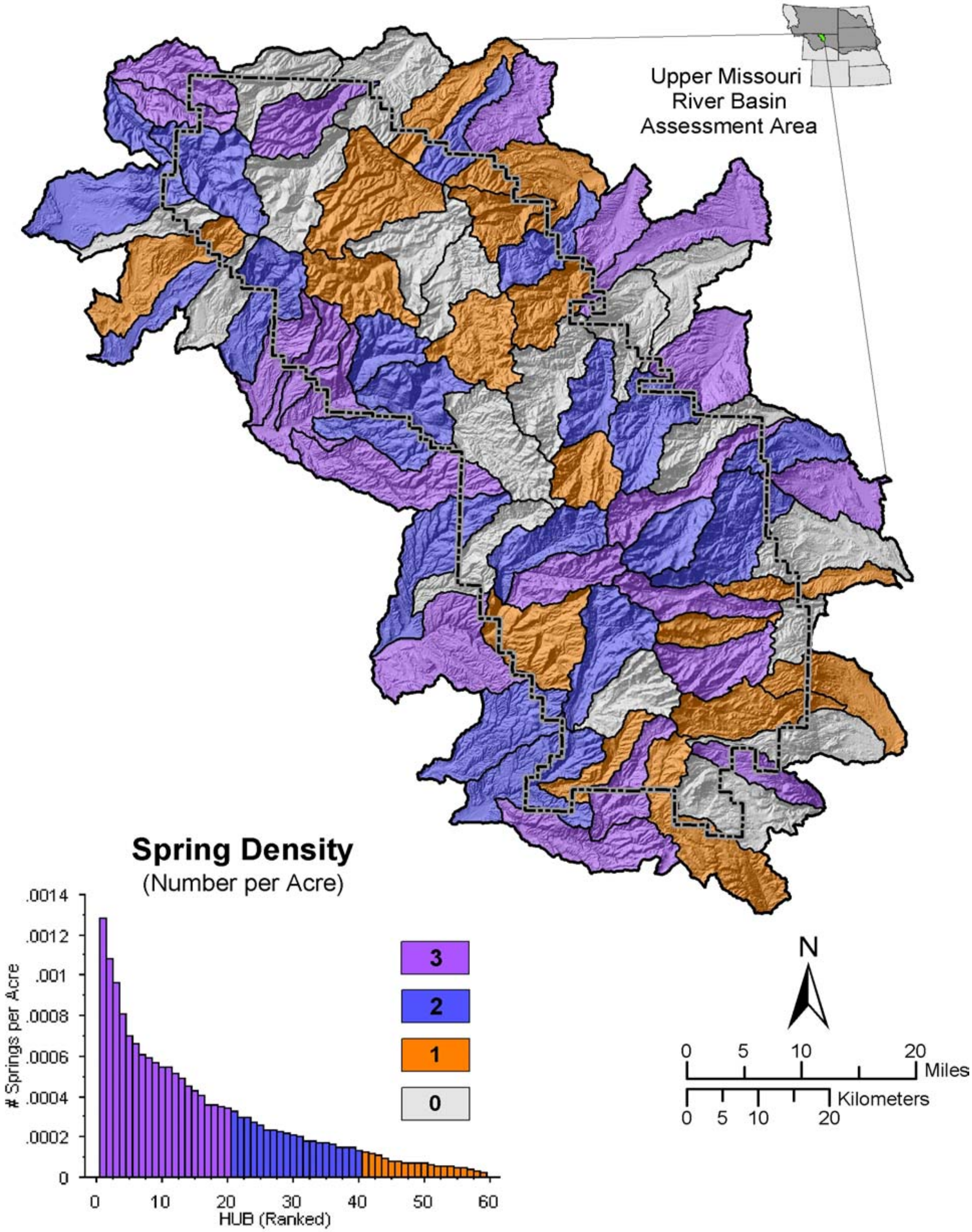

Figure 2.13. Density of springs at the management scale**.**

Information Needs

Information on spring locations at the management scale was available through U.S. Geological Survey topographic quadrangles. This information probably identifies only a portion of the springs present in the study area. While springs and seeps have been used for domestic and agricultural purposes for centuries, their ecological importance is only beginning to be understood. Several plants and animals on the Region 2 sensitive species list are associated with springs, especially plants. In addition, springs are typically the water source for wetlands, such as fens, which are also rare. A thorough inventory or summarization of existing information on springs is needed if an evaluation of these resources can occur. In addition, information on anthropogenic influences on springs, such as domestic and agricultural use is necessary and would provide the information to evaluate anthropogenic influences.

Management Implications and Relationship to Ecological Drivers

As mentioned previously, springs are relatively rare (fig. 2.13) but are an important aquatic, riparian, and wetland resource. They are typically quite small however, and can be identified and managed effectively. Since springs are fed by an upwelling of groundwater often associated with calcareous geology they start at a "point source" which can be identified and is not typically dependant on other land management considerations. Once the spring leaves the ground however, land management activities such as water capture, grazing and ground disturbing activities can have a profound effect on their form and function.

Once an analysis is conducted to determine the extent of influence from anthropogenic sources, protection is probably the best management consideration of high priority springs. Changing the hydrologic regime of springs can have a dramatic effect on the form and function of springs because they typically have a relatively constant discharge. The flora and fauna associated with springs also are adapted to this consistent flow. If a spring has been severely impacted from years of use, the discharge may be reestablished, but the flora and fauna may have been replaced. Because of their constant flow regime, habitats associated with springs (e.g., fens) contain relicts of the last ice age, and are found nowhere else in the landscape. Possibly the best management consideration is to locate springs that are relatively unimpacted and protect their integrity through proper management.

Water Use Cluster Analysis

A cluster analysis of the five individual activity measurements of the water use category was performed to identify the additive effects of anthropogenic water use activities on aquatic, riparian, and wetland resources. These five individual measurements include: 1) ditch ratio (feet per stream mile); 2) diversion ratio (number of diversions per stream mile); 3) affected segment percentage (miles of affected segments per total stream miles); 4) percentage of streams inundated by reservoirs (miles of inundated stream per total stream miles); and 5) percentage of streams affected by an upstream reservoir (miles of affected stream per total stream miles). Prior to the cluster analysis, HUBs where no water use activity was present were assigned as Cluster 0 because they had no data (e.g., information) to contribute. Cluster analysis was performed on the remaining HUBs using PC-ORD2, which identified three clusters based on 25% information remaining (table 2.6; figs. 2.14-2.15). The clusters derived from this analysis are independent of the riparian and wetland clusters derived in the ecological driver analysis presented in Chapter 2 in Report 1 of this assessment. Therefore these clusters will contain the suffix 'wu' indicating they are related to the 'water use' activity analysis.

Analysis of variance (ANOVA) was performed on data from Clusters 2wu and 3wu to see if values for individual activity measurements differed between clusters (See GIS Appendix, Staley 2004). Clusters 0wu and 1wu were excluded from the analysis because they contained little or no activity. Significance was assigned at the 95% level (e.g., $\alpha = 0.05$).

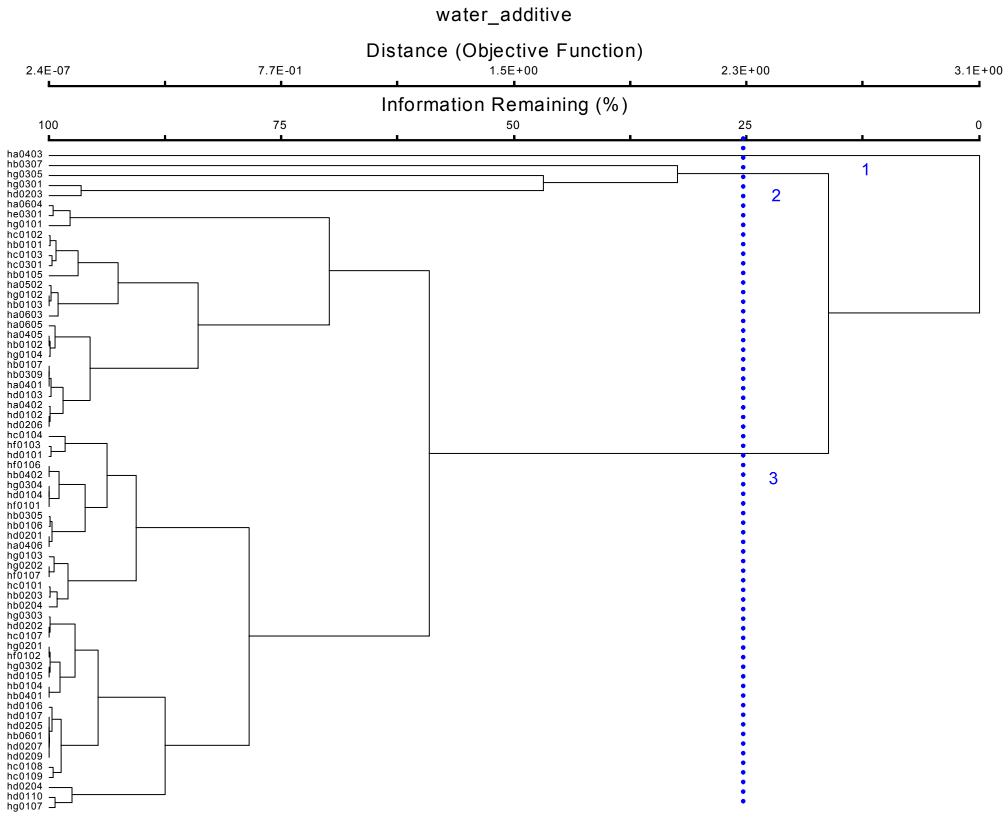

Figure 2.14. Dendrogram identifying the results of the additive effects analysis of the water use category. Sixty of 74 6th level HUBS are included in the analysis. The dashed vertical line denotes the 25% information loss cutpoint, and numbers denote clusters.

Table 2.6. Mean criteria values for each water use cluster.

Water Use Category: Cluster Analysis Results				
	Cluster (n=number of HUBs)			
Individual Activity Measurement	**Cluster 0wu** (n=8)	**Cluster 1wu** (n=1)	**Cluster 2wu** (n=4)	**Cluster 3wu** (n=61)
Mean Ditch Ratio	0.000	0.000	0.000	**633.475**
Mean Diversion Ratio	0.000	0.001	**0.066**	**0.060**
Mean Percent Segments Affected by Diversions	0.000	0.000	**0.041**	**0.057**
Mean Percent Inundated Streams	0.000	0.000	**0.104**	**0.016**
Mean Percent Affected By Reservoir	0.000	0.000	**0.415**	**0.189**

The "Percent of Streams Inundated by a Reservoir" was the only individual activity measurement that differed between Clusters 2wu and 3wu. All other measurements were statistically similar or the data were too sparse to allow comparison.

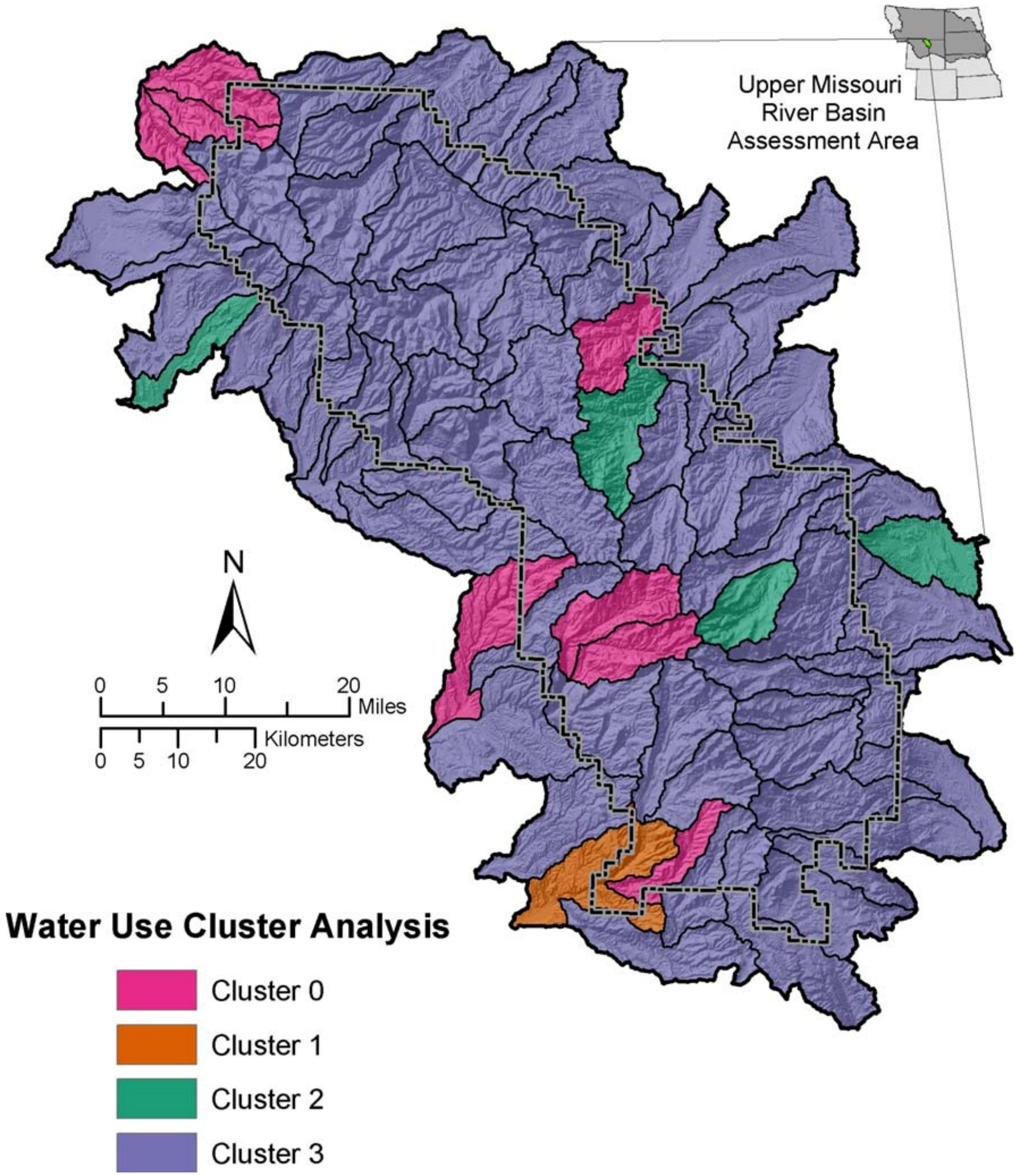

Figure 2.15. Cluster analysis of water use criteria.

Most of the HUBs are influenced to some degree by water use activities. Cluster 0wu contains eight HUBs that are not influenced by the water use activities included in this analysis. Cluster 1wu contains only one HUB and has an extremely small percentage of stream length affected by diversions. HUBs in Clusters 0wu and 1wu could be used as "reference" watersheds for monitoring programs, or may be suitable recovery sites for threatened and endangered native species. Cluster 2wu contains four HUBs, and is affected by diversions and reservoirs. Cluster 3wu contains 61 HUBs, and is the only cluster influenced by water transmission ditches, a feature which sets it apart from the other clusters.

These results may be helpful in setting priorities for further analysis relating to the influence of water related activities on aquatic, riparian, and wetland resources.

Cumulative Percentile Ranking

In contrast to the results from the cluster analysis, the groups produced from the rank sum additive effects framework were more evenly distributed across the Forest (fig. 2.16). Group 4 includes 16 HUBs, most of which are concentrated in the middle-eastern portion of the Forest (fig. 2.16). Of the sixteen 6^{th} level HUBs in this rank category, there are only three that are totally within the Bighorn National Forest boundary. HUB 100902060302 had a rank sum of 14, meaning that it was ranked consistently in the highest category for most of the individual activity analyses. A total of four other HUBs exhibited additive rankings of 12, also indicating relatively high additive rankings for this use category.

Group 3 includes nineteen HUBs that could be considered "intermediate" as their rank sum values all lay between 4 and 7 (fig. 2.16). Only two of the nineteen HUBs in group 3 are located entirely within the Bighorn National Forest boundary, whereas most HUBs are located around the flanks of the Big Horn Mountains.

Group 2 includes nineteen HUBs with relatively low rank sum values, which range from 2 to 3. Five of nineteen HUBs in the group are located entirely within the Forest boundary. There are several others however, that are almost entirely within the Forest boundary, with just a small corner outside.

Group 1 contains 12 HUBs that had rank sums of 0 or 1. HUBs in Group 1 are primarily located in the southwestern portion of this scale, with several other HUBs scattered across the management scale. Half the HUBs in this group are found entirely within the boundary of the Bighorn National Forest, and the remainder intersecting the Forest.

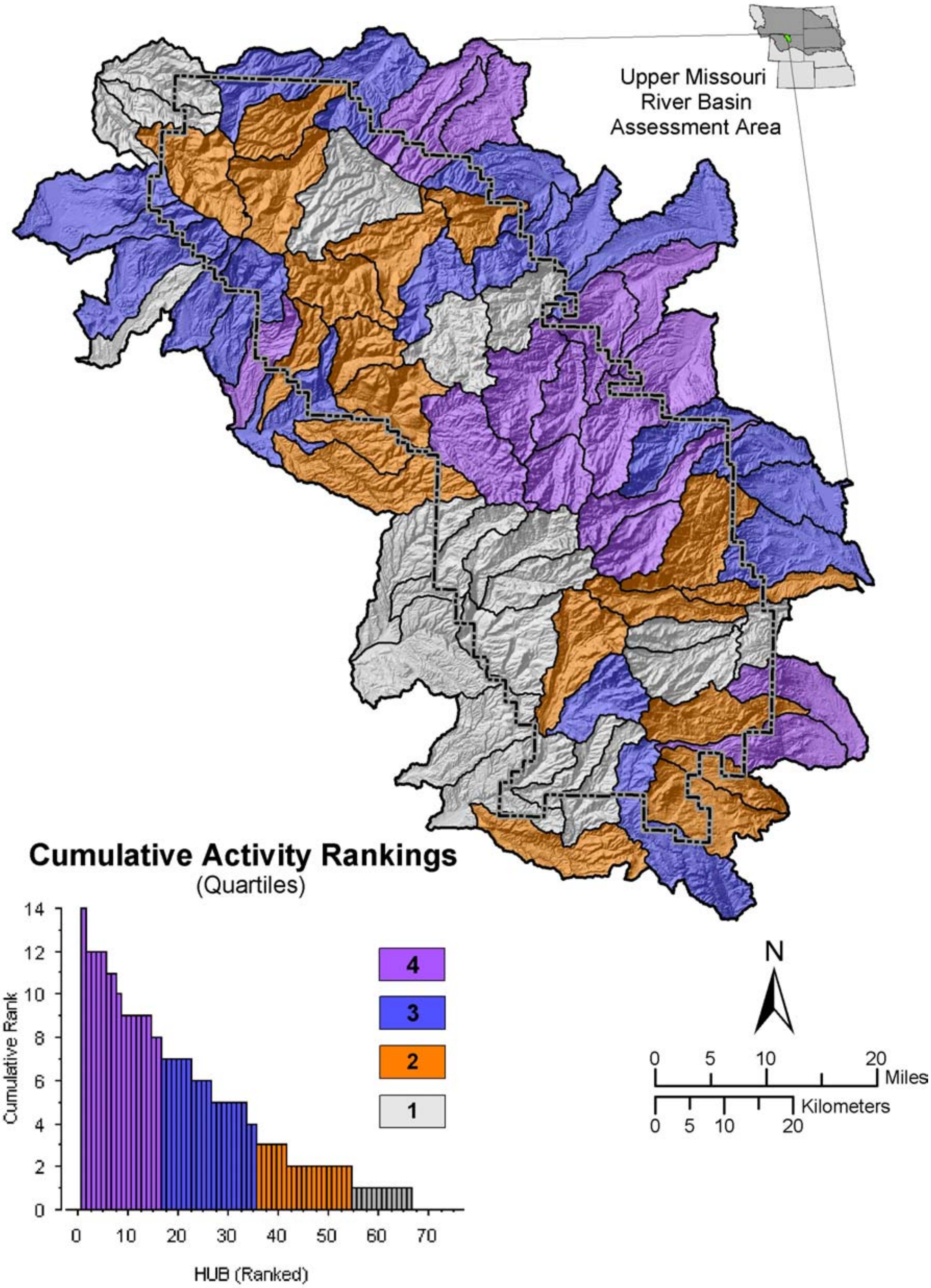

Figure 2.16. Additive water use activity rankings

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Chapter 3
Transportation Category

Key Findings

1. There are approximately 15,462 road miles at the landscape scale, with the density (road mile/ square mile) outside the Bighorn National Forest (BNF) boundary being slightly more (1.51) than inside (1.16) the Forest.
2. A comparison of road density within 4th level HUBs, both inside and outside the BNF boundary, revealed that the Crazy Woman HUB within the BNF boundary had the highest density (2.39 miles/ square mile/ 4th level HUB inside the BNF).
3. All 6th level HUBs within the BNF boundary had roads within the valley bottoms, with the ratio ranging from slightly more than 0 to 1.3 miles of roads in the valley bottom/ stream mile/ 6th level HUB.
4. Foot trails were identified throughout the BNF, with the highest densities associated with aquatic, riparian, and wetland resources located primarily in the south-central and southeastern portion of the Forest.
5. More than 50% of the 6th level HUBs within the BNF have at least 50% of the area open to cross-country OHV use.
6. There are no 6th level HUBs within the BNF that exhibit OHV trail density in the valley bottom greater than 0.9 miles/ stream mile/ 6th level HUB.
7. The additive effects analysis revealed only very minor portions of six 6th level HUBs that are not influenced by activities in the transportation category within the BNF.
8. The 6th level HUBs with the highest influence of transportation appears to be in the very northern and central portion of the BNF, with the remainder of the Forest exhibiting fewer influences.
9. Of a possible cumulative ranking value of 30 (meaning that each of the 10 parameters measured would have to have the highest rank of 3), more than 45 of the 74 the 6th level HUBs had values of half of the potential ranking value.

Influence of Roads

Basin Scale

The development of motorized transportation routes in the Bighorn ecosystem did not occur until after 1910. Cars in this area were an extreme rarity up until 1913. The rapidly growing availability of automobiles beginning in the 1920s stimulated a demand for more and better roads in the area. Roads soon replaced the wagon trails that had served to move goods and services into the area over the previous thirty years.

Tourism has provided the stimulus for much of the major road development in the area. In 1912, a group called the Black and Yellow Trail Association promoted a marked highway that would connect the upper Mid-west to Yellowstone National Park. The road would pass through the town of Buffalo and head over the mountains to Tensleep and on to Yellowstone. The road was completed in 1920. Highway 16 now follows much of the route of the original Black and Yellow trail (fig. 3.1).

In later years, roads were developed to support ranching, farming, and mineral operations within the area. During the early part of the 1920s oil, gas, and coal mining were beginning to boom in the area. The development of energy resources outside of the major tourist routes spurred significant road building throughout the Big Horn Mountains that continues today.

Interstate 25 (I-25) is the primary highway route along the Front Range of the Rocky Mountains (fig. 3.1). Many towns and cities are built along this route because of its desirable location along the more inhospitable mountain areas, as well as the relative ease of transporting people and goods. I-25 traverses the eastern flanks of the Big Horn Mountains, with the towns of Buffalo and Sheridan located along its route. Between these towns, I-25 changes to I-90, although the general route north is the same. This highly traveled interstate brings tourists, business people, and associated businesses, as well as people seeking new homes in the Rocky Mountains.

There are two major transportation routes through the Bighorn National Forest. Highway 14 accesses the northern half of the Forest (fig. 3.1). Highway 14 splits into two routes at Burgess Junction. The northern route is called Highway 14A and provides access to the town of Lovell, Wyoming. Highway 14 continues down Shell Canyon and accesses the town of Greybull, Wyoming. The southern route across the Forest is via Highway 16 and provides access between the towns of Buffalo and Tensleep, Wyoming. These highways can accommodate passenger as well as commercial vehicles across the Big Horn Mountains. Both of these routes intersect the I-25/I-90 route, making it a convenient transportation route for travelers.

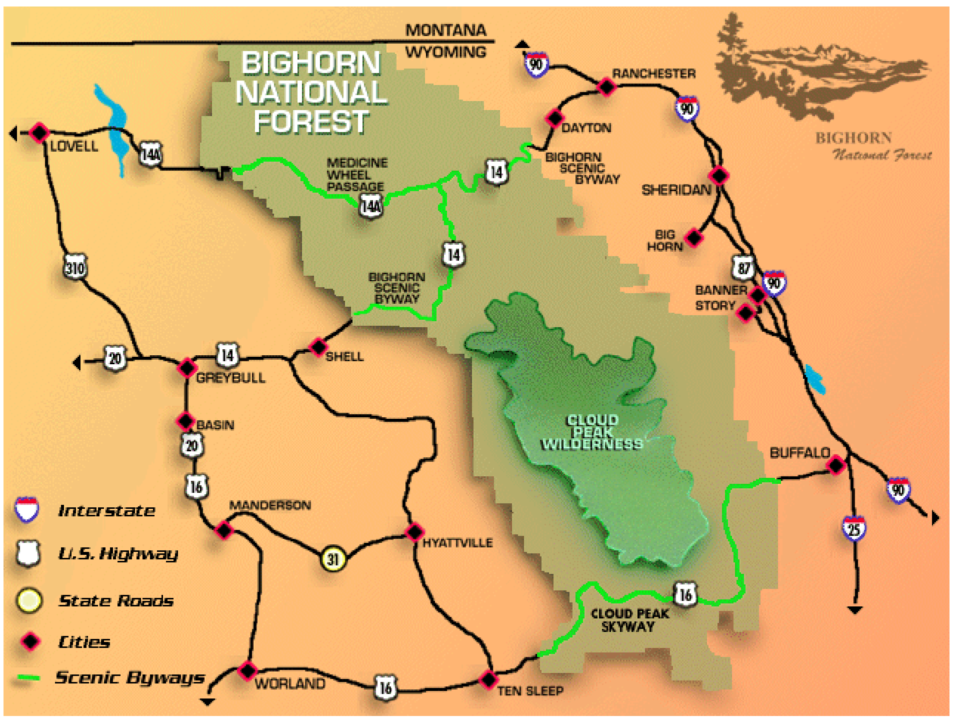

Figure 3.1. The Bighorn National Forest showing major highways and population centers. Figure courtesy of the Bighorn National Forest.

Landscape Scale

The 4th level HUBs in the assessment area all contain roads, which are generally well dispersed throughout this scale (table 3.1, fig. 3.2). There are approximately 16,500 miles of road within all 4th level HUBs in the assessment area, comprised of surfaced as well as less maintained routes.

The highest road miles are contained in the Upper Tongue watershed (3,850 miles) and the least are in Clear Creek (1,532 miles). The highest amount of roads on the Bighorn National Forest is also contained in the Upper Tongue watershed (532 miles) while the least is in the Middle Fork of Powder River (33 miles).

Table 3.1. Road measurement comparisons between 4th level HUBs and relationship between Bighorn National Forest lands and lands outside its boundary.

4th Level HUB Name	Total Miles of Road	Total Road Density (miles of road/mile^2 of 4th level HUB)	Road Density Outside of National Forest Boundary (miles/ mile^2)	Forest Road Density (miles/ mile^2)
Nowood River	3,025	1.50	1.58	1.12
Big Horn Reservoir	2,114	1.17	1.18	1.14
Little Big Horn River	1,763	1.36	1.40	1.16
Upper Tongue	3,850	1.52	1.60	1.16
Middle Fork Powder River	1,567	1.60	1.60	1.70
Crazy Woman	1,607	1.68	1.60	2.39
Clear Creek	1,532	1.33	1.61	0.63
	Total=15,462	Mean=1.45	Mean=1.51	Mean=1.16

A comparison between total road ratios within and outside of the Bighorn National Forest reveals that the average ratio within the Forest boundary is almost 0.5 miles per square mile less than the ratio outside of the Forest boundary. Only two of the seven 4th level HUBs have higher ratios, with the Crazy Woman HUB being noticeably more. While five of the 4th level HUBs within the Forest boundary have less road ratios than outside the Forest boundary, the Clear Creek HUB is noticeably less (0.98 miles of road per mile).

Management Scale

There are currently approximately 1,818 miles of roads in the Bighorn National Forest (table 3.2). This system of identified roads accesses an area of approximately 1,738 square miles (approx. 1.04 miles of road per square mile of National Forest), including wilderness and private lands. The pattern of roads within the Bighorn National Forest boundary indicates that they are generally well dispersed, except for the Cloud Peak Wilderness area. The road system in this assessment area varies from high standard U.S. highways to primitive, abandoned "two track trails". There are probably some unauthorized roads, which are not inventoried or included in this analysis.

Table 3.2. Miles of road by maintenance for roads under USDA Forest Service jurisdiction.

Classification	Description	Length (%) (miles)
Level 1	Closed to public travel – can be used intermittently for management purposes.	538
Level 2	Maintained for use by high clearance vehicles.	745
Level 3	Maintained for use by a prudent driver in a passenger car.	162
Level 4	Maintained for use by passenger cars with a moderate degree of user comfort. Usually double lane, gravel roads.	98
Level 5	Maintained for a high degree of user comfort, double lane, often paved.	1
Unclassified	Estimated, not inventoried.	274
	Total	1,818

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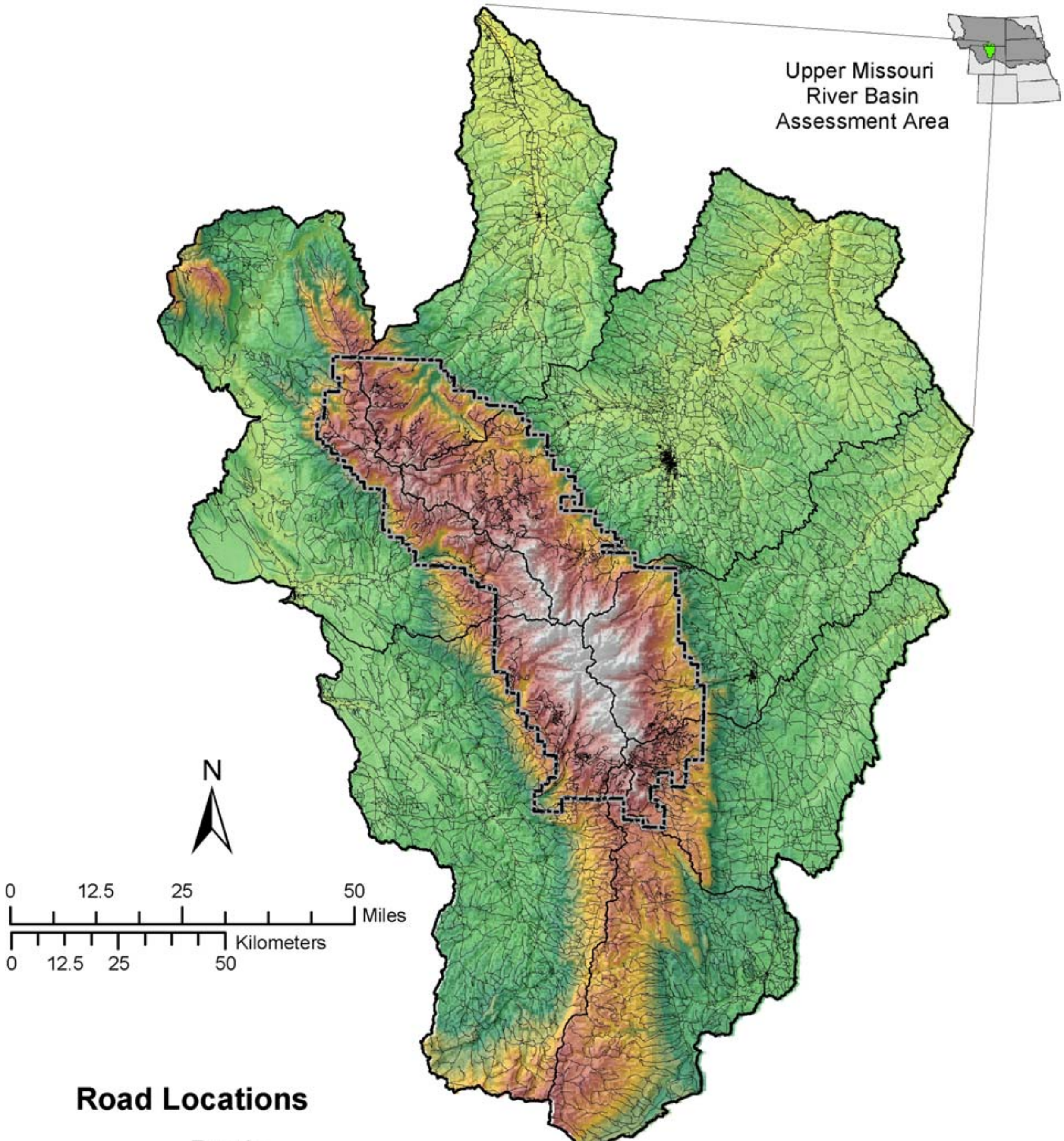

Figure 3.2. Road locations at the landscape scale.

The roads within the assessment area under Forest Service jurisdiction are grouped into categories called maintenance levels (table 3.2). Maintenance levels are classified into 5 categories, with 5 being the highest standard and 1 being the lowest standard. There may also be additional roads no longer required for management purposes, or which have been created by off-road vehicle use, but there still exists a road 'footprint.' These roads are called unclassified, and the mileage of these unclassified roads is an approximation.

While this classification of roads is important for maintenance and management purposes, it does not necessarily help determine the influence roads have on aquatic, riparian, and wetland resources. The position on the landscape (e.g., within the valley bottom versus uplands), structural association (e.g., culverts) and surface composition (surfaced vs. non-surfaced) are better determiners of their influence on these resources. We have attempted in this analysis to focus on specific measurements, which are more indicative of the relationship between roads and aquatic, riparian, and wetland resources. The following analysis addresses these considerations.

The total road ratio (miles/stream mile/6th level HUB) ranged from 3.18 for HUB 100800080405 to 0.02 for HUB 10090206030 and is represented in Figure 3.3. There were no HUBs at this scale without some level of roads present. Clearly, two thirds of the HUBs contained ratios greater than one, while most of the HUBs exhibited ratios greater than 0.5. These results are only relative to the HUBs that intersect the Bighorn National Forest boundary, and are not meant to be a level of impact. However, there does appear to be a relatively wide distribution of roads across this scale, with the HUBs associated with the Cloud Peaks Wilderness and isolated HUBs along the steep flanks of the Big Horn Mountains having lower ratios (fig. 3.3). These values are meant to provide a comparison of relative values for HUBs and do not reflect the size of the HUB within the Bighorn National Forest.

To focus more directly on the influence that roads have on stream and riparian resources, the density of unsurfaced roads in the valley bottom within the assessment area was measured (fig. 3.4). Results from the unsurfaced road analysis show that ratios (unsurfaced road miles in the valley bottom/stream mile/6th level HUB) ranged from approximately 0 for ten HUBs to 1.28 for HUB 100902010301 (fig. 3.4). The highest one third of the ratios were above 0.4, with a concentration generally in the southern portion of the Forest, and the rest scattered across the remainder of the HUBs. Because of their location in close proximity to streams and riparian areas, and general erosive nature, results of this analysis indicate that there are non-surfaced roads throughout the Bighorn National Forest that could be influencing stream and riparian ecosystems. While the ratio values are not a measure of impacts, they could be used to identify areas for future inventories and monitoring.

There is approximately only 1 mile of Forest Service road that is paved within the Bighorn National Forest (fig. 3.5). As a result, we are not going to address this section of road at this scale. This section is better addressed at the reach/site scale.

The ratio of both surfaced and unsurfaced roads intersecting wetlands was evaluated, based on the riparian and wetland delineation of Girard et al. (1997) (fig. 3.6). Delineations for wetland ecosystems were separated from riparian ecosystems for this analysis. Road density for wetlands (feet of roads within wetlands/total wetland acres/6th level HUB) values ranged from 0 to 43.7 feet. There were three HUBs in particular that exhibited densities higher than the rest: 100800100402 (43.7), 100800080502 (39.78), and 100902060104 (36.68), although a total of five had values greater than 25. These values appear to be relatively small. Therefore, a thorough evaluation at the reach/site scale is necessary in order to evaluate a particular road's influence on associated wetlands.

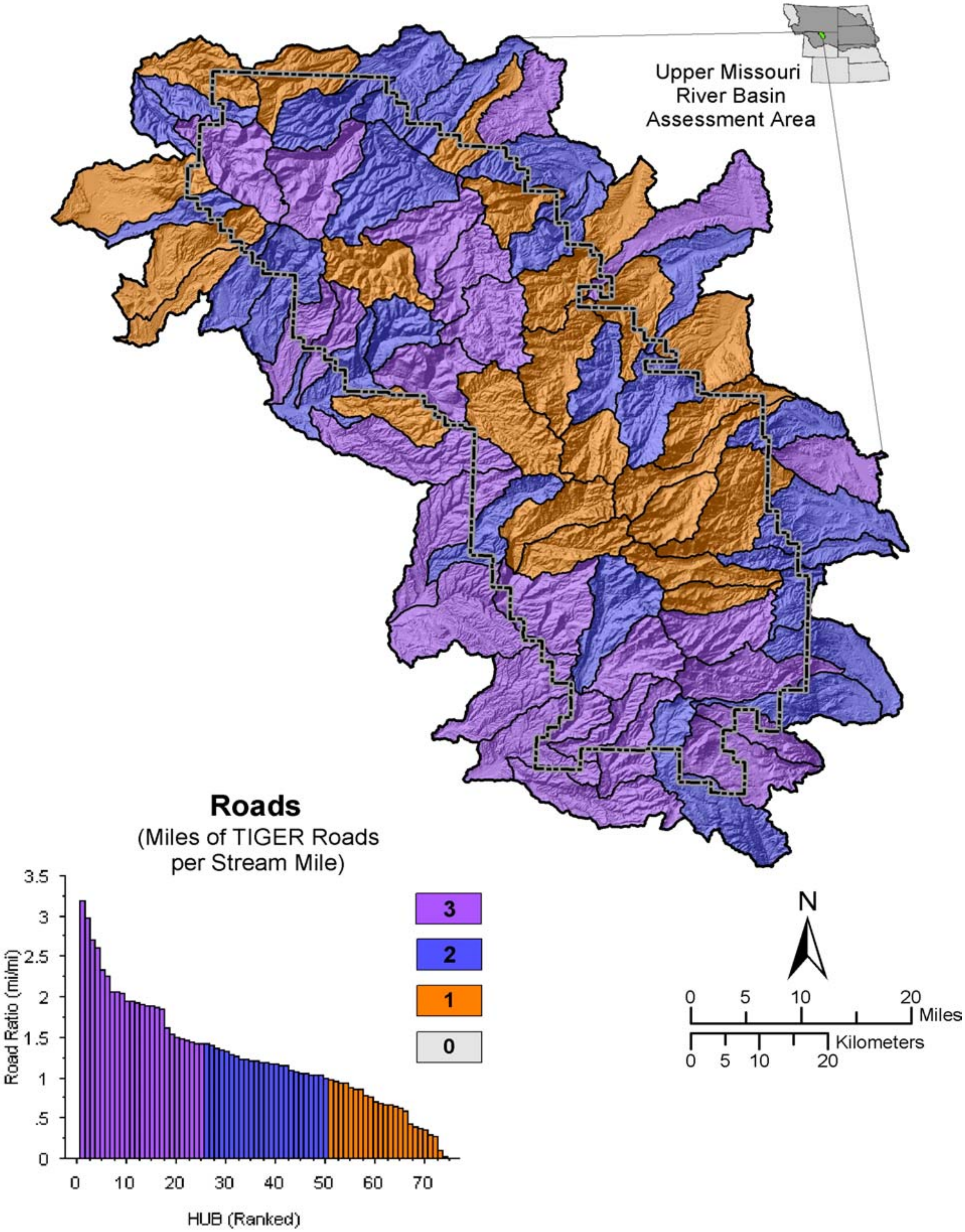

Figure 3.3. Rank and distribution of the road to stream ratios at the management scale. The two highest ranked 6th level HUBs for this analysis were 100800080405 and 100902050101 respectively.

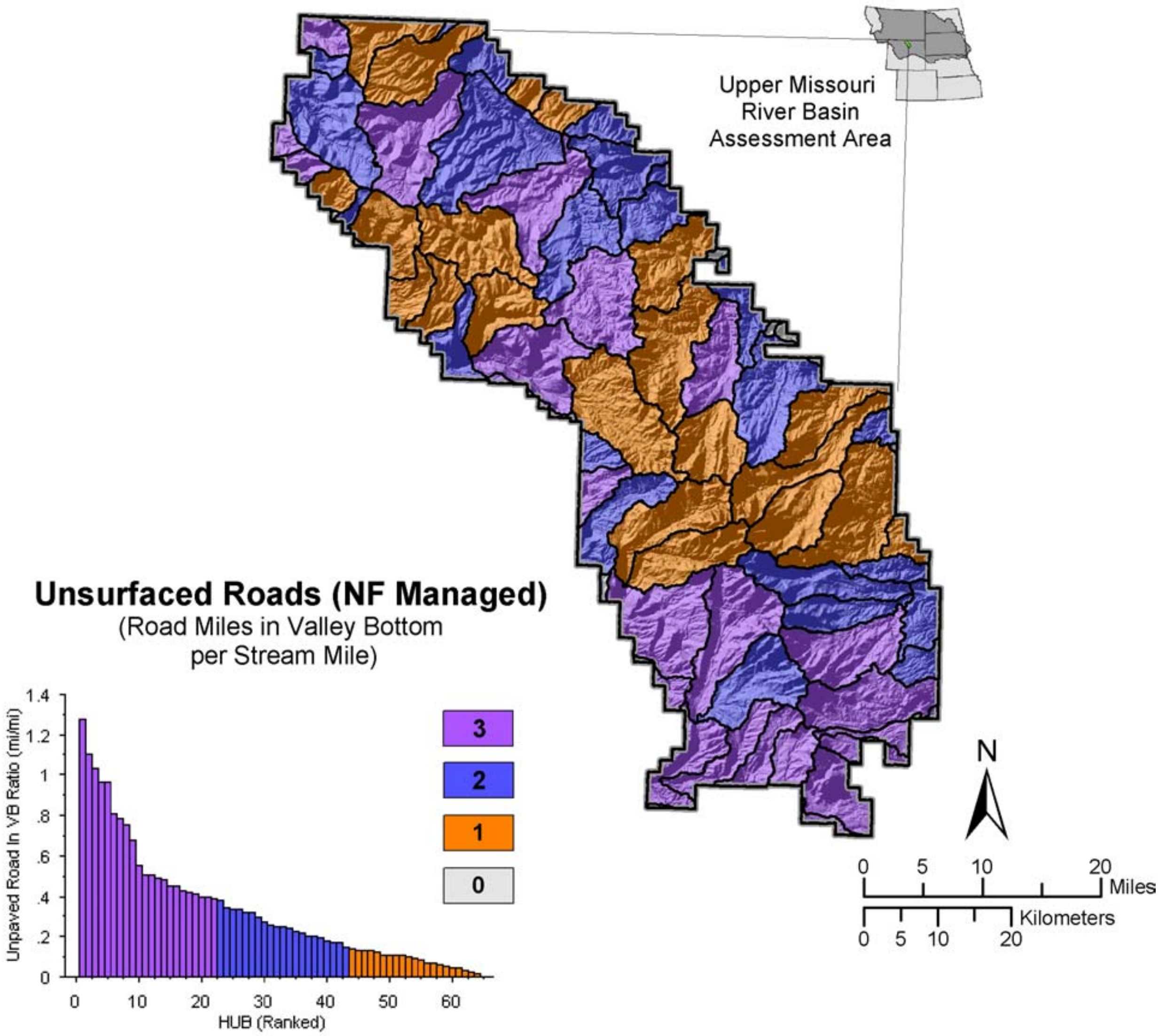

Figure 3.4. Rank and distribution of unsurfaced roads to stream miles in valley bottoms within the Bighorn National Forest. The five highest ranked 6th level HUBs in this analysis are: 100902010301, 100800100105, 100800080405, 100800080606, and 100800080502 respectively.

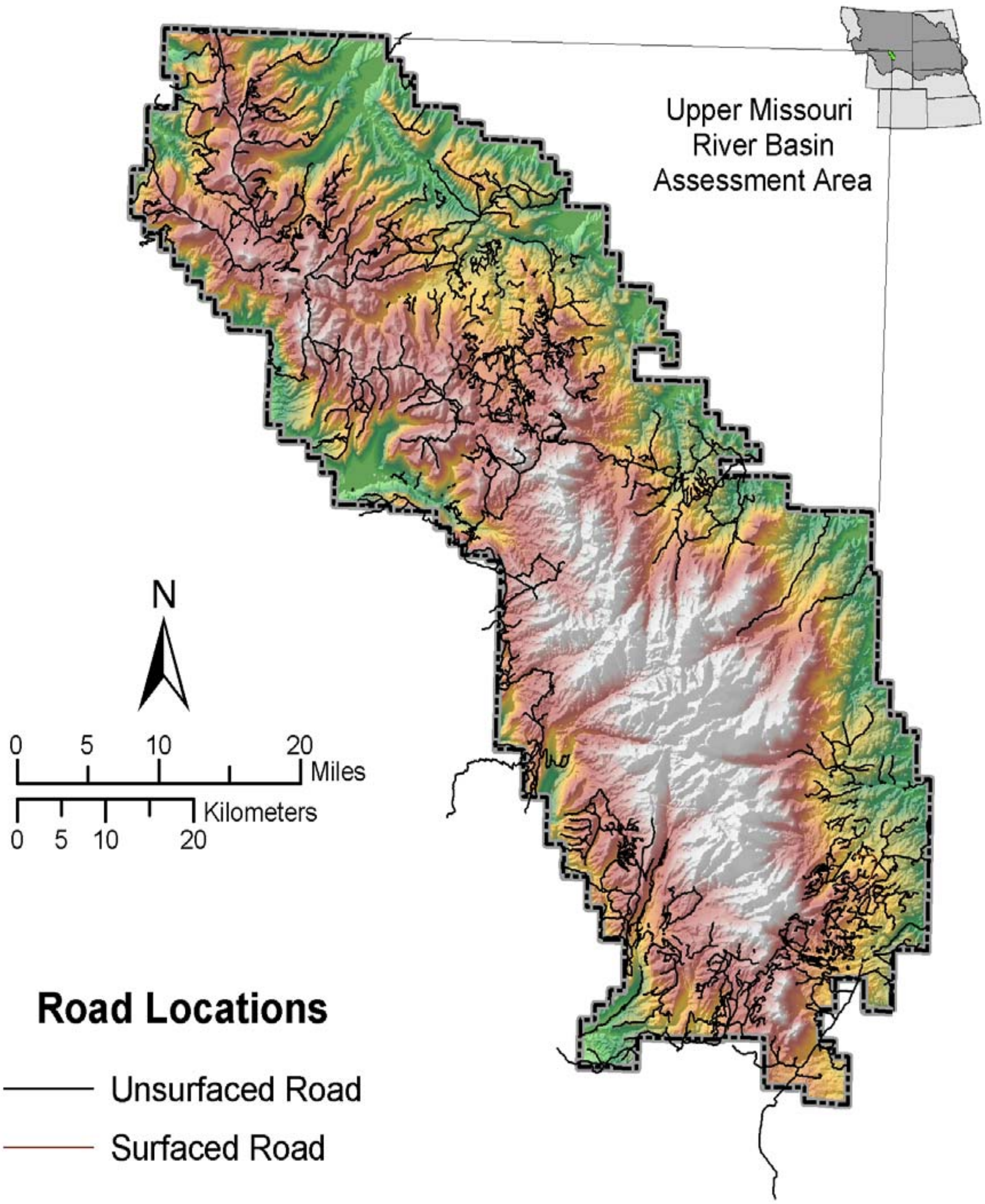

Figure 3.5. Location of unsurfaced and surfaced roads in the Bighorn National Forest.

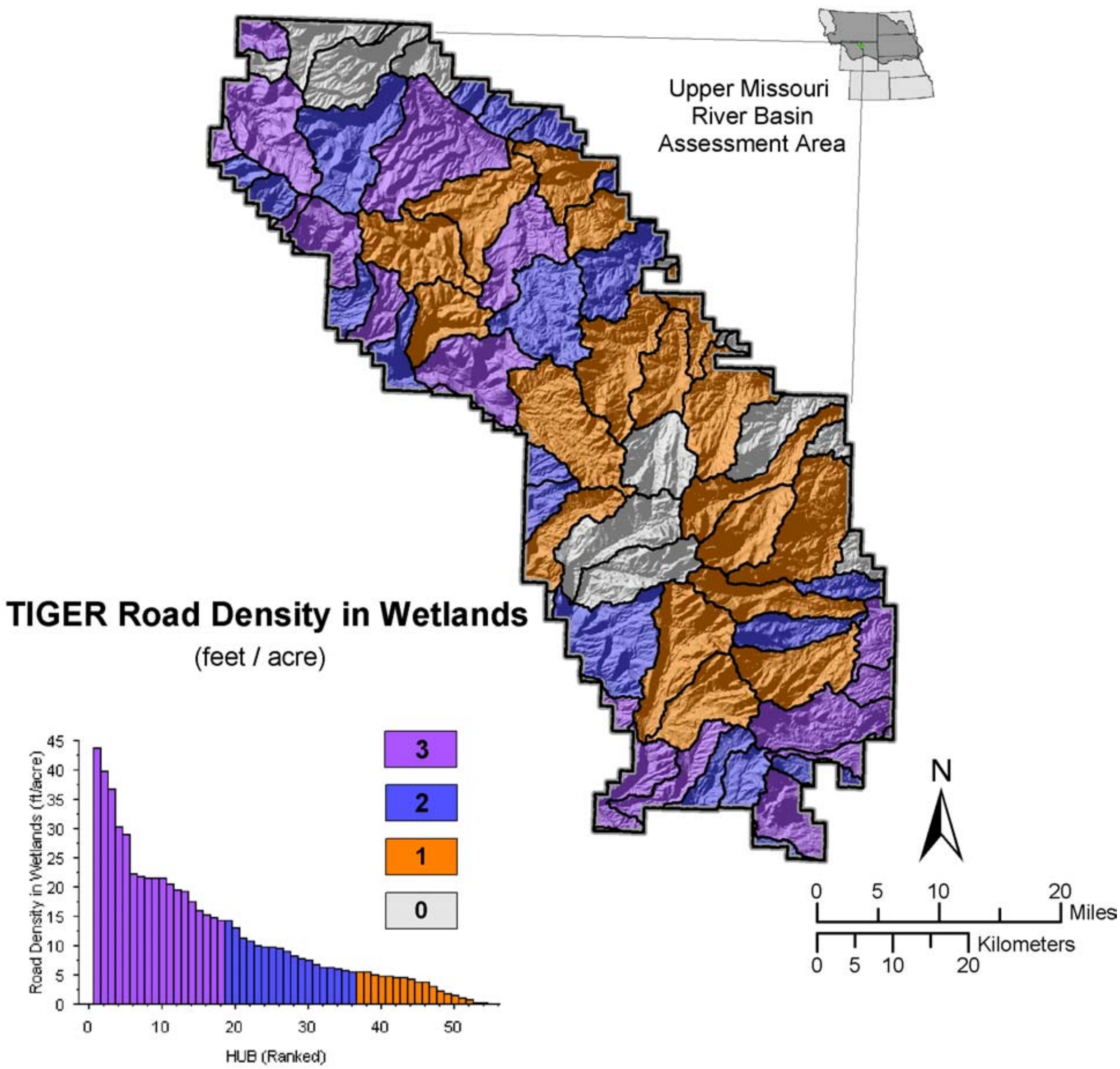

Figure 3.6. Rank and distribution of road densities in identified wetlands within the Bighorn National Forest boundary. The 6th level HUBs which ranked the highest for this analysis were: 100800100402, 100800080502, and 100902060104 respectively.

Stream crossings have been identified as being a significant point of sediment delivery to many streams (Havlick 2002). During the field seasons of 1999-2002, field crews from the Bighorn National Forest inventoried all stream crossings in the Tongue, Porcupine, Shell, Paintrock, and Tensleep 5th level HUBs. The inventory identified stream crossings in need of replacement, removal, or rehabilitation. Nearly 80% of all stream crossings showed a detectable effect on the stream. It is presumed that a sizable amount of unnatural stream sediment is being contributed at stream crossings. The Forest has initiated a long-term program of inventory and treatment of stream crossings at the 6th level watershed scale.

Poorly designed or installed stream crossings are also having an effect on the ability of fish and other aquatic biota to move freely within the watersheds. Common problems include; outfall drops that are too high, lack of resting pools below culverts, and excessive water velocities through, or insufficient water depth within culverts. Bridges have the least effect on fish passage.

Figure 3.7 presents the number of stream crossings per stream mile of 6th level HUB. The highest ratio for stream crossings was 2.07 (HUB 100800080606), while two HUBs contained no identified crossings. Of the total, approximately 29 percent of the watersheds have less than 0.5 stream crossings per square mile of watershed. Watersheds with more than 0.5 stream crossings per square mile are at higher risk of road-related watershed impacts. The recent inventory results indicate that if 80% of a sub-sample have been identified as possibly causing either migratory or sediment problems, and 71% have ratios higher than a level identified as being important for watershed health, there may be watershed related issues. Certainly, any watershed with over two crossings per stream mile could be considered a high risk for issues related to overall watershed health and aquatic biota population fragmentation.

There is currently less than 10% of the 6th level HUBs on the Bighorn National Forest with a completed road analysis that includes culverts and stream crossings. Road conditions are likely to improve as more watersheds have a roads analysis completed and road dollars are directed to these areas to implement recommendations from the analysis. This analysis should be valuable in determining priorities for future roads analysis.

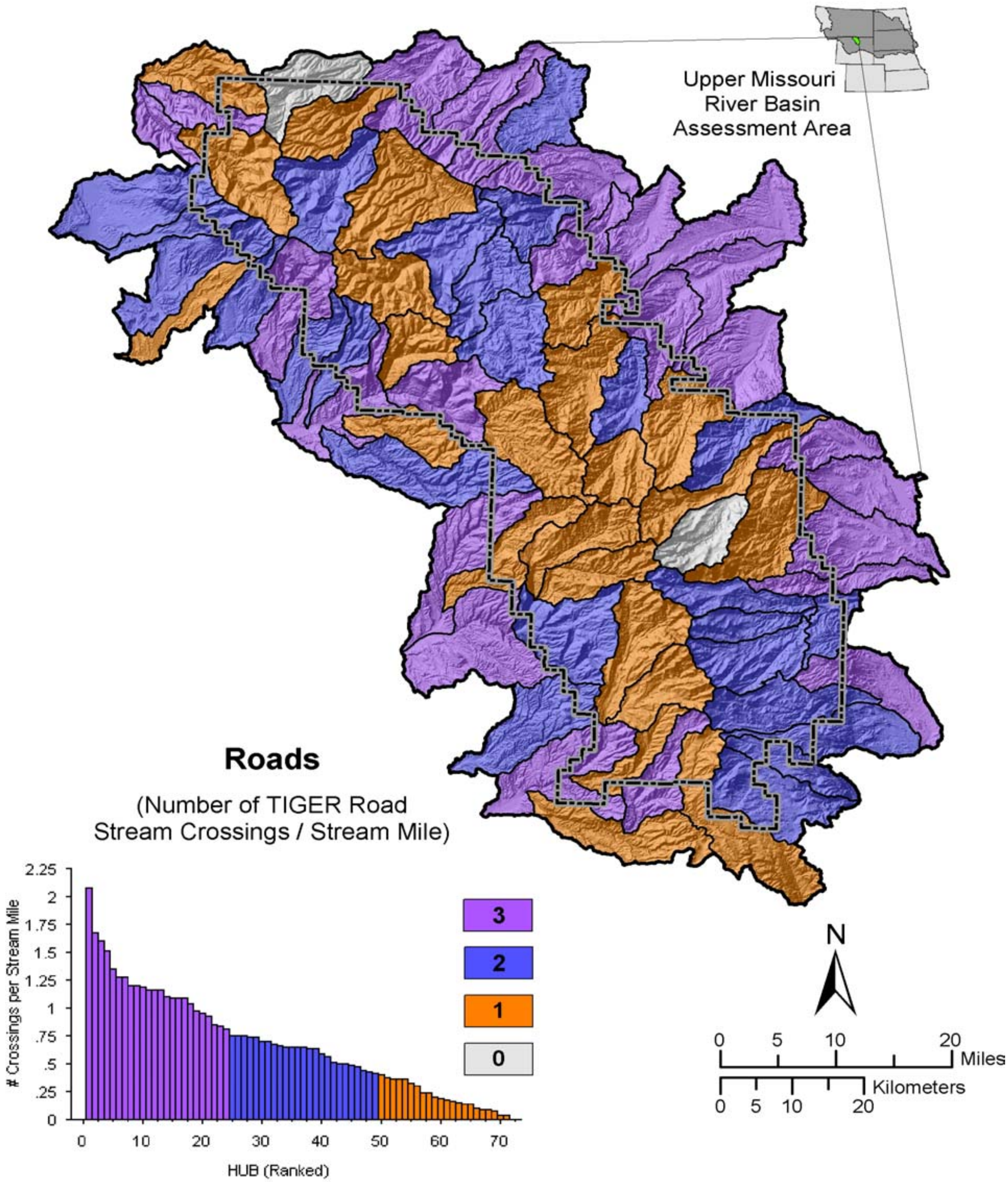

Figure 3.7. Rank and distribution of roads crossing streams per stream mile at the management scale. The highest ratio of road crossings for a 6th level HUB was in 100800080606.

Reach/Site Scale

In order to identify specific influences from roads on aquatic, riparian, and wetland resources, analysis at the reach/site scale is critical. Watersheds with the highest priority for more detailed analysis can be determined from the 6th level HUB assessments.

There are many techniques available for inventorying stream crossings. The following should be considered for a reach/site scale analysis:

1. Are the crossings adequate to pass the design flow including associated debris?
2. Is the crossing appropriate for the expected traffic levels?
3. Is fish passage an issue? If so, is the crossing designed to allow unimpeded passage of aquatic organisms?
4. Are Best Management Practices adequate to prevent chronic inputs of sediment into the stream?

Information Needs

It would be beneficial for aquatic, riparian, and wetland resource management if the Bighorn National Forest could continue the annual inspection of stream crossings within the 6th level HUB (management) scale. The information collected could be used to determine which crossings are performing as intended, and which are in need of treatment.

The Forest could aggressively move to complete more roads analysis at this scale to set priorities for management. The road analysis procedure will identify roads that are not needed to meet management objectives and will help identify roads that are having watershed impacts.

Management Implications and Relationship to Ecological Drivers

Various structures and components are needed to manage and operate those roads under Forest Service jurisdiction. For those roads in the Bighorn National Forest, there are twenty-four bridges and seven major culverts, not counting bridges and major culverts currently under special use permit. A major culvert includes those culverts with end-openings greater than 35 square feet. These structures along with the roads themselves represent a great investment in the transportation system, as well as a huge cost for annual maintenance and, over the years, a resulting backlog of maintenance needs. Table 3.3 shows the breakdown of annual and deferred maintenance needs by maintenance level.

Table 3.3. Deferred maintenance costs for the Bighorn National Forest. The costs were estimated from performing condition surveys on level 3, 4, and 5 roads on the Bighorn National Forest in 1999, and from a random sample of level 1 and 2 roads in 2000. Costs per mile were interpolated from these surveys. Total needs for annual maintenance in Bighorn National Forest = $2,818,139.14. Total needs for deferred maintenance in Bighorn National Forest = $4,972,125.57. In addition, deferred maintenance for road bridges and major culverts is = $263,679.

Maintenance Level	Miles	Annual Cost/Mile	Deferred Cost/Mile
1	580.89	$683	$886
2	759.77	$920	$2,316
3	191.59	$6,561	$8,109
4	77.68	$5,991	$14,730

Current funding levels for road maintenance over the past three years have remained fairly constant, with an approximate allocation of $460,000. This amount appears to be a marginal amount to meet the Forest's needs. The Bighorn National Forest Land Management (BNFLM) Plan standards for full maintenance are also not being met under current allocations. Currently, the BNFLM direction states "to keep roads open to public use unless financing is not available to maintain the facility, or use is causing unacceptable damage to soil and water resources". Based on current deferred maintenance and annual maintenance needs, BNFLM direction is not being met.

The ecological driver analysis for this assessment evaluated predictions of wetland and riparian abundance, sediment movement, and areas of varying fisheries and aquatic production. In addition, each resource area was given a sensitivity rating for management activities for 6th level HUBs. This information should be valuable in combination with the results described in this section to identify areas of management focus related to current roads and crossings, as well as predictions of proposed future roads. The ecological driver analysis (see Chapter 2 in Report 1 of this assessment) showed that some clusters predicting a high abundance of riparian and wetland ecosystems could be areas of "high sensitivity" for the presence of roads to aquatic, riparian, and wetland resources. In addition, clusters with a high percentage of steep gradient stream channels, non-calcareous geology in the rain-and-snow zone could be considered areas of high sediment transport, eventually entering stream courses. HUBs in this cluster group could move sediment into more productive low stream gradient reaches and downstream clusters with potentially high fishery and instream production. Sediment settles into the lower gradient and high habitat areas, reducing habitat and ultimately productivity. It is important that HUBs in clusters downstream from road inventories and potential projects be evaluated. If these downstream HUBs have cluster characteristics related to low stream gradients, they might be particularly sensitive to sediment transport from upstream.

Influence of Trails: Non-Motorized

Basin Scale

At this scale, trail networks and trail traffic probably have no discernable ecological significance. However, for perhaps several thousand years, there has been human occupation in the Upper Missouri River Basin. During that time, there was a network of trails developed around and through the Big Horn Mountains. That network survives even to this day in the form of roads, highways, and trails through the area.

Most of the travel through the area followed along the major rivers and streams. These trails generally began at the Yellowstone River and progressed south up the major drainages such as the Big Horn, Tongue, and Powder Rivers. The rivers facilitated the major north-south movement on either side of the Big Horn Mountains. Trails going east-west into the mountains also followed streams and rivers that had their headwaters in the mountains.

The most well known trail in the area is probably the "Bozeman Trail". In 1862, a trail pioneered by John M. Bozeman was established on the east side of the Big Horn Mountains. The trail became a principal route for miners, the military, and homesteaders from the Platte River to the Yellowstone River. Today, much of the length of Interstate 25 follows Bozeman's original 1862 trail.

Landscape Scale

The majority of human trails existing today are located on public lands. Watersheds with the highest concentration of public lands can be expected to have the highest concentrations of human trails, although access, proximity to population centers, and areas of interest will influence the values.

Table 3.4 illustrates the amount of public lands versus private lands in each of the 4th level HUBs in the assessment area. The 4th level HUBs on the west side of the Forest have significantly more public lands than private, with the exception of the Little Big Horn HUB which is located primarily on the Crow Indian Reservation. The direct opposite is true for the east side of the Forest where the plains area is dominated by private ranches.

The settlers that arrived in the area in 1878 found an existing network of trails. Those on the low country, like the Bridger Trail on the east side of the mountains in the Big Horn Basin, and the Bozeman Trail to the east of the mountains, were deeply scarred by the wheels of many heavy wagons. In the mountains, the tracks were strictly narrow trails made by men, horses and mules, and occasionally by the horse-drawn travois of the Indian. They followed routes quite constrained by the rough topography (Murray 1980).

Table 3.4. Area in square miles of public lands versus private lands in the assessment area.

4th Level HUB Name	HUB Location East or West of Continental Divide	Miles^2 of Public Lands	Miles^2 of Private Lands
Big Horn Reservoir	West	1,565.12	237.70
Nowood River	West	1,301.72	711.20
Crazy Woman	East	185.88	768.89
Little Big Horn River*	East	1,217.67	80.13
Upper Tongue River	East	685.22	1,847.94
Middle Fork Powder River	East	374.86	606.34
Clear Creek	East	324.55	829.05

**High proportion of lands outside the Bighorn National Forest is located in the Crow Indian Reservation.*

Management Scale

Most trails identified at this scale appear to be associated with the lower elevation portions of the Bighorn National Forest, with the exception of relatively long trail networks associated with the Cloud Peaks Wilderness (fig. 3.8). The highest concentration of trails is located in the southeast and southwest portions of the Forest.

The highest ratio of trails within the Bighorn National Forest is 4.04 miles per stream mile per 6th level HUB (HUB 100901010102), while seventeen of the HUBs intersecting the Forest boundary do not have identified trails (fig. 3.9). It should be noted however that of the seventeen HUBs without trails on the Forest, only seven have any appreciable proportion on Forest Service lands. The remainder of these HUBs is located primarily on private land and most likely has very limited access to the National Forest. The highest density of trails are associated with HUBs that intersect the Cloud Peaks Wilderness area, while a few other relatively high ratio HUBs are scattered throughout the Forest (fig. 3.8).

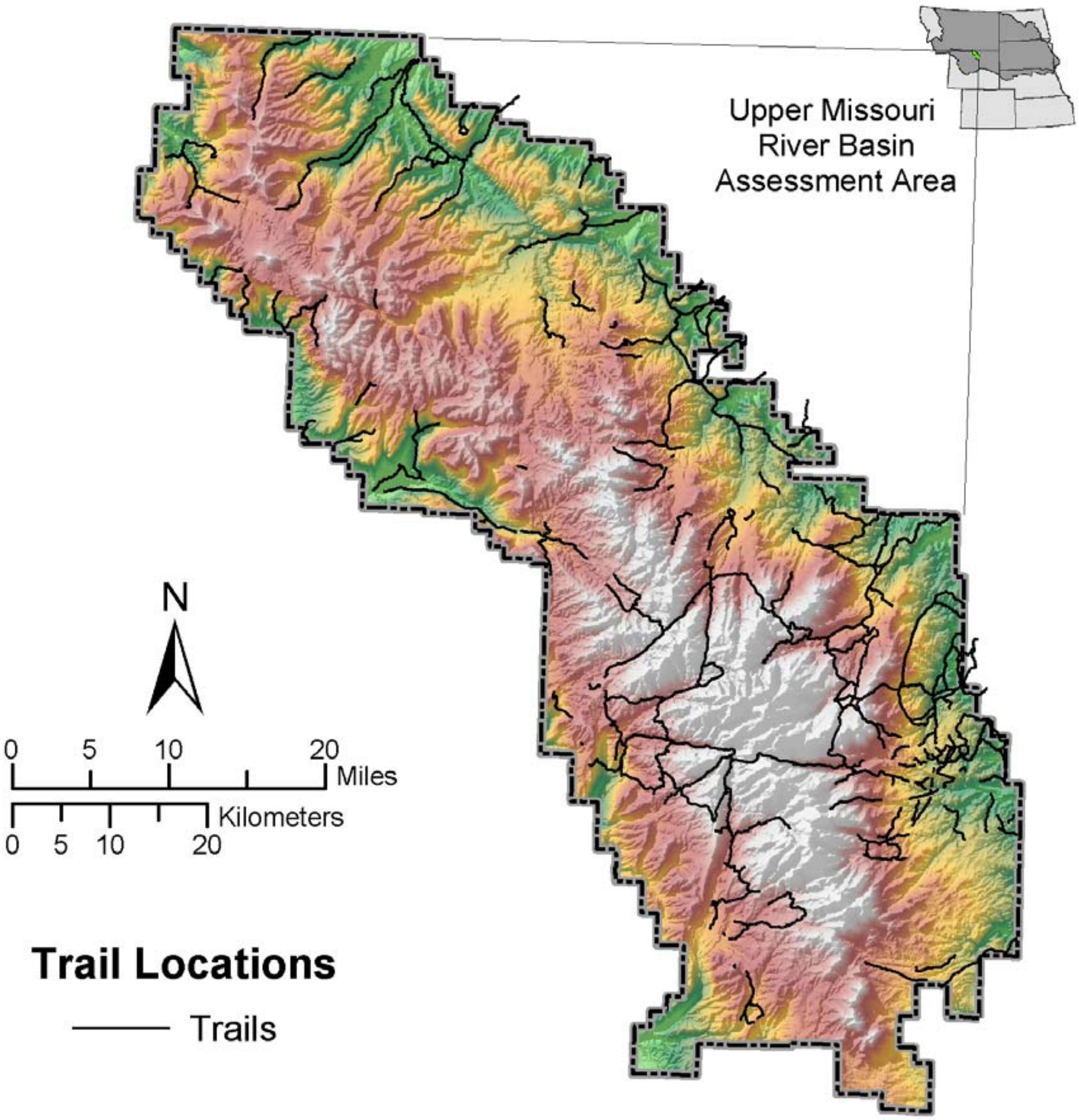

Figure 3.8. Location of foot trails within the Bighorn National Forest.

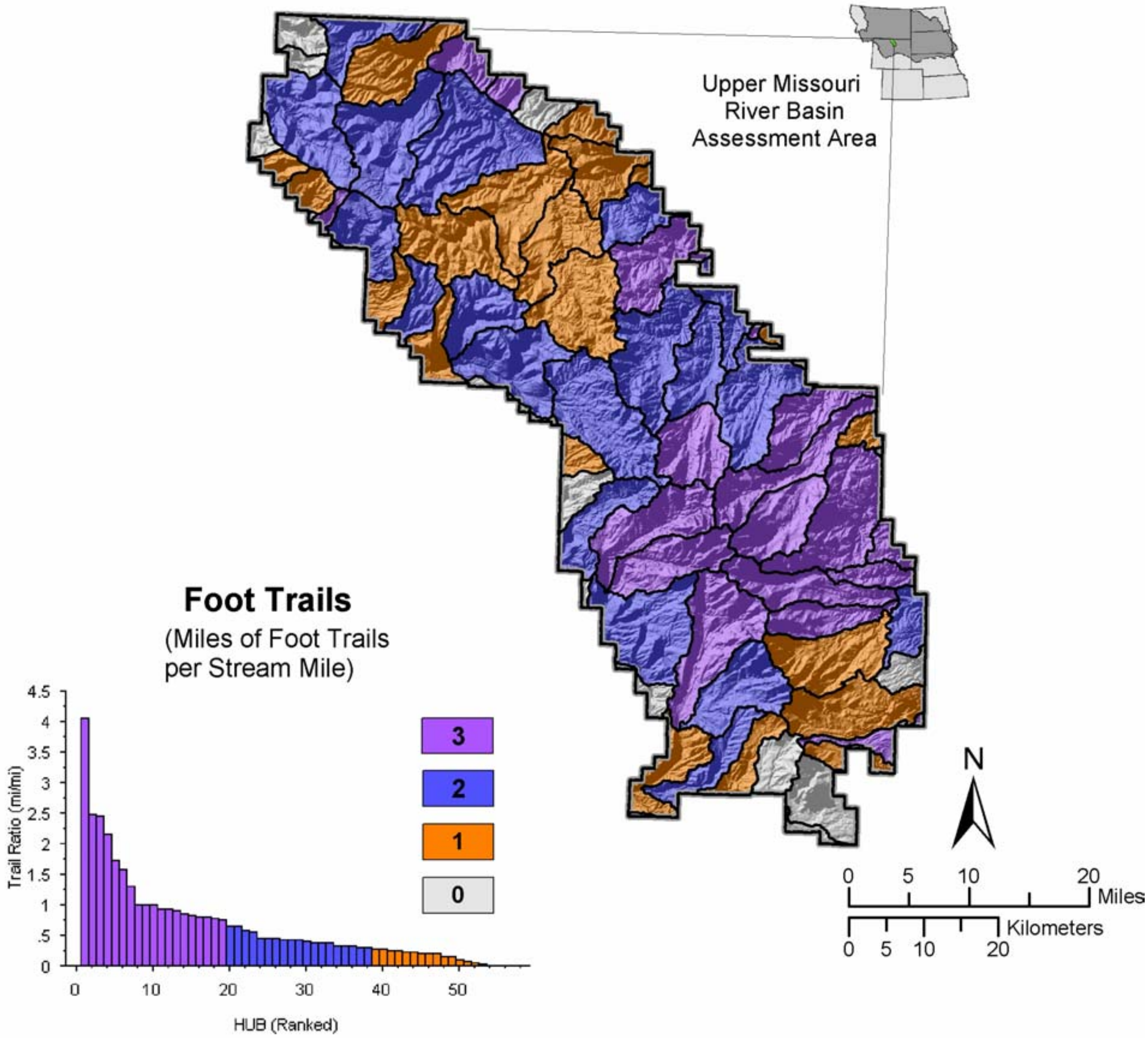

Figure 3.9. Rank and distribution of foot trails to stream miles within the Bighorn National Forest. The highest rank is for 6th level HUB number 10090101010.

There are approximately 546 miles of non-motorized trails on the Bighorn National Forest, and those located within valley bottoms are more likely to influence adjacent riparian areas and streams. Figure 3.10 illustrates the ratio of non-motorized trails within the valley bottom for each stream mile for a particular 6th level HUB. Values for the ratio of trails in the valley bottom to stream miles for each HUB range from zero for 23 HUBs to 1.2 for HUB 100902060202. Generally, the highest-ranking HUBs are located in the south-central portion of the Forest. The HUBs with no trails in the valley bottom are located in areas where only a relatively small proportion of the HUB is within the Forest boundary. These results indicate that access and the terrain is probably not conducive to trail locations in those areas.

Figure 3.11 illustrates the HUBs intersecting the Bighorn National Forest with the associated ranking of watersheds based on stream crossing density. There are twenty-six 6th level HUBs with no apparent stream crossings, while the highest value was 3.7 crossings per stream mile for HUB 100901010102. The highest-ranking HUBs were generally located in the south-central portion of the Forest, while the HUBs with no trails located in the valley bottom were associated with HUBs having only a small portion of the HUB within the Forest boundary. There is probably very limited access to these HUBs due to their location along the steep slopes on the edge of the Forest and surrounding private land.

All the HUBs with no stream crossings have a limited amount of area within the Bighorn National Forest. These results indicate there may be access to those portions of the HUBs within the National Forest. All the 6th level HUBs that are entirely within the National Forest boundary exhibited some stream crossings, while there were six that exhibited ratios of more than one crossing for each stream mile in that HUB. While these values appear to be relatively high, more than two-thirds of the HUBs exhibited values less than 0.5 crossings for each stream mile within their respective HUBs.

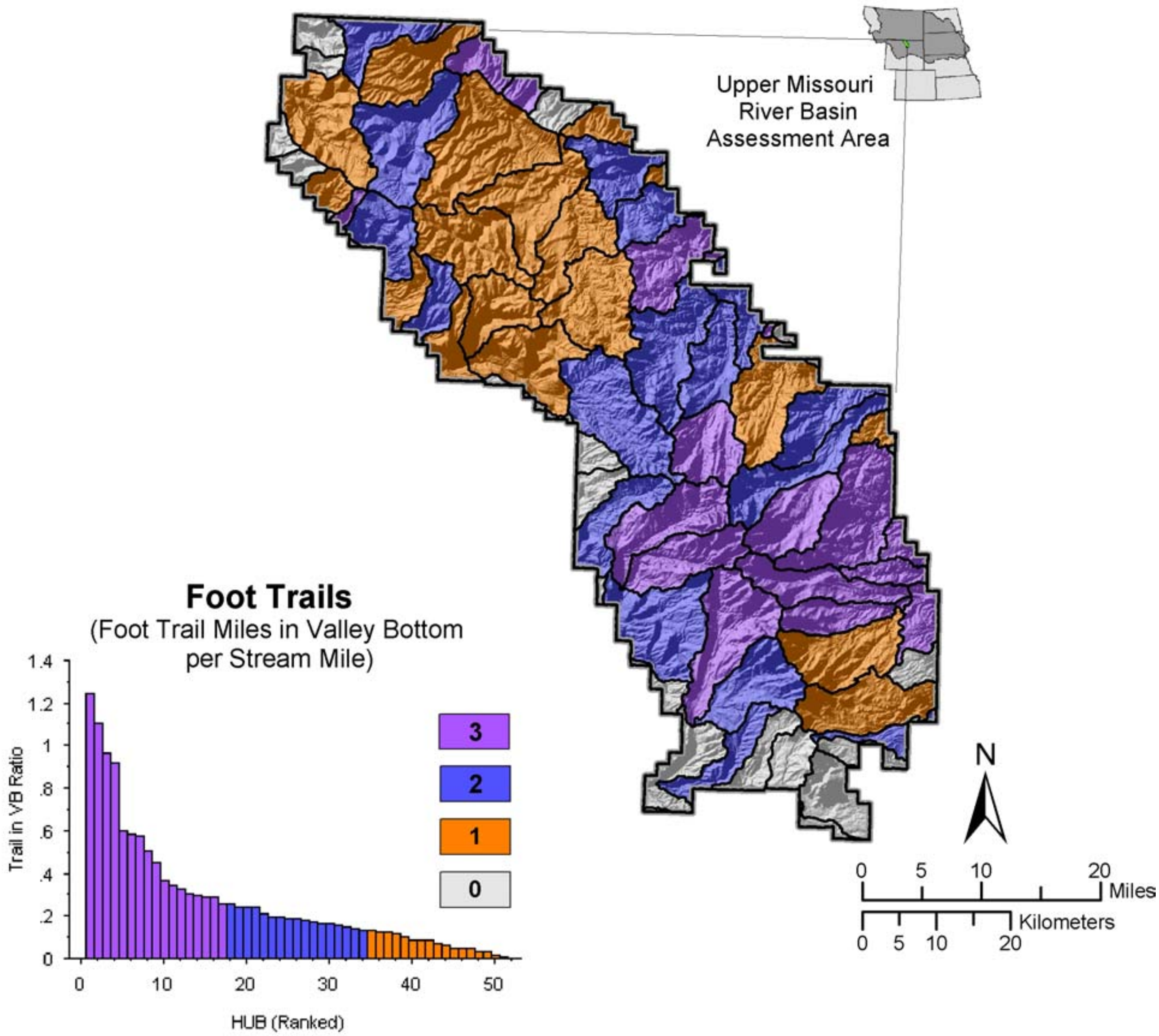

Figure 3.10. Distribution and ranking of foot trail ratio within the valley bottom for 6th level HUBs at the management scale. HUBs 100902060202, 100901010209, 100902060107, and 100902060201 exhibited the highest ranking within this analysis**.**

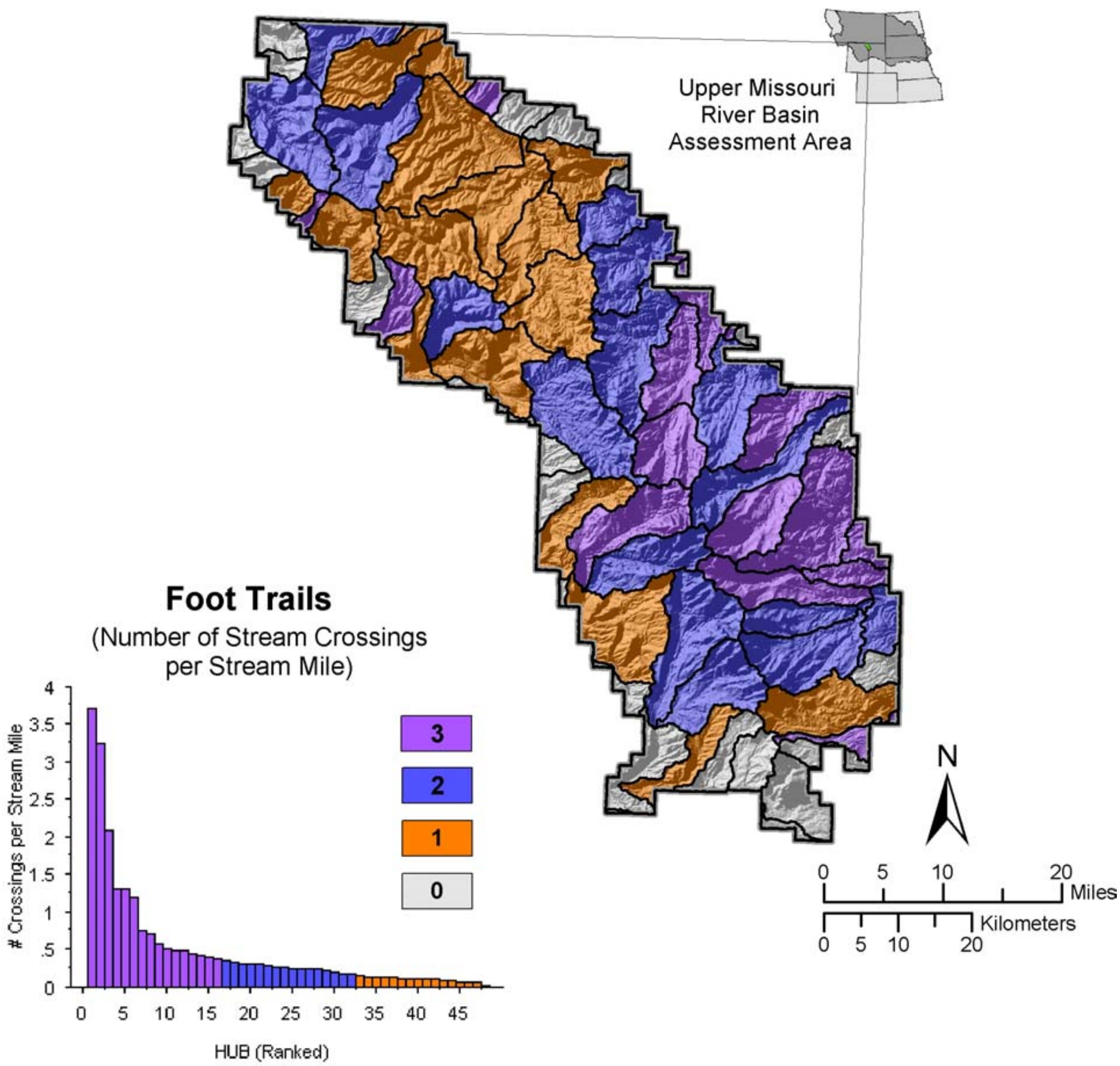

Figure 3.11. Stream crossings ratios for foot trails within the Bighorn National Forest. The three highest ratios were for HUBs 100901010102, 100800100105, and 100901010205, respectively.

In addition to trails within the valley bottom, wetland crossings can result in higher sediment transfer to these ecosystems than trails adjacent to them. Trails intersecting wetlands can impede the limited flow that feeds them and interrupt some of the chemical reactions that sustain them. Figure 3.12 illustrates the ratio of trails traversing wetlands. The wetland-crossing ratio ranges from zero in 48 of the 6th level HUBs to 103.4 for HUB 100901010207. These results indicate there is very limited influence of trails intersecting wetlands within the Bighorn National Forest, and all of it in the northern portion of the Forest.

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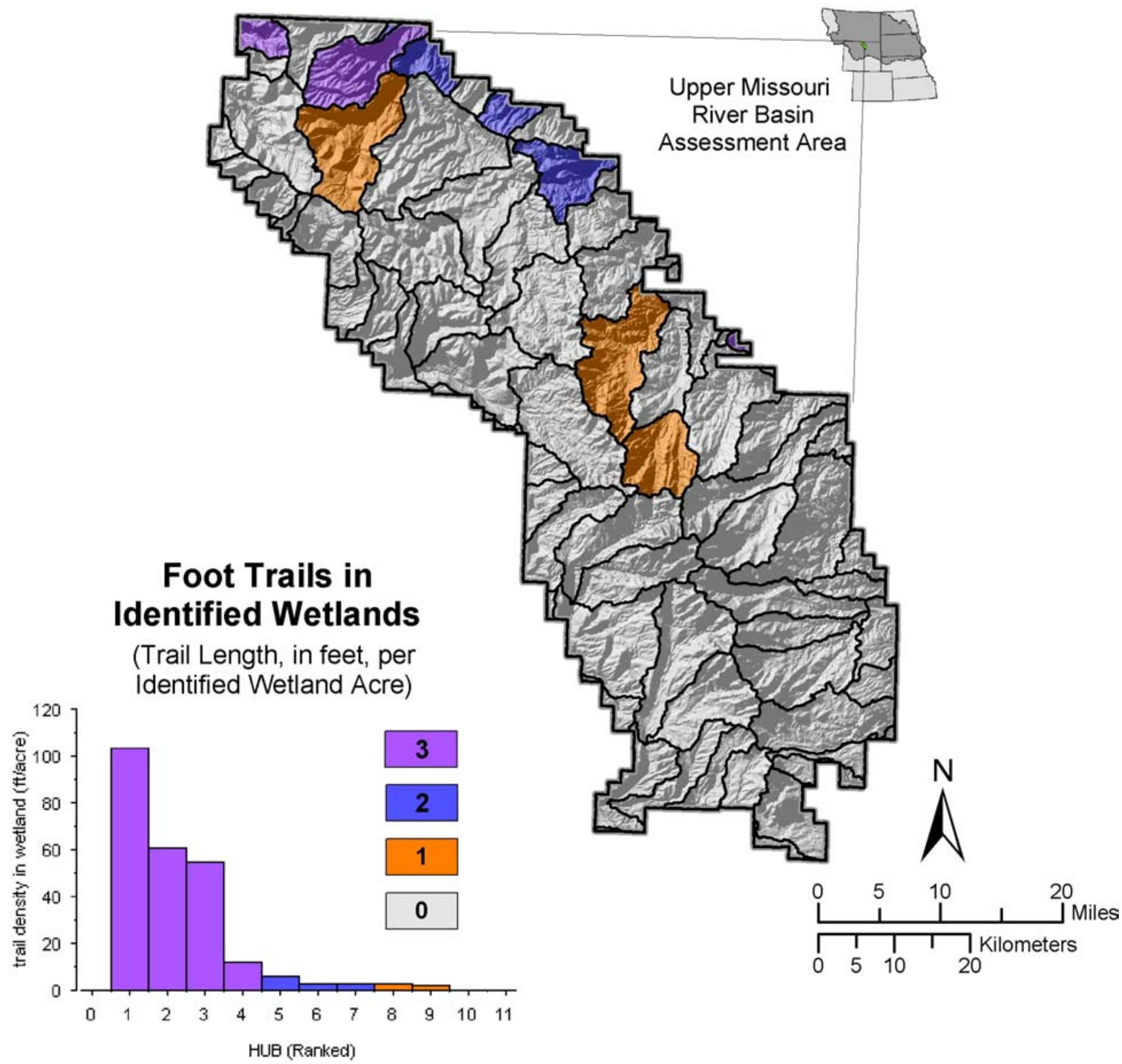

Figure 3.12. Density of foot trails within identified wetlands. HUB 100901010207 exhibited the highest density value.

Reach/Site Scale

At the reach/site scale, trails located within the valley bottom and adjacent to or intersecting wetlands should be given priority for reach/site scale assessments. Specific questions that should be considered include the following:

1. Are there rare species concerns associated with trail location?
2. Are there the presence or risk of presence of non-native, invasive species such as plants, fish, or disease associated with the trails?
3. What is the relationship between trail location and sediment production to the riparian and/or wetland environment?
4. What is the influence of recreational users on populations of vertebrate, invertebrate, and plant species?
5. What is the effect of trails and associated uses on water quality?
6. Is the recreational use associated with the trail, such as dispersed camping negatively influencing aquatic, riparian, and wetland resources?
7. Are trails intercepting water flow from upslope, which may influence aquatic, riparian, and wetland resources downslope (primarily wetland ecosystems)?

Information Needs

Trails and roads have similar influences on aquatic, riparian, and wetland resources, albeit trails to a lesser extent. Trail information was adequate to address the level of analysis needed at the scales we used. In order to address specific influences within the valley bottom, intersecting wetlands and crossing stream inventories of their specific influences must be made. The condition of stream crossings, influence on invasive species and erosion processes should all be considered. One area of investigation might be the relationship between reintroduction and presence of rare species (e.g., Yellowstone Cutthroat trout) and trail location. Recent disease (e.g., whirling disease) and invasive species (e.g., Canadian thistle) introductions from unsuspecting visitors on trails could be extremely deleterious to native species and reintroduction efforts.

Management Implications and Relationship to Ecological Drivers

Foot trails and the activities associated with them are an integral part of the National Forest system. Without them, most people would not have access to remote areas of the Bighorn National Forest. Although they have similar influences to aquatic, riparian, and wetland resources, they are far less impactive. However, foot trails located in wetlands and adjacent to streams with occasional crossings can have localized and in some cases wide spread impacts. While it has been historically desirable to build trails and roads within riparian areas and associated streams for a variety of recreational values (e.g., aesthetics), we are just starting to realize the influences that they have (Havlick 2002). Consideration for other resource values, such as native species and riparian and wetland function could be included in future trial construction and maintenance goals.

The same relationship between roads and ecological drivers and foot trails exists. Trails associated with HUBs in clusters with steep stream channels and non-calcareous geology would be expected to produce more sediment than lower gradient channels with calcareous geology. However, trails associated with clusters exhibiting a high probability of wetland and riparian abundance could have direct influences on vegetation and hydrologic conditions. In addition, those clusters predicting high riparian and wetland densities exhibit relatively higher diversity of plants and animals associated with them. Avoidance and direct contact with many of these species could result in a reduction in biodiversity and loss of intolerant species.

Photo 3.1. Road crossing on lands administered by the USDA Forest Service.

Influence of Railroads

Basin Scale

Railroads in the Upper Missouri River Basin progressed into the upper basin from the north and east during the late 1800s. They did not attempt to cross major mountain ranges such as the Big Horn Mountains because of the difficult terrain. Instead, they chose to follow the pre-existing wagon road routes and stayed at the base of the mountains.

The Bozeman Trail was established in 1862 as a way to travel between the Platte River to the south and the mining country north in Montana. This road remained the primary artery by which the commerce on the east side of the Big Horn Mountains moved until the first railroad reached Sheridan in 1892.

Like the first wagon roads into the area, railroad grades could not traverse steep slopes. The flanks of the Big Horn Mountains were prohibitively steep and the narrow canyons too rocky and treacherous for railroad construction. Therefore, the first railroad into the region came from the east and crossed the Powder River and terminated at the booming prairie town of Sheridan, WY.

Until 1892, when the railroad was built to Sheridan, the main mail and light express, and passenger service into the Powder River Basin was via the Rock Creek Stage Line (Murray 1980). The railroad made the overland trip from Rock Creek or from Douglas over the old Bozeman Trail obsolete. The Sheridan Inn was the point where people and goods were either delivered or received by the stagecoach service, mail trains, or overland wagon trains (Murray 1980).

In 1900, the first railroad was built into the Big Horn Basin, west of the Big Horn Mountains, by the C.C. & Q. railroad. The line went south from Billings to Frannie, WY. From there the railroad went to Cody. Prior to the railroad, goods were taken overland in large wagon trains from Billings. In 1906, the C.B. & Q railroad was built through Lovell and south through Basin, WY. (Conner 1940)

By the early 1900s the railroad was interested in pushing further up the Big Horn River valley to access the increasing acres of irrigated croplands to the south. The railroad was extended south from Basin, WY to Thermopolis and ultimately through the Wind River Canyon with access to Casper, WY (Murray 1980).

The town of Buffalo was the last town at the base of the Big Horn Mountains to be connected to the railroad system. During the initial period of railroad expansion during the late 1890s, the town of Buffalo remained unconnected. Finally in 1918, the first train of the Wyoming Railroad pulled into the eagerly waiting community of Buffalo. Prior to that time, Buffalo relied on wagon roads to access railroad terminals in Clearmont or Sheridan.

Following the completion of railroads into the Powder and Big Horn Basins, the local communities quickly began to grow and diversify. Ranchers and farmers now had a reliable way to ship their locally grown grain and cattle to the markets in the east. The towns of Sheridan, Buffalo, and Lovell could now receive homesteaders that had previously been reluctant to move into the area. Following the mining excitement in the late 1890s, the railroad would bring in hundreds of thousands of pounds of mining equipment and tools into the area.

Railroads remained the primary mode of transportation for another 40 years until surfaced roads connected the valley with the mountain environment.

Landscape Scale

The development of the railroad system generally followed the pre-existing wagon road network in the Upper Missouri River Basin. By the early 1900s the existing rail system was completed.

The rail system in the Upper Missouri River Basin generally parallels the Big Horn Mountains on the east and west and is approached from both the east and west. No rail lines were constructed through or across the Big Horn Mountains due to the prohibitively steep slopes along the flanks of the mountains.

Table 3.5 displays the current data on the amount of railroad influence at the landscape scale.

Table 3.5. Railroad miles within the 4th level HUBs in the Upper Missouri River Basin. There are no railroads in 4th level HUBs within the Bighorn National Forest boundary.

4th Level HUB Name	Total Miles of Rail Lines	Miles of Rail Lines within Valley Bottom	Total # of Stream Crossings per Mile of Stream
Big Horn Reservoir	20	8	0.04
Nowood River	0	0	0
Crazy Woman	0	0	0
Little Big Horn River	65	17	0.34
Upper Tongue River	34	20	0.33
Middle Fork Powder River	0	0	0
Clear Creek	53	7	0.07
Totals	**172**	**52**	

There are approximately 172 miles of rail line within the analysis area. The railroad pattern within the 4th level HUB boundaries can be seen on Figure 3.13.

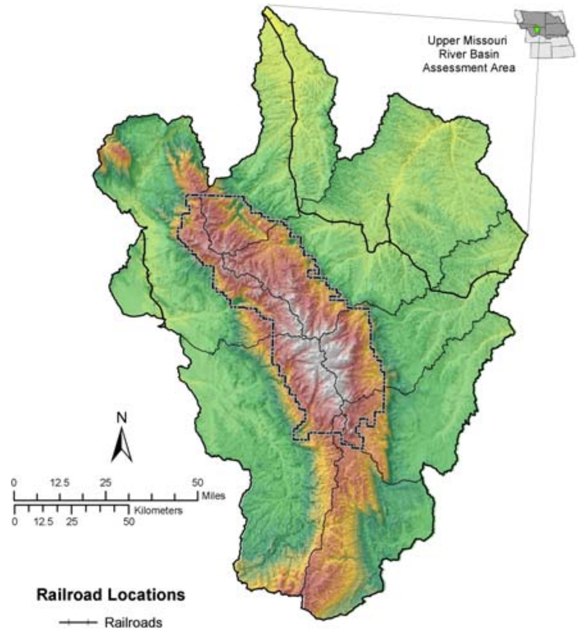

Figure 3.13. Map of railroad locations at the 4th level HUB, landscape level.

The map shows that the north-south railroad line comes up the Little Big Horn River and crosses over the top of the divide into the Tongue River watershed at Parkman. From Parkman, the railroad goes south to Sheridan and then goes east to Wyarno and into the Clear Creek watershed at Ulm. From Ulm, the railroad continues east until it moves out of the Clear Creek watershed near Leiter.

There are no rail lines within the boundary of the Bighorn National Forest. All railroads are located off the mountain and along the mid to lower portions of the 4th level HUBs.

Table 3.5 shows that the Little Big Horn River 4th level HUB has the highest total miles of railroad. However, the Upper Tongue 4th level HUB has more miles of rail line within the valley bottom and has nearly the same number of stream crossings per mile of stream as the Little Bighorn HUB. Based on this table, it is reasonable to conclude that the Upper Tongue and Little Big Horn 4th level HUBs have the highest risk to aquatic resources from rail lines.

Railroads in the analysis area are not directly affecting the aquatic environment in the Bighorn National Forest. There may be some level of channel confinement, erosion, and chemical contamination within the lower sections of 4th level HUBs. At this point, no new rail lines are likely to be built on the Forest and the existing rail lines are not likely to be expanded within the analysis area.

Management Scale

There are no rail lines within any of the 6th level HUBs that intersect the Bighorn National Forest boundary. There are no effects of rail lines in the 6th level HUBs within the Bighorn National Forest. It is unlikely that any future rail lines will be built within the Forest boundary.

Reach/Site Scale

There is currently no need to address reach/site effects of rail lines within the Bighorn National Forest. It is unlikely that rail lines will ever be built into the National Forest due to the difficult terrain and the absence of a need to cross the Forest.

Influence of Off-Road Vehicles

Basin Scale

Off-highway vehicle sales are growing rapidly in the west (e.g., ATVs, dirt motorcycles). Nationwide sales statistics confirm the trend. The ATV market grew at a 23% annual rate from 1998 through 1999, and for five years before that the annual growth rate was 12%, according to a report in the Wall Street Journal.

Determining off-road vehicle effects at the basin scale are difficult to quantify and must be addressed qualitatively. It is expected that the highest frequency of off-road vehicle use will generally be in the following environments:

1. High existing road densities.
2. Where vegetation (e.g., trees) and terrain do not preclude off-road travel.
3. Places where roads come near but do not directly access points of recreational interest (e.g., lakes, hunting camps, fishing streams).
4. Concentrations of publicly owned land.

Photo 3.2. Snowmobiles are popular in the winter on Forest Service lands.

Off-road travel at the basin scale will be widely dispersed or patchy over most of the landscape and highly concentrated near points of interest. Ownership will play a major role in the patchiness of OHV impacts. Private lands are to be expected to have the least OHV impact and public lands will have the most. Within the assessment area, there are large amounts of Bureau of Land Management (BLM) property in the Powder River Basin and in the Big Horn Basin. Table 3.6 displays the acres of public and privately owned lands within each 4th level HUB.

Table 3.6. Land ownership by 4th level HUB.

4th Level HUB Name	Miles^2 of BLM	Miles^2 of FS	Miles^2 of Private or Other
Big Horn Reservoir	747.76	371.05	684.01
Nowood River	969.50	329.09	714.30
Crazy Woman	86.54	99.34	768.89
Little Big Horn River	0	220.42	1077.38
Upper Tongue River	53.64	520.37	1959.15
Middle Fork Powder River	354.73	20.13	606.34
Clear Creek	25.20	299.35	829.05

The terrain is generally flat to rolling on non-Forest Service lands and vegetation is generally not limited near the Bighorn National Forest. Therefore, the watersheds with the highest concentration of BLM lands are expected to have the highest accessibility to OHV use. However, there are very few recreational destinations on BLM and much of the OHV opportunities may go unused.

Many of the recreational destinations, such as lakes and fishing streams, occur on Forest Service lands. However, the terrain and vegetation limit opportunities. Therefore, much of the OHV use occurs on trails, or high in watersheds were the slopes are gentler. The watersheds with the most Forest Service ownership higher in the area are where the highest risk of OHV use and impact exist. Therefore, the 4th level HUBs with the highest likelihood of OHV use are:

1. Upper Tongue River
2. Clear Creek
3. Little Big Horn River

Landscape Scale

While the Bighorn National Forest records activities such as off-highway vehicle use, it is not possible to make a comparison outside of its boundaries, especially on private land. As a result, comparisons for the landscape scale will be made based on analysis within the National Forest boundary.

Recreation use on the Bighorn National Forest is steadily increasing (Bighorn National Forest, internal inventory reports). Not only are the amounts of visits increasing, the complexity of uses and user expectations are increasing. Increased and changing dispersed recreation use has heightened the issue of recreation and travel management that needs to be addressed as we enter into the next decade of management for the Bighorn National Forest.

Dispersed recreation use, especially snowmobiles and ATV motorized use, has grown substantially since 1985. There were few if any ATVs on the Forest at that time and now there may be several hundred on any weekend day on the Forest. The use of ATVs is very popular for summer riding and camping and also during the fall hunting season. Because of this growth, there are more conflicts for those seeking a more primitive experience on the Forest.

The Bighorn National Forest currently has numerous OHVs trails (fig. 3.14) that are well dispersed throughout the Forest. Also the Forest currently has a sizable number of acres open to cross-country motorized travel (fig. 3.15).

The miles of user-created trails in these areas have increased as a result, and are very difficult to quantify or maintain (B. Bohn, Bighorn National Forest, oral commun.). The notice of intent published in the Federal Register November 10, 1999 identified the need to eliminate cross-country travel except on designated routes. However, this notice has not yet been implemented.

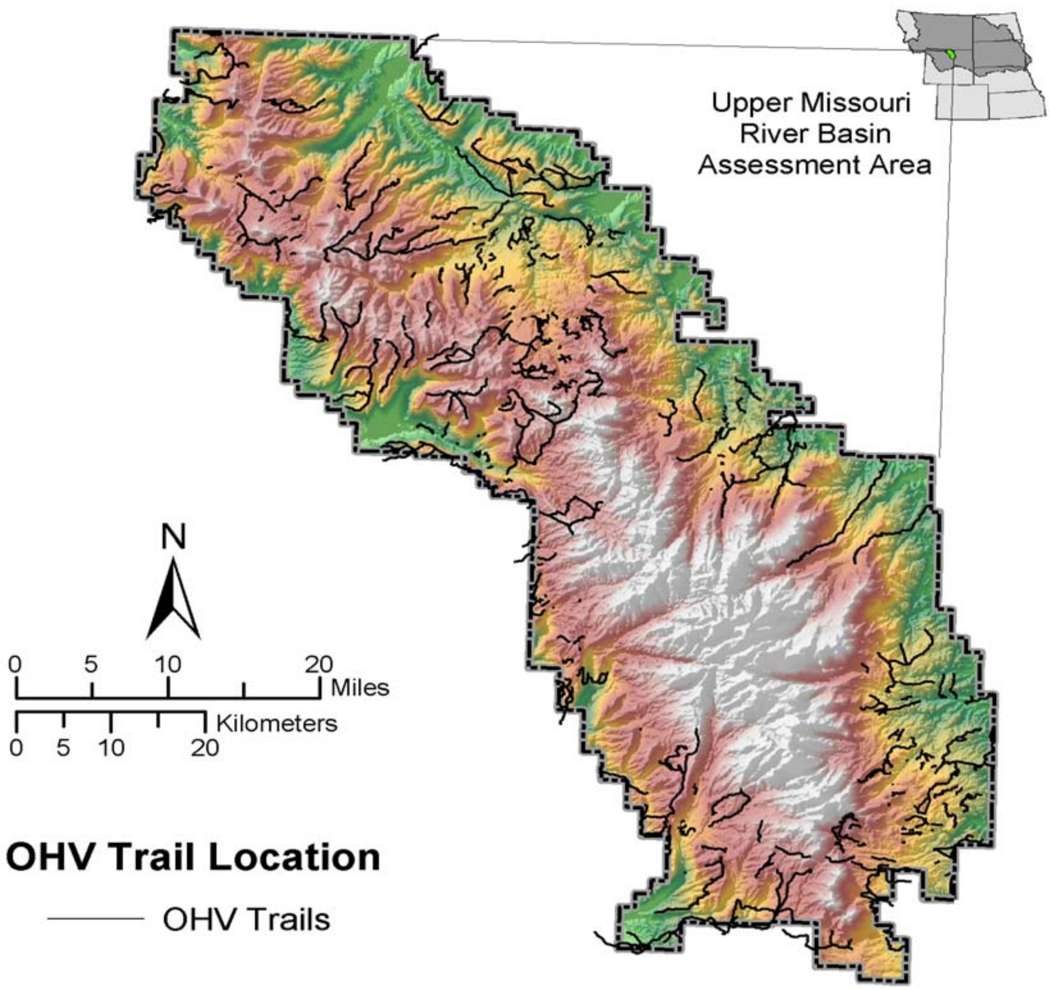

Figure 3.14. Location of OHV trails within the Bighorn National Forest.

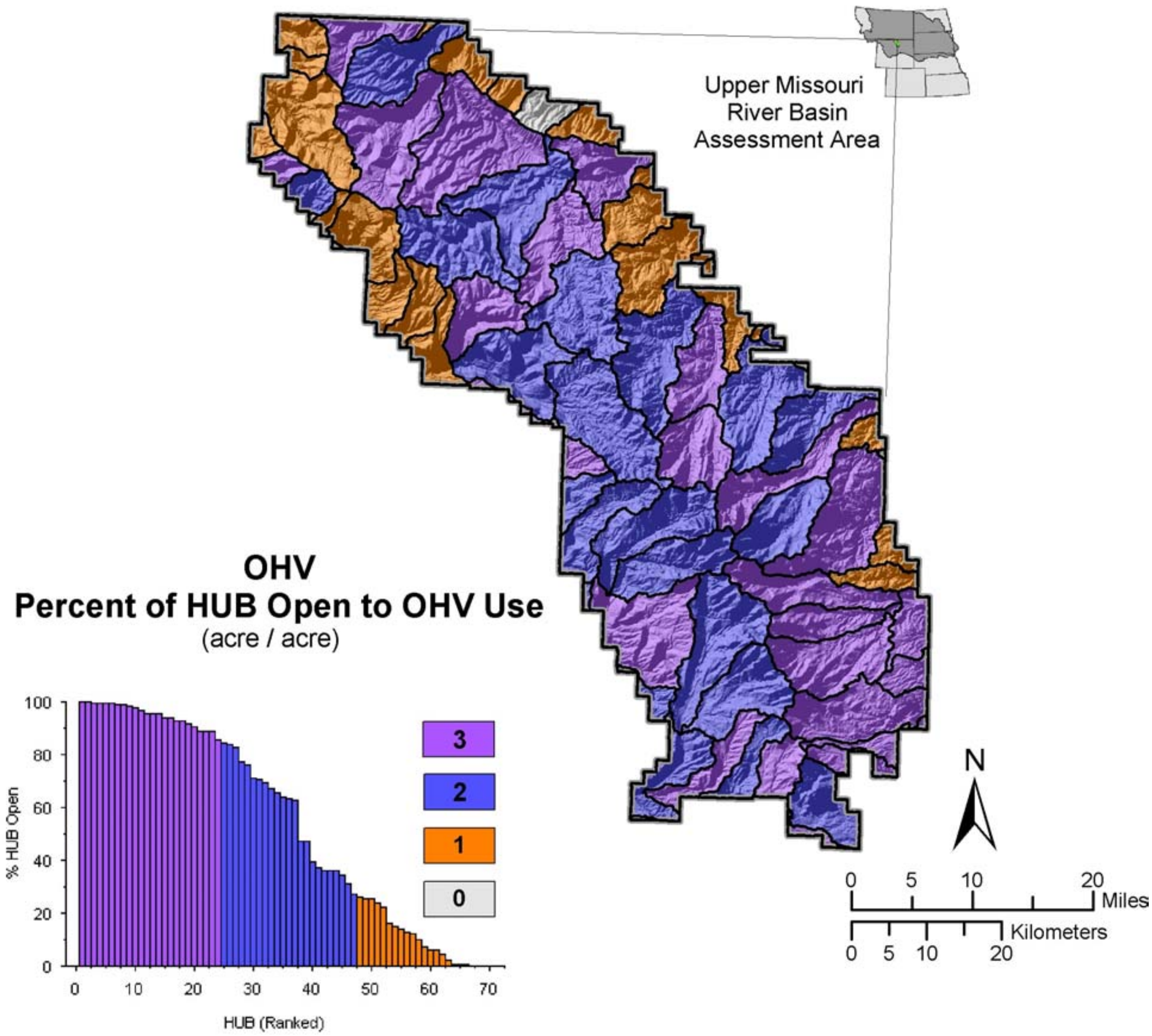

Figure 3.15. Rank and distribution of the percent area of HUB that is open to OHV within the Bighorn National Forest.

Management Scale

Four maps to illustrate the relationship between OHV use and aquatic, riparian, and wetland resources at the management scale include the following: percentage of area open to "cross-country" use (fig. 3.15); OHV stream crossings (fig. 3.17); ratio of OHV trails in the valley bottom (fig. 3.18); and wetland crossings (fig. 3.19). There is a considerable amount of the Bighorn National Forest that is open to cross-country OHV use (fig. 3.15). More than one third of the HUBs intersecting the National Forest boundary are over 80% open to cross-country OHV use, while more than one half of the National Forest is more than 50% open. There are four HUBs intersecting the Bighorn National Forest boundary that exhibit no cross-country use within the Forest boundary. However, these HUBs occupy a very small portion of the entire HUB they are located in (fig. 3.15). There are nineteen 6th level HUBs that have over 90% of their area open to cross-country

OHV use. While these results do not illustrate the influence they have on aquatic, riparian, and wetland resources, they are similar to other motorized vehicles. Currently there is no data to illustrate the influences these activities have on the surrounding landscape. However, visitor use information conducted in 1991 by the Bighorn National Forest indicates that mechanical travel and viewing comprised over 30% of the recreational activities on the Forest (table 3.7). While this category includes other activities, such as sightseeing by car, it is also a disproportionate amount of the recreation on the Bighorn National Forest. Specific trends in OHV use would be helpful to quantify more fully the influences on the surrounding landscape.

The total miles of OHV trails per stream mile for each 6th level HUB ranged from zero for nine of the 6th level HUBs to 6.5 for HUB 100800100105 (fig. 3.16). There were thirteen 6th level HUBs that had trail ratios higher than one, with the remainder less than one. The results of this analysis indicate that while a large percentage of the Bighorn National Forest is open to cross-country OHV use, trails are generally not excessive. Formalized trails are generally distributed throughout the Forest (fig. 3.14). There are four 6th level HUBs in particular that exhibit higher ratios of miles of trail per stream mile than the other; 100800100105, 100800080502, 100800100401, 100800080405.

The results of the OHV stream crossing analysis are presented in Figure 3.17. Due to a lack of information outside of its boundaries, analysis could only be used for areas within the Bighorn National Forest. Because the values are recorded on a "per area basis", the ranked values can be compared, regardless of the size of the HUB. A total of twenty-seven 6th level HUBs exhibited no OHV stream crossings, while the highest number was 1.3 crossings per mile for HUB number 100800100603. This analysis revealed few trends, with HUBs in various ranks distributed throughout the Bighorn National Forest. The lowest ranked HUBs appear to be in the southern and far northern portions of the Forest, and the highest ranked HUBs in the middle. However, there are HUBs in both categories that do not follow this trend.

OHV use within the valley bottom may result in considerably more influences to stream and riparian resources. While trails in the upland areas can also produce sediment that may influence these resources, the presence of OHV and other trails can result in additional influences on vegetation, compaction and sedimentation through over bank flooding. The results of the analysis of OHV trail presence in valley bottoms are presented in Figure 3.18. Similar trends were found for this analysis as were found for the OHV stream crossing analysis (fig. 3.17). This similarity is not surprising considering the close proximity of trails located within the valley bottoms and stream systems. There were a total of ten 6th level HUBs without OHV trails within the valley bottom, and the highest ranked HUB (100800100105) exhibited a ratio of approximately 0.9 miles of OHV trail in the valley bottom. While there appears to be a trend between stream crossings and OHV use in the valley bottom, it is surprising to see that the HUB with the highest number of miles in the valley bottom per stream miles had no stream crossings. These results cannot be explained by this analysis, although there may have been an avoidance of stream crossings in this particular HUB because of the difficulty of crossing, concern of resource damage, or location of the destination(s).

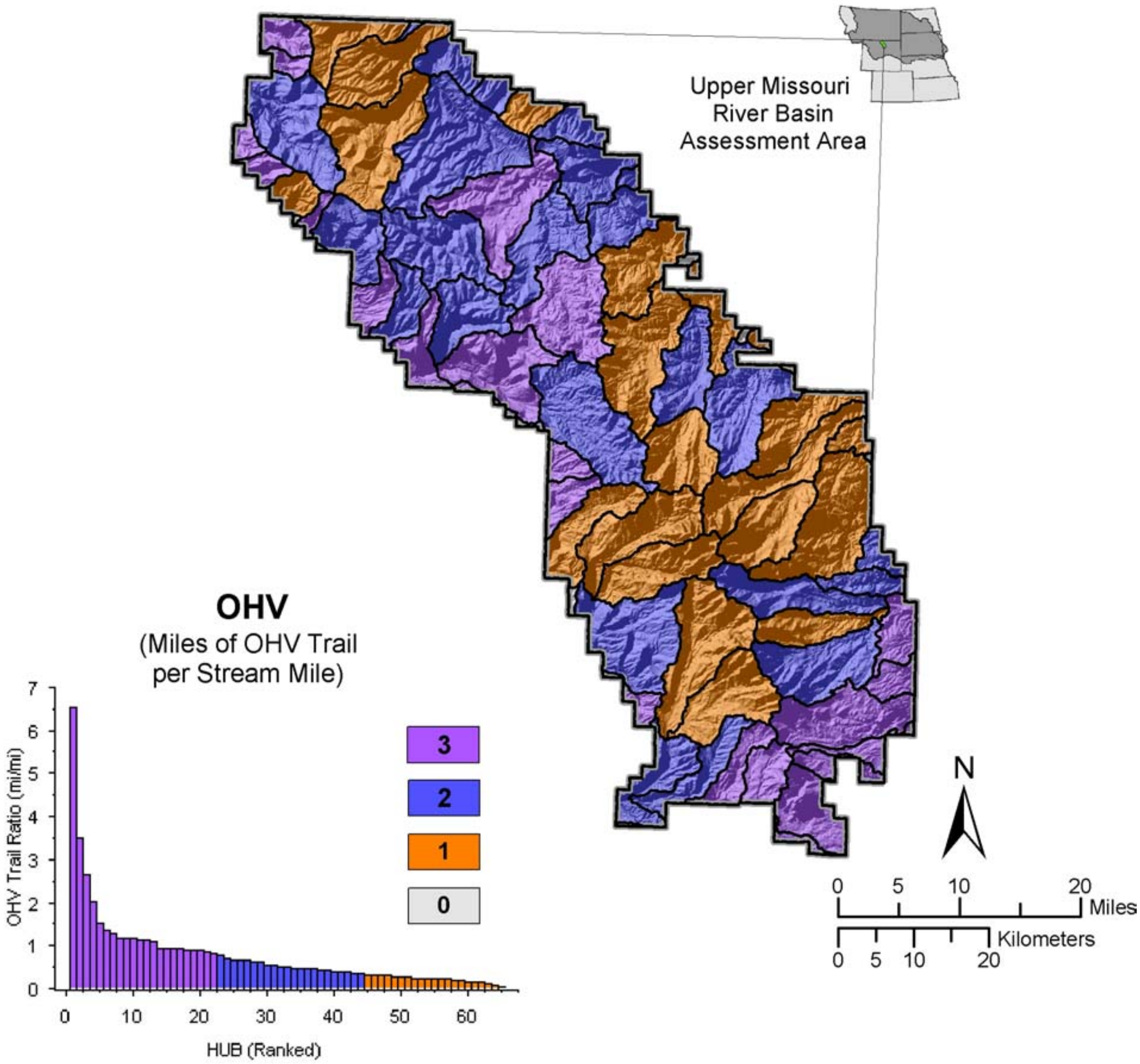

Figure 3.16. Rank and distribution of OHV trails to stream mile within the Bighorn National Forest boundary. OHV trail ratios were greater than 2 for the following 6th level HUBs: 100800100105, 100800080502, 100800100401, 100800080405.

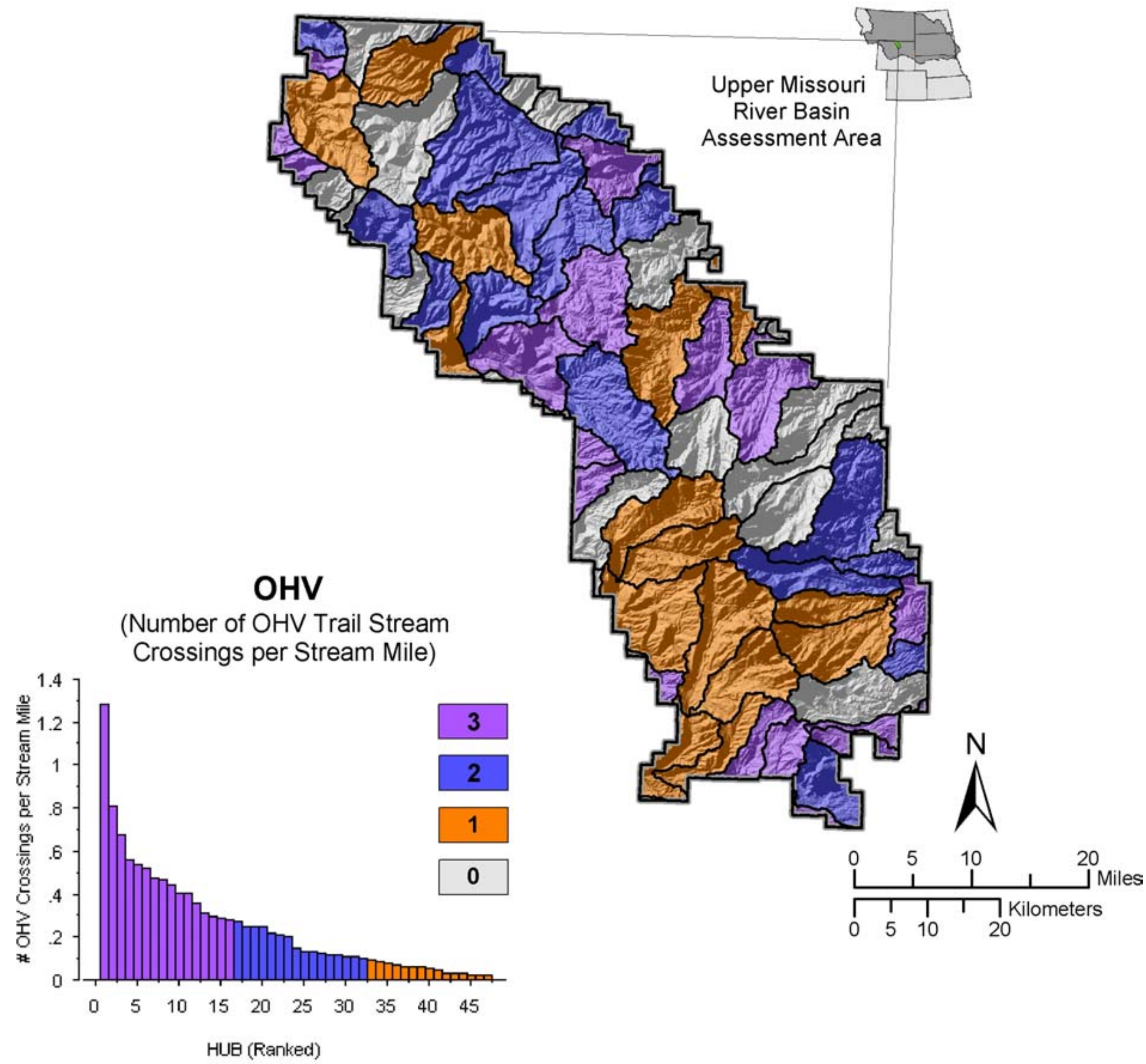

Figure 3.17. Rank and distribution of OHV trails that cross-streams to stream mile within the Bighorn National Forest. Sixth level HUBs 100800100603, 100800080502, and 100902010301 exhibit the highest ranks respectively.

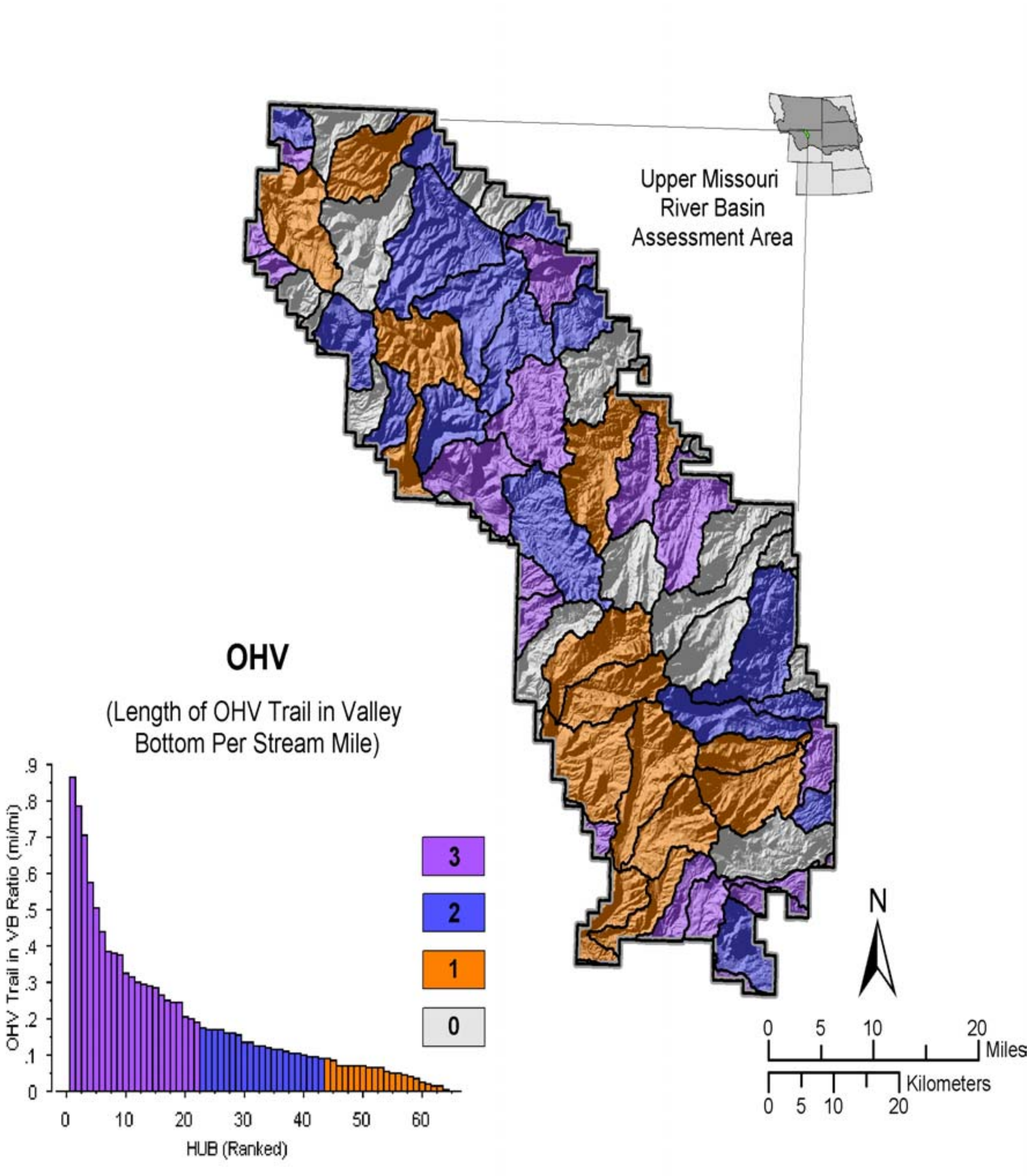

Figure 3.18. Rank and distribution of OHV trails in valley bottoms per stream mile within the Bighorn National Forest. A total of five 6th level HUBs exhibited ratios greater than 0.5: 100800100105, 100800100401, 100800080502, 100902010301, and 100800080405 respectively.

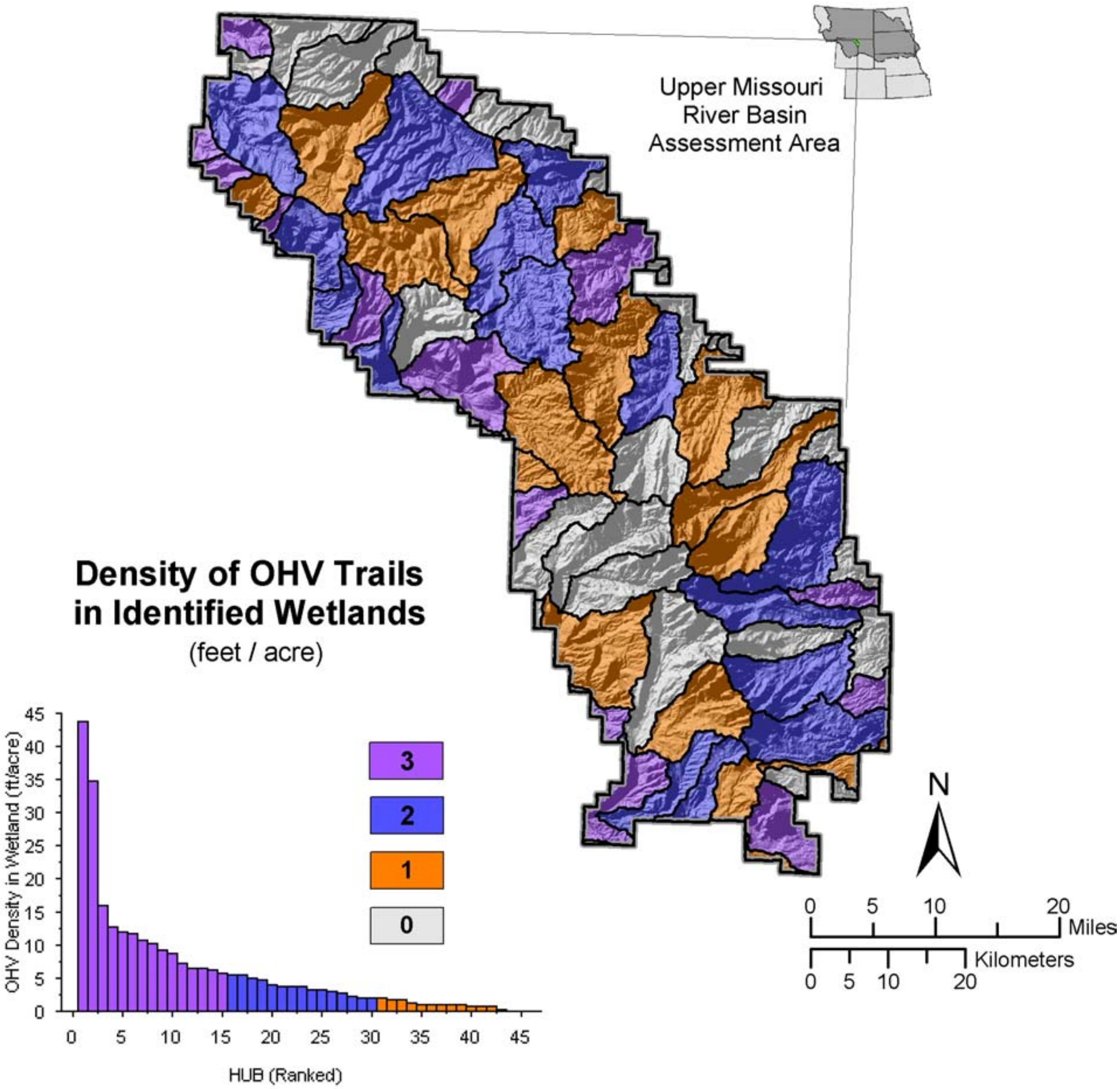

Figure 3.19. Density of OHV trails within identified wetlands. The two highest-ranking HUBs are 100800100402 and 100800080502.

Table 3.7. Recreation use on the Bighorn National Forest in 2001.

Activity	Thousands of Recreation Visitor Days	Percent of Total Use
Camping, picnicking and swimming	318.2	19
Mechanized travel & viewing scenery	**490.6**	**30**
Hiking & horseback, Climbing	213.8	13
Resorts, cabins, organization camps	262.7	16
Winter sports (downhill skiing)	8.6	1
Winter sports (cross country skiing)	30.7	2
Winter – snowmobiling	51.5	3
Winter – other	17.6	1
Hunting	53.4	3
Fishing	81.5	5
Nature study	16.6	1
Other activities	106.3	6
Wilderness use (included in above)	70.0	0
Total	1,651.5	**100**

There were a total of thirty 6th level HUBs within the Bighorn National Forest that did not have OHV trails intersecting wetlands (fig. 3.19). There were a total of 30 HUBs without trails intersecting wetland ecosystems. Given the high number of HUBs with OHV trails present (figs. 3.14, and 3.16), to some extent there is an obvious avoidance of wetlands in some areas. These figures do not take into consideration other trails that are not on the trail system in open, cross-country portions of the Forest. The highest values were for HUBs 100800100402 (43.7 feet per acre) and 100800080502 (34.8 feet per acre). Considering that these values are for the entire HUB, they either occupy a relatively small area or there are considerable trails within wetland ecosystems. There are also six 6th level HUBs without OHV trails intersecting wetlands, mostly in the southern and western portions of the Forest.

Reach/Site Scale

The reach/site scale is the appropriate scale to quantify the direct influences of OHV use on aquatic, riparian, and wetland ecosystems. Priority should be given for areas adjacent to and crossing these resources. Inventories could focus on the magnitude and distribution of damage to soils, vegetation, channels, water quality, and biota due to OHV use. Specific questions related to this activity at the reach/site scale include:

1. Is OHV use restricted to a single route, or are multiple routes being used?
2. Are all the routes quantified as well as their influence on aquatic, riparian, and wetland resources as it relates to the analysis presented above?
3. Is excessive aquatic, riparian, and wetland vegetation being disturbed, and soils being compacted?
4. Is there noticeable soil movement into aquatic, riparian, and wetland resources?
5. Are their noticeable invasive species (e.g., plants) colonizing the areas associated with OHV use?
6. Are their influences of OHV use and rare native flora and fauna, as well as desirable nonnative species?
7. Are their water quality concerns related to OHV use other than sediment (e.g., fuel leakage, material transported into an area)?
8. Has OHV use and influences on aquatic, riparian, and wetland resources been monitored to identify trends over time?

Information Needs

Monitoring reports by the Bighorn National Forest have shown the need to address issues and concerns related to recreation and travel management. The 1999 monitoring report from the Forest included the following results:

1. Increased use of ATVs creates challenges for managing the recreation program for ATV enforcement, maintenance, user conflicts and road and trail damage.
2. Twenty percent of inventoried campsites were exhibiting conditions that would not meet Forest Plan standards.
3. The Forest Plan gives no assistance in setting priorities to fulfill recreational needs.
4. Continue the moratorium on new outfitter/guide permits and need to complete a needs analysis.

Dispersed recreation use and associated travel management are constrained by impacts on resources and the intolerance of one user group for another. Environmental education may help increase the potential to resolve the issues and concerns.

Management Implications and Relationship to Ecological Drivers

Off-highway vehicle use is becoming more popular throughout the United States. They are relatively inexpensive, easy to operate, all ages can operate them, and they are quite maneuverable in a forest setting. Because of these factors their use in the Bighorn National Forest is also increasing. While there are some trails identified for OHV use on the Forest, a large percentage of the area is open to cross country travel. The results of our analysis indicates that most of the Forest outside of areas designated as wilderness are being utilized through trail systems and cross country. However, it is difficult to quantify the full use of OHVs because of the relatively unrestricted use.

The results of the ecological driver analysis reveal that there are clusters of 6th level HUBs that would be sensitive to any type of transportation activity. Clusters indicating a relatively high percentage of wetlands and/or riparian areas could be considered high-risk areas for direct influences to aquatic, riparian, and wetland resources from OHV use if they were not located outside of these ecosystems. Trails and off-trail use could produce large amounts of sediment if they were located in clusters that exhibited the characteristics conducive to soil movement (e.g., moderate to steep stream gradients, non-calcareous geology, and rain-and-snow climate conditions). HUBs upstream from lower risk HUBs could be the receiving or depositional areas for sediment produced upstream. The following additive influence portion of this section is important for this use category, since the influences are very similar.

Transportation Cluster Analysis

A cluster analysis of the five criteria of the transportation category was performed to identify the additive effects of transportation activities on aquatic, riparian, and wetland resources. Ten criteria were used in the cluster analysis, and are summarized in Table 3.8. This analysis was performed at the management scale, with data existing for all portions of the 74 HUBs within the Bighorn National Forest boundary. The transportation activity clusters have been assigned the suffix 't' to distinguish them from the ecological driver analyses clusters in Chapter 2 of Report 1 of this assessment. HUBs where no transportation activities were present were removed from the dataset prior to the cluster analysis, and assigned as Cluster 0t. The cluster analysis was performed in PC-ORD2, with four clusters identified at 25% of the information remaining (fig. 3.20). Each cluster has been labeled on the dendrogram. Table 3.9 summarizes the mean criteria values for each cluster. When mapped (fig. 3.21) Clusters 3t and 4t comprise a majority of the Bighorn National Forest. Clusters 1t and 2t are found where only a small percentage of the total HUB area is located within the National Forest. An analysis of variance (ANOVA) statistical test was utilized to examine the clusters for significant differences in criteria values (table 3.10).

Table 3.8. Summary of criteria used in transportation cluster analysis.

Criteria	Explanation
Road Ratio	Length of Road per Stream Length (mile/stream mile)
Road Crossing Ratio	Number of Road - Stream Crossings per Stream Length (#/stream mile)
Unpaved in Valley Bottom Ratio	Length of Unpaved Road in Valley Bottom per Stream Length (mile/stream mile)
Road Density in Wetlands	Density of Roads within Identified Wetlands (feet/acre)
Trail Crossing Ratio	Number of Trail - Stream Crossings per Stream Length (#/stream mile)
Trail in Valley Bottom Ratio	Length of Trails in Valley Bottom per Stream Length (mile/stream mile)
Percent HUB Open to OHV Use	Percent of HUB Open to OHV Use (acre/acre)
OHV Trail in Valley Bottom Ratio	Length of OHV Trails in Valley Bottom per Stream Length (mile/stream mile)
OHV Crossing Ratio	Number of OHV Trail - Stream Crossings per Stream Length (#/stream mile)
OHV Trail Density in Wetland	Density of OHV Trails within Identified Wetlands (feet/acre)

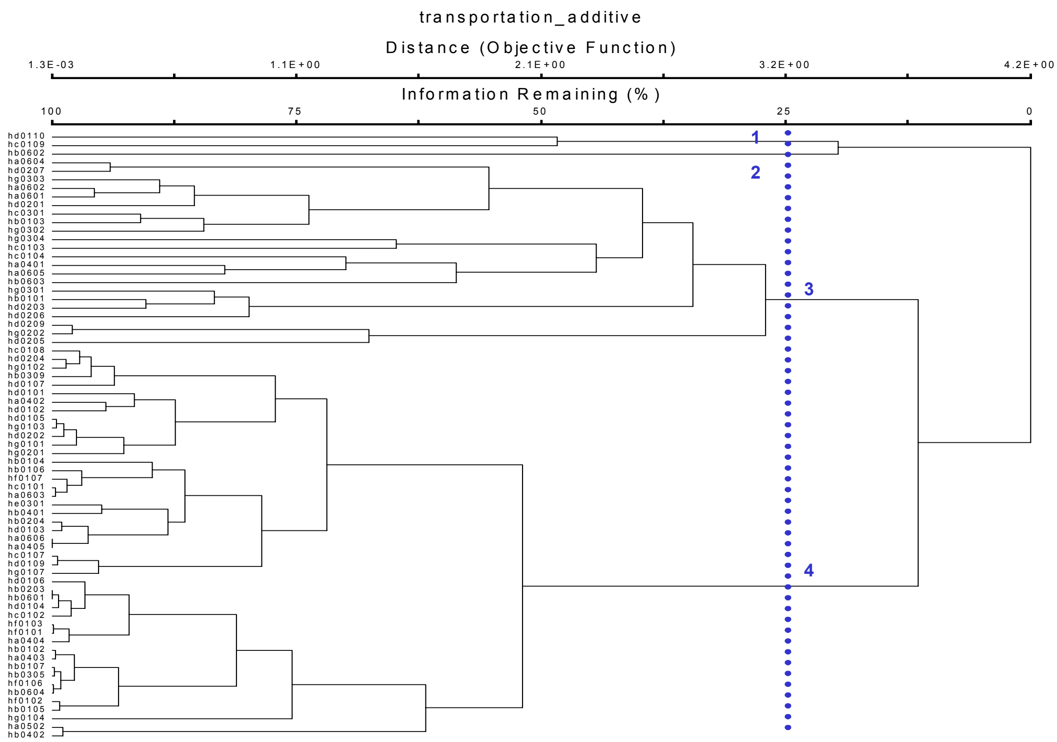

Figure 3.20. Dendrogram produced by cluster analysis of transportation criteria.

Table 3.9. Cluster analysis: mean values for each criterion.

Criteria	Population	Cluster 0t	Cluster 1t	Cluster 2t	Cluster 3t	Cluster 4t
n	n = 74	n = 3	n = 2	n = 1	n = 22	n = 46
Road Ratio	1.317	0	0	0	0.527	1.867
Road Crossing Ratio	0.328	0	0	0	0.073	0.492
Unpaved in Valley Bottom Ratio	0.289	0	0	0	0.113	0.41
Road Density in Wetlands	8.629	0	0	0	0.48	13.652
Trail Crossing Ratio	0.324	0	0	0	0.499	0.282
Trail in Valley Bottom Ratio	0.187	0	0	0	0.301	0.157
Percent HUB Open to OHV Use	0.517	0	0.015	0.125	0.486	0.595
OHV Trail in Valley Bottom Ratio	0.165	0	0	0	0.073	0.231
OHV Crossing Ratio	0.157	0	0	0	0.103	0.203
OHV Trail Density in Wetland	3.663	0	0	0	0.249	5.774

Highest Mean Value
Middle Mean Value
Lowest Mean Value
Mean Value = 0

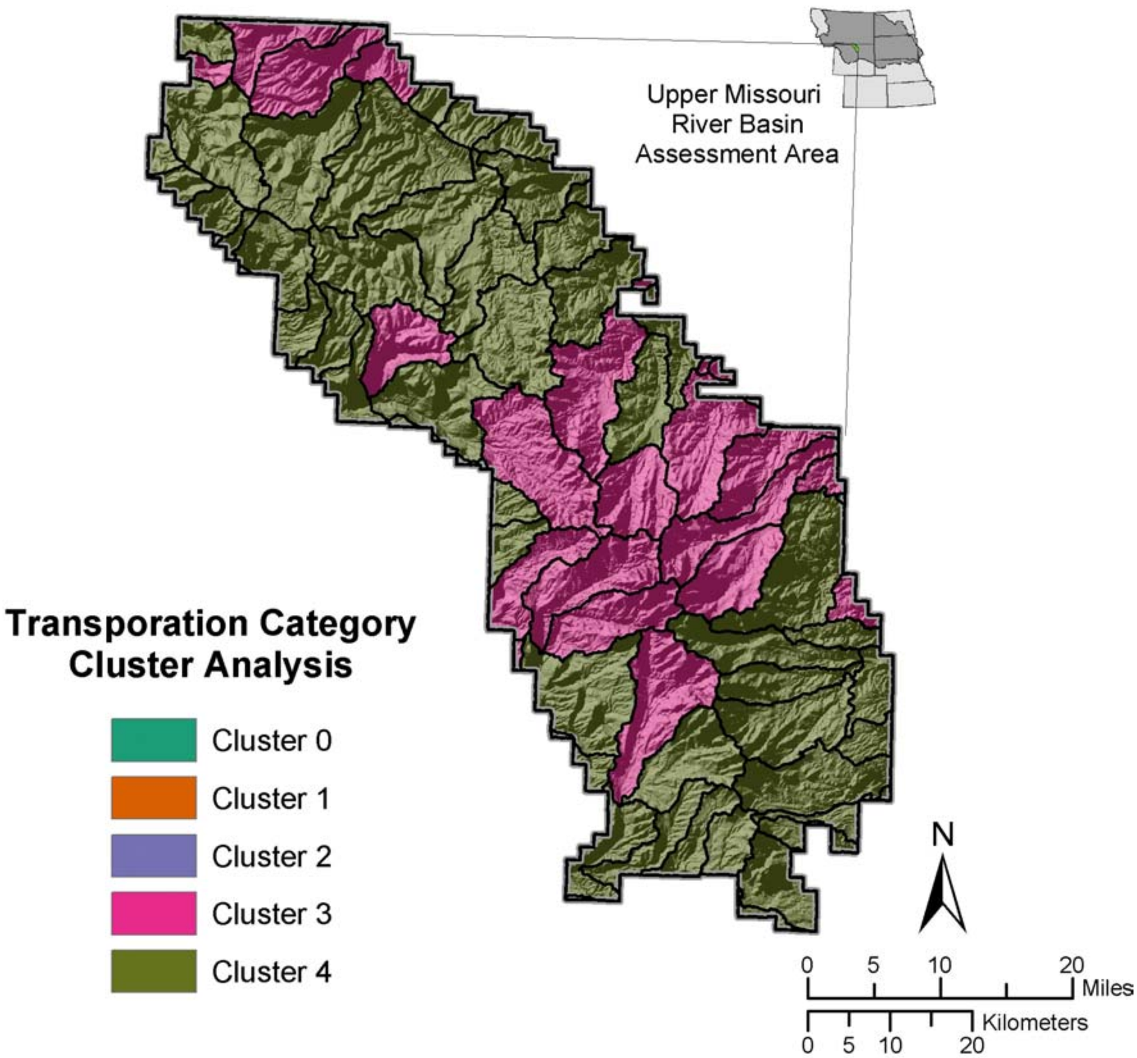

Figure 3.21. Cluster analysis results for transportation category.

Table 3.10. ANOVA results summary; test for significant differences between clusters for each transportation criterion.

Criteria	F Value	P Value
Road Ratio	10.260	<.0001
Road Crossing Ratio	11.050	<.0001
Unpaved in Valley Bottom Ratio	7.350	<.0001
Road Density in Wetlands	11.840	<.0001
Trail Crossing Ratio	0.830	0.500
Trail in Valley Bottom Ratio	2.080	0.090
Percent HUB Open to OHV Use	3.410	0.010
OHV Trail in Valley Bottom Ratio	5.090	0.001
OHV Crossing Ratio	1.530	0.200
OHV Trail Density in Wetland	3.000	0.020

Alpha = .05

Significant Difference (purple)
Not Significant Difference (orange)

Cumulative Percentile Ranking

When mapped (fig. 3.22), the distribution of those HUBs most affected by the transportation criteria reflects a fairly obvious spatial pattern. Clusters 0t, 1t, and 2t include HUBs with only a small portion of their surface area lying within the Forest boundary. These HUBs are not impacted by transportation activity, as their access is limited by the lack of an existing transportation network. The HUBs that have a majority of their surface area within the Cloud Peak Wilderness Area are relatively not impacted by motorized transportation activities, and comprise a majority of the HUBs within Cluster 3t. The HUBs identified as belonging to Cluster 3t that are not incorporated in a roadless/wilderness area have limited access for motorized vehicle traffic. The main transportation activity occurring in Cluster 3t is that of foot traffic. However the difference in the values of the foot trail activity within Cluster 3t was not statistically significant when compared to the other clusters. The motorized traffic occurring in Cluster 4t is significantly higher than the other three clusters. Majorities of the surface area of these HUBs are not located within a roadless/wilderness area. Also, these HUBs are generally in close proximity, and easily accessed by major transportation corridors. Generally, Clusters 0t, 1t, and 2t are the least impacted HUBs, while Cluster 3t is moderately impacted, and Cluster 4t is the most impacted by transportation activities.

The sum of the percentile ranks of the ten criteria of the transportation category was calculated to identify the additive effects of transportation activity on aquatic, riparian, and wetland resources. The ten criteria used in this analysis are summarized in Table 3.8. This analysis was performed at the management scale, with data existing for all portions of the 74 HUBs within the Bighorn National Forest boundary. Quartile values were then identified for the cumulative rankings. The quartiles were used as a means of grouping the cumulative ranks (fig. 3.22). Group 1 identifies those HUBs within the lowest quartile of cumulative rankings. Group 2 identifies those HUBs within the 25th – 50th percentiles of cumulative rankings. Group 3 identifies those HUBs within the 50th – 75th percentiles of cumulative rankings. Group 4 identifies those HUBs within the highest quartile of cumulative rankings. HUB 100902050103 has the highest cumulative ranking value of 27 out of a possible 30 total percentile groupings.

This analysis is relative only to the portion of the 6th level HUBs surface area within the Bighorn National Forest boundary, and is intended to provide the reader with the additive rankings at this scale. Unlike the previous methodology, the results are evenly distributed across the total number of HUBs at this scale.

Those HUBs receiving a cumulative ranking of 4 are located in the northern and southern ends of the Bighorn National Forest (fig. 3.22). Of the thirteen 6th level HUBs in this rank category, there are only four that are totally within the Bighorn National Forest boundary. There was one HUB's value that was 27 out of a possible 30 in this analysis (100902050103), meaning that it was ranked consistently in the highest rank category for most of the activity analyses relative to the other activities. A total of seven other HUBs exhibited additive rankings of 23, also indicating relatively high additive rankings for this use category.

Rank number 3, 6th level HUBs could be considered "intermediate" as their values all lay between 21 and 17 (fig. 3.22). While these HUBs may have individual analysis results in the highest rank, generally they are lower. There are a total of 26 HUBs in this rank category, with only five located entirely within the Bighorn National Forest boundary. Most of the HUBs in this category are located in the central portion of the Bighorn National Forest.

Rank number 2, 6th level HUBs have relatively low additive rank values, with values ranging from 12 to 15. There are a total of fourteen HUBs in this category, with five located entirely within the Forest boundary. These HUBs appear to be relatively dispersed throughout the National Forest.

HUBs receiving the lowest ranking (value = 1) are considered to be the least affected by transportation activity. There are a total of 21 HUBs in this category, with only one HUB completely contained by the National Forest.

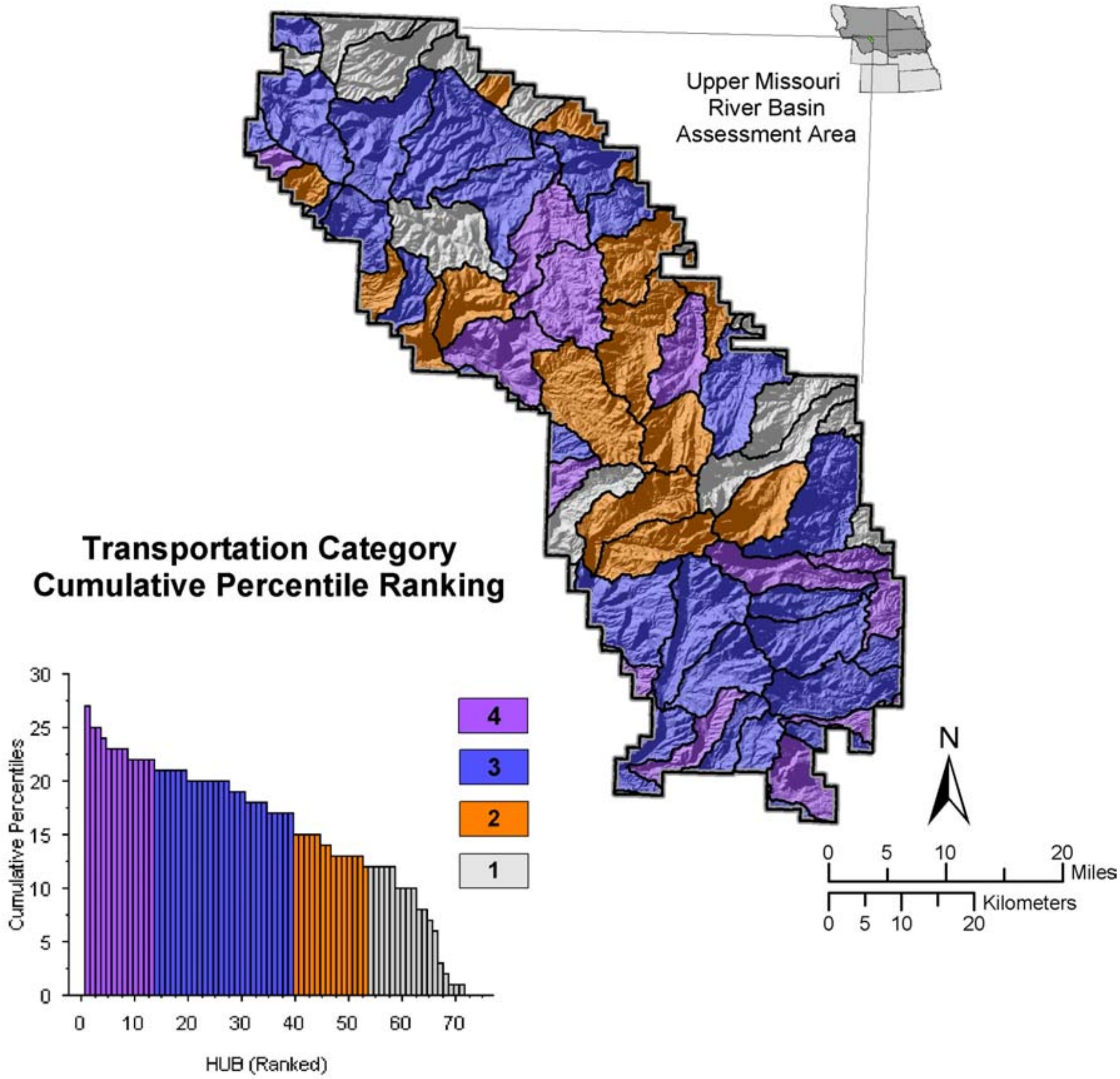

Figure 3.22. Cumulative percentile rankings for the transportation category.

Chapter 4
Recreation Category

Key Findings

1. At the landscape scale, lands available to the public for recreation is approximately 45% of the land base, with National Forest Service lands accounting for only 17%.
2. Seventy-five percent of dispersed sites within the Bighorn National Forest were within 100 meters of a road and over 90% were within 150 meters of a valley bottom. There is a direct correlation between dispersed recreation sites and their proximity to lakes.
3. Developed recreation sites are uncommon in the Bighorn National Forest (BNF), with the highest ratio of sites in a valley bottom per 6th level HUB being 0.0007 (sites in the valley bottom/ stream mile/ 6th level HUB).
4. The Lower South Tongue River, Upper Tongue River, Fool Creek, and Upper North Fork Crazy Woman Creek 6th level HUBs have the highest potential of dispersed recreation sites per valley bottom.
5. Only three 6th level HUBs within the management scale have percentages of more than 25% for the percentage of stream mile downstream of ski areas/ total stream mile/ 6th level HUB.
6. The additive effects analysis revealed that 42 of the 6th level HUBs were relatively uninfluenced by recreational activities.
7. Fifteen 6th level HUBs had the highest values for all measured recreational activities except for being downstream of ski areas. Four 6th level HUBs had the highest values for being downstream of ski areas and to a lesser degree other recreational influences.
8. The cumulative ranking of influences from recreational activities revealed a broad distribution throughout the BNF.

Influence of Developed and Dispersed Recreation

Basin Scale

Statewide, visitations to National Areas (e.g., monuments, historic sites, recreation areas, and parks) located in Wyoming have totaled at least 6.1 million, and visitations to State of Wyoming parks and recreation areas totaled at least 2.1 million from 1996-2000 (Wyoming Almanac 2002). Wyoming's tourism industry accounted for nearly $1.7 billion in direct expenditures in 2000 (State of Wyoming, 2003-04 Biennium Budget Request, http://ai.state.wy.us/budget/pdf/00085.pdf), and expenditures related to fishing constituted one of the most economically important activities (e.g., nearly $700 million in 2000; Wyoming Almanac 2002). Ultimately, recreational demands in the State are increasing, and the Upper Missouri Basin itself could result in corresponding increases in influence on aquatic, riparian, and wetland resources.

In the context of this scale, the Big Horn Mountains are a "travel-through recreation area" between Mount Rushmore and Yellowstone National Park (fig. 4.1). In 2002 there were 2,943,586 visitors to Yellowstone (NPS 2003c) and 2,159,189 visitors to Mount Rushmore (NPS 2003b). Similarly, visitation rates to the Big Horn Mountains also depend on public interest and use of other close-by attractions. For example, in 2002, many of the almost 419,000 visitors (NPS 2003a) to the Little Big Horn Battlefield National Monument also took advantage of opportunities in the Big Horn Mountains.

Developed and Dispersed Recreation: In the Upper Missouri River Basin, developed recreational opportunities include camping and picnicking in established sites, downhill skiing, and related resort activities, water recreation (e.g., marinas and boat launches), and sightseeing or visiting locations of natural or cultural importance. Dispersed recreational opportunities in the region include: cross country skiing, snowshoeing, rock climbing, rafting, kayaking, snowmobiling, off-highway vehicle (OHV) use, hiking, backcountry camping, fishing, hunting, mountain biking, horseback riding, and wildlife viewing. These attractions draw local, national, and overseas visitors.

The Bighorn National Forest provides important public access to high country and mountain recreation for residents of north-central Wyoming in addition to travel-through visitors traveling between Mount Rushmore and Yellowstone.

The Forest recorded 1,712,800 forest-recreation visitor days in 1998 (USFS 1998) Slightly decreased levels were recorded for the year 2000 (USFS 2000).

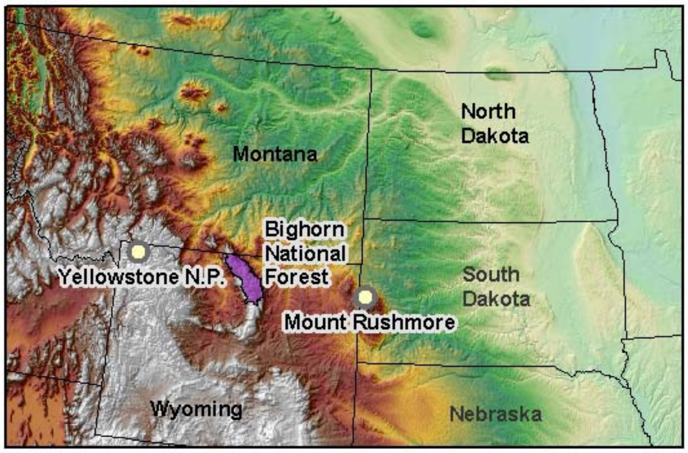

Figure 4.1. Relief map of Wyoming and adjacent states showing the location of the Bighorn National Forest in north-central Wyoming. The Big Horn Mountains are an important crossroads for regional and local travelers and recreationists.

Landscape Scale

Approximately 38% percent of the aquatic, riparian, and wetland assessment area is public land (e.g., BLM and U.S. Forest Service, table 4.1 and fig. 4.2). On these lands, the public may find access to recreational sites and opportunities in a variety of settings. Recreation sites vary from highly developed to primitive. Use can range from day visits to developed sites to extended visits for backcountry camping. Recreational opportunities include access to important historic and archeological sites, hunting, fishing, skiing, camping, hiking, and all-season sporting activities. Naturally, visitation and use varies with season, accessibility, site condition, and cost.

Table 4.1. The surface-ownership distribution within the assessment area. BLM and U.S. Forest Service lands comprise about 38% percent of the total area.

Surface Owner	Acres	Miles^2	Percent of Total
Other	61,433	96	0.89%
BIA and Tribal	643,957	1,006	9.37%
Bureau of Land Management	1,459,833	2,281	21.25%
Forest Service	1,175,104	1,836	17.10%
Private	3,082,355	4,816	44.86%
State	448,534	701	6.53%
Total	6,871,216	10,736	100.00%

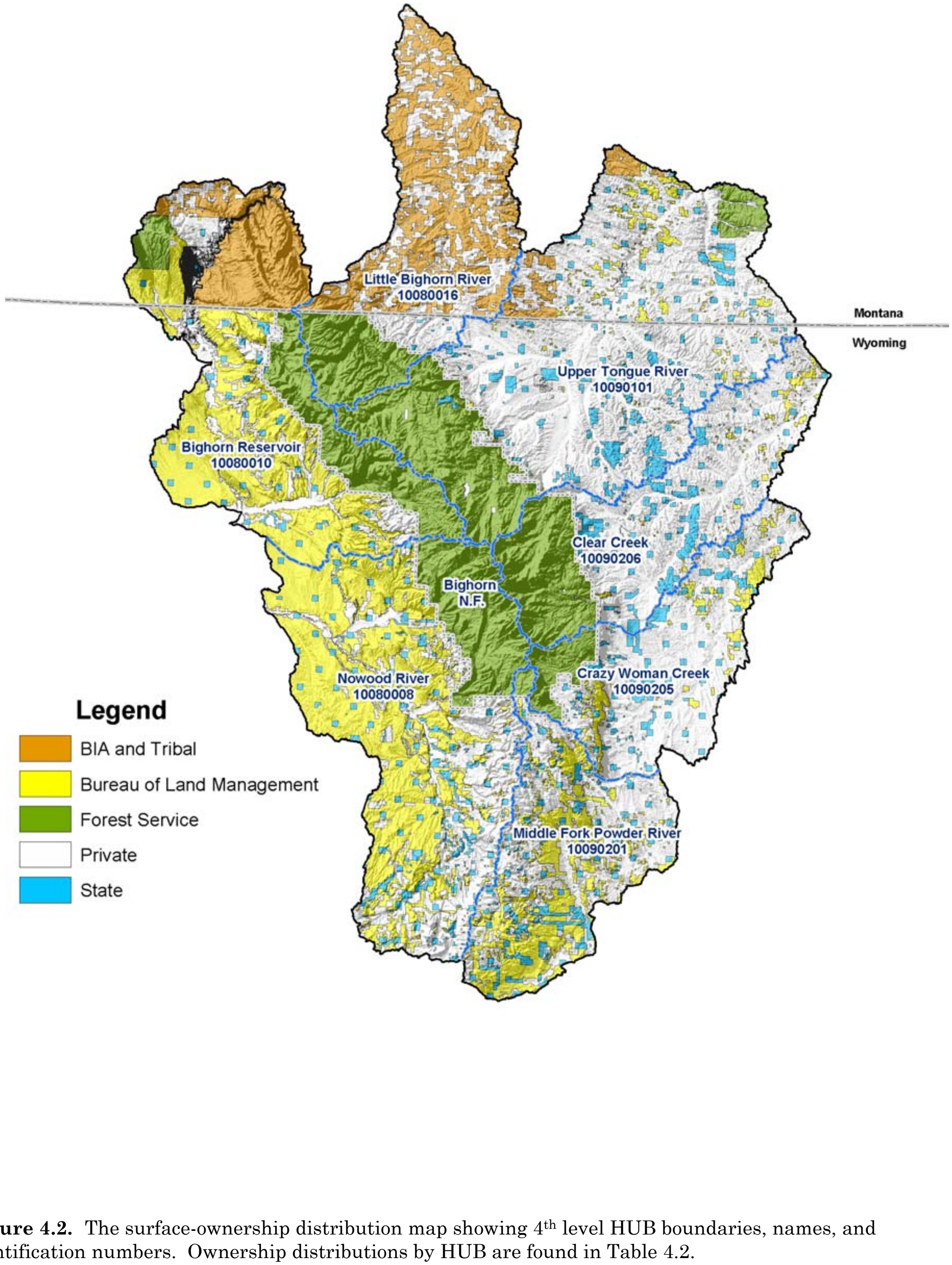

Figure 4.2. The surface-ownership distribution map showing 4th level HUB boundaries, names, and identification numbers. Ownership distributions by HUB are found in Table 4.2.

Table 4.2. Land ownership by 4th level HUB. Nowood River and Big Horn Reservoir HUBs (10080008 and 10080010 respectively) are federally owned predominantly west of the Big Horn Mountains while east of the divide ownerships are mixed to predominantly private. Tribal and BIA ownership is an important characteristic to the north.

4th Level HUB Code	4th Level HUB Name	Jurisdiction	Acres	Miles^2	Pct of HUB	HUB Acres
10080008	Nowood River	Other	610	1	0%	
		Private	364,763	570	28%	
		Public	834,432	1,304	**65%**	
		State	88,458	138	7%	1,288,262
10080010	Big Horn Reservoir	Other	7,446	12	1%	
		Private	169,637	265	15%	
		Public	740,788	1,157	**64%**	
		State	30,244	47	3%	
		Tribal	205,695	321	18%	1,153,810
10080016	Little Big Horn River	Other	2,126	3	0%	
		Private	289,341	452	35%	
		Public	142,425	223	**17%**	
		State	3,686	6	0%	
		Tribal	393,011	614	47%	830,590
10090101	Upper Tongue River	Other	6,444	10	0%	
		Private	1,055,270	1,649	65%	
		Public	388,860	608	**24%**	
		State	125,402	196	8%	
		Tribal	45,250	71	3%	1,621,225
10090201	Middle Fork Powder River	Private	318,884	498	51%	
		Public	240,755	376	**38%**	
		State	68,332	107	11%	627,970
10090205	Crazy Woman Creek	Private	428,346	669	70%	
		Public	117,599	184	**19%**	
		State	65,110	102	11%	611,054
10090206	Clear Creek	Other	2,148	3	0%	
		Private	456,115	713	62%	
		Public	212,739	332	**29%**	
		State	67,303	105	9%	738,305
Public Land includes: BLM and U.S. Forest Service			6,871,217	10,736		6,871,217

Developed recreation: The landscape scale includes developed recreation opportunities both inside and outside of the Bighorn National Forest. Table 4.3 illustrates the availability of recreation sites and opportunities both inside and outside the Forest boundary.

Within the boundaries of the Bighorn National Forest, there are 59 recreation sites comprised of a visitor center, campgrounds, picnic areas, fishing areas, interpretive sites, lookouts, and trail heads. Of these, 38 are considered to be developed recreation sites in this analysis (table 4.4).

Outside the Forest, additional developed recreational opportunities may be found on public lands including the BLM, National Park Service, Bureau of Reclamation, and state lands (table 3.20). Developed recreation on BLM lands is generally limited in magnitude, scope, and season. The BLM maintains only a few developed recreation sites, each having only limited facilities.

The majority of use of the developed sites is confined to the fall hunting season (T. Bills and J. Johnson oral commun., 2003). The Little Big Horn Battlefield National Monument provides day visitor and interpretive facilities only. The Big Horn Canyon Recreation Area, managed by the Bureau of Reclamation provides a range of developed recreation facilities for boating, fishing, picnicking, and 200 camping sites (USBR 2003).

Table 4.3. Developed recreation sites by 4th level HUB. "I" denotes sites within the Bighorn National Forest Boundary, and "O" denotes those sites outside the Forest boundary.

4th Level HUB Name & Code	Examples of Developed Recreation Sites in the Region
Big Horn Reservoir 10080010	Bureau of Reclamation, Big Horn Canyon Recreational Area (O) Antelope Butte Ski Area (I)
Nowood River 10080008	Big Horn Mountain Ski Area (I) Bighorn National Forest, Meadowlark Lake (I)
Crazy Woman 10090205	None
Little Big Horn River 10080016	Bureau of Reclamation, Yellowtail Dam (O) National Park Service, Little Big Horn Battlefield (O)
Upper Tongue River 10090101	Bighorn National Forest, Sibley Lake Recreation Area (I) State of Montana, Tongue River Reservoir (O)
Middle Fork Powder River 10090201	BLM, Middle Fork Powder River Recreation Area (O)
Clear Creek 10090206	State of Wyoming, Lake De Smet (O)

The 38 developed recreation sites are distributed among five of the seven 4th level HUBs. Figure 4.3 illustrates the location of these sites and their distribution among the seven 4th level HUBs. The relative influence of these sites on aquatic systems is suggested by the ratio between the number of recreation sites and stream mileage by 4th level HUB (fig. 4.4).

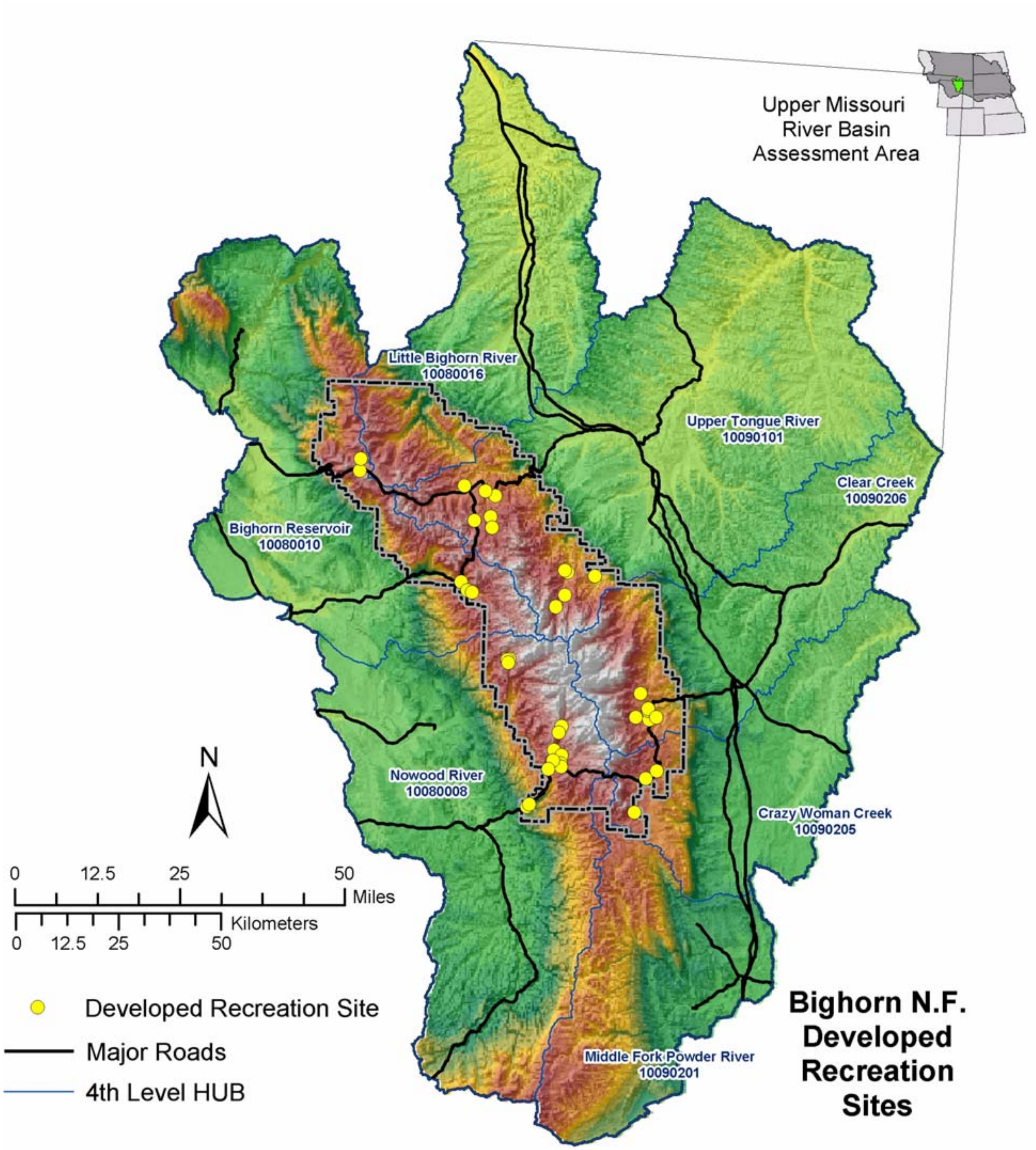

Figure 4.3. Developed recreation sites in the Bighorn National Forest along with major roads at the landscape scale. HUBs 10080016 and 10090201 are not influenced by these sites. Site locations near major regional highways makes these sites accessible to local and long distance travelers.

Table 4.4. Counts of Bighorn National Forest developed recreation sites by 4th level HUB.

4th Level HUB Code	4th Level HUB Name	Number of Sites
10080008	Nowood River	13
10090206	Clear Creek	6
10090101	Upper Tongue River	11
10090205	Crazy Woman Creek	3
10080010	Big Horn Reservoir	5
	Total	38

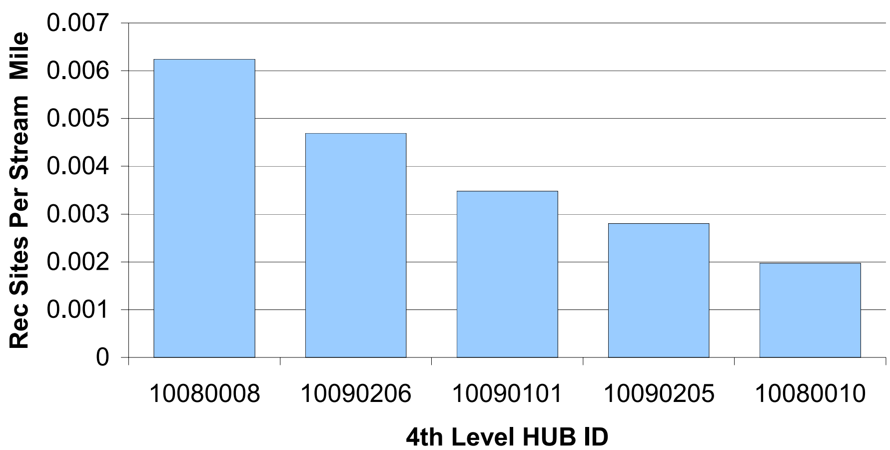

Figure 4.4. The number of Bighorn National Forest developed recreation sites per 4th level HUBs per stream mile. Of the seven 4th level HUBs, developed recreation sites influence the five HUBs shown here.

Dispersed recreation: Nearly 3,000 non-wilderness and approximately 1,400 wilderness dispersed recreation sites have been identified under various forest surveys in the 1980s, late 1990s, and recently in 2001 and 2002 (USDA 2003a). An additional indeterminate number of sites exist on BLM lands in the landscape assessment area. In the landscape area, site concentrations are most pronounced in the Big Horn Mountains and drop off sharply as upland forest lands give way to less desirable foothills and dry plains settings. Site use in these less desirable settings on BLM lands increases during hunting season, however, but even then measures of site occupation remain lower than on the Bighorn National Forest (J. Johnson, oral commun., 2003).

Not all of the estimated 3,000 non-wilderness and 1,400 wilderness dispersed recreation sites have been mapped and digitized for analysis at the completion of this assessment. There are, however, 2,102 dispersed site locations from the 1980s to 2002 surveys both mapped and digitized (fig. 4.5).

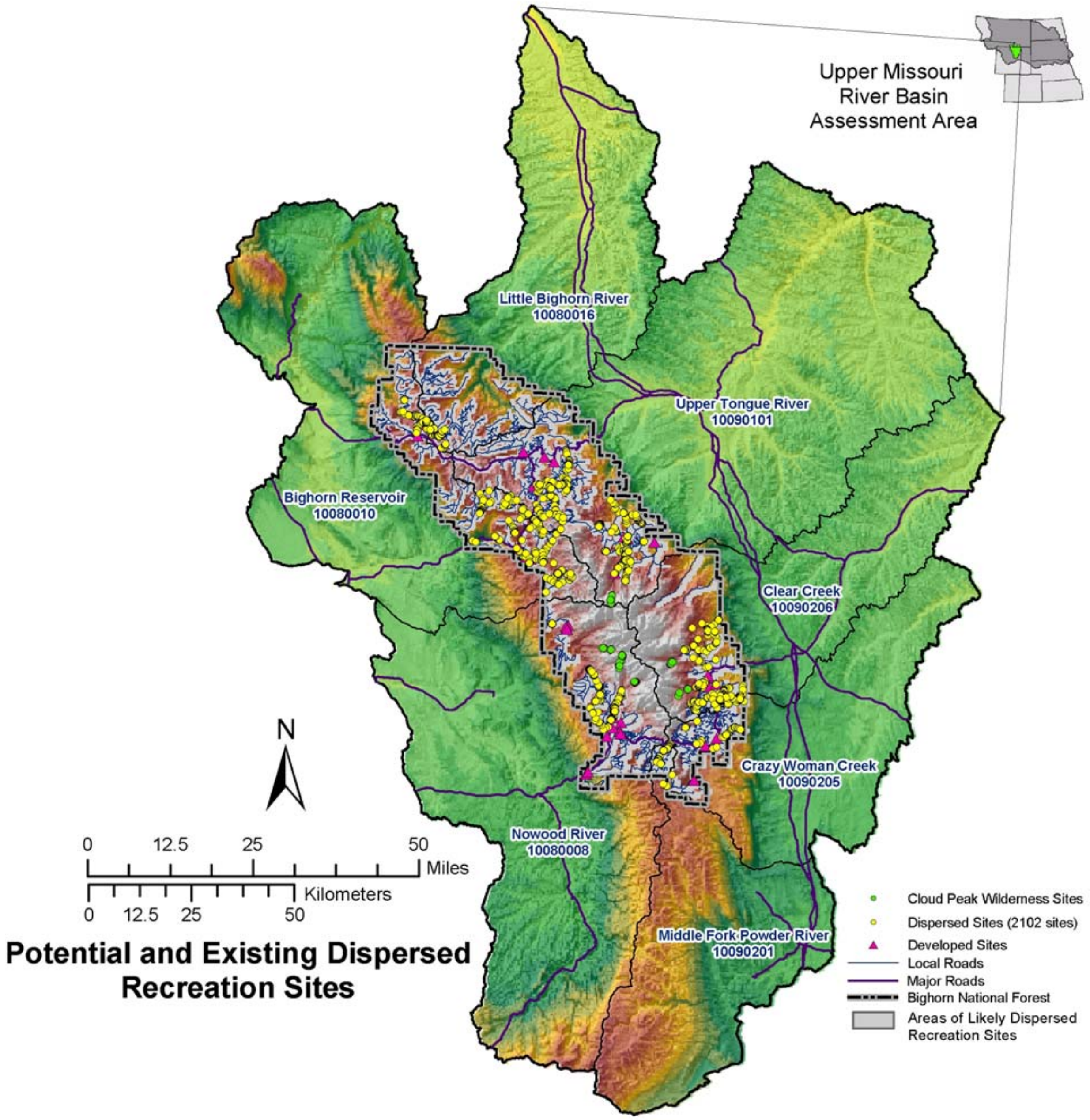

Figure 4.5. 2,102 points from the 1980s to 2002 dispersed recreation site surveys along with developed recreation sites, roads, and areas of likely dispersed recreation site occurrence. 'Likely Dispersed Recreation Sites' provide the basis for estimating overall site influence by 4th level HUB.

In Figure 4.5, those areas described as 'Likely' for dispersed recreation site occurrences have been determined by evaluation of characteristics of areas where the 2,102 known sites from various surveys occur. In these data there is a strong correlation between elevation, slope, and distance to roads and the existing sites. These are best illustrated in Figures 4.6 - 4.8.

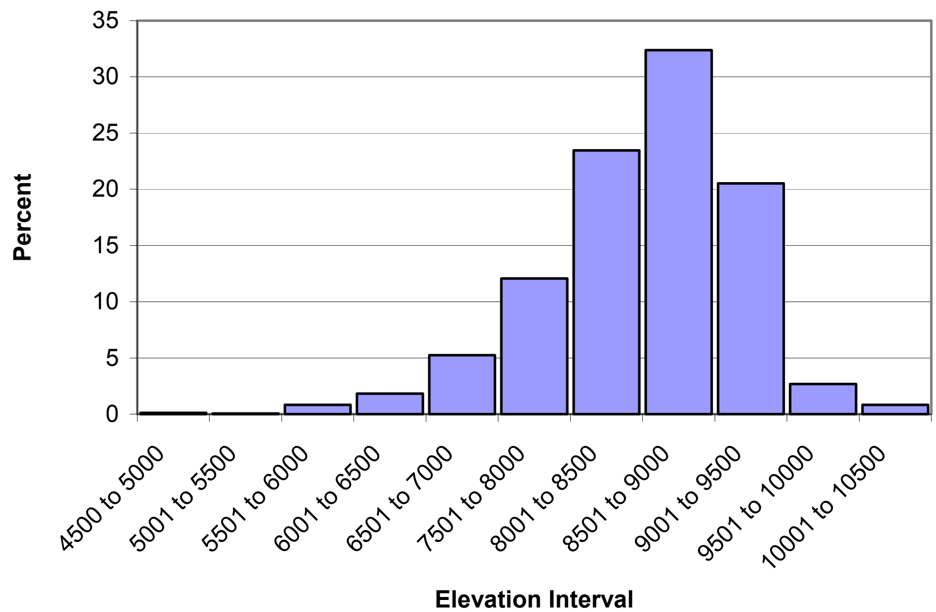

Figure 4.6. Correlation between 2,102 dispersed recreation sites and elevation. 93% percent fall in the intervals from 6,001 to 9,500 feet. 78% percent of the entire National Forest is in the same range.

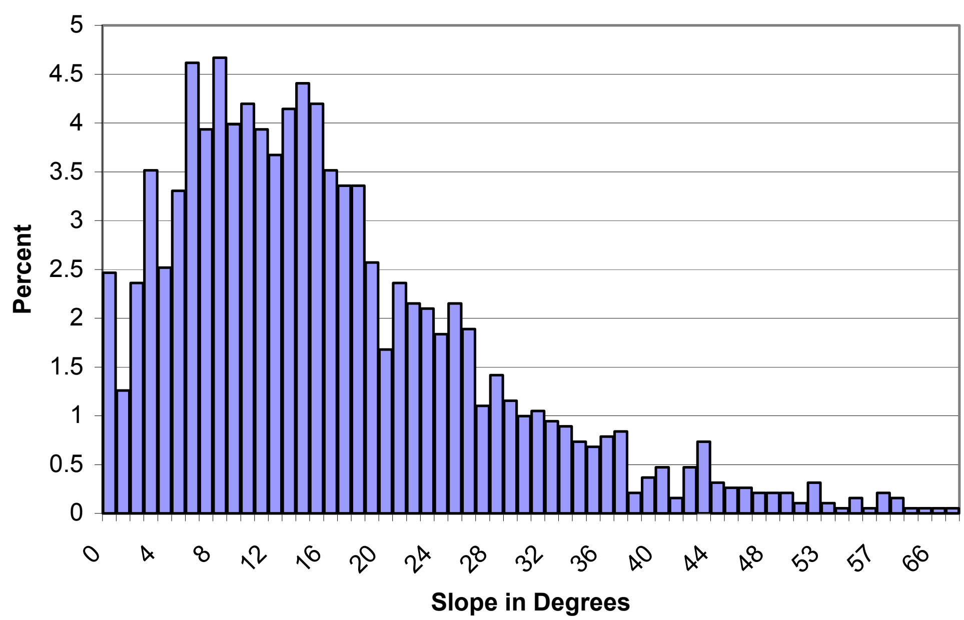

Figure 4.7. Correlation between 2,102 dispersed recreation sites and slope. 93% percent fall in the intervals from 0 and 35 degrees slope. The diminishing percentages below slopes of 8 degrees may be an artifact of digital elevation model (DEM) processing (e.g., it would be reasonable to expect to find somewhat higher percentages of sites in the nearly flat range of 0 to 8 degrees).

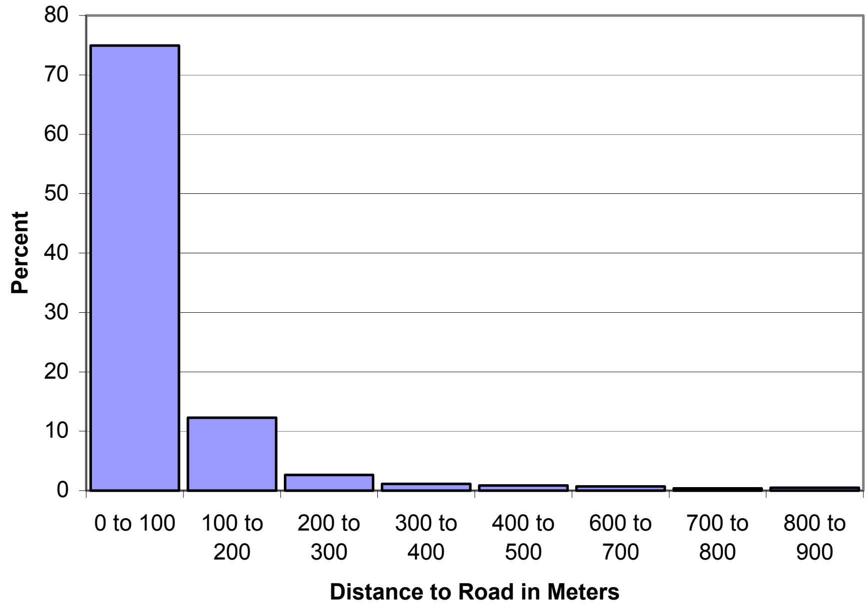

Figure 4.8. Correlation between 2,102 dispersed recreation sites and distance to roads. 91% fall in the intervals from 0 to 400 meters (nearly 75% are from 0 to 100 meters). Road proximity is the strongest indicator of dispersed recreation site occurrence for the 2,102 sites evaluated compared to elevation and slope.

The relationship shown in Figures 4.6 – 4.8 applies to areas within the Bighorn National Forest only. These three relationships may be combined to predict the likelihood of dispersed recreation site locations in those areas absent from the surveys conducted in the Forest thus far. The model created in this way yields about 280,000 acres of land in the National Forest with a strong likelihood of dispersed recreation sites. Dividing the estimated total non-wilderness 3,000 sites into this area, an overall site density of about 0.01 sites per acre exists. Furthermore, these areas may then be summarized by 4th level HUB and by stream miles. These summaries by 4th level HUB give insight into the landscape level influences of dispersed recreation on the Bighorn National Forest. Table 4.52 summarizes these potential areas and stream miles by 4th level HUB. Figures 4.9 – 4.11 further illustrate these relationships.

Table 4.5. Summary of potential dispersed recreation site areas showing potential number of sites per 4th level HUB and potential number of sites per stream mile per HUB. The potential number of sites are based on the ratio of 3,000 sites / 279,624 acres. Sites per stream mile are then obtained by dividing the potential number of HUB sites by total HUB stream miles.

4th Level HUB Code	4th Level HUB Name	Acres of High Potential	Potential Number of Sites	Potential Number of Sites per Stream Mile Landscape	Potential Number Sites per Stream Mile in National Forest
10090201	Middle Fork Powder River	6,668	72	0.07	7.9
10090206	Clear Creek	28,208	303	0.24	1.4
10090205	Crazy Woman Creek	33,257	357	0.33	4.5
10080016	Little Big Horn River	38,106	409	0.29	2.1
10080010	Big Horn Reservoir	44,835	481	0.19	1.8
10080008	Nowood River	47,877	514	0.25	2.2
10090101	Upper Tongue River	80,674	866	0.27	2.0
	Total	279,624	3,000		

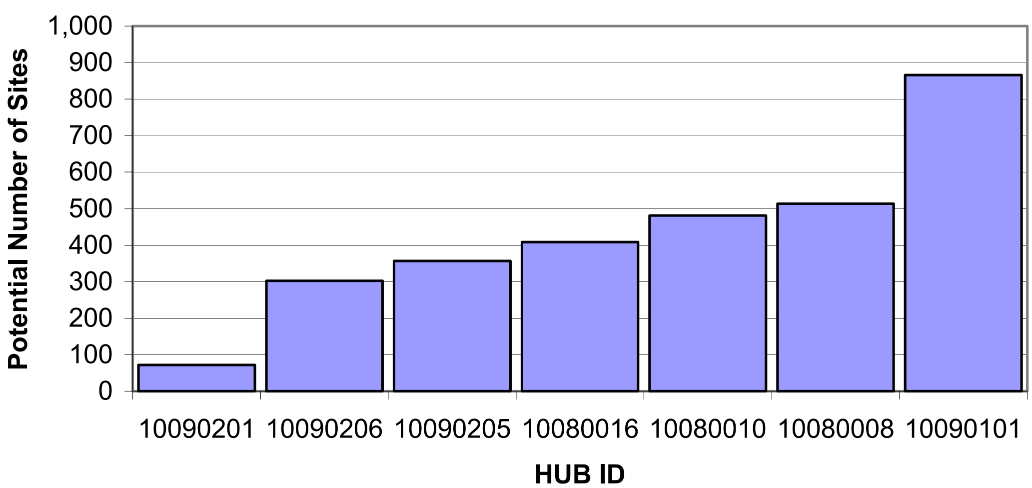

Figure 4.9. Potential number of sites by 4th level HUB. The Middle Fork Powder River HUB (10090101) stands out with a potential over 800 dispersed recreation sites strongly indicative of high road mileage/density in that HUB.

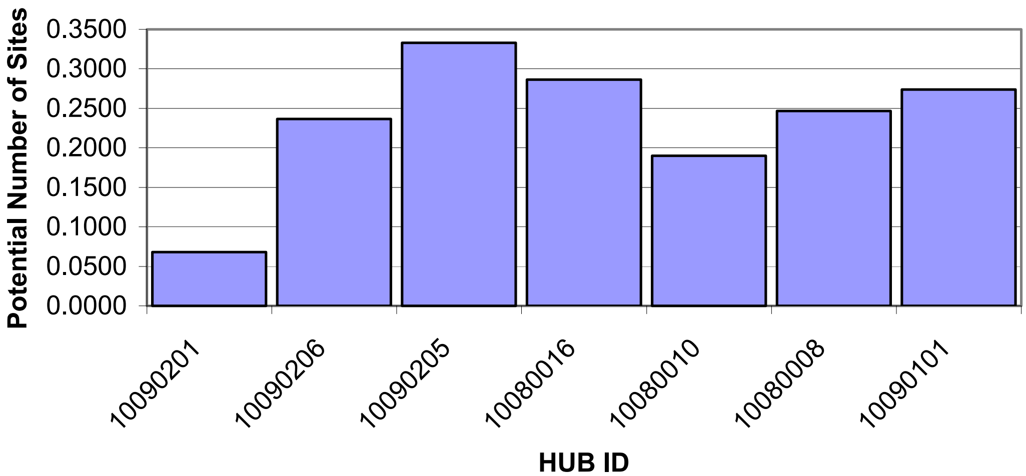

Figure 4.10. Within the overall landscape, the potential number of dispersed recreation sites to stream mile by 4th level HUB.

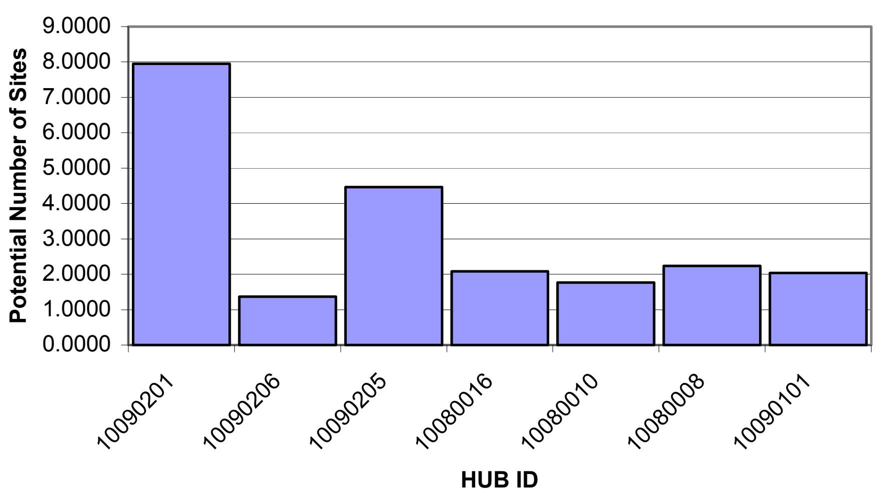

Figure 4.11. Within the Bighorn National Forest, the potential number of dispersed recreation sites to stream mile by 4th level HUB.

Management Scale

Developed Recreation: There are 38 developed recreation sites in the Bighorn National Forest (figs. 4.12a, 4.12b and fig. 4.13). These 38 sites include both campgrounds and picnic grounds and are generally located along existing travel ways, with access provided by three Scenic Byway routes.

Interpretive services are provided at three major sites: the Burgess Visitor Center on US Highway 14, the Shell Falls Visitor Center on US Highway 14, and the Medicine Wheel Historic Preservation site on US Highway 14A. Visitor use of interpretive centers has averaged over 400,000 from 1998-2001, with approximately 80% of this value coming from visits to Shell Falls (USFS 1998, 2000, 2001).

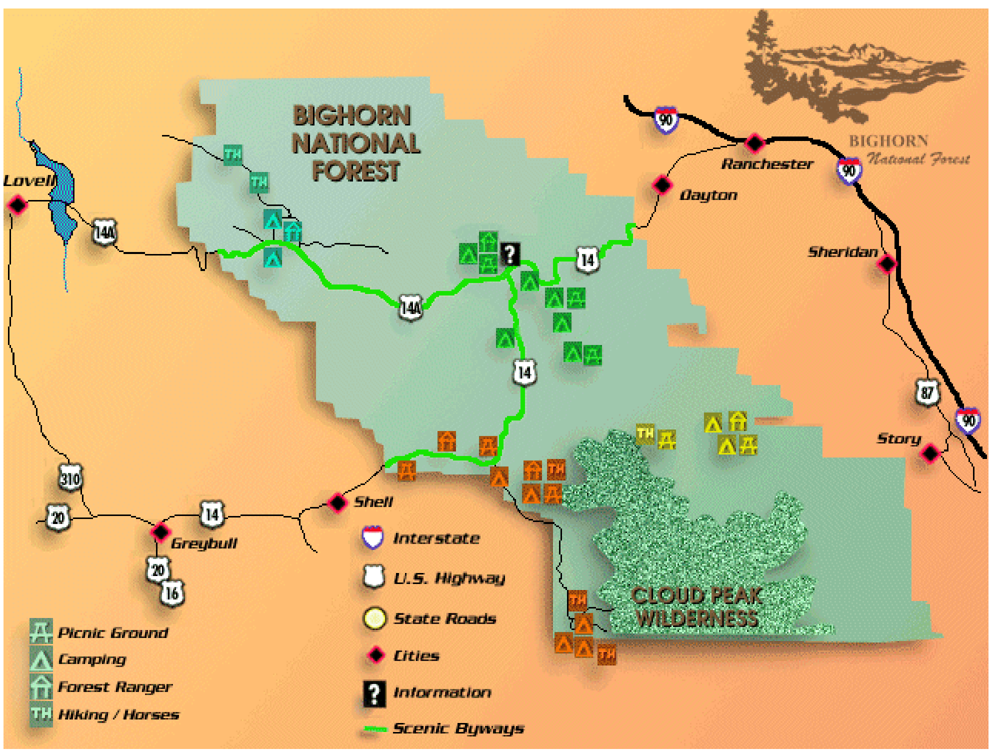

Figure 4.12a. Recreation sites and principal roads in the northern half of the Bighorn National Forest (maps courtesy of Bighorn National Forest).

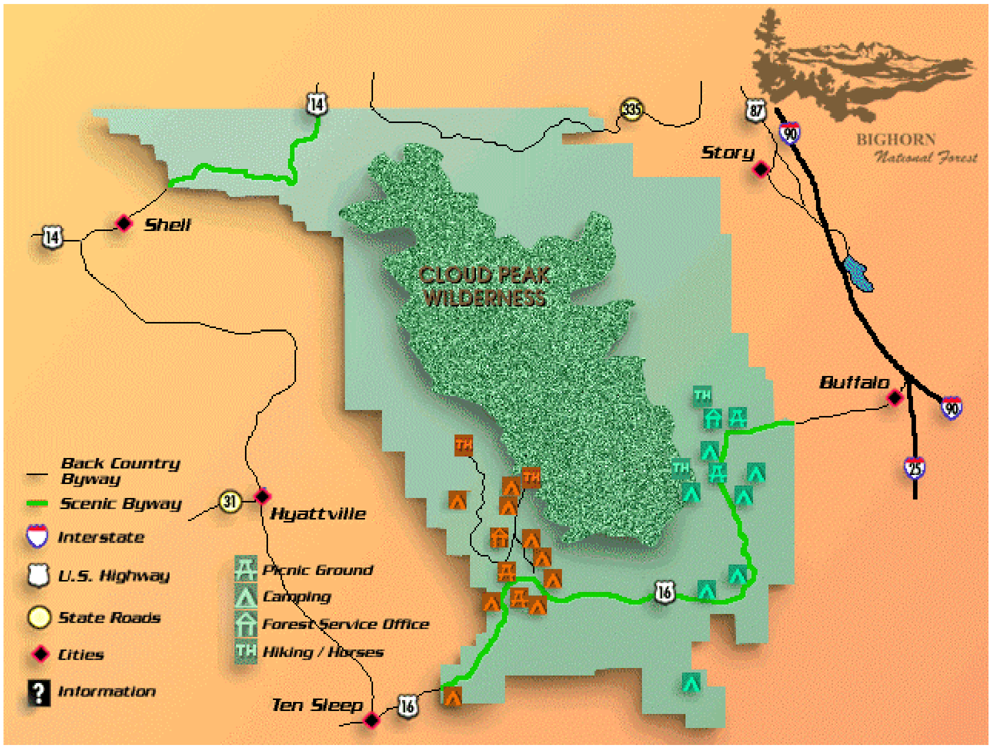

Figure 4.12b. Recreation sites and principal roads in the southern half of the Bighorn National Forest.

Within the Bighorn National Forest, most developed campgrounds are managed through a concessionaire program. The season is from May to September and campgrounds are open only during a portion of May and September. Campground occupancy during 2000 was 20% in May, 40% in June, 87% in July, 84% in August, and 46% in September.

The potential influence of developed recreation sites use on aquatic, riparian, and wetland resources is variable among 6th level HUBs. It is recognized that some sites do tend to be located in riparian habitats and so corresponding influences may be anticipated there. When we evaluated the number of recreation sites per stream mile per 6th level HUB (fig. 4.13) two 6th level HUBs stood out (100902050103 and 100902060102).

The majority (63%) of developed recreation sites were located in valley bottoms, which further increases the probability of influences on aquatic, riparian, and wetland resources (table 4.63) by recreation sites use. Again, 100902050103 and 100902060102 are watersheds of particular interest because they have the greatest density of sites in valley bottoms (fig. 4.14).

Table 4.6. Distribution of developed recreation sites among 6th level HUBs and comparison with valley bottom sites. Only the 19 HUBs containing the 38 geo-referenced developed recreation sites inside the Forest boundaries are presented.

6th Level HUB Code	Developed Recreation Sites	Developed Recreation Sites in Valley Bottom
100800080401	5	4
100800080402	3	2
100800080403	2	0
100800080601	2	1
100800080605	1	1
100800100102	3	3
100800100601	2	1
100901010102	1	0
100901010103	2	1
100901010104	3	2
100901010201	2	2
100901010202	2	2
100902050206	1	0
100902050101	1	0
100902050103	1	1
100902050106	1	0
100902060101	2	1
10090206 0102	3	2
10090206 0103	1	1
Total	38	24 (63%)

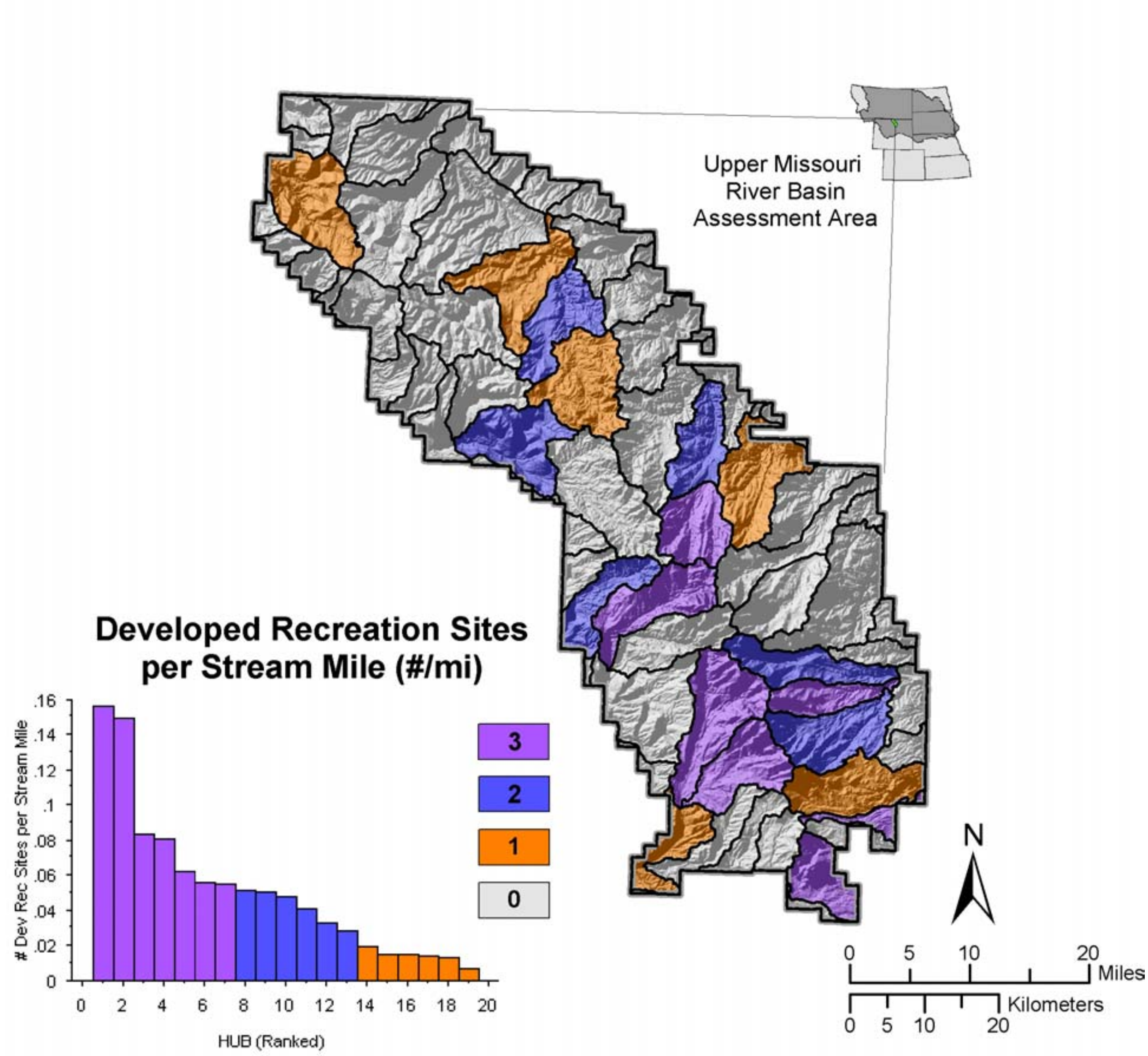

Figure 4.13. Developed recreation sites per stream mile per 6th level HUB at the management scale. The two highest ranked 6th level HUBS are 100902050103 and 100902060102.

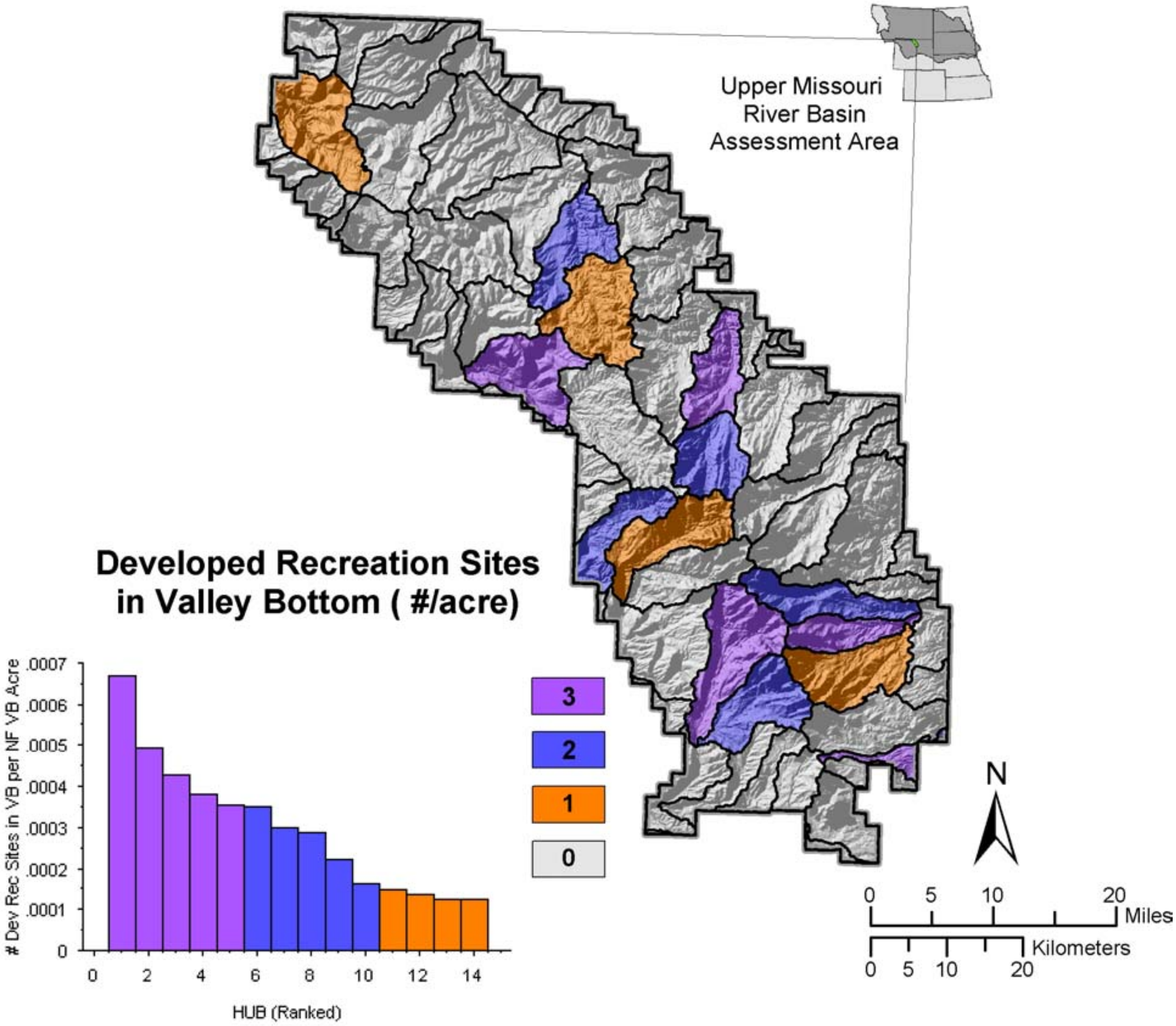

Figure 4.14. Developed recreation sites in valley bottoms (#/acre/6th level HUB). The two highest ranked 6th level HUBS are 100902050103 and 100902060102**.**

Dispersed Recreation: The Big Horn Mountains are becoming increasingly popular and serve an increasing diversity of recreation interests. The rate of current use exceeds earlier Forest plan projections (USFS 2000, 2001). In the past, dispersed recreation program activities included popular traditional activities such as fishing, hunting, hiking, horseback riding, dispersed back country camping, and winter activities such as snowmobiling and cross-country skiing. Today, program activities have expanded in scope to meet demands for all terrain vehicles (ATVs), mountain biking, and rock climbing.

The influence of dispersed recreation can be characterized at the management scale by evaluating the dispersed recreation potential to determine: 1) the potential numbers of sites per 6th level HUB per acre; and 2) number per valley bottom acre per HUB.

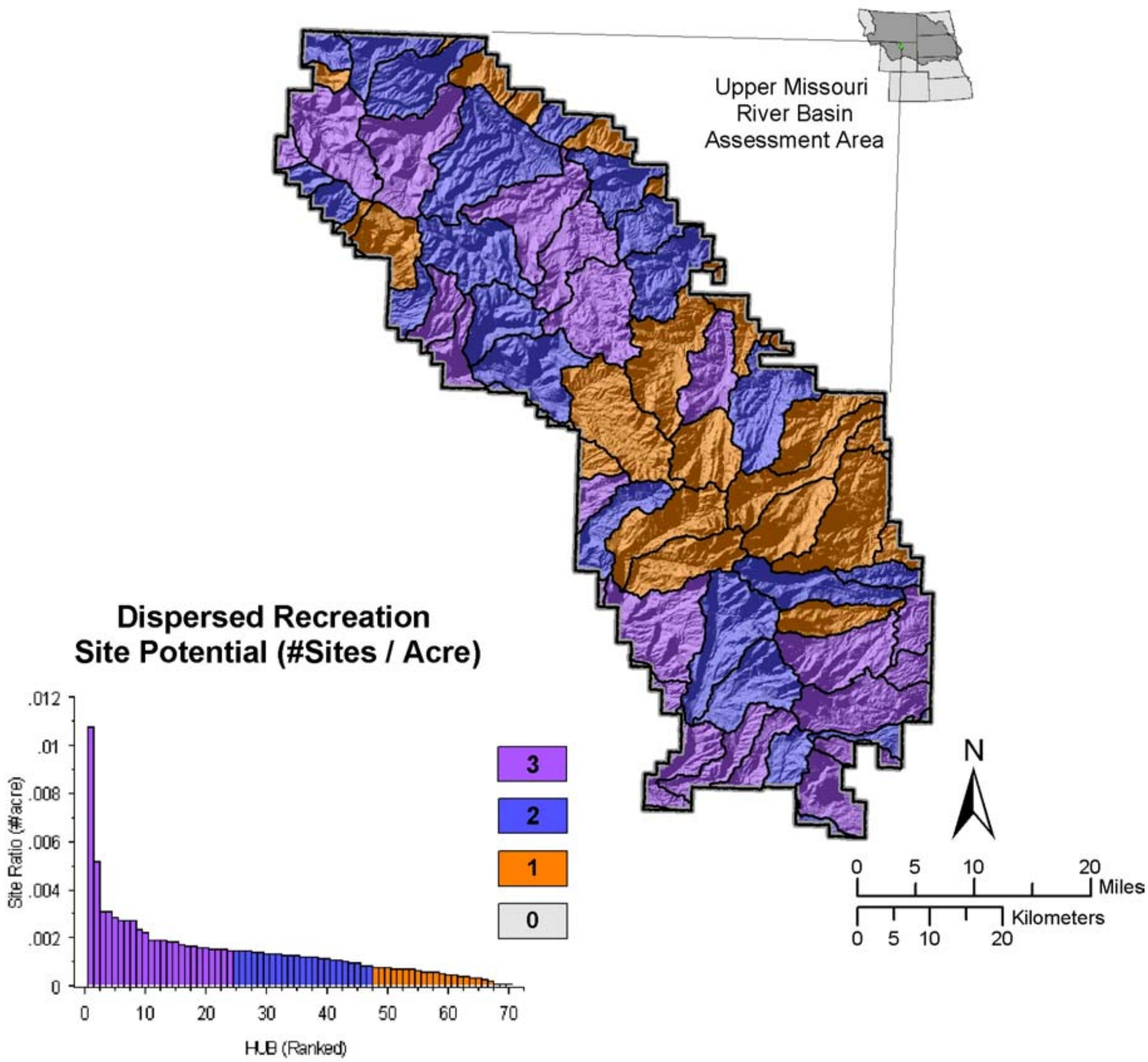

Figure 4.15. The potential number of dispersed sites per National Forest acre by 6th level HUB. HUBs 100800100602 and 100800080406 have the highest number of sites/acre but readers should note that only a very small portion of these two HUBs is contained within the National Forest boundary.

The predictive model, as introduced at the landscape scale, based on elevation, slope, and proximity to roads is especially informative at the management scale. Figure 4.15 shows the distribution, by 6th level HUB, of the potential number of sites per National Forest acre. The areas with the highest ratio are watersheds with high road densities especially along the central upland spine north of the Cloud Peak Wilderness and then again south of the wilderness. The top five HUBS are in descending order: 100800100602, 100800080406, 100902050101, 100902050102 and 100901010104.

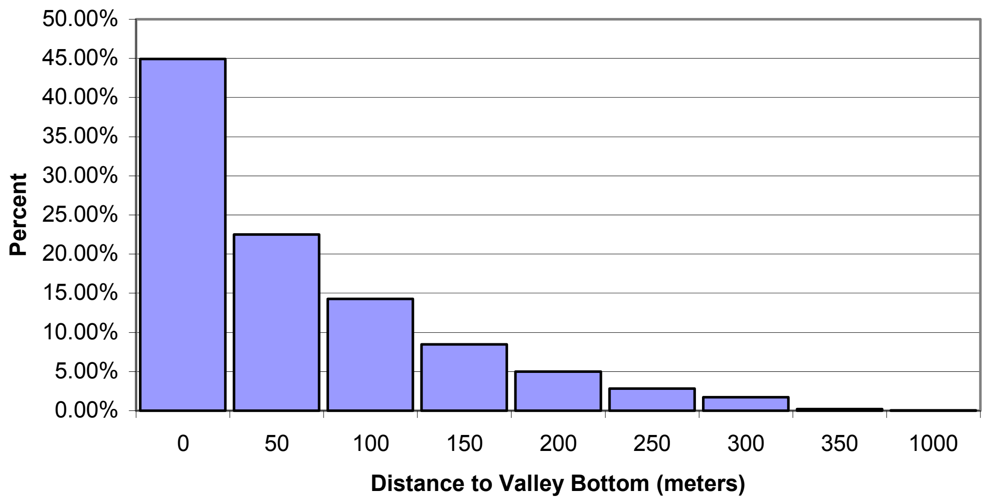

Figure 4.16. Over 90% of the 2,102 dispersed recreation sites fall within 150 meters or less of a valley bottom. Nearly 45% fall inside a valley bottom.

There appears to be a strong relationship between the 2,102 dispersed recreation sites, and valley bottoms in the Bighorn National Forest. Figure 4.16 shows that over 90% of the 2,102 sites fall within 150 meters of a valley bottom. Nearly 45% are inside a valley bottom area

Consequently, nearly all of the valley bottom areas in the Bighorn National Forest are potentially influenced by activity and disturbances associated with dispersed recreation sites. Overall, the average ratio is about 0.002 sites per valley bottom acre. Table 4.7 lists the top four sites with a range of .006 up to .007 sites per valley bottom acre. See Figure 4.17 for the potential dispersed recreation sites per valley bottom acre.

Table 4.7. The 6th level HUBs with the highest potential number of dispersed recreation sites per valley bottom area (e.g., acres). A value of 0.01 would equate to 10 sites per 1,000 valley bottom acres.

6th Level HUB Code	6th Level HUB Name	Number of Sites per Valley Bottom Acre
100901010104	Lower South Tongue River	0.0071
100901010103	Upper Tongue River	0.0069
100901010102	Fool Creek	0.0068
100902050101	Upper North Fork Crazy Women Creek	0.0065

Assessments of developed recreation sites could benefit from additional information on the types of recreation sites (e.g., those with or without paved parking lots or those with or without onsite sewage facilities) and would be a useful addition to the analysis at this scale, as it would help project where particular recreation-related impacts may affect aquatic resources.

Completion of GPS-based mapping of dispersed recreation sites throughout the Bighorn National Forest would improve the assessment of dispersed recreation throughout the Forest. Systematic surveys well beyond high use areas outside of 300 meters proximity to roads would enhance the ability to measure and model dispersed recreation. Moreover, completion of disturbance measures for the existing mapped dispersed sites along with the same measures for newly mapped sites would enhance estimates of specific influences on aquatic, riparian, and wetland resources.

It is likely that the predictive model defined above that integrates elevation, slope, and road proximity to define areas of high potential for dispersed recreation sites could be enhanced somewhat by further integration of valley bottom areas. In this analysis the strong correlation between existing dispersed recreation sites and valley bottom areas was recognized only after integration and analysis of elevation, slope, and road proximity.

Furthermore, evaluation of the 2,102 dispersed recreation sites suggests also a relationship between dispersed recreation sites and proximity to lakes. Figure 4.18 suggests a possible correlation between lakes and dispersed recreation sites. Visual inspection of the data shows a correlation between dispersed recreation sites and upland lake settings (fig. 4.19). However, the correlation does not appear to be strongly expressed throughout the Forest. Additional survey and evaluation of the data would likely allow more concrete associations to be identified.

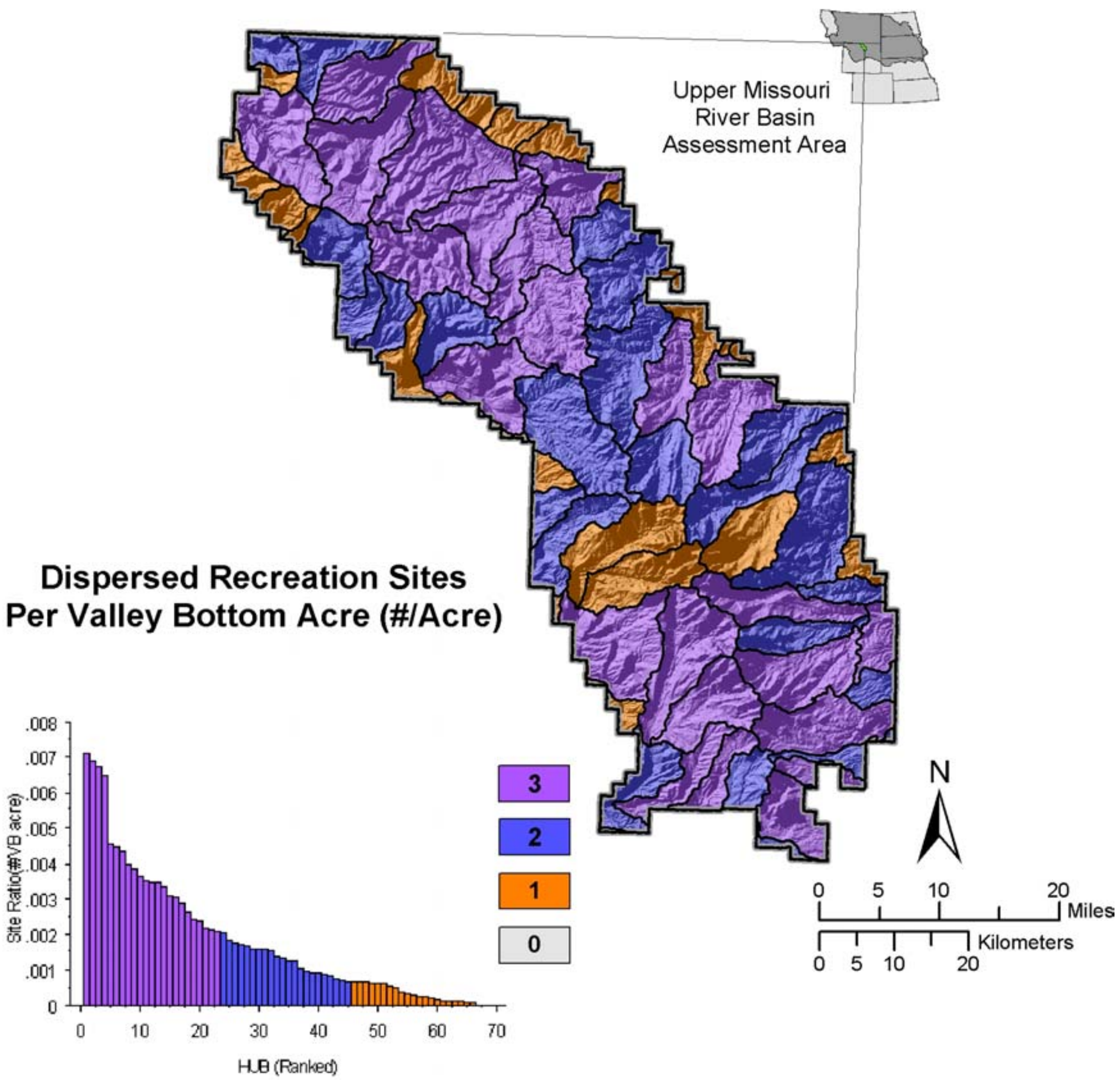

Figure 4.17. Potential dispersed recreation sites per valley bottom acre. The top four range from 0.007 down to 0.006 sites per valley bottom acre. See Table 4.7 for 6th level HUB codes and names.

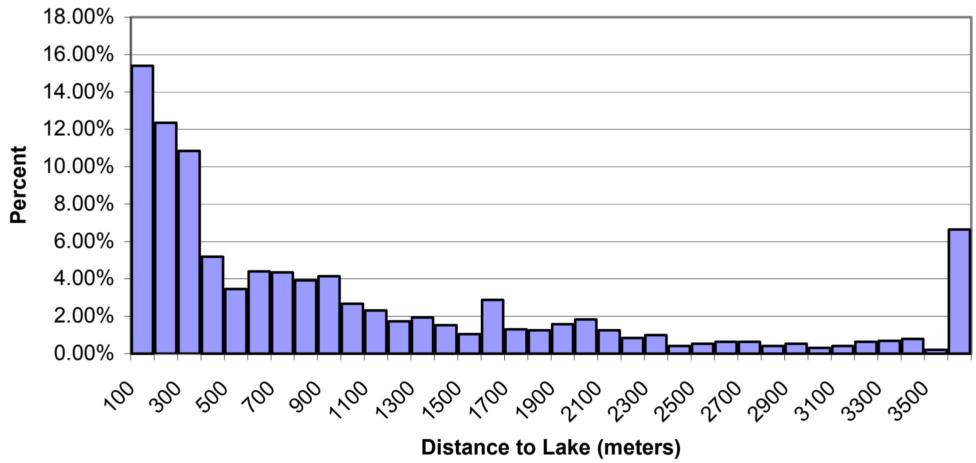

Figure 4.18. Nearly 66% of the 2,102 dispersed recreation sites fall within 1,000 meters of a lake. On an area-by-area basis the proportions can be significantly higher than 66%. Additional surveys and analysis of popular lakeside camping areas would be helpful in determining the influence of dispersed recreation on aquatic, riparian, and wetland values.

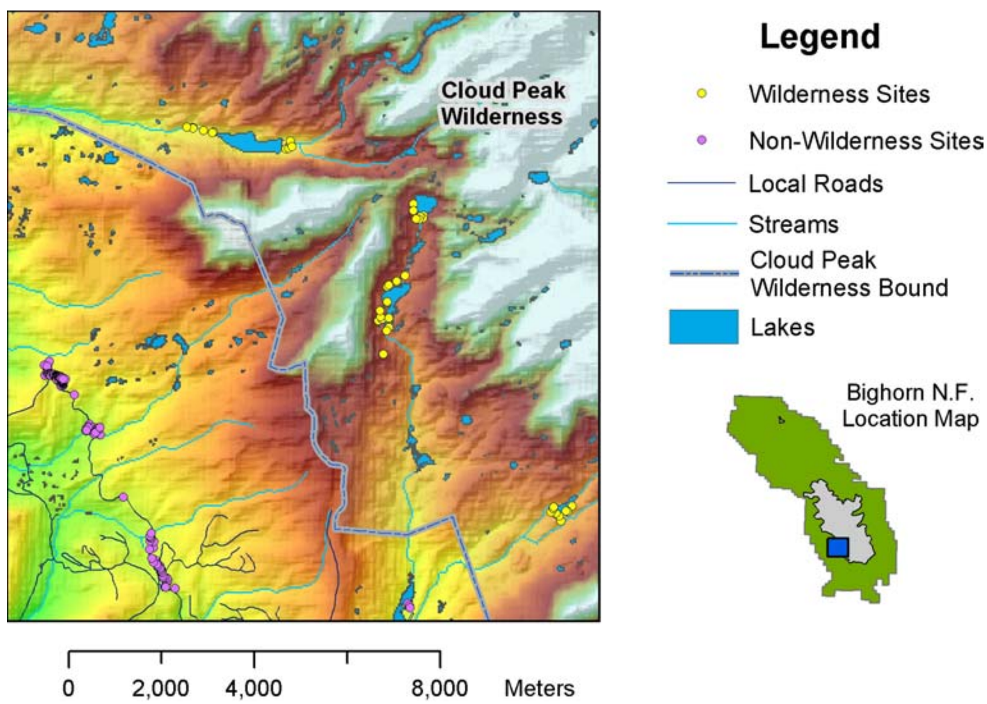

Figure 4.19. Example of a setting inside the Cloud Peak Wilderness where there is a strong correlation between lakes and the dispersed recreation sites (yellow symbols). Outside of the wilderness area a strong correlation to roads is evident. Elevations in this figure range from about 7,500 to 13,000 feet.

Reach/Site Scale

A host of issues and questions could be addressed at the reach/site scale in order to determine the influence of recreational activities in the Bighorn National Forest so that project level analyses are in accordance with Federal Land Policy and Management Act (FLPMA) directives concerning species viability and ecological sustainability. To evaluate the present and future potential influences of recreation on the Forest the following are values that should be addressed at the reach/site level: water quality; stream channel maintenance and sediment input; sensitivity of terrestrial, riparian, and aquatic vegetation; and the potential for direct (e.g., mortality or removal) and indirect effects on aquatic biota influences from recreation.

Specific questions related to resource values include, but are not limited to:

1. Will sustaining current levels of recreational use or will expected increases in recreational use result in:
   a. Altered hydrology
   b. Unacceptable changes in water quality caused by point and non-point pollution sources
   c. Increased sediment yield
   d. Increased channel alteration
   e. Degradation of riparian habitat
   f. Higher fishing pressure that results in population-level effects on game species or sensitive native species such as Yellowstone cutthroat trout
   g. Introduction of exotic or invasive species
2. Are developed or dispersed recreational activities more harmful to fluvial processes and aquatic organisms? Are specific recreational activities (e.g., hiking vs. OHVs) more harmful than others?
3. Should certain types of recreational activities be restricted if they are determined to be disproportionately harmful to aquatic, riparian, and wetland resources (e.g., 1a-1g above)?

Information Needs

Developed Recreation: Inventories could be conducted at the reach/site scale anytime that developed recreation sites are located near water. A primary concern at the reach/site scale is septic system and outhouse locations, as these may be sources of water contamination. Recording visitor use at these sites may also be useful to identify locations where existing septic systems and outhouse facilities may be overtaxed and have the potential to fail. In addition, the aerial extent and surface composition of parking areas could be measured because they have the potential to affect hydrology and speed the delivery of sediments and contaminants to streams.

Dispersed Recreation: The Forest began an inventory of dispersed recreation sites on all districts in 2002. This inventory will continue and will produce maps, pictures, and quantitative data on the impact each site may be having on aquatic and riparian resources. Continued mapping and geo-referencing of new data will be critical to accurately present the extent of dispersed recreation in the Forest. In addition, given the variation in recreation modes (e.g., motorized, on foot, on skis, on bicycles, on water, etc.), the specific type of impact each of these activities has on aquatic, riparian, and wetland resources should be measured (e.g., water quality, vegetation, biota, etc.). Because recreational use must be balanced with ecological sustainability, identifying recreational activities that have a large cumulative effect on aquatic, riparian, and wetland areas will be useful information to both manage the resource and resolve potential user conflicts. Because of the tendency for dispersed recreation to occur in and subsequently impact riparian habitats, another useful measurement at this scale would be the width of riparian areas adjacent to dispersed recreation sites.

Influence of Ski Area Development

Basin Scale

Ski area density in the Upper Missouri River Basin is low relative to the density of major ski areas and resorts in the Upper Colorado River Basin (e.g., Aspen, Vail, Steamboat, and Breckenridge). Ski areas in Montana and in the Upper Missouri River Basin include: Great Divide, Discovery Basin, Bridger Bowl, Big Sky, and Red Lodge.

Landscape Scale

Downhill skiing in the assessment area is limited to two ski areas in the Big Horn Mountains: Antelope Butte and Big Horn Mountain. These areas are considered a regional destination for local skiers and snowboarders in such communities as Sheridan and Buffalo, Wyoming. The areas do not draw a significant number of visitors from outside of the region.

Antelope Butte Ski Area is located approximately 35 miles east of Greybull, WY and 80 miles west of Sheridan, WY on US Highway 14, and has been managed under a special use permit as a ski area since 1963. Antelope Butte Ski Area serves primarily as a winter recreation area providing service to Nordic and alpine skiers, snowboarders, and snowmobilers. There are a total of 200 acres of skiable terrain at Antelope Butte ski area. Most skiers currently are from the local communities of Sheridan, Ranchester, Dayton, Greybull and Basin. In recent years, out-of-state skiers and skiers from communities at some distance from Antelope Butte have started to ski there looking for a smaller more family-oriented ski area (Antelope Butte draft EA 1999). Summer recreation opportunities at Antelope Butte are limited.

Big Horn Mountain Ski Area is located 48 miles east of Worland, WY and 45 miles west of Buffalo, WY, just south of US Highway 16 in the southern Big Horn Mountains. Big Horn Mountain is the larger of the two ski areas in the Forest, and has a triple chair lift, a double chair lift, a beginner lift, and 20 runs. Moreover, it also has on-site overnight accommodations with Meadowlark Lake Resort and Deer Haven Lodge, and additional recreational facilities. Snowmaking capabilities were recently added (Big Horn Mountain EA 2001). Overall, ski area development is currently of minor consequence at the landscape scale. Both ski areas are relatively small (<450 acres). Combined, the Antelope Butte and Big Horn Mountain downhill ski areas record about 10,000 skier visits per year. A review of past use at the ski areas shows an erratic use/activity pattern due primarily to snow conditions and ski-lift capacity. Both areas were recently expanded to increase capacity and visitor service (Antelope Butte draft EA 1999; Big Horn Mountain Decision Memo 1999) in anticipation of expanded activity and use in the future.

Management Scale

The 370.5 acres of Antelope Butte Ski Area are entirely within HUB 100800100102, and the combined 439.5 acres of Big Horn Mountain Ski Area are divided between HUBs 100800080402 (403.1 acres) and 100800080403 (36.4 acres).

Stream and riparian dynamics adjacent to and downstream from these two ski areas are subject to increased nonpoint pollution, sedimentation, and stream dewatering from snowmaking. The Antelope Butte and Big Horn Mountain Ski Areas potentially influence just over 57 miles of downstream stream segments for seventeen HUBs contained within the management scale (fig. 4.20). Of these seventeen watersheds, three stand out as having from 28% to 35% percent of the total watershed stream length influenced by upstream ski activity and facilities (fig. 4.21). These three HUBs are: 100800100102 (34.7%), 100800080403 (33.7%) and 100800100104 (28.4%). The remaining fourteen HUBs contain from 5% to less than 1% of potentially influenced stream length for each HUB.

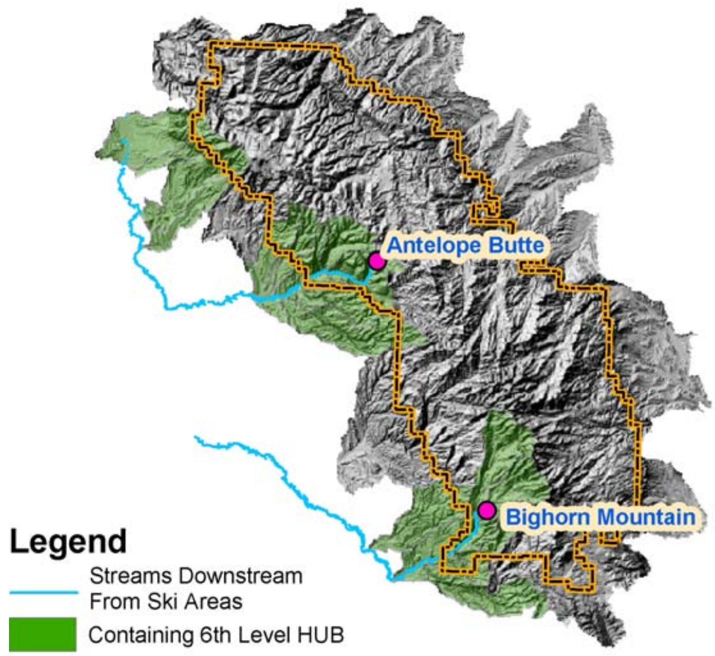

Figure 4.20. Streams are shown that are downstream from the Antelope Butte and Big Horn Mountain Ski Areas and the 6th level HUBs intersecting those streams are highlighted in green. Table 4.8 lists the 17 HUBs that include ski area-influenced streams.

Table 4.8. Seventeen 6th level HUBs in the Bighorn National Forest include streams influenced by ski areas and related activities. The list of HUBs is sorted in ascending order of the percentage. Percentages indicate the ratio of HUB total stream length to stream lengths downstream of ski areas.

6th Level HUB Code	6th Level HUB Name	Percent of HUB Downstream
100800100401	Five Springs Creek	0.1%
100800080502	Brockenback Creek	0.1%
100800100309	Crystal Creek	0.2%
100800100106	Trapper Creek	0.4%
100800080406	Lower Canyon Creek	0.5%
100800100307	Salt Creek	0.6%
100800100105	White Creek	0.7%
100800100107	Horse Creek	0.8%
100800100103	Cedar Creek	0.9%
100800080401	Upper Tensleep Creek	0.9%
100800100402	Big Horn River-Willow Creek	1.1%
100800100204	Lower Beaver Creek	1.7%
100800080404	Leigh Creek	1.8%
100800080402	East Tensleep Creek	5.8%
100800100104	Shell Creek-Cottonwood Creek	28.4%
100800080403	Lower Tensleep Creek	33.8%
100800100102	Shell Creek-Granite Creek	34.7%

Reach/Site Scale

Inventory and monitoring at the reach/site level is important to understand the influence of ski area development on aquatic, riparian, and wetland resources, and to ensure that project level analyses are in accordance with Federal Land Policy and Management Act (FLPMA) directives concerning species viability and ecological sustainability and the Clean Water Act of 1972.

Changes in water quality, stream channel maintenance and sediment input, requirements and sensitivity of terrestrial, riparian, and aquatic vegetation, and the potential for direct and indirect effects on aquatic biota are aquatic, riparian, and wetland values that must be addressed at the reach/site scale to evaluate potential influences of ski areas in the Forest.

Specific questions related to resource values include, but are not limited to:

1. Does operation of current ski area facilities influence resources via:
   a. Altered hydrology (e.g., increased runoff from ski runs, water use for snowmaking)
   b. Changes in water quality (e.g., point and nonpoint pollution)
   c. Increased sediment yield (e.g., fine sediment deposition)

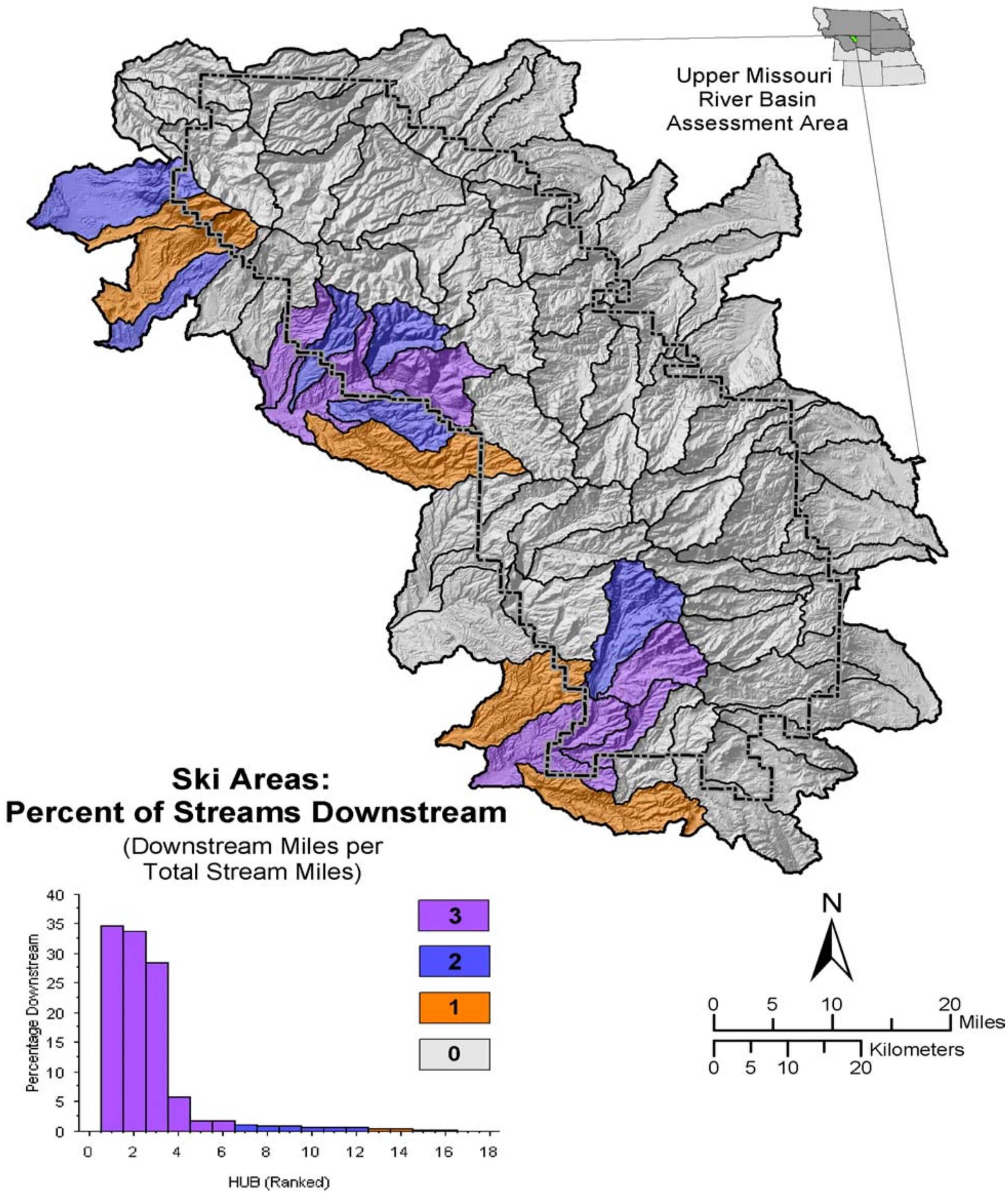

Figure 4.21. Percentage of total stream miles versus miles downstream from ski areas at the management scale. The three strongly influenced HUBs are 100800100102 (Shell Creek-Granite Creek), 100800080403 (Lower Tensleep Creek), and 100800100104 (Creek-Cottonwood Creek).

   d. Channel alteration (e.g., degrading stream banks via ski run crossings)
   e. Degradation of riparian or habitat (e.g., direct removal of vegetation to maintain ski runs, draining of wetlands)
2. To what degree are aquatic, riparian, and wetland sources affected in HUBs closely associated with ski areas (e.g., HUBs 100800100102, 100800080403, and 100800100104)?
3. Will future ski area development or expansion illicit changes listed above in number 1 (a-e) above?

Information Needs

Although the downhill ski area density relative to Bighorn National Forest is low at the landscape and management scales, local effects can still be apparent. Specific measurements that can be used to determine effects are:

1. Timing and magnitude of high-flow events in ski areas compared to adjacent unaffected stream reaches (upstream or adjacent watershed).
2. Area of wetland drained or flooded by ski area development.
3. Site attributes (e.g., slope, geology) of disturbed areas.
4. Particle size distribution or other measures to determine changes in stream sediment composition (e.g., siltation).
5. Identify locations of high sediment yield to streams.
6. The number of stream channels crossed by ski runs.
7. Location and type of wetlands in or near ski area developments.
8. Size, location, and surfacing of parking lots, roads, or other impervious surfaces.
9. Amount of water use (snowmaking, direct consumption, waste water treatment).
10. Extent of stream dewatering or reduction in lake level from snowmaking activities at Antelope Butte.
11. Abundance and diversity of: a) aquatic invertebrate and fish communities downstream from ski area developments; and b) flora and fauna in wetlands adjacent to and downstream from ski area developments.

Recreation Cluster Analysis

A cluster analysis of the three activities identified in the recreation category was performed to identify the additive effects of recreation activities on aquatic, riparian, and wetland resources. Five criteria were used in the cluster analysis, and are summarized in Table 4.9. This analysis was performed at the management scale, with data existing for all portions of the 74 HUBs within the Bighorn National Forest boundary. The 'rec' suffix has been assigned to the clusters of this analysis. HUBs where no recreation activities were present were removed from the dataset prior to the cluster analysis, and assigned as Cluster 0rec. The cluster analysis was performed in PC-ORD2, with four clusters identified at 25% of the information remaining (fig. 4.22). Each cluster has been labeled on the dendrogram. Table 4.10 summarizes the mean criteria values for each cluster.

When mapped (fig. 4.23) Clusters 1rec and 2rec comprise a majority of the Bighorn National Forest. Clusters 3rec and 4rec are found along the western flanks of the Forest. Cluster 0rec contains those HUBs that have only a small percentage of their total area within the National Forest. An analysis of variance (ANOVA) statistical test was utilized to examine the clusters for significant differences in criteria values (table 4.11).

Table 4.9. Summary of criteria used in the recreation cluster analysis.

Criterion	Explanation
Developed Recreation Site Density	Number of Developed Recreation Sites per Acre
Developed Recreation Site Density in Valley Bottom	Number of Developed Recreation Sites in Valley Bottom per Acre
Dispersed Site Potential Density	Number of Potential Dispersed Recreation Sites per Acre
Dispersed Site Potential Density in Valley Bottom	Number of Potential Dispersed Recreation Sites in Valley Bottom per Acre
Percent Downstream from Ski Area	Percent of Stream Length Downstream of Ski Area

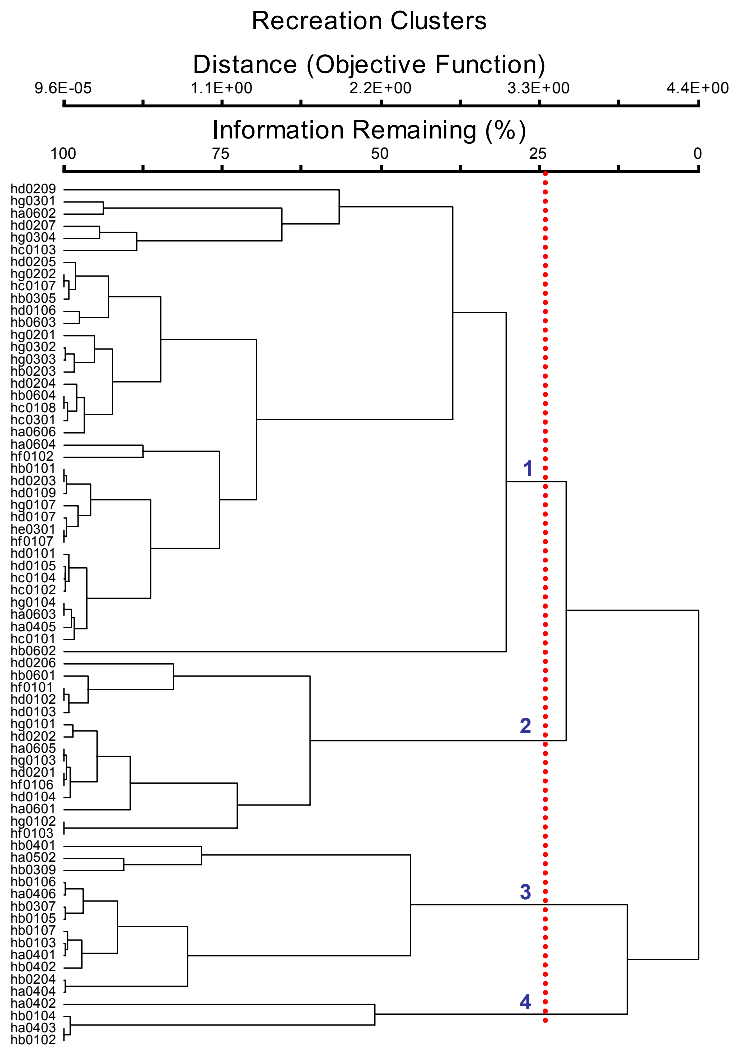

Figure 4.22. Dendrogram produced by cluster analysis of recreation criteria.

Table 4.10. Cluster analysis showing mean values for each criterion.

	Population	**Cluster 0rec**	**Cluster 1rec**	**Cluster 2rec**	**Cluster 3rec**	**Cluster 4rec**
Number (n)	n = 74	n = 3	n = 39	n = 15	n = 13	n = 4
Number Developed Recreation Sites per Stream Mile	0.013	0.000	0.000	0.053	0.006	0.026
Number Developed Recreation Sites in Valley Bottom (VB) per NF VB Acre	0.000056	0.000000	0.000000	0.000206	0.000033	0.000167
Dispersed Site Potential Ratio (#/acre)	0.002	0.000	0.001	0.004	0.001	0.002
Dispersed Site Potential VB Ratio (#/VB acre)	0.001	0.000	0.001	0.002	0.002	0.001
Percentage Downstream	1.520	0.000	0.000	0.000	0.748	25.682

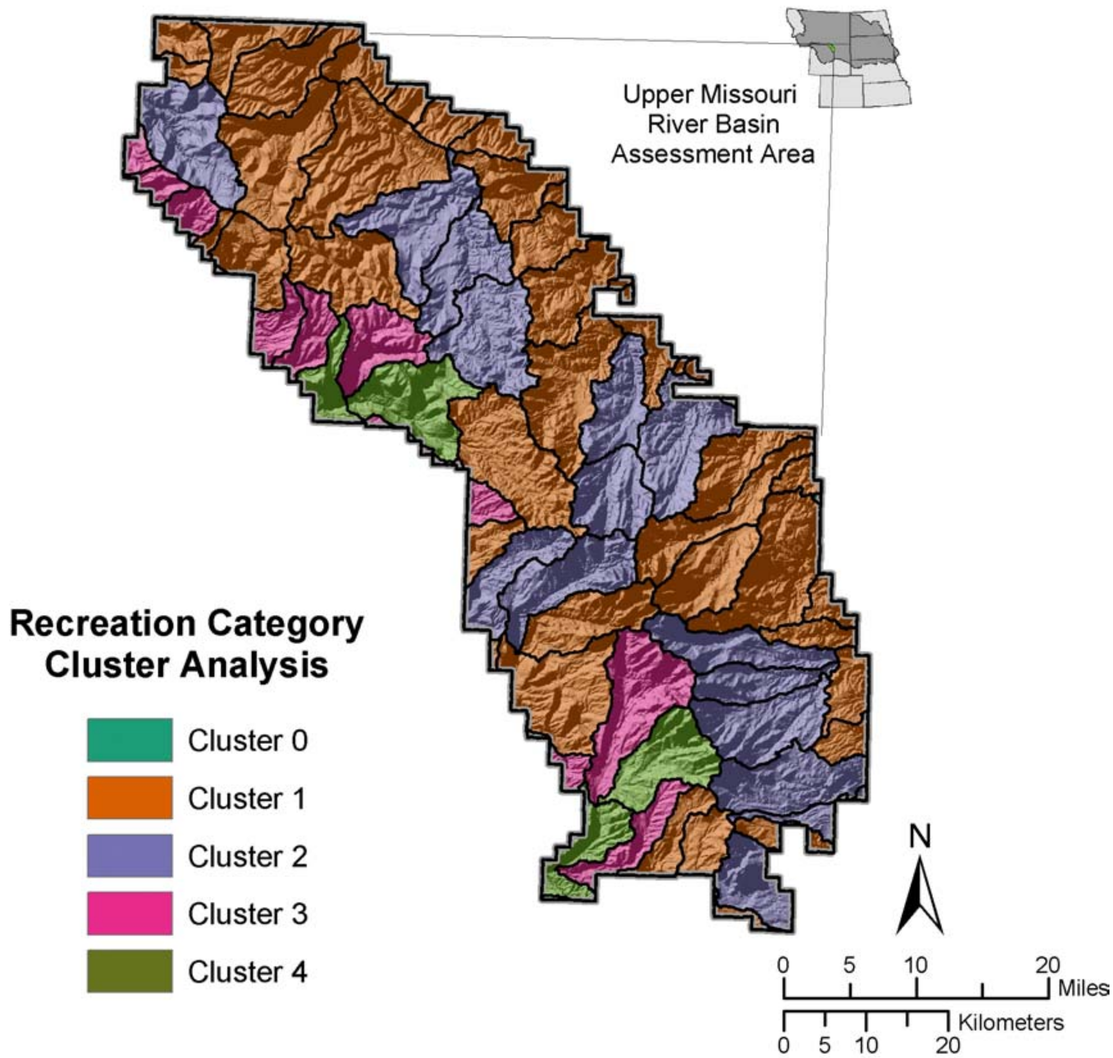

Figure 4.23. Cluster analysis results for recreation category.

Table 4.11. ANOVA results summary showing test for significant differences between clusters for each recreation criterion.

Criterion	F Value	Probability > F
Developed Recreation Site Density	14.8187	< .0001
Developed Recreation Site Density in Valley Bottom	10.9522	< .0001
Dispersed Site Potential Density	7.8916	< .0001
Dispersed Site Potential Density in Valley Bottom	0.9743	0.4273
Percent Downstream from Ski Area	77.3825	< .0001

Alpha = .05

Statistically Significant (purple)
Not Statistically Significant (orange)

Cumulative Percentile Ranking

The distribution of clusters reflects a general spatial pattern (fig. 4.23). Those HUBs that have the highest recreation densities (both developed and dispersed) are clustered along major transportation corridors, including highways, dirt roads, foot trails, and OHV trails. These HUBs are generally included in Clusters 2rec and 3rec. Cluster 1rec does not contain many developed and dispersed recreation sites, or is affected by an upstream ski resort. This cluster is generally located away from transportation corridors, in the more remote portions of the National Forest. Cluster 4rec is the only cluster that contains HUBs that have a percentage of their total stream lengths directly downstream of a ski area. These ski areas are on the western slope of the Big Horn Mountains, thus Cluster 4rec is scattered among those HUBs on the western side of the Forest. Cluster 0rec is not immediately evident on Figure 4.23. The HUBs comprising Cluster 0rec are those who have a very small percentage of their total area contained within the Forest.

The sum of the percentile ranks of the five criteria of the recreation category was calculated to identify the additive effects of transportation activity on aquatic, riparian, and wetland resources. The five criteria used in this analysis are summarized in Table 4.10. This analysis was performed at the management scale, with data existing for all portions of the 74 HUBs within the Bighorn National Forest boundary. Quartile values were then identified for the cumulative rankings. The quartiles were used as a means of grouping the cumulative ranks (fig. 4.24). Group 1 identifies those HUBs within the lowest quartile of cumulative rankings. Group 2 identifies those HUBs within the 25th – 50th percentiles of cumulative rankings. Group 3 identifies those HUBs within the 50th – 75th percentiles of cumulative rankings. Group 4 identifies those HUBs within the highest quartile of cumulative rankings. HUB 100800100102 has the highest cumulative ranking value of 13 out of a possible 15-percentile sum.

This analysis is relative only to the portion of the 6th level HUBs surface area within the Bighorn National Forest boundary, and is intended to provide the reader with the additive rankings at this scale. Unlike the previous methodology, the results are evenly distributed across the total number of HUBs at this scale.

Groups 3 and 4, which have the higher cumulative percentile rankings, are clustered in the southern and central portions of the Forest. These areas are proximate to major transportation corridors, such as highways, unsurfaced roads, foot trails, and OHV trails. The HUBs including the Cloud Peak Wilderness is included in the highest category because of its high trail density, and lower elevation developed recreation sites. Groups 1 and 2 are those areas in the more remote portion of the Bighorn National Forest, and contain few recreation sites. The three HUBs that contain the two ski areas are all included in Group 4.

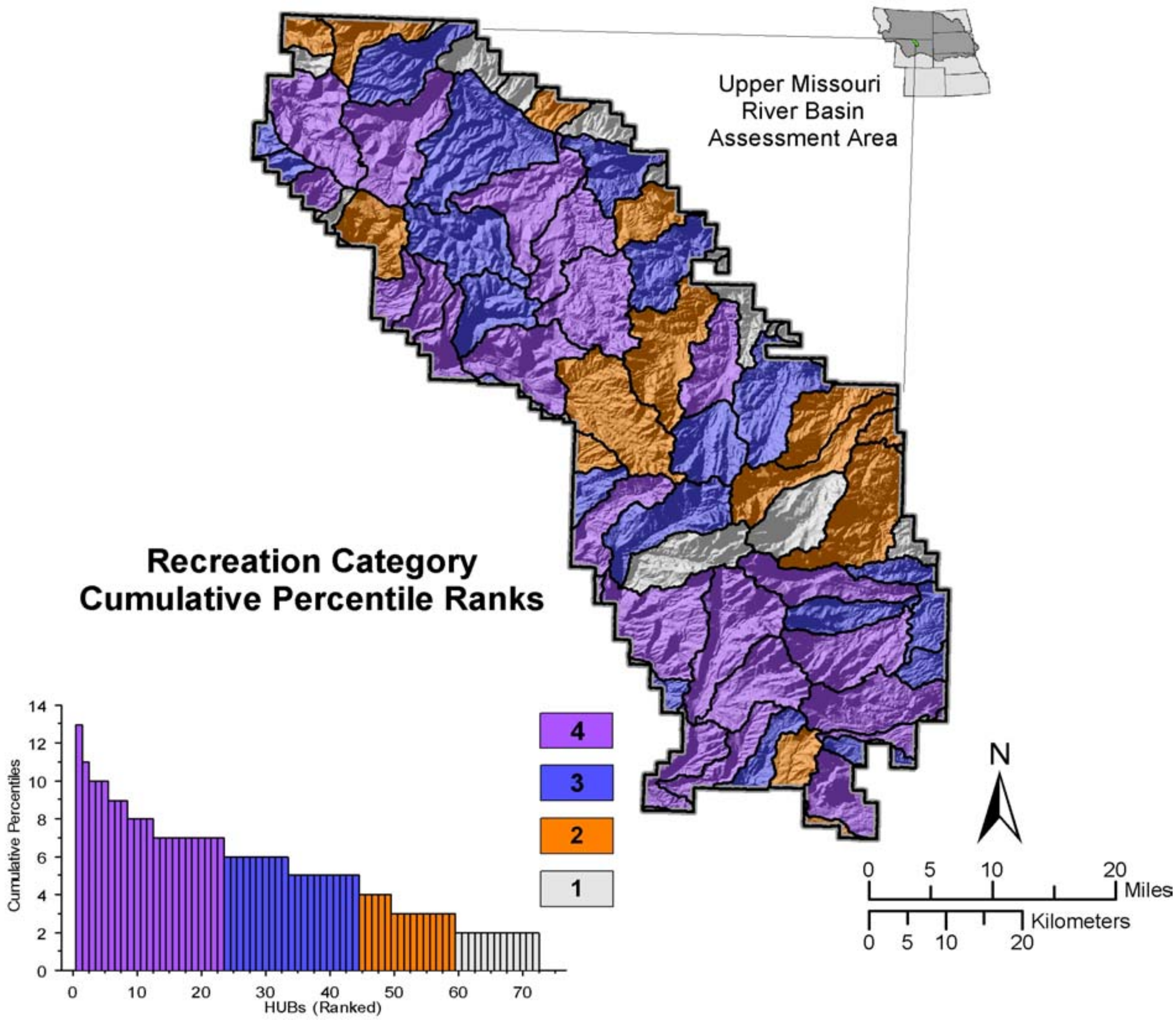

Figure 4.24. Recreation category showing cumulative percentile rankings.