

Sam Houston National Forest Roads Analysis Report

1. The Roads Analysis Process (Step 1)

1.1 Introduction

Roads analysis is an integrated interdisciplinary approach to transportation planning, addressing both existing and proposed roads. It makes no decisions nor does it allocate resources for specific purposes. Roads analysis provides information for decision making by examining important issues related to roads. Road analysis helps implement forest plans by identifying road management issues, concerns, and opportunities to be addressed. The analysis process can also identify any needs for changes in forest plans.

A roads analysis can be conducted at various scales, ranging from the forest-scale (this analysis) to the smaller watershed and project-scales. The results of each level of analysis, in terms of the issues addressed, the information sources used, and the scope of the recommendations offered, will differ in detail, but should be consistent and integrated across analysis scales.

Since this analysis is a broad forest-scale analysis, individual roads were not analyzed. The forest roads system as a whole was reviewed. Site-specific road issues, concerns, and opportunities will be identified and addressed during smaller project-scale analyses. The issues, concerns, and recommendations identified at the forest-scale serve as a guide for analyses conducted at the smaller project-scales.

This forest-scale analysis will help identify issues, concerns, and opportunities for proposed management actions that may be considered in subsequent site-specific project-scale analyses. The goal of this roads analysis is to evaluate the existing road system on the Sam Houston National Forest (NF), to update the road atlas and associated road data, and to determine internal and external issues from an ecological, social, and economic perspective. This analysis was based on the existing transportation system, existing forest plan resource allocations and direction, and current budget trends.

This forest-scale roads analysis provides a guide for more site-specific project-scale analyses.

1.1.1 Background

In 1999, the Washington Office of the USDA Forest Service (FS) published Miscellaneous Report FS-643 titled *"Roads Analysis: Informing Decisions about Managing the National Forest Transportation System"*. The objective of roads analysis is to provide decision-makers with critical information to develop road systems that are safe, provide for resource management needs, are responsive to public needs, are affordable, and minimize adverse environmental effects.

On January 12, 2001, the Forest Service adopted a final policy governing the national forest transportation system. The intended effects of this final policy, and accompanying amended 7700 Manual direction, are to ensure that decisions to construct, reconstruct, or decommission roads will be better informed by using a roads analysis, as described in Miscellaneous Report FS-643. A roads analysis may be completed at different scales, but generally begins with a broad forest-scale analysis to provide a framework for future analyses.

1.2 The Process

The roads analysis process described in Miscellaneous Report S-643 includes six steps for producing information and maps for decision-makers. Although the analysis consists of six sequential steps, the process may necessitate revisiting steps as information is compiled during the analysis process. The amount of time and effort spent on each step will differ, based on site-specific situations and available information. The six steps in the process are:

- Step 1. Setting up the analysis.
- Step 2. Describing the situation.
- Step 3. Identifying issues.
- Step 4. Assessing benefits, problems, and risks.
- Step 5. Describing opportunities and setting priorities.
- Step 6. Reporting.

1.3 Scope of the Analysis

A roads analysis can be conducted at multiple scales, ranging from the forest-scale to the smaller watershed and project scales. The issues generated and the recommendations offered are to be commensurate with the level of the detail at which the analysis is conducted. It is important to emphasize that roads analysis in itself does not result in a decision, but provides information to support decisions by disclosing important social, economic, and ecological issues and effects relevant to road management proposals. Actual road management decisions made by responsible officials must be disclosed in appropriate National Environmental Policy Act (NEPA) documents.

This forest-scale analysis focuses on the public road system serving the Sam Houston NF including Federal, State, and County roads. The term “Forest Service Road”, as used throughout this report, is synonymous with the term “National Forest System Road”² (see Appendix L *Glossary* for definitions). In addition, a “public road” refers to roads which are open to public use. Forest Service (FS) roads maintained to Maintenance Level (ML) 3, 4, or 5 are suitable for public travel in a low-clearance vehicle (passenger car). Only FS roads are assigned a maintenance level. See the *2.2.2 Maintenance Levels* section and Appendix E *Maintenance Levels* table for more information. This forest-scale analysis will only address the public State, County, and ML-3, 4, and 5 FS roads.

The ML-1 and ML-2 FS roads and unclassified roads will be analyzed during subsequent site-specific project-scale planning. The individual ML-1 and ML-2 FS roads will be evaluated to determine if the Road Management Objective is appropriate and if the road should be maintained, reconstructed, relocated, or decommissioned. The unclassified roads will be inventoried and evaluated to determine whether the roads should be classified as ML-1 or ML-2 roads or obliterated. The individual ML-3, 4, and 5 FS roads may also be re-evaluated at this time.

1.3.1 Analysis Area Boundaries

The boundaries of this roads analysis area will be the transportation planning boundaries for the Sam Houston NF. The boundaries will encompass the State highways, County roads, and FS roads serving the national forest lands and adjacent private lands, corporate timberlands, and associated public and private developments. The boundaries will be U.S. Highway 59 on the east, State Highways 150 and 156 on the northeast, State Highways 19 and 30 on the northwest, State Highway 1486 on the west and State Highway 105 on the south. I-45, the primary north-south route from Houston, splits the Sam Houston NF into western and eastern halves.

² A classified forest road under the jurisdiction of the Forest Service. The term “National Forest System Roads” is synonymous with the term “forest development roads” as used in 23 U.S.C. 205.

1.3.2 Analysis Objectives and Reporting

The product of a forest-scale roads analysis is a report for decision-makers with accompanying maps. The report provides information, identifies issues, and describes opportunities to consider in subsequent project-scale decisions.

This forest-scale roads analysis report will provide the following information:

- Inventory and atlas of the forest roads³ system including State, County, and ML-3, 4, and 5 FS roads on the Sam Houston NF.
- Identify forest roads system issues to be addressed in project-scale analyses.
- Identify forest roads system opportunities within the context of existing land and resource management direction for the Sam Houston NF.
- Identify significant social and environmental issues, concerns, and opportunities to be addressed in subsequent project-level decisions.
- Document coordination efforts with other government agencies and jurisdictions.

This report contains the following sections:

Executive Summary

1. The Roads Analysis Process (Step 1).
2. The Existing Road System (Step 2).
3. Identification of Significant Issues (Step 3).
4. Assessment of Issues (Step 4).
5. Recommendations, Opportunities, and Priorities (Step 5).

References

Appendices

- A. Maps of Forest Roads.
- B. State Highways.
- C. County Road Cooperative Agreements.
- D. Forest Service ML-3, 4, and 5 Roads.
- E. Maintenance Levels.
- F. Traffic Service Levels.
- G. Road Management Objectives.
- H. Summary of Current *Plan* Direction.
- I. Assessment of Issues (Step 4).
- J. Assessment of Road Stream Crossings (October 29, 2000 2600 Memo).
- K. Public Involvement.
- L. Glossary

1.4 Information Needs

This analysis will use existing sources of information. The Geographic Information System (GIS) spatial information and corresponding INFRA (Infrastructure) descriptive information will be reviewed, corrected, and updated to include all State, County, and ML-3, 4, and 5 FS roads on the forest roads system.

³ "Forest Roads" as defined in Title 23, Section 101 of the United States Code (23 U.S.C. 101), are any roads wholly or partially within, or adjacent to, and serving National Forest System lands and which are necessary for the protection, administration, and utilization of National Forest System lands and the use and development of its resources. (See Appendix L *Glossary* for definitions.)

1.4.1 Public Involvement

A letter was mailed to Federal, State and County government agencies, and other interested parties to solicit comments during this process. See Appendix K *Public Involvement* for a copy of the letter and a list of the government agencies and other interested parties to whom the letter was mailed.

Since many of the roads serving national forest and adjacent private lands are County roads, County Commissioners were identified as important contacts for public involvement. County Commissioners conduct the County road management and maintenance. Those whose precincts contain national forest lands were contacted. The County Judges of those counties were also contacted. Both officials have the knowledge needed to identify mutual concerns and opportunities.

Since many State roads also serve as arterial roads for the forest roads system, the Texas Department of Transportation (TXDOT) was contacted to solicit comments.

1.4.2 Interdisciplinary Team (IDT) Members and Participants

The members of the IDT and their duties are:

- | | |
|-----------------------|----------------------------|
| 1. Don Benner | Team Leader |
| 2. Steven Lewis | Transportation Planner |
| 3. Debra Hooks | GIS Assistant |
| 4. Paul Dufour | Forester |
| 5. Stan Gilstrap | Engineering Technician |
| 6. George Willard | Civil Engineer |
| 7. LaDonna Buhlig | GIS Specialist |
| 8. Terry Terry | INFRA Specialist |
| 9. Dave Peterson | Fisheries Biologist |
| 10. Rodney Peters | Soil Scientist |
| 11. Eddie Taylor | Wildlife Biologist |
| 12. Catherine Albers | Recreation Program Manager |
| 13. Nancy Snoberger | Landscape Architect |
| 14. Stephen Clarke | Entomologist |
| 15. Converse Griffith | Botanist |
| 16. Belinda Yount | Special Uses |
| 17. John Ippolito | Archeologist |
| 18. Ron Haugen | Fire Management Officer |

2. The Existing Road System (Step 2)

2.1 The Existing Road System

The road system on the Sam Houston NF is composed of State, County, and FS roads and serves as access for a variety of public, private, and national forest management needs. The roads are needed,

- for access to national forest lands,
- for access to adjoining private lands and corporate timberlands, and
- for access to adjoining residential areas,

and are considered part of the forest roads system. As footnoted earlier, Title 23, Section 101 of the United States Code (23 U.S.C. 101), defines "Forest Roads" as any road wholly or partially within, or adjacent to, and serving National Forest System lands and which is necessary for the protection, administration, and utilization of National Forest System lands and the use and development of its resources. See Appendix L *Glossary* for definitions.

The Final Environmental Impact Statement (FEIS) for the 1996 Revised Land and Resource Management Plan (the *Plan*) states (p136),

“With State, County, and Forest Service routes, a transportation system now exists that meets the need for access into most areas. The transportation system varies in its ability to meet expected needs and demands on the current condition of each facility and its intended use. The current inventory contains all arterial and collector roads needed for administration on the NFGT. However, some of these roads exist at a standard lower than needed to meet safety requirements and access needs of the NFGT and rural and urban neighbors.”

The forest roads system varies in its ability to provide for different traffic and demands depending on the current condition of the roads and the type of traffic use. Road standards vary from two-lane high-speed State highways to single-lane dirt roads barely passable with low-clearance passenger cars.

The public roads that are maintained for use by low-clearance passenger cars are the focus of this forest-scale roads analysis. These include the State Highways, County roads and ML-3, 4, and 5 FS roads open to public uses which serve national forest lands.

These roads are comprised mostly of State and County roads. The State and County roads comprise about three-quarters (71 percent) of the forest roads system addressed in this analysis. See Table 2 and Figure 1.

Table 2. Composition of Forest Roads System (SHNF)

Jurisdiction	Miles	Percentage
State	355	50%
County	148	21%
Forest Service (ML-3, 4, 5)	207	29%
Total	710	100%

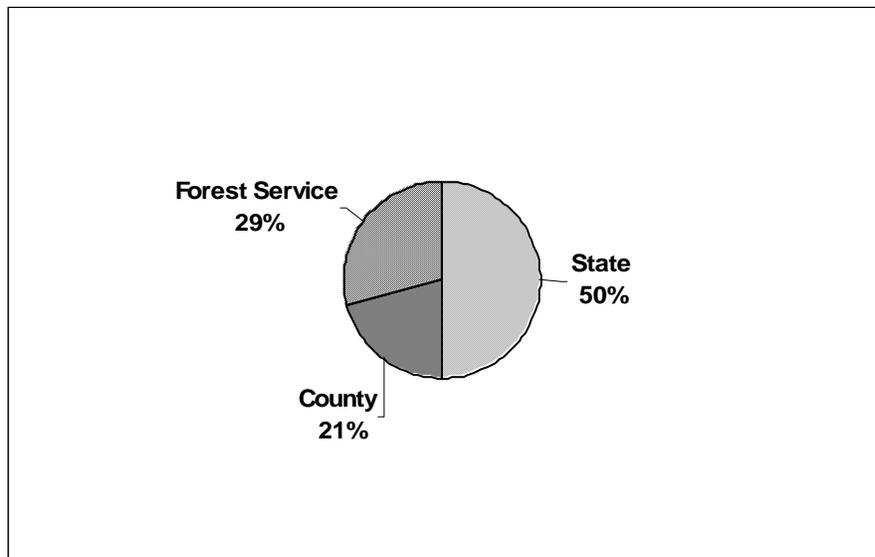


Figure 1. Roads by Jurisdiction (SHNF)

2.1.1 History of Road Development

The Sam Houston National Forest (SHNF) lies in Walker, Montgomery, and San Jacinto Counties in southeast Texas. The SHNF is named in honor of General Sam Houston, Commander of the Texas forces during the Texas Revolution and first President of the Republic of Texas. His home was at Huntsville, Texas on the northern part of the national forest.

Most of the major roads serving the national forest lands are State Highways or County roads open to public traffic that existed before the Sam Houston NF was established.

The first settlers in the area settled alongside the rivers. The soil was fertile and the rivers could be used for transportation. Commerce with Gulf Coast ports was conducted by flatboat and steamboat via the San Jacinto and Trinity Rivers.

The present road system has evolved primarily through timber harvesting operations starting when the timber industry moved to the south from the Great Lakes Region in the late 1800s. Sawmill development and logging came slowly to this area. But, with the publication of a bulletin in 1880 extolling the volumes of timber available for harvest, logging activity increased.

An influx of land speculators and lumber companies entered the east Texas area in the early 1900s. Large scale lumber manufacturing began in the early 1900s. During this period, land speculators and lumber companies began purchasing large tracts of timberland. The virgin timber was logged by building narrow gauge railroad or tram lines into the timberlands. The main rail lines were constructed along with additional spur lines to tap most of the stands of pine timber for the mills. Steam skidders mounted on rail cars pulled logs to the rail sides with heavy cables. The logs were loaded on flat cars and hauled to the mills for sawing into lumber. The remains of some of these old tram lines are still visible. Some road routes follow the routes of the old logging railroads and trams. As the merchantable timber was cut out, the large sawmills began to close.

Extensive logging in this area began in 1893 when C.D. Oliphant constructed a mill at Elmina, 12 miles south of Huntsville. This mill ownership changed several times, with the capacity increasing with each change of ownership. From 1911 to 1932, when the mill burned, it was operated by the Walker Lumber Co.

In 1906, the Foster Lumber Co. erected a double band sawmill seven miles west of Cleveland, establishing the town of Fostoria. In 1922, a railroad was built to the north of the mill, but it was abandoned in 1935 when Fostoria Lumber Co. lands were sold to the Forest Service.

In 1915, the Delta Land and Timber Co. erected a double band sawmill. In 1935, the mill was bought by the Conroe Lumber Corporation which operated it for a short period of time before disbanding it.

As the merchantable timber was cut out and the sawmills ceased operations, the cost of holding the logged land became a financial burden. In the midst of the Great Depression, it was difficult to find buyers with the ability to finance a large land acquisition. At this point, there was an opportunity to offer the lands to the federal government.

In 1933, the Governor of the State of Texas signed a resolution urging the purchase of land as National Forest. The first options on land were taken in 1934. In 1935-36, the Forest Service bought all the lands within the proclaimed boundary owned by the following three large land owners: Delta Land & Timber Co. (81,000 acres), Foster Lumber Co. (32,000 acres), and Gibbs Bros & Co. (22,000 acres) constituting most (83%) of the present national forest acreage.

The acquired timber stands were in very poor shape. Most of the acquired lands had been cut over at least once, generally to a 10" diameter limit. There were no provisions made for reforestation.⁴

The Sam Houston NF was proclaimed a National Forest by President Franklin Roosevelt in 1936.

The Sam Houston NF lands are scattered and intermingled with private lands and corporate timberlands. The national forest lands comprise only one-third (33%) of the lands within the proclaimed boundaries of the Sam Houston NF.

Roads were constructed or reconstructed by the Civilian Conservation Corps (CCC) in the 1930s. The CCC began extensive road building in 1933, prior to establishment of the national forest, and received more impetus in 1936 when the national forest was established.

Transportation Plans for the Sam Houston NF were approved on April 7, 1945 and on December 7, 1950. These Plans were prepared in accordance with instructions issued by the Washington Office on March 29, 1939. The 1950 Transportation Plan stated,

"The primary State highways through and around the National Forest serve as a skeleton base on which to build the system of development roads necessary to the protection, administration, and use of the Forest."

Those State highways were designated as Forest Highways.

In the 1950s, there was increased demand for timber to support the post World War II building boom. From 1950 - 1959, the average volume of timber harvested from the Sam Houston NF increased to about 20 million board feet annually with a corresponding increase in road construction and reconstruction. Many roads were constructed and reconstructed from 1950 - 1995 in support of a timber management program which continued to harvest an average of about 20 million board feet annually.

In 1969, the construction of a dam on the West Fork of the San Jacinto River by the San Jacinto River Authority brought changes to the area. The resulting 20,985 acre Lake Conroe split the western half of the Sam Houston NF (west of I-45) and flooded some of the most productive sites, particularly those best suited for growing bottomland hardwoods. The lake brought an increase in recreation use and a change in the predominant type of forest user. The lake led to the construction of developed recreation sites. There were also residential subdivisions and recreation sites developed on intermingled private lands.

In 1974, the Forest Service discussed right-of-way needs and road maintenance responsibilities with the Counties. The Forest Service requested that the Counties legally describe their road system so that the roads used for access by the Forest Service would be on a public road system. Since that time, the counties have passed resolutions declaring the County roads as public roads and, thereby, guaranteeing the Forest Service access. Also discussed in 1974, were possible cooperative agreements concerning road maintenance. Roads were identified, both County and FS roads, that provide access to national forest lands. In 1977, the first cooperative agreements were signed by the Counties. Cooperative agreements enable the Forest Service and the County to assist one another with the improvement and maintenance of roads not under their jurisdiction.

Over the past 100 plus years, an extensive forest roads system has developed to serve public, private, and national forest resource management and administrative needs; as well as provide access to adjacent private lands and corporate timberlands.

⁴ *Timber Management Plan* for the Sam Houston NF approved by Chief Lyle F. Watts on August 1, 1950

In the past, the local population derived their livelihood from cattle, farming, and timber. However, this situation is dramatically changing. The population and the land use is becoming more urban. The overwhelming influence on the area is the growth of the Houston metropolitan area. Much of the intermingled private land is being developed for subdivisions. An increasing percentage of the residents live adjacent to the National Forest and commute to jobs in Houston, Conroe, or Huntsville.

As a result of the increasing recreation use from urban residents, the Lone Star Chapter of the Sierra Club has cooperated with the Forest Service to locate and maintain the 128 mile long Lone Star Hiking Trail (LSHT). There are portions of the trail that follow road rights-of-way. The LSHT has been designated a National Recreation Trail.

Limited road maintenance funds have made the maintenance of existing FS roads a challenge. The limited funds have usually been inadequate to maintain the entire forest road system to desired standards.

2.1.2 The Transportation Atlas

The Forest Transportation Atlas is a dynamic collection of geo-spatial, tabular and other data for roads, trails, and airfields to support analysis needs for resource management objectives identified in land management plans. The Forest Road Atlas is a component of the Forest Transportation Atlas dealing with roads.

The Forest Roads Atlas consists of electronic road data including GIS geo-spatial information and associated INFRA descriptive information. The tables and maps in this report were derived from this GIS and INFRA road data.

Road data can exist in many forms including:

- maps of roads (paper or digital electronic format)
- databases such as descriptive INFRA road data
- surveys such as road condition surveys
- road right-of-way easements or other court records
- road use agreements or permits
- road maintenance plans (annual or deferred road maintenance plans)
- road maintenance cost records
- transportation plans and roads analyses RAP reports
- Road Management Objectives.

2.1.3 The Minimum Forest Road System

An important part of roads analysis is to identify the minimum forest road system that is necessary for the protection, administration, and utilization of national forest lands and the development and use of national forest resources. However, the minimum forest road system can not be completely identified during this forest-scale roads analysis because ML-1 and ML-2 FS roads will be addressed during more site-specific project-scale analysis.

The FEIS for the *Plan* says (p136),

“With State, County, and Forest Service routes, a transportation system now exists that meets the need for access into most areas.”

The minimum forest road system consists of the existing State, County, and ML-3, 4, and 5 FS roads addressed in this forest-scale roads analysis; as well as, the existing ML-1 and 2 FS roads which will be addressed in more site-specific project-scale roads analyses. However, subsequent

site-specific project-scale roads analyses may determine that certain existing roads are no longer needed or that certain additional roads are needed.

As stated earlier, the analysis of the balance of the forest roads system (including ML-1 and 2 FS roads) will be addressed during more site-specific project-scale planning.

2.1.4 Forest Highways

The Forest Highway System includes major State, County, and FS roads that are within and adjacent to the proclaimed national forest boundary. These Forest Highways provide access to the national forest lands and the intermingled private lands and corporate timberlands. There are 22 Forest Highways designated under the Public Lands Highways Program of the Transportation Equity Act for the 21st Century (TEA21) on the Sam Houston NF roads system. The Federal Highway Administration (FHWA), FS, TXDOT and, where appropriate, Counties jointly designate Forest Highways. There are about 169 miles of Forest Highways on the Sam Houston NF roads system and most, about 100 miles (60 percent), of these Forest Highways are State Highways. See Table 3 below for a list of the Forest Highways. These Forest Highways qualify for federal funding for improvement and enhancement. The FHWA, FS, and TXDOT jointly select projects to be included in the Forest Highway program. Forest Highway funding can be used for the planning, design, and reconstruction of these designated routes. Other work can include parking areas, interpretive signing, acquisitions of scenic easements or sites, and sanitary and water facilities.

Our review of the Forest Highways on the forest roads system generated two recommendations.

- Forest Highway 207: The 2.9 mile segment of the old Dodge Road across private lands south of US-190 is no longer on the Walker County road system. It may be impassable to public use. The 5.0 mile segment of the old Dodge Road from US-190 south to FS 246 should be deleted from Forest Highway 207 and the FS 246 road should be added. This route change will provide interconnected Forest Highways open to public use between TX-150 and US-190.
- Consider adding the 16 miles of FM 2025 between Cleveland, TX and Coldspring, TX to the Forest Highway system. The addition of FM 2025 to the Forest Highway system would interconnect the Forest Highways on the eastern side of the Sam Houston NF.

(Insert Sam Houston NF Forest Highways Map)

Table 3. Forest Highways (Sam Houston NF)

Forest Highway No.	Road ID	Road Name	Begins	Ends	Length	Jurisdiction
29	FM 1375		FM 149	200	15.0	State
31	FM 2693	Brandy Creek Rd	TX-150	FM 2778	3.9	State
52	FM 2666	Big Creek Rd	TX-150	FM 2025	7.4	State
70	FM 149	Richards Montgomery Rd	FM 1097	Richards City Limits	13.5	State
71	FM 1097		FM 149	MTG-Bethel Rd	1.6	State
71	MTG-Bethel	Bethel Rd	FM 1097	FM 149 / FM 1791	4.6	Montgomery Co.
72	FM 1791		FM 149	FS Boundary	4.5	State
73	FM 1374	Possum Walk Rd	McDonald Creek Rd	I-45	8.3	State
74	FM 2296	Phelps Rd	US 190	US 75	7.4	State
75	FM 2929	Four Notch Rd	US 190	FM 2296	4.1	State
76	FM 1725	Maynard Grady Rd	TX-150	TX-105	20.4	State
77	FM 945	Evergreen Cleveland Rd	TX-150	FM 2025	13.3	State
200	200	Boswell Creek Rd	206	WLK-Four Notch Rd	2.5	FS
202	JAC-John Warren	John Warren Rd	TX-150	202	1.7	San Jacinto Co.
202	202	Big Woods Rd	JAC-John Warren Rd	207	5.9	FS
204	204	Caney Creek Rd	FM 1375	Lake Conroe	5.0	FS
206	WLK-Watson Lake	Watson Lake Rd	FM 2296	WLK-Three Notch Rd	1.6	Walker Co.
206	WLK-Three Notch	Three Notch Rd	WLK-Watson Lake Rd	206	1.8	Walker Co.
206	206	Phelps Rd	WLK-Three Notch Rd	200	3.1	FS
207	207	Dodge Rd	JAC-Big Woods Rd	County Line	4.7	FS
207	207	Dodge Rd	County Line	246	1.8	Walker Co.
207	246	Watergate Rd	207	206	0.8	FS
208	208	County Line Rd	215	FM 1791	6.3	FS
215	215	Stubblefield Lake Rd	FM 1375	WLK-Stubblefield Lake Rd	2.9	FS
215	WLK-Stubblefield Lake Rd	Stubblefield Lake Rd	215	FM 1374	2.2	Walker Co.
217	217	Big Creek Rd	TX-150	221	2.8	FS
221	221	Red Rd	FM 2025	JAC-221	7.2	FS
221	JAC-221	Red Rd	221	US 59	2.4	San Jacinto Co.
234	234	Hostetter Lake Rd	FM 1375	Lake Conroe	4.5	FS
274	274	Mercy Rd	FM 945	JAC-Fostoria Tram	1.8	FS
274	JAC-Fostoria Tram	Fostoria Tram Rd	274	MTG-Fostoria Tram	4.4	San Jacinto Co.
274	MTG-Fostoria Tram	Fostoria Tram Rd	JAC-Fostoria Tram	TX-105	1.6	Montgomery Co.

2.1.5 Public Forest Service Roads (PFSR)

Some FS roads are “open to public traffic” and appear similar to the State and County roads. These FS roads have a similar function and accommodate similar traffic volumes as the lower standard single and double-lane State and County roads. Many of the State and County roads are eligible to receive funding from the Highway Trust Fund and other state or local funds. However, most FS roads do not meet the funding criteria of these funding programs.

As a public road agency, the Forest Service is designating FS roads that,

- will be open to public traffic on a regular and consistent basis, and
- provide critical access to recreation sites and areas

as Public Forest Service Roads (PFSR). These roads will meet all the requirements for “public roads” as defined in 23 U.S.C. 101.⁵

The goals of the PFSR program are to:

1. Provide safe and efficient access to destinations in the National Forests and Grasslands;
2. Provide a seamless road system between State and County roads and sites on the National Forests and Grasslands;
3. Reduce soil erosion and improve water and air quality; and
4. Encourage economic development of rural communities through development of roads.

The PFSR program will complement the Forest Highway program and provide public access to points beyond the Forest Highways. Most Forest Highways are State highways; however, most Public Forest Service Roads are FS roads. The Forest Service PFSR program identifies roads meeting PFSR criteria and estimates the amount of road work and funding required to bring individual roads up to safe, environmentally sound standards. There are 12 PFSR roads designated on the forest roads system. See Table 4 below for a list of the Public Forest Service Roads on the Sam Houston NF. Note that the reconstruction of the Stubblefield Road is the top PFSR priority on the National Forests and Grasslands in Texas.

Table 4. Public FS Roads (SHNF)

Road ID	Road Name	Length	Estimated Cost	NFGT Priority
215	Stubblefield Lake Rd	5.4	\$ 8,162,000	1
	WLK-Stubblefield Lake Rd			
234	Hostetter Lake Rd	3.7	\$ 4,555,000	6
200	Boswell Creek Rd	18.5	\$16,200,000	10
202	Big Woods Rd			
206	Phelps Rd			
207	Dodge Rd			
208	County Line Rd	6.3	\$ 3,060,000	11
274	Mercy Rd (Shell Rd)	2.4	\$ 2,748,000	15
274A	Mercy Spur			
205	Cagle RA	1.5	\$ 1,210,000	20
217	Big Creek SA	2.8	\$ 2,200,000	24
221	Red Rd	9.6	\$ 6,980,000	26

⁵ U.S. Department of Agriculture, Forest Service. Public Forest Service Roads. 2000. Washington, DC.

(Insert Sam Houston NF Public Forest Service Roads Map)

2.2 Road Attributes

2.2.1 Functional Classification

Roads can function as arterial, collector, or local roads. The classification of a road as arterial, collector, or local is dependent on the scope of the analysis. For example, if the scope of the analysis were nationwide, only interstate highways would be classified as arterial roads. The FSH 7709.54 - Forest Transportation Terminology Handbook defines these functional classes as follows:

Arterial Road: A road that serves as access to and through large land areas. Arterial roads are usually state roads or public highways.

Collector Road: A road that serves smaller land areas than an arterial road. Collector roads serve all types of traffic and usually connect arterial roads to local forest roads or terminal sites.

Local Road: A forest road that connects terminal sites with collector or arterial roads. Local roads are generally shorter roads and usually serve specific users or activities.

The FEIS for the *Plan* says (p136),

“The current inventory contains all arterial and collector roads needed for administration on the NFGT.”

The **Arterial** roads are primarily State highways; the **Collector** roads are composed of State, County and FS roads; and the **Local** roads are primarily County and FS roads.

Of the ML-3, 4, and 5 FS roads on the Sam Houston NF, 0 percent are **Arterial** roads, 22 percent are **Collector** roads, and 78 percent are **Local** roads. Most of the FS roads addressed in this analysis are Local roads. See Table 5 and Figure 2 below. The **Arterial** roads are typically two-lane paved roads connected to State Highways. The **Collector** roads are typically two-lane gravel roads connected to State Highways or County roads. The **Local** roads connect forest sites (e.g., campgrounds, trailheads, and logging sites) with Collector roads or Arterial roads.

Table 5. Functional Class of Roads by Jurisdiction (SHNF)

Jurisdiction	Functional Class			
	Arterial	Collector	Local	Total
State	70%	30%	0%	100%
County	0%	58%	42%	100%
Forest Service (ML-3, 4, & 5)	0%	22%	78%	100%

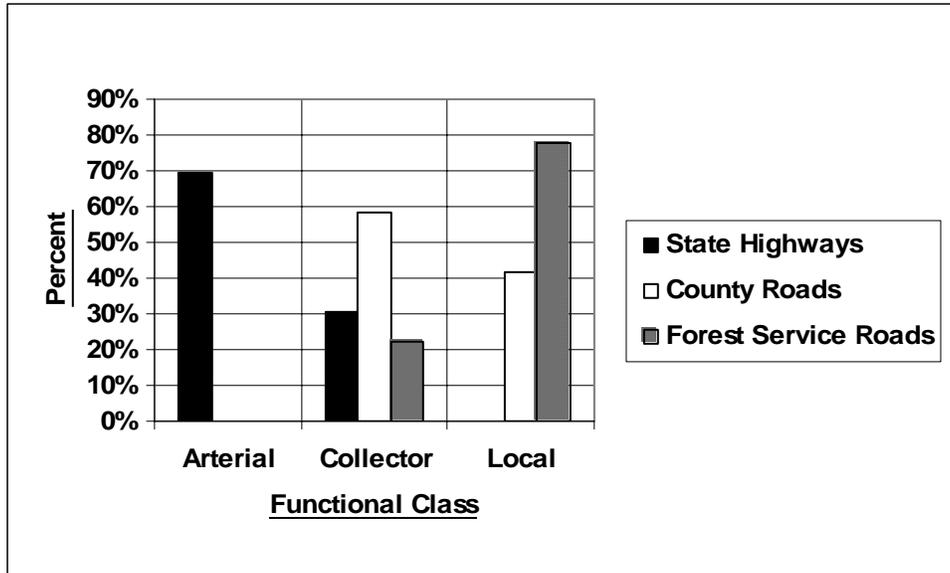


Figure 2. Functional Class by Jurisdiction (SHNF)

The three principal attributes of FS roads are,

- the road maintenance level,
- the road surface type, and
- the road closure status.

These attributes best characterize a road in terms of its suitability for public and administrative use and the degree of user safety and user comfort associated with its use.

2.2.2 Maintenance Levels (ML)

Roads are maintained to different levels depending on land and resource management objectives; user safety; volume and composition of traffic; traffic speed; road surface type; and user comfort. Maintenance levels describe the level of maintenance service provided and required for a specific road, and must be consistent with Road Management Objectives (RMOs). Maintenance levels are determined from information provided in the RMO established for each road.

Road Management Objectives (RMOs) are discussed in detail under [2.3 Road Management Objectives](#).

Roads may be maintained at one level, but planned to be maintained at a different level in the future. The maintenance levels can be either “operational” maintenance levels or “objective” maintenance levels.

Operational Maintenance Level: The maintenance level currently assigned to a road considering the current traffic, road condition, budget constraints, and environmental concerns. In other words, it is the level to which a road is currently being maintained.

Objective Maintenance Level: The maintenance level to be assigned at a future date considering future road management objectives, anticipated traffic, budget constraints, and environmental concerns.

The **objective maintenance level** may be lower than, the same as, or higher than the **operational maintenance level**. Roads may be currently maintained at one level, while planned for maintenance at a different level at a future date.

The transition from an **operational maintenance level** to an **objective maintenance level** may be dependent on completion of road improvements, disinvestments (e.g. removal of improvements such as culverts), or activities (e.g. timber sales).

Maintenance levels are not assigned to State or County roads.

There are five maintenance levels (FSH 7709.58 – Transportation System Maintenance Handbook). See Appendix E for a tabular description of the general relationship between maintenance levels.

Maintenance Level 3, 4, and 5 roads provide access for all types of traffic (including low-clearance passenger car traffic). Table 6 and Figure 3 display the miles of ML-3, 4, and 5 roads under Forest Service jurisdiction. Most of the FS roads addressed in this analysis are ML-3 roads.

Table 6. Functional Class of FS Roads by Maintenance Level (SHNF)

Forest Service Roads Functional Class	Maintenance Level			
	3	4	5	Total
Arterial	0.0	0.0	0.0	0.0
Collector	41.0	1.8	2.9	45.7
Local	147.0	6.5	8.0	161.5
Total Miles	188.0	8.3	10.9	207.2

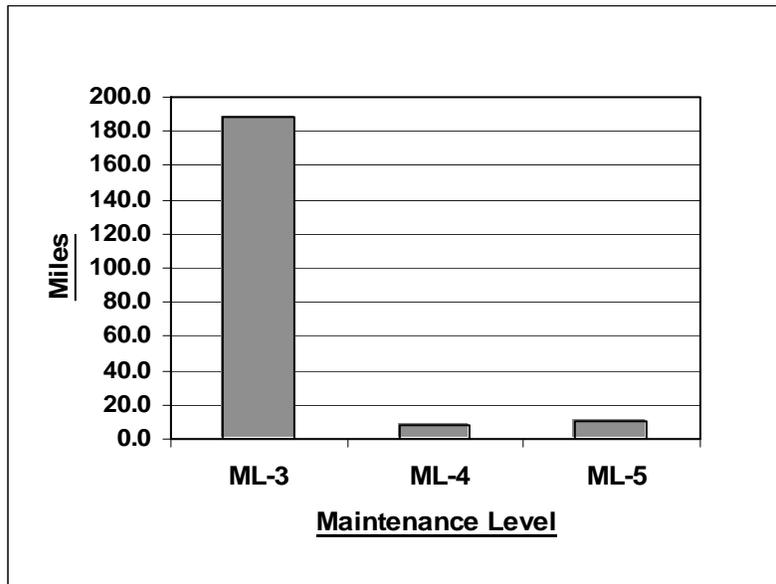


Figure 3. Maintenance Levels 3, 4, & 5 FS Roads (SHNF)

Table 7 displays the maintenance levels of all FS roads on the Sam Houston NF. (Note: Since ML-1 and ML-2 roads are not addressed in this analysis, this additional information is shown to provide a better perspective of the whole forest roads system).

Table 7. Percentage of Maintenance Level 1, 2, 3, 4, & 5 FS Roads (SHNF)

Maintenance Level	Percentage
1 – Closed to Vehicular Traffic	~ 57 %
2 – Suitable for High Clearance Vehicles	~ 8 %
3 – Suitable for Low Clearance Vehicles	32 %
4 – Moderate Degree of User Comfort	1 %
5 – High Degree of User Comfort	2 %

Examples and brief descriptions of the different road maintenance levels follow.

Maintenance Level 5



**Figure 4. FS Road 215 – Stubblefield Lake Road (SHNF)
Forest Highway / Public Forest Service Road
Bituminous Surface Treatment**

Level 5 is assigned to roads that provide a high degree of user comfort and convenience. These roads are normally double-lane, paved roads; but some may be aggregate surfaced.

The appropriate traffic management strategy is to "encourage" traffic. See Appendix E *Maintenance Levels* table. Maintenance Level 5 roads account for about 5 percent of the ML-3, 4, and 5 FS roads (about 2 percent of all ML-1, 2, 3, 4, and 5 FS roads). They are usually associated with highly developed recreation areas and would not be considered for decommissioning.

Maintenance Level 4



**Figure 5. FS Road 234 – Hostetter Lake Road (SHNF)
Forest Highway / Public Forest Service Road
Aggregate Surfaced**

Level 4 is assigned to roads that provide a moderate degree of user comfort and convenience at moderate travel speeds. Most roads are double-lane and aggregate surfaced; however, some roads may be single-lane. Some roads may be dust abated or paved. The most appropriate traffic management strategy is to "encourage" traffic. However, traffic management strategy may "prohibit" specific classes of vehicles or users at certain times. See Appendix E *Maintenance Levels* table. Maintenance Level 4 roads account for about 4 percent of the ML-3, 4, and 5 FS roads (about 1 percent of all ML-1, 2, 3, 4, and 5 FS roads). These roads are usually used for public access not related to use of national forest lands and would not be considered for decommissioning. These roads may be considered for transfer to County or State jurisdiction.

Maintenance Level 3



**Figure 6. FS Road 208 – County Line Road (SHNF)
Forest Highway / Public Forest Service Road
Aggregate Surfaced**

Level 3 is assigned to roads, open and maintained for travel by a prudent driver in a standard passenger car. User comfort and convenience are not considered priorities. Roads in this maintenance level are typically low speed, single-lane roads with turnouts and spot surfacing. Some roads may be fully surfaced with either native material or aggregate. Appropriate traffic management strategies are either "encourage" or "accept" traffic. However, traffic management strategy may "discourage" or "prohibit" specific classes of vehicles or users at certain times. See Appendix E *Maintenance Levels* table.

Maintenance Level 3 roads account for about 91 percent of the ML-3, 4, and 5 FS roads (about 32 percent of all ML-1, 2, 3, 4, and 5 FS roads) addressed in this analysis. These are the primary access roads to most national forest lands, used by the majority of forest visitors. Some of these roads are seasonally closed to public motorized traffic by gates. These roads would rarely be considered for decommissioning.

Although ML-1 and 2 roads are not addressed in this analysis, their descriptions follow.



**Figure 7. FS Road 234C – Hostetter Spur Road (SHNF)
Native Material**

Level 2 is assigned to roads suitable for use by high clearance vehicles. Passenger car traffic is not a consideration. Traffic is normally minor, usually consisting of one or a combination of administrative, permitted, dispersed recreation, or other specialized uses. Limited log truck traffic occurs at this level. The appropriate traffic management strategies are to either discourage or prohibit passenger cars or to accept or discourage high clearance vehicles. About 8 percent of all ML-1, 2, 3, 4, and 5 FS roads on the Sam Houston NF are maintained at this level. Many of these roads are seasonally closed to public motorized traffic by gates. Some of these roads may be considered for decommissioning in the future.

Level 1 is assigned to roads during the time the roads are closed to motorized traffic. The planned closure period must exceed one year. Basic custodial maintenance is performed to minimize damage to adjacent resources and to protect the road to facilitate future management activities. Emphasis is given to maintaining drainage structures. Planned road deterioration may occur at this level. The appropriate traffic management strategies are to "prohibit" and "eliminate" traffic.

Roads receiving ML-1 maintenance may be of any type, class, or construction standard, and may be managed at any other maintenance level during the time they are open for traffic. However, while being maintained at ML-1, roads are closed to motorized traffic; but may be open and suitable for non-motorized uses. The majority (about 57 percent) of all ML-1, 2, 3, 4, and 5 FS roads on the Sam Houston NF are currently maintained at ML-1. When not needed to provide access to accomplish specific objectives, roads may be maintained at this level in order to reduce

road maintenance costs or open road densities for wildlife habitat. Some of these roads may be considered for decommissioning in the future.

2.2.3 Type of Surfacing

Closely related to operational maintenance level are the types of surfacing found on forest roads. Road surface type is also an indicator of user comfort and, to a lesser degree, user safety. Road surfaces may consist of asphalt pavement, bituminous chip seal, crushed aggregate, improved native materials (pit-run aggregate), or native materials (dirt). Roads may be surfaced with other than native material for a variety of reasons. These include minimizing the potential for surface erosion and sediment production, stabilizing the road surface for all weather use, providing for increased user comfort or user safety, improving economy of operations, or any combination of these.

It is important to note that there are only limited sources of aggregate for roads in east Texas. For example, crushed limestone aggregate is usually shipped from central Texas by rail. However, local sources of other aggregate such as sandstone are available for road surfacing.

Table 8 displays the miles of different surface types on FS roads on the Sam Houston NF. Note that most ML-5 roads have a paved or bituminous surface, while most ML-3 roads have a crushed aggregate surface, and most ML-2 roads contain a native materials surface.

Table 8. Surface Type on FS Roads by Maintenance Level (SHNF)

Forest Service Roads	Maintenance Level				
Surface Type	1	2	3	4	5
Bituminous Treatment					1 %
Crushed Aggregate or Gravel	~ 5 %	~ 3 %	25 %	1 %	
Improved Native Material	~ 2 %	~ 1 %	4 %		
Native Material	~ 49 %	~ 5 %	4 %		

As shown in Table 9 and Figure 8, most of the FS roads addressed in this analysis are ML-3 roads with crushed aggregate surfacing.

Table 9. Miles of Surface Type on ML-3, 4, & 5 FS Roads (SHNF)

Forest Service Roads	Maintenance Level			
Surface Type	3	4	5	Total
Bituminous Treatment	1.7		10.7	12.4
Crushed Aggregate or Gravel	147.1	8.3	0.2	155.6
Improved Native Material	20.5			20.5
Native Material	18.7			18.7
Total Miles	188.0	8.3	10.9	207.2

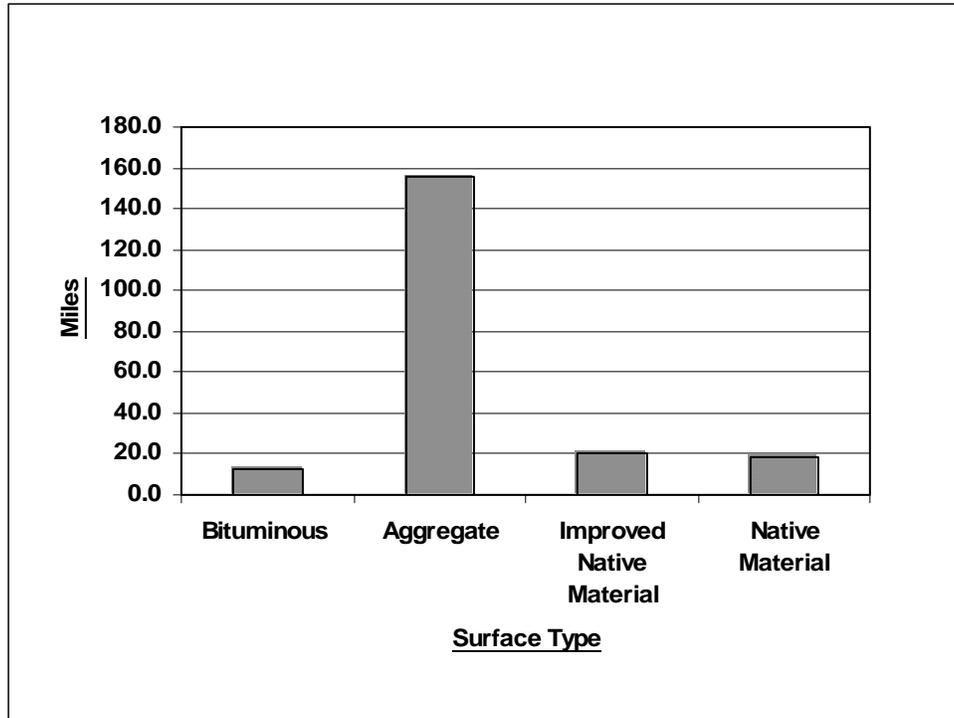


Figure 8. Surface Type on ML-3, 4, & 5 FS Roads (SHNF)

2.2.4 Road Closures

Road closures and road use restrictions are instituted when road use conflicts exist. These conflicts may include wildlife habitat protection, road surface erosion prevention and control measures, user safety, and other resource protection or public safety concerns. Closure periods may last anywhere from a few hours to years. Maintenance Level 1 roads, which are associated with intermittent periods of use, are typically closed year-round with gates or earthen barriers between periods of use. Maintenance Level 2 and 3 roads are occasionally closed seasonally with gates. Maintenance Level 4 and 5 roads are not normally closed.

2.2.5 Traffic Service Levels (TSL)

Traffic Service Levels (TSL) describe the road traffic characteristics and operating conditions. These levels are identified as a result of transportation planning activities.

Appendix F contains descriptions of the four different TSL for FS roads. The four different TSL are:

- A. Free Flowing with Mixed Traffic.
- B. Congested during Heavy Mixed Traffic.
- C. Flow Interrupted or Slowed by Mixed Traffic or Road Conditions.
- D. Single Use - Not Suitable for Mixed Traffic.

These TSL reflect traffic characteristics that influence the selection of road design criteria and describe the operating conditions for the road.

The TSL reflect a number of factors, such as speed, travel time, traffic interruptions, freedom to maneuver, user safety, user comfort, and operating cost. These factors, in turn, affect design elements, such as type of surface, number of lanes, lane widths, curve widening, sight distances, turnout spacing, design speed, horizontal and vertical alignment, and turnarounds. Table 10 displays the percentage of Traffic Service Levels of all FS roads on the Sam Houston NF.

Table 10. Traffic Service Level of FS Roads by Maintenance Level (SHNF)

Forest Service Roads Traffic Service Level	Maintenance Level				
	1	2	3	4	5
A – Free Flowing Mixed Traffic					<1 %
B – Congested During Heavy Traffic				<1 %	<1 %
C – Flow Interrupted or Slowed	~ 12 %	~ 1 %	18 %	<1 %	<1 %
D – Single Use	~ 45 %	~ 7 %	14 %		

Table 11 and Figure 9 display the miles of TSL of ML-3, 4, and 5 FS Roads on the Sam Houston NF. Most of the ML-3, 4, and 5 FS roads addressed in this analysis are ML-3 TSL-C or TSL-D roads.

Table 11. Miles of Traffic Service Levels of ML-3, 4, & 5 FS Roads (SHNF)

Forest Service Roads Traffic Service Level	Maintenance Level			
	3	4	5	Total
A – Free Flowing Mixed Traffic			5.1	5.1
B – Congested During Heavy Traffic	1.7	2.8	5.6	10.1
C – Flow Interrupted or Slowed	103.3	5.5	0.2	109.0
D – Single Use	83.0			83.0
Total Miles	188.0	8.3	10.9	207.2

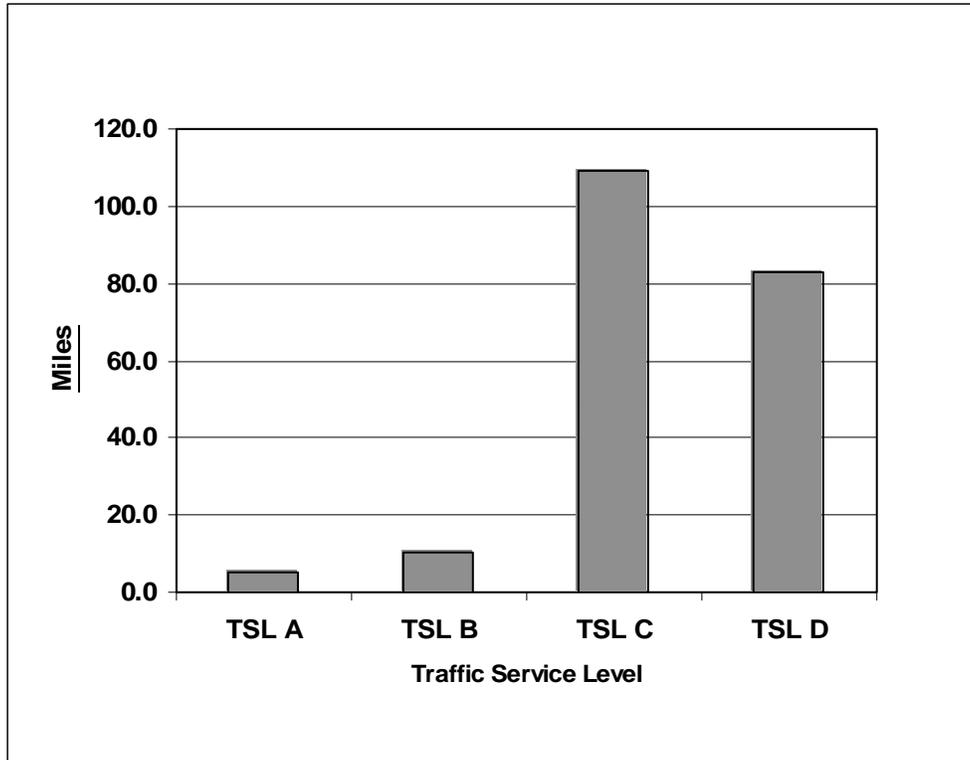


Figure 9. Traffic Service Levels of ML-3, 4, & 5 FS Roads (Sam Houston NF)

The above descriptions of road attributes shows that most of the ML-3, 4, and 5 FS roads addressed in this analysis are,

- ML-3 (suitable for low clearance passenger cars),
- surfaced with crushed aggregate, and
- TSL-C (slow flow) or TSL-D (single use).

2.3 Road Management Objectives (RMO)

A challenge for land and resource management is to provide adequate road access for various purposes while protecting the resources. Road Management Objectives (RMO) are developed to protect resources, provide for resource management access, and meet user needs. These needs are determined through the planning process and the objectives are approved by Line Officers (Forest Supervisor or District Ranger). The RMO describe the specific purpose of a road and provide design criteria for planned roads, as well as establish operation and maintenance criteria for planned or existing roads. The Forest Service road system is planned, managed, and maintained on the basis of the RMO established for each road.

Road Management Objectives (RMO) should be reviewed and re-evaluated during project-scale road analyses.

The RMO establish how we will endeavor to manage a road. The NFGT have established four generic RMO to use. See Appendix G for copies of the four generic RMO. However, the actual RMO developed for each road are based on site-specific resource requirements and may differ from established generic standards. The four generic RMO have been established for the following four groups of roads:

1. Maintenance Level 4 and 5 - Traffic Service Level A, B, and C Roads.
2. Maintenance Level 3 - Traffic Service Level C Roads.
3. Maintenance Level 2 - Traffic Service Level C and D Roads.
4. Maintenance Level 1 - Traffic Service Level D Roads.

The RMO is developed from land and resource management direction, *Plan* standards and guidelines, data concerning the type and extent of traffic to be served by the road, environmental constraints, and mitigating measures to be employed. This information is used to prepare specific objectives that define the purpose of the road and describe how the road will be designed, used, and maintained.

2.4 Road Maintenance Funding

Generally, the Sam Houston NF is receiving inadequate road maintenance funds. The road maintenance funds allocated are only about 14 percent of the estimated amount of funds needed.

From 1999 to 2002, the NFGT conducted road condition surveys on ML-3, 4, and 5 FS roads to determine annual and deferred maintenance needs based on existing conditions. Table 12. *Road Maintenance Funds Needed Annually* shows that about \$1.0 million is needed annually to fully maintain the ML-3, 4, and 5 FS roads on the Sam Houston NF. This is the average annual funding needed to maintain the roads at the “objective” maintenance level, not at the current “operational” maintenance level. See Appendix L *Glossary* for an explanation of terms. The costs include road maintenance activities such as surface blading, ditch cleaning, culvert cleaning, road surfacing repair and replacement, signing, vegetation removal, hazard tree removal, down tree removal, and road closure device repair. The costs also include other direct project costs, such as project management, contracting, and contract administration, and other indirect project costs.

Table 12. Road Maintenance Funds Needed Annually (SHNF)

Sam Houston NF			
Maintenance Level	Needed / Mile ¹	Miles	Total Needed
Maintenance Level 3	\$4,452	188.0	\$836,976
Maintenance Level 4	\$4,948	8.3	\$ 41,068
Maintenance Level 5	\$6,767	10.9	\$ 73,760
Total		207.2	\$951,804
NFGT			
Maintenance Level	Needed / Mile ¹	Miles	Total Needed
Maintenance Level 3	\$4,452	617.5	\$2,749,110
Maintenance Level 4	\$4,948	71.8	\$ 355,266
Maintenance Level 5	\$6,767	26.0	\$ 175,942
Total		715.3	\$3,280,318

¹ Average Western Gulf Coastal Plains' costs/mile (Texas, Louisiana, Mississippi).

Table 13. *Road Maintenance Funds Available Annually* displays the amount of road maintenance funds spent annually on the ML-3, 4, and 5 FS roads for the Sam Houston NF as compared to the NFGT as a whole.

Table 13. Road Maintenance Funds Available Annually (SHNF)

Sam Houston NF			
Fiscal Year	Fund Code	Expenditures ¹	% of Funds Needed
2000	(N/A) ²	(N/A) ²	
2001	CMRD-MT 04	\$132,557	14 %
2002	CMRD-CR 04	\$135,851	14 %
Average		\$134,204	14 %
NFGT			
Fiscal Year	Fund Code	Expenditures ¹	% of Funds Needed
2000	PAMR	\$552,835	17 %
2001	CMRD-MT	\$637,791	19 %
2002	CMRD-CR	\$715,025	22 %
Average		\$635,217	19 %

¹ Includes direct project and overhead expenditures.

² District allocations and expenditures were not split-out as separate accounts from NFGT accounts.

It is difficult to establish a general trend for road maintenance budgets because,

- for several years prior to FY 2001, the NFGT used a unified budget that did not split-out District allocations and expenditures as separate accounts, and
- fund codes changed every fiscal year from FY 2000 thru FY 2002.

Deferred maintenance is work that can be deferred without loss of road serviceability until such time as the work can be economically or efficiently performed. Deferred maintenance is most often associated with road surface replacement and drainage maintenance, followed by roadside brushing and signing maintenance. Based on the recent condition surveys, FS roads have culverts to be replaced, culverts to be cleaned, and ditches to be cleaned and reshaped. This road maintenance work should be given top priority to protect streams and associated aquatic ecosystems.

Due to reduced budgets and increased workloads due to reductions in the workforce, road signing has become a low priority, and has developed a big backlog of deferred work.

Table 14. *Deferred Road Maintenance Funds Needed* shows that about \$8.1 million is needed to complete the backlog of deferred maintenance to upgrade the ML-3, 4, and 5 FS roads to a standard that meets the “objective” maintenance levels. Most of this deferred road maintenance work involves,

- resurfacing roads for public safety, for resource protection, or for preserving road prism
- replacing culverts that are failing, that are prohibiting fish passage, or that are too small
- signing, and
- removing encroaching vegetation.

Table 14. Deferred Road Maintenance Funds Needed (SHNF)

Sam Houston NF			
Maintenance Level	Needed / Mile ¹	Miles	Total Needed
Maintenance Level 3	\$ 35,374	188.0	\$6,650,312
Maintenance Level 4	\$ 44,599	8.3	\$ 370,172
Maintenance Level 5	\$103,119	10.9	\$1,123,997
Total		207.2	\$8,144,481
NFGT			
Maintenance Level	Needed / Mile ¹	Miles	Total Needed
Maintenance Level 3	\$ 35,374	617.5	\$21,843,445
Maintenance Level 4	\$ 44,599	71.8	\$ 3,202,208
Maintenance Level 5	\$103,119	26.0	\$ 2,681,094
Total		715.3	\$27,726,747

¹ Average Western Gulf Coastal Plains' costs/mile (Texas, Louisiana, Mississippi).

This indicates that there is a big backlog of deferred road maintenance to bring ML-3, 4, and 5 FS roads up to the “objective” maintenance level standards.

The Forest Supervisor or District Ranger has authority to take different actions to deal with inadequate road maintenance budgets, such as reprogramming funds, entering cost-sharing agreements, transferring roads to other public agencies, reducing road maintenance levels, closing or decommissioning roads, etc. A conscious decision to either reduce the established maintenance level or close the road should be made to provide for public safety.

2.5 Road Density

The spatial distribution and arrangement of the roads system on the landscape determines their impact on a number of resources. Road density, usually expressed in terms of miles of road per square mile of landscape, may be an indicator of such effects as the potential for wildlife disturbance, habitat fragmentation, recreation opportunities, and the cumulative potential for erosion and sedimentation from road surfaces. Road density information is useful, but is also notoriously difficult to interpret. For example, the physical characteristics of roads vary. The State Highway right-of-ways are considerably wider than Forest Service roads. Further, some effects are associated with road use rather than the mere physical presence of roads. Confining the analysis to open roads may account for some of this difference, but road-use characteristics can change seasonally or periodically. In addition, it is often impossible to separate the effects of roads from the effects of changes in land uses that roads support. Road density information at the forest scale should be regarded as interesting and suggestive, but tenuous. Road densities are more properly evaluated at the project scale, where detailed information may be gathered pertaining to physical road characteristics and road use patterns. In order to maximize the validity of interpretations, the information gathered must be tailored very closely to the specific question or issue being addressed.

Table 15 displays the current road densities of State, County, and ML-3, 4, and 5 FS roads on all national forest lands on the Sam Houston NF including the Little Lake Creek Wilderness Area. Please note that the table does not include the ML-1 and ML-2 FS roads, unclassified FS roads, and private or other roads on national forest lands.

Table 15. Road Density on National Forest Lands (SHNF)

Jurisdiction	Miles	Miles / Square Mile
State	62.9	0.25
County	62.7	0.25
FS (ML-3, 4, 5)	195.0	0.8
Totals	320.6	1.3

3. Identification of Significant Issues (Step 3)

Issues were generated from public responses during the revision of the *Plan*, local knowledge of the Roads Analysis IDT, public responses to a variety of project proposals, and discussions with other public agencies like the Federal Highway Administration and TXDOT. Some issues will be addressed in this forest-scale analysis; however, issues concerning specific roads or site-specific circumstances will be addressed during project-scale planning.

3.1 Forest Plan Issue Summary

The issue of Roads and Trails was one of fifteen identified during the scoping process conducted for the revision of the *Plan*. The *Plan EIS* (page 51) described the issue as follows:

“Road reconstruction may cause an increase in erosion, sedimentation, and water yield. Mitigation measures for these actions are included within the standards and guidelines to maintain sediment and water quality within acceptable levels. Road reconstruction may include relocating portions of the road bed, surfacing with gravel, constructing dips, and installing culverts, all of which will reduce the sediment yield once in place.”

3.2 Significant Issues Identified

The following issues were identified during this forest-scale roads analysis. Issues concerning specific roads or site-specific situations will be addressed during smaller project-scale analyses.

- Does the current forest road system adequately serve users and protect resources?
 - The most important concern is public safety.
 - The protection of natural resources is the next most important concern.
- The County roads are important to the Forest Service. About one-fifth (21 percent) of the forest roads addressed in this analysis are County roads. In 1974, the Forest Service first discussed road maintenance responsibilities with the Counties. A cooperative agreement concerning road maintenance was proposed. In 1977, the first cooperative agreements were signed by the counties. The current cooperative agreements cover 82 different roads – 69 County roads and 13 Forest Service roads. See Table 16 below.

Table 16. Road Cooperative Agreements (SHNF)

Current Cooperative Agreements			
County	FS Roads	County Roads	Total Roads
Walker County	3	26	29
Montgomery County	8	10	18
San Jacinto County	2	33	35
Total Roads	13	69	82

The original agreements have been amended over the years and need to be updated to reflect the current road numbers, names, and lengths.

- There are roads under Forest Service jurisdiction that provide access for rural communities, residences, or private inholdings; serve as school bus or mail routes; or have other features that require regular and emergency maintenance. These roads may be more appropriately managed under State or County jurisdiction by public agencies with adequate road maintenance expertise, personnel, and equipment.
- There are roads under County jurisdiction that provide access across national forest lands to adjoining private lands. These roads are usually under special use permit to the County, but provide access for the landowner(s). The special use permittee should be responsible for the road maintenance.
- Generally, the Sam Houston NF is receiving inadequate road maintenance funds. The road maintenance funds allocated are only about 14 percent of the estimated amount of funds needed. However, the Forest Supervisor and District Ranger have authority to take different actions to deal with inadequate road maintenance budgets, such as reprogramming funds, entering cost-sharing agreements, transferring roads to other public agencies, reducing road maintenance levels, closing or decommissioning roads, etc.
- Roads that cross streams or streamside riparian areas affect stream structure and water quality. Each stream crossing can potentially alter stream structure and introduce sediment and other contaminants.
- Are road right-of-ways needed to access national forest lands?
- Is the GIS spatial data and INFRA tabular data for forest roads complete and correct?

4. Assessment of Issues (Step 4)

This section addresses issues associated with the management of forest roads serving the Sam Houston NF and is included in Appendix I *Assessment of Issues*.

5. Recommendations, Opportunities, and Priorities (Step 5)

5.1 Introduction

The identification (Step 3) and assessment (Step 4) of the roads issues addressed in this forest-scale analysis provide a basis to make recommendations, identify opportunities, and set priorities for management of the Sam Houston NF forest roads system. In accordance with FS-643 "Roads Analysis" process, this information was used to make the following recommendations, identify the following opportunities and set priorities.

5.2 Recommendations and Opportunities

5.2.1 Forest-Scale Recommendations and Opportunities

Providing for public safety; preserving roads with adequate surfacing, drainage, and maintenance; and protecting resources are the first priorities for road management. The following recommendations and opportunities were developed during this process.

1. Review and establish standard road construction designs, drawings, and specifications to implement the *Plan* Forest Wide (FW) 053 Standard, "Design and construct roads... to minimize siltation and maintain to provide surface drainage away from streams and into vegetated buffer strips or other filtering system."
 - Consider establishing silt fencing specifications to protect streams from siltation during ground disturbing activities.

2. Road wing ditches concentrate water flows. The run-off from one wing ditch can combine with the run-off from other wing ditches to further concentrate water flows in natural drainages. On-the-ground inspections reveal that the run-off from road wing ditches can start and increase erosion where the run-off reaches stream banks. Review and establish standard road construction designs, drawings, and specifications to implement the *Plan* FW-053 Standard, "to provide surface water drainage away from streams and into vegetated buffer strips or other filtering system". To reduce water flows and run-off from wing ditches, consider,
 - spacing wing ditches closer together,
 - reducing the run-off from wing ditches by constructing a "J" hook at the outlet end of wing ditches to slow water flow and provide for percolation in a settling basin, and
 - other actions as necessary.

3. Road plans and specifications designed to implement the *Plan* FW-053 Standard, "to provide surface water drainage away from streams and into vegetated buffer strips or other filtering system", should be reviewed during pre-work conferences with contractors to ensure everyone is aware of the requirements.

4. Review and establish standard road construction designs, drawings, and specifications to implement the *Plan* FW-055 Standard, "Provide road... design and construction that allows unrestricted fish passage", for appropriate streams. Culverts should be designed and installed to,
 - provide for a natural stream bed substrate,
 - not increase stream flow velocity to the rate that turbulence creates a cavity at the end of the culvert or erodes the stream banks, and
 - not spread low stream flows to the point that the streams are no longer navigable by fish.

Consider partially burying oversized culverts.

5. Periodically review the cooperative road maintenance program and the current cooperative agreements for County roads with County Commissioners. County Commissioners are not always aware of the existing agreements.

6. Our review of the Forest Highways generated the following two recommendations.
 - Forest Highway 207: The 2.9 mile segment of the old Dodge Road across private lands south of US-190 is no longer on the Walker County road system. It may be impassable to public use. The 5.0 mile segment of the old Dodge Road from US-190 south to FS 246 should be deleted from Forest Highway 207 and the FS 246 road should be added. This route change will provide interconnected Forest Highways open to public use between TX-150 and US-190.
 - Consider adding the 16 miles of FM 2025 between Cleveland, TX and Coldspring, TX to the Forest Highways system. The addition of FM 2025 to the Forest Highways system would interconnect the Forest Highways on the eastern side of the Sam Houston NF.

7. Periodically inspect existing special use roads to ensure that road construction and maintenance practices protect forest resources and provide for public safety.

8. There are roads on the Sam Houston NF that,
 - our records indicate are under County jurisdiction, but
 - are no longer claimed as County roads by the County.
 These roads usually provide access across national forest lands to adjoining private lands. These roads are usually under special use permit to the County, but provide access for the landowner(s). The special use permittee should be responsible for the road maintenance. If the permittee is the County, the road should be open to public use.
9. Review proposed special use road locations on-the-ground with interdisciplinary specialists as necessary for their recommendations on road location, construction, and maintenance requirements before approving special use permit. Implement the *Plan* MA-10b-38 Standard,
 - “Authorize only one private access road per private tract, regardless of multiple ownership. Avoid committing national forest land as access to substitute for lack of internal access to private land due to poor sub-division planning or uncooperative neighbors...”
10. Road maintenance funding is not always sufficient to maintain roads to desired standards. Review and establish road maintenance practices to effectively and efficiently use limited road maintenance funds and to protect resources from road maintenance impacts, such as,
 - road maintenance practices to prevent undue disturbance of ditches.
11. Establish guidelines to better manage the motor-grader blading of road surfaces and ditches to prevent the unnecessary disturbance of stabilized soils. Review and establish road maintenance practices to better prevent sedimentation of streams.
12. Provide cost-effective temporary bridge options to cross streams to isolated tracts.
13. Collect and establish a reference library of information on road maintenance and construction pertaining to mitigating impacts on resources.
14. Provide training on road maintenance and construction practices that mitigate impacts on resources.

5.2.2 Project-Scale Recommendations and Opportunities

Although sub-forest scale issues are not addressed in detail in this report, the following list of issues may need to be reviewed during site-specific analyses. This is not an all-encompassing list; generally other issues pertaining to individual roads may arise during project-scale analyses.

5.2.2.1 General

1. The forest roads stream crossings should be inventoried during site-specific project-scale analyses to identify stream sedimentation and fish passage problems. This includes State, County, and Forest Service road stream crossings on the forest roads system.
2. Identify forest roads that,
 - need resurfacing, reconstruction, or relocation to provide for public safety, protect forest resources, or provide for anticipated traffic associated with project proposals,
 - consistently contribute sediment to streams at stream crossings, and
 - have stream crossing structures that prohibit fish passage.

3. Cooperate with Counties,
 - to maintain, resurface, or reconstruct County roads to provide for public safety, protect forest resources, or provide for anticipated traffic associated with project proposals,
 - to construct and maintain drainage ditches to minimize stream sedimentation and to provide surface drainage away from streams and into settling basins, vegetated buffer strips, or other filtering systems,
 - to repair or reconstruct stream crossings that prohibit fish passage,
 - to assist counties in maintenance, resurfacing, or reconstruction of roads through cost-share agreements, and
 - to seek funds such as Capital Improvement or Road & Trail Deposit Funds (10 Percent Funds) to assist counties in road maintenance, resurfacing, and reconstruction.

4. Identify roads under Forest Service jurisdiction that provide access for rural communities, residences, or private inholdings; serve as school bus or mail routes; or have other features that require regular and emergency maintenance. The roads may be more appropriately managed under State or County jurisdiction by public agencies with adequate road maintenance expertise, personnel, and equipment.
 - Consider transferring the roads to the State or County.

5. Road maintenance funding is not always adequate to maintain roads to desired standards. Identify ways to reduce road maintenance costs, such as,
 - Are there roads appropriate for transfer to the County or the State?
 - Are there roads where the maintenance level can be reduced?
 - Are there roads which are no longer needed and can be decommissioned?

6. Review RMOs for FS roads.
 - Are road maintenance levels appropriate for current and anticipated traffic?
 - Are special resource considerations appropriate?

7. Review the GIS location and INFRA data for ML-1 and ML-2 FS roads.
 - Are roads needed for current and future access?
 - Are roads no longer needed for public use or to manage forest resources?
 - Plan to decommission and obliterate such FS roads.

8. Locate and assess unclassified roads.
 - Are unclassified roads needed for current and future access?
 - Are unclassified roads no longer needed for public use or to manage forest resources?
 - Plan to decommission and obliterate such roads.

9. Identify road right-of-ways needed to access national forest lands.
 - Pursue the acquisition of permanent right-of-ways.
 - Pursue the acquisition of temporary right-of-ways where,
 - access will not be needed again in the future, and
 - a permanent right-of-way can not be acquired.

10. Inventory and evaluate FS road signs.
 - Install signs that provide for public safety and meet established standards.

11. Due to the 9-1-1 initiative to name or number all roads for identification during emergency calls, check the current County road names, numbers, and lengths against,
 - current cooperative agreements, and
 - GIS and INFRA road data.
 Update cooperative agreements as necessary.

5.2.2.2 Specific

12. An assessment of road stream crossings identified the following problems on the Sam Houston NF (see Appendix J for more site specific information):

- Road: 200 Location: 1.6 mi from Road 207
Problem: Unclog 24" culvert and rehab gullies formed from wing ditches
- Road: 200 Location: 2.5 mi from Road 207
Problem: Control road ditch drainage
- Road: 200 Location: 3.6 mi from Road 207
Problem: Replace 24" culvert with bridge or arch culvert
- Road: 200 Location: Boswell Creek
Problem: Replace culvert with larger buried culvert or arch culvert.
- Road: 204 Location: Peach Creek south of Road 248
Problem: Replace 24" culvert with larger buried culvert on proper grade and control road drainage.
- Road: Old Road off Road 204 Location: Tributary of Peach Creek
Problem: Block old road and rehabilitate stream crossing and channel
- Road: 206A Location: Briar Creek
Problem: Decommission segment of old road at stream crossing
- Road: 207 Location: 0.5 mi southeast of Road 200
Problem: Replace rusted 36" culvert and control road drainage
- Road: 207 Location: 0.9 mi southeast of Road 200
Problem: Replace rusted 36" culvert and control road drainage
- Road: 207 Location: Hopkins Branch
Problem: Replace 36" culvert with larger buried culvert on proper grade and control road drainage
- Road: 207 Location: 2.2 mi southeast of Road 200
Problem: Control road drainage with wing ditches and rehabilitate gullies
- Road: 207 Location: 2.5 mi southeast of Road 200
Problem: Control road drainage with wing ditches and rehabilitate gully
- Road: 207A Location: 2.9 mi from Road 207
Problem: Control road drainage with wing ditches and rehabilitate gullies.
- Road: 207A Location: Pea Creek
Problem: Replace 60" culvert with larger partially buried culvert and divert road drainage away from streamcourse.
- Road: 208 Location: 0.45 mile northwest Road 215
Problem: Replace 2' culvert with larger culvert on proper grade.

- Road: 208 Location: 0.7 mile northwest Road 215
Problem: Replace 2' culvert with larger culvert on proper grade and rehabilitate gullies.
- Road: 208 Location: 0.9 mile northwest Road 215
Problem: Replace 18" culvert with larger culvert on proper grade.
- Road: 208 Location: 1.5 miles northwest Road 215
Problem: Rehabilitate wing ditch and construct wing ditches.
- Road: 208 Location: 2.0 miles northwest Road 215
Problem: 2' culvert creating impoundment above culvert with large drop below culvert outlet.
- Road: 208 Location: 4.0 miles northwest Road 215
Problem: Good example of 42" corrugated arch culvert installation.
Road drainage ditch downcutting and forming gully.
- Road: 208 Location: 4.7 miles northwest Road 215
Problem: 18" culvert on too steep a grade causing gully.
- Road: 215 Location: 0.3 mile northeast Road 208
Problem: Replace 5' culvert with larger partially buried culvert.
Control road drainage and rehabilitate gullies.
- Road: 217 Location: Big Creek
Problem: Locate and control sources of turbidity in watershed upstream.
- Road: 217 Location: Little Creek
Problem: Divert road ditch drainage away from streamcourses.
- Road: 221 Location: 0.5 miles north of Road 217
Problem: Replace 36" culvert with larger partially buried culvert and divert road drainage away from streamcourse.
- Road: 221 Location: 1.0 miles north of Road 217
Problem: Replace 36" culvert with larger partially buried culvert and divert road drainage away from streamcourse.
- Road: 221 Location: 1.55 miles north of Road 217
Problem: Replace 32" culvert with larger partially buried culvert and divert road drainage away from streamcourse.
- Road: 221 Location: 1.9 miles north of Road 217
Problem: Replace double 36" culverts with larger partially buried culverts and divert road drainage away from streamcourse.
- Road: 223 Location: 0.8 mile from Road 213
Problem: Replace 18" culvert with larger partially buried culvert
- Road: 223 Location: 0.6 mile from Road 213
Problem: Replace 36" culvert with larger partially buried culvert and divert road drainage away from streamcourse.

- Road: 223 Location: 0.4 mile from Road 213
Problem: Construct and reconstruct wing ditches to divert road drainage away from streamcourse.
- Road: 223 Location: 0.7 mile from Four Notch Road
Problem: Replace 48" culvert with larger partially buried culvert and divert road drainage away from streamcourse.
- Road: 223 Location: 0.9 mile from Four Notch Road
Problem: Replace 48" culvert with larger partially buried culvert and divert road drainage away from streamcourse.
- Road: 228F Location: On branch of Neblett's Creek
Problem: 48" culvert prevents fish passage.
- Road: 261 Location: On branch of East Fork San Jacinto River
Problem: Replace double 64" culverts with larger partially buried culverts and divert road drainage away from streamcourse.
- Road: 262 Location: At end of road at East Fork San Jacinto River
Problem: 24" culvert blocked.
- Road: FM 1791 Location: Caney Cr about 0.4 mile south Road 208
Problem: 30" culvert prevents fish passage. Control road drainage and rehabilitate road ditch gullies. Discuss with TXDOT representatives.
- Road: FM 1791 Location: Caney Cr about 2.1 mile south Road 208
Problem: Widening of stream channel causing drainage problems.
- Road: FM 1791 Location: Caney Cr about 2.4 mile south Road 208
Problem: Concrete bridge failing. Discuss with TXDOT representatives.
- Road: FM 2025 Location: Hickman Branch
Problem: Construct wing ditches to divert road drainage away from streamcourse and repair collapsing wing wall.
- Road: FM 2666 Location: Tarkington Bayou
Problem: Construct wing ditches to divert road drainage away from streamcourse.
- Road: FM 2666 Location: West of FS 217A
No problem. Good example of a wing ditch on a Farm-to-Market road.

13. INFRA Data indicates the following roads under Forest Service jurisdiction are maintained by the County.

- o Consider transferring these roads to the County if the roads,
 - are heavily used by public traffic, or
 - are thru roads which,
 - connect State or County roads with other State or County roads, or
 - access residential areas.

Table 17. FS Roads Maintained by the County (SHNF).

ROAD NUMBER	ROAD NAME	LENGTH (Miles)	COUNTY	ML
204	Caney Creek	2.5	Montgomery	3
204A	Dunlap	0.8	Montgomery	3
204E		0.4	Montgomery	3
2043	Little Sam Forest	0.6	Montgomery	3
2045	Bear Canyon	0.3	Montgomery	3
206	Phelps	2.0	Walker	3
208	County Line	1.5	Walker	3
209	Farris	0.3	Montgomery	3
212	Scotts Ridge	1.2	Montgomery	5
2135	Flamingo Lake	0.5	Montgomery	3
219A	Perry Williams	1.3	Montgomery	3
224	Corral	1.7	Montgomery	3
246	Watergate	0.8	Walker	3
274	Mercy	1.8	San Jacinto	4

5.3 Questions to Address during Project-Scale Analyses

The *Assessment of Issues* (see Appendix I) addressed the 71 questions from Appendix 1 of the FS-643 report “Roads Analysis: Informing Decisions about Managing the National Forest Transportation System”(USDA 1999) as well as 11 other questions. The questions from FS-643 focus on general ecological, social, and economic concerns associated with roads. The other questions focus on other concerns raised during the analysis of this forest roads system.

Some of the questions are adequately addressed in this document and do not need further consideration. However, some questions need to be reviewed during project-scale analyses when the issues arise. Where identified as an issue, the following questions should be addressed during project-scale analyses.

Ecosystem Functions and Processes (EF) (1): What ecological attributes, particularly those unique to the region, would be affected by roading of currently unroaded areas?

EF (2): To what degree do the presence, type, and location of roads increase the introduction and spread of exotic plant and animal species, insects, diseases, and parasites? What are the potential effects of such introductions to plant and animal species and ecosystem function in the area?

Aquatic, Riparian Zone, and Water Quality (AQ) (2): How and where does the road system generate surface erosion?

AQ (4): How and where do road-stream crossings influence local stream channels and water quality?

AQ (8): How and where does the road system affect wetlands (and riparian areas)?

AQ (10): How and where does the road system restrict the migration and movement of aquatic organisms? What aquatic species are affected and to what extent?

AQ (12): How and where does the road system contribute to direct habitat loss for at-risk aquatic species?

AQ (14): To what extent does the road system overlap with areas of exceptionally high aquatic diversity or productivity or with areas containing threatened, endangered, or sensitive aquatic species or species of interest?

Terrestrial Wildlife (TW) (1): What are the direct effects of the road system on terrestrial species habitat?

TW (4): How does the road system directly affect unique communities or special features in the area?

Mineral Management (MM) (1): How does the road system affect access to locatable, leasable, and salable minerals?

Water Production (WP) (2): How does road development and use affect water quality in municipalities?

Special Forest Products (SP) (1): How does the road system affect access for collecting special forest products?

Special Uses (SU) (1): How does the road system affect managing special use permit sites (concessionaires, communication sites, utility corridors, etc)?

Unroaded Recreation (UR) (2): Is developing new roads into unroaded areas, decommissioning of existing roads, or changing the maintenance of existing roads causing substantial changes in the quantity, quality, or type of unroaded recreation opportunities?

Roaded Recreation (RR) (2): Is developing new roads into unroaded areas, decommissioning of existing roads, or changing the maintenance of existing roads causing substantial changes in the quantity, quality, or type of road-related recreation opportunities?

General Public Transportation (GT) (4): How does the road system address the safety of road users?

Administrative Use (AU) (2): How does the road system affect investigative or enforcement activities?

Passive-Use Value (PV) (1): Do areas planned for road building, closure, or decommissioning have unique physical or biological characteristics, such as unique natural features and threatened or endangered species (see TW4)?

PV (2): Do areas planned for road building, closure, or decommissioning have unique cultural, traditional, symbolic, sacred, spiritual, or religious significance?

PV (3): What, if any, groups of people (ethnic groups, subcultures, and so on) hold cultural, symbolic, spiritual, sacred, traditional, or religious values for areas planned for road entry or road closure?

PV (4): Will building, closing, or decommissioning roads substantially affect passive-use value?

RR (5): What are road-related recreation users' attachments to roads in the area, how strong are their feelings, and are alternative opportunities and locations available?

Social Issues (SI) (4): How does the road system affect cultural and traditional uses (such as plant gathering, and access to traditional and cultural sites) and American Indian treaty rights?

SI (6) and SI (7): How is the social and economic health of communities affected by road management and management of unroaded areas (for example, lifestyles, businesses, tourism industry, infrastructure maintenance)?

SI (9): What are traditional uses of animal and plant species in the area of analysis?

Other Questions

4.2.2 Are there opportunities to reconstruct, relocate, close, or decommission roads on the forest roads system to solve problems or be more consistent with *Plan* direction?

4.2.4 Are there opportunities to change road maintenance practices to better care for natural resources?

4.2.6 Are there opportunities to improve County roads on the forest roads system under cooperative agreements?

4.2.7 Are there opportunities to transfer the jurisdiction of FS roads to the County?

4.2.8 Should any roads be considered for designation as Forest Highways? Are there opportunities to transfer the jurisdiction of any Forest Highways to the State?

4.2.9 Are existing FS roads no longer needed to meet future access needs?

4.2.10 Are road improvements or additional roads needed to provide adequate access for forest users, resource management, or protection?

4.2.11 Are road right-of-ways needed to provide access to national forest lands for use, management, or protection?

References

- Barton, J.R., D.A. White, P.V. Winger, & E.J. Peters. 1972. The effects of highway construction on the fish habitat in the Weber River, near Henefer, Utah. Report Number REC-ERC-72-17. Bureau of Reclamation, Engineering Research Center, Colorado.
- Binkley, D. & Brown, T.C. 1993. Forest practices as nonpoint sources of pollution in north america. *Water Resources Bulletin* 29:729-740. American Water Resources Association.
- Castro, J. 2003. Geomorphologic impacts of culvert replacement and removal: Avoiding channel incision. U.S. Fish and Wildlife Service. Portland, OR.
- Coburn, C.B., Jr., B.L. Ridley, & G.K. Ensor. 1984. Evaluation of highway impacts and mitigation measures of wildlife habitat. Tennessee Technological University, Cookeville, Tennessee.
- Ellis, M.M. 1936. Erosion silt as a factor in aquatic environments. *Ecology*, Vol. 17:29-42.
- Filipek, S.P. 1993. Timber harvest. Impacts on Warmwater Streams: Guidelines for Evaluation (C.F. Bryan & D.A. Rutherford eds.) pp. 227-244. Southern Division, American Fisheries Society, Little Rock, Arkansas.
- Geist, V. 1978. Harassment of wildlife. *Big Game of North America* (J.L. Schmidt & D.L. Gilbert eds.) pp. 287-293. Stackpole Books, Harrisburg, Pennsylvania. 494 pp.
- Hassler, T.J. 1970. Environmental influences on early development and year class strength of northern pike in Lake Oahe and Sharpe, South Dakota. *Transactions of the American Fisheries Society* 99:369-375.
- Hediger, H. 1964. *Wild animals in captivity*. Dover Publications, Inc., New York, 207 pp.
- Jackson, J.A. 1983. Possible effects of excessive noise on red-cockaded woodpeckers. *Red-cockaded Woodpecker Symposium Proceedings*, pp. 38-40.
- Luedtke, R.J., M.A. Brusven & F.J. Watts. 1976. Benthic insect community changes in relation to in-stream alterations of a sediment-polluted stream. *Melandria* 23:21-39.
- Sheldon, J.M. & R.D. Pollock. 1966. Siltation and egg survival in incubation channels. *Transactions of the American Fisheries Society* 95:183-187.
- U.S. Department of Agriculture, Forest Service. *Public Forest Service Roads*. 2000. Washington, DC.
- U.S. Department of Agriculture, Forest Service. 2000a. *Water & the Forest Service*. Washington, DC. 27 p.
- U.S. Department of Agriculture, Forest Service. 2000b. *Forest roads: A synthesis of scientific information*. Washington DC. 117 p.
- U.S. Department of Agriculture, Forest Service. 2000c. *Drinking water from forests and grasslands: A synthesis of the scientific literature*. Southern Research Station. Asheville, NC.
- Weisenberger, M.E., P.R. Krausman, M.C. Wallace, D.W. DeYoung & O.E. Maugen. 1996. Effects of simulated jet aircraft noise on heart rate and behavior of desert ungulates. *Journal Wildlife Management* 60(1):52-61.

White, R.J., & O.M. Brynildson. 1967. Guidelines for management of trout stream habitat in Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin 39, Madison, WI.