# ROADWAY NEEDS REPORT

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## DESCRIPTION

# ROADWAY NEEDS REPORT
# TO THE
# BOARD OF SUPERVISORS

**APRIL 2002**

## INTRODUCTION

The purpose of this report is to present the roadway maintenance and construction needs of Cochise County. The report will briefly describe the current County roadway system, noting key deficiencies and estimating the resources needed to properly address the deficiencies.

The County presently maintains 1,442 miles of roads, of which 579 miles are paved and 863 miles are dirt. The paved roads consist 102 miles of major collectors, 143 miles of minor collectors and 334 miles of local roads and streets. The dirt roads consist of collectors and local roads with traffic volumes less than 400 vehicles per day (vpd).

There are 2,470 additional miles of sub-standard dirt roads used by the public in the County that are **not** maintained by the County. Some of these roads are in public right-of-way and others in private easements. A quirk of Arizona State land development law allows the construction of roads to access developing land that do not meet County roadway standards. These substandard roads are being created in Arizona counties on a continuing basis. These roads are not eligible for publicly funded maintenance until they are constructed to county roadway standards.

### MANAGEMENT AND FUNDING OF THE ROADWAY SYSTEM

The County is divided into three political areas, each represented by an elected supervisor. Prior to 1978, elected supervisors directed road maintenance personnel and road maintenance in their political areas. In 1978, the Board passed Resolution 78-44 establishing the Cochise County Highway Department and delegating the responsibility for operation, maintenance and construction of County roadways to the county engineer. To facilitate road maintenance, the County is divided into two areas with separate maintenance crews each headed by a Highway Superintendent. Figure 1 shows the population and road miles for each of the three political subdivisions. Figure 2 shows the road miles for each road maintenance area. And Figure 3 shows the boundaries of these two distinct ways of subdividing the County.

Funds used to maintain and construct County roads are derived from State **H**ighway **U**ser **R**evenue **F**unds commonly referred to as **HURF**. HURF is made up fuel taxes and vehicle license taxes collected by the State. The State disburses HURF to the Arizona

Department of Transportation (ADOT), Arizona Department of Public Safety (DPS), Arizona cities and Arizona counties using a very complex formula established in law by the Arizona State legislature. The order of priorities set by the State for distributing HURF is ADOT and DPS, Arizona cities, the two metropolitan counties namely Maricopa and Pima, and finally the thirteen rural counties. The Board of Supervisors, therefore, does not determine the amount of HURF coming to the County each year. However the Board does determine how these funds are spent within the County.

## SELECTED STATE STATUTES PERTAINING TO COUNTY ROAD MAINTENANCE

This section describes the major statutory provisions that govern roadway maintenance in Cochise County.

### Declared County Highways

Any route that the Board deems as meeting a "public necessity" can be "declared" a County road by formal action of the Board. The process to declare a county road is stipulated in ARS 28-6701 through 6703. Once a road is formally "declared" by the Board, public funds can then be used for right-of-way acquisition, engineering and survey, construction and maintenance of the route. The Board has to carefully weigh the public necessity against the resources needed to properly construct and maintain the road. The County currently maintains approximately 1,000 miles of declared roads.

### Primitive Roads

The County maintains certain roads as "Primitive Roads". Primitive roads are classified in accordance with ARS 28-6705 and 6706. These statutes stipulate that primitive roads are substandard dirt roads that have been maintained by the County prior to June 13, 1975. On this date, Arizona counties were granted authority to establish road construction standards and to require that roads constructed from then on meet those standards before receiving publicly funded maintenance. Primitive roads are signed as such as a warning to the public of substandard conditions. This allows the County to provide minimal maintenance with minimal exposure to liability. There are three important statutory stipulations pertaining to Primitive Roads:

1. Primitive Roads must be public. In other words, the County must have clear title to the right-of-way.

2. Public funds can only be used to **maintain** these roads not to **improve** them. Minimal maintenance is all that is allowed.

3. Maintenance of these roads is discretionary and not mandatory. The Board **may** provide for the maintenance of these roads if, in their judgment, resources are available.

There are approximately 207 miles of Primitive Roads in the maintenance system.

**Subdivision Roads**

Some of the roads maintained by the County have been laid out, opened and constructed without cost to the County pursuant to an approved plat in accordance with ARS 11-802 and 11-806.1. These roads have been constructed since June 13,1975 in accordance with County "subdivision road" standards at no cost to the County. These roads are, therefore, eligible for publicly funded maintenance. There are approximately 58 miles of properly constructed subdivision roads in the maintenance system.

**Other County Highways and Roads**

Many County roads are old highways that have been maintained for decades by the County. ARS 28-7041 states that if a road was opened, laid out or established or maintained by the State or the County for ten years or more before January 1, 1960 and that has been used continuously by the public for free travel is a declared public highway regardless of an error, defect or omission in the process of establishing it as a County road. This statute does not give the County a clear title to the right-of-way, but it does allow the use of public funds to maintain the road. The County has several pre-1960 maps that document the location of these old routes. The County assumes that the road is within public right-of-way, but there is no clear documentation of public ownership.

ARS 28-7042 is related to the above statute and states that routes that were in use for at least two years prior to August 12, 1927 are public roadways with a right-of-way width of sixty-six feet. Again the County has historic pre-1927 maps that document these old routes.

The County provides maintenance to about 177 miles of old roads that meet the criteria of either of these two statutes. The following table summarizes the miles of maintained road by legal status:

**TABLE 1**
**SUMMARY OF COUNTY ROAD MILES BY LEGAL STATUS**

| STATUTORY STATUS | ROAD MILES |
|---|---|
| Declared County Highways | 1,000 |
| Declared Primitive Roads | 207 |
| Subdivision Roads | 58 |
| Historic County Roads | 177 |
| **TOTAL** | **1,442** |

The 2,470 miles of roads in the County that are not maintained by the County fall outside of these statutes. In order for the "non-maintained" roads to qualify for public maintenance, the local residents are required to raise the funds to properly construct the road to County standards.

## ROADWAY PLANNING GUIDELINES AND FUNDING NEEDS

In order to evaluate County roadway needs, it is necessary to briefly present the construction guidelines against which each road is to be measured.

The American Association of State Highway Transportation Officials (AASHTO) recently published new guidelines for low volume roads in time for the analysis in this report. A "low volume" road is defined as having an **A**verage **D**aily **T**raffic count (ADT) of less than 400 **v**ehicles **p**er **d**ay (vpd). Of the 1,442 miles of County maintained roads about 1,191 miles or 83% carry an ADT of less that 400 vpd. This report will take into account the new AASHTO standards. The following table shows the breakdown of road miles by traffic volume.

**TABLE 2**
**PAVED VERSUS DIRT ROAD MILES BY TRAFFIC VOLUME**

| Traffic Volume Vehicles per Day | Paved Miles | Dirt Miles | Total Miles |
|---|---|---|---|
| >400 | 251 | 0 | 251 |
| <399 | 328 | 863 | 1,191 |
| **TOTALS** | 579 | 863 | 1,442 |

### Structural Guidelines for Commercial Truck Traffic

Of the 251 miles of major and minor collectors, only 18 miles are constructed to withstand large volumes of heavy commercial truck traffic. Proposed guidelines for roads with heavy truck traffic call for asphalt pavement to be at least 28 feet wide and four inches thick on six inches of crushed mineral aggregate commonly called **a**ggregate **b**ase **c**ourse (ABC). Truck traffic on a collector also requires a well-constructed shoulder beyond the pavement

to allow vehicles to safely park alongside the road away from traffic. The width of shoulders varies according to design speeds and traffic volume.

**Structural Guidelines for Light Vehicle Traffic**

Of the 251 miles of major and minor collectors, only 74 miles meet County standards for light vehicle traffic.

Planning guidelines stipulate pavement widths that vary from 24 feet to 28 feet depending on design speeds and traffic volumes. Shoulders also vary accordingly. Minimum pavement thickness is required to be two inches of asphalt on six inches of ABC.

Drainage structures are not required for roadways with ADT's less than 100. Drainage structures for roadways with ADT's between 100 and 400 should be able to pass the 2-year storm under the road. If a readily available alternated route exists then no structure is needed. Drainage structures on roadways with ADT's between 400 and 1,000 should pass the 5-year storm under the road. Drainage structures on roadways with ADT's greater than 1,000 should be able to pass the 10-year storm, or a less frequent storm as determined by the county engineer, under the road. In every case where drainage structures are placed the 100-year flow should be able to pass over the road at a depth of less than 1 foot.

**Paving Threshold for Dirt Roads**

There are no dirt roads with traffic volumes greater than 400 vpd. Therefore, the new AASHTO guidelines apply. AASHTO's guidelines significantly change construction concepts for low volume roads. The guidelines acknowledge that for economic reasons, many low volume roads are not paved. AASHTO acknowledges that crash rates for unpaved roads are greater than paved roads when daily traffic volumes are greater than 250 vpd and that paving a dirt road would result in one less severe crash every 10 to 15 years in the traffic range of 300 to 350 vpd.

An economic threshold analysis for paving a dirt road is presented in the appendix. This analysis shows that high-speed (this means that normal travel speeds exceed 45 mph) dirt roads should optimally be paved when the average daily traffic reaches 370 vehicles per day. The economic analysis method used assumes that capital is scarce, opportunity cost of capital is high, and there are competing demands for funding other projects. The method considers the following factors:

- Construction costs of upgrading to a chip seal pavement
- Reconstruction costs of chip seal roads every 20 years
- Annual maintenance costs of a dirt road versus a paved road
- Vehicle operating costs on a dirt road versus a paved road
- Opportunity cost of capital

- Expected annual traffic growth rate

Based on safety considerations and economic factors, it is recommended that upgrading a high-speed (>45 mph) dirt road to a chip seal should be planned when the average daily traffic reaches 300 vpd and be completed by the time the average daily traffic reaches 350 vpd. All dirt roads should be paved when the daily traffic volume reaches 400 vpd.

**Dirt Roads**

Dirt roads are a fact of life in Cochise County. They are muddy when it rains and dusty and wash-boarded when the weather is dry. Many dirt roads become impassable during heavy rains. Recent studies have related health problems to breathing airborne dust caused by traffic on dirt roads. Dirt roads were generally acceptable years ago when travel speeds seldom exceeded 25 to 35 mph. However, drivers today expect to drive at much higher speeds making dirt road maintenance much more difficult and dirt road travel much more hazardous.

AASHTO recommends that speed limits not exceed 45 mph for dirt roads. Studies have shown that widening dirt roads does not increase safety. Wider dirt roads tend to encourage higher speeds thus adversely affecting safety.

None of the dirt roads in the maintenance system currently meet the safety or economic criteria for paving.

**Guidelines for Dirt Roads with Average Daily Traffic Volumes Greater Than 100**

There are approximately 111 miles of dirt roads with average daily traffic volumes greater than 100 vpd. These roads should have a travel way at least 20 feet wide and be surfaced with four to six inches of crushed mineral aggregate herein referred to as “gravel”. The main advantage of a gravel surface over a dirt surface is that a gravel surface would be **all weather**. Maintenance costs would be much less than a chip seal surface and about the same as a dirt surface. However, like a dirt surface, a gravel surface would be dusty when dry and would washboard.

A recent survey of Arizona Counties showed that nine of the fifteen counties blade their higher volume dirt roads every two to four weeks. Five counties, including Cochise County, blade higher volume roads once every six weeks. Two counties blade their roads once every twelve weeks. Four of fifteen counties, namely: Mojave, Pima, Pinal and Yuma apply water when blading. All fifteen counties blade primitive roads and lower volume dirt roads only two to three times per year.

**PRIORITIES OF RESOURCE ALLOCATIONS**

County resources for road construction and maintenance are very limited and constraining. Therefore, all activities and expenses of the department must be carefully prioritized.

The three main governing principles for prioritizing department resources are:

- Roadway safety
- Preservation of public investment in existing structures and pavements
- Road surface improvements

Most agree that safety should be the greatest concern and first priority; however, in practice the greatest number of complaints by area residents are for smoother, more comfortable riding surfaces. The most frequent complaint called into the department concerns rough, dusty conditions of dirt roads. It is easy to lose sight of what the priorities ought to be. Guided by the principles listed above the following activities are listed in order of recommended priorities:

1. Activities that deal directly with safety such as sign maintenance and placement, striping--including edge striping, pothole patching, eliminating roadside obstacles, roadside maintenance, sand bar removal and gully repair after storms, keeping pavement edges flush with adjacent shoulders, inspecting and repairing cattle guards and bridges, and roadside mowing.
2. Establishing and maintaining proper drainage. This includes establishing and maintaining crowns and roadside ditches, and establishing self-cleaning wash crossings. Major wash crossings should be culverted or hardened with concrete aprons. Proper drainage adds substantially to road preservation and safety.
3. Pavement maintenance activities such as routine chip sealing, crack sealing, pavement recycling and overlays
4. Unpaved surface maintenance such as routine blading, reshaping, and spot gravelling.
5. Upgrading dirt roads to chip seal surfaces.
6. Upgrading high volume collectors to asphalt surfaces.

## RESOURCE NEEDS

### Maintenance Needs

Roadway maintenance expenses constitute a major percentage of Cochise County's highway budget. The Arizona Association of County Engineers (AACE) recently contracted for a report of roadway needs for all Arizona Counties. The AACE report indicates that Cochise County should be spending about $8,389,000 maintaining the roadways, bridges and appurtenant facilities annually. The County presently spends about $4,800,000 or 57% of what is needed.

The 43% shortfall is the highest priority roadway funding need for the County. Among the highest priority maintenance needs are $160,000 annually for sign maintenance, $236,000

annually for edge striping. These two areas are high priorities because they directly improve driving safety.

## Operations and Management

The department is required to provide engineering, survey, planning and inspection, record keeping and other management duties pertaining to the public right-of-ways and also handling public inquiries. The AACE report estimates the annual cost of this to be $838,900. This is in line with our actual expenses for these services.

## Improvements Needed for Existing Bridges

Inspecting and evaluating bridges is very important and requires specialized training. Therefore, ADOT provides bridge inspection services for cities and counties in the State. ADOT officials estimate that $9,581,000 will be needed over the next 10 years for bridge replacements.

ADOT receives funds from the Federal government for bridge replacements to distribute to counties and cities. The current bridge replacement underway at Bisbee Junction is using these funds. The County needs to continue to apply for these funds. The next project should be the one lane bridge over the San Pedro River on Hereford Road. The first step should be to obtain expert advise on the environmental issues and feasibility of such a project.

Most of the other recommendations by ADOT pertain to narrow bridges on dirt roads leading into the US Forest Service lands. These are low volume roads and the new AASHTO guidelines allow for narrow bridges on such roads. Therefore, the need to replace these bridges is not critical. There are no bridges that are currently structurally unsound.

## Roadway Needs for Light Vehicle Traffic

There are 251 miles of paved roads with traffic counts greater than 400 vpd. Of those, 74 miles meet the planning guidelines for pavement for light vehicles. The amount of funds needed to construct the remaining 186 miles in conformance with light vehicle guidelines is $37,676,000.

The funding needs to remove roadside obstacles from all high-speed County roads are yet to be determined. The funding needs for drainage improvements for all County roads are

yet to be determined. The highest priority drainage improvement needs are shown in Table 3 on Page 16.

There are 1.85 miles of dirt roads with traffic counts over 300 vpd. Adjacent businesses are upgrading Glenn Road (0.14-mile), and Ten Pond Place (0.05-mile) for the use of their clients. Funds needed to construct the remaining 1.66-miles in conformance with light vehicle standards are $166,000.

The County maintains about 110-miles of dirt roads with traffic counts over 100 vpd. Funds needed to place a gravel surface on these roads in conformance with all-weather guidelines are $8,224,000.

Table 4 on Page 17 lists the long distant dirt roads that carry higher speed traffic (45 mph) in the County. County visitors that are not familiar with road conditions and characteristics drive these roads. These roads should be considered for gravelling and more frequent blading also. Cost to gravel the 203 miles shown in Table 4 is $15,225,000.

The frequency of blading the 313 miles of dirt roads discussed above should be increased from six weeks to four weeks at a cost of $130,000 annually.

**Right-of-Way**

There are 826 miles of roads in the County's maintenance system **without perfected right-of-way**. Funds needed to perfect the right-of-way are $10,456,000. The County has been successful in obtaining Heritage Grant funds to acquire right-of-way for roads serving public lands. We will continue to apply for these funds.

**Commercial Truck Traffic Guidelines**

There are 197 miles of major and minor collectors with traffic volumes greater than 500 vehicles per day that should be constructed to commercial truck traffic standards. Only 18 miles meet commercial truck traffic standards. Funds needed to construct the remaining 206 miles in conformance with commercial truck traffic guidelines are $539,153,000.

**New Roads**

Growth is moderate for most of the County. The growth in the area south of Sierra Vista is robust and the need for a couple of new roads in the area is apparent. A planning study is needed to identify traffic patterns, the need for new routes and the location of new routes. A couple of possibilities are for an east-west road between Moson Road and State Route

92 to supplement Ramsey Road, a north-south road between Hereford and State Route 90 to supplement Moson Road. An estimated $12,000,000 will be needed for new routes south of Sierra Vista.

A summary of the roadway needs for the years 2003 to 2013 is presented in Table 6 on Page 18.

### Upgrading Dirt Roads to Chip Seal Surfaces

Many County residents inquire about chip sealing a dirt road used by them. The costs of upgrading a dirt road to a chip seal surface are between $100,000 to $160,000 per mile depending on drainage and design speeds. To pave all 863 miles of dirt roads would take from $86.3 to $138.1 million. The annual maintenance costs would also increase by $4,574,000 if all 863 miles were chip sealed. The costs of upgrading a dirt road to a gravel surface, assuming modest changes in alignment and drainage improvements, are about $75,000 per mile. To gravel all 863 miles of dirt roads would take about $64.7 million. The reality is that there will be dirt roads in the County maintenance system for the foreseen future.

The Board of Supervisors has provided a cooperative program to assist residents interested in getting a road chip sealed. The requirements for County-maintained roads are that residents provide the right-of-way and the funds to purchase the materials to chip seal the road. The County provides the engineering, equipment and labor to perform the work. The requirements for a road not maintained by the County are that residents provide the right-of-way and the funds for materials, equipment and labor. The County provides the engineering and the other resources at cost.

## POTENTIAL SOURCES OF ADDITIONAL FUNDS

The huge deficit in maintenance and capital improvement resources, indicated in Table 6, could be funded from sources other than HURF. Some possibilities are:

- A transportation sales tax of ½ cents could produce about $5.25 million annually. This tax requires voter approval and would likely have to be shared with the cities.
- A portion of the existing County sales tax could be allocated for roadway improvements.
- ARS 28-6712 allows the Board to designate a portion of the property tax for roadway maintenance and improvements. There is room within the tax ceiling to do this. The Board is currently not using $1.18 of potential levy. A $0.05 tax levy increase would yield $250,000 per year.
- Support efforts with the State Legislature to increase the fuels tax. All highway agencies in the State are experiencing significant funding shortfalls. A united statewide effort is needed.
- Continue to encourage County residents to take advantage of the cooperative program to upgrade dirt roads to chip seal surfaces.

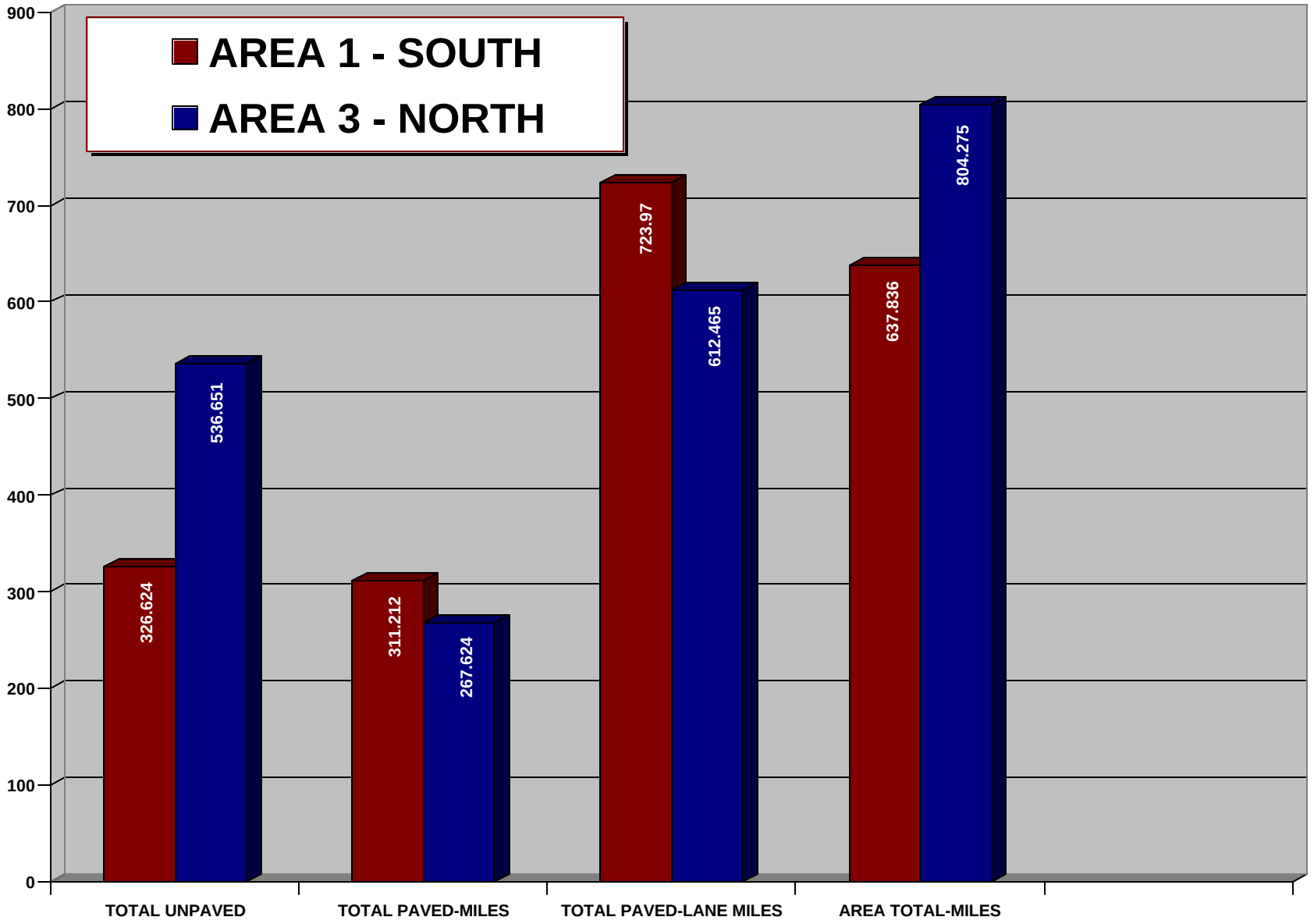
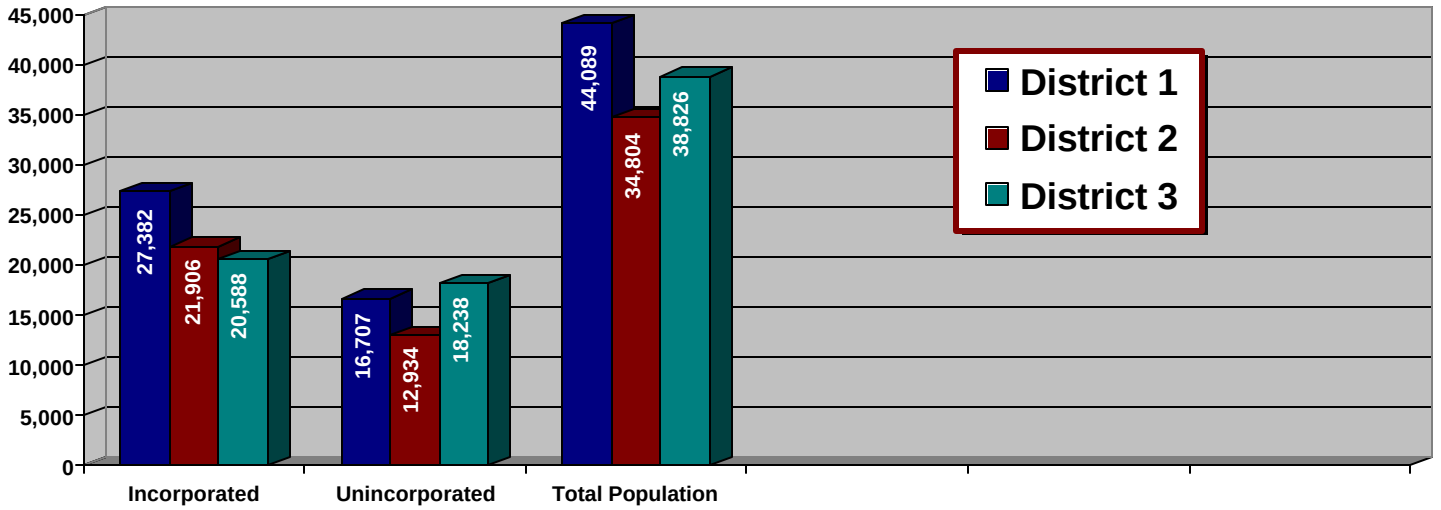
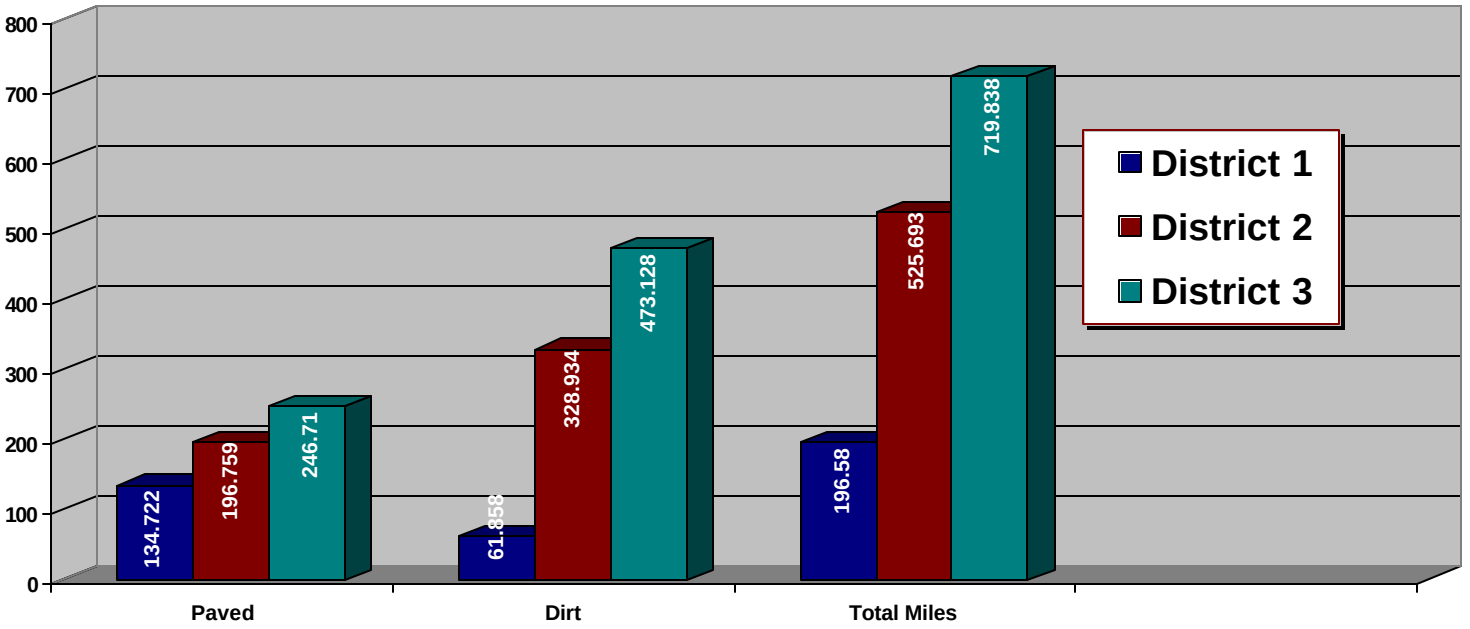



**Figure 2** **AREA TOTALS**




**Population Totals by District**

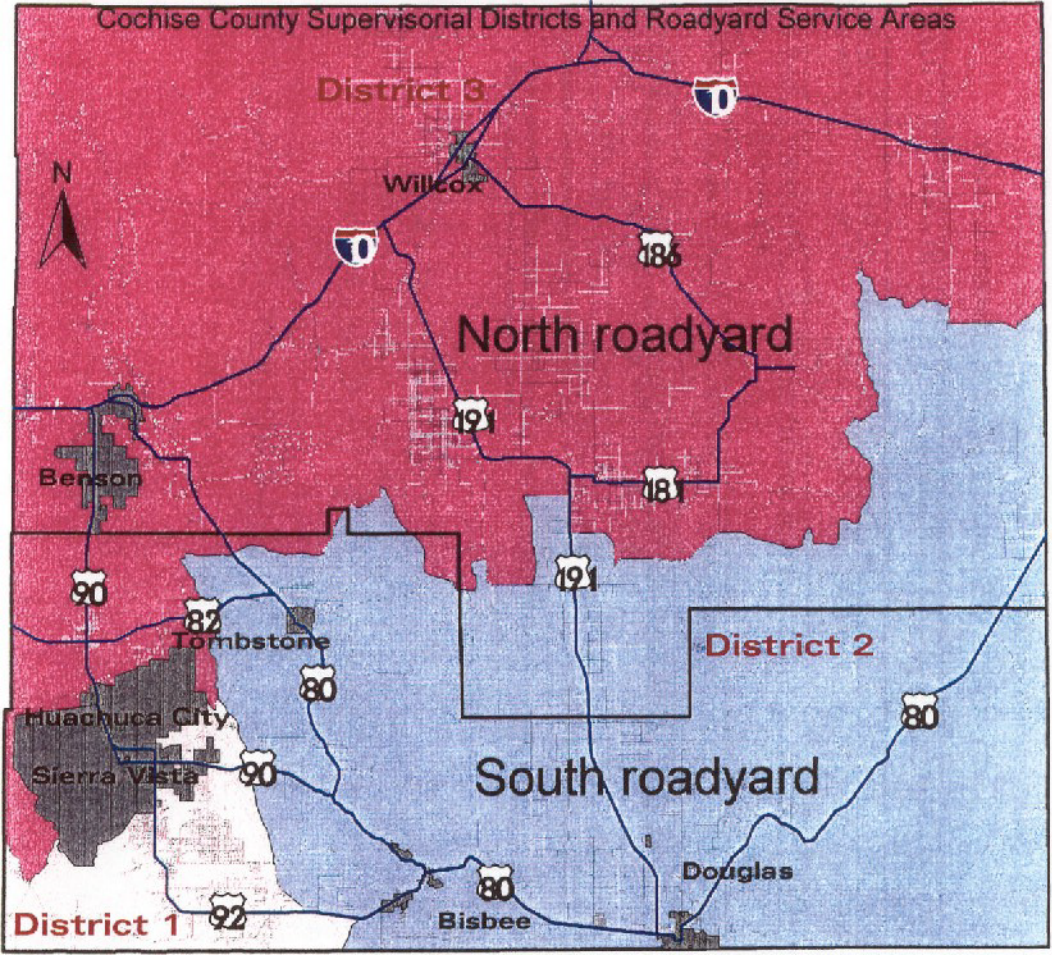



**Maintained Road Miles Outside of Corporate Limits By District**

**Figure 1**

## Population and Road Miles By District

Mileage Data Source is the 2002 Needs Study. Population Data Source is the 2000 Census prior to Redistricting, provided by IT/GIS


Cochise County Supervisorial Districts and Roadyard Service Areas
District 3
N
Willcox
10
186
North roadyard
191
Benson
181
90
82
Tombstone
191
District 2
80
Huachuca City
Sierra Vista
90
South roadyard
80
Douglas
80
District 1
92
Bisbee

fig

**TABLE 3**
**HIGHEST PRIORITY DRAINAGE IMPROVEMENT PROJECTS**

| ROAD | LOCATION | STRUCTURE SIZE | ESTIMATED COST IN DOLLARS |
|---|---|---|---|
| Davis Road | MP 10 | Bridge 150’ long, 36’ wide | 1,500,000 |
| Davis Road* | MP 13 | 2-cell, 6’ high x 8’ wide, 100’ long RCBC** | 200,000 |
| Gleeson Road | Walnut Gulch | Bridge 240’ long, 36’ wide | 2,400,000 |
| Bisbee Junction* | Railroad Xing | | 700,000 |
| Dragoon Road | 0.1 mile south I-10 | 2-cell, 3’ high x 10’ wide, 50’ long RCBC**, | 150,000 |
| Dragoon Road | MP 6.4 | 2-cell 6’ high x 10’ wide, 50’ long RCBC** | 250,000 |
| Ocotillo Road | MP 1.6 | RCBC size to be determined | 150,000 |
| Sibyl Road | Gila Wash Xing | Concrete apron | 150,000 |
| | | **TOTAL PLUS 20% FOR ENGINEERING** | **6,600,000** |

**TABLE 4**

**LOW VOLUME, HIGH SPEED, DIRT ROADS ELIGIBLE FOR LIMITED SURFACE & DRAINAGE IMPROVEMENTS & TO BE BLADED EVERY MONTH***

| ROAD NUMBER | ROAD NAME | ADT | BMP | EMP |
|---|---|---|---|---|
| 631 | Middlemarch | 140 | 0.0 | 2.0 |
| 388 | Gleeson | 140 | 0.0 | 3.0 |
| 22 | Apache Pass | 100 | 0.0 | 8.0 |
| 1229 | Cascabel | 95 | 12.0 | 32.2 |
| 381 | Geronimo Trail | 95 | 2.4 | 13.7 |
| 388 | Gleeson | 85 | 3.0 | 13.0 |
| 623 | Mescal | 70 | 2.9 | 8.9 |
| 166 | Central Hwy | 70 | 0.0 | 6.0 |
| 554 | Leslie Canyon | 65 | 10.0 | 28.8 |
| 70 | Bell Ranch | 60 | 3.0 | 8.1 |
| 463 | Ironwood | 60 | 0.0 | 2.2 |
| 1029 | Turkey Creek | 60 | 0.0 | 4.5 |
| 631 | Middlemarch Road | 60 | 2.0 | 9.9 |
| 674 | State Line | 60 | 0.0 | 4.2 |
| 390 | Ghost Town Trail | 40 | 0.0 | 14.6 |
| 214 | Foothills | 50 | 0.0 | 6.9 |
| 206 | Manzora | 50 | 0.0 | 5.8 |
| 884 | Noland | 40 | 6.2 | 15.8 |
| 575 | Luzena | 40 | 0.0 | 7.0 |
| 381 | Geronimo Trail | 40 | 13.7 | 31.2 |
| 842 | Rucker | 40 | 0.0 | 20.5 |
| 249 | Davis | 40 | 25.6 | 33.2 |
| 1119 | Woods Canyon | 30 | 8.0 | 12.3 |
| | **Total** | | | **203.0** |

* These roads are classified as “major access” roads using AASHTO Low Volume Road definitions.

**TABLE 5**
**SUMMARY OF ROADWAY NEEDS LISTED IN ORDER OF PRIORITY**
**For Years the 2003-2013**

| CATEGORY | AMOUNT In Dollars | REMARKS |
|---|---|---|
| Maintenance | 83,890,000 | Projected to spend $51,960,000 or only 62% of what is needed! |
| Operations & Management | 8,389,000 | Projected to meet these needs |
| Drainage Improvements On Major Collectors | 6,600,000 | Projected to meet these needs |
| Gravel Dirt Roads (ADT's>100) | 8,224,000 | Projected to meet these needs |
| Right-of-Way | 10,456,000 | Grants can meet some of these needs |
| Existing Bridges | 9,581,000 | Grants can meet most of these needs |
| Gravel Dirt Roads (Table 4) | 15,225,000 | |
| Upgrade Existing Paved Roads for Light Vehicles | 37,676,000 | Estimates have not been made for needed drainage structures or removal of roadside obstacles for these categories. Projected revenues can only meet less than 7% of needs shown in the remaining 4 categories |
| Upgrade Existing Paved Roads for Commercial Trucks | 53,153,000 | |
| New Roads | 12,000,000 | |
| **Total Projected Revenue** | **83,000,000** | |

**APPENDIX A BENEFIT/ COST ANALYSIS**

**"Typical Local Road"**

**Construction Cost:** C = $105,000

Work includes: Clear and grub right-of-way, construct roadway with drainage ditches, place 4" of ABC and a double chip seal

**Reconstruction Costs:** R = $35,000 every 20 years

Work includes: Clear and grub right-of-way, mill old chip seal surface into base, re-compact the base, and surface with double chip seal

**Maintenance Costs:**

Dirt road M = $1,840 annually
Paved road M'= $4,020 annually
M-M' = -$2,180

**Vehicle Operating Costs:**

On dirt road c = $0.19
On paved road c' = $0.16
$\Delta$ speed = 30 mph – 25 mph = 5 mph @ $10/hr = $0.04

cc' = 0.19 – 0.16 + 0.04 = 0.07

**Opportunity Cost of Capital:** $i$ = 6% = 0.06

**Traffic Growth Rate per Annum:** $r$ = 0.027

**Break Even Analysis:**

$$Q_{BE} = \frac{C + \frac{R}{(1+i)^N - 1} - \frac{M - M'}{i}}{365(c - c')\frac{1+r}{i-r}} = \frac{105{,}000 + \frac{35{,}000}{(1+0.06)^{20} - 1} + \frac{2{,}180}{0.06}}{365(0.07)\frac{1+0.027}{0.06-0.027}} = 198 \text{ vpd}$$

say 200 vpd

**Optimal Analysis:**

$$Q_{OPT} = \frac{Ci + \frac{Ri}{(1+i)^N - 1} - (M - M')}{365(c - c')} = \frac{105{,}000(0.06) + \frac{35{,}000(0.06)}{(1+0.06)^{20} - 1} + 2{,}180}{365(0.07)} = 369 \text{ vpd}$$

say 370 vpd

## Major Collector with Commercial Truck Traffic

C = $152,000 R = $52,500 c-c' = 0.10

$$Q_{BE} = \frac{152{,}000 + \frac{52{,}500}{(1+0.06)^{20} - 1} + \frac{2{,}180}{0.06}}{365(0.10)\frac{1+0.027}{0.06 - 0.027}} = 187 \text{ vpd}$$

say 190 vpd

Includes 8" of ABC and triple