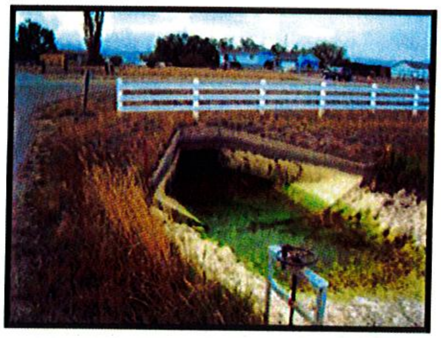
North Montana Avenue (North of Lincoln Road) – Preliminary Engineering Report

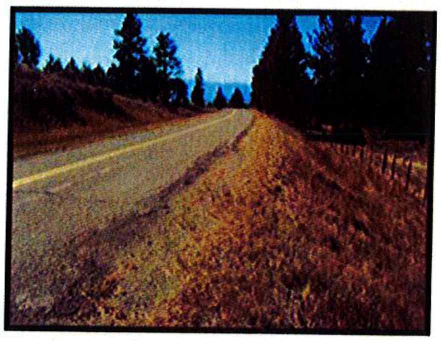
LEWIS & CLARK COUNTY

RPA PROJECT NO. 09503.000

Prepared For:

Lewis & Clark County
3402 Cooney Drive
Helena, MT 59602





Prepared By:

Robert Peccia & Associates
825 Custer Avenue
Helena, MT 59601
www.rpa-hln.com

December, 2009

STATE OF MONTANA
THOMAS ROSS CAVANAUGH
10833PE
LICENSED
PROFESSIONAL ENGINEER

12-11-09

Supplement to the 2009 North Montana Ave. (North of Lincoln Road) Preliminary Engineering Report

LEWIS & CLARK COUNTY

RPA PROJECT NO. 10501.000 – TASK 04

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Lewis & Clark County
3402 Cooney Drive
Helena, MT 59602

Prepared By:

Robert Peccia & Associates
825 Custer Avenue
Helena, MT 59601
www.rpa-hln.com

March 2012

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Executive Summary

PURPOSE AND OBJECTIVES

This is a supplement to the 2009 North Montana Avenue (North of Lincoln Road) Preliminary Engineering Report (PER). The primary purpose of the 2009 PER was to identify geometric deficiencies and recommend improvements, and to provide an engineered surfacing design to meet a 20-year performance period.

Geometric recommendations were based on meeting minimum County road design criteria as presented in the County's subdivision regulations. The PER's road surfacing design was developed for traffic loading impact *specific* to the road segment. The surfacing design also meets the County's minimum requirements as shown in the County's Typical Section No. 4 – Major Collector, with the exception of including an additional 7 inch depth of subbase course. The 2009 PER surfacing recommendation is based on a reconstruction with new, virgin road surfacing materials.

The purpose and objective of this supplemental report is to assess the surfacing improvements from a rehabilitation perspective; one in which to utilize the existing materials in place to the extent practical. The existing materials would then be supplemented with new materials as needed to provide a road that is structurally equivalent to that designed in the 2009 PER.

This report analyzes two road surface rehabilitation methods:

- ✓ Pulverize and blend the existing road surfacing and finish with a new asphalt surfaced mat, or;
- ✓ Mill and overlay the existing road.

LOCATION & DESCRIPTION

The project limits within this PER supplement is the same as the 2009 PER.

SUMMARY OF FINDINGS

Two road surface rehabilitation alternatives were analyzed: mill and overlay versus pulverizing the existing material and finishing with a new asphalt mat. Both resulted in very similar construction cost estimates, at about **$390,000 per mile**. Itemized costs for both alternatives are presented later in the report.

Design Controls and Criteria

REFERENCE STANDARDS

The reference standards used in this PER supplement are those accepted by Lewis and Clark County Subdivision Regulations. The American Association of State Highway and Transportation Officials (AASHTO) *1993 Guide for Design of Pavement Structures* and Montana Department of Transportation (MDT) guidance documents were specifically used to develop the road surfacing rehabilitation alternatives presented herein.

TRAFFIC

The same traffic data used in the 2009 PER is used herein.

CRASH HISTORY

Crash data is not applicable in this report since the purpose and objective is to provide alternative surfacing rehabilitation techniques in lieu of a full-depth road surface reconstruction.

EXISTING ROADWAY TYPICAL SECTION

Other than resurfacing, this PER supplement report does not address modifying the road typical to bring it into compliance with current County standards for ditch depths, shoulder widths, clear zone improvements, etc. The 2009 PER addresses reconstruction needs.

SURFACING DESIGN PARAMETERS

Existing Conditions

Four soil borings were completed along the alignment as part of the 2009 PER to evaluate the existing road's surfacing section and subgrade quality. The table below summarizes the existing conditions.

Table 1 - Summary of Boring Conditions

Boring	ST-1	ST-2	ST-3	ST-4
Approximate Location	MP 0.22	MP 1.35	MP 2.45	MP 3.45
Existing Asphalt Thickness	3 ½"	6 ½"	6"	4"
Existing Base Thickness	8 ½"	5 ½"	2 ½"	2"
Existing Subbase Thickness	-	-	-	-
Existing Base Quality	Poor	Poor	Good	Good
Subgrade / Unified Soil Class	Clayey Sand (SC)	Sandy Lean Clay (CL)	Clayey Gravel (GC)	Clayey Sand (GC)
Blows Per Foot (BPF)	16, 10	4, 6	20, 14	22, 17
Moisture Condition	Over 1-2%	Over 2%	Near	Below
Risk of Subgrade Failure	Moderate	High	Low	Low

The 2009 PER surfacing design is based on traffic counts and projected traffic growth from historical North Montana Avenue data. The traffic volume and vehicle classification counts were then used to estimate the projected traffic *loading,* or surfacing impact, in terms of Equivalent Single Axle Loads (ESALs). The project design is based on a 20-year performance period. The 2009 PER projected the 20-year performance period loading to be an estimated 313,112 ESALs.

Structural Number and Layer Coefficients

The calculated Structural Number (SN) to design the recommended surfacing section for the desired performance is SN = 2.42. The SN is an abstract number expressing the structural strength required for the subgrade soil to support the ESALs. It therefore can be observed that it is not arbitrary, but specific to the road being analyzed.

The relationship of SN is given in the following equation as it relates to layer coefficients (a) and thickness of the material (D) applicable to the layer coefficient.

$SN = a_i \times D_i$

Subscript "i" represents the particular layer of the material. The top surfacing asphalt would be assigned i= 1, and the next lower layer of crushed top surfacing is assigned layer i=2, etc.

As it can be seen in Table 2 on the following page, material layer coefficients vary based on material types and the process to develop the material (e.g. crushed aggregate versus unprocessed native aggregate). Hot plant mix asphalt surfacing purposely blended with quality aggregate and select oil has higher strength (coefficient) per inch of material depth than that of an equivalent depth of gravel road base. It can be reasoned however, that economics are taken into consideration in surfacing design since higher quality (higher coefficient) material is generally more expensive than lower quality (lower coefficient) material.

This report uses material coefficients generated by the Montana Department of Transportation (MDT). These are similar to what AASHTO recommends, yet have been developed based on rigorous laboratory testing and field results applicable to our local material characteristics.

Table 2 - Road Surfacing Material Layer Coefficients

Virgin Materials	Coefficient, "a" (per Inch)
Plant Mix Surfacing (All Grades)	0.41
Crushed Aggregate Course	0.14
Milled Plant Mix Surfacing	0.12
Pulverized Plant Mix Surfacing/Crushed Aggregate Course Mixture	0.12
Treated Base Course	0.20

Existing Materials	Coefficient "a" (per Inch)
Plant Mix Surfacing (All Grades)	0.33
Crushed Aggregate Course	0.12
Milled Plant Mix Surfacing	0.12
Pulverized Plant Mix Surfacing/Crushed Aggregate Course Mixture	0.12
Treated Base Course	0.20
Non-Blended/Non-Crushed Pit Run Subbase	0.07

SURFACING REHABILITATION ALTERNATIVES

For this study, the surfacing rehabilitation alternatives to the 2009 PER full-depth surfacing reconstruction include:

- ✓ In-place pulverizing/blending with new hot plant mix asphalt surfacing, and
- ✓ Mill and overlay

In-Place Pulverization with New Hot Plant Mix Asphalt Surfacing

Examination of Table 1 indicates that the existing surfacing section nearer to the beginning of the project (Lincoln Road) has an overall thicker layer of surfacing materials. Soil borings ST-1 and ST-2 were both measured 12 inches deep before encountering subgrade. Conversely, borings ST-3 and ST-4 have 8-1/2 inches and 6 inches of surfacing, respectively.

These variable surfacing depths are taken into consideration for this report's design depth to pulverize in place material. For the purpose of this report, we estimate pulverizing and blending together the existing asphalt surfacing and base materials to a depth of about 6 inches. As can be seen from soil boring ST-4, this depth will pulverize/blend the majority of surfacing material without blending lesser quality subgrade material into the mixture. If introduced into the blend, subgrade soils could reduce the quality of the blended base.

The mixed blend of crushed asphalt surfacing and base material then would be shaped and compacted as new road base. On top of the road base, a 4 inch layer of new crushed top surfacing would be placed to provide an additional drainage layer. The rehabilitated road base would be topped with a new 3 inch compacted depth of hot plant mix asphalt surfacing.

The calculation below shows that the proposed pulverized base with new asphalt concrete mat would achieve the desired structural integrity, by meeting or exceeding the SN = 2.42 previously discussed.

SN = $a_i \times D_i$, where desired SN = 2.42.

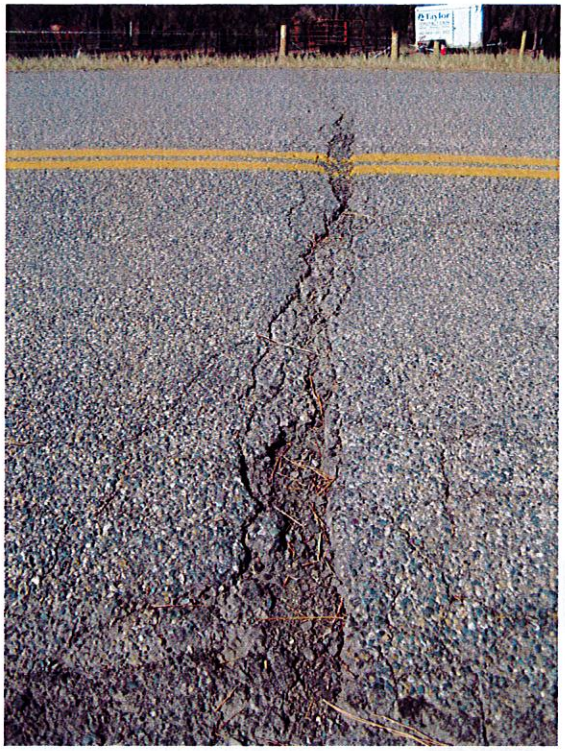
Where,
$a_1 \times D_1 = (0.41) \times (3.0)$ for 3 inch compacted depth new hot plant mix asphalt surfacing.
$a_2 \times D_2 = (0.14) \times (4.0)$ for 4 inch compacted depth new crushed top surfacing
$a_3 \times D_3 = (0.12) \times (6.0)$ for 6 inch compacted depth pulverized/blend base

Resulting in SN = (0.41 x 3.0) + (0.14 x 4.0) + (0.12 x 6.0) = 2.51

The desired SN 2.42 is exceeded by design. Likely the average design SN would be slightly higher since nearer to the beginning of the project, an amount of existing base would be in place not incorporated into the pulverized mix. This lower base material would add some structural bearing capacity. The depth of pulverizing and blending would have to be monitored and adjusted to ensure that the work does not kick up subgrade material into the blend, and to increase the depth where necessary to sufficiently cut below the variable depth asphalt surface layer.

Mill and Overlay

This second surfacing rehabilitation technique identified in this report is to mill the existing surfacing prior to placing a hot plant mix asphalt overlay. The intent would be to mill to a depth to remove superficial cracks. This then would limit crack sealing quantities. However, the existing asphalt surfacing is also experiencing some moderate to significant cracking. This is exemplified in the photos on the following page. Milling will not address significant cracks shown in the upper photo. These significant cracks should be saw cut and patched prior to overlay.



Milling prior to overlay also provides the additional benefit of re-establishing the highway crown by removing ruts. The milling technique may however encounter limitations on this specific project. The existing road surfacing is likely a composite of the original surfacing with multiple blade patches and chip seals. These layers of material could instead break up and fragment during the surface milling operation. The other limitation is the depth that the milling could be accomplished. Based on Table 1, the milling may only be able to remove up to 2 inches of existing asphalt, leaving 1-1/2 inches in place, as shown in boring ST-1. Or as shown in borings ST-2 and ST-3, milling could remove over 4 inches of existing asphalt and still have 2 or more inches remaining in place to serve as a platform to place the overlay.

For the purposes of this estimate, the milling depth will be 2 inches deep. Based on Table 1 soil borings, the average remaining asphalt surfacing depth would be approximately 3 inches after milling. The average existing base thickness is approximately 4.6 inches. We have rounded down to 4 inches for estimating. The geotechnical evaluation tested the existing base quality to vary from poor to good. In assigning a relative layer coefficient, "a", to the base material, we have used an averaged coefficient of good crushed aggregate base (a = 0.12) and non-blended, uncrushed base (a = 0.07). The resulting average coefficient for the existing base is a = 0.10.

The amount of new hot plant mix asphalt overlay to be placed on the milled surface would need to be 3.5 inches as shown below.

$SN = a_i \times D_i$, where desired SN = 2.42.

Where,
$a_1 \times D_1 = (0.41) \times (3.5)$ for 3-1/2 inch compacted depth new hot plant mix asphalt surfacing.
$a_2 \times D_2 = (0.25) \times (3.0)$ for 3 inch compacted depth existing asphalt in place, with some alligator cracking and transverse cracking
$a_3 \times D_3 = (0.10) \times (4.0)$ for 4 inch compacted depth existing base aggregate material

Resulting in $SN = (0.41 \times 3.5) + (0.25 \times 3.0) + (0.10 \times 4.0) = 2.58$

The desired SN 2.42 is exceeded by design. Note in the calculations above a layer coefficient 0.25 was used for the existing asphalt in place. We utilized a reasonable value based on the range of coefficients recommended by AASHTO in their manual (Table 5.2). Unlike the coefficients developed by MDT as previously shown in Table 2, the AASHTO table takes into consideration the degree of alligator and transverse cracking in the existing asphalt surfacing when assigning an estimated layer coefficient.

Miscellaneous Pre-Surfacing Preparations

The roadway will require some preparations prior to undertaking the resurfacing, regardless of which surfacing rehabilitation technique is undertaken. The performance life of the road could be greatly reduced without first undertaking the appropriate preparations.

Recommended surfacing preparations:

- ✓ Complete soft spot digouts and replace with quality backfill.

The geotechnical evaluation noted that the road's subgrade quality varies with areas of low, moderate and high risks of failure to maintain its structural integrity. Materials with high clay content above optimum moisture are most susceptible. The cause is likely due to moisture intruding through surface cracks. Repeated traffic on the susceptible subgrade will eventually cause the material to lose its structural capacity to resist continued axle loading.

- ✓ Crack Sealing

There will likely be an amount of cracks remaining in the mill and overlay alternative after the top surfacing is milled to the desired depth. These cracks should be routed depending on the size of the crack, and cleaned with compressed air jetting prior to applying a bituminous crack sealant.

- ✓ Hot Plant Mix Asphalt Leveling Courses

We have not included in this estimate the need for applying leveling courses prior to overlaying the milled surface. We presume milling 2 inches of existing surfacing prior to the overlay will adequately remove wheel path rutting.

- ✓ Improvements to Drainage Features

The roadway's hydraulic conveyance features should be closely examined prior to planning a major surface rehabilitation. Opportunity to replace failing culverts (crushed, separated joints, undersized pipes, corroded pipes, etc.) is best if undertaken prior to the road surface being improved. The exception to this is if culverts needing maintenance will only require lining or end extensions. In particular, undersized culverts should be replaced prior to surfacing to eliminate having to cut and trench through a new, improved asphalt mat.

Cost Estimate

Full Road Reconstruction

The following table summarizes the estimated cost to construct North Montana Avenue from Lincoln Road north. This is as identified in the 2009 PER and reproduced herein. This reconstruction estimate includes all associated work to address improving roadside safety, improving drainage conveyance features, and preparing the corridor for future need by securing right of way.

Major Work Feature	Unit	Unit Cost	# of Units	Total Cost
Survey - Staking and Grade Control	LS	$45,000.00	1	$45,000
Borrow for Embankment	CY	$7.00	28692	$200,844
Topsoil - Salvage and Place	CY	$4.05	4600	$18,630
Excavation - Unclassified	CY	$5.50	47628	$261,954
MPDES Permit Fees	LS	$900.00	1	$900
Temporary Erosion Control - LS	LS	$8,000.00	1	$8,000
Crushed Top Surfacing (3-inch Depth)	CY	$25.41	8249	$209,607
Select Base Course (6-inch Depth)	CY	$12.00	16499	$197,988
Subbase Course Material (7-inch Depth)	CY	$12.00	19249	$230,988
Aggregate Treatment (Prime)	SQ YDS	$0.41	83776	$34,348
Chip Seal Cover	SQ YDS	$0.69	79787	$55,053
Plant Mix Asphalt Paving	Ton	$81.38	13793	$1,122,474
Emulsified Asphalt Seal (CRS-2P)	Ton	$647.86	135.6	$87,850
Reset Mailbox	Each	$200.83	40	$8,033
Traffic Gravel	CY	$19.03	2700	$51,381
Remove/Reset Signs	Each	$184.30	20	$3,686
Interim Striping - Yellow Paint	Gal	$34.18	62	$2,119
Final Striping - Yellow Paint	Gal	$34.18	62	$2,119
Interim Striping - White Paint	Gal	$34.30	124	$4,253
Final Striping - White Paint	Gal	$34.30	124	$4,253
Remove Existing Culverts	LF	$12.27	2800	$34,356
Approach/Relief Drain Pipe - 18/24 Inch Diam.	LF	$50.17	2650	$132,951
Drainage Pipe 36 Inch Diam	LF	$96.79	92	$8,905
Drainage Pipe 48 Inch Diam	LF	$134.68	87	$11,717
Drainage Pipe 60 Inch Diam	LF	$179.77	80	$14,382
Siphon 54 Inch Diam	LF	$250.00	120	$30,000
Farm Fence - Type Type 5M	LF	$2.25	17952	$40,392

Fence Panel - Single	Each	$145.92	36	$5,253
Fence Panel - Double	Each	$233.67	36	$8,412
Remove Existing Fence	LF	$0.49	3000	$1,470
Guardrail	LF	$19.77	2890	$57,135
Guardrail Terminal Section	Each	$2,804.91	6	$16,829
Seeding	Acre	$294.16	20.7	$6,089
Fertilize Seed	Acre	$120.84	20.7	$2,501
Condition Seedbed Surface	Acre	$221.51	20.7	$4,585
Geotextile - Subgrade Stabilization	SY	$1.50	13125	$19,688
Subgrade Stabilization Gravel (10 – inch Depth)	CY	$8.00	4026	$32,208
Subexcavation	CY	$5.50	4026	$22,143
Traffic Signal	LS	$68,000.00	1	$68,000
Add One Left Turn Lane	LS	$100,000.00	1	$100,000
Subtotal - Construction	**$3,166,496**			
Preliminary, Final Engineering, Geotechnical & Survey	8% of Construction			$253,320
Construction QA/QC	4% of Construction			$126,660
Contractor Mobilization	5% of Construction			$158,325
Contingency	10% of Construction			$316,650
Traffic Control During Construction	8% of Construction			$253,320
Right-of-Way Appraisals by Agent	LS			$100,000
Right-of-Way Acquisition by Agent	LS			$75,000
Purchase Right-of-Way	Acre	$32,000	5.2	$166,400
Total Est. Road Reconstruction Cost (2009)	**$4,616,171**			
Est. Total Road Cost Per Mile	**Miles**	**$4,616,171**	**/ 3.5 Mi =**	**$1,318,906**
Alternate – Add Sanitary Sewer Main	**Per Mile**	**$211,200**	**x 3.5 Mi**	**$739,200**
Alternate – Add Water Main	**Per Mile**	**$396,000**	**x 3.5 Mi**	**$1,386,000**
Alternate – Add Bicycle/Ped. Path Reconstruction	**Per Mile**	**$77,825**	**x 3.5 Mi**	**$272,388**

LS = Lump Sum, CY = Cubic Yard, SQ YDS = Square Yards, GAL = Gallon, LF = Linear Feet

Road Surfacing Rehabilitation

The following tables show the estimated costs of the two road surfacing rehabilitation alternatives.

Alternative 1 – In Place Pulverization with New Hot Plant Mix Asphalt Surfacing

Major Work Feature	Unit	Unit Cost	# of Units	Total Cost
Pulverize/Blend 6" Depth Existing Asphalt & Base	SY	$1.25	49280	$61,600
4" Depth New Crushed Top Surfacing	CY	$25.41	5700	$144,837
3" Depth Hot Plant Mix Asphalt Paving	Ton	$81.38	9,000	$732,420
Chip Seal and Cover Aggregate	SQ YDS	$2.00	49280	$98,560
Aggregate Treatment (Prime)	SQ YDS	$0.41	49280	$20,205
Asphalt Tack Coat	SQ YDS	$0.10	49280	$4,928
Interim Striping - Yellow Paint	Gal	$34.18	62	$2,119
Final Striping - Yellow Paint	Gal	$34.18	62	$2,119
Interim Striping - White Paint	Gal	$34.30	124	$4,253
Final Striping - White Paint	Gal	$34.30	124	$4,253
Geotextile - Subgrade Stabilization	SY	$1.50	13125	$19,688
Subgrade Stabilization Gravel (10 – inch Depth)	CY	$8.00	4026	$32,208
Subexcavation	CY	$5.50	4026	$22,143
Subtotal - Construction	**$1,149,333**			
Traffic Control During Construction (LS)	**$30,000**			
Subtotal – Contingencies and Mobilization (15% of Construction)	**$172,400**			
Total - Construction	**$1,351,733**			
Total – Construction / Cost Per Mile (3.5 Mi Total)	**$386,210**			

LS = Lump Sum, CY = Cubic Yard, SQ YDS = Square Yards, GAL = Gallon, LF = Linear Feet

Alternative 2 – Mill and Overlay

Major Work Feature	Unit	Unit Cost	# of Units	Total Cost
Mill 2" Existing Asphalt Surfacing	SY	$1.35	49280	$66,528
Crack Sealing	LF	$1.00	44352	$44,352
3.5" Depth Hot Plant Mix Asphalt Paving	Ton	$81.38	10,480	$852,862
Chip Seal and Cover Aggregate	SQ YDS	$2.00	49280	$98,560
Asphalt Tack Coat	SQ YDS	$0.10	98560	$9,856
Interim Striping - Yellow Paint	Gal	$34.18	62	$2,119
Final Striping - Yellow Paint	Gal	$34.18	62	$2,119
Interim Striping - White Paint	Gal	$34.30	124	$4,253
Final Striping - White Paint	Gal	$34.30	124	$4,253
Geotextile - Subgrade Stabilization	SY	$1.50	13125	$19,688
Subgrade Stabilization Gravel (10 – inch Depth)	CY	$8.00	4026	$32,208
Subexcavation	CY	$5.50	4026	$22,143
Subtotal - Construction	**$1,158,941**			
Traffic Control During Construction (LS)	**$30,000**			
Subtotal – Contingencies and Mobilization (15%)	**$173,841**			
Total - Construction	**$1,362,782**			
Total – Construction / Cost Per Mile (3.5 Mi Total)	**$389,366**			

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December, 2009

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Executive Summary

PURPOSE AND OBJECTIVES

This roadway Preliminary Engineering Report (PER) was prepared by Robert Peccia and Associates (RPA) under contract with Lewis and Clark County, Montana. The contract is administered by the Lewis and Clark County Public Works office. The study segment is a portion of North Montana Avenue, north of the City of Helena. The study segment is further described in the following section titled "Location & Description". This segment of North Montana Avenue is considered a high-priority road by County staff to receive reconstructive improvements. The prioritization is in some part due to the road's increasing maintenance needs indicative of the impacts caused by current traffic use. In addition, when compared to other portions of the County, this area has experienced a tremendous amount of residential subdivision construction in recent years. Development has added a proportional amount of new traffic, which will continue to contribute to the road's deterioration.

This PER is prepared as an initial task to analyze the deficiencies of the roadway. By evaluating the road's structural and geometric deficiencies or needs, and obtaining an initial snapshot of what improvements are necessary to meet or exceed County road standards, Lewis and Clark County can then better identify funding needs, and begin subsequent planning for engineering and construction.

In accordance with Chapter XI of the current December 18, 2007 Lewis and Clark County Subdivision Regulations (Amended March 5, 2009), Part H Streets and Roads, the County will also utilize this document to calculate the pro rata cost share of each new subdivision that contributes traffic impacts to this study segment as a part of its impact corridor. The pro rata share for each impact will then be reserved to help build the funding needed to ultimately reconstruct the roadway as a whole or in phases.

RPA has prepared this report with services rendered to meet or exceed those of the practicing consulting engineering industry under similar budget and time restraints. No warranty, expressed or implied, is made.

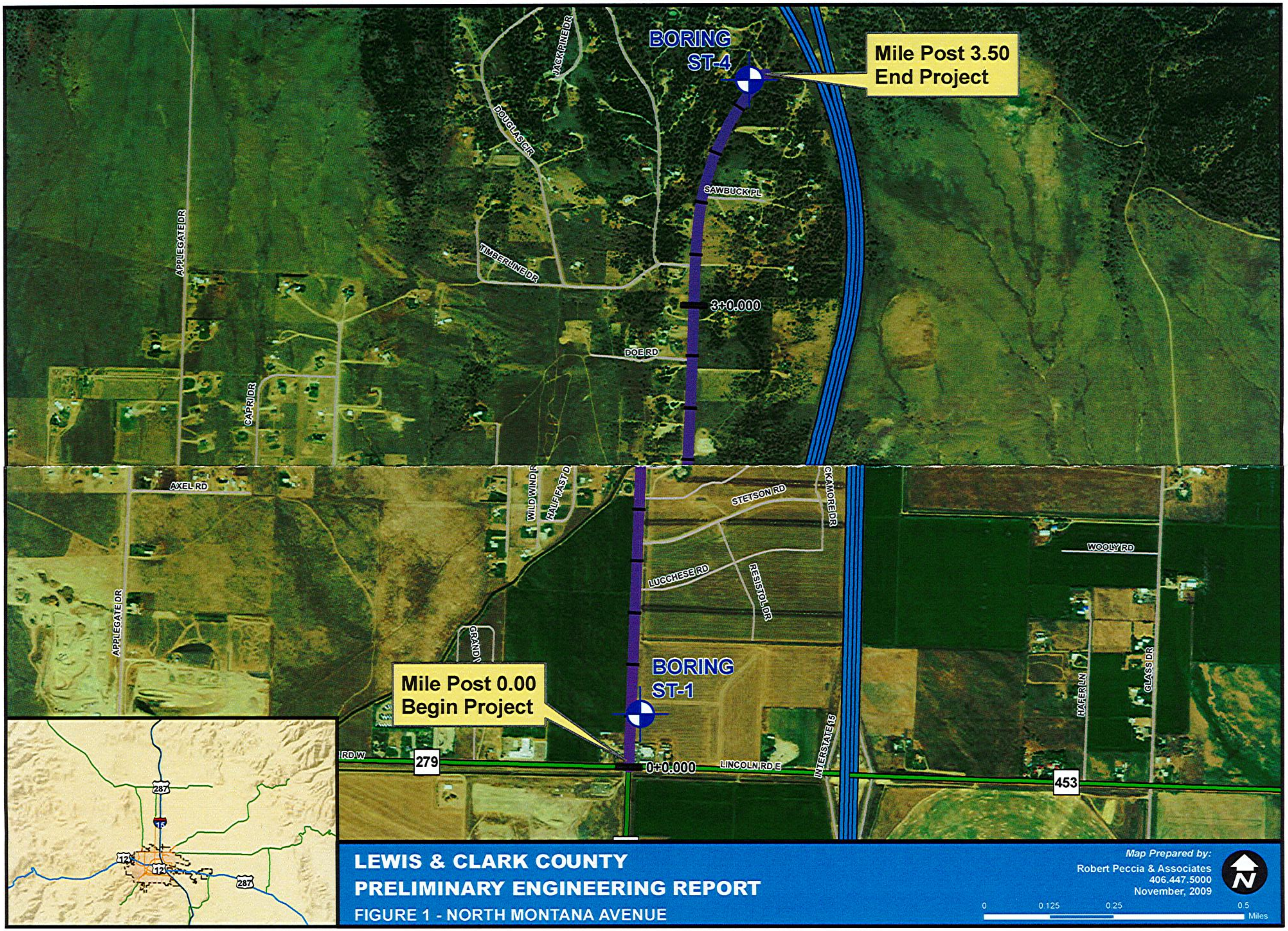
LOCATION & DESCRIPTION

The North Montana Avenue study segment for this PER lies within what is locally known as the North Helena Valley. The study area begins at the intersection of Lincoln Road East (Montana Secondary Highway 279) that is approximately 0.4 miles west of the Interstate 15 / Lincoln Road interchange. From the beginning, the project extends north for approximately 3.5 miles, terminating where the paved section of the road ends. Refer to the following project location map, **Figure 1**. The ending location is at a widened turnaround area that is frequently used by school buses. For the purpose of this study, Milepost [MP] 0.00 is considered as the intersection of Lincoln Road, with the mileposts increasing in a south to north direction. From Milepost 0.00, North Montana Avenue continues due north along the section lines common to Sections 17 and

18, 7 and 8, and 5 and 6 in Township 11 North [T. 11 N.], Range 3 West [R. 3 W.]. The project terminus at MP 3.5 ends within the southwest quarter of Section 32, T. 12 N., R. 3 W.

SUMMARY OF FINDINGS

The existing roadway does not meet several minimum design criteria presented as guidance by the American Association of State Highway and Transportation Officials (AASHTO), or the minimum standards set by Lewis and Clark County. Likewise, the current pavement structure is deficient to meet the needs of the projected loadings it will experience within the study's evaluation period. Although the horizontal and vertical alignments are generally within minimum accepted standards, the aspects of the highway measured from the edge of the traveled way outward to include cut and fill slopes are below safety standards for a facility classified as a Major Collector. Based on the evaluation presented herein, we estimate the cost to reconstruct the road to meet assigned design criteria to be approximately $1.3 million per mile. This cost estimate includes further engineering, traffic control during construction, right-of-way acquisition and other contingencies.



LEWIS & CLARK COUNTY
PRELIMINARY ENGINEERING REPORT
FIGURE 1 - NORTH MONTANA AVENUE

Design Controls and Criteria

METHODOLOGY TO DEVELOP REPORT

Field methods to obtain existing geometric information were used to expedite the process to meet the budget constraint and time period allocated in the scope of work. The work is indicative of the preliminary nature of this project's current status and level of design and development. Explicitly, formal survey work of setting control and then completing instrumental topographical survey was not completed. As such, CADD based design work has not been undertaken, except for some basic diagramming. Field reviews were completed in September 2009, including a "windshield review" with the Lewis and Clark County Public Works Road Superintendent. For on site field reviews, most measurements were taken with a steel tape. Longer measurements were obtained using a wheel tape. For slope or grade estimates, a four-foot long digital smart level was used to record the information in degrees or percent format. This then was converted to approximate slope rates, such as horizontal:vertical (h:v) for describing existing road fill or cut slope rates as an example. For longer measurements, such as checking sight distances, a hand-held laser rangefinder was used. GIS information was used to minimize walking or windshield review time. An amount of certificates of survey and subdivision plats were referenced as a means to crosscheck information, but by no means was a full record research performed. The original road construction of record was referenced. The Federal Aid Project (FAP) 269-B as-built construction drawings and record right-of-way plans were obtained from the Montana Department of Transportation. This original highway project appears to be dated back to 1933.

REFERENCE STANDARDS

The reference standards used in this study are those specified by the Lewis and Clark County Subdivision Regulations. Specifically, in the Road Standards, referenced documents include AASHTO and MDT publications amongst others. These standards were followed, with the County standards governing all others if design information is provided for the specific item being evaluated. If we deemed it appropriate to use other reference materials, then those materials are documented in this report.

PHYSICAL CHARACTERISTICS

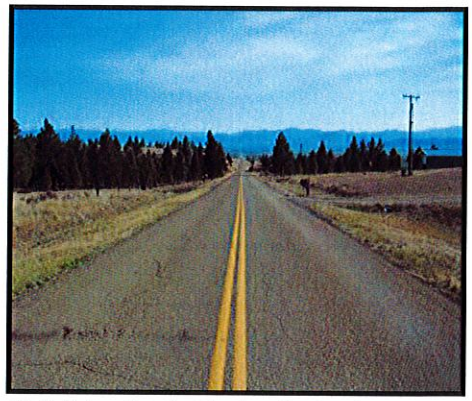


Photo 1: Level terrain rising to rolling terrain.

Design criteria for assessing improvements being considered for a roadway are in some part governed by the terrain that the roadway traverses. Terrain classifications are level, rolling and mountainous. The terrain of this roadway study segment is generally level from the beginning of the project, MP 0.0, northerly to approximately MP 2.0 at the intersection with Prairie Road. Road grades in the lower segment nearer to the project beginning vary slightly from 0.4% to less than 1.0% just south of Valley View Road [MP 1.0]. North of Valley View Road, the grade continues to rise on a steeper slope, but does not cross substantial drainage draws that would require a rolling alignment. Therefore it still is consistent with level terrain to about MP 2.0. North of Valley View Road the road grades are approximately 2.0% up to 3.0%+. North of MP 2.0 (Prairie Road), the terrain generally enters into rolling hills with intermittent cross-drainage draws as the roadway climbs out of the Helena valley. Road grades vary in this segment, however all still being on a positive up gradient slope. The steepest road grade is approximately 5.50% at about MP 2.65.

The area is semi-arid. Few significant cross-draining structures were observed during field reviews. The predominant drainage is from north to south parallel to the road alignment with more transverse crossings occurring in the rolling terrain. The lower valley exhibits primarily dry semi-arid vegetation such as sagebrush and native grasses nearer to the road interspersed with developed landscaping. As the terrain climbs and rolls into draws, evergreens are the predominant trees mixed with some small open parks.

The area is rural, but continues to be developed with major subdivisions creating suburban residential tracts. The area east of the road is somewhat more constricted for future development due to the proximity of the parallel running Interstate 15. At its closest point in this study area, the interstate is approximately 750 feet east of North Montana Avenue at about MP 2.0 (Prairie Road).

North Montana Avenue within the study area is functionally classified as a Major Collector. This classification serves to collect traffic from abutting properties via local road intersections, and distribute to other roads of equal or higher classification.

EXISTING RIGHT-OF-WAY

Research indicates that highway right-of-way for this road segment was initially acquired under State of Montana Federal Aid Project 269 B. Property secured for road construction purposes was obtained by easement in the name of the State of Montana Highway Commission to be used by the State and its successors (i.e. Lewis and Clark County) in interest as long as the right-of-way is used as a public highway. A sample easement executed for Project FAP 269 B is included in **Appendix C**.

At the beginning of the PER study area, MP 0.00 at Lincoln Road; the right-of-way is 80' wide overall for 280 feet north of the intersection. At that point, the right-way widened an additional 10 feet on the west side (50 feet from centerline), to be 90 feet overall. This width was held for approximately 3,500 feet at which point the west side line establishing the right-of-way is widened an additional 20 feet for an overall width of 110 feet. The 110 feet of overall right-of-way is carried through northerly to the north line of Sections 17 and 18, T. 11 N., R. 3 W. This is at the intersection of North Montana Avenue with Valley View Road, or project MP 1.00.

From MP 1.00 to MP 2.00, which MP 2.00 approximately corresponds to the north line of Sections 7 and 8, T. 11 N., R. 3 W., the highway project FAP 269 B acquired 60 feet of right-of-way on the west, and 40 feet on the east for an overall width of 100 feet. MP 2.00 at the approximate north line of Section 7 is the intersection of North Montana Avenue with Prairie Road.

The acquired right-of-way from Prairie Road north through Sections 5 and 6, T. 11 N., R. 3 W. is apparently 100 feet overall (50 feet left and right of centerline). This 100 feet of right-of-way extends to the south line of Sections 31 and 32, T. 12 N., R.3 W., corresponding to just slightly north of this study's MP 3.00.

From MP 3.00 northerly through the horizontal curve deflecting right (northeasterly) to the end of this study area, the acquired right-of-way from FAP 269 B is 80 feet wide.

In addition to the FAP 269 B project right-of-way plans, an amount of certificates of survey and subdivision plats were reviewed to also ascertain existing right-of-way conditions. The sample records reviewed correlated with the record highway drawings. As a last means of checking, GIS also reflected the record drawings.

The minimum County standard right-of-way is 100 feet for Major Collectors. Based on this, to reconstruct the road to minimum standards, the existing right-of-way near the beginning and ending locations of the study area may be 10 to 20 feet less than required.

DESIGN SPEED

Design speed is a selected speed used to determine multiple aspects of roadway design criteria. Design speed is selected in relation to topography, vehicle operating speeds, roadside development, and the functional classification of the highway. The American Association of State Highway and Transportation Officials (AASHTO) publication "A Policy on Geometric Design of Highways and Streets - 2004" (the Green Book as commonly referred to by the industry) states that the selection of the design speed for roads other than constrained local streets, should be made to use the speed that is the highest practical to attain the desired degree of safety, mobility, and efficiency subject to environmental, economic and other social, political or aesthetic constraints. Further, the design speed should be higher than the running speed of a large proportion of drivers.

In Appendix J, Table A, Road Standards, of the Lewis and Clark County Subdivision Regulations, the specified design speed applicable to North Montana Avenue in this segment is 55 miles per hour (mph) for level terrain and 45 mph for rolling terrain. A copy of Table A is included in

Appendix C. As noted above, the functional classification of this road is a Major Collector. AASHTO guidance further states that designs should exceed their criteria where practical. Every effort should be made to obtain the best possible alignment, grade, sight distance, and improved road cross-sectional elements that are consistent with terrain, present and anticipated development, safety and available funds.

Exhibit 6-1 of the AASHTO Green Book, reproduced in **Appendix C**, is a table of suggested minimum design speeds for Rural Collectors. For over 2000 vehicles per day, AASHTO's minimum design speeds are 60 mph for level terrain and 50 mph for rolling terrain. In reference to this, the County's design speeds may be somewhat low. AASHTO recommends, where practical, to consider using design speeds higher than those shown in the exhibit.

Exhibit 6-4 of the Green Book, contained in **Appendix C**, specifies maximum suggested grades, in percent (%), for specified design speeds of Rural Collector highways. For 55 mph design speeds, level terrain can have a highway grade of up to 6%. For 60 mph in the same terrain, the maximum grade is 5%. For rolling terrain, the maximum suggested grades are 7% and 6%, respectively, for 55 mph and 60 mph design speeds. For the subject project, there are no existing grades exceeding those recommended based on the terrain criteria, and the exhibit suggests that the higher design speed of 55 mph for rolling terrain in this study area is appropriate.

In terms of the highway's horizontal alignment, except for the terminus of the project, which is on a horizontal curve, the roadway exhibits a tangential centerline. This is a result of the original road being built to generally follow section lines. The vertical alignment is consistent, albeit increasing in vertical grades as a driver travels south to north. Many of the grade changes do not have vertical curves. Although spot speed checks were not undertaken as a part of this project, we presume the operating speeds of those vehicles in the rolling terrain are not operating at or below the implied design speed of 45 mph but instead are somewhat higher due to the consistent grades and lack of horizontal alignment deflections.

The highway is currently signed for a regulatory speed limit of 55 mph. This is less than the 70 mph daytime and 65 mph nighttime regulatory speed limit established by Montana law for similar facilities. The posted speed limit has been set by a speed study requested by the County, and conducted by the Montana Department of Transportation. Based on this and the above comparisons, for purposes of this study we have selected a design speed of 55 mph to provide continuity in the study segment.

TRAFFIC

Lewis and Clark County completes annual traffic counts for roads under their jurisdiction. The County recognizes the importance of methodically collecting traffic data to analyze traffic growth characteristics and help assess each road's maintenance needs.

Abelin Traffic Services (ATS) of Helena has in the recent years been contracted with the County to complete their Traffic Count Program. The 2009 traffic counts for this road segment were completed by ATS in August. ATS converts the raw data traffic counts into Average Annual Daily Traffic (AADT) to provide an accurate AADT traffic volume regardless of which month, day or hours the counts were performed. The 2009 AADT for this road is 4,396 vehicles per day as reported by ATS. For the purpose of this study, ATS completed a traffic classification count to help analyze the traffic mix. This then was used to complete a road surfacing evaluation.

Lewis and Clark County also provided RPA with the historical traffic counts for this segment of North Montana Avenue. The AADT counts date back 20 years to give a very good baseline of information to characterize traffic growth. The historic traffic counts as well as the 2009 ATS traffic classification counts are shown in **Appendix A**. The identification number for the study area is 7A-78 (North Montana Avenue, North of Lincoln Road).

RPA plotted the historic traffic counts in Microsoft Excel to assess the annual growth rate. A linear trend line was established from the historical counts and used to project out to a 20-year evaluation period to year 2029. Based on the trend line, the yearly growth rate within the 20-year performance period is approximately 3.0%. The estimated AADT for year 2029 is 7,916 vehicles per day. The trend line graph is also shown in **Appendix A**.

CRASH HISTORY

Crash data for the road segment studied was requested from the MDT Safety Management Engineer on September 4, 2009. The crash summary and detailed crash data was received on September 28, 2009, including 0.2 miles on each side of Lincoln Road (State Secondary Route 279) at its intersection with North Montana Avenue.

There were twenty-four reported crashes between January 2004 and December 2008 along North Montana Avenue from the intersection of Lincoln Road north to the end of the study area. The majority of the reported crashes occurred along the southern portion of the road, near the intersection with Lincoln Road. A concentration of four crashes occurred at or in close proximity to the access points with Bob's Valley Market; three crashes occurred at the intersection with Lincoln Road along the northern leg of Montana Avenue. No other major crash concentrations were noted. Twelve of the reported crashes were "non-junction" related crashes, three of which occurred in the ditch. Ten of the reported crashes resulted in injuries, none of which resulted in fatalities. Seven crashes occurred when the road conditions were icy, wet, snowy or slushy.

HORIZONTAL ALIGNMENT

The horizontal road alignment of North Montana Avenue is tangential in a north/south direction. The tangent sections of the road are primarily a result of the road following the section lines. One horizontal curve exists at the terminus of the project, beginning near MP 3.1. The radius of this curve is 2,865 feet and the deflection angle is 35°34' according to the construction plans of project FAP 269-B. The curve length is approximately 1,778 feet.

Table A of the County's Road Standards contained in Appendix J of the Subdivision Regulations (see Appendix C of this report), lists the minimum centerline curvature for a Major Collector as

440 feet for rolling terrain. Based on this, the existing curve exceeds County standards, however the County standard appears to be less than what AASHTO recommends.

Pursuant to AASHTO guidance depicted in Exhibit 3-15, using a side friction factor of f=0.13 and a conservative maximum superelevation rate of e=8.0%, yields the minimum recommended radius of horizontal curvature of 960 feet. The existing curve exceeds this minimum. A copy of Exhibit 3-15 is included in Appendix C.

We also referred to the MDT road design guidelines to compare the measured superelevation rate to their design criteria. A few spot measurements completed during a field review measured the superelevation rate of the horizontal curve as approximately 6.0%. For a design speed of 55 mph, and a superelevation of 6.0%, the radius of curvature under MDT standards would be between 1,920 feet and 2,470 feet. Based on the MDT road design guidelines it should be 5% for the existing horizontal curve at MP 3.1. Conversely, the horizontal curve based on the superelevation better meets 60 mph design standards, which is greater than the chosen design speed, and therefore is within acceptable allowances.

In conclusion, the existing road alignment appears to exceed minimum county, MDT and AASHTO standards for horizontal curvature. Not withstanding other geometric features related to the alignment, no substantial adjustments to the horizontal curve alignment at MP 3.1 are expected when this highway's design for reconstruction is to be undertaken.

VERTICAL ALIGNMENT

The County road regulations list their maximum allowable grades for Major Collectors as those pursuant to AASHTO standards. Exhibit 6-4 of the AASHTO Green Book identifies suggested maximum grades for Rural Collectors in specific terrain and design conditions. For the chosen design speed of 55 mph, the maximum grade for level terrain is 6%, and the maximum grade for rolling terrain is 7%. According to the as-built plans of FAP 269-B, the maximum grades in either the level or rolling terrain do not exceed these standards. With this, no substantial changes are expected to the vertical alignment grades.

SIGHT DISTANCE

The discussions above regarding horizontal and vertical alignment elements focused on whether or not horizontal curvature and vertical grades meet standards. Applicable to these geometric features is the design element of sight distance. The measure of a driver's sight distance is critical to safely avoid collisions with objects. This is measured by stopping sight distance in both horizontal and vertical planes. In addition, to promote efficiency of the highway facility relative to its functional classification, an amount of passing sight distance for drivers to enter the opposing lane to pass vehicles is desired.

The project has one horizontal curve near the terminus of the study area. We used a hand-held laser rangefinder to measure sight distances along points within the inside lane of the curve to determine whether or not some projections, such as signs, trees or cut slopes interfere with the driver's ability to stop once they react to an object seen within this curve. This methodology is crude and would need to be verified by more accurate means, but we found the rangefinder was able to read up to approximately 280 yards (840 feet) along a chord on the inside of the curve. Based on the road grades within the horizontal curve, and the design speed, we feel that the horizontal stopping sight distance is adequate as referenced to Exhibit 3-2 of the AASHTO Green Book. This reference lists the stopping sight distance as a minimum of 469 feet based on the upgrade of the road at that location.

Stopping sight distance as applied to the vertical alignment of a roadway can be assessed by the rate of curvature, K, of each crest or sag vertical curve. Exhibit 6-2 of the AASHTO Green Book, contained in **Appendix C**, lists the various criteria for both crest and sag vertical curves. Based on a design speed of 55 mph, to achieve the minimum stopping sight distance of 495 feet, the minimum design K for a crest vertical curve is 114 and a sag vertical curve is 115. If the actual K for a crest or vertical curve exceeds these values, then the stopping sight distance as a driver passes over these curves is deemed acceptable.

The apparent worst-case crest vertical curve in terms of sight distance on the project, that with the lowest K, is at approximately MP 2.74. According to as-builts, the length of the crest vertical curve is 400 feet, and the difference in grades is 3.00% (5.50% - 2.50%). This results in K equaling 133. K exceeds that recommended by AASHTO and therefore has a stopping sight distance adequate for the chosen design speed.

Likewise, the sag vertical curves on the existing highway were reviewed for stopping sight distance. Exhibit 6-2 of the AASHTO Green Book specifies the minimum K to achieve the stopping sight distance as 115 for a design speed of 55 mph. Upon review of the FAP 269-B as-builts, two sag vertical curves do not meet this requirement. These are at approximate MP 2.50 and MP 2.88. These curves have a K of 93 and 87, respectively for curve lengths of 200 feet each. To meet the design criteria, each curve would have to be lengthened as a part of reconstruction to about 250 feet and 300 feet (rounded to the nearest 50 feet). Lengthening the curves would result in a slight grade raise for each.

EXISTING ROADWAY TYPICAL SECTION

Roadway Surfacing Section

As indicated from the as-built construction plans, the original roadbed was built on a 25.9-foot wide subgrade. Over the subgrade, 5-inches (loose lift) of gravel surfacing was spread and compacted to form a 24-foot wide travel way, for two 12-foot travel lanes. Over the years, MDT had placed one or more layers of base courses, asphalt plant mix surfacing, and seal coats. Since the time period Lewis and Clark County adopted the maintenance requirements from the MDT, at over twenty years ago, the County has performed road maintenance on an as-needed basis as budgets allow. Most maintenance work has consisted of cold patching potholes, blade patching larger surface breakup areas and chip sealing.

Soil borings completed as a part of this study indicate that the current existing asphalt surfacing ranges from 3 ½ -inches to 6 ½-inches thick. The existing base aggregate course thickness ranges from 2-inches to 8 ½-inches thick. Two samples qualified the base gravel quality as poor, while two rated the material as good. The two locations with good base course material, however, were 2 ½-inches thick or less. Further, the surfacing evaluation also compared the base aggregate samples to the Lewis and Clark County crushed top surfacing and select base course gradation requirements. The base samples did not meet County specifications due to primarily excessive fines passing the No. 200 sieve size. Refer to the pavement evaluation contained in Appendix B of this report for additional information.

Roadway Typical Section – Level Terrain

Near Avian Road, Valley View Road and Hunter Road, we completed surface measurements of North Montana Avenue to determine the road's sectional dimensions in the level terrain. Measurements taken include surfacing widths, cut and fill slope rates, ditch widths and depth of the roadside ditch. Each varied slightly from one another. The top surface measured to have 11 to 12 foot travel lanes for a total width of 22 – 24 feet wide. The difference in surfacing width could be attributed to determining the location of the edge of pavement, which exhibited some shoulder breakup. The surfacing inslopes from the edge of the pavement to the ditch or fill foreslope hingepoint measured to be about 10:1 to 12:1 (horizontal:vertical).

The roadside ditch foreslope on the west side of the road appeared to be flatter than that on the east side in the locations reviewed. The foreslope on the west side was measured in one spot to be about 3:1 while the majority appeared to be 4:1. On the east side, the ditch foreslopes were generally about 2.5:1.

Most roadside ditch depths in locations measured were about 5+ feet deep from the center of the road to the bottom of the ditch. In all cases, the ditch was somewhat trapezoidal in shape with a width of about 4-6 feet wide sloping slightly upward away from the road.

Backslope lengths and slope rates cutting up and away from the roadside ditch varied supposedly dependent on available right-of-way or the need to excavate material to build the road embankments. Most backslopes were about 3:1 or 3.5:1. One slope was measured at about 7:1. The steepest typical ditch backslope measured was about 2:1.

On the west side of the highway, from Lincoln Road to Prairie Road there is a 10-foot wide paved shared-use bicycle/pedestrian path. Its offset from the westerly right-of-way fence varied from about 5 – 12 feet to accommodate a utility corridor. The roadside backslopes cut downward from the path to the ditch bottom. **Figure 2** below is a diagram of the roadway typical cross sectional elements in the level terrain based on composite field measurements and record drawings. In the figure, the existing right-of-way is shown as 60 feet/40 feet on the west side/east side of centerline. However, as previously discussed in the report, right-of-way splits of 50/40, 70/40 and 50/50 feet on the west/east side of centerline is also applicable. This could also account for some variation in cut and fill slope rates to best fit within the available right-of-way.

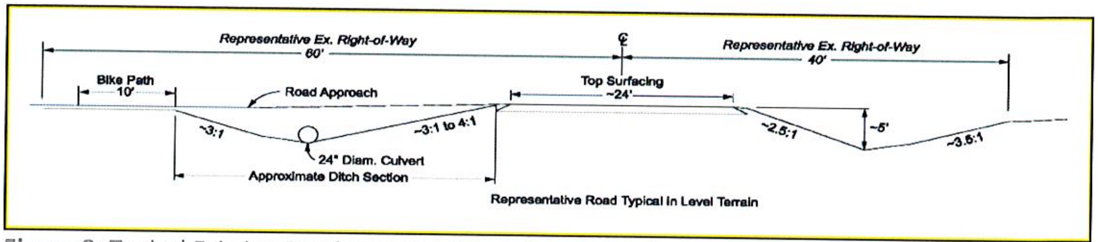


Figure 2: Typical Existing Road Cross Section in Level Terrain

Roadway Typical Section - Superelevated

The only superelevated road section is near the end of the study area, which corresponds to the only horizontal curve. The cross-slope of the road was measured to be at about a 6% superelevation. In this section, the top surface width of the road was measured to be about 20-feet wide, or about 2 to 4 feet less in width than the typical section observed in the level terrain. **Figure 3** below is a diagram of the roadway section along the horizontal curve beginning at about MP 3.1 based on composite field measurements and record drawings.

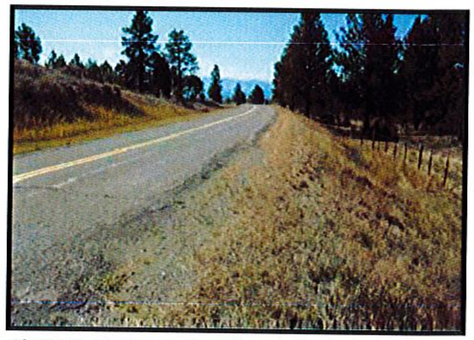


Photo 2: Looking south at the existing horizontal curve located at *approximately MP 3.1. This photo is similar to Figure 3.*

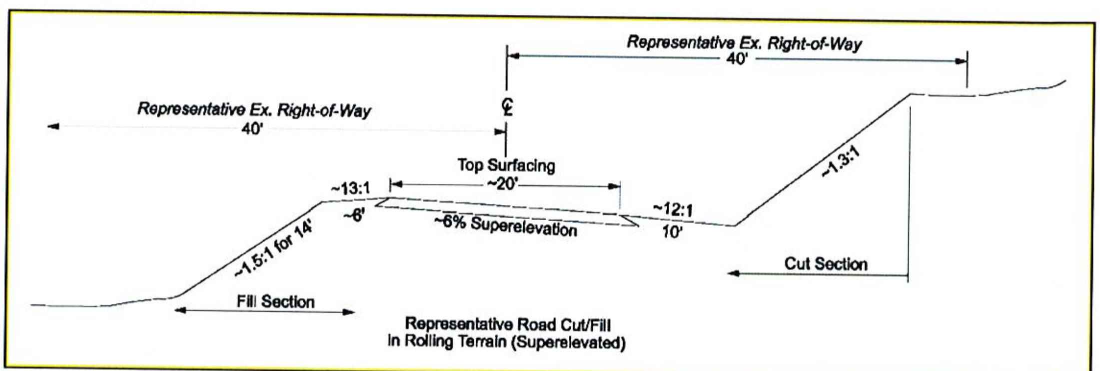


Figure 3: Existing Typical Superelevated Road Section

Roadway Typical Section – Fill Slope in Rolling Terrain

Figure 4 below is a diagram of a sample road fill section in the rolling terrain. This crossing is typical of the larger drainage crossings, and is based on the field measurements taken at a 36-inch reinforced concrete culvert crossing at approximate MP 2.56.

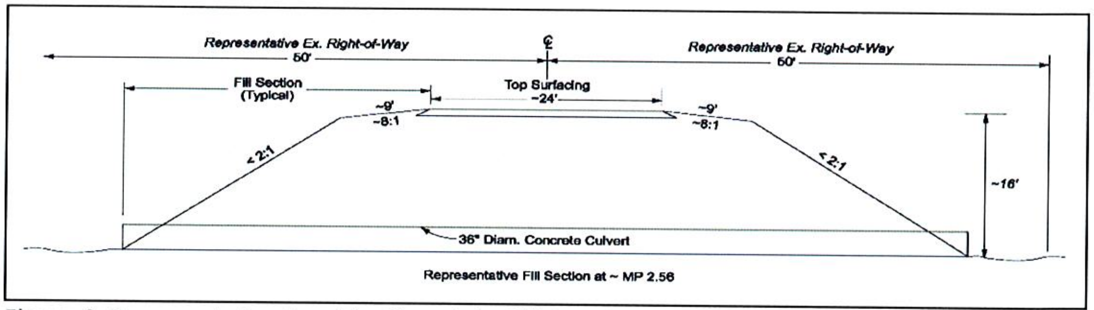


Figure 4: Representative Road Section of the Fill Crossing MP 2.56

PROPOSED ROADWAY TYPICAL SECTION

Preliminary Surfacing Design

For this study, four soil borings were completed along the alignment to evaluate the existing road's surfacing section and subgrade quality. For this study, a preliminary surfacing section was developed based on laboratory tests of the soil samples and projected traffic data. This pavement design is used within this study to estimate reconstruction impacts and costs. As such, the preliminary surfacing design is developed to also meet or exceed the surfacing requirements of the Lewis and Clark County Road Regulations for this Major Collector highway.

Based on the input parameters and the approach of analyzing the pavement design to be in accordance with the County Subdivision Regulations, the recommended reconstruction should have a new pavement section meeting or exceeding the structural integrity of the following (refer to **Appendix B** for the full pavement design evaluation):

- 3" Thick (Compacted) New Asphalt Pavement
- 3" Thick (Compacted) Crushed Top Surfacing
- 6" Thick (Compacted) Select Base Course (3-Inch Minus Gradation)
- 7" Thick (Compacted) Subbase Course (3-Inch Minus Gradation)
- **19" Total Thickness**

Design Clear Zone

Typical highway crashes either involve incidents on the road, or collisions with fixed features off of the road, such as bridge piers, sign supports, overhead utility poles, culverts, and ditches. To counteract the affects of off-road errant vehicles, agencies implement a traversable and unobstructed roadside area beyond the edge of the traveled way for higher volume, rural facilities. Obstacles within the "clear zone" are evaluated to be removed, relocated, redesigned or shielded. The basic parameters to establish the appropriate design clear zone is the road's design speed, design traffic volume, and design roadside cut and fill slope rates.

Lewis and Clark County Road Standards references roadside clear zone requirements to those recommended by AASHTO. A portion of Table 3.1 of the AASHTO 2006 Roadside Design Guide is reproduced below. This shows the recommended clear zones based on the design speed and traffic volume parameters. The clear zone shown below is measured in feet from the edge of the traveled way.

Table 1: Roadside Clear Zone Requirements

		Foreslopes			Backslopes		
Design Speed	**Design AADT**	**6H:1V or Flatter**	**5H:1V to 4H:1V**	**3H:1V**	**3H:1V**	**5H:1V to 4H:1V**	**6H:1V or Flatter**
55 mph	Over 6,000	22-24	26-32	**	16-18	20-22	22-24

** Since recovery is less likely on the unshielded, traversable 3H:1V slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of the slope. Determination of the width of the recovery area at the toe of the slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety, needs and crash histories.

Applying the minimum allowable foreslope rate of 4:1 as shown in Figure 4 of Appendix J of the County's Subdivision Regulations yields a 26 – 32 foot recommended clear zone. For the purposes of this study, we are applying the minimum recommended design clear zone of 26 feet to develop the proposed road template. This minimum recommended clear zone would reduce construction impacts, road reconstruction costs, and reduce right-of-way acquisition.

Surfacing Width

Figure 4 contained in Appendix J of Lewis and Clark County's Subdivision Regulations depicts the County's minimum standard road typical for a two-lane Major Collector. Each travel lane is to be 12-feet wide. The shoulder width can vary between 4 feet and 8 feet, as measured between the edge of the travel lane to the edge of the surfacing. To determine an appropriate shoulder width, we referred to the AASHTO Green Book for guidance. Exhibit 6-5 as referenced in **Appendix C**, specifies the minimum shoulder width as 8 feet for a design volume of greater than 2,000 vehicles per day. Based on this, the recommended overall road surfacing width for reconstruction to accommodate two travel lanes and shoulders is 40 feet.

Design Typical Section

The following **Figure 5** is the preliminary design typical road section.

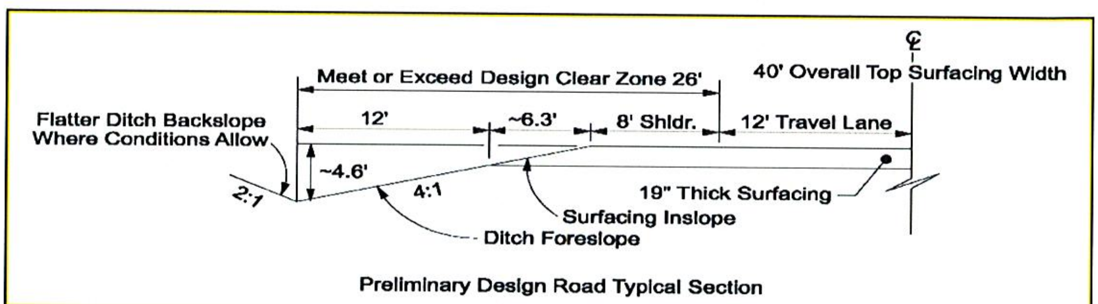


Figure 5: Proposed Road Template Meeting Clear Zone Requirements

The design typical is based on the recommended surfacing section thickness developed under this study's pavement design. This thickness will yield an approximate surfacing inslope distance of 6.3 feet based on the 4:1 minimum allowable slope rate pursuant to County standards. The 8-foot shoulder as discussed above is the width recommended by AASHTO. The v-ditch in the configuration shown should be located at or beyond the design clear zone as recommended by AASHTO. As such, the 12-foot ditch foreslope is chosen to place the ditch at the recommended offset. The 2:1 ditch backslopes are included to further reduce roadside impacts attributed to the widened road template. Flatter ditch backslopes are recommended where site conditions allow.

Miscellaneous Grading, Cut and Fill Slopes

To estimate earthwork and miscellaneous other feature impacts to reconstruct the roadway in level terrain, we applied the design typical section, shown in Figure 5 over the existing road template estimated from field measurements, Figure 2. The estimate is based on the reconstruction closely following the existing horizontal and vertical alignments. The superimposed typical section is shown below in **Figure 6**.

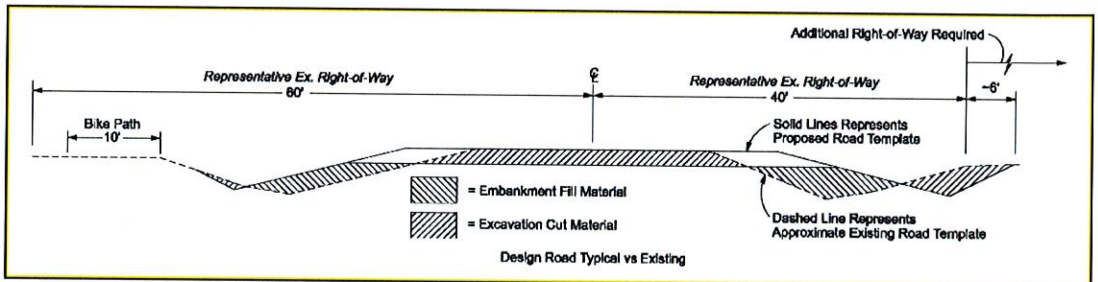


Figure 6: Estimated Cut/Fill Impacts in Level Terrain

Applying the proposed road design (Figure 5) to embankment sections such as those encountered in the rolling terrain (Figure 4) produces additional quantifiable information. For fill sections such as those shown in Figure 4 we assume that 2:1 fill slopes will be utilized to limit right-of-way acquisition. Based on this, new guardrail is projected to be needed when the road is reconstructed in fill sections similar to those shown in Figure 4.

A rock cut near MP 2.50 is very near the traveled way at about 5 foot offset from the edge of pavement and well within the design clear zone. This rock cut slope is about 270 feet long and estimated to be at about a 1.25H:1V slope rate. The rock outcroppings are jagged and an errant vehicle could be susceptible to snagging. Due to the limits of the existing right-of-way, we assume the amount of additional rock cut undertaken to reconstruct the road would be held to a minimum amount. In addition, due to the rock cut proximity to the roadway we further assume that the full recommended clear zone would not be implemented

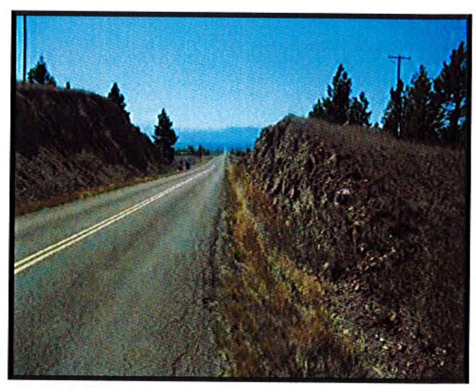


Photo 3: The reconstructed road should shield rock cuts unless they are removed from being within the clear zone

and guardrail would instead be installed in the roadway reconstruction to shield the cut slope.

Geotechnical Considerations

Geotechnical evaluations were not undertaken other than the soil borings and laboratory analysis needed to develop a preliminary pavement design. When further design engineering is undertaken in subsequent tasks to develop the roadway reconstruction project(s), additional geotechnical engineering is warranted to confirm such items as slope stability, subgrade stabilization limits, final cut/fill slope rates, foundation settlement, and excavation/embankment shrink factors.

During the course of developing the pavement design, the boring identified as ST-2 encountered sandy lean clay subgrade that was soft and over optimum moisture content. The geotechnical engineer evaluated this subgrade to have a high risk of subgrade failure during construction. ST-2 is located at approximate MP 1.35.

Of the four soil borings taken, subgrade samples from the two in the level terrain had moderate to high-risk indicators of subgrade failure during construction. The two borings taken in the northern half of the study area, or within the more rolling terrain, showed a low risk of becoming unstable due to construction. The soil borings completed for this project are located on a vicinity map contained in the surfacing evaluation report in **Appendix B**, and their approximate locations are again depicted in Figure 1.

Based on the preliminary indications arrived at in the development of the proposed pavement design, we anticipate the need for some subgrade stabilization during the course of reconstruction. For the purpose of completing the road reconstruction cost estimate, we are including an estimate for increasing the subbase material by an additional 10-inches. This additional bridging material will be applied over a geosynthetic fabric to complete the subgrade stabilization. Subgrade stabilization is further discussed in the pavement design contained in **Appendix B**.

UTILITIES

How the road reconstruction may affect utility installations was estimated by completing buried utility locates in four sample locations. The sample locations were chosen at intersections to also help ascertain what utilities were buried along public road approaches. We completed "all-call" utility locates on about September 16, 2009. After receiving notification that utility locates were done, we then diagramed each site and completed a general windshield review of above ground utility features. Locates were completed approximately 100 feet north and south of each intersection throughout the right-of-way corridor.

Utility locates indicate that two to five buried telephone lines are generally located along the westerly right-of-way. Most were located under the shared-use bicycle/pedestrian path in the locations where it is present. In some locations, the lines diverged from being under the path to being under the ditch backslope.

All locations had one buried gas line also located along the west side of the highway. Its location varied from being between the right-of-way fence and the bike path; to being buried under the road ditch inslope.

Two buried telephone lines were also located on the road's east backslope in one of the four samples.

Overhead power is located throughout the project's length running along the far westerly right-of-way.

Miscellaneous above ground telephone cans and service connection points are installed at intermittent locations near the buried telephone.

An estimated cost of relocating utilities is not included in this document. We understand the respective utility owners bear the cost of relocating their services in conflict with road reconstruction as a result of being in the County's public right-of-way.

PROPERTY VALUES

Previously in this report, we estimated the existing highway right-of-way widths based on records researched. The section of the report addresses how land valuations were estimated. Later, the report estimates the amount of additional new right-of-way to be required based on comparing the construction width of the developed preliminary road typical section to the width of existing right-of-way.

The land to be acquired for new right-of-way currently consists of residential, commercial or agricultural uses. The predominant land use along this study segment is currently residential or bare land agricultural. We presume the highest and best use of the current bare land agricultural property is that to be developed into a residential subdivision.

To assign fully defendable and accountable costs to right-of-way impacts is outside the scope and budget of this document. To do so would require the preparation of multiple appraisals. By virtue of the amount of parcels adjoining this highway's right-of-way, the appraiser fee to complete this work could amount to over one hundred thousand dollars based on industry rates. Instead, to obtain a reasonable estimate of right-of-way acquisition costs, we contacted a local appraiser to complete a brief research of recent comparable sales in the Helena Valley for similar size parcels.

In his brief research, the appraiser found that commercial tracts of 1- 5 acres sold for $18,000 to $42,000 per acre, with $32,000 per acre as a reasonable average for similar properties in mixed-use areas with no zoning. Residential tracts of similar size experienced a selling price of about $18,000 - $40,000 per acre. Small tracts of less than one acre did however sell for about $250,000 in some locations. For this estimate, we are basing all per acre impacts as residential, or commercial tracts with no impacts to features in the property other than the acquisition of land. That is, the estimate applied herein does not account for improvements such as landscaping, fencing, lawn, sprinkler irrigation, etc. We further have assumed that most residential tracts are served by community water and sewer, and service connections will be outside the acquired right-of-way.

Based on the above, we have assumed for this estimate that the cost to acquire land for right-of-way from a parcel to be $32,000 per acre. To acquire the necessary right-of-way, the property must first be appraised. We estimate the appraiser fees for researching comparable sales history, preparing the property valuations, and obtaining title evidence will cost approximately $2,000 per parcel. For impacts to an estimated fifty parcels, the assumed appraiser fees amount to approximately $100,000. An assigned land acquisition agent would then use the appraisals to negotiate and procure the necessary right-of-way. For the number of potential parcels affected, we project agent fees could amount to $75,000.

DRAINAGE & HYDRAULICS

The existing highway generally follows the north/south terrain slope. As such, the primary hydraulic conveyance features of this highway consist of its roadside ditch and multiple approach culverts installed under each intersection or driveway. Except for the rolling terrain in the north portion of the study area, which crosses two predominant east/west drainage basins, there are few major highway cross-drains.

Approach Culverts

As shown in the previous Figure 6, road reconstruction will require rebuilding intersections to match new roadside elevations and replacing underlying approach culverts. For estimating culvert replacement costs, we first obtained from GIS and a windshield survey, the approximate number of access points in which approach culverts would be needed. We estimate there are approximately 30 approaches and the same amount of driveways intersecting North Montana Avenue in the study area. At the time of the future reconstruction, with the addition of new subdivisions, we assume the number of new approaches would increase to approximately 40 or more. Each approach will need to be rebuilt according to County standards, with a conservative estimate of being either the minimum standards shown in County Road Typical No. 1 or No. 2. We presume no further driveways will be built accessing North Montana Avenue. This is in accordance with current regulations.

For this study, replacement culvert lengths are estimated based on the allowable County standard minimum top width of the approach or driveway it serves. Refer to later parts of this report for the estimate used to identify the cost of reconstructing this highway.

Mainline Cross Drains

The table below summarizes the larger cross-draining hydraulic conveyance features within the study area.

Table 2: Existing Mainline Cross-Drains

Approximate Milepost	Diameter or Span	Rise	Length	Remarks
0.58	4'	4'	90'	Irrigation Siphon with Inlet/Outlet Flared End Wingwalls (14' Each)
0.71	48"	NA	68'	RCP installed under FAP 269 B
0.77*	5'*	3'*	42'*	*Conc. Box installed under FAP 269 B
				Irrigation Ditch Now Apparently Abandoned
2.48	60"	NA	72'	RCP installed under FAP 269 B
2.56	36"	NA	84'	RCP installed under FAP 269 B

* Footnote: This box culvert is not included in the estimated cost to reconstruct the highway since it is presumed to be abandoned with no further need to convey irrigation water.

The 4'x4' concrete box siphon at MP 0.58 is operated by the Helena Valley Irrigation District. This is one of many similar crossings within the Helena Valley on this irrigation system. The volume of irrigating water in the canal and through the siphon is monitored by the District. In extreme events, when the canal upstream may take on additional precipitation runoff that exceeds the capacity of the canal, it is plausible that the water could overtop the siphon inlet. If this were to occur, the runoff would run down the roadside ditch in a southerly direction along the west side of North Montana Avenue to possibly overwhelm the capacity of the downstream hydraulic conveyance features. In the preparation of this report, we did not coordinate with the Helena Valley Irrigation District to ascertain if this scenario has occurred. We presume that the likelihood would be fully analyzed in subsequent project development and engineering since the siphon will likely require reconstruction when the highway is re-built to reset the siphon's elevations to match the road reconstruction, and to reconstruct the inlet and outlet flared ends outside the new highway right-of-way. For reconstruction cost estimating purposes, further described later in this report, we have used a 54" diameter round siphon, which has the same approximate end-area of the 4'x4' box.

Except for the 5'x3' concrete box at MP 0.77, which appears to have been installed for an irrigation ditch, now apparently abandoned, all other drains should also be perpetuated. These features were installed under the original highway construction project and are therefore believed to be at least 70 years old. Field review indicates that they have held up relatively well; yet exhibit joint separation with weathered concrete including some exposed reinforcement. Due to the lack of remaining perceived design life and the need to widen the road, this study anticipates full replacement of these drains with new pipes of similar size and increased lengths estimated to meet the need of the widened highway.

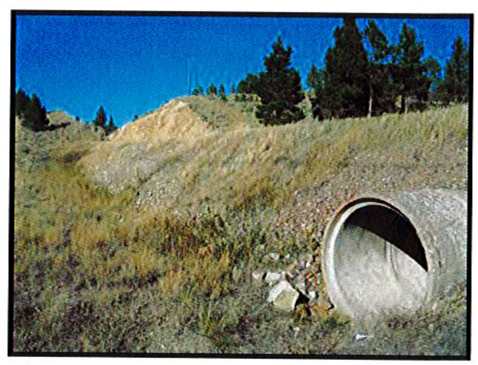


Photo 4: Existing 60" drain under fill slopes similar to that shown in Figure 4

Moisture content tests were performed on all of the penetration test samples from the borings. The moisture contents are indicated on the boring logs and were either compared to the optimum moisture content determined by our standard Proctor (described below) or typical optimum moisture contents for these types of soils. Based on these moisture content tests, the subgrade conditions in Borings ST-1 and ST-2 are over optimum moisture content. The moisture contents of the subgrade in Boring ST-3 are near optimum, while in Boring ST-4, the moisture contents are likely below optimum.

Groundwater. Groundwater was not encountered in the four borings to their termination depth of 5 1/2 feet at the time of our fieldwork. We wish to point out that clay subgrades were encountered by the borings. Several days may be required for groundwater levels to develop and stabilize in these types of clay soils. Surface water can also become trapped on top of these clay soils (perched groundwater), and then be encountered during construction.

Laboratory Tests

Two base course and two subgrade samples were selected for laboratory tests. The results are summarized in Table 2 below and are attached to this report.

Table 2. Summary of Laboratory Tests

Sample	Atterberg Limits			P200	Standard Proctor		CBR Value
	LL	PL	PI		MDD	OMC	
Base Course, ST-1	24	15	9	19.2%	---	---	---
Base Course, ST-2	32	16	16	24.6%	---	---	---
Composite Subgrade, ST-1 and ST-4	27	16	11	26.5%	136.9	7.9%	8.1
Subgrade, ST-2	40	17	23	54.4%	118.8	13.3%	9.7

MDD = Maximum Dry Density (ASTM D 698), pounds per cubic foot (pcf)
OMC = Optimum Moisture Content

As can be seen above, the base course samples tested from Borings ST-1 and ST-2 were plastic, having plasticity indexes of 9 and 16, respectively. The percent-finer-than-a-200-sieve (P200) of these samples were about 19 and 25 percent as well. These results indicate the base course classifies as low plasticity clayey sand, which would be considered a poor quality base course. A Laboratory Test of Aggregate sheet compares these base samples to the Lewis and Clark crushed top surfacing and select base course gradation requirements. The base samples tested did not meet the specifications.

Standard Proctors (ASTM D 698) and California bearing ratio (CBR) tests were performed on the two subgrade samples indicated above. CBR values for these samples were 8.1 and 9.7.

Pavement Analysis and Recommendations

Available Information. Robert Peccia & Associates provided us with the traffic information indicated on the attached graph for Roadway 7A-78, which represents N. Montana Avenue north of Lincoln Road. As can be seen, the 2009 AADT count is 4,396 and the projected 2029 AADT is 7,916. A linear relationship was used to estimate the increase in AADT over this 20-year period. Based on the AADT trend line, the yearly growth rate within the 20-year performance period is approximately 3.0%. Abelin Traffic Services (ATS) performed the various traffic counts on this and numerous other Lewis and Clark County roads as part of the County's annual traffic count program. The 2009 traffic count summary for Roadway 7A-78 by ATS is attached and includes traffic classification counts. This summary shows the relative percentages and daily traffic of the 13 standard classes of vehicles using the road.

Method. Pavement sections for the roadway were evaluated using DARWin™, a computer program based on the *1993 AASHTO Guide for Design of Pavement Structures*. The AASHTO Pavement Design Method is based on numerous input parameters, each affecting the required total pavement thickness for a given road. Based on the traffic information provided by Robert Peccia & Associates and ATS, we were able to perform a rigorous traffic analysis to determine the design Equivalent Single 18-kip Axle Load (ESAL). The rigorous traffic analysis is included in the DARWin output. The input parameters and traffic information are summarized in Table 3 below.

Table 3. Summary of Pavement Design Assumptions and Analysis

Parameter:	
Road Classification	Major Collector
2009 AADT	4,396
2029 AADT	7,916
Estimated Annual Growth	3.0%
Performance Period	20 Years
Initial Serviceability	4.2
Terminal Serviceability	2.5
Reliability	90
Number of Lanes in Design Direction	1
Percent All Trucks in Design Lane	50
Percent Trucks in Design Direction	100
18-kip ESALs	313,112

As can be seen above, we calculated a design ESAL of 313,112 for N. Montana Avenue, which is considered a major collector. For our calculations, vehicle/truck factors were used for the 13 classes of vehicles counted in the ATS traffic classification count. These vehicle/truck factors were obtained from the *washington.edu* website, and the table is attached.

The DARWin pavement design uses roadbed soil resilient modulus (M_R) to identify subgrade strength. CBR is another method of representing subgrade strength. Correlations of these subgrade strength parameters are contained in the *1993 AASHTO Design of Pavement Structures* manual. For soils having CBR values less than 10, the manual indicates the following equation can be used.

M_R (psi) = 1,500 x CBR

As previously indicated in Table 2, CBR values of 8.1 and 9.7 were determined for subgrade samples along this roadway. When considering that sandy lean clay was encountered along a portion of the roadway, it is our opinion a design CBR of one standard deviation below the mean should be used. This results in a CBR of 7.8, which results in an M_r equal to 11,700.

Pavement Sections. Pavement sections were analyzed in general accordance with the Lewis and Clark Subdivision Regulations dated December 18, 2007. Based on this approach and the above input parameters and design information, our recommended pavement section is summarized in Table 4 below.

Table 4. Recommended Pavement Section

Asphalt Pavement	3"
Crushed Top Surfacing	3"
Select Base Course*	6"
Subbase Course*	7"
Total	19"

*Per Table B-4 of Lewis and Clark Subdivision Regulations dated 12/18/2007, 3-inch minus sandy gravel should be used as Select Base Course and Subbase Course.

Constructability.

General. A common problem in roadway construction is encountering unstable subgrades. Unstable subgrades are those subgrade soils that are excessively wet and soft, and cannot support heavy rubber-tired construction equipment as well as cannot be compacted to specification. They commonly occur beneath existing roads where surface water has seeped through cracks and become trapped in the underlying base course and subgrade. This water saturates the clays, reducing their shear strength, and the clay subgrade becomes too soft and wet to support the heavy rubber-tired construction equipment. When this occurs during fast-tracked construction projects, it can cause delays, which then results in change orders.

As previously indicated in Table 1, Boring ST-2 encountered sandy lean clay that was rather soft and over optimum moisture content. We considered this subgrade to have a "high" risk of subgrade failure during construction. Boring ST-1 encountered wet clayey sand subgrade, which has a "moderate" risk of subgrade failure during construction.

Identification of Unstable Areas. When considering total reconstruction, the best method of determining unstable subgrades is to perform proof rolling observations directly on the exposed subgrade. Proof rolling should be performed with a loaded tandem axle dump truck or equivalent. Unstable areas are those subgrade soils where proof rolling indicates 1/2 inch or more of deflection is occurring. Another method of determining unstable subgrades is whether or not they can be recompacted to specification, typically 95 percent of their standard Proctor maximum dry density. Where unstable subgrades are identified, we recommend installing a stabilized pavement section as described below.

Stabilized Pavement Section. Two alternatives for stabilized pavement sections are indicated in Table 5 below. Alternatives 1 and 2 are stabilized pavement sections using geosynthetics, which are available in Montana.

Table 5. Stabilized Pavement Section for Excessively Soft (Unstable) Subgrade Areas

Item	Alternative 1	Alternative 2
Asphalt Pavement	3"	3"
Crushed Top Surfacing	3"	3"
Select Base and/or Subbase	20"	23"
Geosynthetic	Tensar BX 1300 over Class 2 Non-woven Fabric	Mirafi HP 570

Other Alternatives. We suggest also contacting Lewis and Clark County personnel and/or discussing these types of stabilized pavement sections with the contractor, who may have other alternatives for constructing pavements on unstable subgrades. Another alternative is to allow unstable subgrades to possibly dry out during construction. For this approach, several weeks of warm, windy weather will likely be needed to allow the exposed conditions to dry out and become more stable. We have found, however, that the construction schedule of most contractors does not allow them to wait for these areas to dry out and become stable.

Some consideration can also be given to specifying that all construction activities are performed with low-pressured ground equipment. In Montana, however, this equipment is generally not readily available by most earthwork and paving contractors.

Specifications

When the N. Montana Avenue reconstruction project(s) are undertaken, we recommend all earthwork, subgrade preparation, gravel base and subbase, and asphalt pavement be specified and constructed in accordance with Montana Public Works Standard Specifications (MPWSS). The Montana Department of Transportation (MDT) Specifications for Road and Bridge Design can also be used, however, they are slightly more stringent. If geosynthetics are utilized, we recommend they be placed and constructed in accordance with the manufacturer's recommendations.

Observation and Testing

We recommend the pavement subgrades be observed by a geotechnical engineer or an engineering assistant working under the direction of a geotechnical engineer to see if the materials are similar to those encountered by the borings. During construction, we recommend density tests be taken on the recompacted subgrade and compacted crushed top surfacing, select base, and subbase courses. The thicknesses of crushed top surfacing, select base, and subbase should also be checked to confirm they meet specifications.

We also recommend density testing of the asphaltic concrete surface and Marshall tests on asphaltic concrete mix to evaluate strength and air voids. Cores of asphalt concrete should be taken at intervals to evaluate pavement thickness and compaction. Paving observations should also be performed to confirm the specified thickness of asphalt is provided throughout the roadway.

General Recommendations

Basis of Recommendations. The analyses and recommendations submitted in this report are based upon the data obtained from the borings performed at the locations indicated on the attached sketch. Often, variations occur between these borings, the nature and extent of which do not become evident until additional exploration or construction is conducted. A reevaluation of the recommendations in this report should be made after performing on-site observations during construction to note the characteristics of any variations. The variations may result in additional earthwork and construction costs, and it is suggested that a contingency be provided for this purpose.

It is recommended that when the road is reconstructed, we or another qualified geotechnical engineering firm be retained to perform the observations and testing program for the site preparation. This will allow correlation of the soil conditions encountered during construction to the soil borings.

Groundwater Fluctuations. We made water level observations in the borings at the times and under the conditions stated on the boring logs. These data were interpreted in the text of this report. The period of observation was relatively short, and fluctuation in the groundwater level may occur due to rainfall, flooding, irrigation, spring thaw, drainage, and other seasonal and annual factors not evident at the time the observations were made. Design drawings and specifications and construction planning should recognize the possibility of fluctuations.

Use of Report. This report is for the exclusive use of the Robert Peccia & Associates to use in conjunction with the preliminary road reconstruction analysis being completed by them for the County. In the absence of our written approval, we make no representation and assume no responsibility to other parties regarding this report. The data, analyses and recommendations may not be appropriate for other structures or purposes. We recommend parties contemplating other alignments or purposes contact us.

Level of Care. Services performed by SK Geotechnical Corporation personnel for this project have been conducted with that level of care and skill ordinarily exercised by members of the profession currently practicing in this area under similar budget and time restraints. No warranty, expressed or implied, is made.

We appreciate the opportunity to provide these services for you. If we can be of further assistance, please contact us at your convenience.

Sincerely,

Professional Certification
I hereby certify that this report was prepared by me and that I am a duly Licensed Professional Engineer under the laws of the State of Montana.

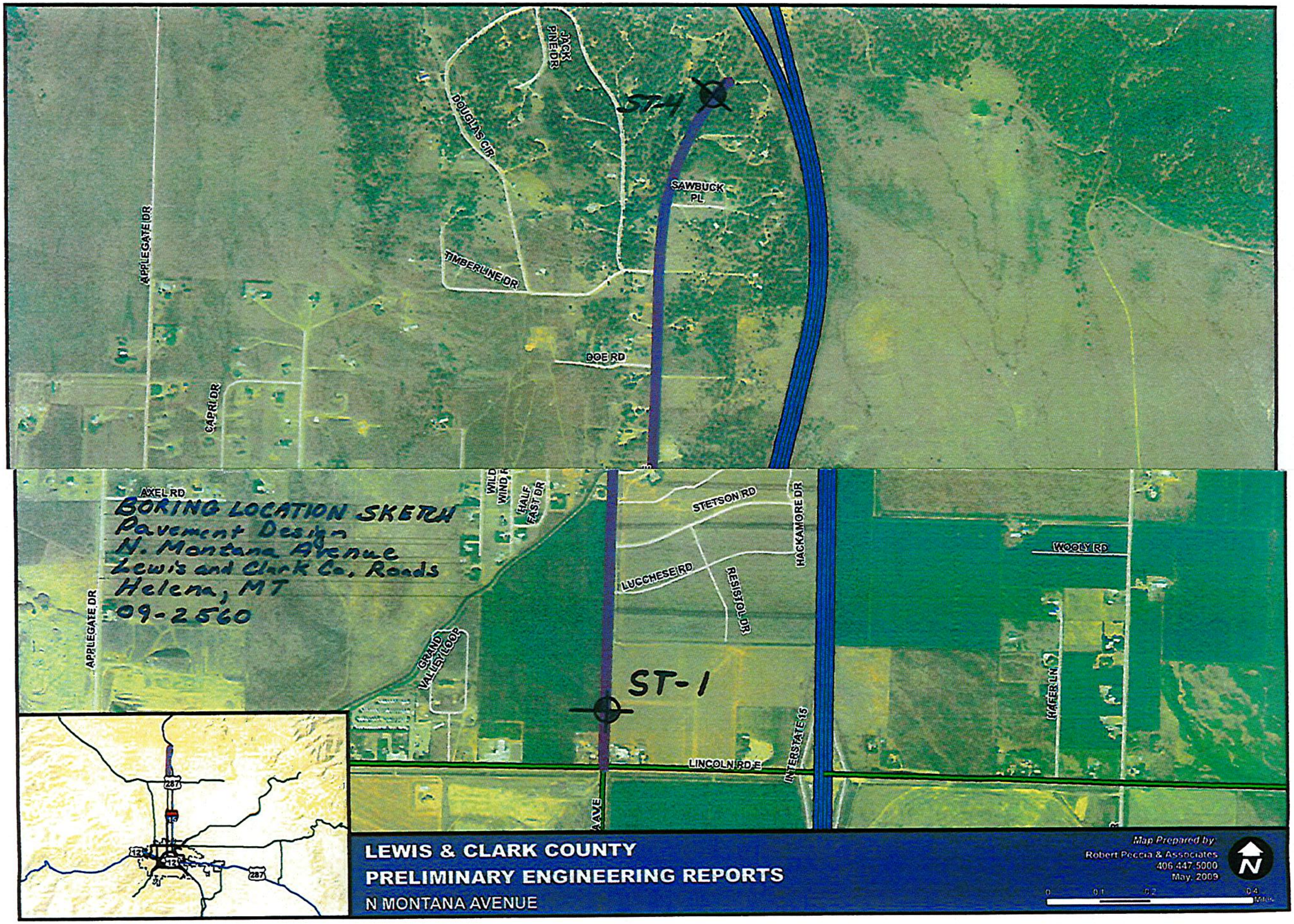
MONTANA
GREGORY T. STAFFILENO
No. 10798 P.E.
REGISTERED PROFESSIONAL ENGINEER

Gregory T. Staffileno, PE
Principal Geotechnical Engineer
License Number 10798PE

Cory G. Rice, PE
Reviewing Engineer

gts/cgr:khr

Attachments:
Boring Location Sketch
Descriptive Terminology
Log of Boring Sheets ST-1 through ST-4
Laboratory Tests
Laboratory Test of Aggregate
DARWin Pavement Analysis
RPA Traffic Curve
Abelin Traffic Data
Washington DOT Vehicle/Truck Factors



LEWIS & CLARK COUNTY
PRELIMINARY ENGINEERING REPORTS
N MONTANA AVENUE

SK GEOTECHNICAL

Descriptive Terminology

Standard D 2487
Classification of Soils for Engineering Purposes
(Unified Soil Classification System)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests [A]				Soil Classification: Group Symbol	Soil Classification: Group Name [B]
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines [C]	$C_U \geq 4$ and $1 \leq C_C \leq 3$ [E]	GW	Well graded gravel [F]
			$C_U < 4$ and/or $1 > C_C > 3$ [E]	GP	Poorly graded gravel [F]
		Gravels with Fines More than 12% fines [C]	Fines classify as ML or MH	GM	Silty gravel [F, G, H]
			Fines classify as CL or CH	GC	Clayey gravel [F, G, H]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines [D]	$C_U \geq 6$ and $1 \leq C_C \leq 3$ [E]	SW	Well graded sand [I]
			$C_U < 6$ and/or $1 > C_C > 3$ [E]	SP	Poorly graded sand [I]
		Sands with Fines More than 12% fines [D]	Fines classify as ML or MH	SM	Silty sand [G, H, I]
			Fines classify as CL or CH	SC	Clayey sand [G, H, I]
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silts and Clays Liquid Limit less than 50	Inorganic	PI > 7 and plots on or above "A" line [J]	CL	Lean clay [K, L, M]
			PI < 4 or plots below "A" line [J]	ML	Silt [K, L, M]
		Organic	Liquid limit – oven dried / Liquid limit – not dried < 0.75	OL	Organic clay [K, L, M, N] Organic silt [K, L, M, O]
	Silts and Clays Liquid limit 50 or more	Inorganic	PI plots on or above "A" line	CH	Fat clay [K, L, M]
			PI plots below "A" line	MH	Elastic silt [K, L, M]
		Organic	Liquid limit – oven dried / Liquid limit – not dried < 0.75	OH	Organic clay [K, L, M, P] Organic silt [K, L, M, Q]
Highly Organic Soils		Primarily organic matter, dark in color, and organic odor		PT	Peat

[A] Based on the material passing the 3" (75 mm) sieve.

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols
- GW-GM well-graded gravel with silt
- GW-GC well-graded gravel with clay
- GP-GM poorly graded gravel with silt
- GP-GC poorly graded gravel with clay

[D] Sands with 5 to 12% fines require dual symbols.
- SW-SC well-graded sand with clay
- SP-SM poorly graded sand with silt
- SP-SC poorly graded sand with clay

[E] $C_U = D_{50} / D_{10}$
$C_C = (D_{30})^2 / (D_{10} \times D_{50})$

[F] If soil contains ≥ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel", whichever is predominant.

[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

[M] If soil contains ≥ 30% plus No. 200 predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.

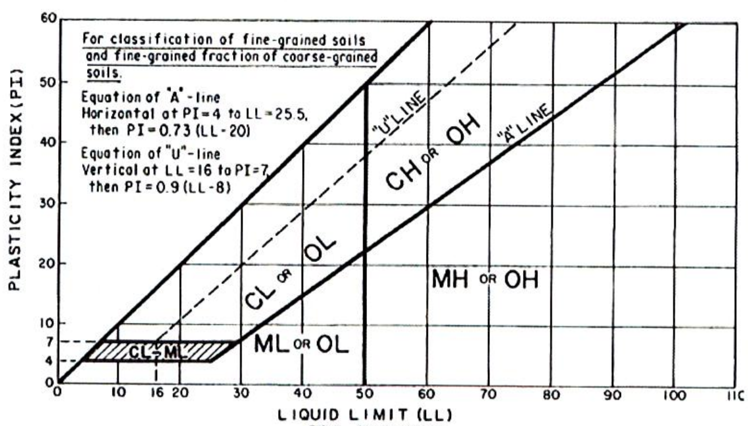


FIG. 4 Plasticity Chart

Laboratory Tests

DD	Dry density, pcf	OC	Organic content, %
WD	Wet density, pcf	P_{200}	% passing 200 sieve
LL	Liquid limit	PL	Plastic limit
PI	Plasticity index	MC	Natural moisture content, %
qu	Unconfined compressive strength, psf		
qp	Pocket penetrometer strength, tsf		

Particle Size Identification

- Boulders .... over 12"
- Cobbles .... 3" to 12"
- Gravel
  - coarse .... 3/4" to 3"
  - fine .... No. 4 to 3/4"
- Sand
  - coarse .... No. 4 to No. 10
  - medium .... No. 10 to No. 40
  - fine .... No. 40 to No. 200
- Silt .... No. 200 to .005 mm
- Clay .... less than .005 mm

Relative Density of Cohesionless Soils

- very loose .... 0 to 4 BPF
- loose .... 5 to 10 BPF
- medium dense .... 11 to 30 BPF
- dense .... 31 to 50 BPF
- very dense .... over 50 BPF

Consistency of Cohesive Soils

- very soft .... 0 to 1 BPF
- soft .... 2 to 3 BPF
- rather soft .... 4 to 5 BPF
- medium .... 6 to 8 BPF
- rather stiff .... 9 to 12 BPF
- stiff .... 13 to 16 BPF
- very stiff .... 17 to 30 BPF
- hard .... over 30 BPF

Moisture Content (MC) Description

rather dry	MC less than 5%, absence of moisture, dusty
moist	MC below optimum, but no visible water
wet	MC over optimum, visible free water, typically below water table
saturated	Clay soils were MC over optimum

Drilling Notes

Standard penetration test borings were advanced by 3¼" or 4¼" ID hollow-stem augers, unless noted otherwise. Standard penetration test borings are designated by the prefix "ST" (split tube). Hand auger borings were advanced manually with a 2 to 3" diameter auger to the depths indicated. Hand auger borings are indicated by the prefix "HA."

Sampling. All samples were taken with the standard 2" OD split-tube sampler, except where noted. TW indicates thin-walled tube sample. CS indicates California tube sample.

BPF. Numbers indicate blows per foot recorded in standard penetration test, also known as "N" value. The sampler was set 6" into undisturbed soil below the hollow-stem auger. Driving resistances were then counted for second and third 6" increments and added to get BPF. Where they differed significantly, they were separated by backslash (/). In very dense/hard strata, the depth driven in 50 blows is indicated.

WH. WH indicates the sampler penetrated soil under weight of hammer and rods alone; driving not required.

Note. All tests were run in general accordance with applicable ASTM standards.

SK GEOTECHNICAL
2611 Gabel Road
P. O. Box 80190
Billings, MT 59108-0190
Phone: 406.652.3930
Fax: 406.652.3944

LOG OF BORING

PROJECT: 09-2560
PAVEMENT DESIGN
Lewis and Clark County Roads
Helena, Montana

BORING: **ST-1**

LOCATION:
N. Montana Avenue, see attached sketch.

DRILLED BY: C. Larsen | METHOD: 3 1/4" HSA, Automatic | DATE: 7/10/09 | SCALE: 1" = 1'

Elev.	Depth	Symbol	Description of Materials	BPF	WL	MC (%)	Remarks
	0.0		FILL: 3 1/2" of Asphalt Pavement.				Base course bag sample: LL=24, PL=15, PI=9 P_{200}=19.2%
	0.3		FILL: 8 1/2" of Clayey Sand with Gravel Base Course.				
	1.0	SC	CLAYEY SAND with GRAVEL, fine- to coarse-grained, low plasticity, brown, moist, loose to medium dense. (Alluvium)	9/10/6		8.8	
							Composite subgrade bag sample ST-1 and ST-4: LL=27, PL=16, PI=11 P_{200}=26.5%
				4/3/7		10.1	
	3.0	GP	POORLY GRADED GRAVEL with SAND, fine- to coarse-grained, gray, moist, medium dense. (Alluvium)				
				9/11/11		3.5	
	5.5		END OF BORING Water not observed with 4' of hollow-stem auger in the ground. Water not observed to dry cave-in depth of 1 1/2' immediately after withdrawal of auger.				

BORING BPF WL MC 2560.GPJ LAGNNN06.GDT 9/15/09

SK GEOTECHNICAL
2611 Gabel Road
P. O. Box 80190
Billings, MT 59108-0190
Phone: 406.652.3930
Fax: 406.652.3944

LOG OF BORING

PROJECT: 09-2560 **PAVEMENT DESIGN** Lewis and Clark County Roads Helena, Montana	BORING: **ST-2** LOCATION: N. Montana Avenue, see attached sketch.

DRILLED BY: C. Larsen	METHOD: 3 1/4" HSA, Automatic	DATE: 7/10/09	SCALE: 1" = 1'

Elev.	Depth 0.0	Symbol	Description of Materials	BPF	WL	MC (%)	Remarks
			FILL: 6 1/2" of Asphalt Pavement.				Base course bag sample: LL=32, PL=16, PI=16 P_{200}=24.6% MC=6.8%
	0.5		FILL: 5 1/2" of Clayey Sand with Gravel Base Course.				
	1.0	CL	SANDY LEAN CLAY, low plasticity, brown, moist to wet, rather soft to stiff. (Alluvium)	6/2/2		15.4	Subgrade bag sample: LL=40, PL=17, PI=23 P_{200}=54.4%
				2/2/4		13.5	
				3/5/10		7.4	
	5.5		END OF BORING Water not observed with 4' of hollow-stem auger in the ground. Water not observed to dry cave-in depth of 1 1/2' immediately after withdrawal of auger.				

BORING BPF WL MC 2560.GPJ LAGNNN06.GDT 9/15/09

SK GEOTECHNICAL
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P. O. Box 80190
Billings, MT 59108-0190
Phone: 406.652.3930
Fax: 406.652.3944

LOG OF BORING

PROJECT: 09-2560 **PAVEMENT DESIGN** Lewis and Clark County Roads Helena, Montana	BORING: **ST-3** LOCATION: N. Montana Avenue, see attached sketch.

DRILLED BY: C. Larsen	METHOD: 3 1/4" HSA, Automatic	DATE: 7/10/09	SCALE: 1" = 1'

Elev.	Depth 0.0	Symbol	Description of Materials	BPF	WL	MC (%)	Remarks
			FILL: 6" of Asphalt Pavement.				
	0.5		FILL: 2 1/2" of Gravel Base Course.				
	0.8	GC	CLAYEY GRAVEL, fine- to coarse-grained, low plasticity, brown, moist, loose to medium dense. (Alluvium)	8/10/10		8.1	
				6/9/5		8.5	
				14/6/4		4.5	
	5.5		END OF BORING Water not observed with 4' of hollow-stem auger in the ground. Water not observed to dry cave-in depth of 2' immediately after withdrawal of auger.				

BORING BPF WL MC 2560.GPJ LAGNNN06.GDT 9/15/09

PEDESTRIAN AND BICYCLE FACILITIES

Pedestrians and Bicyclists are served along a portion of this highway by a 10-foot wide asphalt paved path. The path runs adjacent to the westerly highway right-of-way, generally offset 5 to 10 feet inward from the right-of-way fence. Figure 2 depicts the path's location in relation to the road. The paved path begins at the beginning of the study area, MP 0.00 (Lincoln Road intersection), and extends northward to end at the intersection of Prairie Road, approximate MP 2.00.

Based on Figure 6, we assume the reconstructed road will not impact the existing shared-use path. Further, for segment(s) of the highway to be reconstructed north of Prairie Road, the widened highway template should allow for utilities and a future path in the same general location along the westerly right-of-way. However, an assumption herein is that the paved path will not be extended in the foreseeable future. This is based on it not being identified as a bike/pedestrian route in the Greater Helena Area Transportation Plan – 2004 Update. As such under this study, no costs are being attributed to reconstructing this path as part of the base cost of rebuilding the road. However, an alternative cost on constructing the path on a per-mile basis is included in this report for planning purposes should the final design 1) require reconstructing the existing bike path even though it is unanticipated in this report, or 2) should an extension of the bike path be further justified and included in the future road reconstruction.

Finally, should the road ultimately be reconstructed to include the desired 8-foot shoulder widths (refer to Figure 5), then some arguments may be made that the existing path would not have to be reconstructed should it be impacted by road widening, nor would an extension of the path north of its current terminus be necessary. This is because an 8-foot wide shoulder is by industry standards adequate for conveying bicyclists along the transportation corridor, and an additional 8-foot of paved path for bicyclists could be considered cost redundant. The argument could be further that the need for additional right-of-way for road building purposes could be reduced or eliminated if the highway reconstruction were to utilize the area currently reserved for the shared use path. However, given the high operating speed of the highway traffic, it is obvious that maintaining the separated bicycle/pedestrian path increases the safety of its bicycle users as compared to using a 8-foot wide roadside shoulder. As a shared-use path, it is a vital component to safely convey pedestrians, including children that use the facility to and from the Jim Darcy Elementary School.

AUXILIARY TURN LANES

The existing highway is a two-lane facility with no auxiliary lanes for left or right turns. The scope of this work does not include completing definitive turn lane warrant studies at key intersections. However, when the highway design is initiated, it can be reasonably ascertained that one or more turn lanes may be warranted along this segment of North Montana Avenue. Therefore for the benefit of this study, we have included an estimated cost to construct a left-turn lane serving an approach in a non-signalized intersection. The discussion on traffic control signals follows this section. Turn lanes should be considered at each signalized intersection.

We based the estimated turn lane geometrics for a left-turn lane on the guidelines presented by MDT in their Traffic Engineering Manual. We assume that the shoulder widths in the location of a turn lane will be reduced from the design width of 8-feet wide, to 4-feet wide. This is due to the perceived extreme impacts caused by the additional right-of-way expansion to fit the additional auxiliary lane beyond the needs to fit the road reconstruction. For a 55 mph design speed, the lane shift bay taper rate will be 55:1 to shift the through lanes outward. An interior bay taper rate of 18:1 is used for vehicles entering the left turn lane. From the left turn bay entry, the recommended deceleration distance is 480 feet. The deceleration is assumed to initiate at the beginning of the left turn bay taper. Since intersection turning movement counts have not been completed as a part of this study, we assume the storage length needed is minimal and left-turning vehicles will complete the maneuver with adequate gaps present in the opposing traffic stream without coming to a stop in most instances. Based on the above, the minimum length left turn lane will require approximately 220 feet of total length for lane shift tapers entering and exiting the left turn area, and 480 feet of auxiliary lane including its bay taper. The total length of road widening for a minimum length left turn lane would then be about 700 feet.

TRAFFIC SIGNALS

A signal warrant analysis was not completed under this study. However, for purposes of estimating the full potential reconstruction cost of the study area, we presume that signal warrants will eventually be met for a signal to be considered, and installed to replace the current four-way stop controlled intersection at North Montana Avenue and Lincoln Road. Therefore, an estimated cost to install signal hardware has been included.

Reconstruction Cost Estimate

The following table summarizes the estimated cost to reconstruct North Montana Avenue from Lincoln Road north. Following the table below, the report briefly discusses how some of the number of units shown in the table were estimated. The units were then multiplied by the average unit cost. To arrive at an average unit cost, we reviewed the bid history of four highway projects currently under construction in the Helena Valley. These projects ranged from full highway reconstructions to spot safety improvement projects. It should be noted that the County could similarly improve North Montana Avenue by either several smaller spot improvements projects, or larger-length reconstructions.

Major Work Feature	Unit	Unit Cost	# of Units	Total Cost
Survey - Staking and Grade Control	LS	$45,000.00	1	$45,000
Borrow for Embankment	CY	$7.00	28692	$200,844
Topsoil - Salvage and Place	CY	$4.05	4600	$18,630
Excavation - Unclassified	CY	$5.50	47628	$261,954
MPDES Permit Fees	LS	$900.00	1	$900
Temporary Erosion Control - LS	LS	$8,000.00	1	$8,000
Crushed Top Surfacing (3-inch Depth)	CY	$25.41	8249	$209,607
Select Base Course (6-inch Depth)	CY	$12.00	16499	$197,988
Subbase Course Material (7-inch Depth)	CY	$12.00	19249	$230,988
Aggregate Treatment (Prime)	SQ YDS	$0.41	83776	$34,348
Chip Seal Cover	SQ YDS	$0.69	79787	$55,053
Plant Mix Asphalt Paving	Ton	$81.38	13793	$1,122,474
Emulsified Asphalt Seal (CRS-2P)	Ton	$647.86	135.6	$87,850
Reset Mailbox	Each	$200.83	40	$8,033
Traffic Gravel	CY	$19.03	2700	$51,381
Remove/Reset Signs	Each	$184.30	20	$3,686
Interim Striping - Yellow Paint	Gal	$34.18	62	$2,119
Final Striping - Yellow Paint	Gal	$34.18	62	$2,119
Interim Striping - White Paint	Gal	$34.30	124	$4,253
Final Striping - White Paint	Gal	$34.30	124	$4,253
Remove Existing Culverts	LF	$12.27	2800	$34,356
Approach/Relief Drain Pipe - 18/24 Inch Diam.	LF	$50.17	2650	$132,951
Drainage Pipe 36 Inch Diam	LF	$96.79	92	$8,905
Drainage Pipe 48 Inch Diam	LF	$134.68	87	$11,717
Drainage Pipe 60 Inch Diam	LF	$179.77	80	$14,382
Siphon 54 Inch Diam	LF	$250.00	120	$30,000
Farm Fence - Type Type 5M	LF	$2.25	17952	$40,392
Fence Panel - Single	Each	$145.92	36	$5,253

Fence Panel - Double	Each	$233.67	36	$8,412
Remove Existing Fence	LF	$0.49	3000	$1,470
Guardrail	LF	$19.77	2890	$57,135
Guardrail Terminal Section	Each	$2,804.91	6	$16,829
Seeding	Acre	$294.16	20.7	$6,089
Fertilize Seed	Acre	$120.84	20.7	$2,501
Condition Seedbed Surface	Acre	$221.51	20.7	$4,585
Geotextile - Subgrade Stabilization	SY	$1.50	13125	$19,688
Subgrade Stabilization Gravel (10 – inch Depth)	CY	$8.00	4026	$32,208
Subexcavation	CY	$5.50	4026	$22,143
Traffic Signal	LS	$68,000.00	1	$68,000
Add One Left Turn Lane	LS	$100,000.00	1	$100,000
Subtotal - Construction	**$3,166,496**			
Preliminary, Final Engineering, Geotechnical & Survey	8% of Construction			$253,320
Construction QA/QC	4% of Construction			$126,660
Contractor Mobilization	5% of Construction			$158,325
Contingency	10% of Construction			$316,650
Traffic Control During Construction	8% of Construction			$253,320
Right-of-Way Appraisals by Agent	LS			$100,000
Right-of-Way Acquisition by Agent	LS			$75,000
Purchase Right-of-Way	Acre	$32,000	5.2	$166,400
Total Est. Road Reconstruction Cost (2009)	**$4,616,171**			
Est. Total Road Cost Per Mile	**Miles**	**$4,616,171**	**/ 3.5 Mi =**	**$1,318,906**
Alternate – Add Sanitary Sewer Main	**Per Mile**	**$211,200**	**x 3.5 Mi**	**$739,200**
Alternate – Add Water Main	**Per Mile**	**$396,000**	**x 3.5 Mi**	**$1,386,000**
Alternate – Add Bicycle/Ped. Path Reconstruction	**Per Mile**	**$77,825**	**x 3.5 Mi**	**$272,388**

LS = Lump Sum, CY = Cubic Yard, SQ YDS = Square Yards, GAL = Gallon, LF = Linear Feet

ESTIMATING PROCEDURE

Grading

- The Excavation – Unclassified quantity was estimated from Figure 6 by calculating the end section cut areas and multiplying by the applied length to generate a volume. A percentage of this was increased to factor in additional excavation for miscellaneous other features, such as re-building road approaches, excavating for culvert installations, etc.

- The Borrow for Embankment quantity was similarly estimated from Figure 6. A 20% shrink factor was first applied to the quantity estimated to complete the roadway widening. This quantity was then deducted from the excavation quantity to arrive at an estimated borrow quantity. For the rolling terrain, the embankment needed was estimated by reviewing Figures 3 and 4 and applying a road-widening estimate based on the proposed road width template. For larger fill slopes, we would assume embankments are constructed on a 2H:1V slope rate.

- Topsoil Salvage and Placing was calculated based on a percentage of the road excavation quantity.

Surfacing

- The miscellaneous road surfacing quantities such as the crushed aggregate course, plant mix asphalt paving, prime, and seal coat were estimated based on the recommended pavement design and the proposed surfacing width as shown in Figure 5.

- A nominal amount of Traffic Gravel was included to allow for a temporary wearing course for traffic driving on the unfinished subgrade.

- Interim paint quantities were included to delineate the road centerline and shoulder lines prior to the road receiving a chip seal. Final paint quantities would then be applied after the chip seal.

Drainage

- The summarized length of minor drainage pipe lengths was estimated based on approaches and their assumed cross-sectional characteristics such as slope rate and depth of cover. Approach top widths were estimated as either being an average of 24 feet for more major approaches, and 12 feet or greater for single-resident driveway accesses. We estimated 30 major approaches (24 feet wide) and 30 driveways (12 feet wide) would require reconstruction. The approach pipes would consist of 18-inch minimum diameter to meet the County's minimum requirements for a Major Collector approach drain. A quantity of 24-inch diameter cross drains is included in the estimate to serve as highway relief pipes for minor terrain breaks, such as cross-draining gullies and draws in localized drainage basins.

- Lengths of pipes 36-inch diameter or larger were estimated by increasing record lengths as described on the as-built drawings to account for the widened road template.

Fencing

- For this project, we assumed most right-of-way acquisition would occur on the east side of the road only. This then would preserve the majority of the utilities along the westerly right-of-way and the adjacent bike/pedestrian path. To re-fence the right-of-way, we assumed using a typical 5-strand barbwire with metal posts.

Guardrail

- The estimated need for guardrail was based on the deeper fill slope embankments observed during field reviews and compared back to as-built drawings. We also assume due to the proposed roadway widening, that an amount of guardrail would be installed on the outside of the horizontal curve at the end of the project to help reduce right-of-way acquisition attributable to otherwise flatter fill slopes. The need for guardrail was also applied toward a few locations where existing rock cuts are in close proximity to the edge of the road.

Roadside Revegetation

- The predominant amount quantified for seeding, fertilizer and seedbed conditioning was based on end section measurements taken of the finished slopes shown in Figure 6.

Subgrade Stabilization

- The pavement design included with this report identifies some areas as having poor quality subgrade material. We estimated an amount of stabilization gravel to be placed over a geotextile fabric based on the recommendations contained in the pavement design. Similarly, we estimated the amount of geotextile needed on a range of digouts based on the subgrade width derived from Figure 5.

Traffic Signal

- The estimated cost to install traffic signal hardware for one intersection is based on the bid history of components currently being installed by MDT around the Helena area.

Left-Turn Lane Widening

- The estimated cost to widen the roadway to install a single turn lane is based on proportion to that cost to construct the roadway with no turn lane.

Right-of-Way

- To estimate appraisal costs for right-of-way acquisition, we applied a $2,000 per parcel fee for an assumed 50 parcels. A similar approach was taken to estimate fees for an agent to prepare closing documents, negotiate the right-of-way and file documents for record.

- The existing right-of-way width appears to vary from 80 feet, 90 feet and 100 feet with the majority being at 100 feet. This is based on a cursory check of the existing right-of-way as shown on the Highway Project FAP 269 B record drawings to that arranged in GIS. Pursuant to Figure 6, we assumed a minimal 110 feet of right-of-way would be needed to reconstruct the road, or an additional 10 feet beyond the existing average right-of-way width. The additional 10 feet is based on the road-widening cut and fill impacts of about 6 feet over the majority of terrain as shown in Figure 6. To account for a clear area to relocate buried utilities, we added an additional 4 feet to the top of cut or base of fill. This amounts to plus 10 feet. To obtain the 5.2 Acre estimate of new right-of-way needed, we deducted the record right-of-way widths from the estimated 110 feet average width needed, over the applicable lengths shown in the FAP 269 B record drawings. Note, that with the addition of new turn lane(s), the needed right-of-way would increase from that estimated herein.

- We used $32,000 per acre land valuation to estimate the cost to acquire land for right of way purposes. This valuation is based on limited coordination with a local appraiser whom completed a brief research of the area to obtain comparable sales history. The comparable sales research yielded transactions amounting to $18,000 to $42,000 per Acre for mixed use, non-zoned commercial tracts with no ordinances ranging between 1 – 5 Acres. Similarly, residential tracts from 1/4 – 4 Acres sold for $18,000 to $40,000 per Acre, with mid-to-high $20,000 per Acre being predominant. In some cases, highly sought after tracts were much higher in per acre price. We applied the assumption that bare land agricultural tracts would be negotiated by the owner at residential tract values (given the opportunity to subdivide as the highest and best use), and that the cost per acre is based on all similar size parcels.

Miscellaneous

- The number of mailboxes to replace was based on a windshield survey estimate. Should the Post Master allow, the County desires consolidating mailboxes into localized bank installations. This could reduce installation costs to be less than the estimate shown.

- The estimate includes a per mile cost to install an 8" water main and an 8" sanitary sewer main for future services. The estimate is based on an installed cost of $75 per linear foot for the water main, and $40 per linear foot for the sewer main. For planning purposes, the County desires to include an estimate since installing a water main and/or sanitary sewer main would likely be cost-effective to complete at the time the roadway is being reconstructed.

- A per mile estimate is included to construct a 10 foot wide shared-use bicycle/pedestrian path should the existing path be impacted or lengthened. The estimate uses 2-inch thick plant mix asphalt surfacing over 4 inches of crushed top surfacing aggregate base.

Appendix A

Traffic Counts for North Montana Avenue North of Lincoln Road

YEAR → 1989 → → 2008

cv06	7A-46	Applegate Drive	North of Valley View	238	1) 218	240	308	323	315	285	322	346	345	387	NCT	NCT	414	491	NCT	NCT	498	709	432
cv05	7A-47	Applegate Drive	South of Brookings Rd.	459	1) 391	454	449	442	449	429	476	523	500	554	NCT	NCT	658	737	NCT	NCT	1,195	991	716
cv04	7A-48	Applegate Drive	North of Lincoln Rd.	NCT	1) 449	619	464	479	450	NCT	501	596	581	633	NCT	NCT	782	897	NCT	NCT	922	MDT	850
cv03	7A-49	Applegate Drive	South of Lincoln Rd.	NCT	1) 614	726	582	788	770	NCT	786	944	841	705	NCT	NCT	758	1,049	NCT	NCT	1,019	MDT	
cv02	7A-50	Applegate Drive	North of John G. Mine Rd.	NCT	1) 300	290	357	335	323	NCT	609	759	729	731	NCT	NCT	977	982	NCT	NCT	520	831	800
cv01	7A-51	Applegate Drive	South of John G. Mine Rd.	NCT	1) 241	283	240	245	304	NCT	1) 459	479	460	440	NCT	NCT	539	582	NCT	NCT	580	520	585
cv31	7A-52	Lincoln Road	East of Applegate Dr.	NCT	1) 1,659	1,531	1,763	1,249	2,094	NCT	2,437	2,404	2,682	2,542	NCT	NCT	2,849	NCT	NCT	NCT	3,693	MDT	
cv68	7A-53	Green Meadow Drive	North of Lincoln Rd.	NCT	NCT	NCT	526	483	533	514	728	788	941	756	NCT	NCT	840	877	NCT	NCT	854	MDT	900
cv30	7A-54	Lincoln Road	West of Applegate Dr.	NCT	1) 1,217	1,261	1,312	1,492	1,600	NCT	1,880	1,777	1,994	1,854	NCT	NCT	1,990	NCT	NCT	NCT	2,496	MDT	2,890
cv21	7A-55	John G. Mine Road	East of Applegate Dr.	NCT	1) 227	311	282	316	268	NCT	1) 843	452	557	648	NCT	NCT	686	799	NCT	NCT	901	861	847
cv104	7A-56	Lone Mountain Dr.	North of Lincoln Rd.											92	NCT	NCT	137	204	NCT	NCT	314	MDT	
cv20	7A-57	John G. Mine Road	West of Applegate Dr.	NCT	1) 230	?) 70	202	219	177	NCT	322	412	400	461	NCT	NCT	447	570	NCT	NCT	554	512	571
cv64	7A-58	John G. Mine Road	East of Green Meadow Dr.	NCT	NCT	NCT	283	261	254	NCT	350	421	397	353	NCT	NCT	444	516	NCT	NCT	536	548	619
cv66	7A-59	John G. Mine Road	West of Green Meadow Dr.	NCT	NCT	NCT	NCT	NCT	170	183	272	318	291	152	NCT	NCT	216	174	NCT	NCT	228	253	215
cv74	7A-60	Norris Road	East of Green Meadow Dr.	NCT	NCT	NCT	354	318	330	NCT	413	428	552	467	NCT	NCT	500	645	NCT	NCT	525	483	601
cv75	7A-61	Masonic Home Road	East of Frontage Rd.	NCT	NCT	NCT	387	354	386	386	480	502	378	478	NCT	NCT	578	575	NCT	NCT	561	544	575
cv84	7A-62	Timber Trail Drive	West of Hauser Dam Rd.	NCT	NCT	NCT	NCT	NCT L)	219	73	103	150	184	202	NCT	NCT	182	190	NCT	NCT	166	202	217
cv59	7A-63	Hauser Dam Road	North of Lincoln Rd. East	NCT	NCT	115	366	412	567	318	403	515	512	534	NCT	NCT	668	621	NCT	NCT	702	858	677
cv29	7A-64	Hauser Dam Road	South of Lincoln Rd. East	NCT	214	188	378	227	427	328	1) 347	446	498	490	NCT	NCT	800	713	NCT	NCT	884	774	768
cv28	7A-65	Lake Helena Drive	North of Deal Ln.	176	298	290	332	306	358	255	299	424	352	583	NCT	NCT	735	804	NCT	NCT	985	938	842
cv27	7A-66	Lake Helena Drive	South of Deal Ln.	[illegible]	223	206	247	259	[illegible]	278	345	446	[illegible]	526	NCT	NCT	[illegible]	873	NCT	NCT	974	989	880
cv26	7A-67	Lake Helena Drive	North of York Rd.	183	NCT	342	326	487	597	620	654	1,125	975	989	NCT	NCT	1,354	2,025	NCT	NCT	2,091	1960	2,060
cv25	7A-68	Lake Helena Drive	South of York Rd.	NCT	114	333	192	223	250	201	253	326	220	444	NCT	NCT	722	1,250	NCT	NCT	1,243	1188	1,265
cv24	7A-69	Lake Helena Drive	North of Canyon Ferry Rd.	NCT	1) 163	375	221	254	256	247	271	279	379	502	NCT	NCT	771	983	NCT	NCT	1,619	1513	1,667
cv23	7A-70	Lake Helena Drive	South of Canyon Ferry Rd.	NCT	1) 398	1,109	601	772	936	741	653	994	1,020	1,113	NCT	NCT	1,918	2,900	NCT	NCT	2,690	2574	2,546
cv13	7A-71	Deal Road	East of Lake Helena Dr.	68	?) 118	NCT	140	125	150	162	180	247	187	353	NCT	NCT	313	405	NCT	NCT	411	393	290
cv14	7A-72	Deal Road	1.2 mi. West of York Rd.	81	NCT	95	113	115 L)	128	136	103	112	79	119	NCT	NCT	150	181	NCT	NCT	272	210	166
cv65	7A-73	Hart Drive	East of York Rd.	NCT	NCT	NCT	NCT	NCT	182	244	236	251	236	281	NCT	NCT	241	259	NCT	NCT	298	287	250
cv87	7A-74	Keir Drive	North of Keir Rd.	NCT	NCT	NCT	NCT	NCT	278	345	315	283	302	384	NCT	NCT	431	422	NCT	NCT	335	189	133
cv66	7A-75	Hart Drive	North of Canyon Ferry Rd.	NCT	NCT	NCT	NCT	NCT L)	42	45	47	84	80	63	NCT	NCT	69	108	NCT	NCT	90	115	92
cv12	7A-76	Canyon Ferry Road	East of Lake Helena Dr.	NCT	1) 1,119	1,170	1,735	1,767	2,060	2,056	1,974	1,769	1,817	2,245	NCT	NCT	2,171	NCT	NCT	NCT	2,714	2804	2,651
cv78	7A-77	Glass Drive	North of Lincoln Rd.	NCT	NCT	NCT	395	427	485	469	486	544	586	590	NCT	NCT	533	512	NCT	NCT	604	604	619
cv63	7A-78	Montana Avenue	North of Lincoln Rd.	NCT	NCT	1,288	1,457	1,496	1,650	1,821	2,038	2,380	2,693	2,635	NCT	NCT	3,331	3,406	NCT	NCT	3,910	MDT	4,020
cv67	7A-79	Lincoln Road	East of Montana Ave.	NCT	NCT	1) 1,820	3,006	3,137	3,183	3,366	3,774	4,789	4,332	4,093	NCT	NCT	4,513		NCT	NCT	5,991	MDT	
cv11	7A-80	Canyon Ferry Road	West of Lake Helena Dr.	NCT	1) 1,573	1,951	2023	2,102	2,379	2,471	2,329	2,348	2,251	2,807	NCT	NCT	2,974	NCT	NCT	NCT	3,518	3502	3,613
cv50	7A-81	York Road	West of Lake Helena Dr.	869	1,001	1,099	1,399	1,092	1,529	1,551	1) 1,872	1,712	1,858	1,843	NCT	NCT	2,088	NCT	NCT	NCT	3,413	2420	1,924
cv22	7A-82	Lake Helena Drive	North of Old US 12	NCT	1) 2,323	3,682	2,273	2,375	2,690	3,499	3,872	3,715	4,138	4,341	NCT	NCT	3,881	5,911	NCT	NCT	2,617	4394	3,898
cv32	7A-83	Old US 12	West of Lake Helena Dr.	NCT	1) 887	2,221	1,142	1,237	1,424	1,678	1,286	1,738	1,619	2,086	NCT	NCT	2,758	2,676	NCT	NCT	2,584	2399	2,078
cv33	7A-84	Old US 12	East of Lake Helena Dr.	NCT	1) 1,021	1,777	65	83 L)	105	136	2,835	2,536	2,972	3,053	NCT	NCT	2,549	3,235	NCT	NCT	3,281	3024	2,476
cv100	7A-85	Remington St.	East of Lake Helena Dr.											1,388	NCT	NCT	1,424	NCT	NCT	NCT	1,237	1232	1,337
cv106	7A-86	Boundary St.	East of Lake Helena Dr.											832	NCT	NCT	931	NCT	NCT	NCT	1,070	1069	1,151
cv80	7A-87	Spokane Creek Road	South of Matt Staff Rd.	NCT	NCT	NCT	NCT	310	547	841	1) 653	719	810	696	NCT	NCT	774	1,157	NCT	NCT	1,022	MDT	1,170
cv92	7B-38	Franklin Mine Rd.	East of Head Dr.							313	333	335	312	289	NCT	NCT	457	422	NCT	NCT	471	341	359
cv91	7B-39	Head Dr.	North of Franklin Mine Rd.							328	366	416	356	308	NCT	NCT	459	414	NCT	NCT	372	353	326
cv19	7B-40	Head Drive	North of Country Club Ave.	W) 324	1) 335	1) 425	339	403	288	307	355	444	377	358	NCT	NCT	370	393	NCT	NCT	429	DEL.	DELETED
cv90	7B-41	Head Dr.	South of Franklin Mine Rd.							260	336	312	262	237	NCT	NCT	372	340	NCT	NCT	378	380	333
cv07	7B-42	Birdseye Road	North of Barret Rd.	1,094	1) 1,180	726	1,200	1,395	1,364	1,517	1,398	1,332	1,426	1,408	NCT	NCT	1,455	1,736	NCT	NCT	1,515	1564	1,475
cv16	7B-43	Franklin Mine Road	West of Green Meadow Dr.	W) 1,216	1) 765	803	249	1,225	1,115	689	837	816	800	903	NCT	NCT	871	891	NCT	NCT	986	826	813
cv57	7B-44	McHugh Drive	South of Forestvale Rd.	NCT	[illegible]	[illegible]	NCT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NCT	NCT	[illegible]	[illegible]	NCT	NCT	[illegible]	[illegible]	[illegible]
cv56	7B-45	McHugh Drive	North of Forestvale Rd.	NCT	[illegible]	[illegible]	NCT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NCT	NCT	[illegible]	[illegible]	NCT	NCT	[illegible]	[illegible]	[illegible]
cv52	7B-46	Forestvale Road	East of Green Meadow Dr.	NCT	398	549	370	457	498	423	494	522	511	615	NCT	NCT	586	610	NCT	NCT	531	478	452
cv53	7B-47	Forestvale Road	West of McHugh Dr.	NCT	419	528	NCT	537	512	618	589	557	634	639	NCT	NCT	572	727	NCT	NCT	654	613	1,475
cv64	7B-48	Forestvale Road	East of McHugh Dr.	NCT	503	600	NCT	699	658	727	843	667	698	634	NCT	NCT	636	752	NCT	NCT	756	690	597
cv55	7B-49	Forestvale Road	West of Montana Ave.	NCT	789	NCT	946	900	881	1,108	1,002	1,047	1,043	1,086	NCT	NCT	1,105	1,013	NCT	NCT	1,007	1010	858
cv95	7B-50	Frontage Dr.	North of Sierra Rd.											524	NCT	NCT	594	518	NCT	NCT	799	827	572

Basic Axle Class Summary: 7A-78

(DEFAULTB) Description	Lane	#1 Cycle	#2 Cars	#3 2A-4T	#4 Buses	#5 2A-SU	#6 3A-SU	#7 4A-SU	#8 4A-ST	#9 5A-ST	#10 6A-ST	#11 5A-MT	#12 6A-MT	#13 Other	Error	Total
TOTAL COUNT :	#1.	39	3241	1511	0	18	18	5	40	4	3	2	1	10	24	4916
	#2.	52	3466	1550	0	14	8	2	29	5	7	2	1	4	79	5219
		91	6707	3061	0	32	26	7	69	9	10	4	2	14	103	10135
Percents :	#1.	1%	66%	31%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	49%
	#2.	1%	66%	30%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	2%	51%
		1%	66%	30%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	1%	
Average :	#1.	1	69	32	0	0	0	0	1	0	0	0	0	0	1	104
	#2.	1	74	33	0	0	0	0	1	0	0	0	0	0	2	111
		2	143	65	0	0	0	0	2	0	0	0	0	0	3	215
Days & ADT :	#1.	1.9	2510													
	#2.	1.9	2665													
		1.9	5175													

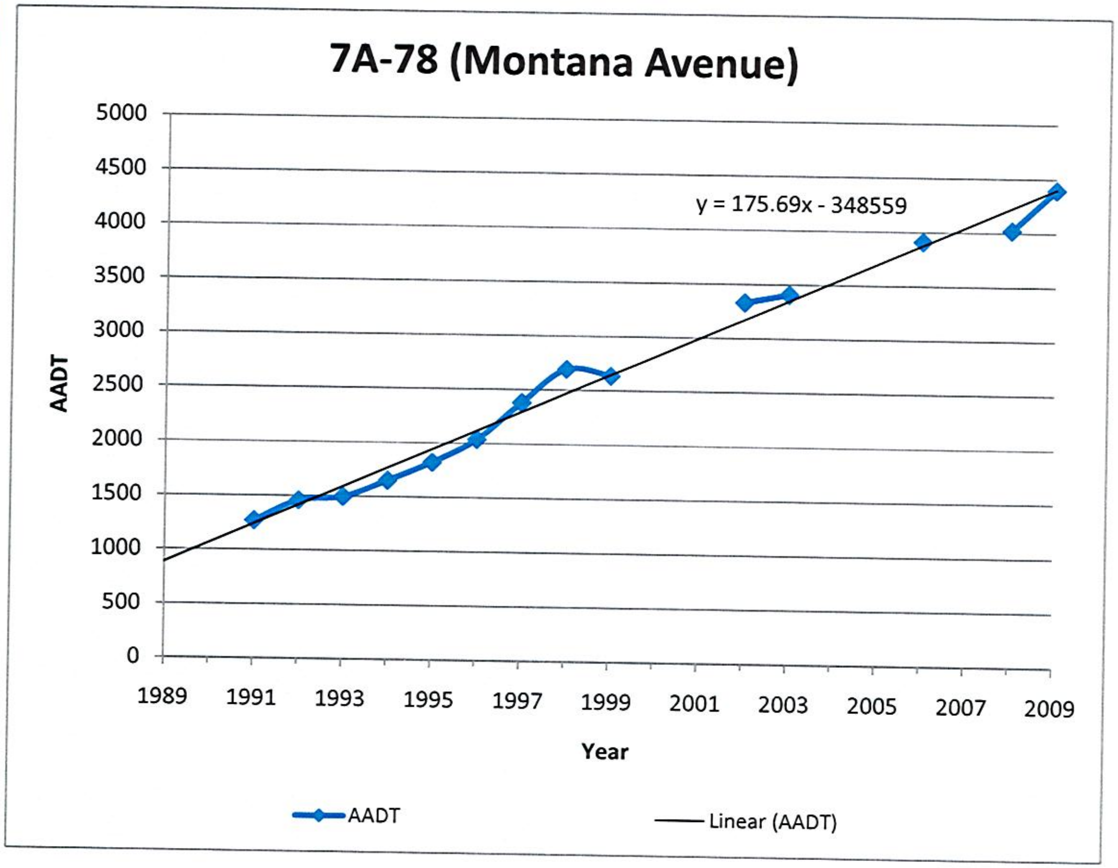
Tom, I looked at the traffic data sheets and those numbers are not ADT values for the roads. Here are the numbers that you should be using for the AADT values on these roads. Note that these values are the ADT numbers collected in the filed factor by the MDT annual count factors to create AADT volumes (0.85 for August counts). Give me a call if you have any questions.

7A-65 = 880
7A-69 = 2401
7A-78 = 4396
7B-02 = 1170
7B-42 = 1773

Bob Abelin, P.E.
Abelin Traffic Services
406-459-1443

7A-78 (Montana Avenue - North of Lincoln Road)

Year	AADT
1989	
1990	
1991	1268
1992	1457
1993	1496
1994	1650
1995	1821
1996	2038
1997	2380
1998	2693
1999	2635
2000	
2001	
2002	3331
2003	3406
2004	
2005	
2006	3910
2007	
2008	4020
2009	4396
2029	**7916**



2009	4402
2029	7916
Yearly Growth Rate	**2.98%**

Appendix B

Pavement Design for North Montana Avenue North of Lincoln Road

SK GEOTECHNICAL

September 18, 2009

Project 09-2560

Mr. Tom Cavanaugh, P.E.
Robert Peccia & Associates
Via Email: *tom@rpa-hln.com*

Dear Tom:

Re: Pavement Evaluation, N. Montana Avenue, Lewis and Clark County Road Improvement Projects, Helena, Montana

The pavement evaluation for the above-referenced project has been completed. The purpose of the pavement evaluation was to perform soil borings along the alignment and laboratory tests on selected samples to assist Robert Peccia & Associates and Lewis and Clark County to complete initial preliminary engineering analysis for a future reconstruction of a portion of N. Montana Avenue. The pavement evaluation was performed in general accordance with our Subconsultant Agreement dated June 11, 2009.

Project Information

It is our understanding N. Montana Avenue north of Lincoln Road is considered one of Lewis and Clark County's high priority roads to receive reconstructive improvements. Depending on funding availability, the intent will be for whole or parts of the road to be reconstructed to meet or exceed minimum County standards. . The portion of road being evaluated in this report, in conjunction with other preliminary engineering work, is from the intersection of Lincoln Road East (State Secondary Highway 279) extending northward for 3 1/2 miles to where the existing roadway basically ends at a turnaround area. The N. Montana Avenue roadway limits considered for this pavement evaluation are shown on the attached Boring Location Sketch. At this time, the engineering evaluation along N. Montana Avenue is based on a total reconstruction need with a new pavement section to bring the road into compliance of meeting or exceeding the minimum road standards in accordance with the Lewis and Clark Subdivision Regulations dated September 18, 2007. Approaching the preliminary engineering as a total reconstruction project will likely present the most conservative cost analysis to assist the County in earmarking funding. This pavement evaluation is being prepared to supplement the preliminary engineering analysis.

Field Procedures

On July 10, 2009, Borings ST-1 through ST-4 were performed along the 3 1/2-mile alignment being considered for reconstruction. Therefore, the borings were located slightly over 1 mile apart. Boring locations were selected by our personnel and were generally alternated from the northbound and southbound lanes. The locations of Borings ST-1 through ST-4 are shown on the attached sketch. To perform the borings, single lane closure traffic control was performed while drilling.

The borings were performed with a truck-mounted core and auger drill. Sampling of the borings was performed in accordance with American Society for Testing and Materials (ASTM) Method of Test D 1586, "Penetration Test and Split-Barrel Sampling of Soils." Using this method, we advanced the borehole with hollow-stem auger to the desired test depth. Then a 140-pound hammer falling 30 inches drove a standard, 2-inch OD, split-barrel sampler a total penetration of 1 1/2 to 2 feet below the tip of the hollow-stem auger. The blows for the 1 1/2-foot of penetration are indicated on the boring logs, and are an index of soil strength characteristics. The last 1-foot portion of each penetration test is the N-value, and referred to as blows per foot (BPF) in this report.

While drilling, our engineering assistant measured the thickness of the existing asphalt pavement and underlying gravel base course to the nearest 1/2 inch. We wish to point out, however, that measuring the existing base thickness to the nearest 1/2 inch can be difficult due to previous construction activities along the roadway. Bag samples of the existing base course and subgrade were collected from some of the borings. The borings were then backfilled by our drill crew, and the pavement surface was patched with cold-mix asphalt.

The soils encountered in the borings were visually and manually classified in accordance with ASTM D 2488, "Standard Practice for Description and Identification of Soils (Visual – Manual Procedures)." A summary of the ASTM classification system is attached. All samples were then returned to our laboratory for review of the field classifications by a geotechnical engineer. Representative samples will remain in our office for a period of 60 days to be available for your examination.

Results

General. Log of Boring sheets indicating the depth and identification of the various soil strata, the penetration resistance, laboratory test data, and water level information are attached. It should be noted that the depths shown as boundaries between the strata are only approximate. The actual changes may be transitions and the depths of changes vary between borings.

Geologic origins presented for each stratum on the Log of Boring sheets are based on the soil types, blows per foot, and available common knowledge of the depositional history of the site. Because of the complex glacial and post-glacial depositional environments, geologic origins are frequently difficult to ascertain. A detailed evaluation of the geologic history of the roadway as well as review of contour maps and cross sections was not performed.

The general profile encountered by the four borings was existing pavement underlain by gravel base course over clayey sand, sandy lean clay, and clayey gravel subgrades. Table 1 below summarizes the existing pavement and subgrade conditions encountered at the four borings.

Table 1. Summary of Boring Conditions – N. Montana Avenue

Boring	ST-1	ST-2	ST-3	ST-4
Existing Pavement	3½"	6½"	6"	4"
Existing Base Thickness	8½"	5½"	2½"	2"
Existing Base Quality	Poor	Poor	Good	Good
Subgrade	Clayey Sand (SC)	Sandy Lean Clay (CL)	Clayey Gravel (GC)	Clayey Sand (GC)
BPF	16, 10	4, 6	20, 14	22, 17
Moisture Condition	Over 1 – 2%	Over 2%	Near	Below
Risk of Subgrade Failure	Moderate	High	Low	Low

General Statistical Summary

Existing Base Course: 2 of 4 borings (50%) encountered POOR quality base course
2 of 4 borings (50%) encountered GOOD quality base course, but is likely too thin to salvage

Subgrade Conditions: 1 of 4 borings (25%) have HIGH risk to become unstable during construction
1 of 4 borings (25%) have MODERATE risk to become unstable during construction.
2 of 4 borings (50%) have LOW risk to become unstable during construction

Existing Pavement Section. As indicated in Table 1 above, the four borings encountered existing asphalt pavement to depths ranging from 3 1/2 to 6 1/2 inches. Beneath the existing pavement, Borings ST-1 and ST-2 encountered poor quality clayey sand base course, which extended to a depth of about 1 foot. Borings ST-3 and ST-4 encountered relatively good quality base course, however, this base course thickness was only 2 1/2 and 2 inches, respectively. Penetration tests were performed in the base course directly beneath the asphalt surface while drilling. In general, penetration resistances in the base course typically ranged from 6 to 9 blows for 6 inches of penetration, indicating it was medium dense.

Subgrade. Beneath the existing base course, Borings ST-1 and ST-4 encountered clayey sand with gravel to a depth of 3 feet underlain by poorly graded gravel. Boring ST-2 encountered sandy lean clay subgrade while Boring ST-4 encountered clayey gravel subgrade. Penetration resistances in the clayey sand and clayey gravel subgrades typically ranged from 10 to 22 BPF, indicating these materials were medium dense. The penetration resistances in the gravel encountered in Borings ST-1 and ST-4 were 22 and 8 BPF, respectively, indicating these gravels were medium dense to loose. The penetration resistances in the sandy lean clay were only 4 and 6 BPF, indicating the lean clay was rather soft to medium consistent.

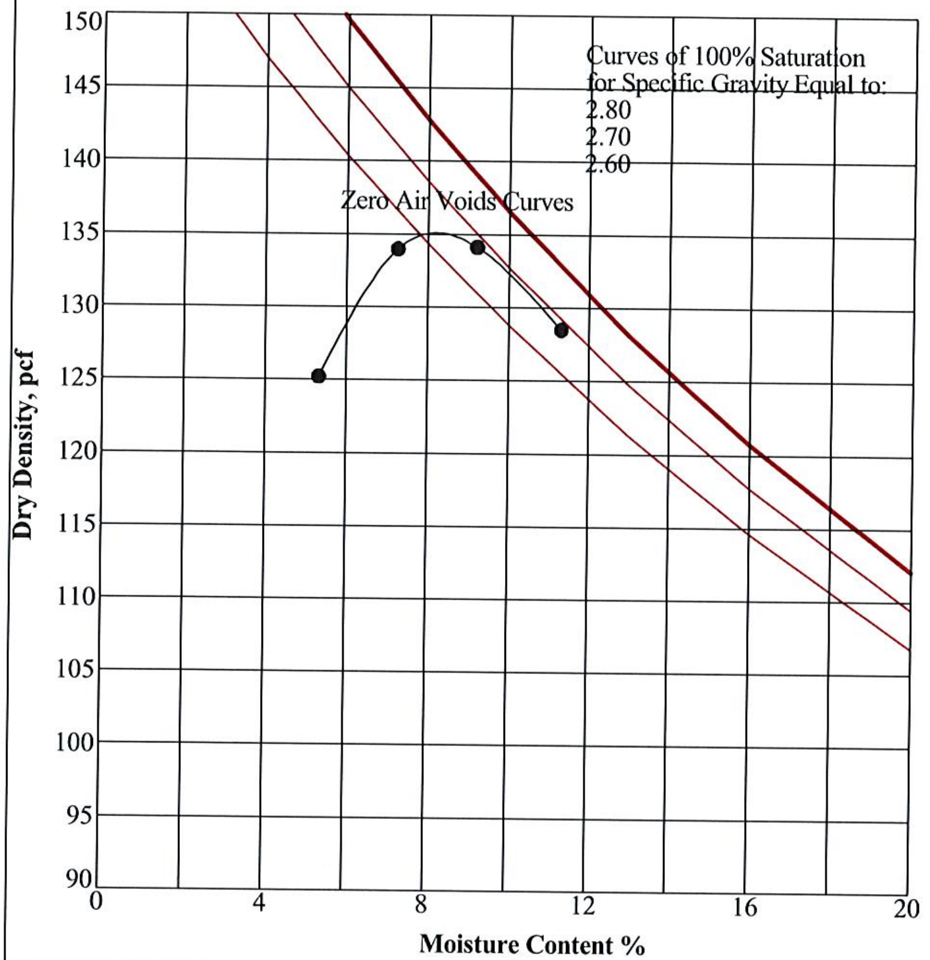
SK GEOTECHNICAL
2611 Gabel Road
P. O. Box 80190
Billings, MT 59108-0190
Phone: 406.652.3930
Fax: 406.652.3944

LOG OF BORING

PROJECT: 09-2560 **PAVEMENT DESIGN** Lewis and Clark County Roads Helena, Montana	BORING: **ST-4** LOCATION: N. Montana Avenue, see attached sketch.
DRILLED BY: C. Larsen / METHOD: 3 1/4" HSA, Automatic	DATE: 7/10/09 / SCALE: 1" = 1'

Elev.	Depth (0.0)	Symbol	Description of Materials	BPF	WL	MC (%)	Remarks
	0.3		FILL: 4" of Asphalt Pavement.				
	0.5		FILL: 2" of Gravel Base Course.				
	3.0	SC	CLAYEY SAND with GRAVEL, fine- to coarse-grained, low plasticity, brown, wet, medium dense. (Alluvium)	11/8/14		4.8	Composite subgrade bag sample ST-1 and ST-4: LL=27, PL=16, PI=11 P_{200}=26.5%
				11/9/8		2.7	
	5.5	GP	POORLY GRADED GRAVEL with SAND, fine- to coarse-grained, reddish gray, rather dry, loose. (Alluvium)	5/4/4		4.1	
			END OF BORING Water not observed with 4' of hollow-stem auger in the ground. Water not observed to dry cave-in depth of 2 1/2' immediately after withdrawal of auger.				

BORING BPF WL MC 2560.GPJ LAGNNN06.GDT 9/15/09



ASTM D 4718 Oversize Correction

Maximum Dry Density, pcf	***Optimum Moisture Content %***
136.9	*7.9*

ASTM C 127

Coarse Specific Gravity = 2.67
Absorption = 1.2%

Fine Portion

ASTM D 698 Method C with Correction

Maximum Dry Density, pcf	Optimum Moisture Content %
135.3	8.3

Rammer Type: Mechanical
Preparation Method: Moist

Soil Description (Visual-Manual)

CLAYEY SAND with GRAVEL, fine- to coarse-grained, low plasticity, brown, moist.

Sieve Size	**% Retained**
1 1/2"	0
3/4"	5.9
3/8"	17
#4	33

Sample No:	---
Lab Sample No:	P-1
Date Sampled:	07/10/2009
Sampled By:	Drill Crew
Date Received:	07/15/2009
Sampled From:	ST-1 and ST-4
Depth:	Subgrade
Performed by:	MBK/SKG
Date Performed:	07/28/2009

Comments

Additional Remarks

SK GEOTECHNICAL
2611 Gabel Road
P.O. Box 80190
Billings, MT 59108-0190
Phone: 406.652.3930
Fax: 406.652.3944

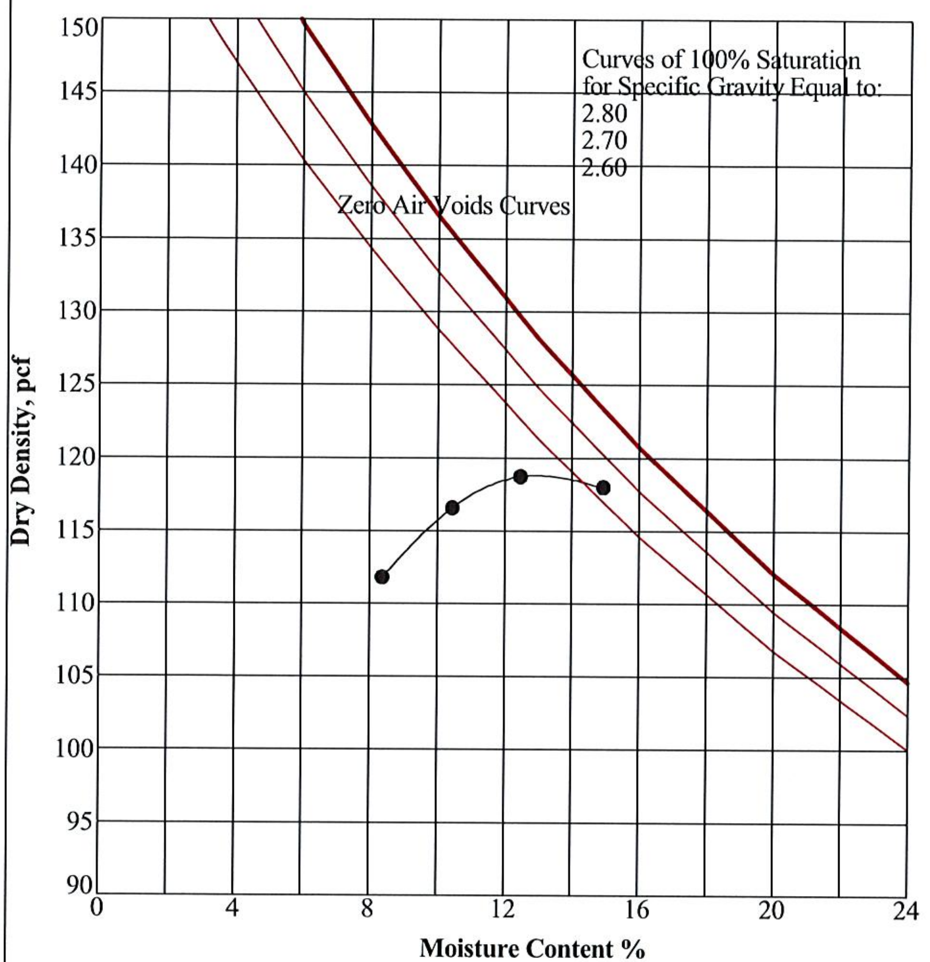
Laboratory Compaction Characteristics of Soil (Proctor)

Project No.: 09-2560
Lewis and Clark County Roads
Helena, Montana

PROCTOR

P-1

9/15/09



ASTM D 698 Method C

Maximum Dry Density, pcf	Optimum Moisture Content %
118.8	**13.3**

Rammer Type: Mechanical
Preparation Method: Moist

Soil Description (Visual-Manual)

SANDY LEAN CLAY, low plasticity, brown, moist.

Sieve Size	% Retained
1 1/2"	0
3/4"	0
3/8"	4
#4	10

Sample No:	---
Lab Sample No:	P-2
Date Sampled:	07/10/2009
Sampled By:	Drill Crew
Date Received:	07/15/2009
Sampled From:	ST-2
Depth:	Subgrade
Performed by:	MBK/SKG
Date Performed:	07/28/2009

Comments

Remarks

SK GEOTECHNICAL
2611 Gabel Road
P. O. Box 80190
Billings, MT 59108-0190
Phone: 406.652.3930
Fax: 406.652.3944

Laboratory Compaction Characteristics of Soil (Proctor)

Project No.: 09-2560
Lewis and Clark County Roads
Helena, Montana

PROCTOR

P-2

9/15/09

California Bearing Ratio Test

(ASTM D 1883 /AASHTO T 193)

Project: 09-2560 Lewis and Clark County Roads **Date:** 09/15/09

Boring: ST-1 and ST-4 **Sample:** P-1 **Depth:** Subgrade

Sample Description: Clayey Sand with Gravel, fine- to coarse-grained, low plasticity, brown, moist.
(Remolded to 95% relative compaction.)
(Sample was submersed in water and allowed to saturate for 96.0 hours.)

Maximum Dry Density: 135.3 pcf Procedure: ASTM D 698 Method C

Initial			**Final**		
Wt. Specimen + Tare Wet	624.8	gms	Wt. Specimen + Tare Wet	1239.2	gms
Wt. Specimen + Tare Dry	583.0	gms	Wt. Specimen + Tare Dry	1152.4	gms
Wt. Tare	147.8	gms	Wt. Tare	298.1	gms
Moisture Content	9.6%		Moisture Content	10.2%	

Initial Wt.	4792.5	gms	Diameter	6.00	in	Initial Ht.	4.58	in

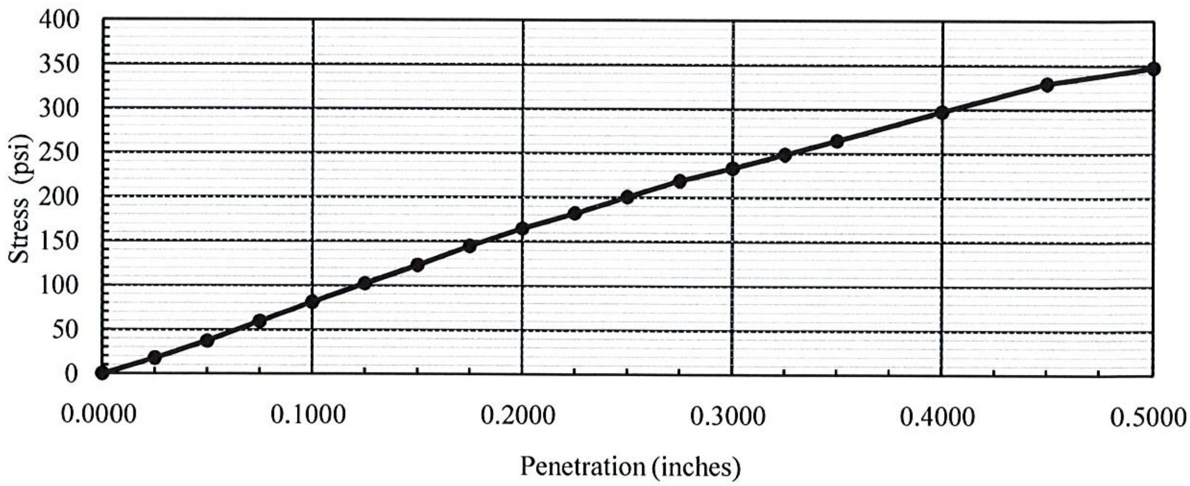
Initial Dry Unit Wt.	128.6	pcf	Initial Relative Compaction	95.1%
Final Dry Unit Wt.	128.6	pcf	Final Relative Compaction	95.1%

Swell Test

Surcharge Weight	22.5	lbs	Surcharge Pressure	133.4	psf		
Initial Dial Rdg.	0.5000		Final Dial Rdg.	0.5000		Swell	0.0%

CBR Test

Surcharge Weight	22.5	lbs	Surcharge Pressure	128.1	psf
CBR @ 0.1 in.	**8.1**		CBR @ 0.2 in	**11.0**	



SK GEOTECHNICAL

California Bearing Ratio Test

(ASTM D 1883 /AASHTO T 193)

Project: 09-2560 Lewis and Clark County Roads **Date:** 09/15/09

Boring: ST-2 **Sample:** P-2 **Depth:** Subgrade

Sample Description: Sandy Lean Clay, low plasticity, brown, moist.
(Remolded to 95% relative compaction.)
(Sample was submersed in water and allowed to saturate for 96.2 hours.)

Maximum Dry Density: 118.8 pcf Procedure: ASTM D 698 Method C

Initial			**Final**		
Wt. Specimen + Tare Wet	929.7	gms	Wt. Specimen + Tare Wet	970.2	gms
Wt. Specimen + Tare Dry	853.6	gms	Wt. Specimen + Tare Dry	862.1	gms
Wt. Tare	305.1	gms	Wt. Tare	282.1	gms
Moisture Content	13.9%		Moisture Content	18.6%	

Initial Wt. 4373.2 gms Diameter 6.00 in Initial Ht. 4.58 in

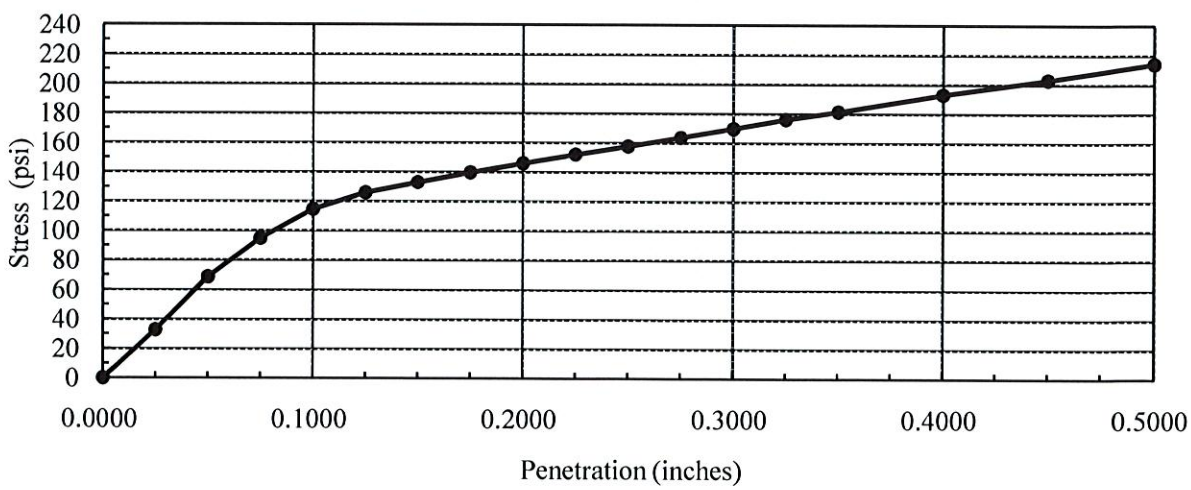
Initial Dry Unit Wt. 113.0 pcf Initial Relative Compaction 95.1%
Final Dry Unit Wt. 112.4 pcf Final Relative Compaction 94.6%

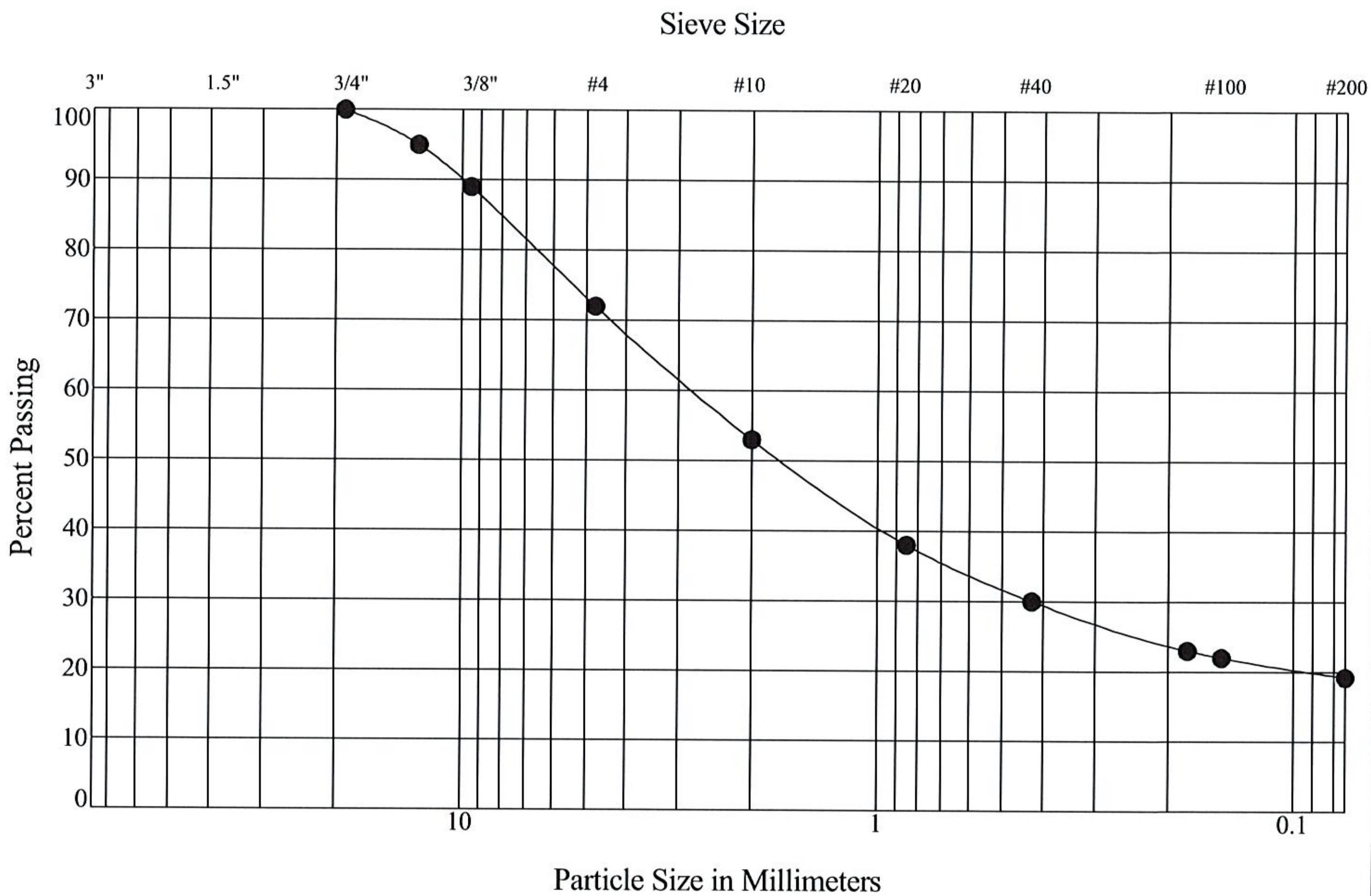
Swell Test

Surcharge Weight 22.5 lbs Surcharge Pressure 133.4 psf
Initial Dial Rdg. 0.5000 Final Dial Rdg. 0.5233 Swell 0.5%

CBR Test

Surcharge Weight 22.5 lbs Surcharge Pressure 128.1 psf
CBR @ 0.1 in. **11.5** CBR @ 0.2 in **9.7**





Gravel		Sand		
coarse	fine	coarse	medium	fine

Percent Passing U.S. Standard Sieve Size

3"	1 1/2"	3/4"	3/8"	#4	#10	#20	#40	#80	#100	#200
		100	89	72	53	38	30	23	22	19.2

Boring No.: ST-1
Sample No.: Base Course
Depth: Base Course

Date Received: 07/15/2009

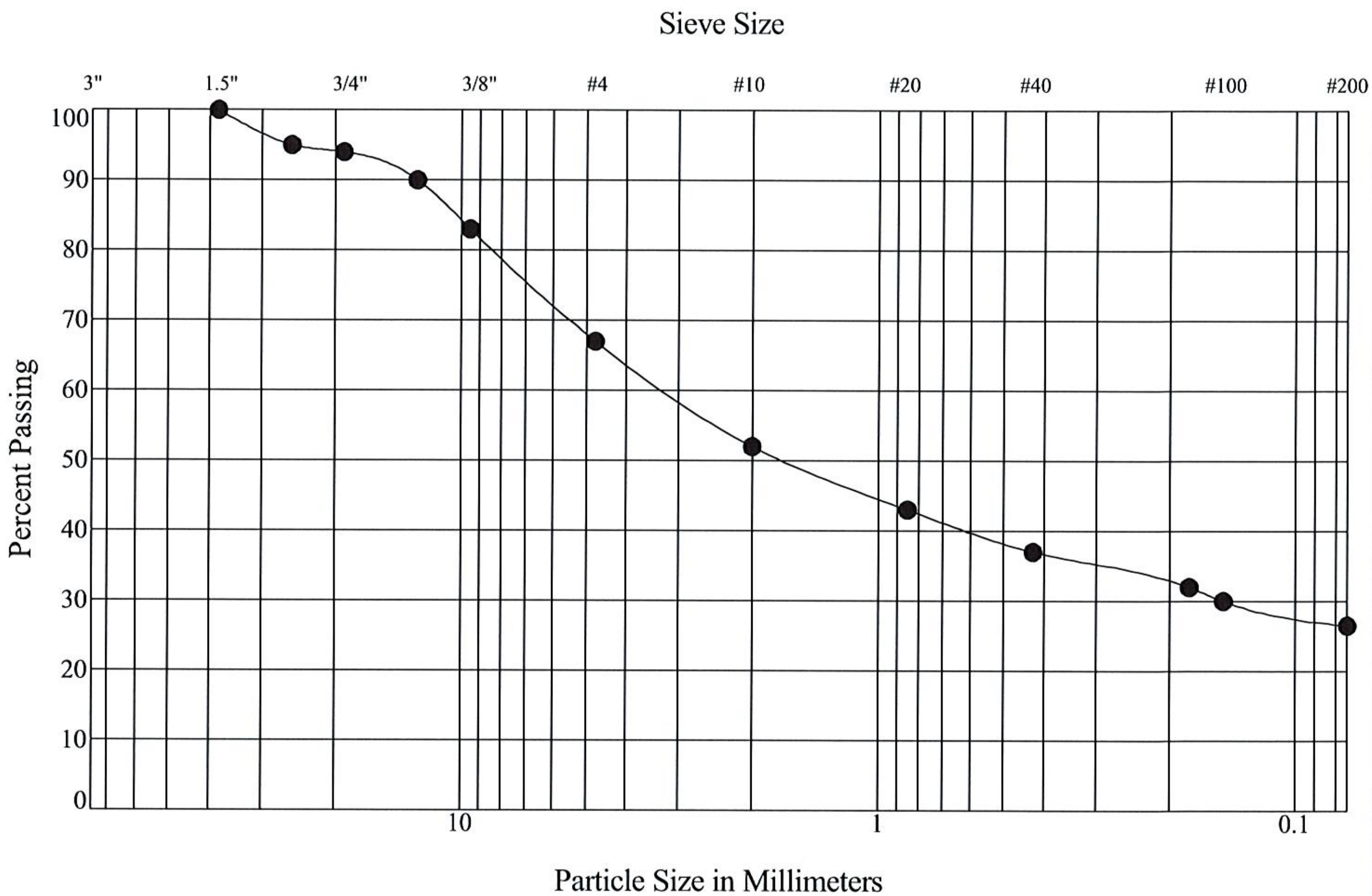
Percent Gravel: 28.0
Percent Sand: 52.8
Percent Silt + Clay: 19.2
ASTM Group Name: CLAYEY SAND with GRAVEL

Liquid Limit:	24
Plastic Limit:	15
Plasticity Index:	9
Classification:	SC
Moisture Content:	5.9%

SK GEOTECHNICAL
2611 Gabel Road
P. O. Box 80190
Billings, MT 59108-0190
Phone: 406.652.3930
Fax: 406.652.3944

Sieve Analysis
Project Number: 09-2560
Lewis and Clark County Roads
Helena, Montana

9/15/09



Gravel		Sand		
coarse	fine	coarse	medium	fine

Percent Passing U.S. Standard Sieve Size

3"	1 1/2"	3/4"	3/8"	#4	#10	#20	#40	#80	#100	#200
	100	94	83	67	52	43	37	32	30	26.5

Boring No.: ST-1 and ST-4 Date Received: 07/15/2009
Sample No.: P-1
Depth: Subgrade

Percent Gravel: 33.0
Percent Sand: 40.5
Percent Silt + Clay: 26.5
ASTM Group Name: CLAYEY SAND with GRAVEL

Liquid Limit:	27
Plastic Limit:	16
Plasticity Index:	11
Classification:	SC
Moisture Content:	

SK GEOTECHNICAL
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P. O. Box 80190
Billings, MT 59108-0190
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Sieve Analysis
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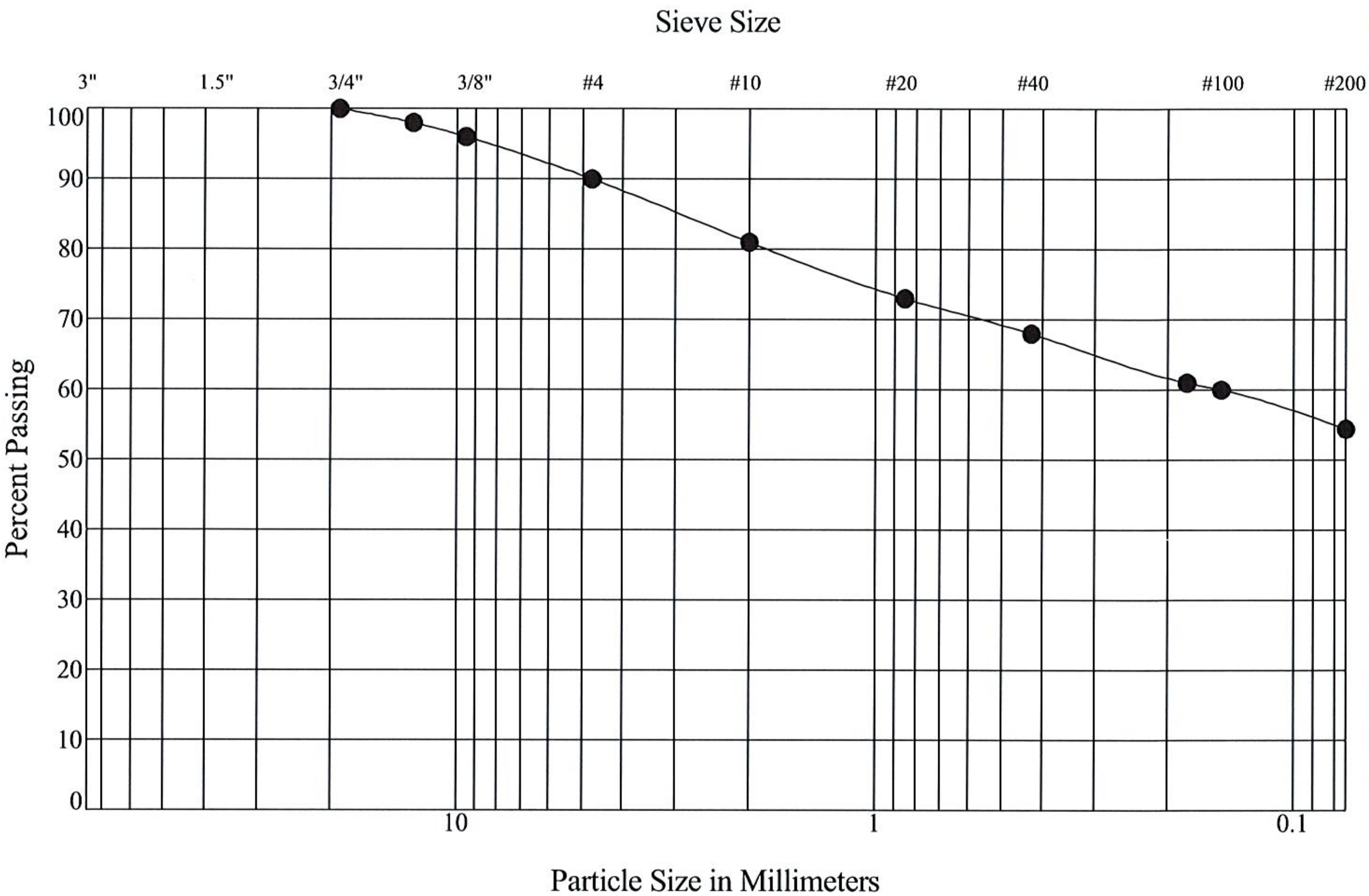
Lewis and Clark County Roads
Helena, Montana

9/15/09



Gravel		Sand		
coarse	fine	coarse	medium	fine

Percent Passing U.S. Standard Sieve Size

3"	1 1/2"	3/4"	3/8"	#4	#10	#20	#40	#80	#100	#200
		100	96	90	81	73	68	61	60	54.4

Boring No.: ST-2
Sample No.: P-2
Depth: Subgrade

Date Received: 07/15/2009

Liquid Limit:	40
Plastic Limit:	17
Plasticity Index:	23
Classification:	CL
Moisture Content:	

Percent Gravel: 10.0
Percent Sand: 35.6
Percent Silt + Clay: 54.4
ASTM Group Name: SANDY LEAN CLAY

SK GEOTECHNICAL
2611 Gabel Road
P. O. Box 80190
Billings, MT 59108-0190
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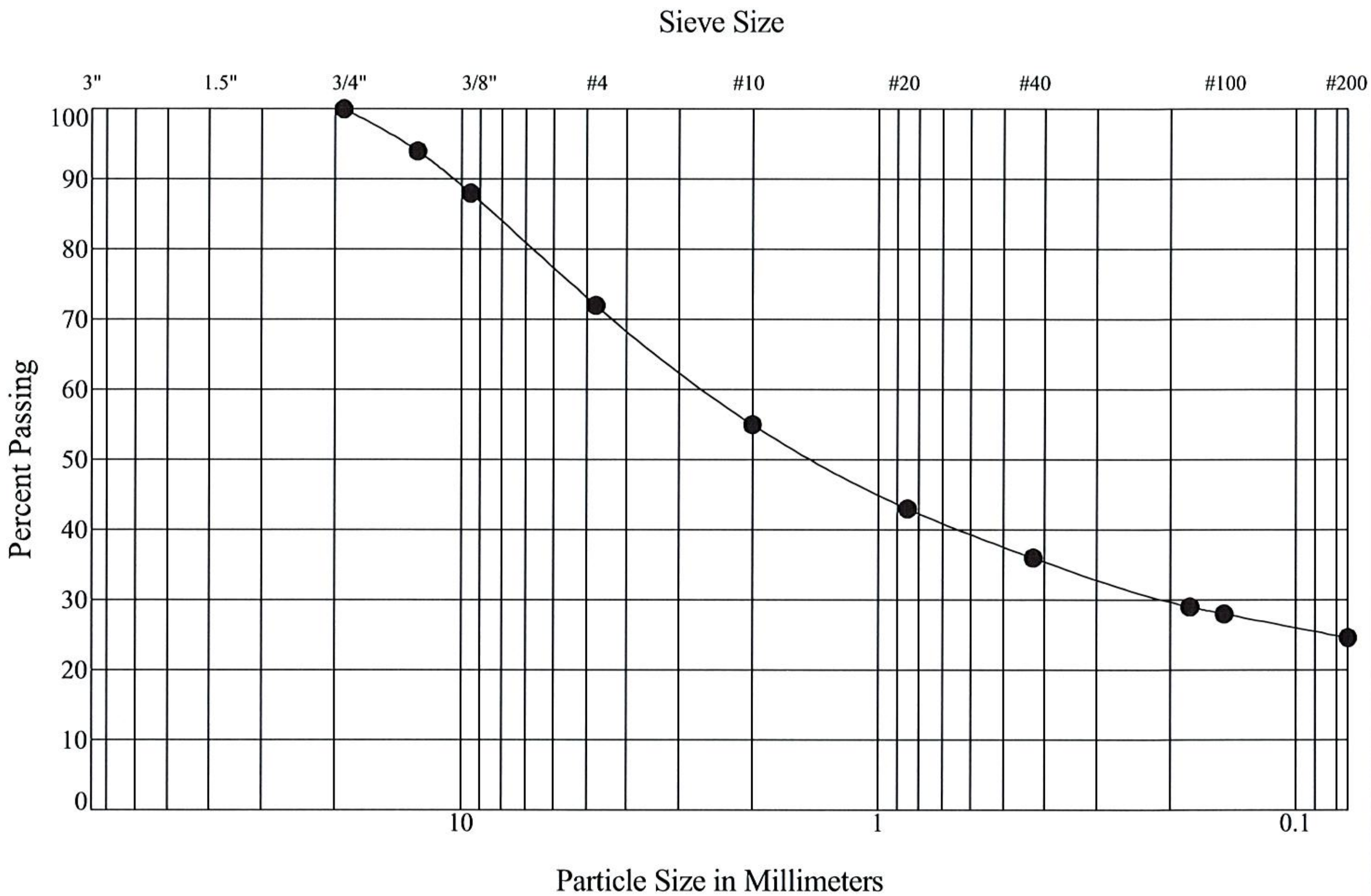
Sieve Analysis
Project Number: 09-2560
Lewis and Clark County Roads
Helena, Montana

9/15/09



Gravel		Sand		
coarse	fine	coarse	medium	fine

Percent Passing U.S. Standard Sieve Size

3"	1 1/2"	3/4"	3/8"	#4	#10	#20	#40	#80	#100	#200
		100	88	72	55	43	36	29	28	24.6

Boring No.: ST-2
Sample No.: Base Course
Depth: Base Course

Date Received: 07/15/2009

Percent Gravel: 28.0
Percent Sand: 47.4
Percent Silt + Clay: 24.6
ASTM Group Name: CLAYEY SAND with GRAVEL

Liquid Limit:	32
Plastic Limit:	16
Plasticity Index:	16
Classification:	SC
Moisture Content:	6.6%

SK GEOTECHNICAL
2611 Gabel Road
P. O. Box 80190
Billings, MT 59108-0190
Phone: 406.652.3930
Fax: 406.652.3944

Sieve Analysis

Project Number: 09-2560
Lewis and Clark County Roads
Helena, Montana

9/15/09

Laboratory Test of Aggregate

Date: September 15, 2009

Project: **09-2560 Pavement Evaluation**
N. Montana Avenue
Lewis and Clark County Road
Improvement Projects
Helena, Montana

To: Mr. Tom Cavanaugh
Robert Peccia & Associates
P. O. Box 5653
Helena, Montana 59604-5653

Copies:

Gradation (ASTM C 136)

			12/18/2007 Lewis and Clark Subdivision	
Sieve Size	**ST-1 Base Course**	**ST-2 Base Course**	**Crushed Top Surfacing**	**Select Base Course**
1 1/2"	100	100	---	100
3/4"	100	100	100	---
1/2"	95	94	---	---
No. 4	72*	72*	40 – 70	25 – 60
No. 10	53	55	25 – 55	---
No. 40	30	36	---	---
No. 100	22	28	---	---
No. 200	19.2*	24.6*	2 – 10	2 – 12

Remarks: *Do not meet specifications.

DARWin(tm) - Pavement Design

A Proprietary AASHTOWARE(tm)
Computer Software Product

Flexible Structural Design Module

Project Description
North Montana Avenue, Lewis and Clark County, Montana

Flexible Structural Design Module Data

18-kip ESALs Over Initial Performance Period:	313,112
Initial Serviceability:	4.2
Terminal Serviceability:	2.5
Reliability Level (%):	90
Overall Standard Deviation:	.45
Roadbed Soil Resilient Modulus (PSI):	11,700
Stage Construction:	1
Calculated Structural Number:	2.42

Specified Layer Design

Layer:	1
Material Description:	Asphalt Pavement
Structural Coefficient (Ai):	.41
Drainage Coefficient (Mi):	1
Layer Thickness (Di) (in):	3.00
Calculated Layer SN:	1.23
Layer:	2
Material Description:	Crushed Top Surfacing
Structural Coefficient (Ai):	.14
Drainage Coefficient (Mi):	1
Layer Thickness (Di) (in):	3.00
Calculated Layer SN:	.42
Layer:	3
Material Description:	Select Base Course
Structural Coefficient (Ai):	.07
Drainage Coefficient (Mi):	.9
Layer Thickness (Di) (in):	6.00
Calculated Layer SN:	.38
Layer:	4
Material Description:	Subbase Course
Structural Coefficient (Ai):	.07
Drainage Coefficient (Mi):	.9
Layer Thickness (Di) (in):	7.00
Calculated Layer SN:	.44
Total Thickness (in):	19.00
Total Calculated SN:	2.47

Rigorous ESAL Calculation

Initial Performance Period (years):	20
Initial Two-Way Daily Traffic (ADT):	4,396
Number of Lanes In Design Direction:	1
Percent of All Trucks In Design Lane (%):	50
Percent Trucks In Design Direction (%):	100
Growth:	Simple

Class: 1
% of ADT: .89
Annual % Growth: 3
Average Initial Truck Factor (ESALs/truck): .0001
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 18

Class: 2
% of ADT: 66.27
Annual % Growth: 3
Average Initial Truck Factor (ESALs/truck): .0003
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 4,102

Class: 3
% of ADT: 30.2
Annual % Growth: 3
Average Initial Truck Factor (ESALs/truck): .004
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 24,924

Class: 4
% of ADT: 1.01
Annual % Growth: 3
Average Initial Truck Factor (ESALs/truck): .57
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 118,781

Class: 5
% of ADT: .31
Annual % Growth: 3
Average Initial Truck Factor (ESALs/truck): .26
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 16,630

Class: 6
% of ADT: .25
Annual % Growth: 3
Average Initial Truck Factor (ESALs/truck): .42
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 21,664

Class: 7
% of ADT: .06
Annual % Growth: 3
Average Initial Truck Factor (ESALs/truck): .42
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 5,199

Class: 8
% of ADT: .68
Annual % Growth: 3
Average Initial Truck Factor (ESALs/truck): .3
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 42,090

Class: 9
% of ADT: .08
Annual % Growth: 3
Average Initial Truck Factor (ESALs/truck): 1.2
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 19,807

Class: 10
% of ADT: .08
Annual % Growth: 3

Average Initial Truck Factor (ESALs/truck): .93
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 15,351

Class: 11
% of ADT: .03
Annual % Growth: 3
Average Initial Truck Factor (ESALs/truck): .82
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 5,076

Class: 12
% of ADT: .01
Annual % Growth: 3
Average Initial Truck Factor (ESALs/truck): 1.06
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 2,187

Class: 13
% of ADT: .13
Annual % Growth: 3
Average Initial Truck Factor (ESALs/truck): 1.39
Annual % Growth in Truck Factor: 0
Accumulated 18K ESALs over Performance Period: 37,283

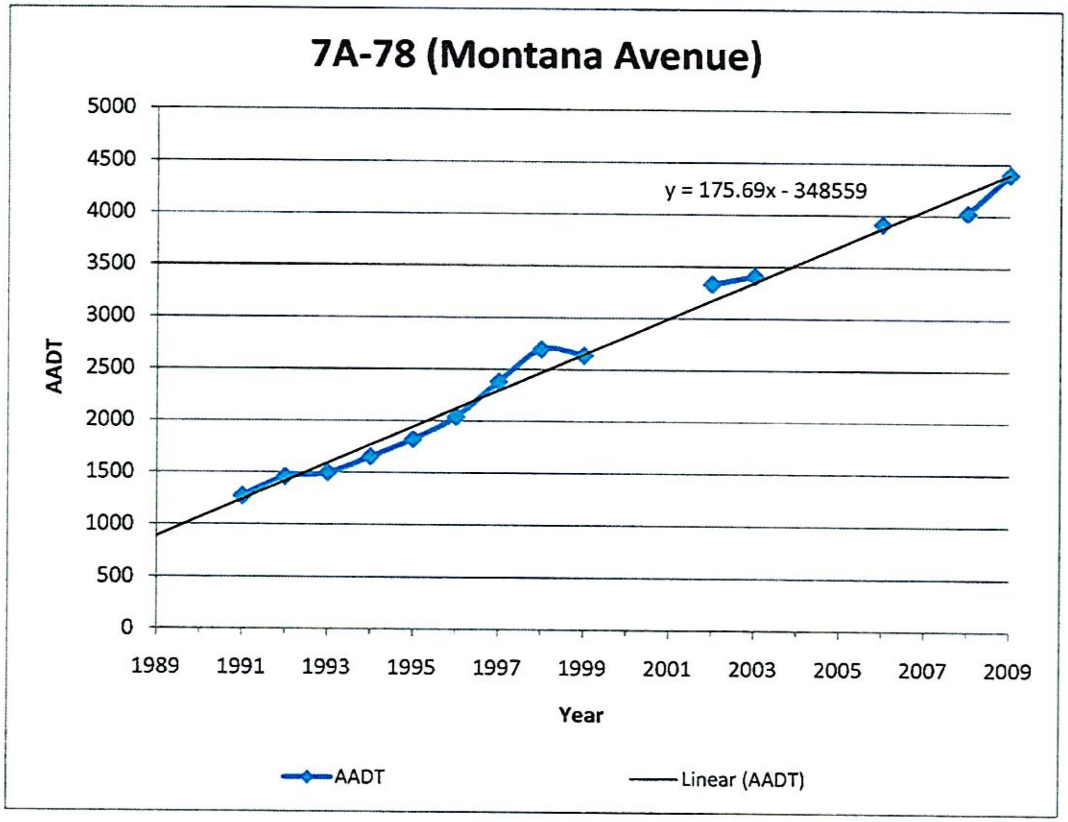
Total % of ADT (should be 100): 100.00
Cumulative Esals for all Classes: 313,112

Basic Axle Class Summary: 7A-78

(DEFAULTB) Description	Lane	#1 Cycle	#2 Cars	#3 2A-4T	#4 Buses	#5 2A-SU	#6 3A-SU	#7 4A-SU	#8 4A-ST	#9 5A-ST	#10 6A-ST	#11 5A-MT	#12 6A-MT	#13 Other	Error	Total
TOTAL COUNT :	#1.	39	3241	1511	0	18	18	5	40	4	3	2	1	10	24	4916
	#2.	52	3466	1550	0	14	8	2	29	5	7	2	1	4	79	5219
		91	6707	3061	0	32	26	7	69	9	10	4	2	14	103	10135
Percents :	#1.	1%	66%	31%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	49%
	#2.	1%	66%	30%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	2%	51%
		1%	66%	30%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	1%	
Average :	#1.	1	69	32	0	0	0	0	1	0	0	0	0	0	1	104
	#2.	1	74	33	0	0	0	0	1	0	0	0	0	0	2	111
		2	143	65	0	0	0	0	2	0	0	0	0	0	3	215
Days & ADT :	#1.	1.9	2510													
	#2.	1.9	2665													
		1.9	5175													

7A-78 (Montana Avenue - North of Lincoln Road)

Year	AADT
1989	
1990	
1991	1268
1992	1457
1993	1496
1994	1650
1995	1821
1996	2038
1997	2380
1998	2693
1999	2635
2000	
2001	
2002	3331
2003	3406
2004	
2005	
2006	3910
2007	
2008	4020
2009	4396
2029	**7916**



2009	4402
2029	7916
Yearly Growth Rate	**2.98%**

Class	Type	Description	Typical ESALs per Vehicle[2]
1	Motorcycles	All two- or three-wheeled motorized vehicles. Typical vehicles in this category have saddle type seats and are steered by handle bars rather than wheels. This category includes motorcycles, motor scooters, mopeds, motor-powered bicycles, and three-wheel motorcycles. This vehicle type may be reported at the option of the State.	0,0 negligible
2	Passenger Cars	All sedans, coupes, and station wagons manufactured primarily for the purpose of carrying passengers and including those passenger cars pulling recreational or other light trailers.	0,0003 negligible Table 0.4
3	Other Two-Axle, Four-Tire Single Unit Vehicles	All two-axle, four tire, vehicles, other than passenger cars. Included in this classification are pickups, panels, vans, and other vehicles such as campers, motor homes, ambulances, hearses, and carryalls. Other two-axle, four-tire single unit vehicles pulling recreational or other light trailers are included in this classification.	0,004 negligible Table 0.4
4	Buses	All vehicles manufactured as traditional passenger-carrying buses with two axles and six tires or three or more axles. This category includes only traditional buses (including school buses) functioning as passenger-carrying vehicles. All two-axle, four-tire single unit vehicles. Modified buses should be considered to be a truck and be appropriately classified.	0.57
5	Two-Axle, Six-Tire, Single Unit Trucks	All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having two axles and dual rear wheels.	0.26
6	Three-Axle Single Unit Trucks	All vehicles on a single frame including trucks, camping and recreational vehicles, motor homes, etc., having three axles.	0.42
7	Four or More Axle Single Unit Trucks	All trucks on a single frame with four or more axles.	0.42
8	Four or Less Axle Single Trailer Trucks	All vehicles with four or less axles consisting of two units, one of which is a tractor or straight truck power unit.	0.30
9	Five-Axle Single Trailer Trucks	All five-axle vehicles consisting of two units, one of which is a tractor or straight truck power unit.	1.20
10	Six or More Axle Single Trailer Trucks	All vehicles with six or more axles consisting of two units, one of which is a tractor or straight truck power unit.	0.93
11	Five or Less Axle Multi-Trailer Trucks	All vehicles with five or less axles consisting of three or more units, one of which is a tractor or straight truck power unit.	0.82
12	Six-Axle Multi-Trailer Trucks	All six-axle vehicles consisting of three or more units, one of which is a tractor or straight truck power unit.	1.06

13	Seven or More Axle Multi-Trailer Trucks	All vehicles with seven or more axles consisting of three or more units, one of which is a tractor or straight truck power unit.	1.39

Note 1: In reporting information on trucks the following criteria should used:

1. Truck tractor units traveling without a trailer will be considered single unit trucks.
2. A truck tractor unit pulling other such units in a "saddle mount" configuration will be considered as one single unit truck and will be defined only by the axles on the pulling unit.
3. Vehicles shall be defined by the number of axles in contact with the roadway. Therefore, "floating" axles are counted only when in the down position.
4. The term "trailer" includes both semi- and full trailers.

Note 2: Based on the overall ESAL per vehicle class for 10 weigh-in-motion (WIM) sites averaged over a one-year period. The averaging method treats all pavements the same (i.e., no separate LEFs for flexible and rigid pavements) and all axles as singles. This approach produces LEFs similar to the 1993 AASHTO Guide's LEFs for single axles assuming SN = 5 and p_t = 2.5.

Figure 4: FHWA Class 5

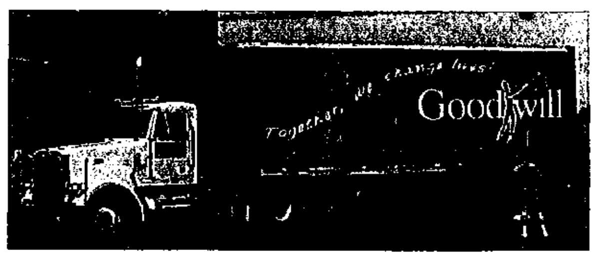


Figure 5: FHWA Class 8

Figure 6: FHWA Class 11

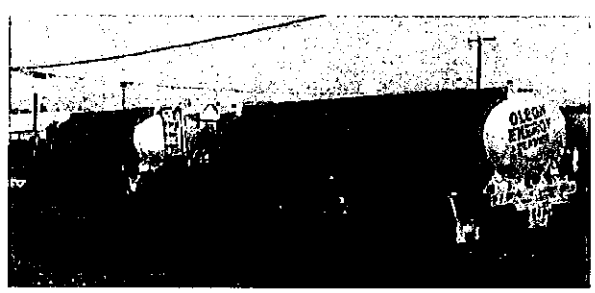


Figure 7: FHWA Class 10

Appendix C

Sample Project Road Easement & Design Reference Exhibits

HWD—SHC—Form 30-A—1M- 33.

COPY

State Highway Commission of Montana

Federal Aid Project No. 369-B County of Lewis and Clark

HIGHWAY RIGHT OF WAY EASEMENT

Know All Men By These Presents:

That CHEVALLIER LIVESTOCK COMPANY, a corporation organized and existing under and by virtue of the laws of the State of Montana,

of Helena, Montana for, and in consideration of the

sum of

lawful money of the United States to it in hand paid by the State of Montana, the receipt whereof is hereby acknowledged, does hereby grant, bargain, sell and convey unto the State of Montana, an easement and right of way for the construction of a State highway over, across, covering and embracing the following described parcel s of land, to-wit:

A tract of land in the SE¼ SE¼ of Section 31, T. 12 N., R. 3 W., M.P.M., Lewis and Clark County, Montana, more particularly described as follows:

All that land in said SE¼ SE¼ lying east of a line parallel to and 40 feet westerly, when measured at right angles, from the following described center line: Beginning at a point on the south line of said Section 31, which said point bears easterly along said south line a distance of 2627.7 feet, more or less, from the south quarter corner of said Section 31; thence from the said point of beginning, N. 0° 35' E., 523.1 feet; thence along a curve to the right of 2865.0 feet radius, 551.1 feet to a point, which said point is north 1045.6 feet and east 2691.3 feet, more or less, from the south quarter corner of said Section 31, and containing in all 1.23 acres, more or less.

Also a tract of land in the N½ NE¼ of Section 31, T. 12 N., R. 3 W., M.P.M., Lewis and Clark County, Montana, more particularly described as follows:

A strip of land 90 feet wide, being 50 feet wide on the southerly side and 40 feet wide on the northerly side of the following described center line: Beginning at a point on the east line of said Section 31, which said point bears southerly along said east line a distance of 1019.7 feet, more or less, from the northeast corner of said Section 31; thence from the said point of beginning, N. 60° 35' W., 435.8 feet; thence along a curve to the right of 5730.0 feet radius, 345.9 feet to a point; also a strip of land 80 feet wide, being 40 feet wide on each side of the following described center line; thence continuing from the last described point, along a curve to the right of 5730.0 feet radius, 328.1 feet; thence N. 53° 50' W., 773.3 feet to a point on the north line of said Section 31, which said point bears westerly along said north line a distance of 1567.2 feet, more or less, from the northeast corner of said Section 31, and containing in all 3.64 acres, more or less.

Also a tract of land in the W½ SW¼ and the N½ of Section 19, T. 12 N., R. 3 W., M.P.M., Lewis and Clark County, Montana, more particularly described as follows:

A strip of land 110 feet wide, being 70 feet wide on the westerly side and 40 feet wide on the easterly side of the following described center line: Beginning at a point on the south line of said Section 19, which said point bears easterly along said south line a distance of 1130.6 feet, more or less, from the southwest corner of said Section 19; thence from the said point of beginning, along a curve to the right of 3820.0 feet radius, 718.8 feet; thence N. 23° 22' W., 1658.3 feet; thence along a curve to the right of 716.3 feet radius, 981.0 feet; thence N. 55° 07' E., 1480.6 feet to a point; also a strip of land 90 feet wide, being 40 feet wide on the northerly side and 50 feet wide on the southerly side of the following described center line; thence continuing from the last described point, N. 55° 07' E., 983.5 feet; thence along a curve to the left of 1432.5 feet radius, 370.8 feet; thence N. 40° 17' E., 345.7 feet to a point; also a strip of land 140 feet wide, being 60 feet wide on the northwesterly side and 80 feet wide on the southeasterly side of the following described center line; thence continuing from the last described point, N. 40° 17' E., 441.0 feet to a point on the north line of said Section 19, which said point bears easterly along said north line a distance of 589.4 feet, more or less, from the north-quarter corner of said Section 19, and containing in all 17.17 acres, more or less, excepting, however, 3.77 acres herein described which constitute a part of an existing public highway. (Gross acreage 17.17; present highway acreage 3.77; net acreage 13.40).

(18.27 acres of land at

It is further agreed between the parties hereto, for the consideration hereinbefore mentioned, that the undersigned shall build or reset any fence along the right of way herein described as has been heretofore agreed upon.

TO HAVE AND TO HOLD all of the above described and conveyed property unto the State of Montana, and its successor or successors in interest as long as the same is used as a public highway.

IN WITNESS WHEREOF the undersigned has caused these presents to be executed by its officers thereunto duly authorized and its corporate seal to be hereto affixed, this 31st day of August A. D. 1933

ATTEST: Geo. E. Stadler
Geo. E. Stadler, Secretary

CHEVALLIER LIVESTOCK COMPANY
By P. N. Chevalier
P. H. Chevallier, President

Seal

STATE OF MONTANA
County of Lewis and Clark } ss.

On this 31st day of Aug. A. D. 1933 before me Hoil Johnson a Notary Public in and for the State of Montana personally appeared P. H. Chevallier, known to me to be the President of CHEVALLIER LIVESTOCK COMPANY, the corporation that executed ~~known to me to be the person whose name~~ subscribed to the within instrument and acknowledged to me that such corporation executed the same.

IN WITNESS WHEREOF, I have hereunto set my hand and affixed my Notarial Seal the day and year in this certificate first above written.

Hord Johnson
Notary Public for the State of Montana
Residing at Helena, Montana
My Commission expires March 23, 1934

Notarial Seal.

70-73-75

COPY

LEWIS AND CLARK COUNTY

259-B
(F. A. P. NO.)

HIGHWAY RIGHT OF WAY EASEMENT

CHEVALLIER LIVESTOCK COMPANY

TO

STATE OF MONTANA

Recording No. 51471

Filed for recording with the County Clerk and Recorder of L&C County on 9-23 1933 and recorded in book 110 Deeds on page 170

Original deed filed with the Secretary of State on 10-6 1933

TABLE A
COUNTY ROAD DESIGN CRITERIA

	Terrain	Major Collector	Minor Collector	Local Road
Design Speed (MPH)	Level	55	50	30
	Rolling	45	40	25
	Mountainous	45	30	20
Curvature - Minimum at Centerline (feet)	Level	575	575	250
	Rolling	440	440	175
	Mountainous	330	300	110
Minimum Stopping Sight Distance (feet)	Level	per AASHTO	425	200
	Rolling	"	305	150
	Mountainous	"	200	110
Maximum Grade	Level	per AASHTO	6%	6%
	Rolling	"	8%	9%
	Mountainous	"	10%	11%
Length of Maximum Grade (feet)		per AASHTO	per AASHTO	per AASHTO
Minimum Grade		0.5%	0.5%	0.5%
Superelevation		per AASHTO	per AASHTO	N/A
Minimum Intersection Spacing (feet)		500	275	150
Driveway Spacing (feet)		45	45	40
Maximum Length of Cul-de-Sac (feet)		Not Allowed	Not Allowed	See Chapter XI.H.11
Minimum Radius of Cul-de-Sac (feet)		Not Allowed	Not Allowed	48
Sight Distance Triangle (feet)	Level	300	255	120
	Rolling	210	170	95
	Mountainous	210	120	80
Minimum Right of Way Width		100	80	60
Minimum Right of Way Radius for Cul-de-sac (feet)		NA	NA	48
Vertical Clearance (feet)		16.5	16.5	14.5
Intersection Curb Return Radii (feet)		25	25	15
Minimum Sidewalk Width (feet)		5	5	5
Sidewalk Offset From Back of Curb (feet)		5-10	5-10	5
Bike Lane Width (feet)		4-8	4-8	N/A
Minimum Culvert Diameter (inches)		18	15	15
Minimum Culvert Cover		Meet or exceed suppliers recommendations	Meet or exceed suppliers recommendations	Meet or exceed suppliers recommendations
Minimum Culvert Grade		0.5%	0.5%	0.5%
Culvert Material		Support HS-20 Loading	Support HS-20 Loading	Support HS-20 Loading

Metric							US Customary						
Design speed (km/h)	Stopping sight distance (m)						Design speed (mph)	Stopping sight distance (ft)					
	Downgrades			Upgrades				Downgrades			Upgrades		
	3 %	6 %	9 %	3 %	6 %	9 %		3 %	6 %	9 %	3 %	6 %	9 %
20	20	20	20	19	18	18	15	80	82	85	75	74	73
30	32	35	35	31	30	29	20	116	120	126	109	107	104
40	50	50	53	45	44	43	25	158	165	173	147	143	140
50	66	70	74	61	59	58	30	205	215	227	200	184	179
60	87	92	97	80	77	75	35	257	271	287	237	229	222
70	110	116	124	100	97	93	40	315	333	354	289	278	269
80	136	144	154	123	118	114	45	378	400	427	344	331	320
90	164	174	187	148	141	136	50	446	474	507	405	388	375
100	194	207	223	174	167	160	55	520	553	593	469	450	433
110	227	243	262	203	194	186	60	598	638	686	538	515	495
120	263	281	304	234	223	214	65	682	728	785	612	584	561
130	302	323	350	267	254	243	70	771	825	891	690	658	631
							75	866	927	1003	772	736	704
							80	965	1035	1121	859	817	782

Exhibit 3-2. Stopping Sight Distance on Grades

Decision Sight Distance

Stopping sight distances are usually sufficient to allow reasonably competent and alert drivers to come to a hurried stop under ordinary circumstances. However, these distances are often inadequate when drivers must make complex or instantaneous decisions, when information is difficult to perceive, or when unexpected or unusual maneuvers are required. Limiting sight distances to those needed for stopping may preclude drivers from performing evasive maneuvers, which often involve less risk and are otherwise preferable to stopping. Even with an appropriate complement of standard traffic control devices in accordance with the MUTCD (6), stopping sight distances may not provide sufficient visibility distances for drivers to corroborate advance warning and to perform the appropriate maneuvers. It is evident that there are many locations where it would be prudent to provide longer sight distances. In these circumstances, decision sight distance provides the greater visibility distance that drivers need.

Decision sight distance is the distance needed for a driver to detect an unexpected or otherwise difficult-to-perceive information source or condition in a roadway environment that may be visually cluttered, recognize the condition or its potential threat, select an appropriate speed and path, and initiate and complete the maneuver safely and efficiently (7). Because decision sight distance offers drivers additional margin for error and affords them sufficient length to maneuver their vehicles at the same or reduced speed, rather than to just stop, its values are substantially greater than stopping sight distance.

Drivers need decision sight distances whenever there is a likelihood for error in either information reception, decision making, or control actions (8). Examples of critical locations where these kinds of errors are likely to occur, and where it is desirable to provide decision sight distance include interchange and intersection locations where unusual or unexpected maneuvers are required, changes in cross section such as toll plazas and lane drops, and areas of concentrated

METRIC

Design Speed (km/h)	Maximum e (%)	Maximum f	Total $(e/100 + f)$	Calculated Radius (m)	Rounded Radius (m)
15	4.0	0.40	0.44	4.0	4
20	4.0	0.35	0.39	8.1	8
30	4.0	0.28	0.32	22.1	22
40	4.0	0.23	0.27	46.7	47
50	4.0	0.19	0.23	85.6	86
60	4.0	0.17	0.21	135.0	135
70	4.0	0.15	0.19	203.1	203
80	4.0	0.14	0.18	280.0	280
90	4.0	0.13	0.17	375.2	375
100	4.0	0.12	0.16	492.1	492
15	6.0	0.40	0.46	3.9	4
20	6.0	0.35	0.41	7.7	8
30	6.0	0.28	0.34	20.8	21
40	6.0	0.23	0.29	43.4	43
50	6.0	0.19	0.25	78.7	79
60	6.0	0.17	0.23	123.2	123
70	6.0	0.15	0.21	183.7	184
80	6.0	0.14	0.20	252.0	252
90	6.0	0.13	0.19	335.7	336
100	6.0	0.12	0.18	437.4	437
110	6.0	0.11	0.17	560.4	560
120	6.0	0.09	0.15	755.9	756
130	6.0	0.08	0.14	950.5	951
15	8.0	0.40	0.48	3.7	4
20	8.0	0.35	0.43	7.3	7
30	8.0	0.28	0.36	19.7	20
40	8.0	0.23	0.31	40.6	41
50	8.0	0.19	0.27	72.9	73
60	8.0	0.17	0.25	113.4	113
70	8.0	0.15	0.23	167.8	168
80	8.0	0.14	0.22	229.1	229
90	8.0	0.13	0.21	303.7	304
100	8.0	0.12	0.20	393.7	394
110	8.0	0.11	0.19	501.5	501
120	8.0	0.09	0.17	667.0	667
130	8.0	0.08	0.16	831.7	832
15	10.0	0.40	0.50	3.5	4
20	10.0	0.35	0.45	7.0	7
30	10.0	0.28	0.38	18.6	19
40	10.0	0.23	0.33	38.2	38
50	10.0	0.19	0.29	67.9	68
60	10.0	0.17	0.27	105.0	105
70	10.0	0.15	0.25	154.3	154
80	10.0	0.14	0.24	210.0	210
90	10.0	0.13	0.23	277.3	277
100	10.0	0.12	0.22	357.9	358
110	10.0	0.11	0.21	453.7	454
120	10.0	0.09	0.19	596.8	597
130	10.0	0.08	0.18	739.3	739
15	12.0	0.40	0.52	3.4	3
20	12.0	0.35	0.47	6.7	7
30	12.0	0.28	0.40	17.7	18
40	12.0	0.23	0.35	36.0	36
50	12.0	0.19	0.31	63.5	64
60	12.0	0.17	0.29	97.7	98
70	12.0	0.15	0.27	142.9	143
80	12.0	0.14	0.26	193.8	194
90	12.0	0.13	0.25	255.1	255
100	12.0	0.12	0.24	328.1	328
110	12.0	0.11	0.23	414.2	414
120	12.0	0.09	0.21	539.9	540
130	12.0	0.08	0.20	665.4	665

US Customary

Design Speed (mph)	Maximum e (%)	Maximum f	Total $(e/100 + f)$	Calculated Radius (ft)	Rounded Radius (ft)
10	4.0	0.38	0.42	15.9	16
15	4.0	0.32	0.36	41.7	42
20	4.0	0.27	0.31	86.0	86
25	4.0	0.23	0.27	154.3	154
30	4.0	0.20	0.24	250.0	250
35	4.0	0.18	0.22	371.2	371
40	4.0	0.16	0.20	533.3	533
45	4.0	0.15	0.19	710.5	711
50	4.0	0.14	0.18	925.9	926
55	4.0	0.13	0.17	1186.3	1190
60	4.0	0.12	0.16	1500.0	1500
10	6.0	0.38	0.44	15.2	15
15	6.0	0.32	0.38	39.5	39
20	6.0	0.27	0.33	80.8	81
25	6.0	0.23	0.29	143.7	144
30	6.0	0.20	0.26	230.8	231
35	6.0	0.18	0.24	340.3	340
40	6.0	0.16	0.22	484.8	485
45	6.0	0.15	0.21	642.9	643
50	6.0	0.14	0.20	833.3	833
55	6.0	0.13	0.19	1061.4	1060
60	6.0	0.12	0.18	1333.3	1330
65	6.0	0.11	0.17	1656.9	1660
70	6.0	0.10	0.16	2041.7	2040
75	6.0	0.09	0.15	2500.0	2500
80	6.0	0.08	0.14	3047.6	3050
10	8.0	0.38	0.46	14.5	14
15	8.0	0.32	0.40	37.5	38
20	8.0	0.27	0.35	76.2	76
25	8.0	0.23	0.31	134.4	134
30	8.0	0.20	0.28	214.3	214
35	8.0	0.18	0.26	314.1	314
40	8.0	0.16	0.24	444.4	444
45	8.0	0.15	0.23	587.0	587
50	8.0	0.14	0.22	757.6	758
55	8.0	0.13	0.21	960.3	960
60	8.0	0.12	0.20	1200.0	1200
65	8.0	0.11	0.19	1482.5	1480
70	8.0	0.10	0.18	1814.8	1810
75	8.0	0.09	0.17	2205.9	2210
80	8.0	0.08	0.16	2666.7	2670
10	10.0	0.38	0.48	13.9	14
15	10.0	0.32	0.42	35.7	36
20	10.0	0.27	0.37	72.1	72
25	10.0	0.23	0.33	126.3	126
30	10.0	0.20	0.30	200.0	200
35	10.0	0.18	0.28	291.7	292
40	10.0	0.16	0.26	410.3	410
45	10.0	0.15	0.25	540.0	540
50	10.0	0.14	0.24	694.4	694
55	10.0	0.13	0.23	876.8	877
60	10.0	0.12	0.22	1090.9	1090
65	10.0	0.11	0.21	1341.3	1340
70	10.0	0.10	0.20	1633.3	1630
75	10.0	0.09	0.19	1973.7	1970
80	10.0	0.08	0.18	2370.4	2370
10	12.0	0.38	0.50	13.3	13
15	12.0	0.32	0.44	34.1	34
20	12.0	0.27	0.39	68.4	68
25	12.0	0.23	0.35	119.0	119
30	12.0	0.20	0.32	187.5	188
35	12.0	0.18	0.30	272.2	272
40	12.0	0.16	0.28	381.0	381
45	12.0	0.15	0.27	500.0	500
50	12.0	0.14	0.26	641.0	641
55	12.0	0.13	0.25	806.7	807
60	12.0	0.12	0.24	1000.0	1000
65	12.0	0.11	0.23	1224.6	1220
70	12.0	0.10	0.22	1484.8	1480
75	12.0	0.09	0.21	1785.7	1790
80	12.0	0.08	0.20	2133.3	2130

Note: In recognition of safety considerations, use of e_{max} = 4.0% should be limited to urban conditions.

Exhibit 3-15. Minimum Radius Using Limiting Values of e and f

Type of terrain	Metric: Design speed (km/h) for specified design volume (veh/day)			US Customary: Design speed (mph) for specified design volume (veh/day)		
	0 to 400	400 to 2000	over 2000	0 to 400	400 to 2000	over 2000
Level	60	80	100	40	50	60
Rolling	50	60	80	30	40	50
Mountainous	30	50	60	20	30	40

Note: Where practical, design speeds higher than those shown should be considered.

Exhibit 6-1. Minimum Design Speeds for Rural Collectors

Metric				US Customary			
Design speed	Design stopping sight distance	Rate of vertical curvature, K^a (m/%)		Design speed	Design stopping sight distance	Rate of vertical curvature, K^a (ft/%)	
(km/h)	(m)	Crest	Sag	(mph)	(ft)	Crest	Sag
20	20	1	3	15	80	3	10
30	35	2	6	20	115	7	17
40	50	4	9	25	155	12	26
50	65	7	13	30	200	19	37
60	85	11	18	35	250	29	49
70	105	17	23	40	305	44	64
80	130	26	30	45	360	61	79
90	160	39	38	50	425	84	96
100	185	52	45	55	495	114	115
				60	570	151	136

[a] Rate of vertical curvature, K, is the length of curve per percent algebraic difference in the intersecting grades (i.e., $K = L/A$). (See Chapter 3 for details.)

Exhibit 6-2. Design Controls for Stopping Sight Distance and for Crest and Sag Vertical Curves

Metric			US Customary		
Design speed (km/h)	Design passing sight distance (m)	Rate of vertical curvature, K^a (m/%)	Design speed (mph)	Design passing sight distance (ft)	Rate of vertical curvature, K^a (ft/%)
30	200	46	20	710	180
40	270	84	25	900	289
50	345	138	30	1090	424
60	410	195	35	1280	585
70	485	272	40	1470	772
80	540	338	45	1625	943
90	615	438	50	1835	1203
100	670	520	55	1985	1407
			60	2135	1628

[a] Rate of vertical curvature, K, is the length of curve per percent algebraic difference in the intersecting grades (i.e., $K = L/A$). (See Chapter 3 for details.)

Exhibit 6-3. Design Controls for Crest Vertical Curves Based on Passing Sight Distance

	Metric								US Customary								
	Maximum grade (%) for specified design speed (km/h)								Maximum grade (%) for specified design speed (mph)								
Type of terrain	30	40	50	60	70	80	90	100	20	25	30	35	40	45	50	55	60
Level	7	7	7	7	7	6	6	5	7	7	7	7	7	7	6	6	5
Rolling	10	10	9	8	8	7	7	6	10	10	9	9	8	8	7	7	6
Mountainous	12	11	10	10	10	9	9	8	12	11	10	10	10	10	9	9	8

Note: Short lengths of grade in rural areas, such as grades less than 150 m [500 ft] in length, one-way downgrades, and grades on low-volume rural collectors may be up to 2 percent steeper than the grades shown above.

Exhibit 6-4. Maximum Grades for Rural Collectors

Metric					US Customary				
Design speed (km/h)	Minimum width of traveled way (m) for specified design volume (veh/day)[a]				Design speed (mph)	Minimum width of traveled way (ft) for specified design volume (veh/day)[a]			
	under 400	400 to 1500	1500 to 2000	over 2000		under 400	400 to 1500	1500 to 2000	over 2000
30	6.0[b]	6.0	6.6	7.2	20	20[b]	20	22	24
40	6.0[b]	6.0	6.6	7.2	25	20[b]	20	22	24
50	6.0[b]	6.0	6.6	7.2	30	20[b]	20	22	24
60	6.0[b]	6.6	6.6	7.2	35	20[b]	22	22	24
70	6.0	6.6	6.6	7.2	40	20[b]	22	22	24
80	6.0	6.6	6.6	7.2	45	20	22	22	24
90	6.6	6.6	7.2	7.2	50	20	22	22	24
100	6.6	6.6	7.2	7.2	55	22	22	24	24
					60	22	22	24	24
	Width of shoulder on each side of road (m)					Width of shoulder on each side of road (ft)			
All speeds	0.6	1.5[c]	1.8	2.4	All speeds	2.0	5.0[c]	6.0	8.0

[a] On roadways to be reconstructed, a 6.6-m [22-ft] traveled way may be retained where the alignment and safety records are satisfactory.

[b] A 5.4-m [18-ft] minimum width may be used for roadways with design volumes under 250 veh/day.

[c] Shoulder width may be reduced for design speeds greater than 50 km/h [30 mph] as long as a minimum roadway width of 9 m [30 ft] is maintained.

See text for roadside barrier and offtracking considerations.

Exhibit 6-5. Minimum Width of Traveled Way and Shoulders

Drivers who inadvertently leave the traveled way can often recover control of their vehicles if foreslopes are 1V:4H or flatter and shoulders and ditches are well rounded or otherwise made traversable. Such recoverable slopes should be provided where terrain and right-of-way conditions allow.

Where provision of recoverable slopes is not practical, the combinations of rate and height of slope provided should be such that occupants of an out-of-control vehicle have a good chance of survival. Where high fills, right-of-way restrictions, watercourses, or other problems render such designs impractical, roadside barriers should be considered, in which case the maximum rate of fill slope may be used. Reference should be made to the current edition of the AASHTO *Roadside Design Guide* (3). For further information, see the section on "Traffic Barriers" in Chapter 4.

Cut sections should be designed with adequate ditches. Preferably, the foreslope should not be steeper than 1V:3H and, where practical, should be 1V:4H or flatter. The ditch bottom and slopes should be well rounded, and the backslope should not exceed the maximum needed for stability.