

ROCKY MOUNTAIN NATIONAL PARK INTERSECTION IMPROVEMENT

Deer Ridge Junction, Estes Park, Colorado



KARVR CONSULTING

Karla Berrum
Robert Farrell
Vince Nocito
Andrew Reed
Robert Rivera

A report submitted to the University of Colorado at Denver, Civil Engineering
Department in partial fulfillment of the Senior Design course

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Dedication and Acknowledgement

KARVR would like to thank Brooke Rosener and the Central Federal Lands Highway Division for their support and guidance throughout the Rocky Mountain National Park Intersection Improvement project.

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May 12, 2020

Ms. Brooke Rosener
Central Federal Lands Highway Division (CFLHD)
12300 W. Dakota Ave.
Lakewood, Colorado 80228

Subject: Final Report of Findings and Recommendations
Rocky Mountain National Park (RMNP) Intersection Improvement
Deer Ridge Junction, Estes Park, Colorado

Dear Ms. Rosener:

KARVR would like to thank you and CFLHD for providing an engineering design opportunity for our Senior Design project at the University of Colorado Denver. The focus of our involvement was to provide alternatives with respect to the intersection alignment, traffic calming, and parking areas of Deer Ridge Junction.

As we understood the Senior Design project directives, our efforts were in support of a larger project that CFLHD envisions completing to provide transportation improvements within Rocky Mountain National Park. The overall CFLHD project spans approximately 5 miles, beginning in the vicinity of the Beaver Meadows Entrance Station and ending at Deer Ridge Junction.

As part of our investigation into feasible alternatives for Deer Ridge Junction, the necessary improvements related to transportation, safety, hydraulic design, pavement and materials were considered with the intention to minimize pedestrian-traffic conflicts and expand parking capacity. As you know, a site visit was performed on March 9, 2020 to collect data at Deer Ridge Junction. The following report contains our findings, conclusions, and recommendations for Deer Ridge Junction.

1.0 Introduction

Rocky Mountain National Park is located in Colorado and is generally situated between Estes Park to the east and Grand Lake to the west. There are three relevant park entrance stations to the park for vehicles: The Beaver Meadows Entrance Station, the Fall River Entrance Station, and the Grand Lake Entrance Station.

Each entrance station is accessed from a two-lane highway. The three entrance roadways join forming a T-intersection known as Deer Ridge Junction. Currently, the Central Federal Land Highway Division of the U.S. Department of Transportation's Federal Highway Administration is investigating pedestrian safety, visitor parking and intersection operational improvement opportunities. The addition of a designated off-street parking surface will increase the need for management of the runoff from precipitation events.

2.0 Project Background

The Rocky Mountain National Park Intersection Improvement project is more specifically an intersection commonly known as Deer Ridge Junction. The intersection is consisting of three main roads meeting each other at the intersection. Trail Ridge Road is coming into the intersection for the South-West side, Beaver Meadows Road coming in from the South-East side, and Fall River Road coming from the North side connecting both streets into one T-intersection. Throughout the years the intersection has been experiencing more traffic flow in all directions and pedestrian crossings as well from the South side to the North side. The area has multiple limits of disturbance that cannot be crossed to work on limiting the total space.

The purpose of our involvement is to find current and future traffic needs of the intersection and develop detailed recommendations for the design of the Rocky Mountain National Park

Intersection. The improvements include a new parking lot that can hold thirty parking spaces, making a connection with the trail and the parking lot, hydraulic design for storm water, and roadway design.

3.0 Purpose

The Rocky Mountain National Park Intersection consists of three approaches to the intersection. Beaver Meadows Road is a two-lane road and carries the most traffic traveling from the highest utilized entrance of the Rocky National Park, the Beaver Meadows Entrance Station. Fall River Road is a connection from Beaver Meadows Road to hotels and campgrounds for the tourists to access. Trail Ridge Road does not see as much traffic flow from its entrance station at Grand Lake, but it is an access for tourists to travel on it and see other parts of Rocky Mountain National Park.

Rocky Mountain National Park has experienced and continues to see considerable growth in park visits. In 2018 the Rocky Mountain National Park received 4.6 million visitors throughout the year. Tourists like to visit the area for its species, wildlife, trails and aquatic ecosystems. During the summer is when the park receives the highest number of recreational visitors.

Currently, visitors are parking on the shoulders of the roadways approaching Deer Ridge Junction, which is creating an unsafe environment for pedestrians crossing the road at random locations. Although the parking demand is high during the peak summer months of June to September, parking is limited in the area and this leads to motorists increasingly exchanging safety for access to the nearby Deer Mountain trailhead. As mentioned, to the east of Deer Ridge Junction a trail crosses Beaver Meadows Road from north to south. A marked crosswalk is not present at the intersection or at the trail crossing.

4.0 Jurisdictions having Authority

Rocky Mountain National Park is under the jurisdiction of the U.S. National Park Service. There are three relevant vehicle entrances into Rocky Mountain National Park that provide access to the Deer Ridge Junction. These roadways—US 36 and US 34—are under the jurisdiction of the U.S. Department of Transportation (USDOT).

5.0 Applicable Codes

Although the project does not consist of any proposed buildings, future works may include the addition of a restroom structure for park visitors. Accordingly, any building within Rocky Mountain National Park would be subject to the 2018 International Building Code (IBC) with Appendices. In subject matters where the IBC is silent, the National Fire Protection Association (NFPA) 101 Life Safety Code is to be referenced. For existing buildings, the 2018 International Existing Building Code (IEBC) with Appendices would be applicable.

Since historical structures may be found in national parks, it is important to note the National Park Service’s policy regarding modifications to historic structures:

“[E]very attempt will be made to comply with national building and fire codes. When these cannot be met without significantly impairing a structure’s integrity and character, management and use of the structure will be modified to minimize potential hazards rather than modifying the structure itself.”

6.0 Findings

6.1 Traffic Analysis

The traffic analysis considered for this project references the CO FTNP ROMO 11(4) Beaver Meadows Road Crash Data Analysis, provided by our client the Federal Highway Administration. Furthermore, the National Park Service provides data on their website. The table below from the NPS shows a monthly breakdown of traffic counts for Beaver Meadows Road for 2019. This vehicle operators must also consider the cycling community who utilize the narrow shoulders on either side. Cyclists are always required to ride in a single file, and they typically ride with the flow of traffic. Pedestrian access is also a major consideration for this junction as there are two hiking trails, Ute Trail on the southern portion of the junction and Deer Mountain Trail on the north side of the junction.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
14,831	17,255	26,870	30,421	51,505	104,230	134,367	116,190	120,247	62,886	21,943	21,050

6.1.1 Traffic Volumes

The annual total for 2019 was 721,795 vehicles, which compared with 2014 is 182,559 more vehicles. This 34% increase in five years shows the urgency with which action needs to be performed on Deer Ridge Junction. Our study also considered the monthly high of 134,367 vehicles in July 2019. The peak of traffic typically takes place from June – September. Of this traffic volume, many types of vehicles are common. Passenger vehicles, recreational vehicles like trucks and tour buses, and park shuttle buses are all among the most common vehicles. Additionally, our design considerations ensure that a WB-50 vehicle can use all aspects of the road.

6.1.2 Crash History

The crash history for Trail Ridge Road

6.2 Roadway Design

6.2.1 Roadway Geometry

Deer Ridge Junction consists of two intersecting roadways. The roadway segments approaching the intersection are approximately 23 feet wide with 11-foot lanes in each direction. At the intersection, the roadways are divided by medians with existing vegetation on each approach.

The Trail Ridge Road leg has four 11-foot lanes, two lanes in each direction, with a 10-foot median. The two approach lanes include mandatory left-turn and through-traffic movements.

The Beaver Meadows Road leg has four 11-foot lanes, two lanes in each direction, with a 10-foot median. The two approach lanes include mandatory right-turn and through-traffic movements.

The Fall River Road leg has two 20-foot lanes, one lane in each direction, with an 8-foot median.

The approach lane widens at the intersection to accommodate right-turn and left-turn movement; this allows right turning movements to continue while a vehicle is waiting to make a left turn. A left-turn queue length in excess of 130 feet is likely to stall right-turn movements until the queue is reduced.

6.2.2 Traffic Signage

The existing traffic signage in the vicinity of Deer Ridge Junction contains standard regulatory and guide signs. Exhibit 3 contains pictures captured during the site visit that include examples of traffic signs located at the intersection. As typical within national parks, signs are supported using wooden posts and object marker applications use retroreflective tape applied to wooden bollards.

The regulatory signage at Deer Ridge Junction includes Keep Right signs at the medians, Stop signs for the Fall River Road approach to the intersection, and mandatory movement lane control signs for through and turning traffic. Speed limit signs posted along Trail Ridge Road and Fall River Road indicate the speed limit is 35 miles per hour on all approaches to the intersection. Deer Ridge Junction has Recreation and Cultural Interest type guide signs on all approaches to the intersection. The existing guide signs inform road users traffic of nearby destination such as Estes Park, visitor centers, areas of interest, and US 34 and US 36 route directions.

6.2.3 Pavement Markings

The pavement markings at Deer Ridge junction are typical applications of markings and are used to supplement the existing traffic signs by delineating traffic lanes, conveying lane use assignments and roadway alignment. Exhibit 3 contains pictures from the site visit that show examples of the pavement markings at the intersection.

6.2.4 Intersection Alternatives

No-build

6.2.4.1 Alternative A – Roundabout

6.2.4.2 Alternative B – All-way Stop Control

6.2.4.3 Alternative C – Continuous lane

6.3 Parking Design

Parking Lot

Parking Lot (Modified)

Street parking (same)

6.4 Hydraulic Design

6.4.1 Drainage Basins

Drainage Basins are designated by a capital letter followed by a number. The letter “O” signifies that the basin was already existing and was not affected by the disturbance of construction. On the contrary, the letter “P” signifies a new basin which is proposed as an effect of new construction or disruption. There are a

6.4.2 Estimated runoff

6.4.2.1 Rational Method

6.4.2.2 Storm Culvert Design

6.4 Hydraulic Design

Understanding the intersections characteristics is essential to calculate the total runoff. The calculated runoff is an important factor in our design because we want to make the intersection safer in all design aspects. Our hydraulic design is proposed to withstand the runoff produced by the intersection’s basins.

6.4.1 Drainage Basins

At Deer Ridge Junction the runoff that is produced is divided into ten specific basins. The drainage basins are areas where different forms of precipitation become surface water and converge to a single point. Based on the elevations and lengths of the basins' we are able to calculate the slope of each basin and understand the direction flow will be traveling. Our design classified basins that are existing and will remain the same and proposed basins that will be added into the intersections design. A total of six basins are currently existing and four new basins will be proposed. Figure () specifically points out each basin and its direction flow through the Deer Ridge Junction. Area of each basin and imperviousness percentage were the factors that helped calculate the runoff of each basin. The percentage of impervious was determined based on the type land surface. Basins P1, P2, and P3 had a total runoff of 2.32 cfs flowing through the intersection.

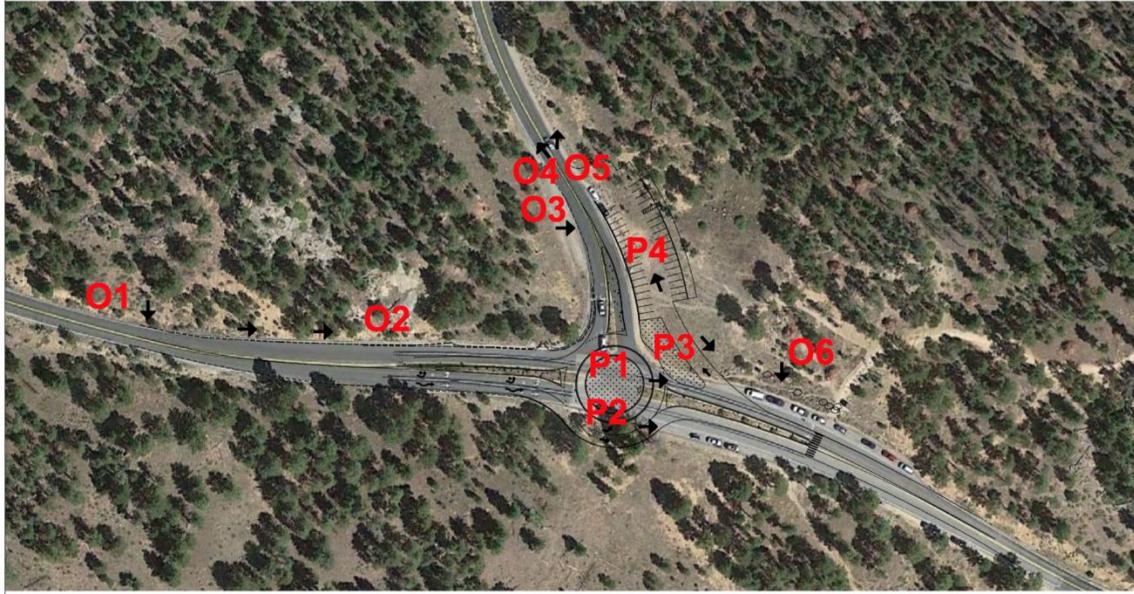


Figure :

O-Existing Basin

P-Proposed Basin

Arrows pointing the direction flow will travel based on contours

6.4.2.1 Rational Method

To calculate our total runoff from both drainage basins we utilized the Rational Method. The Rational Method calculates runoff for areas that contain 90 acres or less. Because the total number of acres in our design is 16.79 acres which is less than 90 acres the Rational Method was applied to calculate the total runoff. The Rational Method Formula to calculate peak flow over a basin is as follows:

$$Q = CIA$$

Q = total flow of runoff (cfs, m³/s)

C = runoff Coefficient (unitless)

I = rainfall intensity (in/hr)

Area = total basin area (acres)

The value for C (runoff coefficient) is determined by the ratio of runoff volume to the rainfall volume. To calculate our runoff coefficients for our specific basins we utilized Table 6-4, and choose what soil group our location contained and the percent impervious. From our findings we found soil group D is located in the Deer Ridge Junction intersection.

Table 6-4. Runoff coefficient equations based on NRCS soil group and storm return period

NRCS Soil Group	Storm Return Period						
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
A	$C_A = 0.84i^{1.302}$	$C_A = 0.86i^{1.276}$	$C_A = 0.87i^{1.232}$	$C_A = 0.88i^{1.124}$	$C_A = 0.85i+0.025$	$C_A = 0.78i+0.110$	$C_A = 0.65i+0.254$
B	$C_B = 0.84i^{1.169}$	$C_B = 0.86i^{1.088}$	$C_B = 0.81i+0.057$	$C_B = 0.63i+0.249$	$C_B = 0.56i+0.328$	$C_B = 0.47i+0.426$	$C_B = 0.37i+0.536$
C/D	$C_{C/D} = 0.83i^{1.122}$	$C_{C/D} = 0.82i+0.035$	$C_{C/D} = 0.74i+0.132$	$C_{C/D} = 0.56i+0.319$	$C_{C/D} = 0.49i+0.393$	$C_{C/D} = 0.41i+0.484$	$C_{C/D} = 0.32i+0.588$

Figure

The value *i* is the percent imperviousness as a decimal value multiplied by the specific year used added to a specific value.

The value for *I* (Rainfall intensity (in/hr)) is determined by the average rainfall rate in in/hr for the period of maximum rainfall equal to the time of concentration. Using the formula below Intensity for flow can be calculated.

$$I = \frac{28.5P_1^{Tr}}{(10 + T_d)^{0.789}}$$

where:

I = rainfall intensity in (in/hr)

P₁ = one-hour rainfall depth (in)

T_d = rainfall duration in (minutes)

To determine the value for P₁ NOAA ATLAS 14 was utilized. The following PDS-based precipitation frequency estimates with 90% confidence Interval (in inches/hour)¹ table P₁ for a 10-year event for one hour was determined to be 0.983.

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour) ¹										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	2.44 (1.87-3.17)	2.81 (2.16-3.66)	3.58 (2.74-4.67)	4.36 (3.31-5.71)	5.64 (4.27-8.00)	6.79 (4.99-9.73)	8.11 (5.75-11.9)	9.59 (6.53-14.6)	11.8 (7.72-18.4)	13.6 (8.62-21.4)
10-min	1.79 (1.37-2.32)	2.06 (1.58-2.68)	2.62 (2.00-3.42)	3.19 (2.43-4.18)	4.13 (3.13-5.86)	4.97 (3.65-7.12)	5.93 (4.21-8.74)	7.02 (4.78-10.7)	8.62 (5.65-13.5)	9.97 (6.31-15.6)
15-min	1.45 (1.12-1.89)	1.67 (1.28-2.18)	2.13 (1.63-2.78)	2.59 (1.97-3.40)	3.36 (2.54-4.76)	4.05 (2.97-5.79)	4.82 (3.42-7.10)	5.71 (3.89-8.66)	7.01 (4.59-11.0)	8.10 (5.13-12.7)
30-min	0.916 (0.706-1.19)	1.06 (0.812-1.37)	1.34 (1.03-1.75)	1.64 (1.25-2.15)	2.12 (1.61-3.01)	2.56 (1.88-3.67)	3.06 (2.17-4.51)	3.62 (2.47-5.50)	4.46 (2.92-6.97)	5.15 (3.26-8.09)
60-min	0.572 (0.440-0.745)	0.646 (0.496-0.841)	0.808 (0.619-1.06)	0.983 (0.749-1.29)	1.28 (0.978-1.84)	1.56 (1.15-2.25)	1.88 (1.34-2.78)	2.25 (1.54-3.43)	2.80 (1.84-4.39)	3.26 (2.06-5.12)

Figure

T_d (Rainfall duration time) also equal to time of concentration (t_c) is calculated using the overland flow time and the channelized flow time equation as followed below:

$$\text{overland flow time } t_i = \frac{0.395(1.1-C)\sqrt{L_i}}{S_i^{0.33}}$$

where:

t_i = overland flow time in minutes

L_i = overland length (ft)

S_i = overland slope (ft/ft)

C = runoff coefficient

$$\text{channelized flow time } t_t = \frac{L_t}{60K\sqrt{S_t}} = \frac{L_t}{60V_t}$$

t_t = channelized flow time in minutes

L_t = length of channelized flow (ft)

S_t = waterway slope (ft/ft)

K = conveyance coefficient (ft/ft)

V_t = travel time velocity (ft/s) = $K\sqrt{S_t}$

Table 6-2. NRCS Conveyance factors, K

Type of Land Surface	Conveyance Factor, K
Heavy meadow	2.5
Tillage/field	5
Short pasture and lawns	7
Nearly bare ground	10
Grassed waterway	15
Paved areas and shallow paved swales	20

Figure

$$\text{computed } t_c = t_i + t_t$$

t_c = computed time of concentration (minutes)

t_i = overland flow time (minutes)

t_t = channelized flow time (minutes)

Regional time of concentration is another equation used in the design to calculate the time of peak flow. The equation is as followed:

$$t_c = (26 - 17i) + \frac{L_t}{60(14i+9)\sqrt{S_t}}$$

t_c = minimum time of concentration for first design point

L_t = length of channelized flow path (ft)

S_t = slope of channelized flow path (ft/ft)

i = imperviousness (expressed as a decimal)

The final time of concentration is chosen based on the smaller value of the computed t_c and the regional t_c .

Utilizing Mile High Flood District Peak Runoff Prediction by Rational Method excel spread sheets calculated the total peak flow for our design. The Rational Calcs excel spread sheet allows for each basin to have its own peak flow calculated with the following fields: area of sub catchment, NCRCS soil group, percent imperviousness, overland flow length and slope, and channelized flow length and slope. Entering the fields calculated the following: overland and channelized flow time, time of concentration: computed and regional, runoff coefficients, rainfall intensity, and peak flows for 2yr, 5yr, 10yr, 25yr, 100yr, and 500yr. For our specific design we have chosen a 10yr event design with a total flow of 15.75cfs

Storm Culverts

The purpose of installing storm culverts is to transport flow under roadways from one point to another. Storm culverts are an efficient way for rain flow to travel without having flow on roads. At the moment at the Deer Ridge Intersection there are two 24-inch Corrugated Metal Pipes (CMP) installed. The first CMP storm culvert is placed west of the intersection with a length of 76ft having flow travel from the north side of Trail Ridge Road to the south end. The Second CMP culvert is placed to the east side of the intersection with a length of 60ft having flow travel from the Deer Ridge intersection. During the site visit our team found that both storm culverts are not in functioning conditions because they are completely buried. The storm culvert located underneath Trail Ridge Road has a flow of 12.75cfs and the storm culvert located underneath Beaver Meadows Road has a flow 1.67cfs. Our drainage design proposes for both storm culverts to be replaced with a 18 inch CMP for the culvert located on Trail Ridge Road and an 8 inch CMP for the culvert located on Beaver Meadows Road.

6.6.2 Alternative B All Way Stop Control Design

Utilizing a three-way stop design recommends the fewest changes to the existing Deer Ridge Junction Intersection. Instead of implementing traffic lights/signalization that require power sources and maintenance, the four stop signs will control traffic from all directions. Beaver Meadows Road will be redesigned to no longer have the parking area located to the right side along the Deer Mountain Trailhead. Beaver Meadows Road will have a pedestrian crossing connecting the Deer Mountain Trailhead from the south side to the north side for the public to access. Traffic coming from Beaver Meadows Road will be able to flow into the parking lot, continue straight towards Trail Ridge Road, or turn right onto Fall River Road. A fourth flow will be added to the traffic of Beaver Meadows Road coming from the parking lot right before the intersection.

Traffic coming from Beaver Meadows Road has the options of turning left or continue straight towards Trail Ridge Road. The only flow affecting and slowing down the west side is flow coming from Fall River Road where the flow is spilt into right turns and left turns. All right turns have been designed to accommodate all types of vehicles accessing the intersection.

Currently the intersections has three medians placed in the middle of each road. The all way stop will incorporate the medians and use them as safety barriers, so drivers approaching the intersection slow down. The medians can also be utilized as refuge for pedestrians who are crossing the roads to access the parking lot or the trail.

Applying an all way stop will be an efficient way to control the traffic flow from all directions, but it is important to consider the stop signs will require replacement if struck by a vehicle. Before placing the stop signs it is important to consider the location of the stop signs and consider the possibilities of them being hit by vehicles coming from all directions.

6.6.2 Alternative C Continuous Lane:

A continuous lane design incorporates one stop sign for the overall intersection specifically placed on Fall River Road before entering the Deer Ridge intersection. This design will allow flow from Trail Ridge Road and Beaver Meadows Road to have continuous traffic flow. Both flows will be able to turn right or left or continue straight towards either Trail Ridge Road or Beaver Meadows Road. Traffic flow coming from Fall River Road will be controlled through the stop sign with left and right turns.

6.2.2 Alternate Evaluation:

To propose the best design our team evaluated all three alternatives based on the following factors cost, reduction in traffic, safety, and compliance with the client’s vision intended. In evaluating each alternative, we created a table that ranks each design based on the chosen factors. Each alternative was ranked on a number scale from 1-10 for each factor, where 10 is the highest value and considered most effective.

Table

Rating each alternative

Factors of Effectiveness Considered	Roundabout Design	All Way Stop Control Design	Continuous Lane Design
Cost	5	7	10
Efficiency	10	6	5
Safety	9	6	5
Compliant with client's vision	9	7	7
Total	33	26	27

After conducting an evaluation analysis of each alternative the roundabout design was found to have the highest effectiveness rate in each of the factors of effectiveness considered.

7.0 Recommendations

Alternative A Roundabout Design

8.0 Sequence

9.0 Costs

10.0 Future Work/Study

KARVR recommends a licensed engineer at minimum review any of the proposed works or recommendations contained in this report. Prior to construction a Professional Engineer shall verify all calculations and design specifications.

A bathroom for the public should be implemented for the parking lot. Throughout Rocky Mountain National Park there are bathrooms placed in the parking areas for the public to use.

A shuttle system should be applied with the new intersection and parking lot added to the park.

The parking lot has a specified number of parking spaces for the visitors to utilize, so a shuttle system would be the best way to transport the visitors who are not able to park at the new parking lot.

11.0 References

1. American Association of State Highway and Transportation Officials (AASHTO), *A Policy of Geometric Design of Highways and Streets*, 7th ed., 2018, AASHTO, Washington, D.C.
2. Colorado Department of Transportation (CDOT), *Roadside Design Guide, 2018*, CDOT, Denver, CO.
3. U.S. Department of Transportation (USDOT), Federal Highway Administration (FHWA). *Crash Data Analysis Rocky Mountain National Park*, April 2019, USDOT FHWA.
4. National Park Service, *Rocky Mountain National Maps*, <http://nps.gov/carto/app/#!/maps/alphacode/ROMO>, accessed Feb 15, 2019.
5. U.S. Department of Transportation, Federal Highway Administration. *Manual on Uniform Traffic Control Devices*, 2009 ed. Rev 2., May 2012, USDOT FHWA.
- 6.

<https://www.nps.gov/romo/learn/historyculture/brief.htm>

<https://www.doi.gov/blog/7-things-you-didnt-know-about-rocky-mountain-national-park>

<https://www.nps.gov/dscw/ds-architectural.htm#nps> Building codes

https://www.nps.gov/policy/mp/policies.html#_Toc157232636 Historical structures

<https://www.nps.gov/romo/planyourvisit/maps.htm> Shuttle maps

<https://www.nps.gov/romo/planyourvisit/fees.htm> Fees

https://www.fhwa.dot.gov/policyinformation/tmguides/tmg_2013/vehicle-types.cfm vehicle category classes

11.0 Disclaimer

The assumptions, findings, calculations, and conclusions expressed and described in this report and its exhibits were developed by undergraduate civil engineering students who are not licensed professional engineers. This report was prepared as an academic exercise as partial fulfillment of the Civil Engineering Senior Design course. Pursuant to C.R.S. §12-25, no part of this report should be used for planning, budgeting, construction, or fiscal related decisions without a complete review and written endorsement from an independent, qualified, and licensed engineer

who can assume responsible charge of the project and who is willing and able to become the engineer of record for all aspects of the study, calculations, findings, recommendations, and the project in part and in whole.

A complete copy of this report was provided to the client without any financial reimbursement to its authors or the University of Colorado. The client may keep one copy of the report and is hereby given permission to copy and share the report as their needs dictate; however, a copy of this disclaimer shall accompany all copies made. By the acceptance of and/or use of this report and the exhibits hereto, the client and all reviewers of the content included herein shall indemnify and hold harmless the University of Colorado; the College of Engineering, Design and Computing; University employees; and the authors of this report from any and all liability. Of whatsoever nature, that may result from such review, acceptance, or use.

12.0 Conclusion and Summary

An analysis of our findings will be provided in the following section. We will propose our determination of the best alternative in addition to our reasoning.

Exhibit 1
Site Map

Exhibit 2
Aerial Photograph

Deer Ridge Junction



Exhibit 3
Site Photographs



Description: East of Beaver Meadows Road exit before entering US-34 or Fall River Road

View Direction: East



Description: West of Fall River Road exit before entering Beaver Meadows Road or Fall River Road

View Direction: West



Description: Parking area located near Deer Mountain Trail

View Direction: East

Exhibit 4
Calculations

PEAK RUNOFF PREDICTION BY THE RATIONAL METHOD

Version 2.00 released May 2017
Urban Drainage and Flood Control District
Denver, Colorado

Purpose: This workbook applies the Rational Method to estimate stormwater runoff and peak flows from small urban catchments (typically less than 90 acres)

Function:

1. To calculate the runoff coefficient, C for a catchment
2. To calculate the time of concentration, and then compare with the regional time of concentration limit used for the Denver region. The smaller one is recommended as the rainfall duration for use with the Rational Method.
3. To calculate the design rainfall intensity and resulting peak flow rate.

Content: The workbook consists of the following five sheets:

Intro Describes the purpose of each sheet in the workbook.

Rational Calcs Performs Rational Method calculations, $Q = CIA$

Weighted C Supporting tool to calculate area-weighted runoff coefficients from sub-areas.

Weighted Slope Supporting tool to calculate length-weighted slope from multiple flow reaches.

Weighted Tc Supporting tool to calculate reach-weighted time of concentration from multiple flow reaches.

Design Info Provides background information from the USDCM

Acknowledgements: **Spreadsheet Development Team:**
Derek N. Rapp, P.E.
Peak Stormwater Engineering, LLC
Holly Piza, P.E. and Ken MacKenzie, P.E.
Urban Drainage and Flood Control District

Comments? Direct all comments regarding this spreadsheet workbook to:

Revisions? Check for revised versions of this or any other workbook at:

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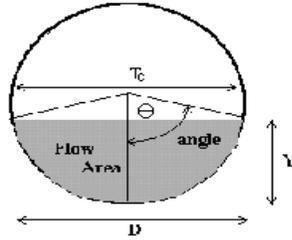
[Version 3.05, Released November 2017 \(click here to check for newer version\)](#)

**Urban Drainage and Flood Control District
Denver, Colorado**

Purpose:	This workbook aids in analyzing the flow conditions in circular and box culverts, and calculates the vertical profile along the culvert.
Function:	<ol style="list-style-type: none">1. To calculate normal and critical flow conditions in a circular pipe.2. To calculate normal and critical flow conditions in a box culvert.3. To determine headwater depth for a culvert by comparing inlet vs. outlet control.5. To Determine the vertical profile along the culvert.
Content:	The workbook consists of the following five sheets (excluding this sheet): Pipe Calculates normal and critical flow conditions in a circular pipe. Box Calculates normal and critical flow conditions in a box culvert. Culvert Rating Determines the headwater for a circular or rectangular culvert. HW & Outlet Protection Determines the headwater and required outlet protection sizes. Profile Determines the vertical profile of the culvert and soil cover. Design Info Provides backup data, including values of Manning's n for culvert design.
Acknowledgements:	Spreadsheet Development Team: Dr. James C.Y. Guo, P.E. Professor, Department of Civil Engineering University of Colorado at Denver Ken A. MacKenzie, P.E. Urban Drainage and Flood Control District Jason S. Stawski, E.I. Urban Drainage and Flood Control District
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CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

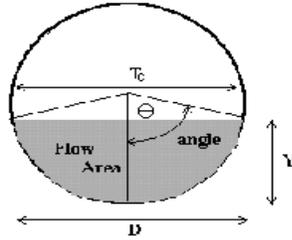
Project: Deer Ridge Junction- Rocky Mountain National Park
 Pipe ID: West Culvert



Design Information (Input)	
Pipe Invert Slope	So = 0.0450 ft/ft
Pipe Manning's n-value	n = 0.0150
Pipe Diameter	D = 18.00 inches
Design discharge	Q = 12.75 cfs
Full-flow Capacity (Calculated)	
Full-flow area	Af = 1.77 sq ft
Full-flow wetted perimeter	Pf = 4.71 ft
Half Central Angle	Theta = 3.14 radians
Full-flow capacity	Qf = 19.36 cfs
Calculation of Normal Flow Condition	
Half Central Angle (0<Theta<3.14)	Theta = 1.76 radians
Flow area	An = 1.09 sq ft
Top width	Tn = 1.47 ft
Wetted perimeter	Pn = 2.63 ft
Flow depth	Yn = 0.89 ft
Flow velocity	Vn = 11.70 fps
Discharge	Qn = 12.75 cfs
Percent Full Flow	Flow = 65.9% of full flow
Normal Depth Froude Number	Fr _n = 2.40 supercritical
Calculation of Critical Flow Condition	
Half Central Angle (0<Theta-c<3.14)	Theta-c = 2.48 radians
Critical flow area	Ac = 1.67 sq ft
Critical top width	Tc = 0.92 ft
Critical flow depth	Yc = 1.34 ft
Critical flow velocity	Vc = 7.64 fps
Critical Depth Froude Number	Fr _c = 1.00

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: Deer Ridge Junction- Rocky Mountain National Park
 Pipe ID: East Culvert



Design Information (Input)	
Pipe Invert Slope	So = 0.0450 ft/ft
Pipe Manning's n-value	n = 0.0150
Pipe Diameter	D = 8.00 inches
Design discharge	Q = 1.67 cfs
Full-flow Capacity (Calculated)	
Full-flow area	Af = 0.35 sq ft
Full-flow wetted perimeter	Pf = 2.09 ft
Half Central Angle	Theta = 3.14 radians
Full-flow capacity	Qf = 2.23 cfs
Calculation of Normal Flow Condition	
Half Central Angle (0<Theta<3.14)	Theta = 1.87 radians
Flow area	An = 0.24 sq ft
Top width	Tn = 0.64 ft
Wetted perimeter	Pn = 1.24 ft
Flow depth	Yn = 0.43 ft
Flow velocity	Vn = 7.00 fps
Discharge	Qn = 1.67 cfs
Percent Full Flow	Flow = 74.9% of full flow
Normal Depth Froude Number	Fr _n = 2.02 supercritical
Calculation of Critical Flow Condition	
Half Central Angle (0<Theta-c<3.14)	Theta-c = 2.48 radians
Critical flow area	Ac = 0.33 sq ft
Critical top width	Tc = 0.41 ft
Critical flow depth	Yc = 0.60 ft
Critical flow velocity	Vc = 5.07 fps
Critical Depth Froude Number	Fr _c = 1.00

Exhibit 5
Sketches/Diagrams/Plans/Drawings

Exhibit 6
Copy of Referenced Materials

Deer Ridge Junction Traffic Counts

