



Wasted Potential LLC  
1000 E. University Ave.  
Laramie, WY 82071

February 10, 2022

City of Cheyenne City Council  
2101 O'Neil Ave.  
Cheyenne, WY 82001

Dear City Council Members:

Please consider the following design work for the water retention and pipeline project for the development area North of Dell Range Ave. between Whitney Ave. and Van Buren Ave. The attached plan will provide an overview of the project and report on our company's plan and organization.

For logistical purposes, the project has been broken down into three areas of design; geotechnical, hydrological, and transportation. These areas are reflected in the organization methods of our company with respect to this project design.

Wasted Potential LLC. is committed to successful and safe engineering practices. We are pleased to have the opportunity to be working hand in hand with the City of Cheyenne to provide a full project design to your milestone specifications.

If you have any questions or need additional information, please feel free to contact our project manager at (307) 315-3744 or [wstewar4@uwyo.edu](mailto:wstewar4@uwyo.edu).

Sincerely,

Wasted Potential LLC., Laramie Project Team  
William Stewart – Project Manager  
Alex Fabricus – Hydrologist  
Luke Barron – Hydrologist  
Hannah Reiter – Geotechnical  
Brandon Baggs – Geotechnical  
Cooper Skoric – Hydrologist/ Transportation  
Ryan Curtis – Transportation

## **Final Report**

University of Wyoming  
C.E. 4900 - Senior Design  
Professor Barker  
Team 1

Due: May 9, 2022

Brandon Baggs, Luke Barron, Ryan Curtis, Alex Fabricus, Hannah Reiter, Cooper Skoric, and  
William Stewart

## Table of Contents

Introduction .....	1
Site, Location, and Background.....	1
Responsibilities .....	1
Team Responsibilities .....	1
Individual Responsibilities.....	3
Schedule.....	6
Hydrology .....	9
Existing Drainage Analysis .....	9
Detention .....	9
Pipeline and Inlets .....	18
Extended Basin .....	20
Geotechnical .....	23
Soil Properties.....	23
Roadway Substrates.....	25
Trenching Safety .....	27
Trenching Options for Trench Depth .....	27
Trenching Design.....	28
Earthwork Volumes .....	30
Transportation.....	32
TTC Plan and Traffic Analysis .....	32
Roads & Sections.....	40
Pavement & Concrete Design .....	42
Pavement Striping Plan.....	46
Summary .....	48
References .....	49
Appendix A.....	51
Appendix B.....	52

## Table of Figures

Figure 1: Project Site Overview.....	1
Figure 2: Minimum Milestones.....	3
Figure 3: Critical Pathways.....	6
Figure 4: 15% Gantt Chart.....	7
Figure 5: 35% Gantt Chart.....	7
Figure 6: 70% Gantt Chart.....	8
Figure 7: 100% Gantt Chart.....	8
Figure 8: Overview of Drainage Basin.....	9
Figure 9: SWIMM 100-yr Storm Storage.....	10
Figure 10: SWIMM Maximum Volume Water.....	11
Figure 11: NE Detention Pond Outlet Structure.....	12
Figure 12: Class 1 Rip-Rap.....	13
Figure 13: Basin 1 Delineation.....	13
Figure 14: Northern Basins Along Van Buren Ave.....	15
Figure 15: Southern Basins Along Van Buren Ave.....	15
Figure 16: Inlet Location Along Van Buren Ave.....	17
Figure 17: Pipeline Diameter Map.....	18
Figure 18: Pipeline Hydraflow.....	19
Figure 19: Pipeline Conflict Points.....	19
Figure 20: SW Spillway Profile.....	21
Figure 21: Given Bore log Locations.....	23
Figure 22: Gradation Curve of In-Situ Soil.....	25
Figure 23: Dell Range Soil Profile.....	26
Figure 24: Van Buren Soil Profile.....	26
Figure 25: Dry Creek Soil Profile.....	26
Figure 26: Required Open Trenching Side Slopes.....	27
Figure 27: Typical Trench Shoring Options.....	28
Figure 28: Typical TTC Setup.....	32
Figure 29: Signs and Sizes.....	32
Figure 30: Legend of TTC Elements.....	33
Figure 31: Channelization Devices.....	33
Figure 32: Traffic Control Elements.....	34
Figure 33: Dell Range and Van Buren Intersection TTC and Detour.....	35
Figure 34: First Inlet Set TTC (East Side).....	36
Figure 35: First Inlet Set TTC (West Side).....	36
Figure 36: Liberty Street TTC and Detour.....	37
Figure 37: Green River Street (East) TTC and Detour.....	37
Figure 38: Green River Street (West) TTC and Detour.....	38
Figure 39: Rock Springs Street TTC and Detour.....	38
Figure 40: Eastview Street TTC and Detour.....	39
Figure 41: Rawlins Street TTC and Detour.....	39
Figure 42: Rawlins Street TTC.....	39
Figure 43: Rawlins Cross Section (Sta: 1+00 to Sta: 4+23).....	40

Figure 44: Rawlins Cross Section (Sta: 4+23 to Sta: 10+45)..... 41

Figure 45: Van Buren Cross Section (Sta: 10+45 to Sta: 36+41) ..... 41

Figure 46: Dell Range Cross Section (Sta: 36+41 to Sta: 48+21) ..... 41

Figure 47: Dell Range Cross Section (Sta: 51+18 to Sta: 59+15) ..... 42

Figure 48: Dell Range Pavement Design Report ..... 43

Figure 49: Van Buren Pavement Design Report..... 43

Figure 50: Rawlins Pavement Design Report ..... 44

Figure 51: Detectable Warning Surface ..... 45

Figure 52: Type A Curb and Gutter ..... 45

Figure 53: Locations of Added Concrete ..... 46

Figure 54: Dell Range Striping Plan (2 Lane & Transition) ..... 46

Figure 55: Dell Range Striping Plan (3 Lane) ..... 46

Figure 56: Van Buren Existing Striping Plan ..... 47

Figure 57: Van Buren Proposed Striping Plan ..... 47

Figure 58: Typical Open Channel Cross Section of NE Basin..... 51

Figure 59: Open Channel Profile of NE Basin ..... 51

Figure 60: Pipeline Horizontal Profile ..... 51

Figure 61: IDF Curves ..... 52

Figure 62: Taper Length Hand Calculations ..... 53

### Table of Tables

Table 1: Objectives by Area ..... 2

Table 2: Transportation Milestone Responsibilities ..... 4

Table 3: Hydrology Milestone Responsibilities ..... 4

Table 4: Geotechnical Milestone Responsibilities ..... 5

Table 5: Presentation and Report Schedule ..... 5

Table 6: NE Detention Pond Storage ..... 11

Table 7: Basin 1 Runoff Delineation..... 14

Table 8: NE Basin and Swale Volume Design ..... 14

Table 9: Weighted Runoff Coefficient Area Percentages ..... 16

Table 10: Time of Concentrations, Intensities, and Runoff volumes..... 16

Table 11: Capture and release Volumes Along Van Buren Ave. .... 17

Table 12: SE Detention Pond Volume Solutions ..... 21

Table 13: SW Spillway Design ..... 21

Table 14: SW Extended Basin Storage Table..... 22

Table 15: Given Soil Properties ..... 24

Table 16: Sieve Analysis Gradation ..... 24

Table 17: Atterberg Limits of In-Situ Soil ..... 25

Table 18: Vertical Trench Stresses ..... 28

Table 19: Horizontal Soil Pressures..... 29

Table 20: Maximum Lateral Earth Pressure Depth ..... 30

Table 21: Cut Volumes ..... 30

Table 22: Fill Volumes ..... 31

Table 23: Cut and Fill Summary ..... 31

Table 24: Taper Lengths..... 35  
Table 25: Traffic Counts ..... 40  
Table 26: Crash Data (2019-2020) ..... 40  
Table 27: 100% Design Focus..... 48

### Table of Equations

Equation 1: Rational Method..... 10  
Equation 2: Open Channel Design - Hydraulic Radius ..... 12  
Equation 3: Open Channel Design - Wetted Perimeter ..... 12  
Equation 4: Manning Equation ..... 14  
Equation 5: Horizontal Soil Stress ..... 29  
Equation 6: Rankine’s Theory of Lateral Earth Pressures ..... 30  
Equation 7: merging Taper Lengths ..... 34  
Equation 8: Time of Concentration..... 52  
Equation 9: WQVC Equation ..... 52

## Introduction

### Site, Location, and Background

A storm draining system is to be designed in the city of Cheyenne, Wyoming to allow for future residential development and control storm drainage. A retention pond will be designed on the North side of Dell Range Boulevard between Van Buren Avenue and Whitney Avenue. The retention pond will then feed into a pipe that runs West underneath Dell Range to the Van Buren intersection. The pipe will then run South beneath Van Buren to the Rawlins Street intersection and finally drain into Dry Creek. Before being released into Dry Creek. The collected water will enter a sedimentation pond to limit the environmental impact of the new drainage path. There are several storm drains along Van Buren that will feed into the pipe. The project overview is outlined in Figure 1.



Figure 1: Project Site Overview

The section of Dell Range under construction along with the entirety of Van Buren and the East section of Rawlins Street will have phased closures to traffic during construction of the project. As a result, a phased traffic control system is to be designed to allow adequate traffic flow and ease of access to residences and businesses. Once the storm system is in place, a complete asphalt overlay will be performed. The pavement used will be designed in accordance with the Wyoming Department of Transportation (WYDOT) and the City of Cheyenne specifications. Lastly, the traffic signals on the project will be adjusted to accommodate a traffic increase on Dell Range and Van Buren.

## Responsibilities

### Team Responsibilities

The team will work collaboratively on all areas of design. For logistical management, the design will be broken down into 3 areas of design: transportation, hydrology, and geotechnical, a project manager will

also be chosen to help stay organized. To manage the learning requirements of the class, several objectives have been set within the areas of transportation engineering, geotechnical engineering, hydrology, and project management. The objectives can be seen below in Table 1.

*Table 1: Objectives by Area*

Transportation	Geotechnical	Hydrology	Project Management
<ul style="list-style-type: none"> <li>• Temporary Traffic Control Plan</li> <li>• Road pavement, profile, and section design</li> <li>• Intersection design/control</li> </ul>	<ul style="list-style-type: none"> <li>• Soil Properties</li> <li>• NE Detention Pond Earthwork</li> <li>• SW Extended Detention Basin Earthwork</li> <li>• Pipeline earthwork</li> <li>• Trenching design</li> <li>• Roadway substrate</li> </ul>	<ul style="list-style-type: none"> <li>• Drainage analysis of plot and inputs</li> <li>• Detention pond Extended Detention Basin</li> <li>• Pipeline profile and design</li> <li>• Roadway drainage and inlets</li> <li>• Release of detention pond</li> <li>• Release Design for EDB</li> </ul>	<ul style="list-style-type: none"> <li>• Coordination efforts, presentations &amp; reports</li> <li>• File Management</li> <li>• Support in discipline area work</li> <li>• Daily attendance reports</li> <li>• Weekly update meeting with Dr. Barker</li> </ul>

The Transportation objectives will ensure safety during the phased construction plan; repave the road with an emphasis on traffic volume, safety, and water drainage; drawings of a typical profile, section, and each intersection will be produced from the design process. The temporary traffic control plan will be a phased approach with priority given to safety. The road pavement, profile and section design will be designed with thought given to longevity, economics, water drainage, and traffic volume increase. The intersection control will also be designed for longevity, economics, safety, and drainage.

The geotechnical objectives will be the foundation of all the work. Data will be evaluated to determine the soil properties so that all designs will be accurate. Both the NE and SW ponds will have earthwork completed to the size specified by the hydrology team. The pipeline earth work will be trenched with an extreme emphasis placed on safety. Finally, the road substrate will be designed to provide adequate support and safety.

The hydrology objectives will focus on the water throughout the various locations of the project. The drainage basin will be analyzed to properly size the NE pond. The pipeline release rate will be looked at to properly size the pipeline. The incoming storm drainage rates and roadway drainage will be considered to size the SW detention pond. The design of the detention pond will be so that any environmental impact upon release of the water into Dry Creek will be limited.

Project management objectives are in place to help organize and direct, design, and to lead and participate in team collaboration. The project manager will help all the other three areas coordinate design and keep all files organized to do so. The project manager will also meet with Dr. Barker and take attendance so that the class learning objectives in the syllabus are completed. The project manager will also provide support when necessary to any group in the design process.

The objectives outlined in Table 1 will be achieved throughout the design process. The objectives will lay the groundwork for completion of the objectives outlined in the course syllabus. The given milestones for the project are shown in Figure 2 and will be the guideline for the completion of the objectives in Table 1. The team will strive to stay within the milestone timeline. This will ensure timeliness.

<b>Timeline</b>	<b>Transportation (1)</b>	<b>Hydraulics (4)</b>	<b>Geotechnical (2)</b>
15% Conceptual Week 4	Preliminary Ideas for Temporary Traffic Control (TTC)	Preliminary NE Basin Preliminary Inlet Basins Preliminary Pipeline Profile Rain flows & intensities	Method for Soil Properties Earthwork Requirements (cut / fill / compaction) Preliminary Trenching Requirements
35% Completion Week 7	Traffic Analysis for TTC Preliminary TTC Design	<b>NE Drainage Area Q &amp; Volume Inlet Drainage Area Qs &amp; Volumes</b> Preliminary NE Detention Pond Preliminary SW Detention Pond	Preliminary roadway substrates OSHA/Safety Requirements for Trenching Trenching Options for Trench Depths
70% Completion Week 11	<b>TTC Design</b> Preliminary Safety Analysis of TTC <b>Roadway pavement design</b> Preliminary Road Drainage	<b>NE Detention Pond Extended Detention Basin Pipeline Profile</b> Preliminary Pipeline Design	<b>Cut and Fill for NE Detention Pond Cut and Fill for SW Detention Pond Roadway substrates</b> Preliminary Trenching and Compaction Design
100% Completion Week 14	<b>Safety Analysis of TTC Roadway sections, profiles &amp; drainage Intersection Design/Control</b>	<b>NE Detention Pond Release SE EBD Water Quality Plate Design Road Drainage Pipeline Design</b>	<b>Trenching and Compaction Design</b>
Final Report Week 14	<b>Integrated, Complete and Organized Project Report with Design Drawings</b>		

Figure 2: Minimum Milestones

Many of the minimum milestones will depend upon other milestones from another area of design. This will be discussed more in depth in the schedule section of the introduction.

**Individual Responsibilities**

While the team will work collaboratively on all areas of design. For individuals to utilize their strengths to a higher degree; individuals will work primarily within one of the design areas of transportation, hydrology, and geotechnical. In addition, an individual will serve as a project manager.

William was chosen to be the project manager as he has taken a PDE in each of the hydrology, transportation, and geotechnical areas. William has a knowledge base to help aid in all areas of design. This will be useful if one area falls behind. William has also taken several classes involving presentation and technical writing and will be able to lead the charge for each report and presentation. William has also won several Wyoming state public speaking awards and can help with the presenting part of the presentations.

The transportation team will be headed by Ryan. Ryan wants to work in transportation upon graduation. He has worked alongside civil engineers the past three summers for the Wyoming Department of Transportation (WYDOT). During his time with WYDOT he assisted with various projects assessing the quality of work performed and tested various materials used throughout construction. Ryan will bring a passion for the area and will be invaluable to the team. Cooper will assist Ryan in the transportation area as needed.

Brandon and Hannah will perform the geotechnical side of this project. Brandon has been installing pipelines his entire life on his family ranch. He also has construction experience in stormwater, sewer, hydronix, and water main installation. Hannah is familiar with soil properties and their importance when it comes to the placement and development of structures. Hannah enjoys the evaluation of soil and looks forward to continuing geotechnical practices in her future.

Alex and Luke will primarily head up the hydrology area of the design. Luke wants to help with maintaining and researching the Water Energy Nexus for the state of Wyoming to help produce as much energy as possible while using as little fresh water as possible. Alex will help with the design of the conduit, the inlet and outlet. Alex is working for a water resource engineering firm so this has and will continue to be part of his daily life throughout his career. Cooper will assist in the hydrology work

throughout the project. He will be working as a nuclear engineer in the Navy after graduation and will be working with fluids daily to help run the reactor.

The breakdown of each individual milestone for each member of the team is shown in Table 2, Table 3, and Table 4. For many milestones, many team members will assist, one person will be chosen to be responsible for the end numbers and design so that there is no confusion or missed milestones.

*Table 2: Transportation Milestone Responsibilities*

<b>Milestone</b>	<b>Responsible, (Assisting)</b>
Preliminary Ideas for Temporary Traffic Control	Ryan, (Cooper)
Traffic Analysis for TTC	Ryan
Preliminary TTC Design	Cooper, (Ryan)
TTC Design	Ryan, (Cooper)
Preliminary Safety Analysis of TTC	Cooper, (Ryan)
Roadway pavement design	Ryan, (Cooper)
Preliminary Road Drainage	Ryan, (Cooper)
Safety Analysis of TTC	Ryan
Roadway sections, profiles & drainage	Ryan, (Cooper)
Intersection Design/Control	Cooper, (Ryan)

Ryan will take the lead on most of the transportation milestones. Cooper will take the lead on some of the preliminary designs as Ryan works on analysis and alternative routes. Cooper will take the lead on the intersection design work. Ryan has experience with producing drawings in Civil 3D, so he will initiate those.

*Table 3: Hydrology Milestone Responsibilities*

<b>Milestone</b>	<b>Responsible, (Assisting)</b>
Preliminary NE Basin	Luke, (Alex)
Preliminary Inlet Basins	Alex, (Luke)
Preliminary Pipeline Profile	Cooper
Rain flows & intensities	Luke and Alex
NE Drainage Area Q & Volume	Luke, (Alex)
Inlet Drainage Area Qs & Volumes	Alex, (Luke)
Preliminary NE Detention Pond	Luke, (Alex)
Preliminary SW Detention Pond	Alex, (Luke)
NE Detention Pond	Luke, (Alex)
Extended Detention Basin	Alex, (Luke)
Pipeline Profile	Cooper
Preliminary Pipeline Design	Cooper
NE Detention Pond Release	Luke, (Alex)
SE EBD Water Quality Plate Design	Alex, (Luke)
Road Drainage	Cooper
Pipeline Design	Cooper

Luke will take the lead on the NE basin. Alex will take charge of the SW pond. They will assist one another on the ponds as well. This will ensure the two largest individual milestones are divided among the hydrologists. Cooper will take the lead on most of the pipeline work. This will take pressure off Luke and Alex and help them to be able to focus more on the design of the ponds and roadway drainage systems.

*Table 4: Geotechnical Milestone Responsibilities*

<b>Milestone</b>	<b>Responsible, (Assisting)</b>
Method for Soil Properties	Brandon
Earthwork Requirements (cut / fill / compaction)	Brandon, (Hannah)
Preliminary Trenching Requirements	Hannah, (Brandon)
Preliminary roadway substrates	Brandon, (Hannah)
OSHA/Safety Requirements for Trenching	Hannah
Trenching Options for Trench Depths	Brandon, (Hannah)
Cut and Fill for NE Detention Pond	Brandon, (Hannah)
Cut and Fill for SW Detention Pond	Brandon, (Hannah)
Roadway substrates	Brandon, (Hannah)
Preliminary Trenching and Compaction Design	Brandon, (Hannah)
Trenching and Compaction Design	Brandon, (Hannah)

Brandon will head up most of the design for the earthwork requirements and trenching. Hannah will take the lead on most of the preliminary design. This will allow Brandon to work with the hydrology team to size the ponds. The trenching will be done co-operatively, Brandon will be responsible for the final results, but the work will be split close to 50-50 on all trenching.

While no minimum milestones are listed for the project manager, the timelines for the presentations and reports are shown in Table 5.

*Table 5: Presentation and Report Schedule*

<b>Presentation and Report</b>	<b>Due Date</b>
Draft Timeline and Responsibility Report	2/7/22
Draft Timeline and Responsibility Presentation	2/9/22
Timeline and Responsibilities Report	2/14/22
15% Conceptual Design Presentation	2/23/22
35% Completion Presentation	3/23/22
35% Completion Report	3/23/22
70% Update Presentation	4/11/22
70% Update Report	4/13/22
Final Project Presentation	5/2/22
Final Project Report and Evaluation	5/9/22

William will assist in design work in any of the categories as needed. He is also responsible for all reports and presentations. When parts of the reports and presentations require the knowledge of those

who have done the design work, William will get the needed information and numbers from those who did the design.

Schedule

The minimum milestone timeline will be followed as a basis for the task completion schedule. An emphasis will be placed upon the projects critical pathways of milestones that must be completed before another milestone can be completed. Figure 3 shows the critical pathways below.

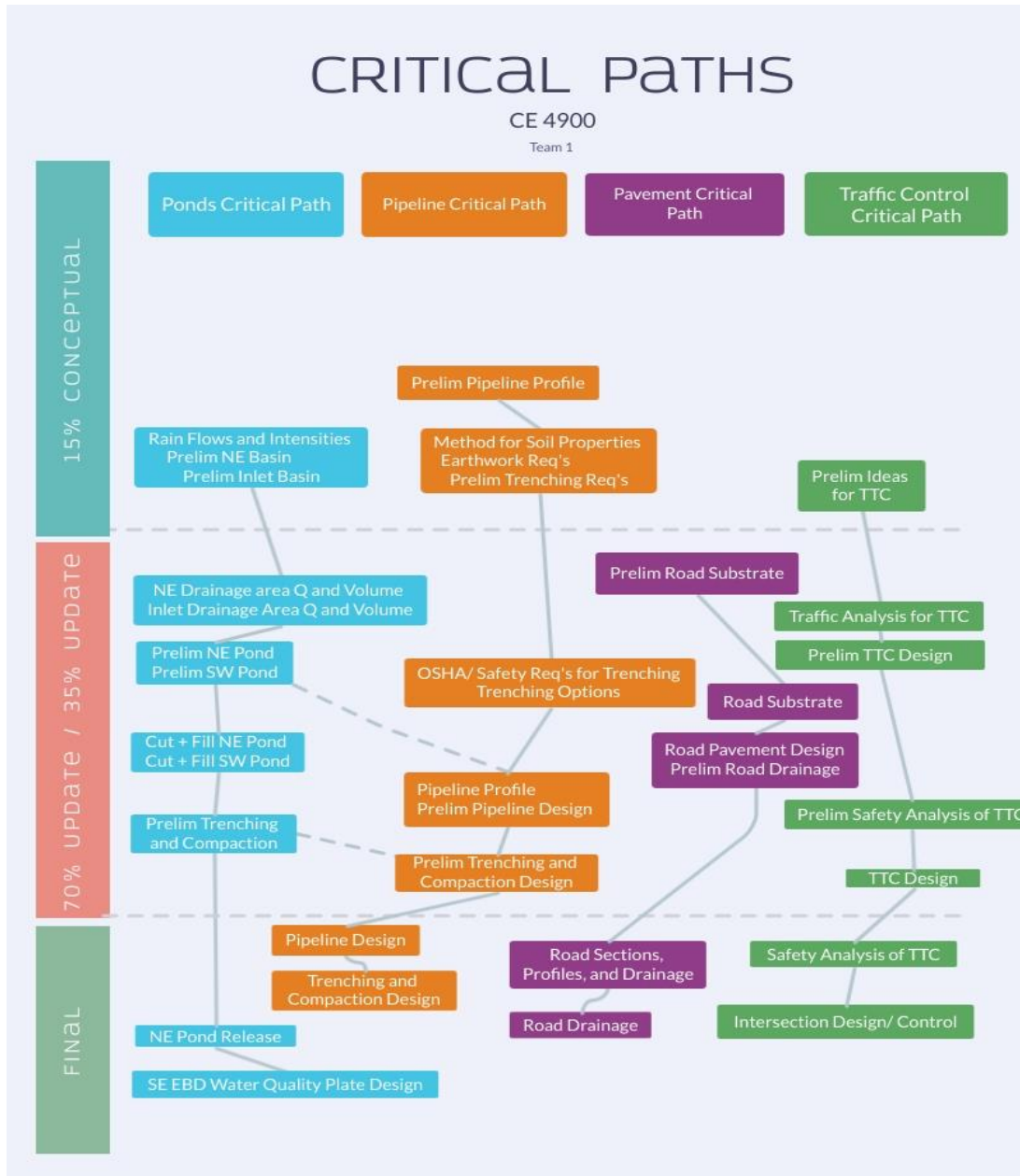


Figure 3: Critical Pathways

The critical pathways shown in Figure 3 will help guide the task completion schedule. The task completion will be scheduled so that the critical pathways are considered so that there is never a bottle

neck in the workflow. Figure 4 below shows the work completion schedule of the Gantt chart for the 15% completion stage. Figure 5 shows the 35% completion stage; Figure 6 shows the 70% Update stage and Figure 7 shows the final Completion Stage.

The 15% milestones, shown in Figure 4, were completed by Mid-February.

### City of Cheyenne Water Works

Wasted Potential Engineering LLC

PM - William Stewart  
 Hydrologists: Alex, Luke, and Cooper  
 Geologists: Brandon and Hannah  
 Transportations: Ryan and Cooper

Project Start: Mon, 1/17/2022  
 Display Week: 1

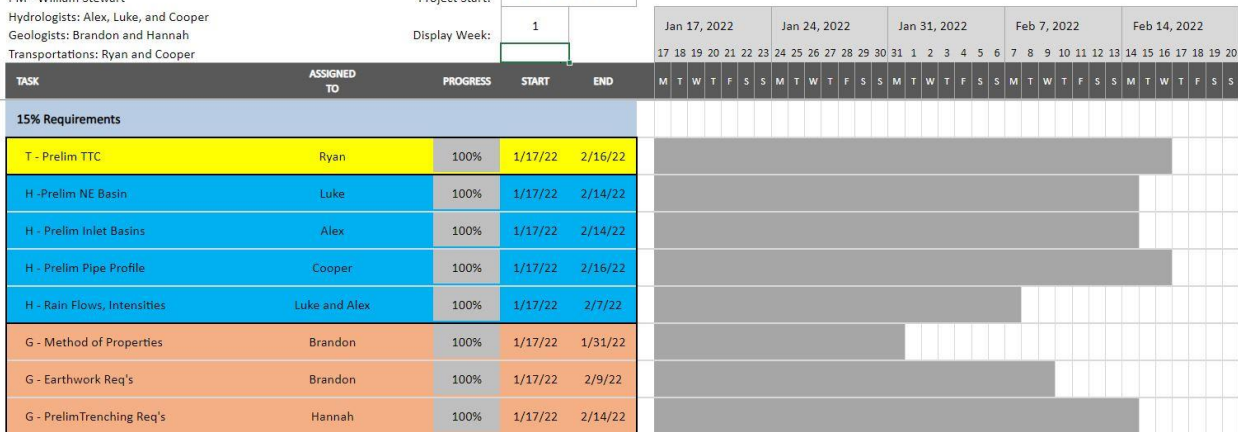


Figure 4: 15% Gantt Chart

The 30% milestones, shown in Figure 5, were completed by early May.

### City of Cheyenne Water Works

Wasted Potential Engineering LLC

PM - William Stewart  
 Hydrologists: Alex, Luke, and Cooper  
 Geologists: Brandon and Hannah  
 Transportations: Ryan and Cooper

Project Start: Mon, 1/17/2022  
 Display Week: 5



Figure 5: 35% Gantt Chart

The 70% milestones, shown in Figure 6, were completed by early April, before spring break

**City of Cheyenne Water Works**

Wasted Potential Engineering LLC

PM - William Stewart  
 Hydrologists: Alex, Luke, and Cooper  
 Geologists: Brandon and Hannah  
 Transportations: Ryan and Cooper

Project Start:   
 Display Week:

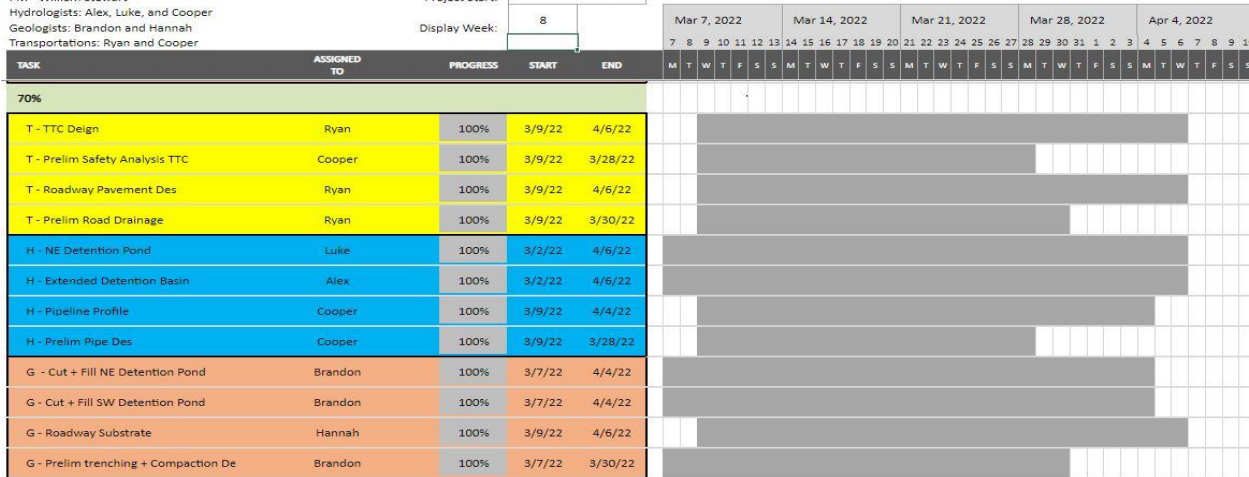


Figure 6: 70% Gantt Chart

The 100%, shown in Figure 7, were completed by April 25<sup>th</sup>.

**City of Cheyenne Water Works**

Wasted Potential Engineering LLC

PM - William Stewart  
 Hydrologists: Alex, Luke, and Cooper  
 Geologists: Brandon and Hannah  
 Transportations: Ryan and Cooper

Project Start:   
 Display Week:



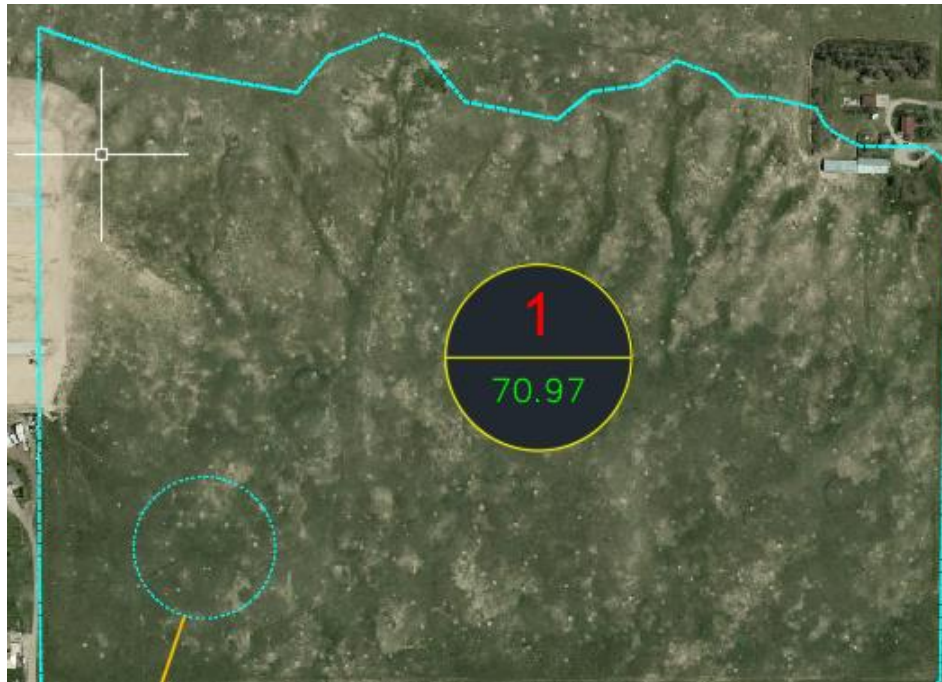
Figure 7: 100% Gantt Chart

The Gantt chart will be used to keep all involved in the project on task and organized. If an individual starts to run behind and needs help, the project manager will be contacted and the project manager and anyone who is ahead in their design will help the person who is behind schedule.

## Hydrology

### Existing Drainage Analysis

The purpose of this project is to design a water collection and distribution system for an area of land the City of Cheyenne had expressed interest in developing. The land the city wants to develop lies on the North side of Dell Range Ave. between Whitney Ave. and Van Buren Ave. The area of land that will contribute to the drainage is 70.97 acres in area. This watershed delineation was found using surveying data as well public topography data (Cvar, 2022). Figure 8 shows an overview of the land to be developed.



*Figure 8: Overview of Drainage Basin*

Pre-existing utilities are also a cause for concern; there are electrical, wastewater, and other drainage conduits that must be examined before the installation of the new conduit (Cvar, 2022). The Area as well as the appropriate design storm must be closely considered in accordance with the Cheyenne Unified Development Code, CUDC (City of Cheyenne, 2012).

### Detention

A detention pond must also be implemented to control the flow rate entering the drainage system. The overall design of the detention pond will be directly related to the amount of runoff generated by the area, design storm, and the amount of urbanization that will come with the development of the land (Cvar, 2022). The pipe design, slope, material, and positioning are also being investigated. The slope and the diameter of the pipe are directly proportional to the flow rate and will receive special attention in the design phases. The max allowable flow rate is .23 ft<sup>3</sup>/sec/acre (City of Cheyenne, 2012).

This SWIMM calculated basin flow rate is a maximum of 240 cubic feet per second (Version 5.2.0; EPA, 2022). This flowrate was calculated using the SWIMM program developed by the Environmental Protection Agency (Version 5.2.0; EPA, 2022). SWIMM uses the rational method equation to form an accurate prediction about the max runoff that will be observed. The runoff coefficient  $C$  is based off how much rainfall would infiltrate soil and how much would be converted to overland flow and eventually become runoff. The  $C$  value for this equation is based on a 45% imperviousness post urbanization (Cvar, 2022), intensity comes from a 100-yr recurrence (City of Cheyenne, 2022), and has the calculated area of 70.97 acres. In the case of a 100-yr storm (Cvar, 2022), a volume of 510,000 cubic feet or 11.7 acre-ft of overland flow would become runoff need to be stored and released at a flowrate that abides by the Cheyenne Unified Development Code (City of Cheyenne, 2012). Figure 9 displays the time frame in which 100-yr storage would occur and Figure 10 shows the maximum volume of water that would occur from a 100-yr storm (SWIMM, 2022).

$$Q = CIA$$

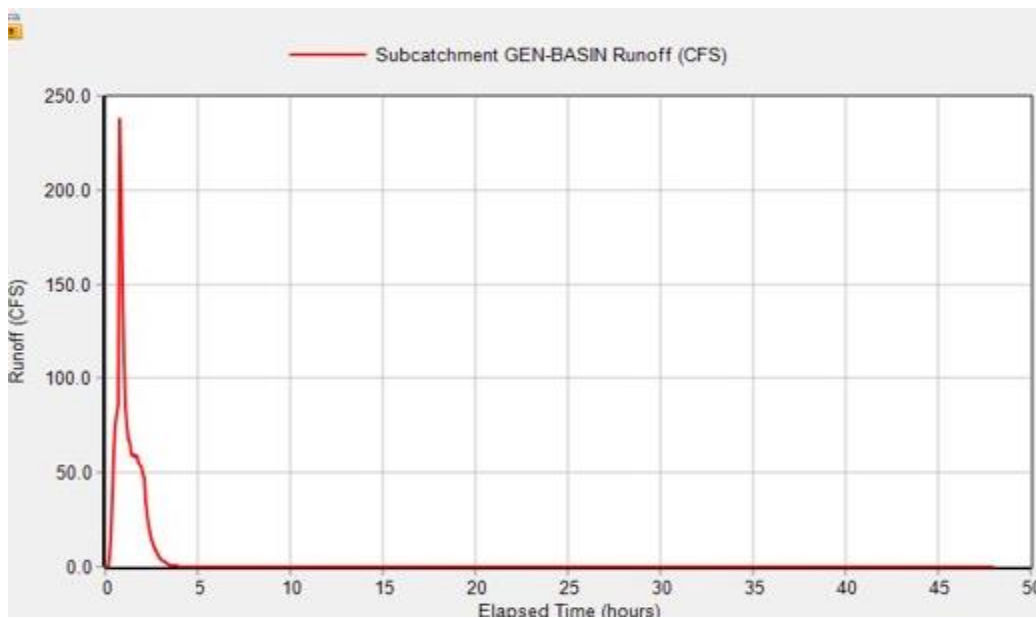
*Equation 1: Rational Method*

Where,

$C$  = Runoff Coefficient

$I$  = Rainfall Intensity (in/hr)

$A$  = Runoff area (acres)



*Figure 9: SWIMM 100-yr Storm Storage*

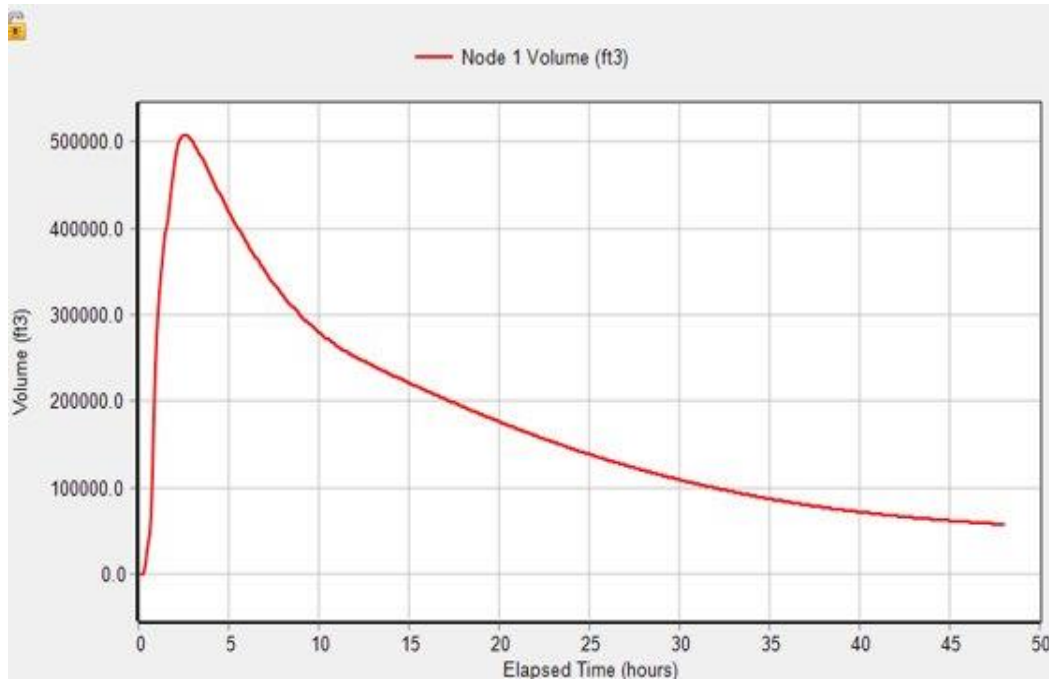


Figure 10: SWIMM Maximum Volume Water

The final Northeast detention pond design resulted in a total volume of 571,610 cubic feet at a depth of 7 feet (Version 2022; Autodesk, 2022). The Northeast detention pond volumes for each contour line can be seen in Table 6. Exceeding the required volume of 510,000 cubic feet (Version 2022; Autodesk, 2022). The detention pond is designed to catch all hold all runoff in worst case scenario to avoid flooding of the Dell Range roadway. The detention pond has a 4:1 side slope to the highwater line around the approach of the pond for safety and to meet Cheyenne Unified Development Code (City of Cheyenne, 2012). Pond highwater line then has a 3:1 side slope to the pond floor where the detention pond has a 1% slope towards the outlet structure of the pond (City of Cheyenne, 2012). The outlet of the detention pond is also set 1 foot lower than the design highwater line. Therefore, the outflow structure will be flowing at max flowrate, 15.34 cubic feet per second, before the pond has reached full volume. Design of the outflow structure for the detention pond is displayed in Figure 11.

Table 6: NE Detention Pond Storage

STAGE STORAGE TABLE						
ELEV	AREA (sq. ft.)	DEPT H (ft)	AVG END INC. VOL. (cu. ft.)	AVG END TOTAL VOL. (cu. ft.)	CONIC INC. VOL. (cu. ft.)	CONIC TOTAL VOL. (cu. ft.)
6,018.000	3,693.58	N/A	N/A	0.00	N/A	0.00
6,019.000	30,645.33	1.000	17169.45	17169.45	14992.68	14992.68
6,020.000	88,620.40	1.000	59632.86	76802.31	57126.36	72119.03
6,021.000	92,683.94	1.000	90652.17	167454.48	90644.58	162763.61
6,022.000	96,802.75	1.000	94743.35	262197.83	94735.88	257499.49
6,023.000	100,988.66	1.000	98895.71	361093.53	98888.32	356387.82
6,024.000	105,241.66	1.000	103115.16	464208.69	103107.85	459495.67
6,025.000	109,561.75	1.000	107401.70	571610.40	107394.46	566890.13

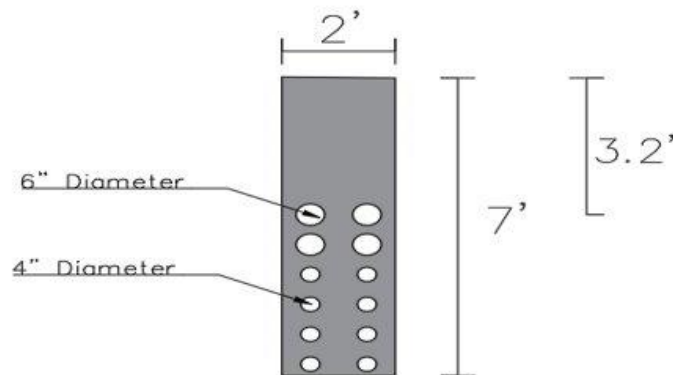


Figure 11: NE Detention Pond Outlet Structure

In order to transfer the runoff into the northeast detention basin, a triangular swale will be placed at the bottom of the basin in order to redirect the water into the northeast detention pond. This swale was designed using the best hydraulic section equations for a trapezoid. Equation 2 and Equation 3 were used to design the cross section of the channel as seen in Figure 58 Appendix A (Version 2022; Autodesk, 2022). The vertical profile of the swale is shown in Figure 59 Appendix A (Version 2022; Autodesk, 2022). The CUDC desires grass lined channels, however the maximum allowable velocity for erosion prone soil is 5 ft/s (City of Cheyenne, 2012). Unfortunately, due to the large flowrate of the channel the 5 ft/s threshold will be exceeded when grass is used (Version 2022; Autodesk, 2022). The sides of the channel will be Class-1 Rip Rap, shown in Figure 12. Class-1 Rip Rap is a large aggregate that weighs between 15 and 50 pounds with a diameter between 18 and 26 inches (State of Alabama, n.d.). Adding Class-1 rip rap will negate erosion of the channel and keep the velocity of the channel under 7 ft/s which is the threshold for non-erodible soil (Cvar, 2022).

$$R = \frac{my}{2(1 + m^2)^{\frac{1}{2}}}$$

Equation 2: Open Channel Design - Hydraulic Radius

$$P = 2y(1 + m^2)^{\frac{1}{2}}$$

Equation 3: Open Channel Design - Wetted Perimeter

Where;

$m$  = channel side slopes

$R$  = Hydraulic Radius

$P$  = Wetted perimeter

$y$  = Swale Depth



Figure 12: Class 1 Rip-Rap

Figure 13 below shows the portion of Basin 1 that will have runoff drain directly into the detention pond, and the portion that will need to be transported by the swale. Of the 70.97 acres, 19.48 will drain directly into the detention basin itself and the other 51.49 acres will be transported into the detention pond by the swale. Table 7 below displays how much runoff the swale will need to account for and how much runoff will flow directly into the basin. The Hydraflow Express extension in Civil 3D was used to develop the cross section of the swale (Version 2022; Autodesk, 2022). The Hydraflow Express extension uses the manning equation to determine the flowrates and velocities of an open channel system. The manning equation is shown as Equation 4 below:

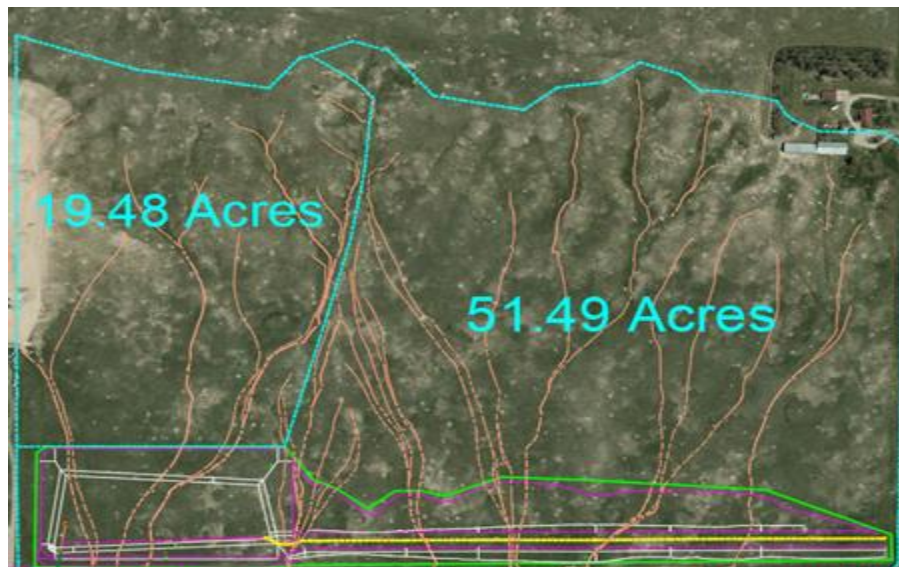


Figure 13: Basin 1 Delineation

Table 7: Basin 1 Runoff Delineation

Swale Design	Total	Swale	Pond
Area (acre)	70.97	51.49	19.48
Runoff (acre-in/hr)	240.00	174.12	65.88
Runoff (cfs)	241.99	175.57	66.42

$$Q = \frac{1.49}{n} (A)(R_H)^{\frac{2}{3}}(S_0)^{\frac{1}{2}}$$

Equation 4: Manning Equation

Where;

$$Q = \text{flowrate} \left( \frac{ft^3}{sec} \right)$$

$n$  = manning coeff.

$A$  = channel area ( $ft^2$ )

$R_H$  = Hydraulic Radius (ft)

$S_0$  = slope (unitless)

Large manning coefficient values result in reduced flowrate and velocity. The channel illustrated was created using certain user inputs. First, a triangular channel was chosen. The engineers at Wasted Potential thought this was the most appropriate cross section. The CUDC requires 4:1 side slope, therefore the channel was designed using 4:1 side slope for both sides of the channel (City of Cheyenne, 2012). The depth of the channel is designed to be 3 feet (Version 2022; Autodesk, 2022). The slope was designed to have a 1% slope from east to west with respect to the basin (Cvar, 2022). With these specifications considered, the design details are shown in Table 8. This channel design needs to be able to accommodate for 176 cubic feet per second of flow. The channel design that will be implemented will be able to accommodate 208 cubic feet per second of flow at a maximum velocity of 5.78 feet per second (Cvar, 2022). This maximum velocity is below the CUDC maximum allowable design code of 7 ft/s for non-erodible soil (City of Cheyenne, 2012).

Table 8: NE Basin and Swale Volume Design

Depth (ft)	Q (cfs)	Area (sf)	Velocity (ft/s)	Yc (ft)	Top Width (ft)
3	208	38	5.78	2.79	24

Inlets along Van Buren will be implemented at every intersection to capture excess runoff that occurs on that stretch of roadway. Watershed delineation was done using contour lines, slopes, and spot elevations on Civil 3d (Version 2022; Autodesk, 2022). The delineation of the watersheds along Van Buren are shown in Figure 14 and Figure 15 below. Each material throughout the basins has a specific runoff coefficient shown in Table 9. The value of the runoff coefficient is dependent on the rainfall intensity and the material. More impervious materials and heavier rainfall intensities will yield a larger coefficient which results in a larger runoff flowrate.

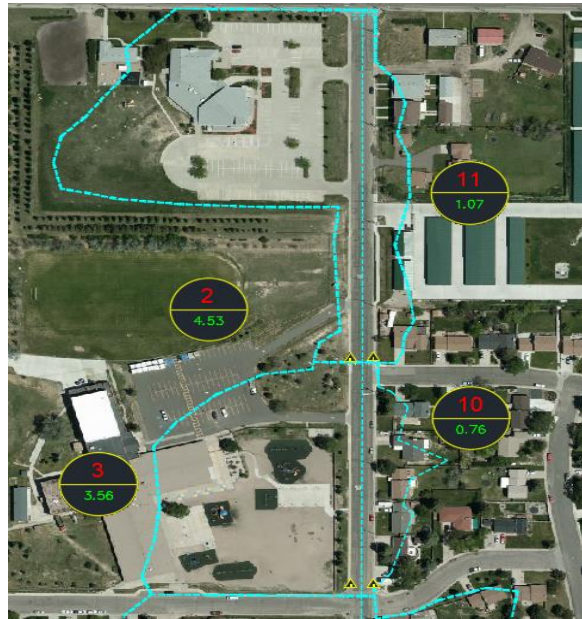


Figure 14: Northern Basins Along Van Buren Ave.

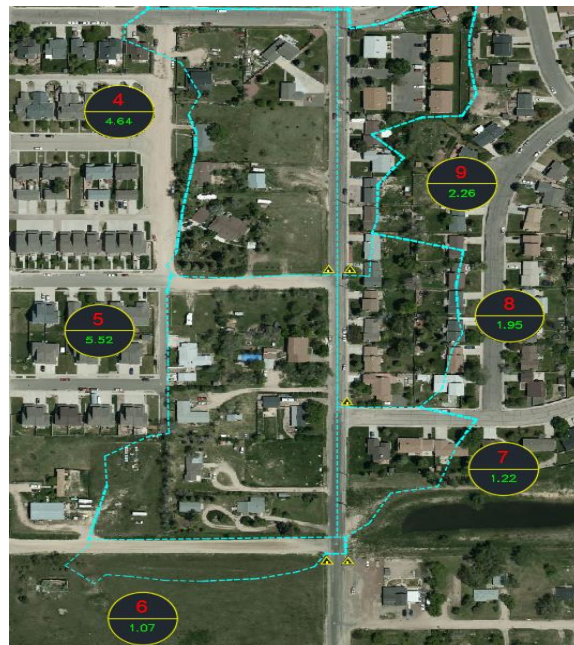


Figure 15: Southern Basins Along Van Buren Ave.

Table 9: Weighted Runoff Coefficient Area Percentages

Perecent impervious	Percent Imp	C2	C5	C100
Roofs	90.00%	0.74	0.77	0.85
Concrete	90.00%	0.84	0.86	0.86
Asphalt	100.00%	0.74	0.77	0.77
Gravel	40.00%	0.29	0.32	0.61
Open	2.00%	0.01	0.01	0.44

Each basin can be made of five different ground materials: roofs, concrete, asphalt, gravel, and open. Every basin along Van Buren has its own unique make up of these materials. Weighted C values were given in order to find the runoff each basin produces (City of Cheyenne, 2012). The C values were calculated by weighing how much area each material covered in relation to the whole basin (Cvar, 2022). Basins with a larger area of concrete would generate more runoff than a basin that is mostly covered by open area of gravel. The time of concentration for each basin was also found using Civil 3D (Version 2022; Autodesk, 2022). The time of concentration for each basin was also assumed to be the duration of the storm. This simulates the worst-case scenario where 100% of the basin area is contributing to runoff simultaneously. Figure 61 in Appendix B was used to find the storm intensity that was dependent on the duration (City of Cheyenne, 2012). Table 10 below shows weighted C values for each basin, and runoff that will occur. Only Basin 1 has a 100-yr runoff since Basin 1 and only Basin 1 is being designed for a 100-yr storm. The runoff shown here for Basin 1 is under the assumption that the basin is not yet urbanized. As previously stated, SWIMM was used to generate a runoff estimate when the basin becomes urbanized (Version 5.2.0; EPA, 2022).

Table 10: Time of Concentrations, Intensities, and Runoff volumes

BASIN	Area (acres)	C5	C100	Flow Length (ft)	Timec (min)	5-Yr Intensity (in/hr)	100-Yr Intensity (in/hr)	5-Yr Runoff (acre-in/hr)	100-Yr Runoff (acre-in/hr)	Volume (acre-in)
1	70.97	0.01	0.49	1937.3	20.76	NA	4.8	NA	166.93	N/A
2	4.53	0.44	0.65	1497	18.32	2.8	NA	5.54	NA	1.69
3	3.56	0.36	0.61	546	13.03	3.25	NA	4.22	NA	0.92
4	4.64	0.16	0.51	1000	15.56	3.15	NA	2.30	NA	0.60
5	5.52	0.09	0.48	926	15.14	3.1	NA	1.61	NA	0.41
6	1.07	0.03	0.45	552	13.07	3.22	NA	0.11	NA	0.02
7	1.23	0.34	0.60	602	13.34	3.19	NA	1.34	NA	0.30
8	1.95	0.23	0.55	470	12.61	3.33	NA	1.52	NA	0.32
9	2.26	0.31	0.59	836	14.64	3.09	NA	2.19	NA	0.53
10	0.76	0.47	0.66	411	12.28	3.29	NA	1.18	NA	0.24
11	1.07	0.38	0.61	726	14.03	3.15	NA	1.29	NA	0.30

Inlets are being implemented along Van Buren in order to catch the runoff that occurs. Denver Type 13 inlets are being used to transfer the runoff from overland flow to open channel flow. Figure 16 below demonstrates how the inlets will be placed along Van Buren geographically. The city of Cheyenne asked that inlets be implemented at each intersection (City of Cheyenne, 2012). The red triangles in Figure 16 show the points at which each inlet will be set. Denver Type A inlets will be used in order to capture that excess runoff from Van Buren. Table 11 below shows how much water drains into each inlet. Each basin contributes to an inlet. How much water that inlet captures is shown below in Table X. Not every inlet will capture all the runoff flowing to it, represented by the released column. The amount

released from an inlet will be added to the next inlet capture. The released runoff will continue flowing until it is captured by an inlet.



Figure 16: Inlet Location Along Van Buren Ave.

Table 11: Capture and release Volumes Along Van Buren Ave.

Basin	Runoff (cfs)	Inlet	No. Inlets	Capture %	Captured (cfs)	Released (cfs)
1	N/A	N/A	N/A	N/A	N/A	N/A
2	5.54	1	2	74.00%	4.10	1.44
3	4.22	3	2	66.00%	3.74	1.92
4	2.30	5	2	68.00%	2.87	1.35
5	1.61	8	3	100.00%	3.07	0.00
6	0.11	8				
7	1.34	9	3	100.00%	1.74	0.00
8	1.52	7	2	81.00%	1.73	0.41
9	2.19	6	2	76.00%	1.94	0.61
10	1.18	4	1	75.00%	1.09	0.36
11	1.29	2	1	79.00%	1.02	0.27

### Pipeline and Inlets

A reinforced concrete pipeline will be used to take the water collected in the northwest detention pond down to the southern detention pond. The pipeline will follow the streets of Del Range, Van Buran, and Rawlins before finally being released to the detention pond. Along the path of Van Buran, basins have been developed to determine the amount of water that will be flowing into inlets along the side of the road. Inlets along the road will be type A to be in accordance with the CUDC (City of Cheyenne, 2012). The pipeline will also change in diameter as needed to accommodate the extra volume of water flowing into it. The different diameters of the pipeline will vary from 30 inches, 36 inches and 42 inches. The length of the 30-inch pipeline will be 2435 feet. The 36-inch pipeline will be 1530 feet, and the 42-inch pipeline will be 1620 feet. This can be seen below in Figure 17. The 42-inch pipeline is in red, 36-inch in green and 30-inch in blue. The Northeast and Southwest basins can also be seen as yellow circles in the figure.



Figure 17: Pipeline Diameter Map

Using Hydraflow, a program in Civil 3D, the diameters and slopes of the pipeline were tested to make sure the hydraulic grade line was below the pipe (Version 2022; Autodesk, 2022). The information from Hydraflow can be seen below in Figure 18. Along with the changing diameter of the pipeline, the slope will vary to ensure that it is missing existing water and sewer lines. The slope of the pipe will never be less than .5% to ensure adequate flow throughout the storm line (Cvar, 2022).

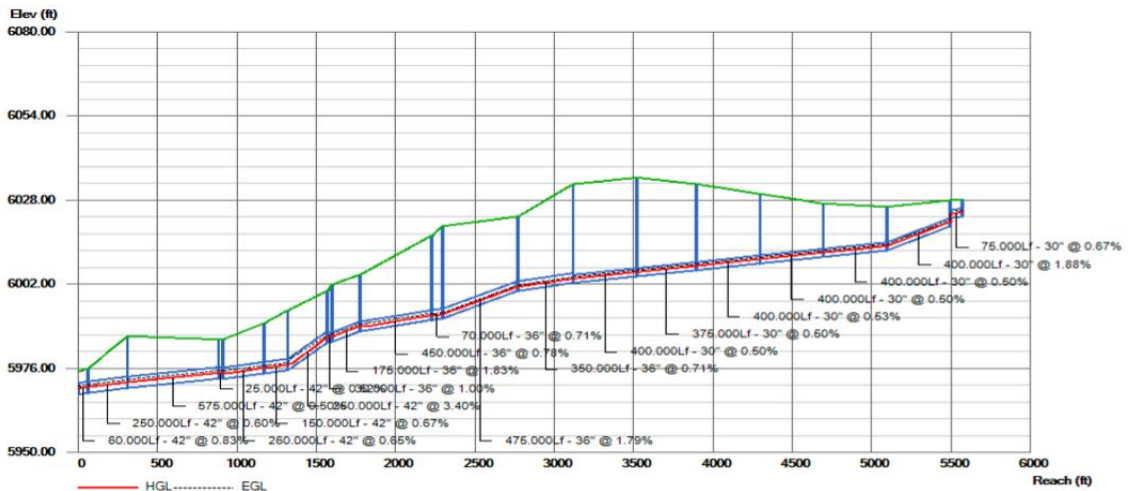


Figure 18: Pipeline Hydraflow

There are two major conflict points for the pipeline as it flows down Del Range where the pipe will cross water and sewer lines. The major conflicts happen at the intersections of Del Range and Rawlins, and the intersection of Del Range and East View. The water and sewer lines cannot be moved so the construction of the storm pipe must be moved to go around them. This can be seen in Figure 19. There are two six-inch water lines five feet under the ground that the storm line will go under. A minimum of 1 foot of clearance must be kept from the water lines. There are also two eight-inch sewer lines that the storm line must pass by. The depths of the sewer lines are 15 and 13 feet, giving enough room for the storm line to pass between them and the water lines. A minimum clearance of 18-inches will be kept from the sewer lines (Cvar, 2022).

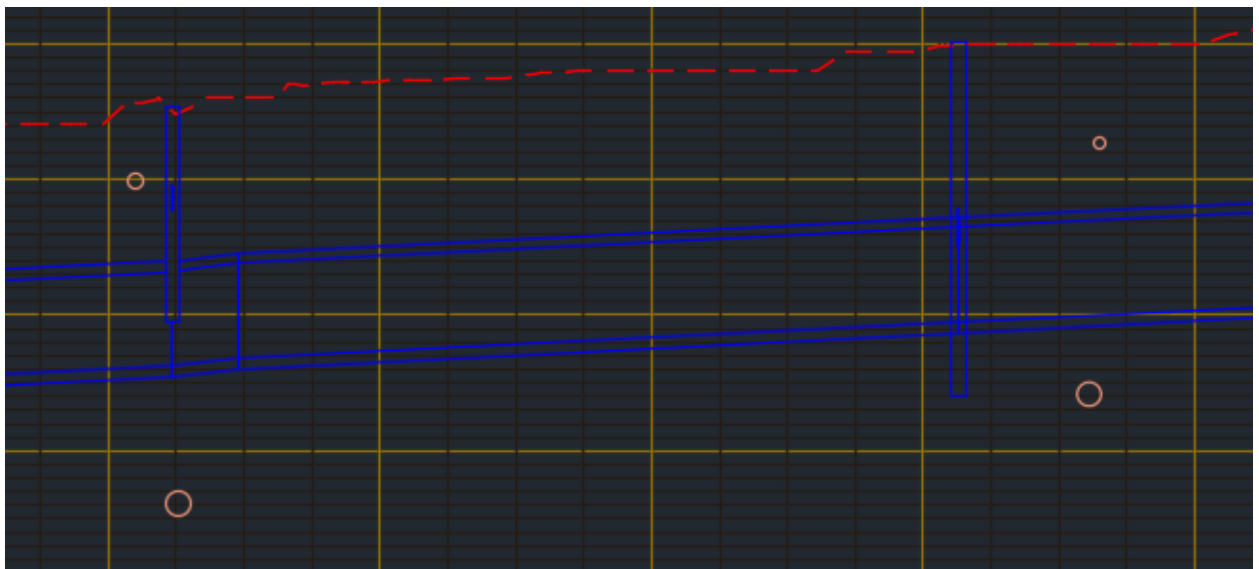


Figure 19: Pipeline Conflict Points

Manholes will be placed at every location of inlets and every change in slope for the pipeline. Manholes will also be placed every 400 feet for the 30-inch pipeline where there are no changes of slope or direction. Additionally, manholes will also be placed every 600 feet for the 42-inch pipeline where there are no changes of slope or direction (City of Cheyenne, 2012). There will be a total of 19 manholes throughout the entire section. This will allow maintenance to be done on the storm line as needed. These locations can also be seen in Figure 19 as the orange vertical lines.

### Extended Basin

The southern detention pond is only designed for the inlet volumes of the drainage areas entering the storm pipe. The northern detention basin is designed to handle a larger surcharge of water and will drain very slowly. The southern detention pond can accommodate large storms and heavy rainfall, but a spillway will be implemented to lead directly to Dry Creek. The spillway will be lined with type 1 riprap so the water flow will be slowed and avoid erosion (Cvar, 2022). Pond volume is not the main driving factor for the southern detention basin. Design criteria consists of site location, maintenance, shape, slope, safety, and aesthetics are all design parameters.

The water released from the detention pond will be controlled with a trash rack and well screen placed over 3 rows of 0.375 square inches orifice holes (Cvar, 2022). The outflow structure is designed to restrict the flow of unwanted debris from the environment while still allowing the pond to drain sufficiently while being fed by the newly installed stormwater pipeline. Connecting the outflow structure of the retention pond is a drainage pipe that will allow the treated water to safely discharge into Dry Creek. The southern detention pond will be added to the South-East intersection of Rawlins and Van-Buren. Once the water level reaches a specified elevation of 2.33 feet, discharge to Dry Creek will begin. Three separate rows of orifices holes are spaced every 2.33 feet to allow sufficient drainage (Version 2022; Autodesk, 2022). The water will have time to settle in the southern detention basin. The design of our sedimentation basin will accommodate the larger debris and allow it to settle without directly flowing into the environment. The placement of the 15-inch RCP exiting pipe connected to the outlet structure orifice plate is installed with specific height to keep the clean, environmentally safe, water flowing to the creek flow discharge but keep harmful debris and sediment inside the southern detention basin (Fabricus, 2022).

Using the WQCV equation (City of Cheyenne, 2012), shown in Equation 8 in Appendix B, to determine the approximate southern detention pond volume was found to be 0.33 acre-ft and is displayed in Table 12. The site located on the South side of Rawlins Street is estimated to be 1 acre and will be able to fit in the desired site location (Version 2022; Autodesk, 2022). The layout of the pond shape is now driven by maintenance accessibility. Extended detention ponds must be accessible for cleaning and the elevation contours of the ground will be examined to determine the best access point and outflow drainage pipe location. The spillway location is directly over the top of the outflow drainage pipe and the spillway is only to be used in extreme flood conditions. The outflow structure is held in place with rip rap and if excessive flooding does occur then water will exit through the spillway located directly behind the outflow structure. The spillway is 10 ft in width and 0.5 ft in depth and can have a maximum flowrate of 12.36 cubic feet per second. Spillway design is shown below in Figure 20 and Table 13 (Ekka, 2020).

Table 12: SE Detention Pond Volume Solutions

BASIN	% impervious	Area (acres)	WQCV (watershed inches)	Required storage volume (acre-ft)
1	0.45	70.97195225	0.19294875	1.141162456
2	0.48	4.531255739	0.201240865	0.075989485
3	0.44	3.561685032	0.189908809	0.05636628
4	0.20	4.641597796	0.11599988	0.044868732
5	0.12	5.515472911	0.079139064	0.036374114
6	0.05	1.066873278	0.034501062	0.003067355
7	0.42	1.228213958	0.18578761	0.019015578
8	0.28	1.954522498	0.145659271	0.023724527
9	0.38	2.260606061	0.174048323	0.032787891
10	0.57	0.758838384	0.226365997	0.014314601
11	0.47	1.071166208	0.198720678	0.017738573
			Sum (acre-ft)	1.465409593
			Volume (ft^3)	63833.24185

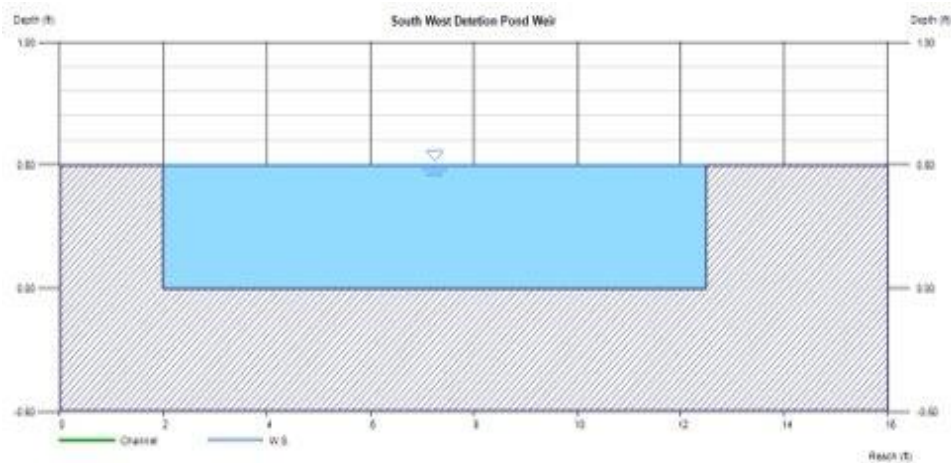


Figure 20: SW Spillway Profile

Table 13: SW Spillway Design

Depth	Q
(ft)	(cfs)
0.25	4.371
0.30	5.745
0.35	7.240
0.40	8.846
0.45	10.55
0.50	12.36

The Southwest retention pond has a total volume capacity of 1.04 acre-ft after it's finished design. The total volume and depth of the pond can be seen in Table 14. The excessive size allows for the pond to retain more contaminants and makes it easier to move equipment around it when it needs to be maintained or cleaned from trash. The outflow structure and spillway are also located in the southwest corner of the pond to make maintenance of trash screens easily accessible (Robinson, 1998).

Table 14: SW Extended Basin Storage Table

STAGE STORAGE TABLE						
ELEV	AREA (sq. ft.)	DEPT H (ft)	AVG END INC. VOL. (cu. ft.)	AVG END TOTAL VOL. (cu. ft.)	CONIC INC. VOL. (cu. ft.)	CONIC TOTAL VOL. (cu. ft.)
5,965.000	2,604.68	N/A	N/A	0.00	N/A	0.00
5,966.000	3,240.22	1.000	2922.45	2922.45	2916.67	2916.67
5,967.000	3,934.67	1.000	3587.45	6509.90	3581.83	6498.51
5,968.000	4,688.03	1.000	4311.35	10821.25	4305.85	10804.36
5,969.000	5,500.29	1.000	5094.16	15915.40	5088.75	15893.11
5,970.000	6,371.45	1.000	5935.87	21851.27	5930.53	21823.65
5,971.000	7,301.52	1.000	6836.48	28687.75	6831.20	28654.85
5,972.000	8,290.49	1.000	7796.00	36483.76	7790.77	36445.62
5,973.000	9,338.37	1.000	8814.43	45298.18	8809.23	45254.85

The exact treatments and discharge rate from the outlet will be adhered to from the CUDC (City of Cheyenne, 2012). Dry Creek is a natural water flow way that can only have safe water for discharging. This natural runoff creek can also only handle so much water to avoid erosion and other environmental fallouts. This factor in mind is why the retention basin will be designed to hold and discharge storm water slowly. Therefore, there will not be any trash, unwanted sediment builds up and too high discharge velocity.

The southern detention pond also needs to be maintained. This means that the pond will have to be cleaned from debris and sediment every few years based on the overall flow rate of the new storm pipe system. The pond is designed to collect unwanted debris and over time the sedimentation basin will accumulate as sediment. The overall design of the sedimentation basin is driven by maintenance and clean water drainage. All extended basins must be maintained and be easily accessible for scheduled or needed attention. The final design will have a scheduled time of 10 years to be an average expected cleaning time for the sedimentation basin. Mainly, driven by the rainfall experienced in the Cheyenne, WY area from year to year.

## Geotechnical

The purpose of the Geotechnical design portion of this project is to determine soil properties, quantities of earthwork volumes for the Northeast Detention Pond, Southwest Extended Detention Basin, and Pipeline, design a safe construction method for trenching, determine applicable roadway substrates and compaction. Soil properties will be found using the description given on pre-existing geotechnical investigation bore logs performed by WYDOT (WYDOT, 2022).

Trench design will be in compliance with the Cheyenne city municipal code section 02220 (City of Cheyenne, 2014) along with the current OSHA regulations (OSHA, 2015). All fill material will meet the minimum milestones per grading requirements in section 02190. Compaction and excavation will be determined by the codes in section 02210.

## Soil Properties

Wyoming Department of Transportation (WYDOT) provided bore logs from a pre-existing geotechnical investigation to Wasted Potential LLC for this project. However, the bore log locations were determined to be from a different project or location as depicted in Figure 21.

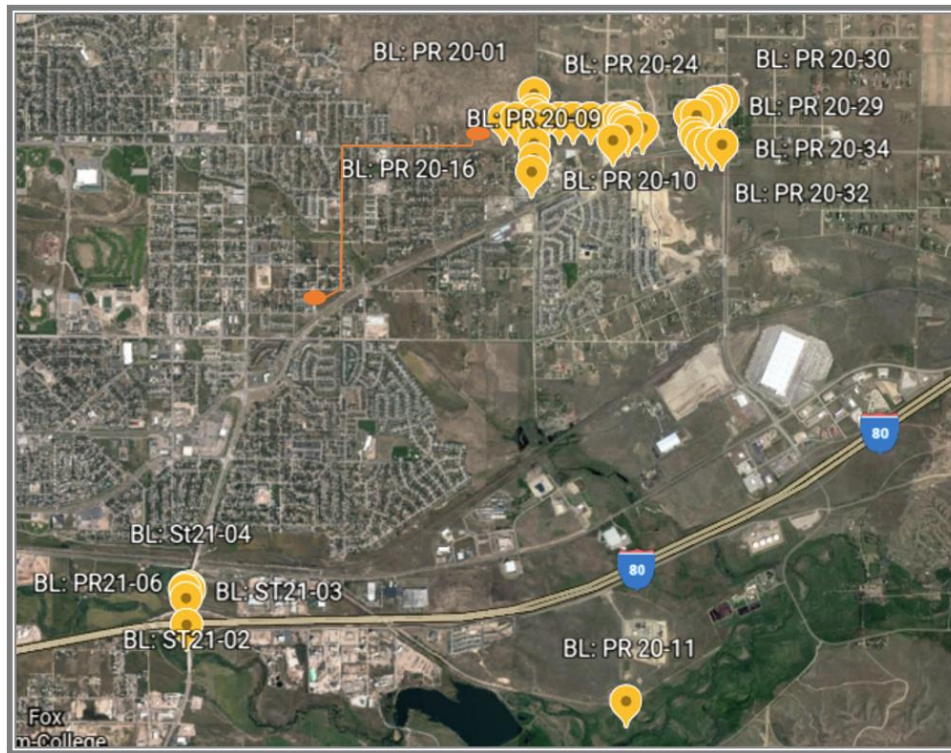


Figure 21: Given Bore log Locations

The orange line is the proposed project designation. The bore log locations are indicated by the yellow pin markers. After conversing with the City of Cheyenne, it was determined that no further drilling was to be done for geotechnical investigating. A proposal of using the nearest bore log information with respect to the project was approved. The information for determining soil properties was approved to be on bore logs PR 20-01 through PR 20-22 for Dell Range and Van Buren, and ST 21-02 for Rawlins. These bore logs indicated there is no water table located on Dell Range or Van Buren, but a water table at 10 feet on Rawlins.

Using the provided WYDOT data and data from Lindeburg, soil properties such as unit weight, friction angle, active lateral earth pressures, cohesion, and soil type could be estimated. These values can be seen in Table 9 (Lindeburg, 1975).

*Table 15: Given Soil Properties*

<b>Dry Creek Soil Properties</b>					
Depth (ft)	Unit Weight ( $\gamma$ , pcf)	Friction Angle ( $\varphi^\circ$ )	Lateral Earth Pressure (Kp)	Cohesion (Su,tsf)	Soil Type
0-6	100	30	0.33	.5	C
6-18	117	20	0.49	.5	C
<b>Dell Range Soil Properties</b>					
Depth (ft)	Unit Weight ( $\gamma$ , pcf)	Friction Angle ( $\varphi^\circ$ )	Lateral Earth Pressure (Kp)	Cohesion (Su,tsf)	Soil Type
0-5	115	36	0.26	.35	C
5-10	120	36	0.26	.35	C
10-15	120	36	0.26	.35	C
15-18	135	36	0.26	.35	C
<b>Van Buren Soil Properties</b>					
Depth (ft)	Unit Weight ( $\gamma$ , pcf)	Friction Angle ( $\varphi^\circ$ )	Lateral Earth Pressure (Kp)	Cohesion (Su,tsf)	Soil Type
0-3	Unknown	Unknown	Unknown	Unknown	C
3-10	100	31	0.32	.25	C
10-13	99	26	0.39	.25	C

To determine in situ specific values such as compaction data and roadway substrates, Wasted Potential LLC had a third party collect field samples and conduct soil testing. The testing consisted of a Sieve Analysis (ASTM 6913), Atterberg Limits test (ASTM 4318), and a Compaction test (ASTM 4254). These tests provided the pertinent information needed to classify the in-situ soil. The Sieve Analysis and compaction data can be referenced in Table 16, Figure 22, and Table 17.

*Table 16: Sieve Analysis Gradation*

<b>Sieve Results</b>					
Sieve Number	Sieve Weight	Combined Weight	Weight Retained	Percent Retained	Percent Passing
4	1.1	1.25	0.15	10%	90%
8	1.15	1.25	0.1	7%	83%
20	0.9	1.12	0.22	15%	69%
40	0.85	1.1	0.25	17%	52%
100	0.7	0.97	0.27	18%	34%
200	0.75	1.12	0.37	25%	9%
pan	0.8	0.93	0.13	9%	0%
total			1.49		

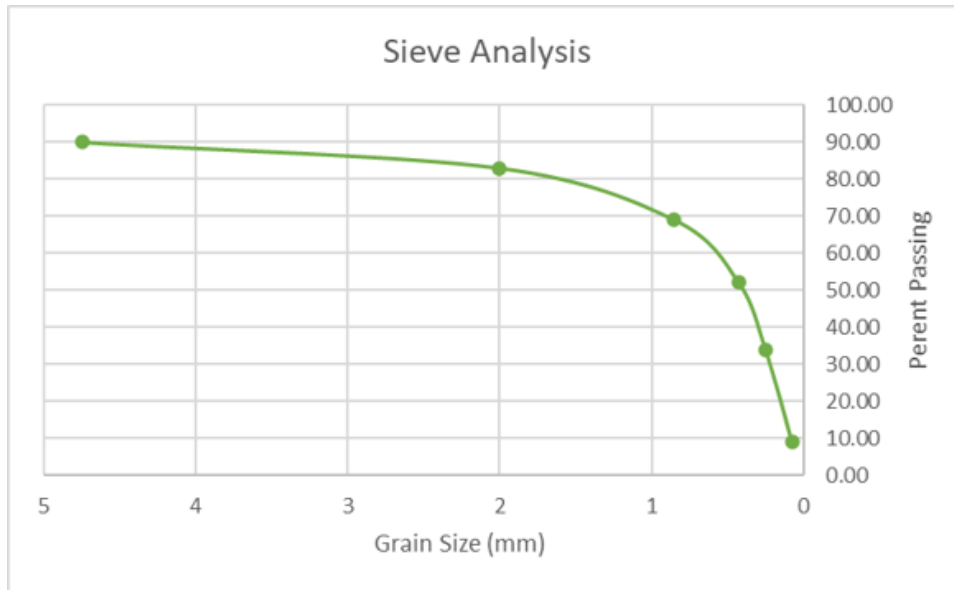


Figure 22: Gradation Curve of In-Situ Soil

Table 17: Atterberg Limits of In-Situ Soil

Cu	2.5
Cc	1.225
PI(%)	27.1
LL(%)	41.3
PL(%)	14.2

### Roadway Substrates

Using the gradation results from Table 10 and the Atterberg Limit results from Table 11 subgrade classification could be determined from the AASHTO classification criteria as an A-2-7. The resistance modulus ( $M_r$ ) was found to be 30,000 psi and the California Bearing Ratio (CBR) was found to be 20. After discussion with the Transportation Engineer, it was decided that soil would not be imported for the subbase material, rather the existing native soil would be used.

Concluding the soil properties resulted in the following soil profiles in Figure 23, Figure 24, and Figure 25.

### Dell Range Soil Profile



Figure 23: Dell Range Soil Profile

### Van Buren Soil Profile



Figure 24: Van Buren Soil Profile

### Dry Creek Soil Profile



Figure 25: Dry Creek Soil Profile

## Trenching Safety

OSHA has specific trenching safety requirements that must be met. Firstly, a safety checklist is provided to allow a competent person to make sure that the project is cleared for the site location as well as determine all equipment needed. The list is as follows: traffic, proximity and physical condition of nearby structures, soil classification, surface and groundwater, location of the water table, overhead and underground utilities, weather, quantity of shoring or protective systems that may be required, fall protection needs, number of ladders that may be needed, and other equipment needs (OSHA, 2015).

Once the site has successfully gone through the checklist, precautions must be taken in order to prevent cave-ins. Ways in which OSHA generally requires employers to protect workers from these incidents include sloping and benching the sides of the excavation, supporting the sides of the excavation, and placing a shield between the side of the excavation and the work area. It has been determined that the sloping requirement for all soils can be met using a slope ratio of 1 ½:1, shown in Figure 26.

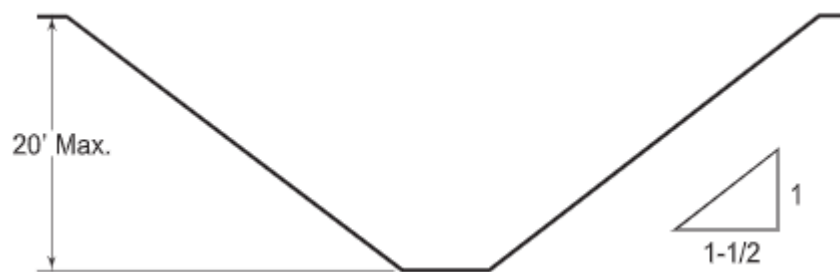


Figure 26: Required Open Trenching Side Slopes

It is important to note that the depth of the trench plays a big factor in the ways in which a project can properly proceed in meeting all OSHA requirements. These important depth requirements include egress for workers must be present at least every 25 ft horizontally, atmospheric conditions must be tested below 4 feet, and all projects with depths greater than 20 ft deep must be approved by a Professional Engineer (OSHA, 2015).

## Trenching Options for Trench Depth

There are multiple factors that play a part in the final determination of what trench method should be used. These considerations include soil classification, depth of cut, water content of soil, and weather. Once these factors are known, the type of trench method can be determined through analysis (Trench Shoring Company, 2022).

The trenching options evaluated for this project include sloping, benching, shoring, and shielding. See Figure 27 below for examples of each trench option. After evaluation, the sloping and benching methods were ruled out as there is a limited amount of project space, and the shielding

method was ruled out as it is very labor intensive and therefore, not the most economical. This leaves the Shoring Method as the best solution for this project due to its economic efficiency.

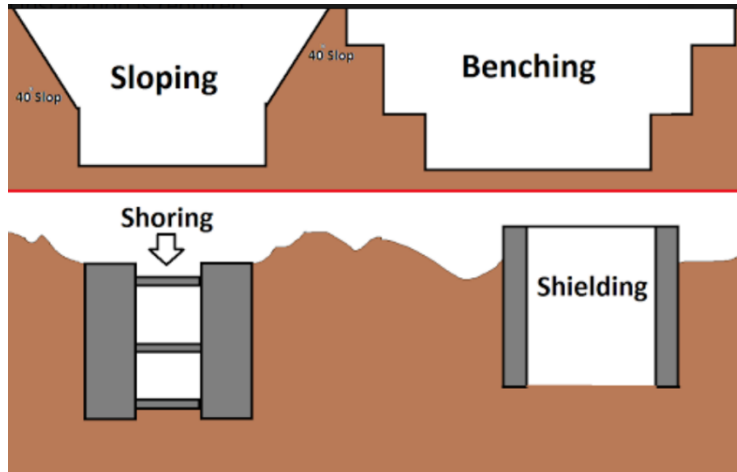


Figure 27: Typical Trench Shoring Options

**Trenching Design**

The City of Cheyenne does not require a Professional Engineer to stamp trench methods or designs above 20 feet in depth unless otherwise directed (City of Cheyenne, 2012). Van Buren and Rawlins do not meet the criteria for a Professional Engineer design. This trench design will be focused on Dell Range. Using the soil property values calculated in Table 15 the following vertical stress profiles in Table 18 can be determined.

Table 18: Vertical Trench Stresses

Vertical Stress Values (psf)			
Depth(ft)	Dell Range	Van Buren	Dry Creek
0	0	0	0
2	230	0	200
4	460	400	400
6	695	600	600
8	935	800	834
10	1175	1000	1068
12	1415	1180	1302
14	1655	1360	1536
16	1910	1540	1770
18	2180	1720	2004
20	2450	1900	2238
22	3395	2530	3057

The deepest part of the trench will be along Dell Rang at a depth of 22 feet. To reach a depth of this magnitude a stackable trench shoring method must be utilized. At 22 feet the trench box will experience a max total vertical force of 3,395 psf. Using the active lateral earth coefficient calculated in Table 18 a horizontal force can be calculated using Equation 5. Since there is no water table assumed to be present on Dell Range, we can neglect water pressure in Equation 5

$$\sigma_h = k_a \sigma_v - u_w$$

*Equation 5: Horizontal Soil Stress*

Where;

$\sigma_h$ - total horizontal stress

$\sigma_v$ - total vertical stress

$k_a$ - active lateral earth pressure

$u_w$ - pore water pressure

Using the values calculated at a depth of 22 feet in Table 18 the total horizontal stress can be determined. The greatest horizontal stress the trench box will endure is 882.7 pounds per square foot as shown in Table 19.

*Table 19: Horizontal Soil Pressures*

<b>Horizontal Stress Values (psf)</b>			
Depth	Dell Range	Van Buren	Dry Creek
0	0	0	0
2	59.8	0	66
4	119.6	128	132
6	180.7	192	198
8	243.1	256	408.66
10	305.5	320	523.32
12	367.9	460.2	637.98
14	430.3	530.4	752.64
16	496.6	600.6	867.3
18	566.8	670.8	981.96
20	637	741	1096.62
22	882.7	986.7	1497.93

Using Equation 6 lateral pressures can be calculated where the maximum stress will occur on the trench box. This ensures the maximum lateral earth pressure (MLEP) does not occur at a pin connection. The pin connections are not as strong as the shield on the trench box, thus failure by shearing/buckling could occur if the exerted earth pressure occurs at a connection. These values can be found in Table 20.

$$R = \Sigma \left( \frac{PR}{P} \right) \qquad \text{Equation 6: Rankine's Theory of Lateral Earth Pressures}$$

Where;

*P*- force at a point

*R*- depth from a point

Table 20: Maximum Lateral Earth Pressure Depth

Location	Depth from Surface (ft)
Dry Creek	4.54
Dell Range	13.93
Van Buren	5

The values referenced in Table 20 were critical in determining a trench box height. Most trench boxes come in standard heights of 4, 6, 8, and 10-feet. These heights are decided using three main parameters: trench depth, MLEP, and pipe clearance. During analysis of the trench box, it was observed that our MLEP location on Dell Range was right at a connection with a 6-foot-tall trench box. Thus, it was concluded that an 8-foot-tall trench box would be used to ensure proper pipe clearance, adequate stacking ability in order to reach a depth of 22 feet, and that the location of the MLEP was not at a pin connection.

The City of Cheyenne and the industry standard for a factor of safety must be a minimum of 1.5 (City of Cheyenne, 2012). The City of Cheyenne also states in Section 02220 that the trench width must be a minimum of the outside pipe diameter plus 12" but must not exceed the outside pipe diameter plus 24" (City of Cheyenne, 2012). These parameters were taken into consideration when selecting a trench box. A factor of safety of 1.5 increases the total horizontal stress to 1324.05 psf. Dell Range will have a 42" outside diameter pipe, thus a minimum trench width must be 4.5 feet with a maximum trench width of 5.5 feet.

### Earthwork Volumes

The proposed storm sewer depth combined with pond gradations present extensive earthwork volumes for this project. This data can be found in Table 21, Table 22, and Table 23.

Table 21: Cut Volumes

Cut Volumes (CY)			
North-East Detention Pond and Open Channel	South-West Sediment Basin	Trench	Total
73,011.67	3,036.60	22,842.33	85,816.53

Table 22: Fill Volumes

<b>Fill Volumes (CY)</b>				
North-East Detention Pond and Open Channel	South-West Sediment Basin	Trench	Type 1 Pipe Bedding Material	Total
18,703.95	113.00	24,353.00	2,201.1	45,371.05

Table 23: Cut and Fill Summary

<b>Summary (CY)</b>		
Total Cut	Total Fill	Spoilage
85,816.53	45,371.05	40,445.48

The total cut will be approximately 85,816.53 cubic yards. The total fill will be approximately 45,371.05 cubic yards. This fill value includes the 2,201.1 cubic yards of type 1 bedding material for the pipe installation. The pipe bedding material will need to be imported to the project as the native soil does not meet the gradation requirements specified by the city of Cheyenne in section 02225-Part 2-A.1, leaving a spoilage of 40,445.48 cubic yards (City of Cheyenne, 2012).

## Transportation

### TTC Plan and Traffic Analysis

A one-way, temporary signal operation will be used for the temporary traction control during trenching and pipe installation. A general traffic control set up along with the corresponding signage can be shown in Figure 28 and Figure 29 shows the signs and corresponding road sizes used throughout the project as per the Manual on Uniform Traffic Control Devices (Federal Highway Administration, 2020)



Figure 28: Typical TTC Setup

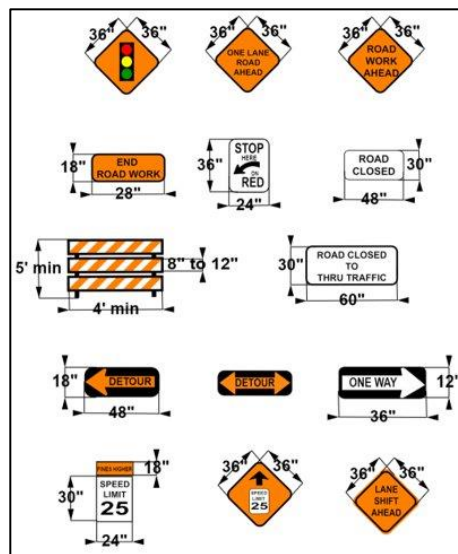


Figure 29: Signs and Sizes

Figure 30 shows a legend of the elements used in all temporary traffic control setups. In order to increase safety to traveling public and construction workers, concrete jersey barrier will be used as the channelization devices during pipe installation. During paving, drums will be used in place of concrete barrier. The selected channelization devices can be shown in Figure 31. Any time trenching occurs at a resident's approach, half of the approach will be trenched at a time to always allow access.

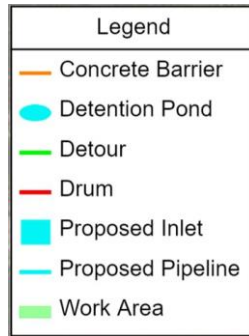


Figure 30: Legend of TTC Elements

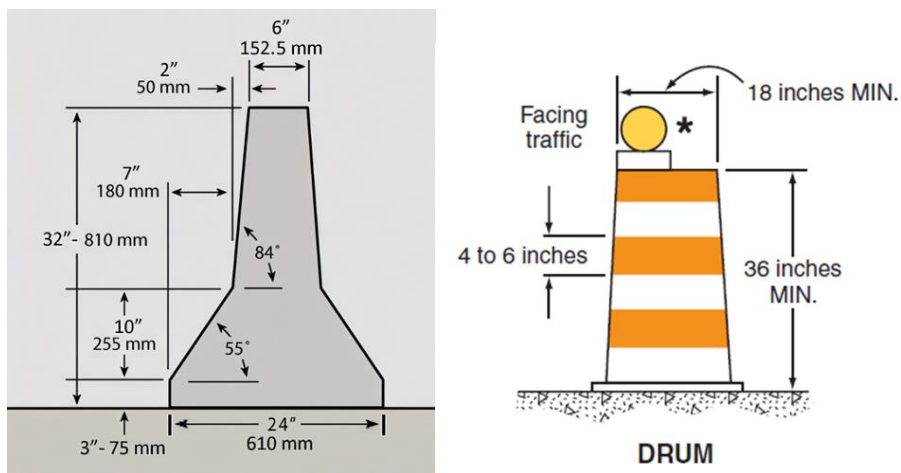


Figure 31: Channelization Devices

Figure 32 depicts various elements of a typical traffic control section. Although this shows a single lane closure on a two-way road, the same elements will still apply for this project. Due to the limited workspace, the minimum lateral buffer space of 10 feet will be used and there will be no longitudinal buffer space at the end of the work zone. These selections can be made because the channeling devices used are concrete jersey barrier therefore incident risk is minimal. The activity area will vary depending on the distance to residences' approaches. The entry longitudinal buffer space and tapers will also vary depending on the street under construction.

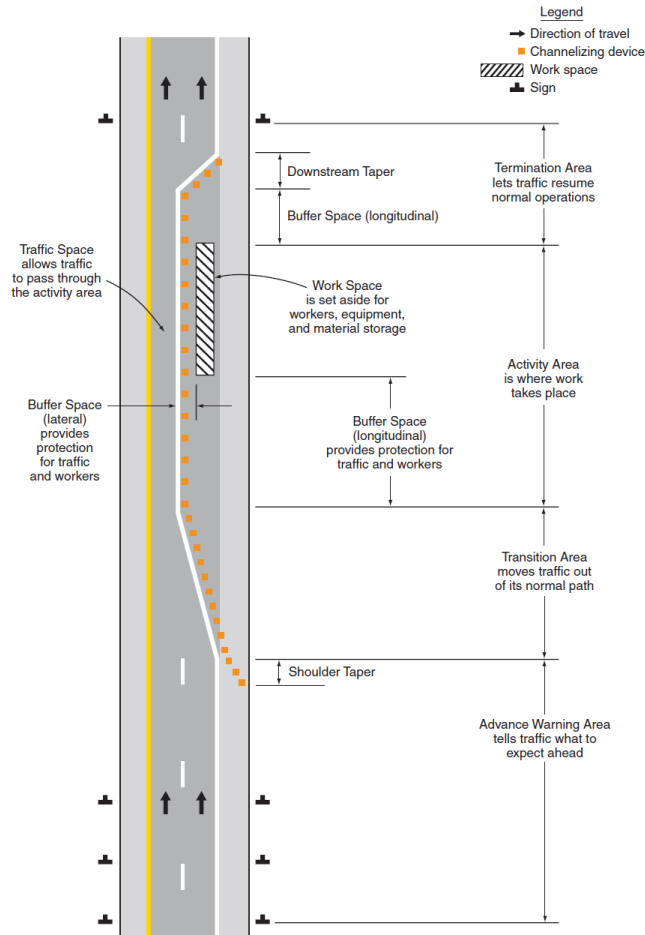


Figure 32: Traffic Control Elements

Merging taper lengths will be calculated using Equation 7.

$$L = \frac{WS^2}{60}$$

Equation 7: merging Taper Lengths

Where;

*L* = Taper length in feet

*W* = Width of offset in feet

*S* = Anticipated operating speed in mph



Due to the 11 inlets to be installed on Van Buren, multiple partial detours will be needed. Each traffic control set up will be the same as Dell Range. When an inlet is installed on the East side of Van Buren, if a side street isn't blocked off, the typical set up will be used. Figure 34 and Figure 35 show a typical traffic control for inlet installation. The roadway will be closed half at a time laterally.

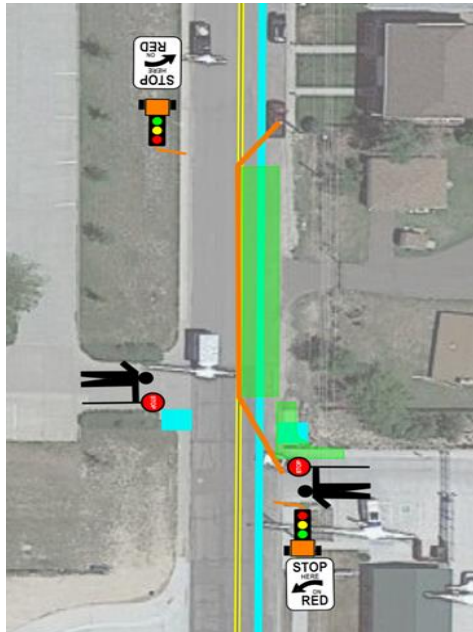


Figure 34: First Inlet Set TTC (East Side)

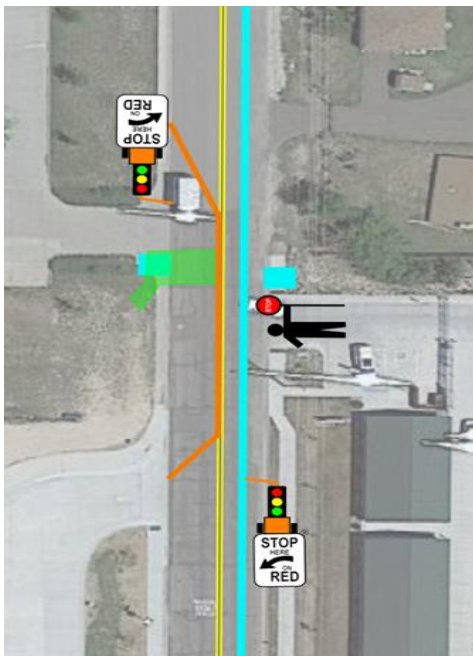


Figure 35: First Inlet Set TTC (West Side)

Flaggers will be placed at any driveway or approach across from the work zone to assist traffic access and flow. All other inlet TTC will be set up in a similar fashion with the exception of detours for certain areas. Figure 36 through Figure 41 show the roads that will be blocked during inlet installation and the corresponding detour route.



Figure 36: Liberty Street TTC and Detour

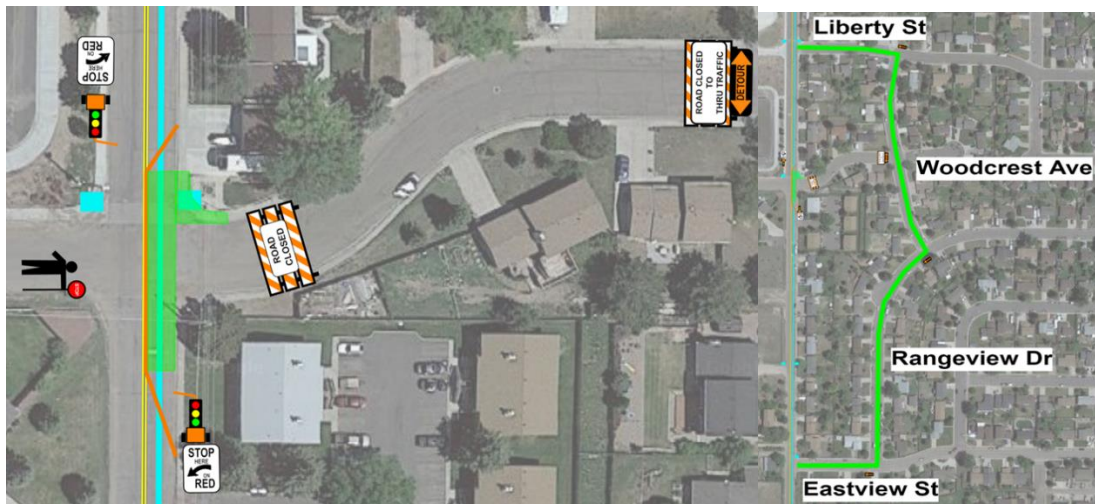


Figure 37: Green River Street (East) TTC and Detour



Figure 38: Green River Street (West) TTC and Detour



Figure 39: Rock Springs Street TTC and Detour



Figure 40: Eastview Street TTC and Detour

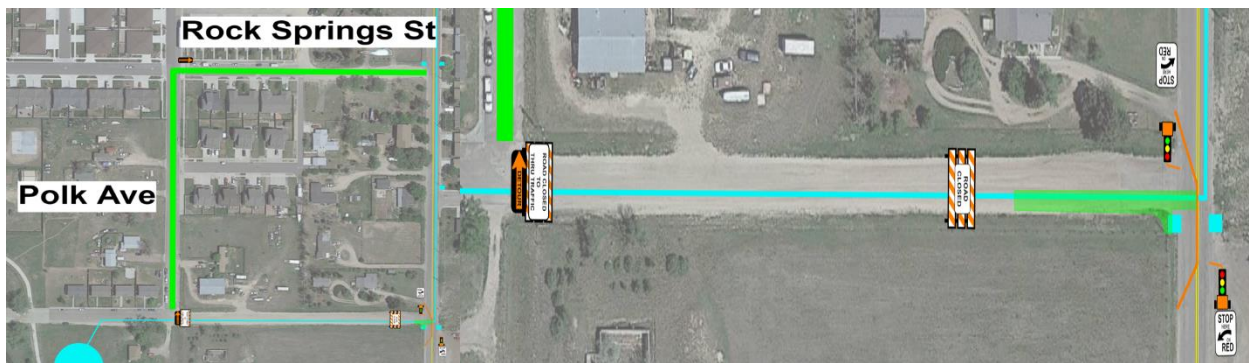


Figure 41: Rawlins Street TTC and Detour

For the remainder of Rawlins Street trenching, the typical TTC setup will be used as shown in Figure 42.



Figure 42: Rawlins Street TTC

During the paving portion of the project, the exact same traffic control set up will be used with some exceptions. A one-way flagger control operation will be used so no temporary traffic signals will be used. Additionally, all channelization devices used will be drums instead of concrete barriers. There will also be additional flaggers at each side street and approach within the paving area to assist traffic in and out of the work zone (AASHTO, 2018).

With the information available through the Cheyenne MPO database, the most recent traffic counts were recorded (City of Cheyenne, n.d.). This data can be found in Table 25. Along with the traffic count data, the Cheyenne MPO database also provides the most recent crash data for the area. Table 26 shows the available crash data for Dell Range, Van Buren, and Rawlins (City of Cheyenne, 2022).

Table 25: Traffic Counts

	Dell Range	Van Buren	Rawlins
AADT (veh/day)	9290	1744	146
Growth Factor (%)	5	3	3
Classification	Principal Arterial	Major Collector	Minor Collector

Table 26: Crash Data (2019-2020)

Crash Cause	Speed	Alcohol	Roadway Characteristics
Dell Range	2	0	0
Van Buren	2	1	0
Rawlins	0	0	0

Based on the crash data, all incidents within the work area and the chosen detour routes were due to human error. Therefore, no additional precautions will need to be implemented during construction.

### Roads & Sections

Proposed cross sections were developed for each roadway using Civil 3D software (Version 2022; Autodesk, 2022). All roadways will maintain a 2% cross slope to promote drainage (City of Cheyenne, 2012). Beginning at station 1+00 to station 4+23, Rawlins Street has a paved section that will be partially reconstructed as shown in Figure 43.

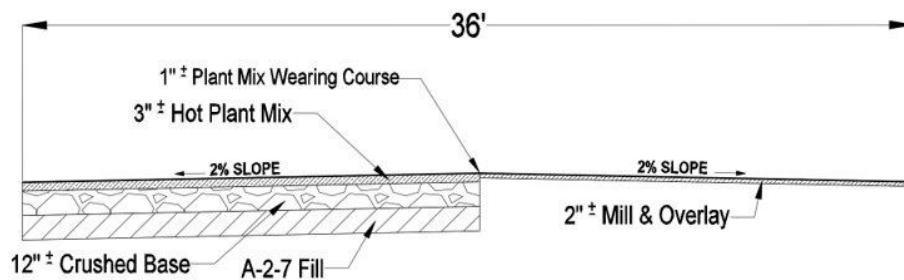


Figure 43: Rawlins Cross Section (Sta: 1+00 to Sta: 4+23)

The remaining section of Rawlins Street is not currently paved. This will result in a full reconstruction; a proposed cross section of this reconstruction can be found in Figure 44.

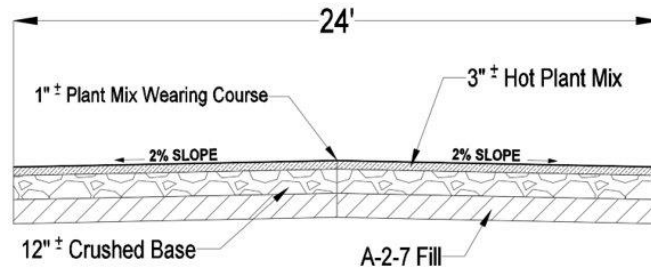


Figure 44: Rawlins Cross Section (Sta: 4+23 to Sta: 10+45)

Next, Van Buren Avenue has a consistent cross section throughout. Existing curb and gutter as well as sidewalk will be replaced if needed. Additionally, there are three sections throughout Van Buren that will have sidewalk with curb and gutter added. All concrete work will be explored further in the Pavement & Concrete Design section. A proposed cross section of Van Buren can be found in Figure 45.

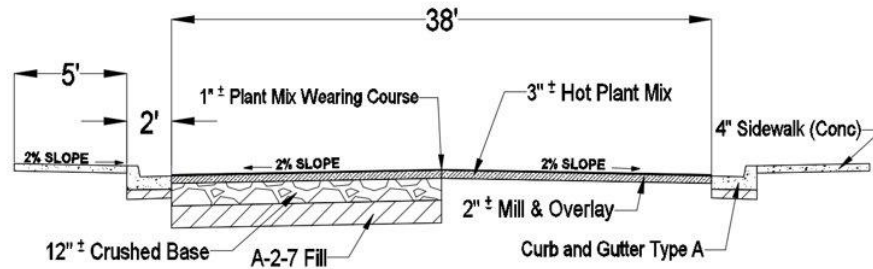


Figure 45: Van Buren Cross Section (Sta: 10+45 to Sta: 36+41)

Finally, Dell Range Boulevard has two different cross sections due to the varying widths. The initial section is composed of two drive lanes, two shoulders, and a left turn lane. This proposed cross section is shown in Figure 46.

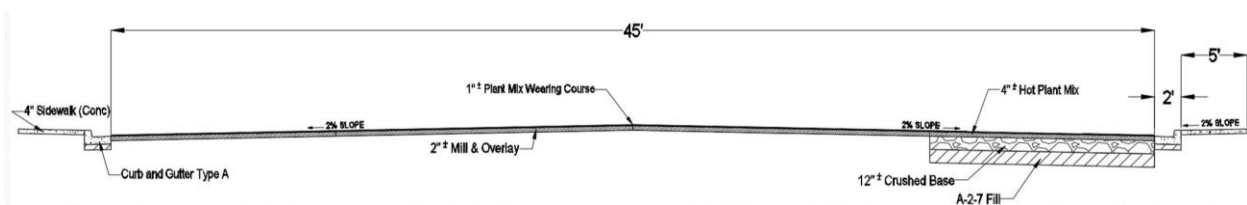


Figure 46: Dell Range Cross Section (Sta: 36+41 to Sta: 48+21)

The final section of Dell Range does not include a turn lane, so the roadway is much narrower. In addition, the current roadway doesn't include sidewalks or curbs and gutters. The reconstructed section will include these elements on the North side of Dell Range. This will allow encouraged foot traffic for the proposed development area North of Dell Range.

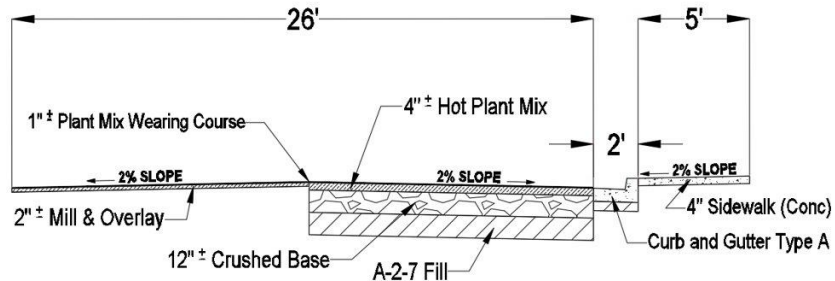


Figure 47: Dell Range Cross Section (Sta: 51+18 to Sta: 59+15)

### Pavement & Concrete Design

The pavement thickness was determined using the Mechanistic Empirical Pavement Design Guide (Federal Highway Administration, 1995). Traffic volumes and roadway classifications from above were used for the traffic input for the program as well as the growth rates. Additionally, to reduce construction times, the same mix design will be used for both the plant mix wearing course and hot plant mix on all streets. The wearing course will use oil PG 70-28 and the hot plant mix will use oil PG 58-22 (Asphalt Paving Association, n.d.). Another parameter needed for this program is climate data. The closest climate station in the program is in Bosler, Wyoming; therefore, this location will be used to simulate climate conditions in Cheyenne. Finally, 12" of W graded base will be placed beneath each roadway to assist with load distribution as well as subsurface drainage. The department of transportation in Wyoming performed a study at various aggregate pits around the state. One of the pits analyzed included Simon's Pit which is the closest aggregate pit to Cheyenne (WYDOT, 2022). This study showed that at an optimum moisture content of 6.4% for Simon's W base, the resilient modulus is 26826 pounds per square inch. This value will also be used in the MEPDG software (Version 2022; Federal Highway Administration, 2022). Finally, a design life of 10 years will be used for all roadways. Figure 48, Figure 49, and Figure 50 show the output reports from the MEPDG for each roadway in design (Federal Highway Administration, 2020).

Design Inputs					
Design Life:	10 years	Base construction:	May, 2023	Climate Data	41.5, -105.625
Design Type:	FLEXIBLE	Pavement construction:	September, 2023	Sources (Lat/Lon)	
		Traffic opening:	September, 2023		

Design Structure			Traffic			
Layer type	Material Type	Thickness (in)	Volumetric at Construction:		Age (year)	Heavy Trucks (cumulative)
Flexible	Default asphalt concrete	1.0	Effective binder content (%)	7.0	2023 (initial)	9,290
Flexible	Default asphalt concrete	4.0	Air voids (%)	5.0	2028 (5 years)	9,331,220
NonStabilized	Crushed stone	12.0			2033 (10 years)	20,783,200
Subgrade	A-2-7	Semi-infinite				

Design Outputs					
Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	121.16	90.00	100.00	Pass
Permanent deformation - total pavement (in)	0.50	0.39	90.00	99.86	Pass
AC bottom-up fatigue cracking (% lane area)	20.00	9.26	90.00	99.87	Pass
AC thermal cracking (ft/mile)	700.00	217.25	90.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	12.10	90.00	99.99	Pass
Permanent deformation - AC only (in)	0.25	0.12	90.00	100.00	Pass

Figure 48: Dell Range Pavement Design Report

Design Inputs					
Design Life:	10 years	Base construction:	May, 2023	Climate Data	41.5, -105.625
Design Type:	FLEXIBLE	Pavement construction:	September, 2023	Sources (Lat/Lon)	
		Traffic opening:	September, 2023		

Design Structure			Traffic			
Layer type	Material Type	Thickness (in)	Volumetric at Construction:		Age (year)	Heavy Trucks (cumulative)
Flexible	Default asphalt concrete	1.0	Effective binder content (%)	7.0	2023 (initial)	1,744
Flexible	Default asphalt concrete	3.0	Air voids (%)	5.0	2028 (5 years)	1,603,640
NonStabilized	Crushed stone	12.0			2033 (10 years)	3,434,200
Subgrade	A-2-7	Semi-infinite				

Design Outputs					
Distress Prediction Summary					
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	200.00	107.23	80.00	100.00	Pass
Permanent deformation - total pavement (in)	0.65	0.30	80.00	100.00	Pass
AC bottom-up fatigue cracking (% lane area)	35.00	0.99	80.00	100.00	Pass
AC thermal cracking (ft/mile)	700.00	144.28	80.00	100.00	Pass
AC top-down fatigue cracking (% lane area)	25.00	9.59	80.00	99.99	Pass
Permanent deformation - AC only (in)	0.25	0.07	80.00	100.00	Pass

Figure 49: Van Buren Pavement Design Report

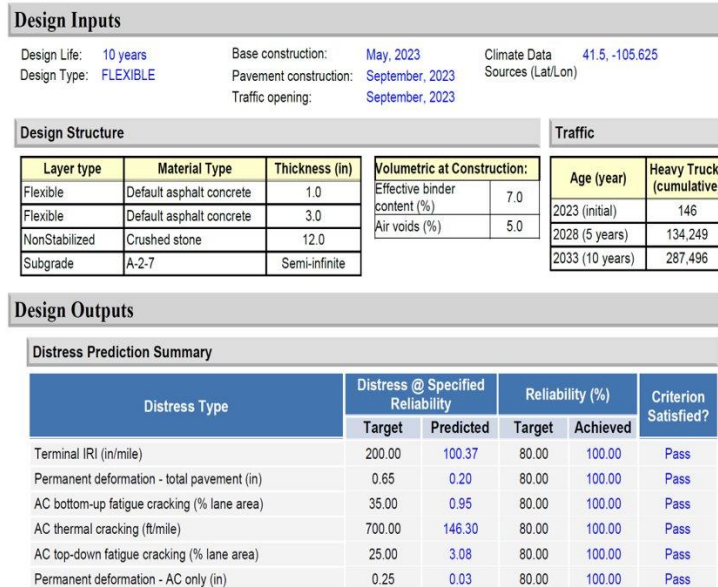


Figure 50: Rawlins Pavement Design Report

A trial-and-error technique was used to determine satisfactory asphalt thickness. The minimum asphalt thicknesses were initially tested for the corresponding roadway class for Dell Range, Van Buren, and Rawlins. These minimum thicknesses are 4, 3 and 3 inches, respectively. The selected minimum thicknesses resulted in a pass for the input conditions. The MEPDG software performs various calculations for failures such as terminal international roughness index, pavement deformation, bottom-up fatigue cracking, thermal cracking, and top-down fatigue cracking (Version 2022; Federal Highway Administration, 2022). These failures are tested for the duration of the design life and if there is no failure occurring, the “Criterion Satisfied” column will display “Pass” as shown in the three figures above.

The existing pavement conditions were assessed for Dell Range, Van Buren, and Rawlins. Currently, there is some transverse cracking on Dell Range due to shrinkage. The state of the roadway on Van Buren is very poor possibly from being past the pavement service life. The paved section of Rawlins is in a similar condition as Van Buren. Based on these conditions, a 2” mill and overlay will be performed on the sections of roadway that aren’t excavated.

Using Civil 3D, the estimated asphalt quantity was determined (Version 2022, Autodesk, 2022). Using a unit weight of 150 pounds per cubic foot for both the plant mix wearing course and hot plant mix, it was determined that 1,244 tons of plant mix wearing course and 3,247 tons of hot plant mix will be needed.

Class A concrete will be used for all concrete work on the project. Based on site visits and online map analysis, approximately 10% of existing curbs, gutters, and sidewalks will be replaced due to poor condition (Version 3.48, Google, 2020). This results in approximately 565 feet of replacement. Additionally, 12 of the crosswalk ramps on the project are not ADA compliant. Detectable warning surfaces will need to be installed. An example of this device is shown in Figure 51.

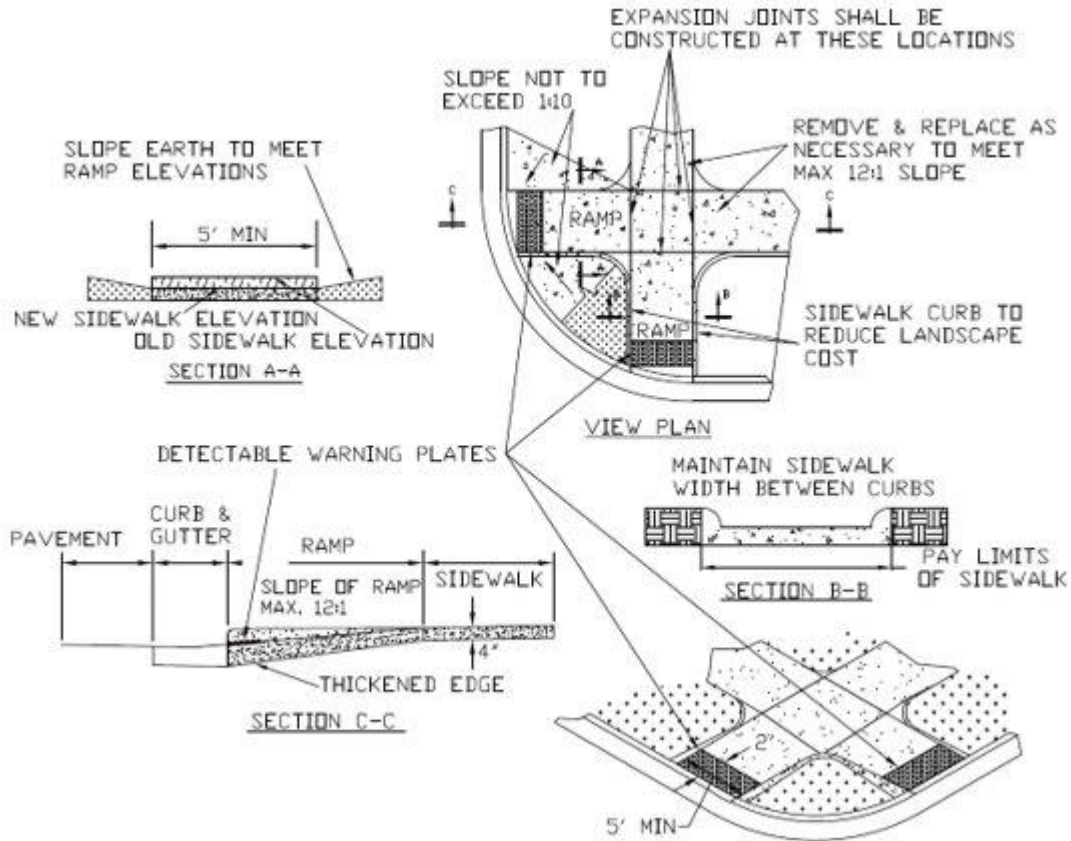


Figure 51: Detectable Warning Surface

Sidewalks with curbs and gutters will need to be added to accommodate the new inlets. Type A curb and gutter, shown in Figure 52, will be used as per City of Cheyenne specs (City of Cheyenne, 2012). The new sidewalk will be five feet wide and four inches thick. The sidewalk will also be sloped longitudinally at 2% into the curb and gutter for drainage (City of Cheyenne, 2012). A total of 2,542 feet of each will be added. This results in 156.67 cubic yards of sidewalk and 133.96 cubic yards of curb and gutter. The locations of added concrete are depicted by red lines in Figure 53.

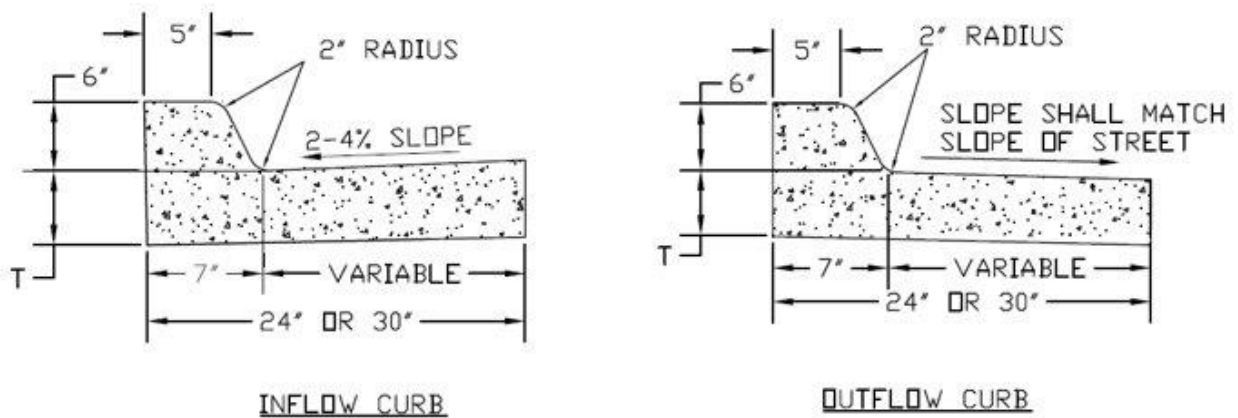


Figure 52: Type A Curb and Gutter



Figure 53: Locations of Added Concrete

### Pavement Striping Plan

Dell Range varies in width due to the two-lane transitioning to a two-lane roadway with a turning lane. Figure 54 and Figure 55 below show the proposed striping plan for Dell Range.



Figure 54: Dell Range Striping Plan (2 Lane & Transition)



Figure 55: Dell Range Striping Plan (3 Lane)

The two-lane portion of Dell Range will include a continuous 4 inch double yellow line. Within the transition zone, a 120-foot transition taper will be added in the Eastbound Lane. The striping for this section will include a 4-inch yellow line with a 4-inch broken yellow line. The broken line will consist of 10-foot lengths and 30-foot gaps. The left turn lane will be separated from the drive lane by an 8-inch solid white line. The longitudinal stop bar will be 12 inches thick and placed 4 feet from the intersection. Figure 56 shows the existing striping plan for Van Buren. Currently, Van Buren has two 11-foot drive lanes and two 8-foot park lanes. A road diet adjustment will be made for the striping on this roadway. Due to future urbanization in the area as well as the school location on Van Buren, this roadway shall be adjusted to accommodate bike traffic. The road diet adjustment can be shown in Figure 57. This striping plan includes two 10-foot drive lanes, two 5-foot bike lanes, and one 8-foot park lane on the East side of Van Buren. The park lane on the West side of Van Buren was found to be unnecessary due to the dedicated parking lots for the school and church, therefore, it will be removed.



Figure 56: Van Buren Existing Striping Plan

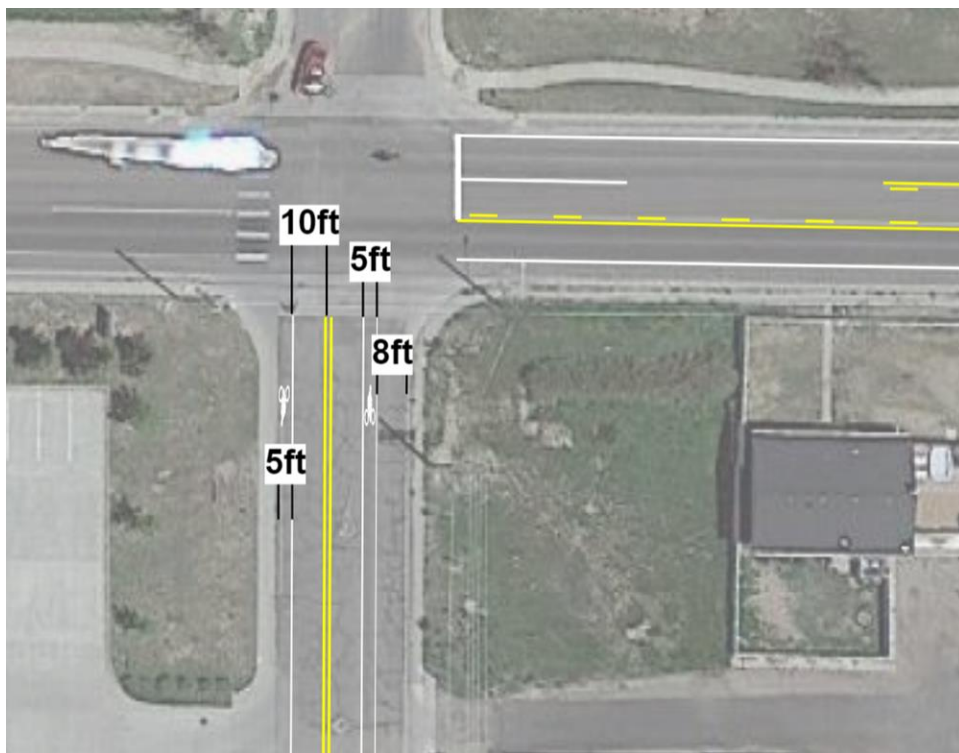


Figure 57: Van Buren Proposed Striping Plan

## Summary

The above report will be Wasted Potential LLC.'s approach to this project. Wasted Potential is one company, one team, with 4 divisions: hydrology, transportation, geotechnical, and project management.

The minimum milestones for design work in geotechnical, transportation, and hydrology have all been accomplished through the Final minimum milestones shown in Figure 2. What each team will be working on in the future is shown in Table 27

*Table 27: 100% Design Focus*

Transportation	Geotechnical	Hydrology	Project Management
<ul style="list-style-type: none"> <li>• TTC Design</li> <li>• Roadway Pavement Design</li> <li>• Roadway Drainage</li> </ul>	<ul style="list-style-type: none"> <li>• Cut and Fill Totals</li> <li>• Roadway Substrate</li> <li>• Final Trenching and Compaction Design</li> </ul>	<ul style="list-style-type: none"> <li>• NE Detention Pond</li> <li>• Extended Detention Basin</li> <li>• Pipeline Design</li> </ul>	<ul style="list-style-type: none"> <li>• Coordination efforts</li> <li>• File Management</li> <li>• Weekly update meeting</li> <li>• CE 4010 HW</li> </ul>

As the project is finalized, we will keep the city council, city planning office, city engineering office, and all others with vested interest informed.

We hope you will find our quality of engineering work as well as our company's vision to fit well with what you are looking for in this project. If you have any questions, please do not hesitate to contact Wasted Potential LLC.

## References

- Asphalt Paving Association. (n.d.). *Scapa Design Guide*. Retrieved April 13, 2022, from [https://www.scasphalt.org/uploads/5/6/3/8/56382339/scapa\\_design\\_guide\\_3rd\\_edition\\_\\_6-30-20\\_.pdf](https://www.scasphalt.org/uploads/5/6/3/8/56382339/scapa_design_guide_3rd_edition__6-30-20_.pdf)
- Autodesk. (2022). *Civil 3DVersion (2022)*.
- AASHTO. (2018). *Policy on geometric design of highways and streets (7th edition)*. American Association of State Highway and Transportation Officials.
- City of Cheyenne. (n.d.). *City of Cheyenne - Traffic*. City of Cheyenne. Retrieved March 23, 2022, from <https://www.cheyennecity.org/Your-Government/Departments/Public-Works/Traffic>
- City of Cheyenne. (2012, January 23). *Unified Development Code - Cheyenne*. Unified Development Code. Retrieved March 23, 2022, from [https://www.cheyennecity.org/files/sharedassets/public/departmentsplanningdevelopment/udc\\_2019-1\\_web\\_201910091215564793.pdf](https://www.cheyennecity.org/files/sharedassets/public/departmentsplanningdevelopment/udc_2019-1_web_201910091215564793.pdf)
- City of Cheyenne. (2022, April 11). *Data & Maps*. Cheyenne MPO. Retrieved April 13, 2022, from <https://www.plancheyenne.org/data/>
- Cvar, A. (2022, February). *Senior Design - Cad Pipeline Design. C.E. 4090*. Laramie, WY; Online.
- Cvar, A. (2022, February). *Senior Design - Drainage Basin Area. C.E. 4090*. Laramie, WY; Online.
- Cvar, A. (2022, February). *Senior Design - Drainage Inlet Design. C.E. 4090*. Laramie, WY; Online.
- Cvar, A. (2022, March). *Senior Design - Cad Cut and Fills. C.E. 4090*. Laramie, WY; Online.
- Cvar, A. (2022, March). *Senior Design - Detention Pond Design. C.E. 4090*. Laramie, WY; Online.
- OSHA. (2015). *Trenching and excavation safety - occupational safety and ...* Trenching and Excavation Safety. Retrieved March 23, 2022, from <https://www.osha.gov/sites/default/files/publications/osha2226.pdf>
- Ekka, S. A., Rujner, H., Leonhardt, G., Blecken, G.-T., Viklander, M., & Hunt, W. F. (2020, December 23). *Next Generation Swale Design for stormwater runoff treatment: A comprehensive approach*. *Journal of Environmental Management*. Retrieved April 13, 2022, from <https://www.sciencedirect.com/science/article/pii/S0301479720316819>
- EPA. (2022, February 1). *Storm Water Management Model (SWMM) Version (5.2.0)*.
- Fabricus, A., & Ohara, N. (2022, March 9). *Design of Swale*. personal.
- Federal Highway Administration, & U.S. Department of Transportation. (1995, February). *Comprehensive Truck Size and Weight Study*. Retrieved April 13, 2022, from <https://www.fhwa.dot.gov/reports/tswstudy/TSWwp3.pdf>

- Federal Highway Administration. (2020). *Pavements - federal highway administration - fhwa.dot.gov*. Retrieved April 13, 2022, from <https://fhwa.dot.gov/pavement%20/materials/materialsummary.cfm>
- Federal Highway Administration. (January, 2022). *Asphalt Design Criteria*. Version 2022.
- Lindeberg, A., & Bowels, J. (1975, May 1). Soil properties influencing swelling in Canfield ... - wiley online library. *Soil Properties Influencing Swelling in Canfield and Geeburg Soils*. Retrieved May 9, 2022, from <https://access.onlinelibrary.wiley.com/doi/abs/10.2136/sssaj1975.03615995003900030034x>
- Google. (May, 2020). *Google Earth*. Version 3.48
- OSHA. (2015). *Trenching and excavation safety*. *Trenching and Excavation Safety*. Retrieved May 9, 2022, from <https://www.osha.gov/sites/default/files/publications/osha2226.pdf>
- Roberson, J. A., Cassidy, J. J., & Chaudhry, M. H. (1998). *Hydraulic engineering*. Wiley.
- State of Alabama. (n.d.). *RIP-Rap Classification Specifications*. *Rip-Rap Classification Specifications*. Retrieved April 13, 2022, from [https://surface-mining.alabama.gov/p3962r2/data/attachments/riprap\\_specs.pdf](https://surface-mining.alabama.gov/p3962r2/data/attachments/riprap_specs.pdf)
- Trench Shoring Company. (2022). *Steel Trench Shields & Manhole Boxes*. *Steel Trench Shields & Manhole Boxes - Trench Shoring Company - Shoring, Trench Shoring Equipment, Trench Safety*. Retrieved April 13, 2022, from <https://www.trenchshoring.com/trench-safety-equipment/trench-manhole-boxes>
- WYDOT. (2022, January). *WYDOT Road Design Reference Manual*. *Manuals and publications*. Retrieved March 23, 2022, from [https://www.dot.state.wy.us/home/engineering\\_technical\\_programs/manuals\\_publications.html](https://www.dot.state.wy.us/home/engineering_technical_programs/manuals_publications.html)

### Appendix A

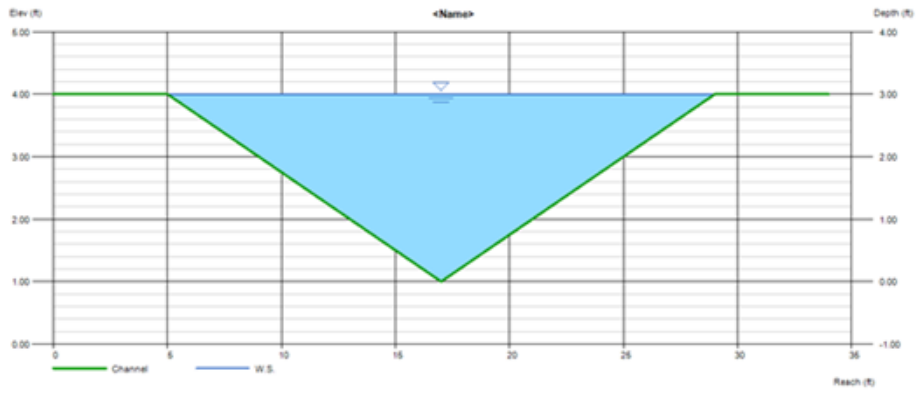


Figure 58: Typical Open Channel Cross Section of NE Basin

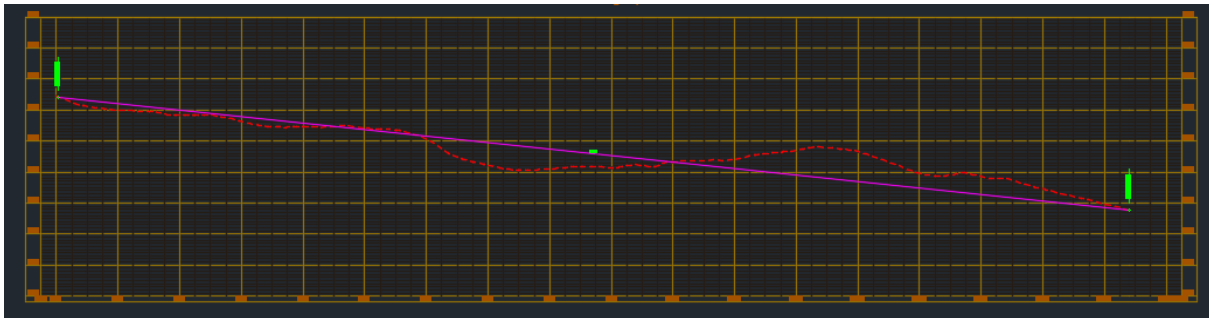


Figure 59: Open Channel Profile of NE Basin



Figure 60: Pipeline Horizontal Profile

Appendix B

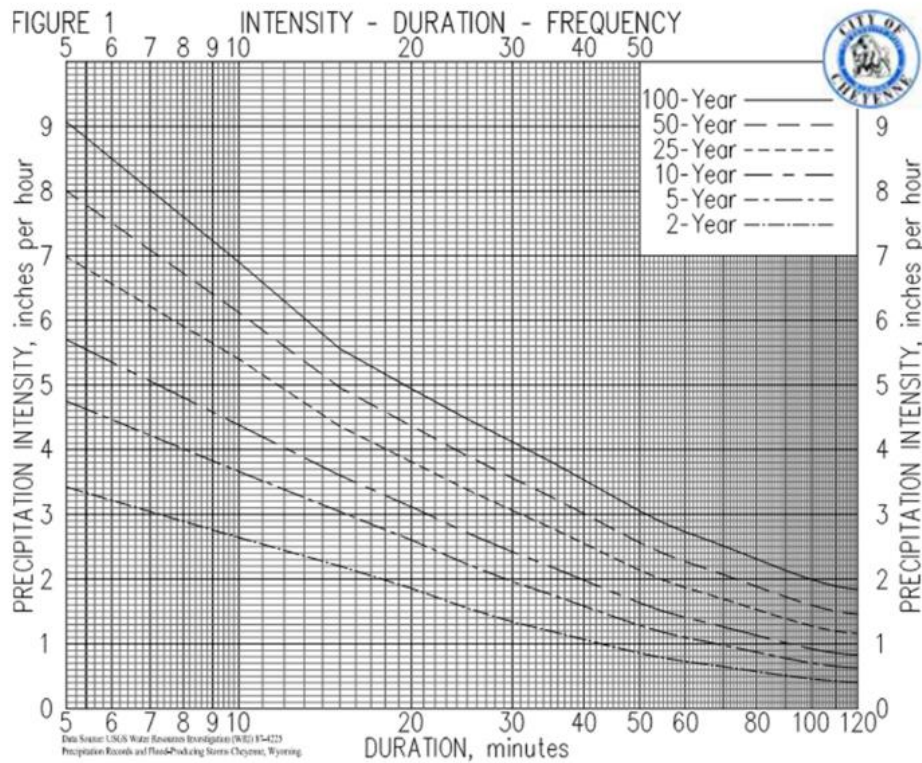


Figure 61: IDF Curves

$$T = \left( \frac{l}{180} \right) + 10$$

Equation 8: Time of Concentration

Where,

L = The longest distance for water to travel for each basin.

$$WQCV = a(0.91I^3 - 1.19I^2 + 0.78I)$$

Equation 9: WQVC Equation

Where,

I = Storm Intensity

UNIVERSITY OF WYOMING  
COLLEGE OF ENGINEERING AND APPLIED SCIENCE

Name: Senior Design

Date: \_\_\_\_\_ Class: \_\_\_\_\_ Assignment: Dell Range Examples

**Taper Lengths:**

$$\text{Merging taper length } (L) = \frac{WS^2}{60}$$

For Dell Range  $S = 35 \text{ mph}$ ,  $W = 12 \text{ ft}$

$$L = \frac{(12 \text{ ft})(35 \text{ mph})^2}{60} \Rightarrow L = 245 \text{ ft}$$

Shifting taper lengths  $(L_s) = 0.5L$

$$L_s = 0.5(245 \text{ ft}) = 122.5 \Rightarrow L_s = 125 \text{ ft}$$

**Directional Design Hour Volume:**

$$DDHV = ADT \cdot K \cdot D$$

For Dell Range East Approach  $ADT = 12716 \text{ veh/day}$

For Urban Area  $K = 0.09$ ,  $D = 0.60$

$$DDHV = (12716 \text{ veh/day})(0.09)(0.60) \Rightarrow DDHV = 687 \text{ veh/hr}$$

**Design Equivalent Axle Load:**

$$\text{Average annual traffic} = ADT \cdot 365 = (12716 \text{ veh/day}) \cdot 365$$

$$\text{Average annual traffic} = 2847000 \text{ veh/yr}$$

Dell Range Truck Factor & Distribution of Trucks (Growth Rate = 12.58)

Single Unit	Truck Factor	Distribution of Trucks	EAL
2-axle, 4 tire	0.002	0.67	47992.45
2-axle, 6 tire	0.24	0.15	1889349
3 axle or more	1.02	0.03	1095947
Multiple Unit			
4 axle or less	0.71	0.03	762865
5 axle	0.97	0.12	4168896
6 axle or more	0.91	0	0
Total			$7.37 \times 10^6$

Ex: (2-axle, 4 tire):  $(2847000 \text{ veh/yr})(12.58)(0.002)(0.67) \Rightarrow EAL = 47992.45$

Figure 62: Taper Length Hand Calculations