NORTHERN ARIZONA UNIVERSITY

College of Engineering, Forestry, and Natural Sciences

CENE - 486C Engineering Design

RYAN'S TRAIL ROAD REDESIGN

Coconino County, Flagstaff, Arizona

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1.0 Project Introduction

1.1 Problem Statement

The residents of Lockett Ranches requested a feasibility analysis for Ryan's Trail to determine different roadway improvement alternatives. The client additionally requested the development of construction plans for an asphalt road on Ryan's Trail, for potential future installment.

Photo by: McKenzie Moten

Figure 1: Ryan's Trail South-bound

1.2 Deliverables

The Ryan's Trail Capstone Team performed a feasibility analysis of several roadway improvement materials for a private, quarter-mile, and unpaved roadway. The analysis addresses the capital costs, operations and maintenance costs, and salvage costs while analyzed over a 20-year life cycle for three different alternatives. The team additionally developed construction plans for an asphalt road improvement, including a hydrology and hydraulics analysis of the site in suitable programs to determine proper drainage.

2.0 Project Analysis

2.1 Project Location

Ryan’s Trail is located northwest of Flagstaff city limits, in Coconino County [Figure 2]. The road is within the residential community development Lockett Ranches. Ryan’s Trail is east off of Hattie Greene Road, after following Quintana Drive from North Fort Valley Road [Figure 3].

Figure 2: Location of Flagstaff, Arizona [1]

Figure 3: Location of Ryan’s Trail North of Flagstaff [1]

2.2 Existing Conditions

The road currently consists of mostly exposed loam soil, with a combination of crushed cinders and gravel on top [Figures 4 and 5]. The maximum amount of gravel, cinders, or a combination of the two at any point on the trail is no more than six inches in depth. The consistency of the materials are not equal across the area of the road surface, and potholes are commonly created.

2.2.1 Existing Materials

There are five residential homes that access Ryan's Trail. The major traffic on the road consists of personal vehicles, pedestrians, and bicyclists. The road is 1,420 feet in length, with a 21,000-square foot area, and an average road width varying between twelve to sixteen feet.

Figure 4: Current Cinder Roadway Material

Figure 5: Current Loam and Soil Roadway Material

2.2.2 Existing Utilities

The existing utilities under Ryan's Trail include gas, water, electric, and cable. The water on the site is pulled from a residential well system that is directed off of N. Wildcat Trail. Blue Stake was contracted to professionally call out the utilities to prevent incidents such as gas leaks or other damages. By identifying the utilities, the team was able to accurately add these features to the mapped road, as well as design around the existing as-builts. The Blue Stake results can be seen in Figure 6.

Figure 6: Blue Stake Results [2]

2.3 Feasibility Analysis

The feasibility analysis presented below is the result of bringing all values to the present worth of cost (PWOC). This includes initial construction costs, operation and maintenance costs and salvage values of the three analyzed materials. The service life of the analysis was 20 years, which was the longest service life of the analyzed alternatives, belonging to asphalt. Three percent was the professionally chosen compound interest factor for the life-cycle cost analysis. The material alternatives were chosen based on professional engineering advice, client preferences, background research, and the existing conditions of the site. These alternatives are aggregate base, gravel, and asphalt as described in further detail in the sections below.

2.3.1 Alternative 1 - Aggregate Base

The first alternative we proposed wass an improved dirt road. The road section consists of a six-inch aggregate base material compacted to 95% [Figure 7]. This material would require maintenance every one to two years. The non-monetary benefits of this alternative are that it is a non-intrusive material and has a rural appearance. However, it can cause a significant amount of dust, potholes are created easily, and if maintenance is neglected the service life will become extremely short.

Drawing by: Trevor Snipes

Figure 7: Proposed Compacted Aggregate Base

The installation cost of dirt is approximately $21,000 because it is expensive to have it compacted and the installation requires a water truck on site for dust control. The operation and maintenance costs are composed of an annual minimal amount of dirt to be delivered, as well as delivery every other year of sufficient dirt to bring the road back up to grade and recompact. The salvage value of approximately $700 is the amount of material that the client would have after the project has been "retired" that she would be able to sell [Table 1].

Table 1: Cost Breakdown for AB Over 20 Year Span

Item	Cost ($)
Capital Costs	$20,900
Operation & Maintenance Costs	$7,195
Salvage Value	($730)
TOTAL	$27,365

As seen in Table 1, the total cost of aggregate is approximately $30,000, which is the cheapest project out of all of the considered alternatives.

2.3.2 Alternative 2 – Gravel

The second alternative proposed is a ⅜" crushed gravel driveway [Figure 8]. The gravel would be distributed on top of the compacted native material at two to four inches. This option would reduce dust, and improve the overall appearance, however there are negative impacts. An uneven surface is created easily and it requires frequent maintenance.

Drawing by: Trevor Snipes

Figure 8: Proposed Crushed Stone Section

The initial construction cost of installing gravel is nearly equivalent to that of dirt because it requires little to no compaction. It costs about $21,000 to maintain a gravel option. This is composed of an approximate $400 annual price for having more gravel delivered and about $10,000 to maintain every three years. The reason that this cost is significantly higher than the repair of the aggregate alternative is due to the complete removal of gravel from the road to repair the aggregate base before the repair of the gravel. The salvage Value is $3,946.

Table 2: Cost Breakdown for Gravel Over 20 Year Span

Item	Cost ($)
Capital Costs	$20,350
Operation & Maintenance Costs	$21,460
Salvage Value	$3,946
TOTAL	$37,864

The total cost of the gravel project is about $40,000. This is a more expensive option than aggregate alone, but is less expensive than asphalt by about $120,000.

2.3.3 Alternative 3 – Asphalt

The third proposed alternative is an asphalt driveway. This alternative consists of a three-inch asphaltic concrete layer over six inches of aggregate base course [Figure 9]. An asphalt driveway would make snow removal easier than the existing conditions, as well as offer a longer life than the other two alternatives. It increases home value, and allows all weather access. However, it is susceptible to cracking, requires annual inspections, and needs sealant every 5 years unlike the other options.

Drawing by: Trevor Snipes

Figure 9: Proposed A.C. Over Base Pavement Section

The construction cost of asphalt is about $100000. This is intensive process that requires heavy equipment. The operation and maintenance costs are composed of annual inspections that can be performed by the homeowner because Ryan's Trail is not owned by the city or county. It is also composed of the need for sealant every five years. The salvage value is significantly higher than the other options, however it is necessary to note that the while the material is more valuable, it must to be removed at the end of its service life unlike aggregate or gravel.

Table 3: Cost Breakdown for Asphalt Over 20 Year Span

Item	Cost ($)
Capital Costs	$108,000
Operation & Maintenance Costs	$81,982
Salvage Value	$30,452
TOTAL	$159,530

2.4 Summary of Costs

This section displays the total cost of each material alternative throughout a 20 year-lifespan, as shown in Table 4.

Table 4: Total Cost of Individual Alternatives Over 20 Year Span

Alternatives	Cost
Dirt	$27,365
Gravel	$37,864
Asphalt	$159,530

Asphalt is the most expensive, while the dirt alternative is the least expensive. Each alternative has its own non-monetary benefits as discussed in the previous discussions that the client may take into consideration.

3.0 Project Development

3.1 Design Criteria

The criteria of the asphalt roadway design were divided into requirements and goals. The requirements of the design included a cost effective design, durability of the roadway structure, and proper drainage with the addition of asphalt on the surface. The goals of the design were developed by the team members and include the ease of snow removal, the reduction in damage to vehicles and homes, and the suitability of the roadway for all vehicles, bicycles, and pedestrians.

3.2 Proposed Asphalt Installation

3.2.1 Road Typical Section

The road section shown in Figure 10 is implemented at the northerly end of Ryan's Trail from Station 0+00 to Station 3+66.91. There begins a twenty and a half foot transition from a twelve foot wide section, to a sixteen foot wide section as shown in Figure 11.

Figure 10: Typical 12' Road Section

Figure 11: Typical 16' Road Section

3.3 Proposed Roadway Analysis

Construction plans for an asphalt road installation at Ryan's Trail are included with this report. The plans follow the procedures and standards of the Coconino County Design and Construction Manual.

3.3.1 Road Quantities

Table 5 displays important quantities related to the construction of the project. Table 6 displays important items that are to be protected in place due to their proximity to the proposed construction.

Table 5: Quantities on Ryan's Trail Design

Item	Quantity
Asphaltic Concrete	190 CU YDS
Aggregate Base Course	380 CU YDS
Corrugated Metal Pipe (CMP)	36 LF
Cut	50 CU YDS
Fill	550 CU YDS

Table 6: Protect in Place Values for Ryan's Trail

Item	Quantity
Trees	18 EA
Water Valve	1 EA
Utility Boxes	3 EA

3.3.2 Site Hydrology

Proper analysis of the proposed designs was initiated by determining the difference in surface runoff prior to construction and post construction. The Coconino County Standards classify compacted A.B. as an impervious material, which required the use of the Rational Discharge Equation to determine the surface runoff [3]. By implementing specific runoff coefficients, intensities, and applying them over the area of Ryan's Trail the developed the values seen in Table 7. The difference between the before and after construction values are very minimal for the site area, and can be negated. To ensure the accuracy of the calculations, Bentley FlowMaster software was used to verify the surface flow over the areas and slopes of the site drainage paths.

$$Q = C*i*A$$

Equation 1: Rational Discharge Equation

Table 7: Pre- and Post Development Hydrology [3]

	Rational (50 year)	Rational (100 year)
Pre-Development	5.07 cfs	6.12 cfs
Post-Development	6.05 cfs	7.30 cfs

3.3.3 Culvert Analysis

The site was divided into four sub-basins to more accurately determine the surface runoff, after construction, through the seven culverts on the site. Because the culverts are not sequential to each other, it was necessary to analyze the drainage areas into specific culverts. Utilizing the 50-year and 100-year storm data, the culverts were individually analyzed using Bentley CulvertMaster software which provided the systems discharges, velocities, and slopes [4]. The analysis provided evidence that a new culvert was required to ensure proper drainage across the area. With this addition, the site will be able to manage the 50-year and 100-year storms efficiently. The location of the new proposed culvert will be at the northern end of the road, before the road roundabout. Note the construction plans for the proposed culvert positioning. Refer to Appendix for individual culvert analysis reports and rainfall intensities.

Table 8: 50-Year Storm Culvert Analysis

Culvert	**Discharge (cfs)**	**Slope (ft/ft)**	**Velocity (ft/s)**
1 Existing	0.34	0.037	2.80
1 Proposed	0.34	0.017	2.18
2	0.39	0.004	2.26
3	0.41	0.001	2.30
4	1.56	0.004	3.31
5	1.41	0.003	3.21
6	0.59	0.001	2.53
7	0.34	0.004	2.18

Table 9: 100-Year Storm Culvert Analysis

Culvert	**Discharge (cfs)**	**Slope (ft/ft)**	**Velocity (ft/s)**
1 Existing	0.41	0.037	2.96
1 Proposed	0.41	0.017	2.30
2	0.47	0.004	2.38
3	0.49	0.001	2.40
4	1.85	0.004	3.48
5	1.68	0.003	3.38
6	0.70	0.001	2.65
7	0.40	0.004	2.28

3.3.3.1 Proposed Culvert Detail

Below is the detailed proposed culvert design. This design developed is an 18-inch culvert beneath the three inches of asphalt concrete and 3 inches of aggregate base. The design was based on the knowledge of the existing culverts as well as the calculated culvert discharges and headwater levels.

Figure 12: Proposed Culvert Detail

4.0 Summary of Engineering Work

4.1 Staffing and Cost of Services

The project required five departments of engineering services, each with their respective pay rates and benefits percentages. The departments include the Project Manager, Design Engineer, Drafter, Survey Crew, and Technician. Initially, the project was estimated to require a total of 555 hours of work for a cost of $47,031. The project concluded with a total of 510 hours of work for a total cost of $45,487. The team initially overestimated the number of hours required to complete the project, primarily because of exaggerated timing for tasks. However, after reallocating the hours among the different departments per the actual time the tasks required, there was a reduction in cost of services and hours.

Table 10: Cost of Engineering Services and Staffing

4.2 Schedule

The schedule developed for the course of the project remained on-time for majority of the design process. There were specific issues that arose during the material analysis phase that caused the development of the feasibility analysis to be delayed. This did not majorly affect the progression of the project, but it did prevent the drafter from developing the most current set of construction plans. These minor delays affected the schedule and staffing, and the team had to work together to solve the problems professionally and ensure the project be completed on time. The team addressed these issues with professional aptitude, and completed the project on time.

Table 11: Tasks and Corresponding Start and End Dates

Task	**Start**	**Finish**
1.0 Site Investigation	1/19/2018	1/26/2018
2.0 Site Map	1/26/2018	2/02/2018
3.0 Conceptual Design	2/02/2018	2/22/2018
4.0 Hydrology/Hydraulics	2/22/2018	3/15/2018
5.0 Life Cycle Cost Analysis	3/15/2018	3/30/2018
6.0 Final Design	3/30/2018	4/25/2018
7.0 Project Management	1/19/2018	5/11/2018

5.0 Design Recommendations

5.1 Summary of Work

Based on the analysis performed, aggregate base is the cheapest initial option for the client. However, gravel has the most practical life-span based on the materials service life costs, as well as the durability of the material. Asphalt is the most expensive option, and the team analyzed the material costs to provide a reference point while comparing the material alternatives. The team performed the feasibility analysis of the three materials, as well as developed construction plans for a potential future installment of asphalt. Along with the construction plans of an asphalt road design, the team analyzed the drainage of the site. The area of Ryan's Trail is sufficient to handle both a 50-year and 100-year storm before and after the installation of asphalt. To improve the quality of the drainage on the site, the team recommends the addition of another culvert unit near the northern end of the road. This addition is in par with Coconino County Standards, as well as the engineering analysis of the Ryan's Trail Capstone Team. In total the project required 510 hours of work, with minimal schedule delays, and was completed to professional standards.

5.2 Future Work

With the completion of the design and analysis phases of the project, the future work is the implementation phase. This would require the developed construction plans be transferred to a professional engineer for approval. From there, the client may hire a contractor to complete the construction of the project, or the client may implement an alternative road material prior to the asphalt design installation.

6.0 References

[1] *Global Information System Arc Map*. ESRI, 2018.

[2] "Arizona 811 - Know whats below. Call or Click before you dig.", *Arizona 811*, 2018. [Online]. Available: http://www.azbluestake.com/. [Accessed: 27- Apr- 2018].

[3] Stormwater (Multi-Sector General Permit/MSGP) | City of Flagstaff Official Website. [Online]. Available: https://www.flagstaff.az.gov/3281/Industrial-Stormwater. [Accessed: 20-Mar-2018].

[4] Bentley CulvertMaster. (2009). Watertown, CT 06795 USA: Northern Arizona University FLA.

[5] Autodesk AutoCAD. (2018). Autodesk, Inc.

[6] Bentley FlowMaster V8i. (2009). Watertown, CT 06795 USA: Bentley Systems, Inc.

[7] U.S. Geological Survey (1988). Flood Hydrology Near Flagstaff, Arizona. 87-4210. Tucson, Arizona: City of Flagstaff, pp.10-24.

7.0 Appendix A- Culvert Related Data

[1] Northern Arizona Rainfall Intensities

[2] Culvert 1 (Existing), CulvertMaster Results Comparing 50-year data to 100-year data

[3] Culvert 1 (Proposed), CulvertMaster Results Comparing 50-year data to 100-year data

[4] Culvert 2, CulvertMaster Results Comparing 50-year data to 100-year data

[5] Culvert 3, CulvertMaster Results Comparing 50-year data to 100-year data

[6] Culvert 4, CulvertMaster Results Comparing 50-year data to 100-year data

[7] Culvert 5, CulvertMaster Results Comparing 50-year data to 100-year data

[8] Culvert 6, CulvertMaster Results Comparing 50-year data to 100-year data

[9] Culvert 7, CulvertMaster Results Comparing 50-year data to 100-year data

8.0 Appendix B- Cost Related Data and Hand Calculations

[1] Life Cycle Cost Analysis Hand Calculations for Asphalt

[2] Life Cycle Cost Analysis Hand Calculations for Gravel

[3] Life Cycle Cost Analysis Hand Calculations for Aggregate Base

[4] Life Cycle Cost Analysis Excel Spreadsheet Calculator