Clinton Iowa Trails:

Bikeable and Bike-friendly Trail

Project Manager: Kyler Hugg

Team Members: Bryan Chia, Ashton Johnson

IOWA

Civil and Environmental Engineering

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Section I: Executive Summary

Communities around the country are increasingly utilizing a "Trail Town" model for economic and public health revitalization. Clinton, located along the Mississippi River in East-Central Iowa, is one of many communities that are currently undergoing this overhaul. With a population of around 25,000, Clinton has changed its' focus to the betterment of community safety and the quality of its citizens lives. The installation of sustainable dedicated bike paths help provide transportation, recreational opportunities, and focus on improvement for community connectivity. The City of Clinton has, over the last few years, made strides to create a more bikeable and bike-friendly community, with several trail projects already complete and a handful more already in the design process.

A multi-phase trail project is proposed to expand upon an existing trail system and connect Lincoln Way (US Route 30) to South Ninth Street along the western edge of Clinton's busy downtown district. Refer to *Figure 1* in Appendix 1 for the general location of this project. Upon approval, sections of the existing railway will be decommissioned, removed, and restored back to nature in addition with the new bikeway installation. The following is a project breakdown for each key factor in our proposal.

1. *Construct approximately 2 miles of new sustainable trail*
2. *Remove approximately 1.04 miles of decommissioned railway*
3. *Convert approximately 2,000 linear feet of existing roadway to include bikeway*
4. *Design of trail crossing over tributary creek*
5. *Construct new trailhead utilities and public facilities*
6. *Provide public safety features along trail network*

The prominent portion of this project is the "rails-to-trails" configuration, converting the 1.04 miles of preexisting railway to bikeway. Due to this conversion, we are not expecting any negative impacts on sensitive plant or wildlife habitat with this segment. The conversion of road along Lincoln Boulevard, see *Figure 2,* will include a redesign of the road network to allot for the inclusion of bikeable lanes. Our proposal is to remove on-street parking from the northeast bound lane and dedicate this exclusion to multiple-direction bikeways. The next significant feature for consideration is the design selection for the Mill Creek trail bridge. This structure will progress travelers from the south side of a tributary to Mills Creek to the north before intersecting 14th Street. Refer to *Figure 3* for the general location of the crossing.

The eminent statistic when considering a new bike trail design is safety. A total of 932 bicyclists in the United States were killed in crashes with motor vehicles in 2020 (Insurance Institute for Highway Safety, May 2022). Refer to *Figure 4* for statistical data. In order to forgo public and biker safety we have proposed multiple features within our design. Foremost, all roads and pedestrian crossings shall be compliant with SUDAS (Iowa Statewide Urban Design and Specifications) standards. Also, adequate light sources are to be constructed along the trail to promote a safe environment for after dark travelers. Trailhead facilities are also included in the consideration of public safety. We propose public parking, bike utilities and tools, as well as public restrooms and map locations to also be designed with public safety in mind. In order to achieve these means, lighting will be a necessity at these locations.

With the help of the City of Clinton, and outsourcing property data from Beacon Schneider, the entirety of the corridor we are proposing is encompassed by city owned property. Therefore, no financial implications are derived from the necessity to purchase additional parcels for trail construction. Since the property is city owned, financial focus can be outsourced to the more prominent trail features. The bulk of this cost is in rail removal, grading, and PCC concrete. A total cost estimation for the Clinton Trail is approximated to be $1.31 Million. Removing the 1.04 miles of railway will be an incentive for construction compensation. The length of rail, 1.04 miles, at the steel scrap price of $0.15 to $0.28 per pound would reimburse the construction at an average price of $95,000.

Our final portion of the proposal is designated to the trailhead facility as well as construct a bridge over a tributary creek. Our trailhead facility will include adequate parking, restrooms, bike repair tools, proper light fixtures, and trail map locations. The bike trail bridge will be constructed offsite as a precast bridge, selected by the City of Clinton, and placed on site where the abutments will be already in place. Trailhead facilities will be proposed to accommodate for a maximum of 40 parking spaces. Additionally, supplemental features will include bicycle plazas, trash collection bins, lighting, and the trail head facility building. This building will accommodate toilets (flush or non-flush), information boards, and resting benches. The bridge, placed nearly a half-mile from the beginning of the trail, will provide a crossing for users over a tributary to Mills Creek. The prefabricated bridge will be approximately 45-feet in length and will feature a simple steel truss design with a concrete deck floor.

With this trail design, suggested phasing of the trail is included to allow the project to be done in various pieces, should funding require doing so. This will aid in the cost of the project to span out the expenditures over a period of time specified by the city. The trail is split into three main segments according to priority of importance determined by the design team. Each segment will be constructed with a 10-foot width of Portland Cement Concrete, or PCC paved at a 6" depth. 2-foot unpaved shoulders will also be constructed on each side of the trail to provide a safety buffer for trail users.

The first phase includes the entirety of the length of trail. The trail begins at Lincoln Way (US Route 30) and will follow a previously constructed levee to the east of Mill Creek. The trail will break away from the levee and follow a property line shared with the City of Clinton and Legend's Sports Bar before turning to parallel South 21st Street. The trail will make an at-grade crossing with a semi-active railroad line and shortly following, an intersection at South 21st Street. The trail then follows an existing dormant railroad bed to the Northeast, before crossing an at-grade intersection with South 19th Street and continuing to the northeast. Approximately 0.5 miles following the intersection with South 19th Street, a 45-foot trail bridge will be constructed over a tributary creek to allow for trail crossings over the creek bed. The trail continues to the northeast, crosses South 14th Street at-grade, and continues along the tributary creek until the segment ends at a 5-way intersection with Lincoln Boulevard, 11th Avenue South, and South 12th Street. A roadway sharing design will follow Lincoln Boulevard to the northeast along the southern edge of the roadway. This design will remove mildly used parking spaces and create a shared-use lane. As the trail reaches the intersection with Lincoln Boulevard and South 10th Street, it will follow an existing sidewalk path along the eastern edge of South 10th Street and follow the sidewalk to the northeast and end at the intersection of 8th Avenue South and South 9th Street, adjacent to the Clinton Community College.

The first phase will include constructing a trail-head facility and accompanying amenities. The facility will include two ADA compliant restrooms. These restrooms will feature hot water fed from a water heater in an attached utility room. The building will also be attached to nearby sewer systems. Amenities for the trailhead facility will include a bicycle repair station, as well as informational kiosks and bike racks. An unpaved parking lot, in sharing with Legend's Sports Bar, will be regraded to provide parking space for users of the trail.

A second phase will involve paving a parking lot surrounding the trailhead facility. This new paved lot will provide a visual separation from the Legend's parking lot and to provide a smoother path to the trail. The parking lot is designed to be approximately   square feet in size to accommodate adequate parking spaces.

A third phase focuses on the separation of the roadway and trail in the section of the shared roadway alignment along Lincoln Boulevard. Hashed paint markings will be placed with spacing as defined by the Highway Administration. Removable bollards will also be placed 15 feet apart to provide extra safety between the trail users and nearby vehicular traffic.

A fourth and final phase will reconstruct 10-foot width sections in locations where the trailway makes at-grade crossings with roadways. These crossings will be constructed using stamped concrete at the depth of the roadway to provide a visual crossing alert for both the roadway and trail. The total cost of all phases designed for the Clinton trails is estimated to be approximately $1.22 Million. The phases as described above have been selected to assist in offsetting the burden of the cost all at once.

Section II: Organization Qualifications and Experience

We are a team of Civil Engineering students from The University of Iowa. Our focus areas are transportation and management. Our team is comprised of three members: Kyler Hugg, Bryan Chia, and Ashton Johnson. In this project, a considerable amount of work focuses on the area of transportation by converting the rails to trails. Additionally, the conversion of current road networks allow for the designation of bikeways in tandem with traffic.

Kyler has had ample experience working with a private firm located in Southeast Iowa for 3 and a half years. His work experience has encompassed a few sectors of civil engineering. From the extensive variety of civil engineering projects, he has been involved in road design and construction, trail design and construction, watermain construction, site surveying, property surveying, and materials testing for PCC, asphalt, brick and mortar, subbase, and soil density and compaction. Working alongside peers and experienced professionals in the realm of civil engineering, he has adopted knowledge of the design process, project planning, quality testing of construction materials, and the experience to comprehend project plans in order to guide teams to completion of designs.

Ashton Johnson has worked with the Iowa Department of Transportation for the past two summers. The main project assigned was the I-80/I-380 systems interchange located outside of the Iowa City/Coralville metro. Working alongside other Department of Transportation staff, experience, and knowledge of reading plans and performing quality testing of construction materials for both roadways and bridges was gained.

Bryan had experience with a private firm located in South El Monte for summer in 2021. His work contains horizontal alignment, vertical alignment and grading for the site and parking lot. Besides that, he helps to plot drawing into the correct template for clients to view. Working alongside engineers, he has acknowledged skills in design process and able to solve grading issues.

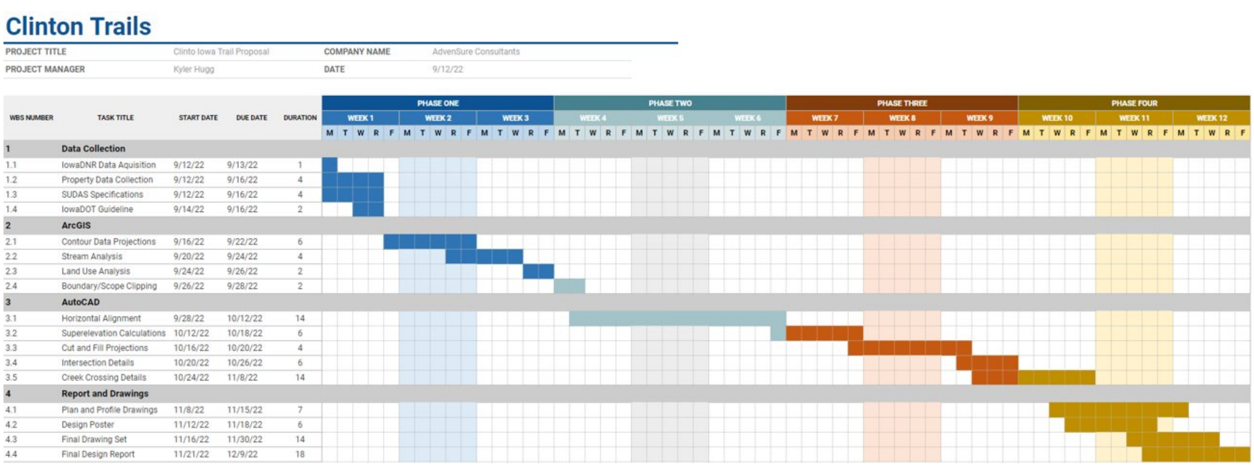
Section III: Proposed Services

Project Scope

The goal of our project is to convert unused rails into trails to the busy downtown district of the City of Clinton, so that the community will benefit from a better environment and traffic reduction by increasing the rate of pedestrians and bikers. In the project, we are developing a new trails system by adding sidewalks and trails from Lincoln Way to South 9th Street. Refer to *Figure 1* for map location.

Work Plan

The contract period starts from September 12, 2022, to December 9, 2022. The project was initially proposed on September 14, 2022, to faculty and clients from City of Clinton. After the proposal, research and design for the new trails system in the City of Clinton will begin. Drafts for design drawings, design report, and poster will be completed by November 18, 2022. We will give a summary presentation to clients regarding the completed design process of the project. On December 9, 2022, the final versions of the design report, design drawings, and poster for the project will be submitted to respective client.



The figures above are the Gantt Charts providing a visual aid for our Work Plan agenda.

Methods and Design Guides

For the design process, we are using Beacon Schneider to view city information of Clinton. We will be researching and analyzing the geospatial data by using ArcMap (ArcGIS). In the design process, we are using Autodesk Civil 3D Imperial to design the sidewalks and trails. We will be using the following design manuals: SUDAS and Iowa Code of Ordinances for the design process. In addition, we will use the Iowa DOT design manual as reference to our drawings.

Section IV: Constraints, Challenges, and Impacts

The City of Clinton's proposed trail network poses creative challenges to provide a quality product for the customers' future use. One constraint the design team faced was the placement of the trail within public Right of Way, while also minimizing the impact to private property along the trail corridor. This required the use of Beacon Schneider to allow the trail to be of maximum benefit to the community.

Some challenges were also present in the design of the Clinton adaptation of the 'Rails to Trails' concept. One challenge being the existing rail that is present within some sections of the proposed trail. While the difficulty of removing the existing rail should remain low, the cost estimated with removing the rail will be higher due to the weight of the material.

Another challenge was to determine the best method of designing the trail and roadway or railway intersections. In particular, the trail near the southern terminus required a railway crossing with a mildly used rail line. Near the center of the proposed trailway, a stream and roadway crossing on 14th Street required creative methods to effectively and safely move both pedestrian and vehicular traffic by constructing a new crossing to the southwest of 14th Street

A third challenge in designing was providing a parking and trail head facility for the proposed trail. The trail corridor is placed within existing roadway infrastructure as well as private homes and commercial properties, creating a unique situation to provide a space for visitors to the city especially.

One major factor of this specific trail connection is to provide a facility to link the downtown area of Clinton, to its southern commercial and industrial district. The new trail connection brings the potential for increased revenue to the commercial business in the area as traffic along the trail corridor rises. It is also a considerable note that the proposed trail will require passing near the Clinton Community College as well as residential homes along Lincoln Boulevard, potentially creating visibility issues for users of the trail.

Section V: Alternative Solutions

Various options were presented for the trailway, including crossings and routes for the trail. Near the beginning of the trailway, it was suggested to allow bicycles to utilize the existing Harrison Drive and South 21st Street and begin constructing the trail shortly following the existing railroad crossing. This option was ruled out due to the easy access to a nearby levee, which will also connect to the existing trailway underpass with US Highway 30. The trailhead facility, which was designed to be attached to the trail segment following exiting the levee for easy access to the trailhead facilities, will also provide ease of access to the rest of the trail systems, eliminating the need to utilize South 21st Street.

A second alternative was the option of constructing a new bridge or to utilize an existing crossing at South 14th Street. It was decided to construct a new facility due to the geometry of the bridge requiring the trail to be designed at an undesirable angle. Constructing a new facility downstream from the tributary creek allows the trail to cross South 14th Street perpendicularly.

Section VI: Design Details

Trail Path Cross Section

Prior to placement of trailway, clearing and grubbing will be required for approximately 7200 feet of the length of the trail system at a width of approximately 14 feet. This specified section will also require removal of existing rail tracks and ties. A short segment of approximately 550 feet along Lincoln Boulevard and 8th Avenue South, near the Clinton Community High School, will require removal of the existing sidewalk to allow construction of the proposed trail as depicted in the drawing sheets on pages D.21 and D.22.

The trail consists of Portland Cement Concrete (PCC) as the constructed material for the trail. To allow maintenance vehicles to traverse the levee near US Highway 30, proper widths and depths of the trail are designed as determined by the SUDAS and Iowa DOT standards. The PCC trail will be placed on top of a 12-inch layer of granular subbase to ensure durability of the trail. Existing ballast rock along the existing dormant rail track will be removed prior to placement of the granular subbase. The specified trail width and depth of 10 feet and 6 inches respectively will allow the passing of maintenance vehicles to gain access to the lift pump near Harrison Drive and 21st street as well as the passing of emergency vehicles, if required. A cross slope of 2% was chosen to allow drainage of rainwater off of the facilities. The direction of the cross slope varies along the trail so as to utilize the tributary creek along the trail for water runoff collection. A 2-foot shoulder was added to each side of the trail path to provide side protection of trail riders. A detailed cross section is provided in the drawing sheets for the trail on page B.1.

A design speed of 18 mph was selected based on the naturally flat layout of the land within the City of Clinton as well as the trail generally following a straight pathway. This provides for a horizontal radius of 60 feet to selected for trail riders to navigate curves where they occur. A minimum vertical radius of 50 feet was selected based off of grade change ranges along the alignment sections.

Lincoln Way (US Route 30) to 21st Street Levee

The trail will follow a path utilizing a current levee constructed along Mill Creek. As required by the Army Corps of Engineers, the trail must only add to the levee. The trail and subbase cannot interfere with the existing levee elevations. The alignment will extend along the levee before exiting along a fence line separating a local business and an open grass space. Due to a narrow horizontal clearance between the trail and the existing business, a retaining wall will be constructed for approximately 200 feet to bring the trail from the levee to the ground elevations near 21st street. Utility maintenance vehicles will be able to access the trail at the intersection of Lincoln Way (US Route 30) and Harrison Drive to be able to reach the lift station located along the levee. The placement of the retaining wall section is provided in attached drawing sheets on page D.2. Calculations and dimensions for the design of the retaining wall are shared with the bridge abutments and are provided in Appendix 2.

Roadway Sharing along Lincoln Boulevard

To save on costs of constructing a new trail section, paint markings and bollards will be placed along the south side of Lincoln Boulevard to allow for a connection between 11th Avenue South and 8th Avenue South, which will remove current parking conditions along that side of the roadway. This separation from the roadway will provide an added measure of safety to trail riders from vehicular traffic sharing the roadway.

Creek Crossing Between South 19th Street and South 14th Street

A 45-foot trail bridge will be constructed to provide a crossing for trail users over a tributary creek for Mills Creek. The bridge will be made of steel in a truss pattern, complete with a concrete deck. This will allow for emergency vehicles to traverse the crossing in the event of an emergency located along the trail in the vicinity of the bridge. The bridge will be prefabricated in an off-site facility and delivered to the site and placed on pre-constructed abutments. Calculations and dimensions for the abutments are located in Appendix 2.

Trail Head Facilities and Parking Lot

The trail head facility will be complete with two restrooms, both of which are ADA compliant. The building will also have a utility room for cleaning supplies as well as a hot water tank to supply to the hand washing sinks for the restrooms. The building cross section is provided in the drawing sheets on page B.2. The amenities surrounding the trailhead facility include a bicycle repair stations as well as informational kiosks. An overview of the trailhead facilities and amenities are located in the drawing sheets on page A.3.

Section VII: Project Cost Estimate

The cost estimation was split into the four main phases for the construction of the trailway and other proposed facilities. Prior to trail construction, clearing and grubbing, as well as the rail track removal will be required. Clearing and grubbing will utilize a 14-foot width to account for both the width of the trail pavement as well as the shoulders on each side of the pavement and is estimated to cost $12,200. The rail track removal will cost approximately $61,000. Since it is unlikely that the track will be repurposed for the trail or for other projects, it can also be sold to assist in offsetting the cost of construction for the trail. Based on current market prices, the track length can potentially be scrapped for a gain of $95,000. The existing rail bed ballasts will also be removed prior to placement of the subbase. Removal of an existing sidewalk located near Clinton Community Schools will also take place prior to placement of the new pavement, with an estimated cost of $3,350 for the existing 5-foot pavement width.

All proposed trail pavements will be placed onto a 12-inch depth bed of granular subbase. The cost for material and placement of the subbase is estimated to be $91,300. The trail will then be uniformly paved at a 10-foot width and 6-inch depth. Alignment plans and profiles for the proposed trail paving is provided in the plan drawing sheets on pages D.1 through D.22. Based on the cross section for the trail, the estimated cost for pavement is approximated to be $481,700. The retaining wall will utilize modular blocks to protect the height of the trail with Legend's Sports Bar with an estimated cost of $90,000. The height of the wall will extend 4 feet above the trail pavement height to provide safety for the trail users.

The trail building, mechanical components, surrounding amenities will cost approximately $81,000 combined. The overview and cross section of the trailhead facility is provided in the drawing sheets on pages A.3 and B.2, respectively.

A total cost estimation for the first phase of the trail is approximated at $910,050.00. With added contingencies and engineering costs, the grand total of the first phase is $1.05 Million. With each additional phase, an added cost is also provided in Table 2 below. The total project cost, including all phases, is approximated at $1.22 Million. A breakdown of phase 1 as well as estimations for each additional phase are shown below in Table 1 and Table 2 as well as in Appendix 1.

Table 1: Trail Quantities and Price Estimation

Item	Length	Price
Clearing and Grubbing (14-foot width)	8723.95 linear feet 2.80 acre	$4351.11 per acre $12,200.00 total
Removal of Railroad Track	7174.28 linear feet	$8.50 per linear foot $61,000.00 total
Granular Subbase (10-foot width)	8723.95 linear feet 11700.09 sq. yd.	$7.80 per sq. yd. $91,300.00 total
Trail Bridge and Abutment	45 feet (1 total)	$89,500.00 total
Removal of Existing Sidewalk (5-foot width)	537.92 linear feet 298.84 sq. yd.	$11.24 per linear foot $3,350.00 total
6" PCC Pavement (10-foot width)	8723.95 linear feet 11700.09 sq. yd.	$41.17 per sq. yd. $481,700.00 total
Modular Block Retaining Wall (8-foot height)	200 linear feet 1600 sq. ft.	$56.22 per sq. ft. $90,000 total

Table 2: Total Cost Estimations

Trail Path Total	$829,050.00
Trail Head Facility	$45,000.00
Trail Head Amenities	$36,000.00
Phase 1 Total	$910,050.00
Contingencies (10% Total)	$91,000.00
Engineering and Administration (5% Total)	$45,500.00
Phase 1 Grand Total	$1,046,550.00
Phase 2: Parking Lot Total 6" Pavement Depth, 2247.7 SY	$102,100.00
Phase 3: Shared Roadway Separation	$43,500.00
Phase 4: Intersection Reconstruction	$32,500.00
Project Grand Total	**$1,224,650.00**

Section VIII: Glossary of Terms

The following definitions are from the “AASHTO Guide for the Development of Bicycle Facilities” (or AASHTO Bike Guide).

Bicycle Facilities: A general term denoting improvements and provisions to accommodate or encourage bicycling, including parking and storage facilities, and shared roadways not specifically defined for bicycle use.

Bicycle Lane or Bike Lane: A portion of roadway that has been designated for preferential or exclusive use by bicyclists by pavement markings and, if used, signs. It is intended for one-way travel, usually in the same direction as the adjacent traffic lane, unless designed as a contra-flow lane.

Bicycle Network: A system of bikeways designated by the jurisdiction having authority. This system may include bike lanes, bicycle routes, shared use paths, and other identifiable bicycle facilities.

Bicycle Plaza or Bike Rack: A stationary fixture to which a bicycle can be securely attached.

Bikeway: A generic term for any road, street, path, or way that in some matter is specifically designated for bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other transportation modes.

Rail-to-Trail: A shared use path, either paved or unpaved, built within the right-of-way of a former railroad.

Shared Lane: A lane of a traveled way that is open to both bicycle and motor vehicle travel.

Traveled Way: The portion of the roadway intended for the movement of vehicles, exclusive of shoulders and any bike lane immediately inside of the shoulder.

Section VIII: Appendices

Appendix 1:

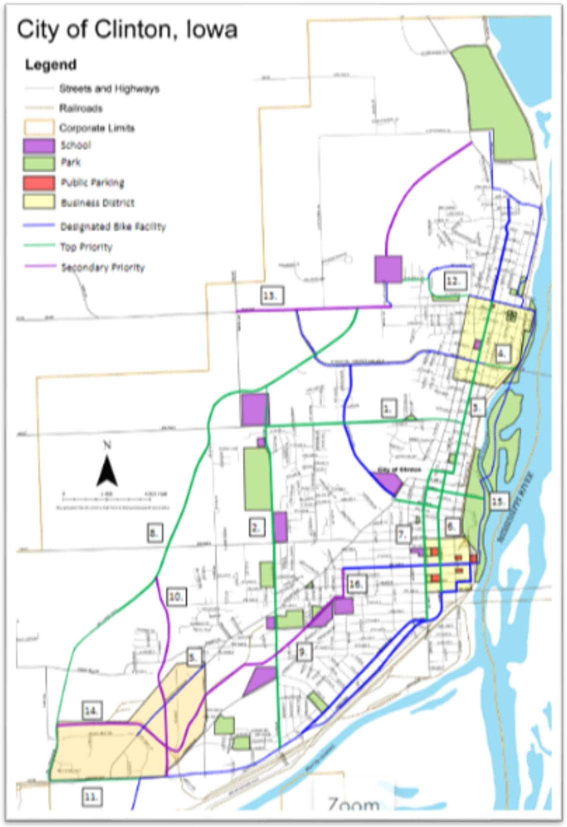


Figure 1: Priority list of future bike trails, both under construction and to be considered. Our focus in the graphic above is trail number 9.

Figure 2: Aerial image of Lincoln Boulevard (central roadway heading at a 45-degree angle from Twelfth Street (western boundary) to Tenth Steet (eastern boundary).

Figure 3: Aerial image of the proposed Mills Creek Crossing. The outlined area, shown in blue, indicates the city owned region where a proper crossing can be constructed.

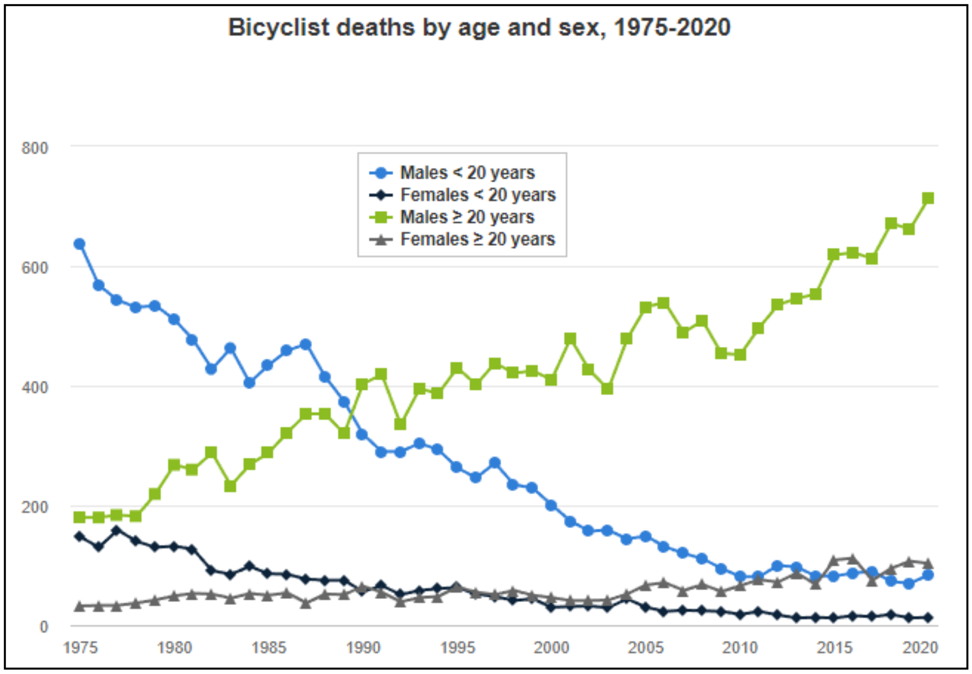


Figure 4: Statistical data of annual deaths by age and sex, provided by Insurance Institute for Highway Safety.

Table E1: Trail Quantities and Price Estimation

Item	Length	Price
Clearing and Grubbing (14-foot width)	8723.95 linear feet 2.80 acre	$4351.11 per acre $12,200.00 total
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Table E2: Total Cost Estimations

Trail Path Total	$829,050.00
Trail Head Facility	$45,000.00
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6” Pavement Depth, 2247.7 SY	
Phase 3: Shared Roadway Separation	$43,500.00
Phase 4: Intersection Reconstruction	$32,500.00
Project Grand Total	**$1,224,650.00**

Additional References:

https://iowadot.gov/design/design-manual

https://www.iowadot.gov/iowabikes/trails/web-pdf/IowaTrails2000/Chapter5.pdf

https://iowasudas.org/manuals/design-manual/#chapter-12-sidewalks-and-bicycle-facilities

https://nacto.org/references/aashto-guide-for-the-development-of-bicycle-facilities-2012/

https://intrans.iastate.edu/app/uploads/2019/08/concrete_trails_guide.pdf

https://cdn1.sph.harvard.edu/wp-content/uploads/sites/1666/2016/07/Promoting-Bicycling-through-Creative-Design.pdf

https://www.iihs.org/topics/fatality-statistics/detail/bicyclists#:~:text=A%20total%20of%20932%20bicyclists,their%20lowest%20point%20in%202010.

https://www.fs.usda.gov/sites/default/files/fs_media/fs_document/CDT_trailhead_guidelines_0.pdf

Team Member Resumes:

Ashton Johnson Resume.pdf

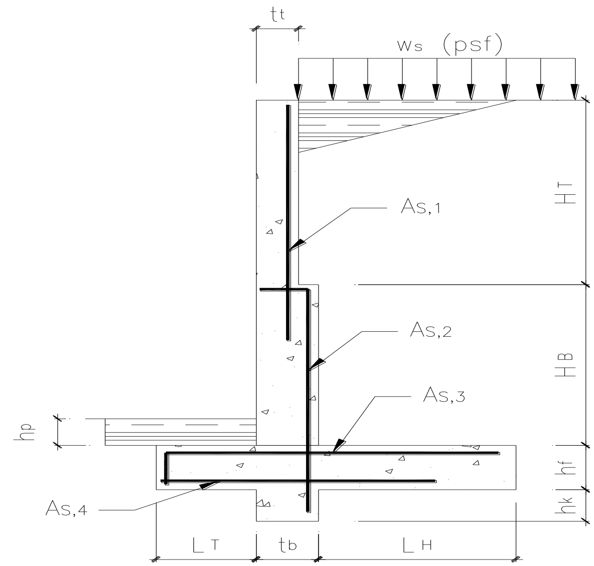
Bryan_Chia_Resume.pdf

Appendix B: Retaining Wall and Bridge Abutment Design

Retaining Wall Design Based on ACI 318-02

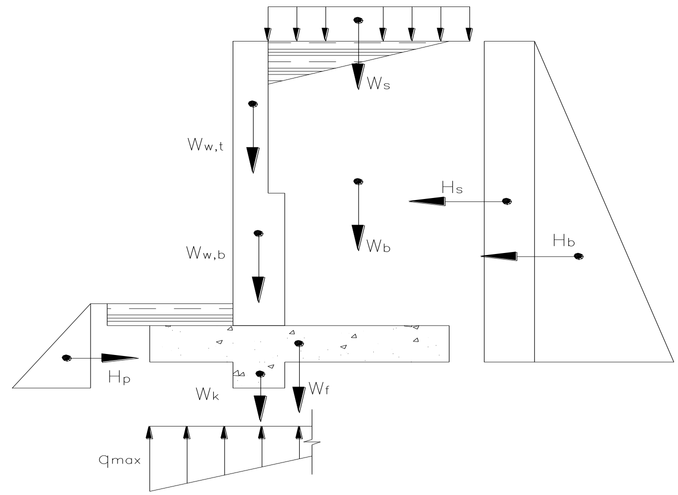
INPUT DATA & DESIGN SUMMARY

CONCRETE STRENGTH	f_c'	=	2	ksi			
REBAR YIELD STRESS	f_y	=	40	ksi			
LATER SOIL PRESSURE	P_a	=	30	pcf (equivalent fluid pressure)			
PASSIVE PRESSURE	P_p	=	350	psf / ft			
SURCHARGE WEIGHT	w_s	=	200	psf			
FRICTION COEFFICIENT	μ	=	0.3				
ALLOW SOIL PRESSURE	Q_a	=	3	ksf			
THICKNESS OF TOP STEM	t_t	=	6	in			
THICKNESS OF KEY & STEM	t_b	=	6	in			
TOE WIDTH	L_T	=	2	ft			
HEEL WIDTH	L_H	=	1	ft			
HEIGHT OF TOP STEM	H_T	=	3	ft			
HEIGHT OF BOT. STEM	H_B	=	3	ft			
FOOTING THICKNESS	h_f	=	10	in			
KEY DEPTH	h_k	=	10	in			
SOIL OVER TOE	h_p	=	10	in			
TOP STEM REINF. ($A_{s,1}$)	1	#	6	@	16	in o.c., at middle	
BOT. STEM REINF. ($A_{s,2}$)	2	#	7	@	8	in o.c., at each face	
TOP REINF.OF FOOTING ($A_{s,3}$)		#	6	@	8	in	
BOT. REINF.OF FOOTING ($A_{s,4}$)		#	5	@	12	in	**[THE WALL DESIGN IS ADEQUATE.]**



ANALYSIS

SERVICE LOADS



$H_b = 0.5\,P_a\,(H_T + H_B + h_f)^2$	=	0.58	kips
$H_s = w_s\,P_a\,(H_T + H_B + h_f)\,/\,\gamma_b$	=	0.37	kips
$H_p = 0.5\,P_p\,(h_p + h_f + h_k)^2$	=	1.41	kips
$W_s = w_s\,(L_H + t_b - t_t)$	=	0.20	kips
$W_b = [H_T\,(L_H + t_b - t_t) + H_B\,L_H]\,\gamma_b$	=	0.60	kips
$W_f = h_f\,(L_H + t_b + L_T)\,\gamma_c$	=	0.38	kips
$W_k = h_k\,t_b\,\gamma_c$	=	0.06	kips
$W_{w,t} = t_t\,H_T\,\gamma_c$	=	0.23	kips
$W_{w,b} = t_b\,H_B\,\gamma_c$	=	0.23	kips

FACTORED LOADS

$\gamma H_b = 1.6\,H_b$	=	0.93	kips
$\gamma H_s = 1.6\,H_s$	=	0.59	kips
$\gamma W_s = 1.6\,W_s$	=	0.32	kips
$\gamma W_b = 1.2\,W_b$	=	0.72	kips
$\gamma W_f = 1.2\,W_f$	=	0.46	kips
$\gamma W_k = 1.2\,W_k$	=	0.07	kips
$\gamma W_{w,t} = 1.2\,W_{w,t}$	=	0.28	kips
$\gamma W_{w,b} = 1.2\,W_{w,b}$	=	0.28	kips

OVERTURNING MOMENT

	H	γH	y	H y	γH y
H_b	0.58	0.93	2.33	1.35	2.17
H_s	0.37	0.59	3.50	1.30	2.07
Σ	0.95	1.52		**2.65**	4.24

RESISTING MOMENT

	W	γW	x	W x	γW x
W_s	0.20	0.32	3.17	0.63	1.01
W_b	0.60	0.72	3.17	1.90	2.28
W_f	0.38	0.46	1.83	0.70	0.84
W_k	0.06	0.07	2.33	0.14	0.16
$W_{w,t}$	0.23	0.28	2.33	0.54	0.65
$W_{w,b}$	0.23	0.28	2.33	0.54	0.65
Σ	1.70	2.13		**4.45**	5.59

OVERTURNING FACTOR OF SAFETY

$$SF = \frac{\Sigma Wx}{\Sigma Hy} = 1.67 > 1.5$$

[Satisfactory]

CHECK SOIL BEARING CAPACITY (ACI 318-02 SEC.15.2.2)

$L = L_T + t_b + L_H$ = 3.67 ft

$e = \frac{L}{2} - \frac{\Sigma Wx - \Sigma Hy}{\Sigma W}$ = 0.86 ft

$$q_{MAX} = \begin{cases} \frac{\Sigma W\left(1+\frac{6e}{L}\right)}{BL}, & for \quad e \le \frac{L}{6} \\ \frac{\Sigma W}{3B(0.5L-e)}, & for \quad e > \frac{L}{6} \end{cases}$$

= 0.70 ksf < Q_a **[Satisfactory]**

CHECK FLEXURE CAPACITY, $A_{S,1}$ & A_{S2}, FOR STEM (ACI 318-02 SEC.15.4.2, 10.2, 10.5.4, 7.12.2, 12.2, & 12.5)

			At top srem			At base of bottom stem		
$M_u = \gamma\left(\frac{P_a y^3}{6} + \frac{P_a y^2 w_s}{2\gamma_b}\right)$		=	0.65	ft-kips ,		3.46	ft-kips	
$P_u = \gamma W_w$		=	0.36	kips ,		0.72	kips	
$\phi M_n = \phi\left[A_S f_y\left(d - \frac{A_S f_y - P_u}{1.7bf'_c}\right)\right]$		=	4.25	ft-kips ,		12.06	ft-kips	
			>	M_u			>	M_u
				[Satisfactory]				**[Satisfactory]**
where	d	=	4.00	in ,		4.70	in	
	b	=	12	in ,		12	in	
	ϕ	=	0.7	,		0.7		
	A_s	=	0.33	in^2 ,		0.9	in^2	
	ρ	=	0.007			0.016		
$\rho_{MAX} = 0.75\left(\frac{0.85\beta_1 f'_c}{f_y}\frac{87}{87+f_y}\right)$		=	0.016			0.016		
			>	ρ			>	ρ
				[Satisfactory]				**[Satisfactory]**
$\rho_{MIN} = 0.0018\frac{t}{d}$		=	0.004			0.003		
			<	ρ			<	ρ
				[Satisfactory]				**[Satisfactory]**

CHECK SHEAR CAPACITY FOR STEM (ACI 318-02 SEC.15.5.2, 11.1.3.1, & 11.3)

		At top stem			At base of bottom stem		
$V = \gamma\left(\frac{P_a y^2}{2} + \frac{w_s P_a y}{\gamma_b}\right)$	=	0.50	kips ,		1.44	kips	
$V_{allowable} = 2\phi bd\sqrt{f'_c}$	=	3.94	kips ,		4.63	kips	
		>	V			>	V
			[Satisfactory]				**[Satisfactory]**

where ϕ = 0.75 (ACI 318-02, Section 9.3.2.3)

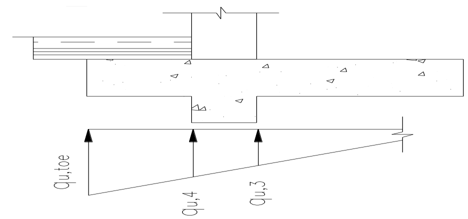
CHECK HEEL FLEXURE CAPACITY, $A_{S,3}$, FOR FOOTING (ACI 318-02 SEC.15.4.2, 10.2, 10.5.4, 7.12.2, 12.2, & 12.5)

$\rho_{MAX} = 0.75\left(\frac{0.85\beta_1 f'_c}{f_y}\frac{87}{87+f_y}\right)$ = 0.016

$\rho_{MIN} = \frac{0.0018}{2}\frac{h_f}{d}$ = 0.001

$$M_{u,3}=\begin{cases}\frac{L_H}{2}\left(\gamma w_s+\gamma w_b+\frac{L_H}{L}\gamma w_f\right)-\frac{\left(q_{u,3}+2q_{u,heel}\right)bL_H^2}{6}, & for \quad e_u\le\frac{L}{6}\\ \frac{L_H}{2}\left(\gamma w_s+\gamma w_b+\frac{L_H}{L}\gamma w_f\right)-\frac{q_{u,3}bS^2}{6}, & for \quad e_u>\frac{L}{6}\end{cases}$$

= 0.80 ft-kips



$$\rho=\frac{0.85f_c^{'}\left(1-\sqrt{1-\frac{M_{u,3}}{0.383bd^2f_c^{'}}}\right)}{f_y}$$

= 0.000

where	d	=	8.63	in	$q_{u,toe}$	=	1.57	ksf
	e_u	=	1.30	ft	$q_{u,heel}$	=	n/a	ksf
	S	=	-1.05	ft	$q_{u,3}$	=	-1.02	ksf

$(A_{S,3})_{required}$ = 0.13 in^2 / ft < $A_{S,3}$ **[Satisfactory]**

CHECK TOE FLEXURE CAPACITY, A_{S4}, FOR FOOTING (ACI 318-02 SEC.15.4.2, 10.2, 10.5.4, 7.12.2, 12.2, & 12.5)

$$\rho_{MAX}=0.75\left(\frac{0.85\beta_1f_c^{'}}{f_y}\frac{87}{87+f_y}\right)$$

= 0.016

$$\rho_{MIN}=MIN\left(\frac{4}{3}\rho,\ \frac{0.0018}{2}\frac{h_f}{d}\right)$$

= 0.000

$$M_{u,4}=\frac{\left(q_{u,4}+2q_{u,toe}\right)bL_T^2}{6}-\frac{L_T^2}{2L}\gamma w_f$$

= 1.49 ft-kips

where	d	=	8.69	in
	$q_{u,4}$	=	-0.37	ksf

$$\rho=\frac{0.85f_c^{'}\left(1-\sqrt{1-\frac{M_{u,4}}{0.383bd^2f_c^{'}}}\right)}{f_y}$$

= 0.000

$(A_{S,4})_{required}$ = 0.05 in^2 / ft < $A_{S,4}$ **[Satisfactory]**

CHECK KEY CAPACITY FOR FOOTING

$1.5\,(H_b + H_s)$ = 1.73 kips < $H_p + \mu\,\Sigma W$ = 2.64 kips

[Satisfactory]

Techincal References:

1. Alan Williams: "Structuiral Engineering Reference Manual", Professional Publications, Inc, 2001.
2. Alan Williams: "Structuiral Engineering License Review Problems and Solutions", Oxford University Press, 2003.