THE UNIVERSITY OF IOWA
IOWA INITIATIVE
FOR SUSTAINABLE COMMUNITIES

FINAL DELIVERABLE

Title	Bellevue Flood Mitigation and Stormwater Management
Completed By	Jack Gorman, Keishanique Moton-Tyler, Brendan Swanson, Andrew Van Sickle
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Instructor	Richard Fosse
Community Partners	City of Bellevue

This project was supported by the Iowa Initiative for Sustainable Communities (IISC), a community engagement program at the University of Iowa. IISC partners with rural and urban communities across the state to develop projects that university students and IISC pursues a dual mission of enhancing quality of life in Iowa while transforming teaching and learning at the University of Iowa.

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Evaluation of the Impacts of the Proposed Floodplain Map Updates

May 14, 2021

IOWA

SEAL OF THE CITY OF BELLEVUE

H2PROS

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SECTION I

EXECUTIVE SUMMARY

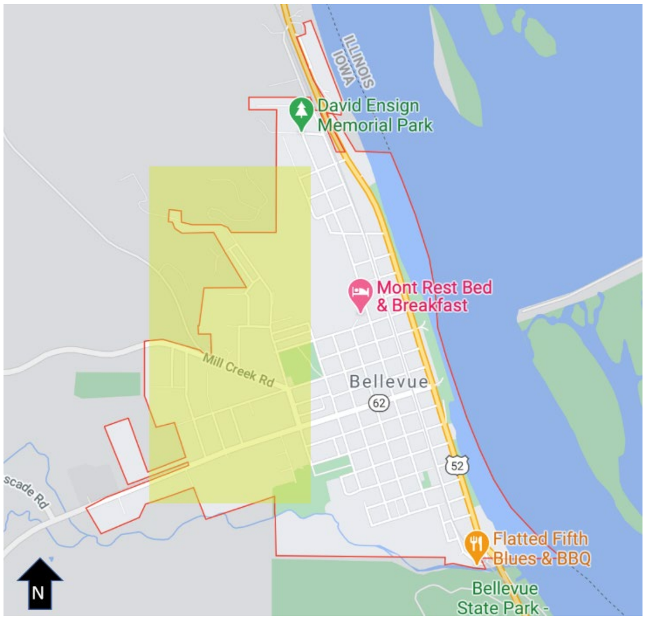

Figure 1: Overview of Project Area in Bellevue, IA

Recent updates to the flood maps of Bellevue, Iowa, have carried serious impacts for citizens within the community. The updates have added multiple homes along the Dutel Hollow main branch and Dutel Hollow second branch drainageways to the 100-yr floodplain that were not there previously. The addition of these homes into the floodplain will trigger lenders to require homeowners purchase flood insurance to mitigate the risk of living in the newly expanded floodplain. The City of Bellevue would like to explore available options that may take these homes out of the floodplain and prevent future development from adversely impacting the floodplain.

After a site visit, the team realized that the drainage system was unusually complex and modeling the entire drainage corridor would not be possible due to time limitations and lack of detailed survey information. Through meetings with the client and stakeholders in the community, the team learned that the culvert beneath Highway 62 may not be sized to meet the current stormwater flows of the community. Considering this new information, the team decided to investigate the effects of resizing the culvert beneath Highway 62 to see if changes to the culvert could lower the water surface profile enough to remove homes from the floodplain. However, even if resizing the culvert can significantly reduce the 100-yr. floodplain, there may be reasons that the project is not implemented or, it is many years down the road before construction will take place. Because of this, the team decided to also examine choices homeowners can consider to manage their risks that is independent of a large-scale project.

The City of Bellevue provided the team with the preliminary Flood Insurance Rate Study drafted by Federal Emergency Management Agency (FEMA). Using the information provided in this document, as well as LiDAR data gathered by the Iowa Department of Natural Resources (IDNR) in 2010, a hydraulic model of Dutel Hollow main branch, Dutel Hollow second branch, and their confluence with Mill Creek was created using in HEC-RAS. The shaded area in **Figure 1** shows the extent of the model. The water surface profile around the Highway 62 culvert given in the Flood Insurance Rate Study was used to calibrate the HEC-RAS model to match the existing conditions around the culvert. Simulations were then performed with different sized culverts to examine their impacts on the water surface profile.

From the results of the HEC-RAS model, it was determined that resizing the culvert under Highway 62 to a 16 ft. by 6 ft. precast concrete box culvert should lower the water surface profile enough to remove several homes from the 100-yr floodplain. The total project cost of replacing the culvert under Highway 62 was estimated at $387,000. It should be noted that the new culvert will only initially benefit those residents between Hwy 62 and Park St. Over time, multiple projects will be necessary to extend these benefits. A significant channel would need to be constructed north of Hwy 62 and all culverts enlarged as the improvements work their way upstream.

Although our model suggests that replacing the culvert with a 16 ft. by 6 ft. precast concrete box culvert looks promising, we recommend that our findings be confirmed by another design professional that can work with actual detailed survey information. The model is sensitive to the features of the land and drainage structures. We used the approximate data that was available to us, which may yield poor results.

As noted above, the team thought about a variety of options homeowners can consider independent of relying on a large project implemented by the City and/or the state in mitigating their flood risk. The options the team chose to evaluate were boiled down to two options; rely on flood insurance to manage the floodplain risk or build a flood wall around the walkout basement of their home to remove them from the 100-yr floodplain. These two choices were believed to be the most feasible for the homes impacted by the new flood maps. After meeting with a stakeholder, the team was provided with a flood insurance quote of roughly $4,000 a year from one of the homeowners in Bellevue. The present worth of an annual flood insurance premium of $4,000 for a 30-year mortgage, with an interest rate of 3%, was calculated to be $78,500. This provides an estimate to the homeowner to use when considering what is the best choice: flood insurance or a flood wall.

For a flood wall to remove a home from the floodplain, the wall must provide at least one foot of freeboard above the design flood elevation. The flood wall design must also be certified by a registered design professional to ensure the flood wall will function correctly and provide adequate protection to the home. The cost of constructing a 4-foot-high flood wall, 90 feet long was estimated to be $22,000.

With regard to future developments, the City of Bellevue has stormwater ordinances already in place to limit the negative impacts development has on stormwater runoff. These ordinances are comparable with actions taken by other cities and Bellevue is to be commended for taking these difficult steps. Given the unpopular nature of these regulations, developers often seek variances from their requirements. We recommend that any such requests be carefully evaluated for adverse impacts before being granted.

Finally, it is important to note that while the culvert and channel improvements may reduce the floodplain enough that it no longer touches the homes, it will still cover some of their property. We have seen conflicting information about whether this would still trigger the requirement to purchase flood insurance. This question must be answered before considering an investment in the culvert and channel improvements. Little is to be gained if flood insurance is still required after the culvert is enlarged.

SECTION II

Name of Organization

Note: H2PROS is a fictitious name created for the project.

Organization Location Contact Information

Project Lead:	Jack Gorman
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Organization and Design Team Description

Jack Gorman
Project Manager
Environmental Engineering

Keishanique Moton-Tyler
Editor / Graphics
Civil Engineering

Brendan Swanson
Tech Support
Environmental Engineering

Andrew Van Sickle
Editor / Graphics
Civil Engineering

Experience with Similar Projects

Jack Gorman

Technical areas: HEC-HMS, HEC-RAS, WinTR-55, MATLAB, ArcGIS, ModelMuse, MODFLOW

Class experience: Water Resource Design, Water Resources Engineering, Groundwater

Keishanique Moton-Tyler

Technical areas: HEC-HMS, WinTR-55, MATLAB, ArcGIS

Classwork: Hydrology

Brendan Swanson

Technical areas: HEC-HMS, WinTR-55, MATLAB, ModelMuse, ArcGIS, AutoDesk.

Classwork: in water and wastewater treatment, hydrology, groundwater, hydraulics, water resource engineer.

Andrew Van Sickle

Technical areas: HEC-HMS, HEC-RAS, WinTR-55, MATLAB, ModelMuse, MODFLOW, PEAKFQ, AutoDesk, EPANET

Classwork: Water Resources Design, Hydrology, Groundwater, Water Resources Engineering

SECTION III

Project Scope

The City of Bellevue floodplain maps are currently undergoing review by FEMA, who has a released a draft of their findings. Although these are preliminary updates, it has been observed that several residences along the main branch of Dutel Hollow and the Dutel Hollow second branch have now been identified to be in the 100-yr. floodplain and at risk for flooding. This report seeks to evaluate the impacts of floodplain changes and explore ways to mitigate the new risks that have been identified.

To mitigate their risk, homeowners added to the floodplain will be required, by their lender, to purchase flood insurance. Homeowners could also construct a flood wall to provide adequate protection to their home so that flood insurance is no longer required. This strategy includes identifying the criteria necessary for the flood walls to ensure adequate protection to eliminate the flood insurance requirement. Another option that will be evaluated is a large-scale project that will enlarge the culverts in the drainageways to lower the water surface profile enough that multiple homes can be removed from the floodplain.

Work Plan

The first task undertaken by the team was to research the site area and collect data relevant to the project. All team members spent the first two weeks of the semester finding information and sharing it with the team. Using the initial data, the team started developing concepts to mitigate the impact of stormwater along the west end drainage corridor of Bellevue. Concept development continued for several weeks of the semester as new data and information became available to the team. Information provided through emails and a meeting with a stakeholder in the community was vital in determining dimensions of existing culverts to complete the modeling process. The concepts explored ranged from the available options if no changes are made to the drainage corridor, to major improvements of the channel capacity that would lower the floodplain and reduce the floodplain area.

Building the hydraulic model in HEC-RAS was undertaken by Keishanique. She worked closely with faculty to troubleshoot and refine the model over multiple weeks to supply a model for the team. While Keishanique was building the model, the other team members began exploring other strategies to help develop a multifaceted approach. Brendan examined the current stormwater ordinances in Bellevue and compared them to other communities in Iowa to see if ordinances changes could be recommended. To begin the analysis of drainageway alterations, Andrew designed a channel from Mill Creek up to Highway 62. Jack was responsible for researching floodproofing options for homeowners along the west end drainage corridor. Brendan, Andrew, and Jack all worked collectively to evaluate the effects of installing a new culvert under Highway 62.

When the final design was agreed upon, Andrew and Jack began its cost estimation and drafting the final report. Keishanique completed the drawing set for the project and worked alongside Brendan and Jack to design the final presentation. Creating the final poster was undertaken by Brendan. All team members worked together to revise the final deliverables and make improvements. **Figure 2** below presents a Gantt chart outlining the tasks completed and the time taken to finish them.

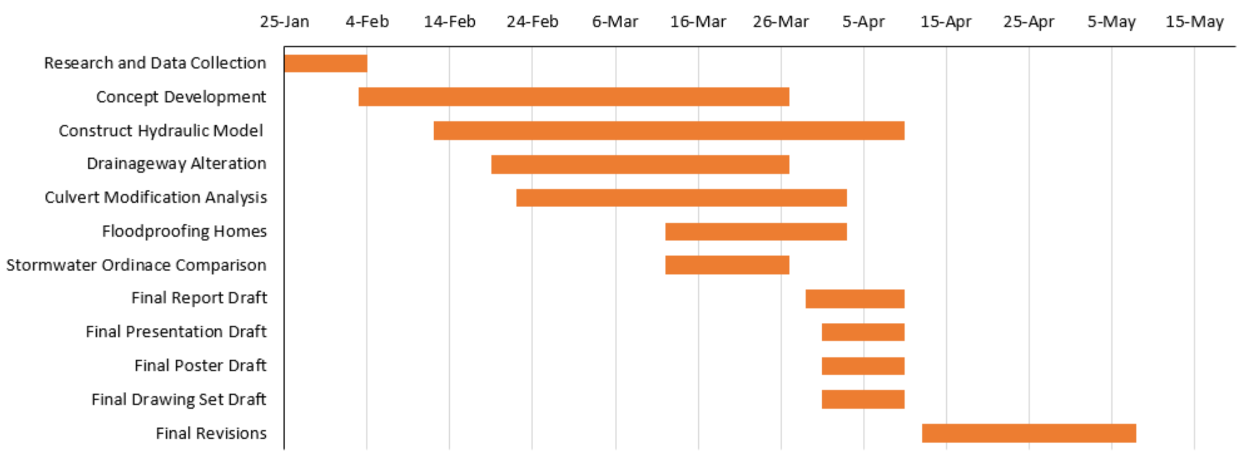

Figure 2: Gantt Chart for Bellevue Stormwater Project

SECTION IV

Constraints

The project has various constraints that makes this a unique problem where a one size fits all approach cannot be used. The first constraint for this project includes the preliminary updated floodplain map for the 100-year floodplain. While we can mitigate the floodplain and have a plan of action for future uses upstream, we cannot change where citizens have already built their residents. Lack of accurate survey data was another major constraint that hindered the project. Without accurate data, the model was calibrated off the water surface profile in the preliminary flood report.

Challenges

The project's entire drainage basin covers a vast area. The team's course of action was to focus on a small portion of the floodway and investigate a smaller portion. This portion included the confluence of Mill Creek and Dutel Hollow main branch. Going up this drainage corridor, space for the team's design is limited. Knowing the elevation and extent of the floodplain that could be reduced by redesign of the culvert will need to be known before the City considers with this capital investment. The team's design for project phases would need to happen in sequential order, downstream to upstream, using a floodway mitigation plan for the city.   Most of the drainageway resides within private property and dictates how large a re-designed channel can be. The lack of available space limits the number of viable options normally used in controlling runoff channel flow. Since the new floodplain will affect private residences, a challenge arises for homeowners in deciding how to mitigate their flood risks. The team showed what the cost-benefit analysis of purchasing flood insurance verses floodproofing their homes by constructing a flood wall around their home, one of the methods in FEMA's *Homeowners Guide to Retrofitting* document.

Societal Impacts

This project could have several societal impacts on the community of Bellevue, including influences on the population, economy, community resources, and property rights of the citizens in Bellevue. The new floodplain maps have identified risks that property owners were previously unaware of. Once known, lenders require that these risks be mitigated through the purchase of flood insurance. This can add a significant expense to the household budget.

Construction for culvert modification would require Highway 62 to be closed, a major roadway through Bellevue. Businesses that rely on this roadway for potential customers may experience a decrease in revenue. Those in the community who use Highway 62 for transportation will experience a disruption in their daily commute. Closure of the road may also delay the response of emergency vehicles and present a safety concern. The construction to alter the drainageway would take place in the backyard of several households, posing a noise disturbance and safety concern for those with children.

The acquisition of the private property to make alterations to the drainageway may have a negative effect on the relationship between the city and property owners. If an agreement for the transfer of property cannot be reached and eminent domain must be used, negative feelings about the project may arise in the community and prevent it from being considered an improvement for Bellevue.

Section V

Alternative Solutions That were Considered

The team considered several design alternatives during the design process. The first alternative was to “do nothing” and make no changes to the drainage corridor. This option would rely on homeowners to purchase flood insurance to mitigate the risk of living in a floodplain. This alternative would eliminate any construction costs for the city of Bellevue but would leave homeowners with the costs of flood insurance.

The second alternative examined was to look at floodproofing homes to eliminate the need for flood insurance. The two floodproofing concepts explored were using shields or barriers to cover openings of the home and constructing a flood wall around the backside of the home. The shields for the home would be placed into tracks installed on the doorway or window, and then drilled down to secure them in place. A reinforced concrete flood wall around the home would be constructed to take the home out of the floodplain and could be aesthetically designed to complement the home.

The next alternative examined was expanding the channel and related drainage structures to lower the water surface profile was an alternative the team studied. A larger, more defined channel would allow water to leave the drainage corridor more quickly and help prevent water from backing up behind culverts. Coupling the channel expansion with an increase in the capacity of the culverts would intensify these effects and aid in preventing water from backing up behind culverts. This alternative could remove multiple homes from the floodplain and provide an area of recreation if a trail is constructed along the expanded channel. However, the costs to acquire the necessary property and construct these concepts would be a considerable amount for a community the size of Bellevue. Construction of these concepts would also cause significant disruptions to traffic on along the drainageway and be a disturbance to homeowners near the construction area.

Creating storage upstream in the drainage corridor to lower the water surface profile was a concept the team assessed. Storing water upstream and releasing it slowly over time would decrease the peak runoff during storm events and lower the water surface profile downstream. A drawback to this concept is that a hazard would be created for the homeowners downstream of the stored water. If a large-scale storage structure failed, a flood wave would run down the drainage corridor putting citizens in danger and potentially damaging homes. The cost of construction, as well as finding a suitable location for a storage structure large enough to lower the water surface profile, would be additional challenges for this alternative.

Section VI

Final Mitigation Strategies

Manage Risk with Insurance

If the City decides to take no action the default method of managing the risk of flooding will be flood insurance. While this is a viable way to manage risk, the City may wish to explore other options that may have lower costs for homeowners. However, flood insurance must be considered as an option because better solutions may not be available or feasible.

Individual Home Flood Walls

The installation of a flood wall around the affected homes located in the new FEMA flood map would help to alleviate the need for flood insurance. A flood wall with 1 foot of freeboard would be constructed around vulnerable areas of the resident's home to take the home out of the 100-yr floodplain. This flood wall would contain drainage holes at the base of the wall to allow for drainage during normal storm events. In the event of a flood event, the drainage hole would need to be plugged and a sump pump would need to be placed on the inside of the wall to drain any water accumulated behind the flood wall. This flood wall would prevent water from the drainage corridor from affecting the houses located in the flood plain. Flood wall size would vary from home to home as the water level and elevation of each home varies along the floodplain. The cost to construct a flood wall would fall to the homeowners. Flood walls can be worked into an existing patio and may become an aesthetic landscaping feature. Plan set sheet 2 contains a standard design of a flood wall with an assumed heigh of 48 inches. An example of this concept is below in **Figure 3 & 4.**

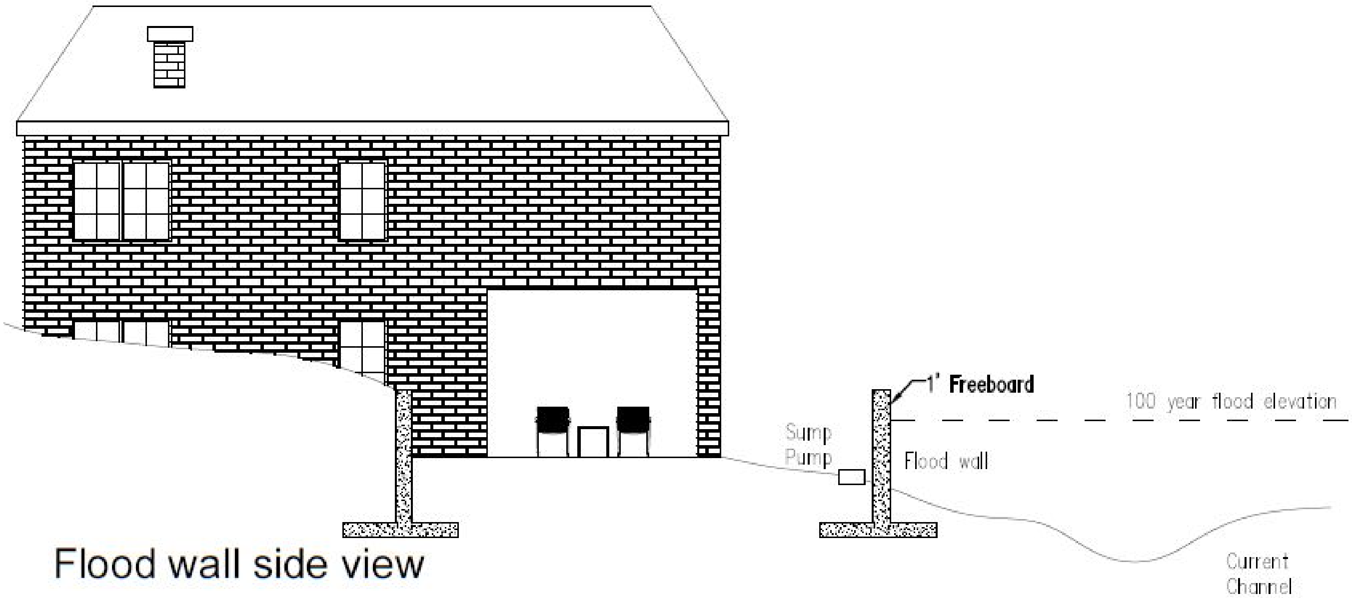

Figure 3: Profile view of Flood wall around a home

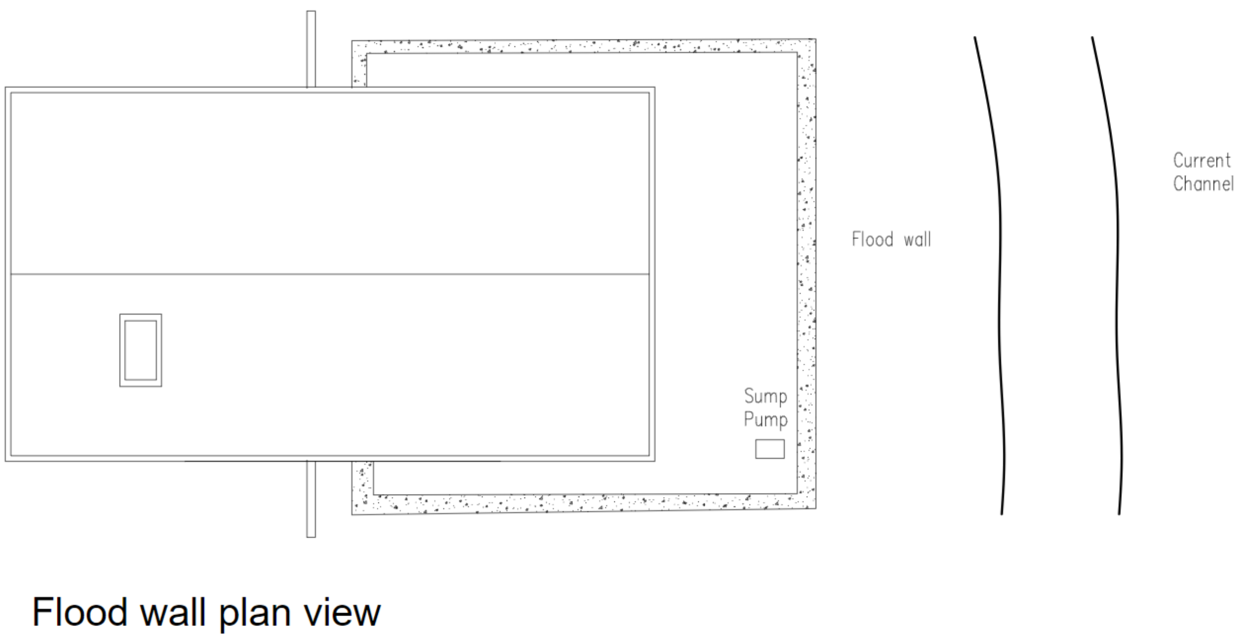

Figure 4: Plan View of Flood wall around a home.

Flood wall design should be signed off by a licensed engineer to make sure that the design can with stand hydrostatic forces from predicted flood waters. It is important to note that the flood walls cannot be constructed in the floodway.

Resized Highway 62 Culvert

The design of culverts will be sized to reduce the flood level upstream of the culvert enough to remove some of the homes from the floodplain, if possible. Flows of the predicted 100-year flood found in *Table 10* of the *FEMA Flood Insurance Rate Study report* provided by the city. The calculations used Manning's equation with the available *n* – factors found in *Table 14* of the *Flood Insurance Rate Study* to calibrate the model results. As seen in **Figure 5** FEMA's flood was approximated at 621 ft of elevation above Hwy 62.

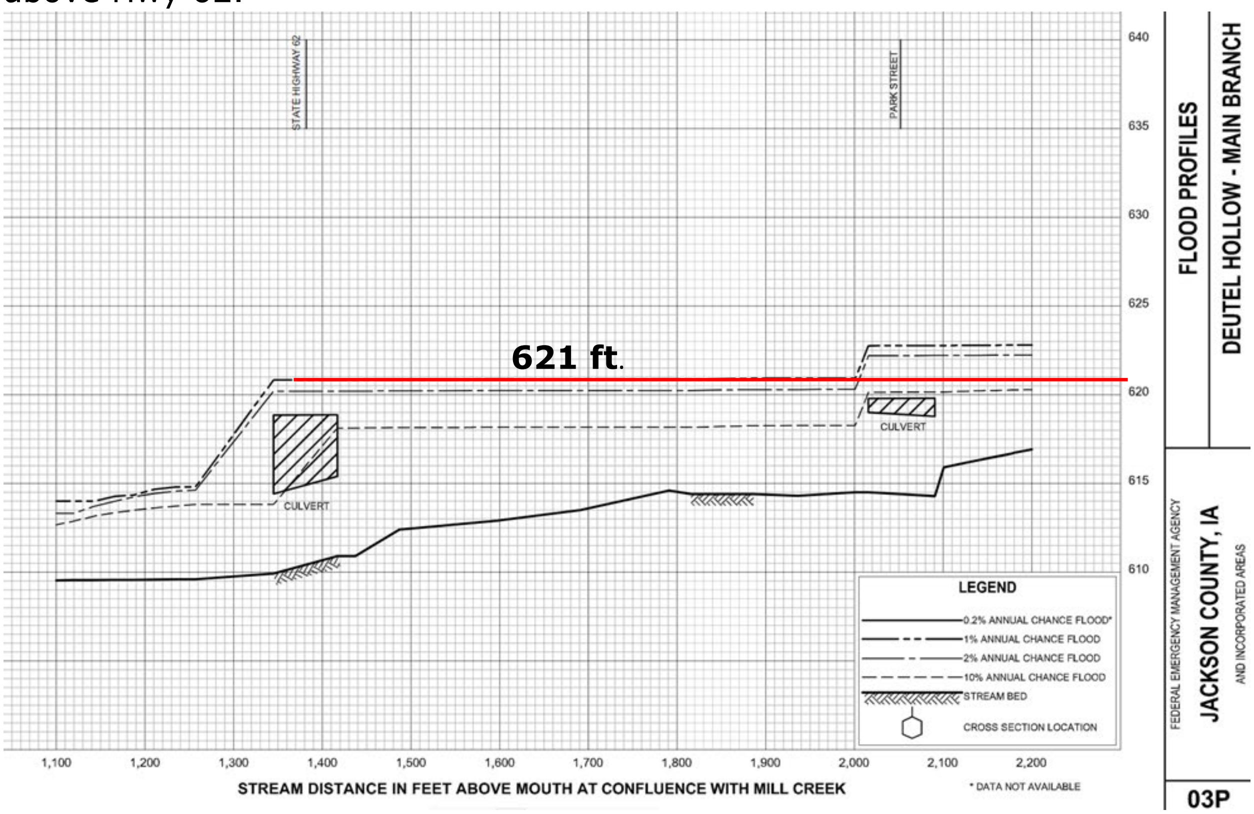

Figure 5: Flood Levels from FEMA Flood report

Comparing that to the model achieved was 620 ft in **Figure 6**. This can be explained with the lack of accurate survey data and accuracy of the channel characteristics.

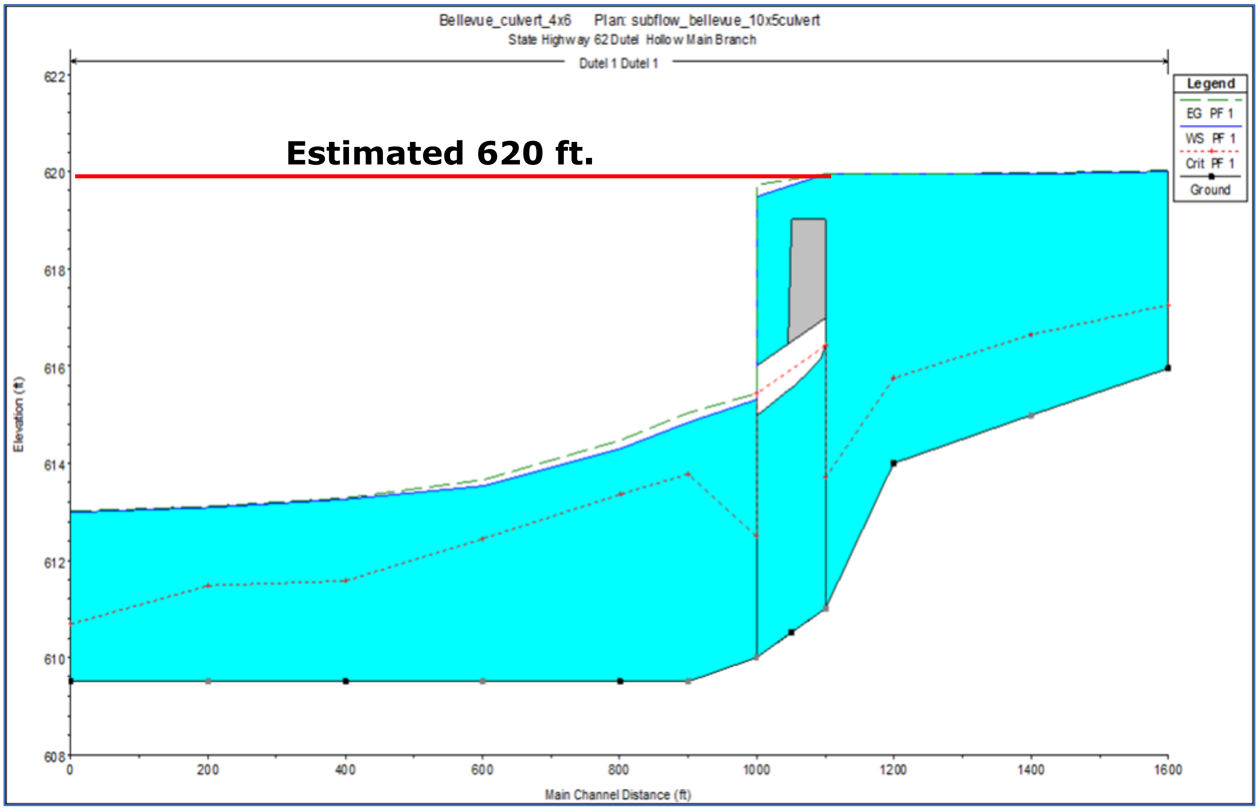

Figure 6: HEC-RAS Model graph for Hwy 62.

Since we could not accurately model exactly to the FEMA Flood report, we explored using 16 x 6 pre-cast box culvert to evaluate the drop in water elevation. From our results **Figure 7** we were able to achieve approximately 3 ft drop in backwater behind Hwy 62.

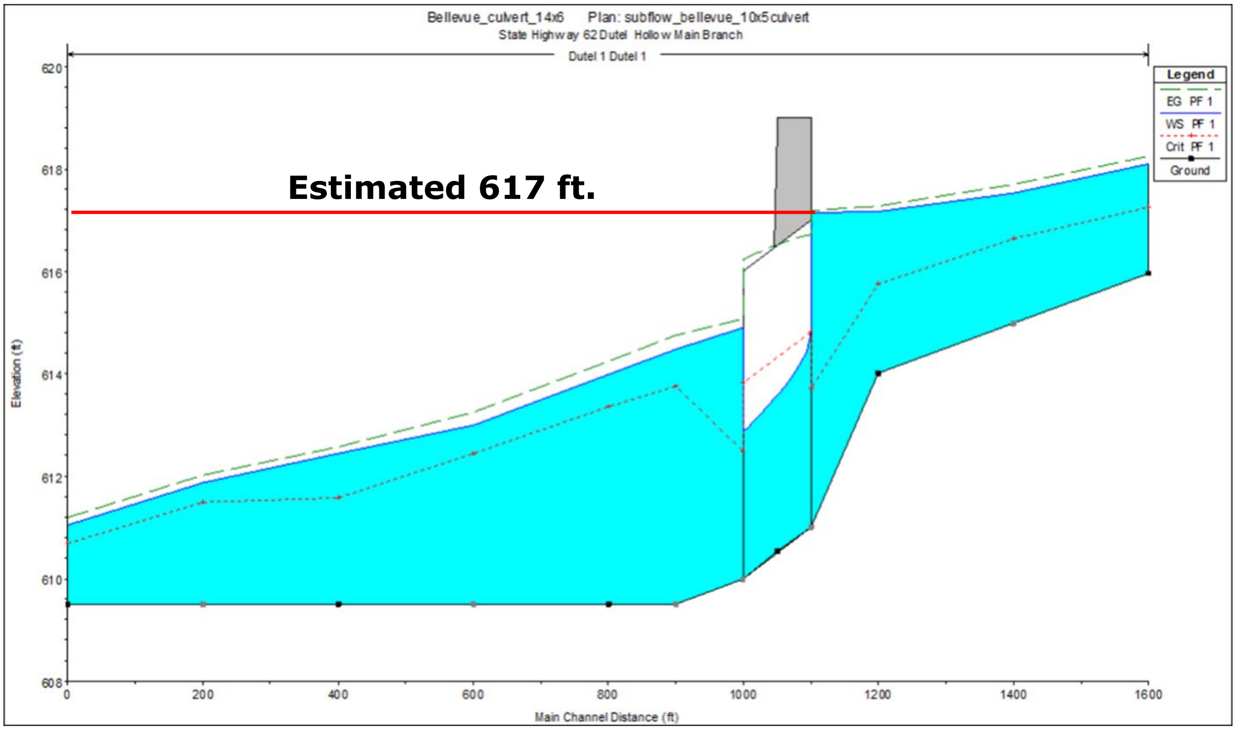

Figure 7: 16 x 6 culvert results

These results should be used as a guide only and not a deciding factor to increase the culvert size. A hydrologic model of the area should be taken with accurate survey data to allow for more precise water level measurements in the drainage way and at the culvert. Also, it is important to note that lenders may still require the need for flood insurance for the property if even if the level of water does not reach the structure on the property. This question needs to be answered before considering whether to enlarge the Hwy 62 culvert. This could also be used as a first phase of a multiple phase project approach that reaches the headwaters of Dutel Hollow. Phases would happen sequential as the City moves up the drainage way. Investigating and improving culverts and the drainage channel. Phase 2 would include Hwy 62 to Park St. Phase 3 would include Park St. to Mill Creek Rd. Phase 4 would include Mill Creek Rd. to Dunn St. With Phase 5 going form Dunn St. to Dutel Ct.

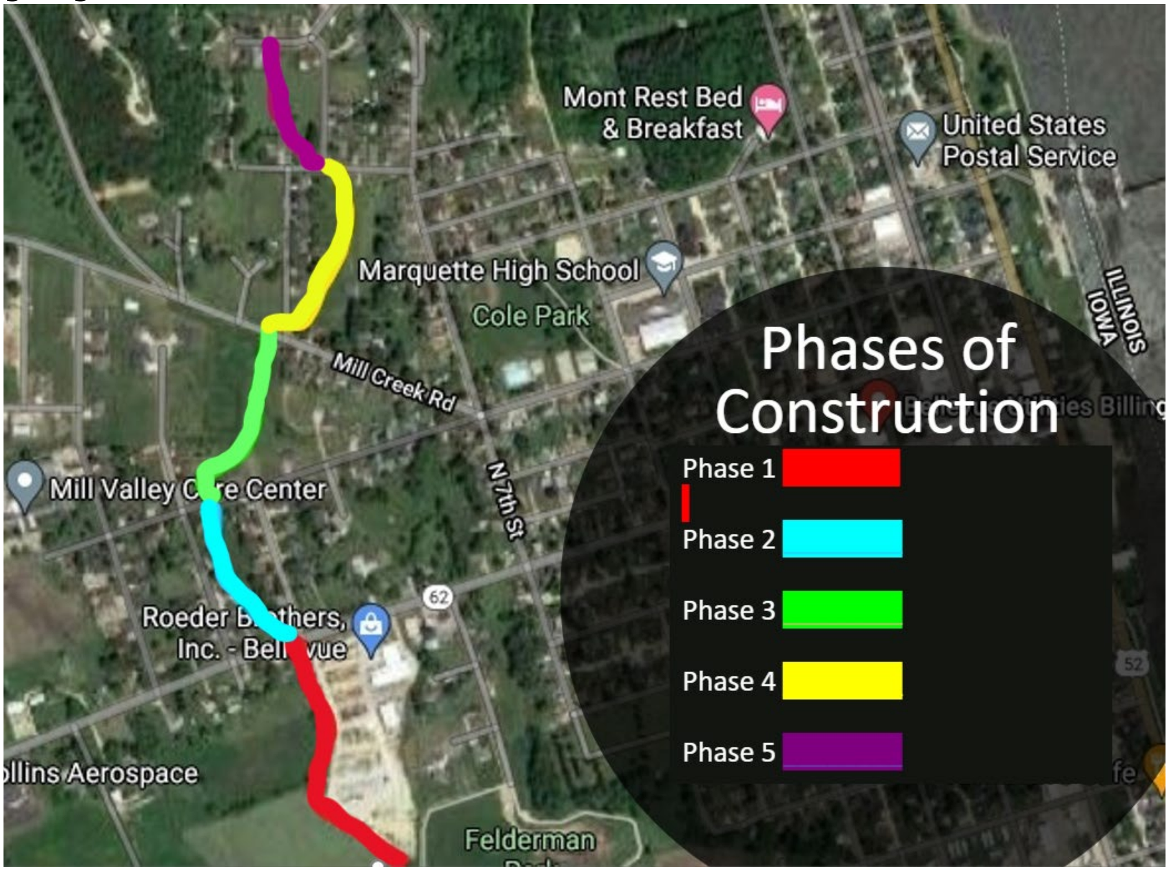

Figure 8: Overview of sequential phases for channel and culvert improvements.

Note: future phases have not been designed, but the cost of each phase will range from $70,000 to $250,000 depending on amount of work required to complete the phase.

Section VII

Engineer Cost Estimate

Present Worth of Flood Insurance

The present worth of flood insurance was calculated to compare the cost of purchasing flood insurance over the life of a mortgage, versus building a flood wall now. Information shared with the team from a stakeholder disclosed that a property owner had received a flood insurance quote of $4000 a year. Over the course of a 30-year mortgage with a 3% interest rate, the present worth of this flood insurance was calculated to $78,500, shown in **Appendix A**. Now that a multiplier has been calculated for these variables, any annual premium can be multiplied by 19.63 to find the present worth if the same 30-year mortgage and 3% interest are assumed.

Construction of Individual Flood Walls

With the information provided in the document Analyzed Unit Cost Schedule, published online by the Iowa state government, the estimated cost of constructing a flood wall 4 feet high and 90 feet long is shown below. It should be noted that the actual height of each floodwall will vary depending on the elevation of the home relative to the 100-year flood elevation.

Item	Quantity	Unit	Unit Price	Total
Reinforced concrete wall 12" Thick	360	PSFSA	$ 27.50	$ 9,900.00
Foundation concrete	480	CF	$ 4.10	$ 1,968.00
Sump Pump Installation	1	EACH	$ 450.00	$ 450.00
Waterproofing	360	PSFSA	$ 1.10	$ 396.00
Aesthetic	360	PSFSA	$ 8.45	$ 3,042.00
Construction Total				$15,756.00
Engineering Service			20%	$ 3,151.20
Contingency			20%	$ 3,151.20
Total				**$22,000.00**

Note: All final reported costs used the RSMeans rounding standards to determine final estimate.

Resized Highway 62 Culvert

Using the IDOT’s Bid Tabs for a majority of the items, the following cost estimates were made to replace the culvert under Highway 62. The only items that did not use the IDOT’s Bid Tabs are the precast concrete 16’ by 6’ culvert and flared end pieces. These items were taken from the Colorado’s Department of Transportation construction cost data, published online.

Item	Quantity	Unit	Unit Price	Total
Removal of pavement	284	SY	$ 8.93	$ 2,536.12
Removal of culvert	1	LS	$ 18,194.47	$ 18,194.47
Removal of sidewalk	48	SY	$ 9.21	$ 442.08
Removal of intakes	2	EACH	$ 674.06	$ 1,348.12
Precast Concrete Box Culvert, 16' X 16'	65	LF	$ 2,900.00	$ 188,500.00
Precast Concrete Box Culvert, 16' X 6' Flared End Piece	2	EACH	$ 15,000.00	$ 30,000.00
Replace Water Main, trenched, 12" DIP	84	LF	$ 87.42	$ 7,343.28
Removal and reinstall storm sewer pipe less than 36"	84	LF	$ 300.00	$ 25,200.00
Removal and reinstall of fence	32	LF	$ 37.89	$ 1,212.48
Steel beam guardrail	64	LF	$ 23.58	$ 1,509.12
Granular Backfill	93	CY	$ 44.55	$ 4,143.15
4" concrete sidewalk	256	SF	$ 6.16	$ 1,576.96
Seeding and fertilization	0.12	ACRE	$ 3,500.00	$ 420.00
Mobilization, erosion control	4	EACH	$ 500.00	$ 2,000.00
PCC Pavement	284	SY	$ 46.94	$ 13,330.96
Construction Total				$ 297,756.74
Administration & Engineering			20%	$ 59,551.35
Contingency			10%	$ 29,775.67
Total				**$ 387,000.00**

Appendix

A: Managing Risk with Insurance

Equation 1: Uniform series, present worth

$A := 4000$ annual cost dollars

$i := 0.03$ interest rate

$n := 30$ years

P = present worth

$$P := \frac{(1+i)^n - 1}{i \cdot (1+i)^n} \cdot A = 78402$$

P=$78,500

B: Individual Flood Walls

Lateral Pressure on Cantilever Wall: assumed values
Wall height 4 ft.
Water height 3 ft.
Soil Cover 1 ft.
Soil Active pressure coff 0.33

$\gamma_{water} := 62.4 \frac{lbf}{ft^3}$ $\gamma_{concrete} := 150 \frac{lbf}{ft^3}$ $W_{thickness} := 1\ ft$ $W_{Height} := 5\ ft$

$H_{soil} := 1\ ft$ $\gamma_{soil} := 110 \frac{lbf}{ft^3}$ $B_{width} := 4\ ft$ $B_{Height} := 1\ ft$

$H_{0.01\_Flood} := 3\ ft$ $K_a := 0.33$

$$P_{water} := \gamma_{water} \cdot H_{0.01\_Flood} = 187.2 \frac{lbf}{ft^2}$$

$$F_{soil} := \gamma_{soil} \cdot H_{soil} \cdot K_a = 36.3 \frac{lbf}{ft^2}$$

$$M_{overturn} := \left(P_{water} \cdot \left(\frac{H_{0.01\_Flood}}{3}\right)\right) + \left(P_{water} \cdot \frac{H_{soil}}{3}\right) = 249.6 \frac{lbf}{ft}$$

$$W_{wall} := \left(W_{thickness} \cdot W_{Height} \cdot \gamma_{concrete}\right) + \left(B_{width} \cdot B_{Height} \cdot \gamma_{concrete} + \left(1.5\ ft \cdot H_{soil} \cdot \gamma_{soil}\right)\right) = 1515 \frac{lbf}{ft}$$

C: HEC-RAS Modeling

Model check Calculations from HEC-RAS using Manning's equation and Froude number to verify the model.

Reach	River Sta	Q Total (cfs)	Manning #	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude #	W.P. Total (ft)	W.P. Total (ft)	Hydr Radius (ft)
Dutel 1	1600	676	0.032	619.99	617.25	620.02	0.00019	1.33	528.16	183.72	0.13	184.03	184.03	2.87
Dutel 1	1200	676	0.033	619.94	615.75	619.96	0.000094	1.12	613.58	150.64	0.09	151.35	151.35	4.05
Dutel 1	800	676	0.038	614.3	613.35	614.46	0.005148	3.29	223.8	200	0.42	202.01	202.01	1.11
Dutel 1	400	676	0.047	613.25	611.58	613.29	0.00103	1.78	416.23	200	0.2	203.11	203.11	2.05
Dutel 1	0	676	0.05	613	610.69	613.02	0.000333	1.2	606.66	200	0.12	206.19	206.19	2.94

Froude Number Calculations from Model Station 1200

$$Velocity := 1.12 \frac{ft}{s} \qquad Gravity := 32.2 \frac{ft}{s^2} \qquad Depth := 4.07\ ft$$

$$F_r := \frac{Velocity}{\sqrt{Gravity \cdot Depth}} = 0.098$$

$$n := 0.033 \qquad Area := 613.58\ ft^2 \qquad R := 4.05\ ft \qquad Slope := 0.0000927 \frac{ft}{ft}$$

$$Q := \frac{1.486}{n} \cdot Area \cdot R^{\frac{2}{3}} \cdot Slope^{0.5} = 675.905 \frac{s}{ft^{\frac{1}{3}}} \cdot \frac{ft^3}{s}$$

References

Federal Emegency Management Agency. (2019). *Flood Insurance Study (Jackson County, Iowa).*

Federal Emergency Management Agency. (2014, June). Homeowner's Guide to Retrofitting (Six way to Protect your Home from Flooding. *3 rd*.

Mark, M. (2021, Feb-Apirl). (H2Pros, Interviewer) Bellevue, Iowa.